Computational Hydraulics and Hydrology

An Illustrated Dictionary

Nicolas G. Adrien

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To my wife Vivianne and my children
Claude, Huguette, and Florence
To the memory of Mother Massoule
To the memory of Antoine Télémaque

About the Author

Nicolas G. Adrien is an independent consulting engineer in Florida. He has a civil engineering degree from the University of Haiti and two master's degrees, in environmental engineering and water resources, from Harvard University. He is a registered professional engineer in three states, a certified environmental engineer, a Fellow of the American Society of Civil Engineers, and a Life Member of the American Water Works Association. He is listed in five *Who's Who* publications. For more than 30 years, he has provided engineering management and environmental planning services to well-known U.S. consulting firms, government agencies, and international organizations. He has authored or edited numerous technical reports, including a recent 17-volume sewer modeling study for Miami–Dade County, Florida.

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Formatting and Editing Notes

1. The first letter of each entry is capitalized, except such items as e.g., i.e., in, ft, m, ha.
2. Terms of more than one word are listed alphabetically as they are used, that is, under the modifying word, if any, and not under the noun; e.g., *pump characteristic curve* is listed under the letter **p**, *channel roughness* under **c**, and *best management practice* under **b**.
3. Terms are listed alphabetically on a letter-by-letter basis; that is, word spaces, commas, slashes, hyphens, and the like are ignored. For example, *wetted perimeter* is listed before *wet weather*, *modeling* is listed before *model limitations*.
4. Definitions of two equivalent or synonymous terms are often repeated under both terms for the reader's convenience.
5. Slightly different meanings for a term are numbered 1, 2, and so on; in general, the first definition is the most applicable to computational hydraulics or hydrology.
6. An effort was made to acknowledge trademarks and copyrights; this does not guarantee that all registered trademarks have been identified.
7. Compound terms — consisting of two or more words that work together to express a concept — may be written as one word, as a hyphenated compound, or with spaces between the parts. In general:
   - Permanent compounds, as established in general usage or in current technical literature, are written as one word (e.g., backwater, baseflow, bedload, cleanout, groundwater, stormwater).
   - Familiar and often used compounds of two short nouns or a short adjective and a short noun are written as one word (e.g., baseflow, flowrate, runtime, timestep, wetwell).
   - Most two-word compound adjectives are hyphenated to avoid ambiguity (open-channel flow); the hyphen is dropped when the meaning is clear.
   - Compounds nouns are written open (e.g., conduit factor, attribute table).
   - Compound adjectives are hyphenated or written solid depending on the context (e.g., total dynamic head, block-centered model).
8. Units of quantities in definitions, equations, and formulas are generally expressed in the MLT (mass, length, time) system, unless specific dimensions, such as acre or minute, apply.
9. Spelling generally follows *Webster's New Universal Unabridged Dictionary*, revised and updated 1996 edition.

10. Spelling of compound words or phrases and use of the hyphen generally follow *Merriam Webster's Guide to Business Correspondence*, 2nd edition, 1996.
11. There does not seem to be any clear-cut or general rule on the use of adjective or possessive forms of proper names that precede such words as coefficient, equation, formula, effect, distribution, law, method, number, and principle. For example, the *Webster's New Universal Unabridged Dictionary*, 1996 edition lists the following: Archimedes' principle, Avogadro's law, Avogadro's number, Bernoulli distribution, Bernoulli effect, Bernoulli equation, Bernoulli's differential equation, Bernoulli's theorem, Bernoulli's trials, Coriolis effect, Coriolis force, Descartes' law, Gauss law, Gauss's law, Gaussian curve, Gaussian distribution, Gaussian image, Gaussian integer, Lagrange's method, Lagrange's theorem, LaGrange function, LaGrange point, Laplace equation, Laplace transform, Markov chain, Markov process, Newton's law, Newton's method, Poisson distribution, Poisson's ratio, Pythagorean theorem, Snell's law. The forms used here were selected according to the prevailing usage in the references listed in Section IV.

Table of Contents

Section I

A

Abandoned well A well for which use has been permanently discontinued or that is in a state of disrepair such that it cannot be used for its intended purpose.

abcd model A method proposed for the simulation of direct runoff within a basin. *See* National Water Assessment model. Also called **Thomas model**.

Abnormal erosion Erosion beyond the rate of the natural geologic process; caused by such human activities as construction and agriculture. Also called **accelerated erosion**, as opposed to geologic or normal erosion.

Aboveground storage facility A tank or other container, the bottom of which is on a plane not more than 6 in below the surrounding surface (EPA-40CFR113.3-a).

Aboveground tank A tank with its entire surface area above the plane of the adjacent surrounding surface, and its entire surface area, including the tank bottom, can be visually inspected (EPA-40CFR260.10). *See also* onground tank.

Abrupt wave An increase in water depth caused by a sudden change in flow conditions.

Absolute pressure Total pressure, equal to gage pressure plus atmospheric pressure.

Absolute temperature A temperature expressed in function of **absolute zero**, which is the temperature at which a substance does not possess any thermal energy; that is, the molecules of an ideal gas are motionless. Absolute zero temperatures are, depending on the scale: 0 K, 0°R, –273.15°C, and −459.67°F.

Absolute viscosity A measure of the internal resistance of a fluid to flow; equal to the ratio of the viscous shearing stress τ to the velocity gradient $\partial V/\partial s$. Also called **dynamic viscosity** or **coefficient of viscosity**. Absolute viscosity decreases when temperature increases, e.g., for water from 1.8 cP at 0°C to 0.18 cP at 150°C. It is conveniently taken as 1.0 cP for water at room temperature (about 20°C).

Absolute zero *See* absolute temperature.

Absorbing well A well through an impermeable layer to drain water to a permeable one. Sometimes called **dead**, **drain**, or **negative well**.

Accelerated erosion Generally, erosion in excess of what is presumed or estimated to occur naturally and that is a direct result of human activities (e.g., farming, residential or industrial development, road building, or logging). *See also* abnormal erosion; geologic erosion; and normal erosion.

Acceleration head With reciprocating pumps, the flow continuously accelerates and decelerates, requiring additional energy to overcome the acceleration head H_a caused by the fluctuation. H_a is a number equal to the product of the actual length of suction pipe L, the mean velocity of flow in the suction line V, the pump number of rotations per minute or r/min N, and the pump constant C_p divided by the gravitational acceleration g times a fluid factor α, that is:

$$H_a = LVNC_p/\alpha g \qquad \text{(A-1)}$$

H_a is not a headloss because the energy is restored during deceleration. Dampening the pulsation in the suction line can reduce it. The pump constant C_p decreases from 0.20 to 0.04 with the number of cylinders. The fluid factor α is 1.4–1.5 for water (Karassik and Messina, 2000). *See also* dynamic head.

Acceleration of gravity g = 32.2 ft/sec^2 or 9.8 m/sec^2.

Access *See* Microsoft Access.

Access hole *See* manhole.

Accretion The process of gradual land buildup resulting from the natural or artificial deposition of waterborne and airborne materials. *See also* aggradation; groundwater accretion.

Accumulated infiltration (F) The product of available porosity by the distance from the ground surface to the wetting front in the Green–Ampt Equation (G-7).

Accuracy The characteristic of a model that indicates the extent it replicates the true or observed system, i.e., to what extent simulated values correspond to true or observed values. Accuracy (in general, the difference between a measurement or simulation and the true value) is different from precision, which is the ability to reproduce results. Systematic errors cause inaccuracy, while random errors cause imprecision; they can be evaluated and reduced through model validation and a sensitivity analysis (Nix, 1994).

Acid deposition A complex chemical and atmospheric phenomenon that occurs when emissions of sulfur and nitrogen compounds and other substances are transformed by chemical processes in the atmosphere, often far from the original sources, and then deposited on earth in either a wet or a dry form. The wet forms, popularly called **acid rain**, can fall as rain, snow, or fog. The dry forms are acidic gases or particulates (EPA Glossaries).

Acid mine drainage Drainage of water from areas that have been mined for coal or other mineral ores. The water has a low pH because of its contact with sulfur-bearing material, and it is harmful to aquatic organisms (EPA Glossaries).

Acid rain *See* acid deposition.

Acoustic current meter *See* acoustic meter.

Acoustic Doppler current profiler (ADCP) *See* Doppler current profiler. Actually, all Doppler current meters are acoustic.

Acoustic Doppler meter *See* Doppler current meter. *Note*: all Doppler current meters are acoustic.

Acoustic meter A device that uses sound waves to measure the velocity of water currents, based on one transducer to measure wave frequency changes or two transducers to measure the speed of transmission of the sound wave. *See also* Doppler current meter.

Acoustic method Any method that uses the properties of sound (e.g., the velocity of sound in water) to measure discharges of rivers and canals. *See* acoustic meter; Doppler current meter. *See also* ultrasonic method.

ACP Abbreviation for asbestos–cement pipe.

Acre A U.S. Customary System unit of area equal to 43,560 ft^2. Also, 1 acre equals 4,046.86 m^2 or 0.4047 ha.

Acre–foot The volume of water equivalent to a depth of 1 ft over an area of 1 acre, i.e., a volume of 43,560 ft^3 = 1,233,482 l = about 325,851 gal.

Active storage (1) The portion of a pool, pond, or other detention/retention facility actually used for storage and subsequent release of stormwater, as opposed to dead storage or permanent pool. Extended detention dry ponds have only an active storage zone, while a wet pond has both an active storage zone and a permanent pool. The active storage zone is also called **working volume**, as opposed to permanent volume. (2) In water supply, active storage in a reservoir is required to meet water demand. In a multiple-purpose reservoir, active storage corresponds to all intended uses, such as drinking water supply, irrigation, flood control, hydroelectric power generation, and recreation. *See* reservoir storage; useful storage (1).

Actual evaporation e_a The volume of water that evaporates in a given time period, depending on measurements of cumulative precipitation P_c, cumulative runoff R_c, and cumulative soil moisture M_c over the period. It is different from pan evaporation. The following formula is often used, with all the quantities usually expressed as a length or depth, e.g., in inches or centimeters:

$$e_a = P_c - R_c + M_c \tag{A-2}$$

See also actual evapotranspiration; pan evaporation; soil moisture loss equation.

Actual evapotranspiration The evapotranspiration that results from actual field conditions (climate and soil moisture) as compared to the evapotranspiration potential.

ADCP Abbreviation for acoustic Doppler current profiler.

Address matching A procedure used in planning studies to relate street addresses to such attributes as meter locations, census tracts, buildings, or emergency response units. *See also* water meter address matching.

Adhesion water *See* water of adhesion.

AdICPR Abbreviation for Advanced Interconnected Pond Routing.

Adjutage A device, such as a cylindrical or conical tube, inserted into the orifice of a container or a conduit to facilitate or regulate the outflow of water.

Also called **efflux tube**. (From the French word *ajutage,* a variation of *ajustage,* meaning adjustment.)

Adsorption water Water held on the external surface of solid particles or the internal surface of a porous material by molecular forces (physical or chemical bonding).

Advanced Interconnected Pond Routing (AdICPR) A hydrodynamic model developed by Streamline Technologies, Inc., to simulate hydrologic and hydraulic conditions by generating runoff hydrographs and dynamically routing them through dendritic, diverging, looped, or bifurcated stormwater management systems. In stormwater modeling studies, the AdICPR technique uses (1) **stage–area** and **stage–volume nodes** to simulate lakes, retention ponds, inlets with storage above the grate elevation, manholes, and inlets without significant storage; (2) **time-stage nodes** to establish model boundary conditions; and (3) **manhole nodes** to simulate systems regulated by the Federal Emergency Management Agency, which establishes guidelines for headlosses. *See also* directly connected impervious area; pond routing. *See* Section II for further information.

Advection (1) The process of transfer of fluids (vapors or liquids) through a geologic formation in response to a pressure gradient that may be caused by changes in barometric pressure, water-table levels, wind fluctuations, or infiltration (EPA Glossaries). (2) Movement of contaminants with water at the same velocity.

Advection dispersion equation The partial differential formula that expresses the concentration of a substance in terms of the flow and mixing conditions in a medium:

$$\partial C/\partial t = \delta\,(\partial^2 C/\partial x^2) - V(\partial C/\partial x) \tag{A-3}$$

where C = concentration of the substance (mg/l or g/m^3), δ = dispersion coefficient (m^2/sec), t = time (sec), x = distance (m), and V = average velocity (m/sec).

Aeration zone The area between the water table and the ground surface where soil pores are not fully saturated but contain some vadose water. Also called **vadose zone**, **zone of aeration**, **unsaturated zone**, or **undersaturated zone**. *See* subsurface water.

Aerodynamic method A method to estimate evaporation from lakes and reservoirs. It assumes that evaporation E_a is proportional to the difference between saturated vapor pressure p_s at the water surface temperature and the vapor pressure due to moisture in the air p_a and to the wind velocity V_w:

$$E_a = m\,(p_s - p_a)V_w \tag{A-4}$$

where m is a mass transfer coefficient. It is also called the **mass transfer method**. *See also* energy balance or energy budget method; evaporation pan method; Penman method.

Affinity laws *See* pump affinity laws.

Affluent *See* affluent stream.

Affluent stream (or simply affluent) A tributary stream, i.e., a stream that flows into a larger stream. Confluent applies to streams of approximately equal sizes.

A-frame timber dam A fixed dam made of timbers like rafters in a roof, which lie on their side and point upstream, forming a sill and a support for the deck. Also called a **rafter-and-strut framed dam**. *See also* rafter dam.

Aggradation The natural process during which the deposition of detritus, sediment, and similar material raises the level of a streambed or river valley. An **aggrading river** is a river undergoing aggradation. *See also* accretion.

Aggrading river *See* aggradation.

Agricultural drainage Runoff from farmed areas collected through surface channels or underground drains. *See* agricultural pollution.

Agricultural pollution Farming wastes, including runoff and leaching of pesticides and fertilizers, erosion and dust from plowing, improper disposal of animal manure and carcasses, crop residues, and debris (EPA Glossaries).

Air binding The effect of the release of air from water into soil interstices, filter beds, pipes, or pumps. It can affect infiltration into the soil or the filtration process.

Air chamber A compact surge chamber or surge tower with a closed upper end that is installed on the discharge line of a pump to minimize flow and pressure variations. The liquid level in the chamber fluctuates to balance transient conditions in the line.

Air-chamber pump A displacement pump that uses compressed air in lieu of pistons or plungers. Also called an **air-displacement pump**.

Air-displacement pump *See* air-chamber pump.

Air gap Open vertical gap or empty space that separates drinking water supply to be protected from another water system in a treatment plant or other location. The open gap protects the drinking water from contamination by backflow or backsiphonage (EPA Glossaries). *See also* backflow preventer; vacuum breaker.

Airlift Same as **airlift pump**.

Airlift pump A low-efficiency device used mainly in a well for lifting water by forcing compressed air at the bottom of the well. Hydrostatic pressure forces up the resulting mixture into the outlet pipe. It may also consist of two pipes, one inside the other; the compressed air is forced into the inner pipe, and the air–water mixture rises in the outer pipe. Also called simply **airlift**.

Air relief valve A valve in a pipeline or other pressurized container to adjust up or down the internal pressure by admitting or releasing air automatically.

Air test Determines the rate of water leakage in a sewer section by introducing pressurized air into it and measuring the rate of air loss.

Air vent An opening to allow air to flow into or out of pipes, tanks, etc.

Airy, George Biddle *See* hydraulics.

ALERT Acronym for Automated Local Evaluation in Real Time.

Algorithm A set of rules and procedures to solve a problem. In hydraulic modeling and other electronic data processing, computational algorithms perform the numerical procedures required to solve the mathematical representations of the system. A well-known algorithm used to solve nonlinear equations is the Newton–Raphson method, which approximates a function by truncating its Taylor series expansion after the first derivative term.

Allen, Charles Metcalf *See* hydraulics.

Allievi, Lorenzo *See* hydraulics.

Alluvial Of or pertaining to the **alluvium**, which is the detrital material (gravel, sand, mud, silt, etc.) formed or deposited by flowing water. **Alluviation** is the process of deposit accumulation. **Alluvial clay** is such a deposit but is distinct from the clayey material originating at the site. An **alluvial plain** is a level and gently sloping surface formed by alluvial deposits from higher areas. An **alluvial river** results from alluviation and aggradation, with similar bed and bank materials.

Alluvial aquifer A water-bearing formation of sediments deposited by streams or running water, usually representing a good groundwater source.

Alluvial deposit Same as **alluvium**. *See* alluvial.

Alluvial soil The common soil found on riverbeds and flood plains and made up of material deposited by flowing water.

Alphanumeric code (or variable) A code (or variable), often found in computer programs, consisting of letters, numbers, punctuation marks, mathematical and other symbols; for example, S_{f1} for friction headloss at cross-section 1.

Alternate depths The two depths in open-channel flow that correspond to a given specific energy: the subcritical depth and the supercritical depth.

Altitude valve A valve used to shut off the flow into a container automatically when the fluid in the container reaches a certain level.

Ambient Surrounding or encircling. **Ambient temperature** is the temperature of the surrounding medium, e.g., the temperature in a testing laboratory. **Ambient water quality standards** relate to designated criteria and uses of the water under consideration.

AMC Abbreviation for antecedent moisture condition. **AMC-I** = antecedent moisture condition category 1. **AMC-II** = antecedent moisture condition category 2. **AMC-III** = antecedent moisture condition category 3.

AM/FM Abbreviation for automated mapping/facilities management.

AMR. Abbreviation for automatic meter reading.

Anabranch Acronym for anastomotic branch.

Analog device A device that represents data by measurable and continuously variable quantities such as frequency or position, as opposed to a **digital device**, which uses a discrete numerical representation (e.g., digits). An analog computer uses measurable quantities, such as electrical signals, to represent numerical data, while a digital device uses digits (usually in the binary system) to perform its operations. A hard copy is an analog copy or file, which may correspond to an electronic or digital format on a diskette.

Analog model A model based on the similarities between the system under study and another system. For example, a groundwater electrical analog model is based on the similarity between groundwater and electrical flows. *See also* Hele–Shaw model.

Analytical method A method that uses theoretical probability distribution functions in flood frequency analysis. Some of the most widely used distributions are the normal or Gaussian, lognormal, extreme value type I or Gumbel, extreme value type III or Weibull, and log–Pearson type II or gamma distributions. Other methods of frequency analysis include the graphical method using probability paper and the empirical method based on formulas to determine the plotting position of a flood magnitude.

Analytical model (analytical solution) A model that classical methods, e.g., calculus or even elementary algebra, can solve. An example is the Laplace equation to represent groundwater flow. Analytical solutions are exact, as opposed to numerical solutions, but the analytical model itself is usually a crude approximation of the system it represents.

Analytical parameters or variables (modeling) Two parameters or variables used in hydraulic modeling studies based on the Saint-Venant equations: the Manning's roughness coefficient n and the minor loss coefficient or k factor. Analytical parameters are included in the model's governing equations, as opposed to numerical parameters. *See also* model parameters. *See* Section II for further information.

Analytical probabilistic model A model based on long-term rainfall data and used to estimate the performance of stormwater management plans as an alternative to event or continuous simulation methods.

Anastomotic branch An effluent branch that rejoins the main stream downstream, thus forming an island.

Anchor gate A gate anchored into the masonry, e.g., a canal lock gate.

Angle of repose The greatest angle to the horizontal made by a bank of loose earth, gravel, or other unsupported granular material. Also called **natural slope**. *See* Equation (T-11); tractive force theory.

Angle valve A 90° fitting with a valve used in water meters.

ANN Abbreviation for artificial neural network.

ANNIE A nonproprietary computer program written in FORTRAN by the U.S. Geological Survey to manage hydrological time-series data, which can be linked to other models.

Annual average daily flow Same as **annual average flow**.

Annual average flow The total volume of water consumption or wastewater discharge in a year divided by the number of days in the year; usually expressed in million gallons per day (mgd), cubic meters per day (m^3/d), or liters per second (l/sec).

Annual duration series A data set used in frequency analysis, e.g., to establish a flow-duration curve. Given a set of observed or simulated data for N years, the annual duration series then lists the most severe event (flood or drought), arranged from the largest to the smallest, in each year. The **annual flood series** lists the maximum annual floods from the highest (most severe) to the lowest. Likewise, the **annual drought series** lists the minimal annual discharges from the most severe to the least severe. This definition can be adapted to any period other than annual. The annual duration series is different from the exceedance (or partial duration) series. Both contain N events for N years, but the former has one event for each year, while the latter may have two or more events for a given year and none for another. The complete duration series contains all the data recorded over a certain period.

Annual flood The maximum 24-h flowrate of a stream during a period of 12 consecutive months, for example, during the water year.

Annual flood series *See* annual duration series.

Annual load factor In services such as energy or water supply, the ratio of the maximum load over the average load for a period of 1 yr.

Annual mass balance An inventory of water input and output on an annual basis in a basin. *See* mass balance; water budget.

Annual series Same as **annual duration series**.

Antecedent conditions Prior hydrological conditions affecting soil storage and surface runoff; for example, soil moisture and depression storage. *See* antecedent moisture; antecedent precipitation.

Antecedent moisture The moisture of the soil before a runoff event; determined by the summation of daily rainfall in the preceding period. Same as **antecedent-precipitation index**.

Antecedent moisture condition (AMC) The index of soil condition with respect to surface runoff potential before a precipitation event. AMC category 1 (AMC-I) refers to soils that are dry, but not to the wilting point. AMC-II refers to average conditions, and AMC-III to soils that are saturated following a heavy rainfall in the last 5 days. This index is used to determine the curve number (CN) in the Soil Conservation Service (SCS) hydrograph method of computing direct runoff. The SCS classifies as category 1 conditions that correspond to less than 0.5 in or 12.7 mm of rainfall during the previous 5 days, as category 3 conditions that correspond to more than 1.1 in of rainfall during the previous 5 days, and as category 2 intermediate conditions.

Antecedent precipitation (or rainfall) Precipitation (or rainfall) that occurred prior to the runoff event under consideration. The antecedent precipitation index (API) gives an indication of moisture conditions. As a weighted average of current and antecedent precipitation, it improves the correlation between rainfall and runoff. The API on the Nth day of a period I_N may be estimated as:

$$I_N = aI_{N-1} + P_N \qquad \text{(A-5)}$$

where a is a coefficient (approximately 0.9), I_{N-1} is the previous day's API, and P_N is the precipitation on the Nth day. On a yearly basis, the runoff–API curve is practically a straight line. It is one of a few parameters used in runoff analysis. Other parameters include attenuation constant, lag time, peak discharge, plotting time width, rainfall duration, time base, time of concentration, and time of equilibrium.

Antecedent precipitation index (API) The moisture of the soil before a runoff event, determined by the summation of daily rainfall in the preceding period. Also called **antecedent moisture**. *See also* antecedent precipitation.

Antecedent rainfall *See* antecedent precipitation.

Antecedent runoff condition *See* antecedent moisture condition.

Antecedent watershed conditions *See* antecedent conditions.

Anticipated yield The yield of a production well based on pumping tests, neglecting losses during actual operation.

APHA Abbreviation for American Public Health Association.

API Abbreviation for antecedent precipitation index.

Apogee The point on the orbit of the moon (or other heavenly body or man-made satellite) that is farthest from the earth. At that point, the tidal range (**apogean range**) is reduced. The opposite is **perigee**. Tides at the time of the moon's apogee are called **apogean tides**.

Application software Such computer programs as those for word processing, spreadsheets, or database management, which are developed for specific purposes.

Approach channel The stretch of a channel that precedes a control structure. Also called **channel of approach**.

Approach velocity The average velocity in a channel upstream of an obstruction. A variable in the weir equation (W-6) used in the Stormwater Management Model.

Appurtenances Secondary appliances, instruments, machinery attached to a main structure. **Sewer appurtenances** are auxiliary components other than pipes and conduits, such as manholes, inlets, inverted siphons, regulators, flap valves, and junctions. In general, appurtenances are not considered part of the main structure but are necessary for its adequate operation.

Apron A covering in concrete, stone, timber, or other material to protect a hydraulic structure against erosion from flowing water. *See* Figure S-9.

Aqueduct A large, artificial conduit for conveying water, usually a covered masonry conduit built in place at the hydraulic gradient and operated at atmospheric pressure. It may consist of several elements, such as canals, pipelines, and tunnels. For the differences among various watercourses, *see* stream. *See also* flume.

Aquiclude The low-permeability, upper or lower boundary of an aquifer or underground watercourse. It is a porous geologic formation, such as clay, that may contain water, but not of sufficient permeability for significant water transmission through wells and springs. *See also* aquifer; aquifuge; aquitard; subsurface water.

Aquifer An underground geologic formation, or group of formations, containing usable amounts of groundwater that can supply wells and springs (EPA Glossaries). The water-bearing formation or structure usually consists of saturated sands, gravel, fractures, or cavernous and vesicular rock. *See also* aquiclude; aquifuge; aquitard; subsurface water. Figure A-1 illustrates

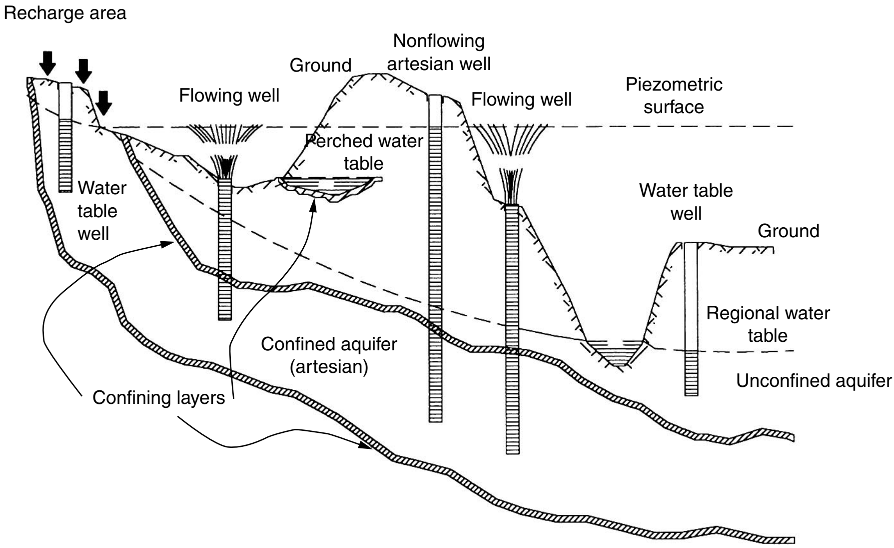


FIGURE A-1 Aquifers and wells.

some of the terms listed below and related to aquifers and wells: artesian aquifer; artesian well; confined aquifer; flowing well; leaky aquifer; leaky confined aquifer; nonflowing well; perched aquifer; phreatic aquifer; piezometric surface; potentiometric surface; pumping test; pump well; recharge area; semiconfined aquifer; unconfined aquifer; water-table aquifer.

Aquifer assimilative capacity The ability of an aquifer to dilute lower quality water without significant impairment relative to the intended use.

Aquifer mining Withdrawal of groundwater from an aquifer in excess of the rate of recharge of the aquifer.

Aquifer recharge area The land area that contributes water to the aquifer.

Aquifer safe yield The quantity of water that can be withdrawn from an aquifer year after year without depleting or otherwise impairing it. *See* safe yield.

Aquifer storage and recovery (ASR) The process of artificially recharging an aquifer (usually in periods of surplus) and subsequently extracting the stored water (usually in periods of deficit or greater demand). An **ASR well**, designed for that purpose, is sometimes used.

Aquifer storage and recovery (ASR) well *See* aquifer storage and recovery.

Aquifer test A technique used to determine the capacity of a well or borehole or the hydraulic properties of an aquifer. The test is conducted by pumping a well at a constant rate over a period of time and recording the drop in the piezometric surface or water table in observation wells. These data are used to calculate the transmissivity, hydraulic conductivity, and storage coefficients. Also called **pumping test** or **pumped-well technique**. It is sometimes called an **auger hole test** when it is performed in shallow auger holes.

Aquifer transmissivity *See* transmissivity.

Aquifuge A geologic formation (e.g., unfissured granite) without interconnected fractures or interstices. It cannot absorb or transmit water. *See also* aquiclude; aquifer; aquitard.

Aquitard A low-permeability geologic formation that may contain groundwater but is not capable of transmitting significant quantities of groundwater under normal hydraulic gradients. In some situations, aquitards may function as confining beds. However, an aquitard may transmit water vertically from one aquifer to another. *See also* aquiclude; aquifer; aquifuge.

Arch dam, arched dam, single-arch dam, arch-gravity dam The first three phrases refer to a curved masonry dam where the arch provides structural stability, while gravity also contributes to stability in the arch-gravity dam. An arch dam transmits the water load horizontally by arch action. It is one of four common dam types, the other three are buttress, embankment, and gravity dams.

Archimedes *See* hydraulics.

Archimedes law The law that states that the buoyant force acting upward on a body floating in a liquid equals the weight of the displaced liquid applied at its center. Discovered by the Greek mathematician and physicist Archimedes circa 285–212 BC, who also discovered the principles of specific gravity and of the lever. *See also* Archimedes principle; buoyancy.

Archimedes principle Buoyancy is the ability, tendency, or power of a body to float or rise in a fluid. The upward pressure exerted by a fluid on an immersed body results from the buoyant force, i.e., the difference in the forces on the bottom and on the top of the body. The Archimedes principle states that the buoyant force is equal to the weight of the displaced fluid and acts vertically upward. *See also* buoyancy.

Archimedes screw A device consisting of a spiral in an inclined cylinder; used for raising water by rotating the cylinder. Also called **water snail**.

ArcInfo A complex, vector-based geographic information system (GIS) program of the Environmental Systems Research Institute, Inc. With ArcInfo, GIS layers can be digitized in vector format from base maps. *See also* ArcView. *See* Section II for further information.

ArcView A Windows™-based geographic information system (GIS) software used to query and analyze spatial data; software developed by Environmental Systems Research Institute, Inc. A desktop mapping and GIS tool, ArcView is easier to learn than ArcInfo, but its functionality is more limited. It can be used for routine display, map plotting, and database query. *See* Section II for further information.

Area-capacity curve The graphical representation of the relationship between the capacity or volume of a reservoir, impoundment, or lake and its surface area.

Area of diversion An area adjacent to a watershed divide that contributes water to the watershed.

Area of influence The land area within the horizontal projection of the cone of depression, i.e., the land area where the water table is perceptibly lowered due to well pumping or other water withdrawal. For a wellfield or group of wells, it is called **zone of influence**. *See also* circle of influence.

Arid Extremely dry or without moisture. Applied to lands or climates with insufficient precipitation for vegetation growth and other purposes. An area receiving fewer than 10 in of rain a year is sometimes considered arid.

Arithmetic and logic unit The part of the central processing unit (CPU) of a computer that performs numerical operations, usually represented by arithmetic operators for addition (+), subtraction (−), multiplication (∗), division (/), etc.

Arithmetic average method A simple, but often incorrect, method of estimating the average precipitation over a given area by computing the arithmetic average of recorded precipitations within or near the area. *See also* isohyetal method; Thiessen polygon method.

AR model Same as **autoregressive model**.

Arroyo A deep gully with steep banks.

Artesian (From Artois, a province of northern France.) Capable of freely rising to the surface. An **artesian aquifer** is an aquifer held under (greater-than-atmospheric) pressure in porous rock or soil confined by impermeable geologic formations; also called a **confined aquifer**, as opposed to an **unconfined** (or **phreatic** or **water-table**) **aquifer**. **Artesian wells** are wells that penetrate an artesian formation; they may be **flowing (artesian) wells** if their water has enough energy to flow from the well without pumping or **nonflowing (artesian) wells** otherwise. **Artesian discharge** is the flowrate of an artesian well. **Artesian pressure** and **artesian head** refer to the pressure exerted by the aquifer against the overlying formation and to the elevation to which water will freely rise in an artesian well. In an **artesian spring**, water flows under pressure through an opening in the formation above the aquifer.

Artesian aquifer An aquifer in which groundwater is confined under pressure that is significantly greater than atmospheric pressure. It is a fully saturated formation of porous rock or soil, overlaid by a confining layer. The potentiometric surface (or hydraulic head) of the water in a confined aquifer is at an elevation that is equal to or higher than the base of the overlying confining layer. Discharging wells in a confined aquifer lower the potentiometric surface, which forms a cone of depression, but the saturated medium is not dewatered. Same as **confined aquifer**. *See* aquifer; Figure A-1.

Artesian basin The area corresponding to an artesian aquifer.

Artesian waste Waste of artesian water at ground surface or below ground because of leaks or lack of capping.

Artesian water Water from an artesian aquifer.

Artesian well A well that penetrates an artesian aquifer. It is a flowing or nonflowing well, depending on whether the piezometric surface is above ground or not, respectively, i.e., whether or not it discharges above ground. *See* Figure A-1. The opposite is a **phreatic** or **water-table well**.

Artificial channel A man-made channel intended for irrigation, navigation, drainage, or any other purpose. It generally has more regular characteristics than a natural channel. The application of Hydraulic principles yields more accurate results in artificial channels.

Artificial neural network (ANN) modeling Same as **neural network modeling**.

Artificial rainfall Water produced or applied artificially by such methods as cloud seeding and rainfall simulation.

Artificial recharge Intentional (artificial) replenishment of an aquifer by such techniques as injection wells, spreading basins, or induced infiltration of surface water. *See also* groundwater recharge.

Artificial watercourse A man-made watercourse, such as a canal.

Asbestos–cement pipe (ACP) A pipe made of a mixture of asbestos fiber and Portland cement; has good hydraulic characteristics because of its smooth inner surface.

As-built drawings (plans) Record drawings (plans) that are assumed to represent accurately existing works. They are usually prepared during or shortly after construction by making appropriate revisions to the original construction drawings (plans).

ASCII Acronym for American standard code for information interchange. A standard for describing computer-readable text, including alphabetic, numeric, and control characters, all coded in hexadecimal notation.

ASR Abbreviation for aquifer storage and recovery.

Assessment district The land area within the territory created for such improvements as drainage, water supply, or wastewater disposal. *See also* drainage district; sewer district.

Assimilative capacity The ability of a water body to receive polluting materials (e.g., wastewater) without degradation of water quality below a defined level. The desirable water quality, resulting from dilution, dispersion, and self-purification, may relate to the protection of the aquatic biota or to human consumption. *See also* aquifer assimilative capacity.

Atlas A sewer atlas is a bound set of maps of a sewer system; it has such information as plans and profiles of the sewer lines; location of pumping stations, treatment plants, manholes, and other appurtenances; sizes; elevations; right-of-way details; etc.

Atmidometer An instrument to measure the evaporation rate of water. Also called an **evaporation gage**, **evaporimeter**, or **atmometer**.

Atmometer An instrument to measure the evaporation rate of water. Also called an **atmidometer**, **evaporation gage**, or **evaporimeter**.

Atmosphere (atm) *See* atmospheric pressure.

Atmospheric moisture Water in various forms in the atmosphere.

Atmospheric pressure The pressure exerted by the atmosphere; decreases with increasing elevation above sea level. At mean sea level, it is 1 **atmosphere** (1 atm) = 14.7 psi under standard conditions. Also called **standard pressure** or **standard atmospheric pressure**. *See also* absolute pressure.

Atmospheric water Water in the atmosphere in the form of rain, water vapor, ice, etc.

Attenuation The reduction from the peak inflow rate to the peak outflow rate as a result of storage, both the process and the result; equal to the difference between these two peak rates. *See* Figure R-3; reservoir storage routing. *See also* flow attenuation.

Attenuation constant A parameter of the Clark method of instantaneous unit hydrograph. It accounts for the effect of channel storage on the hydrograph. It may be estimated as the ratio of the discharge Q* to the slope $\Delta Q/\Delta t$ of the hydrograph at the point of inflection. *See* Figure R-3. It is one of a few parameters used in runoff analysis. Other parameters include antecedent precipitation index (API), lag time, peak discharge, plotting time widths, rainfall duration, time base, time of concentration, and time of equilibrium.

Atterberg limits In soil mechanics, measures of the water content (as a percentage of the dry weight) of soils when they pass from the liquid to the plastic state (**liquid limit**) or from the plastic to the solid state (**plastic limit**). The **plasticity index** is the difference between these two limits.

Attribute An attribute is a fundamental, nongraphic property or a unique item of descriptive information of an object, for example, the diameter, length, roughness, age, and material of a pipe or the identification, type, and depth of a manhole. In geographic information system (GIS) applications, graphic components of the files include points, lines, or polygons. The database component (of nongraphic, alphanumeric elements) is the **attribute table**, which is dynamically linked to the graphic component in a one-to-one relationship.

Audit *See* model audit.

Auger A tool for drilling or boring into unconsolidated earth materials; consists of a spiral blade wound around a central stem or shaft that is commonly hollow (**hollow-stem auger**). Augers are commonly available in flights (sections) that are connected to advance the depth of the borehole (EPA Glossaries).

Auger hole test *See* aquifer test.

Augmentation *See* low-flow augmentation.

AutoCAD® An automated program for computer-aided drafting or design (CAD), developed by Autodesk, Inc., and used to develop realistic, accurate two- and three-dimensional drawings. *See* Section II for further information.

Autocorrelation function An expression used in the regression analysis of time-series data to determine the **autocorrelation coefficient**, which indicates the dependence in successive values of the series. For example, this coefficient may indicate whether the data show a seasonal pattern.

Automated calibration Calibration of an inverse model. Inverse modeling or parameter estimation may be used to manipulate input data or simulated values as compared to measured values. A model may also be calibrated manually by trial and error (Spitz and Moreno, 1996).

Automated Local Evaluation in Real Time (ALERT) A system of flood warning of the National Weather Service; relies on rainfall monitoring and stream gaging.

Automated Mapping/Facilities Management (AM/FM) A computer mapping technique (such as CASS WORKS®) that includes some of the features of a geographic information system (GIS): layers, network analysis, lines, nodes, attributes, and actual locations. It allows the efficient display and processing of graphic information. The FM component provides management capabilities to facilities such as water and sewer works.

Automatic gate A gate that shuts and opens when specified conditions are met, i.e., without human intervention.

Automatic meter reading (AMR) Reading and transmission of customer meters (via telephone lines, radio, or cables) to a remote location for billing.

Automatic recording gage An automatic instrument for measuring and recording such characteristics as pressure, water level, velocity, or rainfall intensity. Also called a **register** or simply a **recording gage**.

Automatic valve A valve that closes or opens when specified conditions are met, i.e., without human intervention.

Autoregressive (AR) model A model to generate a time series of synthetic streamflows, assuming that they follow a Markov process; i.e., each event of the series is correlated with the preceding event. For example, synthetic hydrology assumes a first-order Markov process; i.e., each flow is equal to the flow in the preceding period plus a random component.

Autorun coefficient A parameter of autorun models similar to the autocorrelation coefficient of a Markov process. It is the conditional probability that an observation will exceed the reference event given that a preceding event also exceeds the reference.

Autorun model A model designed to generate time series of synthetic streamflows that preserve the basic characteristics of observed data (e.g., the alternation of wet and dry periods); based on the autorun coefficient and the run lengths. *See also* run (2).

Auxiliary spillway A spillway used to handle frequent outflows while the emergency spillways are used for extreme floods. Also called **service spillway**.

Availability factor *See* pollutant accumulation methods, pollutant availability factor.

Available depression storage *See* depression storage.

Available moisture The part of the water in the soil that can be taken up by plants at rates significant to their growth; the moisture content of the soil in excess of the ultimate wilting point. Same as **available water** (2).

Available porosity (π) The difference between total soil porosity and the initial soil water content in the Green–Ampt infiltration equation. *See* Equation (G-7).

Available water (1) One of two state variables contained in the Thomas (or National Water Assessment) model for simulating direct runoff within a basin. It is the sum of precipitation to the end of a period and soil moisture storage to the end of the preceding period. (2) Water available to plants in the form of moisture excess; expressed in percentage weight of dry soil or in inches per foot of soil; *see* available moisture.

Available yield *See* groundwater yield.

Average annual flood The flood that corresponds to the average discharge of the maximum annual floods in a given period.

Average conveyance One of four equations used in the HEC-2 and HEC-RAS programs to estimate friction loss between two channel cross sections. It represents the friction loss S_f between two cross sections in function of the discharges (Q_1 and Q_2) of the two sections and their conveyances (K_1 and K_2). *See also* average friction slope; geometric mean friction slope; harmonic mean friction slope.

$$S_f = [(Q_1 + Q_2)/(K_1 + K_2)]^2 \qquad \text{(A-6)}$$

Average daily flow In a series of daily flows, it is their sum divided by the number of flows. *See* annual average flow.

Average depth Same as **hydraulic mean depth**.

Average error A measure of model accuracy equal to the average difference between observations and corresponding simulations. The **relative error** is the average error divided by the average observation. *See* Martin and McCutcheon (1999) for details. The average error E_a between N observations O and simulations S is:

$$E_a = (1/N)\ \Sigma\ (O_i - S_i) \qquad \text{(A-7)}$$

where Σ indicates summation from i = 1 to i = N. *See also* relative error.

Average flow velocity (or simply average velocity) (V) The ratio of discharge Q to cross-sectional area A at any point in a channel.

Average friction slope (S_{fa}) One of the four approximations used in the HEC-2 and HEC-RAS programs to estimate friction loss between two channel cross sections. It represents the friction loss S_f between two cross sections in function of the friction slopes (S_{f1} and S_{f2}) of the two sections. *See also* average conveyance; geometric mean friction slope; harmonic mean friction slope.

$$S_{fa} = (S_{f1} + S_{f2})/2 \qquad \text{(A-8)}$$

Average travel distance In a watershed or drainage area, the average of the distances from every point in the area to the first downstream channel; alternatively, the distance from the runoff centroid to the first downstream channel.

Average velocity *See* average flow velocity.

Average year A year in which hydrologic characteristics of a basin are approximately equal to their arithmetic mean over a long period (e.g., temperature, streamflow, precipitation). Sometimes called a **normal year**.

Axial-flow pump A pump that diverts water in the axial direction of the pipeline in which its propeller-type impeller is installed. Also called **propeller pump**.

B

Back-end interface A graphical user interface, i.e., a computer program that processes model output data, usually converting text to graphics. For example, a back-end interface can convert ASCII output to graphs, charts, and plots. Also called **output interface** or **postprocessor**. *See also* front-end interface (input interface or postprocessor).

Backflow (1) A flow reversal due to a pressure differential; in particular, the flow of water or other liquid into a potable water distribution system from any unintended source. (2) A flow back into a container or device by gravity or siphonage. Also called **backsiphonage**. In drinking water systems, such devices or arrangements as check valves, vacuum breakers, double gates, or air gaps are used as backflow preventers. *See also* cross connection.

Backflow connection A plumbing arrangement that makes a backflow possible. *See also* cross connection; interconnection.

Backflow preventer An automatic valve installed to prevent backflow by closing when the flow reverses or when the pressure drops. Less reliable, air gaps and vacuum breakers are sometimes used in residences.

Background conditions The biological, chemical, and physical conditions of a water body upstream from the point or nonpoint source discharge under consideration. Background sampling location in an enforcement action will be upstream from the point of discharge, but not upstream from other inflows. If several discharges to any water body exist and an enforcement action is taken for possible violations to the standards, background sampling will be undertaken immediately upstream from any discharge (EPA-40CFR131.35.d-2).

Background load The level of pollution occurring naturally in a stream or a receiving water prior to effluent discharge, watershed development, or similar event.

Backpressure A pressure that can cause water to backflow into the water supply when a user's water system is at a higher pressure than the public system (EPA-94/04). A backpressure valve can be used to prevent backflows.

Backpressure valve A device that prevents backflows by limiting flow in a piping system to a single direction. Its hinged disk or flap opens in the direction of normal flow and closes to prevent flow reversal. Also called **nonreturn valve** or **check valve**.

Backsiphonage A reverse flow condition created by a difference in water pressures that causes water to flow back into the distribution pipes of a drinking water supply from any source other than an intended one (EPA-94/04). Also called **backflow**.

Backup (or back up) A system, part of a system, or unit used as a reserve, substitute, or alternate. Also called a **standby**. For example, in water and wastewater treatment plants, a diesel engine is often used as a **backup system** for an electric motor. In a pumping station, a **backup pump** is an extra pump for use in case one of the units breaks down; it is usually specified as the largest pump of the station.

Backward difference The result of subtracting f(x – Δx) from f(x) in the Taylor expansion of a function f(x) to obtain an approximation to a partial differential equation. Thus, the backward difference, first-order approximation, after truncation, is:

$$f'(x) = \partial f(x)/\partial x = [f(x) - f(x - \Delta x)]/\Delta x \qquad \text{(B-1)}$$

See also central difference; finite-difference method; forward difference.

Backwater The increased depth of water upstream from a dam or obstruction in a stream channel due to the existence of such obstruction. The **backwater curve** is the longitudinal shape of the water surface in a stream or a conduit subject to a backwater condition or a computed water surface profile for which the depth is greater than the critical depth. In general, when the water surface rises in the direction of flow, the water surface is called a backwater curve. The backwater curve that would form, for example, upstream of a weir or reservoir is sometimes called an M1 water surface profile; it is asymptotic to the horizontal line $y = y_n$, where y is the water depth and y_n is the normal depth. The **backwater effect** is the result of the increased depth. *See* critical flow; drawdown curve; and open-channel flow.

Backwater computations Computations carried out to establish the water surface profile under backwater conditions; i.e., when there is a barrier in the channel, the kinetic energy drops, and the water surface is not parallel to the channel bottom. Such computer programs as HEC-2 facilitate backwater computations. Otherwise, one can use Bakhmeteff's solution or the conveyance method.

Backwater valve A plumbing device in a drain or sewer for preventing backflow.

Bacon, Francis *See* hydraulics.

BACT Acronym for best available control technology.

Baffle A flat board, plate, deflector, or other device in a stream, tank, basin, or the like to regulate fluid flow to obtain more uniform velocities or to reduce short-circuiting.

Bailer A long pipe with a valve at the lower end; used to remove slurry from the bottom or side of a well as it is drilled (EPA Glossaries).

Bakhmeteff backwater solution A tabular method to determine water surface profiles under backwater conditions. It is the solution to the differential equation of the water surface of gradually varied flow (*see*, e.g., Simon and Korom, 1997).

Bakhmeteff, Boris A. *See* hydraulics.

Balancing basin A basin used in a hydraulic system to render uniform the volume and composition of flow. It is often used in a wastewater or water supply system to stabilize influent characteristics ahead of treatment units or to facilitate water distribution to customers. Also called **equalizing basin**. A **balancing reservoir** (or equalizing basin) is defined similarly. **Balancing storage** refers to the volume of water that is transferred from the basin or reservoir back to the system.

Ball joint A flexible and spherical pipe joint.

Ball valve A valve regulated by the position of a free-floating ball that moves in response to fluid or mechanical pressure (EPA Glossaries).

Bank The continuous, sloping land that borders a body of water: river, stream, lake, or sea. **Bank protection** by riprap or other means is sometimes provided against erosion. **Bank storage** is the volume of water stored in the banks of a body of water and released completely or partially when the water surface drops.

Bankfull discharge The discharge of an open channel that is flowing full.

Base flood A flood that has a 1% chance of occurrence in any given year; also known as a 100-yr flood, i.e., a flood with a magnitude equaled once in 100 yr. This term is used in the National Flood Insurance Program to indicate the minimum level of flooding to be used by a community in its floodplain management regulations (EPA 40CFR503.9-b and EPA-40CFR6-AA-a). The **base floodplain** means the land area covered by a 100-yr flood.

Baseflow (1) The sustained part of stream discharge, including groundwater runoff and delayed subsurface runoff, but not direct runoff from precipitation or melting snow. It is usually sustained by drainage from natural storage in groundwater, lakes, or swamps. Baseflow is determined from a measured hydrograph at the basin outlet. Given that total runoff consists of baseflow and direct runoff, for an approximate determination, baseflow may be assumed constant throughout a storm and equal to the total flow before the storm. However, there are more accurate methods of hydrograph separation. **Baseflow recession** occurs when the flowrate starts to decrease in a stream fed by groundwater, as can be observed on the corresponding **baseflow-recession hydrograph**. (2) Same as **dry-weather flow** (1). *See also* base runoff; delayed runoff; Figure R-6; groundwater flow; wastewater flow components.

Baseline The condition of a system at a starting point; can serve as a basis for measurement or for tracking future changes. Impact assessment studies usually include a **baseline alternative**, which is an extension of present conditions with minor improvements; it is different from the no-action alternative. Such studies usually include a **baseline survey** to describe existing environmental and socioeconomic conditions. Water supply and sewerage **baseline data** relate to historical water use and wastewater flows. **Baseline wastewater flow** is the flow of wastewater in a sanitary or combined sewer system during dry weather.

TABLE B-1
Elements of Base Model of a Wastewater Collection System

1. Location of lines and manholes
2. Pipe size, slope, rim elevations for terminal manholes, pump station receiving and discharge manholes
3. Location and type of valves and their normal operation/position
4. Location of pump stations and determination of the pump station service areas
5. Location of force mains and force main connections
6. Force main sizes, begin- and end-point elevations, maximum elevation, valves and fittings
7. Pump station name or number, address
8. Type of station: submersible, flooded suction, suction lift, or booster
9. Discharge condition (force main connection or receiving manhole) and location of discharge
10. Pump information: number of pumps, manufacturer, model number, size, pump serial number, impeller number or size, pump speed, motor horsepower, motor speed, design flow and head, pump curve
11. Piping information: suction and discharge piping, fittings and valves, types and sizes of all items
12. Pump station dimensions: wetwell or drywell depth and diameter or length and width, invert depth, pump start and stop settings, piping elevations

Baseline wastewater flow *See* baseline. *See also* baseflow (2); dry-weather flow (1).

Basemap A map containing the important elements common to all other maps or layers of a set; shows basic data that usually remain constant.

Base model A base hydraulic model constructed from known system characteristics. For a sewer system model, such characteristics may include the data listed in Table B-1. Similarly, Table B-2 lists the common data sources for a groundwater model.

Base runoff Sustained or dry-weather flow; usually groundwater runoff. *See* baseflow; delayed runoff; groundwater flow; rainfall–runoff relationship; runoff.

Base wastewater flow (or baseline wastewater flow) *See* baseline; dry-weather flow (1); wastewater flow components.

BASIC Acronym for beginner's all-purpose symbolic instruction code, a simplified computer programming language.

Basic data Recorded observations and measurements, with little processing, but sometimes including minimal computations. **Basic hydrologic data** include all forms of precipitation, streamflow, evaporation, transpiration, and water surface elevations. *See also* Table B-2 for common data sources used in groundwater models.

TABLE B-2
Common Data for a Base Groundwater Model

Adsorption distribution coefficient
Background concentrations
Contaminant sources
Density and viscosity
Dispersivity
Distribution of hydrogeologic units
Hydraulic conductivity initial water levels, gradients
Molecular diffusion coefficient
Porosity
Recharge/discharge
Soil bulk density
Specific storage
Specific yield
Unsaturated soil properties

Basic groundwater equation The fundamental law governing the movement of groundwater. Same as **Darcy's law**: The velocity or flux is proportional to the rate of hydraulic energy loss.

Basic hydrologic data *See* basic data.

Basic hydrostatic law/equation The equation (H-35) expressing hydrostatic pressure P as the product of fluid density ρ by depth y and the acceleration of gravity g.

Basin The surface area within a drainage area, as in a river basin. Also, a natural or artificial structure that can hold water or other liquids. Storage or sedimentation basins usually designate structures smaller than reservoirs, but larger than tanks.

Basin lag Same as **lag** or **lag time**.

Basin performance equation A statistical, first-order kinetic formula used to estimate the performance (or percentage pollutant removal P_r) of a detention system as a function of a removal efficiency coefficient r, a kinetic coefficient k, the average runoff rate Q, the surface area of the detention unit A, and the coefficient of variation C_v:

$$P_r = r\,[1/(1 + kQC_v/A)]^{(1 + C_v)} \qquad \text{(B-2)}$$

Basin recharge The part of precipitation that does not contribute to streamflow or evapotranspiration but remains in the basin to recharge groundwater; the sum of depression storage and soil moisture. *See* Figure R-6; rainfall–runoff relationship.

BAT Acronym for best available technology (achievable under the Clean Water Act).

Batch process A process that does not operate continuously, but rather in discrete steps or with a limited number of items. A batch concrete plant, e.g., operates with batchers and mixers for the production of concrete. In a **batch reactor**, the vessel is closed after the addition of desired quantities of reactants and catalysts. Water and wastewater can also receive a **batch treatment**: a fixed quantity of water or wastewater is processed in a tank, which is then emptied and refilled, if necessary. *See also* continuous-flow system. **Fill-and-draw** is sometimes used for a batch operation.

Battery of wells A series of wells connected to a single pump for water withdrawal. Also called a **gang of wells**.

Bazin discharge formulas Two formulas proposed by Henri Emile Bazin to compute the flowrate through a conduit or channel and the discharge over a rectangular weir. For conduit flow, the Bazin formula for the Chézy coefficient C_z as a function of the Bazin roughness coefficient (β) and the hydraulic radius R is:

$$C_z = 157.6/(1 + \beta/\sqrt{R}) \quad \text{(B-3)}$$

The second Bazin discharge formula is the same as the weir formula (W-4).

Bazin, Henri Emile *See* hydraulics.

Bazin roughness coefficient A coefficient (β) proposed by Henri Emile Bazin to compute the discharge coefficient C_z in the Chézy formula. Depending on the roughness of the channel, it varies from 0.1 to 3.2.

Beach drift Sediment and other materials deposited in patterns parallel to the contours of a beach by waves and currents. Also called **littoral drift** or **shore drift**.

Bed The bottom of a water body or watercourse (as in streambed, lake bed, riverbed).

Bedload, bed material load, and washload Sediment that moves on or near the streambed at a lower velocity than the water. The coarse sediment is called **bedload**. **Washload,** also called **suspended load** or **fine sediment load**, is the suspended particles not found in the streambed. **Bed material load** comes from the bed, including bedload, but excluding washload. *See also* desilting basin; suspended sediment.

Bed slope The slope of the bed of a stream. Between two cross sections, the bed slope is the difference in elevation of the two sections per unit distance along the bed, measured in the direction of flow. Same as **bottom slope**.

Belanger's critical velocity Same as **critical velocity**. Different from Reynolds critical velocity.

Bell-and-spigot joint An arrangement to join two or more clay pipes directly or through a pipe fitting. Each pipe section has one end in a bell-like shape (with an enlarged diameter and polymeric rings) and the other in a spigotlike shape (with a polymeric sleeve). The spigot of one section fits into the bell of the next section. A joint compound is also added for water tightness. Clay pipes can also have **plain ends** and are then joined through polymeric sleeve casts and plastic corrugated rings. Some **bell-and-spigot fittings** include wyes, tees, reducers, and increasers.

Bellmouth A flared or expanding, round entrance to a conduit or an orifice.

Bellmouthed inlet A bellmouthed entrance to a conduit. Also called **flaring inlet**.

Bellmouthed orifice An orifice with an external short tube with a diameter that increases away from the opening.

Bench-scale model A hydraulic model used in a laboratory to represent a natural system at an appropriate scale. (In general, bench-scale testing is the testing of materials, methods, or processes on a small scale, such as on a laboratory worktable.) An example is the porous-media model to study the movement of groundwater, as in Darcy's experiment. Bench-scale models try to replicate the natural system's characteristics, e.g., geometry and other properties. With the advent of computers and the popularity of numerical models, bench-scale models are used mainly for teaching hydraulic engineering. *See also* porosity, porous-media model.

Bench terracing A mechanical soil conservation measure used in India and elsewhere; a ground slope is converted for cultivation into level steplike fields by half-cutting and half-filling.

Bend A section of pipe that is curved or cast to form an angle. It is used to provide a directional change in a pipeline. Common angles are 90, 45, 22.5, and 11.25°.

Beneficial precipitation (or beneficial rainfall) Precipitation or rainfall that yields water available in the soil for plant growth, after all losses; also called **effective precipitation**. It is different from **effective rainfall**, which is rainfall that produces surface runoff, again after deducting various losses.

Benthic Of or pertaining to a benthos, i.e., the bottom of a body of water.

Berm A sloped wall or embankment (typically constructed of earth, hay bales, or timber framing) used to prevent inflow or outflow of material.

Berm ditch A ditch constructed to collect surface runoff and reduce erosion along a berm. *See also* shoulder ditch.

Bernoulli, Daniel *See* hydraulics.

Bernoulli's law, equation, or theorem For incompressible fluids under uniform steady-flow conditions and in the absence of losses, the energy H in ft-lb/lb (or the head in ft) at any point is the sum of the velocity head, pressure head, and elevation head:

$$H = V^2/2g + p/\gamma + z \qquad \text{(B-4)}$$

where V is the velocity (fps), p is the pressure (psf), z is the elevation (ft above a datum), g is the gravitational acceleration, and γ is the specific weight of the fluid (lb/ft^3). For two points A and B along a conduit or channel, the law may be stated as the law of conservation of energy, which takes into account the conversion of hydraulic energy to heat energy (i.e., the headloss) between the two points:

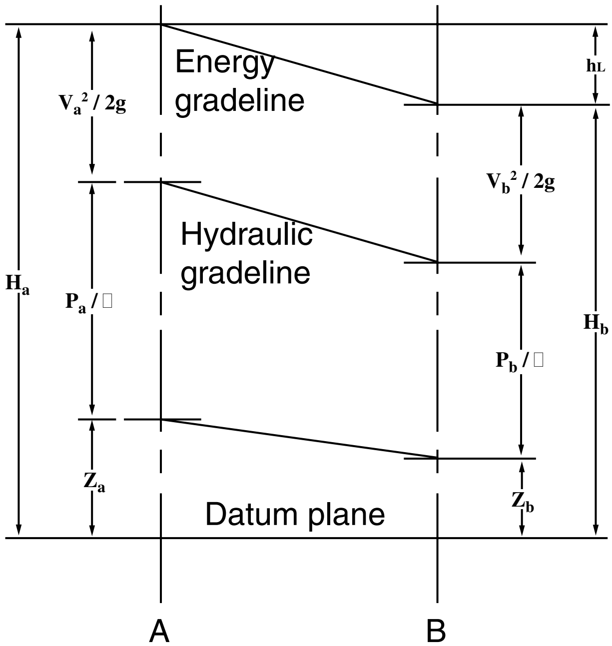


FIGURE B-1 Bernoulli's equation. H_a and H_b represent the total hydraulic energy at points A and B, respectively. See the definition of Bernoulli's law for other notations.

$$V_a^2/2g + p_a/\gamma + z_a = V_b^2/2g + p_b/\gamma + z_b + h_L \quad \text{(B-5)}$$

where the subscripts a and b refer to the flow characteristics at the points A and B, respectively, and h_L is the frictional headloss between them. *See* Figure B-1, which shows the energy gradeline or line of total hydraulic energy available and the hydraulic gradeline or line of piezometric heights (the sum of potential and pressure heads).

Bernoulli's process A process in which the probability of occurrence p of an event is independent of time and past history. For example, in any year, a flood of magnitude x may occur with probability p or not occur with probability 1 − p and the probability that a flood at least as severe will occur k times in N years is given by the binomial distribution function.

Best available technology (BAT) (or best available control technology, BACT) The best technology, treatment techniques, or other means that the EPA administrator finds, after examination for efficacy under field conditions and not solely under laboratory conditions, are available (taking cost into consideration) (EPA-40CFR141.2).

Best hydraulic cross section The cross section that maximizes discharge for a given area and slope. *See also* efficient section; hydraulic efficiency.

Best management practice (BMP) (1) A practice or combination of practices determined to be the most effective and practicable means of controlling point and nonpoint pollutants at levels compatible with environmental quality goals. They include technological, economic, and institutional considerations (EPA Glossaries). (2) The schedules of activities, prohibitions of practices, maintenance procedures, and other management practices to prevent or reduce the pollution of waters of the United States from discharges of stormwater, wastewater effluents, dredged or fill materials, etc. BMPs include methods, measures, practices, or design and performance standards that facilitate compliance with such regulations as effluent limitations or prohibitions and applicable water quality standards. BMPs also include treatment requirements, operating procedures, and practices to control plant site runoff, spillage or leaks, sludge or waste disposal, or drainage from raw material storage (EPA-40CFR122.2 and EPA-40CFR232.2). (3) BMPs are structural, nonstructural and managerial techniques recognized as the most effective and practical means to control nonpoint source pollutants, yet are compatible with the productive use of the resource to which they are applied (EPA Glossaries). (4) In urban stormwater management, BMPs include structural controls or devices for the treatment or storage of runoff to reduce flooding, remove pollutants, and provide other amenities. Stormwater quality ponds are considered among the most effective measures (James, 1994). On construction sites, for example, BMPs generally include measures to prevent erosion, trap pollutants before their discharge, and prevent construction material pollutants from mixing with stormwater. *See also* BMP Planner; stormwater pollution prevention plan. *See* Section II for further information.

bgd Abbreviation for billion gallons per day.

Bias An inadequacy in experimental design that leads to results or conclusions not representative of the population under study. In monitoring or simulation, a tendency of an instrument or model to deviate constantly or systematically from the true value of a measured quantity causes **bias errors**. *See also* precision.

Bidone, Giorgio *See* hydraulics.

Binary Having two parts or components or two possible states or values. A **binary-coded decimal** is a computer code for which a four-bit binary number represents a decimal digit. A **binary digit** (or **bit**) is either of the digits 0 or 1 in the binary number system; also a unit of computer information or of storage capacity corresponding to these digits or to a choice between two likely alternatives, such as yes and no.

Binomial distribution The discrete probability distribution function that corresponds to Bernoulli's process: the probability that an event x of occurrence p will occur k times in n trials is:

$$f(x) = n!p^k(1 - p)^{n-k}/k!(n - k)! \quad \text{(B-6)}$$

The sign ! indicates the factorial of the preceding number.

Biochemical oxygen demand (BOD) A measure of the quantity of oxygen used in the oxidation of organic matter by microorganisms. Usually, the oxidation time and temperature are specified. For example, at 20°C or 68°F, the 5-day BOD or BOD_5 of an average municipal wastewater is approximately 240 mg/l for a per capita water consumption of 100 gal per day. BOD is distinct from the chemical oxygen demand (COD), which measures the amount of oxygen used for the chemical oxidation of organic matter. BOD_5 can be calculated by multiplying the fats, proteins, and carbohydrates by the factors 0.890, 1.031, and 0.691, respectively. Organic acids (e.g., lactic acids) should be included as carbohydrates. The composition of input materials may be based on either direct analyses or generally accepted published values (EPA-40CFR405.11-b).

Bioretention A stormwater management practice that uses native plants and soil conditioning to capture and treat sheet flow from impervious areas. It includes a ponding area over the root zone of the plants, a sandbed to drain and aerate the root zone, and an organic layer on the surface of the soil.

bit Abbreviation for binary digit.

Black-box model Same as **mass–balance model**. In general, a black box is an electronic component with known input and output that can be easily inserted into or removed from a larger system without knowledge of the component's internal structure. *See also* continuity equation.

Black water Water that contains human, animal, or food waste or in general the wastewater generated through toilet use.

Blaney–Criddle method A method proposed and last modified by the NRCS in 1970 to estimate consumptive use (U, in inches per month) as the product of four factors: a mean monthly temperature t (°F), a climatic coefficient related to temperature K_t, a crop growth-stage coefficient K_g, and a monthly percentage of annual daytime hours p:

$$U = p \cdot K_t \cdot K_g \cdot t \qquad \text{(B-7)}$$

Blasius equation An empirical formula relating the pipe friction factor f in the Darcy–Weisbach formula to Reynolds number R_e, particularly valid for $R_e \leq 10{,}000$:

$$f = 0.316/R_e^{0.25} \qquad \text{(B-8)}$$

Bleeder mechanism A mechanism to drain accumulated water in a container, e.g., a pond. In urban stormwater management, some regulatory agencies do not allow bleeder mechanisms to reduce the retained volume of runoff during a storm event.

Blind flange A flange used to close the end of a pipe. It may be a disk with holes for bolting it to a flange.

Block-centered model A type of finite-difference model in which the solutions are calculated at nodes in the center of the model blocks (Spitz and Moreno, 1996).

Blowdown The minimum discharge of recirculating water to remove materials contained in the water, the further buildup of which would cause concentrations that exceed limits established by best engineering practice (EPA-40CFR401.11-p).

Blowoff valve A small, gated takeoff valve installed at a low point in a pressure conduit or at a depression in a pipeline to allow drainage or flushing of the line. Also called a **scour valve** or **washout valve**.

BMP Abbreviation for best management practice.

BMP Planner A decision support system and knowledge base for stormwater quality management; utilizes a dynamic water quality library to which users may contribute data. Consists of simple algorithms to generate pollutant loads and BMP removal rates, as well as provide a guide to effective control of environmental impacts. In addition, it calculates construction and maintenance costs.

BOD Abbreviation for biochemical oxygen demand.

BOD_5 The 5-day measure of the pollutant parameter biochemical oxygen demand or the amount of dissolved oxygen consumed in 5 days by biological processes breaking down organic matter.

Bog An open marsh containing decayed vegetable matter; a wetland that accumulates appreciable peat deposits. Bogs depend primarily on precipitation for their water source and are usually acidic and rich in plant residue with a conspicuous mat of living green moss (EPA Glossaries).

Boiler feedwater Water supplied to a boiler from a tank or a condenser for steam generation. Also called simply **feedwater**.

Booster station A station housing **booster pumps**, which raise the pressure of water or wastewater on the discharge side or lift the liquid to a higher pressure plane. *See* pumping station.

Border An earth ridge or dike constructed to hold irrigation water within specified limits. Also called **border dike**.

Border irrigation Application of water to an area bounded by earth ridges or dikes.

Borehole A hole created or enlarged by a hand or power tool such as a drill or an auger. Same as **drill hole**. **Bored wells** (created by a hand or power auger) are sometimes distinguished from dug, drilled, or driven wells. A percussion or rotary drill is used to excavate **drilled wells**, along with appropriate tools to bring the excavated materials to the surface. A casing equipped with a drive point is used for **driven wells**. Hand tools (picks, shovels, etc.) or sometimes a power shovel and the like are used for **dug wells**.

Borehole log A record of the type and characteristics of the formation penetrated in drilling a borehole by analyzing the cuttings, core recovered, or other information from electronic devices, for example, the elevation of the water table. *See also* drill-hole log; well log.

Borrow pit A pit or other excavation, outside the limits of a road or embankment, from which filling or embanking material is taken.

Bottom slope The slope of the bed of a stream. Between two cross sections, the bottom slope is the difference in elevations of the two sections per unit distance along the bed, measured in the direction of flow. Same as **bed slope**.

Boudin, Emmanuel Joseph *See* hydraulics.

Boundary condition In a modeling exercise, the characteristics of the end points of the model area are called boundary conditions. Contrary to parameters and dependent variables, they are specified and not simulated. Boundary conditions must be specified not only for the outfall, but also for intermediate inflows and outflows and for the independent variables. For example, in a hydrodynamic model, boundary conditions include flows and water surface elevations or a rating curve in the form of a stage–discharge relationship. In a sanitary sewer modeling study, the boundary condition may be a time-stage relationship representing the pressure at the points of connection of various components to a regional transmission system. Monitoring pressures at points of known hydraulic grades can serve to develop such a relationship. In a stormwater management model, boundary conditions may include pond or reservoir stages, as well as the initial stage in each network node at the beginning of the calibration and verification events. In a groundwater model, boundary conditions define flow and transport characteristics at the model boundary; they are selected on the basis of topographic, hydrologic, and geologic data. In a water supply system including a pipeline out of a reservoir, a boundary condition is the constant head at the upstream end of the pipeline. In essence, boundary conditions define the system limits and allow the model user to obtain specific numerical solutions to a given situation from general mathematical formulations. Boundary condition definition entails the identification of the actual boundary (the reservoir, outfall, lake, weir, valve, etc.) and the numerical implication of the condition. *See also* Dirichlet boundary condition; initial conditions; Neumann boundary condition. *See* Section II for further information.

Boundary-layer flow When a fluid flows over a solid surface, the thin layer of fluid in contact with the surface is the **boundary layer**. Velocity is reduced in the vicinity of the boundary because of the forces of adhesion and viscosity. Boundary-layer flow may be laminar or turbulent; it is prevalent in streams and is described in one-dimensional models.

Boundary node A point of known characteristics; for example, in a sewer modeling study, a point in the network where the hydraulic grade is known.

Boussinesq approximation A set of assumptions sometimes used to facilitate the solution of the momentum conservation equation when applied to surface waters: (a) density fluctuations at the surface do not affect flow dynamics or inertia; (b) fluctuations are linearly related to the gradient of the mean; (c) kinematic variations in velocity or momentum are negligible.

Boussinesq coefficient One of two velocity distribution coefficients; *see* Figure V-1; momentum coefficient. The other is the Coriolis or energy coefficient.

Boussinesq equation (1) A nonlinear, partial differential equation representing flow in an unconfined aquifer. It combines Darcy's law, the Dupuit assumption of horizontal flow, the continuity equation, and the rate of change in storage. (2) A formula expressing the unit pressure p in a fill as function of depth d below the surface, the load P, and a slant distance L from the load:

$$p = 3d^3P/2\pi L^5 \qquad \text{(B-9)}$$

Bowen's ratio A heat transfer parameter in the equation of the energy balance method to estimate evaporation from lakes and reservoirs. It varies with the temperatures and pressures at the water surface and in the air.

Box culvert A culvert having a rectangular cross section.

Box drain A small drain having a rectangular cross section.

b/sec Binary digits (bits) per second, a measure of the transmission rate of data.

Brackish water Water with a mineral content between 1,000 and 10,000 mg/l (concentration of dissolved solids), as compared to freshwater, saltwater or saline water, seawater or ocean water, and brine.

Braiding The phenomenon caused in natural streams by currents and sediment transport, which subdivide the stream in several parts separated by spits.

Brake horsepower The actual power required of a motor to drive a pump; equal to the ratio of the water horsepower to the efficiency of the pump. *See* horsepower.

BRANCH Acronym for Branch-Network Dynamic Flow Model of the U.S. Geological Survey.

Branch (1) A small, shallow, natural stream that usually flows continuously, but is turbulent and swift; term used mainly in the southern United States. *See also* stream. (2) A piece of pipe used to make connections in mains.

Branched network As opposed to looped networks, a branched sewer network consists of branch sewers collecting flow from subareas or subcatchments and feeding into main lines or trunk sewers. A branched water supply system is a treelike network in which water flows into the branches from a single trunk. Branched networks are common in irrigation, but rare in potable water supply. *See also* dendritic network.

Branch-Network Dynamic Flow Model (BRANCH) A one-dimensional, dynamic model of the U.S. Geological Survey (USGS) to simulate flow in a channel network (interconnected reaches of rivers or estuaries). Other USGS models are FEQ, FESWMS, and FOURPT.

Branch sewer A sewer collecting wastewater or stormwater from a relatively small area and discharging into another line serving more than one subarea or subcatchment; receives wastewater from both laterals and house connections.

Breach An opening, gap, or rift in a dike, levee, or similar structure; one of the characteristics of a drainage system that can be simulated by the Advanced Interconnected Pond Routing program, along with ordinary links or reaches.

Breaking-wave jump The hydraulic jump that occurs when the downstream Froude number is larger than 2. A breaking wave accompanies an appreciable headloss. *See* Figure H-2; undulating jump.

Breakwater A coastal hydraulic structure built of piles, concrete blocks, large loose rock, etc. from the shore into the littoral zone and designed to protect the littoral zone, as well as shipping and marine structures, from the action of incoming waves. Similar to breakwaters, jetties mainly prevent drift deposit in navigable channels. Other coastal hydraulic structures are seawalls, groins, and revetments.

Bresse, Jacques Antoine Charles *See* hydraulics**.**

Brine Water with a mineral content higher than 35,000 mg/l (concentration of dissolved solids), as compared to freshwater, brackish water, salt or saline water, and seawater or ocean water.

Broad area treatment A treatment method to stabilize a disturbed area by covering it with topsoil and an appropriate seed.

Broad-crested weir A weir with a substantial crest width in the direction of flow over it and no appreciable bottom contraction of the nappe; all weirs having a crest thickness more than 60% of the nappe thickness are considered broad crested. Also called **long-based** or **wide-crested weir**. *See* Figure W-2.

Brook A small, shallow, natural stream that usually flows continuously, but is turbulent and swift; it is not as large as a river or a creek, but not as small and intermittent as the streamlets. *See also* stream.

Brune's trap efficiency curves A set of curves that relate the percentage of sediment trapped by a detention basin (E,%) to the capacity-inflow ratio r of the basin (e.g., in acre-feet/acre-feet per year). The capacity-inflow ratio is actually a measure of detention time. There are three separate curves for fine, median, and coarse solids. For capacity-inflow ratios between 0.0035 and 0.0795, the efficiency varies from 20 to 85% on the median curve and may be estimated from the following equation:

$$E(\%) = 100[1 - 1/(1 + 100r)]^{1.2} \qquad \text{(B-10)}$$

Brush barrier A structure used in the control of sediment on construction sites. It consists of tree limbs, weeds, vines, root mat, soil, rock, and other cleared materials placed at the bottom of a slope.

Bucket The outward curved section at the bottom of a spillway serving to maintain the falling water in the downstream channel. *See* Figure S-9.

Buffer strip A strip of grass or other erosion-resisting vegetation between or below cultivated strips or fields or separating a waterway (ditch, stream, creek) from intensive land use (e.g., by a farm, a residential or commercial subdivision). Also called **filter strip**, **grassed buffer**, and **vegetated filter strip**.

Buffer zone In stormwater management, a vegetation zone that can be used to spread flows and trap sediment in the vicinity of water bodies.

Building drain The lowest horizontal pipe connecting a building's plumbing to the house connection.

Building service The water pipe from the public main to a building.

Building sewer Same as **house connection**.

Bulk density The dry mass of deposited sediment, powdered, or granulated solid material per unit of volume. Also called **dry density**.

Bulk evaporation coefficient A dimensionless coefficient used in the expression of the mass transfer coefficient, which in turn is a factor of the aerodynamic method of estimating evaporation. It has a range of 0.0011 to 0.0014 at an elevation of 25 ft.

Bulkhead A structure of wood, concrete, stone, steel, etc. used to protect a pipe, embankment, or water body from erosion or to separate sections of tanks or vessels.

Buoyancy The ability, tendency or power of a body to float or rise in a fluid; the force supporting a floating body. The upward pressure exerted by a fluid on an immersed body results from the **buoyant force**, which is also called **buoyancy force** or **hydrostatic uplift**. Archimedes' principle states that the buoyant force, equal to the weight of the displaced fluid, acts vertically upward at the **buoyancy center** or center of the displaced mass. A body immersed in a liquid will rise to the surface, float in the liquid, or sink to the bottom, depending on whether its weight is less than, equal to, or larger than the hydrostatic uplift, respectively. The design of ships, the operation of submarines, and the design of pipelines buried in waterlogged soils use buoyancy principles.

Buoyant force *See* buoyancy.

Buoyant hydrostatic force The correct term is simply **buoyant force**.

Buoyant jet A discharge of warm water from a cooling system into an estuary.

Buried channel A former stream channel filled with alluvial or glacial deposits, without any surface indication.

Bury length The distance between the ground surface and the water pipe in a hydrant.

Butterfly gate A gate that acts on a shaft inside a pipe; similar to a butterfly valve.

Butterfly valve A valve that uses a rotating disk to regulate fluid flow in pipes or ducts; the stem-operated disk is parallel to the direction of flow when opened and perpendicular to the flow when closed.

Buttress A pier, wall, or strut at right angle to a restraining wall on the opposite side of the material restrained (e.g., water and soils).

Buttress dam A concrete, or timber and steel, dam consisting of a series of buttresses supporting an upstream face of sloping flat slabs. It is one of four common dam types, the other three are arch, embankment, and gravity dams. *See* Figure B-2.

BWWF Abbreviation for base wastewater flow.

Bypass A system of pipes, conduits, channels, gates, valves, etc. to divert flow from the main path or around a treatment unit, structure, device, fixture, or obstruction. A **bypass channel** (also called **flood-relief channel**) is

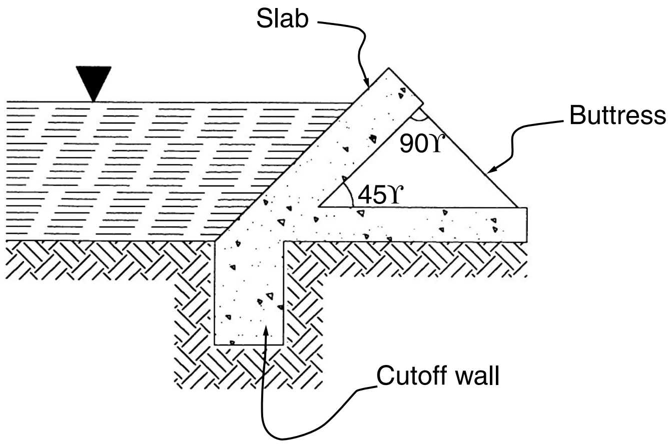


FIGURE B-2 Buttress dam (cross section).

designed to carry excess floodwater from a stream or to divert water from a main channel; *see also* floodway. A **bypass valve** is (1) a valve used to divert fluid to avoid exceeding a pressure limit or (2) a small pilot valve used to equalize pressure on both sides of a larger valve.

Byte A sequence of binary digits treated as a unit by the computer. It is the basic unit of storage needed to store a single character or the amount of information needed to produce one keyboard character, e.g., a letter or a digit.

C

Cache memory Temporary and fast storage in the central processing unit of a computer; accessed before auxiliary storage units for needed information.

CAD Acronym for computer-aided design or computer-aided drafting. Program or programs that enable engineers and designers to sketch and draft technical designs, mechanical parts, and illustrations on the computer. *See* AutoCAD.

CADD Acronym for computer-aided design and drafting.

CAE Acronym for computer-aided engineering.

CAGIS Acronym for CSO Area Geographic Information System, a model for the management of combined sewer overflows (CSO) using a geographic information system (GIS).

Calcareous spring A spring that contains a high concentration of calcium carbonate.

Caliber Internal diameter of a pipe, tube, or other round body.

Calibration (instrument) The process of verifying the precision of an instrument by comparison with a standard or reference.

Calibration (modeling) Generally, model calibration is the iterative process of comparing simulation results to measured data, sometimes collected in independent sets (e.g., flows, pressures, velocities, areas, depths, water surface elevations, concentrations, temperatures), and making modifications to assumed data so that the model simulates the system more accurately. However, there has been some confusion in the use of the terms calibration, validation, and verification as applied to modeling exercises.

- According to Nix (1994), model **validation** includes initial data collection and subsequent model calibration. Sufficient data must be collected and analyzed to define the characteristics of the model domain (e.g., flows, pressures, precipitation, runoff coefficients, etc.). Nix lists four data collection and calibration steps: (a) prioritize the model factors (variables and parameters) according to their pertinence and significance, (b) classify the important model factors as measurable or not, (c) design and implement a data collection program to meet the study objectives, (d) calibrate the model by adjusting the selected parameters. **Validation** helps reduce systematic errors, while a sensitivity analysis allows the assessment of the effects of random errors or uncertainty. Model **verification** is the process of initially checking the model performance, components, and characteristics using known input and output data, sometimes provided by the model developer.

Model calibration is time consuming and often represents a substantial portion of the modeling effort. *See* Section II for further information.

- Spitz and Moreno (1996) defined model **calibration** as the process of altering model input until simulated variables (such as hydraulic heads, pressures, flows, concentrations, potentiometric surfaces) match observed values within a prescribed tolerance. **Calibration** of a groundwater model might involve the following steps: (a) specification of calibration criteria and a calibration protocol; (b) calibration of the flow model before the flow and transport model; (c) simulation of natural background conditions; (d) modification of model assumptions and uncertain input data; (e) prediction of transient, flow, and transport conditions; (f) evaluation of model predictions against historical observations; (g) evaluation of model performance. Model **validation** or model **verification** includes the comparison of the model results with a data set different from the calibration data set and, if the comparison is not satisfactory, the recalibration of the model using both sets of data. Calibration and validation prior to application constitute model **testing**.
- For Martin and McCutcheon (1999), model **calibration** is the process of iteratively changing a handful of critical parameters (selected, e.g., from a literature review) to obtain a reasonable fit between simulations and measured calibration data. "Model **validation**, **evaluation**, **confirmation**, or **testing** is the process of assessing the degree of reliability of the calibrated model using one or more independent data sets. The calibrated model parameters are held constant and the independent initial and boundary conditions used to simulate new conditions.… **Verification** is confirmation of the numerical accuracy of computer codes by comparison of output to exact analytical solutions or independent calculations that are exact.… **Validation testing** is used only to describe the process of confirming that simulations are reasonably accurate and precise using data that are but a measure of the true state of the system being simulated.… **Calibration and validation** are now considered initial steps in an iterative process that can involve repeated calibrations and validations every five years or so" (pp. 77–88). **Final calibration** is the process of calibrating the model using both calibration and validation data; it yields an operational model. Martin and McCutcheon recommended the following procedure: (a) determine the objectives of the modeling project; (b) design an appropriate integration of the modeling and data collection aspects; (c) select an appropriate model; (d) run the model and conduct a preliminary **sensitivity analysis** to define critical parameters and help design and implement a program to collect data (initial and boundary conditions, calibration and validation data) (boldface added by author).

Calibration data Data used in the calibration process. They may include inflow hydrographs, hydraulic characteristics (pump curves, pipe dimensions and elevations), and system fittings such as valves, bends, and tees, as opposed to model simulation parameters (e.g., the timestep), and the variable flows and pressures.

Calibration precision The degree of agreement between measurements of the same known value; expressed as a ratio (p = d/C) of the average difference between the observation and the known parameter d to the known parameter C.

CAM Acronym for computer-aided mapping.

Canal An artificial open channel or waterway used for transportation, irrigation, waterpower, or simply for water conveyance. The distinction between a ditch and a canal is that the former is usually unlined and has a cross-section area less than 6 ft^2. For the differences among various watercourses. *See also* drainage swale.

Canal lock A type of spillway crest gate with a face that is a section of cylinder that rotates about a horizontal axis on the downstream end of the gate. The gate, widely used in large installations, can be raised or lowered by winches or hoists acting on the bottom; it can also be closed under its own weight. Also called **radial gate** and **tainter** or **taintor gate**.

Capacity The ability of an installation to perform or provide a service, such as the ability of a basin to hold water (volume), the ability of a pump to raise wastewater (flow or power), or the ability of a treatment plant to process water or wastewater (flow in mgd, e.g., or pollutant removal in pounds per day). Also, the ability of a utility to meet the demand of its customers. The **capacity curve** of a reservoir is its **storage–capacity curve**, which shows the relationship between its volume of water and the elevation of its water surface. The maximum discharge of a hydraulic structure or the maximum flow that a treatment plant can process is sometimes called its **carrying capacity**.

Capacity–inflow ratio A parameter used in Brune's trap efficiency curves. It is the ratio of the storage capacity of a reservoir, basin, or pond to the annual runoff or essentially the detention time in the unit.

Capillarity A result of surface tension and adhesion between a liquid and a solid surface that draws the liquid upward.

Capillary action Movement of water through small spaces due to **capillary forces** (adhesion of a liquid to a solid surface, which causes the liquid to rise against the surface).

Capillary force *See* capillary action.

Capillary fringe The part of the vadose zone overlying the water table; a porous material that contains capillary water. The capillary fringe may extend or rise to the root zone and be subject to evapotranspiration. *See* Figure S-14; subsurface water.

Capillary lift The height to which water rises in a tube under capillary action.

Capillary pressure The difference between air pressure and water pressure in the vadose zone. *See* capillary fringe.

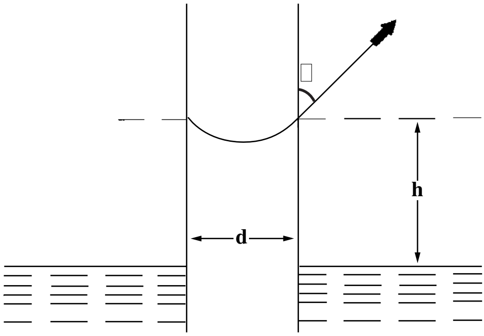


FIGURE C-1 Capillary rise.

Capillary rise The result of capillary action, as may happen in small pores of soils or in small-diameter glass tubes. Equation C-1 expresses the height of the capillary rise h as a function of the diameter d of the glass tube or soil pore, the surface tension of the liquid σ, the angle of adhesion α between the liquid and the tube or soil, the specific weight γ of the liquid (Figure C-1). The capillary rise in soils varies from 3 cm in sand of 2 mm to more than 30 m in clay particles smaller than 0.002 mm.

$$h = 4\sigma \cos \alpha / d\gamma \tag{C-1}$$

Capillary suction The process by which water rises above the water table into the void spaces of a soil due to tension between the water and soil particles. *See also* Green–Ampt equation.

Capillary water Subsurface water in the capillary fringe of the vadose zone. It comes from the intermediate zone by gravity and is held by capillary forces while in transit to the water table. *See* Figure S-14; subsurface water.

Capillary wave A wave with a length shorter than 6.28 cm, as opposed to a gravity wave.

CAPPI Acronym for constant altitude plan precipitation index. A CAPPI map is basically a contour map of the rainfield at a given level above the earth's surface.

Carbonated spring A spring with water that contains carbon dioxide.

Carrying capacity *See* capacity.

Carryover storage Storage designed to compensate for deficits in dry years by holding excess water in wet years. Also called **over-year**, as opposed to within-year, **storage**.

CASCCADE Acronym for Co-evolving Assistant Software for Changing Computational and Data Environments. It links ANNIE (a widely used program to manage hydrological time-series data from U.S. Geological Survey) with SWMM (Stormwater Management Model, developed by the U.S.

Environmental Protection Agency). CASCCADE is a graphical user interface that facilitates data import and export between the main programs.

CASCCADE-2 A version of the computer program CASCCADE that links HEC-DSS (an HEC program to manage hydrological time-series data) and SWMM (Stormwater Management Model, developed by the U.S. Environmental Protection Agency). This graphical user interface facilitates data import and export between the main programs.

CASS WORKS An integrated management software developed by RJN Group, Inc., of Wheaton, IL, for water distribution, sanitary sewers, storm drainage, treatment facilities, parks and recreation, and geographic information system (GIS). The **CASS WORKS database** contains pump station information, such as station address, number of pumps per station, pump make and model, pump speed, horsepower, pump design point, and impeller size. This information may be used in the selection and validation of pump curves to use in a modeling exercise.

CASS WORKS Sewer Hydraulic Modeling Module (CASS WORKS SWMM) A graphical user interface based on the TRANSPORT Block of the Stormwater Management Model (SWMM).

Catalog In computer programs such as HEC-DSS, a catalog is a list of pathnames in the files, with a record of date, time, and origination of the latest changes.

Catastrophic flood A concept used in the safe design of flood mitigation works, particularly for sizing flood control reservoirs; twice the size of the normal maximum flood. Another design concept is the probable maximum flood.

Catch basin A basin, chamber, or well near the curb of a street as a collection point for surface water or stormwater runoff and as a trap for sediment and debris. Curb inlets serve the collection purpose. The current tendency is to omit catch basins in designing inlets and to include adequate self-cleansing velocities in the drains. Cross connections with storm drains and catch basins are often a source of infiltration/inflow in sanitary sewer systems. *See also* curb inlet; inlet.

Catch drain A diversion channel to intercept water above a road or along a slope.

Catchment, drainage area, drainage basin, river basin, or watershed (1) The area of land that drains water, sediment, and dissolved materials to a common outlet at some point along a stream channel (EPA-94/04). (2) The land area that drains into a stream; an area of land that contributes runoff to a specific delivery point. Large watersheds may be composed of several smaller "subsheds," each of which contributes runoff to different locations that ultimately combine at a common delivery point (EPA Glossaries). Catchments can be determined on topographic maps and separated from adjacent areas by divides or ridges. (3) A **catchment area** or **catchment basin** refers to the intake area of an aquifer, to an area tributary to a surface water body, to the drainage area of a sewer, or to a collection area for rainwater to be stored in a reservoir.

Catchment model A conceptual model representing the hydrological interactions occurring in a catchment. It views the catchment as a series of linked storage processes with inflows and outflows. Equations defining storages and flows embody such characteristics as area, soil, vegetation, slope, and drainage to allow the model to predict catchment responses to rainfall. *See also* watershed model.

Catchwork or catchwater (1) A ditch for catching water on sloping land. (2) An artificial irrigation system on sloping land.

Cavitation The action of a centrifugal pump attempting to deliver more water than allowed by suction. Then, the water pressure decreases below vapor pressure, which turns the water into vapor. When the vapor bubbles move to points of higher pressure, they collapse violently, damaging the pumps and the pipes. Cavitation results also from the formation of gas pockets or bubbles on the gate of a valve. Cavitation is accompanied by loud noises that sound like someone is pounding on the impeller or gate with a hammer. Cavitation may also occur under the nappe of a spillway when the actual head over the spillway exceeds the design head by 50% or more. The **cavitation parameter** is a proportionality factor σ equal to the ratio of the net positive suction head H′ to the total pump head H and varying from 0.05 to 1.0. The pump manufacturer usually specifies it. *See* the formula for the net positive suction head (NPSH), Equation (N-11).

$$\sigma = H'/H \tag{C-2}$$

CD Abbreviation for compact disc.

CDF Abbreviation for (1) centralized detention facility and (2) cumulative distribution function.

CDROM or CD-ROM Acronym for compact disc read-only memory. A computer storage disc that uses laser optics instead of magnetic means to read data. *See* ROM.

Celerity The velocity of propagation of a wave through a fluid, due to pressure or gravity, relative to the undisturbed velocity. A wave is a variation in flow. For example, the celerity of a flood wave through a reservoir, usually greater than the flow velocity in the natural channel, is approximately equal to the gravity wave celerity C_g:

$$C_g = \sqrt{gy} \tag{C-3}$$

where y is the depth of water in the reservoir, and g is the acceleration of gravity. In supercritical flow, the mean velocity of the fluid is superior to the celerity of the gravity wave. *See* Courant number; dynamic wave celerity; gravity wave; kinematic wave approximation.

Celsius degree Unit of temperature interval equal to the kelvin; formerly known as degree centigrade. **Celsius scale** is the international name for the **centigrade scale**, for which the freezing point is at 0°C and the boiling point at 100°C at a barometric pressure of 760 mm Hg or 101.325 kPa. The Celsius and Kelvin scales are related as follows: temperature in

Celsius = temperature in Kelvin minus 273.15. To convert to the Fahrenheit scale, multiply degrees centigrade by 1.8 and add 32.

Centipoise (cP) The unit of absolute viscosity. The absolute viscosity of water at room temperature or about 20.2°C is 1 cP.

Central difference The average of a forward difference and a backward difference in the finite-difference method. Thus, the central difference, first-order approximation for a function f(x) is, after truncation:

$$f'(x) = \partial f(x)/\partial x = [f(x + \Delta x) + f(x - \Delta x)]/2\Delta x \qquad \text{(C-4)}$$

See also backward difference; finite-difference method; forward difference.

Central processing unit (CPU) A chip that acts as the brain of the computer; controls and performs all processing activities. Also called **microprocessor**.

Centrifugal pump A continuous-flow pump that moves water and other liquids by accelerating them radially outward in an impeller fixed on a rotating shaft and enclosed in a casing. The pump imparts pressure to the liquid through the centrifugal force created by the impeller. A **centrifugal screw pump** has a screw-type impeller. It is one of the most widely used in water supply, drainage, wastewater disposal, and irrigation. Also called **radial-flow pump**. There are two other types of continuous-flow pumps: axial flow and mixed flow. Noncontinuous-flow pumps are called **positive displacement pumps**.

Centroid time of travel *See* hydraulic residence time.

C factor Pipe roughness coefficient used in the Hazen–Williams formulas.

CFF Abbreviation for confined filtration facility.

CFL stability criterion Courant–Friedrichs–Lewy stability criterion. Same as **Courant stability criterion**.

cfs (or ft³/sec) Abbreviation for cubic foot (feet) per second, a unit of flow equivalent to 1 ft^3 in 1 sec; for the measurement of liquids and gases. 1 ft^3/sec = 448.8 gpm = 0.646 mgd = 28.32 l/sec = 2446.6 m^3/d. Another abbreviation is cusec.

Chamber A space enclosed by walls, e.g., a compartment, the space in a channel lock between the upper and the lower gates, a diversion, grit, or junction chamber.

Chance-constrained optimization An optimization method that uses specialized mathematical models with at least one probabilistic parameter. In stormwater management, e.g., probabilistic parameters include rainfall intensity and infiltration rate.

Channel A natural or artificial waterway that contains flowing water periodically or continuously. It has definite, although variable, geometric characteristics, such as bed, banks, and slope. A channel may also be a ditch or drain excavated for the flow of water. There may be channels within large bodies of water, for example, with the deep areas used for navigation. Channel geometric properties commonly used in hydraulics and hydrology include: the area A, the wetted perimeter P, the top width W, the hydraulic radius R, and the hydraulic mean depth D_m. *See* open channel flow.

Channel improvement The improvement of flow characteristics in a channel by clearing, excavation, shaping, lining, etc. *See also* channel stabilization.

Channelization Straightening and deepening streams so water will move faster, a marsh-drainage tactic that can interfere with waste assimilation capacity, disturb fish and wildlife habitats, and aggravate flooding (EPA-94/04).

Channel of approach The stretch of a channel that precedes a control structure.

Channel-phase runoff Runoff in open channels. *See* runoff.

Channel precipitation The precipitation that falls directly into a channel; a component of overland flow or surface runoff. *See also* rainfall–runoff relationship.

Channel roughness Property of the channel such that it offers frictional resistance to flow; expressed as roughness coefficient or friction factor in the velocity formulas. *See*, for example, Chézy formula; Manning formula.

Channel routing The process of deriving the outflow hydrograph for a river reach from its inflow hydrograph; based on the principle of mass conservation. Channel routing requires solving the gradually varied, unsteady flow equations or using simpler techniques of hydrological routing. The term is also applied to the method of accounting for sources and sinks on the hydrographs, including channel storage. *See* continuity equation.

Channels (in modeling studies) *See* link.

Channel section The cross section of a channel taken perpendicular to the direction of flow. *See also* discharge area; flow area.

Channel stability The condition of an unlined channel with characteristics that do not change significantly over the long term as a result of scour, sediment deposition, or other factors. *See also* extremal hypothesis (or variational principle); regime theory; tractive force theory.

Channel stabilization Channel improvement, mainly for the prevention of erosion, using stone revetment, concrete lining, vegetation, etc.

Channel storage Water temporarily stored in channels while en route to an outlet or the in-channel storage volume depending on the stage of water surface in the channel. Basically, it is the volume of water in the channel at any point. It consists of prism storage and wedge storage. Generally, storage is greater during the rising limb than the receding limb of a storm hydrograph. *See* Figure C-2.

Channel storage routing *See* storage routing.

Characteristic curve *See* pump characteristic curves.

Characteristic length A convenient reference length, often constant, such as the hydraulic radius, a conduit diameter, or the hydraulic mean depth, used in several formulas (e.g., Reynolds number, Froude number).

Characteristics (method of) One of three commonly used methods to solve the one-dimensional, unsteady flow equations. It converts the partial differential equations into ordinary differential equations that can be solved numerically or by a combination of analytical and numerical techniques. The other two common methods are the finite-difference and finite-element methods.

Chart datum Same as **datum plane**.

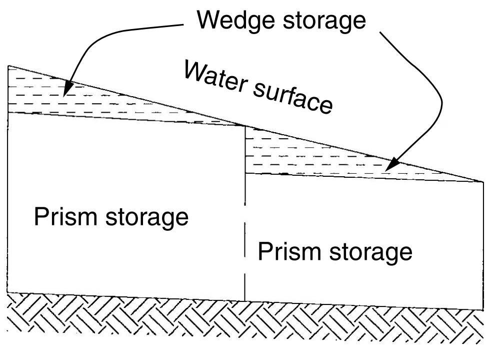


FIGURE C-2 Channel storage.

Check A device or structure installed in a water body to control the flow or the water surface. A **check dam** is a small, low, fixed structure built of timber, loose rock, masonry, brush, concrete, or logs to control water flow in an erodible channel or irrigation canal. It may also be used for groundwater recharge by spreading water in shallow basins. A **check gate** is installed in a canal or ditch to allow water diversion to another channel or to adjacent land. **Check valves** are devices that limit flow in a piping system to a single direction. Their hinged disk or flap opens in the direction of normal flow and closes to prevent flow reversal. Also called **backpressure valve** or **nonreturn valve**.

Chézy coefficient Same as the friction coefficient C_z in the Chézy formula.

Chézy formula A basic hydraulic formula for flow of water in open channels; developed by the French engineer A. Chézy while designing a canal for the Paris water supply in 1768. It expresses the velocity of flow V as a function of the hydraulic radius R, the bed slope S_o, and a friction coefficient C_z, i.e.,

$$V = C_z \sqrt{RS_o} \qquad \text{(C-5)}$$

The friction coefficient depends on the Reynolds number, on boundary roughness, and on channel or conduit geometry. These factors can be expressed by the drag coefficient C_D:

$$C_z = \left(2g/\sqrt{C_D}\right) \qquad \text{(C-6)}$$

where g is the gravitational acceleration. In 1889, Manning presented a formula for this coefficient, which was independently derived by Strickler in 1923 and by others:

$$C_z = R^{1/6}/n \qquad \text{(C-7)}$$

where n is Manning's n factor or coefficient. *See also* Bazin discharge formula; Kutter formula.

Chézy resistance factor The friction coefficient C_z used in the Chézy formula.

Chicago hydrograph method A computational technique for the analysis of Chicago's drainage problems. It may be modified for application to other urban areas. It uses a design hyetograph, Horton's infiltration equation, an ogee-shaped curve for depression storage, and Izzard's overland flow hydrograph.

Chute An inclined hydraulic structure (such as a trough, tube, or shaft) for conveying liquids or granular materials to a lower level. A **chute spillway** includes a steep open channel (the chute or trough), usually wider at the bottom than at the crest to convey the overflow from earth- or rock-fill dams.

Cipolletti weir A trapezoidal weir with notch side slope of one horizontal to four vertical; used to measure flow in open channels, particularly at contractions in streams. The flaring of the sides compensates for the effect of the end contraction. The Cipolletti weir's discharge formula relates the discharge Q(ft^3/sec) to the base width or weir length L (ft) and the weir head or the water depth H (ft) on the upstream side (at a point where the surface curvature does not affect water level):

$$Q = 3.37LH^{1.5} \tag{C-8}$$

See also Figure W-3; Francis formula.

Circle of influence The circular outer edge of a depression produced in the water table by pumping water from a well (EPA-94/04). *See also* cone of depression, cone of influence.

Cistern A small tank or reservoir that stores water (e.g., rainwater) for a home or a farm.

Clarifier A quiescent basin or tank for the removal of suspended (settleable) solids by gravity. Also called **sedimentation basin/sedimentation tank** and **settling basin** or **settling tank**.

Clarifier weir The main device constituting the outlet of a sedimentation tank; designed to skim the clarified liquid from the surface and maintain deposited solids in the tank. Typically it is a 90° V-notch weir with a loading (called weir overflow rate) of 10,000–30,000 gallons per foot per day. *See also* effluent weir; outlet weir.

Clark method A method that uses two **parameters** (time of concentration and storage coefficient) and a simplified form of the continuity equation to develop an instantaneous unit hydrograph, which can then be converted into a unit hydrograph of any duration. The two parameters are usually related through regression equations to basin characteristics such as slope, imperviousness, and drainage basin area. *See also* the SCS hydrograph method; Snyder method.

Clay An inorganic soil material, mainly hydrous aluminum silicate, with grains smaller than 0.005 mm in equivalent diameter, plastic when wet, rigid when dried, and vitrified when fired to high temperatures; used as coagulant aid in water treatment, as lining material in waste disposal, or for the fabrication of sewer pipes. A **clay pipe** or tile consists of clay baked in a kiln. **Clay soil** is a mixture of clay, sand, and silt containing less than 40% of any of these materials. *See also* soil classification.

Clean hydrograph A hydrograph obtained by eliminating undesirable or inaccurate readings from raw field data; e.g., for a representative dry-weather hydrograph, subtract rain days, holidays, weekends, surcharge condition data, etc. *See also* net hydrograph. *See* Section II for further information.

Cleanout A structure or device providing access for inspection and cleaning purposes, e.g., a pipe fitting containing a removable plug for access to a pipe run.

Clean Water Act The 1972 U.S. Federal Water Pollution Control Act regulating discharges into national waters; later renamed Clean Water Act in 1977; updated in 1987. Important sections concern the National Pollution Discharge Elimination System (NPDES), lists of pollutants and limits on their discharge, and best available technology requirements.

Clean-water reservoir In a water supply system, a reservoir that holds treated water before it is distributed to customers. Also called **finished-water reservoir**. *See also* clear well.

Clear well A tank or reservoir of filtered water for filter backwashing; sometimes used simply for storage of filtered water or as chlorine contact chamber. Also called **clear-water basin** or **clear-water reservoir**.

Climatic year A continuous period of 12 months for recording hydrological and climatic data, for example, the period October 1 to September 30 selected by the U.S. Geological Survey. *See also* water year.

Closed basin An area that drains to a depression, lake, pond, etc. that has no surface outlet; loses water by evaporation and percolation. *See also* continental basin.

Closed-conduit flow Flow in a closed conduit, i.e., flow under pressure, as opposed to open-channel flow.

Closed-conduit system A water or sewer system in which all flows are under pressure, i.e., in closed conduits. *See also* manifolded system.

Cloud *See* rain. A **cloudburst** is a very intense rainstorm of short duration over a small area; a storm of an intensity of 4 in/h (100 mm/h) or 10 times the intensity of a heavy storm as defined by the U.S. Weather Bureau. **Cloud detection radars** are weather radars that detect clouds instead of precipitation. **Cloud seeding** is the introduction of silver iodide, dry ice, or other chemicals into clouds to induce rain.

cm Abbreviation for centimeter. 1 cm = 0.01 m = 0.3937 in.

CMP Abbreviation for computer mapping program.

C_n Notation for the Courant number in the definition of the convergence and stability of numerical solutions.

CN Abbreviation for curve number in the SCS method.

Coarse sand Sediment particles larger than 0.5 mm in equivalent diameter. *See also* sand; soil classification.

Coastal hydraulics The study of the effects of wind-induced waves and tidal waves on coastal areas. **Coastal structures**, designed to improve navigation or protect the coast against erosion include jetties, breakwaters, seawalls, groins, and revetments. Coastal hydraulics is also important in the design of docks and wastewater ocean outfalls.

Coastal structures *See* coastal hydraulics.

COBOL Acronym for common business-oriented language, a source-code programming language based on English words and phrases.

Cock A device or mechanism that regulates the flow of liquid, such as a hand-operated valve, faucet, plug, or tap.

COD Abbreviation for chemical oxygen demand.

Code *See* numerical computer code.

Coefficient A quantity, usually represented in formulas or equations by a letter, but determined analytically or empirically.

Coefficient method *See* runoff coefficient.

Coefficient of determination A dimensionless parameter used in regression analysis to measure the degree of correlation between two sets of data. It approaches 1 for a high degree of correlation but approaches 0 when the data are not correlated. For example, in hydraulic modeling, for a set of N observations (O_i through O_N) and N simulated values (S_i through S_N), the coefficient of determination r is

$$r = D_1/[(D_2)\cdot(D_3)]^{0.5} \quad \text{(C-9)}$$

where:

$$D_1 = N\Sigma O_i\ S_i - \Sigma O_i \Sigma S_i$$

$$D_2 = N\Sigma O_i^2 - (\Sigma O_i)^2$$

$$D_3 = N\Sigma S_i^2 - (\Sigma S_i)^2$$

and Σ indicates the summation from i = 1 through i = N. The **correlation coefficient** is the square (r^2) of the coefficient of determination.

Coefficient of permeability *See* hydraulic conductivity; permeability coefficient.

Coefficient of regime The ratio of the maximum daily flow to the minimum daily flow in a given year.

Coefficient of variation (COV) A dimensionless coefficient C_v defined as the ratio of the standard deviation σ to the mean μ of a data set or of a distribution. It provides an idea about the variability of the data set; e.g., it varies between 0.2 and 0.4 for many unregulated streams in the United States and is much lower for regulated streams.

$$C_v = \sigma/\mu \quad \text{(C-10)}$$

Coefficient of viscosity A measure of the internal resistance of a fluid to flow; equal to the ratio of the viscous shearing stress τ to the velocity gradient $\partial V/\partial s$. Also called **absolute viscosity** or **dynamic viscosity**.

Coefficients For model coefficients, *see* model parameters. *See also* acceleration head; Chézy coefficient; composite runoff coefficient; determination coefficient; discharge coefficient; drainage coefficient; energy loss (orifice); equivalent roughness coefficient; Euler number; flow (orifice); Hazen–Williams formula (flow, headloss, and velocity); k-factor; Kutter formula; Lewis number; Manning coefficient; permeability coefficient; Prandtl number; rating curve; roughness coefficient; runoff coefficient; Schmidt number; skew coefficient, skewness; soil storage; time-weighting factor; variation coefficient; viscosity; Weber number.

Cofferdam A temporary damlike structure built around a site to exclude water and provide access. It may consist of single or double sheet piling or an earth embankment.

Coincident draft A design flow used in water supply planning to represent the maximum likely demand for community purposes during a serious fire. It is added to the fire flow requirement to size the transmission and distribution systems.

Colebrook–White equation A formula developed by Colebrook and White; published in 1939. In flow through pipes, it relates the friction factor f to the pipe diameter D, the Reynolds number R_e, and the pipe wall roughness factor ε:

$$f^{-0.5} = -2 \log_{10}[(\varepsilon/3.7D) + 2.51\ f^{-0.5}/R_e] \qquad \text{(C-11)}$$

The Moody diagram solves this equation graphically. The ratio ε/D is called the relative pipe roughness. The roughness factor ε has also been called **sand grain size**, **roughness size**, **equivalent sand grain roughness**, and **magnitude of the average roughness elements of the pipe**. *See also* Moody explicit formula.

Colebrook–White transition formula Same as the **Colebrook–White equation**.

Collection main (1) A public sewer receiving flows from building services or individual systems. (2) A main sewer in a collection system, i.e., receiving flows from branch and submain sewers; also called a **trunk sewer**.

Collection system In wastewater or stormwater management, a system of conduits and pumping stations that receive and convey flows to a treatment plant or a disposal facility.

Collector sewers Pipes used to carry wastewater from individual sources to an interceptor sewer that will carry it to a treatment plant (EPA-94/04).

Collector well A vertical vault connecting a series of horizontal shafts for the collection of groundwater near a river.

Colloidal dispersion A mixture resembling a true solution, but containing one or more substances finely divided but large enough to prevent passage through a semipermeable membrane. It consists of particles that are larger than molecules, settle out very slowly with time, scatter a beam of light, and are too small for resolution with an ordinary light microscope (EPA-40CFR796.1840-i).

Colloids (colloidal matter, colloidal solids) Finely divided solids that do not dissolve, but remain dispersed in a liquid for a long time due to their very small size and negative electrical charge, which prevents them from clumping together and settling out. *See* colloidal dispersion; dissolved solids; solids; suspended solids.

Combination flow Any combination of weir flow, low flow, and pressure flow in flow-routing problems involving bridges or culverts. **Weir flow** is flow over the bridge or culvert and the immediate sections of the approach roadway; computed with a weir equation. **Pressure flow** occurs when the upstream energy gradeline is above the low chord of the bridge; the sluice gate equation or the standard orifice equation is used. A **low-flow** condition means that all the water flows through the bridge or culvert opening, and the water surface elevation is not above the low chord.

Combination method A combination of the aerodynamic and energy balance methods to estimate evaporation rates from lakes and reservoirs. *See* Penman method.

COMBINE A time-series module of the Stormwater Management Model (SWMM); used for handling interface files.

Combined sewer A sewer designed to carry both wastewater and stormwater or surface water. Combined sewers sometimes overflow during a heavy storm, by design and at selected locations, when the combined flow exceeds the capacity of the sewers. The excess is frequently discharged directly to a receiving stream without treatment or to a holding basin for subsequent treatment and disposal (EPA Glossaries). (A separate sewer system has separate sanitary and storm sewers.)

Combined sewer overflow Discharge of a mixture of stormwater and untreated wastewater when the flow capacity of a sewer system is exceeded during rainstorms. Stormwater runoff may also carry toxic chemicals from industrial areas or streets. (EPA-94/04).

Combined sewer system A sewer system that conveys wastewater to a treatment plant during dry weather, but conveys both wastewater and stormwater to treatment or overflow works during wet weather.

Common sewer A sewer that is available to all abutting properties. *See also* public sewer.

Community water system A public water supply system of a certain size, e.g., serving at least 15 connections or 25 year-round residents. Also called a **public water system**.

Compact disk or disc (CD) An optical disk on which digitized matter such as computer data or music is encoded. Currently, a CD can store 600 MB.

Compact disk, read-only memory (CDROM or CD-ROM) A computer storage disk that uses laser optics instead of magnetic means to read data. *See* read-only memory.

Compiler A program that transforms computer codes into executable files.

Complete duration series The complete set of data recorded over a certain period. *See also* annual duration series; exceedance series; partial duration series; time series.

Completely mixed flow *See* complete mixing.

Complete mixing A flow or treatment condition that assumes all incoming material to a unit is distributed instantly and uniformly, thus creating uniform pollutant concentration throughout the unit. Under complete mixing conditions, the fate of pollutants may be represented by a first-order decay equation; i.e., the change in pollutant mass in the unit equals the influent mass minus the effluent mass minus the first-order decay of pollutant (*see*, e.g., Nix, 1994):

$$d(C \cdot v)/dt = QC_i - QC - K_d \cdot C \cdot v \qquad \text{(C-12)}$$

with C = effluent pollutant concentration (ML^{-3}), C_i = influent pollutant concentration (ML^{-3}), K_d = decay coefficient (T^{-1}), Q = inflow rate (L^3T^{-1}), t = time (T), and v = volume of water in the unit (L^3). *See also* continuous stirred reactor; plugflow.

Composite roughness A measure of the overall roughness of a channel as a function of the characteristics of its elements. Also called **equivalent roughness** or **roughness height**.

Composite roughness coefficient An average or equivalent coefficient used in HEC-2 and other models to represent a channel with major changes in cross-section geometry or in roughness. The water area is subdivided fictitiously into N subareas, each having a known wetted perimeter P_i and roughness coefficient n_i. The composite or equivalent roughness coefficient n_c is:

$$n_c = (\Sigma P_i n_i^{1.5}/P)^{2/3} \qquad \text{(C-13)}$$

where P is the total wetted perimeter of the section, and Σ is the summation from i = 1 to i = N (Hoggan, 1997). *See also* equivalent roughness coefficient; Figure C-3.

Composite runoff coefficient *See* runoff coefficient.

Composite sample The flow-weighted average of several samples taken over a given period, as compared to a grab sample, which is a single sample representative of the composition of the flow at a particular time and place.

Composite unit hydrograph A unit hydrograph for a drainage area A developed by (a) dividing the area into N subareas (A_1 through A_N), (b) constructing independently the unit hydrographs of the subareas, and (c) adding up the ordinates of these unit hydrographs, taking care to shift the values on the timescale to reflect the different travel times from the various subareas.

Compound channel A channel with properties that vary over the cross section. To solve discharge problems, divide the cross section into simple subsec-

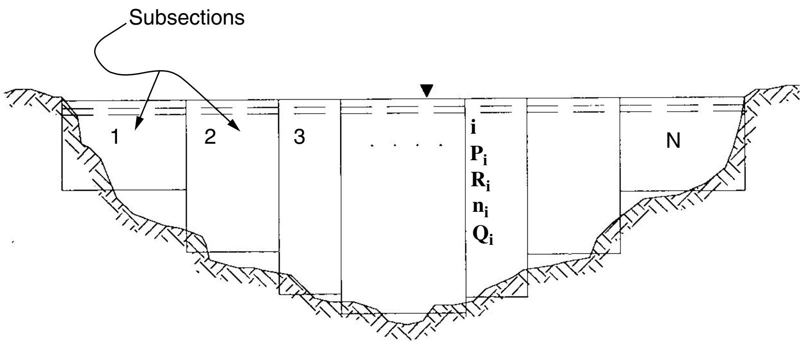


FIGURE C-3 Compound channel.

tions. *See* composite roughness coefficient; conveyance; equivalent roughness coefficient; Figure C-3.

Compound hydrograph The hydrograph of an intermittent storm event obtained by adding the hydrographs of the subevents.

Compound pipe A pipeline or a loop made of two or more pipes.

Compound tube A tube made of several tubes of different cross or longitudinal sections.

Compound weir A weir made of two or more sections, e.g., a trapezoidal or rectangular section with a V-notch weir at the bottom. The lower V-notch allows better accuracy in measuring low flows, while the full section can measure larger peak flows than a triangular weir. *See* Figure W-4.

Computational blocks *See* model computational blocks.

Computational efficiency (C_e) The accuracy of an algorithm per unit execution time, computed as:

$$C_e = k/\varepsilon \cdot T \qquad \text{(C-14)}$$

where k is a proportionality constant, T is the central processing unit (CPU) execution time, and ε is the error in the approximate solution.

Computational hydraulics The development and application of computer programs in the solution of hydraulic research and design problems. *See also* hydraulic modeling.

Computational hydraulics approach The basic approach of computational hydraulics starts with a mathematical model, i.e., a set of mathematical equations that defines the fluid flow problem under consideration. As these partial differential or integral equations cannot usually be solved analytically, a numerical method is used to discretize them to algebraic forms that a computer can solve. The three basic discretization approaches are currently the finite-difference, the finite-element, and the finite-volume methods.

Computational hydrology The development and application of computer programs to carry out the operations required in hydrologic data processing and hydrologic computations. The Hydrologic Engineering Center (HEC) of the U.S. Army Corps of Engineers and the Natural Resources Conservation Service (NRCS, formerly SCS) of the U.S. Department of Agriculture have supported the development of some of the better-known hydrologic computer programs: the HEC series, TR-20, and TR-25, for example. *See* Table M-1 for some commercial software developers and available programs. *See also* computational hydraulics; hydraulic modeling.

Computational solution error The error introduced by the discretization process in a computational solution, which is usually an iterative process. For a stable algorithm, the difference between the true solution and the approximate solution (i.e., the error) is reduced at each successive iteration by refining the discretization grid. *See also* error criterion.

Computational techniques Techniques used to replace fluid dynamics differential equations with algebraic equations that the computer can solve, e.g., the finite-difference, finite-element, and finite-volume methods. *See also* discretization.

Computer-aided design and drafting (CADD) An automated computer program used in mapping, drafting, and architectural and engineering design.

Computer-aided engineering (CAE) The use of computer programs and tools in the solution of engineering problems.

Computer-aided mapping (CAM) The use of CADD-based programs and tools in standard mapping operations. It is one of the three current tools used for developing comprehensive mapping programs for infrastructure elements (e.g., a sewer system). *See also* Automated Mapping/Facilities Management; geographic information system.

Computerized sewer collection and transmission system model A computer model that can simulate the operation of a sewer system. *See* Section II for further information.

Computer mapping program (CMP) A comprehensive program of data collection, mapping, and data management services based on all available, up-to-date information from personnel, records, and field investigations. Currently, three technologies are used to develop a CMP: computer-aided mapping (CAM), geographic information system (GIS), and automated mapping and facilities management (AM/FM).

Computer model A model designed to be solved using a computer, as opposed to an analytical model, for example. Because of the capacity to carry out mathematical operations at great speed, the computer is an excellent tool to perform complex simulations. Not all models are computerized. In urban stormwater management; e.g., Stormwater Management Model (SWMM) Level I is a simple, noncomputerized model for estimating annual runoff and pollutant loading, while the full SWMM is a complex hydraulic model that cannot be solved without a computer.

Concentration time Same as **time of concentration**.

Conceptual model A simplified representation of the system under consideration, e.g., a simple flowchart, schematic, or equation that provides a first approximation.

Concordant flow method An extension of the unit hydrograph method, proposed by the Natural Resources Conservation Service (NRCS) to estimate the effects of control structures on peak flowrates. It uses the formula

$$Q = CRA(1 - r) + Q'A' \quad \text{(C-15)}$$

where Q = peak flowrate, C = an empirical coefficient depending on hydrograph characteristics, A = watershed area, A′ = part of the watershed area affected by the control structure, R = depth of direct runoff (the ratio of the volume of runoff to the drainage area), Q′ = the average release rate from the control structure, and r = the ratio A′/A.

Conditions I, II, III *See* antecedent moisture condition.

Conductance The capacity of a water sample to carry an electrical current; related to the concentration of ionized substances in the water. Its measurement is a rapid method of estimating the dissolved solids content of the sample. Also called **specific conductance**.

Conductivity (1) A measure of the ability of water and solutions to carry an electric current. (2) A coefficient of proportionality that describes the rate at which a fluid (e.g., water or gas) can move through a permeable medium. Conductivity is a function of both the intrinsic permeability of the porous medium and the kinematic viscosity of the fluid that flows through it (EPA Glossaries). *See* hydraulic conductivity.

Conductor A vertical pipe leading from a roof drain or gutter down to the ground, a cistern, a storm drain, or other means of disposal. Also called **downcomer, downspout**, or **leader**.

Conduit In general, a conduit is a natural or artificial channel, open or closed, for the conveyance of water or other fluids. In a closed conduit, water flows under pressure; open conduit flow is by gravity. In a sewer system model such as the Stormwater Management Model (SWMM), conduits or links are pipes and channels as opposed to nodes. *See* link; link–node network.

Conduit connectivity table An output file table of the XP-SWMM (Stormwater Management Model) showing the following for each input: the corresponding conduit name, the upstream and downstream nodes, as well as the upstream and downstream elevations.

Conduit convergence criterion *See* convergence criterion.

Conduit deflection angle A factor used in the determination of headlosses at bends in drainage design studies.

Conduit factor table An output file table of the XP-SWMM (Stormwater Management Model) showing the various conduit factors.

Cone of depression The depression, roughly conical in shape, produced in the water table by the pumping of water from a well. Also defined as the area around a discharging well where pumping has lowered the potentiometric surface. In an unconfined aquifer, the cone of depression is a cone-shaped depression in the water table where the medium has actually been dewatered. Also called **cone of influence**. *See also* circle of influence.

Confidence level The probability that an interval between two confidence limits will contain an event or a population value.

Confidence limits The limits within which, at a certain confidence level, the true value of a result lies. For example, if the estimated value of a variable is X, the standard error of estimate E, and the known Student's t statistic t, then the confidence limits are $(X - E \cdot t)$ and $(X + E \cdot t)$. The range $[(X - E \cdot t) - (E + E \cdot t)]$ is called the **confidence interval**.

Confined aquifer An aquifer in which groundwater is confined under pressure that is significantly greater than atmospheric pressure. It is a fully saturated formation of porous rock or soil overlaid by a confining layer. The potentiometric surface (or hydraulic head) of the water in a confined aquifer is at an elevation that is equal to or higher than the base of the overlying confining layer. A discharging well in a confined aquifer lowers the potentiometric surface, which then forms a cone of depression, but the saturated medium is not dewatered (EPA Glossaries). Same as **artesian aquifer**. *See* aquifer; Figure A-1.

Confined filtration facility (CFF) A facility used to control the quality of stormwater runoff. It is a self-contained sand filter with a collection system to convey the treated effluent to a receiving water.

Confined flow equation An equation used for the study of steady flow to fully penetrating wells through confined aquifers of constant thickness and infinite extent. Based on Darcy's law, it assumes horizontal flow with a velocity proportional to the tangent (instead of the sine) of the hydraulic gradient. It is widely used in assessing an aquifer's hydraulic characteristics from field test results or in determining the discharge of a well, knowing the hydraulic conductivity. *See* Dupuit equation; Figure T-1; Theim equation; well flow equations.

Confined groundwater (or simply confined water) The water in a confined aquifer.

Confined-water well A well that taps a confined aquifer.

Confining bed A geologic formation, impermeable or of low hydraulic conductivity, above, beneath, or around an aquifer.

Confining layer A geologic formation characterized by low permeability that inhibits the flow of water. The **confining layer** or **stratum** may be directly above or below an aquifer. *See also* aquiclude; aquifer; aquifuge; aquitard. A stratum is a single bed or layer or a number of more or less homogeneous layers.

Confirmation (or confirmation testing) *See* calibration.

Confluent As an adjective: running or flowing together or blending into one. As a noun: one of two or more confluent streams; the junction of these streams is their **confluence**.

Confluent stream A stream that flows together and blends with another of about the same size. When one stream is much smaller than the other, it is called an **affluent** or a **tributary**.

Conjugate depths In an open channel, the depths before (y_1) and after (y_2) a hydraulic jump. Also called **sequent depths**. For a rectangular channel, they are related to the Froude number F_r as follows:

$$y_2/y_1 = 0.5\left(\sqrt{1+8\,F_r^2}-1\right) \tag{C-16}$$

Conjunctive use A water resources management approach involving the use of all water resources in a region (surface, ground, etc.) for optimal results, e.g., a larger and more dependable yield. An important aspect of **conjunctive water management** is the use of recharged aquifers as underground storage, which eliminates the need for surface reservoirs and pipelines and reduces evaporation losses.

Conjunctive water management *See* conjunctive use.

Connate water Interstitial water in the zone of saturation, but entrapped in sediments or igneous rocks at the time of their deposition. *See* subsurface water.

Consent agreement A written agreement, signed by the parties, containing stipulations or conclusions of fact or law and a proposed penalty or proposed revocation or suspension acceptable to both complainant and respondent (EPA-40CFR22.03).

Consent decree A legal document approved by a judge that formalizes an agreement reached between the Environmental Protection Agency (EPA) and potentially responsible parties (PRPs) through which PRPs will conduct all or part of a cleanup action at a Superfund site, cease or correct actions or processes that are polluting the environment, or otherwise comply with EPA-initiated regulatory enforcement actions to resolve the contamination at the Superfund site involved. The consent decree describes the actions PRPs will take and may be subject to a public comment period (EPA Glossaries). Similar decrees may be signed regarding water pollution control actions. In general, a consent decree is a binding agreement settling all questions in a dispute between two parties. *See* Section II for further information.

Conservation (of resources) A resource management approach that discourages loss or waste. A **conservation district** is a governmental agency that implements soil and water conservation measures. A utility **conservation rate** is a rate established to discourage waste or reduce use of water, electricity, etc.; it is usually an increased rate or a rate structure such as marginal cost pricing, which charges more for additional units. **Conservation storage** is storage of water for future use.

Conservation laws Principles derived from Newtonian mechanics that state that basic properties (such as energy, mass, momentum) cannot be created or destroyed but can be transferred or transformed. Examples of the application of the laws of conservation are **conservation of energy** (first law of thermodynamics; Bernoulli's equation; equivalence between energy, work, heat), **conservation of mass** (continuity equation, mass–balance models, storage equation, materials balances), and **conservation of momentum** (Newton's first law of motion, momentum equation). *See also* Saint-Venant equations.

Conservation reservoir A reservoir with gate-controlled outlets that retains water for a relatively long time (e.g., several months) and releases it in times of insufficient flow for domestic or industrial use. Also called an **impounding reservoir** or **storage reservoir**. Storage reservoirs are also used for flood mitigation with appropriately large spillways or sluiceways for rapid drawdowns. *See also* retarding basin, which has no gate or other regulating device.

Conservation storage *See* conservation.

Consistency A necessary, but not sufficient, condition for an approximate numerical solution to converge to the true solution of a partial differential equation of flow. It implies that the algebraic equations formed by discretization are equivalent to the differential equation when the finite increments tend to zero. *See also* convergence.

Consistent hydrograph *See* depth-area option.

Consistent numerical solution *See* convergence.

Constant altitude plan precipitation index *See* CAPPI.

Constant-speed pump A pump designed to operate at a constant speed and discharge at a constant rate, given the headloss and the pump characteristic curve. The opposite is a variable-speed pump.

Constant spring A spring with discharge that does not vary much from the average discharge; for example, the variation may not exceed 33%.

Constant threshold area method One of two current methods for providing drainage network data (channel sources) to digital elevation models (DEMs). The other is the slope-dependent critical support area method.

Constriction A natural or man-made obstruction (such as a gorge, bridge, pier, weir, orifice) that reduces the flow area of a waterway or conduit. Same as **contraction.**

Constructed wetland A wetland built and operated as an aquatic treatment system to minimize point and nonpoint source pollution prior to its discharge into receiving waters.

Consumptive use (1) A water use that removes water from the available supply and does not return it to a water resource system (e.g., manufacturing, agriculture, food preparation), as compared to an **instream use**, which takes place within the stream channel (e.g., hydroelectric power generation, navigation, water quality improvement, fish propagation, recreation). (2) Also used to designate the loss of irrigation water due to evapotranspiration. **Consumptive waste** is water that is returned to the atmosphere without further use. To estimate consumptive use, *see also* Blaney–Criddle method; Penman–Monteith method. (3) More generally, in agriculture, consumptive use includes not only evapotranspiration, but also a small quantity of water contained in plant tissue.

Contaminant Any biological, chemical, physical, or radiological substance or matter that has an adverse effect on air, soil, or water. Also, a substance that causes the concentration of that substance in groundwater to exceed the specified maximum contaminant level. Or, a substance that causes an increase in the concentration of that substance in the groundwater when the existing concentration of that substance exceeds the specified maximum contaminant level. *See also* pollutant.

Contamination The introduction of a contaminant into water in a concentration that renders the water unfit for its next intended use.

Continental basin The region of a continent that is made up of areas that drain to lakes, depressions, etc. without a surface outlet; they lose water by evaporation and percolation. *See also* closed basin.

Continuity equation (or storage equation) One of two equations used to solve hydraulic and hydrologic flow routing problems; the other is the momentum equation. The continuity equation is based on the principle of conservation of mass (reportedly first formulated by Leonardo da Vinci) and may be written in several forms, e.g.,

$$dS/dt = I - O \qquad \text{(C-17)}$$

where dS/dt represents the rate of change in storage over time, and I and O are, respectively, inflow and outflow rates. For steady-state conditions, I = O or dS/dt = 0. The same form of the continuity equation (i.e., change in storage = inflow − outflow) is often used in **black-box models**. An example is the establishment of a mass balance for a groundwater system. In such a system, inflow and outflow may include natural groundwater recharge or discharge, exchanges with surface water, subsurface flow over the boundary, leakage to or from adjacent aquifers, local infiltration or exfiltration. Using another form of the continuity equation, an algorithm of the Stormwater Management Model (SWMM) simulates the changes in volume or depth of runoff in a watershed:

$$dv/dt = d(A \cdot y)/dt = A \cdot e - Q \qquad \text{(C-18)}$$

with $v = A \cdot y$ = volume of water, A = watershed area, y = depth of water over the watershed, t = time, e = rainfall excess, and Q = discharge or flowrate. For gradually varied, unsteady open-channel flow with negligible lateral inflow, the partial differential form of the continuity equation expresses that the sum of inflows and outflows to a control volume equals the change in the amount of water in the control volume, or

$$\partial Q/\partial x + \partial A/\partial t = 0 \qquad \text{(C-19)}$$

where A = flow area, x = longitudinal distance, and t = time. The complete dynamic-wave form of the continuity equation is:

$$A \cdot \partial V/\partial x + V \cdot W \cdot \partial y/\partial x + W \cdot \partial y/\partial t = q \qquad \text{(C-20)}$$

where V = average velocity of water, W = top width of flow, and q = local inflow. Hydraulic flow routing uses both the continuity and the momentum equations. *See also* Saint-Venant equations.

Continuity error An indicator of the accuracy of the simulation performed by a model. For example, in the XP-SWMM (Stormwater Management Model), the output file provides in absolute and relative terms the continuity error at a junction, defined as the difference between the initial volume plus the inflow and the final volume plus the outflow.

Continuous analysis A simplification of continuous simulation in hydrological modeling; uses continuous historical hydrographs to evaluate the performance of proposed alternatives.

Continuous-flow pump A pump made up of a rotating element called an impeller and enclosed in a casing that connects to the pipeline. Radial-flow or centrifugal, axial-flow or propeller, and mixed-flow pumps are of the continuous-flow category and are also called **rotodynamic pumps**. The other broad category is positive displacement pumps.

Continuous-flow stirred-tank reactor (CFSTR) A theoretical reactor with uniform concentration resulting from contents being completely mixed continuously. Also, a reactor that satisfies or approaches complete mixing conditions, a convenient simplification for such complex phenomena as watershed thermal processes. Also called **continuously stirred tank reactor**.

Continuous-flow system A system that operates continuously at a more or less steady flowrate, as opposed to an intermittent operation, a batch process, or a fill-and-draw system.

Continuous-flow tank A tank that is part of a continuous-flow system.

Continuously stirred tank reactor (CSTR) Same as **continuous-flow stirred-tank reactor**.

Continuous model A model that uses continuous simulation, as opposed to a single-event model. Single-event modeling (or simply **event modeling**) aims at drainage efficiency during rare storms, produces a hydrological response (for example, a peak flow) to a single, wet-weather event and requires the determination of antecedent conditions. **Continuous modeling** simulates the response of a watershed to a historic or synthetic rainfall time series that includes wet and dry processes; it does not require the estimate of antecedent conditions. Continuous modeling is more appropriate in the appreciation of long-term environmental effects, for example, in the assessment of nonpoint source pollution impacts.

Continuous modeling *See* continuous model.

Continuous simulation (1) The simulation of a process or system over many sequential cases (e.g., in preliminary or planning investigations), as opposed to single-event simulation carried out for a single event (e.g., in engineering design activities). (2) Preprocessing rainfall records into sequences of wet events that are then input to a model. *See* simulation.

Contour or contour line (1) A line connecting points of the same elevation above mean sea level (MSL) or another datum. The difference in elevation between two adjacent contours is the **contour interval**. A **contour basin**

is a basin with boundaries (e.g., levees) that follow contour lines. A **contour map** or **contour plot** shows surface configuration by means of contour lines labeled according to their elevations. (2) Sometimes used to designate on a map or a graph points that have the same characteristics, such as pressure or rainfall.

Contour irrigation An irrigation method by which water is applied to strips of land separated by ridges that are established along contour lines.

Contracted weir A rectangular weir with a notch opening that is smaller than the width of the upstream channel, thus causing both a horizontal and a vertical contraction of the nappe. The opposite is a full-width or suppressed weir. *See* Figure W-5; weir equation. For rectangular contracted weirs with both length L and side contraction that exceed three times the head H, the discharge Q may be estimated as:

$$Q = 3.27(L - 0.2H)H^{1.5} \qquad \text{(C-21)}$$

Contraction The reduction of the cross-sectional area of a conduit, pipe, channel, nappe, or stream. Also, same as **constriction**. The **contraction coefficient** in a discharge formula accounts for the effect of the constriction (e.g., weir, orifice); it is taken as the ratio of the smallest cross-sectional area in the constriction to the nominal area of the constriction. A **contraction loss** is one of several minor headlosses, due to the reduction of the size of a conduit or channel, considered in hydraulic modeling studies.

Control float A float installed in a container to control pump operation.

Control flume *See* control structures.

Controlled spillway A spillway that has crest gates to adjust the outflow.

Control point A point in a channel at which the relationship between discharge and head or depth is known, e.g., spillway, flow-measuring devices (weir, flume, gate), point of critical depth. Control points are used in the establishment of surface profiles. *See* control structures.

Control structures/control works Hydraulic structures or devices through which a fluid may flow and the flowrate can be measured; also called **outlet structures**. Control structures may be used as diversion works at the head or diversion point of a conduit or canal. Control structures include weirs, gates, manholes, etc., as well as reservoirs and other works for flood control. They may affect the quantity and timing of the releases or simply the manner of operation. Sharp-crested weirs are the most common controls in water supply and wastewater engineering. A **control flume** has a constriction with minimum head to measure the flow. Similar to a **control reach** in an open channel. In general, a **control section** is a cross section in which discharge is uniquely related to depth of flow or to energy head, for example, at the point of critical depth in open channels.

Convection The motion and mixing caused in a fluid by gravity and temperature-induced density differences.

Convective acceleration force A term in the momentum equation represented by $[(V/g) \cdot \partial V/\partial x]$, where V is the average velocity, g is the gravitational acceleration, and x is the longitudinal distance. *See* Saint-Venant equations.

Convective diffusion equation A partial differential equation used in the Muskingum–Cunge method of flood routing analysis. It relates the rates of change of the flood discharge Q with respect to time t and the longitudinal distance x to the wave celerity in the longitudinal direction c to the lateral inflow per unit of channel length q_L and to hydraulic diffusivity μ:

$$\partial Q/\partial t + c\cdot\partial Q/\partial x = \mu\cdot\partial^2 Q/\partial x^2 + c\cdot q_L \tag{C-22}$$

See also Equation H–16; hydraulic conductivity; Muskingum–Cunge method.

Convective precipitation or rainfall Precipitation or rainfall caused by rising moisture-laden air. *See* frontal precipitation.

Convergence With the advent of computers, most hydraulic modeling problems are solved numerically, e.g., using the finite-difference method. A satisfactory numerical solution is convergent, stable, and consistent. **Convergence** means that the numerical solution to the finite-difference equation approaches the exact or analytical solution as the finite difference increments (Δx, Δt, etc.) approach zero. An iterative algorithm converges if the truncation error decreases with successive steps. The iterative procedure stops when the error is within a specified error tolerance. **Stability** refers to the behavior of numerical errors during computation. Numerical errors (e.g., truncation errors, roundoff errors, dispersion, oscillation) occur during the solution procedures. The total error at any step is the difference between the actual current solution and the analytical solution. The procedure is stable if the error at any step i is smaller than the error at the preceding step (i − 1); the solution is unstable if the error grows larger with succeeding steps. For example, when the solution results in unrealistic or unbalanced heads, flows, or concentrations, it is unstable. Selecting appropriate timesteps and other finite-difference increments can improve stability and convergence. Stability implies convergence, but not necessarily to the correct solution. The correct solution must also be **consistent**; that is, the equations with the finite-difference operators approach the differential equations as the finite-difference elements Δx, Δt, etc. approach zero. In other words, the discretization process must be reversible: the algebraic equations thus generated must be equivalent to the original differential equations when the elements tend to zero. *See* Section II for further information.

Convergence criterion Used to determine the convergence of a numerical solution. It is an error tolerance specified as acceptable to stop the iteration.

Conveyance (1) The act of bringing (water or wastewater, e.g.) from one place to another. (2) In open-channel flow, the conveyance K_c is the discharge carrying capacity of the channel, calculated as the ratio of the flow Q to the square root of the bottom slope S_0 or:

$$K_c = Q\sqrt{S_0} = \delta AR^{2/3}/n \quad \text{(C-23)}$$

where, as in the Manning formula, δ = 1.0 or 1.49, A is the area of flow, R is the hydraulic radius, and n is the roughness coefficient. It is used mainly for solving discharge problems in compound channels. If a cross section has a number N of subsections with different characteristics, the conveyance of the ith subsection (of area A_i, hydraulic radius R_i, and roughness n_i) is:

$$K_{ci} = \delta A_i R_i^{2/3}/n_i \quad \text{(C-24)}$$

and total conveyance is:

$$K_c = \sum_{i=1}^{N} K_{ci} \quad \text{(C-25)}$$

Conveyance may also be used (a) to determine the energy and momentum coefficients and (b) in solving flow problems under gradually varying conditions. *See also* equivalent roughness coefficient. (3) In irrigation, **conveyance losses** from a canal, a reservoir, or a conduit consist of losses due to leakage, seepage, evaporation, transpiration, and operational waste or in general losses between the point of diversion and the point of delivery.

Conveyance equation The formula relating conveyance to discharge and channel bottom slope. *See* Equation C-23.

Conveyance factor Same as **conveyance** (2).

Conveyance method A simplified method that provides an approximate solution to the differential equation of the water surface of gradually varied flow. It is used to determine the water surface profile under backwater conditions. It assumes that the water surface is parallel to the channel bottom over distances less than 800 ft. The conveyance equation is used to compute the difference in elevation Δy between two points separated by a short distance L as a function of discharge Q and conveyance K_c:

$$\Delta y = LQ^2/K_c^2 \quad \text{(C-26)}$$

See also backwater computations; Bakhmeteff backwater solution.

Conveyance system mapping One of the important preliminary tasks in the development of a computer model for a sewer system. *See* Section II for further information.

Cooling pond A pond or other outside depression designed to receive hot process water for cooling by evaporation, convection, and radiation before water reuse or discharge.

Core *See* model core.

Core wall Same as **cutoff wall**.

Coriolis coefficient One of two velocity distribution coefficients; *see* energy coefficient; Figure V-1. The other is the Boussinesq or momentum coefficient.

Coriolis force After Gaspard Gustave de Coriolis's formulation in 1835. Due to the earth's rotation, the Coriolis force, acting on a particle, is equal and opposite to the product of the mass of the particle by its Coriolis acceleration. The **Coriolis acceleration** of a particle in a rotating coordinate system is the difference between its acceleration with respect to a fixed coordinate system and the sum of its centripetal acceleration and its rotating coordinate acceleration. The **Coriolis effect** results from the Coriolis force; it is a deflection of any moving body with respect to the earth's surface: Bodies moving horizontally in the Northern Hemisphere are deflected to the right; in the Southern Hemisphere, they are deflected to the left. In hydraulic modeling, the Coriolis effect is usually negligible unless the Rossby number R_o is small (e.g., $R_o < 0.1$). The dimensionless Rossby number depends on the mean velocity in the horizontal plane, the Coriolis frequency (approximately 0.0001/sec) and the horizontal length scale. For small Rossby numbers, the Coriolis effect must be included among the sources and sinks in the momentum equation.

Coriolis frequency (F_c) A parameter used in the Rossby number; equal to twice the local velocity of deflection.

Correlation coefficient The square of the coefficient of determination. A dimensionless parameter used in linear regression analysis to measure the goodness of fit of a data series. A coefficient of 1.0 indicates perfect fit, while a coefficient of 0 indicates no correlation.

Cosmic water Water that reaches the earth from space.

Cost–benefit analysis A quantitative evaluation of the costs that would be incurred versus the overall benefits to society of a proposed action.

Cost-effective alternative An alternative control or corrective method identified after analysis as the best available in terms of reliability, performance, and cost.

Cost-effectiveness analysis An analysis to determine among several alternatives which one yields the optimum effect at the most reasonable cost, i.e., which is the most effective in meeting economic, financial, technical, environmental, and other objectives. The cost-effective solution is not necessarily the least-cost solution. *See also* life-cycle costing.

Coupling A metal collar, a sleeve, or other device with internal threads used to connect two sections of threaded pipe or hose.

Courant–Friedrichs–Lewy (CFL) stability criterion *See* Courant number.

Courant number (C_n) A number used in hydraulic modeling applications to define the stability of numerical solutions. It is calculated as:

$$C_n = C_d \cdot \Delta t / \Delta x \qquad \text{(C-27)}$$

where C_d is the wave celerity, Δx is the distance between elements, Δt is the time increment or timestep, t is the time, and x is the distance. A numerical solution is stable when $C_n \leq 1$, exact (i.e., corresponding to the analytical solution) when $C_n = 1$, and unstable when $C_n > 1$. The **Courant condition**, **Courant criterion**, or **CFL stability criterion** is a restriction on the timestep Δt with respect to the distance increment Δx and the dynamic wave celerity C_d to control the stability of the numerical solution:

$$\Delta t \leq \Delta x / C_d \qquad \text{(C-28)}$$

For more information, *see* Section II; Courant number equations.

Courant timestep The timestep in numerical simulations, as determined from the Courant condition; that is, a time increment less than or equal to the ratio of the distance increment to the dynamic wave celerity. *See* Courant number.

COV Abbreviation for coefficient of variation.

Coverage A geographic information system (GIS) file in ArcInfo; like shapefile in ArcView. *See* Section II for further information.

cp Abbreviation for centipoise, a measure of absolute viscosity.

CPU Abbreviation for central processing unit.

Crank–Nicholson scheme A scheme based on the finite-difference approximation using a time-weighting factor of 0.5, i.e., halfway between an explicit and an implicit solution. *See also* Preissmann scheme; time-weighting factor.

Creager enveloping curves A series of curves proposed in 1945 to compute peak flood flows when sufficient data are not available for the hydrograph methods. They are based on the following empirical formula:

$$Q = 46CA^{\alpha}$$

with

$$\alpha = 0.894A^{-0.048} - 1 \qquad \text{(C-29)}$$

where Q is the peak discharge, A is the drainage area in square miles, and C is a coefficient that depends on the drainage area.

Creek A natural stream of water that drains a relatively small basin, as opposed to a river for a relatively large basin. Rills and rivulets are even smaller. All these streams flow in a definite direction, within their channels along thalwegs, and usually discharge into another water body.

Creep ratio An empirical parameter used in design to prevent seepage under dams. It is the ratio L/H, where H is dam height, and L is the length of the area of contact between the soil and the base of the dam. To prevent the phenomenon of piping, the creep ratio must be above certain limits that depend on soil type. *See also* critical gradient (2).

Crest (1) The top of structures such as dams, dikes, or spillways or the bottom edge of weirs over which water passes. (2) The summit or highest point of a wave, the peak of a flood, or the highest elevation of flood waters. (3) The top part of a storm hydrograph, between the points of inflection on the rising and recession limbs. *See* Figures E-3, H-3, U-2, and U-3.

Crest control A method of raising or lowering the crest of a dam by a device on the spillway, depending on water surface elevation.

Crest gate A gate on the spillway crest of a dam to control the water level or the discharge over the spillway. It also increases reservoir storage and head during low flows. Common types include flashboards, stop logs, bear-trap, drum, sliding, and tainter (or taintor) gates.

Crib A structure of rectangular or round frames of timber horizontally on top of each other to form a wall. A **crib dam** consists of driftbolted cribs facing upstream, covered and filled as necessary to provide watertightness and stability. A **crib weir** is a diversion weir made of cribs filled as necessary to provide stability.

Crick A variant of creek, sometimes used in the northern United States.

Critical-action floodplain *See* floodplain.

Critical depth (y_c) In open channel flow, the depth for which the specific energy E is minimum for a given discharge Q or the discharge is maximum for a given specific energy. Given the critical flow equation, critical depth in wide channels occurs in general when:

$$Q^2W = gA^3 \tag{C-30}$$

For a rectangular channel:

$$y_c = (q^2/g)^{1/3} \tag{C-31}$$

with the discharge per unit of surface width of channel:

$$q = Q/W \tag{C-32}$$

where W is the surface width, A is the cross-sectional area, and g is the gravitational acceleration. This flow characteristic serves to determine the flow regime: on a mild slope, the critical depth is smaller than the normal depth y_n, and the flow is subcritical; on a steep slope, the critical depth is greater than the normal depth, and the flow is supercritical.

Critical drawdown period In the operation of a lake or reservoir, it is the time between the beginning of drawdown and the lowest useful water surface elevation.

Critical drought In water resources planning studies, it is the design drought or sometimes the drought of record.

Critical flow In open-channel flow, critical flow is a transition between two varied-flow conditions: subcritical and supercritical flows. Critical flow occurs in flow measurement devices such as weirs and at or near free discharges. It corresponds to a minimum specific energy for a given discharge or a maximum discharge for a given specific energy. Specific energy E is defined as the sum of the depth of flow y and the velocity head $V^2/2g$, where V is the average velocity and g is the acceleration of gravity. *See* critical flow equation. Some other characteristics of critical flow are:

1. The mean velocity is equal to the celerity of a gravity wave, i.e., $V = \sqrt{gy}$.
2. The Froude number equals 1, i.e., $F_r = 1$. When the Froude number is close to 1, the flow is unstable and subject to wave formation.
3. The velocity head is half of the depth, i.e., $V^2/2g = y/2$, for a rectangular channel.
4. Under critical or supercritical flow conditions, a wave cannot move upstream as the water velocity exceeds the wave celerity; i.e., downstream conditions or controls do not affect upstream sections hydraulically.
5. Flow is supercritical if (a) $F_r > 1$, (b) the mean velocity is greater than the celerity of the gravity wave, (c) the normal depth y_n is less than the critical depth y_c, or (d) the normal slope S_n exceeds the critical slope S_c.
6. Flow is subcritical if (a) the mean velocity is smaller than the celerity of the gravity wave, (b) $F_r < 1$, (c) $y_n > y_c$, or (d) $S_n < S_c$; then, disturbances travel upstream and downstream.

Critical flow equation In open-channel flow, the relationship between specific energy E, depth of flow y, average velocity V, and the gravitational acceleration g:

$$E = y + V^2/2g \qquad \text{(C-33)}$$

For a rectangular channel, it may be written as

$$E = y + q^2/2gy^2 \qquad \text{(C-34)}$$

or as Equation C-30 for any wide channel. Q is the discharge, W is the surface width, and the unit discharge q = Q/W. *See* Figure S-5 for plots of the specific energy equation.

Critical flow exponent *See* flow exponents.

Critical gradient (1) Same as **critical slope** S_c. (2) One of two parameters used in design to prevent seepage under dams. The critical gradient G* depends on the specific gravity s of the soil and its void ratio (i.e., the ratio of the volume of voids to the volume of solids r):

$$G^* = (s - 1)/(1 + r) \qquad \text{(C-35)}$$

See also creep ratio.

Critical moisture content The moisture content of a saturated soil that does not tend to take in or expel water.

Critical slope (S_c) (or critical gradient) The slope of a conduit or channel corresponding to uniform flow at critical depth. It is equal to the loss of head per foot at the critical depth. The critical slope is also the minimum slope that will produce critical flow. It may be computed from the Manning equation using the flow Q, flow area A, the depth of flow y, the gravitational acceleration g, roughness coefficient n, and hydraulic radius R resulting from the critical depth:

$$S_c = (nQ/\delta AR^{2/3})^2 = gyn^2/(\delta^2 R^{4/3}) \qquad \text{(C-36)}$$

with $\delta = 1.0$ for metric units or 1.49 for English units. *See* open-channel flow.

Critical velocity (1) In open-channel flow, Belanger's critical velocity V_c is that velocity corresponding to the critical flow condition, i.e., the point of minimum specific energy and maximum discharge. In a rectangular channel, it is such that the velocity head is one half of the critical depth y_c; i.e.,

$$V_c^2/2g = 0.5y_c \qquad \text{(C-37)}$$

In general, the critical velocity is the velocity of the gravity wave; it may be computed as the ratio of the critical discharge to the critical flow area or, as for the critical slope, from the Manning formula. Belanger's critical velocity is different from Reynolds critical velocity. *See also* open-channel flow. (2) Critical velocity may also be defined as the minimum velocity that will prevent silting in a channel and computed as:

$$V_c = 1.17\sqrt{fR} \qquad \text{(C-38)}$$

with a friction factor (f):

$$f = \sqrt{8d} \qquad \text{(C-39)}$$

d is the diameter (in inches) of the predominant type of soil transported, and R is the hydraulic radius in feet. (3) The velocity above which erosion will occur. *See* erosion threshold flow. (4) There is also a critical velocity for liquid turbulence to prevent polarization.

Cross A pipe fitting with four branches along two perpendicular axes.

Cross connection An actual or potential connection, usually unintended or undesirable, between two water conduits or bodies; for example, (1) between a potable water supply and a wastewater or otherwise polluted source or (2) between sanitary and storm sewers. *See also* backflow; backsiphonage; interconnection.

Cross, Hardy *See* hydraulics.

Cross section In a stream, conduit, pipe, or channel, the cross section is the intersection with a vertical plane normal to the direction of flow and bounded by the wetted perimeter P and the surface width W. The **cross-sectional area** is the surface area of the cross section.

Crown The inside top of the arch of a sewer, covered channel, or conduit. *See* Figure S-3.

Crump weir A long-based weir having a triangular longitudinal profile, with side slopes of 1:2 upstream and 1:5 downstream. It assumedly performs better than other types of weir under submerged conditions. *See* Figure W-6.

Culvert (1) A sewer, conduit, or drain crossing under a road, railroad, canal or other earthworks for the free passage of surface water. (2) Any bridge waterway structure with a span shorter than 20 ft. (3) One or more adjacent pipes or enclosed conduits for carrying a watercourse beneath a road or other earthworks. (4) Culverts are one type of reach used in the stormwater management model advanced interconnected pond routing (AdICPR). The principal elements of a culvert include the barrel (under the fill), headwalls, wingwalls, endwalls, and energy dissipater. The culvert is also characterized by its entrance, exit, headwater, tailwater, and inlet or outlet control. **Outlet control** exists when the discharge of the culvert depends on all hydraulic variables, while for **inlet control** only entrance conditions and culvert size govern. (In addition to culverts and bridges, dips are used to carry cross drainage.)

Culvert headwater The depth of water at the entrance of the culvert; measured from the upstream invert of the culvert.

Culvert tailwater The depth of water at the exit of the culvert; measured from the downstream invert.

Cumulative distribution function (CDF) An equation representing the probability that a variable is less than or equal to a given value as a function of this variable. The derivative of the CDF is the probability distribution function (PDF). *See also* exceedance frequency distribution; Figure F-7.

Cumulative frequency The frequency that indicates the probability that a variable is less than or equal to a given value. *See also* exceedance frequency.

Cumulative rainfall to date Cumulative rainfall since the beginning of the current water year.

Cumulative runoff The total runoff volume over a period of time; often plotted against time to yield a mass curve. Also called **mass runoff**.

Cumulative volume curve A plot of cumulative discharge against time. Also called **mass discharge curve**.

Cunette A longitudinal trough at the bottom of a conduit to facilitate self-cleansing velocities at low flows.

Curb cork Same as **curb stop**.

Curb inlet A stormwater intake structure installed in the curb and gutter of a roadway to allow runoff into a storm or combined sewer. *See also* catch basin.

Curb stop A valve near the curb, between the water main and a building connection; it is used to start or stop water service to the building. Also called **curb cork**.

Current meter An instrument to measure the velocity of flowing water. It consists of a cup- or propeller-type rotor installed on a horizontal or vertical axis. *See also* optical current meter; Price current meter. There are three other related terms that are not clearly defined in the literature (Parker, 1997). **Current-type flowmeter**: a mechanical device to measure liquid velocity; the moving liquid turns a small windmill-type vane. **Velocity-type flowmeter**: a turbine-type fluid-flow measurement device in which the fluid flow actuates the movement of a wheel or turbine-type impeller, giving a volume-type reading. **Rotating meter**: same as **velocity-type flowmeter**.

Curve number (CN) A number from 1 to 100 that represents the properties of the type of soil and ground cover or land use for determining precipitation excess or losses resulting from a rainfall event. Used in the Soil Conservation Service (SCS) rainfall/runoff model, it may be computed from the following equations:

$$CN = 1000/(S + 10) \qquad \text{(C-40)}$$

$$Q = (P - I_a)^2/(P - I_a + S) \qquad \text{(C-41)}$$

where S is the soil storage or maximum runoff retention, P is the depth of rainfall, I_a represents initial abstraction, and Q is the depth of runoff, all in inches. Soil storage is a function of soil characteristics, the cover complex (land uses, practices, hydrologic conditions), and antecedent moisture conditions. It has been found that I_a is approximately 0.2S. Thus,

$$Q = (P - 0.2\ S)^2/(P + 0.8\ S) \qquad \text{(C-42)}$$

The SCS technique is widely used to determine peak flows in storm sewer design, as an alternative to the rational formula. The CN replaces the runoff coefficient and, moreover, accounts for the effects of infiltration, detention storage, and duration of excess rainfall.

Cusec Abbreviation of cubic foot (feet) per second. *See also* cfs.

Cutoff (1) A natural or artificial channel that straightens a stream and bypasses large bends, thereby increasing channel slope and reducing erosion. (2) An impermeable wall or diaphragm beneath the base or within the abutments of a dam to minimize seepage.

Cutoff trench A trench below the foundation line of a dam or similar structure; filled with an impervious material and designed as a watertight barrier.

Cutoff wall (or core wall) A thin, watertight wall or footing of clay or concrete; built up from a cutoff trench or around the headwall and lipwall of a dam as protection against seepage.

Cutwater A sharp-edged structure around a bridge pier as protection against the flow of water, ice, and debris.

Cybernet® An AutoCAD add-in program, developed by Haestad Methods, Inc., for the design and analysis of pipe distribution systems under pressure flow. Cybernet allows graphical representation of the hydraulic system by manual construction or by conversion of polylines with an existing AutoCAD file. Data are contained within the AutoCAD file and viewed through the model control center. Cybernet's output options include: computer generated reports, color-coded graphics, and data contours (e.g., pressure contours). The program's algorithms are based on the Kentucky Pipe Model module. Cybernet's input consists of the network of pipes, nodes, and pumps with their characteristics: demands, junction elevations, pump curves, and pipe diameters. *See also* extended period simulation. *See* Section II for further information.

Cyclic depletion The process of withdrawing water at a rate that exceeds water replenishment during a given cycle.

D

d… The operator for the first derivative of a function or variable in several formulas.

d²… The operator for the second derivative of a function or variable in several formulas.

d'Alembert, Jean Le Rond *See* hydraulics.

Dam A barrier constructed across a watercourse for impoundment, diversion, navigability, or power generation purposes. *See also* dike; embankment. Dams may be classified according to their functions, according to design considerations, or according to the materials used in their construction. *See* the following types of dam: arch; arch gravity; buttress; check; coffer; crib; debris; detention; diversion; earth; earth fill; embankment; gravity; hydraulic fill; impounding; masonry; rock fill; rock filled crib; roller compacted concrete; single arch; spillway; storage; timber; timber crib; wicket.

DAMBREAK Acronym for Dam-Break Flood Forecasting.

Dam-Break Flood Forecasting (DAMBREAK) Model A National Weather Service computer model to simulate dam breaks and route the resulting flood hydrographs through a downstream channel.

Dam toe The downstream edge at the base of the dam.

Dangling lines In geographic information system (GIS) applications, dangling lines are lines that are meant to form polygon sides, but do not close, leaving a gap.

Darcian velocity *See* Darcy flux.

Darcy A unit for the measure of permeability.

Darcy flux The specific discharge, or flux per unit area per unit time, in Darcy's law. Sometimes called **Darcy velocity** or **Darcian velocity**.

Darcy, Henri Philibert Gaspard A French engineer (1803–1858) who, in a book on municipal water supplies, proposed the relationship that is widely used in the study of groundwater flow. In 1856, he conducted experiments for the design of sand filters at the city of Dijon, France. *See* Darcy's law.

Darcy's law An empirical relationship between hydraulic gradient and the viscous flow in the saturated zone of a porous medium under laminar conditions. The flux of vapors through the voids of the vadose zone can be related to a pressure gradient through the air permeability by Darcy's law (EPA Glossaries). The generalized Darcy's law, also called **Darcy's law of seepage**, states that the flow velocity V (actually the flux) at any point in a permeable material is proportional to the rate of hydraulic energy loss $\Delta h/\Delta L$ at that point; i.e.,

$$V = K \cdot \Delta h/\Delta L = k(\Delta h/\Delta L) \cdot \gamma/\mu \quad \text{(D-1)}$$

where K is the coefficient of permeability or hydraulic conductivity; k is the intrinsic permeability; and γ and μ, respectively, are the specific weight and dynamic viscosity of the fluid. (In a sand filter, for example, h could be the headloss and L the thickness of the filter.) For flow in porous media, Darcy's law is valid up to Reynolds numbers between 1 and 10.

Darcy velocity In groundwater flow, the discharge q per unit cross-sectional area, taken as:

$$q = K \cdot \Delta h/L \quad \text{(D-2)}$$

with K = hydraulic conductivity, L = length or thickness of the medium, and Δh = headloss over L. Also called **Darcy flux**, **Darcian velocity**, **discharge velocity**, or **specific discharge** (2).

Darcy–Weisbach equation A turbulent flow equation established in 1850 on the basis of experiments. It expresses the energy loss or headloss h_f for flow in pipes as a function of pipe length L between two sections, pipe internal diameter D, the velocity head, and a resistance coefficient or friction factor of the pipe f:

$$h_f = f \cdot (L/D) \cdot (V^2/2g) \quad \text{(D-3)}$$

where V is the average velocity, and g is the gravitational acceleration. Under laminar-flow conditions, the friction factor is:

$$f = 64/R_e \quad \text{(D-4)}$$

where R_e is the Reynolds number. For turbulent flow in smooth pipes and with $R_e > 4000$, the friction factor may be estimated from

$$\sqrt{f} \cdot \left[\log\left(R_e \cdot \sqrt{f}\right) - 0.8\right] = 1 \quad \text{(D-5)}$$

See the Chézy and Manning formulas for more traditional methods of open-channel design. *See also* the Blasius equation for an empirical formula for the friction factor.

Darcy–Weisbach roughness coefficient The dimensionless coefficient f in the Darcy–Weisbach equation.

Data Generally, any type of information (e.g., observations and measurements of physical facts, occurrences, and conditions) presented in numbers, words, or graphics.

Database An organized, indexed collection of related data; i.e., a program for storing, retrieving, and managing information. A set of data files on one or more related subjects. *See* Section II for further information.

Database component Same as **attribute table**; one of two components of geographic information system (GIS) data.

Database management system (DBMS) A program designed to create and maintain databases. Some current developers of DBMSs are Informix, Microsoft, and Oracle.

Data capture The process of transforming data into digital format for use in geographic information system (GIS) operations by digitization, electronic scanning, or manual methods.

Data Storage System (DSS) Also called **HEC-DSS**, it is a nonproprietary computer program developed in FORTRAN by the U.S. Army Corps of Engineers' Hydrologic Engineering Center to facilitate the efficient storage, manipulation, and retrieval of time-series and paired data in water resources studies. DSS uses direct-access files and allows the transfer of data between applications programs. DSS includes a series of utility programs for editing (DSSUTL), tabular or graphical display (DSPLAY), report production (REPGEN), mathematical operations (DSSMATH), etc.

Data Storage System Utility Program (DSSUTL) An HEC-DSS general utility program developed by the U.S. Army Corps of Engineers to manipulate, edit, or display data stored in DSS files. DSSUTL also allows the user to exchange (import or export) time-series data between DSS and DSS spreadsheets or database programs.

Datum plane A permanently established horizontal plane, surface, or level used as a reference to compute heights, depths, soundings, ground and water surface elevations, and tidal data. Mean sea level is the most generally used datum. However, mean low water and lower low water are also used on the Atlantic Coast and Pacific Coast of the United States, respectively. *See also* NGVD. Also called **chart datum**, **datum level**, **reference level**, or **reference plane**.

Da Vinci, Leonardo *See* hydraulics.

DBMS Abbreviation for database management system.

DCIA Abbreviation for directly connected impervious area.

Dead end The end of a water main not connected to other parts of the distribution network.

Dead storage The portion of a pond or reservoir below the lowest outlet of the structure and thus not available for use except for sediment collection. *See* Figure R-2; reservoir storage.

Dead water Standing or still water or water that fails to circulate for the proper operation of a structure or equipment. Different from dead well.

Dead well A well through an impermeable layer to drain water to a permeable one. Sometimes called **absorbing**, **drain**, or **negative well**. Different from dead water.

Debris dam A fixed dam across a stream channel to retain debris. A **debris basin** traps debris or sediment behind a low dam across a stream channel.

Debugging The process of detecting, locating, and correcting errors in computer hardware or software. In a modeling exercise, debugging is the procedure that involves checking the input data for inadequacies and errors while running the model. *See* Section II for further information.

Decay coefficient *See* infiltration decay coefficient.

Decay rate *See* recession decay rate.

Deep injection well A well used to discharge water or waste into a deep underground stratum.

Deep well A drilled well that draws water or minerals from below shallow impermeable strata or injects wastewater below such strata. In **deep-well injection,** raw or treated wastes are pumped for containment in the pores of permeable subsurface rock.

Deep-well disposal Disposal of wastewater to underground formations through a deep well.

Deep-well pump A centrifugal or reciprocating pump for lifting water from a deep well. *See* deep-well turbine pump; submersible pump.

Deep-well submersible pump A pump for use in a deep well. The impeller is installed near the water surface to avoid cavitation, while the motor is at the bottom, just below the impeller.

Deep-well turbine pump A multistage centrifugal pump for use in a deep well. The impeller is installed close to the water surface to avoid cavitation, while the motor is at ground level. Also called **vertical turbine pump**.

Degree–day factor *See* snowmelt.

Degree–day method A simple method for estimating the magnitude of snowmelt as a function of daily temperatures. *See* snowmelt formulas. Also called **temperature index method**.

Degree Engler A measure of the viscosity of a fluid as determined by the Engler viscometer.

Delayed runoff The groundwater that flows into a stream as a result of past infiltrated precipitation. Also called **baseflow**, **base runoff**, or **groundwater flow**.

Demand Flow entering or leaving a junction (node) in hydraulic modeling.

Demand curve A plot of the demand (flow) versus time at a junction.

Dendritic network A treelike or branched network without loops. All flow in a dendritic network converges in a single sink, as in a sewer or drainage system, or originates from a single source, as in an irrigation or a branched water supply system. A **dummy sink** may be used to convert multiple sinks (e.g., multiple sewer outfalls) to a single downstream sink; similarly a **dummy source** may be used to convert multiple sources to a single upstream source.

Densimetric Froude number (F_{rd}) The Froude number adjusted for density variations. It represents the ratio of inertia to buoyancy forces and is used as an approximation of the gradient Richardson number. It is a function of the average velocity V, the gravitational acceleration g, a characteristic length L, the average fluid density ρ, and the density difference over the depth Δρ. Flow is subcritical or supercritical according to whether F_{rd} is less or more than 1.

$$F_{rd} = V\sqrt{\rho}/\sqrt{g \cdot K \cdot \Delta\rho} \quad \text{(D-6)}$$

Density (ρ) The mass of substance contained in a unit volume. The density of water reaches a maximum of 1000 kg/m^3 = 1 kg/l = 1.941 $slugs/ft^3$ at about 4°C or 39°F. It decreases to 958 kg/m^3 or 1.860 $slugs/ft^3$ at 100°C or 212°F. *See also* bulk density; probability density.

Density current Water flowing through a larger body of water and retaining its identity because of its different density. *See also* density flow; density stratification.

Density flow Water movement at or near the surface of a reservoir due to an inflow of a different density. *See also* density current; density stratification.

Density function *See* probability density.

Density stratification The formation of layers of different densities in a body of water. *See also* density current; density flow.

Dependable yield *See* safe yield.

Depletion Water withdrawal from surface or ground sources at rates exceeding the replenishment or recharge rates.

Depletion curve In hydraulics, a graphical representation of water depletion from storage-stream channels, surface soil, and groundwater. A depletion curve can be drawn for baseflow, direct runoff, or total flow (EPA-94/04).

Depressed pipe *See* inverted siphon.

Depressed sewer A section of a gravity sewer line constructed lower than adjacent sections to pass under an obstruction. Also called **inverted siphon**, **sag line**, or **sag pipe**. *See* inverted siphon for illustration and more detail. *See also* dive culvert.

Depression head The drop in water surface of a well and of the adjacent water table caused by pumping. Same as **drawdown**.

Depression storage (or pocket storage) The volume of water detained in low-lying areas or surface depressions during runoff events. It does not contribute to surface runoff and will subsequently evaporate or infiltrate into the soil. *See also* rainfall–runoff relationship. It is sometimes called **maximum depression storage**, a capacity that is reduced by precipitation and replenished by evaporation and infiltration. On the other hand, the **available depression storage** at any time S_d depends on antecedent conditions and may be calculated as the sum of the available depression storage after the previous storm S_{d0} and the storage recovered since then:

$$S_d = S_{d0} + t \cdot k_e \quad \text{(D-7)}$$

where k_e is the pan evaporation rate, and t is the time since the previous storm.

Depth–area–duration analysis An analysis conducted to establish a relationship between the size of a drainage basin and the maximum precipitation depths for various durations. The results of the analysis are presented as curves of equal duration on a semilogarithmic graph of area versus

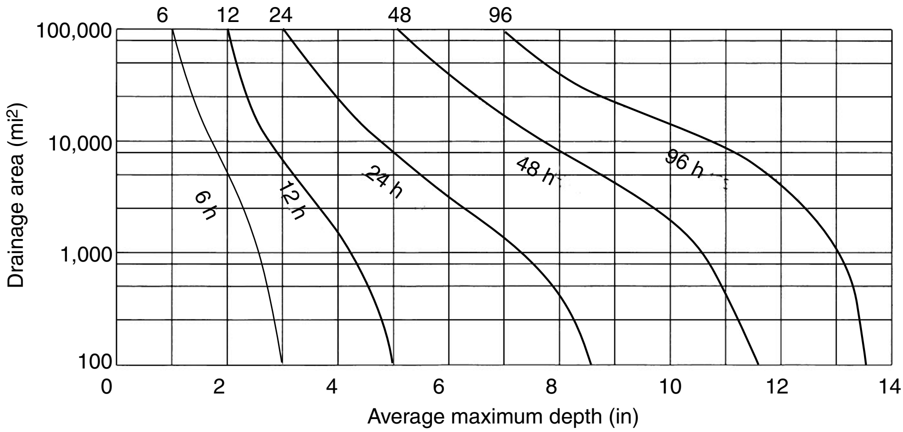


FIGURE D-1 Depth–area–duration analysis.

maximum depth. It is used in studies of probable maximum precipitation. *See* Figure D-1. The **depth–area–duration curve** is a graphical representation of the depth of rainfall of a given storm as a function of the storm duration and the area it covers.

Depth–area option A procedure in the HEC-1 model using index hydrographs to obtain a consistent hydrograph at any location in a drainage basin. An **index hydrograph** corresponds to a specific precipitation depth (or quantity) and a fixed set of hyetographs. Interpolation between two appropriate index hydrographs depending on the contributing area of a location produces a **consistent hydrograph** for that location.

Depth of runoff Same as **runoff depth**.

Derived quantity *See* fundamental quantity.

Descartes, René *See* hydraulics.

Designated uses Water uses identified in state water quality standards that must be achieved and maintained as required under the Clean Water Act, e.g., public water supply, irrigation, cold water fisheries.

Design capacity The average daily flow that a treatment plant or other facility is designed to accommodate.

Design criteria Guidelines, including construction details and materials, processes, unit sizes, etc., for the preparation of final engineering documents for a facility or process to achieve its intended function.

Design discharge In hydraulic studies, the maximum capacity that a hydraulic structure is designed to handle. It affects the cost of the structure and depends on such criteria as the acceptable risk level and corresponding return period. *See also* design flow; design storm.

Design event The event used as a basis for the design of such structures as dams and reservoirs, taking into account relevant technical, economic, and other factors, e.g., design flood for flood control works, design drought for water supply reservoirs, design flow for water quality protection, and design storm for drainage. *See also* probable maximum flood/precipitation/storm; standard project flood.

Design flood *See* design storm.

Design flow In water quality studies such as waste load allocations, a low-flow criterion of the form pQt is the minimum average flow Q over the period p expected to occur once in t years. For example, the 7Q10 flow is the minimum 7-day average flow expected once in 10 years. Also defined as the 7-day, consecutive low flow with a 10-yr return period or the lowest streamflow for 7 consecutive days that would be expected to occur once in 10 yr. The 7Q20 and 30Q20 flows are the average streamflows equaled or exceeded on the average once every 20 yr (i.e., 5% of the time) over periods of 7 days and 30 days, respectively. *See also* design discharge. The probability p that the flow will exceed Q in any given year is

$$p = 1 - 1/t \tag{D-8}$$

and the probability p′ that the flow Q will occur at least once in N years is

$$p' = 1 - (1 - 1/t)^N \tag{D-9}$$

Design life The estimated number of years of service of an installation or any component or equipment thereof.

Design storm An observed, hypothetical, or synthetic storm assigned a certain frequency and often used in planning or design studies. Its magnitude, intensity, duration, and pattern over time do not exceed the capacity of the project under consideration (e.g., a drainage system, bridge, culvert, dam, or flood control project). A **design flood** is defined similarly. Common design storms are (a) **10-yr, 24-h precipitation event**: the maximum 24-h precipitation event with a probable recurrence interval of once in 10 yr as established by the Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service, or equivalent regional or state rainfall probability information; and (b) **10-yr**, **24-h rainfall**; **25-yr**, **24-h precipitation**; and **25-yr**, **24-h rainfall**, which are similarly defined (EPA-40CFR436.21-c, EPA-40CFR412.11-e, etc.). The **10-yr**, **24-h storm** is also defined as a rainfall event of 24-h duration and 10-yr frequency that is used to calculate the runoff volume and peak discharge rate to a best management practice (BMP). Similarly, the **25-yr**, **24-h storm** is an event of 24-h duration and 25-yr frequency (EPA Glossaries). The **100-yr**, **72-h storm** is an event of 72-h duration and 100-yr frequency and is similar for the **100-yr**, **72-h peak stage**.

Design storm event *See* design storm; storm event.

Desilting area An area covered with vegetation that is used for silt and sediment control in flowing water.

Desilting basin A basin for removing silt and sediment from streamflow or runoff, e.g., just below the diversion structure of a canal. Also called **desilting works**.

Destratification Elimination or reduction of density or thermal stratification by vertical mixing within a lake or reservoir.

Detention In the management of stormwater or combined sewer overflows, detention is the slowing, attenuating, or dampening of flows by temporarily holding the water on a surface area, in a storage basin, or within the sewer system.

Detention basin, detention pond, detention reservoir, detention tank, holding pond, retarding basin, retarding reservoir, storage basin, storage reservoir Structures built, with or without outlet control, to hold temporarily excess water such as streamflow, stormwater, and runoff. **Detention** or **retarding basins**, and **detention** or **retarding reservoirs**, used for flood control, temporarily store streamflow until the stream has sufficient capacity for the ordinary flow plus the release from the basins or reservoirs; they have no control gates. **Storage basins** or **storage reservoirs**, also designed and operated for flood mitigation, are equipped with gates and valves for adequate regulation. **Ponds** are natural or artificial bodies of water of limited size; they are used in stormwater or wastewater management. The Environmental Protection Agency defines a **holding pond** as a pond or reservoir, usually made of earth, built to store polluted runoff. It is current practice for municipalities to require land developers to install **detention basins** or holding ponds to keep the peak runoff from an area at the same level as before development. **Detention tanks** are used mainly in wastewater management to even out surges and allow biological, chemical, or physical treatment. *See also* dry detention; forebay; wet basin.

Detention dam A small dam constructed to impound surface runoff temporarily and retard flood flows or to remove sediment from runoff.

Detention lag The period between the moment a change is made and the moment such a change is finally sensed by the associated measuring instrument (EPA Glossaries).

Detention pond, detention reservoir *See* detention basin.

Detention/retention The distinction between detention and retention is not always clear, and the two words are sometimes used interchangeably, e.g., in stormwater management. The fundamental concept behind both is the same, that is, holding excess water for later release when the natural or artificial receiving or processing system can better accommodate it. The water and wastewater glossary (American Public Health Association et al., 1981) lists the following terms: detention dam, detention reservoir, detention tank, detention time, retention (as a part of precipitation), retention capacity, retention period, retention ponds, retention time. It defines detention time as "the period of time that a water or wastewater flow is *retained* in a basin, tank or reservoir for storage or completion of physical, chemical, or biological reactions" and retention time as "the period that water and wastewater, at a given hydraulic loading, will be *retained* in a reactor, unit process or facility" (pp. 99, 307). One possible distinction may be that **detention** refers to the temporary storage for a period of 24 to 72 h with subsequent release to a receiving water, and **retention** refers to on-site storage with disposal by infiltration or evaporation, i.e., without release (Harper, 1999). A **retention/detention pond** is a dual system with offline retention followed by diversion to a detention pond. In subsurface retention systems, perforated piping allows the release of stormwater into the soil at a controlled rate. On the other hand, subsurface detention piping captures excess runoff and conveys it slowly to the stormwater collection system. Retention and detention systems are sometimes classified on the basis of detention time: (a) *detention system* for a period of a few hours to a few days, (b) *retention system* for weeks or months, (c) *dry system* or *wetland* when the holding is intermittent.

Detention storage The volume of water contained in runoff during precipitation. It is subject to evaporation and eventually contributes to streamflow.

Detention tank *See* detention basin.

Detention time (1) The calculated time required for a small amount of water to pass through a tank, basin, reservoir, pond, etc., at a given flowrate. (2) The actual time that a small amount of water is in a settling basin, flocculating basin, or rapid-mix chamber. (3) In storage reservoirs, the length of time water will be held before use (EPA-94/04). (4) The time that stormwater remains in a BMP unit; for a runoff event, the theoretical detention time is the average time that stormwater remains in the BMP unit during release. (5) Same as **retention time**, **hydraulic retention time**, or **retention period**, i.e.,

$$t = v/Q \tag{D-10}$$

or the time t that water, wastewater, or stormwater remains in a reactor, unit process, storage basin, or any similar facility of volume v at a discharge rate Q. This formula and the above definitions correspond to an *average*; actual residence times vary widely, particularly in stormwater systems. *See also* detention/retention.

Determination coefficient *See* coefficient of determination.

Deterministic model A mathematical model that always yields the same output for a given input without any consideration for risk and uncertainty (as opposed to a stochastic model). Often, deterministic models are based on physical relationships without a need for experimental data. The terms *deterministic model* and *mechanistic model* are sometimes used interchangeably. *See also* parametric model; pseudodeterministic model; statistical model.

Deviate (K′) A parameter of the log Pearson type III distribution; depends on the skew coefficient and on the return period (or exceedance probability) of the event.

Dewatering Removal or draining of the water from a container such as a tank, a basin, or a trench. Also the separation or removal of a portion of the water in sludge or slurries.

Diagonal-flow pump Pump that directs the fluid diagonally — instead of radially or axially — through the impeller.

Diaphragm A thin sheet placed between parallel parts of a device to increase its rigidity.

Diaphragm pump (1) A pump that uses a flexible diaphragm attached to a vertical cylinder to move liquids. The movement of the diaphragm successively creates suction and discharge. (2) A metering pump that uses a diaphragm to separate the operating parts from the pumped fluid or from hydraulic fluid.

Diaphragm valve A fluid valve that uses a diaphragm as the open–close element.

Differential gage Same as **differential-pressure gage**.

Differential manometer A type of differential-pressure gage. *See* manometer for details.

Differential-pressure gage An instrument that measures the relative difference in pressure between two points of a fluid in a pipe or other container. *See also* differential manometer.

Diffuse source of pollution A phrase sometimes applied to urban stormwater runoff because of both its point and nonpoint characteristics. *See* nonpoint source; point source; Table P-1.

Diffusing pit A pit that functions as a diffusing well.

Diffusing well Same as **diffusion well**.

Diffusion approximation A simplification used in the Muskingum–Cunge (flood routing) method to solve the Saint-Venant equations. *See* convective diffusion equation.

Diffusion well A well used to add water to an aquifer. Also called a **recharge well**. *See also* diffusing pit; diffusing well.

Digital device or representation *See* analog device.

Digital elevation model (DEM) One of two techniques based on the geographic information system (GIS) used in hydrologic modeling (as an alternative to maps and field surveys) to provide a digital representation of watershed topographical characteristics. The other type is a digital terrain model (DTM). The U.S. Geological Survey (USGS) produces and distributes DEMs (corresponding to 7.5-min quadrangle maps of the United States) that are inexpensive and widely used, but their accuracy and resolution vary.

Digital line graph (DLG) In hydrologic modeling applications, a digital line graph is a map of contour data stored in digital form that can be converted to a digital elevation model.

Digital terrain model (DTM) One of two techniques based on the geographic information system (GIS) used in hydrologic modeling to provide a digital representation of watershed topographical characteristics. The other type is a digital elevation model.

Digitization The conversion of data into digital form; i.e., the conversion of data into digits, especially for use by a computer; e.g., the conversion of spatial features of a sewer map (pipes, manholes, etc.) from a hard copy to an electronic format using a hand-held instrument or the conversion of an analog image into a digital form. The digitizing technique uses such devices as digitizers, digitizing tables, and digitizing tablets to convert the analog data to digital form.

Dike An embankment or ridge constructed on dry ground to prevent the movement of liquid or the overflow of lowlands, retain floodwater, act as a barrier to prevent a spill from spreading, etc. A dike differs from a dam, which is constructed across a watercourse or a stream channel.

Dilution factor The ratio (at the point of disposal) of the flow of receiving water to the flow of wastewater, treated effluent, or stormwater discharged. *See also* dilution ratio.

Dilution method A method used to evaluate a stream discharge Q by injecting a tracer of known concentration C_1 and flowrate Q_1 and measuring its concentration C_2 at a point downstream. *See also* salt method.

$$Q = Q_1(C_1 - C_2)/C_2 \qquad \text{(D-11)}$$

Dilution ratio The ratio of the volume of water in a stream to the volume of incoming water. It affects the ability of the stream to assimilate waste. *See also* dilution factor.

Dimension A basic quantity or characteristic of physical systems such as force, mass, temperature, length, and time. Most hydraulics problems use one of two sets of dimensions: the FLT (force–length–time) system or the MLT (mass–length–time) system.

Dimensional analysis A method for deriving dimensionless relationships within physical systems or for comparing the quantities occurring in a problem without actually solving the problem. This comparison may be made through the use of dimensionless numbers.

Dimensional analysis theorem or Π (capital Greek letter *pi*) theorem A statement presented in 1915 by Buckingham (but apparently first derived by Riabonchinsky in 1911) and used in conducting dimensional analysis. Essentially, in a problem or formula involving d derived quantities and f fundamental quantities, there are d – f dimensionless numbers, each number involving the f fundamental quantities plus one more quantity. For example, by taking the ratio of the inertia force ma to the gravity force mg, viscous force τA, pressure force ΔpA, and surface tension force σL, one may derive, respectively, the Froude, Reynolds, Euler, and Weber numbers, with m = mass, A = area, a = acceleration, $\tau\rho$ = shear stress, g = gravitational acceleration, Δp = pressure, L = length, and σ = surface tension.

Dimensional homogeneity The property of an equation when both sides are expressed in, or can be reduced to, the same combination of fundamental dimensions (mass, length, time).

Dimensional matrix The matrix of m columns of variables and n rows of dimensions used in dimensional analysis, with m > n. The governing variables are placed in the first n columns. *See* Figure D-2 for an example related to the Darcy–Weisbach headloss formula.

Headloss Variables and Dimensions

L = length
M = mass
T = time
V = velocity = LT^{-1}
D = pipe diameter = L

ρ = density = ML^{-3}
h_f = head loss = L
μ = viscosity = $ML^{-1}T^{-1}$
f = roughness = L
L = pipe length = L

	V	D	ρ	h_f	μ	f	L
M	0	0	1	0	1	0	0
L	1	1	–3	1	–1	1	1
T	–1	0	0	0	–1	0	0

Darcy–Weisbeck formula

$$h_f = f \cdot \frac{L}{D} \cdot \frac{V^2}{2g}$$

FIGURE D-2 Dimensional matrix.

Dimensionless hydrograph A unit hydrograph used in the Soil Conservation Service (SCS) synthetic unit hydrograph method, for which the discharge is expressed as the ratio of the actual discharge to the peak discharge and the time as the ratio of the time to lag time. It may be used also to compare unit hydrographs from different drainage basins or from different storm patterns. In the SCS method, the peak discharge Q_p in cfs is computed as DAR/T_p, where A is the drainage area in square miles, D is the peak rate factor, R is the runoff depth in inches, and T_p is the time to peak in hours. The peak rate factor D is sometimes taken as 484 but can actually vary widely, e.g., from 300 in flat, swampy country to 600 in steep terrain. The time to peak is equal to the lag time plus half the duration of rainfall excess. The lag time itself is sometimes taken as 60% of the time of concentration. *See* equivalent triangular unit hydrograph; Figure E-3.

Dimensionless numbers In hydraulics, a series of fundamental parameters derived from governing equations or by dimensional analysis: Courant, densimetric Froude, Euler, Froude, gradient Richardson, kinematic wave, Lewis, Mach, Peclet, Prandtl, Reynolds, Rossby, Schmidt, Weber.

Dimensionless unit hydrograph Same as **dimensionless hydrograph**.

Dip A simple structure used to carry drainage across a road, as an alternative to a bridge or a culvert, where streamflow is infrequent or of short duration. The lowering of the roadbed to match the bottom of the channel is designed to minimize interference with streamflow and to provide appropriate protection against scouring.

Direct evaporation Loss of water by evaporation from surface water bodies and oceans, as opposed to evaporation from land areas.

Direct flow measurement *See* discharge measurement.

Directly connected impervious area (DCIA) The total impervious area that drains directly to the conveyance system within a drainage basin without any flow across pervious areas, e.g., roof tops, driveways, roadway sections, piped connections of impervious surfaces to the sewers, and parking areas draining directly to the inlets without contacting grass areas. DCIA is an element of the advanced interconnected pond routing model; it does not contribute to soil storage. *See also* effective impervious area.

Direct runoff (or storm runoff) (1) Water that flows over the ground surface or through the ground directly into streams, rivers, and lakes (EPA-94/04). (2) The portion of precipitation that reaches a stream shortly after rainfall and remains in the river basin for only a few days. It is the sum of surface runoff and interflow and the difference between streamflow and baseflow. It corresponds to precipitation excess. Also called **direct streamflow** or **quick-response runoff**. *See also* Figure R-6; rainfall–runoff relationship.

Direct service area The area receiving complete sewer service from a central sewer authority, as opposed to other utilities that provide only collection service within their own boundaries but deliver their flows to the central agency for transmission, treatment, and final disposal. *See* Section II for further information.

Direct streamflow *See* direct runoff.

Dirichlet boundary condition An auxiliary condition imposed for the computational solution of a fluid flow problem; in the form of the value of a function, e.g., the head at the entrance of a reservoir or a velocity component at an inflow boundary. *See also* Neumann boundary condition.

Discharge (1) Flow of surface water in a stream or canal or the outflow of groundwater from a flowing artesian well, ditch, or spring. The word also applies to discharge of liquid effluent from a facility or of chemical emissions into the air through designated venting mechanisms (EPA-94/04). In various regulations, the Environmental Protection Agency (EPA) defines discharge as including any spilling, leaking, pumping, pouring, emitting, emptying, or dumping. (2) In general, in hydraulics, hydrodynamics, or hydrology, discharge, flow, or flowrate is the flux of water through an area from a stream, canal, conduit, pump, tank, etc. By definition, discharge Q is the product of the flow area A by the velocity V of the flowing water or

$$Q = A \cdot V \tag{D-12}$$

an expression of the conservation of mass principle. It may also be computed by formulas (Darcy–Weisbach, Chézy, Manning) or from field measurements using the stage–discharge relationship or the velocity–area method. *See* discharge measurement; open-channel flow.

Discharge area (or flow area) (A) The cross-sectional area normal to the direction of flow; used in the computation of the discharge Q of a stream, a pipe, or a conduit by multiplying it by the flow velocity V. Also used in

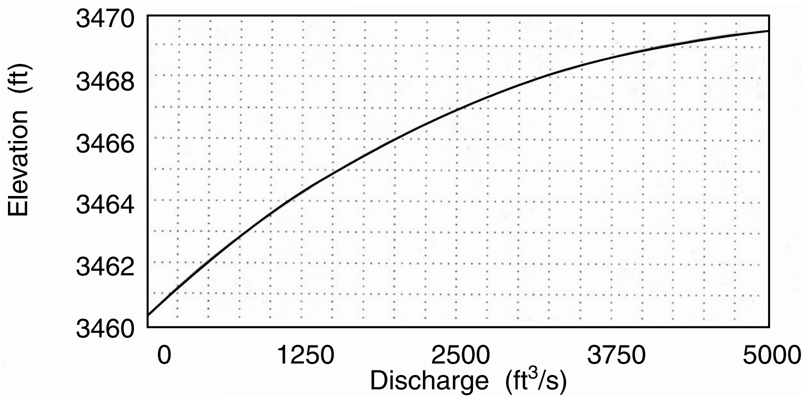


FIGURE D-3 Discharge rating curve.

the determination of the hydraulic radius R, which is the ratio of the flow area to the wetted perimeter. *See* channel section; open-channel flow.

Discharge balancing method *See* Hardy Cross method.

Discharge capacity The maximum flowrate that can pass through a hydraulic structure, such as a conduit, a channel, or a treatment plant.

Discharge coefficient A coefficient used in the weir, orifice, and other formulas or in electromagnetic current meters. To obtain the actual flow through an orifice, weir, nozzle, or current meter, the theoretical discharge is multiplied by this coefficient. *See* orifice flow Equations O-7 and O-8; weir Equations W-4 through W-8.

Discharge curve A graphical representation of the relationship between discharge and a pertinent hydraulic property such as depth of flow or gage height. Same as **rating curve** and **discharge rating curve**. *See* Figure D-3.

Discharge duration curve A curve that shows the percentage of time streamflow is less than or equal to various discharges during a certain period or the percentage of time the discharges are equaled or exceeded. The shape of the curve varies with the time unit selected. In addition, the curve may show the expected minimum and maximum discharges. *See* Figure D-4.

Discharge head A measure of the pressure exerted by a fluid at the point of discharge, for example, the vertical distance between the intake level of a water or wastewater pump and the level of discharge. Also called **dynamic discharge head**. *See* dynamic head.

Discharge hydrograph (or flow hydrograph) A graph of discharge versus time for the flow in a stream or conduit. In hydrology, the discharge hydrograph reflects the nature of a flood as well as the physiographic and climactic conditions of the drainage basin. For a single storm, it consists of a rising limb, a peak, and a receding limb. At any time, the discharge is the sum of baseflow and direct runoff. *See* Figure D-5.

Discharge manhole A manhole receiving a discharge, for example, from a pump station. *See also* discharge node.

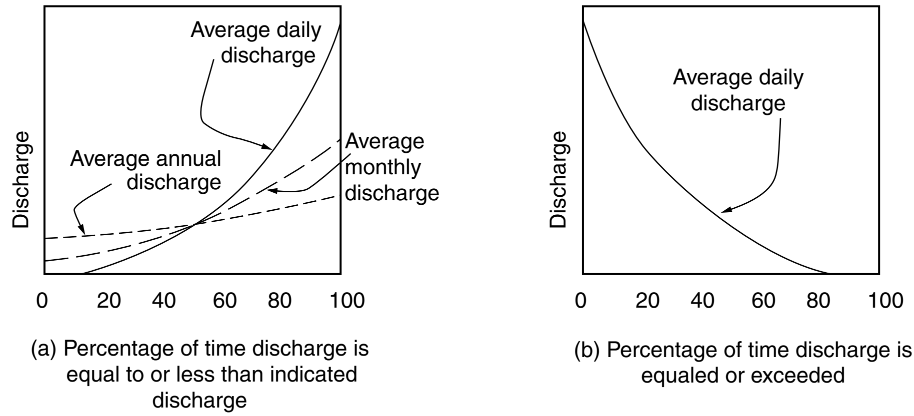


FIGURE D-4 Discharge–duration curve.

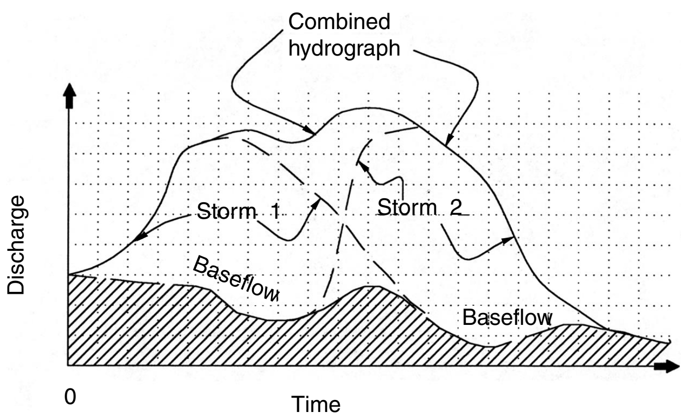


FIGURE D-5 Discharge hydrograph (two storms).

Discharge measurement (or flow measurement) The determination of the discharge in a canal, conduit, stream, orifice, etc. using such devices as a current meter, weir, or Pitot tube. **Direct determinations** use measurements of volume or weight in a given time, as in a positive displacement meter. In **indirect determinations**, a flow characteristic such as pressure or water surface elevation is measured and used in a formula to compute flowrate.

Discharge node In finite-difference models, a discharge node represents a discharge condition such as a well in groundwater studies or a manhole in wastewater systems.

Discharge rating curve Same as **discharge curve** or **rating curve**. *See* Figure D-3.

Discharge table A table showing the correspondence between discharge and a pertinent hydraulic property such as depth of flow or gage height. *See also* rating table.

Discharge velocity In groundwater flow, it is the discharge per unit cross-sectional area, computed using Darcy's law. Also called **Darcy velocity** or **specific discharge** (2). *See* Equation (D-2).

Discrete modeling The use of difference equations instead of differential equations in modeling applications.

Discretization (1) Subdivision of the model attributes into smaller elements, e.g., the model area into cells or the time domain into timesteps. It also refers to the use of discrete instead of continuous measurements, e.g., hourly flows or concentrations. (2) The process of entering field data into a computational model as a set of coordinates that allows the calculation of hydraulic parameters. (3) The process of converting the governing equations (usually continuous, partial differential) into algebraic equations to be solved by a computer.

Disk drive A device that stores, reads, or writes data from a disk; it may be a hard drive or a floppy (flexible) disk drive. Data recording on the disk may be magnetic or optical.

Diskette A flexible medium used in a floppy disk drive of a computer; has concentric rings for recording information magnetically or optically. Same as **floppy disk**.

Displacement ejector An ejector that lets a liquid accumulate in a pressure chamber and displaces it with compressed air when the liquid level reaches a certain elevation.

Displacement pump Moves water through the alternate filling and emptying of the pump chamber by the movement of a piston or similar device. *See also* positive displacement pump.

Display The image that appears on a screen such as that of the monitor of a personal computer system; used to display the result of a computer operation.

Disposal well A well used for the disposal of waste into a subsurface formation.

Dissolved oxygen (DO) The oxygen freely available in aqueous solutions; vital to fish and other aquatic life and for odor prevention. DO levels are an important indicator of a water body's ability to support desirable aquatic life. Secondary and advanced wastewater treatment plants are generally designed to ensure adequate DO in receiving waters (EPA Glossaries).

Dissolved solids Disintegrated organic and inorganic matter in water that can pass through a 0.45-μm pore-diameter filter. *See also* colloids; filterable residues; solids; suspended solids; total dissolved solids.

Distributed model A deterministic urban runoff model that accounts for spatial variations in function of the position in the watershed, e.g., through the use of contour lines to represent a specific characteristic. The definition of a distributed model requires such physiographic data as: channel network configuration, location of drainage divides, channel length and slope. These data can be obtained from maps and field surveys or from digital elevation models. Also called **distributed watershed model**. *See also* lumped models; pseudodistributed model.

Distribution and distribution function *See* probability density.

Distribution graph A type of unit hydrograph with percentages of the total runoff volume (instead of flows) as ordinates. This hydrograph assumedly represents all storms of a given duration in the basin. *See also* dimensionless hydrograph.

Distribution reservoir A reservoir in the distribution network of a water supply system that provides local storage in case of an emergency and to respond to daily fluctuations in demand. Also called **distributing reservoir**. *See also* service storage.

Distribution storage The local storage in a water supply system. *See* distribution reservoir.

Distribution system The system of conduits and appurtenances used to deliver municipal or irrigation water to consumers.

Distributive-parameter model A type of micromodel used to simulate the urban hydrology processes and involving all the detailed physical properties of the system under consideration. The opposite, or macro, approach leads to a lumped-parameter model. To compensate for the large number of parameters, the distributive-parameter model uses such simplifications as the kinematic wave approximation.

Ditch A small channel constructed through earth or rock to convey drainage or irrigation water or to bury pipelines, cables, etc. A ditch differs from a canal in that the former usually is unlined and has a cross-sectional area less than 6 square feet. *See also* drainage swale. A **ditch check** is a barrier (such as a small dam or a series of small dams) installed in a road ditch to reduce velocity and decrease erosion.

Diurnal hydrograph Shows the diurnal fluctuations in water consumption, wastewater discharge, or pollutant concentration, hour by hour, usually from 12:00 a.m. to 12:00 midnight. *See* Figure D-6.

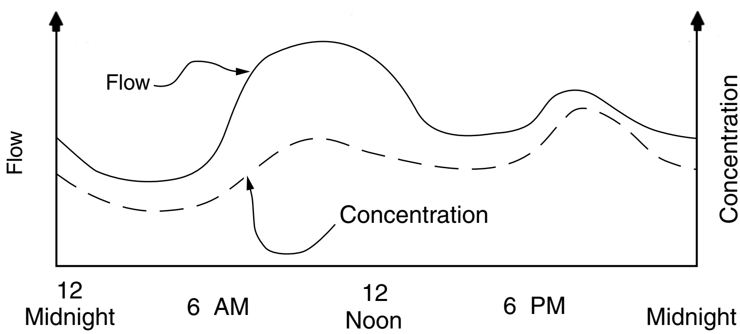


FIGURE D-6 Diurnal hydrograph.

Dive culvert A culvert that functions as an inverted siphon: it has two sections, the first sloping down, and the second sloping up, with the outlet lower than the inlet.

Diversion The redirection of stream, wastewater, or storm flows using a channel, canal, pipeline, or other conduit. The flows are diverted to protect a site from flooding, overflow, or erosion for use or safe disposal in another site. Also called **terrace** or **diversion terrace** when built across a slope to control surface runoff and soil erosion. A **diversion bank** or **diversion berm** is the part of the diversion that prevents water from flowing onto lower lying areas.

Diversion area An area adjacent to a watershed divide, but contributing water to that watershed.

Diversion box A small diversion chamber.

Diversion canal An artificial channel for diverting water from one point to another.

Diversion chamber A chamber designed to divert all or part of a stream or other flow.

Diversion channel An artificial channel carrying water from a diversion dam or diverting water from a main channel.

Diversion dam A fixed dam for diverting streamflow from its course into canals or other conveyance systems. *See also* diverting weir.

Diversion gate A gate that is used to divert water from a main channel into another.

Diversion link An alternative flow path or multiple pipes between two nodes. Also called **multiple conduit** or **multiple link**.

Diversion manhole A manhole that functions as a diversion chamber.

Diversion terrace *See* diversion.

Diversion tunnel An underground passageway for diverting water from a site.

Diversion works Dams, pump stations, weirs, etc. and appurtenances used to divert water.

Diverting weir A weir over which excess water, stormwater, or wastewater is allowed to flow. Diverting weirs are used in wastewater treatment plants, for example, as a bypass to prevent surcharging of upstream units in case of electrical or mechanical failure of screening devices. Same as **overfall weir** or **overflow weir**. *See also* diversion dam; movable weir.

Division weir A device or structure used in irrigation systems to obtain a more accurate distribution of flow than provided by a simple division box. In addition to the weir plate, it contains dividers downstream to distribute the nappe.

DLG Abbreviation for digital line graph.

DO Abbreviation for dissolved oxygen.

Domain *See* model domain.

Domestic sewage Untreated sanitary wastes that pass through a sewer system [EPA-40CFR261.4-(a)(ii)]. Wastewater is now the generally accepted term for the spent or used water from all sources. Sewage, as distinguished from industrial and institutional wastewaters, is produced by households and commercial establishments.

Domestic wastewater *See* domestic sewage.

Dominant discharge The most representative discharge of a stream; e.g., the discharge that would not alter the channel characteristics (cross section, bend, slope, etc.) over the long run.

Doppler current meter An acoustic instrument that uses a single transducer to measure current velocities. The procedure is to project a sound signal of known frequency into the water and to measure the Doppler shift, which is proportional to the water velocity past the meter. (The **Doppler shift** is the difference between the frequency of the signal and that of the reverberation due to interaction with particles carried by the flow.)

Doppler current profiler (or Doppler meter) Same as **Doppler current meter**.

Doppler radar A radar that uses the Doppler shift to measure the speed of a moving target.

Doppler ultrasonic flowmeter A device to measure the velocity of fluid flow using the Doppler shift of high-frequency sound waves.

DOS Acronym for disk operating system.

Double-action device/mechanism A device/mechanism that acts in two directions, such as a reciprocating piston in a cylinder with a chamber at each end. A **double-action pump** admits water on both sides of the piston, thereby ensuring a more or less constant discharge.

Double-suction impeller An impeller with two suction inlets.

Double-suction pump A centrifugal pump with a suction pipe on both ends.

Double-wall cofferdam A cofferdam of two rows of sheet piling with sand in the intermediate space.

Downcomer Same as **downspout**.

Downgradient The direction of groundwater flow, i.e., in the direction of decreasing static head; the same as downstream for surface water.

Downspout A vertical pipe leading from a roof drain or gutter to the ground, a cistern, a storm drain, or other means of disposal. Also called **conductor**, **downcomer**, or **leader**.

Downstream control A stormwater management option that involves in-pipe control measures (in the collection system) or end-of-pipe measures to treat runoff before its discharge to receiving waters, as opposed to source control measures that tend to reduce runoff volumes.

Draft The process of withdrawing water or the quantity of water drawn from a tank, reservoir, stream, etc.

Draft tube One of the four basic parts of reaction hydraulic turbines, such as the Francis and the Kaplan turbines. The other parts are the scroll case, the wicket gates, and the runner. The draft tube is a conical tube designed to decelerate the flow from the runner.

Drag The resistance of a liquid to the sedimentation or flotation of suspended particles. The drag coefficient is a measure of this resistance.

Drag coefficient (C_D) (1) A dimensionless coefficient that expresses the nature of flow and channel characteristics, as in the Chézy coefficient. (2) A dimensionless measure of the resistance to the settling or flotation of suspended solids, depending on their characteristics (size, shape, density, terminal settling velocity); defined as the ratio of the force per unit area to the stagnation pressure:

$$C_D = F_D/(0.5\rho V^2 A) \quad \text{(D-13)}$$

where F_D is the drag force, A is the surface area on which it acts, V is the average velocity, and ρ is the fluid density. It may also be computed as a function of the Reynolds number R_e:

$$C_D = (24/R_e) + (3/\sqrt{R_e}) + 0.34 \quad \text{(D-14)}$$

See also Chézy coefficient; friction coefficient/factor; Stokes law.

Drain A channel, buried pipe, lined or unlined ditch, or other conduit that carries off liquids by gravity. Drains that carry stormwater, wastewater, or a combination of both are called storm, sanitary, or combined sewers, respectively. **Relief drains** are used to dewater a construction site with a high water table. *See also* building drain; French drain; underdrain.

Drainage (1) Same as **drainage water**. (2) Removal of excess ground-, surface-, or stormwater from structures or from an area by gravity or pumping to prevent inconvenience or protect against losses. (3) Same as **drainage area** or **watershed**. (4) The drainage system: channels, ditches, drains, pump stations, manholes, and other appurtenances. (5) Water lost from the soil by percolation. **Soil drainage** refers to the frequency and duration of periods when the soil is not saturated; water is removed fast from well-drained soils, but slowly from poorly drained or waterlogged soils.

Drainage area (1) Same as **drainage basin** or **watershed**. (2) The area of a drainage basin expressed in acres, square miles, hectares, etc. (3) Also, the area served by a storm sewer system. *See* catchment.

Drainage basin (1) The area of land that drains water, sediment, and dissolved materials to a common outlet at some point along a stream channel (EPA-94/04). (2) The area from which a single drainage system carries surface runoff away; also called **catchment area**, **drainage area**, **watershed**. (3) The largest natural drainage area subdivision of a continent; e.g., the United States has been divided at one time or another, for various administrative purposes, into some 12 to 18 drainage basins (American Public Health Association et al., 1981). *See* catchment; drainage area; watershed.

Drainage canal A canal that drains an area having no natural outlet for precipitation.

Drainage coefficient The discharge of an underdrainage system designed to remove excess rainfall water for salinity control or other purposes. The coefficient is expressed as inches of depth of water per 24 h or as a percentage of the mean annual rainfall. Also called **drainage modulus**.

Drainage delineation map A map showing the various elements of drainage of an area: topography, hydrologic features, existing and proposed development.

Drainage density The relative density of natural drainage channels in a given area; i.e., the ratio of miles (or kilometers) of channel to square miles (or square kilometers) of area.

Drainage district (1) A legally established agency or organization for the design, construction, financing, operation, and maintenance of a drainage system. When part of a state or local government, it may be called a drainage authority or a drainage department. (2) The territory within the area served by this system, which may include more than one political subdivision as well as industrial parks and other private users. *See also* sewer district.

Drainage divide The line that separates one drainage basin from another; it follows the ridges or summits that form the exterior of the drainage basins. Also called **topographic divide** or **watershed divide**.

Drainage equilibrium The condition that exists when the water table does not change over a certain period because the volume of water input to the underground reservoir equals the volume of water withdrawn from it.

Drainage gallery A gallery parallel to the crest of a dam and designed to divert upstream seepage from the downstream face.

Drainage modulus Same as **drainage coefficient**.

Drainage network diagram A diagram that represents on the computer screen the drainage elements exactly as they appear in reality. *See also* schematic diagram.

Drainage swale An open channel to convey runoff from the bottom or top of a slope; has a lining of vegetation, asphalt, concrete, etc. to prevent erosion. Trapezoidal swales often have the following characteristics: a minimum bottom width of 24 in, a uniform longitudinal grade of 2–5%, a side slope of 3:1 with a minimum depth of 12 in or a side slope of 2:1 with a minimum depth of 18 in (Dodson, 1999). *See also* canal; ditch.

Drainage system A network of pipes, pumps, structures, and appurtenances designed and operated to effect drainage.

Drainage water Incidental surface waters from such sources as rainfall, permafrost melt, or snowmelt (EPA-40CFR440.141-3). Ground-, surface-, or stormwater collected by a drainage system and discharged into a natural waterway. Different from drain well and drainage well.

Drainage well (1) In general, it is a well constructed to receive runoff as a stormwater management structure. *See also* drywell. (2) A well drilled to carry excess water off agricultural fields. Because it acts as a funnel from the surface to the groundwater, a drainage well can contribute to groundwater contamination (EPA-94/04). (3) A vertical shaft in a masonry dam designed to divert seepage away from the downstream face. (4) A well to carry water or wastewater into underground strata. Different from drain well and drainage water.

Drain tile A perforated drain used at the bottom of a building foundation, in trenches of short lengths, to collect and carry off excess groundwater. Also used for underground disposal of wastewater.

Drain well A well through an impermeable layer to drain water to a permeable one. Sometimes called **absorbing**, **dead**, or **negative well**. *See also* drainage well.

Drawdown (1) The drop in surface elevation or in water level resulting from the withdrawal of water, as when a well is pumped or when a pond loses water by infiltration and evaporation. (2) The quantity of water drawn from a tank or reservoir or the drop of water level of the tank or reservoir. *See also* depression head; drop (2).

Drawdown curve The longitudinal shape of the water surface in a stream or a conduit in which the actual depth of flow y is between the critical depth y_c and the normal depth y_n, i.e.,

$$y_c \leq y \leq y_n$$

or

$$y_n \leq y \leq y_c$$

for example, at a free outfall or at the transition from a mild channel slope to a steep slope. In general, when the water surface drops in the direction of flow, the water surface profile is called a drawdown curve. *See also* backwater; critical flow; open-channel flow.

Drawdown period (or drawdown time) The time t_d necessary to empty a detention pond without any additional inflow; i.e., the ratio of the active storage volume v_a to the constant water release rate Q. It may be taken as twice the steady-state detention time t_s in an extended detention dry pond (James, 1996):

$$t_d = 2t_s = v_a/Q \qquad \text{(D-15)}$$

Dredging Removing, or the removal of, sediment and other solid matter from the bottom of a water body.

Drill cuttings The particles generated by drilling into subsurface geologic formations and carried to the surface with the drilling fluid (EPA-40CFR435.11-h).

Drilled well and **drill hole** *See* borehole.

Drill-hole log A record of the type and characteristics of the formation penetrated in drilling a borehole by analyzing the cuttings, core recovered, or other information (e.g., the elevation of the water table) from electronic devices. *See also* borehole log; well log.

Drilling fluid The circulating fluid used in the rotary drilling of wells to clean and condition the hole and counterbalance formation pressure. A water-based drilling fluid is the conventional **drilling mud** in which water is the continuous phase and the suspending medium for solids, whether or not oil is present. An oil-based drilling fluid has diesel oil, mineral oil, or some other oil as its continuous phase with water as the dispersed phase (EPA-40CFR435.11-i).

Drilling mud A heavy suspension used in drilling injection and other wells; introduced down the drill pipe and through the drill bit (EPA-40CFR144.3).

Drinking water supply Any raw or finished water source that is or may be used by a public water system or as drinking water by one or more individuals.

Drip irrigation An irrigation method using perforated plastic pipes at the base of the plants. It realizes water savings (due to a reduction of evaporation and percolation) and sometimes economy of nutrients as well as salinity reduction. Also called **trickle irrigation**. Other basic irrigation methods include: flooding, furrow, sprinkler, and subirrigation.

Driven well *See* borehole.

Driving head (1) The adjusted head h′ across a weir to account for the restriction on flow imposed by a tide gate. *See* effective driving head; Equation E-1. (2) In Darcy's law, the driving head is used to determine the hydraulic energy loss.

Drop (1) A hydraulic structure used to drop the water level and dissipate energy. Same as **drop structure**. *See also* chute; drop spillway; fall. (2) The magnitude of the actual drop in water level or the difference in water surface elevations upstream and downstream of an obstruction. *See also* drawdown (2); fall.

Dropdown curve The longitudinal profile of the water surface in the vicinity of a drop. *See also* drawdown curve.

Drop inlet An overfall structure consisting of a vertical riser connected to a discharge pipe.

Drop inlet spillway A spillway consisting of (a) a lip or inlet supported by a vertical shaft and (b) a horizontal outlet conduit or tunnel (which may also be the diversion tunnel). It is often used to save space. The inlet may be a weir with funnel-shaped entrance, a morning-glory, or a circular overflow lip. Also called a **shaft spillway**. *See* Equation S-13; Figure S-6.

Drop manhole A manhole used to match the grades of two sewer lines with a considerable difference (e.g., more than 2 ft). The wastewater from the incoming line falls through a vertical pipe to the elevation of the outgoing line. *See* Figure D-7.

Dropout orifice An orifice at the bottom of a sump for diverting wastewater from a stormwater system during dry weather to a sanitary sewer system. (The Stormwater Management Model [SWMM] simulates this orifice by converting it to an equivalent pipe using the standard orifice equation and the Manning equation.) Also called **sump orifice**.

Drop shaft The vertical or inclined part of a drop structure, sometimes in the form of a circular pipe.

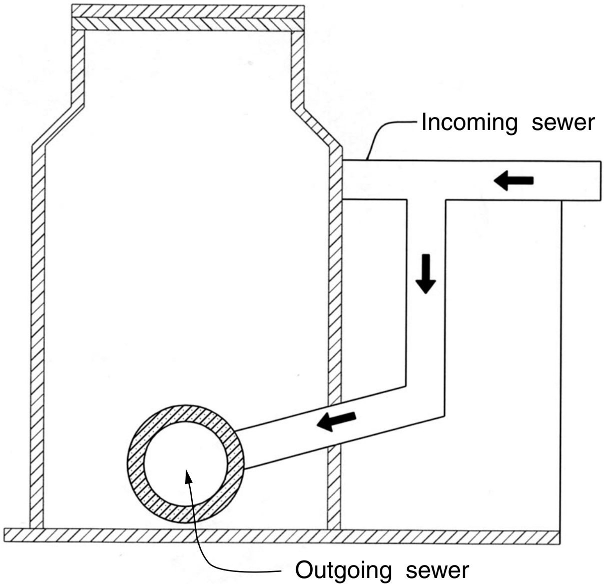


FIGURE D-7 Drop manhole.

Drop spillway A spillway, usually less than 20 ft high, over which water drops without touching the vertical downstream face.

Drop structure A structure, such as a drop inlet, drop manhole, drop spillway for dropping water, stormwater, or wastewater to a lower level. The drop, vertical or inclined, is for energy dissipation or other purposes. (The Advanced Interconnected Pond Routing Model allows for the simulation of drop structures.)

Drought An extended, indefinite, period of dry weather or deficient precipitation resulting in an inability to meet normal domestic, industrial, or agricultural water demands. Drought is sometimes defined in terms of a particular project by determining low-flow frequency curves or flow-duration curves. **Drought conditions** refer to an extended period of dry weather.

Drowned weir Same as **submerged weir**.

Drum gate A movable crest gate in the form of a sector of a circle hinged at the apex and operated by reservoir pressure to open or close a spillway. Other crest gates include flashboards, stop logs, tainter or taintor gates, bear-trap gates, and sliding gates.

Dry accumulation rate The rate of accumulation (exceptionally, the rate of decrease) of sediment from runoff events during dry weather. *See also* wet rate.

Dry connection Service connection to a water or wastewater line when the line is empty or otherwise not in service.

Dry-day, dry-period flow The average wastewater flow during a dry day of the dry season, i.e., without any influence of rain; it may, however, contain a certain quantity of groundwater infiltration. Same as **dry-weather flow** or the sum of base wastewater flow and infiltration.

Dry-day, dry-period hydrograph A diurnal hydrograph based on dry-day, dry-period flows.

Dry density The mass of deposited sediment, powdered or granulated solid material per unit of volume. Also called **bulk density**.

Dry detention, dry detention basin, dry pond Stormwater quality ponds are usually classified as wet ponds and extended dry detention ponds (or simply dry detention ponds or dry ponds). Regardless of the inflow rate, an **extended dry detention pond** is designed to operate with a constant outflow rate during and between runoff events until the pond is empty or drains down to a permanent pool of water. Depending on the loading cycle, the runoff volume, the duration of the dry and wet periods, the extended dry detention ponds may be empty, full, partly full, or overflowing. These ponds remove low-to-moderate amounts of pollutants by sedimentation, help control flood, and reduce downstream scouring and peak stormwater discharges. *See also* detention basin; stormwater retention; wet basin.

Dry-pit pump A pump operated without a wetwell, with the liquid conducted to and from the unit by piping.

Dry pond *See* dry detention.

Dry season The period of the year when atmospheric precipitation is less intense than average. For example, the dry season in southeastern Florida is between November and April, when about one third of the annual precipitation of 60 in falls.

Dry-weather flow (1) The flow of wastewater in a sanitary or combined sewer system during dry weather. It is not affected by recent or current rain; it includes domestic, industrial, commercial, and institutional wastes as well as groundwater infiltration but excludes any stormwater or surface water. Same as **dry-day**, **dry-period flow**. (2) Streamflow during dry weather, consisting usually of groundwater. *See* baseflow.

Dry-weather hydrograph Same as **dry-day**, **dry-period hydrograph**.

Drywell (1) The dry compartment of a pumping station where the pumps are located, as opposed to the wetwell. (2) Same as **drainage well** (1). An infiltration device for stormwater disposal; sometimes installed on residential properties to receive water from roof drains. (3) A well that has been completely drained or a well that produces no water.

Dry year A year of drought, with precipitation or streamflow less than normal.

DSPLAY A module of the HEC-DSS program that enables the user to display on the computer screen data from a DSS file in tabular or graphic form.

DSS Abbreviation for data storage system. A **DSS file** allows direct access to specific records. **DSSMATH** is a utility program of HEC-DSS for mathematical data manipulation. It can carry out a number of operations, such as the computation of correlation coefficients, trigonometric functions, modified Puls routing, temperature conversion from one scale to another, and time-series cyclic analysis. **DSSUTL** is the abbreviation for the data storage system utility program.

Dual pond Same as **retention/detention pond**.

Du Bois, Paul François Dominique *See* hydraulics.

Duct A tube, channel, conduit, etc. for the conveyance of a fluid; ranges from a few inches in diameter to many square feet in cross section.

Dug well *See* borehole.

Dummy sink and **dummy source** *See* dendritic network.

Dump valve A valve at the bottom of a tank or container to empty it quickly in case of an emergency.

Duplex pump A reciprocating pump consisting of two side-by-side cylinders connected to the same suction and discharge lines, one exerting suction and the other exerting discharge.

Duplex station A pumping station having two pumps.

Dupuit, Arsene Jules Emile *See* hydraulics.

Dupuit equation An equation used for the study of steady flow to a fully penetrating well through an unconfined aquifer of infinite extent. It applies Darcy's law and assumes horizontal flow with a velocity proportional to the tangent (instead of the sine) of the hydraulic gradient. It is widely used in assessing an aquifer's hydraulic characteristics from field test results or in determining well discharge when the hydraulic conductivity is known. *See* Figure D-8; Theim Equation (T-4); well flow equations. Dupuit equation is usually written as follows:

$$Q = \pi K (H^2 - h^2)/\ln(R/r) \qquad \text{(D-16)}$$

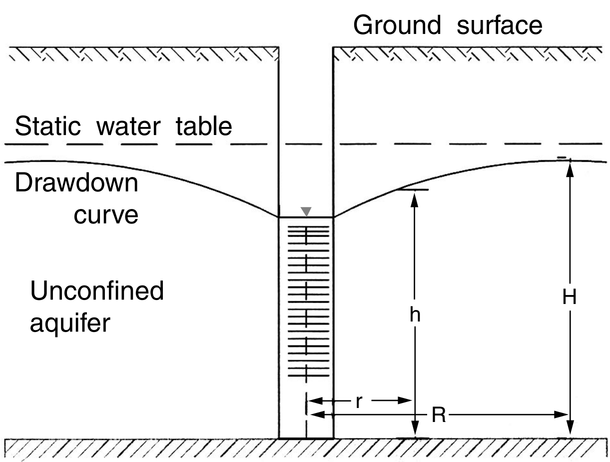


FIGURE D-8 Dupuit equation for unconfined flow.

where Q = discharge from the well, K = hydraulic conductivity of the aquifer, H = water-table elevation at distance R, and h = water-table elevation at distance r.

DWOPER *See* Dynamic Wave Operation Model.

Dynamic conditions How a system or an individual unit functions with respect to time. In hydraulic modeling, dynamic analysis involves the simulation of varying flow conditions and their effects on such variables as water quality, whereas steady-flow analysis is based on the assumption of some critical or design flows. In the continuous simulation of ponds for the control of urban runoff quality, dynamic conditions, as opposed to quiescent conditions, imply varying inflows or outflows. The **dynamic sedimentation rate** D_d, mass/time, may be estimated as a function of the sedimentation efficiency E_d (dimensionless); the pond discharge rate Ω (m^3/h); the particle settling velocity V_s (m/h); the pond surface area A ($m^{2)}$; and the long-term average suspended solids concentration of the incoming runoff C_o (*see* Guo and Adams in James, 1994):

$$D_d = E_d \cdot \Omega \cdot C_o \tag{D-17}$$

and

$$E_d = 1 - \exp(-V_s \cdot A/\Omega) \tag{D-18}$$

Dynamic data exchange A mechanism that allows a personal computer user to automate the exchange of information between files by copying and pasting.

Dynamic discharge head Same as **discharge head**.

Dynamic flow Same as **unsteady flow**.

Dynamic flow modeling and **dynamic flow routing.** *See* flow routing.

Dynamic head (also called **total dynamic discharge head, total dynamic head,** or **total head)** When a pump is lifting or pumping water, the vertical distance (in feet) from the elevation of the energy gradeline on the suction side of the pump to the energy gradeline on the discharge side of the pump (EPA Glossaries). In general, total dynamic head (TDH) is the total energy that a pump must impart to a fluid to move it from one point to another or the head against which the pump works. The pump head H represents the net work done on a unit weight of fluid from the inlet or suction flange to the discharge flange, as illustrated in Figure P-6:

$$H = (p/\gamma + V^2/2g + z)_{discharge} - (p/\gamma + V^2/2g + z)_{suction} \tag{D-19}$$

where H = pump head, pump total head, or total dynamic head (TDH); γ = specific weight of fluid; p = static pressure; V = average fluid velocity; g = gravitational acceleration; z = elevation above or below a datum, also called elevation or potential head; p/γ = pressure head or flow work;

$V^2/2g$ = velocity head or kinetic energy; $(p/\gamma + V^2/2g + z)_{discharge}$ = discharge head, dynamic discharge head, or total dynamic discharge head; $(p/\gamma + V^2/2g + z)_{suction}$ = suction head or dynamic suction head when it is positive, suction lift or dynamic suction lift when it is negative. Note that internal pump losses are not added to the suction lift or subtracted from the suction head. Note also that acceleration head in reciprocating pumps is not a headloss. *See also* pump head terms.

Dynamic pressure The pressure exerted by a fluid in motion, as opposed to static pressure.

Dynamic sedimentation rate *See* dynamic conditions.

Dynamic settling Settling of particles in moving water, as opposed to quiescent settling. (In extended detention wet ponds, particle settling is assumed to be quiescent in the permanent pool between runoff events and dynamic in the active storage zone.)

Dynamic similarity *See* hydraulic model.

Dynamic suction head The vertical distance from the source of supply, when pumping proceeds at required capacity, to the center of the pump, minus the velocity head, and the entrance and friction losses. **Dynamic suction lift** is similarly defined, but with the addition of the velocity head and entrance and friction losses. Internal pump losses are not added or subtracted in either case. *See* dynamic head; pump head terms.

Dynamic viscosity (μ) A measure of the internal resistance of a fluid to flow; equal to the ratio of the viscous shearing stress τ to the velocity gradient $\partial V/\partial s$. Also called **absolute viscosity** or **coefficient of viscosity**.

Dynamic watershed concept One of three common theories of runoff generation: only the saturated portion of the drainage area contributes runoff, which source area expands at the beginning of a rainstorm and contracts toward the end of the storm. It is also called the **saturation overland flow concept** or the **variable source area concept**. The other two common theories are Horton overland flow and subsurface stormflow.

Dynamic wave celerity A wave is a variation in flow, and the wave celerity is the speed of travel of the wave, which differs from the water velocity. In a dynamic wave, the flow varies with both distance and time; thus, it is unsteady and nonuniform. (A kinematic wave is unsteady, but uniform over a short distance; i.e., the flow and depth of flow vary with time, and the water surface is parallel to the bottom.) In open-channel flow, the dynamic wave celerity C_d or net wave velocity relative to the channel banks is the average water velocity V plus or minus the gravity wave celerity $(gy)^{0.5}$, i.e.,

$$C_d = V \pm \sqrt{gy} \tag{D-20}$$

where g is the acceleration of gravity, and y is the water depth. Often, particularly when there are no lateral inflows, the kinematic wave approximation is sufficient. *See* gravity wave celerity.

Dynamic wave equations A set of two basic equations for one-dimensional unsteady flow in open channels. Same as **Saint-Venant equations**. The **dynamic wave method** uses these equations for flow routing.

Dynamic Wave Operation (DWOPER) Model A model developed by the National Weather Service to simulate unsteady flow in a network of channels or pipes. It uses an implicit, finite-difference method to solve the Saint-Venant equations and has an automatic calibration feature for the determination of the roughness coefficient.

Dyne The unit of force in the CGS (centimeter–gram–second) system: it is the force that imparts an acceleration of 1 cm/sec/sec to a mass of 1 g.

E

Earth dam A dam with a main section that consists of earth, sand, rock, gravel, and silt; has an impervious core in clay or concrete. Also called an **earth-fill dam**. *See also* hydraulic-fill dam.

Earth reservoir A lined or unlined reservoir with embankments from excavated materials.

Earth Resource Data Analysis System (ERDAS) An image-processing, raster-based geographic information system.

Easement The legal right held by one person, usually without profit, to use the land owned by another person for a limited purpose, for example, for the construction, operation, and maintenance of water and sewer facilities. *See also* leasehold; right-of-way.

EasyLogger A stormwater data logger made by Omnidata International, Inc., of Logan, UT.

Ebb The flowing back of tidewater (away from the shore or downstream) or the recession from a flooding condition; the return of the tidal wave to the sea. In a body of water subject to the tide, an **ebb current** flows toward the sea or downstream. The **ebb tide** or **falling tide** occurs at the ebb period of tidal flow.

Economic life The number of years after which structures, equipment, and other capital goods should be replaced or abandoned to minimize their life cycle costs (capital, operation, maintenance, repair). Sometimes called **project life**.

Eddy flow Same as **turbulent flow**.

EDU Abbreviation for equivalent dwelling unit.

Eductor A hydraulic device used to create a negative pressure (suction) by forcing a liquid through a restriction, such as a venturi. An eductor or aspirator (the hydraulic device) may be used in the laboratory in place of a vacuum pump.

Effective discharge area The nominal or calculated area of flow through a pressure-relief valve or similar device; used to determine the flow capacity of the device.

Effective driving head The adjusted head h' across a weir to account for the restriction on flow imposed by a tide gate. The manufacturer Armco proposed an empirical formula for effective head as a function of the head h before correction, the gravitational acceleration g, and the upstream velocity V:

$$h' = h - (4/g) \cdot V^2 \cdot \exp(-1.15V/h^{0.5}) \qquad \text{(E-1)}$$

Effective head The head available for the production of hydroelectric power after the deduction of frictional, entrance, and other losses, except turbine losses. Also called **net head**.

Effective impervious area (EIA) In stormwater modeling studies, the fraction of the total drainage area that is impervious and directly connected to the drainage system. *See also* directly connected impervious area.

Effective infiltration capacity The hydraulic conductivity actually measured in field studies of flow through porous media, as compared to the theoretical hydraulic conductivity in Darcy's formula. It reflects the effect of upward airflow on water infiltration. For a timestep Δt; a constant thickness L; heads of H and H_0 at the time of concern and at the previous time, respectively; the effective infiltration capacity is:

$$K_e = (L/\Delta t) \ln[(L + H_0)/(L + H)] \qquad \text{(E-2)}$$

Effective porosity The ratio (or percentage) of the volume of liquid obtained from a saturated volume of rock or soil under a given hydraulic condition to the total volume of soil or rock.

Effective precipitation (1) Precipitation that yields water available in the soil for plant growth, after all losses; also called **beneficial precipitation**. (2) Precipitation that produces surface runoff, again after deducting various losses.

Effective rainfall *See* effective precipitation.

Effective rainfall depth The average runoff depth P_e over a drainage area A, computed as the ratio of the volume of surface runoff v to the area. On a storm hydrograph, the volume of runoff is the area under the curve and above the baseflow line. Also called **net rainfall depth**.

$$P_e = v/A \qquad \text{(E-3)}$$

Effective size The diameter of the particles in a granular sample (filter medium) for which 10% of the total grains are smaller and 90% are larger on a weight basis. Effective size is obtained by passing granular material through sieves with varying dimensions of mesh and weighing the material retained by each sieve. The effective size is also approximately the average size of the grains (EPA Glossaries).

Efficient section A channel cross section that maximizes discharge for a given area and slope. *See* best hydraulic cross section; hydraulic efficiency.

Effluent Treated or untreated wastewater that flows out of a treatment plant, sewer, or industrial outfall. Generally refers to wastes discharged into surface waters (EPA-94/04). Also, dredged material or fill material, including return flow from confined sites (under CWA, the Clean Water Act) (EPA-400CFR232.2). *See* Figure T-3.

Effluent guidelines Technical Environmental Protection Agency (EPA) documents that set effluent limitations for given industries and pollutants (EPA-94/04).

Effluent limitation Any restriction established by a state or the Environmental Protection Agency (EPA) administrator on quantities, rates, and concentrations of chemical, physical, biological, and other constituents discharged from point sources into navigable waters, the waters of the contiguous zone, or the ocean, including schedules of compliance. Or, simply, restrictions established on quantities, rates, and concentrations in wastewater discharges (EPA-94/04).

Effluent standard Same as **effluent limitation**, including the prohibition of any discharge.

Effluent weir A dam or a weir at the outflow end of a watercourse, sedimentation basin, or other hydraulic structure. *See also* clarifier weir; outlet weir.

Efflux tube A device, such as a cylindrical or conical tube, inserted into the orifice of a container or a conduit to facilitate or regulate the outflow of water. Also called **adjutage**.

e.g. Abbreviation of Latin expression *exempli gratia*, meaning *for example.*

Eiffel, Alexandre Gustave *See* hydraulics.

Ejector A device for dispersing chemical solutions into water under treatment (EPA-94/04). More generally, a device that moves fluids or solids by entrainment in air or water under pressure.

Elapsed-time meter A meter that records the duration of operation of a pump or other device. It is sometimes used in lieu of, or in addition to, a flowmeter to monitor the operation of a pumping station. If the pump operates at a constant rate per hour, the elapsed time can be used to determine the flow or volume pumped in any desired period. Some agencies place a limit on the nominal average pump operating time (NAPOT) of fixed-speed pumps or the nominal average power consumption (NAPC) of variable-speed and multiple-speed pumps. The elapsed-time meter serves to monitor NAPOT.

Elbow A fitting used to connect two pipes at an angle, usually 90°. Also called an **ell** or **L**.

Electrical analog model A groundwater model based on the similarities between groundwater and electrical flows.

Electrical log, electric log, electric well log A recorded measurement of the conductivities and resistivities of the rocks and their fluid contents down the uncased portions of a well.

Electrical logging Use of electrical logs to obtain a record of formations penetrated while creating a well.

Electric conductivity meter A portable device that uses sodium chloride as a tracer to estimate the discharge of small streams; based on the correspondence between salt concentration and conductivity. The streamflow is correlated with the tracer concentration.

Electromagnetic flowmeter, electromagnetic meter A flowmeter using (a) two coils to produce an electromagnetic field and a current in a moving fluid and (b) two electrodes that measure this current. The flowrate is directly proportional to the voltage at the electrodes.

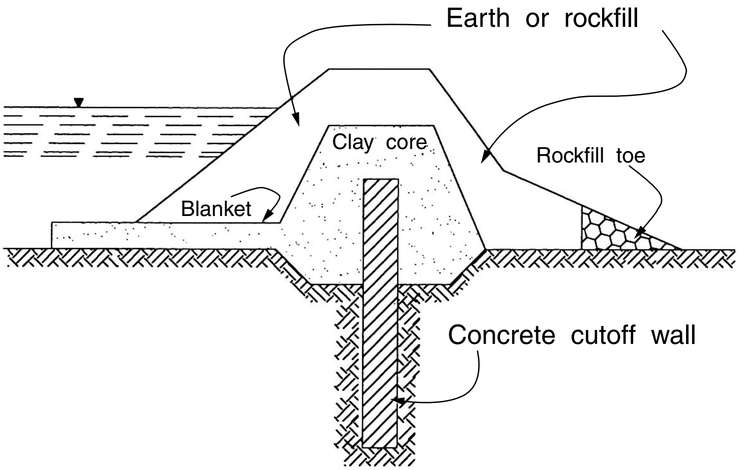


FIGURE E-1 Embankment dam.

Electromagnetic logging A method of well logging using transmitter and receiver coils to induce and measure electromagnetic fields within the formations penetrated.

Elevated storage Storage of water in an elevated tank.

Elevated tank A tank supported above ground by a tower, posts, or columns. It stores water for local distribution where a ground-level reservoir is inadequate. *See* water tower.

Elevation energy, elevation head The element of the total dynamic head of a pump that represents the elevation of the fluid above or below a datum. Also called **potential head** or **potential energy**. *See also* dynamic head; hydraulic energy; pump head terms.

Ell (or "L") A fitting used to connect two pipes at an angle, usually 90°. Also called an **elbow**.

Embankment A ridge of earth, stone, or other material to contain water within certain limits or a ridge to carry a road or a railroad at a higher level than the surrounding terrain.

Embankment dam An earth-fill or rock-fill dam with an impermeable core or upstream blanket to control seepage. The core may consist of silt or clay, with or without a concrete cutoff wall. Side slopes on both faces vary from 1:2 to 1:4. It is one of four common dam types; the other three are arch, buttress, and gravity dams. *See* Figure E-1.

EMC Abbreviation for event mean concentration.

Emergency spillway A spillway designed to discharge flows in excess of the capacity of the main spillway. *See also* auxiliary spillway; service spillway.

Empirical formula/method A formula or method based more on observations and practice than on theoretical considerations, e.g., the plotting position in frequency analysis, the Creager and Myers–Jarvis enveloping curves in peak runoff discharge computations.

Empirical model A representation of chemical or physical processes by generalities and simplifications based on observations, measurements, or practical experience rather than solely on principles or theory, e.g., the Darcy and Manning equations. Most analytical and numerical models include empirical elements. Also called **lumped-parameter model**.

Encounter probability The probability that an event X with a return period of T years will occur during a period of N years. For example, the designer of a flood control structure may want to determine the probability that the design flood X will occur during the life N of the structure. *See also* Equation R-11; recurrence interval.

End-of-pipe alternative A stormwater management strategy that usually consists of a traditional drainage system for runoff collection and transmission to an **end-of-pipe facility** (e.g., a wet pond or a constructed wetland) for treatment and disposal. Other strategies are source or downstream control or a combination of source controls and end-of-pipe facilities.

Energy The capacity to do work, usually expressed as the capacity per unit mass of fluid, as compared to **power**, which is the work done per unit of time. Hydraulic energies include potential (or elevation) energy, pressure energy, and kinetic energy. Energy loss (or headloss) occurs when friction converts part of the hydraulic energy into heat energy. Total energy is the sum of these three energies. *See* Bernoulli's law.

Energy balance method (or energy budget method) One of the most accurate methods to estimate evaporation from lakes and reservoirs. It derives the evaporation rate from a heat balance for the entire water body. (Other commonly used methods are the Penman, aerodynamic, and evaporation pan methods.) It estimates evaporation E_e as a function of the total heat input H_i, the heat leaving the water H_o, and the heat change ΔH in the water:

$$E_e = (H_i - H_o - \Delta H)/[\rho\lambda(1 + R)] \qquad \text{(E-4)}$$

where ρ = density of evaporated water, λ = latent heat of vaporization, and R = a heat transfer parameter called Bowen's ratio.

Energy coefficient A coefficient affecting the velocity head and used to correct the energy equation for application to open channels with variable velocity laterally and over the depth of flow. Same as **Coriolis coefficient**. *See* Figure V-1; velocity distribution coefficients.

Energy conservation law The principle according to which energy cannot be destroyed but can be converted. *See* Bernoulli's equation; Figure B-1.

Energy dissipation The conversion of the mechanical energy of flowing water into heat energy by hydraulic jumps, baffles, buckets, and aprons in spillways and stilling basins.

Energy gradeline (EGL) The elevation of the energy head of water flowing in a pipe, conduit, or channel. The line is drawn above the hydraulic gradeline a distance equal to the velocity head of the water flowing at each section or point along the pipe or channel (EPA Glossaries). The total energy H is the sum of the water surface elevation h and the velocity head $V^2/2g$, i.e.,

$$H = h + V^2/2g \quad \text{(E-5)}$$

In steady uniform flow, the EGL is parallel to the water surface and to the bottom of the channel or conduit. The **hydraulic gradeline** corresponds to the water surface in open-channel flow or the line to which water would rise in pressurized flow if the conduit were freely vented. The **energy gradient** is the slope of the energy gradeline, as the **hydraulic gradient** is the slope of the hydraulic gradeline. The **energy head** is the height of the hydraulic gradeline above the center line of a conduit plus the mean velocity head. The energy and hydraulic gradelines slope downward in the direction of flow (because of friction losses) and rise or drop abruptly with the introduction or withdrawal of energy by pumps or turbines. *See* Figure E-2. Sometimes called **energy line** or **energy gradient line**.

Energy gradient The difference in total (energy) head per unit horizontal distance measured in the direction of flow. *See* energy gradeline.

Energy line A line joining the elevations of the energy heads; same as **energy gradeline**.

Energy loss The difference in total (energy) head between two sections of a conduit or channel. Same as **headloss**.

Engels, Hubert *See* hydraulics.

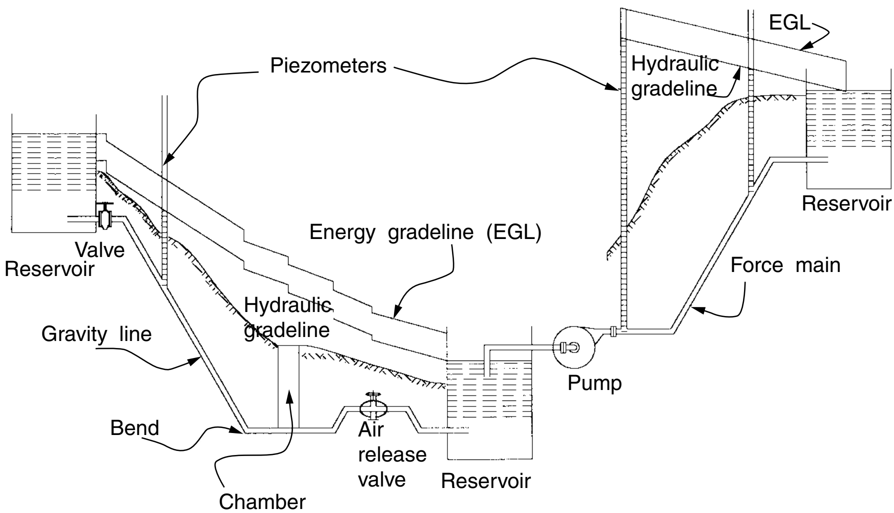


FIGURE E-2 Energy gradeline (EGL) and hydraulic gradeline in water pipes.

Engineering hydrology The subject that covers the quantitative aspects of the rainfall–runoff relationship, particularly the variation of runoff over time for the prediction of design events such as floods and droughts.

Engler viscometer An instrument designed to determine the degree Engler, a measure of the viscosity of a fluid.

Enlargement loss The headloss caused by the sudden change in water velocity at an enlargement of the cross section of a conduit or channel. The **enlargement coefficient** in a discharge formula accounts for the effect of the change. *See also* contraction loss; expansion loss; minor losses.

Entrance head The head required for water to flow into a conduit, channel, or hydraulic structure.

Entrance lock A lock between the tideway and an enclosed basin to allow vessels to pass either way when the levels of the two water bodies differ. Also called **tidal lock** or **tide lock**.

Entrance loss The head required to overcome resistance to entrance of water into a conduit, channel, or hydraulic structure. Also called **entry loss** or **inlet loss**. *See also* exit loss.

Environmental Fluid Dynamics Code (EFDC) A public domain, three-dimensional model that simulates flow, transport, and other processes in surface waters.

Environmental Protection Agency (EPA or **USEPA)** An agency of the U.S. government primarily responsible for enforcing federal environmental laws. It also conducts research in the field, issues helpful guidelines, and develops tools such as the Stormwater Management Model (SWMM).

Ephemeral stream A stream that flows only in direct response to precipitation in the immediate watershed or in response to the melting of a cover of snow and ice; has a channel bottom that is always above the local water table. An ephemeral stream may flow only 10% of the time. *See also* gully; intermittent stream; perennial stream; ravine; rill; rivulet.

EPS Abbreviation for extended period simulation.

Equalization storage *See* equalizing basin.

Equalizer A culvert installed in a roadbed where there is no drainage channel. The culvert is designed to equalize water levels on both sides of the road, thereby reducing seepage across the embankment. Also called an **equalizing culvert**.

Equalizing basin A basin used in a hydraulic system to render uniform the volume and composition of the flows. It is often used in wastewater and water supply systems to provide stable influent characteristics ahead of treatment units or to facilitate water distribution to customers. Also called **balancing basin**. An **equalizing reservoir** is defined similarly. **Equalization storage** refers to the volume of water in the basin or reservoir.

Equalizing culvert Same as **equalizer**.

Equalizing reservoir Also called **balancing reservoir**. *See* equalizing basin.

Equation of state An empirical relationship among some physical properties of water such as density, temperature, salinity, and turbidity; e.g., the relationship between water density ρ and (a) the density ρ_T of pure water at temperature T, (b) the changes in density due to turbidity or suspended solids $\Delta\rho_{SS}$ and to salinity or dissolved solids $\Delta\rho_{DS}$:

$$\rho = \rho_T + \Delta\rho_{SS} + \Delta\rho_{DS} \quad \text{(E-6)}$$

Equipment *See* facilities.
Equipotential Same as **equipotential line**.
Equipotential lines Straight or curved parallel lines of equal energy or equal hydraulic head. They are normal to the streamlines, with which they constitute the flownet. *See* Figure F-2.
Equivalent conduit length *See* equivalent pipes.
Equivalent diameter For noncircular conduits flowing full or partly full, the equivalent diameter is equal to four times the hydraulic radius. It may be used in the Darcy–Weisbach formula to calculate the headloss.
Equivalent dwelling unit (EDU) A convenient concept used in water, wastewater, and similar studies; the size, water use, wastewater production, etc. of the average household. *See also* population equivalent.
Equivalent length of fittings *See* equivalent pipes.
Equivalent n value *See* equivalent roughness coefficient.
Equivalent pipes Two pipes or two systems of pipes are said to be equivalent when their headlosses are equal for equal discharges. Similarly, one pipe may be equivalent to a system of pipes. The **equivalent length** of a pipefitting is the length of pipe that would yield the same headloss as the fitting for a given discharge. It is expressed as a multiple of the pipe diameter or as the ratio of the length L to the diameter D. From the Darcy–Weisbach formula, the headloss h_f in the fitting is:

$$h_f = f \cdot (L/D) \cdot (V^2/2g) \quad \text{(E-7)}$$

or

$$h_f = k \cdot (V^2/2g) \quad \text{(E-8)}$$

with

$$k = f \cdot (L/D) \quad \text{(E-9)}$$

where f is the friction factor, V is the average velocity, and g is the gravitational acceleration. The coefficient k, called the minor loss coefficient (sometimes referred to as the k-factor), is constant for a given fitting and does not vary with the Reynolds number R_e. The k is not a friction factor but is a function of changes in direction, obstructions, or changes in velocity.
Equivalent roughness A parameter r used in the hydraulic design and modeling of open channels to represent the overall roughness of a compound section.

The HEC-2 model uses the following equation to relate equivalent roughness to the Manning roughness coefficient n and the hydraulic radius R:

$$n = R^{1/6}/21.94\ [1.086 + \log_{10}(R/r)] \qquad \text{(E-10)}$$

Also called **roughness height**. *See* composite roughness coefficient; equivalent roughness coefficient. *See also* Figure C-3.

Equivalent roughness coefficient In a compound channel, for a wetted perimeter with N subsections of different roughness coefficients (from n_1 to n_N), an average or equivalent roughness coefficient n_e is defined as the weighted average of the coefficients of the various subsections and is determined as follows (Martin and McCutcheon, 1999):

$$n_e = P \cdot R^{5/3} \Big/ \left(\sum_{i=1}^{N} P_i \cdot R_i^{\ 5/3} / n_i \right) \qquad \text{(E-11)}$$

where P_i = the wetted perimeter of the ith subsection, P = the total wetted perimeter of the section, R = the hydraulic radius of the section, R_i **=** the hydraulic radius of the ith subsection, and n_i = the roughness coefficient of the ith subsection. *See also* composite roughness coefficient; Figure C-3.

Equivalent sand grain size A factor that represents the roughness of a pipe. Also called **equivalent sand roughness**, a concept introduced in 1894 by Johann Nikuradse, who coated pipe walls with sand of various grain sizes to study the effects of pipe roughness on flow. *See also* roughness coefficient.

Equivalent Solids Reservoir (ESR) A method used to model the washoff and transport of pollutants in stormwater management studies.

Equivalent triangular unit hydrograph A triangle, in the Soil Conservation Service (SCS) method, that is a straight-line approximation of the dimensionless unit hydrograph such that (a) its surface area is equal to the area under the SCS dimensionless unit hydrograph, (b) its base is on the time axis, and (c) its apex coincides with the maximum of this hydrograph. On the assumption that the triangular hydrograph is equivalent to the dimensionless unit hydrograph, the peak discharge Q_p is computed as a function of a coefficient C (varying from 300 in flat areas to 600 in steep terrain, with an average of 484), the drainage area A, and the time to peak T_p. *See* Figure E-3.

$$Q_p = C \cdot A/T_p \qquad \text{(E-12)}$$

ERDAS Acronym for Earth Resource Data Analysis System.

Erosion The wearing away of the land surface by running water, waves, moving ice, or wind or by such processes as mass wasting. **Geologic erosion**

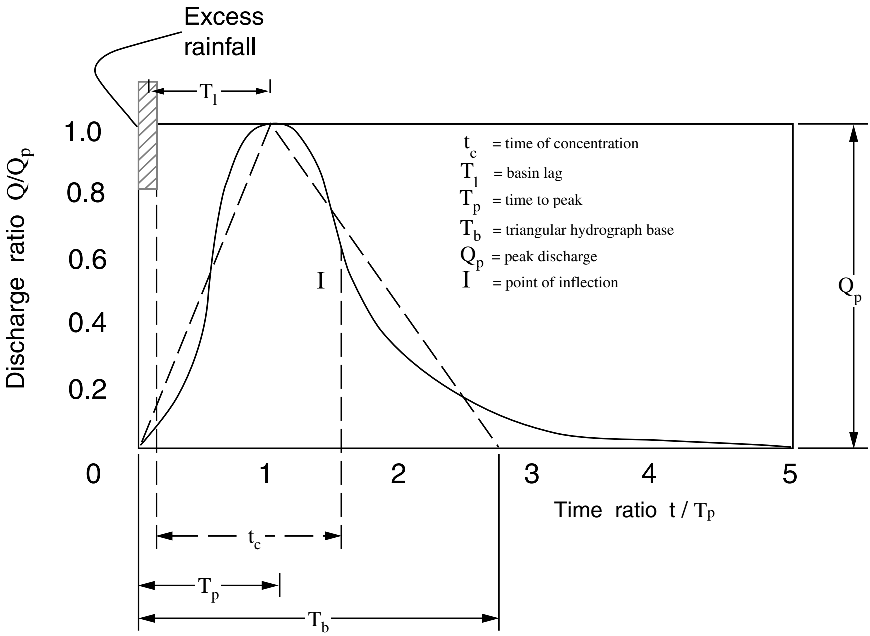


FIGURE E-3 Equivalent triangular unit hydrograph.

refers to natural erosion processes occurring over long time spans. **Accelerated erosion** generally refers to erosion in excess of what is presumed or estimated to be naturally occurring levels and that is a direct result of human activities (e.g., farming, residential or industrial development, road building, or logging) (Hawley and Parsons in Dodson, 1999).

Erosion threshold flow The flow that is expected to result in a velocity above which erosion of a given channel at a specific location will occur.

Error analysis An analysis conducted to determine the difference between a model prediction and the actual condition and to identify error sources. The error analysis may also seek to determine the overall uncertainty assigned to each significant parameter or variable. *See also* modeling error; Monte Carlo method; sensitivity analysis.

Error criterion A criterion used to determine whether a numerical model solution is convergent. *See also* computational solution error; Courant–Friedrichs–Lewy stability criterion; modeling error.

Estuary A region of interaction between rivers and near-shore ocean waters, where tidal action and river flow mix fresh and saltwater. Estuaries include bays, river mouths, salt marshes, and lagoons. These brackish water ecosystems shelter and feed marine life, birds, and wildlife (EPA-94/04). More simply, an estuary is a coastal water body at the mouth of a river, where the seatide meets the river current.

ET Abbreviation for evapotranspiration.

Euler, Leonhard *See* hydraulics. **Euler number** is a dimensionless hydraulic number equal to the ratio of the inertia force to the pressure force; used in the formulas of the friction factor in pipe flow or drag coefficient in water bodies.

Evaporation The process by which water is converted into a vapor, or the quantity of water that evaporates. It depends on temperature, wind velocity, and relative humidity. For measuring evaporation from surface water, *see* evaporation pan. Evaporation from land surfaces is less than by plant transpiration, and the two are usually lumped into evapotranspiration. *See* actual evaporation; pan evaporation.

Evaporation gage An instrument to measure the evaporation rate of water. Also called **atmidometer**, **atmometer**, or **evaporimeter**.

Evaporation pan An evaporation gage consisting of a circular or square pan. The National Weather Service's standard class A pan is made of unpainted galvanized iron, with a diameter of 4 ft and a depth of 10 in.

Evaporation pan method The oldest and most widely used method to estimate evaporation from lakes and reservoirs. The evaporation pan is usually mounted on a wooden frame 1 ft above the ground and filled to a depth of 8 in. The evaporation from the pan is multiplied by a pan coefficient, which varies seasonally and geographically. Other commonly used methods include the aerodynamic, energy balance, and Penman methods.

Evaporation pond A pond for water evaporation under the influence of solar heat; for example, an area where sewage sludge is dumped and dried.

Evaporation rate The quantity or depth (in, mm, cm) of water that evaporates from a given surface per unit of time (day, month, year).

Evaporation tank An evaporation gage used under controlled conditions and consisting of a tank for the determination of the quantity of evaporation at a given location.

Evaporative discharge The discharge of groundwater to the atmosphere or through vegetation, as opposed to a hydraulic discharge.

Evaporator A device that uses heat to vaporize water or a solvent from a solution.

Evaporimeter An instrument to measure the evaporation rate of water. Also called an **atmidometer**, **atmometer**, or **evaporation gage**. *See also* evaporation pan.

Evapotranspiration (ET) The combined water withdrawal by evaporation (from water surfaces, soil, vegetation, and subsurface sources) and by transpiration from plants growing in the soil; this is about two thirds of the precipitation over land surfaces. *See* the Penman–Monteith method for the evaluation of potential evapotranspiration. *See also* consumptive use.

Evapotranspiration tank (or **evapotranspirometer)** An instrument that measures evapotranspiration; consists of a tank filled with representative soils and plant materials. Soil–water level is held constant in the tank. *See also* lysimeter.

Event *See* storm event.

Event mass The product of a (storm) event mean concentration by the total runoff volume; a direct measure of event washoff.

Event mean concentration (EMC) The arithmetic mean concentration of a pollutant during a storm event; from grab or composite sampling. Because of first-flush phenomena, short-duration storms usually have higher EMCs than average or long-duration storms.

Event modeling and event simulation *See* continuous model.

Exceedance frequency The exceedance probability expressed as a percentage. Also called **percentage chance exceedance**. *See also* cumulative distribution function; cumulative frequency; Figure F-7.

Exceedance frequency distribution A cumulative frequency distribution or a curve indicating the exceedance probability of event magnitudes.

Exceedance interval The average period of time between events of interest; calculated as the reciprocal of the exceedance probability. Also called **recurrence interval** or **return period**.

Exceedance probability The probability that an event of a given magnitude will be equaled or exceeded in any given year; the reciprocal of the recurrence interval or return period. Also called **relative exceedance frequency**. *See also* exceedance series; frequency analysis.

Exceedance series The set of the N top events, ranked in descending order of magnitude, in the results of a simulation run or in a series of field observations related to N time periods; e.g., the 30 largest floods in 30 yr. The exceedance probability p and the return period t of the ith event of the series are (with i = 1 for the largest):

$$p = i/(N + 1) \quad \text{(E-13)}$$

and

$$t = 1/p = (N + 1)/i \quad \text{(E-14)}$$

The exceedance series differs from the annual duration series. They both contain N events for N years, but the former has one event for each year, while the latter may have two or more events for one year and none for another. *See also* partial duration series.

Excessive infiltration/inflow The quantities of infiltration/inflow (I/I) that can be economically eliminated from a sewerage system by rehabilitation; determined in a cost-effectiveness analysis that compares the costs for correcting the I/I conditions to the costs for transportation and treatment of the I/I (EPA-40CFR35.905). *See also* nonexcessive infiltration; nonexcessive inflow.

Excessive precipitation (or **excessive rainfall**) Precipitation (or rainfall) with an intensity that exceeds normal limits defined by the U.S. Weather Bureau. *See* excess rainfall; Table E-1.

TABLE E-1
Excessive Rainfall

Location	Normal Rainfall Limits, Inches	
	First 30 min	First 60 min
Atlantic Coast and Gulf Coast states	0.9	1.5
Other states	0.5[a]	0.8[a]

[a] More generally by the equation:

$$P = (t + 20)/100 \quad \text{(E-15)}$$

where P is precipitation (inches) and t is duration (minutes).

Excess rainfall The portion of rainfall that leaves the drainage area on the ground surface in a short time. Also called **overland flow**, **storm flow**, or **surface runoff**. Different from excessive rainfall.

Execution time For model execution time, *see* model run.

Exempted aquifer An aquifer or its portion that meets the criteria in the definition of "underground source of drinking water," but that has been exempted (EPA-40CFR144.3 or EPA-40CFR146.3). Underground bodies of water defined in the Underground Injection Control program as aquifers that are potential sources of drinking water although not used as such and thus exempted from regulations barring underground injection activities (EPA-94/04).

Exfiltration (1) Leakage of water from a water main or wastewater or stormwater from a sewer to the surrounding ground from unintentional openings. Exfiltration is often considered in the analysis of infiltration/inflow problems in sewer systems; the analysis is thus called infiltration/exfiltration/inflow or I/E/I analysis. (2) The flow of groundwater into ditches and channels. (3) Intentional leakage of stormwater from French drains over the duration of a storm event. (4) The quantity of water that leaks.

Exfiltration pipe A pipe used to let water leak to the surrounding ground; e.g., a French drain.

Exit loss The headloss resulting from a velocity reduction when water leaves a hydraulic structure. *See also* entrance loss.

exp Abbreviation for the exponential function.

Expansion loss One of several minor headlosses; due to the augmentation of the size of a conduit or channel. *See also* enlargement loss.

Explicit model A numerical model that uses parameter or unknown variable values (e.g., heads, discharges, concentrations) at the beginning of the timestep in the computational algorithms; i.e., it uses only values from the previous timestep. *See also* implicit model. An **explicit numerical solution** can be similarly defined.

Exponential probability distribution A probability distribution that is an exponential function of the variable. It is sometimes used in hydrological analysis, mainly because of its ease of mathematical manipulation. For example, in the modeling of stormwater management ponds, such variables (x) as rainfall duration, rainfall volume, or interevent time may be represented by the exponential distribution $f_x(x)$, with a parameter a depending on local conditions:

$$f_x(x) = a \cdot \exp(-ax) \text{ with } x > 0 \text{ and } f_x(x) = 0 \text{ with } x \leq 0 \qquad \text{(E-16)}$$

EXSUDS Abbreviation for Extended Statistical Urban Drainage Simulator.

Extended-detention basin A dry-detention basin that releases stormwater slowly or contains a permanent pool of water.

Extended dry-detention pond *See* dry detention; stormwater retention.

Extended period simulation (EPS) A water distribution model that allows the user to identify situations other than worst cases, which are the focus of steady-state distribution models. For example, Haestad Methods' WaterCAD® and Cybernet® can evaluate pumping and piping capacity, tank volume and elevation, effects on pressures and flows, movement of contaminants and chemical constituents, etc.

Extended Statistical Urban Drainage Simulator (EXSUDS) A set of computer models used to investigate quality aspects of urban runoff control alternatives, while the original SUDS concerns the quantity aspects of stormwater control ponds.

EXTRAN Block The **extended transport program** is one of four major computational blocks of the U.S. Environmental Protection Agency Stormwater Management Model. It treats the sewer system as a link–node network. For flow routing through the network, it uses the Saint-Venant equations for the conservation of mass and momentum. These equations are combined into one basic flow equation with essentially two variables: the discharge Q and the hydraulic head H. The equation is:

$$gA(\partial H/\partial x) - 2V(\partial A/\partial t) - V^2(\partial A/\partial x) + (\partial Q/\partial t) + gAS_f = 0 \qquad \text{(E-17)}$$

where A = cross-sectional area of flow, g = acceleration of gravity, H = y + z = hydraulic head, n = Manning roughness coefficient, Q = discharge or flowrate, R = hydraulic radius, t = time, V = average flow velocity, x = distance along the conduit, y = water depth, z = conduit invert elevation, and δ = 1.49 for English units and 1.0 for metric units; and

$$S_f = \text{friction slope} = Q^2/[(\delta/n)^2 A^2 R^{4/3}] \qquad \text{(E-18)}$$

The flow equation may be solved numerically in combination with the continuity equation:

$$\partial Q/\partial x + \partial A/\partial t = 0 \qquad \text{(E-19)}$$

The size of the timestep and the conduit lengths are important considerations for numerical stability.

Extraordinary storm *See* storm severity.

Extremal hypothesis The theory of channel design, according to which an alluvial channel adjusts its shape to maximize its sediment transport capacity or to minimize its stream power. Also called **variational principle**. *See also* channel stability; regime theory; tractive force theory.

Extreme event An event for which the frequency or probability of occurrence is much lower than average, for example, floods, droughts, unusually high or low flows, high or low depths of a navigable water. *See also* design flow; design storm; exceedance probability; optimum design discharge; optimum design flood; probable maximum flood; standard project flood.

Extreme value distributions Distribution functions used to represent rare events. Hydrologic analysis, e.g., uses the extreme value (Gumbel) type I, log-Pearson type III, normal, three-parameter gamma (Pearson type III), two-parameter gamma, and two-parameter lognormal distributions. The general extreme value distribution has three parameters: location x_o, scale K, and shape n. For a random variable x, the distribution is defined by the following equations:

Probability:

$$f(x) = (1/K) \exp(-y - e^{-y}) \qquad \text{(E-20)}$$

Cumulative probability:

$$F(x) = \exp(-e^{-y}) \qquad \text{(E-21)}$$

Reduced variate:

$$x = x_o + (1 - e^{-ny})K/n \qquad \text{(E-22)}$$

For n = 0, it is the extreme value type I or Gumbel distribution. For n < 0, it is the type II, and for n > 0, the type III or Weibull.

Extreme value function type I A density function f(x) representing the probability of a rare event x, depending on a scale parameter n, and a measure of central tendency b. Also called **Gumbel distribution**:

$$f(x) = n \cdot \exp[-\, n \cdot (x - b) - \exp - n \cdot (x - b)] \qquad \text{(E-23)}$$

See also gamma distribution; lognormal distribution, log-Pearson distribution; normal density, normal distribution.

Extrinsic property A characteristic of a body that can be measured (e.g., temperature, flow, pollutant concentration, density, velocity) but is not conserved; it cannot be used in accordance with the law of conservation to predict changes in the body. *See also* intrinsic property.

Eytelwein, Johann Albert *See* hydraulics.

F

Facilities or equipment Buildings, structures, and process or production equipment or machinery that form a permanent part of a new pollution source and that will be used in its operation if these facilities or equipment are of such value as to represent a substantial commitment to construct. It excludes facilities or equipment used in connection with feasibility, engineering, and design studies regarding the source or water pollution treatment for the source (EPA-40CFR122.29-–5). *See also* facility.

Facilities plans Plans and studies related to the construction of treatment works necessary to comply with the Clean Water Act. A facilities plan provides information on needs, the cost-effectiveness of alternatives, a recommended plan, an environmental assessment of the recommendations, descriptions and costs of the treatment works, and a completion schedule.

Facility All or any portion of buildings, structures, equipment, roads, walks, parking lots, rolling stock or other conveyances, or other real or personal property (EPA-40CFR12.103).

Fahrenheit scale A temperature scale with the freezing point of water at 32°F and the boiling point at 212°F at a barometric pressure of 1 atm (760 mm Hg).

Fall A sudden drop in water surface elevation or the difference in the water surface elevations of two points. Also, the required drop to facilitate proper flow in a pipe.

Falling limb The second part of a single-storm discharge hydrograph representing the withdrawal of water from storage after storm discharge has peaked. Also called **receding limb** or **recession limb**. *See also* RDI/I hydrograph.

Falling tide Same as **ebb tide**.

Fall turnover *See* turnover.

Fast watershed delineation method A method for obtaining fast and consistent watershed delineation from a digital elevation model using a desktop geographic information system (GIS) program.

Fathom A unit of length equal to 6 ft; used in nautical measurements.

Feeder canal (or **conduit, pipe, etc.)** A canal (conduit, pipe, etc.) that conveys water to a larger canal (conduit, pipe, etc.).

Feedpipe (or feedpump) A pipe or pump used to supply water to a boiler.

Feedwater or boiler feedwater The water supplied to a boiler from a tank or a condenser for steam generation.

Fen A type of wetland that accumulates peat deposits. Fens are less acidic than bogs, deriving most of their water from groundwater rich in calcium and magnesium (EPA-94/04).

FESWMS Acronym for Finite-Element Surface-Water Modeling System.

Fick's laws of diffusion Two physical chemistry laws proposed to explain the process of mass transfer of a substance by diffusion in a medium, e.g., the diffusion and transport of contaminants in water. The first law, similar to Darcy's law, states that the diffusive flux M is proportional to the concentration gradient (the partial derivative of concentration C with respect to distance x). According to the second law, the rate of change (partial derivative of concentration with respect to time t) is proportional to the rate of change of the concentration gradient. D is the coefficient of diffusion (in area per time) in both equations. For the first law:

$$M = -D\ (\partial C/\partial x) \qquad \text{(F-1)}$$

For the second law:

$$\partial C/\partial t = D(\partial^2 C/\partial x^2) \qquad \text{(F-2)}$$

Field capacity (or field moisture capacity) A parameter related to the water content of a soil or rock. *See* specific retention. It is the moisture content of soil in the field some time after reaching saturation and after free drainage has practically ceased or the quantity of water held in a soil by capillary action after the gravitational or free water has drained; expressed as moisture percentage on a dry weight basis. It is sometimes called **field carrying capacity**.

Field data In hydraulic modeling, field data are collected mainly for the establishment of a base model and for calibration. Data collection is usually divided into three categories. (a) Physical data to construct the base model: verification of system characteristics such as pipe roughness, pump head and discharge characteristics, valve status (open or closed), tank diameters and elevations, control switch settings. (b) Operational data through short-term continuous monitoring: flows and water surface elevations at the boundaries, flows and pressures at other key locations, demands from high-consumption customers. (c) Reactive data: system response to extreme situations, e.g., fire, power outage, extreme storm. *See also* base model; calibration; Table B-1.

Field moisture capacity Same as **field capacity**.

Field permeability coefficient The flow of water through a cross-sectional area 1 mi wide and 1 ft thick under a hydraulic gradient of 1 ft/mi and at the ambient water temperature. *See also* standard permeability coefficient.

File Transfer Protocol (FTP) An Internet utility.

Fill-and-draw system *See* batch process; continuous-flow system.

Filling Deposition of dirt, mud, or other materials into aquatic areas to create more dry land, usually for agricultural or commercial development purposes, often with ruinous ecological consequences (EPA-94/04).

Filterable residues Solid particles that pass through the filter during water filtration; mostly dissolved solids, but also some colloids, while a small portion of the dissolved solids is retained on the filter material. *See also* solids.

Filter blanket A layer of sand and gravel to retain fines.

Filter fence A temporary fence used in construction sites for sediment control in shallow overland flow. It consists of a geotextile fabric stretched across a series of posts and supported by a wire fence, with a backfilled trench at the lower edge. Also called a **silt fence**.

Filter strip Strip or area of vegetation used for removing sediment, organic matter, and other pollutants from runoff and wastewater (EPA-94/04). Also, a stormwater pollution control measure consisting of a strip of permanent, close-growing vegetation that retards the flow of runoff and reduces the pollutant load to the receiving water. Used as an outlet or pretreatment device, as well as above dams, diversions, and other hydraulic structures. Also called **buffer strip**, **grassed buffer**, and **vegetated filter strip**.

Filtration rate Rate of application of water to a filter; expressed as the ratio of the flowrate to the surface area of the filter (e.g., in gpm/ft^2 or in mgd/acre).

Final calibration *See* calibration.

Final effluent Effluent from the last unit of a wastewater treatment plant.

Fine sand Sand particles with a diameter between 0.10 mm and 0.25 mm. *See also* coarse sand; medium sand; soil classification.

Fine sediment load The portion of the suspended solid load composed of smaller particles than those generally found in the streambed. These smaller particles are transported without deposition. Also called **washload**. *See also* bedload.

Finished water Water that has passed through a water treatment plant; the treatment processes are completed or "finished." The water is ready to be delivered to consumers (EPA-94/04).

Finished-water reservoir In a water supply system, a reservoir that holds treated water before it is distributed to customers. Also called **clean-water reservoir**. *See also* clear well.

Finishing water Processed water used to remove waste plastic material generated during a finishing process or to lubricate a plastic product during a finishing process. It includes water used to machine or assemble intermediate or final plastic products (EPA-40CFR463.2-e).

Finite-difference method Applied by substituting finite-difference equivalents for partial derivatives in differential equations that cannot be solved exactly. The finite-difference equations can be solved numerically as the computer can process algebraic expressions like the finite differences, but not the partial derivatives. Most finite-difference expressions are based on Taylor series expansions of continuous functions, truncated after the first or second derivative term. The approximation introduces a truncation error by neglecting the higher order derivative terms. For example, the finite-difference form of the continuity equation is:

$$\Delta Q/\Delta x + \Delta A/\Delta t = 0 \qquad \text{(F-3)}$$

See also finite-element method; finite-volume method.

Finite-difference model A numerical model that uses the finite-difference method; i.e., a model with partial differential equations that are replaced by finite-difference equations.

Finite-element method An approximation method for analyzing hydraulic and other continuous systems by breaking them into discrete or finite elements. It is an alternative to the finite-difference method. The finite-element method seeks a solution for each element and then assembles the individual solutions to obtain a solution for the entire system, with appropriate adjustments to minimize errors. The first step is by piecewise interpolation and the second by weighted residual construction. *See also* finite-difference method; finite-volume method.

Finite-element model In hydraulic modeling, a finite-element model is a numerical approximation of the governing equation by integrating the constituting elements rather than by partial differentiation.

Finite-Element Surface-Water Modeling System A program developed by the U.S. Geological Survey to model two-dimensional surface water flow at bridge crossings.

Finite-volume method An approximation method for analyzing hydraulic and other continuous systems by breaking them into discrete or finite volumes. It is similar to the finite-difference method, but it discretizes the governing equation in integral (instead of differential) form. *See also* finite-element method.

Firm yield Same as **safe yield**.

First draw The water that immediately comes out when a tap is first opened; likely to have the highest level of lead contamination from plumbing materials (EPA Glossaries).

First flush In stormwater and combined sewer overflow management studies, the first flush refers to the action of the first storm of the rainy season (and less often to the first part of any storm). The first flush usually carries an unusually high pollution load, consisting of sediment from soil erosion; oil, grease, and heavy metals from automobiles; and nitrates and phosphates from fertilizers. For the first flush of a storm event, pollutant concentration decreases as the flow duration increases.

First-flush effect The result of the first-flush phenomenon, i.e., higher pollutant concentrations in runoff at the beginning of a storm event or at the beginning of the rainy season. For example, concentrations of the 5-day biochemical oxygen demand (BOD_5) and total suspended solids (TSS) may drop by two thirds within the first hour of a storm event. First-flush loads are a primary target in modeling studies for the abatement of stormwater pollution. *See also* event mean concentration.

First-order reaction A reaction in which the rate of disappearance of a chemical is directly proportional to the concentration of the chemical and is not a function of the concentration of any other chemical present in the reaction mixture (EPA-40CFR796.3700-v). For example, in stormwater modeling studies, a first-order reaction is sometimes assumed for the removal efficiency of the settling process:

$$C = C_0 \cdot \exp(-kt) \qquad \text{(F-4)}$$

where C_0 and C are pollutant concentrations initially and at time t, respectively, and k is the reaction rate constant. (Actually, the rate of change is $dC/dt = -kC$.)

Fittings Pipefittings are connections in a piping system that modify the size or the direction of the conduits. Velocity or direction changes cause minor (head) losses proportional to the velocity head. Besides valves, orifices, nozzles, and venturi meters, which also cause minor headlosses, examples of fittings include elbows, bends, standard tees, basket strainers, couplings, unions, reducers, and increasers.

Five-yr, 6-h precipitation event The maximum 6-h precipitation event with a probable recurrence interval of once in 5 yr as established by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service, or equivalent regional or rainfall probability information (EPA-40CFR440.141-5).

Fixed groundwater Subsurface water occurring in fine-grained rocks or in subcapillary openings of clays and silts. It does not move by gravity and is considered attached to the formation. *See* Figure S-14; subsurface water.

Fixed solids The residue of the ignition of a water or wastewater sample corresponding to the nonvolatile, inorganic suspended and dissolved solids of the sample. *See also* volatile solids.

Fixed system head Same as **static head**.

Fixture unit A parameter used to estimate domestic and institutional water uses and corresponding wastewater generation. The fixture unit method assumes a flow per plumbing fixture. This term includes installed receptacles, devices, or appliances either supplied with water or receiving on discharge liquids, liquidborne wastes, or both. Examples of plumbing fixtures are water closets, sinks, bathtubs, dishwashers, and drinking fountains. The flowrate per fixture varies widely, e.g., from 17 gal/h for a restaurant kitchen sink to 150 gal/h for a public park shower.

Flange A projecting rim, collar, edge, lip, or ring installed on a shaft, pipe, etc. for strengthening or jointing purposes. A flange union is used to join two pipe sections; it consists of two flanges screwed and bolted or welded to the ends of the pipes. This constitutes a flanged joint. A flanged pipe has flanges at the ends.

Flap gate A gate that opens or closes by rotation around hinges at the top. A flap valve opens (in the direction of flow) or closes (with flow reversal) by rotation about a hinged flap.

Flaring inlet A bellmouthed entrance to a conduit. Also called **bellmouthed inlet**.

Flashboard A low, temporary barrier of boards along the crest of a dam spillway to increase storage capacity. It is a type of crest gate for small installations under low heads.

Flashflood A flood of short duration and high intensity over a small area.

Flat-crested weir A measuring weir with a crest that is horizontal, in the direction of flow, and a length that is large compared to its head.

Flat slope A channel slope less than the critical slope at a given flowrate; the opposite of steep slope. Also called **mild slope**.

FLDWAV Acronym for Flood Wave Model.

Flexible joint A joint between two pipe sections such that one can be deflected without affecting the other. An example is the mechanical pipe joint, which includes lugs and bolts.

Flexible-joint pipe A cast iron pipe that can be installed under water and can be deflected without damage or risk of leakage.

Flight sewer A sewer with a series of steps to reduce the velocity on a steep grade.

Flo-Mate A portable flowmeter manufactured by Marsh-McBirney, Inc., of Frederick, MD.

Flood (or flooding) (1) A general and temporary condition of partial or complete inundation of normally dry land areas from the overflow of inland or tidal waters, runoff of surface waters from any source, or flooding from any other source (EPA-40CFR6-AA-c). (2) Excessive streamflow resulting from precipitation or snowmelt and causing a watercourse to overtop its banks and flow onto the floodplain. (3) A relatively high discharge or any discharge exceeding a designated value.

Flood analysis techniques Methods used in estimating discharges from drainage areas and their consequences; e.g., the rational method or overland flow hydrograph for small areas, the unit hydrograph for up to 2000 mi^2, and flood routing above 2000 mi^2.

Flood bypass Same as **flood-relief channel**.

Flood control The use of hydraulic structures such as levees, dams, walls, reservoirs, floodways, and other means to prevent or reduce flooding. Absolute flood control is normally not feasible, physically or economically. Flood mitigation is a more appropriate term.

Flood-control storage Storage provided for floodwaters until they can be safely released downstream.

Flood-control works Such hydraulic structures as levees, dams, walls, reservoirs, and floodways.

Flood dam A dam for the storage of floodwaters.

Flood-damage mitigation Same as **flood mitigation**.

Flooded suction station A type of wastewater pumping station, as opposed to submersible or suction lift stations.

Flood event An independent episode of flow variations in a watercourse with a distinct rise, peak, and recession as shown on a storm hydrograph. *See also* storm event. A flood event is separated from adjacent events by a dry period during which streamflow is equal to baseflow.

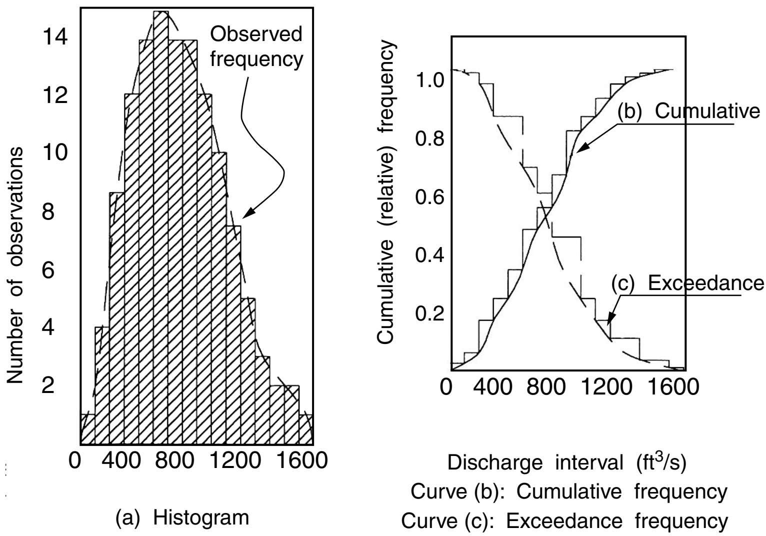


FIGURE F-1 Flow–mass curves.

Floodflow The discharge of a watercourse during a flood.

Flood frequency The reciprocal of flood probability. That is, the frequency with which a flood is expected to occur over a long period of time; e.g., the 50-yr flood is expected to be equaled or exceeded on the average once every 50 yr. *See* frequency analysis.

Flood Frequency Analysis A computer program of the Hydrologic Engineering Center (HEC-FFA) that computes flood frequencies using the log-Pearson type III distribution and maximum streamflows according to established federal guidelines. Some of its computations include plotting positions by the Weibull, median, or Hazen methods; frequency curve ordinates; and confidence limits for 5 and 95% levels.

Flood frequency curve A curve that plots, as a result of a flood frequency analysis, flood magnitudes versus their exceedance probabilities. *See* Figure F-1.

Floodgate A gate used to restrain flow when closed or to allow a flood to pass when opened.

Flood hydrograph The plot of streamflow versus time following a rainstorm. It usually separates baseflow from the surface runoff component and shows the corresponding rainfall.

Flooding *See* flood.

Flood insurance study A study that establishes floodway boundaries to accommodate a baseflood of a given frequency.

Flood mitigation The use of hydraulic structures and other means to reduce flood damage to an acceptable minimum. *See also* flood control.

Floodpeak The maximum discharge recorded during a flood.

Floodplain The flat, or nearly flat, lowland area adjacent to inland and coastal waters and within the perimeter subject to inundation by floods of a given frequency. More generally, the floodplain or flood polygon is the part of a river valley that water covers when the river overtops its banks. The Environmental Protection Agency (EPA) (40CFR6-AA-d) further defines a **base floodplain** (the 100-yr floodplain or 1% chance floodplain) and the **critical-action floodplain** (the 500-yr floodplain or the 0.2% floodplain).

Floodplain analysis A hydrologic and hydraulic study to establish such characteristics as discharge-frequency curves and stage–discharge rating curves for key locations of a drainage basin. General **floodplain information** includes basin hydrology (precipitation–runoff relationships, discharge hydrographs), frequency analysis, and water surface profiles.

Floodplain zoning A land management approach of local agencies to restrict development in floodplains and regulate land use in flood hazard areas; for example, the lowest floor of a structure must be above the elevation of the 100-year flood.

Flood polygon *See* floodplain.

Flood probability The reciprocal of flood frequency; that is, the probability that a flood of a given magnitude or a larger flood will occur in the period under consideration. For example, the 50-yr flood has a probability of 1/50 or 2%.

Flood proofing Modification of structures and facilities, their sites, and their contents, including individual measures (such as levees and floodwalls) and nonstructural measures, to protect the contents or the upper floors of buildings against the effects of floodwaters.

Flood-protection works Hydraulic structures for the protection of life and property against flood damage.

Flood-relief channel A channel designed to carry excess floodwater from a stream. Also called **flood bypass**. *See also* bypass; floodway.

Flood risk A measure of the exposure to flooding; for example, the probability that a flood of a certain magnitude will occur in a given period.

Flood routing Analysis of the flow, timing, and shape of a flood wave along a river or channel or in a reservoir. For a given reach of channel, the discharge variation at the downstream end may be determined from the upstream variation. In reservoir routing, the outflow hydrograph is determined from the inflow hydrograph. Flood routing is important for such protective measures as the timely evacuation of threatened populations. *See also* flow routing. Common flood routing techniques use hydraulic or hydrologic methods such as the Saint-Venant (unsteady-flow) equations, their diffusion approximation (the Muskingum–Cunge method), or their kinematic wave approximation, the modified Puls method, the Muskingum method, and a combination of steady-state backwater computations and modified Puls.

Floodstage An arbitrary gage height or water surface elevation selected to define a flood.

Floodwall An old and widely used masonry structure to protect lands from flood damage. A kind of longitudinal masonry dam or wall parallel to a watercourse. *See also* levee.

Flood wave An increase in streamflow caused by precipitation (or the failure of a hydraulic structure) and its subsequent recession.

Flood Wave Model (FLDWAV) A flood routing model developed by the National Weather Service for flood forecasting, floodplain mapping, and channel improvement.

Floodway A channel designed to carry excess floodwater from a stream. Same as **flood-relief channel**. *See also* bypass. The floodway may simply be a portion of the channel and floodplain reserved for the flow of floodwaters; in flood insurance studies, the floodway must be wide enough to discharge the 100-yr flood with an increase of 1 ft or less in the water surface elevation.

Flo-Poke A portable instrument to measure flowrate; manufactured by ISCO, Inc., of Lincoln, NE.

Floppy disk A flexible plastic disk, magnetically coated and protected by a jacket for storing relatively small amounts of microcomputer and minicomputer data. Also called a **diskette**. Current 3.5-in diskettes have a capacity of 1.44 MB, as opposed to hard disks, for which the capacity is currently rated in gigabytes. *See also* diskette.

Flo-Tote An open-channel flowmeter equipped with a computer and manufactured by Marsh-McBirney, Inc., of Frederick, MD. *See* Section II for further information.

Flow The movement of a fluid stream from one point to another; the fluid itself or the quantity of fluid per unit time, i.e., the same as discharge or flowrate. (The word *flow* applies equally to the forward movement of solids.) The two types of fluid flow are open-channel or gravity flow and pressurized flow. *See* discharge; flowrate; open-channel flow.

Flowage The act of flowing; e.g., the flow of water, wastewater, or sludge through the various units of a treatment plant. Also called **flow line**, as represented on a process flow diagram or a hydraulic profile.

Flo-Ware A software of Marsh-McBirney, Inc., of Frederick, MD, for logging data from flowmeters. *See* Section II for further information.

Flow area Same as **discharge area**. *See also* open-channel flow.

Flow attenuation The process of reducing the peak flowrate in a system by redistributing the same volume of liquid over a longer period of time.

Flow augmentation The increase of natural streamflow by water from an impoundment.

Flow balance An inventory of all identified water quantities entering, leaving, or accumulating in a system (e.g., a basin, a reservoir) or a quantitative analysis of the changes occurring in the system. The balance is between precipitation and other inputs on the one hand and outflows such as runoff, evapotranspiration, groundwater recharge, and streamflow on the other hand. *See also* mass balance.

Flow calibration The adjustment of flows in a wastewater collection network to obtain a balance between the various inflows and outflows. *See* Section II for further information.
Flowchart A detailed graphical representation of the operations necessary for the execution of a task such as manufacturing or data processing. Symbols are used to represent operations, equipment, and materials. Also called **flowsheet** or **flow diagram**.
Flow coefficient *See* discharge coefficient.
Flow control device A device that controls the rate of flow of a fluid manually or automatically. Called **rate-of-flow controller** when automatic.
Flow control valve A valve that controls flowrate by differential pressure across an orifice.
Flow diagram Same as **flowchart**.
Flow diversion structures Structures used to divert water from a stream, a pipe, a network, or other body of water, for example: boxes, canals, chambers, channels, dams, ditches, gates, manholes, terraces, weirs.
Flow-duration curve A curve that shows the percentage of time that streamflow is less than or equal to various flowrates during a certain period of time or the percentage of time the flows are equaled or exceeded. The shape of the curve varies with the time unit selected. In addition, the curve may show the expected lowest and highest flows. Same as **discharge-duration curve**. *See* Figure D-3.
Flow equalization weir A weir included in the control structure ahead of such units as clarifiers to ensure equal flow distribution.
Flow exponents Two exponents used in the expression of critical discharge Q_c and normal flow conveyance K_c as functions of the depth of flow y:

$$Q_c^2 = gf(y^C) \tag{F-5}$$

and

$$K_c^2 = ay^N \tag{F-6}$$

where g = gravitational acceleration, a = coefficient characteristic of the channel, C = **critical flow exponent**, and N = **normal flow exponent**.
Flow gradient The change in flow Q per unit of longitudinal distance x. (The base algorithm of EXTRAN uses the continuity equation to replace the flow gradient term $\partial Q/\partial x$ in the momentum equation by the opposite of the rate of change of the flow area $-\partial A/\partial t$.)
Flow hydrograph Same as **discharge hydrograph**.
Flowing (artesian) well A well penetrating a confined aquifer in which the piezometric surface is above the ground; i.e., the pressure is sufficient to make the well discharge water above ground without any lifting device, such as a pump. *See* Figure A-1.
Flow line *See* flowage.

FlowLogger A flow-measuring device manufactured by ISCO, Inc., of Lincoln, NE.

Flow–mass curve A plot of cumulative streamflows versus time or date. *See* Figure F-1.

Flow measurement Same as **discharge measurement**.

Flowmeter A gage indicating the velocity of wastewater moving through a treatment plant or of any liquid moving through various industrial processes. More generally, any instrument for measuring flowrate, velocity, or pressure of a fluid. Also called **fluid meter**. *See also* magnetic flowmeter; manometer; orifice; Parshall flume; pitometer; venturi; weir.

Flowmeter accuracy The closeness of the measurement made by a flowmeter to the reference value of the flow measured; expressed as the difference between the measurement and the reference value (EPA-40CFR72.2).

Flow model A representation of the flow of a fluid. For water, most current models are mathematical, based on the principles of conservation of mass (continuity) and momentum as governing equations. They include hydraulic, hydrodynamic, and hydrologic models. Hydraulic models are more approximate than hydrodynamic models; a hydraulic model may be as simple as the one-dimensional application of the Chézy or Manning equation, while the solution of most hydrodynamic models requires advanced numerical methods. Hydraulic models are sometimes simplified as zero-dimensional models (e.g., the continuity equation), one-dimensional models (e.g., a longitudinal average across the sections), or two-dimensional models (by vertical or horizontal averaging). Hydrologic models are even simpler, based only on the continuity or mass conservation principle in the form of the storage equation.

Flow net A network of two sets of straight or curved lines that constitutes a solution to the Laplace equation for steady-state groundwater flow. The streamlines (describing the flow paths of water particles) are normal to the equipotential lines (lines of equal energy or equal hydraulic head). *See* Figure F-2.

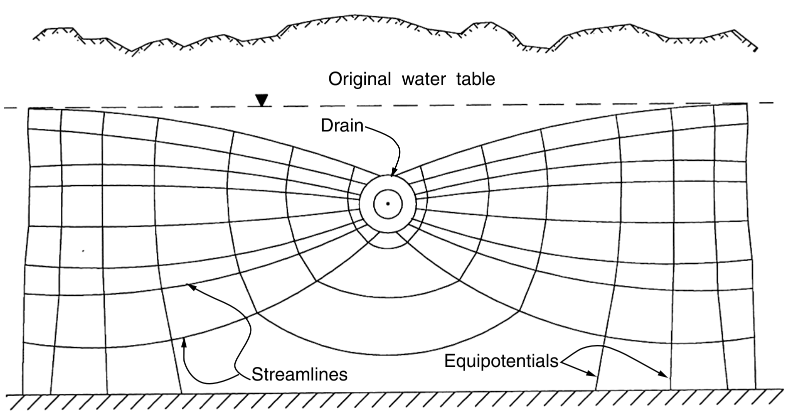


FIGURE F-2 Flownet.

Flow nozzle A flowmeter that uses pressure difference or differential head to measure flowrate in a closed conduit.

Flowpath The actual route followed by runoff in a watershed from a divide to the first downstream channel. It is used to determine the average slope of a catchment or subcatchment in digital elevation models.

Flow profile, regime, region, or zone Flow profile or water surface profile is the longitudinal profile of the water surface. **Flow regime** (or **flow region**, **flow zone**) refers to the classification of open-channel flow as normal or critical. Further definitions of flow profiles and flow regimes require the introduction of other open-channel notions (which are also repeated alphabetically in this dictionary).

- **Specific** energy **E** is the sum of the depth of flow y and the velocity head $V^2/2g$. *See* Equation C-35.
- **The Chézy, Manning, or other uniform-flow formulas determine normal flow conditions**. Normal flow characteristics include the normal discharge Q_n, depth y_n, slope S_n, and velocity V_n. Given a uniform discharge Q_n, the Manning equation can be solved iteratively for the normal depth y_n.
- **Critical flow** occurs when the specific energy is minimum for a given discharge (or when the discharge is maximum for a given specific energy). Its characteristics are the critical discharge Q_c, depth y_c, slope S_c, and velocity V_c. *See* Figure S-5. The critical depth can be determined from the specific energy equation if the discharge is expressed as a function of depth; the critical slope can then be calculated from the Manning equation.
- **Actual flow** is **subcritical** when the depth y_n is larger than the critical depth y_c and **supercritical** when $y_n < y_c$. Actual flow occurs under nonuniform conditions, e.g., as gradually varied flow with characteristics of discharge Q, depth y, slope S_0, and velocity V. There are three actual flow regimes (also called regions or zones), depending on the size of the actual depth with respect to the critical and normal depths: For Region 1:

$$y > y_n \text{ and } y > y_c$$

For Region 2:

$$y_c \le y \le y_n \text{ or } y_n \le y \le y_c$$

For Region 3:

$$y < y_n \text{ and } y < y_c$$

- The combination of 3 flow regimes (1, 2, 3) and 5 channel slopes (C, H, M, N, S) determines the 15 flow profiles (or water surface profiles), some of which are shown in Figures M-5 and S-10. The channel slope S_0 may be mild (M) when $S_0 < S_c$; steep (S) when $S_0 > S_c$; critical (C) when $S_0 = S_c$; horizontal (H) when $S_0 = 0$; and adverse (A) when $S_0 < 0$. The profiles in Regions 1 and 3 are backwater curves; those in Region 2 are drawdown curves.

Flow proportional composite sample A sample composed of grab samples collected continuously or discretely in proportion to the total flow at time of collection or to the total flow since collection of the previous grab sample. The grab volume or frequency of grab collection may be varied in proportion to flow (EPA-40CFR471.02-rr).

Flowrate The volume per time unit given to the flow of gases or other fluid substance that emerges from an orifice, pump, or turbine or passes along a conduit or channel (EPA-40CFR146.3). The rate, expressed in gallons or liters per hour, at which a fluid escapes from a hole or a fissure in a tank. Such measurements are also made of liquid waste, effluent, and surface water movement (EPA-94/04). The term *flowrate* applies as well to the volume or mass of solid material that passes through a cross section of conduit in a given time, measured, for example, in kg/h or m^3/day. Common flowrate units in the water and wastewater field are acre-feet/day, gal/day, gal/m, million gal/day, ft^3/sec, m^3/sec, l/sec, and l/day.

Flow regime (or flow region) *See* flow profile.

Flow regulation device or structure Same as **flow regulator**.

Flow regulator A device or structure used to control the flow or the level of water or wastewater in a canal, conduit, channel, basin, or treatment unit. *See also* flow control device.

Flow routing Flow routing is essentially the study of the effects of flows applied to a system such as a stream, a river system, a watershed, a sewer or a drainage network. The flow routing process uses established equations or models to produce an outflow hydrograph from an inflow hydrograph. Most forecasting models include both hydrologic and hydraulic elements. The hydrologic part expresses relationships between hydrological variables such as runoff and precipitation, while the hydraulic part is concerned with the flow of water through the system. **Hydrologic flow routing** is based on the form of the continuity equation, which is also called the **storage equation**: the rate of change in storage dS/dt is equal to the difference between inflow I and outflow O rates. *See* Equation C-17. Under steady-state conditions, inflow rate and outflow rate are equal, and the rate of change in storage is null (dS/dt = 0). Hydrologic routing methods include empirical techniques, unit hydrographs, inflow–outflow relationships, and solution of the continuity equation. Hydrologic routing can produce outflow hydrographs from inflow hydrographs, determine storage changes as a function of flow, or produce inflow hydrographs from storage and outflow data. **Hydrologic methods** can also be used in flood estimation (at a downstream location from an upstream inflow) and in flood routing. *See also* modified Puls method; Muskingum method. **Hydraulic flow routing** (or **dynamic flow modeling**) methods use both the continuity and the momentum equations to determine such characteristics as discharge, depth (stage), velocity, and flow area. Hydraulic routing problems are solved numerically; the solution techniques depend on the flow classification: steady, uniform, unsteady, or nonuniform. These techniques include the Saint-Venant energy and continuity equations, the Muskingum–Cunge method, the Chézy and Manning equations, the finite-difference and finite-element methods, and link–node models. *See also* dynamic wave equations; kinematic wave approximation; pond routing.

Flowsheet Same as **flowchart**.

Flow splitter A box or chamber that splits incoming flow into two or more streams.

Flow through The continuous or intermittent passage of a fluid in a conduit or container with no recycling.

Flow tolerance (φ) The difference between the flow in a conduit from the current iteration and the flow from the previous iteration; used as a convergence criterion in numerical modeling. *See also* numerical parameters.

Flow totalizer A type of flowmeter that shows the cumulative volume at all times; to obtain the volume for a given period, subtract the volume for the previous period from the cumulative volume. The average flow in that period is the volume divided by the length of the period.

Flow transition A change in direction, slope, or cross section that results in a change in the state of open-channel flow; e.g., when channel slope changes abruptly from mild to steep (or vice versa), the flow changes from subcritical to supercritical (or vice versa). *See* Figure F-3.

Flow transition region The range of flow conditions in which the Reynolds number R_e does not indicate whether flow is laminar or turbulent; namely, $2000 < R_e < 4000$. To the left of that range, flow is laminar; to the right, it is turbulent.

Flow transmitter An instrument that measures flows in pipelines and converts them into electrical signals transmitted to distant receivers.

Flow valve A valve that automatically closes when the flowrate reaches a certain level.

Flow weighting The adjustment of pollutant concentrations for the effect of flow in a series of measurements.

Flow work The ratio of static pressure p to the specific weight of the fluid γ in the formula of Equation D-19 of dynamic head. Same as **pressure head**.

Flow zone Same as **flow regime**. *See* flow profile.

fl oz Abbreviation for fluid ounce.

Fluid Any material or substance that flows or moves, whether in a semisolid, liquid, sludge, gas, or any other form or state (EPA-40CFR144.3 or EPA-40CFR146.3). More generally, an inelastic substance that assumes the shape of its container and can flow and deform continuously under the

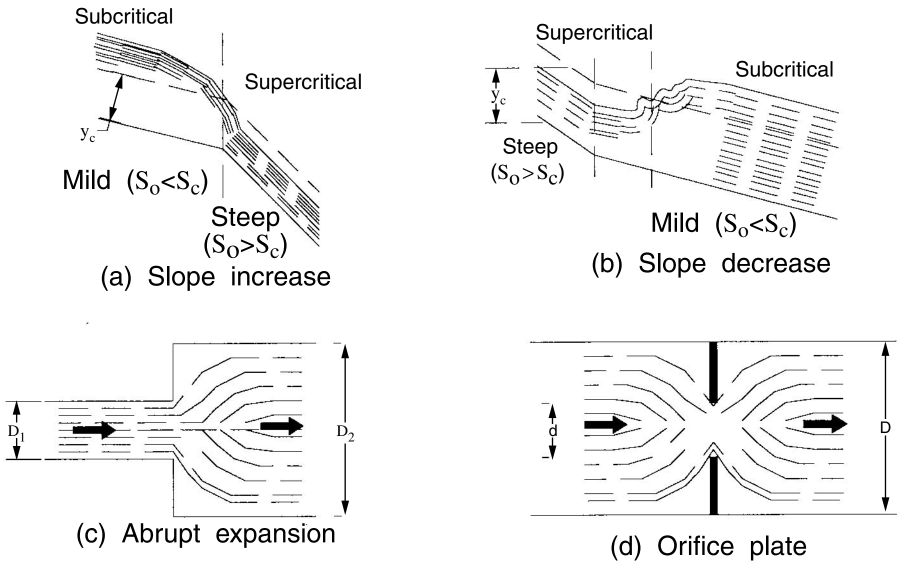


FIGURE F-3 Flow transitions.

effect of a shear force without returning to its original disposition. Fluids include liquids and gases. Fluid properties include bulk modulus (force/surface), density or mass density (mass/volume), mass, specific gravity or relative density (dimensionless), specific weight (force/volume), surface tension (force/length), viscosity (mass/length/time), volume, weight (force).

Fluid mechanics A branch of engineering science that studies the aspects of fluid behavior of interest to civil engineers, particularly hydraulics, which concentrates on the study of water and other liquids.

Fluid meter Same as **flowmeter**.

Fluid ounce (fl oz) A unit for the measurement of liquid volumes, equal to 1/16 liquid pint or 231/128 in^3. (The U.K. fluid ounce is 1/20 pint.)

Fluid potential (Φ) The quantity of energy per unit mass or the product of the gravitational acceleration g by the hydraulic head H:

$$\Phi = gH \tag{F-7}$$

Flume (1) A deep and narrow channel, especially that of a mountain stream. (2) An open channel of wood, masonry, metal, or reinforced concrete, elevated or on a grade, used to carry water for power, transport, etc. across valleys and minor depressions or over obstructions. For the differences among various watercourses, *see also* aqueduct; stream. (3) A flow-measuring device in which the flow is locally accelerated by a streamlined lateral contraction (then called a venturi flume) or the lateral contraction and a hump in the invert. Critical flow usually occurs in the throat (or

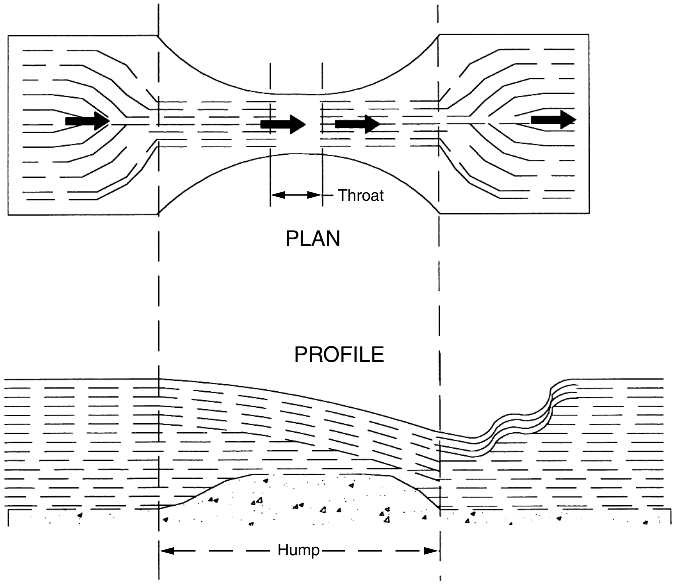


FIGURE F-4 Flume (measuring).

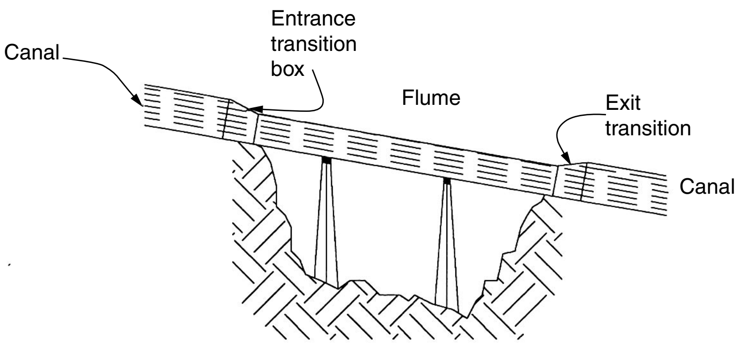


FIGURE F-5 Flume (over depression).

narrowest section). *See* Parshall flume (an example of a venturi flume). *See also* Figures F-4 (flume with a hump) and F-5 (flume over a depression).

Flush (1) To open a water tap to clear all the water that may have been sitting in the pipes for a long time. In new homes, to flush a system means to send large volumes of water through the unused pipes to remove loose particles of solder and flux. (2) To force large amounts of water through liquid to clean piping or tubing and storage or process tanks (EPA-94/04).

Flush gate A gate for flushing a channel that lies below the gate of a dam.

Flushing A method used to clean water distribution lines. Hydrants are opened and water with a high velocity flows through the pipes and flows out the hydrants.

Flushing chamber A chamber or tank that holds water or wastewater for periodic releases to flush a sewer or a water closet. Also called **flush tank**.

Flushing manhole A manhole with a gate or other device to hold wastewater that will be released to flush the downstream section.

Flush tank Same as **flushing chamber**.

Flush valve A valve to flush a toilet or other container.

Fluvial deposit Deposit of sediment by flowing water.

Fluvial erosion Erosion caused by flowing water.

Flux A flowing or flow; a flowrate per unit area ($ft^3/sec/ft^2$) or expressed as velocity (ft/sec).

Flygt Pump and other products of the ITT Flygt Corporation of Trumbull, CT.

Fog *See* rain.

Foot (ft) The unit of length in the English system; equal to 12 in or 0.3048 m.

Footage A length in feet.

Foot valve A type of check valve located at the bottom end of the suction pipe on a pump. It opens when the pump operates to allow water to enter the suction pipe but closes when the pump shuts off to prevent water from flowing out of the suction pipe (EPA Glossaries).

Force main A pressurized sewer line that conveys wastewater or stormwater from a pumping station to another force main, a manhole, a treatment plant, or a point of disposal. A gravity sewer flowing full is said to be under surcharge conditions, but is not called a force main. Velocities in force mains are usually greater than in gravity sewers. A force main may also be a pipeline supplying water from pumps, as opposed to a gravity main, but a pressurized water supply pipe is usually called a **water main**. *See also* pumping line, pumping main. Also called **pressure main**.

Forcing functions The causes of change in hydraulic, hydrodynamic, or water quality modeling. Also called **sinks** and **sources**. The change may be related to water mass or to momentum. Sources and sinks include (a) *processes* such as evaporation, precipitation, inflows, outflows, nonpoint runoff of stormwater, point discharges, withdrawals, injection or extraction wells in groundwater, seepage, infiltration; (b) *forces* such as buoyancy, Coriolis force, friction, gravity; and (c) *changes* in the masses of water constituents such as hydrophobic chemicals.

Forebay (1) A small regulating reservoir at the head of the penstock of a hydroelectric power plant or at the head of a water supply pipeline or channel. (2) A section receiving the influent of a stormwater detention basin, separated by a wall or a dike, and used to facilitate routine cleaning by capturing debris and sediment.

Formazin turbidity unit (FTU) A standard measure of turbidity. *See also* JTU.

Formula translation (FORTRAN) A high-level computer programming language that uses algebraic formulas.

Forward difference The result of subtracting f(x) from f(x + Δx) in the Taylor expansion of a function f(x) to obtain an approximation to a partial differential equation. The forward difference, first-order approximation, after truncation, is:

$$f'(x) = \partial f(x)/\partial x = [f(x + \Delta x) - f(x)]/\Delta x \qquad \text{(F-8)}$$

See also backward difference; central difference; finite-difference method.

Fossil groundwater The portion of a groundwater reservoir that has been in storage for a very long time, as opposed to the water that is renewed as part of the current hydrologic cycle. Its use constitutes **groundwater mining** and cannot continue indefinitely. However, withdrawals of fossil groundwater may occur on a temporary and limited basis.

Foster–Meyer equation In stormwater quality models, a formula used to simulate the capacity of a channel or conduit to transport bedload sediment. *See* Simplified Particulate Transport Model; Yalin–Einstein equation.

Four-Point Model (FOURPT) A model developed by the U.S. Geological Survey to simulate flow in a network of open channels and hydraulic structures.

FOURPT Acronym for Four-Point Model.

fps (or ft/sec) Abbreviation for feet/second or foot (feet) per second; a unit of velocity, with 1 ft/sec = 0.3048 m/sec.

Francis formula An expression of flow Q over a rectangular, sharp-crested, suppressed weir of length L and head H, where H ≤ L/3:

$$Q = 3.33LH^{1.5} \qquad \text{(F-9)}$$

It also applies to the Cipolletti weir with a slight modification:

$$Q = 3.37LH^{1.5} \qquad \text{(F-10)}$$

Francis turbine A reaction hydraulic turbine with radial inward flow and medium speed. It consists of four basic parts: a scroll case, wicket gates, a runner, and a draft tube. The Francis turbine is usually installed for heads between 100 ft and 1000 ft and for loads above 50%. *See also* Kaplan turbine.

Francis wheel A water wheel with inward flow.

Freeboard The vertical distance between the top of a hydraulic structure and the normal maximum liquid level; provided to prevent overflows due to liquid movement. For example: (1) the vertical distance between the top of a tank or surface impoundment dike and the surface of the waste contained therein; (2) the vertical distance from the normal water surface to the top of the confining wall; (3) the vertical distance from the sand surface to the underside of a trough in a sand filter (EPA-40CFR260.10 and EPA-94/04).

Free-falling weir or free-fall weir Same as **free weir**.

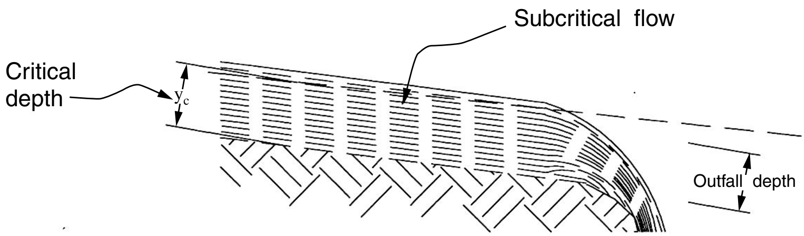


FIGURE F-6 Free outfall.

Free groundwater Same as **free water**.

Free liquid A liquid that readily separates from the solid portion of a waste under ambient temperature and pressure (EPA-40CFR260.10). **Free moisture** is liquid that will drain freely by gravity from solid materials (EPA-CFR240.101-I).

Free outfall A type of outfall structure without a gate. Also, two of three types of discharge points or boundary conditions used in the Stormwater Management Model (SWMM), corresponding to backwater-free discharges to (1) a gravity element (manhole) and (2) a pump station wetwell. (The third type is a pressure discharge.) *See* Figure F-6.

Free surface The boundary of a liquid in contact with the atmosphere.

Free-surface flow Same as **open-channel flow**.

Free water Water occurring just below the water table, moving according to the slope of the latter and extending down to the first confining bed. Also called **free groundwater** or **mobile water** but sometimes confused with gravitational water. *See* subsurface water.

Free weir A weir that is not submerged and that falls over the crest without any tailwater interference. Also called a **free-fall weir**, a **free-falling weir**, or a **friction weir**.

French drain An underground passage for water. Consists of a trench loosely filled with coarse rock or stones and covered with earth; the stones decrease in size from bottom to top. While they are not satisfactory for permanent underdrainage because of the required maintenance, French drains are sometimes recommended among the best management practices in stormwater management when the underlying soils are permeable.

Frequency The number of occurrences of an event or a phenomenon in a given period.

Frequency analysis The use of statistical concepts to analyze hydrologic data and derive their frequency distribution as well as their return period or recurrence interval. *See* exceedance frequency; Figure F-1; flood frequency; floodplain analysis; frequency curve; plotting position; return period.

Frequency curve A graphical representation of the frequency of occurrence of an event; i.e., a curve that shows the probability that an event of equal or greater magnitude will occur during a specified period. Usually on logarithmic or semilogarithmic paper, the curve plots an event characteristic

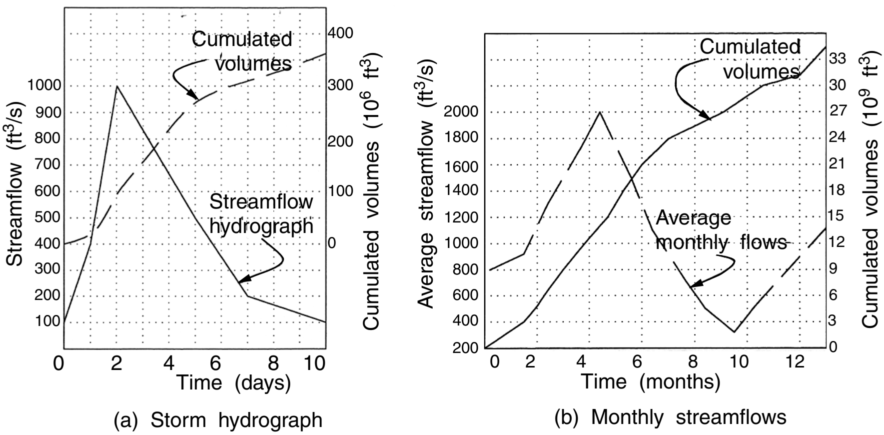


FIGURE F-7 Frequency analysis.

(e.g., peak flow, runoff volume, low flow) versus the recurrence interval. For the frequency curve of rare events (floods, droughts, etc.), the annual series is better suited than the exceedance (or partial duration) series. *See* Figure F-1.

Frequency distribution The distribution or relative arrangement of frequencies attached to an event (or specific values of a random variable) over the range of its occurrence. With large amounts of data (e.g., in hydrology), it is sometimes convenient to arrange and analyze them in classes. Common theoretical frequency or probability distributions used in hydrology are the normal, exponential, gamma, log-Pearson type III, lognormal, and Gumbel. *See* Figure F-7.

Freshwater Water with a low mineral content, as expressed by a concentration of dissolved solids (DS) of less than 1000 mg/l. *See also* brackish water; brine; saline estuarine waters; saltwater or saline water; seawater or ocean waters.

Freshwater lake Any inland pond, reservoir, impoundment, or other similar body of water that has recreational value, that exhibits no oceanic or tidal influences, and that has a total dissolved solids concentration of less than 1% (EPA-40CFR35.1604-2).

Friction coefficient/friction factor A coefficient used in hydraulic formulas to reflect the energy gradient caused by friction; i.e., a measure of the resistance to fluid flow. It depends on the Reynolds number of the flow and on the roughness of the conduit wall. *See also* Darcy–Weisbach equation; Manning formula.

Friction force A term of the momentum equation represented by the friction or energy slope S_f. *See* Saint-Venant equations.

Friction head, friction headloss, The head (also called **pressure** or **energy**) lost by a fluid flowing in a pipe or channel as a result of turbulence caused by velocity and the roughness of the pipe and channel walls and restrictions caused by fittings. Water flowing in a conduit loses pressure or energy as a result of friction losses (EPA Glossaries).

Friction slope The slope of the energy line at a cross section of channel or conduit. It may be determined from the Manning formula if the other variables are known (discharge, water surface elevation, roughness coefficient, and hydraulic radius). The HEC-2 and HEC-RAS models use four approximations of friction slope between two cross sections: average friction slope, average conveyance, geometric mean friction slope, and harmonic mean friction slope.

Friction weir Same as **free weir**.

Frontal precipitation Precipitation occurring at the frontal surface. *See also* convective precipitation.

Frontal surface Surface of separation between two air masses of different temperatures and humidities.

Front-end interface One of two types of graphical user interface; i.e., a computer program that processes model input data, usually converting graphics to text. For example, a front-end interface can convert AutoCAD drawings and other graphics for input to the Stormwater Management Model (SWMM) as ASCII files. Also called **input interface** or **preprocessor**. *See also* back-end interface (output interface or postprocessor).

Froude number (F_r) A dimensionless number equal to the ratio of the average flow velocity V to the square root of the product of the gravitational acceleration g by a characteristic length L such as the hydraulic mean depth; i.e.:

$$F_r = V/\sqrt{gL} \tag{F-11}$$

When the characteristic length equals the depth of flow y, as in a rectangular channel, the Froude number becomes the ratio of the average velocity to the celerity of the gravity wave; i.e.:

$$F_r = V/\sqrt{gy} \tag{F-12}$$

The Froude number determines the regime of flow, which is critical, subcritical, or supercritical if F_r is, respectively, equal to, less than, or greater than 1.0. Flow conditions tend to become unstable when F_r is close to 1.0 and result in wave formation. The Froude number is also an element of the general equation of gradually varied flow. *See also* critical flow; densimetric Froude number; hydraulics; open-channel flow; specific energy curve.

ft Abbreviation for foot (feet), a unit of length; 1 ft = 12 in = 0.3048 m.

FTP Abbreviation for File Transfer Protocol, an Internet utility.

ft/sec Abbreviation for foot (feet) per second, a unit of velocity.

FTU Abbreviation for formazin turbidity unit, a standard measure of turbidity. *See also* JTU.

Fugitive water Water leaking from impounding reservoirs, irrigation works, or other containers.

Full Equations Model A model developed by the U.S. Geological Survey to simulate streamflow using dynamic wave equations with control structures.

Full pond elevation The maximum pool elevation in a reservoir during normal operation, i.e., in the absence of a flood. It corresponds to the spillway crest. *See* reservoir storage; Figure R-2. Also called **normal pool level**.

Full pool The condition of a pond or other impoundment at normal water level.

Full-width weir *See* suppressed weir.

Fully penetrating well A well that extends through the entire thickness of an aquifer (including screen, casing, and piping).

Fundamental dimension Same as **fundamental quantity**.

Fundamental groundwater law The basic law governing the movement of groundwater. Same as **Darcy's law**: The velocity or flux is proportional to the rate of hydraulic energy loss.

Fundamental quantity One of five characteristics of a body or system that can be measured, but cannot be expressed in simplest terms: mass, length, time, temperature, and force. Such quantities are also called **dimensions**. Other physical characteristics are derived quantities; they can be expressed in terms of the fundamental quantities, e.g., velocity, pressure, and density. To compare their differences, *see also* extrinsic property; intrinsic property.

Fuzzy logic The application of approximate, nondiscrete rules to process control. In a fuzzy system, the process is too complex to be modeled conventionally, thus yielding results that are generally soft, with no precise boundaries.

Fuzzy programming An optimization technique that assigns acceptable ranges to the objectives, variables, and parameters instead of fixed values; the boundary between acceptable and unacceptable values is unclear or *fuzzy*. The technique attempts to minimize the difference between the levels of desired performance and of the lowest acceptable performance. It may be used advantageously to reduce costs in engineering problems usually solved on the basis of rigid design guidelines or rules of thumb. For example, a flow velocity of 2.00 ft/sec in gravity sewers is acceptable, but 1.99 ft/sec violates the guideline.

Fuzzy tolerance A parameter in geographic information system (GIS) applications specified when a polygonal coverage is created from an AutoCAD file.

G

Gabion A basket of metal iron, wicker work, or other material and filled with earth or stones; used as a foundation mat, as a military defense, or to control erosion. Also called a **pannier**.

Gage (or **gauge**) (1) A device for measuring the elevation of the water surface above some datum. (2) A device for measuring such characteristics as pressure, rainfall amount or intensity, and depth of snowfall.

Gage height The water surface elevation above a datum; measured on a gage.

Gage pressure The pressure within a closed container or pipe as measured with a gage. In contrast, absolute pressure is the sum of atmospheric pressure and gage pressure. Most pressure gages read in gage pressure or psig (pounds per square inch gage).

Gaging station A location on a watercourse for measuring the gage height.

Gallon (gal) A unit of volume for the measurement of liquids; equal to 231 in^3 or 128 fl oz in the United States. Thus, 1 gal = 0.1336806 ft^3 = 3.7854118 l. Note that the U.K. gallon or **imperial gallon** is equal to 160 fl oz or 4.54609 l, i.e., about 1.2 U.S. gallons.

Gamma distribution A probability distribution used in computational hydrology for the analysis of rare events or for the generation of basin mean precipitations. It incorporates the gamma function. For the **two-parameter gamma**:

$$f(x) = [\Gamma(n)/K^n]x^{n-1}\exp(-x/K) \quad \text{(G-1)}$$

For the **three-parameter gamma** (also called Pearson type III):

$$f(x) = [\Gamma(n)/K^n](x - x_0)^{n-1}\exp[-(x - x_0)/K] \quad \text{(G-2)}$$

where f(x) is the density function of a random variable x, Γ(n) is the gamma function, with n, K, and x_0, respectively, its shape, scale, and location parameters. *See* extreme value distributions; Nash model.

Gamma function A function Γ(n) of a shape parameter n obtained by integrating over the positive domain a function of a random variable x that includes n as an exponent. Used for estimating unit hydrograph parameters (in the Nash model) and for modeling the long-term performance of stormwater ponds (James, 1994, 1996). *See* gamma distribution. The gamma function is:

$$\Gamma(n) = \int x^{n-1} \exp(-x)dx \quad \text{(G-3)}$$

where ∫ denotes integration from zero to infinity.

Gang of wells A series of wells connected to a single pump for water withdrawal. Also called a **battery of wells**.

Ganguillet, Emile Oscar *See* hydraulics.

GA parameters Three parameters of the Green–Ampt (GA) infiltration equation: available (soil) porosity, capillary suction, and hydraulic conductivity.

Gasket A small part made of rubber, metal, or rope, usually in the form of a sheet or ring, used for packing a piston or placing around a joint to make it watertight. Also called **static seal**.

Gate A door or other movable watertight barrier for controlling the passage of materials through a pipe, channel, or other waterway.

Gate valve A valve with a closing element that is a disk fitting tightly over an opening.

Gauge *See* gage.

Gaussian distribution The Gaussian or normal distribution is one of a few distributions used to simulate extreme events. It corresponds to the normal density function f(x), the parameters of which are the mean μ and standard deviation σ. *See* Equation (N-17); Figure N-1.

GAWSER Acronym for Guelph All-Weather Sequential Events Runoff.

GB Abbreviation for gigabyte(s), a unit of the storage capacity of a computer drive. *See also* gigabyte.

Gear pump A positive rotary pump that uses two meshing gear wheels to move the fluid from suction to discharge.

GeoCAD A computer program developed by the RJN Group, Inc., of Wheaton, IL, to integrate the Stormwater Management Model's (SWMM's) TRANSPORT Block with software programs of the Oracle Corporation.

Geographic information system (GIS) A computer system designed for storing, analyzing, manipulating, and displaying data in a geographic context (EPA-94/04). A system of computer hardware, software, and procedures designed to support the capture, management, manipulation, analysis, modullary, and display of spatially referenced data for solving complex planning and management problems. *See* GIS software. *See* Section II for further information.

Geological log A detailed description of all underground features (depth, thickness, type of formation) discovered during the drilling of a well (EPA-94/04). *See also* geophysical log.

Geologic erosion Natural erosion processes occurring over long (geologic) time spans. *See also* accelerated erosion.

Geometric mean friction slope (S_{fg}) The square root of the product of the friction slopes (S_{f1} and S_{f2}) at two points or two cross sections. It is one of four approximations used in the HEC-2 and HEC-RAS models to estimate the friction loss between two cross sections. *See also* average conveyance; average friction slope; friction slope; harmonic mean friction slope.

$$S_{fg} = (S_{f1} \cdot S_{f2})^{0.5} \quad \text{(G-4)}$$

Geometric similarity *See* hydraulic model.

Geophysical log A record of the structure and composition of the earth encountered when drilling a well or similar type of test hole or boring. *See also* geological log.

Gigabyte A unit used to measure the capacity of computer hard drives, random access memory, or other storage devices, often abbreviated GB or gig; from the prefix *giga*, meaning 1 billion. Actually, 1 GB equals a little more than 1 billion bytes (2^{30} = 1,073,741,824).

GIS Abbreviation for geographic information system.

GIS polygonal coverage A geographic information system (GIS) file composed of polygons and including an attribute table. It represents an element of a study, such as a pump station service area.

GIS software A geographic information system (GIS) database management software that allows the user to import, manage, query, analyze, and visualize mappable features on, above, or below the surface of the earth. In addition to ArcInfo and ArcView, GIS programs include ARC-CAD by ESRI; AutoCAD Map and Auto CAD World by Autodesk, Inc.; GeoMedia and FRAMME by the Intergraph Corp.; Map Factory by Macintosh; Map Info by MapInfo; SmallWorld by SmallWorld, Inc.; Formida Fire by Formida; Blue Marble by Blue Marble geoGraphics; GIS/CAD products by Bentley Systems; SpatialInsight GIS by Sedona GeoServices; Oracle Spatial by Oracle Corp.; and Sylvan Mapping OCS by Sylvan Mapping. *See also* modeling software; Table M-1.

Global method Computational hydraulic techniques use global or local methods to discretize the partial differential equations governing fluid flow. In **local methods** (such as the finite-difference, finite-element, and finite-volume methods), the approximating algebraic equations apply to adjacent grid points. In a **global method**, such as the spectral method, amplitudes associated with various frequencies replace the dependent variables.

Global positioning system (GPS) A new technology to determine elevations and locations using three-dimensional signals from satellites. It is a system of satellites orbiting the earth twice daily to transmit precise time and position signals. With GPS, water and sewer system elements (hydrants, valves, inverts, wetwells, etc.) can be surveyed with excellent accuracy. *See also* modeling software; Table M-1.

Globe valve A valve consisting of a movable disk as closing element and a matching ring seat in a spherical body.

Gooseneck A portion of a service connection between the water distribution main and a meter (EPA Glossaries). Also called a **pigtail**.

gpd (or gal/day) Abbreviation for gallon(s) per day, a unit of flow or discharge.

gpd/in.-mi (or gal/day/in.-mi) Abbreviation for gallon(s) per day per inch diameter per mile. A measure of the rate of infiltration/inflow (I/I) in a gravity sewer. For example, if a 15-in sewer section of 1100 ft has an I/I flow of 10,000 gal/day, its I/I rate is 10,000 gal/day/(15 in × 1100 ft/5280 ft/mi) = 3200 gal/day/in.-mi. Some regulatory agencies specify

5000 gal/day/in.-mi as a maximum I/I rate for sewer performance or as a guideline for cost-effectiveness analysis of sewer system rehabilitation.

gpm (or gal/min) Abbreviation for gallon(s) per minute, a unit of flow, often used to define the discharge capacity of a pump; 1 gal/min = 0.00144 million gal/day = 0.002228 ft^3/sec = 0.0631 l/sec = 5.4510 m^3/day.

GPS Abbreviation for global positioning system.

Grab sample A single sample representative of the composition of the flow at a particular time and place, as compared to a **composite sample**, which is a flow-weighted average of several samples taken over a given period of time.

Grade (1) The elevation of the invert or the bottom of a pipeline, canal, culvert, or similar conduit. (2) The inclination or slope of a pipeline, conduit, stream channel, or natural ground surface; usually expressed in terms of the ratio or percentage of number of units of vertical rise or fall per unit of horizontal distance. A 0.5% grade would be a drop of a half foot per hundred feet of pipe (EPA Glossaries). (3) The finished surface of a structure such as a canal bed, roadbed, top of embankment, or bottom of excavation.

Graded stream A stream that has a stable channel.

Gradient The change in quantity over distance; the rate of change of any characteristic per unit length; e.g., bottom slope, which may be expressed in ft/ft, m/m, or as a percentage. Examples are elevation gradient, hydraulic gradient, pressure gradient, and velocity gradient.

Gradient algorithm An algorithm of the **linear method** used in the Cybernet™ model to linearize flowrates in the energy conservation equation. The method involves an iterative, matrix solution of the governing equation.

Gradient Richardson number (R_i) The ratio of buoyancy to mixing energy; named after Lewis F. Richardson, who studied stratified flow stability in 1920. With the Reynolds number, it is used to determine whether a stratified flow is turbulent and stable ($R_i > 0$) or unstable ($R_i < 0$). It is also used in mixed-layer and turbulent diffusion models of lakes, reservoirs, and estuaries. This number is a function of the fluid density ρ, the vertical coordinate z, the horizontal velocity U, and the acceleration of gravity g, i.e.:

$$R_i = -g \cdot (\partial \rho/\partial z)/(\partial U/\partial z)^2 \qquad \text{(G-5)}$$

See also open-channel flow.

Gradually varied flow In varied flow, depth and velocity change with distance along the stream or conduit. If the depth changes over a relatively long distance, the flow is gradually varied; if the change is abrupt, the flow is rapidly varied. *See* open-channel flow; Figure O-2.

Graphic component One of the two types of component of geographic information system (GIS) data. GIS graphic components include points, lines, or polygons. The other type is a database component or attribute table. The two components are dynamically linked in a one-to-one relationship.

Graphical user interface (GUI) A graphical output hardware and software system that simplifies user interface with the computer in such tasks as model building and debugging by displaying three-dimensional plan views and profiles of the system. It includes a pointing device, such as a mouse or a trackball, and icons that represent files, programs, and system utilities. A GUI replaces commands with an intuitive pictorial interface consisting of menus, dialog boxes, input and output windows, and icons; e.g., in the HEC-RAS model, a set of menus and screens allows the user to perform file management, data entry and editing, hydraulic simulation, display of input and output data, printing, and access to online help. CASCCADE-2 is a GUI that integrates two models: HEC-DSS and Stormwater Management Model (SWMM). GUIs can also be established with such programs as AutoCAD, geographic information system (GIS), automated mapping/facilities management, and database management system (DBMS). *See also* Model Turbo View EXTRAN.

Grassed buffer A strip of grass or other erosion-resisting vegetation between or below cultivated fields or separating a waterway from an intensive land use area (e.g., a farm or a residential subdivision). Also called **buffer strip**, **filter strip**, and **vegetated filter strip**.

Grassed waterway Natural or constructed watercourse or outlet that is shaped or graded and established in suitable vegetation for the disposal of runoff without erosion (EPA-94/04).

Gravitational acceleration (or acceleration of gravity) A factor used in several fluid mechanics formulas. It varies between 9.78 and 9.82 m/sec^2 on the surface of the earth. In engineering applications, it is usually taken as $g = 32.2\ ft/sec^2$ or $9.81\ m/sec^2$.

Gravitational water Water that moves by gravity from the soil and pellicular subzones through the capillary fringe and the water table. Sometimes called **vadose water** or lumped with pellicular water as **intermediate groundwater** or **intermediate vadose water**. *See* Figure S-14; subsurface water. Sometimes confused with free water.

Gravity The gravitational attraction at the surface of the planet.

Gravity collection Wastewater or stormwater collection involving only open-channel flow (no pumping station and no force main).

Gravity dam A concrete or rubble masonry dam that depends on its own weight for stability against overturning or sliding horizontally. It has a nearly triangular transverse cross section. It is one of four common dam types. The other three types are arch, buttress, and embankment dams. *See* Figure G-1.

Gravity force A term in the momentum equation represented by the invert or bottom slope S_0. *See* Saint-Venant equations.

Gravity junction In a sewer system modeling study, a gravity junction has at least one gravity conduit or is a wetwell connected to a lift station, as opposed to a pressure junction, for which all the conduits are under pressure.

Gravity main A pipeline supplying water by gravity, as opposed to a force main.

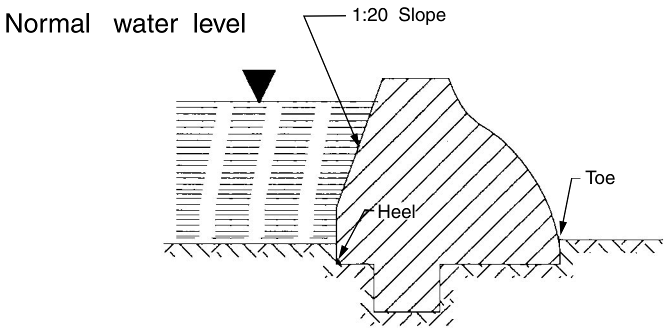


FIGURE G-1 Gravity dam (cross section).

Gravity sewer A sewer with open-channel flow, as opposed to a force main, for which flow is under pressure.

Gravity spillway A widely used structure for passing the overflow of a dam. Its main part is an S-shaped channel from the crest to the toe or bucket, usually with an energy dissipation apparatus such as an apron or a stilling basin. *See also* Figure S-9; overflow spillway.

Gravity system A network of gravity sewers.

Gravity wave A wave having a length longer than 6.28 cm, as opposed to a capillary wave. *See also* long wave; short wave.

Gravity wave celerity (C_g) A wave is a variation in flow, with a speed of travel called wave celerity, different from the water velocity. The gravity wave celerity is the velocity of a wave through water due to gravity. It is the square root of the product of the water depth y by the acceleration of gravity g, i.e.,

$$C_g = \sqrt{gy} \tag{G-6}$$

See also dynamic wave celerity; kinematic wave celerity.

Graywater All nontoilet household wastewater from sinks, basins, baths, and showers; that is, domestic wastewater that does not contain excreta and is expected to contain considerably fewer pathogenic microorganisms than sewage. Also called **sullage**. *See also* sanitary water.

Green–Ampt equation An adaptation of Darcy's law by W. A. Green and G. A. Ampt in 1911 to determine the infiltration rate (f, in/hr) of rainfall into soil under homogeneous conditions and negligible ponding depth as a function of (a) hydraulic conductivity K (in/hr); (b) the **capillary suction** at the wetting front S_c (with the **wetting** front defined as the interface between the wet and dry soils); (c) available porosity π, which is the difference between the total soil porosity and the initial soil water content; (d) accumulated infiltration F (in), i.e., the product $\pi \cdot L$ of available porosity by the distance L from the ground surface to the wetting front:

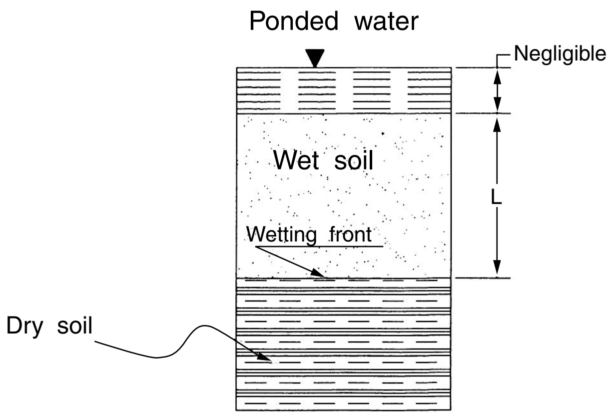


FIGURE G-2 Green–Ampt infiltration model.

$$f = K(1 + \pi \cdot S_c/F) = K(1 + S_c/L) \qquad \text{(G-7)}$$

See Figure G-2; Holton loss function; curve number.

Green–Ampt function Same as **Green–Ampt equation**.

Green–Ampt infiltration equation or function Same as **Green–Ampt equation**.

Greywater Same as **graywater**.

Grinder pump A mechanical device that shreds solids and raises wastewater to a higher elevation through pressure sewers (EPA-94/04).

Grit Sand, gravel, cinders, and other suspended solid matter with settling velocities and specific gravities substantially greater than those in the organic solids of wastewater. Grit is usually removed in a grit chamber to protect subsequent treatment units from abrasion.

Groin A coastal hydraulic structure perpendicular to the shoreline, such as a low wall, a crib, a row of piles, or a stone jetty, to prevent beach erosion by reducing the littoral movement of sand. *See also* breakwater; bulkhead; jetty; revetment; seawall.

Ground cover Plants grown to keep soil from eroding.

Ground-level storage Storage of water in a container with a bottom that is at or below the surface of the ground. *See also* elevated storage.

Groundwater The supply of fresh water found beneath the earth's surface, usually in aquifers, which supply wells and springs. Because groundwater is a major source of drinking water, there is growing concern over contamination from leaching agricultural or industrial pollutants or leaking underground storage tanks (*see* Safe Drinking Water Act) (EPA-94/04).

Groundwater accretion The fraction of precipitation that percolates through the soil into the groundwater reservoir and later flows to a stream as spring or seepage water. It is the main source of base runoff or dry-weather flow in unregulated streams. Also called **groundwater runoff**. *See also* Figure R-6; rainfall–runoff relationship.

Groundwater classification *See* subsurface water.

Groundwater discharge (1) Discharge of subsurface water where the water table intersects the land surface, e.g., through springs and seepage outcrops, or to the atmosphere by evaporation. (2) Groundwater entering near coastal waters that has been contaminated by landfill leachate, deep well injection of hazardous wastes, septic tanks, etc. (*see* Safe Drinking Water Act) (EPA-94/04).

Groundwater divide Similar to a watershed boundary, it defines underground the limits of the areas that contribute water to a stream. Also called **phreatic divide**.

Groundwater flow The portion of precipitation that infiltrates to the saturation zone and contributes ultimately to a surface stream baseflow. *See also* groundwater accretion; subsurface stormflow.

Groundwater flow equation The fundamental law governing **groundwater movement**. Same as **Darcy's law**: the velocity or flux is proportional to the rate of hydraulic energy loss.

Groundwater hydraulics The field that studies the movement, availability, recharge, etc. of groundwater. *See also* hydrogeology.

Groundwater hydrology The study of the origin, nature, and occurrence of subsurface water, as well as its movement through and seepage from the underground formations. The general **hydrologic equation** relates the various recharge factors ΣR to discharges SD and change in storage ΔS:

$$\Sigma R = \Sigma D + \Delta S \qquad \text{(G-8)}$$

See also hydrography (or surface water hydrology); hydrometeorology.

Groundwater infiltration (1) Same as **infiltration**. (2) Water that enters a treatment facility as a result of the interception of natural springs, aquifers, or runoff that percolates into the ground and seeps into the treatment facility's tailings pond or wastewater holding facility and that cannot be diverted by ditching or grouting the tailings pond or wastewater holding facility (*see* Clean Water Act) (EPA-40CFR440.132-d). *See also* infiltration/inflow.

Groundwater level The level of the surface of the saturated zone. *See* groundwater table.

Groundwater migration A phenomenon sometimes observed in sewer system rehabilitation by which the infiltration removed from one source migrates to other sources that were either inactive or less active before rehabilitation. It has been observed that migration effects can travel as much as 200 ft to reach unrehabilitated sources.

Groundwater mining Withdrawal of groundwater over a period of time in excess of the rate of aquifer recharge. *See also* fossil groundwater.

Groundwater model A representation of a groundwater system used, sometimes in conjunction with field monitoring and laboratory studies, to predict the natural flow and transport processes. Groundwater models may be as simple as Darcy's law or as complicated as a set of several hundred nonlinear equations to be solved numerically.

Groundwater movement *See* groundwater flow equation.

Groundwater recharge Replenishment of groundwater naturally or artificially, including infiltration from rainfall and snowmelt or from surface water, leakage through confining layers, water from diffusion or spreading operations. *See* artificial recharge.

Groundwater runoff Same as **groundwater accretion**.

Groundwater table The level of groundwater; the upper surface of the zone of saturation of groundwater above an impermeable layer of soil or rock (through which water cannot move), as in an unconfined aquifer. This level can be near the surface of the ground or far below it. In the unconfined aquifer, the fluid at the water surface is at atmospheric pressure (EPA Glossaries). Sometimes simply called **water table**.

Groundwater under the direct influence of surface water Any water beneath the surface of the ground with (1) significant occurrence of insects or other macroorganisms, algae, or large-diameter pathogens such as *Giardia lamblia*; (2) significant and relatively rapid shifts in water characteristics such as turbidity, temperature, conductivity, or pH that closely correlate to climatological or surface water conditions. The state must determine direct influence for individual sources in accordance with its criteria. The state's determination of direct influence may be based on site-specific measurements of water quality or documentation of well construction characteristics and geology with field evaluation (EPA-40CFR141.2).

Groundwater wave An oscillatory movement of the water table caused by a substantial addition of water in a short period and over a small area. Also called **phreatic wave**.

Groundwater yield The quantity of water that can be extracted from an underground formation. The **safe yield** of an aquifer refers to the quantity of water that can be withdrawn annually from it without impairing its quality or causing excessive development and operation costs. Neglecting pumping costs, an upper limit on **available yield** is the mean annual precipitation minus runoff, evapotranspiration, and subsurface discharge. More appropriately, the concept of **perennial yield** also takes into consideration the recharge capability of a basin.

Guelph All-Weather Sequential Events Runoff (GAWSER) A deterministic hydrologic model used to compute total streamflow from rainfall and snowmelt.

Guglielmini, Domenico *See* hydraulics.

GUI Acronym for graphical user interface.

Gully A small, elongated, and deep channel created by the eroding action of running water, usually dry except after a rainstorm, icemelt, or snowmelt. Gullies are similar to but smaller than ravines and deeper than rills or rivulets. *See* stream for the difference among various watercourses. **Gully erosion** is severe erosion in which trenches are cut to a depth greater than

1 ft or 30 cm. Generally, ditches deep enough to cross with farm equipment are considered gullies (EPA Glossaries).

Gumbel distribution A statistical distribution of extreme values suggested by E. J. Gumbel in 1945 for flood frequency analysis. It states that the probability of occurrence p of an event equal to or greater than X is such that

$$p = 1 - \exp[-\exp(-b)] \qquad \text{(G-9)}$$

$$b = (X - \mu + 0.45\sigma)/0.7797\sigma \qquad \text{(G-10)}$$

and

$$\sigma = \sqrt{\Sigma(X-\mu)^2/(N-1)} \qquad \text{(G-11)}$$

where N is the number of values or events in the series, μ is the average of these N values, and σ is their standard deviation. Also called **extreme value type I distribution**. *See also* gamma distribution; lognormal distribution; log-Pearson type III for other extreme value distributions.

Gutter (1) A shallow surface or trench provided at the margin of a roadway or beside a canal for surface drainage. (2) A trough along the eaves or on the roof of a building to carry off rainwater.

H

H2Onet® Integrated water distribution analysis and optimization software developed by MW Soft, Inc., of Pasadena, CA. It includes five utility programs to (a) track flow and velocity in pipes, pressure and flow at nodes, water height and volume in tanks, movement and fate of constituents in the system; (b) formulate and assess improvement solutions; (c) determine pipe roughness coefficients that best match field observations; (d) locate the minimum number of isolation valves to close to separate a pipe from the rest of the network; and (e) reduce the model size for easier analysis, e.g., by removing pipes with less than a specified diameter.

ha Abbreviation for hectare.

Haestad severity index (HSI) A dimensionless index proposed by Haestad Methods, Inc., of Waterbury, CT, to define the severity of rainfall events in replacement of their return period. This method assumes that the severity index S_L of an event is directly proportional to its duration D (hours) and its return period t (years):

$$S_L = D \cdot t \quad \text{(H-1)}$$

with level 1 representing the smallest magnitude of interest (e.g., D = 0.1 and t = 0.1), level 10 indicating an event of "catastrophic" magnitude (e.g., D = 240 and t = 500), and the other levels (L = 2 through 9) determined as follows:

$$\ln(S_L) = \ln(S_1) + 1.81116(L - 1) \quad \text{(H-2)}$$

By plotting return periods as ordinates and durations as abscissas on logarithmic paper, the Haestad severity index levels can be obtained as parallel lines and the severity level of an event can be determined. For example, a 100-yr storm of 1-h duration would have approximately the same severity index level as a 10-yr storm of 11-h duration.

Hagen, G. *See* hydraulics.

Hagen–Poiseuille equation Equation that expresses the frictional headloss h_f for laminar flow in a pipe of diameter D and length L as:

$$h_f = 32\,\mu\, LV/\rho g D^2 \quad \text{(H-3)}$$

where μ = absolute viscosity, V = average velocity, ρ = fluid density, and g = gravitational acceleration.

Hard copy A paper copy of a map or document, as opposed to an electronic copy on a disk.

Hard disk A rigid magnetic disk, fixed within a drive, for storing relatively large amounts of computer data (as opposed to a diskette or floppy disk).

Hard drive A computer's main internal storage device; its capacity is expressed in a multiple of bytes, such as megabytes or gigabytes.

Hardware The physical equipment of a computer system, such as the computer, monitor, keyboard, mouse, and printer; the other important part of the system is the software.

Hardy Cross method A procedure published by Hardy Cross in 1936 to solve water supply network problems. It requires the assumption of flows in each pipe (method of **discharge balancing**) or the assumption of a piezometric head at each junction (method of **head balancing**), and the satisfaction of the principle of continuity at each node. Flows are corrected iteratively until an acceptable level of error is reached, subject to a headloss of zero around any closed loop.

Harmonic mean friction slope (S_{fh}) One of the four approximations used in the HEC-2 and HEC-RAS models to estimate the friction loss between two points or two cross sections. It is equal to twice the product of the friction slopes (S_{f1} and S_{f2}) at the two points divided by their sum. *See also* average conveyance; average friction slope; friction head; friction headloss, friction loss; geometric mean friction slope.

$$S_{fh} = 2 \cdot S_{f1} \cdot S_{f2}/(S_{f1} + S_{f2}) \qquad \text{(H-4)}$$

Hazen formula One of three commonly used formulas in frequency analysis to determine the plotting position p of the event of rank i in a series of N events; i.e., where to locate the coordinate of the event on the probability axis:

$$p = 100(i - 0.5)/N \qquad \text{(H-5)}$$

See also exceedance series; frequency curve; median formula; Weibull formula.

Hazen–Williams formula A widely used empirical formula to calculate pressure pipe friction for water flowing under turbulent conditions. It yields results comparable to those for the Darcy–Weisbach formula at moderately high Reynolds numbers. It expresses flow Q in a pipe in function of its diameter D, slope S_o, and a friction coefficient C between 100 and 150 depending on the material and age of the pipe:

$$Q = a \cdot C \cdot D^{2.63} S_o^{0.54} \qquad \text{(H-6)}$$

with a = 0.432 for English units (cubic feet per second and feet), and a = 0.278 for metric units (cubic meters per second and meters).

Equivalent formulas for the **Hazen–Williams headloss** h_f and average velocity V are:

$$V = b \cdot C \cdot R^{0.63} S_o^{0.54} \quad \text{(H-7)}$$

and

$$h_f = c \cdot V^{1.85} L/(C^{1.85} D^{1.165}) \quad \text{(H-8)}$$

with b = 1.318 for English or 0.849 for metric units, c = 3.02 for English or 6.79 for metric units, R is the hydraulic radius, and L is the length of the pipe. *Note*: Allen Hazen and Gardner Williams developed the formula in 1905. Other related contributions of Hazen include (a) research on water filtration at the Lawrence Experiment Station in Massachusetts, (b) extensive work on the theory of sedimentation, and (c) development of the principles of probability to determine the safe yield of impounding reservoirs. Williams was a professor at the University of Michigan.

Hazen–Williams headloss. *See* Hazen–Williams formula.

Hazen–Williams roughness coefficient (C). A coefficient that expresses the influence of the material and age of a pipe on the flow velocity in the pipe. Used in the Hazen–Williams formula**,** it varies from 100 to 150.

Head. (1) The vertical distance (in feet) equal to the pressure (in psi) at a specific point. The pressure head is equal to the pressure in psi times 2.31 ft/psi (EPA Glossaries). (2) The kinetic or potential energy of each unit weight of a liquid expressed as the vertical height through which a unit weight would have to fall to release the average energy possessed. (3) The source or upper end of a system, as in headwall, headwater, and headworks. *See also* acceleration head; discharge head; dynamic discharge head; dynamic head; dynamic suction lift; elevation energy; headloss; kinetic head; potential head; pressure head; static head; suction head; suction lift; total dynamic discharge head; total head; velocity head; weir, weir head.

Head balancing method. *See* Hardy Cross method.

Head–discharge curve. A plot of the head–discharge relationship of a pump.

Head–discharge relationship. The relationship showing the discharge capacity of a pump as a function of the head it has to overcome. For a given pump, the higher the head, the lower the capacity, and vice versa. *See* pump characteristic curves.

Header. A manifold or other pipe, conduit, or chamber fitted with several smaller outlet pipes to distribute fluid.

Head gate. A gate at the entrance, starting point, or upstream end of a pipeline, penstock, canal, lock, or irrigation ditch.

Headloss The head, pressure, or energy lost in a pipe or channel as a result of turbulence caused by the velocity of the flowing fluid and the roughness of the pipe and channel walls or restrictions caused by fittings. Water flowing in a pipe loses head, pressure, or energy as a result of friction losses (EPA Glossaries). Headloss does not include changes in the elevation of the hydraulic gradeline unless the hydraulic and energy lines are parallel to each other. Formulas for the calculation of headlosses include those developed by Darcy–Weisbach, Hazen–Williams, and Manning. Also called **energy loss**.

Headloss coefficients The coefficients in the various flow and velocity formulas that indicate the energy lost as a result of friction and velocity or direction changes; for example, Chézy's C_z, critical velocity's f, Darcy–Weisbach's f, equivalent roughness n_e, Hazen–Williams C, Manning's n, minor or local headloss k, or orifice c.

Headmeter A flowmeter that operates on pressure changes.

Head tolerance (φ) The difference between the depth at a junction from the current iteration and the depth from the previous iteration; used as a convergence criterion in numerical modeling. *See also* numerical parameters.

Headwall A retaining wall (of stone, metal, concrete, or wood) at the end or at the outlet of such structures as chutes, culverts, drains, or pipes. A retaining wall serves various purposes: protection from scouring or undermining, hydraulic efficiency, flow diversion.

Headwater (1) The source of a river, including any emerging groundwater; the waters from which it rises, or its upper reaches. (2) The water upstream of hydraulic works.

Headwater stream A stream that forms the source of another, larger stream.

Headworks The initial structures and devices at the head or diversion point of a conduit, canal, water, or wastewater treatment plant.

Heavy rain Rain falling with an intensity greater than 0.3 in./h.

HEC Abbreviation for Hydrologic Engineering Center of the U.S. Army Corps of Engineers, the developer of the following computer programs. **HEC-1** is a flood hydrograph program that simulates the precipitation–runoff process for a basin and determines discharge hydrographs for single-storm events at desired locations of the basin. Additional program options include the simulation of snowfall and snowmelt, dam safety analysis, pumping and diversion simulation, estimation of unit hydrograph and loss-rate parameters for individual basins, and multiple-flood and multiple-plan analyses, and the simulation of the precipitation depth–area relationship. HEC-1's river basin modeling options include the establishment of discharge hydrographs at subbasin outlets, channel and reservoir routing, and the combination of hydrographs from other program components. **HEC-2** establishes water surface profiles for one-dimensional, steady, gradually varied streamflows using the standard-step method. **HEC-4** produces a sequence of synthetic flows based on recorded streamflows at 10 stations. **HEC-5** is a reservoir simulation model (Simulation of Flood Control and Conservation System) that simulates the operation of a network of reservoirs and channels. For **HEC-DSS**, *see* Data Storage System.

For **HEC-FFA**, *see* Flood Frequency Analysis. For **HEC-IFH**, *see* Interior Flood Hydrology. For **HEC-RAS**, *see* River Analysis System. It is an upgrade of HEC-2, including a graphical user interface and data storage and management.

Hectare (ha) A unit of area in the metric system equal to 100 acres or 10,000 m^2. Also, 1 ha equals 2.471 acres or 107,639 ft^2.

Heelpost A post that secures the hinges of a gate or door. Same as **hinge post** or **quoin post**.

Hele–Shaw model A two-dimensional groundwater model based on the analogy with the movement of a viscous fluid such as glycerin between two parallel plates. Also called **viscous fluid model** or **parallel-plate model**, it is used for the investigation of unsteady flows with irregular boundaries and nonuniform permeability.

Hertz (Hz) The number of complete electromagnetic cycles or waves in 1 sec of an electrical or electronic circuit. Also called the **frequency** of the current.

Hinge post Same as **heelpost**.

Histogram A graph (Figure F-7) of a frequency distribution as a series of rectangles with bases on the horizontal axis representing class intervals and heights representing frequencies.

Holding pond A pond or reservoir, usually made of earth, built to store polluted runoff or other liquids. *See also* detention basin.

Hollow-stem auger *See* auger.

Holton loss function An equation that uses soil moisture to determine infiltration rates f (in./h) as a function of a growth index of plant maturity g (dimensionless, between 0 and 1), the infiltration rate of available moisture storage a (in./h), the volume v (in) of unused moisture storage in the controlling zone of soil profile, and a limiting infiltration rate f_L (in./h).

$$f = g \cdot a \cdot v^{1.4} + f_L \qquad \text{(H-9)}$$

See also Green–Ampt infiltration equation; Horton infiltration equation; curve number.

Horizon *See* soil horizon.

Horizontal-plane model A two-dimensional model integrated over the depth of flow; i.e., it includes length and width as variables.

Horizontal pump A reciprocating pump with a piston or plunger that moves horizontally or a centrifugal pump with a horizontal shaft.

Horsepower (HP) A unit of power equivalent to 550 foot-pounds per second or 745.7 W. For example, it is used to express the theoretical power requirement, or **water horsepower**, of an electric motor to drive a pump and is calculated as:

$$HP = \gamma QH/550 \qquad \text{(H-10)}$$

where γ = specific weight of the fluid (pounds per cubic foot), Q = fluid discharge (cubic feet per second), and H = total dynamic head (feet). To obtain the actual power needed, or **brake horsepower** hp, one must consider the efficiency e of the pump, which also depends on the discharge and the head:

$$hp = HP/e \tag{H-11}$$

Horton equation, Horton infiltration equation An equation that expresses the infiltration capacity into the soil or infiltration rate f (ft/sec) in terms of a minimum or ultimate infiltration rate f_L (ft/sec), an initial or maximum infiltration rate f_0 (ft/sec), a decay coefficient k (sec^{-1}), and the time t (sec) from the beginning of the storm:

$$f = f_L(f_0 - f_L)\exp(-kt) \tag{H-12}$$

At the end of a rainstorm, the soil recovers its infiltration capacity as follows:

$$f = f_0(f_0 - f_L)\exp[-k'(t - t')] \tag{H-13}$$

where k′ (sec^{-1}) is the recovery decay coefficient, and t′ (sec) is the projected recovery time (i.e., when $f = f_L$). *See also* Green–Ampt equation; Holton loss function; curve number.

Horton infiltration capacity recovery *See* Horton infiltration equation.

Horton overland flow concept A common theory of runoff generation: when rainfall intensity exceeds the soil infiltration capacity, the entire drainage area can contribute overland flow to direct streamflow. *See also* saturation overland flow concept; subsurface stormflow.

Hot spring A spring with a temperature higher than the average human body temperature of 98.6°F or 37°C.

House connection The pipe carrying wastewater from a house drain to a common or public sewer or to a point of immediate disposal. Also called **building sewer** or **house sewer**.

House drain The horizontal pipe in a basement receiving wastewater from soil stacks.

HP Water horsepower, as opposed to brake horsepower (hp).

hp Abbreviation for horsepower, a standard unit of power, equal to 550 foot-pounds per second or approximately 745.7 W. Also used to designate brake horsepower, as opposed to water horsepower (HP).

HSI Abbreviation for Haestad severity index.

HSP-F Abbreviation for Hydrological Simulation program — FORTRAN.

Huygens, Christiaan *See* hydraulics.

HYDRA Acronym for Hydrologic Data Retrieval and Alarm System, a computer modeling program.

Hydraulic calibration Adjustment to properties of nodes and links and to other pump-related hydraulic properties in a modeling application, as opposed to hydrologic calibration, which is the adjustment of model input hydrographs in accordance with climactic conditions best representing a typical dry day of a dry period. *See* calibration.

Hydraulic cleaning A method used to clean sewer lines with such devices as high-velocity jet cleaners that pump water to remove sediment and other debris. *See also* mechanical cleaning.

Hydraulic coefficient (h_c) A coefficient that reflects the influence of the slope S_0 and roughness factor n of a channel, conduit, or sewer on its discharge by the Manning equation. The coefficient is:

$$h_c = S_0^{0.5}/n \quad \text{(H-14)}$$

Hydraulic conductivity A coefficient of proportionality that describes the rate at which water can move through a permeable medium. Hydraulic conductivity is a function of both the intrinsic permeability of the porous medium and the kinematic viscosity of the water that flows through it. Also referred to as the **coefficient of permeability** (EPA Glossaries). It is used in the Darcy formula for groundwater flow and has the same unit as velocity. It is expressed as the product of the density ρ of the fluid by the gravitational acceleration g divided by the dynamic viscosity μ:

$$K = \rho \cdot g/\mu \quad \text{(H-15)}$$

Hydraulic data *See* hydraulic parameters.

Hydraulic depth Same as **hydraulic mean depth**.

Hydraulic diffusivity (μ) A parameter in the convective diffusion equation of the Muskingum–Cunge method of flood routing. It is equal (in ft^2/sec) to the ratio of the discharge Q (ft^3/sec) to twice the product of the top width of water surface W (ft) by the bed slope S_0 (dimensionless):

$$\mu = Q/2 \cdot W \cdot S_0 \quad \text{(H-16)}$$

Hydraulic discharge The discharge of groundwater through springs and seepage outcrops, as opposed to evaporative discharge.

Hydraulic drop A drop in the hydraulic gradeline or in the water surface elevation as a result of a structure (e.g., a weir) or a transition (e.g., when the bottom slope changes from mild to steep). *See also* Figures F-3, O-2; hydraulic jump.

Hydraulic efficiency The property of a cross section that maximizes the flow Q, given a flow area A, a channel slope S_0, and a roughness coefficient n. From the Manning or Chézy equations, an efficient cross section has the maximum hydraulic radius R. *See* hydraulic radius for some efficient sections. *See also* best hydraulic cross section; efficient section.

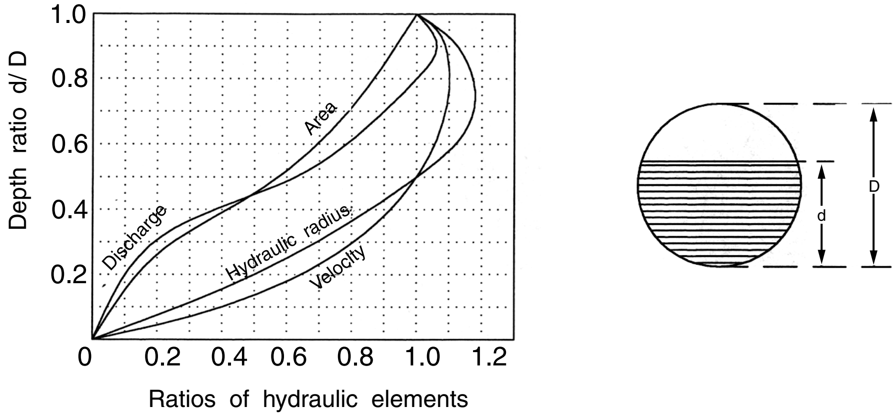


FIGURE H-1 Hydraulic elements graph.

Hydraulic elements The variables, parameters, or quantities included in such flow formulas as Manning's or Darcy–Weisbach's: depth, velocity, discharge, hydraulic radius, flow area, friction factor, mean hydraulic depth, wetted perimeter, etc. For circular conduits flowing partially filled, a **hydraulic elements graph** (also called **partial flow diagram**) shows how the ratios of the partial elements to full elements vary with the depth ratio. *See* Figure H-1. Note that a pipe flowing partially filled may carry a discharge larger than the full discharge; for example, at a depth ratio of 90%, the discharge ratio is approximately 106%.

Hydraulic energy The energy stored in fluids in one of three forms: kinetic, potential, or pressure energy. *See* Bernoulli's law; energy.

Hydraulic engineering A branch of civil engineering that deals with the planning, design, and construction of hydraulic structures, waterworks, hydroelectric power plants, and the like.

Hydraulic-fill dam An earth-fill dam constructed using water to transport and place the materials.

Hydraulic flow routing *See* flow routing.

Hydraulic grade In any water body, the hydraulic grade of a section is the piezometric level of the water at that section, i.e., the elevation to which water would rise in a freely vented pipe under atmospheric pressure at that section. In open-channel flow, the hydraulic grade is at the free water surface. The hydraulic grade H_g is such that

$$P = \rho \cdot g \cdot (H_g - z) \quad \text{(H-17)}$$

where P is the pressure, ρ is the density of the fluid, g is the acceleration of gravity, and z is the elevation above or below a datum. *See also* hydraulic gradient; hydraulic gradeline.

Hydraulic gradeline (HGL) In any water body, the hydraulic gradeline is a profile of the piezometric level of water at all points along a line. In a closed conduit flowing full, it is a line joining the elevations to which water would stand in risers or vertical pipes connected to the conduit at their lower end and open at their upper end. In open-channel flow, the hydraulic gradeline is the free water surface. In general, the hydraulic gradeline is one velocity head ($V^2/2g$) below the energy gradeline, and the elevation H_g of the hydraulic gradeline is from Equation H-17:

$$H_g = z + P/rg$$

where P is the pressure, ρ is the density of the fluid, g is the acceleration of gravity, and z is the elevation above or below a datum. The hydraulic gradeline is one of the outputs of hydraulic models. It is also used in the engineering design of water and wastewater facilities; *see* hydraulic profile. *See also* energy gradeline; Figure E-2; hydraulic grade; hydraulic gradient. Sometimes called **hydraulic gradient**.

Hydraulic gradeline profile The proper term is either **hydraulic gradeline** or **hydraulic profile**.

Hydraulic gradient (1) In general, the direction of groundwater flow due to changes in the depth of the water table. (2) The change in total potentiometric (or piezometric) head between two points divided by the horizontal distance separating the two points. (3) The slope of the hydraulic gradeline; also called **hydraulic slope**. This is the slope of the water surface in an open channel, the slope of the groundwater table, or the slope of the water pressure for pipes under pressure. (4) The hydraulic gradeline itself. *See* Figure E-2. In the groundwater field, hydraulic gradient (a) is a factor in Darcy's formula for groundwater flow; (b) is a driving force in advection and in contaminant travel; and (c) follows more or less the ground topography in the absence of significant sinks and sources. *See also* Darcy's law; energy gradient; hydraulic gradeline.

Hydraulic head (or simply head) The height of the free surface of a body of water above a given point beneath the surface.

Hydraulic jump The sudden and turbulent rise in water surface elevation (and increase in depth of flow) that occurs in open channels when a high flow velocity is retarded; the velocity changes from supercritical to subcritical with a corresponding loss of specific energy ΔE. Hydraulic jumps are sometimes used for energy dissipation and increased mixing and reaeration. Hydraulic jumps occur as surge waves when channel slope changes abruptly, or downstream of such structures as drop structures, spillways, sluice gates, and venturi flumes. *See* Figure H-2. *See also* critical flow.

Hydraulic jump equation An equation resulting from the application of the momentum principle to a hydraulic jump. It relates the two conjugate depths to the Froude number. For a rectangular channel, the two conjugate depths y_1 (supercritical) and y_2 (subcritical) are related as follows:

$$y_2 = 0.5y_1 \sqrt{\left(1 + 8F_1^2\right)} - 1 \qquad \text{(H-18)}$$

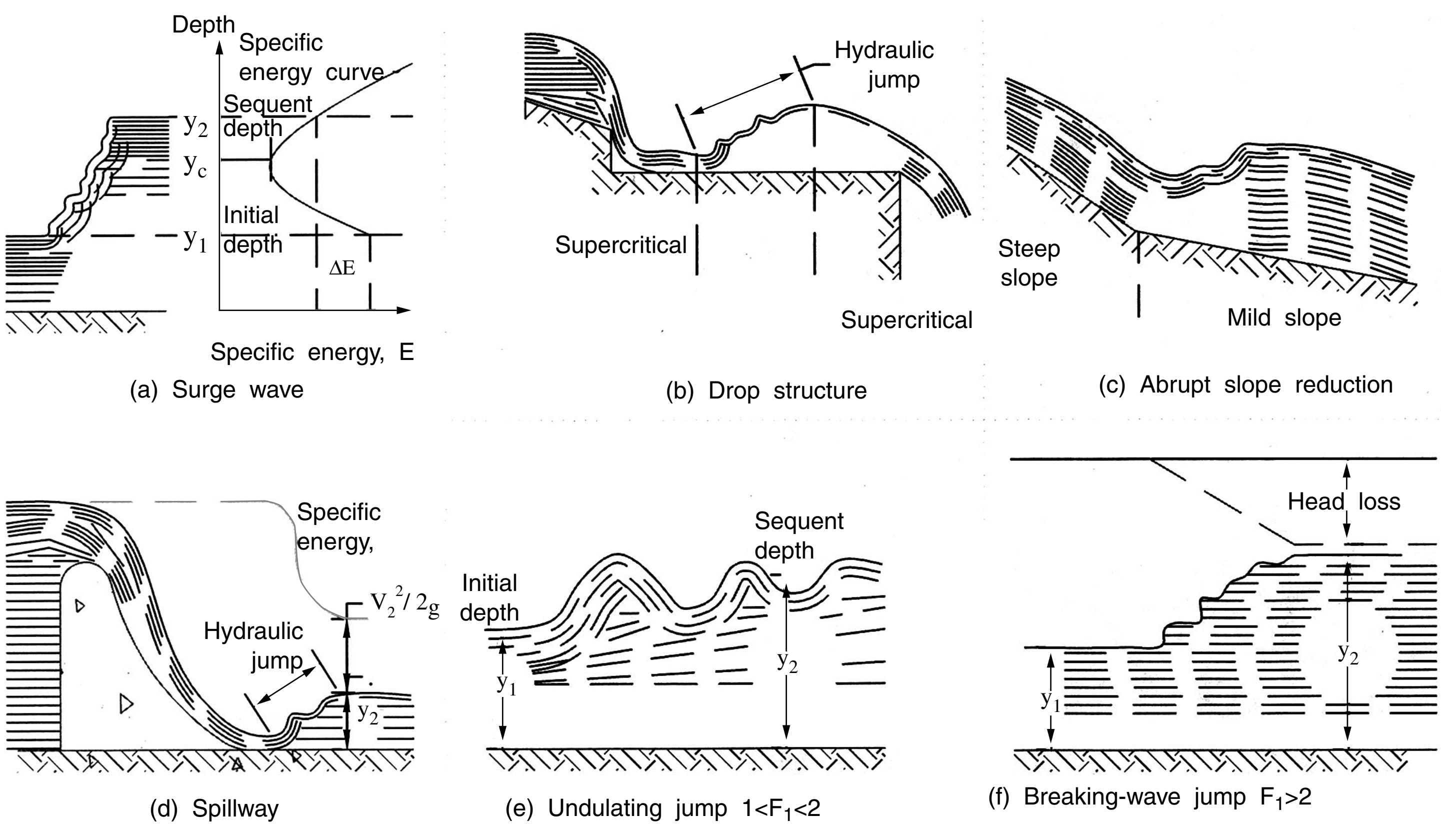


FIGURE H-2 Hydraulic jump examples.

Hydraulic jump equation

where F_1 is the Froude number at the beginning of the jump. It is an undulating jump if $1 < F_1 < 2$ and a breaking-wave jump when $F_1 > 2$.

Hydraulic loading The flow (volume per unit time) or the flow per unit surface area applied to a water, wastewater, or stormwater treatment or storage facility.

Hydraulic losses The friction and minor headlosses.

Hydraulic mean depth (D_m) The ratio

$$D_m = A/W \tag{H-19}$$

of flow area A to surface width W. It is different from the hydraulic radius, although sometimes the two terms are used interchangeably. Also called **hydraulic depth** or **average depth.** *See also* hydraulic radius; open-channel flow characteristics.

Hydraulic method A method that uses both the continuity and momentum principles to estimate flow variations in a channel, as opposed to hydrologic methods, which use only the continuity equation. *See also* flow model; flow routing; kinematic wave approximation; Muskingum–Cunge method; Saint-Venant equations.

Hydraulic model A physical or mathematical representation of fluid flow. Physical hydraulic models are full- or reduced-scale prototypes used to conduct experiments. For mathematical models, *see* flow model. Physical models must have the properties of (a) **dynamic similarity** (similarity between the inertia forces of the model and prototype); (b) **geometric similarity** (all lengths of the model are in the same ratio to the corresponding lengths of the prototype); (c) **kinematic similarity** (the ratio of the velocities in the model and prototype is constant throughout the system).

Hydraulic modeling A method based on models for the solution of hydraulic research and design problems. Most current hydraulic modeling applications use computerized simulations. Hydraulic modeling is the culmination of several decades of development of the fundamental concepts of hydraulics and the more recent advances in computer hardware and software. *See also* computational hydraulics. *See* Table M-1 for a list of some software developers and computer modeling programs commercially available. Agencies such as the U.S. Army Corps of Engineers and the U.S. Environmental Protection Agency have supported the development of such powerful programs as the HEC series and the Stormwater Management Model (SWMM). *See* Section II for further information.

Hydraulic parameters, data, properties; hydrologic data, parameters, properties All these terms relate to the input data to insert in a hydraulic or hydrologic model. In general, **hydraulic parameters** or **properties** are network specific, while **hydrologic parameters** or **properties** apply to the geography, meteorology, etc. of the area. **Hydraulic parameters** affect or characterize the flow of fluids. They include the various empirical and other coefficients used in the flow and velocity formulas, such as the Manning roughness factor n, the weir and orifice coefficients, and the minor losses or k-factor. **Hydrologic parameters** affect or characterize the rainfall–runoff relationship, including the drainage or watershed area, rainfall depth, rainfall distribution, unit hydrograph, peak rate factor, runoff curve number (CN), directly connected impervious areas (DCIAs), and time of concentration.

Hydraulic population equivalent *See* population equivalent.

Hydraulic profile A graphical summary presentation of the hydraulic calculations performed for the various trains in a water or wastewater treatment facility (liquid treatment, residuals processing, effluent disposal). The profile starts at the downstream control point (e.g., the receiving water) and goes back to the head end of the facility. It includes, for average and peak flowrates, water surface elevations, hydraulic control devices such as valves and weirs, and sometimes the ground surface and structure elevations. The hydraulic profile serves various purposes: to ensure adequate hydraulic gradient, to determine required pump heads, and to prevent flooding of the facilities or backup under peak flow conditions. *See* Figures E-2, S-2; hydraulic gradeline; sewer profile.

Hydraulic properties *See* hydraulic parameters.

Hydraulic pump Same as **hydraulic ram**.

Hydraulic radius (R) A widely used hydraulic property defined as the ratio of the cross-sectional area of flow A to the wetted perimeter P:

$$R = A/P \qquad \text{(H-20)}$$

The **wetted perimeter** is the length of the line of intersection of the flow area with the wetted surface of the channel; i.e., it does not include the surface width W in an open channel. *See also* hydraulic mean depth. The hydraulic radii of some common cross sections follow. For a rectangle of width B and depth of flow y:

$$R = yB/(2y + B) \qquad \text{(H-21)}$$

For a trapezoid of base B, water depth y, side angle θ, and x = cot θ:

$$R = y(B\cdot\sin\theta + y\cdot\cos\theta)/(B\cdot\sin\theta + 2y)$$
$$= y(B + xy)/\sqrt{1+x^2} \qquad \text{(H-22)}$$

For a triangle of side angle θ, and x = cot θ:

$$R = 0.5y\cos\theta = xy/2\sqrt{1+x^2} \qquad \text{(H-23)}$$

For a semihexagonal section (side angle θ = 60°):

$$R = y(y + 1.732B)/(1.732B + 4y) \qquad \text{(H-24)}$$

For a semihexagonal section (side angle θ = 60°) with the depth of flow such that the base B is equal to the side:

$$R = y/2 = 0.433B \qquad \text{(H-25)}$$

For a parabola with $0 < 4y/W < 1$, where W is the surface width, a reasonable approximation is:

$$R = 2yW^2/(3W^2 + 8y^2) \qquad \text{(H-26)}$$

For wide channels, e.g., when $B \geq 100y$, a convenient assumption for overland flow analysis is:

$$R \cong y \qquad \text{(H-27)}$$

The hydraulic radius appears in several hydraulic formulas, e.g., the Reynolds number (as the characteristic length), channel conveyance, critical slope, equivalent roughness, kinematic wave approximation, Chézy and Manning equations. For a channel or conduit of given flow area, roughness coefficient, and bottom slope, the best hydraulic cross section is defined as the section that yields the maximum discharge. According to the Manning or Chézy equation, this corresponds to the maximum hydraulic radius and the minimum wetted perimeter. For a rectangular section, this requires that the depth of flow equal half the surface width or B = 2y, and the hydraulic radius is R = B/4 = y/2. For a trapezoid, the section of maximum discharge is half a regular hexagon, with θ = 60°, and R = y/2 = 0.433B. In open-channel flow, the half-circle is the cross section with the highest efficiency; its hydraulic radius is $R = D/4 = (A/4\pi)^{1/2}$, D is its diameter. *See* Figure O-1; hydraulic efficiency; open-channel flow.

Hydraulic ram A device for lifting water using the impulse of larger masses of water in coordination with the pressure waves created by water hammer. The driving water may or may not be from the same source as the water supplied, and the ratio of the two masses is usually between 2:1 and 6:1. Also called **water ram** or **hydraulic pump**. In a simple form, the device uses the energy of a descending mass of water to raise part of the mass to a higher level.

Hydraulic residence time Hydraulic residence time, time of flow, or time of travel, an important parameter in water quality studies, is the time water spends in a water body. In stormwater management models, the time of concentration is an example of hydraulic residence time. If the volume v and the flow Q are known, the hydraulic residence time t is their ratio:

$$t = v/Q \qquad \text{(H-28)}$$

The time of travel in streams may be computed as the ratio of distance x to velocity V or the ratio of length of channel L to wave celerity c:

$$t = x/V \tag{H-29}$$

and

$$t = L/c \tag{H-30}$$

In tracer studies, the **centroid time of travel** t_c is:

$$t_c = \sum C \cdot t / \sum C \tag{H-31}$$

where C is the dye or tracer concentration at time t. $\sum$ indicates the summation at various times and concentrations.

Hydraulic retention time Same as **detention time**, **retention period**, or **retention time**; i.e., the time t = v/Q that water, wastewater, or stormwater is retained in a reactor, storage basin, unit process, or any similar facility of volume v at a given hydraulic loading or discharge rate Q.

Hydraulic routing Analysis of the movement of a flood wave using the differential equations of unsteady flow in open channels. *See* flow routing.

Hydraulics, hydrodynamics, hydrology Three branches of science and engineering that treat the properties and movement of water and other fluids; the distinction among the three is not always clear, particularly regarding water. They are all common to several fields or professions that involve water resources. Hydraulics and hydrodynamics deal with the motion of water and other fluids. **Hydraulics** studies the laws governing the motion of water and other liquids as well as their engineering applications. **Hydrodynamics** (also called **hydromechanics**) is the branch of physical science (specifically fluid dynamics) that studies the motion of fluids (particularly liquids) and the forces acting on them and on immersed bodies. **Hydrology** is concerned only with water, not the other fluids, and is in fact the study of the **hydrologic cycle.** Simply put, hydraulics is the study of fluid flow, while hydrology is mainly the study of runoff resulting from precipitation. Another related branch of physical science is **fluid mechanics**, which deals with the flow of fluids and the way they respond to and exert forces; the subject of hydraulics is often included in college courses on fluid mechanics. Engineers and scientists who made significant contributions to hydraulics, mainly in the past three centuries, include (Chadwick and Morfett, 1998; Morris and Wiggert, 1972; Simon and Korom, 1997) the following:

- Daniel **Bernoulli** (Switzerland, 1700–1782), Jean LeRond **D'Alembert** (France, 1717–1783), and Leonhard **Euler** (Switzerland, 1707–1783) in the development of hydrodynamics from mathematical principles and physical observations.
- Antoine **Chézy** (France, 1718–1798), Johann Albert **Eytelwein** (Germany, 1764–1848), Henri de **Pitot** (France, 1695–1771), Giovanni **Poleni** (Italy, 1683–1761), and Giovanni Battista **Venturi** (Italy,

1746–1822) in the investigation of discharge coefficients and flow measurement.

- Jacques Antoine Charles **Bresse** (France, 1822–1883), Henri Philibert Gaspard **Darcy** (France, 1803–1858), G. H. L. **Hagen** (Germany, 1797–1884), Jean Louis **Poiseuille** (France, 1799–1869), Sir Osborne **Reynolds** (England, 1842–1912), and Julius **Weisbach** (Germany, 1806–1871) in the study of turbulence and frictional resistance in pipe and channel flow through experimentation.
- Louis-Marie Henri **Navier** (France, 1785–1836) and Sir George **Stokes** (England, 1819–1903) in "classical hydrodynamics," which emphasizes mathematical methods.
- Ludwig **Prandtl** (Germany, 1875–1953) and Theodor **von Kármán** (Hungary, 1881–1963) in fluid mechanics as a combination of "classical hydrodynamics" and "experimental hydraulics."

Others, who made specific contributions, are:

- George Biddle **Airy** (England, 1801–1892) — first workable formula of wave mechanics, used in coastal hydraulics.
- Charles Metcalf **Allen** (United States, 1871–1950) — salt velocity method applied in the use of tracers for flow measurement.
- Lorenzo **Allievi** (Italy, 1856–1941) — application of slow valve closures to water hammer analysis.
- **Archimedes** (Greece, circa 285–212 BC), who discovered the Archimedes law, the principle of specific gravity, and the principle of the lever.
- Francis **Bacon** (England, 1561–1626) — first experimental proof of the compressibility of water.
- Boris A. **Bakhmeteff** (Russia, 1880–1951) — tabular solution to the backwater equation; introduction of the notion of specific energy in 1912.
- Henri Emile **Bazin** (France, 1829–1917) — development of coordinates to determine the shape of spillways.
- Jean-Baptiste **Belanger** (France, 1789–1874) — formal solution of the hydraulic jump problem and elementary formulation of gradually varied flow.
- Georgio **Bidone** (Italy, 1781–1839) — study of hydraulic jump.
- Paul Heinrich **Blasius** (Germany, 1883–) — studies on smooth pipes and relationship between friction factor and Reynolds number.
- Jean **Borda** (France, 1733–1799) — efflux through orifices and use of factor 2g in formulas.
- Emmanuel Joseph **Boudin** (Belgium, 1820–1893) — classification of open-channel flow zones according to mild or steep slopes.
- Joseph **Boussinesq** (1842–1929) — hydraulic theory and design.
- Joseph **Bramah** (1748–1814) — development of the hydraulic press.
- Edgar **Buckingham** — *see* Riabouchinsky.

- Hardy **Cross** (United States) — application of the relaxation method to the solution of pipe network problems (1936).
- Leonardo **da Vinci** (Italy, 1452–1519) — first formal statement of the law of conservation of mass or continuity equation.
- Gaspard **de Coriolis** (France, 1792–1843) — studies on velocity distributions and Coriolis force.
- René **Descartes** (France, 1596–1650) — first formulation of the law of momentum conservation.
- Paul François Dominique **du Bois** (France, 1847–1924) — formulation of sediment transport.
- Arsene Jules **Dupuit** (France, 1804–1866) — groundwater well discharge formula and water surface profiles in open-channel flow.
- Alexandre Gustave **Eiffel** (France, 1832–1923) — study of drag coefficients.
- Hubert **Engels** (Germany, 1854–1945) — investigation of erosion and sediment transportation.
- Benoit **Fourneyron** (France, 1802–1867) — development of the first practical hydraulic turbine.
- J. B. **Francis** (United States, 1815–1892) — Francis turbine and Francis weir formula.
- William **Froude** (England, 1810–1897) — reportedly used the Froude number in the study of ship models.
- Emile Oscar **Ganguillet** (Switzerland, 1818–1894) — coauthor of the Kutter formula.
- Dominico **Guglielmini** (Italy, 1655–1710) — early studies of erosion.
- Allen **Hazen** (United States, 1869–1930) — coauthor of the Hazen–Williams formula.
- Clemens **Herschel** (United States, 1842–1930) — development of the venturi meter.
- Christiaan **Huygens** (Holland, 1629–1695) — first determination of the value of the gravitational acceleration, approximately g = 32.2 ft/sec/sec or 9.81 m/sec/sec.
- Nicolai **Joukowsky** (1847–1921) — studies in aerodynamics and water hammer.
- Alexander **Koch** (Germany, 1852–1923) — introduction of the specific energy equation.
- Wilhelm **Kutter** (Switzerland, 1818–1888) — coauthor of the Kutter formula.
- Joseph Louis **Lagrange** (France, 1736–1813) — derivation of the formula of gravity wave celerity.
- Robert **Manning** (Ireland, 1816–1897) — author of the Manning formula.
- Mansfield **Merriman** (1848–1925) — establishment of the first hydraulics laboratory in the United States at Lehigh University.
- Lewis F. **Moody** (United States, 1880–1953) — author of the Moody diagram.

- Sir Isaac **Newton** (England, 1642–1727) — fundamental laws of motion as a basis of hydraulics, particularly the relationships between mass, force, and density.
- Johann **Nikuradse** (Russia, 1894–?) — investigation of the effect of pipe roughness on flow.
- Ralph L. **Parshall** (United States, 1881–1960) — measurement of small open-channel flows.
- Blaise **Pascal** (France, 1623–1662) — essential completion of hydrostatic theory.
- Dimitri P. **Riabouchinsky** (Russia, 1882–1962) — the Π theorem, a method of forming dimensionless groups of variables; introduced in the United States by Edgar Buckingham.
- John Scott **Russell** (Scotland, 1808–1882) — recommendation of the formula of gravity wave celerity; *see also* Lagrange.
- John-Claude Barre de **Saint-Venant** (France, 1797–1886) — Saint-Venant equations and wave celerity.
- John **Smeaton** (England, 1724–1792) — invention of the hydraulic ram and experiments on water wheels.
- Richard V. **Southwell** (England, 1888–?) — introduction of the relaxation method, used to solve pipe network problems by trial and error.
- Simon **Stevin** (Holland, 1548–1620) — principle used to determine the equation of the hydrostatic force.
- Evangelista **Torricelli** (Italy, 1608–1647) — approximate orifice formula.
- **U.S. Army Corps of Engineers** (mainly through such centers as Hydrologic Engineering Center and the Waterways Experiment Station) — several contributions, for example, the Muskingum method of flood routing and the exponential formula of spillway design.
- Moritz **Weber (**Germany, 1871–1951) — development of the Weber number as capillary parameter.
- Gardner **Williams** (United States) — coauthor of the Hazen–Williams formula.
- Nicolai E. **Zhukovsky** (Russia, 1847–1921) — theory of water hammer.

Hydraulic slope The slope of the hydraulic gradeline. Also called **hydraulic gradient**.

Hydraulic structure Any of a number of engineering works to control the flow, quality, or distribution of water, wastewater, or stormwater or to maintain water levels in streams and channels. Hydraulic structures may range under the following classifications: collection, conveyance, diversion, energy dissipation, flow control, flow measurement, hydraulic machinery, quality control, river training, sediment control, shore protection, storage, waterway stabilization. Examples of hydraulic structures include breakwater, bridge, canal, conduit, culvert, dam, dike, drain, embankment, flume, gate, groin, headworks, hydraulic ram, infiltration gallery, inlet, intake, jetty, levee, lock, open channel, orifice, outfall, outlet, pier, pipe, pump station, reservoir, revetment, seawall, sewer, sluiceway, spillway, stilling basin, surge tank, tank, treatment plant, turbine, valve, well.

Hydraulic transient A hydraulic phenomenon lasting only a short duration, e.g., water hammer or surge. It is caused when valves are opened or closed suddenly or when pumps start or stop.

Hydraulic turbine A machine that uses the energy of an elevated water tank for the generation of mechanical energy.

Hydraulic valve A valve operated by a hydraulic device.

Hydrodynamic equations The three basic equations that describe flow problems in hydraulics: the continuity, energy, and momentum equations. *See* Saint-Venant equations for a combination of the continuity and momentum principles.

Hydrodynamic model *See* flow model.

Hydrodynamics *See* hydraulics.

Hydrogeologic cycle *See* hydrologic cycle.

Hydrogeology The geology of groundwater, with particular emphasis on the chemistry and movement of water. Hydrogeology actually concerns all aspects of subsurface water, although engineering applications deal mostly with groundwater movement and distribution. *See also* groundwater hydraulics; groundwater hydrology.

Hydrograph Basically, a plot of a hydraulic property (usually the discharge) versus time. While the ordinate of the graph represents discharge or flow, the area under the curve represents volume (of runoff, streamflow, etc.). Examples of a hydrograph are (a) a graphical representation of a stream discharge (streamflow) at a single location; (b) a graph showing, for a given point on a stream or conduit, the discharge, stage, velocity, or other hydraulic property as a function of time; (c) a time sequence of runoff discharge versus duration time of a storm; (d) a unit hydrograph for stormwater runoff analysis; (e) a graph of average or peak wastewater flows, during dry or wet weather, over the 24 h of the day (called **diurnal hydrograph**); (f) flood and stage hydrographs showing the variation of a flood discharge Q and elevation h with time, according to a stage–discharge relationship or rating curve, with a common form of rating curve:

$$Q = a \cdot h^{b} \qquad \text{(H-32)}$$

where a and b are constants for a given stream location; (g) an inflow hydrograph. *See* clean hydrograph; Figures D-6, H-3, I-1, R-1, U-2, U-3; net hydrograph; stage–discharge relationship; unit hydrograph.

Hydrograph analysis An approach to differentiate between various flow components of a hydrograph. (1) In wastewater modeling, **hydrograph decomposition** is a method of estimating the different components of wastewater flow and analyzing flow monitoring data to derive dry-weather flow, groundwater infiltration, and rainfall-dependent infiltration/inflow. (2) In stormwater studies, **hydrograph separation** is the production of a

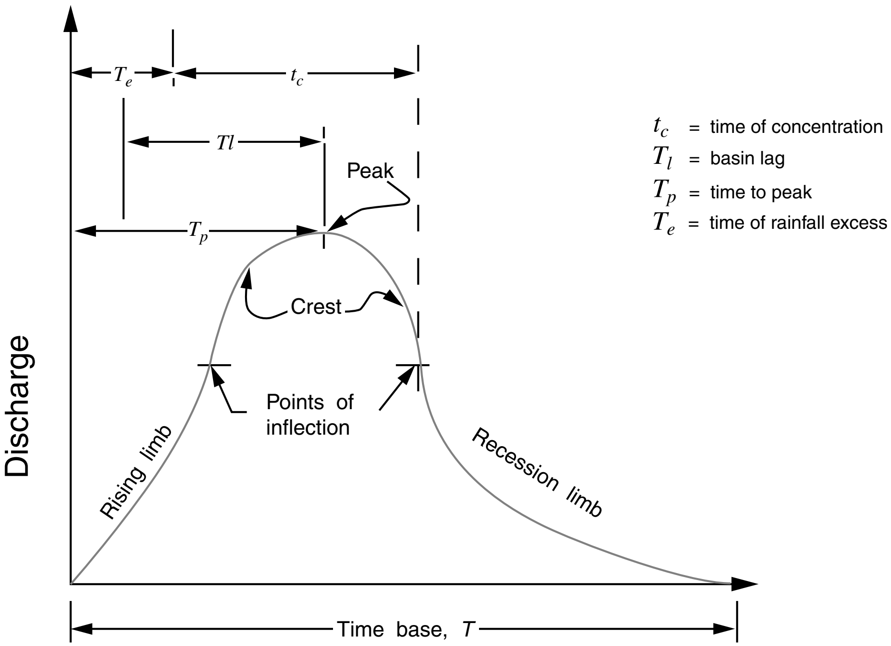


FIGURE H-3 Hydrograph times.

direct runoff hydrograph by removing baseflow from the total runoff hydrograph. *See* baseflow; unit hydrograph separation. *See* Section II for further information.

Hydrograph crest The top part of a storm hydrograph, between the two inflection points on the rising and recession limbs. *See* Figure H-3.

Hydrograph peak The highest point on a hydrograph or the maximum discharge caused by a storm; it usually occurs during the time of concentration, when all the areas of the drainage basin are contributing runoff to the station or point under consideration. *See* Figure H-3.

Hydrograph ratio *See* RDII parameters.

Hydrograph rise time Same as **hydrograph time to peak**.

Hydrograph separation *See* hydrograph analysis.

Hydrograph synthesis The development of hydrographs that are not based entirely on field data for a given station or point, but on some characteristics of the station and some field data from a neighboring or similar station. For example, synthetic hydrographs, sometimes called **regional unit hydrographs**, can be derived from meteorological, topographic, and geometric characteristics of a watershed and applied to ungaged stations of that watershed or of other watersheds with similar characteristics. Wastewater flow hydrographs can also be developed for unmonitored pump stations from measured hydrographs of adjacent stations with similar land use characteristics. The Corps of Engineers and the Soil

Conservation Service use different methods for hydrograph synthesis. *See also* synthetic/synthesized hydrograph.

Hydrograph time base The duration of the runoff period, as measured on the time axis of the hydrograph. *See also* hydrograph times; unit hydrograph. *See* Figure H-3.

Hydrograph times Various time-related parameters used in hydrologic studies, some of which are shown on Figure H-3: basin lag or lag time (T_l), hydrograph rise time or hydrograph time to peak (T_p), hydrograph time base (T), interevent time, time of concentration (t_c), time of equilibrium, time of rainfall excess (T_e).

Hydrograph time to peak (T_p) An empirical parameter of the Soil Conservation Service (SCS) unit hydrograph method that depends on watershed characteristics and is similar to the time of concentration in the rational method. Sometimes called **hydrograph rise time**, it is the time from the beginning of a storm event to the time the unit hydrograph reaches its peak. It is usually estimated as:

$$T_p = T_e + T_l \quad \text{(H-33)}$$

where T_e is the time of rainfall excess, and T_l is the drainage lag, which is approximately 60% of the time of concentration. *See* Figure H-3.

Hydrography The study, description, measurement, and mapping of seas and oceans (oceanography), reservoirs and lakes (limnology), rivers, and their adjacent land areas, including the determination of water flows, precipitation, evaporation, and other phenomena, as well as navigational and commercial uses. It is a branch of hydrology; also known as **surface water hydrology**. *See also* groundwater hydrology; hydrometeorology.

Hydrological cycle Same as **hydrologic cycle**.

Hydrological Simulation Program — FORTRAN (HSP-F) A computer program developed by Hydrocomp, Inc., in 1980 for the U.S. Environmental Protection Agency to simulate, continuously or discretely, hydrologic and associated water quality processes in soils, streams, and lakes, particularly pollutant transport and shallow groundwater flows.

Hydrologic calibration Adjustment of model input hydrographs in accordance with factors such as climatic conditions best representing a typical dry day of a dry period. This procedure is more like hydrologic input adjustment than model calibration. *See also* calibration.

Hydrologic cycle Movement or exchange of water between the atmosphere and the earth. Also called **water cycle**. The **hydrogeologic cycle** is similarly defined: the natural process recycling water from the atmosphere down to (and through) the earth and back to the atmosphere again (EPA-94/04). The hydrologic cycle comprises the unending processes controlling the distribution and movement of water on the earth's surface, in the soil, and in the atmosphere: evaporation from the oceans and the earth, transport over the land masses, condensation of the water vapor, fog or cloud

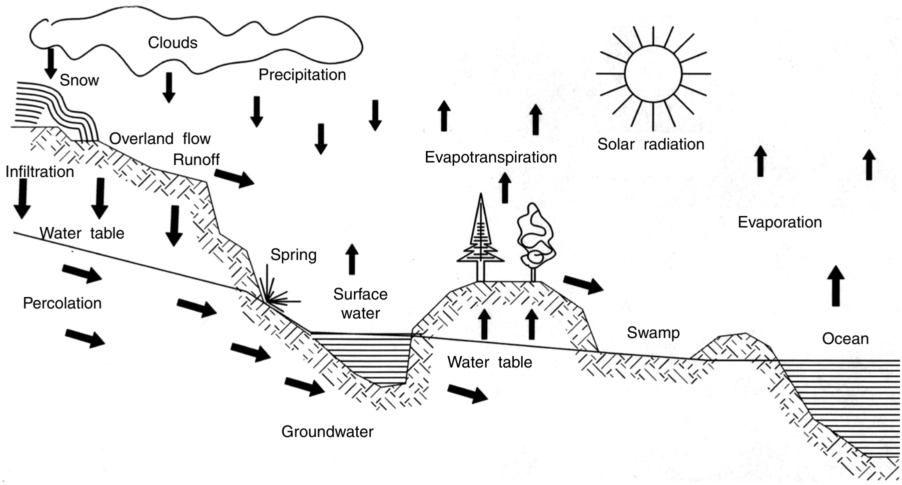


FIGURE H-4 Hydrologic cycle.

formation, precipitation, evapotranspiration, depression storage, infiltration, percolation, runoff ultimately to the oceans, etc. Evaporation and transpiration account for two thirds of the precipitation over land, and runoff to oceans accounts for the remaining third. *See also* Figure H-4; rainfall–runoff relationships.

Hydrologic data *See* hydraulic parameters.

Hydrologic Data Retrieval and Alarm System (HYDRA) A computer modeling program.

Hydrologic Engineering Center (HEC) A center of the U.S. Army Corps of Engineers that develops many guidelines, programs, models, etc. related to floodplain hydraulics and hydrology and other subjects. *See* HEC-1, HEC-2, HEC-DSS, HEC-RAS; Storage Treatment Overflow Runoff Model.

Hydrologic equation An equation that expresses equilibrium between the various flow components, e.g., (a) recharge, discharge, and storage — *see* Equation (G-8); or (b) inflow, outflow, and storage (*see* any form of the continuity equation).

Hydrologic flow routing *See* flow routing.

Hydrologic method A method that uses only the continuity principle to investigate flow variations, as compared to a hydraulic method, which uses both the continuity and the momentum equations. *See also* flow model; flow routing.

Hydrologic parameters, hydrologic properties *See* hydraulic parameters.

Hydrologic routing Analysis of the movement of a flood wave using the continuity equation and a storage–discharge relationship. *See* flow routing.

Hydrologic system A group of interrelated surface and groundwater bodies or other components within the same basin.

Hydrology The science that treats the waters of the earth; their occurrence, circulation, and distribution; their chemical and physical properties; and their reaction with their environment, including their relation to living things. *See also* groundwater hydrology; hydraulics; hydrography; hydrologic cycle; hydrometeorology.

Hydrometeorology The study of atmospheric water. *See also* groundwater hydrology and hydrography.

Hydrometer An instrument that indicates by direct reading such characteristics as density and specific gravity of a liquid. It is a graduated tube weighted to float upright in the liquid.

Hydrometry Measurement of the density or specific gravity of a liquid, especially using a hydrometer.

Hydropneumatic A small water system in which a pump is automatically controlled by the air pressure in a compressed air tank. Same as **hydropneumatic tank**.

Hydropneumatic tank A compressed-air tank that stores liquids under pressure, thus using pressure head instead of elevation head; usually installed in small water or wastewater systems because of its high capital cost. Also called **hydropneumatic**.

Hydrostatic approximation The simplified momentum equation in two-dimensional and three-dimensional models; when the vertical momentum is negligible, e.g., in one-dimensional, vertical models of lakes and reservoirs:

$$\partial P/\partial z = -\rho g \tag{H-34}$$

where ρ is the water density, P is the mean pressure, g is the gravitational acceleration, and z is the vertical coordinate.

Hydrostatic equation The equation expressing hydrostatic pressure P as the product of the fluid density ρ by its depth y and the acceleration of gravity g:

$$P = \rho g y \tag{H-35}$$

Also called **hydrostatic law** or **basic hydrostatic equation**.

Hydrostatic level The level to which water from an artesian aquifer or from a conduit under pressure would rise in an open tube. *See also* Figure E-2; hydraulic gradeline.

Hydrostatic pressure The pressure exerted by a body of water due to depth alone or by the weight of groundwater at higher levels in the same saturation zone.

Hydrostatic uplift Same as **buoyant force**.

Hyetograph (From the Greek *hyetos*, meaning rain.) A graphical representation of rainfall intensity, rainfall excess, or rainfall volume over an area versus time. *See* Figure H-5.

Hygroscopic water Water in soil that cannot evaporate or drain by gravity because of its equilibrium with atmospheric water vapor.

Hypercritical flow Same as **supercritical flow**.

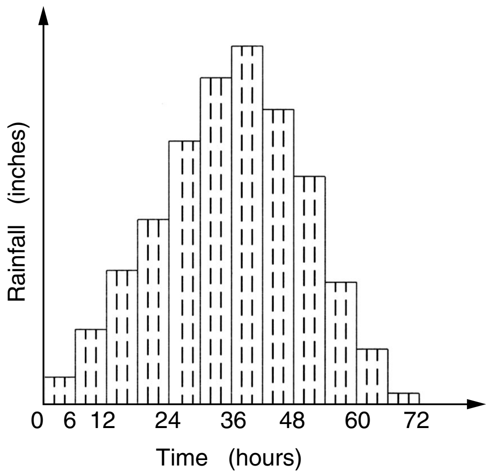


FIGURE H-5 Hyetograph.

Hypolimnion Bottom waters of a thermally stratified lake. The hypolimnion of a eutrophic lake is usually low or lacking in oxygen.

I

Icemelt Water derived from the melting of ice. *See also* melt water.

Icon An image, a representation, or a picture on the computer screen indicating a specific command to the computer.

Iconic model A model that is an image of the prototype, e.g., a blueprint, a sewer atlas, or a maquette. Other types of model include analog, physical or scale, and symbolic models.

ID Abbreviation for inside diameter.

Ideal fluid A fictitious fluid that would be inviscid (i.e., without viscosity) and incompressible and would have uniform density and no surface tension. The assumption of ideal flow is convenient and produces results that are fairly accurate for actual fluids. Also called **perfect fluid**.

IDF Abbreviation for intensity–duration–frequency.

i.e. Abbreviation for Latin expression *id est*, meaning that is.

IET Abbreviations for interevent time.

IFORM A rainfall file format defined by the RAIN module of the Stormwater Management Model (SWMM).

I/I Abbreviation for infiltration/inflow.

I/I analysis An engineering and economic analysis demonstrating possible excessive or nonexcessive infiltration/inflow.

I/I ordinance *See* Section II for further information.

I/I performance standard *See* infiltration/inflow.

ILLUDAS Acronym for Illinois Urban Drainage Simulator, a model developed by the Illinois State Water Survey in 1974 to simulate inlet hydrographs based on rainfall and other data. It incorporates such other models as Manning's equation, Izzard's overland flow formula, Horton's equation, and the Puls method.

Impeller The rotating set of vanes in a blower, axial or centrifugal pump, turbine, or mixing apparatus; designed to impel rotation to a fluid mass. *See also* rotor.

Impermeable or impervious Not easily penetrated. The property of a material or soil that does not allow, or allows only with great difficulty, the movement or passage of water at ordinary hydrostatic pressure; e.g., impervious surfaces include pavement and rooftops. Permeability is an important factor in runoff studies. *See also* permeable.

Impervious core The core of impervious material such as compacted clay or concrete of an earth dam. It is installed to prevent the flow of water between the upstream and downstream faces of the dam.

Imperviousness Percentage of a drainage area that is impervious.

Imperviousness coefficient The decimal or percentage ratio of the impervious area to the total area.

Implicit model A model that uses parameter values or unknown variables (concentrations, discharges, hydraulic heads, etc.) at the end of the timestep in the computational algorithms, i.e., it uses values from the previous as well as the current timesteps. An **implicit numerical solution** can be similarly defined. *See also* explicit model.

Impounding dam A barrier across a stream to create a reservoir. *See also* impoundment.

Impounding reservoir A reservoir with gate-controlled outlets that retains surface water for a relatively long period of time (at least several months) and releases the stored water in times of insufficient flow for domestic or industrial use. Also called a **storage reservoir**.

Impoundment To impound is to gather and enclose a liquid, especially water for irrigation, flood control, water supply, hydropower, or similar purpose. An impoundment is a natural or man-made pond, lake, reservoir, basin, tank, or similar space used for the storage, regulation, and control of water. An artificial impoundment is created by such engineering structures as dams, levees, or dikes. *See also* impounding dam; impounding reservoir; surface impoundment.

Impulse pump A device, like the hydraulic ram, that lifts water using the impulse principle.

Impulse turbine A hydraulic device that converts pressure (potential) energy into velocity (kinetic) energy, which is absorbed by the rotor. Water discharged through a nozzle strikes buckets on the perimeter of a water wheel and causes the wheel to rotate and produce power. The most common impulse turbine uses the Pelton wheel. *See also* reaction turbine.

in Abbreviation for inch (inches), a unit of length; 1 in = 1/12 ft = 2.54 cm.

Inactive storage Capacity provided in a reservoir or other impoundment between the active storage and the outlet for such nonconsumptive, secondary uses as recreation, fisheries management, and water quality enhancement. *See* Figure R-2; reservoir storage.

Inch-diameter * foot, inch-diameter * mile *See* inch–foot, inch–mile.

Inch–foot (feet) The characteristic of a sewer line obtained by multiplying its diameter in inches by its length in feet. Similarly, **inch–mile** is obtained by multiplying its diameter in inches by its length in miles. Used in the definition of infiltration/inflow (I/I) performance standard and gal/day/in.-mi.

Incline A structure that allows the passage from one level to the next in a navigation canal.

Index hydrograph *See* depth–area option.

Indirect flow measurement *See* discharge measurement.

Individual drain system The system used to convey waste from a process unit, product storage tank, or waste management unit to the first common downstream junction box. The term includes all process drains and common junction boxes, together with their associated sewer lines and other junction boxes, down to the receiving oil–water separator (EPA-40CFR60.691 and DPA-40CFR61.341).

Individual system A privately owned alternative wastewater treatment works (including dual waterless/graywater systems) serving one or more principal residences or small commercial establishments. Normally, these are onsite systems with localized treatment and disposal of wastewater but may be systems utilizing small-diameter gravity, pressure, or vacuum sewers conveying treated or partially treated wastewater. These systems can also include small-diameter gravity sewers carrying raw wastewater to cluster systems (EPA-40CFR35.2005-18).

Induction flowmeter. An instrument for measuring the flow of a liquid using a tube in a magnetic field.

Induction pump. A pump operated by electromagnetic induction.

Induction valve. A valve that draws fluid into the cylinder of a positive-displacement pump, engine, or compressor. Same as **inlet valve**.

Inertia. The property that translates into resistance to changes in the momentum of a body.

Inferential flowmeter. An indirect flow determination device. It measures and translates a phenomenon associated with flow, such as the drop in static pressure at a restriction in a conduit, water surface elevation, or the rotation of an impeller or rotor. *See also* discharge measurement.

Inferential liquid-level meter. A device that determines indirectly the level of a liquid by measuring and translating a phenomenon associated with this level, for example, the buoyancy of an immersed body or pressure at the surface.

Infiltration. (1) Water other than wastewater that enters a sewer system (including sewer service connections and foundation drains) from the ground through such means as defective pipes, pipe joints, connections, or manholes. Infiltration does not include, and is distinguished from, inflow (EPA-40CFR35.2005–20 or EPA-40CFR40CFR35.905). (2) The technique of applying large volumes of wastewater to land to penetrate the surface and percolate through the underlying soil (EPA-94/04). (3) The movement of water through the soil surface and into the soil. **Infiltration capacity** is the maximum rate at which water will enter the soil in a given condition. **Infiltration coefficient** is the ratio of infiltration to precipitation. **Infiltration rate** is the actual rate of absorption of water by the soil during a storm; it is equal to the smaller of the infiltration capacity and the rainfall rate. *See also* Green–Ampt equation; Holton loss function; Horton equation, Horton infiltration equation; curve number.

Infiltration basin/pond A retention basin or pond excavated into permeable soil for the temporary storage of stormwater runoff, which drains by infiltration or percolation, but is not discharged directly into receiving water. In addition to storage, infiltration basins provide a certain level of stormwater treatment by retaining settleable solids. Design parameters include basin volume, bottom area subject to infiltration, and hydraulic conductivity of the underlying soil. *See also* stormwater retention. Other stormwater infiltration units are drywells and infiltration trenches.

Infiltration capacity *See* infiltration (3).

Infiltration capacity recovery The restitution of the soil capacity to let runoff infiltrate after a rainfall event. *See also* capacity recovery Equations H-12 and H-13; Horton equation, Horton infiltration equation.

Infiltration coefficient *See* infiltration (3).

Infiltration decay coefficient A coefficient used in Equation H-12 (the Horton infiltration equation) and in the equation for infiltration capacity recovery, Equation H-13.

Infiltration ditch A ditch with its bottom below the water table; collects groundwater for discharge into a canal, well, or sump.

Infiltration gallery A subsurface groundwater collection system, typically shallow, constructed with open-jointed or perforated pipes that discharge collected water into a watertight chamber, from which the water is pumped to treatment facilities and into the distribution system. Usually located close to streams or ponds (EPA-94/04). A horizontal underground conduit into a water-bearing formation — often under a riverbed — to collect percolating water.

Infiltration head The water pressure at the point of infiltration into a sewer.

Infiltration/inflow (I/I) The total quantity of water from both infiltration and inflow without distinguishing the source (EPA-40CFR35.905). Often abbreviated as I/I or I&I. **Excessive I/I** is the quantity of I/I that can be economically eliminated from a sewerage system by rehabilitation, as determined in a cost-effectiveness analysis that compares the costs for correcting the infiltration/inflow conditions to the total costs for transportation and treatment of the I/I (EPA-40CFR35.905). Basically, **infiltration** is groundwater flow during a dry or wet season, while **inflow** is stormwater during a wet season or surface water, but both use capacity in the conveyance and treatment facilities. In general, infiltration is larger on an average basis and affects both treatment and collection facilities, while inflow affects peak flows and transmission lines. I/I may be expressed as total flow in such units as gallons per day or million gallons per day or as rate in gallons per day per inch diameter per mile of sewer (gal/day/in.-mi). For example, some agencies have established an **I/I performance standard** of 5000 gal/day/in.-mi; i.e., it is presumed that it is not cost-effective to remove I/I below this rate.

Infiltration/inflow analysis *See* I/I analysis.

Infiltration/inflow hydrograph A diurnal hydrograph of infiltration/inflow in a sewer system or for a limited area such as a pump station service area. The I/I hydrograph can be added to the dry-weather flow hydrograph to produce the total hydrograph.

Infiltration pond *See* infiltration basin/pond.

Infiltration rate The quantity of water that can enter the soil in a specified time interval. *See also* infiltration (3).

Infiltration sump A deep chamber, with perforated walls, filled with sand or gravel; used for the infiltration of runoff into the ground and thereby reducing inflow to a combined sewer system. A sedimentation chamber usually precedes the sump to remove suspended solids.

Infiltration trench Used to treat stormwater, provide groundwater recharge, and reduce peak flows. Infiltration trenches may be installed under parking lots and roads and close to residential or commercial areas. *See also* drywell; infiltration basin/pond.

Infiltration tunnel An infiltration gallery.

Infiltrometer An instrument to measure the infiltration rate (in/h) as the difference between the amount of water applied and the amount of runoff divided by the period of percolation.

Inflow (1) Water other than wastewater that enters a sewer system (including sewer service connections) from sources such as roof leaders, cellar drains, yard drains, area drains, drains from springs and swampy areas, manhole covers, cross connections between storm sewers and sanitary sewers, catch basins, cooling towers, stormwaters, surface runoff, street washwaters, or drainage. Inflow does not include, and is distinguished from, infiltration (EPA-40CFR35.2005–21). (2) In stormwater modeling, net inflow is the difference between precipitation intensity and the rates of infiltration or evaporation. *See also* infiltration/inflow.

Inflow hydrograph The graphical representation of storm discharge at the beginning of a catchment or a stream reach against time. It is an S-shaped curve with the base discharge Q_o as initial ordinate and a maximum Q_p at the time of concentration t_c. *See* Figure I-1.

Inflow pollutant load *See* pollutant load.

Influence *See* area of influence; circle of influence; cone of depression, cone of influence; zone of influence.

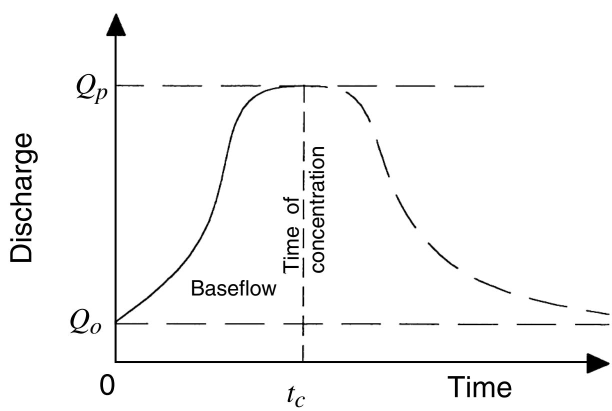


FIGURE I-1 Inflow hydrograph.

Influent Water, wastewater, stormwater, or other liquid flowing into a reservoir, basin, pumping station, or treatment unit.

Influent weir A weir at the inflow end of a sedimentation basin, channel, or other hydraulic structure.

Initial abstraction One of the parameters used in the Soil Conservation Service (SCS) loss method to compute accumulated runoff. Sometimes abbreviated IA or represented by the symbol I_a, it is approximately 20% of the potential maximum retention after the beginning of runoff. It has been observed that not all the water from a storm event contributes to runoff or to a flood because of rainfall losses to land-cover interception, depression storage, infiltration, and evapotranspiration. Initial abstraction may be defined as the volume or depth of potential runoff that is lost to depression storage and to the initial wetting of the soil. Other terms used similarly include (American Public Health Association et al., 1981) **initial abstraction retention**, the total rainfall volume that does not cause significant direct runoff; **initial detention**, water in surface depressions or in transit when runoff begins; **initial loss**, the sum of interception, surface wetting, and infiltration; and **initial rain**, which occurs before depression storage is completely filled. *See also* curve number; SCS runoff equation; surface abstraction.

Initial conditions The numbers representing the conditions of flow at some initial time in a modeling application. They are required at each node for all dependent variables (head, pressure, concentration, velocity, stage, etc.) at the beginning of a simulation exercise based on a numerical model. In iterative procedures, initial conditions are selected to arrive first at a stable solution, and intermediate results become initial conditions for the next step. In steady-state models, they save computational efforts to reach a solution. *See also* boundary condition.

Initial depth *See* sequent depths.

Initial stage Stage in a node at the beginning of a storm event or other simulation, as opposed to a warning stage.

Injection well A well into which fluids are injected for waste disposal, improving the recovery of crude oil, solution mining, etc. (EPA-94/04). The **injection zone** is the geological formation that receives the fluids through the well. *See also* underground injection.

Inlet In general, a connection, entrance, or orifice for the admission of a fluid. In drainage or stormwater collection networks, inlets are connections between the catchment area and drains or sewers for the admission of surface or stormwater. Inlets are also structures at the entrance or diversion ends of a conduit. *See also* catch basin; curb inlet.

Inlet control In the design of a culvert, inlet control means that only entrance conditions and culvert size govern, while outlet control exists when discharge depends on all hydraulic variables (length, slope, pipe diameter, roughness, etc.).

Inlet loss The head required to overcome resistance to entrance of water into a conduit, channel, or hydraulic structure. Also called **entry loss** or **entrance loss**. *See also* exit loss.

Inlet time The time it takes stormwater from any point of the drainage area to reach an inlet. Also called **overland time**. *See* Kerby formula. *See also* time of concentration (which is sometimes computed as the sum of the inlet time of the most distant point of the area and the time of flow in the sewer or drain).

Inlet valve Draws fluid into the cylinder of a positive displacement pump, engine, or compressor. Also called **induction valve**.

Inlet well A well, surface opening, compartment, or chamber in which water or wastewater is collected and to which the suction pipe of a pump is connected. Also called **wetwell**.

Inline equipment Equipment installed within a process line, a network, or the like, e.g., an inline pump, flowmeter, or nozzle mixer. In sanitary engineering, **inline storage** is the storage of stormwater or wastewater within an existing sewer system. Obstructions such as dams or weirs are used to block the flow and create a backup and storage, with a resulting attenuation of peak flows. *See also* offline storage.

Input interface A type of graphical user interface, i.e., a computer program that processes model input data, usually converting graphics to text, e.g., an input interface can convert AutoCAD drawings and other graphics for input to the Stormwater Management Model (SWMM) as ASCII files. Also called **front-end interface** or **preprocessor**. *See also* back-end interface (output interface or postprocessor).

Input–output model A zero-dimensional model based on the principle of mass balance; used, for example, in water quality studies. *See also* mass–balance model.

Input variables Variable quantities that are not affected by other variables. *See* model input.

Inside diameter (ID) A cylindrical or circular pipe is characterized by two diameters, found on a section perpendicular to the axis: The inside diameter is equal to the outside diameter minus the pipe thickness. Both diameters can be measured on a straight line passing through the center of the section. *See also* nominal diameter.

Instantaneous unit hydrograph (IUH) The basic concept of the Clark method to establish a unique unit hydrograph for a drainage basin: it is the hydrograph resulting from spreading uniformly and instantaneously 1 unit of rainfall excess over the basin.

Instream use A water use that takes place within the stream channel (e.g., hydroelectric power generation, navigation, water quality improvement, fish propagation, recreation), as compared to a **consumptive use** (e.g., manufacturing, agriculture, food preparation), which removes water from the available supply.

Instream Water Temperature Model (SNTEMP) A model of the U.S. Fish and Wildlife Service that predicts streamwater temperatures from hydrological and meteorological conditions and from stream geometry.

Intake chamber A chamber that gradually narrows to a tunnel at the head end of some hydraulic structures to minimize undesirable effects of currents.

Integral square error (ISE) A measure of goodness of fit between observed and simulated hydrographs:

$$\mathrm{ISE} = 100\sqrt{\Sigma\left(O_i - S_i\right)^2} \Big/ \Sigma S_i \qquad \text{(I-1)}$$

where O_i and S_i represent, respectively, the observed and simulated values at time i, $\sum$ is the summation from i = 1 to i = N, and N is the number of pairs of values.

Integrated flow curve A mass diagram with discharge as the ordinate and time as the abscissa.

Integrated hydrograph A graph on rectangular coordinates; used in storage and streamflow regulation studies, usually with time as abscissa and a cumulative quantity (e.g., storage volume or total discharge) as ordinate. Also called **mass diagram** or **summation hydrograph**.

Integrator A device or meter that continuously measures and calculates total flows in gallons, cubic feet, or some other unit of volume. Also called a **totalizer**.

Intensity–duration–frequency (IDF) The relationship among rainfall intensity, rainfall duration, and storm frequency. **Rainfall intensity** is the amount of rain per unit of time, expressed in in/h or mm/h. **Rainfall duration** is the total time over which rainfall occurs. The **storm frequency** is the return interval at which the specific intensity is expected to recur. The intensity–duration–frequency relationship is presented graphically as a series of rainfall-intensity curves, expressing the relation between rates of rainfall and their duration. Each curve of the series is for a storm frequency, indicating the number of years during which the intensities will not be exceeded more than once on average.

Intercepting sewer Same as **interceptor**.

Interception (1) The portion of precipitation retained on buildings and vegetation without reaching the ground because it eventually evaporates; the process itself. *See also* Figure R-6; rainfall–runoff relationship. (2) The process of diverting wastewater from a main sewer (usually a combined sewer) for conveyance to a treatment plant.

Interceptor A sewer that intercepts wastewater and sometimes predetermined quantities of stormwater from a combined sewer system for conveyance to a treatment plant or to an outfall. Also called **intercepting sewer** or **interceptor sewer**.

Interceptor drain A subsurface drain used to remove water from sloping soils that are excessively wet or subject to slippage.

Interceptor sewers Large sewers that, in a combined system, control the flow of wastewater to the treatment plant. In a storm, they allow some of the wastewater to flow directly into a stream, thus keeping it from overflowing into the streets. Also used in separate systems to collect the flows from main and trunk sewers and carry them to treatment plants (EPA-94/04).

Interconnected ponds Ponds in series are interconnected if a downstream pond affects the hydraulics of an upstream pond or if the water surface fluctuations at the outfall affect the hydraulics of the downstream pond. Otherwise, the series of ponds is standard. *See also* Advanced Interconnected Pond Routing; pond routing.

Interconnection The physical connection between two networks, e.g., two water supply systems or two sewer networks. *See also* backflow connection; cross connection.

Interevent time (IET) *See* minimum interevent time.

Interface The common boundary layer between a liquid and a solid, between two fluids such as water and a gas, or between a liquid (water) and another liquid (oil) (EPA Glossaries).

Interflow (1) The portion of precipitation that reaches a stream after infiltration into the soil and after lateral flow, without reaching the water table. Also called **subsurface stormflow** or **throughflow**, as opposed to the other part of subsurface runoff that reaches the saturated zone. *See also* Figure R-6; rainfall–runoff relationship. (2) The movement of water between layers of different densities in a lake or reservoir. (3) Lateral movement of water in the upper layer of soil. *See also* unsaturated zone; upper zone storage.

INTERHYMO A single-event hydrologic model that simulates runoff hydrographs from highway interchanges.

Interior area A low-lying area protected from direct flooding of lakes, rivers, or tides by levees, floodwalls, or seawalls.

Interior Flood Hydrology A computer program of the Hydrologic Engineering Center (HEC-IFH) that performs continuous simulation and hypothetical event analyses for interior area floods.

Intermediate groundwater Subsurface water in the vadose zone between soil water and the capillary fringe. Also called **intermediate vadose water**, it includes pellicular water and gravitational water. *See* Figure S-14; subsurface water.

Intermittent stream (1) A stream or reach of a stream that does not flow year-round, but flows only when it receives baseflow during wet periods, groundwater discharge, protracted contributions from melting snow, or other erratic surface and shallow subsurface sources (Hawley and Parsons, 1980, in Dodson, 1999). (2) A stream or reach of a stream that drains a watershed of at least 1 mi^2, or a stream or reach of a stream that is below the local water table for at least some part of the year, and obtains its flow from both surface runoff and groundwater discharge. An intermittent stream flows between 10% and 80% of the time. Intermittent stream is sometimes confused with ephemeral stream (*see*, e.g., American Public Health Association et al., 1981). *See also* gully; perennial streams; ravine; rill; rivulet.

Internal inspection An activity of a sewer system evaluation survey. It involves inspecting sewer lines that have previously been cleaned. Inspection may be accomplished by physical, photographic, or television methods.

Internal water The second broad category of subsurface water. Unlike interstitial water, internal water is chemically combined with the rock formations at enormous depths and under great pressures. *See* Figure S-14; subsurface water.

Interstitial water Water contained in rock fractures (voids or interstices) comprising vadose water just below the ground surface and a deeper layer of phreatic or groundwater. *See* Figure S-14; subsurface water.

Intrinsic permeability A coefficient k that expresses the ability of a porous medium to transmit a given fluid:

$$k = \mu K/\gamma = q\nu/gi \tag{I-2}$$

where μ and ν, respectively, are the dynamic and kinematic viscosities of the fluid; K is the hydraulic conductivity; γ is the specific weight of the fluid; q is the unit (or specific) discharge, which is the discharge per unit cross-sectional area; g is the gravitational acceleration; and i is the hydraulic gradient. Also called specific **permeability**, sometimes expressed in darcys.

Intrinsic property A characteristic of a body that cannot be measured directly (e.g., energy, mass, momentum), but may be derived from its relationships with extrinsic properties such as weight, temperature, concentration, density, or flow velocity, which are measurable, but not conserved. Intrinsic properties are conserved; i.e., they can be used to predict changes in the body in accordance with the laws of conservation. Examples of fundamental relationships between intrinsic and extrinsic properties are (a) heat content or heat energy, which is the product of density, specific heat, temperature, and volume; (b) mass, which is the product of density and volume; (c) momentum, which is the product of mass and velocity, i.e., the product of density, volume, and velocity. *See also* fundamental quantity for a comparison with derived quantity.

Inverse model A model to represent a system based on some characteristics, e.g., a groundwater model based on known heads and concentrations (Spitz and Moreno, 1996).

Invert The floor, bottom, or lowest point of the internal surface of a conduit, aqueduct, sewer, tunnel, manhole, or canal at any cross section. *See* Figure S-3.

Inverted manometer *See* manometer.

Inverted siphon A section of a gravity sewer constructed lower than adjacent sections. It is not a siphon but a U- or V-shaped section dropped below the hydraulic gradeline to pass under an obstruction or obstacle (railway, highway cut, stream, subway, valley, tidal estuary, or other depression). The inverted siphon flows full under positive pressure. Also called

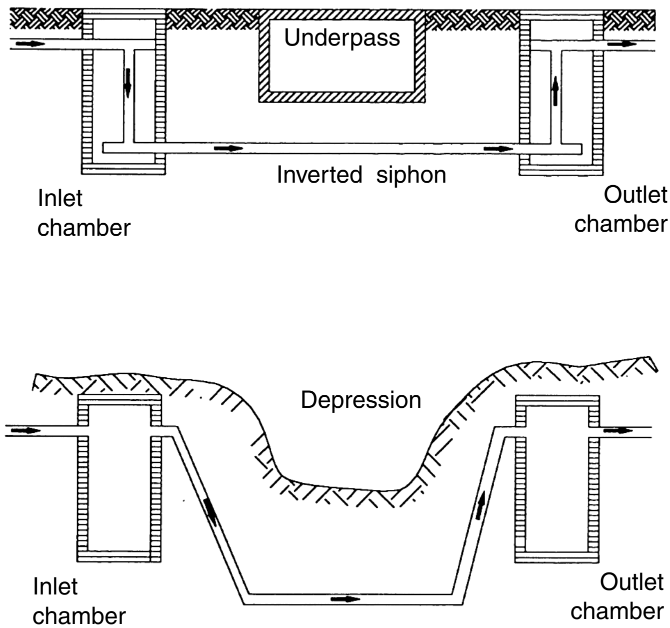


FIGURE I-2 Inverted siphons.

depressed pipe, **depressed sewer**, **dive culvert**, **sag line**, or **sag pipe**. **Depressed sewers** are usually designed as multiple pipes, one of which carries the minimum flow and maintains self-cleansing velocities. Besides the pipe, the inverted siphon includes inlet and outlet chambers. An inverted siphon may also be used (instead of a flume) when a canal must cross a depression. *See* Figure I-2.

Irrigation return water Drainage water from irrigated lands.

ISCO, Inc. A manufacturer, with headquarters in Lincoln, NE, of instruments such as rain gages and portable recording flowmeters.

ISE Abbreviation for integral square error.

Isochrones Lines of equal travel times to a given point, such as an inlet or an outlet.

Isohyet (From the Greek prefix *isos* meaning equal, similar, and the Greek word *hyetos* for rain.) An imaginary line on the earth's surface or a line on a map connecting the points of equal precipitation during a given time period or for a particular storm event. Also a line or contour of equal concentration. *See* Figure I-3.

Isohyetal map A map of contours of equal rainfall (isohyets); indicates the distribution of precipitation over an area during a given period. *See* Figure I-3.

Isohyetal method One of three methods used for spatial averaging of precipitation. Given an isohyetal map, to determine the average precipitation depth over an area, locate the centroid of the area and interpolate between

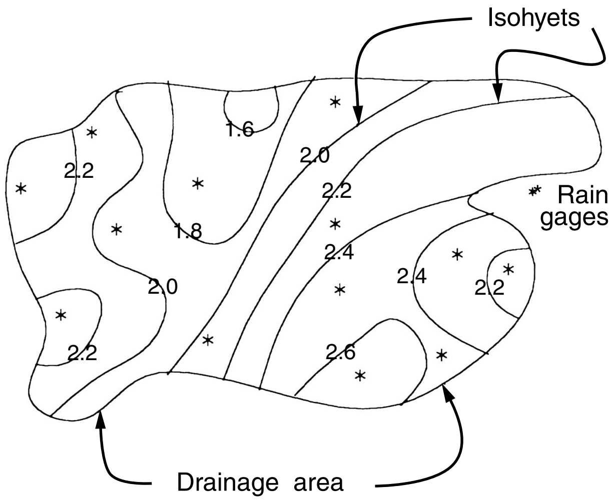


FIGURE I-3 Isohyetal map.

the two adjacent isohyets. *See also* arithmetic average method; Thiessen polygon method.

Isopiestic line (From the Greek prefix *isos*, meaning equal, and *piezo* for pressure.) An imaginary line connecting all points of equal elevation to which water of an aquifer under pressure would rise freely or all points of equal altitude in an unconfined aquifer. An **isopiestic** or **piezometric map** shows the shape of the piezometric surface, which corresponds to the static level of the aquifer (also the surface defined by the water level in a group of wells, i.e., the artesian equivalent of the water table).

Iteration Repetition of a computing procedure by replacing old values of an unknown by the most recently computed value until the iteration residual error is within acceptable limits.

Iteration residual error The remaining error in an iterative procedure in which iterations are terminated on satisfaction of a specified error criterion. *See also* convergence.

IUH Abbreviation for instantaneous unit hydrograph.

Izzard's formula A formula developed by C. F. Izzard in 1943 to estimate the time of concentration t_c or time to equilibrium flow in the application of the rational method:

$$t_c = 526.76kL^{1/3}i_e^{-2/3} \tag{I-3}$$

with

$$k = (0.0000276i_e + c)/S^{1/3} \tag{I-4}$$

L = distance of flow (m), i_e = excess rainfall (mm/h), c = retardance coefficient, and S = slope. This form of the formula is presented by McGhee (1991). Linsley et al. (1992) and Gupta (2001) presented two different forms. The retardance coefficient varies from 0.007 for a very smooth pavement to 0.06 for dense bluegrass sod.

J

Jack-and-bore A method of installation of water, sewer, and other underground conduits when it is not desirable to disturb the ground above the conduit, e.g., to cross a busy roadway or to avoid a contaminated area. It is a combination of the jacking and boring methods.

Jackson turbidity unit (JTU) A standard measure of turbidity. *See* JTU.

Jet pump A pump using an accelerating jet of air to entrain another fluid and deliver it at a higher pressure. Jet pumps and **jet ejectors** are used in wells and for dewatering.

Jetty A coastal hydraulic structure built of piles, concrete blocks, large loose rock, etc. from the shore into the littoral zone and designed mainly to prevent drift deposit in a navigable channel. Also called **wharf** or **pier**. Breakwaters are similar to jetties, but designed to protect the littoral zone from incoming waves. *See also* groin; revetment; seawall.

Joint The connection between two pipe sections, often with a third part, that may include nuts, bolts, joint compound, etc. Typically, iron pipe joints for water supply are of the following varieties: ball, bell-and-spigot, Dresser coupling, flanged, mechanical, push-on, threaded, and Victaulic coupling. Concrete pipes used in sewer work typically have joints in rubber gasket, mortar or mastic packing, O-ring gasket, spigot groove with O-ring. *See also* flexible joint.

Joint compound A synthetic compound used in pipe joints instead of lead for water tightness.

JTU (Jackson turbidity unit) A standard measure of turbidity based on the observation of the outline of a candle. The FTU (formazin turbidity unit, based on a known chemical reaction) and the NTU (nephelometric turbidity unit, measured by an instrument) are more reproducible and more currently used.

Junction In modeling applications, junctions or nodes (e.g., manholes, pump stations, storage units, flow dividers) are volumetric units that receive water from and release it to links or channels and conduits. Nodes also receive inflows to the network. The continuity equation is solved at the junctions, which are characterized by their volumes, surface areas, and heads. The volume and surface of a junction include one half of all the channels connected to it. *See also* link–node network.

Junction box A protective enclosure for the connection or termination of electrical wires and cables. In sewer networks, a manhole or other access point to a sewer line or a pump station.

Junction chamber A chamber or large conduit section for the junction of two or more conduits.

Junction invert The invert of the lowest conduit connecting to the junction. Such information may be available on as-built drawings or may be determined from sewer line length and slope.

Junction manhole A manhole at the intersection of two or more sewers.

Junction node Any node where two or more conduits meet. *See also* network equations.

K

Kaplan turbine A propeller-type hydraulic turbine that has adjustable blades and gates to accommodate load changes and increase efficiency: efficiency drops only 2% from full load to 40% load. Like the Francis turbine, it is a reaction turbine with four basic parts: scroll case, wicket gates, runner, and draft tube.

Karst Terrain with characteristics of relief and drainage arising from a high degree of rock solubility in natural waters. The majority of karst occurs in limestones, but it may also form in dolomite, gypsum, and salt deposits. Features associated with karst terrains typically include: irregular topography, sinkholes, vertical shafts, abrupt ridges, caverns, abundant springs, and disappearing streams. Karst aquifers are associated with karst terrain (EPA-40CFR300-AA).

KB Abbreviation for kilobyte(s); 1 KB is approximately 1000 bytes.

Kelvin Unit of absolute temperature equal to 1/273.16 of the absolute temperature of the triple point of water (ice, liquid, and vapor). Also called **degree Kelvin**. *See also* Celsius degree.

Kentucky Pipe Model A hydraulic model with algorithms that are used in the Cybernet™ model.

Kerby formula An equation proposed by W. S. Kerby in 1959 for the computation of inlet or overland time (t, min) in storm drainage design:

$$t = 0.827(L \cdot n)^{0.467}/S^{0.2335} \quad \text{(K-1)}$$

where $L \leq 1200$ ft, distance from the inlet to the farthest tributary point; n = a retardance coefficient between 0.02 and 0.80; and S = average slope.

Key manhole An important manhole, such as a manhole where two sewer lines meet, a manhole where the pipe size changes, or a receiving manhole.

Key parameters In hydraulic and hydrologic modeling, key parameters include peak flow, time to peak, runoff volume, time of concentration, runoff curve number, conduit roughness coefficient, entrance and exit losses, and other losses (contraction, expansion, bending).

k-factor A factor used in the computation of minor or local headlosses caused by geometric changes, obstructions, or fittings. It serves to express these minor headlosses in function of the kinetic energy or velocity head or as an equivalent length of pipe. In streams, the minor loss coefficient varies from 0.1 for a gradual contraction to 0.6 for an abrupt contraction and from 0.3 to 0.8 for similar expansions. For valves and fittings in pipes, the k-factor may vary widely, for example, from 0.2 for a wide-open gate valve, to 5.6 for a half-open gate valve, to 10 for a wide-open globe valve. *See* equivalent pipes; minor losses.

kg Abbreviation for kilogram(s).

Kill A small, shallow, natural stream that usually flows continuously, but is turbulent and swift; term used mainly in New York State. *See also* stream.

Kilobyte (KB) A unit of measurement of the storage capacity of a computer drive (the random access memory or the hard drive); from the prefix *kilo*, meaning 1000. Actually, 1 KB equals a little more than 1000 bytes ($2^{10} = 1024$).

Kilogram (kg) The unit of mass in the MKS (meter–kilogram–second) system; equal to 1000 g or approximately 2.205 lb.

Kinematic flow number (or kinematic wave number) (K_f) The product of channel length L, bottom slope S_o, and the acceleration of gravity g divided by the square of the average longitudinal velocity V, i.e.:

$$K_f = L \cdot S_o \cdot g/V^2 \qquad \text{(K-2)}$$

The kinematic wave approximation is valid for $K_f > 10$ and a Froude number $F_r < 2$.

Kinematic overland flow method *See* kinematic routing.

Kinematic routing (1) A flood or flow routing method based on the kinematic wave approximation; usually applied to a shallow flow, such as overland runoff on flat surfaces and wide channels. The discharge Q is assumed to be proportional to the depth of flow y according to the equation:

$$Q = a \cdot y^b \qquad \text{(K-3)}$$

where a and b are the coefficient and exponent of the stage–discharge relationship. Kinematic routing is sometimes modified by setting the slope equal to the difference between the water surface elevations at the beginning and end of the reach divided by the length of the reach. *See also* kinematic wave equation. (2) Alternatively, kinematic routing may use a form of the continuity equation combined with a flow equation (e.g., the Manning equation).

Kinematics The study of the motion of a system without reference to the forces that act on it.

Kinematic similarity *See* hydraulic model.

Kinematic viscosity (ν) The ratio of dynamic viscosity to mass density. Kinematic viscosity is a measure of a fluid's resistance to gravity flow: the lower the kinematic viscosity, the easier and faster the fluid will flow (EPA Glossaries). *Also see* viscosity.

Kinematic wave approximation A method of solving unsteady flow problems by assuming that gravity forces predominate over inertia forces and are in equilibrium with frictional forces. It is used in the TRANSPORT Block of the Stormwater Management Model (SWMM). It indicates that the discharge Q is a function of depth only. The kinematic wave approximation neglects the dynamic terms of the momentum equation and indicates that flow variations will propagate only in a downstream direction. It cannot simulate backwater or sewer surcharge conditions. The kinematic wave celerity C_k depends on the channel width and the discharge. The kinematic wave approximation is generally valid when the Froude number F_r is less than 2 and the kinematic flow number K_f is more than 10.

Kinematic wave celerity (C_k) The velocity of the kinematic wave, computed as follows:

$$C_k = (1/W)(dQ/dy) \tag{K-4}$$

where W is the channel width, Q is the discharge, and y is the water depth.

Kinematic wave equation An equation that expresses the kinematic wave approximation. It is a nonlinear, one-dimensional partial differential equation obtained by combining the continuity equation with a simplified energy equation, assuming that the friction slope S_f is equal to the bed slope S_0. It can take several forms (Martin and McCutcheon, 1999), e.g.:

$$\partial h/\partial x + n^2V^2/(\delta^2 R^{4/3}) = 0 \tag{K-5}$$

$$\partial y/\partial t + (1/W)\cdot(dQ/dy)\cdot(\partial y/\partial x) = \partial y/\partial t + C_k\cdot(\partial y/\partial x) = 0 \tag{K-6}$$

where $C_k = (1/W)\cdot(dQ/dy)$ = celerity of the kinematic wave; h = water surface elevation; n = Manning's roughness coefficient; Q = discharge; R = hydraulic radius; t = time; V = average longitudinal velocity; W = channel width; x = length along the longitudinal axis; y = mean depth of flow; δ = unit conversion factor = 1.0 for SI and 1.49 for English units. In overland flow simulation for stormwater management, the kinematic wave equation can be solved numerically for the depth of flow y as a function of position x, time t, the difference between rainfall intensity i and infiltration f, and flow per unit width q:

$$\partial y/\partial t + \delta(m/n)\sqrt{S_0}\, y^{m-1}\,(\partial y/\partial x) = i - f \tag{K-7}$$

and

$$q = (\delta/n)\sqrt{S_0}\, y^m \tag{K-8}$$

where S_0 is the slope, and m is a nonlinear overland flow parameter for the kinematic wave (Medina and Jacobs in James, 1994). The **overland time of concentration** t_c for small urban watersheds, based on the kinematic wave theory, is (McCuen, 1989):

$$t_c = 0.01567L^{0.6}n^{0.6}i^{-0.4}S_f^{-0.33} \quad \text{(K-9)}$$

where L is the overland flow length, and S_f is the friction slope. The HEC-1 model uses a continuity equation with lateral inflow q_0 and a simplified Manning equation where the flow Q is proportional to a power of the cross-sectional area A, with the coefficient and the exponent the kinematic wave parameters (Hoggan, 1996).

Kinematic wave method A method used in modeling rainfall–runoff relationships as an alternative to the unit hydrograph approach. It is based on the kinematic wave approximation.

Kinematic wave model *See* kinematic wave approximation.

Kinematic wave number Same as **kinematic flow number**.

Kinetic energy Kinetic energy is the energy of a moving body as a result of its motion. The **kinetic head** is the element of total dynamic head of a pump that represents the kinetic energy or velocity head $V^2/2g$, for which V is the average fluid velocity and g is the gravitational acceleration. Same as **velocity head**. *See also* dynamic head.

Kinetic head *See* kinetic energy.

Kinetic rate coefficient A number that describes the rate at which a water constituent, such as biochemical oxygen demand or dissolved oxygen, rises or falls (EPA-94/04).

Kinetics (1) The branch of mechanics that studies the motion of material bodies under the action of given forces; the dynamics of material bodies. (2) The study of the rate of change in physical, chemical, or biological processes.

km Abbreviation for kilometer(s); 1 km = 1000 m = 3280.84 ft = 0.6214 mi.

Koch, Alexander *See* hydraulics.

Kutter formula An empirical formula developed by E. Ganguillet and W. R. Kutter in 1869 to determine the value of the Chézy coefficient C_z. In the Kutter formula, this coefficient depends on the channel slope S_0, the hydraulic radius R, and a roughness coefficient n.

L

L (or ell) A fitting used to connect two pipes at an angle, usually 90°. Also called an **elbow**.

L (or l) Abbreviation for liter(s).

Labyrinth spillway An overflow spillway with a sawtooth crest to increase its length and capacity.

Lacey's formulas A set of equations proposed for the design of stable channels in erodible or alluvial materials. *See also* Equations R-12 through R-14; regime theory.

Lacustrine Of or pertaining to lakes; living or growing in lakes; originating from the bottom or along the shore of lakes. A **lacustrine plain** is the bed of a former lake that disappeared.

Lag (1) Drainage lag in the formula of hydrograph time to peak (Equation H-33); estimated as the distance on the timescale between the centroid of the rainfall and the peak discharge. It is one of two basic parameters used in the Snyder unit hydrograph method; the other is the storage coefficient. (2) The time difference between peak inflow and peak outflow as a result of storage. *See* Figure R-3; reservoir storage routing. Also called **lag time** or **basin lag**.

Lagging The process according to which there is a lag time between the peaks of the inflow and outflow hydrographs as an effect of storage. Also called **translation**. *See* Figure R-3; reservoir routing.

Lagoon (1) A shallow pond in which sunlight, bacterial action, and oxygen work to purify wastewater; also used for storage of wastewater or spent nuclear fuel rods. (2) A shallow body of water, often separated from the sea by coral reefs or sandbars (EPA-94/04).

Lagrange, Joseph Louis *See* hydraulics.

Lagrange multiplier method A method used to maximize or minimize an objective function subject to a constraint. It combines the objective function with the constraint equation times a parameter called the Lagrange multiplier. The problem is solved by setting the derivative of the combined function equal to zero.

Lag time Same as **lag**; one of a few parameters used in runoff analysis. *See also* antecedent precipitation index; attenuation constant; peak discharge; plotting time widths; rainfall duration; time base; time of concentration; time of equilibrium.

Laminar flow The smooth and orderly flow of a viscous fluid in parallel layers. Each layer moves with respect to adjacent layers with a constant velocity. Exchanges between layers are limited to molecular and thermal diffusion and molecular transfer of momentum. The opposite of laminar flow is turbulent flow. The Reynolds number R_e determines whether flow is laminar ($R_e < 2100$) or turbulent ($R_e > 4000$). Between these two numbers, the flow may be laminar or turbulent, depending on other factors. Laminar flow occurs when average velocity is relatively low and energy head lost is mainly through viscosity. Under laminar flow conditions, the friction factor f in the Darcy–Weisbach formula is $f = 64/R_e$. In most cases, water or wastewater flow in conduits is turbulent. For example, in a 12-in diameter pipe, laminar flow cannot exist for velocities exceeding 0.05 ft/sec. Laminar flow is sometimes called **streamline flow** or **viscous flow**. *See* open-channel flow.

Lamphole A vertical pipe or shaft that was formerly used for sewer inspection; allows a light to be lowered from the ground into the sewer line. Currently, manholes are designed for sewer inspection and other purposes.

Lamping Use of a lamphole for sewer inspection.

LAN Acronym for local area network.

Land accretion The process of recovering land in a wet area, such as marshland or land by the sea, by such methods as the planting of special species or filling with dredged and other materials. *See also* land reclamation.

Land application (1) The spraying or spreading of sewage sludge on the land surface, the injection of sewage sludge below the land surface, or the incorporation of sewage sludge into the soil so that the sludge can either condition the soil or fertilize crops or vegetation grown in the soil (EPA-40CFR503.11-h). (2) The discharge of wastewater onto the ground for treatment or reuse (EPA-94/04).

Land disposal The placement of wastes in or on the land, except in a corrective action management unit, including but not limited to placement in a landfill, surface impoundment, waste pile, injection well, land treatment facility, salt dome formation, underground mine or cave, or placement in a concrete vault, or bunker intended for disposal purposes (EPA-40CFR268.2-c).

Landpan An evaporation pan used on land.

Land reclamation The process of recovering wet, desert, or waste land for urban, agricultural, or other purposes. Land reclamation techniques include: drainage, irrigation, flood protection, planting, and filling. *See also* land accretion.

Landsat (or LANDSAT) A satellite imagery system to gather and transmit geographical information (e.g., data about the earth's resources, topography, etc.).

Laplace equation A partial differential equation that describes groundwater flow. For steady, two-dimensional flow, it is:

$$\partial^2\phi/\partial x^2 + \partial^2\phi/\partial y^2 = 0 \qquad \text{(L-1)}$$

with

$$\phi = -kh + C \quad \text{(L-2)}$$

where ϕ is a velocity potential, k is a constant that depends on the fluid and the solid medium, h is the drop in groundwater table between two points, C is an integration constant, and x and y are the coordinates of the points.

Large water system A water supply system serving more than 50,000 people.

Lateral A secondary pipe extending from a main water pipe or header. Also a lateral sewer.

Lateral flow spillway (or lateral spillway) A spillway that discharges the overflow into a channel parallel to the crest, using up very little space in the cross section even for a long crest. Also called **side-channel spillway**. *See* Figure S-7.

Lateral sewer A pipe that runs under streets and receives wastewater from homes and businesses, as opposed to domestic feeders and main trunk lines. Also, a sewer that discharges into a branch or other sewer and has no tributary.

Laundering weir The overflow weir of a sedimentation basin.

lb Abbreviation for pound.

Leachate Water that collects contaminants (soluble, suspended, or miscible materials) as it trickles through wastes, pesticides, or fertilizers. Leachate may occur in farming areas, feedlots, and landfills and may result in hazardous substances entering surface water, groundwater, or soil (EPA-94/04 and 40CFR257.2).

Leader A vertical pipe leading water from a roof drain or gutter to the ground, a cistern, a storm drain, or other means of disposal. Also called **conductor**, **downspout**, or **downcomer**.

Lead joint Lead wool or molten lead used as the connection between two pipe sections. *See also* joint; joint compound.

Leakage The uncontrolled loss of water from hydraulic structures, or from one aquifer to another, caused by hydrostatic pressure.

Leakage coefficient (L_k) A coefficient that indicates the extent a semipervious layer will allow vertical leakage from an aquifer. It is the ratio of the coefficient of permeability K′ of the semipervious layer to its thickness L′:

$$L_k = K'/L' \quad \text{(L-3)}$$

Also called **leakance**. *See* leakage factor; retardation coefficient.

Leakage detector An instrument or a device used for finding leakage-causing small cracks or holes in the walls of containers or conduits of gas, water, or wastewater. The instrument or device may function on the principle that a leaking fluid is audible. One such device is called the waterphone. Also called **leakage finder**, **leak detector**, or **leak finder**.

Leakage factor (L_f) A factor used in solving the equation of flow through a leaky aquifer and defined as:

$$L_f = \sqrt{KL/K'/L'} = (L \cdot L_r) \quad \text{(L-4)}$$

where K = permeability coefficient of the aquifer, L = thickness of the aquifer, K′ = permeability coefficient of the semipervious layer, L′ = thickness of the semipervious layer, L_r = retardation coefficient = KL′/K′. *See also* leakage; retardation coefficient.

Leakance Same as **leakage coefficient** in relation to a leaky aquifer.

Leaky aquifer An aquifer such that water leaks in or out of it either naturally because of a semipervious overlying or underlying bed or through a man-made encased opening. Also called a **semiconfined aquifer**. A **leaky-confined aquifer** is an aquifer underlain by a confining layer, but overlain by a semipervious layer and a phreatic aquifer.

Leaping weir A device such as a gap or an opening in the invert of a combined sewer to let the dry-weather flow fall to a sanitary sewer. Also called a **separating weir**.

Leasehold The legal right held by one person, in consideration of rent or other compensation, to use the land owned by another person for a specified purpose, e.g., for the construction, operation, and maintenance of water and sewer facilities. *See also* easement; right-of-way.

Left bank The left-hand bank of a stream for an observer looking downstream.

Length of equivalent pipe *See* equivalent pipes.

Lentic water A relatively calm or standing water body such as a lake, a reservoir, or a pond, as opposed to a lotic or running water body such as a river or a canal.

Levee An earth dike or embankment alongside a river or other water body to prevent inundation of bordering land or to contain the river within its banks. It functions like a longitudinal dam. *See also* floodwall.

Lewis number One of three dimensionless numbers related to turbulent mixing. *See* Prandtl, Schmidt, and Lewis numbers.

Life-cycle cost The total cost of equipment, facilities, and other capital goods over their economic life, including capital, operation, maintenance, and repair.

Life-cycle costing A method of project evaluation to determine the most economical among the technically feasible alternatives by estimating their life-cycle costs. *See also* cost-effectiveness analysis.

Lift pump A pump for lifting fluid to the pump's own level; e.g., a pump that lifts wastewater in a sewer to allow gravity flow.

Lift station *See* pumping station.

Light rain Rain falling with an intensity greater than that of a trace (0.005 in), but less than 0.10 in per hour.

Limnology A subdivision of hydrology. *See* surface water hydrology.

Linear method *See* gradient algorithm.

Line digitization A method for converting paper maps to digital form. *See also* scanning.

Line manhole A manhole installed in a sewer line (a) at a point where the line changes direction or changes grade or (b) to maintain the distance between manholes below the recommended maximum. Other manholes are provided for the connection of other sewers.

Liner Often used interchangeably with lining, which is more common in the water, wastewater, and waste disposal fields.

Lining In general, a material, such as clay, asphalt, and plastic membranes, used or suitable for covering the inner surface of something. (1) A replaceable tubular sleeve inside a hydraulic or pump-pressure cylinder. (2) A protective layer attached or bonded to the inside of a tank, reservoir, pond, or conduit to protect it against corrosion, resist erosion, prevent seepage, or reduce friction losses. (3) A string of casing in a borehole. (4) A layer of plastic, dense clay, or other impermeable material that prevents leachate from reaching the groundwater. (5) An insert or sleeve for sewer pipes to prevent leakage or infiltration.

Link, channel, or conduit In the link–node network of flow modeling, a link, channel, or conduit conveys the fluid between two junctions (or nodes). The model solves the momentum equation in its differential or partial-difference form in each link. There is no spatial variation in any link. The following parameters characterize the links: length L, width W, cross-sectional area A, frictional resistance coefficient (e.g., the Manning roughness coefficient n), flow velocity V, and hydraulic radius R or depth of flow y.

Link–node network For simulation purposes, networks such as wastewater and stormwater collection systems are divided in nodes connected by links. A link connects two nodes. A node or junction (e.g., a manhole or gaging station) may be associated with one or more links. Within each link, flow is assumed to be constant or uniform. Variations occur at the junctions.

Lip The edge, projecting or not, of a structure, such as the overflow lip of a shaft or drop-inlet spillway or the area of the crest of any spillway where overflow starts. *See* Figure S-6.

Liquid limit The water content of soils when they pass from the liquid to the plastic states. *See* Atterberg limits.

Liter (l or L) A metric system unit of volume for the measurement of liquids and gases; equal to 1 dm^3 or 0.001 m^3. Also, 1 l equals 0.264 gal or 0.0353 ft^3.

Littoral drift Sediment and other materials deposited in patterns parallel to the contours of a beach by waves and currents. Also called **beach drift** or **shore drift**.

Littoral zone The part of the coastal area where waves and currents can move sediment or, practically, the area along the shoreline between the high and low water levels. The littoral zone may also include a permanent shallow area where aquatic vegetation grows.

Live storage In a reservoir or other impoundment, the volume between the outlet and the full-pond line; i.e., the sum of the active storage and inactive storage. Also called **useful storage**, it can be used for any principal or secondary purpose. *See* Figure R-2; reservoir storage.

Loading The rate at which liquids or pollutants are introduced to a unit; expressed as flow, flow per unit area, mass per unit time, or mass per unit area, e.g., mgd, gpd/ft^2, kg/day, or lb/ft^2/day.

Loading capacity The most loading that a water can receive without violating water quality standards (EPA-40CFR130.2-f).

Loading cycle In stormwater management, the loading cycle of detention ponds is the time between the starting points of consecutive runoff events. *See* dry detention.

Local acceleration force A term of the momentum equation represented by $[(1/g)\partial V/\partial t]$, where g is the gravitational acceleration, V is the average velocity, and t is the time. *See* Saint-Venant equations.

Local area network (LAN) An interconnected group of computers in a limited geographic area or a combination of hardware and software to share files and exchange messages within an office or a factory.

Local headlosses Same as **minor losses**.

Local method Computational hydraulic techniques use global or local methods to discretize the partial differential equations governing fluid flow. In **local methods** (such as the finite-difference, finite-element, and finite-volume methods), the approximating algebraic equations apply to adjacent grid points. In a **global method**, such as the spectral method, amplitudes associated with various frequencies replace the dependent variables.

Location parameter (x_0) A parameter of extreme value distributions, such as the three-parameter gamma distribution. *See also* scale parameter (n); shape parameter (K).

Lock A chamber or other structure in a canal or other waterway with gates at both ends to lower and raise vessels from one level to another. The **lock chamber** is the section of the waterway between the gates. Each **lock gate** is a pair of movable doors.

log Abbreviation for base 10 logarithm.

Lognormal (or log-normal) distribution A special case of the log-Pearson type III distribution (when the skew coefficient is equal to zero); used in the frequency analysis of floods and other extreme events. It is obtained from the normal distribution by substituting the natural logarithm log x for the random variable x. Thus, the lognormal probability P(x) of an event (x) is:

$$P(x) = \exp\ \{-0.5[\log x - \mu)/\sigma^2]^2\}/[x\cdot\sigma\sqrt{2\pi}] \qquad \text{(L-5)}$$

for the **two-parameter distribution,** and

$$P(x) = \exp\{-0.5[\log(x - x_0) - \mu]/\sigma^2]^2\}/[(x - x_0)\cdot\sigma\sqrt{2\pi}] \qquad \text{(L-6)}$$

for the **three-parameter distribution**, where μ is the mean, and σ is the standard deviation. These two parameters are estimated for a sample from the population. The third parameter x_0 is the location parameter. The number π = 3.1416.

Log-Pearson type III distribution A probability distribution used in the frequency analysis of floods and other extreme events, with parameters of the mean μ of the logarithms of the event magnitudes, their standard deviation σ, and a skew coefficient G. The probability of a flood or extreme event x is such that

$$\log x = \mu + K' \cdot \sigma \quad \text{(L-7)}$$

$$G = N\Sigma(\log x - \mu)^3/[(N - 1)(N - 2)\sigma^3] \quad \text{(L-8)}$$

N is the number of items in the series, e.g., the number of years of record. The parameter K′ (called "deviate") is selected from published tables based on the computed value of G and the desired return period. The U.S. Water Resources Council has adopted this distribution for use in flood frequency analysis. The log-Pearson type III density function f(x) is related to the gamma function Γ(n):

$$f(x) = [(x - x_0)^{n-1}/K] \cdot \{\exp[(x_0 - x)/K]\}/[K \cdot x \cdot \Gamma(n)] \quad \text{(L-9)}$$

where n, K, and x_0 are the shape, scale, and location parameters, respectively, of the gamma function. For Γ(n), *see* Equation (G-3) under the gamma function.

Log weir A triangular weir made of logs placed in the direction of flow with butt ends downstream.

Long-based weir Same as **broad-crested weir**.

Long wave A type of gravity wave that interacts with the bottom of the body of water because of its relatively large wavelength.

Looped network A network containing at least one loop (where two pipes intersect twice), as opposed to a branched or treelike network. Urban water supply networks are usually looped to provide added reliability through redundancy.

Looped storage–outflow relationship The relationship in flood routing represented graphically by a loop for which two values of outflow correspond to one value of storage, and vice versa. The HEC models use the Muskingum method to simulate a looped storage–outflow relationship.

Loop equation A hydraulic analysis equation that expresses the continuity and energy relations in terms of unknown flowrates. A given problem is translated by a system of nonlinear equations, usually solved numerically or by a procedure such as the Hardy Cross method. *See also* network equation; node, node equation.

Loop method Method using the loop equation in the Hardy Cross method. *See also* nodal method.

Loss of head Same as **headloss**.

Lotic water A running watercourse such as a river or a canal, as opposed to a lentic or standing water body such as a reservoir or a lake.

Lower zone nominal soil storage *See* upper zone storage.

Low flow (1) Streamflow during the driest period of the year. Also called **minimum flow**. *See also* design flow. (2) A flow condition in flow routing problems; *see* combination flow.

Low-flow augmentation An addition to streamflow during periods of low flow, e.g., to meet required dilution ratios.

Low-flow channel A channel designed to carry low flows, particularly one within a larger channel or within a dry basin to carry low runoff flows or baseflow directly from the inlet to the outlet without detention.

Low-flow criterion A criterion that defines the minimum flow acceptable for a given purpose. For example, in water quality studies, the *7Q10* flow is the minimum 7-day average flow expected once in 10 yr. *See* design flow.

lpd (or l/day) Abbreviation for liter(s) per day.

Lumped models Lumped models, lumped black-box modeling, and lumped-parameter model all refer to the use of generalities and simplifications to simulate complex events or relations. A deterministic urban runoff model that assumes all characteristics are constant is a **lumped model**; i.e., any system characteristic has a single value throughout the watershed. *See also* distributed model; pseudodistributed model. The phrase **lumped black-box modeling** refers to hydrologic simulation based on a direct relation between runoff and rainfall or between discharge and rainfall. A **lumped-parameter model**, or an **empirical model**, represents chemical or physical processes by generalities and simplifications based on observations, measurements, or practical experience rather than solely on principles or theory. The Darcy and Manning equations, e.g., are empirical models. Most analytical and numerical models include empirical elements. The **lumped-parameter modeling approach** is one of two basic approaches in urban hydrology simulations (the other is the distributive parameter method). The lumped-parameter approach uses only the most relevant characteristics of a system, e.g., actual rainfall data and a limited number of parameters to derive runoff.

Lysimeter An evapotranspiration tank that includes provision for drainage of the soil water. It measures evapotranspiration (consumptive use) as the difference between water applied to the tank surface and water draining from the bottom, with corrections for changes in soil moisture.

M

m Abbreviation for meter(s), a metric or SI unit equal to 3.281 ft.

M1, M2, M3 Water surface profiles for, respectively, backwater curve on a mild slope, drawdown curve on a mild slope, and backwater curve on a mild slope.

Mach number A dimensionless number equal to the ratio of the inertia force to the elastic force.

Macro Abbreviation for macroinstruction, a routine inside a computer program to automate repetitive tasks; i.e., a series of commands that can be accomplished by a single command.

Magnetic flowmeter A device used to measure fluid flow through a pipe. It consists of an electromagnet placed perpendicular to the pipe and a galvanometer to measure the intensity of the electromotive force created, which is proportional to the flow velocity. Magnetic meters can also be used to measure velocities in rivers and lakes.

Main A principal pipe, conduit, or line in a water, gas, or electricity distribution system; a duct or pipe that supplies or drains ancillary branches.

Main canal The irrigation canal from the source of water to the distribution system.

Main sewer *See* trunk sewer.

Maintenance The upkeep and repair of facilities, excluding their replacement. In engineering economics, maintenance costs are usually included with operation costs under operation and maintenance (O&M).

Maintenance hatch Same as **manhole**.

Major blockage A blockage that impedes wastewater flow or the operations involved in a sewer system evaluation survey such as cleaning of sewer sections and television inspection. Structural defects, sewer collapses, or excessive debris may constitute major blockages.

Major municipal separate sewer outfall (1) A municipal storm sewer outfall discharging from a single pipe with an inside diameter of 36 in or more or its equivalent (discharge from a single conveyance other than circular pipe that is associated with a drainage area of more than 50 acres). (2) For municipal storm sewers that receive stormwater from lands zoned for industrial activity (based on comprehensive zoning plans or the equivalent), an outfall that discharges from a single pipe with an inside diameter of 12 in or more or from its equivalent (discharge from other than a circular pipe associated with a drainage area of 2 acres or more) (EPA-40CFR122.26-5). Also called a **major outfall**.

Major sewer line *See* trunk sewer.

Major treatment works (1) Larger publicly owned treatment works (POTWs) with flows of at least 1 mgd or serving a population equivalent to 10,000 persons. (2) Other POTWs having significant water quality impacts (EPA-94/04). *See also* significant municipal facilities.

Manhead *See* manhole.

Manhole (MH) (1) A hole through which a person may enter a sewer, tank, boiler, or similar structure. (2) A gravity sewer appurtenant structure, usually where two or more sewer sections meet. Manholes are provided every 300 or 400 ft for inspection or whenever the sewer changes size or slope. Also called **access hole**, **maintenance hatch**, **manhead**, or **manway**. *See* terminal manhole.

Manhole invert The lowest point of the interior of a manhole**.**

Manhole junction A node used by the Advanced Interconnected Pond Routing (AdCIPR) technique in stormwater management modeling to simulate systems regulated by the Federal Emergency Management Agency, which establishes guidelines for entrance, exit, and bend losses.

Manifold A large pipe with several apertures or branches for multiple connections or to permit flow diversions from one of several sources or to one of several discharge points. Also called a **header**.

Manifolded system A sewer system consisting of pump stations and force mains, without any element open to the atmosphere (a manhole or a gravity line). *See also* closed-conduit system.

Manning coefficient (n) Same as **Manning roughness coefficient**.

Manning composite roughness coefficient, Manning equivalent roughness coefficient *See* composite roughness coefficient; compound channel; equivalent roughness coefficient.

Manning formula An empirical equation published by Manning in 1890 for open-channel flow. He derived the formula by curve fitting to observations in large rivers and channels. It expresses the average longitudinal velocity V as a function of the hydraulic radius R of the channel, the channel slope S_0, and a roughness coefficient or retardance factor of the channel lining n:

$$V = (\delta/n)R^{2/3}S_0^{1/2} \quad \text{(M-1)}$$

where δ is a unit conversion constant = 1.00 for SI units and 1.49 for English units. It is similar to the formula established theoretically by Chézy in 1775; in fact, the two formulas are identical if the Chézy roughness factor C_z is taken as:

$$C_z = (\delta/n)\cdot R^{1/6} \quad \text{(M-2)}$$

It is also equivalent to the kinematic wave equation (which assumes equilibrium between gravitational and frictional forces) under steady, uniform flow conditions. Known in Europe as the Strickler formula, the Manning equation is widely used in the United States to determine discharges and flow velocities, to estimate the effects of friction in the momentum equation, and to solve for depth of flow y using the Newton–Raphson method for example. It can also be used to determine the Chézy coefficient. In the Stormwater Management Model (SWMM), the RUNOFF, EXTRAN, and TRANSPORT Blocks use the Manning equation (Nix, 1994) to simulate surface runoff or to estimate the friction slope S_f, respectively, in the forms:

$$dy/dt = i_e - [(\delta W)/(An)](y - y_p)^{5/3} S_0^{1/2} \quad \text{(M-3)}$$

and

$$S_f = Q^2/[(\delta/n)^2 A^2 R^{4/3}] \quad \text{(M-4)}$$

where, in addition to the variables and parameters defined above, A = drainage area; i_e, rainfall excess; Q = runoff flowrate; t = time; W = width of overland flow; and y_p = depth of maximum depression storage.

Manning roughness coefficient The empirical bottom roughness coefficient n in the Manning formula, which reflects the effect of channel or conduit roughness on the velocity of flow: roughness retards the flow, increases the potential for infiltration, and decreases erosion. The roughness coefficient varies from 0.025–0.033 for natural, clean, straight, full-stage channels without ripples to 0.070–0.150 for weedy reaches or floodways with heavy underbrush. Where field measurements are not possible, the Manning coefficient may be estimated from an empirical formulation such as:

$$n = 0.031 d^{1/6} \quad \text{(M-5)}$$

where d is the size of channel particles (Martin and McCutcheon, 1999). For open-channel flow in pipes, it may vary from 0.009 to 0.017. *See also* equivalent roughness coefficient.

Manometer An instrument for measuring fluid pressure, particularly water pressure in a pipe or other container. The simple manometer is a piezometer tube bent into a U-shaped loop and containing a manometer fluid such as mercury or oil; one end is connected to a tap in the pipe, and the other end is open to the atmosphere. *See* Figure M-1. The fluid pressure at the tap P_t is determined from the formula:

$$P_t = \gamma' \cdot z - \gamma \cdot h \quad \text{(M-6)}$$

where γ' and γ represent, respectively, the unit weights of the manometer fluid and the fluid in the pipe, h is the elevation difference between the tap and the lower manometer fluid column, and z is the elevation difference between the two manometer columns. A **differential manometer** serves to measure the pressure difference between two sources or two taps, with

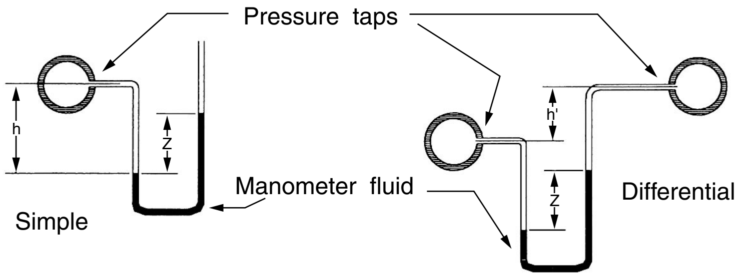


FIGURE M-1 Manometers.

each end of the tube connected to a tap. *See* Figure M-1. If the fluid specific weight is the same (γ) for both sources and h′ is the elevation difference between the two taps, the pressure difference ΔP is:

$$\Delta P = \gamma(h' - z) + \gamma \cdot z \tag{M-7}$$

An **inverted manometer** is an inverted U-shaped differential manometer for use with manometer fluids lighter than the fluids in the sources.

Manway *See* manhole.

Marine sanitation device Any equipment for installation onboard a vessel and designed to receive, retain, treat, or discharge sewage and any process to treat such sewage (EPA-40CFR140.1-c).

Markov model A model based on a Markov process; i.e., each event of a series is correlated with the preceding events. *See* autoregressive model.

Marsh–McBirney, Inc. A manufacturer of flow-metering equipment, such as the Flo-Tote meter, as well as meters to measure current and sediment concentrations. Developer of flow measurement software such as Flo-Ware. Headquartered in Frederick, MD.

Masonry dam A dam of concrete, stone, or brick masonry or concrete blocks set in mortar.

Mass The quantity of matter in a body as measured by its inertia; a quantitative measure of a body's resistance to acceleration. Also defined as the inverse of the ratio of the body's acceleration to the acceleration of a standard mass under otherwise identical conditions. The gravitational force on an object is proportional to its mass.

Mass balance An inventory of all identified materials (fluids, solids) entering, leaving, or accumulating in a system (e.g., a basin, a reservoir) or a quantitative analysis of the changes occurring in the system. When the inventory concerns only flows (e.g., in a water or wastewater system), it is called a water balance or a flow balance. A basic hydrologic balance includes such components as rainfall, runoff, evapotranspiration, infiltration, groundwater recharge, baseflow, and direct surface discharge. *See* mass curve or Rippl diagram; mass diagram. Also called **material** or **materials balance**. *See also* solids balance.

Mass–balance model A simple model based on the principle of mass conservation and focused on balancing inputs and outputs from the model area; it is often used in problems of water quality, hydrodynamics, and water transport. In groundwater simulation, such models balance flows or solute concentrations over the volume of the groundwater system. Also called **black-box model**, **single-cell model**, and **zero-dimensional model**. *See also* input–output model.

Mass curve (or Rippl diagram) A mass diagram for the study of storage from the yield of a water supply source; in effect, it is a cumulative curve of net inflow to a reservoir, with the inflow at any time the slope of the curve. *See* Figure R-4. A similar mass runoff curve may be obtained by plotting total runoff volume against time over a storm duration. One application of the mass diagram is for the estimation of storage requirements, given a record of streamflows or runoff values, and a schedule of water withdrawals or drafts: the curve is obtained by plotting the cumulative difference S between draft D and recorded flow Q versus time, i.e.,

$$S = \sum(D - Q) \qquad \text{(M-8)}$$

See also sequential mass–curve method.

Mass density Same as **density**.

Mass diagram A graph on rectangular coordinates often used in storage and streamflow regulation studies, with time usually on the abscissa axis and a cumulative quantity (storage volume or total discharge) as the ordinate. Also called **integrated** or **summation hydrograph**.

Mass discharge curve A plot of cumulative discharge against time. Also called **cumulative volume curve**.

Mass flowrate The mass of a constituent in a wastewater stream; determined by multiplying the average concentration of that constituent in the wastewater stream by the annual volumetric flowrate and density of the wastewater stream (EPA-40CFCR63.111).

Mass runoff Same as **cumulative runoff**. *See also* mass curve.

Mass transfer method A method to estimate evaporation from lakes and reservoirs. It assumes that evaporation is proportional to the difference between saturated vapor pressure at the water surface temperature and the vapor pressure due to moisture in the air and to the wind velocity. Also called **aerodynamic method**. *See* Equation (A-4). Other methods include the evaporation pan, energy balance or energy budget, and the Penman methods.

Mass transfer model A model proposed for the process of mass transfer of a substance from one phase to another. It is based on Fick's first law of diffusion, for which a mass transfer coefficient m replaces the diffusion coefficient, and the concentration gradient is taken as the difference between the saturation concentration C_s and the actual concentration C of the substance:

$$M = m(C_s - C) \qquad \text{(M-9)}$$

where M is the diffusive flux. *See also* aerodynamic method; Fick's laws of diffusion.

Material balance (or materials balance) Same as **mass balance**.

Mathematical model A set of mathematical relationships representing the behavior of a system. Open-channel flow models are generally partial differential or integral equations that cannot be solved analytically. Such models are also used to describe groundwater flow and transport processes. Mathematical models are deterministic (or mechanistic) or stochastic. Examples of simple mathematical models are the rational formula to determine the peak runoff discharges and the Streeter–Phelps formulation of the dissolved oxygen sag in a receiving stream. A mathematical model may also consist of thousands of relationships.

MATHPK A mathematics and statistics module of the program HEC-DSS.

Maximum contaminant level (MCL) The maximum permissible level of a contaminant in a public water system; an EPA enforceable standard.

Maximum contaminant level goal (MCLG) Under the Safe Drinking Water Act, a nonenforceable concentration of a drinking water contaminant, set at a level at which no known or anticipated adverse effects on human health occur and that allows an adequate safety margin. The MCLG is usually the starting point for determining the regulated maximum contaminant level (EPA-94/04). Also called a **recommended maximum contaminant level** (RMCL).

Maximum depression storage The maximum surface storage due to ponding, surface wetting, and interception. Surface runoff occurs only after the maximum depression storage is satisfied. *See* depression storage.

Maximum filtration volume option A feature of the RUNOFF and EXTRAN Blocks of the Stormwater Management Model (SWMM) that converts all rainfall on a pervious surface to runoff after a specified infiltration volume or satisfaction of a specified condition, such as saturation of the perched water table.

Maximum flow The largest volume of water through a stream, unit, or structure in a given time period.

Maximum infiltration capacity Same as **soil storage**. A limit on the quantity of rainfall that can be infiltrated in a given hydrologic unit.

Maximum mining yield The maximum flowrate that can be extracted from a particular groundwater storage. *See also* groundwater mining; safe yield.

Maximum rated horsepower The maximum brake horsepower output of an engine as stated by the manufacturer in the sales and service literature (EPA-40CFR86.082.2).

Maximum surface abstraction available *See* surface abstraction.

Maximum sustained yield The maximum rate at which a groundwater source can be used over the long term. *See also* safe yield.

MB Abbreviation for megabyte.

MCL Abbreviation for maximum contaminant level.
MCLG Abbreviation for maximum contaminant level goal.
MC method The Muskingum–Cunge method, used in flood routing models.
Mean annual precipitation The average of annual precipitation amounts over a long period.
Mean annual runoff *See* runoff.
Mean depth Same as **hydraulic mean depth**.
Mean relative error Same as **relative error**.
Mean sea level (MSL) The average sea level for all stages of the tide.
Mean section and midsection methods Two of four common methods of discharge computation based on the measurement of flow velocity and depth. In the mean section method, a cross section is divided into subsections by verticals. The discharge q through each subsection is taken as the product of its width W by averages of the depths y_1 and y_2 and velocities V_1 and V_2 at the two limiting verticals:

$$q = W(y_1 + y_2)(V_1 + V_2)/4 \quad \text{(M-10)}$$

The **midsection method** is similar but uses the velocity and depth of each vertical and half of the width of the adjacent subsections:

$$q = Vy(W_1 + W_2)/2 \quad \text{(M-11)}$$

See Figure M-2. The other two methods are the velocity–contour and velocity–depth integration methods.
Mean velocity The ratio of the discharge Q to the cross-sectional area A for a section, or to the average cross-sectional area for a reach.
Mechanical cleaning A method to remove sediment and other debris from sewer lines with such devices as rodding or bucket machines and winch-pulled brushes. *See* hydraulic cleaning.
Mechanical pipe joint *See* flexible joint.
Mechanical pump A pump that conveys fluid by direct contact of the fluid with a moving part of the pump.

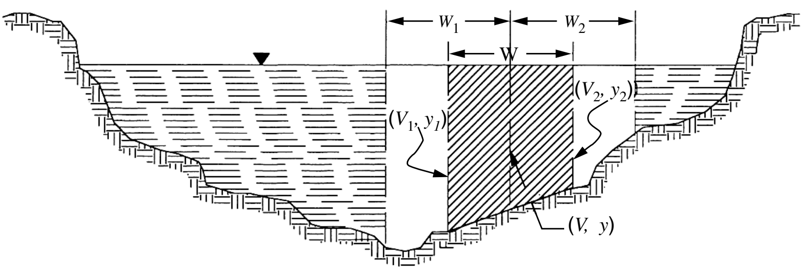


FIGURE M-2 Mean section and midsection methods.

Mechanistic model A mathematical model that translates the cause-and-effect relationships with certainty, as opposed to empirical and statistical models, which require only a minimum of understanding of the underlying processes. *See also* deterministic model.

Median formula One of three commonly used formulas in frequency analysis to determine the plotting position p of the event of rank i in a series of N events; i.e., where to locate the coordinate of the event on the probability axis:

$$p = 100(i - 0.3)/(N + 0.4) \quad \text{(M-12)}$$

See also exceedance series; frequency curve; Hazen formula; Weibull formula.

Medicinal spring A spring with water that has curative or medicinal properties or substances.

Medium sand Sand particles with a diameter between 0.25 mm and 0.50 mm. *See also* coarse sand; fine sand; soil classification.

Medium-size water system A public water system serving between 3,300 and 50,000 persons.

Megabyte (MB or meg) A unit to measure the capacity of computer hard drives, random access memory, or other storage devices; from the prefix *mega* meaning 1 million. Actually, 1 MB equals a little more than 1 million bytes (2^{20} = 1,048,576).

Megahertz (MHz) A radio-frequency unit, also used to measure a computer speed or clock speed, equal to 1 million cycles per second. The greater the clock speed, the faster the computer. A 486 computer, e.g., has a speed of 66 MHz, while Pentium™® processors start at 75 MHz. Of course, the faster the processor, the less time it will take to perform a given operation. Simulation time is inversely proportional to the computer speed.

Meinzer's classification A classification of groundwater into two main components and several subcomponents. *See* subsurface water.

Meinzer unit A unit used by the U.S. Geological Survey to measure the permeability coefficient and hydraulic conductivity; it is the rate of flow of water at 60°F, in gallons per day, through a cross section of 1 ft^2, under a hydraulic gradient of 100%.

Melt water Icemelt and snowmelt; i.e., water derived from the melting of ice and snow.

Membrane model A model of a system based on the similarity between its behavior and that of a membrane. Used mainly in groundwater modeling to study the deformation of the water table resulting from water extraction. The equation describing steady flow in a homogeneous groundwater system is based on this analogy (Spitz and Moreno, 1996); it relates groundwater recharge per unit area N and water-table elevation h to the hydraulic conductivity K and the radial distance r from a coordinate origin:

$$d^2h/dr^2 + (1/r)\cdot(dh/dr) = -N/(K\cdot h) \quad \text{(M-13)}$$

Memory In a computer, a group of circuit elements that can store data.

Merriman, Mansfield *See* hydraulics.

Metalimnion The middle layer of a thermally stratified lake or reservoir. In this layer, there is a rapid decrease in temperature with depth. Also called **thermocline** (EPA-94/04).

Meteorology The study of atmospheric structure, composition, and phenomena, including precipitation and other elements of weather and climate.

Meter A device that measures and usually indicates the value of a quantity, e.g., water meter, gas meter, electric meter. A water meter is usually installed in a meter box for the protection of the instrument. The box is located outside the building to facilitate access for reading.

Metric ton A unit of mass or weight of 1000 kg or about 2205 lb. Also called a **tonne**.

Metric units A decimal system of units based on the meter for length, the second for time, and the kilogram for mass; 1 m = 100 cm = 1000 mm = 0.001 km = 3.28 ft; 1 kg = 1000 g = 0.001 metric ton = 2.205 lb. *See also Système International*.

MG Abbreviation for million gallons; 1 MG = 133,681 ft^3 = 3,785.4 m^3.

mg Abbreviation for milligram(s).

mgd (or million gal/day) Abbreviation for million gallon(s) per day; a unit used to measure discharges or flow capacities of treatment plants, pump stations, sewer lines, and similar facilities; 1 million gal/day = 1.5472 ft^3/sec = 43.8125 l/sec = 3785.4 m^3/day.

mgid (or million gal imperial/day) Abbreviation for million gallon(s) imperial per day; 1 million gal imperial/day = 1.2 million gal/day. *See* gallon.

mg/l (or mg/L) Abbreviation for milligram(s) per liter, a unit of concentration.

MH Abbreviation for manhole or maintenance hatch.

mho The unit of conductivity (electrical conductance), the reciprocal of resistivity; mho is the backward spelling of ohm, the unit of resistivity.

MHz Abbreviation for megahertz.

mi Abbreviation for mile(s); 1 mi = 5280 ft = 1.609 km.

Microgram (μg) A unit of mass equal to 1/1,000,000 of a gram or about 0.000000035 oz.

Micrometer (μm) A unit of length equal to 1/1,000,000 of a meter or 1/1,000 of a millimeter. Also called **micron**.

Micron Same as **micrometer**, or 1/1,000,000 of a meter, approximately 0.00004 in.

Microprocessor A chip that acts as the brain of the computer, controlling and performing all processing activities. Also called **central processing unit** (CPU).

Microsoft Access™ A relational database management system that stores data in related tables and can use more than one table simultaneously. Besides tables, it includes forms, macros, queries, and reports.

Midsection method *See* mean section and midsection methods.

Mild slope A channel slope less than the critical slope at a given flowrate; the opposite of steep slope. Also called **flat slope**.

Milligram (mg) A unit of mass equal to 1/1000 of a gram.

Milligram(s) per liter (mg/l or mg/L) A common unit of measurement of concentrations of dissolved or suspended materials.

Milliliter (ml or mL) A unit of volume equal to 1/1000 of a liter or 1 cm^3.

Mine drainage Water drained, pumped, or siphoned from an active mine or postmining area.

Mineral A natural substance, usually inorganic, of definite chemical composition and crystal structure. The dissolved substances most commonly encountered in natural waters result from the combination of the cations sodium (Na), potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), and manganese (Mn) with the anions bicarbonate (HCO_3), carbonate (CO_3), sulfate (SO_4), and chloride (Cl).

Mineralization The conversion of a compound from an organic form to an inorganic form as a result of microbial decomposition.

Mineral spring A spring with water that contains significant amounts of dissolved minerals. **Mineral water** is carbonated water, soda water, or water that comes from a mineral spring.

Minimum annual flood The smallest of the annual floods in a period of record.

Minimum flow (1) The smallest volume of fluid through a stream, unit, or structure within a given period. (2) Streamflow during the driest period of the year; also called **low flow**. *See also* design flow.

Minimum interevent time (IET) A statistically determined minimum dry-weather period that distinguishes one independent wet-weather event from the next. Interevent time T is an important parameter that serves to characterize rainfall events, along with volume v (mm) and event duration t (h). It has been assumed that these three parameters are mutually independent and exponentially distributed as follows (Guo and Adams in James, 1994):

$$f_v(v) = \zeta \cdot e^{-\zeta v}, \quad \zeta = 1/|v| \tag{M-14}$$

$$f_t(t) = \lambda \cdot e^{-\lambda t}, \quad \lambda = 1/|t| \tag{M-15}$$

and

$$f_T(T) = \psi \cdot e^{-\psi T}, \quad \psi = 1/|T| \tag{M-16}$$

where ζ, λ, and ψ are parameters derived from rainfall records. The IET is very variable, from 6 h in the eastern United States to 300 h on the West Coast.

Minimum pool elevation In a reservoir or other impoundment, the minimum water level during normal operation, corresponding to the invert of the outlet conduit, and to the upper level of the dead storage or permanent pool. *See also* Figure R-2; reservoir storage.

Mining *See* groundwater mining.

Minor loss coefficient (or **k-factor)** A coefficient used in the computation of minor or local headlosses. It serves to express these minor losses in function of the kinetic energy or velocity head or as an equivalent length of pipe. In streams, the minor loss coefficient varies from 0.1 for a gradual contraction to 0.6 for an abrupt contraction and from 0.3 to 0.8 for similar expansions. In sewer system modeling, the minor loss coefficient simulates the friction losses contributed by all the fixtures and valves in a pumping station piping. *See* equivalent pipes; k-factor. *See* Section II for further information.

Minor losses (or local headlosses) In addition to friction losses, minor losses or local headlosses are energy or headlosses due to flow contraction or expansion or to obstacles such as weirs and bridges. Minor losses are caused in pipes by abrupt changes in size, bends, elbows, junctions, valves, and fittings. Local or minor losses may be neglected for long pipes but are significant in a section 100 ft or shorter. Such losses are usually expressed in function of the kinetic energy or velocity head ($V^2/2g$) multiplied by an appropriate minor loss coefficient or k-factor. An alternative method is the equivalent conduit length technique: a length of pipe estimated to cause the same pressure drop as the fitting or geometric change is added to the actual pipe length. It has been found that the equivalent length is almost constant, while the k-factor decreases with the size of the fittings. *See* equivalent pipes; k-factor.

Minor treatment works Publicly owned treatment works with flows less than 1 million gal per day. *See also* major treatment works.

Mitci formula An equation proposed by the U.S. Department of Transportation to compute the runoff coefficient C in the rational formula, with P = imperviousness (percentage) and t = time from the beginning of rainfall to the time the design intensity is reached (minutes):

$$C = [0.98tP/(4.54 + t)] + [0.78\ (1 - P)t/(31.17 + t)] \qquad \text{(M-17)}$$

Mixed-flow pump A pump that combines features of both axial and radial-flow pumps: centrifugal force and the lift of the vanes provide impulse, while flow is admitted axially but discharged radially and axially.

ml (or mL) Abbreviation for milliliter(s); 1 ml = 0.001 l.

MLRP Abbreviation for Multiple Linear Regression Program.

mm Abbreviation for millimeter(s): 1 in = 25.4 mm or 1 mm = 0.0394 in.

Mobile water Water that occurs just below the water table, moves according to the slope of the water table, and extends down to the first confining bed. Also called **free groundwater** or **free water**; sometimes confused with gravitational water. *See* Figure S-14; subsurface water.

ModClark A subbasin routing method of the Hydrologic Engineering Center's hydrologic modeling system. It is a conceptual runoff model based on a modification of the Clark unit hydrograph and is capable of tracking rainfall losses and rainfall excess for each radar grid cell of the National Weather Service. *See also* next-generation radar.

Model A scaled reproduction of a system, a mental conceptualization, an empirical relationship, or a series of mathematical and statistical equations representing a system. In any case, it is an imperfect representation, but a valuable tool to study or predict a variety of conditions and obtain answers that would be impractical by measuring or observing the actual system. The advent of high-speed computers (hardware) and development of advanced programs (software) has enhanced all these model properties. Computer models are real electronic laboratories to conduct experiments, evaluate scenarios, plan and design projects. *See also* the following types of model. (Definitions of the types of model are summarized below for convenience.)

analog model — A model based on the similarities between the system under study and another system or process.

analytical model — A model that can be solved by such classical methods as calculus or even elementary algebra.

base model — A model constructed from known system characteristics.

bench-scale model — A hydraulic model used in a laboratory to represent the natural system at an appropriate scale.

black-box model — Same as **mass–balance model**. (A black box is an electronic component with known input and output that can be easily inserted into or removed from a larger system without knowledge of the component's internal structure.)

block-centered model — A finite difference model in which the solutions are calculated at nodes in the center of the model blocks.

conceptual model — A simplified representation of the system under consideration.

continuous model — A model that uses continuous simulation, as opposed to a single-event model.

deterministic model — A mathematical model that always yields the same output for a given input without any consideration for risk and uncertainty.

empirical model — A representation of chemical or physical processes by generalities and simplifications based on observations, measurements, or practical experience rather than solely on principles or theory.

explicit model — A numerical model that uses parameter values or unknown variables at the beginning of the timestep in the computational algorithms.

groundwater model — A model designed to produce information necessary for the evaluation and forecast of groundwater flow and transport processes.

Hele–Shaw model — A two-dimensional groundwater model based on the analogy with the movement of a viscous fluid between two parallel plates.

horizontal-plane model — A two-dimensional model integrated over the depth of flow.

iconic model — A model that is an image of the prototype.

implicit model — A numerical model that uses parameter values or unknown variables at the end of the timestep in the computational algorithms.

inverse model — A model to define a system based on some characteristics.

lumped-parameter model — Same as **empirical model**. *See* lumped models.

mass–balance model — A simple model based on the principle of mass conservation and focused on balancing inputs and outputs from the model area.

mathematical model — A set of mathematical relationships that represent the behavior of a system.

mechanistic model — A mathematical model that translates the cause-and-effect relationships with certainty.

membrane model — A model of a system based on the similarity between its behavior and that of a membrane.

numerical model — A model that uses a numerical method, as opposed to an analytical model.

one-dimensional model — A model that includes only one space dimension, usually a longitudinal average across the sections.

parallel-plate model — Same as **Hele–Shaw model**.

physical-scale model — A reduced-scale representation that reproduces the predominant features of a prototype.

porous-media model — A bench-scale model to study the movement of groundwater through porous media.

pseudodeterministic model — An apparently deterministic model because it always yields the same output for a given set of input data, but a certain amount of uncertainty is inherent in its governing equations.

random walk model — A groundwater model that simulates the transport of particles through their random path in the flow field.

single-cell model — Same as **mass–balance model**.

single-event model — *See* continuous model.

statistical model — Same as **stochastic mathematical model**.

stochastic mathematical model — A model that includes statistical elements in the definition of a problem and yields different outputs for a given set of inputs. The output of a stochastic model is actually a set of expected values.

symbolic model — A model that substitutes mathematical relationships for the relevant features of the prototype.

two-dimensional model — A model that includes only two space dimensions, usually by horizontal or vertical averaging.

vertical-plane model — A two-dimensional model integrated over the width of the channel or body of water.

viscous fluid model — Same as **Hele–Shaw model**.

zero-dimensional model — Same as **mass–balance model**.

Model accuracy *See* accuracy.

Model audit Comparison of model predictions to actual (future) outcomes.

Model boundary The limit of the model domain; i.e., the interface between the domain of simulation and the surrounding environment, including boundary conditions, which represent influences external to the domain. *See also* model domain; model frame, model framework.

Model calibration *See* calibration.

Model code Same as **numerical computer code**.

Model complexity Complexity of flow models relates to the simplifications used in the solution of the governing equations and to the amount of data required for calibration. Complex models are usually solved by numerical methods because their governing equations cannot be solved analytically. Simplifications include (a) the assumption of uniform steady flow; (b) the kinematic wave approximation (instead of the dynamic wave equation); (c) the hydrostatic approximation (instead of the full vertical momentum equation); (d) the assumptions of steady, uniform flow of the Manning, Chézy, and Darcy–Weisbach equations; (e) exclusion of some sources and sinks from water balances or their representation by a single input to the model.

Model components Model components are the core, input, and output (James, 1994; Nix, 1994; Spitz and Moreno, 1996). The **core** is a set of mathematical relationships to define and simulate the behavior of the system, numerical procedures and algorithms to solve these relationships, and bookkeeping procedures. The **input** (or **model factors**) consists of the parameter values, input or independent variables, and initial values of output variables (or initial conditions). The model **output** consists of the output variable data and output statistics.

Model computational blocks Computational blocks perform the calculations to produce the output, using the governing equations, the algorithms, and the input data, as opposed to service blocks, which perform auxiliary functions. The Stormwater Management Model's computational blocks, e.g., include EXTRAN, RUNOFF, STORAGE/TREATMENT, and TRANSPORT.

Model confirmation *See* calibration.

Model confirmation testing *See* calibration.

Model construction A step in the modeling process construction that consists of the establishment of the base model, definition of the model domain, boundary and initial conditions, discretization level, and collection of input data. In essence, when the model is constructed, it is ready to run. Also called **model setup**.

Model core The set of mathematical relationships used in a model to simulate the behavior of the system studied, including the numerical computer code to solve the governing equations. These relationships involve the model variables, coefficients, and parameters.

Model debugging *See* debugging.

Model development The process of constructing, testing, and calibrating a model. A developed model is ready to perform the desired simulations.

Model development includes all the steps of model construction, plus debugging, sensitivity analysis, and calibration.

Model discretization Subdivision of the model attributes into smaller elements, for example, subdivision of the model area into cells or the time domain into timesteps.

Model domain The area of interest to the model user, e.g., a river basin, the service area of a sanitary or combined sewer system; that is, the area where the model calculations take place. *See also* model frame, model framework.

Model efficiency The ratio of the number of iterations used in the model to the minimum number of iterations required for the solution; the lower the ratio, the greater the efficiency.

Model evaluation *See* calibration.

Model execution time Same as **model runtime**. *See* model run.

Model factors As a group, same as **model input**. *See* model components.

Model final calibration *See* calibration.

Model frame, model framework The layout of the system to be modeled. The definition of a model's frame or framework may also consist of specifying the model's boundaries, the level of detail required, the inputs and outputs. *See also* model boundary; model domain.

Modeling (or **modelling)** The quantitative or mathematical simulation of a system (also phenomenon, event, or the like) by a model designed to adequately represent the actual system by replicating its properties, laws, and behavior. The simulation experiment allows the prediction of the behavior of the actual system under various conditions that cannot be easily studied on the actual system. *See also* simulation.

Modeling component *See* model component.

Modeling efficiency *See* model efficiency.

Modeling error The difference between model predictions and actual or observed conditions due to a variety of sources: the numerical approximation, input data, truncation, roundoff, conceptualization, interpretation, etc. An error analysis may be conducted to determine the size of this difference and to identify error sources. *See also* convergence.

Modeling software Computer programs used in modeling applications and including not only techniques for the solution of the governing equations, but also related applications such as geographic information system (GIS) mapping and computer-aided design. *See* Table M-1 for a list of some programs related to hydraulic or hydrologic modeling.

Model input The set of data needed to define the system and inserted into the model after construction and before the actual simulations. Input (or **model factors**) consists of parameter values, input variables, and initial values of state and output variables. **Model input data** are the information about the system required by the model to produce an approximate solution of the governing equations, e.g., the data included in the base model. *See* Tables B-1 and B-2.

TABLE M-1
Examples of Modeling Software

Software Developer and Contact	Product
Able Software Co., www.ablesw.com: Info@ablesw.com	**R2V**: GIS/GPS, map digitizing
Applied Flow Technology, www.aft.com: Info@aft.com	**Computer modeling software**: network pipe flow
Bo Webber, Consultant: Fax 205-879-7232	**BOPUMP**: modeling, multibranch pumping
BOSS International, www.bossintl.com: Info@bossintl.com	**BOSS RMS and BOSS RiverCAD**: river modeling system **BOSS EMS-EPANET**: modeling system **MIKE SWMM**: stormwater and wastewater modeling **Computer modeling software**: hydrology, hydraulics, water distribution, sewer design
CADapult, Ltd., www.cadapult.net: GISdesign@aol.com	CAD, GIS/GPS, mapping
CAiCE Software Corp., www.caice.com: caice@caice.com	Mapping, stormwater and wastewater modeling
Cartegraph Systems, Inc., www.cartegraph.com: info@cartegraph.com	**CARTEmaster**: GIS/GPS software **SEWERview**: storm and sanitary sewer network analysis **WATERview**: water distribution system analysis
Environmental Modeling Systems, Inc., www.EMS-I.com: Info@EMS-I.com	**SMS**: surface water modeling **GMS**: groundwater modeling **WMS**: watershed modeling
Geo-Slope International, Ltd., www.geo-slope.com: Info@geo-slope.com	Geotechnical and geoenvironmental modeling
GEOPAK Corp., a Bentley Affiliate, www.geopak.com: Sales@geopak.com	**GEOPAK® Drainage Visual**: storm drainage design and analysis
GEOSPAN Corporation, www.geospan.com: Gilkey@geospan.com	GIS/GPS software
Haestad Methods, Inc., www.haestad.com: info@haestad.com	**CYBERNET/WATERCAD (3.0)**: water distribution network modeling and analysis **SEWERCAD**: sanitary sewer modeling **STORMCAD 3.0**: storm sewer design and analysis **FLOWMASTER 6.0**: hydraulic modeling **CULVERTMASTER**: culvert design and analysis
Intergraph Corporation, www.ingr.com: civil@ingr.com	Mapping, storm and sanitary sewer analysis
KYPIPE, www.kypipe.com: KPFS@bigfoot.com	**PIPE2000**: hydraulic modeling
Laser Data-Images, www.laser-data-images.com: Sales@laser-data-images.com	Drawing, scanning, and conversion into CAD files

(continued)

TABLE M-1 (CONTINUED)
Examples of Modeling Software

Software Developer and Contact	Product
MW Soft, www.mwsoft.mw.com: h2onet@mw.com	**H2ONET (3.0)**: water distribution management
Pizer, Inc., www.pizer.com: Sales@pizer.com	GIS; storm, sanitary, combined sewer modeling; I/I features
Research Engineers, Inc., www.reiusa.com: Info@reiusa.com www.reiusa.com	**AutoCIVIL:** mapping; sanitary and storm sewer, water system analysis
XP Software, Inc., www.xpsoftware.com: Info@xpsoftware.com	**Computer modeling software**: stormwater and wastewater management

Note: CAD, computer-aided design or drafting; GIS/GPS, geographic information system/global positioning system; I/I, infiltration/inflow.

Source: Anon., Computer software buyer's guide categorical listing, *Civil Eng.*, 79–101, July 1999.

Model instability A numerical model or its numerical procedure is unstable if the error grows larger with succeeding iterative steps. *See* convergence for further discussion and for the distinction among stability, convergence, and consistency.

Model limitations *See* model complexity; simulation.

Modelling Same as **modeling**.

Model maintenance The set of activities required to keep a developed model current. The most important model maintenance procedures include re-creating the background files, updating the base model, and updating the model input database. *See* Section II for further information.

Model operation and maintenance (O&M) manual A manual that describes the model in detail, its algorithms, its limitations, how it works, and how to maintain it.

Model output The set of output and state variable data and output statistics. The output of a numerical model includes numbers, graphs, and texts that represent system characteristics such as flows, pressures, and heads at specific points and times. Model output data consists of numerical and graphical results of the model computations, including any texts produced.

Model parameterization The definition and initial estimation of the parameters, coefficients, and constants of the model's governing equations.

Model parameters Model parameters or coefficients are quantities derived or computed from field data, which do not change during the simulation. These are the flow parameters or coefficients that appear in the governing equations, such as the friction factor or the minor loss coefficient, sometimes called **analytical variables**. *See* model components. Model parameters also include quantities required for the efficient performance of the modeling procedures, for example, the timestep, the time-weighting factor, and the underrelaxation parameter, which are sometimes called **numerical variables**.

Model run, runtime, execution time A **run** is a single execution of a model, i.e., a single performance of all the computational and administrative procedures of the model. Model **runtime** or **execution time** is the time required to complete one model run on the computer. Runtime is a function of both the model complexity and the speed of the computer used.

Model selection factors The considerations made in selecting a certain model for a particular application, e.g., (a) suitability of the model to the objective of the application; (b) the organizational capabilities, in-house modeling experience, availability of suitable hardware, and adequately trained personnel to run the selected model; (c) organizational commitment to modeling as a tool and to the selected model in particular.

Model service blocks *See* model computational blocks.

Model setup Same as **model construction**.

Model size The number of elements that the model has to process, which affects the required capacity of the computer, efficiency, runtime, and other model attributes. For example, the number of nodes, the number of links, and the number of pumps and pump stations may define the size of a wastewater collection system model. When ordering software from a developer, the model size must be specified. *See* Section II for further information.

Model solution The process of running the model to solve the governing equations and obtain values for the dependent variables or the actual result of the simulations. Generally, solutions include analytical and numerical methods. Model solution techniques include the procedures, algorithms, and methods used to solve the governing equations of a model.

Model stability A numerical model or its numerical procedure is stable if the error at any step n is smaller than the error at the preceding step n – 1; the solution is unstable if the error grows larger with succeeding steps. *See* convergence for further discussion and for the distinction among stability, convergence, and consistency.

Model testing *See* calibration.

Model Turbo View EXTRAN (MTVE) A graphical output display software produced in 1990 by 10 Brooks Software of Ann Arbor, MI, that enables the graphical and dynamic display of simulation results and features three-dimensional plotting of hydraulic gradelines and graphical identification of model instability. *See* Section II for further information.

Model validation *See* calibration.

Model validation testing *See* calibration.

Model verification *See* calibration.

Moderate rain Rain falling with an intensity between 0.10 and 0.30 in per hour.

MODFLOW Abbreviation for Modular Three-Dimensional Finite-Difference Groundwater Flow Model. A program used to evaluate current steady-state groundwater conditions.

Modified Blaney-Criddle *See* Blaney-Criddle method.

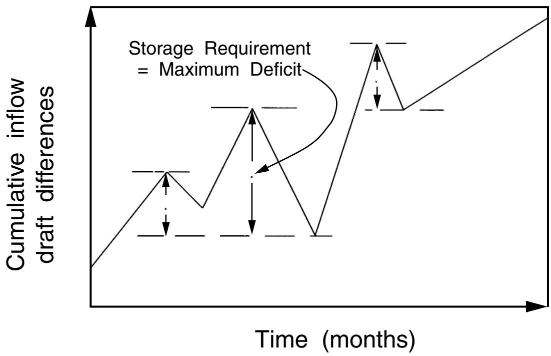


FIGURE M-3 Modified mass diagram.

Modified mass diagram An alternative method to the mass curve or Rippl diagram to determine storage requirement given a known sequence of inflows and drafts. Instead of cumulated inflows and outflows, the method uses their cumulated differences. Sometimes called **nonsequential mass curve method**. *See* Figure M-3; sequent peak procedure.

Modified Puls method A finite-difference algorithm to solve the continuity equation (stated as rate of change in volume equals the inflow rate minus the outflow rate) for flow routing through a detention unit in the STORAGE/TREATMENT Block of the Stormwater Management Model (SWMM). The governing equation is:

$$dv/dt = I - O \tag{M-18}$$

where v is the volume of water in the unit; I and O, respectively, are the inflow and outflow rates; and t is time. The modified Puls method is also used for flood routing in the HEC-1 model.

Modular Three-Dimensional Finite-Difference Groundwater Flow Model (MODFLOW) A program used to evaluate current steady-state groundwater conditions.

Moisture Water or other liquid causing wetness or dampness on a surface.

Moisture characteristic curve A graphical representation of the relationship between capillary pressure and volumetric moisture content of a soil sample. It is an inclined S-shaped curve, which also shows the sample's specific retention and specific moisture capacity. Also called **soil-water retention curve**. *See* Figure M-4.

Moisture content The quantity or weight percentage of water in a mass of soil, wastewater, sludge, screenings, or other by-products. *See also* volumetric moisture content.

Moisture deficit The difference between soil moisture capacity and actual soil moisture content or moisture storage.

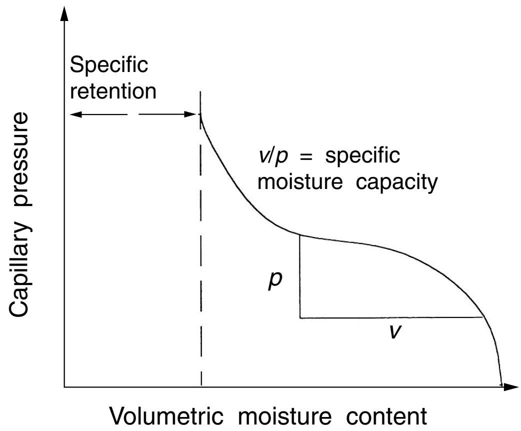


FIGURE M-4 Moisture characteristic curve.

Moisture gradient The difference in moisture content between two points in the soil or between the surface and inner portion of a body such as a section of wood.

Moisture-holding capacity The capacity of soils to retain moisture against the gravitational pull; i.e., the quantity of water that a soil can retain permanently.

Moisture penetration The depth of moisture in soils after irrigation or rainfall.

Moisture tension The energy that holds water in the soil. *See* pF.

Molecular viscosity *See* viscosity.

Momentum coefficient A coefficient used to correct the momentum equation so that it can apply to open-channel flow with variable velocity laterally and over the depth of flow. Also called **Boussinesq coefficient**. *See* Figure V-1; velocity distribution coefficients.

Momentum conservation *See* conservation laws; intrinsic property; momentum equation.

Momentum equation Linear or vector momentum (or simply momentum) is the product of mass by velocity (when velocity is negligible compared to the speed of light). The momentum equation, based on the principle of momentum conservation (reportedly first formulated by René Descartes), expresses that there is equilibrium among the various forces in action. For a body of water, these forces are: pressure $\partial y/\partial x$, convective acceleration $(V/g)\cdot\partial V/\partial x$, local acceleration $(\partial V/\partial t)/g$, gravity S_0, and friction S_f. The partial differential form of the momentum equation is:

$$\partial y/\partial x + (V/g)\cdot\partial V/\partial x + (1/g)\cdot\partial V/\partial t + S_f - S_0 = 0 \qquad \text{(M-19)}$$

where g = gravitational acceleration, S_0 = invert or bottom slope, S_f = friction or energy slope, t = time, V = average velocity, x = longitudinal distance, and y = depth of flow. *See also* intrinsic property; kinematic wave equation; Saint-Venant equations.

Monitoring well A well used to obtain samples for analysis or to measure groundwater levels. Also called a **sampling well**.

Monte Carlo analysis *See* Monte Carlo method.

Monte Carlo method (or simulation) A simulation technique, usually carried out on a computer, used to obtain an approximate solution to a mathematical or physical problem by substituting sample values for a probability distribution. The method is an efficient alternative to continuous simulation in hydrology; e.g., a storm event may be treated as a random variable of known distribution, selected from historical precipitation or streamflow data. The technique is also used in stochastic groundwater modeling and in the analysis of modeling errors.

Monthly flood The maximum 24-h flowrate of a stream during a specific calendar month.

Moody diagram A diagram used to determine the friction factor f as a function of Reynolds number R_e and relative pipe roughness for turbulent flow of incompressible fluids like water. It is a graphic solution of the Colebrook–White equation, prepared by L. F. Moody.

Moody explicit formula A transformation of the Colebrook–White transition formula; expresses explicitly the pipe friction factor f as a function of pipe diameter D, Reynolds number R_e, and pipe roughness factor ε:

$$f = 0.0055[1 + (2000\ \varepsilon/D + 1{,}000{,}000/R_e)] \qquad \text{(M-20)}$$

Morning-glory spillway A shaft (or drop-inlet) spillway with a circular lip or a flared inlet; often used for large dams. *See* Equation (S-13); Figure S-6.

Most probable number (MPN) The most probable number of organisms (usually coliform group bacteria) in a 100-ml sample. It is derived from a statistical analysis of the number of positive and negative results of tests on multiple portions of equal volume.

Movable weir A temporary weir or similar structure that can be removed from and replaced in a channel or an adjustable overflow weir in a sedimentation tank. *See also* diverting weir.

MPN Abbreviation for most probable number.

M profile An open-channel flow profile that corresponds to a mild slope. It is a backwater curve (M1 or M3) or a drawdown curve (M2), depending on the relationship among the actual depth, the normal depth, and the critical depth of flow. *See* Figure M-5; S profile.

MS4 Abbreviation for municipal separate storm sewer system. An **MS4 permit** authorizes stormwater discharges from municipal systems, subject to two standards that prohibit nonstormwater discharges into the system and require the maximum possible reduction of pollutants.

MSL Abbreviation for mean sea level, a reference used in expressing elevations. *See also* NGVD.

MTOPOND A computer program of the Ontario (Canada) Ministry of Transportation; developed to simulate the quality control performance of stormwater retention ponds.

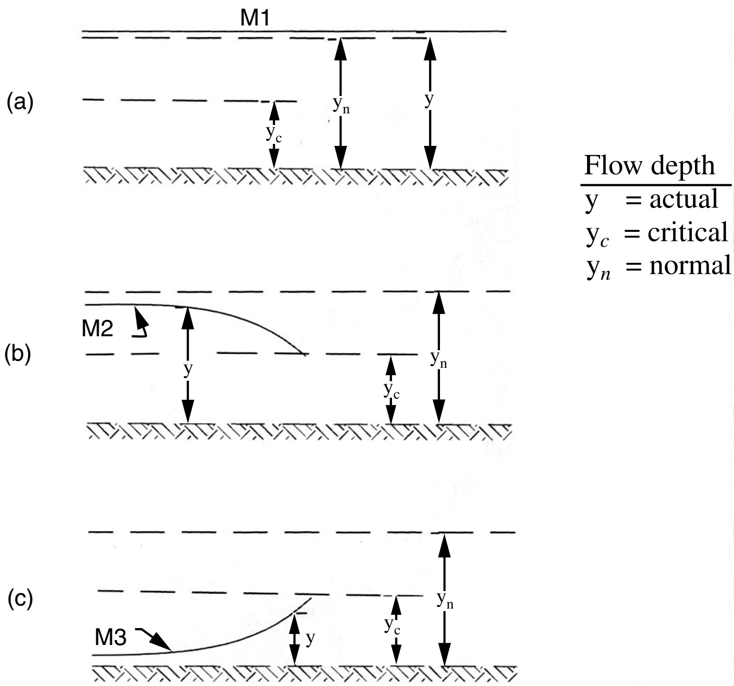


FIGURE M-5 M profiles.

MTVE Abbreviation for Model Turbo View EXTRAN, a graphical output display software.

Mud cake The caked layer of clay that forms on the walls of a well or borehole as a result of the filtration of the water out of the drilling mud.

Mud valve A plug valve used to drain sediment from the bottom of settling tanks or sedimentation basins.

Multiple conduit An alternative flow path or multiple pipes between two nodes. Also called **diversion link** or **multiple link**.

Multiple linear regression A technique using the least-squares method to estimate the value of one variable (or parameter) from two or more other variables (or parameters).

Multiple link Same as **multiple conduit**.

Multiple linear regression program (MRP) A computer program developed by HEC for the analysis of floodplain hydrology and hydraulics data.

Multiple-use (or multipurpose) reservoir A reservoir designed and operated for two or more (sometimes conflicting) purposes, such as municipal water supply, flood mitigation, navigation, irrigation, power development, recreation, and pollution abatement.

Multipurpose reservoir Same as **multiple-use reservoir**.

Multistage pump A centrifugal pump that uses multiple impellers operating in series in the same casing to increase the head of the discharging fluid.

Municipal separate storm sewer One of two basic types of public storm sewers. A conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, or storm basins) (a) owned or operated by a state, city, town, borough, county, parish, district, association, or other public body; (b) designed or used for collecting or conveying stormwater; (c) that is not a combined sewer; (d) that is not part of a publicly owned treatment works (EPA-40CFR122.26–8). The other type of public drainage is a combined sewer system (CSS).

Municipal sewage Wastes (mostly liquid) originating from a community; may be composed of domestic wastewater and industrial discharges.

Muskingum–Cunge method (MC method) A kinematic, nonlinear flow routing method proposed by W. Miller and J. Cunge in 1975. In the HEC and other models, it provides an approximate solution of Equation (C-22), the convective diffusion equation, with

$$c = (\partial Q/\partial A)_x \qquad \text{(M-21)}$$

and

$$\mu = Q/(2WS_0) \qquad \text{(M-22)}$$

where c, μ, Q, A, W, and S_0 are, respectively, the wave celerity, hydraulic diffusivity, discharge, area of flow, top width of the water surface, and bed slope. When applied to the HEC-1 model, the MC method requires the input of four parameters: a representative cross section, a reach length, the Manning roughness coefficients, and the bed slope. *See* Hoggan (1997).

Muskingum method A flow routing method that allows the determination of an outflow hydrograph given an inflow hydrograph, a time interval Δt between two points (1 and 2), a storage constant K, and a dimensionless weighting coefficient X that ranges from 0 to 0.5. The Muskingum routing equation, combining the storage equation at times 1 and 2 with the continuity equation, relates the outflow (or discharge at time 2, Q_2) to the discharge at time 1 Q_1, and the inflows q_1 and q_2 and to three routing coefficients C_1, C_2, and C_3:

$$Q_2 = C_1q_2 + C_2q_1 + C_3Q_1 \qquad \text{(M-23)}$$

$$C_1 = (0.5\Delta t - KX)/(0.5\Delta t + K - KX) \qquad \text{(M-24)}$$

$$C_2 = (0.5\Delta t + KX)/(0.5\Delta t + K - KX) \qquad \text{(M-25)}$$

$$C_3 = (K - KX - 0.5)/(0.5\Delta t + K - KX) \qquad \text{(M-26)}$$

The user selects values of Δt and X, while K (about the travel time of a flood wave through the reach) may be determined graphically. With its concepts of prism storage and wedge storage, the Muskingum method, contrary to the modified Puls method, can handle looped storage–outflow situations. *See* Hoggan (1997) and Martin and McCutcheon (1999).

Muskingum routing coefficients The three coefficients C_1, C_2, and C_3 in the routing equation of the Muskingum method.

Muskingum routing equations *See* Equations M-23 through M-26; Muskingum method.

Muskingum routing parameters The two parameters used, along with the time interval, to define the routing equation of the Muskingum method: the storage constant K and the weighting coefficient X.

Myers–Jarvis equation An empirical formula used in flood flow computations. It relates a flood peak discharge Q to the drainage area A and a coefficient C, the last determined as an intercept of the log–log plot of available Q-versus-A data:

$$Q = C\sqrt{A} \qquad \text{(M-27)}$$

N

N Abbreviation for newton(s), the SI unit of force.

NAPC Acronym for nominal average power consumption, a parameter used to determine the adequacy of a sewer transmission system's multiple- or variable-speed pumps: The capacity of a pump station is inadequate if its NAPC exceeds a certain value. *See also* elapsed-time meter.

NAPOT Acronym for nominal average pump operating time, a parameter used to determine the adequacy of a sewer transmission system with fixed-speed pumps; if a pump station's NAPOT exceeds a certain value (e.g., 10 h a day on a monthly basis), the capacity is inadequate. *See also* elapsed-time meter.

Nappe (From the French word for sheet.) The stream of water overflowing a weir, dam, or spillway. The ratio of the nappe thickness to the crest thickness differentiates between sharp-crested and broad-crested weirs. *See* Figures S-9, W-2, W-5.

Nash model An equation based on the convergence of hydrologic and geomorphologic approaches; used for estimating unit hydrograph shape n and scale K parameters:

$$Q(t) = [t^{n-1} \exp(-t/K)]/\Gamma(n)K^n \quad \text{(N-1)}$$

with

$$Q_p = (n-1)^n/[T_p(n-1)! \exp(n-1)] \quad \text{(N-2)}$$

where Q(t) is the unit hydrograph ordinate at time t, Γ (n) is the gamma function, Q_p is the peak discharge, and T_p is the hydrograph time to peak. The sign ! denotes the factorial of the number that precedes it. *See* James (1996).

National Geodetic Vertical Datum *See* NGVD.

National Oceanic and Atmospheric Administration (NOAA) An agency of the government of the United States that, along with its National Weather Service and National Climatic Data Center, publishes information used in the development of design storms: maps of precipitation depths, precipitation depth estimates for selected durations and frequencies.

National Pollutant Discharge Elimination System (NPDES) A provision of the Clean Water Act (CWA) that prohibits the discharge of pollutants into waters of the United States unless a special permit is issued by the U.S. Environmental Protection Agency, a state, or when delegated, a tribal government on an Indian reservation (EPA-94/04). This national program issues, modifies, revokes, and reissues, terminates, monitors, and enforces permits and imposes and enforces pretreatment requirements under sections 307, 318, 402, and 405 of CWA (EPA-40CFR122.2). An amendment of the CWA established a phased approach for stormwater discharge regulation.

National Storm Water Program A two-phase program established under a provision of the 1987 water quality amendment of the Clean Water Act (CWA): (a) regulation of stormwater discharges associated with industrial activity, stormwater discharges from large- and medium-size municipal separate storm sewer systems (MS4), and stormwater discharges contributing to a violation of a water quality standard or contributing pollutants significantly to waters of the United States; (b) identification of additional sources of stormwater contamination and establishment of procedures and methods to control them.

National Water Assessment Model A method proposed for the simulation of direct runoff within a basin. It incorporates the following equations and variables:

$$W_i = P_i + S_i - 1 \tag{N-3}$$

$$Y_i = E_i + S_i \tag{N-4}$$

$$Y_i = (W_i + b)/2a - \sqrt{[(W_i + b)/2a]^2 - W_i b/a} \tag{N-5}$$

$$S_i = Y_i e^{-P_i E_i/b} \tag{N-6}$$

$$R_i = c(W_i - Y_i) \tag{N-7}$$

$$Q_i = (1 - c)(W_i - Y_i) \tag{N-8}$$

$$G_i = (R_i + G_i - 1)/(d + 1) \tag{N-9}$$

$$D_i = dG_i \tag{N-10}$$

where a = runoff propensity parameter, b = upper limit of the sum of evapotranspiration and soil moisture storage, c = a parameter that reflects the groundwater fraction of mean runoff, d = fraction of groundwater storage discharged, D = groundwater discharge, E = actual evapotranspiration, G = groundwater storage, i represents the ith period, P = precipitation, Q = direct runoff, R = groundwater recharge, S = soil moisture storage, W = available water (sum of precipitation and previous moisture storage), and Y = sum of evapotranspiration and soil moisture storage. Also called **Thomas model** or **abcd model**.

National Weather Service (NWS) A subdivision of the National Oceanic and Atmospheric Administration of the United States; operates numerous centers throughout the country for the collection, processing, and publication of meteorological and hydrological data. Its technical publications **NWS TP-40** and **NWS TP-49** present maps of precipitation depths with selected exceedance frequencies and storm durations. In the 1970s, NWS deployed the Automated Local Evaluation in Real Time (ALERT), a flood notification system based on rain and stream gages linked to radio transmitters. More recently, NWS deployed NEXRAD (next-generation radar) to show the location and direction of rainstorms.

National Weather Service River Forecasting System (NWSRFS) A watershed simulation model developed by the National Weather Service. It uses historic data to forecast streamflows and other hydrologic variables.

Nationwide Urban Runoff Program (NURP) An intensive 3-year investigation of urban runoff characteristics in the United States; sponsored by the U.S. Environmental Protection Agency (USEPA) in the early 1980s.

Natural flow Streamflow under natural conditions (i.e., conditions not affected by such regulating structures as reservoirs, diversions, and other controls). The opposite of regulated flow.

Natural Resources Conservation Service (NRCS) New name of the U.S. Soil Conservation Service (SCS).

Natural slope *See* angle of repose.

Navier, Louis-Marie Henri *See* hydraulics.

Navigable waters Traditionally, waters sufficiently deep and wide for navigation by all or specified vessels; such waters in the United States come under federal jurisdiction and are protected by certain provisions of the Clean Water Act (EPA-94/04).

Navigation dam A structure that can raise or lower the level of a body of water and increase its depth to allow navigation.

Needle weir A type of movable-frame weir made of vertical square timbers. *See also* rolling-up curtain weir.

Negative head A headloss in excess of the static head or the negative pressure due to clogging of a rapid sand filter.

Negative pressure Pressure less than atmospheric pressure.

Negative well A well through an impermeable layer to drain water to a permeable one. Sometimes called **absorbing**, **dead**, or **drain well**.

Nephelometer (From the Greek prefix *nephelo*, meaning cloud.) An instrument for measuring the concentration of a suspension (e.g., of bacteria, suspended solids, or other substances) by its scattering of a beam of light.

Nephelometric turbidity unit (NTU) Unit of turbidity as determined by a nephelometer. *See also* formazin turbidity unit and JTU.

Net head The head available for the production of hydroelectric power after the deduction of frictional, entrance, and other losses, except turbine losses. Also called **effective head**.

Net hydrograph Hydrograph of a station obtained by subtracting the hydrographs of upstream stations from the actual flows recorded at the station. *See also* clean hydrograph.

Net inflow In stormwater modeling, net inflow is the difference between precipitation intensity and the rates of infiltration or evaporation. *See also* infiltration/inflow; inflow.

Net peak flow The portion of peak flow contributed by direct runoff; i.e., the total peak flow minus the corresponding baseflow.

Net positive suction head (NPSH) The minimum suction head H′ required for a pump to operate or the absolute pressure at the suction intake of the pump. It varies with the absolute gage pressure at the centerline of the pump intake p_i, the vapor pressure p_v, and specific weight γ of the liquid pumped; the velocity V at the intake; and gravitational acceleration g:

$$\mathrm{NSPH} = H' = (p_i - p_v)/\gamma + V^2/2g \qquad \text{(N-11)}$$

The allowable NSPH may be less than zero for pumps of high specific speeds. The NSPH is used to define the cavitation parameter; *see* Equation (C-2).

Net rainfall The difference between total rainfall and losses from surface runoff.

Net rainfall depth *See* effective rainfall depth.

Network characteristics Features required for the simulation of water distribution or wastewater collection networks, e.g., components such as pipes, pumps, manholes, and valves or operating conditions such as pressures, elevations, and valve status (open or closed).

Network equations A system of p simultaneous equations that express the conditions of continuity (j equations) and energy or momentum conservation [(L + s − 1) equations] in a network, where p is the number of pipes or conduits, j is the number of junction nodes, L is the number of primary loops, and s is the number of constant pressure external demand or supply nodes (Thorley and Wood in Ouazzar et al., 1988a): (a) At each junction node, the external demand or supply Q_e is equal to the difference between the flows in Q_i and out Q_o, i.e., j equations of the form:

$$Q_e = Q_i - Q_o \qquad \text{(N-12)}$$

(b) For each primary loop, the energy lost F(Q), the energy supplied P(Q), and the difference in energy between the two nodes ΔE are equal, with all three terms expressed in function of the flowrate Q, i.e., (L + s − 1) equations of the form:

$$F(Q) = P(Q) = \Delta E \qquad \text{(N-13)}$$

with

$$p = j + L + s - 1 \qquad \text{(N-14)}$$

Neumann boundary condition An auxiliary condition imposed for the computational solution of a fluid flow problem. It is in the form of the derivative of a function, e.g., the rate of change of discharge or velocity. *See also* Dirichlet boundary condition.

Neural network A computer program linking various inputs through interconnected associations to solve problems of prediction, classification, transformation, and modeling.

Neural network modeling A modeling approach that uses artificial intelligence to imitate the functioning of the human brain in associating or selecting among various process modules.

Neutral depth Same as **normal depth**.

Newton (N) The SI unit of force; after Sir Isaac Newton. It is the force exerted by 1 kg: N = 1 kg times the gravitational acceleration = 0.225 pound-force.

Newtonian flow Flow of Newtonian fluids, with a viscosity independent of shear rate.

Newtonian fluids Water and other fluids with a viscous shearing stress τ that is the product of the coefficient of viscosity μ by the velocity gradient $\partial V/\partial s$ between the fluid layers according to Newton's law of viscosity:

$$\tau = \mu \cdot \partial V/\partial s \qquad \text{(N-15)}$$

where V is the mean velocity, and s is the vertical distance. *See also* viscosity.

Newton–Raphson method An iterative technique used to find an approximate solution to an equation f(x) = 0. It is based on the truncation of the Taylor series expansion of f(x) after the first derivative term:

$$x_{i+1} = x_i - f(x_i)/f'(x_i) \qquad \text{(N-16)}$$

where $f'(x)$ is the first derivative of f(x), and x_i is the solution at step i. The procedure starts with an initial estimate of the solution x_0 (i = 0) to compute x_1, which is used to compute x_2 and so on until the difference between two successive solutions meets a specified tolerance. The Newton–Raphson method is often used to solve simultaneous nonlinear flow equations.

Newton, Sir Isaac *See* hydraulics.

NEXRAD Acronym for next-generation radar.

Next-generation radar (NEXRAD) A type of weather radar installation used in virtual rain gages to measure rainfall by interpreting the image created by rain. Developed by the National Weather Service in 1992, this Doppler radar system measures radio signals reflected from falling raindrops. NEXRAD provides real-time precipitation data for each grid of 6 mi^2, a considerable improvement over a typical urban watershed rain gage, which covers an area of 100 mi^2. *See also* ModClark. *See* Section II for further information.

NGVD (National Geodetic Vertical Datum) A reference used for elevations. The U.S. Coast Guard and Geodetic Survey use the sea level datum of 1929. *See also* mean sea level; sea-level datum.

Nikuradse, Johann *See* hydraulics.

NOAA Acronym for National Oceanic and Atmospheric Administration. *See* National Oceanic and Atmospheric Administration.

Nodal diagram A diagram illustrating the model layout, including nodes and conduits. *See also* schematic diagram.

Nodal method A hydraulic analysis method used to solve network problems. It assumes headlosses at each junction, computes the corresponding flows, applies a correction factor, and repeats the procedure until the continuity equation is satisfied at all junctions. *See* Hardy Cross method; loop method.

Node *See* junction; link–node network. A **node equation** in hydraulic analysis expresses the continuity and energy relations in terms of unknown (node) heads. A given problem is translated by a system of nonlinear equations, usually solved numerically or by a procedure such as the Hardy Cross method. *See also* loop equation; network equations. In stormwater management modeling, the **node initial stage** is the stage at the beginning of the storm event simulation, while a **node warning stage** is a user-defined reference point for comparison of results; the Advanced Interconnected Pond Routing (AdICPR) technique does not use it in computations.

Nominal average power consumption *See* NAPC.

Nominal average pump operating time *See* NAPOT.

Nominal diameter Diameter used for general identification, not necessarily the same as the actual diameter. For sand particles and similar materials, the nominal diameter is the diameter of a sphere of the same volume as the given particle. *See also* inside diameter; outside diameter.

Noncommunity water system *See* community water system; public water system. Noncommunity systems may be transient or nontransient.

Non-DCIA Abbreviation for nondirectly connected impervious areas; i.e., impervious surfaces that have pervious surfaces between their boundaries and the sewers.

Nonexcessive infiltration The quantity of flow that is less than 120 gal per capita per day (domestic baseflow and infiltration) or the quantity of infiltration that cannot be economically and effectively eliminated from a sewer system as determined in a cost-effectiveness analysis (EPA-40CFR35.2005–28). *See also* excessive infiltration/inflow.

Nonexcessive inflow The maximum total flowrate during storm events that does not result in chronic operational problems related to hydraulic overloading of the treatment works or that does not result in a total flow of more than 25 gal per capita per day (domestic baseflow plus infiltration plus inflow). Chronic operational problems may include surcharging, backup, bypasses, and overflows (EPA-40CFR35.2005–29). *See also* excessive infiltration/inflow.

Nonfilterable residues Solid particles that do not pass through the filter during water filtration; they are mostly suspended solids, but also include some colloids and even a small portion of dissolved solids retained on the filter material. *See also* solids.

Nonflowing (artesian) well An artesian well that does not discharge water above ground without a lifting device. Also called **pump well**.

Non-Newtonian flow Flow of fluids with a viscosity rate that varies with shear rate.

Nonpoint pollutant *See* nonpoint source.

Nonpoint pollution Man-made or man-induced pollution originating from a nonpoint source.

Nonpoint source A diffuse pollution source (i.e., without a single point of origin or not introduced into a receiving stream from a specific outlet). The pollutants may be carried off the land by stormwater. Common nonpoint sources are agriculture, forestry, natural mineral springs, urban runoff, mining, construction, dams, channels, highway deicing salts, land disposal, saltwater intrusion, and city streets (EPA-94/04). Also, a pollution source that generally is not controlled by establishing effluent limitations under sections 301, 302, and 402 of the Clean Water Act. **Nonpoint source pollutants** are not traceable to a discrete identifiable origin, but generally result from land runoff, precipitation, drainage, or seepage (EPA-40CFR35.1605.4). *See also* diffuse source of pollution; point source; and Table P-1.

Nonpotable water Water that is either not safe or not satisfactory for drinking and cooking because it contains objectionable pollution, contamination, minerals, or infective agents.

Nonreturn valve A device that limits flow in a piping system to a single direction. Its hinged disk or flap opens in the direction of normal flow and closes to prevent flow reversal. Also called **backpressure valve** or **check valve**.

Nonsequential mass curve method *See* modified mass diagram.

Nonstructural alternative In stormwater management, an alternative that does not involve a sewer system, e.g., initiatives to reduce or eliminate stormwater flows: downspout disconnection, porous pavements, rain barrels, soak pits, etc.

Nonuniform flow The opposite of uniform flow; i.e., a flow with depth, width, discharge, or velocity that is not constant. If any characteristic changes, the flow is varied, gradually or abruptly. Gradually varied flow takes place in the vicinity of the transition between subcritical and supercritical flows, e.g., at the intersection of mild and steep bottom slopes.

No-ponding option Same as **sealed option** and the opposite of ponding option. In XP-SWMM (Stormwater Management Model) modeling, the sealed option does not allow ponding at a junction.

Normal density, normal distribution The normal distribution is one of a few distributions used to simulate extreme events. It corresponds to the normal density function f(x), with the mean μ and standard deviation σ as parameters. Also called **Gaussian distribution**. *See* Figure N-1.

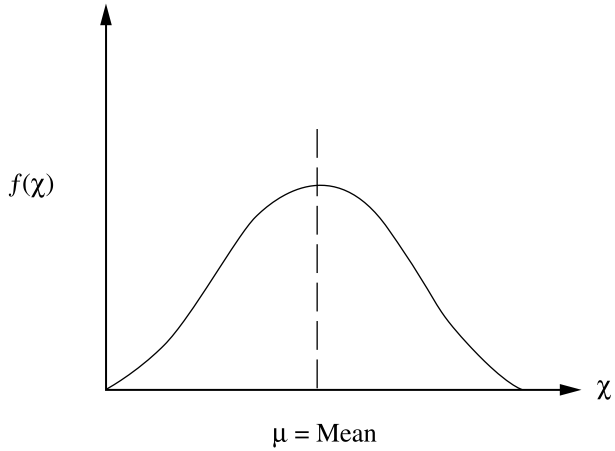


FIGURE N-1 Normal distribution.

$$f(x) = \exp[-(x - \mu)^2/2\sigma^2]/[\sigma\sqrt{2\pi}] \quad \text{(N-17)}$$

Normal depth (y_n) In open-channel flow, the depth of uniform flow or the hypothetical depth of steady–nonuniform flow as determined, e.g., by the Manning or Chézy formulas. It corresponds to uniform velocity for a given flow and to a water surface parallel to the channel bottom. Sometimes called **neutral depth**. Normal depth also designates the depth of water measured perpendicular to the bed. *See* normal flow.

Normal erosion Erosion processes occurring over long time spans. *See also* accelerated erosion.

Normal flow The conceptual open-channel flow under uniform or steady–nonuniform conditions. Normal discharge and its characteristics (normal depth, normal slope, and normal velocity) may then be determined from the Chézy or Manning formulas. Normal flow conditions very rarely exist in nature because of changes in channel properties (bottom slope, roughness, cross-sectional area). *See* open-channel flow. The EXTRAN Block of the Stormwater Management Model (SWMM) uses a **normal flow equation** when (a) the channel flow Q computed by the finite-difference form of the Saint-Venant equation is positive, (b) the water surface slope is less than the slope of the conduit, and (c) the normal flow Q_n is less than the channel flow Q:

$$Q_n = \sqrt{gS_0A_{up}R_{up}{}^{2/3}} \quad \text{(N-18)}$$

where g = gravitational acceleration, S_o = bed slope, and A_{up} and R_{up} = cross-sectional area and hydraulic radius, respectively, at the upstream end of the conduit.

Normal flow exponent *See* flow exponents.

Normalizing A procedure used in the analysis of time-series data and consisting of the comparison of current to historical data from several sources. With this procedure, it is sometimes possible to solve problems of missing records and differences in record lengths.

Normal maximum flood A concept sometimes used in the design of flood mitigation projects. If the specific peak discharge Q/A is plotted against the drainage area A, with Q the peak discharge, the resulting curve defines the normal maximum flood. *See also* catastrophic flood; probable maximum flood.

Normal pool level The maximum pool elevation in a reservoir during normal operation, i.e., in the absence of a flood. It corresponds to the spillway crest. *See* Figure R-2; reservoir storage. Also called **full pond elevation**.

Normal slope (S_n) and **normal velocity** Respectively, the bottom slope and velocity of flow corresponding to normal flow conditions. *See* open-channel flow.

Normal year A year in which hydrologic characteristics of a basin are approximately equal to their arithmetic mean over a long period. Sometimes called an **average year**.

Nozzle A cone-shaped, tubelike device, usually streamlined, for accelerating and directing a fluid with pressure that decreases as it leaves the nozzle.

NPDES Abbreviation for National Pollutant Discharge Elimination System. An **NPDES permit** is issued pursuant to section 402 of the Clean Water Act. An **NPDES State** is a state or interstate water pollution control agency with an NPDES permit program approved pursuant to section 402 of the Clean Water Act.

NPSH Abbreviation for net positive suction head; **NPSHA** is the abbreviation for net positive suction head available; **NPSHR** is the abbreviation for net positive suction head required.

NRCS Abbreviation for Natural Resource Conservation Service, formerly the Soil Conservation Service (SCS). For the **NRCS method**, *see* dimensionless hydrograph; RDII equations; SCS hydrograph method.

NTU Abbreviation for nephelometric turbidity unit.

Numbers *See* dimensionless numbers.

Numerical computer code A set of instructions to solve the governing equation of a numerical model on a computer. This code becomes the model when the specific input data, such as boundary conditions, are inserted.

Numerical error An error occurring in a numerical solution, e.g., a truncation error, roundoff error, numerical dispersion, or oscillation.

Numerical instability The characteristic of a divergent or unstable numerical solution; results from errors that grow out of control instead of going to zero with successive iterations. *See also* model stability.

Numerical method A method that converts differential equations into algebraic difference forms that can be solved, usually by computer programs, for unknown values at incremental, finite points in space and time. Examples of numerical methods include the finite-difference method, the finite-element method, and the method of characteristics. The numerical solution is an approximation to the exact solution; the difference between the two is the discretization or truncation error of the numerical solution. The numerical solution is stable, consistent, or convergent if the error tends to zero as the difference approximations — such as the timestep Δt and the distance step Δx — approach zero. Discretization errors may grow out of control and cause divergent or unstable solutions. The numerical solution diverges from the exact solution because of instability if $\Delta t > \Delta x/C_d$ (where C_d is the wave celerity). *See* Courant number. A convergent numerical solution may still be inaccurate when $\Delta t < \Delta x/C_d$ because of numerical diffusion.

Numerical model A model that uses a numerical method, as opposed to an analytical model. Most current numerical models are executed with a computer model and may be defined as a computer program, including (a) the mathematical equation describing the phenomenon or system under study, (b) the numerical computer code to solve these governing equations, and (c) the particular application of the model.

Numerical parameters Parameters used in numerical methods to control the output of the simulation, including time-weighting factor θ, underrelaxation parameter ω, flow tolerance φ, head tolerance ϕ, and timestep Δt. *See* Section II for further information.

Numerical solution A solution obtained by numerical methods.

NURP Acronym for Nationwide Urban Runoff Program.

NWS Abbreviation for National Weather Service.

NWSRFS Abbreviation for National Weather Service River Forecasting System, a watershed simulation model. For **NWS TP-40** and **NWS TP-49**, *see* National Weather Service.

O

OASIS Acronym for Online Access and Service Information System.

Occasional storm *See* storm severity.

Ocean disposal The disposal of effluents and residuals into the ocean by such methods as barging or through an ocean outfall. Because of the significant dilution available, ocean disposal usually requires lower than secondary treatment, but water quality modeling is required to ensure adequate mixing.

Oceanography A subdivision of hydrology. *See* hydrography.

Ocean outfall The facilities required for the disposal of wastewater, treatment plant effluents, or stormwater into the ocean. They usually include a pump station and a pipeline with a single outlet or a diffuser structure and their appurtenances. The pipeline requires a special design to maintain its stability and integrity. Also called a **submarine outfall**.

Ocean waters Coastal waters landward of the baseline of the territorial seas, the deep waters of the territorial seas, or the waters of the contiguous zone. Seawater or ocean water has about 35,000 mg/l of dissolved solids (DS). *See also* brackish water; brine; freshwater; saltwater.

OD Abbreviation for outside diameter.

Offline equipment Equipment or subsystem out of service; in standby, maintenance, or mode of operation other than online; also, equipment installed out of process line or outside a network. In sanitary engineering, **offline storage** is the storage of stormwater or wastewater outside an existing sewer system, usually in a tank to which the liquid waste is diverted from the main sewer system. *See also* inline equipment, inline storage.

Offline node In a wastewater collection model, an offline node represents a wetwell from which water is pumped into the system according to a pump curve.

Offline pump station A pump station with a wetwell; the rate of pumping depends on the volume of water in the wetwell. An offline station may also pump according to the head difference over the pumps. *See* online pump station; pumping station.

Offline storage *See* offline equipment.

Offset distance One of two positional parameters used in ArcView for address matching; it is a constant specified by the user to place the point at a given distance from the street segment. (The other parameter is the squeeze factor.) Careful use of offset distances and squeeze factors can improve the positional accuracy of the resulting point geographic information system (GIS) file.

Offset manhole A manhole installed tangentially to a sewer line rather than on the centerline.

Offstream use Withdrawal of surface or ground water at one location for use at another location.

Ogee spillway Same as **overflow** or **gravity spillway**. So called because of the double curve or S-curve of its channel.

O&M Abbreviation for operation and maintenance.

Ombrometer An instrument for collecting rain and measuring its depth. Also called a **pluviometer**, **rain gage**, or **udometer**.

Ombroscope An instrument that indicates whether it is raining.

Once-through cooling water Water passed through the main cooling condensers in one or two passes to remove waste heat and that does not come into contact with any raw material or intermediate or finished product (EPA-40CFR419.11-e and EPA-40CFR423.11-g). *See also* recirculated cooling water.

One-dimensional model A model that includes only one space dimension, usually an average across the sections. It is a simplification of the two-dimensional model that often makes an analytical solution possible. For streams, one-dimensional hydraulic models focus on boundary-layer flow along the longitudinal axis, while one-dimensional vertical models are used for many lakes and reservoirs. *See also* flow model; two-dimensional model.

One-hundred-year (100-yr) flood A flood that has a 1% chance of being equaled or exceeded in any given year. The 100-yr floodplain is any land area that is subject to a 1% or greater chance of flooding in any given year from any source.

One-lag serial coefficient (r_1) A serial coefficient that indicates that each value x_{i+1} in a time series depends only on the previous value x_i, the number of observations in the series n, the mean observation μ, and the standard deviation of the series σ:

$$r_1 = \sum_{i=1}^{n-1} [(x_{i+1} - \mu)(x_i - \mu)]/(n-1)\sigma^2 \qquad \text{(O-1)}$$

One-yr, 2-yr, and 10-yr, 24-h precipitation event The maximum 24-h precipitation event with a probable recurrence interval of once in 1, 2, and 10 yr, respectively, as defined by the National Weather Service or equivalent regional or rainfall probability information.

Onground tank A tank situated in such a way that its bottom is on the same level as the adjacent surrounding surface and the external tank bottom cannot be visually inspected (EPA-40CFR260.10). *See also* aboveground tank.

Online pump station or booster station A station that pumps according to the level of the water surface at the junction being pumped; it has no wetwell.

It may also operate according to the head difference over the pumps. *See also* offline pump station; pumping station.

On-site source control In general, the practice of reducing pollutants at their source. In stormwater management, it is the use of measures designed to retain stormwater at or near the point of rainfall, as opposed to conveyance through a sewer system and use of end-of-pipe facilities. Source controls that promote infiltration and reduce runoff include the discharge of roof leaders to pervious areas, reduced lot grading, rear-yard ponding, soak-away pits, and rural road cross sections instead of the urban standard of curb and gutter.

On-site stormwater retention The control of peak stormwater discharge within the site producing it. It is a common requirement of local and state regulatory agencies for all new development or redevelopment projects to install detention basins or holding ponds to keep the peak runoff from an area at the same level as before development.

Open channel A natural or artificial waterway or conduit in which liquids flow with a free surface, i.e., under atmospheric pressure. Examples of open channel include all natural streams (rivers, creeks, brooks, ravines) as well as artificial channels (aqueducts, canals, chutes, culverts, ditches, flumes, partially full conduits, tunnels).

Open-channel flow Flow of a fluid, with a free surface open to the atmosphere, in an open channel or in a closed conduit flowing partly full. The opposite is pressurized flow, such as in a closed conduit flowing full or in a confined aquifer. Free surfaces are subject to atmospheric pressure of 1 atm, which is equal to 14.7 psi = 101.4 kN/m^2 = 29.92 in (760 mm) of mercury = 33.90 ft of water at average sea level under standard conditions. *See* Figures O-1 and O-2 for cross sections and open-channel flow profile, respectively. Common characteristics of open-channel flow include area A; bottom width B; depth y; discharge, flowrate, or simply flow Q; velocity V; Froude number F_r:

$$F_r = V/\sqrt{gy} \qquad \text{(O-2)}$$

For geometric properties of particular cross sections, *see* Table O-1 and Figure O-2. The hydraulic mean depth D_m is:

$$D_m = A/B \qquad \text{(O-3)}$$

and the hydraulic radius R is:

$$R = A/P \qquad \text{(O-4)}$$

For the longitudinal profile of the water surface (or the hydraulic grade-line) in open-channel flow, *see* Figures M-5 and S-10. The Reynolds number is:

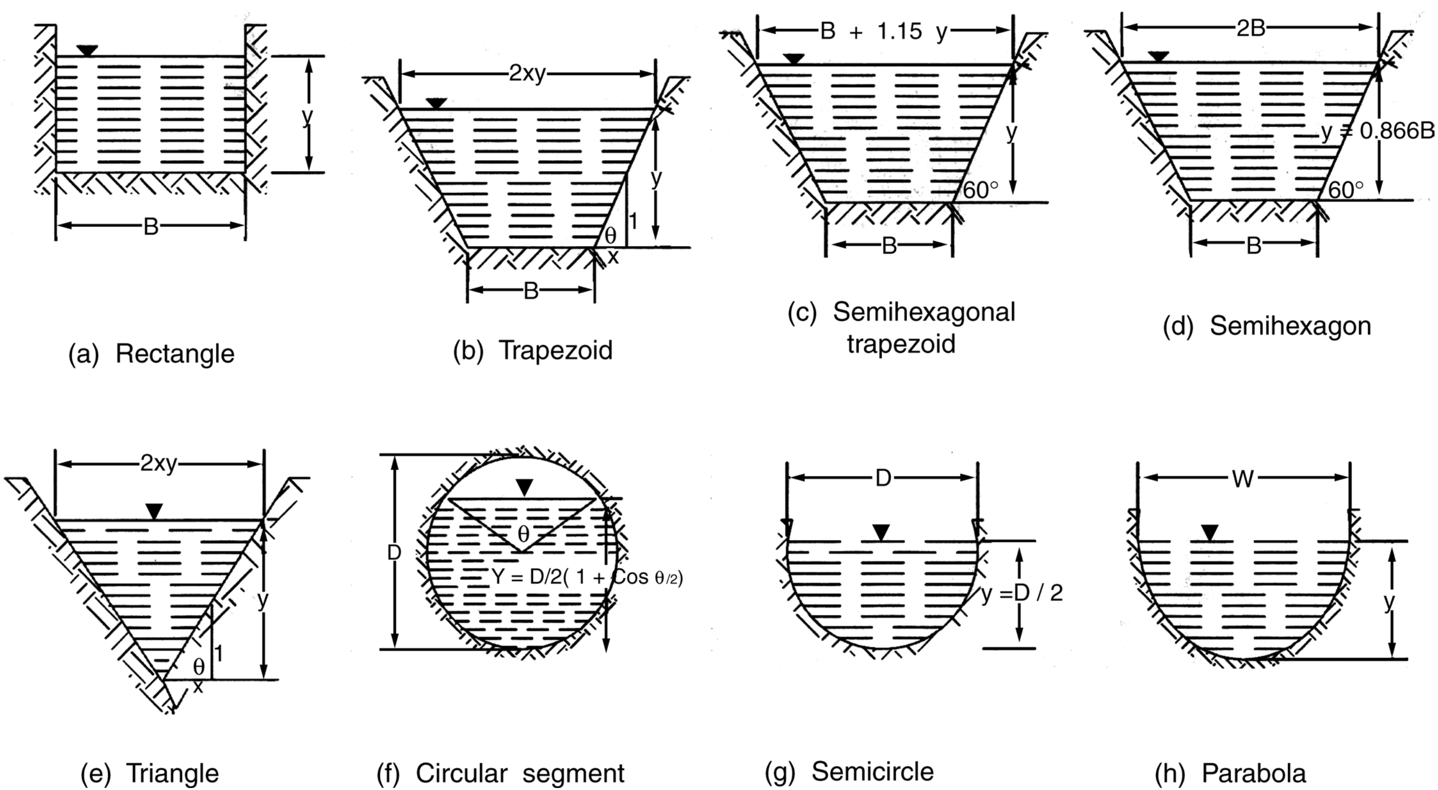


FIGURE 0-1 Open-channel cross sections.

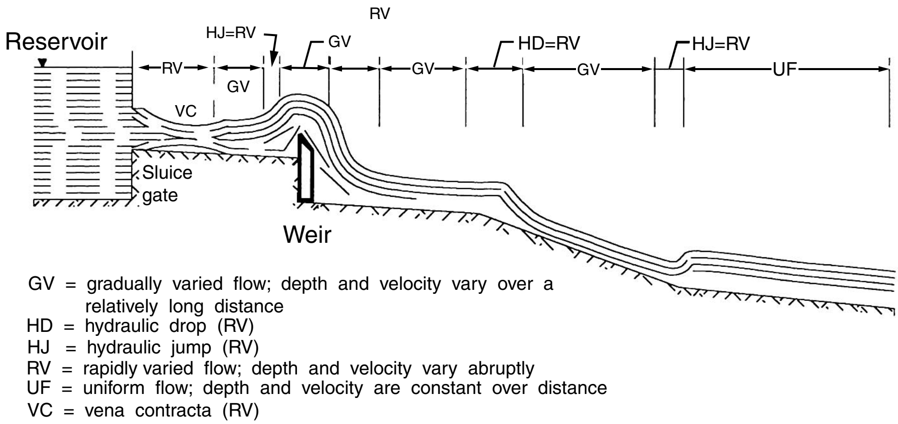


FIGURE O-2 Open-channel flow.

$$R_e = VL_s/\nu \qquad \text{(O-5)}$$

where V, L_s, and ν, respectively, are the mean velocity, a characteristic length, and the kinematic viscosity. Other characteristics are roughness coefficient n, slope S_0, stage h, surface width W, types of flow (laminar or turbulent; uniform or varied; steady or unsteady; critical, subcritical, or supercritical; stratified or not). The general equation of gradually varied flow is:

$$dy/dx = (S_o - S_f)/(1 - F_r^2) \qquad \text{(O-6)}$$

where S_f is the slope of the total energy line, S_o is the bed slope, y is the depth of flow, x is the longitudinal distance, and F_r is the Froude number.

Open conduit *See* open channel.

Open-ended valve Any valves, except pressure-relief valves, with one side of the valve seat in contact with process fluid and one side open to the atmosphere, either directly or through open piping (EPA-40CFR60.481).

Open hole An unobstructed borehole or well, a borehole being drilled without cores, a borehole or well not lined with steel tubing.

Open-hole test A test to measure *in situ* the hydraulic conductivity of soils, as used in the determination of the required length of French drains.

Open-impeller pump A pump that has no attached side wall, usually installed in wastewater and sludge-handling facilities because it can pass larger debris than a closed-impeller pump.

Open-water boundary An imaginary boundary used to divide a water body so that a limited area of it can be simulated, e.g., the seaward boundary in an estuary model or the boundary between the near-shore region of a lake in a circulation and water quality simulation.

Operating system (OS) The program that controls the operation of a processor by providing for input/output, allocation of memory space, translation of

Table O-1
Geometric Properties of Channel Cross Sections

	Rectangle	Trapezoid	Semihexagonal	Semihexagon
Bottom width B	B	B	B	B
Depth of flow Y	Y	Y	Y	0.866B
Side angle θ	90°	θ	60°	60°
Top width W	B	$B + 2Y \cot\theta$	$B + 1.1547\,Y$	2 B
Area of flow A	YB	$Y(B + Y \cot\theta)$	$Y(B + 0.5774Y)$	1.2990B
Wetted perimeter P	$B + 2Y$	$B + 2Y/\sin\theta$	$B + 2.3094Y$	3B
Hydraulic radius R	$R = n/d$ $n = BY$ $d = B + 2Y$	$R = n/d$ $n = Y(B \sin\theta + Y \cos\theta)$ $d = B \sin\theta + 2Y$	$R = n/d$ $n = Y(1.7321B + Y)$ $d = 1.7321B + 4Y$	$R = 0.433B = Y/2$
Hydraulic mean depth D_m	$D_m = Y$	$D_m = n/d$ $n = Y(B + Y \cot\theta)$ $d = B + 2Y \cot\theta$	$D_m = n/d$ $n = Y(B + 0.5774Y)$ $d = B + 1.1547Y$	$D_m = 0.6495B = 0.75\,Y$

	Circular Segment	Semicircle	Triangle	Parabola
Bottom width B	0	0	0	0
Depth of flow Y	$Y = 0.5D(1 + \cos\theta/2)$	$Y = D/2$	Y	Y
Side angle θ	θ[a]	θ[a] $= \pi = 180°$	θ	NA
Top width W	$D \sin\theta/2$	D	$W = 2\,xY = 2Y \cot\theta$	W
Area of flow A	$D^2(\theta - \sin\theta)/8$	$\pi D^2/8 = 0.3927D^2$	$Y^2 \cot\theta = xY^2$	2 WY/3
Wetted perimeter P	$D\theta/2$	$\pi D/2 = 1.5780D$	$2Y/\sin\theta = 2Y(1 + x^2)^{0.5}$	$W + 8Y^2/3W$[b]
Hydraulic radius R	$R = n/d$ $n = D(\theta - \sin\theta)$ $d = 4\theta$	$R = D/4$	$0.5Y \cos\theta = xY/2(1 + x^2)^{0.5}$	$2W^2Y/(3W^2 + 8Y^2)$[b]
Hydraulic mean depth D_m	$D_m = n/d$ $n = D(\theta - \sin\theta)$ $d = 8 \sin\theta/2$	$D_m = 0.3927D$	Y/2	2Y/3

Note: NA, not applicable; x = cot θ.

[a] Center angle.
[b] For $0 < 4y/W < 1$.

Operating system (OS)

programs, data input, manipulation, maintenance, retrieval, storage, and output functions. Examples of operating systems are DOS (disk operating system), Windows®, and Linux.

Operational model A model that is ready for the intended use; i.e., a model that has gone through all the steps of development, including final calibration, sensitivity analysis, as well as error and uncertainty analysis.

Operation and maintenance (O&M) (1) Control of the unit processes and equipment of a facility. This includes personnel and financial management, records, laboratory control, process control, safety and emergency operation planning. (2) Preservation of functional integrity and efficiency of equipment and structures. This includes preventive maintenance, corrective maintenance, and replacement of equipment as needed (EPA-40CFR35.2005-30).

Optical current meter A device consisting mainly of a stroboscope for measuring the velocity of moving water without installation in the stream; particularly useful in flood flow measurements. *See also* Price current meter.

Optimum design discharge In flood mitigation analyses, the optimum design discharge is the peak flow corresponding to a project with minimum costs, including capital expenditures, operation and maintenance costs, as well as monetary values of flood damages. Also called **optimum design flood**, which may be characterized by both its magnitude and its return period. *See also* probable maximum flood.

Optimum design flood *See* optimum design discharge.

Ordinary storm *See* storm severity.

Orifice An opening (hole) in a plate, wall, or partition. An **orifice flange** or **plate** placed in a pipe consists of a slot or a calibrated circular hole smaller than the pipe diameter. The pressure difference in the pipe above and at the orifice may be used to determine the flow in the pipe (EPA Glossaries). *See* Figure O-3; orifice (large); orifice flow; dropout or sump orifice.

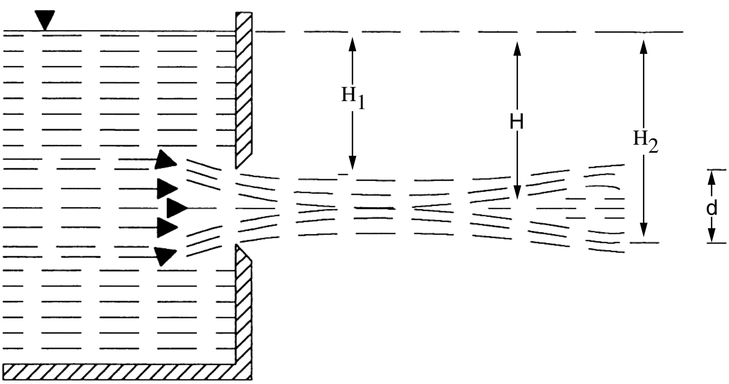


FIGURE O-3 Orifice flow.

Orifice (large) An orifice with a diameter or opening d that exceeds 20% of the head H; i.e., $d > 0.2$ H. *See* Figure O-3. *See also* Equation (O-8) for a large rectangular orifice.

Orifice flow Flow through an orifice in the side or the bottom of a container. For a small orifice (with respect to the head H over the center of the opening), the **Torricelli equation** expresses the actual discharge Q as:

$$Q = KA\sqrt{2gH} \tag{O-7}$$

where K is the orifice flow coefficient, A is the orifice area, and g is the gravitational acceleration. *See also* sluice, sluice flow. For a large rectangular orifice of length L and heads H_1 and H_2 over its top and bottom, the theoretical flow is:

$$Q = 2KL\sqrt{2g}\left(H_2^{1.5} - H_1^{1.5}\right)/3 \tag{O-8}$$

Orifice meter A device to measure flow based on the differential pressure across a restriction and on the pressure exerted on the system.

Orifice plate A flow measurement device for liquids or gases; uses a restrictive orifice consisting of a machined hole that produces a jet effect. Typically, the orifice meter consists of a thin plate with a square edged, concentric, and circular orifice. The pressure drop of the jet effect across the orifice is proportional to the flowrate. The pressure drop can be measured with a manometer or differential pressure gage (EPA Glossaries). The **orifice-plate discharge equation** expresses the flow Q through an orifice plate as a function of the energy loss coefficient c, the orifice area A, the ratio d/D of the diameters of the orifice and pipe, the pressure differential ΔP, the specific gravity of the fluid γ, the flow coefficient K, and the acceleration of gravity g:

$$Q = cA(2g\Delta P/\gamma)^{1/2}/[1 - c^2(d/D)^4] \tag{O-9}$$

or

$$Q = KA(2g\Delta P/\gamma)^{1/2} \tag{O-10}$$

with

$$K = c/[1 - c^2(d/D)^4] \tag{O-11}$$

The coefficients c and K may be determined experimentally for given orifice sizes and Reynolds numbers. *See also* discharge coefficient; Figure O-4. Flow through an orifice plate is similar to flow through a venturi meter, but with a lower discharge coefficient.

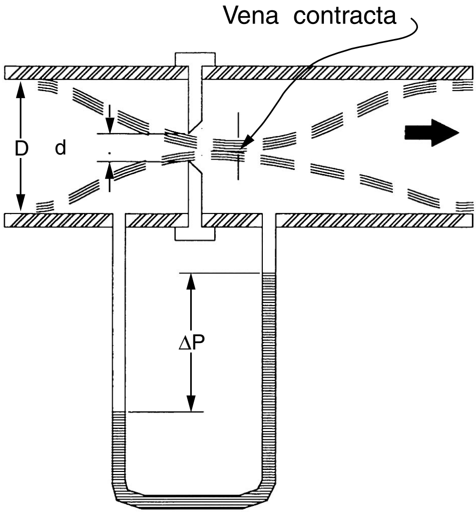


FIGURE O-4 Orifice plate (flow measurement).

OS Abbreviation for operating system.

Ounce (oz) A unit of mass equal to 1/16 pound or approximately 28.35 g.

Outfall (1) The place where effluent is discharged into receiving waters. (2) A point at which a municipal separate storm sewer discharges to waters in the United States, excluding open conveyances that connect two municipal separate storm sewers or pipes, tunnels, or other conveyances that connect segments of the same stream or other waters of the United States and are used to convey waters of the United States (EPA-40CFR122.26-9). (3) An **outfall sewer** receives wastewater from a sewer network or from a treatment plant and carries it to a point of final disposal. A **wastewater outfall** is an outlet or a structure for final wastewater disposal. **Outfall structures** are structures for wastewater or stormwater outfall, such as those that the Stormwater Management Model (SWMM) can simulate: transverse weirs with or without tide gates, side flow weirs without tide gates, and free outfalls without tide gates.

Outlet (1) The point at which water discharges from a stream, river, lake, tidal basin, pipe, channel or drainage area. (2) Opening near the bottom of a dam for draining the reservoir. (3) The discharge opening from a water distributing system, a boiler, heating system, or any water-operated device or equipment. An **outlet channel** is a channel or waterway that carries water away from a lake, reservoir, or other body of surface water or from man-made structures such as terraces, subsurface drains, diversions, or impoundments.

Outlet control (1) The device that controls the discharge of a hydraulic structure in function of its headwater, when the device is installed at the outlet. (2) In culvert design, **outlet control** exists when discharge depends on all hydraulic variables (e.g., length, slope, roughness, pipe diameter), while **inlet control** means that only entrance conditions and culvert size govern.

Outlet structures Same as **control structures**.

Outlet weir The main structure or device constituting the outlet of a sedimentation tank; installed at the discharge side of a rectangular or square tank or around the periphery of a circular tank. *See also* clarifier weir; effluent weir.

Outliers Data points that do not follow the general trend on the plot of a data set. Outliers possess particular characteristics that cause them not to fit a general probability density function, but they are often among the most important observations of the data set. An example of an outlier is a 100-yr event falling in a 1-yr period.

Output interface *See* back-end interface.

Output variables *See* model output.

Outside diameter (OD) The outer diameter of a pipe, including the wall thickness. *See also* inside diameter; nominal diameter.

Overbank flow Streamflow in excess of the capacity of the channel and occurring on the banks or part of the floodplain.

Overdraft The pumping of water from a groundwater basin or aquifer in excess of the supply flowing into the basin; it results in a depletion or "mining" of the groundwater in the basin (EPA-94/04).

Overfall The part of a dam over which water flows or the actual water flow over the dam.

Overfall dam A dam without a separate spillway; i.e., the dam crest is designed to accommodate overflows. Also called **spillway dam**.

Overfall weir Same as **overflow weir**.

Overflow (1) The intentional or unintentional diversion or discharge of untreated wastewater or stormwater to the environment; caused by inadequate conveyance or treatment capacity, electrical or mechanical failure, line blockages or restrictions, or human error. (2) The actual volume of liquid that overflows; i.e., the volume of wastewater or stormwater that exceeds the capacity of the conveyance or treatment facilities. (3) The water that exceeds the ordinary limits such as stream banks, the spillway crest, or the ordinary level of a container. *See also* reservoir storage; surcharge storage. (4) An overflow structure or device that allows the discharge of the excess liquid, such as (a) **overflow channel** or spillway channel (an artificial waterway from a reservoir, aqueduct, or canal); (b) **overflow manhole**, used mostly in combined sewer systems, at pump stations, or at treatment plants; (c) **overflow spillway** (also called **ogee spillway** or **gravity spillway**), i.e., a widely used structure to discharge the overflow of a dam; (d) **overflow weir** (sometimes called an **overfall weir** or a **diverting weir**), i.e., a weir over which excess water, stormwater, or wastewater is allowed to flow. *See also* combined sewer overflow. In wastewater treatment, the **overflow rate**, also called the **surface loading rate**, is a design and operation parameter for settling tanks and clarifiers; expressed in gallons per day per square foot, it is equal to the ratio of the average flowrate (gal/day) to the surface area of tank (ft^2). *See also* weir exponent, weir overflow rate (or weir loading).

Overflow frequency curve A curve that shows the number of overflows versus the depth of storage facilities in stormwater pollution control studies.

Overflow manhole *See* overflow.

Overflow pipe A pipe installed in a water tank or other container to prevent the liquid from rising above a certain level. The top of the pipe is open at the desired level, and its bottom drains outside the container. Also called **overflow standpipe**.

Overflow rate *See* overflow.

Overflow spillway A widely used structure for conveying the overflows of gravity and other types of dam through a steeply sloping S-shaped channel between its crest and bucket or toe. The prevention of cavitation and energy dissipation (through such means as aprons, buckets, hydraulic jumps, or stilling basins) are important considerations in the design of an overflow spillway. Also called **gravity spillway** or **ogee spillway**. *See* Figure S-9. The discharge Q over the spillway is a function of the length L of the crest, the head H over the spillway, and a discharge coefficient K, which varies with the head:

$$Q = KLH^{1.5} \tag{O-12}$$

Overflow structure A weir or other structure to allow water to spill freely to a lower level or into another carrier.

Overflow tower A device placed on one or more summits of a closed conduit to control the pressure by discharging water. *See also* pressure-relief device or valve.

Overflow weir *See* overflow.

Overland flow (1) Also called **excess rainfall**, **storm flow**, or **surface runoff**, it includes overland runoff and the precipitation that falls directly into streams, brooks, rivulets, ravines, and rills. *See also* rainfall–runoff relationship. (2) A land application technique that treats wastewater by allowing it to flow over a sloped surface. As water flows over the surface, contaminants are absorbed, and the water is collected at the bottom of the slope for reuse (EPA-94/04).

Overland flow element One of three basic elements of the HEC-1 model to simulate the runoff process, it is a rectangular plane characterized by a unit width, a typical length, a representative slope, a roughness coefficient, its percentage of the subbasin area, infiltration, and loss rate parameters. The other two elements are a collector channel and a main channel.

Overland flow technique Use of Izzard's formula to estimate the time of concentration.

Overland runoff The portion of precipitation that reaches the nearest channel by flowing over the ground surface or by combining with the interflow as subsurface runoff. *See* Figure R-6; inlet time, Izzard's formula; rainfall–runoff relationship.

Overland time The time it takes stormwater from any point or surface of the drainage area to reach an inlet. *See* Kerby formula; time of concentration (which is sometimes computed as the sum of the overland time of the most distant point of the area and the time of flow in the sewer or drain). Also called **inlet time**.

Overland time of concentration *See* kinematic wave equation.

Overrelaxation factor *See* relaxation factor.

Overshoot A response or result that exceeds what is expected, or the amount of the excess. Conversely, for **undershoot**. In groundwater modeling, e.g., an overshoot may be a head or a concentration output that is larger than the actual value. In geographic information system (GIS) procedures, an undershoot is a kind of dangling line that is left too short, creating a gap in a polygon's boundary.

Overshot wheel A vertical wheel turned by the weight of water in buckets attached to the rim. *See also* water wheel.

Overtopping Flowing over the top of a dam, embankment, or the like.

Overturning Same as **turnover**.

Over-year storage Storage designed to compensate for deficits in dry years by holding excess water in wet years. Also called **carry-over**, as opposed to within-year, **storage**.

Oz Abbreviation for ounce.

P

Package (wastewater treatment) plant A prefabricated treatment plant that performs one or more processes for small flows, usually in a single tank.

Paired data (1) Data that represent two variables, one of which depends on the other according to a relationship such as a curve or an equation, e.g., flow–frequency curves, stage–discharge relationships, and a unit hydrograph ordinate as a function of the drainage area. Given historical data on two related variables or parameters, their relationship may be defined using regression analysis. (2) Paired data may also represent the same variable or parameter from two different sources, e.g., observation or measurement and simulation.

Palatable water Water at a desirable temperature and free from objectionable tastes, odors, colors, and turbidity (EPA-94/04).

Palmer–Bowlus flume A type of venturi flume that uses a constricted throat to measure flow in manholes and partially full pipes. Its flat bottom makes it easier (than the Parshall flume) to install in an existing structure.

Pan coefficient The ratio of evaporation from a large body of water to that measured in an evaporation pan.

Pan evaporation The evaporation rate as determined by the method of evaporation pan. *See also* actual evaporation; actual evapotranspiration; soil moisture loss equation.

Pannier A basket of metal iron, wicker work, or other material; filled with earth or stones and used as a foundation mat, as a military defense, or to control erosion. Also called a **gabion**.

Parabolic interpolation A procedure in the HEC-RAS model to speed the iterative solution of the specific energy equation (Hoggan, 1997).

Parabolic weir A weir that has a parabolic notch and a vertical axis. *See* Figure W-7.

Parallel-finger weir A type of launder installed on supporting weirs as part of the sludge collection equipment in wastewater sedimentation tanks.

Parallel-plate model A two-dimensional groundwater model based on the analogy with the movement of a viscous fluid, such as glycerin, between two parallel plates. Also called **viscous fluid model** or **Hele–Shaw model**.

Parameter A variable, measurable property with a value that is a determinant of the characteristics of a system; e.g., temperature, pressure, and density are parameters of the atmosphere (EPA-94/04). *Also see* model parameters.

Parameterization The definition and initial estimation of a model's parameters, coefficients, and constants.

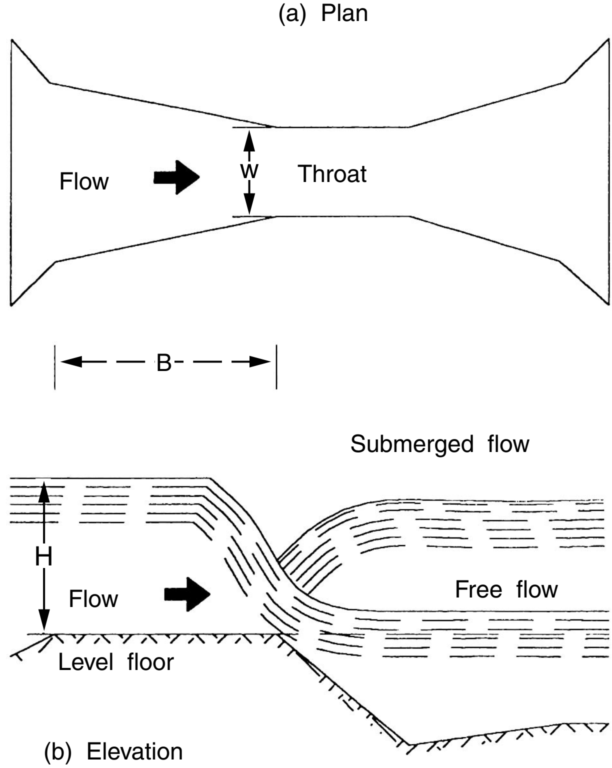


FIGURE P-1 Parshall flume.

Parametric model A model that has both deterministic and stochastic characteristics; i.e., the model yields the same output from a given input once its parameters are determined, but the parameters vary with observed data. Also called a **pseudodeterministic model**.

Parshall flume A calibrated device developed by R. L. Parshall for the measurement of small open-channel flows. It consists of a converging section, a throat with a sill (creating critical flow conditions), and a diverging (or expanding) section. *See* Figure P-1. The discharge Q is determined as a function of the throat width W and the upstream water depth H (Simon and Korom, 1997):

$$Q = 4W \cdot H^x \text{ with } x = 1.522W^{0.226} \qquad \text{(P-1)}$$

Parshall, Ralph Leroy *See* hydraulics.

Partial duration curve A plot of a partial duration series, usually on semilogarithm paper, with the average recurrence interval as the abscissa and the event magnitude as the ordinate.

Partial duration series A series of extreme events (e.g., floods or droughts) more severe than some arbitrary base. There may be more than one extreme event in some periods, while some other periods may not be represented at all. Thus, this series differs from the annual duration series, but it is the same as the exceedance series if the number of events in the series equals the number of periods.

Partial flow diagram Also called a **hydraulic elements graph**; for circular conduits flowing partially filled, it shows how the ratios of the partial elements vary with the depth ratio. *See* Figure H-1.

Partial series *See* partial duration series.

Partial source area A theory of runoff generation similar to the Horton overland flow concept, but with a reduced area contributing to runoff (as opposed to the entire drainage area).

Particle A very small solid suspended in water or wastewater; it can vary widely in size, shape, density, and electrical charge. Colloidal and dispersed particles can be gathered together by coagulation and flocculation.

Particulate As an adjective: of, pertaining to, or composed of particles. As a noun: a separate and distinct particle or a material composed of such particles. Particulates are also fine liquid or solid particles such as dust, smoke, mist, fumes, or smog found in air or emissions.

Particulate matter Any finely divided solid or liquid material, other than uncombined water (EPA-40CFR61.171).

Parts per billion (ppb) *See* parts per million.

Parts per million (ppm), parts per billion (ppb), and parts per million by volume (ppmv) Units commonly used to express contamination ratios or other concentrations, as in establishing the maximum permissible amount of a contaminant in water, land, or air; 1 ppm means 1 part of a substance contained in 1 million parts of a solid, liquid, or gas on a weight or volume basis, and this is similar for 1 ppb. In water and wastewater calculations, ppm is approximately equal to, and has been largely replaced by, mg/l. The unit ppmv is used mainly for gases; it means a volume/volume ratio that expresses the volumetric concentration of a gaseous contaminant in 1 million unit volumes of air.

Pascal (Pa) The standard international unit of vapor pressure (or pressure in general); defined as newtons per square meter (N/m^2). A newton is the force necessary to give acceleration of 1 m/sec^2 to 1 kg of mass (EPA-40CFR796.1950-ii); 1 Pa is approximately 6895 psi.

Pathname A unique name that identifies a data set stored in records or files of such computer programs as ANNIE and HEC-DSS. The pathname may include such descriptive information as project name, data type, and timestep. *See also* catalog.

P_{av} Notation for average annual precipitation.

Paved chute A slope drain constructed on the surface of the slope and covered with concrete or other impenetrable materials.

PC Abbreviation for personal computer,

PCA Abbreviation for principal component analysis.

PCSWMM A personal computer version of Stormwater Management Model (SWMM) distributed by Computational Hydraulics, Inc., of Guelph, Ontario, Canada.

PDF (or pdf) Abbreviation for probability density (or distribution) function.

Peak The maximum quantity occurring over a relatively short period of time, such as 1 h. Also called **peak demand** or **peak load**. Peaks are sometimes defined for longer periods, e.g., peak monthly wastewater flows.

Peak demand (or peak load) The maximum momentary load on a utility such as an electric generating plant or a water, stormwater, or wastewater pump station or treatment plant. In sanitary engineering, the peak hydraulic demand is expressed in flow per hour or a shorter period of time.

Peak design flowrate The peak discharge that a facility is designed to accommodate.

Peak discharge (or peak flow) (1) The maximum instantaneous, hourly, or other flow to a treatment plant, pumping station, or other facility. In streamflow studies, the peak discharge corresponds to the maximum water surface elevation during a given storm event and at a given location. It is a widely used parameter in the hydraulic design of pipes, pumping stations, treatment plants, inlets, culverts, detention facilities, etc. (2) **Peak flow** is one of the four parameters of Snyder's method of synthetic hydrograph. *See also* lag time; rainfall duration; time base. Other parameters used in runoff analysis include antecedent precipitation index (API), attenuation constant, plotting time width, time of concentration, and time of equilibrium.

Peak flow study A study to determine the likelihood of sewer overflows and the cost-effective measures to prevent or alleviate them, including the upgrading of collection and transmission facilities.

PEAKFQ A model developed by the U.S. Geological Survey to carry out flood frequency and magnitude computations using the log-Pearson type III distribution.

Peaking factor The ratio of peak to average flows. *See also* peak rate factor.

Peak load Same as **peak demand**.

Peak rate factor (PRF) A parameter used in the Soil Conservation Service dimensionless unit hydrograph method to relate the peak discharge to the drainage area, the runoff depth, and the time to peak.

Pearson distributions Two extreme event probability distributions commonly used in hydrological analysis: the Pearson type III distribution (also called the three-parameter gamma distribution) and the log-Pearson type III distribution. Both correspond to density functions f(x) of a random variable x and include the gamma function $\Gamma(n)$ with its three parameters: scale K, shape n, and location x_0.

Peclet criterion A limit set on the Peclet number to control numerical dispersion. To ensure numerical stability and minimize dispersion in a groundwater transport model, e.g., a Peclet number less than 2 is recommended (Spitz and Moreno, 1996).

Peclet number (P_e) A dimensionless number that indicates when advection dominates ($P_e >> 1$) or turbulence mixing dominates ($P_e << 1$). The Peclet number is the ratio of the advective flux to the dispersive flux, i.e., the product of a characteristic length L_s and mean velocity V in the direction of that length divided by an appropriate mixing or diffusion coefficient ε. The Peclet number is sometimes used to control the stability of numerical solutions in hydraulic modeling. (The symbols << and >> mean, respectively, much less than and much more than.) *See* Peclet criterion.

$$P_e = L_s \cdot V/\varepsilon \qquad \text{(P-2)}$$

Pellicular water Subsurface water that adheres to soil particles after drainage by gravity. Also called **water of adhesion**, it is found between the soil and gravity subzones. It can be absorbed by roots and is subject to evapotranspiration. *See* Figure S-14; subsurface water.

Pelton turbine A hydraulic turbine of the impulse type that converts water energy into kinetic energy and discharges the water through a nozzle into buckets on the perimeter of a wheel. The wheel rotates to provide energy. Also called **Pelton wheel**.

Penman method A combination of the aerodynamic and energy balance methods to estimate the evaporation rate E_p from lakes and reservoirs. It is a weighted average of the aerodynamic estimate E_a and the energy balance estimate E_e; the weighting factors are the gradient of saturated vapor pressure π (from the aerodynamic method) and the psychrometric constant (from the energy balance method). *See also* evaporation pan method.

$$E_p = (E_a + \pi E_e)/(\gamma + \pi) \qquad \text{(P-3)}$$

Penman–Monteith method A modification of the Penman method by introducing a factor to account for plant transpiration so that the Equation P-3, the modified equation, can be used to estimate potential evapotranspiration over a drainage basin. See Gupta (2001) for the complete **Penman–Monteith equation**.

Penstock A pipeline or conduit, controlled by valves, that carries water from the intake to the turbine of a hydroelectric plant or a valve or sluice gate for regulating flows. *See* forebay.

Pentium™ A microprocessor chip manufactured by the Intel Co. and used in computers.

Percentage saturation The amount of a substance that is dissolved in a solution compared to the amount that could be dissolved in it.

Perched aquifer An unconfined body of water lying on an impermeable layer in the zone of aeration, i.e., above the main water table. **Perched groundwater** is separated from the main reservoir by a formation of very low permeability. Also called **perched water** or a zone of unpressurized water held above the water table by impermeable rock or sediment (EPA-94/04). The **perched water table** is the water surface of a body of perched groundwater. *See also* aquifer; Figure A-1.

Percolating water Water that passes through rocks or soil under the force of gravity.

Percolation The movement of water downward and radially through subsurface soil layers, continuing downward to the groundwater. Can also involve upward movement of the water or the slow seepage of water through a filter (EPA-94/04).

Percolation test A test to determine the percolation rate of water through soil by measuring the drop in water level in a test hole over a period of time. Also called **perc test**.

Perennial stream A stream that flows continuously during all seasons, in dry as well as wet years, as a result of groundwater discharge or surface runoff. Its water surface is generally lower than the adjoining water table. A **perennial interrupted stream** has perennial stretches separated by ephemeral or intermittent stretches. A perennial stream flows more than 80% of the time. *See also* ephemeral stream; gully; intermittent stream; ravine; rill; rivulet. A **perennial spring** discharges continuously during all seasons, in dry as well as wet years.

Perennial yield The quantity of groundwater available for use without impairing the aquifer. It is equal to the recharge capability of the basin, taking into account the volume of underground storage and the recharge potential. *See also* groundwater yield.

Perfect fluid A fictitious fluid that would be incompressible and inviscid (i.e., without viscosity) and would have uniform density and no surface tension. The convenient assumption of perfect flow produces results that are fairly accurate for actual fluids. Also called **ideal fluid**.

Performance characteristics Certain properties used for the selection of pumps and pump systems, their comparison and performance evaluation: capacity, head, power, efficiency, and specific head. They depend on pump size, speed, and design. *See* pump characteristic curves.

Perigee The point on the orbit of the moon (or other heavenly body or man-made satellite) that is closest to the earth. At that point, the tidal range (**perigean range**) is increased. The opposite is apogee.

Perimeter bank A temporary barrier, usually of compacted soil, around a construction site for runoff and sediment control.

Peripheral weir The outlet weir of a circular settling tank for effluent discharge.

Permanent pool The portion of a pond, tank, or other detention/retention facility that is considered dead storage, as opposed to the active storage zone, which releases water during storm events. Extended detention dry ponds have only an active storage zone, while a wet pond has both an active storage zone and a permanent pool. Also called **permanent volume**. *See* Figure R-2; reservoir storage.

Permeability Property of a soil or other material that permits the movement of water through it. The capacity of a rock to transmit water. Also, the rate at which liquids pass through soil or other material in a specified direction. Same as **perviousness**. Often used synonymously with hydraulic conductivity or coefficient of permeability.

Permeability coefficient The flowrate through permeable materials under a hydraulic gradient. The U.S. Geological Survey uses the Meinzer unit, which is the rate of flow of water at 60°F in gallons per day through a cross section of 1 ft^2 under a hydraulic gradient of 100%. This is the standard **coefficient of permeability**. There is also the **field coefficient of permeability**, which is the flow through a cross-sectional area 1 mi wide and 1 ft thick under a hydraulic gradient of 1 ft/mi and at the ambient water temperature. *See also* Darcy's law; hydraulic conductivity; time of concentration (formula).

Permeable (or pervious) Said of soils having a texture with communicating interstices of capillary size, which allows the movement or passage of water under ordinary head differences. *See* permeability coefficient.

Permeameter A device used to measure permeability.

Permitted capacity The maximum average flow that a treatment plant is allowed to process as determined on its National Pollutant Discharge Elimination System (NPDES) permit.

Personal computer A microcomputer designed for use by an individual. A PC system usually includes a central processing unit with memory drives, a monitor, a keyboard, and a printer.

Pervious Same as **permeable**. A pervious surface allows water to infiltrate to the subsurface.

Perviousness *See* permeability.

PET Acronym for potential evapotranspiration.

Petcock A small valve or faucet used for draining excess or waste from a container, fitting, or other device.

Petrogenesis, petrogeny, petrography *See* petrology.

Petrology (From the Greek words *petra*, meaning rock, or *petros*, a stone) The branch of science that studies rocks — their origin and formation (**petrogenesis** or **petrogeny**) and their description and classification (**petrography**).

pF The symbol for the common (base-10) logarithm of the head (in centimeters of water) required to produce a suction equal to the capillary potential. It is used as a measure of moisture tension.

pH The negative base-10 logarithm of the hydrogen ion concentration (or the logarithm of the reciprocal of hydrogen ion concentration). An expression of the intensity of the basic or acid condition of a liquid. The pH may range from 0 to 14, where 0 is the most acid, 7 is neutral. Natural waters usually have a pH between 6.5 and 8.5.

Phreatic From the Greek *phreas*, meaning artificial well. Denoting or pertaining to groundwater, to the water table, or to the layers of soil and rock below the water table, but above the zone of rock flowage. *See* Figure S-14.

Phreatic aquifer An aquifer containing water that is not under pressure. Its upper boundary (contrary to that of an artesian aquifer) is the water table below the vadose zone. The water level in a well through a phreatic aquifer is the same as the water table outside the well. *See also* Figure S-14; subsurface water. Also called **unconfined aquifer** or **water-table aquifer**.

Phreatic decline The decline or downward movement of the water table.

Phreatic divide Similar to a watershed boundary, the phreatic divide defines underground the limits of the areas that contribute water to a stream. Also called **groundwater divide**.

Phreatic fluctuation The fluctuation of the water table.

Phreatic line In an earthfill dam, the topmost seepage line. More generally, the upper boundary of the water table or a line of atmospheric pressure in the vadose zone. Also called **saturation line**.

Phreatic rise The rise or upward movement of the water table.

Phreatic surface *See* water table.

Phreatic water (or **simply groundwater)** Subsurface water in the zone of saturation, just below the water table and also in unconnected pores of rocks. It is subdivided into free water, water in aquicludes and aquifers, fixed groundwater, and connate water. Sometimes phreatic water is distinguished from artesian water. *See* Figure S-14; subsurface water.

Phreatic wave An oscillatory movement of the water table caused by a substantial addition of water in a short period and over a small area. Also called **groundwater wave**.

Phreatic well A well that penetrates a phreatic aquifer; its water level is the same as the outside water table. Also called a **water-table well**. The opposite is an artesian well. *See* Figure A-1.

Physical inspection An activity of a sewer system evaluation survey; designed to determine the physical condition of the sewers and the potential sources of infiltration/inflow. It involves crawling or walking through accessible pipelines. *See* internal inspection; physical survey.

Physical-scale model A physical representation of a prototype at a full or reduced scale, but preserving the predominant characteristics of the prototype. Accurate physical models have the properties of dynamic similarity, geometric similarity, and kinematic similarity. *See* hydraulic model. The use of a model that neglects some of the features of the prototype introduces an error called the scale effect. Also called **scale model** or **physical model**. Other types of model are analog, iconic, and symbolic models.

Physical survey An activity of a sewer system evaluation survey, designed to determine specific flow characteristics, groundwater levels, and physical condition of the sewer system, in areas suspected of causing excessive infiltration/inflow. *See also* physical inspection.

Pi (π) theorem A statement used in conducting dimensional analysis and relating dimensionless numbers to fundamental quantities. *See* dimensional analysis theorem.

Piecewise interpolation The first of two steps to achieve discretization in the finite-element method and obtain a local solution. *See also* weighted residual construction.

Pier *See* jetty.

Piezo Prefix from the Greek for pressure.

Piezometer An instrument for measuring pressure in fluids or compressibility of materials. It may consist of a small pipe or tube attached to a conduit or tank and connected to a manometer. A vessel may be used to measure compressibility as the change in volume of a substance in response to hydrostatic pressure.

Piezometer opening A small hole normal to the wall of a pipe or container under pressure; used for the connection of static pressure monitors. Also called **pressure tap** or **static pressure tap**. *See also* Figure M-1; manometer.

Piezometer tube A simple device to measure liquid pressure in a closed pipe; consists of a transparent vertical or slanted tube tapped into the pipe. The liquid rises in the tube to a height such that the static pressure in the tube equals that of the pipe. Also called **piezometric tube**.

Piezometric head The sum of the elevation and pressure heads or the difference between total head and velocity head. It corresponds to the hydraulic gradeline and indicates the level to which water would rise in a piezometer tube. In open-channel flow, it corresponds to the water surface. Also called **piezometric height**.

Piezometric level The level to which water will rise in a tube penetrating an artesian aquifer.

Piezometric map, piezometric surface, piezometric surface map These terms refer to isopiestic lines of an aquifer. These imaginary lines connect points of equal elevation of an unconfined aquifer or points of equal piezometric level in an artesian aquifer. The **piezometric surface,** or **potentiometric surface**, indicates the static level of an aquifer, e.g., as the surface defined by the water levels in a group of wells; it is the artesian equivalent of the water table. The **piezometric** or **isopiestic map** shows the shape of the piezometric surface with the piezometric contour lines.

Piezometric tube Same as **piezometer tube**.

Pigtail A portion of a service connection between the water distribution main and a meter (EPA Glossaries). Also called a **gooseneck**.

Pint American unit used to measure the volume of liquids, equal to 1/8 gal, 297/8 in^3, or approximately 0.4731 l.

Pipe (or piping) A hollow cylinder or tubular conduit that is constructed of metal, clay, plastic, wood, or concrete and used to conduct fluids or finely divided solids.

Pipe bedding The surface, foundation, or bottom layer on which a pipe is installed.

Pipe bit A bit used for socketing a pipe in bedrock.

Pipe box A casing packed with loose materials and enclosing a set of pipes.

Pipe characteristics Properties of a pipe that affect fluid flow, e.g., roughness coefficient and k-factors.

Pipe clamp A device used in pipework to grasp and hoist or suspend pipes.

Pipe classification A system for rating certain types of pipe and pipe fitting according to their working pressures. It applies to pipes used under pressure, mainly in drinking water networks, for example, asbestos–cement, cast iron, ductile iron, glass, and plastic pipes. The pipe class indicates its pressure rating, including allowances for surges. *See also* pipe schedule.

Pipe culvert A buried pipe used as a culvert.

Pipe cutter A machine or tool used for cutting cast-iron pipe and copper tubing. It consists of three rolling blades or cutting wheels that are forced inward by screw pressure as the tool rotates around and cuts the pipe.

Pipe diameter The nominal or inside diameter of a circular pipe. *See also* pipe schedule.

Pipe elbow meter A variable head meter for measuring flow around an elbow.

Pipe finder A device that locates underground metal piping magnetically or electronically.

Pipe fitter A person who performs piping work: installation, fitting, threading, and repair.

Pipe fitting The work performed by a pipe fitter.

Pipe fittings Various pieces used in connection with pipes, e.g., bends, bushings, caps, couplings, crosses, diminishers, elbows, joints, nipples, plugs, reducing sockets, tees, unions.

Pipe flow Fluid conveyance in closed conduits, as compared to open-channel flow.

Pipe flow methods Approaches used in the analysis of flow in closed conduits, e.g., to determine energy losses or required pipe sizes. The empirical, scientific, and conveyance methods are based on the Hazen–Williams (Equation H-8), Darcy–Weisbach (Equation D-3), and conveyance (Equation C-26) formulas. The Hardy Cross method is used to solve small pipe network problems.

Pipe gallery A gallery or conduit (in a treatment plant, for example) for the installation of pipes and accessories, with appropriate space allowance for maintenance and repair.

Pipe gauge A number that indicates the thickness of the sheet metal used in the fabrication of a steel pipe.

Pipe grade The slope of a pipe section.

Pipe joint sealing A method of sealing a defective pipe joint by injection of chemical grout from inside the pipe.

Pipe layer A person who performs or has experience in pipeline laying.

Pipe laying The installation of buried pipelines.

Pipeline Pipes jointed and connected to control devices for conducting fluids or finely divided solids.

Pipeliner A person or firm with experience in pipe laying or actually performing such work.

Pipeline reconstruction A sewer rehabilitation method that repairs an existing pipeline *in situ* by inserting a liner into the line at the point of defect.

Pipe run A series of pipe sections or the path of a piping system.

Pipe saw A power tool that is used to cut or grind iron, steel, and concrete pipes.

Pipe scale Rust and corrosion materials that are formed on the inside walls of pipes.

Pipe schedule A sizing system of arbitrary numbers that specifies the inside and outside diameters of each pipe size. This term is used for steel, wrought iron, and some types of plastic pipe and to describe the strength of some types of plastic pipe (EPA Glossaries). For example, a plastic pipe schedule 40, common in water and wastewater work, with a nominal diameter of 16 in, actually has an inside diameter of 15 in. *See also* pipe classification.

Pipe sleeve A hollow insert in the form of a masonry wall for the installation of a pipe.

Pipe tap A small threaded opening into the wall of a pipe for sampling, connecting, or measuring devices.

Pipework Same as **piping** (2).

Pipe wrench A tool with fixed and movable toothed jaws to grip pipes, rods, and similar objects when the tool is turned in one direction only.

Piping (1) A phenomenon that accompanies seepage underneath a dam; water carries some of the finer materials away from the dam, which may cause excessive leakage or failure. *See also* creep ratio; quicksand. (2) Same as pipe; pipes, collectively; or a system of pipes, fittings, and appurtenances. Also called **pipework**.

Piston pump A displacement pump that moves and imparts pressure to fluids through a reciprocating piston or plunger in a cylinder; single action or double action, depending on whether the piston acts in one end or both ends of the cylinder. Same as **reciprocating pump**.

Pitometer, Pitot–static tube, Pitot tube These are all differential-head meters; devices that indicate velocity heads ($V^2/2g$) in pipes and are used for calculating the velocity V of flowing fluids, for establishing velocity profiles, for computing flows, for investigating waste and leakage. They measure the pressure P at the center in a Pitot tube and the static pressure P′ in a static tube. *See* Figure P-2. With a flow coefficient K, a fluid specific weight γ, and a gravitational acceleration g:

$$V = K \cdot [2g(P - P')/\gamma]^{0.5} \tag{P-4}$$

However, the distinction between one term and the others is not always clear. See, e.g., *Webster's New World Dictionary of American English*, 3rd edition (1991) for definitions of Pitot–static tube, Pitot tube, and static tube; American Public Health Association et al. (1981) for definitions of pitometer and Pitot tube; Linsley et al. (1992, page 36) for a discussion of Pitot–static tubes, pitometers, and Cole pitometers; Simon and Korom (1997, pp. 77–79) for a discussion of Pitot, static, and Prandtl tubes; Chadwick and Morfett (1998, pp. 40–41) for a discussion of velocity measurement. A **pitometer survey** is a survey of a water distribution system using a pitometer to determine velocities at various points as well

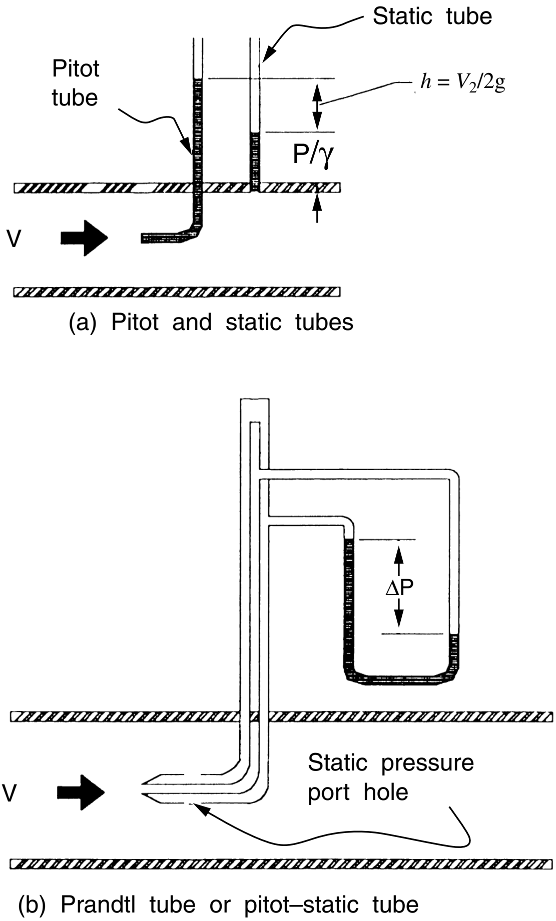


FIGURE P-2 Pitot tube.

as the conditions of the piping system. The **Pitot–static tube** is a device used to measure the velocity of flowing fluids; it consists of the combination of a Pitot tube and a static tube. Also called **Prandtl tube**. The **Pitot tube** is a device for measuring the total pressure of a fluid stream; essentially, a tube attached to a manometer at one end and pointed upstream at the other (EPA Glossaries).

Pitot, Henri de *See* hydraulics.

Pixel The tiny dots that form an on-screen image or the smallest image-forming unit of a video display (from *pix* for photographs or movies, and *el*ements).

Plain joint *See* bell-and-spigot joint.

Planning and plans The planning process identifies problems, defines objectives, collects information, analyzes alternatives, and determines necessary activities and courses of action. **Plans** are reports and drawings, including a narrative operating description, prepared to describe a facility and its proposed operation (EPA-40CFR256.06 and EPA-40CFR240.101-t).

Plasticity index (PI) The difference between the liquid limit and plastic limit of a soil; in other words, the range of water content in a plastic soil. The **plastic limit** (PL) is a measure of the water content of soils passing from the plastic to the solid state or the lower limit of the plastic state of a soil. **Plastic soils** are typically silts and clays or soils that deform without shearing. *See* Atterberg limits.

Plotting position An estimate of the probability or return period of an event in the exceedance series to determine its abscissa on the frequency curve. Three commonly used formulas for calculating plotting positions are the Hazen, median, and Weibull formulas.

Plotting time widths Two parameters used to draw a synthetic unit hydrograph given the peak discharge, the time to peak, and the lag time. The two parameters, time width at 50% of peak discharge W_{50} and time width at 75% of peak discharge W_{75}, are determined by the following equations of the Corps of Engineers (Gupta, 2001):

$$W_{50} = 770(A/Q)^{1.08} \quad \text{(P-5)}$$

and

$$W_{75} = 440(A/Q)^{1.08} \quad \text{(P-6)}$$

where A is the drainage area (mi^2), and Q is the peak discharge (ft^3/sec). The time widths are expressed in hours. *See also* Equations U-5 and U-6, which differ from Equations P-5 and P-6; unit hydrograph. Plotting time width is a parameter used in runoff analysis. Other parameters are antecedent precipitation index (API), attenuation constant, lag time, peak discharge, rainfall duration, time base, time of concentration, and time of equilibrium.

Plugflow The type of flow that occurs in tanks, basins, or reactors when a slug of water moves through without ever dispersing or mixing with the rest of the water flowing through (EPA-94/04). Flow in which fluid and solid particles move as well-mixed discrete parcels or volumes — without mixing between adjacent parcels — and are discharged in the same sequence that they enter. *See also* completely mixed flow. Under plugflow conditions, the fate of pollutants, in one-dimensional, longitudinal models of lakes and reservoirs, may be represented by a first-order decay equation (Martin and McCutcheon, 1999):

$$\partial C/\partial t = -K_d \cdot C - V \cdot \partial C/\partial x \quad \text{(P-7)}$$

where C is the constituent concentration, t is the time, K_d is a first-order decay coefficient, V is the average longitudinal velocity, and x is the longitudinal coordinate.

Plugging The act or process of stopping the flow of water, oil, or gas into or out of a formation through a borehole or well penetrating that formation (EPA-40CFR144.3).

Plug meter A variable-area flowmeter in which a tapered flow in an orifice is raised until the resulting opening is sufficient to handle the fluid flow.

Plumbing The pipes and fixtures used to supply and distribute water in a building and evacuate wastewater therefrom. *See also* house connection; house drain; public sewer; soil pipe; soil stack; waste pipe. For **plumbing fixtures,** *see* fixture unit. A **plumbing system** is the set of all elements that provide water supply and wastewater as well as stormwater disposal to a building, including pipes, pumps, fixtures, appurtenances, etc.

Plume A visible or measurable discharge of a contaminant from a given point of origin; e.g., a discrete volume of wastewater or drainage floating in estuarial or coastal waters. Can be visible or thermal in water as it extends downstream from the pollution source or visible in air as, for example, a plume of smoke (EPA-94/04).

Plunger pump A reciprocating pump with a plunger that does not contact the cylinder walls, but enters and withdraws from it through packing glands.

Pluviograph An instrument that measures and graphically records the cumulative rainfall as a function of time. Also called **recording rain gage**. *See also* hyetograph.

Pluviometer A device for catching rain and measuring its depth. Also called a **rain gage**.

PMF Abbreviation for probable maximum flood.

PMP Abbreviation for probable maximum precipitation.

PMS Abbreviation for probable maximum storm.

Pneumatic Of or pertaining to air, gases, wind; filled with compressed air. An airlift pump is used in **pneumatic pumping**. A **pneumatic tank** is a holding tank under pressure used in a closed water supply system instead of a pump to avoid surges associated with pump starts and stops. *See also* hydropneumatic tank.

Pocket storage Same as **depression storage**.

Point precipitation/rainfall Precipitation/rainfall measured at a single station or gage, as opposed to the average precipitation over an entire area.

Point source In general, a stationary location or fixed facility from which pollutants are discharged, any single identifiable source of pollution, e.g., a pipe, ditch, ship, ore pit, factory smokestack (EPA-94/04). Concerning water pollution, a point source is any discernible, confined, and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, landfill leachate collection system, and vessel or other floating craft from which pollutants are or may be discharged. It does not include return flows from irrigated agriculture or agricultural

TABLE P-1
General Differences between Point and Nonpoint Sources

Point Sources	Nonpoint Sources
Origin and cause	
Single source, discrete point	Many locations or sources, diffuse distribution
Domestic, industrial, and commercial water uses	Runoff from precipitation or groundwater movement
Means of abatement and control	
Wastewater treatment before discharge	Reduction or prevention of release of pollutants
Compliance with regulatory permits, inspections, and monitoring	Best management practices, change in land use activities, voluntary compliance, or regulation

stormwater runoff (EPA-40CFR122.2). Table P-1 shows some differences between point and nonpoint sources (Nix, 1994). *See* diffuse source of pollution; nonpoint source.

Poise A measure of absolute viscosity, equal to 1/10 of a newton-second per square meter (0.1 $N \cdot sec/m^2$) or 100 cP. Named after Jean-Louis Poiseuille.

Poiseuille, Jean-Louis *See* hydraulics.

Poleni, Giovanni *See* hydraulics.

Pollutant (or contaminant) Any substance introduced into the environment that adversely affects the usefulness of a resource (EPA-94/04). An element, compound, or mixture; an organic substance; an inorganic substance; a combination of organic and inorganic substances; or a pathogenic organism that, after discharge and on exposure, ingestion, inhalation, or assimilation into an organism either directly from the environment or indirectly by ingestion through the food chain could cause death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions (including malfunction in reproduction), or physical deformations in either organisms or their offspring (EPA-40CFR503.9-t and EPA-40CFR300.5).

Pollutant accumulation methods Two methods used in the Corps of Engineers' Storage Treatment Overflow Runoff Model (STORM) to simulate the concentration of six pollutants (biochemical oxygen demand [BOD], suspended solids, coliforms, etc.) in runoff. In one method, the concentration is a function of dust and dirt accumulation on streets. In the other, pollutant accumulation is simply based on a rate per unit area. In the same model, **pollutant availability factor** indicates that not all of an accumulated pollutant is washed off with runoff at any given time; it varies with the pollutant itself and with the runoff rate from impervious areas.

Pollutant export *See* pollutant load.

Pollutant load The amount of pollutant carried to a unit (**inflow pollutant load**) or from that unit (**pollutant export**), usually expressed in mass (pounds or kilograms). The **pollutant loading** or **pollutant load rate** is the mass of pollutant per unit time or the mass of pollutant per unit area (e.g., kg/day, $lb/ft^2/day$). In stormwater management, the yearly export and inflow loads L (lb) of such pollutants as nitrogen and phosphorus may be estimated from the yearly rainfall depth P (in), two dimensionless factors that adjust the rainfall depth for storms that produce runoff C, and for imperviousness I, the flow-weighted mean concentration of the pollutant C_0 (mg/l), and the drainage area A (acres) (James, 1994):

$$L = [(P)\cdot(C)\cdot(I)/12](C_0)\cdot(A)\cdot(2.72) \quad \text{(P-8)}$$

Pollution Generally, the presence of matter or energy for which the nature, location, or quantity produces undesired environmental effects. Under the Clean Water Act, e.g., the term is defined as the man-made or man-induced alteration of the physical, biological, chemical, and radiological integrity of water (EPA-94/04). **Pollution prevention** is the active process of identifying areas, processes, and activities that create excessive waste by-products for substitution, alteration, or elimination of the process to prevent waste generation (EPA-94/04). A **pollutograph** is a plot similar to a hydrograph; it shows the variations of a pollutant concentration or a pollutant load versus time.

Polygonal coverage A geographic information system (GIS) file composed of polygons. In GIS procedures, **polylines** are entities composed of line segments connected end to end by vertices.

Polyvinyl chloride (PVC) A tough, environmentally indestructible plastic that releases hydrochloric acid when burned (EPA-94/04). A material used to fabricate water and wastewater piping.

Pond A natural or man-made body of freshwater smaller than a lake and larger than a pool.

Ponding The impoundment of streamflow to create a pond. Ponding also refers to the situation when water backs up in a channel, ditch, or conduit because of insufficient capacity at a downstream point. The **ponding option** is an XP-SWMM (Stormwater Management Model) option that allows water to be stored at a junction without increasing the hydraulic gradeline until there is sufficient hydraulic capacity for the water to rejoin the network. The opposite is the sealed option.

Pond routing The routing of flows resulting from a storm through a detention pond or a series of detention ponds; i.e., a mathematical modeling of the pond's response to a given storm event's hydrograph. The output consists of water surface elevations, outflows, and storage volumes during and following the storm. A series of ponds (and the corresponding routing technique) is standard or interconnected depending on whether a downstream pond affects the hydraulics of an upstream pond. For the standard routing technique, the outfall water surface must not affect the downstream pond. An interconnected pond system is said to be subject to time-variant tailwater conditions because water surfaces depend not only on inflow

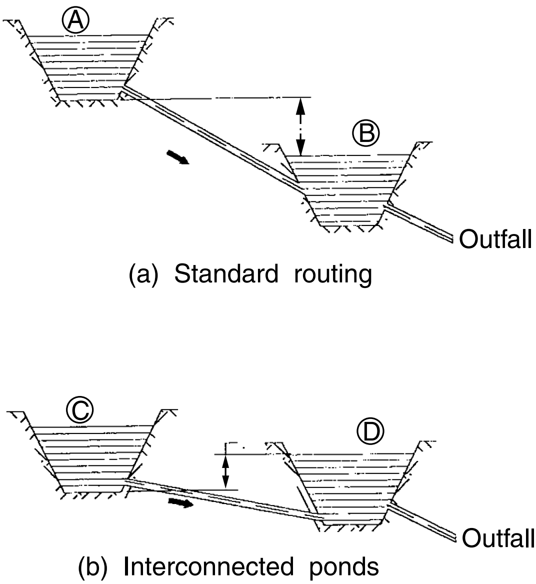


FIGURE P-3 Pond routing. (Courtesy of Haestad Methods, Inc.)

and pond geometry, but also on outflow and outfall. Standard pond routing techniques, based on the storage form of the continuity equation, include: storage indication, modified Puls, and level pool routing. Analyses of interconnected ponds may be conducted with the Advanced Interconnected Pond Routing (AdICPR). *See* Figure P-3; flow routing.

Pond water surface area When used for the purpose of calculating the volume of wastewater that may be discharged, the water surface area of the pond created by the impoundment for storage of process wastewater at normal operating level. This surface shall in no case be less than one third of the surface area of the maximum amount of water that could be contained by the impoundment. The normal operating level shall be the average level of the pond during the preceding calendar month (EPA-40CFR421.61-d).

Population equivalent The estimated population that would contribute a given load of water, wastewater, solid waste, etc. It is usually applied to nondomestic users such as industrial, commercial, or institutional establishments and relates to a specific parameter such as flow, 5-day biochemical oxygen demand (BOD), or total suspended solids (TSS). In wastewater studies, e.g., per capita daily values commonly used include a flow of 100 gal, 0.20 lb of TSS and 0.17 lb of BOD. Thus, a wastewater stream of 50,000 gal/day carrying 102 lb of BOD and 105 lb of TSS would have a **hydraulic population equivalent** of 500, but population equivalents of 600 with respect to BOD and 525 with respect to TSS. A related concept is **equivalent dwelling unit**, which is the average household size.

Pore volume (1) The total volume of pore space in a given volume of rock or sediment; it usually relates to the volume of air or water that must be moved through contaminated material to flush the contaminants. (2) The volume of water or air that will completely fill all of the void space in a given volume of porous matrix. Pore volume is equivalent to the total porosity. The rate of decrease in the concentration of contaminants in a given volume of contaminated porous media is directly proportional to the number of pore volumes that can be exchanged (circulated) through the same given volume of porous media (EPA Glossaries).

Porewater pressure Pressure below the water table, similar to hydrostatic pressure. It is equal to ($h\gamma$) at a point of depth h below the water table, with γ the specific weight of water.

Porosity Degree to which soil, gravel, sediment, or rock is permeated with pores or cavities through which water or air can move (EPA-94/04). The percentage of such pores or cavities. *See also* bulk density; effective porosity; specific retention; specific yield. **Porous** materials have pores or cavities through which fluids or light may pass. A **porous-media model** is a bench-scale model to study the movement of groundwater through porous media; e.g., the studies of Darcy in 1856 led to the equation that defines groundwater flux as a function of hydraulic conductivity and hydraulic gradient. A **porous pavement** reduces imperviousness and surface runoff; it is made of asphalt, special concrete (without the finer sediment), or interlocking open-cell cement blocks over a base of coarse gravel.

Porous-media models *See* porosity.

Positive displacement pump A piston, diaphragm, gear, or screw pump in which liquid is drawn into a space; its pressure is increased for its discharge. It delivers a constant volume with each stroke and is often used for pumping out groundworks. The other broad category of pumps includes continuous-flow or rotodynamic pumps.

Postprocessor A type of graphical user interface; i.e., a computer program that processes model output data, usually converting text to graphics. For example, a postprocessor can convert the Stormwater Management Model's (SWMM's) ASCII output to graphs, charts, and plots. Also called **output interface** or **back-end interface**. *See also* front-end interface (input interface or preprocessor).

Potable water Water that is safe *and* satisfactory for drinking and cooking. Safe water does not contain harmful organisms, toxic materials, or chemicals. Water that has objectionable odor, color, taste, or mineral problems may still be safe for drinking but is not considered potable.

Potential energy Same as **potential head**.

Potential evapotranspiration (PET) The magnitude of evapotranspiration under ideal conditions, specifically when soil moisture is not a limiting factor.

Potential head The element of the total dynamic head of a pump that represents the elevation of the fluid above or below a datum. Also called **elevation**

head, **elevation energy**, **potential energy**. *See also* dynamic head; hydraulic energy; pump head terms.

Potentiometric surface The imaginary surface defined by the water level in wells tapping the confined or semiconfined groundwater zone. Also called **piezometric surface**.

POTW Abbreviation for publicly owned treatment works. The **POTW treatment plant** is the portion of the POTW that is designed to provide treatment (including recycling and reclamation) of municipal sewage and industrial waste (EPA-40CFR403.3-p).

Pound (lb) A unit of mass equal to approximately 0.4536 kg.

Pound per square foot (psf) A unit of pressure equal to a force of 1 lb applied uniformly over an area of 1 ft^2. **Pound per square inch** (**psi**) is a unit of pressure equal to a force of 1 lb applied uniformly over an area of 1 in^2. **Pound per square inch absolute** (**psia**) is the absolute pressure of 1psi. **Pound per square inch differential** (**psid**) is the pressure differential in psi between two points in a fluid. **Pound per square inch gage** (**psig**) is a gage pressure of 1 psi.

ppb Abbreviation for parts per billion.

ppm Abbreviation for parts per million.

ppmv Abbreviation for parts per million by volume.

pQt *See* design flow.

Practicable Available and able to be done after taking into consideration cost, existing technology, and logistics in light of overall project purposes. Also, capable to be used consistent with: performance in accordance with applicable specifications, availability at a reasonable price, availability within a reasonable period of time, and maintenance of a satisfactory level of competition. The test of what is practicable depends on the situation and includes consideration of the pertinent factors, such as environment, community welfare, cost, or technology (EPA-40CFR230.3-q, EPA-40CFR248.4-bb, and EPA-40CFR6-AA-g).

Prandtl, Ludwig *See* hydraulics.

Prandtl, Schmidt, and Lewis numbers (P_r, S_c, L_e) Three dimensionless numbers used to determine which turbulent mixing terms predominate. They are ratios of the mixing coefficients of turbulent eddy viscosity ν_e, thermal diffusivity D_t, and mass diffusivity D_i. These numbers are normally equivalent, and each is approximately equal to 1. *See* Martin and McCutcheon (1999):

$$P_r = \nu_e/\rho \cdot D_t \tag{P-9}$$

$$S_c = \nu_e/\rho \cdot D_i \tag{P-10}$$

and

$$L_e = D_i/D_t \tag{P-11}$$

Prandtl tube A device used to measure the velocity of flowing fluids; consists of a Pitot tube combined with a static tube. Also called **Pitot–static tube**. *See* Figure P-2; pitometer.

Precipitation The process by which atmospheric moisture falls onto a land or water surface as rain, snow, hail, or other forms of moisture (EPA Glossaries). The amount of such precipitation is divided into three main components: direct runoff, river basin recharge, and groundwater accretion. *See* hydrologic cycle; rainfall–runoff relationship.

Precipitation excess The difference between precipitation rate and the combined losses by evaporation, transpiration, and infiltration. *See also* rainfall excess. It corresponds to direct runoff, i.e., the water that flows over the surface during a storm.

Precipitation gage A device for catching precipitation and measuring its depth; a rain gage.

Precipitation intensity Volume of precipitation per unit of time, usually expressed in inches of water per hour or in millimeters of water per hour.

Precipitation–Runoff Modeling System (PRMS) A distributed-parameter model developed by the U.S. Geological Survey to simulate watershed response to rainfall and snowmelt. Its output includes streamflows, storm hydrographs, and sediment yields.

Precision The standard deviation of replicated measurements. Variation about the mean of repeated measurements, expressed as one standard deviation about the mean (EPA-40CFR53.23-e and EPA-40CFR86.082.2). *See also* accuracy. **Precision errors** are caused in simulation or monitoring by random deviations from true values, deviations due to limitations of the model or instrument. *See also* bias.

Preissmann scheme An implicit finite-difference scheme used in models of unsteady river flows. For example, in the Preissmann four-point scheme, the partial derivatives with respect to space and time are replaced by weighted averages based on weighting factors of $\theta = 0.5$ for time and $0.5 \leq \theta \leq 1$ for space. In the EXTRAN Block of the Stormwater Management Model (SWMM), a **Preissmann slot** technique is used to maintain free-surface flow so that the governing equations can be applied to surcharge and pressure flow conditions. *See also* Crank–Nicholson scheme.

Preparatory cleaning An activity of a sewer system evaluation survey involving adequate cleaning prior to inspection of sewer lines that were previously identified as potential sources of excessive infiltration/inflow. *See also* hydraulic cleaning; mechanical cleaning.

Preprocessor A type of graphical user interface; i.e., a computer program that processes model input data, usually converting graphics to text; e.g., a preprocessor can convert AutoCAD drawing and other graphics for input to the Stormwater Management Model (SWMM) as ASCII files. Also called **input interface** or **front-end interface**. *See also* back-end interface (output interface or postprocessor).

Pressure A type of stress exerted uniformly in all directions; the total load or force per unit area acting on a surface; measured in various units, such as pascals and pounds per square inch.

Pressure discharge One of three types of discharge points or boundary conditions used in the Stormwater Management Model (SWMM). The other two types are free outfalls and discharges to a manhole or to a pump station wetwell.

Pressure drop The difference (expressed in kilopascals or another convenient unit) in static pressure measured immediately upstream and downstream of a component.

Pressure energy Same as **pressure head**.

Pressure flow A flow condition in flow routing problems. *See* combination flow.

Pressure force A term in the momentum equation represented by $\partial y/\partial x$, with y the depth of flow and x the longitudinal distance. *See* Saint-Venant equations.

Pressure gage An instrument with a metallic sensing element or a piezoelectric crystal for measuring the pressure of fluids or solids. *See also* piezometer.

Pressure gradient A pressure differential in a given medium (e.g., water or air) that tends to induce movement from areas of higher pressure to areas of lower pressure.

Pressure head The vertical distance (in feet) equal to the pressure (in psi) at a specific point. The pressure head is equal to the pressure in psi times 2.31 ft/psi (EPA Glossaries). In the expression of total dynamic head of a pump, pressure head is equal to the ratio of the static pressure p to the specific weight γ of the fluid or p/γ. Also called **pressure energy** or **flow work**. *See also* Bernoulli's law; dynamic head formula Equation D-19.

Pressure junction (node) A junction (node) for which all connected conduits have pressure flow. In a model, it is an imaginary sealed node used to connect two force mains. The opposite is a gravity junction (node).

Pressure main A pressurized sewer line that conveys wastewater or stormwater from a pumping station to another pressure main, to a manhole, to a treatment plant, or to a point of disposal. A gravity sewer flowing full is said to be under surcharge conditions but is not called a pressure main. Velocities in pressure mains are usually greater than in gravity sewers. A pressure main may also be a pipeline supplying water from pumps, as opposed to a gravity main, but a pressurized water supply pipe is usually called a water main. *See also* pumping line. Also called **force main**.

Pressure node Same as **pressure junction**.

Pressure-regulating valve A safety device that maintains the downstream pressure at a set value. *See also* pressure-relief device or valve.

Pressure-relief device or valve A safety device used to prevent operating pressures from exceeding the maximum allowable working pressure of the process equipment. A common pressure-relief device is a spring-loaded **pressure-relief valve**. Devices that are actuated either by a pressure less than or equal to 2.5 psig or by a vacuum are not pressure-relief devices

(EPA-40CFR63.161). Pressure-relief devices are sometimes called simply **pressure reliefs**. Pressure-relief valves reclose automatically on return to normal operating conditions. *See also* overflow tower; safety valve.

Pressure sewers A system of pipes in which water, wastewater, or other liquid is pumped to a higher elevation (EPA-94/04).

Pressure-sustaining valve A device that maintains the upstream pressure at a set value by limiting the flow.

Pressure switch A device that determines whether a line is open or closed by controlling the fluid's pressure or grade.

Pressure tap A small hole normal to the wall of a pipe or container under pressure; used for the connection of static pressure monitors. Also called **piezometric opening** or **static pressure tap**. *See* Figure M-1; manometer.

Pressure transducer A device (usually part of an instrument) that detects pressure in a fluid and converts it to an electrical signal; this signal can be used to determine the fluid pressure, which is proportional to the change in measured voltage. For enhanced precision, the electrical signal can be amplified.

Pressure valves *See* pressure-regulating valve; pressure-relief valve; pressure-sustaining valve.

Pressurized flow Flow under pressure, as opposed to gravity flow. *See* flow.

Pretreatment Processes used to reduce, eliminate, or alter the nature of wastewater pollutants from nondomestic sources before they are discharged into publicly owned treatment works (POTWs) (EPA-94/04). The reduction or alteration may be obtained by physical, chemical, or biological processes, process changes, or other means, except as prohibited. Appropriate pretreatment technology includes control equipment, such as equalization tanks or facilities, for protection against surges or slug loadings that might interfere with or otherwise be incompatible with the POTW (EPA-40CFR403.3-q).

PRF Abbreviation for peak rate factor.

Price current meter A device commonly used to measure stream velocity; consists of conical cups and an assembly mounted on a vertical strap. It is reasonably accurate (within 2%) in the range 0.025–7.5 ft/sec and for depths as shallow as 0.5 ft. The number of revolutions of the assembly is directly proportional to the velocity of the water. *See also* optical current meter.

Primary drinking water regulation A regulation of public water supply systems specifying contaminant levels that (the Environmental Protection Agency assumes) will not affect human health adversely.

Primary loop A combination of pipes and junctions that make up a single closed-loop system. *See* network equations.

Primary meter A device installed directly in the flow to be measured (e.g., a Parshall flume, venturi meter, orifice), as opposed to other types of metering devices, such as pressure transducers or Doppler meters, which cause lower headlosses but may be less accurate.

Prime mover An element, such as water, wind, or electricity, that puts a machine in motion, or a device, such as a water wheel, that transforms the energy from a natural source. In a power plant, a prime mover transforms thermal or pressure energy into mechanical energy.

Priming The action of starting the flow of fluid in a pump or siphon, e.g., by filling the pump with water to allow suction by the impeller.

Principal component analysis (PCA) A display method for mapping multivariate data into a two-dimensional plane. See James (1996) for more details.

Prismatic channel A channel of constant shape and slope along the flowpath; a convenient assumption in some hydraulic computations that permits the use of normal flow equations.

Prism storage In the Muskingum and other methods of flood routing, prism storage is the storage under the steady-flow water surface profile, while wedge storage is the additional storage under actual conditions. *See also* channel storage; Figure C-2.

Privately owned treatment works A system or device that is not a POTW and that is used to treat wastes from any facility with an operator that is not the operator of the treatment works (EPA-40CFR122.2). Or simply, a waste treatment works that is not owned by a state, unit of local government, or Indian tribe.

Private pump station A pump station owned and operated by a private entity, such as a land developer, hospital, or shopping center, as opposed to a publicly owned or operated station.

Private sewer *See* public sewer.

PRMS Abbreviation for Precipitation–Runoff Modeling System.

Probabilistic model A model that includes statistical elements in the definition of a problem. Its input data include random variables to account for uncertainty. For example, statistical groundwater models describe random movements of solutes using statistical theory. Unlike a deterministic model, the probabilistic model yields different outputs for a given set of inputs. Its output is actually a set of expected values rather than deterministic values for the variables; i.e., each prediction has a certain probability attached to it. Also called **statistical** or **stochastic model**. *See also* parametric model; pseudodeterministic model.

Probability density A function P(x) of a random variable x with an integral over a given interval that gives the probability that the value of the variable lies within the interval. *See* Figure P-4: the probability that the random variable x lies between x_1 and x_2 is the area under the curve between $x = x_1$ and $x = x_2$. For a discrete variable, the function that yields the probability that the variable will have a given value is called a **probability distribution**. The distribution function is the integral of the density function over a given interval; it is also defined as the distribution or relative arrangement of probabilities attached to an event (or specific values of a random variable) over the range of its occurrence. With large amounts of data, e.g., in hydrology, it is sometimes convenient to arrange and analyze them in classes. Common theoretical frequency or probability distributions used

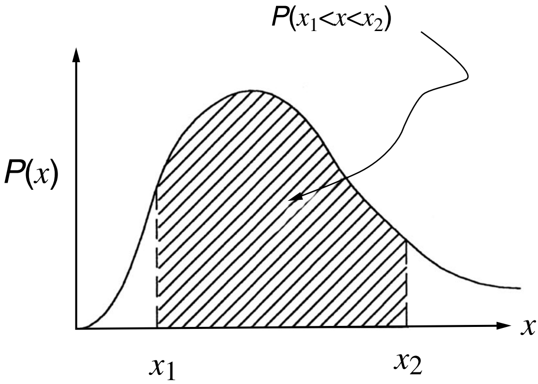


FIGURE P-4 Probability density.

in hydrology are the normal, exponential, log-Pearson type III, two- and three-parameter lognormal, two- and three-parameter gamma, and Gumbel.

Probable maximum flood (PMF), probable maximum precipitation (PMP), and probable maximum storm (PMS) **PMF** is an estimate of the most severe flood that can be expected in a planning area; based on a meteorological estimate of rainfall and other available data. It is used in the design of spillways and other flood control structures. Hydrologic modeling uses the PMS to generate the PMF. The **PMS** corresponds to the most severe hydrologic conditions expected in a planning area based on recorded data: probable maximum precipitation, unit hydrograph, baseflow, infiltration, rainfall loss, etc. The National Weather Service specifies four conditions for the PMS: the location of the storm center, the size of the storm area, the storm orientation, and the temporal arrangement of precipitation amounts. *See also* standard project flood. The **PMP** is an estimate of the greatest precipitation depth that can be expected in a planning area. Based on recorded maximum storms, drainage area, storm duration, time of year, moisture, and other hydrologic factors, it is used to derive the probable maximum storm. The National Oceanic and Atmospheric Administration's National Weather Service develops PMP for various areas of the United States.

Process wastewater Any water that comes into contact with any raw material, product, by-product, or waste during manufacturing or processing. Examples are product tank blowdown or feed tank drawdown; water formed during a chemical reaction or used as a reactant, water used to wash impurities from organic products or reactants, water used to cool or quench organic vapor streams through direct contact, and condensed steam from jet ejector systems pulling vacuum on vessels containing organics (EPA-94/04 and EPA-40CFR63.101).

Profile A plot of elevations versus distances on a longitudinal section or a cross section. In particular, a graphical representation of water surface elevation, conduit invert and crown, ground, and hydraulic gradeline. *See also* hydraulic profile; sewer profile; soil profile.

Program A set of instructions to control a machine or a process. *See also* software.

Project approach report A report to present the approach to a particular project. An approach report for a sewer modeling project may include (a) model's name, type, specific attributes, characteristics, and limitations; (b) base algorithms for each major computational function; (c) identification of all input parameters, constants, assumed values, and expected outputs; (d) computer hardware and personnel to develop and run the model. See Section II for further information.

Project life The number of years after which structures, equipment, and other capital goods should be replaced or abandoned to minimize their life-cycle costs (capital, operation, maintenance, repair). Also called **economic life**.

Propeller pump A pump that discharges water in the axial direction of the pipeline in which its propeller-type impeller is installed. Also called **axial-flow pump**.

Proportional weir A flow-measuring structure such that the discharge Q is directly proportional to the head H. (In contrast, discharge varies with the 1.5 power and the 2.5 power, respectively, of the rectangular and triangular weir heads.) The proportional weir has a horizontal crest and at least one side (the Sutro weir) or both sides (the Rettger weir) curved so that the half width of the notch x varies with the inverse of the square root of the elevation above the crest y. The curved sides may be shaped according to

$$x = K/2y^{0.5} \qquad \text{(P-12)}$$

where K is a coefficient. The proportional weir is used for irrigation diversions, for measuring very small flows, or for regulating wastewater velocity in grit chambers (Linsley et al., 1992; McGhee, 1991). *See* Figure W-8. Also called **proportional flow weir**.

Pseudodeterministic model An apparently deterministic model because it always yields the same output for a given set of input data, but a certain amount of uncertainty is inherent in its governing equations. Most, if not all, water distribution, urban runoff, groundwater transport, wastewater collection, and water quality models are actually pseudodeterministic models that include both deterministic and stochastic elements. Even field-collected data have a certain level of uncertainty, variability, or inaccuracy. Same as **parametric model**.

Pseudodistributed model A deterministic urban runoff model that divides the watershed into uniform subwatersheds; i.e., each subwatershed is "lumped," meaning that all its characteristics are constant, but different from those of other subwatersheds. *See also* distributed model; lumped models.

psi Abbreviation for pound(s) per square inch. A unit of pressure or pressure drop across a flow resistance; 1 psi is equivalent to the pressure exerted by 2.31 ft of water column. The abbreviation for pound(s) per square inch gage is **psig**, and **psia** is pound(s) per square inch absolute, such that: 0 psig = 14.696 psia = 1.0 atm. Pound(s) per square inch differential is indicated by **psid**. Pound(s) per square inch gage is indicated by **psig**, i.e., the pressure within a closed container or pipe measured with a gage in psi.

Psychrometric constant A parameter that depends on the specific heat of moist air and the latent heat of vaporization. It is used to determine the Bowen ratio in the energy balance method for estimating evaporation from lakes and reservoirs.

Publicly owned treatment works (POTW) A waste treatment works owned by a state, unit of local government, or Indian tribe; usually designed to treat domestic wastewater (EPA-94/04). Any devices or systems used in the storage, treatment, recycling, and reclamation of municipal sewage or industrial wastes of a liquid nature that are owned by a state or municipality. This definition includes sewers, pipes, or other conveyances only if they convey wastewater to a POTW providing treatment (EPA-40CFR122.2 and EPA-40CFR403.3-o). The term also means the municipality that has jurisdiction over the indirect discharges to and the discharges from such a treatment works (EPA-40CFR117.1).

Public sewer A common sewer owned and operated by a public agency or utility, as opposed to a privately owned sewer.

Public water system A system for the provision to the public of piped water for human consumption if such system has at least 15 service connections or regularly serves an average of at least 25 individuals daily at least 60 days of the year. Such a system includes (a) any collection, treatment, storage, and distribution facilities under control of the operator of such system and (b) any collection or pretreatment storage facilities not under such control that are used primarily in connection with such system (EPA-40CFR142.2).

Puls method *See* modified Puls method.

Pump A mechanical device installed in a water or sewer system or other liquid-carrying pipeline that moves the liquid to a higher level. More generally, a pump is a mechanical device that applies pressure to raise or lift a fluid or to cause the fluid to flow. *See* the following types of pump: airlift pump; axial-flow pump; centrifugal pump; constant-speed pump; continuous-flow pump; deep-well pump; deep-well turbine pump; diagonal-flow pump; diaphragm pump; displacement pump; double-action device/mechanism, double-action pump; double-suction pump; dry-pit pump; gear pump; horizontal pump; jet pump; mixed-flow pump; multistage pump; open-impeller pump; piston pump; plunger pump; positive displacement pump; propeller pump; reciprocating pump; rotary pump; rotodynamic pumps; screw pump; single-action pump; single-stage pump; submersible pump; suction pump; sump pump; vacuum pump; variable-speed pump; vertical pump; volute pump; windmill, wind pump.

Pump affinity laws Basic relationships that indicate how the capacity or discharge Q, head H, and power P of a centrifugal pump change with changes in its impeller diameter D or its rotational speed N for the same fluid. These relationships are not valid for simultaneous changes in impeller diameter and rotational speed or for significant changes in pump efficiency. (The subscripts 1 and 2 refer to the pump before and after the change in diameter or speed, respectively.)

$$Q_1/Q_2 = D_1/D_2 = r \text{ (assuming constant speed)} \tag{P-13}$$

$$H_1/H_2 = r^2 \tag{P-14}$$

$$P_1/P_2 = r^3 \tag{P-15}$$

$$Q_1/Q_2 = N_1/N_2 = R \text{ (assuming constant diameter)} \tag{P-16}$$

$$H_1/H_2 = R^2 \tag{P-17}$$

$$Q_1/Q_2 = R^3 \tag{P-18}$$

Pumpage The total volume of water pumped in a given period.

Pump characteristic curves, pump performance curves (or simply pump curves) A set of curves, prepared by a pump manufacturer and showing graphically the relationships between the pump discharge capacity, head, power, and efficiency for a given speed. The graph is a plot of efficiency (%), head (ft), and brake horsepower versus flow capacity (usually gpm). For a given speed, to increase the head is to decrease the flow capacity and vice versa, and the rating of a pump corresponds to the combination of head and discharge that yields the maximum efficiency. *See* Figure P-5.

Pump characteristics Certain properties of pumps and pump systems that are used for their selection, comparison, and performance evaluation: capacity, head, power, efficiency, and specific head. They depend on pump size, speed, and design. *See* pump characteristic curves.

Pumped-well technique A technique used to determine the capacity of a well or borehole or the hydraulic properties of an aquifer. The test is conducted by pumping a well at a constant rate over a period of time and recording the drop in the piezometric surface or water table in observation wells. These data are used to calculate the transmissivity, hydraulic conductivity, and storage coefficients. Also called **pumping test** or **aquifer test**.

Pump head terms Common terms related to pumping; used in the design and operation of pumps and pump stations, some of which are included in

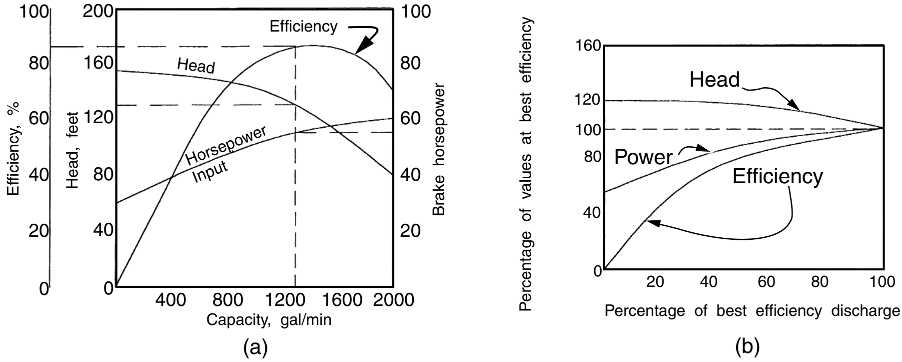


FIGURE P-5 Pump characteristic curves (typical, centrifugal pumps): (a) Peak efficiency of 86% for a 1300 gal/min discharge, a 130-ft head, and 55 horsepower; (b) percentage of values at best efficiency for head, power, and efficiency.

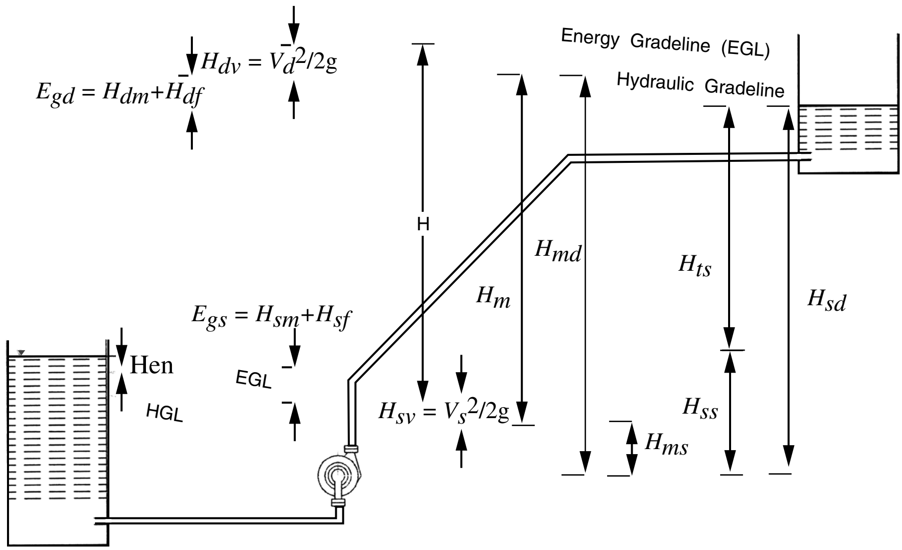


FIGURE P-6 Pump head terms with suction head.

Equation (D-19) and illustrated in Figure P-6. They are listed below, from suction to discharge. *See also* system head-capacity curve.

Suction (gage) pressure head — The ratio of the suction gage pressure P_s to the specific weight γ of the fluid, i.e., P_s/γ.

Suction velocity head (H_{sv}) — The kinetic energy of the fluid at suction, a function of the velocity V_s at the suction nozzle, i.e., $V_s^2/2g$, where g is the acceleration of gravity. It is the distance between the energy gradeline (EGL) and the hydraulic gradeline (HGL) at suction.

Suction elevation head — The elevation Z_s of the suction gage above the datum.

Suction (total) head (H_s) — The sum of the three preceding heads; i.e.,

$$H_s = P_s/\gamma + V_s^2/2g + Z_s \quad \text{(P-19)}$$

Suction entrance head (H_{en}) — The difference between the fluid level and the beginning of the EGL at suction.

Minor suction head (H_{sm}) — The sum of the fitting and valve losses occurring in the suction piping.

Suction frictional headloss (H_{sf}) — The head in the suction piping.

Suction energy gradient (E_{gs}) — The drop in the energy gradeline (or the hydraulic gradeline) from suction to pump or the sum of the minor suction headloss and the suction frictional headloss; i.e.,

$$E_{gs} = H_{sm} + H_{sf} \quad \text{(P-20)}$$

Static suction head (H_{ss}) — Vertical distance between the fluid level at suction and the centerline of the pump when the pump is at a lower level than the fluid.

Static suction lift (H_{sl}) — Vertical distance between the fluid level at suction and the centerline of the pump when the pump is at a higher level than the fluid.

Manometric suction head (H_{ms}) — The gage reading at the suction nozzle of the pump in reference to the center of the pump impeller. It is also the distance between the center of the pump and the point at which the suction hydraulic gradeline meets the vertical line through that center.

Manometric discharge head (H_{md}) — The gage reading at the discharge nozzle of the pump in reference to the center of the pump impeller. It is also the distance between the center of the pump and the point at which the suction hydraulic gradeline meets the vertical line through that center.

Manometric head (H_m) — The algebraic sum of the manometric suction and discharge heads. It represents the pressure head developed by the pump. Graphically, it is the vertical distance between the suction and discharge hydraulic gradelines:

for a suction lift:

$$H_m = H_{md} + H_{ms} \quad \text{(P-21)}$$

for a suction head:

$$H_m = H_{md} - H_{ms} \quad \text{(P-22)}$$

Static discharge head (H_{sd}) — The vertical distance between the fluid level at discharge and the centerline of the pump.

Static head (or **total static head) (H_{ts})** — The algebraic sum of the static heads at suction and discharge. Graphically, it is the difference in elevation between the two fluid levels:

for a **suction lift:**

$$H_{ts} = H_{sd} + H_{ss} \quad \text{(P-23)}$$

for a suction head:

$$H_{ts} = H_{sd} - H_{ss} \quad \text{(P-24)}$$

Discharge frictional headloss (H_{df}) — The head lost in the discharge piping.

Minor discharge headloss (H_{dm}) — The sum of the fitting and valve losses occurring in the discharge piping.

Discharge energy gradient (E_{gd}) — The drop in the energy gradeline (or the hydraulic gradeline) from the pump to the discharge or the sum of the minor discharge headloss and the discharge frictional headloss, i.e.,

$$E_{gd} = H_{dm} + H_{df} \quad \text{(P-25)}$$

Discharge (gage) pressure head — The ratio of the discharge gage pressure P_d to the specific weight γ of the fluid, i.e., P_d/γ.

Discharge velocity head (H_{dv}) — The kinetic energy of the fluid at discharge; a function of the velocity V_d at the discharge nozzle, i.e., $V_d^2/2g$, where g is the acceleration of gravity. It is the distance between the energy gradeline and the hydraulic gradeline at discharge.

Discharge elevation head — The elevation Z_d of the discharge gage above the datum.

Discharge (total) head (H_d) — The sum of the three preceding heads, i.e.,

$$H_d = P_d/\gamma + V_d^2/2g + Z_d \quad \text{(P-26)}$$

Total dynamic head (TDH) — The total head against which the pump works. Used to determine the pump horsepower requirements, it may be computed two ways: as the difference between the discharge head H_d and the suction head H_s or as the sum of the various headlosses defined above. Graphically, it is the distance between the two points at which the suction and discharge energy gradelines meet the vertical through the center of the pump.

$$H = TDH = (H_d) - (H_s) \quad \text{(P-27)}$$

$$H = H_{sf} + H_{sm} + H_{en} + H_{sl} + H_{sd} + H_{df} + H_{dm} + H_{dv} \quad \text{(P-28)}$$

$$H = H_{sf} + H_{sm} + H_{en} - H_{ss} + H_{sd} + H_{df} + H_{dm} + H_{dv} \quad \text{(P-29)}$$

Other terms sometimes used include:

Dynamic discharge head — Same as **discharge head**.

Dynamic head — Same as **total dynamic head**.

Dynamic suction head — Same as **suction head**.

Flow work — The ratio of static pressure to the specific weight of the fluid.

Kinetic energy — Same as **velocity head**.

Net positive suction head (NPSH) — The minimum suction head required for the pump to operate.

Potential head — Same as **elevation energy**, **elevation head**.

Pump head — Net work done on a unit weight of the fluid from inlet or suction flange to discharge flange.

Pump total head — Same as **pump head**.

System head — Same as **total dynamic head**.

Total head — Same as **total dynamic head**.

Pump house *See* pumping station.

Pump import file In a sewer collection modeling application, the pump file, to be imported into the model, contains such information as pump name, pump flowrate–dynamic head relationship (pump curve), pump station on/off elevations, number of pumps per station, and initial wetwell depth.

Pumping head The sum of static and friction heads.

Pumping line The discharge line from a pump or a **pumping main**; i.e., a pressurized pipeline for the conveyance of water, wastewater, stormwater, or other fluids. *See also* force main.

Pumping station area The area that contributes wastewater to a given pumping station, excluding the areas of any upstream stations. Same as **pumping station service area**.

Pumping station, booster station, lift station, pump station There exists some confusion in the use of these phrases. Some writers use them interchangeably. See, e.g., their definitions according to the American Public Health Association et al. (1981). For water distribution and wastewater or stormwater collection systems, the following definitions can be used: **Booster pumps** raise the pressure of water or wastewater on their discharge side. The pumps may be installed on the pressurized pipelines or force mains or housed in a booster station. The pressure is added directly to the force main, without a wetwell. A **lift station** contains pumps that elevate wastewater in a sewer to allow gravity flow. Usually, it is the cost-effective alternative to a deeper gravity line. **Pump stations** (interchangeably, pumping stations) contain water or wastewater pumps and their appurtenances, mechanical devices installed in sewer or water systems or other liquid-carrying pipelines that move the liquids to a higher level (EPA-94/04). They receive their inflow in a wetwell or other appropriate basin and discharge the outflow into a force main. Structures

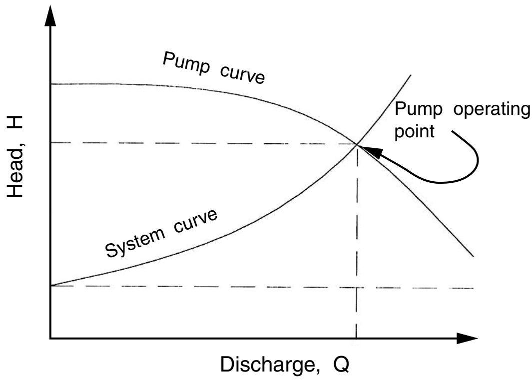


FIGURE P-7 Pump operating point.

sheltering small water pumps are called pump houses. *See also* offline pump station; online pump station.

Pumping station service area Same as **pumping station area**.

Pumping test A technique used to determine the capacity of a well or borehole or the hydraulic properties of an aquifer. The test is conducted by pumping a well at a constant rate over a period of time and recording the drop in the piezometric surface or water table in observation wells. These data are used to calculate the transmissivity, hydraulic conductivity, and storage coefficients. Also called **aquifer test** or **pumped-well technique**.

Pumping water level The vertical distance in feet from the centerline of the pump discharge to the level of the free pool while water is drawn from the pool.

Pump operating point The intersection of a pump head-capacity curve and the characteristic curve of the system in which the pump operates. *See* Figure P-7.

Pump performance curves Same as **pump characteristic curves**.

Pump pit A drywell containing a pump below ground.

Pump primer A vacuum pump used for priming another pump.

Pump stage The number of impellers in a centrifugal pump, e.g., single stage or double stage.

Pump station Same as **pumping station**.

Pump well An artesian well that does not discharge water above ground without a lifting device. Also called **nonflowing well**.

Purveyor (water) An agency or person that supplies water.

PVC Abbreviation for polyvinyl chloride, a material used to fabricate water and wastewater piping.

Q

qt Abbreviation for quart.

QuadraScan™ A hydraulics and analysis package developed by ADS Environmental Services, Huntsville, Alabama for data collection, trending, reporting, and file management.

Quality assurance A series of planned or systematic actions required to provide adequate confidence that a product or service will satisfy given needs. A **quality assurance plan** describes an orderly assembly of management policies, objectives, principles, organizational responsibilities, and procedures designed to achieve the quality objectives of a program or project (EPA-40CFR30.200 and EPA-40CFR35.6015-39). A **quality assurance statement** describes how precision, accuracy, completeness, and compatibility will be assessed and is sufficiently detailed to allow an unambiguous determination of the quality assurance practices to be followed throughout a project (EPA-40CFR30.200). **Quality assurance/quality control** is a system of procedures, checks, audits, and corrective actions to ensure that technical and reporting activities are of the highest achievable quality.

Quality control A series of activities to achieve and maintain the desired level of quality in manufacturing or service operations: inspections, analyses, reviews, corrective changes, etc.

Quantity balance method A procedure used in water distribution problems to satisfy the continuity or conservation of mass principle. It assumes the piezometric head at a junction or the headloss in a pipe to determine the pipe discharge through a formula such as the Darcy–Weisbach equation.

Quart (qt) A unit of volume for the measurement of liquids, equal to $^1/_2$ gal, 2 pt, 57.75 in^3, or approximately 0.9464 l.

Quench tank A water-filled tank used to cool incinerator residues or hot materials during industrial processes (EPA-94/04).

Query A procedure to answer questions in a computer program.

Quick-response runoff One of two basic components of a flood hydrograph; the other is baseflow. Also called **surface runoff** or **direct runoff**.

Quicksand An unstable condition that occurs when the hydraulic gradient of the seepage lines under a structure is higher than unity. It causes the material underneath the structure to have fluid characteristics and lose its bearing capacity. *See also* creep ratio; pipe.

Quiescent settling The settling of solid particles in still water, i.e., a body of water at rest, without any inflow or outflow, as opposed to dynamic settling. In extended detention wet ponds, particle settling is assumed to be quiescent in the permanent pool between runoff events and dynamic in the active storage zone.

Quoin post A post that secures the hinges of a gate or door. Same as **hinge post** or **heelpost**.

R

Radar From *ra*dio *d*etecting *a*nd *r*anging. A system or device using beamed and reflected radio waves for detecting and locating objects, measuring distances and speeds; also used in storm detection, mapping, navigation, and for other purposes. *See also* NEXRAD.

Radial flow Flow of a fluid along the radii of a rotating container, that is, from the center to the periphery or vice versa. A radial-flow tank is a circular tank that has radial flow, with the inlets at the center and the outlets on the periphery in radial inward flow and vice versa in radial outward flow.

Radial gate A type of spillway crest gate with a face that is a section of cylinder that rotates about a horizontal axis on the downstream end of the gate. The gate, widely used in large installations, can be raised or lowered by winches or hoists acting on the bottom; it can also be closed under its own weight. *See also* drum gates; flashboards; stop logs. Also called **tainter** or **taintor gate** and **canal lock**.

Radial inward flow, radial outward flow *See* radial flow.

Rafter dam A fixed dam built of horizontal timbers that meet in the center of the stream like rafters in a roof. If the rafters lie on their side and point upstream, forming a sill and a support for the deck, the dam is called a **rafter-and-strut framed dam** or an **A-frame timber dam**.

RAIN A time-series management module of Stormwater Management Model (SWMM) that processes precipitation data.

Rain Water condensed from vapor and falling in particles too heavy to be held by the atmosphere; raindrops usually have a diameter of at least 0.5 mm and fall at a speed of 10 ft/sec. **Fog** is a cloudlike mass of smaller water particles suspended in the atmosphere close to the ground when the temperature is above freezing and the relative humidity is higher than 97%. A **cloud** is a mass of water droplets that are too small to fall to the earth and remain suspended at a considerable distance. A **rain day** is a period of 24 h during which a minimum of rainfall is recorded. For **rain event**, *see* storm event. **Rainfall** is atmospheric precipitation in the form of rain or the quantity of rain expressed in volume or depth, e.g., cubic feet or inches.

Rainfall curve (1) A curve that shows the cumulative depth of rainfall throughout a storm duration; used to simulate different storms, e.g., two storms of the same total depth and volume. (2) The Soil Conservation Service (SCS) 24-h rainfall curves for regions of the United States, which show rainfall cumulative fractions (from 0 to 1) as a function of time in hours (from 0 to 24) and can be used to create a design rainfall curve: For a given time, simply multiply the corresponding rain fraction by the total rainfall depth. *See also* curve number.

Rainfall-dependent infiltration/inflow (RDI/I or RDII) Stormwater or groundwater that enters a wastewater collection and transmission system in direct response to a rainfall event. Also called **rainfall-derived infiltration/inflow**. *See* rainfall-induced infiltration. *See also* Section II for further information.

Rainfall-dependent peak flow management study A study to characterize rainfall-dependent infiltration/inflow into a sewer system, predict corresponding peak flows, and assess the ability of existing facilities to handle such flows.

Rainfall depth The volume of rainfall divided by the drainage area; usually expressed in inches or millimeters.

Rainfall-derived infiltration/inflow Same as **rainfall-dependent infiltration/inflow**.

Rainfall distribution curve A curve that defines how the rainfall volume is distributed throughout the storm event. The Soil Conservation Service has developed a series of 24-h curves applicable to regions of the United States. *See also* rainfall curve.

Rainfall event Similar definition as for storm event.

Rainfall excess The rate of net inflow to a watershed or subwatershed in feet per second or meters per second; that is, the difference between rainfall intensity and the rate of combined losses by evaporation, transpiration, and infiltration.

Rainfall-induced infiltration (RII) A form of infiltration that behaves somewhat similar to, and is sometimes confused with, stormwater inflow. RII generally occurs during or immediately after rainfall events. It is caused by the seepage of percolating rainwater into manhole, pipe, and lateral defects that lie near or are readily reached from the ground surface. *See also* rainfall-dependent infiltration/inflow.

Rainfall intensity (or rainfall rate) Volume of rainfall per unit of time; usually expressed in inches per hour or in millimeters per hour. Obtained by dividing the depth of rainfall by the duration under consideration.

Rainfall-intensity curve A graphical representation of the relationship between rainfall intensity (as ordinate) and rainfall duration (as abscissa) for a given storm frequency, i.e., for a number of years during which the intensity corresponding to a storm duration will not be exceeded more than once on the average. *See also* intensity–duration–frequency.

Rainfall loss The portion of rainfall that does not contribute to direct runoff, e.g., land-cover interception, depression storage, infiltration, and evapotranspiration.

Rainfall rate Same as **rainfall intensity**.

Rainfall–runoff relationship A relationship between the volume of rainfall and the corresponding volume of runoff. Basically, rainfall = direct or storm runoff + initial abstraction + losses. Or direct runoff = precipitation – basin recharge – groundwater accretion. *See also* basin recharge; depression storage; direct runoff or storm runoff; Figures H-4 and H-5; groundwater accretion, groundwater runoff; hydrologic cycle; interception; interflow; overland flow; overland runoff; precipitation; rainfall severity index; rainfall simulation; rain gauge (or gage); retention; runoff generation; soil moisture; subsurface runoff; total runoff.

Rainfall severity index A dimensionless index proposed to define the severity of rainfall events based on their duration and return period. *See* Haestad severity index.

Rainfall simulation An activity of a sewer system evaluation survey that involves determining the impact of rainfall and/or runoff on the sewer system. Rainfall simulation may include dyed water or water flooding of storm sewer sections, ponding areas, stream sections, and ditches. In addition, other techniques such as smoke testing and water sprinkling may be used.

Rain gage A device for measuring the amount or intensity of rainfall. Generally, it is a container for catching rain and measuring its depth. Also called a **pluviometer**.

Rain-intensity gage An instrument that measures the instantaneous rainfall intensity. Also called **rate of rainfall gage**.

Random access memory (RAM) The temporary storage area of a computer, usually measured in megabytes, used to load program instructions and store files currently in use.

Random walk model A groundwater model that simulates the transport of particles through their random path in the flow field. It yields the distribution rather than the concentration of particles.

Rapid flow Same as **supercritical flow**.

Rapidly varied flow Flow occurring with a sudden change in channel geometry or flow regime; caused by some obstacle or a change in slope and accompanied by a hydraulic jump, e.g., flow over sharp-crested weirs, broad-crested weirs, or in venturi flumes. *See* Figure O-2; open-channel flow.

Raster-based storage A current method of processing geographic information system (GIS) data for use in hydrologic modeling. (**Raster** is defined as the pattern of scanning lines on a picture tube that is not receiving any signal.) *See also* triangular irregular network.

Rated flow The flowrate through a vessel or piping system under normal conditions. **Rated horsepower** is the maximum power output that a prime mover (e.g., an engine or turbine motor) is allowed to generate under normal and continuous operating conditions.

Rate-of-flow controller An automatic device used to control the rate of flow.

Rate-of-rainfall gage Same as **rain-intensity gage**.

Rating curve A graphical representation of the relationship between two variables. More specifically, a curve that expresses the relationship between the discharge of a hydraulic entity at a given location and a pertinent hydraulic condition or characteristic that affects the discharge. The hydraulic entity may be a stream, an open conduit, or a gate, meter, or other hydraulic structure or instrument. The pertinent condition or characteristic may be the depth of flow, gage height, pressure, hydrostatic head, velocity of approach, or the stage or elevation at or near the location. *See*, e.g., spillway rating curve. The rating curve may be a graphical representation of a rating table. Also called **discharge curve**, **discharge rating curve**, or **stage–discharge relationship**. In hydraulic modeling, the rating curve defines flow Q as a function of stage h or elevation above a datum and may be used as a boundary condition in lieu of flows and water surface elevations at the downstream boundary. The following equation is sometimes used to define the rating curve:

$$Q = a \cdot h^b \qquad \text{(R-1)}$$

where a and b are empirical coefficients. The rating curve may also be a representation of any relationship between depth and flow, e.g., the Manning equation. The stage–area and stage–storage relationships are similar concepts in hydraulic modeling. *See* Figures D-5 and S-13. Similarly, a rating table shows the correspondence between two variables over a given range and is used to graph the rating curve; also called a **discharge table**.

Rating table A table showing the correspondence between two variables or quantities. It is called a discharge table when the two variables are discharge and a pertinent hydraulic property.

Rational channel design The determination of the best characteristics (width, depth, and slope) of a channel to ensure its stability, e.g., by the solution of a system of three equations in the three variables: a flow equation, a sediment transport equation, and a third equation. *See also* extremal hypothesis.

Rational formula A 19th century formula to calculate the peak runoff discharge Q (cfs) at a point as a function of rainfall intensity i (in/h), drainage area A (acres), and a runoff coefficient C (dimensionless):

$$Q = CiA \qquad \text{(R-2)}$$

The intensity used corresponds to the design recurrence interval and to a storm duration equal to the time of concentration. The coefficient C reflects the combined effects of land uses, surface storage, imperviousness, infiltration, and evaporation. It may be calculated as a function of the storm duration t in minutes (McGhee, 1991):

$$C = 0.175t^{1/3} \qquad \text{(R-3)}$$

for impervious areas, or

$$C = 0.3\ t/(20 + t) \qquad \text{(R-4)}$$

for improved pervious surfaces. The rational formula has no valid basis but uses the fact that 1 in/h over 1 acre is approximately equal to 1 cfs.

Its assumptions are not always valid, e.g., uniform distribution of rainfall over the drainage area, constant rainfall intensity throughout the storm duration, peak runoff at a point occurring when the entire area is contributing flow to the point. With Q in m^3/s, i in mm/h, and A in hectares, the equivalent SI formula is:

$$Q = CiA/360 \qquad \text{(R-5)}$$

Rational method A simple, widely used method for computing the peak runoff rate from a small drainage area, based on the rational formula, e.g., in the design of storm sewers, culverts, and detention ponds. Recommended limitations on the size of the drainage area vary, e.g., from 10 acres (Linsley et al., 1992) to 3 km^2 (McGhee, 1991). *See* SCS runoff equation.

R_{av} Notation for the average annual runoff in the Stormwater Management Model (SWMM) Level I formula.

Ravine A small, elongated, deep channel created by the eroding action of running water. Some ravines flow continuously; others are dry except after a rainstorm, icemelt, or snowmelt. Ravines are similar to, but larger than, gullies, rills, or rivulets. *See* stream.

Raw data Any laboratory worksheets, records, memoranda notes, or exact copies thereof that are the result of original observations and activities of a study and are necessary for the reconstruction and evaluation of the report of that study. In the event that exact transcripts of raw data have been prepared (e.g., tapes that have been transcribed verbatim, dated, and verified accurate by signature), the exact copy or exact transcript may be substituted for the original source as raw data. Raw data may include photographs, microfilm or microfiche copies, computer printouts, magnetic media, including dictated observations, and recorded data from automated instruments (EPA-40CFR160.3).

Raw sewage, raw wastewater Untreated wastewater and its contents.

Raw water Intake water prior to any treatment or use. Also a water supply source from a spring, stream, aquifer, or lake.

RDI Abbreviation for rainfall-derived (or dependent) infiltration.

RDI/I (or RDII) Abbreviation for rainfall-dependent (or derived) infiltration/inflow.

RDII development The process of estimating the volume and duration of RDII; based on rainfall and wastewater flow monitoring data. *See* Section II for further information.

RDII equations The equations used to determine RDII flows. RDII hydrographs are represented by three triangles, and the following formula expresses the peak flow Q_p corresponding to a unit rainfall Q, both in inches, as a function of the RDII parameters:

$$Q_p = 2(r_h)Q/[T_p(1 + r_r)] \qquad \text{(R-6)}$$

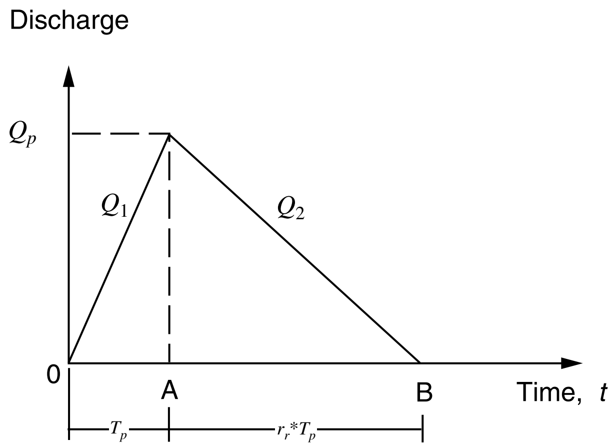


FIGURE R-1 Rainfall-dependent (or derived) infiltration/inflow equations.

Rising limb Q_1 and falling or recession limb Q_2 flows at any time t are

$$Q_1 = t(Q_p)/T_p \text{ with } t \leq T_p \tag{R-7}$$

and

$$Q_2 = Q_p[1 - (t - T_p)/(T_p)(r_r)] \text{ with } t \geq T_p \tag{R-8}$$

where r_h, T_p, and r_r are the following RDII parameters, respectively: the hydrograph ratio, the hydrograph time to peak, and the recession time ratio. *See* Figure R-1.

RDI/I hydrograph A diurnal hydrograph of rainfall-dependent infiltration/inflow in a sewer system or for a limited area such as a pump station service area. The RDI/I hydrograph can be added to the dry-weather flow hydrograph to produce the total wet-weather hydrograph. *See* RDII development.

RDII parameters Three parameters used to compute peak RDII flows. They are the hydrograph ratio r_h or the ratio of the hydrograph volume to the rainfall volume; the hydrograph time to peak T_p; and the recession time ratio r_r or the ratio of the time for the flow to recede to zero to the time to peak. *See* Figure R-1; RDII equations.

RDI/I unit hydrograph The ratio of the RDI/I hydrograph to the total volume of RDI/I.

R_e Notation for the Reynolds number.

Reach A portion of a waterway between two locks, gages, stations, or other points, usually a short length with uniform characteristics (discharge, area, depth, slope) or a long straight stretch. In nonuniform flow modeling, streams or channels are divided into reaches or stretches of uniform geometric and hydraulic properties.

Reaction turbine A type of hydraulic turbine, the reaction turbine (e.g., the Francis and Kaplan turbines) uses the steady-flow principle of fluid acceleration: nozzles are mounted on the moving element, and the flow from upstream to downstream occurs in a closed conduit. *See also* impulse turbine.

Read-only memory (ROM) Memory containing data that can be read, but not modified. *See also* CDROM.

Reaeration Introduction of air into the lower layers of a reservoir. As the air bubbles form and rise through the water, the oxygen from the air dissolves into the water and replenishes the dissolved oxygen. The rising bubbles also cause the lower waters to rise to the surface, where they take on oxygen from the atmosphere.

Real fluid A fluid that does not possess one or more of the characteristics of ideal fluids, particularly the absence of viscosity.

Rear-yard ponding A runoff reduction measure using rear yards for the storage and infiltration of stormwater from rooftops (e.g., the equivalent of 20 mm of runoff).

Receding limb In a typical single-storm hydrograph with the approximate shape of a triangle, the receding limb represents withdrawal of water from storage after surface inflow has stopped; direct runoff decreases until discharge is exclusively baseflow. In an RDII hydrograph, the receding limb represents the decreasing discharge until it is reduced to the dry-weather flow. Sometimes called **falling limb** or **recession limb**. *See also* Figure R-1; RDII equations; rising limb. *See* Figure H-3.

Receiving manhole The manhole that receives the flow of a gravity sewer ahead of a pump station, as opposed to the discharge manhole, which receives the discharge from a pump station. *See also* key manhole.

Receiving water A body of water (river, lake, ocean, estuary, stream) into which treatment plant effluents, untreated wastewater, stormwater, or combined wastes are discharged.

Recession Withdrawal of the water stored in a stream channel during the rising limb of a storm. The **recession curve** is the part of the receding limb of a storm hydrograph from the point of inflection that represents the baseflow and such contributions as valley or channel storage. Assuming no further inflow and an initial discharge Q_o when recession starts, the recession curve may be expressed as the discharge Q_t at time t:

$$Q_t = K^t Q_o \qquad \text{(R-9)}$$

K is a recession constant. *See* Figure H-2. The **recession decay rate** is a variable used in the formulation of baseflow in HEC-1 simulations; defined as the ratio of the recession limb flow at one time to the recession limb flow 1 h later (Hoggan, 1997). **Recession limb** is the same as **receding limb**. The **recession threshold** is the point on the receding limb of a hydrograph at which flow assumedly starts to recede at an exponential rate, but it is sometimes considered as the point at the beginning of the straight-line portion of the semilog plot of flows versus time. The **recession time ratio**, in a RDII triangular unit hydrograph, is the ratio of the time to recede to zero from the peak flow to the hydrograph time to peak. *See* RDII equations; RDII parameters.

Recession decay rate *See* recession.

Recharge The natural or artificial process of adding water to the saturated zone of an aquifer from precipitation or by percolation from the soil surface, infiltration from surface streams, deep-well injection, or other means. **Recharge area** is a land area in which water reaches the zone of saturation or an artesian aquifer, naturally or artificially, e.g., where rainwater soaks through the earth to reach an aquifer. A major recharge area is an area where a major part of the recharge of an aquifer occurs. *See* aquifer; Figure A-1. **Recharge basin** is a basin constructed in sandy material to recharge an aquifer from streamwater or stormwater, thus capturing flood and other flows that would otherwise be lost to the ocean. Other means of groundwater recharge include check dams, recharge wells, seepage ponds, and underground leaching systems. **Recharge rate** is the volume of water per unit of time that replenishes or refills an aquifer. A **recharge well** or **diffusion well** allows water to flow into an aquifer for groundwater recharge purposes.

Reciprocating pump A displacement pump that moves and imparts pressure to fluids through a reciprocating piston or plunger in a cylinder; called single action or double action depending on whether the piston acts in one end or both ends, respectively, of the cylinder. Also called a **piston pump**.

Recirculated cooling water Water that is passed through the main condensers to remove waste heat, passed through a cooling device to remove such heat from the water, and then passed again, except for blowdown, through the main condenser (EPA-40CFR423.11-h). *See also* once-through cooling water.

Reclaimed wastewater Wastewater that has been recovered for some useful purpose, usually after some treatment to meet the requirements of the intended use. **Reclaimed water** is wastewater or stormwater that has been recovered for reuse. **Reclamation** is the process of recovering a resource such as land or water (e.g., in the form of wastewater or stormwater) and improving it so that it can be used or reused instead of wasted. Land can be reclaimed by irrigation, drainage, or flood protection. Wastewater can be renovated by advanced waste treatment and be reused as cooling water, as irrigation water, for groundwater recharge, or for other purposes. *See also* wastewater reuse.

Recommended maximum contaminant level (RMCL) Under the Safe Drinking Water Act, a nonenforceable concentration of a drinking water contaminant; set at a level at which no known or anticipated adverse effects on human health occur and that allows an adequate safety margin. Also called a **maximum contaminant level goal** (MCLG).

Recording gage An instrument that measures and automatically records (graphically or acoustically) one or more variables. Also called a **register** and an **automatic recording gage**.

Recording rain gage A rain gage that automatically records the cumulative rainfall as a function of time. Also called **pluviograph**. *See also* hyetograph.

Rectangular sharp-crested weir *See* Francis formula.

Rectangular weir A simple weir with a rectangular notch for flow measurement. It can extend across the full width of the channel (suppressed weir), or it can have a notch narrower than the channel, thus causing a contraction of the nappe at both ends (contracted weir). In a rectangular weir, the discharge varies with the 1.5 power of the head. *See also* Figure W-5; weir equation.

Recurrence interval (or return period) The average interval of time units within which the magnitude of a particular event (storm, flood, drought, etc.) will be equaled or exceeded. Usually, the time unit is 1 year, which is also the time span between two successive observations. For example, the 50-yr flood or a flood of greater magnitude is not expected to occur more than once in 50 yr. **Exceedance probability** or **relative exceedance frequency** is the reciprocal of the return period. That is, it is the probability that the event magnitude will be equaled or exceeded in any given year; e.g., the exceedance probability of the 50-yr flood is 1/50 = 0.02 or 2%. There are several ways to express that a given event has a recurrence interval of t yr or a probability p (or 100 p%). First, t = the average interval of time between the occurrence of the event and that of an event of the same or greater magnitude. Second, $t = 1/p$ or $p = 1/t$ or

$$p \cdot t = 1 \tag{R-10}$$

Third, the probability that the event will not occur in any given year is $1 - p$. Fourth, the probability that at least one such event or one of a greater magnitude will occur in a sequence of N years, called the **encounter probability**, is:

$$p' = 1 - (1 - p)^N \tag{R-11}$$

Reducer A pipe or fitting larger at one end than at the other, threaded inside or flanged; used to join two pipes of different size. A **reducing coupling** is used to connect a smaller and a larger pipe. A **reducing tee** connects a branch to a main pipe, with at least one of the outgoing sections smaller than the main.

Reference level A permanently established horizontal plane, surface, or level used as a reference to compute heights, depths, soundings, ground elevations, water surface elevations, and tidal data. Mean sea level is the most generally used datum. However, mean low water and lower low water are also used on the Atlantic and Pacific Coasts, respectively, of the United

States. *See also* NGVD. Also called **chart datum**, **datum level**, **datum plane**, or **reference plane**.

Regenerative pump A centrifugal pump with rotating vanes that converts mechanical impulse and centrifugal force into pressure to raise low volumes of liquid at high heads. *See also* turbine pump.

Regime theory An empirical approach to the design of stable channels in erodible or alluvial materials. It uses the following formulas, proposed by G. Lacey (Gupta, 2001):

$$V = 1.15(fR)^{0.5} = 16R^{2/3}S^{1/3} \quad \text{(R-12)}$$

$$P = 2.67Q^{0.5} \quad \text{(R-13)}$$

$$f = 1.76d^{0.5} \quad \text{(R-14)}$$

where V = mean velocity (fps); R = mean hydraulic radius (ft); P = wetted perimeter (ft); Q = design discharge (ft^3/sec); S = longitudinal slope; f = sediment factor (or silt factor), varying from less than 1.0 for fine silt to almost 10 for medium boulders, cobbles, and shingles; and d = mean grain diameter. *See also* channel stability; extremal hypothesis; tractive force theory.

Regional unit hydrograph *See* hydrograph synthesis; unit hydrograph.

Register An automatic instrument for measuring and recording such characteristics as pressure, water level, velocity, or rainfall intensity. Also called a **recording gage**.

Regular junction A junction that does not make allowance for storage. *See* ponding option.

Regulated flow Streamflow that has been affected by such hydraulic structures as reservoirs, diversions, other controls. The opposite of natural flow. Weirs or orifices may also regulate conduit flow. For **regulation**, *see* flow regulator. A **regulator** is a structure or device that maintains a quantity at a desired value or varies it according to a predetermined plan; for example, regulators control the flow or level of water or wastewater at intakes, in canals, channels, reservoirs, or treatment units.

Relative density (or specific gravity) The dimensionless ratio of the density of a substance to a standard density. For liquids, the standard density is that of water at 4°C, i.e., 1000 kg/m^3 or 1 kg/l; in U.S. customary units, it is 1.941 slugs/ft^3.

Relative error A measure of model accuracy equal to the average error divided by the average observation. (The **average error** is the average difference between observations and simulations.) *See* Martin and McCutcheon (1999). In a modeling application, the mean relative error (RE) for any variable X is:

$$RE = |X_m - X_s|/X_m \quad \text{(R-15)}$$

where X_m and X_s, respectively, are the measured (or observed) and simulated values. *See also* average error; Equation A-7.

Relative exceedance frequency Same as **exceedance probability**. *See* recurrence interval.

Relative hydraulic conductivity The ratio of the hydraulic conductivity K′ of an unsaturated soil sample to the saturated hydraulic conductivity K. It is a function of volumetric moisture content.

Relative pipe roughness (or simply relative roughness) The ratio of the pipe wall thickness ε to the pipe diameter D. It is used in the Moody diagram to determine the friction factor f applicable to turbulent flow of incompressible fluids.

Relaxation factor In an iterative procedure, a factor that modifies the last value computed for an unknown by weighting it with the value from the previous iteration. The overrelaxation or underrelaxation parameter is used in combination with the time-weighting factor to achieve a convergent, stable, and continuous numerical solution at all model junctions for the specified timesteps. A **relaxation method** is an iterative procedure to solve a problem, e.g., an equation or system of equations that without a ready analytical solution. The Hardy Cross method is such a procedure. It is used in the solution of water supply network problems.

Reliability The complement of risk; i.e., the probability that a system will perform as designed and will reach its objective. A **reliability analysis** is an exercise to evaluate the reliability of a simulation, prediction, assessment, or the like to achieve a desired result, considering the effects of uncertainty, randomness, and other factors. *See also* risk of failure. The **reliability index** is a relative measure of reliability and risk. For a given performance parameter, the reliability index ρ may be defined as the ratio of its mean μ to its standard deviation σ:

$$\rho = \mu/\sigma \quad \text{(R-16)}$$

where μ and σ, respectively, are the mean and standard deviation of the measurements.

Relief drain A drain used to dewater a construction site with a high groundwater table. *See also* subsurface drain. A **relief sewer** is intended to carry flows in excess of the capacity of a district or of another sewer. The relief sewer may or may not rejoin the original sewer downstream; it is sometimes called **relief line** or **relief sewer line**.

Relief valve A pressure-relief valve or a valve used to relieve unplanned, nonroutine discharges. Also, a valve that automatically introduces air into a line to raise internal pressure above atmospheric pressure. *See also* safety valve.

Relief well A well draining a stratum to relieve waterlogging at the surface.

Remote sensing A process of data collection, mapping, analysis, or interpretation from a distance, e.g., aerial photogrammetry, global positioning system (GPS), satellite imaging. It uses such equipment as broadband sensors, satellite and aircraft scanners.

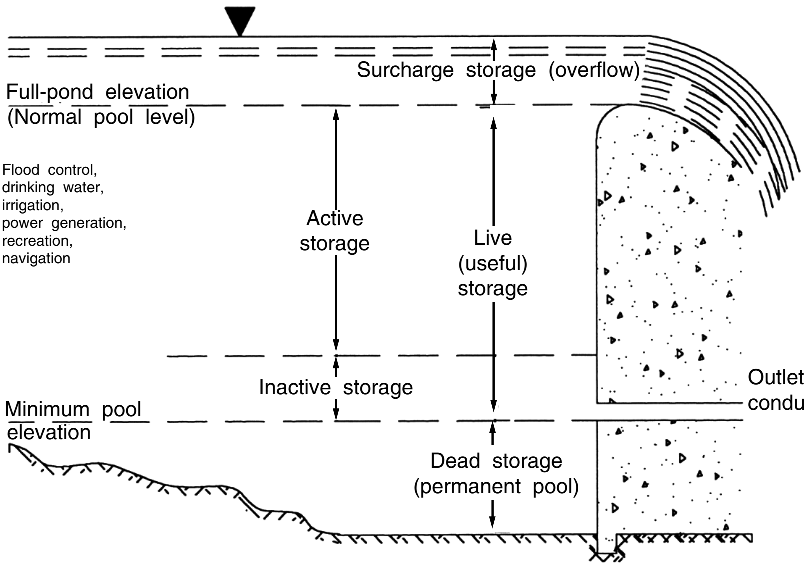


FIGURE R-2 Reservoir storage.

REPGEN A report generation module of the HEC-DSS computer program.

Replacement cost The capital needed to purchase and install all the depreciable components in a facility (EPA-40CFR60.481).

Repose *See* angle of repose.

Reserve capacity The capacity in excess of current demand built into such installations as water and wastewater facilities to accommodate future population or commercial or industrial growth.

Reservoir Any natural or artificial holding area used to store, regulate, or control water or other liquids. A pond, lake, tank, basin, etc. created by the construction of an engineering structure such as a dam to store water for recreation, flood mitigation, water supply, or hydroelectric power production.

Reservoir routing *See* reservoir storage routing.

Reservoir storage The total volume of water in a reservoir at any time. *See* Figure R-2. Its various elements may include: active storage (also called **working volume**), inactive storage, live storage (also called **useful storage**), surcharge storage or overflow, dead storage (or permanent pool), total storage.

Reservoir storage routing Flow (or flood wave) routing through an unregulated reservoir. Outflow and storage depend on the water level and on the inflow hydrograph. The outflow hydrograph is based on the principle of mass conservation in the form of the storage equation. *See* Figure R-3. As the inflow hydrograph rises, excess water goes into storage. Outflow reaches its peak after inflow, at which time storage starts to decrease. The time

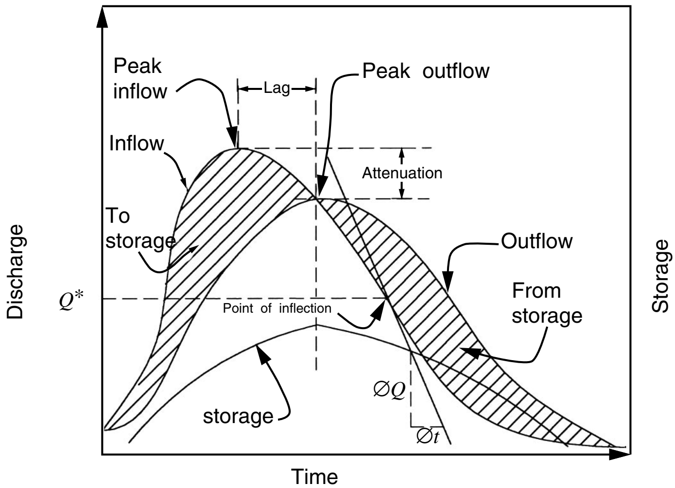


FIGURE R-3 Reservoir storage routing [attenuation constant = Q*/(ΔQ/Δt)].

difference between the two peaks is the lag time, and the difference between peak inflow and peak outflow is the attenuation. *See* modified Puls method.

Reservoir yield The rate of water withdrawal that a given storage reservoir can sustain during a specified period, e.g., from 1 day for a water distribution reservoir to more than a year for a storage reservoir. *See* Figure S-13; safe (or firm) yield; storage–yield relationship.

Residence time The average length of time that a solid particle or a volume of liquid remains in a process, a tank or other unit, or a system. *See also* hydraulic residence time.

Residual error *See* iteration residual error.

Resistance-rate flowmeter A device for measuring liquid flowrates. It combines a differential manometer and a resistance-rod assembly and translates electrically the variations of the manometer fluid level into flows. Also called **resistive flowmeter**.

Retaining wall (1) A wall, usually earthen, around a storage tank or a tank farm; used to hold liquid in place if tanks begin to leak. Also called **retainer wall**. (2) A wall built to hold back a bank of earth or other material or to keep water from flooding. *See also* headwall.

Retardance coefficient (1) A coefficient in the Kerby formula for inlet time. It is analogous to the coefficient of roughness: the higher the coefficient, the longer the inlet time (i.e., the slower the flow). It varies from 0.02 for impervious surfaces to 0.80 in timberland or dense grasses. (2) A similar coefficient in the Izzard's formula for time of concentration or time to equilibrium; it varies from 0.007 for smooth surfaces to 0.06 for dense bluegrass turf.

Retardation coefficient (L_r) A coefficient used in solving the equation of flow through a leaky aquifer and defined as follows:

$$L_r = KL'/K' \quad \text{(R-17)}$$

K is the permeability coefficient of the aquifer, and L′ and K′, respectively, are the semipervious layer's thickness and permeability coefficient. *See* leakage coefficient; leakage factor.

Retarding basin/retarding reservoir (1) A basin/reservoir in a river or valley, designed and operated for flood mitigation through temporary storage, with fixed, automatic outlets. *See* detention basin; storage reservoir. (2) A basin/reservoir in a combined sewer system; installed in advance of junctions of submains and interceptors to improve wastewater interception as well as retard and equalize flows.

Retarding measure A measure, such as grassed drains, retarding basins, or constricted outlets on stormwater drains, designed to delay stormwater and thereby reduce flow peaks.

Retarding reservoir *See* detention basin; retarding basin.

Retention The part of precipitation that does not escape as runoff; that is, the difference between precipitation and total runoff. Retention is the same as **basin recharge**. *See* detention/retention; rainfall–runoff relationship.

Retention basin/retention pond (1) A basin/pond designed to capture stormwater permanently, such as an infiltration basin/pond. The stormwater entering the basin or pond is not discharged directly into a receiving water. (2) Same as **retarding basin**. (3) A basin/pond, enclosed by artificial dikes, used for wastewater treatment and/or storage. *See also* stormwater retention.

Retention/detention ponds A dual system of stormwater management using first infiltration and evaporation in an offline retention pond and then temporary storage in a detention pond when the flow exceeds the capacity of the retention pond. Also called **dual ponds**.

Retention period Same as **detention time**, **hydraulic retention time**, or simply **retention time**. That is, the time t that water, wastewater, or stormwater is retained in a reactor, unit process, storage basin, or any similar facility of volume v at a given hydraulic loading or discharge rate Q:

$$t = v/Q \quad \text{(R-18)}$$

Retention pond *See* retention basin/retention pond; retention/detention ponds.

Retention structures In stormwater management, retention structures include artificial wetlands and ponds designed to maintain a permanent pool of water. For **retention tank**, *see* wet basin.

Retention time Same as **detention time**, **hydraulic retention time**, or **retention period**.

Rettger weir A weir with horizontal crest and sides curved such that the discharge is proportional to the head above the crest. *See also* Figure W-8; proportional weir.

Return flow (1) That portion of the water diverted from a stream that finds its way back to the stream channel either as surface or underground flow. (2) In wastewater studies, the term *return flow* is sometimes used to designate the portion of water use included in the wastewater discharge. *See also* spent water.

Return period Same as **recurrence interval**.

Revetment A blanket of stone, concrete, or other material laid on beaches, embankments, and shores to protect them against erosion from oncoming waves. Other coastal hydraulic structures include: jetties, breakwaters, seawalls, groins, and bulkheads.

Revolution(s) per minute (r/min) A unit of angular velocity of a body that rotates through an angle of 360° so that every point in the body returns to its original position in 1 min. The abbreviation r/min (or rpm) is commonly used to express the specific speed of pumps and turbines.

Revolution(s) per second (r/sec) A unit of angular velocity of a body that rotates through an angle of 360° so that every point in the body returns to its original position in 1 sec.

Reynolds averaged equations Same as **Reynolds equations**.

Reynolds critical velocity Velocity at the point at which the flow condition changes from laminar (streamline) or nonturbulent and friction becomes proportional to the square instead of the first power of the velocity. It differs from the usual definition of critical velocity or Belanger's critical velocity in open-channel flow.

Reynolds equations A set of six equations that define motion and constituent transport under turbulent conditions: (1) the equation of state (expressing fluid density as a function of constituent concentration and temperature); (2) the continuity and constituent transport equations in partial differential form; and (3) three partial differential momentum equations (in the x, y, z directions). *See* Martin and McCutcheon (1999).

Reynolds number A dimensionless parameter widely used in fluid mechanics to characterize the flow regime as laminar or turbulent; named in honor of Sir Osborne Reynolds, who studied turbulent flows in the late 19th century and developed this number. As the ratio of inertia forces to viscous forces, the Reynolds number R_e is the product of the fluid density ρ by the mean velocity V by a characteristic length L_s divided by the fluid absolute viscosity μ or simply the product of the mean velocity by the characteristic length divided by the kinematic viscosity ν:

$$R_e = \rho \cdot V \cdot L_s/\mu = V \cdot L_s/\nu \quad \text{(R-19)}$$

For open-channel flow, the characteristic length is the hydraulic radius R, and the flow is laminar for $R_e < 500$ and turbulent when $R_e > 2000$.

Between these two numbers, the flow may be laminar or turbulent, depending on other factors. Similarly, in closed conduits flowing full (i.e., under pressure), using the diameter D as the characteristic length, the Reynolds number becomes

$$R_e = \rho \cdot V \cdot D/\mu = V \cdot D/\nu \qquad \text{(R-20)}$$

Then, the flow is laminar for a Reynolds number less than 2100 and turbulent for $R_e > 4000$. For groundwater flow, Darcy's law is valid for Reynolds numbers smaller than 1, i.e., for practically all natural porous media. *See* friction factor formulas for laminar flow, Equation D-4, and turbulent flow, Equation D-5. *See also* hydraulics; open-channel flow.

Riabouchinsky, Dimitri Pavlovich *See* hydraulics.

Richardson number *See* gradient Richardson number.

Right bank The right-hand bank of a stream for an observer looking downstream.

Right-of-way The right of passage over a piece of land or the actual land used for the construction of roads, water and sewer facilities, railroads, etc. *See also* easement; leasehold.

RII Abbreviation for rainfall-induced infiltration.

Rill A small, elongated, deep channel created by the eroding action of running water, usually dry except after a rainstorm, icemelt, or snowmelt. Rills or rivulets are similar, to but smaller and less deep than, gullies. *See* stream.

Riparian doctrine/riparian rights The doctrine or common law governing the use of water resources in the eastern United States, under which land owners are entitled to use the water on or bordering their property, including the right to prevent diversion or misuse of upstream waters. **Riparian land** is land that borders on surface water (EPA Glossaries).

Rippl diagram Same as **mass curve**. After W. Rippl, who published an article ("The Capacity of Storage Reservoirs for Water Supply") in the *Proceedings of the Institution of Civil Engineers*, 71, 270 (1883). *See also* Figure R-4; sequential mass–curve method.

Riprap Broken stones, rocks, or boulders placed on dams, levees, dikes, or other embankments or used in river and harbor work for protecting earth surfaces against the action of waves and currents. Also used as roadway filling.

Riser A vertical steam, water, or gas pipe, duct, or conduit that extends at least one full story of a building. Also the vertical pipe supplying water to an elevated tank. Also called a **riser pipe**.

Rising limb The first part of a storm (or RDII) hydrograph at which direct runoff (or I/I) increases until the discharge reaches a peak. Its shape depends on storm duration and intensity, antecedent moisture conditions, and drainage basin characteristics. RDII hydrographs are often represented by triangles; then, the rising limb is a straight line. *See also* Figure R-1; RDII equations; receding limb.

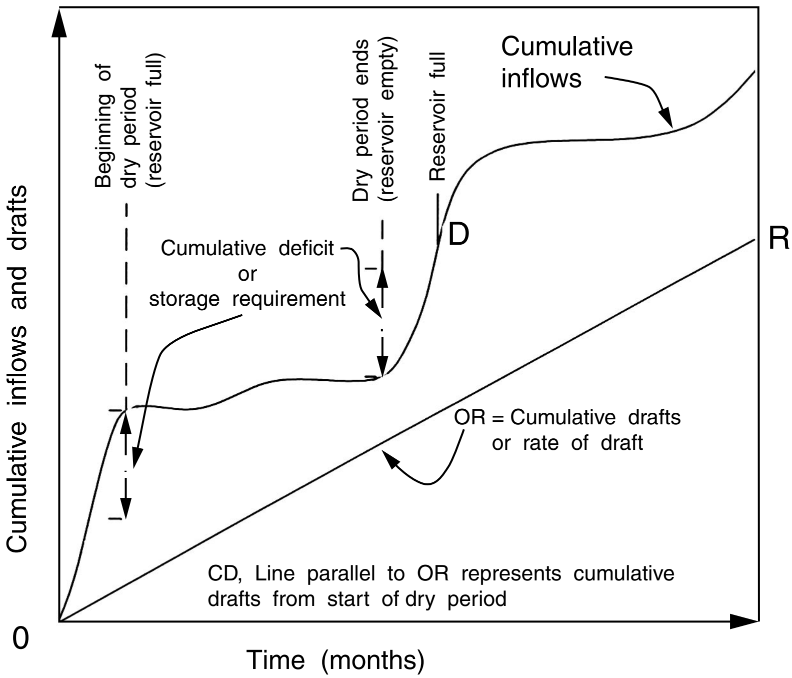


FIGURE R-4 Rippl diagram method.

Risk of failure The probability that a structure or project will fail within a given period. If the exceedance probability of an event is p, the risk of failure (i.e., the probability p′ that at least one such or greater event will occur in a sequence of N years) is based on the binomial distribution $p' = 1 - (1 - p)^N$, which is the same as for the recurrence interval, i.e., Equation R-11. For example, the risk of failure over the next 50 years (N = 50) of a project designed with an exceedance probability of 0.1% (i.e., p = 0.001) is p′ = 0.0488 or almost 5%. *See also* reliability, reliability analysis, reliability index. There are other definitions of risk, for example, (1) the reciprocal of the expected length of time before failure (i.e., the return period); (2) the expected cost or consequence of failure; and (3) the actual cost associated with failure. Failure of a system means that the system fails to reach the desired objective (B. C. Yen in Ouazzar et al., 1988c). Conversely, if an acceptable risk level u, as a percentage chance, is selected for the design life N of a structure, the corresponding return period t (yr) is:

$$t = 1/[1 - (1 - u)^{1/N}] \qquad \text{(R-21)}$$

For example, the return period corresponding to a design life of 40 yr and an acceptable risk of 0.04 (i.e., 1 chance in 25 for failure) is 980 yr.

River A natural stream of water; drains a basin of considerable area and empties into an ocean, a lake, or another river. *See also* stream.

River Analysis System A computer program of the Hydrologic Engineering Center (HEC-RAS) that is intended to replace HEC-2 in the computation of water surface profiles, with additional capability for unsteady flow analysis and calculations of sediment transport. It consists of a graphical user interface, elements for hydraulic analysis and file management, graphics, and reporting utilities.

Riverbank The rising stretch of land at the left or right edge of a river. *See* left bank; right bank.

River basin The land area drained by a river and its tributaries. *See also* catchment; drainage area; drainage basin; watershed.

River basin precipitation-runoff model A network of computational components programmed to simulate surface runoff and compute discharge hydrographs at locations of interest; frequently called a **watershed model** (Hoggan, 1997). HEC-1 is such a model.

Riverbed The channel in which a river flows or has flowed; also defined as the bottom of the river below its usual water surface, excluding the riverbanks.

River engineering A branch of engineering relating to the improvement of rivers and their banks for the movement of goods and people. It encompasses a set of methods and structures, e.g., training, embankment, dams, locks, reservoirs.

River gage A device, such as the staff gage or wire-weight gage, for measuring the river stage at a specific point.

River mile A number indicating the distance in miles from the stream headwaters or origin.

River sleeve A sleeve used to protect pipe joints laid underwater.

River system A hydrologic system consisting of a main stream (or river) and its tributary creeks, brooks, ravines, etc.

River training The realignment of a stream to a straighter and more regular course by eliminating the bends and protecting the new banks. *See* Figure R-5.

River valley The stretch of low land drained or watered by a river on both sides.

Rivulet Same as **rill**.

RMCL Abbreviation for recommended maximum contaminant level.

Rock-fill dam A dam constructed of rocks or stones, either loosely placed or placed in layers and compacted. The rocks support an impermeable face (e.g., in reinforced concrete) or have an impervious clay core in the center of the embankment. There is no considerable difference between a rock-fill dam and an earth-fill dam. *See also* embankment dam; Figure E-1.

Rock-filled crib dam A dam constructed of cells of timber driftbolted together and filled with rocks and with a watertight face.

Rodding A method for cleaning sections of small sewers of debris. It uses a rodding machine to insert and move a set of flexible rods through the sewer section.

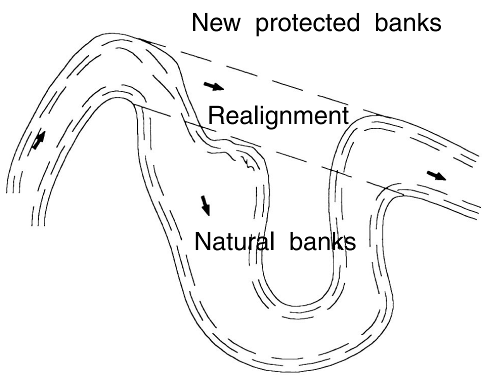


FIGURE R-5 River training.

Roller-compacted concrete dam A dam designed with features of both concrete gravity and earth-fill dams and built with roller-compacted concrete.

Rolling-up curtain weir A movable weir made of horizontal lathes and water-tight hinges. *See also* needle weir.

Roof drain A drain that receives water collected on the surface of a roof for discharge through a downspout (or leader). A **roof leader** is a vertical pipe leading water from a roof drain or gutter to the ground, a cistern, the storm drain, or other means of disposal; also called **downspout** or **downcomer**. **Roof water** is stormwater from building roofs.

Rossby number (R_o) The ratio of advective forces to Coriolis forces; calculated as the ratio of the mean velocity in the horizontal plane V_H to the product of the Coriolis frequency F_c by the horizontal length scale L_s:

$$R_o = V_H/F_c \cdot L_s \tag{R-22}$$

The Coriolis frequency is approximately $F_c = 0.0001/s$. *See* Coriolis force.

Rotameter An instrument for measuring the flowrate of a fluid; consists of a tapered vertical tube in which the fluid flows upward, lifting a weight or float until the fluid force just balances its weight.

Rotary drill A drilling machine that rotates the drill bits attached to rigid, tubular rods and forces down water or mud to remove waste materials; used in **rotary drilling** of boreholes.

Rotary pump A self-priming displacement pump that moves fluids by the action of two rotary elements, alternatively drawing and discharging. It is usually installed for low pressures and small discharges.

Rotating meter *See* current meter.

Rotodynamic pumps Continuous-flow pumps made up of a rotating element called an impeller and enclosed in a casing that connects to the pipeline: radial-flow or centrifugal, axial-flow or propeller, and mixed-flow pumps. The other broad category of pump is positive displacement.

Rotor Generally, it is a rotating part of a machine. *See also* impeller; stator. It has also been defined as the rotating member of a turbine, blower, fan, axial or centrifugal pump, mixing apparatus, alternating electrical motor, propeller meter, electric generator, or motor.

Roughness coefficient (or roughness factor) Roughness is a characteristic of channels and conduits related to their resistance to fluid flow. **Roughness** retards the flow, increases the potential for infiltration, and decreases erosion. The roughness factor indicates the roughness of the channel or conduit (as a result of fabrication, use, biological growth, etc.), indicates the effects of roughness on energy losses in the flowing fluid, and is used as an empirical coefficient in several hydraulic formulas (Bazin's coefficient β, Chézy's C_z, Darcy–Weisbach's friction f, Hazen–Williams' friction C, Kutter's roughness n, Manning's roughness n). The roughness factor in the Colebrook–White equation is also called **equivalent sand grain**, **roughness element magnitude**, **roughness size**, or **sand grain size**.

Roughness height In a compound channel, for a wetted perimeter with N subsections of different roughness coefficients, roughness height is the weighted average of the coefficients of the various subsections. Also called **equivalent roughness coefficient**. *See also* composite roughness coefficient; (channel) conveyance; Equation (E-11).

Roughness size Same as **roughness coefficient**.

Rounded-crest weir A weir that has a crest curved or rounded upward in the direction of flow, entirely or only at both ends. *See also* Figure W-9.

Round-nosed weir A broad-crested weir similar to the rectangular weir or the rounded-crest weir except that it has only the downstream end rounded. *See* Figure W-10.

Round off error The error due to the limit in significant figures of the computer or other processing device. *See also* modeling error.

Routing *See* flood routing; flow routing.

rpm, r/min Abbreviationss for revolution(s) per minute.

r/sec Abbreviation for revolution(s) per second.

Rubble dam A dam built with rough and broken stones or bricks without mortar.

Rule curve A curve used in the operation of multiple-purpose reservoirs; generally a graph that shows water surface elevation in the reservoir versus time (months of the year). It is established on the basis of historical data and project purposes.

Run (1) The continuous time period of a unit operation, a process, or a test. A **model run** is a single execution of a model, i.e., a single performance of all the computational and administrative procedures of the model. **Model runtime** or **model execution time** is the time required to complete one model run on the computer, i.e., the time required to perform all these procedures. **Runtime** is a function of both the model complication and the speed of the computer used. *See also* runtime (of pumps). (2) A succession of similar events preceded and followed by events of a different kind; e.g., a time series of streamflows with periods of deficit and surplus with respect to a reference value. (3) A shallow, natural stream that usually flows continuously, but is turbulent and swift. It is not as large as a river or a creek, but not as small and intermittent as a streamlet. *See also* stream.

Runner One of the four basic parts of reaction hydraulic turbines, such as the Francis and the Kaplan turbines. The other parts are the draft tube, scroll case, and wicket gates. The runner rotates under the weight of the flowing water and turns the generator, thus converting the pressure and kinetic energy into work.

Runoff That part of precipitation, snowmelt, or irrigation water that runs off the land into streams or other surface water. It can carry pollutants from the air and land into receiving waters. Any rainwater, leachate, or other liquid that drains over land from any part of a facility (EPA-94/04, EPA-40CFR241.101-q, and EPA-40CFR260.10). Basically, runoff is the part of precipitation that eventually reaches the surface streams, including direct runoff (overland flow plus interflow) as well as groundwater runoff, but excluding basin recharge (interception, depression storage, soil moisture) and other losses. *See also* rainfall–runoff relationship for the definition of these terms. Other runoff terms are base runoff, channel-phase runoff, cumulative runoff, delayed runoff, direct runoff, groundwater flow, groundwater runoff, mass runoff, mean annual runoff, overland runoff, runoff depth, runoff intensity, runoff rate, subsurface runoff, surface runoff, urban runoff.

RUNOFF Block One of four major computational blocks of the U.S. Environmental Protection Agency Storm Water Management Model (SWMM). Its main output is surface runoff and pollutant loads in response to precipitation and surface pollutant accumulations. It divides the drainage area into relatively homogeneous subareas, each having one inflow (precipitation) and several discharges, including: evaporation, infiltration, and surface runoff. RUNOFF solves numerically the continuity and Manning equations through the finite-difference method and the Newton–Raphson algorithm to obtain depths of flow and discharges. RUNOFF simulates pollutant loads in one of two ways: as a first-order function of the amount of pollutant on the subarea surface at any time or as a simple function of the runoff rate.

Runoff coefficient (1) The fraction of total rainfall that will appear at a facility as runoff. (2) The ratio of total runoff to total rainfall after subtracting basin recharge (soil moisture, depression storage, and interception). Also sometimes defined as the ratio of maximum rate of runoff to the uniform rainfall rate with a duration equaling or exceeding the time of concentration (American Public Health Association et al., 1981). Used in the past in the so-called rational formula to determine runoff rate. Currently, the **coefficient method** is more commonly used (Nix, 1994):

$$Q = C(P - D) \tag{R-23}$$

where Q is the runoff rate in inches/hour, C is the composite runoff coefficient, P is precipitation intensity in inches/hour, and D is the available depression storage in inches. The composite runoff coefficient is the weighted average coefficient for the various land uses in the area under consideration:

$$C = C_1 + (C_2 - C_1)\sum_{i=1}^{N}(L_i)(F_i) \tag{R-24}$$

where C_1 and C_2 are the runoff coefficients for pervious and impervious surfaces, respectively; L_i is the fraction of land use i in the area; F_i is the pervious fraction of land use i; and N is the number of land uses in the area. *See also* Mitci formula.

Runoff curve number *See* curve number.

Runoff depth The ratio of the volume of runoff over a watershed to the area of the watershed; usually expressed in inches or millimeters. Sometimes, it is divided by the storm duration to produce the runoff intensity or runoff rate in inches per hour or millimeters per hour.

Runoff distribution curve A plot of the typical distribution of runoff from a drainage area showing the percentage of total runoff over storm duration.

Runoff event An episode of runoff following a storm event.

Runoff generation The process by which runoff occurs as a result of a rainstorm. There are several theories of the rainfall–runoff relationship or methods to compute runoff. *See*, e.g., rational method; unit hydrograph method. *See also* dynamic watershed concept; Horton overland flow concept; subsurface stormflow. *See* Figure R-6.

Runoff intensity The volume of runoff from a drainage area per unit of time; expressed in cubic feet per second, cubic feet per second per square mile, or inches depth per hour. The last unit makes the runoff intensity comparable to the rainfall intensity.

Runoff propensity parameter A parameter used in the National Water Assessment Model to account for the fact that runoff tends to occur before the soil is fully saturated.

Runoff rate Same as **runoff intensity**.

Runoff volume The volume of runoff during a specified time or for the duration of a storm; expressed in inches of depth, in acre-feet, or any other volume unit.

Run-of-river plant/project A power plant/project designed to operate without the benefit of a storage reservoir. Also called **streamflow plant/project**.

Run-on Any rainwater, leachate, or other liquid that drains overland onto any part of a facility.

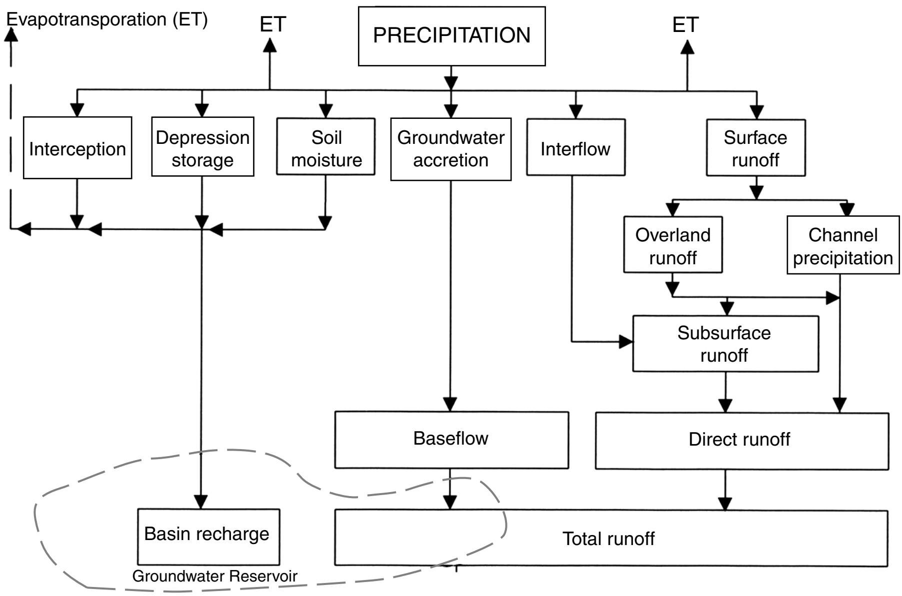


FIGURE R-6 Runoff generation.

Runtime The period of time that a device, piece of machinery, unit, process, etc. is under operation. Pump runtime is an important output in sewer system modeling applications. *See also* model run, runtime; NAPOT.

R_{up} Notation for the hydraulic radius of the upstream end of a conduit in the normal flow equation, Equation (N-18).

Russell, John Scott *See* hydraulics.

S

Saddle spillway A spillway constructed through a saddle and usually discharging into a channel that leads to the downstream portion of the impounded stream. (A **saddle** is a steel or concrete structure above ground.)

Safe Drinking Water Act (SDWA) A 1974 act that (1) requires the U.S. Environmental Protection Agency to establish a drinking water priority list of contaminants that may adversely affect human health and to promulgate regulations for 25 new contaminants every 3 yr; (2) set standards for maximum contaminant levels and maximum contaminant level goals for certain chemical and bacteriological pollutants in public drinking water systems; and (3) regulate underground injection systems. *See also* Clean Water Act.

Safety valve A valve normally closed that automatically opens when prescribed conditions are exceeded in a pipeline or other closed containers of fluids. For example, an automatic valve that opens when pressure becomes excessive in a steam boiler or a pressure cooker. Also called **safety relief valve**. *See also* pressure-relief device or valve; relief valve.

Safe velocity A noneroding and self-cleansing velocity; i.e., it is large enough to maintain sediments in suspension, but without damaging the conduit or channel.

Safe water Water that does not contain harmful bacteria, toxic materials, or chemicals and is considered safe for drinking even though it may have taste, odor, color, and certain mineral problems (EPA-94/04). Drinking water should be not only safe, but also palatable, i.e., free of these problems.

Safe yield The annual amount of water that can be taken from a source or supply over a period of years without depleting that source beyond its ability to be replenished naturally in "wet years" (EPA-94/04). Safe yield is sometimes taken as the minimum yield recorded in the past or defined as the maximum **dependable draft** that can be made continuously on a source of surface water or groundwater supply over a given period of time, during which the probable driest period, and therefore period of greatest deficiency in water supply, is likely to occur. Dependability is relative and is a function of storage provided and drought probability (American Public Health Association et al., 1981; Parker, 1997. The safe yield of a surface stream is close to its average flow with adequate storage; otherwise, it is its lowest dry-weather flow. The concept of safe yield does not imply 100% reliability or zero risk. Also called **firm yield**. *See also* groundwater yield.

Sag line A section of a gravity sewer constructed lower than adjacent sections to pass under an obstruction. Also called **depressed sewer**, **sag pipe**, or **inverted siphon**. *See* dive culvert; inverted siphon.

Saint-Venant equations (After Jean-Claude Barre de Saint-Venant, researcher who first used them in 1871 in the analysis of one-dimensional unsteady flow.) Two partial differential forms of the continuity and momentum equations are used in the simulation of one-dimensional, gradually varied flow in open channels. The first regards continuity:

$$\partial Q/\partial x + \partial A/\partial t = 0 \quad \text{(S-1)}$$

The second regards momentum:

$$\partial y/\partial x + (V/g)\cdot\partial V/\partial x + (1/g)\cdot\partial V/\partial t + S_f - S_0 = 0 \quad \text{(S-2)}$$

The Saint-Venant equations are solved numerically in hydraulic routing to determine flow characteristics such as discharge Q, depth y, and average velocity V in function of the cross-sectional area of flow A, the gravitational acceleration g, the friction or energy slope S_f, the invert or bottom slope S_0, the time t, and the longitudinal distance x. The **continuity equation** expresses that the sum of inflows to and outflows from a control volume $\partial Q/\partial x$ is equal to the change in the amount of water in the control volume $\partial A/\partial t$. The **momentum equation** indicates that there is equilibrium among the various forces in action: pressure force $\partial y/\partial x$, convective acceleration force $(V/g)\cdot\partial V/\partial x$, local acceleration force $(1/g)\cdot\partial V/\partial t$, gravity force S_0, and friction force S_f. The friction force can be determined from the Manning equation:

$$S_f = Q^2/[(\delta/n)^2 A^2 R^{4/3}] \quad \text{(S-3)}$$

Saline contamination Contamination of a water supply by saline water.

Saline estuarine waters Those semienclosed coastal waters that have a free connection to the territorial sea, undergo net seaward exchange with ocean waters, and have salinities comparable to those of the ocean. Generally, these waters are near estuaries and have cross-sectional annual mean salinities greater than 25 parts per 1000 (EPA-40CFR125.58-q). *See also* saline water.

Saline intrusion The penetration of saltwater into a freshwater body; a salt wedge.

Saline spring A spring with water that contains a significant amount of sodium chloride (NaCl) or other salts. Also called a **salt spring**. *See also* saline water.

Saline water Water with a fairly high mineral content as expressed by a concentration of dissolved solids between 10,000 and 35,000 mg/l. Also called

saltwater. *See also* brackish water; brine; freshwater; ocean waters; saline estuarine waters; seawater.

Saline water reclamation Treatment of brine or brackish waters for the removal of salts to provide water for drinking and other municipal uses. Common treatment methods are ion exchange, distillation, reverse osmosis, evaporation, and crystallization.

Salinity The presence or relative concentration of dissolved salts (mostly sodium chloride) or dissolved minerals in water. Expressed as milligram per liter of chlorine or milligram per liter of total dissolved solids.

Saltation Transportation of sand and gravel particles by an intermittent, leaping movement in air or running water.

Salt method Same as **dilution method**, but with a salt solution as tracer. It is a method used to evaluate a stream discharge by injecting a salt solution of known concentration and flowrate and measuring its concentration at a point downstream. *See* Equation D-11. This procedure is often used to measure discharges in closed conduits under pressure, e.g., through a hydraulic turbine. Another form is the **salt velocity method**, which uses a small quantity of salt or a radioactive isotope for measuring the velocity and discharge of flowing water. The travel time between two points is computed on the basis of the electrical conductivity or radiation level at these two points.

Salt spring Same as **saline spring**.

Salt velocity meter The device that is used in the salt velocity method.

Salt velocity method A method for determining the velocity of a stream using the electrical conductivity of a salt solution. *See* salt method.

Saltwater Same as **saline water**.

Saltwater intrusion The invasion of fresh surface or groundwater by salt water. If it comes from the ocean, it may be called seawater intrusion (EPA-94/04). *See also* Figure S-1; saline intrusion.

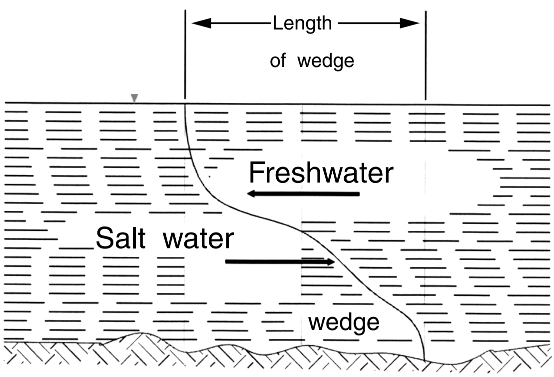


FIGURE S-1 Saline intrusion.

Salt wedge The volume of saltwater that intrudes into a body of freshwater as a result of density differences. *See* Figure S-1; saline intrusion.

Salt well A well bored or driven to obtain brine.

Sampling well A well used to obtain samples for analysis or to measure groundwater levels. Also called a **monitoring well**.

Sand (1) A loose, gritty material of easily distinguishable grains of worn or disintegrated rock (mostly quartz or silicon dioxide) varying from about 0.05 mm to 2 mm in equivalent diameter (according to the classification of the U.S. Department of Agriculture). It is sometimes subdivided into very fine sand, fine sand, medium sand, coarse sand, and grit or fine gravel. (2) A type of sediment carried by water or ice and deposited along shores, in riverbeds, or in deserts. Coarse sand particles are larger than 0.5 mm, while very fine sand particles have diameters between 0.10 and 0.25 mm. *See* soil classification.

Sand drain A vertical boring through clay or silt and filled with sand and gravel for drainage.

Sand filter A unit consisting of beds of sand installed underground in trenches or precast concrete boxes or above ground to remove fine suspended materials from water, wastewater, or stormwater. In wastewater treatment, air and bacteria decompose additional wastes filtering through the sand so that cleaner water drains from the bed. Sand filters are commonly used to treat runoff from large buildings, access roads, and parking lots and in sludge drying beds.

Sand grain size A factor used in studying the roughness of pipes. *See* equivalent sand grain size.

Sand pump A simple centrifugal-type device for pumping mud and liquids laden with sand or gravel out of boreholes without excessive clogging or damage. It is a hollow cylinder, open at the top, with a ball or clack valve at the bottom. Also called **sludger** or **shell pump**.

Sand trap A device installed in a conduit to trap and remove sand and soil particles from water. *See also* sediment trap (1).

Sanitary collection system The sewer network for the collection and conveyance of municipal wastewater, including sewers, pumping stations, and their appurtenances. *See also* combined sewer; sanitary sewer system; storm drain, storm sewer.

Sanitary connection The connection of a residence, a commercial establishment, or an industrial establishment to a public water supply or a sanitary sewer system.

Sanitary engineering The branch of civil engineering dealing with works and activities for the protection and promotion of public health, particularly the design, construction, and operation of water supply and treatment; wastewater collection and treatment; drainage; and solid waste disposal facilities.

Sanitary sewage Wastewater containing human wastes from residences and commercial, institutional, and industrial establishments, but excluding any process or hazardous wastes. It constitutes the major portion of municipal wastewater. The term **sanitary sewage** is becoming obsolete and replaced by domestic or sanitary wastewater.

Sanitary sewer A sewer intended to carry only sanitary wastewater (i.e., liquid and water-carried wastes from residences, commercial buildings, industrial plants, and institutions) together with minor quantities of groundwater, stormwater, and surface waters that are not admitted intentionally. Or, an underground pipe that carries off only domestic or industrial waste, not stormwater (EPA-40CFR35.2005-37, EPA-40CFR35.905, and EPA-94/04). *See* combined sewer; storm sewer.

Sanitary sewer overflow Discharge of untreated wastewater when the flow capacity of a sanitary sewer system is exceeded, usually during rainstorms or as a result of infiltration/inflow. *See also* overflow.

Sanitary sewer system A network of facilities for the collection, transmission, treatment, and disposal of sanitary wastewater. *See also* combined sewer; sanitary collection system; sewerage; sewer system; storm sewer.

Sanitary survey An on-site review of the water sources, facilities, equipment, operation, and maintenance of a public water system to evaluate the adequacy of those elements for producing and distributing safe drinking water (EPA-94/04).

Sanitary wastewater Liquid and water-carried wastes from residences, commercial buildings, industrial plants, and institutions together with minor quantities of groundwater, stormwater, and surface waters that are not admitted intentionally.

Sanitary water Water discharged from sinks, showers, kitchens, or other nonindustrial operations, but not from commodes (EPA-94/04). *See also* graywater; sullage.

Sanitation Control of physical factors in the human environment that could harm development, health, or survival (EPA-94/04). More generally, sanitation is the science and practice of healthy environmental measures, such as potable water supply, drainage, wastewater and solid waste disposal, ventilation, etc.

Saturated zone That part of the earth's crust in which all voids are filled with water (EPA-40CFR258.2) or the area below the water table where all open spaces are filled with water (EPA-94/04). Actually, a portion of this water is subsurface runoff in the **temporary** saturation zone; it will become overland runoff before reaching the **permanent** zone of saturation, which is actually the groundwater. *See* subsurface water.

Saturation The condition of a liquid (water) when it has taken into solution the maximum possible quantity of a given substance at a given temperature and pressure (EPA-94/04).

Saturation line Same as **phreatic line**.

Saturation overland flow concept One of three common theories of runoff generation: only the saturated portion of the drainage area contributes runoff, which source area expands at the beginning of a rainstorm and contracts toward the end of the storm. It is also called the **variable source area**

concept or the **dynamic watershed concept**. The other two common theories are Horton overland flow and subsurface stormflow.

Saturation zone Same as **saturated zone**.

Saunders airlift pump A type of airlift. A low-efficiency device used mainly in a well for lifting water out of pumps by forcing compressed air at the bottom of the well. Hydrostatic pressure forces up the resulting mixture into the outlet pipe.

SCADA Acronym for supervisory control and data acquisition.

SCADA-Flo™ An open-channel transmitter manufactured by Marsh-McBirney, Inc., of Frederick, MD.

Scale effect The error introduced by the use of a physical-scale model instead of the prototype; i.e., the difference between the behavior of the model and that of the prototype.

Scale model A physical representation of a prototype at a full or reduced scale, but preserving the predominant characteristics of the prototype. Accurate physical models have the properties of dynamic, geometric, and kinematic similarity. *See* hydraulic model. The use of a model that neglects some of the features of the prototype introduces an error called the **scale effect**. Also called **physical-scale** or **physical model**. Other types of model are analog, iconic, and symbolic models.

Scale parameter (K) One of the three parameters of extreme value distributions, such as the gamma function used in the Nash model; the others are the shape parameter n and the location parameter x_0. The scale and shape parameters are related to the hydrodraph time to peak T_p (James, 1996):

$$K = T_p/(n - 1) \tag{S-4}$$

Scanning A method to convert a paper map to digital form using a beam of light or electrons over the map to reproduce it. Another method of conversion is **line digitization**. Scanning is more efficient than digitization for maps to be archived, but requires more postprocessing for immediate use.

Scatter diagram, scattergraph, scatter plot Graphical representation of the differences between observed values and model predictions. These graphs are used with statistical analysis to evaluate the degree of agreement between observations and predictions and, in a sense, judge model performance. Scattergraphs can also be used to verify the repeatability and accuracy of flow monitoring data, e.g., by plotting velocity versus depth of flow in a conduit or open channel, with a trend line through the points, and comparing the field results with the theoretical relationship. *See* Section II for further information.

Schematic diagram (or schematics) A schematic diagram is a simplified representation of a physical system by a flowchart between nodes and links. It may be developed by discretizing the elements of the system. Sewer system schematics are prepared, e.g., as maps — without scale but with the direction of flow — showing the general location of the conduits, the treatment plants, pump stations, valves, manholes, and other appurtenances. In sewer system modeling, schematics are also called **nodal diagrams**. With the advent of computers and their graphic capabilities, **drainage network diagrams** tend to replace the schematic diagrams since the former can represent on the computer screen the drainage elements exactly as they appear in reality. Drainage network diagrams can be prepared from digitized sewer system maps or atlases. **Schematization** is the representation of key features of a system by a schematic diagram or by a computational procedure in a model.

Schmidt number One of three dimensionless numbers used to determine which turbulent mixing conditions prevail. *See* Prandtl, Schmidt, and Lewis numbers.

Scouring basin A basin that stores water for release when needed to maintain a desired depth in an entrance channel. Also called **sluicing pond**.

Scouring velocity The minimum velocity required for a fluid in motion to dislodge and carry away material particle accumulations in a conduit, pipeline, or waterway. In the water and wastewater applications of sedimentation, the horizontal velocity V just sufficient to cause scour is (McGhee, 1991):

$$V = [8\beta(\gamma - 1)g \cdot d/f]^{0.5} \quad \text{(S-5)}$$

where β is a dimensionless constant ranging from 0.04 to 0.06, f is the Darcy–Weisbach friction factor (usually between 0.02 and 0.03), γ is the specific gravity of the particles, d is the equivalent diameter of the particles, and g is the gravitational acceleration. *See also* self-cleansing velocity.

Scour valve A small, gated takeoff valve installed at a low point in a pressure conduit or at a depression in a pipeline to allow drainage or flushing of the line. Also called a **blow-off** valve or **washout valve**.

Screen pipe A perforated pipe with an appropriate straining material around it to admit well water and exclude sand and other solid particles.

Screw pump A low-lift, high-capacity pump that raises water by means of a helical impeller in its casing.

Scroll case A basic part of reaction hydraulic turbines, such as the Francis and the Kaplan turbines. The other parts are the draft tube, the wicket gates, and the runner. The scroll case conveys the flowing water from the supply pipe to the wicket gates and to the runner.

SCS Abbreviation for the Soil Conservation Service of the U.S. Department of Agriculture. For the **SCS 24-h rainfall curve**, *see* rainfall curve. **SCS CN** is the abbreviation for SCS curve number. For **SCS dimensionless unit hydrograph**, *see* SCS hydrograph method.

SCS hydrograph method A Soil Conservation Service (SCS) method of generating runoff hydrographs using preselected rainfall distributions, appropriate peak rate factors, storm duration, total rainfall amounts, basin areas, SCS curve numbers, directly connected impervious areas (DCIAs), and times of concentration. Such hydrographs are used as input to Advanced

Interconnected Pond Routing (AdICPR), Stormwater Management Model (SWMM), and other models. The SCS method is one of three commonly used methods of generating synthetic unit hydrographs (the other two are the Clark and the Snyder methods). The SCS method uses the concept of a dimensionless unit hydrograph, a mass curve, and an equivalent triangular unit hydrograph to derive the equation of the peak discharge as well as the flows in the rising and receding limbs. *See also* dimensionless hydrograph; RDII equations.

SCS runoff equation An equation recommended by the Soil Conservation Service (SCS) to determine the accumulated runoff or runoff depth Q over a drainage area, expressed in inches or millimeters, as a function of the accumulated rainfall depth P and the maximum retention of water by the soil S:

$$Q = (P - 0.2S)^2/(P + 0.8S) \qquad \text{(S-6)}$$

The factor S is related to the curve number (CN) as follows:

$$CN = 1000/(S + 10) \qquad \text{(S-7)}$$

S-curve method A procedure to convert a unit hydrograph of one duration to a hydrograph of another duration by lagging and combining equally spaced unit hydrographs of the same duration.

SDWA Abbreviation for Safe Drinking Water Act.

Seagate A gate that protects a harbor or tidal basin from the sea.

Sealed option The opposite of ponding option. In XP-SWMM (Stormwater Management Model) modeling, the sealed option does not allow ponding at a junction.

Sea-level datum The average surface level of the sea or mean sea level, uninfluenced by tidal movement or waves, adopted as a reference for heights and elevations. *See also* NGVD.

Seawall A wall of concrete, metal, or stone or an embankment built to protect the coastline against erosion, encroachment, and flooding caused by wave action. *See also* groin. Other coastal hydraulic structures include jetties, breakwaters, and revetments.

Seawater Water with a high mineral content, as expressed by a concentration of dissolved solids of about 35,000 mg/l. *See also* brackish water; brine; freshwater; saline estuarine waters; saline water.

Seawater intrusion *See* saltwater intrusion.

sec Abbreviation for second(s).

Secant method A procedure in the HEC-RAS model used to determine the critical depth in the iterative solution of the specific energy equation. *See also* parabolic interpolation (Hoggan, 1997).

Secure maximum contaminant level Maximum permissible level of a contaminant in water delivered to the free-flowing outlet of the ultimate user or of contamination resulting from corrosion of piping and plumbing caused by water quality (EPA Glossaries). *See also* maximum contaminant level; maximum contaminant level goal.

Seddon's principle Approximation of the velocity V of a flood wave using a discharge rating curve to determine the number of routing steps N of the modified Puls method (Hoggan, 1997):

$$N = K/\Delta t = L/(V \cdot \Delta t) = L \cdot W/(\Delta t \cdot dQ/dy) \quad \text{(S-8)}$$

where K is the travel time through the reservoir, Δt is the timestep (computational time interval), L is the reach length, W is the channel width, and dQ/dy is the slope of the discharge rating curve.

Sediment Mineral or organic material that is in suspension, is transported, or has been moved from its site of origin by water, wind, ice, or mass wasting and has come to rest on the earth surface either above or below sea level (Hawley and Parsons in Dodson, 1999). Soil, sand, and minerals washed from land into water, usually after rain. They pile up in reservoirs, rivers, and harbors, destroying fish and wildlife habitat and clouding the water so that sunlight cannot reach aquatic plants. Careless farming, mining, and building activities will expose sediment materials, allowing them to wash off the land after rainfall (EPA-94/04). Streams carry sediment in the suspended form and as bedload.

Sedimentation The process of settling out by gravity of suspended solids (sediment) from water, wastewater, or other liquids. In water and wastewater treatment, the process is carried out in a sedimentation tank, sedimentation basin, or clarifier and is sometimes enhanced by coagulation and flocculation. Also called **settling**.

Sedimentation basin/sedimentation tank A quiescent basin/tank for the removal of suspended (settleable) solids by gravity. Also called **clarifier** and **settling basin/tank**.

Sedimentation pond with displacement A stormwater settling pond without volume control, but with a permanent pool. There is no discharge from the pond between storm events. *See also* stormwater retention.

Sedimentation tank *See* sedimentation basin/sediment tank.

Sediment discharge Dry weight of sediment per unit of time. Same as **sediment load**.

Sediment discharge curve The graph of sediment discharge as ordinate and river stage as abscissa at a given point, such as a sediment station. *See also* sediment transport curve.

Sediment factor A factor in Lacey's regime theory formula for the effect of sediment size. Also called **silt factor**. *See* Equations R-14 through R-16.

Sediment forebay One of the two main storage compartments of a stormwater detention pond; designed to capture sediment.

Sediment load Dry weight of sediment per unit of time. Same as **sediment discharge**.

Sediment removal efficiency (E) A formula proposed by Thomas R. Camp in 1946 and used in stormwater modeling to estimate the performance of extended detention wet ponds (James, 1996):

$$E = 1 - (1 + A \cdot V/nQ)^{n} \quad \text{(S-9)}$$

where A is the active storage surface area of the facility, V is the settling velocity, n is a turbulence or short-circuiting parameter, and Q is the average constant release rate from the facility.

Sediment retention pond A temporary device formed by excavation or embankment to retain sediment from runoff.

Sediment station A station for the collection of sediment samples.

Sediment tank A portable metal tank providing at least 10 min of storage for sediment to settle out discharges from a construction site. *See also* sedimentation tank.

Sediment transport curve The graph of the amount of sediment transported by a stream (in tons per day) as a function of stream discharge (in cubic feet per second). *See also* sediment discharge curve.

Sediment trap (1) A device installed in a conduit to trap and remove sediment from water. *See also* sand trap. (2) A temporary device to retain runoff from a small drainage area and allow silt to settle out. It consists of an excavated pond or a basin formed by an embankment across a low area or drainage swale, with an outlet or spillway of large stones or aggregates.

Sediment trapping efficiency The percentage of sediment trapped in a reservoir or a detention basin. It may be estimated using Brune's trap efficiency curves as a function of the ratio of reservoir capacity to annual flow.

Sediment yield The quantity of sediment arriving at a specific location.

Seepage Percolation of water through the soils from unlined canals, ditches, laterals, watercourses, or water storage facilities. Also, the slow movement of water through small cracks, pores, or interstices of a material into or out of a body of surface or ground water.

Seepage pond A pond constructed to allow wastewater, stormwater, or other surface water to percolate and recharge underground formations. Other means of groundwater recharge include check dams, recharge wells, spreading grounds, and underground leaching systems.

Segregated storm sewer system A drain or collection system designed and operated for the sole purpose of collecting runoff at a facility and segregated from all other individual drain systems (EPA-40CFR61.341).

Self-cleansing velocity A flow velocity expected to prevent deposition of solids in sewers. A minimum velocity of 2.0 fps is often recommended, but in general, the self-cleansing velocity V is:

$$V = C\sqrt{kd(\gamma_s - \gamma)/\gamma} \quad \text{(S-10)}$$

where C = Chézy coefficient of roughness, k = a coefficient that depends on the porosity ratio of the sediment and the slope of the sewer and varies from 0.04 to more than 0.80, d = sediment diameter, γ = specific weight of the wastewater, and γ_s = specific weight of the sediment. *See also* scouring velocity.

Semiconfined aquifer An aquifer partially confined by soil layers of low permeability through which recharge and discharge can still occur. Also called **leaky aquifer**.

Sensitivity analysis In a modeling exercise, it is an analysis to determine which factors, parameters, initial conditions, and boundary conditions affect significantly the results of the simulation. These parameters and conditions are varied individually or in groups by constant percentages. Sometimes a precalibration sensitivity analysis is conducted to determine important model factors. The postcalibration analysis will then examine the impact of errors in model parameters, input variables, or initial values of state variables on predicted values. The final result of the analysis is a comparison of percentage changes in model output versus percentage changes in factors or parameters. A sensitivity analysis is not as rigorous as an error analysis, which can determine model validity by assigning uncertainties to important parameters and conditions. *See* Section II for further information.

Separate sewer system A sewer system consisting of separate sewers to carry wastewater (sanitary sewers) and stormwater/surface water (storm sewers), as opposed to a combined sewer system.

Separating weir A device such as a gap or an opening in the invert of a combined sewer to let the dry-weather flow fall to a separate sanitary sewer. Also called **leaping weir**.

Septage The liquid and solid material pumped from a septic tank, cesspool, or similar domestic wastewater treatment system or holding tank when the system is cleaned or maintained.

Septic system An on-site system designed to treat and dispose of wastewater from individual residences or commercial establishments. A typical septic system consists of a **septic tank** that receives and treats the wastewater and a system of tile lines or a pit for disposal of the liquid effluent through the soil. Bacteria in the tank decompose the solids, which must be pumped out periodically and hauled to a treatment facility. *See also* soil absorption field.

Sequential mass–curve method A procedure that determines storage requirement as the maximum cumulative difference between inflows to and drafts from a reservoir during periods of drought. Also called **Rippl diagram method**. *See* Figure R-4; modified mass diagram; sequent peak procedure.

Sequential reservoir routing The use of historical records (inflows and outflows or drafts) to determine reservoir storage requirements. *See* modified mass diagram; sequential mass–curve method; sequent peak procedure.

Sequent depths The depths before y_1 and after y_2, a hydraulic jump. Also called **conjugate depths**. *See* Equation C-16 for the relationship between conjugate depths and the Froude number. (It is more appropriate to call y_1 the initial depth and y_2 the sequent depth.)

Sequent peak procedure A procedure developed by H. A. Thomas and M. B. Fiering of Harvard University (Cambridge, MA) to determine minimum storage requirements given a sequence of streamflows and a corresponding sequence of drafts. The procedure is applied as follows and as sketched in Table S-1 (Fair et al., 1966): (a) The flows Q_i and drafts D_i are given for each period i. (b) The surplus or deficit for each period is $Q_i - D_i$. A peak P_j or a trough T_j is noted when $\sum i$ reverses direction. (c) The minimum storage requirement S* is the maximum difference between a peak and its subsequent trough:

$$S^* = \max(P_j - T_j) \qquad \text{(S-11)}$$

(d) Given the storage capacity S*, the actual storage S_i at the end of period i is:

$$S_i = \text{minimum } \{S^*, [S_{i-1} + (Q_i - D_i)]\} \qquad \text{(S-12)}$$

(e) There is waste W_i when the sum of storage and surplus exceeds the storage capacity S*:

$$W_i = \text{maximum } \{0, [(Q_i - D_i) - (S^* - S_{i-1})]\}$$

See also Figure R-4; modified mass diagram; sequential mass-curve method.

TABLE S-1
Sequent Peak Procedure

Sequence of periods (e.g., months)	Flow Q	Draft D	Surplus or Deficit Q − D	Cumulative Deficit or Surplus ΣQ − D	Storage S	Waste W	Reservoir State[a]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1	Q_1	D_1	$Q_1 - D_1$	Σ_1	S_1	W_1	R, F, S, E
2	Q_2	D_2	$Q_2 - D_2$	Σ_2	S_2	W_2	R, F, S, E
3	Q_3	D_3	$Q_3 - D_3$	Σ_3	S_3	W_3	R, F, S, E
—	—	—	—	—	—	—	R, F, S, E
i − 1	Q_{i-1}	D_{i-1}	$Q_{i-1} - D_{i-1}$	Σ_{i-1}	S_i −1	W_i − 1	R, F, S, E
i	Q_i	D_i	$Q_i - D_i$	Σ_i	S_i	W_i	R, F, S, E
i + 1	Q_{i+1}	D_{i+1}	$Q_{i+1} - D_{i+1}$	Σ_{i+1}	S_i + 1	W_i + 1	R, F, S, E
—	—	—	—	—	—	—	R, F, S, E
N	Q_N	D_N	$Q_N - D_N$	Σ_N	S_N	W_N	R, F, S, E

[a] R = rising, F = falling, S = spilling, E = empty.

Serial correlation coefficient A parameter that indicates dependence in successive elements of a time series or elements of the series that are more than one interval apart; for example, whether hydrological data show a seasonal pattern. Also called **autocorrelation coefficient**.

Serpentine weir A type of outlet weir sometimes installed in sedimentation tanks to increase the effective length of a peripheral weir by extending the weir pans inward from the effluent trough in a winding way.

Service, service connection, service connector, service line, service meter, service pipe *See* water service connection.

Service reservoir A reservoir in a water distribution system that provides local storage in case of an emergency and to respond to daily fluctuations in demand. Also called **distribution** or **distributing reservoir**. *See also* service storage.

Service spillway A spillway designed to handle frequent or average overflows (also called an **auxiliary spillway**) while the emergency spillways are used for extreme floods.

Service storage The total distribution storage requirement in a water supply system for three main purposes: demand equalization over a 24-h period, fire reserve, and emergency reserve against the risk of interruption due to inspection and repair. (With adequate service storage, the supply conduits or transmission lines are designed only for the maximum daily rate instead of the much higher rate of distribution lines.) Also called **distributing** or **distribution reservoir**.

Settling *See* sedimentation.

Settling basin A quiescent basin for the removal of suspended (settleable) solids by gravity. Also called **clarifier** and **sedimentation basin**. In general, settling refers to the gravity separation of heavy materials from light materials. Settling basins are used not only in stormwater and wastewater treatment, but also to trap stream sediment ahead of a reservoir or to treat factory effluents. A **settling chamber** is a vessel, while a **settling reservoir** consists of a series of settling basins.

Settling pond Defined similar to settling basin.

Settling tank A holding tank for wastewater; heavier particles sink to the bottom for removal and disposal. *See also* settling basin.

Settling velocity The velocity at which particles settle in air, water, or wastewater.

Seven-day, consecutive low flow with a 10-year return frequency (7Q10) The lowest streamflow for 7 consecutive days expected to occur once in 10 yr. *See* design flow.

Severity index *See* Haestad severity index.

Sewage Human body wastes and the wastes from toilets and other receptacles intended to receive or retain body wastes. The waste and wastewater produced by residential and commercial sources and discharged into sewers. *See also* wastewater.

Sewage collection system Each, and all, of the common lateral sewers within a publicly owned treatment system that are primarily installed to receive wastewater directly from facilities that convey wastewater from individual

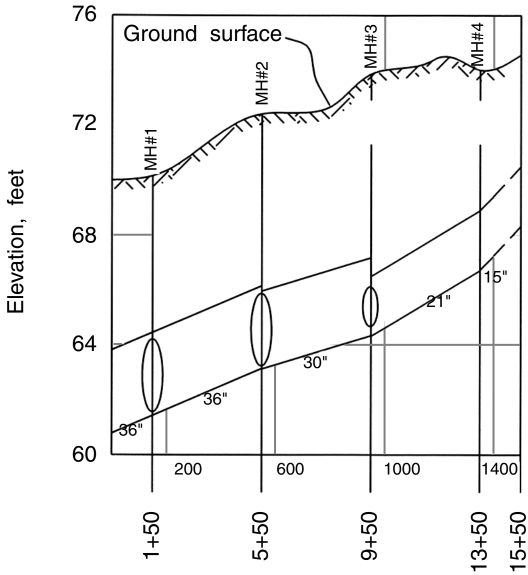


FIGURE S-2 Sewer profile example.

structures or from private property and that include service connection Y fittings designed for connection with those facilities. The facilities that convey wastewater from individual structures, from private property to the public lateral sewer, or their equivalent are specifically excluded from the definition, with the exception of pumping units and pressurized lines for individual structures or groups of structures when such units are cost-effective and are owned and maintained by the grantee (EPA-40CFR35.905). *See also* sewer system.

Sewer A channel or conduit that carries wastewater or stormwater runoff from the source to a treatment plant or receiving stream. *See also* combined sewer; sanitary sewers; storm sewers. *See* Figures S-2 and S-3. **Sewerage** is the collection, conveyance, treatment, and disposal of liquid wastes; same as **sewer system**. For **sewer appurtenances**, *see* appurtenances. For **sewer atlas**, *see* atlas. For **sewer authority**, *see* sewer district.

SewerCAD® A sewer modeling program developed by Haestad Methods, Inc., of Waterbury, CT. *See* StormCAD.

Sewer collection system Piping, pumps, conduits, and other equipment necessary to collect and transport the flow of surface water runoff resulting from precipitation or domestic, commercial, or industrial wastewater to and from retention areas or any areas treatment is designated to occur. The collection of stormwater and wastewater does not include treatment except when incidental to conveyance. A stormwater sewer system is a drain-and-collection system designed and operated for the sole purpose of collecting stormwater; it is segregated from the wastewater collection system (EPA-40CFR280.12 and EPA-40CFR60.691).

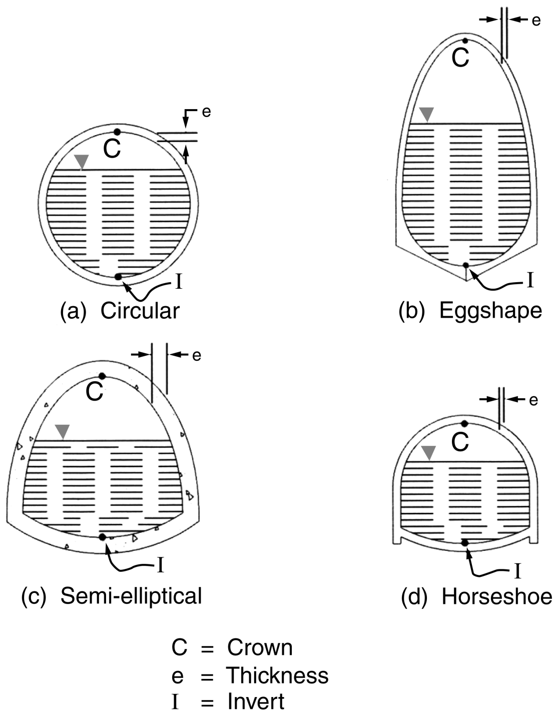


FIGURE S-3 Sewer sections.

Sewer crown The inside top of the arch of a sewer. *See* Figure S-3.

Sewer district A legally established agency or organization for the design, construction, financing, maintenance, and operation of a sewer system. The territory within the area served by this system, which may include more than one political subdivision as well as industrial parks and other private users. If part of a state or local government, it may be called a **sewer authority** or a **sewer department**. *See also* drainage district.

Sewer invert The lowest point of the internal surface of a sewer. *See* Figure S-3.

Sewer-level remote telemetry (SLRT) The process of measuring, often continuously, data about a sewer system, (e.g., discharge, depth of flow, pressure, water level) and transmitting such data to a control center over telephone lines, by radio, or over cable lines. Note: the word *remote* is redundant. *See also* supervisory control and data acquisition (SCADA).

Sewer line A lateral, branch line, trunk line, or other enclosed conduit, including grates, trenches, etc., used to convey wastewater streams or residuals to a downstream waste management unit (EPA-40CFR63.111). For **sewer manhole**, *see* manhole. A **sewer outfall** or **sewer outlet** is an outlet, structure, or point of final discharge of stormwater, wastewater, or treatment plant effluent.

Sewer profile A longitudinal profile along the axis of flow in a sewer, showing such elements as sewer size, distances, ground elevations, manhole locations, energy and hydraulic gradelines, and tributary lines. Typically, the horizontal scale is between 1:500 and 1:1000, and the vertical scale is 10 times greater. *See* Figure S-2; hydraulic profile.

Sewer rehabilitation Repair work on sewer lines, manholes, and other sewer system appurtenances that have been determined to contribute excessive infiltration/inflow. The repair work may involve grouting of sewer pipe joints or defects, sewer pipe relining, inversion and sliplining, sewer pipe replacement, etc.

Sewershed The land area served by a sewer or sewer system. *See* sewer territory.

Sewer system All the components used in providing sewer service to customers within a given territory: land, buildings, gravity lines, force mains, manholes and other appurtenances, pumping stations, treatment facilities, etc. The sewer system may correspond to a given sewer district and may include one or more treatment plants. A regional system may include several local subsystems. For example, within Miami–Dade County (Florida), some municipalities (or volume sewer customers) collect wastewater within their boundaries and deliver it to the county facilities for transmission, treatment, and disposal.

Sewer system evaluation survey (SSES) An engineering investigation to evaluate infiltration/inflow (I/I) into a sanitary sewer system and whether and to what extent it is cost-effective to rehabilitate the system and to determine the appropriate rehabilitation techniques. After a desktop analysis reveals that I/I may be excessive, the SSES is planned using existing records. Then, a field survey is conducted to determine the structural integrity of the sewers and the sources of I/I; such techniques as visual inspection, smoke testing, dye-water testing, and night flow isolation are used. Finally, flow monitoring establishes the basis for the rehabilitation program.

Sewer territory The land area within the boundaries of a sewer district.

Sewer utility A utility that provides sewer service.

Shaft spillway A spillway consisting of (a) a lip or inlet supported by a vertical shaft and (b) a horizontal outlet conduit or tunnel (which may also be the diversion tunnel). It is often used to save space. The inlet may be a weir with funnel-shaped entrance, a morning glory, or a circular overflow lip. *See* Figure S-6. The U.S. Bureau of Reclamation proposes the following formula for the discharge Q:

$$Q = 6.28KrH \qquad \text{(S-13)}$$

where K = discharge coefficient, r = radius of the crest, H = head over the weir. Also called a **drop-inlet spillway**.

Shallow-water equations Differential equations derived for gradually varied, one-dimensional, unsteady flow in open channels; also known as Saint-Venant equations.

Shapefile A geographic information system (GIS) file in ArcView; *see also* coverage. *See* Section II for further information.

Shape parameter (n) One of the three parameters of extreme value distributions such as the gamma function used in the Nash model; the other two are the scale and location parameters. *See also* Equation S-4.

Sharp-crested weir A device or structure, usually made of a plastic or metal plate, used for flow distribution or flow measurement. Materials used in wastewater treatment also include steel, stainless steel, fiberglass, and aluminum. Its crest is so thin that water flowing over it touches only a line. Also called **thin-plate weir**. *See also* broad-crested weir.

Shear velocity (V*) The square root of the ratio of the shear stress at the bottom of a channel τ_0 to the water density ρ. For steady uniform flow in a wide channel of bottom slope S_0 and mean depth y (Martin and McCutcheon, 1999):

$$V^* = \sqrt{gyS_0} \quad \text{(S-14)}$$

where g is the gravitational acceleration.

Sheet flow Flow in a relatively thin sheet of generally uniform thickness, e.g., overland stormwater flow.

Shell pump A simple centrifugal-type device for pumping mud and liquids laden with sand or gravel out of boreholes without excessive clogging or damage. It is a hollow cylinder, open at the top, with a ball or clack valve at the bottom. Also called **sludger** or **sand pump**.

Shock load The arrival at a water treatment plant of raw water containing unusual amounts of algae, colloidal matter, color, suspended solids, turbidity, or other pollutants (EPA-94/04). More generally, a sudden increase in the hydraulic, organic, or other loading to a facility. Also called a **slug load**.

Shore drift Sediment and other materials deposited in patterns parallel to the contours of a beach by waves and currents. Also called **beach drift** or **littoral drift**.

Short-circuiting Uneven flow through a tank, vessel, or other unit resulting from such factors as density currents or inadequate mixing and causing the time of travel for parts of the flow to be less than the hydraulic residence time.

Short wave A type of gravity wave that does not interact with the bottom of the body of water because its wavelength is much shorter than the depth of water.

Shoulder ditch A ditch constructed to collect surface runoff above a cut and reduce erosion. *See also* berm ditch.

Shutter weir A movable weir made of shutters or panels.

SI Abbreviation for *Système International*.

Siamese A standpipe installed close to ground level outside a building; has two or more inlet connections for fire hoses and to the sprinkler system of the building. Also called **Siamese connection**. *See also* standpipe.

Side-channel spillway A spillway that discharges the overflow into a channel parallel to the crest; uses up very little space in the cross section even for a long crest. Also called **lateral spillway**. *See* Figure S-7.

Side-flow weir A diverting weir on the side of a channel or conduit. It may also be used in an outfall structure without a tide gate. In the weir equation, the exponent for a side-flow weir is taken as 5/3, as opposed to 3/2 for a transverse weir. Also called **side weir**.

Side outlet orifice An orifice on the side of a sump for diverting wastewater from a stormwater system during dry weather to a sanitary sewer system; the Stormwater Management Model (SWMM) simulates this orifice by converting it to an equivalent pipe using the standard orifice and the Manning equations.

Side weir Same as **side-flow weir**.

Sidewater depth The depth of water measured along a vertical interior wall of a reservoir, tank, basin, etc.

Significant municipal facilities Publicly owned treatment plants that discharge 1 million gal per day or more and are therefore considered by states to have the potential to affect substantially the quality of receiving waters (EPA-94/04). *See also* major treatment works.

Significant rainfall event A rainfall event that produces runoff with a rainfall depth of 0.04 inch in 1 h, 0.06 inch in 3 h, or 0.10 inch in 5 h. Adjacent significant rainfall events are separated from each other by at least 3 h, with a rainfall intensity less than 0.02 in/h. *See also* minimum interevent time.

Significant source of groundwater An aquifer that (a) is saturated with water having less than 10,000 mg/L of total dissolved solids; (b) is within 2,500 ft of the land surface; (c) has a transmissivity greater than 200 gal/day/ft, provided that any formation included within the source of groundwater has a hydraulic conductivity greater than 2 gal/day/ft^2; and (d) is capable of continuously yielding at least 10,000 gal/day to a pumped or flowing well for a period of at least a year. Or, an aquifer that provides the primary source of water for a community water system (EPA-40CFR191.12).

Silt Sedimentary material composed of fine or intermediate-size mineral particles, varying from fine sand to clay, i.e., from 0.005 mm to 0.05 mm in equivalent diameter. Suspended in still water or carried by moving water, it often accumulates on the bottom of rivers, deltas, bays, tanks, basins, and reservoirs. *See* soil classification.

Siltation (or silting) Deposition of silt and in general other soil particles on the bed of a body of water; results in the filling up or raising of the bed.

Silt basin A basin in a storm sewer to reduce the velocity of flow and allow sediment to settle.

Silt factor A factor in Lacey's regime theory formula for the effect of sediment size. Also called **sediment factor**. *See* Equations R-14 through R-16.

Silt fence A temporary fence used in construction sites for sediment control in shallow overland flow. It consists of a geotextile fabric stretched across a series of posts and supported by a wire fence with a backfilled trench at the lower edge. Also called a **filter fence**.

Silting Same as **siltation**. The silting index is a measure of the tendency of a fluid stream to cause silting at valves and flow constrictions.

Simplified Particulate Transport Model (SIMPTM) A continuous stormwater quality model that simulates the process of pollutant accumulation and washoff and the effectiveness of street sweeping as well as other practices in improving the quality of urban runoff.

SIMPTM Acronym for Simplified Particulate Transport Model.

Simulation The process of mimicking some of the behavior of a system with a different system, e.g., with computers, models, and other equipment. Or, the representation of physical systems and phenomena by mathematical models; the conduct of experiments with a model to understand better present or future conditions of the actual system, predict outcomes, or evaluate scenarios. All models are imperfect tools, with inherent errors in the representation of reality and limitations on input data adequacy. The model user must always interpret simulation results. A computer does not validate a model; it simply facilitates calculations and record keeping. *See also* modeling. **Simulation efficiency** is the same as **model efficiency**.

Simulation of Flood Control and Conservation System A reservoir simulation model developed by the Hydrologic Engineering Center to simulate the operation of a network of reservoirs and channels. Also called **HEC-5**.

Simulation of Water Resources in Rural Basins (SWRRB) A model developed by the U.S. Department of Agriculture to simulate hydrologic elements as well as processes such as storage, sedimentation, and the fate of contaminants.

Simulation output Same as **model output**.

Simulation parameter Same as **model parameter**.

Simulator A computer or other machine that performs simulations.

Single-action pump A reciprocating pump with suction action only on one side of the piston and with intermittent discharge. *See also* single-stage pump.

Single-arch dam, arch dam, arched dam, arch–gravity dam The first three phrases refer to a curved masonry dam for which the arch provides structural stability, while gravity also contributes to stability in the arch–gravity dam. An arch dam transmits the water load horizontally by arch action. It is one of four common dam types; the other three are buttress, embankment, and gravity dams.

Single-cell model Same as mass–balance model. Different from single-event model.

Single-event model A model that simulates a single event, e.g., for the analysis of design conditions, as opposed to a model that uses continuous simulation in preliminary or planning investigations. Different from single-cell model. *See* continuous model.

Single-event simulation The simulation of a system or process over a single event, as opposed to continuous simulation. *See* continuous model.

Single-stage pump A centrifugal pump with only one impeller. *See also* single-action pump.

Sink Place in the environment where a compound or material collects. *See also* sources and sinks. *See* dendritic network for dummy sinks.

Sinuous flow Same as **turbulent flow**.

Siphon A closed conduit in the approximate form of an inverted U or V with a shorter leg above the hydraulic gradeline, where flow is forced up by atmospheric pressure, and a longer leg, where flow is downward (by gravity). The pressure in the shorter leg is less than atmospheric, and a vacuum is necessary in the conduit to start the flow. Priming the siphon creates the vacuum at the crown. After priming, the siphon's discharge Q is a function of its cross-sectional area A, its head H, the gravitational acceleration g, and a coefficient of discharge K (usually about 0.9):

$$Q = KA\sqrt{2gH} \tag{S-15}$$

An inverted siphon or depressed sewer is not a siphon. It is a U- or V-shaped section of gravity sewer dropped below the hydraulic gradeline beneath an obstacle (railway, highway cut, stream, gully, subway, etc.). *See also* siphon spillway.

Siphon spillway A spillway that is designed and works as a self-priming siphon. It is usually a short, enclosed conduit of relatively considerable capacity, either with a free discharge or a submerged outlet. *See* Figure S-8. At low flows, the siphon spillway operates like an overflow spillway with a crest that is at point P on the invert of the bend and head H that is the difference in elevation between the reservoir water surface and point P. At high flows, the discharge is calculated with the orifice formula; the head is the elevation difference between the reservoir water surface and the end of the siphon H′ in the free discharge or the tailwater H″ in the case of a submerged outlet.

Skew coefficient A parameter G of the log-Pearson type III distribution that indicates the skewness of the curve and allows this distribution to represent data that do not fit the normal distribution. It commonly varies between –3.0 and +3.0. It is used with a selected exceedance probability to determine the Pearson type III deviate from published tables. When G = 0, the log-Pearson type III reduces to the lognormal distribution. **Skewness** is a measure of the asymmetry or lack of symmetry of the data represented by the lognormal or other statistical distributions. The **skew coefficient** in general is:

$$G = N\left[\sum_{i=1}^{N}(x_i - \mu)^3\right] \Big/ \left[(N-1)(N-2)\sigma^3\right] \tag{S-16}$$

where N = number of values in the sample, x_i = the ith value in the sample, μ = the mean of the N values, and σ = the standard deviation of the sample. *See* Equation L-8.

Sleeve A tubular piece of metal, plastic or the like designed to fit over another part such as a pipe or a rod; for example, a pipe fitting for uniting two sections of equal size.

Sliding-panel weir A movable weir made of wooden panels that slide in the grooves of fixed frames.

Slip joint A telescoping joint between two parts, e.g., where the end of one pipe is inserted into the flared end of another pipe.

Slippage The leakage of fluid in a pump mechanism. Also called **slippage loss**.

Slope–area method A procedure to determine peak discharges by applying Manning's formula to a reach of channel with known characteristics and where high water marks are visible.

Slope-dependent critical support area method A current method for providing drainage network data (channel sources) to digital elevation models. *See also* constant threshold area method.

Slope drain A temporary or permanent pipe or a paved chute used to reduce the risk of erosion by carrying runoff from the top to the bottom of a saturated slope.

SLRT Abbreviation for sewer-level remote telemetry.

Sludger A simple centrifugal-type device for pumping mud and liquids laden with sand or gravel out of boreholes without excessive clogging or damage. It is a hollow cylinder, open at the top, with a ball or clack valve at the bottom. Also called **sand pump** or **shell pump**.

Slug load The arrival at a water treatment plant of raw water containing unusual amounts of algae, colloidal matter, color, suspended solids, turbidity, or other pollutants (EPA-94/04). More generally, a sudden increase in the hydraulic, organic, or other loading to a facility. Also called a **shock load**.

Sluice An artificial channel or passage for water at high velocity with a flow that is regulated by a gate or a valve; sometimes used to drain surplus water or eject debris. Also, the body of water retained by a floodgate. A sluiceway. **Sluice flow** is flow through a culvert or similar structure under high head. *See also* orifice flow.

Sluice gate The manual or power-operated vertical slide gate of a sluice or any vertical gate designed to slide in the operation of masonry dams, reservoirs, tanks, or other structures.

Sluiceway A pipe, tunnel, or culvert through a dam or a hillside for drawing water from a reservoir when needed or for draining the site during construction.

Sluicing pond A pond that stores water for release when needed to maintain a desired depth in an entrance channel. Also called **scouring basin**.

SMIFF Acronym for Spatial Mapping for Integrated Flood Forecasting.

Smoke test An inexpensive and quick method of detecting inflow sources in a sewer system. After partially sealing a sewer section, a nontoxic smoke bomb is ignited and forced into it by an air blower. A technician observes and records, in written and photographic forms, the sources of smoke emission. Such sources may include roof leaders, cellars, yards, area drains, foundation drains, abandoned building sewers, faulty connections, illegal connections, sewer cross connections, catch basins, structural damage, and leaking joints.

Smooth pipe equation An expression of the friction factor f for smooth pipes as a function of Reynolds numbers up to $R_e = 100{,}000$:

$$f = 0.316/R_e^{0.25} \qquad \text{(S-17)}$$

Snowfall Precipitation in the form of snow or a snowstorm. Also, the intensity of a snowstorm, expressed in depth (inches) per hour.

Snow gage A device for measuring the depth of snow.

Snowmelt The runoff from melting snow or the period of year when it occurs. The degree–day method may be used to determine snowmelt magnitude S_m (inches/day) for a given area as a function of the mean daily air temperature T (°F) or the maximum daily air temperature T_m (°F), a melt rate coefficient C, and a base temperature of 32°F for T and 40°F for T_m:

$$S_m = C(T - 32) \qquad \text{(S-18)}$$

and

$$S_m = C(T_m - 40) \qquad \text{(S-19)}$$

The coefficient C, also called **degree–day factor**, ranges from 0.015 to 0.200; e.g., it has been taken as 0.08 for the western United States and 0.02 for southern Ontario, Canada. *See also* melt water.

SNTEMP Acronym for the Instream Water Temperature Model of the U.S. Fish and Wildlife Service. Predicts streamwater temperatures from hydrological conditions, meteorological conditions, and stream geometry.

Snyder method A commonly used method to develop synthetic unit hydrographs for input to such models as HEC-1. (*See also* Clark method; SCS hydrograph method.) The Snyder method defines the unit hydrograph by two formulas for the peak discharge Q_p (cubic feet per second) and the standard lag time T_l (hours) (Hoggan, 1997):

$$Q_p = 640 \cdot C \cdot A \cdot / T_l \qquad \text{(S-20)}$$

$$T_l = C_s (L_1 L_2)^a \qquad \text{(S-21)}$$

where C is a dimensionless coefficient accounting for runoff conditions, including storage; A is the drainage area (square miles); C_s is a coefficient representing basin slopes and storage (from 0.4 in steep slopes to 8.0 in flat areas); L_1 is the length (miles) of the main channel from the basin outlet to the divide; L_2 is the length (miles) of the main channel to a point opposite the centroid of the basin; and a is a coefficient that depends on the characteristics of the watershed. Two other parameters are also used in defining the shape of the unit hydrograph (Gupta, 2001), i.e., the unit hydrograph time base T and the standard duration of rainfall T_e:

$$T = 3 + T_l/8 \quad \text{(S-22)}$$

and

$$T_e = T_l/5.5 \quad \text{(S-23)}$$

Snyder's parameters The parameters used in the Snyder method for synthetic unit hydrographs: peak flow Q_p, lag time T_l, time base T, and standard duration of rainfall T_e.

Soakage trench A runoff reduction measure using on-site pits for the infiltration of stormwater from disconnected downspouts.

Soakaway pit An on-site pit, used as a runoff reduction measure, for the storage and infiltration of stormwater from rooftops (e.g., the equivalent of 20 mm of runoff).

Socket pipe A cast iron pipe fitting with a socket at one end and a spigot at the other.

Software The programs, routines, or symbolic languages of a computer, such as the operating system or applications like those for word processing, games, spreadsheets, database management, network solution, mapping, Cybernet, XP-SWMM (Stormwater Management Model). Also, the list of instructions for the computer to perform a given task or tasks.

Soil The unconsolidated mineral and organic material on the immediate surface of the earth that serves as a natural medium for the growth of land plants, including, but not limited to organic matter, silts, clays, sands, gravel, and small rocks. Its formation and properties are determined by various factors, such as: parent material, climate, macroorganisms and microorganisms, topography, and time (EPA-40CFR192.11-d and EPA-40CFR796.2700-iv).

Soil absorption field A subsurface area containing a trench or bed with clean stones and a system of piping through which treated wastewater may seep into the surrounding soil for further treatment and disposal (EPA-94/04). Often combined with a septic tank to form a septic system.

Soil aggregate The combination of soil particles (sand, silt, clay) into secondary units. These units may be arranged in the profile in a distinctive characteristic pattern that can be classified on the basis of size, shape, and degree of distinctness into classes, types, and grades (EPA-40CFR796.2700-v and EPA-40CFR2750-iv).

Soil and water conservation practices Control measures consisting of managerial, vegetative, and structural practices to reduce the loss of soil and water.

Soil classification (1) The classification of soil according to the size of its particles. The classification of the U.S. Department of Agriculture (USDA) (which classification differs from that of the International Society of Soil Science) is shown in Table S-2. (2) The definition of various types of soil according to the proportions of sand, silt, and clay that they contain. *See* Figure S-4. The various types are sand, silt loam, silt, light clay, loamy

TABLE S-2
USDA Soil Classification

Soil Class	Equivalent Diameter, mm	Soil Class	Equivalent Diameter, mm
Grit or fine gravel	1.00–2.00	Very fine sand	0.05–0.10
Coarse sand	0.50–1.00	Silt	0.005–0.05
Medium sand	0.25–0.50	Clay	0.005
Fine sand	0.10–0.25		

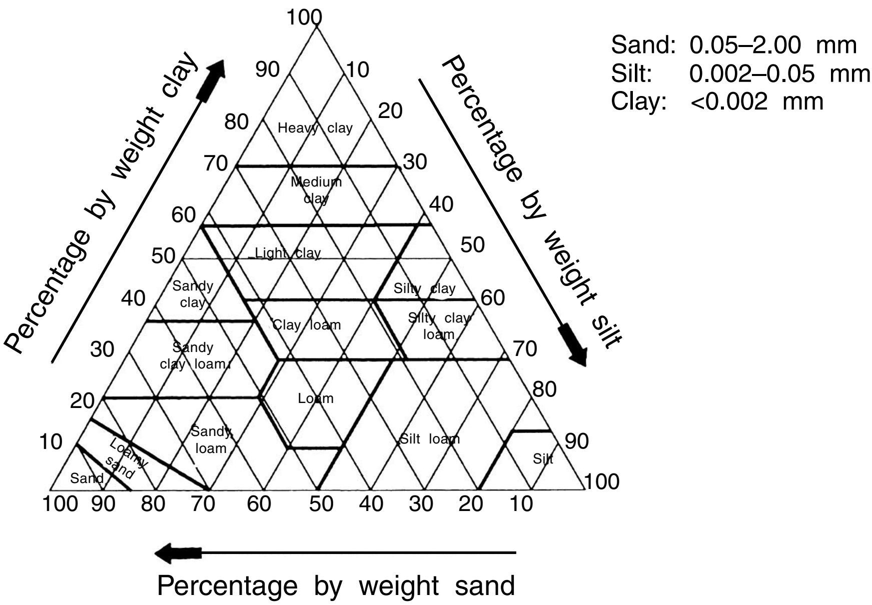


FIGURE S-4 Soil classification.

sand, sandy clay loam, silty clay loam, medium clay, sandy loam, sandy clay, silty clay, heavy clay, loam, clay loam.

Soil–complex-cover method A method used in the Corps of Engineers' Storage Treatment Overflow Runoff Model (STORM) to compute runoff from a subwatershed. The U.S. Soil Conservation Service developed it on the basis of empirical relationships between rainfall and direct runoff.

Soil Conservation Service (SCS) Former name of an agency of the U.S. Department of Agriculture that provides technical assistance for resource conservation to farmers; to other federal, state, and local agencies; and to local soil conservation districts. Also publishes bulletins on hydrological methods. Currently called Natural Resources Conservation Service.

Soil drainage *See* drainage (5).

Soil horizon A layer of soil, approximately parallel to the soil surface, with distinct characteristics produced by soil-forming processes.

Soil line A cast iron or plastic pipe that conveys discharges from toilet fixtures or the like, and sometimes from waste pipes, from a building into the soil drain. Also called **soil pipe**. *See also* waste pipe.

Soil moisture Subsurface water in the form of moisture in the vadose zone, including soil water (available to root plants by abstraction) and pellicular water or the water held by molecular attraction on the surface of soil particles. The last is not readily available to plants. *See also* subsurface water. Soil moisture contributes to evapotranspiration and to basin recharge, but not to total runoff. *See also* Figure R-6; rainfall–runoff relationship.

Soil moisture budget A moisture-accounting balance among precipitation, surface runoff, subsurface outflow, actual evapotranspiration, and change in moisture storage. *See* soil moisture loss equation.

Soil moisture loss equation A simplified representation of the moisture loss in soils; derived from the soil moisture budget. It expresses actual evapotranspiration E_a in terms of the effective root density R_d, a **soil water retention factor S_r**, the **soil storage capacity** S_c, the **soil water level** (or soil water balance) from the previous time period Z, and the evapotranspiration potential E_p:

$$E_a = E_p R_d S_r Z/S_c \qquad \text{(S-24)}$$

The **soil water balance** each month Z_i is determined as a function of the value of the previous month Z_{i-1}, the monthly rainfall R_m, the surface evaporation E_s, and the actual evapotranspiration E_a:

$$Z_i = Z_{i-1} + R_m - E_s - E_a \qquad \text{(S-25)}$$

$$E_s = (1.3 - R_d)\cdot R_m \qquad \text{(S-26)}$$

The parameters effective root density, soil water retention, and soil water storage depend on vegetation types, soil characteristics, and crop patterns (J. A. Dyer in Ouazar et al., 1988b).

Soil pipe A cast iron or plastic pipe that conveys discharge from toilet fixtures or the like, and sometimes from waste pipes, from a building into the soil drain. Also called **soil line**. *See also* waste pipe. (2) A bell-and-spigot cast iron pipe of limited strength.

Soil profile The vertical cross section of a soil showing its three horizons: the rich, dark topsoil of 50–300 mm and a paler and poorer layer of 400 mm that form the A horizon; the denser, brighter, and poorer subsoil of 100 mm to 2.0 m or horizon B; and finally horizon C, which has variable thickness and composition.

Soil series The basic unit of soil classification; a subdivision of a family. A series consists of soils that were developed under comparable climactic and vegetational conditions. The soils comprising a series are essentially alike in all major profile characteristics except for the texture of the A horizon (i.e., the surface layer of soil) (EPA-40CFR796.2700-xi).

Soil stack The main vertical pipe that receives the wastewater of a building from soil lines and waste pipes. *See also* house drain; soil pipe.

Soil storage (S) The volume of rainfall stored in the soil and thus not available for runoff. Sometimes divided into lower and upper nominal soil storage. In the Soil Conservation Service (SCS) method, soil storage is the same as the maximum infiltration of the soil. It may be computed if the SCS CN (curve number) is known:

$$S = (1000/CN) - 10 \tag{S-27}$$

or from the equation

$$S = S_s(1 - P_i) \tag{S-28}$$

with S_s = compacted soil storage coefficient, and P_i = drainage basin percentage imperviousness.

Soil structure The arrangement of soil particles into aggregates.

Soil texture The proportions of soil particles (sand, silt, clay) in a soil profile.

Soil type *See* soil classification.

Soil water Water in the vadose zone (or zone of aeration) immediately below the ground surface accessible to the roots of common plants and thus subject to significant evapotranspiration. *See* Figure S-14; subsurface water.

Soil water balance, soil water level, soil water retention factor, soil water storage capacity *See* soil moisture loss equation.

Solar pond A pond that uses direct solar heating for evaporation.

Sole-source aquifer (SSA) An aquifer that supplies 50 percent or more of the drinking water of an area or an aquifer that has been designated an SSA by the Administrator of the U.S.EPA (EPA-94/04).

Solids In water, wastewater, or stormwater engineering, the suspended, colloidal, or dissolved volatile or nonvolatile substances contained in the liquid or removed from it by such processes as sedimentation and filtration. **Dissolved solids** are molecules or ions held by the molecular structure of the water; they are generally smaller than 0.001 μm, pass through the 0.45-μm pore-diameter filter, and are sometimes called **filterable residues**. **Suspended solids**, larger than molecules, are supported by buoyant and viscous forces in the water; larger than 1 μm, they are retained on the filter and sometimes called **nonfilterable residues**. **Colloids** are intermediate between suspended and dissolved particles, ranging in size from 0.001 to 1 μm. *See also* filterable residues; nonfilterable residues.

Solids balance An inventory of all identified solids entering, leaving, or accumulating in a system (e.g., basin, tank, reservoir) or a quantitative analysis of the changes occurring in the system. *See also* mass balance; material balance.

Sonic meter A flow-measuring device that uses a pressure wave through the fluid. *See* acoustic meter.

SOR Abbreviation for surface overflow rate.

Sounding tube A pipe or tube used for measuring the depths of water.

Source control In general, the practice of reducing pollutants at their source. *See* on-site source control for stormwater reduction measures. *See also* downstream control; end-of-pipe alternative.

Sources and sinks The causes of change in hydraulic, hydrodynamic, or water quality modeling (Martin and McCutcheon, 1999). Also called **forcing functions**. The change may be related to water mass or to momentum. Sources and sinks include (a) **processes** such as evaporation, precipitation, inflows, outflows, nonpoint runoff of stormwater, point discharges, withdrawals, injection or extraction wells in groundwater, seepage, infiltration; (b) **forces** such as buoyancy, Coriolis force, friction, gravity; and (c) **changes** in the masses of water constituents, such as hydrophobic chemicals. *See also* dendritic network for dummy sources and sinks.

Southwell, Richard Vynne *See* hydraulics.

Space discretization The division of the space domain into cells or distance steps (Δx) for the application of numerical methods in computer simulations.

Spatially varied flow A flow in which depth and velocity vary with distance.

Spatial Mapping for Integrated Flood Forecasting (SMIFF) A geographic information system (GIS) model that converts water level predictions from a hydrodynamic model such as Dynamic Wave Operation Model (DWOPER) (or other hydraulic models such as HEC-2 or Stormwater Management Model [SWMM]) into a flood surface, which can be compared by overlay to the elevations of an urban network.

Specific capacity (Q_s) The ratio of well yield Q to total drawdown h in a pumped well:

$$Q_s = Q/h \tag{S-29}$$

Specific conductance A rapid method of estimating the dissolved solids content of a water supply by testing the capacity of the water to carry an electrical current, which is related to the concentration of ionized substances in the water (EPA Glossaries). Also called **conductance**.

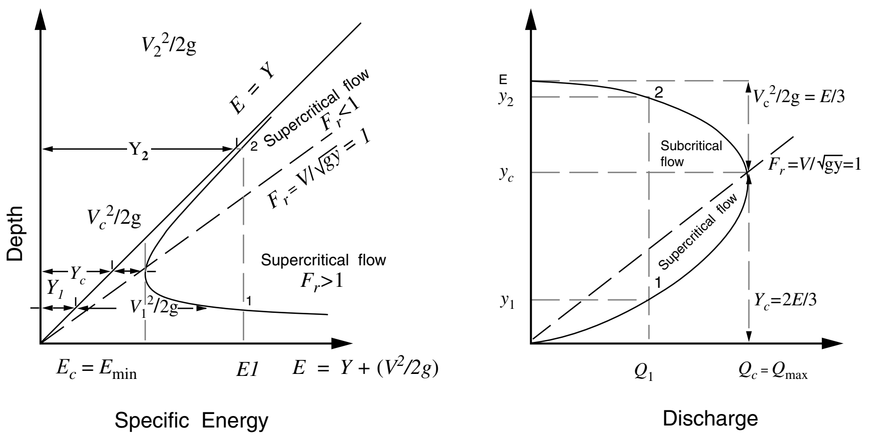
Specific discharge (1) The discharge per unit area; e.g., a stream discharge in cubic feet per second divided by the corresponding drainage area in square miles; often used to define flood magnitudes. (2) Flowrate over a cross-sectional area of soil; i.e., the Darcy flux or flux per unit area per unit time in Darcy's law; also called **Darcy velocity** or **discharge velocity**. *See* Equation D-2.

Specific energy Introduced by Bakhmeteff in 1912, it is the energy head E above the low point in a channel or the sum of the depth of flow y and the velocity head, i.e.,

$$E = y + V^2/2g \tag{S-30}$$

with V = the average velocity, and g = the gravitational acceleration. *See* critical flow equation.

Specific energy curve A plot of the specific energy equation, holding the discharge Q or the energy E constant. *See* Figures S-5a and 5b with the following notations: E = specific energy = $y + V^2/2g$; E_1 = specific energy at point 1. At constant discharge, there is a second point 2 on the curve with the same energy; thus, two depths y_1 and y_2 correspond to supercritical and subcritical flow, respectively. E_c = energy under critical flow conditions; also the minimum specific energy, corresponding to the critical depth y_c. E_{min} = minimum specific energy occurring at critical depth, i.e., E_c. F_r = Froude number = $V/\sqrt{gy}$; g = gravitational acceleration; Q = discharge; Q_1 = discharge at point 1. At constant specific energy, there is a second point 2 on the curve with the same discharge; thus, two depths y_1 and y_2 correspond to supercritical and subcritical flow, respectively. Q_c = discharge under critical flow conditions; also the maximum discharge, corresponding to the critical depth y_c. Q_{max} = maximum discharge, occurring at critical depth, i.e., Q_c. V = average velocity; V_1 = velocity at point 1; V_2 = velocity at point 2; V_c = velocity at the critical point; y_1 = depth at point 1; y_2 = depth at point 2; y_c = critical depth, which defines critical flow with minimum specific energy and maximum flow.



(a) Constant discharge = *Q* (b) Constant specific energy = *E*

FIGURE S-5 Specific energy equation.

Specific gravity (or relative density) The dimensionless ratio of the density of a substance to a standard density. For liquids, the standard density is that of water at 4°C, i.e., 1000 kg/m^3 or 1 kg/l; in U.S. customary units, it is 1.941 $slugs/ft^3$.

Specific mass Same as **specific gravity** or relative density of sediment.

Specific peak discharge The ratio of the peak discharge Q to the drainage area A. *See also* normal maximum flood.

Specific permeability A coefficient k that expresses the ability of a porous medium to transmit a given fluid. *See* Equation I-2; intrinsic permeability.

Specific retention The quantity of water retained in soil or rock by capillary forces against the force of gravity after a drop of the water table or after a saturated sample has been allowed to drain. Specific retention is the difference between porosity and specific yield. It is expressed as a ratio or a percentage of the volume of water retained to the volume of the soil or rock. Specific retention is one of the factors affecting the infiltration of rain or snowmelt. The difference between specific retention and two other expressions related to soil water content is not always clear. See, e.g., the definitions in American Public Health Association et al. (1981) and Symons et al. (2000) for **field capacity** and **field moisture capacity**.

Specific speed (N_s) A performance parameter used in the rating or selection of pumps and turbines. Expressed in revolutions per minute (r/min), it relates rotational speed N (r/min), total dynamic head H (ft), and discharge Q (gal/min), or power output P (hp or kW) at optimum performance; for pumps:

$$N_s = NQ^{0.5}/H^{0.75} \quad \text{(S-31)}$$

and for turbines:

$$N_s = NP^{0.5}/H^{1.25} \quad \text{(S-32)}$$

To obtain dimensionless specific speeds K_N, divide N_s by an appropriate power of the gravitational acceleration g and the density ρ of the fluid: For pumps:

$$K_N = N_s/g^{0.75} \quad \text{(S-33)}$$

and for turbines:

$$K_N = N_s/\rho^{0.5}g^{1.25} \quad \text{(S-34)}$$

See also pump characteristic curves.

Specific storage The ratio of the storage coefficient to the thickness of the aquifer.

Specific weight (or unit weight) (γ) The weight of a unit volume of fluid equal to the product of the fluid density ρ by the gravitational acceleration g:

$$\gamma = \rho g \tag{S-35}$$

For water at 10°C or 50°F, $\gamma = 62.4$ lb/ft^3 or 9.81 kN/m^3.

Specific yield The amount of water (as a ratio or percentage by volume) that a unit volume of saturated permeable rock will yield when drained by gravity. Specific yield applies to an unconfined aquifer; it is similar to, but less than, porosity. Specific yield is also called **effective porosity** or **useful storage**. The corresponding term for an artesian aquifer is **storage coefficient**. For a well, the **specific well yield** is the maximum flowrate at which the well can yield water under specified conditions of drawdown or pump size.

Spent water The portion of the community water supply that is discharged in sewers or individual disposal units. With infiltration and inflow, it constitutes wastewater. It is the difference between the water supplied and various other uses, such as fire fighting and lawn watering. *See also* return flow (2).

Spill crest elevation Elevation at which no further hydraulic gradeline will develop at a junction.

Spillway A waterway, like an open or closed channel, in or about a dam, canal, or other hydraulic structure to convey surplus water, thus protecting the structure and its appurtenances from damages by major floods. It is often a rectangular concrete channel conveying water at supercritical velocity and such that the bottom of the channel approximates the underside of the nappe of a corresponding sharp-crested weir. The spillway may also serve to regulate the reservoir level. Its principal components are (1) a flow regulation structure such as a weir, (2) a discharge channel to convey the outflow, and (3) a terminal or energy-dissipating element. A **controlled spillway** has crest gates to adjust the outflow. The following characteristics or elements pertain to spillways: apron, auxiliary spillway, bucket, cavitation, chute, chute spillway, drop-inlet spillway, emergency spillway, energy dissipation, face, gate, gravity spillway, labyrinth spillway, lateral spillway, lip, morning-glory spillway, ogee spillway, overflow spillway, rating curve, service spillway, shaft spillway, side-channel spillway, siphon spillway, spillway channel, spillway dam, stepped spillway, stilling basin, tailrace, toe, trough, tunnel. *See* Figures S-6 through S-9.

Spillway channel Same as **overflow channel**. An artificial waterway designed to handle overflows from a reservoir, aqueduct, or canal. *See also* overflow spillway.

Spillway dam A dam without a separate spillway; i.e., the dam crest is designed to accommodate overflows. Also called an **overfall dam**.

Spillway rating curve A curve showing the spillway discharge as a function of the head over the spillway crest; based on the weir equation.

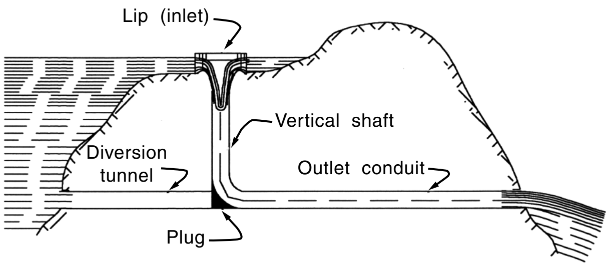


FIGURE S-6 Spillway (shaft).

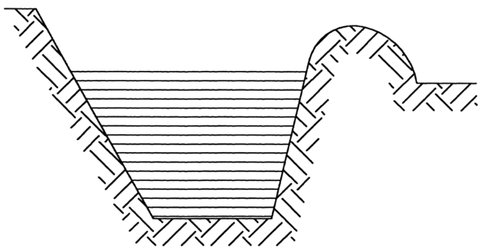


FIGURE S-7 Spillway (side channel).

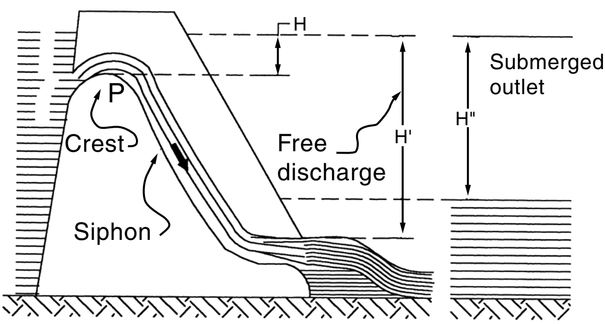


FIGURE S-8 Spillway and siphon.

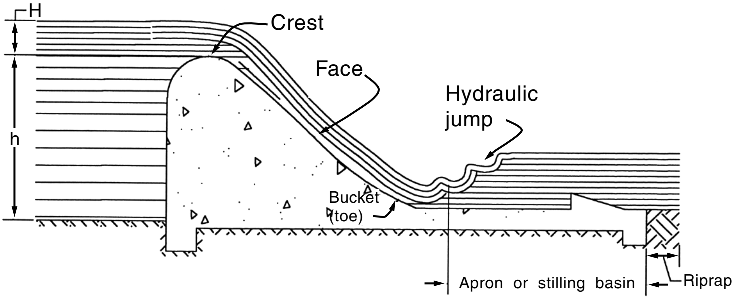


FIGURE S-9 Spillway.

Splash block A runoff reduction measure using a block to receive stormwater from disconnected downspouts; the stormwater is then allowed to infiltrate on site.

Splitter box *See* weir splitter box.

SPM Abbreviation for Storage Pumping Model.

Spreading basin A basin constructed to receive diverted stormwater or other surface water, which is allowed to percolate to the zone of saturation. Other means of groundwater recharge include: check dams, recharge basins, recharge wells, seepage ponds, and underground leaching systems.

Spreadsheet Short for *electronic spreadsheet*, a computer program that organizes rows and columns of numerical data for desired computations and displays the results in a table format.

Spring Groundwater that seeps out of the earth where the water table intersects the ground surface.

Springmelt The process by which warm temperatures melt winter snow and ice. Because various forms of acid deposition may have been stored in the frozen water, the melt can result in abnormally large amounts of acidity entering streams and rivers, sometimes causing fishkills (EPA Glossaries). Also called **spring thaw**.

Spring turnover *See* turnover.

Sprinkler irrigation Irrigation through a piping system that is under pressure from an elevated tank or from direct pumping. Other basic irrigation methods include furrow, flooding, subirrigation, and trickle or drip.

S profile An open-channel flow profile corresponding to a steep slope. It is an S1 (backwater) curve, S2 (drawdown) curve, or S3 (backwater) curve, depending on the relationship between the actual depth y, the critical depth y_c, and the normal depth y_n of flow: (a) for S1, $y > y_n$ and $y > y_c$; (b) for S2, $y_n = y = y_c$; (c) for S3, $y < y_n$ and $y < y_c$. *See* Figure S-10; M profile.

Squeeze factor One of two positional parameters of ArcView for address matching; it is a percentage of the road length used to prevent addresses at the beginning of a block from placement at the intersection. (The other parameter is offset distance.) Careful use of squeeze factors and offset distances can improve the positional accuracy of the resulting point geographic information system (GIS) file.

SSA Abbreviation for sole-source aquifer.

SSARR Acronym for Streamflow Synthesis and Reservoir Regulation, a runoff model.

SSES Abbreviation for sewer system evaluation survey.

Stability (1) Behavior of a stable numerical solution, i.e., the characteristic of a numerical procedure in which errors decrease with succeeding steps or in which round-off errors of the algorithm are negligible. *See* convergence. (2) Characteristic of a watercourse or channel that has not suffered, or is protected from, erosion or deposition. *See also* channel stability; extremal hypothesis (or variational principle); regime theory, tractive force theory. A **stable channel** is a channel with a cross section, slope, and alignment

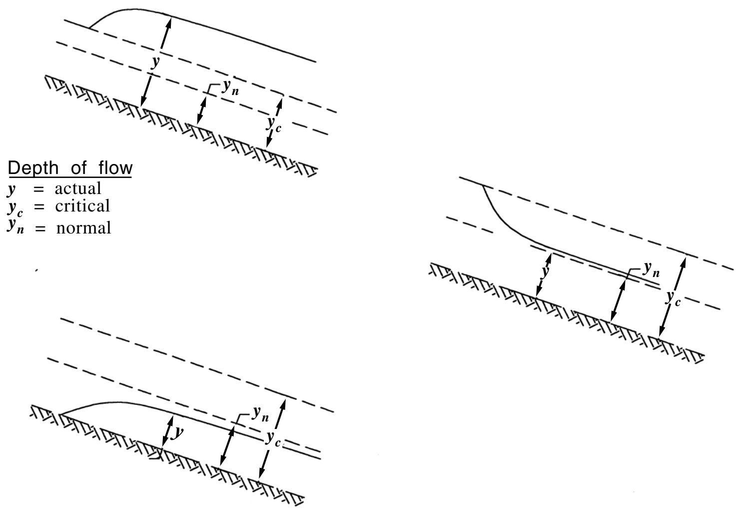


FIGURE S-10 S profiles.

that do not vary significantly and in which sediment deposition and scour are in equilibrium.

Stable numerical solution A solution obtained by an iterative procedure in which the numerical error at any step is smaller than the error at the preceding step; the solution is unstable if the error grows larger with succeeding steps. *See* convergence.

Staff gage A graduated, usually vertical, scale placed so that the height of a fluid (e.g., the stage of a stream) may be read directly.

Stage The variable water surface or its elevation above its minimum or above or below any chosen datum, which may be an established low-water level. It is an important boundary condition and calibration parameter in flow and water quality modeling. It is measured in the field through graduated staff, crest, and automatic gages. *See* open-channel flow.

Stage–area nodes or stage–volume nodes In stormwater management modeling, nodes used by the Advanced Interconnected Pond Routing (AdICPR) technique to simulate lakes, retention ponds, inlets with storage above the grate elevation, and manholes and inlets without significant storage.

Stage–area relationship A relationship such as a curve, an equation, or a table that can be used to determine the area of flow as a function of stage or depth.

Stage–discharge relationship A relationship that allows the estimation of the discharge Q of a stream, river, conduit, etc. based on its stage or depth of flow h. The relationship may be a rating curve, a rating table, or an equation like:

$$Q = a \cdot h^b \qquad \text{(S-36)}$$

where a and b are empirical coefficients. A similar definition applies to the relationship between discharge and gage height at a gaging station. *See* Figure D-5. The stage–discharge relationship is used in stormwater modeling to derive outflow hydrographs. For reservoir routing (McCuen, 1989), assuming a sharp-crested weir and a discharge coefficient of 0.61, the stage–discharge relationship may take the form:

$$Q = 3.3Lz^{1.5} \tag{S-37}$$

where Q is the discharge in cubic feet per second, L is the weir length in feet, and z is the elevation head in feet.

Stage hydrograph A plot of stage versus time at a given point or cross section. It can be converted to a discharge hydrograph using a rating curve.

Stage–storage area Area of a network element that has a stage–storage relationship.

Stage–storage curve A graphical representation of the stage–storage relationship.

Stage–storage relationship A relationship such as a curve, a table, or an equation that allows the estimation of storage (in a stream or a conduit) as a function of stage. Used in wastewater modeling to determine the volume of storage available in gravity sewers as a means to attenuate peak flows. In reservoir routing, given the contour lines of a site, the stage–storage relationship may be derived from a discrete form of the storage equation (McCuen, 1989):

$$\Delta S = 0.5(A_i + A_{i+1})\Delta y \tag{S-38}$$

where ΔS represents the storage increment; A_i and A_{i+1} are the surface areas for the ith and (i + 1)th contours, respectively; and Δy is the depth increment. *See* Section II for further information. *See* Figure S-11.

Stage–storage volume Volume of a network element that has a stage–storage relationship.

Stage–volume nodes Same as **stage–area nodes**.

Standard deviation A statistic used as a measure of dispersion or variation in a distribution; equal to the square root of the variance (the arithmetic average of the squares of the deviations from the mean of the distribution); usually represented by the Greek letter σ.

Standard error of estimate (S_e) A statistic used to indicate the dispersion in the distribution of differences between expected and observed values. It is the ratio of the sample standard deviation σ to the square root of the sample size N:

$$S_e = \sigma/N^{0.5} \tag{S-39}$$

Standard permeability coefficient The rate of flow of water at 60°F in gallons per day through a cross section of 1 ft^2 under a unit hydraulic gradient

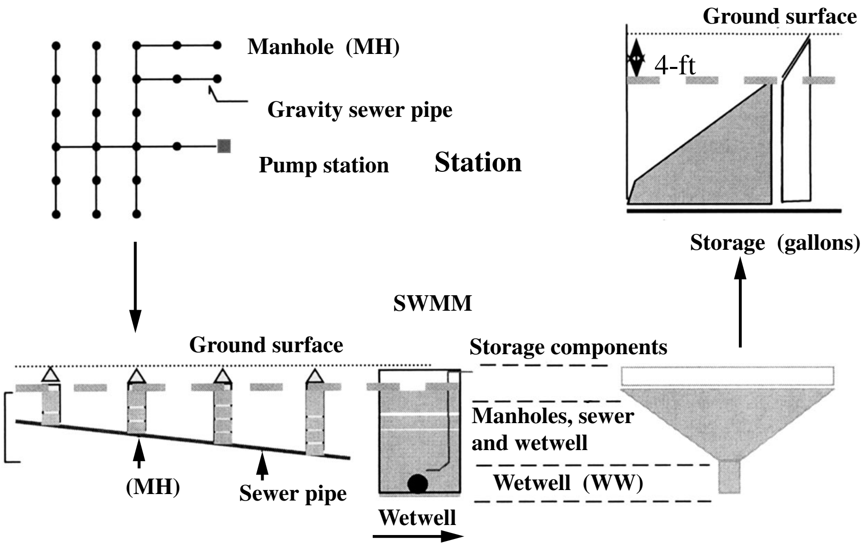


FIGURE S-11 Stage–storage relationship. (Reprinted with permission from the PBSJ Corporation.)

(or 100%). The U.S. Geological Survey uses the meinzer as the unit. *See also* field permeability coefficient.

Standard pressure A pressure of 760 mm Hg (29.92 in Hg).

Standard project flood A flood that may be expected from the most severe combination of meteorological and hydrologic conditions that are considered reasonably characteristic of the region involved, excluding extremely rare combinations. It is about half of the probable maximum flood. The **standard project storm** is a design criterion used by the U.S. Army Corps of Engineers to study hydraulic structures and is based on the definition of a standard project flood.

Standard pond, standard pond-routing technique *See* interconnected ponds; pond routing.

Standard step method A simplified procedure used to determine water surface profiles of nonuniform flow or the changes in water surface elevation between adjacent cross sections on the basis of energy losses. Also known as the **step method**, it is used in both the HEC-2 and HEC-RAS simulation programs. *See* Hoggan (1997) and Martin and McCutcheon (1999) for details.

Standard temperature A temperature of 20°C (68°F).

Standby, standby pump, standby system Same as **backup**, **backup pump**, **backup system**.

Standpipe (1) A vertical pipe, tower, or tank with a height greater than its diameter; used to store water in a distribution system, maintain a required head in a water supply system, or provide relief from surges of pressure in pipelines. (2) A fixed vertical pipe in a building or structure for supplying fire hoses; connected usually with a Siamese outside the building.

State equation *See* equation of state.

State variable A variable that varies with input variables and other state variables. *See* model input.

Static discharge head The vertical distance between the centerline of a pump and the water level in the discharge tank. *See also* Figure P-6; pump head terms.

Static head Head resulting from elevation differences (e.g., the difference in elevations of the headwater and tailwater in a pipeline or a power plant) or the vertical distance between a fluid's supply surface level and its free discharge level. Also called **fixed system head** because it does not vary with flow. *See also* dynamic head.

Static pressure The pressure exerted by a body at rest, for example, hydrostatic pressure. In still water, it is the vertical distance (in feet) from a specific point to the water surface. Static pressure in pounds per square inch is equal to static head in feet times 0.433 psi/ft.

Static pressure tap A small hole normal to the wall of a pipe or container under pressure; used for the connection of static pressure monitors. Also called **piezometric opening** or **pressure tap**. *See also* Figure M-1; manometer.

Static pressure tube Same as **static tube**.

Static seal A small part made of rubber, metal, or rope, usually in the form of a sheet or ring, placed around a joint to make it watertight. Also called **gasket**.

Static suction head, static suction lift *See* pump head terms.

Static tube A perforated, tapered tube placed parallel to a fluid stream and connected to a manometer to measure the static pressure in the stream. Also called **static pressure tube**.

Static water depth The vertical distance from the centerline of the pump discharge to the surface level of the free pool while no water is drawn from the pool or water table.

Static water level Elevation or level of the water table in a well when the pump is not operating. Also, the level or elevation to which water would rise in an open tube connected to an artesian aquifer or a conduit under pressure.

Statistical approach, statistical method The use of probability density functions fitted to storm event statistics to estimate or predict the performance of a stormwater detention system. *See also* basin performance equation; Brune's trap efficiency curves.

Statistical (or stochastic) model A stochastic model includes statistical elements in the definition of a problem. Its input data include random variables to account for uncertainty. For example, statistical groundwater models describe random movements of solutes using statistical theory. Unlike a deterministic model, the stochastic model will yield different outputs for a given set of inputs. The output of a stochastic model is actually a set of expected values rather than deterministic values for the variables; i.e., each prediction has a certain probability attached to it. Also called **probabilistic model**. *See also* parametric model; pseudodeterministic model.

Statistical Urban Drainage Simulator (SUDS) A package of analytical probabilistic models developed to predict the hydraulic performance of stormwater storage and treatment facilities. *See also* Extended Statistical Urban Drainage Simulator.

Statistic t *See* Student's t test.

Stator A stationary machine part in or about which a rotor turns, especially the stationary parts in the magnetic circuits. It applies to an electric generator or motor. *See* impeller; rotor.

STATS (Statistical Analysis of Time-Series Data) A computer program of the U.S. Army Corps of Engineers Hydrologic Engineering Center that reduces time-series data to a few meaningful statistics or curves.

Steady flow A flow with a rate or discharge that does not change over time. The opposite is unsteady or dynamic flow. A **steady uniform flow** has constant velocity and flowrate; the velocity vector does not change in direction or magnitude. The flow may be **steady nonuniform** when the flowrate remains constant, but the velocity changes with a corresponding change in the other hydraulic characteristics (area, slope). Uniform flow is often a useful approximation in steady-state applications; however, most open-channel flows in water and wastewater applications occur under varied flow conditions.

Steady-state condition (or simply steady state) A condition of equilibrium, i.e., no net accumulation, no change over time. It applies to the laws of conservation of properties such as energy, mass, and momentum. Steady state is reached when the effects of transport and all processes of a given property, including sources and sinks, are in equilibrium.

Steady-state flow Fluid flow without any change in composition or phase equilibrium relationships.

Steady uniform flow *See* steady flow.

Steep slope A channel slope greater than the critical slope at a given flowrate; the opposite of mild slope.

Step drawdown test A pumping test conducted for multiple periods and at different discharge rates on production wells to determine aquifer and well loss coefficients.

Step method Same as **standard step method**.

Stepped spillway A spillway with steps on its face to dissipate energy.

Stevin, Simon *See* hydraulics.

Stick gage A vertical rod or stick anchored in a container; used as a gage to observe the variation of liquid levels.

Stilling basin A basin (structure or excavation) designed to increase tailwater depth and reduce the velocity or turbulence of water from an outfall, spillway, chute, etc. It may consist of a level apron at the foot of the structure with chute blocks, baffle piers, and an end sill. Sometimes called **stilling bay** or **stilling box**. *See* Figure S-12.

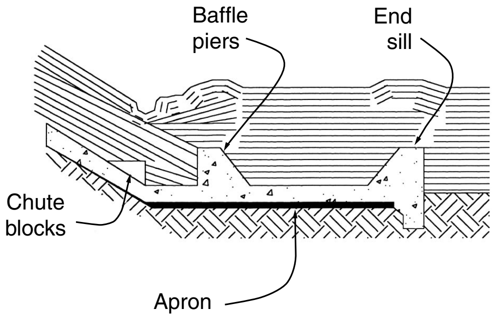


FIGURE S-12 Stilling basin.

Stilling well A chamber, pipe, or tube used with water-measuring devices to dampen waves or surges in a large body of water.

Stochastic mathematical model, stochastic model *See* statistical model.

Stochastic process A sequence of events governed by chance or a process involving or containing random variables. The opposite of a deterministic process. **Stochastic methods** are used to generate synthetic records of hydrologic data such as streamflows and rainfall.

Stochastic variable A random variable.

Stokes law A formula that expresses the terminal settling velocity V of a discrete particle in a fluid as a function of particle diameter d and density ρ, gravitational acceleration g, and the fluid density ρ′, and absolute viscosity μ:

$$V = g \cdot d^2(\rho - \rho')/18 \cdot \mu \tag{S-40}$$

Stokes, Sir George *See* hydraulics.

Storage The impounding of water, stormwater, or wastewater for future use or release. Storage implies a longer retention time than pondage, regulation, or detention. *See* elevated storage; ground-level storage; prism storage; reservoir storage; wedge storage.

Storage basin/storage reservoir A basin/reservoir in a river or valley designed and operated for flood mitigation through temporary storage, with outlets equipped with gates and valves for adequate regulation. *See* detention basin.

Storage–capacity curve A curve expressing the relationship between the water surface elevation of a reservoir and the volume of water in the reservoir. Also called a **storage curve** or a **capacity curve**.

Storage coefficient (1) A coefficient that accounts for storage and other runoff conditions in the Snyder method for the establishment of synthetic hydrographs. (2) The volume of water taken from or into storage by a vertical column of an artesian aquifer with a base of 1 ft^2 and a drop of 1 ft in the piezometric surface. Also called **storativity**. The corresponding term for a water-table aquifer is **specific yield**.

Storage curve Same as **storage–capacity curve** or simply a capacity curve.

Storage dam A dam used to impound water for such uses as water supply, as opposed to other types of dam (e.g., detention and diversion dams).

Storage devices Flow control devices that provide storage of excessive upstream flows and attenuate peak flows.

Storage equation *See* continuity equation. It is an axiom stating that outflow equals inflow plus or minus change in storage.

Storage-indication curve A curve used in the modified Puls method of reservoir routing to compute values of outflow Q and storage S for subsequent iterations. It plots outflow Q versus **storage indication**, which is defined as $S/\Delta t + Q/2$, where Δt is the routing period.

Storage junction (or storage node) A gravity junction with a stage–storage relationship, usually representing a pump station wetwell.

Storage Pumping Model (SPM) A computer program developed by Lawler, Matusky, and Skelly Engineers to simulate the operation of offline storage facilities using data generated by EXTRAN and its postprocessors.

Storage reservoir A reservoir with gate-controlled outlets that retains surface water for a relatively long period (at least several months) and releases the stored water in times of insufficient flow for domestic or industrial use. Also called an **impounding reservoir** or **conservation reservoir**. Storage reservoirs are also used for flood mitigation with appropriately large spillways or sluiceways for rapid drawdowns. *See also* retarding basin, which has no gate or other regulating device.

Storage routing The concept of flow routing in a channel, as compared to reservoir routing: a river is considered as a succession of reservoirs, the outflow from one is the inflow to the next. A critical step in the procedure is the determination of the storage–outflow relationship for the reaches. *See also* modified Puls method. *See* Hoggan (1997) for details.

STORAGE/TREATMENT Block One of four computational blocks of the U.S. Environmental Protection Agency Stormwater Management Model. This block routes flow and pollutants from other blocks or other sources through a storage or treatment facility. For flow through detention units, it uses the modified Puls method: The continuity equation is solved through the finite-difference method. It simulates similar pollutant concentrations in a completely mixed flow, but with an additional term to account for pollutant reactions by first-order decay. For pollutant removal, STORAGE/TREATMENT uses a set of particle-settling equations.

Storage–yield relationship A procedure (equation, graph, etc.) used to determine storage requirements for water supply or other purposes; based on inflows and drafts or outflows. It can also be used to determine reservoir yield. *See* Figure S-13; mass curve.

Storativity Same as **storage coefficient** (2).

STORM Acronym for Storage Treatment Overflow Runoff Model.

Storm A meteorological phenomenon of some magnitude/rate/intensity that produces atmospheric precipitation (rain, snow, hail, fog) or wind, e.g., rainstorm, snowstorm, windstorm.

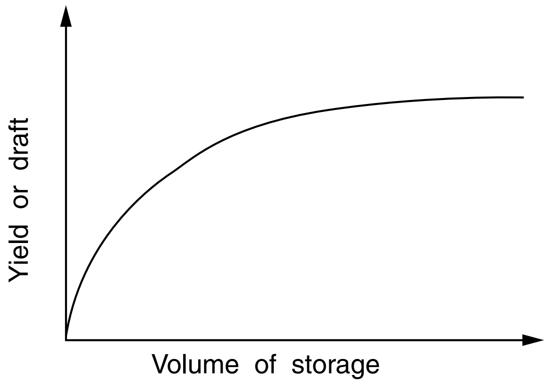


FIGURE S-13 Storage–yield relation.

StormCAD® A storm sewer modeling framework developed by Haestad Methods, Inc., of Waterbury, CT. Used as a stand-alone interface or as an application of other programs (e.g., AutoCAD and geographic information system [GIS]) for hydraulic modeling, graphical editing, results presentation, data sharing, and data exchange. *See also* SewerCAD; WaterCAD.

Storm drain A drain designed to carry stormwater, surface water, groundwater, subsurface water, building drainage, condensate, cooling water, and other similar discharges to a storm sewer or a combined sewer. Also called **storm sewer.**

Storm drainage model A mathematical description of the processes or phenomena involved in storm drainage, e.g., hydrological processes (precipitation, depression storage, evapotranspiration, infiltration, runoff); hydraulic processes (flow routing through channels, sewers, control devices, treatment or storage facilities); water quality processes (erosion, sedimentation, pollutants deposition, diffusion, dispersion, or transport).

Storm event An independent episode of precipitation separated from adjacent episodes by a minimum of dry time, called the **minimum interevent time**. Any precipitation activity that does not follow this minimum dry-weather period belongs to the event containing the previous activity. When stormwater storage facilities are used or required, a storm event begins when storage is required and ends when the facility is empty.

Storm flow The portion of precipitation that leaves the drainage area on the ground surface in a short time. Also called **surface runoff**, **overland flow**, or sometimes **excess rainfall**.

Storm intensity Same as **rainfall intensity**.

Storm overflow Sewer overflow due to stormwater. A weir, orifice, or other device to allow a sewer overflow or the discharge of excess flows. A **storm overflow sewer** carries the excess storm flow from a main sewer to an independent outlet.

Storm runoff Same as **direct runoff**; i.e., the portion of precipitation that reaches a stream promptly after rainfall and remains in the river basin for only a few days. It is the sum of surface runoff and interflow. *See* Figure R-6; rainfall–runoff relationship.

Storm severity An expression of the severeness or frequency of a storm. A storm is sometimes said to be **ordinary** when it is expected to occur once in 5 to 10 yr and **extraordinary** or **occasional** for a return period of 10 to 25 yr. *See also* excessive precipitation; extreme event; Haestad severity index.

Storm sewage Refuse liquids and wastes carried by sewers during or following rainfall. Also called **storm wastewater**. For **storm sewer**, *see* storm drain. **Storm sewer discharge** is the discharge of water from a storm sewer into a receiving water.

Stormwater Stormwater runoff, snowmelt runoff, and surface runoff and drainage, all resulting from precipitation, that either runs off from the surface into a stream, is captured by a storm or combined sewer, or percolates into the soil. Sometimes called **storm sewage**.

Stormwater collection system *See* sewer collection system.

Stormwater management The collection, transmission, storage, treatment, and final disposal of stormwater to reduce flooding, reduce pollutants, and provide other amenities.

Stormwater Management Model (or SWMM) A large and complex program developed over many years by the U.S. Environmental Protection Agency (EPA) to simulate the flow of stormwater and the movement of pollutants over the ground surface, through pipe and channel networks, through storage and treatment facilities, and final disposal into receiving waters. A very widely used urban stormwater model appropriate for single-event or continuous simulation and for planning as well as design. This program, different from SWMM Level I, consists of four computational blocks (EXTRAN, RUNOFF, STORAGE/TREATMENT, TRANSPORT Blocks) and six service blocks (COMBINE, EXECUTIVE, GRAPH, RAIN, STATISTICAL, TEMP). The computations of the four main blocks concern the following: (a) Dry-weather flows from the drainage area's socioeconomic characteristics (except for commercial and industrial flows, which can be imputed). (b) Wet-weather flows from the drainage area's hydrologic, hydraulic, and physical data. (c) Pollutant generation and transport. (d) The possibility to combine dry- and wet-weather flows for combined sewer flows. (e) The ability to define various scenarios for the assessment of conveyance system performance. SWMM is a public domain program, but various special or expert versions exist, such as PCSWMM of Computational Hydraulics, Inc. (Guelph, Ontario), and XP-SWMM of XP Software, Inc. (Tampa, FL, and Portland, OR). There are also special graphical user interfaces (GUIs) for the program, e.g., CASS-WORKS-SWMM of the RJN Group (Wheaton, IL) and WSWMM or SWMM for Windows® of the U.S. EPA. These special versions and GUIs solve some of the problems of the original program: lack of graphics features, pull-down menus, spreadsheet data input and editing, color plots, online help, etc. (James, 1996). *See* Section II for further information.

Stormwater Management Model Level I (or SWMM Level I) A simple model for a preliminary evaluation of urban stormwater problems and potential strategies. Completely different from the full-fledged SWMM, it can be run manually and offers a useful method to estimate annual runoff and pollutant loads. SWMM Level I's equations are:

$$R_{av} = CP_{av} - 5.234S_d^{0.5957} \quad \text{(S-41)}$$

$$S_d = 0.25(1 - I/100) - 0.0625I/100 \quad \text{(S-42)}$$

$$C = 0.15(1 - I/100) + 0.9I/100 \quad \text{(S-43)}$$

$$I = 9.6D_p^{0.573-0.039\log Dp} \quad \text{(S-44)}$$

where R_{av} = average annual runoff in inches/year; C = runoff coefficient; P_{av} = average annual precipitation in inches/year; S_d = weighted maximum depression storage in inches; I = imperviousness (percentage of drainage area that is impervious); and D_p = population density, population per acre.

Stormwater overflow Same as **storm overflow**.

Stormwater overflow sewer Same as **storm overflow sewer**.

Stormwater pollution prevention plan (SWPPP) An important part of the permit application for industrial stormwater discharges; designed to eliminate, minimize, or reduce pollution due to stormwater discharges from a site. Dodson (1999) recommended the consideration of the following categories of best management practices (BMPs) in preparing a SWPPP: good housekeeping, preventive maintenance, spill prevention and response procedures, inspections, employee training, record keeping and internal reporting procedures.

Stormwater quality control facilities Facilities designed to reduce the pollutant loads from stormwater into receiving waters, e.g., retention basins, sedimentation ponds, wet settling ponds. *See also* best management practices.

Stormwater quality ponds Wet or dry ponds designed to treat stormwater.

Stormwater retention Retention/detention basins, ponds, reservoirs, tanks are used in stormwater management to reduce the flooding and water quality impacts of storm runoff. Some of these structures can achieve a high degree of removal of such pollutants as biochemical oxygen demand (BOD), sediment, metals, or nutrients. In most of them, the most important design and control parameter is the **retention period**, also called **detention time** or **retention time**, i.e., the time t required to displace the volume v of the structure at a given flowrate Q:

$$t = v/Q \quad \text{(S-45)}$$

Stormwater retention facilities include dry detention basin, extended dry detention pond, infiltration basin/infiltration pond, sedimentation pond with displacement, wet retention basin/wet retention pond/wet settling basin/wet settling pond.

Stormwater runoff The portion of precipitation that becomes runoff.

Straight-edge weir A weir having a straight or vertical edge as opposed to trapezoidal or triangular weirs.

Stratification The formation of layers of different densities or different temperatures in a body of water. *See* density stratification; thermal stratification.

Straw bale A temporary barrier of straw or similar material used for sediment control in runoff from a small drainage area, sometimes with a stone trap at the opening to serve as a filtering device.

Stream A current or flow of water or other fluid, especially water running along the surface of the earth, with a bed and banks. More specifically, a **watercourse** is a natural or artificial stream of water, from the rivers and creeks to the rills or rivulets. All these streams flow in a definite direction, within their channels, along thalwegs, and usually discharge into another stream or body of water such as a lake or an ocean. The largest streams are the rivers and creeks, the difference is between the size of the drainage basin. The **river** is a natural stream of water draining a relatively large basin and emptying into an ocean (e.g., the Mississippi River), another river (e.g., the Missouri River), or a lake (e.g., the Niagara River). A **creek** (sometimes spelled "**crick**" in the northern United States) drains a relatively smaller basin and usually discharges into a river or another creek. **Brooks** and **runs** are smaller, shallow, natural streams that usually flow continuously, but are turbulent and swift. They are not as large as rivers and creeks, but not as small and intermittent as the streamlets. Other terms for small, fast-flowing streams are **branch** and **kill** used, respectively, in the southern United States and in New York State. **Ravines, gullies,** and **rills** are small, elongated, deep channels created by the erosive action of running water. The difference between them relates to size: a gully is smaller than a ravine, but larger than a rill. Also, gullies and rills are dry except after or during a rainstorm or snowmelt. Some ravines flow continuously; others are intermittent. Rills are sometimes called **rivulets**. **Aqueducts**, **canals**, **ditches**, **drainage swales**, **flumes**, and **pipelines** are artificial channels for water conveyance. An aqueduct is usually a large covered conduit in masonry, while a flume is used to carry water over or across an obstacle. The distinction between a ditch and a canal is that the former is usually unlined and has a cross section of less than 5 or 6 ft^2. A swale conveys runoff from a slope. A pipeline is a series of jointed pipes. Natural streams may be **perennial** (flowing more than 80% of the time), **intermittent** (flowing between 10% and 80% of the time), or **ephemeral** (flowing 10% or less of the time).

Streambank The rising stretch of land at the left or right edge of a stream. *See also* left bank; right bank.

Streambed The channel through which a natural stream of water runs or used to run; also defined as the bottom of the stream below its usual water surface, excluding the streambanks.

Stream discharge The flowrate in a stream at a given point, e.g., a stream gaging station.

Streamflow The water flowing in a channel or the flowrate of the stream. At any time, streamflow is the sum of baseflow (or base runoff) and direct streamflow (or direct runoff).

Streamflow plant/project A power plant/project designed to operate without the benefit of a storage reservoir. Also called **run-of-river plant/project**.

Streamflow record A listing of the daily, monthly, or annual discharges recorded for a stream at a given point or station. The record may be continuous from a starting date, or in some cases, there are gaps.

Streamflow regulation The control of stream discharge for various purposes (e.g., flood mitigation, water quality enhancement through dilution, and navigation) by such measures as impoundment, release of impounded water, and diversion.

Streamflow Synthesis and Reservoir Regulation (SSARR) A model developed by the U.S. Army Corps of Engineers to estimate runoff from rainfall, snowmelt, and watershed characteristics.

Stream gaging The measurement of stream discharge at a point or gaging station, usually by measuring the velocity and cross section of flow, as well as recording the stage to establish a stage–discharge relationship.

Streamlet A small stream such as a ravine, gully, rill, or rivulet.

Streamline Streamlines are straight or curved parallel lines that describe the flowpaths of groundwater particles. They are normal to the equipotential lines, with which they constitute the flownet. *See* Figure F-2.

Streamline flow Same as **laminar flow**.

Street wash Surface runoff from streets.

Strickler formula The form of the Manning formula used in continental Europe. It was derived independently by the Swiss engineer A. Strickler in 1923.

Student's t-test A test to determine whether the differences between the mean of paired data (e.g., measurement or observation and simulation) are significant. It is based on the dimensionless **Student's t-statistic**:

$$T = (E_a - \delta)/\sigma \tag{S-46}$$

where E_a is the average error as defined by the formula of Equation A-7, δ is the true difference between the paired data, and σ is the standard deviation of the differences.

Subbing Same as **subirrigation**.

Subcritical depth A depth of flow greater than the critical depth and corresponding to subcritical flow. *See* critical depth; critical flow.

Subcritical flow A varied-flow condition on a mild slope for which the depth of flow is greater than the critical depth (the slope is less than the critical slope, and the velocity is less than the critical velocity). This is the prevailing condition in most natural and man-made channels. Also called **tranquil flow**. *See also* critical flow; normal flow; rapid flow; supercritical flow.

Subdrainage Natural or artificial removal of excess groundwater (e.g., by pipe drains) from beneath a lined conduit (sewer, storm drain, canal, tunnel) or beneath a dam or other structure.

Subirrigation An irrigation method that supplies water to crops through pipes below the ground surface or through ditches that allow the water to seep into and maintain a high capillary fringe. Also called **subbing**. *See also* sprinkler irrigation; trickle irrigation.

Submarine outfall The facilities required for the disposal of wastewater, treatment plant effluents, or stormwater into the ocean. They usually include a pumping station, a pipeline with a single outlet or a diffuser structure, and their appurtenances. The pipeline requires special design considerations to maintain its stability and integrity. *See also* ocean disposal. Also called an **ocean outfall**.

Submarine pipeline Any pipeline installed underwater or on the bed of an ocean or waterway to transport water or other fluids. *See also* submarine outfall.

Submerged orifice An orifice discharging completely underwater.

Submerged outlet An outlet entirely covered by water.

Submerged spillway A spillway with a crest elevation that is lower than the downstream water level.

Submerged weir A weir (or dam) with a crest that is lower than or at the same elevation as the downstream water level. Also called **drowned weir**. For a submerged weir, the flow equation is modified by the addition of a submergence coefficient. Alternatively, the Villemonte equation may be used; it relates the submerged discharge to the free discharge and to the upstream and downstream heads. The **depth of submergence** (**h_s**) is the elevation difference between the downstream water surface and the weir crest. *See* weir equation. *See also* Figure W-11 and compare it to the free-flow weir of Figure W-5.

Submergence (1) The condition of orifices, outlets, spillways, dams, and weirs operating underwater or with a crest elevation lower than the downstream water level. The term also applies to a flooded pump suction inlet. (2) Same as **submergence ratio**. (3) The depth of flooding over a pump suction inlet.

Submergence coefficient (K′) A coefficient in the flow formula for a submerged weir representing the reduction in driving head. It varies inversely with the submergence ratio R′, from 0 to 1 as R′ goes from 1 to 0; e.g., K′ = 0.97 for R′ = 0.30, and K′ = 0.40 for R′ = 0.40.

Submergence depth (h_s) *See* submerged weir.

Submergence ratio (R′) A ratio used in the determination of the submergence coefficient:

$$R' = (y_2 - y_0)/(y_1 - y_0) \qquad \text{(S-47)}$$

where y_0, y_1, and y_2 represent, respectively, the height of the weir crest above the node invert, the water depth on the upstream side, and the water depth on the downstream side of the weir.

Submersible pump A pump, including its motor, installed in a protective housing and operating underwater, e.g., the motor and pump unit installed in a well. A **submersible pump station** houses submersible pumps. *See also* booster station; flooded suction station; suction lift station.

Subshed The drainage area of a tributary stream. *See* watershed.

Subsidence The lowering of the natural land surface in response to: earth movements; lowering of fluid pressure; removal of underlying supporting material by mining or solution of solids, artificially or from natural causes; compaction due to wetting (hydrocompaction); oxidation of organic matter in soils; or added load on the land (EPA-40CFR146.3).

Subsurface drain A perforated pipe or conduit installed beneath the ground surface to lower the water table and dewater an area, e.g., relief drains designed as a network when the water table is high and interceptor drains for areas with soils wet or subject to slippage.

Subsurface runoff The portion of precipitation that consists of interflow and overland runoff after reaching the temporary saturation zone without penetrating the water table. *See* Figure R-6; rainfall–runoff relationship.

Subsurface stormflow (1) Same as **interflow**. (2) A common theory of runoff generation: in a densely vegetated area, the ground absorbs most of the rainfall, which moves through the aeration zone to surface streams. *See also* Horton overland flow concept; saturation overland flow concept.

Subsurface water All water below the earth's surface. *See* Figure S-14. According to Meinzer's and other classifications, it includes two main components: interstitial and internal. Related terms listed and defined alphabetically in this dictionary include aquifer, capillary water, connate water, fixed groundwater, free water, gravitational water, internal water interstitial water, pellicular water, phreatic water, soil water, unproductive formations, vadose water. Other subsurface water terms are aeration zone, confining bed, intermediate groundwater, intermediate vadose water, saturation zone, unsaturated zone, water of adhesion.

Suction head *See* dynamic head.

Suction lift The negative pressure (in feet or meters of water or in inches or centimeters of mercury vacuum) on the suction side of the pump. The pressure can be measured from the centerline of the pump down to the elevation of the hydraulic gradeline on the suction side of the pump (EPA Glossaries). *See also* dynamic head.

Suction line A pipe or tubing feeding into the inlet of a pump or other fluid-impelling devices.

Suction piping The inlet piping or suction side of a pump.

Suction pump A pump that uses atmospheric pressure to raise water by pushing it into a partial vacuum.

SUDS Acronym for Statistical Urban Drainage Simulator.

Sullage Same as **graywater**.

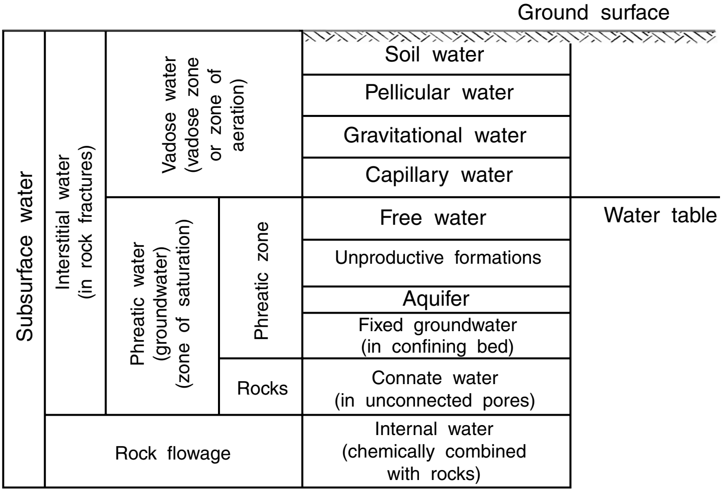


FIGURE S-14 Subsurface water.

Summation hydrograph A graph on rectangular coordinates often used in storage and streamflow regulation studies. Time is usually represented on the abscissa, while a cumulative quantity (e.g., storage volume or total discharge) is the ordinate. Also called **integrated hydrograph** or **mass diagram**.

Sump (1) A pit, tank, or reservoir that receives and temporarily stores stormwater, wastewater, or water for subsequent removal (usually by pumping). (2) Any pit or reservoir that meets the definition of tank and those troughs/trenches connected to it that serve to collect hazardous waste for transport to hazardous waste storage, treatment, or disposal facilities (EPA-40CFR260.10).

Sump orifice An orifice at the bottom of a sump for diverting wastewater from a stormwater system during dry weather to a sanitary sewer system; the Stormwater Management Model (SWMM) simulates this orifice by converting it to an equivalent pipe using the standard orifice equation and the Manning equation. Also called **dropout orifice**.

Sump pit Same as **sump**.

Sump pump A small, single-stage vertical pump, a submerged centrifugal pump, or an ejector used to drain sumps, shallow pits, or wetwells.

Supercritical depth A depth of flow less than the critical depth and corresponding to supercritical flow. *See* critical depth; critical flow.

Supercritical flow A varied-flow condition on a steep slope for which the depth of flow is less than the critical depth (the slope is greater than the critical slope, the velocity is greater than the critical velocity, and the Froude number is greater than 1). This condition occurs at some hydraulic structures (e.g., spillways, chutes) and in mountain streams. Also called **rapid flow** and **hypercritical flow**. *See* critical flow; normal flow; sinuous flow; subcritical flow; turbulent flow.

Supervisory control and data acquisition (SCADA) An information system used at wastewater treatment plants to control and continuously monitor the operation of sewer collection networks by transmitting data over telephone lines, by radio, or over cable lines. SCADA allows the remote control of such devices as pumps and valves and the remote acquisition of such data as flows, pressures, and water levels. Current telemetry systems allow direct input of field data into collection system models. *See also* sewer-level remote telemetry. *See* Section II for further information.

Supply zone A Cybernet® node description used for water distribution purposes.

Suppressed weir A weir that extends to one side or both sides of the upstream channel, thus preventing the contraction of the nappe on the flush side. It is usually designed with an air vent to avoid creating under the nappe a vacuum that can interfere with flow measurements. The opposite is a contracted weir. Also called **full-width weir**.

Surcharge (1) The flow condition in a gravity sewer flowing full or in a manhole or pump station wetwell connected to such a sewer or the flow condition in a sewer when the hydraulic gradeline is above the crown. Also defined as the condition when the flow exceeds the hydraulic capacity of a gravity sewer or when the depth of flow equals or exceeds the diameter of the discharging line. *See* Figure S-15. (2) The depth of wastewater in a manhole above the crown of a gravity sewer under surcharge condition.

Surcharge coefficient A coefficient that modifies the orifice equation for application to a surcharged weir.

Surcharge condition Same as **surcharge** (1). Some models (such as the TRANSPORT Block of the Stormwater Management Model [SWMM]) cannot simulate surcharge conditions; they clip any flows in excess of the open-channel capacity of a conduit, temporarily storing them for later release. *See* Figure S-15.

Surcharged manhole A manhole receiving flow in excess of the capacity of the outgoing sewer or receiving flow from a sewer under surcharge condition. *See* Figure S-15.

Surcharged pump station A pump station that operates with the wetwell level above the invert of the incoming gravity line, creating a restricted flow instead of an open-channel flow. *See* Section II for further information.

Surcharge storage Additional storage above the full-pond line of a reservoir; generally used for flood mitigation. Also called **overflow**. *See* Figure R-2; reservoir storage.

Surface abstraction, surface detention, surface storage The distinction, if any, among these terms is not always clear; all relate to the precipitation–runoff relationship. **Surface abstraction** appears as one of the components of a water balance model for stormwater management applications (Graham et al. in James, 1996, p. 120). It is indicated that: “During a precipitation event, the available surface abstractions are filled first, before runoff.” The term that is actually factored into the water budget is *maximum surface abstraction available*, represented by the symbol IA, which may suggest that it is the same as **initial abstraction**, a parameter

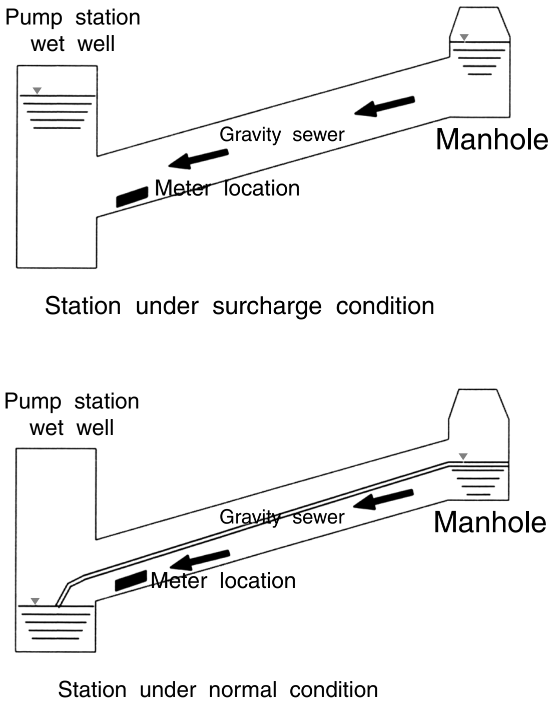


FIGURE S-15 Surcharge condition.

in the Soil Conservation Service (SCS) formulation. **Surface detention,** as defined in the Glossary of Water and Wastewater Engineering (APHA et al., 1981, p. 382) is: "that part of the rain which remains on the ground during rainfall and either runs off or infiltrates after the rain ends; does not include depression storage. The depression depth increases until discharge reaches equilibrium with rate of supply equal to surface runoff." **Surface retention** is the sum of interception and depression storage (Linsley et al., 1992, p. 47). **Surface storage** is listed as a component of the hydrological model of the WATFLOOD flood forecasting system (Kouwen and Soulis in James, 1996) but is not defined.

Surface evaporation Evaporation from the surface of water bodies, moist soil, snow, or ice; sometimes computed by subtracting infiltration and direct runoff from rainfall. *See also* soil moisture budget.

Surface impoundment (or simply impoundment) A natural topographic depression, man-made excavation, or diked area formed primarily of earthen materials (although it may be lined with man-made materials) that is not an injection well and that is designed to hold an accumulation of liquid wastes or wastes containing free liquids. Examples of surface impoundments are holding, storage, settling, and aeration pits, ponds, and lagoons (EPA-40CFR280.12, EPA-40CFR61.341, EPA-40CFR63.111, EPA-94/04, and EPA-40CFR260.10).

Surface loading rate In wastewater treatment, the surface loading rate (also called the **overflow rate**) is one of the design criteria for settling tanks; expressed in gallons per day per square foot, it is equal to the ratio of the average flowrate (in gallons per day) to the surface area of tank (in square feet).

Surface overflow rate (SOR) Same as **surface loading rate**.

Surface runoff Precipitation, snowmelt, or irrigation in excess of what can infiltrate the soil surface and be stored in small surface depressions; a major transporter of nonpoint source pollutants (EPA-94/04). It includes overland runoff and the precipitation that falls directly into the channels. Also called **overland flow**, **excess rainfall**, or **storm flow**. *See* quick-response runoff; rainfall–runoff relationship.

Surface storage *See* surface abstraction.

Surface tension The tensile force per unit length at the surface of a liquid; results from the interaction of the molecules, which tends to produce a meniscus at the surface. Surface tension is usually negligible, except in low flows. *See* Weber number.

Surface water All water open to the atmosphere and subject to surface runoff. All water naturally open to the atmosphere (rivers, lakes, reservoirs, ponds, streams, impoundments, seas, estuaries, etc.) and all springs, wells, or other collectors directly influenced by surface water (EPA-40CFR141.2 and EPA-94/04).

Surface water hydrology The study, description, measurement, and mapping of seas and oceans (**oceanography**), reservoirs and lakes (**limnology**), rivers and their adjacent land areas, including the determination of water flows, precipitation, evaporation, and other phenomena, as well as navigational and commercial uses. Also called **hydrography**. *See also* groundwater hydrology; hydrometeorology.

Surface width (W) The width of a channel section at the free surface; measured in a cross section normal to the direction of flow. Also called **top width**. *See* Figure O-1.

Surficial soil infiltration The water movement between the ground surface and the upper soil storage zone. This water goes to upper soil storage after upper soil evapotranspiration and recharge to groundwater. Also called **upper soil infiltration**.

Surge A sudden increase in a flow characteristic, often discharge or pressure, but also pollutant concentration, pH, or temperature.

Surge chamber A chamber or tank connected to a pipe and located at or near a valve that may quickly open or close or a pump that may suddenly start or stop. When the flow of water in a pipe starts or stops quickly, the surge chamber allows water to flow into or out of the pipe and minimizes any sudden positive or negative pressure waves or surges in the pipe (EPA Glossaries). *See also* Figure S-16.

Surge control tank (1) A large pipe or storage reservoir sufficient to contain the surging liquid discharge of the process tank to which it is connected

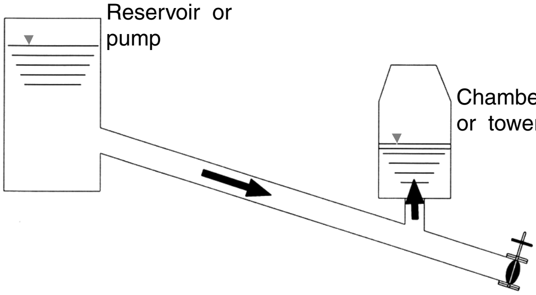


FIGURE S-16 Surge chamber/tank/tower.

(EPA-40CFR264.1031). (2) A standpipe or storage reservoir designed to absorb the sudden pressure increases in a closed conduit and to provide water when the pressure drops. *See also* Figure S-16; surge chamber. Also called **surge tank**.

Surge protection The reduction of the effects of unsteady flows by mechanical or hydraulic means, such as reducing valve closures, air chambers, surge tanks, or surge towers.

Surge tank Same as **surge control tank**.

Surge tower A large vertical pipe or tube connected to a pipeline or structure it is designed to protect, usually close to the valve or other device causing a surge. *See also* Figure S-16; surge chamber.

Suspended Elements that are retained by a 0.45-µm membrane filter.

Suspended-frame weir A timber weir with steel frames that can be raised during floods.

Suspended load The load of suspended sediment in flowing water; generally expressed as mass per unit time (e.g., kilograms or pounds per day). It is fine sediment, as compared to coarse material, which is called **bedload**. *See also* washload.

Suspended sediment Fine soil particles in suspension in water. *See also* suspended load.

Suspended solids Small particles of solid pollutants that float on the surface of, or are suspended in, wastewater or other liquids. They resist removal by conventional means (EPA Glossaries). *See also* colloids; dissolved solids; nonfilterable residues; solids.

Suspended water The portion of subsurface water found in the vadose zone (or aeration zone) between the ground surface and the water table. Also called **vadose water**, it includes soil, pellicular, gravitational, and capillary water. *See* Figure S-14; subsurface water.

Sutro weir A weir or dam having a horizontal crest and at least one curved side; the head above the crest is directly proportional to the discharge. *See also* Figure W-8; proportional weir.

Swale *See* drainage swale.

Swamp A type of wetland dominated by woody vegetation but without appreciable peat deposits. Swamps may be freshwater or saltwater and tidal or nontidal (EPA-94/04).

Sweet water Brackish water that does not meet potable water standards but is sometimes used for drinking. *See also* freshwater.

SWMM Abbreviation for Stormwater Management Model.

SWMM Level I Abbreviation for Stormwater Management Model Level I.

SWPPP Abbreviation for stormwater pollution prevention plan.

SWRRB Abbreviation for Simulation of Water Resources in Rural Basins.

Symbolic model A model that substitutes a set of mathematical relationships for the relevant features of a system or prototype. All computational hydraulics models are examples. Other types of model include analog, iconic, and physical models.

Synthetic hyetographs Rainfall intensity graphs derived from National Weather Service data. For example, for a given area, a hyetograph corresponding to a specific storm duration and return period can be constructed.

Synthetic streamflows A series of streamflows generated from and statistically similar to historical flows: The synthetic and historical records have the same mean, standard deviation, coefficient of skewness, and serial correlation. *See* autoregressive model; Markov model.

Synthetic/synthesized hydrograph A hydrograph developed on the basis of some characteristics of the station under consideration and some field data from a neighboring or similar station. For ungaged sites, two common methods are (a) Snyder's, on the basis of lag time, peak flow, time base, and rainfall duration; and (b) that of the Soil Conservation Service, on the basis of an average dimensionless hydrograph. The Clark instantaneous unit hydrograph method may also be used. *See also* hydrograph synthesis. *See* Section II for further information.

Synthetic unit hydrograph *See* synthetic/synthesized hydrograph.

Systematic errors Errors that can be predicted because they are produced by the same cause; unlike random errors, they give a definite bias to the result and do not balance each other. Systematic errors in modeling can be reduced through model validation, while random errors may be assessed through a sensitivity analysis.

System characteristic curve A graphical representation of the system head in a pumping installation as a function of static head and discharge. *See* Figure S-17; system head curve.

***Système International* (SI)** A decimal system of units used in scientific work and commercially throughout the world; based on the meter as unit of length, the second as unit of time, and the kilogram as unit of mass: 1 m = 100 cm = 1000 mm = 0.001 km = 3.281 ft; 1 kg = 1000 g = 0.001 metric ton = 2.2046 lb. Other basic SI units include the ampere (A) for electric current, the kelvin (K) for temperature, the mole (mol) for amount of matter, and the candela (cd) for luminous intensity. SI also has supplementary, additional, and derived units for acceleration, angles, force,

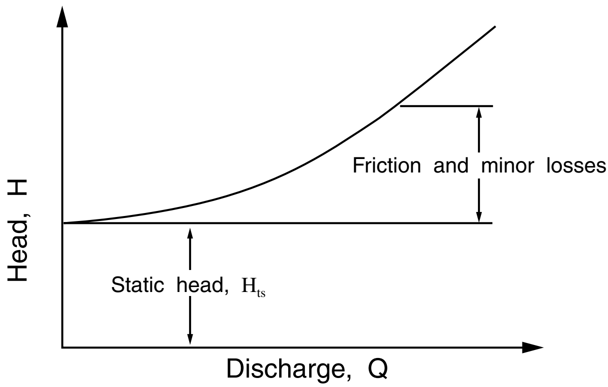


FIGURE S-17 System head curve.

pressure, surface area, velocity, volume, etc. (The English or U.S. customary units are the foot/second/pound.) *See* metric units.

System head The total head (or total dynamic head) against which a pump or system of pumps works. It is the sum of the static and dynamic heads. *See also* Equation S-48; Figure S-17; system head curve.

System head-capacity curve (or system head curve) A graphical representation of the system head in a pumping installation. It is the graph of system total dynamic head H as a function of static head H_{ts} and the discharge Q according to the equation:

$$H = H_{ts} + 0.0252\ [(fLQ^2/d^5) + (\sum kQ^2/d^4)] \qquad \text{(S-48)}$$

where f = Darcy–Weisbach friction factor, L = pipe length, d = pipe diameter, and k = minor loss coefficient. *See* Figure S-17.

T

Tailrace A flume or channel leading water away from a spillway, waterwheel, or similar structure. *See also* apron; Figure S-9.

Tailwater (1) The runoff of irrigation water from the lower end of an irrigated field. (2) Discharge at the downstream end of waterworks; e.g., the stretch of river below a dam.

Tainter gate A type of spillway crest gate with a face that is a section of cylinder that rotates about a horizontal axis on the downstream end of the gate. The gate, used in large installations, can be raised or lowered by winches or hoists acting on the bottom; it can also be closed under its own weight. Other crest gates include flashboards, stop logs, sliding gates, bear-trap gates, and drum gates. Also spelled **taintor gate** or called **radial gate** and **canal lock**.

Tank In general, a tank is a large container, receptacle, or structure for holding, storing, or transporting a liquid or gas. In water and wastewater conveyance and treatment, tanks are used for such operations or processes as aeration, disinfection, equalization, sedimentation, holding, mixing, and chemical feeding. **Tankage** is the capacity or contents of a storage tank.

Taylor series expansion The expansion of a continuous function f(x), often used to determine iteratively the approximate value of a dependent variable, i.e.,

$$f(x + \Delta x) = f(x) + \partial x \cdot \partial f/\partial x + (\Delta x^2/2!) \cdot (\partial^2 f/\partial x^2) + (\Delta x^3/3!) \cdot (\partial^3 f/\partial x^3) + \ldots \qquad \text{(T-1)}$$

or

$$f(x_{i+1}) = f(x_i) + f'(x_i) \cdot (x_{i+1} - x_i) + [f''(x_i)/2!] \cdot (x_{i+1} - x_i)^2 + [f'''(x_i)/3!] \cdot (x_{i+1} - x_i)^3 + \ldots \qquad \text{(T-2)}$$

where Δx is an increment of the independent variable x, the symbol ! indicates the factorial of the preceding number, and i represents the iteration step. *See* Newton–Raphson method.

TAZ Acronym for traffic analysis zone.

TDH Abbreviation for total dynamic discharge head.

TDS Abbreviation for total dissolved solids.

Technical Release 20 (or **TR-20**) A computer simulation model developed by the Soil Conservation Service in 1973 for hydrologic routing.

Technical Release 55 (TR-55) iA Soil Conservation Service document (Urban Hydrology for Small Watersheds, 1975) that defines an overland flow method to compute the time of concentration.

Telemeter (or **telemetering system)** (1) The equipment for measuring, transmitting, and receiving data (such as flow, water level, temperature, pressure, radiation, etc.) at a distance, by wires, radio waves, or other means. (2) An instrument for measuring the distance to a remote object.

Telemetry The science or process of telemetering or the use of a telemetering system. *See also* sewer level remote telemetry; supervisory control and data acquisition.

TeleTote™ An open-channel electromagnetic flowmeter manufactured by Marsh-McBirney, Inc., of Frederick, MD.

Television inspection A technique that uses a specially designed closed-circuit television camera to observe the conditions in sewer lines. The camera, equipped with a light source for illumination, is mounted on a casing and pulled through the sewer with cables, or a self-propelled camera is used. The television monitor displays the results, which can be documented by videotapes or photographs. *See also* internal inspection.

TEMP A time-series management module of the Stormwater Management Model (SWMM) that processes air temperature data.

Temperature index method A simple method used to estimate the magnitude of snowmelt as a function of daily temperatures. *See* snowmelt. Also called **degree–day method**.

Tensiometer A device used to measure the negative pressure (or tension) with which water is held in the soil; a porous, permeable ceramic cup connected through a tube to a manometer or vacuum gage.

Ten-yr, 24-h rainfall (precipitation) event. *See* design storm.

Terminal manhole The most upstream manhole in a gravity sewer line. Terminal manholes are used to determine the boundaries of service areas.

Terminal settling velocity The vertical velocity V of a suspended particle or its maximum rate of unhindered sedimentation. It may be determined from Stokes law, Equation (S-40), or from Newton's law:

$$V = 2\sqrt{g(\rho - \rho')d/3\rho C_D} \tag{T-3}$$

where g is the acceleration of gravity; d and ρ are the particle diameter and mass density, respectively; ρ′ is the fluid density; and C_D is the drag coefficient.

Terrace A broad channel, bench, or embankment constructed across a slope to intercept runoff and detain it or channel it to protected outlets, thereby reducing erosion from agricultural areas (EPA Glossaries). *See also* diversion. **Terracing** is a system of dikes built along the contours of sloping farmland to hold runoff and reduce erosion.

Testing *See* calibration.

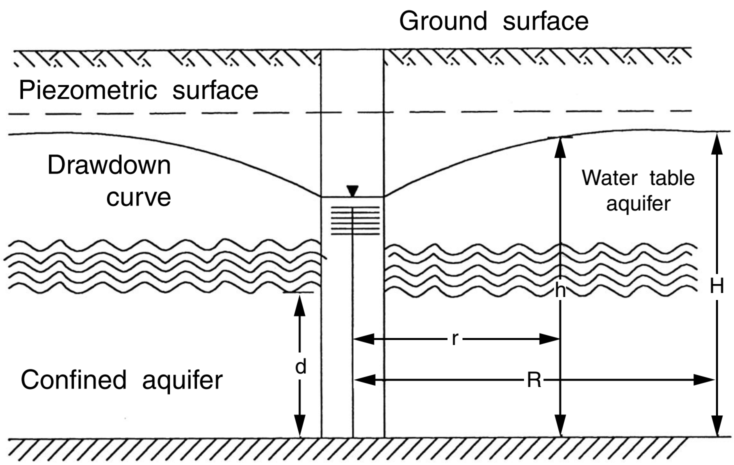


FIGURE T-1 Theim equation for confined flow.

Test well A well or other device installed in an infiltration basin to monitor infiltration rates.

Thalweg The line connecting the lowest points in each cross section of a valley.

Theim equation An equation used for the study of steady flow to a fully penetrating well through a confined aquifer of constant thickness and infinite extent. It applies Darcy's law and assumes horizontal flow with a velocity proportional to the tangent (instead of the sine) of the hydraulic gradient. It is widely used in assessing an aquifer's hydraulic characteristics from field test results or in determining the discharge of a well if the hydraulic conductivity is known. *See* Dupuit equation; Figure T-1; and well flow equations. The Theim equation is usually written as follows:

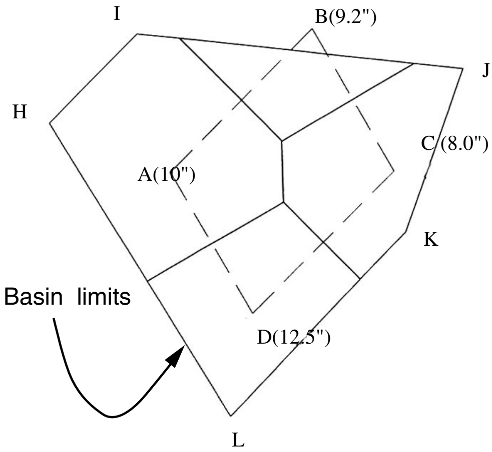
$$Q = 2\pi Kb(H - h)/\ln(R/r) \quad \text{(T-4)}$$

where Q = discharge from the well, K = hydraulic conductivity of the aquifer, b = thickness of confined aquifer, H = piezometric head at distance R, and h = piezometric head at distance r.

Thermal stratification The formation of layers of different temperatures in a body of water. *See also* density stratification.

Thermocline The middle layer of a thermally stratified lake or reservoir. In this layer, there is a rapid decrease in temperature with depth. Also called **metalimnion**.

Thiessen polygon method A method used in hydrological analysis to determine the spatial distribution of rainfall: given a number of gaging stations, to determine to which parts of the drainage basin each gage reading applies, perpendicular bisectors are drawn to the straight lines joining the station locations. Figure T-2 illustrates the procedure for a simple case: the drainage area HIJKL and the four gauging stations A, B, C, and D. Two



Station	Rainfall, inches	Tributary Area, acres	Rainfall Volume, acre-in.
A	10.0	126	1260
B	9.2	30	276
C	8.0	112	896
D	12.5	132	1650
		400	4082
Mean rainfall = 4082 acre-in./400 acre = 10.205 inches.			

FIGURE T-2 Thiessen polygon method.

other methods for spatial averaging of rainfall data are the arithmetic average and the isohyetal method.

Thin-plate weir A device or structure, usually made of a plastic or metal plate, used for flow distribution or flow measurement. Materials used in wastewater treatment also include: steel, stainless steel, fiberglass, and aluminum. Its crest is so thin that water flowing over it touches only a line. Also called **sharp-crested weir**. *See* broad-crested weir; Figure W-5b.

Thirty-day average The arithmetic mean of pollutant parameter values of samples collected in a period of 30 consecutive days (EPA-40CFR133.101-b). The 30-day limitation is the value that should not be exceeded by the average of daily measurements taken during any 30-day period (EPA-40CFR429.11-j). The 30-day rolling average is any value arithmetically averaged over any consecutive 30 days (EPA-40CFR52.74–1).

Thomas model A method proposed for the simulation of direct runoff within a basin. *See* National Water Assessment model. Also called **abcd model**.

Thomson weirs V-notch weirs with an angle of 60° or 90° providing approximate measures of discharge Q (gpm) as a function of H, the depth of water on the upstream side. For the 60° weir:

$$Q = 1.31H^{2.5} \quad \text{(T-5)}$$

For the 90° weir:

$$Q = 2.28H^{2.5} \quad \text{(T-6)}$$

See also weir equation.

Three-parameter gamma distribution or function *See* gamma distribution; gamma function.

Three-point method A method to determine flow velocities by taking the average of velocity measurements at three flow depths, for example, at the 0.2, 0.6, and 0.8 points.

Three-point operating curve An approximate representation of the relationship between pump head and discharge by three points on the pump curve.

Three-point stage–discharge curve An approximate representation of the relationship between water depth (stage) and pump discharge.

Threshold event A rainfall of a certain volume used as a minimum to define a significant rainfall event (i.e., producing runoff). For example, 0.04, 0.06, and 0.10 in of rainfall within 1, 3, and 5 h, respectively.

Throat The narrowest portion or the minimum cross-sectional area of a constricted duct, a venturi tube, a nozzle, or a flume.

Throughflow The portion of precipitation that reaches a stream after infiltration into the soil and after lateral flow, without reaching the water table. Same as **interflow**. *See* Figure R-6; runoff generation.

Tidal current The horizontal movement of the water under tidal influence.

Tidal lock A lock between the tideway and an enclosed basin to allow vessels to pass either way when the levels of the two water bodies are different. Also called **entrance lock** or **tide lock**.

Tidal range The difference in elevation between high and low tides.

Tide The periodic rise and fall of the surface level of oceans, bays, gulfs, inlets, and estuaries that results from the gravitational attraction of the moon and sun on the earth. A **tide gage** is a device or an instrument for measuring the height of a tide. A **tide gate** is a gate or an opening through which water flows in one direction, but the gate closes to prevent flow in the other direction, e.g., to prevent flow reversal due to tidal action. The gate is usually installed at the end of a conduit, channel, outfall, or overflow structure, discharging into a water body with a fluctuating surface. *See* effective driving head. A **tide lock** is the same as **tidal lock**.

TIGER Acronym for Topographically Integrated Geographic Encoding and Referencing.

Tillage Plowing, seedbed preparation, and cultivation practices.

Timber dam (or timber-crib dam) A dam made of timbers framed into cribs filled with rocks.

Time base (T) The time between the beginning and the end of the direct runoff. It is a parameter used in runoff analysis. Other parameters include antecedent precipitation index, attenuation constant, lag time, peak discharge, plotting time width, rainfall duration, time of concentration, or time of equilibrium. *See also* SCS hydrograph method; Snyder method.

Time discretization The division of the time domain into timesteps Δt for the application of numerical methods in computer simulations.

Time invariance principle One of the assumptions underlying the application of the unit hydrograph methods: the unit hydrograph of a drainage basin for a given effective rainfall is independent of the time of occurrence.

This allows the addition or superimposition of unit hydrograph ordinates of common duration.

Time of concentration (t_c) (1) The time required for water to move from the hydraulically most distant point of the drainage area to the outlet or design point under consideration. Used in the rational formula to determine the peak runoff flow under the assumption that the flow reaches a peak when the entire drainage area is contributing runoff. (2) Sometimes called **time of equilibrium**, which is the time when the rate of runoff equals the rate of rainfall. (3) Based on a rainfall hyetograph, the resulting runoff hydrograph, the rainfall excess, and the direct runoff (Gupta, 2001; McCuen, 1989): the time of concentration is, on the timescale, the distance between the center of mass of rainfall excess and the inflection point on the recession of the direct runoff hydrograph, or t_c = the difference between the end of rainfall excess and the inflection point. *See also* hydraulic residence time; hydrograph times. *See* Section II for further information. Time of concentration is one of a few parameters used in runoff analysis. *See also* antecedent precipitation index; attenuation constant; lag time; peak discharge, plotting time widths; rainfall duration; time base.

Time of equilibrium Time required for the rate of runoff to equal the rate of rainfall; sometimes also called **time of concentration** (2).

Time of travel *See* hydraulic residence time.

Time series A sequence of values arranged in order of occurrence. **Time-series data** are observations recorded at specified times, usually at regular intervals, e.g., daily precipitation, hourly temperature, daily flow. Such data are used in frequency analysis.

Time-stage node In stormwater management modeling, a node used by the Advanced Interconnected Pond Routing (AdICPR) technique to establish model boundary conditions.

Time-stage relationship A relationship of stage or depth of flow versus time. *See* Section II for further information.

Timestep (Δt) The time interval used to discretize continuous events for the application of numerical methods. The governing equations are solved at every step, beginning with the initial condition at time t = 0. Timestep is an important parameter, normally selected small enough to achieve stability and accuracy, and avoid numerical dispersion, but not too small so as to limit computation time. It affects the efficiency and stability of numerical solution procedures. An optimal timestep may be determined based on test runs, starting with a given timestep and decreasing it until the change in output becomes insignificant. *See also* convergence; Courant number; numerical parameters. *See* Section II for further information.

Time stepping Same as **time discretization** or the division of the time domain into timesteps Δt for the application of numerical methods in computer simulations.

Time to peak *See* hydrograph time to peak.

Time-variant tailwater condition A situation in which the water surface in a water body depends not only on the inflow and the characteristics of the body, but also on the outflow and outlet structures, e.g.: (a) two ponds directly connected, with inverts at or near the same elevation; (b) a pond with a tidal outfall into the ocean; (c) a pond with an outfall into a stream subject to time-variant conditions. *See* Haestad Methods (1998); interconnected ponds.

Time-weighting factor (θ) A parameter used in the finite-difference method to determine the exact position between two adjacent time lines. Varying between $\theta = 0$ for an explicit solution and $\theta = 1$ for an implicit solution, this factor plays an important role in the stability of numerical procedures. The Crank–Nicholson scheme corresponds to $\theta = 0.5$ (Spitz and Moreno, 1996). When the dependent variables (flow, head, etc.) are expressed as functions of time f(t), the time-weighting factor is applied to the difference equations as follows:

$$f(t + \Delta t) = (1 - \theta)\cdot f(t) + \theta\cdot f(t + \Delta t) \tag{T-7}$$

where Δt is the timestep. *See* Preissmann scheme for a recommended range of time-weighting factors and Section II for further information. *See also* numerical parameters.

TIN Acronym for triangular (or triangulated) irregular network.

TMDL Abbreviation for total maximum daily load.

Toe The downstream edge of the base of a dam, spillway, or similar structure.

Tonne Same as **metric ton**, a unit of mass or weight equal to 1000 kg or approximately 2205 lb.

Topographic divide The line that separates one drainage basin from another; it follows the ridges or summits forming the exterior of the drainage basins. Also called **drainage divide** or **watershed divide**.

Topologically Integrated Geographic Encoding and Referencing (TIGER) A digital map database of the U.S. Census Bureau that automates mapping and related geographic activities.

Topsoil The upper layer of soil; generally darker and richer than the subsoil. *See* soil profile.

Top width Same as **surface width**. The width of a channel section at the free surface; measured in a cross section normal to the direction of flow. *See* Figure O-1.

Torricelli equation *See* orifice flow.

Torricelli, Evangelista *See* hydraulics.

Total dissolved solids (TDS) The total filterable residue that passes through a standard glass fiber filter disk and remains after evaporation and drying to a constant weight at 180°C; considered a measure of the dissolved salt content of the water (EPA-40CFR131.35.d-16).

Total dynamic discharge head (or total dynamic head, TDH) Same as **dynamic head**.

Total energy The sum of the three forms of hydraulic energy: potential, kinetic, and pressure. Same as **total head**.

Total filterable residue *See* total dissolved solids.

Total head Same as **dynamic head**. In open-channel flow, the flow depth plus the velocity head.

Totalizer A device or meter that continuously measures and calculates total flows in gallons, million gallons, cubic feet, or other unit of volume measurement. Also called an **integrator**.

Total maximum daily load (TMDL) The sum of the individual nonpoint sources and natural background. If a receiving water has only one point source discharger, the TMDL is the sum of that point source waste load allocation plus the load allocations for any nonpoint sources of pollution and natural background sources, tributaries, or adjacent segments. TMDL can be expressed in terms of mass per time, toxicity, or other appropriate measure. If best management practices or other nonpoint source pollution controls make more stringent load allocations practicable, then waste load allocations can be made less stringent. Thus, the TMDL process provides for nonpoint source control tradeoffs (EPA-40CFR130.2-i).

Total pumping head A measure of the total energy imparted by a pump to a fluid; equal to the algebraic difference between the total discharge head and the total suction head.

Total runoff The sum of direct runoff and groundwater runoff; i.e., the total volume of runoff from a drainage area for a definite period of time or for the duration of a given storm. *See* Figure R-6; rainfall–runoff relationship.

Total soil storage shut-off option A special feature added to the Stormwater Management Model (SWMM) program by Camp Dresser and McKee, Inc., to establish a maximum infiltration capacity or maximum soil storage.

Total solids The materials in sewage sludge that remain as residue when the sludge is dried at 103 to 105°C (EPA-40CFR503.31-I). Also, the sum of dissolved, colloidal, and suspended solids in water or wastewater.

Total static head *See* pump head terms for definition.

Total storage The sum of all storage elements of a reservoir or other impoundment (surcharge, active, inactive, dead). *See* reservoir storage and Figure R-2.

Total suspended particles A method of monitoring particulate matter by total weight.

Total suspended solids (TSS) A measure of the suspended solids in wastewater, effluent, or water bodies; determined by tests for total suspended nonfilterable solids. *See* suspended solids (EPA Glossaries).

TR-20, TR-55 *See* Technical Release 20.

Tractive force theory An approach to the design of stable channels in erodible or alluvial materials: the channel characteristics are selected to keep the forces of the moving water on the bed and slopes below the permissible stresses. For a trapezoidal channel, the following equations may be used (Gupta, 2001):

$$F_b = \gamma y S \quad \text{(T-8)}$$

$$F_s = 0.76\gamma y S \tag{T-9}$$

and

$$K = (\sin^2 \theta - \sin^2 \alpha)/\sin \theta \tag{T-10}$$

where F_b = maximum unit tractive force or stress on the bed, F_s = maximum unit tractive force or stress on the sides, γ = specific weight of water, y = water depth in the channel, S = bed slope, K = factor of permissible stress on the sides, θ = angle of side slope to the horizontal, and α = angle of repose of the material. *See also* channel stability; extremal hypothesis; regime theory.

Traffic analysis zone (TAZ) A unit used along with census tract to compile, analyze, or process socioeconomic data such as population and employment. Such data are used in developing estimates and forecasts for wastewater collection system models.

Training *See* river training.

Tranquil flow A varied-flow condition on a mild slope; the depth of flow is greater than the critical depth (the slope is less than the critical slope, and the velocity is less than the critical velocity). This is the prevailing condition in most natural and man-made channels. Also called **subcritical flow**. *See also* critical flow; normal flow; supercritical or rapid flow.

Transducer A device or substance that converts energy from one form to another; e.g., from mechanical energy to electrical energy. Commonly used in flow monitoring.

Transients Phenomena that last only a short duration. Hydraulic transients like water hammer or surge are caused when valves are opened or closed suddenly or when pumps start or stop.

Transition region *See* flow transition region.

Translation The process according to which there is a lag time between the peaks of the inflow and outflow hydrographs as an effect of storage. Also called **lagging**. *See* Figure R-3; reservoir storage routing.

Transmission In a sewer system, transmission is the further conveyance of flow from local areas. Transmission takes place in trunk or main sewers, as opposed to collection in branch sewers. In regional sewer systems, wastewater is often collected in gravity sewers and pumped to transmission mains that eventually discharge into a treatment plant.

Transmission line A pipeline that transports raw water from its source to a water treatment plant, then to the distribution grid system (EPA-94/04).

Transmissive fault or fracture A fault or fracture that has sufficient permeability and vertical extent to allow fluids to move between formations (EPA-40CFR146.61).

Transmissive fracture *See* transmissive fault.

Transmissivity (1) The hydraulic conductivity integrated over the saturated thickness of an underground formation. The transmissivity of a series of formations is the sum of the individual transmissivities of each formation comprising the series (EPA-40CFR191.12). (2) The ability of an aquifer to transmit water through its entire thickness. Transmissivity T is the product of thickness b by hydraulic conductivity K for an aquifer of uniform thickness:

$$T = Kb \tag{T-11}$$

Transpiration The process by which water vapor is lost to the atmosphere from living plants. The term can also be applied to the quantity of water thus dissipated (EPA Glossaries). Plant transpiration is similar to animal perspiration. Transpiration is generally larger than evaporation and depends on vegetation types, soil moisture, and meteorological conditions. In most engineering applications, transpiration and evaporation are considered as evapotranspiration because it is difficult to measure them separately.

Transport The flux of a property (e.g., energy, mass, momentum) into or out of a system.

TRANSPORT Block One of four major computational blocks of the U.S. Environmental Protection Agency's Stormwater Management Model (SWMM). The TRANSPORT Block uses the Saint-Venant equations to route throughout the sewer system flows and pollutants from other blocks or from manual input. It uses the kinematic wave approximation and cannot simulate backwater and surcharge conditions. It figures changes in pollutant concentrations on the basis of a completely mixed reactor with first-order decay. TRANSPORT can estimate dry-weather flows as well as infiltration/inflow.

Transverse weir A weir across a channel or conduit used as an outfall structure, with or without a tide gate, as opposed to a side-flow weir. For a transverse weir, the flow exponent is 3/2 in the weir equation.

Trap *See* sediment trap.

Trap efficiency The ratio or percentage of sediment retained to the sediment load. *See also* Brune's trap efficiency curves.

Trapezoidal weir A weir with a trapezoidal notch. *See also* the Cipolletti and compound weirs of Figures W-3 and W-4, respectively.

Travel time *See* hydraulic residence time.

Treatment plant An important component of water supply or wastewater disposal systems; contains a number of units and processes to produce a finished water or a wastewater effluent of a specified quality. *See* Figure T-3.

Treatment works Any devices and systems used for the storage, treatment, recycling, and reclamation of municipal wastewater, domestic wastewater, or liquid industrial wastes or necessary to recycle or reuse water at the most economical cost over the useful life of the works. These include intercepting sewers, outfall sewers, wastewater collection systems, individual systems, pumping, power, and other equipment and their appurtenances; extensions, improvement, remodeling, additions, and alterations thereof; elements essential to provide a reliable recycled supply; any required land;

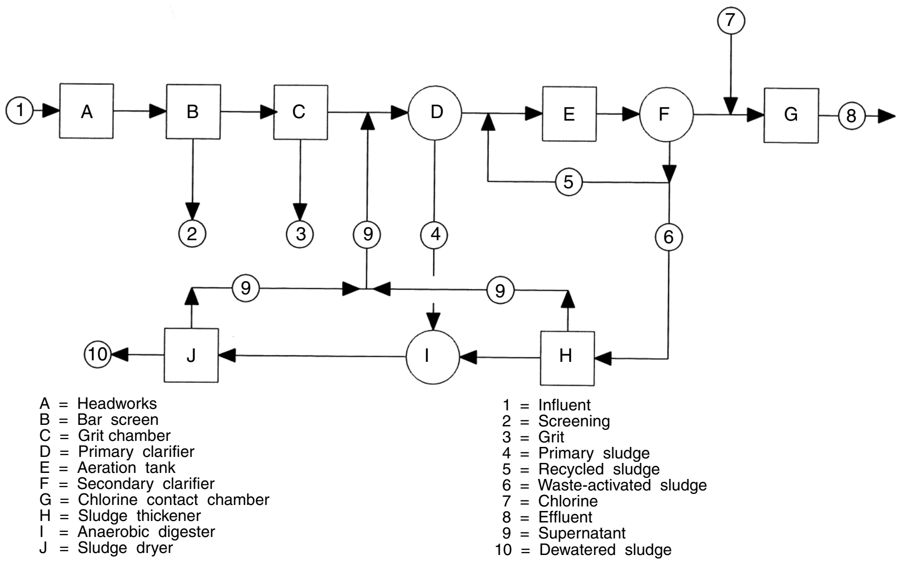


FIGURE T-3 Wastewater treatment plant.

or any other method or system for preventing, abating, reducing, storing, treating, separating, or disposing of municipal or industrial waste, including waste in combined sewer systems (EPA-40CFR35.905).

Triangular (or triangulated) irregular network (TIN) One of three current methods of processing geographic information system (GIS) data for use in hydrologic modeling. It represents the earth's surface as a set of fully connected triangles. The other two methods are raster-based storage and vector- or contour-based line networks (Hoggan, 1997).

Triangular-notch weir A weir with a V-shaped notch for measuring small flows. Discharge varies with the 2.5 power of weir head. Also called **triangular weir**, **V-notch weir**, **Vee weir**, **V-notched weir**. The discharge Q of a free-flow triangular weir is a function of the head H, the notch angle θ, and the discharge coefficient K:

$$Q = KH^{2.5}(\tan \theta/2) \qquad \text{(T-12)}$$

See compound weir; Figures W-4 and W-12; Thomson weirs.

Triangular unit hydrograph *See* equivalent triangular unit hydrograph; Figure E-3.

Trickle irrigation An irrigation method that uses perforated plastic pipes at the base of the plants and realizes water savings (due to considerable reduction of evaporation and percolation) and sometimes economy of nutrients as well as salinity reduction. Also called **drip irrigation**. *See also* sprinkler irrigation; subirrigation.

Trough A long, narrow, open structure (channel or conduit) for holding or conveying water or other liquids; e.g., the steep open channel of a chute spillway (also called **chute**).

Truncation error The error introduced in finite-difference models by neglecting higher order derivative terms in the Taylor series expansions. *See* finite-difference method; modeling error.

Trunk sewer A sewer, generally part of the transmission system, that receives flow from smaller lines, such as branch or lateral sewers, or from other trunk lines. Also called **main sewer** or **major sewer line**. *See* Section II for further information.

TSS Abbreviation for total suspended solids.

t statistic *See* Student's t test.

Turbidimeter A device that measures turbidity. *See* nephelometer.

Turbidity A cloudy condition in water due to suspended silt or organic matter. Or, the clarity of water expressed as nephelometric turbidity units (NTUs) and measured with a calibrated turbidimeter (EPA-94/04 and EPA-40CFR131.35,d-19). Suspended matter in water or wastewater that interferes with the passage of light.

Turbine A machine that has a rotor with vanes or blades; driven by the pressure, momentum, or reactive thrust of a moving fluid. Hydraulic turbines are power-generating machines classified as impulse or reaction turbines. They transform the kinetic and potential energy of water into mechanical power.

Turbine pump A centrifugal pump with fixed vanes; converts the velocity energy into pressure head. A turbo pump is a pump powered by a turbine. *See also* regenerative pump.

Turbulence closure The problem of describing the turbulent correlations or stress terms introduced in the Reynolds equations. Four parameters sometimes used to define **turbulence conditions** are the dimensionless Peclet P_e, Lewis L_e, Prandtl P_r, and Schmidt S_c numbers. The Peclet number is similar to the Reynolds number, except that it substitutes an appropriate mixing or diffusion coefficient for the kinematic viscosity. The other three numbers are ratios of mixing coefficients. For details, *see* Martin and McCutcheon (1999). **Turbulence parameterization** is the use of parameters to define turbulence conditions.

Turbulent flow The opposite of laminar flow; i.e., the unsteady, random motion of fluid particles, with mixing between adjacent layers and predominance of higher velocities and energy headlosses. The Reynolds number R_e determines whether flow is laminar or turbulent. In most cases, water or wastewater flow in conduits is turbulent. For turbulent flow of incompressible fluids like water, the friction factor f can be determined from the Moody diagram as a function of R_e and the relative pipe roughness. Also called **eddy flow** or **sinuous flow**.

Turning basin The area provided at the end of a narrow waterway to allow ships to turn around.

Turnover The phenomenon that occurs in lakes in the spring (spring turnover) when temperatures rise above the freezing point; surface ice melts into higher density water and tends to sink, causing the turnover. In the fall, density also rises at the surface, and the water becomes colder, causing a similar turnover. Also called **overturning**.

Twenty-five-yr, 24-h rainfall event The maximum 24-h rainfall event with a probable recurrence interval of once in 25 yr as defined by the National Weather Service in Technical Paper No. 40, Rainfall Frequency Atlas of the United States (May 1961) and subsequent amendments in effect (EPA-40CFR418.11-e).

Two-dimensional model A model that includes only two space dimensions, usually by horizontal or vertical averaging. For example, a two-dimensional groundwater model may neglect flow and transport components in either the horizontal or vertical direction to yield predictions in the other two directions. *See also* flow model.

Two-yr, 24-h precipitation event The maximum 24-h precipitation event with a probable recurrence interval of once in 2 yr as defined by the National Weather Service in Technical Paper No. 40, "Rainfall Frequency Atlas of the United States" (May 1961) or equivalent regional or rainfall probability information developed therefrom (EPA-40CFR434.11-t).

Type III distributions Two extreme-value distributions used in flood and drought studies. *See* log-Pearson type III distribution; Weibull distribution.

U

Ultrasonic method A method of open-channel discharge measurement using the velocity of ultrasound (a sound with a frequency greater than 20,000 Hz) in water. It consists of two transducers M and N, installed obliquely on opposite banks of the channel, and of the apparatus to measure the ultrasound velocity. *See also* acoustic method; Doppler current meter; Figure U-1. The discharge Q is:

$$Q = \Delta y L^2 (\tan \theta)/2P \qquad \text{(U-1)}$$

where Δ = difference between the travel times from M to N and from N back to M, P = product of these two travel times, L = distance from M to N, y = average depth of flow along the path MN, and θ = angle between MN and the direction of flow.

Unaccounted flow (or unaccounted-for water) The portion of water withdrawn from a supply source that is not assigned to a specific user. This includes all losses from the point of withdrawal to the customer meters, from leaks in the distribution lines, to unauthorized connections, and to malfunctioning meters or errors in meter readings.

Unconfined aquifer An aquifer containing water that is not under pressure; the water level in a well through an unconfined aquifer is the same as the water table outside the well. Also called **phreatic aquifer** or **water-table aquifer**.

Unconfined flow equation An equation used for the study of steady flow to a fully penetrating well through an unconfined aquifer of infinite extent. It applies Darcy's law and assumes horizontal flow with a velocity proportional to the tangent (instead of the sine) of the hydraulic gradient. It is widely used in assessing an aquifer's hydraulic characteristics from field test results or in determining well discharge when the hydraulic conductivity is known. *See also* the Dupuit equation, Equation D-16; Figure D-8; Theim equation; and well flow equations.

Underdrain A drain to remove groundwater, stormwater, or the drainage from water or wastewater structures; for example, the perforated plastic pipes installed at the bottom of an infiltration basin to collect and remove excess stormwater.

Underflow The concentrated solids removed from the bottom of a tank or basin or the washwater distributed throughout a filter for backwash.

Underground drinking water source *See* underground source of drinking water.

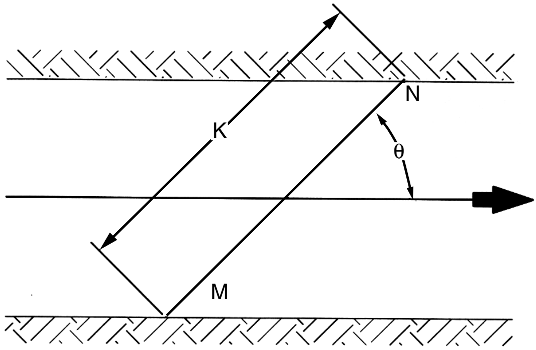


FIGURE U-1 Ultrasonic discharge measurement.

Underground injection The subsurface emplacement of fluids through a bored, drilled, or driven well or a dug well, for which the depth of the dug well is greater than the largest surface dimension (EPA-40CFR260.10). *See also* injection well.

Underground injection control The program under the Safe Drinking Water Act that regulates the use of wells to pump fluids into the ground (EPA-94/04).

Underground source of drinking water An aquifer currently used as a source of drinking water or capable of supplying a public water system. It has a total dissolved solids content of 10,000 mg/l or less and is not an "exempted aquifer" (EPA-94/04).

Underrelaxation In an iterative procedure, the modification of the last value computed for an unknown by weighting it with the value from the previous iteration. *See also* numerical parameters. For the underrelaxation factor or parameter, *see* relaxation factor; in XP-SWMM (Stormwater Management Model), it ensures that the junction convergence criterion is satisfied. *See* sensitivity analysis for the use of underrelaxation parameters in a sewer modeling study.

Undersaturated zone Same as **unsaturated zone**.

Undershoot A response or result that falls short of what is expected or the amount of the deficit. Conversely, for overshoot. In groundwater models, e.g., an undershoot may be a head or a concentration output that is smaller than the actual value. In geographic information system (GIS) procedures, an undershoot is a kind of dangling line that is left too short, creating a gap in the boundary of a polygon.

Undulating jump The hydraulic jump that occurs when the upstream Froude number is between 1 and 2. It is a series of undulations with no appreciable headloss. *See also* breaking-wave jump; Figure H-1.

UNET Acronym for Unsteady-Flow Network Model.

Unified soil classification system (USCS) A classification system for the identification of soils according to their particle size, gradation, plasticity index, and liquid limit.

Uniform flow Flow is uniform when its characteristics (depth, width, velocity, discharge) do not change along the channel or conduit. If one characteristic changes, the flow is varied or nonuniform. *See also* Figure O-2; open-channel flow.

Unit hydrograph (or unitgraph) The hydrograph of 1 in of storm runoff generated by a rainstorm of fairly uniform intensity within a specified period of time (EPA Glossaries). The unit hydrograph method is a procedure developed by L. K. Sherwood in 1932 to derive runoff rates from a watershed by analogy with observed rainfall and hydrographs from the same watershed. It is based on the assumption that, for a given watershed, storms of the same duration will produce runoff hydrographs of equal time bases and with ordinates proportional to the rainfall excess. *See* distribution graph; hydrograph time base. The unit hydrograph method has been applied to small urban watersheds of up to approximately 40 km^2 (McGhee, 1991), and the shape of the hydrograph can be determined from the following equations, based on a 10-min unit time:

$$T_r = 4.1\,L^{0.23}S_o^{-0.25}I^{-0.18}k^{1.57} \tag{U-2}$$

$$T_b = 71.21AQ^{-0.95} \tag{U-3}$$

$$Q = 13.27A^{0.96}T_r^{-1.07} \tag{U-4}$$

$$W_{50} = 12.08A^{0.93}Q^{-0.92} \tag{U-5}$$

$$W_{75} = 7.21A^{0.79}Q^{-0.78} \tag{U-6}$$

where A = watershed area (km^2); I = imperviousness (%); k = conveyance factor (0.6–1.3); L = total distance along main channel (m); Q = peak discharge (m^3/sec per mm net rain); S_o = main channel slope (generally neglecting upper 20% of upstream length); T_b = hydrograph time base (min); T_r = hydrograph rise time, or time to peak (min); W_{50} = width of hydrograph at 50% of Q (min); and W_{75} = width of hydrograph at 75% of Q (min). *See* Equations (P-5) and (P-6), which differ from Equations (U-5) and (U-6); Figure U-2; hydrograph times; instantaneous unit hydrograph; plotting time widths.

Unit hydrograph method A procedure to establish the total runoff hydrograph of a storm in four steps: (a) Determine the rainstorm hyetograph. (b) Determine the rainfall excess over the storm duration by subtracting rainfall losses from the hyetograph. (c) Convert rainfall excess (e.g., inches/hour) into direct runoff (e.g., cubic feet per second). (4) Add baseflow to direct runoff to obtain total runoff over time (e.g., cubic feet per second). *See* Figure U-3.

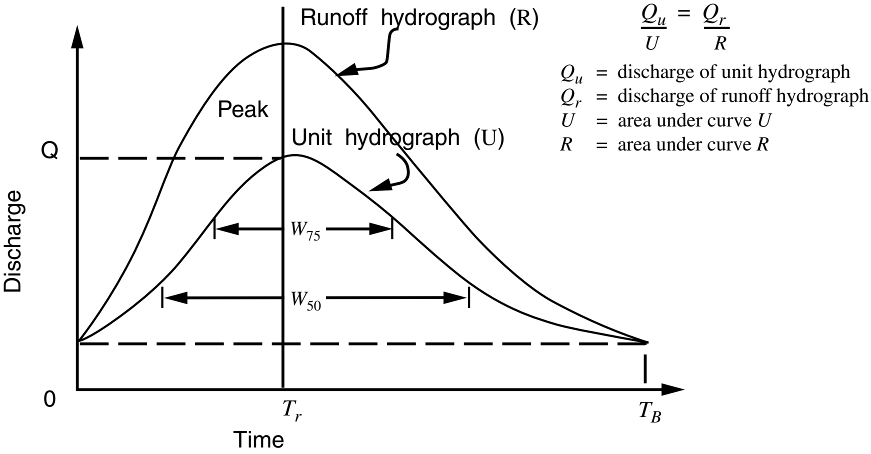


FIGURE U-2 Unit hydrograph method.

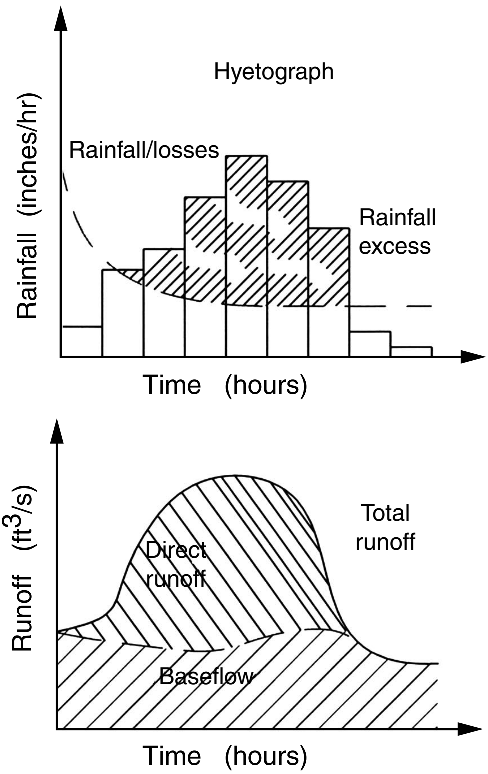


FIGURE U-3 Unit hydrograph from runoff hydrograph.

Unit hydrograph separation The separation of effective rainfall from precipitation losses and the separation of baseflow from surface flow. *See also* hydrograph analysis.

Universal Process Modeling (UPM) An empirical modeling technique that can interpret and evaluate environmental data.

UNIX Trademark used by Bell Laboratories for a general-purpose, time-sharing computer disk operating system.

Unsaturated zone The area between the water table and the ground surface where soil pores are not fully saturated but contain vadose water. Also called **aeration zone** (or **zone of aeration**), **vadose zone**, or **undersaturated zone**. *See* Figure S-14; subsurface water. (Vadose water includes all suspended water in the form of soil, pellicular, gravitational, and capillary water.)

Unsteady flow (or dynamic flow) The opposite of steady flow; that is, a flow with a rate or discharge that changes over time.

Unsteady-Flow Network Model (UNET) A model developed by the Hydraulic Engineering Center to simulate open-channel flow, including levees, bridges, dams, and other hydraulic structures.

Unsteady nonuniform flow Flow with a velocity and discharge that vary with time and position at every point along the channel or conduit.

UPM Abbreviation for Universal Process Modeling.

Upper soil infiltration The water movement between the ground surface and the upper soil storage zone. This water goes to upper soil storage after upper soil evapotranspiration and recharge to groundwater. Also called **surficial soil infiltration**.

Upper zone storage The area below the ground surface where interflow occurs. *See also* unsaturated zone. Other terms used in relation to the unsaturated zone are upper soil storage, upper zone nominal soil storage (SU), and lower zone nominal soil storage (SL). With P as the annual precipitation, the last two terms can be approximated by (James, 1996):

$$SL = 101.6 \text{ mm} + 0.125 \text{ P} \tag{U-7}$$

and

$$SU = 0.08 \text{ SL} \tag{U-8}$$

Upstream face The side of a dam, weir, or similar structure nearer the source of water.

Urban hydrology The application of hydrologic principles to urban or urbanizing areas, particularly for the management of stormwater runoff.

Urban runoff Stormwater from city streets and adjacent domestic or commercial properties that carries pollutants of various kinds into the sewer systems and receiving waters (EPA-94/04).

Urban stormwater model A model, such as a computer program, that simulates the movement and fate of stormwater and pollutants through an urban area in response to hydrological as well as other conditions. Well-known urban stormwater models include SWMM (Stormwater Management Model) Level I, STORM (Storage Treatment Overflow Runoff Model), HSPF (Hydrological Simulation Program – Fortran), and SWMM.

USACE Acronym for U.S. Army Corps of Engineers.

USDA Abbreviation for the U.S. Department of Agriculture, which includes the Natural Resources Conservation Service (formerly the Soil Conservation Service).

USEPA Abbreviation for the U.S. Environmental Protection Agency.

USCS Abbreviation for unified soil classification system.

Useful storage (1) In a reservoir or other impoundment, the volume between the full-pond line and the outlet; i.e., the sum of the active storage and inactive storage. It can be used for all the principal and secondary purposes. Also called **live storage**. *See* reservoir storage; Figure R-2. (2) Same as specific yield for groundwater.

USGS Abbreviation for U.S. Geological Survey.

Utility (1) A business organization, often as a monopoly in its service area, subject to governmental regulation and providing an essential commodity or service to the public, such as drinking water, gas, electricity, drainage, sewerage. (2) A program that improves the performance of other programs, such as an antivirus program in a computer, a program to facilitate file organization or retrieval, or a graphical user interface. Examples of utilities are several programs used to manipulate or display data stored in the Hydraulic Engineering Center Data Storage System (HEC-DSS): DSSUTL, DSPLAY, REPGEN, DSSMATH.

V

Vacuum breaker A device installed in a pipeline to prevent backflow or backsiphonage by relieving a complete or partial vacuum. *See also* air gap; backflow preventer.

Vacuum pump A pump that creates a partial vacuum in a closed container; liquid is forced up by pressure differential. Often used in sludge dewatering, groundwater degasification, and the maintenance of suction lifts.

Vadose water (From the Latin *vadosus*, meaning shallow.) In the undersaturated zone (or aeration zone), vadose water includes all suspended water in the form of soil, pellicular, gravitational, and capillary water. Also called **suspended water**. *See* Figure S-14; subsurface water.

Vadose zone The area between the water table and the ground surface where soil pores are not fully saturated but contain some water. Also called **aeration zone** (or **zone of aeration**), **unsaturated zone**, or **undersaturated zone**. *See* Figure S-14; subsurface water.

Validation *See* calibration.

Value engineering A specialized cost-control technique that uses a systematic and creative approach to identify and to focus on unnecessarily high cost items in a project to arrive at a cost saving without sacrificing the reliability or efficiency of the project. Also, a similar analysis of each contract term or task to ensure that its essential function is provided at the overall lowest cost (EPA-40CFR35.2005-53 and EPA-40CFR35.6015-53).

Valve A device used to regulate the magnitude and direction of fluid flow in machinery and piping systems. It consists essentially of a shell and a movable control element fitted to the shell such that it can open, close, or obstruct ports and passageways. The following types of valve are common in water and wastewater engineering: air, air and vacuum, air relief, automatic, backpressure, ball, blowoff, butterfly, bypass, check, flow control, foot, four way, globe, hydraulic, negative pressure, plug, pressure reducing, pressure regulating, pressure relief, reducing, relief, rotary, safety, stop, throttle, vacuum.

Vapor pressure The pressure of the vapor in equilibrium with a liquid or solid.

Variable-level storage facility In water supply and water distribution systems, a storage facility that accommodates changes in water levels due to inflows or outflows.

Variable source area concept One of three common theories of runoff generation: only the saturated portion of the drainage area contributes runoff; this source area expands at the beginning of a rainstorm and contracts toward the end of the storm. It is also called the **saturation overland**

flow concept or the **dynamic watershed concept**. The other two common theories are Horton overland flow and subsurface stormflow.

Variable-speed pump A pump that is designed to operate at a variable speed and discharge at a rate that varies with the electrical current input. The opposite is a constant-speed pump.

Variance The second moment about the mean of a frequency distribution function. It is the square of the standard deviation (σ^2) and is also used to measure the magnitude of the dispersion in a population or a data set.

Variate An individual value of a variable such as flood or wastewater flow, rainfall depth or intensity, maximum daily temperature, etc.

Variational principle The theory of channel design according to which an alluvial channel adjusts its shape to maximize its sediment transport capacity or to minimize its stream power. Also called **extremal hypothesis**. *See also* channel stability; regime theory; tractive force theory.

Variation coefficient *See* coefficient of variation.

Vee weir Same as **V-notched weir**.

Vegetated filter strip A strip of grass or other erosion-resisting vegetation between or below cultivated strips or fields or separating a waterway (ditch, stream, creek) from an intensive land use (e.g., a farm, a residential or commercial subdivision). Also called **buffer strip**, **filter strip**, and **grassed buffer**.

Vegetative controls Nonpoint source pollution control practices that involve vegetative cover to reduce erosion and minimize loss of pollutants.

Velocity The speed of flow or the ratio of the distance traveled to the time of travel, usually expressed in feet per second (ft/sec) or meters per second (m/sec). Velocity in any channel varies with channel characteristics. For convenience, an **average flow velocity** V at any cross section is defined as the ratio of the discharge Q to the cross-sectional area A. *See* celerity.

Velocity–area method A method for estimating the discharge of an open channel by dividing a cross section into subareas, measuring the velocity and surface area of each subarea, calculating and adding the discharge in each subarea. *See* Martin and McCutcheon (1999).

Velocity–contour method A common method of discharge computation based on the measurement of flow velocity and depth: contours representing velocity distribution in a channel cross section are used to estimate the areas between successive contours and plot velocities versus cumulated area. The area under this curve is the discharge through the cross section. *See also* mean section and midsection methods; velocity–depth integration method.

Velocity–depth integration method A common method of discharge computation based on the measurement of flow velocity and depth: from the measurements of depth and velocity at verticals of a cross section, a plot of the product velocity by depth is drawn versus distance across the section. The area under this curve is the discharge through the cross section. *See also* mean section and midsection methods; velocity–contour methods.

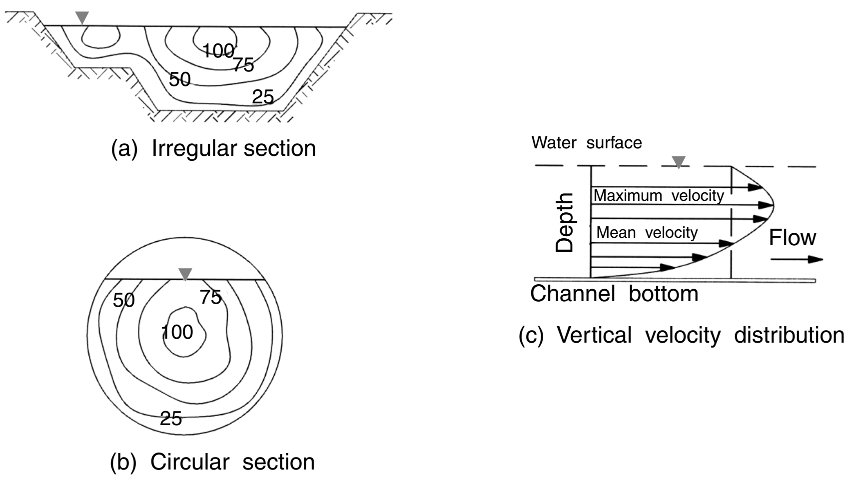


FIGURE V-1 Velocity distribution (contour numbers represent percentages of maximum velocity).

Velocity distribution The variation of flow velocity vertically or laterally across the cross section of an open channel because of the free surface and shear stress at the boundaries. The maximum velocity normally occurs below the free surface. As the energy and momentum equations imply constant velocity, their proper use requires two correcting factors: the energy or Coriolis coefficient α and the momentum or Boussinesq coefficient β. *See* Figure V-1.

Velocity distribution coefficients Two factors that are used to correct the energy and momentum equations so that they can apply to open-channel flow with variable velocity across the cross section and over the depth of flow. *See* Figure V-1. These coefficients, α (energy or Coriolis) and β (momentum or Boussinesq), affect the velocity head or kinetic energy ($V^2/2g$) and the momentum ($\gamma QV/g$), respectively:

$$\alpha = (\sum u^3 \Delta A)/V^3 A \qquad \text{(V-1)}$$

$$\beta = (\sum u^2 \Delta A)/V^2 A \qquad \text{(V-2)}$$

where γ = specific weight of the fluid, V = average velocity = $(\sum \Delta A u)/A$, A = total cross-sectional area, ΔA = elementary area, u = velocity in elementary area, g = gravitational acceleration. The energy coefficient varies approximately from 1.05 for turbulent pipe flow to 2.00 for some rivers. The momentum coefficient varies similarly from 1.02 to 1.35.

Velocity gradient The change in velocity per unit distance along the vertical velocity curve.

Velocity head Term variously defined as (a) head of a moving fluid, (b) kinetic energy in a hydraulic system, (c) the vertical distance through which a body would have to fall under the force of gravity to acquire a given velocity, and (d) the theoretical height that a fluid may be raised by its kinetic energy. The velocity head is calculated as the ratio of the square of the mean velocity V to twice the gravitational acceleration g or $V^2/2g$. It is a factor in several formulas: critical flow or specific energy, Equation (C-35); Darcy–Weisbach, Equation (D-3); dynamic head, Equation (D-19); energy gradeline elevation, Equation (E-5); equivalent pipes, Equation (E-7); weir, Equation (W-6). Velocity head is one of two convenient ways to express headlosses; the other is equivalent pipe lengths.

Velocity potential (Φ) The product of piezometric (or pressure) head H by a constant hydraulic conductivity K through an aquifer:

$$\Phi = KH \tag{V-3}$$

Velocity pressure The kinetic pressure in the direction of flow necessary to cause a fluid at rest to flow at a given velocity. It is usually expressed in inches of water gage (EPA-29CFR1910.94b).

Vena contracta (Latin for contracted vein.) The minimum cross section of the jet stream emerging from an orifice; the reduction of the jet below the orifice diameter is caused by the convergence of the streamlines. *See* Figure O-4.

Venturi A flow-measuring device. A **venturi flume** is an open flume, used to measure flow, with a constriction that causes a drop in the hydraulic gradeline. *See also* Parshall flume. A **venturi meter** is an instrument for measuring fluid flow in closed conduits; consists of a **venturi tube** (a narrowed section tapering to the conduit diameter at each end) and a flow- or pressure-registering device. Velocity increases and pressure decreases in the throat section. Discharge Q is estimated from the pressure head differential Δp indicated by a manometer, the discharge coefficient K, the conduit diameter D, the gravitational acceleration g, the density γ' of the manometer fluid, the density γ of the fluid measured, and the ratio r = D/d of the conduit diameter D to the throat diameter d. *See* Figure V-2. Flow through a venturi meter is similar to flow through an orifice plate, but with a higher discharge coefficient.

Venturi, Giovanni Battista *See* hydraulics.

Verification *See* calibration.

Vertical model Same as **vertical-plane model**.

Vertical-plane model A two-dimensional model integrated over the width of the channel or body of water; i.e., it includes length and depth of flow as variables.

Vertical pump A reciprocating pump with a piston or plunger that moves horizontally or a centrifugal pump with a horizontal shaft.

Vertical turbine pump Same as **deep-well turbine pump**.

Victaulic coupling A device that joins two pipe sections, each with a groove at the end. It includes a rubber ring around the joint and two semicircular bands bolted over the ring.

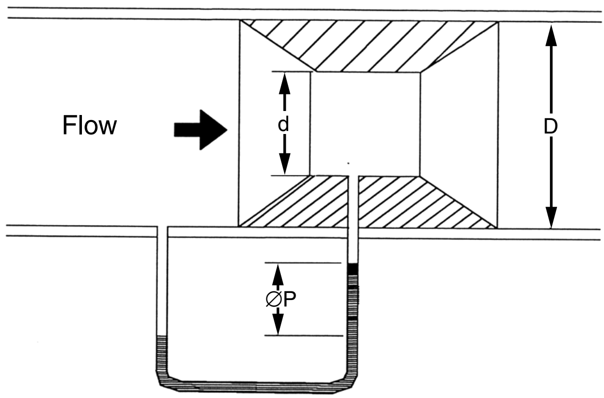


FIGURE V-2 Venturi meter (flow measurement).

Villemonte equation A formula for the discharge Q_s of a submerged weir in terms of the free weir discharge Q, the heads upstream H_u and downstream H_d, and a coefficient a:

$$Q_s = Q[1 - (H_d/H_u)^a]^{0.385} \quad \text{(V-4)}$$

Virtual rain gage (VRG) A weather radar installation developed by WSI Corporation to monitor rainfall by interpreting the image created by rain. The VRG estimates rainfall every 15 min over a 2 km × 2 km pixel, as compared to a 12-in diameter rain gage. *See* Section II for further information.

Viscometer An instrument for measuring fluid viscosity.

Viscosity A measure of the internal friction of a fluid that provides resistance to shear within the fluid. The greater the forces of internal friction (i.e., the greater the viscosity), the less easily the fluid will flow (EPA Glossaries). **Molecular viscosity** (or simply viscosity) is the property of a fluid that makes it resist the tendency to deform or flow under external forces. For water and other Newtonian fluids, Newton's law of viscosity states that the viscous shearing stress τ is the product of the coefficient of viscosity μ by the velocity gradient $\partial V/\partial s$ between the fluid layers:

$$\tau = \mu \cdot \partial V/\partial s \quad \text{(V-5)}$$

where V is the mean velocity, and s the vertical distance. **Absolute viscosity** μ (or **dynamic viscosity**, also called **coefficient of viscosity**) is a measure of internal resistance to flow. **Kinematic viscosity** ν is the ratio of absolute viscosity to the fluid density ρ, i.e.,

$$\nu = \mu/\rho \quad \text{(V-6)}$$

Viscosity is an element of the Reynolds number, which indicates whether flow is laminar or turbulent, and of the hydraulic conductivity formula. Absolute viscosity varies with temperature; e.g., $\mu = 0.0008$ kg/m/sec at 30°C and $\mu = 0.0018$ kg/m/sec at 0°C.

Viscous flow Same as **laminar** flow.

Viscous fluid model A two-dimensional groundwater model based on the analogy with the movement of a viscous fluid, such as glycerin, between two parallel plates. Also called **Hele-Shaw Model** or **parallel-plate model**.

Vitrified clay A heat-treated clay product used to make pipes and bricks.

V-notched weir (or **V-notch weir)** A weir with a V-shaped notch for measuring small flows. Also called **triangular weir**, **triangular-notch weir**, or **Vee weir**.

Void ratio (r_v) The ratio of the volume of voids V_v to the volume of solids V_s of a soil sample; porosity p is the ratio of voids to the total volume:

$$r_v = V_v/V_s = p/(1 - p) \tag{V-7}$$

Volatile solids A volatile substance evaporates readily. In water or wastewater analysis, volatile solids are those that are lost on ignition at 550°C. *See also* fixed solids.

Volumetric moisture content (V_m) The volume of water contained in a soil sample; i.e., the product of the weight of moisture W_m by the bulk density of soil ρ_s divided by the density of water ρ_w:

$$V_m = W_m \rho_s/\rho_w \tag{V-8}$$

Volute pump A centrifugal pump in a spiral casing.

von Kármán, Theodore *See* hydraulics.

von Neumann analysis A commonly used method of determining the stability of a computational algorithm. At each step, errors are expanded as finite Fourier series and tested for decay (stability) or amplification (instability) at the next step.

VRG Abbreviation for virtual rain gauge.

W

Warning stage *See* node, node warning stage.

Washload The portion of the suspended solid load composed of smaller particles than those generally found in the streambed; particles transported without deposition. Also known as **fine sediment load**. *See also* bedload.

Washoff The transport of sediment or other pollutants from ponds, watersheds, etc. during a storm event.

Washout valve A valve used to drain or flush a pipeline. Also called **blowoff valve** or **scour valve**.

Wasteload allocation The maximum load of pollutants each discharger of waste is allowed to release into a particular waterway. Discharge limits are usually required for each specific water quality criterion violated or expected to be violated. The portion of a stream's assimilative capacity assigned to an individual discharge (EPA-94/04).

Waste pipe In general, a pipe that drains liquid waste or excess liquids. In plumbing, it conveys the wastes of a building (from a basin, bath, or sink), other than those from water closets or similar fixtures, to a soil pipe, soil stack, or the house drain. *See also* soil line; soil pipe.

Wastewater (1) The spent or used water from a home, community, farm, or industry that contains dissolved or suspended matter (EPA-94/04). *See also* sewage. (2) Organic hazardous air pollutant-containing water, raw material, intermediate product, byproduct, coproduct, or waste material that exits equipment in a chemical manufacturing process and either (a) contains a total volatile organic hazardous air pollutant concentration of at least 5 ppm by weight and has a flowrate of 0.02 L per minute or greater or (b) contains a total volatile organic hazardous air pollutant concentration of at least 10,000 ppm by weight at any flowrate. Wastewater includes process wastewater and maintenance wastewater (EPA-40CFR63.101).

Wastewater collection system *See* sewer collection system.

Wastewater facilities Sewers, pumping stations, treatment plants. More generally, the structures, equipment, processes required to collect, convey, treat, and dispose of wastewater, including sludge handling and disposal.

Wastewater facilities plans Plans and studies related to the construction of wastewater treatment works necessary to comply with the Clean Water Act or the Resource Conservation and Recovery Act (RCRA). A facilities plan investigates needs and provides information on the cost-effectiveness of alternatives, a recommended plan, an environmental assessment of the recommendations, and descriptions of the treatment works, costs, and a completion schedule (EPA-94/04).

Wastewater flow components The three main contributions to wastewater flow: base wastewater flow (BWWF; sometimes called **return flow**), groundwater infiltration (GWI), and rainfall-dependent infiltration/inflow (RDI/I). The sum of BWWF and GWI makes up dry-weather flow. *See* hydrograph analysis.

Wastewater outfall The outlet or structure of final wastewater disposal.

Wastewater reclamation The recovery of wastewater and its improvement to meet the requirements of the intended reuse. *See also* reclaimed wastewater, reclamation.

Wastewater return rate The ratio of base wastewater flow (BWWF or return flow) to water consumption; usually less than 1.0 because some water used (e.g., for lawn watering and car washing) may not reach the sewers.

Wastewater reuse The use of reclaimed wastewater in such applications as agricultural irrigation, landscape irrigation, industrial cooling, boiler feed, process water, heavy construction, groundwater recharge, streamflow augmentation, fire protection, toilet flushing, etc. *See also* reclaimed wastewater, reclamation.

Waste weir A short section of a canal or open conduit designed with a level crest to allow spilling of excess water. *See also* diverting weir; spillway.

Water balance A mass balance for water in a hydrologic system or in a water supply/wastewater system; i.e., an inventory of all identified water or wastewater quantities entering, leaving, or accumulating in the system or a quantitative analysis of the changes occurring in the system. *See also* groundwater mining; water budget.

Water balance equation A form of the continuity equation that expresses quantitatively the processes of the hydrologic cycle for a given point, boundary, or basin: precipitation, surface and groundwater inflows, evapotranspiration, surface and groundwater outflows, storage changes.

Water budget An average annual water balance, including such components as precipitation, snowmelt and rainfall runoff, evapotranspiration, infiltration, surficial and deeper groundwater recharge. Determination of the water budget requires the quantification of the average volumes of storage and rates of movement among the various components. It uses the storage form of the continuity equation. For example, the surface water budget may be stated as follows: the change in surface water storage is equal to rainfall, plus snowmelt, minus upper soil infiltration, minus surface runoff; all the quantities are expressed in millimeters or inches. Through its RUNOFF and EXTRAN Blocks, the Stormwater Management Model (SWMM) program can be used to study surface water interactions, while MODFLOW allows the evaluation of steady-state groundwater conditions.

WaterCAD® A water distribution modeling program developed by Haestad Methods, Inc., of Waterbury, CT. *See also* extended period simulation; StormCAD.

Watercourse A natural or artificial stream of water, from rivers to rills, including canals, ditches, etc. *See* stream.

Water cycle Movement or exchange of water between the atmosphere and the earth. Also called **hydrologic cycle**. The **hydrogeologic cycle** is similarly defined as the natural process of recycling water from the atmosphere down to (and through) the earth and back to the atmosphere again (EPA-94/04). The water cycle comprises the unending processes that control the distribution and movement of water on the earth's surface, in the soil, and in the atmosphere: evaporation from the oceans and the earth, transport over the land masses, condensation of the water vapor, fog or cloud formation, precipitation as rainfall or snowfall, evapotranspiration, depression storage, infiltration, percolation, ultimate runoff to the oceans, etc. Evaporation and transpiration account for two thirds of the precipitation over land, and runoff to oceans accounts for the remaining third. *See* Figure H-4; rainfall–runoff relationship.

Water equivalent of snow The depth of water resulting from the melting of accumulated snow.

Water hammer The fluctuation in pressure that accompanies a sudden change in velocity. Also the sound like someone hammering on a pipe that occurs when a valve is opened or closed very rapidly. When a valve position is changed quickly, the water pressure in a pipe will increase and decrease back and forth very quickly. This rise and fall in pressure can cause serious damage to the system (EPA Glossaries).

Water-holding capacity The quantity of water retained in soil or rock by capillary forces against the force of gravity after a drop of the water table or after a saturated sample has been allowed to drain. It is the difference between porosity and specific yield. *See* specific retention.

Water horsepower The theoretical power required of a motor to drive a pump, assuming 100% efficiency. *See* horsepower.

Water loss The portion of precipitation that does not become surface or subsurface water, i.e., specifically evapotranspiration.

Water main The water pipe beneath a street from which water is delivered to customers through service lines.

Water meter address matching A procedure used in the estimation and projection of water uses and wastewater flows. With a geographic information system (GIS) program, water meters are referenced to their true location in a street network. Within that program, such operations as the computation of flows by pumping station area can be easily carried out.

Water of adhesion Subsurface water that adheres to soil particles after drainage by gravity. Also called **pellicular water**, it is found between the soil and gravity subzones. It can be absorbed by roots and is subject to evapotranspiration. *See* Figure S-14; subsurface water.

Water phone A device used for finding leakage-causing small cracks or holes in the walls of water or wastewater containers or conduits. The device functions on the principle that a leaking fluid is audible. *See also* leakage detector.

Water pollution The presence in water of enough harmful or objectionable material to damage the water's quality.

Water purveyor An agency or person that supplies water (usually potable water).

Water quality-based limitations Effluent limitations applied to dischargers when mere technology-based limitations would cause violations of water quality standards. Usually applied to dischargers into small streams.

Water quality-based permit A permit with an effluent limit more stringent than one based on technology performance. Such limits may be necessary to protect the designated use of receiving waters (i.e., recreation, irrigation, industry, or water supply).

Water quality criteria Levels of water quality expected to render a body of water suitable for its designated uses. Criteria are based on specific levels of pollutants that would make the water harmful if used for drinking, swimming, farming, fish production, or industrial processes (EPA-94/04).

Water quality-limited segment Any segment for which it is known that water quality does not meet applicable water quality standards or is not expected to meet applicable water quality standards, even after the application of the technology-based effluent limitations required by Sections 301(b) and 306 of the act (EPA-40CFR130-2.j).

Water quality standards Ambient standards for water bodies adopted by a state and approved by the Environmental Protection Agency. The standards prescribe the use of the water body and establish the water quality criteria that must be met to protect designated uses. Water quality standards are to protect the public health or welfare, enhance the quality of water, and serve the purposes of the Clean Water Act.

Water ram A device for lifting water using the impulse of larger masses of water in coordination with the pressure waves created by water hammer. *See* hydraulic ram.

Water reclamation The recovery of wastewaters and stormwaters and their renovation to meet the requirements of the intended use. *See also* reclaimed wastewater, reclamation.

Water resources Potentially useful forms or sources of water as found in the various points of the hydrologic cycle, e.g., clouds, rain, snow, ice, surface water, groundwater, reclaimed or reused water, and seawater. Water resources systems include natural elements (atmosphere, watersheds, channels, wetlands, floodplains, lakes, estuaries, etc.) and constructed facilities (dams, canals, etc.).

Water service connection All the piping and appurtenances required to provide water to a consumer, from the public distribution main to the consumer's system; also called **service line** or sometimes simply **service**, including **service connection** or **service connector**, the pipe that carries water from the main to a curb stop; **service pipe**, the pipeline from the curb stop to the meter; **meter and appurtenances**, such as corporation stop, curb box, and shutoff valve.

Watershed The land area that drains into a stream; an area of land that contributes runoff to a specific delivery point. Large watersheds may be composed of several smaller "subsheds," each of which contributes runoff to different locations that ultimately combine at a common delivery point (EPA Glossaries). A small watershed is sometimes defined as having less than 30 mi^2 or 80 km^2. A divide or ridge topographically defines a watershed. Also called **drainage area**, **drainage basin**, or **river basin**. *See also* catchment. **Watershed divide** is the line that separates one drainage basin from another; it follows the ridges or summits forming the exterior of the drainage basins. Also called **drainage divide** or **topographic divide**. (In British usage, the drainage area, drainage basin, or river basin is called a *catchment*, while the word *watershed* refers to the divide between two catchments.)

Watershed model A basic model to evaluate the rainfall–runoff interactions in a river basin. Through a series of computations, it simulates surface runoff and determines discharge hydrographs at selected sites. HEC-1 from the U.S. Army Corps of Engineers Hydrologic Engineering Center is such a program. It has three main components; the first two produce hydrographs of subbasin runoff and channel and reservoir routing, while the third component combines these two sets of hydrographs. *See also* catchment model.

Watershed yield The portion of precipitation on a drainage basin that can be collected for various uses, including direct runoff and groundwater infiltration. *See also* safe yield.

Water snail A device consisting of a spiral in an inclined cylinder used for raising water by rotating the cylinder. Also called **Archimedes screw**.

Waterspout A pipe or orifice through which water is discharged or by which it is conveyed.

Water supplier One who owns or operates a public water system. *See also* water purveyor.

Water supply augmentation The increase of the quantity or the improvement of the utility of fresh water available by such methods as weather modification (to increase precipitation or reduce evapotranspiration), seawater desalting, urban and agricultural water conservation, wastewater reclamation and reuse, and groundwater storage.

Water supply engineering The branch of civil engineering that deals with the design, construction, and operation of water supply and treatment facilities. *See also* sanitary engineering.

Water supply system The structures, equipment, organization required to collect, treat, store, and distribute potable water from source to consumer.

Water surface profile The longitudinal profile of the water surface (or the hydraulic gradeline) in open-channel flow; defined according to the flow regimes. *See* flow profile.

Water surface profile models Computer models developed separately by the Natural Resource Conservation Service (NRCS) (WSP2) and the U.S. Geological Survey (USGS) in association with the Federal Highway

Administration (WSPRO). Both models use historic data to determine flood frequencies and magnitudes. In addition, WSP2 can perform bridge computations, while WSPRO can also be used for highway design and floodplain mapping.

Water system appurtenances Auxiliary components other than pipes and conduits used in a water distribution system, e.g., valves and fire hydrants.

Water table The level of groundwater; the upper surface of the saturation zone of groundwater above an impermeable layer of soil or rock (through which water cannot move), as in an unconfined aquifer. This level can be near the surface of the ground or far below it. In an unconfined aquifer, the fluid at the water surface is at atmospheric pressure (EPA Glossaries). Also called **groundwater table**. Same as **phreatic surface**.

Water-table aquifer An aquifer containing water that is not under pressure. Its upper boundary (contrary to that of an artesian aquifer) is the water table below the vadose zone. Also called **unconfined aquifer** or **phreatic aquifer**. The water level in a well through a phreatic aquifer is the same as the water table outside the well. *See also* Figure S-14; subsurface water.

Water-table well Same as **phreatic well**.

Water tower A standpipe or tower with a tank for storing water at an adequate pressure for distribution. It provides storage for local distribution where a ground-level reservoir would be inadequate. Also called an **elevated tank**.

Waterway A channel or depression for the passage of water or any body of water — other than the sea — used for transportation.

Water well An excavation for which the intended use is for location, acquisition, development, or artificial recharge of groundwater (excluding sandpoint wells) (EPA-94/04).

Water wheel A vertical wheel turned by the weight of water in containers attached to the rim; it is used to operate machinery. A wheel with buckets for drawing or raising water is also called a water wheel. *See also* overshot wheel.

Waterworks The system of facilities used in the supply, transmission, treatment, storage, and distribution of water to consumers, e.g., pipes, reservoirs, pumps, and appurtenances.

Water year A continuous period of 12 months for recording hydrological and climatic data; e.g., the period October 1 to September 30 selected by the U.S. Geological Survey. *See also* climatic year.

Wave An oscillatory movement, in the form of a moving ridge or swell, that causes the surface of a body of water to rise and fall. *See* Figure W-1; coastal hydraulics. The main characteristics of a wave are **wave amplitude** or **wave height H** (the distance from crest to trough); **wave celerity c** (the ratio of the wave length L to the wave period T), also called **phase velocity**; **wave crest**, the highest point of the moving ridge; **wave frequency 1/T**, the inverse of the wave period; **wavelength L**, the distance from crest to crest; **wave number k**, the ratio of 2 to the wavelength, i.e., $k = 2/L$; **wave period T**, the time interval between the passage of two

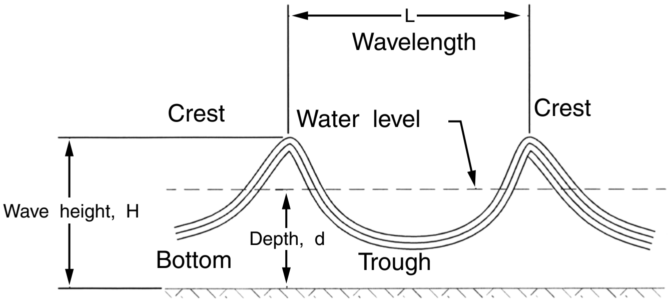


FIGURE W-1 Wave characteristics.

successive crests or two successive troughs by a fixed point; **wave trough** (the lowest point of the moving water); **phase velocity** (same as **wave celerity**). *See also* the following types of wave: abrupt; capillary; flood; gravity; groundwater; long; phreatic; short.

Wave celerity Wave celerity c is often computed as:

$$c = V \pm \sqrt{gy} \quad \text{(W-1)}$$

where g is gravitational acceleration, V is the average velocity, and y is the depth of flow. J.-C. B. de Saint-Venant introduced the term wave celerity in the 19th century. *See also* celerity; Courant number; dynamic wave celerity; gravity wave; kinematic wave equation.

Weather modification *See* cloud, cloud seeding; water supply augmentation.

Weber, Moritz *See* hydraulics.

Weber number (W_e) A dimensionless number equal to the ratio of the inertia force to the surface tension force:

$$W_e = V\sqrt{\rho L / T_s} \quad \text{(W-2)}$$

where ρ is fluid density, V is the mean velocity, L is the length under consideration, and T_s is the surface tension.

Wedge storage Under flood conditions, the storage additional to the steady-flow storage. It is positive in the rising stage and negative in the receding stage of a flood wave. *See also* channel storage; Figure C-2.

Weibull distribution Same as the extreme value distribution type III.

Weibull formula One of three commonly used formulas in frequency analysis to determine the plotting position p of the event of rank i in a series of N events; i.e., where to locate the coordinate of the event on the probability axis:

$$p = 100(i)/(N + 1) \quad \text{(W-3)}$$

See also exceedance series; frequency curve; Hazen formula; median formula.

Weight The gravitational force with which the earth (or another celestial body) attracts an object; equal to the product of the object's mass by the acceleration of gravity.

Weighted four-point method A method used in several hydraulic models for solving the continuity and momentum equations. *See* Martin and McCutcheon (1999).

Weighted residual construction The second and final step to achieve discretization in the finite-element method and obtain algebraic equations as approximations to the governing differential equations of flow. *See also* piecewise interpolation.

Weighted residual method A method that solves differential equations by first assuming an approximate solution and then selecting a sufficiently large number of coefficients or weights to reduce the errors or residuals. Examples are the finite-element and finite-volume methods.

Weighting coefficient (or weighting factor) (1) A coefficient or factor used in numerical modeling to ensure stability of the solutions by determining the exact position between two adjacent timelines. *See* flow weighting; time-weighting factor. (2) A dimensionless constant from 0 to 0.5 used in the Muskingum flood routing method.

Weir (1) A wall or plate placed in an open channel to measure the flow of water. (2) A wall or obstruction used to control flow from settling tanks and clarifiers to ensure a uniform flowrate and avoid short circuits (EPA-94/04). (3) Any natural or man-made regular obstruction over which flow occurs. Typically, while flowing over the weir, water passes from subcritical to critical conditions, and the weir equation describes the relationship between the subcritical depth and the critical flow. The **crest** of the weir is the bottom edge of the opening over which water flows. The **crest height h** is its distance to the bottom of the body of water, and the **crest width** or **length L** is the width or length of the weir. The **nappe** is the overfalling stream of water (from the French term for sheet). The weir **head H** is the height of the pool above the crest and is measured upstream where it is unaffected by curvature of the water surface. *See* Figures W-2 through W-12. Weirs are inexpensive, easy to install, and easy to use, as compared to other means of flow measurement. However, they cause high headlosses, require periodic cleaning, and are not always accurate, particularly when affected by excessive approach velocities and debris. *See* the following types of weir: broad-crested; Cipolletti; clarifier; compound; contracted; crib; Crump; diverting; division; drowned; effluent; flow equalization; free; friction; influent; leaping; log; long based; movable; needle; outlet; overfall; overflow; parabolic; parallel finger; peripheral; proportional; proportional flow; rectangular; Rettger; rolling-up curtain; rounded crest; round nosed; separating; serpentine; sharp crested; shutter; side flow; sliding panel; straight edge; submerged; suppressed; suspended

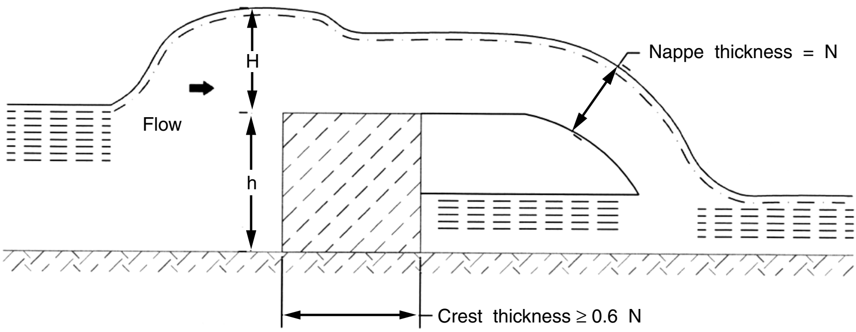


FIGURE W-2 Weir (broad crested).

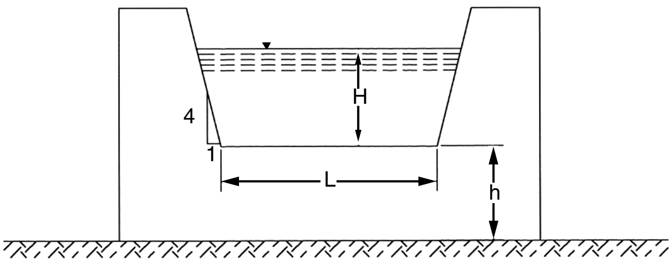


FIGURE W-3 Weir (Cipolletti).

frame; Sutro; thin plate; Thomson; transverse; trapezoidal; triangular notch, triangular; vee; V notched or V notch; waste; wide crested.

Weir diversion A flow transfer mechanism that provides relief to a sanitary sewer system during periods of storm runoff.

Weir equation An equation used to determine the discharge Q over a weir as a function of the weir geometry and the head H above the weir. For example, for a rectangular weir:

$$Q = K(2g)^{1/2}LH^{3/2} \tag{W-4}$$

For a 60° triangular weir:

$$Q = 0.179(2g)^{1/2}H^{5/2} \tag{W-5}$$

where K is a flow coefficient, L is the length of the weir or the width of the channel, g is the acceleration of gravity, and H is the head on the weir. The weir formulas used in the Stormwater Management Model (SWMM) are as follows: In general,

$$Q = KL[(H + V^2/2g)^a - (V^2/2g)^a] \tag{W-6}$$

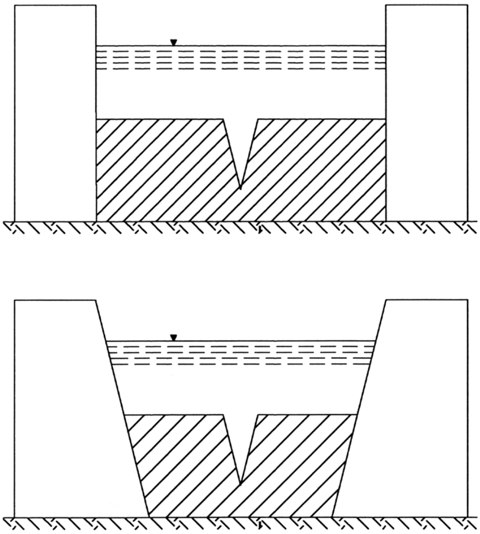


FIGURE W-4 Weir (compound).

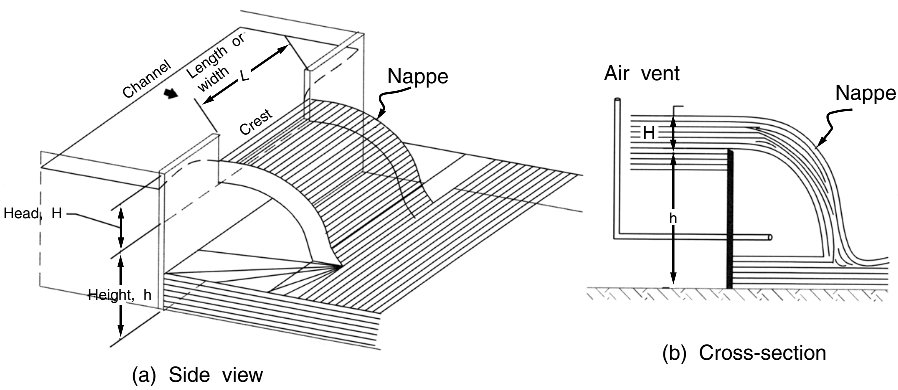


FIGURE W-5 Weir (contracted, rectangular).

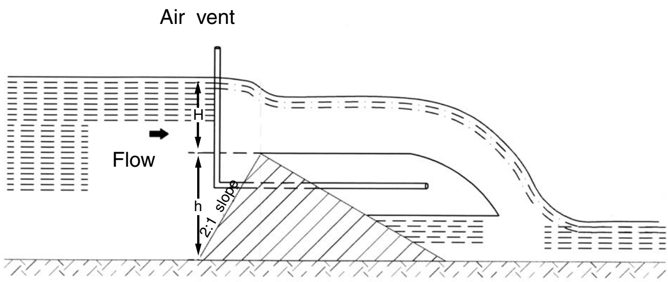


FIGURE W-6 Weir (Crump).

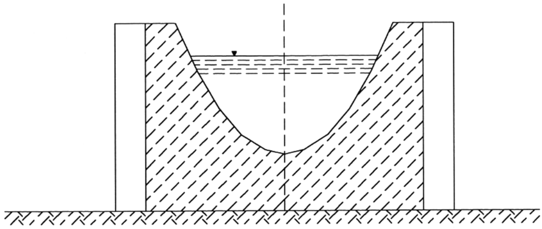


FIGURE W-7 Weir (parabolic).

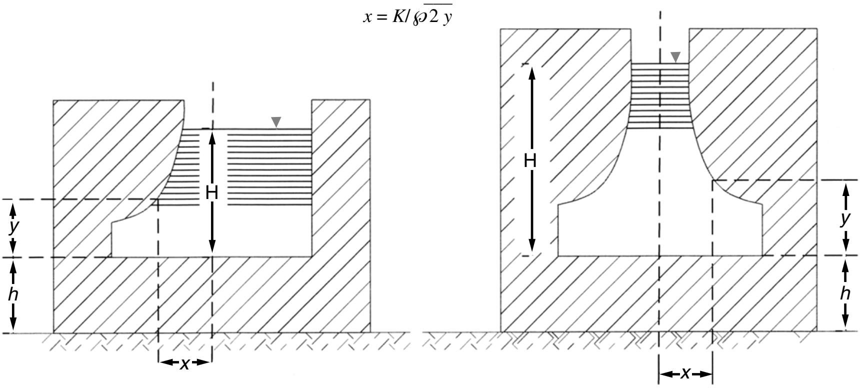


FIGURE W-8 Weir (proportional).

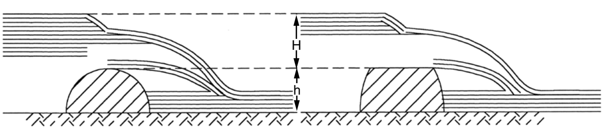


FIGURE W-9 Weir (rounded crest).

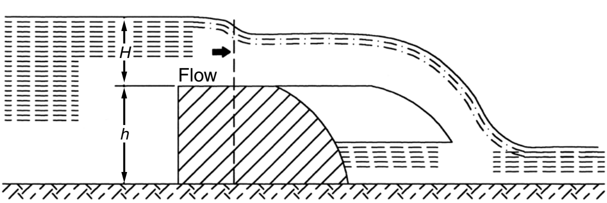


FIGURE W-10 Weir (rounded nose).

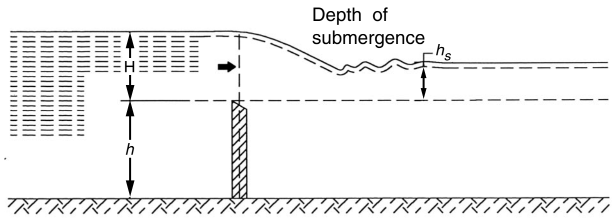


FIGURE W-11 Weir (submerged).

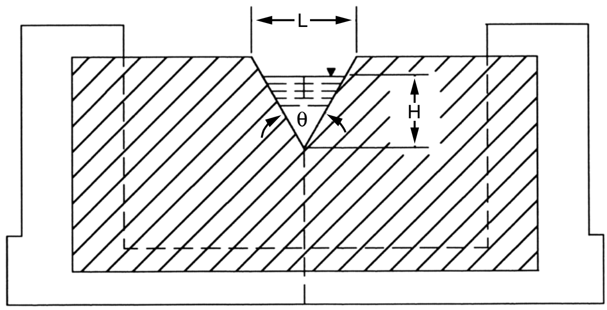


FIGURE W-12 Weir (triangular or V notch).

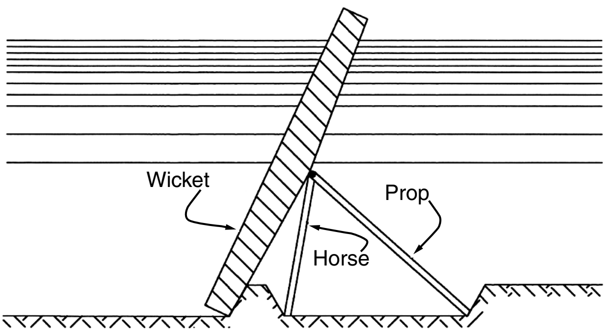


FIGURE W-13 Wicket dam.

For a submerged weir:

$$Q = K'KL(y_1 - y_0)^{3/2} \tag{W-7}$$

For a surcharged weir:

$$Q = K''L(y_3 - y_0)[2g\ \forall(y_2, y_0)]^{1/2} \tag{W-8}$$

where a is the weir exponent (a = 3/2 for a transverse weir, and a = 5/3 for a side-flow weir); K′ is the submergence coefficient; K″ is the weir surcharge coefficient, V is the approach velocity; y_0, y_1, y_2, and y_3 are the height of the weir crest above the node invert, the water depth on the upstream side of the weir, the downstream depth, and the distance to the top of the weir opening, respectively. The term ∀(y2, y0) means the larger of the two depths y_2 and y_0. *See also* Cipolletti weir; discharge coefficient; Francis formula; Thomson weirs.

Weir exponent An exponent used in a weir equation, Equation W-6. **Weir flow** is a flow condition in flow routing problems. *See* combination flow for definition. For **weir head**, *see* weir. **Weir loading** is the ratio of the flowrate from a basin or tank to the length of weir, for example, and is expressed in gallons per day per foot, an important parameter used in clarifier design. Also called **weir overflow rate**. For **weir nappe**, *see* weir. A **weir splitter box** is a device used in wastewater sludge handling to minimize fluctuations in digester feed rates. The **weir surcharge coefficient** is a coefficient that modifies the orifice equation for application to a surcharged weir.

Weisbach, Julius *See* hydraulics.

Well A bored, drilled, or driven shaft or a dug hole (generally of a cylindrical form), often walled with bricks or tubing to prevent the earth from caving in; its depth is greater than the largest surface dimension, and its purpose is to reach underground water supplies or oil or to store or bury fluids below ground (EPA-94/04 and EPA-40CFR260.10).

Well core A sample of the rocks penetrated in a well or borehole.

Wellfield Area containing one or more wells that produce usable amounts of water or oil.

Well flow equations Two equations proposed for the study of steady groundwater flow that is confined, or unconfined, called the Theim and Dupuit equations, respectively. They apply Darcy's law to fully penetrating wells through aquifers of infinite extent. They also assume horizontal flow (i.e., horizontal streamlines and vertical equipotentials) and a flow velocity proportional to the tangent instead of the sine of the hydraulic gradient (i.e., hydraulic gradient = slope of water table). These assumptions are not always valid, but the well flow equations are widely used to assess an aquifer's hydraulic characteristics from field test results or to determine discharge when the hydraulic conductivity is known. *See* Figures D-8 and T-1.

Wellhead The top of a well.

Wellhead protection area A protected surface and subsurface zone surrounding a well or wellfield supplying a public water system to keep contaminants from reaching the well water (EPA-94/04).

Well injection The subsurface emplacement of fluids or disposal of liquid wastes through a bored, drilled, or driven well or through a dug well with a depth that is greater than the largest surface dimension (EPA-40CFR144.3 and EPA-40CFR165.1-aa). *See also* underground injection.

Well log *See* borehole log.

Well monitoring The measurement, by on-site instruments or laboratory methods, of the quality of water in a well.

Well plug A watertight and gastight seal installed in a borehole or well to prevent the movement of fluids.

Well stimulation In deep well injection, it is the use of such processes as surging, jetting, blasting, acidizing, or hydraulic fracturing to clean a well bore, enlarge channels, and increase pore space in the interval to be injected, thus making it possible for wastewater to move readily into the formation (EPA-40CFR146.3).

Wet accumulation rate *See* wet rate.

Wet basin (or pond) A basin (or pond) designed to maintain a permanent pool of water and a working volume to temporarily store stormwater under quiescent conditions. It then releases water slowly over a few days, providing moderately high pollutant removal and attenuation of peak storm flows. **Retention tanks** are similar, but without the permanent pool. *See also* dry detention; stormwater retention.

Wetlands Areas that are saturated by surface or groundwater with vegetation adapted for life under those soil conditions, such as swamps, bogs, fens, marshes, and estuaries (EPA-94/04).

Wet pond *See* wet basin.

Wet rate The rate of solids accumulation during a storm event, expressed in pounds per paved acre per inch rainfall or pounds per curb mile per inch rainfall. *See also* dry accumulation rate.

Wet retention basins (or ponds) Same as **wet basin** (or **pond**). **Wet retention storage** is storage of stormwater in a wet retention structure.

Wet season The period of the year when atmospheric precipitation is more intense than average. For example, the wet season in southeastern Florida is May through October, when two thirds of the annual precipitation of 60 inches falls.

Wet settling basins (or ponds) Same as **wet basin** (or **pond**).

Wetted perimeter The length of the wetted contact between a flowing fluid and its channel; measured perpendicular to the direction of flow and used in the computation of hydraulic radius. *See* open-channel flow for the wetted perimeters of some particular cross sections.

Wetting front The interface between the wet and dry soils in the Green–Ampt equation, Equation G-7.

Wet-weather flow The average or peak flow during the wet season or as a result of rainfall. In wastewater systems, wet-weather flow includes dry-weather flow, infiltration, and inflow.

Wetwell A compartment or chamber in which water or wastewater is collected and to which the suction pipe of a pump is connected. Also called **inlet well**.

Wharf *See* jetty.

Wholesale customer A wastewater customer that pays for sewer service on a wholesale basis; i.e., usually a large user that pays at a rate lower than the retail rate. *See* Section II for further information.

Wicket dam A movable dam that consists of a wicket (a wooden or steel shutter) held against the water load by a hinged prop and horse. *See* Figure W-13.

A **wicket gate** is one of the four basic parts of reaction hydraulic turbines, such as the Francis and the Kaplan turbines. The other parts are the scroll case, the draft tube, and the runner. The wicket gates open or close to control the flowrate of water to the turbine in response to the power demand.

Wide-crested weir *See* broad-crested weir.

Williams, Gardner S. *See* hydraulics.

Wilting point The minimum quantity of water in a given soil necessary to maintain plant growth. Below the wilting point, the leaves begin to drop and shrivel.

Windmill A machine driven by wind energy acting on a number of vanes; used for such operations as pumping water or grinding. A **wind pump** is driven by a windmill, which rotates the pump's multiple-blade propeller.

Wingwall Extension of the headwall of a dam or a culvert; intended to direct and confine flow.

Wire-to-wire efficiency The efficiency of a pump and motor together.

Wire-weight gage A stream-gaging device that uses a weight suspended on a wire lowered to the water surface from a point of known elevation.

Within-year storage Storage designed to compensate for deficits in a dry season by holding excess water in a wet season. Also called **seasonal**, as opposed to carryover, **storage**.

Working volume Same as **active storage**. *See* Figure R-2; reservoir storage.

Workover fluids Salt solutions, weighted brines, polymers, or other specialty additives used in a producing well to allow for maintenance, repair, or abandonment procedures (EPA-40CFR435.11-z).

WSP2 Abbreviation for the water surface profile model of the Natural Resource Conservation Service (NRCS).

WSPRO Abbreviation for the water surface profile model of the U.S. Geological Survey.

Wye A pipe branching off a straight main run at an angle of 45°.

X — Y — Z

XP-SWMM A computer program used for free-surface modeling, gravity system modeling, and flow networks. It is an adaptation of the Stormwater Management Model (SWMM) by XP Software, Inc., of Portland, OR. XP-SWMM contains two layers for stormwater simulation (RUNOFF for surface water runoff and EXTRAN for channel, pump, weir, and conduit routing); two layers for sanitary sewer simulation (TRANSPORT for dry-weather inflow and EXTRAN); and three layers for combined sewer simulation (RUNOFF, TRANSPORT, and EXTRAN). XP Software added many enhancements and error corrections to the 1989 release of the Environmental Protection Agency's (EPA's) SWMM 4.0. *See* Section II for further information.

Xtools Sample Extension In a geographic information system (GIS), an add-on to ArcView version 3.0a for overlay functionalities such as the identity command.

Yalin–Einstein equation In stormwater quality models (such as SIMPTM), a formula used to simulate the capacity of a channel or conduit to transport suspended sediment loads. *See also* Foster–Meyer equation.

Y branch Same as **wye**.

Yield The quantity of water (expressed as a flowrate or total volume per year) that can be collected for a given use from surface or groundwater sources (EPA-94/04). *See also* safe yield; watershed yield.

Zero-dimensional model Same as **mass–balance model**. *See also* flow model.

Zhukovsky, Nicolai Egorovich *See* hydraulics.

ZID Abbreviation for zone of initial dilution.

Zone of aeration The comparatively dry soil or rock located between the ground surface and the top of the water table (EPA-94/04). Also called **vadose zone**. *See* Figure S-14; subsurface water.

Zone of influence The land area within the horizontal projection of the cones of depression of the wells in a wellfield; corresponds to the area of influence for a single well.

Zone of initial dilution (ZID) The region of initial mixing surrounding or adjacent to the end of the outfall pipe or diffuser ports, provided that the ZID may not be larger than allowed by mixing zone restrictions in applicable water quality standards (EPA-40CFR125.58-w).

Zone of saturation *See* saturation zone.

Section II

Examples of Computational Hydraulics Applications

These examples are presented to illustrate the application of some of the concepts defined in Section I. They are drawn from the following engineering reports, as listed in Section IV: Adrien et al. (1999); Post, Buckley, Schuh, and Jernigan (September 1996, April 1998, July 1998, October 1998).

Advanced Interconnected Pond Routing (AdICPR) This hydrodynamic model, along with the Soil Conservation Service (SCS) hydrograph method, was used in the surface water management plan for the Miami–Dade County Homestead Regional Airport and the drainage design report for Broward County Aviation Department.

Analytical parameters, analytical variables The Volume Sewer Customers (VSC) modeling study tested four n and five k values and recommended a default value of n = 0.012, but the default value for k would vary with the pump station layout.

ArcInfo and ArcView In these sewer system modeling studies, ArcInfo and ArcView were used in creating geographic information system (GIS) maps of pump station service areas.

AutoCAD® For the Volume Sewer Customers (VSC) collection and transmission system model, hard copy sewer atlases provided by the municipalities were scanned and converted to AutoCAD. A macroroutine was inserted into the files to determine pipe lengths and depths so that the gravity pipe and manhole data could subsequently serve to determine stage–storage relationships.

Best management practice (BMP) The Homestead Regional Airport study recommended broad-crested control weirs and French drains as BMPs.

Boundary condition The Volume Sewer Customers (VSC) modeling study used as boundary conditions the pressures at the points of connection of the local sewer systems to the regional sewer system. Flows and pressures were monitored at these points.

Calibration In a recent sewer modeling study, **hydraulic calibration** was defined as the adjustment to the properties of nodes and links best representing the system conduits, manholes, and valving options and to other pump-related hydraulic properties. **Hydrologic calibration** was defined as the adjustment of model input hydrographs in accordance with climactic conditions best representing a typical dry day of a dry period. The results of the calibration process showed a hydrologic difference of 3% and a hydraulic difference of 0.4% between simulated and observed values.

Clean hydrograph In the Volume Sewer Customers (VSC) modeling study, processing criteria were established to filter unusable data automatically: (a) minimum and maximum water-level settings to eliminate negative readings and surcharged pipe data; (b) minimum and maximum velocities to eliminate readings due to surcharge conditions or malfunctioning meters; and (c) visual examination of scatter plots to eliminate obviously erroneous data points.

Computerized sewer collection and transmission system model In some recent modeling studies, the consultant evaluated the following computerized models for use in the Miami–Dade Water and Sewer service area: CalcFlow, CASS Works, CivilSoft, Cybernet, ExpertWare, Kentucky Pipe Model, Stoner Work Station, SWRMDL, WaterWorks for AutoCAD, and XP-SWMM (Stormwater Management Model).

Consent decree The Environmental Protection Agency (EPA) Second and Partial Consent Decree required the Volume Sewer Customers (VSC) and county sewer modeling studies. The decree alleged that the wastewater management operations of the county posed a danger to human health and required the county, among a number of improvements, to install and maintain a computerized collection and transmission model.

Convergence In the Volume Sewer Customers (VSC) modeling study, convergence was the principal objective of the sensitivity analysis conducted for the selection of analytical and numerical parameters.

Conveyance system mapping In these modeling studies, the sewer systems were mapped to obtain (a) a digital layout of the pump stations, force mains, and major gravity lines and (b) a digital map of the gravity collection systems to calculate the stage–storage relationship for input to the model.

Courant number (C_n) To run applications of the Stormwater Management Model (SWMM), the consultant selected a Courant timestep Δt as follows: For closed conduits:

$$\Delta t = \Delta x/\{1\}V + \sqrt{gy}$$

For open conduits:

$$\Delta t = \Delta x/\{1\}V + \sqrt{gA / W}$$

where V is the average conduit velocity, y is the conduit depth, g is the gravitational acceleration, W is the width of the conduit, and A is the conduit cross-sectional area.

Coverage The Volume Sewer Customers (VSC) modeling study used coverages and shapefiles for land use, traffic analysis zone, municipal boundary, street network, pump station area, gravity line, force main, pump station, and manhole layers.

Cybernet® In the Volume Sewer Customers (VSC) model study, the consultant used Cybernet as a quality control tool for the main model, the XP-SWMM (Stormwater Management Model), and to estimate peak manifold system conditions with all pumps in the system running. Input consisted of data provided by or collected from the VSCs. Individual VSC sewer atlases were digitized into AutoCAD computer files and then referenced into the model of each VSC to construct pipes and nodes on top of the existing drawing to scale. Use of Cybernet required the determination of default system settings as follows: pipe friction formula and constant = Hazen–Williams; kinematic viscosity = 1.06E-005 (or 0.0000106); flow unit gal/min; maximum number of trials dependent on run; relative accuracy dependent on run; specific gravity of the fluid = 1.00. The VSCs or equipment manufacturers provided the pump curves. The consultant collected wetwell elevations in the field and assumed junction elevations at 5.0 ft above mean sea level (MSL).

Database The Volume Sewer Customers (VSC) modeling study used Microsoft Access® to perform the data management tasks. Due to the magnitude and complexity of the project, traditional data-processing tools like spreadsheets were inadequate to perform the data compilation and analysis. The model development required planning and creation of extensive databases to handle the input–output (I/O) operations for the model. The consultant developed several databases in Access®, which proved to be a powerful, but relatively simple-to-use, tool. These databases served as pre- and postprocessors for the VSC model. They include the following: (a) hydrograph generation database, which is a set of tables that translates the hydrograph development process into sequential queries and creates the hydrograph import files; (b) pump dimensions/pump curves database, which is another set of tables to aid in pump station data import, for which the pump import file includes the pump name, pump discharge–dynamic head relationship (pump curve), pump station on/off elevations, number of pumps per station, and initial wetwell depth; (c) minor losses (K-factors) database, which was designed to compute the overall minor loss coefficient for each of the 350 pump stations in the model; and (d) pump stage–storage database, which was designed to generate the stage–storage input in four steps.

Debugging In the Volume Sewer Customers (VSC) modeling study, after the data check of the XP-SWMM (Stormwater Management Model), the consultant used the output file for model debugging, placing a particular emphasis on (a) input data such as pipe lengths, Manning's coefficients, pipe diameters, manhole types, manhole elevations, ground and invert elevations, stage–area relationships, and pump station piping; (b) model results or parameters such as timesteps, junction convergence, overall efficiency, junction surcharges, velocities, pressures, pump runtimes, outflows, overall and continuity errors; (c) model details indicative of model size. Overall, the VSC model includes 24 outfalls, 350 pump stations, 735 pumps, 1263 nodes, 903 pipes, and 1259 links.

Direct service area In Miami–Dade County, Florida, the Water and Sewer Department (MDWASD) provides complete service to part of the county, while some municipalities, as Volume Sewer Customers (VSC), provide only collection service. MDWASD's direct service area comprises the city of Miami, some other municipalities, and the unincorporated areas. In the VSC study, the consultant established sewer collection system models for the direct service area and each of the 16 VSCs separately and then integrated all the individual models into an overall county model.

Flo-Tote To generate input hydrographs, the consultant monitored 295 of the 350 Volume Sewer Customers (VSC) pump stations using Flo-Tote meters. (The other 55 stations could not be monitored because of low flows, surcharge conditions, or manual operation.) The open-channel sensor portion of the meter uses an electromagnetic velocity transducer to measure the velocity of the water moving through the pipe and a solid-state pressure transducer to measure the level. The open-channel sensor is secured in the pipe by a sensor-mounting band. Flow data are stored in the Flo-Tote computer mounted under the wetwell, manhole cover, or hatch.

Flo-Ware The Volume Sewer Customers (VSC) modeling study used the plots and graphs generated by Flo-Ware for comparison with scatter plots as well as dry-weather hydrographs from raw data.

Flow calibration The Volume Sewer Customers (VSC) modeling study used monitored data from pump station areas and transmission stations at points of connection to obtain a flow balance between the regional system and the tributary municipalities.

Geographic information system (GIS) In one of the modeling projects, the consultant used ArcInfo and ArcView, both developed by the Environmental Systems Research Institute, Redlands, California. The advantages of using GIS in addition to AutoCAD maps are twofold. First, by overlaying the pump station area boundaries on the gravity elements of the conveyance system, the stage–storage relationship can be derived. Second, with the overlay and spatial query capabilities of GIS, inventories of all elements of the sewer system can easily be generated.

Hydraulic modeling (or computational hydraulics) Since 1995, a consulting firm has been assisting the Miami–Dade Water and Sewer Department (MDWASD) in the development, implementation, and updating of a virtual dynamic computer model to predict pressures, flows, and total wastewater volume in MDWASD's collection and transmission system. The model uses the Stormwater Management Model (SWMM) program developed by XP Software, Inc., and various technologies such as WSI's NEXRAD Weather for Windows and Virtual Rain Gauge, global positioning systems (GPSs), geographic information systems (GISs), supervisory control and data acquisition systems (SCADAs), and infrastructure databases. The model was developed first for the direct service area of Miami–Dade County, which encompasses approximately 1000 pump stations, and then for the 16 volume sewer customers with a total of 350 pump stations. Finally, the 17 models were integrated into one big model of the regional sewer system.

Hydrograph analysis In two wastewater collection modeling studies, a consultant used hydrograph decomposition for a wet-weather day. The base wastewater flow exhibited a typical diurnal variation, with peaks occurring between 6:00 and 9:00 a.m. and minimum flows occurring at night.

Infiltration/inflow (I/I) ordinance An ordinance of Miami–Dade County, Florida (Metropolitan Dade County Ordinance 96-166), also known as the Volume Sewer Customers (VSC) ordinance. It requires all publicly owned or operated sanitary sewer collection systems of the county to participate in a computerized model to optimize transmission capacity and to facilitate the evaluation of the impact of I/I rehabilitation programs.

Minor loss coefficient or k-factor In a sewer modeling project, a consultant designed a k-factor database to compute the overall minor loss coefficient k_{eq} for each of the 350 pump stations. The relevant data for computing the k-factors were collected and stored in a pump dimension database. Individual factors used to calculate the overall factor ranged from 0.05 for a cone valve or an 11° elbow, to 0.90 for a side-outlet elbow, and to 2.50 for a fully open check valve.

Model maintenance For the Miami–Dade County, Florida, wastewater collection model, a consultant recently recommended two levels of maintenance, standard maintenance (monthly or quarterly) and emergency maintenance, to handle major operations such as flow transfers, pipeline closures, and reroutes. The duties of the model maintenance staff would include (a) updating the piping database; (b) updating the pump curves, dimensions, and other elements of the pump station database; (c) updating the sewer system database (valves, connections, pipe fittings, operational changes, flows, pressures, supervisory control and data acquisition system [SCADA] calibration, dry-weather hydrographs, wet-weather hydrographs); (d) maintaining the rain gage and virtual rain gage data; (e) updating the stage–storage database; (f) performing ongoing model verification and calibration.

Model size For the Miami–Dade (FL) modeling assignments, a consultant ordered the Stormwater Management Model (SWMM) for 5000 pipes.

Model Turbo View EXTRAN (MTVE) For use in the Miami–Dade (FL) wastewater system modeling by a consultant, the XP-SWMM (Stormwater Management Model) was made compatible with MTVE. Because of the size of Miami–Dade's system, viewing results of the system in a clear and concise manner is necessary for checking output. MTVE is an effective tool in analyzing the network once the model run is completed because it graphically shows pressures and flows in pipes and nodes at each iteration. It is also helpful in locating problem areas in a large network for further analysis.

Next-generation radar (NEXRAD) In sanitary sewer modeling studies for Miami–Dade County, Florida, a consultant used two NEXRAD sites as virtual rain gages (VRGs) to estimate rainfall quantities and intensities every 15 min across the entire service area. The VRG data are continuously adjusted by comparison with actual ground gages and are processed for calibration of influent hydrographs at local pumping stations.

Numerical parameters In the Volume Sewer Customers (VSC) model study, the consultant tested a range of values for the numerical parameters and recommended the following: (a) time-weighting factor $\theta = 0.75$; (b) underrelaxation parameter $\omega = 0.85$; (c) flow tolerance $\varphi = 0.01$; (d) head tolerance $\phi = 0.005$; (e) timestep $\Delta t = 5$ sec.

Project approach report For the Miami–Dade County, Florida, the Water and Sewer Department (MDWASD) model required under an Environmental Protection Agency (EPA) consent decree, the Model Project Approach Report included: (a) model's name, type, specific attributes, characteristics, and limitations; (b) base algorithms for each major computational function; (c) identification of all input parameters, constants, assumed values, and expected outputs; (d) computer hardware and personnel to develop and run the model.

Rainfall-dependent infiltration/inflow (RDII) development In two sewer modeling studies for Miami–Dade County and 16 municipalities in Florida, the consultant used the following procedure (see Figures R-1 and R-3): (a) Install several long-term flowmeters at the main wastewater pumping stations and group them to correspond to 12 rain gages. (b) Identify significant storm events from the rain gage data. (c) Plot the wastewater flows for each significant storm event, including pre- and poststorm flows, and determine the storm's RDII for each meter (Figures R-1b and R-3). (d) For each meter, plot RDII volume versus rainfall for several storms and establish an RDII–rainfall relationship. (e) Derive RDII flows for selected storm events and monitored pumping stations and prorate the RDII response to upstream stations on an appropriate basis, such as sewer length or drainage area.

Scatter diagram, scattergraph, scatter plot For the Volume Sewer Customers (VSC) model, the consultant monitored approximately 300 pump stations, created scatter plots of water level versus flow velocity for each meter, and used these plots to filter the data by eliminating any obviously erroneous or inconsistent points. The result was a set of "clean" dry-weather hydrographs for use as input to the model.

Sensitivity analysis In the Miami–Dade County, Florida, the Water and Sewer Department (MDWASD) and Volume Sewer Customers (VSC) modeling studies, a consultant tested model stability and model efficiency for sensitivity to analytical and numerical parameters: (a) Model continuity and runtime improved with increasing values of the underrelaxation parameter ω from 0.60 to 0.85. Continuity improved by 4%, and model runtime decreased by 2 min. (b) Variations of the time-weighting factor θ from 0.55 to 0.85 did not produce any significant changes, but the combinations ($\theta = 0.60$, $\omega = 0.85$ and $\theta = 0.75$, $\omega = 0.85$) yielded the best results in terms of continuity, convergence, and efficiency for the gravity systems and manifold systems, respectively. (c) Between the flow and head tolerance combinations of (0.001, 0.001) and (0.005, 0.005), the continuity error increased by 5.8%. (d) Between timesteps Δt of 5 and 45 sec, the continuity error increased by 12% for a gravity system, and junction convergence decreased for a manifold system. (e) Between −10 and 30% of the default value of the Manning's roughness coefficient n total pump runtime increased by an average of 1.6 h per day, and the average of all junction hydraulic gradeline (HGL) elevations increased by 5 ft. (f) Between −50 and +20% of the default value of the minor loss coefficient or k-factor (depending on the pump station layout) of the pump runtime increased by 0.6 h per pump per day, but there was no significant change in pressure.

Shapefile In the Volume Sewer Customers (VSC) modeling study, a consultant used coverages and shapefiles for land use, traffic analysis zone, municipal boundary, street network, pump station area, gravity line, force main, pump station, and manhole layers.

Stage–storage relationship In a computerized model of a wastewater collection system, a consultant used a stepwise linear depth–volume relationship to represent storage in the sewer collection system and pump station wetwells. The purpose of this procedure is to determine the inline storage capacity of the collection systems upstream of the pumping stations for use in attenuating peak flows and for providing a more stable operation of the stations. Figure S-11 schematically presents the generation of the pump station stage–storage curve. This procedure was repeated for all pump stations with gravity collection systems. Once defined, the stage–storage curve was input into the XP-SWMM (Stormwater Management Model) at the pump station wetwell nodes. A wetwell node represents the available collection system storage upstream of the pump station corresponding to the depth in the wetwell. As the wastewater level in the wetwell rises in response to a storm event, the influent sewer pipe is submerged, and the wastewater levels in the upstream gravity collection system begin to rise. The collection system stores the wastewater until the system pumps the flow out, and wastewater levels in the wetwell drop.

The storage provided by the sewer lines and manholes attenuates the peak flows to the wetwell and helps prevent a wetwell overflow.

Stormwater management model (SWMM) The virtual dynamic computer model adaptation of SWMM was used recently to predict potential sanitary sewer overflows resulting from peak flows in the sewer systems of the Miami–Dade Water and Sewer Department and its 16 Volume Sewer Customers. The combined regional system has a total of approximately 1300 pump stations and 3700 miles of sewer. For more details about this experience, see Walch et al. (1998) and the following terms in this section: analytical parameters, ArcInfo, AutoCAD, base model, boundary condition, calibration, clean hydrograph, computerized sewer collection and transmission model, conduit connectivity table, consent decree, convergence, conveyance system mapping, Courant number, coverage, Cybernet, database, debugging, direct service area, diurnal hydrograph, Flo-Tote, Flo-Ware, flow calibration, geographic information system, hydraulic modeling, hydrograph analysis, Microsoft Access, minor losses, model maintenance, model size, model Turbo View EXTRAN, numerical parameters, project approach report, scatter diagram, sensitivity analysis, Shapefile, stage–storage, supervisory control and data acquisition, surcharge condition, synthetic/synthesized hydrograph, time–stage, timestep, time-weighting factor, underrelaxation, virtual rain gage, water meter address matching, wet-weather flow, XP-SWMM.

Supervisory control and data acquisition (SCADA) SCADA data (mainly pump station runtime hours and operating pressures) were used in the calibration and verification of Miami–Dade County, Florida, the Water and Sewer Department's (MDWASD's) virtual dynamic model.

Surcharged pump station In the Volume Sewer Customers (VSC) sewer modeling study, a consultant monitored 350 pump stations and found that some stations were surcharged temporarily, and other stations were surcharged all the time. The flow-monitoring data obtained under surcharge are not useful because it is no longer an open-channel flow; the flow is restricted and subject to fluctuations based on the changing levels due to pump operation. The consultant developed synthetic hydrographs for surcharged stations.

Synthetic/synthesized hydrograph In the Volume Sewer Customers (VSC) sewer modeling study, a consultant could not establish a valid hydrograph based on field-monitored data for 55 of 350 pump stations because either they had very low flows or they operated under surcharge conditions. To develop synthetic hydrographs for these stations, the consultant used the average return flow estimate Q_r for a given (unknown) pump station area and a known hydrograph from a neighboring pump station area with similar land use characteristics:

$$Q_t = q_t \cdot Q_r / q_r$$

where t = time, Q_t = unknown flow at time t (gal/min or million gal/day), q_t = known flow at time t (gal/min or million gal/day), Q_r = return flow estimate for unknown pump station area (gal/day or million gal/day), q_r = return flow estimate for known pump station area (gal/day or million gal/day).

Time of concentration (t_c) In two recent stormwater management studies, a consultant used two approaches to estimate the time of concentration: (a) the Soil Conservation Service (SCS) Technical Release Number 55 (TR-55) overland flow method and (b) the time of travel in the conveyance system based on an average velocity of 2.0 ft/sec plus 10 min to reach the inlet. The TR-55 formula is:

$$t_c = (L_p/V_p + L_i/V_i + L/V)/60$$

where t_c = time of concentration (min); L = channel length (ft); L_i = impervious travel length (ft); L_p = pervious channel length (ft); V = channel/surface velocity = 1.5 ft/sec; V_i = impervious velocity = $20.3282(S_i)^{1/2}$ (ft/sec); V_p = pervious velocity = $16.1345(S_p)^{1/2}$ (ft/sec); S_i = impervious slope (ft/ft); and S_p = pervious slope (ft/ft). Time of concentration is one of a few parameters used in runoff analysis. Other parameters include antecedent precipitation index (API), attenuation constant, lag time, peak flow, plotting time width, standard duration of rainfall, time base.

Time-stage relationship In a recent wastewater collection modeling study, a consultant derived a boundary condition as a time-stage relationship developed from pressure data.

Timestep (Δt) In the Miami–Dade County, Florida, the Water and Sewer Department (MDWASD) and Volume Sewer Customers (VSC) conveyance system modeling studies using the Stormwater Management Model (SWMM), the consultant tested timesteps varying from 5 to 45 sec. The consultant determined that it is best to specify a timestep equal to the average computed in the EXTRAN iteration summary table.

Time-weighting factor (θ) See **Preissmann scheme** for a recommended range of time-weighting factors and sensitivity analysis for the use of weighting factors in the Volume Sewer Customers (VSC) modeling. See also **numerical parameters**.

Trunk sewer In a sewer system modeling study for the Miami–Dade Water and Sewer Department, a consultant defined *major sewer lines* as all manifolded force mains and gravity lines 20 in or larger and all gravity interceptor lines conveying wastewater from one pumping station discharge into another pumping station area.

Underrelaxation factor or parameter See **sensitivity analysis** for the use of underrelaxation parameters in a sewer modeling study.

Virtual rain gage (VRG) For the calibration of the Miami–Dade County, Florida, the Water and Sewer Department (MDWASD) sewer collection model, a consultant combined VRG rainfall monitoring with geographic information system (GIS) coverages of the study area; the VRG data were continuously adjusted to the 14 existing field rain gages.

Wholesale customer In Miami–Dade County, Florida, the Homestead Air Force Base (a federal establishment), which collects its own wastewater and uses the county facilities for treatment and disposal, is a wholesale customer, while the Miami International Airport (a county establishment) does the same thing but is a retail customer.

XP-SWMM For use in the Miami–Dade County, Florida, the Water and Sewer Department (MDWASD) sewer modeling projects, at the request of the consultant, XP Software added three custom enhancements: (a) the ability to use a range of minor loss coefficients, depending on a pump station layout, thus providing the user an additional parameter for calibration; (b) compatibility with Model Turbo View EXTRAN (MTVE), enabling the graphical and dynamic display of results, such as pressures and flows; (c) activating the Bestpump, Nozcontl, and Juntime features for better model solutions. These features allow the model user to optimize pump operation, remove iteration checks on depth changes in a manhole, or check junction timestep limitations at each iteration, respectively.

Section III

Additional Terms

Sections I and II present the definitions and illustrations of some basic terms of water conveyance and computational hydraulics. However, the vocabulary of these fields is more extensive. Here is a list of other terms likely to be found in the technical literature. They were not included due to size limitations. Interested readers may find their definitions in the following references. See Section IV for the full titles of the references. This list includes numerous brand names, trademarks, or other commercial terms, generally identified by the symbol ®, whether registered or not.

{1} American Public Health Association (1981); {2} Bouwer (1978); {3} Symons et al. (2000); {4} Cairncross and Feachem (1993); {5} Linsley et al. (1992); {6} Gupta (2001); {7} Salvato (1992); {8} McGhee (1991); {9} Fair et al. (1966); {10} Chadwick and Morfett (1998); {11} Simon and Korom (1997); {12} Martin and McCutcheon (1999); {13} Grigg (1996); {14} Parker (1997); {15} Merritt et al. (1996); {16} Brater et al. (1996); {17} Baumli (1982); {18} Manahan (1997); {19} Abbott and Minns (1998); {20} Pankratz (1996); {21} Pinder (2002); {22} Wurbs and James (2002); {23} Morris and Wiggert (1972); {24} Biswas (1997); {25} Hammer and Hammer (1996); {26} Maidment (1993); {27} Karassik and Messina (2000); {28} Mather (1984); {29} Pereira and Gowing (1998)

Section IV

Sources of Terms and Definitions

Abbott, M.B. and Minns, A.W., *Computational Hydraulics*, 2nd ed., Ashgate Publishing, Burlington, VT, 1998.

Adrien, N.G. (Ed.), Christ, T.J., Hamid, R., Garz, J. Patterson, R., and Ross, S., *Draft VSC Collection and Transmission System Model Report*, December 1999.

American Public Health Association, American Society of Civil Engineers, American Water Works Association, and Water Pollution Control Federation. *Glossary of Water and Wastewater Engineering*, 3rd ed., Denver, CO, 1981.

Anon., Computer software buyer's guide categorical listing. *Civil Eng.*, 79–101, July 1999.

Baumli, G.R., Ed., *Principles of Project Formulation for Irrigation and Drainage Projects*, American Society of Civil Engineers Irrigation and Drainage Division, New York, NY, 1982.

Biswas, A.K., Ed., *Water Resources: Environmental Planning, Management, and Development*, McGraw-Hill, New York, 1997.

Bouwer, H., *Groundwater Hydrology*, McGraw-Hill, New York, 1978.

Brater, E.F., King, H.W., Lindell, J.E., and Wei, C.Y. (contributor), *Handbook of Hydraulics*, 7th ed., McGraw-Hill Professional, New York, 1996.

Cairncross, S. and Feachem, R., *Environmental Health Engineering in the Tropics*, 2nd ed., John Wiley and Sons, New York, 1993.

Chadwick, A. and Morfett, J., *Hydraulics in Civil and Environmental Engineering*, 3rd ed., Routledge, London, 1998.

Dickinson, R.E., *XP-SWMM 32 Training Notes and Workbook*, XP Software, Tampa, FL, 1997.

Dodson, R.D., *Stormwater Pollution Control — Municipal, Industrial, and Construction NPDES Compliance*, 2nd ed., McGraw-Hill, New York, 1999. Includes definitions drawn from Hawley, J.W. and Parsons, R.B., Glossary of Selected Geomorphic and Geologic Terms, Mimeo, USDA Soil Conservation Service, West National Technical Center, Portland, OR, 1980.

EPA-40CFRxxx. 40 Code of Federal (environmental) Regulations, Parts xxx.

EPA-94/04. Terms of Environment: Glossary, Abbreviations, and Acronyms. Environmental Protection Agency, April 1994. EPA175-B-94-015, Washington, D.C.

EPA Glossaries. Updated frequently. A series of glossaries placed on the World Wide Web at http://www.epa.gov; http://www.epa.gov/OCPAterms/aterms.html; http://www.epa.gov/watrhome/pubs/gloss2.html; http://www.epa.gov/swerust1/cat/tumgloss.html.

Fair, G.M., Geyer, J.C., and Okun, D.A., *Water and Wastewater Engineering. Volume 1. Water Supply and Wastewater Removal*, John Wiley and Sons, New York, 1966.

Fletcher, CA.J., *Computational Techniques for Fluid Dynamics. Volume 1. Fundamental and General Techniques*, 2nd ed., Springer-Verlag, Berlin, 1997.

Grigg, N.S., *Water Resources Management. Principles, Regulations, and Cases*, McGraw-Hill, New York, 1996.

Gupta, R.S., *Hydrology and Hydraulic Systems*, 2nd ed., Waveland Press, Prospect Heights, IL, 2001.

Hammer, M.J. and Hammer, M.J., Jr., *Water and Wastewater Technology*, 3rd ed., Prentice Hall, New York, 1996.

Harper, H.H., Pollutant removal efficiencies for typical stormwater management systems in Florida, *Florida Water Res. J.*, 22–26, September 1999.

Hoggan, D.H., *Computer-Assisted Floodplain Hydrology and Hydraulics*, 2nd ed., McGraw-Hill, New York, 1997.

James, W., Ed., *Current Practices in Modeling the Management of Stormwater Impacts. Proceedings of the 1993 Conference on Stormwater and Water Quality Management Modeling*, CRC Press/Lewis Publishers, Boca Raton, FL, 1994.

James, W., Ed., *Advances in Modeling the Management of Stormwater Impacts. Proceedings of the March 1995 Stormwater and Water Quality Management Modeling Conference, Toronto, Canada*. Ann Arbor Press, Chelsea, MI, 1996.

James, W., Ed., *Advances in Modeling the Management of Stormwater Impacts, Volume 5. Proceedings of the February 1996 Stormwater and Water Quality Management Modeling Conference, Toronto, Canada*. CHI Publications/Ann Arbor Press, Chelsea, MI, 1997.

Karassik, I.J. and Messina, J.P., Eds., *Pump Handbook*, 3rd ed., McGraw-Hill Professional, New York, 2000.

Lee, C.C., *Dictionary of Environmental Legal Terms*, McGraw-Hill, New York, 1997.

Linsley, R.K., Franzini, J.B., Freyberg, D.L., and Tchobanoglous, G., *Water Resources Engineering*, 4th ed., McGraw-Hill, New York, 1992.

Maidment, D.R., ed., *Handbook of Hydrology*, McGraw-Hill Professional, New York, 1993.

Maidment, D. and Dlokic, D., *Hydrologic and Hydraulic Modeling Support with Geographic Information Systems*, Environmental Systems Research Institute, Redlands, CA, 2000.

Manahan, S.E., *Environmental Science and Technology*, CRC Press/Lewis Publishers, Boca Raton, FL, 1997.

Martin, J.L. and McCutcheon, S., *Hydrodynamics and Transport for Water Quality Modeling*, CRC Press/Lewis Publishers, Boca Raton, FL, 1999.

Mather, J.R., *Water Resources Distribution, Use, and Management*, John Wiley and Sons, New York, 1984.

McCuen, R.H., *Hydrologic Analysis and Design*, Prentice Hall, New York, 1989.

McGhee, T.J., *Water Supply and Sewerage*, 6th ed., McGraw-Hill, New York, 1991.

Merriam-Webster's Guide to Business Correspondence, 2nd ed., Merriam-Webster, Springfield, MA, 1996.

Merritt, F.S., Loftin, M.K., and Ricketts, J.T., Eds., *Standard Handbook for Civil Engineers*, 4th ed., McGraw-Hill, New York, 1996.

Morris, H.M. and Wiggert, J.M., *Applied Hydraulics in Engineering*, 2nd ed., John Wiley and Sons, New York, 1972.

Nix, S.J., *Urban Stormwater Modeling and Simulation*, CRC Press/Lewis Publishers, Boca Raton, FL, 1994.

Ouazzar, D., Brebbia, C.A., and Barthet, H., Eds., *Computer Methods and Water Resources, First International Conference, Morocco. Volume 2: Computational Hydraulics*, Computational Mechanics Publications, Southampton, U.K., and Springer-Verlag, Berlin, 1988a.

Ouazzar, D., Brebbia, C.A., and de Kosinsky, V., Eds., *Computer Methods and Water Resources, First International Conference, Morocco. Volume 3: Computational Hydrology*, Computational Mechanics Publications, Southampton, U.K., and Springer-Verlag, Berlin, 1988b.

Ouazzar, D., Brebbia, C.A., and Stout, G.E., Eds., *Computer Methods and Water Resources, First International Conference, Morocco. Volume 6: Water Quality, Planning, and Management*, Computational Mechanics Publications, Southampton, U.K., and Springer-Verlag, Berlin, 1988c.

Pankratz, T.M., *Concise Dictionary of Environmental Engineering*, CRC Press/Lewis Publishers, Boca Raton, FL, 1996.

Parker, S.P., Ed., *Dictionary of Engineering*, McGraw-Hill, New York, 1997.

Peavey, H.S., Rowe, D.R., and Tchobanoglous, G., *Environmental Engineering*, McGraw-Hill, New York, 1985.

Pereira, L.S. and Gowing, J., Eds., *Water and the Environment. Innovation Issues in Irrigation and Drainage*, E & FN Spon, London, 1998.

Pinder, G.F., *Groundwater Modeling Using Geographical Information Systems*, John Wiley and Sons, New York, 2002.

Post, Buckley, Schuh, and Jernigan, A series of technical modeling documents prepared for the Miami–Dade Water and Sewer Department and other clients: Collection and Transmission System Model Report, September 1996; Miami–Dade County–Homestead Regional Airport — Surface Water Management Master Plan, April 1998; Pump Station 416 Subsystem Modeling Report, July 1998; Fort Lauderdale–Hollywood International Airport — Draft Design Drainage Report (in association with EAC Consulting), October 1998.

Roberson, J.A. and Crowe, C.T., *Engineering Fluid Mechanics*, 3rd ed., Houghton Mifflin, Boston, 1985.

Salvato, J.A., *Environmental Engineering and Sanitation*, 4th ed., John Wiley and Sons, New York, 1992.

Simon, A.L. and Korom, S.F., *Hydraulics*, 4th ed., Prentice Hall, New York, 1997.

Spitz, K. and Moreno, J., *A Practical Guide to Groundwater and Solute Transport Modeling*, John Wiley and Sons, New York, 1996.

Strafaci, A.M., Ed., *Essential Hydraulics and Hydrology*, Haestad Press, Waterbury, CT, 1998.

Symons, J.M., Bradley, L.C., Jr., and Cleveland, T. C., *The Drinking Water Dictionary*, American Water Works Association, Denver, CO, 2000.

Walch, M.P., Christ, T.J., Leo, K.S., Ross, S.L., and Brant, W.M., Preventing sewer overflows — combining new technologies with computer modeling to prevent sanitary sewer overflows resulting from peak flow conditions, *Florida Water Res. J.*, 4, 23–24, April 1998.

Water Environment Federation and American Society of Civil Engineers, *Design of Municipal Wastewater Treatment Plants*, Vols. 1 and 2, WEF Manual of Practice No. 8, ASCE Manual and Report on Engineering Practice No. 76, 1992.

Webster's New Universal Unabridged Dictionary, 1996.

Webster's New World Dictionary of American English, 3rd ed., V. Neufeldt, Ed., Webster's New World, Cleveland, 1991.

Wurbs, R.A. and James, W.P., *Water Resources Engineering*, 2nd ed., Prentice Hall, New York, 2002.