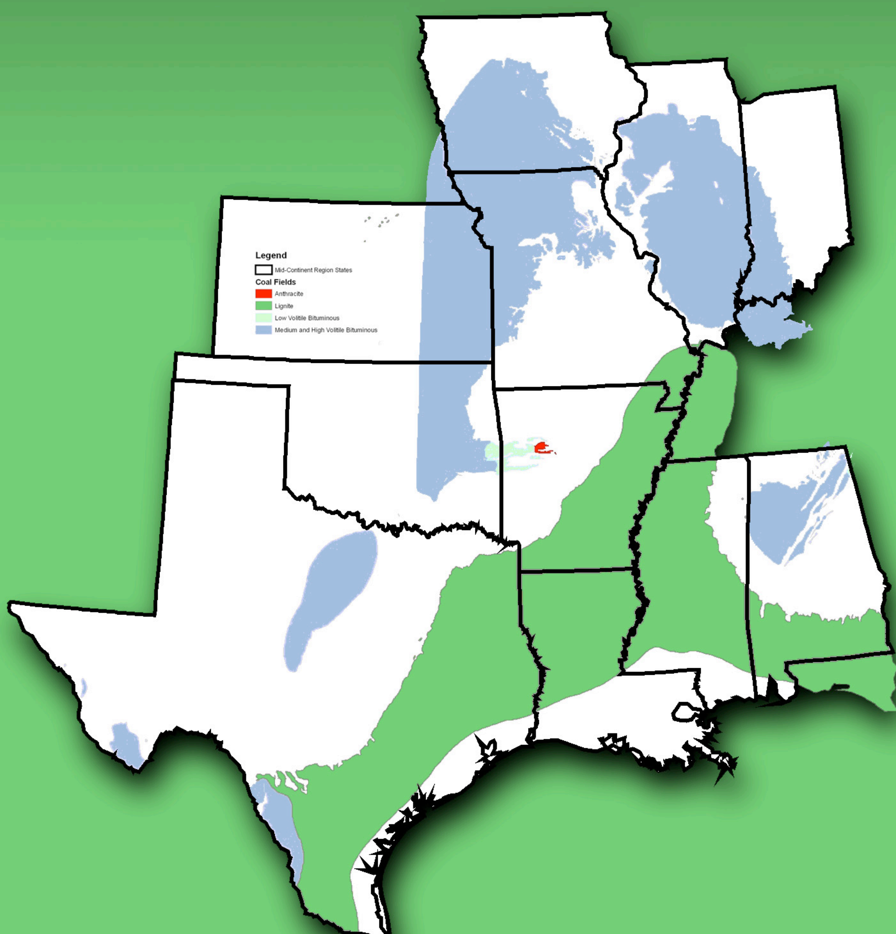
TECHNICAL REFERENCE FOR THE
MID-CONTINENT REGION:

HYDROLOGIC CONSIDERATIONS FOR PERMITTING AND LIABILITY RELEASE

PROBABLE HYDROLOGIC CONSEQUENCES (PHC) DETERMINATION
HYDROLOGIC RECLAMATION PLAN (HRP)
CUMULATIVE HYDROLOGIC IMPACT ASSESSMENT (CHIA)
POSTMINING HYDROLOGIC ASSESSMENT (PHA)



SURFACE MINING CONTROL AND RECLAMATION ACT
30 years
1977 - 2007
RECLAIM THE FUTURE

US Department of the Interior Office of Surface Mining
Mid-Continent Region

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List of Acronyms and Initialisms

AMD	Acid Mine Drainage
BTCA	Best Technology Currently Available
CBM	Coal Bed Methane
CCB	Coal Combustion By-Product
CFR	Code of Federal Regulations
CHIA	Cumulative Hydrologic Impact Assessment
CIA	Cumulative Impact Area
CWA	Clean Water Act
HRP	Hydrologic Reclamation Plan
NNP	Net Neutralization Potential
NPDES	National Pollutant Discharge Elimination System
OSM	Office of Surface Mining Reclamation and Enforcement
PHA	Postmining Hydrologic Assessment
PHC	Probable Hydrologic Consequence
SMCRA	Surface Mining Control and Reclamation Act
TDS	Total Dissolved Solids
TMDL	Total Maximum Daily Load

INTRODUCTION

Coal mining, like any other activity that significantly disturbs earth materials, has the potential to adversely affect the quality and quantity of surface and ground water within the vicinity of the mining operations. Adverse impacts may include decreased water availability, increased mineralization and changes in stream loading. Proper planning of the mining operations, along with contemporaneous reclamation, can greatly decrease or prevent unwanted effects and restore or enhance premining hydrologic conditions.

Public Law 95-87, the Surface Mining Control and Reclamation Act of 1977 (SMCRA), requires coal mining and reclamation activities be conducted in a manner that minimizes disturbance to the existing hydrologic balance and prevents long-term adverse impacts to areas both on and off the permitted site (30 CFR 780.21(h)). The term "hydrologic balance" refers to the relationship between the quality and quantity of water flowing into, stored within, and flowing out of a hydrologic unit. A hydrologic unit may be a surface-water drainage basin or subsurface soil or rock layers that store and transmit water. Regulations also require the mining operation be designed in a way that will prevent material damage to the hydrologic balance outside the permit area (30 CFR 780.21(h)). The definition of material damage has not been standardized since it is specific to each mine site. In general, material damage implies some functional impairment of surface lands, features, structures, facilities, or water resources that results in the land's inability to support current or reasonably foreseeable uses. The consequences of material damage may include a significant loss in productive capability or loss of income from the land. Hydrologic balance and material damage are central concepts for all hydrologic considerations for permitting and liability release.

A probable hydrologic consequences (PHC) determination is a discussion with explicit findings of how a proposed operation might affect the quality and quantity of surface- and ground-water systems within, and adjacent to, the proposed permit area (30 CFR 780.21(f)). This determination is written by the permit applicant for inclusion in the permit application package and is based on existing hydrologic, geologic and other pertinent information relative to the site. A hydrologic reclamation plan (HRP) is also part of the permit application package. It describes how disturbance to the hydrologic balance within the permit and adjacent areas will be minimized during the period of mining and reclamation until final reclamation liability release (30 CFR 780.21(h)). A cumulative hydrologic impact assessment (CHIA) is a consideration of how effects on surface- and ground-water systems by a proposed mining operation might combine with similar effects from any existing operation still under reclamation liability within a specified cumulative impact area. The assessment is based on the probable hydrologic consequences determination, hydrologic reclamation plan and other pertinent data and is prepared by the regulatory authority (30 CRF 780.21(g)). Finally, a postmining hydrologic assessment (PHA) is a conception that follows from 30 CFR 800.40(b)(1) and (c)(3). This evaluation, conducted at the time the permittee requests final release from reclamation liability, is the regulatory authority's last opportunity to examine whether pollution of surface and subsurface water is occurring. More generally, it is a determination whether the permittee has successfully completed mining and reclamation operations with regard to having adequately protected the hydrologic balance.

In May of 2002, the Office of Surface Mining distributed *Permitting Hydrology, A Technical Reference Document for Determination of Probable Hydrologic Consequences (PHC) and Cumulative Hydrologic Impact Assessments (CHIA), Baseline Data*. The 2002 document outlined approaches on a national level for obtaining geologic and hydrologic information to be used in the review and preparation of coal mine permit applications. This publication, *Technical Reference for the Mid-Continent Region: Hydrologic Considerations for Permitting and Liability Release* provides a systematic approach to the analysis of existing site conditions and offers various tools that can be used to predict possible hydrologic impacts due to a proposed mining operation. Although most of the information in this document is applicable to coal mining throughout the nation, the focus is on relevant issues within the Mid-Continent Region.

Each of the four major hydrologic considerations for permitting and liability release that is discussed in this document has its own abbreviation (i.e. PHC, HRP, CHIA, PHA); however, not every state in the region will necessarily use these specific designations. For example, it is common practice in some states to incorporate the hydrologic reclamation information into the PHC rather than having a separate section specifically titled the HRP. Also, a state's review of a bond-release request might not produce a report titled a PHA even though the evaluation process could have proceeded in much the same way as outlined in this technical reference document. It should not be inferred that a state's nonuse of any of these abbreviations means the state did not adequately appraise the associated hydrologic issue.

It is important to note the use of this technical reference document is not mandated by any state or federal agency. Material presented here is based on sound approaches intended to aid in the development of an adequate PHC, HRP, CHIA, and PHA. While a great deal of thought went into the identification of topics in the Mid-Continent Region that require consideration in these hydrologic discussions, plans, and assessments, there are, undoubtedly, additional issues that have not been addressed. Furthermore, every state in the region has an approved program that meets the requirement of SMCRA and may have developed additional permitting systems and processes for assuring effective hydrologic evaluations. Therefore, this technical reference document should be utilized as a framework—adding, removing, or modifying topics as necessary.

PROBABLE HYDROLOGIC CONSEQUENCES (PHC)

The PHC determination addresses the anticipated effects of the planned mining operation and subsequent reclamation on the quality and quantity of surface- and ground-water systems within, and adjacent to, the proposed permit area. It is prepared by the applicant and is based on the existing geologic and hydrogeologic settings of the site. The applicant is required to make specific findings in the PHC regarding the proposed operation.

A comprehensive PHC includes, at a minimum, discussions concerning: overburden properties; disposal/storage operations for coal processing waste, non-coal waste, coal combustion byproducts, etc.; erosion and sediment control measures; mining methods; coal-bed methane recovery; subsidence; and mine pools. Generally, the PHC also gives information about alternate water supplies and describes the water-monitoring plan (sample stations, sampling methods and frequencies, field measurements and laboratory analyses, and reporting schedule) that will be used to document both the short-term and long-term effects on local water resources. Both the PHC and the hydrologic reclamation plan may present similar information about some of these topics. Therefore, to limit repetition in this document, only the hydrologic reclamation plan presented in the following section will discuss monitoring plans and alternate water sources.

An outline of suggested minimal requirements for PHC determinations can be found in Appendix B.

Overburden Properties

As part of the permitting process, the applicant must include sufficient geologic information to not only describe and characterize the subsurface strata but also to determine if potentially acid- or other toxic-forming materials exist within the proposed permit area down to and including the stratum immediately below the lowest coal seam to be mined (30 CFR 780.22(a)(2)). The Code of Federal Regulations at 30 CFR 701.5 defines *acid-forming materials* as "…earth materials that contain sulfide minerals or other materials which, if exposed to air, water or weathering processes, form acids that may create acid drainage." This same regulation defines *toxic-forming materials* as "…earth materials or wastes which, if acted upon by air, water, weathering or microbiological processes, are likely to produce chemical or physical conditions in soils or water that are detrimental to biota or uses of water." While the PHC should be comprehensive with regard to the properties of the overburden materials, the focus of the discussion must be on the possible effects of the materials on surface and ground water.

Coal-mining states throughout the nation commonly delineate potentially acid- or toxic-forming materials as those containing a net potential deficiency in calcium carbonate (neutralization potential) of five tons or more per 1,000 tons of material (T/KT). This deficiency represents the difference between the maximum potential acidity (based on total sulfur) and the neutralization potential. Although this method is widely used, caution should be exercised since delineation of potentially problematic strata is generally more complex than simply computing the net neutralization potential (NNP). For example, a calculated NNP more positive than -5 T/KT but with an accompanying fizz rating of "0" may indicate the presence of the iron carbonate siderite which ultimately is not a source of alkalinity. Fizz rating is an important qualitative ranking of how the material reacts to a weak acid and should be an integral part of any laboratory overburden analysis (Sobek et al., 1978).

Besides NNP values, some states within the Mid-Continent Region recognize geologic units with pH values of <4 or >8.5 standard units and/or a total sulfur content of >2% as potentially problematic. Furthermore, electrical conductivity measurements >8 millimhos per centimeter or a sodium adsorption ratio >12 often denote materials that would be unacceptable for placement in the vegetation root zone.

The PHC should not only identify which materials may be acid- or otherwise toxic-forming, but also give the percentages of these materials present across the proposed permit area. The discussion should state the volume of suspect materials that may be disturbed and present any planned special handling plans to mitigate their effects. Special handling measures include isolation of the toxic materials in the spoil profile (above the water table – "high and dry"; below the water table – "down and deep"), disposal at an approved off-site facility, and mixing suspect materials with innocuous or neutralizing matter. The PHC should identify the percentage of overburden strata that contain excess alkalinity that may aid in counteracting adverse effects of acid-producing strata when the two materials are backfilled together in the mine pits.

For more information concerning overburden analyses, please refer to the reference document *Permitting Hydrology, A Technical Reference Document for Determination of Probable Hydrologic Consequences (PHC) and Cumulative Hydrologic Impact Assessments (CHIA), Baseline Data (2002*) previously distributed by the Office of Surface Mining. In addition, *Coal Mine Drainage Prediction and Pollution Prevention in Pennsylvania* (1998) is an excellent resource on acid-base accounting and other topics.

Disposal/Storage Operations

Spoil

The PHC should include a discussion of disposal and storage operations with emphasis on possible effects on surface and ground water. During surface mining, spoiled strata from the active pit are placed within the previously mined area and reclaimed according to the approved reclamation plan. The primary issue with spoil deposition in terms of surface and ground water is the potential for acid generation and drainage. Proper placement and quick burial of potentially acid-forming materials can dramatically reduce or prevent acidic conditions (Infanger and Hood, 1980). The PHC should address the type, thickness, and mode of emplacement of topsoil/capping material. A discussion of the storage/disposal of development waste should be part of the PHC completed for underground mining operations.

Coal Processing Waste

Coal processing and its waste disposal is another mine activity that potentially can affect water resources. This type of waste is generated by the crushing, screening, and washing raw coal and may consist of both coarse and fine particles. During surface mining, coarse coal refuse is generally disposed of in the active pit simultaneously with spoil material or placed in a designated area (refuse pile) within the permitted area.

Coal processing waste hauled back to the surface mine pits may generate acid. Proper placement and relatively quick covering of refuse with nontoxic spoil, along with the addition of alkaline-rich matter, can greatly reduce the likelihood of acid mine drainage. As with spoil placement, care must be taken to ensure the construction of a generous, nontoxic rooting zone. Refuse should be placed either high in the pit profile (above the water table) or deep within the pit to ensure the material remains saturated and oxygen free. Refuse should not be deposited at a depth where periodic wet/dry conditions occur because this situation is optimum for acid generation. If the refuse is placed shallow in the pit, a competent cap must be used to prevent or reduce infiltration of precipitation. While awaiting deposition, the refuse should not be stored in a location where it can contact surface water (i.e. near a stream channel or drainage way).

If coarse coal refuse is planned for disposal in refuse piles (common in underground mining operations), the characteristics of the material that will form the base of the pile, as well as the underlying geologic material, should be investigated. Materials with low permeabilities will restrict the downward movement of drainage from the refuse, thus protecting underlying aquifers. Refuse piles may require a system of underdrains to channel seepage to approved sediment basins. While drains may be successful during active mining, thought must be given as to how treatment of the drainage will be maintained when performance bond has been released. Again, the use of low-permeability capping material will inhibit infiltration of precipitation.

Fine coal refuse is often disposed of in surface impoundments (slurry ponds) transported through overland pipelines. When siting the location of these ponds, it is crucial that a thorough characterization of the geologic material(s) underlying the proposed slurry ponds be obtained prior to construction. Likewise, characterization of earth materials adjacent to a proposed slurry pond is needed when placement will occur near unmined strata (e.g. in final-cut impoundments). Low-permeability materials restrict migration of mineralized water from the slurry into surface and ground water. Although manufactured liners can prevent leakage, liners are expensive and care must be taken during installation to avoid puncture or tearing. Generally, coal companies will choose to use in situ material (or material brought in from a nearby "borrow area") to form a natural liner if the material contains sufficient clay that can be compacted to the desired permeability. In addition to discussing potential problems associated with the planned disposal, the PHC should explore the possibility of leaks or breakage along pipelines conveying slurry to the deposition site.

Along with the underlying geologic material, the PHC should discuss the proposed design of the surface impoundments. Proper design and maintenance are crucial in preventing failure that could result in the discharge of coal slurry into adjacent waterways and ground water. Slurry spills can also occur due to a subsidence event; therefore, it is important to know whether there are underground workings in the vicinity of the planned impoundments.

Coal processing waste deposited in underground mine workings may affect the future use of the water that eventually fills the mine voids and may impact the quality of ground water in aquifers that are hydrologically connected to the mine workings. The PHC should address the expected water quality of the mine pool following coal processing waste disposal and project its possible impact on nearby aquifers. The expected volume of the mine pool is also important as underground works that are fully inundated inhibit acid generation; however, mine pools under sufficient hydraulic pressure can blow out. Finally, the PHC should discuss the location of the mine voids planned for coal processing waste disposal with regard to their surface-discharge potential. Mine workings located below drainage have less potential to discharge to surface waters than mines located above drainage.

Noncoal Waste
The disposal of noncoal wastes such as grease, lubricants, solvents, and paints is addressed in the PHC. At a minimum, the applicant should identify the type of wastes, disposal locations and options, temporary storage sites, compaction standards, setback requirements, and reclamation plans. Disposal, whether temporary or permanent, should not occur where the waste, or leachate from the waste, can contaminate surface or ground water.

Coal Combustion Byproducts
As with any activity with the potential to impact water resources, the PHC must address the disposal or beneficial use of coal combustion byproducts (CCBs). The discussion should include the following topics: (1) physical and chemical characteristics of ash material; (2) the proposed locations and disposal methods (backfill, monofill, etc.); (3) reclamation of disposal area; and (4) monitoring requirements and other pertinent information. The applicant must discuss the potential for CCBs to affect surface and ground water as well as specify mitigation efforts should such a condition occur.

Erosion and Sediment Control

The PHC should address the effects of the proposed operation on sediment yield from disturbed areas during mining/reclamation activities and after final bond release. Activities associated with surface mining, as well as activities in the surface effects area of underground mines, must be planned and executed in a manner to prevent erosion and control the amount of sediment entering waterways. Failure to do so can result in increased sediment loads in receiving streams that can have a detrimental effect on aquatic organisms, affect stream velocities and alter existing stream geometries. As with all pertinent parameters, the average concentration of total suspended solids in all applicable stream channels and water bodies must be established prior to mining to allow comparisons of these levels with those detected once activities at the site have begun.

Operational activities used to minimize erosion and control excess sediment yield to receiving streams include stabilization of disturbed areas through land shaping, runoff diversions, temporary and permanent vegetative methods, mulching, regulating stream channel velocities, adequate siltation structures and chemical treatment. The PHC should identify the proposed methods of erosion and sediment controls that will be used during active operations and the anticipated results of these measures.

Mining Methods

Surface Mining
Coal producers in the Mid-Continent Region use both surface (area, thin-seam/auger) and underground (room and pillar, longwall) mining methods. Currently, surface mining is the most common method; however, some states are witnessing an increase in underground operations as shallow coal reserves are depleted. Both types of mining methods have the potential to adversely affect local water resources. The PHC should identify and discuss the proposed mining method.

Surface mining disrupts large volumes of earth materials resulting in possible impacts to surface water bodies and aquifers. Waterways may receive increased sediment load from disturbed areas or from effluent discharging from inadequately designed or poorly maintained sediment basins. Mine operations may also temporarily or permanently relocate waterways resulting in temporal changes in water quality and/or volume.

During mining, both gaining streams (effluent streams) and losing streams (influent streams) near the mine site may decrease in volume as ground water is redirected into the active pit. This occurrence is generally temporary with premining flow conditions reestablished once mining and recharge in the backfilled mine pits is complete and final-cut lakes fill. In addition to overland flow from the mine site, water quality in streams may be degraded by mineralized water within the spoil seeping through channel beds of effluent waterways.

Aquifers within, and adjacent to, a surface coal mine can be adversely impacted by mining operations. Those within the coal extraction zone are destroyed possibly diminishing the volume of water available to wells both upgradient and downgradient of the mine pit. Water loss may be temporary with volume returning (or increasing) once mining activities are complete and the spoil material has recharged. However, since the water within the recharged mine pit may be more mineralized as compared to pre-mining aquifer quality, the water available to surrounding aquifers may be of lesser quality.

Aquifers underlying surface mines are generally not impacted due to the presence of low-permeability material (i.e. underclay, shale) located beneath the lowest coal seam extracted. When present in sufficient thickness, these strata inhibit the migration of water from within the pit into underlying aquifers. If more permeable material is present beneath the coal seam, and the hydraulic head difference between the water within the pit and the underlying aquifer is sufficient to initiate downward movement, mineralized water from within the mine pit can infiltrate lower aquifers possibly degrading water quality. If the target coal seam is underlain by a confined aquifer of significant aerial extent, and hydraulic head conditions are favorable, it is possible for water to enter the pit floor from the underlying aquifer either directly or through cracks/fissures necessitating the need for the pit to be pumped. Ground water may also flow into the pit through improperly sealed boreholes or wells.

Blasting of the consolidated strata during active mining operations may induce fractures or increase the aperture of existing fractures in bedrock located near the blast zone. Blast-induced fractures that occur in an aquifer or that connect previously separate water-bearing formations can have a major effect on ground-water availability and quality. The PHC should consider the possibility of impact to water-bearing units as a result of blasting within the mine site.

The PHC must identify and discuss existing mine workings within and adjacent to the proposed permit area. Prospective mine areas may have flooded underground workings which, if encountered during mining, could result in large quantities of water entering the surface pit or underground mine tunnels. Such an influx of water is not only a safety issue but also an operational challenge due to disposal or treatment needs.

The lowering of water levels in abandoned underground mines may result in subsidence due to the loss of hydrostatic pressure exerted on the roof and overlying strata. When possible, the hydraulic head in nearby abandoned workings should be measured prior to mining and then monitored during mining and reclamation activities. The PHC should address the existing hydrologic conditions of the abandoned workings and discuss the potential impacts to the proposed operation and surrounding area should the underground workings be breached.

Underground Mining
While underground mining operations generally disturb less ground surface and generate less waste rock than surface mines, both types of mining can have similar adverse affects on the hydrologic balance. The PHC should discuss those activities that require sediment control measures and water management plans such as topsoil removal, sediment basin construction, diversion ditch layout, and support facilities and processing plant siting. Development of the shaft necessitates the need to consider overburden characteristics, temporary and permanent disposal of development waste and possible diminution in water quality/quantity servicing nearby domestic wells. A proposal to process coal calls for a discussion of gob and slurry disposal (including waste transportation methods) and consideration of the water source for the processing operation. In addition to the preceding topics, PHCs completed for underground mining operations should discuss subsidence and the quality and quantity of mine-pool water.

Subsidence events can be either unexpected or designed as part of the mining operation. In longwall mining, surface subsidence is planned and occurs shortly after coal extraction along a panel. Conversely, mines using the room-and-pillar method are designed to prevent subsidence by leaving sufficient coal pillars to support the overlying strata. However, the pillars may deteriorate over time resulting in subsidence decades after the mine closed. Regardless of mining technique, subsidence near surface impoundments or waterways can partially or fully drain these features as water moves down through cracks and fissures into the mine void. Ground-water availability at wells located in or near subsided ground can be similarly diminished as fractures emanating from the subsidence zone intersect and drain water-bearing units.

Once underground mining is complete, the resulting mine voids may fill with water. The volume of water entering the subsurface workings is dependant on various factors including local climate, depth of the workings, and hydrologic setting. Geochemistry of the coal seam, roof and floor determines whether pooled water will be acidic and have excess amounts of iron, sulfate and manganese that may restrict or limit its use. The PHC should pay particular attention to those situations where mine workings are liable to flood. Water within flooded mine workings may discharge to the land surface as seeps, or if sufficient hydraulic pressure develops, pooled water may erupt forcefully.

Coal-Bed Methane Recovery
SMCRA does not contain regulations specifically addressing the recovery of coal-bed methane (CBM) nor does the recovery of this gas facilitate coal mining. However, SMCRA regulations do require that mining activities be conducted to minimize disturbances of the hydrologic balance within the permit and adjacent areas and to prevent material damage to the hydrologic balance outside the permit area. Therefore, if CBM recovery activities are to be carried out within a SMCRA permitted area, or if such operations are occurring in proximity to the SMCRA site, the PHC should address any possible cumulative effect of the coal extraction and CBM recovery on local water resources.

CBM recovery can affect surface and ground water in various ways. To produce CBM, the hydrostatic pressure within a water-saturated coal seam must be reduced by pumping the formation water. The bound water is often saline and may contain elevated concentrations of fluoride, ammonia, sulfate or other constituents; therefore, disposal options for the water may be limited. Although the quantity of ground water that must be pumped from the coal will diminish over time, initial quantities can be quite large. Ground water conveyed to the surface during methane recovery may be injected into porous strata not hydrologically connected to the coal bed, discharged into surface drains, or pumped into holding ponds.

Injection of CBM-produced saline or otherwise low-quality water into aquifers or other geologic strata is relatively expensive and can cause subsurface pollution. The applicant and regulatory authority should collect data concerning existing water quantity and quality in the receiving porous strata and identify the aerial extent of those zones before infection begins. In addition, if the receiving unit is an aquifer, the applicant should measure its hydraulic characteristics (permeability, porosity, etc.) and identify customary or potential use of its water.

Discharging CBM water to surface drains and holding ponds is more economical than injecting it underground. However, saline water pumped into surface waterways can contaminate that resource and harm aquatic life. Furthermore, waterways and impoundments can lose water to underlying aquifers, and an influx of mineralized water into a subsurface receiving unit may limit or prevent the usage of that formation as a water supply.

Findings

Federal regulations at 30 CFR 780.21(f) enumerate the minimum PHC findings required of a coal permit applicant. The applicant must find:

- Whether adverse impacts may occur to the hydrologic balance.
- Whether acid- or other toxic-forming materials are present in amounts that could contaminate surface and ground water.
- Whether the planned operation may, in the near term, contaminate, diminish, or interrupt a water resource in legitimate use within or adjacent to the proposed permit area.
- What effect the proposed operation will have on:
    - Sediment yield from the disturbed area.
    - Acidity, total suspended solids, dissolved solids, and other water-quality characteristics of local importance.
    - Flooding or stream-flow alteration.
    - Ground- and surface-water availability.
    - Other characteristics as required by the regulatory authority.

HYDROLOGIC RECLAMATION PLAN (HRP)

All permit applications for surface and underground coal mining must include an HRP. The HRP is a detailed description of the measures to be taken during and after mining (until release of the performance bond) to meet two standards: (1) minimization of all surface- and ground-water hydrologic impacts within and adjacent to the permit area; and (2) prevention of material damage outside the permit area. Material damage is assessed on the basis of permanent or long-term impacts to useable ground- and surface-water resources. Preventive measures proposed in the design and implementation of a HRP must generally employ the best technology currently available (BTCA) for both standards and must include contingency plans for mitigation of hydrologic impacts, should they occur.

An outline of suggested minimal requirements for the HRP can be found in Appendix C.

HRP Elements

Coal mining can potentially affect the hydrologic balance within and adjacent to the permitted area in various ways. For example, without proper sediment control measures in place, mining can cause increased sediment loads in waterways. In addition, mining operations expose additional rock and mineral surfaces to weathering which may result in the generation of acidic or other toxic conditions. Mining may also intercept ground-water systems causing drastic changes from premine flow patterns and rates (OSM, 1991; 1997).

The HRP must describe specific activities (or reference such activities committed to in the operation plan) that will minimize impacts to ground- and surface-water resources and prevent material damage to the hydrologic balance outside the permit area. The applicant must address any potential adverse deviations from baseline conditions. This may be done in part by considering the following specific elements known to be associated with surface and underground coal mining.

Acid Mine Drainage (AMD)

Prevention of surface- and ground-water degradation by acidic mine discharge is paramount. The HRP must discuss the potential for generating acidic water and identify measures to minimize that contaminant. Two general approaches are used during mining to inhibit the development of AMD—controlled placement of overburden materials and careful management of water. Special handling of troublesome strata (pyritic, or in some cases, alkaline materials) limits the exposure of these materials to oxidizing conditions.

Under the proper setting, acid generation can be controlled by flooding potentially problematic materials. Oxygen diffuses very slowly and has limited solubility in water. Stagnant, no-flow conditions within a saturated zone several tens of feet thick inhibits oxygen diffusion and produces an anoxic (oxygen free) state. Submergence or flooding is most successful at mines in flat terrain where ground-water gradients are low, the zone of saturated spoil is thick, and subsurface water discharging into the spoil travels a long way from the aquifer recharge area. Submergence should not be used in hilly terrain where gradients and flow velocities are too great to achieve stagnant, anoxic conditions. In these situations, submergence may actually promote acid generation.

Acid-forming materials can be inundated in a permanent impoundment or segregated and placed under a non-toxic layer that will preclude oxidation and the subsequent development of AMD seeps. Keep in mind, impounding structures constructed of coal mine waste (i.e., coal processing waste and underground development waste) or intended to impound such waste cannot be retained permanently as part of the approved postmining land use (30 CRF 816.84 (b)(1)). Also, permanent impoundments are not allowed on completed refuse piles (30 CRF 816.83 (c)(3)). When considering inundation, projecting reliable postmining water table levels is essential. The applicant and the regulatory authority should be cognizant of those scenarios where resaturation can occur from the surface.

Submergence or flooding is also used to prevent AMD from underground mines. Key considerations to keep in mind when contemplating submergence or flooding for underground mines are whether the mine is located above or below drainage and the ability of mine seals and outcrop barriers to prevent both significant seepage and catastrophic failure under hydrostatic pressure. Flooding to prevent AMD may be more successful in below-drainage mines. Nevertheless, flooding above-drainage mines is typically practiced through the use of "wet" seals that allow water to drain but exclude air entry. Sealing and flooding above-drainage mines does reduce acid loading but can be technically difficult to achieve a long-term effective, stable system. There are no guidelines addressing specific criteria to be used in determining outcrop barrier thickness with regard to flooding underground workings. Likewise, a consensus for a "standard" engineering design approach is lacking for outcrop barriers and seals.

Another method of controlled placement is the isolation of potentially acid- or toxic-forming materials above the water table: This technique attempts to prevent the reactive material from coming into contact with water. Infiltration can be greatly reduced by compacting pyrite-bearing spoil and capping it with clay or other low-permeability materials. The capping approach can be extended to complete encapsulation on top, bottom and sides as a further effort to isolate the material from water contact. Complete isolation from water, however, is difficult to achieve. Clay caps and other barriers are prone to leakage, and the sporadic infiltration of rain or snowmelt may periodically leach the spoil.

Water management strategies, both during and after mining, are another option for reducing acid generation. This type of strategy can include the following:

- Proper placement and rough grading of spoil material to prevent ponding and subsequent infiltration
- Prompt removal of pit water during surface mining
- Isolation of affected pit water from non-contaminated sources (no commingling)
- Construction of underdrain systems to route water away from acid-forming materials
- Diversion of surface-water drainage away from pyrite-bearing spoil or through alkaline material.

Alkaline substances can be added to potentially acid-toxic earth materials to minimize or prevent AMD. This addition can be accomplished by mixing alkaline earth materials with the acid-or toxic-forming substances to obtain a net alkalinity, or by adding the alkaline materials in concentrated placements. A third variant of the alkaline placement technique is encapsulation with alkaline material above and below the acid-producing zone.

"Alkaline recharge" employs trenches loaded with alkaline material (usually a combination of soluble sodium carbonate and crushed limestone) to charge infiltrating waters with high doses of alkalinity sufficient to overwhelm any acid produced within the backfill. This approach is highly dependent on proper location of the alkaline trenches in order to provide maximum inflow of high-alkaline water to the acid-producing zones. Although this method may be useful under certain conditions, some field investigations suggest the distribution of the alkalinity from trenches may be limited (Dale, unpublished field study, 2004).

Although AMD may not be anticipated, this phenomenon may occur regardless of preventive measures implemented during mining. Consequently, the HRP must contain plans for timely mitigation of any such event. The plan may be general, but it should provide for an evaluation period, mitigation work, and follow-up monitoring with periodic re-evaluation. Detailed mitigation plans must be developed on a site-specific basis for each occurrence.

Active treatment methods of acidic waters (chemical additions, pump and treat systems, etc.) are not viable long-term mitigation solutions; however, passive treatment systems may provide a suitable option for the mitigation of AMD. Passive treatment technology has been studied since 1978, and the research and development is voluminous and ongoing. It is important to remember, passive treatment systems may require periodic maintenance that extends beyond the point of final bond release.

Limestone has been one of the more commonly used materials in passive treatment systems. Although it is relatively inexpensive and easy to obtain, limestone-based systems can fail due to armoring of the rock. Metals precipitated from the AMD coat the limestone, reducing its ability to dissolve and provide alkalinity. Precipitated metals also fill pore spaces restricting flow through the gravel body. All alkaline substances used to treat AMD will have a finite useful life; therefore, a key design consideration must be the length of time the material will provide alkalinity.

Low-volume treatment of acidic waters by a passive treatment system (e.g., permanent wetlands) may be satisfactory; however, success is dependent on the geometry and stability of the system and the magnitude of the acidity problem. Constructed wetlands utilize soil and water-borne microbes associated with wetland plants to remove dissolved metals from mine drainage. Initial design and construction costs may be significant; however, unlike chemical treatments, permanent wetlands have low maintenance requirements.

Regardless of the mitigation method chosen, close coordination with, and approval by, the regulatory authority is necessary since findings must be made at the time of final bond release that the hydrologic balance has been protected and that material damage outside the permit area has not occurred. For areas where mitigation is deemed not feasible, the operation plan must be designed to avoid such areas during mining.

Non-Acidic Mine Drainage

Acidity problems may not be the only effects to the hydrologic balance from coal mining. Mining may also lead to poor ground- and surface-water quality exhibited as high total dissolved solids (TDS)(i.e. sulfates and chlorides). Areas of mining that have low precipitation coupled with high evaporation rates (e.g. south Texas) are particularly susceptible to these problems. Problems are exacerbated by the creation of a spoil aquifer system with low-quality water in an area where little ground water existed prior to mining. Again, the HRP must discuss possible adverse impacts to surface- and ground-water resources from the planned mining operation and address mitigation plans for conditions that arise from failure of the HRP.

Sediment Control Measures
Sediment production is a function of runoff rates and the susceptibility of earth materials to erosion (OSM, 1991). When preparing the HRP, the applicant must consider prevention of additional contributions of suspended solids to stream flow using the BTCA. Three strategies to reduce erosion and transport of sediment are: (1) expose the smallest possible area of bare soil for the shortest possible time; (2) minimize sheet erosion by stabilizing reclaimed soils with scarification and mulch; and (3) prevent sediment from leaving the permit area. Limiting the area or time of exposure and minimizing sheet erosion are generally accomplished through efficient planning and execution of clearing, grubbing, mining, backfilling, grading, replacement of topsoil, and revegetation. Preventing sediment from leaving the permit area is generally achieved through the proper construction and maintenance of diversions, sedimentation ponds, and other siltation structures.

Recharge Capacity
Regulations require the permittee to restore the approximate premining recharge capacity in the postmine area. Even though aquifers within the coal-extraction zone will be destroyed, the ability of the backfill to absorb and transmit water necessary to support the intended postmine land use (as measured relative to the premining land use) must be preserved. In addition, protection measures are required to prevent diminution of springs and the destruction of wetlands in areas adjacent to mining. Jurisdictional wetland mitigation and restoration require consultation with the U.S. Army Corps of Engineers.

Disposal Activities
The HRP must address disposal activities involving coal processing waste, coal combustion by-products, and noncoal waste. In addition to federal requirements, disposal of these materials are usually subject to state laws and regulations that may be described in the mining permit. The water-monitoring plan should be designed to detect solutes from wastes and by-products.

Water Monitoring
A water-monitoring program is necessary for assessing compliance with regulatory requirements. It also provides a useful opportunity for tracking trends that may indicate a future problem. Trend analysis may prompt mitigation action that prevents damage from occurring.

<u>Surface Water</u>
Minimum permit applications requirements for baseline surface-water information can be found in 30 CFR 780.21(b) and 784.14(b). Baseline surface-water data are essential since both surface and underground mining have the potential to disrupt and permanently alter surface-water systems. Mining-related effects on baseflow and storm hydrograph peaks may result from: pumping discharges to adjacent watersheds; altering runoff characteristics by changing groundcover; disrupting drainage patterns by modifying the size of drainage areas; and storing overland flow in temporary detention structures or permanent impoundments.

An applicant must identify all surface-water bodies that could be measurably affected by the proposed operation. These resources include waterways, streams, rivers, ponds ("tanks" in

Texas), and lakes. The surface-water description must also delineate the watersheds affiliated with the permit area. By rule, surface-water sampling plans (baseline and compliance monitoring) must be designed to detect seasonal variations in both water quantity and quality. The applicant should explain why each monitoring station is placed where it is and describe how data from these sites will be used to track mining effects on the hydrologic balance and surface-water users. Typically, both upstream and downstream monitoring stations are needed to effectively evaluate any impacts. For maximum continuity, the monitoring plan should incorporate as many baseline stations as possible.

Very large mine areas may encompass many watersheds of similar size, topography, and erosional characteristics. In this case, a permittee may be able to monitor representative disturbed and undisturbed watersheds (termed "paired" watersheds) in lieu of total-mine monitoring. Preapplication consultation with the regulatory authority is advisable for those contemplating this option.

Regulations dictate that each station in the surface-water monitoring plan established to monitor water quality effects be sampled and reported at least every three months. Based on a state's monitoring criteria and the specific site conditions, the regulatory authority may require more frequent monitoring. Monitoring parameters must be useful for demonstrating whether the hydrologic balance is protected from the effects of regulated coal mining. At a minimum, measurements are required for TDS or specific conductivity corrected to 25 °C, total suspended solids, pH, total iron, total manganese, and flow rate. The applicant must give a detailed description of the sampling protocol.

The regulatory authority may approve changes in the surface-water sampling plan if the applicant demonstrates with monitoring data that continued monitoring of certain parameters or specific monitoring stations is no longer needed to protect the hydrologic balance. In general, point-source monitoring under the National Pollutant Discharge Elimination System (NPDES) cannot be modified except by the agency responsible for issuing and administering the NPDES permit. The permit-issuing agency, however, may grant limited NPDES administrative responsibilities to the coal regulatory authority.

<u>Ground Water</u>

In developing an effective ground-water monitoring plan, the permittee must be cognizant of the established ground-water flow directions, both for overburden and underburden aquifers, and must design a plan that incorporates monitoring of both upgradient and downgradient areas. As with surface-water monitoring, the incorporation of baseline monitoring wells and other baseline sampling locations (e.g., springs or seeps) into the plan will maximize the continuity of the data for their intended purpose. In addition to monitoring changes to the quantity and quality of the ground-water resources, the plan should also be designed to detect any changes in flow direction during the course of mining and confirm the re-establishment of the ground-water system after mining is completed prior to final bond release.

Regulations dictate that each well or other sampling location in the ground-water monitoring plan established to monitor water quality effects be sampled and reported at least every three months for TDS or specific conductance, pH, total iron, total manganese, and water level. The regulatory authority may add other constituents of local importance as identified from baseline monitoring or overburden analyses. Additional constituents would be those that might be at concentrations high enough to jeopardize current or postmining ground-water uses. A preapplication meeting would be the time for consultation between the prospective permittee and regulatory authority on suitable monitoring locations and parameters.

The applicant must justify each component of the proposed ground-water monitoring plan including any variations among monitoring stations. For example, when large-area dewatering is proposed, the monitoring plan may incorporate piezometers for measuring the water table or potentiometric surface. Piezometers are not intended for the collection of water samples and may be located within the area of affect but at some distance from the permit area. The monitoring plan must also discuss the fate of monitoring wells and piezometers once mining and reclamation activities are complete.

The regulatory authority may approve modifications to ground-water monitoring requirements provided the applicant, through an analysis of baseline and subsequent monitoring data, demonstrates the proposed change will not hinder the detection of adverse impacts to the hydrologic balance. Conversely, the regulatory authority may require additional monitoring stations and/or parameters if the monitoring record indicates that such a change is necessary to meet statutory objectives.

Replacement of Water Supply
Regulations require that users of ground and surface water be protected from the effects of surface and underground coal mining activities. The permittee must provide a suitable replacement for a water supply in use that is contaminated, diminished, interrupted, or destroyed by the permittee's mining activities. Replacement water shall be available until such time when the adverse effect is no longer occurring. The HRP must describe plans for such eventualities and contingencies in sufficient detail to allow the regulatory authority to assess their viability. Also, the regulatory authority may require a special, targeted monitoring program in addition to the overall long-term water-monitoring plan when water supplies are likely to be threatened.

Plans for water-supply replacement must be based on a thorough survey of water users within the area of potential impact. This premining survey generally includes the locations of all domestic wells or surface-water sources along with water-quality and quantity data sufficient to show seasonal variations. When available, well completion information (i.e., depth, drilling method, and construction) is also included in the premining survey. Assessments of actual effects during and after mining may be conducted by the permittee and/or the RA with the existing water data measured against the baseline information submitted in the permit application. Lacking that detailed level of information, general water-quality criteria may be used to assess impacts. Useful criteria may be found in the Clean Water Act and Drinking Water Act as administered by the state; NPDES permit(s); established total maximum daily loads (TMDLs); and university extension service publications dealing with livestock watering and irrigation.

CUMULATIVE HYDROLOGIC IMPACT ASSESSMENT (CHIA)

The Surface Mining Control and Reclamation Act (SMCRA) requires the regulatory authority to assess the probable cumulative impacts of all anticipated mining in a given area to assure that the proposed operation has been designed to prevent material damage to the hydrologic balance outside the permit area. Hydrologic balance is the relationship between the quantity and quality of water flowing into, stored within, and discharging from a unit such as a drainage basin, aquifer, soil zone, lake, or reservoir. The regulatory authority must complete this assessment before issuing a permit to conduct surface coal mining and reclamation operations. The Office of Surface Mining Reclamation and Enforcement (OSM) has termed this evaluation a *cumulative hydrologic impact assessment.* What follows is a suggested process by which regulatory authorities in the Mid-Continent Region might prepare a reasonable and technically sound CHIA.

This technical reference document is written primarily in the context of the regulatory authority having to write a CHIA upon receipt of a permit application package for a new mine. The term *permit application package* refers to the document (often a set of three-ring binders) containing all information required by the regulatory authority for a business entity to obtain and hold a valid coal mining permit throughout the resource recovery and reclamation phases.

After a permit is issued, certain administrative actions will require the regulatory authority to reevaluate an existing CHIA. The regulatory authority must decide whether a CHIA needs to be modified in light of some proposed revision to an approved permit application package. As a practical matter, to trigger a reevaluation of the CHIA, a permit revision would have to involve activity that could potentially affect the hydrologic balance.

Prior to starting the CHIA process, the regulatory authority should review the permit application and determine whether the hydrologic information, data analyses and PHC statement in the application are acceptable. Do these items provide a complete and adequate description of the hydrologic systems that will be affected by the proposed operation? Does the application specify the magnitude of those effects? If these questions have not been answered or if the regulatory authority has not made such a determination, the CHIA process should not begin until these issues are resolved.

The CHIA is distinct from the PHC, although elements of the PHC are used to support and develop the CHIA. The CHIA is the responsibility of the regulatory authority, whereas the applicant must provide the PHC in the permit application package. The PHC focuses on how the proposed mining operation might affect hydrologic conditions within the permit and adjacent areas; the scope of the CHIA is much broader. A CHIA examines how the hydrologic affects of the proposed operation might add to those effects from other anticipated mining operations.

Anticipated mining is that set of SMCRA-regulated work sites, distributed across a landscape, over which hydrologic impacts from coal removal and reclamation could potentially combine to a measurable extent. A cumulative impact area (CIA) is uniquely associated with anticipated mining.

The term *anticipated mining* is from SMCRA, sections 507(b) and 510(b). In common parlance, *anticipated* connotes something that is expected to occur. However, federal coal regulations at 30 CFR 701.5, under the definition of cumulative impact area, assign a more expansive meaning to the term *anticipated mining*.

Anticipated mining includes prospective mining operations and all existing operations. A prospective mining operation primarily would be the proposed operation for which a permit application package has been submitted to the regulatory authority, but it also could possibly be a future operation for which there is adequate baseline and mine-development information. A future operation may be identified as such in the permit application under review or may have been discussed in some other permit application package that was subsequently approved to be a permit. Mine development information for leased federal coal could qualify as a future operation. In all cases, one could reasonably expect the regulatory authority would approve these operations some time in the future when formal application is made to bring them under permit.

An existing operation may be in the coal-production phase, may involve only reclamation activity, or may have been idled by temporary cessation or permit-revocation action. The defining characteristic of this class of existing operations is that the permittee still has reclamation liability for at least some portion of the acres that had been included in a permit issued under an approved, SMCRA-compliant permanent program. Another class of existing operations would be those mining activities for which a permit was not required under SMCRA (for example, coal recovery incidental to the extraction of other minerals).

Hydrologic impacts of individual mining operations will be minimized, though not eliminated, by adherence to mining regulations. Remaining or residual impacts, however small and individually insignificant, may, with the development of additional mines, accumulate to magnitudes that are significant and potentially damaging to the hydrologic balance. The CHIA is necessary to assure that such aggregate impacts will not be overlooked in the routine processing of individual permit applications. A CHIA could result in the denial or delay of a mining permit should the regulatory authority find that the proposed operation has credible potential for significantly damaging the hydrologic balance.

One might ask whether a CHIA is required if the proposed mine would be the first in some broad area. After all, the operative word in the CHIA concept is *cumulative* which seemingly necessitates the potential interaction of two or more anticipated mining operations. This issue was addressed in a preamble to OSM rules and regulations (OSM, 1983a). A commenter wanted OSM to state that when a proposed mine would be the first in an area, there would be no cumulative impacts and, therefore, no need for a CHIA. The OSM response was as follows:

> *While it may be possible that for a single hydrologically isolated mine the probable hydrologic consequences determination made by the operator would be adopted by the regulatory authority as the CHIA, nevertheless such a conclusion must be reached by the regulatory authority on a case-by-case basis.*

Hydrologic impact assessment is not a precise process. Because of the many uncertainties associated with hydrologic estimation, predictions made under the process proposed here, or under any similar process, must be considered as probable in nature rather than exact. Therefore, the regulatory authority must have the option of using professional judgment to make the final material damage determination. This should not detract from the significance of the process if the determination is based on the facts produced by a comprehensive analysis. Likewise, use of qualitative methods and techniques for the analysis is an acceptable option if the regulatory authority can show these to be adequate for the specific site situation.

Often, a permitting action that requires a CHIA will be for an operation in an area that had already been assessed for hydrologic impacts. As much as possible, the previously prepared CHIA should be reused in the new assessment. Not only does this save time for the regulatory authority, but it ensures some degree of continuity in how potential environmental effects of mining operations are evaluated in a given area. In particular, once material damage criteria have been established for a specific area, they would be applicable, with little modification, to all future CHIAs in that area.

Elements of the CHIA

CHIA development is a documented process that proceeds in a logical manner through a set of elements. It involves the analysis of critical aspects of the hydrologic system within a defined area. The purpose of the analysis is to predict the type and magnitude of impacts to the hydrologic system attributable to the proposed operation in conjunction with other anticipated mining. Thus, during the CHIA process, the regulatory authority should:

1. Provide general information about the situation and conditions dealt with in the CHIA by noting:
    - Why the CHIA is necessary (new mine application or significant permit revision).
    - Who is proposing the action that requires a CHIA.
    - Where the new regulated activity will occur.
    - What sort of mining activity is proposed for the site.
    - Whether any previously prepared CHIAs are incorporated into, or are related to, the present CHIA effort.
2. Specify all anticipated mining operations.
3. Delineate the cumulative impact area.
4. Give baseline hydrologic conditions.
5. Identify hydrologic resources likely to be affected by the proposed operation.
6. Establish material damage criteria.
7. Make a material-damage determination from estimated impacts of mining on hydrologic resources.
8. Prepare a statement of findings.

Some of the procedures and hydrologic concerns discussed in this technical reference document may not apply to every CHIA. Within the constraints of good hydrologic practice and those imposed by statutory and regulatory requirements, the regulatory authority has wide latitude to determine the exact manner in which individual elements will be evaluated. An assessment may be based on professional judgment or determined using rigorous analytical techniques. Professionals conducting the assessment should justify their specific assumptions and decisions. This justification is an important aspect of the CHIA process.

Cumulative Impact Area (CIA)

A CHIA is required by SMCRA for each application for a new mine permit or request to significantly revise an existing permitted operation. It is an integral part of the permit decision package. However, a CHIA is not unique to a specific minesite or permit area, but rather it applies to a CIA. The CIA is that region, including the proposed permit area, within which impacts on surface- and ground-water systems resulting from the proposed operations may interact with hydrologic impacts from all other anticipated mining.

The term *impact* does not necessarily indicate a severe or adverse condition. As used in this document, an impact is a measurable change in some characteristic which defines the quality or quantity of a water resource. The occurrence of an impact is distinct from the severity of the impact. Determination of the potential seriousness of impacts is considered a separate and distinct issue in the CHIA process.

A mining impact area is that zone where measurable changes to the hydrologic system have occurred or are likely to occur due to coal recovery and reclamation activities. The only way to delineate the true impact area is by monitoring representative hydrologic parameters at numerous sites over the total time period during which the impacts occur (from before mining until after hydrologic equilibrium is restored after mining). Since the impact area will not be known until after mining and reclamation are completed, it is not useful in preparing the CHIA. Therefore, the CHIA includes an estimation of the size, shape and location of the impact area which becomes the working CIA.

Qualitative Delineation of the Working CIA

The first step in delineating the CIA is to identify anticipated mining. This may be done by first locating the proposed operation in the landscape. Next, seek other mining operations, existing or prospective, whose hydrologic effects could combine with those of the proposed operation. Mining effects on both surface- and ground-water systems must be considered. The surface-water CIA is the geographic region that drains or impounds water that has a measurable chemical signature acquired through contact with anticipated mining and/or has discharge characteristics that can be attributed to activity at anticipated mining operations. The ground-water CIA is the geographic region overlying a three-dimensional body of porous, permeable earth material saturated with water that could be measurably affected in terms of quantity and quality by anticipated mining. A surface-water impact area may have a different size and shape compared to those of the associated ground-water system. The analysis procedures should take into account the interrelationships between the surface- and ground-water systems. The composite of these surface- and ground-water impact areas is the CIA.

The process for identifying anticipated mining at this initial phase is purely qualitative and founded on professional judgment. Consider the surface-water system. Runoff from the site of the proposed operation will eventually commingle with runoff from all other mine sites within a major river basin. However, it is unlikely that Congress intended anticipated mining to routinely include operations within whole river systems, as might be required if the preceding rationale were strictly followed. The downstream extent of a CIA that is environmentally comprehensive and also satisfies the intent of SMCRA probably lies somewhere between the downstream boundaries of the proposed permit area and the farthest downstream mine in the river basin. The additive effects between the proposed mining area and each other site within the basin must be measurable. Spatially remote sites may be eliminated for that reason.

The process of delineating the CIA focuses on the proposed mine site and runs through a series of pair-wise considerations. From the proposed mine, go out to the nearest potential anticipated mine site. Find the closest point on the common receiving stream below these two sites. How does the combined area of the two mine sites compare to the drainage area above the evaluation point on the receiving stream? One could reasonably expect that the cumulative effect of runoff from two mines could have a measurable impact on a small common watershed. That impact may not be measurable if the watershed above the evaluation point is orders of magnitude larger than the combined mine area. Increasingly distant mine sites are subjected to this qualitative, pair-wise evaluation process. Those sites that would likely have measurable cumulative effect on the common receiving stream qualify as anticipated mining. Nearness to the proposed operation alone may not be a valid criterion for identifying anticipated mining. The closest site may be in a different drainage basin, and the shared receiving stream may be quite remote.

A first approximation of the surface-water CIA is made by locating the furthest point upstream on the common receiving stream through which passes runoff from anticipated mining operations. Trace the watershed for that point. That watershed will contain the anticipated mining plus, most likely, a great deal of area that could not have contact with mine runoff, because it is at a higher altitude than anticipated mining operations. The regulatory authority must decide to either delineate the surface-water CIA as a watershed or restrict it to only that portion of the land surface that truly conveys mine runoff. The latter would begin as zones of overland flow across anticipated mine sites. From these zones, runoff would eventually be conducted through a system of merging stream channels and floodplains. The scale at which the surface-water CIA is mapped may determine which of these two alternatives would be more appropriate. Anticipated mining distributed over a large area would have to be displayed on a small-scale map. Here, a surface-water CIA would be better depicted as a watershed; otherwise the downstream true area of contact with mine-affected runoff would simply appear as a network of fine lines.

The process for approximating the ground-water CIA follows that for the surface-water CIA. Again, the first step is to identify anticipated mining. Anticipated mining in terms of ground-water effects may not be the same set of sites that comprises anticipated mining for surface-water impacts. Should the proposed operation potentially jeopardize one or more aquifers, then every other operation that might also measurably affect these same aquifers would qualify as anticipated mining. Hydrologic impacts in this context might include solute plumes from mine workings or draw-down cones from mine dewatering wells.

A conceptual model of the sub-surface flow system is essential for predicting possible movement of solute plumes. The model must identify the aquifer or aquifers that might be affected by mining and identify their areas of recharge and discharge. Hydrogeologic information needed to develop the model should be provided in the PHC determinations for the proposed operation and other anticipated mine operations.

Having identified anticipated mining, the next step is to trace the boundary of the ground-water CIA. For each at-risk aquifer, choose a series of conceptualized flow lines along which pollutants from a given anticipated mine operation might travel. These flow lines would be deduced from the potentiometric surface as revealed by water-level monitoring data. Pick a location along each of these lines that mark the furthest estimated advance of a measurable concentration of some mine pollutant. Connect the points and extend the boundary upgradient around the anticipated mine. Adjust the boundary to include areas that are expected to experience significant lowering of water levels as a result of pit or aquifer dewatering

An aquifer affected by mining may discharge to the surface. The zone along which this occurs is the line of transition from potential ground-water impacts to surface-water impacts, and, as such, locally establishes the downgradient border of the ground-water CIA. The discharge areas of some aquifers may be so far from anticipated mining that migration of degraded water to these points would require decades or centuries. A boundary of the CIA could be set along some line upgradient from the discharge zone to mark the estimated extent of a hypothetical degraded water plume after a specified travel time. The regulatory authority should discuss the rationale for choosing the travel time used in this determination. Given the right hydrogeologic setting, hydrodynamic dispersion—the process by which ground water containing a solute is diluted with uncontaminated ground water as it moves through an aquifer—ensures that the solute concentration will eventually drop to a level too small to be environmentally significant. Ground-water modeling may be used to estimate where a hypothetical contaminant plume fades into insignificance.

The zone of impacted ground water around the proposed operation may merge with affected ground water from one or more anticipated mine operation resulting in a cumulative effect on the water resource. On the other hand, geology, geomorphology and past mining activity may create highly localized flow systems in a coal field such that the proposed mine operation, in terms of ground water, may be hydrologically isolated from all other operations. Suppose, for example, the target coal seam is the primary water storage and transporting stratum. Further suppose, a previous operation had long ago mined the more accessible portions of the coal along the contour. This left a ring of abandoned surface-water impoundments around what had once been economically unrecoverable coal. The remnant coal bed aquifer is recharged by infiltration through the overburden and it discharges into the abandoned mine pits.

If the regulatory authority finds that a scenario such as described above applies to the proposed mine operation for which the CHIA is being written, there is no cumulative ground-water impact area. Otherwise, an impact area would be delineated for each affected aquifer. The ground-water CIA is the composite area of the individual aquifer impact area. The working CIA is the composite of the surface- and ground-water CIAs. The regulatory authority is responsible for delineating a CIA that makes environmental sense. By strictly "following the water," the regulatory authority should be blind to administrative boundaries. A CIA can extend across state lines.

Figures 1 through 5 illustrate the process for defining the CIA. The two ground-water impact areas do not intersect (Fig. 4); therefore, there is no cumulative effect of mining on the ground-water system. However, impacted ground water would discharge to the receiving stream shared by the two anticipated mining operations. The surface-water system ties the two ground-water impact area together within the working CIA.

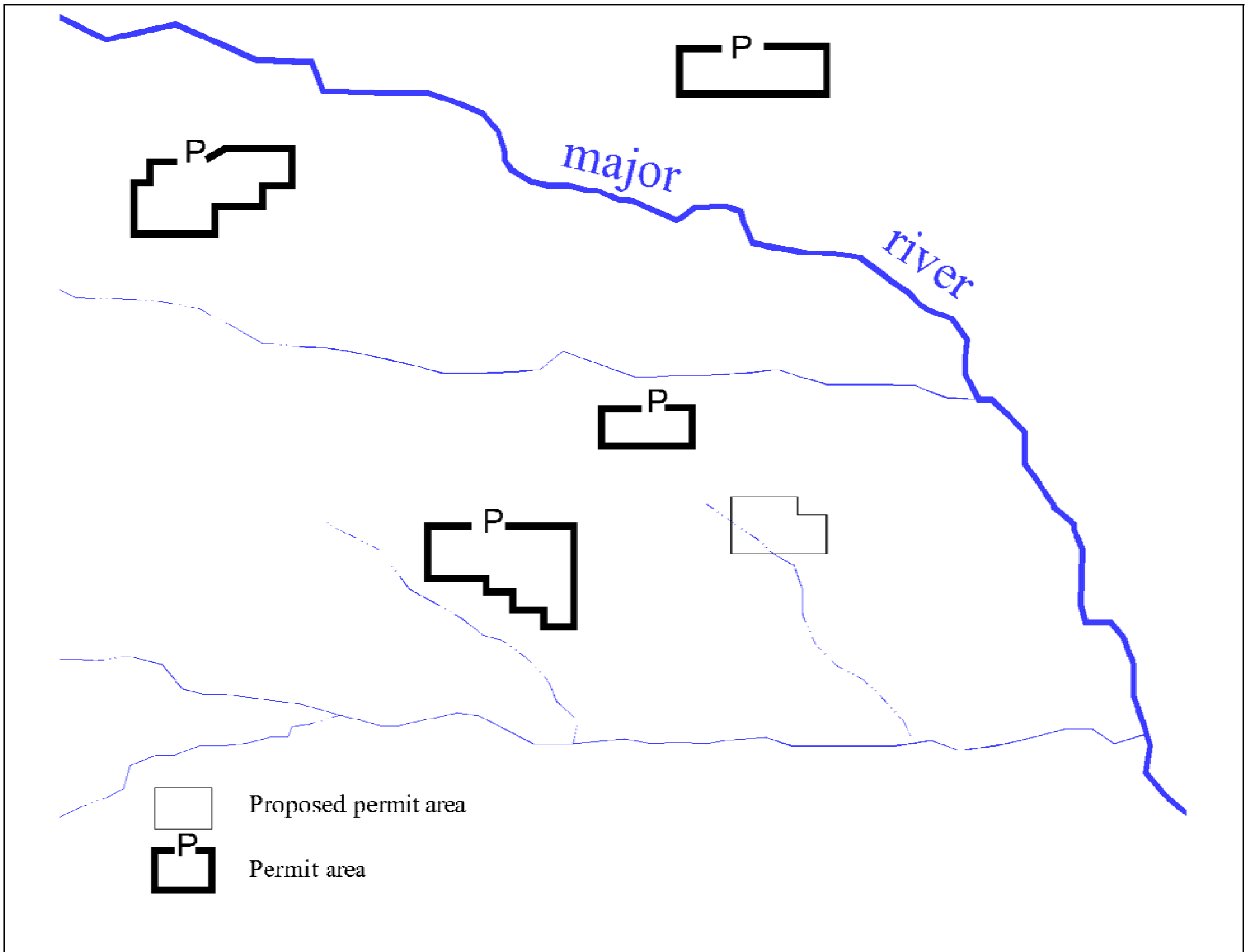

Figure 1 Proposed and existing mine permit areas.

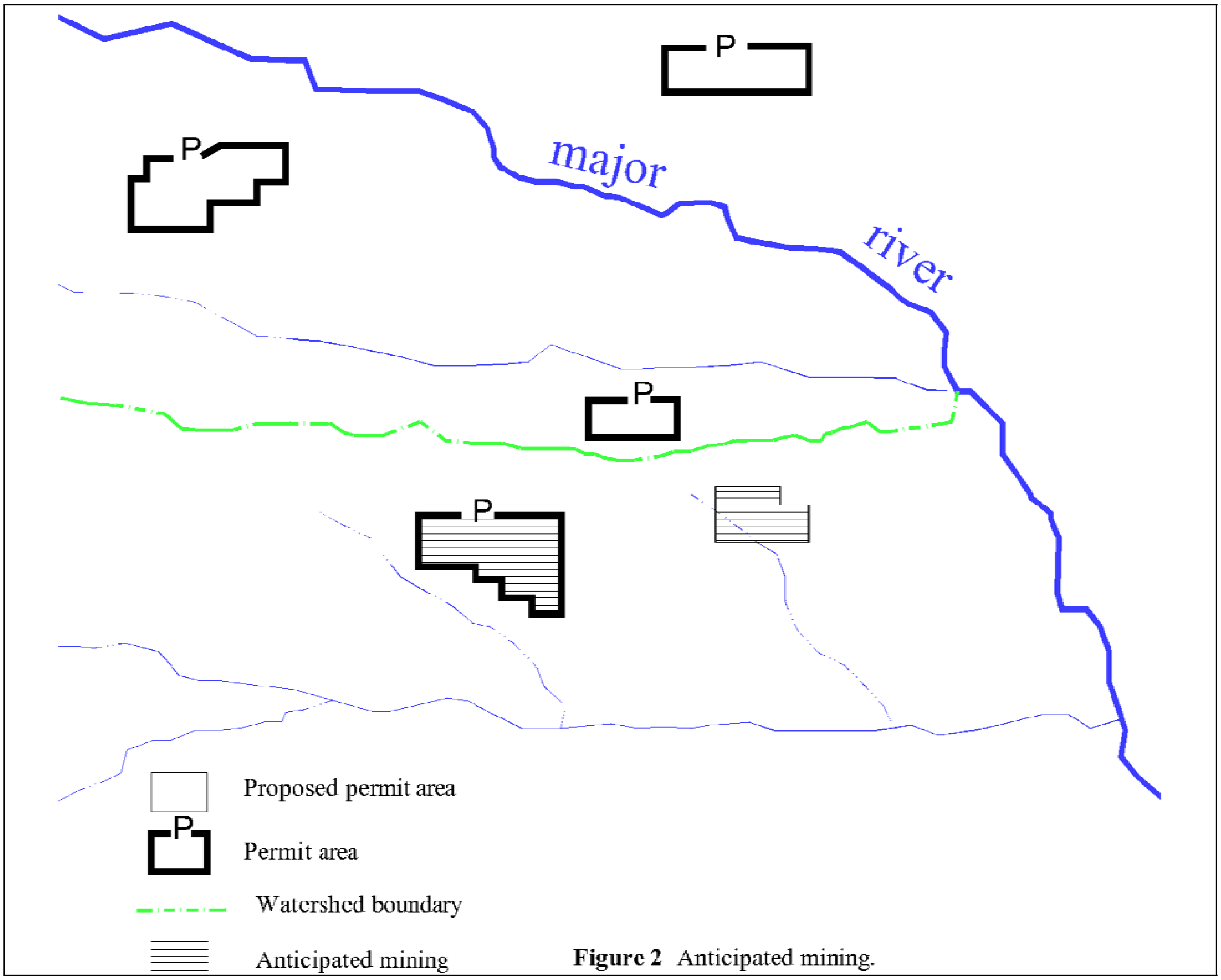

Figure 2 Anticipated mining.

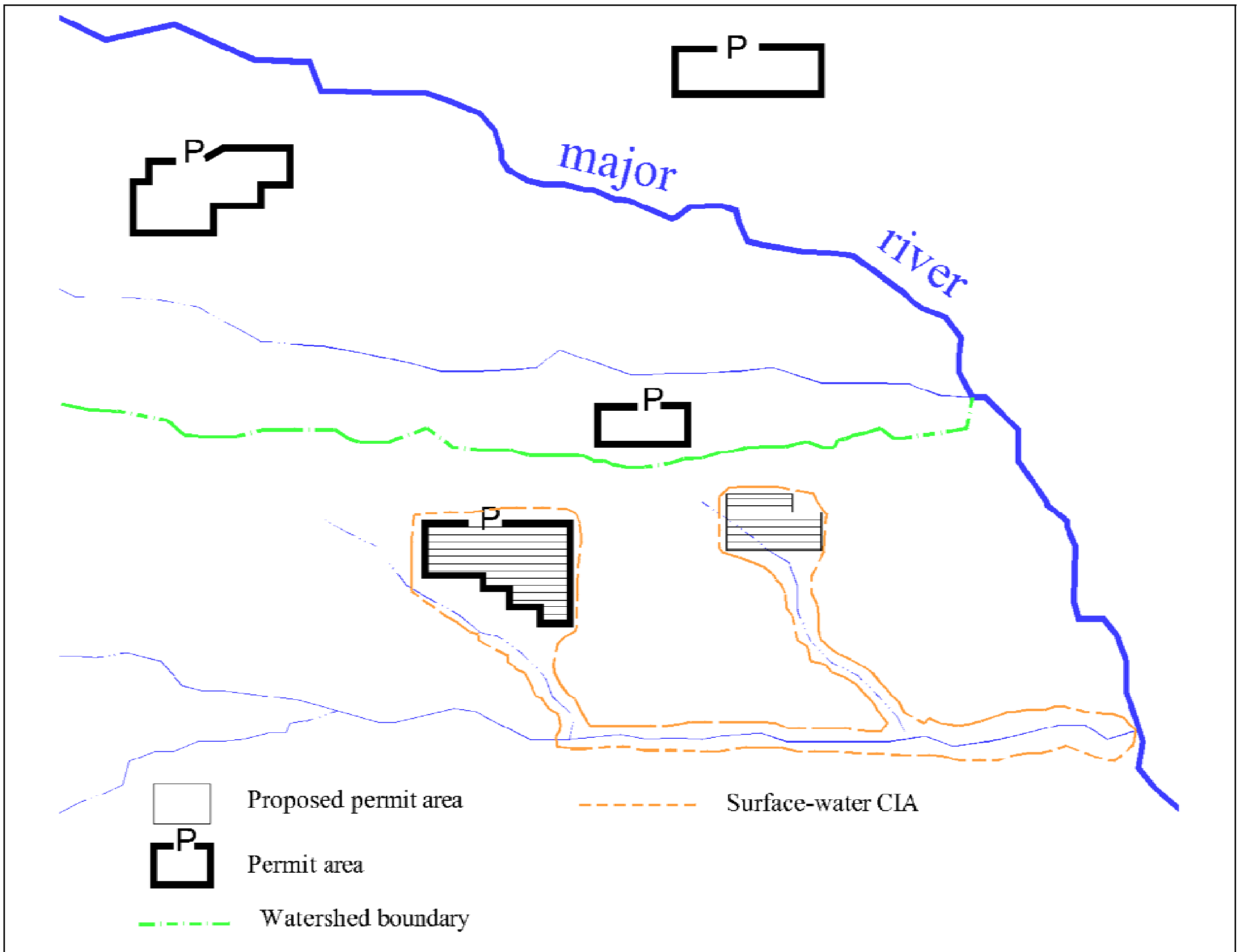

Figure 3 Delineation of surface-water CIA.

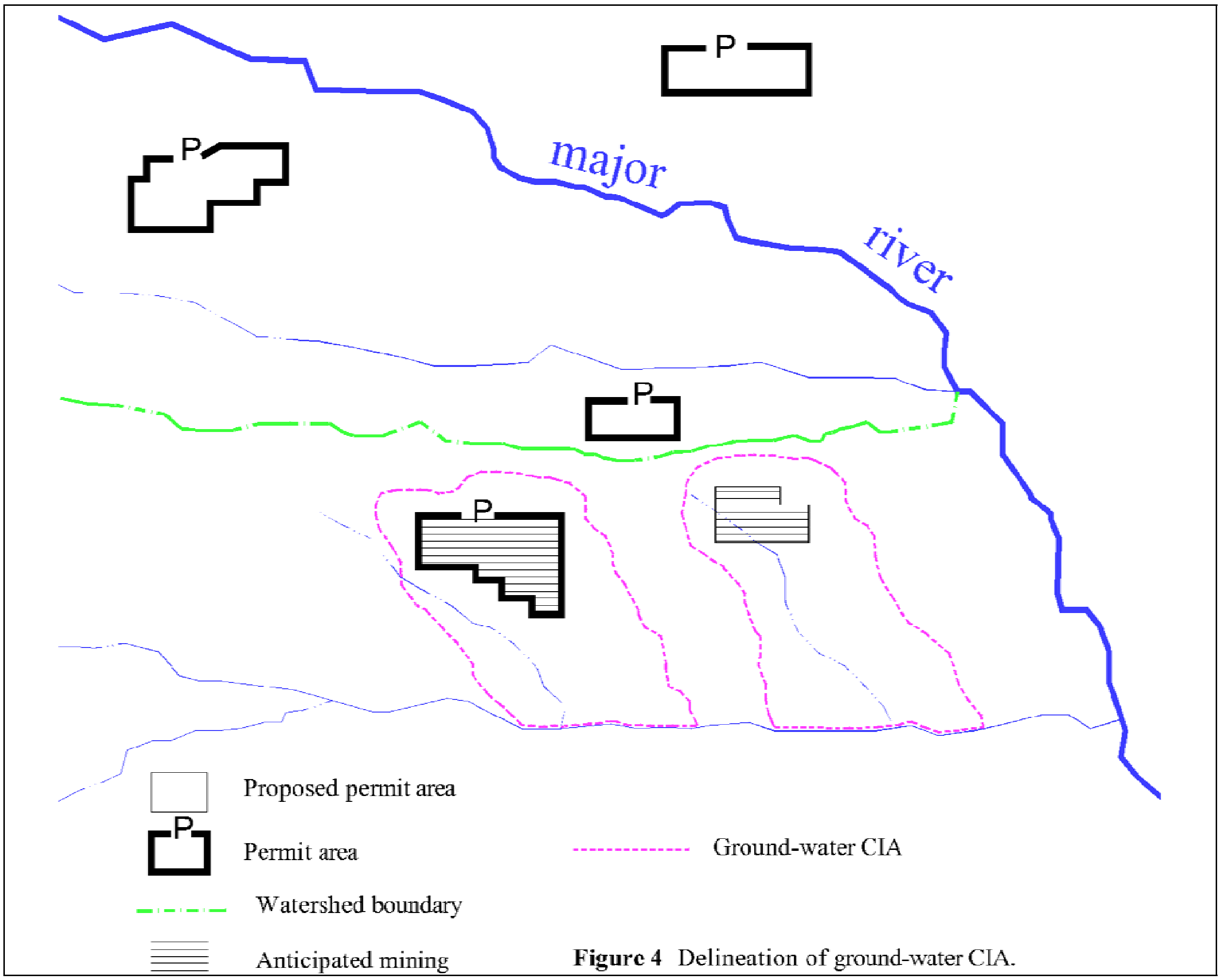

Figure 4 Delineation of ground-water CIA.

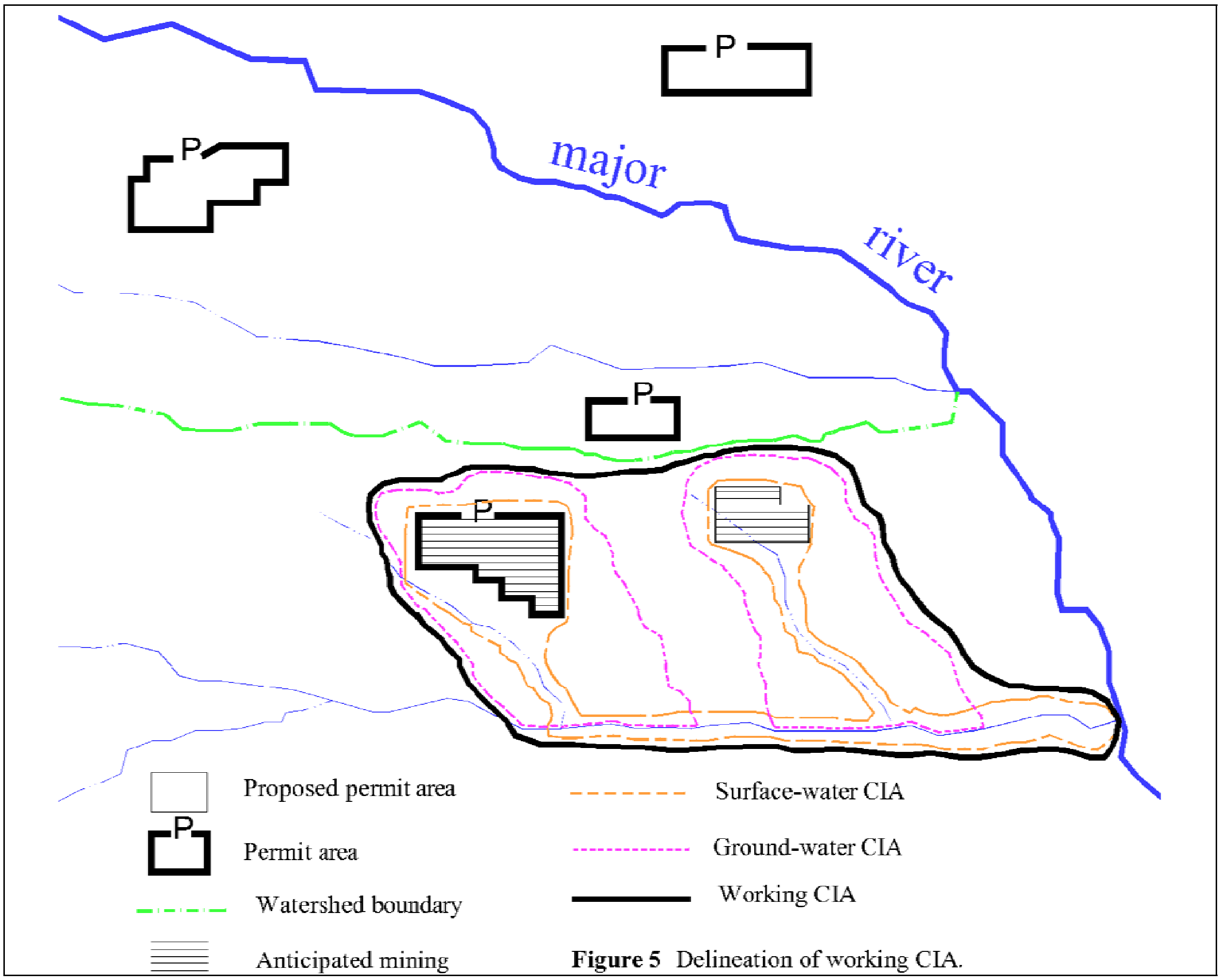

Figure 5 Delineation of working CIA.

Should the CIA of a mining operation cross into an adjoining state, it may be prudent for the regulatory authority writing the CHIA to provide notice of the CIA and impending permit action to relevant authorities in the adjoining state Notification may result in a cooperative effort to ensure the mining activities do not have a cumulative adverse effect on water resources of each state's respective territory. Cooperation between the states may result in an exchange of experience and experts, as well as exchanges in information on water management regulations and guidelines. Communication may result in joint participation in scientific and specialist meetings and may lessen the possibility of future legal proceedings involving the coal-mine operation.

In those situations where there is a potential for a transborder hydrologic impact as a result of the proposed mining operation, the state regulatory authorities may want to consider committing themselves to the development of early detection schemes and relevant action plans. By working together, the states may be able to prevent or lessen the effect of the proposed operation on common water resources.

Quantitative Check of the Working CIA

A simplistic, qualitative consideration of dilution effect in the downstream direction could be a basis for identifying anticipated mining and estimating the surface-water CIA. The next step in the CHIA process would be to develop criteria for checking the validity of that estimate. By definition, a hydrologic impact is a *measurable* change. Quantitative criteria should specify the parameters to be evaluated and the associated ranges of measurement error.

Once developed, the criteria can be applied along receiving streams common to the proposed operation and other presumptive anticipated mining operations in its vicinity. Several points may be tested where more than one common stream originates in or flows through the working CIA. When appropriate, upstream as well as downstream evaluation points should be located. The downstream limit of the working CIA should be a point in the flow system below which impacts from designated anticipated mining, when added to those from mine operations outside the working CIA, would be less than the inherent error of the measurement techniques used.

Lumb (1982) gives a formula for estimating the concentration of an aqueous constituent at a given critical point in a drainage basin. Constituents that might be used in this mass-balance technique—for example, chloride, sulfate and TDS—would be treated as conservative solutes. Conservative solutes do not precipitate, react with sediments, or undergo biological decay. A mass-balance analysis requires some measured concentrations, and that may limit the choice of the solute. Chloride is a true conservative solute that is widely used in tracer studies, but it may not be as routinely measured in mid-continent coal-producing areas as sulfate or TDS. Sulfate is a quasi-conservative solute. It can exist at high concentration in stream water before it begins to be removed from solution by the precipitation of gypsum, a quite-soluble hydrous calcium-sulfate mineral. Barium sulfate and strontium sulfate are much less soluble than gypsum, but neither barium nor strontium is found in much abundance in natural waters (Fetter, 1993). Sulfate is derived from the oxidation of sulfide minerals and is a primary chemical constituent indicating coal-mine drainage. Consequently, coal regulations may require permittees to routinely monitor sulfate in streams and ground water. In addition, the NPDES permit may mandate regular measurement of sulfate in water running off the mine site.

Strictly speaking, TDS is not a solute, because it is the sum of all dissolved species. Some components of TDS such as heavy metals are themselves not conservative solutes, because they readily adsorb on sediment particles that may settle and not reach the downstream critical evaluation point. Nevertheless, because sulfate is probably the major component of TDS from coal field runoff, TDS may be considered a quasi-conservative solute.

Baseline Conditions

Baseline information characterizes the state of the hydrologic system before the proposed mine operation imposes any changes to that system. Much of the needed hydrologic and geologic information should be available in the permit application package. If anticipated mining includes existing operations, then the water–monitoring record for those operations becomes part of the baseline data set for the CHIA.

Minimum baseline surface-water information is an inventory of streams, lakes and impoundments in the proposed permit and adjacent areas with a description of the seasonal variability in flow rates, quality and usage of those water resources. Water quality is to be characterized by measurement of at least total suspended solids, TDS (or electrical conductivity corrected to 25ºC), pH, total iron, and total manganese. Baseline acidity and alkalinity information should be provided if there is a potential for acid drainage from the proposed mining operation.

At a minimum, baseline ground-water information should include a water-user survey which identifies the location and ownership of wells and springs within and adjacent to the proposed permit area and the approximate rates of usage or discharge of those ground-water resources. Minimum requirements also include seasonal measurements of depth-to-water in the coal seam and each water-bearing stratum above and potentially affected stratum below the coal seam. The permit application package is to contain data on the seasonal quality of water produced from these strata with that quality characterized by measurement of at least TDS (or electrical conductivity corrected to 25ºC) pH, total iron, and total manganese.

In the context of the CHIA, the term *adjacent area* means a zone extending out from the permit boundary where water resources are, or reasonably could be, expected to be adversely affected by mining operations (surface or underground) associated with that permit. The boundary of the water-user survey area coincides with the outside edge of the specified adjacent area (Fig. 6).

Some regulatory authorities may establish a single, fixed zone for all water-user surveys. That zone might coincide with the preblasting survey area which is located within one-half mile of any part of the permit boundary. Furthermore, a regulatory authority may choose to require a permit applicant to establish the baseline quality of impounded water or private well water within the survey zone and measure the productive capacity of those private wells. Water-user inventory information would be used to determine whether mining has adversely affected individual water supplies.

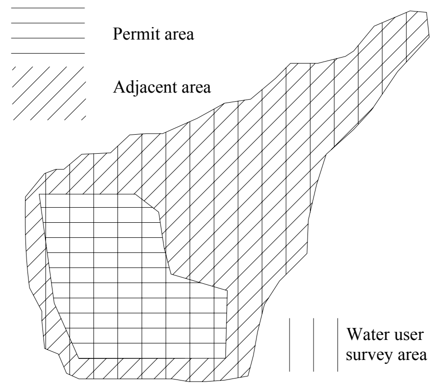

Figure 6 Relationship between permit area, adjacent area, and water-user survey area.

In-depth information about collecting, evaluating and using baseline water data in the permitting process can be found in *Permitting Hydrology, A Technical Reference Document for Determination of Probable Hydrologic Consequences (PHC) and Cumulative Hydrologic Assessment (CHIA)—Baseline Data* (OSM, 2002). This document covers a wide range of topics such as: geology, overburden analysis, quality assurance/quality control procedures, data management and analysis software, national data bases and it includes a mid-continent (Texas) site among its regional examples of baseline information.

Identification of Hydrologic Concerns

The regulatory authority must identify changes to hydrologic resources that could result from the proposed operation in conjunction with other anticipated mining operations and estimate the importance and likelihood of those changes. Hydrologic concerns are an expression of potential impacts related to water use, hydrologic balance and geomorphology. In order to judge the severity of potential problems, it is necessary to select measurable physical or chemical characteristics that relate to the specified problems. The regulatory authority will establish material damage criteria from among the hydrologic concerns.

Most concerns will be specified in the PHC portion of the permit application package. Others may be inferred from hydrologic characteristics of the permit and adjacent areas. Concerns grow out of a consideration for: (1) the location of the source of supply for all surface-water and ground-water uses, (2) the quantity and quality of water required to meet demands of the different uses, and (3) the susceptibility of land to erosion or burial under excess sediment. Publications of state agencies may provide information related to local or regional problems that could be applicable to specific concerns in the cumulative impact area. The regulatory authority should check for the presence of officially designated impaired streams (those qualifying under Section 303(d) of the Clean Water Act).

Section 303(d) of the Federal Clean Water Act (Title 33 Chapter 26 Subtitle III §1313(d)) requires states to identify waters that do not meet water quality standards after applying certain required technology-based effluent limits (*impaired* water bodies). States must compile this information in a list and submit the list to EPA for review and approval. As part of this listing process, states are required to rate waters/watersheds in order of priority for future development of total maximum daily loads (TMDLs). States have ongoing efforts to monitor and assess water quality, to prepare the Section 303(d) list and to subsequently develop TMDLs. A state's most recent 303(d) list can be found through www.epa.gov/OWOW/tmdl/.

Table 1 shows interrelationships between water use, hydrologic balance and geomorphic conditions. Hydrologic concerns may relate to more than one of the three factors. For example, flow rate applies to water availability, seasonal variation and channel erosion. Each factor should be considered separately. The regulatory authority's objective is to identify quantity and quality criteria that will protect water use, the hydrologic balance and maintain geomorphic stability.

Table 1 Potential hydrologic concerns as related to the cumulative impact area

WATER USE

1. Domestic
2. Agricultural
   a. Irrigation
   b. Livestock
3. Industrial
   a. Boiler/process
   b. Cooling
   c. Hydro power
4. Instream
   a. Aquatic life
   b. Recreation

CUMULATIVE IMPACT AREA HYDROLOGIC BALANCE

1. Base flow
2. Surface-water quantity
3. Surface-water quality
4. Ground-water quantity
5. Ground-water quality

GEOMORPHIC CONDITIONS

1. Upland erosion
2. Channel erosion
3. Excess sedimentation

HYDROLOGIC CONCERNS

1. **Quality** (both surface and ground water)
   a. pH, acidity/alkalinity
   b. Dissolved solids
   c. Sediment
   d. Temperature
   e. Toxic constituents
   f. Sodium adsorption ratio
   g. Odor, color, staining

2. **Quantity**
   a. Surface water
      1) Flow rate
      2) Volume
      3) Distribution
      4) Seasonal variation
   b. Ground water
      1) Transmissivity/hydraulic conductivity
      2) Potentiometric/water-table surface
      3) Direction of flow
      4) Recharge/discharge

3. **Geomorphology**
   a. Slope instability due to excess pore-water pressure
   b. Stream channelization—loss of meander pattern
   c. Pool-riffle ratio

Baseline data should identify water use in the permit and adjacent areas of each operation that qualifies as anticipated mining. Ideally, this should cover all land within the CIA where water resources are, or reasonably might be, adversely affected by surface- or underground-mining activity. As illustrated in Table 1, water use can be sorted into a number of categories. Agricultural water might be used for irrigation or livestock watering. Demand for irrigation water should peak about the same time throughout the CIA. If the balance between water supply and demand is tenuous under baseline conditions, then the regulatory authority should be concerned that any reduction in water availability that might result from the proposed operation could harm water users. Quality parameters for irrigation are usually TDS, sodium-adsorption ratio and concentration of potentially toxic constituents such as boron. The regulatory authority might find that crops typically grown in the CIA have particular sensitivity to other parameters. A high level of suspended solids and an objectionable taste, odor, or color can cause farm animals to drink less than they should. A state's university extension service should have guidance documents on water-quality criteria for livestock drinking. The U.S. EPA has set national drinking water standards for domestic water.

Primary standards are enforceable for public water systems; secondary standards are non-enforceable guidelines regarding contaminates that may cause cosmetic effects (skin or tooth discoloration) or aesthetic effects (taste, odor, or color). Constituents of concern in domestic water include: TDS, sulfates, nitrites, radioactivity, hardness, sediment, pH, Fe, Mn and bacterial quality. Usually mid-continent coal mining will not affect bacterial or radiological characteristics of water. Different water-quality criteria apply to different industrial uses for that water. An industrial use may be as process water in a manufacturing or food preparation operation, cooling or boiler-feed water, or hydro power. Quality criteria for industrial water are not necessarily less restrictive than those for drinking water. Instream use usually requires a certain minimum flow before adverse impacts occur. Temperature, pH, sediment load and solute concentrations may limit a stream's use for fish propagation. Suitable ranges of values are species dependent. Unique situations, such as the protection of endangered or threatened species and their habitats, may require other considerations as determined by the U.S. Fish and Wildlife Service. Boating and swimming are examples of recreational use. These activities could be restricted by water quantity changes and they require certain water chemistry for safe whole-body contact.

Hydrologic concerns vary across the eleven states of the Mid-Continent Region because of differences in precipitation amounts, temperature, water uses, geomorphic conditions and geology. Typical hydrologic concerns are listed below and include only some of the possibilities. At each specific site and CIA, the hydrologic concerns must be determined on the basis of water usage in the area, established water-quality standards and local hydrologic conditions.

1. Reductions in the quantity of available surface water and ground water may be critical, because existing supplies in the region are relatively scarce. Available supplies may be reduced as a result of changes in surface runoff conditions or lowering of ground-water levels.
2. Increases in TDS or sodium adsorption ratios in surface water or ground water may cause critical crop production losses where supplies are used for irrigation.
3. Increases in the concentration of total suspended solids may cause destruction of aquatic habitat or the loss of reservoir storage capacity due to siltation.
4. Changes in flow rates or suspended-solids load of a stream can change the erosional balance (down cutting of channels, silting up of pools and riffles or altering channel sinuosity).

5. Mine spoil or coal processing waste may release excessive concentrations of some chemical constituents into water supplies rendering the water unsuitable for industrial processes or harming aquatic organisms.
6. Changes in conditions affecting surface-water runoff may add to the flood hazard of a watershed.

Things other than regulated coal mining can stress the hydrologic system. Existing or potential sources of impacts within the CIA may include logging, agriculture, reservoir releases, oil and gas production activity, effluent from public or private sewage systems, landfills and non-coal mining operations (sand and gravel workings, rock quarries, etc.).

Establishing Material Damage Criteria

Section 510(b)(3) of SMCRA requires the regulatory authority to determine whether the proposed operation has been designed so that its impact on water resources, when combined with impacts from all other anticipated mining, will prevent material damage to the hydrologic balance outside the permit area. Neither SMCRA nor its enabling federal regulations define the term *material damage to the hydrologic balance.* Federal regulations at 30 CFR 701.5 define material damage in the context of subsidence, and these regulations go on to specifically tie the meaning of the expression *materially damage the quantity and quality of water* to alluvial valley floors. These definitions contain a key concept—material damage occurs when some customary or reasonably foreseeable use is denied or significantly degraded by the mining operation. Each Mid-Continent Region state may define the term *material damage to the hydrologic balance* as appropriate to that state. Nevertheless, one might declare the expression to mean any long-term or permanent change in the quantity or quality of surface or subsurface water caused by coal mining and reclamation operations that precludes customary or designated use for those affected water resources (as recognized by the regulatory authority) or that results in property damage, and such change can not be satisfactorily mitigated.

Mining may not only degrade the environment in terms of water use by people or fauna, but it may cause property damage by altering stream channel stability or peak-flow discharges. Material damage is too expensive to mitigate. Material damage implies that mining cannot proceed because the impact is deemed too severe. Examples of material damage are permanent destruction of a major regional aquifer and long-term contamination of an aquifer in use for which there is no suitable replacement water supply.

A measure of the severity of a mine's affect on the environment might be the extent to which a given aspect of the hydrologic balance deviates from baseline conditions. This approach could rely on the calculation of a prediction interval; the width of the interval is a function of the variability and size of the baseline data set. The prediction interval estimates bounds on some future parameter, specifically the next k measurements from a given monitoring station. The number of future values, k, may be as small as one. Values measured after the baseline study period that fall outside the prediction interval indicate the baseline and post-baseline populations are statistically different at some specified level of confidence (often 95%) and that some activity in the CIA has affected the hydrologic balance. For water contaminants, comparison is usually made to the upper prediction limit. A future value above the upper prediction limit is taken to be statistically significant evidence of contamination. As few as four (eight or more is preferred) baseline values are needed to calculate the prediction interval. Baseline data must be normally distributed or able to be transformed into a normal distribution (e.g. taking the natural logarithm of each value). Non-parametric prediction intervals can be calculated for non-normally distributed data or data that includes a high proportion of nondetects, but more baseline values are needed than with the parametric method. See EPA, 1992 for a discussion of prediction intervals.

Statistically valid evidence of contamination does not prove material damage. Surface coal mining will likely add pollutants to local water resources, at least for the short term. The regulatory authority should establish material damage in terms of specified water uses. Material damage criteria based on water use should consider both in-stream and out-of-stream requirements. This means that water-contact recreation, fish habitat and the needs of aquatic organisms must receive equal consideration with industrial, domestic and agricultural uses.

The Clean Water Act (common name for the 1977 amendment to the Federal Water Pollution Control Act Amendments of 1972) established the basic structure for regulating the discharge of pollutants into waters of the United Sates. The Act also required states to set water quality standards for contaminants in surface water and, through implemented regulations, mandated that states develop an anti-degradation policy. The Federal Register, Vol. 48, No. 217, Tuesday, November 8, 1983, explains the anti-degradation policy and presents a three-tiered approach to maintaining and protecting various levels of water quality and uses. At its base (40 CFR 131.12(a)(1)) regulations require that existing instream water uses and the level of water quality necessary to protect the existing uses shall be maintained and protected. The second level (§131.12(a)(2)) provides protection of actual water quality in areas where the quality of the water exceeds levels necessary to support propagation of fish, shellfish/wildlife and recreation in and on the water. Some limited water-quality degradation is allowed after extensive public involvement as long as the water quality remains adequate to fully protect existing uses. Finally, §131.23(a)(3) provides special protection of *outstanding National resource waters* for which ordinary use classification and water-quality criteria do not suffice. These include the highest quality waters of the United States, and those that are important, unique or sensitive ecologically but with existing water quality that may not be particularly high.

The anti-degradation policy <u>does not</u> prohibit any activity that would reduce water quality. Rather, the policy is directed against those activities that would partially or completely eliminate an existing water use. An existing use can be established by demonstrating that a use has actually occurred since November 28, 1975, or that the water quality is suitable to allow that use to occur.

Lumb (1982) recognized that the regulatory authority must determine material damage to the hydrologic balance by identifying water uses and the acceptable level of impact. He further recognized that numeric stream standards indirectly or directly relate to material damage, and one can compare these numbers to estimate conditions that might result from the proposed mine operation. The regulatory authority should include a rationale for each limit placed on a water quantity or quality characteristic beyond which, material damage may occur. This technical reference document makes no distinction among the terms *limit*, *criterion*, *standard*, and *threshold*.

Material damage criteria provide standards against which the regulatory authority compares predicted hydrologic impacts from anticipated mining. The comparison is made at some evaluation point that is sufficiently remote from the proposed operation so that it can also be measurably affected by all other anticipated mining but not so remote that effects from the proposed mine would be too slight to measure.

Multiple agencies within a state may have standards for attainment of specified-use water quality. EPA (1986) provides information on the toxic levels of many water-polluting substances relative to specific uses which is often mirrored in state standards. Counties and cities (especially the larger metropolitan areas) may also have their own water standards. Should a CIA cross a state line, the regulatory authority must set material damage thresholds that protect water uses in that neighboring state.

Specified water uses may include: aquatic life, human health for drinking water or fish consumption, recreation, industrial, livestock watering, and irrigation. Damage to the specified use occurs when a pollutant or condition has excessive concentration or magnitude, the duration of the harmful event is too long, and the frequency of the harmful event is too high. The regulatory authority may quantify possible mine-related changes in water characteristics in the CIA and compare those changes to established standards. But, the regulatory authority must always be mindful that a predicted exceedence in a criterion would not be considered material damage to the hydrologic balance unless the duration and frequency of the event will likely cause long-term denial or impairment of a specified or customary water use.

The regulatory authority should assemble existing standards that apply to the hydrologic resources of the CIA and determine which, if any, of the hydrologic concerns of the CHIA are not covered by those standards. Although material damage criteria may not be established for all the constituents of concern, water quality issues can generally be addressed with established standards. Indeed, the regulatory authority is more likely to confront a situation where standards are much more comprehensive than would apply to coal mines. For example, published standards typically include markers for biological contamination (fecal and coliform bacteria) and many organic compounds (pesticides, herbicides, solvents) plus a host of inorganic compounds for which there would neither be baseline data nor a requirement by the regulatory authority for coal permittees to systematically measure these solutes in the waters of the CIA. Should the proposed operation include a plan to deposit coal combustion by-products at the mine, however, the regulatory authority might have to set material damage criteria for a large suite of constituents.

Hydrologic concerns that are most likely to lack standards relate to ground water. In situations where the aquifer discharges into the surface stream system, the effects of this discharge on the quality of surface flows should be considered in developing material damage criteria for ground-water quality. Major concerns about the cumulative impacts of the mining on ground-water availability, on the other hand, tend to focus on pumping requirements and maintenance of baseflow to streams. Mining may draw down the potentiometric surface of aquifers near active workings. One may express material damage criteria for ground-water quantity in terms of changes in these water levels. Deleterious changes can also be in the opposite direction. High water tables can damage fields and pastures, flood basements or cause landslides when pore water pressure within slopes becomes excessive. Material damage criteria may need to address both increases and decreases in hydraulic head. The development of these criteria then becomes a matter of determining how much change in head can be sustained without rendering a water supply unusable or causing other environmental problems.

Geomorphic concerns are another area where the regulatory authority may find it difficult to set material damage criteria. Soil conservation agencies may have soil-loss guidelines the regulatory authority might cautiously adopt as material damage criteria. Upland erosion, per se, is not a hydrologic issue; the fouling of surface water with sediment from those areas is. Mines can alter stream flow which can affect streambed morphology by the loss, gain or displacement of pools and riffles. Sinuosity of the channel may also change to accommodate mine-related disturbance in the watershed. These disturbances can affect aquatic life which is an instream water use. One might be able to place a threshold on geomorphic changes above which material damage occurs, but the regulatory authority will have to predict the magnitude of a geomorphic response to some specified change in the hydrologic regime in order to test whether the proposed operation will cause material damage.

Analysis of Cumulative Hydrologic Impacts

The regulatory authority's task is to estimate the magnitude of change in indicator parameters that can be expected as a result of mining. Indicator parameters are those water-quality, water-quantity and perhaps geomorphic measures that have been assigned material damage criteria. Estimating future values of hydrologic parameters is uncertain at best, as is the task of clearly defining what constitutes material damage and what does not. One cannot be certain of the correctness of answers provided by hydrologic-estimating procedures. Also, different procedures may result in a range of values that straddle critical levels. Damage levels may cover ranges rather than be single, precise values. To make material damage determinations solely by comparing estimated values to single-value criteria ignores the natural variability of hydrologic processes.

Methods for predicting cumulative impacts may be either qualitative or based on empirical equations and statistical analyses. Qualitative methods rely heavily on the experience/training of the user and minimize the need for numerical calculations. A qualitatively defined material damage threshold requires a qualitative analysis of cumulative hydrologic impacts. Results are more general than those achieved through quantitative methods which require more data. Quantitative techniques may vary from fairly simple analyses to more intricate methods utilizing complex calculations or modeling. The regulatory authority should consider the accuracy needed for a particular impact analysis, the information available for the CIA and the time and resources available to do the analysis. Ultimately, only long-term monitoring is the test for the accuracy of any CHIA prediction.

Analysis of cumulative hydrologic impacts could be a three-step process: (1) selection of an analytical approach; (2) selection of the specific techniques and methodologies to be used; and (3) analysis. Two basic analytical approaches might apply to the CHIA. One approach is to combine estimated values of indicator parameters presented in the PHC portions of individual mine plans into composite impact values for the CIA. Use of this approach requires the regulatory authority to develop a PHC for any anticipated mining operation for which a PHC is not available. The other approach is to make an independent hydrologic analysis of the CIA using raw data provided in the permit application packages for anticipated mine operations, as well as pertinent data from post-baseline water monitoring reports for stations throughout the CIA. Among anticipated mining operations, different analysts perhaps using different sets of analytical techniques may have prepared the PHCs. Under the combinational approach, the actual summing of these PHC results to obtain the cumulative impacts would involve yet another set of techniques and another analyst (that is, the regulatory authority). Each analyst is likely to make assumptions about the hydrologic system. On the other hand, the independent analytical approach ensures the same evaluation techniques would be applied over the entire CIA by the same analyst.

After choosing an analytical approach, the regulatory authority selects suitable hydrologic estimation techniques in step two of the analysis process. The combination approach for some hydrologic parameters requires a procedure for compiling individual estimated values that goes beyond simple addition. For example, a discharge-weighted technique is needed to find the concentrations of solutes at different locations in the stream system.

Lumb(1982) provides guidance and examples for determining mining impacts. His mass-balance estimate is appropriate for solutes that are not likely to precipitate. Baseline or background concentrations of these solutes are needed for the general area—the surface- and ground-water basins potentially affected by the proposed operation. An estimate of solute concentrations is also needed for the proposed permit area. Estimates may be those given in the PHC or those independently made by the regulatory authority. The new concentration at some evaluation point (the critical point) is:

$$C_{nc} = \frac{Q_a C_a + Q_c[(A_c - A_a)/ A_c] C_g}{Q_a + Q_c[(A_c - A_a)/ A_c]}$$

Where:
C_{nc} = new concentration at the critical point,
C_g = concentration from the general area,
C_a = concentration from the anticipated mine area,
A_c = drainage area above the critical point
A_a = anticipated mine area in the drainage basin,
Q_a= average flow from the anticipated mining area in the drainage basin, and
Q_c = average flow at the critical point

Each state or larger subdivision of the Mid-Continent Region will have published equations for determining low, average and peak stream flows. For example, the U.S. Geological Survey has a series of open-file reports of water-resources investigations for the western interior coal province covering areas in Iowa, Kansas, Missouri, Oklahoma and Arkansas. See Appendix C of OSM (2002) for more information on these national coal area hydrology reports.

Under an independent analysis approach, the selected technique should adequately account for the dominant hydrologic processes occurring in the CIA. These processes define a real system and constitute the all-important conceptual hydrologic model. A step beyond the conceptual model is one that uses mathematical equations to simulate water flow or solute concentrations. The mass-balance estimate above is a simple model of that type. Other analytical models may be solved to find the area of drawdown from pit pumping. Equations governing the system processes in all but the simplest hydrologic systems are either too numerous or too complicated to be solved directly. Therefore, computers are needed to solve numerical models - those models that address complex boundary conditions or where the values of parameters vary within the area of interest. However, as the capability of the model increases, the required input data also increases. The regulatory authority may find the type of hydrologic information available or the distribution/density of the data sets is not appropriate for numerical modeling.

Every analytical or numerical model has a set of assumptions. Meeting those assumptions is extremely important to the validity of the output. A model can provide excellent results when assumptions are met and data sets are extensive enough to allow adequate calibration and verification of the model. Whatever techniques or combinations of techniques are selected, the analytical process should have the capability of predicting water quantity and quality changes under seasonal conditions. It should also have the capability of determining magnitudes of changes and of routing those changes through the system to the downgradient boundary of the CIA. The time span for the analysis period should cover the mining, reclamation and post-reclamation phases in order to determine the magnitude and timing of maximum impacts and the rates of recession from the maximum values.

The third step in the analysis of hydrologic impacts is to estimate the mine impacts using the chosen technique and comparing the results for each indicator parameter to the corresponding material-damage threshold. Any condition for comparison should be given as part of the identification of hydrologic concerns. For instance, the flow state under which the concentration of dissolved solids is to be evaluated should be part of the information that characterizes the concern for salt loading. The specific wording of these criteria becomes especially important when, with each additional mine, cumulative impact magnitudes approach critical levels. Material damage criteria and the estimated values for the indicator parameters should be stated in similar terms and units.

If an estimate indicates that material damage thresholds may be exceeded, the regulatory authority might re-evaluate the impact prediction procedures and make appropriate changes. For example, the regulatory authority may have initially assumed worst-case scenarios in which maximum impacts from all anticipated mining occur simultaneously. While this very conservative approach simplifies the estimation process and is a good way to begin, it would probably not be realistic. The regulatory authority could rerun the analysis to only estimate impacts from prospective mining operations (the proposed operation and any qualifying future operations). The balance of anticipated mining would be existing operations and the hydrologic impacts from these operations already accounted for in the background or baseline CIA conditions. A further refinement in the analysis would be to estimate impacts in light of the planned timing and sequence of land disturbance at the proposed mine. Such adjustments are acceptable and proper. However, it would be difficult for the regulatory authority to justify re-evaluations in which individual input parameter values are adjusted to obtain favorable output magnitudes.

If the impact estimate is positive (material damage to the hydrologic balance is probable), and the regulatory authority determines no further evaluation of the estimate is warranted, the positive finding is reported, granting of the permit is delayed and the CHIA process is finished for the time being. Mitigating actions by the company to further minimize impacts of the proposed mine would be handled outside the CHIA process as part of the overall permit processing procedure.

Statement of Findings

A regulatory authority's final act in the preparation of a CHIA is to write the statement of findings. The purpose of the CHIA is to determine whether the effects of the proposed operation, when added to those of existing or other anticipated mining operations, may cause material damage to the hydrologic balance outside the proposed permit area. Up to this point of preparing a statement of findings, the regulatory authority will have presented all pertinent information and will have qualitatively and quantitatively evaluated the information in a valid, defensible manner. The regulatory authority will have (1) provided information of a general nature that adds to the understanding of the situation and conditions dealt with in the CHIA such as why the CHIA is necessary; (2) specified anticipated mining; (3) delineated the cumulative impact area; (4) examined baseline water-monitoring data and PHC determination and found them adequate; (5) identified hydrologic concerns; (6) established material damage criteria; and (7) predicted cumulative hydrologic impacts and compared them to the material damage criteria. The regulatory authority will have provided supporting evidence and rationale for choices made along the process leading to the finding. The findings should explicitly affirm or negate that the proposed mining has been designed to prevent material damage to the hydrologic balance outside the permit area. Any special condition or stipulation that qualifies the finding must be stated as well.

An outline of suggested minimal requirements for CHIAs can be found in Appendix D.

POSTMINING HYDROLOGIC ASSESSMENT (PHA)

The term *postmining hydrologic assessment (PHA)* is not listed as an explicit heading in 30 CFR 780.21. Rather, the concept of the PHA can be inferred from the requirements found in 30 CFR 800.40(b)(1). These requirements specify that the regulatory authority must determine whether pollution of surface and subsurface water is occurring (or whether the probability of such occurrence exists) prior to release of the reclamation performance bond. An operator must have successfully completed coal mining and reclamation activities before the regulatory authority releases Phase III bond. One measure of this success is the mine's effect on the hydrologic balance - the relationship between the quantity and quality of water flowing into, stored within, and discharging from a hydrologic unit.

When considering a request for bond release (particularly a request for final bond release), the regulatory authority must conduct a PHA. The PHA is fundamentally a process of analyzing the water-monitoring record from the permit and surrounding area to determine if the mining operation affected the hydrologic balance of the area or caused material damage off the permitted site. Like the PHC and the CHIA, the PHA requires a clear understanding of the intended postmining water use. Ideally, the regulatory authority will have been regularly evaluating water data throughout the course of mining and reclamation operations. Disturbing hydrologic trends should have been addressed long before a permittee applies for final liability release. The occasion of writing a PHA is not the time for surprises!

Hydrologic Balance, Postreclamation

The permittee and regulatory authority must understand those elements of the mining environment that can adversely affect the hydrologic balance and, subsequently, impede the release of a reclamation bond. It is generally more cost effective and less complicated to address potential problems while actively mining rather than waiting until the reclamation or post-reclamation phase. Upfront preventive measures will pay enormous dividends once an area has been reclaimed and requested for liability release. It is not profitable for a permittee to have repeated enforcement actions or costly corrective maintenance work. Correspondingly, a regulatory authority would like to avoid seemingly endless inspections and associated paperwork or expensive litigation on what is, and should be, an essentially reclaimed site.

The regulatory authority should consider a number of questions about the hydrologic balance when determining whether bond should be released:

- Has the recharge capacity of the mine site been restored?
- Are post-reclamation water qualities, quantity, and flow rates significantly different from premining?
- Are there any trends in the water-monitoring record?
- Have there been any problems or complaints from water users?
- Have drainage issues been raised?
- Have any seeps developed?
- Is AMD present at the site?
- Have all monitoring wells (those installed by the operator and not transferred for domestic use) been properly plugged and abandoned?

As required by 30 CFR 816.41(b)(2), mining and reclamation activities for both surface and underground coal mines must be conducted so that the premining recharge capacity of the reclaimed area is restored. Restoration of recharge capacity does not mean that spoil has to be fully recharged before the permittee can be released from final reclamation liability. Minesite conditions, both at the surface and in the subsurface, must be conducive to establishing some underground water-bearing potential provided that condition existed prior to mining. Runoff from the postreclamation site is often managed in such a way as to aid in ground-water recharge provided the HRP does not require the recharge to be limited or restricted (i.e. because of potentially acid- or toxic-forming materials). The regulatory authority may evaluate whether recharge capacity has been restored by tracking water level changes in spoil wells and/or monitoring wells and private wells adjacent to the reclaimed area.

The water-monitoring record consists of two temporal phases: baseline and everything after baseline until final liability release (the latter could be referred to as the operations phase). The regulatory authority might subdivide the postbaseline phase into the period of active coal removal/reclamation and the post-reclamation time when mine activity is limited to maintenance work. Data review should include the records for upstream/upgradient and downstream/downgradient monitoring stations to evaluate the quality and quantity of water entering as well as exiting the site.

As illustrated in Figure 7, a regulatory authority must consider whether water currently on or leaving the mine site is of acceptable quality prior to releasing bond. One can consider current water quality as that characterized by the most recently analyzed samples. For example, the set might be the last eight samples. Monitoring frequency will then define the word *current* in terms of a specific time period. The regulatory authority should avoid choosing only the most recent sample to represent current conditions because of naturally variable water chemistry.

For a given monitoring station, the regulatory authority may statistically compare some measure of central tendency (the mean or median) of baseline data to that of data collected during mining and reclamation. In addition, the data should also be evaluated for trends. The water-monitoring record also lends itself to statistical analysis that looks for changes with distance. Comparisons of central tendency can be made between upstream and downstream stations or upgradient and downgradient wells. The regulatory authority could use nonparametric statistical tests (Mann-Whitney W for comparison of medians and Kendall Tau for trend tests). When permanent impoundments are in the proposed release area, the regulatory authority should review the NPDES monitoring record for that water body, assuming the principal spillway is an NPDES outfall.

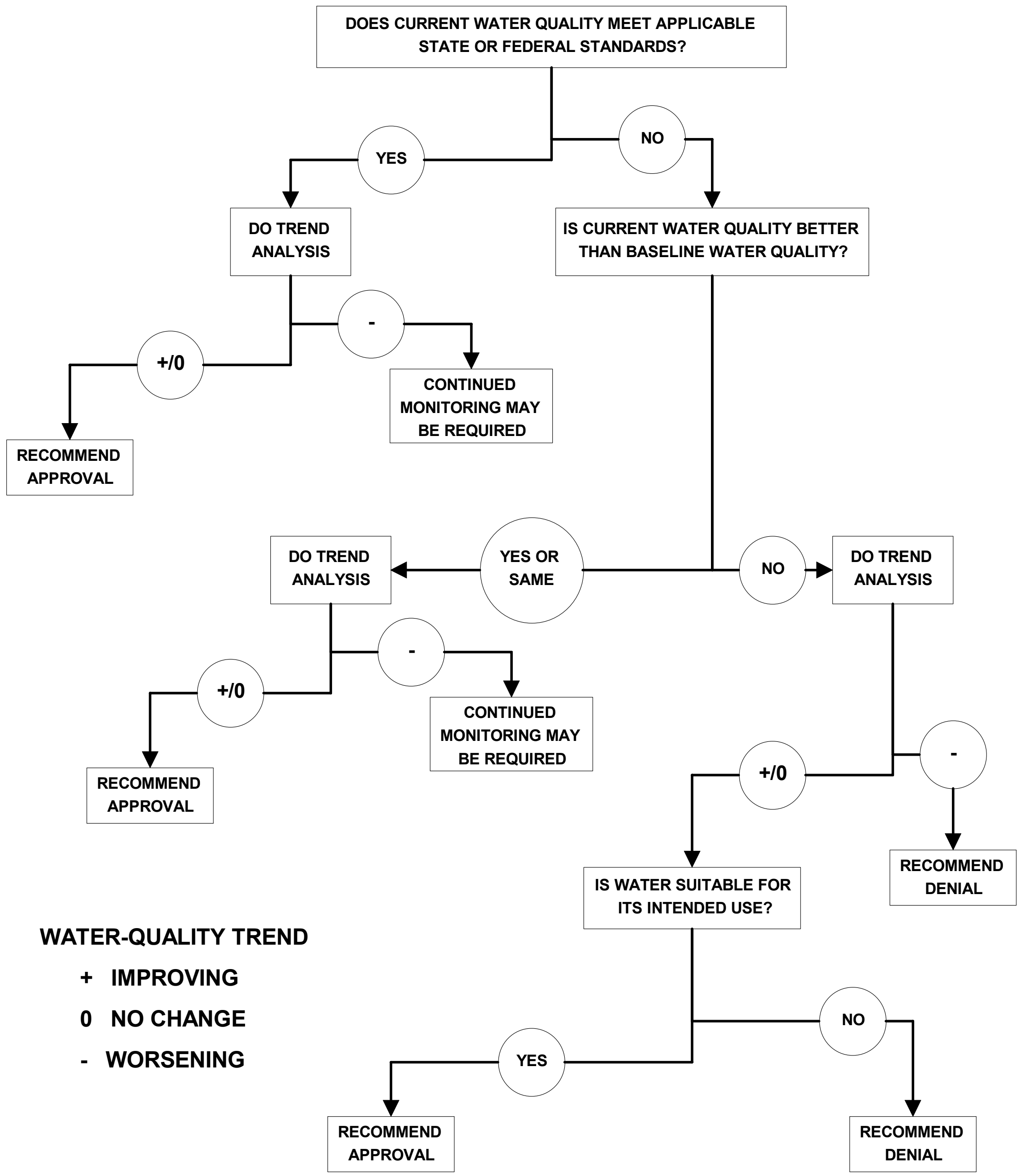

Figure 7 Decision flow chart for water-quality consideration of the postmining hydrologic assessment.

The regulatory authority should be mindful of a potential bond-release scenario in which the permittee divides a large area into small parcels which, in turn, are submitted for liability release one by one. An individual parcel targeted for release might not be hydrologically related to a monitoring well and only remotely associated with established stream stations. How then would the regulatory authority avoid having to assert in a PHA for each such small parcel that there is simply insufficient data to determine whether the permittee's operations on that particular tract had affected water resources as monitored over a much larger area? Pursuing bond release in a piecemeal fashion, a permittee could seemingly whittle reclamation liability down to nothing even though the water record indicates mining-related problems.

An outline of suggested minimal requirements for the PHA can be found in Appendix E.

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Appendix A

GLOSSARY OF WATER-RELATED WORDS*

A–Horizon — The uppermost zone in the *Soil Profile*, from which soluble *Salts* and *Colloids* are leached, and in which organic matter has accumulated. Generally this represents the most fertile soil layer and constitutes part of the *Zone of Eluviation*.

Abandoned Well — A well which is no longer used or a well removed from service; a well whose use has been permanently discontinued or which is in a state of such disrepair that it cannot be used for its intended purpose. Generally, abandoned wells will be filled with concrete or cement grout to protect underground water from waste and contamination.

Abatement — Reducing the degree or intensity of, or eliminating, pollution, as a water pollution abatement program.

Abrasion — Removal of stream-bank soil as a result of sediment-laden water, ice, or debris rubbing against the bank.

Absolute Humidity — The actual weight of water vapor contained in a unit volume of the atmosphere, usually expressed in grams of water per kilogram of air. Compare to *Relative Humidity*.

Absorption — (1) The entrance of water into the soil or rocks by all natural processes, including the infiltration of precipitation or snowmelt, gravity flow of streams into the valley alluvium into sinkholes or other large openings, and the movement of atmospheric moisture. (2) The uptake of water or dissolved chemicals by a cell or an organism (as tree roots absorb dissolved nutrients in soil). (3) More generally, the process by which substances in gaseous, liquid, or solid form dissolve or mix with other substances. Not to be confused with *Adsorption*.

Absorption Loss — The loss of water by *Infiltration* or *Seepage* into the soil during the process of priming, i.e., during the initial irrigation of a field; generally expressed as flow volume per unit of time.

Accretion — The slow addition to land by deposition of water-borne sediment. An increase in land along the shores of a body of water, as by *alluvial* deposit.

Acid — (1) Chemicals that release hydrogen ions (H^+) in solution and produce hydronium ions ($H3O^+$). Such solutions have a sour taste, neutralize bases, and conduct electricity. (2) Term applied to water with a pH of less than 7.0 on a pH scale of 0 to 14.

Acid-Forming Material — Material containing sulfide minerals or other materials, which if exposed to air, water, or weathering processes will form sulfuric acid that may create *Acid Mine Drainage*.

Acid Mine Drainage (AMD) — Acidic water that flows into streams from abandoned mines or piles of mining waste or tailings. The acid arises from the oxidation of iron sulfide compounds in the mines by air, dissolved oxygen in the water, and chemoautotrophs, which are bacteria that can use the iron sulfide as an energy source. Iron sulfide oxidation products include sulfuric acid, the presence of which has reduced or eliminated aquatic life in many streams in mining regions. Also see *Open-Pit Mining* and *Yellowboy*. Also referred to as *Acid Mine Waste*.

Acid Neutralizing Capacity (ANC) — (1) A measure of the ability of water or soil to resist changes in pH. (2) The equivalent sum of all bases or base-producing materials, solutes plus particulates, in an aqueous system that can be titrated with acid to an equivalence point. The term designates titration of an *unfiltered* sample (formerly reported as alkalinity).

Acid Rain — Rainfall with a pH of less than 7.0. One of the principle sources is the combining of rain (H2O) and sulfur dioxide (SO2), nitrous oxides (NOx), and carbon dioxide (CO2) emissions which are byproducts of the combustion of fossil fuels. These oxides react with the water to form sulfuric (H2SO4), nitric (HNO3), and carbonic acids (H2CO3). Long-term deposition of these acids is linked to adverse effects on aquatic organisms and plant life in areas with poor neutralizing (buffering) capacity. Also see *Acid Deposition*.

Acid Soil (Alkaline Soil, Neutral Soil) — A description of one aspect of a soil's chemical composition. Many plants will grow best within a range of pH rating from slightly acid to slightly alkaline. A pH rating of 7 means that the soil is neutral; a pH below 7 indicates acidity; a pH above 7 indicates alkalinity.

Acidic — The condition of water or soil that contains a sufficient amount of acid substances to lower the pH below 7.0.

Acidity — A measure of how acid a solution may be. A solution with a pH of less than 7.0 is considered acidic. Solutions with a pH of less than 4.5 contain mineral acidity (due to strong inorganic acids), while a solution having a pH greater than 8.3 contains no acidity.

Active Fault — A fault that has undergone movement in recent geologic time (the last 10,000 years) and may be subject to future movement. Also see *Fault*.

Active Storage Capacity — (1) The total amount of usable reservoir capacity available for seasonal or cyclic water storage. It is gross reservoir capacity minus inactive storage capacity. (2) More specifically, the volume of water in a reservoir below the maximum controllable level and above the minimum controllable level that can be released under gravity. In general, it is the volume of water between the outlet works and the spillway crest. In some instances, *Minimum Pool* operating constraints may prevent lowering the reservoir to the level of the outlet works, and the water below the minimum pool level is not considered to be in active storage.

Adhesion — Molecular attraction that holds the surfaces of two substances in contact, such as water and rock particles. Also, the attraction of water molecules to other materials as a result of hydrogen bonding.

Adiabatic — Applies to a thermodynamic process during which no heat is added to or withdrawn from the body or system concerned. In the atmosphere, adiabatic changes of temperature occur only in consequence of compression or expansion accompanying an increase or decrease of atmospheric pressure. Thus, a descending body of air undergoes compression and adiabatic cooling.

Adiabatic Lapse Rate — The theoretical rate at which the temperature of the air changes with altitude. The temperature change is due to the pressure drop and gas expansion only, and no heat is considered to be exchanged with the surrounding air through convection or mixing. The *Dry Adiabatic Lapse Rate* for air not saturated with water vapor is 0.98EC per 100 meters (5.4EF per 1,000 feet). The *Wet Adiabatic Lapse Rate* for air saturated with water vapor is about 0.60EC per 100 meters (3.3EF per 1,000 feet).

Adit — A horizontal or nearly horizontal passage, driven from the surface, for the working or dewatering of a mine. Also referred to as *Drift*, *Shaft*, or *Portal*.

Adjudication — (1) Refers to a judicial process whereby water rights are determined or decreed by a court of law. (2) A court proceeding to determine all rights to the use of water on a particular stream system or within a specific ground water basin.

Adsorption — (1) The adherence of ions or molecules in solution to the surface of solids. (2) The adherence of a gas, liquid, or dissolved material on the surface of a solid. (3) The attraction and adhesion of a layer of ions from an aqueous solution to the solid mineral surfaces with which it is in contact. An example is the adsorption of organic materials by activated carbon. Not to be confused with *Absorption*.

Adsorption Isotherm - the graphical representation of the relationship between the solute concentration and the mass of the solute species adsorbed on the aquifer sediment or rock.

Advection — (1) The process by which solutes are transported by the bulk of flowing fluid such as the flowing ground water. (2) The horizontal transfer of heat energy by large-scale motions of the atmosphere.

Aeolian Soil — Soil transported from one area to another by the wind.

Aeration (Unsaturated) Zone — The zone between the land surface and the water table which characteristically contains liquid water under less than atmospheric pressure and water vapor and air or other gases at atmospheric pressure. The term *Unsaturated Zone* is now generally applied.

Aerobic — Characterizing organisms able to live only in the presence of air or free oxygen, and conditions that exist only in the presence of air or free oxygen. Contrast with *Anaerobic*.

Aerobic Bacteria — Single-celled, microscopic organisms that require oxygen to live and are partly responsible for the *Aerobic Decomposition* of organic wastes.

Aerobic Decomposition — The biodegradation of materials by aerobic microorganisms resulting in the production of carbon dioxide, water, and other mineral products. Generally a faster process than *Anaerobic Decomposition*. Also see *Aerobic Bacteria*.

Aerobic Treatment — The process by which microbes decompose complex organic compounds in the presence of oxygen and use the liberated energy for reproduction and growth. Such processes may include extended aeration, trickling filtration, and rotating biological contactors.

Affected Environment — (1) Existing biological, physical, social and economic conditions of an area subject to change, both directly and indirectly, as the result of a proposed human action. (2) The chapter in an Environmental Impact Statement (EIS) describing current environmental conditions.

Affluent (Stream) — A stream or river that flows into a larger one; a *Tributary*.
Age (of Ground water) — An approximation of the time between the water's penetration of the land surface at one location and its later presence at another location.

Agglomeration — (Water Quality) The grouping of small suspended particles into larger particles that are more easily removed through filtration, skimming, or settling. Also see *Coagulation*.

Aggradation — (1) The raising of stream beds or flood plains by deposition of sediment eroded and transported from upstream. (2) The build-up of sediments at the headwaters of a lake or reservoir or at a point where stream flow slows to the point that it will drop part or its entire sediment load. (3) The building of a floodplain by sediment deposition; the filling of a depression or drainage way with sediment; the building of a fan by deposition of an alluvial mantle. (4) Modification of the earth's surface in the direction of uniformity of grade or slope, by *Deposition*, as in a river bed. Opposite of *Degradation*.

Aggrade — The raising of a stream-channel bed with time due to the *Deposition* of sediment that was eroded and transported from the upstream watershed or the channel.

Aggrading — The building up of a stream channel which is flowing too slowly to carry its sediment load.

Air Injection — In ground water management, the pumping of compressed air into the soil to move water in the *Unsaturated Zone* (*Vadose Zone*) down to the *Saturated Zone* (*Phreatic Zone*), or *Water Table*.

Algae — Simple single-celled, colonial, or multi-celled, mostly aquatic plants, containing chlorophyll and lacking roots, stems and leaves. Aquatic algae are microscopic plants that grow in sunlit water that contains phosphates, nitrates, and other nutrients. Algae, like all aquatic plants, add oxygen to the water and are important in the fish food chain.

Algal Bloom — (1) Rapid growth of algae on the surface of lakes, streams, or ponds; stimulated by nutrient enrichment. (2) A heavy growth of algae in and on a body of water as a result of high phosphate concentration such as from farm fertilizers and detergents. It is associated with *Eutrophication* and results in a deterioration in water quality. Also spelled *Algae Bloom*.

Algorithm — A series of well-defined steps used in carrying out a specific process. May be in the form of a word description, an explanatory note, a diagram or labeled flow chart, or a series of mathematical equations.

Alkali — Any strongly basic (high pH) substance capable of neutralizing an acid, such as soda, potash, etc., that is soluble in water and increases the pH of a solution greater than 7.0. Also refers to soluble salts in soil, surface water, or ground water.

Alkaline — Sometimes water or soils contain an amount of *Alkali* substances sufficient to raise the pH value above 7.0 and be harmful to the growth of crops. Generally, the term alkaline is applied to water with a pH greater than 7.4.

Alkalinity — (1) Refers to the extent to which water or soils contain soluble mineral salts. Waters with a pH greater than 7.4 are considered alkaline. (2) The capacity of water for neutralizing an acid solution. Alkalinity of natural waters is due primarily to the presence of hydroxides, bicarbonates, carbonates and occasionally borates, silicates and phosphates. It is expressed in units of milligrams per liter (mg/l) of $CaCO_3$ (calcium carbonate). A solution having a pH below 4.5 contains no alkalinity.

Allochthonous Material — Organic material that falls into a stream from the surrounding land. Compare to *Autochthonous Material*.

Alluvial — (1) Pertaining to processes or materials associated with transportation or deposition by running water. (2) Pertaining to or composed of *alluvium*, or deposited by a stream or running water. (3) An adjective referring to soil or earth material which has been deposited by running water, as in a riverbed, flood plain, or delta.

Alluvion — (1) The flow of water against a shore or bank. Inundation by water; flood. (2) (Legal) The increasing of land area along a shore by deposited *Alluvium* or by the recession of water.

Alluvium — (1) A general term for deposits of clay, silt, sand, gravel, or other particulate material that has been deposited by a stream or other body of running water in a streambed, on a flood plain, on a delta, or at the base of a mountain. (2) A general term for such unconsolidated detrital material deposited during comparatively recent geologic time by a stream or other body of running water as a sorted or semi-sorted sediment in the bed of the stream or its flood plain or delta, or as a cone or fan at the base of a mountain slope; especially such a deposit of fine-grained texture (silt or silty clay) deposited during time of flood. Also see *Alluvion*.

Alternatives — Courses of action which may meet the objectives of a proposal at varying levels of accomplishment, including the most likely future conditions without the project or action.

Altitude — The vertical distance of a level, a point, or an object considered as a point, measured from *Mean Sea Level (MSL)*.

Ambient Water Quality Standards — The allowable amount of materials, as a concentration of pollutants, in water. The standard is set to protect against anticipated adverse effects on human health or welfare, wildlife, or the environment, with a margin of safety in the case of human health.

Amictic Lake — A lake that does not experience mixing or turnover on a seasonal basis. Also see *Dimictic Lake*.

Anabranch — A diverging branch of a river which re-enters the main stream.

Anaerobe — An organism that does not require oxygen to maintain its life processes.

Anaerobic — Characterizing organisms able to live and grow only where there is no air or free oxygen, and conditions that exist only in the absence of air or free oxygen.

Anaerobic Decomposition — The degradation of materials by *Anaerobic* microorganisms living beneath the ground or in oxygen-depleted water to form reduced compounds such as methane or hydrogen sulfide. Generally a slower process than *Aerobic Decomposition*.

Analog — A continuously variable electrical signal representing a measured quantity. For example, electrical signals such as current, voltage, frequency, or phase used to represent physical quantities such as water level, flow, and gate position.

Analytical Model — A model that provides approximate or exact solutions to simplified forms of the differential equations for water movement and solute transport. Such models generally require the use of complex calculations and the use of computers.

Anastomosing — The branching and rejoining of channels to form a netlike pattern.

Anhydride — A chemical compound formed from another, often an acid, by the removal of water.

Anhydrous — Without water, especially water of crystallization; not hydrated (*Dehydrated*).

Anion — In an electrolyzed solution, the negatively charged particle, or ion, which travels to the anode and is therefore discharged, evolved, or deposited. Also, by extension, any negative ion.

Anisotropy — (1) The condition of having different properties in different directions. (2) The condition under which one or more of the hydraulic properties of an aquifer vary according to the direction of the flow.

Annular Space — The space between two cylindrical objects, one of which surrounds the other, such as the space between the wall of the drilled hole and the casing, or between a permanent casing and the borehole.

Annulus — For a well, the space between the pipe and the outer wall (casing) of the borehole, which may be a pipe also (the well casing).

Anoxia — (1) Absence of oxygen. (2) The total deprivation of oxygen, as in bodies of water, lake sediments, or sewage.

Anoxic — (1) Denotes the absence of oxygen, as in a body of water. (2) Of, relating to, or affected with anoxia; greatly deficient in oxygen; oxygenless as with water.

Antecedent Streams — Antecedent streams are those in place before the rising of mountain chains. As the mountains rise, the streams cut through at the same rate and so maintain their positions.

Antidegradation Policy (or Clause) — Rules or guidelines that are required of each state by federal regulations implementing the *Clean Water Act (CWA)*, stating that existing water quality be maintained even if the current water quality in an area is higher than the minimum permitted as defined by federal ambient water quality standards. Some controlled degradation is permitted in support of economic development.

Approximate Original Contour — The surface configuration achieved by backfilling and grading of mined areas so that the reclaimed area, including any terracing or access roads, closely resembles the general surface configuration of the land prior to strip mining and blends into and complements the drainage pattern of the surrounding terrain.

Aquatic — (1) Consisting of, relating to, or being in water; living or growing in, on, or near the water. (2) Taking place in or on the water. (3) An organism that lives in, on, or near the water.

Aquatic Life — All forms of living things found in water, ranging from bacteria to fish and rooted plants. Insect larva and zooplankton are also included.

Aqueous — (1) Relating to, similar to, containing, or dissolved in water; watery. (2) (Geology) Formed from matter deposited by water, as certain sedimentary rocks.

Aquiclude (Confining Bed) — A formation which, although porous and capable of absorbing water slowly, will not transmit water fast enough to furnish an appreciable supply for a well or spring. Aquicludes are characterized by very low values of *leakage* (the ratio of vertical *Hydraulic Conductivity* to thickness), so that they transmit only minor inter-aquifer flow and also have very low rates of yield from compressible storage. Therefore, they constitute boundaries of aquifer flow systems.

Aquifer — (1) A geologic formation, a group of formations, or a part of a formation that is water bearing. (2) A geological formation or structure that stores or transmits water, or both, such as to wells and springs. (3) An underground layer of porous rock, sand, or gravel containing large amounts of water. Use of the term is usually restricted to those water-bearing structures capable of yielding water in sufficient quantity to constitute a usable supply. (4) A sand, gravel, or rock formation capable of storing or conveying water below the surface of the land. (5) A geologic formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.

Aquifer, Basin-Fill — An aquifer located in a basin surrounded by mountains and composed of sediments and debris shed from those mountains. Sediments are typically sand and gravel with some clay.

Aquifer Compaction — Term used to describe the effects of emptying or overdrawing an aquifer; overdrafts tend to collapse the structure of the aquifer such that the original volume cannot be restored. May also be associated with a general *Land Subsidence* in the surrounding ground level as the result of such compaction.

Aquifer, Confined — An aquifer which is bounded above and below by formations of impermeable or relatively impermeable material. An aquifer in which ground water is under pressure significantly greater than atmospheric and its upper limit is the bottom of a bed of distinctly lower hydraulic conductivity than that of the aquifer itself. See *Artesian Aquifer*.

Aquifer, Fractured Bedrock — An aquifer composed of solid rock, but where most water flows through cracks and fractures in the rock instead of through pore spaces. Flow through fractured rock is typically relatively fast.

Aquifer, Leaky (Semi-Confined) — An aquifer overlaid and/or underlain by a thin semipervious layer through which flow into or out of the aquifer can take place.

Aquifer, Perched — A ground water unit, generally of moderate dimensions, that occurs whenever a ground water body is separated from the main ground water supply by a relatively impermeable stratum and by the *Zone of Aeration* above the main water body.

Aquifer, Saline/Poor Quality — An aquifer containing water that is high in total dissolved solids, and is unacceptable for use as drinking water.

Aquifer, Sandstone — The type of aquifer supplying ground water to large parts of the United States upper Middle West, Appalachia, and Texas. The water-bearing formation is often contained by shale strata, and the water has high levels of iron and magnesium.

Aquifer System — A body of permeable and relatively impermeable materials that functions regionally as a water-yielding unit. It comprises two or more permeable units separated at least locally by confining units (*Aquitards*) that impede ground-water movement but do not greatly affect the regional hydraulic continuity of the system. The permeable materials can include both saturated and unsaturated sections.

Aquifer Test — A test to determine hydrologic properties of an aquifer, involving the withdrawal of measured quantities of water from, or the addition of water to, a well and the measurement of resulting changes in head in the aquifer both during and after the period of discharge or addition (recharge).

Aquifer, Unconfined — An *Aquifer* made up of loose material, such as sand or gravel, that has not undergone lithification (settling). In an unconfined aquifer the upper boundary is the top of the *Zone of Saturation* (water table).

Aquifuse — A formation that has no interconnected openings and hence cannot absorb or transmit water.

Aquitard — A saturated, but poorly permeable bed that impedes ground-water movement and does not yield water freely to wells, but which may transmit appreciable water to or from adjacent aquifers and, where sufficiently thick, may constitute an important ground-water storage unit. Aquitards are characterized by values of leakance that may range from relatively low to relatively high. Areally extensive aquitards of relatively low leakance may function regionally as boundaries of aquifer flow systems.

Area of Influence of a Well - the area surrounding a well over which the potentiometric surface has changed as the result of pumping ground water from or recharging ground water to an aquifer. Same as Zone of Influence. This is not to be confused with the Capture area of a well.

Argillic Alteration (Argillization) — A form of *Hydrothermal* alteration in which certain minerals of rock are converted to clay minerals.

Armor — To protect fill slopes, such as the sides of a levee, by covering them with erosion-resistant materials such as rock or concrete.

Armoring — (1) Formation of a layer of rocks on the surface of a streambed that resists erosion by water flows. The rocks can be naturally occurring, caused by the scour of smaller particles from high discharges, or placed by humans to stop channel erosion. (2) A facing layer (protective cover), or *Rip Rap*, consisting of very large stones placed to prevent erosion or the sloughing off of a structure or embankment. Also, a layer of large stones, broken rocks or boulders, or precast blocks placed in random fashion on the upstream slope of an *Embankment Dam*, on a reservoir shore, or on the sides of a channel as a protection against waves, ice action, and flowing water. The term armoring generally refers only to very large rip rap. (3) Armoring of limestone is a common cause of failure in limestone-based systems for treatment of acid mine drainage. Armoring occurs when acid mine drainage sludge or 'yellowboy' coats rocks and fills in the pore spaces in streambeds. For flow-through passive treatment systems, iron hydrolysis and precipitation reactions coat the limestone resulting in less surface area available for limestone dissolution.

(United States) Army Corps of Engineers (Corps or COE) — Originally formed in 1775 during the Revolutionary War by General George Washington as the engineering and construction arm of the Continental Army. Initially, the Corps of Engineers built fortifications and coastal batteries to strengthen the country's defenses and went on to found the Military Academy at West Point, help open the West, and to develop the nation's water resources. In its military role, the COE plans, designs, and supervises the construction of facilities to insure the combat readiness of the U.S. Army and Air Forces. In its civilian role, the COE has planned and executed national programs for navigation and commerce, flood control, water supply, hydroelectric power generation, recreation, conservation, and preservation of the environment. In a very general sense, the U.S. Army Corps of Engineers has a primary responsibility for water projects which protect property from potential flood damage, whereas the (U.S. Department of the Interior) *Bureau of Reclamation (USBR)* is responsible for primarily western water projects with respect to developing water sources for agriculture and commerce. In reality, however, quite often these federal agencies' project goals overlap with USBR's dams and reservoirs providing important flood protection and the COE's water projects — dams, locks, and canals — providing important water transportation linkages and benefits to commerce. [See Appendix E–2 for the U.S. Army Corps of Engineers' organizational structure and primary missions and objectives.]

Artesian — A commonly used expression, generally synonymous with *Confined* and referring to subsurface (ground) bodies of water which, due to underground drainage from higher elevations and confining layers of soil material above and below the water body (referred to as an *Artesian Aquifer*), result in underground water at pressures greater than atmospheric.

Artesian Aquifer — A commonly used expression, generally synonymous with (but a generally less favored term than) *Confined Aquifer*. An artesian aquifer is an aquifer which is bounded above and below by formations of impermeable or relatively impermeable material. An aquifer in which ground water is under pressure significantly greater than atmospheric and its upper limit is the bottom of a bed of distinctly lower hydraulic conductivity than that of the aquifer itself.

Artesian Pressure — The pressure under which *Artesian Water* in an *Artesian Aquifer* is subjected, generally significantly greater than atmospheric

.

Artesian Water — Ground water that is under pressure when tapped by a well and is able to rise above the level at which it is first encountered. It may or may not flow out at ground level. The pressure in such an aquifer commonly is called *Artesian Pressure*, and the formation containing artesian water is an *Artesian Aquifer* or *Confined Aquifer*.

Artesian Well — (1) A well bored down to the point, usually at great depth, at which the water pressure is so great that the water is forced out at the surface. The name is derived from the French region of Artois, where the oldest well in Europe was bored in 1126. (2) A well tapping a *Confined* or *Artesian Aquifer* in which the static water level stands above the top of the aquifer. The term is sometimes used to include all wells tapping confined water. Wells with water levels above the unconfined water table are said to have positive artesian head (pressure) and those with water level below the unconfined water table, negative artesian head. If the water level in an artesian well stands above the land surface, the well is a *Flowing Artesian Well*. If the water level in the well stands above the water table, it indicates that the artesian water can and probably does discharge to the unconfined water body.

Artesian Zone — A zone where water is confined in an aquifer under pressure so that the water will rise in the well casing or drilled hole above the bottom of the confining layer overlying the aquifer.

Artificial Recharge — (1) The addition of surface water to a ground water reservoir by human activity, such as putting surface water into a *Spreading Basin*. (2) The designed (as per man's activities as opposed to the natural or incidental) replenishment of ground water storage from surface water supplies such as irrigation or induced infiltration from streams or wells. There exist five (5) common techniques to effect artificial recharge of a ground water basin:

- [1] ***Water Spreading*** consisting of the basin method, stream-channel method, ditch method, and flooding method, all of which tend to divert surface water supplies to effect underground infiltration;
- [2] ***Recharge Pits*** designed to take advantage of permeable soil or rock formations;
- [3] ***Recharge Wells*** which work directly opposite of pumping wells, although they generally have limited scope and are better used for deep, confined aquifers;
- [4] ***Induced Recharge*** which results from pumping wells near surface supplies, thereby inducing higher discharge towards the well; and
- [5] ***Wastewater Disposal*** which includes the use of secondary treatment wastewater in combination with spreading techniques, recharge pits, and recharge wells to reintroduce the water into deep aquifers thereby both increasing the available ground water supply and also further improving the quality of the wastewater.

  Also referred to as *Induced Recharge*.

Attached Ground Water — The portion or amount of alkali substances in the ground sufficient to raise the pH value above 7.0 or to be harmful to the growth of crops, a condition called alkaline.

Attenuation — (1) Generally, a term used to describe the slowing, modification, or diversion of the flow of water as with *Detention* and *Retention*. (2) (Water Quality) The process of diminishing contaminant concentrations in ground water, due to filtration, biodegradation, dilution, sorption, volatilization, and other processes.

Atterberg Limits — The transition points between various states of soil consistency. The Atterberg Limits consist of: (1) the liquid limit (water content at which the soil passes from the liquid to the plastic state); (2) the plastic limit (water content at which the soil passes from the plastic to the semi-solid state); and (3) the shrinkage limit (water content at which the soil passes from the semi-solid to the solid state).

Autochthonous Material — (1) Pertaining to substances, materials, or organisms originating within a particular waterway and remaining in that waterway. (2) Organic material produced in the stream usually through primary production. Compare to *Allochthonous Material*.

Available Water — The portion of water in a soil that can be absorbed by plant roots, usually considered to be that water held in the soil against a tension of up to approximately 15 atmospheres.

Available Water Holding Capacity — The capacity of a soil to hold water in a form available to plants. Also, the amount of moisture held in the soil between field capacity, or about one-third atmosphere of tension, and the wilting coefficient, or about 15 atmospheres of tension.

Average Annual Recharge — The amount of water entering an aquifer on an average annual basis. In many, if not most, hydrologic conditions, "average" has little significance for planning purposes as there may exist so few "average" years in fact.

Avulsion — (1) The sudden movement of soil from one property to another as a result of a flood or a shift in the course of a boundary stream. (2) A forcible separation or detachment; a sudden cutting off of land by flood, currents, or change in course of a body of water; especially one separating land from one person's property and joining it to another's. (3) A sudden cutting off or separation of land by a flood or by an abrupt change in the course of a stream, as by a stream breaking through a meander or by a sudden change in current, whereby the stream deserts its old path for a new one. (4) A sudden loss or gain of land as the result of action of water or a shift in a bed of a river which has been used as a boundary by property owners. If land is lost as a result of avulsion the riparian owner does not lose title to the land that has been lost; the boundary lines remain the same. This is not true when land is lost by erosion.

-B-

B–Horizon — (1) The lower soil zone which is enriched by the deposition or precipitation of material from the overlying zone, or *A–Horizon*. (2) A mineral horizon of a soil, below the A-horizon, sometimes called the *Zone of Accumulation* and characterized by one or more of the following conditions: an illuvial accumulation of humus or silicate clay, iron, or aluminum; a residual accumulation of sesquioxides or silicate clays; darker, stronger, or redder coloring due to the presence of sesquioxides; a blocky or prismatic structure. Along with the A–horizon soil zone, these two zones constitute part of the *Zone of Eluviation*.

Backbar Channel — A channel formed behind a bar connected to the main channel but usually at a higher bed elevation than the man channel. Backbar channels may or may not contain flowing or standing water.

Backfill, or Backfilling — process of filling the notches carved in the earth from strip mining in order to restore the original slope. This is intended to reduce soil erosion and allow for the reestablishment of vegetation.

Baffle — A flat board or plate, deflector, guide, or similar device constructed or placed in flowing water or slurry systems to cause more uniform flow velocities to absorb energy and to divert, guide, or agitate liquids.

Bailer — An instrument such as a long pipe with a valve at the lower end used to extract a water sample from a ground water well. Also used to remove slurry from the bottom or side of a well as it is being drilled.

Bank, and Banks — The slope of land adjoining a body of water, especially adjoining a river, lake, or a channel. With respect to flowing waters, banks are either right or left as viewed facing in the direction of the flow. As *Banks*, a large elevated area of a sea floor.

Bank and Channel Stabilization — Implementation of structural features along a streambank to prevent or reduce bank erosion and channel degradation.

Bankfull Channel — The stream channel that is formed by the dominant discharge, also referred to as the active channel, which meanders across the floodplain as it forms pools, riffles, and point bars.

Bankfull Stage — The stage at which a stream first begins overflows its natural banks. More precisely, an established river stage at a given location along a river which is intended to represent the maximum safe water level that will not overflow the river banks or cause any significant damage within the river reach. Bankfull stage is a hydraulic term, whereas *Flood Stage* implies resultant damage.

Bank Storage — The water absorbed into the banks of a stream, lake, or reservoir, when the stage rises above the water table in the bank formations, then returns to the channel as effluent seepage when the stage falls below the water table. Bank storage may be returned in whole or in part as seepage back to the water body when the level of the surface water returns to a lower level.

Bar — (1) A sand or gravel deposit found on the bed of a stream that is often exposed during low-water periods. (2) An elongated landform generated by waves and currents, usually running parallel to the shore, composed predominantly of unconsolidated sand, gravel, stones, cobbles, or rubble and with water on two sides. (3) A component landform comprised of elongate, commonly curving, low ridges of well sorted sand and gravel that stand above the general level of a *Bolson* floor and were built by the wave action of a Pleistocene lake. (4) A unit of pressure equal to 10^6 dynes per cm^2, 100 kilopascals, or 29.53 inches of mercury.

Base — (1) Any of various typically water-soluble and bitter tasting compounds that in solution have a pH greater than 7, are capable of reacting with an acid to form a salt, and are molecules or ions able to take up a proton from an acid or able to give up an unshared pair of electrons to an acid. (2) Chemicals that release hydroxide ions (OH^-) in solution. Such solutions have a soapy feel, neutralize acids, and conduct electricity.

Base Flow — (1) The flow that a perennially flowing stream reduces to during the dry season. It is supported by ground water seepage into the channel. (2) The fair-weather or sustained flow of streams; that part of stream discharge not attributable to direct runoff from precipitation, snowmelt, or a spring. Discharge entering streams channels as effluent from the ground water reservoir. (3) The volume of flow in a stream channel that is not derived from surface run-off. Base flow is characterized by los flow regime (frequency, magnitude, and duration daily, seasonally, and yearly), by minimum low flow events and in context of the size and complexity of the stream and its channel.

Base Level — (1) The elevation to which a stream-channel profile has developed. (2) The lowest level to which a land surface can be reduced by the action of running water.

Base Runoff — Sustained or fair weather runoff. In most streams, base runoff is composed largely of ground-water effluent. The term base flow is often used in the same sense as base runoff. However, the distinction is the same as that between streamflow and runoff. When the concept in the terms base flow and base runoff is that of the natural flow in a stream, base runoff is the more appropriate term.

Base Width — (1) The time interval between the beginning and end of the direct runoff produced by a storm. (2) The time period covered by a *Unit Hydrograph*.

Baseline — The condition that would prevail if no action were taken.

Baseline (Data) — A quantitative level or value from which other data and observations of a comparable nature are referenced. Information accumulated concerning the state of a system, process, or activity before the initiation of actions that may result in changes.

Basic Hydrologic Data — Includes inventories of features of land and water that vary only from place to place (e.g., topographic and geologic maps), and records of processes that vary with both place and time (e.g., records of precipitation, streamflow, ground-water, and quality-of-water analyses). *Basic Hydrologic Information* is a broader term that includes surveys of the water resources of particular areas and a study of their physical and related economic processes, interrelations and mechanisms.

Basin — (1) (Hydrology) A geographic area drained by a single major stream; consists of a drainage system comprised of streams and often natural or man-made lakes. Also referred to as *Drainage Basin*, *Watershed*, or *Hydrographic Region*. (2) (Irrigation) A level plot or field, surrounded by dikes, which may be flood irrigated. (3) (Erosion Control) A catchment constructed to contain and slow runoff to permit the settling and collection of soil materials transported by overland and rill runoff flows. (4) (Nautical) A naturally or artificially enclosed harbor for small craft, such as a yacht basin.

Basin Fill — Unconsolidated material such as sand, gravel, and silt eroded from surrounding mountains and deposited in a valley.

Basin-Floor Remnant — A flattish topped, erosional remnant of any former landform of a basin floor that has been dissected following the incision of an axial stream.

Basin Lag — (1) The time from the centroid (centermost point in time based on total period rainfall) of rainfall to the hydrograph peak. (2) The time from the centroid of rainfall to the centroid of the *Unit Hydrograph*.

Basin of Origin — The area (hydrographic region or area) from in surface waters naturally occur or from which ground water is removed.

Bathometer — An instrument used to measure the depth of water.

Bathymetric Map — A map showing the depth of water in lakes, streams, or oceans.

Bathymetry — (1) The measurement of the depth of large bodies of water. (2) The measurement of water depth at various places in a body of water. Also the information derived from such measurements.

Bathythermograph — An instrument designed to record water temperature as a function of depth.

Baumé — Being, calibrated in accordance with, or according to either of two arbitrary hydrometer scales for liquids lighter than water or for liquids heavier than water that indicate specific gravity in degrees.

Bayou — In general, a creek, secondary watercourse, or minor river, tributary to another river or other body of water. A term regularly used in the lower Mississippi River basin and in the Gulf-coast region of the United States to denote a large stream or creek, or small river, characterized by a slow or imperceptible current through alluvial lowlands or swamps. May also refer to an estuarial creek or inlet on the Gulf coast; a small bay, open cove, or harbor; also, a lagoon, lake or bay, as in a sea marsh or among salt-marsh islands.

Bed — (1) The bottom of a body of water, such as a stream. (2) An underwater or intertidal area in which a particular organism is established in large numbers. (3) (Geology) A rock mass of large horizontal extent bounded, especially above, by physically different material (as in *Bedrock*).

Bed Load — (1) Sediment particles up to rock, which slide and roll along the bottom of the streambed. (2) Material in movement along a stream bottom, or, if wind is the moving agent, along the surface. (3) The sediment that is transported in a stream by rolling, sliding, or skipping along or very close to the bed. In USGS reports, bed load is considered to consist of particles in transit from the bed to an elevation equal to the top of the bed-load sample nozzle (usually within 0.25 feet of the streambed). Contrast with material carried in *Suspension* or *Solution*.

Bed Load Discharge — The quantity of sediment, typically measured in tons per day, that is moving as bed load, reported as dry weight, that passes a cross section in a given time.

Bed Material — The sediment mixture of which a streambed, lake, pond, reservoir, or estuary bottom is composed.

Bedrock — (Geology) The solid rock beneath the soil (*Zone of Aeration* or *Zone of Saturation*) and superficial rock. A general term for solid rock that lies beneath soil, loose sediments, or other unconsolidated material.

Bedscarp (Nick Point) — An abrupt change in grade in the bottom of a stream channel that moves progressively upstream; the change in grade forms a waterfall. Also, the location where a streambed is actively eroding downward to a new base level.

Beheaded Stream — The lower section of a stream that has lost its upper portion through diversion or *Stream Piracy*.

Beneficial Use (of Water) — (1) The amount of water necessary when reasonable intelligence and diligence are used for a stated purpose. (2) A use of water resulting in appreciable gain or benefit to the user, consistent with state law, which varies from one state to another. Most states recognize the following uses as beneficial:

[1] domestic and municipal uses;
[2] industrial uses;
[3] irrigation;
[4] mining;
[5] hydroelectric power;
[6] navigation;
[7] recreation;
[8] stock raising;

[9] public parks;
[10] wildlife and game preserves.

(3) The cardinal principle of the *(Prior) Appropriation Doctrine*. A use of water that is, in general, productive of public benefit, and which promotes the peace, health, safety and welfare of the people of the State. A certificated water right is obtained by putting water to a beneficial use. The right may be lost if beneficial use is discontinued. A beneficial use of water is a use which is of benefit to the appropriator and to society as well. The term encompasses considerations of social and economic value and efficiency of use. In the past, most reasonably efficient uses of water for economic purposes have been considered beneficial. Usually, challenges have only been raised to wasteful use or use for some non-economic purpose, such as preserving instream values. Recent statutes in some states have expressly made the use of water for recreation, fish and wildlife purposes, or preservation of the environment a beneficial use.

Benefit-Cost Ratio — (1) The relationship of the economic benefits of an action to its total costs. (2) An economic indicator of the efficiency of a proposed project, computed by dividing benefits by costs; usually, both the benefits and the cost are discounted, so that the ratio reflects efficiency in terms of the present value of future benefits and costs.

Benthic — (1) The bottom of lakes or oceans. See *Benthic Region*. (2) Referring to organisms that live on the bottom of water bodies. See *Benthic Invertebrates* and *Benthic Organisms*.

Benthic Region — The bottom of a body of water, supporting the *Benthos*.

Bentonite — A clay material that swells as it dries, filling gaps and sealing itself against a well casing. It is commonly used to seal abandoned dewatering wells at mines. Concrete, by contrast, shrinks as it cures, and can therefore leave gaps around a wellhead casing that can allow contaminated water from the surface to penetrated into the well.

Bernoulli Effect — The phenomenon of internal pressure reduction with increased stream velocity in a fluid.

Bernoulli's Equation — Under conditions of steady flow of water, the sum of the velocity head, the pressure head, and the head due to elevation at any given point is equal to the sum of these heads at any other point plus or minus the head losses between the points due to friction or other causes.

Berm — (1) A narrow ledge or path as at the top or bottom of a slope, stream bank, or along a beach. (2) (Dam) A horizontal step or bench in the upstream or downstream face of an *Embankment Dam*.

Best Available Demonstrated Technology (BADT) — The level of effluent limitation technology required by the 1972 *Clean Water Act (CWA)* to be used in setting new source performance standards for new industrial direct dischargers of water pollutants.

Best Available Technology Economically Achievable (BAT) — A national goal under the *Water Pollution Control Act* of 1972 (*Public Law 92–500*, commonly referred to as the *Clean Water Act*) which provides that industry shall use the best treatment technically and economically achievable for a category or class of point sources. Under this concept, pollution control will consider such factors as the age of the facilities and equipment involved, processes employed, engineering aspects of the control techniques, process changes, cost of the reductions, and environmental impacts other than water quality, including energy requirements.

Best Conventional Control Technology (BCT) — The level of water pollution control technology required of existing dischargers for the treatment of conventional pollutants by the 1977 *Clean Water Act*

(CWA).

Best Management Practices (BMP) — (1) A generally accepted practice for some aspect of natural resources management, such as water conservation measures, drainage management measures, or erosion control measures. Typically incorporates conservation criteria. (2) A set of field activities that provide the most effective means for reducing pollution from a nonpoint source. (3) Accepted methods for controlling *Non-Point Source (NPS) Pollution* as defined by the 1977 *Clean Water Act (CWA)*; may include one or more conservation practices. Also refers to water conservation techniques of proven value. See, for example, *Best Management Practices (BMP) – Urban Water Use*.

Best Practicable Control Technology (BPT) — A national goal under the *Water Pollution Control Act* of 1972 (*Public Law 92–500*, or the *Clean Water Act*) which provides that industry shall use the best treatment practices practical, with due consideration to cost, age of the plant and equipment, and other factors.

Bicarbonate — (Water Quality) A compound containing the HCO3 group, for example, sodium bicarbonate (NaHCO3), which ionizes in solution (water) to produce $HCO3^{-}$. Also see *Carbonate* and *Carbonate Buffer System*.

Bifurcate — Dividing structure which splits the flow of water.

Bimodal Distribution — (Statistics) A collection of observations with a large number of values centered (as in a *Normal Distribution*) around each of two points. For example, in a sampling of the heights of a population, the sample results would tend to be concentrated around an average heights for males and a second average height for females.

Biochemical Oxygen Demand (BOD) — (1) A measure of the quantity of dissolved oxygen, in milligrams per liter, necessary for the decomposition of organic matter by microorganisms, such as bacteria. (2) A measure of the amount of oxygen removed from aquatic environments by aerobic micro-organisms for their metabolic requirements. Measurement of BOD is used to determine the level of organic pollution of a stream or lake. The greater the BOD, the greater the degree of water pollution. Also referred to as *Biological Oxygen Demand (BOD)*.

Biodegradable — Capable of being decomposed by biological agents or microorganisms, especially bacteria. The property of a substance that permits it to be broken down by micro-organisms into simple, stable compounds such as carbon dioxide and water.

Biological Opinion — A document which states the opinion of the *U.S. Fish and Wildlife Service (USFWS)* as to whether a federal action is likely to jeopardize the continued existence of a threatened or endangered species or result in the destruction or adverse modification of critical habitat.

Biological Oxygen Demand (BOD) — (1) The amount of oxygen required to stabilize decomposable matter by aerobic action. (2) (Water Quality) An indirect measure of the concentration of biologically degradable material present in organic wastes. It usually reflects the amount of oxygen consumed in five days by biological processes breaking down organic waste. Also see *BOD5*. Also referred to as *Biochemical Oxygen Demand (BOD)*.

Bioremediation — Simply, the use of biological techniques to clean up pollution. More specifically, the use of specialized, naturally-occurring micro-organisms with unique biological characteristics, appetites, and metabolisms as a form of waste cleanup. A critical underpinning of this process is the ability to

economically generate a sufficient biomass of the appropriate microbes to accomplish in weeks or months what would normally take nature years to do. Typically, this is done either by applying a sufficient concentration of such microbes directly to the polluted area or by applying various concentrations of chemicals which, in turn, stimulate and foster the rapid growth of appropriate micro-organisms.
Biotechnical Slope Protection — A process involving the use of live and dead woody cuttings and poles or posts collected from native plants to revegetate watershed slopes and stream banks. The cuttings, posts, and vegetative systems composed of bundles, layers, and mats of the cuttings and posts provide structure, drains, and vegetative cover to repair eroding and slumping slopes. Also referred to as *Soil Bioengineering*.

Blending — The mixing or combination of one water source with another, typically a finished source of water with raw water to reuse water while still satisfying water quality standards, for example, mixing of product water from a desalting plant with conventional water to obtain a desired dissolved solids content, or mixing brine effluents with sewage treatment plant effluents in order to reduce evaporation pond size.

Blinds — Water samples containing a chemical of known concentration given a fictitious company name and slipped into the sample flow of the lab to test the impartiality of the lab staff.

Bloom — (1) In aquatic ecosystems, the rapid growth or proliferation of algae, commonly referred to as *Algal Bloom* or *Algae Bloom*; often related to pollution, especially when pollutants accelerate growth. (2) Also a visible, colored area on the surface of bodies of water caused by excessive planktonic growth.

Blowout — A sudden escape of a confined gas or liquid, as from a well.

Bog — (1) A term frequently associated with *Wetlands*, bogs are poorly drained freshwater wetlands that are characterized by a build-up of peat. Sphagnum mosses are also frequently found in many bogs. (2) A quagmire filled with decayed moss and other plant and vegetable matter; wet spongy ground, where a heavy body is apt to sink; a small, soggy marsh; a morass. (3) (Ecology) A wet, overwhelmingly vegetative substratum which lacks drainage and where humic and other acids give rise to modifications of plant structure and function. 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. Only a restricted group of plants, mostly *mycorrhizal* (fungi, heaths, orchids, and saprophytes), can tolerate bog conditions. Also referred to as *Peat Bog*. Also see *Peatland*.

Bog Hole — A hole containing soft mud or quicksand.

Borehole — A hole bored or drilled in the earth, as an exploratory well; a small-diameter well drilled especially to obtain water.

Bottom — (1) The deepest or lowest part, as the bottom of a well. (2) The solid surface under a body of water. (3) Often *Bottoms*: Low-lying alluvial land adjacent to a river, also referred to as bottomland.

Bottomland, also Bottom Land (Soils) — A general term describing generally rich, loamy or fine-textured and poorly drained soils, overlying a shallow water table or possibly adjacent to a stream, lake or other body of water, that exhibits relatively good water holding capacity and slow to moderate infiltration of irrigation water; often associated with a river's floodplain.

Boulder — Rock fragments larger than 60.4 cm (24 inches) in diameter.

Brackish — Having a somewhat salty taste, especially from containing a mixture of seawater and fresh water. Also see *Brackish Water*.

Brackish Water — Generally, water containing dissolved minerals in amounts that exceed normally acceptable standards for municipal, domestic, and irrigation uses. Considerably less saline than sea water. Also, *Marine* and *Estuarine* waters with *Mixohaline* salinity (0.5 to 30‰ due to ocean salts). Water containing between 1,000–4,000 parts per million (PPM) *Total Dissolved Solids (TDS)*. The term brackish water is frequently interchangeable with *Saline Water*. The term should not be applied to inland waters.

Braided Stream — (1) A stream which divides into a network of channels branching and reuniting, separated by islands. (2) A complex tangle of converging and diverging stream channels (*Anabranches*) separated by sand bars or islands. Characteristic of flood plains where the amount of debris is large in relation to the discharge.

Branch — (1) A tributary of a river or other body of water. (2) A divergent section of a river, especially near the mouth.

Breach — A gap or rift, especially in or as if in a solid structure such as a dike or dam.

Break — (1) To emerge above the surface of the water. (2) (Geology) A marked change in topography such as a fault or deep valley.

British Thermal Unit (BTU) — A unit of heat energy equal to the amount of heat required to raise the temperature of one pound of water one degree *Fahrenheit*. More precisely, the quantity of heat required to raise the temperature of one pound of water from 60EF to 61EF at a constant pressure of one atmosphere. Also, the quantity of heat equal to 1/180 of the heat required to raise the temperature of one pound of water from 32EF (its freezing point) to 212EF (its boiling point) at a constant pressure of one atmosphere. The British Thermal Unit is used when the measurement is in degrees Fahrenheit (EF) on the *Fahrenheit Scale* and the *Calorie* is used when temperature is measured in degrees *Celsius* (EC) on the *Centigrade Scale*.

Brook — A natural stream of water, smaller than a river or creek; especially a small stream or rivulet which breaks directly out of the ground, as from a spring or seep; also, a stream or torrent of similar size, produced by copious rainfall, melting snow and ice, etc.; a primary stream not formed by tributaries, though often fed below its source, as by rills or runlets; one of the smallest branches or ultimate ramifications of a drainage system.

Brownian Movement — The constant, random, zigzag movement of small particles dispersed in a fluid medium, caused by collision with molecules of the fluid. Also referred to as *Brownian Motion*.

Buffer — A solution which is resistant to pH changes, or a solution or liquid whose chemical makeup tends to neutralize acids or bases without a great change in pH. Surface waters and soils with chemical buffers are not as susceptible to acid deposition as those with poor buffering capacity.

Buffer Strips — (1) Strips of grass or other erosion-resisting vegetation between or below cultivated strips or fields. (2) Grassed or planted zones which act as a protective barrier between an area which experiences livestock grazing or other activities and a water body. Also referred to as a *Buffer Zone*.

Buffer Zone — (1) A protective, neutral area between distinct environments. (2) An area which acts to minimize the impact of pollutants on the environment or public welfare. For example, a buffer zone may be established between a compositng facility and nearby neighborhoods to minimize odor problems. Also see *Buffer Strips*.

-C-

C–Horizon — A layer of unconsolidated material, relatively little affected by the influence of organisms and presumed to be similar in chemical, physical, and mineralogical composition to the material from which at least a portion of the overlying *Solum* has developed.

Calcareous — Formed of calcium carbonate or magnesium carbonate by biological deposition or inorganic precipitation in sufficient quantities to effervesce carbon dioxide visibly when treated with cold 0.1 normal hydrochloric acid. Calcareous sands are usually formed of a mixture of fragments of mollusk shell, echinoderm spines and skeletal material, coral, foraminifera, and algal platelets.

Calcareous Fens — *Peatlands* formed in areas of ground water discharge, where cold, anoxic, mineral-rich water provides a specialized habitat for disproportionately large numbers of rare and endangered plants. Many of the plants found in calcareous fens are species which would be typical of more northern habitats. The health of such fens is inextricably linked to the presence of the upwelling ground water.

Calcic Horizon — A secondary *Calcium Carbonate* accumulation in the lower *B-Horizon* that occurs as coatings on *Clasts* and as lenses in fine-grained sediment matrices; it is at least 15 centimeters (5.9 inches) thick and contains 15 percent or more calcium carbonate.

Calcite — (Geology) Calcium carbonate (CaCO3), with hexagonal crystallization, a mineral found in the form of limestone, chalk, and marble.

Calcium Carbonate — Chemical symbol: CaCO3. The principal hardness and scale-causing compound in water. A white precipitate that forms in water lines, water heaters, and boilers in hard water areas; also known as scale. Also the principal chemical composition of *Tufa*, a calcareous and siliceous rock deposit of springs, lakes, or ground water.

Calcium Hydroxide — A white crystalline strong alkali Ca(OH)2 that is used especially to make mortar and plaster and to soften water.

Calibrated Model - a model for which all residuals between calibration targets and corresponding model outputs, or statistics computed from residuals, are less than pre-set acceptable values.

Calibration - the process of refining the model representation of the hydrogeologic framework, hydraulic properties, and boundary conditions to achieve a desired degree of correspondence between the model simulations and observations of the ground water flow system, which includes both measured hydraulic head and flux.

Calibration Target - measured, observed, calculated, or estimated hydraulic heads or ground water flow rates that a model must reproduce, at least approximately, to be considered calibrated.

Caliche — (1) A soil layer near the surface, more or less cemented by secondary carbonates of calcium or magnesium precipitated from the soil solution. It may occur as a soft, thin soil horizon, as a hard, thick bed just beneath the *Solum*, or as a surface layer exposed by erosion. (2) *Alluvium* cemented with sodium nitrate, chloride, and/or other soluble salts in the nitrate deposits of Chile and Peru. Also referred to as *Hardpan*.

Calorie — (Abbreviation cal) (1) Basically, A unit of heat energy equal to the amount of heat needed to raise the temperature of one gram of water one degree *Celsius* (EC). More precisely, any of several approximately equal units of heat, each measured as the quantity of heat required to raise the temperature of 1 gram of water by 1EC from a standard initial temperature, especially from 3.98EC (corresponding to the maximum density of water), 14.5EC, or 19.5EC, at 1 atmosphere pressure. Also referred to as the *Gram Calorie* and the *Small Calorie*. (2) The unit of heat equal to 1/100 the quantity of heat required to raise the temperature of 1 gram of water from 0EC (its freezing point) to 100EC (its boiling point) at 1 atmosphere pressure. Also referred to as the *Mean Calorie*. (3) The unit of heat equal to the amount of heat required to raise the temperature of 1 kilogram of water by 1EC at 1 atmosphere pressure. Also referred to as the *Kilocalorie*, *Kilogram Calorie*, and *Large Calorie*. (4) A unit of energy-producing potential equal to this amount of heat that is contained in food and released upon oxidation by the body. Also referred to as the *Nutritionist's Calorie*. The calorie is used when temperature is measured in degrees *Celsius* (EC) on the *Centigrade Scale*. The *British Thermal Unit (BTU)* is used when the measurement is in degrees *Fahrenheit* (EF) on the *Fahrenheit Scale*.

Candidate Species — Plant or animal species designated by the Department of the Interior, *U.S. Fish and Wildlife Service (USFWS)* as candidates for potential future listing as an *Endangered Species* or *Threatened Species* pursuant to the *Endangered Species Act (ESA)* of 1973; plant or animal species that are candidates for designation as endangered (in danger of becoming extinct) or threatened (likely to become endangered).

Cap — A layer of clay, or other impermeable material installed over the top of a closed landfill to prevent entry of rainwater and minimize *Leachate*.

Capa (Critical Aquifer Protection Area) — As defined in the *Safe Drinking Water Act (SDWA)*, is all or part of an area located within an area for which an application of designation as a sole or principal source aquifer (pursuant to Section 1424[e]) has been submitted and approved by the Administrator not later than 24 months after the date of enactment and which satisfies the criteria established by the Administrator; and all or part of an area that is within an aquifer designated as a *Sole Source Aquifer (SSA)*, as of the date of the enactment of the *Safe Drinking Water Act (SDWA)* amendments of 1986, and for which an area wide ground-water protection plan has been approved under Section 208 of the *Clean Water Act (CWA)* prior to such enactment.

Capacity, Field or Soil — The amount of water held in a soil sample after the excess gravitation water has drained away.

Capillarity — (1) The property of tubes or earth-like particles with hairlike openings which, when immersed in fluid, raise (or depress) the fluid in the tubes above (or below) the surface of the fluid in which they are immersed. (2) The interaction between contacting surfaces of a liquid and a solid that distorts the liquid surface from a planar shape. Also referred to as *Capillary Action* or *Capillary Attraction*.

Capillary Action — (1) The action by which water is drawn around soil particles because there is a stronger attraction between the soil particles and the water molecules themselves. (2) The movement of water within the interstices of a porous medium due to the forces of adhesion, cohesion, and surface tension acting in a liquid that is in contact with a solid. Synonymous with the terms *Capillarity*, *Capillary Flow*, and *Capillary Migration*.

Capillary Attraction — The force that results from greater adhesion of a liquid to a solid surface than internal cohesion of the liquid itself and that causes the liquid to be raised against a vertical surface, as water is in a clean glass tube. It is the force that allows a porous material like soil to soak up water from lower levels.

Capillary Fringe — (1) The zone at the bottom of the *Zone of Aeration* (*Vadose Zone*) where ground water is drawn upward by capillary force. (2) The zone immediately above the *Zone of Saturation* (or *Ground water Table*) in which underground water is lifted against gravity by surface tension (*Capillary Action*) in passages of capillary size.

Capillary Water — (1) Water held in the soil above the *Phreatic Surface* by capillary forces; or soil water above hydroscopic moisture and below the field capacity. (2) A continuous film of water found around soil particles.

Capillary Zone — The soil area above the water table where water can rise up slightly through the cohesive force of *Capillary Action*.

Capture — (1) Water withdrawn artificially from an aquifer is derived from a decrease in storage in the aquifer, a reduction in the previous discharge from the aquifer, an increase in the recharge, or a combination of these changes. The decrease in discharge from an aquifer plus the increase in recharge. Capture may occur in the form of decreases in the ground-water discharge into streams, lakes, and the ocean, or from decreases in that component of *Evapotranspiration* derived from the *Zone of Saturation*. (2) Diversion of the flow of water in the upper part of a stream by the headward growth of another stream.
Capture Zone — The zone around a well contributing water to the well; the area on the ground surface from which a well captures water.

Carbonate — (1) The collective term for the natural inorganic chemical compounds related to carbon dioxide that exist in natural waterways. (2) A sediment formed by the organic or inorganic precipitation from aqueous solution of carbonates of calcium, magnesium, or iron. The $CO3^{-2}$ ion in the *Carbonate Buffer System*. Combined with one proton, it becomes *Bicarbonate*, $HCO3^{-}$ and with two protons, *Carbonic Acid*. The carbonate ion forms a solid precipitant when combined with dissolved ions of calcium or magnesium.

Carbonate Aquifer — An aquifer found in limestone and dolomite rocks. Carbonate aquifers typically produced hard water, that is, water containing relatively high levels of calcium and magnesium.

Carbonate Buffer System — The most important buffer system in natural surface waters and wastewater treatment, consisting of a carbon dioxide, water, carbonic acid, *Bicarbonate*, and *Carbonate* ion equilibrium that resists changes in the water's pH. For example, if acid materials (hydrogen ions) are added to this buffer solution, the equilibrium is shifted and carbonate ions combine with the hydrogen ions to form bicarbonate. Subsequently, the bicarbonate then combines with hydrogen ions to form carbonic acid, which can dissociate into carbon dioxide and water. Thus the system pH is unaltered even though acid was introduced.

Carbonate Hardness — Water hardness caused by the presence of *Carbonate* and *Bicarbonate* of calcium and magnesium. Also see *Temporary Hardness*.

Carbonate Rock — (Geology) A rock consisting chiefly of carbonate minerals, such as limestone and dolomite.

Carbonation, Ground water — The dissolving of carbon dioxide in surface water as it percolates through the ground. The carbon dioxide reacts with water to form carbonic acid, a weak acid that causes the water to have a slightly acidic pH.

Carbonic Acid — A weak, unstable acid, H2CO3, present in solutions of carbon dioxide and water. The carbonic acid content of natural, unpolluted rainfall lowers its pH to about 5.6.

Casing — The steel conduit required to prevent waste and contamination of the ground water and to hold the formation open during the construction or use of the well. A tubular structure intended to be water tight installed in the excavated or drilled hole to maintain the well opening and, along with cementing, to confine the ground waters to their zones of origin and prevent the entrance of surface pollutants.

Catchment Area — (1) The intake area of an aquifer and all areas that contribute surface water to the intake area. (2) The areas tributary to a lake, stream, sewer, or drain. (3) A reservoir or basin developed for flood control or water management for livestock and/or wildlife. See also *Drainage Area*; *Watershed*.

Categorical Exclusion — A class of actions which either individually or cumulatively would not have a significant effect on the human environment and therefore would not require preparation of an *Environmental Assessment (EA)* or an *Environmental Impact Statement (EIS)* under the *National Environmental Policy Act (NEPA)*.

Cation — The positively charged particle or ion in an electrolyzed solution which travels to the cathode and is there discharged, evolved, or deposited. Also, by extension, any positive ion.

Cation Exchange — A chemical process in which *Cations* of like charge are exchanged equally between a solid, such as zeolite, and a solution, such as water. The process is often used to soften water.

Cation Exchange Capacity (CEC) — The total of exchangeable cations that a soil can adsorb; expressed in milliequivalents per 100 grams (g) of soil.

Caustic — Alkaline or basic.

Caving — The collapse of a stream bank by undercutting due to wearing away of the toe or an erodible soil layer above the toe.

Cavitation — (1) A process of erosion in a stream channel caused by sudden collapse of vapor bubbles against the channel wall. (2) The formation of cavities filled with air and water vapor due to internal pressure reduced below atmosphere. (3) The formation and collapse of gas pockets or bubbles on the blade of an impeller or the gate of a valve; collapse of these pockets or bubbles drives water with such force that it can cause pitting of the gate or valve surface.

Cell - also called element, a distinct one- two- or three-dimensional model unit representing a discrete portion of a physical system with uniform properties assigned to it.

Celsius [Temperature Scale] (C) — (1) Relating to, conforming to, or having the international thermometric scale on which the interval between the triple point of water and the boiling point of water is divided into 99.99 degrees with 0.01° representing the *Triple Point* and 100° the boiling point at one atmosphere of pressure; Abbreviation C; Compare to *Centigrade [Temperature Scale]*. The Celsius scale, which is identical to the centigrade scale, is named for the 18th-century Swedish astronomer Anders Celsius, who first proposed the use of a scale in which the interval between the freezing and boiling points of water is divided into 100 degrees. By international agreement, the term Celsius has officially replaced Centigrade. (2) Unit of measure for the *Centigrade Temperature Scale* of measuring temperature, as contrasted with the *Fahrenheit* unit of measure. The formula for converting a Celsius temperature to Fahrenheit temperature is FE = [9/5CE + 32]. Also see *Temperature Scale*.

Centigrade [Temperature Scale] (C) — Relating to, conforming to, or having a thermometric scale on which the interval between the freezing point of water and the boiling point of water is divided into 100 degrees with 0° representing the freezing point and 100° the boiling point at one atmosphere of pressure; Abbreviation C; Compare to *Celsius [Temperature Scale]*. The Centigrade scale is identical to the Celsius scale; however, by international agreement, the term Celsius has officially replaced Centigrade. Contrast with the *Fahrenheit Temperature Scale*, using degrees *Fahrenheit* (EF), in which 32EF above the 0E(F) mark indicates the freezing point of water and 212EF indicates the boiling point of water (at sea level). Also see *Temperature Scale*.

Chalk — A mineral composed mainly of the calcareous shells of various marine microorganisms, but whose matrix consists of fine particles of calcium carbonate, some of which may have been chemically precipitated.

Chalybeate — Tasting like iron, as water from a mineral spring.

Channel — (1) (Watercourse) A natural stream that conveys water; a natural or artificial watercourse with definite bed and banks to confine and conduct flowing water; a ditch or channel excavated for the flow of water. River, creek, run, branch, anabranch, and tributary are some of the terms used to describe natural channels, which may be single or *Braided*. Canal, aqueduct, and floodway are some of the terms used to describe artificial (man-made) channels. (2) (Landform) The bed of a single or braided watercourse that commonly is barren of vegetation and is formed of modern alluvium. Channels may be enclosed by banks or splayed across and slightly mounded above a fan surface and include bars and dumps of cobbles and stones. Channels, excepting floodplain playas, are landform elements.

Channel Bank — The sloping land bordering a channel. The bank has steeper slope than the bottom of the channel and is usually steeper than the land surrounding the channel.

Channel Capacity — The maximum rate of flow that may occur in a stream without causing overbank flooding; the maximum flow which can pass through a channel without overflowing the banks.

Channel Inflow — Water which at any instant is flowing into the channel system from surface flow, subsurface flow, base flow, and rainfall directly on the channel.

Channel Lining — Protection of the channel bottom and banks with concrete or *Riprap*.

Channel Modification — The modification of the flow characteristics of a channel by clearing, excavation, realignment, lining, or other means to increase its capacity. Sometimes the term is used to connote *Channel Stabilization*.

Channel Realignment — The construction of a new channel or a new alignment which may include the clearing, snagging, widening, and/or deepening of the existing channel.

Channel Stabilization — Erosion prevention and stabilization of velocity distribution in a channel using jetties, drops, revetments, vegetation, and other measures.

Channelization — (1) The artificial enlargement or realignment of a stream channel. (2) Straightening a stream or river to allow water to travel through the area more quickly. (3) The process of changing an straightening the natural path of a waterway. Channelization is often used as a means of flood control, but its negative effects often outweigh its advantages. For example, channelization often damages wetlands associated with rivers and streams.

Check Dam — (1) A structure placed bank to bank downhill from a headcut on a hillslope to help revegetate a gully. (2) A small dam constructed in a gully or other small watercourse to decrease the streamflow velocity, minimize channel erosion, promote deposition of sediment, and to divert water from a channel.

Chemical Oxygen Demand (COD) — (Water Quality) (1) A measure of the chemically oxidizable material in the water which provides an approximation of the amount of organic and reducing material present. The determined value may correlate with *Biochemical Oxygen Demand (BOD)* or with carbonaceous organic pollution from sewage or industrial wastes. (2) A chemical measure of the amount of organic substances in water or wastewater. A strong oxidizing agent together with acid and heat are used to oxidize all carbon compounds in a water sample. Non-biodegradable and recalcitrant (slowly degrading) compounds, which are not detected by the test for BOD, are included in the analysis. The actual measurement involves a determination of the amount of oxidizing agent (typically, potassium dichromate) that is reduced during the reaction.

Chemical Weathering — The gradual decomposition of rock by exposure to rainwater, surface water, atmospheric oxygen, carbon dioxide and other gases in the atmosphere, as well as compounds secreted by organisms. Compare to *Physical Weathering*.

Chlorides — Negative chlorine ions, Cl^{-}, found naturally in some surface waters and ground waters and in high concentrations in seawater. Higher-than-normal chloride concentrations in fresh water, due to sodium chloride (table salt) that is used on foods and present in body wastes, can indicate sewage pollution. The use of highway deicing salts can also introduce chlorides to surface water or ground water. Elevated ground water chlorides in drinking water wells near coastlines may indicate *Saltwater Intrusion*.

Chlorine — One of a group of elements classified as the halogens. Chlorine, Cl2, the most common halogen, is a greenish yellow gas with an irritating odor. Chlorine is very reactive; it forms salts with metals, forms acids when dissolved in water, and combines readily with hydrocarbons. Various forms of chlorine are used to disinfect water. Chlorine is produced by the electrolysis of brine (a concentrated salt solution). Atomic number 17; atomic weight 35.45; freezing point –100.98EC; boiling point –34.6EC; specific gravity 1.56 (–33.6EC).

Chute, or Chute Cutoff — As applied to stream flow, the term "chute" refers to a new route taken by a stream when its main flow is diverted to the inside of a bend, along a trough between low ridges formed by deposition on the inside of the bend where water velocities were reduced. Compare with *Neck Cutoff*.

Circumneutral — Term applied to water with a pH of 5.5 (acidic) to 7.4 (alkaline).

Clast (Clastic) — (1) Pertaining to a rock or sediment composed principally of broken fragments that are derived from pre-existing rocks or minerals and that have been transported some distance from their places of origin. (2) An individual constituent, grain, or fragment of a sediment or rock, produced by the mechanical weathering (disintegration) of a larger rock mass.

Clay — (1a) A fine-grained, firm earth material that is plastic when wet and hardens when heated, consisting primarily of hydrated silicates of aluminum and widely used in making bricks, tiles, and pottery; (1b) A hardening or non-hardening material having a consistency similar to clay and used for modeling. (2) (Geology) A sedimentary material with grains smaller than 0.2 millimeters in diameter. (3) Moist, sticky earth; mud.

Clay Liner — A layer of clay soil that is added to the bottom and sides of a pit designed for use as a disposal site for potentially dangerous wastes. The clay prevents or reduces the migration of liquids from the disposal site.

Claypan — (1) A dense, compact layer in the subsoil having a much higher clay content than the overlying material from which it is separated by a sharply defined boundary. Such layers are formed by the downward movement of clay or by synthesis of clay in place during soil formation. Claypans are usually hard when dry, and plastic and sticky when wet. They usually impede movement of water and air, and the growth of plant roots. (2) (Australian) A shallow depression in which water collects after rain. Also see *Hardpan*.

Clay Soil — A soil composed of microscopically small mineral particles that are flattened and fit closely together; spaces between particles for air and water are also small. When clay soil gets wet it dries out slowly because the downward movement if water, i.e., drainage, is slow.

Clean Water Act (CWA) [Public Law 92–500] — More formally referred to as the *Federal Water Pollution Control Act*, the Clean Water Act constitutes the basic federal water pollution control statute for the United States. Originally based on the *Water Quality Act* of 1965 which began setting water quality standards. The 1966 amendments to this act increased federal government funding for sewage treatment plants. Additional 1972 amendments established a goal of zero toxic discharges and "fishable" and "swimmable" surface waters. Enforceable provisions of the CWA include technology-based effluent standards for point sources of pollution, a state-run control program for nonpoint pollution sources, a construction grants program to build or upgrade municipal sewage treatment plants, a regulatory system for spills of oil and other hazardous wastes, and a *Wetlands* preservation program (Section 404).

Clean Water Act (CWA), Section 319 — A federal grant program added by Congress to the CWA in 1987 and managed by the *U.S. Environmental Protection Agency (EPA)*, Section 319 is specifically designed to develop and implement state *Nonpoint Source (NPS) Pollution* management programs, and to maximize the focus of such programs on a watershed or waterbasin basis with each state. Today, all 50 states and U.S. territories receive Section 319 grand funds and are encouraged to use the funding to conduct nonpoint source assessments and revise and strengthen their nonpoint source management programs. Before a grant is provided under Section 319, states are required to: (1) complete a Nonpoint Source (NPS) Assessment Report identifying state waters that require nonpoint source control and their pollution sources; and (2) develop Nonpoint Source Management Programs that outline four-year strategies to address these identified sources.

Clean Water Standards (EPA) — Generally refers to any enforceable limitation, control, condition, prohibition, standard, or other requirement which is promulgated pursuant to the *Federal Water Pollution Control Act (Clean Water Act) [Public Law 92–500]* or contained in a permit issued to a discharger by the *U.S. Environmental Protection Agency (EPA)* or by a state under an approved program, as authorized by Section 402 of the Clean Water Act, or by local governments to ensure compliance with pretreatment regulations as required by Section 307 of the Clean Water Act.

Closed Basin — A hydrographic basin (basin, area or sub-area) is considered closed with respect to surface water flow if its topography prevents the occurrence of visible surface water outflow. It is closed hydrologically if neither surface nor underground water outflow can occur.

Coal Slurry Pipeline — A pipeline which transports pulverized coal suspended in liquid, usually water.

Cobble — Rock fragments 7.6 cm (3 inches) to 25.4 cm (10 inches) in diameter.

Code of Federal Regulations (CFR) — (1) The annual compilation of all current regulations that have been issued in final form by any federal regulatory agency. (2) The codification of the general and permanent rules initially published in the Federal Register by the executive departments and agencies of the federal government. The publication is organized by subject titles. Environmental regulations are covered under Title 40, Protection of the Environment.

Code Selection - the process of choosing the appropriate **computer code**, algorithm, or other analysis technique capable of simulating those characteristics of the physical system required to fulfill the modeling project's objective(s).

Coefficient of Roughness — Factor in fluid flow determination expressing the character of a surface and its fractional resistance to flow. Also referred to as *Roughness Coefficient*.

Coefficient of Runoff — Factor in the rational runoff formula expressing the ratio of peak runoff rate to rainfall intensity.

Coefficient of Storage — The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head.

Coefficient of Transmissivity (*t*) — The rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of the aquifer under a unit *Hydraulic Gradient*. It is equal to an integration of the hydraulic conductivities across the saturated part of the aquifer perpendicular to the flow paths. Also, the rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient. Transmissivity values are given in gallons per minute through a vertical section of an aquifer 1 foot wide and extending the full saturated height of an aquifer under a hydraulic gradient of one in the *English Engineering System*; in the *Standard International System*, transmissivity is given in cubic meters per day through a vertical section of an aquifer 1 meter wide and extending the full saturated height of an aquifer under hydraulic gradient of one. It is a function of properties of the liquid, the porous media, and the thickness of the porous media. Also see *Transmissivity*.

Coefficient of Viscosity — The degree to which a fluid resists flow under an applied force, measured by the tangential friction force per unit area divided by the velocity gradient under conditions of streamline flow.

Cofferdam — A temporary watertight enclosure that is pumped dry to expose the bottom of a body of water so that construction, as of piers, a dam, and bridge footings, may be undertaken. Also, a watertight chamber attached to the side of a ship to facilitate repairs below the water line. A *Diversion Cofferdam* prevents all downstream flow by diverting the flow of a river into a pipe, channel, or tunnel.

Collector Well — A well located near a surface water supply used to lower the water table and thereby induce infiltration of surface water through the bed of the water body to the well.

Colloidal Suspension — Suspension in water of particles so finely divided that they will not settle under the action of gravity, but will diffuse, even in quiet water, under the random impulses of *Brownian Movement*. Particles typically range in size from about one micron (0.000001 millimeter) to about one millimicron; however, there is no distinct differentiation by particle size between true *Suspension* and colloidal suspension or between colloidal suspension and *Solution*.

Colloids — (1) Any substance with particles in such a fine state of subdivision dispersed in a medium (for example, water) that they do not settle out, but not in so fine a state of subdivision that they can be said to be truly dissolved. (2) Quantities of extremely small particles, typically 0.0001 to 1 micron in size, and small enough to remain suspended in a fluid medium without settling to the bottom. Substances that, when apparently dissolved in water or other liquid, diffuse not at all or very slowly through a membrane and show other special properties, as lack of pronounced effect on the freezing point or vapor pressure of the solvent. Colloids represent intermediate substances between a true dissolved particle and a suspended solid, which will settle out of solution.

Colluvial Material — (Geology) Material consisting of *Alluvium* in part and also containing angular fragments of the original rocks. Typically found at the bottom or on the lower slopes of a hill.

Colluvium — (1) A general term used to describe loose and incoherent deposits of rock moved downslope by gravitational force in the form of soil *Creep*, slides, and local wash. (2) A general term applied to any loose, heterogeneous, and incoherent mass of soil material or rock fragments deposited chiefly by gravity-driven mass-wasting usually at the base of a steep slope or cliff, for example, talus, cliff debris, and avalanche material. (3) *Alluvium* deposited by unconcentrated surface run-off or sheet erosion, usually at the base of a slope. Also see *Colluvial Material*.

Compaction — A physical change in soil properties that result in an increase in soil bulk density and a decrease in *Porosity*. The packing together of soil particles by forces exerted at the soil surface, resulting in increased soil density.

Compliance Monitoring — (Water Quality) Collection and evaluation of data, including self-monitoring reports, and verification to show whether pollutant concentrations and loads contained in permitted discharges are in compliance with the limits and conditions specified in the permit.

Composite Sample — (Water Quality) A representative water or wastewater sample made up of individual smaller samples taken at periodic intervals.

Compound — A substance composed of separate elements, ingredients, or parts. Water is a compound consisting of hydrogen and oxygen, chemical symbol H2O.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) — Also referred to as the *Superfund Law*, this statute, originally enacted in 1980 and substantially modified in 1986, establishes the *U.S. Environmental Protection Agency's (EPA)* authority for emergency response and cleanup of hazardous substances that have been spilled, improperly disposed of, or released into the environment. The primary responsibility for response and cleanup is on the generators or disposers of the hazardous substances, with a backup federal response using a trust fund provision.

Computer Code (computer program) - the assembly of numerical techniques, bookkeeping, and control language that represents the model from acceptance of input data and instructions to delivery of output. Examples: MODFLOW, BIOSCREEN, MT3D, etc.

Concentrate — To make a solution or mixture less dilute, as by removing water from a solution.

Concentration — (1) The density or amount of a substance in a solution. (2) The amount of *Solute* present in proportion to the total *Solution*. More specifically, a measure of the average density of pollutants or other constituents, usually specified in terms of mass per unit volume of water or other *Solvent* (e.g., milligrams per liter) or in terms of relative volume of solute per unit volume of water (e.g., parts per million).

Concentration Gradient - The rate of change in solute concentration per unit distance at a given point and in a given direction.

Concentration Time — The period of time required for storm runoff to flow from the most remote point of a catchment or drainage area to the outlet or point under consideration. Concentration time varies with depth of flow and channel condition.

Conceptualization Error - A modeling error where model formulation is based on incorrect or insufficient understanding of the modeled system.

Conceptual Model - An interpretation of the characteristics and dynamics of an aquifer system which is based on an examination of all available hydrogeological data for a modeled area. This includes the external configuration of the system, location and rates of recharge and discharge, location and hydraulic characteristics of natural boundaries, and the directions of ground water flow throughout the aquifer system.

Condemnation — Taking private property for public use, with compensation to the owner, under the right of *Eminent Domain*.

Condensation — (1) (Physics) The process by which a gas or vapor changes to a liquid or solid; also the liquid or solid so formed. (2) (Chemistry) A chemical reaction in which water or another simple substance is released by the combination of two or more molecules. The opposite of *Evaporation*. In meteorological usage, this term is applied only to the transformation from vapor to liquid.

Conductance — A rapid method of estimating the dissolved solids content of a water supply by determining the capacity of a water sample to carry an electrical current.

Conductivity — A measure of the ability of a solution to carry an electrical current.

Conductor Casing — The temporary or permanent steel casing used in the upper portion of the borehole to prevent collapse of the formation during the construction of the well or to conduct the gravel pack to the perforated or screened areas of the casing.

Cone of Depression (COD)/Cone of Influence (COI) — A cone-like depression of the water table or other piezometric surface that has the shape of an inverted cone and is formed in the vicinity of a well by withdrawal of water. The surface area included in the cone is known as the area of influence of the well. Also referred to as the *Pumping Cone* and the *Cone of Drawdown*.

Confined Aquifer — (1) An aquifer containing water between two relatively impermeable boundaries. The water level in a well tapping a confined aquifer stands above the top of the confined aquifer and can be higher or lower than the water table that may be present in the material above it. In some cases the water level can rise above the ground surface, yielding a flowing well. (2) An aquifer or water-bearing subsurface stratum which is bounded above and below by formations of impermeable or relatively impermeable material; a water-bearing formation whose upper boundary is a layer which does not transmit water readily. (3) An aquifer in which ground water is under pressure significantly greater than atmospheric and its upper limit is the bottom of a bed of distinctly lower hydraulic conductivity than that of the aquifer itself. See *Artesian Aquifer*.

Confined Ground Water — A body of ground water covered by material so impervious as to sever the hydraulic connection with overlying ground water except at the intake or recharge area. Confined water moves in pressure conduits due to the difference in head between intake and discharge areas of the confined water body.

Confined Water (Artesian) — Water under artesian pressure. Water that is not confined is said to be under water table conditions.

Confining Bed — A body of "impermeable" material stratigraphically adjacent to one or more aquifers. It may lie above or below the aquifer. In nature its hydraulic conductivity may actually range from nearly zero to some value distinctly lower than that of the aquifer. In some literature, the term confining bed has now supplanted the terms *Aquiclude*, *Aquitard*, and *Aquifuge*. Also referred to as *Confining Layer*.

Confining Unit — A hydrogeologic unit of relatively impermeable material, bounding one or more aquifers. This is a general term that has replaced *Aquitard*, *Aquifuge*, and *Aquiclude* and is synonymous with *Confining Bed*.

Confluence — (1) The act of flowing together; the meeting or junction of two or more streams; also, the place where these streams meet. (2) The stream or body of water formed by the junction of two or more streams; a combined flood.

Connate Water — Water that was trapped in the interstices of a sedimentary or extrusive igneous rock at the time of its deposition. It is usually highly mineralized and frequently saline.

Consequent Stream — A stream following a course that is a direct consequence of the original slope of the surface on which it developed.

Conservation District — A public organization crated under state-enabling law as a special purpose district to develop and carry out a program of soil, water, and related resource conservation, use, and development within its boundaries. In the United States, such districts are usually a subdivision of state government with a local governing body and are frequently called a soil conservation district or a soil and water conservation district.

Conservation Easement — An agreement negotiated on privately owned lands to preserve open space or protect certain natural resources.

Consolidated Aquifer — An aquifer made up of consolidated rock that has undergone solidification or lithification.

Consolidated Formation — Geological formations which occur naturally and have been turned to stone. The term is sometimes used interchangeably with the word *Bedrock*. It includes rock such as basalt, rhyolite, sandstone, limestone and shale. Typically, these formations will stand at the edges of a bore hole without caving.

Consolidation — (Soil Mechanics) Adjustment of a soil in response to increased load; involves squeezing of water from the pores and a decrease in void ratio (pore space). Frequently the geologic term *Compaction* is used instead.

Constant-Head Node - a location in the discretized ground water flow model domain (node) where the hydraulic head remains the same over the time period considered.

Constituents — Any of the chemical substances found in water. Typically, measurements of such constituents in sampled drinking water may consist of *Total Dissolved Solids (TDS)*, Hardness (concentrations of Calcium and Magnesium, specifically), Sodium, Potassium, Sulfate, Chloride, Nitrate, Alkalinity, Bicarbonate, Carbonate, Fluoride, Arsenic, Iron, Manganese, Copper, Zinc, Barium, Boron, Silica, as well as other physical characteristics and properties such as water color, turbidity, pH, and electro-conductivity (EC).

Constructed Wetlands — (1) Wetlands constructed by man either as part of a *Wetland Banking*, *Wetland Clumping (Aggregation)*, or *Wetland Mitigation* program, or to achieve some other environmental preservation or restoration program. (2) (Water Quality) Wetlands constructed specifically for the purpose of treating waste water effluent before re-entering a stream or other body of water or being allowed to percolate into the ground water. Also see *Lagoon*.

Contaminant Fate - chemical changes and reactions that change the chemical nature of the contaminant, effectively removing the contaminant from the subsurface hydrologic system.

Contaminant Transport Model - a model describing the movement of contaminants in the environment.

Contaminant Transport Velocity - is the rate in which contamination moves through an aquifer.

Contamination (Water) — Impairment of the quality of water sources by sewage, industrial waste, or other matters to a degree which creates a hazard to public health. Also, the degradation of the natural quality of water as a result of man's activities. There is no implication of any specific limits, since the degree of permissible contamination depends upon the intended end use, or uses, of the water.

Continuous-Record Station (USGS) — A gaging station site that meets either of the following conditions: (1) Stage or streamflow are recorded at some interval on a continuous basis; the recording interval is usually 15 minutes, but may be less or more frequent; (2) water quality, sediment, or other hydrologic measurements are recorded at least daily.

Continuous Sample — A flow of water from a particular place in a plant to the location where samples are collected for testing. May be used to obtain *Grab Samples* or *Composite Samples*.

Creek — A small stream of water which serves as the natural drainage course for a drainage basin; a flowing rivulet or stream of water normally smaller than a river and larger than a brook. The term is often relative according to size and locality. Some creeks in a humid region would be called rivers if they occurred in an arid area.

Creep — Slow mass movement of soil and soil material down relatively steep slopes, primarily under the influence of gravity but facilitated by saturation with water and by alternate freezing and thawing.

Crenulation — Small-scale folding that is superimposed on larger-scale folding. Crenulations may occur along the cleavage planes of a deformed rock.

Critical Aquifer Protection Area (CAPA) — As defined in the *Safe Drinking Water Act (SDWA)*, is all or part of an area located within an area for which an application of designation as a sole or principal source aquifer (pursuant to Section 1424[e]) has been submitted and approved by the Administrator not later than 24 months after the date of enactment and which satisfies the criteria established by the Administrator; and all or part of an area that is within an aquifer designated as a sole source aquifer (SSA), as of the date of the enactment of the Safe Drinking Water Act Amendments of 1986, and for which an area-wide ground water protection plan has been approved under Section 208 of the *Clean Water Act (CWA)* prior to such enactment.

Critical Area — An area that, because of its size, location, condition, or importance, must be treated with special consideration because of inherent site factors and difficulty of management. Also, a severely eroded, sediment-producing area that requires special management to establish and maintain vegetation to stabilize the soil.

Critical (Ground Water) Area — An area that has certain ground water problems, such as declining water levels due, for example, to the use of underground water that approaches or exceeds the current recharge rate. These designated areas are usually limited in their development and use.

Critical Flow — (1) The flow conditions at which the discharge is a maximum for a given specific energy, or at which the specific energy is a minimum for a given discharge. (2) In reference to Reynolds' critical velocities, the point at which the flow changes from streamline or non-turbulent to turbulent.

Critical Low-Flow — Low flow conditions below which some standards (*Criteria*) do not apply. The impacts of permitted discharges are typically analyzed at critical low-flow.

Cumulative Impact — The environmental impacts of a proposed action in combination with the impacts of other past, existing and proposed actions. Each increment from each action may not be noticeable but cumulative impacts may be noticeable when all increments are considered together.

Current — (1) The portion of a stream or body of water which is moving with a velocity much greater than the average of the rest of the water. The progress of the water is principally concentrated in the current. (2) The swiftest part of a stream; (3) A tidal or nontidal movement of lake or ocean water; (4) Flow marked by force or strength.

Current Meter — An instrument for measuring the velocity of water flowing in a stream, open channel, or conduit by ascertaining the speed at which elements of the flowing water rotate a vane or series of cups.

Cut Bank — The outside bank of a bend, often eroding opposite a point bar.

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Darcy's Law — An empirically derived equation for the flow of fluids through porous media. It is based on the assumption that flow is laminar and inertia can be neglected, and states that velocity of flow is directly proportional to *Hydraulic Gradient*. For ground water, this is equivalent to the velocity being equal to the product of the hydraulic gradient and the effective subsoil conductivity or permeability. See *Specific Discharge* (*Specific Flux*).

Datum — Any numerical or geometric quantity or set of such quantities that may serve as a reference or base for other, comparable quantities. For example, *Mean Sea Level (MSL)* is the datum used on most topographic maps. However, most river gages use an arbitrary elevation above the *National Geodetic Vertical Datum (NGVD)* of 1929 for use as a zero datum (e.g., datum equals 3412.6 feet above NGVD of 1929). Datums are always chosen so there will never be negative stages.

Debris Flow — (1) A moving mass of rock fragments, soil, and mud with more than one-half of the material being larger than sand size. (2) A mass movement involving rapid flowage of debris of various kinds under various conditions; specifically, a high-density *Mudflow* containing abundant coarse-grained materials and resulting almost invariably from an unusually heavy rain. (3) The rapid mass movement of a dense, viscous mixture of rock fragments, fine earth, water and entrapped air that almost always follows a heavy rain. A mudflow is a debris flow that has predominately sand size or smaller particles.

Declared Underground Water Basin — An area of a state designated in some states by their respective State Engineers to be underlain by a ground water source having reasonably ascertainable boundaries. By such a designation, the State Engineer assumes jurisdiction over the appropriation and use of ground water from the source. May not be applicable in states which already claim regulatory rights over both surface and ground waters.

Deflocculate — To cause the particles of the disperse phase of a colloidal system to become suspended in the dispersion medium.

Deflocculating Agent — A material added to a suspension to prevent settling.
Degradation (River Beds or Stream Channels) — The general lowering of the streambed by erosive processes, such as scouring by flowing water. The removal of channel bed materials and downcutting of natural stream channels. Such erosion may initiate degradation of tributary channels, causing damage similar to that due to gully erosion and valley trenching. Opposite of *Aggradation*.

Degradation Constant - term used to address the decay of contaminant concentration due to factors other than dispersion.

Degrade — The lowering of a stream-channel bed with time due to the erosion and transport of bed materials or the blockage of sediment sources.

Dehydrate — (1) To remove bound water or hydrogen and oxygen from (a chemical compound) in the proportion in which they form water. (2) To remove water from (as foods). (3) To remove water from; make *Anhydrous*. (4) To Lose water or moisture; become dry.

Deionization — The removal of all charged atoms or molecules from some material such as water. For example, the removal of salt from water involves the removal of sodium ions (Na^{+}) and chloride ions (Cl^{-}). The process commonly employs one resin that attracts all positive ions and another resin to capture all negative ions.

Deionize — To remove ions from water by *Ion Exchange*. See *Deionization*.

Delay Time — Duration of time for contamination or water to move from point of concern to the well; analogous to time-of-travel.

Delegated State — A state (or other governmental entity such as a tribal government) that has received authority from the *U.S. Environmental Protection Agency (EPA)* to administer an environmental regulatory program in lieu of a federal counterpart. As used in connection with *National Pollutant Discharge Elimination System (NPDES)*, *Underground Injection Control (UIC)*, and *Public Water System (PWS)* programs, the term does not connote any transfer of federal authority to a state. Also see *Primacy*.

Delta — (1) An alluvial deposit made of rock particles (sediment and debris) dropped by a stream as it enters a body of water. (2) A plain underlain by an assemblage of sediments that accumulate where a stream flows into a body of standing water where its velocity and transporting power are suddenly reduced. (3) The low, nearly flat, alluvial tract of land deposited at or near the mouth of a river, commonly forming a triangular or fan-shaped plain of considerable area enclosed and crossed by many distributaries of the main river. Originally so named because many deltas are roughly triangular in plan, like the Greek letter delta (Ä), with the apex pointing upstream.

Demineralization, also Demineralize — The act or treatment process that removes dissolved minerals or mineral salts from a liquid, such as water.

De Minimis — Derived from the Latin meaning that the law does not care for or take notice of very small or trifling matters. De minimis water uses are those deemed by law to be too insignificant to notice.

Dendritic — (1) A drainage pattern in which tributaries branch irregularly in all directions from and at almost any angle to a larger stream. (2) A tree-like pattern, typical of most drainage networks. From an aerial view, it resembles the branching pattern of trees.

Denitrification — The removal of nitrate ions ($NO3^-$) from soil or water; involves the *Anaerobic* biological reduction of nitrate to nitrogen gas. The process reduces desirable fertility of an agricultural field or the extent of undesirable aquatic weed production in aquatic environments. Also see *Denitrifying Bacteria*.

Density — (1) Matter measured as mass per unit volume expressed in pounds per gallon (lb/gal), pounds per cubic foot (lb/ft^3), and kilograms per cubic meter (kg/m^3). The mass of quantity of a substance per unit volume. (2) (Biology) The number per unit area of individuals of any given species at any given time. A term used synonymously with *Population Density*.

Density Stratification — The arrangement of water masses into separate, distinct horizontal layers as a result of differences in density. Such differences may be caused by differences in temperature or dissolved and suspended solids. Also see *Thermal Stratification*.

(United States) Department of the Interior (USDI) — Originally established by Congress in 1849 as the executive department of the United States government, the USDI's function has changed from that of performing housekeeping duties for the federal government to its present role as custodian of the nation's natural resources. As the nation's principal conservation agency, the USDI has the responsibility of protecting and conserving the country's land, water, minerals, fish, and wildlife; of promoting the wise use of all these natural resources; of maintaining national parks and recreation areas; and of preserving historic places. It also provides for the welfare of American Indian reservation communities and of inhabitants of island territories under U.S. administration. As of 1988 the USDI managed more than 220 million hectares (550 million acres, or 850,000 square miles) of federal resource lands; about 340 units of the national park system; 70 fish hatcheries, and 442 *National Wildlife Refuges (NWF)*; and numerous reclamation dams that provide water, electricity, and recreation. The USDI also constructs irrigation works, enforces mine safety laws, makes geological surveys and prepares maps, conducts mineral research, and administers wild and scenic rivers as well as national and regional trails. The USDI is currently in charge of the *Bureau of Indian Affairs (BIA)*, the *U.S. Fish and Wildlife Service (USFWS)*, the *National Park Service (NPS)*, and the *U.S. Geological Survey (USGS)*. It also oversees the Bureau of Mines, which is responsible for ensuring that the nation has adequate mineral supplies and for overseeing and evaluating all aspects of minerals research; the *U.S. Bureau of Land Management (BLM)*, which manages public lands and their resources; the *U.S. Bureau of Reclamation (USBR)*, which assists local governments in reclaiming arid lands in western states and provides programs for hydro-electric power generation, flood control, and river regulation; the Minerals Management Service, which deals with leasable minerals on the Outer Continental Shelf and ensures efficient recovery of mineral resources; and the Office of Surface Mining Reclamation and Enforcement, which helps to protect the environment from adverse effects of coal mining operations. Other agencies under the USDI's jurisdiction include the

Office of Small and Disadvantaged Business Utilization and the Office of Territorial and International Affairs.

Depletion — (1) The water consumed within a service area or no longer available as a source of supply; that part of a withdrawal that has been evaporated, transpired, incorporated into crops or products, consumed by man or livestock, or otherwise removed. (2) Net rate of water use from a stream or ground water aquifer for beneficial and nonbeneficial uses. For irrigation or municipal uses, the depletion is the headgate or wellhead diversion minus return flow to the same stream or ground water aquifer. For agriculture and wetlands, it is the *Evapotranspiration of Applied Water (ETAW)* (and *Evapotranspiration (ET)* of flooded wetlands) plus irrecoverable losses. For urban water use, it is the ETAW (water applied to landscaping or home gardens), sewage effluent that flows to a salt sink, and incidental ET losses. For instream use, it is the amount of dedicated flow that proceeds to a salt sink and is not available for reuse.

Depletion (Ground Water) — The withdrawal of water from a ground water source at a rate greater than its rate of recharge, usually over an extended period of several years.

Depletion (Streamflow) — The amount of water that flows into a valley, or onto a particular land area, minus the water that flows out of the valley or off from the particular land area.

Depletion Curve — (Hydraulics) A graphical representation of water depletion from storage-stream channels, surface soil, and ground water. A depletion curve can be drawn for base flow, direct runoff, or total flow.

Deposition — The accumulation of material dropped because of a slackening movement of the transporting medium, e.g., water or wind. Also, the transition of a substance from the vapor phase directly to the solid phase, without passing through an intermediate liquid phase, also referred to as *Sublimation*.

Depression Storage — (1) Water contained in natural depressions in the land surface, such as puddles. (2) Water that is temporarily detained on the surface of the earth in puddles and cavities that have little or no surface outlet.

Depth of Runoff — The total runoff from a drainage basin divided by its area. For convenience in comparing runoff with precipitation, depth of runoff is usually expressed in inches during a given period of time over the drainage area expressed in inches per square mile.

Desiccation — (1) Loss of water from pore spaces of sediments through compaction or through evaporation caused by exposure to air. (2) (Geology) Used to refer to a long period of time between *Pluvial* (wet) episodes.

Desiccation Cracks — Surface fractures that can result from the drying of soil or porous sedimentary rock.

Designated Ground Water Basin — A basin where permitted ground water rights approach or exceed the estimated average annual recharge and the water resources are being depleted or require additional administration. Under such conditions, a state's water officials will so designate a ground water basin and, in the interest of public welfare, declare *Preferred Uses* (e.g., municipal and industrial, domestic, agriculture, etc.). Also referred to as *Administered Ground water Basin*.

Designated Uses — Those water uses identified in state water quality standards that must be achieved and maintained as required under the *Clean Water Act (CWA)*. Such uses may include cold water fisheries, public water supply, irrigation, recreation, minimum stream flows, etc.

Designated Watersheds — Watershed areas that have been set aside as sources of municipal water or other similar purposes would be included in this category. Other uses are either modified or excluded.

Detachment — The removal of transportable fragments of soil material from a soil mass by an eroding agent, usually falling raindrops, running water, or wind. Through this process, soil particles or aggregates are made ready for transport, the first stage in soil erosion.

Detention Basin — A relatively small storage lagoon for slowing stormwater runoff, generally filled with water for only a short period of time after a heavy rainfall.

Detention Facility — A surface water runoff storage facility that is normally dry but is designed to hold (detain) surface water temporarily during and immediately after a runoff event. Examples of detentional facilities are: natural swales provided with crosswise earthen berms to serve as control structures, constructed or natural surface depressions, subsurface tanks or reservoirs, rooftop storage, and infiltration or filtration basins.

Detention Storage — (1) The volume of water, other than *Depression Storage*, existing on the land surface as flowing water which has not yet reached the channel. (2) Water temporarily detained in the non-capillary pores of the soil, free to move by gravity, which it generally does within about 24 hours of the event that filled the pores.

Detention Time — (1) The theoretical calculated time required for a small amount of water to pass through a tank at a given rate of flow. (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 being used.

Detrital — (Geology) Clastic; rock and minerals occurring in sedimentary rocks that were derived from pre-existing igneous, sedimentary, or metamorphic rocks.

Detritus — (1) The heavier mineral debris moved by natural water courses, usually in the form of *Bed Load*. (2) The sand, grit, and other coarse material removed by differential sedimentation in a relatively short period of detention. (3) Bits of vegetation, animal remains, and other organic material that form the base of food chains in wetlands and many other kinds of habitats.

Dewater, and Dewatering — (1) To remove water from a waste produce or streambed, for example. (2) The extraction of a portion of the water present in sludge or slurry, producing a dewatered product which is easier to handle. (3) (Mining) The removal of ground water in conjunction with mining operations, particularly open-pit mining when the excavation has penetrated below the ground-water table. Such operations may include extensive ground-water removal and, if extensive enough and if not re-injected into the ground water, these discharges may alter surface water (stream) flows and lead to the creation of lakes and wetland areas. As such water removals only last so long as the mine is in operation, eventually surface water impacts, if present, will be eliminated, consequently jeopardizing surface water uses, such as irrigation, livestock, wildlife, or riparian habitat that may have become dependent upon the continuation of these temporary flows. Also, when the mine dewatering operations cease, the remaining open pit will eventually begin to fill up with ground water, resulting in significantly increased evaporation from ground water reservoirs.

Diatomaceous Earth — A yellow, white or light-gray material composed of the siliceous shells of *Diatoms* (fossilized diatoms) and used in water filtration to filter out solid waste in wastewater treatment plants; also used as an active ingredient in some powdered pesticides. Also referred to as *Diatomite*.

Diffusion — The movement of a substance from an area of high concentration to an area of low concentration. Turbulent diffusion results from atmospheric motions diffusing water, vapor, heat, and other gaseous components by exchanging parcels called eddies between regions in space in apparent random fashion.

Diffusion Coefficient — (1) The rate at which solutes are transported at the microscopic level due to variations in the solute concentrations within the fluid phases. (2) The rate of dispersion of a chemical caused by the kinetic activity of the ionic or molecular constituents. Also referred to as the *Coefficient of Molecular Diffusion*.

Dike — (1) (Engineering) An embankment to confine or control water, especially one built along the banks of a river to prevent overflow of lowlands; a levee. (2) A low wall that can act as a barrier to prevent a spill from spreading. (3) (groin, spur, jetty, deflector, boom) A structure designed to: (a) reduced water velocity as stream flow passes through the dike so that sediment deposition occurs instead of erosion (permeable dike), or (b) deflect erosive currents away from the stream bank (impermeable dike). (4) (Geology) A tabular body of igneous (formed by volcanic action) rock that cuts across the structure of adjacent rocks or cuts massive rocks.

Dilute — To make thinner or less concentrated by adding a liquid such as water.

Dilution — The reduction of the concentration of a substance in air or water.

Dimictic Lake (or Reservoir) — A stratified lake or reservoir that experiences two periods of full mixing or *(Fall and Spring) Overturns* annually. The water in lakes layer in response to differences in the temperatures of surface and deep waters. The surface water will be warmer because of radiant heating by the sun, and the bottom water will be cooler and therefore denser. The waters in these two layers (termed the *Epilimnion* on the surface and *Hypolimnion* on the bottom) are separated by a boundary referred to as the *Thermocline*. This layering is disrupted in response to variation in air temperature associated with changes in the seasons of the year. As the epilimnion cools, it sinks, mixing the water within the lake. Contrast with *Meromictic Lake*.

Discharge — (1) The volume of water (or more broadly, the volume of fluid including solid- and dissolved-phase material), that passes a given point in a given period of time. (2) The flow of surface water in a stream or the flow of ground water from a spring, ditch, or flowing artesian well. (3) (Hydraulics) The rate of flow, especially fluid flow; the volume of fluid passing a point per unit time, commonly expressed as cubic feet per second, million gallons per day, gallons per minute, or cubic meters per second.

Discharge (Hydrologic) — (1) The volume of water passing through a channel during a given time, usually measured in cubic feet per second (cfs). (2) In its simplest concept, discharge means outflow and is used as a measure of the rate at which a volume of water passes a given point. Therefore, the use of this term is not restricted as to course or location, and it can be used to describe the flow of water from a pipe or a drainage basin. With reference to ground water, the process by which ground water leaves the *Zone of Saturation* via *Evaporation*, *Evapotranspiration*, or by flow to the surface through springs and seeps. The data in the reports of the *U.S. Geological Survey (USGS)* on surface water represent the total

fluids measured. Thus, the terms discharge, streamflow, and runoff represent water with the solids dissolved in it and the sediment mixed with it. Of these terms, discharge is the most comprehensive. The discharge of drainage basins is distinguished as follows:
[1] ***Yield*** — The total water runout or "water crop" and includes runoff plus underflow;
[2] ***Runoff*** — That part of water yield that appears in streams; and
[3] ***Streamflow*** — The actual flow in streams, whether or not subject to regulation or underflow. Each of these terms can be reported in total volumes (e.g., acre-feet) or time-related rates of flow (e.g., cubic feet per second or acre-feet per year).

Discharge Area — (1) An area in which ground water is discharged to the land surface, surface water, or atmosphere. (2) An area in which there are upward components of hydraulic head in the aquifer. Ground water is flowing toward the surface in a discharge area and may escape as a spring, seep, or base flow, or by evaporation and transpiration.

Discharge Permit — A permit issued by the state to discharge effluent into waters of the state.

Discharge Point — A location at which effluent is released into a receiving stream or body of water.

Discretization - is the process of subdividing the continuous model and/or time domain into discrete segments or cells. Algebraic equations which approximate the governing flow and/or transport equations are written for each segment or cell.

Dispersivity - a scale dependent property of an aquifer that determines the degree to which a dissolved constituent will spread in flowing ground water. Dispersivity is comprised of three directional components - longitudinal, transverse and vertical.

Dispersion - process by which some of the water molecules and solute molecules travel more rapidly than the average linear velocity and some travel more slowly; spreading of the solute in the direction of the ground water flow (longitudinal dispersion) or direction perpendicular to ground water flow (transverse dispersion).

Dispersion Coefficient - (1) a measure of the spreading of a flowing substance due to the nature of the porous medium, with its interconnected channels distributed at random in all directions; (2) the sum of the coefficients of mechanical dispersion and molecular diffusion in a porous medium.

Displacement — (Geology) The distance by which portions of the same geological layer are offset from each other by a fault.

Dissection — The partial erosional destruction of a land surface or landform by gully, arroyo, canyon or valley cutting leaving flattish remnants, or ridges, or hills or mountains separated by drainageways.

Dissolved — That material in a representative water sample that passes through a 0.45-micrometer membrane filter. This is a convenient operational definition used by federal agencies that collect water data. Determination of "dissolved" constituents are made on subsamples of the filtrate.

Dissolved Load — All the material transported by a stream or river in solution, as contrasted with *Bed Load* and *Suspended Load*.

Dissolved Oxygen (DO) — (1) Concentration of oxygen dissolved in water and readily available to fish and other aquatic organisms. (2) The amount of free (not chemically combined) oxygen dissolved in water, wastewater, or other liquid, usually expressed in milligrams per liter, parts per million, or percent of saturation. The content of water in equilibrium with air is a function of atmospheric pressure, temperature, and dissolved-solids concentration of the water. The ability of water to retain oxygen decreases with increasing temperature or dissolved solids, with small temperature changes having the more significant offset. Photosynthesis and respiration may cause diurnal variations in dissolved-oxygen concentration in water from some streams. Adequate concentrations of dissolved oxygen are necessary for the life of fish and other aquatic organisms and the prevention of offensive odors. Dissolved oxygen levels are considered the most important and commonly employed measurement of water quality and indicator of a water body's ability to support desirable aquatic life. The ideal dissolved oxygen level for fish is between 7 and 9 milligrams per liter (mg/l); most fish cannot survive at levels below 3 mg/l of dissolved oxygen. Secondary and advanced wastewater treatment techniques are generally designed to ensure adequate dissolved oxygen in waste-receiving waters.

Dissolved Solids — (1) Minerals and organic mater dissolved in water. (2) The dissolved mineral constituents or chemical compounds in water or solution; they form the residue that remains after evaporation and drying. Excessive amounts of dissolved solids make water unfit to drink or use in industrial processes.

Dissolved-Solids Concentration — For water this concentration is determined either analytically by the "residue-on-evaporation" method, or mathematically by totaling the concentrations of individual constituents reported in a comprehensive chemical analysis. During that analytical determination of dissolved solids, the bicarbonate (generally a major dissolved component of water) is converted to carbonate. Therefore, in the mathematical calculation of dissolved-solids concentration, the bicarbonate value, in milligrams per liter, is multiplied by 0.4926 to reflect the change. Alternatively, alkalinity concentration (as in mg/L of $CaCO_3$) can be converted to carbonate concentration by multiplying by 0.60.

Distributary — A diverging stream which does not return to the main stream, but discharges into another stream or the ocean. Also refers to conduits that take water from a main canal for delivery to a farm.

Distributary Channel (or Stream) — A river branch that flows away from a main stream and does not rejoin it. Characteristic of *Deltas* and *Alluvial Fans*.

Distribution Coefficient - the quantity of the solute, chemical or radionuclide sorbed by the solid per unit weight of solid divided by the quantity dissolved in the water per unit volume of water.

Distribution Graph (Distribution Hydrograph) — A *Unit Hydrograph* of direct runoff modified to show the portion of the volume of runoff that occurs during successive equal units of time.

Disturbed Area — (Geology) Area where vegetation, topsoil, or overburden has been removed, or where topsoil, spoil, and processed waste has been placed.

Diversion — (1) A structure in a river or canal that divers water from the river or canal to another watercourse. (2) The transfer of water from a stream, lake, aquifer, or other source of water by a canal, pipe, well, or other conduit to another watercourse or to the land, as in the case of an irrigation system. Also, a turning aside or alteration of the natural course of a flow of water, normally considered physically to leave the natural channel. In some states, this can be a consumptive use direct from a stream, such as by livestock watering. In other states, a diversion must consist of such actions as taking water through a canal or conduit.

Divide — An imaginary line indicating the limits of a sub-basin, sub-watershed, or watershed; the boundary line along a topographic ridge or high point which separates two adjacent drainage basins. Also referred to as *Ridge Lines*.

Domestic Well — A water well used solely for domestic, i.e., residential or household purposes to include both indoor and outdoor water uses. Such wells are generally not required to be permitted; however, they may have restrictions in terms of daily pumping amounts, for example, 1,800 gallons per day.

Downgradient — The direction that ground water flows; similar to "downstream" for surface water flows.

Downgradient Well — One or more monitoring wells placed to sample ground water that has passed beneath a facility with the potential to release chemical contaminants into the ground. Results of testing downgradient well water are compared with data from an *Upgradient Well* to determine whether the facility may be contaminating the ground water.

Drainage — (1) The removal of excess surface water or ground water from land by means of surface or subsurface drains. (2) Improving the productivity of agricultural land by removing excess water from the soil by such means as ditches or subsurface drainage tiles (pipes). (3) The downward movement of water through the soil. When this occurs rapidly, the soil is referred to as "well drained"; otherwise poorly drained. Most plant roots need oxygen as well as water, and soil that remains saturated (poorly drained) deprives roots of necessary oxygen. (4) Soil characteristics that affect natural drainage.

Drainage Basin — (1) The land area drained by a river. (2) Part of the Earth's surface that is occupied by a drainage system with a common outlet for its surface runoff. (3) Part of the surface of the earth that is occupied by a drainage system, which consists of a surface stream or a body of impounded surface water together with all tributary surface streams and bodies of impounded surface water. The term is used synonymously with *Watershed*, *River Basin*, or *Catchment*.

Drainage Class, Soils — The relative terms used to describe natural drainage and corresponding types of soils are as follows:

[1] ***Excessive*** – Excessively drained soils are commonly very porous and rapidly permeable, and have low water-holding capacity;

[2] ***Somewhat Excessive*** – Somewhat excessively drained soils are also very permeable and are free from mottling throughout their profile;

[3] ***Good*** – Well drained soils that are nearly free of mottling and are commonly of intermediate texture;

[4] ***Moderately Good*** – Moderately well drained soils that commonly have a slowly permeable layer in or immediately beneath the solum. They have uniform color in the surface layers and upper subsoil, and mottling in the lower subsoils and substrata;

[5] ***Somewhat Poor*** – Somewhat poorly drained soils are wet for significant periods, but not all the time. They commonly have a slowly permeable layer in their profile, a high water table, additions through seepage, or a combination of these conditions;

[6] ***Poor*** – Poorly drained soils are wet for long periods of time. They are light gray and generally are mottled from the surface downward, although mottling may be absent or nearly so in some soils.

Drainage Divide — The line of highest elevations which separates adjoining drainage basins.

Drawdown — (1) The act, process, or result of depleting, as a liquid or body of water as in the lowering of the water surface level due to release of water from a reservoir. (2) The magnitude of lowering of the surface of a body of water or of its piezometric surface as a result of withdrawal of the release of water there from. (3) The decline of water below the static level during pumping. (4) (Water Table) The lowering of the elevation of the *Ground water Table*, usually from pumping wells, but can occur naturally during periods of prolonged drought. At the well, it is the vertical distance between the static and the pumping level.

Driller's Well Log — A log kept at the time of drilling showing the depth, thickness, character of the different strata penetrated, location of water-bearing strata, depth, size, and character of casing installed.

Drilling Mud — A mixture of clay, water, and other materials, often bentonite clay and barite, commonly used in drilling with a rotary drill rig. The mud is pumped down the drill pipe and through a drill bit and back up to the surface between the drill pipe and the walls of the hole. The mud helps lubricate and cool the drill bit as well as carry the cuttings to the surface. The mud also stabilizes the hole. Also referred to as *Drilling Fluid*.

Drinking Water — A term used synonymously with *Potable Water*, and refers to water that meets federal drinking water standards of the *Safe Drinking Water Act [SDWA] (Public Law 93–523)* as well as state and local water quality standards and is considered safe for human consumption. Freshwater that exceeds established standards for chloride content and dissolved solids limits is often referred to as slightly saline, brackish, or nonpotable water and is either diluted with fresher water or treated through a desalination process to meet drinking-water standards for public supply.

Drinking Water Standards — Drinking water standards established by state agencies, the U.S. Public Health Service, and the *U.S. Environmental Protection Agency (EPA)* for drinking water throughout the United States. [See Appendix B–1 for regulated contaminants and Appendix B–2 for proposed contaminants to be regulated by the *Safe Drinking Water Act [SDWA] (Public Law 93–523)*]

Drumlin — An elongated hill or ridge of *Glacial Drift*.

Dry Adiabatic Lapse Rate — The *Adiabatic Lapse Rate* for air not saturated with water vapor, or 0.98EC per 100 meters rise (5.4EF per 1,000 feet), expressed as:

ãd = –dT/dz

where: dT is the change in air temperature; dz is the change in altitude; and ãd is the dry adiabatic lapse rate. Compare to *Wet Adiabatic Lapse Rate*.

Dynamic Equilibrium — (1) (General) An open system in a steady state in which there is continuous inflow of materials, but within which the form or character of the system remains unchanged. (2) (Surface Water) Within dynamic equilibrium the channel exhibits patterns of erosion and deposition but there is no net change in the input and output of materials. The state is stable but features may change over time. (3) (Ground water) A condition of which the amount of recharge to an aquifer equals the amount of natural discharge.

Dystrophic Lake — A lake characterized by a lack of nutrients, and often having a low pH (acidic) and a high humus content. Plant and animal life are typically sparse, and the water has a high oxygen demand. This stage follows the *Eutrophic Phase* in the life cycle of a lake.

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Easement — A legal instrument enabling the giving, selling, or taking or certain land or water rights without transfer of title, such as for the passage of utility lines. An affirmative easement gives the owner of the easement the right to use the land for a stated purpose. A negative easement is an agreement with a private property owner to limit the development of his land in specific ways.

Effective Porosity — The amount of interconnected pore space through which fluids can pass, expressed as a percentage of the total volume occupied by the interconnecting interstices. Porosity may be primary, formed during deposition or cementation of the material, or secondary, formed after deposition or cementation, such as fractures. Part of the total porosity will be occupied by static fluid being held to the mineral surface by surface tension, so effective porosity will be less than total porosity.

Effluent — (1) Something that flows out or forth, especially a stream flowing out of a body of water. (2) (Water Quality) Discharged wastewater such as the treated wastes from municipal sewage plants, brine wastewater from desalting operations, and coolant waters from a nuclear power plant.

Effluent Guidelines — Technical *U.S. Environmental Protection Agency (EPA)* documents which set effluent limitations for given industries and pollutants.

Effluent Limitation — An amount or concentration of a water pollutant that can be legally discharged into a water body by a *Point Source (PS)*, expressed as the maximum daily discharge, the maximum discharge per amount of product, and/or the concentration limit in the wastewater stream, as a 24–hour or 30–day average. The applicable technology-based standard is set by the *U.S. Environmental Protection Agency (EPA)* by *Standard Industrial Classification (SIC) Code*, but differs between new and existing sources and by broad types of water pollutants: conventional pollutants, toxic pollutants, nonconventional, nontoxic pollutants; dredge and fill wastes; and heat discharges.

Effluent Seepage — Diffuse discharge of ground water to the ground surface.

Effluent Standard — The maximum amounts of specific pollutants allowable in wastewater discharged by an industrial facility or wastewater treatment plant. The standards are set for individual pollutants and apply across all industrial categories. This term can be contrasted with *Effluent Limitations*, which are set for individual pollutants by *Standard Industrial Classification (SIC) Code*.

Effluent Streams — Effluent streams are those leaving a lake. Also referred to as *Gaining Stream*. Also see *Stream*.
Eh - also known as redox potential. Eh is a numerical measure of the intensity of oxidation or reducing conditions. A positive potential indicates oxidizing conditions and a negative potential indicates reducing conditions.

Electrical Conductivity — A measure of the salt content of water.

Electrical Log — A record of electrical-resistivity tests made at various depths in a well.
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Electrolyte — (1) (Chemistry) Any compound that dissociates into ions when dissolved in water. The solution that results will conduct an electric current. For example, table salt (NaCl) is an electrolyte. (2) (Physiology) Any of various ions, such as sodium, potassium, or chloride, required by cells to regulate the electric charge and flow of water molecules across the cell membrane.

Elevation Datum Plane — Arbitrary surface that serves as a common reference for the elevations of points above or below it. Elevations are expressed in terms of feet, meters, or other units of measure and are identified as negative or positive depending on whether they are above or below the datum plane.

Elevation Head — The potential energy in a hydraulic system, represented by the vertical distance between the hydraulic system (pipe, channel, etc.) and a reference level, and expressed in length units. The sum of the elevation head and the *Pressure Head* is equal to the *Hydraulic Head*. Also referred to as the *Total Head*.

Eluviation — (1) The removal of soil material in suspension (or in solution) from a layer or layers of a soil. (2) The transportation of dissolved or suspended material within the soil by the movement of water when rainfall exceeds evaporation.

Embankment — An artificial deposit of material that is raised above the natural surface of the land and used to contain, divert, or store water, support roads or railways, or for other similar purposes.

Emergency Spillway — A dam spillway built to carry runoff in excess of that carried by the principal spillway; a secondary spillway designed to operate only during exceptionally large floods. Also referred to as *Auxiliary Spillway*.

Energy Dissipator — (1) A structure for slowing the fast moving spillway flows of a dam in order to prevent erosion of the stream channel below the dam. (2) An apron of rocks, logs, concrete baffles, or other materials that slows down water flowing through a culvert or ditch, or over a dam, and thereby reduces its erosive force.

Entrainment — (Streams) (1) To be moved by water motion involuntarily. (2) The incidental trapping of fish and other aquatic organisms in the water, for example, used for cooling electrical power plants or in waters being diverted for irrigation or similar purposes.

Environmental Assessment (EA) — An environmental analysis prepared pursuant to the *National Environmental Policy Act (NEPA)* that presents the first thorough examination of alternative plans to positively demonstrate that the environmental and social consequences of an applicable project or action were considered. If it is determined that proposed actions would not have a significant impact on the environment, then a *Finding of No Significant Impact (FONSI)* would be issued. If it is shown that such activities do, in fact, significantly impact the environment or are otherwise deemed controversial, then an *Environmental Impact Statement (EIS)* will normally be required.

Environmental Impact Statement (EIS) — A report required by Section 102(2)(c) of Public Law 91–190, *National Environmental Policy Act (NEPA)*, for all major projects which significantly impact on the quality of the human environment or are environmentally controversial. The EIS is a detailed and formal evaluation of the favorable and adverse environmental and social impacts of a proposed project and its alternatives. A tool for decision making, the EIS describes the positive and negative effects of an undertaking and cites possible, less environmentally disruptive alternative actions. Also see *Environmental Assessment (EA)*.

(United States) Environmental Protection Agency (EPA) — The U.S. Environmental Protection Agency (EPA) is responsible for implementing the federal laws designed to protect the environment. EPA endeavors to accomplish it mission systematically by proper integration of a variety of research, monitoring, standard-setting, and enforcement activities. As a complement to its other activities, EPA coordinates and supports research and antipollution activities of state and local governments, private and public groups, individuals, and educational institutions. EPA also monitors the operations of other Federal agencies with respect to their impact on the environment. EPA was created through Reorganization Plan #3 of 1970, which was devised to consolidate the federal government's environmental regulatory activities into a single agency. The plan was sent by the President to Congress on July 9, 1970, and the agency began operation on December 2, 1970. EPA was formed by bringing together 15 components from 5 executive departments and independent agencies. Air pollution control, solid waste management, radiation control, and the drinking water program were transferred from the Department of Health, Education, and Welfare (now the Department of Health and Human Services). The federal water pollution control program was taken from the Department of the Interior, as was part of a pesticide research program. From the Department of Agriculture, EPA acquired authority to register pesticides and to regulate their use, and from the Food and Drug Administration, EPA inherited the responsibility to set tolerance levels of pesticides in food. EPA was assigned some responsibility from the Atomic Energy Commission, and absorbed the duties of the Federal Radiation Council. The enactment of major new environmental laws and important amendments to older laws in the 1970s and 1980s greatly expanded EPA's responsibilities. The agency now administers ten comprehensive environmental protection laws:

[1] Clean Air Act (CAA)
[2] Clean Water Act (CWA)

[3] Safe Drinking Water Act (SDWA)

[4] Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, or "Superfund")

[5] Resource Conservation and Recovery Act (RCRA)

[6] Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)

[7] Toxic Substances Control Act (TSCA)

[8] Marine Protection, Research, and Sanctuaries Act (MPRSA)

[9] Uranium Mill Tailings Radiation Control Act (UMTRCA)

[10] Pollution Prevention Act The primary mandates for the water-related programs administered through the EPA Water Management Division are the *Federal Water Pollution Control Act (Public Law 92–500)*, as amended, commonly referred to as the *Clean Water Act (CWA)*, and the *Safe Drinking Water Act (SDWA — Public Law 93–523)*. The CWA addresses the discharge of pollutants from point and nonpoint sources into waters of the United States (as defined). The goal of the SDWA is to protect public health over lifetime exposure to drinking water by ensuring that the source water as well as the system storage distribution and service lines are free and protected from contamination. EPA water-related programs establish national and regional objectives, promote delegation of programs to states (primacy), and support that delegation in a manner that ensures achievement of required objectives. Also see *Science Advisory Board (SAB)*. [See Appendix E–1 for a more complete description of the organizational structure of the U.S. Environmental Protection Agency.]

Eolian — Pertaining to the wind; especially said of rocks, soils, and deposits (such as loess, dune sand, sand from volcanic tuffs) whose constituents were transported (blown) and laid down by atmospheric currents, or of landforms produced or eroded by the wind, or of sedimentary structures (such as ripple marks) made by the wind, or of geologic processes (such as erosion and deposition) accomplished by the wind.

Ephemeral (Stream) — A stream that flows only in direct response to precipitation, and thus discontinues its flow during dry seasons. Such flow is usually of short duration. Most of the dry washes of more arid regions may be classified as ephemeral streams. Also see *Stream*.

Equipotential Line — A line in a field of flow such that the total head is the same for all points on the line; therefore, the direction of flow is perpendicular to the line at all points.

Equipotential Surface — A surface (or line) in a three-dimensional ground-water flow field such that the total hydraulic head is the same everywhere on the surface.

Erosion — (1) Detachment of soil particles under the influence of water and/or wind. (2) The wearing away and removal of materials of the earth's crust by natural means. (3) The process by which flood waters lower the ground surface in an area by removing upper layers of soil. As usually employed, the term includes weathering, solution, corrosion, and transportation. The agents that accomplish the transportation and cause most of the wear are running water, waves, moving ice, and wind currents. Most writers include under the term all the mechanical and chemical agents of weathering that loosen rock fragments before they are acted on by the transportation agents; a few authorities prefer to include only the destructive effects of the transporting agents. Various types of water erosion include:

[1] ***Accelerated*** – Erosion much more rapid than normal, natural, or geologic erosion, primarily as a result of the influence of the activities of man or, in some cases, of other animals or natural catastrophes that expose bare surfaces, for example, forest fires;
[2] ***Geological*** – The normal or natural erosion caused by geological processes acting over long geologic periods and resulting in the wearing away of mountains, the building up of floodplains, coastal plains, etc., and also referred to as natural erosion;
[3] ***Gross*** – A measure of the potential for soil to be dislodged and moved from its place of origin, not necessarily the amount of soil that actually reaches a stream or lake, but the amount of soil that can be calculated from water and wind equations;
[4] ***Gully*** – The erosion process whereby water accumulates in narrow channels and, over short periods of time, removes soil from this narrow area to considerable depths, ranging from 1–2 feet (0.3–0.6 meters) to as much as 75–100 feet (23–31 meters);
[5] ***Natural*** – The wearing away of the earth's surface by water, ice, or other natural agents under natural environmental conditions of climate, vegetation, etc., undisturbed by man, and also referred to as geological erosion;
[6] ***Normal*** – The gradual erosion of land used by man that does not greatly exceed natural erosion;
[7] ***Overfall*** – Erosion caused by water flowing over an overfall;
[8] ***Rill*** – An erosion process in which numerous small channels only several inches deep are formed; occurs mainly on recently cultivated soils and/or recent cuts and fills;
[9] ***Sheet*** – The removal of a thin, fairly uniform layer of soil from the land surface by runoff waters;
[10] ***Shore*** – Removal of soil, sand, or rock from the land adjacent to a body of water due to wave action;
[11] ***Splash*** – The spattering of small soil particles caused by the impact of raindrops on wet soils. The loosened and spattered particles may or may not be subsequently removed by surface runoff;
[12] ***Streambank*** – Scouring of material and the cutting of channel banks by running water;
[13] ***Streambed*** – Scouring of material and cutting of channel beds by running water;
[14] ***Undercutting*** – Removal of material at the base of a steep slope, overfall, or cliff by falling water, a stream, wind erosion, or wave action; the removal steepens the slope or produces an overhanging cliff.

Erosion Control — Materials, structures, and actions utilized and taken to reduce or prevent erosion. The application of necessary measures including artificial structures, vegetative manipulation, water control, or physical soil changes to minimize soil erosion.

Erosion, Gully — The widening, deepening, and headcutting of small channels and waterways due to erosion.

Erosion, Rill — Removal of soil by running water with formation of shallow channels that can be smoothed out completely by normal cultivation (tillage).

Erosion, Sheet — The removal of a fairly uniform layer of soil or materials from the land surface by the action of rainfall and runoff water.

Escarpment — A steep slope or long cliff that results from erosion or faulting and separates two relatively level areas of differing elevations; the topographic expression of a fault.

Esker — A narrow ridge of gravelly or sandy glacial outwash material deposited by a stream in an ice tunnel within a glacier.

Estuarine — (1) Of, pertaining to, or formed in, an *Estuary*. (2) One of the classification systems under the *Wetlands* and *Deepwater Habitats* classification system. See *Wetlands*. [Also see Appendix D–2, Wetlands and Deepwater Habitats, for additional information on this classification system and specific characteristics of Estuarine Systems.]

Estuarine Waters — Deepwater tidal habitats and tidal wetlands that are usually enclosed by land but have access to the ocean and are at least occasionally diluted by freshwater runoff from the land (such as bays, mouths of rivers, salt marshes, lagoons, etc.).

Estuary — (1) An area where fresh water meets salt water; for example, bays, mouths of rivers, salt marshes, and lagoons. (2) That portion of a coastal stream influenced by the tide of the body of water into which it flows, for example, a bay or mount of a river, where the tide meets the river current; an area where fresh and marine waters mix. The *Coastal Zone Management Act* of 1972 defines an estuary as "that part of a river or stream or other body of water having unimpaired connection with the open sea, where the sea-water is measurably diluted with freshwater derived from land drainage." These brackish water ecosystems shelter and feed marine life, birds, and wildlife.

Eutrophic (Water) — Pertaining to a lake or other body of water characterized by large nutrient concentrations such as nitrogen and phosphorous and resulting high productivity. Such waters are often shallow, with algal blooms and periods of oxygen deficiency. Slightly or moderately eutrophic water can be healthful and support a complex web of plant and animal life. However, such waters are generally undesirable for drinking water and other needs. Degrees of *Eutrophication* typically range from *Oligotrophic* water (maximum transparency, minimum chlorophyll–a, minimum phosphorus) through *Mesotrophic*, *Eutrophic*, to *Hypereutrophic* water (minimum transparency, maximum chlorophyll–a, maximum phosphorus). Also see *Carlson's Trophic State Index (TSI)* and *(Mean) Trophic State Index (TSI)*.

Eutrophication — (1) The degradation of water quality due to enrichment by nutrients, primarily nitrogen (N) and phosphorus (P), which results in excessive plant (principally algae) growth and decay. When levels of N:P are about 7:1, algae will thrive. Low dissoved oxygen (DO) in the water is a common consequence. (2) The process of enrichment of water bodies by nutrients. (3) Over-enrichment of a lake or other water body with nutrients, resulting in excessive growth of organisms and the depletion of oxygen. Degrees of *Eutrophication* typically range from *Oligotrophic* water (maximum transparency, minimum chlorophyll–a, minimum phosphorus) through *Mesotrophic*, *Eutrophic*, to *Hypereutrophic* water (minimum transparency, maximum chlorophyll–a, maximum phosphorus). Eutrophication of a lake normally contributes to its slow evolution into a *Bog* or *Marsh* and ultimately to dry land. Eutrophication may be accelerated by human activities and thereby speed up the aging process.

Eutrophic Lakes — Lakes that are rich in nutrients and organic materials, therefore, highly productive for plant growth. These lakes are often shallow and seasonally deficient in oxygen in the *Hypolimnion*. Also see *Oligotrophic Lakes*.

Evaporation — (1) The physical process by which a liquid (or a solid) is transformed to the gaseous state. (2) The process by which water is changed from a liquid to a vapor. In *Hydrology*, evaporation is vaporization that takes place at a temperature below the boiling point. Also see *Evapotranspiration*.

Extrusive Bedrock — (Geology) Those *Igneous Rocks* derived from volcanic lavas that cooled on the surface of the earth. This lava cools rapidly and forms fine-textured rocks such as basalt and andesite.

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Fahrenheit Temperature Scale — A thermometric scale on which the freezing point of water is at 32EF (Fahrenheit) above the 0E(F) mark on the scale, and the boiling point of water is at 212EF. The Fahrenheit temperature scale was designed by German physicist Daniel Fahrenheit and is commonly used in the United States. Contrast with the *Centigrade Temperature Scale*, using degrees *Celsius* (EC), in which 0E(C) marks the freezing point of water and 100EC indicates the boiling point of water (at sea level). The formula for converting a Fahrenheit temperature to Celsius is CE=5/9 x (FE – 32).

Fall Overturn — A physical phenomenon that may take place in a body of water during early autumn. The sequence of events leading to fall overturn include:
[1] The cooling of surface waters;
[2] A density change in surface waters producing convection currents from top to bottom;
[3] The circulation of the total water volume by wind action; and
[4] Eventual vertical temperature equality. The overturn results in a uniformity of the physical and chemical properties of the entire water body. Also referred to as *Fall Turnover*. Also see *Spring Overturn*.

Falling Limb — The portion of the *Hydrograph* trace immediately following the peak and reflecting the decreasing production of storm flow.

Farmland, Prime — As defined in the *Farmland Protection Policy Act of 1981*: Land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops, and is available for these uses (urban areas are not included). It has the soil quality, growing season, and moisture supply needed for the economic production of sustained high yields of crops when treated and managed (including water management) according to acceptable farming methods. Prime farmland includes land that is being used currently to produce livestock and timber, but it excludes land committed to urban development or water storage.

Fault — (Geology) A fracture in rock along which movement can be demonstrated. A fracture in the earth's crust forming a boundary between rock masses that have shifted. Faults may be classified as follows:

- [1] ***Active Fault*** – A fault that has moved recently and which is likely to move again, usually defined as one that has shown movement within the last 11,000 years and can be expected to move again within the next 100 years;
- [2] ***Potentially Active Fault*** – A fault that moved within the Quaternary Period (i.e., within the last 2 million years) or a fault which, because it is judged to be capable of ground rupture or shaking, poses an unacceptable risk for a proposed project or structure;

[3] ***Historically Active Fault*** – A fault active within the last 200 years;
[4] ***Inactive Fault*** – A fault which has shown no evidence of movement in recent geologic time and no potential for movement in the relatively near future.

Fault Creep — A very slow movement along a fault which is unaccompanied by perceptible earthquakes.

Fault Escarpment — (Geology) A fracture or fracture zone along which there has been displacement of one side with respect to the other.

Fault-Line Scarp — A steep slope produced along an old fault line by differential weathering and erosion, rather than by fault movement.

Fault Scarp — A cliff formed by a fault, usually modified by erosion unless the fault is very recent.

Fault Trace — The intersection of a fault and the earth's surface as often revealed by dislocation of fences and roads and/or by ridges and furrows in the ground.

Fauna — (1) A term used to describe the animal species of a specific region or time. (2) All animal life associated with a given habitat, country, area, or period.

Feasibility Study (FS) — (1) A complete assessment of alternative courses of action to solve one or more problems, to meet needs, and to recommend the most practical course of action consistent with state and local planning objectives. (2) (Environmental) Analysis of the practicability of a proposal, e.g., a description and analysis of potential cleanup alternatives for a site such as one on the *National Priorities List (NPL)*. The feasibility study usually recommends selection of a cost-effective alternative. It usually starts as soon as the *Remedial Investigation (RI)* is underway; together, they are commonly referred to as the "RI/FS".

Federal Water Pollution Control Act (Public Law 92–500) — More commonly referred to as the *Clean Water Act (CWA)*, constitutes the basic federal water pollution control statute for the United States. Originally based on the *Water Quality Act* of 1965 which began setting water quality standards. The 1966 amendments to this act increased federal government funding for sewage treatment plants. Additional 1972 amendments established a goal of zero toxic discharges and "fishable" and "swimmable" surface waters. Enforceable provisions of the CWA include technology-based effluent standards for point sources of pollution, a state-run control program for nonpoint pollution sources, a construction grants program to build or upgrade municipal sewage treatment plants, a regulatory system for spills of oil and other hazardous wastes, and a wetlands preservation program.

Fen — Low land covered wholly or partly with water; a *Moor* or *Marsh*. A type of *Wetland* that accumulates peat deposits. Fens are less acidic than *Bogs*, deriving most of their water from ground water rich in calcium and magnesium.

Ferrous Sulfate — A greenish crystalline compound, $FeSO4•H2O$, used as a pigment, fertilizer, and feed additive, in sewage and water treatment, and as a medicine in the treatment of iron deficiency. Also called *Copperas*.

Field Characterization - a review of historical, on- and off-site, as well as surface and sub-surface data and the collection of new data to meet project objectives; field characterization is a necessary prerequisite to the development of a conceptual model.

Fill — (Geology) Any sediment deposited by any agent such as water so as to fill or partly fill a channel, valley, sink, or other depression.

Fill Material — Soil that is placed at a specified location to bring the ground surface up to a desired elevation or angle of slope.

Filling — Depositing dirt, mud or other materials into aquatic areas to create more dry land, usually for agricultural or commercial development purposes, and frequently with ruinous ecological consequences. Also see *Wetland Banking*, *Wetland "Clumping" (Aggregation)*, and *Wetland Mitigation*.

Finding of No Significant Impact (FONSI) — A document prepared by a federal agency showing why a proposed action would not have a significant impact on the environment and thus would not require the preparation of an *Environmental Impact Statement (EIS)*. A FONSI is based on the results of an *Environmental Assessment (EA)*.

Finite Difference Method (FDM) - a discretization technique for solving a partial differential equation (PDE) by (1) replacing the continuous domain of interest by a finite number of regular-spaced mesh- or grid-points (i.e., nodes) representing volume-averaged sub-domain properties; and (2) by approximating the derivatives of the PDE for each of these points using finite differences; the resulting set of linear or nonlinear algebraic equations is solved using direct or iterative matrix solving techniques.

Finite Element Method (FEM) - similar to finite difference method with the exception that (1) the mesh may consist of regular or irregular-spaced grid points which may have irregular shapes; and (2) the PDE is approximated using the method of weighted residuals to obtain a set of algebraic equations. These algebraic equations are solved using direct or iterative matrix solving techniques.

Finite Difference Model - a type of numerical model that uses a mathematical technique called the finite-difference method to obtain an approximate solution to the governing partial differential equation (in space and time).

Finite Element Model - a numerical model that uses a mathematical technique called the finite-element method to obtain an approximate solution to the governing partial differential equation (in space and time).

(United States) Fish and Wildlife Service (USFWS) — Part of the U.S. Department of the Interior, the early beginnings of the Fish and Wildlife Service go back to 1871 when the federal government established the Commissioner of Fisheries. In 1896, the Division of Biological Survey was established within the Department of Agriculture. In 1939, these functions were transferred to the Department of the Interior. Then in 1940, these functions were formally consolidated and redesignated as the Fish and Wildlife Service. Further reorganization came in 1956 when the Fish and Wildlife Act created the Bureau of Sport Fisheries and Wildlife. An amendment to this act in 1974 designated the Bureau as the U.S. Fish and Wildlife Service. Today the USFWS consists of a headquarters in Washington, D.C., eight regional offices, and over 700 field units and installations. Included are more than 470 National Wildlife Refuges, comprising more than 90 million acres, 57 fish and wildlife research laboratories and field units, 43 cooperative research units at universities across the country, nearly 135 national fish hatcheries and fishery assistance stations, and a nationwide network of law enforcement agents and biologists. The functions of the USFWS primarily includes the following:

[1] Acquires, protects and manages unique ecosystems necessary to sustain fish and wildlife,

such as migratory birds and endangered species;

[2] As specified in the *Endangered Species Act (ESA)* (1973), as amended, and in conjunction with the *National Marine Fisheries Service (NMFS)*, determines critical habitat and develops recovery plans for protected endangered and threatened species of plants and animals;

[3] Operates fish hatcheries to support research, develop new techniques and fulfill the public demand for recreational fishing;

[4] Operates wildlife refuges to provide, restore, and manage a national network of lands and waters sufficient in size, diversity and location to meet society's needs for areas where the widest possible spectrum of benefits associated with wildlife and wildlands is enhanced and made available;

[5] Conducts fundamental research on fish, wildlife and their habitats to provide better management and produce healthier and more vigorous animals; also protects fish and wildlife from dislocation or destruction of their habitats;

[6] Renders financial and professional assistance to states, through federal aid programs, for the enhancement and restoration of fish and wildlife resources;

[7] Establishes and enforces regulations for the protection of migratory birds, marine mammals, fish and other non-endangered wildlife from illegal taking, transportation or sale within the United States or from foreign countries; and

[8] Communicates information essential for public awareness and understanding of the importance of fish and wildlife resources, and changes reflecting environmental degradation that ultimately will affect the welfare of human beings.

Fixed Ground Water — Water held in saturated material within pore spaces so small that it is permanently attached to the walls, or moves so slowly that it is usually not available as a source of water for pumping.

Flood Plain, also Floodplain — (1) (FEMA) Any normally dry land area that is susceptible to being inundated by water from any natural source. This area is usually low land adjacent to a river, stream, watercourse, ocean or lake. (2) A strip of relatively smooth land bordering a stream, built of sediment carried by the stream and dropped in the slack water beyond the influence of the swiftest current. It is called a *Living Flood Plain* if it is overflowed in times of high water but a *Fossil Flood Plain* if it is beyond the reach of the highest flood. (3) The lowland that borders a stream or river, usually dry but subject to flooding. (4) The transversely level floor of the axial-stream drainageway of a semi-bolson or of a major desert stream valley that is occasionally or regularly alluviated by the stream overflowing its channel during flood. (5) The land adjacent to a channel at the elevation of the bankfull discharge, which is inundated on the average of about 2 out of 3 years. The floor of stream valleys, which can be inundated by small to very large floods. The one-in-100-year floodplain has a probability of 0.01 chance per year of being covered with water. (6) That land outside of a stream channel described by the perimeter of the *Maximum Probable Flood*. Also referred to as a *Flood-Prone Area*.

Flood Stage — (1) An elevation for the water level at high flows. (2) The elevation at which overflow of the natural banks of a stream or body of water begins in the reach or area in which the elevation is measured.

Floor — A generic term for the nearly level, lower-part of an inter-montane basin (a bolson or semi-bolson) or a major desert stream valley.

Flora — (1) A term used to describe the entire plant species of a specified region or time. (2) The sum total of the kinds of plants in an area at one time. All plant life associated with a given habitat, country, area, or period. *Bacteria* are considered flora.

Flow — (1) The movement of water. (2) The rate of water discharged from a source given in volume with respect to time.

(Ground Water) Flow Model — (1) A digital computer model that calculates a hydraulic head field for the modeling domain using numerical methods to arrive at an approximate solution to the differential equation of ground-water flow. (2) Any representation, typically using plastic or glass cross-sectional viewing boxes, with representative soil samples, depicting ground-water flows and frequently used for educational purposes.

Flow, Laminar — Flow of water in well-defined flow lines in which the viscous force is predominant; in channels it occurs at a *Reynolds Number* smaller than 500–2,000 and through porous media at Reynolds Number smaller than 1–10.

Flow, Natural — The rate of water movement past a specified point on a natural stream from a drainage area which has not been affected by stream diversion, storage, import, export, return flow or change in consumptive use resulting from man's modification of land use. Natural flow rarely occurs in a developed country.

Flow, Net — A graphical representation of flow lines and *Equipotential Lines* for two-dimensional, steady-state ground-water flow.

Flow, Overland — The flow of rainwater or snowmelt over the land surface toward stream channels. Upon entering a stream, it becomes runoff.

Flow Path — The subsurface course a water molecule or solute would follow in a given ground-water velocity field.

Flow Rate — (1) The speed or rate at which water is taken from a water course or the speed at which it flows past a point, usually measured in gallons per hour or cubic feet per second (cfs). (2) The rate, expressed in gallons or liters-per-hour, at which a fluid escapes from a hole or fissure in a tank. Such measurements are also made of liquid waste, effluent, and surface water movement.

Flow, Turbulent — A flow in which successive flow particles follow independent path lines, and head loss varies approximately with the square of the velocity. In stream channels it occurs at a *Reynolds Number* greater than 5,000.

Flow, Uniform — A characteristic of a flow system where specific discharge has the same magnitude and direction at any point.

Flow Velocity — (1) The volume of water flowing through a unit cross-sectional area of an aquifer. Also referred to as *Specific Discharge*. (2) Speed at which water moves during a flood. Velocities usually vary across the floodplain. They are usually greatest near the channel and lowest near the edges of the floodplain.

Flowing Well — An *Artesian Well* having sufficient head to discharge water above the land surface; a well where the *Piezometric Surface* lies above the ground surface.

Flowmeter — A gauge indicating the velocity of wastewater moving through a treatment plant or of any liquid moving through various industrial processes.

Fluve — A linear depression, rill, gully, arroyo, canyon, valley, etc., of any size, along which flows at some time, a drainageway.

Fluvial — Of or pertaining to rivers and streams; growing or living in streams or ponds; produced by the action of a river, stream or flood flow, as in a fluvial plain.

Fluvial Geomorphology (Geomorphologist) — The science concerned specifically with the influences of water and rivers on the erosional cycle of land deposition and degradation over time. While hydrology concentrates on the description, measurement, and analysis of precipitation and the flow of water on the earth's surface and underground, fluvial geomorphology concentrates on understanding the processes that govern the influence of water on the landscape over time.

Flux - the volume of fluid crossing a unit cross-sectional surface area per unit time.

Fold — (Geology) A bend or flexure in a layer or layers of rock.

Footslope — The relatively gently sloping, slightly concave slope component of an erosional slope that is at the base of the backslope component. Synonymous with *Pediment*.

Ford — (1) A shallow place in a body of water, such as a river, where one can cross by walking or riding on an animal or in a vehicle. (2) An at-grade stream crossing that uses the bottom of the channel in lieu of a bridged or culverted crossing.

(United States) Forest Service (USFS) — The largest and most diverse agency of the U.S. Department of Agriculture, the Forest Service provides leadership in the management, protection, and use of the nation's forests and rangelands, which comprise almost two-thirds of the nation's federally owned lands. The creation of the Forest Service go back to 1891 when the President was authorized to establish Forest Reserves from forest and range lands in the *Public Domain*. In 1905 the responsibilities for the management and protection of these Forest Reserves was transferred from the Department of the Interior to the Department of Agriculture and the Forest Service was formally established. The Forest Reserves were then renamed National Forests. Today the Forest Services manages 156 National Forests, 19 National Grasslands, and 16 Land Utilization Projects that make up the National Forest System located in 44 states, Puerto Rico, and the Virgin Islands. Much of the nation's fresh water supply flows from National Forest System lands and insuring adequate yields of high quality water and continuing soil productivity are primary aims of the Forest Service's watershed management programs. The Forest Service manages more than 14 percent of the nation's 1.2 billion acres of forest range. This National Forest System (NFS) rangeland is managed to conserve the land and its vegetation while providing food for both domestic livestock and wildlife. The Forest Service manages fish and wildlife habitat on the National Forests and National Grasslands in cooperation with the individual states' fish and game departments. Of the 191 million acres of National Forests, 86.5 million acres are classified as commercial forests, available for, and capable of, producing crops of industrial wood. National Forest timber reserves are managed on a sustained-yield basis to produce a continuous supply of wood products to meet the nation's economic demands while maintaining the productive capacity of these lands. In 1924 the Forest Service pioneered the establishment of wilderness areas on National Forest lands. National Forest lands are a major source of mineral and energy supplies with regulatory and management responsibilities for mineral activities shared with the Department of the Interior, Bureau of Mines. The Forest Service, with one of the world's largest wildland firefighting forces, provides direct fire protection and control for National Forest System lands as well as cooperative fire control on several million additional acres. The Forest Service is responsible for the forest management aspects of the Watershed Protection and Flood Prevention Program administered by the *Natural Resources Conservation Service (NRCS)*. The Forest Service also participates in the forestry aspects of the River Basin Program, which guides and coordinates water and related land resource planning among several federal departments. The Forest Service operates an extensive forestry research program consisting of eight Forest and Range Experiment Stations, a Forest Products Laboratory, and 75 research labs located throughout the U.S., Puerto Rico, and the Pacific Trust Territories. The Forest Service is organized into nine (9) regions as listed below (regional headquarters are in parentheses):

- [1] ***Eastern Region*** (Milwaukee, Wisconsin) – Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Delaware, Maryland, West Virginia, Ohio, Indiana, Michigan, Illinois, Missouri, Iowa, Wisconsin, Minnesota;
- [2] ***Southern Region*** (Atlanta, Georgia) – Virginia, North Carolina, South Carolina, Kentucky, Tennessee, Georgia, Florida, Alabama, Mississippi, Arkansas, Louisiana, Oklahoma, Texas;
- [3] ***Rocky Mountain Region*** (Denver, Colorado) – South Dakota, Nebraska, Kansas, Wyoming, Colorado;
- [4] ***Northern Region*** (Missoula, Montana) – North Dakota, Montana, Idaho (northern part only), South Dakota (northwest corner only), Wyoming (northwest corner only);
- [5] ***Intermountain Region*** (Ogden, Utah) – Nevada, Utah, Idaho (except northern portion), Wyoming (western portion only);
- [6] ***Southwest Region*** (Albuquerque, New Mexico) – Arizona, New Mexico;
- [7] ***Pacific Northwest Region*** (Portland, Oregon) – Washington, Oregon;
- [8] ***Pacific Southwest Region*** (San Francisco, California) – California, Hawaii;
- [9] ***Alaska Region*** (Juneau, Alaska) – Alaska.

Formation — (Geology) A body of rock or soil of considerable thickness that has characteristics making it distinguishable from adjacent geologic structures.

Fossil Water — Limited subterranean water deposits laid down in past ages but drawn on by modern man.

Fracture — A general term for any break in rock, which includes cracks, joints, and faults.

Fractured Bedrock Aquifer — An aquifer composed of solid rock, but where most water flows through cracks and fractures in the rock instead of through pore spaces. Flow through fractured rock is typically relatively fast.

Fragile Area — Areas that, due to steepness, soil type, exposure, and cover, are especially subject to soil erosion and rapid deterioration. Also referred to as *Critical Area*.

Freeboard — (1) The vertical distance between a design maximum water level and the top of a structure such as a channel, dike, floodwall, dam, or other control surface. The freeboard is a safety factor intended to accommodate the possible effect of unpredictable obstructions, such as ice accumulation and debris blockage, that could increase stages above the design water surface. (2) (Nautical) The distance between the water line and the uppermost full deck of a ship. For dams, the terms "net freeboard", "dry freeboard", "flood freeboard", or "residual freeboard" refer to the vertical distance between the estimated maximum water level and the top of a dam. "Gross freeboard" or "total freeboard" is the vertical distance between the maximum planned controlled retention water level and the top of a dam. (3) (FEMA) A factor of safety expressed in feet above a design flood level for flood protective or control works. Freeboard is intended to allow for all of the uncertainties in analysis, design and construction which cannot be fully or readily considered in an analytical fashion.

Free Flow — (Hydraulics) Flow through or over a structure not affected by submergence or backwater.

Free-Flowing Stream — A stream or a portion of a stream that is unmodified by the works of man or, if modified, still retains its natural scenic qualities and recreational opportunities.

Free-Flowing Well — An *Artesian Well* in which the potentiometric surface is above the land surface. Also see *Potentiometric Surface*.

Free Ground Water — Water in interconnected pore spaces in the *Zone of Saturation* down to the first impervious barrier, moving under the control of the water table slope.

Free Water Surface (FWS) Constructed Wetland — A type of constructed wetland, a man-made marsh-like area used to treat wastewater. In this type of wetland, the effluent flows through various aquatic plants, with the water level exposed to the air. While this type of wetland is relatively easy to construct, it is not as effective as the *Subsurface Flow (SF) Constructed Wetland* with respect to associated odors, potential for insect breeding, and risk of public exposure and contact with the water in the system. Also see *Wetlands, Benefits*.

French Drain — An underground passageway for water through the interstices among stones placed loosely in a trench.

Fresh-Salt Water Interface — The region where fresh water and salt water meet.

Freshwater (Fresh Water) — (1) Of, relating to, living in, or consisting of water that is not salty. (2) Water with salinity less than 0.5‰ (parts per thousand) dissolved salts. (3) Water that contains less than 1,000 milligrams per liter (mg/l) of dissolved solids; generally, more than 500 mg/l of dissolved solids is undesirable for drinking and many industrial uses. (4) (Nautical) Accustomed to sailing on inland waters only as a fresh water sailor. Also see *Sweet Water*.

Freshwater Marsh — (1) Open wetlands that occur along rivers and lakes, and in many other areas. Sedges, reeds, rushes, and grasses are the dominant plants in freshwater marshes. (2) A *Circumneutral Ecosystem* of more or less continuously water-logged soil dominated by emersed herbaceous plants, but without a surface accumulation of peat.

Freshwater Swamps — Forested or shrubby wetlands. *Pocosins* and heaths are two examples of freshwater swamps.

Friable — (1) Said of a rock or mineral that crumbles naturally or is easily broken, pulverized, or reduced to powder, such as a soft or poorly cemented sandstone. (2) Said of a soil consistency in which moist soil material crushes easily under gentle to moderate pressure (between thumb and forefinger) an coheres when pressed together.

Fringe Water — Water occurring in the *Capillary Fringe*.

Fringe Marsh — A saturated, poorly drained area, intermittently or permanently water covered, close to and along the edge of a land mass.

Front — (1) Land bordering a lake or river. (2) (Meteorology) A line of separation or interface between air masses of different temperatures or densities.

Frontage — Land adjacent to something, such as a body of water.

Frost Heave — Ruptured soil, rock, or pavement caused by the expansion of freezing water immediately beneath the surface.

Frost Line — The depth to which frost penetrates the earth.

-G-

Gabion — A wire cage, usually rectangular, filled with cobbles and used as a component for water control structures or for channel and bank protection.

Gaging Station — A particular site on a stream, canal, lake, or reservoir where systematic observations of *Gage Height* or discharge are obtained through mechanical or electrical means. When used in connection with a discharge record, the term is applied only to those gaging stations where a continuous record of discharge is computed. Also referred to as a *Gage*.

Gaining Stream — A stream or reach of a stream, the flow of which is being increased by the inflow of ground water seepage or from springs in, or alongside, the channel. Also referred to as an *Effluent Stream*. Also see *Stream*.

Geographic Information System (GIS) — A computer information system that can input, store, manipulate, analyze, and display geographically referenced (spatial) data to support the decision-making processes of an organization. A map based on a database or databases. System plots locations of information on maps using latitude and longitude.

Geography — The science of the earth and life, especially the description of land, sea, air, and the distribution of plant and animal life, including man and his industries, with reference to the mutual relations among these diverse elements. As general areas of study, geography is divided into:

[1] ***Mathematical Geography*** — deals with the figure and motion of the earth, of its seasons, tides, etc., of its measurement, and of its representation on maps and charts by various methods of projection;

[2] ***Physical Geography*** — deals with the exterior physical features and changes of the earth's land, water, and air;

[3] ***Biological Geography*** — has to do with the relation of living things to their physical environment; and

[4] ***Commercial Geography*** — deals with commodities, their place of origin, paths of transactions, etc.

Geohydrology — A term which denotes the branch of *Hydrology* relating to subsurface or subterranean waters; that is, to all waters below the surface. Related terms include *Geohydrologic* and *Geohydrologist*.

Geologic Erosion — Normal or natural erosion caused by geological processes acting over long geologic periods and resulting in the wearing away of mountains, the building up of flood plains, coastal plains, etc.

Geologic Log — A detailed description of all underground features (e.g., depth, thickness, type of formation, etc.) discovered during the drilling of a well.

Geological Survey — A systematic examination of an area to determine the character, relations, distribution and origin or mode of formation, of its rock masses and other natural resources.

(United States) Geological Survey (USGS) — An agency of the U.S. Department of Interior responsible for providing extensive earth-science studies of the Nation's land, water, and mineral resources. The USGS was established by an act of Congress on March 3, 1879, to provide a permanent federal agency to conduct the systematic and scientific "classification of the public lands, and examination of the geological structure, mineral resources, and products of national domain." An integral part of that original mission is to publish and distribute the earth-science information needed to understand, plan the use of, and manage the nation's energy, land, mineral, and water resources. Since 1879, the research and fact-finding role of the USGS has grown and been modified to meet the changing needs of the nation it serves. As part of that evolution, the USGS has become the map-making agency for the federal government, the primary source of data on surface- and ground-water resources of the nation, and the employer of the largest number of professional earth scientists. The USGS is organized into three operational Divisions: the National Mapping Division (NMD), charged with development and application of mapping and *Geographic Information System (GIS)* technology; the Geologic Division (GD), which conducts geologic mapping and research; and the Water Resources Division (WRD). The mission of the Water Resources Division of the USGS is to provide the hydrologic information and understanding needed to manage the nation's water resources to benefit its residents. Typical water resource programs sponsored by the WRD include:

- [1] Data collection to aid in evaluating the quantity, quality, distribution, and use of the nation's water resources;
- [2] Analytical and interpretive water-resources appraisals to describe the occurrence, quality, and availability of surface and ground water throughout the nation;
- [3] Basic and problem-oriented research in hydraulics, hydrology, and related fields of science and engineering;
- [4] Scientific and technical assistance in hydrology to other federal, state, and local agencies;
- [5] Development and maintenance of national computer data bases and associated Geographic Information Systems (GIS) of hydrologic data — streamflow, water quality and biology, ground water characteristics, and water use; and
- [6] Public distribution of water-resources data and results of water-resources investigations through reports, maps, computerized information services, and other forms of release. Programs of the Water Resources Division are funded under three types of arrangements:

  - [1] ***Federal Program*** — funding is appropriated directly to USGS by the U.S. Congress for projects of national interest;
  - [2] ***Cooperative Program*** — funding is shared by USGS and interested state and local agencies; and
  - [3] ***Other Federal Agencies (OFA) Program*** — funding is supplied by federal agencies requesting technical assistance from the USGS. The Water Resources Division's headquarters is at the USGS National Center in Reston, Virginia. Regional offices are maintained in Reston; Atlanta, Georgia; Denver, Colorado; and Menlo Park, California. With the exception of the National Research Program (NRP) centers at Reston, Denver, and Menlo Park, most of the WRD program is distributed to 51 USGS District Offices organized by state boundaries.

Geomorphic Surface — A mappable area of the land surface formed during a defined time period by deposition or erosion (or both, in different parts) of at least a thickness of material sufficient to accommodate a pedogenic soil. Its age (i.e., period of formation) ordinarily is defined by relations to other geomorphic surfaces, or by the soils or sediments that form or underlie the surface.

Geomorphology (Geomorphic) — That branch of both physiography and geology that deals with the form of the earth, the general configuration of its surface, and the changes that take place in the evolution of land forms. The term usually applies to the origins and dynamic morphology (changing structure and form) of the earth's land surfaces, but it can also include the morphology of the sea floor and the analysis of extraterrestrial terrains. Sometimes included in the field of physical geography, geomorphology is really the geological aspect of the visible landscape. Also see *Geomorphology, Historical*, and *Geomorphology, Process*.

Geomorphology, Historical — Historical geomorphology represents one branch of *Geomorphology* which provides the means to analyze the long-term change in landforms through the concept of cyclic change. The concepts evolved at the turn of the 20th century and were put forward by the American geologist William Morris Davis. The theory stated that every landform could be analyzed in terms of structure, process, and stage. Structure and process are treated by the science of geomorphology. However, the concept of stage introduced the element of time, and is subject to a far greater degree of interpretation. As postulated by Davis, every landform underwent development through a predictable, cyclic sequence: i.e., youth, maturity, and old age. Historical geomorphology relies on various chronological analyses, notably those provided by stratigraphic studies of the last 2 million years, known as the *Quaternary Period*. The relative chronology usually may be worked out by observation of stratigraphic relationships, with the time intervals involved established more precisely by dating methods such as historical records, radiocarbon analysis, tree-ring counting (*Dendrochronology*), and paleomagnetic studies. By applying such methods to stratigraphic data, a quantitative chronology of events is constructed that provides a means for calculating long-term rates of change. Also see *Geomorphology, Process*.

Geomorphology, Process — The second branch of *Geomorphology*, process geomorphology analyzes contemporary dynamic processes at work in landscapes. The mechanisms involved are weathering and erosion and combine processes that are in some respects destructive and in others constructive. The bedrock and soil provide the passive material, whereas the climatic regime and crustal dynamics together provide the principal active variables.

Geophysical Log — A record of the structure and composition of the earth encountered when drilling a well or similar type of test or boring hole.

Geophysics, also Geophysical — The study of the physical characteristics and properties of the earth, including geodesy, seismology, meteorology, oceanography, atmospheric electricity, terrestrial magnetism, and tidal phenomena.

Glacial Drift — All earth material transported and deposited by the ice and/or by water flowing from a glacier. It consists of rock flour, sand, pebbles, cobbles, and boulders, and may occur in a heterogeneous mass or be reasonably well sorted, depending on the manner of deposition.

Glacial Epochs — (Geology) Any of those parts of geological time, from Pre-Cambrian time onward in both the Northern and Southern hemispheres, during which a much larger portion of the earth was covered by glaciers than at present. More specifically refers to the latest of the glacial epochs, that of the Quaternary period, known as the *Pleistocene Epoch*, beginning some 3 million years ago, during which Canada, northern and northeastern U.S., northern and northwestern Europe, and northern Asia, together with most high mountain regions in the Northern Hemisphere were largely covered with ice. It has been divided into a number of stages. Those recognized for the interior of North America are, in order of age: *Jerseyan* or *Nebraskan* (glacial); *Aftonian* (interglacial); *Kansan* (glacial); *Yarmouth* and *Buchanan* (interglacial); *Illinoian* (glacial); *Sangamon* (interglacial); *Iowan* (glacial); *Peorian* (interglacial); *Earlier Wisconsin* (glacial); an unnamed (interglacial) interval; *Later Wisconsin* (glacial); *Champlain* (glaciolacustrine epoch).

Glacial Outwash — Stratified material, chiefly sand and gravel deposited by meltwater streams in front of the margin of a glacier.

Glacial Period — (Geology) The period of time encompassing the *Glacial Epochs*.

Glacial Till — Till is the mixture of rocks, boulders, and soil picked up by a moving glacier and carried along the path of the ice advance. The glacier deposits this till along its path — on the sides of the ice sheet, at the toe of the glacier when it recedes, and across valley floors when the ice sheet melts. These till deposits are akin to the footprint of a glacier and are used to track the movement of glaciers. These till deposits can be good sources of ground water, if they do not contain significant amounts of impermeable clays.

Glacier Meal — Finely ground rock particles produced by glacial abrasion. Also referred to as *Rock Flour*.

Glaciofluvial Deposits — Material moved by glaciers and subsequently sorted and deposited by streams flowing from the melting ice. The deposits are stratified and may occur in the form of outwash plains, deltas, kames, eskers, and kame terraces. Also see *Glacial Action*, *Glacial Drift* and *Glacial Till*.

Glaciolacustrine — (Geology) Pertaining to, or characterized by, glacial and lacustrine processes or conditions applied especially to deposits made in lakes.

Glade — An open, spacious *Wetland*, as in the *Everglades*.

Glauconite — A greenish clay mineral, a hydrous silicate of potassium, iron, aluminum, or magnesium, (K,Na)(Al,Fe,Mg)2(Al,Si)4O10(OH)2, found in greensand and used as a fertilizer and water softener.

Global Positioning System (GPS) — A system which verifies latitude and longitude of a location on the ground through the use of a transmitter and a remote (satellite) vehicle.

Grab Sample — Typically, a single water or air sample drawn over a short time period. As a result, the sample is not representative of long-term conditions at the sampling site. This type of sampling yields data that provides a snapshot of conditions or concentrations at a particular point in time.

Graben — (Geology) (1) A depressed tract bounded on at least two sides by faults and generally of considerable length as compared to its width. (2) A rather steeply sided valley formed when faulting caused a block-shaped area to drop relative to the surrounding terrain. Lake Tahoe, situated on the border between the states of California and Nevada, occupies a graben.

Graded Stream — A stream in which, over a period of years, the slope is delicately adjusted to provide, with available discharge and with prevailing channel characteristics, just the velocity required for transportation of the sediment load supplied from the drainage basin. Also, a stream in which most irregularities, such as waterfalls and cascades, are absent. Streams tend to cut their channels lower at a very slow rate after they become graded.

Grade Stabilization Structure — A structure for the purpose of stabilizing the grade of a gully or other watercourse, thereby preventing further head-cutting or lowering of the channel grade.

Gradient — Degree of incline; slope of a stream bed. The vertical distance that water falls while traveling a horizontal distance downstream. Also see *Hydraulic Gradient* and *Temperature Gradient*.

Gram Molecular Weight (GMW) — The mass, in grams, of a substance equal to its molecular weight. For example, the molecular weight of water (H2O) is 18 (the sum of the atomic weights of two hydrogen atoms and one oxygen atom), so its gram molecular weight is 18 grams. The amount of a material equal to its gram molecular weight comprises one gram-mole of the substance.

Granite — (Geology) A light-colored plutonic igneous rock made up of interlocking grains of glassy or milky quartz, white or pink feldspar, and specks of dark mica or hornblende. The Sierra Nevada Mountains (California and Nevada) are made up of granite and similar rock types.

Gravel — A mixture composed primarily of rock fragments 2 mm (0.08 inch) to 7.6 cm (3 inches) in diameter. Usually contains much sand.

Gravel Envelope — In well construction, a several-inch thickness of uniform gravel poured into the annular space between the well casing and the drilled hole. Also referred to as *Gravel Pack*.

Gravitational Head — Component of total *Hydraulic Head* related to the position of a given mass of water relative to an arbitrary datum.

Gravitational Water — Water that moves into, through, or out of a soil or rock mass under the influence of gravity.

Gravity Flow — The downhill flow of water through a system of pipes, generated by the force of gravity.

Greenbelt — (1) A strip of natural vegetation growing parallel to a stream that provides wildlife habitat and an erosion and flood buffer zone. This strip of vegetation also retards rainfall runoff down the bank slope and provides a root system that binds soil particles together. (2) An area where measures are applied to mitigate fire, flood and erosion hazards to include fuel management (suppression of combustibles), land use planning, and development standards. More traditionally, an irrigated landscaped buffer zone between developed areas and wildlands, usually put to additional uses such as parks, bike and riding trails, golf courses, etc.

Ground Rupture — The movement of the ground along one side of a *Fault* relative to the other side, caused by an earthquake.

Ground Truth — (Data Analysis and Interpretation) Verification of aerial photointerpretation by observers on the ground.

Ground Water, also Ground water — (1) Generally, all subsurface water as distinct from *Surface Water*; specifically, the part that is in the saturated zone of a defined aquifer. (2) Water that flows or seeps downward and saturates soil or rock, supplying springs and wells. The upper level of the saturate zone is called the Water Table. (3) Water stored underground in rock crevices and in the pores of geologic materials that make up the earth's crust. Ground water lies under the surface in the ground's *Zone of Saturation*, and is also referred to as *Phreatic Water*.

Ground Water Barrier — Rock, clay, or other natural or artificial materials with a relatively low permeability that occurs (or is placed) below ground surface, where it impedes the movement of ground water and thus causes a pronounced difference in the heads on opposite sides of the barrier.

Ground Water Basin — A ground-water reservoir together with all the overlying land surface and the underlying aquifers that contribute water to the reservoir. In some cases, the boundaries of successively deeper aquifers may differ in a way that creates difficulty in defining the limits of the basin. A ground-water basin could be separated from adjacent basins by geologic boundaries or by hydrologic boundaries.

Ground Water, Confined — Ground water under pressure significantly greater than atmospheric, with its upper limit the bottom of a bed with hydraulic conductivity distinctly lower than that of the material in which the confined water occurs.

Ground Water Discharge — (1) The flow of water from the *Zone of Saturation*. (2) (Water Quality) Ground water entering near coastal waters which has been contaminated by landfill leachate, deep well injection of hazardous wastes, septic tanks, etc.

Ground Water Divide — A line on a water table on either side of which the water table slopes downward. It is analogous to a drainage divide between two drainage basins on a land surface. It is also the line of highest *Hydraulic Head* in the water table or *Potentiometric Surface*.

Ground Water Flow — (1) Water that moves through the subsurface soil and rocks. (2) The movement of water through openings in sediment and rock that occurs in the *Zone of Saturation*.

Ground Water Flow Model — (1) A digital computer model that calculates a hydraulic head field for the modeling domain using numerical methods to arrive at an approximate solution to the differential equation of ground-water flow. (2) Any representation, typically using plastic or glass cross-sectional viewing boxes, with representative soil samples, depicting ground-water flows and frequently used for educational purposes.

Ground Water, Free — Unconfined ground water whose upper boundary is a free water table.

Ground Water Hydraulics — The study of the movement of water, especially water under pressure and water's movement through various soil medium.

Ground Water Hydrology — The branch of *Hydrology* that deals with ground water; its occurrence and movements, its replenishment and depletion, the properties of rocks that control ground water movement and storage, and the methods of investigation and utilization of ground water. Also referred to as *Ground Water Hydraulics*, although this term pertains more to the study of the motion of water.

Ground Water Law — The common law doctrine of *Riparian Rights* and the doctrine of prior appropriation (*Appropriative Rights*) as applied to ground water.

Ground Water Level — The elevation of the water table or another potentiometric surface at a particular location.

Ground Water Mining — (1) The withdrawal of ground water through wells, resulting in a lowering of the ground water table at a rate faster than the rate at which the ground water table can be recharged. (2) The withdrawal of water from an aquifer in excess of recharge which, if continued over time, would eventually cause the underground supply to be exhausted or the water table could drop below economically feasible pumping lifts.

Ground Water Modeling Code - the computer code used in ground water modeling to represent a non-unique, simplified mathematical description of the physical framework, geometry, active processes, and boundary conditions present in a reference subsurface hydrologic system.

Ground Water Mound — Raised area in a water table or other *Potentiometric Surface*, created by *Ground Water Recharge*. See *Ground water Mounding*.

Ground water Mounding — Commonly, an outward and upward expansion of the free water table caused by shallow re-injection, percolation below and impoundment, or other surface recharge method (essentially, the reverse of the cone of depression effect created by a pumping well). Mounding can alter ground water flow rates and direction; however, the effects are usually localized and may be temporary, depending upon the frequency and duration of the surface recharge events.

Ground Water Outflow — That part of the discharge from a drainage basin that occurs through the ground water. The term "underflow" is often used to describe the ground water outflow that takes place in valley alluvium (instead of the surface channel) and thus is not measured at a gaging station.

Ground Water Overdraft — The condition of a ground water basin in which the amount of water withdrawn by pumping exceeds the amount of water that recharges the basin over a period of years during which water supply conditions approximate average. Sometimes used interchangeably with *Ground Water Mining*.

Ground Water, Perched — Ground water that is separated from the main body of ground water by an impermeable (unsaturated) layer.

Ground Water Plume — A volume of contaminated ground water that extends downward and outward from a specific source; the shape and movement of the mass of the contaminated water is affected by the local geology, materials present in the plume, and the flow characteristics of the area ground water.

Ground Water Prime Supply — The long-term average annual percolation to the major ground water basins from precipitation falling on the land and from flows in rivers and streams. Also includes recharge from local sources that have been enhanced by construction of spreading ground or other means. Recharge of imported and reclaimed water is not included nor is recharge using applied irrigation water.

Ground Water Recharge — (1) The infiltration of water into the earth. It may increase the total amount of water stored underground or only replenish the ground water supply depleted through pumping or natural discharge. (2) The natural or intentional infiltration of surface water into the *Zone of Saturation*, i.e., into the *Ground Water*. (2) Inflow of water to a ground water reservoir (Zone of Saturation) from the surface. Infiltration of precipitation and its movement to the water table is one form of natural recharge. Also, the volume of water added by this process.

Ground Water Reservoir — An aquifer or aquifer system in which ground water is stored. The water may be introduced into the aquifer by artificial or natural means.

Ground Water Reservoir Storage — The amount of water in storage within the defined limit of the aquifer.

Ground Water Runoff — A portion of runoff which has passed into the ground, has become ground water, and has been discharged into a stream channel as spring or seepage water.

Ground Water Storage Capacity — The space or voids contained in a given volume of soil and rock deposits. Also, the reservoir space contained in a given volume of deposits. Under optimum conditions of use, the usable ground water storage capacity volume of water that can be alternately extracted and replaced in the deposit, within specified economic limitations.

Ground Water System — All the components of subsurface materials that relate to water, including *Aquifers* (confined and unconfined), *Zones of Saturation*, and *Water Tables*.

Ground Water Table — (1) The depth below the surface of the ground where the soil is saturated (the open spaces between the individual soil particles are filled with water). (2) The upper surface of the *Zone of Saturation* for underground water. It is an irregular surface with a slope or shape determined by the quantity of ground water and the permeability of the earth materials. In general, it is highest beneath hills and lowest beneath valleys. Also referred to as the *Water Table*.

Ground Water, Unconfined — Water in an aquifer that has a water table.

Ground Water Under the Direct Influence (UDI) of Surface Water — Any water beneath the surface of the ground with: (1) a significant occurrence of insects or other microorganisms, algae, or large-diameter *Pathogens*; or (2) significant and relatively rapid shifts in water characteristics such as turbidity, temperature, conductivity, or pH which closely correlate to climatological or surface water conditions. Under direct influence conditions are determined for individual sources in accordance with criteria established by the state.

Ground Water Velocity — The rate of water movement through openings in rock or sediment. Also see *Darcy's Law*.

Grout Curtain — (Dam) A barrier produced by injecting grout into a vertical zone, usually narrow horizontally, in the foundation of a dam to reduce seepage under the dam. Also referred to as *Grout Cutoff*.

Gully, also Gulley — (1) A channel or miniature valley cut by concentrated runoff but through which water commonly flows only during and immediately after heavy rains or during the melting of snow; may be *Dendritic* or branching or it may be linear, rather long, narrow, and of uniform width. (2) A small valley or gulch. The distinction between *Gully* and *Rill* is one of depth. A gully is sufficiently deep that it would not be obliterated by normal tillage operations, whereas a rill is of lesser depth and would be smoothed by ordinary farm tillage.

Gully Erosion — The widening, deepening, and headcutting of small channels and waterways due to erosion; severe erosion in which trenches are cut to a depth greater than 30 centimeters (approximately one foot). Also see *Erosion*.

Gully Reclamation — Projects designed to prevent erosion in gullies by either filling them in or planting vegetation to stabilize the banks. May include the use of small dams of manure and straw, earth, stone, or concrete to collect silt and gradually fill in channels of eroded soil.

Gumbo — A fine, silty soil, common in the southern and western United States, that forms an unusually sticky mud when wet.

-H-

Hardness — (1) A characteristic of water which describes the presence of dissolved minerals. Carbonate hardness is caused by calcium and magnesium bicarbonate; noncarbonate hardness is caused by calcium sulfate, calcium chloride, magnesium sulfate, and magnesium chloride. (2) A property of water which causes an increase in the amount of soap that is needed to produce foam or lather and that also produces scale in hot water pipes, heaters, boilers and other units in which the temperature of water is increased materially. Hardness is produced almost completely by the presence of calcium and magnesium salts in solution. The following scale may assist in appraising water hardness, measured by weight of dissolved salts (in milligrams) per unit (in liters) of water:

[1] ***Soft*** — 0–60 milligrams/liter (mg/l);
[2] ***Moderately Hard*** — 61–120 mg/l;
[3] ***Hard*** — 121–180 mg/l; and
[4] ***Very Hard*** — over 180 mg/l
.

Hardpan — (1) A layer of nearly impermeable soil beneath a more permeable soil, formed by natural chemical cementation of the soil particles. (2) A hard impervious layer composed chiefly of clay or organic materials cemented by relatively insoluble materials, which does not become plastic when wet, and definitely limits the downward movement of water and roots.

Hard Water — Water which forms a precipitate with soap due to the presence of calcium, magnesium, or ferrous ions in solution.

Head — Difference in elevation between intake and discharge points for a liquid. In geology, most commonly of interest in connection with the movement of underground water.

Head, Static — The height above a standard datum of the surface of a column of water (or other liquid) that can be supported by the static pressure at a given point. The static head is the sum of the *Elevation Head* and the *Pressure Head*.

Head, Total — The sum of the *Elevation Head* (distance of a point above datum), the *Pressure Head* (the height of a column of liquid that can be supported by static pressure only at the point), and the *Velocity Head* (the height to which the liquid can be raised by its own kinetic energy. Also see *Hydraulic Head*.

Headward Erosion — Erosion which occurs in the upstream end of the valley of a stream, causing it to lengthen its course in that direction.

Headwater(s) — (1) The source and upper reaches of a stream; also the upper reaches of a reservoir. (2) The water upstream from a structure or point on a stream. (3) The small streams that come together to form a river. Also may be thought of as any and all parts of a river basin except the mainstream river and main tributaries.

Heavy Metals — (1) Those metals that have high density; in agronomic usage these include copper, iron, manganese, molybdenum, cobalt, zinc, cadmium, mercury, nickel and lead. These substances are considered toxic at specified concentrations. (2) Metals having a specific gravity of 5.0 or greater; generally toxic in relatively low concentrations to plant and animal life and tend to accumulate in the food chain. Examples include lead, mercury, cadmium, chromium, and arsenic.

Heterogeneity — Characteristic of a medium in which material properties vary from point to point. Contrast with *Homogeneity*.
Heterotrophic — Pertains to a system in which respiratory demand exceeds *Photosynthesis*. In a heterotrophic system biological fertility is based upon past production, organic matter accumulation and material imported from other systems (e.g., *Allochthonous Material* falling from terrestrial systems into aquatic systems.)

"Highest and Best Use" — The classification of water based on an analysis of the greatest needs of the future. Certain quantities of water (rights) are reserved for appropriation according to this classification.

History Matching - Also referred to as **Model Verification.**

Hoarfrost — A silvery-white deposit of ice needles formed by direct condensation at temperatures below freezing due to nocturnal radiation. Hoarfrost forms during still, clear nights, is small in amount, needlelike in texture, the "needles" approximately perpendicular to the objects on which they occur, and most abundant along the edges. Sometimes confused with *Rime*.

Hogback Ridge — Any ridge with a sharp summit and steep slopes of nearly equal inclination on both flanks, and resembling in outline the back of a hog.

Holistic — Of, concerned with, or dealing with wholes or integrated systems rather than with their parts. With respect to water-related issues, the term most typically describes an analytical and planning approach which examines and considers the inter-related linkages and interdependencies of a socioeconomic system with resource use, pollution, environmental impacts, and preservation of an entire ecosystem.

Holocene — (Geology) The present epoch of time, beginning about 10,000 years ago. Also see *Quaternary*.

Hummock — (1) A small but steep, irregular hill rising above the general level of the surrounding land; a low mound or ridge of earth, a knoll. (2) Also *Hammock*. A tract of forested land that rises above an adjacent marsh in the southern United States. (3) A ridge or hill of ice in an *Ice Field*.

Hydraulic Barrier — (1) Modifications to a ground-water flow system that restrict or impede movement of water and contaminants. (2) Also, a barrier developed in the *Estuary* by the release of fresh water from upstream reservoirs to prevent intrusion of sea water into the body of fresh water. (3) A barrier created by injecting fresh water to control seawater intrusion in an aquifer, or created by water injection to control migration of contaminants in an aquifer.

Hydraulic Conductivity (Ê) — Simply, a coefficient of proportionality describing the rate at which water can move through an aquifer or other permeable medium. The density and kinematic viscosity of the water must be considered in determining hydraulic conductivity. More specifically, the volume of water at the existing kinematic viscosity that will move, in unit time, under a unit *Hydraulic Gradient* through a unit area measured at right angles to the direction of flow, assuming the medium is isotropic and the fluid is homogeneous. In the Standard International System, the units are cubic meters per day per square meter of medium ($m^3/day/m^2$) or m/day (for unit measures).

Hydraulic Conductivity, Effective — The rate of water flow through a porous medium that contains more than one fluid (such as water and air in the unsaturated zone), which should be specified in terms of both the fluid type and content and the existing pressure.

Hydraulic Gradient (*I*) — (1) The slope of the water surface. (2) The gradient or slope of a water table or *Piezometric Surface* in the direction of the greatest slope, generally expressed in feet per mile or feet per feet. Specifically, the change in static head per unit of distance in a given direction, generally the direction of the maximum rate of decrease in head. The difference in hydraulic heads (h1 – h2), divided by the distance (L) along the flowpath, or, expressed in percentage terms:

$I = (h1 - h2) / L \times 100$

A hydraulic gradient of 100 percent means a one foot drop in head in one foot of flow distance.

Hydraulic Head — (1) The height of the free surface of a body of water above a given point beneath the surface. (2) The height of the water level at the headworks or an upstream point of a waterway, and the water surface at a given point downstream. (3) The height of a hydraulic grade line above the center line of a pressure pipe, at a given point.

Hydraulic Permeability — The flow of water through a unit cross-sectional area of soil normal to the direction of flow when the *Hydraulic Gradient* is unity.

Hydraulic Radius — (1) Cross-sectional area divided by the wetter perimeter. (2) The cross-sectional area of a stream of water divided by the length of that part of its periphery in contact with its containing conduit; the ratio of area to wetted perimeter. Also referred to as *Hydraulic Mean Depth*.

Hydric Soil — A soil that, in its undrained condition, is saturated, flooded, or ponded long enough during the growing season to develop *Anaerobic* conditions that favor the growth and regeneration of hydrophytic vegetation (*Hydrophytes*).

Hydrocarbons — Chemical compounds that consist entirely of carbon and hydrogen, such as petroleum, natural gas, and coal.

Hydrogen — (Chemical symbol H) An element commonly isolated as a colorless, tasteless, odorless gas, inflammable (burning with a hot, almost nonluminous flame to form water), and lighter than any other known substance. Free hydrogen occurs only very sparingly on the earth, though it is abundant in the atmospheres of the sun and many stars. Hydrogen is combined with *Oxygen* in *Water* (H2O), of which it constitutes 11.188 per cent by weight. It is also a constituent of most organic compounds, of acids and bases. Ordinary hydrogen gas is diatomic (its molecules consisting of two atoms, H2), but dissociates into free atoms at high temperatures. The hydrogen atom is the simplest of all atoms, the ordinary isotope (H^1) consisting of a single proton and a single valence electron. It is accompanied by a minute amount of a heavier isotope called Deuterium (H^2 or D) which is used in *Heavy Water* (D2O). Atomic number 1; atomic weight 1.00797; melting point –259.14EC (–434.45EF); boiling point –252.8EC (–423.04EF); density at 0EC (32EF) 0.08987 gram per liter.

Hydrogen Bond — A type of chemical bond caused by electromagnetic forces, occurring when the positive pole of one molecule (e.g., water) is attracted to and forms a bond with the negative pole of another molecule (e.g., another water molecule).

Hydrogen Sulfide (Gas) — Chemical symbol H2S, hydrogen sulfide is produced naturally by the *Anaerobic Decomposition* of any type of organic or inorganic matter that contains sulfur, e.g., rotting eggs, wallboard decomposition in landfills, the formation of natural gas from decomposing plant life, sulfate decomposition in sewers, etc. However produced, hydrogen sulfide presents severe health and corrosion hazards as well as being an odor nuisance. Few gases are as potent as hydrogen sulfide to the human olfactory senses. The human nose can detect the rotten egg odor at a level of only 0.4 parts per billion (ppb); few other compounds can be detected at such low levels of concentration.

Hydrogeologic — Those factors that deal with subsurface waters and related geologic aspects of surface waters.

Hydrogeologic Parameters — Numerical parameters that describe the hydrogeologic characteristics of an aquifer such as *Porosity*, *Permeability*, and *Transmissivity*.

Hydrogeologic Unit — Any soil or rock unit or zone that because of its hydraulic properties has a distinct influence on the storage or movement of ground water.

Hydrogeological Cycle — The natural process recycling water from the atmosphere down to (and through) the earth and back to the atmosphere again. Also see *Hydrologic Cycle*.

Hydrogeology — The part of geology concerned with the functions of water in modifying the earth, especially by erosion and deposition; geology of ground water, with particular emphasis on the chemistry and movement of water.

Hydrograph — (1) A graphic representation or plot of changes in the flow of water or in the elevation of water level plotted against time. (2) The trace of stage (height) or discharge of a stream over time, sometimes restricted to the short period during storm flow. (3) A graph showing stage, flow, velocity, or other hydraulic properties of water with respect to time for a particular point on a stream. Hydrographs of wells show the changes in water levels during the period of observation.

Hydrographic Area — In its most general sense, may refer to an defined geographic area, sub-area, sub-basin, basin, region or watershed encompassing the drainage area or catchment area of a stream, its tributaries, or a portion thereof. Typically defined as a study area for analysis or planning purposes in which the land or undersea contours results in surface water flows or measures of elevation draining to a single point. At its smallest extent, a hydrographic area may encompass a single valley containing a single stream system, or a portion of a valley or stream system with distinctive drainage characteristics. At its greatest extent, a hydrographic area may encompass the entire drainage area of a major river system, e.g., the Mississippi River hydrographic area, including all tributary rivers, streams and other sources of surface water flow. Conventionally, a number of hydrographic subareas comprise a hydrographic area whereas a number of hydrographic areas comprise a hydrographic basin or region.

Hydrographic Survey — An instrumental survey to measure and determine characteristics of streams and other bodies of water within an area, including such things as location, areal extent, and depth of water in lakes or the ocean, the width, depth, and course of streams; position and elevation of high water marks; location and depth of wells.

Hydrologic Balance — An accounting of all water inflows to, water outflows from, and changes in water storage within a hydrologic unit over a specified period of time.

Hydrologic Basin — The complete drainage area upstream from a given point on a stream.

Hydrologic Benchmark — A hydrologic unit, such as a basin or a ground-water body, that because of its expected freedom from the effects of man, has been designated as a benchmark. Data from such basins may provide a standard with which data from less independent basins can be compared so that changes wrought by man's interference can be distinguished from changes caused by variations in the natural regimen.

Hydrologic Benchmark Station — A station that provides hydrologic data for a basin in which the hydrologic regimen will likely be governed solely by natural conditions. Data collected at a benchmark station may be used to separate effects of natural from human-induced changes in other basins that have been developed and in which the physiography, climate, and geology are similar to those in the undeveloped benchmark basin..

Hydrologic Budget — An accounting of the inflow, outflow, and storage in a hydrologic unit, such as a drainage basin, aquifer, soil zone, lake, reservoir, or irrigation project.

Hydrologic Cycle — (1) The cycling of water from the atmosphere, onto and through the landscape and eventually back into the atmosphere. (2) The circuit of water movement from the atmosphere to the earth and return to the atmosphere through various stages or processes such as precipitation, interception, runoff, infiltration, percolation, storage, evaporation, and transportation. Also referred to as the *Water Cycle* and *Hydrogeologic Cycle*.

Hydrologic Unit — (1) A geographic area representing part or all of a surface drainage basin or distinct hydrologic feature. (2) (USGS) A geographic area representing part or all of a surface drainage basin or distinct hydrologic feature as defined by the former Office of Water Data Coordination and delineated on the State Hydrologic Unit Maps by the U.S. Geological Survey. Each hydrologic unit is identified by an 8-digit number. (3) A classification of soils concerning water infiltration characteristics used in hydrologic analyses. See *Hydrologic Unit Maps*.

Hydrologic Unit Maps [USGS] — A set of maps developed by the U.S. Geological Survey (USGS) that present information on drainage, culture, hydrography, and hydrologic boundaries and codes of (1) the 21 major water-resources regions and the 222 subregions designated by the U.S. Water Resources Council, (2) the 352 accounting units of the U.S. Geological survey's National Water Data Network, and (3) the 2,149 cataloging units of the U.S. Geological Survey's "Catalog of Information on Water Data." The hydrologic unit map series was initiated in the fall of 1972 by the U.S. Geological Survey's Office of Water Data Coordination, in cooperation with the U.S. Water Resources Council and supported by the U.S. Geological Survey's Resources and Land Information program. These maps and associated codes provide a standardized base for use by water-resources organizations in locating, storing, retrieving, and exchanging hydrologic data, in indexing and inventorying hydrologic data and information, in cataloging water-data acquisition activities, and in a variety of other applications. Because the maps have undergone extensive review by all principal federal, regional and state water-resource agencies, they are widely accepted for use in planning and describing water-use and related land-use activities, and in geographically organizing hydrologic data. The maps depict a hydrologic system that divides the United States into 21 major regions. These regions are further subdivided into 222 subregions, 352 accounting units, and finally, into 2,149 cataloging units. These four levels of subdivisions, used for the collection and organization of hydrologic data, are referred to as *Hydrologic Units*. Also see *Water Resources Regions [United States]*.

Hydrologic Units (Classification Codes) [USGS] — A means by which the Unites States has been divided and subdivided into successively smaller *Hydrologic Units* which have been classified into four levels consisting of 21 major water resources regions, 222 subregions, 352 accounting units and 2,149 cataloging units. The first level of this U.S. Geological Survey (USGS) classification system divides the U.S. into 21 major geographic areas, or regions. These geographic areas (hydrologic areas based on surface topography) contain either the drainage area of a major river or the combined drainage areas of a series of rivers. Eighteen of the regions occupy the land area of the conterminous U.S.; Alaska is region 19, the Hawaiian Islands constitute region 20, and Puerto Rico and other outlying Caribbean areas are region 21. (The Pacific Trust Territories are a potential region 22.) The second level of classification divides the 21 regions into 222 subregions. A subregion includes the area drained by a river system, a reach of a river and its tributaries in that reach, a closed basin(s), or a group of streams forming a coastal drainage area. The third level of classification subdivides many of the subregions into accounting units. These 352 hydrologic accounting units nest within, or are equivalent to, the subregions. The accounting units are used by the USGS for designing and managing the National Water Data Network. The fourth level of classification is the cataloging unit, the smallest element in the hierarchy of hydrologic units. A cataloging unit is a geographic area representing part or all of a surface drainage basin, a combination of drainage basins, or a distinct hydrologic feature. These units subdivide the subregions and accounting units into smaller areas (2,149 in the U.S.) that are used by the USGS for cataloging and indexing water-data acquisition activities in the "Catalog of Information on Water Data." An eight-digit code uniquely identifies each of the four levels of classification within four two-digit fields. The first two digits identify the water resources region; the first four digits identify the subregions; the first six digits identify the accounting unit; and the addition of two more digits identify the cataloging unit. See *Water Resources Regions [United States]* for a complete listing of the 21 major water resources regions.

Hydrology — (1) The science of waters of the earth, their occurrence, distribution, and circulation; their physical and chemical properties; and their reaction with the environment, including living beings. (2) The study of the movement and storage of water in the natural and disturbed environment. (3) The condition of the aquatic environment at some specified time and place. Most frequently, the term is used in reference to water on the surface of the land, in the soil and underlying rocks, and in the atmosphere.

Hydroseeding — Dissemination of seed under pressure, in a water medium. Mulch, lime, and fertilizer can be incorporated in the spraying mixture.

Hydrostatic Head — A measure of pressure at a given point in a liquid in terms of the vertical height of a column of the same liquid which would produce the same pressure.

-I-

Identification — (Statistics) A term used to describe the ability to determine an econometric model's structural parameters, i.e., the coefficients of the exogenous (or independent) variables. An econometric model is said to be exactly identified if the data support a unique set of parameters for the independent variables. A model is said to be *Under-identified* if there is no way of estimating all the structural parameters and *Over-identified* if more than one value is obtainable for some parameters.

Igneous Rock — (Geology) A rock formed by the solidification of molten materials (magma). The rock is extrusive (or volcanic) if it solidifies on the surface and intrusive (or plutonic) if it solidifies beneath the surface.

Illinoian — (Geology) Of or relating to one of the glacial stages of the *Pleistocene* epoch which occurred in North America, which consisted of the *Nebraskan* (first stage), *Kansan* (second stage), *Illinoian* (third stage), and *Wisconsin* (fourth stage).

Impaired — Water bodies that cannot reasonably be expected to attain or maintain applicable water quality standards, and at least one beneficial use shows some degree of degradation.

Impermeability — Characteristic of geologic materials that limit their ability to transmit significant quantities of water under the pressure differences normally found in the subsurface environment.

Impermeable — Unable to transmit water; 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. Not the same as *Nonporous*.

Impermeable Material — A material that has properties preventing movement of water through it. Nonporous.

Impervious — A term denoting the resistance to penetration by water or plant roots; incapable of being penetrated by water; non-porous

Impoundment — (1) Generally, an artificial collection or storage of water, as a reservoir, pit, gugout, or sump. (2) A body of water such as a pond, confined by a dam, dike, floodgate or other barrier. It is used to collect and store water for future use. (3) (Water Quality) Generally an artificial collection and storage area for water or wastewater confined by a dam, dike, floodgate, or other barrier.

Inactive Storage — Lake or reservoir storage not available for release without pumping.

Incidental Recharge — Ground water recharge (infiltration) that occurs as a result of human activities unrelated to a recharge project, for example, irrigation and water diversion (unlined canals). Also see *Artificial* (or *Induced*) *Recharge*, *Natural Recharge*, and *Perennial Yield*.

Incised Channel (River) — (1) A river which cuts its channel through the bed of the valley floor, as opposed to one flowing on a floodplain; its channel formed by the process of degradation. (2) A stream that has degraded and cut its bed into the valley bottom. Indicates accelerated and often destructive erosion.

Indicator Species — (Environmental) Any organism that by its presence or absence, its frequency, or its vigor indicates a particular property of its surrounding environment. A species whose presence is a sign that certain environmental conditions exist. Also see *Management Indicator Species*.

Induced Recharge — The designed (as opposed to the natural or incidental) replenishment of ground water storage from surface water supplies. There exist five (5) common techniques to effect artificial recharge of a ground water basin:

[1] ***Water Spreading*** consisting of the basin method, stream-channel method, ditch method, and flooding method, all of which tend to divert surface water supplies to effect underground infiltration;
[2] ***Recharge Pits*** designed to take advantage of permeable soil or rock formations;
[3] ***Recharge Wells*** which work directly opposite of pumping wells although have limited scope and are better used for deep, confined aquifers;
[4] ***Induced Recharge*** which results from pumping wells near surface supplies thereby inducing higher discharge towards the well; and
[5] ***Wastewater Disposal*** which includes the use of secondary treatment wastewater in combination with spreading techniques, recharge pits, and recharge wells to reintroduce the water to deep aquifers thereby both increasing the available ground water supply and also further improving the quality of the wastewater. Also referred to as *Artificial Recharge*. Also see *Natural Recharge*, *Incidental Recharge*, and *Perennial Yield*.

Infiltrate, also Infiltration — (1) The rate of movement of water from the atmosphere into the soil; that portion of rainfall or surface runoff that moves downward into the subsurface rock and soil; the entry of water from precipitation, irrigation, or runoff into the soil profile. (2) The flow of a fluid into a substance through pores or small openings; to cause a liquid to permeate a substance by passing through its interstices or pores. It connotes flow into a substance in contradistinction to the word *Percolation*, which connotes flow through a porous substance. Also the process whereby water passes through an interface, such as from air to soil or between two soil horizons. (3) The technique of applying large volumes of waste water to land to penetrate the surface and percolate through the underlying soil.

Infiltration and Inflow — (Water Quality) The entrance of ground water (infiltration) or of surface water (inflow) into sewer pipes. Ground water can seep through defective pipe joints or cracked pipe sections; roof or basement drains are sources of surface water inflow. Excessive infiltration and inflow can cause sewers to back up or can overload sewage treatment plants, causing a reduction in treatment time or a complete bypass of the treatment process during periods of significant rainfall.

Infiltration Capacity — The maximum rate at which the soil, when in a given condition, can absorb falling rain or melting snow.

Infiltration Rate — Rate of downward movement or flow of water from the surface into the soil. (1) The rate at which infiltration takes place, expressed in depth of water per unit time, usually in inches per hour. (2) The rate, usually expressed in cubic feet per second, or million gallons per day per mile of waterway, at which ground water enters an infiltration ditch or gallery, drain, sewer, or other underground conduit.

Inflow — (1) The act or process of flowing in or into. (2) Something that flows in or into, as all water that enters a *Hydrologic System*. (3) (Water Quality) Water, other than wastewater, that enters a sanitary sewer system (including sewer service connections) from sources such as roof leaders, cellar drains, yard drains, area drains, foundation drains, drains from springs and swampy areas, manhole covers, cross connections between storm sewers and sanitary sewers, catch basins, cooling towers, surface runoff, street wash waters, or drainage. Inflow does not include, and is distinguished from, *Infiltration*.

Influent Seepage — The movement of gravity water in the *Zone of Aeration* from the ground surface toward the water table.

Influent Stream — A stream that contributes water to the *Zone of Saturation* and to *Bank Storage*. This term has generally been replaced by the term *Losing Stream*. Also see *Stream*.

Influent Water — Water that flows into sink holes, open cavities, and porous materials and disappears into the ground.

Injection — Generally refers to a system of artificially introducing surface water into the ground water system as a means of storage or recharge. Most typically, this includes the use of *Recharge Wells* which work directly opposite of pumping wells to inject surface water into underlying formations. Depending on the water-bearing formation, these methods may have limited usefulness and are generally better used for pumping water into deep, confined aquifers. (Water Quality) Refers to a system of subsurface disposal of brine effluent into an acceptable formation. Also see *Induced Recharge*.

Injection Well — Refers to a well constructed for the purpose of injection treated wastewater directly into the ground. Wastewater is generally forced (pumped) into the well for dispersal or storage into a designated aquifer. Injection wells are generally drilled into nonpotable aquifers, unused aquifers, or below freshwater levels.

Injection Zone — A geological formation receiving fluids through an *Injection Well*.

Instream Flow — (1) The amount of water remaining in a stream, without diversions, that is required to satisfy a particular aquatic environment or water use. (2) Nonconsumptive water requirements which do not reduce the water supply; water flows for uses within a defined stream channel. Examples of instream flows include:

- [1] ***Aesthetics*** — Water required for maintaining flowing steams, lakes, and bodies of water for visual enjoyment;
- [2] ***Fish and Wildlife*** — Water required for fish and wildlife;
- [3] ***Navigation*** — Water required to maintain minimum flow for waterborne commerce;
- [4] ***Quality Dilution*** — Water required for diluting salt and pollution loading to acceptable concentrations; and
- [5] ***Recreation*** — Water required for outdoor water recreation such as fishing, boating, water skiing, and swimming. Also referred to as *Instream Use*.

Interference (Wells) — A change in the water level of one well caused by the pumping at another well. The condition occurring when the area of influence of a water well comes into contact with or overlaps that of a neighboring well, as when two wells are pumping from the same aquifer or are located near each other.

Interfluve — (1) The area between rivers; especially the relatively undissected upland or ridge between two adjacent valleys containing streams flowing in the same general direction. (2) The elevated areas between two *Fluves* (drainageways) that sheds water to them.

Intermediate Zone — The subsurface water zone below the *Root Zone* and above the *Capillary Fringe*.

Intermittent Stream — A stream that carries water only part of the time, generally in response to periods of heavy runoff either from snowmelt or storms; a stream or part of a stream that flows only in direct response to precipitation. It receives little or no water from springs or other sources. It is dry for a large part of the year, generally more than three months. Flow generally occurs for several weeks or months in response to seasonal precipitation, due to ground water discharge, in contrast to the *Ephemeral Stream* that flows but a few hours or days following a single storm. Also referred to as *Seasonal Streams*. Also see *Stream*.

Intermontane Basin — A generic term for wide structural depressions between mountain ranges that are partly filled with alluvium and are called "valleys" in the vernacular. Intermontane basins may be drained internally (*Bolsons*) or externally (*Semi-Bolsons*).

Internal Drainage — (1) Movement of water down through soil to porous aquifers or to surface outlets at lower elevations. (2) Drainage within a basin that has no outlet.

Interstate Waters — According to federal law, interstate waters are defined as: (1) rivers, lakes and other waters that flow across or form a part of state or international boundaries; (2) waters of the Great Lakes; and (3) coastal waters whose scope has been defined to include ocean waters seaward to the territorial limits and waters along the coastline (including inland steams) influenced by the tide.

Interstices — The openings or pore spaces in a rock, soil, and other such material. In the *Zone of Saturation* they are filled with water. Synonymous with *Void* or *Pore*.

Interstitial — Referring to the *Interstices* or pore spaces in rock, soil, or other material subject to filling by water.

Intramontane Basin — A relatively small structural depression within a mountain range that is partly filled with alluvium and commonly drains externally through a narrower mountain valley.

Intrinsic Permeability — Pertaining to the relative ease with which a porous medium can transmit a liquid under a hydraulic or potential gradient. It is a property of the porous medium and is independent of the nature of the liquid or the potential field.

Intrusive — Where a fluid (e.g., magma) has penetrated into or between other rocks, but has solidified before reaching the surface.

Intrusive Bedrock — (Geology) Denoting igneous rocks in a molten state which have evaded other, older rock formations and cooled below the surface of the earth. These magmas are slow-cooling and form coarse-textured rocks, such as granite.

Inverse Method - a method of calibrating a ground water flow model using a computer code to systematically vary inputs or input parameters to minimize residuals or residual statistics.

Ion — (1) An atom or molecule that carries a net charge (either positive or negative) because of an imbalance between the number of protons and the number of electrons present. If the ion has more electrons than protons, it has a negative charge and is called an anion; if it has more protons than electrons it has a positive charge and is called a cation. (2) (Water Quality) An electrically charged atom that can be drawn from waste water during electrodialysis.

Ion Exchange — The substitution of one *Ion* for another in certain substances. Either *Anion Exchange* or *Cation Exchange* is possible. The most common cation exchange involves the conversion of *Hard Water* to *Soft Water* by means of a *Water Softening* process. Hard water contains the divalent ions of calcium (Ca^{+2}) and magnesium (Mg^{+2}), which cause soap and detergents to form precipitates in water. A *Water Softener* consists of a resin that is saturated with sodium ions (Na^{+}). As hard water percolates through the resin, the ions of calcium or magnesium are removed as they attach to the resin, thus releasing (being exchanged for) sodium ions.

Ionic Strength — The weighted concentration of ions in solutions, computed by the formula:
Ionic Strength = ½3($Zi^{2}Ci$)
where:
Z = the charge on a particular ionic species; and
C = the concentration of a particular ionic species.

Isobar — A line on a weather map connecting points of equal atmospheric pressure. Also referred to as *Isopiestic*.

Isobath — An imaginary line on the earth's surface or a line on a map connecting all points which are the same vertical distance above the upper or lower surface of a water-bearing formation or aquifer.

Isochrone — Plotted line graphically connecting all points having the same time of travel for contaminants to move through the saturated zone and reach a well.

Isoconcentration — Graphic plot of points having the same contaminant concentration levels.

Isohyet — A line drawn on a map connecting points that receive equal amounts of rainfall.

Isohyetal — Indicating equal rainfall, generally expressed as lines of equal rainfall.

Isohyetal Line — A line drawn on a map or chart joining points that receive the same amount of precipitation. Also referred to as an *Isohyet* and *Isopluvial Line*.

Isopiestic — Having, or denoting, equal pressure; *Isobaric*.

Isopleth — A graph showing the occurrence or frequency of any phenomenon as a function of two variables

Isotherm — A line drawn on a weather map or chart linking all points of equal or constant temperature.

Isothermy — In *Limnology*, a state in which a lake is at the same temperature throughout and is well-mixed. Periods of isothermy occur in Spring and Autumn in *Dimictic Lakes*.

Isotropy — That condition in which a medium has the same properties in all directions.

-J-

Jackson Turbidity Unit (JTU) — The JTU is a measurement of the turbidity, or lack of transparency, of water. It is measured by lighting a candle under a cylindrical transparent glass tube and pouring a sample of water into the tube until an observer looking from the top of the tube cannot see the image of the candle flame. The number of JTU's varies inversely and nonlinearly with the height of the sample (e.g., a sample which measures 2.3 cm has a turbidity of 1,000 JTU's whereas a sample measuring 72.9 cm has a turbidity of 25 JTU's).

Jurisdictional Wetland — An area that meets the criteria established by the *U.S. Army Corps of Engineers (Corps or COE)* for a *Wetlands* (as set forth in their ***Wetlands Delineation Manual***). Such areas come under the jurisdiction of the Corps of Engineers for permitting certain actions such as dredge and fill operations. See *Wetlands*. [Also see ***Classification of Wetlands and Deepwater Habitats of the United States***, U.S. Department of the Interior, Fish and Wildlife Service (USFWS).

Juvenile Water — Water brought to the surface or added to undergournd supplies from magma.

-K-

Kansan — (Geology) Of or relating to one of the glacial stages of the *Pleistocene* epoch which occurred in North America, which consisted of the *Nebraskan* (first stage), *Kansan* (second stage), *Illinoian* (third stage), and *Wisconsin* (fourth stage).

Karst, also Karstic Region — Limestone and dolomite areas with a topography peculiar to and dependent on underground solution and the diversion of surface waters to underground routes. Characteristic of an area of irregular limestone in which erosion has produced fissures, sinkholes, underground streams, and caverns. Also referred to as *Karst Topography*.

Karst Hydrology — The branch of *Hydrology* that deals with the hydrology of geological formations having large underground passages or fractures which enable underground movement of large quantities of water.

Karst Topography — The structure of land surface resulting from limestone, dolomite, gypsum beds, and other rocks formed by dissolution and characterized by closed depressions, sinkholes, caves, and underground drainage.

Karstic River — A river which originates from a karstic spring or flows in a *Karstic Region*.

Kelvin (K) — The *SI Unit* of temperature. The base unit of temperature in the International System of Units that is equal to 1/273.16 of the Kelvin scale temperature of the triple point of water. Zero Kelvin is *Absolute Zero*, and an interval of 1 K is equal to 1E on the *Celsius Scale* (*Centigrade Temperature Scale*) and 1.8E on the *Fahrenheit Temperature Scale*. 0EC = 273.15 K.

Kelvin Scale — An absolute scale of temperature in which each degree equals one kelvin. Water freezes at 273.15 K and boils at 373.15 K.

Kettle — (1) (Geology) A depression left in a mass of *Glacial Drift*, formed by the melting of an isolated block of glacial ice. (2) A pothole.

Keyway (Key) — The notch excavated into the side of a gully or stream to anchor a check dam or other structure.

Kinematic Viscosity — The ratio of dynamic viscosity to mass density. It is obtained by dividing dynamic viscosity by the fluid density. Units of kinematic viscosity are square meters per second.

Kinetic Energy (k) — The energy inherent in a substance because of its motion, expressed as a function of its velocity and mass, or $MV^2/2$.

Kriging - a geostatistical interpolation procedure for estimating spatial distributions of model inputs from scattered observations.

-L-

Laboratory Blank — An artificial sample, usually distilled water, introduced to a chemical analyzer to observe the response of the instrument to a sample that does not contain the material being measured. The blank can also detect any contamination occurring during laboratory processing of the sample.

Lacustrine — Pertaining to, produced by, or inhabiting a lake.

Lacustrine Deposits — Stratified materials deposited in lake waters and later become exposed either by the lowering of the water level or by the elevation of the land.

Lacustrine Wetlands — According to criteria of the U.S. Fish and Wildlife Service (USFWS), *Lacustrine Wetlands* are greater than 20 acres and have less than 30 percent cover of persistent vegetation. Also see *Wetlands*. [See Appendix D–2 for an explanation of the USFWS Wetland and Deepwater Habitat Classification System and more detailed information on these Systems.]

Lagoon — (1) A shallow lake or pond, especially one connected with a larger body of water. (2) The area of water enclosed by a circular coral reef, or atoll. (3) An area of shallow salt water separated from the sea by sand dunes. (4) A metaphorical term for the ponding area behind a Pleistocene offshore or barrier bar (beaches) that collects fine textured sediments. (5) (Water Quality) Lagoons are scientifically constructed ponds in which sunlight, algae, and oxygen interact to restore water to a quality equal to effluent from a secondary treatment plant.

Lagoon System — (Water Quality) A system of scientifically construction Lagoons or ponds in which sunlight, algae, and oxygen interact to restore water to a quality equal to effluent from a *Secondary Treatment Plant*.

Laminar Flow — A flow in which fluid moves smoothly in streamlines in parallel layers or sheets. The stream lines remain distinct and the flow directions at every point remain unchanged with time. It is characteristic of the movement of ground water. Contrasts with turbulent flow. Synonymous with *Streamline Flow* and *Viscous Flow*.

Landform — (Geography) (1) A discernible natural landscape that exists as a result of wind, water or geological activity, such as a plateau, plain, basin, mountain, etc. (2) A three dimensional part of the land surface, formed of soil, sediment, or rock that is distinctive because of its shape, that is significant for land use or to landscape genesis, that repeats in various landscapes, and that also has a fairly consistent position relative to surrounding landforms.

Landscape — (1) (Geography) All the natural features, such as fields, hills, forests, and water that distinguish one part of the earth's surface from another part. Usually refers to that portion of land or territory which the eye can comprehend in a single view, including all of its natural characteristics. These characteristics are a result not only of natural forces but of human occupancy and use of the land as well. (2) (Ecology) A heterogeneous area composed of a cluster of interacting *Ecosystems* that are repeated in similar form throughout the area. Forest landscapes of the Southwest United States usually range from hundreds to thousands of acres and are the result of geologic, edaphic (soil), climatic, biotic, and human influences.

Land Use — The primary or primary and secondary uses of land, such as cropland, woodland, pastureland, etc. The description of a particular land use should convey the dominant character of a geographic area, and thereby establish the types of activities which are most appropriate and compatible with primary uses.

Langelier Index (LI) — An expression of the ability of water to dissolve or deposit calcium carbonate scale in pipes. The index has important implications in industrial water system where the formation of scale or sludge can cause equipment or process failure. The index is calculated from direct measurements of the following in the water system: pH, alkalinity, calcium concentrations, total dissolved solids, and temperature. A positive value indicates a tendency to form scale, and a negative value means the water will dissolve scale and may be corrosive.

Lateral Moraines — The ridges of *Glacial Till* that mark the sides of a glacier's path. Also see *Moraines*, *Terminal Moraines*, and *Recessional Moraine*.

Lateritic Soil — Land that consist of minerals that are rich in iron and aluminum compounds, other minerals having been removed by *Leaching*. The land is hard and unsuitable for agricultural use.

Leach — (1) To apply water in excess of a crop's needs to flush out salts from the root zone. (2) To remove soluble or other constituents from a medium by the action of a percolating liquid, as in leaching salts from the soil by the application of water.

Leachate — Liquid which has percolated through the ground, such as water seeping through a sanitary landfill, wastes, pesticides, or fertilizers. Leaching may occur in farming areas, feedlots, and landfills, and may result in hazardous substances entering surface water, ground water, or soil.

Leached Layer (Soil) — A soil layer or an entire soil profile from which the soluble materials (CaCO3 and MgCO3 and material more soluble) have been dissolved and washed away by percolating waters.

Leaching — (1) The washing out or flushing of a soluble substance from an insoluble one. (2) The flushing of salts from the soil by the downward percolation of applied water. (3) The process by which soluble materials in the soil, such as salts, nutrients, pesticide chemicals or contaminants, are washed into a lower layer of soil or are dissolved and carried away by water. Also see *Leachate*.

Leakage — (1) (Hydrology) The flow of water from one *Hydrogeologic Unit* to another. This may be natural, as through a somewhat permeable confining layer, or *Anthropogenic*, as through an uncased well. It may also be the natural loss of water from artificial structures, as a result of *Hydrostatic Pressure*. (2) (Dams) The uncontrolled loss of water by flow through a hole or crack.

Leakance - (1) the ratio of the vertical hydraulic conductivity of a confining unit divided by its thickness; (2) the rate of flow across a unit (horizontal) area of a semipervious layer into (or out of) an aquifer under one unit of head difference across this layer. Synonymous with coefficient of leakage.

Leaky Aquifer — An artesian or water table aquifer that loses or gains water through adjacent semipermeable *Confining Units*.

Left Bank — The left-hand bank of a stream viewed when the observer faces downstream.

Lentic — Characterizing aquatic communities found in standing water.

Lentic System — A non-flowing or standing body of fresh water, such as a lake or pond. Compare to a *Lotic System*.

Lentic Waters — Ponds or lakes (standing water).

Levee — (1) A natural or man-made earthen obstruction along the edge of a stream, lake, or river. Also, a long, low embankment usually built to restrain the flow of water out of a river bank and protect land from flooding. If built of concrete or masonry, the structure is usually referred to as a flood wall. The term *Dike* is commonly used to describe embankments that block an area on a reservoir rim that are lower than the top of the main dam. (2) (FEMA) A man-made structure, usually an earthen embankment, designed and constructed in accordance with sound engineering practices to contain, control or divert the flow of water so as to provide protection from temporary flooding.

Levee (Natural) — Bank of sand and silt built by a river during floods, where the *Suspended Load* is deposited in greatest quantity close to the river. The process of developing natural levees tends to raise river banks above the level of the surrounding flood plains. A break in a natural levee is sometimes called a *Crevasse*.

Levee (Manmade) — An embankment, generally constructed on or parallel to the banks of a stream, lake or other body of water, for the purpose of protecting the land side from inundation by flood water or to confine the stream flow to its regular channel.

Limb (Rising or Falling) — The part of the *Hydrograph* in which the discharge is steadily increasing or decreasing.

Lime — Calcium oxide (CaO) used in many water and wastewater treatment operations such as softening, coagulation and phosphorus removal. Also referred to as *Quicklime*.

Limestone — (Geology) A sedimentary rock composed of calcite, or calcium carbonate (CaCO3), and sometimes containing shells and other hard parts of prehistoric water animals and plants. When chemical conditions are right, some calcite crystallizes in sea water and settles to the bottom to form limestone.

Limicolous — Living in mud.

Liming — The application of lime to land, primarily to reduce soil acidity and supply calcium for plant growth. Liming an acid soil to a pH of about 6.5 is desirable to maintain a high degree of availability of most of the nutrient elements required by plants.

Limnetic — Referring to a standing water *Ecosystem* (ponds or lakes); of, relating to, or inhabiting the open water of a body of fresh water, as a limnetic environment or *Limnetic Zone*.

Limnetic Zone — The open water of a pond or lake supporting *Plankton* growth.

Limnology — The branch of *Hydrology* pertaining to the study of freshwater, the aquatic environment and its life; the study of the physical, chemical, hydrological, and biological aspects of fresh water bodies. Related terms include *Limnological*, *Limnologic*, and *Limnologist*.

Limnology Hydrobiologist — A person who undertakes the biological study of bodies of water.

Lineament — (Geology) An essentially rectilinear topographic feature resulting from a fault or zone of faulting. Frequently such areas provide indications of available ground water sources.

Liner — (1) (Water Quality) A low-permeability material, such as clay or high-density polyethylene, used for the bottom and sides of a landfill. The liner retards the escape of *Leachate* from the landfill to the underlying ground water. (2) An insert or sleeve for sewer pipes to prevent leakage or infiltration.

Liquefaction — (1) (General) The act or process of making or becoming liquid; especially the conversion of a solid into a liquid by heat, or of a gas into a liquid by cold or pressure. (2) (Soils) The sudden and spontaneous large decrease of the shearing resistance of a cohesionless soil, caused by a collapse of the structure from shock or other types of strain and associated with a sudden but temporary increase in the pore-fluid pressure resulting in the temporary transformation of the material into a fluid mass.

Lithology — (Geology) (1) The scientific study of rocks, usually with the unaided eye or with little magnification. (2) Loosely, the structure and composition of a rock formation. (3) The description of rocks, especially sedimentary *Clastics* and especially in hand specimen and in outcrop, on the basis of such characteristics as color, structures, mineralogic composition, and grain size.

Littoral — The region along the shore of a non-flowing body of water; corresponds to *Riparian* for a flowing body of water. More specifically, the zone of the sea flood lying between the tide levels.

Littoral Zone — (1) The shallow area near the shore of a non-flowing body of water; that portion of a body of fresh water extending from the shoreline lakeward to the limit of occupancy of rooted plants. (2) A strip of land along the shoreline between the high and low water levels.

Load — The amount of material that a transporting agency, such as a stream, a glacier, or the wind, is actually carrying at a given time. Also, the amount of power delivered to a given point. In this respect:

[1] ***Base Load*** = The minimum load in a stated period of time.
[2] ***Firm Load*** = That part of the system load which must be met on demand.
[3] ***Peak Load*** = Literally, the maximum load in a stated period of time. Sometimes the term peak load is used in a general sense to describe that portion of the load above the base load.

Loam — (1) A soil consisting of a friable mixture of varying proportions of clay, silt, and sand. A soil which has nearly equal proportions of silt, sand and clay. The word is used by gardeners to mean a soil that is rich in organic material, does not compact easily, and drains well after watering. (2) A rich, permeable soil composed of a *Friable* mixture of relatively equal and moderate proportions of clay, silt, and sand particles, and usually containing organic matter (humus) with a minor amount of gravelly material. It has somewhat gritty feel yet is fairly smooth and slightly plastic. Loam may be of residual, fluvial, or *Eolian* origin, and includes many loesses and many of the alluvial deposits of *Flood Plains*, *Alluvial Fans*, and *Deltas*.

Loamy — Said of a soil (such as a clay loam and a loamy sand) whose texture and properties are intermediate between a coarse-textured or sandy soil and a fine-textured or clayey soil.

Loess (Soil) — A fine-grained, yellowish-brown, extremely fertile loam deposited mainly by the wind and found widely in North America, Asia, and Europe. Such soils are highly susceptible to water erosion.

Losing Stream — A stream or reach of a stream that is losing water by seepage into the ground. Also referred to as an *Influent Stream*. Also see *Stream*.

Lunette — A broad, low-lying, typically crescent-shaped mound of sandy or loamy matter that is formed by the wind, especially along the windward side of a lake basin.

Lysimeter — (1) An artificial device for evaluating the *Water Budget* by enclosing a block of soil, often on a scale, with equipment for monitoring inputs and outputs. (2) A field-situated tank or container filled with soil and planted to a crop. Crop consumptive use is measured by weighing or volumetrically monitoring this tank. Also a device for measuring the percolation of water through soils and for determining the soluble constituents removed in the drainage.

-M-

Magma — (Geology) Molten rock found in the mantle, beneath the cruse of the earth. When forced toward the surface, magma cools and solidifies to become *Igneous* rock.

Marine — (1) Of or pertaining to the sea; having to do with the ocean or the things peculiar to the ocean. (2) A system within the *Wetlands and Deepwater Habitat Classification System*. Also see *Deepwater Habitats* and *Wetlands*. [See Appendix D–2 for an explanation of the Wetland and Deepwater Habitat Classification System according to USFWS criteria.]

Marl — A mixture of clays, carbonates of calcium and magnesium, and remnants of shells, forming a loam useful as a fertilizer.

Marsh — A term frequently associated with *Wetlands*. An area of soft, wet, low-lying land, characterized by grassy vegetation that does not accumulate appreciable peat deposits and often forming a transition zone between water and land. A tract of wet or periodically inundated treeless land, usually characterized by grasses, cattails, or other monocotyledons (sedges, lilies, irises, orchids, palms, etc.). Marshes may be either fresh or saltwater, tidal or non-tidal.

Marshland — Treeless land in which the water table is at, above, or just below the surface of the ground; it is dominated by grasses, reeds, sedges, and cattails. These plants typify *Emergent Vegetation*, which has its roots in soil covered or saturated with water and its leaves held above water.

Marsh, Tidal — A low, flat area traversed by interlacing channels and tidal sloughs and periodically inundated by high tides. Vegetation in such areas usually consists of salt-tolerant plants, or *Halophytes*.

Mass Movement — (Geology) The downslope movement of a portion of the land's surface (i.e., a single landslide or the gradual downhill movement of the whole mass of loose earth material) on a slope face. All movement of soil and bedrock materials occurring below the soil surface such as landslips, landflows, rock slides, slumps, etc.

Mathematical Model - a set of mathematical equations expressing the physical system and including simplifying assumptions; (b) the representation of a physical system by mathematical expressions from which the behavior of the system can be deduced with know accuracy.

Maximum Contaminant Level (MCL) — (1) Legally enforceable standards regulating the maximum allowed amount of certain chemicals in drinking water. MDLs must be met by the time water reaches an individual's property. (2) The designation given by the *U.S. Environmental Protection Agency (EPA)* to water quality standards promulgated under the *Safe Drinking Water Act (SDWA)* (Public Law 93–523).

As prescribed by the EPA after research of a contaminant, the MCL is the greatest amount of a contaminant that can be present in drinking water *without* causing a risk to human health. MCLs are set for certain inorganic and organic chemicals, turbidity, coliform bacteria, and certain radioactive materials.

Meander Belt — The zone along a valley floor that encloses a meandering river.

Meander Breadth — The distance between the lines used to define the *Meander Belt*.

Meander Length — The distance in the general course of the meanders between corresponding points of successive meanders of the same phase.

Metamorphic Rock — (Geology) A sedimentary or igneous rock that has been changed by pressure, heat, or chemical action. For example, limestone, a sedimentary rock, is converted to marble, a metamorphic rock.

Metamorphism — A change in the constitution of rock; specifically a pronounced change effected by pressure, heat, and water that results in a more compact and more highly crystalline condition.

Meteoric Water — Ground water derived primarily from precipitation and the atmosphere.

Micrograms per Gram (µg/g) — A unit expressing the concentration of a chemical constituent as the mass (micrograms) of the element per unit mass (gram) of material analyzed.

Micrograms per Liter (µg/l) — A unit expressing the concentration of a chemical constituents in water as the mass (micrograms) of the element per unit volume (liter) of material analyzed. One thousand micrograms per liter is equivalent to one *Milligram per Liter (mg/l)*. This measure is also equivalent to *Parts Per Billion (PPB)*.

Microsiemens per Centimeter (µS/cm) — A unit expressing the amount of electrical conductivity of a solution as measured between opposite faces of a centimeter cube of solution at a specified temperature. Siemens is the International System of Units nomenclature. It is synonymous with mhos and is the reciprocal of resistance measured in ohms.

Micron (µ) — A unit of length equivalent to a micro-meter (µm), or one-millionth of a meter (10^{-6} meter). Micrometer is the preferred term.

Milliequivalents per Liter (MEQ/L) — An expression of the concentration of a material dissolved in water, calculated by dividing the concentration, in milligrams per liter, by the *Equivalent Weight* of the dissolved material. For example, the equivalent weight of aluminum is 9.0. A water concentration of aluminum of 1.8 milligrams per liter equals an aluminum concentration of 0.2 milliequivalent per liter.

Milligrams Per Liter (mg/l) — A unit of the concentration of a constituent in water or wastewater and expresses the concentration of chemical constituents in water as the mass (milligrams) of constituent per unit volume (liter) of water. Concentration of suspended sediment also is expressed in mg/l and is based on the mass of dry sediment per liter of water-sediment mixture. It represents 0.001 gram of a constituent in 1.000 milliliter (ml) of water. It is approximately equal to one part per million (PPM). The term has replaced parts per million in water quality management.

Mine Drainage — Water pumped or flowing from a mine.

Mineral — Any naturally occurring inorganic material with an orderly internal arrangement of atoms and specific physical and chemical properties.

Mineralization — (1) The general process by which elements present in organic compounds are eventually converted into inorganic forms, ultimately to become available for a new cycle of plant growth. (2) The process whereby concentrations of minerals, such as salts, increase in water, often as a natural process resulting from water dissolving minerals found in rocks and soils through which it flows.

Mineral Resource — Known mineral deposits of an area which have present or future utility.

Mineral Soil — Soil composed of predominantly mineral rather than organic materials.

Mining (of an Aquifer) — Withdrawal over a period of time of ground water that exceeds the rate of recharge of the aquifer.

Mining Water Use — Water use for the extraction of minerals occurring naturally including solids, such as coal and ores; liquids, such as crude petroleum; and gases, such as natural gas. Also includes uses associated with quarrying, well operations (*Dewatering*), milling (crushing, screening, washing, flotation, and so forth), and other preparations customarily done at the mine site or as part of a mining activity, such as dust control, maintenance, and wetland restoration. Generally, most of the water used at a mining operation is self-supplied.

Mitigation — (1) (Environmental, General) Actions designed to lessen or reduce adverse impacts; frequently used in the context of environmental assessment. (2) (NEPA) Action taken to avoid, reduce the severity of, or eliminate an adverse impact. Mitigation can include one or more of the following:

[1] avoiding impacts;
[2] minimizing impacts by limiting the degree or magnitude of an action;
[3] rectifying impacts by restoring, rehabilitating, or repairing the affected environment;
[4] reducing or eliminating impacts over time; and
[5] compensating for the impact by replacing or providing substitute resources or environments to offset the loss.

Mixed Boundary – is a linear combination of head and flux at a boundary. An example of a mixed boundary is leakage between a river and an underlying aquifer.

Model — (1) (General) An idealized representation of reality developed to describe, analyze, or understand the behavior of some aspect of it. (2) (Mathematical and Statistical) A simulation, by descriptive, conceptual, statistical, or other means, of a process or thing that is difficult or impossible to observe directly, as in an *Economic Consumption Model* or a *River Flow Model*. A descriptive or conceptual model is one which represents the structure or mechanisms of a model but does not specify the relationships in numerical form. The concept of a (simulation) quantitative model is to approximate reality by means of a quantifiable process such as a mathematical equation or series of equations. In this way the model may be used to simulate various changes in conditions in a "what if" or predictive framework. The fundamental premise of model building is that within some defined bounds of statistical probability a model may be constructed based upon the past behavior of some numeric quantity or variable, or a set of such variables, so as to be able to predict the future behavior of that variable. The actual structure of the model represents the underlying set of assumptions about a phenomenon based on the model builder's view of reality, theoretical underpinnings, proven or probable causal relationships, and deductions and inferences from past observations and experience. To be manageable and useful as a predictive tool, the model must sufficiently simplify the complexities of reality so as to lend itself to some quantifiable structure. However, this simplifying process must not be so extensive as to weaken the model's validity and negate its usefulness as an explanatory and predictive tool.

Model Construction - the process of transforming the conceptual model into a parameterized mathematical form; as parameterization requires assumptions regarding spatial and temporal discretization, model construction requires a-priori selection of computer code.

Model Grid - system of connected nodal points superimposed over the problem domain to spatially discretize the problem domain into cells (finite difference method) or elements (finite element method) for the purpose of numerical modeling.

Modeling - the process of formulating a model of a system or process.

Model Input - the constitutive coefficients, system parameters, forcing terms, auxiliary conditions and program control parameters required to apply a computer code to a particular problem.

Modeling Objectives - the purpose(s) of a model application.

Model Verification - in model application: a) the procedure of determining if a (site-specific) model's accuracy and predictive capability lie within acceptable limits of error by tests independent of the calibration data; b) in model application: using the set of parameter values and boundary conditions from a calibrated model to acceptably approximate a second set of field data measured under similar hydrologic conditions. Also referred to as History Matching.

Molar — A solution containing the indicated number of *Moles* of solute per liter of solution.

Mole — (Chemistry) The mass of a compound in grams numerically equal to its molecular weight. Also, the mass of a compound containing Avogadro's number of molecules.

Molecular Diffusion — The process in which solutes are transported at the microscopic level due to variations in the solute concentrations within the fluid phases. Also see the *Coefficient of Molecular Diffusion*.

Molecular Weight — The sum of the atomic weights of the atoms in a molecule. For example, the molecular weight of water (H2O) is 18, the sum of the atomic weights of two hydrogen atoms (1+1=2) and oxygen (16).

Molecule — A group of atoms held together by chemical bonds. They may be either atoms of a single element (O2) or atoms of different elements that form a compound (H2O). The smallest amount of a compound which has all the properties of the compound.

Monitoring Well — (1) A well used to obtain water quality samples or measure ground water levels. (2) (Water Quality) A well drilled in close proximity to a waste storage or disposal facility, or hazardous waste management facility or *Superfund Site* to check the integrity of the facility or to keep track of leakage of materials into the adjacent ground water.

Monomictic — Lakes or reservoirs which are relatively deep, do not freeze over during the winter, and undergo a single stratification and mixing cycle during the year (usually in the fall).

Moraine — An accumulation of boulders, stones, or other debris carried and deposited by a glacier. Moraines, which can be subdivided into many different types, are deposits of *Glacial Till*. *Lateral*

Moraines are the ridges of till that mark the sides of the glacier's path. *Terminal Moraines* are the material left behind by the farthest advance of the glacier's toe. Each different period of glaciation leaves behind its own moraines. Also see *Recessional Moraine*.

[Ground water] Mounding — Commonly, an outward and upward expansion of the free water table caused by shallow re-injection, percolation below and impoundment, or other surface recharge method (essentially, the reverse of the cone of depression effect created by a pumping well). Mounding can alter ground water flow rates and direction; however, the effects are usually localized and may be temporary, depending upon the frequency and duration of the surface recharge events.

Muck — (1) A moist, sticky mixture, especially of mud and filth. (2) Highly decomposed organic material in which the original plant parts are not recognizable. Muck contains more mineral matter and is usually darker than *Peat*. (3) Earth, rocks, or clay excavated in mining.

Mulch — (1) A substance placed over the soil surface to inhibit weed growth, conserve moisture, and in some cases, prevent heat loss. Examples include straw, wood chips, and leaves. (2) A natural or artificial protective layer of suitable materials, usually of organic matter such as leaves, straw, or peat, placed around plants that aid in soil stabilization, soil moisture conservation, prevention of freezing, and control of weeds, thus providing micro-climatic conditions suitable for germination and growth of selected vegetation.

Mulching — The use of plant residues or other suitable materials on the soil surface, primarily to reduce evaporation of water and erosion of soil.

-N-

Nanograms per Liter (ng/L) — A unit expressing the concentration of chemical constituents in solution as mass (nanograms) of solute per unit volume (liter) of water. One million nanograms per liter is equivalent to 1 milligram per liter (mg/L)

National Environmental Policy Act (NEPA) — A 1970 Act of Congress that requires all federal agencies to incorporate environmental considerations into their decision-making processes. The act requires an *Environmental Impact Statement (EIS)* for any "major federal action significantly affecting the quality of the human environment."

National Pollutant Discharge Elimination System (NPDES) — The program established by the *Clean Water Act (CWA)* that requires all *Point Sources (PS)* of pollution discharging into any "waters of the United States" to obtain a permit issued by the *U.S. Environmental Protection Agency (EPA)* or a state agency authorized by the federal agency. The NPDES permit lists permissible discharges and/or the level of cleanup technology required for wastewater.

National Primary Drinking Water Regulations (NPDWR) — Regulations for public drinking water supply systems that include health-based standards for various contaminants, and monitoring and analysis requirements. Issued by the *U.S. Environmental Protection Agency (EPA)* under authority of the *Safe Drinking Water Act (SDWA)*. While the NPDWR set standards protective of the public health, the *National Secondary Drinking Water Regulations (NSDWR)* set aesthetic standards for drinking water, i.e., color, odor, taste, etc.

National Secondary Drinking Water Regulations (NSDWR) — Regulations governing the operation of public water supply systems under the *Safe Drinking Water Act (SDWA)*. The regulations define secondary maximum contaminant levels, the maximum concentrations of certain substances in drinking water that affect its aesthetic quality. While the NSDWR set aesthetic standards for drinking water, i.e., color, odor, taste, etc., the *National Primary Drinking Water Regulations (NPDWR)* set standards protective of the public health.

Natural Flow — The rate of water movement past a specified point on a natural stream from a drainage area for which there have been no effects caused by stream diversion, storage, import, export, return flow, or change in *Consumptive Use* caused by man-controlled modification to land use. Natural flow rarely occurs in a developed county.

Natural Recharge — The replenishment of ground water storage from naturally-occurring surface water supplies such as precipitation and stream flows. Also see *Artificial* (or *Induced*) *Recharge*, *Incidental Recharge*, and *Perennial Yield*.

(United States) Natural Resources Conservation Service (NRCS) — Formerly known as the *Soil Conservation Service (SCS)*, an agency of the U.S. Department of Agriculture, the Natural Resources Conservation Service (NRCS) had its beginnings with a 1929 emergency act of Congress in response to the famous Dust Bowl when land practices, primarily in the Midwest Farm Belt, caused extensive soil erosion and threatened the food production of the United States. Initially, ten experiment stations were established to work with Land Grant Universities to study soil erosion and ways to prevent it. As a result of these initial efforts, the Soil Erosion Service was established in 1933 to show American farmers new ways of preventing and recovering from soil erosion. In 1935 Congress changed the Soil Erosion Service into the Soil Conservation Service and made it a permanent agency of the U.S. Department of Agriculture. In 1994 the name was change to Natural Resources Conservation Service to denote a broader role of responsibility in natural resource conservation. Presently, the NRCS works in three primary areas: (1) soil and water conservation; (2) resource inventories; and (3) rural community development. These activities are covered under a number of direct NRCS programs, involving only NRCS resources, and NRCS assisted programs, involving the NRCS and at least one other government agency.

Direct NRCS Programs:

[1] Technical Assistance
[2] Great Plains Conservation Program
[3] Watershed Protection, Long-Term Contracts (Public Law 566)
[4] USDA Compliance Plans

NRCS Assisted Programs:

[1] Agriculture Conservation Program
[2] Water Bank Program
[3] Colorado River Salinity Control Program
[4] Conservation Reserve Program
[5] Water Quality Incentive Program
[6] Emergency Conservation Program
[7] Wetlands Reserve Program

Natural Sink — A habitat that serves to trap or immobilize chemicals such as plant nutrients, organic pollutants, or metal ions through natural processes. For example, a river that enters a swamp may carry a substantial amount of dissolved plant nutrients. The natural biological activity of the swamp may remove these nutrients to such an extent that the water exiting the swamp is relatively low in nutrient concentrations. The swamp has then served as a sink to trap the nutrients that are no longer available for subsequent plant growth downstream from the swamp. Also referred to as a *Nutrient Sink*.

Nebraskan — (Geology) Of or relating to one of the glacial stages of the *Pleistocene* epoch which occurred in North America, which consisted of the *Nebraskan* (first stage), *Kansan* (second stage), *Illinoian* (third stage), and *Wisconsin* (fourth stage).

Nephelometer — A device which measures the intensity of light scattered at right angles to its path through a sample. It is used to measure turbidity, and the results are expressed in *Nephelometric Turbidity Units* (NTUs).

Nephelometric — A method of measuring turbidity in a water sample by passing light through the sample and measuring the amount of the light that is deflected.

Nephelometric Turbidity Unit (NTU) — (1) A unit of measure for the turbidity of water resulting from the use of a *Nephelometer* and based on the amount of light that is reflected off the water. (2) The measurement for reporting turbidity that is based on the use of a standard suspension of Formazin. Turbidity measured in NTU uses nephelometric methods that depend on passing specific light of a specific wavelength through the sample. This unit is not identical to the *Jackson Turbidity Unit (JTU)*.

Neritic — Of the shallow regions of a lake or ocean that border the land. The term is also used to identify the biota that inhabit the water along the shore of a lake or ocean.

Neritic Zone — The relatively shallow water zone that extends from the high tide market to the edge of the *Continental Shelf*. May also refer to such shallow water regions of lakes.

Neutralization — (1) (Chemistry) A reaction between an acid and a base that yields a salt and water. (2) The equalization of hydrogen and hydroxyl ion concentrations such that the resulting solution is neither acidic nor basic; also, decreasing the acidity or alkalinity of a substance by adding alkaline or acidic materials, respectively.

Neutral Soil — A soil in which the surface layer, at least to normal plow depth, is neither acid nor alkaline in reaction, approximately 7.0 pH.

Nick Point (Bedscarp) — (1) The point at which a stream is actively eroding the streambed to a new base level. (2) An abrupt change in grade in the bottom of a stream channel that moves progressively upstream; the change in grade forms a waterfall. Also, the location where a streambed is actively eroding downward to a new base level.

Nitrates — Nitrates represent a class of chemical compounds having the formula NO3 . Nitrate salts are used as fertilizers to supply a nitrogen source for plant growth. Nitrate additions to surface waters can lead to excessive growth of aquatic plants. The presence of nitrates in ground water occurs from the conversion of nitrogenous matter into nitrates by bacteria and represents the process whereby ammonia in wastewater, for example effluent discharges from septic tank systems, is oxidized to nitrite and then to nitrate by bacterial or chemical reactions. High ground water nitrate levels can cause methemoglobinemia in infants.

Nitrification — The conversion of nitrogenous matter into *Nitrates* by bacteria; the process whereby ammonia in wastewater is oxidized to nitrite and then to nitrate by bacterial or chemical reactions.

Nitrogen — (1) (General) Chemical symbol N, the gaseous, essential element for plant growth, comprising 78 percent of the atmosphere, which is quite inert and unavailable to most plants in its natural form. (2) One of the three primary nutrients in a complete fertilizer and the first one listed in the formulation on a fertilizer label: 10-8-6 (nitrogen, phosphorus, potassium). (3) (Water Quality) A nutrient present in ammonia, nitrate or nitrite or elemental form in water due possibly to *Nonpoint Source (NPS)* pollution or improperly operating wastewater treatment plants.

Nitrogen-Fixing Plants — Plants that can assimilate and fix the free nitrogen of the atmosphere with the aid of bacteria living in the root nodules. Legumes with the associated rhizobium bacteria in the root nodules are the most important nitrogen-fixing plants.

No Action Alternative — Projected baseline condition, or anticipated future condition without a given action being taken. The expected future condition if no action is taken—not necessarily the same as the present condition. The effects of action alternatives are measured against this baseline condition.

Node (Nodal Point) - in a numerical model, a location in the discretized model domain where a dependent variable (hydraulic head) is computed.

Noncohesive Soil — Soil particles that have no natural resistance to being pulled apart at their point of contact, for example, silt, sand, and gravel.

Non-Degradation Policy — An environmental policy which disallows any lowering of naturally occurring quality regardless of preestablished health standards.

Non-Point Source (NPS) Pollution — (1) Pollution discharged over a wide land area, not from one specific location. (2) Water pollution caused by diffuse sources with no discernible distinct point of source, often referred to as runoff or polluted runoff from agriculture, urban areas, mining, construction sites and other sites. These are forms of diffuse pollution caused by sediment, nutrients, organic and toxic substances originating from land use activities, which are carried to lakes and streams by surface runoff. Technically, non-point source pollution, also referred to as *Non-Point Water Pollution*, means any water contamination that does not originate from a "point source," which is designated in the *Clean Water Act (CWA)* as pollution that can be clearly identified as a discharge from a pipe, ditch, or other well-defined source. Non-point source pollution, by contrast, is contamination that occurs when rainwater, snowmelt, or irrigation washes off plowed fields, city streets, or suburban backyards. As this runoff moves across the land surface, it picks up soil particles and pollutants such as nutrients and pesticides. Some of the polluted runoff infiltrates into the soil to contaminate (and recharge) the ground water below. The rest of the runoff deposits the soil and pollutants in rivers, lakes, wetlands, and coastal waters. Originating from numerous small sources, non-point source pollution is widespread, dispersed, and hard to pinpoint. Compared with point source pollution, it is diffuse and difficult to control or prevent. It has been estimated that non-point source pollution accounts for more than one-half of the water pollution in the United States today.

Nonuniform Flow — (Hydraulics) Flow in which the mean velocity or cross-sectional area vary at successive channel cross-sections. If the velocity at a given cross-section is constant with time, it is referred to as *Steady Nonuniform Flow*. If the velocity changes with time at each cross-section, it is known as *Unsteady Nonuniform Flow*.

No-Flow Boundary - model boundary which is a Specified Flux Boundary where the assigned flux is equal to zero. Also see Boundary condition.

Normal Fault — (Geology) A *Fault* in which the hanging wall appears to have moved downward relative to the footwall.

NPDES Permit — A permit issued under the *National Pollutant Discharge Elimination System (NPDES)* for companies discharging pollutants directly into the waters of the United States.

NTU — A unit of measure for the turbidity water based on the amount of light that is reflected off the water. See *Nephelometric Turbidity Unit*.

Numerical Methods - in subsurface fluid flow modeling, a set of procedures used to solve the ground water flow equations in which the applicable partial differential equations are replaced by a set of algebraic equations written in terms of discrete values of state variables (e.g. hydraulic head) at discrete points in space and time. The most commonly used numerical methods in ground water models re the finite-difference method, the finite-element method, the boundary element method and the analytic element method.

Numerical Model - in subsurface fluid flow modeling, a mathematical model that uses numerical methods to solve the governing equations of the applicable problem.

Numerical Solution - an approximate solution of a governing (partial) differential equation derived by replacing the continuous governing equation with a set of equations in discrete points of the model's time and space domains.

-O-

Observation Well — A well used to monitor changes in water levels of an aquifer and to obtain samples for water quality analyses. Also see *Wellhead Protection Program*.

Open or Screened Interval — The length of the unscreened opening or of a well screen through which water enters a well, in feet below land surface.

Open-Pit Mining — The process of removing mineral deposits that are found close enough to the surface so that the construction of tunnels (underground mining) is not necessary. The soil and strata that cover the deposit are removed to gain access to the mineral deposit. The primary environmental concerns related to this technique are the disposition of spoils removed to gain access to the deposit and the scoring of the landscape that remains following the complete removal of the mineral deposit. Erosion and water pollution are also concerns because runoff from the mining area is frequently rich in sediments and minerals which may pollute receiving streams. Furthermore, when the resulting pit extends below the water table, it may necessitate the removal of ground water that infiltrates the mining pit, potentially altering the ground water flow with possible implications on the water table and ground water characteristics. Also referred to as *Strip Mining* or *Surface Mining*. Also see *Acid Mine Drainage*, *Dewater* and *Dewatering*, and *Yellowboy*.

Orogenic — (Geology) Pertaining to the process of mountain-building, especially by the folding of the earth's crust. Also see *Diastrophic* and *Tectonic*.

Osmosis — The selective passage of liquids through a semipermeable membrane in a direction which tends to make concentrations of all substances on one side of the membrane equal to those on the other side. The semipermeable membrane allows the passage of water but prevents the passage of substances dissolved in the water. The water movement is from the more dilute solution toward the more concentrated solution, and will continue until the two solutions are equal in concentration. If pressure is applied to the more concentrated side, the flow of water will reverse, from the concentrated side to the more dilute side, a condition termed *Reverse Osmosis*.

Other Water Use — Water used for such purposes as heating, cooling, irrigation (public-supplied only), lake augmentation, and other nonspecific uses. The water can be obtained from a *Public Water Supply*

System, or may be self supplied.

Outflow, also Outflows — (1) To issue or stream out, in or as if in a flow from a body of water. (2) Process of flowing out; includes all water that leaves a *Hydrologic System*.

Output - in subsurface fluid flow modeling, all information that is produced by the computer code.

Overburden — The earth, rock, and other materials that lie above a desired ore or mineral deposit.

Over Calibration - achieving artificially low residuals by inappropriately adjusting model input parameters without field data to support the adjusted model parameter values.

Overland Flow — (1) Surface runoff. (2) The flow of rainwater or snowmelt over the land surface toward stream channels. (3) (Water Quality) The discharge of wastewater in such a way that it flows over a defined land area prior to entering a receiving stream. The movement over vegetated land fosters the removal of plant nutrients from the wastewater and constitutes a form of *Tertiary Wastewater Treatment*. After it enters a stream, it becomes *Runoff*.

Overturn — (1) The sinking of surface water and rise of bottom water in a lake or sea that results from changes in temperature that commonly occur in spring and fall. (2) One complete cycle of top to bottom mixing of previously stratified water masses. This phenomenon may occur in the spring or fall, or after storms, and results in uniformity of chemical and physical properties of water at all depths. Also referred to as *Turnover*, e.g., *Fall Turnover* and *Spring Turnover*.

Oxbow — An abandoned meander in a river or stream, caused by neck cutoff. Used to describe the U-shaped bend in the river or the land within such a bend of a river.

Oxbow Lake — An abandoned meander isolated from the main stream channel by deposition, and filled with water.

Oxidation (Oxidizing) — (1) A chemical reaction that involves combination with oxygen or the loss of electrons. (2) The process of increasing the positive valence or of decreasing the negative valence of an element or ion. (3) The process by which electrons are removed from atoms or ions, also, reduction. (4) (Water Quality) The addition of oxygen that breaks down organic waste or chemicals such as cyanides, phenols, and organic sulfur compounds in sewage by bacterial and chemical means.

Oxidation-Reduction Potential — The electric potential required to transfer electrons from one compound or element (the *Oxidant*) to another compound (the *Reductant*); used as a qualitative measure of the state of oxidation in water treatment systems.

Oxygen Deficit — (Water Quality) The difference between observed oxygen concentration and the amount that would theoretically be present at 100 percent saturation for existing conditions of temperature and pressure.

Oxygen Demand — The need for molecular oxygen (O2) to meet the needs of biological and chemical processes in water. The amount of molecular oxygen that will dissolve in water is extremely limited; however, the involvement of oxygen in biological and chemical processes in extensive. Consequently, the amount of oxygen dissolved in water becomes a critical environmental constraint on the biota living in the water. The metabolism of large organisms like submerged plants and fish, the microorganisms engaged in decomposition, and spontaneous chemical reactions all require (demand) a portion of a limited resource, molecular oxygen. Also see *Biochemical Oxygen Demand (BOD)*.

Oxygen Depletion — The removal of *Dissolved Oxygen* from a body of water as a result of bacterial metabolism of degradable organic compounds added to the water, typically caused by human activities.

-P-

Palustrine — Pertaining to a *Marsh* or *Wetlands*; wet or marsh habitats.

Palustrine Wetlands — Used in the wetlands classification system by the *U.S. Fish and Wildlife Service (USFWS)* to refer to wetlands that are vegetated-dominated by trees, shrubs, herbaceous plants, mosses or lichens. See *Wetlands (General)*, *Wetlands (COE and EPA)*, *Wetlands (USFWS)*, *Wetlands (NRCS)*, *Wetlands, Palustrine*, and *Wetlands, Benefits*. [See Appendix D–2 for an explanation of the Wetland and Deepwater Habitat Classification System according to U.S. Fish and Wildlife Service (USFWS) criteria and more detailed information of these systems.

Parameter - any of a set of physical properties which determine the characteristics or behavior of a system.

Parameter Identification Model (inverse model) - a computer code for determination of selected unknown parameters and stresses in a ground water system, given that the response of the system to all stresses is known and that information is available regarding certain parameters and stresses.

Partial Penetration — A well constructed in such a way that it draws water directly from a fractional part of the total thickness of the aquifer. The fractional part may be located at the top, the bottom, or anywhere else in the aquifer.

Particle Size — The diameter (usually the intermediate diameter), in millimeters, of suspended sediment or bed material determined by either sieve or other sedimentation methods. The sedimentation-method utilizes the principle of Stokes Law to calculate sediment particle sizes. Sedimentation methods (pipet, bottom-withdrawal tube, visual-accumulation tube, Sedigraph) determine fall diameter of particles in either distilled water (chemically dispersed) or in native water (the river water at the time and point of sampling).

Particle Size Classification — Agrees with recommendations made by the *American Geophysical Union Subcommittee on Sediment Terminology*. The particle size classification is as follows:

[1] ***Clay*** – 0.00024–0.004 millimeters (mm);
[2] ***Silt*** – 0.004–0.062 mm;
[3] ***Sand*** – 0.062–2.0 mm; and
[4] ***Gravel*** – 2.0–64.0 mm.

Partitioning Function - a mathematical relation describing the distribution of a reactive solute between solution and other phases.

Parts Per Billion (PPB) — The number of "parts" by weight of a substance per billion parts of water. Used to measure extremely small concentrations.

Parts Per Million (PPM) — The number of "parts" by weight of a substance per million parts of water. This unit is commonly used to represent pollutant concentrations. Large concentrations are expressed in percentages.

Peak Flow — The maximum instantaneous discharge of a stream or river at a given location. It usually occurs at or near the time of maximum stage.

Pebble — A small stone, especially one worn smooth by erosion. (Geology) A rock fragment between 4 and 64 millimeters (0.16 and 2.51 inches) in diameter, especially one that has been naturally rounded.

Pecelt Number - a relationship between the advective and diffusive components of solute transport expressed as the ratio of the product of the average interstitial velocity, times the characteristic length, divided by the coefficient of molecular diffusion; small values indicate diffusion is the dominant transport process, large values indicate advection dominance.

Pediment — (Geology) (1) A broad, gently sloping rock surface at the base of a steeper slope, often covered with *Alluvium*, formed primarily by erosion. (2) A broad, flat or gently sloping, rock-floored erosion surface or plain of low relief, typically developed by subaerial agents (including running water) in an arid or semiarid region at the base of an abrupt and receding mountain front or plateau escarpment, and underlain by bedrock (occasionally by older alluvial deposits) that may be bare but more often partly mantled with a thin and discontinuous veneer of alluvium derived from the upland masses and in transit across the surface. The longitudinal profile of a pediment is normally slightly concave upward, and its outward form may resemble a bajada (which continues the forward inclination of a pediment). Unlike a *Bajada*, however, which a it closely resembles, a pediment is a surface of erosion whereas a bajada is a surface of deposition. In fact, the top of a bajada often merges with trailing portions of a pediment.

Pedisediment — A layer of sediment, eroded from the shoulder and backslope of an erosional slope, that lies on and is, or was, being transported across a pediment (footslope).

Pedogenic (Pedogenesis) — The process of soil formation. Also see *Pedology*.

Pedology — The scientific study of soils, their origins, characteristics, and uses.

Pelagic — Referring to the open sea at all depths (pelagic animals live in the open sea and are not limited to the ocean bottom).

Pelite — (Geology) A sedimentary rock composed of fine fragments, as of clay or mud.

Peneplain, also Peneplane — (Geology) A nearly flat land surface representing an advanced stage of erosion.

Perched Ground Water — Ground water in a saturated zone of material underlain by a relatively impervious stratum which acts as a barrier to downward flow and which is separated from the main ground water body by a zone of unsaturated material above the main ground water body.

Perched Streams — Perched streams are either *Losing Streams* or *Insulated Streams* that are separated from the underlying ground water by a zone of aeration. Also see *Stream*.

Perched Water Table — The top of a *Zone of Saturation* that bottoms on an impermeable horizon above the level of the general water table in the area. Is generally near the surface, and frequently supplies a hillside spring.

Percolating Waters — Underground waters whose course and boundaries are incapable of determination. Waters which pass through the ground beneath the earth's surface without a definite channel. May be rainwater slowly infiltrating through the soil or water seeping through the banks or the bed of a stream, but these waters have left the flow of the stream so that they no longer may be characterized as a part of the stream flow. It is presumed that ground waters percolate.

Percolation — (1) The movement, under hydrostatic pressure, of water through the interstices of a rock or soil. Also, the movement of water within a porous medium such as soil toward the water table without a definite channel. (2) The entrance of a portion of the streamflow into the channel materials to contribute to ground water replenishment.
(3) Slow seepage of water through a filter.

Percolation, Deep — The amount of water that passes below the root zone of the crop or vegetation.

Percolation Rate — The rate, usually expressed as a velocity, at which water moves through saturated granular material. Also applies to quantity per unit of time of such movement and has been used erroneously to designate *Infiltration Rate* or *Infiltration Capacity*.

Percolation Test — (1) A procedure to measure the drainage characteristics of the soil on a lot. Such tests are required in the proper design of septic tank drainfields. (2) A soil test to determine if soil will take sufficient water seepage for use of a septic tank.

Perennial Stream — A stream that flows from source to mouth throughout the year. Also see *Stream*.

Perennial Yield (Ground Water) — The amount of usable water of a ground water reservoir that can be withdrawn and consumed economically each year for an indefinite period of time. It cannot exceed the sum of the *Natural Recharge*, the *Artificial* (or *Induced*) *Recharge*, and the *Incidental Recharge* without causing depletion of the ground water reservoir. Also referred to as *Safe Yield*.

Perforation of Wells — Holes in the casing of wells which allow water to flow into the well.

Perlite, also Pearlite — A natural volcanic glass similar to obsidian but having distinctive concentric cracks and a relatively high water content. In a fluffy heat-expanded form perlite is used as a lightweight aggregated, in fire-resistant insulation, and in soil for potted plants.

Permanent Hardness — Water hardness that cannot be reduced or removed by heating the water, a reflection of the presence of dissolved calcium, magnesium, iron and other divalent metal ions. These ions will react to form insoluble precipitates.

Permeability — (1) The capacity of soil, sediment, or porous rock to transmit water; the property of soil or rock that allows passage of water through it. (2) For a rock or an earth material, the ability to transmit fluids; the rate at which liquids pass through soil or other materials in a specified direction. It is measured by the rate at which a fluid of standard viscosity can move through a material in a given interval of time under a given *Hydraulic Gradient*. Permeability for underground water is sometimes expressed numerically as the number of gallons per day that will flow through a cross section of 1 square foot, at 60EF, under a hydraulic gradient of 100 percent. Permeability is equal to velocity of flow divided by hydraulic gradient. The following permeability terms apply:

[1] ***Very Slow*** – less than 0.05 inch per hour;
[2] ***Slow*** – 0.05 to 0.20 inch per hour;
[3] ***Moderately Slow*** – 0.20 to 0.80 inch per hour;
[4] ***Moderate*** – 0.80 to 2.50 inches per hour;
[5] ***Moderately Rapid*** – 2.50 to 5.0 inches per hour;

[6] ***Rapid*** – 5.0 to 10.0 inches per hour; and
[7] ***Very Rapid*** – More than 10.0 inches per hour.

Permeability Coefficient — The rate of flow of water through a unit cross-sectional area under a *Unit Hydraulic Gradient* at the prevailing temperature (*Field Permeability Coefficient*), or adjusted to 15EC (59EF). See *Permeability*, above.

Permeability, Effective — Observed permeability of a porous medium to one fluid phase, under conditions of physical interaction between the phase and other fluid phases present.

Permeability, Intrinsic — (1) Relative ease with which porous medium can transmit a fluid under a potential gradient, as a property of the medium itself. (2) Property of a medium expressing the relative ease with which fluids can pass through.

Permeability Soil — The quality of a soil horizon that enables water or air to move through it. The permeability of a soil may be limited by the presence of one nearly impermeable horizon even though the others are permeable.

Permeable — Having pores or openings that permit liquids or gasses to pass through.

pH (Hydrogen Ion Concentration, or Potential of Hydrogen) — (1) A convenient method of expressing the acidity or basicity of a solution in terms of the logarithm of the reciprocal (or negative logarithm) of the hydrogen ion concentration. The pH scale runs from 0 to 14; a pH value of 7.0 indicates a neutral solution. Values above 7.0 pH indicate basicity (basic or alkaline solutions); those below 7.0 pH indicate acidity (acidic solutions). Natural waters usually have a pH between 6.5 and 8.5. Because the units are derived from common logarithms, a difference of one pH unit indicates a tenfold (10^1) difference in acidity; similarly, a difference of two units indicates a hundredfold (10^2) difference in acidity. The term originally derived from "potential of hydrogen," or hydrogen power. (2) A term indicating the hydrogen ion concentration of a solution, i.e., a measure of the solution's acidity. The term (from French, pouvoir hydrogène, or literally, "hydrogen power") is defined as the negative logarithm of the concentration of H+ ions (protons): pH = –log10 [H^+], where [H^+] is the concentration of H^+ ions in moles per liter (see *Mole*). Because H^+ ions associate with water molecules to form hydronium ($H3O^+$) ions (see *Acid* and *Base*), pH also is often expressed in terms of the concentration of hydronium ions. In pure water at 22° C (72° F),$H3O^+$ and hydroxyl (OH^-) ions exist in equal quantities; the concentration of each is 0.107 moles/liter. Consequently, the pH of pure water is –log (0.107), which equals log 107, or 7. If an acid is added to water, however, an excess of $H3O^+$ ions is formed; their concentration can range between 0.106 and 0.10 moles/liter, depending on the strength and amount of the acid. Therefore, acid solutions have a pH ranging from 6 (for a weak acid) to 1 (for a strong acid). Inversely, a basic solution has a low concentration of $H3O^+$ ions and an excess of OH^- ions, and the pH ranges from 8 (for a weak base) to 14 (for a strong base). The presence and concentration of many dissolved chemical constituents found in water are, in part, influenced by the hydrogen-ion activity of water. Biological processes including growth, distribution of organisms, and toxicity of the water to organisms are also influenced, in part, by the hydrogen-ion activity of water.

Phreatic — Of or relating to ground water.

Phreatic Line — The line marking the upper surface of the *Zone of Saturation* in the soil.

Phreatic Surface — A term equivalent to the *Ground water Surface* or the *Water Table*; the free surface of ground water at atmospheric pressure.

Phreatic Water — Synonymous with the *Zone of Saturation*.

Physical Weathering — The breaking down of parent rock into bits and pieces by exposure to temperature changes and the physical action of moving ice and water, growing roots, and human activities such as farming and construction. Compare to Chemical Weathering.

Picocurie (PC, pCi) — One trillionth (1×10^{-12}) of the amount of radioactivity represented by a curie (Ci). A curie is the amount of radioactivity that yields 3.7×10^{10} radioactive disintegrations per second. A picocurie yields 2.22 dpm (disintegrations per minute).

Piedmont — (1) An area, plain, slope, glacier, or other feature at the base of a mountain, for example, a foothill or a *Bajada*. In the United States, the Piedmont (region) is a plateau extending from New Jersey to Alabama and lying east of the Appalachian Mountains. (2) Lying or formed at the base of a mountain or mountain range; for example, a piedmont terrace or a piedmont pediment.

Piedmont Slope — A major physiographic part of an *Intermontane Basin* that comprises all of the constructional and erosional, major and component landforms from the basin floor to the mountain front and on into alluvium-filled mountain valleys.

Piezometer — (1) An instrument used to measure pressure head in a conduit, tank, soil, etc. It usually consists of a small pipe or tube tapped into the side of the container, so that the inside end is flush with, and normal to, the water face of the container and is connected with a manometer pressure gage, mercury or water column, or other device for indicating pressure head. (2) An instrument for measuring pore water pressure within soil, rock, or concrete. (3) Also, an instrument for measuring the compressibility of liquids.

Piezometer (Open Well) — A well structure or tube which allows the level of saturation within a dam to be measured.

Piezometric Head — Synonymous with *Hydraulic Head*, which is now commonly used.
Piezometric Surface — An imaginary surface that everywhere coincides with the static level of the water in the aquifer. This term is now generally considered to be obsolete, being replaced by the term *Potentiometric Surface*.

Piping — (1) The progressive development of erosion of a dam structure by seepage, appearing downstream of the dam as a hole or seam discharging water that contains soil particles. (2) The process by which water forces an opening around or through a supposedly sealed structure, such as a check dam or levee. As water flows through, the opening usually grows larger and the water carries away sediment or levee material. Also referred to as *Internal Erosion*.
Pirate Stream — One of two streams in adjacent valleys that has been able to deepen its valley more rapidly than the other, has extended its valley headward until it has breached the divide between them, and has captured the upper portion of the neighboring stream.

Plain — (1) Level or gently rolling land, usually below 2,000 feet (610 meters) in elevation. (2) A flat, undulating, or even rolling area, larger or smaller, that includes few prominent hills or valleys, that usually is at low elevation in reference to surrounding areas, and that may have considerable overall slope and local relief.

Plateau — A level, elevated land area, usually between 2,000 and 6,000 feet (610–1,830 meters) in elevation.

Pleistocene — (Geology) Of, belonging to, or designating the geologic time, rock series, and sedimentary deposits of the earlier of the two epochs of the Quaternary Period. This epoch was characterized by the alternate appearance and recession of northern glaciation and the appearance of the progenitors of human beings. Also commonly referred to as the *Ice Age*, the Pleistocene covered a period of time from about 2 million years ago to 10,000 years ago and immediately preceded the Holocene Epoch, or the period from 10,000 years ago to the present. The late Pleistocene is generally considered to be the Wisconsinan Age (North America), which extended from about 300,000 years ago to 10,000 years ago and the beginning of the Holocene.

Pliocene — (Geology) The epoch immediately preceding the *Pleistocene* which lasted for about 10 million years' duration from about 12 million years ago to about 2 millions years ago.

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.

Pluvial — (1) Of having to do with rain; rainy. (2) To flow, pour, or fill. (3) (Geology) Formed or caused by the action of rain, as a pluvial deposit. (4) (Geology) More specifically, the two or more Wisconsin stages, of the late *Pleistocene* age (epoch), when the western United States waterbasins were filled with lakes. The *Early Pluvial* period consisted of periods of high humidity so remote as to have left no clear-cut shore features; the *Postpluvial* period represented a period of desiccation following the last high lake stage.

Pluvial Lake — A lake formed during a pluvial (rainy) period.

Pluvial Period — A period of increased rainfall and decreased evaporation, which prevailed in nonglaciated areas during the time of ice advance elsewhere.

Pluvious — Characterized by heavy rainfall; rainy.

Pocosin — An upland swamp of shallow water of the coastal plain of the Southeast United States; a "Dismal", as used in the southern United States.

Point Bar — A bank on the inside of a meander bend that has built up due to sediment deposition opposite a pool.

Point Discharge — The instantaneous rate of discharge, in contrast to the mean rate for an interval of time.

Point Source (PS) — (1) A stationary or clearly identifiable source of a large individual water or air pollution emission, generally of an industrial nature. (2) Any discernible, confined, or discrete conveyance from which pollutants are or may be discharged, including (but not limited to) pipes, ditches, channels, tunnels, conduits, wells, containers, rolling stock, concentrated animal feeding operations, or vessels. Point source is also legally and more precisely defined in federal regulations. Contrast with *Non-Point Source (NPS) Pollution*.

Point Source (PS) Pollution — (1) Pollution originating from any discrete source. (2) Pollutants discharged from any distinct, identifiable point or source, including pipes, ditches, channels, sewers, tunnels, wells, containers of various types, concentrated animal-feeding operations, or floating craft. Also referred to as *Point Source of Pollution*. Also see *Non-Point Source (NPS) Pollution*.

Pore Pressure — Pressure exerted by fluid in the void space of soil or rock; the interstitial (pore) movement of water that may take place through a dam, its foundation, or its abutments.

Pore Space — That portion of rock or soil not occupied by solid mineral matter and which may be occupied by ground water.

Porosity — Most generally, porosity is the property of containing openings or interstices. In rock or soil, it is the ratio (usually expressed as a percentage) of the volume of openings in the material to the bulk volume of the material. With respect to water, porosity is a measure of the water-bearing capacity of a formation. However, with respect to water extraction and movement, it is not just the total magnitude of porosity that is important, but the size of the voids and the extent to which they are interconnected, as the pores in a formation may be open, or interconnected, or closed and isolated. For example, clay may have a very high porosity with respect to potential water content, but it constitutes a poor medium as an aquifer. More important in this respect are a formation's *Effective Porosity* (defined below) and its *Specific Retention*.

Porosity, Effective — The amount of interconnected pore space in a material available for fluid transmission; expressed as a percentage of the total volume occupied by the interconnecting interstices. Porosity may be primary, formed during deposition or cementation of the material, or secondary, formed after deposition or cementation, such as fractures.

Porous — A condition which allows liquids to pass through.

Postprocessing - using computer programs to analyze, display and store results of model simulations.

Potential — (1) (Hydrology and Hydraulics) Any of several scalar variables, each involving energy as a function of position or condition; of relevance here is the fluid potential of ground water. (2) (Water Quality) A water quality issue or problem identified by a river authority as being a potential problem, or a problem without current supporting data.

Potential Drop — Difference in total head between two *Equipotential Lines*.

Potential Evapotranspiration — (1) The maximum quantity of water capable of being evaporated from the soil and transpired from the vegetation of a specified region in a given time interval under existing climatic conditions, expressed as depth of water. (2) The water loss that will occur if at not time there is a deficiency of water in the soil for use by vegetation.

Potential Yield (or Well Capacity) — The maximum rate at which a well will yield water under a stipulated set of conditions, such as a given drawdown, pump, and motor or engine size. Well capacity may be expressed in terms of gallons per minute, cubic feet per second, or other similar units.

Potentiometric Surface — A surface which represents the static head of ground water in tightly cased wells that tap a water-bearing rock unit (i.e., aquifer). In relation to an aquifer, the potentiometric surface is defined by the levels to which water will rise in tightly cased wells. If the head varies significantly with depth in the aquifer, then there may be more than one potentiometric surface. The *Water Table* is a particular potentiometric surface for an *Unconfined Aquifer*. This term has generally replaced the term *Piezometric Surface*.

Precipitant — An agent added to a liquid mixture to encourage the formation of solid materials that will settle from the mixture. For example, alum (aluminum sulfate) is added to sewage to promote the formation of *Floc*, which facilitates the removal of organic materials from the wastewater.

Precipitate — A solid which forms from a liquid suspension as a result of a chemical reaction. The material (floc) is insoluble in water and will settle out over time.

Preprocessing - using computer programs to assist in preparing data sets for use with generic simulation codes; may include grid generation, parameter allocation, control parameter selection, and data file formatting.

Pressure Head — The relative pressure (excess over atmospheric pressure) divided by the unit weight of water; expressed in units of height.

Primacy — (1) Term used to denote that individual states have been delegated the authority to implement the requirements, as prescribed by the *U.S. Environmental Protection Agency (EPA)*, of the *Safe Drinking Water Act (SDWA)* and amendments thereto. (2) Primary enforcement responsibility for administration and enforcement of the primary drinking water regulations and related requirements applicable to public water systems within a state.

Primary Drinking Water Standards — Enforceable standards related directly to the safety of drinking water; set by the U.S. Environmental Protection Agency (EPA).

Primary Standards — (Water Quality) Standards set by the *U.S. Environmental Protection Agency (EPA)* for the maximum amount of pollutants that can be present in air and water without adverse health effects on humans. The primary standards for drinking water are set for 20 materials, ranging from arsenic to fluoride and from pesticides to radionuclides. Compare to *Secondary Standards*.

Farmland, Prime — As defined in the *Farmland Protection Policy Act of 1981*: Land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops, and is available for these uses (urban areas are not included). It has the soil quality, growing season, and moisture supply needed for the economic production of sustained high yields of crops when treated and managed (including water management) according to acceptable farming methods. Prime farmland includes land that is being used currently to produce livestock and timber, but it excludes land committed to urban development or water storage.

Principal Spillway — Allows discharge of water from a reservoir when the water level exceeds the top of the spillway. Principal spillways are used to allow small inflows to be released from the reservoir. Also see *Spillway*.

Propylitic — (Geology) A type of *Hydrothermal* alteration characterized by the formation of calcite, chlorite, epidote, serpentine, quartz, pyrite, and iron oxides.

Provenance — For sediment, the source area or source bedrock or source sediment.

Public Law 92–500 (PL 92–500) — The *Water Pollution Control Act* of 1972 which set goals and timetables for attaining water quality standards. See *Water Pollution Control Act*.

Public Law 93–523 (PL 93–523) — The *Safe Drinking Water Act (SDWA)* of 1974 which established primary and secondary quality standards for drinking water. See *Safe Drinking Water Act (SDWA)*.

Public Scoping — The process of soliciting public comments on the issues to be examined in environmental documents such as an *Environmental Impact Statement (EIS)* or water planning documents. The process can be carried out by public meetings, soliciting written comments, or both. The identification of issues, alternatives, impacts, mitigation and/or monitoring all may be addressed during the scoping process.

Pump — A device which moves, compresses, or alters the pressure of a fluid, such as water or air, being conveyed through a natural or artificial channel.

Pumping Test — A test that is conducted to determine aquifer or well characteristics. More specifically, a test made by pumping a well for a period of time and observing the change in *Hydraulic Head* in the aquifer. A pump test may be used to determine the capacity of the well and the hydraulic characteristics of the aquifer. Also referred to as *Aquifer Test*.

Purge — To force a gas through a water sample to liberate volatile chemicals or other gases from the water so their level can be measured.

-Q-

Qualitative Analysis — (Data Analysis) The examination or analysis of a phenomenon to determine its qualitative characteristics versus its quantitative characteristics, i.e., characteristics for which precise numerical identification are not appropriate. Also see *Quantitative Analysis*.

Quantitative Analysis — (Data Analysis) The examination of phenomena using actual observed data with an intention to explain historical behavior and/or predict the future behavior of some phenomenon. Also see *Qualitative Analysis*.

Quartz — (Geology) The most common rock-forming mineral. It is made up of silicon dioxide (SiO2). Quartz crystals may be glassy or opaque (milky quartz) and exist in a variety of colors including white, rose, smoky gray, and purple.

Quartzite — (Geology) A hard *Metamorphic Rock* made up of interlocking quartz grains that have been cemented by silica.

Quaternary Period — (Geology) A period consisting of approximately the last 2 million years of earth history, encompassing both the *Pleistocene* and the *Holocene* epochs.

Quicklime — Another term for lime, or calcium oxide (CaO), used in many water and wastewater treatment operations such as softening, coagulation, and phosphorus removal.

-R-

Radial Drainage — An arrangement of stream courses in which the streams radiate outward in all directions from a central zone or inward from all directions to a central area.

Radial Flow — The flow of water in an aquifer toward a vertically oriented well.

Radioisotope — Isotopic forms of an element that exhibit radioactivity. Isotopes are varieties of a chemical element that differ in atomic weight, but are very nearly alike in chemical properties. The difference arises because the atoms of the isotopic forms of an element differ in the number of neutrons in the nucleus. For example, ordinary chlorine is a mixture of isotopes having atomic weights of 35 and 37, and the natural mixture has an atomic weight of about 35.543. Many of the elements similarly exist as mixtures of isotopes, and a great many new isotopes have been produced in the operation of nuclear devices such as the cyclotron. There are 275 isotopes of the 81 stable elements, in addition to more than 800 radioactive isotopes.

Radionuclides — Radioactive chemicals that are usually naturally occurring and found in drinking water. Typical radionuclides for which the *U.S. Environmental Protection Agency (EPA)* has established *Maximum Contaminant Levels (MCLs)* as part of its enforcement of the *Safe Drinking Water Act (SDWA)* include radium 226 and 228, gross alpha particle activity, and beta particle activity.

Radius of Influence — The radial distance from the center of a well bore to the point where there is no lowering of the water table or *Potentiometric Surface* (the edge of its *Cone of Depression*).

Radon — A radioactive element, chemical symbol Rn, atomic number 86, and atomic weight 222 (Radon–222). Radon is a colorless, tasteless, odorless, naturally-occurring inert gas derived from the natural breakdown (i.e., radioactive decay) of three radioactive isotopes: uranium–238, uranium–235, and thorium–232. These isotopes are typically found in igneous and metamorphic rocks, such as granite and gneiss, and in sedimentary rocks such as organic-rich black shale, phosphatic rock, and coal. Uranium–238 is the most common parent of radon gas because it comprises more than 99 percent of uranium and thorium isotopes found on earth. Radon–222, one of the most common radioactive daughter elements of uranium–238 decay has a relatively short half-life of only 3.8 days. Consequently, radon–222 is relatively unstable and more likely to decay and emit radiation at any particular moment. Daughter isotopes of radon–222 have an even shorter half-life, resulting in a cascade or "burst" of radiation from radon and its daughter products. Radon occurs in ground water, but not in surface water due to its high volatility. In ground water, radon will stay in solution until the pressure on the ground water is decreased. Due to its short half-life and the slow rate of natural ground water flow, radon in ground water typically cannot migrate far from its source. Radon is relatively easy to remove from water; several effective options for the treatment of radon in water include storage, adsorption on *Granular Activated Carbon (GAC)*, and aeration. It has been proposed that radon provides about one-half of the radiation to which the average American is exposed. The chemically inert gas enters homes through soil, water, and building materials. The threat is not uniformly distributed across the United States. An important source of personal exposure to radon appears to be drinking water obtained from wells. The threat comes from the inhalation of the gas released from water during showering, bathing, cooking, and other water uses. Ingestion of water does not appear to present a threat.

Rain — (1) The liquid form of precipitation. (2) Water falling to earth in drops that have been condensed from moisture in the atmosphere. Generally larger than 0.02 inches (0.05 cm) in diameter and which fall in still air at velocities usually greater than 10 feet (3.0 meters) per second.

Rapid Drawdown — Lowering the elevation of water against a bank faster than the bank can drain, leaving a pressure imbalance that may cause the bank to fail.

Ravine — (1) A deep, narrow valley or gorge in the earth's surface worn by running water. (2) A small narrow steep-sided valley that is larger than a gully and smaller than a canyon and that is usually worn by running water.

Reach (of River) — (1) Most generally, any specified length of a stream, channel, or conveyance. (2) A length of channel which is uniform in its discharge depth, area, and slope; a relatively homogeneous length of stream having a similar sequence of characteristics. (3) A length of channel for which a single gage affords a satisfactory measure of the stage and discharge. (4) The length of a river between two gaging stations.

Reaction Path Modeling - a simulation approach to studying the chemical evolution of a (natural) system.

Readily Water-Soluble Substances — In water pollution, chemicals that are soluble in water at a concentration equal to or greater than one milligram per liter (mg/l).

Reaeration — (1) Absorption of oxygen into water from the atmosphere. The rate of reaeration is proportional to the oxygen deficit. (2) Introduction of air into the lower layers of a reservoir. As the air bubbles form and rise through the water, the oxygen 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 more oxygen from the atmosphere.

Reaeration (of Streams) — The natural process by which flowing stream water is mixed with the atmosphere, resulting in the addition of *Dissolved Oxygen* to the water.

Reasonable Pump Lift — A determination of the rate and volume of water to be pumped from an aquifer. The reasonable pump lift (rate of withdrawal) would include consideration of:

[1] water quality in the aquifer or the basin, including sea water intrusion, base of fresh water, and lateral or vertical migration of contaminants;
[2] the ground water management program;
[3] the thickness of the aquifer;
[4] the depth of existing wells;
[5] the capital cost of new wells;
[6] the net cash flow; and
[7] the total amount of ground water that can be extracted during one water year by the total number of existing wells.

Recarbonation (Recarbonization) — (Water Quality) The process of introducing carbon dioxide as a final stage in the lime-soda ash softening process. This lowers the pH and converts carbonates to bicarbonates, thereby stabilizing the solution against precipitates of carbonates.

Receiving Waters — (1) Rivers, lakes, oceans, or other water courses or bodies of water that receive waters from another source. (2) (Water Quality) Bodies of water that receive treated or untreated effluent discharges.

Recessional Moraine — *Glacial Till* occurring as ridges where the front of a retreating glacier temporarily held a fixed position. Also see *Moraines*, *Lateral Moraines*, and *Terminal Moraines*.

Recession Hydrograph (Curve) — A *Hydrograph* which shows the decreasing rate of runoff following a period of rain or snowmelt. Since *Direct Runoff* and *Base Runoff* recede at different rates, separate curves, called direct runoff recession curves, are generally drawn. Use of the term *Depletion Curve* in the sense of base runoff recession is not recommended.

Recharge (Hydrologic) — (1) The downward movement of water through soil to ground water. (2) The process by which water is added to the *Zone of Saturation*. (3) The introduction of surface or ground water to ground water storage such as an aquifer. Recharge or replenishment of ground water supplies consists of three (3) types:

[1] ***Natural Recharge*** which consists of precipitation or other natural surface flows making their way into ground water supplies;
[2] ***Artificial or Induced Recharge*** which includes actions by man specifically designed to increase supplies in a ground water reservoirs through various methods such as water spreading

(flooding), ditches, and pumping techniques; and

[3] ***Incidental Recharge*** which consists of actions, such as irrigation and water diversion, which add to ground water supplies but are intended for other purposes. Recharge may also refer to the amount of water so added.

Recharge Area (Ground water) — (1) The land area over which precipitation infiltrates into soil and percolates downward to replenish an aquifer. (2) The area in which water reaches the *Zone of Saturation* by surface infiltration. Infiltration moves downward into the deeper parts of an aquifer in a recharge area. Also referred to as a *Recharge Zone*.

Recharge, Artificial — The designed (as opposed to the natural or incidental) replenishment of ground water storage from surface water supplies. There exist five (5) common techniques to effect artificial recharge of a ground water basin:

[1] ***Water Spreading*** consisting of the basin method, stream-channel method, ditch method, and flooding method, all of which tend to divert surface water supplies to effect underground infiltration;

[2] ***Recharge Pits*** designed to take advantage of permeable soil or rock formations;

[3] ***Recharge Wells*** which work directly opposite of pumping wells although have limited scope and are better used for deep, confined aquifers;

[4] ***Induced Recharge*** which results from pumping wells near surface supplies thereby inducing higher discharge towards the well; and

[5] ***Wastewater Disposal*** which includes the use of secondary treatment wastewater in combination with spreading techniques, recharge pits, and recharge wells to reintroduce the water to deep aquifers thereby both increasing the available ground water supply and also further improving the quality of the wastewater.

Recharge Basin — A surface facility, often a large pond, used to increase the infiltration of surface water into a ground water basin.

Recharge Boundary — An aquifer system boundary that adds water to the aquifer. Streams and lakes are typical recharge boundaries.

Recharge, Incidental — Ground water recharge (infiltration) that occurs as a result of human activities unrelated to a recharge project, for example, irrigation and water diversion (unlined canals). Also see *Artificial* (or *Induced*) *Recharge*, *Natural Recharge*, and *Perennial Yield*.

Recharge, Natural — The replenishment of ground water storage from naturally-occurring surface water supplies such as precipitation and stream flows. Also see *Artificial* (or *Induced*) *Recharge*, *Incidental Recharge*, and *Perennial Yield*.

Recharge Rate — The quantity of water per unit of time that replenishes or refills an aquifer.

Recharge Well — Used in conjunction with artificial or induced ground water recharge techniques, the recharge well works directly opposite of pumping wells to induce surface water into the ground water system. Based on the nature of the soil and rock being recharged, the use of recharge wells typically have limited scope and are better employed for recharging deep, confined aquifers. Also see *Injection*.

Recharge Zone — A land area into which water can infiltrate into an *Aquifer* relatively easily. The infiltration replenishes the aquifer. The location is also referred to as a *Recharge Area*.

Reclamation — (1) The process of land treatment that minimizes water degradation, air pollution, damage to aquatic or wildlife habitat, flooding, erosion, and other adverse effects from surface mining operations including adverse surface effects incidental to underground mines, so that mine lands are reclaimed to a usable condition which is readily adaptable for alternate land uses and creates no danger to public health or safety. The process may extend to affected land surrounding mining lands, and may require backfilling, grading, resoiling, revegetation, soil compaction, stabilization, and other measures. (2) May also apply to other land uses and land types, for example, the reclaiming of waste, desert, marshy or submerged land for cultivation, preservation, reuse, etc.

Recommended Maximum Contaminant Level (RMCL) — The maximum level of a contaminant in drinking water at which no known or anticipated adverse affect on human health would occur, and that includes an adequate margin of safety. Recommended levels are nonenforceable health goals. Also see *Maximum Contaminant Level (MCL)*.

Recorder, Steam Flow — A mechanical apparatus which records a continuous record of a water level or other hydrologic factors such as water temperature, flow rates, etc.

Recording Gage — A *Gage* which provides a continuous recording of the parameter being monitored. For example, see *Stream Gaging*.

Recoverable Ground Water — The amount of water which may be physically and economically withdrawn from the ground water reservoir.

Recovery — The process by which the decline of an endangered or threatened species is arrested or reversed, and threats to its survival are neutralized, so that its long-term survival in nature can be ensured.

Reference Wetland — A wetland within a relatively homogeneous biogeographic region that is representative of a specific hydrogeomorphic wetland type.

Regime — "Regime theory" is a theory of the formation of channels in material carried by the stream. Used in this sense, the word "regime" applies only to streams that take at least part of their boundaries from their transported load and part of their transported load from their boundaries, carrying out the process at different places and times in any one stream in a balanced or alternating manner that prevents unlimited growth or removal of boundaries. A stream, river, or canal of this type is called a "regime stream, river, or canal." A regime channel is said to be "in regime" when it has achieved average equilibrium; that is, the average values of the quantities that constitute regime do not show a definite trend over a considerable period, generally, approximately a decade. In unspecialized use, "regime" and "regimen" are synonymous.

Regimen of a Stream — The system or order characteristic of a stream, i.e., its habits with respect to velocity and volume, form and changes in channel, capacity to transport sediment, and amount of material supplied for transportation. The term is also applied to a stream which has reached an equilibrium between corrosion and deposition or, in other words, to a graded stream.

Regulatory Floodplain — (1) That portion of the floodplain subject to floodplain regulations (usually the floodplain inundated by the one-percent chance flood). (2) Flood hazard area within which a community regulates development, including new construction, the repair of substantially damaged buildings, and substantial improvements to existing buildings. In communities participating in the *National Flood Insurance Program (NFIP)*, the regulatory floodplain must include at least the area inundated by the *Base Flood*, also referred to as the *Special Flood Hazard Area (SFHA)*.

Regulatory Floodway — (1) The channel and that portion of the adjacent land area that is required through regulations to pass flood flows without increasing the water surface elevation more than a designated hight. (2) As adopted into a community's floodplain management ordinance, is defined by the *Federal Emergency Management Agency (FEMA)* as the stream channel plus that portion of the overbanks that must be kept free from encroachment in order to discharge the 1-percent annual chance flood without increasing flood levels by more than 1 foot (some states specify a smaller allowable increase). The intention of the floodway is not to preclude development. Rather, it is intended to assist communities in prudently and soundly managing floodplain development and prevent additional damages to other property owners. The community is responsible for prohibiting encroachments, including fill, new construction, and substantial improvements, within the floodway unless it has been demonstrated through hydrologic and hydraulic analyses that the proposed encroachment will not increase flood levels within the community. In areas that fall within the 1-percent annual chance floodplain, but are outside the floodway (termed the floodway fringe), development will, by definition, cause no more than a 1-foot increase in the 1-percent annual chance water-surface elevation. Floodplain management through the use of the floodway concept is effective because it allows communities to develop in flood-prone areas if they so choose, but limits the future increases of flood hazards to no more than 1 foot.

Remediation — (Environmental) Cleanup or other methods used to remove or contain a toxic spill or hazardous materials from a Superfund site.

Remnant — A remaining part of some larger landform or of a land surface that has been dissected or partially buried.

Remote Sensing — The measurement or acquisition of information of some property of an object or phenomenon by a recording device that is not in physical or intimate contact with the object or phenomenon under study. Also, the utilization at a distance (as from aircraft, spacecraft, satellites, or ships) of any device and its attendant display for gathering information pertinent to the environment, such as measurements of force fields, electromagnetic radiation, infrared sensing, land use, water bodies, etc. Such systems typically employ devices such as cameras, lasers, radio frequency receivers, radar systems, infrared detectors, sonar seismographs, gravimeters, magnetometers, and scintillation counters.

Replenishment — The act of replenishing an aquifer, usually through artificial recharge, to offset excess ground water pumping.

Residual - the difference between the model-computed and field-measured values of a variable, such as hydraulic head or ground water flow rate, at a specific time and location.

Retardation Factor - is used to simulate the resistance of the contamination to move through the ground water aquifer. A factor of one (1) represents the least resistance while increasing values show increasing resistance.

Retention — That part of the precipitation falling on a drainage area that does not escape as a surface streamflow, during a given period.

Retention Basin — A permanent lake or pond used to slow stormwater runoff. Also see *Detention Basin*.

Retention Storage — Water retained in the capillary pores of the soil, not free to move by gravity, and in large part available to plants.

Retention Time — The interval of time that some waste, fluid or other material is in a treatment facility or process unit.

Return Flow — (1) The amount of water that reaches a ground or surface water source after release from the point of use and thus becomes available for further use. (2) That part of a diverted flow which is not consumptively used and returns to its original source or another body of water. (3) (Irrigation) Drainage water from irrigated farmlands that re-enters the water system to be used further downstream. Such waters may contain dissolved salts or other materials that have been leached out of the upper layers of the soil.

Reverse Osmosis — (1) (Desalination) Refers to the process of removing salts from water using a membrane. With reverse osmosis, the product water passes through a fine membrane that the salts are unable to pass through, while the salt waste (brine) is removed and disposed. This process differs from electrodialysis, where the salts are extracted from the feedwater by using a membrane with an electrical current to separate the ions. The positive ions go through one membrane, while the negative ions flow through a different membrane, leaving the end product of freshwater. (2) (Water Quality) An advanced method of water or wastewater treatment that relies on a *Semipermeable Membrane* to separate waters from pollutants. An external force is used to reverse the normal osmotic process resulting in the solvent moving from a solution of higher concentration to one of lower concentration.

Revetment — (1) A facing of stone, bags, blocks, pavement, concrete, or sandbags, or other materials, used to protect a bank of earth from erosion. (2) A retaining wall. (3) A structure built along the coast to prevent erosion and other damage by wave action; similar to a sea wall.

Reynolds Number [Re or 1] — A dimensionless number used as an index of fluid flow characteristics in a pipe, duct, or around an obstacle. The expression for fluid flow in a pipe or duct is equal to:

$$U = (V \text{ x } d \text{ x } \tilde{n})/\mu$$

where: V is the fluid velocity; d is the pipe or duct diameter; $\tilde{n}$ is the fluid density; and μ is the fluid dynamic viscosity.

For fluid flow around a particle it takes the form:

$$U = (dp \text{ x } vr \text{ x } \tilde{n})/\mu$$

where: dp is the particle diameter; vr is the velocity of the particle relative to the fluid; $\tilde{n}$ is the fluid density; and μ is the fluid viscosity.

For fluid flow in a pipe or duct, a Reynolds number below about 2,100 is considered to be streamline, smooth, or *Laminar Flow*; above 4,000 the flow is turbulent; 2,100–4,000 is a transition zone. For the flow of fluid around a particle, a Reynolds number less than 1.0 is considered laminar flow and as the value increases above 1.0 turbulence increases. The difference between the conditions for laminar flow around particles and in pipes is explained by the impact of inertial forces as the fluid flows around a particle compared to the straight flow in a pipe or duct.

Ridge Lines — Points of higher ground that separate two adjacent streams or *Watersheds*. Also referred to as *Divides*.

Ridgeline Remnant — A narrow ridge with a fully rounded crest that is accordant with the crests of similar nearby ridges. Together these accordant crests approximately mark the position of a preexisting land surface that has been destroyed by dissection.

Riffle — (1) A shallow rapids, usually located at the corssover in a meander of the active channel. (2) Shallow rapids in an open stream, where the water surface is broken into waves by obstructions such as shoals or sandbars wholly or partly submerged beneath the water surface. (3) Also, a stretch of choppy water caused by such a shoal or sandbar; a rapid; a shallow part of the stream.

Rift — A shallow or rocky place in a stream, forming either a ford or a rapid.

"Right of Free Capture" — The idea or concept that the water under a person's land belongs to that person and they are free to capture and use as much as they want. Also called the "law of the biggest pump." Does not apply where both surface water and ground water are regulated. Also referred to as the "Right of Capture."

Rill, also Rille — (1) A small brook; a rivulet. Also small, water-formed ridges that generally may be smoothed by normal tilling methods. (2) A small, intermittent watercourse with steep sides; usually only several centimeters deep; caused by waterborne soil erosion.

Rill Erosion — (1) Removal of soil by running water with formation of shallow channels that can be smoothed out completely by normal tillage. (2) Removal of soil particles from a bank slope by surface runoff moving through relatively small channels. The water collecting from these small channels may then concentrate into a larger channel downhill to form the start of a gully.

Rime — (1) A coating of ice, as on grass and trees, formed when extremely cold water droplets freeze almost instantly on a cold surface. (2) A white frost of congealed dew or vapor. An accumulation of granular ice tufts on the windward sides of exposed objects, particularly on grass and trees, slightly resembling *Hoarfrost*, but formed only from undercooled fog or cloud and always built out directly against the wind.

Riparian — Pertaining to the banks of a river, stream, waterway, or other, typically, flowing body of water as well as to plant and animal communities along such bodies of water. This term is also commonly used for other bodies of water, e.g., ponds, lakes, etc., although *Littoral* is the more precise term for such stationary bodies of water. Also refers to the legal doctrine (*Riparian Doctrine* and *Riparian Water Rights*) that says a property owner along the banks of a surface water body has the primary right to withdraw water for reasonable use. Also see *Riverine*.

Riparian Areas (Habitat) — (1) Land areas directly influenced by a body of water. Usually such areas have visible vegetation or physical characteristics showing this water influence. Stream sides, lake borders, and marshes are typical riparian areas. Generally refers to such areas along flowing bodies of water. The term *Littoral* is generally used to denote such areas along non-flowing bodies of water. (2) (USFWS) Plant communities contiguous to and affected by surface and subsurface hydrologic features of perennial or intermittent *Lotic* and *Lentic* water bodies (rivers, streams, lakes, or drainage ways). Riparian areas have one or both of the following characteristics: (a) distinctively different vegetative species than adjacent areas, and (b) species similar to adjacent areas but exhibiting more vigorous or robust growth forms. Riparian areas are usually transitional between *Wetlands* and *Uplands*.

Riparian Ecosystem — A transitional ecosystem located between aquatic (usually *Riverine*) and terrestrial (upland) environments. Riparian ecosystems are identified by distinctive soil characteristics and vegetation communities that require free water.

Riparian Habitat — Areas adjacent to rivers and streams with a high density, diversity, and productivity of plant and animal species relative to nearby uplands.

Riparian Land — (1) Land situated along the bank of a stream or other, generally flowing bodies of water. (2) Land so situation with respect to a body of water that, because of such location, the possessor of the land is entitled to the benefits incident to the use of the water.

Riparian Rights — (1) Water rights based on the ownership of land bordering a river or waterway. (2) A concept of water law under which authorization to use water in a stream is based on ownership of the land adjacent to the stream and is normally not lost if not used. (3) The rights of the owners of lands on the banks of watercourses, relating to the water, its use, ownership of soil under the stream, accretion, etc. The term is generally defined as the right which every person through whose land a natural watercourse runs has to the benefit of the stream as it passes through his land for all useful purposes to which it may be applied. Such rights include those such as hunting, fishing, boating, sailing, irrigating, and growing and harvesting wild rice, which rights extend over lakes and wetlands. See *Riparian Doctrine*. Also see *Riparian Water Rights*.

Riparian Vegetation — Plants adapted to moist growing conditions found along waterways and shorelines. They are frequently important to wildlife habitat because of their greater density and succulence.

Riparian Water — Water which is below the highest line of normal flow of the river or stream, as distinguished from flood water.

Riparian Zone — (1) Areas adjacent to a stream that are saturated by ground water or intermittently inundated by surface water at a frequency and duration sufficient to support the prevalence of vegetation typically adapted for life in saturated soil. (2) The transition area between the aquatic ecosystem and the nearby, upland terrestrial ecosystem. Zones are identified by soil characteristics and/or plant communities and include the wet areas in and near streams, ponds, lakes, springs and other surface waters. Also see *Riparian Areas*.

Rip Rap (also Riprap) — A facing layer (protective cover) of stones placed to prevent erosion or the sloughing off of a structure or embankment. A layer of man-made hard, durable material for bank protection and stabilization usually consisting of rock or stone. On steeper inclines, the stones may be secured with wire on some form of link fencing material. Also, a layer of large stones, broken rock, or precast blocks placed in random fashion on the upstream slope of an *Embankment Dam*, on a reservoir shore, or on the sides of a channel as a protection against waves, ice action, and flowing water. Very large rip rap is sometimes referred to as *Armoring*.

Ripple — (1) To form or display little undulations or waves on the surface, as disturbed water does. (2) To flow with such undulations or waves on the surface.

Ripple Mark — One of a series of small ridges produced especially on sand by the action of wind, a current of water, or waves.

Riser — A vertical pipe as for water.

Rising Limb — The increasing portion of the storm *Hydrograph*. Contrast to *Falling Limb*.

River — A natural stream of water of considerable volume, larger than a brook or creek. A river has its stages of development, youth, maturity, and old age. In its earliest stages a river system drains its basin imperfectly; as valleys are deepened, the drainage becomes more perfect, so that in maturity the total drainage area is large and the rate of erosion high. The final stage is reached when wide flats have developed and the bordering lands have been brought low.

River Banks — (1) The boundaries which confine the water to its channel throughout the entire width when the stream is carrying its maximum quantity of water. (2) The portion of the channel cross section that restricts lateral movement of water at normal discharges. Banks often have a gradient steeper than 45 degrees and exhibit a distinct break in slope from the stream bed.

River Basin — (1) A term used to designate the area drained by a river and its tributaries. (2) The are from which water drains to a single point; in a natural basin, the drainage area contributing flow to a given point on a stream.

River Channels — Natural or artificial open conduits which continuously or periodically contain moving water, or which forms a connection between two bodies of water.

Riverine — (1) Relating to, formed by, or resembling a river including tributaries, streams, brooks, etc. (2) Pertaining to or formed by a river; situated or living along the banks of a river, for example, a "riverine ore deposit." Also see *Riparian*.

Riverine (Systems) — Open-water habitats. Typically include all open water areas that occur within a defined channel of a stream as well as along perennial and intermittent stretches of streams and along some major dry washes. In some cases, riverine systems are bounded by *Palustrine Wetlands* that develop in the floodplain on either side of the defined channel. The riverine system and the adjacent palustrine wetlands are often referred to as *Riparian Habitat*. Also see *Wetlands* and *Wetlands, Paulustrine*. [See Appendix D–2 for an explanation of the Wetland and Deepwater Habitat Classification System and more detailed information on these Systems.]

River Reach — Any defined length of a river.

Rivers, Classifications — Classifications of waterways included in the *National Wild and Scenic Rivers System* are as follows:

[1] ***Recreational Rivers*** — Rivers or sections of rivers that are readily accessible by road or railroad, that may have some development along their shoreline, and that may have undergone some impoundment or diversion in the past.

[2] ***Scenic Rivers*** — Rivers or sections of rivers that are free of impoundments, with shorelines or watersheds still largely primitive, and shorelines largely undeveloped but accessible in places by roads.

[3] ***Wild Rivers*** — Rivers or sections of rivers that are free of impoundments and generally inaccessible
except by trail, with watersheds or shorelines essentially primitive and waters unpolluted.

River Stage — The elevation of the water surface at a specified station above some arbitrary zero datum (level).

Riverwash — Barren alluvial land, usually coarse-textured, exposed along streams at low water, and subject to shifting during normal high water.

Rivulet — A small stream or brook; a streamlet.

Roche Moutonnée — An elongated mound of bedrock worn smooth and rounded by glacial abrasion.

Rock Flour — Finely ground rock particles produced by glacial abrasion. Also referred to as *Glacier Meal*.

Roil — To make a liquid cloudy, muddy, or unsettled by stirring up the sediment.

Roily — Water of a liquid that is turbid, muddy, agitated or disturbed.

Roughness — A term used by hydraulic engineers and hydrologists designating a measurement or estimate of the resistance that streambed materials, vegetation, and other physical components contribute to the flow of water in the stream channel and floodplain. It is commonly measured as the Manning's roughness coefficient.

Roughness Coefficient — (Hydraulics) A factor in velocity and discharge formulas representing the effect of channel roughness on energy losses in flowing water.

Routing (Hydraulics) — (1) The derivation of an outflow *Hydrograph* of a stream from known values of upstream inflow, using the wave velocity and/or the storage equation. (2) A technique used to compute the effect of channel storage and translation on the shape and movement of a flood wave through a river reach.

Rugosity — A term used to indicate the degree of roughness of a test-well caused by drilling and subsequent washouts. In some wells, rugosity is caused by the intersection of fractures with the test well and may be an indication of secondary *Porosity* development and possible zones of increased *Transmissivity*.

Run — (1) To flow, especially in a steady stream. (2) A pipe or channel through which something, i.e., water, flows. (3) A fall or slide, as of sand or mud. (4) The migration of fish, especially in order to spawn; a group or school of fish ascending a river in order to spawn, i.e., the seasonal upstream migration of *Anadromous* fish. (5) (Irrigation) The distance of gravity flow from the point of release to the end of the area to be watered. (6) (Nautical) To sail or steer before the wind or on an indicated course. (7) (Geology) A vein or seam, as of ore or rock.

Runnel — (1) A rivulet; a brook. (2) A narrow channel or course, as for water.

Runoff — (1) That portion of precipitation that moves from the land to surface water bodies. (2) That portion of precipitation which is not intercepted by vegetation, absorbed by the land surface or evaporated, and thus flows overland into a depression, stream lake or ocean (runoff called "immediate subsurface runoff" also takes place in the upper layers of the soil). (3) That part of the precipitation, snow melt, or irrigation water that appears in uncontrolled surface streams, rivers, drains or sewers. It is the same as streamflow unaffected by artificial diversions, imports, storage, or other works of man in or on the stream channels. Runoff may be classified according to speed of appearance after rainfall or melting snow as direct runoff or base runoff, and according to source as surface runoff, storm interflow, or ground-water runoff. (4) The total discharge described in (1), above, during a specified period of time. (5) Also defined as the depth to which a drainage area would be covered if all of the runoff for a given period of time were uniformly distributed over it.

Meteorological Factors Affecting Runoff:

[1] Type of precipitation (rain, snow, sleet, etc.);
[2] Rainfall intensity;
[3] Rainfall amount;
[4] Rainfall duration;
[5] Distribution of rainfall over the drainage basin;
[6] Direction of storm movement;
[7] Antecedent precipitation and resulting soil moisture; and
[8] Other meteorological and climatic conditions which affect evapotranspiration such as temperature, wind, relative humidity, and season.

Physical Basic Characteristics Affecting Runoff:

[1] Land use;
[2] Vegetation;
[3] Soil type;

[4] Drainage area;
[5] Basin shape;
[6] Elevation;
[7] Slope;
[8] Topography;
[9] Direction of orientation;
[10] Drainage network patterns; and
[11] Ponds, lakes, reservoirs, sinks, etc. in the basin which prevent or alter runoff from continuing downstream.

Runoff Curve Number — A rainfall-runoff parameter commonly used in the U.S. Department of Agriculture, *Natural Resources Conservation Service (NRCS)*, formerly the *Soil Conservation Service (SCS)*, hydrologic procedures. The larger the runoff curve number, the greater the percentage of rainfall that will appear as runoff. The runoff curve number is a function of soil type, land use, and land management practices.

Runoff Cycle — That portion of the *Hydrologic Cycle* between incident precipitation over land areas and its subsequent discharge through stream channels or *Evapotranspiration*.

Runoff, Direct — The runoff entering stream channels most immediately after rainfall or snowmelt. It consists of surface runoff plus interflow and forms the bulk of the *Hydrograph* of a flood. Direct runoff plus *Base Runoff* compose the entire flood hydrograph.

Runoff, Ground Water — That part of the runoff which has passed into the ground, has become ground water, and has been discharged into a stream channel as spring or seepage water. Also referred to as *Base Runoff* or *Base Flow*.

Runoff, Surface — (1) That part of the runoff which travels over the soil surface to the nearest stream channel. (2) That part of the runoff of a drainage basin that has not passed beneath the surface since precipitation. Surface runoff is not the same as direct runoff.

Runs — An area of swiftly flowing water, without surface agitation or waves, which approximates uniform flow and in which the slope of the water surface is roughly parallel to the overall gradient of the stream reach.

-S-

Safe Drinking Water Act [SDWA] (Public Law 93–523) — An amendment to the *Public Health Service Act* which established primary and secondary quality standards for drinking water. The SDWA was passed in 1976 to protect public health by establishing uniform drinking water standards for the nation. In 1986 SDWA Amendments were passed that mandated the *U.S. Environmental Protection Agency (EPA)* to establish standards for 83 drinking water contaminants by 1992 and identify an additional 25 contaminants for regulation every 3 years thereafter.

Safe Yield — (1) The rate at which water can be withdrawn from supply, source, or an aquifer over a period of years without causing eventual depletion or contamination of the supply. (2) A rate of extraction that does not deplete the basin over time. (3) (Ground water) The amount of water that can be withdrawn from an aquifer without producing an undesired effect. (4) (Surface Water) The amount of water than can be withdrawn or released from a reservoir on an ongoing basis with an acceptably small risk of supply interruption (i.e., reducing the reservoir storage to zero.) More commonly referred to a

Perennial Yield and *Sustained Yield*. Generally consists of the rate of *Natural Recharge*, *Artificial* (or *Induced*) *Recharge*, and *Incidental Recharge*.

Saline/Poor Quality Aquifer — An aquifer containing water that is high in total dissolved solids, and is unacceptable for use as drinking water.

Saline Water — Water containing dissolved solids; generally referring to solid contents in excess of 1,000 parts per million (ppm) *Total Dissolved Solids (TDS)*. The *U.S. Geological Survey (USGS)* classifies the degree of salinity of these more mineralized bodies of water as follows:
[1] ***Slightly Saline*** — 1,000–3,000 ppm;
[2] ***Moderately Saline*** — 3,000–10,000 ppm;
[3] ***Very Saline*** — 10,000–35,000 ppm; and
[4] ***Brine*** — More than 35,000 ppm.

Salinity — (1) The concentration of dissolved salts in water or soil water. Salinity may be expressed in terms of a concentration or as an electrical conductivity. When describing salinity influenced by seawater, salinity often refers to the concentration of chlorides in the water. (2) The relative concentration of salts, usually sodium chloride, in a given water sample. It is usually expressed in terms of the number of parts per thousand (‰) or parts per million (ppm) of chloride (Cl). Although the measurement takes into account all of the dissolved salts, sodium chloride (NaCl) normally constitutes the primary salt being measured. Salinity can harm many plants, causing leaves to scorch and turn yellow and stunting plant growth. As a reference, the salinity of seawater is approximately 35‰ or 35,000 ppm. See *Salts* for comparative salt concentrations in water. Also see *Total Dissolved Solids*.

Salinity Intrusion — The movement of salt water into a body of fresh water. It can occur in either surface water or ground water bodies.

Salinization — The accumulation of salts in soil to the extent that plant growth is inhibited. This is a common problem when crops are irrigated in arid regions; much of the water evaporates and salts accumulated in the soil.

Salt — (1) Most generally, all the minerals dissolved in water. (2) A chemical class of ionic compounds formed by the combination of an acid and a base. Most salts are the result of a reaction between a metal and one or more nonmetals. See *Salts*, below.

Salt-Water Intrusion — The invasion of a body of fresh water by a body of salt water, due to its greater density. It can occur either in surface or ground-water bodies. The term is applied to the flooding of freshwater marshes by seawater, the migration of seawater up rivers and navigation channels, and the movement of seawater into freshwater aquifers along coastal regions.

Sand — Composed predominantly of coarse-grained mineral sediments with diameters larger than 0.074 mm (0.0029 inch) and smaller than 2 mm (0.079 inch) in diameter.

Sandbar — A ridge of sand built up by currents, especially in a river or in coastal waters.

Sandstone Aquifer — The type of aquifer supplying ground water to large parts of the United States upper Middle West, Appalachia, and Texas. The water-bearing formation is often contained by shale strata, and the water has high levels of iron and magnesium.

Sandy Soil — Soils that have comparatively large particles that are rounded rather than flattened. Compared to clay soils, sandy soils contain much more soil and air, drain well, and warm quickly. They also dry out quickly, which necessitates more frequent watering that washes out valuable nutrients. Also referred to as “light” soil.

Saturated — (1) Generally, filled to capacity; having absorbed all that can be taken up; soaked through with moisture. (2) (Hydrologic) A condition often used in reference to soils in which all voids or pore spaces between soil particles are filled with water. (3) (Chemistry) Describes a solution in its most concentrated state in which dissolved material can remain in solution under given conditions of temperature, pressure, etc.

Saturated Flow — The liquid flow of water in soils that occurs when the soil pores in the wettest part of the soil are completely filled with water and the direction of flow is from the wettest zone of higher potential to one of lower potential.

Saturated Soils — Soils that have absorbed, to the maximum extent possible, water from rainfall or snowmelt. Any further precipitation on saturated soils will result in surface runoff with down-gradient affects on flooding and erosion.

Saturated Thickness (Aquifer) — The thickness of the portion of the aquifer in which all pores, or voids, are filled with water. In a *Confined Aquifer*, this is generally the aquifer thickness. In an *Unconfined Aquifer*, this is the distance between the water table and the base of the aquifer.

Saturated Zone — (1) The part of a water bearing layer of rock or soil in which all spaces, large or small, are filled with water. (2) The zone in the earth’s crust, extending from the water table downward, in which all open pore spaces in the soil or rock are filled with water at greater than atmospheric pressure. A termed used synonymously with the *Zone of Saturation*. Also referred to as *Phreatic Zone*.

Saturation — The condition of a liquid when it has taken into solution the maximum possible quantity of a given substance at a given temperature and pressure.

Saturation Point — That point at which a soil or an aquifer will no longer absorb any amount of water without losing an equal amount.

Saturation, Zone of — The zone below the *Water Table* in which all pore spaces are filled with ground water. The water table is the top of the zone of saturation in an unconfined aquifer. Also referred to as the *Phreatic Zone*.

Scarify — In land *Restoration* activities, to stir the surface of the ground with an implement in preparation for replanting.

Scarp — (1) A line of cliffs produced by faulting or by erosion. The term is an abbreviated form of *Escarpment*, and the two terms commonly have the same meaning, although “scarp” is more often applied to cliffs formed by faulting. (2) A relatively steep and straight, cliff-like face or slope of considerable linear extent, breaking the general continuity of the land by separating level or gently sloping surfaces lying at different levels, as along the margin of a plateau, mesa, terrace, or bench.

Scenic Rivers — A classification under the national *Wild and Scenic Rivers Act* to include those rivers or sections of rivers that are free of impoundments, with shorelines or watersheds still largely primitive and shorelines largely undeveloped, but accessible in places by roads. The following represents restrictions applying to such designated rivers:

(1) ***Timber Production*** – A wide range of silvicultural practices could be allowed if such practices are carried on so that there is no substantial adverse effect on the river and its immediate environment. The river area should be maintained in its near natural environment.

Timber outside the boundary but within the visual scene area should be managed and harvested in a way that provides special emphasis on visual quality.

(2) ***Water Supply*** – All water supply dams and major diversions are prohibited.

(3) ***Hydroelectric Power*** – No development of hydroelectric power facilities would be allowed.

(4) ***Flood Control*** – Flood control dams and levees would be prohibited.

(5) ***Mining*** – Subject to regulations (i.e., 36 CFR 228) that the Secretaries of Agricultural and Interior may prescribe to protect the values of rivers included in the national system. New mining claims and mineral leases could be allowed and existing operations allowed to continue. However, mineral activity must be conducted in a way that minimizes surface disturbances, sedimentation and pollution, and visual impairment.

(6) ***Road Construction*** – Roads may occasionally bridge the river area and short stretches of conspicuous or longer stretches on inconspicuous and well screened roads or screened railroads could be allowed. Consideration will be given to the type of use for which roads are constructed and the type of use that will occur in the river area.

(7) ***Agriculture*** – A wider range of agricultural uses is permitted to the extent currently practices. Row crops are not considered as an intrusion of the 'largely primitive" nature of scenic corridors if there is not a substantial adverse effect on the natural-like appearance of the river area.

(8) ***Recreational Development*** – Larger scale public use facilities, such as moderate size campgrounds, public information centers, and administrative headquarters are allowed if such structures are screened from the river. Modest and unobtrusive marinas also can be allowed.

(9) ***Structures*** – Any concentrations of habitations are limited to relatively short reaches of the river corridor. New structures that would have a direct and adverse effect on river values would not be allowed.

(10) ***Utilities*** – New transmission lines, gas lines, water lines, etc., are discouraged. Where no reasonable alternative exists, additional or new facilities should be restricted to existing right-of-way. Where new rights-of-ways are indicated, the scenic, recreation, and fish and wildlife values must be evaluated in the selection of the site.

(11) ***Motorized Travel*** – Motorized travel on land or water may be permitted, prohibited or restricted to protect the river values. Also see *Wild and Scenic Rivers Act*, *Wild Rivers*, and *Recreational Rivers*.

Scour — (1) To clear, dig, or remove by or as if by a powerful current of water. (2) The erosive action of running water in streams, which excavates and carries away material from the bed and banks. Scour may occur in both earth and solid rock material. (3) The powerful and concentrating clearing and digging action of flowing air or water, especially the downward erosion by stream water in sweeping away mud and silt on the outside curve of a bend, or during time of flood. (4) A place in a stream bed swept (scoured) by running water, generally leaving a gravel bottom. (5) The process by which flood waters remove soil around objects that obstruct flow, such as the foundation walls of a house.

S–Curve — The mass curve corresponding to a *Unit Hydrograph* or a distribution graph.

(Well) Seal — (Hydraulics) The watertight seal established in the annular space between the outermost water well casing and the drill hole to prevent the inflow and movement of surface water or shallow ground water, or to prevent the outflow or movement of water under artesian pressures. The term also includes a *Sanitary Seal*.

Seasonal or Intermittent Streams — Streams which flow only at certain times of the year when it receives water from springs, rainfall, or from surface sources such as melting snow. Also see *Stream*.

Seasonal Wetlands — Wetland areas flooded or taking on the characteristics of a wetland only during specific periods of the year or seasons. Also see *Wetlands* and *Prairie Potholes*.

Secchi Depth — A relatively crude measurement of the turbidity (cloudiness) of surface water. The depth at which a *Secchi Disc (Disk)*, which is about 10–12 inches in diameter and on which is a black and white pattern, can no longer be seen.

Secchi Disc (Disk) — A circular plate, generally about 10–12 inches (25.4–30.5 cm) in diameter, used to measure the transparency or clarity of water by noting the greatest depth at which it can be visually detected. Its primary use is in the study of lakes. Also see *Secchi Depth*.

Secondary Drinking Water Regulations — Non-enforceable regulations applying to public water systems and specifying the maximum contamination levels that, in the judgement of the *U.S. Environmental Protection Agency (EPA)*, are required to protect the public welfare. These regulations apply to any contaminants that may adversely affect the odor or appearance of such water and consequently may cause people served by the system to discontinue its use. Term may be used synonymously with *Secondary Drinking Water Standards*.

Secondary Drinking Water Standards — Non-enforceable standards related to the aesthetic quality of drinking water such as those relating to taste and odor; generally set by the *U.S. Environmental Protection Agency (EPA)* or state water-quality enforcement agencies based on EPA guidance. Term may be used synonymously with *Secondary Drinking Water Regulations*.

Secondary Maximum Contaminant Level (SMCL) — The maximum concentration or level of certain water contaminants in public water supplies set by the *U.S. Environmental Protection Agency (EPA)* to protect the public welfare. The secondary levels are written to address aesthetic considerations such as taste, odor, and color or water, rather than health standards. Also see *Primary Drinking Water Standards*, *Maximum Contaminant Level (MCL)*, and *Maximum Contaminant Level Goal (MCLG)*.

Secondary Porosity — The porosity that results from fractures and solution channels.

Section 404 Permit — The *Wetland* dredge and fill permit issued under regulations written to conform to *Section 404* of the *Clean Water Act (CWA)*. The permit is actually granted by the *U.S. Army Crops of Engineers (COE)*.

Sediment — (1) Soil particles that have been transported from their natural location by wind or water action; particles of sand, soil, and minerals that are washed from the land and settle on the bottoms of wetlands and other aquatic habitats. (2) The soil material, both mineral and organic, that is in suspension, is being transported, or has been moved from its site of origin by erosion (by air, water, gravity, or ice) and has come to rest on the earth's surface. (3) Solid material that is transported by, suspended in, or deposited from water. It originates mostly from disintegrated rocks; it also includes chemical and biochemical precipitates and decomposed organic material, such as humus. The quantity, characteristics, and cause of the occurrence of sediment in streams are influenced by environmental factors. Some major factors are degree of slope, length of slope, soil characteristics, land usage, and quantity and intensity of precipitation. (4) In the singular, the word is usually applied to material in suspension in water or recently deposited from suspension. In the plural the word is applied to all kinds of deposits from the waters of streams, lakes, or seas, and in a more general sense to deposits of wind and ice. Such deposits that have been consolidated are generally called sedimentary rocks. (5) Fragmental or clastic mineral particles derived from soil, alluvial, and rock materials by processes of erosion, and transported by water, wind, ice, and gravity. A special kind of sediment is generated by precipitation of solids from solution (i.e., calcium carbonate, iron oxides). Excluded from the definition are vegetation, wood, bacterial and algal slimes, extraneous lightweight artificially made substances such as trash, plastics, flue ash, dyes, and semisolids.

Sediment Control — The control of movement of sediment on the land, in a stream or into a reservoir by means of manmade structures; such as debris dams, wing dams, or channelization; land management techniques, or natural processes.

Sediment Load — (1) The soil particles transported through a channel by stream flow. (2) The total sediment, including bedload plus suspended sediment load, is the sediment being moved by flowing water in a stream at a specified cross section.

Sediment Load, Total — Also referred to as the total load, a term that refers to the total sediment (bed load plus suspended-sediment load) that is in transport. The term needs to be qualified, however, such as "annual suspended-sediment load" or "sand-size suspended-sediment load," and so on. It is not synonymous with total sediment discharge.

Sediment Storage — The accumulation, in a reservoir, of sediment that would normally be carried downstream without the project.

Sedimentary Rock — (Geology) Rock formed of sediment, especially from mechanical, chemical, or organic processes, and specifically: (1) clastic rock, such as conglomerate, sandstone, and shale, formed of fragments of other rock transported from their sources and deposited in water; and (2) rocks formed by precipitation from solution, as rock salt and gypsum, or from secretions of organisms, such as most limestone. Many sedimentary rocks show distinct layering, which is the result of different types of sediment being deposited in succession. Also see *Igneous Rock* and *Metamorphic Rock*.

Sedimentation — (1) Strictly, the act or process of depositing sediment from suspension in water. Broadly, all the processes whereby particles of rock material are accumulated to form sedimentary deposits. Sedimentation, as commonly used, involves not only aqueous but also glacial, aeolian, and organic agents. (2) (Water Quality) Letting solids settle out of wastewater by gravity during treatment.

Sediments — Soil, sand, and minerals washed from the 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.

Seep — (1) To pass slowly through small openings or pores; ooze. (2) Ground water emerging on the face of a stream bank. (3) An area which slowly passes water out of the ground to the surface, or where water moves slowly from surface bodies to ground water bodies, as from canals and ditches into the underlying ground water table. (4) An area of minor ground water outflow onto the land surface or into a stream channel or other water body. Flows are usually too small to be a spring.

Seepage — (1) The passage of water or other fluid through a porpus medium, such as the passage of water through an earth embankment or masonry wall. (2) Ground water emerging on the face of a stream bank. (3) The slow movement of water through small cracks, pores, *Interstices*, etc., of a material into or out of a body of surface or subsurface water. (4) The *Interstitial* movement of water that may take place through a dam, its foundation, or its *Abutments*. (5) The loss of water by infiltration into the soil from a canal, ditches, laterals, watercourse, reservoir, storage facilities, or other body of water, or from a field. Seepage is generally expressed as flow volume per unit of time. During the process of priming (a field during initial irrigation), the loss is called *Absorption Loss*.

Seepage Face - a physical boundary segment of a ground water system along which ground water discharges and which is present when a water table surface ends at the downstream external boundary of a flow domain; along this boundary segment, of which the location of the upper end is a-priori unknown, water pressure equals atmospheric pressure and hydraulic head equals elevation head. Commonly referred to as "seeps" or "springs".

Seeps — Ground water/surface water connections caused by river or stream erosion into a near-surface aquifer.

Semi-Analytical Model - a mathematical model in which complex analytical solutions are evaluated using approximate techniques, resulting in a solution discrete in either the space or time domain.

Semiaquatic — Adapted for living or growing in or near water; not entirely aquatic.

Semiarid — A term applied to regions or climates where moisture is normally greater than under arid conditions but still definitely limits the growth of most crops. Dryland farming methods or irrigation generally are required for crop production. The upper limit of average annual precipitation in the cool semiarid regions is as low as 15 inches (38.1 cm). Whereas in tropical regions it is as high as 45 or 50 inches (114.3 or 127.0 cm).

Semiconfined (Aquifer) — An aquifer that has a "leaky" confining unit and displays characteristics of both confined and unconfined aquifers, typically evidencing low permeability through which recharge and discharge can still occur. Also see *Leaky Aquifer*.

Semipermeable — (1) Partially permeable. (2) Allowing passage of certain, especially small, molecules or ions but action as a barrier to others. Used of biological and synthetic membranes.

Senile — (Geology) Worn away nearly to the base level, as at the end of an erosion cycle.

Sensitivity - the variation in the value of one or more output variables (such as hydraulic heads) or quantities calculated from the output variables (such as ground water flow rates) due to changes in the value of one or more inputs to a ground water flow model (such as hydraulic properties or boundary conditions).

Sensitivity Analysis - a procedure based on systematic variation of model input values (1) to identify those model input elements that cause the most significant variations in model output; and (2) to quantitatively evaluate the impact of uncertainty in model input on the degree of calibration and on the model's predictive capability.

Settleable Solids — Most generally, all solids in a liquid that can be removed by stilling the liquid. In the *Imhoff* cone test, the volume of matter in a one-liter sample that settles to the bottom of the cone in one hour. (Water Quality) Bits of debris, sediment, or other solids that are heavy enough to sink when a liquid waste is allowed to stand in a pond or tank. Also see *Settling Chamber* and *Settling Pond*.

Settling Pond — (Water Quality) An open *Lagoon* into which wastewater contaminated with solid pollutants is placed and allowed to stand. The solid pollutants suspended in the water sink to the bottom of the lagoon and the liquid is allowed to overflow out of the enclosure.

Shaft — A vertical or inclined opening of uniform and limited cross section made for finding or mining ore, raising water, or ventilating underground workings (as in a cave).

Shallow Well — A well with a pumping head of 20 feet or less, permitting use of a suction pump.

Sheet — (Geology) A broad, relatively thin deposit or layer of *Igneous* or *Sedimentary Rock*.

Sheet Erosion — (1) The removal of thin, fairly uniform layer of soil or materials from the land surface by the action of rainfall and runoff water. (2) The removal by surface runoff of a fairly uniform layer of soil from a bank slope from *Sheet Flow* or runoff that flows over the ground surface as a thin, even layer not concentrated in a channel.

Sheet Flow — An overland flow or downslope movement of water taking the form of a thin, continuous film over relatively smooth soil or rock surfaces and not concentrated into channels larger than rills.

Significant Hydrologic Resources (SHR) — Generally refers to either federally significant resources, e.g., wetlands, which meet federal definitions and guidelines, or regionally designated significant resources which do not meet such federal definitions or guidelines, e.g., stream and riparian environments, playas, spring fed stands of riparian vegetation, and other wetland areas.

Silica — (Geology) Silicon dioxide (SiO2). It occurs in crystalline (quartz), amorphous (opal), or impure (silica sand) forms.

Sill — (1) A submerged ridge at relatively shallow depth separating the basins of two bodies of water. (2) A horizontal beam forming the bottom of the entrance to a lock. (3) Also, a low, submerged dam-like structure built to control riverbed scour and current speeds. (4) (Geology) An intrusive body of igneous rock of approximately uniform thickness and relatively thin compared with its lateral extent, which has been emplaced parallel to the bedding or schistosity of the intruded rocks.

Silt — (1) Sedimentary particles smaller than sand particles, but larger than clay particles. (2) An intermediate soil textural class consisting of particles between 0.05 and 0.002 millimeters in diameter.

Siltation — The deposition of finely divided soil and rock particles upon the bottom of stream and river beds and in reservoirs.

Simulation - in ground water modeling, one complete execution of a ground water modeling computer program, including input and output. Simulation is sometimes also used broadly to refer to the process of modeling in general.

Sink — (1) Generally, a dry or intermittently dry lakebed in the lowest spot of a closed valley; a depression in the land surface, especially one having a central playa or saline lake with no outlet. Salt contents are generally quite high. The term sink is interchangeable with the term *Playa*. Also see *Natural Sink*. (2) (Environmental) A place in the environment where a compound or material collects.

Sinkhole — A depression in the earth's surface caused by dissolving of underlying limestone, salt, or gypsum. Drainage is provided through underground channels which may be enlarged by the collapse of a cavern roof. Also see *Karst*.

Sinuous (Stream) — Characterized by many curves or turns; winding.

Site Characterization - (1) a general term applied to the investigation activities at a specific location that examines natural phenomena and human-induced conditions important to the resolution of environmental, safety and water resource issues; (2) means the program of exploration and research, both in the laboratory and in the field, undertaken to establish the geologic conditions and the ranges of those parameters of a particular site relevant to the program. Site characterization includes geophysical testing, borings, surface excavations, excavation of exploratory shafts, limited subsurface lateral excavations and borings and in situ testing at depth needed to determine the suitability of the site.

Slickensides — (Geology) A smooth striated polished surface produced on rock by movement along a fault.

Slope — The side of a hill or mountain, the inclined face of a cutting, canal or embankment or an inclination from the horizontal. In the United States, it is measured as the ratio of the number of units of horizontal distance to the number of corresponding units of vertical distance. The term is expressed as a percent when the slope is gentle, in which cast the term *Gradient* is also used.

Slough — (1) A place of deep mud or mire; a wet or marshy place as a swamp or marshland creek. Also a side channel or inlet as from a river; ordinarily found on or at the edge of the flood plain or a river; a *Bayou*. (2) (Localized) In the Mississippi Valley and in California, a tide flat or bottom-land creek. (3) (Sewage Disposal) Of a filter, to cast off a thin film of scum or a mass of bacterial growth or fungus. (4) Also *Slue*. A stagnant swamp, marsh, bog, or pond, especially as part of a bayou, and inlet, or a backwater.

Sloughing (or Sloughing Off) — Movement of a mass of soil down a bank into the channel (also called *Slumping*). Sloughing is similar to a landslide.

Soda Ash — (Water Quality) Also known as *Sodium Carbonate*, typically of chemical symbol Na2CO3, a salt of strong alkaline taste used in making glass, soap, paper, chemical reagents and to remove non-carbonate hardness from water.

Sodicity (of Soils) — A measure of the excess sodium in a soil which imparts a poor physical condition to the soil. *Sodic Soils* are generally impermeable to water, which makes it difficult to germinate crops.

Sodium Adsorption Ratio (SAR) — An expression of relative activity of sodium ions in exchange reactions with soil, indicating the sodium or alkali hazard to soil. It is calculated from the expression:

$$SAR = (Na)/[(Ca + Mg)/2]^{1/2}$$

where all quantities are expressed in milliequivalents per liter (meg/L). It is a particularly important measure in waters used for irrigation purposes. Waters range in respect to sodium hazard from those which can be used for irrigation on almost all soils to those which are generally unsatisfactory for irrigation.

Sodium Bicarbonate — (Wastewater Treatment) A white crystalline salt, NaHCO2, less soluble than *Sodium Carbonate* and having only a slight alkaline taste. Used as a *Coagulant Aid* in the neutralization process of wastewater treatment plants, it promotes more rapid settling, increases the efficiency of the coagulation process and extends the pH range to a level at which *Alum* (aluminum sulfate), a common inorganic coagulant, is effective.

Sodium Carbonate — (Water Quality) Any carbonate of sodium, typically Na2CO3, a salt of strong alkaline taste, found in nature, as in soda lakes, but more often made artificially and used extensively in making glass, soap, paper, chemical reagents and in the softening of water. Also referred to as *Soda Ash*.

Soft Water — Water that contains low concentrations of metal ions such as calcium and magnesium. This type of water does not precipitate soaps and detergents. Compare to *Hard Water*.

Soil — The meaning of this term varies depending on the field of consideration: (1) *Pedology* — the earth materials which have been so modified and acted upon by physical, chemical, and biological agents that it will support rooted plants; (2) *Engineering Geology* — the layer of incoherent rock material that nearly everywhere forms the surface of the land and rests on *Bedrock*, also called *Regolith*; (3) Ecology — A dynamic natural body on the surface of the earth in which plants grow, composed of mineral and organic materials and living forms.

Soil Classification — — The systematic arrangement of soils into groups or categories on the basis of their characteristics. Broad groupings are made on the basis of general characteristics and subdivisions on the basis of more detailed differences in specific properties. *Soil Taxonomy* is the study of soil classification systems. For a description of soil classifications, see *Land Capability Classes*.

Soil Creep — The slow mass movement of soil materials down slopes primarily under the influence of gravity, but facilitated by saturation with water and/or by alternating freezing and thawing.

Soil Erodibility — An indicator of a soil's susceptibility to raindrop impact, runoff, and other erosive processes.

Soil Erosion — The detachment and movement of soil from the land surface by wind or water.

Soil Moisture (Soil Water) — Water diffused in the upper part of the *Unsaturated Zone* (*Zone of Aeration*) of the soil, from which water is discharged by the *Transpiration* of plants, by *Evaporation*, or *Interflow*. Also referred to as *Soil Moisture Content* or *Available Water Content (AWC)*.

Solubility — The relative capacity of a substance to serve as a solute. Sugar has a high solubility in water, whereas gold has a low solubility in water.
Solum — The top two soil layers, composed of the topsoil (*A–Horizon*) and the subsoil (*B–Horizon*, or layer of leached material deposition). The solum excludes the parent material layer (*C–Horizon*). Also referred to as the *Zone of Eluviation*. Also see *Soil Profile*.

Solute — (1) Any material which is dissolved in another, such as salt dissolved in water. (2) Any substance that is
dissolved in water.

Solute Transport — The movement of dissolved substances through a *Hydrogeologic Unit*.

Solute Transport Model — Mathematical model used to predict the movement of solutes (generally contaminants) in an aquifer through time.

Solution — A homogeneous mixture of a solute in a solvent. For example, when sugar (the solute) is dissolved in water (the solvent), the molecules that comprise the sugar crystal are separated from one another and dispersed throughout the liquid medium.

Solution Channel — Tubular or planar channel formed by solution in carbonate-rock terrains, usually along joints and bedding planes.

Source - a process, or a feature from which, water, vapor, NAPL, solute or heat is added to the ground water or vadose zone flow system.

Source of Contaminants - the physical location (and spatial extent) of the source contaminating the aquifer; in order to model fate and transport of a contaminant, the characteristics of the contaminant source must be known or assumed.

Source Loading - the rate at which a contaminant is entering the ground water system at a specific source.

Specific Capacity (of a Well) — In ground water hydrology, the ratio of the discharge or yield of a well, usually measured in gallons per minute per foot, to drawdown after a period of sustained pumping.

Specific Conductance — A measure of the ability of water to conduct an electrical current as measured using a 1–cm cell and expressed in units of electrical conductance, i.e., siemens or microsiemens (µS or µmho) at 25 EC. Specific conductance is related to the type and concentration of ions in solution and can be used for approximating the total dissolved solids (TDS) content of water by testing its capacity to carry an electrical current. Commonly, the concentration of dissolved solids (in milligrams per liter, mg/L) is from 55 to 75 percent of the specific conductances (in microsiemens, µS). This relation is not constant from stream to stream, and it may vary in the same source with changes in the composition of the water. For comparison, the specific conductance of sea water is approximately 50,000 µS, which is equivalent to a TDS concentration of about 35,000 milligrams per liter (mg/l). (Water Quality) Specific conductance is used in ground water monitoring as an indication of the presence of ions of chemical substances that may have been released by a leaking landfill or other waste storage or disposal facility. A higher specific conductance in water drawn from *Downgradient Wells* when compared to *Upgradient Wells* indicates possible contamination from the facility.

Specific Discharge (Specific Flux) — For ground water, the rate of discharge per unit area, measured at right angles to the direction of flow.

Specific Drawdown — The drawdown in a well per unit discharge.

Specific Gravity (SG or SP GR) — (1) The ratio of the density of a substance to the density of some substance (as pure water) taken as a standard when both densities are obtained by weighing in air. (2) The ratio of the mass of a solid or liquid to the mass of an equal volume of distilled water at 4EC (39EF) or of a gas to an equal volume of air or hydrogen under prescribed conditions of temperature and pressure. Relative to water, the specific gravity (SG) is given by:

SG = ñ/ñw

where ñ is the density (weight per unit volume) of the unknown substance and ñw is the density of water. The parameter has no units and is frequently used to determine the concentration of a *Solution*.

Specific Storage — The volume of water removed or added within the unit volume of an aquifer per unit change in head.

Specific Yield (of an Aquifer) — The volume of water available per unit volume of aquifer, if drawn by gravity. Specific yield is expressed as a percent. For example, if 0.2 cubic meter of water will drain from 1 cubic meter of aquifer sand, the specific yield is 20 percent.

Specific Yield (Ground Water) — The ratio of the volume of water that a rock will yield by gravity, after being saturated, to its own volume, expressed as a percentage.

Specified Flux Boundary - model boundary condition in which the ground water flux is specified; also called fixed or prescribed flux, or Neumann boundary condition.

Specified Head Boundary (Constant Head) - a model boundary at which the hydraulic head is specified; also called fixed or prescribed head, or Dirichlet boundary condition.

Spit — (1) A narrow point of land extending into a body of water. (2) A brief, scattered fall of rain or snow.

Spring (Water) — (1) A concentrated discharge of ground water coming out at the surface as flowing water; a place where the water table crops out at the surface of the ground and where water flows out more or less continuously. (2) A place where ground water flows naturally from a rock or the soil into the land surface or into a body of surface water. Its occurrence depends on the nature and relationship of rocks, especially permeable and impermeable strata, on the position of the water table, and on the topography.

Spring, Cold — A spring whose water has a temperature appreciably below the mean annual atmospheric temperature in the area.

Spring, Hot — A thermal spring whose temperature is above that of the human body.

Spring Overturn — A physical phenomenon that may take place in a lake or similar body of water during the early spring, most frequently in lakes located in temperate zones where the winter temperatures are low enough to result in freezing of the lake surface. The sequence of events leading to spring overturn include: (1) the melting of ice cover; (2) the warming of surface waters; (3) density changes in surface waters producing convection currents from top to bottom; (4) circulation of the total water volume by wind action; and (5) vertical temperature equality. The overturn results in a uniformity of the physical and chemical properties of the entire water mass. Also see *Fall Overturn*. Also referred to as *Spring Turnover*.

Static Head — The difference in elevation in feet between the water surface of the body of water being pumped and the centerline of the discharge pipe at the point of release. It is the lift measured in feet.

Static Level (Ground Water) — The level of water in a nonpumping or nonflowing well. For the purpose of computing the drawdown, it generally is the water level immediately before pumping begins.

Static Lift — The vertical distance between source and discharge water levels in a pump installation.

Static Pressure — The pressure exerted by a still liquid or gas, especially water or air.

Static Water Depth — (Hydraulics) For a water well, the vertical distance from the centerline of the pump discharge down to the surface level of the free pool while no water is being drawn from the pool or water table.

Static Water Level — (1) The elevation or level of the water table in a well when the pump is not operating. (2) The level or elevation to which water would rise in a tube connected to an *Artesian Aquifer* or basin in a conduit under pressure.

Steady Flow — Flow in which the rate remains constant with respect to time at a given cross-section.

Steady State — (1) State of balance in a *Hydrologic System* where little or no change in hydraulic head occurs through time. (2) In a system with a flow-through of material (e.g., water) or energy, the equilibrium condition in which the flow in equals the flow out.

Stewardship — (Ecology) (1) Caring for land and associated resources and maintaining healthy ecosystems for future generations. (2) Administrative and/or custodial actions taken to preserve and protect the *Natural Resources*, particularly the plant (*Flora*) and animal (*Fauna*) life, of an area or *Ecosystem*.

Stochastic Hydrology — That branch of *Hydrology* involving the manipulation of statistical characteristics of hydrologic variables with the aim of solving hydrologic problems, using the stochastic properties of the events.

Stochastic Process — (Statistics) A process in which the dependent variable is random (so that the prediction of its values depends on a set of underlying probabilities) and the outcomes at any instant is not known with certainty. A process is said to be stochastic when its future cannot be predicted exactly from its past; describing an event or process that involves random chance or probability. A stochastic relationship is assumed to be inexact and therefore involves a *Disturbance (or Error) Term* which is used to account for the unexplainable portion of the relationship. Consequently, a simple (stochastic) functional relationship shows that for any time period, *t* (where *t*=1, 2, ..., n), the relationship between the dependent (*Endogenous*) variable, Y, and the independent (*Exogenous*) variable, X, may be written as:

Yt = á + â Xt + åt

where: Y represents the dependent variable of variable to be explained; t represents time periods of observation (i.e., t=1,2,...,n); á (*alpha*) represents the constant term (without a time reference); â (*beta*, also a constant term without a time reference) represents the coefficient of the independent variable, X; X represents the independent, or explanatory variable; and å (*epsilon*), the error term, represents the value of the unexplained disturbance term.

Storage — (1) Water artificially impounded in surface or underground reservoirs for future use. (2) Water naturally detained in a drainage basin, such as ground water, channel storage, and depression storage. The term *Drainage Basin Storage*, or simply *Basin Storage*, is sometimes used to refer collectively to the amount of water in natural storage in a drainage basin. (3) (Water Quality) The temporary holding of waste pending treatment or disposal, as in containers, tanks, waste piles, and surface impoundments.

Storage, Specific (Ground Water) — The amount of water released from or taken into storage per unit volume of a porous medium per unit change in head.

Storativity — The volume of water that a permeable unit, i.e., aquifer, will absorb or expel from storage per unit surface area per unit change in head. In an unconfined aquifer, the storativity value is equal to the *Specific Yield*. The specific yield of the aquifer can be used to estimate the time between when pumping begins and equilibrium ground water conditions are reached.

Strata — (Geology) Distinct horizontal layers in geological deposits. Each layer may differ from adjacent layers in terms of texture, grain size, chemical composition, or other geological criteria. The term is also applied to layering of other material such as the atmosphere.

Stratification — The arrangement of a body of water, such as a lake, into two or more horizontal layers of differing characteristics, such as temperature, density, etc. Also applies to other substances such as soil and snow, etc.

Stratigraphy — (1) The branch of geology which treats the formation, composition, sequence and correlation of the layered rocks as parts of the earth's crust. (2) The branch of geology that deals with the definition and description of major and minor natural divisions of rocks (mainly sedimentary, but not excluding igneous and metamorphic) available for study in outcrop or from subsurface, and with the interpretation of their significance in geologic history. It involves interpretation of features of rock strata in terms of their origin, occurrence, environment, thickness, lithology, composition, fossil content, age, history, paleogeographic conditions, relation to organic evolution, and relation to other geologic concepts. (3) The arrangement of strata, especially as to geographic position and chronological order of sequence.

Stratum — A horizontal layer or section.

Stream — A general term for a body of flowing water; natural water course containing water at least part of the year. In *Hydrology*, the term is generally applied to the water flowing in a natural channel as distinct from a canal. More generally, as in the term *Stream Gaging*, it is applied to the water flowing in any channel, natural or artificial. Some classifications of streams include, *in relation to time*:

[1] ***Ephemeral Streams*** — Streams which flow only in direct response to precipitation and whose channel is at all times above the water table.

[2] ***Intermittent or Seasonal Streams*** — Streams which flow only at certain times of the year when it receives water from springs, rainfall, or from surface sources such as melting snow.

[3] ***Perennial Streams*** — Streams which flow continuously.And, *in relation to ground water*:

[4] ***Gaining Streams*** — Streams or a reach of a stream that receive water from the zone of saturation. Also referred to as an *Effluent Stream*.

[5] ***Insulated Streams*** — Streams or a reach of a stream that neither contribute water to the zone of saturation nor receive water from it. Such streams are separated from the zones of saturation by an impermeable bed.

[6] ***Losing Streams*** — Streams or a reach of a stream that contribute water to the zone of saturation. Also referred to as an *Influent Stream*.

[7] ***Perched Streams*** — Perched streams are either losing streams or insulated streams that are separated from the underlying ground water by a zone of aeration.

Stream Capture — The process whereby a stream rapidly eroding headward cuts into the divide separating it from another drainage basin, and provides an outlet for a section of a stream in the adjoining valley. The lower portion of the partially diverted stream is called a *Beheaded Stream*. Also referred to as *Stream Piracy*.

Stream Channel — The bed where a natural stream of water runs or may run; the long narrow depression shaped by the concentrated flow of a stream and covered continuously or periodically by water.

Stream, Effluent — A stream or reach of a stream fed by ground water. It is also referred to as a *Gaining Stream*. See *Stream*.

Stream, Ephemeral — A stream that flows only in response to precipitation. See *Stream*.

Streamflow — The discharge that occurs in a natural channel. Although the term "discharge" can be applied to the flow of a canal, the word streamflow uniquely describes the discharge in a surface stream course. Streamflow is a more general term than "runoff" as streamflow may be applied to discharge whether or not its is affected by diversion or regulation.

Streamflow Depletion — The amount of water that annually flows into a valley or onto a particular land area minus the amount that flows out of the valley or away from the particular land area. It is also the amount of water taken from a stream.

Streamflow Regulation — The artificial manipulation of the flow of a stream.

Stream Gradient — A general slope or rate of change in vertical elevation per unit of horizontal distance of the water surface of a flowing stream.

Stream, Influent — A stream that contributes water to the *Zone of Saturation*. Also referred to as a *Losing Stream*. See *Stream*.

Stream, Intermittent — A stream that flows only part of the time or through only part of its reach. See *Stream*.

Streamlet — A small stream.

Stream Load — All the material transported by a stream or river either as visible sediment (*Bed Load* and *Suspended Load*) or in solution (*Dissolved Load*).

Stream Order — (1) Designation of stream segments within a drainage basin; a system of numbering streams according to sequence of tributary size. The smallest perennial tributary is designated as order 1, the junction of two first-order streams produces a stream segment of order 2, etc. (2) A method of numbering streams as part of a drainage basin network as adopted by the *U.S. Geological Survey (USGS)*. The smallest unbranched mapped tributary is a first-order stream, the stream receiving the tributary is a second-order stream, and so on, with the main stream always of the highest order. It is usually necessary to specify the scale of the map used, as a first-order stream on a 1:62,500 map may be a third-order stream on a 1:12,000 map. Tributaries which have no branches are designated as of the first order, streams which receive only first-order tributaries are of the second order, larger branches which receive only first-order and second-order tributaries are designated third order, and so on, the main stream being always of the highest order.

Stream, Perennial — A stream that flows continuously. See *Stream*.

Stream Piracy — The process whereby a stream rapidly eroding headward cuts into the divide separating it from another drainage basin, and provides an outlet for a section of a stream in the adjoining valley. The lower portion of the partially diverted stream is called a *Beheaded Stream*. Also referred to as *Stream Capture*.

Stream Reach — The continuous portion of a stream channel and adjoining floodplain from one selected point to another, usually measured along the *Thalweg* of the channel.

Stream Segment — (Water Planning) Surface waters of an approved planning area exhibiting common biological, chemical, hydrological, natural, and physical characteristics and processes. Segments will normally exhibit common reactions to external stresses, for example, discharge or pollutants.

Stream Terrace — (1) A surface representing remnants of a stream's channel or flood plain when the stream was flowing at a higher level. Subsequent downward cutting by the stream leaves remnants of the old channel or flood plain standing as a terrace above the present level of the stream. (2) A transversely level erosional remnant of a former axial stream or major desert stream floodplain that slopes in the same direction as the adjacent, incised stream, and is underlain by well sorted and stratified sand and gravel or by loamy or clayey sediments.

Stream, Underground — A subsurface stream which has all the characteristics of a water-course on the surface — a definite channel with bed and banks, a definite stream of water, and a definite source(s) of supply.

Strip Mining — The process of removing mineral deposits that are found close enough to the surface so that the construction of tunnels (underground mining) is not necessary. The soil and strata that cover the deposit are removed to gain access to the mineral deposit. The primary environmental concerns related to this technique are the disposition of spoils removed to gain access to the deposit and the scoring of the landscape that remains following the complete removal of the mineral deposit. Water pollution is also a concern because runoff from the mining area is frequently rich in sediments and minerals. Furthermore, such operations sometimes necessitate the removal of ground water that infiltrates the mining pit, consequently altering the ground water flow with potential implications on the water table and aquifer characteristics. Also referred to as *Open-Pit Mining* or *Surface Mining*.

Subsequent Stream — A tributary stream flowing along beds of less erosional resistance, parallel to beds of greater resistance. Its course is determined subsequent to the uplift that brought the more resistant beds within its sphere of erosion.

Subsidence — (1) The sinking of the land surface due to a number of factors, of which ground water extraction is one. (2) A sinking of a large area of the earth's crust. Typically this may result from the over-pumping of a basin's water table and the inability of the soils to re-absorb water from natural or artificial injection. Also frequently results from overdrafts of the aquifer and its inability to fully recharge, a process termed *Aquifer Compaction*.

Subsoil — Soil material underlying the surface soil.

Superfund Law (Comprehensive Environmental Response, Compensation, and Liability Act — CERCLA) — This statute, originally enacted in 1980 and substantially modified in 1986, establishes the *U.S. Environmental Protection Agency's (EPA)* authority for emergency response and cleanup of hazardous substances that have been spilled, improperly disposed of, or released into the environment. The primary responsibility for response and cleanup is on the generators or disposers of the hazardous substances, with a backup federal response using a trust fund provision.

Superfund List — A list of the hazardous waste disposal sites most in need of cleanup. The list is updated annually by the *U.S. Environmental Protection Agency (EPA)* based primarily on how a site scores using the *Hazard Ranking System*. Also referred to as the *National Priorities List (NPL)*.

Superfund Site — A hazardous waste landfill on the *National Priorities List (NPL)* (also referred to as the *Superfund List*) being cleaned up by the responsible parties or using proceeds from the *Hazardous Substances Superfund*.

Superimposed Stream — A stream whose present course was established on young rocks burying an old surface. With uplift, this course was maintained as the stream cut down through the young rocks to and into the old surface.

Superposition Principle - the addition or subtraction of two or more different solutions of a governing linear partial differential equation (PDE) to obtain a composite solution of the PDE. As an example, the superposition of drawdown caused by a pumping well on a regional, nonpumping potentiometric surface.

Surface Casing — The well pipe inserted as a lining nearest to the surface of the ground to protect the well from near-surface sources of contamination.

Surface Impoundment — (Water Quality) The treatment, storage, or disposal of liquid hazardous wastes, such as in tanks, ponds, pits, or lagoons. An indented area in the land's surface for such storage and treatment.

Surface Mining — The process of removing mineral deposits that are found close enough to the surface so that the construction of tunnels (underground mining) is not necessary. The soil and strata that cover the deposit are removed to gain access to the mineral deposit. The primary environmental concerns related to this technique are the disposition of spoils removed to gain access to the deposit and the scoring of the landscape that remains following the complete removal of the mineral deposit. Water pollution is also a concern because runoff from the mining area is frequently rich in sediments and minerals. Furthermore, such operations sometimes necessitate the removal of ground water that infiltrates the mining pit, consequently altering the ground water flow with potential implications on the water table and aquifer characteristics. Also referred to as *Open-Pit Mining* or *Strip Mining*. Also see *Dewatering*.

Surface Mining Control and Reclamation Act — An act passed in 1977 requiring that mine operators take measures to avoid acid or other toxic mine drainage. To correct existing acid drainage problems, the section of the law dealing with abandoned mine land states that land and water affected by mining that took place before 1977 can be cleaned up with fees paid by coal operators into the *Abandoned Mine Reclamation Fund*. About 90 percent of existing stream damage in the United States is from underground coal mining that took place before 1977. The federal enforcement agency is the U.S. Department of the Interior, Bureau of Mines, Office of Surface Mining Reclamation and Enforcement (OSM).

Surface Runoff — That part of the runoff which travels over the soil surface to the nearest stream channel. It is also defined as that part of the runoff of a drainage basin that has not passed beneath the surface since precipitation. Also applies to snowmelt or irrigation water in excess of what can infiltrate the soil surface and be stored in small surface depressions. In terms of surface water quality, surface runoff may constitute a major transporter of *Non-Point Source (NPS) Pollution*. The term is misused when applied in the sense of *Direct Runoff*. Also see *Runoff*, *Direct Runoff*, *Overland Flow*, *Ground-Water Runoff*, and *Surface Water*.

Surface Water — (1) An open body of water such as a stream, lake, or reservoir. (2) Water that remains on the earth's surface; all waters whose surface is naturally exposed to the atmosphere, for example, rivers, lakes, reservoirs, ponds, streams, impoundments, seas, estuaries, etc., and all springs, wells, or other collectors directly influenced by surface water. (3) A source of drinking water that originates in rivers, lakes and run-off from melting snow. It is either drawn directly from a river or captured behind dams and stored in reservoirs. Also see *Ground Water Under the Direct Influence (UDI) of Surface Water*.

Suspended Sediment — Very fine soil particles which remain in suspension in water for a considerable period of time without contact with the bottom. Such material remains in suspension due to the upward components of turbulence and currents and/or by *Colloidal Suspension*.

Suspended Solids (SS) — Solids which are not in true solution and which can be removed by filtration. Such suspended solids usually contribute directly to turbidity. Defined in waste management, these are small particles of solid pollutants that resist separation by conventional methods. Suspended solids (along with *Biochemical Oxygen Demand — BOD*) is a measurement of water quality and an indicator of treatment plant efficiency. Also see *Suspended Particulate Matter*.

Suspended, Total — The total amount of a given constituent in the part of a representative suspended-sediment sample that is retained on a 0.45-micrometer membrane filter. This term is used only when the analytical procedure assures measurement of at least 95 percent of the constituent determined.

Knowledge of the expected form of the constituent in the sample, as well as the analytical methodology used, is required to determine when the results should be reported as “suspended, total”. Determinations of “suspended, total” constituents are made either by analyzing portions of the material collected on the filter or, more commonly, by the difference, based on
determinations of (1) dissolved and (2) total concentrations of the constituent.

Sustained Yield — (1) (General) Achievement and maintenance, in perpetuity, of a high-level annual or regular periodic output or harvest of the various renewable land and water resources. (2) (Hydrology) The amount of water that may be removed (say, through ground water pumping) from an hydrographic area during a period of time without affecting future yields. Under such conditions, sustained yield is approximately equal to annual recharge. Contrast with *Ground water Mining*. (3) (Ecology) The perpetual output of a renewable resource, achieved and maintained at a given management intensity, without impairment of the productivity of the land.

Swale — (1) A slight depression, sometimes swampy, in the midst of generally level land. (2) A shallow depression in an undulating ground moraine due to uneven glacial deposition. (3) A long, narrow, generally shallow, trough-like depression between tow beach ridges, and aligned roughly parallel to the coastline. (4) A piece of meadow, often a slight depression or valley, as in a plain or moor, marshy and rank with vegetation. Swales usually carry flows only during or immediately after rainfall or snowmelt events. Swales vary in size from small conveyances providing drainage along roadways and behind or between buildings to larger waterways.

Swamp — A term frequently associated with *Wetlands*. Wet, spongy land; low saturated ground, and ground that is covered intermittently with standing water, sometimes inundated and characteristically dominated by trees or shrubs, but without appreciable peat deposits. Swamps may be fresh or salt water and tidal or non-tidal. It differs from a *Bog* in not having an acid substratum.

Sweet (Water) — Water that is pleasing to the senses; agreeable and not saline or polluted; drinkable; *Potable*. Also see *Freshwater*.

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Tacking — The binding of *Mulch* fibers by mixing them with an adhesive chemical compound during land *Restoration* projects.

Tafoni — Natural cavities in rocks formed by weathering.

Tailings — The waste material remaining after metal is extracted from ore.

TDS (Total Dissolved Solids) — All the solids (usually mineral salts) that are dissolved in water. Used to evaluate water quality.

Technology-Based Standards — (EPA) Effluent limitations applicable to direct and indirect sources which are developed on a category-by-category basis using statutory factors, not including water-quality effects.

Temperature Gradient — The rate of change of temperature with increase in height or decrease in depth.

Temperature Inversion — A surface cooling at the earth’s surface which sometimes leads to an increase in temperature with altitude.

Temperature Regulation — The processes through which an organism's temperature is adjusted to certain metabolic requirements or conditions in its environment. For example, the act of human perspiration promotes surface skin evaporation which cools the body.

Temperature Scale — The temperature scale adopted by a 1960 international conference was based on a fixed temperature point, the *Triple Point* of water, at which the solid, liquid, and gas are in equilibrium. The temperature of 273.16 K (Kelvin) was assigned to this point. The freezing point of water was designated as 273.15 K, equaling exactly 0° on the *Celsius Temperature Scale*. The Celsius scale, which is identical to the *Centigrade Temperature Scale*, is named for the 18th-century Swedish astronomer Anders Celsius, who first proposed the use of a scale in which the interval between the freezing and boiling points of water is divided into 100 degrees. By international agreement, the term Celsius has officially replaced Centigrade.

Terminal Moraine — Constitutes the material (*Glacial Till*) left behind by the farthest advance of a Glacier's toe. Each different period of glaciation leaves behind its own uniquely developed moraines.
Terminus — Refers to the location of water's final destination, as in the terminus of a river system being a *Terminal Lake*.

Terrace — (1) (Erosion and Irrigation) An embankment or combination of an embankment and channel constructed across a slope to control erosion by diverting and temporarily storing surface runoff instead of permitting it to flow uninterrupted down the slope. Outlets may be soil infiltration only, vegetated waterways, tile outlets, or combinations thereof. (2) (Geological) An old alluvial plain, ordinarily flat or undulating, bordering a river, lake, or the sea. Stream terraces are frequently called second bottoms, as contrasted to flood plains, and are seldom subject to overflow. Marine terraces were deposited by the sea and are generally wide. (3) Also, a *Berm* or discontinuous segments of a berm, in a valley at some height above the *Flood Plain*, representing a former abandoned flood plain of the stream.

Terracing — A series of levels on a hillside, one above the other; dikes built along the contour of sloping farm land that hold runoff and sediment to reduce erosion. Hillside farming on terraces greatly reduces water erosion of soil.

Test Hole (Test-Well) — (Hydraulics) A well hole drilled for experimental or exploratory purposes.

Texture — Refers to relative proportions of clay, silt, and sand in soil.

Thalweg – (Geology) 1**.** The line defining the lowest points along the length of a river bed or valley. 2. A subterranean stream.

Thatch — Dead stems that build up beneath certain ground covers and lawn grasses, sometimes becoming so thick and compressed as to impede infiltration by water.

Thermal Gradient — A temperature difference between two areas.

Threatened Species — Any plant or animal species likely to become an "endangered" species within the foreseeable future throughout all of a significant area of its range or natural habitat; identified by the Secretary of the Interior as "threatened", in accordance with the 1973 *Endangered Species Act (ESA)*.

Till (Glacial) — Till is the mixture of rocks, boulders, and soil picked up by a moving *Glacier* and carried along the path of the ice advance. The glacier deposits this till along its path — on the sides of the ice sheet, at the toe of the glacier when it recedes, and across valley floors when the ice sheet melts. These till deposits are akin to the footprint of a glacier and are used to track the movement of glaciers. These till deposits can be good sources of ground water, if they do not contain significant amounts of impermeable clays. Also see *Moraines*, *Lateral Moraines*, and *Terminal Moraines*.

Tilth — (1) The general physical condition of soil as it relates to agriculture use. (2) Land used for agriculture, as opposed to pasture or forest.

Titrant — A solution of known strength or concentration; used in *Titration*.

Titration — (Chemistry) (1) A method, or the process, of determining the strength of a solution, or the concentration of a substance in solution, in terms of the smallest amount of it required to bring about a given effect in reaction with another known solution or substance, as in the neutralization of an acid by a base. (2) A process whereby a solution of known strength (the *Titrant*) is added to a certain volume of treated sample containing an indicator. A color change shows when the reaction is complete (the end point).

Titrator — An instrument, usually a calibrated cylinder (tube-form), used in *Titration* to measure the amount of *Titrant* being added to the sample.

Toe — (1) The downstream edge at the base of a dam. (2) The break in slope at the foot of a stream bank where the bank meets the bed. (3) The line of a natural or fill slope where it intersects the natural ground. (4) The lowest edge of a backslope of a cut where it intersects the roadbed or bench.

Topographic Maps — Maps with lines showing equal elevation or a region's relief; also showing natural and man-made surface features, including hills, valleys, rivers, and lakes; and man-made features such as canals, bridges, roads, cities, etc.

Total Carbon (TC) — (Water Quality) A measure of the amount of carbon-containing compounds in water. The measure includes both organic and inorganic forms of carbon as well as compounds that are soluble and insoluble. The typical laboratory analysis involves the conversion of all forms of carbon to carbon dioxide and the subsequent measurement of the carbon dioxide produced. The parameter represents an estimate of the strength of wastewater and the potential damage that an effluent can cause in a receiving stream or other body of water as a result of the removal of *Dissolved Oxygen* from the water. The measurement of total carbon requires less sample, is more rapid, and yields more reproducible results than the measurement of either the *Chemical Oxygen Demand (COD)* or the *Biochemical Oxygen Demand (BOD)*. Also see *Total Organic Carbon (TOC)*.

Total Constituent — The total amount of a given constituent in a representative suspended-sediment sample, regardless of the constituent's physical or chemical form. This term is used only when the analytical procedure assures measurement of at least 95 percent of the constituent present in both the dissolved and suspended phases of the sample. A knowledge of the expected form of the constituent in the sample, as well as the analytical methodology used, is required to judge when the results should be reported as "total". (Not that the word "total" serves a double meaning here, first indicating that the sample consists of a suspended-sediment mixture and second that the analytical method determined all of the constituent in the sample.)

Total Discharge — The quantity of a given constituent, measured as dry mass or volume, that passes a stream cross section per unit of time. When referring to constituents other than water, this term needs to be qualified, such as "total sediment discharge", "total chloride discharge", etc.

Total Dissolved Solids (TDS) — (Water Quality) A measure of the amount of material dissolved in water (mostly inorganic salts). Typically aggregates of carbonates, bicarbonates, chlorides, sulfates, phosphates, nitrates, etc. of calcium, magnesium, manganese, sodium, potassium, and other cations which form salts. The inorganic salts are measured by filtering a water sample to remove any suspended particulate material, evaporating the water, and weighing the solids that remain. An important use of the measure involves the examination of the quality of drinking water. Water that has a high content of inorganic material frequently has taste problems and/or water hardness problems. As an example, water that contains an excessive amount of dissolved salt (sodium chloride) is not suitable for drinking. High TDS solutions have the capability of changing the chemical nature of water. High TDS concentrations exert varying degrees of osmotic pressures and often become lethal to the biological inhabitants of an aquatic environment. The common and synonymously used term for TDS is “salt”. Usually expressed in milligrams per liter. Also see *Hard Water* and *Salinity*.

Total Hardness — The total dissolved salts in water, expressed as total parts of dissolved salts in a million parts of water. Also see *Hard Water*.

Total Head — Energy contained by fluid because of its pressure, velocity, and elevation, usually expressed in feet of fluid (foot-pounds per pound).

Total Inorganic Carbon (TIC) — (Water Quality) The total amount of inorganic salts of carbonates and bicarbonates present in water without regard as to whether the salts are in suspended particulate form or dissolved. Water that contains an excessive amount of these salts is considered to be *Hard Water*. The dissolved materials interfere with the functioning of soaps and detergents and can form adherent scale in boilers, pipes, and steam equipment.

Total Inorganic Nitrogen (TIN) — A measure of the total *Nitrate*, *Nitrite*, and *Ammonia* concentrations of a body of water, typically measured in milligrams per liter (mg/l) or micrograms per liter (µg/l). From the point of view of a planktonic algae, nitrate, nitrite, and ammonia are all very suitable sources of nitrogen for growth. Also see *Carlson’s Trophic State Index (TSI)*.

Total Inorganic Phosphate (TIP) — A measure of the concentration of usable phosphorus (soluble *Phosphates*) contained in a body of water. Soluble phosphates readily contribute to algae growth in water. Also see *Carlson’s Trophic State Index (TSI)*.

Total Kjeldahl Nitrogen (TKN) — The total concentration of nitrogen in a sample present as ammonia or bound in organic compounds.

Total Load — All of a constituent in transport. When referring to sediment, it includes suspended load plus bed load.

Total Maximum Daily Load (TMDL) — (Water Quality) The maximum quantity of a particular water pollutant that can be discharged into a body of water without violating a water quality standard. The amount of pollutant is set by the *U.S. Environmental Protection Agency (EPA)* when it determines that existing, *Technology-Based* effluent standards on the water pollution sources in the area will not achieve one or more *Ambient Water Quality Standards*. The process results in the allocation of the TMDL to the various *Point Sources (PS)* of pollutants in the area.

Total Organic Carbon (TOC) — (Water Quality) A measure of the amount of organic materials suspended or dissolved in water. The measure is very similar to the assay of the total carbon content; however, samples are acidified prior to analysis to remove the inorganic salts of *Carbonates* and *Bicarbonates*. The assay of total organic carbon represents an estimation of the strength of wastewater and the potential damage that an effluent can cause in a receiving body of water as a result of the removal of *Dissolved Oxygen* from the water. The measurement of total organic carbon requires less sample, is more rapid, and yields more reproducible results than the measurement of either the *Chemical Oxygen Demand (COD)* or the *Biochemical Oxygen Demand (BOD)*. As a pollution indicator, this method is more reliable than the assay of *Total Carbon (TC)* when the wastewater contains high amounts of total inorganic carbon as well.

Total Recoverable Constituent — The amount of a given constituent that is in solution after a representative suspended-sediment sample has been digested by a method (usually using a dilute acid solution) that results in dissolution of only readily soluble substances. Complete dissolution of all particulate matter is not achieved by the digestion treatment, and thus the determination represents something less than the "total" amount (that is, less than 95 percent) of the constituent present in the dissolved and suspended phases of the sample. To achieve comparability of analytical data, equivalent digestion procedures are required of all laboratories performing such analyses because different digestion procedures are likely to produce different analytical results.

Total Solids (TS) — (Water Quality) A measure of the amount of material that is either dissolved or suspended in a water sample, obtained by allowing a known volume to evaporate and then weighing the remaining residue. Total solids equals the sum of the measurements of *Total Dissolved Solids (TDS)* and *Total Suspended Solids (TSS)*.

Total Suspended Solids (TSS) — (Water Quality) Solids, found in waste water or in a stream, which can be removed by filtration. The origin of suspended matter may be man-made wastes or natural sources such as silt. Compare to *Total Dissolved Solids (TDS)*.

Toxicity Characteristic Leaching Procedure (TCLP) — A test that measures the mobility of organic and inorganic chemical contaminants in wastes. The test, designed by the *U.S. Environmental Protection Agency (EPA)*, produces an estimate of the potential for *Leachate* formation by a waste if it is placed in the ground. If the TCLP is applied to a solid waste sample and the extract leached from the waste or the solid waste sample itself contains concentrations of specified materials exceeding allowable levels, the waste is defined as a *Hazardous Waste*, meeting the toxicity characteristic.

Toxic Materials — Any liquid, gaseous, or solid substance or substances in a concentration which, when applied to, discharged to, or deposited in water or another medium may exert a poisonous effect detrimental to people or to the propagation, cultivation, or conservation of animals, or other aquatic life.

Trace Elements — Elements essential to plant or animal life but required only in small amounts, such as the trace amounts of manganese, zinc, iron, molybdenum, cobalt, and copper.

Trace Metals — A general term for metals found in small quantities (less than 1 milligram per liter — mg/l) in water, usually due to their insolubility.

Transient Conditions - a condition in which system inputs and outputs are not in equilibrium so that there is a net change in the system with time.

Transient Flow - a condition that occurs when at any location in a ground water or vadose zone flow system the magnitude and/or direction of the specific discharge changes with time.

Transmissibility (Ground Water) — The capacity of a rock to transmit water under pressure. The coefficient of transmissibility is the rate of flow of water, at the prevailing water temperature, in gallons per day, through a vertical strip of the aquifer one foot wide, extending the full saturated height of the aquifer under a hydraulic gradient of 100 percent. A *Hydraulic Gradient* of 100 percent means a one foot drop in head in one foot of flow distance.

Transmissivity, also Coefficient of Transmissivity (ô) — The ability of an aquifer to transmit water. The rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of the aquifer under a unit *Hydraulic Gradient*. It is equal to an integration of the hydraulic conductivities across the saturated part of the aquifer perpendicular to the flow paths. Also, the rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient. Transmissivity values are given in gallons per minute through a vertical section of an aquifer 1 foot wide and extending the full saturated height of an aquifer under a hydraulic gradient of one in the *English Engineering System*; in the *Standard International System*, transmissivity is given in cubic meters per day through a vertical section of an aquifer 1 meter wide and extending the full saturated height of an aquifer under hydraulic gradient of one. It is a function of properties of the liquid, the porous media, and the thickness of the porous media. Also see *Coefficient of Transmissivity*.

Trellis Pattern — A roughly rectilinear arrangement of stream courses in a pattern reminiscent of a garden trellis, developed in a region where rocks of differing resistance to erosion have been folded, beveled, and uplifted.

Turbid — (1) Having the lees or sediment disturbed; roiled; cloudy. (2) Not clear or translucent; clouded, muddy; dull; impure; polluted. Also see *Turbidity*.

Turbidimeter — A device used to measure the degree of turbidity, or the density of suspended solids in a sample.

Turbidity — (1) A measure of the reduced transparency of water due to suspended material which carries water quality implications. The term "turbid" is applied to waters containing suspended matter that interferes with the passage of light through the water or in which visual depth is restricted. The turbidity may be caused by a wide variety of suspended materials, such as clay, silt, finely divided organic and inorganic matter, soluble colored organic compounds, plankton and other microscopic organisms and similar substances. Turbidity in water has public health implications due to the possibilities of pathogenic bacteria encased in the particles and thus escaping disinfection processes. Turbidity interferes with water treatment (filtration), and affects aquatic life. Excessive amounts of turbidity also make water aesthetically objectionable. The degree of the turbidity of water is measured by a *Turbidimeter*. (2) The collective optical properties of a water sample that cause light to be scattered and absorbed rather than transmitted in straight lines; the higher the intensity of scattered light, the higher the turbidity. Turbidity is expressed in nephelometric turbidity units (NTU) or Formazin turbidity units (FTU) depending on the method and equipment used.

Turbidity Current — A current in which a limited volume of turbid or muddy water moves relative to surrounding water because of its greater density.

Turnover, Spring — A physical phenomenon that may take place in a lake or similar body of water during the early spring, most frequently in lakes located in temperate zones where the winter temperatures are low enough to result in freezing of the lake surface. The sequence of events leading to spring overturn include: (1) the melting of ice cover; (2) the warming of surface waters; (3) density changes in surface waters producing convection currents from top to bottom; (4) circulation of the total water volume by wind action; and (5) vertical temperature equality. The overturn results in a uniformity of the physical and chemical properties of the entire water mass. Also referred to as *Spring Overturn*. Also see *Fall Overturn*.

-U-

Unbiased Sample — (Statistics) A sample is said to be unbiased if its behavior and characteristics are representative of the total *Population*.

Unconfined — Conditions in which the upper surface of the *Zone of Saturation* forms a water table under atmospheric pressure.

Unconfined Aquifer — An aquifer containing water that is not under pressure; the water level in a well is the same as the water table outside the well. An unconfined aquifer made up of loose material, such as sand or gravel, that has not undergone lithification (settling). In an unconfined aquifer the upper boundary is the top of the *Zone of Saturation* (water table).

Unconsolidated Deposits (Sediment) — Sediment not cemented together; may consist of sand, silt, clay, and organic material.

Unconsolidated Formation — Natural earth formations that have not been turned to stone, such as alluvium, soil, gravel, clay, sand and overburden.

Underflow — (1) (Surface and Ground water) The downstream flow of water through the permeable deposits underlying a stream. (2) (Water Quality) The slurry of concentrated solids or *Sludge* that is removed from the bottom of a *Settling Tank*, *Clarifier*, or *Thickener*. (3) Submerged gravity-driven flows which occur when inflows to a water body are denser than the ambient water. The inflow subsequently plunges and continues as a distinct flow which can be envisioned as a submerged stream. Underflows, also called *Density Current*, are known to form intermittently on coastal continental shelves, in reservoirs and at effluent discharge sites.

Underground Water — Water below the surface of the ground. Also referred to as *Ground water*, *Ground Water*, *Subsurface Water*, and *Subterranean Water*.

Unimpaired Flow — The flow past a specified point on a natural stream that is unaffected by stream diversion, storage, import, export, return flow, or change in use caused by modifications in land use.

Unit Hydrograph — (1) The *Hydrograph* of direct runoff from a storm uniformly distributed over the drainage basin during a specified unit of time; the hydrograph is reduced in vertical scale to correspond to a volume of runoff from the drainage basin of one inch. (2) The hydrograph of surface runoff (not including ground water runoff) on a given basin due to an effective rain falling for a unit of time.

Unsaturated Flow — Movement of water in a porous medium in which the pore spaces are not filled with water and the direction of flow is from the wetter zone of higher potential to one of lower potential.

Unsaturated Zone — (1) The portion of the soil profile which contains both air and water. Water in this zone cannot enter a well. (2) The subsurface zone between the water table (*Zone of Saturation*) and the land surface where some of the spaces between the soil particles are filled with air. It includes the root zone, intermediate zone, and capillary fringe. The pore spaces contain water, as well as air and other gases at less than atmospheric pressure. Saturated bodies, such as *Perched Ground Water*, may exist in the unsaturated zone, and water pressure within these bodies may be greater than atmospheric. Also referred to as the *Vadose Zone* or, less frequently, the *Zone of Aeration*.

Unsteady Flow — Flow that is changing with respect to time.

Upgradient Well — A ground water monitoring well, such as those required at facilities that treat, store, or dispose of hazardous waste using surface impoundments or landfills, that allows sampling and analysis of ground water that is upstream from the facility, before the ground water is possibly affected by any escaping contaminants. The results of the analyses are used for comparison to the results of ground water sampled from *Downgradient Wells*.

Uplands — (1) The ground above a floodplain; that zone sufficiently above and/or away from transported waters as to be dependent upon local precipitation for its water supplies. (2) Land which is neither a *Wetland* nor covered with water.

Uplift — (Hydraulics) The upward pressure of water on the base of a structure or the upward pressure in the pores of a material, i.e., *Interstitial Pressure*.

Upstream — Toward the source or upper part of a stream; against the current. In relation to water rights, the term refers to water uses or locations that affect water quality or quantity of downstream water uses or locations.

Usable Storage Capacity — The available storage capacity plus the remaining ground water storage within a reasonable pump lift. Specific yield of the sediments is used in calculating estimates of usable storage capacity.

-V-

Vadose — Of, relating to, or being water that is located in the *Zone of Aeration* in the earth's crust above the ground water level.

Vadose Zone — The subsurface zone between the water table (*Zone of Saturation*) and the land surface where some of the spaces between the soil particles are filled with air. Also referred to as the *Unsaturated Zone* or, less frequently, the *Zone of Aeration*.

Vadose Water — Water occurring in the *Unsaturated Zone* (*Vadose Zone*) between the land surface and the water table.

Vale — A valley, often coursed by a stream; a dale.

Valley — (1) An area of land that is lower than the land on either side of it. (2) An elongated depression cut by stream erosion and associated water erosion on its sideslopes (stream valley). Also used in the vernacular for *Intermontane* and *Intramontane Basins*. Also see *U-Shaped Valleys* and *V-Shaped Valleys*.

Velocity, Average Interstitial (õ) — The average rate of ground-water flow in interstices, expressed as the product of *Hydraulic Conductivity* and *Hydraulic Gradient* divided by the *Effective Porosity*. It is synonymous with *Average Linear Ground-Water Velocity* or *Effective Velocity*.

Velocity Head — Energy contained by fluid because of its velocity; usually expressed in feet of fluid (foot-pounds per pound).

Velocity (of Water in a Stream) — Rate of motion of a stream measured in terms of the distance its water travels in a unit of time, usually expressed in feet per second.

Venturi — A short tube with a constricted throat used to determine fluid pressures and velocities by measurement of differential pressures generated at the throat as a fluid traverses the tube.

Venturi Effect — The increase in the velocity of a fluid stream as it passes through a constriction in a channel, pipe, or duct. Calculated by the *Continuity Equation*, or

$$Q = VA$$

where Q is the volumetric flow rate, A is the Area of flow, and V is the fluid velocity. Because Q does not change, as A gets smaller then V must increase.

Venturi Meter — A meter, developed by Clemens Herschel, for measuring flow of water or other fluids through closed conduits or pipes. It consists of a venturi tube and one of several forms of flow registering devices.

Venturi Tube — A closed conduit that gradually contracts to a throat, causing a pressure head by which the velocity through the throat may be determined.

Vernal Pools — (1) *Wetlands* that occur in shallow basins that are generally underlain by an impervious subsoil layer (e.g., a clay pan or hard pan) or bedrock outcrop, which produces a seasonally perched water table. (2) A type of *Wetland* in which water is present for only part of the year, usually during the wet or rainy seasons (e.g., spring). Also referred to as *Temporary Wetland*.

Viscosity (ç) — A measure of the resistance of a fluid to flow. For liquids, viscosity increases with decreasing temperature. For gases, viscosity increases with increasing temperature. Expressed as mass per length-time (e.g., kilograms per meter-second). A common viscosity unit is the *Poise*. One poise equals 1.0 gram per centimeter-second. Also referred to as *Dynamic Viscosity*.

Void — The pore space or other openings in rock. The openings can be very small to cave size and are filled with water below the *Water Table*.

Void Ratio — Ratio of volume of intergranular voids to volume of solid material in a sediment or sedimentary rock.

Voids — A general term for pore spaces or other openings in rock.

V-Shaped Valleys — Valleys typically eroded by stream action. *U-Shaped Valleys*, by contrast, are characteristic of glacial erosion.

-W-

Wash — (1) To carry, erode, remove, or destroy by the action of moving water. To be carried away, removed, or drawn by the action of water. Removal or erosion of soil by the action of moving water. (2) A deposit of recently eroded debris. (3) Low or marshy ground washed by tidal waters. A stretch of shallow water. (4) (Western United States) The dry bed of a stream, particularly a watercourse associated with an alluvial fan, stream, or river channel. Washes are often associated with arid environments and are characterized by large, high energy discharges with high bed-material load transport. Washes are often intermittent and their beds sparsely vegetated. (5) Loose or eroded surface material (such as gravel, sand, silt) collected, transported, and deposited by running water, as on the lower slopes of a mountain range, especially coarse alluvium. (6) Turbulence in air or water caused by the motion or action of an oar, propeller, jet, or airfoil.

Water (H2O) — The liquid that descends from the clouds in rain and which forms streams, lakes, and seas, and is a major constituent of all living matter. Pure water consists of *Hydrogen* (11.188 percent by weight) and *Oxygen* (88.812 percent by weight) in the proportion of two atoms of hydrogen to one of oxygen (H2O), and is an odorless, tasteless, transparent liquid which is very slightly compressible. It has a slightly blue color which is observable only in thick layers of the liquid. At its maximum density, 39.2EF (or 4EC), it is the standard for specific gravities, one cubic centimeter weighing one gram. Water's weight per gallon (at 15EC or 59EF) is 8.337 pounds (3.772 kilograms). It is also the standard for specific heats. Its own specific heat is very great. It freezes at 32EF (0EC) and boils at 212EF (100EC) under atmospheric pressure at sea level. Pure water is an extremely poor conductor of electric current, although many *Aqueous* (water-based) solutions are conductors. Water is the most important of solvents, dissolving many gases, liquids, and solids. Natural waters of the earth, as those of springs, rivers, or the oceans, contain more or less dissolved matter, which is mostly removed by distillation. Rain water is nearly pure. Water is important chemically as a solvent and dissociating agent, as a catalytic agent, and often as one of the substances taking part in a chemical reaction. Ordinary water, described above, is a mixture of molecules containing hydrogen of atomic weight 1, with a small proportion (about 0.015 per cent) of molecules containing hydrogen of atomic weight 2. This later kind of water, termed *Heavy Water* or *Deuterium Oxide*, D2O, can be separated by fractional electrolysis or distillation and in other ways and is used as a moderator in certain nuclear reactors.

Water Audit — A procedure that combines flow measurements and listening surveys (leak detection) in an attempt to give a reasonably accurate accounting of all water entering and leaving a system.

Water Balance — (1) A measure of the amount of water entering and the amount of water leaving a system. Also referred to as *Hydrologic Budget*. Also see *Hydrologic Equation*. (2) The ratio between the water assimilated into the body and that lost from the body; also, the condition of the body when this ratio approximates unity.

Water Color — One of the most immediately apparent attributes of many natural waters and one that, together with visual clarity, strongly influences human aesthetic perception and recreational use. Color of waters is a guide to their composition, and remote sensing of water color is increasingly being used to infer water quality, particularly suspended solids and phytoplankton concentrations. The color of water, with water considered a translucent (i.e., not transparent) material, is commonly associated with transmitted light, for example, the color seen by a diver beneath the water's surface. However, the color of natural waters as observed from above is that associated with the upwelling light field that results from back scattering of sunlight illuminating the water volume. In this manner, the color of natural waters can be objectively specified using their spectral *Reflectance*, where the reflectance is defined as the ratio of the upwelling light to incident (downwelling) light.

Water Policy — Those actions governing the management, administration, and procedures used to implement and direct a formal *Water Planning* process by which water rights, water uses, and water diversions are evaluated, ranked, and allocated on the basis of specific public policy goals and objectives and designated, either by legislative mandate, regulation, or fiat, *Preferred Uses*. Similar in scope and purpose to water planning, a water policy approach to water planning is also inherently concerned with various aspects of water resource development, transport, water treatment, allocation among various competing uses, conservation, waste-water treatment, re-use, and disposal. However, unique to the water policy approach is that water-related actions are specifically governed by pre-determined, publicly-approved water-related stipulations such as environmental impacts, quality of life values, *"Highest and Best Use"* concepts and criteria, water quality standards, conservation issues, industry sector water allocations, economic diversity goals, etc. To effect such a policy approach to water planning, a *Public Scoping* process is essential to ascertain, quantify, and rank the specific policy goals used to allocate limited water resources among competing uses. Also see *Water Plan*.

Water Pollution — Generally, the presence in water of enough harmful or objectionable material to damage the water's quality. More specifically, pollution shall be construed to mean contamination of any waters such as will create or is likely to create a nuisance or to render such waters harmful, detrimental or injurious to public health, safety or welfare, or to domestic, municipal, commercial, industrial, agricultural, recreational, or other legitimate uses, or to livestock, wild animals, birds, fish or other aquatic life, including but not limited to such contamination by alteration of the physical, chemical or biological properties of such waters, or change in temperature, taste, color or order thereof, or the discharge of any liquid, gaseous, radioactive, solid or other substances into such waters. More simply, it refers to quality levels resulting from man's activities that interfere with or prevent water use or uses.

Water Quality — (1) A term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose. (2) The chemical, physical, and biological condition of water related to beneficial use.

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 (e.g., drinking, recreation, industrial, irrigation, etc.).

Water Quality Criteria — A specific level or range of levels of water quality necessary for the protection of a water use; levels of water quality expected to render a body of water suitable for its designated use. The criteria are set for individual pollutants and are based on different water uses, such as a public water supply, an aquatic habitat, and industrial supply, or for recreation.

Water Quality Standards — (1) A plan for water quality management containing four major elements: water use; criteria to protect uses; implementation plans, and enforcement plans. An anti-degradation statement is sometimes prepared to protect existing high quality water sources. (2) State-adopted and *U.S. Environmental Protection Agency (EPA)* approved ambient standards for water bodies. The standards prescribe the use of the water body and establish the water quality criteria that must be met to protect designated uses.

Water Resources Regions [United States] — A designated natural *Drainage Basin* or *Hydrologic Area* that contains either the drainage area of a major river or the combined drainage areas of two or more rivers. Of the 21 designated water-resources regions, delineated by the *Water Resources Council* in 1970, 18 are in the conterminous United States, and one each are in Alaska, Hawaii, and Puerto Rico. The following represents a listing of U.S. water-resources regions and the states primarily and partly included:

- [1] ***Region 01 — New England Region*** (Maine, New Hampshire, Massachusetts, Connecticut, Rhode Island, and part of Vermont)
- [2] ***Region 02 — Mid-Atlantic Region*** (New York, Pennsylvania, New Jersey, Maryland, Washington D.C., Virginia, and parts of Vermont and West Virginia)
- [3] ***Region 03 — South Atlantic–Gulf Region*** (North Carolina, South Carolina, Georgia, Alabama, Florida, and parts of Virginia and Mississippi)
- [4] ***Region 04 — Great Lakes Region*** (Michigan, and parts of Wisconsin, Indiana, Ohio, and New York)
- [5] ***Region 05 — Ohio Region*** (Indiana, Ohio, West Virginia, Kentucky, and parts of Illinois, Tennessee, Virginia, Pennsylvania, and New York)

[6] ***Region 06 — Tennessee Region*** (Tennessee and parts of Alabama, Georgia, Virginia, and North Carolina)
[7] ***Region 07 — Upper Mississippi Region*** (Minnesota, Wisconsin, Iowa, Illinois, and parts of Missouri and Indiana)
[8] ***Region 08 — Lower Mississippi Region*** (parts of Arkansas, Mississippi, Louisiana, Tennessee, Kentucky, and Missouri)
[9] ***Region 09 — Souris–Red–Rainy Region*** (parts of North Dakota and Minnesota)
[10] ***Region 10 — Missouri Region*** (Montana, Wyoming, North Dakota, South Dakota, Nebraska, and parts of Colorado, Kansas, Missouri, Iowa, and Minnesota)
[11] ***Region 11 — Arkansas–White–Red Region*** (Oklahoma and parts of Colorado, New Mexico, Kansas, Texas, Missouri, Arkansas, and Louisiana)
[12] ***Region 12 — Texas–Gulf Region*** (Texas and parts of New Mexico and Louisiana)
[13] ***Region 13 — Rio Grand Region*** (New Mexico and parts of Texas and Colorado)
[14] ***Region 14 — Upper Colorado Region*** (parts of Utah, Colorado, Wyoming, Arizona, and New Mexico)
[15] ***Region 15 — Lower Colorado Region*** (Arizona and parts of California, Nevada, Utah, and New Mexico)
[16] ***Region 16 — Great Basin Region*** (Nevada and parts of Utah, California, Oregon, Idaho, and Wyoming)
[17] ***Region 17 — Pacific Northwest Region*** (Washington, Oregon, Idaho, and parts of Montana, Wyoming, Nevada, and Utah)
[18] ***Region 18 — California Region*** (California and parts of Oregon and Nevada)
[19] ***Region 19 — Alaska Region*** (Alaska)
[20] ***Region 20 — Hawaii Region*** (Hawaii)
[21] ***Region 21 — Caribbean Region*** (Puerto Rico)

Watershed — (1) An area that, because of topographic slope, contributes water to a specified surface water drainage system, such as a stream or river. An area confined by topographic divides that drains a given stream or river. (2) (Catchment) The natural or disturbed unit of land on which all of the water that falls (or emanates from springs or melts from snowpacks), collects by gravity, and fails to evaporate, runs off via a common outlet. (3) All lands enclosed by a continuous hydrologic drainage divide and lying upslope from a specified point on a stream; a region or area bounded peripherally by a water parting and draining ultimately to a particular water course or body of water. Also referred to as *Water Basin* or *Drainage Basin*. (4) A ridge of relatively high land dividing two areas that are drained by different river systems. Also referred to as *Water Parting*.

Watershed Management — (1) The planned manipulation of one or more factors of the natural or disturbed drainage so as to effect a desired change in or maintain a desired condition of the water resource. (2) The analysis, protection, development, operation or maintenance of the land, vegetation and water resources of a drainage basin for the conservation of all its resources for the benefit of its residents. Watershed management for water production is concerned with the quality and timing of the water which is produced. Also referred to as *Water Management* and *Basin Management*.

Watershed Planning — The formulation of a plan, based on the concept of a *Watershed*, a *Water Basin*, a *Hydrologic Region*, or a *Hydrologic Study Area (HSA)*, with the intent to assess climatological conditions, inventory existing ground and surface water resources, determine current water uses, project future socioeconomic and environmental demands for those resources, and explore feasible water-balancing options, so as to maximize the benefits to the inhabitants of a study area while simultaneously preserving and protecting the region's wildlife, habitat, and environmental conditions.

Watershed Project — A comprehensive program of structural and nonstructural measures to preserve or restore a water shed to good hydrologic condition. These measures may include detention reservoirs, dikes, channels, contour trenches, terraces, furrows, gully plugs, revegetation, and possibly other practices to reduce flood peaks and sediment production.

Watershed Protection — The treatment of watershed lands in accordance with such predetermined objectives as the control of erosion, stream flow, silting floods, and water, forage, or timber yield. Also see *Watershed Planning*.

Watershed Protection Approach (WPA) — A type of pollution management program supported by the *U.S. Environmental Protection Agency (EPA)* as being the most effective mechanism for achieving clean water and healthy, sustainable ecosystems throughout the United States. The WPA is a "placed-based" strategy that integrates water quality management activities within hydrologically defined drainage basins or watersheds as opposed to using conventional, politically-defined boundaries. The WPA allows stakeholders to tailor corrective actions to local concerns within the coordinated framework of a state, Tribal, and national water program. In addition, an emphasis on public participation provides the opportunity to incorporate environmental justice issues into watershed management. Six basic objectives form the general foundations of EPA's watershed protection process:

- [1] identifying critical watersheds with EPA and state participation;
- [2] clearly defining the problems, general causes, and specific sources of risks and impairments to the watershed;
- [3] developing potential pollution prevention and control strategies;
- [4] implementing point and nonpoint source controls;
- [5] developing scientifically valid and practical indicators for gauging and reducing the risks in the watershed; and
- [6] developing ecological criteria that states may use in formulating future watershed protection standards.

Water Table — (1) The surface of a ground water body at which the water is at atmospheric pressure; the upper surface of the ground water reservoir. (2) The upper surface of the *Saturated Zone* that determines the water level in a well in an *Unconfined Aquifer*. (3) The level of ground water; the upper surface of the *Zone of Saturation* for underground water. It is an irregular surface with a slope or shape determined by the quantity of ground water and the permeability of the earth material. In general, it is highest beneath hills and mountains and lowest beneath valleys. Also referred to as *Ground Water Table*.

Water-Table Aquifer — An *Unconfined Aquifer* within which is found the water table.

Water Table, Perched — The surface of a local zone of saturation held above the main body of ground water by an impermeable layer or stratum, usually clay, and separated from the main body of ground water by an unsaturated zone.

Water Use, Types — The use of water may be classified by specific types according to distinctive uses, such as the following:

- [1] Commercial Water Use
- [2] Domestic Water Use
- [3] Hydroelectric Power Water Use
- [4] Irrigation Water Use
- [5] Livestock Water Use
- [6] Mining Water Use
- [7] Navigational Water Use
- [8] Other Water Use
- [9] Public Water Use (same as *Utility Water Use*)

[10] Residential Water Use (same as *Domestic Water Use*)
[11] Rural Water Use
[12] Thermoelectric Power Water Use

Water Well — An excavation where the intended use is for location, acquisition, development, or artificial recharge of ground water.

Water Witch — A person who predicts the presence of underground water with hand-held tools such as forked twigs (*Divining Rod*) or metal rods. The *United States Geological Survey (USGS)* and the National Water Well Association do not advise against using a water witch to search for ground water, but say that there is no scientific basis for the belief in water witchery. Also see *Douse* (also *Dowse* or *Dowsing*).

Water Withdrawal — Water removed from ground water or surface water for use.

Water Yield — Runoff, including ground water outflow that appears in the stream, plus ground water outflow that leaves the basin underground. Water yield is the precipitation minus the *Evapotranspiration*.

Well (Water) — (1) An excavation (pit, hole, tunnel), generally cylindrical in form and often walled in, drilled, dug, driven, bored, or jetted into the ground to such a depth as to penetrate water-yielding geologic material and allow the water to flow or to be pumped to the surface. (2) An artificial excavation put down by any method for the purposes of withdrawing water from the underground aquifers. A bored, drilled, or driven shaft, or a dug hole whose depth is greater than the largest surface dimension and whose purpose is to reach underground water supplies or oil, or to store or bury fluids below ground.

Well Capacity (or Potential Yield) — The maximum rate at which a well will yield water under a stipulated set of conditions, such as a given drawdown, pump, and motor or engine size. Well capacity may be expressed in terms of gallons per minute, cubic feet per second, or other similar units.

Well, Fully Penetrating — A well drilled to the bottom of an aquifer, constructed in such a way that it withdraws water from the entire thickness of the aquifer.

Well Function — The mathematical function by means of which the unsteady drawdown can be computed at a given point in an aquifer at a given time due to a given constant rate of pumping from a well.

Wellhead — (1) The source of a well or stream. (2) A principal source; a *Fountainhead*. (3) The physical structure, facility, or device at the land surface from or through which ground water flows or is pumped from subsurface, water-bearing formations.

Well Interference — The effects of neighboring pumping wells on the discharge and drawdown at a particular pumping well.

Well Logs — A record that is kept during well drilling of the various formations and rock materials and the depths at which they are encountered. Synonymous with *Water Well Report*.

Well Screen — A filtering device used to keep sediment from entering a water well.

Well Stimulation — Cleaning, enlarging, or increasing the pore space of a well used for the *Injection* of fluids into subsurface geological strata.

Well Yield — The volume of water discharged from a well in gallons per minute or cubic meters per day.

Wet Adiabatic Lapse Rate — The rate of temperature decrease as a parcel of air saturated with water rises and the pressure decreases, given by:

ãs = –*dT*/*dz*

where:*dT* is the temperature change;*dz* is the change in altitude; and ãs is the saturated (wet) *Adiabatic Lapse Rate*.

Because moisture is condensing in the rising parcel of air and releasing latent heat, the temperature drop with increasing altitude is less than the (dry) adiabatic lapse rate, or about 0.6EC per 100 meters (3.3EF per 1,000 feet). The rate assumes that there is no exchange of heat between the parcel and the surrounding air by conduction or mixing.

Wetland Banking — A term used to describe actions required to be taken on the part of developers to mitigate and replace the loss of wetlands. Through various federal and state regulations governing land use on wetlands, when impacts to wetlands cannot be avoided or minimized, wetlands must be replaced. The replacement process allows for the creation or restoration of any number of wetlands to provide replacement credit for future wetlands impacts or debits, i.e., reductions in existing wetlands. Wetland banking not only insures successful wetland restoration, but also typically requires that replacement occurs before targeted wetlands are removed, thereby at least temporarily increasing the overall amount of wetlands. Also, wetland banking credits may frequently be sold in an open market arrangement thereby facilitating both more efficient land use planning and habitat preservation. Wetland creation under the wetland banking process also allows planners to target wetland construction in precisely those areas and watersheds which have the greatest need for the benefits of wetlands, e.g., flood storage, water quality improvement, habitat creation or preservation, etc.

Wetland Mitigation — Unlike *Wetland Banking* or *Wetland "Clumping" (Aggregation)*, Wetland Mitigation deals with those actions taken to avoid, minimize, or deter the need to adversely affect existing *Wetlands* and similar habitats. Wetland mitigation deals in three fundamental areas:

[1] ***Avoidance*** — involving a comprehensive evaluation of practicable alternatives to the proposed actions to demonstrate that the least environmentally damaging practicable alternative that satisfies the project purpose has been selected;

[2] ***Minimization*** — where some actions adversely affecting existing wetland areas are unavoidable, then steps must taken to insure that such adverse effects are minimized to every extent possible; and

[3] ***Compensatory Mitigation*** **—** in the case of extensive or substantive wetland impacts, then alternative actions must be taken in conjunction to the proposed project to insure that new areas are added to existing wetland inventory (banking) and/or that alternative and comparable wetland habitat is created (clumping and aggregation).

Wetland banking and clumping (aggregation) concepts are only involved in the compensatory mitigation stage, and possibly the minimization of impacts stage, when all other actions have failed to prevent substantive impacts on existing wetlands. Also see *Wetland Mitigation Bank*.

Wetland Mitigation Bank — An arrangement whereby private developers buy credits of an acre or so each for the right to drain and build on *Wetlands* on their own property. The practice is generally permitted under *Section 404* of the federal *Clean Water Act (CWA)*, which requires developers to provide an equal amount of *Constructed Wetlands* for each acre of wetland destroyed. As an additional requirement, the mitigating wetlands must be created on land that historically was a wetland at one time or another. Developers are also required to both restore and maintain the mitigating wetlands. In states without enabling legislation for such banks, jurisdiction falls under the authority of the *U.S. Army Corps of Engineers (COE)*.

Wetlands, also Wetland (General) — Wetlands are those areas where water saturation is the dominant factor determining the nature of soil development and the types of plant and animal communities living in the surrounding environment. The identification of wetlands and associated habitats is regulated by complex federal legislation. The *U.S. Environmental Protection Agency (EPA)*, the *U.S. Army Corps of Engineers (COE)*, the (U.S. Department of Agriculture) *Natural Resources Conservation Service (NRCS)* (formerly the *Soil Conservation Service — SCS*), and the (Department of the Interior) *U.S. Fish and Wildlife Service (USFWS)*, have developed definitions of wetlands in response to their regulatory responsibilities. The single feature that all wetlands have in common is a soil or substrate that is saturated with water during at least a part of the growing season. These saturated conditions control the types of plants and animals that live in these areas. Other common names for wetlands are *Sloughs*, *Ponds*, *Swamps*, *Bogs*, and *Marshes*. Basically, all definitions of wetlands require that one or more attributes be met:

[1] ***Wetland Hydrology*** — At some point of time in the growing season the substrate is periodically or permanently saturated with or covered by water;
[2] ***Hydrophytic Vegetation*** — At least periodically, the land supports predominantly water-loving plants such as cattails, rushes, or sedges;
[3] ***Hydric Soils*** — The area contains undrained, wet soil which is anaerobic, or lacks oxygen in the upper levels.

Wetlands (COE and EPA) — (Regulatory) The *U.S. Army Corps of Engineers (COE)* and the *U.S. Environmental Protection Agency (EPA)* have adopted a regulatory definition for administering the Section 404 permit program of the *Clean Water Act (CWA)* as follows: [Wetlands are] those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas.

Wetlands (NRCS) — (Technical) The (U.S. Department of Agriculture) *Natural Resources Conservation Service (NRCS)* (formerly the *Soil Conservation Service — SCS*) uses the following definition for identifying wetlands on agricultural land in assessing farmer eligibility for U.S. Department of Agriculture program benefits under the "Swampbuster" provision of the *Food Security Act (FSA)* of 1985. As amended in 1990, the FSA states that the term "wetland," except when such term is part of the term "converted wetland," means land that

[1] has a predominance of hydric soils;
[2] is inundated or saturated by surface or ground water at a frequency and duration sufficient to support a prevalence of hydrophytic vegetation typically adapted for life in saturated soil conditions; and
[3] under normal circumstances does support a prevalence of such vegetation. For purposes of the 1990 amended FSA, and any other act, this term shall not include lands in Alaska identified as having high potential for agricultural development which have a predominance of permafrost soils.

Wetlands (USFWS) — (Regulatory and Environmental) The *U.S. Fish and Wildlife Service (USFWS)* has defined wetlands as follows: Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface, or the land is covered by shallow water. For purposes of this classification, wetlands must have one or more of the following three attributes:

[1] at least periodically, the land supports predominantly *Hydrophytes* (*Hydrophytic Vegetation*);
[2] the substrate is predominantly undrained *Hydric Soils*; and
[3] the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year (*Wetland Hydrology*).The term wetland includes a variety of areas that fall into one of five categories:

[1] areas with hydrophytes and hydric soils, such as those commonly known as marshes, swamps, and bogs;
[2] areas without hydrophytes but with hydric soils — for example, flats where drastic fluctuation in water level, wave action, turbidity, or high concentration of salts may prevent the growth of hydrophytes;
[3] areas with hydrophytes but nonhydric soils, such as margins of impoundments or excavations where hydrophytes have become established but hydric soils have not yet developed;
[4] areas without soils but with hydrophytes such as the seaweed-covered portion of rocky shores; and
[5] wetlands without soil and without hydrophytes, such as gravel beaches or rocky shores without vegetation. While *Wetlands* and *Deepwater Habitats* are defined separately, the USFWS approach to a definition views these two regimes as a continuum of an ecological classification system, and therefore both must be considered in an ecological approach to classification. The deepwater habitat/wetland classification includes five major systems:
    [1] Marine
    [2] Estuarine
    [3] Riverine
    [4] Lacustrine
    [5] Palustrine The first four of these classifications include both wetland and deepwater habitats, but only the Palustrine System includes only wetland habitats. Wetlands have been found to provide many valuable functions to include ground water recharge and discharge, flood flow alteration, sediment stabilization, sediment and toxicant retention, nutrient removal and/or transformation, diverse wildlife and aquatic habitats, and recreation.

Wetlands, Benefits — Since colonial times, an estimated 54 percent of the total wetland areas in the United States have vanished. In a major study by the U.S. Department of the Interior, *U.S. Fish and Wildlife Service (USFWS)*, during the 20 years from the mid-1950s to the mid-1970s, such losses averaged 458,000 acres each year. More recent studies have clearly demonstrated that wetlands are precious ecological resources that nurture wildlife, purify polluted waters, check the destructive power of floods and storms, and provide a variety of recreational activities. The following constitutes a listing of some of the major benefits of these ecological systems:

[1] ***Waterfowl Breeding*** — Over 12 million ducks nest and breed annually in northern U.S. wetlands. This area, when combined with similar habitats in the Canadian prairies, accounts for 60–70 percent of the continent's breeding duck population.
[2] ***Habitat for Waterfowl and Other Birds*** — Some 2½ million of the 3 million mallards in the Mississippi Flyway and nearly 100 percent of our 4 million wood ducks spend the winter in flooded bottomland forests and marshlands throughout the south.
[3] ***Biological Diversity and Wildlife Habitat*** — Wetlands provide food and shelter for a great variety of fur-bearing animals and other kinds of wildlife.
[4] ***Habitat for Threatened and Endangered Species*** — At least one-third of the nation's threatened or endangered species live in wetland areas.
[5] ***Marine Fish and Shellfish Production*** — Roughly two-thirds of our shellfish and important commercial and sport species of marine fish rely on coastal marshes for spawning and nursery grounds.
[6] ***Freshwater Fish*** — Many of the 4½ million acres of open water areas found in our inland wetlands are ideal habitat for such sought-after species as bass, catfish, pike, bluegill, sunfish, and crappie.
[7] ***Timber Production*** — Wetlands, especially bottomland forests, are rich sources of timber.
[8] ***Flood Control*** — Wetlands temporarily store flood waters and thus reduce downstream losses

of life and property.

[9] ***Water Quality*** — Wetlands act as natural water purification mechanisms. They remove silt and filter out and absorb many pollutants such as waterborne chemicals and nutrients.

[10] ***Saltwater Intrusion Control*** — The flow of freshwater through wetlands creates ground water pressure that prevents saltwater from invading public water supplies.

[11] ***Shoreline Stabilization*** — By absorbing wave and storm energy and slowing water currents, wetland vegetation serves as a buffer against shoreline erosion.

[12] ***Reduction of Coastal Storm Damage*** — Coastal marshes and mangrove stands help to blunt the force of major storms.

[13] ***Recreational Opportunities*** — Wetlands offer unspoiled, open space for the aesthetic enjoyment of nature as well as activities such as hiking, fishing, hunting, photography, and environmental education.

[14] ***Ground water Recharge and Discharge*** — Water standing in or slowing moving through wetland areas provides important recharge opportunities to ground waters while water taken from the ground, for example through mine *Dewatering* operations, is frequently released into wetland areas for further treatment of potentially harmful substances.

[15] ***Sediment Stabilization*** — Through their ability to slow the flow of water and the filtering capabilities of associated flora, wetlands provide important functions for the removal and trapping of sediment and other materials in water affecting its *Turbidity* and its levels of *Dissolved* and *Suspended Solids*.

[16] ***Sediment and Toxicant Retention*** — Wetland vegetation inherently provides important functions in the retention and absorption of various dissolved and suspended materials in the waters entering these areas as well as providing for the removal of various chemical and toxic substances as well as some heavy metals.

[17] ***Nutrient Removal and/or Transformation*** — Wetland vegetation readily absorbs for its own use various nitrate and phosphate-based nutrients in the water, thereby increasing *Dissolved Oxygen* levels and the quality of downstream waters.

Wetlands, Constructed — (1) Wetlands constructed by man either as part of a *Wetland Banking*, *Wetland Clumping (Aggregation)*, or *Wetland Mitigation* program, or to achieve some other environmental preservation or restoration program. (2) (Water Quality) Wetlands constructed specifically for the purpose of treating waste water effluent before re-entering a stream or other body of water or being allowed to percolate into the ground water. Also see *Lagoon*.

Wetlands, Jurisdictional — An area that meets the criteria established by the *U.S. Army Corps of Engineers (Corps or COE)* for a *Wetlands* (as set forth in their ***Wetlands Delineation Manual***). Such areas come under the jurisdiction of the Corps of Engineers for permitting certain actions such as dredge and fill operations. See *Wetlands*. [Also see ***Classification of Wetlands and Deepwater Habitats of the United States***, U.S. Department of the Interior, Fish and Wildlife Service (USFWS). Appendix D–2 presents a summarization of this Wetland and Deepwater Habitat Classification System based upon USFWS criteria.]

Wetlands, Palustrine — Wetlands dominated by plants that persist throughout the year or the growing season. These areas are what most people think of when they see the term “wetland”, and include marshes, swamps, bogs, and wet meadows. Palustrine wetlands may be dominated by subtidal, permanently and intermittently flood areas (*Rock Bottom*, *Unconsolidated Bottom*, *Aquatic Bed*, and *Unconsolidated Shore*), mosses and lichens (*Moss-Lichen Wetlands*), erect, rooted, herbaceous hydrophytes such as sedges, rushes, grasses, cattails, and bulrushes (*Emergent Wetlands*), woody vegetation less than 6 meters (20 feet) tall (*Scrub-Shrub Wetlands*), or woody vegetation that is 6 meters (20 feet) or taller (*Forested Wetlands*). Palustrine wetlands may occur in the vicinity of springs, seeps, and flowing wells, on the floodplains of streams and creeks, around the shores of some lakes and reservoirs, adjacent to irrigation canals, and in areas influenced by irrigation or irrigation runoff. The following presents a more detailed description of these wetland classes:

[1] ***Rock Bottom*** — The Class Rock Bottom includes all wetlands and deepwater habitats with substrates having an areal cover of stones, boulders, or bedrock 75 percent or greater and vegetative cover of less than 30 percent. Water regimes are restricted to subtidal, permanently flooded, intermittently exposed, and semipermanently flooded. The rock substrate of the rocky benthic or bottom zone is one of the most important factors in determining the abundance, variety, and distribution of organisms. The stability of the bottom allows a rich assemblage of plants and animals to develop. Rock bottoms are usually high-energy habitats with well-aerated waters.

[2] ***Unconsolidated Bottom*** — The Class Unconsolidated Bottom includes all wetland and deepwater habitats with at least 25 percent cover of particles smaller than stones, and a vegetative cover less than 30 percent. Water regimes are restricted to subtidal, permanently flooded, intermittently exposed, and semipermanently flooded. Unconsolidated bottoms are characterized by the lack of large stable surfaces for plant and animal attachment. They are usually found in areas with lower energy than rock bottoms, and may be very unstable.

[3] ***Aquatic Bed*** — The Class Aquatic Bed includes wetlands and deepwater habitats dominated by plants that grow principally on or below the surface of the water for most of the growing season in most years. Water regimes include subtidal, irregularly exposed, regularly flooded, permanently flooded, intermittently exposed, semipermanently flooded, and seasonally flooded. Aquatic beds represent a diverse group of plant communities that requires surface water for optimum growth and reproduction. They are best developed in relatively permanent water or under conditions of repeated flooding.

[4] ***Unconsolidated Shore*** — The Class Unconsolidated Shore includes all wetland habitats having three characteristics: (1) unconsolidated substrates with less than 75 percent areal cover of stones, boulders, or bedrock; (2) less than 30 percent areal cover of vegetation other than pioneering plants; and (3) any of the following water regimes: irregularly exposed, regularly flooded, irregularly flooded, seasonally flooded, temporarily flooded, intermittently flooded, saturated, or artificially flooded. Unconsolidated shores are characterized by substrates lacking vegetation except for pioneering plants that become established during brief periods when growing conditions are favorable. Erosion and deposition by waves and currents produce a number of landforms such as beaches, bars, and flats, all of which are included in this wetland class.

[5] ***Moss-Lichen Wetlands*** — The Moss-Lichen Wetland Class includes areas where mosses or lichens cover substrates other than rock and where emergents, shrubs, or trees make up less than 30 percent of the areal cover. The only water regime is saturated. Mosses and lichens are important components of the flora in many wetlands, especially in the north, but these plants usually form a ground cover under a dominant layer of trees, shrubs, or emergents. In some instances higher order plants are uncommon and mosses or lichens dominate the flora. Such Moss-Lichen Wetlands are not common, even in the northern United States where they occur most frequently.

[6] ***Emergent Wetlands*** — The Emergent Wetland Class is characterized by erect, rooted, herbaceous hydrophytes, excluding mosses and lichens. This vegetation is present for most of the growing season in most years. These wetlands are usually dominated by perennial plants. All water regimes are included except sub-tidal and irregularly exposed. In areas with relatively stable climatic conditions, Emergent Wetlands maintain the same appearance year after year. In other areas, such as the prairies of the central United States, violent climatic fluctuations cause them to revert to an open water phase in some years. Emergent Wetlands are found throughout the United States and occur in all Wetland Classification Systems except the Marine. Emergent Wetlands are known by many names, including marsh, meadow, fen, prairie pothole, slough, and savanna.

[7] ***Scrub-Shrub Wetlands*** — The Class Scrub-Shrub Wetland includes areas dominated by woody vegetation less than 6 meters (20 feet) tall. The species include true shrubs, young trees, and trees or shrubs that are small or stunted because of environmental conditions. All water regimes except sub-tidal are included. Scrub-Shrub Wetlands may represent a successional stage leading to Forested Wetland, or they may be relatively stable communities. They occur only in the Estuarine and Palustrine Wetland Systems, but are one of the most widespread classes in the United States. Scrub-Shrub Wetlands are known by many names, such as shrub swamp, shrub carr, and pocosin (dismal).

[8] ***Forested Wetlands*** — The Class Forested Wetland is characterized by woody vegetation that is 6 meters (20 feet) tall or taller. All water regimes are included except sub-tidal. Forested Wetlands are most common in the eastern United States and in those sections of the West where moisture is relatively abundant, particularly along rivers and in the mountains. They occur only in the Palustrine and Estuarine Wetland Systems and normally possess an overstory of trees, an understory of young trees or shrubs, and a herbaceous layer. Forested Wetlands in the Estuarine System, which include the mangrove forests of Florida, Puerto Rico, and the Virgin Islands, are known by such names as swamps, hammocks, heads, and bottoms. These names often occur in combination with species names or plant associations such as cedar swamp or bottomland hardwoods.

Wild and Scenic Rivers (Act) — A national system established under the Wild and Scenic Rivers Act of free-flowing rivers and streams which possess one or more of the following outstanding remarkable values: (1) scenic; (2) recreational; (3) geological; (4) fish and wildlife; (5) historic or cultural; or (6) other values, including biological or ecological. There are three classifications of rivers or river segments – wild, scenic and recreational – with classifications based on the condition of the river and the adjacent lands at the time of the study. The act defines these classifications as follows:

(1) ***Wild River*** – Those rivers or sections of rivers that are free of impoundments and generally inaccessible except by trail, with watersheds or shorelines essentially primitive and water unpolluted, representing vestiges of rivers in primitive America;

(2) ***Scenic River*** – Those rivers or sections of rivers that are free of impoundments, with shorelines or watersheds still largely primitive and shorelines largely undeveloped, but accessible in places by roads;

(3) ***Recreational River*** – Those rivers or sections of rivers that are readily accessible by road or railroad that may have some development along their shorelines, and that may have undergone some impoundments or diversions in the past. Also see *Wild Rivers*, *Scenic Rivers*, and *Recreational Rivers* for permitted activities and restrictions.

Wild Rivers — A classification under the national *Wild and Scenic Rivers Act* to include those rivers or sections of rivers that are free of impoundments and generally inaccessible except by trail, with watersheds or shorelines essentially primitive and water unpolluted, representing vestiges of rivers in primitive America. The following represents restrictions applying to such designated rivers:

(1) ***Timber Production*** – Cutting of trees is not permitted unless needed in association with a primitive recreation experience (i.e., clearing for trails and protection of users) or to protect the environment (i.e., fire control). Timber outside the boundary but within the visual corridors will be managed and harvested in a manner to provide special emphasis to visual quality.

(2) ***Water Supply*** – All water supply dams and major diversions are prohibited.

(3) ***Hydroelectric Power*** – No development of hydroelectric power facilities would be permitted.

(4) ***Flood Control*** – No flood control dams, levees, or other works are allowed in the channel or river corridor. The natural appearance and essentially primitive character of the river areas must be maintained.

(5) *Mining* – New mining claims and mineral leases are prohibited within one-quarter mile of the river. Valid claims would not be abrogated. Subject to regulations (i.e., 36 CFR 228) that the Secretaries of Agricultural and Interior may prescribe to protect the rivers included in the National System, other existing mining activity must be conducted in a way that minimizes surface disturbance, sedimentation, and visual impairment. Reasonable access will be permitted.

(6) *Road Construction* – No roads or other provisions for overland motorized travel would be permitted within a narrow incised river valley or, if the river valley is broad, within one-quarter mile of the river bank. A few inconspicuous roads leading to the boundary of the river area at the time of the study will not disqualify wild river classification. Also, unobtrusive trail bridges could be allowed.

(7) *Agriculture* – Agricultural use is restricted to a limited amount of domestic livestock grazing and hay production to the extent currently practiced. Row crops are prohibited.

(8) *Recreational Development* – Major public-use areas, such as large campgrounds, interpretive centers, or administrative headquarters are located outside the wild river area. Simple comfort and convenience facilities, such as fireplaces or shelters may be provided as necessary within the river area. These should harmonized with the surroundings.

(9) *Structures* – A few minor existing structures could be allowed assuming such structures are compatible with the essentially primitive and natural values of the viewshed. New structures would not be allowed except in rare instances to achieve management objectives. Structures and activities associated with fisheries enhancement programs could be allowed.

(10) *Utilities* – New transmission lines, gas lines, water lines, etc., are discouraged. Where no reasonable alternative exists, additional or new facilities should be restricted to existing right-of-way. Where new rights-of-ways are indicated, the scenic, recreation, and fish and wildlife values must be evaluated in the selection of the site.

(11) *Motorized Travel* – Motorized travel on land or water could be permitted, but is generally not compatible with this classification.

Wilderness — Undeveloped land and associated water resources retaining their primeval character and influence, without permanent improvements or human habitation, which is protected and managed so as to preserve its natural condition and that (1) generally appears to have been affected primarily by the forces of nature with the imprint of man's work substantially unnoticeable; (2) has outstanding opportunities for solitude or a primitive and unconfined type of recreation; (3) is of sufficient size so as to make practical its preservation and use in an unimpaired condition; and (4) may also contain ecological, geological, or other features of scientific, educational, scenic, or historical value.

Wilderness Act — A 1964 Act of Congress which established federal *Wilderness Areas*. As defined under this act, wilderness is undeveloped federal land without permanent improvements or human habitation; is protected and managed so as to preserve its natural conditions; has outstanding opportunities for solitude or primitive recreation; has at least 5,000 acres or is of sufficient size to make practical its condition; and may contain features of scientific, educational, scenic, or historical value as well as ecologic and geologic interest.

Wilderness Area — Land where the effects of man are not apparent. Large tracts of land that are set aside and allowed to develop without the intervention of man. Such activities as the construction of roads, development of recreational facilities, removal of trees, or hunting are prohibited. The 1964 *Wilderness Act* allows the U.S. government to set aside sections within the national forests, national parks, and national wildlife refuges as wilderness areas. Currently there are about 450 such areas within the United States totaling 90 million acres, two-thirds of which are in Alaska.

Wildlife Refuge — An area designated for the protection of wild animals, within which hunting and fishing are either prohibited or strictly controlled.

Wisconsin — (Geology) Of or relating to one of the glacial stages of the *Pleistocene* epoch which occurred in North America, which consisted of the *Nebraskan* (first stage), *Kansan* (second stage), *Illinoian* (third stage), and *Wisconsin* (fourth stage).

Witch — To use a divining rod to find underground water or minerals; *Dowse*.

Withdrawal, Water — Water diverted from the ground or diverted from a surface-water source for use. It may be *Consumptively* or *Nonconsumptively* used, beneficially or nonbeneficially used, or returned in part for reuse.

-X-

Xeric — Describing an organism that requires little moisture or a habitat containing little moisture; dry environmental conditions as compared to *Hydric* (wet environmental conditions) and *Mesic* (moderate environmental conditions).

X–Year Flood — The magnitude of a flood which has a 1-in-*X* chance of being exceeded in any future one-year period. For example, a 2–year flood would have a 1-in-2 (50 percent) chance of exceedence in any one year; a 10–year flood, a 1-in-10 (10 percent) chance; a 100–year flood, a 1-in-100 (1 percent) chance, etc. These values are statistically derived, using past flood records. They are used for many reasons, but especially for engineering drainage and water supply structures. As the occurrence of floods is random in time, there is no guarantee that there will not be two *X*–year floods within a given year. There is also no guarantee that there will be an *X*–year flood in an *X*–year time period, or even in a 2*X* period. Finally, an *X–Year, Y–Duration Rain* will not necessarily produce an *X*–year flood. Storm duration and intensity, antecedent moisture and other conditions can cause *X*–year rains to produce more or less than *X*–year floods. For example, a 100–year, 6–hour rain over a very dry basin may only produce a 2–year flood, whereas a 5–year, 6–hour rain over a saturated or burned basin could cause a 100–year flood. Also see *Hundred Year Flood*.

X–Year, Y–Duration Rain — The magnitude of rainfall which has a 1-in-*X* chance of being exceeded in any future one-year time period with a duration of Y [hours or days]. *X*–year rains must have durations associated with them; e.g., 25–year, 6–hour rain, 50–year, 24–hour rain, 100–year, 10–day rain, etc. These values are statistically derived using past rainfall records. Also referred to as *Rainfall Duration-Frequency*. Also see *X–Year Flood*.

-Y-

Yellowboy — Iron oxide flocculent (clumps of solids in waste or water); usually observed as orange-yellow deposits in surface streams with excess iron content. Characterized by unsightly yellowish precipitates of ferric sulfate and hydroxide and frequently observed in many streams polluted by mine drainage.

Yield — (1) The quantity of water expressed either as a continuous rate of flow (e.g., cubic feet per second – cfs) or as a volume per unit of time (e.g., acre-feet per year – AFY) which can be collected for a given use or uses from surface- or ground-water sources on a watershed. The yield may vary with the use proposed, with the plan of development, and also with economic considerations. (2) Total runoff. (3) The streamflow in a given interval of time derived from a unit area of watershed. It is determined by dividing the observed streamflow at a given location by the drainage area above that location and is usually expressed in cubic feet per second per square mile.

Yield, Average Annual — The average annual supply of water produced by a given stream or water development.

Yield, Firm — The maximum annual supply of a given water development that is expected to be available on demand, with the understanding that lower yields will occur in accordance with a predetermined schedule or probability. Sometimes referred to as *Dependable Yield*.

Yield, Gross (Water) — (1) The available water runoff, both surface and subsurface, prior to use by man's activities, use by phreatophytes, or evaporation from free water surfaces. (2) The estimated or actual available water, both surface and sub-surface, prior to agricultural and phreatophytic use. Generally, this water yield is estimated for a stream or streams at a point above the highest diversion for the main body of irrigated land on a flood plain of a valley.

Yield, Perennial — The amount of usable water of a ground-water reservoir that can be economically withdrawn and consumed each year for an indefinite period of time. It cannot exceed the sum of the *Natural Recharge*, the *Artificial* (or *Induced*) *Recharge*, and the *Incidental Recharge* without causing depletion of the ground water reservoir. Also referred to as *Safe Yield*.

Yield, Safe — With reference to either a surface- or ground-water supply, the rate of diversion or extraction for *Consumptive Use* which can be maintained indefinitely, within the limits of economic feasibility, under specified conditions of water-supply development.

Young — (Geology) Being of an early stage in a geologic cycle. Used of bodies of water and land formations.

-Z-

Zeolite — (1) (Geology) Any of various hydrous silicates that are analogous in composition to the feldspars, occur as secondary minerals in cavities of lavas, and can act as an ion-exchanger. (2) (Chemistry) Also, any of various natural or synthesized silicates of similar structure used especially in water softening and as an adsorbent and catalyst. (3) (Water Quality) A type of ion exchange material used to soften water. Natural zeolites are siliceous compounds which remove calcium and magnesium from hard water and replace them with sodium. Synthetic or organic zeolites are ion exchange materials which remove calcium or magnesium and replace them with either sodium or hydrogen.

Zero Discharge — The goal, in the preamble to the *Clean Water Act (CWA)*, of zero pollutants in water discharges.

Zone of Accumulation — The combination of the *A-Horizon* and the *B-Horizon*.

Zone of Aeration — The comparatively dry soil or rock located between the ground surface and the top of the *Water Table*. A zone immediately below the surface of the ground, in which the openings are partially filled with air, and partially with water trapped by molecular attraction. Generally subdivided into: (a) belt of soil moisture; (b) intermediate belt; and (c) capillary fringe. Also referred to as the *Unsaturated Zone* or the *Vadose Zone*.

Zone of Contribution (ZOC) — The area surrounding a pumping well that encompasses all areas or features that supply ground-water recharge to the well.

Zone of Eluviation — The two uppermost zones in the soil profile, consisting of the *A–Horizon*, from which soluble *Salts* and *Colloids* are leached, and in which organic matter has accumulated and generally constitutes the most fertile soil layer, and the *B–Horizon*, or the lower soil zone which is enriched by the deposition or precipitation of material from the overlying zone, or A–horizon. Also referred to as the *Solum*.

Zone of Influence (ZOI) — (1) (Hydrologic) The area surrounding a pumping well within which the water table or *Potentiometric Surfaces* has been changed due to ground-water withdrawal. (2) (Environmental) The geographic area whose social, economic, and/or environmental conditions is significantly affected by changes in the study area.

****Modified after Nevada Division of Water Resources, Department of Conservation and Natural Resources and Michigan Department of Environmental Quality***

Appendix B

SUGGESTED MINIMUM REQUIREMENTS FOR PROBABLE HYDROLOGIC CONSEQUENCES (PHC) DETERMINATION

I. IMPACT ANALYSIS
- A. Presence or absence of acid-forming or other toxic-forming materials that could contaminate surface or ground water
  - 1. Overburden
    - a. Chemical properties (acid/toxic/alkaline potential)
    - b. Percentage of potentially acid- and toxic-forming materials relative to alkaline and non-acidic/non-toxic strata
    - c. Physical properties (i.e. conductivity of spoil)
  - 2. Coal processing waste
    - a. In pit disposal
    - b. Slurry impoundments/pipelines
    - c. Refuse piles
  - 3. Disposal of non-coal waste
  - 4. Disposal of "imported" material (e.g. CCBs, sediment pond sludge, landfills - solid waste)
  - 5. Coal-bed methane recovery
- B. The effect of the proposed operation on sediment yield from the disturbed area during mining and reclamation and after liability release
  - 1. Identify on-site erosion concerns
  - 2. Predict sediment yields from mine plan area both during and after control structures are removed
- C. Short-term and long-term effects of the operation on surface and ground water with regard to total dissolved solids, specific conductivity, total suspended solids, iron, manganese, pH, acidity, alkalinity, water levels/flow and any other parameters pertinent to the area and those included in the baseline testing
  - 1. Short-term impacts (during mining and reclamation)
    - a. Major impacts
    - b. Minor impacts
  - 2. Long-term impacts (post mining and at bond release)
    - a. Major impacts
    - b. Minor impacts
  - 3. Impacts lasting beyond reclamation liability period
    - a. When do changes cease?
    - b. Restoring water table/potentiometric surface
    - c. When do concentrations stop increasing?
    - d. When does water quality return to ambient?
  - 4. Differentiate between on-site and off-site impacts
    - a. On-site: minimize disturbance to hydrologic balance
    - b. Off-site: prevent material damage

D. Possible impact and effects of mining operations on/from existing surface and underground mines (active and inactive) with regard to water quality/quantity

E. Hydrologic consequences specific to underground mining

1. Subsidence

a. Effects on stream flow and quality

b. Effects on ground water (quantity and quality)

2. Mine pools – potential water resource or pollution source?

F. Possible impacts that may cross political boundaries (i.e. state lines)

II. FINDINGS

A. Whether adverse impacts may occur to the hydrologic balance (address possible contamination, diminution, or interruption of surface- or ground-water resources in legitimate use)

B. Whether toxic-forming materials are present that could contaminate surface and/or ground water

C. Whether proposed operation may contaminate, diminish or interrupt current water uses

D. Identify impacts from proposed operation on:

1. Sediment yields

2. Acidity, suspended solids, dissolved solids, etc.

3. Flooding or stream flow alteration

Appendix C

Suggested Minimum Requirements for Hydrologic Reclamation Plan (HRP)

III. Describes plan to meet performance standards in 30 CFR Part 816 including 816.41 (hydrologic balance protection) and 816.43 (diversions)
  - A. Goal: minimize all hydrologic impacts and prevent material damage outside the permit area

IV. Plan must describe preventive and remedial measures that will be used to address **<u>ALL</u>** potential hydrologic impacts identified in the PHC including, but not limited, to:
  - A. AMD
    1. Identify and isolate or otherwise special handle problematic materials
    2. Contingency for temporary water treatment plan
    3. Perpetual water treatment (deep mines)
  - B. Disposal activities (i.e. coal processing waste, CCBs, non-coal waste, etc.)
  - C. Prevention of additional contributions of suspended solids to stream flow using best technology currently available (BTCA)
    1. Control of surface and subsurface drainage
    2. Restoration of approximate pre-mining recharge capacity
       - a. Ensure wetlands, shallow wells and springs are protected
       - b. Mitigate adverse effects of increased infiltration/recharge, if present
  - D. Protection of rights of present water users by providing a specific plan for replacing existing water supplies should they be contaminated, diminished or destroyed by the proposed operation
  - E. Quantitative criteria:
    1. CWA
    2. Effluent limits
    3. TMDLs
    4. Individual state water quality/quantity requirements
    5. Others

V. Surface and ground water monitoring plans
  - A. Parameters for both surface water and ground water
  - B. Sampling locations and rationale for selection
  - C. Sampling frequency and protocol
  - D. Reporting
  - E. How data will be used to determine mining effects on the hydrologic balance

Appendix D

SUGGESTED MINIMUM REQUIREMENTS FOR CUMULATIVE HYDROLOGIC IMPACT ASSESSMENT (CHIA)

VI. INTRODUCTION
- A. Regulatory Basis
- B. Concept of cumulative hydrologic impacts and cumulative impact areas

VII. ELEMENTS OF THE CHIA
- A. Reason for CHIA (new application or significant revision of existing operation)
- B. Cumulative Impact Area (CIA)
  - 1. Definition of a CIA
    - a. The area, including the proposed permit area, within which impacts resulting from the proposed operation may interact with the impacts of all anticipated or existing mining on surface and ground water systems
  - 2. Delineation of working CIA
    - a. Criteria used to include/exclude mining operations of interest
      - (1) First effort – qualitative (tracing watersheds and applying conceptual model of ground water flow)
      - (2) Impact analysis- quantity with model(s) to refine the CIA (Lumb, 1982)
- C. Baseline conditions
  - 1. Surface and ground water quality/quantity
  - 2. Water users and water uses
- D. Identification of hydrologic concerns
  - 1. Surface water
    - a. Changes in flow
    - b. Changes in water chemistry
    - c. Increased sediment load
    - d. Impact on users
  - 2. Ground water
    - a. Aquifer drawdown
    - b. Changes in water chemistry
    - c. Impact on users
- E. Establish material damage criteria
  - 1. Procedure for defining material damage
    - a. Establishing criteria vs. standards vs. thresholds
      - (1) Stress quantitative rather than qualitative (provide an example of both)
    - b. Relation to CWA
    - c. Biologic criteria (biological integrity relative to water quality/quantity)
    - d. Sediment criteria

e. Ground water and surface water criteria (i.e. flow/water level, quality, etc.)
f. Procedure for converting criteria to standards as applicable to guidance document

2. Special cases:
    a. Alluvial valley floor material damage
    b. Subsidence material damage

F. Analyses of cumulative hydrologic impacts
1. PHC life-of-mine impacts for all potential/existing coal mines within the CIA
2. Identify other existing/potential sources of impacts within the CIA:
    a. Logging
    b. Reservoir releases
    c. Coal-bed methane extraction
    d. Trans-basin diversion
    e. Gas wells
    f. Injection wells
    g. Community or industrial effects
    h. Agricultural effects
    i. Non-coal mining (e.g. sand/gravel operations, limestone, etc.)

G. Model cumulative effects of mining impacts:
1. Incorporate non-coal related impacts (if possible)
2. Develop conceptual model
3. Decide what significant impacts need to be modeled (surface/ground water flow and quality)
4. Select model and data to use
5. Determine model nodes (key points, i.e. intakes, water users, significant non-coal mining impacts, etc.)
6. Decide on time frames – short or long term, steady state
7. Decide on seasonal issues (monthly, quarterly, low flow, high flow, etc.)
8. Run model, calibrate, verify, sensitivity analysis
9. Interpret results – compare to baseline
10. Compare to material damage criteria
11. Make decision to:
    a. Approve
    b. Re-do model
    c. Request operator to:
        (1) Change mine plan
        (2) Clean up adjacent mine
        (3) Approach other mines
        (4) Develop mitigation or remedial measures
    d. Change material damage standards
        (1) Approach state agency to change water quality standards
        (2) Mining company can conduct site-specific studies
        (3) Use alternate standards (i.e. biological)
    e. Disapprove – deny permit

H. Findings
    1. Compare predicted impacts to material damage criteria
        a. Are adverse impacts to the hydrologic balance expected due to:
            (1) The planned operations (i.e, mining method, coal processing waste disposal, etc.)?
            (2) Acid- and toxic-forming materials?
            (3) Sediment yields?
            (4) Stream flow alterations?
            (5) Degradation of water quality/quantity
                (a) During mining?
                (b) Post mining?
            (6) Other
    2. Mitigation measures
    3. Sampling plan
    4. Note any special conditions or stipulations that the findings are contingent upon

I. Conclusion (will the addition of the proposed operation to other anticipated or existing mining materially damage the hydrologic balance outside the proposed permit area?)

Appendix E

Suggested Minimum Requirements for Post-Mining Hydrologic Assessment (PHA)

VIII. Bond Release Considerations
- A. Regulatory Basis (Section 519(b)(2))
- B. Hydrologic Balance – Protection/prevention of Material Damage
  - 1. Post-reclamation
    - a. AMD?
    - b. Recharge capacity?
    - c. Surface water
      - (1) Baseline vs. post-reclamation quality/flow rates – trends?
      - (2) Post-reclamation quality vs. water quality standards – trends?
      - (3) Drainage issues?
      - (4) Problems/water-user complaints? If yes:
        - (a) What were CHIA predictions?
        - (b) Variation in mining technique/practice from approved plan?
        - (c) Mitigation?
    - d. Ground water
      - (1) Baseline vs. post-reclamation quality – trends?
      - (2) Post-reclamation quality vs. water quality standards – trends?
      - (3) Water levels – recharge?
      - (4) Seeps?
      - (5) Problems/well complaints? If yes:
        - (a) What were CHIA predictions?
        - (b) Variation in mining technique/practice from approved plan?
        - (c) Mitigation?
  - 2. Recommendation (should permittee be released from final reclamation liability?)

Appendix F

METHODS OF DETERMINING IMPACTS – PROCESSES AND TOOLS

1. **<u>Databases</u>** – Databases are an excellent resource for determining potential impacts to water resources as a result of coal-mining operations. The most relevant database would include the RAs inventory of surface- and ground-water monitoring records collected from the site and other coal or non-coal mining permits near the area of interest. Another major source of ground-water information could include databases from the state's water well agency that maintains inventories of private wells drilled in the area of interest. Another valuable database would include those records from the appropriate state agency responsible for preparing the water quality inventory report pursuant to Section 305(b) of the Federal Water Pollution Control Act.

   Other sources of water databases include:

   - AgNIC is a database of agricultural information resources including information on water.
   - Agricultural Research Service Water Database is a collection of precipitation and streamflow data from small agricultural watersheds in the United States.
   - APIRS Online: The Aquatic, Wetland, and Invasive Plants Database is "a computerized bibliographic database (Copyright University of Florida, 2000) devoted to freshwater aquatic and wetland plants as well as terrestrial and aquatic invasive plants."
   - AWhere by Mud Springs Geographers, Inc. (www.mudsprings.com) is a workforce Geographic Information System (GIS) software package that requires minimal training and is useful to both the casual and power GIS user. This software moves GIS from the lab into the field and boardroom and can be customized. It features a large library of databases and the ability to model climate data. A free trial is available on the website.
   - ChemFinder--Chemical Searching and Information Integration; a chemical database that provides physical property data and 2D chemical structures; also gives access to "the largest single list of chemical information sites (by at least double the size of the next-largest) that we [ChemFinder] are aware of."
   - Drinking Water Research Information Network (DRINK) "is a portal to information on projects funded or performed by water research organizations, government agencies in the U.S., international research organizations and academic institutions focused on drinking water issues. It is a compilation of drinking water project information from partner organizations that creates a single source of ongoing research."
   - EnviroMapper for Water "is a web-based Geographic Information System (GIS) application that dynamically displays information about bodies of water in the United States. This interactive tool allows you to create customized maps that portray the nation's surface waters along with a collection of environmental data."

- Environmental Fate Data Base -- Purposes of the database: "(1) To allow rapid access to all available fate data on a given chemical without having to resort to expensive, time consuming, and inefficient primary literature searches; (2) To identify critical gaps in the available information to facilitate planning of research needs; and (3) To provide a data source for constructing structure-activity correlations for degradability and transport of chemicals in the environment." For more information, see http://www.syrres.com/esc/efdb_info.htm.
- Enviro-Science e-Print Service provides access to "manuscripts of journal articles and book chapters, conference papers, presentations, posters, and selected technical reports in environmental management science."
- Expertise Directories (International Water Resources Association); search or browse to locate water professionals with various areas of expertise.
- Locate Your Watershed is part of the Environmental Protection Agency's Surf Your Watershed site where you can get various types of information--including an Index of Watershed Indicators--about specific watersheds in the United States.
- National Contaminant Occurrence Database "EPA developed the NCOD to satisfy the statutory requirements set by Congress in the 1996 amendments to the Safe Drinking Water Act (SDWA) to maintain a national drinking water contaminant occurrence database using samples data for both regulated and unregulated contaminants in public water systems. This site provides a listing of water sample analytical data that EPA is currently using and has used in the past for analysis, rulemaking, and rule evaluation. The data have been extensively checked for data quality and analyzed for national representative-ness."
- National Environmental Methods Index provides "a mechanism to compare and contrast the performance and relative cost of analytical, test, and sampling methods for environmental monitoring." The index can be used to compare methods based on analyte, media and performance data. NEMI is a project of the Methods and Data Comparability Board, developed with funding from the U.S. Environmental Protection Agency and the U.S. Geological Survey (USGS).
- National Environmental Publications Information System allows you to "search over 11,000 full text, EPA documents online."
- National Hydrography Dataset (NHD) "is a comprehensive set of digital spatial data that contains information about surface water features such as lakes, ponds, streams, rivers, springs and wells. Within the NHD, surface water features are combined to form "reaches," which provide the framework for linking water-related data to the NHD surface water drainage network. These linkages enable the analysis and display of these water-related data in upstream and downstream order."
- National Nutrient Database "stores and analyzes nutrient water quality data and serves as an information resource for states, tribes, and others in establishing scientifically defensible numeric nutrient criteria. It contains ambient data from our Legacy STOrage and RETrieval (STORET) data

system, the US Geological Survey's National Stream Quality Accounting Network (NASQAN) data and National Water Quality Assessment (NAWQA) data, and other relevant sources such as universities and states/tribes. The ultimate use of the data is to derive ecoregional waterbody-specific numeric nutrient criteria. We will also use this database to develop ecoregionally representative nutrient criteria for all waterbodies of the United States."

- National Water Quality Standards Database is a U. S. Environmental Protection Agency database "being developed for the purposes of displaying water quality standards (WQS), including designated uses and criteria, for the Nation's surface waters."
- National Wetlands Inventory provides wetlands maps from the U. S. Fish and Wildlife Service.
- National Wetlands Research Center (NWRC) Publications and Information Products is a database of studies and reports from this organization within the USGS. Note: The database may not display properly when using Netscape (8/24/05).
- Publications Warehouse (USGS) "The reports and thematic maps database currently contains more than 67,000 bibliographic citations [as of 1/13/05], including numbered series begun as early as 1882. Citations and online documents are added regularly. Availability of content ranges from full text to bibliographic citation only."
- Safe Drinking Water Query Form provides access to information about Safe Drinking Water Act violations and enforcement history for public water supplies during the last ten years; see Safe Drinking Water Overview for more information.
- STORET "The U.S. Environmental Protection Agency (EPA) maintains two data management systems containing water quality information for the nation's waters: the Legacy Data Center (LDC), and STORET. The LDC contains historical water quality data dating back to the early part of the 20th century and collected up to the end of 1998. STORET contains data collected beginning in 1999, along with older data that has been properly documented and migrated from the LDC. Both systems contain raw biological, chemical, and physical data on surface and ground water collected by federal, state and local agencies, Indian Tribes, volunteer groups, academics, and others. All 50 States, territories, and jurisdictions of the U.S. are represented in these systems."
- StreamStats "is a Web-based tool that allows users to obtain streamflow statistics, drainage-basin characteristics, and other information for user-selected sites on streams. StreamStats users can choose locations of interest from an interactive map and obtain information for these locations." (Data available for three states as of August 24, 2005.)
- USGS National Water Quality Assessment Data Warehouse "enables water resource managers, scientists, and the public to find data about the quality of the water at 2,800 stream sites and 5,000 wells in 46 states, according to the U. S. Geological Survey (USGS)."

- Water and Climate Bibliography; "a comprehensive database of scientific literature pertaining to climate change and freshwater resources worldwide."
- WATERS (Watershed Assessment, Tracking & Environmental ResultS), from the U. S. Environmental Protection Agency, "unites water quality information that was previously available only from several independent and unconnected databases." See http://www.epa.gov/waters/about/index.html for more information.
- WaterWeb Links Database; links to water-related Web sites searchable by keyword(s), geographic location or language.

2. Data Interpretation – Input data and utilize the Office of Surface Mining (OSM) software to interpret the overburden analyses and/or the surface water and ground water data.

3. Graphs - Useful tools for the applicant and the regulatory authority to determine trends (i.e. fluctuating water levels, water quality quantity, etc.). A variety of useful graphs can be generated by OSM software.

4. Software and Training - computer software can be extremely useful for modeling purposes. The applicant and the regulatory authority should consider using OSM's wide array of the latest software that is tailored for SMCRA-related hydrologic concerns, namely:

Office of Surface Mining's National Technical Training Program (NTTP) Courses (http://www.tips.osmre.gov/training/tips_html/links_nttp.asp):

Acid-Forming Materials: Fundamentals and Applications - This course is designed to provide participants with basic information on the characteristics of potentially acid forming material, their oxidation and production of acid mine drainage/related aquatic toxic materials and extremely acid materials, and potential for mitigation of these impacts.

Acid-Forming Materials: Principles and Processes - This course provides participants with information to upgrade their technical skills and current thinking in the critical aspects of the formation, weathering, and effects of acid forming materials in hydrologic and soil plant systems.

Acid-Forming Materials: Planning and Prevention - This workshop provides participants with information to enhance their knowledge and technical skills in planning mitigation of acid-forming materials impacts in hydrologic and soil and plant systems.

Forensic Hydrology – This course will serve to apply the knowledge gained from other NTTP hydrology, geology, and mining courses taken by the target audience. The course will concentrate on application of field investigative techniques, data collection, data and information analysis and interpretation, report structuring, and litigation preparation. At a minimum the course will address investigations of ground and surface water impacts that occurred as a result of mining. The underlying theme to this course is the philosophical and practical approaches to hydrologic investigations from start to finish. The course is not designed to teach basic hydrogeologic information, report writing, basic instrument use, or background in mining which are taught in other NTTP classes**.**

NEPA Procedures - This course provides training for State and Federal staff involved in Federal mine plan and Federal permit review in the procedures for complying with and drafting environmental documents required by National Environmental Policy Act (NEPA) and other appropriate environmental laws, regulations, and executive orders.

Permit Findings Workshop - This course is a workshop designed to assist regulatory personnel in preparing permit findings that are technically and legally sufficient and appropriately documented so-as to be able to withstand legal challenge and public scrutiny. This course is intended to provide a process orientation and an awareness raising approach or methodology to permit findings.

Permitting Hydrology – This course emphasizes reviewing probable hydrologic consequences determinations, defining material damage, and preparing cumulative hydrologic impact assessments.

Quantitative HydroGeology - This hands-on course will review the underlying assumptions and theories of aquifer characterization and the practical utilization of hydrogeologic principles to understand and analyze ground water movement. The course is intended to be a refresher on hydrogeology and to provide exposure to application of these principles in analysis and investigation of ground water questions. The course will look at confined, unconfined, leaky, and fractured aquifers. Students will work examples applying these principles to coal mining and reclamation-related problems.

Surface and Ground water Hydrology - This course provides participants with information on the basic effects of surface coal mine operations on surface and ground water hydrology.

Office of Surface Mining's Technical Innovation and Professional Services (TIPS) Training (http://www.tips.osmre.gov/training/tips_html/links_nttp.asp):

Advanced Ground water Vistas Modeling for Mine Permitting and Reclamation - An intermediate ground water modeling course using Ground water Vistas software. This course will build on the introductory Ground water Vistas course and discuss integrating Ground water Vistas and ArcGIS, including the delineation of surface water catchments using ArcGIS 'Spatial Analyst'. Topics also include the creation of Ground water Vistas maps, properties and boundary conditions from GIS layers, and exporting grids and model results to ArcGIS with geological, hydrological and hydrogeological data.

Modeling and Analysis with GMS Ground water Modeling Systems - An intermediate course in ground water modeling using GMS - Ground water Modeling Systems software. The course assumes some familiarity with ground water modeling. A series of tutorials and lessons on the GMS interface to MODFLOW/MODPATH/ MT3DMS/RT3D will be presented including an explanation of how to use the Map Module to create numerical models directly from a high-level conceptual model constructed with GIS tools. Analytic element modeling with MODAEM may also be covered. Topics will include the graphical user interface, visualization tools, and presentation graphics.

Modeling and Analysis with Ground water Vistas - This hands-on course will review the underlying assumptions, theories, and practical utilization of numerical flow models and conceptually modeling ground water flow and introduce the use of the Ground water Vistas software. Students will work examples applying this software to coal mining and reclamation related analysis.

Testing and Analysis of Aquifer Characteristics with AQTESOLV -This hands-on course will review the underlying assumptions and theories of aquifer characterization and the practical utilization of analytical ground-water models. The course will provide an introduction to the use of AQTESOLV, including analysis of confined, unconfined, leaky, and fractured aquifers. Students will work examples applying this software to coal mining and reclamation-related analysis including investigating pump tests, slug tests and drawdown analysis.

SEDCAD Applications and Extensions for Mine Permitting and Reclamation - This proposed hands-on intermediate level course will build on the basic assumptions, theories, and practical utilization of the surface flow models and sedimentation characteristics in SEDCAD, and RUSLE. Students will be introduced to the AutoCAD Extension, and will work examples applying these software packages to coal mining and reclamation related situations.

SEDCAD for Mine Permitting and Reclamation - This course presents the assumptions, theories, and practical utilization of the surface flow models in SEDCAD for coal mine permitting and reclamation. An Introduction to the Revised Universal Soil Loss Equation will also be covered. Students will work examples applying this software to mining related and other situations.

AMDTreat - The program offers users a method to predict and model water treatment costs for mine drainage problems. It also allows for the determination of capital cost associated with treatment of polluted mine drainage. AMDTreat provides many different treatment options both for passive and active treatment systems. Over 500 variables are available to the user to customize the costing routines for site-specific conditions.

Mining and Reclamation Introduction to Geochemical Analysis using the Geochemist's Workbench - This hands-on course developed by Rockware for the Office of Surface Mining introduces participants to fundamentals of aqueous geochemistry using The Geochemist's Workbench software to address mining and reclamation analyses. The course introduces the Geochemist's Workbench software and provides hands- on exercises enabling participants to run speciation models, create Eh-pH diagrams, Piper diagrams, and Stiff plots. The GWB Essentials software and the GWB professional software will be introduced and discussed.

Statistics Workshop: Interpretation of Water Quality Date using StatGraphics and AquaChem – This is a hands-on class where participants learn to develop graphics and statistical analyses for technical reports from water quality data using AquaChem and Statgraphics. Students work with their own data sets in workshop type environment.

Water Quality Analysis using AquaChem - This hands-on introductory course covers the basic aspects of water chemistry, water sampling and methods of water quality data evaluation related to coal mining and reclamation using the AQUACHEM software package.

5. Modeling

Geologic

Geologic modeling is the applied science of creating computerized representations of portions of the Earth's crust, especially oil and gas fields and ground water aquifers. This type of modeling is a relatively recent subdiscipline of geology which integrates structural geology, sedimentology, stratigraphy, paleoclimatology, and diagenesis. A geologic formation is generally represented using a 3-dimensional array of relatively small subdivisions, or cells. The creation of geologic models is computationally intense, so this discipline has only existed since the development of high-speed digital processors.

Geologic Modeling is usually divided into four steps (Article on Wikipedia.org - the free online encyclopedia.):

(1) Structural Framework - Incorporating the spatial positions of the major boundaries of the formations, including the effects of faulting, folding, and erosion. The major stratigraphic divisions are further subdivided into layers of cells with differing geometries with relation to the bounding surfaces (parallel to top, parallel to base, proportional). Maximum cell dimensions are dictated by the minimum sizes of the features to be resolved (everyday example: On a digital map of a city, the location of a city park might be adequately resolved by one big green pixel, but to define the locations of the basketball court, the baseball field, and the pool, much smaller pixels need to be used).

(2) Rock Type - Each cell in the model is assigned a rock type. In a coastal clastic environment, these might be beach sand, high water energy marine upper shoreface sand, intermediate water energy marine lower shoreface sand, and deeper low energy marine silt and shale. The distribution of these rock types within the model is controlled by several methods, including map boundary polygons, rock type probability maps, or statistically emplaced based on sufficiently closely spaced well data.

(3) Reservoir Quality - Reservoir quality parameters almost always include porosity and permeability, but may include measures of clay content, cementation factors, and other factors that affect the storage and deliverability of fluids contained in the pores of those rocks. Geostatistical techniques are most often used to populate the cells with porosity and permeability values that are appropriate for the rock type of each cell.

(4) Fluid Saturation - Most rock is completely saturated with ground water. Sometimes, under the right conditions, some of the pore space in the rock is occupied by other liquids or gases. In the energy industry, oil and natural gas are the fluids most commonly being modeled. The preferred methods for calculating hydrocarbon saturations in a geologic model incorporate an estimate of pore throat size, the densities of the fluids, and the height of the cell above the water contact, since these factors exert the strongest influence on capillary action, which ultimately controls fluid saturations.

Surface Water

Integrated surface-water and ground-water modeling is rapidly becoming an integral part of the management of our global water resources. It attempts to simulate the entire land phase of the hydrologic cycle, including:

- Precipitation
- Evapotranspiration
- Overland flow
- Channel flow and Structures
- Unsaturated sub-surface flow
- Saturated ground water flow

Integrated surface-water and ground-water modeling can be used for the analysis, planning and management of a wide range of water resources and environmental problems related to both surface water and ground water, including:

- Surface water impact from ground water withdrawal
- Conjunctive use of ground water and surface water
- Wetland management and restoration
- Aquifer vulnerability mapping with dynamic recharge and surface water boundaries
- Floodplain studies and Flood Forecasting
- Impact studies for changes in land use and climate
- Non Point Source Water Quality (e.g., TMDL) studies

Surface water modeling links:
For sources of surface water modeling:
http://www.mindspring.com/~rbwinston/surf.htm

- www.tsatools.com "TSA TOOLS is a series of Microsoft Excel / VBA based applications intended to offer water resources and civil design professionals flexibility and efficiency in their computational analysis and design."
- The USGS Surface-water quality and flow Modeling Interest Group
- Object Watershed Link Simulation
- Soil and Water Assessment Tool (SWAT) is a river basin scale model developed to quantify the impact of land management practices in large, complex watersheds. www.brc.tamus.edu/swat/index.html
- TR - 55, Urban Hydrology for Small Watersheds, program and documentation.
- Hydrologic Unit Modeling for the United States (HUMUS)
- AUS-IFD Version 1.2 is a MS Windows based program which calculates the design average rainfall intensities and temporal patterns for any location in Australia, using the procedures described in Australian Rainfall and Runoff, 1987.
- Computer-Aided Hydrology & Hydraulics.
- INTERNET SOFTWARE GUIDE FOR ENGINEERS.
- Resource Management Systems Group. Windows version of Catchment Management Support System (CMSS) and other tools.
- Engenious Systems. Inc WaterWorksHMS.
- David G. Tarboton's web page has the codes for the following papers.

    - "A New Method for the Determination of Flow Directions and Contributing Areas in Grid Digital Elevation Models",
    - "Utah Energy Balance Snow Accumulation and Melt Model (UEB)"
    - "A Spatially Distributed Energy Balance Snowmelt Model"
- Hidrosoft.
- Aquarian Software, Inc.
- Science Technology Associates.
- TOPOG is a physically based distributed parameter hydrological model written by researchers and scientists at CSIRO Land and Water, a party in the CRC for Catchment Hydrology.
- Science Technology Associates hydrograph analysis, hydro CD, culvert analysis.
- PCSWMM'96, "a fully windows and web compatible shell for USEPA stormwater management model and related programs".
- Utah Energy Balance Snow Accumulation and Melt Model (UEB).
- Decision Support Systems For Urban Stormwater Management Modelling.
- Check INWSMADA.ZIP: Hydgen for Windows v1.0 "Generates hydrographs in Windows 3.x. It allows you to create pollutographs, rainfall files, watershed files, and flow files. Output can be plotted, printed, or copied to clipboard." I don't know why it is mixed in with "WINDOWS FINANCE PROGRAMS".
- Flow Pro 2.0 by ProSoft Apps: a gradually varied water surface profile program for pipes, culverts, channels, and sluiceways with a wide variety of shapes and sizes. Fully functional demo available for download.
  They also have hydraulic design equations online along with the theory behind them.
- Hydrologic Engineering Center Computer Software, HEC-1, HEC-2, HEC-6.
- Environmental/Hydrologic/Hydraulic/Water Resources computer models mirrored in the Civil & Environmental Engineering Department, ODU.
- Prosoft Apps has Flow Pro 1.0a, a graphical water surface profile program.
- AquaDyn.
- Sewer and Stormwater Network Analysis and Design
- "AquaDyn is a powerful and easy to use hydrodynamic simulation package essential for water resources engineering studies, risk assessment, and impact studies."
- Geo-STORM for ARC/INFO from Innovative System Developers, Inc. demo available.
- Jeremy Benn Associates HEC-RAS, FlowMaster™, CulvertMaster™.
- Complete list of HOMS components from World Meteorological Organization Hydrology and Water Resources Programme.
- TideTracker; Handheld Tide and Current Computer.
- Tide Calculator.
- WWW Tide and Current Predictor.
    - WWW Tide and Current Predictor (Florida).
- Scripps Institution of Oceanography Pier Tide Predictor.
- *NRCS ENGINEERING SOFTWARE TR-20, TR-48, TR-55, TR-61. TR-64.
- Geosoft Ltd produces "Hydroscope - River networks and drainage basin analysis from Digital Elevation Models".

- BOSS International -USA Site has a variety of groundwater and surface water modeling programs. See also:
    - BOSS International - EUROPE Site
    - BOSS International - ASIA Site
- Hydrologic Modeling Resources Links to a wide variety of resources - many with outdated URL's.
- University of Central Florida Civil and Environmental Software A collection of programs for DOS that perform a variety of typical hydroligal analyses.
- A new book: Advances in Modeling the Management of Stormwater Impacts
- USGS Water Resources Applications Software. Too many programs to list.
- Software At The Hydraulics Laboratory at U. S. Army Corps of Engineers, Waterways Experiment Station TABS, CH3D SAM, SMS, GMS, WMS
- Water Resources Publications, LLC Book Publisher; many of the titles include software.
- Water Resources Models at WETnet.
- BAE 473/573 - Introduction to Surface Water Quality Modeling.
- Hydrology Models in GRASS.
- Hydrology and Hydraulics Software from Dodson & Associates.
- MIKE SHE An Integrated Hydrological Modelling System from the Danish Hydraulic Institute.
- Geo-STORM by Innovative System Developers, Inc. simulates watershed and river basin hydrologic and hydraulic processes using information maintained within your ARC/INFO database.
- The River System Simulator (RSS) is a computer-based simulation system for multi-purpose planning and operation of river systems, with special emphasis on hydropower and its environmental effects.
- WATFLOOD is an integrated set of computer programs to forecast flood flows for watershed having response times ranging from one hour to several weeks.
- The Geotechnical & Geo-environmental Software Directory details several hundred programs, software publishers and suppliers in the fields of Geotechnical Engineering, Engineering Geology, Hydrogeology, Geo-environmental Engineering, Data Analysis and Data Visualisation. Also lists other WWW pages with related software. Compiled by Tim Spink.
- ESIE Free Directory of Vendors at CAE Consultants This page gives phone numbers for a large number of vendors. Try looking under "Environmental Engineering".
- Biosystems Analysis Group Oregon State University POND Aquaculture Decision Support Software and Virtual Systems Simulator.
- ITS Resources PC and Mac transportation related software available for purchase.
- TOPMODEL rainfall-runoff modelling.
- IRRISOFT Database on IRRIGATION and HYDROLOGY SOFTWARE.
- Water Erosion Prediction Project. from the National Soil Erosion Research Laboratory.
- ENGINEERING SOFTWARE CENTER.
- Engineering Computer Graphics Laboratory. GMS, WMS, FastTABS, FastSeep, SMS, Cquel

- Water Resources Consulting Services - Hydrology Software TR-55, SWMM, Hec-1Time, Flow-duration template for Quattro Pro, Hydraulics utility programs.
- SWMM. Excerpts from the quarterly newsletter "SWMM News & Notes".
- The electronic catalog at this site lists several surface water models under "Highway Engineering/Hydraulics".
- ECGL SMS (Surface-water Modeling System).
- Register of ecological models. A significant number of surface and groundwater models are included along with a large number of strictly ecological models.
- WETnet Water Resources Models
- EPA Software. at Environmental Protection Agency WWW Server.
- Sea Air Land Modeling Operational Network
- Hydrocomp Home Page
- Software at Environmental HydroSystems, Inc.
- HEC - Software Products at Hydrologic Engineering Center - HEC
- Institute of Hydrology - Software Development
- Cullimore and Ring Technologies, Inc.
- Spatially Distributed Hydrologic modeling
- Water Resource Systems Research Unit SHETRAN a physically based distributed hydrological modeling system. TRACE123 an integrated suite of software designed for a wide range of subsurface pollution problems. MTB (Modified Turning Bands) rainfall modeling system.
- SSIIM for Windows "SSIIM is an abbreviation for Sediment Simulation In Intakes with Multiblock option. The program is designed to be used in teaching and research for hydraulic/river/sedimentation engineering. It solves the Navier-Stokes equations using the control volume method with the SIMPLE algorithm and the k-epsilon turbulence model. It also solves the convection-diffusion equation for sediment transport, using van Rijn's formula for the bed boundary. Also, a water quality module is included."
- David G. Tarboton
- The RiverTools Home Page
- Haestad Methods, Inc
- Computation Fluid Dynamics Codes List at James Todd Ratcliff's homepage.

Ground Water

Ground-water flow models are used to calculate the rate and direction of movement of ground water through aquifers and confining units in the subsurface. These calculations are referred to as simulations. The simulation of ground-water flow requires a thorough understanding of the hydrogeologic characteristics of the site. The hydrogeologic investigation should include a complete characterization of the following:

- Subsurface extent and thickness of aquifers and confining units (hydrogeologic framework),
- Hydrologic boundaries (also referred to as boundary conditions) which control the rate and direction of movement of ground water,
- Hydraulic properties of the aquifers and confining units,
- A description of the horizontal and vertical distribution of hydraulic head throughout the modeled area for both beginning (initial conditions), equilibrium

(steady-state conditions) and transitional conditions when hydraulic head may vary with time (transient conditions), and

- Distribution and magnitude of ground-water recharge, pumping or injection of ground water, leakage to or from surface-water bodies, etc. (sources or sinks, also referred to as stresses). These stresses may be constant (unvarying with time) or may change with time (transient).

The outputs from the model simulations are the hydraulic heads and ground-water flow rates which are in equilibrium with the hydrogeologic conditions (hydrogeologic framework, hydrologic boundaries, initial and transient conditions, hydraulic properties, and sources or sinks) defined for the modeled area.

Through the process of model calibration and verification (discussed in later sections of this document), the values of the different hydrogeologic conditions are varied to reduce any disparity between the model simulations and field data, and to improve the accuracy of the model. The model can also be used to simulate possible future changes to hydraulic head or ground water flow rates as a result of future changes in stresses on the aquifer system.

Fate and Transport Models

Fate and transport models simulate the movement and chemical alteration of contaminants as they move with ground water through the subsurface. These models require the development of a calibrated ground-water flow model or, at a minimum, an accurate determination of the velocity and direction of ground-water flow that has been based on field data. Fate and transport models are used to simulate the following processes:

- Movement of contaminants by advection and diffusion,
- Spread and dilution of contaminants by dispersion,
- Removal or release of contaminants by sorption, or desorption, of contaminants onto, or from, subsurface sediment or rock, or
- Chemical alteration of the contaminant by chemical reactions which may be controlled by biological processes or physical chemical reactions.

In addition to a thorough hydrogeological investigation, the simulation of fate and transport processes requires a complete characterization of the following:

- Horizontal and vertical distribution of average linear ground-water velocity (direction and magnitude) determined by a calibrated ground-water flow model or through accurate determination of direction and rate of ground-water flow from field data,
- Boundary conditions for the solute,
- Initial distribution of solute (initial conditions),
- Location, history and mass loading rate of chemical sources or sinks,
- Effective porosity,
- Soil bulk density,
- Fraction of organic carbon in soils,
- Octanol-water partition coefficient for chemical of concern,

- Density of fluid,
- Viscosity of fluid,
- Longitudinal and transverse dispersivity,
- Diffusion coefficient,
- Chemical decay rate or degradation constant,
- Equations describing chemical transformation processes, if applicable
- Initial distribution of electron acceptors, if applicable.

The outputs from the model simulations are the contaminant concentrations, which are in equilibrium with the ground-water flow system, and the geochemical conditions (described above) defined for the modeled area.

As with ground-water flow models, fate and transport models should be calibrated and verified by adjusting values of the different hydrogeologic or geochemical conditions to reduce any disparity between the model simulations and field data. This process may result in a re-evaluation of the model used for simulating ground-water flow if the adjustment of values of geochemical data does not result in an acceptable model simulation. Predictive simulations may be made with a fate and transport model to predict the expected concentrations of contaminants in ground water as a result of implementation of a remedial action. Monitoring of hydraulic heads and ground-water chemistry will be required to support predictive simulations.

Types of Models

The equations that describe the ground-water flow and fate and transport processes may be solved using different types of models. Some models may be exact solutions to equations that describe very simple flow or transport conditions (analytical model) and others may be approximations of equations that describe very complex conditions (numerical models). Each model may also simulate one or more of the processes that govern ground-water flow or contaminant migration rather than all of the flow and transport processes. As an example, particle-tracking models such as MODPATH simulate the advective transport of contaminants but do not account for other fate and transport processes. In selecting a model for use at a site, it is necessary to determine whether the model equations account for the key processes occurring at the site. Each model, whether it is a simple analytical model or a complex numerical model, may have applicability and usefulness in hydrogeological and remedial investigations.

<u>Analytical Models</u>

Analytical models are an exact solution of a specific, greatly simplified, ground water flow or transport equation. The equation is a simplification of more complex three-dimensional ground water flow or solute transport equations. Prior to the development and widespread use of computers, there was a need to simplify the three-dimensional equations because it was not possible to easily solve these equations. Specifically, these simplifications resulted in reducing the ground water flow to one dimension and the solute transport equation to one or two dimensions. This resulted in changes to the model equations that include one-dimensional uniform ground water flow, simple uniform aquifer geometry, homogeneous and isotropic aquifers, uniform hydraulic and chemical reaction properties, and simple flow or chemical reaction boundaries. Analytical models are typically steady-state and one-dimensional, although selected ground water flow models are two dimensional (e.g. analytical element models), and some contaminant transport models assume one-dimensional ground water flow conditions and one-, two- or three-dimensional transport conditions. Well hydraulics models, such as the Theis or Neumann methods, are examples of analytical one-dimensional ground-water flow models.

Because of the simplifications inherent with analytical models, it is not possible to account for field conditions that change with time or space. This includes variations in ground water flow rate or direction, variations in hydraulic or chemical reaction properties, changing hydraulic stresses, or complex hydrogeologic or chemical boundary conditions.

Numerical Models

Numerical models are capable of solving the more complex equations that describe ground-water flow and solute transport. These equations generally describe multi-dimensional, ground-water flow, solute transport and chemical reactions although there are one-dimensional numerical models. Numerical models use approximations (e.g. finite differences, or finite elements) to solve the differential equations describing ground-water flow or solute transport. The approximations require that the model domain and time be discretized.

The accuracy of numerical models depends upon the accuracy of the model input data, the size of the space and time discretization (the greater the size of the discretization steps, the greater the possible error), and the numerical method used to solve the model equations.

In addition to complex three-dimensional, ground-water flow and solute transport problems, numerical models may be used to simulate very simple flow and transport conditions that may just as easily be simulated using an analytical model. However, numerical models are generally used to simulate problems which cannot be accurately described using analytical models (Michigan Department of Environmental Quality). http://www.michigan.gov/deq/0,1607,7-135-3313_21698---,00.html

For sources of ground-water modeling:
http://www.mindspring.com/~rbwinston/big.htm

- Engineering Software Center
- USGS Ground-Water Software
- U.S. Salinity Laboratory
- Waterways Experiment Station (US Army Corps of Engineers)
- USGS Water Resources Applications Software via the USGS Water Resources page. Nearly all the USGS groundwater programs are available for downloading. Most are in source code form but some have been compiled for a variety of platforms.
- Ground-Water and Vadose Zone Models/Manuals at Center for Subsurface Modeling Support at Kerr Lab includes 13 different programs that are available for downloading including the public domain version of MT3D and BIOPLUME II.
- Models at Databases and Software at Environmental Protection Agency WWW Server.
- International Groundwater Modeling Center serves as a repository for nearly every model that exists. They also provide a variety of other services.

- The Scientific Software Group You can download a demo of Visual MODFLOW among other things. They have an extensive printed catalog as well as web pages on each of their products. You can download individual pages of their catalog in pdf format for more information. They list their programs both alphabetically and by function which makes it a good place to look for more information.
- Complete list of HOMS components from the World Meteorological Organization Hydrology and Water Resources Programme. There is information about a lot of different hydrology programs from many international (mostly governmental) sources.
- RockWare Inc. Earth Science Software has an extensive, well-organized, online catalog.
- The Geotechnical & Geo-environmental Software Directory details several hundred programs, software publishers and suppliers in the fields of Geotechnical Engineering, Engineering Geology, Hydrogeology, Geo-environmental Engineering, Data Analysis and Data Visualisation. Also lists other WWW pages with related software. Compiled by Tim Spink.
- The Hydrogeologist's Home Page has lots of information about all aspects of hydrology.
- ASCE Seepage/Groundwater Modeling Software is a set of links to many sites with information about groundwater modeling. Anyone can add a link to this site by filling out a form including a one paragraph description of their site.
- Hydrology Web

Groundwater Modeling Links

The United States Environmental Protection Agency's Center for Subsurface Modeling Support (CSMoS) provides public domain ground-water and vadose zone modeling software and services to public agencies and private companies throughout the nation. CSMoS is located in Ada, Oklahoma at the National Risk Management Research Laboratory (NRMRL), the U.S. EPA's Center for Ground-Water Research. The primary aims of CSMoS are to provide direct technical support to EPA and State decision makers in subsurface model applications and to manage and support the ground-water models and databases resulting from the research at NRMRL. This research encompasses the transport and fate of contaminants in the subsurface, the development of methodologies for protection and restoration of ground-water quality, and the evaluation of subsurface remedial technologies. As a result, a major focus of CSMoS entails coordinating the use of models for risk assessment, site characterization, remedial activities, wellhead protection, and Geographic Information Systems (GIS) application. In these ways, CSMoS performs an active role in protecting, restoring, and preserving our nation's ground-water resources.

CSMoS integrates numerous individuals and organizations with expertise in all aspects of the environmental field in its effort to apply models to better understand and resolve ground water problems. CSMoS is supported by the scientists and engineers of the NRMRL whose specialties include hydrogeology, chemistry, soil science, biology, environmental engineering, and computer programming. CSMoS provides assistance in the following modeling areas:

- Conceptualization

- Model Development
- Model Application
- Model Distribution
- Model Training and Education

CSMoS is an integral part of the NRMRL's Technology Support Center. CSMoS distributes and services all models and databases developed by the NRMRL and provides general support on model application to ground-water and vadose zone problems. Technical assistance activities include developing educational documents, providing training courses, and distributing update notices and other pertinent information for all software developed at NRMRL as well as software developed under laboratory grants and contracts.