CHAPTER 2

DESIGNATION OF USES

(40 CFR 131.10)

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CHAPTER 2
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2.1 Use Classification - 40 CFR 131.10(a)

A water quality standard defines the water quality goals of a water body or portion thereof, in part, by designating the use or uses to be made of the water. States adopt water quality standards to protect public health or welfare, enhance the quality of water, and serve the purposes of the Clean Water Act. "Serve the purposes of the Act" (as defined in sections 101(a)(2), and 303(c) of the Act) means that water quality standards should:

- provide, wherever attainable, water quality for the protection and propagation of fish, shellfish, and wildlife, and recreation in and on the water ("fishable/swimmable"), and
- consider the use and value of State waters for public water supplies, propagation of fish and wildlife, recreation, agriculture and industrial purposes, and navigation.

These sections of the Act describe various uses of waters that are considered desirable and should be protected. The States must take these uses into consideration when classifying State waters and are free to add use classifications. Consistent with the requirements of the Act and Water Quality Standards Regulation, States are free to develop and adopt any use classification system they see as appropriate, except that waste transport and assimilation is not an acceptable use in any case (see 40 CFR 131.10(a)). Among the uses listed in the Clean Water Act, there is no hierarchy. EPA's Water Quality Standards Regulation emphasizes the uses specified in section 101(a)(2) of the Act (first bullet, above). To be consistent with the 101(a)(2) interim goal of the Act, States must provide water quality for the *protection and propagation of fish, shellfish, and wildlife, and provide for recreation in and on the water* ("fishable/swimmable") where attainable (see 40 CFR 131.10(j)).

DESIGNATED USES
40 CFR 131.3(f)

Uses specified in Water Quality Standards for each water body or segment whether or not they are being attained.

2.1.1 Public Water Supplies

This use includes waters that are the source for drinking water supplies and often includes waters for food processing. Waters for drinking water may require treatment prior to distribution in public water systems.

2.1.2 Protection and Propagation of Fish, Shellfish, and Wildlife

This classification is often divided into several more specific subcategories, including coldwater fish, warmwater fish, and shellfish. For example, some coastal States have a use specifically for oyster propagation. The use may also include protection of aquatic flora. Many States differentiate between self-supporting fish populations and stocked fisheries. Wildlife protection should include waterfowl, shore birds, and other water-oriented wildlife.

To more fully protect aquatic habitats and provide more comprehensive assessments of aquatic life use attainment/non-attainment, it is EPA's policy that States should designate aquatic life uses that appropriately address biological integrity and adopt biological criteria necessary to protect those uses (see Appendix R).

TYPES OF USES
CWA SECTION 303(c)(2)(A)

- Public water supplies
- Protection and propagation of fish, shellfish, and wildlife
- Recreation
- Agriculture
- Industry
- Navigation
- Coral reef preservation
- Marinas
- Groundwater recharge
- Aquifer protection
- Hydroelectric power

2.1.3 Recreation

Recreational uses have traditionally been divided into primary contact and secondary contact recreation. The primary contact recreation classification protects people from illness due to activities involving the potential for ingestion of, or immersion in, water. Primary contact recreation usually includes swimming, water-skiing, skin-diving, surfing, and other activities likely to result in immersion. The secondary contact recreation classification is protective when immersion is unlikely. Examples are boating, wading, and rowing. These two broad uses can be logically subdivided into an almost infinite number of subcategories (e.g., wading, fishing, sailing, powerboating, rafting.). Often fishing is considered in the recreational use categories.

Recreation in and on the water, on the other hand, may not be attainable in certain waters, such as wetlands, that do not have sufficient water, at least seasonally. However, States are encouraged to recognize and protect recreational uses that do not directly involve contact with water, including hiking, camping, and bird watching.

A number of acceptable State options may be considered for designation of recreational uses.

Option 1

Designate primary contact recreational uses for all waters of the State, and set bacteriological criteria sufficient to support primary contact recreation. This option fully conforms with the requirement in section 131.6 of the Water Quality Standards Regulation to designate uses consistent with the provisions of sections 101(a)(2) and 303(c)(2) of the CWA. States are not required to conduct use attainability analyses (for recreation) when primary contact recreational uses are designated for all waters of the State.

Option 2

Designate either primary contact recreational uses or secondary contact recreational uses for all waters of the State and, where secondary contact recreation is designated, set bacteriological criteria sufficient to support primary contact recreation. EPA believes that a secondary contact recreational use (with criteria sufficient to support primary contact recreation) is consistent with the CWA section 101(a)(2) goal. The rationale for this option is discussed in the preamble to the Water Quality Standards Regulation, which states: ". . . even though it may not make sense to encourage use of a stream for swimming because of the flow, depth or the velocity of the water, the States and EPA must recognize that swimming and/or wading may occur anyway. In order to protect public health, States must set criteria to reflect recreational uses if it appears that recreation will in fact occur in the stream." Under this option, future revisions to the bacteriological criterion for specific stream segments would be subject to the downgrading provisions of the Federal Water Quality Standards Regulation (40 CFR 131.10).

Option 3

Designate either primary contact recreation, secondary contact recreation (with bacteriological criteria sufficient to support primary contact recreation), or conduct use attainability analyses demonstrating that recreational uses consistent with the CWA section 101(a)(2) goal are not attainable for all waters of the State. Such use attainability analyses are required by section 131.10 of the Water Quality Standards Regulation, which also specifies six factors that may be used by States in demonstrating that attaining a use is not feasible. Physical factors, which are important in determining attainability of aquatic life uses, may not be used as the basis for not designating a recreational use consistent with the CWA section 101(a)(2) goal. This precludes States from using 40 CFR 131.10(g) factor 2 (pertaining to low-flows) and factor 5 (pertaining to physical factors in general). The basis for this policy is that the States and EPA have an obligation to do as much as possible to protect the health of the public. In certain instances, people will use whatever water bodies are available for recreation, regardless of the physical conditions. In conducting use attainability analyses (UAAs) where available data are scarce or nonexistent, sanitary surveys are useful in determining the sources of bacterial water quality indicators. Information on land use is also useful in predicting bacteria levels and sources.

Other Options

- States may apply bacteriological criteria sufficient to support primary contact recreation with a rebuttable presumption that the indicators show the presence of human fecal pollution. Rebuttal of this presumption, however, must be based on a sanitary survey that demonstrates a lack of contamination from human sources. The basis for this option is the absence of data demonstrating a relationship between high densities of bacteriological water quality indicators and increased risk of swimming-associated illness in animal-contaminated waters. Maine is an example of a State that has successfully implemented this option.

- Where States adopt a standards package that does not support the swimmable goal and does not contain a UAA to justify the omission, EPA may conditionally approve the package provided that (1) the State commits, in writing, to a schedule for rapid completion of the UAAs, generally within 90 days (see conditional approval guidance in section 6.2 of this Handbook); <u>and</u> (2) the omission may be considered a minor deficiency (i.e., after consultation with the State, EPA determines that there is no basis for concluding that the UAAs would support upgrading the use of the water body). Otherwise, failure to support the swimmable goal is a major deficiency and must be disapproved to allow prompt Federal promulgation action.

- States may conduct basinwide use attainability analyses if the circumstances relating to the segments in question are sufficiently similar to make the results of the basinwide analyses reasonably applicable to each segment.

States may add other recreation classifications as they see fit. For example, one State protects "consumptive recreation" (i.e., "human consumption of aquatic life, semi-aquatic life, or terrestrial wildlife that depend on surface waters for survival and well-being"). States also may adopt seasonal recreational uses (see section 2.6, this Handbook).

2.1.4 Agriculture and Industry

The agricultural use classification defines waters that are suitable for irrigation of crops, consumption by livestock, support of vegetation for range grazing, and other uses in support of farming and ranching and protects livestock and crops from injury due to irrigation and other exposures.

The industrial use classification includes industrial cooling and process water supplies. This classification protects industrial equipment from damage from cooling and/or process waters. Specific criteria would depend on the industry involved.

The *Report of the Committee on Water Quality Criteria*, the "Green Book" (FWPCA, 1968) and *Water Quality Criteria 1972*, the "Blue Book" (NAS/NAE, 1973) provide information for certain parameters on protecting agricultural and industrial uses, although section 304(a)(1) criteria for protecting these uses have not been specifically developed for numerous other parameters, including toxics.

Where criteria have not been specifically developed for agricultural and industrial uses, the criteria developed for human health and aquatic life are usually sufficiently stringent to protect these uses. States also may establish criteria specifically designed to protect these uses.

2.1.5 Navigation

This use classification is designed to protect ships and their crews and to maintain water quality so as not to restrict or prevent navigation.

2.1.6 Other Uses

States may adopt other uses they consider to be necessary. Some examples include coral reef preservation, marinas, groundwater recharge, aquifer protection, and hydroelectric power. States also may establish criteria specifically designed to protect these uses.

2.2 Consider Downstream Uses - 40 CFR 131.10(b)

When designating uses, States should consider extraterritorial effects of their standards. For example, once States revise or adopt standards, upstream jurisdictions will be required, when revising their standards and issuing permits, to provide for attainment and maintenance of the downstream standards.

Despite the regulatory requirement that States ensure downstream standards are met when designating and setting criteria for waters, occasionally downstream standards are not met owing to an upstream pollutant source. The Clean Water Act offers three solutions to such problems.

First, the opportunity for public participation for new or revised water quality standards provides potentially affected parties an approach to avoiding conflicts of water quality standards. States and Tribes are encouraged to keep other States informed of their water quality standards efforts and to invite comment on standards for common water bodies.

Second, permit limits under the National Pollutant Discharge Elimination System (NPDES) program (see section 402 of the Act) are required to be developed such that applicable water quality standards are achieved. The permit issuance process also includes opportunity for public participation and, thus, provides a second opportunity to consider and resolve potential problems regarding extraterritorial effects of water quality standards. In a decision in *Arkansas* v. *Oklahoma* (112 section 1046, February 26, 1992), the U.S. Supreme Court held that the Clean Water Act clearly authorized EPA to require that point sources in upstream States not violate water quality standards in downstream States, and that EPA's interpretation of those standards should govern.

Third, NPDES permits issued by EPA are subject to certification under the requirements of section 401 of the Act. Section 401 requires that States grant, deny, or condition "certification" for federally permitted or licensed activities that may result in a discharge to waters of the United States. The decision to grant or to deny certification, or to grant a conditional certification is based on a State's determination regarding whether the proposed activity will comply with applicable water quality standards and other provisions. Thus, States may deny certification and prohibit EPA from issuing an NPDES permit that would violate water quality standards. Section 401 also allows a State to participate in extraterritorial actions that will affect that State's waters if a federally issued permit is involved.

In addition to the above sources for solutions, when the problem arises between a State and an Indian Tribe qualified for treatment as a State for water quality standards, the dispute resolution mechanism could be invoked (see section 1.7, of this Handbook).

2.3 Use Subcategories - 40 CFR 131.10(c)

States are required to designate uses considering, at a minimum, those uses listed in section 303(c) of the Clean Water Act (i.e., public water supplies, propagation of fish and wildlife, recreation, agriculture and industrial purposes, and navigation). However, flexibility inherent in the State process for designating uses allows the development of subcategories of uses within the Act's general categories to refine and clarify specific use classes. Clarification of the use class is particularly helpful when a variety of surface waters with distinct characteristics fit within the same use class, or do not fit well into any category. Determination of non-attainment in waters with broad use categories may be difficult and open to alternative interpretations. If a determination of non-attainment is in dispute, regulatory actions will be difficult to accomplish (USEPA, 1990a).

The State selects the level of specificity it desires for identifying designated uses and subcategories of uses (such as whether to treat recreation as a single use or to define a subcategory for secondary recreation). However, the State must be at least as specific as the uses listed in sections 101(a) and 303(c) of the Clean Water Act.

Subcategories of aquatic life uses may be on the basis of attainable habitat (e.g., coldwater versus warmwater habitat); innate differences in community structure and function (e.g., high versus low species richness or productivity); or fundamental differences in important community components (e.g., warmwater fish communities dominated by bass versus catfish). Special uses may also be designated to protect particularly unique, sensitive, or valuable aquatic species, communities, or habitats.

Data collected from biosurveys as part of a developing biocriteria program may assist States in refining aquatic life use classes by revealing consistent differences among aquatic communities inhabiting different waters of the same designated use. Measurable biological attributes could then be used to divide one class into two or more subcategories (USEPA, 1990a).

If States adopt subcategories that do not require criteria sufficient to fully protect the goal uses in section 101(a)(2) of the Act (see section 2.1, above), a use attainability analysis pursuant to 40 CFR 131.10(j) must be conducted for waters to which these subcategories are assigned. Before adopting subcategories of uses, States must provide notice and opportunity for a public hearing because these actions are changes to the standards.

2.4 Attainability of Uses - 40 CFR 131.10(d)

When designating uses, States may wish to designate only the uses that are attainable. However, if the State does not designate the uses specified in section 101(a)(2) of the Act, the State must perform a use attainability analysis under section 131.10(j) of the regulation. States are encouraged to designate uses that the State believes can be attained in the future.

"Attainable uses" are, at a minimum, the uses (based on the State's system of water use classification) that can be achieved 1) when effluent limits under sections 301(b)(1)(A) and (B) and section 306 of the Act are imposed on point source dischargers and 2) when cost-effective and reasonable best management practices are imposed on nonpoint source dischargers.

2.5 Public Hearing for Changing Uses - 40 CFR 131.10(e)

The Water Quality Standards Regulation requires States to provide opportunity for public hearing before adding or removing a use or establishing subcategories of a use. As mentioned in section 2.2 above, the State should consider extraterritorial effects of such changes.

2.6 Seasonal Uses - 40 CFR 131.10(f)

In some areas of the country, uses are practical only for limited seasons. EPA recognizes seasonal uses in the Water Quality Standards Regulation. States may specify the seasonal uses and criteria protective of that use as well as the time frame for the ". . . season, so long as the criteria do not prevent the attainment of any more restrictive uses attainable in other seasons."

For example, in many northern areas, body contact recreation is possible only a few months out of the year. Several States have adopted primary contact recreational uses, and the associated microbiological criteria, for only those months when primary contact recreation actually occurs, and have relied on less stringent secondary contact recreation criteria to protect for incidental exposure in the "non-swimming" season.

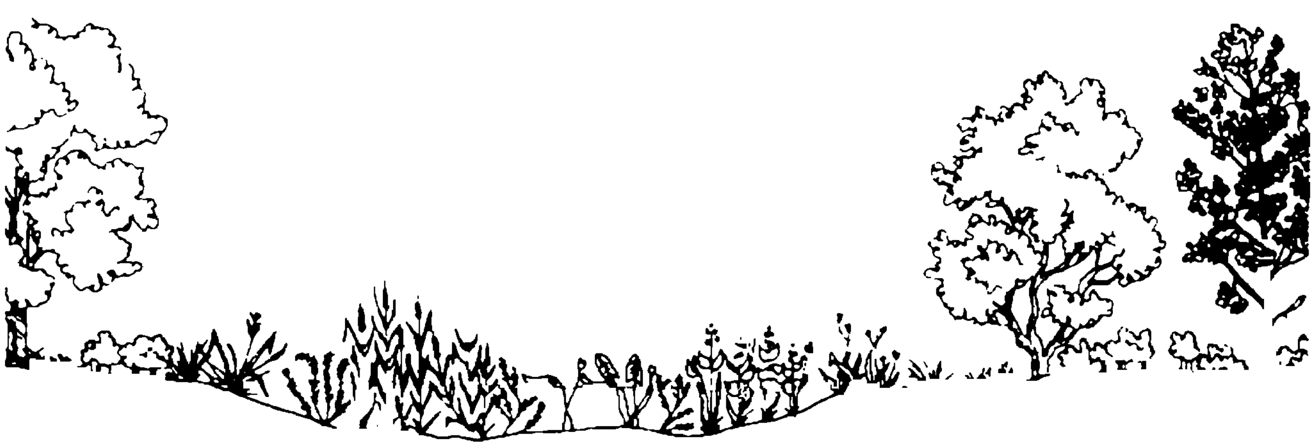
Seasonal uses that may require more stringent criteria are uses that protect sensitive organisms or life stages during a specific season such as the early life stages of fish and/or fish migration (e.g., EPA's *Ambient Water Quality Criteria for Dissolved Oxygen* (see Appendix I) recommends more stringent dissolved oxygen criteria for the early life stages of both coldwater and warmwater fish).

2.7 Removal of Designated Uses - 40 CFR 131.10(g) and (h)

Figure 2-1 shows how and when designated uses may be removed.

2.7.1 Step 1 - Is the Use Existing?

Once a use has been designated for a particular water body or segment, the water body or water body segment cannot be reclassified for a different use except under specific conditions. If a designated use is an existing use (as defined in 40 CFR 131.3) for a particular water body, the existing use cannot be removed unless a use requiring more stringent criteria is added (see



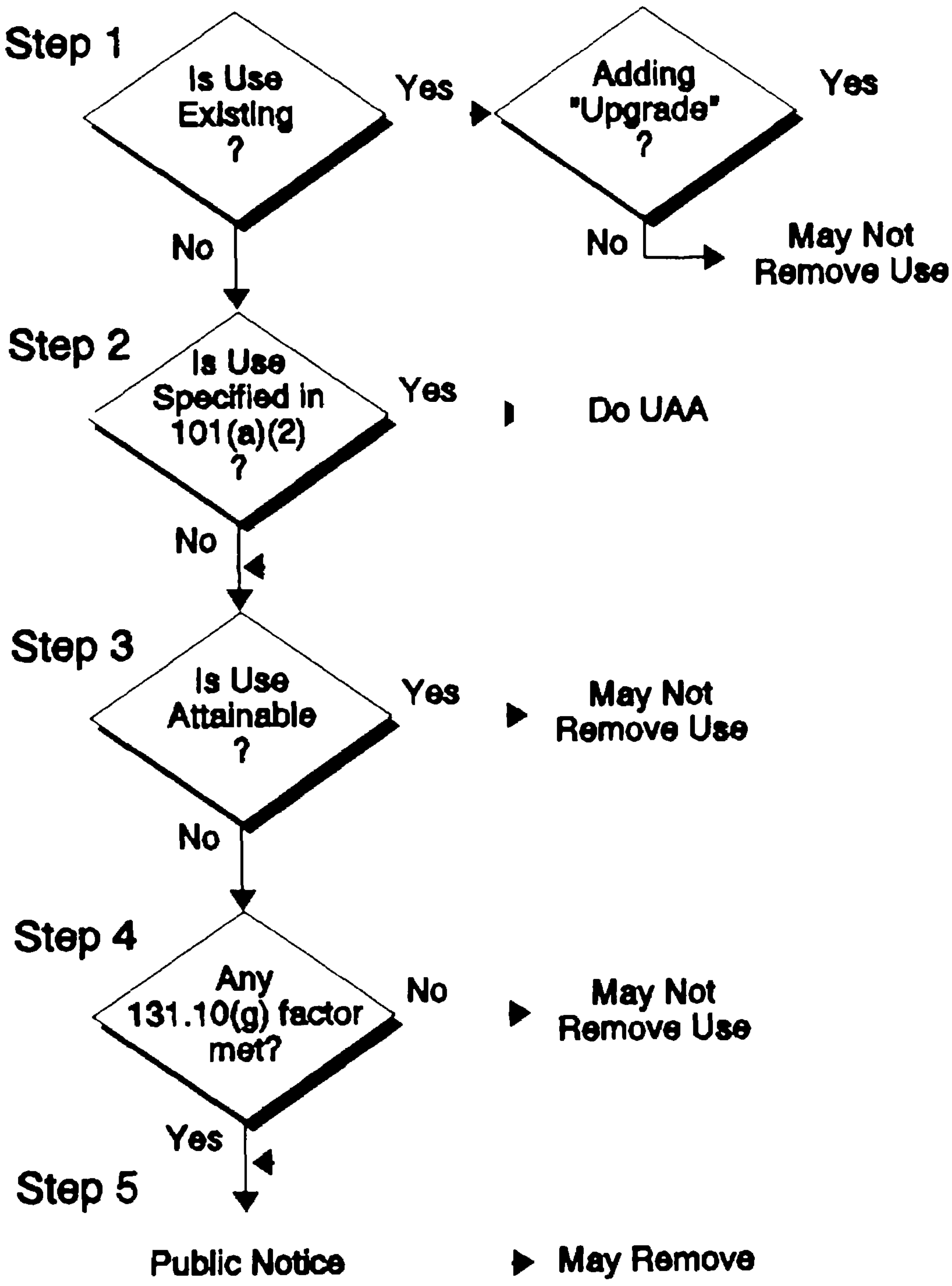


Figure 2-1. Process for Removing a Designated Use

section 4.4, this Handbook, for further discussion of existing uses). However, uses requiring more stringent criteria may always be added because doing so reflects the goal of further improvement of water quality. Thus, a recreational use for wading may be deleted if a recreational use for swimming is added, or the State may add the swimming use and keep the wading use as well.

2.7.2 Step 2 - Is the Use Specified in Section 101(a)(2)?

If the State wishes to remove a designated use specified in section 101(a)(2) of the Act, the State must perform a use attainability analysis (see section 131.10(j)). Section 2.9 of this Handbook discusses use attainability analyses for aquatic life uses.

2.7.3 Step 3 - Is the Use Attainable?

A State may change activities within a specific use category but may not change to a use that requires less stringent criteria, unless the State can demonstrate that the designated use cannot be attained. (See section 2.4, above, for the definition of "attainable uses.") For example, if a State has a broad aquatic life use, EPA generally assumes that the use will support all aquatic life. The State may demonstrate that, for a specific water body, such parameters as dissolved oxygen or temperature will not support trout but will support perch when technology-based effluent limitations are applied to point source dischargers and when cost-effective and reasonable best management practices are applied to nonpoint sources.

2.7.4 Step 4 - Is a Factor from 131.10(g) Met?

Even after the previous steps have been considered, the designated use may be removed, or subcategories of a use established, only under the conditions given in section 131.10(g). The State must be able to demonstrate that attaining the designated use is not feasible because:

(1) naturally occurring pollutant concentrations prevent the attainment of the use;

(2) natural, ephemeral, intermittent, or low-flow conditions or water levels prevent the attainment of the use, unless these conditions may be compensated for by the discharge of sufficient volume of effluent discharges without violating State water conservation requirements to enable uses to be met;

(3) human-caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place;

(4) dams, diversions, or other types of hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the water body to its original condition or to operate such modification in a way that would result in the attainment of the use;

(5) physical conditions related to the natural features of the water body, such as the lack of a proper substrate, cover, flow, depth, pools, riffles, and the like, unrelated to [chemical] water quality, preclude attainment of aquatic life protection uses; or

(6) controls more stringent than those required by sections 301(b)(1)(A) and (B) and 306 of the Act would result in substantial and widespread economic and social impact.

2.7.5 Step 5 - Provide Public Notice

As provided for in section 131.10(e), States must provide notice and opportunity for public hearing in accordance with section 131.20(b) (discussed in section 6.1 of this Handbook). Of course, EPA intends for States to make appropriate use of all public comments received through such notice.

2.8 Revising Uses to Reflect Actual Attainment - 40 CFR 131.10(i)

When performing its triennial review, the State must evaluate what uses are being attained. If a water body is designated for a use that requires less stringent criteria than a use that is being attained, the State must revise the use on that water body to reflect the use that is being attained.

2.9 Use Attainability Analyses - 40 CFR 131.10(j) and (k)

Under section 131.10(j) of the Water Quality Standards Regulation, States are required to conduct a use attainability analysis (UAA) whenever:

(1) the State designates or has designated uses that do not include the uses specified in section 101(a)(2) of the Act; or

(2) the State wishes to remove a designated use that is specified in section 101(a)(2) of the Act or adopt subcategories of uses specified in section 101(a)(2) that require less stringent criteria.

States are not required to conduct UAAs when designating uses that include those specified in section 101(a)(2) of the Act, although they may conduct these or similar analyses when determining the appropriate subcategories of section 101(a)(2) goal uses.

States may also conduct generic use attainability analyses for groups of water body segments provided that the circumstances relating to the segments in question are sufficiently similar to make the results of the generic analyses reasonably applicable to each segment.

As defined in the Water Quality Standards Regulation (40 CFR 131.3), a use attainability analysis is:

> . . . a structured scientific assessment of the factors affecting the attainment of a use which may include physical, chemical, biological, and economic factors as described in section 131.10(g).

The evaluations conducted in a UAA will determine the attainable uses for a water body (see sections 2.4 and 2.8, above).

The physical, chemical, and biological factors affecting the attainment of a use are evaluated through a *water body survey and assessment*. The guidance on water body survey and assessment techniques that appears in this Handbook is for the evaluation of fish, aquatic life, and wildlife uses only (EPA has not developed guidance for assessing recreational uses). Water body surveys and assessments conducted by the States should be sufficiently detailed to answer the following questions:

- What are the aquatic use(s) currently being achieved in the water body?
- What are the causes of any impairment of the aquatic uses?
- What are the aquatic use(s) that can be attained based on the physical, chemical, and biological characteristics of the water body?

The analysis of economic factors determines whether substantial and widespread economic and social impact would be caused by pollution control requirements more stringent than (1) those required under sections 301(b)(1)(A) and (B) and section 306 of the Act for point source dischargers, and (2) cost-effective and reasonable best management practices for nonpoint source dischargers.

2.9.1 Water Body Survey and Assessment - Purpose and Application

The purpose of this section is to identify the physical, chemical, and biological factors that may be examined to determine whether an aquatic life protection use is attainable for a given water body. The specific analyses included in this guidance are optional. However, they represent the type of analyses EPA believes are sufficient for States to justify changes in uses designated in a water quality standard and to determine uses that are attainable. States may use alternative analyses as long as they are scientifically and technically supportable. This guidance specifically addresses streams and river systems. More detailed guidance is given in the *Technical Support Manual: Waterbody Surveys and Assessments for Conducting Use Attainability Analyses, Volume I* (USEPA, 1983c). EPA has also developed guidance for estuarine and marine systems and lakes, which is summarized in following sections. More detailed guidance for these aquatic systems is available in the *Technical Support Manual, Volume II, Estuarine Systems*, and *Volume III, Lake Systems* (USEPA, 1984a,b).

Several approaches for analyzing the aquatic life protection uses to determine if such uses are appropriate for a given water body are discussed. States are encouraged to use existing data to perform the physical, chemical, and biological evaluations presented in this guidance document. Not all of these evaluations are necessarily applicable. For example, if an assessment reveals that the physical habitat is the limiting factor precluding a use, a chemical evaluation would not be required. In addition, wherever possible, States also should consider grouping together water bodies having similar physical, chemical, and biological characteristics either to treat several water bodies or stream segments as a single unit or to establish representative conditions applicable to other similar water bodies or stream segments within a river basin. Using existing data and establishing representative conditions applicable to a number of water bodies or segments should conserve the limited resources available to the States.

Table 2-1 summarizes the types of physical, chemical, and biological factors that may be evaluated when conducting a UAA. Several approaches can be used for conducting the physical, chemical, and biological evaluations, depending on the complexity of the situation. Details on the various evaluations can be found in the *Technical Support Manual: Waterbody Surveys and Assessments for Conducting Use Attainability Analyses, Volume I* (USEPA, 1983c). A survey need not consider all of the parameters listed; rather, the survey should be designed on the basis of the water body characteristics and other considerations relevant to a particular survey.

These approaches may be adapted to the water body being examined. Therefore, a close working relationship between EPA and the States is essential so that EPA can assist States in determining the appropriate analyses to be used in support of any water quality standards revisions. These analyses should be made available to all interested parties before any public forums on the water quality standards to allow for full discussion of the data and analyses.

2.9.2 Physical Factors

Section 101(a) of the Clean Water Act recognizes the importance of preserving the physical integrity of the Nation's water bodies. Physical habitat plays an important role in the overall aquatic ecosystem and impacts the types and number of species present in a particular body of water. Physical parameters of a water body are examined to identify factors that impair the propagation and protection of aquatic life and to determine what uses could be obtained in the water body given such limitations. In general, physical parameters such as flow, temperature, water depth, velocity,

PHYSICAL FACTORS	CHEMICAL FACTORS	BIOLOGICAL FACTORS
♦ **instream characteristics** - size (mean width/depth) - flow/velocity - annual hydrology - total volume - reaeration rates - gradient/pools/ riffles - temperature - sedimentation - channel modifications - channel stability	♦ **dissolved oxygen** ♦ **toxicants** ♦ **suspended solids** ♦ **nutrients** - nitrogen - phosphorus ♦ **sediment oxygen demand** ♦ **salinity**	♦ **biological inventory (existing use analysis)** - fish - macroinvertebrates - microinvertebrates - phytoplankton - periphyton - macrophytes ♦ **biological potential analysis** - diversity indices
♦ **substrate composition and characteristics** ♦ **channel debris** ♦ **sludge deposits** ♦ **riparian characteristics** ♦ **downstream characteristics**	♦ **hardness** ♦ **alkalinity** ♦ **pH** ♦ **dissolved solids**	- HSI models - tissue analyses - recovery index - intolerant species analysis - omnivore-carnivore analysis ♦ **biological potential analysis** - reference reach comparison

Table 2-1. Summary of Typical Factors Used in Conducting a Water Body Survey and Assessment

substrate, reaeration rates, and other factors are used to identify any physical limitations that may preclude attainment of the designated use. Depending on the water body in question, any of the physical parameters listed in Table 2-1 may be appropriately examined. A State may use any of these parameters to identify physical limitations and characteristics of a water body. Once a State has identified any physical limitations based on evaluating the parameters listed, careful consideration of "reversibility" or the ability to restore the physical integrity of the water body should be made. Such considerations may include whether it would cause more environmental damage to correct the problem than to leave the water body as is, or whether physical impediments such as dams can be operated or modified in a way that would allow attainment of the use.

Several assessment techniques have been developed that correlate physical habitat characteristics to fishery resources. The identification of physical factors limiting a fishery is a critical assessment that provides important data for management of the water body. The U.S. Fish and Wildlife Service has developed habitat evaluation procedures (HEP) and habitat suitability indices (HSI). Several States have begun developing their own models and procedures for habitat assessments. Parameters generally included in habitat assessment procedures are temperature, turbidity, velocity, depth, cover, pool and riffle sizes, riparian vegetation, bank stability, and siltation. These parameters are correlated to fish species by evaluating the habitat variables important to the life cycle of the species. The value of habitat for other groups of aquatic organisms such as macroinvertebrates and periphyton also may be considered. Continued research and refinement of habitat evaluation procedures reflect the importance of physical habitat.

If physical limitations of a stream restrict the use, a variety of habitat modification techniques might restore a habitat so that a species could thrive where it could not before. Some of the techniques that have been used are bank stabilization, flow control, current deflectors, check dams, artificial meanders, isolated oxbows, snag clearing when determined not to be detrimental to the life cycle or reproduction of a species, and installation of spawning beds and artificial spawning channels. If the habitat is a limiting factor to the propagation and/or survival of aquatic life, the feasibility of modifications might be examined before additional controls are imposed on dischargers.

2.9.3 Chemical Evaluations

The chemical characteristics of a water body are examined to determine why a designated use is not being met and to determine the potential of a particular species to survive in the water body if the concentration of particular chemicals were modified. The State has the discretion to determine the parameters required to perform an adequate water chemistry evaluation. A partial list of the parameters that may be evaluated is provided in Table 2-1.

As part of the evaluation of the water chemistry composition, a natural background evaluation is useful in determining the relative contribution of natural background contaminants to the water body; this may be a legitimate factor that effectively prevents a designated use from being met. To determine whether the natural background concentration of a pollutant is adversely impacting the survival of species, the concentration may be compared to one of the following:

- 304(a) criteria guidance documents; or
- site-specific criteria; or
- State-derived criteria.

Another way to obtain an indication of the potential for the species to survive is to determine if the species are found in other waterways with similar chemical concentrations.

In determining whether human-caused pollution is irreversible, consideration needs to be given to the permanence of the damage, the feasibility of abating the pollution, or the additional environmental damage that may result from removing the pollutants. Once a State identifies the chemical or water quality characteristics that are limiting attainment of the use, differing levels of remedial control measures may be explored. In addition, if instream toxicants cannot be removed by natural processes and cannot be removed by human effort without severe long-term environmental impacts, the pollution may be considered irreversible.

In some areas, the water's chemical characteristics may have to be calculated using predictive water quality models. This will be true if the receiving water is to be impacted by new dischargers, changes in land use, or improved treatment facilities. Guidance is available on the selection and use of receiving water models for biochemical oxygen demand, dissolved oxygen, and ammonia for instream systems (USEPA, 1983d,e) and dissolved oxygen, nitrogen, and phosphorus for lake systems, reservoirs, and impoundments (USEPA, 1983f).

2.9.4 Biological Evaluations

In evaluating what aquatic life protection uses are attainable, the biology of the water body should be evaluated. The interrelationships between the physical, chemical, and biological characteristics are complex, and alterations in the physical and/or chemical parameters result in biological changes. The biological evaluation described in this section encourages States to:

- provide a more precise statement of which species exist in the water body and should be protected;
- determine the biological health of the water body; and
- determine the species that could potentially exist in the water body if the physical and chemical factors impairing a use were corrected.

This section of the guidance will present the conceptual framework for making these evaluations. States have the discretion to use other scientifically and technically supportable assessment methodologies deemed appropriate for specific water bodies on a case-by-case basis. Further details on each of the analyses presented can be found in the *Technical Support Manual for Conducting Use Attainability Analyses* (USEPA, 1983c).

Biological Inventory (Existing Use Analysis)

The identification of which species are in the water body and should be protected serves several purposes:

- By knowing what species are present, the biologist can analyze, in general terms, the health of the water body. For example, if the fish species present are principally carnivores, the quality of the water is generally higher than in a water body dominated by omnivores. It also allows the biologist to assess the presence or absence of intolerant species.
- Identification of the species enables the State to develop baseline conditions against which to evaluate any remedial actions. The development of a regional baseline based upon several site-specific species lists increases an understanding of the regional fauna. This allows for easier grouping of water bodies based on the biological regime of the area.
- By identifying the species, the decision-maker has the data needed to explain the present condition of the water body to the public and the uses that must be maintained.

The evaluation of the existing biota may be simple or complex depending on data availability. As much information as possible should be gathered on the categories of organisms listed in Table 2-1. It is not necessary to obtain complete data for all six categories. However, it is recommended that fish should be included in any combination of categories chosen because:

- the general public can relate better to statements about the condition of the fish community;
- fish are typically present even in the smallest streams and in all but the most polluted waters;
- fish are relatively easy to identify, and samples can be sorted and identified at the field site;
- life-history information is extensive for many fish species so that stress effects can be evaluated (Karr, 1981). In addition, since fish are mobile, States are encouraged to evaluate other categories of organisms.

Before any field work is conducted, existing data should be collected. EPA can provide data from intensive monitoring surveys and special studies. Data, especially for fish, may be available from State fish and game departments, recreation agencies, and local governments, or through environmental impact statements, permit reviews, surveys, and university or other studies.

Biological Condition/Biological Health Assessment

The biological inventory can be used to gain insight into the biological health of the water body by evaluating:

- species richness or the number of species;
- presence of intolerant species;
- proportion of omnivores and carnivores;
- biomass or production; and
- number of individuals per species.

The role of the biologist becomes critical in evaluating the health of the biota because the knowledge of expected richness or expected species comes only from understanding the general biological traits and regimes of the area. Best professional judgments by local biologists are important. These judgments are based on many years of experience and on observations of the physical and chemical changes that have occurred over time.

Many methods for evaluating biotic communities have been and continue to be developed. The *Technical Support Manual for Conducting Use Attainability Analyses* (USEPA, 1983c) and *Rapid Bioassessment Protocols for Use in Streams and Rivers* (USEPA, 1989e) describe methods that States may want to consider using in their biological evaluations.

A number of other methods have been and are being developed to evaluate the health of biological components of the aquatic ecosystem including short-term *in situ* or laboratory bioassays and partial or full life-cycle toxicity tests. These methods are discussed in several EPA publications, including the *Biological Methods Manual* (USEPA, 1972). Again, it is not the intent of this document to specify tests to be conducted by the States. This will depend on the information available, the predictive accuracy required, site-specific conditions of the water body being examined, and the cooperation and assistance the State receives from the affected municipalities and industries.

Biological Potential Analysis

A significant step in the use attainability analysis is the evaluation of what communities could potentially exist in a particular water body if pollution were abated or if the physical habitat were modified. The approach presented is to compare the water body in question to reference reaches within a region. This approach includes the development of baseline conditions to facilitate the comparison of several water bodies at less cost. As with the other analyses mentioned previously, available data should be used to minimize resource impacts.

The biological potential analysis involves:

- defining boundaries of fish faunal regions;
- selecting control sampling sites in the reference reaches of each area;
- sampling fish and recording observations at each reference sampling site;
- establishing the community characteristics for the reference reaches of each area; and
- comparing the water body in question to the reference reaches.

In establishing faunal regions and sites, it is important to select reference areas for sampling sites that have conditions typical of the region.

The establishment of reference areas may be based on physical and hydrological characteristics. The number of reference reaches needed will be determined by the State depending on the variability of the waterways within the State and the number of classes that the State may wish to establish. For example, the State may want to use size, flow, and substrate as the defining characteristics and may consequently desire to establish classes such as small, fast running streams with sandy substrate or large, slow rivers with cobble bottom. It is at the option of the State to:

- choose the parameters to be used in classifying and establishing reference reaches; and
- determine the number of classes (and thus the refinement) within the faunal region.

This approach can also be applied to other aquatic organisms such as macroinvertebrates (particularly freshwater mussels) and algae.

Selection of the reference reaches is of critical importance because the characteristics of the aquatic community will be used to establish baseline conditions against which similar reaches (based on physical and hydrological characteristics) are compared. Once the reference reaches are established, the water body in question can be compared to the reference reach. The results of this analysis will reveal whether the water body in question has the typical biota for that class or a less desirable community and will provide an indication of what species may potentially exist if pollution were abated or the physical habitat limitations were remedied.

2.9.5 Approaches to Conducting the Physical, Chemical, and Biological Evaluations

In some cases, States that assess the status of their aquatic resources, will have relatively simple situations not requiring extensive data collection and evaluation. In other situations, however, the complexity resulting from variable environmental conditions and the stress from multiple uses of the resource will require both intensive and extensive studies to produce a sound evaluation of the system. Thus, procedures that a State may develop for conducting a water body assessment should be flexible enough to be adaptable to a variety of site-specific conditions.

A common experimental approach used in biological assessments has been a hierarchical approach to the analyses. This can be a rigidly tiered approach. An alternative is presented in Figure 2-2.

The flow chart is a general illustration of a thought process used to conduct a use attainability analysis. The process illustrates several alternative approaches that can be pursued separately or, to varying degrees, simultaneously depending on:

- the amount of data available on the site;
- the degree of accuracy and precision required;
- the importance of the resource;
- the site-specific conditions of the study area; and
- the controversy associated with the site.

The degree of sophistication is variable for each approach. Emphasis is placed on evaluating available data first. If information is found to be lacking or incomplete, then field testing or field surveys should be conducted.

The major elements of the process are briefly described below.

Steps 1 and 2

Steps 1 and 2 are the basic organizing steps in the evaluation process. By carefully defining the objectives and scope of the evaluation, there will be some indication of the level of sophistication required in subsequent surveys and testing. States and the regulated community can then adequately plan and allocate resources to the analyses. The designated use of the water body in question

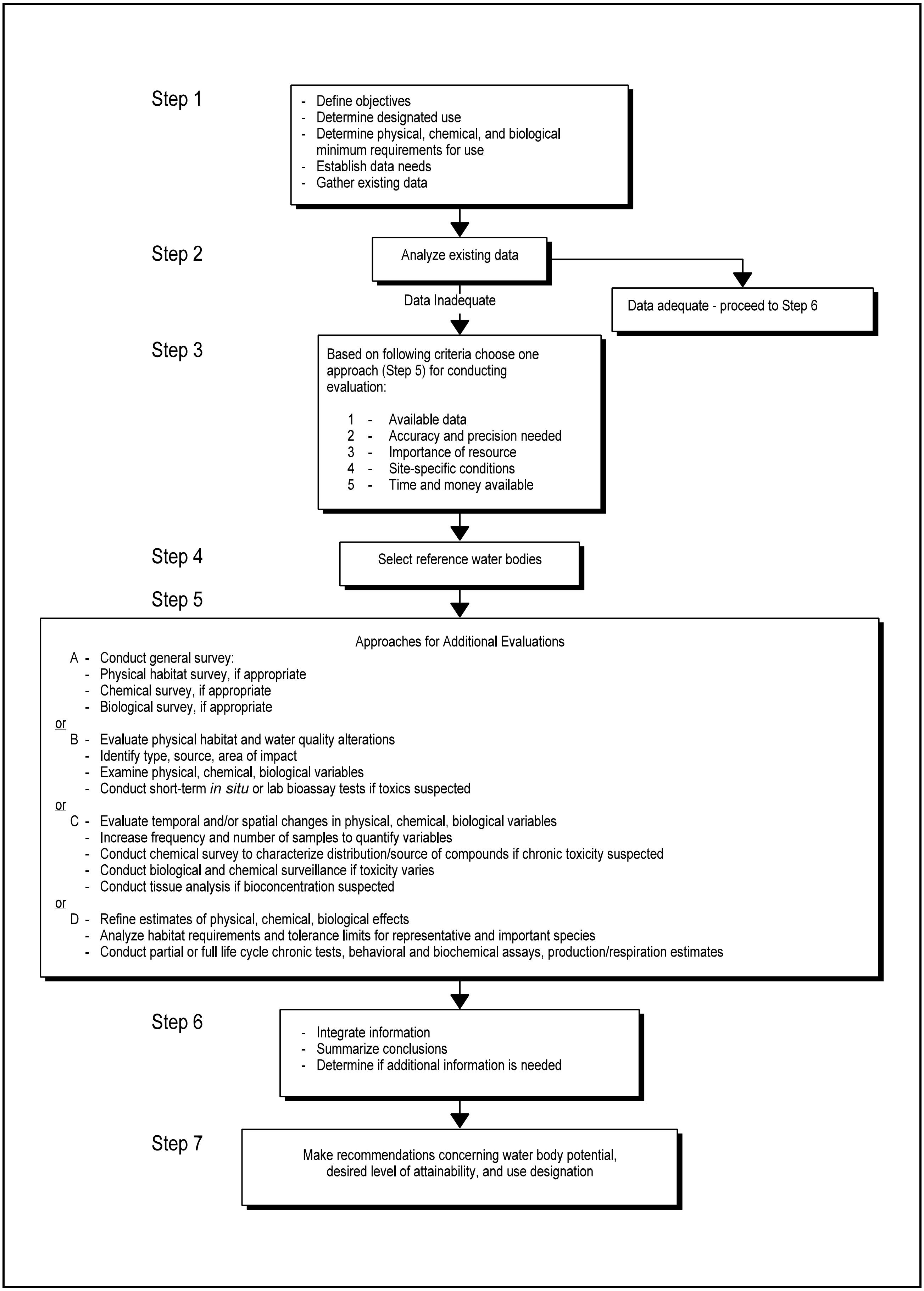


Figure 2-2. Steps in a Use Attainability Analysis

should be identified as well as the minimum chemical, physical, and biological requirements for maintaining the use. Minimum requirements may include, for example, dissolved oxygen levels, flow rates, temperature, and other factors. All relevant information on the water body should be collected to determine if the available information is adequate for conducting an appropriate level of analysis. It is assumed that all water body evaluations, based on existing data, will either formally or informally be conducted through Steps 1 and 2.

Steps 3 and 4

If the available information proves inadequate, then decisions regarding the degree of sophistication required in the evaluation process will need to be made. These decisions will, most likely, be based on the five criteria listed in Step 3 of Figure 2-2. Based on these decisions, reference areas should be chosen (Step 4), and one or more of the testing approaches should be followed.

Steps 5A, B, C, D

These approaches are presented to illustrate several possible ways of analyzing the water body. For example, in some cases chemical data may be readily available for a water body but little or no biological information is known. In this case, extensive chemical sampling may not be required, but enough samples should be taken to confirm the accuracy of the available data set. Thus, to accurately define the biological condition of the resource, 5C may be chosen, but 5A may be pursued in a less intensive way to supplement the chemical data already available.

Step 5A is a general survey to establish relatively coarse ranges for physical and chemical variables, and the numbers and relative abundances of the biological components (fishes, invertebrates, primary producers) in the water body. Reference areas may or may not need to be evaluated here, depending on the types of questions being asked and the degree of accuracy required.

Step 5B focuses more narrowly on site-specific problem areas with the intent of separating, where possible, biological impacts due to physical habitat alteration versus those due to chemical impacts. These categories are not mutually exclusive but some attempt should be made to define the causal factors in a stressed area so that appropriate control measures can be implemented if necessary.

Step 5C would be conducted to evaluate possibly important trends in the spatial and/or temporal changes associated with the physical, chemical, and biological variables of interest. In general, more rigorous quantification of these variables would be needed to allow for more sophisticated statistical analyses between reference and study areas which would, in turn, increase the degree of accuracy and confidence in the predictions based on this evaluation. Additional laboratory testing may be included, such as tissue analyses, behavioral tests, algal assays, or tests for flesh tainting. Also, high-level chemical analyses may be needed, particularly if the presence of toxic compounds is suspected.

Step 5D is, in some respects, the most detailed level of study. Emphasis is placed on refining cause-effect relationships between physical-chemical alterations and the biological responses previously established from available data or steps 5A through 5C. In many cases, state-of-the-art techniques will be used. This pathway would be conducted by the States only where it may be necessary to establish, with a high degree of confidence, the cause-effect relationships that are producing the biological community characteristics of those areas. Habitat requirements or tolerance limits for representative or important species may have to be determined for those factors limiting the potential of the ecosystem. For these evaluations, partial or full life-cycle toxicity tests, algal assays, and sediment bioassays may be needed along with the shorter term bioassays designed to elucidate sublethal effects not readily apparent in toxicity tests (e.g., preference-avoidance responses, production-respiration estimates, and bioconcentration estimates).

Steps 6 and 7

After field sampling is completed, all data must be integrated and summarized. If this information is still not adequate, then further testing may be required and a more detailed pathway chosen. With adequate data, States should be able to make reasonably specific recommendations concerning the natural potential of the water body, levels of attainability consistent with this potential, and appropriate use designations.

The evaluation procedure outlined here allows States a significant degree of latitude for designing assessments to meet their specific goals in water quality and water use.

2.9.6 Estuarine Systems

This section provides an overview of the factors that should be considered in developing use attainability analyses for estuaries. Anyone planning to conduct a use attainability analysis for an estuary should consult the *Technical Support Manual: Waterbody Surveys and Assessments for Conducting Use Attainability Analyses, Volume II: Estuarine Systems* (USEPA, 1984a) for more detailed guidance. Also, much of the information for streams and rivers that is presented above and in Volume I of the Technical Support Manual, particularly with respect to chemical evaluations, will apply to estuaries and is not repeated here.

The term "estuaries" is generally used to denote the lower reaches of a river where tide and river flows interact. Estuaries are very complex receiving waters that are highly variable in description and are not absolutes in definition, size, shape, aquatic life, or other attributes. Physical, chemical, and biological attributes may require consideration unique to estuaries and are discussed below.

Physical Processes

Estuarine flows are the result of a complex interaction of the following physical factors:

- tides;
- wind shear;
- freshwater inflow (momentum and buoyancy);
- topographic frictional resistance;
- Coriolis effect;
- vertical mixing; and
- horizontal mixing.

In performing a use attainability study, one may simplify the complex prototype system by determining which of these effects or combination of effects is most important at the time scale of the evaluation (days, months, seasons, etc.).

Other ways to simplify the approach to analyzing an estuary is to place it in a broad classification system to permit comparison of similar types of estuaries. The most common groupings are based on geomorphology, stratification, circulation patterns, and time scales. Each of these groupings is discussed below.

Geomorphological classifications can include types such as drowned river valleys (coastal plain estuaries), fjords, bar-built estuaries, and other estuaries that do not fit the first three classifications (those produced by tectonic activity, faulting, landslides, or volcanic eruptions).

Stratification is most often used for classifying estuaries influenced by tides and freshwater inflows. Generally, highly stratified estuaries have large river discharges flowing into them, partially mixed estuaries have medium river discharges; and vertically homogeneous have small river discharges.

Circulation in an estuary (i.e., the velocity patterns as they change over time) is primarily affected by the freshwater outflow, the tidal inflow, and the effect of wind. In turn, the difference in density between outflow and inflow sets up secondary currents that ultimately affect the salinity distribution across the estuary. The salinity distribution is important because it affects the distribution of fauna and flora within the estuary. It is also important because it is indicative of the mixing properties of the estuary as they may affect the dispersion of pollutants (flushing properties). Additional factors such as friction forces and the size and geometry of the estuary also contribute to the circulation patterns. The complex geometry of estuaries, in combination with the presence of wind, the effect of the Earth's rotation (Coriolis effect), and other effects, often results in residual currents (i.e., of longer period than the tidal cycle) that strongly influence the mixing processes in estuaries.

Consideration of time scales of the physical processes being evaluated is very important for any water quality study.

Short-term conditions are much more influenced by a variety of short-term events that perhaps have to be analyzed to evaluate a "worst case" scenario. Longer term (seasonal) conditions are influenced predominantly by events that are averaged over the duration of that time scale.

Estuary Substrate Composition

Characterization of sediment/substrate properties is important in a use attainability analysis because such properties:

- determine the extent to which toxic compounds in sediments are available to the biota; and
- determine what types of plants and animals could potentially become established, assuming no interference from other factors such as nutrient, dissolved oxygen (DO), and/or toxics problems.

The bottom of most estuaries is a mix of sand, silt, and mud that has been transported and deposited by ocean currents or by freshwater sources. Rocky areas may also be present, particularly in the fjord-type estuary. None of these substrate types is particularly hospitable to aquatic plants and animals, which accounts in part for the paucity of species seen in an estuary.

The amount of material transported to the estuary will be determined by the types of terrain through which the river passes, and upon land use practices that may encourage runoff and erosion. It is important to take land use practices into consideration when examining the attainable uses of the estuary. Deposition of particles varies with location in the estuaries and velocity of the currents.

It is often difficult for plants to colonize estuaries because of a lack of suitable anchorage points and because of the turbidity of the water, which restricts light penetration (McLusky, 1971). Submerged aquatic vegetation (SAV) (macrophytes) develops in sheltered areas where silt and mud accumulate. These plants help to slow the currents, leading to further deposition of silt. The growth of plants often keeps pace with rising sediment levels so that over a long period of time substantial deposits of sediment and plant material may be seen.

SAV serves very important roles as habitat and as a food source for much of the biota of the estuary. Major estuary studies have shown that the health of SAV communities serves as an important indicator of estuary health.

Adjacent Wetlands

Tidal and freshwater wetlands adjacent to the estuary can serve as a buffer to protect the estuary from external phenomena. This function may be particularly important during wet weather periods when relatively high stream flows discharge high loads of sediment and pollutants to the estuary. The wetlands slow the peak velocity, to some extent alleviate the sudden shock of salinity changes, and filter some of the sediments and nutrients that would otherwise be discharged directly into the estuary.

Hydrology and Hydraulics

The two most important sources of freshwater to the estuary are stream flow and precipitation. Stream flow generally represents the greatest contribution to the estuary. The location of the salinity gradient in a river-controlled estuary is to a large extent a function of stream flow. Location of the iso-concentration lines may change considerably, depending upon whether stream flow is high or low. This in turn may affect the biology of the estuary, resulting in population shifts as biological species adjust to changes in salinity. Most estuarine species are adapted to survive temporary changes in salinity either by migration or some other mechanism (e.g., mussels can close their shells). However, many cannot withstand these changes indefinitely. Response of an estuary to rainfall events depends upon the intensity of rainfall, the drainage area affected by the rainfall, and the size of the estuary. Movement of the salt front is dependent upon tidal influences and freshwater flow to the estuary. Variations in salinity generally follow seasonal patterns such that the salt front will occur farther down-estuary during a rainy season than during a dry season. The salinity profile also may vary from day to day, reflecting the effect of individual rainfall events, and may undergo major changes due to extreme meteorological events.

Anthropogenic activity also may have a significant effect on salinity in an estuary. When feeder streams are used as sources of public water supply and the withdrawals are not returned, freshwater flow to the estuary is reduced, and the salt wedge is found farther up the estuary. If the water is returned, usually in the form of wastewater effluent, the salinity gradient of the estuary may not be affected, although other problems attributable to nutrients and other pollutants in the wastewater may occur.

Salinity also may be affected by the way that dams along the river are operated. Flood control dams result in controlled discharges to the estuary rather than relatively short but massive discharge during high-flow periods. Dams operated to impound water for water supplies during low-flow periods may drastically alter the pattern of freshwater flow to the estuary, and although the annual discharge may remain the same, seasonal changes may have significant impact on the estuary and its biota.

Influence of Physical Characteristics on Use Attainability

"Segmentation" of an estuary can provide a useful framework for evaluating the influence of estuarine physical characteristics such as circulation, mixing, salinity, and geomorphology on use attainability. Segmentation is the compartmentalization of an estuary into subunits with homogeneous physical characteristics. In the absence of water pollution, physical characteristics of different regions of the estuary tend to govern the suitability for major water uses. Once the segment network is established, each segment can be subjected to a use attainability analysis. In addition, the segmentation process offers a useful management structure for monitoring conformance with water quality goals in future years.

The segmentation process is an evaluation tool that recognizes that an estuary is an interrelated ecosystem composed of chemically, physically, and biologically diverse areas. It assumes that an ecosystem as diverse as an estuary cannot be effectively managed as only one unit because different uses and associated water quality goals will be appropriate and feasible for different regions of the estuary. However, after developing a network based upon physical characteristics, sediment boundaries can be refined with available chemical and biological data to maximize the homogeneity of each segment.

A potential source of concern about the construction and utility of the segmentation scheme for use attainability evaluations is that the estuary is a fluid system with only a few obvious boundaries, such as the sea surface and the sediment-water interface. Fixed boundaries may seem unnatural to scientists, managers, and users, who are more likely to view the estuary as a continuum than as a system composed of separable parts. The best approach to dealing with such concerns is a segmentation scheme that stresses the dynamic nature of the estuary. The scheme should emphasize that the segment boundaries are operationally defined constructs to assist in understanding a changeable, intercommunicating system of channels, embayments, and tributaries.

To account for the dynamic nature of the estuary, it is recommended that estuarine circulation patterns be a prominent factor in delineating the segment network. Circulation patterns control the transport of and residence times for heat, salinity, phytoplankton, nutrients, sediment, and other pollutants throughout the estuary. Salinity should be another important factor in delineating the segment network. The variations in salinity concentrations from head of tide to the mouth typically produce a separation of biological communities based on salinity tolerances or preferences.

Chemical Parameters

The most critical chemical water quality indicators for aquatic use attainment in an estuary are dissolved oxygen, nutrients and chlorophyll-a, and toxicants. Dissolved oxygen (DO) is an important water quality indicator for all fisheries uses. In evaluating use attainability, assessments of DO impacts should consider the relative contributions of three different sources of oxygen demand:

- photosynthesis/respiration demand from phytoplankton;
- water column demand; and
- benthic oxygen demand.

If use impairment is occurring, assessments of the significance of each oxygen sink can be used to evaluate the feasibility of achieving sufficient pollution control to attain the designated use.

Chlorophyll-a is the most popular indicator of algal concentrations and nutrient overenrichment, which in turn can be related to diurnal DO depressions due to algal respiration. Typically, the control of phosphorus levels can limit algal growth near the head of the estuary, while the control of nitrogen levels can limit algal growth near the mouth of the estuary; however, these relationships are dependent upon factors such as nitrogen phosphorus ("N/P") ratios and light penetration potential, which can vary from one estuary to the next. Excessive phytoplankton concentrations, as indicated by chlorophyll-a levels, can cause adverse DO impacts such as:

- wide diurnal variations in surface DO due to daytime photosynthetic oxygen production and nighttime oxygen depletion by respiration; and
- depletion of bottom DO through the decomposition of dead algae.

Excessive chlorophyll-a levels also result in shading, which reduces light penetration for submerged aquatic vegetation (SAV). Consequently, the prevention of nutrient over-enrichment is probably the most important water quality requirement for a healthy SAV community.

The nutrients of greatest concern in the estuary are nitrogen and phosphorus. Their sources typically are discharges from sewage treatment plants and industries and runoff from urban and agricultural areas. Increased nutrient levels lead to phytoplankton blooms and a subsequent reduction in DO levels and light penetration, as discussed above.

Sewage treatment plants are typically the major source of nutrients, particularly phosphorus, to estuaries in urban areas. Agricultural land uses and urban land uses represent significant nonpoint sources of nutrients, particularly nitrogen. It is important to base control strategies on an understanding of the sources of each type of nutrient, both in the estuary and in its feeder streams.

Point sources of nutrients are typically much more amenable to control than nonpoint sources. Because phosphorus removal for municipal wastewater discharges is typically less expensive than nitrogen removal operations, the control of phosphorus discharges is often the method of choice for the prevention or reversal of use impairment in the upper estuary (i.e., tidal fresh zone). However, nutrient control in the upper reaches of the estuary may cause algal blooms in the lower reaches, e.g., control of phosphorus in the upper reaches may reduce the algal blooms there, but in doing so also increase the amount of nitrogen transported to the lower reaches where nitrogen is the limiting nutrient causing a bloom there. Tradeoffs between nutrient controls for the upper and lower estuary should be considered in evaluating measures for prevention of reversing use impairment.

Potential interferences from toxic substances, such as pesticides, herbicides, heavy metals, and chlorinated effluents, also need to be considered in a use attainability study. The presence of certain toxicants in excessive concentrations within bottom sediments of the water column may prevent the attainment of water uses (particularly fisheries propagation/harvesting and sea grass habitat uses) in estuary segments that satisfy water quality criteria for DO, chlorophyll-a/nutrient enrichment, and fecal coliform.

Biological Community Characteristics

The *Technical Support Manual, Volume II* (USEPA, 1984a) provides a discussion of the organisms typically found in estuaries in more detail than is appropriate for this Handbook. Therefore, this discussion will focus on more general characteristics of estuarine biota and their adaptations to accommodate a fluctuating environment.

Salinity, light penetration, and substrate composition are the most critical factors to the distribution and survival of plant and animal communities in an estuary. The estuarine environment is characterized by variations in circulation, salinity, temperature, and dissolved oxygen supply. Colonizing plants and animals must be able to withstand the fluctuating conditions in estuaries.

The depth to which attached plants may become established is limited by turbidity because plants require light for photosynthesis. Estuaries are typically turbid because of large quantities of detritus and silt contributed by surrounding marshes and rivers. Algal growth also may hinder light penetration. If too much light is withheld from the lower depths, animals cannot rely heavily on visual cues for habitat selection, feeding, or finding a mate.

Estuarine organisms are recruited from the sea, freshwater environments, and the land. The major environmental factors to which organisms must adjust are periodic submersion and desiccation as well as fluctuating salinity, temperature, and dissolved oxygen.

Several generalizations concerning the responses of estuarine organisms to salinity have been noted (Vernberg, 1983) and reflect a correlation of an organism's habitat to its tolerance:

- organisms living in estuaries subjected to wide salinity fluctuations can withstand a wider range of salinities than species that occur in high-salinity estuaries;

- intertidal zone animals tend to tolerate wider ranges of salinities than do subtidal and open-ocean organisms;

- low intertidal species are less tolerant of low salinities than are high intertidal species; and

- more sessile animals are likely to be more tolerant of fluctuating salinities than organisms that are highly mobile and capable of migrating during times of salinity stress.

Estuaries are generally characterized by low diversity of species but high productivity because they serve as the nursery or breeding grounds for some species. Methods to measure the biological health and diversity of estuaries are discussed in USEPA (1984a).

Techniques for Use Attainability Evaluations

In assessing use levels for aquatic life protection, determination of the present use and whether this corresponds to the designated use is evaluated in terms of biological measurements and indices. However, if the present use does not correspond to the designated use, physical and chemical factors are used to explain the lack of attainment and the highest level the system can achieve.

The physical and chemical evaluations may proceed on several levels depending on the level of detail required, amount of knowledge available about the system (and similar systems), and budget for the use attainability study. As a first step, the estuary is classified in terms of physical processes so that it can be compared with reference estuaries in terms of differences in water quality and biological communities, which can be related to man-made alteration (i.e., pollution discharges).

The second step is to perform desktop or simple computer model calculations to improve the understanding of spatial and temporal water quality conditions in the present system. These calculations include continuous point source and simple box model-type calculations. A more detailed discussion of the desktop and computer calculations is given in USEPA (1984a).

The third step is to perform detailed analyses through the use of more sophisticated computer models. These tools can be used to evaluate the system's response to removing individual point and nonpoint source discharges, so as to assist with assessments of the cause(s) of any use impairment.

2.9.7 Lake Systems

This section will focus on the factors that should be considered in performing use attainability analyses for lake systems. Lake systems are in most cases linked physically to rivers and streams and exhibit a transition from riverine habitat and conditions to lacustrine habitat and conditions. Therefore, the information presented in section 2.9.1 through 2.9.5 and the *Technical Support Manual, Volume I* (USEPA, 1983c) will to some extent apply to lake systems. EPA has provided guidance specific to lake systems in the *Technical Support Manual for Conducting Use Attainability Analyses, Volume III: Lake Systems* (USEPA, 1984b). This manual should be consulted by anyone performing a use attainability analysis for lake systems.

Aquatic life uses of a lake are defined in reference to the plant and animal life in a lake. However, the types and abundance of the biota are largely determined by the physical and chemical characteristics of the lake. Other contributing factors include the location, climatological conditions, and historical events affecting the lake.

Physical Parameters

The physical parameters that describe the size, shape, and flow regime of a lake represent the basic characteristics that affect physical, chemical, and biological processes. As part of a use attainability analysis, the physical parameters must be examined to understand non-water quality factors that affect the lake's aquatic life.

The origins of a lake determine its morphologic characteristics and strongly influence the physical, chemical, and biological conditions that will prevail. Therefore, grouping lakes formed by the same process often will allow comparison of similar lake systems. Measurement of the following morphological characteristics may be of importance to a water body survey:

- surface area;
- volume;
- inflow and outflow;
- mean depth;
- maximum depth;
- length;
- length of shoreline;
- depth-area relationships;
- depth-volume relationships; and
- bathymetry (submerged contours).

These physical parameters can in some cases be used to predict biological parameters. For example, mean depth has been used as an indicator of productivity. Shallow lakes tend to be more productive, and deep, steep-sided lakes tend to be less productive. These parameters may also be used to calculate other characteristics of the lake such as mass flow rate of a chemical, surface loading rate, and detention time.

Total lake volume and inflow and outflow rates are physical characteristics that indirectly affect the lake's aquatic community. Large inflows and outflows for lakes with small volumes produce low detention times or high flow-through rates. Aquatic life under these conditions may be different than when relatively small inflows and outflows occur for a large-volume lake where long detention times occur.

The shape factor (lake length divided by lake width) also may be correlated to chemical and biological characteristics. This factor has been used to predict parameters such as chlorophyll-a levels in lakes. For more detailed lake analysis, information describing the depth-area and depth-volume relationships and information describing the bathymetry may be required.

In addition to the physical parameters listed above, it is also important to obtain and analyze information concerning the lake's contributing watershed. Two major parameters of concern are the drainage area of the contributing watershed and the land uses of that watershed. Drainage area will aid in the analysis of inflow volumes to the lake due to surface runoff. The land use classification of the area around the lake can be used to predict flows and also nonpoint source pollutant loadings to the lake.

The physical parameters discussed above may be used to understand and analyze the various physical processes that occur in lakes. They can also be used directly in simplistic relationships that predict productivity to aid in aquatic use attainability analyses.

Physical Processes

Many complex and interrelated physical processes occur in lakes. These processes are highly dependent on the lake's physical parameters, location, and characteristics of the contributing watershed. Several of the major processes are discussed below.

Lake Currents

Water movement in a lake affects productivity and the biota because it influences the distribution of nutrients, microorganisms, and plankton. Lake currents are propagated by wind, inflow/outflow, and the Coriolis force. For small shallow lakes, particularly long and narrow lakes, inflow/outflow characteristics are most important, and the predominant current is a steady-state flow through the lake. For very large lakes, wind is the primary generator of currents, and except for local effects, inflow/outflow have a relatively minor effect on lake circulation. Coriolis effect, a deflecting force that is the function of the Earth's rotation, also plays a role in circulation in large lakes such as the Great Lakes.

Heat Budget

Temperature and its distribution within lakes and reservoirs affects not only the water quality within the lake but also the thermal regime and quality of a river system downstream of the lake. The thermal regime of a lake is a function of the heat balance around the body of water. Heat transfer modes into and out of the lake include heat transfer through the air-water interface, conduction through the mud-water interface, and inflow and outflow heat advection.

Heat transfer through the air-water interface is primarily responsible for typical annual temperature cycles. Heat is transferred across the air-water interface by three different processes: radiation exchange, evaporation, and conduction. The heat flux of the air-water interface is a function of location (latitude/longitude and elevation), season, time of day, and meteorological conditions (cloud cover, dew-point, temperature, barometric pressure, and wind).

Light Penetration

Transmission of light through the water column influences primary productivity (phytoplankton and macrophytes), distribution of organisms, and behavior of fish. The reduction of light through the water column of a lake is a function of scattering and absorption. Light transmission is affected by the water surface film, floatable and suspended particulates, turbidity, dense populations of algae and bacteria, and color.

An important parameter based on the transmission of light is the depth to which photosynthetic activity is possible. The minimum light intensity required for photosynthesis has been established to be about 1.0 percent of the incident surface light (Cole, 1979). The portion of the lake from the surface to the depth at which the 1.0 percent intensity occurs is referred to as the "euphotic zone."

Lake Stratification

Lakes in temperate and northern latitudes typically exhibit vertical density stratification during certain seasons of the year. Stratification in lakes is primarily due to temperature differences, although salinity and suspended solids concentrations may also affect density. Typically, three zones of thermal stratification are formed.

The upper layer of warmer, lower density water is termed the "epilimnion," and the lower, stagnant layer of colder, higher density water is termed the "hypolimnion." The transition zone between the epilimnion and the hypolimnion, referred to as the "metalimnion," is characterized by the maximum rate of temperature decline with depth (the thermocline). During stratification, the presence of the thermocline suppresses many of the mass transport phenomena that are otherwise responsible for the vertical transport of water quality constituents within a lake. The aquatic community present in a lake is highly dependent on the thermal structure.

With respect to internal flow structure, three distinct classes of lakes are defined:

- strongly stratified, deep lakes characterized by horizontal isotherms;
- weakly stratified lakes characterized by isotherms that are tilted along the longitudinal axis of the reservoir; and
- non-stratified, completely mixed lakes characterized by isotherms that are essentially vertical.

Retardation of mass transport between the hypolimnion and the epilimnion results in sharply differentiated water quality and biology between the lake strata. One of the most important differences between the layers is often dissolved oxygen. As this is depleted from the hypolimnion without being replenished, life functions of many organisms are impaired, and the biology and biologically mediated reactions fundamental to water quality are altered.

Vertical stratification of a lake with respect to nutrients can also occur. Dissolved nutrients are converted to particulate organic material through photosynthetic processes in the epilimnion in ecologically advanced lakes. This assimilation lowers the ambient nutrient concentrations in the epilimnion. When the algae die and sink to the bottom, nutrients are carried to the hypolimnion where they are released by decomposition.

Temperature also has a direct effect on biology of a lake because most biological processes (e.g., growth, respiration, reproduction, migration, mortality, and decay) are strongly influenced by ambient temperature.

Annual Circulation Pattern and Lake Classification

Lakes can be classified on the basis of their pattern of annual mixing. These classifications are described below.

(1) Amictic - Lakes that never circulate and are permanently covered with ice, primarily in the Antarctic and very high mountains.

(2) Holomictic - Lakes that mix from top to bottom as a result of wind-driven circulation. Several subcategories are defined:

- Oligomictic - Lakes characterized by circulation that is unusual, irregular, and short in duration; generally small to medium tropical lakes or very deep lakes.
- Monomictic - Lakes that undergo one regular circulation per year.
- Dimictic - Lakes that circulate twice a year, in spring and fall, one of the most common types of annual mixing in cool temperate regions such as central and eastern North America.
- Polymictic - Lakes that circulate frequently or continuously, cold lakes that are continually near or slightly above 4°C, or warm equatorial lakes where air temperature changes very little.

(3) Meromictic - Lakes that do not circulate throughout the entire water column. The lower water stratum is perennially stagnant.

Lake Sedimentation

Deposition of sediment received from the surrounding watershed is an important physical process in lakes. Because of the low water velocities through the lake or reservoir, sediments transported by inflowing waters tend to settle out.

Sediment accumulation rates are strongly dependent both on the physiographic characteristics of a specific watershed and on various characteristics of the lake. Prediction of sedimentation rates can be estimated in two basic ways:

- periodic sediment surveys on a lake; and
- estimation of watershed erosion and bed load.

Accumulation of sediment in lakes can, over many years, reduce the life of the water body by reducing the water storage capacity. Sediment flow into the lake also reduces light penetration, eliminates bottom habitat for many plants and

animals, and carries with it adsorbed chemicals and organic matter that settle to the bottom and can be harmful to the ecology of the lake. Where sediment accumulation is a major problem, proper watershed management including erosion and sediment control must be put into effect.

Chemical Characteristics

Freshwater chemistry is discussed in section 2.9.3 and in the *Technical Support Manual, Volume I* (USEPA, 1983c). Therefore, the discussion here will focus on chemical phenomena that are of particular importance to lakes. Nutrient cycling and eutrophication are the primary factors of concern in this discussion, but the effects of pH, dissolved oxygen, and redox potential on lake processes are also involved.

Water chemistry in a lake is closely related to the stages in the annual lake turnover. Once a thermocline has formed, the dissolved oxygen levels in the hypolimnion tend to decline. This occurs because the hypolimnion is isolated from surface waters by the thermocline and there is no mechanism for aeration.

The decay of organic matter and the respiration of fish and other organisms in the hypolimnion serve to deplete DO. Extreme depletion of DO may occur in ice- and snow-covered lakes in which light is insufficient for photosynthesis. If depletion of DO is great enough, fish kills may result. With the depletion of DO, reducing conditions prevail and many compounds that have accumulated in the sediment by precipitation are released to the surrounding water. Chemicals solubilized under such conditions include compounds of nitrogen, phosphorus, iron, manganese, and calcium. Phosphorus and nitrogen are of particular concern because of their role in the eutrophication process in lakes.

Nutrients released from the bottom sediments during stratified conditions are not available to phytoplankton in the epilimnion. However, during overturn periods, mixing of the layers distributes the nutrients throughout the water column. The high nutrient availability is short-lived because the soluble reduced forms are rapidly oxidized to insoluble forms that precipitate out and settle to the bottom. Phosphorus and nitrogen are also deposited through sorption to particles that settle to the bottom and as dead plant material that is added to the sediments.

Of the many raw materials required by aquatic plants (phytoplankton and macrophytes) for growth, carbon, nitrogen, and phosphorus are the most important. Carbon is available from carbon dioxide, which is in almost unlimited supply. Since growth is generally limited by the essential nutrient that is in lowest supply, either nitrogen or phosphorus is usually the limiting nutrient for growth of primary producers. If these nutrients are available in adequate supply, massive algal and macrophyte blooms may occur with severe consequences for the lake. Most commonly in lakes, phosphorus is the limiting nutrient for aquatic plant growth. In these situations, adequate control of phosphorus, particularly from anthropogenic sources, can control growth of aquatic vegetation. Phosphorus can in some cases, be removed from the water column by precipitation, as described in the *Technical Support Manual, Volume III* (USEPA, 1984b).

Eutrophication and Nutrient Cycling

The term "eutrophication" is used in two general ways: (1) eutrophication is defined as the process of nutrient enrichment in a water body; and (2) eutrophication is used to describe the effects of nutrient enrichment, that is, the uncontrolled growth of plants, particularly phytoplankton, in a lake or reservoir. The second use also encompasses changes in the composition of animal communities in the water body. Both uses are commonly found in the literature, and the distinction, if important, must be discerned from the context of use.

Eutrophication is often greatly accelerated by anthropogenic nutrient enrichment, which has been termed "cultural eutrophication." Nutrients are transported to lakes from external sources, and once in the lake, may be recycled internally. A consideration of attainable uses in a lake must include an understanding of the sources of nitrogen and phosphorus, the significance of internal cycling, especially of phosphorus, and the changes that might be anticipated if eutrophication could be controlled.

Significance of Chemical Phenomena to Use Attainability

The most critical water quality indicators for aquatic use attainment in a lake are DO, nutrients, chlorophyll-a, and toxicants. In evaluating use attainability, the relative importance of three forms of oxygen demand should be considered: respiratory demand of phytoplankton and macrophytes during non-photosynthetic periods, water column demand, and benthic demand. If use impairment is occurring, assessments of the significance of each oxygen sink can be useful in evaluating the feasibility of achieving sufficient pollution control, or in implementing the best internal nutrient management practices to attain a designated use.

Chlorophyll-a is a good indicator of algal concentrations and of nutrient overenrichment. Excessive phytoplankton concentrations, as indicated by high chlorophyll-a levels, can cause adverse DO impacts such as:

- wide diurnal variation in surface DO due to daytime photosynthesis and nighttime respiration, and

- depletion of bottom DO through the decomposition of dead algae.

As discussed previously, nitrogen and phosphorus are the nutrients of concern in most lake systems, particularly where anthropogenic sources result in increased nutrient loading. It is important to base control strategies on an understanding of the sources of each type of nutrient, both in the lake and in its feeder streams.

Also, the presence of toxics such as pesticides, herbicides, and heavy metals in sediments or the water column should by considered in evaluating uses. These pollutants may prevent the attainment of uses (particularly those related to fish propagation and maintenance in water bodies) that would otherwise be supported by the water quality criteria for DO and other parameters.

Biological Characteristics

A major concern for lake biology is the eutrophication due to anthropogenic sources of nutrients. The increased presence of nutrients may result in phytoplankton blooms that can, in turn, have adverse impacts on other components of the biological community. A general trend that results from eutrophication is an increase in numbers of organisms but a decrease in diversity of species, particularly among nonmotile species. The biological characteristics of lakes are discussed in more detail in the *Technical Support Manual, Volume III.*

Techniques for Use Attainability Evaluations

Techniques for use attainability evaluations of lakes are discussed in detail in the *Technical Support Manual, Volume III.* Several empirical (desktop) and simulation (computer-based mathematical) models that can be used to characterize and evaluate lakes for use attainability are presented in that document and will not be included here owing to the complexity of the subject.

CHAPTER 3

WATER QUALITY CRITERIA

(40 CFR 131.11)

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CHAPTER 3
WATER QUALITY CRITERIA

The term "water quality criteria" has two different definitions under the Clean Water Act (CWA). Under section 304(a), EPA publishes water quality criteria that consist of scientific information regarding concentrations of specific chemicals or levels of parameters in water that protect aquatic life and human health (see section 3.1 of this Handbook). The States may use these contents as the basis for developing enforceable water quality standards. Water quality criteria are also elements of State water quality standards adopted under section 303(c) of the CWA (see sections 3.2 through 3.6 of this Handbook). States are required to adopt water quality criteria that will protect the designated use(s) of a water body. These criteria must be based on sound scientific rationale and must contain sufficient parameters or constituents to protect the designated use.

3.1 EPA Section 304(a) Guidance

EPA and a predecessor agency have produced a series of scientific water quality criteria guidance documents. Early Federal efforts were the "Green Book" (FWPCA, 1968) and the "Red Book" (USEPA, 1976). EPA also sponsored a contract effort that resulted in the "Blue Book" (NAS/NAE, 1973). These early efforts were premised on the use of literature reviews and the collective scientific judgment of Agency and advisory panels. However, when faced with the need to develop criteria for human health as well as aquatic life, the Agency determined that new procedures were necessary. Continued reliance solely on existing scientific literature was deemed inadequate because essential information was not available for many pollutants. EPA scientists developed formal methodologies for establishing scientifically defensible criteria. These were subjected to review by the Agency's Science Advisory Board of outside experts and the public. This effort culminated on November 28, 1980, when the Agency published criteria development guidelines for aquatic life and for human health, along with criteria for 64 toxic pollutants (USEPA, 1980a,b). Since that initial publication, the aquatic life methodology was amended (Appendix H), and additional criteria were proposed for public comment and finalized as Agency criteria guidance. EPA summarized the available criteria information in the "*Gold Book*" (USEPA, 1986a), which is updated from time to time. However, the individual criteria documents (see Appendix I), as updated, are the official guidance documents.

EPA's criteria documents provide a comprehensive toxicological evaluation of each chemical. For toxic pollutants, the documents tabulate the relevant acute and chronic toxicity information for aquatic life and derive the criteria maximum concentrations (acute criteria) and criteria continuous concentrations (chronic criteria) that the Agency recommends to protect aquatic life resources. The methodologies for these processes are described in Appendices H and J and outlined in sections 3.1.2 and 3.1.3 of this Handbook.

3.1.1 State Use of EPA Criteria Documents

EPA's water quality criteria documents are available to assist States in:

- adopting water quality standards that include appropriate numeric water quality criteria;
- interpreting existing water quality standards that include narrative "no toxics in toxic amounts" criteria;