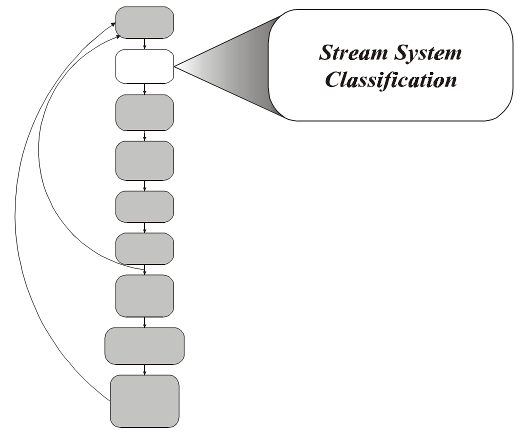
Chapter 2. Stream System Classification



2.1 INTRODUCTION

This chapter discusses classification of streams for water quality assessment and nutrient criteria development. The purpose of classification is to identify groups of rivers or streams that have comparable characteristics (i.e., similar biological, ecological, physical, and/or chemical features) so that data may be compared or extrapolated within stream types. This chapter focuses on providing water quality managers with a menu of tools that can be used to classify the stream system of interest, resulting in different aggregations of physical parameters that correlate with water quality variables.

Classifying rivers and streams reduces the variability of stream-related measures (e.g., physical, biological, or water quality variables) within identified classes and maximizes inter-class variability. Classification schemes based on non-anthropogenic factors such as parent geology, hydrology, and other physical and chemical attributes help identify variables that affect nutrient/algal interactions. Classification can also include factors that are useful when creating nutrient control strategies such as land use characteristics, bedrock geology, and identification of specific point and nonpoint nutrient sources. Grouping streams with similar properties will aid in setting criteria for specific regions and stream system types, and can provide information used in developing management and restoration strategies.

A two-phased approach to system classification is prescribed here. Initially, stream classification is based primarily (though not exclusively) on physical parameters associated with regional and site-specific characteristics, including climate, geology, substrate features, slope, canopy cover, retention time of water, discharge and flow continuity, system size, and channel morphology. The second phase involves further classifying stream systems by nutrient gradient (based upon measured nutrient concentrations and algal biomass). Trophic state classification, in contrast, focuses primarily on chemical and biological parameters including concentrations of nutrients, algal biomass as chlorophyll *a*, and turbidity, and may also include land use and other human disturbance parameters. The additional sub-classification of streams by nutrient condition, in conjunction with an understanding of dose-response relationships between algae and nutrients, helps define the goals for establishing nutrient criteria.

The physical and nutrient characterization discussed above can often be complemented by designated use classifications. These are socially-based classifications developed in accordance with EPA policy and based on the predominant human uses that a State or Tribe has concluded are appropriate for a particular stream or river. Water quality standards, predicated on criteria, are applied to these designated use classifications and are enforceable to protect specified uses. Uses are designated in accordance with relative water quality condition and trophic state. For more information on designated use classifications and their relationship to water quality criteria and standards, see the USEPA Water Quality Standards Handbook (USEPA 1994).

Stream classification requires consideration of stream types at different spatial scales. Drainage basins can be delineated and classified at multiple spatial scales ranging from the size of the Mississippi River basin to the few square meters draining into a headwater stream. The general approach is to establish divisions at the largest spatial scale (river basins of the continent), and then to continue stratification at smaller scales to the point at which variability of algal-nutrient relationships is limited within specific stream classes.

The highest level of classification at the national level is based on geographic considerations. The Nation has been divided into 14 nutrient ecoregions (Omernik 2000) based on landscape-level geographic features including climate, topography, regional geology and soils, biogeography, and broad land use patterns (Figure 4). The process of identifying geographic divisions (i.e., regionalization) is part of a hierarchical classification procedure that aggregates similar stream systems together to prevent grouping of unlike streams. The process of subdividing the 14 national ecoregions should be undertaken by the State(s) or Tribe(s) within each of those ecoregions. Classification of State/Tribal lands invariably involves the professional judgement of regional experts. Experts familiar with the range of conditions in a region can help define a workable system that clearly separates different ecosystem types, yet does not consider each system a special case.

The usefulness of classification is determined by its practicality within the region, State, or Tribal lands in which it will be applied; local conditions determine the appropriate classes. In this Chapter, a regionalization system derived at the national level is presented. This system provides the framework from which State and Tribal water resource management agencies can work to establish appropriate subdivisions. In addition, different classification schemes are presented to provide resource managers with information to use in choosing a stream classification system. It is the intent of this document to provide adequate flexibility to States and Tribes in identifying State and Tribal-specific subregions.

The following sections describe specific examples of first-phase physical classification based on variation in natural characteristics and secondly, nutrient gradient classification schemes for identifying similarities within stream system types. Each classification method is presented and the rationale for its use is provided.

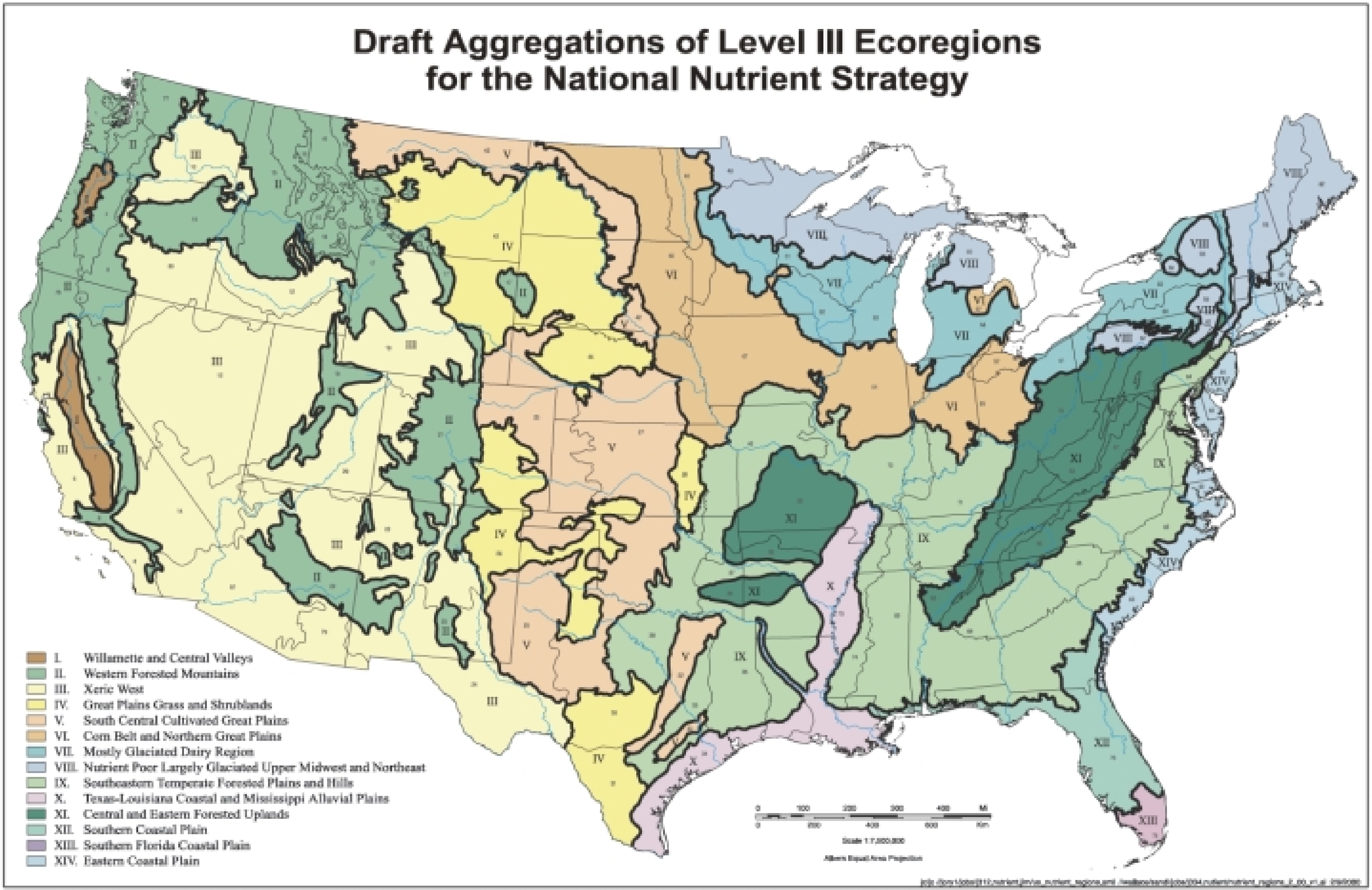


Figure 4. Fourteen nutrient ecoregions as delineated by Omernik (2000). Ecoregions were based on geology, land use, ecosystem type, and nutrient conditions.

2.2 CLASSIFICATION SCHEMES BASED ON PHYSICAL FACTORS

The classification systems described in the following sections (including ecoregional, fluvial geomorphological, and stream order classification schemes) are based on physical stream and watershed characteristics. Stream systems are characterized by the continual downstream movement of water, dissolved substances, and suspended particles. These components are derived primarily from the land area draining into a given channel or the drainage basin (watershed). The climate, geology, and vegetational cover of the watershed are reflected in the hydrological, biological, and chemical characteristics of the stream. Therefore, factors such as general land use, climate, geology and general hydrological properties must be considered regardless of the method of classification used. As described above, the initial classification should be based on physical characteristics of parent geology, elevation, slope, hydrology and channel morphology. Hydrologic disturbance frequency and magnitude are also important when classifying stream systems.

In addition to classification of stream systems, factors contributing to trophic state and macrophyte and algal growth should be considered. Table 1 presents several factors that affect periphyton and plankton biomass levels in stream systems. Macrophyte-dominated systems could occur under conditions similar to those favorable for high periphyton biomass (Table 1), if the velocity is low and the substrate includes organic sediment. Macrophytes are generally unlikely to develop in systems where the stream bottom is composed primarily of gravel or other large substrata (Wong and Clark 1979). The following section specifically addresses the potential effects of hydrology and channel morphology, flow, and parent geology on algal and macrophyte growth within stream systems.

River and stream types (and reaches within these waterbodies) are too diverse to set one criterion for all stream/river types. However, it is not necessarily feasible or recommended to develop site-specific criteria for every stream reach within the U.S. Morphological and fluvial characteristics of a stream influence many facets of its behavior. Streams with similar morphologies may have similar nutrient capacities or similar responses to nutrient loadings. Rivers and streams are very diverse within ecoregions. Reaches within one stream can have a distinct morphology. The geomorphology of a river or stream – its shape, depth, channel materials – affects the way that waterbody receives, processes, and distributes nutrients. Nutrient cycling processes that occur upstream affect communities and processes downstream by altering the form and concentration of nutrients and organic matter in transport (nutrient spiraling); these effects can be further intensified by patch dynamics (Mulholland et al. 1995). The spatial scales which most influence upstream-downstream linkages are the geomorphology-controlled patterns observed at the landscape scale and the nutrient-cycling-controlled patterns observed at the stream reach scale (Mulholland et al. 1995). Therefore, to set appropriate criteria for rivers and streams in an ecoregion, streams must be classified by their morphological characteristics at both the landscape and stream reach scale, with an emphasis on those characteristics most likely to affect nutrient cycling.

ECOREGIONAL CLASSIFICATION

Ecoregions are based on geology, soils, geomorphology, dominant land uses, and natural vegetation (Omernik 1987; Hughes and Larsen 1988) and have been shown to account for variability of water quality and aquatic biota in several areas of the United States (e.g., Heiskary et al. 1987; Barbour et al. 1996). On a national basis, individual streams and rivers are affected by varying degrees of development, and user perceptions of acceptable water quality can differ even over small distances.

Table 1. Geological, physical, and biological habitat factors that affect periphyton and phytoplankton biomass levels in rivers and streams given adequate to high nutrient supply and non-toxic conditions. Note that only one factor is sufficient to limit either phytoplankton or periphyton biomass.

Phytoplankton-Dominated Systems	**Periphyton-Dominated Systems**
High Phytoplankton Biomass · low current velocity(< 10 cm/s)/long detention time (>10 days) and · low turbidity/color and · open canopy and · greater stream depth and · greater depth to width ratio	High Periphyton Biomass · high current velocity (>10 cm/s) and · low turbidity/color and · open canopy and · shallow stream depth and · minimal scouring and · limited macroinvertebrate grazing and · gravel or larger substrata and · smaller depth to width ratio
Low Phytoplankton Biomass · high current velocity (>10 cm/s)/short detention time (<10 days) and/or · high turbidity/color and/or · closed canopy and/or · shallow stream depth	Low Periphyton Biomass · low current velocity (< 10 cm/s) and/or · high turbidity/color and/or · closed canopy and/or · greater stream depth and/or · high scouring and/or · high macroinvertebrate grazing and/or · sand or smaller substrata

Ecoregions are generally defined as relatively homogeneous areas with respect to ecological systems and the interrelationships among organisms and their environment (Omernik 1995). Ecoregions can occur at various scales; broad-scale ecoregions may include the glaciated corn belt of the central and upper Midwest or the arid to semi-arid basin and desert regions of the southwest. At more refined scales, regions within the broader regions can be identified.

Ecoregions serve as a framework for evaluating and managing natural resources. The ecoregional classification system developed by Omernik (1987) is based on multiple geographic characteristics (e.g., soils, climate, vegetation, geology, land use) that are believed to cause or reflect the differences in the mosaic of ecosystems. Omernik's original compilation of national ecoregions was based on a fairly coarse (1:7,500,000) scale that has subsequently been refined for portions of the southeast, mid-Atlantic, and northwest regions, among others (Omernik 1995). The process of defining subregions within an ecoregion requires collaboration with State/Tribal scientists and resource managers. Once appropriate subregions are delineated, reference sites can be identified (see Section 4.2). Similar to the process described for ecoregion refinement, reference site selection involves interactions with scientists and water quality managers that understand local conditions. Field verification techniques, methods for selecting reference sites for small and/or disjunct subregions can be found in Omernik (1995).

Fluvial Geomorphology

Fluvial geomorphology mechanistically describes river and slope processes on specific types of landforms, i.e., the explanation of river and slope processes through the application of physical and chemical principles. The morphology of the present-day channel is governed by the laws of physics through observable stream channel features and related fluvial processes. Stream pattern morphology is directly influenced by eight major variables including channel width, depth, velocity, discharge, channel slope, roughness of channel materials, sediment load and sediment size (Leopold et al. 1964). A change in one variable causes a series of channel adjustments which lead to changes in the other variables, resulting in channel pattern alterations. Many stream classification systems, have a fluvial geomorphologic component.

Rosgen

The stream classification method devised by David Rosgen is a comprehensive guide to river and stream classification (see Rosgen 1994 or 1996). The Rosgen classification system is currently utilized by several States. This system integrates fluvial geomorphology with other stream characteristics. Specifically, Rosgen combines several methods of stream classification into one complete, multi-tiered approach. Rosgen's method has four levels of detail: broad morphological (geomorphic) characterization, morphological description (stream types), stream "state" or condition, and verification. Level I classification, geomorphic characterization, takes into account channel slope (longitudinal profile), shape (plan view morphology, cross-sectional geometry), and patterns. Level I streams are divided into seven major categories and labeled A-G. The Level II morphological delineative criteria include landform/soils, entrenchment ratio, width/depth ratio, sinuosity, channel slope, and channel materials. The 42 subcategories of Level II streams are labeled with a letter and a number, A1-G6 (see Rosgen 1994, 1996). Level III designations are primarily used in specific studies or in restoration projects to assess the quality and/or progress of a specific reach. Level IV classifications may be used to verify results of specific analyses used to develop empirical relationships (such as a roughness coefficient) (Rosgen 1996).

Rivers and streams are complicated systems. A classification scheme is an extreme simplification of the geomorphic and fluvial processes. However, the Rosgen system of classification is a useful frame of reference to :

1. Predict a river's behavior from its appearance;
2. Develop specific hydraulic and sediment relations for a given morphological channel type and state;
3. Provide a mechanism to extrapolate site-specific data collected on a given stream reach to those of similar character; and
4. Provide a consistent and reproducible frame of reference of communication for those working with river systems in a variety of professional disciplines (Rosgen 1994).

Classification of streams and rivers allows comparisons and extrapolation of data from different streams or rivers in an ecoregion. Comparing similar streams may help to predict the behavior of one stream based data and observations from another. *Applied River Morphology* (Rosgen 1996) contains in-depth descriptions of each Level II stream type (A1-G6) and includes photographs and illustrations. Rosgen discusses theoretical characterizations and variables and provides field methods for delineating stream types. The Rosgen classification system may be more detailed than needed for many States and Tribes. For more information on the Rosgen classification system, see Rosgen (1996).

STREAM ORDER

Identifying stream orders in a given delineated watershed can provide a classification system for monitoring streams. A variety of methods have been proposed for ordering drainage networks for stream classification and monitoring. The Horton-Strahler method (Horton 1945; Strahler 1952) is most widely used in the US. Each headwater stream is designated as a first order stream. Two first order streams combine to produce a second order stream, two second order streams combine to produce a third order stream and so on (Figure 5). Only when two streams of the same order are combined does the stream order increase. Numerous lower order streams may enter a main stream without changing the stream order. As a result, utilizing this method for classification may lead to problems of disparity in hydrological and ecological conditions among same order streams even within the same region. Resource managers using stream order as a classification system should ensure that topographic maps used to identify watershed boundaries all utilize the same scale. The inclusion or exclusion of perennial headwater streams should be decided before ordering drainage networks of interest.

Stream order (Strahler 1952) is used to classify streams in the EPA Environmental Monitoring and Assessment Program (EMAP). Sample sites were selected using a randomized sampling design with a systematic spatial component. The survey in the mid-Atlantic region was restricted to wadeable streams defined as 1^{st}, 2^{nd}, or 3^{rd} order as delineated using USGS 1:100,000 scale USGS hydrologic maps that were incorporated into EPA's River Reach File (Version 3). Sample probabilities were set so that approximately equal numbers of 1^{st}, 2^{nd}, and 3^{rd} order stream sites would appear in the sample population. Data were collected at 368 different sites representing 182,000 km of wadeable streams in the mid-Atlantic region (Herlihy et al. 1998).

PHYSICAL FACTORS USED TO CLASSIFY STREAMS AND ANALYZE TROPHIC STATE

The following sections focus on physical characteristics of streams that can be used to sub-classify stream systems. Physical characteristics that can be used for stream classification include system hydrology and morphology, flow conditions, and underlying geology.

Hydrology and Morphology

Hydrologic and channel morphological characteristics are often important determinants of algal biomass. Unidirectional flow of water sets up longitudinal patterns in physical and chemical factors that may also affect macrophyte growth when light and substrate conditions are adequate. Channel morphology or shape of a river or stream channel at any given location is a result of the flow, the quantity and character of the sediment moving through the channel, and the composition of the streambed and banks of the channel including riparian vegetation characteristics (Leopold et al. 1964). Frequent disturbance from floods (monthly or more frequently) and associated movement of bed materials can scour algae from the surface rapidly and often enough to prevent attainment of high biomass (Peterson 1996). In areas with less stable substrata, such as sandy bottomed streams, only slight increases in flow may lead to bed movement and scouring. Scouring by movement of rocks has been directly linked to reduction in algal biomass and subsequent recovery from floods (Power and Stewart 1987). Larger, more stable rocks can have higher periphyton biomass (Dodds 1991; Cattaneo et al. 1997). Thus, in cases where

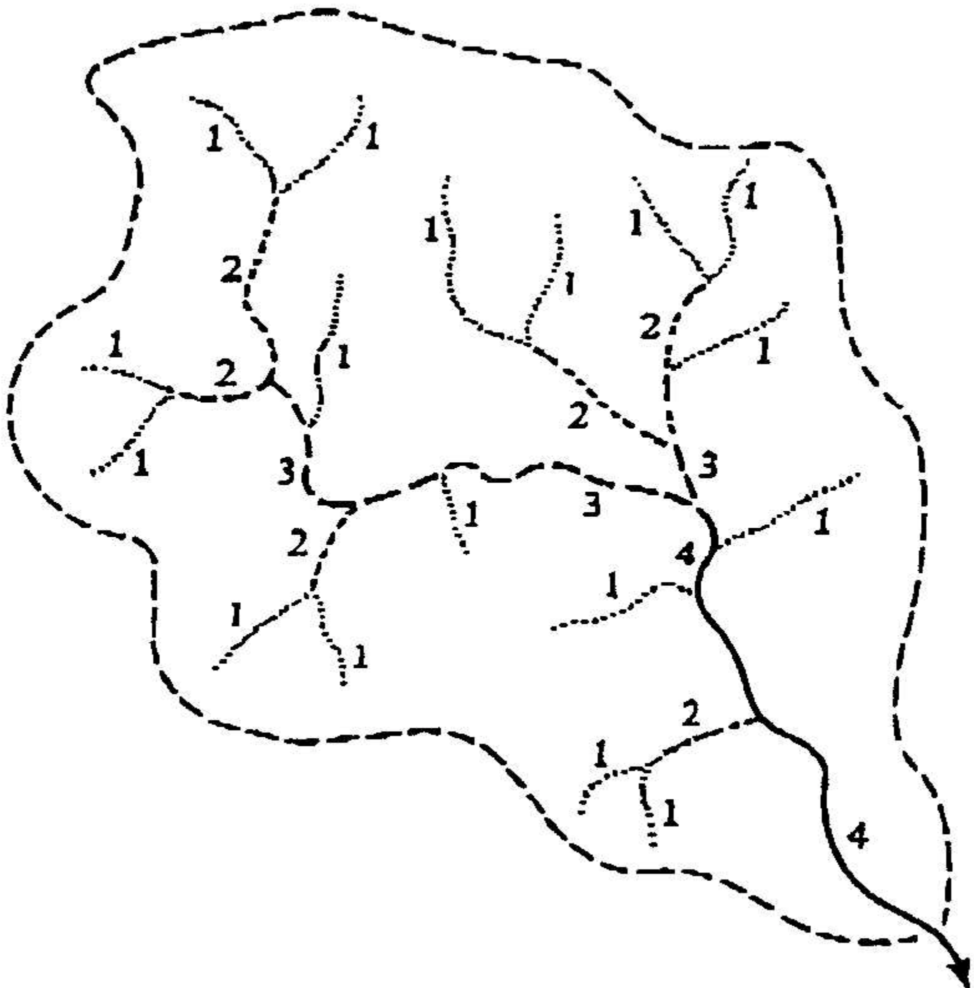


Figure 5. Stream ordering of a watershed basin network using the Strahler method. (Adapted from Strahler [1964]).

there is frequent movement of substrata, high nutrients may not necessarily translate into excessive algal biomass (Biggs et al. 1998a,b).

Consideration of both geology and hydrologic disturbance can provide important insights into factors influencing algal biomass. Research done in New Zealand identified geology, land use patterns, and stream conductivity (as a surrogate for total nutrients) as important determinants of algal biomass because these factors affected nutrient inputs and flood disturbance (Biggs 1995). The effects of disturbance by floods can be complex and complicated by biological factors; very stable stream beds may be associated with an active grazing community and have less biomass than more unstable systems. This notwithstanding, flow regime, channel morphology and bed composition (such as sand versus large boulders) appear to be major controlling factors and should be considered when managing eutrophication in a particular watershed.

Flow Conditions

Low and stable flow conditions should be considered in addition to frequency and timing of floods when physically classifying stream systems. Flood frequency and scouring may be greater in steep-gradient (steep slope) and/or channelized streams and in watersheds subject to intense precipitation events or rapid snow melt. Periods of drying can also reduce algal biomass to low levels (Dodds et al. 1996). A stream may flood frequently during certain seasons, but also remain stable for several months at a time. The effects of eutrophication may be evident during stable low flows. Also, stable flow periods are generally associated with low flow conditions, resulting in the highest nutrient concentration from point source loading. Hence, low-flow periods often present ideal conditions for achieving maximum algal biomass. For these reasons, nutrient control plans may require strategies that vary seasonally (e.g., criteria for a specific system may differ with season or index period).

Underlying Geology

Streams draining watersheds with phosphorus-rich rocks (such as from sedimentary or volcanic origin) may be naturally enriched and the control of algal biomass by nutrient reduction in such systems may be difficult. Bedrock composition has been related to algal biomass in some systems (e.g., Biggs 1995). In addition, nutrient content, and hence algal biomass, often naturally increases as elevation decreases, especially in mountainous areas (Welch et al. 1998). Some naturally phosphorus-rich areas include watersheds draining some volcanic soils, and other areas have high weathering of nitrate from bedrock (Halloway et al. 1998). Review of geologic maps and consultation with a local Natural Resources Conservation Service (NRCS) agent or soil scientist may reveal such problems.

2.3 CLASSIFICATION SCHEMES BASED ON NUTRIENT GRADIENTS

Nutrient loading is the factor most likely to be controlled by humans, but the ability to control algal biomass within the stream itself may be influenced by additional factors. Factors that may control algal biomass in streams include bedrock type and elevation (because they determine the natural or background nutrient supply), physical disturbance (flooding and drying), light, sediment load, and grazing. Many of these factors will be accounted for in the physical classification of stream systems. However, characterization of nutrient gradients in stream systems will be influenced by land use practices as well as point source discharges (Carpenter et al. 1998). The nutrient ecoregions defined by Omernik (2000) separate the country into large ecoregions with common land use characteristics. These ecoregions should be further subdivided for use at the State, Tribal, or local scale.

Changes in the natural processes that control algal production and biomass in a stream or river as one moves downstream through a watershed are obviously an important consideration. The River Continuum Concept (RCC) (Vannote et al. 1980) provides one general model for predictions of stream size effects on algal-nutrient relations. The RCC predicts, among other things, that benthic algal biomass will increase with stream size to a maximum for intermediate stream orders (i.e., third and fourth order stream reaches) as stream width increases and canopy cover consequently decreases. The RCC also suggests that (1) sestonic (suspended) chlorophyll will become more important in larger, slow-moving rivers and (2) turbidity in deep, high order streams causes light attenuation, which tends to prohibit high benthic algal biomass. The RCC may not hold for unforested watersheds (e.g., Dodds et al. 1996) or those with excessive human impacts such as impoundments or severe sediment input from logging. For example, Rosenfield and Roff (1991) observed that stream primary productivity in Ontario streams was largely independent of stream size. However, the RCC is valuable for identifying variables that change with stream size and affect algal-nutrient relations.

CLASSIFICATION BY NUTRIENT ECOREGIONS

The draft nutrient aggregations map of level III ecoregions for the conterminous United States (Figure 4; Omernik 2000) defines broad areas that have general similarities in the quantity and types of ecosystems as well as natural and anthropogenic characteristics of nutrients. As such, ecoregions are intended to provide a spatial framework for the National Nutrient Criteria Program. In general, the variability in nutrient concentrations in streams, lakes, and soils should be less in those ecoregions having higher hierarchical levels, i.e., nutrient concentrations found in level III ecoregions (84 ecoregions delineated for the mainland U.S.) (Omernik 1987), than those of waterbodies located in draft aggregations of Level III ecoregions.

CLASSIFICATION BY TROPHIC STATE

The primary response variable of interest for stream trophic state characterization is algal biomass. Algal biomass is usually concentrated in the benthos of fast-flowing, gravel/cobble bed streams (i.e., periphyton dominated) and measured as benthic chl *a* per unit area of stream substrate. In slow-moving, sediment-depositing rivers (i.e., plankton dominated), algal biomass is suspended in the water column and measured as sestonic chl *a* per unit water volume. Trophic classifications for lakes and reservoirs may be appropriately applied to seston in slow-moving rivers as these classifications are based primarily on chl *a* per unit volume (e.g., OECD 1982). However, lake classification schemes have limited value for fast-flowing streams dominated by benthic periphyton because the limited areal planktonic chlorophyll data available for lakes reveal little differentiation between oligotrophic and eutrophic systems (Dodds et al. 1998).

Nitrogen and phosphorus are important variables for classification of trophic state because they are the nutrients most likely to limit aquatic primary producers and are expressed per unit volume in both fast-flowing streams and slow-flowing rivers. Concentrations of total nutrients and suspended algal biomass are well-correlated in lakes and reservoirs (Dillon and Rigler 1974; Jones and Bachmann 1976; Carlson 1977). Developing predictive relationships between nutrient and algal levels in fast-flowing streams may be difficult considering that most available nutrients are in the water column and most chl *a* is in the benthos. Therefore, trophic state classification for periphyton-dominated stream systems is more appropriately based on benthic or areal algal biomass (e.g., mg/m^2 chl *a*) than on concentrations of N and P.

As stated above, classification of trophic state in stream systems is most appropriately based on algal biomass and secondarily on nutrients. When trophic state classification is based upon nutrients, total water column concentrations (TP and TN) are more appropriate than dissolved inorganic nitrogen (DIN) or soluble reactive phosphorus (SRP). Inorganic nutrient pools are depleted and recycled rapidly. Most monitoring programs will not be able to closely track soluble nutrients in a stream system and should therefore focus on total water column concentration rather than soluble nutrient species.

Additional factors also confound the interpretation of dissolved nutrient data. Algae are able to directly utilize inorganic nutrient pools (DIN and SRP) and deplete these pools if algal biomass is high enough relative to stream size and nutrient load. Thus, moderately low levels of DIN and SRP do not necessarily result in low algal biomass. This seeming contradiction is because the supply rate of inorganic nutrients may still be high even if a large biomass of algae has removed a significant portion of the DIN or SRP from the water column. Algal growth rate (including diatoms and filamentous greens) can be saturated at low dissolved inorganic nutrient concentrations (Bothwell 1985, 1989; Watson et al. 1990; Walton et al. 1995). Total phosphorus and TN may better reflect stream trophic status compared to inorganic P and N because algal drift increases with benthic algal biomass. Thus, as soluble nutrient depletion increases with benthic algal biomass, that depletion can be partially compensated for by increases in particulate fractions of TP and TN resulting from benthic algal drift and suspension in the water column.

A trophic classification scheme for streams and rivers, based on chlorophyll *a* and nutrients, was recently developed by Dodds et al. (1998). The approach used by Dodds et al. was based upon establishing statistical distributions of trophic state-related variables. The data were viewed in two ways: 1) three trophic state categories were constructed based on the lower, middle, and upper thirds of the distributions and were assigned to oligotrophic, mesotrophic and eutrophic categories respectively; and 2) the actual distributions (Table 2) were used to determine the proportion of streams in each trophic category. It should be stressed that this approach proposes

Table 2. Suggested boundaries for trophic classification of streams from cumulative frequency distributions. The boundary between oligotrophic and mesotrophic systems represents the lowest third of the distribution and the boundary between mesotrophic and eutrophic marks the top third of the distribution.

Variable (units)	**Oligotrophic-mesotrophic boundary**	**Mesotrophic-eutrophic boundary**	**Sample size (N)**
mean benthic chlorophyll (mg m^{-2})$^{+}$	20	70	286
maximum benthic chlorophyll (mg m^{-2})$^{+}$	60	200	176
sestonic chlorophyll (μg L^{-1})$^{++}$	10	30	292
TN (μg L^{-1})$^{+,+++}$	700	1500	1070
TP (μg L^{-1})$^{+,++,+++}$	25	75	1366

$^{+}$Data from Dodds et al. (1998); $^{++}$data from Van Nieuwenhuyse and Jones (1996); $^{+++}$data from Omernik (1977).

trophic state categories based on the current distribution of algal biomass and nutrient concentrations which may be greatly changed from pre-human settlement levels. These distributions were determined using data for benthic and sestonic chlorophyll and water column TN and TP from a wide variety of previously published studies. The data were gathered from temperate stream sites located in North America and New Zealand. The data for TN and TP used in this analysis were not taken from the same sources as the data for benthic and sestonic chlorophyll *a*. Hence, the distributions should only be used to link nutrient concentrations and algal biomass in a very general sense.

Management Applications

Classifying streams by trophic state can assist water quality managers in setting criteria and identifying those systems most at risk for impairment by nutrient enrichment. For example, an understanding of stream trophic state and ambient nutrient concentrations allows the manager to determine if the system of interest is eutrophic due to nutrient inputs that are natural or cultural. Comparisons with streams in the same local area that have similar physical characteristics will help clarify this issue prior to making management decisions. Management options may be limited if the condition of the stream is caused by high background levels of nutrient enrichment. However, if nutrient sources are largely cultural, establishing nutrient control strategies may realistically result in improvements in stream trophic state and therefore be useful in managing the stream system.