Stream Ecology 101

What is a Watershed?

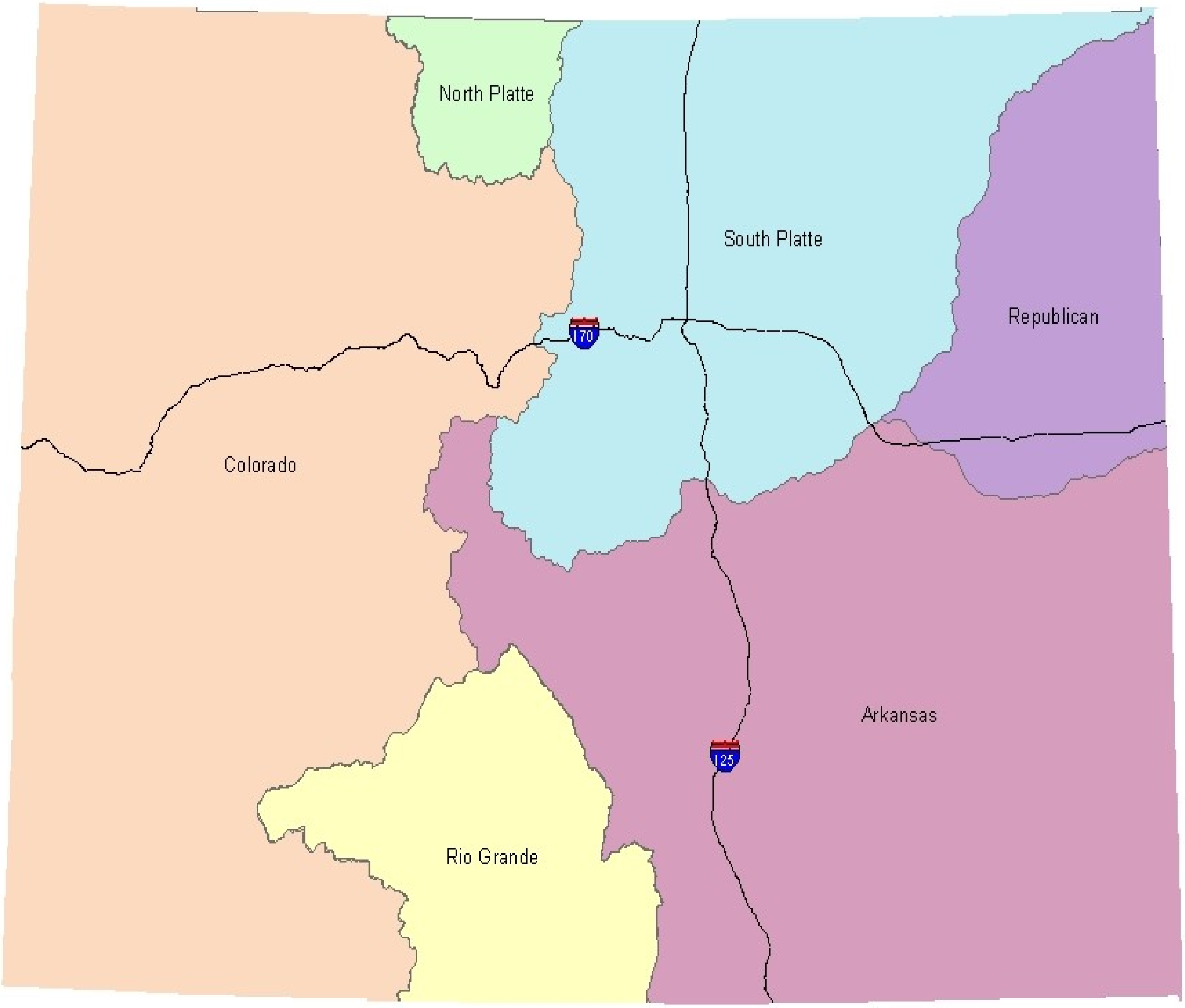
The watershed of a stream or lake (also called a drainage basin or catchment) consists of the land area from which it is receives its water. A watershed is delineated (or marked) by high points in the landscape (mountains, hills and ridges) from which all water flows downhill to a low point such as a river, stream, pond, lake or wetland.

Anywhere you stand in the world you are in a watershed. Each small stream in a landscape is surrounded by its own watershed. Each small stream is a tributary to a larger stream. Added together, such small watersheds make up the watershed for a larger stream or river. The Mississippi River watershed contains thousands of tributary watersheds that collectively cover about 1.2 million square miles or 34% of the land area of the United States. In the United States, tens of thousands of small or sub watersheds comprise 18 major watershed systems. The ultimate destination for all water draining is the ocean.

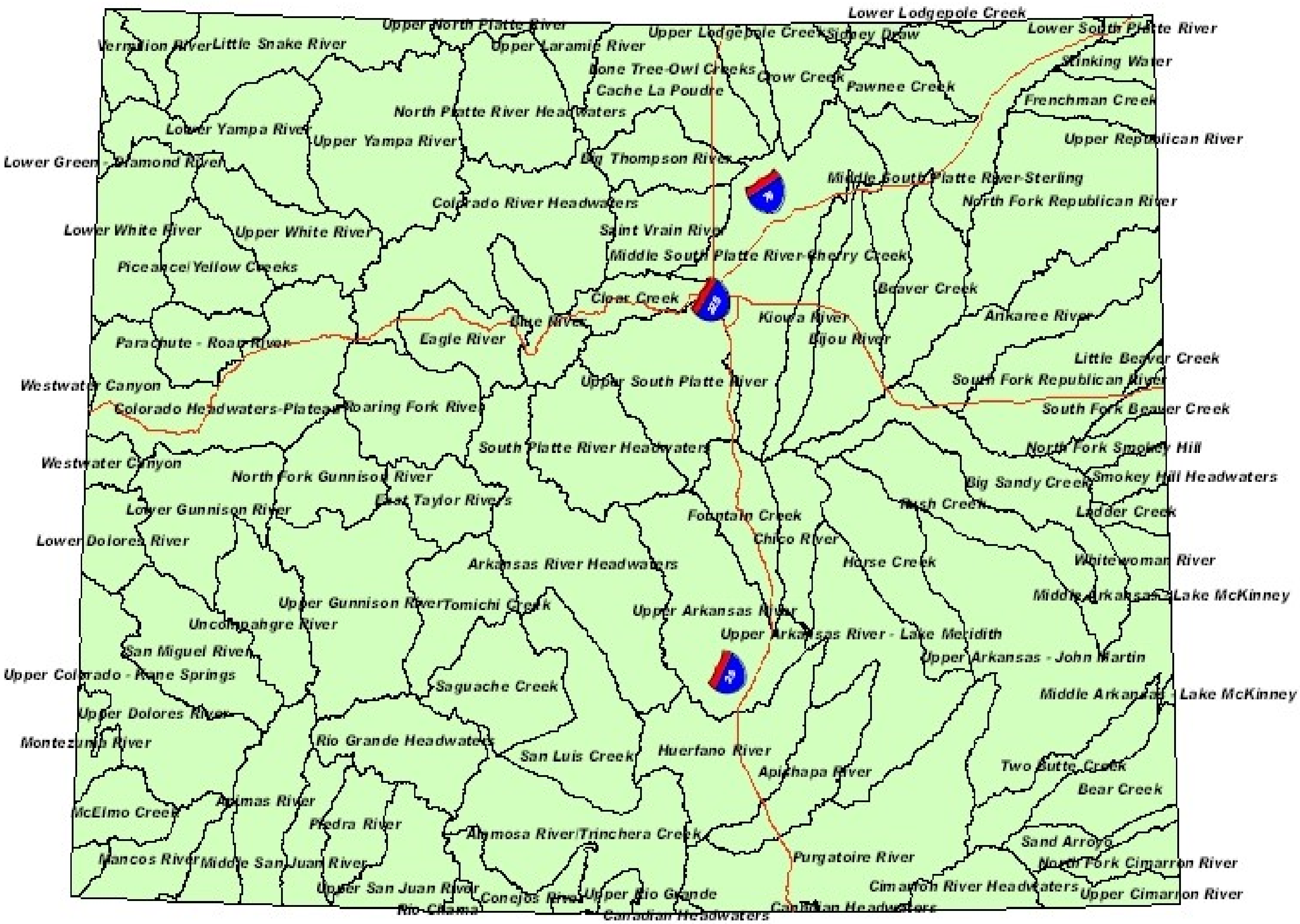
Why delineate a Watershed?

The quantity and quality of the water flowing into your study stream or lake depend on the uses of that water and the land within that watershed. The exception to this is watersheds that take water from another watershed through piping, pumping or tunnels. Then your watershed of interest might be larger than the physical drainage you live in. Whatever happens on the land above affects your sample station or favorite spot. Urbanization, deforestation, floods, fires, improper ranching, agriculture or mining practices, hydrological modifications like reservoirs influence the biological, chemical and physical habitat of a stream ecosystem.

Colorado is unique in that it is only one of two states where water only flows out of the state; almost none flows into the state (three minor exceptions). Do you know the other state? It’s Hawaii. Colorado is a true headwater state, with water leaving this state affecting directly or indirectly 31 other states. Colorado has six major watersheds: Arkansas, Republican, South Platte, North Platte, Colorado and Rio Grande.



Even these watersheds can be divided into smaller watersheds. Take a look at the map below.



Next time you greet a friend, introduce yourself and tell them which watershed you live in.

Physical, Chemical and Biological Stream Attributes

Pretend you are a fish and describe the physical, chemical and biological components of your habitat. Detail the physical attributes of the stream, the rocks in the streambed, the meander in the stream path, and the strength of the banks. Think about the chemical components of your environment, is it alkaline or acidic, high dissolved oxygen levels like those found in swift, turbid mountain streams, or lower levels of the plains where waters are slow and warm? Imagine the biologic components that depend on the river for all stages of their life cycle, the macroinvertebrates, mud snails, and submerged plant life vs. those components who occasionally visit the system for one part of their needs like a drinking deer or muskrat that catches the crawdad.

Physical Habitat	Chemical	Biological
Substrate – size, boulder, rubble, cobble, gravel, sand, muck	Temperature*	Micro Organisms (bacteria, etc.)
Sedimentation – deposits on the substrate	pH*	Macroinvertebrates
Embeddedness – how tightly packed the substrate is	Dissolved Oxygen* Biological Oxygen Demand	Zooplankton
Riparian vegetation – type, width, health	Dissolved organic Carbon*	Aquatic Vegetation (algae, diatoms, periphyton to cattails)
Bank stability	Alkalinity* (HCO^{3-}, CO_3^{2-})	Fish
Width – wet, bank full	Hardness*(Ca^{2+}, Mg^{2+})	Otter, Beavers, etc.
Depth	Metals **	
Velocity – speed of water	Nutrients** - sulfate, chloride, fluoride, nitrogen (total N, NH_4, NH_3+,NO_3, NO^2), phosphorus (Total P, Orth P)	
Gradient or slope	Turbidity*, clarity, Total Suspended Solids, Total Dissolved Solids, Conductivity, Specific Conductance	
Discharge or Flow – volume of water	Herbi's, Fungi's and Pesti's (get it?)	
Amount of meandering or curving	Petroleum Products	
Pool to Riffle Ratio	Radioactive materials	
Width/depth ratio	Pharmaceuticals	
Land use		

What is the ecological significance of all these attributes? How are they related? Can you measure each of them if you had enough time, money and skill? The highlighted items are what we collect or analyze in River Watch. The (*) items would be considered background chemical parameters, or what you would expect to measure in a jar of fresh water anywhere in the world. The (**) items would either not be present, present in natural amounts (like a natural mineralized area) or not present in amounts harmful to aquatic life. Let's look further.

Stream Order

We can use a tool called Stream Order (Strahler 1985), to help us categorize streams in our watershed by size. Use Worksheet 1. Complete this worksheet using these rules:

Rule 1: ***The stream increases in size only when like numbers join,***
A size 1 stream is a stream that is truly the origination of a river; no tributaries flow into it. When a size 1 stream flows into another size 1, the stream then becomes a size 2 below the confluence.

Rule 2: ***The increase in size is only by one increment***
Imagine the worksheet is a watershed that drains into the ocean. Start labeling all size 1 streams, then size 2 streams, and size 3 streams working your way down to the ocean.

Rule 3: ***When unlike numbers join, the stream remains the higher number***

When a lower number stream, for example, a size 1 stream flows into a higher number stream, size 2, the stream remains a size 2 stream below the confluence.

What is the size of the stream before it hits the ocean? If you answered 4, you got it!

If you try this with your watershed, use county or topographic maps for a higher resolution. Place tracing paper on the map and in different colors, label the different stream sizes. What does this mean?

Streams sizes can be generalized into three major categories:

Small	Sizes 1-3
Medium	Sizes 4-6
Large	Sizes 7-12

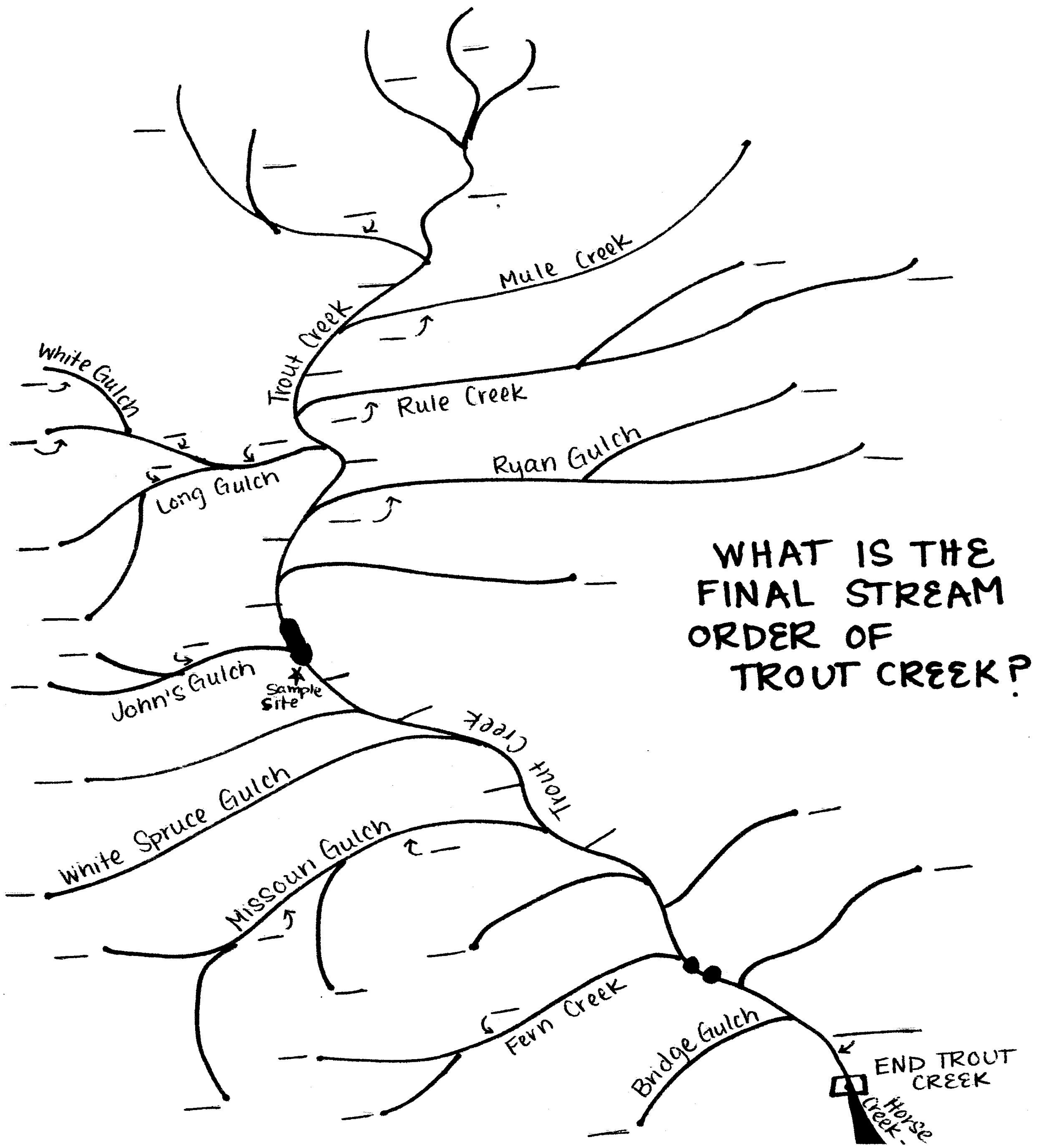
In Colorado, the larger rivers leaving the state are only a size 7 or 8. It’s interesting when you compare that to the Mississippi where the size of the mouth is a size 12. Anywhere in the world you would find in both stream miles and occurrence this ratio:

Small	Sizes 1-3	88%
Medium	Sizes 4-6	10%
Large	Sizes 7-12	2%

Most rivers are small and feed into medium and those into large systems, a connected system. Most dams occur on large and medium sizes and in Colorado, development all that interrupts a river systems connectivity and ability to process nutrients and other functions.

How can we use this information? See the next topic.

Worksheet 1- Stream Order Worksheet



River Continuum Concept – Longitudinal River View

The River Continuum Concept (RCC) (Vannote et al, 1980) is the concept that a river is a predictable physical, chemical and biological continuum of attributes. Stream order can illustrate this. Visualize how physical habitat can change from upstream to downstream. For example, as the stream widens downstream, it gets deeper, the velocity slows, the gradient lessens, and discharge increases.

One common physical attribute in rivers is pool/riffle ratio. Pools are deep areas in the river where water slows and gathers. Riffles are shallow fast moving areas in the river that produce riffles in the water. The larger the river, the larger the pool/riffle ratio.

Pool/riffle ratio in small streams is less than one because there are more riffles. In medium streams the ratio is 1:1. In large streams the pool riffle ratio is greater than one as the river becomes a moving lake.

Chemical attributes change as you travel downstream. These changes can include:

- chemistry parameters
- temperature increases
- dissolved oxygen decreases
- turbidity goes up but clarity goes down
- pH remains about the same (it may increase some)
- most chemical variables increase

Discuss why these changes occur.

For biological attributes, the types of organisms might be the same. For example, there will always be micro and macro organisms, aquatic vegetation and fish, but the species might vary. In Colorado, fish species range from cutthroat trout, to brook trout, rainbow and brown trout, suckers, longnose dace, and sculpin, to warm water species like creek chubs, shiners, daces, and catfish. Colorado does not have large enough rivers to support large communities of zooplankton. Zooplankton occurs in our rivers as escapees of reservoirs or lakes.

In small and medium streams, macroinvertebrate species will be dominated by the three indicators of clean cold water, mayflies, stoneflies and caddisflies. Black flies and other species do occur but in small numbers. These three clean cold water species disappear in large streams as the chemical and physical habitat components no longer support them. Larger river systems are dominated by black flies and species that prefer warmer and slower water and can tolerate a wider spectrum of chemical components.

With macroinvertebrates we also can look at the continuum of their feeding niches, how they obtain food in addition to number and type of species. Based upon millions of years of evolution, macroinvertebrates developed different feeding niches, such as predators, grazers (little cows on the rock grazing periphyton), collectors (build nets and the like to collect food) and shredders. In small rivers the food and energy source is **C**oarse **P**articulate **O**rganic **M**atter (CPOM). There are many shredders (like your tomato plant eaten by an insect), few grazers because the stream is cold, often shaded, days are short, growing season short, not much primary productivity to produce any fine, small, broken down organic matter for food. Conversely, in medium size streams, the stream opens; primary productivity produces plenty of **Fine Particulate Organic Matter (FPOM)**. The mayflies, stoneflies and caddisflies are all there, but specialize more in grazing and collection methods for FPOM. There are still shredders, just not as many. Finally, in large rivers the macroinvertebrate community is primarily collectors and predators. Micro invertebrates change from primarily attached algae and moss to aquatic plants, less attached algae, to floating phytoplankton.

Small rivers cannot produce enough primary productivity or food to support all the organisms who live in them but they get enough organic debris and food from the surrounding landscape. These streams are dependent upon the surrounding watershed and **allochthonous** (non-native material, coming in from outside like sediment, leaves and twigs) or **Coarse Particulate Organic Material** (**CPOM**) like small twigs and leaves. Small rivers are **heterotrophic** (hetero means outside of systems) meaning they get their primary nutrients from outside of themselves. This means the surrounding landscape, how it is managed, the health and condition have a large impact on the food and health of small stream organism, an intimate relationship.

As small rivers grow and become medium rivers, they widen and deepen and benefit from their collective richness and create an **autotrophic system**, (auto means self) meaning a medium size river can produce enough primary productivity inside itself to support itself. These streams are dependent upon the surrounding watershed and **autochthonous** (native material, produced from bacteria, algae and decomposition) or **Fine Particulate Organic Material** (**FPOM**) like small twigs and leaves. Support from the surrounding landscape is still essential but not the primary source.

Medium rivers grow and become large river systems that are wide and deep enough to support themselves but cannot. Why? Think of the Mississippi River, deep and wide but turbid. The Mississippi River is so turbid that sunlight only reaches the top layers. Below the surface the river becomes anaerobic, no oxygen and no primary productivity. These rivers return to **heterotrophic systems**. Where do they get their primary productivity or food primarily? It is not from the surrounding landscape but from all the medium and small streams that comprise and feed it literally. The surrounding landscape and land use is very important still and often due to flood control these systems are cut off from those ecosystems. Dams and diversion as well as land use can interrupt this vital connection for aquatic life.

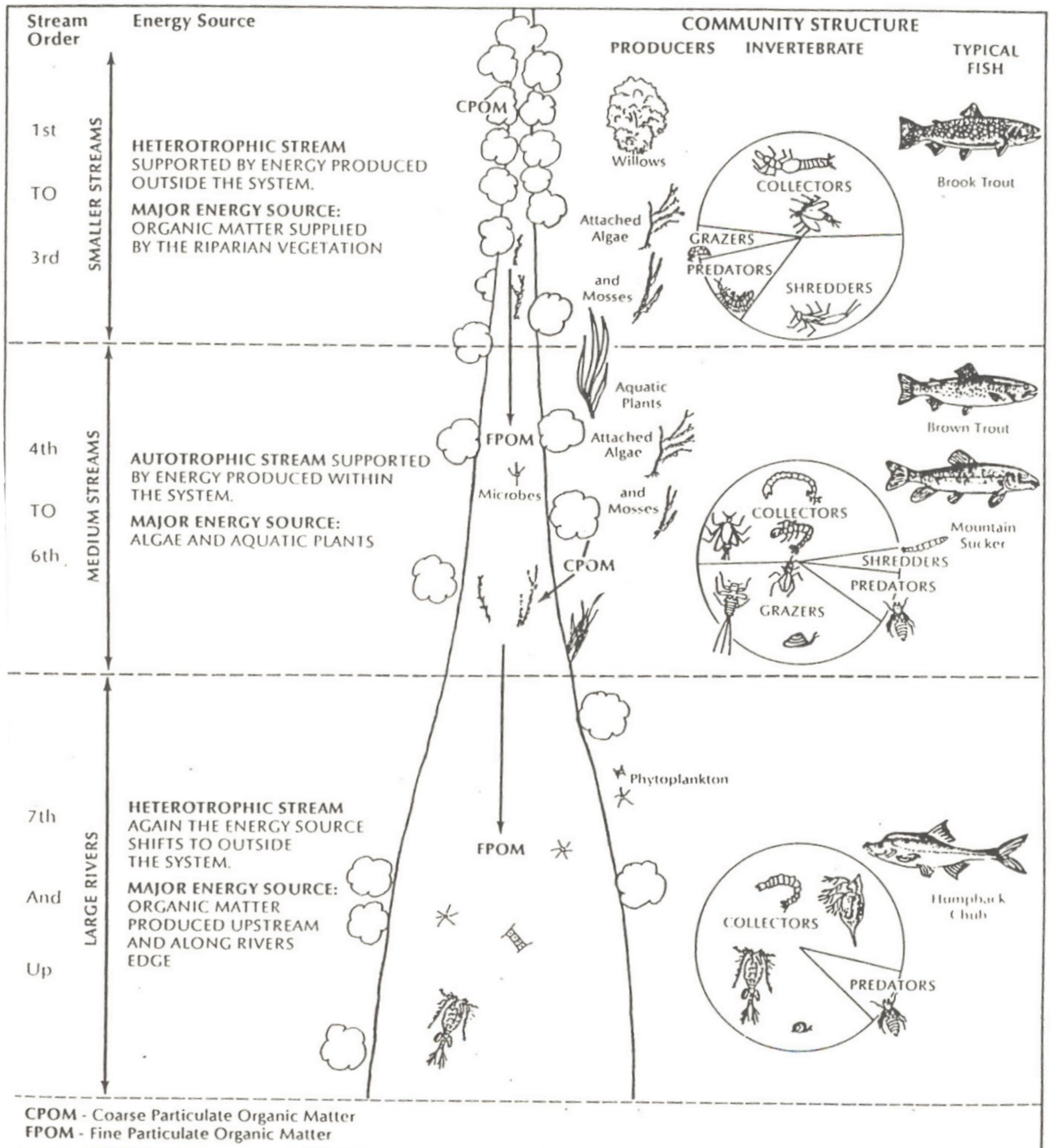
See Figure 1A and 1B to illustrate the RCC.

Figure 1A

COMMUNITY FUNCTION

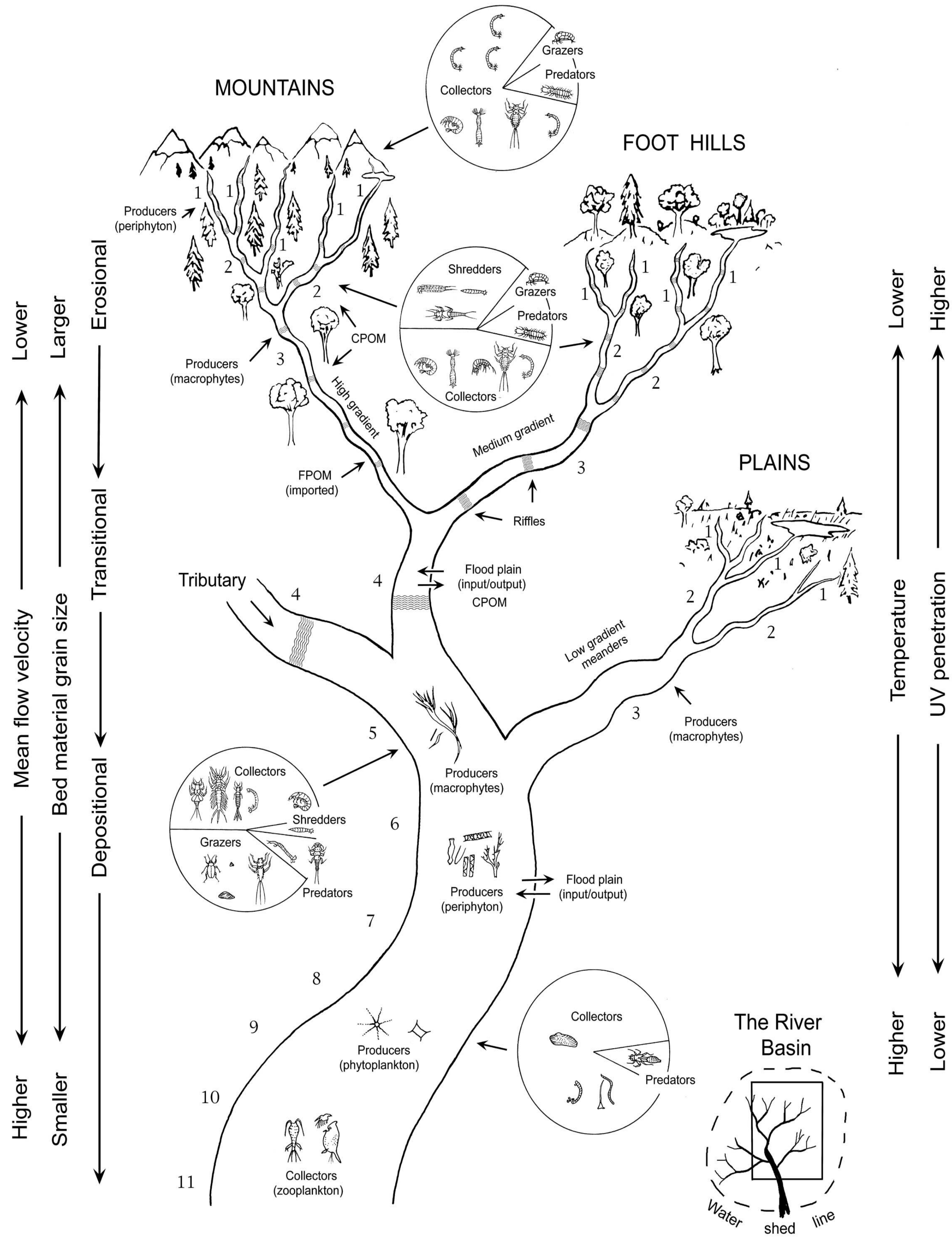
This section describes how the different types of aquatic communities described previously function collectively to create the unique characteristics of a particular ecosystem. The ecological relationships of both streams and lakes are discussed.

BIOLOGICAL PRODUCTIVITY OF STREAMS.--The energy sources within a stream ecosystem change as the stream travels from its headwater to its mouth. Figure 6-7 displays changes in community structure as stream sizes increase. Headwater streams (1-3rd order) are heterotrophic, i.e., supported by energy produced elsewhere. These cold, steep, unproduc-



6-7. The energy source and community structure change as a stream travels from its headwaters to its mouth (adapted from Cummins 1973).

Figure 1B ***Stream Corridor Overview***



Worksheet 2 is an exercise to see if you understand the RCC, make your predictions and provide rationale. More concepts regarding a longitudinal view of the river including drainage patterns, channel forms, pools and riffles and the vegetation corridor follow.

Worksheet 2 – River Continuum Predictions

River Watch River Continuum Predictions

Parameter	↑↓ In Downstream Direction does the Parameter increase of decrease?	Why?
CHEMICAL		
Temperature		
Dissolved O_2		
pH		
Alkalinity		
Hardness		
Metals		
TSS		
Total Nitrogen,		
Ammonia		
Total Phosphorus		
Chloride		
Sulfate		

Parameter	↑↓ In Downstream Direction does the Parameter increase of decrease?	Why?
PHYSICAL HABITAT		
Flow		
Stream Width		
Stream Depth		
Riparian Zone Width		
Riparian Vegetation Type		
Stream Substrate Size		
Pools		
Riffles		
Sedimentation		
Embeddedness		
Canopy Shade		
Bank Stability		
Width/Depth Ratio		

Parameter	↑↓ In Downstream Direction does the Parameter increase of decrease?	Why?
BIOLOGICAL		
Bacteria		
Fine Particulate Organic Matter		
Coarse Particulate Organic Matter		
Periphyton/algae		
Stoneflies		
Mayflies		
Caddisflies		
Dipterans (black flies)		
Trout		
Minnows		

Longitudinal View

The following excerpt is from Stream Corridor Restoration Principles, Processes, and Practices by The Federal Interagency Stream Restoration Working Group. October 1998.

1.C A Longitudinal View Along Corridor

The processes that develop the characteristic structure seen in the lateral view of a stream corridor also influence structure in the longitudinal view. Channel width and depth increase downstream due to increasing drainage area and discharge. Related structural changes also occur in the channel, floodplain, and transitional upland fringe, and in processes such as erosion and deposition. Even among different types of streams, a common sequence of structural changes is observable from headwaters to mouth.

Longitudinal Zones

The overall longitudinal profile of most streams can be roughly divided into three zones (Schumm 1977). Some of the changes in the zones are characterized in Figures 1.27 and 1.28.

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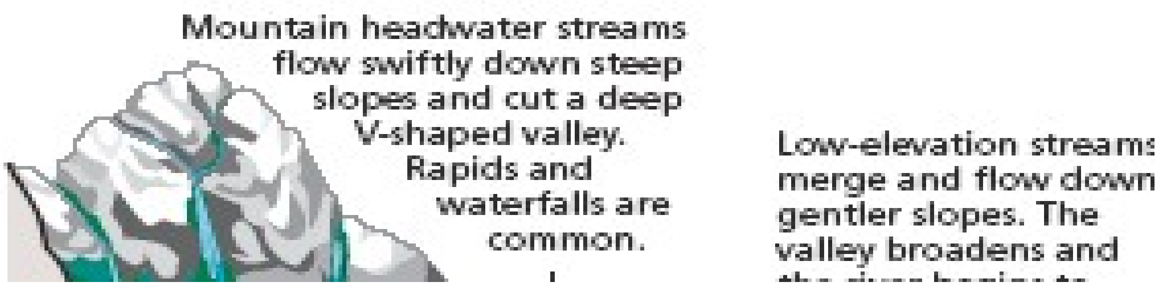

drains water, sediment, and dissolved materials to a common outlet at some point along a stream channel" (Dunne and Leopold 1978). Form varies greatly, however, and is tied to many factors including climatic regime, underlying geology, morphology, soils, and vegetation.

Drainage Patterns

One distinctive aspect of a watershed when observed in planform (map view) is its drainage
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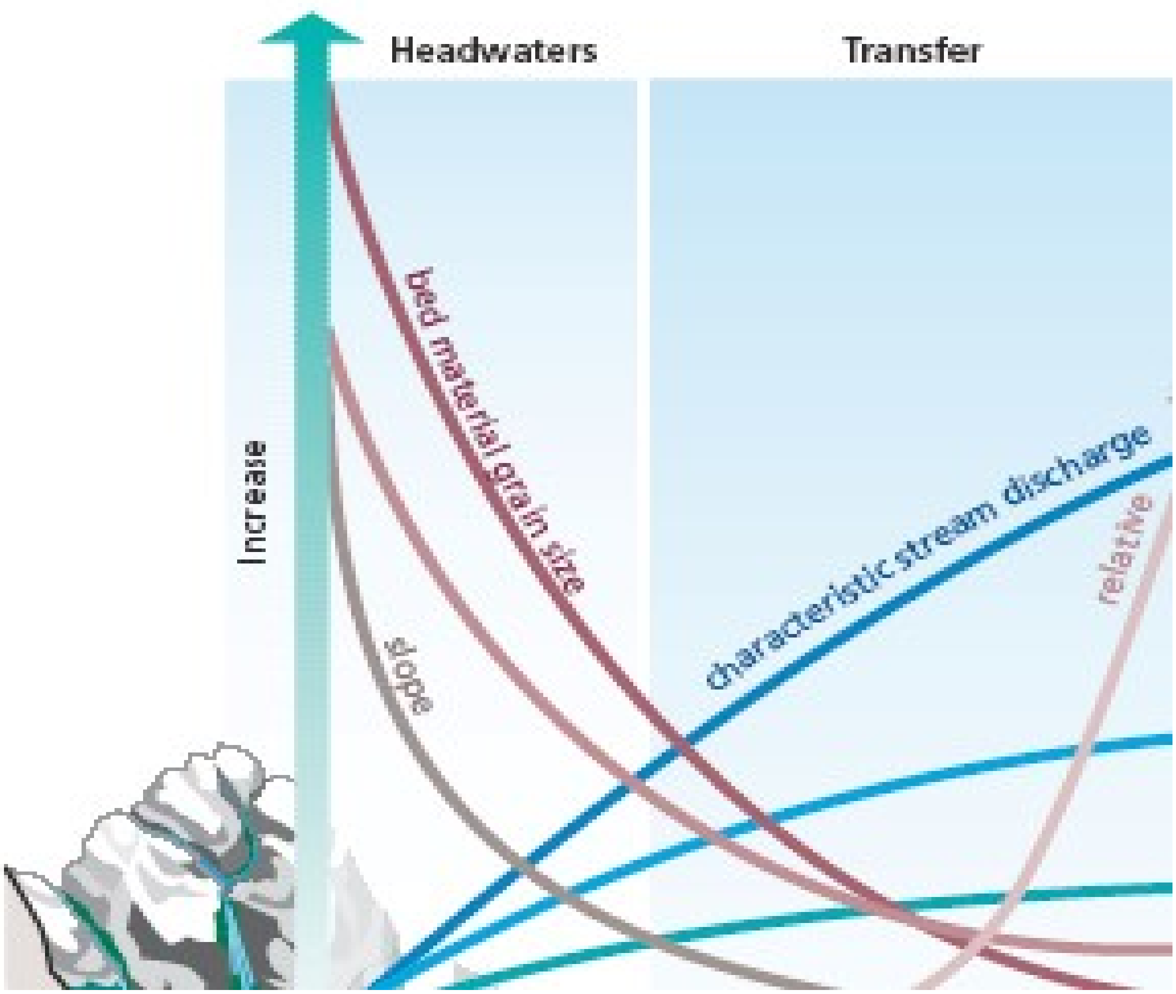

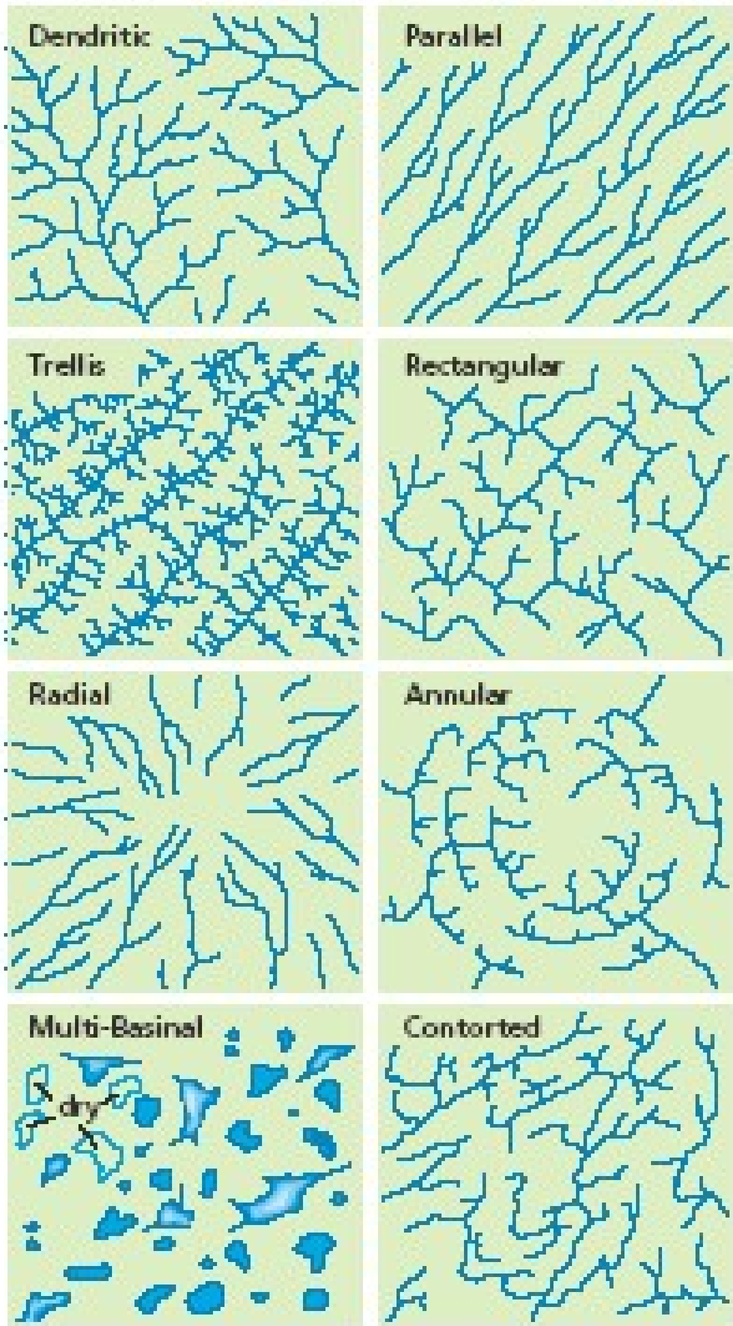

Figure 1.29: Watershed drainage patterns. Patterns are determined by topography and geologic structure.
Source: A.D. Howard, AAPG © 1967, reprinted by permission of the American Association of Petroleum Geologists.

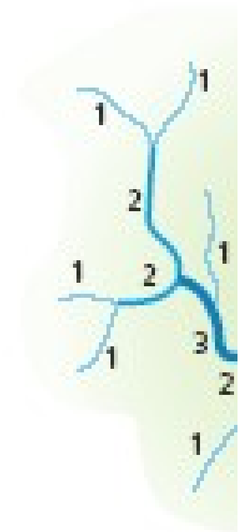

Figure 1.30: St work. Stream ing the hierar watershed.

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Three conditions tend to promote the formation of braided streams:

- Erodible banks.
- An abundance of coarse sediment.
- Rapid and frequent variations in discharge.

Braided streams typically get their start when a central sediment bar begins to form in a channel due to reduced streamflow or an increase in sediment load. The central bar causes water to flow into the two smaller cross sections on either side. The smaller cross section results in a higher velocity flow. Given erodible banks, this causes the channels to widen. As they do this, flow velocity decreases, which allows another central bar to form. The process is then repeated and more channels are created.

In landscapes where braided streams occur naturally, the plant and animal communities have adapted to frequent and rapid changes in the channel and riparian area. In cases where disturbances trigger the braiding process, however, physical conditions might be too dynamic for many species.

The second, less common category of multiple-thread channels is called *anastomosed streams*. They occur on much flatter gradients than braided streams

Sinuosity

Natural channels are rarely
Sinuosity is a term indicati
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(Figure 1.32). The *sinuosity*
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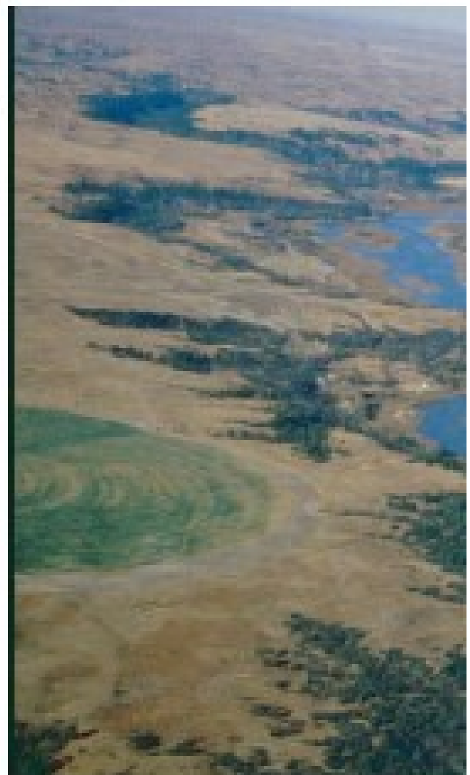
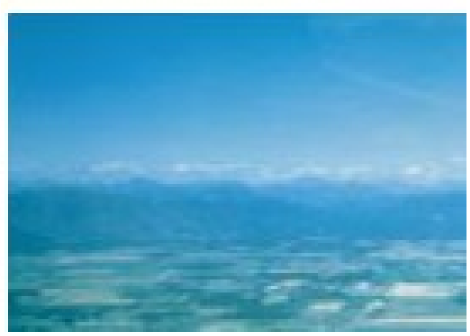
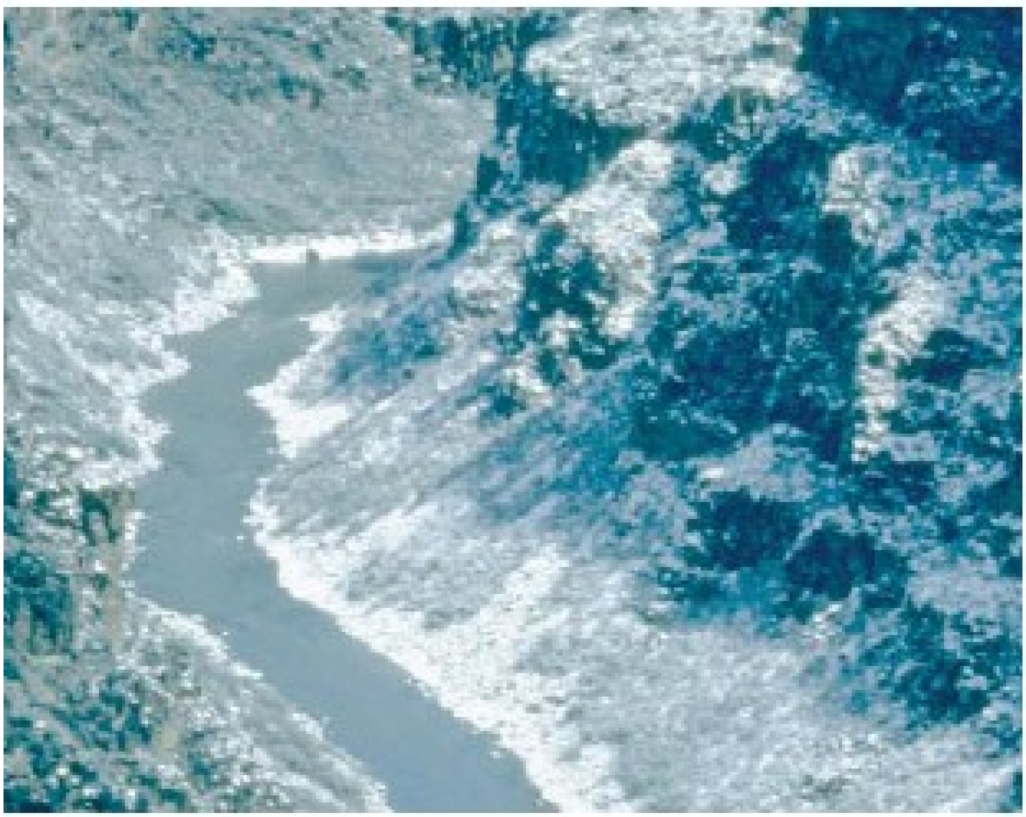


(a)



centerline length by the length of the valley centerline. If the channel length/valley length ratio is more than about 1.3, the stream can be considered meandering in form.

Sinuosity is generally related to the product of discharge and gradient.



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Vegetation Along the Stream Corridor

Vegetation is an important and highly variable element in the longitudinal as well as the lateral view. Floodplains are narrow or nonexistent in Zone 1 of the longitudinal profile; thus flood-dependent or tolerant plant communities tend to be limited in distribution. Upland plant communities, such as forests on moderate to steep slopes in the eastern or northwestern United States, might come close to bordering the stream and create a canopy that leaves little open sky visible from the channel. In other parts of the country, headwaters in flatter terrain may support plant communities dominated by grasses and broad-leaved herbs, shrubs, or planted vegetation.

Despite the variation in plant community type, many headwaters areas provide organic matter from vegetation along with the sediment they export to Zones 2 and 3 downstream. For example, logs and woody debris from headwaters forests are among the most ecologically important features supporting food chains and instream habitat structure in Pacific Northwest rivers from the mountains to the sea (Maser and Sedell 1994).

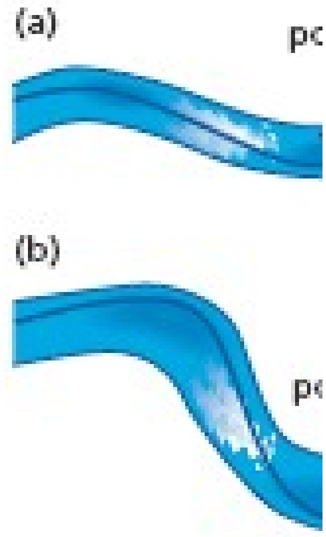

Figure 1.33: Sequen (a) straight and (b) typically form on th and riffles in the str nel where the thalv side to the other.

zone. This phen counteracts the r velop broad and plant communit lower reaches. Tl when land uses i native vegetatior corridor.

Often, a native p placed by a plan nity such as agri residential lawns such as bottomland hardwoods, establish themselves in the deep, rich alluvial soils of the floodplain. The slower flow in the channel also allows emergent marsh vegetation, rooted floating or free-floating plants, and submerged aquatic beds to thrive.

The changing sequence of plant communities along streams from source to mouth is an important source of biodiversity and resiliency to change. Although many, or perhaps most, of a stream corridor's plant communities might be fragmented, a continuous corridor of native plant communities is desirable. Restoring vegetative connectivity in even a portion of a stream will usually improve conditions and increase its beneficial functions.

The River Continuum Concept

The River Continuum Concept is an attempt to generalize and explain longitudinal changes in stream ecosystems (Figure 1.34) (Vannote et al. 1980). This conceptual model not only helps to identify connections between the watershed, floodplain, and stream systems, but it also describes how biological communities develop and change from the headwaters to the mouth. The River Continuum Concept can place a site or reach in context within a larger water-

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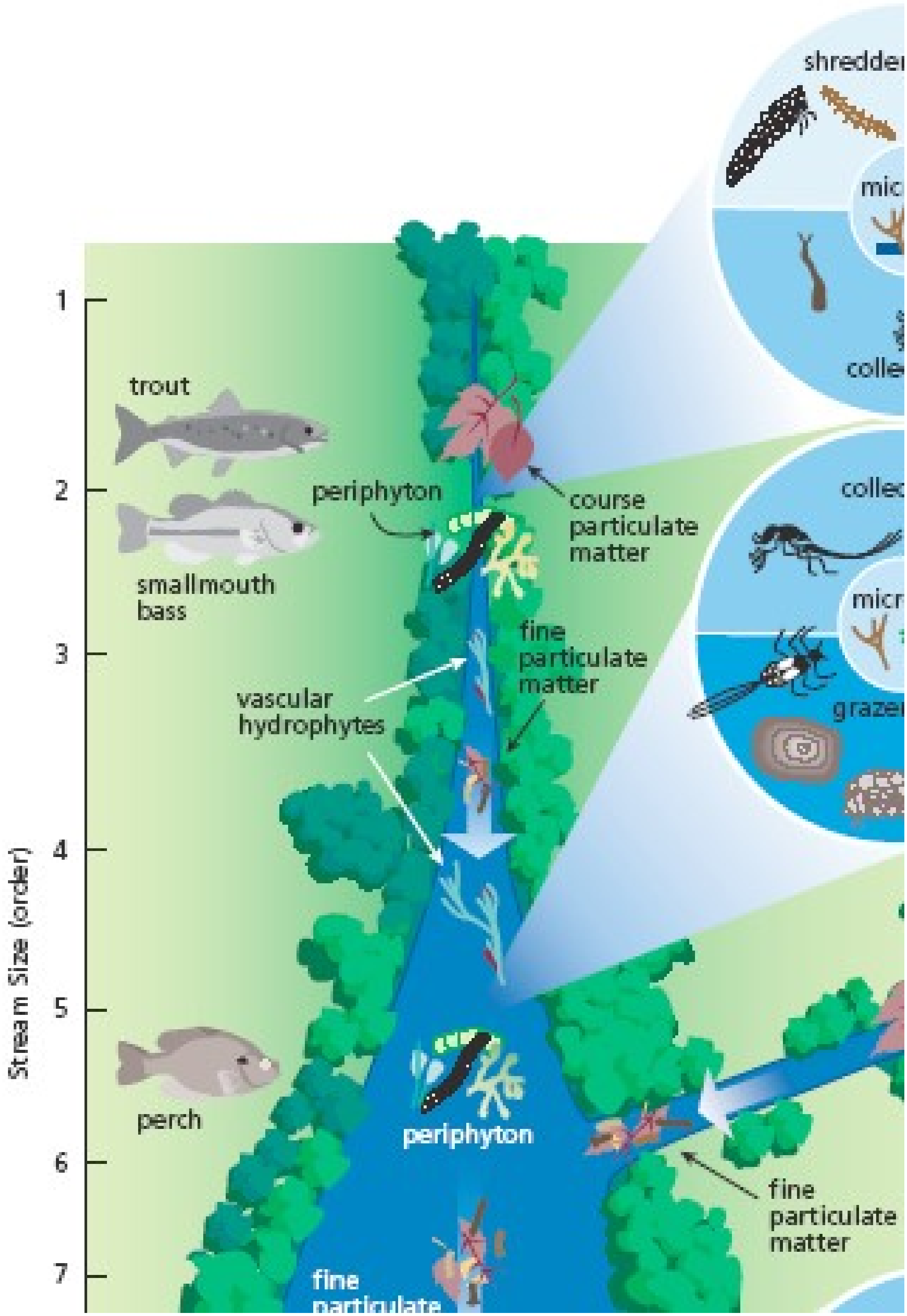
Stream Size (order)
1
2
3
4
5
6
7
trout
smallmouth
bass
perch
periphyton
course
particulate
matter
fine
particulate
matter
vascular
hydrophytes
periphyton
fine
particulate
matter
fine

phytoplankton, but continue to receive heavy inputs of dissolved and ultra-fine organic particles from upstream. Invertebrate populations are dominated by fine-particle collectors, including zooplankton. Large streams frequently carry increased loads of clays and fine silts, which increase turbidity, decrease light penetration, and thus increase the significance of heterotrophic processes.

The influence of storm events and thermal fluctuations decrease in frequency and magnitude, which increases the overall physical stability of the stream.

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River Physical Structure at Multiple Land & Time Scales

As you saw above, rivers can be viewed on a longitudinal scale, from upstream to downstream. Another useful physical structure view of the river ecosystem is from a landscape scale. There are a number of landscape scales to view your river. Pretend you are at your station and a balloon carries you away. At first you can see for 10-20 miles, then 50-100 miles; you see more and more the higher you rise.

These landscape views are generally characterized as site specific or right on the ground at your station, slightly larger would be the stream reach you station is located within, then the sub-watershed, a larger landscape watershed or regional scale. All of these scales provide different information and useful management units.

Another perspective is to view your river over time. You can view any landscape scale perspective overtime. This provides valuable information as well.

Review the information provided below for more detail.

The following excerpt is from Stream Corridor Restoration Principles, Processes, and Practices by The Federal Interagency Stream Restoration Working Group. October 1998.

1.A Physical Structure and Tim Scales

A hierarchy of five *spatial scales,* which range from broad to local, is displayed in Figure 1.2. Each element within the scales can be viewed as an ecosystem with links to other ecosystems. These linkages are what make an ecosystem's external environment as important to proper functioning as its internal environment (Odum 1989).

Landscapes and stream corridors are ecosystems that occur at different spatial scales. Examining them as ecosystems is useful in explaining the basics of how landscapes, watersheds, stream corridors, and streams function. Many common ecosystem functions involve movement of materials (e.g., sediment and storm water runoff), energy (e.g., heating and cooling of stream waters), and organisms (e.g., movement of mammals, fish schooling, and insect swarming) between the internal and external environments (Figure 1.3).

The internal/external movement model becomes more complex when one considers that the external environment of a given ecosystem is a larger ecosystem. A stream ecosystem, for example, has an input/output relationship with the next

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Landscape e terms to defi particular sc

- *Matrix,* th nant and majority c the matrix but theore cover type
- *Patch,* a n that is less ent from,
- *Corridor,* a links othe Typically, gated in s corridor.
- *Mosaic,* a of which interconn scape.

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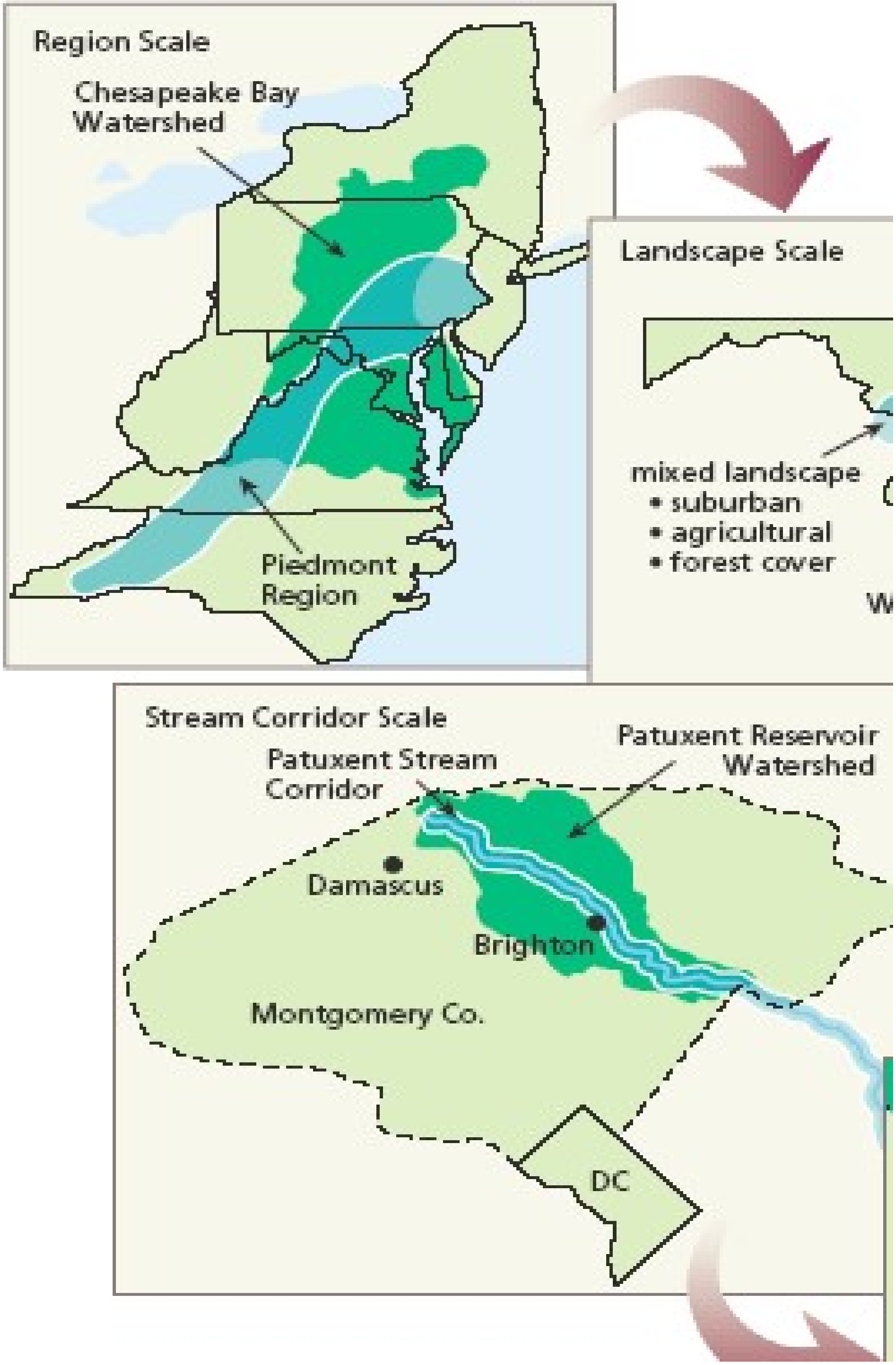
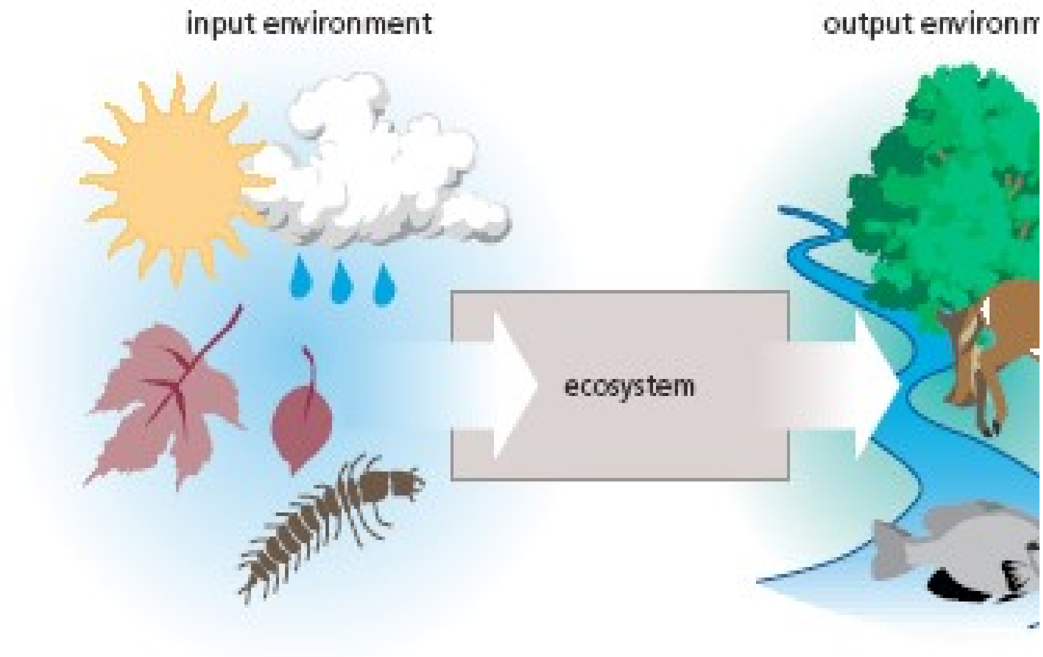

Region Scale
Chesapeake Bay Watershed
Piedmont Region
Landscape Scale
mixed landscape
• suburban
• agricultural
• forest cover
Stream Corridor Scale
Patuxent Stream Corridor
Patuxent Reservoir Watershed
Damascus
Brighton
Montgomery Co.
DC



At the other extreme, the coarsest of the imaging satellites that monitor the earth's surface might detect only patches or corridors of tens of square miles in area, and matrices that seem to dominate a whole region. At all levels, the matrix-patch-corridor-mosaic model provides a useful common denominator for describing structure in the environment.

Figure 1.5 displays examples of the matrices, patches, and corridors at broad and local scales. Practitioners should always consider multiple scales when planning and designing restoration.

Structure at Scales E
the Stream Corridor

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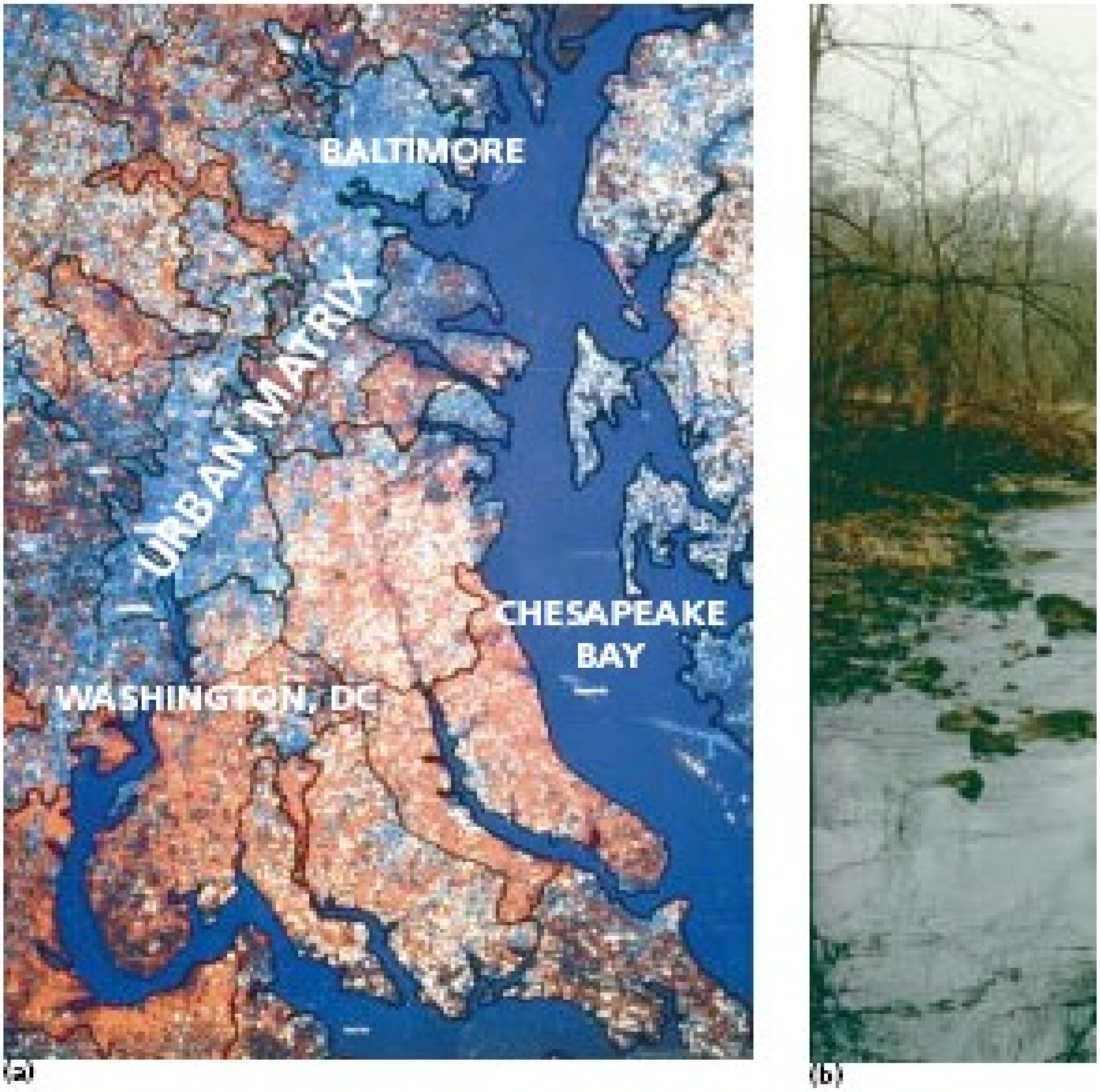

***Figure 1.5:** Spatial structure at (a) broad and (b) local scales. Patches,*
visible at the broad regional scale and the local reach scale.

Regional Scale

A *region* is a broad geographical area with a common macroclimate and sphere of human activities and interests (Forman 1995). The spatial elements found at the regional scale are called landscapes. Figure 1.6 includes an ex-

- Major foreste
  forests in the
- Major metro
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  politan area)
- Major land u

Landscape Scale

A *landscape* is a geographic area distinguished by a repeated pattern of components, which include both natural communities like forest patches and wetlands and human-altered areas like croplands and villages. Landscapes can vary in size from a few to several thousand square miles.

At the landscape scale, patches (e.g., wetlands and lakes) and corridors (e.g., stream corridors) are usually described as ecosystems. The matrix is usually identified in terms of the predominant natural vegetation community (e.g., prairie-type, forest-type, and wetland-type) or land-use-dominated ecosystem (e.g., agricultur

(Figure 1.7).

Landscapes differ from on
based on the consistent pa
by their structural element
predominant land cover th
their patches, corridors, an

Examples of landscapes in
States include:

- A highly fragmented ea
ic of suburban, forest, a
al patches.
- A north-central agricultu
with pothole wetlands a
patches.
- A Sonoran desert matrix
cottonwood corridors.
- A densely forested Pacif
matrix with a pattern of
patches.

Figure 1.6: The New England region. Structure in a region is typically a function of natural cover and land use.

Source: Forman (1995). Reprinted with the permission of Cambridge University Press.

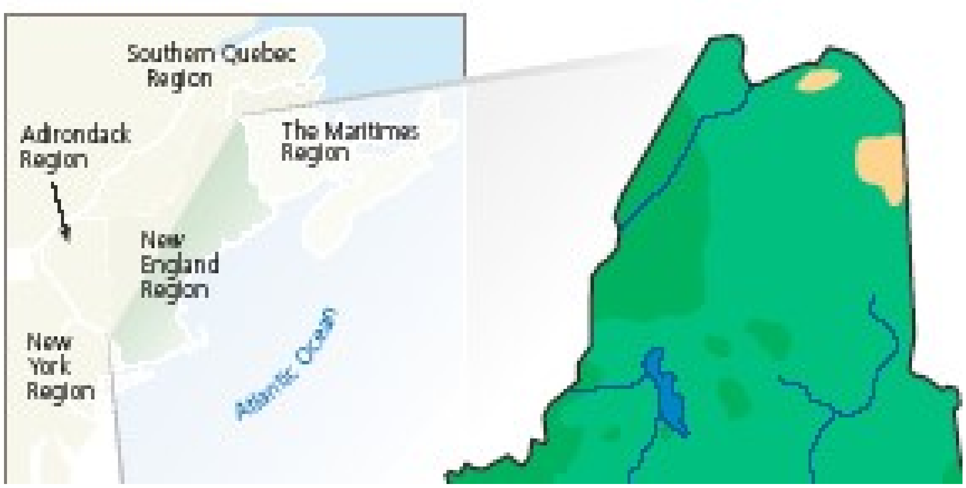

Figure 1.7: Structure at the landscape scale. Patches and corridors are visible within an agricultural matrix.

A woodlot within an agricultural matrix and a wetland in an urban matrix are examples of patches at the landscape scale. Corridors at this scale include ridgelines, highways, and the topic of this document—stream corridors.

At the landscape scale it is easy to perceive the stream corridor as an ecosystem with an internal environment and external environment (its surrounding landscape). Corridors play an impor-

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ments such as upper, middle, and lower watershed zones; drainage divides; upper and lower hillslopes; terraces, floodplains, and deltas; and features within the channel. These elements and their related functions are discussed in sections B and C of this chapter.

In short, watersheds and landscapes overlap in size range and are defined by different environmental processes. Whereas the landscape is defined primarily by terrestrial patterns of land cover that may continue across drainage divides to where the consistent pattern ends, the watershed's boundaries are based on the drainage divides themselves. Moreover, the ecological processes occurring in watersheds are more closely linked to the presence and movement of water; therefore as functioning ecosystems, watersheds also differ from landscapes.

The difference between landscape scale and "watershed scale" is precisely why practitioners should consider both when planning and designing stream corridor restoration. For decades the watershed has served as the geographic unit of choice because it requires consideration of hydrologic and geomorphic processes associated with the

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Structure at the Stream Corridor Scale

The stream corridor is a spatial element (a corridor) at the watershed and landscape scales. But as a part of the hierarchy, it has its own set of structural elements (Figure 1.8). Riparian (streamside) forest or shrub cover is a common matrix in stream corridors. In other areas, herbaceous vegetation might dominate a stream corridor.

Examples of patches at the stream corridor scale include both natural and human features such as:

- Wetlands.
- Forest, shrubland, or grassland patches.
- Oxbow lakes.
- Residential or commercial development.
- Islands in the channel.
- Passive recreation areas such as picnic grounds.

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- The thalweg, the "channel within the channel" that carries water during low-flow conditions.
- Lengths of stream defined by physical, chemical, and biological similarities or differences.
- Lengths of stream defined by human-imposed boundaries such as political borders or breaks in land use or ownership.

Temporal Scale

The final scale concept critical for the planning and design of stream corridor restoration is time.

In a sense, temporal hierarchy parallels spatial hierarchy. Just as global or regional spatial scales are usually too large to be relevant for most restoration initiatives, planning and designing restoration for broad scales of time is not usually practical. Geomorphic or climatic changes, for example, usually occur over centuries to millions of years. The goals of restoration efforts, by comparison, are usually described in time frames of years to decades.

Land use change in the watershed, for example, is one of many factors that can cause disturbances in the stream corridor. It occurs on many time scales,

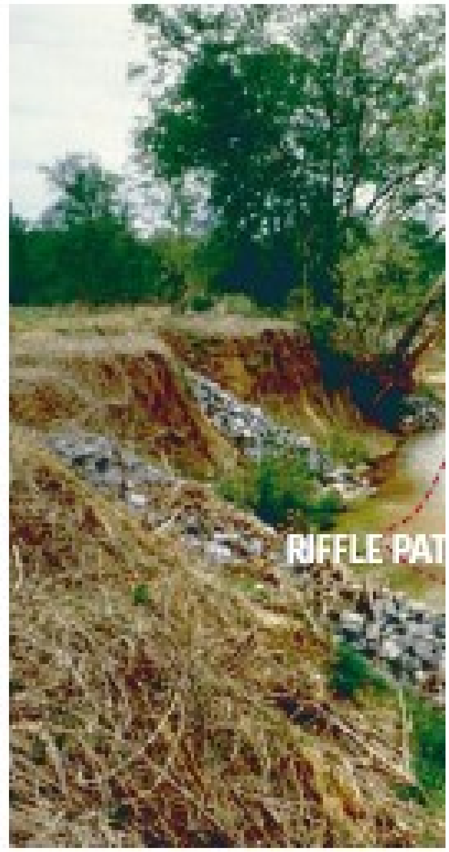


Figure 1.9: Structural elements scale. Patches, corridors, and m within the stream.

planned for in restoration Flood specialists rank the floods in temporal terms s year, 100-year, and 500-yea (10%, 1%, 0.2% chance of See Chapter 7 *Flow Frequer* for more details.). These ca guidance for planning and restoration when flooding

Practitioners of stream cor

Lateral View of the Stream Corridor

Another view of the river is a lateral cross section. The lateral view is looking at stream channel size, flow, ground water relationships, and relationships to the flood plain; transitional upland; and vegetation along the stream corridor; and introducing the flood pulse concept.

Another valuable view of your river ecosystem is to pretend you took a really large knife and cut right through your stream at a 90 degree angle, and could stop the flow, and pick up that stream and look at the cross section you just cut. This cross section could be as large as the stream width, riparian zone next to the stream, and the upland ecosystem adjacent to the riparian zone and stream.

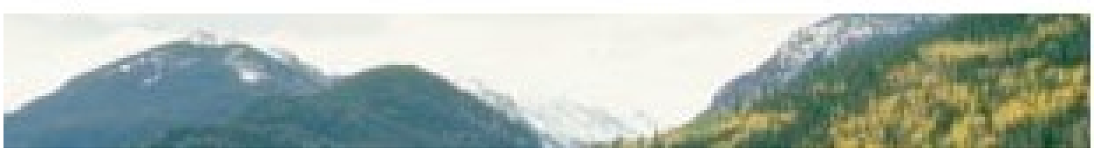
This cross section would be a lateral view of the stream corridor. You could look at stream channel size, shape, flow, relationships between surface and ground water, relationship of the river, riparian zone and upland floodplain chemically, physically and biologically. In this section below we also introduce the flood pulse concept.

The following excerpt is from Stream Corridor Restoration Principles, Processes, and Practices by The Federal Interagency Stream Restoration Working Group. October 1998

1.B A Lateral View Across th

The previous section described how the matrix-patch-corridor-mosaic model can be applied at multiple scales to examine the relationships between the stream corridor and its external environments. This section takes a closer look at physical structure in the stream corridor itself. In particular, this section focuses on the lateral dimension. In cross section, most stream corridors have three major components (Figure 1.10):

(a)



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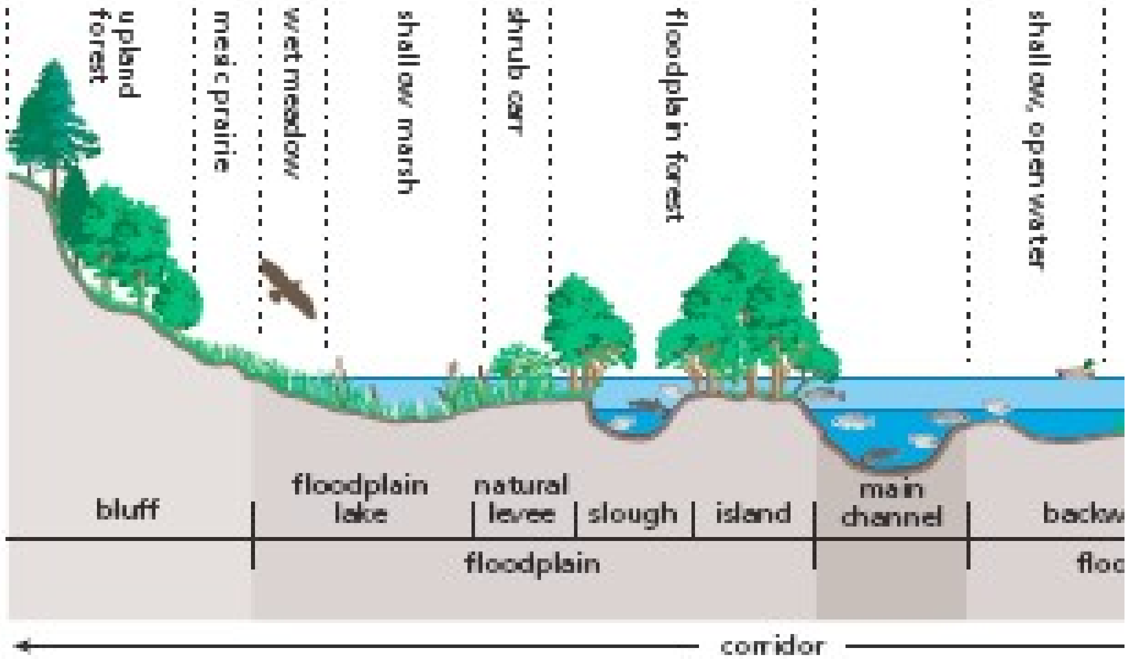

Figure 1.11: A cross section of a river corridor. The three main componen can be subdivided by structural features and plant communities. (Vertica are greatly exaggerated.)

Source: Sparks, Bioscience, vol. 45, p. 170, March 1995. ©1995 American Institute

pass through without spilling over the banks. Two attributes of the channel are of particular interest to practitioners, channel size and streamflow.

Channel Size

Channel size is determined by four basic factors:

- Sediment discharge (Q_s)
- Sediment particle size (D_{50})
- Streamflow (Q_w)
- Stream slope (S)

other variables mu
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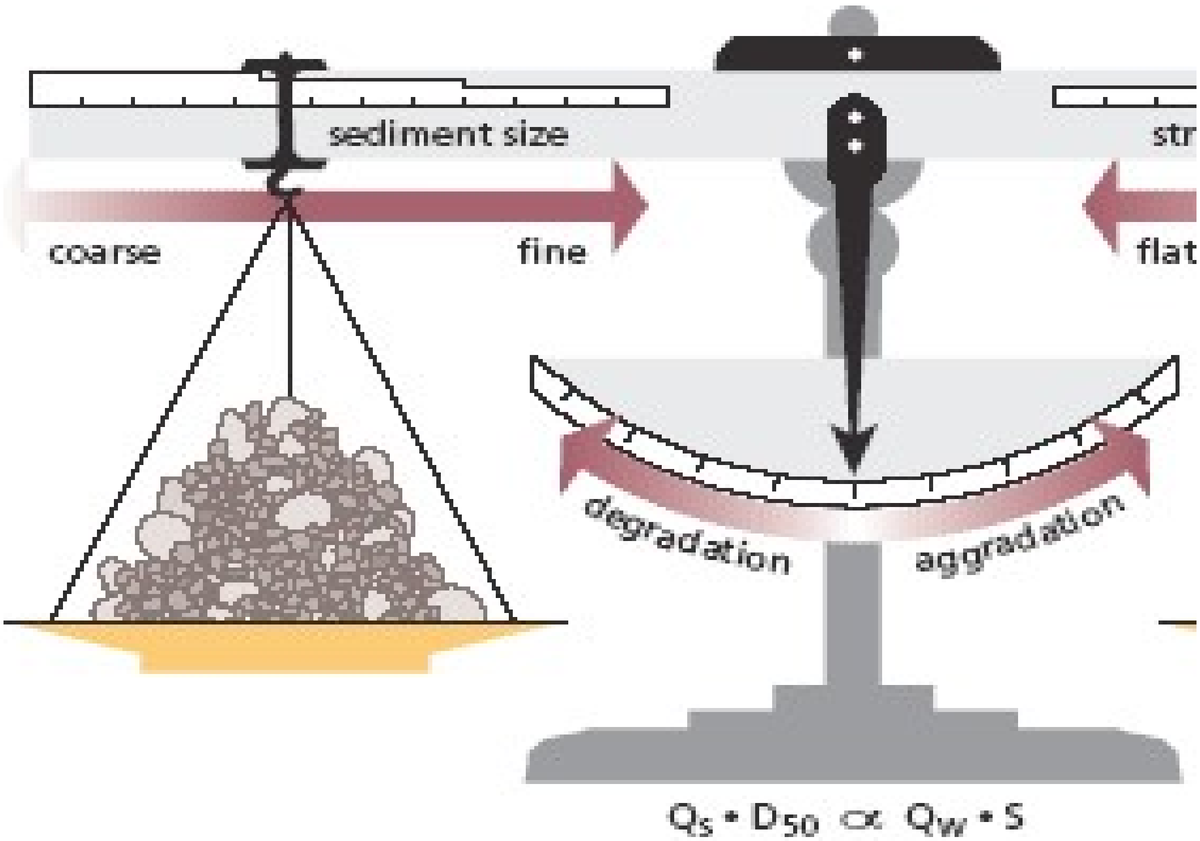


Figure 1.13: Factors affecting channel degradation and aggradation. determined by the stream's energy, the slope, and the flow of water quantity of the sediment particles the stream moves.
Source: Rosgen (1996), from Lane, ***Proceedings***, 1955. Published with the per Civil Engineers.

depending on which direction the balance is tipped.

The stream balance equation is useful for making qualitative predictions concerning channel impacts due to changes in runoff or sediment loads from the watershed. Quantitative predictions, however, require the use of more com-

Streamflow

A distinguishi is streamflow. the ultimate sc itation. The pa takes after it fa fect many aspe

Streamflow at any one time might consist of water from one or both sources. If neither source provides water to the channel, the stream goes dry.

A *storm hydrograph* is a tool used to show how the discharge changes with time (Figure 1.14). The portion of the hydrograph that lies to the left of the peak is called the *rising limb*, which shows how long it takes the stream to peak following a precipitation event. The portion of the curve to the right of the peak is called the *recession limb*.

Channel and Ground Water Relationships

Interactions between ground water and the channel vary throughout the watershed. In general, the connection is strongest in streams with gravel riverbeds in well-developed alluvial floodplains.

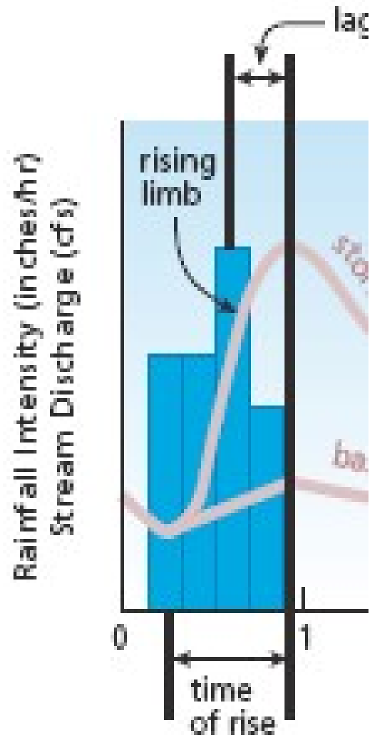
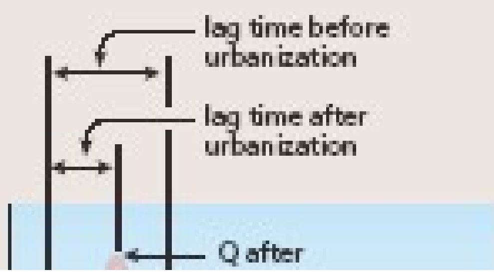


Figure 1.14: A storm hydr graph shows how long a from baseflow to maximu return to baseflow condit



Change in Hydr

The hydrology of urbar and natural vegetation as rooftops, roadways, One of the consequen

Figure 1.16 presents two types of water movement:

- *Influent or "losing" reaches* lose stream water to the aquifer.
- *Effluent or "gaining" reaches* receive discharges from the aquifer.

Practitioners categorize streams based on the balance and timing of the stormflow and baseflow components. There are three main categories:

- *Ephemeral streams* flow only during or immediately after periods of precipitation. They generally flow less than 30 days per year (Figure 1.17).
- *Intermittent streams* flow only during certain times of the year. Seasonal flow in an intermittent stream usually lasts longer than 30 days per year.
- *Perennial streams* flow continuously during both wet and dry times. Baseflow is dependably generated from the movement of ground water into the channel.

Discharge Regime

Discharge is the term used to describe the volume of water moving down the channel per unit time (Figure 1.18). The basic unit of measurement used in the United States to describe discharge is cubic foot per second (cfs).

Figure 1.17: An
streams flow or
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Discharge is

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Q = Discharg

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discharge, it would result in channel morphology close to the existing channel. However, there is no method for directly calculating channel-forming discharge.

An estimate of channel-forming discharge for a particular stream reach can, with some qualifications, be related to depth, width, and shape of channel. Although channel-forming discharges are strictly applicable only to channels in equilibrium, the concept can be used to select appropriate channel geometry for restoring a disturbed reach.

- *Effective discharge*. The effective discharge is the calculated measure of channel-forming discharge.

Computation of effective discharge requires long-term water and sediment measurements, either for the stream in question or for one very similar. Since this type of data is often not available for stream restoration sites, modeled or computed data are sometimes substituted. Effective

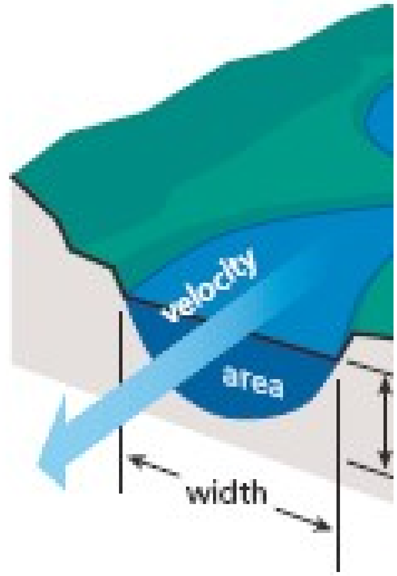

Figure 1.18: Channel discharg
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discharge can be comp
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- *Bankfull discharge*. This
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leave the channel and
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Bankfull discharge is e
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Channel-Forming Discharge

Floodplain

The floor of most stream valleys is relatively flat. This is because over time the stream moves back and forth across the valley floor in a process called lateral migration. In addition, periodic flooding causes sediments to move longitudinally and to be deposited on the valley floor near the channel. These two processes continually modify the floodplain.

Through time the channel reworks the entire valley floor. As the channel migrates, it maintains the same average size and shape if conditions upstream remain constant and the channel stays in equilibrium.

Two types of floodplains may be defined (Figure 1.20):

- *Hydrologic floodplain,* the land adjacent to the baseflow channel residing below bankfull elevation. It is inundated about two years out of three. Not every stream corridor has a hydrologic floodplain.
- *Topographic floodplain,* the land adjacent to the channel including the hydrologic floodplain and other lands up to an elevation based on

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of a given fre
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Landforms and Deposits

Topographic features are formed on the floodplain by the lateral migration of the channel (Figure 1.21). These features result in varying soil and moisture conditions and provide a variety of habitat niches that support plant and animal diversity.

Floodplain landforms and deposits include:

- *Meander scroll,* a sediment formation marking former channel locations.
- *Chute,* a new channel formed across the base of a meander. As it grows in size, it carries more of the flow.
- *Oxbow,* a term used to describe the severed meander after a chute is formed.
- *Clay plug,* a soil deposit developed at the intersection of the oxbow and the new main channel.
- *Oxbow lake,* a b
after clay plugs
main channel.
- *Natural levees,* f
along the bank
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- *Backswamps,* a t
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Transitional Upland Fringe

The transitional upland fringe serves as a transitional zone between the floodplain and surrounding landscape. Thus, its outside boundary is also the outside boundary of the stream corridor itself.

While stream-related hydrologic and geomorphic processes might have formed a portion of the transitional upland fringe in geologic times, they are not responsible for maintaining or altering its present form. Consequently, land use activities have the greatest potential to impact this component of the stream corridor.

There is no typical cross section for this component. Transitional upland fringes can be flat, sloping, or in some cases, nearly vertical (Figure 1.22). They can incorporate features such as hillslopes, bluffs, forests, and prairies, often modified by land use. All transitional upland

fringes have one c
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and stream.

An examination of
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Figure 1.24 preser
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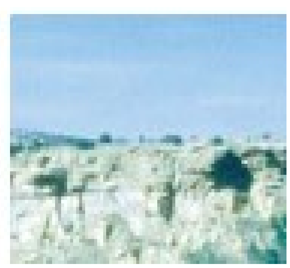

and the channel degrades and widens. The original floodplain is abandoned and becomes a terrace (cross section B). The widening phase is completed when a floodplain evolves within the widened channel (cross section C).

Geomorphologists often classify landscapes by numbering surfaces from the lowest surface up to the highest surface. Surface 1 in most landscapes is the bottom of the main channel. The next highest surface, Surface 2, is the floodplain. In the case of an incising stream, Surface 3 usually is the most recently formed terrace, Surface 4 the next older terrace, and so on. The numbering system thus reflects the ages of the surfaces. The higher the number, the older the surface.

Boundaries between the numbered sur-

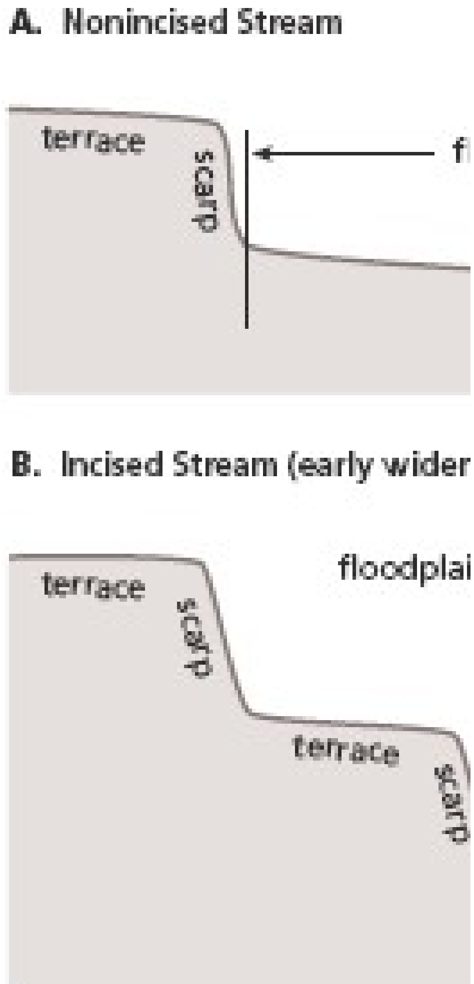

Figure 1.24: Te
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Vegetation is an important and highly variable element in the stream corridor. In some minimally disturbed stream corridors, a series of plant communities might extend uninterrupted across the entire corridor. The distribution of these communities would be based on different hydrologic and soil conditions. In smaller streams the riparian vegetation might even form a canopy and enclose the channel. This and other configuration possibilities are displayed in Figure 1.25

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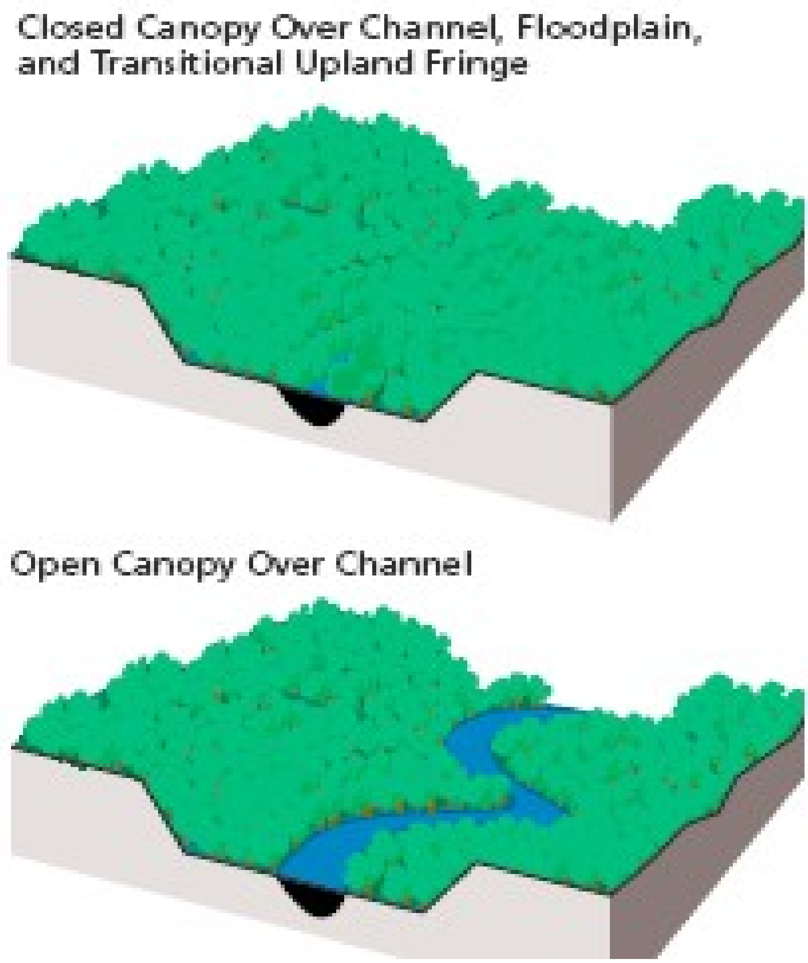

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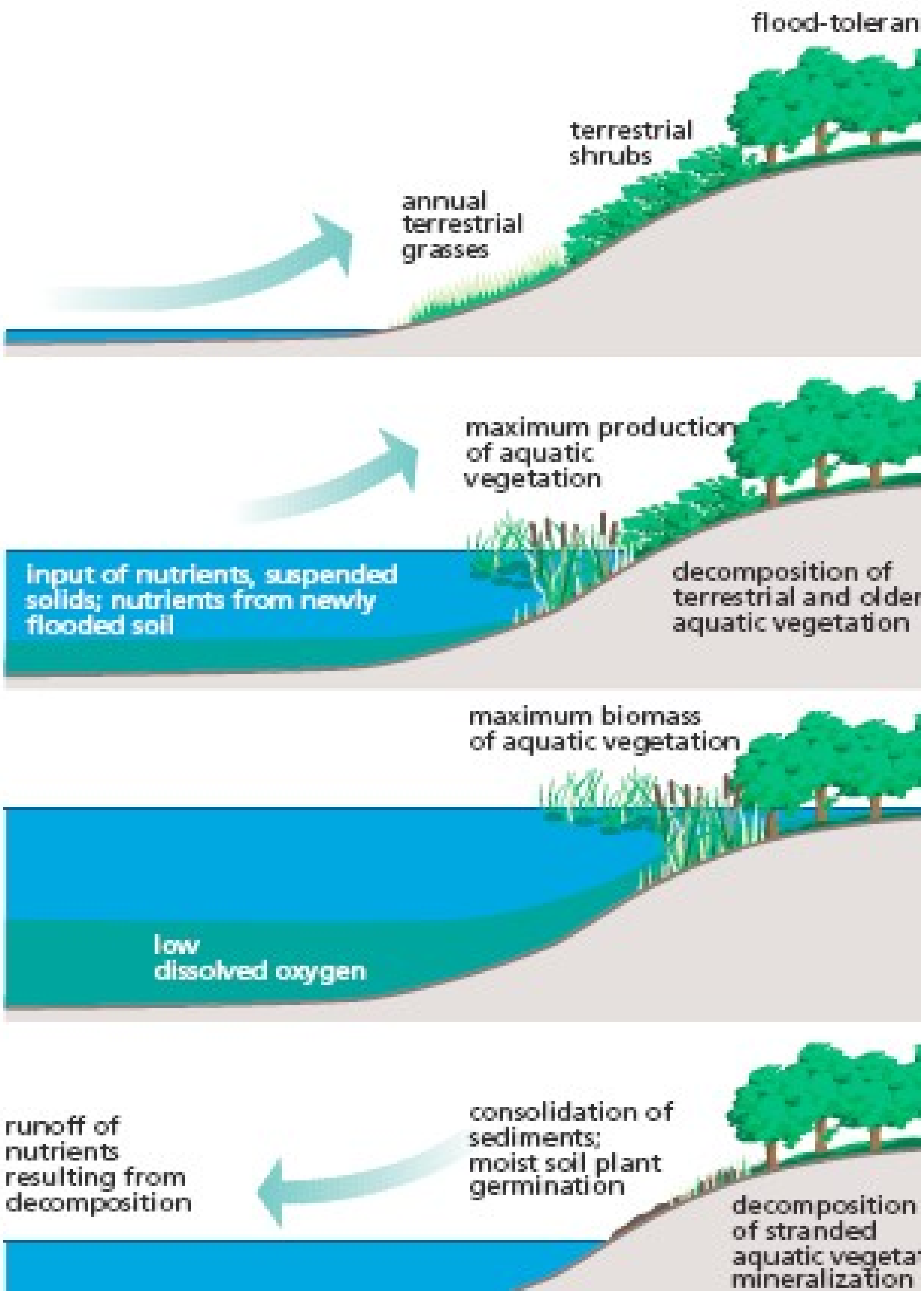
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terrestrial shrubs
annual terrestrial grasses
maximum production of aquatic vegetation
input of nutrients, suspended solids; nutrients from newly flooded soil
decomposition of terrestrial and older aquatic vegetation
maximum biomass of aquatic vegetation
low dissolved oxygen
runoff of nutrients resulting from decomposition
consolidation of sediments; moist soil plant germination
decomposition of stranded aquatic vegeta
mineralization

Worksheet 3 – The Big Picture, Mike Wilde, Glenwood Springs HS

THE BIG PICTURE
OR
HOW DOES IT ALL FIT TOGETHER?

So often in our learning experiences we tend to become so focused on the specific content area that we forget that the world. and all of its parts, are interconnected. It is difficult to teach about aquatic ecology of the rivers of Colorado without also delving into geology, geography, demographics. politics. history (both recent and ancient), math. chemistry, and variuos assorted other topics.

This exercise is intended to begin to give a more "global" perpsective of your comminity. life. and world.

PART ONE: LOCATION

1. Identify as many of the geographic features on the map as possible. I.E. mountain peaks. mountain ranges, parks, cities. rivers, etc.

2. Draw in the continental divide.

3. Place, past and present, mining towns on the map. Make some notation as to what mineral(s) were mined in that region.

4. Map the location and dipersion of various rock types (sedimentary, igneous, metamorphic) on the map.

5. Locate the population center(s) of the state.

6. Locate the agricultural areas of the state.

PART TWO: INTERPRETATION

1. Where is the population? Who has the water?
2. What types of rocks support which types of mineral extraction? Where on rivers are they located?
3. Is there a relationship between the location of towns and rivers? If so, what is it? Why does Glenwood Springs exist?
4. Why is Colorado called "the mother of rivers?"
5. How is water quality affected by development, mining, population, etc.?
6. How were the Rocky Mountains formed?
7. Add anything else that you discovered or found interesting.

We will coming back to this exercise often, keep it handy, try to remember the "big picture", and refer to it often!

Worksheet 4 – Test Your Water Knowledge

TEST YOUR WATER KNOWLEDGE
(Circle the best answer)

1. What percentage of water consumed in Colorado is consumed in the Denver area?

   a) 3% b) 10% c) 20% d) 35% e) 55% f) >60%

2. What percentage of water consumed in Colorado is consumed by Agriculture?

   a) 28% b) 40% c) 66% d) 88% e) >88%

3. How many years does it take to PLAN & DEVELOP a major water project?

   a) 3-5 years b) 6-10 years c) 25-30 years

4. When was the first water right claimed in Colorado?

   a) 1720s b)1820s c)1850s d)1900s e)1910s

5. How may dollars does WATER BASED RECREATION provide to Colorado Economy?

   a) 3000 mil b) 1000 mil c) 970 mil d) 480 mil e) 220 mil

6. How many GALLONS of water does the average URBAN HOUSEHOLD use each year?

   a) 80K b) 135K c) 325K d) 500K e) 800K

7. How many times is water from the South Platte River used between its headwaters and Julesburg?

   a) Twice b) five times c) seven times d) eleven times

8. What is the annual precipitation in Greeley?

   a) 2-4 inches b) 6-8 inches c) 12-14 inches d) 16-17 inches

9. How much moisture is needed to grow an average crop?

   a) 24-30 inches b) 40-45 inches c) 66-72 inches d) 80-84 inches

10. Of the list below, what item takes the most water to produce?

    a) 1 loaf of bread b) 1 pound of potatoes

    c) 1 egg d) 1 quart of milk

Worksheet 4 Answers – Test Your Water Knowledge

TEST YOUR WATER KNOWLEDGE
(Circle the best answer)

1. What percentage of water consumed in Colorado is consumed in the Denver area?

   [a) 3%] b) 10% c) 20% d) 35% e) 55% f) >60%

2. What percentage of water consumed in Colorado is consumed by Agriculture?

   a) 28% b) 40% c) 66% d) 88% **[e) >88%]**

3. How many years does it take to PLAN & DEVELOP a major water project?

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   a) 2-4 inches **[b) 6-8 inches]** c) 12-14 inches d) 16-17 inches

9. How much moisture is needed to grow an average crop?

   [a) 24-30 inches] b) 40-45 inches c) 66-72 inches d) 80-84 inches

10. Of the list below, what item takes the most water to produce?

    a) 1 loaf of bread b) 1 pound of potatoes
    c) 1 egg **[d) 1 quart of milk]**

    a) 75 gal
    b) 20 gal
    c) 120 gal
    d) 250 gal

Worksheet 5 – Know Your Own Biological Address

What Do You know About Your Own Watershed or Biological Address?

I. Materials: Newsprint, Markers, Identification books

II. Reflection of special places in your life, current or past.

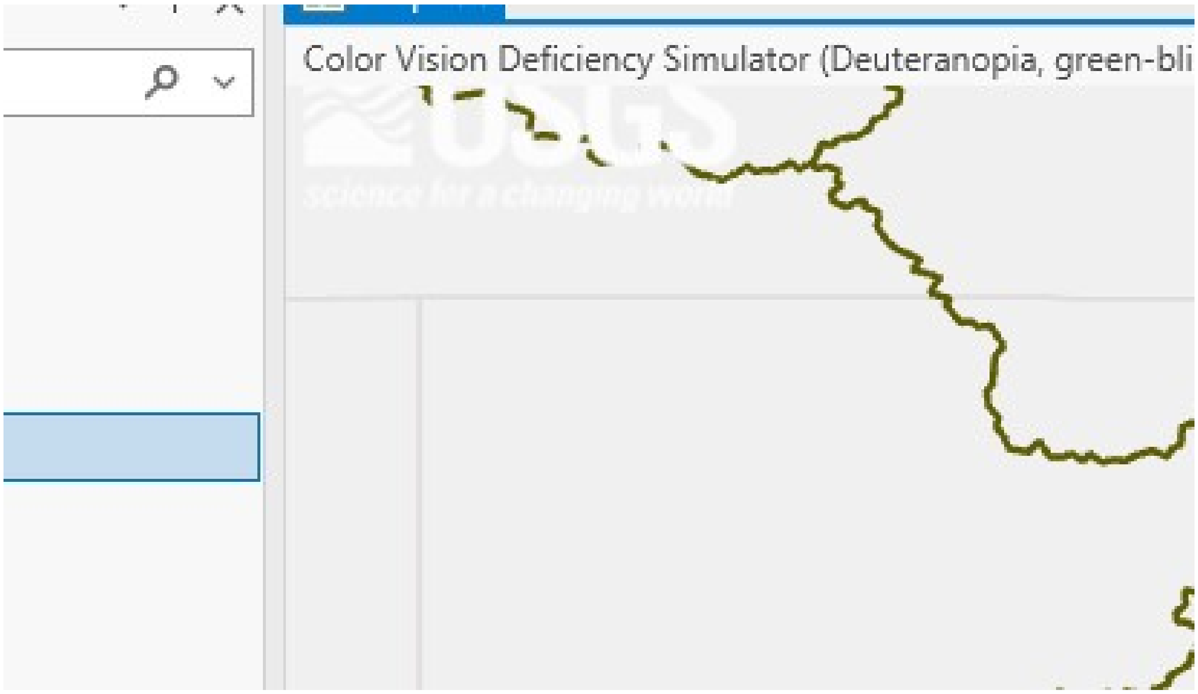
III. In your watershed draw the following items using as many names as possible, do you know the history behind the names?
- All the water, rivers, lakes, reservoirs, ditches, wetlands
- Mountains, hills, knolls
- Geological formations, rock and soil types
- Special places, cultural, spiritual, historical, monuments, parks
- Plants - edible or medicinal, draw 5 (or list)
- Plants – draw native, 2 trees, 2 shrubs, 2 grasses (or list)
- Birds – draw 5 resident and 5 migratory
- Mammals – draw two, species extinct, threatened, native, large, medium, small (or list)
- Reptiles, amphibians and fish – draw on native of each (or list)
- Other?

IV. Represent the following in your drawing:
- Precipitation, types, amount/year, when receive what types)
- Weather – wind directions time of year, storm types
- Last fire, last flood
- Subsistence – technology and subsistence of people past vs. present and their use of land and water

V. Draw a calendar of your watershed at home to include:
- Solstices and equinoxes
- First snow
- All seasons and length of each
- When do deer rut?, migratory birds leave/arrive?, fish spawn?
- When do leaves fall and first flowers bloom
- Other?

VI. Handouts: Outline with Bioregional quiz
Bibliography of sense of place literature

VII. Where are you at – a Bioregional Quiz (can be bias to those who live in country but can be adjusted)
1. Trace the water you drink from precipitation to tap.
2. How many days until the moon is full? (Slack of two days allowed)
3. What soil series are you standing on?
4. What was the total rainfall in your area last year (July – June)? (Slack: 1 inch for every 20 inches)
5. When was the last time a fire burned in your area?
6. What were the primary subsistence techniques of the culture that lived in your area before you?
7. Name five native edible plants in your region and their season(s) of availability.
8. From what direction do winter storms generally come in your region?
9. Where does your garbage go?
10. How long is the growing season where you live?
11. On what day of the year are the shadows the shortest where you live?


Color Vision Deficiency Simulator (Deuteranopia, green-bli