Session 5: Understand Your Watershed: Hydrology and Geomorphology

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Acronyms

BMP - Best management practices
ET - Evapotranspiration
MDNR - Minnesota Department of Natural Resources
TMDL - Total Maximum Daily Load
USEPA - United States Environmental Protection Agency

Introduction

A watershed is an identified geographical area that drains to a common point such as a river, wetland, lake or estuary. Watersheds or subwatersheds are the common physical boundary used to study an impaired river or stream. Watersheds are useful physical boundaries within which to study an impaired waterbody since they integrate the complex physical, chemical and biological processes that ultimately influence waterbody health (Davenport, 2003).

The physical processes, which consist of the hydrologic and geomorphorphic forces within a watershed, are the focus of this chapter. These processes are often the primary factors that influence the health of a waterbody and are therefore must be carefully examined when conducting a TMDL study.

Understanding hydrology (the science of water) and geomorphology (the study of geologic forces that shape the landscape) and their application at various watershed scales is key to understanding water quality impairments. At the most basic level, this involves understanding the hydrologic cycle (also know as the water cycle) as the source of all water at a global, regional and local watershed scale. At a more complex level, it means understanding the unique interplay of the groundwater, surface water, topography, geologic forces and living things within a specific watershed. **Without this understanding, efforts to diagnose a waterbody impairment and to restore beneficial uses will likely prove ineffective.**

This chapter focuses on the basic principles of hydrology and geomorphology and how they interact to affect water quality at a watershed scale. Given the complexity of these two disciplines and the many linkages between them, presenting a general overview of important concepts and principles is challenging at best. Entire books have been written about specific principles within hydrology, for example. This chapter presents a simple overview of the basic principles and concepts within these two disciplines as they relate to watershed management.

This chapter provides only the most essential concepts, intended to stimulate more thorough discussions among you and your colleagues. For more in-depth, complete information on the physical processes within a watershed, we recommend the following resources:

***Hydrology and the Management of Watersheds*, 2003, Kenneth N. Brooks, et. al.**

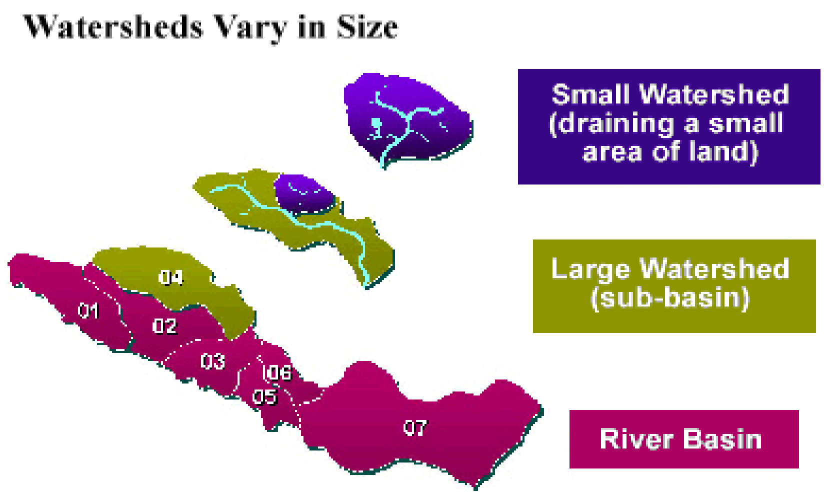
***Watershed Hydrology*, 1996, Peter Block.**

***Environmental Hydrology*, 2004, Andrew D. Ward and Stanley Trimble.**

***Eco-Hydrology*, 1999, Andrew Baird and Robert Wilby.**

What is a Watershed?

A watershed can be defined as all of the land area that drains to a common waterway, such as a stream, lake, estuary or wetland (EPA, 2005). A watershed can be very large (e.g. draining thousands of square miles to a major river or lake or the ocean), or very small, such as a 20-acre watershed that drains to a pond. A small watershed that nests inside of a larger watershed is sometimes referred to as a subwatershed (EPA, 2007).



Source: USEPA, 2007

There are maps and computer databases you can turn to that have watershed boundaries already delineated--particularly for larger basins and watersheds. EPA has a popular internet site called "Surf Your Watershed" found at: http://www.epa.gov/surf (EPA, 2007). Contact MPCA for more detailed information about your watershed.

A. Hydrology

Water is the basis of all life on earth. Hydrology is the study of the distribution, circulation and behavior of water, its chemical and physical properties, and its reaction within a watershed (including all aquatic and terrestrial life) (EPA, 2007).

It would take volumes to discuss all aspects of water on earth, however, basic hydrologic principles can and should be integrated into all TMDL projects. For example, a good hydrologic record (e.g. climate, streamflow and groundwater data) is essential to informing watershed managers about changes in the condition of a stream's habitat, water quality, channel shape, and other physical processes over time (Gordon, 2004).

The Hydrologic Cycle

One of the most important and basic concepts in hydrology is the hydrologic cycle (Figure 2). The hydrologic cycle is a natural, perpetual, solar-driven process that is dependent upon a number of smaller processes:

1. condensation/precipitation
2. evapotranspiration
3. interception
4. infiltration
5. runoff, and
6. storage (groundwater, lakes, wetlands, streams)

(EPA, 2007)

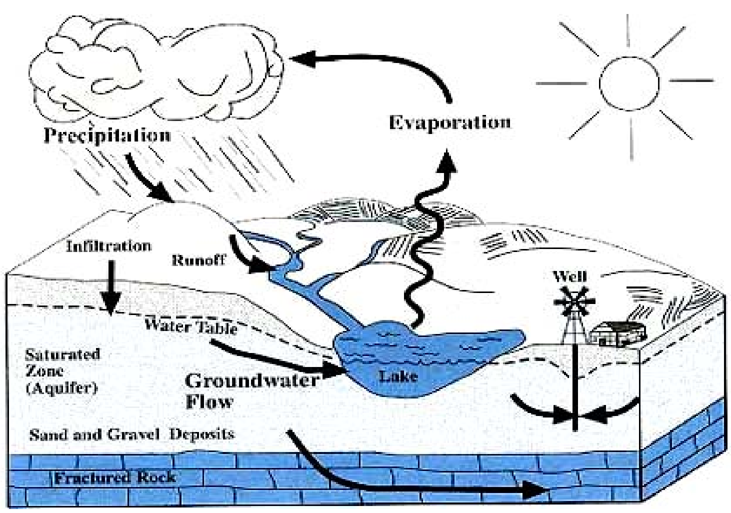


Figure 2: The Hydrologic Cycle

The hydrologic cycle is the continuous process of water movement above and below the earth's surface which feeds flow in our streams, rivers and lakes. The hydrologic cycle interacting with the topography, land use and vegetation in a watershed has significant effects on the quality of our lakes and streams. It is imperative that you and your technical team understand the hydrologic cycle and how its processes affect your particular watershed and the impaired waterbody you want to restore.

Components of the Hydrologic Cycle

The hydrologic cycle is composed of several different, yet integrated, components. The main components are briefly presented below.

1. Condensation/Precipitation

Precipitation occurs when three conditions are met:

- rainfall
- sleet
- snow
- hail
- dew, frost

There are various processes and pathways that determine how much and how fast precipitation becomes streamflow (Brooks, 2003). The pathway from rainfall to streamflow involves a complex combination of surface and subsurface flows that will be different in each and every watershed. These pathways of flow can be difficult to separate because of the interconnectedness of surface and subsurface systems in a watershed.

2. Evapotranspiration

Apart from precipitation, the most significant component of the hydrologic budget is evapotranspiration (ET). Once precipitation occurs, a large percentage of the water falling within a watershed will return to the atmosphere as a result of evapotranspiration (the sum of water losses through evaporation from soils, plant surfaces and waterbodies as well as transpiration through plant leaves) (Brooks, 2003). ET varies regionally and seasonally (Hanson, 1991) and is a significant determinant of how much water will become streamflow.

ET is influenced by land management practices that either remove or alter vegetation. As vegetation is removed or altered, ET decreases. As ET declines, surface runoff and streamflow typically increase, as does the recharge of groundwater aquifers (Brooks, 2003)

3. Interception

Once precipitation has occurred, vegetation and other surfaces can intercept and store water, influencing the amount and pattern of its distribution within a watershed (Brooks, et. al, 2003).
Water can be intercepted by the vegetative canopy within a watershed on branches and stems, or fall to the ground to be stored in leaf litter.

Interception can be an important component of storage within a watershed, especially if forests and other vegetative cover dominate the landscape. Water that is not intercepted is available to either replenish groundwater or become surface, subsurface or groundwater flow (Brooks, et. al., 2003).

When vegetative cover within a watershed is reduced or if soils are compacted, infiltration is diminished and runoff increases. For example, in intensively grazed areas, vegetation is typically removed by livestock. This, in turn, exposes soils to the powerful impact of rainfall and compaction from livestock hooves (Brooks, et. al., 2003). Infiltration in these areas is reduced, surface runoff increases and the movement of pollutants to waterbodies increases.

A goal common in many waterbody restoration plans is to improve infiltration within a watershed. Improved infiltration decreases runoff, reduces stormflow, limits erosion and decreases the delivery of pollutants to the impaired waterbody.

4. Surface Runoff

The term “runoff” refers to the various processes that ultimately produce streamflow (Davenport, 2003). Surface runoff occurs when the soil’s infiltration capacity has been exceeded, excess water collects on the soil surface and it travels down slope (Davenport, 2003). Climate, geology, topography, soil characteristics, and vegetative cover can affect how quickly and how much runoff becomes streamflow.

Surface runoff is the primary mechanisms for transporting nonpoint source pollutants from land to surface waters (Davenport, 2003). Runoff transports pollutants in both dissolved forms and in forms that are attached to sediment (Davenport, 2003). The detachment and transport of pollutants depends on the depth and velocity of runoff (Davenport, 2003).

Generally speaking, the aim of watershed managers is to limit or eliminate runoff since it is the primary mechanism for delivering pollutants to surface waters. Many Best Management Practices (BMPs) are designed with the goal of reducing runoff and improving infiltration.

5. Storage

Precipitation can be stored in depressional areas (stream channels, lakes, wetlands, ponds, puddles), in soil, plants, and aquifers. The amount of streamflow in a waterbody can be influenced by the movement of water between these various forms of storage. Water stored in wetlands or lakes, for example, can feed rivers and streams year-around. Similarly, subsurface flow can sustain streamflow in rivers and streams during dry periods.

Precipitation can be held in storage for short periods or for decades to hundreds of years. For example, storage in the soil as subsurface flow can be short-term. Subsurface flow is precipitation that infiltrates the soil, but arrives relatively quickly to streams to become streamflow. In contrast, precipitation that infiltrates the soil and percolates to deep aquifers may not be discharged to surface water for decades or longer.

Groundwater and Surface Water Interactions

In the past, groundwater and surface water have typically been examined as separate systems. In reality, they are inextricably linked. Pathways of the interaction can be complex; they are neither constantly interacting, nor consistently separate. Their inseparable nature is important to understand when studying streams and water quality. In one instance, groundwater can be a source of flow to streams during dry periods or during winter months, while in another; streams can be a source of water that replenishes underground aquifers.

Ground Water Recharge and Discharge Zones in Watersheds

Groundwater is the water typically found beneath the earth’s surface below unsaturated soil and/or rock. An aquifer is a stratum that transmits groundwater readily. An aquifer can be a small underground lens of sand and gravel, a layer of sandstone, a zone of fractured rock or a layer of cavernous limestone ranging from several hundred meters in thickness and covering hundreds of square miles in area (Brooks, et. al., 2003). Aquifers represent a significant natural storage sink for water within in a watershed.

Groundwater recharge usually takes place where there are more permeable soils or rock near the surface and where there is an excess of soil moisture beyond that which can be held in the soil or used by plant (Brooks, et. al., 2003). Groundwater recharge occurs in specific areas of a watershed, although these areas can be vast (Brooks, et. al., 2003). Depending upon topography, soils and other conditions, the time needed for water to move from recharge zones to discharge points somewhere within the watershed can be minutes to years.

Groundwater discharge is a process that is mostly unseen, however, if it is observed, it is typically seen as springs or seeps near stream banks or along valley walls. Groundwater discharge is continual, assuming that sufficient groundwater supplies are present. Groundwater discharges to surface waters can greatly affect the temperature, dissolved oxygen levels and other characteristics of surface waters. As a result, groundwater discharges can significantly affect the aquatic life in a river or stream.

Gaining and Losing Stream Reaches

Gaining and losing stream reaches are good examples of the interconnectedness of surface and groundwater within a watershed. The influence of one on the other can be significant.

Streams that receive groundwater discharge are called **gaining streams**. When groundwater is discharged to the stream, the stream continues to gain in volume the further downstream you go. In gaining streams, the level of water in the stream is often below the water table. The water table represents the upper saturated boundary of groundwater. This can also be true with lakes and wetlands that receive groundwater discharge. During dry periods, a significant amount of the total flow to some streams can be attributed to groundwater discharge.

Losing streams lose water through the bed and or banks which affects the amount of streamflow. The stream channel in a losing stream is above the groundwater table. Losing streams occur in southeast Minnesota because of karst geology. Karst areas have irregular stone strata which, as a result of erosion, has developed fissures, sinkholes, underground streams, and caverns. In these areas, surface water can move quickly from the stream channel to subsurface flow and groundwater aquifers.

Groundwater/Surface Water Interactions Can Result in Gaining and Losing Stream Reaches

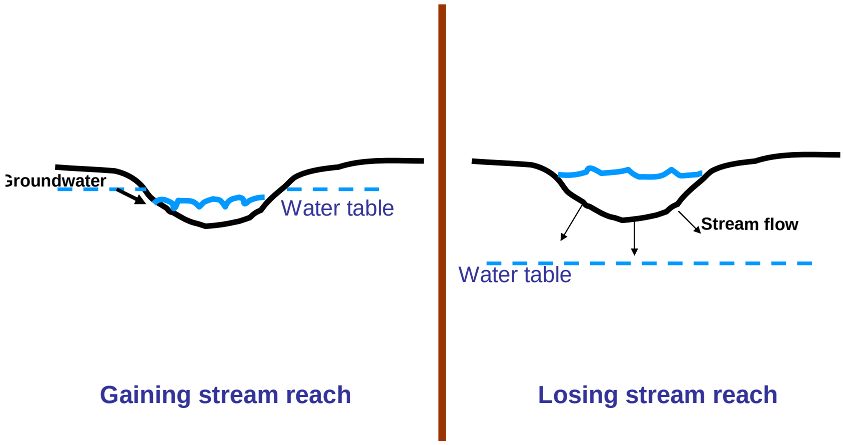


Figure 5: Gaining and Losing Streams

Wetlands are often located in low-lying areas that are directly connected with the groundwater system. They are transitional environments between aquatic and terrestrial ecosystems. Wetlands can be very large in terms of surface area, or be very small, depending on changes in precipitation and storage. As a result, wetlands often are capable of storing large amounts of water during wet periods or floods.

In wetland environments, the water table is found at or near the ground surface year around. For example, the flow-through type of wetland maintains a fairly stable water table in the wetland throughout the year because it is directly connected with the regional groundwater source (Brooks, et. al, 2003). See Figure 6.

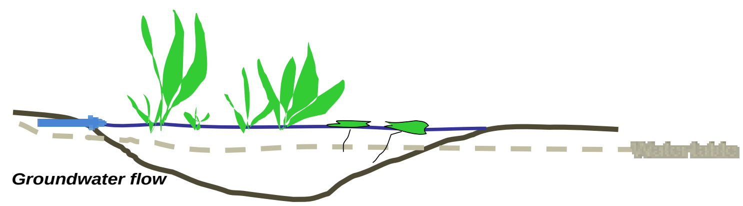


Figure 6: Flow-through wetlands

The hydrologic behavior of a wetland depends largely on whether regional groundwater feeds it. In peatlands, mineral-rich fens are directly connected to the regional groundwater system. As such, there is much variation among fens with respect to how acidic their waters are. See Figure 7.

In mineral-poor bogs, the water tables are typically maintained by precipitation and are perched above the regional water table. Bogs receive little or no discharge of water from groundwater aquifers. Bogs may actually recharge small amounts of water to regional groundwater systems (Brooks, et. al., 2003)

Fen – a type of wetland fed by surface and/or groundwater.

Bog – a type of wetland fed by rainwater and which are often acidic in terms of their water chemistry.

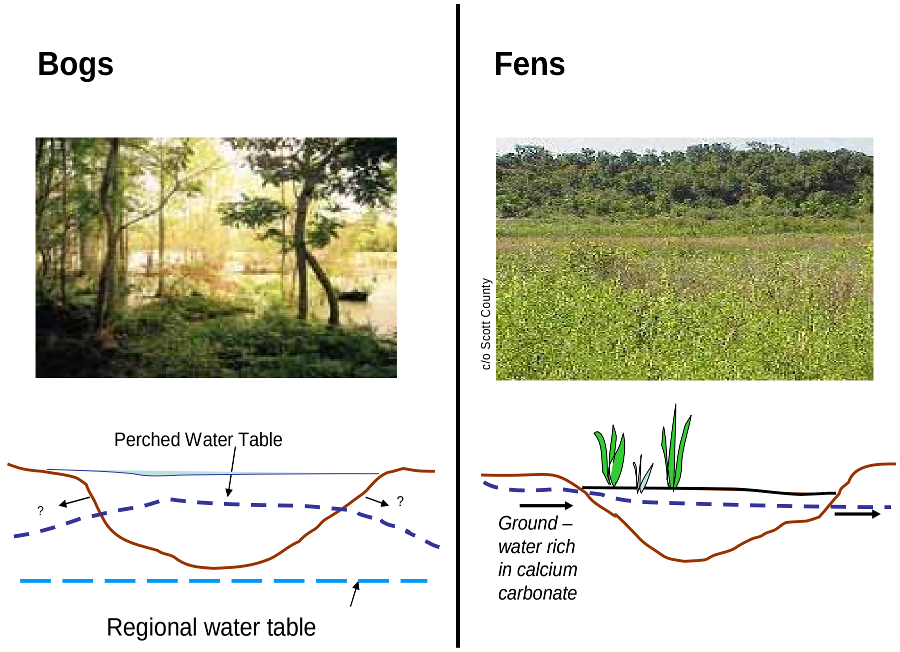


Figure 7: Groundwater Characteristics of Bogs and Fens

Bogs typically experience more seasonal fluctuations in both the water table and streamflow discharges than do fens.

Understand Ground and Surface Water Linkages Before Moving Forward!

The linkages that exist between groundwater and surface water must be studied in each watershed. Lacking this information, erroneous conclusions may be drawn about the causes and sources of impairment. For example, at first glance, a technical team may determine that land use practices in the watershed are causing impairment. However, it is possible that in some cases, low dissolved oxygen impairments may be due to natural conditions. Low dissolved oxygen impairments could be caused by groundwater discharges to the stream during low flow periods. Take the time as a team to understand groundwater/surface water interactions before reaching a conclusion about the cause of water quality impairments in your watershed.

Streamflow

Streamflow and hydrographs

Streamflow is water moving/flowing in a stream or river. Flow rates vary over time due to components of the hydrologic cycle and factors affecting those components. Flow can be depicted as a hydrograph where flow rate is plotted against time. Hydrographs show the length of time it takes for streamflow to peak after a precipitation event. The shorter the lag time between the on-set of a precipitation event and the peak discharge, the more "flashy" surface runoff is and the higher its erosive potential is.

The variability of watersheds and climatic factors means that the shape of hydrographs can vary tremendously. The main factors affecting the shape of a hydrograph are:

- climatic conditions (duration, magnitude of precipitation, etc);
- watershed drainage characteristics (topography);
- soil characteristics (porosity)
- land use (changes from permeable to impermeable cover)

Figure 8 (below) compares two different hydrographs. The dark line represents a hydrograph for a stream which experiences rapid responses from rainfall events. Note the sharp increases in streamflow after a precipitation event, as well as the rapid recession of the flow. This particular hydrograph is for a watershed that is characterized by row crop agriculture where during several months of the year, vegetative cover is minimal.

In contrast, the light line represents a hydrograph for a stream which responds to precipitation events with a slow, less dramatic increase in flow. In this instance, the watershed has stable vegetative cover which increases infiltration and decreases the amount of runoff that can become streamflow.

Hydrographs allow technical staff to see streamflow patterns within the watershed. For this reason, stormflow hydrographs, those that depict stream flow patterns, quantity of flow, flow rate changes, duration of flow levels, etc.) are of particular interest in almost all TMDL studies. The rate, duration and rapidity of change in streamflow are the keys to understanding stream and pollutant transport process within a watershed.

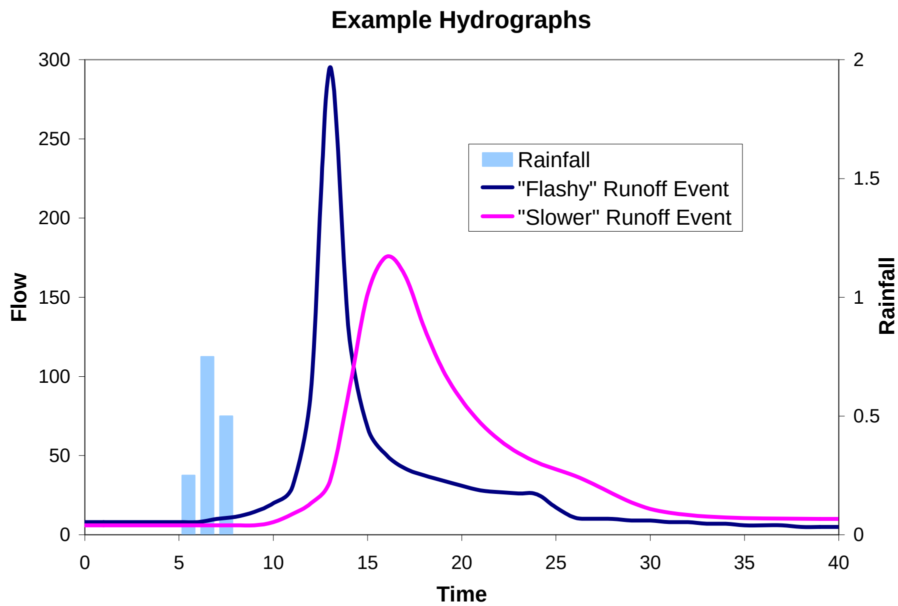


Figure 8: Sample Hydrograph

Influences on Streamflow

Variability in streamflow (across seasons) is natural and necessary to the healthy functioning of river systems. Aquatic life has successfully evolved and adapted over time to significant differences in flow, such as drought or flooding. However, human influences on the landscape (development, dams, farming, etc.) can disrupt the naturally cyclic nature of streamflow, upsetting the natural processes that have evolved over time (MDNR, 2005).

There are a number of important conditions that influence how much of the precipitation that falls within a watershed becomes streamflow. These are briefly discussed below.

1. Climatic conditions and the amount of precipitation within a geographic area are the most important factors affecting streamflow. Snowmelt and spring storms often produce one of the highest annual peak streamflows. During the summer, streamflow typically declines because of the consumption of soil water by vegetation. During these warm, dry months, streamflow is often maintained by groundwater and wetlands (base flow). During the fall, when ET drops off, water levels in lakes, wetlands and streams will rise. If new precipitation is added, peak flows can occur. During winter months, when surface water and soil water freeze, streams are typically fed by warmer groundwater discharge.

Streamflow can also vary significantly across years as a result of natural variations in the weather. Long-term weather patterns, such as drought and wet periods, cause changes in streamflow patterns from year to year. The natural variability between drought and flood years can be important to the healthy functioning of river ecosystems. Flooding can help to form floodplains; spread new, rich, alluvial soils; clear organic debris, prevent encroachment of streamside vegetation; and recharge riverine wetlands. On the other hand, drought, while devastating in the short term, can help to reinvigorate floodplain wetlands and to compact/consolidate alluvial sediments, among other benefits (MDNR, 2005).

2. The Topography (slope of land and the stream channel) within the watershed is a major influence on streamflow. Steep, hilly areas of a watershed drain quickly to the stream, while in flat terrain, water drains at a much slower and more even rate.

The amount of water stored in soils above the stream channel can also influence the amount of streamflow due to displacement. Displacement could be compared to what happens when a garden hose is turned on after it has been sitting in the sun. Initially, the water coming from the hose is warm. Eventually warm water is displaced by cold water from the well. Similarly, new water falling on the uplands surrounding a stream will eventually displace existing subsurface water near the stream. Interflow is that part of excess precipitation that infiltrates soils in the uplands but arrives at the stream over a relatively short period of time. Displacement of subsurface flow can account for a major source of streamflow in some types of watersheds, especially forested watersheds (Brooks, et. al, 2003)

3. Soil characteristics and conditions can affect streamflow. The physical properties of some soils will encourage infiltration and discourage surface runoff, while other soils will have diminished infiltration capacities that result in greater surface runoff that can increase streamflow.

The rate at which precipitation enters the soil surface depends upon several factors, including texture, structure, surface conditions, amount of organic matter, soil depth, presence of large pores (macropores), antecedent soil moisture, etc. The size and interconnection of pores within soils greatly affects how much infiltration will occur at any point in time. Fine-textured soils such as clay have smaller pores and do not infiltrate water as quickly as medium- or coarse-textured soils would. (Brooks, 2003).

Where there is less infiltration, greater surface runoff typically occurs, resulting in a greater and more rapid rise in streamflow in a watershed. When infiltration capacity is high, streamflow will rise more gradually and peak at lower levels.

4. Land cover/land uses can also have a major influence on the amount of precipitation that becomes streamflow. Human activities greatly affect streamflow by decreasing the amount of vegetation on the land. Below are examples of human activities that reduce vegetative cover in a watershed or subwatershed:

- Wetland drainage
- Agricultural drainage
- Home construction
- Road building
- Agriculture
- Clear-cutting of forests

Loss of perennial vegetation influences the following changes in a watershed:

- ET
- speed and intensity of runoff.
- the infiltration capabilities of soils
- the retention or detention storage in the watershed
- surface runoff and streamflow
- surface runoff and decreased movement of water to underground aquifers.

In contrast, abundant vegetation slows runoff, encourages infiltration, and consequently increases the amount of water stored in the watershed. For example, surface runoff moving over bedrock or barren soils moves more quickly to the stream than it would if moving over thick grasses or through a forest under-story.

When organic matter is removed from the land due to cultivation, clear-cutting of forests, wetland drainage, urban development, channelization of streams or other land uses, the amount and speed of surface runoff will increase. Consequently, the potential for increased loadings of nonpoint source to surface water increases.

The presence or absence of vegetation can have a significant effect on water quality in many Minnesota streams. This becomes evident when one looks closely at differences in streamflow over a cropping season.

During the spring and early summer, when crops have not yet been planted and soils are bare, precipitation events typically cause a rapid rise in streamflow due to rapid surface runoff. Hydrographs peak and recede quickly under these conditions.

As the summer progresses and crops become well-established, precipitation events cause only a modest increase in streamflow. Rainfall is largely intercepted and transpired by the crops and the hydrograph peaks at a much lower flow rate. The majority of precipitation that falls, instead of running off land surfaces to the stream, is instead infiltrated to groundwater aquifers, used by plants or returned back to the atmosphere through ET. Maintaining good vegetative cover is an important and effective tool for improving water quality.

B. Geomorphology – The Shape of a River

While physical watershed factors affect hydrology, hydrology also affects some of the physical characteristics of a waterbody and its watershed. Geomorphology is the study of the geologic forces that shape our landscape largely through the action and effects of moving water. Physics can explain why some rivers flow slowly, meandering through a prairie landscape, while others rush quickly through rocky channels and over waterfalls. Large-scale geologic forces such as volcanoes, earthquakes, glaciers, and deposition are all forces that can form a landscape over which water flows. Water flowing over different landscapes, typically responds differently (MDNR, 2005).

Smaller-scale, geologic forces also affect the landscape and the shape of the waterbodies in it. Stream channels form as a result of the interplay between hydraulic forces (erosion, deposition, and resuspension of sediment) and the materials forming the streambed. Stream channels and the water that flows through them (each defined by stream width, depth, velocity, cover and substrate) then determine habitat conditions for aquatic organisms (Annear, 2004).

Channel Shape

Nearly all channels are formed, maintained, and altered by the water and the sediment they carry. Minnesota stream channels that are not impacted by human development are gently rounded in shape and roughly parabolic, but channel forms can vary greatly. Figure 9 represents a cross section of a typical Midwestern stream channel.

A stream channel is comprised of an area that contains continuously or periodically flowing water that is confined by stream banks. The unvegetated sloped bank is called a **scarp**. The deepest part of the channel is called the **thalweg**. The dimensions of a channel cross section are determined over time and through the continuous interaction between water and the landscape.

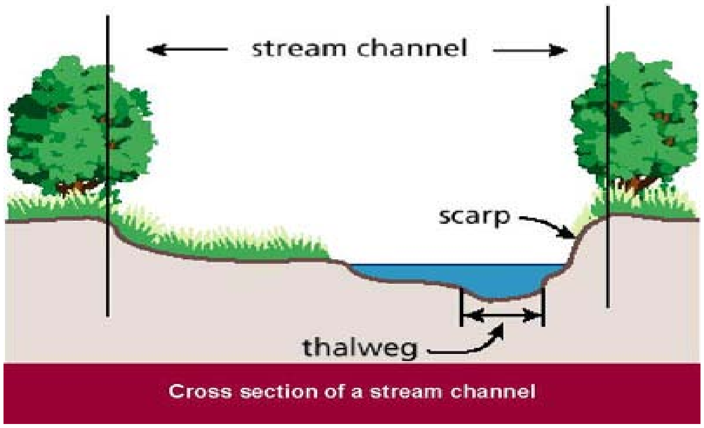


Figure 9: Cross section of a stream channel
(EPA, 2007)

Floods are not the most important flow situation affecting the shape and condition of a stream channel. Rather, bank-full flows typically define a river's shape. Bank-full refers to the water level stage just as it begins to spill out of the channel into the floodplain. It has been found that this flow typically occurs about once every 2.3 years (averaged over wet and dry years) (MDNR 2005) Bankfull flows are subject to minimal flow resistance and are therefore able to transport the greatest loads of sediment (MDNR, 2005)

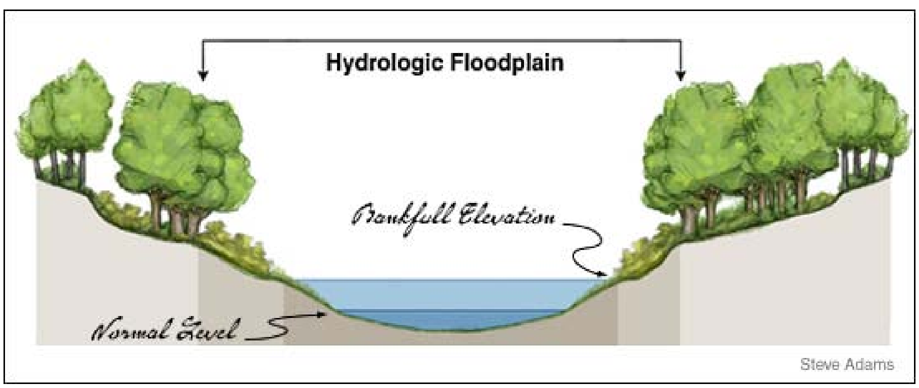


Figure 10: Stream Channel Shape
(MDNR, 2005)

Rivers are constantly changing, but the change can be stable or unstable. Stream morphology expert, Dr. David Rosgen, has identified 10 variables that affect a channel's shape. These variables are determined by the climate and the geology of the area and they interact in predictable and measurable ways.

This classification system helps to predict the form and shape of a stream when there have been changes in a watershed's hydrologic regime due to straightening, increased erosion from upland areas, etc. Rosgen's classification system brings many pieces of stream data together in a useable format. Rosgen's classification system allows watershed managers to predict a stream's behavior from measurements of its appearance. This can be useful when developing an impact assessment for a stream and when developing restoration strategies as well.

Rosgen's classification system considers:

The movement of flow through a stream channel:
- Channel width
- Channel depth
- Water velocity
- Channel slope
- Channel roughness
- Sediment load
- Sediment size
- Material shear stress
- Vegetation
- Channel discharge

(MDNR, 2005)

Changes in any of these variables will affect degradation (sediment removal) or aggradation (sediment deposition) and thereby the channel form.

Aggradation and degradation within a stream channel are important concepts to understand since these are the main mechanisms for sediment storage and release. When sediment supply exceeds stream energy, aggradation occurs (Brooks 2003). Aggradation typically results in the deposition of course material first, while finer particles move further downstream. The streambed begins to rise slowly over time, often resulting in water flowing over the banks (Brooks, 2003).

Degradation takes place slowly under normal conditions. When stream energy exceeds sediment supply, degradation occurs. If the stream channel is in disequilibrium, then degradation can occur more rapidly. Channel cross-sections of degrading stream system tend to be V-shaped due to the differences in flow resistance across the channel. More material is picked up and carried downstream by erosive, concentrated flows, causing a V-shaped channel (Brooks, et. al, 2003).

A healthy stream with good water quality need not be sediment-free. Some sediment deposits are normal and expected. Channels are always changing whether or not they are in equilibrium. The goal is for aggradation and degradation to be in dynamic equilibrium within the channel. Channel equilibrium involves the interplay of four basic factors:

1. Sediment discharge
2. Sediment particle size
3. Streamflow
4. Stream slope

Lane (1955) showed this relationship qualitatively in this way:

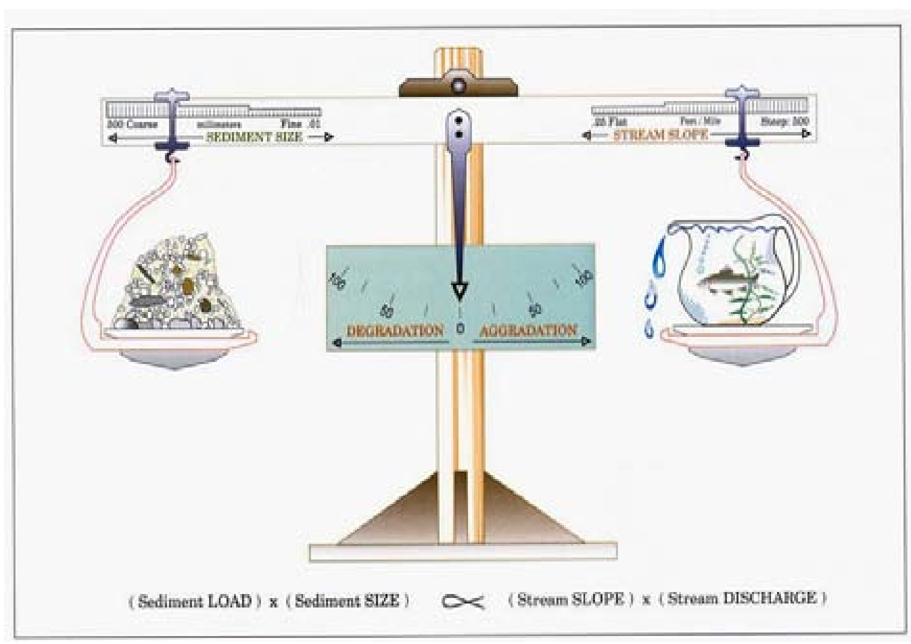


Figure 11: Relationships involved in maintaining a stable channel balance (from Lane 1955, based on Rosgen 1980)

The equation is shown here as a balance, with sediment load on one weighing pan and streamflow on the other. The hook holding the sediment pan can slide along the horizontal arm to adjust according to sediment size. The hook holding the streamflow side can adjust according to stream slope.

Channel equilibrium occurs when all four variables are in balance. If a change occurs, the balance will temporarily be tipped and equilibrium lost. If one variable changes, one or more of the other variables must increase or decrease proportionately, if equilibrium is to be maintained. For example, if channel slope is increased (e.g., by channel straightening) and streamflow remains the same, either the sediment load or the size of the particles must also increase. Likewise, if flow is increased and the slope stays the same, sediment load or sediment particle size has to increase to maintain channel equilibrium. Under the conditions outlined in these examples, a stream seeking a new equilibrium will tend to erode more of its banks and bed, transporting larger particle sizes and a greater sediment load (EPA, 2007).

The stream balance equation is useful for making qualitative predictions concerning channel impacts due to changes in surface runoff or sediment loads from within the watershed. Quantitative predictions, however, require the use of more complex equations (EPA, 2007).

Stream Classification

The types and amounts of sediment traveling throughout a stream system will vary, as will the aquatic life living in them. Within a watershed, depending on historic land use activities, geology, topography, soils, etc., many different channel shapes can exist. Stream systems are inherently complex and challenging to understand. By placing streams into a classification system, we can better comprehend the processes that influence the pattern and character of the stream.

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Stream classification can be helpful in determining:

- The character of the watershed when it was undisturbed
- Current channel conditions
- How the river is changing to accommodate changes in flow volumes, channel alteration, etc.
- Sensitivity to disturbance
- Sediment supply
- Potential for stream bank erosion
- Recovery potential

Such information is helpful when linking past and present land uses to channel changes. Ultimately, this information can also be helpful when planning restoration activities for the waterbody.

Using a stream classification system provides a systematic approach to characterizing the shape and condition of watersheds, yielding consistent results what allow comparisons with other streams (Brooks, et. al., 2003).

There are several stream classification systems available for use. The Rosgen stream classification system is commonly used in Minnesota. Figure 12 presents an overview diagram of Rosgen’s stream classification system. Rosgen classifies streams by morphological characteristics. Generally speaking, the greater the downward slope of a stream, the straighter and deeper it tends to be. As downward slopes decrease, rivers tend to become more sinuous (meandering), wider and shallower.

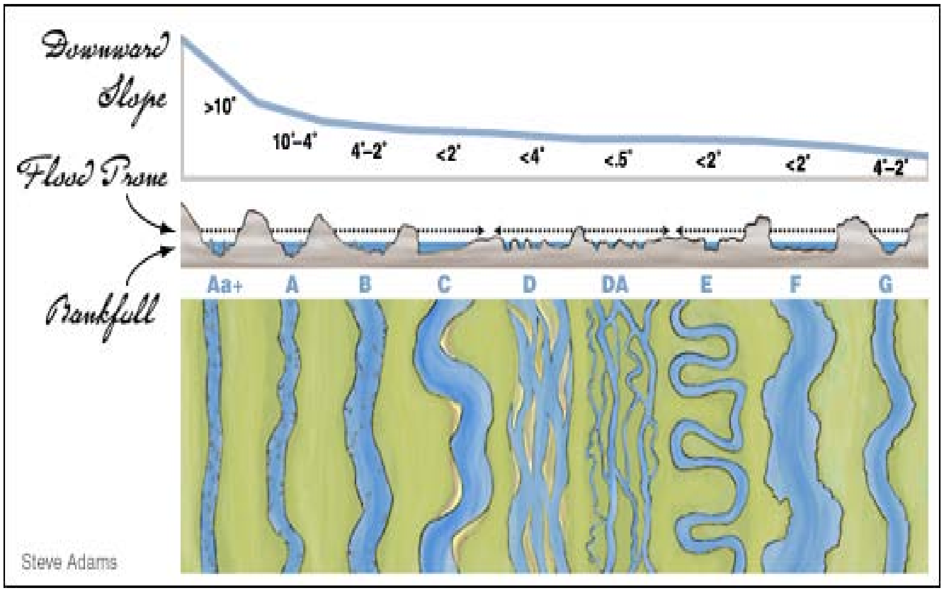

Figure 12: Rosgen Stream Classification (MDNR, 2005)

Photographs of several examples of the types of channel shapes commonly seen in Minnesota are shown below.

A prairie stream is a highly meandering, low-gradient waterbody. It is nearly as deep as it is wide.

Photo: Pat Baskfield, MPCA

A bedrock stream is a steep, fairly straight stream flowing over resistant bedrock. The stream will be much wider than it is deep.

Photo: ©Explore Minnesota Tourism

A ditch is narrow, straight and deep.

Photo: Joe Magner, MPCA

The types and amounts of sediment traveling through these streams will differ, as will the fish and invertebrates living within them. Within a watershed, depending on historic land use activities, geology, topography, soils, etc., many different channel shapes can exist.

Stream systems are inherently complex and challenging to understand. By placing streams into a classification system, we can better comprehend the processes that influence the pattern and character of the stream.

(Repeated from above) Stream classification can be helpful in determining:

- the character of the watershed when it was undisturbed
- current channel conditions
- how the river is changing to accommodate changes in flow volumes/duration, channel alteration etc.
- sensitivity to disturbance
- recovery potential
- sediment supply
- potential for stream bank erosion, etc.

Such information is helpful when linking past and present land uses to channel changes. Ultimately, this information can also be helpful when planning restoration activities for the waterbody.

Connectivity: Linking the Physical Watershed and Stream Channel to Biological Systems

Figure 13: Stream Connectivity (MDNR, 2005)

River Continuum Concept

The River Continuum Concept (Vannote et. al., 1980) describes the evolving patterns and interactions of energy inputs, the physical environment and biological communities as one moves from the source of a stream toward its mouth (longitudinal connectivity).

Developed by a group of stream ecologists, the Continuum Concept hypothesizes that streams exist in a continuous and fairly predictable pattern along their entire length. Generally, as one moves downstream, the physical environment and the biological communities that live there increase in complexity. Stream organisms change predictably along the length of the stream in response to changing food sources (MDNR, 2005).

As one moves from the headwaters of a stream to its mouth, one can find variety with respect to channel width and depths, substrates, and water velocities, all supporting a wide array of aquatic organisms. Therefore, it is critical to study as much of the stream system as possible, not just certain reaches.

Headwaters, midstream and lower reaches are the home to different species of fish and invertebrates, all taking advantage of different habitat niches within the same stream. Biological monitoring results collected as part of a TMDL study can be reviewed and better understood within the context of this predictable pattern of stream evolution.

Understanding connectivity within a stream system should be an important goal of any TMDL studies. Rather than merely focusing on a single impairment on a small reach of a subwatershed, we should instead seek to understand the complex, ever-changing system that it is part of.

Physical Changes in the Shape of Rivers Affects Connectivity

Radical changes in the shape of a river will ultimately destroy connectivity within the stream system. A good example of this is the process of channeling streams. Stream channelization has been a common practice within many watersheds across Minnesota.

<table>
<tr><th>Example: Stream Channelization</th><th>Consequences</th></tr>
<tr><td></td><td>1) Erosion of streambed upstream
2) Downstream sedimentation
3) Increased peak flows
4) Downstream flooding
5) Reduced biodiversity</td></tr>
</table>

Changes in Land use Affect Connectivity

Large-scale development projects contribute to habitat loss and changes in species diversity. The following human development projects can all decrease connectivity within a stream:

- Dams – block movement and migration of fish, block the downstream movement of sediment, disrupt nutrient and energy spiraling, and modify thermal and flow regimes
- Construction activities within the watershed (highways, parking lots, other large impervious surfaces) can greatly increase surface runoff into nearby waterways, which can divert water from recharging groundwater aquifers.
- Water appropriations can reduce stream flows and change the stream's equilibrium.

In addition, the secondary effects of development projects in a watershed also affect connectivity:

- Persistent chemical or thermal pollution may create a barrier within the river that disrupts longitudinal connectivity.
- Invasive species can decimate native species, disrupting part of the river's continuum of biota.

Land use practices and other human influences can all impact connectivity within a stream system. Consider that changes in one natural process or system are likely to impact others. Therefore, it is important to keep linkages between land forms, hydraulic forces and biota in mind. Connectivity provides a holistic framework for understanding the complexity and interrelatedness of all stream systems.

Session 5: Understand Your Watershed: Hydrology and Geomorphology

Take a Holistic Approach to Your TMDL Study

Within a watershed system, everything is ultimately connected and complex. Dr Judith Van Houren, University of Vermont has stated, "Complex and complicated mean two different things. A complex system is far more complicated than the sum of its parts. The whole always has more surprises that not have been predicted by studying individual pieces." A watershed system is made up of integrated wholes whose properties cannot be reduced to those of smaller parts (Center for Ecoliteracy, 2007). An integrated, interdisciplinary approach to developing a TMDL study is therefore essential.

Conducting a TMDL study is a team effort, from the earliest planning stages through completion. Your team should consist of scientists and professionals from a variety of scientific disciplines, including a hydrologist and a geomorphologist.

Each team member has specific expertise to bring to the table, however, their ability to work across disciplines and with other team members will be equally important. As Project Manager, you will need to encourage team members to keep a holistic perspective as you move through the process together.

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