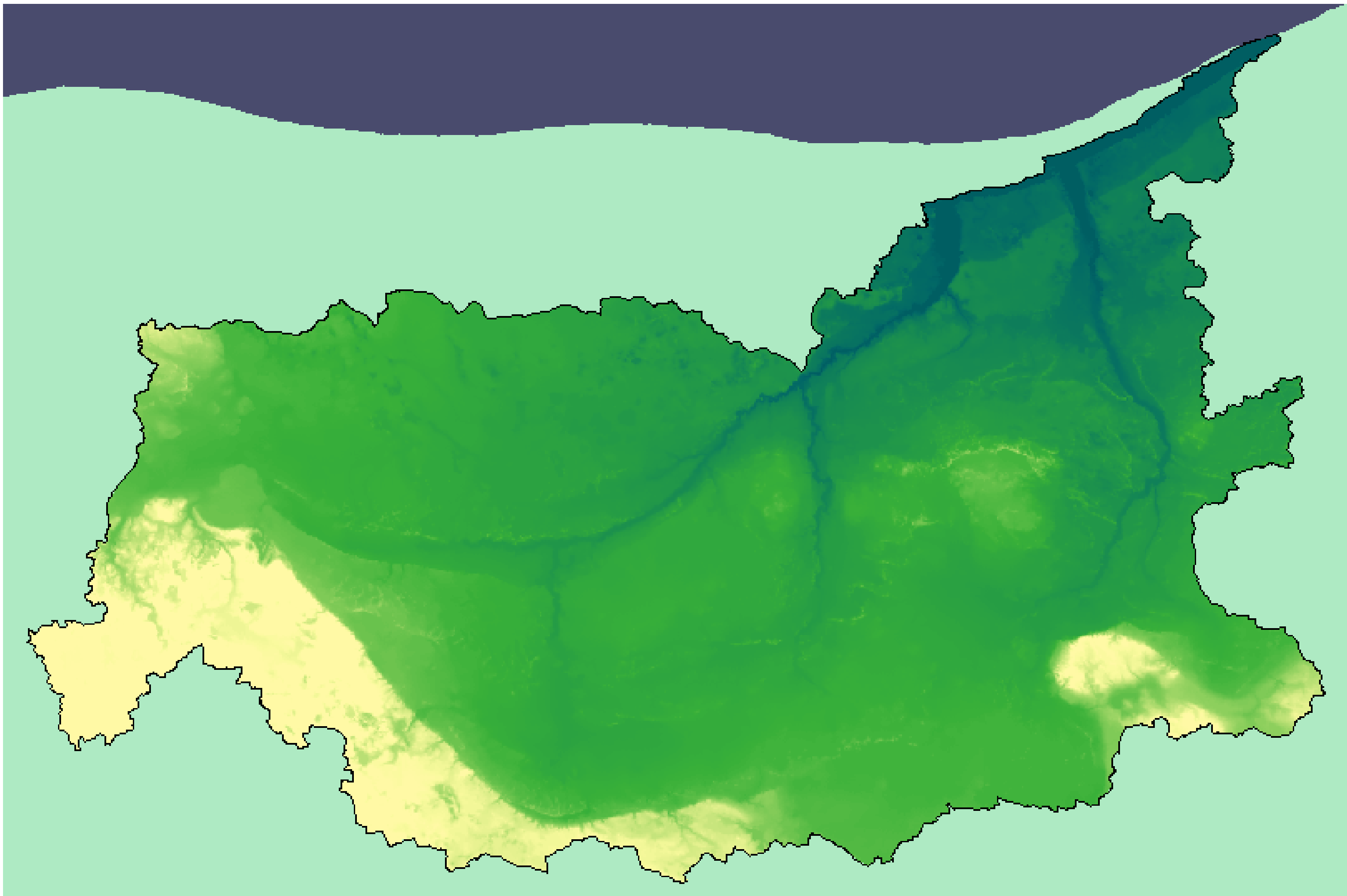
Two Hearted River Watershed Hydrologic Study



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January 18, 2007

DEQ
Michigan's Nonpoint Source Program

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This Nonpoint Source Pollution Control project has been funded wholly by the United States Environmental Protection Agency through a Part 319 grant to the Michigan Department of Environmental Quality. The contents of the document do not necessarily reflect the views and policies of the EPA, nor does the mention of trade names or commercial products constitute endorsement or recommendation for use. For more information, go to www.michigan.gov/deqnps.

The cover depicts the drains, streams, lakes, and rivers and ground elevations of the Two Hearted River Watershed. Lighter colors are higher elevations.

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DEQ Michigan's Nonpoint Source Program

Summary

A hydrologic study of the Two Hearted River watershed was conducted by the Hydrologic Studies Unit (HSU) of the Michigan Department of Environmental Quality (MDEQ) in support of a Two Hearted River Nonpoint Source (NPS) watershed planning project. This hydrologic analysis was conducted to better understand the watershed's hydrologic characteristics, to provide a basis for stormwater management to protect stream morphology, and to help determine the watershed management plan's critical areas. Watershed stakeholders may combine this information with other determinants, such as open space preservation, to decide which locations are the most appropriate for wetland restoration, stormwater infiltration or detention, in-stream Best Management Practices (BMPs), or upland BMPs. Local governments within the watershed could also use the information to help develop stormwater ordinances.

The hydrologic analysis has two land use scenarios corresponding to land cover in 1800 and 1978. General land use trends are illustrated in Figure 1. Additional land use information is provided in the Watershed Description section and in Appendix A of this report.

The Two Hearted River watershed is comprised almost entirely of forest and wetland, with very little urban or agricultural land use. Based on the peak flow dates for USGS gage 04044813 and weather data, the Two Hearted River watershed is a snowmelt-driven system. A snowmelt-driven system is usually much less flashy than storm-driven systems, because the snow pack supplies a steadier rate of flow. However, a rain-on-snow event, where rain and snowmelt simultaneously contribute to runoff, can produce dramatic flow increases. The runoff from the rain and snowmelt also likely occur with saturated or frozen soil conditions, when the ground can absorb or store less water, resulting in more overland flow to surface waters than would occur otherwise. HSU does not expect this watershed to undergo long term hydrologic changes that affect surface runoff volumes or peak flows. Consequently, our hydrologic analysis is an overview of the watershed's hydrologic characteristics, with a general discussion of the types of flows impacted by changes in hydrologic characteristics.

Additional hydrologic information that could be included in the Two Hearted River watershed management plan is available from the Michigan Department of Natural Resources' (MDNR) Two Hearted River Natural River Plan, dated December 1973.

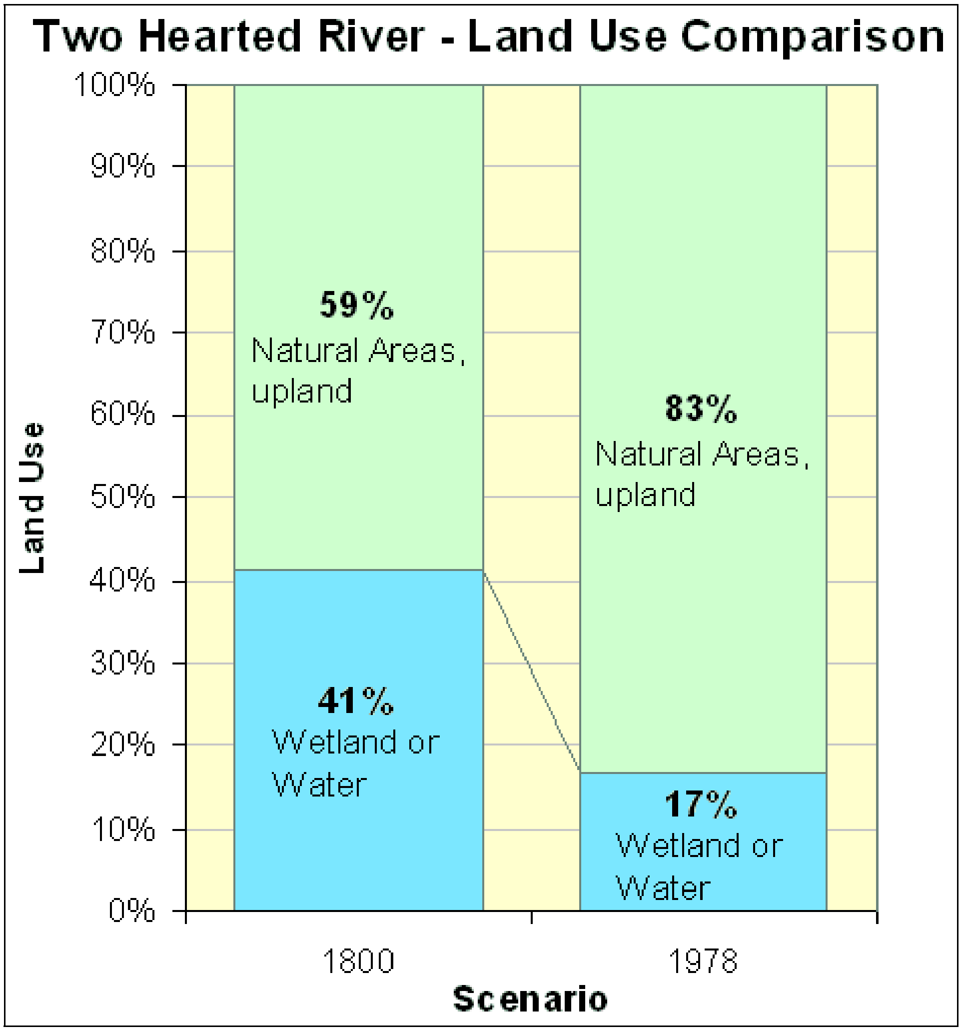

Figure 1: Land Use Comparison, Overall Two Hearted River Watershed

Project Goals

The Two Hearted River hydrologic study was initiated in support of the Central Lake Superior Watershed Partnership, which is developing a watershed management plan for the Two Hearted River watershed. This Two Hearted River hydrologic study is funded by a United States Environmental Protection Agency (USEPA) Part 319 grant administered by the MDEQ. The goals of this Two Hearted River study are to better understand the watershed's hydrologic characteristics and to provide a basis to help protect the Two Hearted River watershed, a designated Outstanding State Resource Water (OSRV).

Watershed Description

The Two Hearted River watershed, Figure 2, drains 207 square miles and outlets to Lake Superior in Luce County. For this report, HSU has defined eight subbasins, Figure 3, ranging in size from 8 to 48 square miles.

A stream's ability to move sediment, both size and quantity, is directly related the stream's slope and flow. Thus steeper reaches generally move larger material, such as stones and pebbles, and the flatter reaches tend to accumulate sediment. According to Rosgen, 1996, "generally, channel gradient decreases in a downstream direction with commensurate increases in streamflow and a corresponding decrease in sediment size." A typical river profile is steeper in the headwaters and flatter toward the mouth. The Two Hearted River's profile, Figure 3, is somewhat different, with a steeper section in the middle. The MDNR Two Hearted River Natural River Plan, 1973, describes this river reach as a series of shallow sandstone ledges with intermittent deep pockets. The steeper reach is likely a reflection of the underlying geology and not an indicator of morphologic instability.

Land use maps based on the MDEQ Geographic Information Systems (GIS) data for 1800 and 1978 are shown in Figures 5 and 6, respectively. Land use within each of the subbasins is also detailed in Appendix A.

The 1800 land use information is provided at the request of the grantee. Land use circa 1800 is from a statewide database based on original surveyors' tree data and descriptions of the vegetation and land between 1816 and 1856. Michigan was systematically surveyed during that time by the General Land Office, which had been established by the federal government in 1785. The detailed notes taken by the land surveyors have proven to be a useful source of information on Michigan's landscape as it appeared prior to wide-spread European settlement. The database creators recognize that there are errors in the database due to interpretation and data input.

The 1978 land cover files represent a compilation of data from county and regional planning commissions or their subcontractors. This data set is intended for general planning purposes. It is not intended for site specific use. Data editing, manipulation, and evaluation was completed by the Michigan State University Center for Remote Sensing and GIS and by the Michigan Department of Natural Resources (MDNR). Files have been checked by MDNR against original MDNR digital files for errant land cover classification codes.

The Natural Resources Conservation Service (NRCS) hydrologic soil group data for the watershed are shown in Figure 7. Hydrologic soil groups, or hydrogroups, are grouped according to the infiltration of water when the soils are thoroughly wet and receive precipitation from long-duration storms, as described in Table 1. Where the soil is given a dual hydrogroup classification, A/D for example, the soil type selected is based on land use. In these cases, the soil type is specified as D for natural land uses, or the alternate classification (A, B, or C) for developed land uses. The soils map resolved for 1978 land use is shown in Figure 8.

Table 1: Soil Hydrogroups

Hydrologic Soil Group	Infiltration Rate when thoroughly wet	Description
A	High	• Sand • Gravelly sand
B	Moderate	• Moderately fine textured to moderately coarse textured soils
C	Slow	• Moderately fine textured to fine textured soils • Soils with a soil layer that impedes downward movement of water
D	Very Slow	• Clays • Soils with a clay layer near the surface • Soils with a permanent high water table

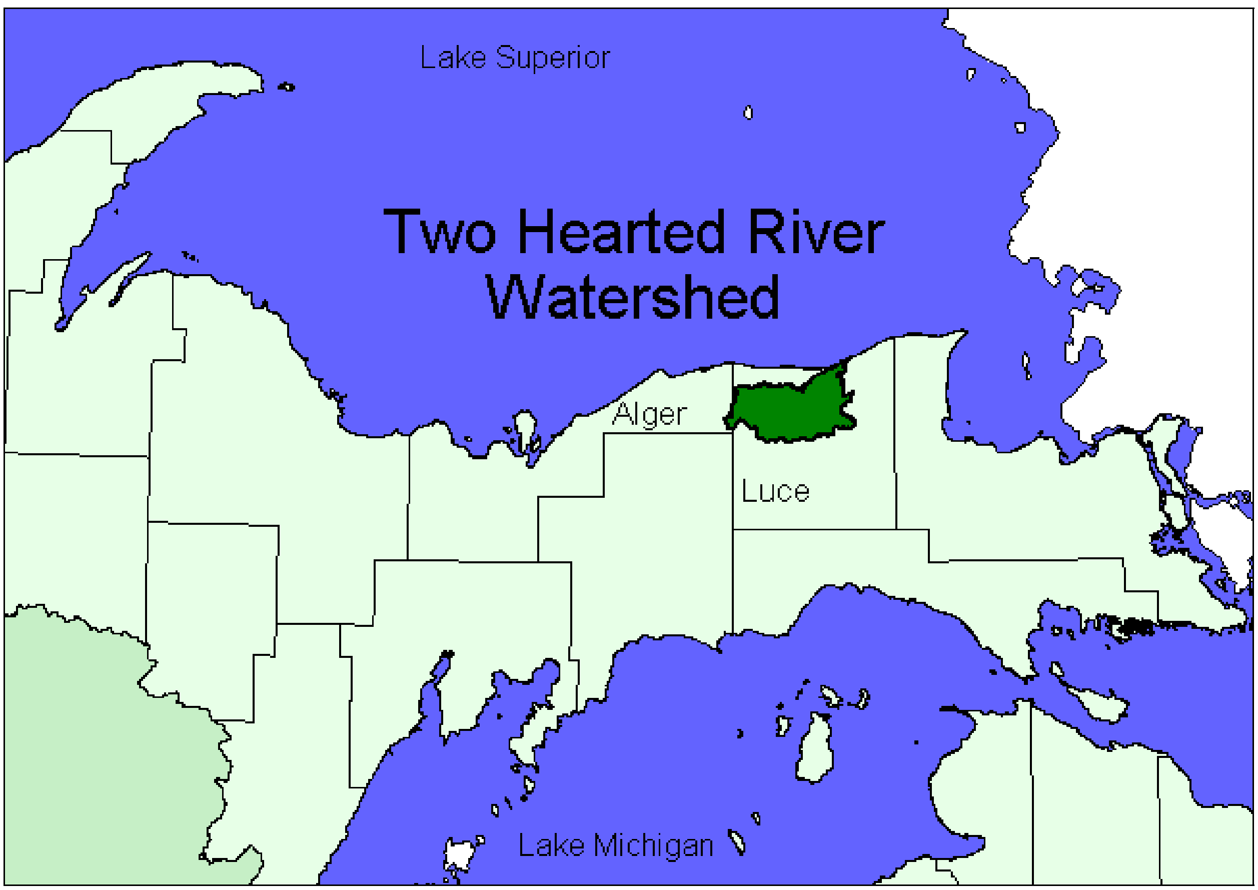

Figure 2: Two Hearted River Watershed Location

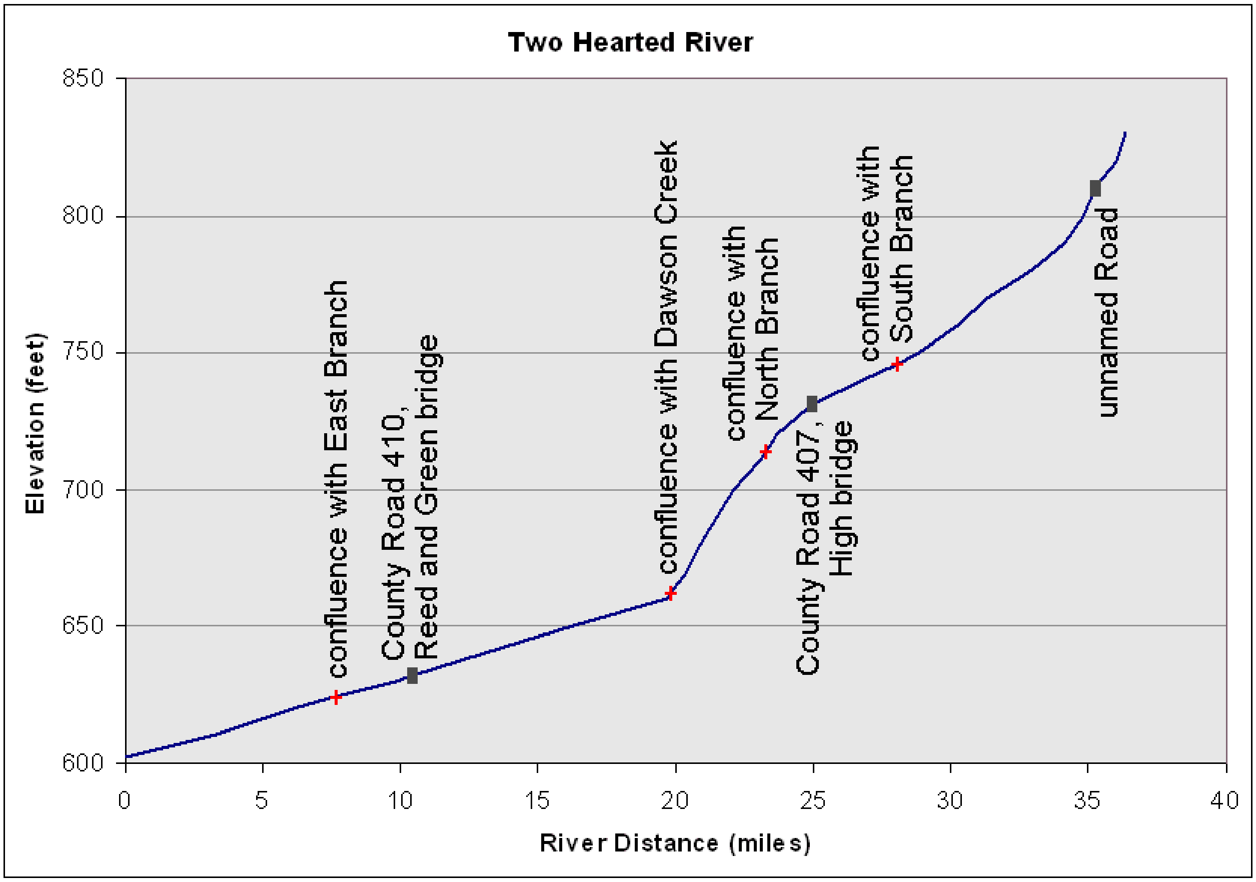

Figure 3: Two Hearted River Profile

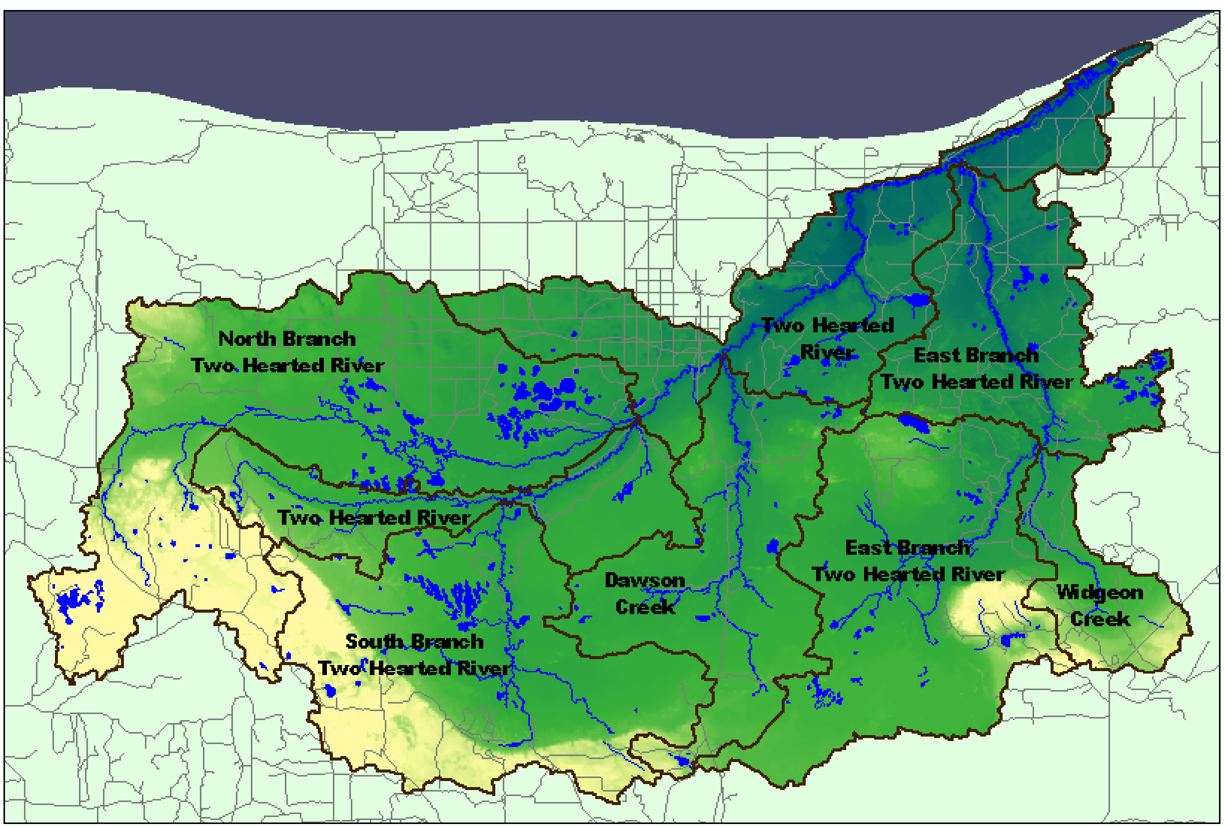

Figure 4: Two Hearted River Subbasin Identification

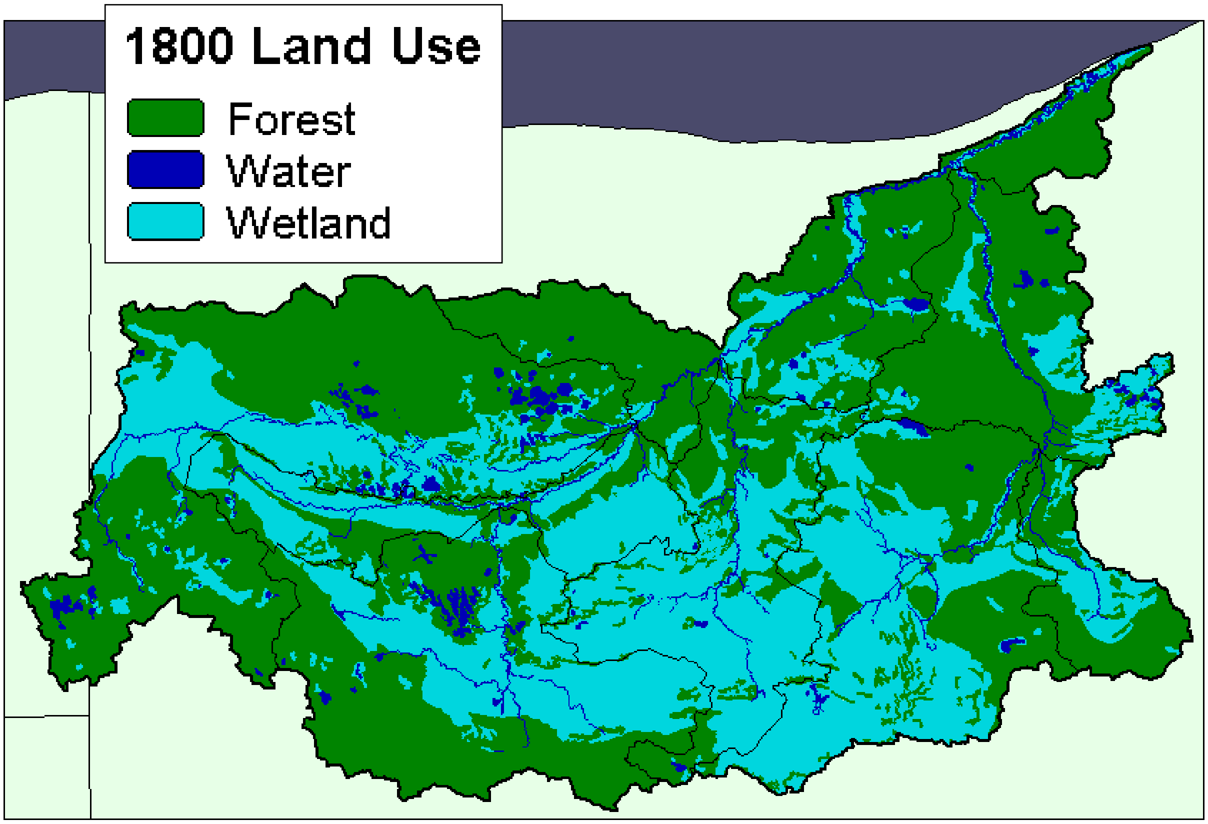

Figure 5: 1800 Land Cover

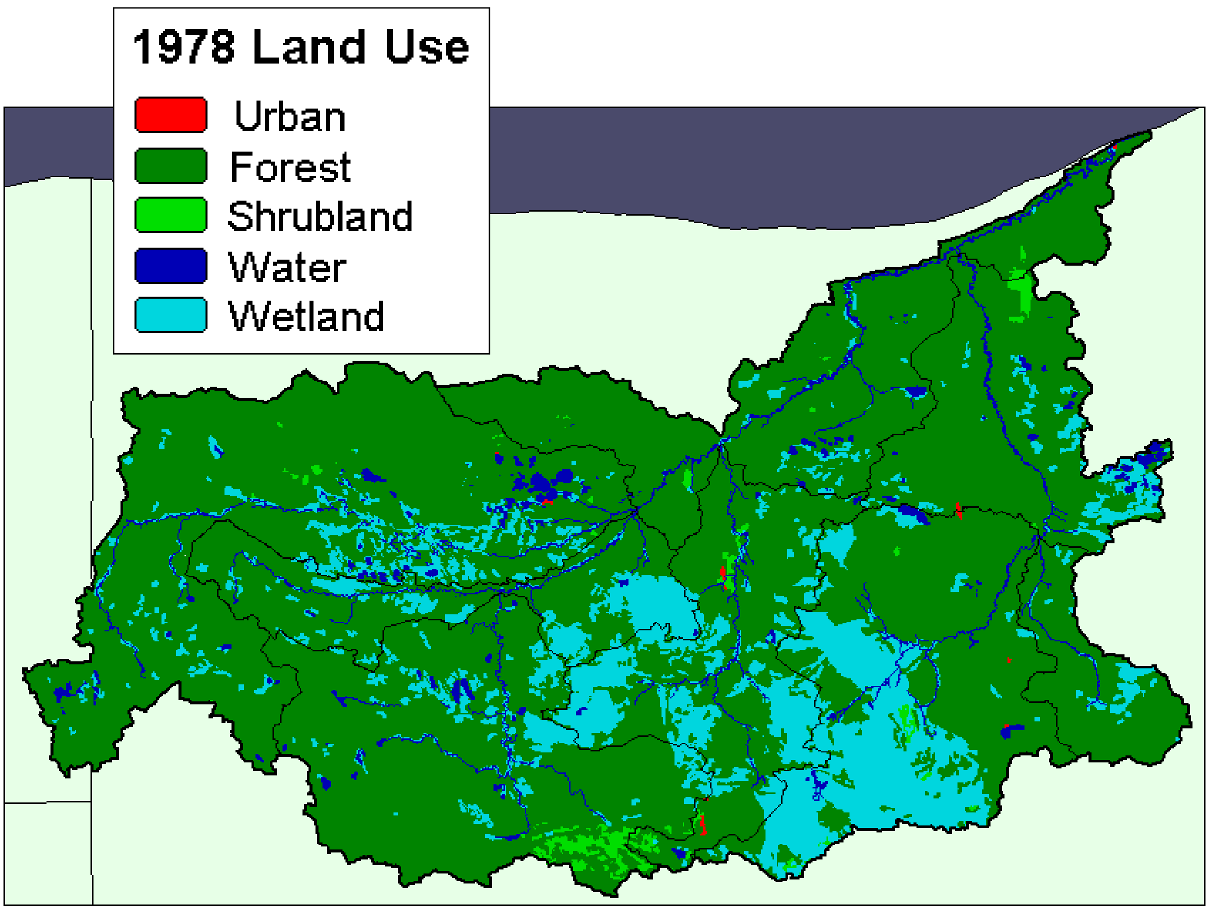

Figure 6: 1978 Land Cover

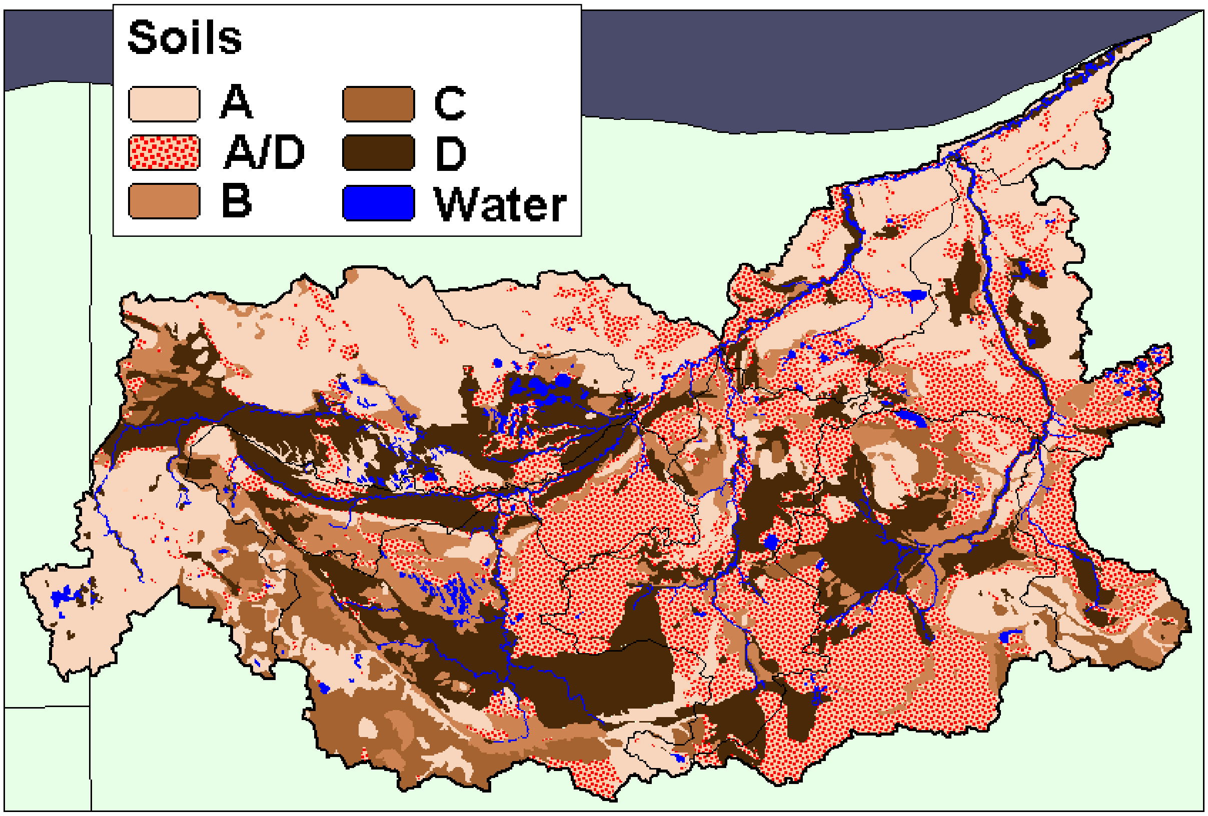

Figure 7: NRCS Soils Data

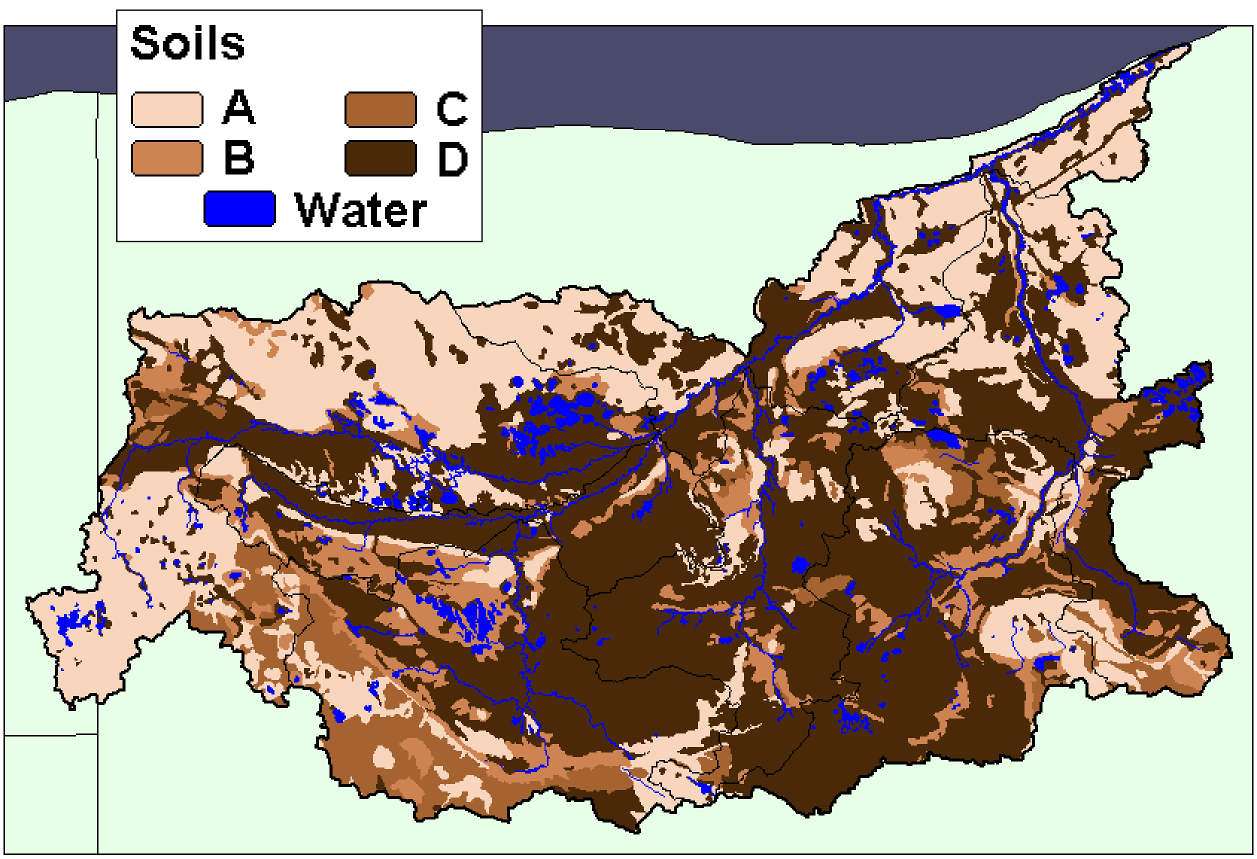

Figure 8: NRCS Soils Data, 1978 Land Cover

Hydrologic Analysis

General Results

The Two Hearted River watershed is comprised almost entirely of forest and wetland, with very little urban or agricultural land use. Based on the peak flow dates for USGS gage 04044813 and weather data, Figures 9 and 10 and Table 2, the Two Hearted River watershed is a snowmelt-driven system. A snowmelt-driven system is usually much less flashy than storm-driven systems, because the snow pack supplies a steadier rate of flow. However, a rain-on-snow event, where rain and snowmelt simultaneously contribute to runoff, can produce dramatic flow increases. The runoff from the rain and snowmelt also likely occur with saturated or frozen soil conditions, when the ground can absorb or store less water, resulting in more overland flow to surface waters than would occur otherwise. HSU does not expect this watershed to undergo long term hydrologic changes that affect surface runoff volumes or peak flows.

Future hydrologic changes can impact local stream flows, water quality, channel erosion, and flooding. These changes can be moderated with effective stormwater management techniques, such as:

- treatment of the “first flush” runoff
- wetland protection
- retention and infiltration of excess runoff
- low impact development techniques
- 24-hour extended detention of 1-year flows
- properly designed detention of runoff from low probability storms

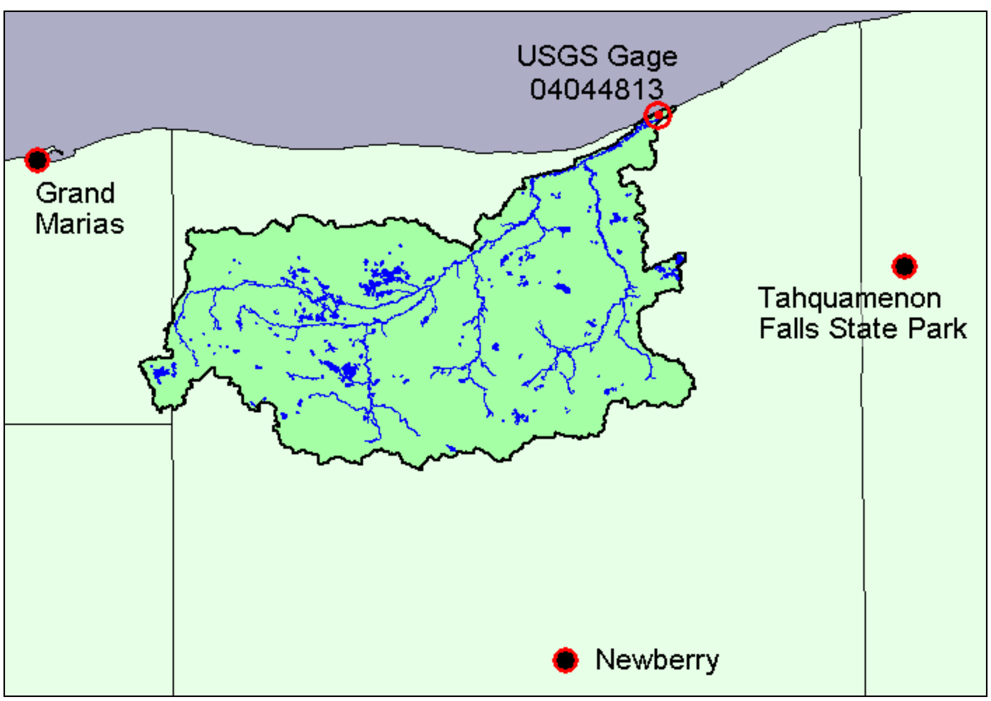

Figure 9: Locations of USGS Gage and National Weather Service Stations

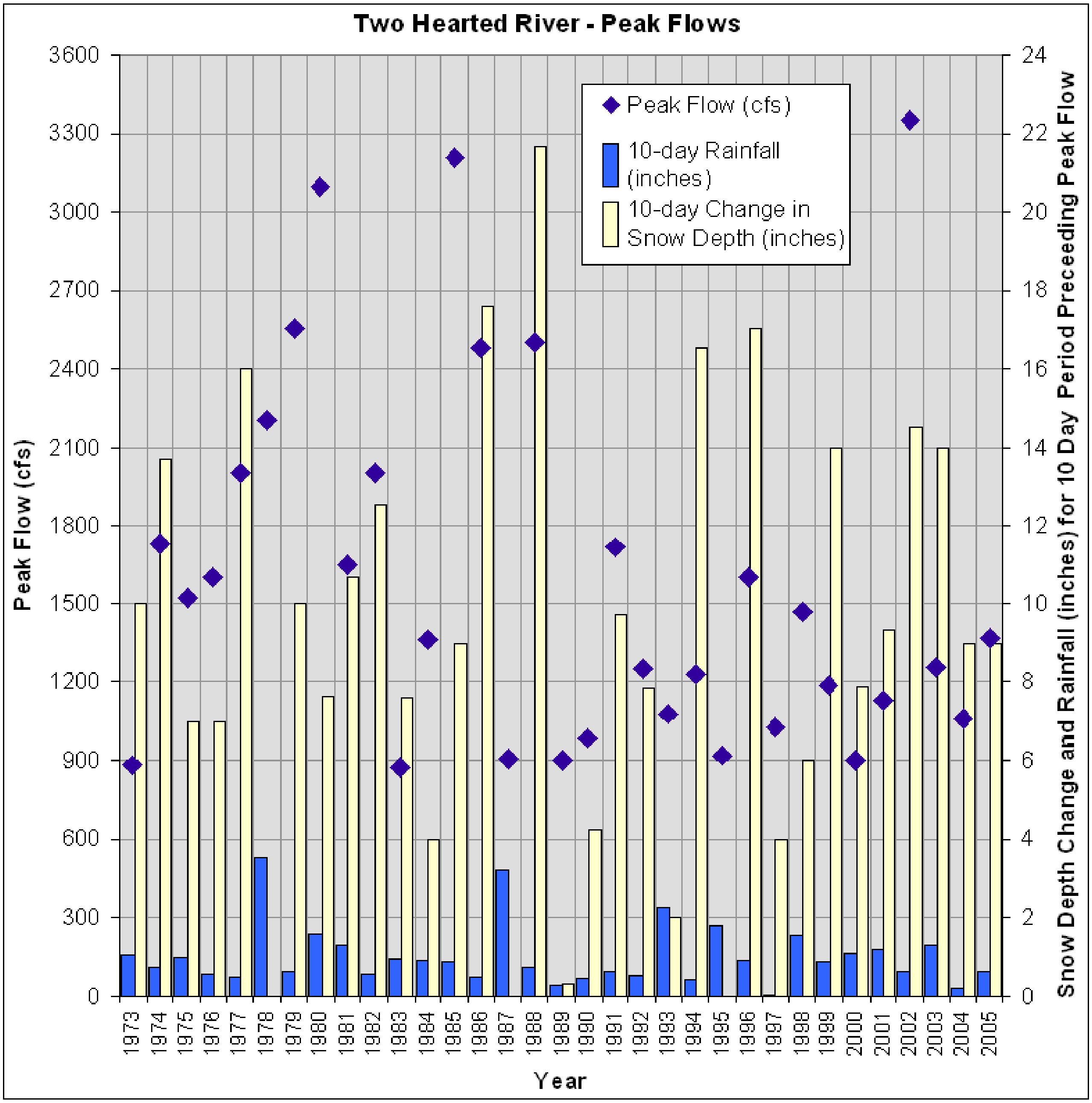

Figure 10: Peak Flows from Two Hearted River USGS Gage 04044813 near Paradise, 10-day Snow Depth Changes and Rainfall averaged from National Weather Stations at Grand Marias, Newberry, and Tahquamenon Falls

Table 2: Peak Flows from Two Hearted River USGS Gage 04044813 near Paradise, 10-day Rainfall and Snowmelt averaged from National Weather Stations at Grand Marias, Newberry, and Tahquamenon Falls

Date	Peak Flow (cfs)	Tahquamenon Falls		Newberry		Grand Marias	
		10-Day Rainfall (inches)	10-Day Snowmelt (inches)	10-Day Rainfall (inches)	10-Day Snowmelt (inches)	10-Day Rainfall (inches)	10-Day Snowmelt (inches)
3/17/1973	885	0.84		0.77	10	1.54	
4/23/1974	1730	1.14	20.1	0.70	7.3	0.36	
5/2/1975	1520	0.80	14	1.11	0	0.99	
4/19/1976	1600	0.58	14	0.44	0	0.67	
4/20/1977	2000	0.32	25	0.58	4	0.52	19
5/15/1978	2200	3.74	0	3.52	0	3.33	0
4/27/1979	2550	0.55	14	0.74	0	0.55	16
4/12/1980	3100	1.79	15.9	1.97	0	1.06	7
4/5/1981	1650	1.43	18	1.73	6	0.79	8 Min.
4/27/1982	2000	0.40	18.5	0.59	12	0.67	6.6 Min.
4/17/1983	880	0.22	7.4	1.94	5.4	0.71	10
4/17/1984	1360	0.75	0	0.62	0	1.32	12
4/25/1985	3210	0.66	M	1.73	10	0.18	8
4/9/1986	2480	M	20.7 Min.	0.60	18	0.41	14
7/22/1987	908	3.56	0	2.84	0	3.33	0
4/9/1988	2500 (est.)	M	29	1.48	14	0.00	22
4/26/1989	903	0.42	0	0.32	0	0.06	1
4/25/1990	987	M	5.6 Min.	0.63	5.2	0.25	2
4/9/1991	1720	M	11.2 Min.	0.89	5	0.30	13
4/22/1992	1250	0.95	9.5 Min.	0.55	5	0.09	9
5/6/1993	1080	2.20	6 Min.	2.48	0	2.05	0
4/19/1994	1230	0.55	M	M	M	0.26	16.5
4/28/1995	917	3.46	0	1.20	M	0.73	M
4/25/1996	1600	1.30	M	0.92	M	0.45	17
4/26/1997	1030	0.04	M	0.00	M	0.06	4
3/31/1998	1470	2.82	M	1.09	M	0.72	6
4/6/1999	1190	1.05	14 Min.	1.05	M	0.43	14
3/9/2000	903	1.55	6.3 Min.	M	M	0.62	9.5
4/12/2001	1130	1.89	~13	1.13	0	0.51	15
4/19/2002	3350	0.81	13	0.51	M	0.51	16
4/21/2003	1260	1.29	~18	M	Trace	1.29	10
4/7/2004	1060	0.21	3 Min.	M	15 Min.	M	9
4/7/2005	1370	0.17	7 Min.	M	M	1.02	11

M = missing data, Min. = minimum, T = trace

Stream Order

Stream order is a numbering sequence which starts when two first order, or headwater, streams join, forming a second order stream, and so on. Two second order streams converging form a third order. Streams of lower order joining a higher order stream do not change the order of the higher, as shown in Figure 11. Stream order provides a comparison of the size and potential power of streams.

The Michigan Department of Natural Resources Institute for Fisheries Research and the USGS Great Lakes Gap have nearly completed a three-year EPA-funded study that provides GIS stream order data for Michigan's streams using the 1:100,000 National Hydrography Dataset (NHD). The Two Hearted River results are shown in Figure 12.

The stream orders shown are not absolute. If larger scale maps are used or actual channels are found through field reconnaissance, the stream orders designated in Figure 26 may increase, because smaller channels are likely to be included. A more detailed analysis, based on 1:24,000 NHD layer, is also being developed.

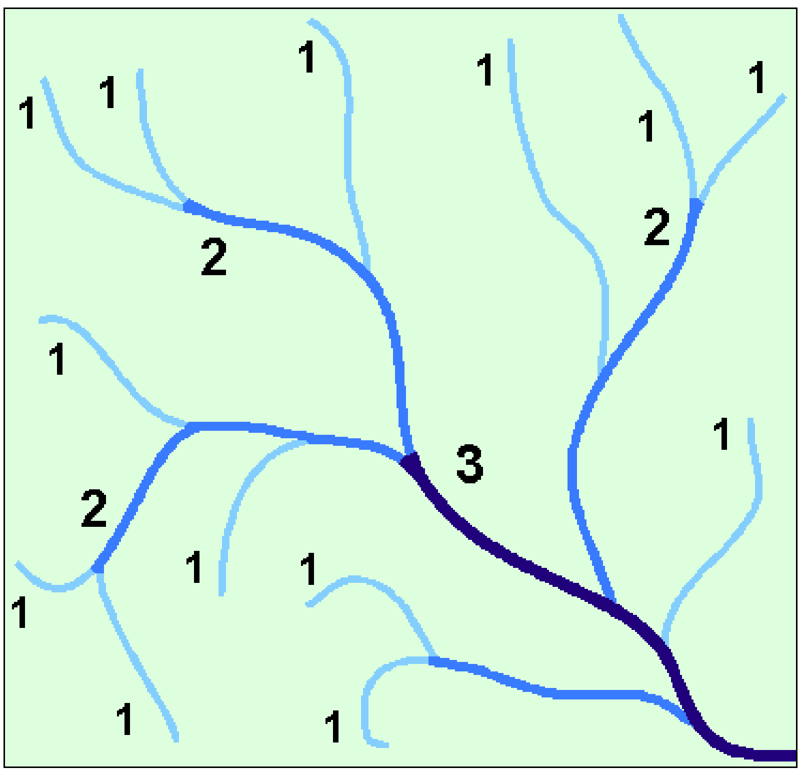

Figure 11: Stream Ordering Procedure

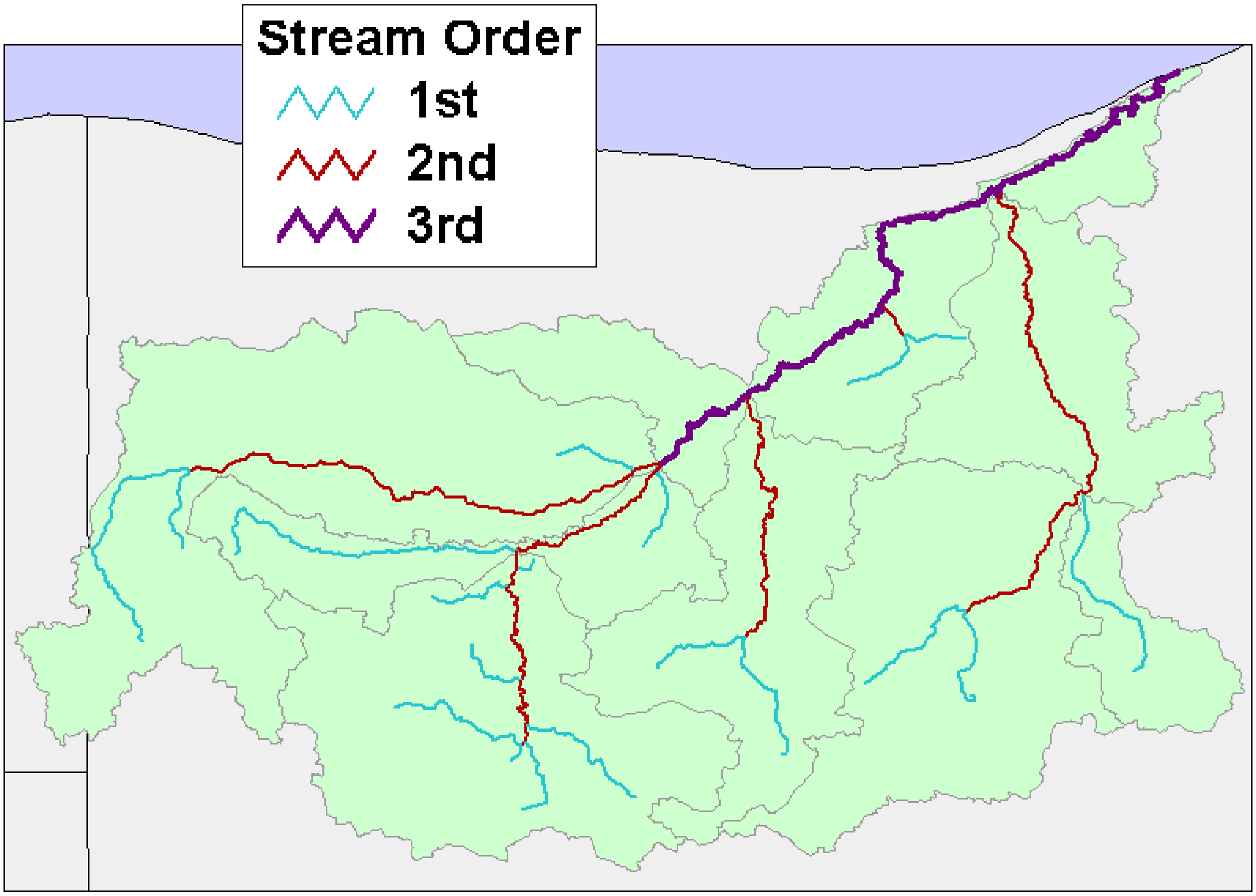

Figure 12: Two Hearted River Watershed Stream Orders

Recommendations

When precipitation falls, it can infiltrate into the ground, evapotranspirate back into the air, or run off the ground surface to a water body. It is helpful to consider three principal runoff effects: water quality, channel shape, and flood levels, as shown in Figure 13.

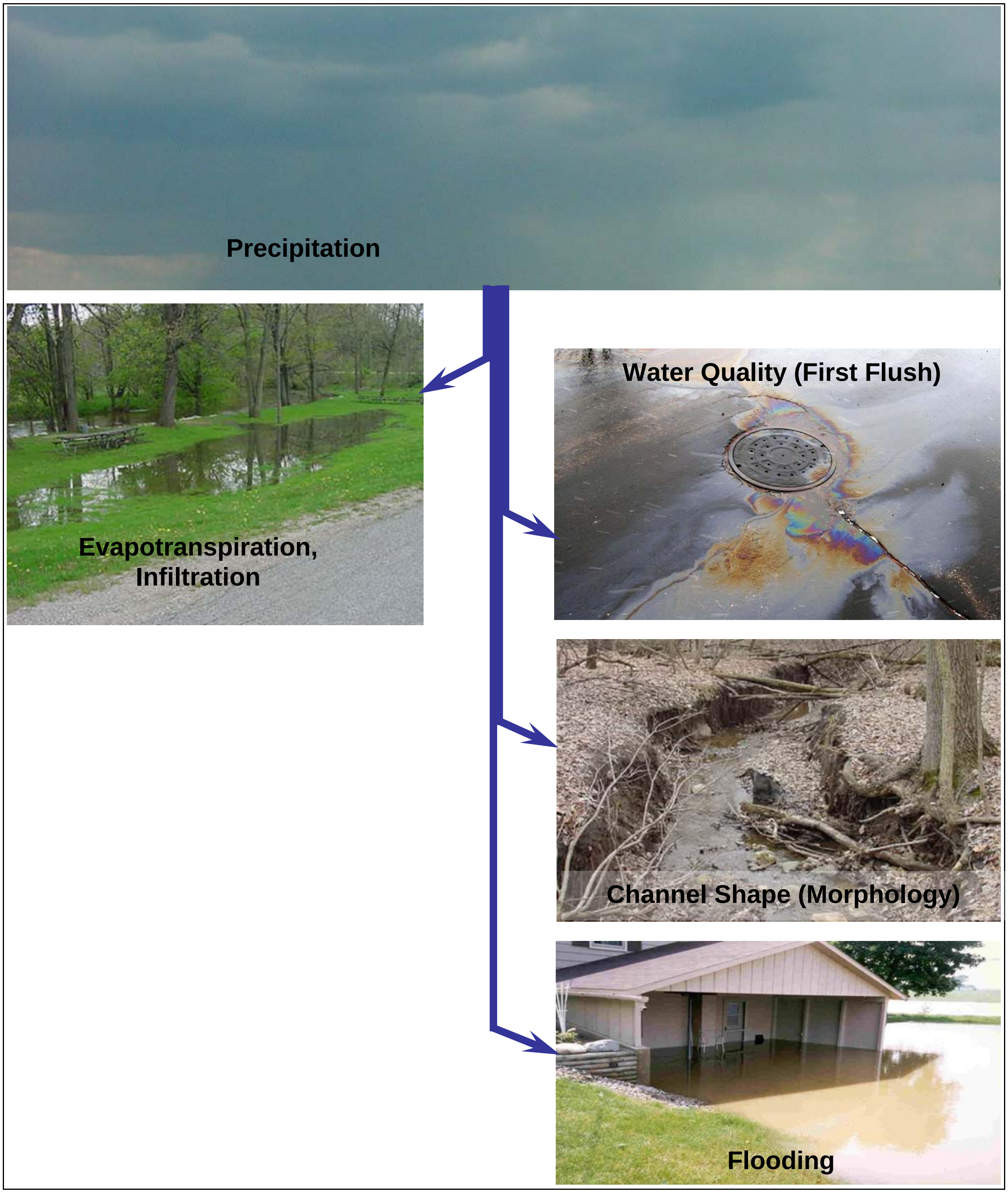

Figure 13: Runoff Impacts

Land use changes that reduce evapotranspiration and infiltration increase runoff. One reason low impact development has become more popular is that it avoids creating more runoff, intercepting and infiltrating the excess instead.

Small runoff events and the first portion of the runoff from larger events is termed the “first-flush”, because it carries the majority of the pollutants. For more information, refer to the Water Quality section.

Larger, but frequent, storms or snowmelts produce the flows that shape the channel. The channel-forming flow in a stable stream usually has a one- to two-year recurrence interval. These relatively modest storm flows, because of their higher frequency, have more effect on channel form than extreme flood flows. Hydrologic changes that increase this flow can cause the stream channel to become unstable. Stormwater management techniques used to mitigate flooding can also help mitigate projected channel-forming flow increases. However, channel-forming flow criteria should be specifically considered in the stormwater management plan so that the selected BMPs will be most effective. For example, detention ponds designed to control runoff from the 4 percent chance, 24-hour storm may do little to control the runoff from the 50 percent chance, 24-hour storm, unless the outlet is specifically designed to do so. For more information, refer to the Stream Channel Protection section.

Increases in the runoff volume and peak flow from large storms, such as the 4 percent chance (25-year), 24-hour storm, could cause or aggravate flooding problems unless mitigated using effective stormwater management techniques. For more information, refer to the Flood Protection section.

Water Quality

Small runoff events and the first portion of the runoff from larger events typically pick up and deliver the majority of the pollutants to a watercourse in an urban area (Menerey, 1999 and Schueler, 2000). As the rain continues, there are fewer pollutants available to be carried by the runoff, and thus the pollutant concentration becomes lower. Figure 14 shows a typical plot of pollutant concentration versus time. The sharp rise in the plot has been termed the "first-flush." Some of the pollutants can settle out before discharging to a stream if this first flush runoff is detained for a period of time. Filtering systems are also used at some sites to treat the first flush stormwater.

Nationally, the amount of runoff recommended for capture and treatment varies from 0.5 inch per impervious acre to the runoff from a 50 percent chance storm. Michigan BMP guidelines recommend capture and treatment of 0.5 inch of runoff from a single site (Guidebook of Best Management Practices for Michigan Watersheds, 1998). The runoff is then released over 24 to 48 hours or is allowed to infiltrate into the ground within 72 hours. Dry detention ponds are less effective than retention or wet detention ponds, because the accumulated sediment in a dry detention pond may be easily resuspended by the next storm (Schueler, 2000).

Runoff from multiple or large sites may exhibit elevated pollutant concentrations longer, because the first flush runoff from some portions of the drainage area will take longer to reach the outlet. For multiple sites or watershed wide design, it is best to design to capture and treat 90 percent of runoff-producing storms. This "90 percent rule" effectively treats storm runoff that could be reaching the treatment at different times during the storm event. It was designed to provide the greatest amount of treatment that is economically feasible. In Michigan, values calculated for these storms range from 0.77 to 1.00 inches. The two values calculated for weather stations in the Two Hearted River watershed climatic region are 0.87 and 0.92 inches. Additional information is available at http://www.deq.state.mi.us/documents/deq-lwm-hsu-nps-ninety-percent.pdf.

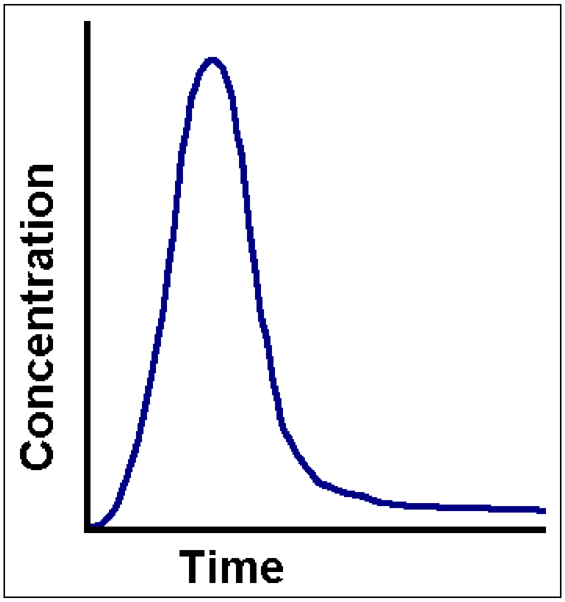

Figure 14: Plot of Pollutant Concentration versus Time

Stream Channel Protection

A stable stream is one that, over time, maintains a stable morphology: a constant pattern (sinuosity), slope, and cross-section, and neither aggrades or degrades. Stream stability is not the absence of erosion; some sediment movement and streambank erosion are natural.

Possible causes of erosion are:

- Natural river dynamics
- Sparse vegetative cover due to too much animal or human traffic
- Concentrated runoff adjacent to the streambank, i.e. gullies, seepage
- In-stream flow obstructions, i.e. log jams, failed bridge supports
- An infrequent event, such as an ice jam or low probability flood
- Unusually large or frequent wave action
- A significant change in the hydrologic characteristics (typically land use) of the watershed

- A change in the stream form impacting adjacent portions of the stream, i.e. dredging, channelization

An assessment of the cause(s) of erosion is necessary so that proposed solutions will be permanent and do not simply move the erosion problem to another location. The first six listed causes can produce localized erosion. Either of the last two causes, however, could produce a morphologically unstable stream. Symptoms of active channel enlargement in an unstable stream include:

- Knickpoint migration of the channel bottom
- Extensive and excessive erosion of the stream banks
- Erosion on the inside bank of channel bends
- Evidence in the streambanks of bed erosion down through an armor layer
- Exposed sanitary or storm sewers that were initially installed under the steam bed

Erosion in a morphologically unstable stream is caused by increases in the relatively frequent channel-forming flows that, because of their higher frequency, have more effect on channel form than extreme flood flows. As shown in Figure 15, multiplying the sediment transport rate curve (a) by the storm frequency of occurrence curve (b) yields a curve (c) that, at its peak, indicates the flow that moves most of the sediment in a stream. This flow is termed the effective discharge. The effective discharge usually has a one- to two-year recurrence interval and is the dominant channel-forming flow in a stable stream.

Increases in the frequency, duration, and magnitude of these flows cause stream bank and bed erosion as the stream adapts. According to the *Stream Corridor Restoration* manual, stream channels can often enlarge their cross-sectional area by a factor of two to five (FISRWG, 10/1998). In *Dynamics of Urban Stream Channel Enlargement, The Practice of Watershed Protection*, ultimate channel enlargement ratios of up to approximately 10 are reported, as shown in Figure 16 (Schueler, 2000).

To prevent or minimize this erosion, watershed stakeholders should specifically consider stormwater management to protect channel morphology. Low impact development and infiltration BMPs can be incorporated to offset flow increases. Stormwater management ordinances can specifically address channel protection. However, where ordinances have included channel protection criteria, it has typically been focused on controlling peak flows from the 2-year storm.

The nationally recognized Center for Watershed Protection asserts that 2-year peak discharge control doesn’t work, because it does not reduce the frequency of erosive bankfull and sub-bankfull flows that often increase as development occurs within the watershed. Indeed, it may actually worsen conditions, since it increases the duration of these erosive, channel-forming flows.

The Center for Watershed Protection suggests requiring 24-hour extended detention for runoff from 1-year storms as one option for protecting channel morphology. The intent is to limit detention pond outflows from these storms to non-erosive velocities, as shown in Figure 17. A few watershed plans funded through the MDEQ Nonpoint Source Program have recommended requirements based on this criterion.

One such example is from the Anchor Bay Technical Report and is shown in Figure 18. This analysis, which applies to one of Michigan's ten climatic regions, is for 2.06 inches of rainfall. The Two Hearted River is in climatic region 7, which has a 50 percent chance (2-year) 24-hour storm design rainfall value of 2.14 inches, as tabulated in *Rainfall Frequency Atlas of the Midwest*, Bulletin 71, Midwestern Climate Center, 1992, pp. 126-129. The MDEQ Nonpoint Source Program is exploring funding this analysis for all of Michigan. The results would be provided to the Two Hearted River stakeholders when available.

Control of channel-forming flows is not essential for some drainage areas. For example, detention designed to prevent streambank erosion may not be needed for runoff routed from a city through storm sewers to a large river, simply because the runoff routed through the storm sewers enters the river well ahead of the peak flow in the river. In this case, the city's management plan for stormwater routed through storm sewers should focus on treating the runoff to maintain water quality and providing sufficient drainage capacity to minimize flooding. Detention/retention might also be encouraged or required for other reasons, such as water quality improvement, groundwater replenishment, or if watershed planning indicates continued regional development would alter the river's flow regime or increase flood levels.

Hydrologic and hydraulic modeling may be justified to determine if runoff from a drainage area should be limited, either by detention or infiltration, to prevent flow or flood level increases or to verify that flood peaks are not increased due to the timing of the peak flows from detention ponds and in the stream. Two Hearted River stakeholders may elect to recommend some conditions when detention or retention for channel protection is not necessary. For example, the watershed stakeholders may adopt a watershed plan that calls for channel protection measures, unless runoff discharges from a storm sewer directly to a fourth order or higher stream, as shown in Figure 26.

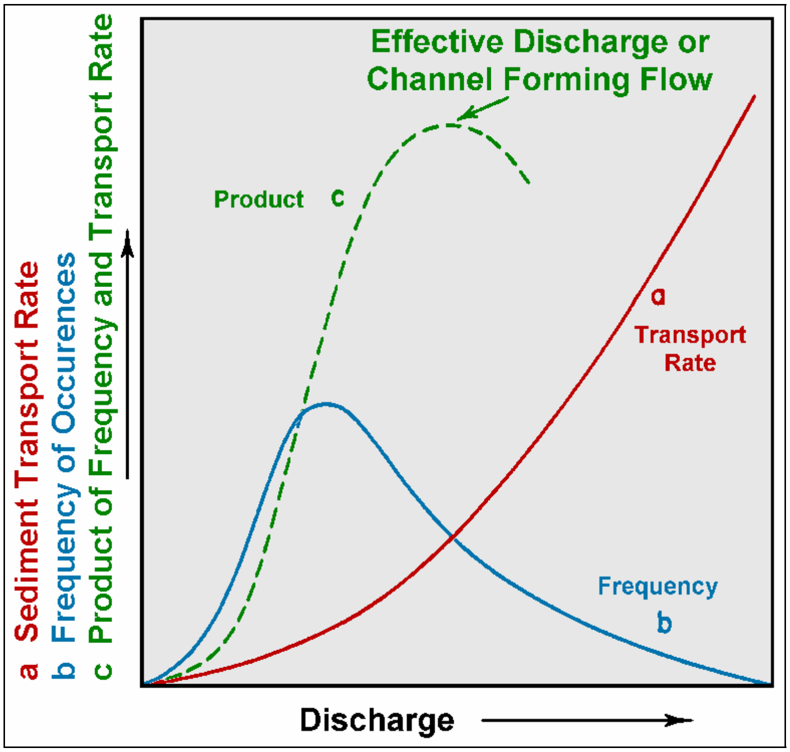

Figure 15: Effective Discharge (from *Applied River Morphology*. 1996. Dave Rosgen)

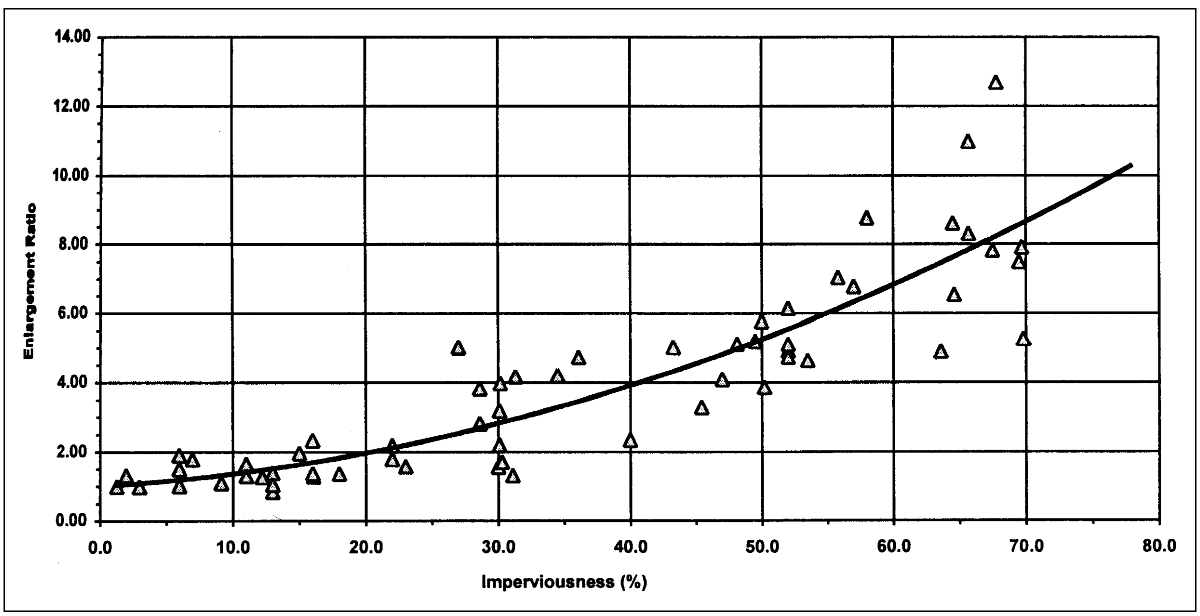

Figure 16: "Ultimate" Channel Enlargement as a Function of Impervious Cover in Alluvial Streams in Maryland, Vermont, and Texas (MacRae and DeAndrea, 1999; and Brown and Claytor, 2000) (From *The Practice of Watershed Protection*, Thomas R. Schueler and Heather K. Holland, 2000)

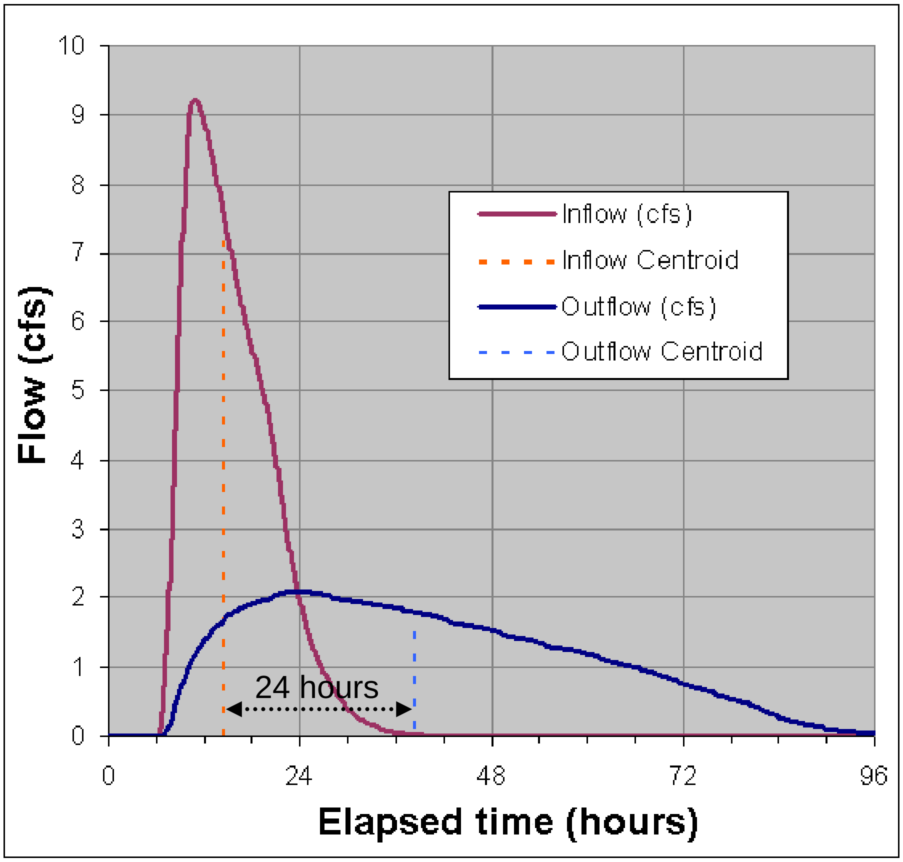

Figure 17: Example of 24-hour extended detention criterion applied to detention pond design

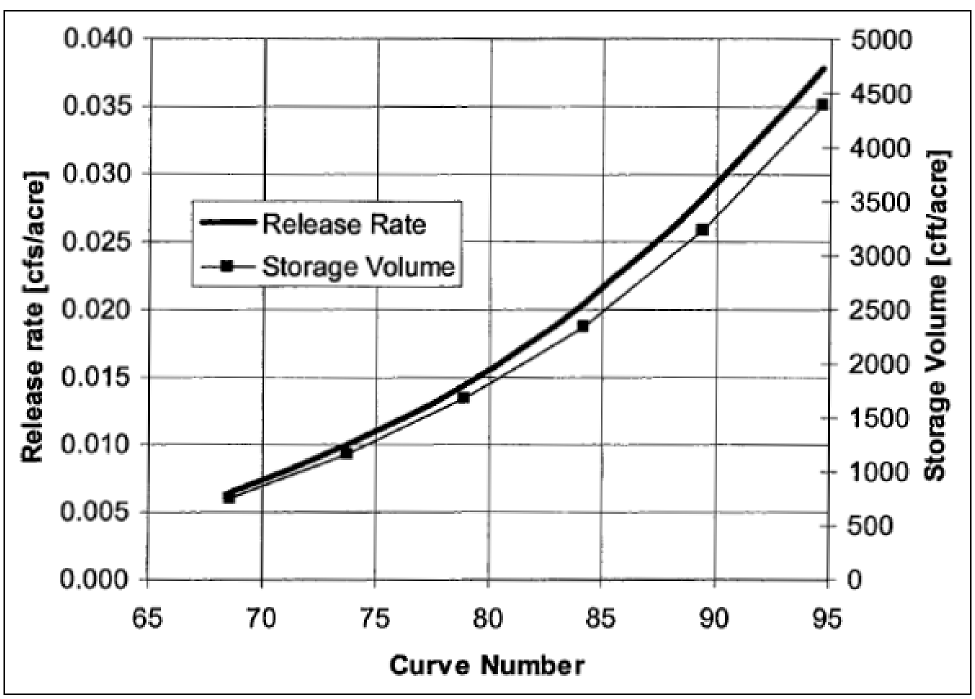

Figure 18: Example of detention pond requirements derived from the 24-hour extended detention criterion

Flood Protection

A river, stream, lake, or drain may occasionally overflow its banks and inundate adjacent land. This land is the floodplain. Typically, a stable stream will recover naturally from these infrequent events. Developments should always include stormwater controls that prevent flood flows from exceeding pre-development conditions and putting people, homes, and other structures at risk. Many localities require new development to control the 4 percent chance flood, commonly called the 25-year flood, with some adding requirements to control the 1 percent chance (100-year) flood.

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Appendix A: Two Hearted River Hydrologic Analysis Data

The following tables summarize the results of the hydrologic analysis by subbasin. These tables are likely to be most useful during the process for defining critical areas for the Two Hearted River Watershed Management Plan. Table A1 presents land use information.

Table A1: Land Use by Subbasins (Land use percentages that round to 0 are not listed)

Description	Scenario	Residential	Institutional	Industrial	Utilities	Gravel Pit	Cemeteries, Outdoor Rec.	Cropland	Orchard	Pasture	Herbaceous Openland	Forest	Water	Wetland	Bare Soil, Sand Dune
Dawson Creek	1800											32%		68%	
	1978										1%	68%		30%	
East Branch, lower	1800											79%	1%	20%	
	1978										2%	89%	2%	7%	
East Branch, upper	1800											42%	1%	57%	
	1978										1%	59%	1%	40%	
North Branch	1800											69%	2%	29%	
	1978											90%	2%	8%	
South Branch	1800											56%	2%	42%	
	1978										3%	89%	1%	7%	
Two Hearted, lower	1800											84%	1%	16%	
	1978										1%	95%	1%	3%	
Two Hearted, upper	1800											31%		69%	
	1978											76%		24%	
Widgeon Creek	1800											68%		32%	
	1978											93%		7%	
Entire Watershed	1800											59%	1%	40%	
	1978										1%	82%	1%	16%	

Appendix B: Glossary

Aggrade - to fill and raise the level of a stream bed by deposition of sediment.

Alluvium - sediment deposited by flowing rivers and consisting of sands and gravels.

Bankfull discharge - that discharge of stream water that just begins to overflow in the active floodplain. The active floodplain is defined as a flat area adjacent to the channel constructed by the river and overflowed by the river at recurrence interval of about 2 years or less. Erosion, sediment transport, and bar building by deposition are most active at discharges near bankfull. The effectiveness of higher flows, called over bank or flood flows, does not increase proportionally to their volume above bankfull in a stable stream, because overflow into the floodplain distributes the energy of the stream over a greater area. See also channel-forming and effective discharge.

Base Flow - the part of stream flow that is attributable to long-term discharge of groundwater to the stream. This part of stream flow is not attributable to short-term surface runoff, precipitation, or snow melt events.

Best Management Practice (BMP) - structural, vegetative, or managerial practices used to protect and improve our surface waters and groundwaters.

Channel-forming Discharge - a theoretical discharge which would result in a channel morphology close to the existing channel. See also effective and bankfull discharge.

Condensation - phase change of water vapor into liquid droplets.

Critical Areas - the geographic portions of the watershed contributing the majority of the pollutants and having significant impacts on the waterbody.

Critical Depth - depth of water for which specific energy is a minimum.

Curve Number - see Runoff Curve Number.

Design Flow - projected flow through a watercourse which will recur with a stated frequency. The projected flow for a given frequency is calculated using statistical analysis of peak flow data or using hydrologic analysis techniques.

Detention - practices which store stormwater for some period of time before releasing it to a surface waterbody. See also retention.

Dimensionless Hydrograph - a general hydrograph developed from many unit hydrographs, used in the Soil Conservation Service method.

Direct Runoff Hydrograph - graph of direct runoff (rainfall minus losses) versus time.

Discharge - volume of water moving down a channel per unit time. See also channel-forming, effective, and bankfull discharge.

Drainage Divide - boundary that separates subbasin areas according to direction of runoff.

Effective Discharge - the calculated measure of channel forming discharge. This calculation requires long-term water and sediment measurements, although modeling results are sometimes substituted. See also channel-forming and bankfull discharge.

Ephemeral Stream - a stream that flows only during or immediately after periods of precipitation. See also intermittent and perennial streams.

Evaporation - phase change of liquid water to water vapor.

Evapotranspiration - the combined process of evaporation and transpiration.

Field Capacity - the amount of water held in soil after gravitational water is drained.

First Flush - the first part of a rainstorm that washes off the majority of pollutants from a site. The concept of first flush treatment applies only to a single site, even if just a few acres, because of timing of the runoff. Runoff from multiple or large sites may exhibit elevated pollutant concentrations longer because the first flush runoff from some portions of the drainage area will take longer to reach the outlet.

Flashiness - has no set definition but is associated with the rate of change of flow. Flashy streams have more rapid flow changes.

Flood Hazard Zone - area that will flood with a given probability.

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

Groundwater - that part of the subsurface water that is in the saturated zone.

Headwater Stream - the system of wetlands, swales, and small channels that mark the beginnings of most watersheds.

Hydraulic Analysis - an evaluation of water elevation for a given flow based on channel attributes such as slope, cross-section, and vegetation.

Hydrograph - graph of discharge versus time.

Hydrogroups - Soil groups used to estimate runoff from precipitation according to the infiltration of water when the soils receive precipitation from long-duration storms.

Hydrologic Analysis - an evaluation of the relationship between stream flow and the various components of the hydrologic cycle. The study can be as simple as determining the watershed size and average stream flow, or as complicated as developing a computer model to determine the relationship between peak flows and watershed characteristics, such as land use, soil type, slope, rainfall amounts, detention areas, and watershed size.

Hydrologic Cycle - When precipitation falls to the earth, it may:

- be intercepted by vegetation, never reaching the ground.
- infiltrate into the ground, be taken up by vegetation, and evapotranspirated back to the atmosphere.
- enter the groundwater system and eventually flow back to a surface water body.
- runoff over the ground surface, filling in depressions.
- enter directly into a surface waterbody, such as a lake, stream, or ocean.

When water evaporates from lakes, streams, and oceans and is re-introduced into the atmosphere, the hydrologic cycle starts over again.

Hydrology - the occurrence, distribution, and movement of water both on and under the earth's surface. It can be described as the study of the hydrologic cycle.

Hyetograph - graph of rainfall intensity versus time.

Impervious - a surface through which little or no water will move. Impervious areas include paved parking lots and rooftops.

Infiltration Capacity - rate at which water can enter soil with excess water on the surface.

Interflow - flow of water through the upper soil layers to a ditch, stream, etc.

Intermittent Stream - a stream that flows only during certain times of the year. Seasonal flow in an intermittent stream usually lasts longer than 30 days per year. See also ephemeral and perennial streams.

Invert - bottom of a channel or pipe.

Knickpoint - a point of abrupt change in bed slope. If the streambed is made of erodible material, the knickpoint, or downcut, may migrate upstream along the channel and have undesirable effects, such as undermining bridge piers and other manmade structures.

Lag Time - time from the center of mass of the rainfall to the peak of the hydrograph.

Losses - rainfall that does not runoff, i.e. rainfall that infiltrates into the ground or is held in ponds or on leaves, etc.

Low Flow - minimum flow through a watercourse which will recur with a stated frequency. The minimum flow for a given frequency may be based on measured data, calculated using statistical analysis of low flow data, or calculated using hydrologic analysis techniques. Projected low flows are used to evaluate the impact of discharges on water quality. They are, for example, used in the calculation of industrial discharge permit requirements.

Morphology, Fluvial - the study of the form and structure of a river, stream, or drain.

Nonpoint Source Pollution - pollutants carried in runoff characterized by multiple discharge points. Point sources emanate from a single point, generally a pipe.

Overland Flow - see Runoff.

Peak Flow - maximum flow through a watercourse which will recur with a stated frequency. The maximum flow for a given frequency may be based on measured data, calculated using statistical analysis of peak flow data, or calculated using hydrologic analysis techniques. Projected peak flows are used in the design of culverts, bridges, and dam spillways.

Perched Ground Water - unconfined groundwater separated from an underlying body of groundwater by an unsaturated zone.

Perennial Stream - a stream that flows continuously during both wet and dry times. See also ephemeral and intermittent streams.

Precipitation - water that falls to earth in the form of rain, snow, hail, or sleet.

Rating Curve - relationship between depth and amount of flow in a channel.

Recession Curve - portion of the hydrograph where runoff is from base flow.

Retention - practices which capture stormwater and release it slowly though infiltration into the ground. See also detention.

Riparian - pertaining to the bank of a river, pond, or small lake.

Runoff - flow of water across the land surface as surface runoff or interflow. The volume is equal to the total rainfall minus losses.

Runoff Coefficient - ratio of runoff to precipitation.

Runoff Curve Number - parameter developed by the Natural Resources Conservation Service (NRCS) that accounts for soil type and land use.

Saturated Zone - (1) those parts of the earth's crust in which all voids are filled with water under pressure greater than atmospheric; (2) that part of the earth's crust beneath the regional water table in which all voids, large and small, are filled with water under pressure greater than atmospheric; (3) that part of the earth's crust beneath the regional water table in which all voids, large and small, are ideally filled with water under pressure greater than atmospheric.

Scarp - the sloped bank of a stream channel.

Sediment - soil fragmental material that originates from weathering of rocks and is transported or deposited by air, water, or ice.

Sinuosity - the ratio of stream length between two points divided by the valley length between the same two points.

Simulation Model - model describing the reaction of a watershed to a storm using numerous equations.

Soil - unconsolidated earthy materials which are capable of supporting plants. The lower limit is normally the lower limit of biological activity, which generally coincides with the common rooting of native perennial plants.

Soil Moisture Storage - volume of water held in the soil.

Stochastic - model that contains a random component.

Storage Delay Constant - parameter that accounts for lagging of the peak flow through a channel segment.

Storage-Discharge Relation - values that relate storage in the system to outflow from the system.

Stream Corridor - generally consists of the stream channel, floodplain, and transitional upland fringe.

Subbasins - hydrologic divisions of a watershed that are relatively homogenous.

Synthetic Design Storm - rainfall hyetograph obtained through statistical means.

Synthetic Unit Hydrograph - unit hydrograph for ungaged basins based on theoretical or empirical methods

Thalweg - the "channel within the channel" that carries water during low-flow conditions.

Time of Concentration - time at which outflow from a basin is equal to inflow or time of equilibrium.

Transpiration - conversion of liquid water to water vapor through plant tissue.

Tributary - a river or stream that flows into a larger river or stream.

Unit Hydrograph - graph of runoff versus time produced by a unit rainfall over a given duration.

Unsaturated Zone - the zone between the land surface and the water table which may include the capillary fringe. Water in this zone is generally under less than atmospheric pressure, and some of the voids may contain air or other gases at atmospheric pressure. Beneath flooded areas or in perched water bodies, the water pressure locally may be greater than atmospheric.

Vadose Zone - see Unsaturated Zone.

Watershed - area of land that drains to a single outlet and is separated from other watersheds by a divide.

Watershed Delineation - determination of watershed boundaries. These boundaries are determined by reviewing USGS quadrangle maps. Surface runoff from precipitation falling anywhere within these boundaries will flow to the waterbody.

Water Surface Profile - plot of the depth of water in a channel along the length of the channel.

Water Table - the surface of a groundwater body at which the water pressure equals atmospheric pressure. Earth material below the groundwater table is saturated with water.

Yield - peak flow divided by drainage area