Watersheds101

Make a Splash Powerpoint with additional notes

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MAKE A SPLASH
USU WATER QUALITY EXTENSION

- What is a watershed?
- How does water move through a watershed?
- What is the link between activities in a watershed and water quality?
- What can you measure and why?

What is a watershed?

Geographic area within which all water drains to a common point.

Picture courtesy of The Watershed Center, Grand Transverse Bay. www.gtbay.org

Watersheds are defined by structure and by function

Elements of watershed structure

Geography	Size, latitude, longitude, elevation, aspect
Climate	Total precipitation, precipitation patterns
Geology	Formation - volcanic, sedimentary, basic rock types, soil types and depth, erosion potential
Vegetation / Animals	Type, native/non native, riparian areas, uplands, patterns of use and migration
Human uses	Development and land use patterns

Watershed Structure

Note how inter-related these are: latitude and longitude and elevation will determine precipitation patterns

Precip itation patterns and total precipitation will determine stream density, total flows, patterns of runoff, etc.

The above properties will determine vegetative patterns

Human uses also have huge influence on vegetative patterns

Vegetation patterns will in turn determine other properties such as shading, shape of stream (to some extent), erosion, etc.

The watershed structure very much affects watershed functions.
Water quality, biological characteristics of the water, etc. represent the response of the structural components

Functions of watersheds

Collect

Process and store

- Water
- Sediments, soils
- Dissolved minerals, metals, nutrients
- Biological material

Transport

Watershed Functions:

Watersheds collect water, but also nutrients (eg acid precipitation), organic material (migration in), wind blown soils, etc.

Watersheds process soils – soil formation, modification/ process geographic forms, plant material produced and stored, used by animals, etc. etc.

Water within a watershed moves through different reservoirs: groundwater, subsurface soil water, in plants and animals, in atmosphere, in lakes, reservoirs, streams, wetlands.

Transportation of water is via streams but also evaporation, movement of animals, runoff, groundwater, etc.

Other types of watershed transport: animal movements, soil erosion, air movement - minerals, metals, nutrients, etc. moving through the watershed (through plants, soils and water). Pollutants are transported to water by these many different vectors.

Watersheds are nested

The scale you work at depends on the question you're answering

What is causing “dead zones” in the Gulf of Mexico?

What is causing the scum in my back yard pond?

What is causing "dead zones" in the Gulf of Mexico?

The entire Mississippi River Basin may be an appropriate scale to consider the dead zone in the Gulf of Mexico.

The anoxic zone in the Gulf of Mexico is about the size of Massachussetts.

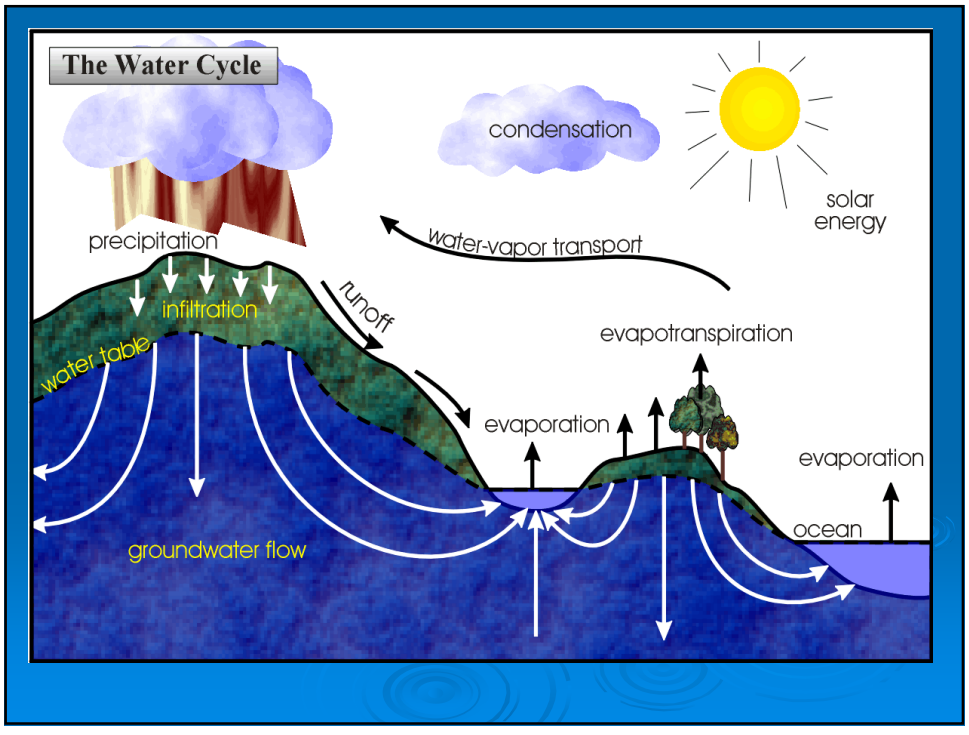
It is caused by eutrophication which is driven by nutrients (mostly nitrogen) entering the river from multiple sources throughout the watershed.

> 400 coastal dead zones have now been discovered around the world

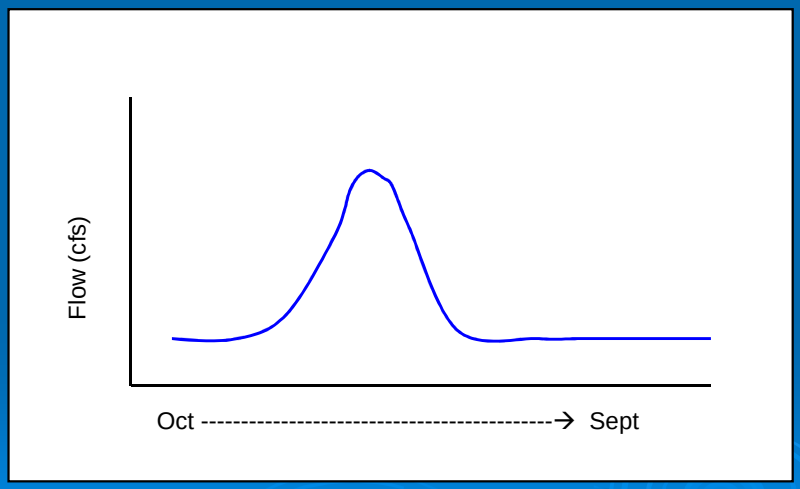
What is causing the scum in my back yard pond?

Scum in a pond may require a much smaller scale.

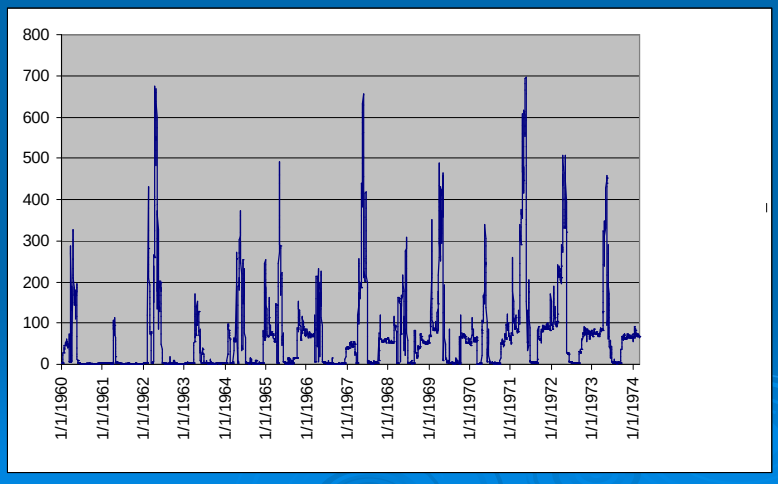
You can see the probable influences for this small pond ..
Horses, other animals, possibly fertilizers and septic systems in these small acreages.

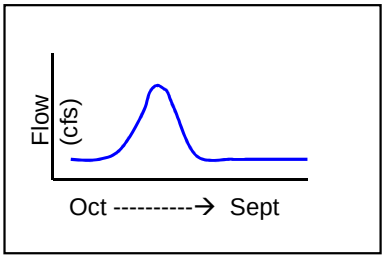


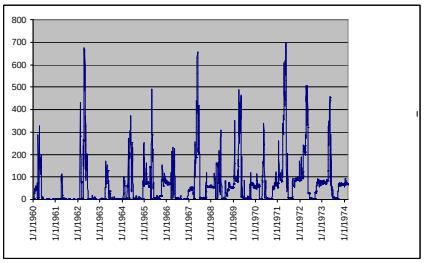
Natural Hydrographs in the west:



Natural variability



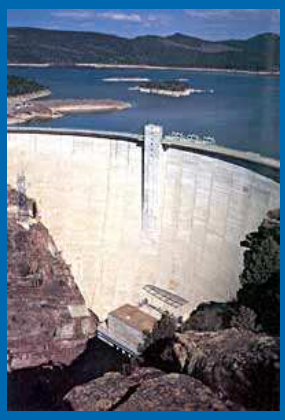




Runoff period (mostly fed by snowmelt in the wests) Versus baseflow (fed by draining of shallow groundwater after flooding has occurred).

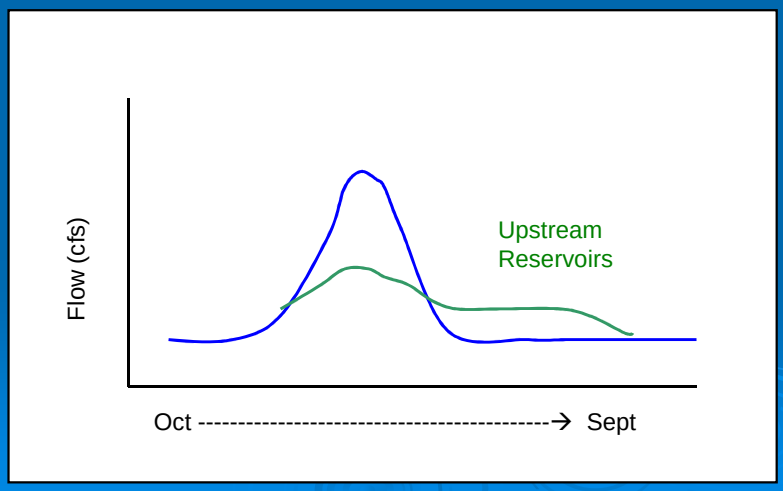
Area under the curve is the total amount of water

We tend to talk about average years, drought and wet years. BUT…Note how variable streams flow can be between years (7 fold difference between years). Notice different types of runoff patterns within a year. An "average" year may not have even occurred during this window of time.



Irrigation impacts

Modified Hydrographs:



NOTES

Reservoir Impacts:

Ask class to describe impact of a reservoir, then show the curve.
NOTE: Area of the curve is a volume (time * cfs). The area under the runoff curve represents the volume that irrigators or municipal planners "capture" for later use.

Describe changes in runoff pattern….(lower peak runoff, higher flows during later summer).

Ask class how these changes from a reservoir could affect functions in the watershed.

Eg. Reservoir will change downstream temperatures (warmer if waters are released from the surface of the res. And colder if waters are released from the bottom of the res.) This is a nice chance to talk about thermal structures of lakes and reservoirs if you want. Can mention implications of these temperature changes on downstream fish. Too cold, and warmwater fish cannot develop fast enough. Too warm and cold water fish may "metabolize themselves to death".

Reservoir Impacts continued:

Eg. Migrating fish (salmon) can be greatly affected by reservoirs. Biggest impact may be loss of high velocity spring flows that move salmon from lakes back to the oceans. Since the salmon evolved with those flows, their transition from freshwater to saltwater fish is timed accordingly. With reservoirs, the journey slows down considerably and many salmon have completed the transition to saltwater fish too soon (eg. Washington / Idaho border).

Eg. Trapping seds in reservoirs, resulting in less sed below reservoir for building point bars and other structural elements of a river.

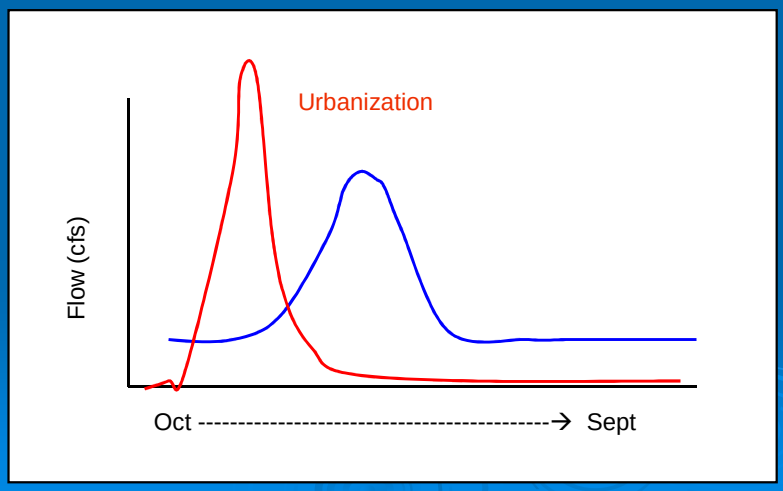
Eg. Reduced flooding flows reduced returned nutrients to flood plain,

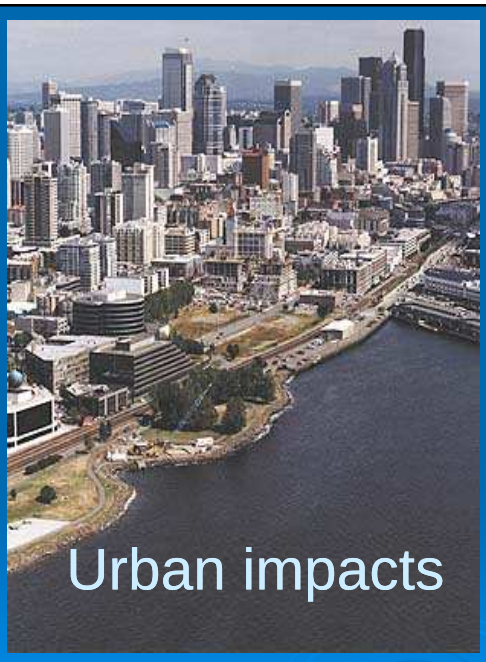
Eg. Reduced flooding means there's no opportunity for flood flows to filter thru riparian area,

Eg. Reduced flooding means no triggering of germination of plants that require flooding (eg. cottonwoods). Because of this you don't see rows of similar aged cottonwoods along old flood levels anymore….more typically we see really old cottonwoods, or cottonwoods that have been planted.

Eg. Reduced backwaters after flooding, which many native fish rely on for "nurseries".

Modified Hydrographs:





Urban impacts

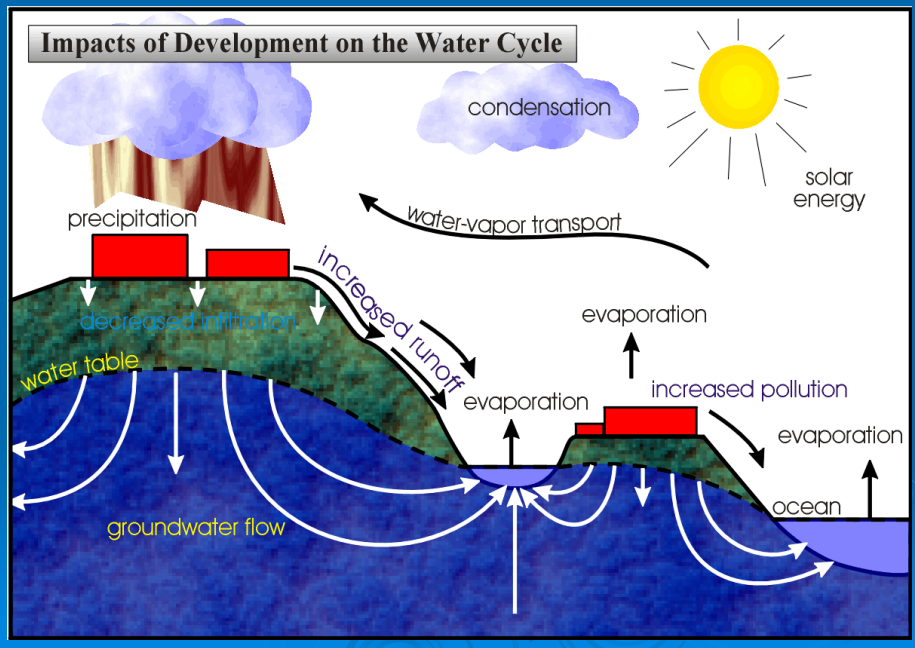
NOTES:

Urbanization Impacts:

Think about how the basic hydrograph might change with urbanization.
Changes to the watershed include lots more pavement, roof tops, roads, and other "impervious surfaces". This results in much less infiltration, more runoff.

Resuilts in greater and more frequent floods.
A previously 25 year return flow may become a 10 year flood as a result.

This has serious implications on channel formation and stream blow outs.
Impacts on groundwater recharge (note loss of base flow).
Impacts on water quality (pollutants don't get processed by soils / plants but rather runoff directly into the stream)



What's the watershed link to water quality?

Everything that happens in a watershed can affect the quality of the water downstream

…."*we all live downstream*"

NOTES: What is the value of clean water?

Drinking water:
- About half of Americans depend on rivers and lakes for dw

Commerce:
- Americans on average eat 15 pounds of fish and and shellfish a year. Nations $45 billion commercial fishing and shellfish industry rely on clean water
- In SE US, over 90% of commercial fish and shellfish catch depend on coastal wetland systems
- Manufacturers use about 13 trillion gallons of water each year (9 times the volume that flows from Mississippi into Gulf of Mexico each day)
- Soft drink industry uses more than 12 billion gallons of water (product valued at $50 billion)

Agriculture:
- About 15% of farm lands are irrigated
- Crops grown on irrigated land = 40% of total crop value ($70 billion/year)

Tourism:
Beaches, rivers, lakes critical to american tourism
Americans take more than 1.8 billion trips each year to water destinations

Quality of life:
- 1997 Money mag survey: clean water ranked 2nd of 41 top factors Americans consider when choosing a place to live
- Proximity to clean water body increases a home's value by 22% (National Association of Home Builders)

Water quality is regulated through Clean Water Act (1972)

Waters of U.S. must be "fishable and swimmable" by 1983

Eliminate all pollution discharge to waters by 1985.

This picture is from the 1952 fire which caused $1.5 million in damage.
The fire in 1969 that sparked the CWA only lasted about 24 minutes.
It was a very routine fire with damages at about $50,000.
Despite the lower magnitude of the fire, it was a time when the country expected change.
Environmental awareness was just starting to catch on.

Despite some waters still being polluted, the CWA was a huge success.
We are doing much better now than we were before with keeping our water clean.

On June 22, 1969, and oil slick debris in the Cuyahoga River caught fire in Cleveland, Ohio, drawing national attention to environmental problems in Ohio and elsewhere in the United States.

This Cuyahoga River fire lasted just thirty minutes, but it did approximately fifty thousand dollars in damage —principally to some railroad bridges spanning the river. It is unclear what caused the fire, but most people believe sparks from a passing train ignited an oil slick in the Cuyahoga River.

This was not the first time that the river had caught fire.
Fires occurred on the Cuyahoga River in 1868, 1883, 1887, 1912, 1922, 1936, 1941, 1948, and in 1952.
The 1952 fire caused over 1.5 million dollars in damage.

On August 1, 1969, Time magazine reported on the fire and on the condition of the Cuyahoga River.
"Some River! Chocolate-brown, oily, bubbling with subsurface gases, it oozes rather than flows.
"Anyone who falls into the Cuyahoga does not drown," Cleveland's citizens joke grimly. "He decays"…

The Federal Water Pollution Control Administration dryly notes: "The lower Cuyahoga has no visible signs of life, not even low forms such as leeches and sludge worms that usually thrive on wastes."
It is also—literally—a fire hazard.

Because of this fire, Cleveland businesses became infamous for their pollution, a legacy of the city's booming manufacturing days during the late 1800s and the early 1900s, when limited government controls existed to protect the environment. EvenCleveland and its residents also became the butt of jokes across the United States, despite the fact that city officials had authorized 100 million dollars to improve the Cuyahoga River's water before the fire occurred. The fire also brought attention to other environmental problems across the country, helped spur the Environmental Movement, and helped lead to the passage of the Clean Water Act in 1972.

What is Clean Water?

Safe to drink ?

Distilled?

Crystal clear?

Ask the class for a good definition of clean water.

Let class offer different definitions.

Then talk about what those definitions might mean…
Eg. We can drink water out of a tap, but would a fish placed in tap water be happy (too much chlorine, low DO).
Eg. Any one still drink out of a stream? Water is perfectly fine for fish even tho there's giardhia and other pathogens.
Distilled water good for chemistry experiments but lacks important minerals for drinking water and for organisms to live in.
Crystal clear water is gorgeous, but it might mask serious problems (metals contamination, acid water).

Crystal clear?

Safe to drink ?

Distilled?

There is no single definition of clean water.

The Clean Water Act defines clean water according to how we use it.

How do we use water?

Beneficial uses:

Drinking water

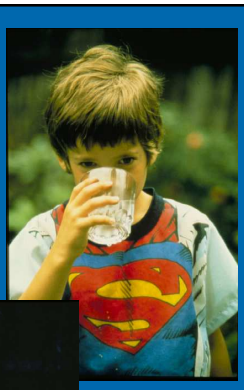
Agriculture

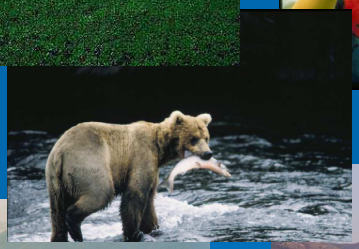
Industry

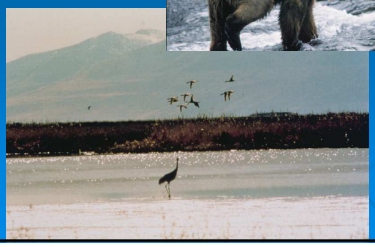
Recreation

Fisheries and other aquatic life

Aesthetics







a little about CWA … 1972 first passed in its current form. Extremely important piece of legislation. Prior to 1972 rivers were burning, Great Lakes were dying.
It's been a huge success, but obviously still much to do.

CWA mostly implemented at a state or tribal level, with EPA oversight.

Beneficial uses:
Note that for surface waters we're referring to drinking water SOURCES
Ag uses include irrigation and livestock watering
Industrial uses include cooling as well as multiple uses in various operations
Rec includes contact and non-contact

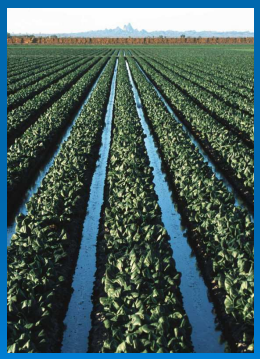
Note that in Idaho, Industry is a beneficial use but there's no such designation in Utah.
May want to talk about the GSL (unique water, state currently working on numeric standards).

May want some "factoids" about GSL at hand….salinity in southern part is ~ 10% (3 times seawater).
Salinity in northern part may be 3 times higher….hence the pink "halophytic or salt loving" bacteria that are all that can grow there.

What pollutants affect the beneficial use of drinking water source?

Bacteria, metals, organic pollutants, nitrates, pH, sediments

What pollutants affect the beneficial use of agriculture?



Salts and a few metals

What pollutants affect the beneficial use of recreation?

Bacteria, pH, turbidity, nitrate, phosphorus, sediments

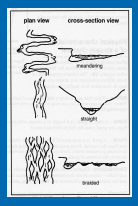
What pollutants affect the beneficial use of aquatic life?

metals, organic pollutants, pH, temperature, dissolved oxygen, ammonia, sediments

How do you know if you've got clean water?

Things to Consider

- **Physical**



- **Biological**

- **Chemical**

Physical habitat monitoring (stream form, substrate)

Advantages:

- Reflects hydrologic impacts
- Relatively low cost

Disadvantages:

- May not reflect actual water quality
- May be subjective, lack of repeatability

Biological monitoring (macroinvertebrates, algae, fish)

Advantages:

- Integrates impacts over time
- Biological impacts = loss of beneficial use
- Easy to collect

Disadvantages:

- Need for reference sites
- High degree of heterogeneity in samples

Chemical monitoring (water column)

Advantages:

Standardized methods
→ repeatable , comparable
Easy to collect
Related to toxicity or other impacts

Disadvantages:

Discontinuous in time and space

Pollution Source Types:

Point sources

Nonpoint sources

Water quality testing targets the pollutants that affect different beneficial uses.

Water measurements we will make or observe in the field.

- Temperature
- Dissolved Oxygen
- pH
- Turbidity
- Riparian (streamside) vegetation
- Flow (qualitative)

Features of the watershed and sources of pollutants that may cause water quality to change.

Structural Elements	Human Impacts
Narrow valley, steep, fast river	Pipes
Wide valley, wide slow river	Canals coming in
Shade near the stream	Changes in flows
Vegetated banks	“rip rap”
	Nearby land uses
	Animals

Why do we care about temperature?

- Fish and other aquatic life
- Other effects….
  - how much oxygen water can absorb
  - How toxic ammonia is

What causes temperatures to rise?

Natural causes:

- Seasons
- Length of river
- Location of river
- Hot springs

Human causes:

- Removal of streamside vegetation (shade)
- Runoff over concrete and other heated surfaces
- Changes in stream shape
- Reductions in flow
- Impoundments
- Industrial discharges

Maximum Temperature :

for warmwater fish is 27 degrees C

for coldwater fish is 20 degrees C

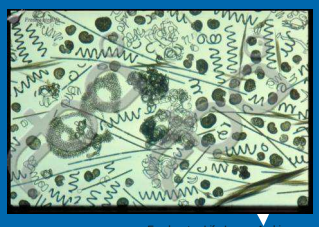
Note that it's hard to get too cold (until it freezes) – things just slow way way down.
Note also that dams may release cold bottom water that slows down the development of native fish….so too cold water CAN have impacts

The biggest concern with excess nutrients is eutrophication

Results in:

- impacts on lake/stream ecology webs;
- toxins;
- drinking water treatment problems;
- other changes in lake chemistry

Excess nutrients → Excess aquatic plants



Freshwater Life Image Archive

Dead plants decay

Low dissolved oxygen

Fish kills

What causes nutrient concentrations to change?

Natural causes:

- Seasonal changes
- Plant uptake

Human causes:

- Land uses in the watershed
  - •Fertilizers, animal manure
  - •Malfunctioning septic systems
  - •Discharges from sewage facilities and acid precipitation
  - Atmospheric inputs

Seasonal Changes – In Utah concentrations are often highest in the spring when snow is melting and runoff from the land brings nutrients from lawns, farms, etc. In fall and winter most water in streams comes from groundwater, which has naturally high nitrate concentrations.

Plant Uptake – When plants are growing they use a lot of nitrate, in the fall and winter when plants die, the nitrate is released back into the water and concentrations increase.

	Phosphorus	Nitrogen
Geochemical Cycling	Slow	Fast
Human-caused sources	Human /animal waste, fertilizer, sediment	Human/animal waste, fertilizer, burning fossil fuels
Gaseous form?	No	Yes
Soluble forms	Orthophosphate Dissolved organic	Nitrate / nitrite / ammonia
Movement through soil / groundwater?	Often no	Yes
Atmospheric deposition?	Dust	NOx, Ammonia
Toxic?	NO	Some forms
Causes eutrophication?	Yes	Yes
Limiting nutrient?	Sometimes	Sometimes

Nutrient Standards for Utah

- The maximum concentration of nitrate allowed in drinking water is 10 mg/L.
- The state of Utah considers nitrate concentrations of 4 mg/L to be an indicator of pollution problems.
- The state of Utah considers phosphorus concentrations of 0.05 mg/L to be an indicator of pollution problems.

Dissolved Oxygen

Why do we care about oxygen?

- Fish and other aquatic life
- Oxygen in water affects solubility of metals and other chemicals

What causes oxygen concentrations to change?

Natural causes:

- Uptake by organisms
- Natural increases in temperature
- Quiet water (low re-oxygenation)

Human causes:

- Any source of biological material that will decay in water
- High temperatures or low flows
- Excessive plant growth in water

Minimum Dissolved Oxygen (mg/L or ppm)

	Cold water 3A	Warm water 3B	Nongame 3C
30 Day Average	6.5	5.5	5.0
1 Day Average	8.0/4.0	5.0/3.0	3.0

Remember that Dissolved oxygen is NOT the bubbles in water. Oxygen molecules are actually dissolved.

Note also that when oxygen concentrations get extremely low, some metals and other elements (such as phosphorus) redissolve from the sediments. These dissolved forms are more reactive, often more toxic.

Note that the Dissolved Oxygen standards concentrations are pretty low… .12 mg/liter is saturated and 6.5 may be too low for some fish.

pH = the level of acidity or alkalinity in a solution.

pH Scale:

Why do we care about pH?

- Low pH can affect membranes
  (eg. gills of fish or macroinvertebrates and eggs)
- At low pH, causes some metals to dissolve into a more toxic form
- At high pH, ammonia is more toxic
- Acid precipitation can cause damage to buildings and statues

What causes pH to rise or fall?

Natural causes:

- Rain is naturally acidic
- Rapid snow melt
- Photosynthesis in water → higher pH

Human causes:

- Combustion causes acids in the atmosphere
  - ➔ acid precipitation
- Industrial discharge
- Mine drainage

An acceptable pH range is 6.5 – 9.0

Note that pH is a log scale so every unit difference ➔ a 10 fold increase or decrease.
(the scale is actually the negative log of the concentration of hydrogen ions in a solution).

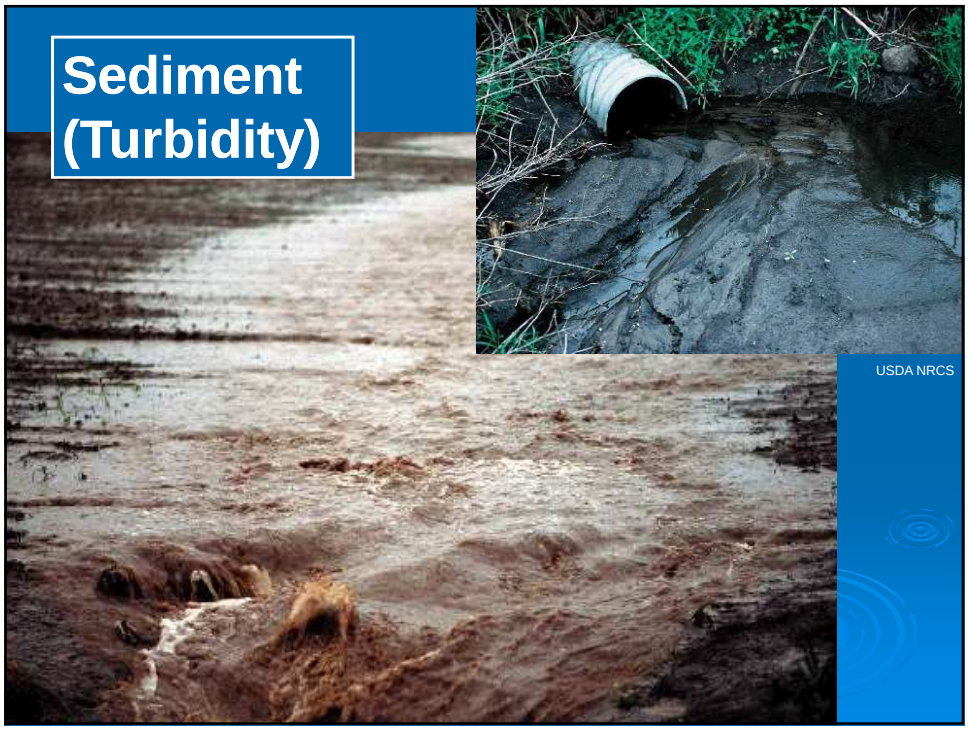
Note that as numbers get lower, the water gets more acidic and vice versa.

Note that 7 is neutral.
Ask what rain water is…..~5.6 (because it dissolved CO2 out of atmosphere as it falls and forms a weak acid).

Note that with temperature we had a Maximum
With DO, we had a minimum,

And with pH, we've got a range.

Also note that the range does not include the pH of rainwater!



Why do we care about sediments in streams and lakes?

- Can fill space between cobble in stream and smother fish eggs and tiny aquatic life.
- Very cloudy water affects visual predators
- Sediments fill in reservoirs,
- Sediments bring nutrients, metals, and more into water

What are sources of sediment in rivers?

Natural causes:

Natural "reworking" of flood plain as stream meanders

Remobilized bedload sediment under high flows

Human causes:

runoff (construction, agriculture, forestry, mining)

stream banks erosion

Total Suspended Solids concentrations

Should not exceed 35 ppm in coldwater fisheries
Should not exceed 90 ppm in warmwater fisheries

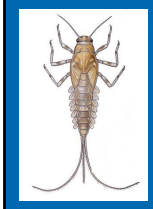
Turbidity should not increase rapidly from site to site

An increase of more than 10 NTUs violoates water quality criteria

Sediment is eroded soil or sand that has entered a waterway. The sediment smothers aquatic habitat, carries pollutants, and reduces water clarity.
Waters that are high in sediment will often appear cloudy or muddy. The sediment covers spawning gravels, clogs fish gills, introduces nutrients such as phosphorus into the water, changes water temperatures, and degrades water quality.
However, sediment also occurs naturally, particularly at times of high flow such as during spring runoff. Don't assume that brown water ALWAYS indicates a serious erosion or pollution problem.

Macroinvertebrates

- **Good Water Quality vs. Poor Water Quality**















Pollution Sensitive: Generally intolerant of organic pollutants and low oxygen conditions

Ephemeroptera




Plecoptera

Trichoptera

Some bugs can't tolerate water pollution, we call these bugs pollution sensitive.

Mayfly
Caddisfly
Water Penny
Planarian
Dobsonfly
Stonefly

Other bugs are less sensitive to pollution...

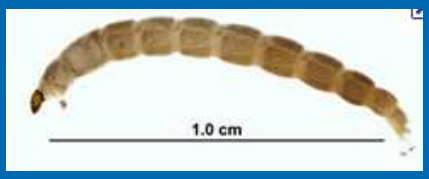
Crayfish
Clam
Fishfly
Sowbug
Scud
Riffle Beetle Larva
Alderfly
Cranefly
Dragonfly
Mussel
Riffle Beetle Adult
Whirligig
Damselfly

Some bugs can live in any kind of water. We call these bugs pollution tolerant.

Leech
Midge
Aquatic Worm
Gilled Snail
Black Fly
Lunged Snail

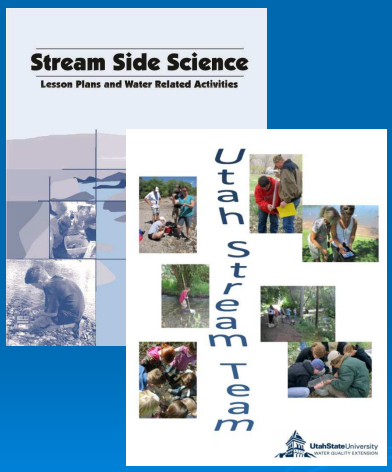
Moderately tolerant taxa

Tolerant taxa



Education and Outreach

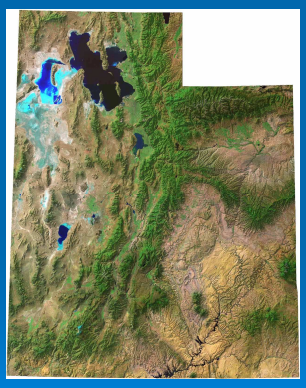
- **Curricula and teacher training**



Education and outreach

- Program delivery
  - Over 8,000 kids per year
    - Camps and field days
    - Classrooms and water fairs

For more information, contact USU Water Quality Extension at (435)797-2580 or visit http://extension.usu.edu/waterquality/

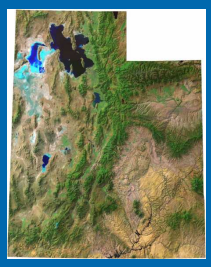


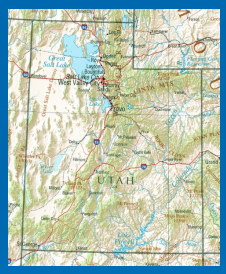
Utah State University
WATER QUALITY EXTENSION

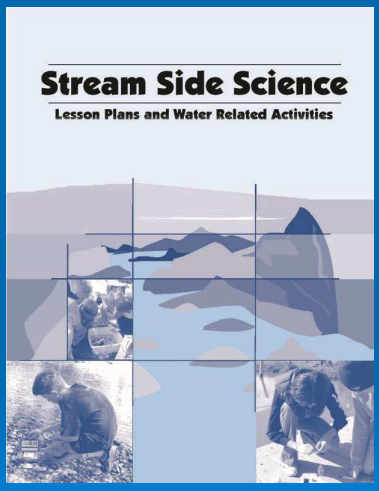
Utah Water

- http://ut.water.usgs.gov/
- http://www.water.utah.gov/waterconditions/BasinDroughtReports/default.asp
- http://www.water.utah.gov/waterconditions/ReservoirStorage/default.asp
- http://www.water.utah.gov/waterconditions/AveragePrecipitation/default.asp
- http://lakepowell.water-data.com/
- http://waterdata.usgs.gov/ut/nwis/uv?site_no=09314500

- For more information, contact USU Water Quality Extension at (435) 797-2580






Stream Side Science
Lesson Plans and Water Related Activities


Utah Stream Team
UtahStateUniversity
WATER QUALITY EXTENSION