**A River Runs Through It**
**by Alice Outwater**

We're here to talk about water in general and the Haw River in particular, and the first question is, why do we care about water? It's not just because we drink it, or because we're 60% water. It's that every one of us has personally connected with the Haw today, whether or not you realize it. When we take a shower or flush the toilet, the water doesn't go into some giant underground tank: it goes back into the Haw. Every day you personally take about 75 gallons of fresh water, and you turn it into wastewater that's back in the Haw within 24 hours. In a way, you could say that the Haw knows a whole lot about you.

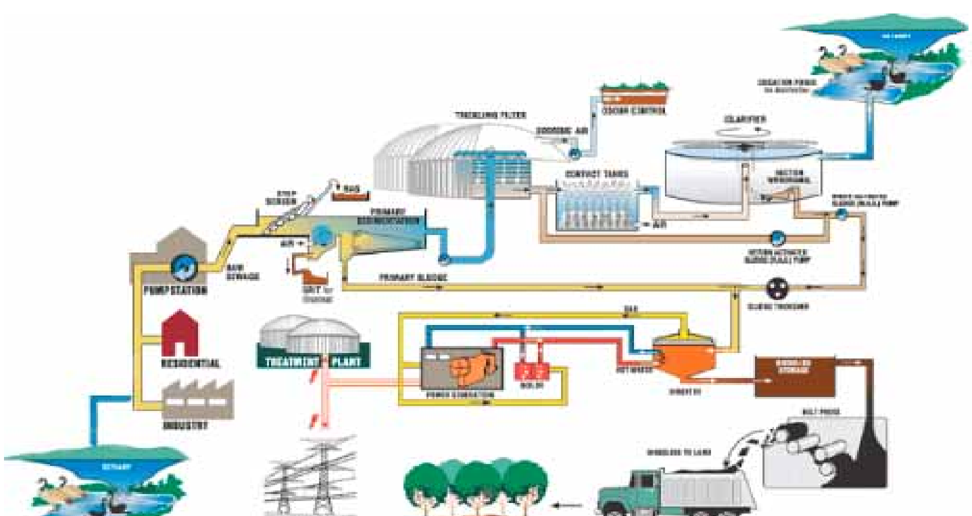
The Haw knows less about me, because I just arrived yesterday, but in the last 24 hours the Haw has dealt with my daily wastes as well. The 75 gallons of water I sent down the drain is about 10 cubic feet of water. It's the amount of water in this box. And if I was statistically average, then almost 20% of that water went down the toilet, where I added about 2 pounds of poop, and a quart and a half of pee. And let's not forget toilet paper!

I used about 12 gallons in the shower, and added a handful of shampoo, some conditioner, some soap and some scrubby stuff. I used about 15 gallons of water washing clothes, and added some detergent. I washed dishes, with more detergent, and sent part of a rotten tomato down the disposal.

And that's just me.

When you think of the 7,000 people in Elon, or the 600,000 people in the Haw River Basin, it's obvious that human inputs can seriously affect water quality.

Until the 1970s, most cities dumped their wastes directly into the river. On the Haw, textile mills dumped their dyes and chemicals in the river since the 1800s. By the time the Clean Water Act passed in 1972, the Haw was too polluted to drink or swim in. Across the country, about 2/3 of our waterways were polluted, and the reason was obvious: sewers from cities and industry dumped wastes directly into the waterways. The end of the pipe was the problem. We called it point source pollution, because the pollutants enter the waterways from a single point, and we knew how to fix it.



Courtesy of Christchurch Water Council, Christchurch, NZ

We built wastewater treatment plants. Water comes in from the reservoir, and we each add our daily load of contaminants, along with industries. Instead of dumping wastes from homes and industries directly into the waterways, we use giant tanks to clean the wastewater before it's returned to the geese and streams.

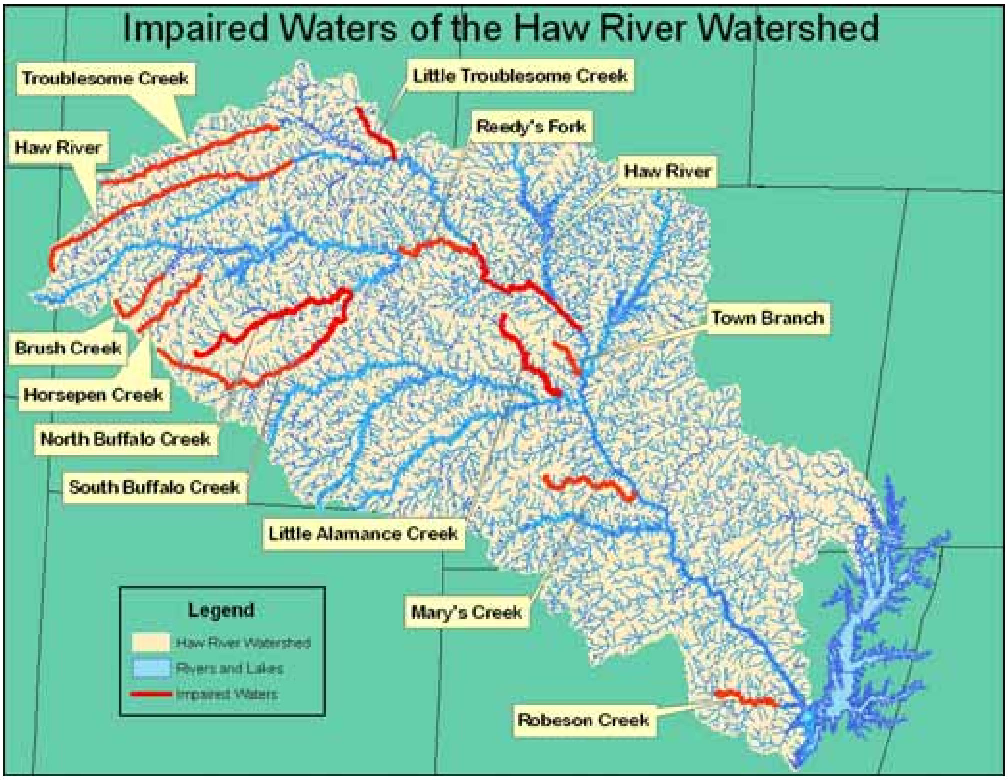
By the time our daily 75 gallons of water reaches the wastewater treatment plant, it looks like grey water with shards of toilet paper mixed in. It's about 2% solids, and the whole purpose of a wastewater treatment plant is to separate those 2% solids out of the water. To clean wastewater, we use the same processes in a wastewater treatment plant that nature uses to clean water in the natural world.

In primary sedimentation tanks, the water is held for a few hours and the solids sink to the bottom and are sent to digesters, where they are consumed by microorganisms; in nature, wetlands and ponds serve as primary sedimentation tanks, and the solids that sink to the bottom are consumed by microorganisms.

In tricking filters, the effluent flows over racks of microorganisms that consume the contaminants, like water flowing through the forest soil. Contact tanks, where effluent flows over microorganisms that consume the contaminants, are like wetlands, where microorganisms consume the contaminants in water. Clarifiers, where biosolids drop out of the effluent, are like lakes and ponds. We didn't invent wastewater treatment; we just compressed natural processes into tanks. And the processes that clean wastewater in the treatment plant are the same processes that clean the waterways in the natural world.

An excellent secondary wastewater treatment plant can remove 95% of the solids in the wastewater, so maybe just 5% of my daily contribution of wastes will be in the Haw tomorrow. Another way to put that is that the Haw gets a pile this size for every 20 people that live here, every day. Wastewater treatment plants work, and we built lots of them. The Haw River Basin, for example, has a total of 90 wastewater treatment facilities, including 14 major plants that treat over 100 million gallons of wastewater a day. Which is a good thing, because there's about 600,000 people living in the Haw River Basin. If every treatment plant in the Basin is 95% effective, the Haw River collects about 30,000 times this box of wastes every day before it hits Jordan Lake.

And that's the least of it.




Officially, the Haw is impaired by sediment and bacteria from agriculture, construction, from urban run-off and logging, by excess phosphorus and nitrogen from lawn fertilizer and from agriculture, and by stormwater from cities and towns. The problem isn't the end of the pipe, because wastewater treatment works. It's everything else. Which brings us to non-point source pollution.

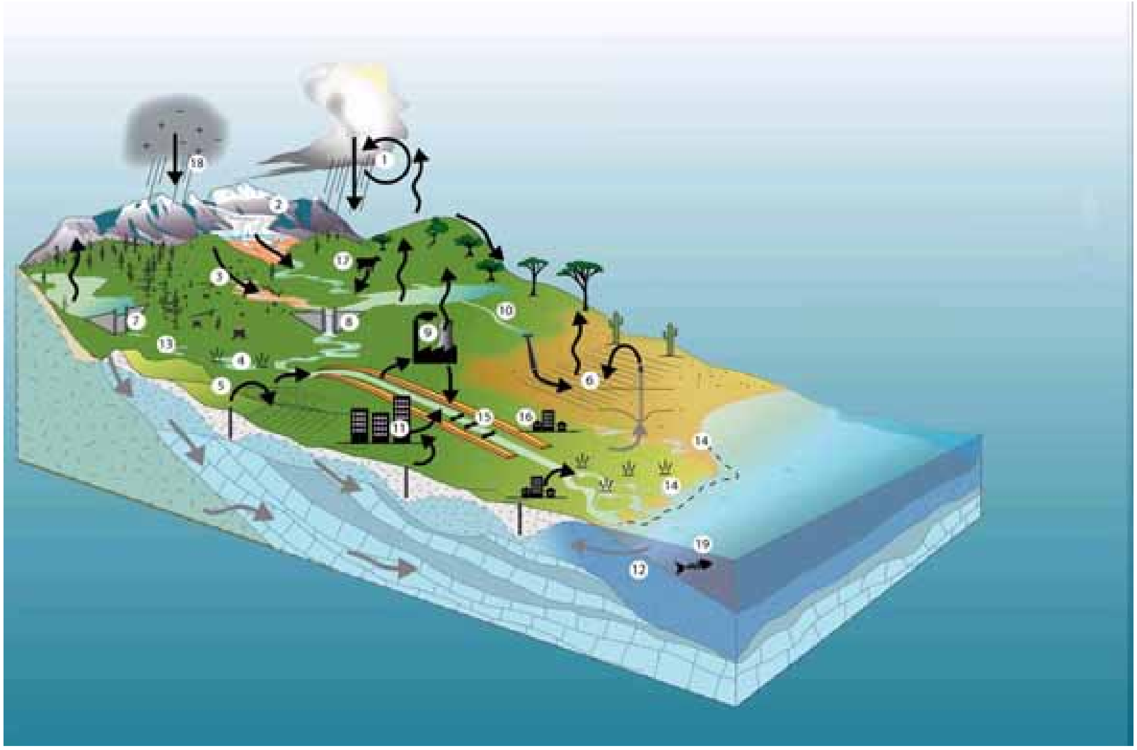


Illustration by Dr. Charles Vorosmarty. Global Water System Project, Bonn, Germany
With Permission

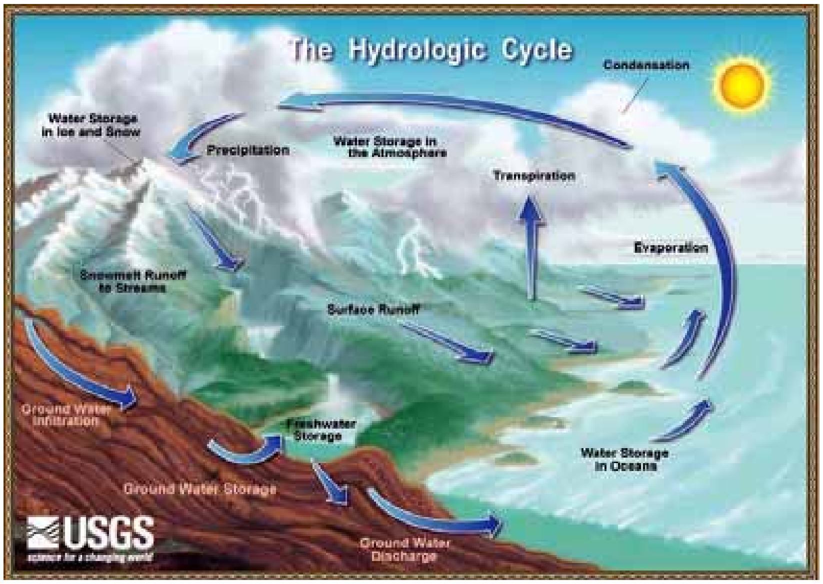
Here we have an illustration of nonpoint source pollution, and it shows the ways we degrade water quality besides what we flush down the sewers.

The rain is acidified, weakening the forests, and it carries mercury from midwestern coal plants.  Where forests are clearcut, runoff increases and rain sweeps sediment into the streams.  Dams alter flows and increase evaporation, while wetlands have been drained, impairing water quality and lowering the water table. Grazing affects runoff and water quality, and irrigation water returns to the system carrying chemicals, nutrients, and silt. Channels, levees and locks modify flows, urban areas and industries contribute contaminants, and settlements alter floodplains.

The Haw River's problems are right here: it's a dammed watershed, with old industrial inputs, major population centers, urban runoff, and industrialized agriculture.  At the same time, we know that healthy watersheds clean the water, and that the life in the waterways removes the impurities in the water: what looks like feces to me is dinner to the microorganisms at the base of the food chain.  So instead of focusing on what we do to the waterways, let's step all the way back and see what happens in a healthy waterways.

Let's look at the water cycle itself.

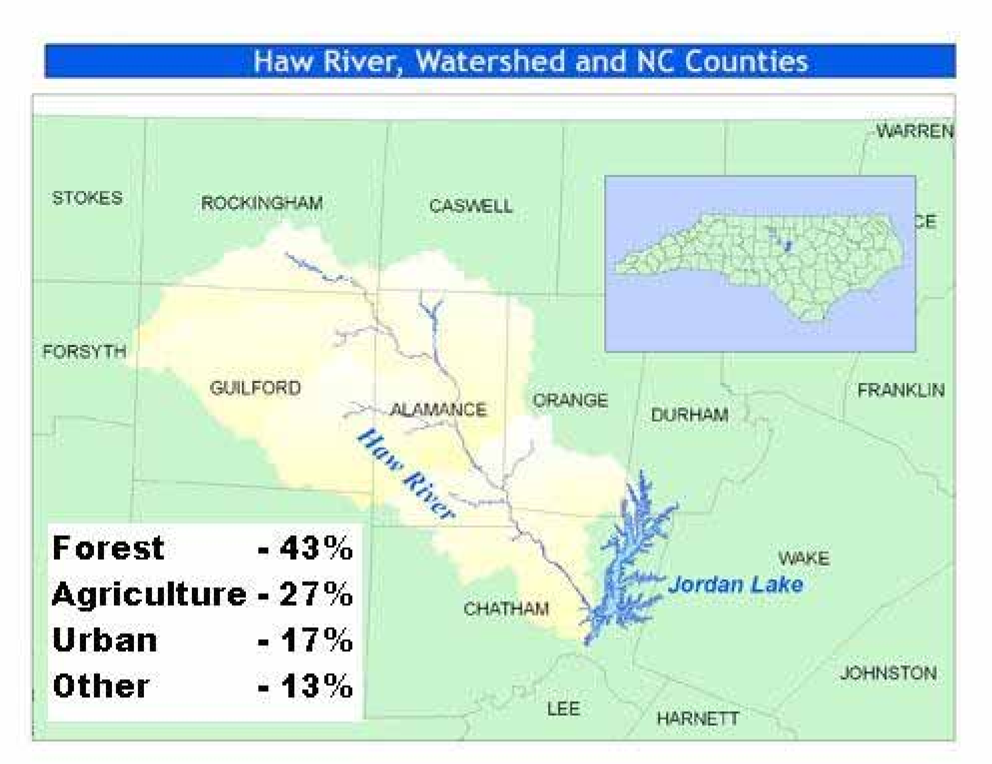
As we all know from sixth grade science, water always in motion from the rain to the mountaintops, through the forests and plains to the sea, and so to the clouds again. Water evaporates and is stored in the atmosphere; it comes down as rain, is taken up by plants and transpires back to the atmosphere. Water is stored on land as ice or snow until it melts and maybe infiltrates down to the groundwater, where it might be stored, or reemerge in springs and streams. And finally, water runs overland to the waterways, picking up silt and contaminants. Since water falls everywhere, water quality in the waterways depends on what the land looks like. Water quality improves when rain soaks into the soil, where the water is filtered and its impurities are consumed by the soil bacteria. Surface runoff, here, impairs water quality, because the water picks up sediment as it flows.




This is the water cycle theoretically.

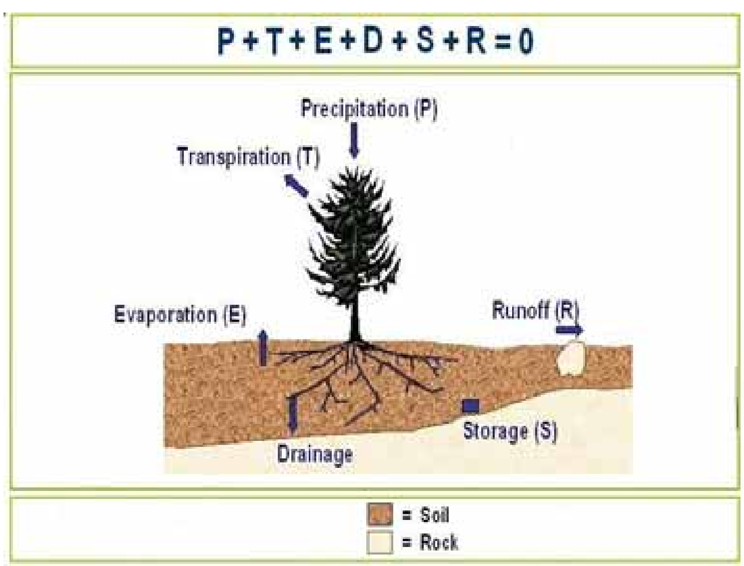
And let's look at the Haw more specifically.

This map shows how the land is used in the Haw River Basin and in the state.



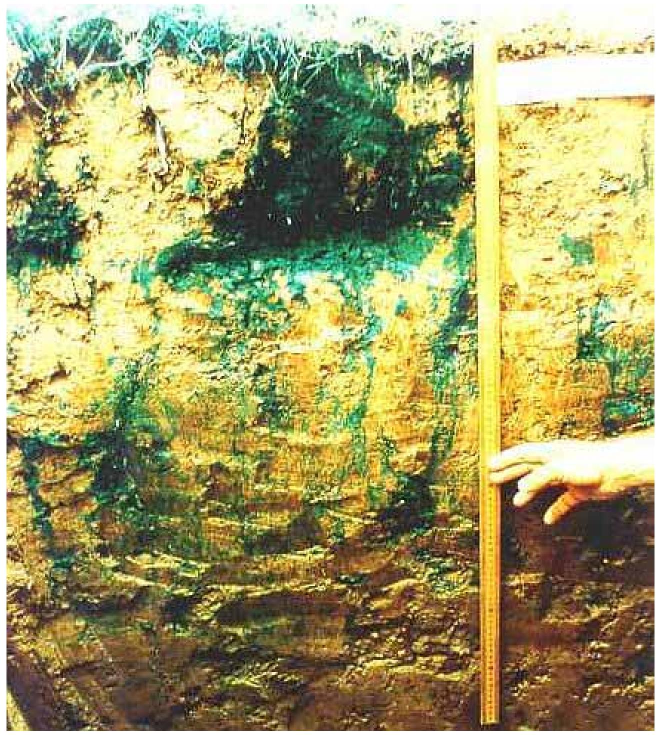

This watershed is 70% forests and farms, and 30% urban and suburban. We may think of this area as developed, but from the rain's point of view the watershed is mostly forest and field. And any individual raindrop that falls on this watershed will most likely fall in a forest. So let's zero right in on a tree that's standing somewhere in Alamance County.

When a single raindrop falls on a tree, the old sixth grade water cycle looks like this:



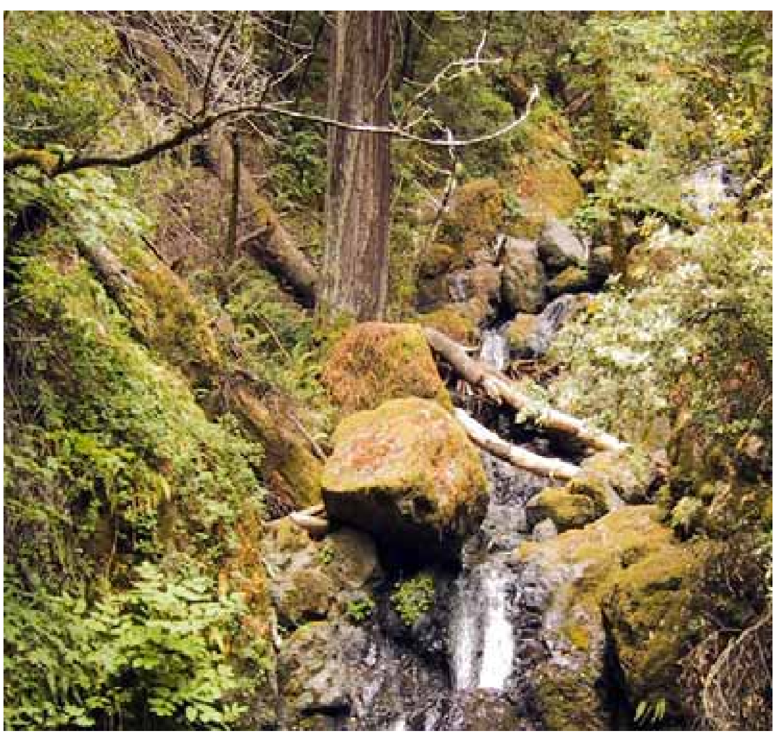

Precipitation comes down as a raindrop that might strike a branch, and drip down the trunk and go into the soil to be taken up by the root system and transpired, or evaporate from the surface of the ground. Over half of the rain that falls on a forest goes directly back into the air through evaporation and transpiration, created a moist microclimate. Some of the rainfall will percolate down through the forest floor to become groundwater that feeds springs and streams, some may stick around as storage, and some of the rainfall will run overground until it reaches a waterway.

The soil is shown as an undifferentiated mass, but it's actually heavily tunneled. This photo shows grasslands soil where dyed water was poured on the surface, and then the cross section was excavated. We can see that water doesn't move uniformly through the soil. There's not a zone of saturation that that moves down from the surface. Instead, the water runs down holes built by animals, through channels left by decayed roots, and through tunnels built by worms and beetles.



Forest soil is more heavily tunneled than grassland soil, and under a healthy forest, over half of the soil is simply space. But under a grassland or forest, it's the roots of the plants and the underground excavators, the worms and beetles and moles that determine how much precipitation soaks into the soil, and how much runs overground. If there's more life in the soil, more tunneling mammals, reptiles, bugs and worms, water quality improves because more water soaks into the soil.

Flury, M., and H. Flühler. 1995. Tracer characteristics of brilliant blue FCF. Soil Science Society of America Journal. 59:22-27.



The water that doesn't sink into the soil--the runoff--collects into rivulets that flow into a brook joined by another and another until ultimately a river reaches the sea.

Runoff always carries silt with it; little rock particles scrubbed from the earth that are fine enough to become suspended in water as it flows downstream. Silt is tiny, and once it's in the waterways, silt provides the inorganic elements that life depends on, while plant debris provides the food for the life in the water.

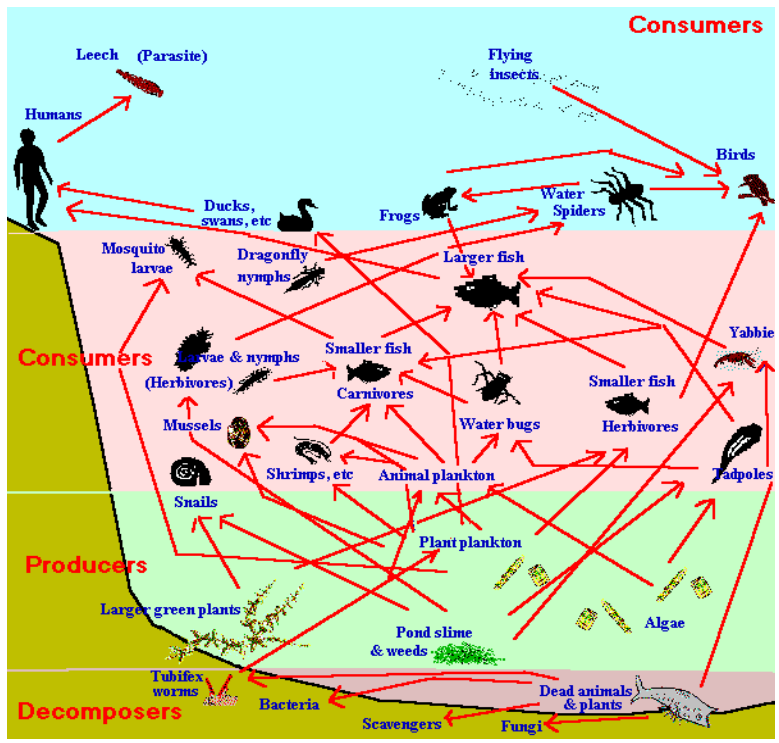
Without silt and

plant material in the water, there would be no life in the water. A healthy stream depends on regular inputs of silt and plant material that makes up the base of the food chain in aquatic ecosystems.

So a clean stream isn't one with no silt or debris/ it's one where there's a balance between the inputs to the stream and the life in the water.

In the headwaters, the trees along the stream shade the water, so plant plankton doesn't contribute many calories to the food web. Mosses on boulders, bedrock and wood cover more than 20% of the stream surface, and there's a patchy blue-green algae community associated with the mosses. Most of the nutrients that feed forest streams are from the trees that topple into the water from the riparian zone. These trunks are broken down by rubbing against the streambed and boulders, and by bacteria, fungi, wood eating larvae, stoneflies, and snails.

In a lake, nutrients cycle from the bottom to the top and back to the bottom again. This diagram of a lake ecosystem is off because the plant plankton depends on sunlight, and is actually a surface layer. Nonetheless, the primary producers--the plants, plant plankton and algae--are eaten by snails and shrimp, tadpoles and animal plankton, which are dinner for fish and bugs that feed larger fish, birds and frogs, which die and sink to the bottom where they're eaten by bacteria and scavengers to become nutrients for the primary producers. The nutrients cycle from the phytoplankton at the top through the bigger things in the middle to the bacteria at the bottom and back up again.

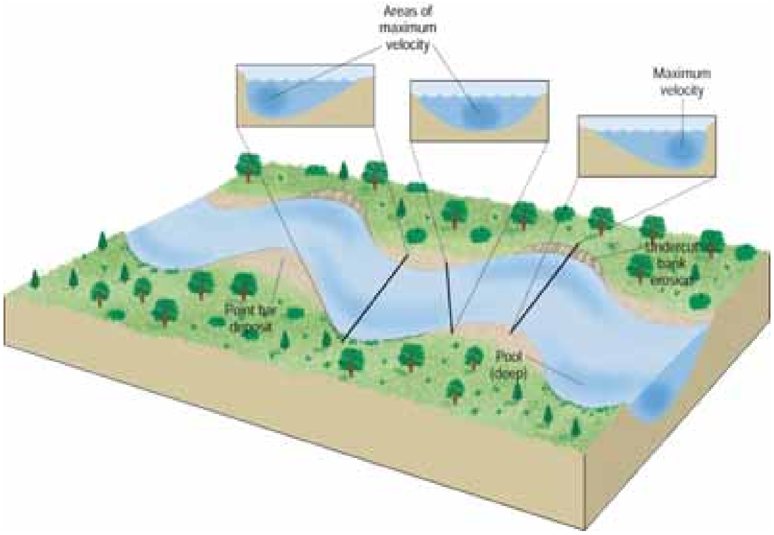



Freshwater Ecology: Pond Food Web,
Yarra Valley Water Education Program, Australia

In a stream, nutrients are swept along in the current, so instead of cycling in place the nutrients spiral down the river system. In a stream flowing through an old forest, logs obstruct the channel and create two kinds of habitat: little pools that retain organic matter and nutrient, and the running water. Little dams formed by fallen trees tighten the nutrient spiral and increase the productivity of the stream ecosystem.

Again, to increase the productivity of the stream ecosystem, and to improve water quality, we like streams interspersed with little ponds that tighten the nutrient spirals and increase the number of creatures that eat the impurities in the water.

Trees continually fall into the water because the waterways aren't fixed on the landscape: they are always moving because of the way water flows.

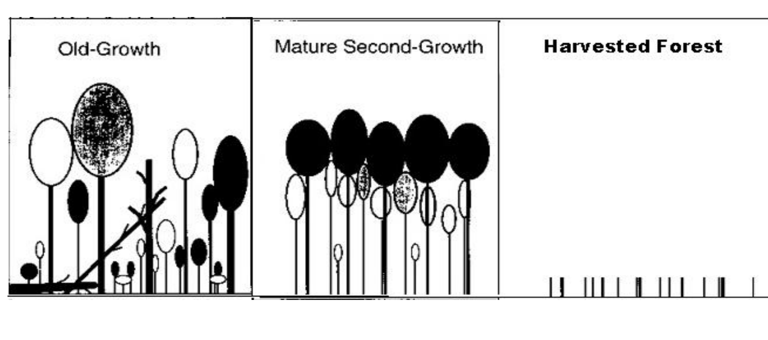



Water that flows in a river moves like a corkscrew, twisting in on itself. The water that flows at the bottom here moves more slowly because of friction between the water and the riverbank, while the water on top moves faster. This dark blue area is the zone where the water moves faster in a straight stretch of river, and the water is moving slower on the edges. When a river bends, the faster water in this blue zone pushes against the outer bank and erodes it, while the slower siltier water at the bottom slips to the inner bank and drops some of its sand or gravel. The faster water pushing against the outside of a curve dumps soil and trees directly into the waterways, and the gravel left at the inner curve is where fish lay their eggs.

The banks are always being pushed out at the bends, while the middle sections get thinner. Over time, a river channel writhes like a snake with the loops sliding downstream and throwing off oxbow lakes as it goes.

Here we have a river writhing downstream. The water is flowing towards us, and has left oxbow lakes behind as its channel moves downstream. The oxbow lake on the left was once part of the river channel, but due to a blockage or flood, the river jumped its banks and formed a new channel. The river is cutting into its banks on the outer curves, depositing silt and gravel on the inner curves, and eventually some of the meanders will meet and form new channels, leaving behind other oxbow lakes.

Waterways move more than we realize, and the changing riverbanks feed trees into the water. During spring runoff or flash floods, trees can pile up in the channel and dam it, forcing the river to jump its banks. Forests clean the waterways, and they change the path that water takes through the land. When we talk about water quality, we're talking about a complex interaction between the land and the water.




Here we have a diagram of a classic old growth forest. There are trees of all ages from very old to very young.  Fallen trees make openings in the canopy that allow young trees to grow.  There's a well-developed understory, a thick layer of duff on the forest floor, and the soil is heavily tunneled.  The pathways water takes through an old growth forest are complex, and the streams are more likely to be pooled by large trunks in the channel.

In a forest managed for timber, the trees are smaller and more uniform in age.  The understory is less developed, so the pathways that water takes from the canopy to the ground is simpler.  The layer of duff on the forest floor isn't as thick, so less water filters down to the water table.  And the forest is cut periodically, when runoff soars and much of the impact on water quality is determined by how much of a buffer zone is left along the edge of the waterways.

We've been looking at forests and waterways as if a forest is simply a collection of trees that provides organic materials for the waterways.  But a forest is home to animals that change the pathways water takes through the land.  So let's go into the forest and see how the forest community affects water quality.

Here we have a familiar cohort of animals.  We have the little creatures that live in the understory and tunnel the forest floor.  There are the grazers that eat the understory and browse the riparian edge, and then there's the beaver that manage the waterways.

In the past, beavers were often kept as pets. Beaver are friendly sociable animals that will follow their owner around like a dog, and like to be rubbed on the belly. But they are a terrible addition to a modern household, because beavers like to build dams. If you leave a beaver alone in a house, it'll cut down the legs of tables and chairs to build little dams between furniture. When they're left outside, they rearrange the waterways.

Canada Science Technology Museum, **Image No.:** CN000942, c. 1931

from Harun Yahya, *Devotion Among Animals: revealing the work of God.* Ch.2. Awareness in Animals: One of the dead ends for the theory of Evolution, Figure 5.

A full-grown beaver can weigh 60 or 70 pounds—the largest recorded in British Columbia is 110 pounds--and since they're strict vegetarians they have sweet meat. To avoid being everyone's favorite prey, they build dams so the water backs up into a pond that hides the underwater entrance to their lodges. Beaver live together in colonies of a half dozen to a dozen individuals. There's the Mom and Dad, this year's litter of 2 to 4 kits and last years teenagers, who leave the pond when they're three years old. Beavers repair their dams every night, and a colony can build a 35-foot dam in a week. In the past, colonies continuously maintained dams for generations, and some of the dams were so large that they literally created lakes.

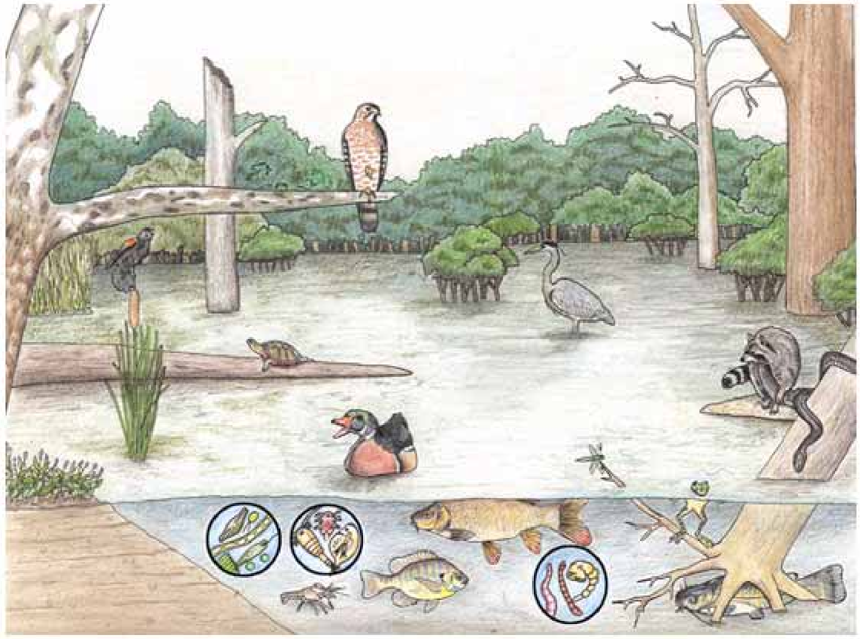
This National Geographic photograph from 1921 shows a beaver dam so old that trees are growing on top of it. Of course, this dam and lake no longer exist, because the beaver were trapped out of most of our states entirely, and their giant multigenerational engineering projects fell in.

But before the Europeans arrived, beaver were one of the most successful mammals in the region. Along thousands of streams lived colony after colony, dam after dam of beaver in close succession, as many as 300 dams per square mile, and each with it's own ring of wetlands. Over thousands of years, beavers captured mountains of topsoil that would have been swept to the sea, building fertile bottomland valleys. And beaver wetlands improve water quality.

Photograph by George Shiras, 3rd *The National Geographic Magazine*, Vol.40, no.2, p.202, [August 1921]

Here we have a stream that beavers have engineered, with all its water-cleaning apparatus laid out. Instead of silty water rushing downstream, the dams have formed settling ponds where the solids drop out. Particles cling to the stalks of the emergent vegetation and settle down to the bottom of the pond where they are consumed by microorganisms. The silt and wastes that we see as water pollutants are food for the wetlands ecosystem. And there are some odd subtle effects as well. Acid rain allows metals to move into the waterways, but when a stream hits a beaver pond, the metals flocculate out. Beaver ponds buffer the water and remove the metal loads associated with acid rain. Meanwhile, the beaver dam increases the amount of edge in the ecosystem, that fruitful zone where two communities meet. There are aquatic species, dryland species, and species that are specific to wetlands.

You get raptors, waders and wood ducks, reptiles, amphibians, crustaceans and fish, and a dense and varied food web. And the crush of life in a wetlands is due to the planktonic community, which transforms water contaminants into the base of the food web. Beaver wetlands increase the amount of life in the waterways. They increase the productivity of the aquatic ecosystem, which cleans the water. And they increase the volume of water that percolates down to the groundwater.



Center for Environmental Education and Natural History at Miami University (Oxford).

This is a cross section of two streams miles apart, with the water level of the streams here, coming right at us. If you add a beaver dam, the water seeping down from the pond and wetlands actually raises the water table, increasing the flow of nearby springs and streams. When you add beavers to the watershed, more water percolates down to the groundwater, and their wetlands act like a soaking up water during high flow and releasing it slowly, reducing the flood crest downstream. And it tightens the nutrient spirals of a stream by adding small ponds that increase the productivity of the stream ecosystem, and the ability of the waterways to clean themselves.

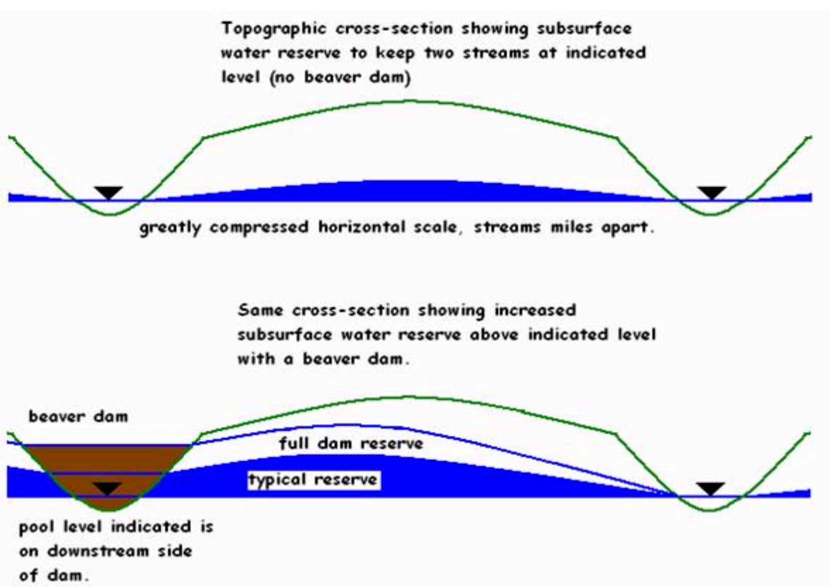



Illustration by Steven Grannes, University of Minnesota M.S. Agricultural Engineering 1984; with permission.

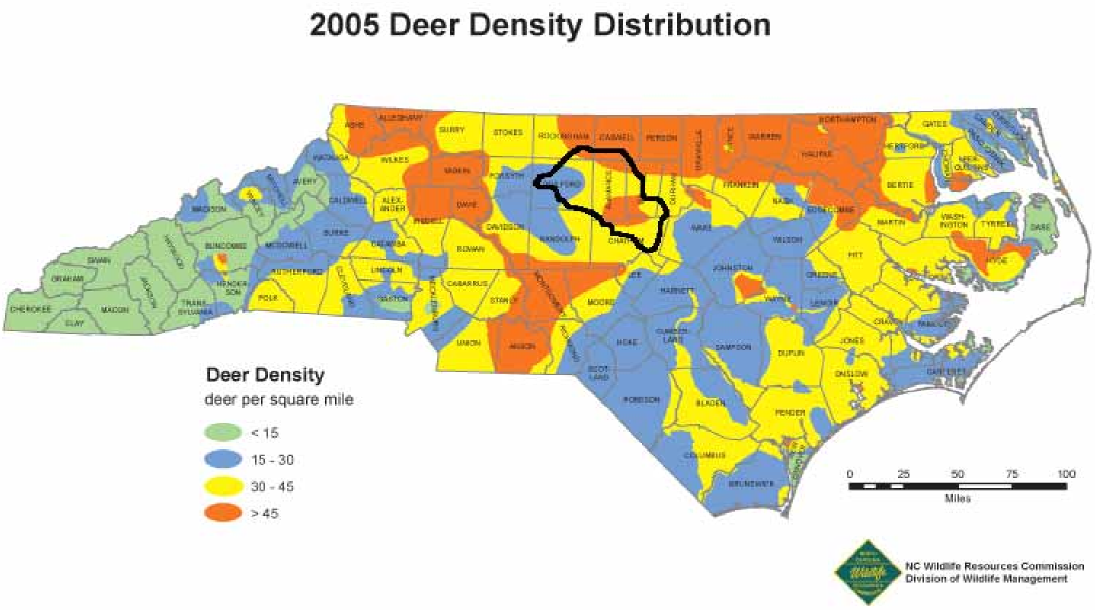
In North Carolina, Beaver were entirely trapped out by the late 1800s, and the species was reintroduced in the late 1930s.  Since then, the beaver populations has grown steadily, and today about a half million beaver build dams in the state.

One easy way to improve water quality is to increase the beaver population.  But that's not so simple in North Carolina, where the state currently spends about $700,000 a year controlling the beaver population.

In North Carolina, as in many areas, the carrying capacity of the land is higher than the social capacity for people to put up with beavers.  These guys like to build dams in culverts, and make hayfields into wetlands.  Beaver are adorable until they flood out your septic system.  So we don't want more beavers in fields or suburbs; we want more beaver in the forest.

Taking one more look at this forest community, we see that the beaver is building wetlands that clean the water, and the chipmunk and mink are building tunnels that make cleaner water.  But the deer is grazing on the understory, and browsing the riparian edge.  It's reducing the cover for the little guys who live on the forest floor and help water soak into the ground.  And it likes to graze on the lush vegetation by the waterways, shaving the riparian edge that cleans and filters the runoff.

In this picture, the top predator that eats the grazers and controls their numbers is missing.  There's no wolf in this picture, no catamounts, and since hunting season is closed, there aren't any hunters.  It's good times for deer these days.




The North Carolina division of wildlife management estimates that there are a million or so deer in the state, and the Haw watershed here is a hot spot for deer, with 30 to 5o or so deer per square mile. This gives us roughly 40,000 deer grazing the watershed.

We didn't understand how wolves organized the grazers until wolves returned to Yellowstone in 1995. Until then, the deer and elk grazed intensively, and particularly liked the lush vegetation along the water's edge. When the wolves arrived, there was one beaver colony in the park.

After ten years of wolf predation, the deer and elk graze in smaller groups, and move more frequently. Wolves hunt along the water's edge, so the grazers don't strip the riparian edge anymore. As a result, the beaver population in the forests has exploded. There was one colony of beavers when the wolves arrived, and ten years later there are nine, with a whole new set of colonies expected to form this summer. And the populations of songbirds have blossomed; with lots of new species and more nesting pairs all round. In Yellowstone, wolves increased the beaver population by 9 times in a single decade.

Yellowstone shows that when you add wolves to the forest, they organize the grazers in ways that improve water quality. Since wolves hunt along the waterways, grazers stay out of the riparian edge. That ungrazed riparian edge helps the beaver survive that uncertain time when they're three years old and leave their parents lodge to build their own dam. A thicker riparian edge lets the three-year-olds to hide until their pond fills in and they finish building their lodge. In Yellowstone, wolves changed the grazing patterns in ways that improved beaver habitat, and beaver populations increased nine times in a decade.

The red wolf was reintroduced to North Carolina really quietly back in the 1980s. Since the first few were released on the Outer Banks, the population has grown steadily until now about a hundred wolves are living in the Alligator River National Wildlife Refuge. But on the Haw Watershed, the wolves are still missing. We have a lot of deer in these counties, and we've taken the role of top predator. But we're not managing their grazing; we're managing their numbers. When predators apply steady low-intensity pressure on grazers, and wait by the water's edge to pounce, grazing patterns change in ways that improve water quality. Instead of stripping the water's edge, grazers run down to drink at a stream and then leave. Instead of grazing intensively in herds and taking out the understory, they graze in smaller groups and move on. So one way to improve water quality in this region is to reintroduce the wolf. Which brings up the cattle, the other big grazer in the area.

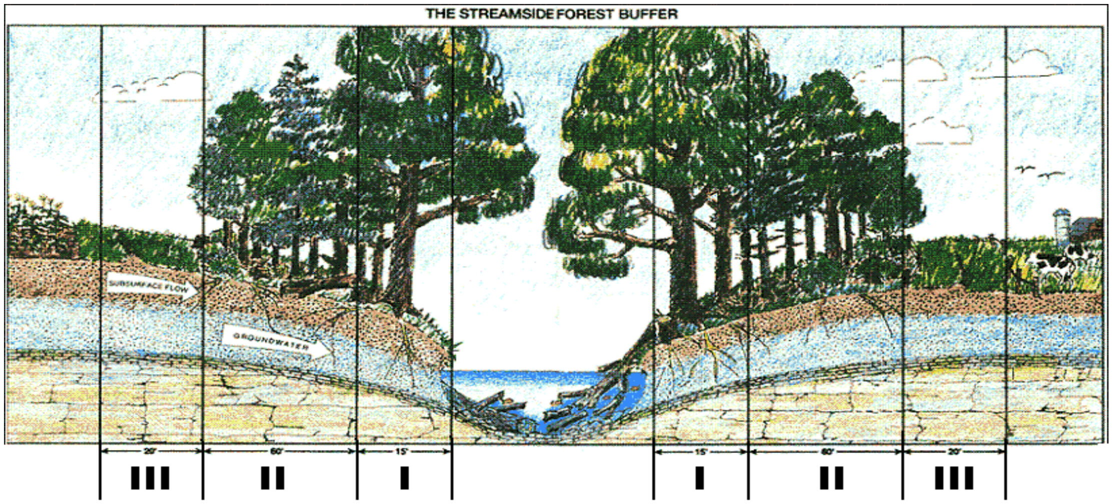
Cattle graze on cleared land, and they browse the riparian edge. In the Haw watershed, there are about 40,000 cattle along with the 40,000 deer, or roughly as many cattle as deer. And both the cows, and the deer, are grazing the edge of the stream, and taking out the edge that cleans the waterways.

We like a healthy riparian edge for many reasons. It screens and filters the runoff, and feeds a steady stream of organic matter to the waterways. It makes the water cooler in summer and warmer in winter. It keeps nitrogen and phosphorus-excess fertilizers and leechate from manure piles from reaching the waterways, and it lowers the amount of silt and bacteria in the water. When you add cattle to a stream, they lounge around in the waterways, and churn the riparian edge into a mud hole. When that green edge is stripped away, the fish that hid in the shadows lose their shelter. Stream temperatures rise, and the sunlight spurs algae growth, decreasing the oxygen content of the water, and the fish population. Silt covers the gravel beds where the fish spawn, there are fewer places for frogs to hide, stream life is simplified and more soil washes into the river. And if trees aren't holding the banks, the stream channel moves more easily, dumping more soil in the waterways.

Courtesy of the Minnesota River Basin Data Center, Minnesota State University, Mankato, MN

This picture here shows the exact reason that agriculture supplies so much of the silt and pollutants to the waterways: grazing animals destroy the green edge that keeps contaminants from reaching the waterways, and plowing the land for crops exposes a huge amount of soil that can be swept into the waterways.

To reduce the water quality impacts of crops and grazing, you let nature take care of the water's edge. Exclusion fencing that keep cattle out of the waterways can have quick water quality improvements. And if exclusion fencing is left up, the grasses and willows make way for trees, and you'll end up with the gold standard of water quality protection, the riparian forest buffer.




United State Department of Agriculture, Forest Service, NA-PR-07-91

Here we have a waterways protected by a riparian forest buffer that removes most of the nitrogen, phosphorus, silt and bacteria from runoff. It's pretty wide. This is a modest USDA buffer of 95', but in the Chesapeake watershed they like a buffer of 300', while the North Carolina Wildlife Resources Commission is asking for 25 to 100 feet. You have three zones. The fifteen foot strip next to the waterway, Zone I, is untouched. The trees shade the water, making cooler water in the summer and warmer water in the winter, while those nice debris dams from the trunks provide cover and food for the aquatic ecosystem. Zone II is 60' of woodlot in this diagram, and the trees extract nitrogen and phosphorus from the run-off. These trees are cut periodically to remove the nutrients sequestered in them and to keep the forest young and fast growing. And Zone III, a 20' buffer, can support some grazing and haying. The forest buffer increases infiltration because its soil is tunneled. It keeps nutrients, silt and pesticides out of the waterways. It slows down the runoff, reducing erosion. And you get a riparian forest buffer naturally, over time, if you exclude livestock and watering facilities from the water's edge. If you plant trees along the bank after fencing, the tree crowns close over a stream in a decade.

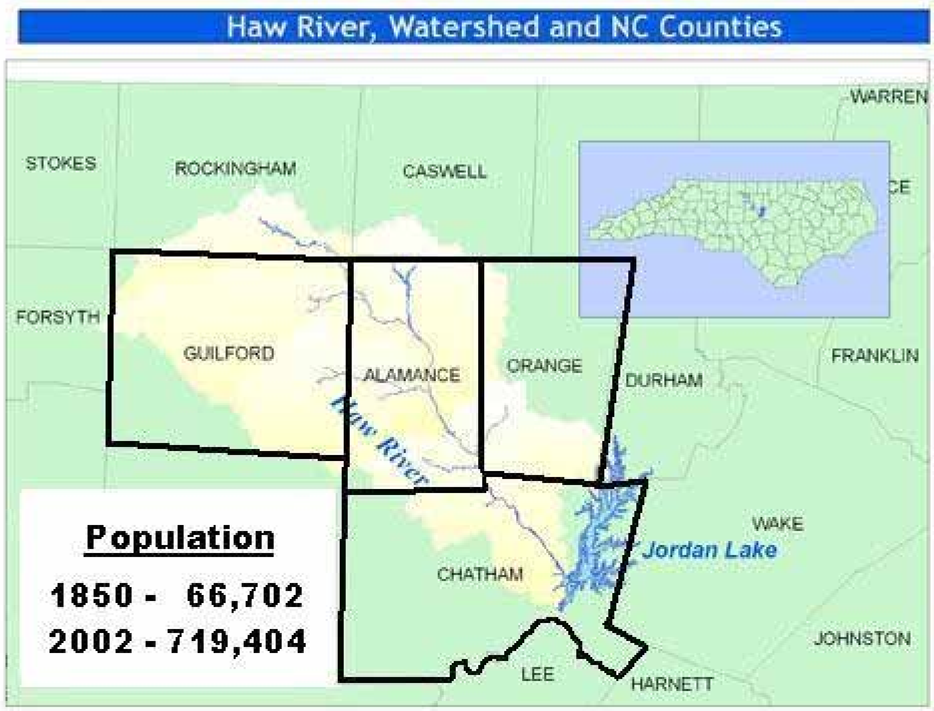
In 1996, the Chesapeake Bay Watershed Alliance decided to add 2,000 miles of forest buffers to their watershed in a decade. By 2002 they had already met their goal, so now they're shooting for 10,000 miles of forest buffers by 2010.

The curious thing about increasing the miles of riparian forest buffers in the watershed is that there's federal and state support for private landowners to create buffer zones, but it's not something that happens top down. It's a bottom up process. Individuals like Professor McFall make buffer zones a reality parcel by parcel, and local environmental groups working with individual landowners are the people who actually increase the miles of buffer zones. If a group like the Haw River Assembly set a goal of a few hundred miles of additional fenced riparian zones or forest buffers, it might prove to be easier to reach than you'd think. And it would improve water quality.

Urban runoff can be treated by that green edge as well. When cities pipe their storm flow into wetlands instead of piping it directly into the river, water quality improves. And when city zoning regulations use green strips to filter runoff from parking lots, and green belts to manage their storm flows, water quality improves.

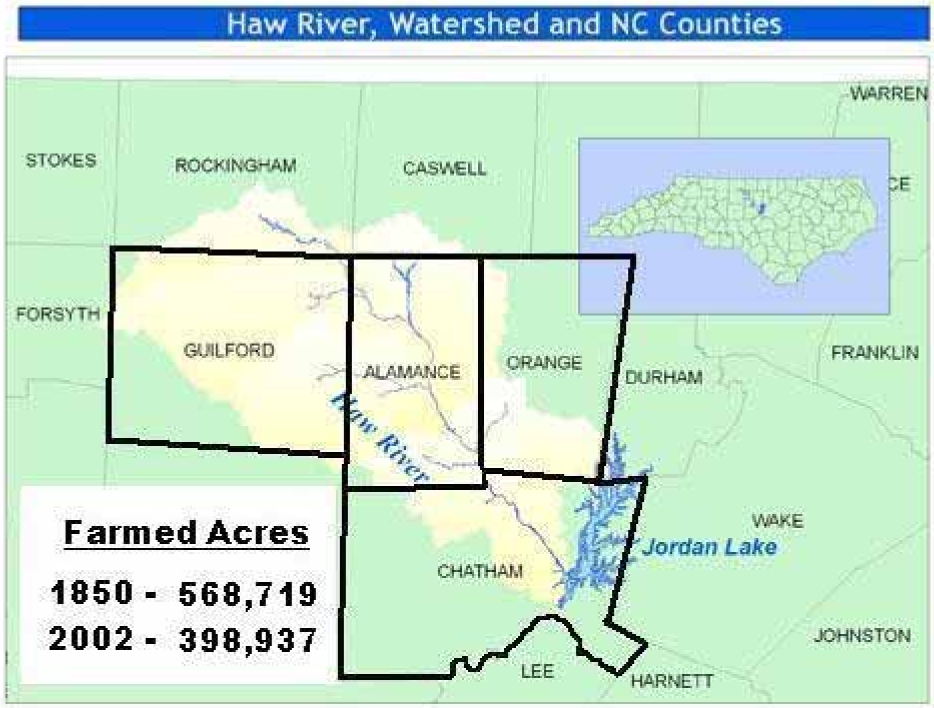
Agriculture is the #1 source of pollutants on the Haw watershed, and that's not just the cows. It's the cumulative affect of every acre of plowed cropland, and every animal. So I thought I'd check how agriculture has changed in this region since plantation days.

The 1850 census lists agricultural production for every county in the US, right down to the exact number of oxen and pounds of beeswax. And the 2002 USDA Census of Agriculture provides the same level of detail for every county 150 years later.




Until now, we've been talking about the Haw watershed, but to look at agricultural production we're going to look at these 4 counties. It's more than just the watershed, but the rest of Orange County drains into Jordan Lake, and so does this part Chatham County.

Now, there's more than 10 times the people living here compared to before the Civil War, but at least half of those people are living in cities, so throughout the watershed it's more like there are 5 times more people on the land than there were in 1850.




There were a lot more farmed acres in 1850 than there are today. The total acreage of these four counties is about 1.4 million acres, so in 1850, the area was 40% farmland, and today it is 28% farmland.

And now let's get down to the nitty gritty

In 1850, there were

1850 census of the united states
Alamance, Guilford, Chatham and Orange counties

66,702 people (17,609 enslaved)

17,137 horses
47,201 milch cows, working oxen + other cattle
47,668 sheep
129,455 swine

They grew
2,385,326 bushels corn
420,763 bushels of wheat
460,167 bushels rye and oats
46,592 bushels irish potatoes
165,798 bushels sweet potatoes
27,526 bushels dried Peas and beans

432,928 pounds butter and cheese
224,582 pounds tobacco.
16,731 Pounds beeswax and honey
769,138 Pounds wool
120,782 Pounds flax
1,598,000 pounds ginned cotton

When you look a the same area 150 years later, some things are still the same

| | 1850 | 2002 |
|---|---|---|
| Horses | 17,137 | 3,200 |
| Cattle | 47,201 | 43,326 |
| Sheep | 47,668 | 2,003 |
| Swine | 129,455 | 10,055 |
| Chickens | --- | 38,600,000 |

They grew

| | | | |
|---|---|---|---|
| Corn for grain | 2,385,326 | 219,861 | bushels |
| Corn for silage | --- | 420,000 | bushel eq. |
| Wheat | 420,763 | 460,167 | bushels |
| Rye/Oats | 528,948 | 42,773 | bushels |
| Irish Potatoes | 46,592 | 4,956 | bushels |
| Sweet Potatoes | 165,798 | 1,980 | Bushels |
| Dried beans + peas | 27,526 | --- | Bushels |
| HAY | 16,738 | 105,313 | tons |
| Butter/ cheese | 432,928 | --- | Pounds |
| Beeswax + Honey | 16,731 | --- | Pounds |
| Flax | 120,782 | --- | Pounds |
| Wool | 769,138 | --- | Pounds |
| Ginned Cotton | 1,598,000 | --- | Pounds |
| Tobacco | 224,582 | 11,919,444 | pounds |

In 1850, we have a system of agriculture where everyone grows a little of everything. In 2002, there are the same number of cattle, we're missing 45,000 sheep and 120,000 pigs. And instead of each farmyard having a flock of chickens that no one bothers to count, there are 38.6 million chickens.

We're growing the same amount of wheat, we're missing most of the rye and potatoes, no dried beans, peas, no fibers, and no butter and beeswax to speak of. We're growing about 8 times more hay than we did in 1850, and we're growing 50 times more tobacco.

And finally we get down to what this census data tells us about water quality. In this watershed, there were more acres plowed 150 years ago than there are today. But instead of animals spread evenly over the landscape, where their manure can be used as fertilizer, there are now huge concentrations of animals that create mountains of manure.

**Manure Production Characteristics**

Values are as produced estimations and do not reflect any treatment. Values do not include bedding. The actual characteristics of manure can vary ±30% from table values. Increase solids and nutrients by 4% for each 1% feed wasted above 5%.

| Animal | Size[1] (lbs) | Total Measure of Manure Quantity *Volume and/or Weight of Manure* (lb/day) | ($ft^3$/day) | (gal/day) | Water (%) | Density (lb/cu.ft.) | Total Solids (lb/day) | Volatile Solids (lb/day) | $BOD_5$ (lb/day) | Nutrient Content (lb/day) (N) | ($P_2O_5$) | ($K_2O$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dairy Cattle | 150 | 13 | 0.20 | 1.5 | 88 | 65 | 1.4 | 1.2 | 0.20 | 0.05 | 0.01 | 0.04 |
| | 250 | 21 | 0.32 | 2.4 | 88 | 65 | 2.3 | 1.9 | 0.33 | 0.08 | 0.02 | 0.07 |
| Heifer | 750 | 65 | 1.0 | 7.8 | 88 | 65 | 6.8 | 5.8 | 1.0 | 0.23 | 0.07 | 0.22 |
| Lactating cow | 1,000 | 108 | 1.7 | 12.7 | 88 | 62 | 10.0 | 8.5 | 1.60 | 0.58 | 0.30 | 0.31 |
| | 1,400 | 148 | 2.4 | 17.7 | 88 | 62 | 14.0 | 11.9 | 2.24 | 0.82 | 0.42 | 0.48 |
| Dry cow | 1,000 | 82 | 1.30 | 9.7 | 88 | 62 | 9.5 | 8.1 | 1.20 | 0.36 | 0.11 | 0.28 |
| | 1,400 | 115 | 1.82 | 13.6 | 88 | 62 | 13.3 | 11.3 | 1.70 | 0.50 | 0.20 | 0.40 |
| Veal | 250 | 9 | 0.14 | 1.1 | 96 | 62 | 0.32 | 0.14 | 0.22 | 0.04 | 0.03 | 0.06 |
| Beef cattle | | | | | | | | | | | | |
| Calf | 450 | 26 | 0.42 | 3.1 | 92 | 63 | 3.40 | 2.88 | 0.58 | 0.14 | 0.10 | 0.11 |
| High forage | 750 | 62 | 1.0 | 7.5 | 92 | 62 | 5.8 | 5.2 | 1.05 | 0.41 | 0.14 | 0.25 |
| High forage | 1,100 | 92 | 1.4 | 11.0 | 92 | 62 | 8.5 | 7.6 | 1.50 | 0.61 | 0.21 | 0.36 |
| High energy | 750 | 54 | 0.87 | 6.5 | 92 | 62 | 4.2 | 3.9 | 1.0 | 0.38 | 0.14 | 0.22 |
| High energy | 1,100 | 80 | 1.26 | 9.5 | 92 | 62 | 6.2 | 5.7 | 1.50 | 0.54 | 0.21 | 0.32 |
| Cow | 1,000 | 63 | 1.00 | 7.5 | 88 | 63 | 7.70 | 6.00 | 1.40 | 0.31 | 0.19 | 0.26 |
| Swine | | | | | | | | | | | | |
| Nursery | 25 | 2.7 | 0.04 | 0.3 | 89 | 62 | 0.27 | 0.22 | 0.09 | 0.02 | 0.01 | 0.01 |
| Grow-Finish | 150 | 9.5 | 0.15 | 1.2 | 89 | 62 | 1.0 | 0.90 | 0.30 | 0.08 | 0.05 | 0.04 |
| Gestating | 275 | 7.5 | 0.12 | 0.9 | 91 | 62 | 0.69 | 0.59 | 0.23 | 0.05 | 0.04 | 0.04 |
| Lactating | 375 | 22.5 | 0.36 | 2.7 | 90 | 63 | 2.25 | 2.03 | 0.75 | 0.18 | 0.13 | 0.14 |
| Boar | 350 | 7.2 | 0.12 | 0.9 | 91 | 62 | 0.66 | 0.59 | 0.23 | 0.05 | 0.04 | 0.04 |
| Sheep | 100 | 4.0 | 0.06 | 0.4 | 75 | 63 | 1.10 | 0.91 | 0.10 | 0.04 | 0.02 | 0.04 |
| Poultry | | | | | | | | | | | | |
| Layer | 4 | 0.26 | 0.004 | 0.031 | 75 | 65 | 0.065 | 0.049 | 0.015 | 0.0035 | 0.0027 | 0.0016 |
| Broiler | 2 | 0.18 | 0.003 | 0.021 | 74 | 63 | 0.047 | 0.034 | 0.010 | 0.0023 | 0.0014 | 0.0011 |
| Turkey | 20 | 0.90 | 0.014 | 0.108 | 75 | 63 | 0.225 | 0.171 | 0.066 | 0.0126 | 0.0108 | 0.0054 |
| Duck | 6 | 0.33 | 0.005 | 0.040 | 73 | 62 | 0.089 | 0.053 | 0.012 | 0.0046 | 0.0038 | 0.0028 |
| Horse | 1,000 | 50 | 0.80 | 5.98 | 78 | 63 | 11.00 | 9.35 | 1.40 | 0.28 | 0.11 | 0.23 |

[1]Weights represent the average size of the animal during the stage of production.

Source: MWPS-18 (1) *Manure Characteristics* (2000). MidWest Plan Service. Iowa State University: Ames, IA.

Here we have a chart of how many pounds of manure is produced by which animal. If you have a 750 pound heifer, you can expect 65 pounds of poop a day, or 7.8 gallons. And we can predict how many pounds of nitrogen, phosphorus and potassium are produced every day. And so it's easy to see how 38.6 million chickens affect the watershed:

## Chicken Manure Production, lbs/day and tons/year

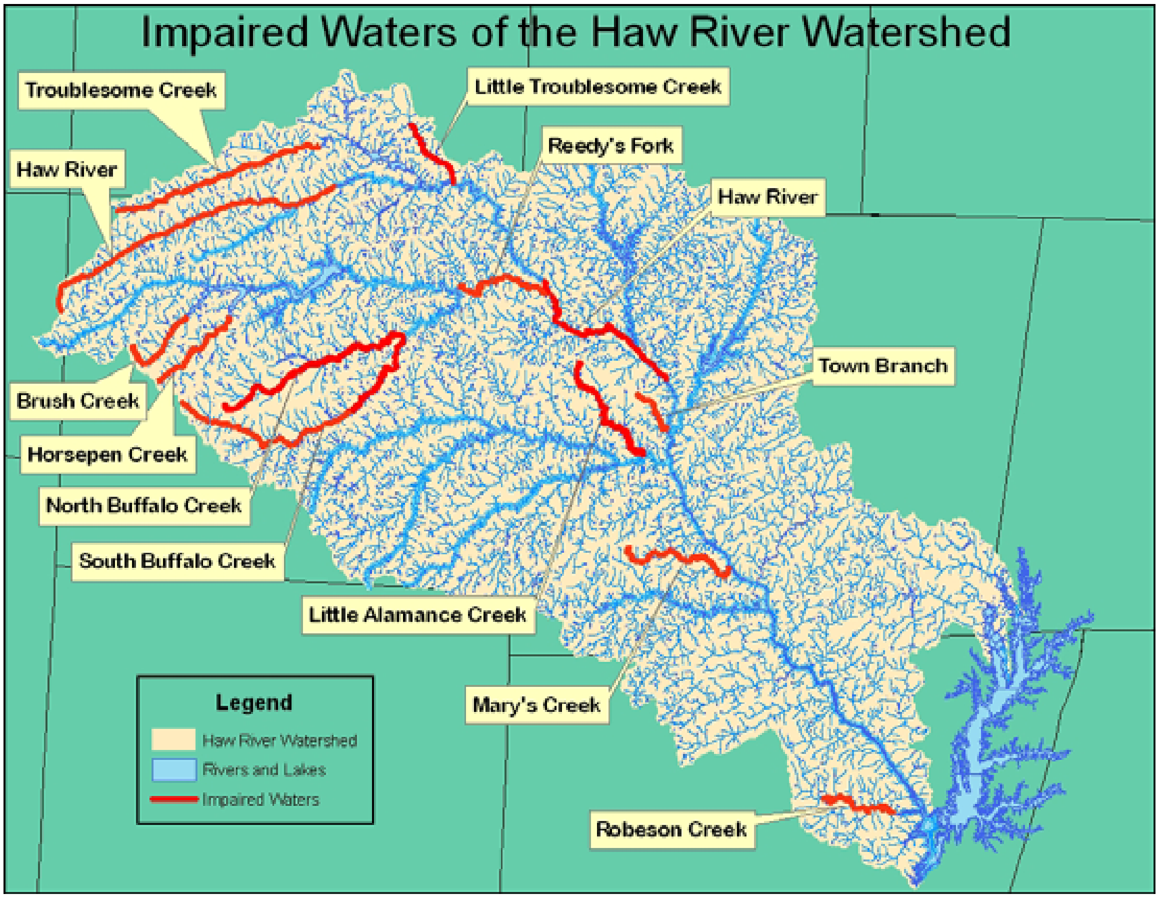
| | Number | lb/day | total lbs/day | Annual tons |
|---|---|---|---|---|
| Layers | 636,222 | 0.26 | 165,418 | 30,189 |
| Broilers | 39,236,164 | 0.18 | 7,062,590 | 1,288,908 |
| | | | 7,227,928 | 1,319,097 |

Nitrogen =
Potassium =
Phosphorus =

We have factory farms where truckloads of feed arrive from afar, but the mountains of manure are spread locally. And from a nutrients, standpoint, it doesn't add up. When fields are over-fertilized, the excess washes into the waterways.  The easiest way to reduce pesticide and herbicide use is to buy organic food.

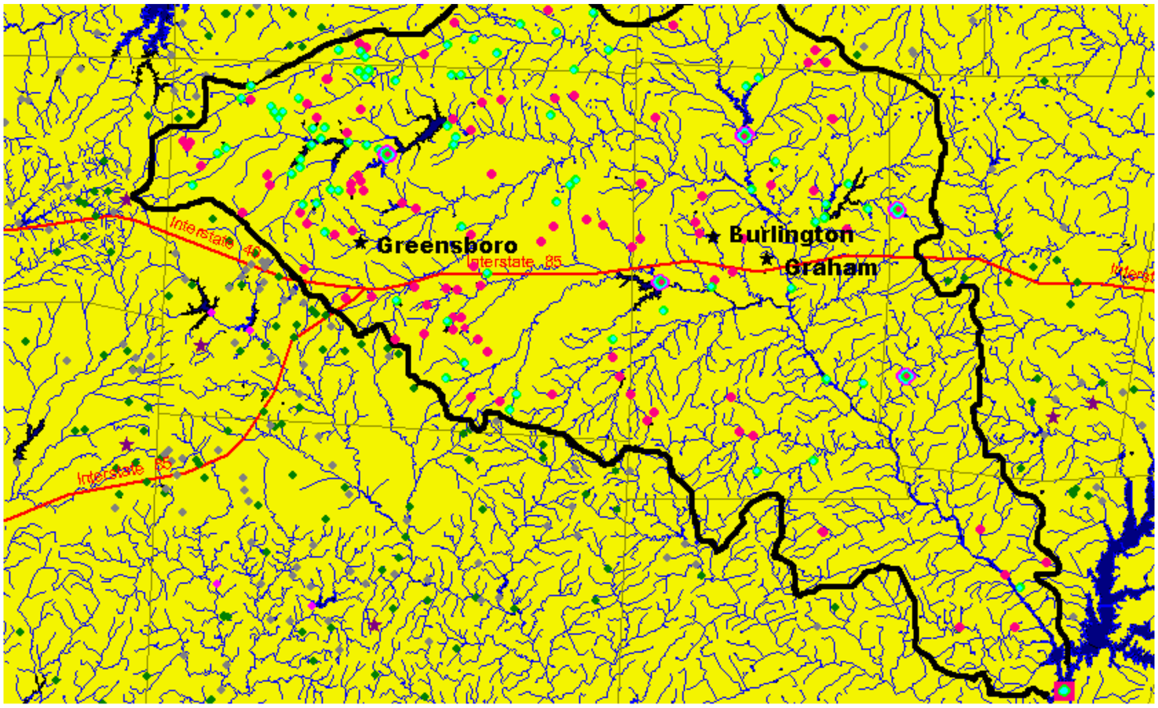
Water quality is affected by the wetlands acreage and the health of the riparian edge. It's affected by factory farming.  It is also affected by dams.

When you look at a map of the watershed, one of the things that jumps out at you is that the Haw watershed has a heck of a lot of dams.

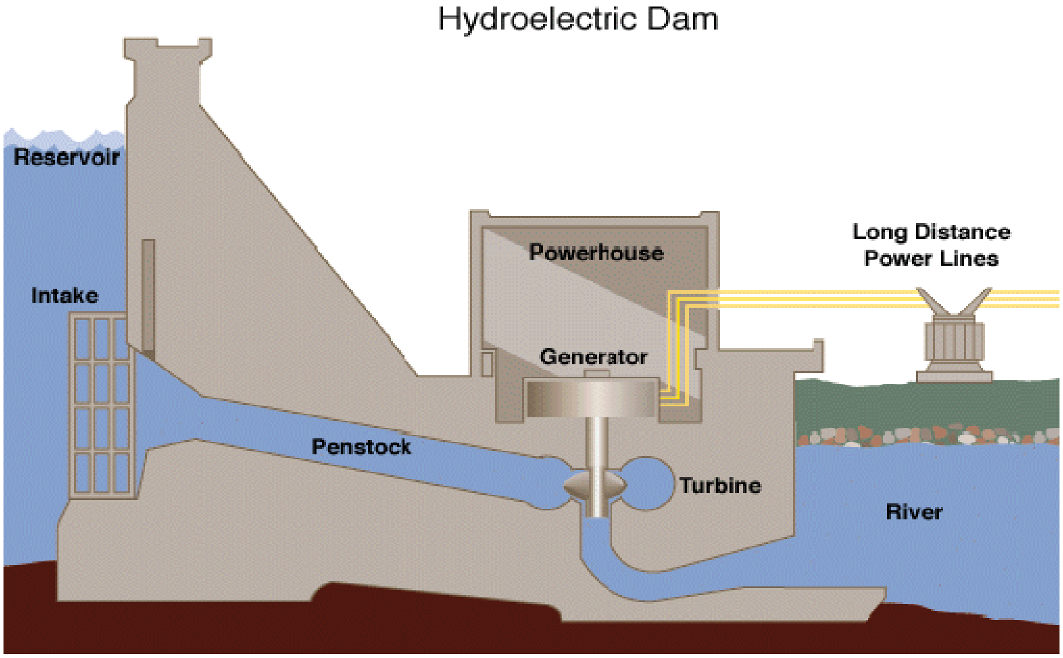



Each one of these swollen spots on the map is a sizable dam, and each dam is plugging up the system and impairing water quality.

Dams are wonderfully multipurpose structures.   They can provide municipal water supplies, flood control and electrical generation, they provide water for irrigation and transportation.  They allow us to control the rivers flow.  And by placing the river's flow under human control, we have changed the biological characteristics of a watershed entirely.




Here we have the number of dams in the watershed from the National Inventory of Dams, total 165. There are 92 dams in this watershed that are less than 25 feet. That's these pink dots. These aqua guys are the 67 dams between 25 and 50 feet, the aqua with the pink dots are 5 big dams between 50 and 100 feet, and one dam that is absolutely huge, over a hundred feet tall. This dam here, the Jordan dam, is so big that it affects flows for dozens of miles upstream, and effectively blocks any water creatures from moving upstream or downstream here/ this watershed is absolutely separated from the lowlands by this dam. And it's not just that the watershed is cut off, it's that big dams change the water itself.




Water that flows in a stream is well mixed and well oxygenated. When water rests in a reservoir, it starts to stratify. All summer long, the cold water sinks and warm water rises, so the temperature gradient is from warm on top to cool on the bottom. The plankton near the surface release oxygen, and when they die and sink to the bottom, they're eaten by bacteria that use oxygen to process the corpses, so the oxygen gradient goes from high on top to low on the bottom. The gradient for organic matter goes from low to high, and there are gradients for nitrogen, phosphorus, calcium, potassium: you name it, most everything stratifies in a reservoir or lake. In the fall, the water in a lake or reservoir overturns, when the top chills and sinks. The top water goes down to the bottom, and the water on the bottom rises to the surface.

This river is fed from the bottom of the reservoir, so it has low oxygen, high organics, low temperature water in the summer, and highly oxygenated, warm water in the fall. It's the opposite of a natural stream.

Meanwhile, water temperature in a natural stream varies between day and night, by maybe 7 degrees in the winter and 20 degrees in the summer. Below a reservoir, the water temperature variation is usually less than 1 degree between day and night. A river below a large reservoir has weird levels of temperature and chemicals, and these gradients persist for dozens of miles downstream.

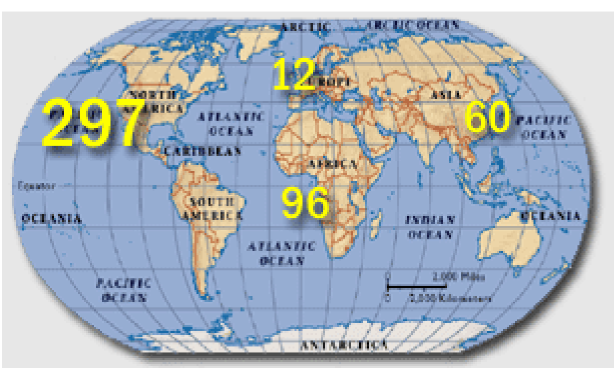
These subtle changes in water chemistry and temperature are academic for humans, but they're dead obvious to aquatic species. A lot of bugs depend on specific water temperatures to hatch.


If you're a mayfly, for example, the eggs start developing when the water is almost freezing. It takes a quick rise in water temperature to hatch, and the nymph needs a few months of water above 65 degrees to mature. Add a dam, and these mayflies are history. Over time, the entire aquatic community of a dammed river begins to look like that of a lake ecosystem.

Dams don't only wipe out the temperature variations in a stream, they wipe out the flow variations as well. Rivers flow high and fast in the spring, when the snow melts and the water stored over the winter is released in a short time. That pulse of water in the spring, and the low flow in the fall, helps shape the river, move sediment in certain ways, and every creature that lives in a river is accustomed to the annual flow variations. When a river is dammed and released to meet human needs, these flow variations disappear, and so do the animals that depend on it.

Dams block the fish that swim in from the sea to spawn, and block that pulse of nutrients that increased the productivity of the stream ecosystem. But the great tragedy in the Haw is that dams not only block fish from the sea, but also fish that used to swim throughout the watershed and spread the native freshwater mussels.

This section of the southeastern US, including the Haw watershed is home to more mussel species than any place on earth. It's the world center for mussels.




We live in a mussel nation. The United States contains the greatest diversity of freshwater mussels of all continents and countries. Approximately 300 species were historically found within the borders of the US.

And mussels are really cute in a way… I mean, if you have a dirty mind, freshwater mussels are as x-rated as you can get. .

You can see that an adult mussel stays put, but when mussels are young they live for a while on the gills or the fins of a fish. Inevitably, some mussels evolved so their larvae lives on specific fish, so when a dam is built that bars the fish from that stretch of the river, the mussels can't reproduce any more. A lot of mussels live to be fifty years old, but with all these dams they're not really managing any more. And silt from agriculture, timberland and construction covers their beds as well. Since they can't reproduce without specific fish, and they can't move, mussels are dying out.

The Haw watershed is pervasively dammed from the smallest tributaries to the main stem of the river. If these dams are discharging from the bottom of the reservoir, they're a problem for stream health; if they're blocking fish passage, they're a problem for stream health. Across the state of North Carolina, there are a total of 2,564 dams. Of these, almost 90% are privately owned, and close to 60% of them were built before 1940.

There's a lot of old dams around, and it's possible that some of these privately owned old blockages are unneeded. If some of these dams were removed, water quality would improve.

As it is, the mussels are the species that are most endangered, but the truth is that any species in North Carolina that depend on the waterways is in trouble.

| | Endangered | Threatened | Special Concern |
|---|---|---|---|
| Mammals | 6 | 2 | 11 |
| Birds | 8 | 4 | 16 |
| Reptiles | 5 | 4 | 11 |
| Crustaceans | - | - | 8 |
| Amphibians | 1 | 4 | 12 |
| Mollusks | 23 | 20 | 30 |
| Fish | 9 | 13 | 27 |

Our management of the NC waterways basically sucks.

How to change dam management.

North Carolina’s constitution says “It shall be the policy of this State to conserve and protect its lands and waters for the benefit of all its citizenry,”

Now, we’ve discussed a lot of non-point source improvements we could make in water quality. And all of these improvements require the participation of private landowners. When it come to reintroducing the wolf, fencing the riparian zone or removing dams, we’re talking about private citizens stepping up to improve water quality.

When it comes to water quality, there are two sides to the problem. There’s how much we dump into the system, the point source and non-point source pollution. And there’s how well the natural system is able to clean itself. We can improve water quality by reducing inputs, and we have. And we can also improve water quality by allowing nature to do her work cleaning the waterways.

If we could reserve a little more forestland, water quality would improve. Maybe there’s room for some wolves in the forests of New York and Maine. Maybe social pressure on beavers would ease if beavers were cast as the only state employees working 24/7 to improve water quality. Additional miles of fenced riparian buffers would improve water quality, and may increase beaver populations.

Water quality would improve if unnecessary dams were removed, which may be a matter of alerting private dam owners that their structures impair stream health, and the fish, frogs and mayflies would greatly appreciate its removal.

We’re working together as states, and our water is much cleaner than it was 40 years ago. If we worked together with nature, we could get the rest of the way to clean water.