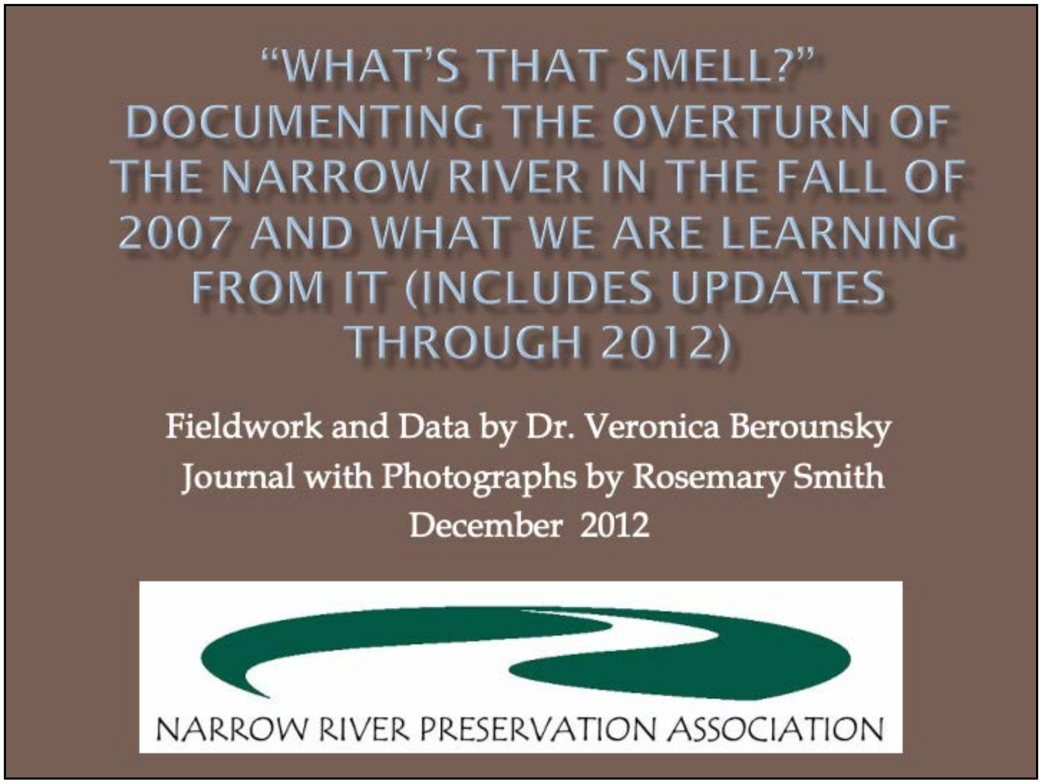


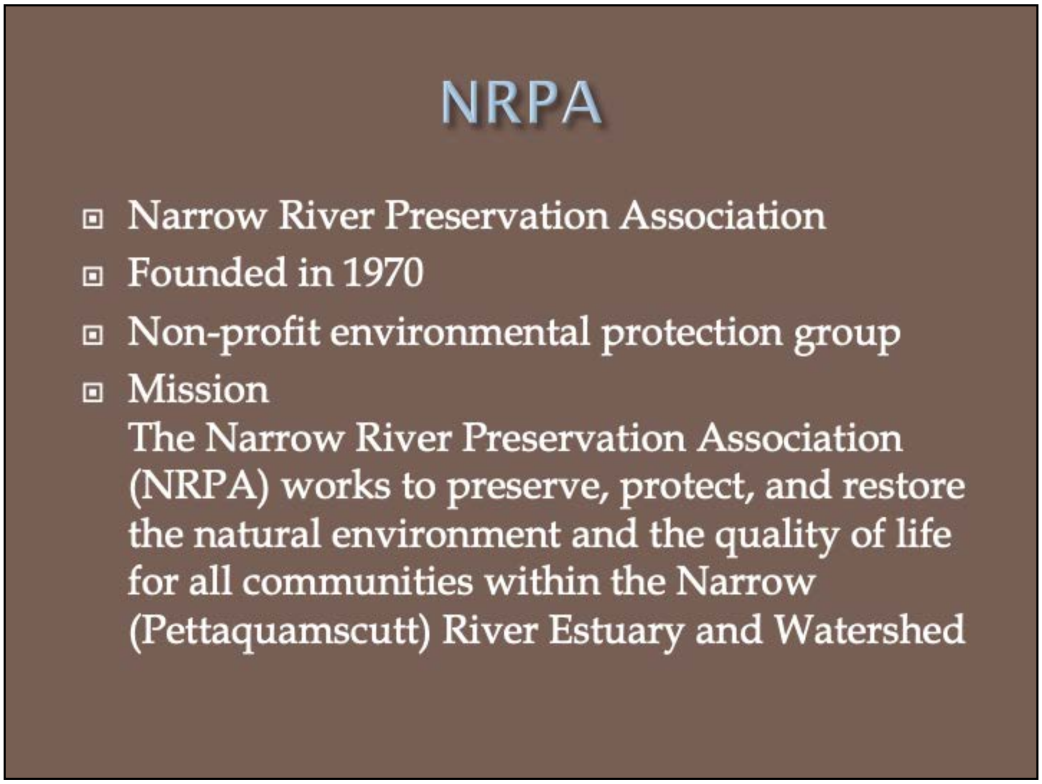
The text accompanying this presentation includes:

- *Journal entries by Rosemary Smith in blue*
- Presentation notes and updates by Veronica Berounsky in black

This presentation was revised in January 2013 for posting on the NRPA website.

What's that Smell?

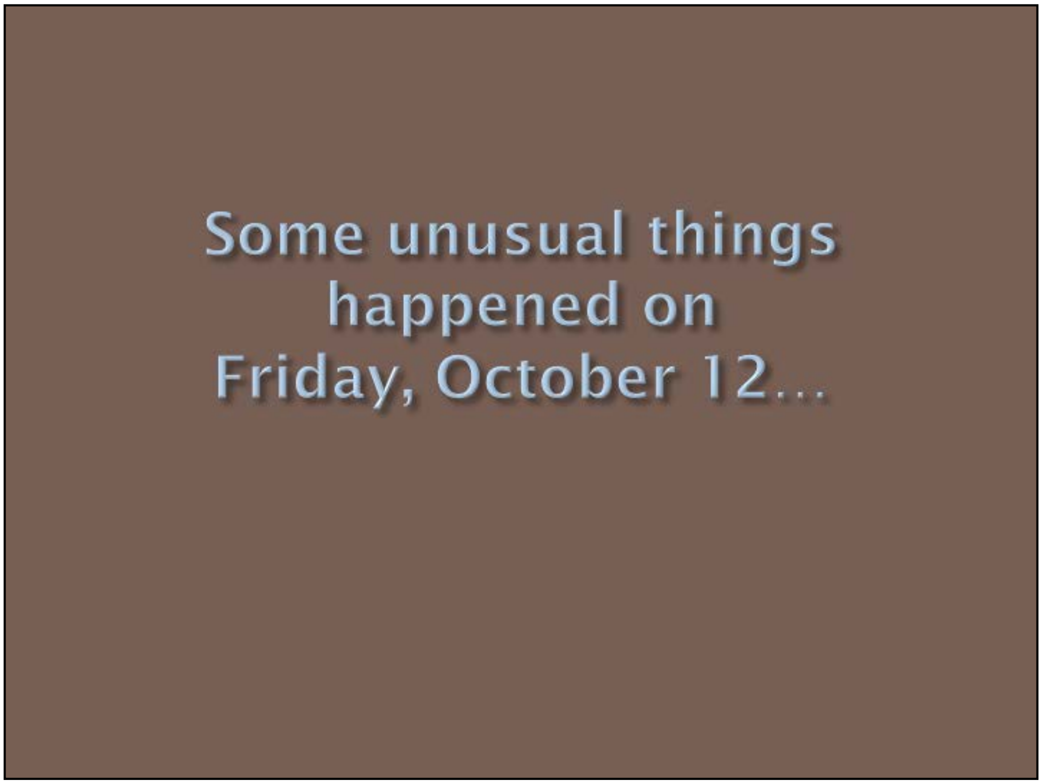
In October of 2007, people around the northern part of the Narrow River noticed a stinky smell – like rotten eggs. What was going on? What was that smell? This slideshow will hopefully help you understand what was going on with maps, diagrams and pictures of Narrow River and its Watershed.



The Narrow River Preservation Association (NRPA) was founded in 1970 as a non-profit, 501(c)(3) environmental protection group with the mission to restore, protect and preserve the quality of the natural environment and communities within the 14 square mile Narrow River Watershed. Dr. Veronica M. Berounsky has been a member of the NRPA Board of Directors since fall 1990.

Rosemary Smith was a new Board member in the fall of 2007.

[Revised 12/18/2012]



Some unusual things happened on the Narrow River in the fall of 2007. It all began on Friday, October 12. The URI Women's Crew Team noticed a strange milky color and an unpleasant smell in the Narrow River by their dock. The next day Dick Lee also noticed big changes in the river while boating in the Upper Pond. Narrow River members of the URI Watershed Watch team were asked to test the water. What was happening to the usually quiet Narrow River?

[Revised 04/08/2008, version 3]

There had been an overturn in the Upper Pond

Aerial photo taken October 17, 2007 by Don Bousquet

What happened was an overturn in Narrow River and this is what it looked like. Notice the milky white quality of the water especially on the left side opposite the point.

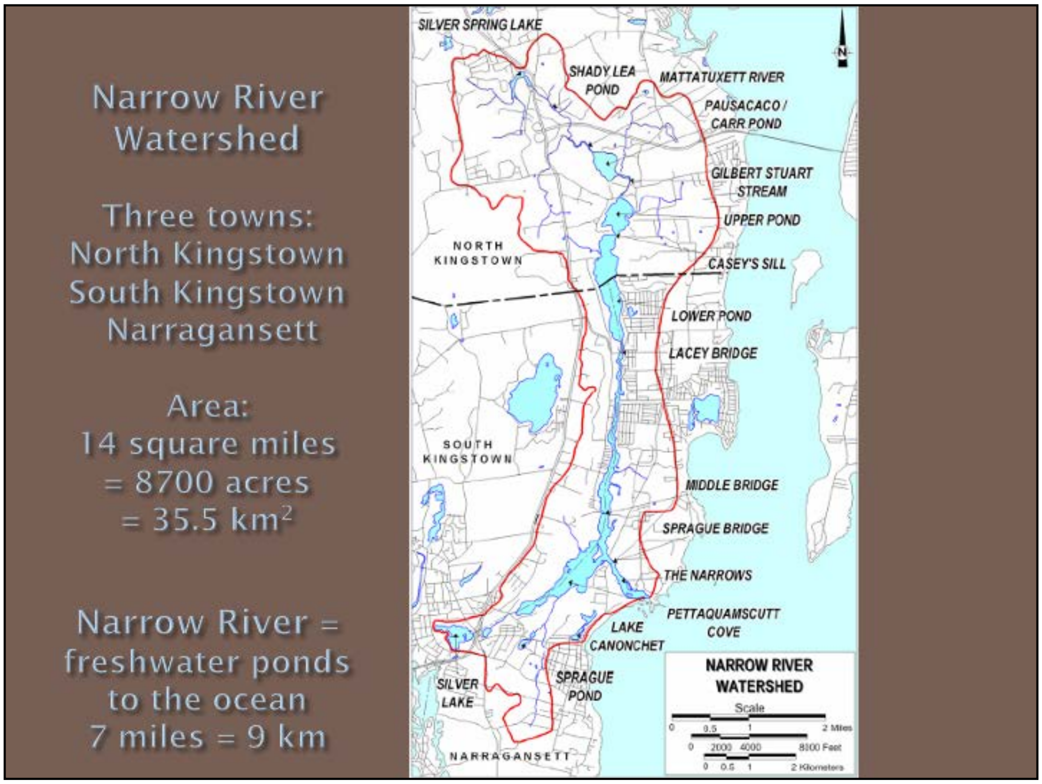
Don Bousquet of Bousquet Aerials took this picture of the north end of Narrow River during the first week of the overturn. This picture was featured in the Providence Journal South County Icon section. Bousquet uses a remotely operated model airplane equipped with a camera to capture these beautiful scenes.

Here is a closer aerial view of Lower Pond.

Note the milky colored water has spread into Lower Pond.

Aerial photo taken Oct ober17, 2007 by Don Bousquet

Another aerial view of Lower Pond includes the URI Crew Team Docks.



Let's orient ourselves to the area. The Pettaquamscutt or Narrow River Watershed is located in Southern Rhode Island. It includes all the land that surrounds and drains into the Narrow River. It comprises about 8,000 acres or 14 square miles and is contained within the towns of Narragansett, North Kingstown and South Kingstown.

The flow of the river starts at Silver Spring Lake in North Kingstown, continues through Carr Pond then by Gilbert Stuart Museum, into the Upper Pond and then into the Lower Pond. It flows under Bridgetown (Lacey) Bridge, out through the narrow part, then under the Middle Bridge. Some of the water flows southwest to Pettaquamscutt Cove while another part flows southeast under Governor Sprague Bridge and out into Narragansett Bay.

[Revised 12/18/2012]

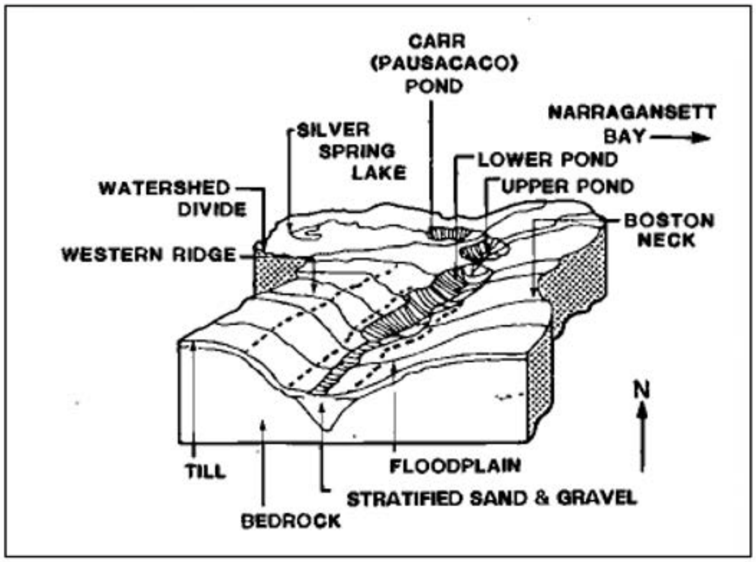


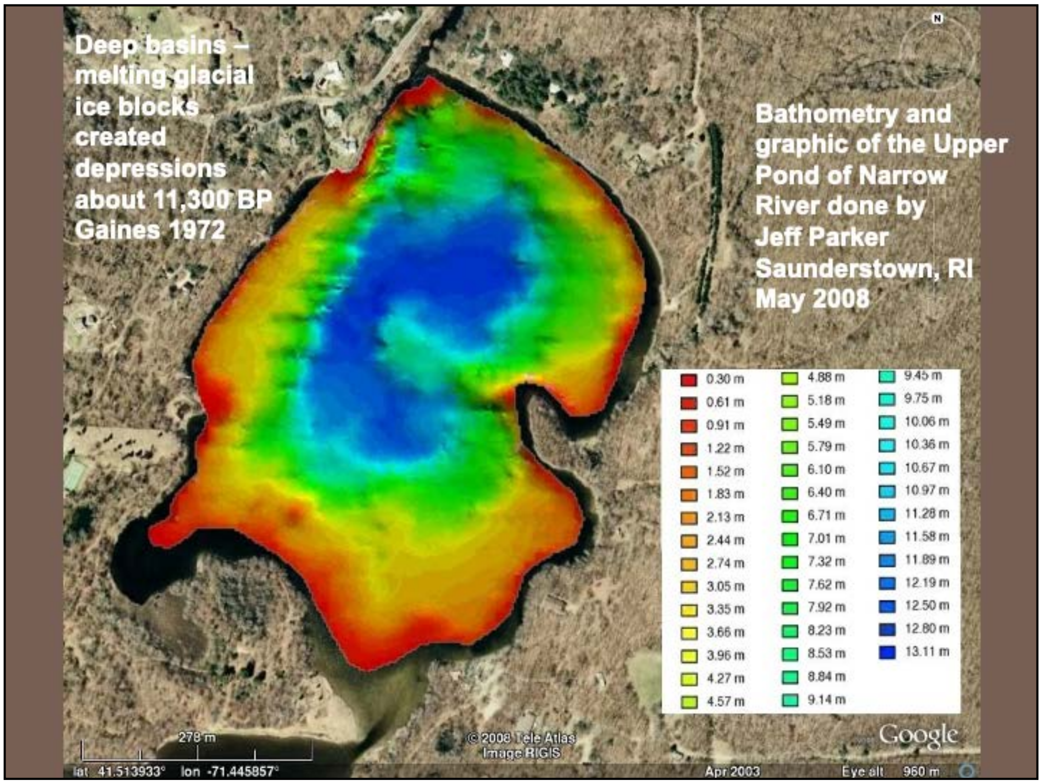
Figure 3-1. A perspective view of the topography and surficial geology of the Narrow River watershed (River Landscapes 1976).

This perspective view of the watershed area is taken from the Narrow River Special Area Management Plan (and it originally came from River Landscapes). If we were standing behind the Narragansett Elementary School looking north, this would be our perspective.

The watershed is shaped like a bathtub. Notice the boundary of the divide. Water flows downhill east from Route 1 towards the river and west from Route 1A.

The Pettaquamscutt or Narrow River runs north-south for approximately 6 miles and empties into the Rhode Island Sound. It is an exceptional body of water. It is more accurately described "as a composite of a tidal inlet and lagoon connected by a narrow channel to a series of kettle hole ponds fed by a small stream." Although it is mostly shallow, the river's upper reaches encompass two unusually steep-sided ponds, one of which plunges to a maximum depth of approximately 60 feet and the other about 40 feet. These characteristics distinguish Narrow River from almost every other estuary in the Continental United States. Scientists from all over the world come to study it!

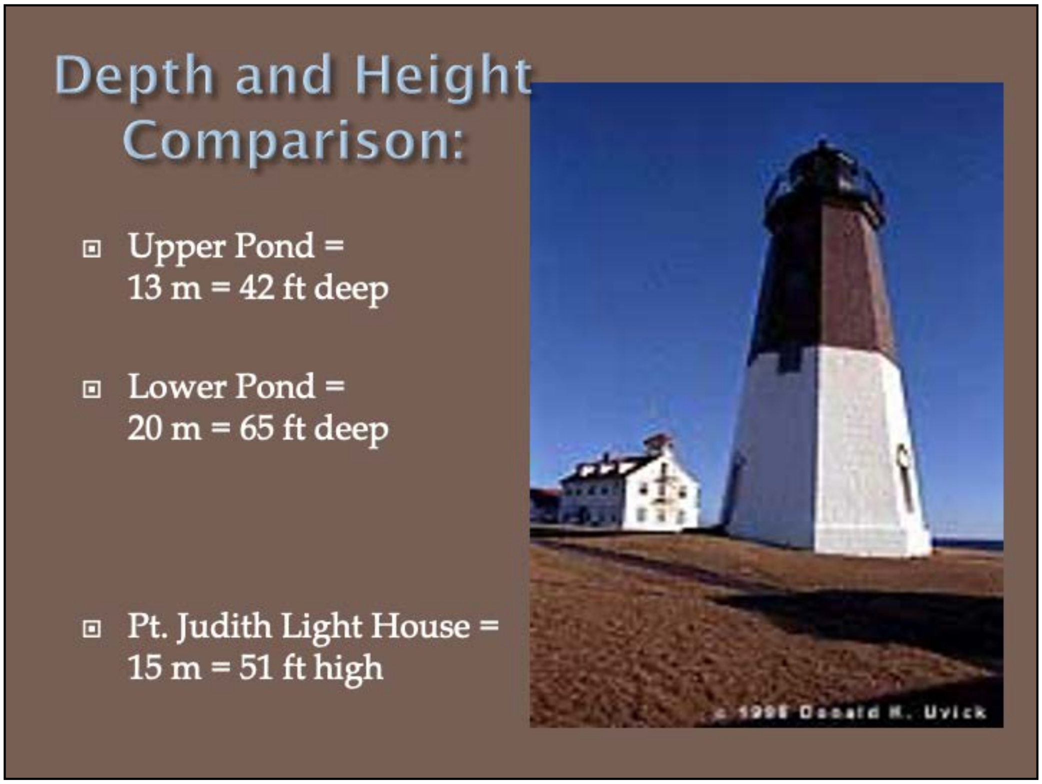
[Revised 04/08/2008]



This graphic shows the depths of Upper Pond. The measurements and the graphic are the work of Jeff Parker, Gilbert Stuart Road, Saunderstown, R.I.

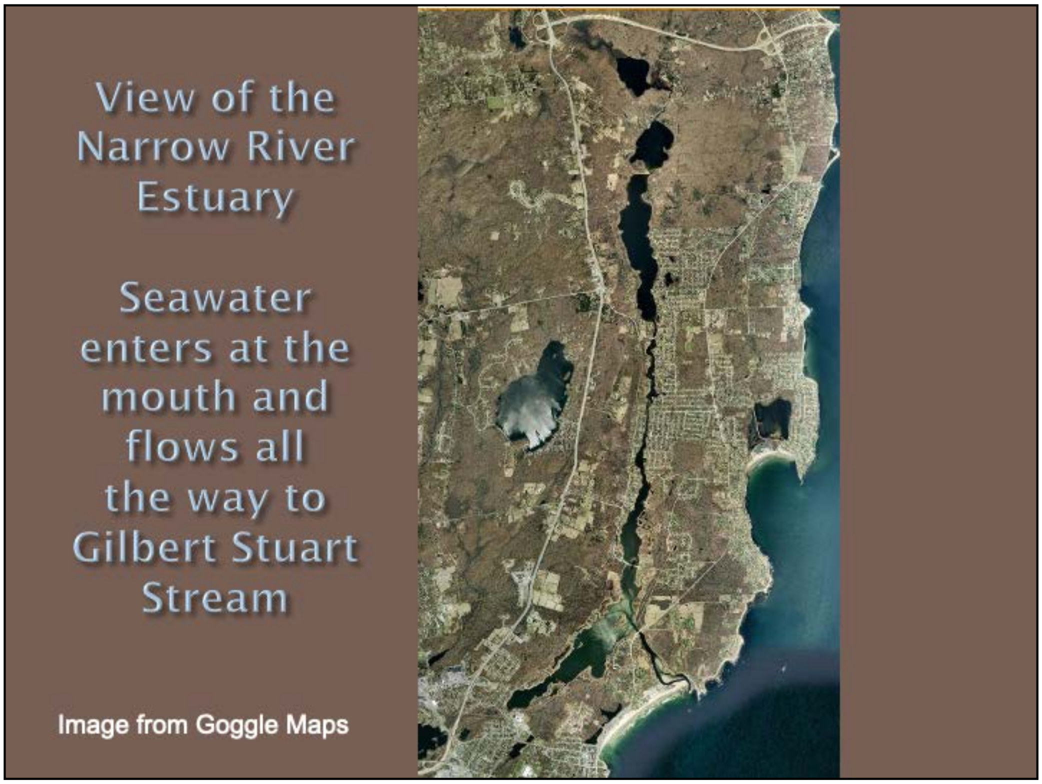
Note how deep Upper Pond is in the middle – about 13 meters or 42 feet. This is a result of glacial ice blocks that created depressions about 11,300 years before present (BP).

[Revised 01-23-2013]



To give you some perspective on how deep the “ponds” are in Narrow River, if you took the Pt. Judith Lighthouse and put it in Upper Pond, only the top 10 feet would show. And if you put the lighthouse in Lower Pond, it would completely disappear!

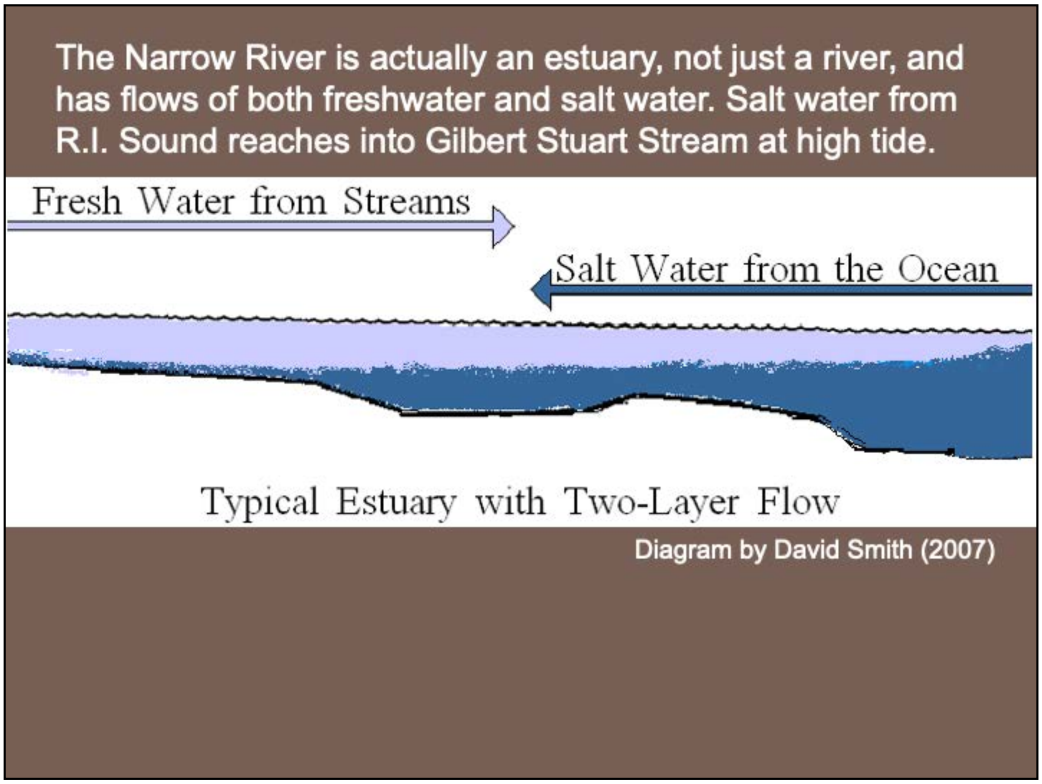
[Revised 01/23/2013]



This is a Google map of the Pettaquamscutt or Narrow River Watershed.

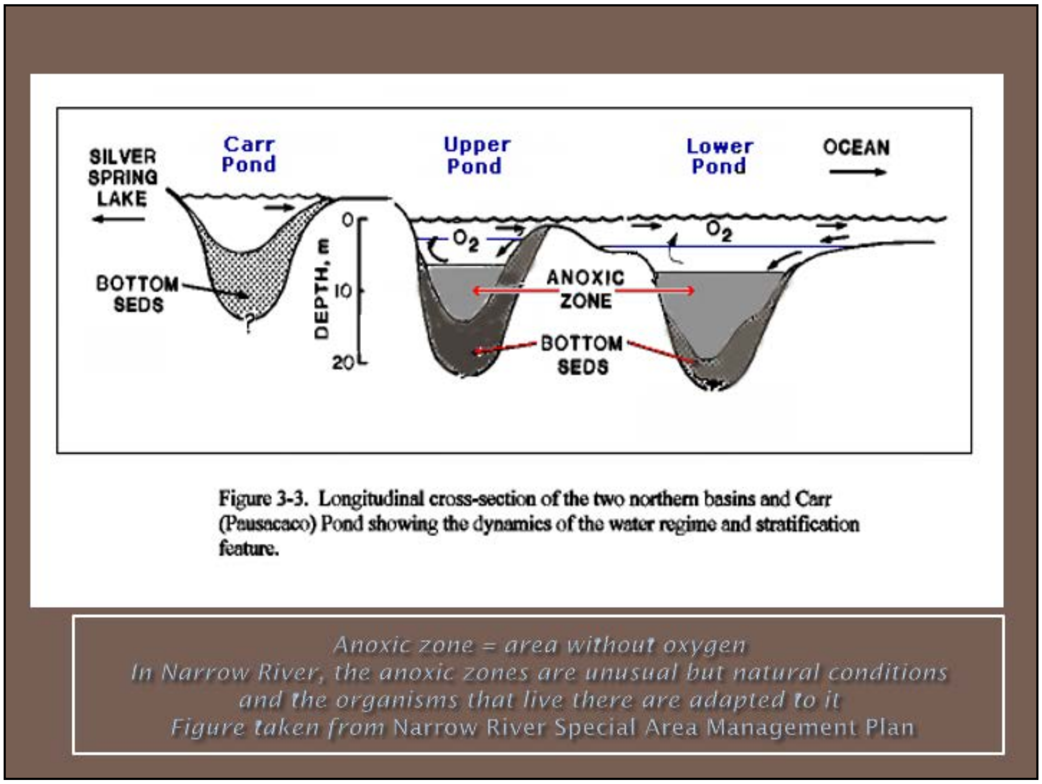
The Narrow River is a mixture of salt and fresh water which makes it an estuary. The salt water flows in during high tide and reaches all the way to Upper Pond.

[Revised 04/22/2008]



Most of Narrow River is a typical two-layered flow of an estuary. Fresh water is on the top. Denser salt water flows along the bottom of the river. Normally there is some mixing of these two layers where they meet.

[Revised 01/23/2013]



This diagram, taken from the *Narrow River Special Area Management Plan*, gives a longitudinal cross-section view of the northern reaches of the Narrow River system and shows the stratification or layers of the system. On the left is Carr (or Pausacaco) Pond, which has completely fresh water. The next area (no basin) is Gilbert Stuart Stream. Next on this diagram are Upper Pond and Lower Pond, the northern basin and southern basin of Narrow River proper. They are separated by Casey Sill. Note how high the river bottom rises between these basins. You can see that the bedrock basins themselves are steep sided and very deep, 20 or more meters (more than 60 feet). The bottoms of these basins have lots of sediments, and there is a thicker layer of sediments in the Upper Pond than in the Lower pond.

The waters here are very deep, about 13 meters or 40 feet in the Upper Pond, and about 20 meters or 60 feet in the Lower Pond. At the surface and for about 3 meters (9 feet) deep, oxygen mixes in from the air and we see a typical estuarine two-layer flow of lighter, fresher water on top and denser saltier water below. These waters are also warmed by the sun during warmer months. Below about 3 meters and down to the bottom, there is a third layer called the anoxic zone. This cooler, saltier water does not come in contact with the air or mix with the upper layers, so organisms use up all the oxygen and it is not replaced.

This almost permanent anoxic zone is an unusual but natural condition and the organisms that live there are adapted for it and are not stressed. (This is not to be confused with water bodies that lose oxygen in the summer and have fish kills.) There are only a few places in the world that have permanent anoxic layers, another reason Narrow River is unique and why scientists come from all over the world to study it!

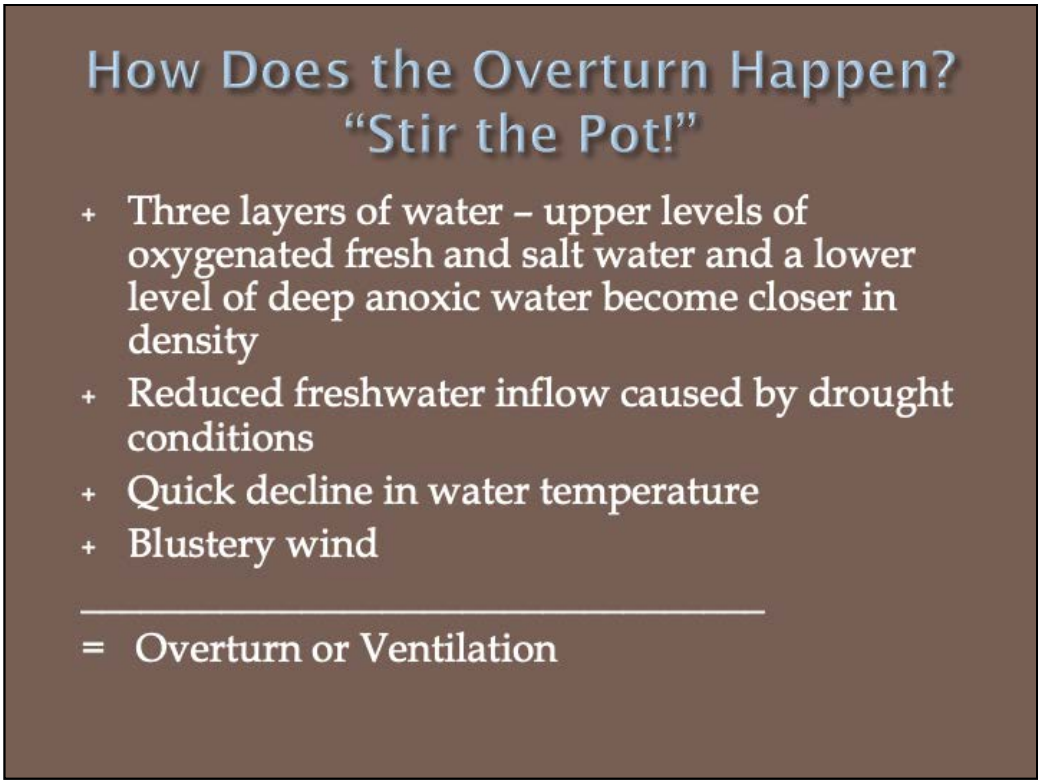
[Revised 01/26/2013]

Overturn of the Upper Pond in Narrow River

- "Rotten egg" smell of hydrogen sulfide
- Milky color of water from the sulfur reacting with air
- Dead fish in water and crabs escaping onto shore due to the sulfur

When the pond overturned on October 12, 2007 the anoxic water rose to the surface. How did scientists and neighbors know that the Upper Pond was changing? They could smell hydrogen sulfide, see the milkiness of the surface water and view evidence of dying fish and crabs.

[Revised 01/23/2013]



How does the overturn happen?

Normally there are three layers of water in the ponds. There is some mixing and some oxygen exchanged between the top two but the anoxic zone is more dense and stays on the bottom. During the cool fall, the top layers cool and become closer in density to the bottom layer.

Due to drought conditions, there is less fresh water at the top layer, and more salt water flows north into the river. Because it is more dense, the cooler, salt water displaces the anoxic water from its place at the bottom of the basin and causes the three layers to mix. This sets up the equation. The triggers for the overturn (what makes it happen on a particular day) are

- A quick decline in water temperature in the fall which cools the surface water and makes it more dense
- The winds' energy helps to mix the water (stir the pot!).

This is similar to making Italian salad dressing. If you have vinegar in a jar and add oil to it, the vinegar sinks to the bottom and the oil floats on top. If you shake the jar, the oil particles are dispersed throughout the salad dressing.

[Revised 04/24/2008]

How Does the Overturn Happen?
"Stir the Pot!"

- Three layers of water – upper levels of oxygenated fresh and salt water and a lower level of deep anoxic water become closer in density
- Reduced freshwater inflow caused by drought conditions
- Quick decline in water temperature
- Blustery wind

= Overturn or Ventilation

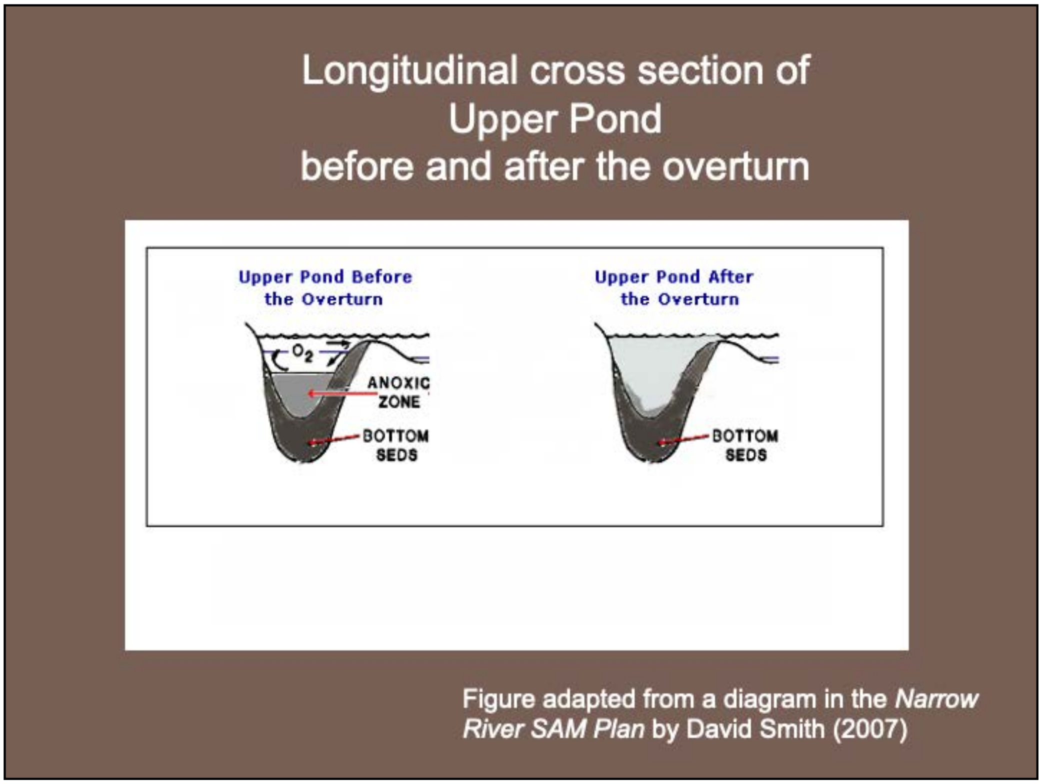
Why does the water look milky after an overturn?

The anoxic water at the bottom of the deep basin of the Upper Pond and the Lower Pond has hydrogen sulfide in it. The anoxic water comes to the surface and mixes with the normally oxygenated water just like mixing oil and vinegar in the salad dressing. The water turns milky and cloudy and a bit yellowish because it is filled with sulfur particulates, in the same way that the salad dressing becomes cloudy and changes color when it is shaken and the oil particles mix with the vinegar.

This resulting water has much less oxygen in it so fish and crabs die, the water chemistry is unusual, and there is a rotten egg smell from the hydrogen sulfide.

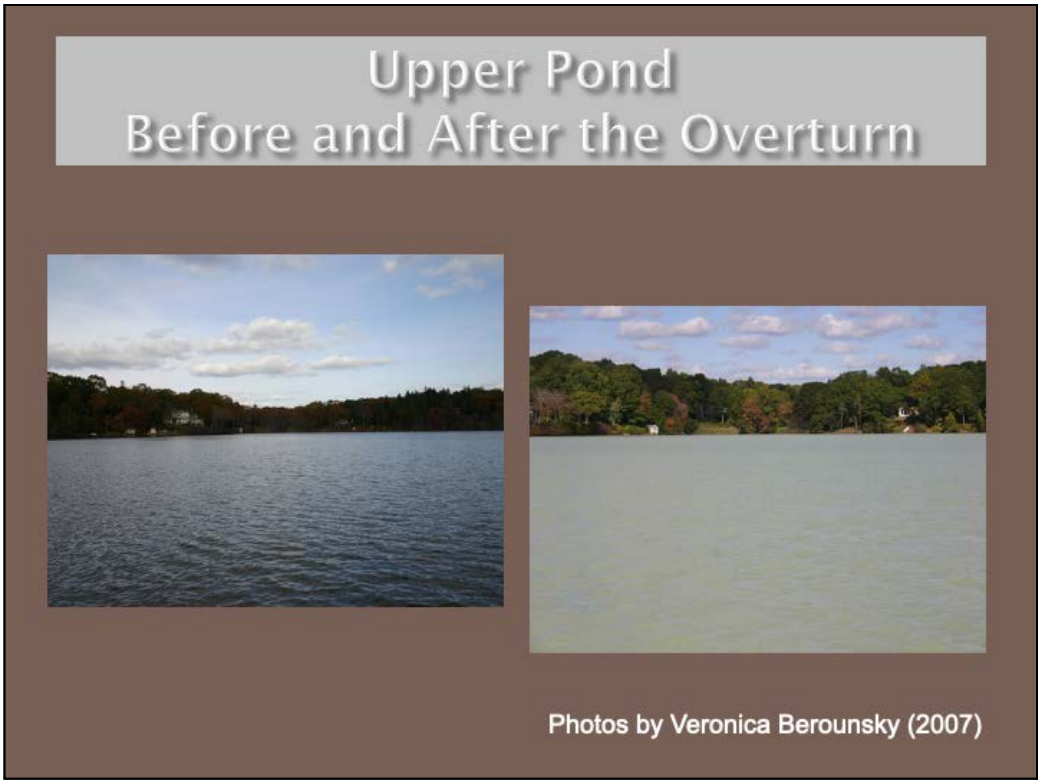
It is important to remember that this is a natural phenomenon – it is not due to pollution or anything spilled – but it is a result of naturally occurring climatic conditions.

[Revised 04/24/2008]



This diagram helps us to visualize what the Upper Pond looked like before and after the overturn. Notice on the right how the anoxic water has mixed with the oxygenated water to form a milky color.

[Revised 01/23/2013]



These two pictures show the change in the color of the water.

Previous Documented Overturns

- November 1957 studied by Don Horton
- November 1971 studied by Arthur Gaines
- October 1990 studied by John Sieburth, Percy Donaghay, Al Hanson and others

- Remember: Overturns in Narrow River are a natural phenomenon due to climate and weather, not because of anything done by humans or by pollution

There were overturns in the Narrow River that are documented and can be found in various reports in the Pell Library at URI Graduate School of Oceanography.

This latest overturn needs to be documented to show its effects on the health of the river.

Overturns in Narrow River do not happen very often, about once every 15 to 20 years. So it is exciting to see one!

With global climate change, we might see either shorter or longer intervals between overturns depending on whether there are more or fewer droughts.

[Revise 04/22/2008]

Dr. Veronica Berounsky

- University of Rhode Island Graduate School of Oceanography
- Narrow River Preservation Association
- Scientist

Photo by Rosemary Smith (2007)

I had the opportunity to meet Dr. Veronica Berounsky through a course that I took that was sponsored by the Narrow River Preservation Association called "Watershed Science for Educators."

Veronica oversees some of the education programs of NRPA and she is passionate about sharing all that goes on within the Pettaquamscutt Watershed. She has her Doctorate in oceanography and a Bachelors in biology, and much of her research is on water quality.

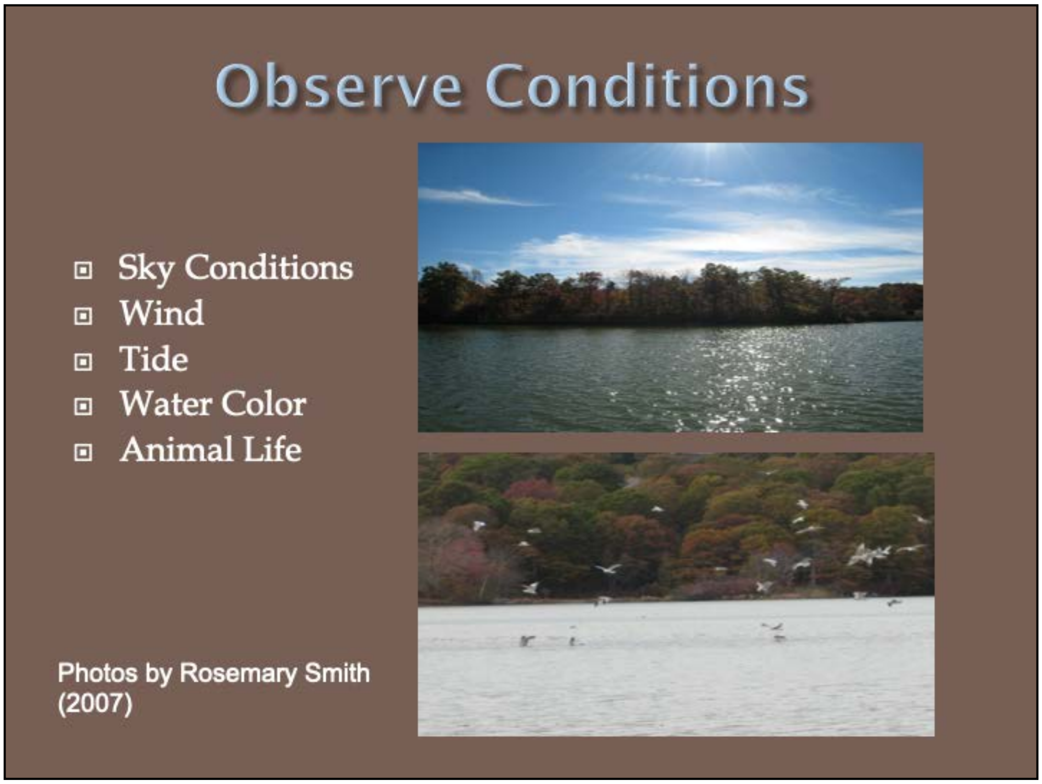
When Veronica emailed me looking for someone to help her with testing of the Upper Pond after the overturn, I jumped at the chance.

[Revised 04/22/2008]

Every expedition team needs a means of transportation and so we used Veronica's boat – Research Vessel Eel – an 18-foot skiff.

Each time Veronica went out on the river she filled the boat with testing equipment. It was her task to "Prepare, Prepare."

Once we were out on the water, there was no time to come ashore to pick up forgotten equipment. We wanted to be able to sample and make measurements in whatever conditions we encountered.



One of the jobs of the team was to take notes on the condition of the river. You could tell if the tide was going in or out by watching the direction of the surface water and the height of the water on the shore line.

The wind either was a help or hindrance. Calm winds made the testing easy. Brisk winds would act as a deterrent by stirring up the water and moving the boat off the testing location. Sometimes even the anchor couldn't keep us steady.

We always kept an eye on the sky as it would indicate a change of weather. There were some beautiful testing days as seen in the top picture.

The milkiness of the surface water told us that the overturn had taken place. The wind and tides pushed that milky water up and down Narrow River.

Sea gulls, osprey and hawks gave us clues as to where fish might be. The shores were sometimes littered with dead fish and crabs.

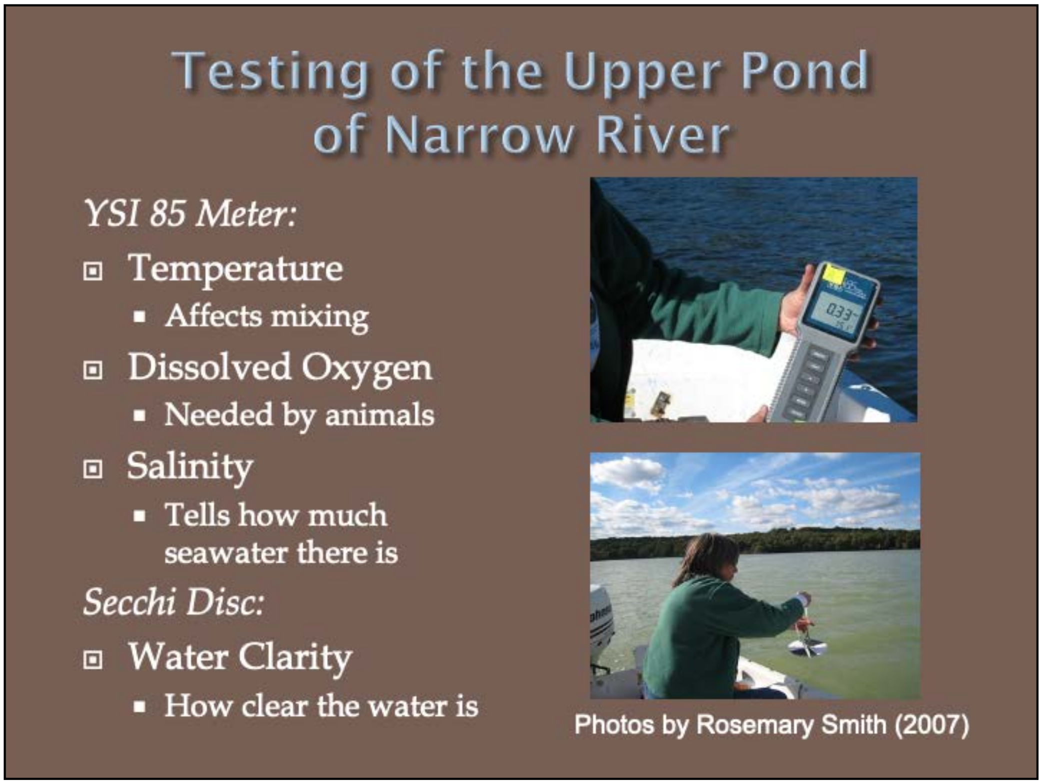
[Revised 04/22/2008]

Movement of Milky Water

Photos by Veronica Berounsky (2007)

Each time we went out to test the water, the surface looked different because wind and temperature conditions could cause more milky water to rise to the surface or could help the milky water flow out.

Along the shore there was evidence of animal life that had been affected by the overturn. On the left is a picture of a crab on shore and another crab trying to bury itself in the sand. The next picture shows small menhaden and alewives on the shore.



To answer the question "How does the overturn affect the Narrow River?" Veronica immediately began to collect data on the temperature, dissolved oxygen and salinity of the water because we didn't know how long the overturn would last.

The principal tool for collecting data was a probe on loan from URI Watershed Watch. The Yellow Springs Instrument YSI 85 enables measurement of oxygen levels at specific depths. Low oxygen near the surface is the prime indicator of the overturn. The YSI 85 also collected important data on water temperature and the salinity (amount of salt) in the water.

Another device called the Secchi Disc was used to determine clarity of the water. Sometimes you could see the disc two or three meters deep in the water and at other times when there was overturned water it was visible only near the surface.

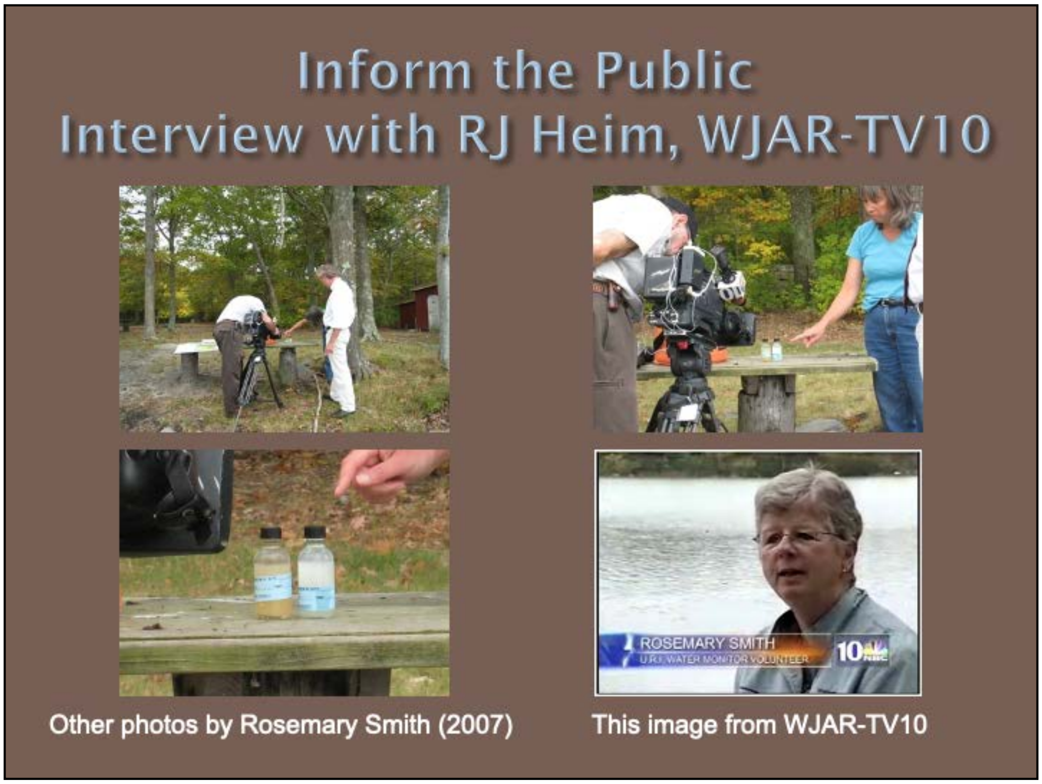
The day after the initial overturn, all these measurements were recorded by Veronica and Linda Green, Director of URI Watershed Watch, at various sites in Upper and Lower Ponds to document the extent of the overturn. Narrow River monitors took readings at their various stations to determine if the overturned water went down the Narrow River.

Sampling for Nutrients: nitrogen and phosphate – needed by plants & animals

Photo of Linda Green of URI Watershed Watch by Dick Lee (2007)

Water samples were also taken for analysis of nutrients (nitrogen and phosphate). This photo shows Linda Green using a Watershed Watch sampler to collect water from various depths beneath the surface. Nutrients are important because plants and animals need them to grow (just like in your garden). The overturn probably affected the concentration of the nutrients in the water.

[Revised 01/24/2013]



Neighbors around the river were wondering what was happening. The press wanted to know what was going on.

Peter Lord, environmental writer for the Providence Journal*, interviewed Veronica and Linda Green as they returned from sampling the water on Sunday, October 14 for an article the following day.*

Four days later RJ Heim of WJAR-TV10 interviewed Rachel Smith, Veronica and myself about the overturn at the Boys and Girls Club Beach on Upper Pond, part of the property of Casey Farm. Veronica displayed two sample bottles which showed the results of a test for oxygen in the water after the overturn.

I spoke about the URI Watershed Watch Volunteer Monitoring Program that I was a part of this past summer where I tested the water at Lacey Bridge on Bridgetown Road.

The hour of filming became 5 minutes of airtime on Channel 10's "Watershed Report" on Thursday, October 18.

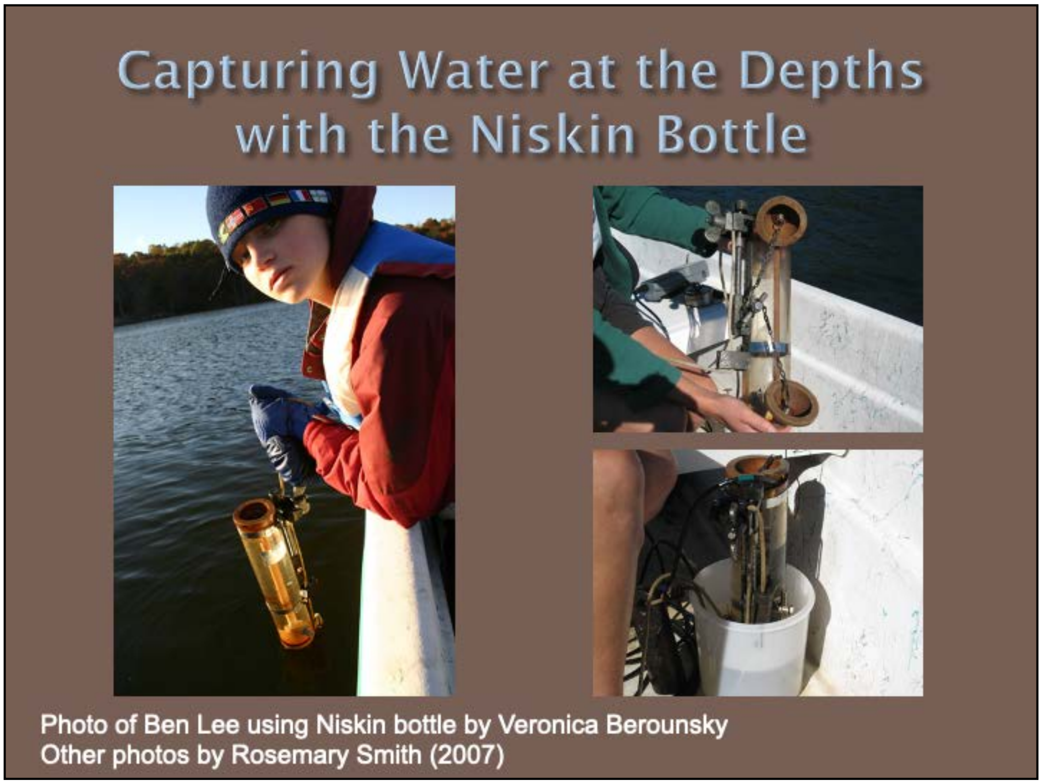
The next week, Mark Schieldrop, wrote a story in the South County Independent *about the overturn.*

[Revised 04/08/2008]

Gathering More Data as the Overturn Continues…

Aerial photo taken October 17, 2007 by Don Bousquet

Now we wanted to continue to document the overturn and see what happened over time. Veronica was assisted by a group of family, friends, fellow scientists, and the NRPA Board of Directors, who went out almost daily to gather data. I offered to help her once a week. This field trip could take anywhere from two to four hours.



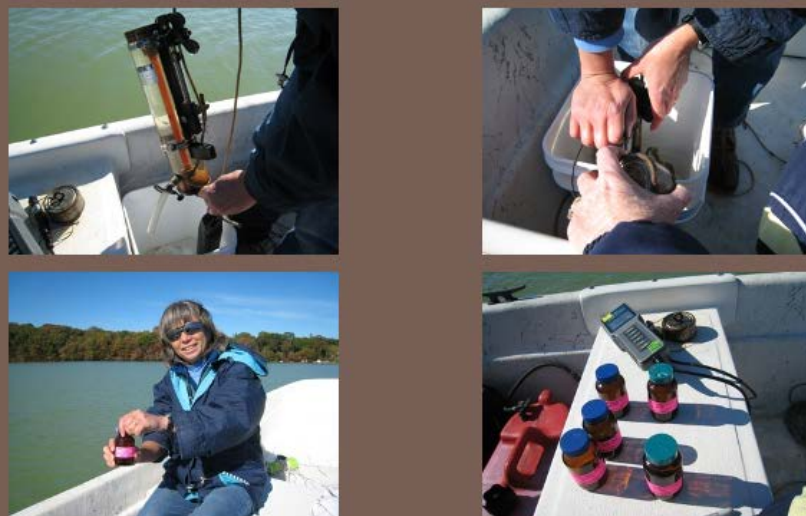
As the collection of data progressed, Veronica was constantly trying to solve problems. The original testing device, YSI 85 with transponder, could only test to 9 meters and the pond was deeper than that. A colleague, Sheldon Pratt, loaned Veronica a Niskin Bottle which allowed her to test the water at greater depths. The bottle (actually a plexiglass tube) was lowered into the water and endcaps were triggered by a "messenger" to close so the tube could captured water at a specific depth. Then we could bring the bottle into the boat and use the YSI 85 to test the water. It took several attempts to find a procedure that didn't let the water flow out prematurely.

In the photo on the left Veronica's son, Ben Lee, helps to test the water.

The Niskin bottle is named after its developer, Shale Niskin.

[Revised 01/23/2013]

Collecting Nutrient Samples at Various Depths with the Niskin Bottle

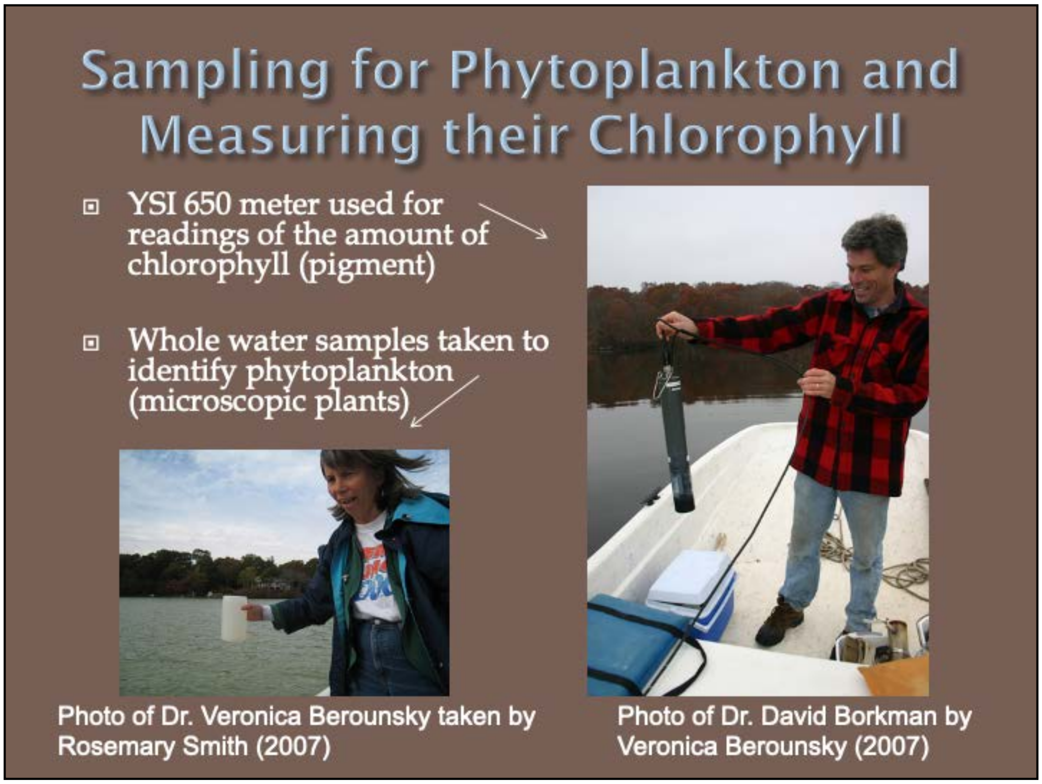


Photos by Rosemary Smith (2007)

We are now adding to our data collection in these photos. Veronica is collecting unfiltered water and placing it in bottles which are labeled with the date and the depth at which the water was collected. Back on shore, some of this water was filtered and frozen. These samples will be analyzed for nitrogen and phosphorous nutrients by URI Watershed Watch.

URI Graduate School of Oceanography marine research scientist Sheldon Pratt studied that animals that lived in and on the bottom sediments. Here he empties the benthic dredge into a pan to examine the sediments. Next he uses a sieve to separate the sediment from smaller benthic animals such as worms and shellfish.

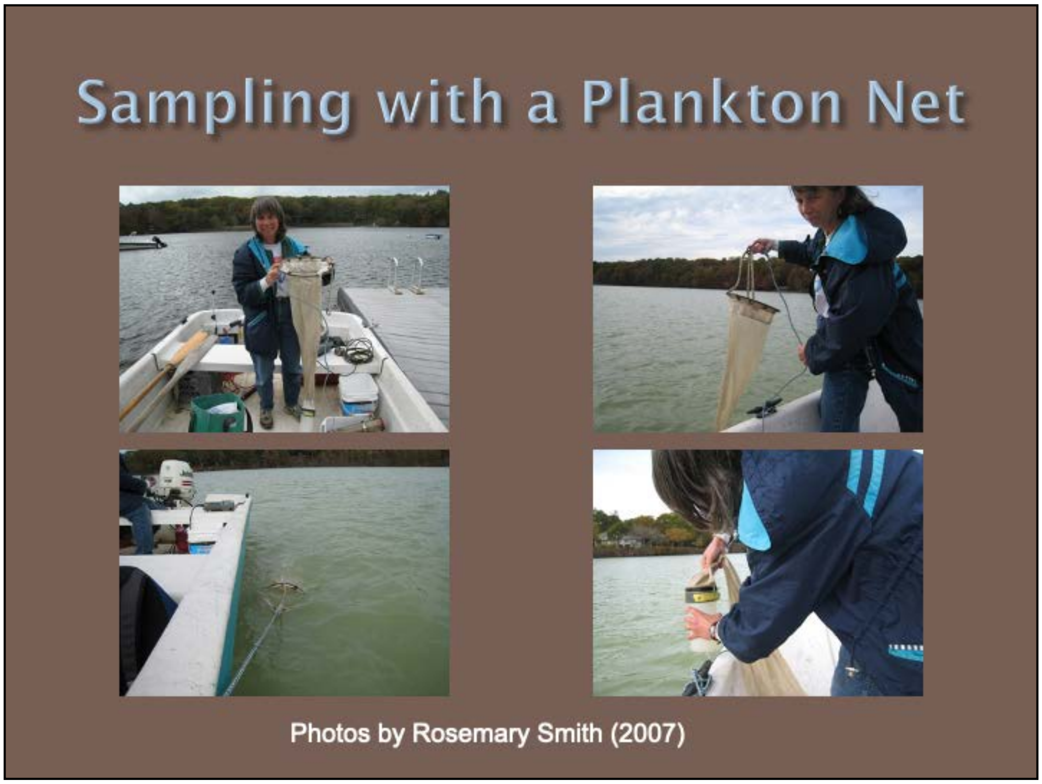
[Revised 01/23/2013]



The water collected will be examined by Dr. David Borkman to see what kind of microscopic life can be found in it.

On the right, David uses a more sophisticated YSI instrument to measure the chlorophyll pigment contained in the phytoplankton.

[Revised 01/23/2013]



Sheldon Pratt loaned Veronica another piece of equipment to catch plankton – phyto (plant) and zoo (animal) microscopic organisms.

This piece of equipment is composed of a windsock-like device which has a bottle at the end of the point. The Plankton Net is made of a fine mesh or net and water flows through it but plankton does not, so they are caught in the bottle. The Net is dragged along the side of the boat to collect more information about the Upper and Lower Ponds.

URI-GSO doctoral student Rich Bell (now Dr. Bell) examines fish that he has caught in a seine two weeks after the overturn. These fish look healthy!

Samples were also taken to look for the amount of sulfur in the water. When oxygen is low in water, sulfur is often high. The water was collected in test tubes and capped on the boat. Veronica added two chemicals to the samples with a special pipette so that the sulfur particulates would sink to the bottom of the test tubes. The test tubes would later be sent to the EPA where they will be placed in a centrifuge and then analyzed by Dr. Warren Boothman. On the left Elizabeth Lee, Veronica's daughter, helps collect samples.

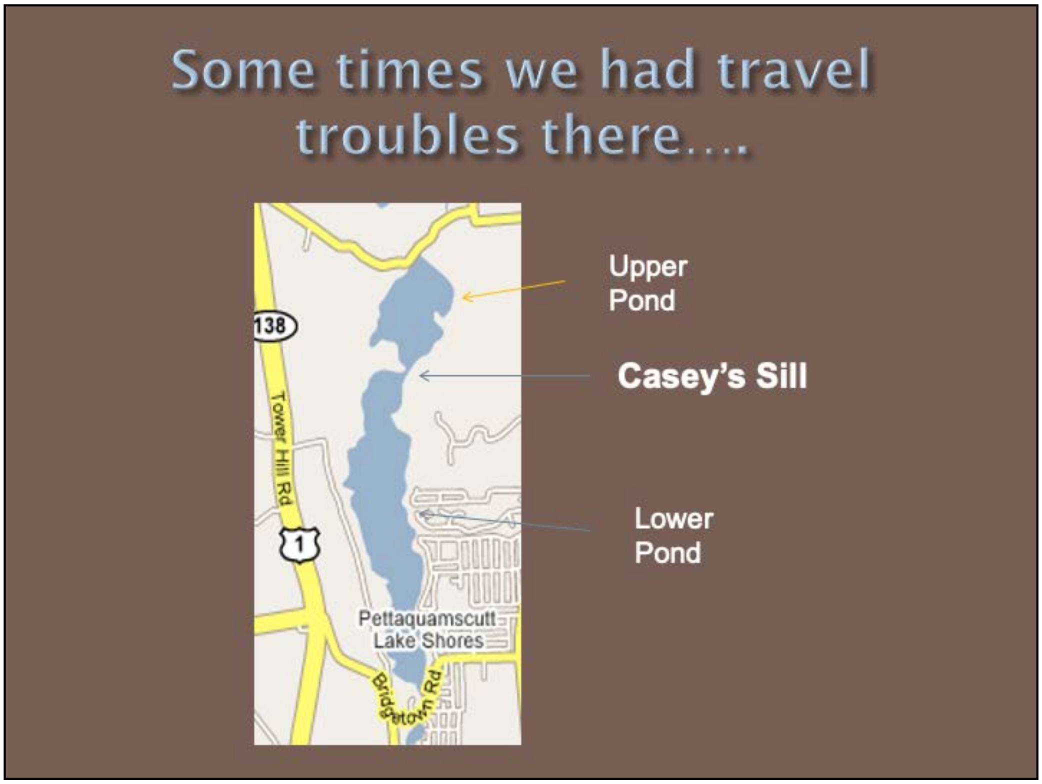
[Revised 04/08/2008]

Here Veronica is taking water samples in the small test tubes for di-nitrogen gas that will be analyzed at the URI Graduate School of Oceanography by Dr. Wally Fulweiler. Di-nitrogen gas occurs when there is no dissolved oxygen in the water.

[Revise 01/25/2013]

Well, I just have to add this slide about my Nemesis, the ancient Greek Goddess of retribution, Casey's Sill. For the most part our expeditions aboard the RV Eel were a joy! Over the six weeks of testing we watched the colors of the leaves change on the trees along the shore of the river. The animal life was active during our first few weeks while the weather was warm.

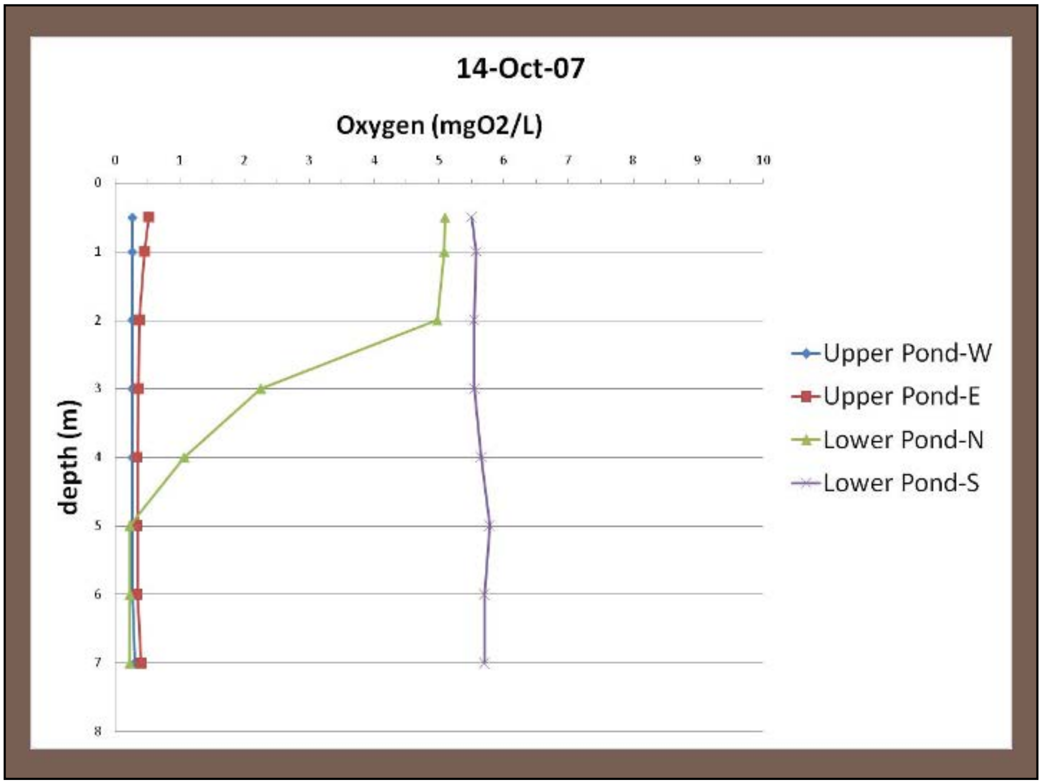
[Revised 04/22/2008]



But each trip required that we travel over the sill or shallow area that was located between Upper and Lower Pond. The conditions were always different. Water depth over the sill depended on the tides and wind but even at high tide it was only about a foot or half a meter deep. There is only a ten to twenty foot wide passage through this area. Sometimes Captain/Dr. Veronica would rev up the engine and we would hydroplane over the sill. There were occasions when we had to use the oars as poles to push the boat. Other times we would feel like we were just going to make it over the area – and bang we would run aground. Twice I flew forward on the boat. Nothing broken. But the approach to the sill either from the north or the south was greeted by a gritting of teeth. "What surprise do you have for us today, Casey's Sill?"

[Revised 04/22/2008]

What was happening
in the water column
right after the overturn?

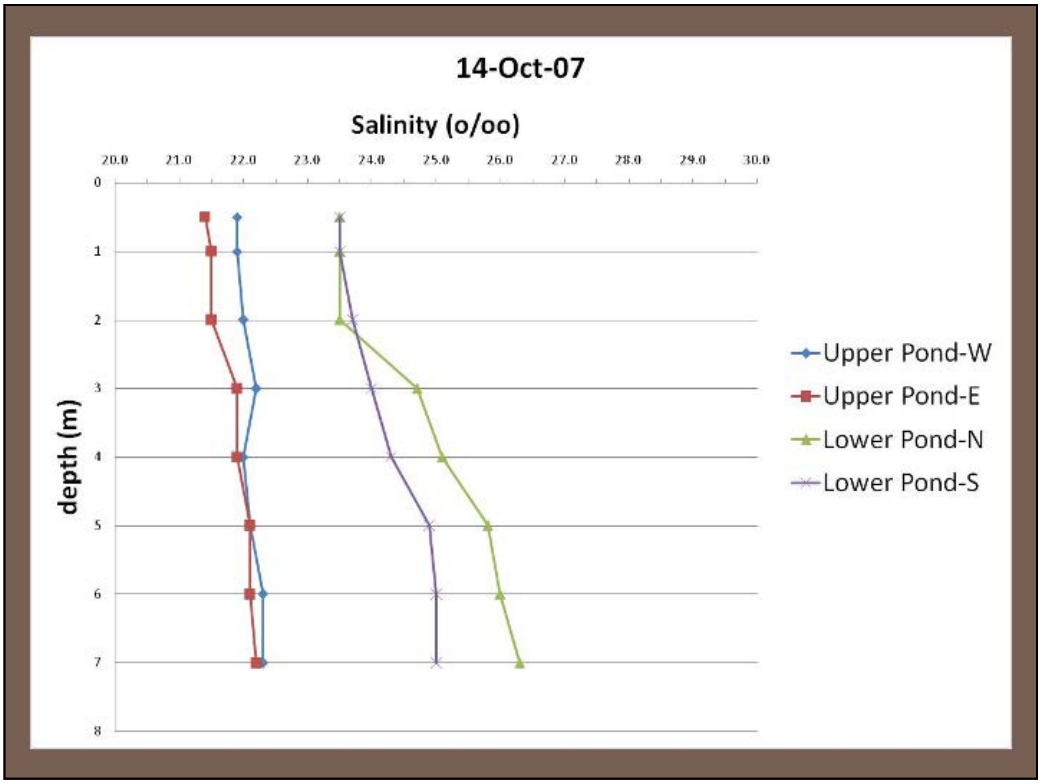


We took our first profiles of oxygen concentrations on Sunday, October 14. We took measurements at two locations in Upper Pond: slightly west (W, blue) of center and slightly east (E, red) of center. Note that the concentrations are almost all the same at both locations and with depth and are very close to zero. The water is well mixed since concentrations do not change with depth.

For comparison we also took measurements at two locations in Lower Pond which did not overturn. The station in the northern end of the pond (N, green) is over the deep hole. The profile here is what we would expect to see in the deep basins – sufficient oxygen in the top few meters of water and then the oxygen decreases to near zero with depth. the near surface oxygen concentrations are a little lower than normal, probably because of overturned water flowing out of Upper Pond.

The station in the southern end of Lower pond (S, purple) is not over the deep hole and so oxygen is sufficient and stays the same with depth.

[Revised 01/25/2013]

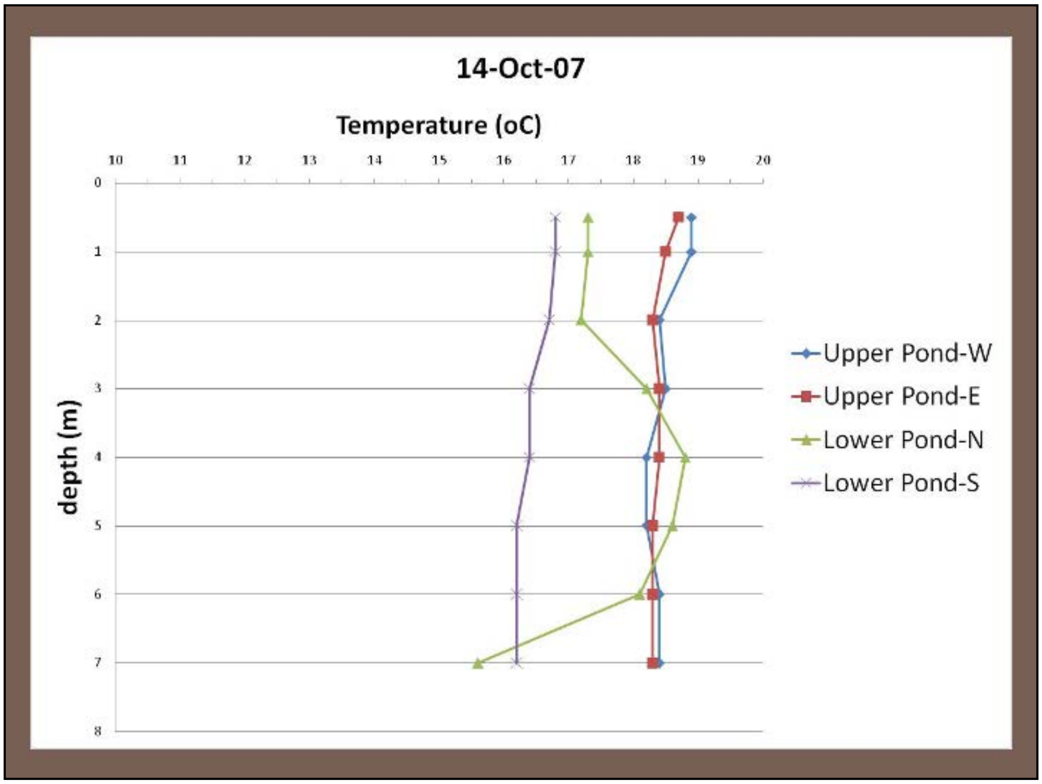


We took our first profiles of salinity values on Sunday, October 14 with the probe that also measured the oxygen. We took measurements at two locations in Upper Pond: slightly west (W, blue) of center and slightly east (E, red) of center. Note that the concentrations at both sites are almost all the same and higher then usual for Upper Pond because of the overturn.

For comparison we also took measurements at two locations in Lower Pond which did not overturn. The station in the northern end of the pond (N, green) is over the deep hole. The profile here is what we would expect to see in the deep basins – lower salinity in the top few meters of water and then the salinity increases with depth.

The station in the southern end of Lower pond (S, purple) is not over the deep hole and so there is less change with depth.

[Revised 01/25/2013]

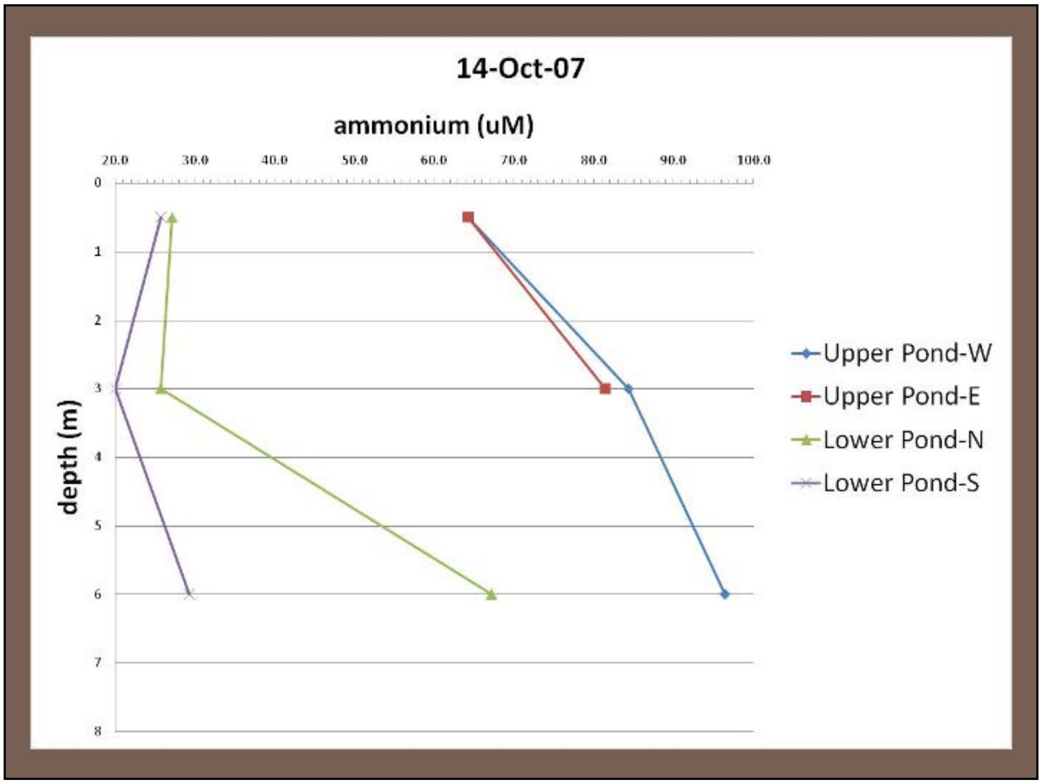


We took our first profiles of temperature on Sunday, October 14. We took measurements at two locations in Upper Pond: slightly west (W, blue) of center and slightly east (E, red) of center. Note that the concentrations are almost all the same at both locations and with depth and are warm at about 19^{o} C.

For comparison we also took measurements at two locations in Lower Pond which did not overturn. The station in the northern end of the pond (N, green) is over the deep hole. There are seasonal temperatures in the top few meters of water and then temperatures increase at depth. Temperatures would be expected to decrease with depth since the bottom waters are generally cooler and saltier, but here we see an increase in temperature to the level seen in Upper Pond. This suggests that there is overturned water at this depth (3-6m) coming from Upper Pond. Then the temperature decreases again at 7m as expected.

The station in the southern end of Lower pond (S, purple) is not over the deep hole and so temperature stays the same with depth. And this is cooler than Upper Pond.

[Revised 01/25/2013]



We took samples for nutrients on Sunday, October 14. Here are the ammonium concentrations. We took measurements at two locations in Upper Pond: slightly west (W, blue) of center and slightly east (E, red) of center. Note that the concentrations are very high, are almost the same at both locations, and increase dramatically with depth. This high ammonium maybe coming out of the sediments as overturned water fills the basin.

For comparison we also took measurements at two locations in Lower Pond which did not overturn. The station in the northern end of the pond (N, green) is over the deep hole. The profile here is what we would expect to see in the deep basins – some ammonium in the top few meters of water and then increasing dramatically with depth but the overall values are lower then in Upper Pond.

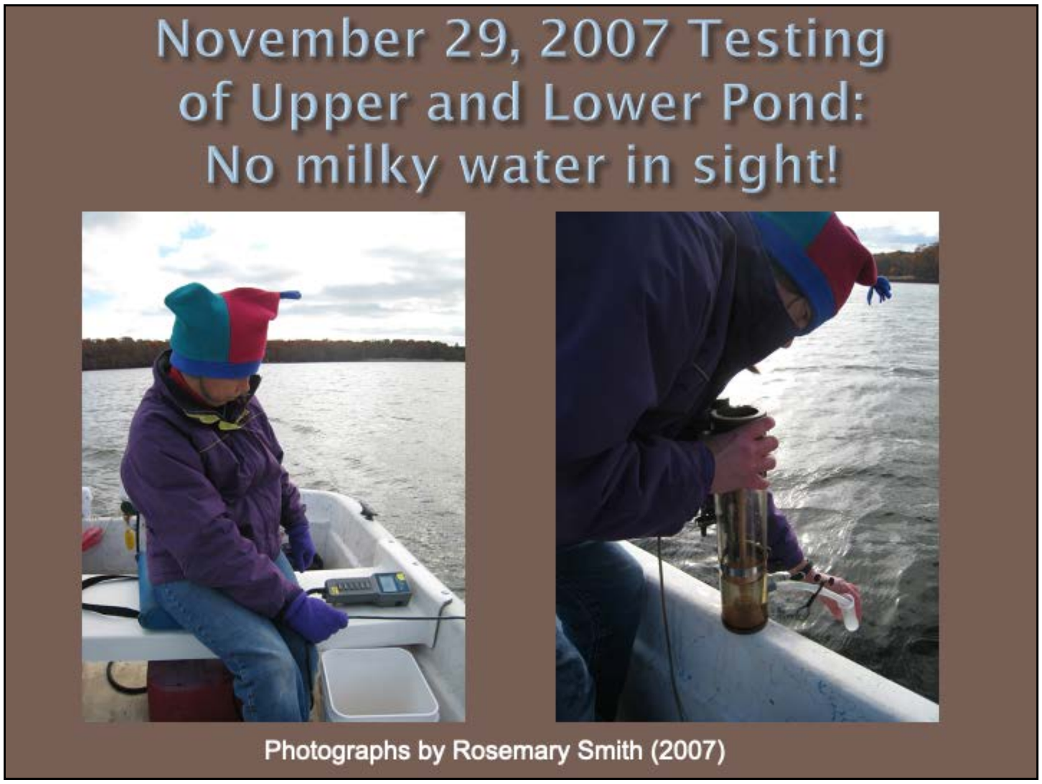
The station in the southern end of Lower pond (S, purple) is not over the deep hole and so there is little change with depth. Also. concentrations are lower here.

[Revised 01/25/2013]

In Summary

Soon after the overturn,
in comparison to Lower Pond that did not overturn,
the water in Upper Pond:

- Was well mixed
- Had less oxygen
- Was warmer
- Had more nitrogen (as ammonium)
- Was less salty
- But it was saltier than usual for Upper Pond

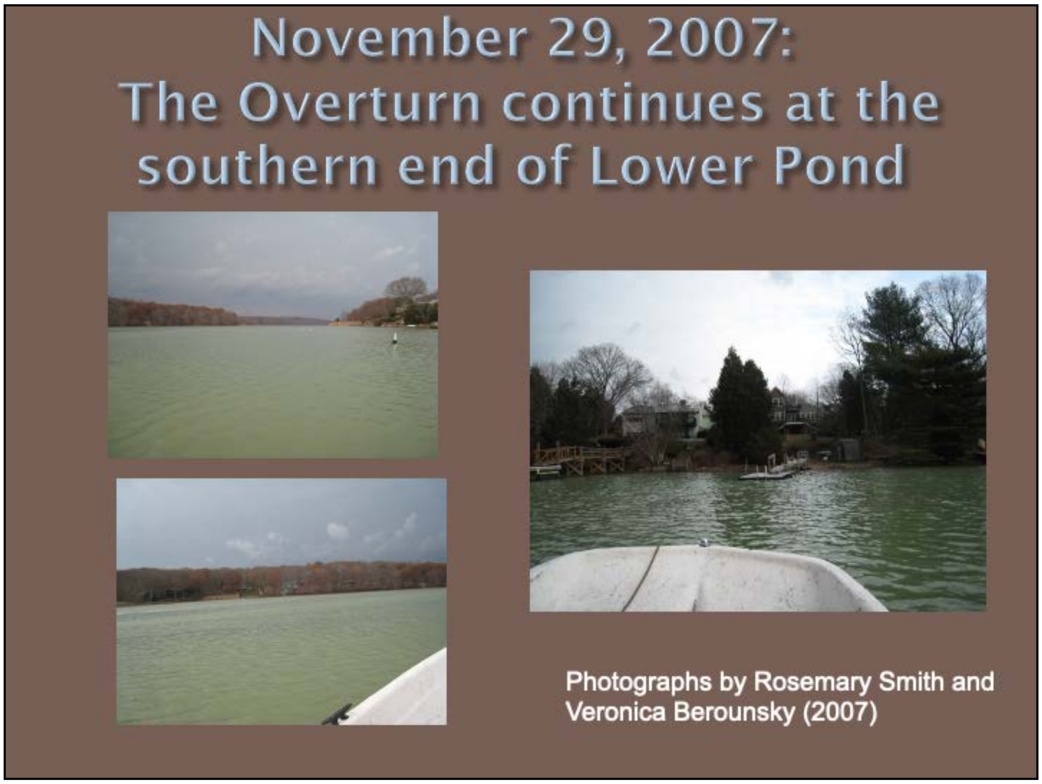


The pleasant testing conditions of the fall began to change as we moved into the cooler weather of late November. Hats, jackets, a couple of pair of mittens, boots and socks helped to maintain some inner warmth.

November 29 was to be the last day of testing aboard the RV Eel. The skiff would be taken out of the water on Saturday as it was getting too cold. Ice would soon be forming on the river. Veronica explained that she would be continuing her testing at the edge of the pond. Several neighbors had given her permission to collect data at their waterfronts.

On this day we sampled both the Upper and Lower Ponds. There was no milky water in sight. The weather was cold and there was a rain/snow storm approaching. This seemed just like a normal day of testing and the ponds were recovering from the overturn.

[Revised 04/22/2008]



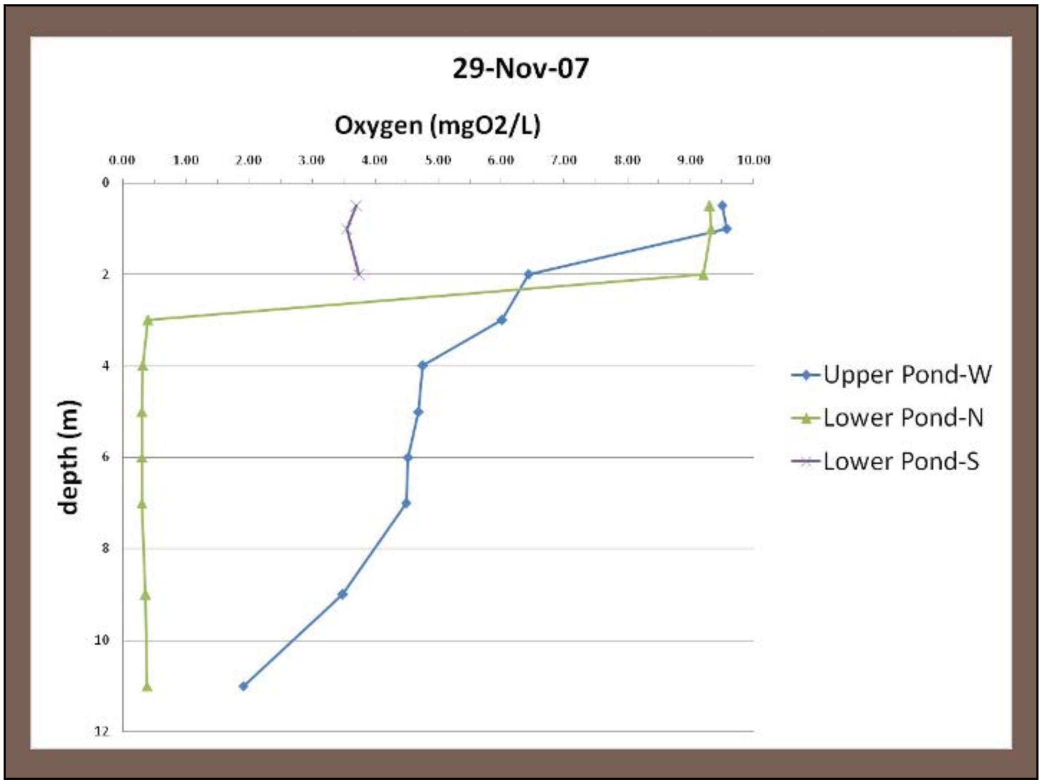
However, as we approached the dock at Veronica’s house at the southern end of Lower Pond near Lacey Bridge, we noticed milky water. Veronica’s children came racing down the dock asking if there had been an overturn near their house. We couldn’t believe our eyes!

[Revised 04/22/2008]

What was happening in the water column on November 29, 2008, seven weeks after the overturn?

There was little evidence of the overturn in the Upper and Lower Ponds, but there was “milky water” near the southern end of the Lower Pond

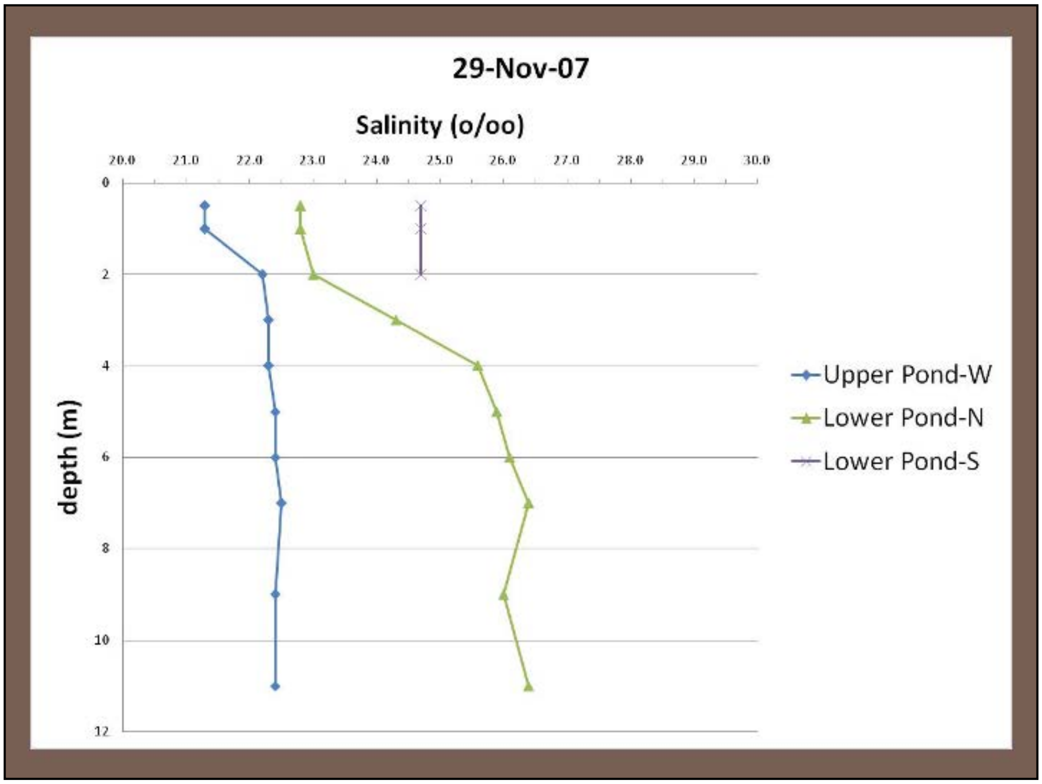
[Revised 04/08/2008]



Here are data from that day, November 29, 2007. We took measurements at one location in Upper Pond: slightly west (W, blue) of center which we now knew was over the deepest part of the basin. Note that now we are seeing differences with depth, oxygen is about normal for the surface waters and it decreases with depth. The water is no longer well mixed but is now showing stratification with layers with different concentrations, but the layers are not as distinct as in Lower Pond.

For comparison we also took measurements at two locations in Lower Pond which did not originally overturn. The station in the northern end of the pond (N, green) is over the deep hole. The profile here is what we would expect to see in the deep basins – normal oxygen levels in the top few meters of water and then the oxygen decreases to near zero with depth. The station in the southern end of Lower pond (S, purple) is not over the deep hole but note how much lower the oxygen is here compared to the other two stations! It is at about the concentration seen in the earlier graphs for Lower pond when milky water flowed past. This is the area where we saw the milky water! Note that the stations over the deep basins have measurements to about 12m deep.

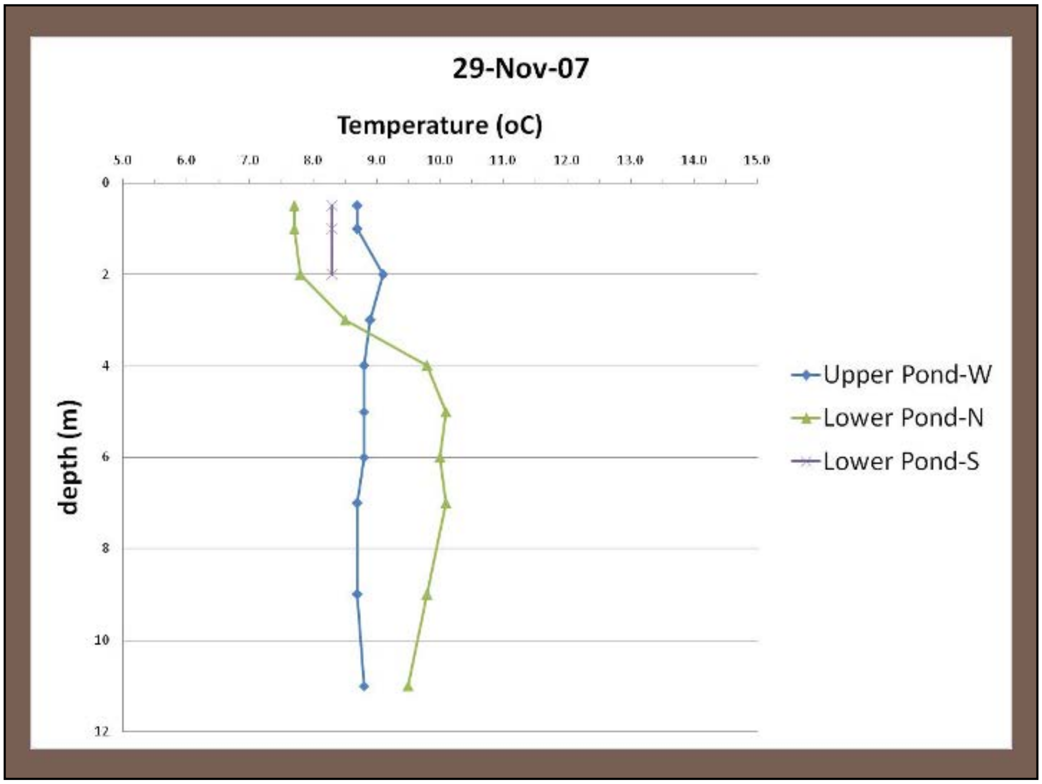
[Revised 01/26/2013]



Here are data from November 29, 2007. We took measurements at one location in Upper Pond: slightly west (W, blue) of center which we now knew was over the deepest part of the basin. Note that now we are seeing differences with depth, salinity is lower in the surface waters and increases with depth. The water is no longer well mixed but is now showing stratification with layers with different concentrations, but the layers are not as different as in Lower Pond.

For comparison we also took measurements at two locations in Lower Pond which did not originally overturn. The station in the northern end of the pond (N, green) is over the deep hole. The profile here is what we would expect to see in the deep basins – lower oxygen levels in the top few meters of water and then the salinity increases with depth. Upper Pond is still less salty then Lower Pond, just as it was right after the overturn. The station in the southern end of Lower pond (S, purple) is not over the deep hole but note how much higher the salinity is here compared to the other two stations! It is at about the concentration seen in the earlier graphs for deep water in Lower pond. This is the area where we saw the milky water! Note that the stations over the deep basins have measurements to about 12m deep.

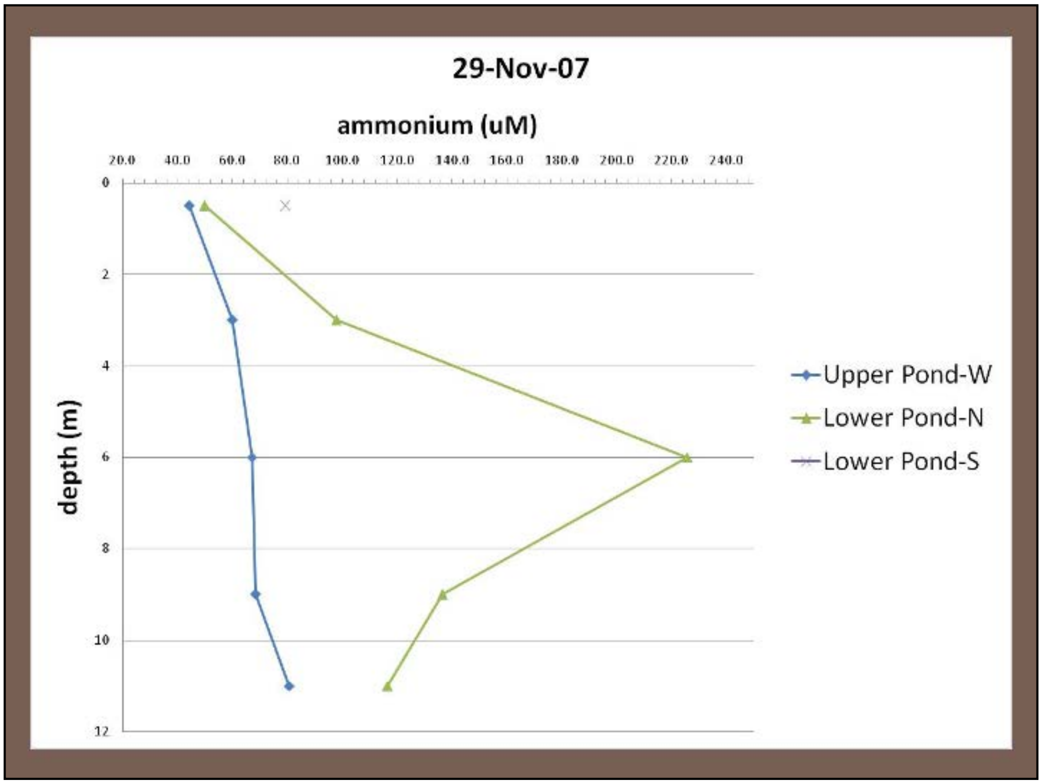
[Revised 01/23/2013]



Here are data from November 29, 2007. We took measurements at one location in Upper Pond: slightly west (W, blue) of center which we now knew was over the deepest part of the basin. In Upper Pond note there are very little differences with depth and temperatures are cooler than right after the overturn. The water is probably well mixed and cooling down for the season.

For comparison we also took measurements at two locations in Lower Pond which did not originally overturn. The station in the northern end of the pond (N, green) is over the deep hole. The profile here is what we would expect to see in the deep basins – lower temperature levels in the top few meters of water and then the temperature increases with depth to 4m and then is about constant. It is interesting that Lower Pond is cooler at the surface and warmer at depth compared to Upper Pond. It seems to be retaining heat at depth better the Upper Pond – probably do to less mixing. The station in the southern end of Lower pond (S, purple) is not over the deep hole and note that the temperature is in between the values at the other two stations. The water at this station has cooled down also compared to right after the overturn. This is the area where we saw the milky water! Note that the stations over the deep basins have measurements to about 12m deep.

[Revised 01/23/2013]



Here are data from November 29, 2007. We took measurements at one location in Upper Pond: slightly west (W, blue) of center which we now knew was over the deepest part of the basin. In Upper Pond note there are only small differences with depth (40-60 uM) and values are lower then right after the overturn (60-100 uM). The water is probably well mixed.

For comparison we also took measurements at two locations in Lower Pond which did not originally overturn. The station in the northern end of the pond (N, green) is over the deep hole. The profile here is interesting – similar to Upper Pond in the surface waters (40uM), then concentrations are higher where oxygen is low, below 3m. The highest values are at mid-depth (220 uM), then values decrease to about 100 uM in the bottom. So there is stratification in Lower Pond.

The station in the southern end of Lower pond (S, purple) is not over the deep hole and note that there is only one measurement there because of the shallow depth. The ammonium is highest here (80 uM) of all the surface waters. This is the area where we saw the milky water! Note that the stations over the deep basins have measurements to about 12m deep.

[Revised 01/26/2013]

Milky Water in Lower Pond

As I disembarked from the boat, we could see that the overturn water had spread to the shore of the south end of Lower Pond. We paused for a moment to have our picture taken. Then Veronica asked that I take pictures at the bridges as I worked my way home to Narragansett Pier.

[Revised 04/08/2008]

North and south of Bridgetown Road at Lacey Bridge you could see the milky water flowing under the bridge.
[Revised 04/08/2008]

Narrow River from Middle Bridge: no milky water visible

North and south of Middle Bridge there seemed to be no discoloration of the water.

[Revised 04/08/2008]

At the Governor Sprague Bridge there was a milky green color in the center of the Narrows to the east of the bridge. Was the milky water from the overturn headed out to Narragansett Bay?

Then it became dark with rain and the colors of the river were no longer visible.

What had started as an ordinary testing day turned into a surprise! The Narrow River was continuing to overturn. The natural phenomenon that had occurred on October 12 was continuing on November 29, seven weeks later. How much longer would this go on?

What have we learned?

- The overturn was a natural event and was caused by water, weather and wind conditions
- The overturn had a negative impact on the organisms living in the Narrow River
- The overturn caused some unusual chemistry in the waters of the Narrow River
- The overturn conditions persisted for at least seven weeks

[Revised 01/26/2013]

We continue our quest to understand these “overturns”…

Dr. Veronica Berounsky’s quest for collecting data on Narrow River is not completed. There are more questions to be answered, more information to be gathered, more research to be done, more presentations about this beautiful watershed to share with the public.

The Pettaquamscutt River Estuary in Southern Rhode Island is a unique treasure!

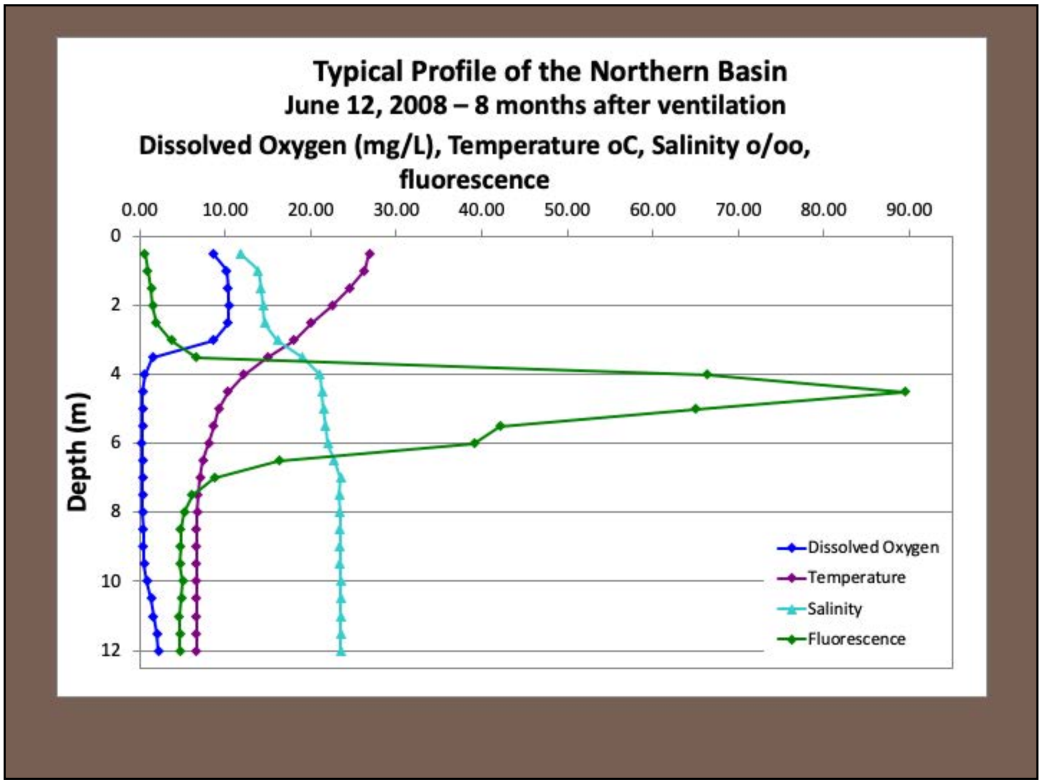
[Revised 04/08/2008]

June 2008 Update:

- The chemistry of the Narrow River slowly returned to normal over the winter
- Now there are more healthy benthic organisms
- Fish have returned and are healthy
- The ecosystem is recovering!

- And new things are being discovered: An unusually intense layer of the plant pigment chlorophyll was found routinely in the water at a depth with very little oxygen

[Revised 01/26/2013]



This graphs shows profiles of dissolved oxygen, temperature, salinity, and fluorescence (a measure of the plant pigment chlorophyll) on June 12, 2008 in the Upper Pond of Narrow River. We can see that the water is no longer well-mixed but instead it is stratified with layers. The surface layer has plenty of oxygen, warm temperatures, some salinity, and little fluorescence (chlorophyll). At the depth where the oxygen disappears, the fluorescence (chlorophyll) has a very high value. In the deeper layer, there is little or no oxygen, temperatures are cooler, salinity is higher, and fluorescence (chlorophyll) is very low again!

[Revised 01/26/2013]

- Has Upper Pond had any other overturns since October 2007?

- Yes. In November of 2010 and again in November of 2012 there were partial overturns in Upper Pond. Because we have continued making weekly measurements we have a record of anoxic water (water without oxygen) coming up to the surface again! But these events lasted only a few days and were not as widespread throughout the pond as the 2007 overturn.

[Revised 01/26/2013]

And the milky-colored water returned for a short while…

Photo of Upper Pond in November 2010 by Veronica Berounsky

Why Is It Important to Study Overturns?

- Basic studies about a system can lead to new knowledge, such as the intense chlorophyll layer
- Studying naturally-occurring anoxic water events and the recovery gives us insight about anoxic events caused by pollution
- Climate change affects weather and sea level, which in turn affect overturns
- Studying systems without oxygen can help us understand the pre-historic ocean, which probably did not have oxygen

We would like to thank:

- **Linda Green of URI Watershed Watch and A. Van Kuren of URI Nixon Lab for Nutrient Analysis**
- **URI Watershed Watch, the URI Marine Ecosystem Research Laboratory and the Narragansett Bay Estuary Project for profiling equipment**
- **All who helped with sampling, data analysis, and discussions!**

[Revised 01/26/2013]

List of Scientific Instruments Used

YSI 85 Meter	Temperature, Dissolved Oxygen and Salinity
Camera	Pictures and Videos
Secchi Disc	Water Clarity
Benthic Sampler and Sieve	Benthic Animals and Sediment
Plankton Net	Phyto and Zoo Plankton
Seine Net	Fish
Niskin Bottle for Water, Test Tubes and Bottles	Nitrogen, Phosphate, and Sulfur Samples

[Revised 04/08/2008]