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Attention: Eric Cody
Friends of Ellisville Marsh, Inc.
P.O. Box 1728
Sagamore Beach, MA 02562

July 12, 2013

Hello Eric,

As we discussed after the summer-2012 monitoring season, I would like to take the opportunity to provide some supplemental comments to the Aquatic Control Technology report "2012 Water and Sediment Quality Survey of Savery Pond – Plymouth MA" (ACT, 2012). In addition to my comments on ACT's analysis of nutrient levels measured in the pond water and sediments, I would like to offer additional comments regarding the hydrology of the pond, its connection to groundwater, and how the groundwater/surface-water connection may be affecting both its water balance and its nutrient balance. Many of my hydrologic comments may also be applicable to other ponds in the region, as most of them are connected to groundwater and therefore affected by impacts associated with groundwater management practices.

As you also know, I am a long-time summer resident of Savery Pond. This summer will be my 51st year on the pond, and my family has owned property on the Pond for over 75 years. In my time there, I've become quite familiar with the local hydrology, the pond conditions, and the cranberry operations that have likely contributed significant amounts of nutrients to the pond. Over the past year, I reviewed the following reports and spoke with the following scientists and water-resource managers:

- USGS Report: *Hydrogeology and Simulation of Groundwater Flow in the Plymouth-Carver-Kingston-Duxbury Aquifer System, Southeastern Massachusetts* (SIR 2009-5063);
- USGS Report: *Hydrogeology and Groundwater Resources of the Coastal Aquifers of Southeastern Massachusetts* (Circular 1338);
- USGS Report: *Use of Numerical Models to Simulate Transport of Sewage-Derived Nitrate in a Coastal Aquifer, Central and Western Cape Cod, Massachusetts* (SIR 2007-5259);
- Fuss & O'Neill Report: *Plymouth-Carver Sole Source Aquifer Action Plan Final Report*, dated August 2007;
- Other scientific reports on nutrient transport through groundwater and discharge to surface water;
- Personal Communication with David Gould and Kim Tower, Department of Marine and Environmental Affairs, Town of Plymouth
- Personal Communication with John P. Masterson, Hydrologist, United States Geological Survey
- Personal Communication with Carolyn DeMoranville, UMass Cranberry Station

- Personal Communication with Jeffrey LaFleur, Cape Cod Cranberry Growers' Association

I will divide this letter up into 2 sections: 1) comments on the ACT report, and 2) additional comments regarding the surface-water/groundwater hydrology.

Comments on ACT Report

I have already provided Friends of Ellisville Marsh (FEM) with a marked-up digital copy of the draft ACT report. Unfortunately, my comments arrived too late to be incorporated into the final report. The following is a summary of my key comments, for detailed comments please see my mark-up version:

1. The “description of tested water quality parameters” would benefit from discussion of the significant of temperature (T) and dissolved oxygen (DO) measurements. This section would also benefit from mention of optimal ranges of nitrogen compounds in pond water.
2. Some discussion to assist in understanding the simultaneous occurrence of low dissolved nutrient levels and algal bloom conditions is warranted.
3. Regarding the late-September grab sample at the bog outfall, it would be useful to relate the presence of high concentrations of dissolved phosphorus (P) to flooding practices on the bog (at least theoretically). Personal communication with Carolyn DeMoranville indicates that if a bog floods for too long, anaerobic conditions can form causing P adsorbed to the soil to be mobilized. It would be worth looking into this, as it identifies a possible farming practice that could be modified.
4. If the bog operation results in drainage during other times in the growing season, outfall samples should be taken during these times to establish whether the September sample is representative and whether seasonal variations exist.
5. The report does not discuss the significance of measured temperatures. Warmer water is more conducive for algal blooms. Temperature can be a significant indicator of the balance between groundwater inflow to the pond (as underwater springs) and atmospheric warming. Long-term temperature trends could be instructive.
6. The report mentions two significant sources of phosphorus. “Moderately high phosphorus content and recycling of phosphorus” is noted for the lake sediments, with higher concentrations measured near the cranberry bogs. Discharge from the east bog (the only bog currently active) is characterized as indicating “significant phosphorus loading”. Past and current bog operations appear to account for much of the available phosphorus in Savery Pond. It would be useful to know whether the “moderately high” concentrations measured in the pond sediments could be reasonably explained in any way other than historic agricultural loading.
7. Sampling performed to date does not seem to have characterized the dominant mechanism for the algal blooms. This mechanism may occur over a short burst, and may be hard to capture with sporadic samples. Composite sampling from multiple locations hasn’t shown the high dissolved phosphorus needed for algal uptake. Composite samples showing high *total* phosphorus (likely particulates/plant matter) and low *dissolved* phosphorus has likely missed the nutrient source fueling the algal blooms. High dissolved phosphorus was observed in FEM’s single grab sample taken from the East Bog outflow in September 2012 (well after the July algal bloom). Future sampling should aim at identifying which of the two phosphorus sources (and what mechanisms) are accountable for the algal blooms.

8. Regarding future sampling programs:
    a. A 2013 sampling plan has not yet been developed. Given current FEM budget constraints, 2013 sampling will likely be sporadic and limited. I look forward to assisting in developing a sampling plan within the next 4 weeks.
    b. It would be good to assemble a table showing the costs of various sampling and monitoring activities from which a sampling plan can be developed.
    c. Given the algal blooms noted in 2010 and 2011, and the fact that existing data suggests that nutrient loading has likely been associated with cranberry farming activities, it may be worthwhile to develop a cooperative sampling program with the UMass Cranberry Station, the Cape Cod Cranberry Growers' Association and/or find a university student interested in studying this under their thesis.
    d. While groundwater typically does not transport significant concentrations of P (which is typically the limiting nutrient for freshwater algal blooms), this can occur under unusually high loading rates. Although not the highest priority under a limited sampling budget, baseline definition of groundwater nutrient concentrations may still be useful. Monitoring groundwater levels is also helpful in assessing the hydraulic gradient to the pond, which may change over time due to municipal pumping (see next section).
    e. I strongly agree with the recommendation to develop a phosphorus budget and model for the pond. Again, this would be a good project for a university student under professorial supervision.
    f. It may be worth considering continuous temperature monitoring in the pond. Many fish biologists use inexpensive (<$100) HOBO dataloggers. Two dataloggers could be attached to a rope running from an anchor at the bottom of the pond to one of the rocks in the submerged rock pile in the center of the pond.
9. Regarding in-pond management of phosphorus, along with the methods of dosing the pond with P-absorbing compounds, might it be worthwhile to consider dredging of high-P sediments near the bog outfalls where P concentrations appear to be highest?

<u>Surface-Water/Groundwater Hydrology</u>

Savery Pond is in connection with shallow groundwater. Pond levels are supported by groundwater inflows via underwater springs and by precipitation on the pond surface. The occurrence of underwater springs is readily noted by swimmers, who have historically detected (and perhaps tried to avoid) "cold spots" where cool groundwater enters the pond. The pond discharges to a small stream which flows out to Ellisville Marsh. The FEM website notes that: *"Savery Pond was historically the most significant source of freshwater flowing into the Ellisville estuary. However, the herring run that connects the pond and marsh is silted over from development and years of neglect, with correspondingly reduced flows"*. The pond level appears to be controlled by an outflow structure at the creek's headwaters. The rate of pond discharge to the stream is equal to the net balance between groundwater inflow, direct precipitation, direct evaporation and other losses associated with the cranberry operations.

The rate of groundwater inflow via springs is controlled by the difference between the pond level and ambient groundwater levels (i.e. the groundwater "gradient" towards the pond). Groundwater levels respond to seasonal and year-to-year climatic variations, to land-use development (e.g. areas where impervious surfaces and soil compaction limit recharge), and to consumptive groundwater withdrawals. Rural residential groundwater pumping for indoor use is predominantly non-consumptive, as most of the water pumped is recharged back into the ground as septic system effluent. Pumping for irrigation can be largely consumptive during the growing season due to evaporative losses from plants and the soil surface. Regional groundwater pumping, such as that practiced by the Town of Plymouth, can include large withdrawals conveyed to distant distribution systems, effectively creating locally consumptive withdrawals. Consumptive withdrawals cause groundwater level declines, which can thereby cause reduced groundwater discharge to nearby surface-water features such as ponds, lakes, wetlands and streams. This phenomenon is accessibly explained in the USGS circular: "*Ground Water and Surface Water A Single Resource*" (http://pubs.usgs.gov/circ/circ1139/).

The amount of groundwater flushing through a pond or lake can affect the likelihood of algal blooms and eutrophication in at least two ways:

1. Reduced groundwater flushing will cause summer lake temperatures to increase because groundwater temperatures are cool relative to summer air temperatures. Biological activity, including algal growth, can be increased due to increased water temperature.
2. Reduced flushing causes longer residence times for water in the pond, during which time nutrients released from lakebed sediments will concentrate in the pond water. Higher rates of flushing will likely reduce nutrient concentrations which feed algal blooms.

A 2005 map of existing water-supply infrastructure prepared for the Town of Plymouth by Wright-Pierce shows 2 public well supplies in the vicinity of Savery Pond. (See the "Ellisville Well" and the "Savory Pond Well" on the map attached to this letter.[1]) The USGS developed a computer model of the Plymouth-Carver-Kingston-Duxbury Aquifer System (SIR 2009-5063) which includes representation of surface-water features and groundwater pumping. The model includes Town-of-Plymouth wells (including the two mentioned above) along with historic and projected future pumping rates. A third local well (#56) is slated for completion next to the Savory Pond Well, and the following past/future withdrawals are reported:

Year	Ellisville Well Pumping (mgd)	Savory Pond Well Pumping (mgd)	Well #56 Pumping (mgd)	Total Local Pumping (mgd)	Total Local Pumping Increase
1985	0.34	0.00	0.00	0.34	n/a
2005	0.51	0.25	0.00	0.76	123%
2030	0.36	0.36	0.36	1.08	215%

All pumping rates above are in million gallons per day (mgd). I do not know the extent to which the pumped groundwater is conveyed to distant distributions systems; however, 1 mgd is a significant amount of water and there is not significant residential development in the immediate Savery Pond vicinity. Therefore, a relatively high portion of local groundwater withdrawals is expected to be effective consumptive.

By simulating surface-water features, the model can be used to predict groundwater exchanges with features such as ponds, lakes, wetlands, streams and coastal estuaries. In fact, the USGS model

[1] http://www.plymouth-ma.gov/Public_Documents/PlymouthMA_Water/Water%20System%20Map/

does simulate groundwater inflow to Savery Pond, groundwater exchange with its outflow stream (the stream is predicted to largely lose flow to groundwater along its course to Ellisville Marsh), and groundwater discharge to Ellisville Marsh. The USGS ran the model under 1995, 2005 and projected 2030 conditions, and I obtained the model files directly from the USGS. I extracted model water budgets for Savery Pond and its outflow stream, as summarized in the table below:

Year	Total Local Pumping Increase	Model Predicted Savery Pond Inflow (cfs)	Cumulative Pond Inflow Change	Model Predicted Seepage Loss from Creek (cfs)	Cumulative Reduction in Creek Flow
1985	n/a	1.18	n/a	-0.49	n/a
2005	123%	0.99	-16%	-0.56	15%
2030	215%	0.97	-17%	-0.52	7%

The model results predict that groundwater inflow to the pond has already decreased by at least 16% since 1985, and that seepage loss *from* the creek has increased by between 7% to 15%. Since pond inflows discharge to the stream, the model predicts about 22% to 31% reduction in streamflow. Model results could similarly be extracted for Ellisville marsh and are expected to show a reduction of freshwater discharge to the marsh. It should be noted that the model is regional in scale and was not specifically calibrated to Ellisville hydrologic features; however, the model results demonstrate how nearby consumptive municipal pumping is likely to affect the water budget for ponds and streams. Both myself and my family members have noticed a reduction in spring discharge (“cold spots”) to Savery Pond over the past 20 years.

The impacts of groundwater pumping on local surface-water features is not limited to the Savery Pond/stream (and Ellisville Marsh) complex, but likely occurs in other areas of increased consumptive groundwater use. Groundwater declines due to pumping have implications for lake levels (where outlet structures do not maintain constant lake stage), rates of groundwater flushing through lakes, rates of groundwater discharge to streams and estuaries, temperatures in surface-water features receiving groundwater discharge, and water-budget effects on associated nutrient budgets.

As noted above, I agree with the recommendation of performing a nutrient budget for the pond. Since nutrients are transported in flowing water, nutrient budgets typically employ estimates of inflows and outflows paired with associated nutrient concentrations. The best way to estimate net groundwater inflow to the pond is via a water balance, where stream outflow is balanced against precipitation and evaporation (easily estimated) to calculate net groundwater inflow. If applicable, this method provides the simplest approach to estimating the flow terms incorporated into a nutrient budget. However, in some cases, lakes and ponds gain groundwater inflow on the upgradient side (where groundwater levels are higher) and emit outflow on the downgradient side (where groundwater levels are lower). In this case, estimating the groundwater inflow *and outflow* components of the water budget is considerably more difficult. Measurement of groundwater elevations in wells relative to the pond surface elevation would be needed to ascertain whether Savery Pond is wholly gaining from groundwater or both gaining and losing depending on location.

In performing a nutrient budget, it may also be the case that making reasonable assumptions helps to constrain the analysis so that certain measurements are not needed. Nutrient concentrations in groundwater *can* be measured by sampling nearby wells, but can also be represented using reasonable ranges to ascertain whether groundwater transport of nutrients is likely to be significant in the pond's nutrient budget. In most cases, phosphorus, the limiting nutrient for algal blooms, is unlikely to be present at significant concentrations in groundwater. Sampling of key local wells could be performed to confirm this; though it may not be the best use of limited funding. In any case, if FEM obtains assistance from a lake ecologist or scientist with knowledge of nutrient cycling and processes, I believe initiating a nutrient budget would be worthwhile to ascertain the key sources and sinks of phosphorus and nitrogen compounds.

Finally, I would recommend that FEM works cooperatively with the cranberry growers on the pond, and potentially with the Cape Cod Cranberry Growers' Association, to address how past and present bog operations may be contributing to current nutrient availability.

I hope that these comments are useful to FEM. I am happy to assist further in developing a sampling plan and improving current understanding of nutrient loading and the hydrology of the pond/stream/marsh complex.

Sincerely,

Peter Schwartzman
Consulting Hydrogeologist

Attachment: Plymouth Water System Map


PLYMPTON
KINGSTON
DUXBURY
CARVER
WAREHAM
SANDWICH
West Plymouth
Plymouth Center
Pine Hills
Bradford
Manomet
Cedarville
DARBY POND WELL
NORTH PLYMOUTH WELL
NORTH PLYMOUTH TANK
HALL ST PRV
SAMOSET ST PRV
SAMOSET ST STANDPIPE
SUMMER ST PRV
HARRINGTON STANDPIPE
DEEP WATER BPS
NEWFIELD ST PRV
STAFFORD ST STANDPIPE
OBERY ST PRV
LOUT POND TANK
NOOK RD. BPS
FEDERAL FURNACE WELL
BRADFORD WELL
CHILTONVILLE STANDPIPE
SOUTH POND WELLS 1 & 2
ROCKY HILL ROAD PRV
PINE HILLS BPS
PINE HILLS TANK
SOUTH PINE HILLS TANK
Great South Pond
MYLES STANDISH STATE PARK
PLYMOUTH
WANNOS POND WELL
Fresh Pond
Halfway Pond
Long Pond
INDIAN HILL TANK
SHIPS POND WELL
SOUTH COASTAL
BUZZARDS BAY
Bloody Pond
SAVORY POND WELL
ELLISVILLE WELL
ELLISVILLE BPS
CEDARVILLE TANK
Little Herring Pond
BUZZARDS BAY WATER DISTRICT SERVICE TERRITORY
Source:
Parcel data was received from the Town of Plymouth.
All data that includes Regulated Department of Environmental Protection Areas was developed by the DEP and distributed through MassGIS
The Water System data was developed by Wright-Pierce using the Master Water System map from the Town of Plymouth.
Legend
Tanks
PRV
Public Well Supply
Booster Pump Station
Service Area Boundaries
Buzzards Bay Water District
Watershed Boundary
Myles Standish State Park
Water Pipes
2" and 4"
6"
8"
10"
12"
16" and 20"
0 3,000 6,000 9,000 12,000
Feet
EXISTING SERVICE ZONES AND INFRASTRUCTURE
Plymouth, Massachusetts
PROJ NO: 10446A
DATE: July 2005
SCALE: AS NOTED
Wright-Pierce
Better Engineering, Better Treatment.
FIGURE: 2 - 1