MASSACHUSETTS
100 Fifth Avenue, 5th Floor
Waltham, Massachusetts 02451
p 781.419.7696

RHODE ISLAND
401 Wampanoag Trail, Suite 400
East Providence, Rhode Island 02915
p 401.434.5560

VIRGINIA
4410 E. Claiborne Square, Suite 334
Hampton, Virginia 23666
p 757.251.3790

February 1, 2013

Mr. Robert C. Hadley
Devol Pond Association
246 Durfee Street.
Fall River, MA 02720

Re: Recommended Remedial Solutions for Devol Pond, Westport, MA
ESS Project No. D168-000

Dear Mr. Hadley:

ESS Group, Inc. (ESS) has prepared this report for the Devol Pond Association (DPA) with the objective of developing recommendations for remedial solutions for Devol Pond and its watershed. DPA is concerned with the severe summer algal blooms in the pond and has documented a trend in the pond over the last decade toward higher nutrient levels and more frequent algae blooms. DPA previously implemented its own water quality survey work in which it discovered significantly elevated phosphorus concentrations emanating from the south end of the pond. Additionally, DPA commissioned a 2009 report that documented generally poor water quality conditions and high levels of photosynthetic productivity.

This report provides a summary of the sampling program carried out by ESS to further examine the sources of elevated phosphorus and propose appropriate management recommendations based on our findings. Additional details on the permitting requirements and costs for implementation of the recommended actions are also provided.

Project Background

Description of Site

Devol Pond is an approximately 103-acre shallow, kettle pond located in the town of Westport, Massachusetts. The immediate pond shoreline is dominated by wetland and forest but some private residences bordered are also present, primarily along the southern and northwestern shorelines. The average depth of the pond is approximately 1.8 meters (5.95 feet) and the volume of the pond is approximately 763,300 cubic meters.

Surface inputs to Devol Pond appear to be primarily sourced from the Narrow Avenue tributary, although smaller surface water inputs are also present on the eastern side of the pond. Direct watershed runoff and groundwater seepage are additional sources to Devol Pond.

The pond watershed is 632 acres and includes forest, wetlands, residences, agricultural land, and other open space (Figure 1). Some of the residential areas and agricultural land in the watershed approach the pond shoreline. The eastern two-thirds of one residential subdivision along Ivy Meadows Lane contain extensive areas of lawn that appear greener than surrounding residential lots and pastures, suggesting that use of phosphorus based fertilizers may be prevalent in this area (Figure 2). Due to the configuration of this road (perpendicular to the pond on a downward slope), it could potentially serve as a conduit for stormwater and associated pollutants into the pond if adequate best management practices (BMPs) have not incorporated into the development.

Previous Studies

Previous studies of Devol Pond were conducted in 2009 by the University of Massachusetts – Dartmouth (UMass-Dartmouth); the DPA also collected additional data in 2011. UMass-Dartmouth collected water quality samples from the pond surface and from the bottom of the pond at its deepest location. The following

parameters were measured for each sample: chlorophyll *a*, total phosphorus, dissolved phosphorus, nitrate nitrogen, total Kjeldahl nitrogen, water color, turbidity and Secchi disk depth, pH, and conductivity. Data were also collected on dissolved oxygen and temperature.

One of the key findings of the 2009 UMass-Dartmouth study was documentation of high densities of blue-green algae (25,000 to >99,000 cells/mL). The Massachusetts Department of Public Health posts advisories at densities exceeding 70,000 cells/mL. Dissolved oxygen levels and pH near the pond surface were also found to be high in Devol Pond (supersaturated dissolved oxygen and pH up to 10.12), presumably due to photosynthetic activity by algae. Corresponding Secchi depth in Devol Pond was between 0.71 feet and 1.41 meters (the state standard for swimming is 1.2 meters or deeper). The total phosphorus concentrations measured in 2009 were between 0.03 mg/L and 0.11 mg/L, with the highest concentrations found at the southern end of the pond. Although Massachusetts has no established statewide phosphorus criteria, concentrations exceeding 0.015 mg/L may begin to generate negative impacts to water quality and those in excess of 0.05 mg/L tend to be associated with excessive algal growth on a regular basis.

The subsequent study of Devol Pond in 2011 consisted of water sampling conducted by the DPA. The water samples, collected at several locations along the south end of the pond's shoreline, were found to contain total phosphorus levels between 0.06 mg/L and 0.41 mg/L. These results reinforce hypothesis that Devol Pond suffers from excessive concentrations of phosphorus.

Study Methods

ESS gathered a limited amount of additional in-pond and in-stream water quality data during 2012 within the pond as well as from the Narrow Avenue tributary. Sediment and water quality samples were collected at Devol Pond on August 23, 2012. A general assessment of in-pond water quality at the surface and bottom of the pond was also completed on this date. Additional water samples were collected by DPA from the Narrow Avenue tributary crossing and a location on Ivy Meadows Lane on November 7, 2012. These sample locations were chosen to confirm phosphorus loading from watershed sources near the southern end of the pond. The samples from both dates were sent to Premier Laboratory, Inc. in Dayville, CT for analysis of total phosphorus. The results were used to estimate hydrologic and nutrient budgets for Devol Pond and inform the management recommendations.

Results

Results of the water sampling showed excessive concentrations of total phosphorus (0.092 mg/L to 0.74 mg/L) from tributary sources (Table 1). These are similar concentrations to those previously recorded in Devol Pond.

Other water quality parameters measured in the field on August 23rd included temperature, dissolved oxygen, conductivity, salinity, pH, and Secchi disk depth (a measure of water clarity). The results for each of these were generally found to be within the same range of values observed in previous samples (Table 1). Although Devol Pond is shallow and unlikely to thermally stratify, the water quality results suggest that dissolved oxygen does drop to anoxic (generally <2 mg/L) levels with depth.

Table 1. Water Quality at In-pond and Watershed Stations in 2012

Station	Date	Secchi Disk (m)	pH	Salinity (ppt)	Conductivity (µS/cm)	Temperature (° C)	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)	Discharge (cfs)	Phosphorus (mg/L)
Pond – surface	8/23/12	0.2	9.2	0.1	116.2	26.8	166.0	13.1	NA	NA
Pond – bottom (2.25 m deep)	8/23/12	NA	NA	NA	159.0	23.8	21.8	1.85	NA	NA
Narrow Ave Tributary	8/23/12	NA	NA	NA	NA	19.4	14.4	1.25	0.1	0.74
	11/7/12	NA	NA	NA	NA	NA	NA	NA	NA	0.37
Ivy Meadows Lane	11/7/12	NA	NA	NA	NA	NA	NA	NA	NA	0.092

The sediment sample collected from the pond found total phosphorous content of 1300 mg/kg in the organic bottom material. Although this study did not specifically investigate phosphorus release from the sediments, some of this phosphorus may become biologically available for uptake by algae under the anoxic conditions that develop during the summer in deeper waters of the pond.

Hydrologic modeling based on the limited information available for Devol Pond suggests that the pond receives the largest volume of input from surface water (51%), but that groundwater (30%) and direct precipitation (18%) also make up a significant portion of total inputs. Surface water can be further broken down into wet weather and dry weather inputs. At Devol Pond, wet weather inputs predominate, accounting for 90% of the total surface water inputs.

Vollenweider (1968) established criteria for calculating the phosphorus load below which no productivity problems were expected (permissible load) and above which productivity problems were almost certain to persist (critical load). Once the nutrient load rises above the permissible load, water quality will begin to deteriorate until nutrient loading increases to a level above the critical load at which point the rate of deterioration will slow since the pond is saturated with nutrients – a state of advanced eutrophication. Based on nutrient modeling Devol Pond, the phosphorus load is estimated to be approximately 258 kg/year, which is well above its permissible load of 83 kg/year and its critical load of 166 kg/year. This is characteristic of a eutrophic (nutrient-rich) pond that would experience significant algae blooms each year (as has been the case at Devol Pond). It also suggests that reduction of watershed sources of phosphorus alone will not be enough to prevent problematic levels of plant or algal growth for the foreseeable future.

Management Recommendations

Due to the fact that internal recycling of phosphorus from bottom sediments is likely the primary source fueling nuisance algae blooms on Devol Pond, ESS recommends focusing current efforts on in-pond controls. The primary options available for in-pond control are detailed in the sections below.

However, long-term efforts to reduce phosphorus inputs from watershed sources will be important to sustaining the benefits of any in-pond actions. As mentioned previously, there may be opportunities to reduce pollutant loading from nearby agricultural and residential areas through implementation of BMPs and regular maintenance of septic systems (or repair of failed systems).

Dredging

Dredging involves the removal of sediments from the pond and is the only in-pond option that would directly remove a primary source of phosphorus. In addition to removing nutrients, dredging works as a control

technique by increasing water volume, and therefore allowing the potential for greater dilution of nutrients mobilized from the sediments.

A key factor influencing the feasibility of dredging Devol Pond is the ability to draw down the pond to allow use of excavation equipment for conventional (dry) dredging. If the pond cannot be effectively drawn down (likely to be the case at Devol Pond), hydraulic (wet) dredging is the primary alternative. However, hydraulic dredging is generally more expensive than conventional dredging and requires a larger and more sophisticated containment area to dewater the sediment as it is removed from the pond. Use of advanced dewatering techniques such as Geotubes (a geotextile fabric for dewatering) or a belt-filter press machine could help circumvent this issue but would add costs over traditional dewatering containment. All of these options require that some land adjacent to the pond be made available for the dewatering process.

Chemical content of the material to be dredged is also an important consideration in determining the feasibility of reuse or disposal. Aside from nutrient content, little is currently known about the bulk physical or chemical characteristics of sediments in Devol Pond. Clean material could potentially have value as soil amendment which would reduce disposal costs or even help offset the cost of the project. However, material that is not suitable for beneficial use would need to either be amended with clean material or trucked offsite for disposal, both of which would increase the cost of dredging.

Beyond the cost of dredging itself, the environmental permitting process is fairly complex and may require up to a year to secure all necessary approvals. Federal, state, and local permits would all be required. Although up-front dredging costs are among the highest of any in-pond management options, the benefits are usually sustained for decades, rather than months or years.

Because of the many different possibilities for dredging, costs vary widely. However, implementation of a hydraulic dredging program would likely range between $25 to $40 per cubic yard, not including design and permitting. Given the limited data that has been collected on sediment volume, only a very approximate cost estimate for dredging out all soft sediments in the pond can be made at this time. Assuming an average muck thickness of 2 feet over the pond yields more than 300,000 cubic yards of soft sediments. Hydraulic dredging of this sediment volume would likely exceed $8 million.

If dredging is an option of interest at Devol Pond, a dredge feasibility study would need to be completed as the first step. This would entail first mapping the extent and thickness of nutrient-laden soft sediments at the pond to calculate a total sediment volume. Core samples would then be collected from representative locations in the pond and sent to a state-certified laboratory for analysis of bulk physical (moisture content and grain size distribution) and chemical (e.g., total organic carbon, metals, extractable petroleum hydrocarbons, volatile organic compounds [VOCs], polychlorinated biphenyls [PCBs], pesticides, and any other pollutants likely to be present) characteristics. A coarse-scale feasibility study, including sediment mapping, collection and processing of three core samples, comparison of pollutant levels to relevant standards for beneficial reuse, and a brief permitting analysis could be completed for approximately $6,000.

Sediment Inversion

Sediment inversion, also known as reverse layering, is a process similar to dredging, but does not involve permanent removal of any sediments from the pond or alteration of average depth. During this process, clean sand is brought up from underlying sediment layers and used to bury the nutrient-laden fine sediments at the surface. The sediment inversion process is complex and requires a specially designed hydraulic jetting barge. One advantage of sediment inversion over dredging is that it does not require a federal permit (although other state and local permits would still be necessary). However, sediment inversion is a relatively new procedure that has not yet established a significant track record. Therefore, both the costs and risks associated with

undertaking a sediment inversion project are likely to be higher than with proven methods such as dredging or nutrient inactivation.

Nutrient Inactivation

Nutrient inactivation is typically used to control algae blooms and improve water clarity in ponds with low flushing rates, such as Devol Pond. This action targets dissolved phosphorus (the form most readily available to plants and algae) and traditionally involves the addition of alum (aluminum sulfate), iron(III) chloride or similar aluminum-based compounds that bind to this phosphorus to allow it to settle into the pond sediments. Nutrient inactivation is usually conducted by applying alum directly to the pond as a single dose. Alum applied near the surface will initially strip available phosphorus from the water column as it settles to bottom of the pond. Once incorporated into bottom sediments, the alum will also bind phosphorus in the sediments, which results in long-term control of internal phosphorus recycling. Based on the slow flushing rate of the Devol Pond, nutrient inactivation would be anticipated to last eight to ten years, possibly much longer if watershed phosphorus sources can also be significantly reduced.

Compounds such as alum have some demonstrated effect on internal nutrient cycling but must be expertly applied and buffered to be effective while avoiding large pH swings and consequent collateral damage to sensitive organisms, such as fish and native mussels.

Nutrient inactivation is most effective and least likely to impact biological resources when focused on anoxic (lacking sufficient dissolved oxygen to support aquatic life) portions of the pond. Devol Pond is shallow and does not truly stratify during the summer. However, based on known bathymetry and dissolved oxygen measurements collected by ESS in 2012, it is likely that at least 50 acres of the pond bottom is anoxic during the summer. Assuming a 50-acre treatment area and given the high levels of phosphorus likely to be accumulated in bottom sediments, the costs for application of a buffered alum treatment would likely range from $130,000 to $190,000.

One new product that does not impact pH and appears to be essentially non-toxic consists of a blend of the rare metal lanthanum with bentonite clay (trade name Phoslock). This product is now registered for use in much of the United States but must be applied by a professional. Unlike alum, Phoslock does not provide significant direct removal of available phosphorus as it settles through the water column, although it appears to be highly effective on phosphorus in sediments. The cost of the lanthanum/bentonite mixture is quite high compared to traditional buffered alum and the additional benefits appear to be minimal. Phoslock treatment costs would run on the order of $190,000 to $250,000 to apply the product to a 50-acre treatment area.

Prior to treatment with either product, the first step would be to complete jar testing on water and sediment collected from Devol Pond. These tests are needed to identify the actual dose of nutrient inactivation product that will be necessary to achieve meaningful reduction of phosphorus levels in Devol Pond and for filing the required Notice of Intent (NOI) with the town of Westport. The cost for this initial study and permitting effort would be on the order of $12,000.

During and shortly after treatment, the pond would be closed to recreation to allow the product to settle and become incorporated into the sediments. Additionally, the pond would need to be monitored to ensure that pH levels are within the desired range and to document any evidence of fish kills or other biological impacts. Some level of post-treatment monitoring is also desirable (and may be required by the Order of Conditions) to evaluate the effectiveness of the treatment on phosphorus levels and algae. The post-treatment monitoring may add some additional cost, depending on the extent of monitoring required.

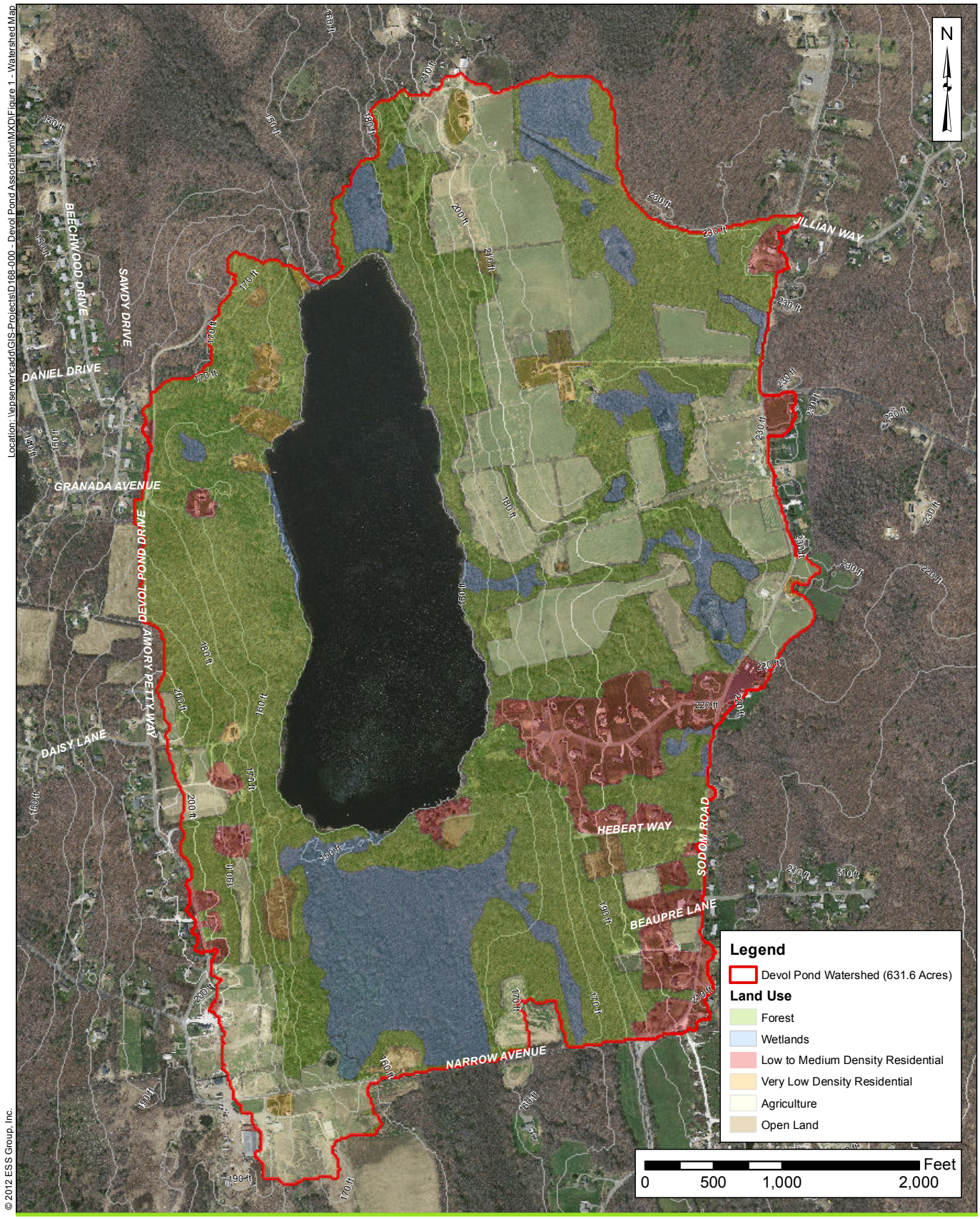
ESS looks forward to working with you in developing and implementing an appropriate approach to the management of Devol Pond. I can be reached at (401) 330-1224 should you have any questions.

Sincerely,

ESS GROUP, INC.

Carl D. Nielsen, CLM
Vice President

Attachments: Figure 1
Figure 2



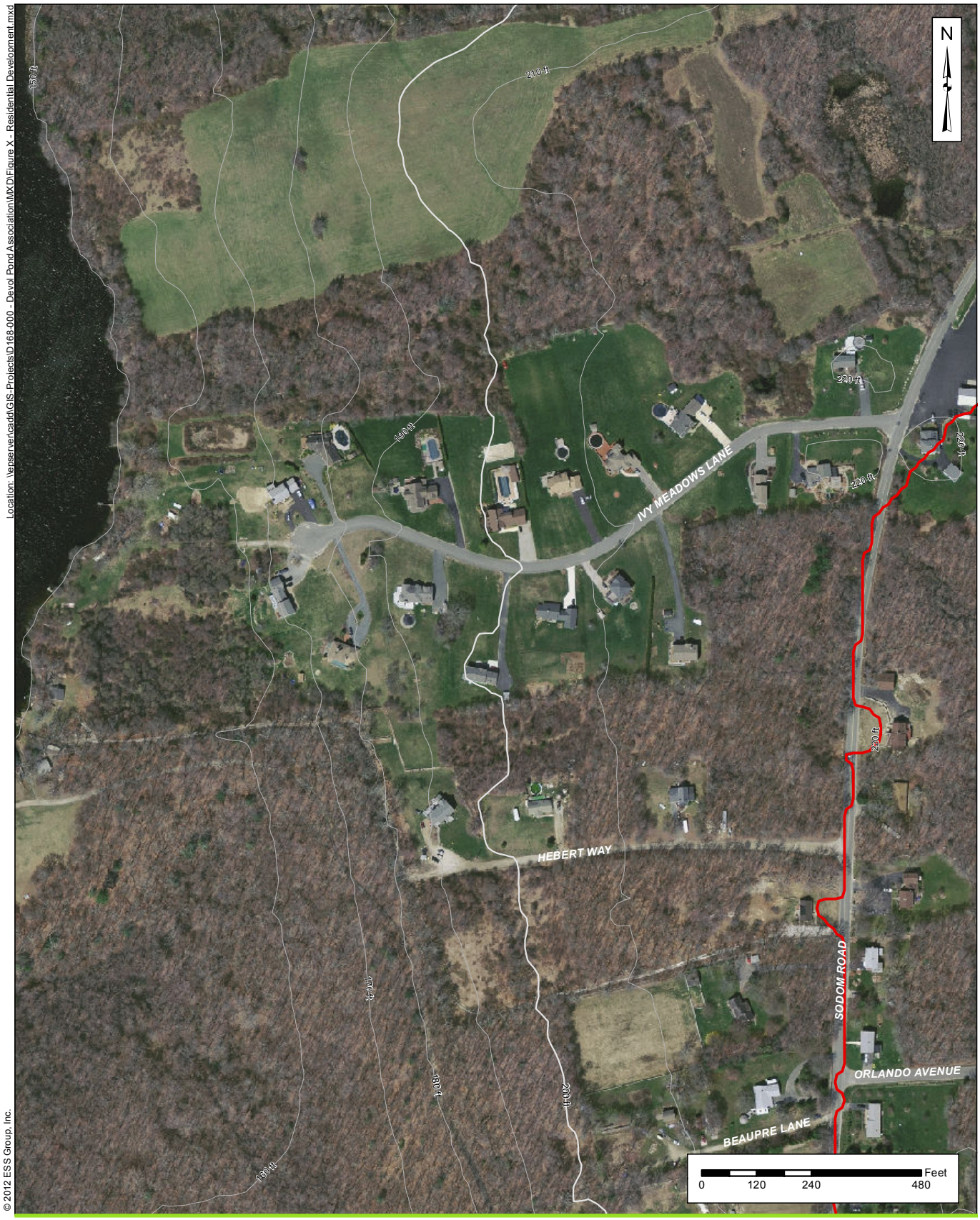
Devol Pond Association
Westport, Massachusetts

1 inch = 1,000 feet

Source: 1) MassDOT, 2012 2) USGS Color Orthoimagery, 2008
3) MassGIS Lidar Data, 2011 4) MassGIS, 2005

Devol Pond Watershed

Figure 1



Location: \\eserver\cadd\GIS-Projects\D168-000 - Devol Pond Association\MXD\Figure X - Residential Development.mxd

Devol Pond Association
Westport, Massachusetts

1 inch = 300 feet

Legend
Devol Pond Watershed

Devol Pond Watershed
Ivy Meadows Lane Area

Source: 1) MassDOT 2012 2) USGS Color Orthoimagery, 2008
3) MASSGIS LiDar Data, 2011

Figure 2