Appendix D

Hydrogeological Report

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Executive Summary

As part of the Harwich Comprehensive Wastewater Management Plan (CWMP), a program for hydrogeologic data-collection and groundwater flow modeling was conducted to predict the impacts of effluent recharge to groundwater at three potential sites in Harwich, Massachusetts. This report describes the hydrogeologic data-collection efforts and the groundwater modeling performed to predict impacts from the proposed effluent recharge.

The sites include an area near the capped Harwich Landfill off of Queen Anne Road (Site HR-12), sports fields at the Harwich High School (now Monomoy Regional) on Oak Street (Site SH-2), and a privately owned parcel identified off of the Orleans-Harwich Road within the Pleasant Bay watershed (Site PB-3). The three sites were screened as presented in Section 9 of the CWMP and are shown in Figure ES-1.

Hydrogeologic data review and field work, including USGS data, previous landfill site investigations (Site HR-12), 2011 supplemental CWMP investigations at sites HR-12 and PB-3, and other data are discussed in Section 2 of this report. Test analysis and results from the 2011 CWMP data collection efforts include boring logs, grain size analysis, infiltration test analysis, groundwater quality results, and a summary of a site visit to the cranberry bogs south of HR-12. The hydrogeologic data review and field work identified a clay layer at HR-12 which impacts groundwater flow rates and direction.

Based on the data review and field work, revisions were made to an existing regional USGS groundwater flow model which had been calibrated for 2003 conditions. Section3 provides information on the MODFLOW model and calibration, including the USGS model used as a basis for the groundwater model, grid and model refinements and adjustments to recharge, clay extent, hydraulic properties, and stream updates.

The model was calibrated to regional groundwater head elevations and 2003 groundwater data from Site HR-12. Recent surface water and groundwater data from 2011 was used to refine the model near HR-12. The revised and recalibrated model was used to assess the flow direction and mounding for recharge flows at the three locations based on the CWMP scenarios.

Three model simulations were completed to assess groundwater recharge scenarios developed for the CWMP. Model simulations and results are discussed in Section 4.

- Simulation 1 is based on the upper end flow loadings for all scenarios for effluent recharge proposed in the CWMP and utilizes all three sites
  - HR-12: 800,000 gpd at a loading rate of 3 gpd/ft^2
  - PB-3: 400,000 gpd at a loading rate of 5 gpd/ft^2
  - SH-2: 210,000 gpd at a loading rate of 1 gpd/ft^2
- Simulation 2 is the maximum loading over a 10 acre area at HR-12 which maintains a minimum four foot depth to the top of the groundwater mound, per MassDEP regulatory guidance.
- Simulation 3 is the same as Simulation 2, but with revisions to the simulation of water levels in the cranberry bogs south of HR-12.

Model simulation results, shown in Table ES-1, indicate that that the selected sites should be able to recharge the proposed CWMP scenario flows in an acceptable manner. Increased flow to Coy Brook near HR-12 would result in enhanced stream flow and would help to maintain a more reliable base flow beneficial for the local cranberry bog agricultural operations, especially during drought conditions.

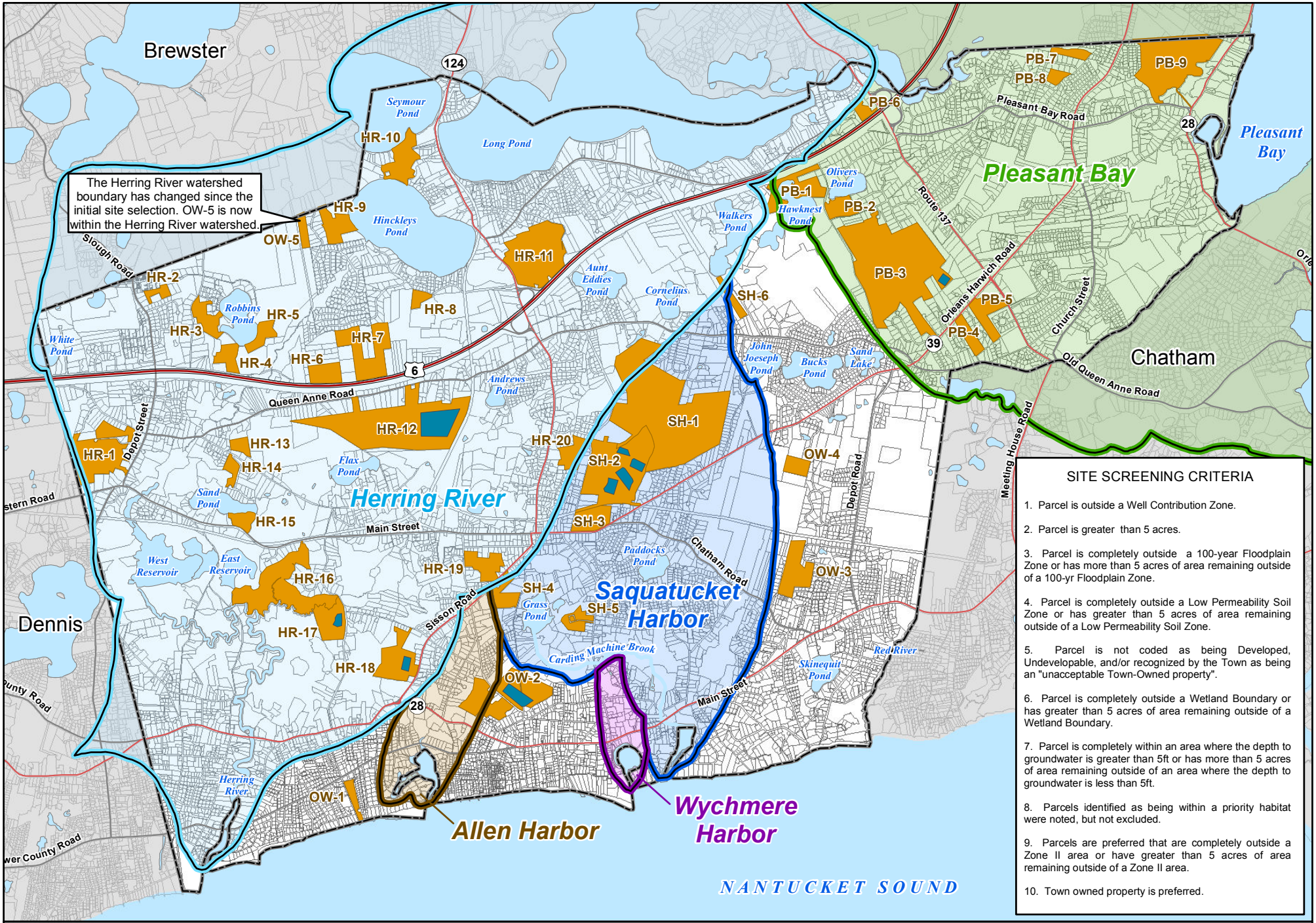
Table ES-1 Simulation Results Summary

Site	Total Recharge (MGD)	Loading Rate (gpd/ft^2)	Basin Area (acres)	Model Sim. Head (ft NGVD29)	Est. Basin Elev. (ft NGVD29)	Est. Depth to GW Mound (ft)	Est. Mound Height (ft)	Est. Stream Inc. (cfs)	% Est. Stream Inc.
Simulation 1 (Upper End of Flow Loading)									
HR-12	0.8	3.0	6.1	36	40	4	10	1	59%
PB-3	0.4	5.0	1.8	34	50	16	3.2		
SH-2	0.21	1.0	4.8	30	46	16	1.9		
Simulation 2 (Maximum Loading)									
HR-12	1.2	2.7	10	36	40	4	10	1.2	69%
Simulation 3 (Maximum Loading With Revisions near Cranberry Bogs)									
HR-12	1.4	3.0	10	36	40	4	10		

These results are shown in Figures ES-2 thru ES-4.

Based on the hydrogeologic findings and the meeting with the MassDEP and CCC, the following items are recommended as part of the implementation phase of the recommended CWMP program.

- Continue monitoring of surface water and groundwater locations to determine seasonal impacts to groundwater, surface water levels and cranberry bogs.
- Develop an adaptive management approach which uses Phase I wastewater effluent flow as a loading test at the selected effluent recharge sites.
- Assess the flow capacity of existing hydraulic structures in Coy Brook, Flax Pond and the downstream cranberry bogs near HR-12 during the design phase to identify and mitigate the potential for blockages or limitations in flow. This analysis should include the culvert which carries Coy Brook under Great Western Road as it has been reported to have problems carrying existing flows at high groundwater periods



SITE SCREENING CRITERIA

1. Parcel is outside a Well Contribution Zone.

2. Parcel is greater than 5 acres.

3. Parcel is completely outside a 100-year Floodplain Zone or has more than 5 acres of area remaining outside of a 100-yr Floodplain Zone.

4. Parcel is completely outside a Low Permeability Soil Zone or has greater than 5 acres of area remaining outside of a Low Permeability Soil Zone.

5. Parcel is not coded as being Developed, Undevelopable, and/or recognized by the Town as being an "unacceptable Town-Owned property".

6. Parcel is completely outside a Wetland Boundary or has greater than 5 acres of area remaining outside of a Wetland Boundary.

7. Parcel is completely within an area where the depth to groundwater is greater than 5ft or has more than 5 acres of area remaining outside of an area where the depth to groundwater is less than 5ft.

8. Parcels identified as being within a priority habitat were noted, but not excluded.

9. Parcels are preferred that are completely outside a Zone II area or have greater than 5 acres of area remaining outside of a Zone II area.

10. Town owned property is preferred.

Legend

- Allen Harbor
- Herring River
- Pleasant Bay
- Saquatucket Harbor
- Wychmere Harbor
- Parcel Remaining After Final Site Screening
- Previously Identified Potential Recharge Site (2006)

Site Locations Map

1 inch = 4,000 feet

0 1,000 2,000 4,000 Feet

Figure ES - 1

CDM Smith

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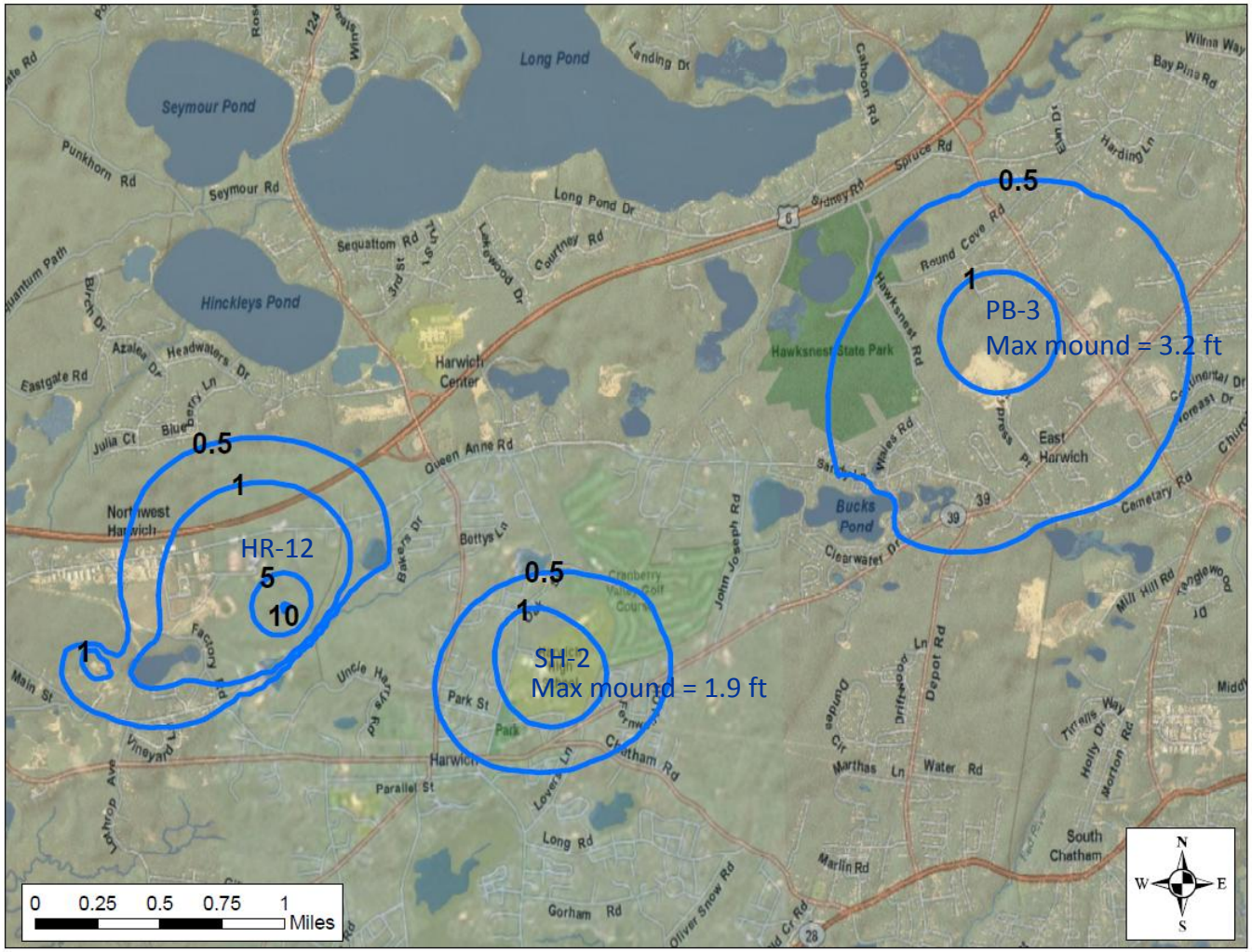
Figure ES-2
Mounding: Simulation 1



CDM Smith

Figure ES-3
Mounding: Simulation 2

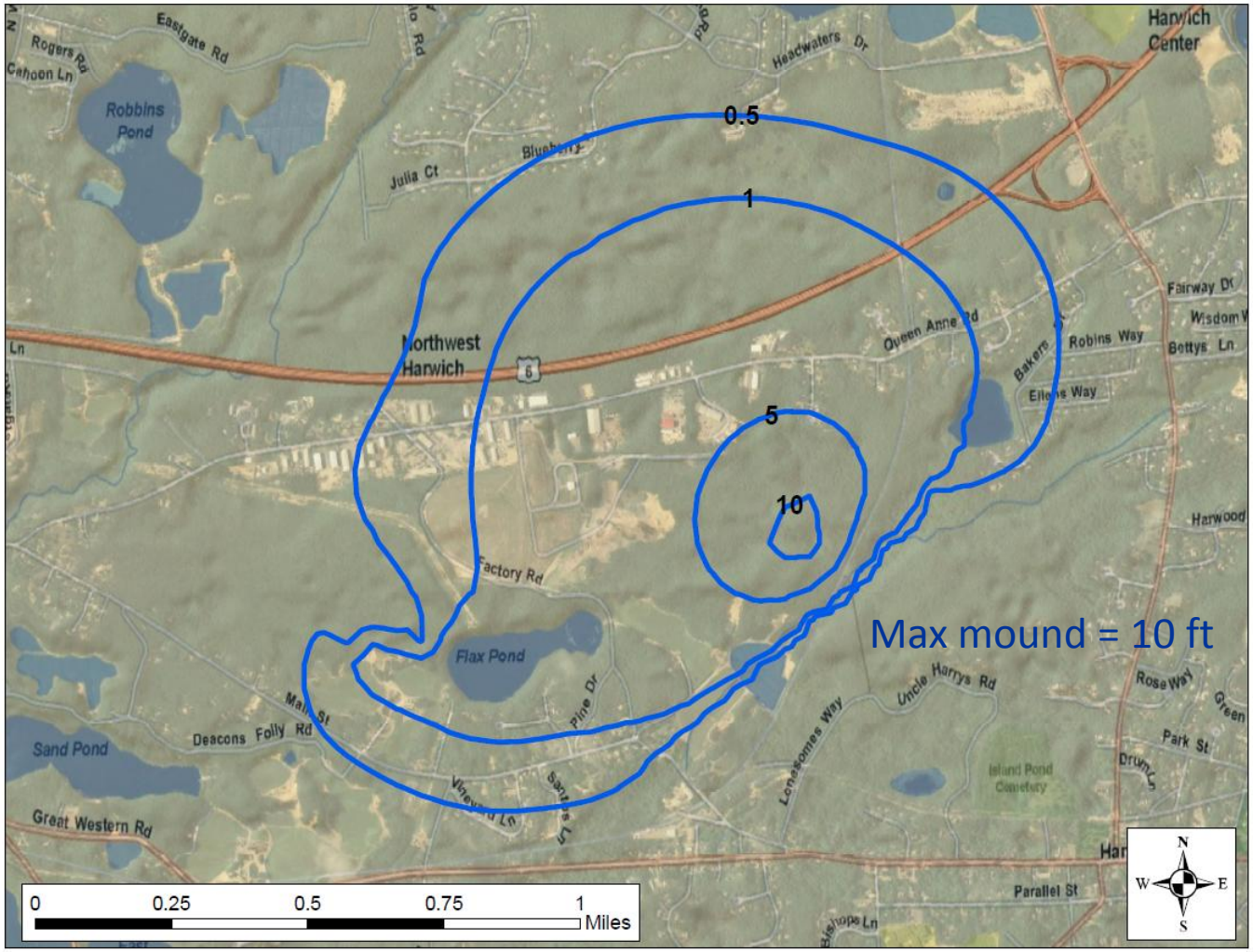
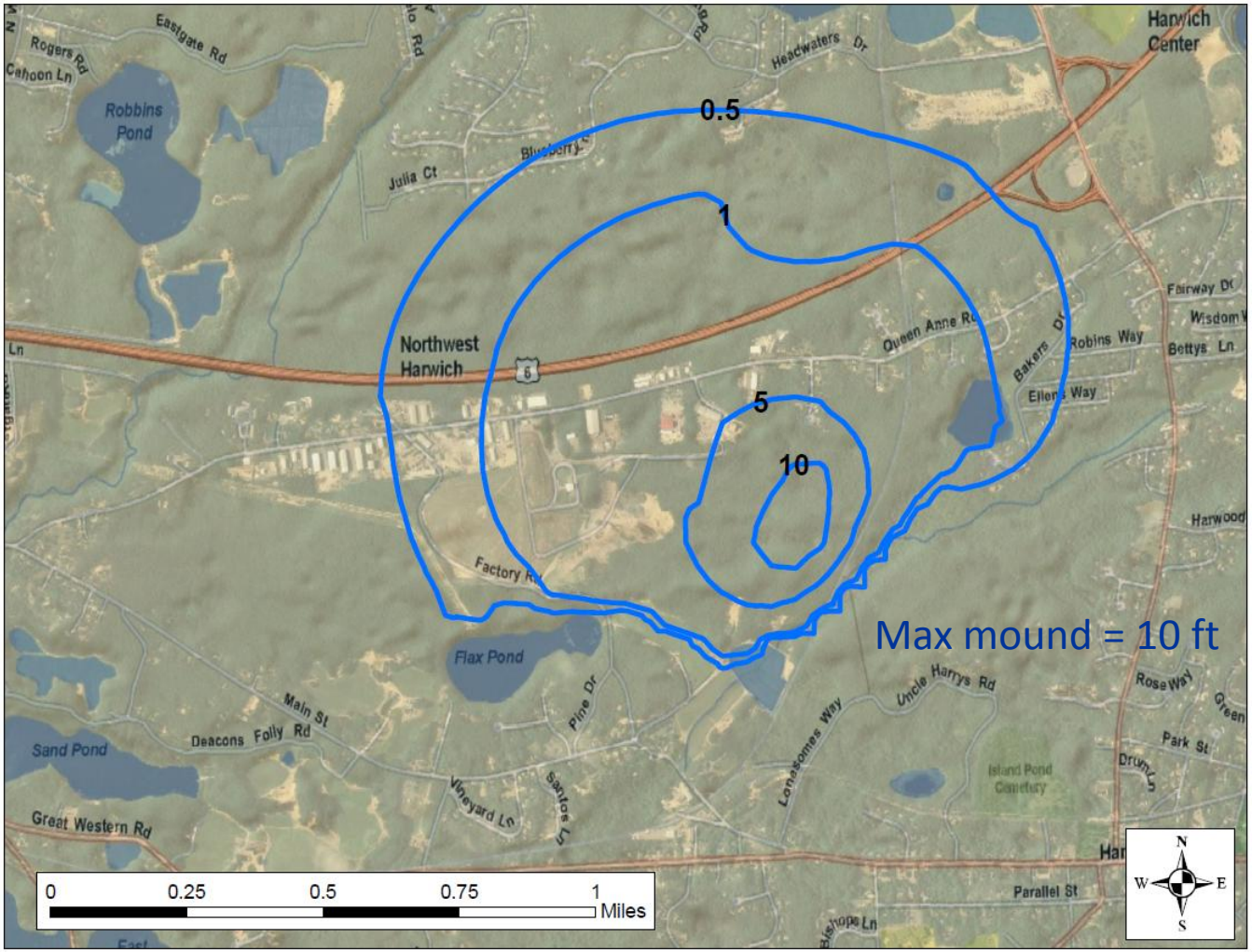


Figure ES-4
Mounding: Simulation 3



Section 1

Introduction

As part of the Harwich Comprehensive Wastewater Management Plan (CWMP), a program for hydrogeologic data-collection and groundwater flow modeling was conducted to predict the impacts of effluent recharge to groundwater at three potential sites in Harwich, Massachusetts. The sites include an area near the capped Harwich Landfill off of Queen Anne Road (site HR-12), sports fields at the Harwich High School on Oak Street (site SH-2), and a privately owned parcel identified off of the Orleans-Harwich Road within the Pleasant Bay watershed (site PB-3). The three sites were screened as presented in Section 9 of the CWMP and are shown in Figure 1-1.

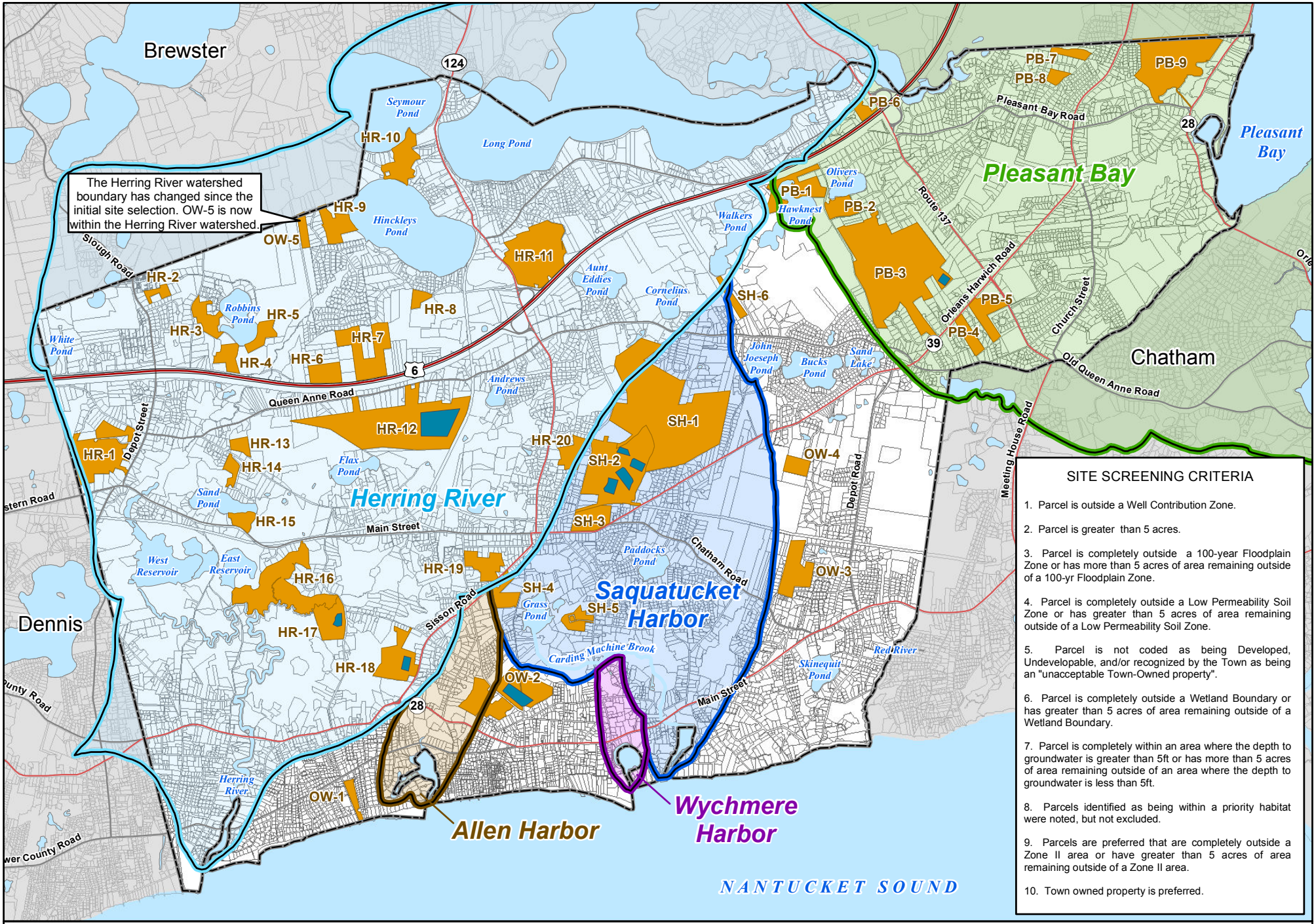
The Harwich Landfill site, HR-12, is a large municipally owned parcel which consists of a capped landfill area in the western end of the site with recycling and waste transfer facilities, and former sludge disposal beds located in the southern portion of the site, north of Flax Pond. Coy Brook is located east of the site near the bike path and water levels in the brook are controlled by structures in the cranberry bogs located southeast of the site. Additional cranberry bogs located east and west of Flax Pond are fed by surface water pumped from the pond. Groundwater and surface water levels in the area are heavily influenced and controlled by operations of the cranberry bogs. Recharge would be via infiltration basins located in the existing wooded southeastern portion of the site.

Subsurface recharge beneath playing fields is proposed for the Harwich High School (future Monomoy High School) site, SH-2. Surface water features near the site are primarily kettle ponds which reflect the groundwater table and likely have little impact on the overall flow patterns.

The third site, PB-3, is located within the Pleasant Bay watershed. The site is primarily uplands adjacent to a former gravel pit with no nearby surface water features. Recharge would be via infiltration basins.

A United Stages Geologic Survey (USGS) MODFLOW groundwater model was used as a basis for site-specific modeling. MODFLOW is a finite-difference groundwater model code developed by the USGS and widely used for groundwater modeling applications. Model refinement efforts were focused on site HR-12. The USGS model simulates annual steady-state conditions for the regional Monomoy Flow Lens. Refinements made to the USGS model included grid discretization, inclusion of site-specific information collected from previous investigations, and inclusion of data collected as part of the CWMP work. The hydrogeologic data-collection efforts focused on site HR-12, and also included limited efforts at site PB-3, as defined in work plan documentation submitted to regulatory reviewers at the Massachusetts Department of Environmental Protection (MassDEP) and the Cape Cod Commission (CCC).

This report describes the hydrogeologic data-collection efforts and the groundwater modeling performed to predict impacts from effluent recharge. A hydrogeologic workplan was submitted to the MassDEP on July 28, 2011. Once approved, field work commenced during August 2011. Initial results from the data-collection and groundwater modeling efforts were presented to the MassDEP and the CCC on December 9, 2011. Comments and recommendations from that meeting were addressed and thus this report serves as a comprehensive summary of the hydrogeologic studies within the current stage of the overall CWMP.



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Site Locations Map

1 inch = 4,000 feet

0 1,000 2,000 4,000 Feet

Figure1 - 1

CDM Smith

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Section 2

Site Investigation Summary

Existing data on subsurface geology and surface water levels, groundwater levels, water quality, sieve analysis and hydraulic testing was reviewed for the three selected effluent recharge sites. This data was supplemented by additional borings, groundwater measurements, groundwater quality sampling, surface water level measurements, infiltration tests and sieve analysis at two of the sites, HR-12 and PB-3. All of this data is summarized herein.

2.1 USGS Data

Regional groundwater levels and surface water stage and flow near HR-12 were obtained from the USGS National Water Information System (NWIS) database. This data was used by the USGS for calibration of the USGS MODFLOW model and was used during the CWMP groundwater flow modeling efforts to confirm the regional model calibration after model refinement. Five wells have a period of record that included the model calibration period of 2003 and were used for regional model calibration. These wells are located in Brewster, Chatham, Harwich and Orleans. The wells are listed in Table 2-1 and shown on Figure 2-1.

Stream discharge for the Herring River, which is located west and north of site HR-12, is available from 1970 to 1988 and from 2007 to the present. Discharge in the Herring River varied from 1 to 31 cfs during the period of record. Recent flow data was used as a check for streamflow in the refined model.

Table 2-1 USGS Wells and Herring River Gage Data

Name	Description	Period of Record
BMW-21	Brewster Groundwater Well	1962 to present
BMW-44	Brewster Groundwater Well	1975 to present
CGW-138	Chatham Groundwater Well	1962 to present
HJW-141	Harwich Groundwater Well	1975 to 2007
OSW-24	Orleans Groundwater Well	1975 to present
01105880	Herring River Gage Located at Rt. 6	1970 to 1988, 2007 to present

2.2 Landfill Site Investigations

A Comprehensive Site Assessment (CSA) of the Harwich Landfill was prepared by Weston & Sampson Engineers in 1991. Assessment activities included borings, well installation and sampling, gas sampling, test pits, hydraulic testing and surface water samples. Locations of CSA landfill monitoring wells with water level data from 2003 are shown in Figure 2-2. Boring logs and water level measurements indicate a significant clay layer under the site.

As part of on-going landfill monitoring, water levels have been measured at 20 wells in the spring and fall from the early 1990s to the present (Figure 2-2). Water levels in wells were generally higher in the spring and lower in the fall. Elevations generally varied 2 to 3 feet between spring and fall in 2003. Wells and water levels measured at these 20 locations during 2003 are listed in Table 2-2. Wells were classified as being in the upper aquifer above the clay layer or in the lower aquifer below the clay

Figure 2-1
USGS Wells and Herring River Gage

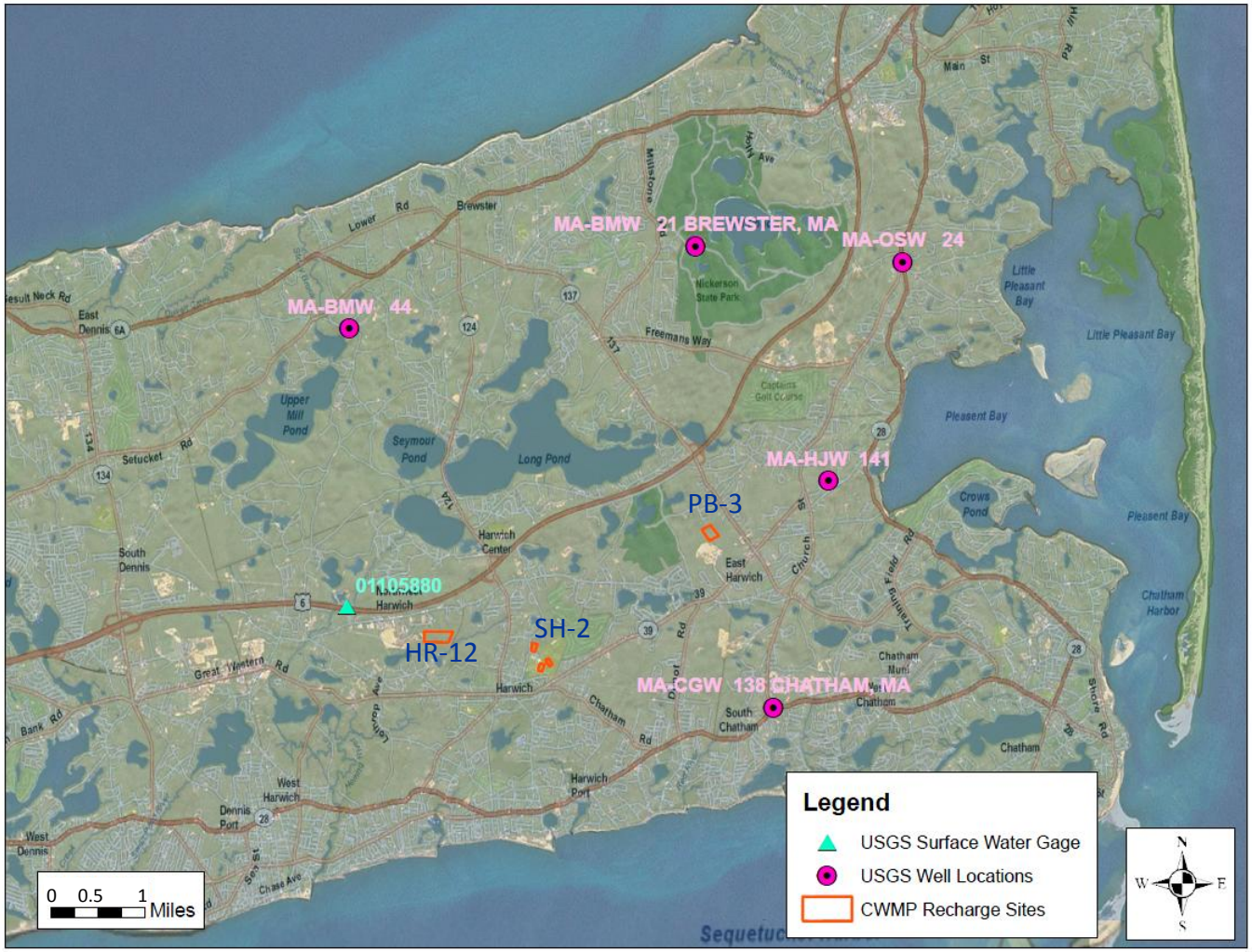
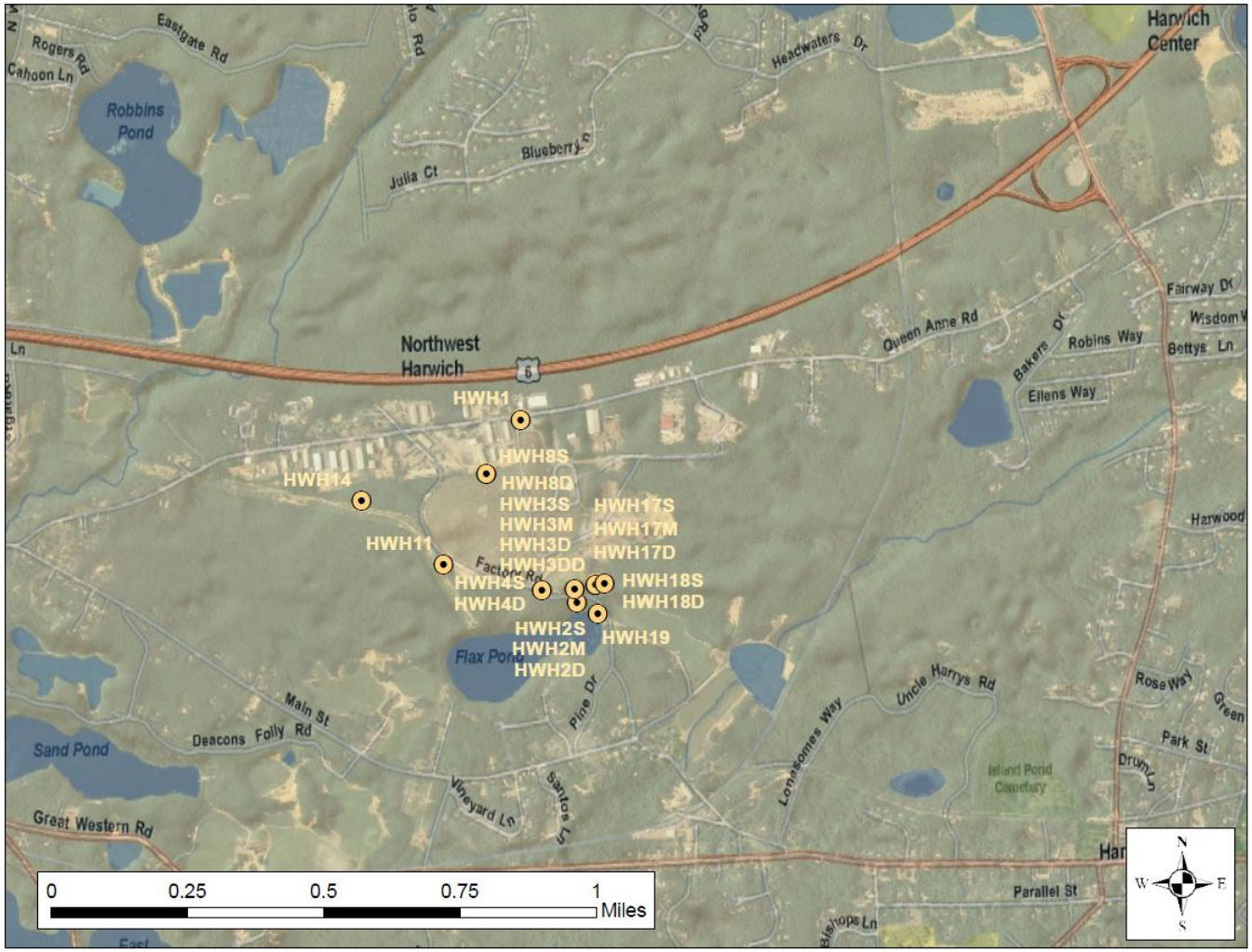


Figure 2-2
Landfill Wells – 2003 Water Level Locations



layer. Six locations have wells located both above and below the clay layer. These locations were used to calibrate vertical head differences. The nested water level measurements show a vertical gradient which is indicative of a significant confining unit (clay). Screen lengths are 5 feet in length with the exception of HWH-18 S which is 10 feet in length.

Table 2-2 Landfill Water Level Summary 2003

Well	Aquifer	Screen Top Elevation (ft)	Screen Bottom Elevation (ft)	Spring 2003 Water Elevation (ft)	Fall 2003 Water Elevation (ft)	Range of 2003 Water Elevations (ft)
HWH-1	Lower	-5.2	-10.2	28.78	25.97	2.81
HWH-2 S	Upper	23.75	18.75	23.31	20.54	2.77
HWH-2 M	Upper	11.41	6.41	23.4	20.71	2.69
HWH-2 D	Lower	-10.85	-15.85	23.21	16.39	6.82
HWH-3 S	Upper	23.65	18.85	23.57	20.85	2.72
HWH-3 M	Upper	11.57	6.57	23.72	20.99	2.73
HWH-3 D	Lower	-7.59	-12.59	18.87	16.29	2.58
HWH-3 DD	Lower	-21.57	-26.57	18.85	16.34	2.51
HWH-4 S	Upper	27.93	22.93	28.88	NM	--
HWH-4 D	Lower	-14.05	-19.05	18.7	15.4	3.3
HWH-8 S	Upper	33.01	28.01	28.48	25.7	2.78
HWH-8 D	Lower	-1.55	-6.55	28.01	25.1	2.91
HWH-11	Lower	1.57	-3.43	17.24	14.78	2.46
HWH-14	Lower	1.48	-3.52	17.09	14.69	2.4
HWH-17 S	Upper	22.13	17.13	23.51	21.04	2.47
HWH-17 M	Upper	7.6	2.6	23.68	21.02	2.66
HWH-17 D	Lower	-19.3	-24.3	19.4	16.84	2.56
HWH-18 S	Upper	23.44	13.44	23.52	21.29	2.23
HWH-18 D	Lower	-19.81	-24.81	18.74	16.13	2.61
HWH-19	Upper	23	18	9.25	6.61	2.64

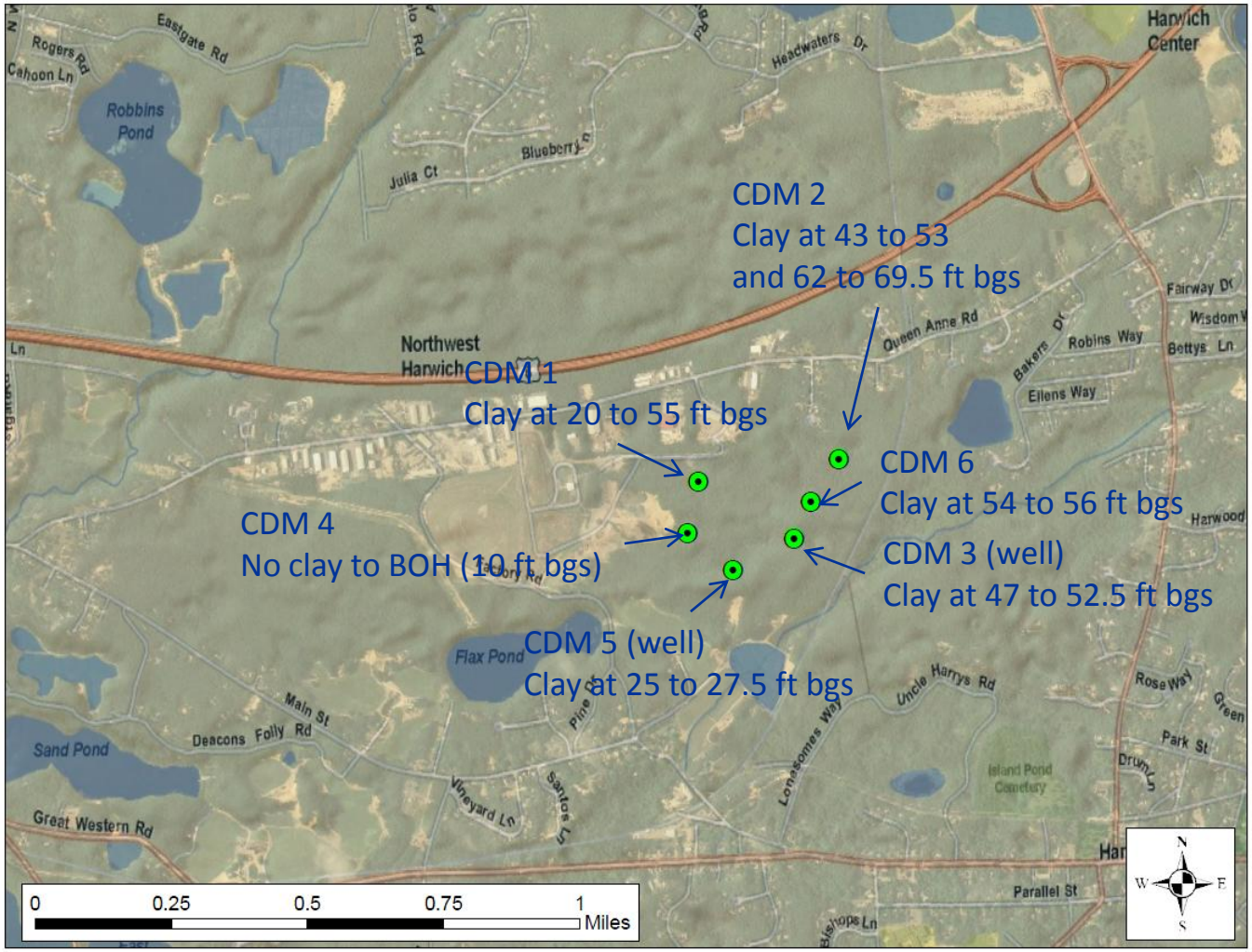
Note: NM – not measured.
HWH-19 measurements are likely incorrect based on known ground and surface water elevations in the area. A new survey would be needed to establish the correct casing and screen elevation.
HWH-2 D spring 2003 water elevation appears to be incorrectly recorded. Recorded spring season water elevations from 2005 to 2011 were between 16.09 and 18.83 ft. The range of water elevations recorded between 2005 and 2011 is 2.78 feet, which is consistent with the water elevation range in other wells in the HWH-2 cluster.

Hydraulic testing results from the CSA report include constant discharge tests, slug tests, and grain size analysis. A summary of hydraulic conductivity values based on these results is shown in Table 3-2.

2.3 2011 Supplemental CWMP Investigations

Additional borings were drilled, three wells were installed, and surface water points were established and surveyed. A round of groundwater samples were collected for water quality analysis at two HR-12 wells. Infiltration tests were performed at three sites at HR-12. Grain size analysis was conducted on 4 samples collected from borings at HR-12. One round of groundwater and surface water elevations were measured in September 2011. Six borings were installed at HR-12 in the eastern portion of the site, one boring was installed at PB-3, and five water level measurement locations were identified and surveyed in along Coy Brook and in Flax Pond near HR-12. Locations of the borings wells and surface water measurement points at HR-12 are shown on Figures 2-3 and 2-4. The location of the boring and well at PB-3 is shown on Figure 2-5. The well at PB-3 was dry and no water level was recorded. Boring logs are summarized in Table 2-3 and included in Appendix A. Infiltration testing results are provided

Figure 2-3
HR-12 CWMP Borings



BOH- bottom of hole
ft bgs – feet below ground surface

Figure 2-4
HR-12 CWMP Surface Water Elevation Measurement Locations

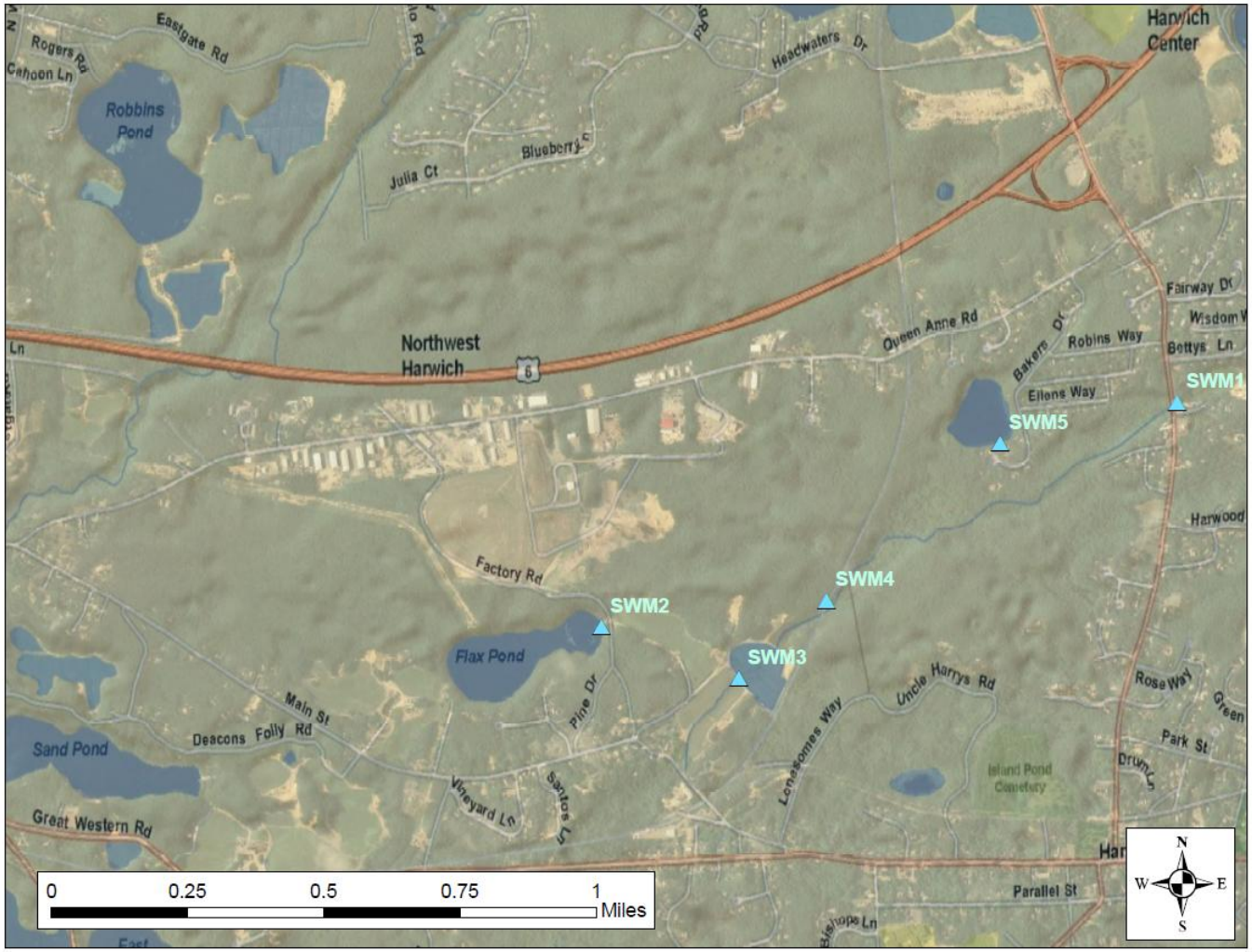
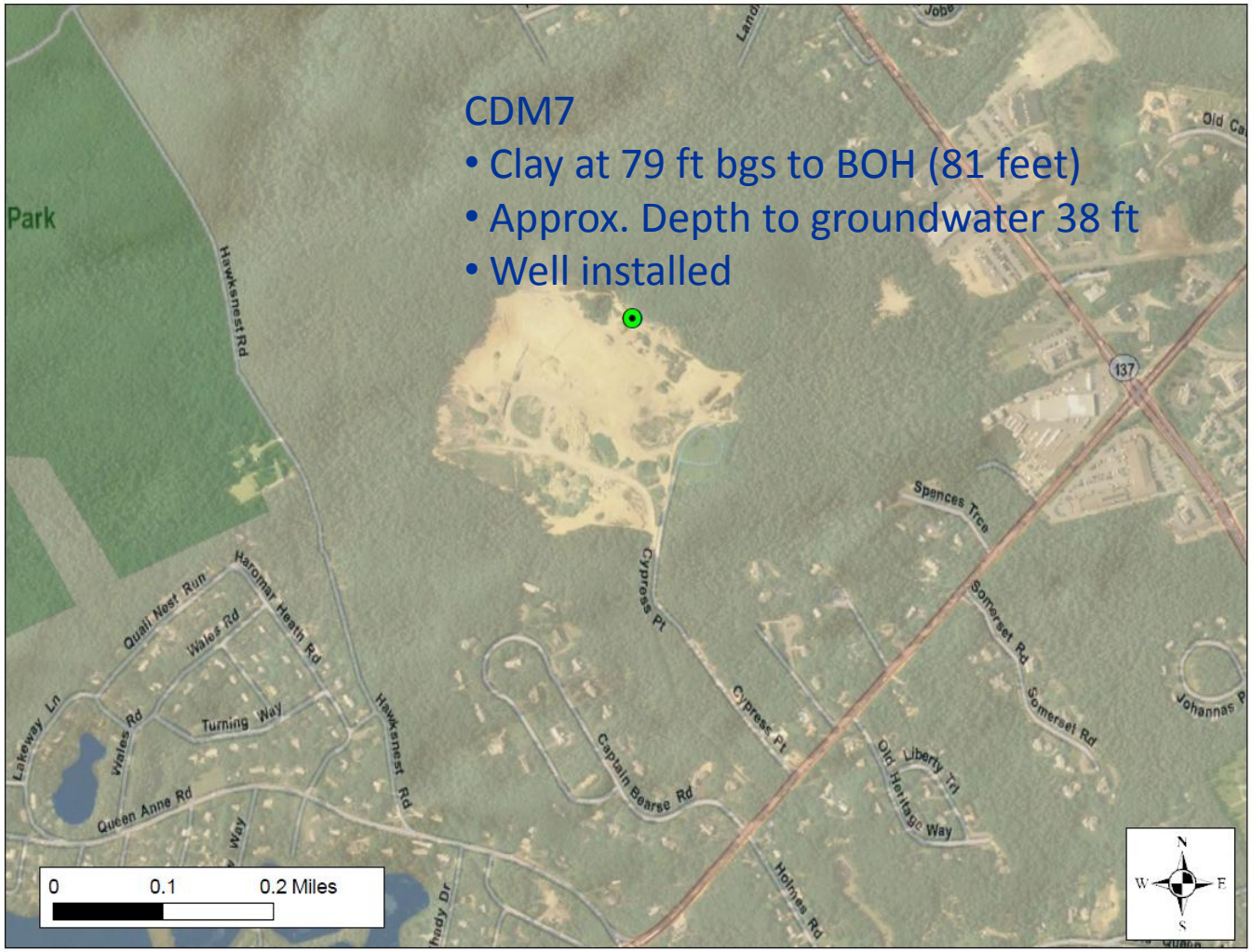


Figure 2-5
PB-3 CWMP Boring



BOH- bottom of hole
ft bgs – feet below ground surface

in Appendix B and grain size analysis is included in Appendix C. Hydraulic conductivity values calculated from the grain size analysis is shown in Table 3-2.

As expected based on the Landfill CSA report, clay was encountered in borings at HR-12. Layers encountered include a sand layer of between 20 and 54 feet thick over a clay layer between 2 and 35 feet thick. A sand layer is below the clay strata. A second clay layer was encountered at CDM-2. Wells were installed in the surficial phreatic layer in two locations, CDM-3 and CDM-5. Results confirm the landfill borings and indicate that clay extends underneath the eastern area of the site. In general, the clay layer was thinner and its contact with the surficial sand layer was deeper in the eastern-most borings, CDM-2, -3 and -6. Cross-sections from west to east through the landfill and from Flax Pond to the northeast are shown in plan view on Figure 2-6 and cross-section in Figures 2-7 and 2-8.

One boring, CDM-7, was installed at PB-3. Clay was encountered in the boring, CDM-7, at a depth of 79 feet below ground surface. A groundwater well was installed at this location.

Table 2-3 CWMP Boring Log Summary

Boring Name	Site	Boring Depth (ft)	Strata Thickness (ft)					Well Installed
			Sand	Clay/Silt	Sand	Clay/Silt	Sand	
CDM-1	HR-12	76	20	35	21 +			
CDM-2	HR-12	86	43	10	9	7.5	16.5 +	
CDM-3	HR-12	61	47	5.5	8.5 +			Y
CDM-4	HR-12	10	>10					
CDM-5	HR-12	61	25	2.5	33.5 +			Y
CDM-6	HR-12	61	54	2	5 +			
CDM-7	PB-3	81	79	2 +				Y

Note: + indicates Strata may be thicker since the bottom of the boring was reached.

Water quality samples were collected at the two CWMP wells at HR-12 on November 16, 2011. Per MassDEP and CCC staff requests, water samples were analyzed for VOCs, surfactants, chloride, fluoride, nutrients, sulfate, total dissolved solids, total metals, and dissolved metals. These parameters were selected to support future site assessment and discharge permitting. Table 2-4 summarizes water quality results for test parameters and detections of filtered (dissolved) metals. Complete groundwater quality results are included in Appendix D.

Figure 2-6
Cross-Section Location Map

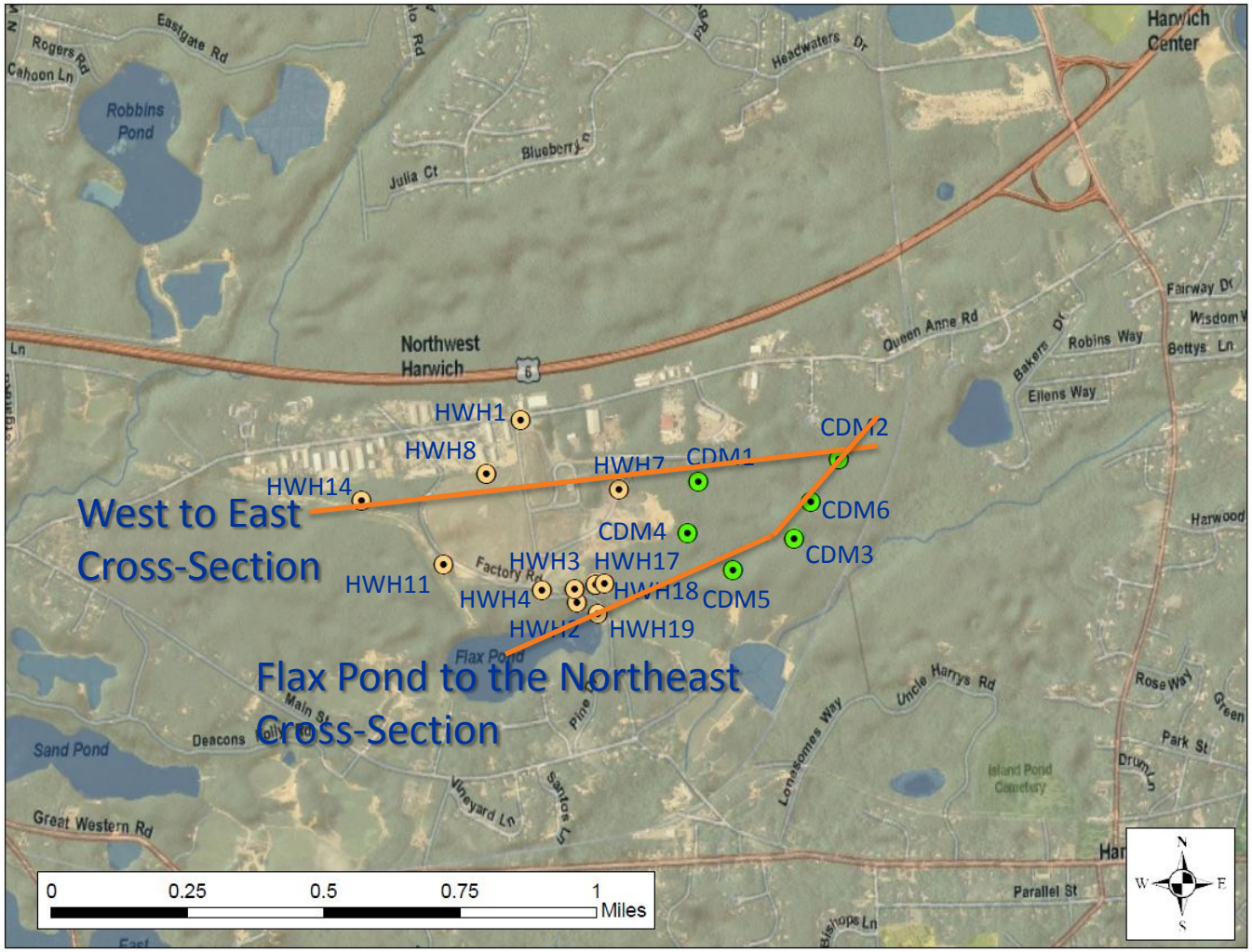
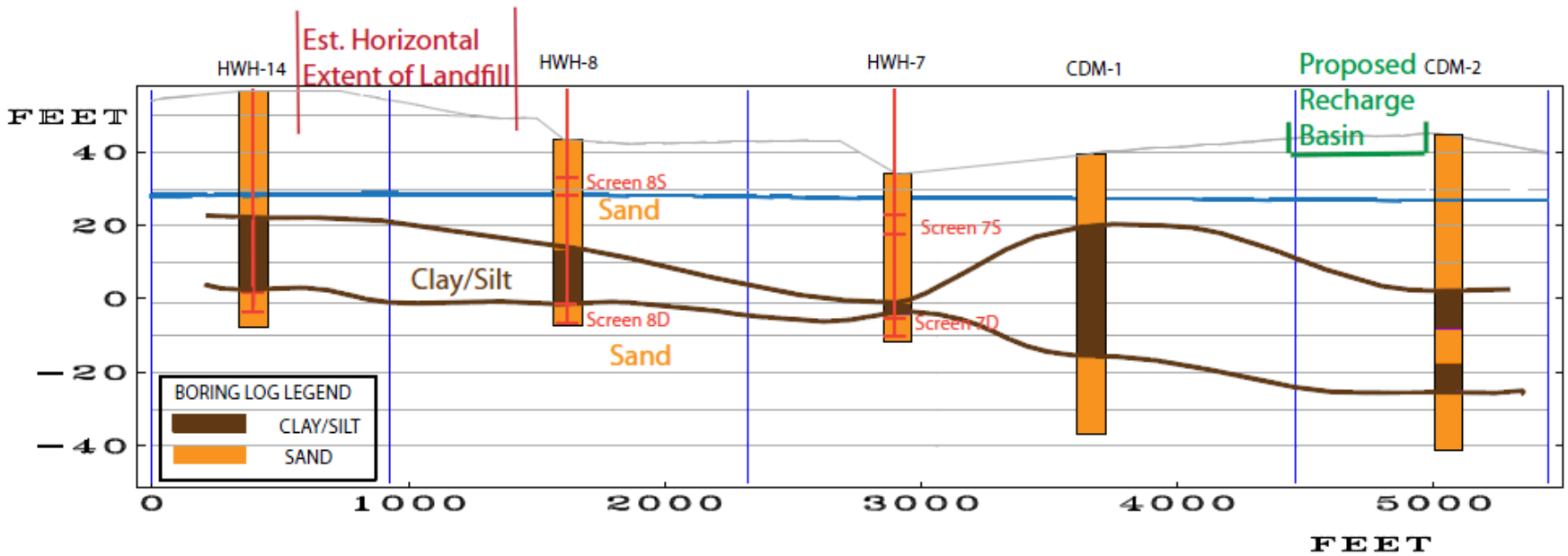
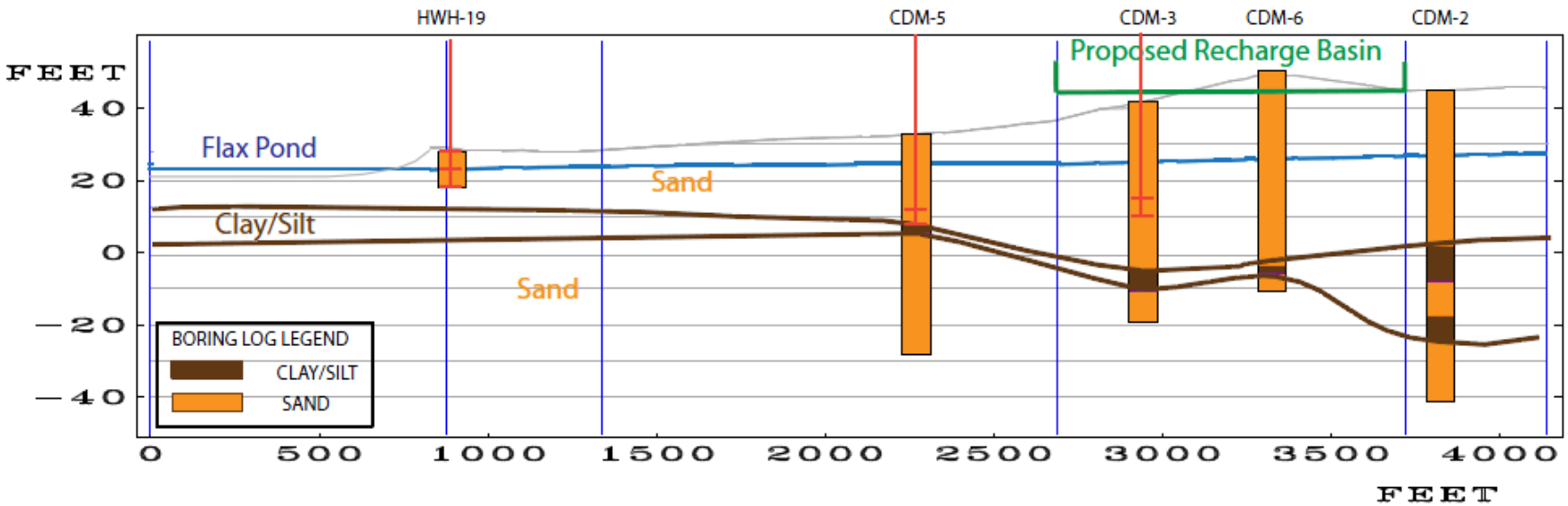


Figure 2-7
West to East Cross-Section HR-12



Ground surface elevations are estimated.

Figure 2-8
Flax Pond to the Northeast Cross-Section HR-12



Ground surface elevations are estimated.

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Table 2-4 CWMP Groundwater Quality Results (11/16/2011)

	Well	CDM-5	CDM-3
Chlorides	mg/L	12	14
Sulfate	mg/L	4.1	4.5
Phosphorus, total	mg/L	non-detect	0.11
Total Dissolved Solids	mg/L	34	37
Nitrate as Nitrogen	mg/L	non-detect	non-detect
Nitrite as Nitrogen	mg/L	non-detect	non-detect
Nitrogen, total	mg/L	non-detect	non-detect
Total Kjeldahl Nitrogen	mg/L	non-detect	non-detect
Metals ,- Filtered			
Barium	mg/L	0.02	0.011
Manganese	mg/L	0.032	0.042
Sodium	mg/L	8.1	9.6
Zinc	mg/L	0.005	0.009

2.4 Other Data Sources

In addition to the site-specific data for HR-12 from the Landfill CSA and data collected as part of the CWMP, logs from public water supply exploratory borings northwest of the Herring River were reviewed for information on potential confining units (clay or silt layers). The area includes public water supply well 10 and a series of test wells.

A series of test wells were installed in October 2001. High levels of iron and manganese indicate that the site is not suitable for public water supply without water treatment. Well logs and pumping results suggest a confining or semi-confining unit of clay. Well logs show this unit has a thickness of between 20 and 70 feet. The top of the clay unit was encountered between 50 and 100 feet below ground surface. (Head First Inc, 2004)

A deep boring was drilled to 400 feet below ground surface in September 2007 to assess whether production wells could be installed in the deep aquifer. Clay and silt was observed at 70 to 128 feet below ground surface and 178 to 340 feet below ground surface. Bedrock was not reached. (Head First Inc, 2007)

Section 3

Model Updates and Calibration

The USGS MODFLOW groundwater flow model for the Monomoy Lens includes the towns of Harwich, Brewster, and Chatham. The USGS developed this model in a cooperative effort with the MassDEP, with the overall objectives including use of the model for helping Cape Cod towns assess impacts of water supply and wastewater management alternatives. Therefore, this model was chosen as the basis for conducting CWMP modeling for Harwich. The model uses 2003 steady-state average annual recharge and pumping conditions to simulate regional flow.

Model refinements and updates were conducted prior to performing the CWMP predictive simulations in order to make the regional model more applicable to a site-specific study. Changes were made to the model grid, the representation of local streams, the inclusion of effluent recharge, and the extent of clay as determined through the supplemental site-specific field data collection efforts. The regional model calibration was verified with calibration targets used by the USGS, and local site-specific adjustments were made to refine the model using gathered groundwater and surface water level data. Unless otherwise noted, model-description statements in this report refer to how the model as developed by the USGS and any refinements or adjustments made for this project are clearly indicated as such.

All elevation data values generated during the CWMP field efforts were adjusted to the model vertical datum of NGVD29 that the USGS used in developing the regional model.

3.1 Grid and Model Refinement

The MODFLOW grid was refined from a cell size of 400 feet by 400 feet to a grid size of 100 feet by 100 feet near the recharge sites as shown in Figure 3-1. Model layers are flat, as designed and implemented by the USGS, and thus the layers do not vary in thickness throughout the model. The only exception is that the two deepest layers have some variation in thickness to help match the observed or estimated bottom of the glacial sediments; this variability in thickness has virtually no effect on the simulation of shallow groundwater flow.

The elevation of the clay layer is based on observed elevations in boring logs and is adjusted in the model in a step-wise (vertical) fashion. The step-wise changes were defined based on initial definition of estimated contact elevations. An example of the step-wise representation is provided in the cross-section shown in Figure 3-2.

Table 3-1 summarizes model layer elevations and hydraulic conductivity value ranges for each model layer. The anisotropy ratios are 10 to 1 for lower conductivity areas and as low as3 to 1 for the highest conductivity areas. Since the lakes and ponds on Cape Cod are primarily groundwater flow-through ponds, they were simulated in the model as areas of high hydraulic conductivity. A horizontal conductivity value of 50,000 feet/day and a vertical conductivity value of 5,000 feet/day were used. After grid refinement, conductivity zones for ponds near the recharge sites were adjusted to better match the horizontal pond extent.

Figure 3-1
USGS MODFLOW Model Grid Refinement

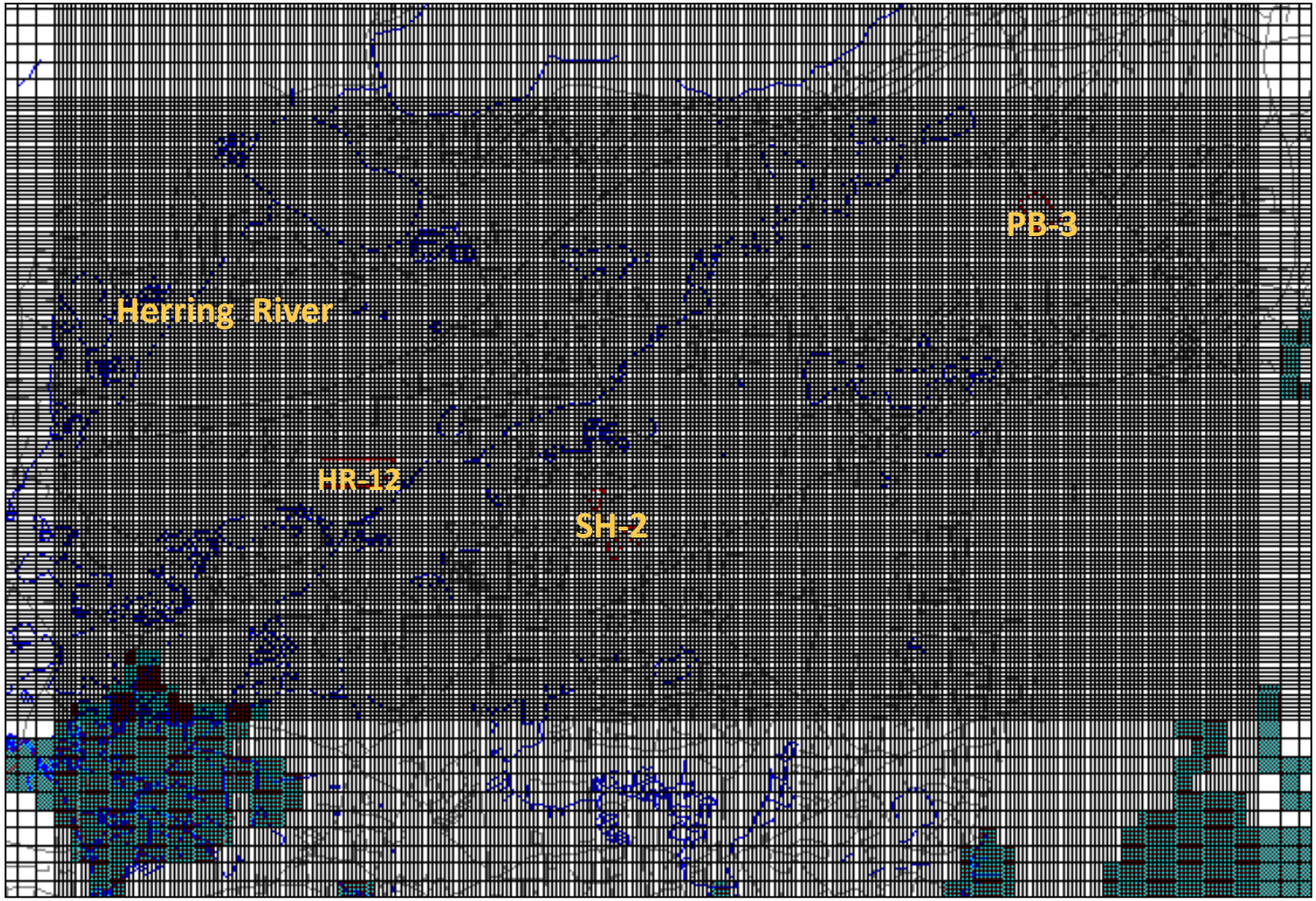

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Figure 3-2
Cross-Section through Groundwater Model

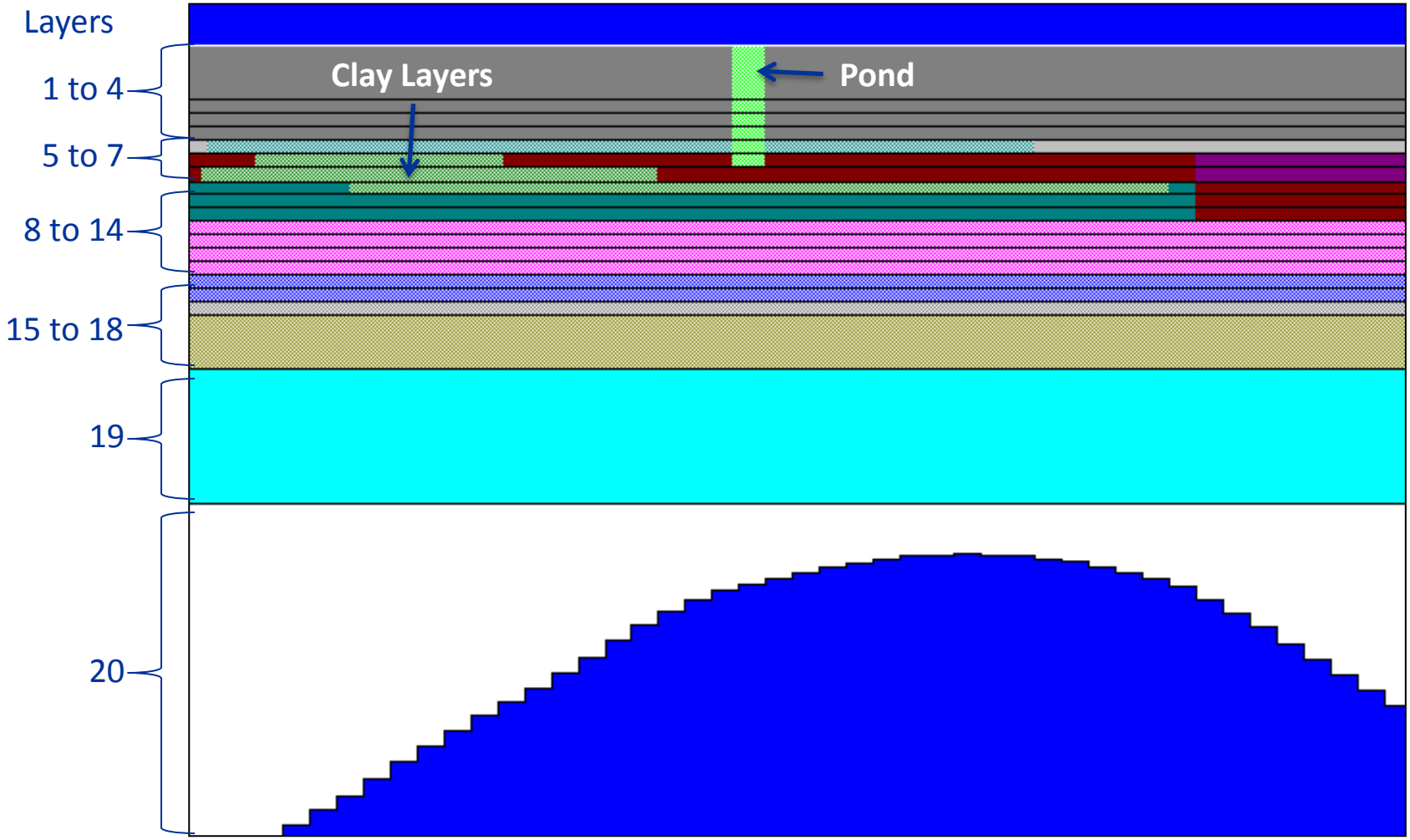

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Table 3-1 Model Layers and Hydraulic Conductivity Values

Layers	Elevation Range (ft)	Layer Thickness (ft)	Horizontal Conductivity (ft/day)	Vertical Conductivity (ft/day)
1, 2, 3	100 to 60, 60 to 50, 50 to 40	40, 10, 10	130 to 300	13 to 100
4, 5	40 to 30, 30 to 20	10, 10	100 to 250	10 to 65
6, 7, 8	20 to 10, 10 to -1, -1 to -10	10, 11, 9	10 to 230	1 to 55
9, 10, 11	-10 to -20, -10 to -30, -30 to -40	10, 10, 10	30 to 200	3 to 35
12, 13	-40 to -50, -50 to -60	10, 10	20 to 130	2 to 13
14, 15, 16	-60 to -70, -70 to -80, -80 to -90	10, 10, 10	10 to 100	1 to 10
17, 18	-90 to -100, -100 to -140	10, 40	10 to 80	1 to 8
19	-140 to between -169 and -240	29 to 100	10 to 30	1 to 3
20	-240 to between -241 and -525	1 to 285	10 to 30	1 to 3

Hydraulic conductivity values used in the USGS groundwater model were similar to values measured as part of the recent field investigations near HR-12. Therefore, horizontal and vertical values used in the USGS model were not adjusted, with the exception of inclusion of the clay layer near HR-12. Table 3-2 summarizes the measured horizontal and vertical hydraulic conductivity results for HR-12. Results are summarized for the upper and lower aquifers at HR-12, including comparison of CWMP estimated values and calibrated hydraulic conductivities in the USGS model. The aquifers are separated by a clay layer.

Table 3-2 Hydraulic Conductivity Value Summary

Source	Landfill CSA			2011 Investigation	USGS
Data Type	Constant Discharge Test	Slug Test	Sieve Analysis	Sieve Analysis	Groundwater Model
Upper Aquifer					
Kh (ft/day)	12 to 221	14	238 to 1745	147 to 275	130 to 180
Kv (ft/day)					13 to 25
Lower Aquifer					
Kh (ft/day)	109 to 200	61 to 84			120 to 130
Kv (ft/day)					12 to 13

3.2 Model Net Recharge

The USGS MODFLOW Model includes three recharge types for general areal net recharge, lake and pond net recharge, and bog and wetland net recharge. Values were established to take into account average annual precipitation and average annual evaporation or evapotranspiration. Model net recharge values are shown in Table 3-3. In areas with increased grid discretization near recharge sites, model recharge zones were updated to better match actual pond and bog extents.

Table 3-3 Model Net Recharge Values

Area	Net Recharge (inches/year)
General	27.3
Lake/Pond	16.0
Bog/Wetland	0.0

3.3 Clay Extent and Hydraulic Properties

Based on boring logs from the CSA and HR-12 recent investigations, a clay layer was added and the extent modified based on model calibration. Horizontal and vertical conductivity values for the clay layer were set to 1 and 0.01 feet/day based on model calibration. In general, the clay layer slopes from a high in the west down towards the east. The layer is thickest and deepest underneath the landfill site and in the southern portion of the site. Figures 3-3 through 3-5 show the extent of the clay layer in model layers 6, 7 and 8. The clay layer was also assumed to extend beneath the school site (SH-2) in order to provide a conservative prediction of that site's effluent loading capacity and amount of water table mounding. Changes were not made to the elevations of the model layers. Therefore, the modeled clay layer is limited to thicknesses of the current model layers, which are around 10 feet (see Table 3-1).

3.4 Stream Updates

Model streams were updated based on grid refinement and elevation data as needed. Streams were simulated as fixed head stream boundaries, which enables simulation of flow between the stream and aquifer and calculation of the total flow within the stream. The USGS model did not include Coy Brook, which is located east of HR-12. This brook was added with stream head and elevation data estimated from measured ground elevations, CWMP measured stream elevations and topographic maps. Modeled streams near HR-12 are shown on Figure 3-6. Figures 3-7 and 3-8 show the elevation of the streambed and stream stage for the Herring River, west of the site, and Coy Brook, east of the site. The average annual stream stage for 2003, used to compare simulated and observed stage, at the USGS Gage on the Herring River is shown with an orange triangle.

3.5 Model Calibration

Groundwater elevation data from 2003 were averaged for each calibration well and used as an average annual value for calibration of the steady-state model. Calibration water level targets included regional USGS groundwater data and 2003 average annual water levels from landfill wells. Surface water and groundwater data measurements from 2011 and observed stream stage at the Herring River Gage at Route 6, shown on Figure 3-7, were also used for conducting an additional model calibration check. Graphical methods (i.e. 45-degree model-vs-data plot and contour-plotting) were used to assess model calibration.

The Palmer Drought Severity Index was used to determine how well 2003 represented average climate for the area. For 2003, the index ranges from 1.1 to 3 indicating a moderately wetter condition as compared to average.

3.5.1 Regional USGS Groundwater Points

Groundwater elevations at five points were used to confirm model calibration and ensure that site-specific model refinements did not adversely impact model calibration. The USGS model simulated water table was also visually compared to the water table from the refined model to ensure no significant regional changes to flow patterns were made. Figure 3-9 shows model calibration to the five regional points which were a close match to the calibration documented by the USGS. Measured and observed values are also displayed in Table 3-4.

Figure 3-3
Clay Extent Layer 6: 10 to 20 feet elevation

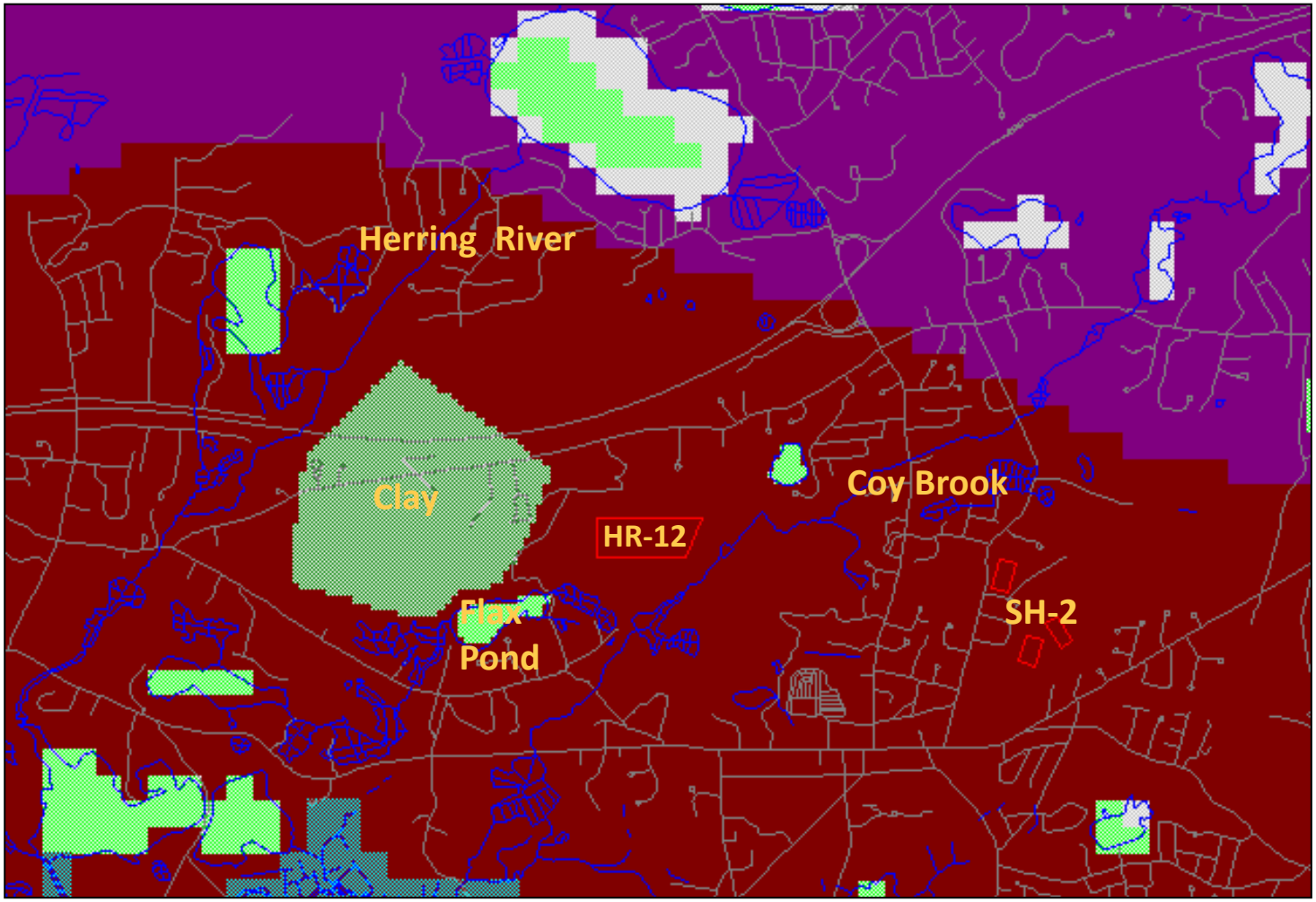

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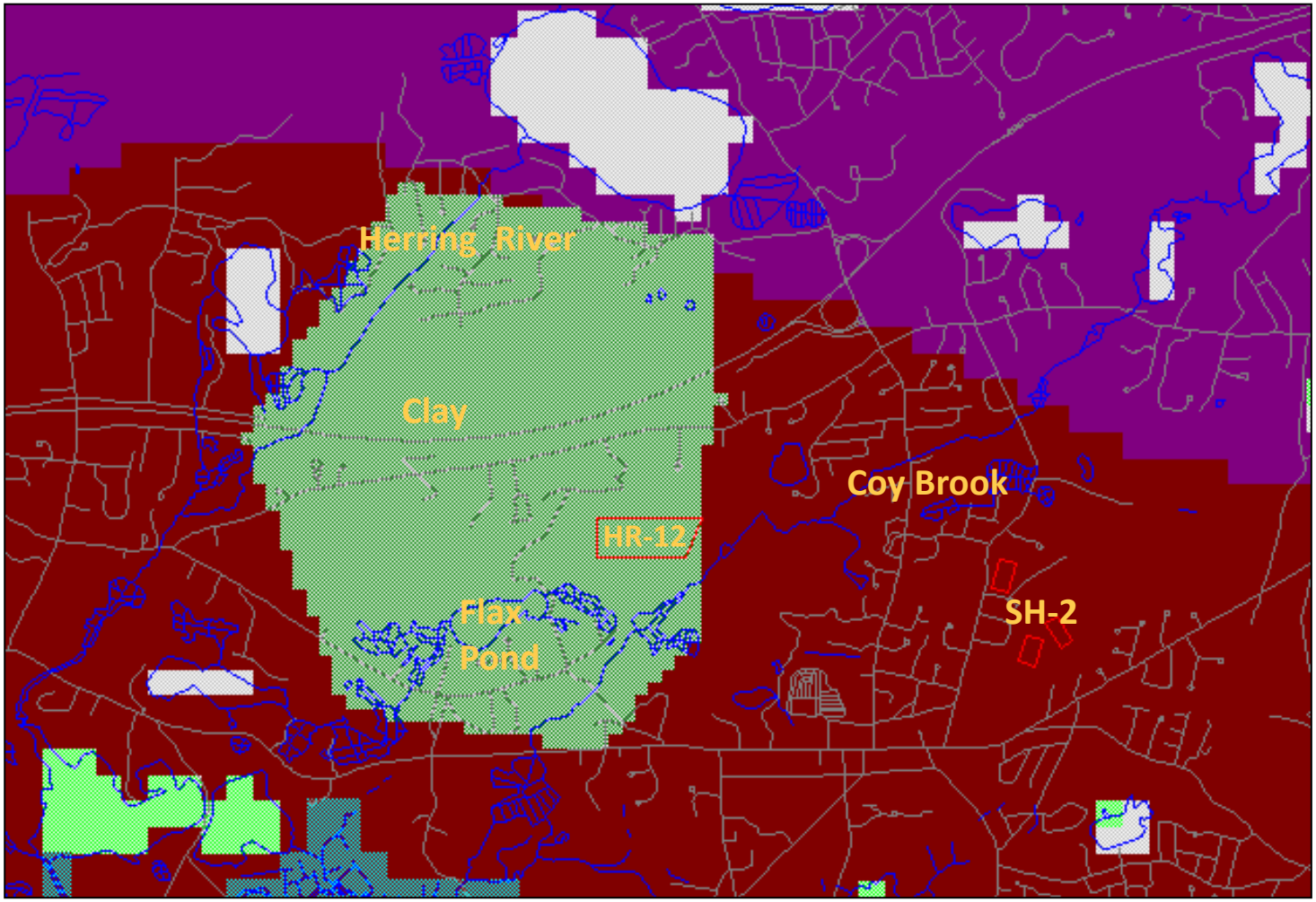
Figure 3-4
Clay Extent Layer 7: -1 to 10 feet elevation



CDM Smith

Figure 3-5
Clay Extent Layer 8: -10 to -1 feet elevation

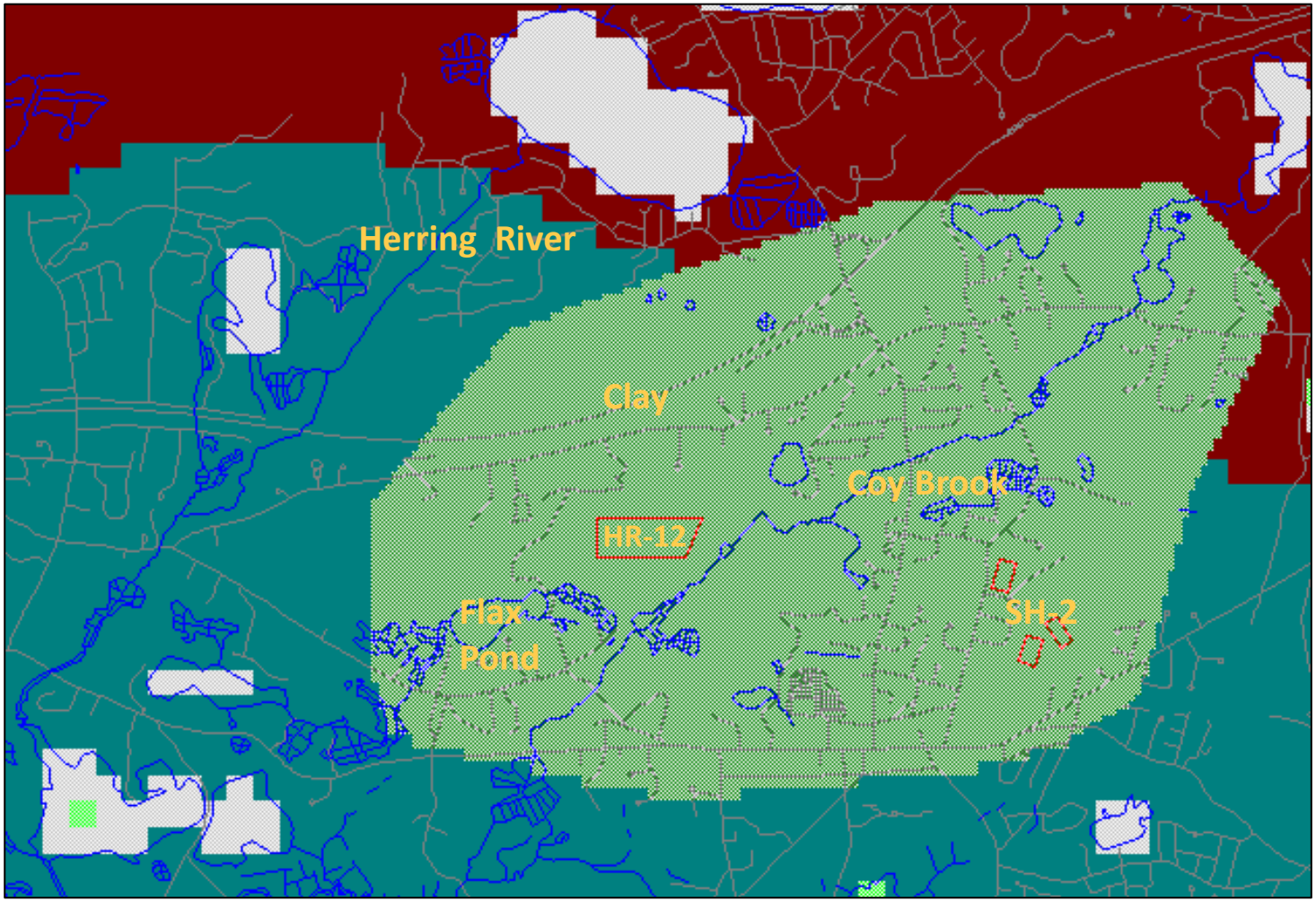


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Figure 3-6
Modeled Surface Water Features near HR-12

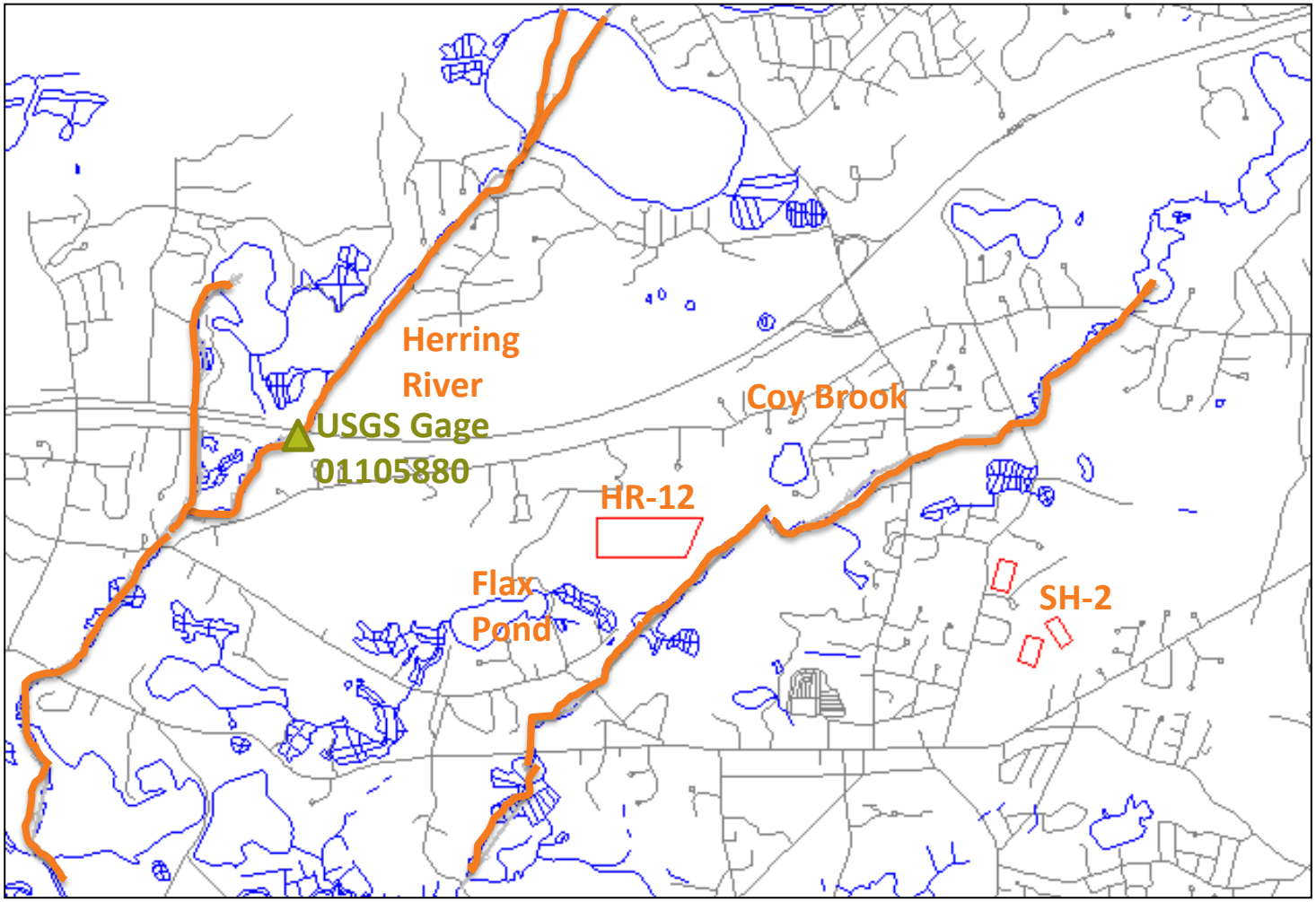

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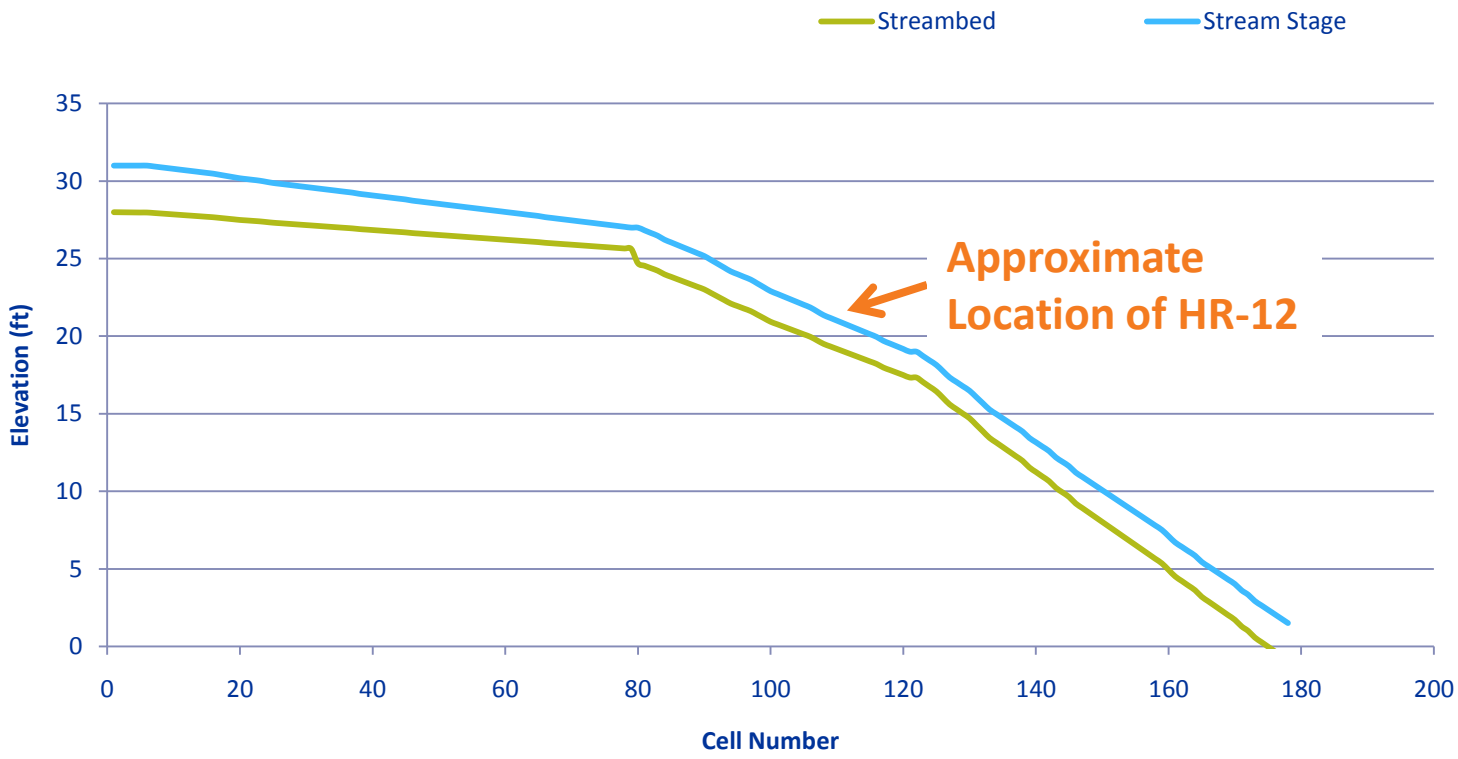
Figure 3-7
Coy Brook Modeled Streambed and Stage



X axis shows the number of model cells from the start of the stream.
Length of stream varies within each cell.

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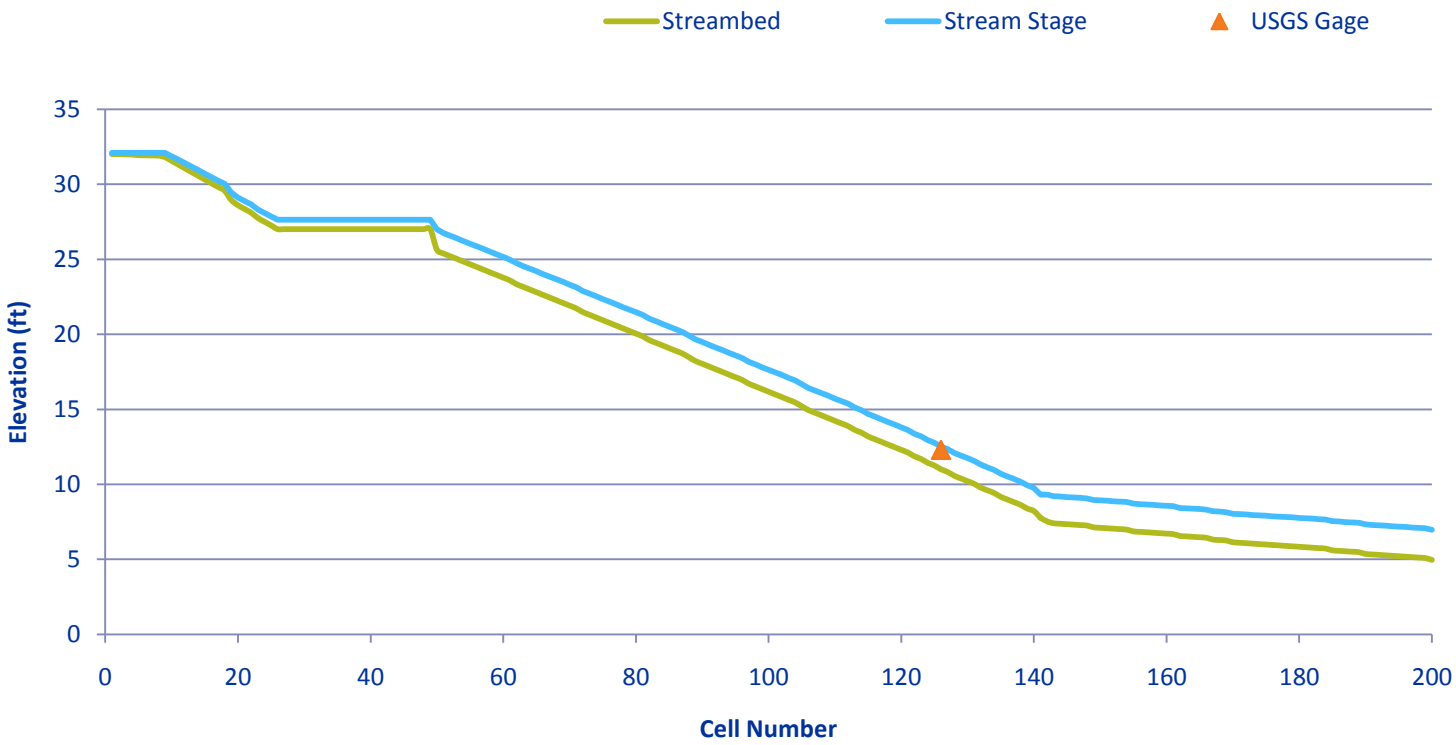
Figure 3-8
Herring River Modeled Streambed and Stage



X axis shows the number of model cells from the start of the stream.
Length of stream varies within each cell.

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Figure 3-9
Model Calibration: USGS Regional Wells

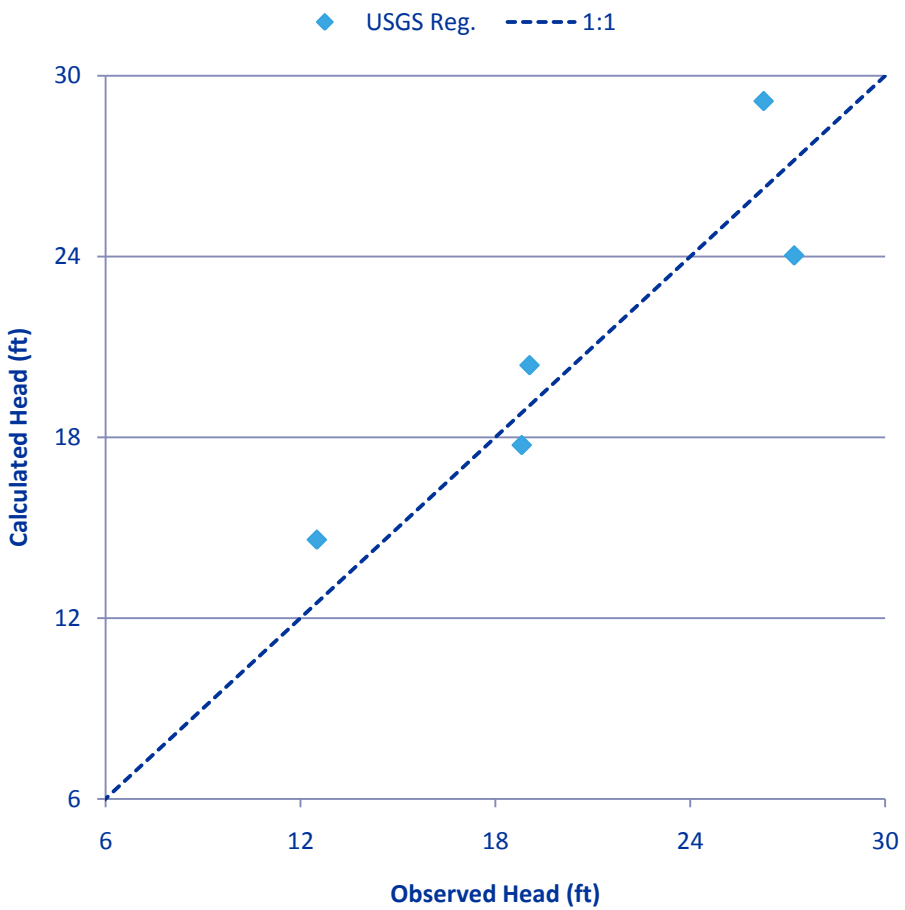

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Table 3-4 Model Calibration for USGS Regional Wells

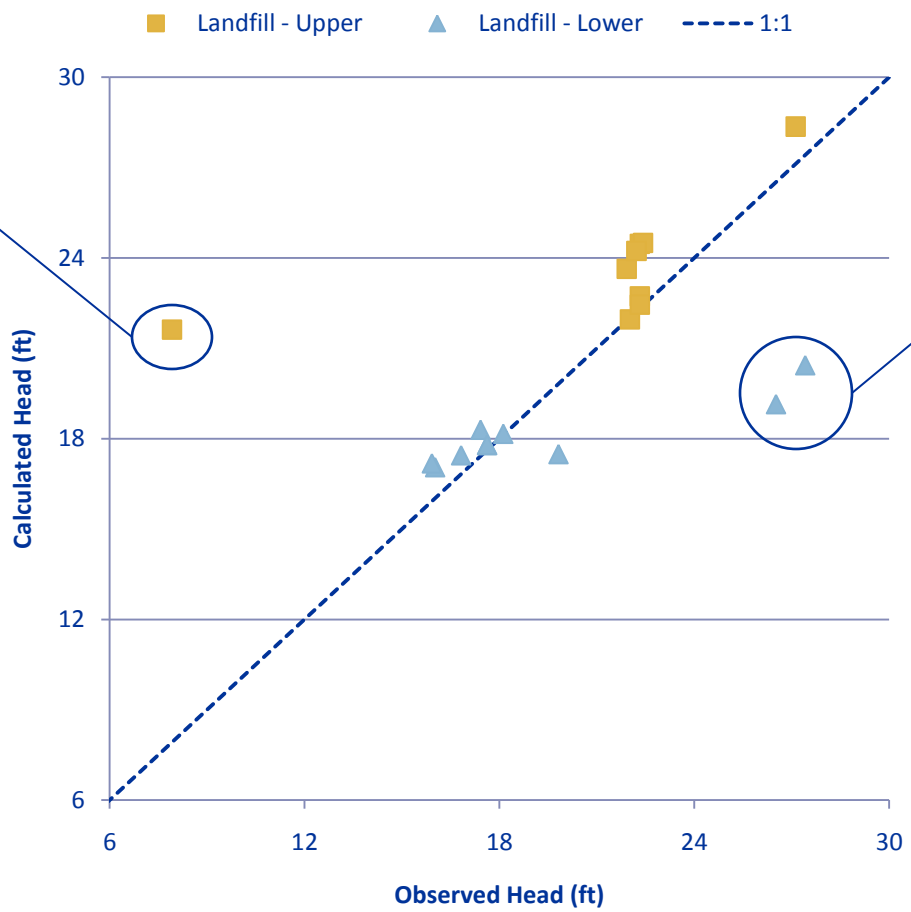
Well	Measured Head (feet)	Modeled Head - CWMP Refined Model (feet)
BMW-21	26.3	29.2
BMW-44	27.2	24.0
CGW-138	12.5	14.6
HJW-141	19.1	20.4
OSW-24	18.8	17.7

3.5.2 Landfill 2003 Average Annual Water Levels

Groundwater elevations at 20 wells were measured twice per year in the spring and fall as part of the Harwich Landfill CSA activities. Measurements from 2003 were averaged to compute an average annual value at each well. Simulated and observed heads are shown in Figure 3-10 and Table 3-5. Each well was identified as being screened in either the upper or lower aquifer unit based on whether it is above or below the observed clay layer. This is important because there is a significant vertical head difference measured between the upper and lower aquifer units, indicative of the low permeability and lateral extensiveness of the clay layer. The model reproduces this vertical head difference nicely throughout the local HR-12 site area, with only 3 monitoring points at which there is a significant mismatch, all three of which may be due to factors that could be explored during future CWMP efforts. The model was not able to replicate observed water levels at one well in the upper aquifer unit (HWH-19) in which the lowest water level was reported, significantly below the lowest head in the lower aquifer unit; thus, measurement error or lack of hydraulic connection is assumed to be the case. Also, the heads measured in two wells in the lower aquifer (HWH-1 and HWH-8D) are significantly higher than simulated in the model; this could be an indication that the wells' screens and/or filter packs may be in hydraulic connection with the upper aquifer unit, or their vertical placement in the simulated stratigraphic sequence may be incorrect. Review of the boring logs suggested a lack of connection to the aquifer for these locations, which could mean that these two wells may be measuring heads within the clay layer that would be higher than the water levels in the lower aquifer unit.

Figure 3-10
Model Calibration: Landfill Wells

Review of the boring logs suggests that this well (HWH-19) may not be connected to the upper aquifer due to heaving sand.



Review of the boring logs suggests that these wells (HWH-1 and HWH-8D) may be connected hydraulically to the upper aquifer.

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Table 3-5 Model Calibration for 2003 Landfill CSA Average Annual Water Levels

Well	Aquifer	Measured Head (feet)	Modeled Head (feet)
HWH-1	Lower	27.4 *	20.4
HWH-2 S	Upper	21.9	23.6
HWH-2 M	Upper	22.0	22.0
HWH-2 D	Lower	19.8	17.5
HWH-3 S	Upper	22.2	24.2
HWH-3 M	Upper	22.3	22.4
HWH-3 D	Lower	17.6	17.8
HWH-3 DD	Lower	17.6	17.8
HWH-4 S	Upper	NM	--
HWH-4 D	Lower	16.8	17.4
HWH-8 S	Upper	27.1	28.4
HWH-8 D	Lower	26.5 *	19.1
HWH-11	Lower	16.0	17.0
HWH-14	Lower	15.9	17.2
HWH-17 S	Upper	22.3	24.5
HWH-17 M	Upper	22.3	22.7
HWH-17 D	Lower	18.1	18.2
HWH-18 S	Upper	22.4	24.5
HWH-18 D	Lower	17.4	18.3
HWH-19	Upper	7.9 *	21.6

* Review of the boring log suggests that the well is not connected to the aquifer.
NM – A value was not recorded in the Fall 2003 round, so an annual water level could not be computed.

3.5.3 Recent Surface Water and Groundwater Data

Water levels at surface and groundwater data points were measured in the fall of 2011. This data set was used to refine the local understanding of groundwater flow, assist with model refinement and will support future CWMP work. Measured water levels are shown in Table 3-6.

Table 3-6 CWMP Observed Water Levels – Fall 2011

Location	Observed Water Elevation (feet) Fall 2011
Groundwater	
CDM-3	19.7
CDM-5	20.1
HWH-7D	20.4
Surface Water	
SWM-1	29.3
SWM-2	20.3
SWM-3	18.5
SWM-4	21.7
SWM-5	27.1

Section 4

Recharge Simulations

The refined and calibrated model was used to simulate scenarios for groundwater recharge effluent loading. Basin layout and loading rates were estimated based on supplemental fieldwork, soil types and experience at similar facilities. The predictive simulations provided the basis for estimating potential impacts to stream flow, for facilitating evaluation of surface water quality based on simulated groundwater to surface water discharge locations, and for assessing the lateral extent and magnitude of water table mounding and groundwater flow field modification.

4.1 Basin Layout and Loading Rates

Two simulations were run to assess proposed CWMP scenarios for the three sites shown on Figure 1-1. A third simulation was run after model calibration and conversations with bog owners and is presented in Section 4-3. Simulation 1 is based on the upper end flow loadings for all scenarios for effluent recharge proposed in the CWMP. Simulation 2 is the maximum loading over ten acres at HR-12 while maintaining a four foot separation distance, per MassDEP regulatory guidance. To determine the maximum load, a fixed head was set over the area of the basin. The simulations used the following loading rates and flows:

- Simulation 1
  - HR-12: 800,000 gpd at a loading rate of 3 gpd/ft^2
  - PB-3: 400,000 gpd at a loading rate of 5 gpd/ft^2
  - SH-2: 210,000 gpd at a loading rate of 1 gpd/ft^2
- Simulation 2:
  - HR-12: Maximum loading over 10 acre area which maintains a minimum four foot depth to the top of the groundwater mound.

Figure 4-1 shows the location of proposed basin layout for HR-12 including an approximate area for the wastewater treatment plant. Proposed basin layouts for Simulation 1 (6 acres) and Simulation 2 (10 acres) are shown.

The upper end flow loadings for the CWMP scenarios can be adequately modeled in a single model simulation (Simulation 1) due to the hydrogeologic separation of the sites. The three sites are located in different groundwater contributing areas and HR-12 and SH-2 are additionally separated by Coy Brook which serves as a boundary condition. Recharge at one site will have a minimal impact on flow at the other two sites.

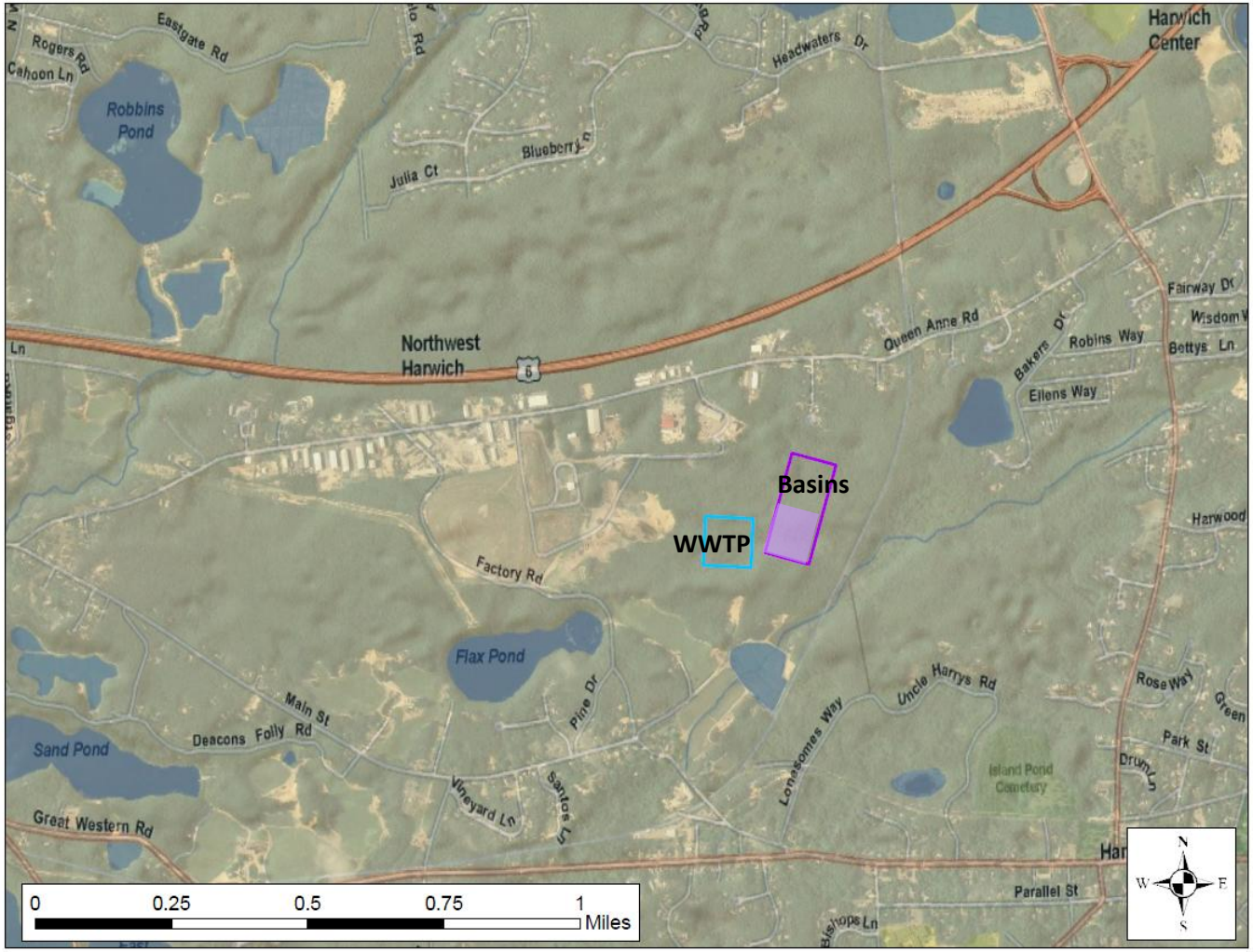
4.2 Simulation Results

The proposed recharge sites can adequately accept the simulated recharge flows while maintaining a four foot separation between the ground surface and the top of the groundwater mound. Results for Simulation 1 and 2 are shown in Table 4-1 including loading rates, estimated basin surface elevation,

Figure 4-1
HR-12 Proposed Basin Area

Purple outline is approximate area for 10 acres of proposed recharge basins

Purple shading is approximate area for 6 acres of proposed recharge basins



WWTP – Approximate area of proposed Wastewater Treatment Plant
Basins – Approximate area of proposed recharge basins

estimated minimum depth to the groundwater mound and estimated stream base flow increases. Because of the fixed head, Simulation 2 assumes that flow will be distributed to maintain the four foot head separation and that some basins will therefore recharge more flow than others. While this simulation approach is able to demonstrate the "optimum" or "maximum" total loading rate by design, the simulated distribution of flow rates from point to point would be operationally different in the field.

Average annual stream flow in Coy Brook near HR-12 is expected to increase by 1 to 1.2 cfs or 59 to 69 % of the average annual model estimated flow. Since streams on Cape Cod are fed primarily by groundwater, flow varies depending on the season. Groundwater flow peaks in early spring with the high water table and decreases during the summer. Effluent recharge flows are expected to be lower in the spring and higher in summer. Thus, the increased flow to Coy Brook would result in enhanced stream flow and would help to maintain a more reliable base flow throughout the year that could be beneficial for the local cranberry bog agricultural operations, especially during drought conditions.

Table 4-1 Simulation Results

Site	Total Recharge (MGD)	Loading Rate (gpd/ft^2)	Basin Area (acres)	Model Sim. Head (ft NGVD29)	Est. Basin Elev. (ft NGVD29)	Est. Depth to GW Mound (ft)	Est. Mound Height (ft)	Est. Stream Inc. (cfs)	% Est. Stream Inc.
Simulation 1 (Upper End of Flow Loading)									
HR-12	0.8	3.0	6.1	36	40	4	10	1	59%
PB-3	0.4	5.0	1.8	34	50	16	3.2		
SH-2	0.21	1.0	4.8	30	46	16	1.9		
Simulation 2 (Maximum Loading)									
HR-12	1.2	2.7	10	36	40	4	10	1.2	69%

4.2.1 Discharge Locations

Discharge locations were identified by using MODPATH to simulate particle movement within the aquifer. Figure 4-2 shows that recharge at HR-12 is simulated to discharge to Coy Brook and the bogs south of the site. Coy Brook flows into the Herring River. Recharge at SH-2 is simulated to discharge into the Bank Street Bogs and Cold Spring Brook, which empty into the Saquatucket Harbor. Recharge at PB-3 flows into Upper Muddy Creek which empties into Pleasant Bay. These results are based on the average annual steady-state conditions for 2003.

Water recharged at site PB-3 flows near public supply wells 4126000-09G and 4126000-10G (labeled as PW-25 and PW-26 in the groundwater model) before discharging to Upper Muddy Creek. Under the annual steady-state conditions simulated in this model, flows from PB-3 are not in the zone of contribution for either well and travel time to Upper Muddy Creek is greater than 10 years. Higher pumping rates and seasonal recharge fluctuations would bring PB-3 into the zone of contribution for these wells, however the time of travel for water recharged at PB-3 to reach these wells is likely greater than 5 years.

Figure 4-3 shows that recharge at HR-12 is simulated to discharge to Coy Brook and the bogs south of the site. Coy Brook flows into the Herring River. Results are similar to Simulation 1 which has a lower loading rate.

Figure 4-2
Flow Direction: Simulation 1

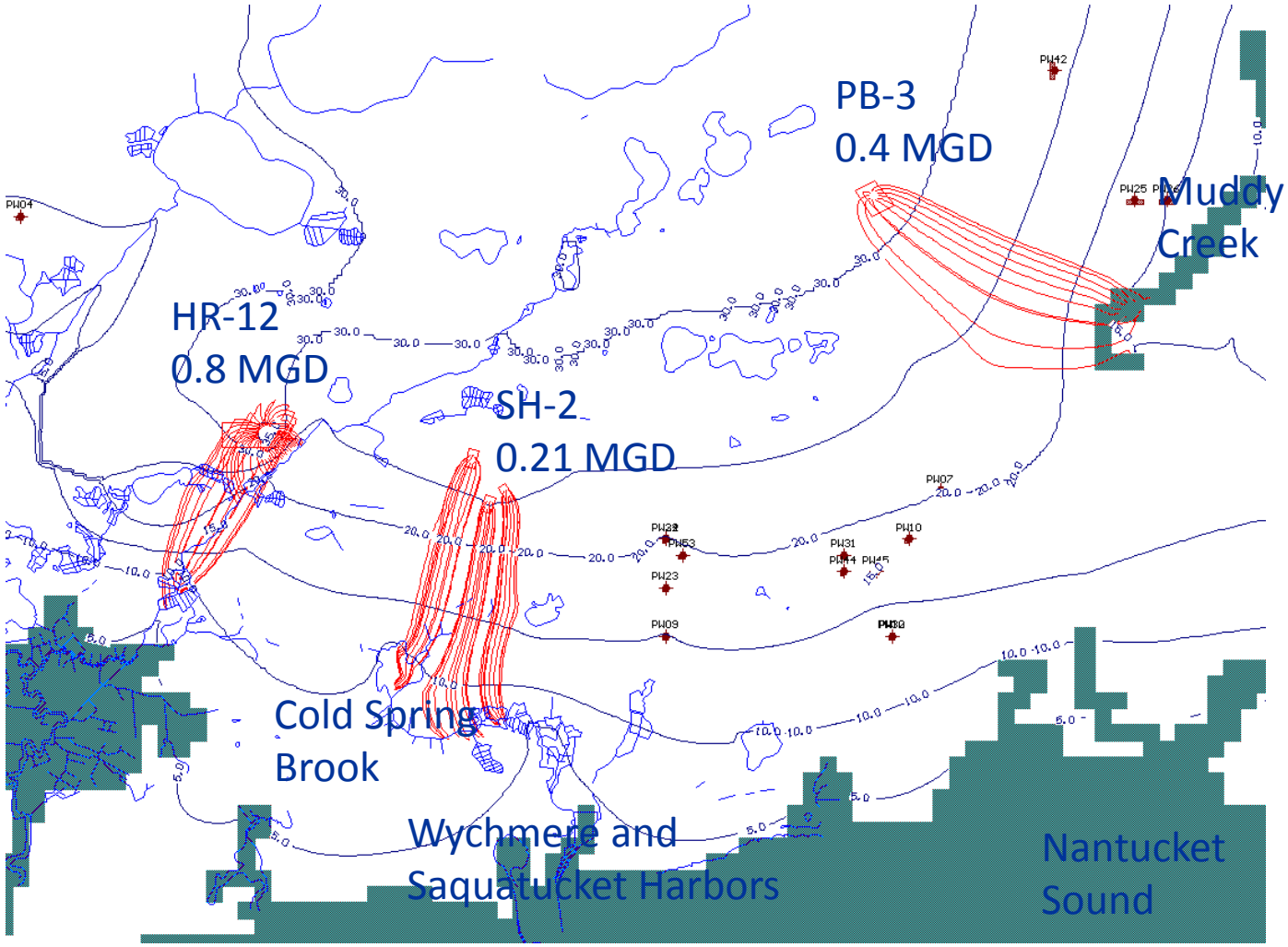
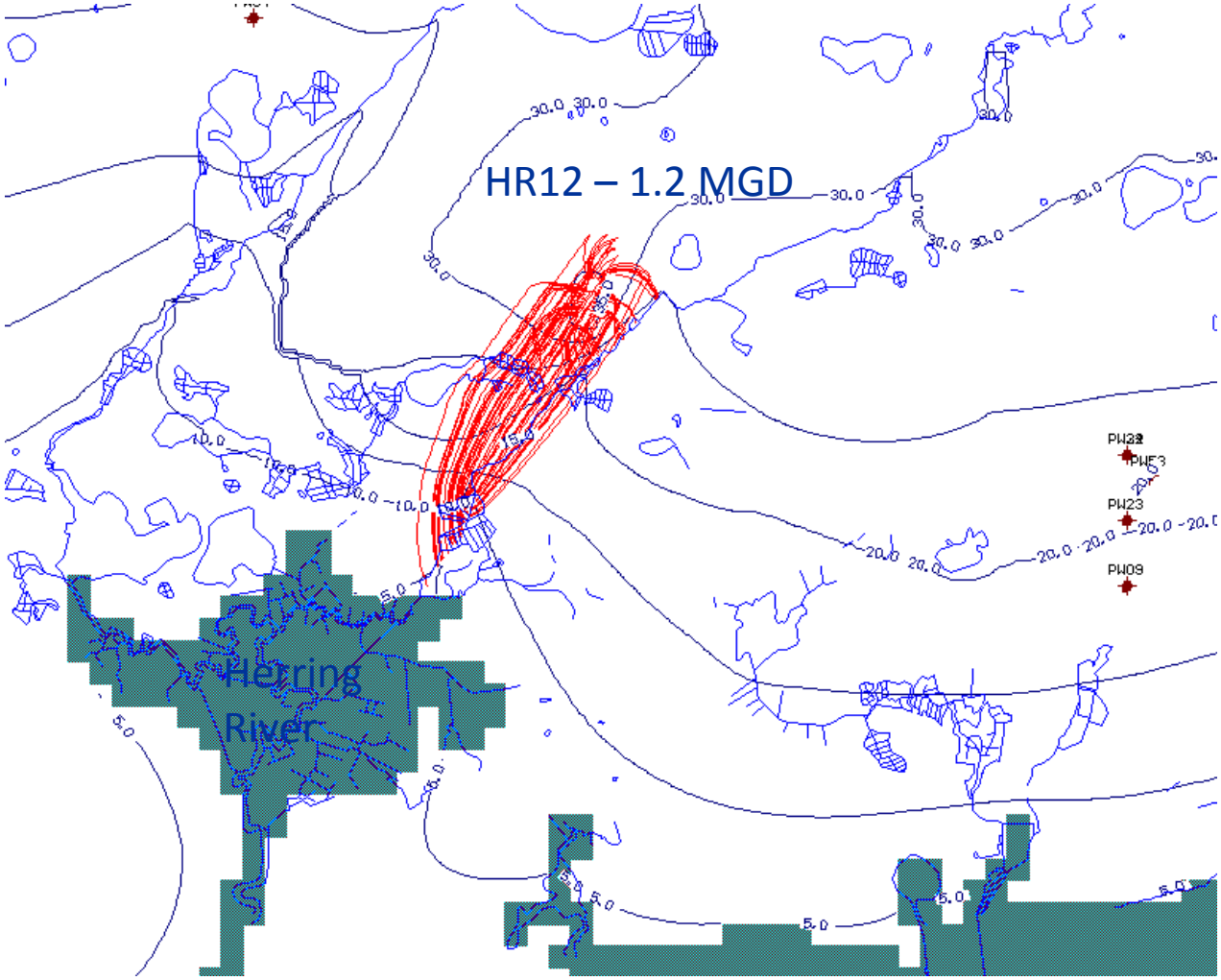


Figure 4-3
Flow Direction: Simulation 2



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Groundwater recharge at HR-12 should not have significant impact on the flow direction and discharge of any remaining contaminants from the landfill.

4.2.3 Water Table Mounding

Water table increases due to the proposed recharge are shown in Figure 4-4 and 4-5. The groundwater mound at SH-2 and PB-3 is 1.9 and 3.2 feet respectively. Due to the depth to groundwater, the rise is not expected to impact nearby receptors. Groundwater mounding at Flax Pond was 1.1 feet for Simulation 1 and 1.4 feet for Simulation 2. Mounding will not likely impact any buildings, residences, or water control structures in nearby cranberry bogs.

4.3 Revised Simulation of Cranberry Bogs

A site visit on January 27, 2012 and conversations with the cranberry bog operators after completion of Simulations 1 and 2 provided additional information on bog operations which impact water elevations in Flax Pond and Coy Brook near site HR-12. Information from the site visit is provided in Appendix E. The site visit revealed that an outlet and pumping system at the west end of Flax Pond allow the bog owner to control the pond level and limit the rise in the pond. The owner of the bog system along Coy Brook indicated that the water control system there is capable of passing significant flow rates through that bog area, including the capacity to drain off a small pond area that is created when Coy Brook backs up behind the cranberry bog inlet flow structures at the far northern end of the bog property immediately adjacent to HR-12. During the visit, there was a multiple foot difference (at least 4 feet) in stage in Coy Brook above and below the inlet structure. Based on these findings, additional refinements were made in the model including the addition of streams and changes in surface water basin elevations and stages in the cranberry bogs east and west of Flax Pond.

The model was adjusted and model calibration verified prior to running the recharge simulation. Appendix F contains the figures and tables showing the model adjusted stream locations, basin elevations and stream stages, revised clay extent, USGS calibration check, and 2003 water level calibration check.

Loading conditions for Simulation 2 were run on the updated model and the results are referred to as Simulation 3. This simulation models the maximum loading over 10 acres which maintains a minimum four foot depth to the top of the groundwater mound. Results of the simulation show a total recharge of 1.4 MGD, or a loading rate of 3.0 gpd/ft^2. Groundwater rise at Flax Pond was limited to 0.1 feet for Simulation 3, due to the additional drains in the cranberry bogs.

Figure 4-4
Mounding: Simulation 1

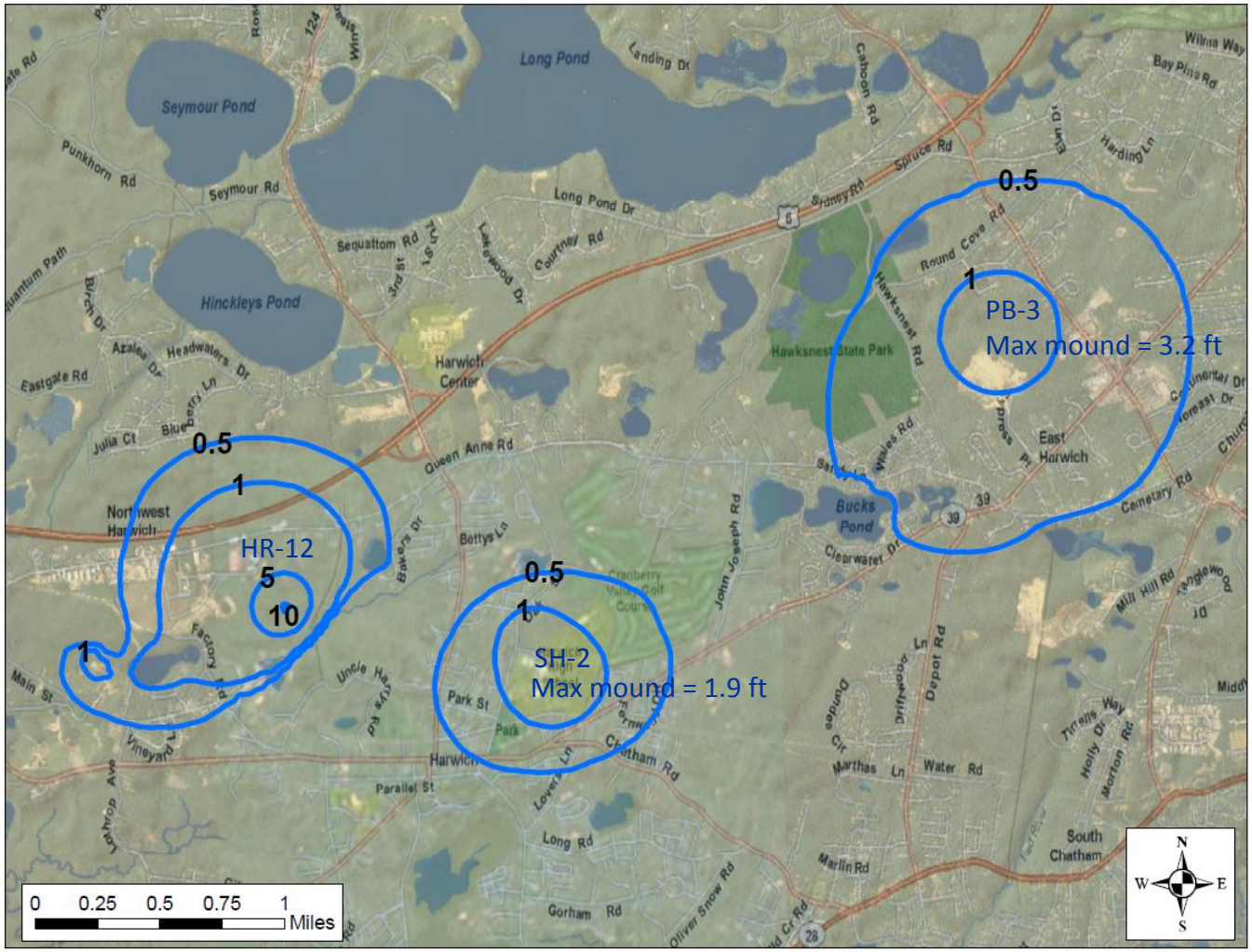


Figure 4-5
Mounding: Simulation 2

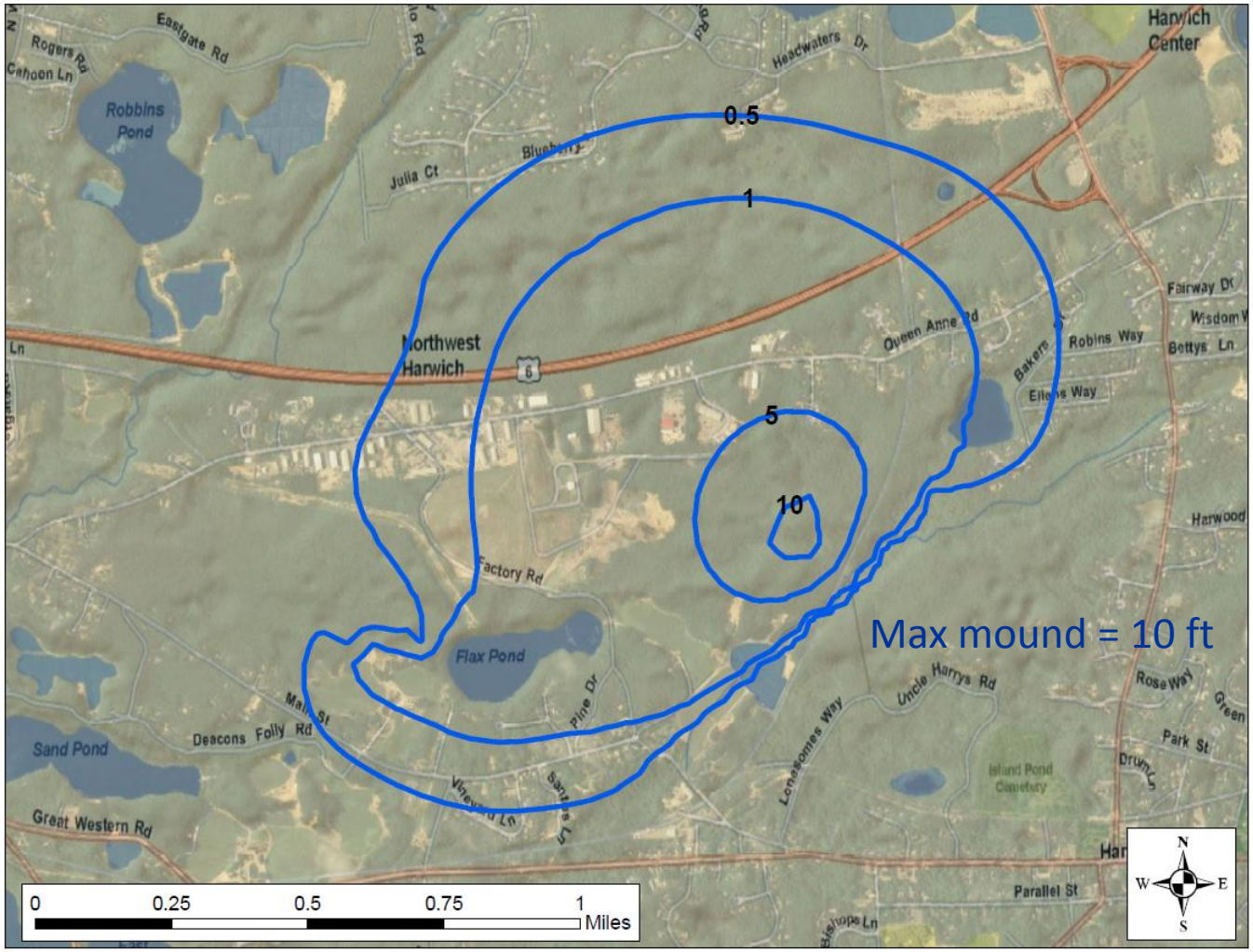
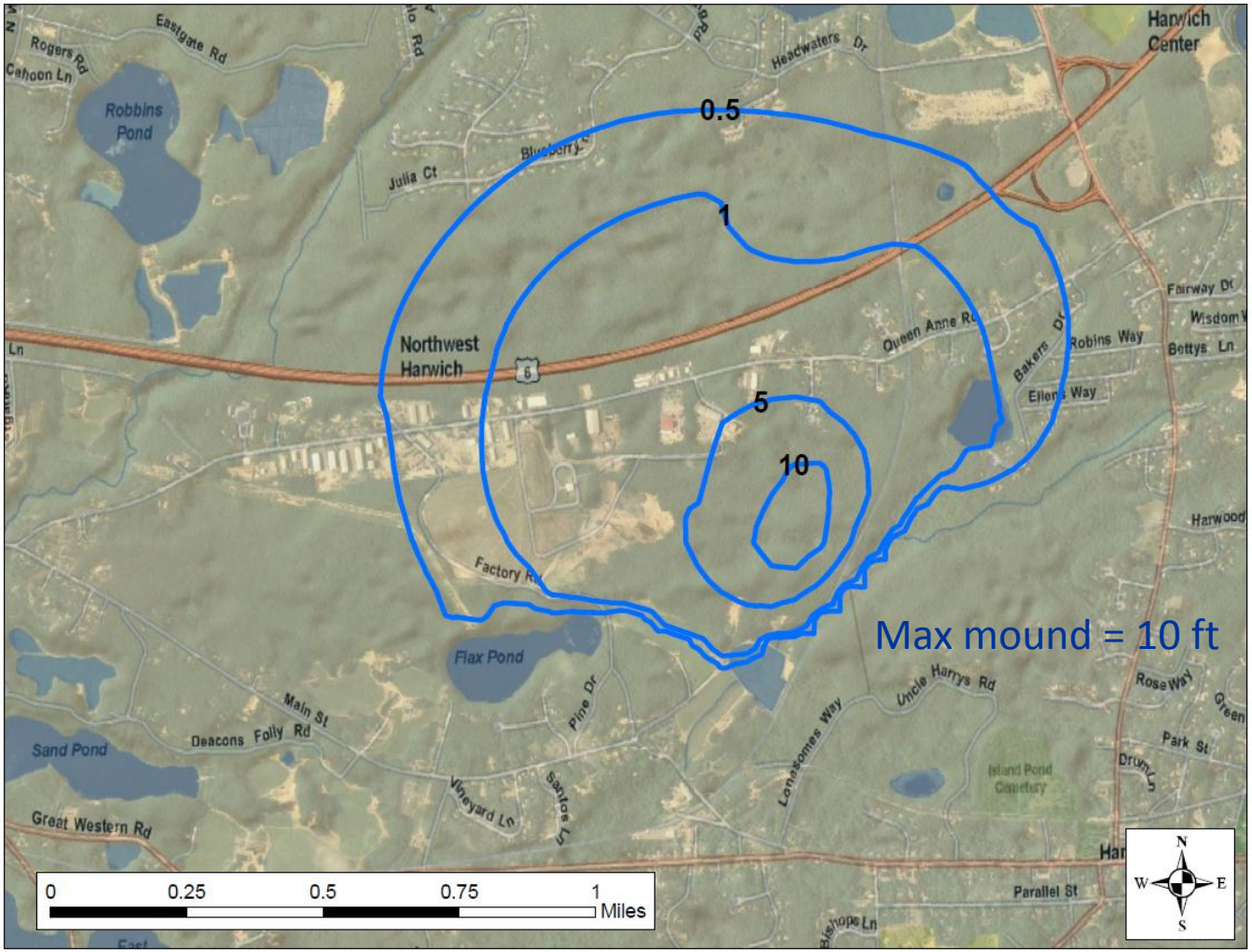


Figure 4-6
Mounding: Simulation 3



Section 5

Summary and Recommendations

Hydrogeologic data review, field work, model revisions and model calibration were completed as part of the hydrogeologic study. The hydrogeologic data review and field work identified a clay layer at HR-12 which impacts groundwater flow rates and direction. Based on the data review and field work, revisions were made to an existing regional USGS model which had been calibrated for 2003 conditions. Revisions included model grid refinement, addition of a clay layer and addition of surface water features near site HR-12. The revised and recalibrated model was used to assess the flow direction and mounding for recharge flows at three locations based on the CWMP scenarios.

Model simulation results, shown in Table 5-1, indicate that that the selected sites should be able to recharge the proposed CWMP scenario flows in an acceptable manner. Increased flow to Coy Brook near HR-12 would result in enhanced stream flow and would help to maintain a more reliable base flow beneficial for the local cranberry bog agricultural operations, especially during drought conditions.

Table 5-1 Simulation Results Summary

Site	Total Recharge (MGD)	Loading Rate (gpd/ft^2)	Basin Area (acres)	Model Sim. Head (ft NGVD29)	Est. Basin Elev. (ft NGVD29)	Est. Depth to GW Mound (ft)	Est. Mound Height (ft)	Est. Stream Inc. (cfs)	% Est. Stream Inc.
Simulation 1 (Upper End of Flow Loading)									
HR-12	0.8	3.0	6.1	36	40	4	10	1	59%
PB-3	0.4	5.0	1.8	34	50	16	3.2		
SH-2	0.21	1.0	4.8	30	46	16	1.9		
Simulation 2 (Maximum Loading)									
HR-12	1.2	2.7	10	36	40	4	10	1.2	69%
Simulation 3 (Maximum Loading With Revisions near Cranberry Bogs)									
HR-12	1.4	3.0	10	36	40	4	10		

Based on the hydrogeologic findings and the meeting with the MassDEP and CCC, the following items are recommended as part of the implementation phase of the recommended CWMP program.

- Continue monitoring of surface water and groundwater locations to determine seasonal impacts to groundwater, surface water levels and cranberry bogs.
- Develop an adaptive management approach which uses Phase I wastewater effluent flow as a loading test at the selected effluent recharge sites.
- Assess the flow capacity of existing hydraulic structures in Coy Brook, Flax Pond and the downstream cranberry bogs near HR-12 during the design phase to identify and mitigate the potential for blockages or limitations in flow. This analysis should include the culvert which carries Coy Brook under Great Western Road as it has been reported to have problems carrying existing flows at high groundwater periods

Section 6

References

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Hydrogeological Report

Appendix A

CAMP DRESSER & McKEE

CDM

Boring Number: CDM-1

Client: Town of Harwich
Project Name: Hydrogeology Evaluation
Project Location: Harwich, Massachusetts
Project Number: 0324-60650

Drilling Contractor/Driller: New Hampshire Boring, Inc. / Todd Penticost
Drilling Method/Casing/Core Barrel Size: Drive and Wash / 4-in/
Hammer Weight/Drop Height/ Spoon Size: 140-lbs lb / 30-in in /2-in
Bore Hole Location: See Boring Location Plan

N: E:

Drilling Date: Start: 8/2/2011 **End:** 8/2/2011

Surface Elevation (ft.):
Total Depth (ft.): 76
Depth to Initial Water Level (ft):

Depth	Date	Time
18.8	8/2/2011	12:00 P.M.

Abandonment Method: Fill with Cuttings
Logged By: J. Morency

Elev. Depth (ft)	Sample Type	Sample Number	Sample Length (in)	Blows per 6 inches	Sample Recovery (in)	Split Spoon Size (O.D.)	Graphic Log	Strata	Material Description	Remarks
0	SS	S-1	24	2 2 3 5	10			Sand	Dry, loose, brown-orange, fine SAND, some silt, trace fine gravel	
	SS	S-2	24	5 4 5 8	6				Dry, loose, brown-orange, fine SAND, some silt, trace fine gravel	
5	SS	S-3	24	4 3 3 4	13				Dry, loose, brown-orange, fine to medium SAND, trace silt	
	SS	S-4	24	6 4 5 5	15				Dry, loose, light brown, fine to medium SAND, trace silt	
	SS	S-5	24	8 6 5 4	7				Dry, medium dense, light brown, fine to coarse SAND, trace silt	
10	SS	S-6	24	5 5 6 6	11				Dry, medium dense, light brown, fine to coarse SAND, trace silt	
	SS	S-7	24	5 5 6 6	18				Dry, medium dense, light brown, fine to medium SAND, trace silt	
15	SS	S-8	24	10 9 9 10	6				Dry, medium dense, light brown, fine to coarse SAND, trace fine gravel, trace silt	
	SS	S-9	24	10 10 9 10	17				Moist, medium dense, light brown, fine to medium SAND, trace silt	
▼										
	SS	S-10	24	4 5	14				A: Wet, medium dense, brown-orange, fine to coarse SAND, little silt	A: (0"-10")

Sample Types

AS - Auger/Grab Sample
CS - California Sampler
BQ - 1.5" Rock Core
NQ - 2" Rock Core
HP - Hydro Punch
SS - Split Spoon
ST - Shelby Tube
WS - Wash Sample
GP - Geoprobe

Consistency vs Blowcount/Foot

Granular (Sand):

V. Loose:	0-4	Dense:	30-50
Loose:	4-10	V. Dense:	>50
M. Dense:	10-30		

Fine Grained (Clay):

V. Soft:	<2	Stiff:	8-15
Soft:	2-4	V. Stiff:	15-30
M. Stiff:	4-8	Hard:	>30

Burmister Classification

and	35-50%
some	20-35%
little	10-20%
trace	<10%

moisture, density, color

Reviewed by: **Date:** **Boring Number: CDM-1**

CAMP DRESSER & McKEE

CDM

Boring Number: CDM-1

Client: Town of Harwich
Project Location: Harwich, Massachusetts
Project Name: Hydrogeology Evaluation
Project Number: 0324-60650

Elev. Depth (ft)	Sample Type	Sample Number	Sample Length (in)	Blows per 6 inches	Sample Recovery (in)	Split Spoon Size (O.D.)	Graphic Log	Strata	Material Description	Remarks
20	SS	S-10	24	6 5	14			Clay	B: Wet, medium stiff, light brown, silty CLAY, trace fine sand	B: (10" - 14")
25	SS	S-11	24	5 7 7 9	24				Wet, stiff, gray, clayey SILT, trace fine sand	
30	SS	S-12	24	4 6 8 8	22				Wet, stiff, gray, SILT and CLAY	
35	SS	S-13	24	5 6 8 9	24				Wet, stiff, gray, CLAY	
40	SS	S-14	24	7 6 8 7	16				Wet, stiff, gray, CLAY, trace fine sand	
45	SS	S-15	24	5 5 11 10	19				Wet, very stiff, gray, CLAY, trace fine sand	

BL HARWICH BORING LOGS.GPJ - 8/24/11

CAMP DRESSER & McKEE

CDM

Boring Number: CDM-1

Client: Town of Harwich
Project Name: Hydrogeology Evaluation
Project Location: Harwich, Massachusetts
Project Number: 0324-60650

Elev. Depth (ft)	Sample Type	Sample Number	Sample Length (in)	Blows per 6 inches	Sample Recovery (in)	Split Spoon Size (O.D.)	Graphic Log	Strata	Material Description	Remarks
								Clay	A: Wet, very stiff, gray CLAY, trace fine sand	A: (0"-12")
50	SS	S-16	24	6 7 11 15	24				B: Wet, very stiff, brown, CLAY	B: (12" - 24")
									A: Wet, hard, brown, CLAY	A: (0"-12")
55	SS	S-17	24	5 9 30 28	24			Sand	B: Wet, very dense, brown with orange staining, fine to medium SAND, some silt	B: (12" - 24")
60	SS	S-18	24	13 18 22 20	20				Wet, dense, light brown, fine to medium SAND, little silt	
65	SS	S-19	24	13 7 13 9	13				Wet, medium dense, light brown, fine to medium SAND, trace silt	
70	SS	S-20	24	30 29 24 28	17				Wet, very dense, light brown, fine SAND, some silt	

BL HARWICH BORING LOGS.GPJ - 8/24/11

CAMP DRESSER & McKEE

CDM

Boring Number: CDM-1

Client: Town of Harwich
Project Name: Hydrogeology Evaluation
Project Location: Harwich, Massachusetts
Project Number: 0324-60650

Elev. Depth (ft)	Sample Type	Sample Number	Sample Length (in)	Blows per 6 inches	Sample Recovery (in)	Split Spoon Size (O.D.)	Graphic Log	Strata	Material Description	Remarks
75	SS	S-21	24	28 32 30 27	10			Sand	Wet, very dense, light brown, fine SAND, some silt	
									END OF BORING = 76'	
80										
85										
90										
95										
100										

BL HARWICH BORING LOGS.GPJ - 8/24/11

CAMP DRESSER & McKEE

CDM

Boring Number: CDM-2

Client: Town of Harwich
Project Name: Hydrogeology Evaluation
Project Location: Harwich, Massachusetts
Project Number: 0324-60650

Drilling Contractor/Driller: New Hampshire Boring, Inc. / Todd Penticost
Drilling Method/Casing/Core Barrel Size: Drive and Wash / 4-in/
Hammer Weight/Drop Height/ Spoon Size: 140-lbs lb / 30-in in /2-in
Bore Hole Location: See Boring Location Plan

N: E:

Drilling Date: Start: 8/3/2011 **End:** 8/4/2011

Surface Elevation (ft.):
Total Depth (ft.): 86
Depth to Initial Water Level (ft):

Depth	Date	Time
20.0	8/4/2011	11:00 P.M.

Abandonment Method: Fill with Cuttings
Logged By: J. Morency

Elev. Depth (ft)	Sample Type	Sample Number	Sample Length (in)	Blows per 6 inches	Sample Recovery (in)	Split Spoon Size (O.D.)	Graphic Log	Strata	Material Description	Remarks
0	SS	S-1	24	2 2 3 4	3				Dry, loose, brown, fine to coarse SAND, little silt	
	SS	S-2	24	2 5 5 4	10				Dry, medium dense, brown-orange, fine to coarse SAND, trace silt, trace fine gravel	
5	SS	S-3	24	3 4 4 6	12				Dry, loose, brown-orange, fine to coarse SAND, trace silt, trace fine gravel	
	SS	S-4	24	5 5 5 7	10				Dry, medium dense, brown-orange, fine to coarse SAND, trace silt, trace fine gravel	
	SS	S-5	24	10 12 13 28	13				Dry, medium dense, brown-orange, fine to coarse SAND, trace silt, trace fine gravel	
10	SS	S-6	24	7 7 8 10	15				Dry, medium dense, brown-orange, fine to medium SAND, trace silt	
	SS	S-7	24	8 7 10 12	12				Dry, medium dense, light brown, fine to medium SAND, trace silt	
15	SS	S-8	24	9 10 11 27	8				Dry, medium dense, orange-brown, fine to coarse SAND, trace fine gravel, trace silt	
	SS	S-9	24	13 11 14 13	8				Dry, medium dense, orange-brown, fine to medium SAND, trace silt	
▼	SS	S-10	24	19 23 22 19	14				Moist, dense, light brown, fine to coarse SAND, trace fine gravel, trace silt	

Sample Types

AS - Auger/Grab Sample
CS - California Sampler
BQ - 1.5" Rock Core
NQ - 2" Rock Core
HP - Hydro Punch
SS - Split Spoon
ST - Shelby Tube
WS - Wash Sample
GP - Geoprobe

Consistency vs Blowcount/Foot

Granular (Sand):

V. Loose:	0-4	Dense:	30-50
Loose:	4-10	V. Dense:	>50
M. Dense:	10-30		

Fine Grained (Clay):

V. Soft:	<2	Stiff:	8-15
Soft:	2-4	V. Stiff:	15-30
M. Stiff:	4-8	Hard:	>30

Burmister Classification

and	35-50%
some	20-35%
little	10-20%
trace	<10%

moisture, density, color

Reviewed by: **Date:** **Boring Number: CDM-2**

CAMP DRESSER & McKEE

CDM

Boring Number: CDM-2

Client: Town of Harwich
Project Location: Harwich, Massachusetts
Project Name: Hydrogeology Evaluation
Project Number: 0324-60650

Elev. Depth (ft)	Sample Type	Sample Number	Sample Length (in)	Blows per 6 inches	Sample Recovery (in)	Split Spoon Size (O.D.)	Graphic Log	Strata	Material Description	Remarks
20										
25	SS	S-11	24	5 5 7 9	17				Wet, medium dense, light brown, fine SAND, little silt	
30	SS	S-12	24	9 7 12 12	19				Wet, medium dense, light brown, fine SAND, little silt	
35	SS	S-13	24	11 14 17 20	13				Wet, dense, light brown, fine to medium SAND, trace silt	
40	SS	S-14	24	16 13 21 14	9				Wet, dense, light brown, fine to medium SAND, trace silt	
45	SS	S-15	24	6 5 7 11	24				Wet, stiff, gray, CLAY	

BL HARWICH BORING LOGS.GPJ - 8/24/11

CAMP DRESSER & McKEE

CDM

Boring Number: CDM-2

Client: Town of Harwich
Project Location: Harwich, Massachusetts
Project Name: Hydrogeology Evaluation
Project Number: 0324-60650

Elev. Depth (ft)	Sample Type	Sample Number	Sample Length (in)	Blows per 6 inches	Sample Recovery (in)	Split Spoon Size (O.D.)	Graphic Log	Strata	Material Description	Remarks
50	SS	S-16	24	8 5 9 9	16				Wet, stiff, gray, silty CLAY	
55	SS	S-17	24	6 8 12 17	11				Wet, medium dense, light gray, fine to coarse SAND, trace silt	
60	SS	S-18	24	11 22 23 13	15				Wet, dense, light gray, fine to coarse SAND, trace silt	
65	SS	S-19	24	9 4 3 4	24				Wet, medium stiff, gray CLAY	
70	SS	S-20	24	13 15 18 17	17				A: Wet, dense, gray, fine SAND, some silt B: Wet, dense, light brown, fine SAND, little silt	A: (0"-6") B: (6" - 17")

BL HARWICH BORING LOGS.GPJ - 8/24/11

CAMP DRESSER & McKEE

CDM

Boring Number: CDM-2

Client: Town of Harwich
Project Location: Harwich, Massachusetts
Project Name: Hydrogeology Evaluation
Project Number: 0324-60650

Elev. Depth (ft)	Sample Type	Sample Number	Sample Length (in)	Blows per 6 inches	Sample Recovery (in)	Split Spoon Size (O.D.)	Graphic Log	Strata	Material Description	Remarks
75	SS	S-21	24	13 13 20 16	18				Wet, dense, light brown, fine SAND, little silt	
80	SS	S-22	24	17 20 21 18	13				Wet, dense, light brown, fine SAND, little silt	
85	SS	S-23	24	13 12 19 16	16				Wet, dense, light brown, fine SAND, some silt	
90									END OF BORING = 86.0'	
95										
100										

BL HARWICH BORING LOGS.GPJ - 8/24/11

CAMP DRESSER & McKEE

CDM

Boring Number: CDM-3

Client: Town of Harwich
Project Name: Hydrogeology Evaluation
Project Location: Harwich, Massachusetts
Project Number: 0324-60650

Drilling Contractor/Driller: New Hampshire Boring, Inc. / Todd Penticost
Drilling Method/Casing/Core Barrel Size: Drive and Wash / 4-in/
Hammer Weight/Drop Height/ Spoon Size: 140-lbs lb / 30-in in /2-in
Bore Hole Location: See Boring Location Plan

N: E:

Drilling Date: Start: 8/4/2011 **End:** 8/5/2011

Surface Elevation (ft.):
Total Depth (ft.): 61
Depth to Initial Water Level (ft):

Depth	Date	Time
21.6	8/5/2011	2:00 P.M.

Abandonment Method: Monitoring Well
Logged By: J. Morency

Elev. Depth (ft)	Sample Type	Sample Number	Sample Length (in)	Blows per 6 inches	Sample Recovery (in)	Split Spoon Size (O.D.)	Graphic Log	Strata	Material Description	Remarks
0	SS	S-1	24	2 3 3 8	16				Dry, loose, dark brown, fine SAND, some silt, trace gravel	
	SS	S-2	24	3 4 3 4	15				Dry, loose, brown-orange, fine to coarse SAND, some silt, trace fine gravel	
5	SS	S-3	24	4 4 6 8	13				Dry, loose, brown-orange, fine to medium SAND, trace silt	
	SS	S-4	24	8 6 10 12	24				Dry, medium dense, brown-orange, fine to coarse SAND, trace silt	
	SS	S-5	24	10 12 13 17	11				Dry, medium dense, brown-orange, fine to coarse SAND, trace silt	
10	SS	S-6	24	16 14 15 20	14				Dry, medium dense, brown-orange, fine to coarse SAND, trace silt	
	SS	S-7	24	9 9 12 5	18				Dry, medium dense, brown-orange, fine to medium SAND, trace silt	
15	SS	S-8	24	14 16 20 23	20				Dry, dense, brown-orange, fine to coarse SAND, trace silt	
	SS	S-9	24	10 12 13 10	23				Dry, medium dense, light brown, fine to medium SAND, trace silt	
	SS	S-10	24	12 15 13 13	15				Dry, medium dense, light brown, fine to coarse SAND, trace silt	

Sample Types

AS - Auger/Grab Sample
CS - California Sampler
BQ - 1.5" Rock Core
NQ - 2" Rock Core
HP - Hydro Punch
SS - Split Spoon
ST - Shelby Tube
WS - Wash Sample
GP - Geoprobe

Consistency vs Blowcount/Foot

Granular (Sand):

V. Loose:	0-4	Dense:	30-50
Loose:	4-10	V. Dense:	>50
M. Dense:	10-30		

Fine Grained (Clay):

V. Soft:	<2	Stiff:	8-15
Soft:	2-4	V. Stiff:	15-30
M. Stiff:	4-8	Hard:	>30

Burmister Classification

and	35-50%
some	20-35%
little	10-20%
trace	<10%

moisture, density, color

Reviewed by: **Date:** **Boring Number: CDM-3**

CAMP DRESSER & McKEE

CDM

Boring Number: CDM-3

Client: Town of Harwich
Project Name: Hydrogeology Evaluation
Project Location: Harwich, Massachusetts
Project Number: 0324-60650

Elev. Depth (ft)	Sample Type	Sample Number	Sample Length (in)	Blows per 6 inches	Sample Recovery (in)	Split Spoon Size (O.D.)	Graphic Log	Strata	Material Description	Remarks
20 ▼										
25	SS	S-11	24	6 6 7 7	11				Wet, medium dense, light brown, fine to coarse SAND, trace fine gravel, trace silt	
30	SS	S-12	24	7 9 10 11	12				Wet, medium dense, light brown, fine to coarse SAND, trace fine gravel, trace silt	
35	SS	S-13	24	5 5 7 7	19				Wet, medium dense, light brown, fine SAND, some silt	
40	SS	S-14	24	11 7 7 7	9				Wet, medium dense, light brown, fine to coarse SAND, little fine to coarse gravel, little silt	
45	SS	S-15	24	8 15 21 12	13				Wet, dense, brown-orange, fine to coarse SAND, some fine to coarse gravel, little silt	

BL HARWICH BORING LOGS.GPJ - 8/24/11

CAMP DRESSER & McKEE

CDM

Boring Number: CDM-3

Client: Town of Harwich
Project Name: Hydrogeology Evaluation
Project Location: Harwich, Massachusetts
Project Number: 0324-60650

Elev. Depth (ft)	Sample Type	Sample Number	Sample Length (in)	Blows per 6 inches	Sample Recovery (in)	Split Spoon Size (O.D.)	Graphic Log	Strata	Material Description	Remarks
50	SS	S-16	24	9 13 15 14	14				A: Wet, very stiff, gray, CLAY and SILT, little fine sand B: Wet, medium dense, brown-orange, fine to coarse SAND and SILT	A: (0"-8") B: (8"-14")
55										
	SS	S-17	24	9 13 21 18	7				Wet, dense, light brown, fine to coarse SAND, some fine gravel, trace silt	
60	SS	S-18	24	16 14 21 20	10				Wet, dense, light brown, fine to coarse SAND, little silt	
65									END OF BORING = 61.0'	
70										

BL HARWICH BORING LOGS.GPJ - 8/24/11

CAMP DRESSER & McKEE

CDM

Boring Number: CDM-4

Client: Town of Harwich
Project Name: Hydrogeology Evaluation
Project Location: Harwich, Massachusetts
Project Number: 0324-60650

Drilling Contractor/Driller: New Hampshire Boring, Inc. / Todd Penticost
Drilling Method/Casing/Core Barrel Size: Drive and Wash / 4-in/
Hammer Weight/Drop Height/ Spoon Size: 140-lbs lb / 30-in in /2-in
Bore Hole Location: See Boring Location Plan

N: E:

Drilling Date: Start: 8/8/2011 **End:** 8/8/2011

Surface Elevation (ft.):
Total Depth (ft.): 10
Depth to Initial Water Level (ft):

Depth	Date	Time
NOT DETECTED		

Abandonment Method: Fill with Cuttings
Logged By: J. Morency

Elev. Depth (ft)	Sample Type	Sample Number	Sample Length (in)	Blows per 6 inches	Sample Recovery (in)	Split Spoon Size (O.D.)	Graphic Log	Strata	Material Description	Remarks
0	SS	S-1	24	1 2 1 2	15				Dry, very loose, brown-orange, fine SAND, some silt, trace fine gravel	
	SS	S-2	24	4 4 6 5	10				Dry, medium dense, brown-orange, fine to coarse SAND, trace fine gravel, trace silt	
5	SS	S-3	24	8 8 9 10	14				Dry, medium dense, brown-orange, fine to coarse SAND, trace fine gravel, trace silt	
	SS	S-4	24	12 10 11 12	16				Dry, medium dense, brown, fine to coarse SAND, trace fine gravel, trace silt	
	SS	S-5	24	9 10 11 13	9				Dry, medium dense, light brown, fine to coarse SAND, little silt, trace fine gravel	
10									END OF BORING = 10.0'	
15										

Sample Types

AS - Auger/Grab Sample
CS - California Sampler
BQ - 1.5" Rock Core
NQ - 2" Rock Core
HP - Hydro Punch
SS - Split Spoon
ST - Shelby Tube
WS - Wash Sample
GP - Geoprobe

Consistency vs Blowcount/Foot

Granular (Sand):

V. Loose:	0-4	Dense:	30-50
Loose:	4-10	V. Dense:	>50
M. Dense:	10-30		

Fine Grained (Clay):

V. Soft:	<2	Stiff:	8-15
Soft:	2-4	V. Stiff:	15-30
M. Stiff:	4-8	Hard:	>30

Burmister Classification

and	35-50%
some	20-35%
little	10-20%
trace	<10%

moisture, density, color

Reviewed by: **Date:** **Boring Number: CDM-4**

CAMP DRESSER & McKEE

CDM

Boring Number: CDM-5

Client: Town of Harwich
Project Name: Hydrogeology Evaluation
Project Location: Harwich, Massachusetts
Project Number: 0324-60650

Drilling Contractor/Driller: New Hampshire Boring, Inc. / Jason Stokes
Drilling Method/Casing/Core Barrel Size: Drive and Wash / 4-in/
Hammer Weight/Drop Height/ Spoon Size: 140-lbs lb / 30-in in /2-in
Bore Hole Location: See Boring Location Plan
N: E:
Drilling Date: Start: 8/9/2011 **End:** 8/9/2011

Surface Elevation (ft.):
Total Depth (ft.): 61
Depth to Initial Water Level (ft):

Depth	Date	Time
12.0	8/9/2011	7:00 A.M.

Abandonment Method: Monitoring Well
Logged By: J. Morency

Elev. Depth (ft)	Sample Type	Sample Number	Sample Length (in)	Blows per 6 inches	Sample Recovery (in)	Split Spoon Size (O.D.)	Graphic Log	Strata	Material Description	Remarks
0	SS	S-1	24	1 2 2 3	7				Dry, loose, brown-orange, fine to medium SAND, little silt, trace fine gravel	
	SS	S-2	24	7 6 8 9	15				Dry, medium dense, light brown, fine to coarse SAND, trace fine gravel, trace silt	
5	SS	S-3	24	8 9 10 11	9				Dry, medium dense, light brown, fine to coarse SAND, trace fine gravel, trace silt	
	SS	S-4	24	6 9 8 9	13				Dry, medium dense, brown-orange, fine to coarse SAND, trace fine gravel, trace silt	
	SS	S-5	24	6 9 9 10	17				Dry, medium dense, light brown, fine to coarse SAND, little fine to coarse gravel, trace silt	
10	SS	S-6	24	7 7 8 12	16				Moist, medium dense, light brown, fine to coarse SAND, trace fine gravel	
▼	SS	S-7	24	6 8 8 11	13				Wet, medium dense, light brown, fine to coarse SAND, trace fine gravel	
15	SS	S-8	24	12 12 15 14	15				Wet, medium dense, brown-orange, fine to coarse SAND, trace fine gravel, trace silt	
	SS	S-9	24	9 13 15 19	17				Wet, medium dense, brown-orange, fine to coarse SAND, trace fine gravel, trace silt	
	SS	S-10	24	8 9 13 16	7				Wet, medium dense, light brown, fine to medium SAND, little silt, trace fine gravel	

Sample Types

AS - Auger/Grab Sample
CS - California Sampler
BQ - 1.5" Rock Core
NQ - 2" Rock Core
HP - Hydro Punch
SS - Split Spoon
ST - Shelby Tube
WS - Wash Sample
GP - Geoprobe

Consistency vs Blowcount/Foot

Granular (Sand):

V. Loose:	0-4	Dense:	30-50
Loose:	4-10	V. Dense:	>50
M. Dense:	10-30		

Fine Grained (Clay):

V. Soft:	<2	Stiff:	8-15
Soft:	2-4	V. Stiff:	15-30
M. Stiff:	4-8	Hard:	>30

Burmister Classification

and	35-50%
some	20-35%
little	10-20%
trace	<10%

moisture, density, color

Reviewed by: **Date:** **Boring Number: CDM-5**

CAMP DRESSER & McKEE

CDM

Boring Number: CDM-5

Client: Town of Harwich
Project Name: Hydrogeology Evaluation
Project Location: Harwich, Massachusetts
Project Number: 0324-60650

Elev. Depth (ft)	Sample Type	Sample Number	Sample Length (in)	Blows per 6 inches	Sample Recovery (in)	Split Spoon Size (O.D.)	Graphic Log	Strata	Material Description	Remarks
20	SS	S-11	24	10 15 15 19	15				Wet, dense, light brown, fine to medium SAND, little silt, trace fine gravel	
	SS	S-12	24	12 13 17 21	14				Wet, dense, light brown, fine to medium SAND, little silt, trace fine gravel	
25	SS	S-13	24	7 10 15 16	20				A: Wet, medium dense, light brown, fine to medium SAND, little silt, trace fine gravel	A: (0"-15")
									B: Wet, medium dense, brown-orange, fine to coarse SAND and CLAY	B: (15"- 20")
30	SS	S-14	24	13 20 31 22	15				Wet, very dense, light brown, fine SAND, little silt	
35	SS	S-15	24	10 26 34 49	8				Wet, very dense, light brown, fine SAND, little silt	
40	SS	S-16	24	9 13 25 19	10				Wet, dense, light brown, fine to coarse SAND, little silt	
45	SS	S-17	24	12 21 16 21	15				Wet, dense, light brown, fine to medium SAND, trace silt	

BL HARWICH BORING LOGS.GPJ - 8/24/11

CAMP DRESSER & McKEE

CDM

Boring Number: CDM-5

Client: Town of Harwich
Project Name: Hydrogeology Evaluation
Project Location: Harwich, Massachusetts
Project Number: 0324-60650

Elev. Depth (ft)	Sample Type	Sample Number	Sample Length (in)	Blows per 6 inches	Sample Recovery (in)	Split Spoon Size (O.D.)	Graphic Log	Strata	Material Description	Remarks
50	SS	S-18	24	13 21 19 22	24				Wet, dense, light brown, fine to medium SAND, trace silt	
55	SS	S-19	24	10 24 22 26	18				Wet, dense, light brown, fine to medium SAND, trace silt	
60	SS	S-20	24	12 13 16 20	20				Wet, medium dense, light brown, fine to medium SAND, trace silt	
									END OF BORING = 61.0'	
65										
70										

BL HARWICH BORING LOGS.GPJ - 8/24/11

CAMP DRESSER & McKEE

CDM

Boring Number: CDM-6

Client: Town of Harwich
Project Name: Hydrogeology Evaluation
Project Location: Harwich, Massachusetts
Project Number: 0324-60650

Drilling Contractor/Driller: New Hampshire Boring, Inc. / Jason Stokes
Drilling Method/Casing/Core Barrel Size: Drive and Wash / 4-in/
Hammer Weight/Drop Height/ Spoon Size: 140-lbs lb / 30-in in /2-in
Bore Hole Location: See Boring Location Plan
N: E:
Drilling Date: Start: 8/10/2011 **End:** 8/11/2011

Surface Elevation (ft.):
Total Depth (ft.): 61
Depth to Initial Water Level (ft):

Depth	Date	Time
27.0	8/11/2011	7:00 A.M.

Abandonment Method: Fill with Cuttings
Logged By: J. Morency

Elev. Depth (ft)	Sample Type	Sample Number	Sample Length (in)	Blows per 6 inches	Sample Recovery (in)	Split Spoon Size (O.D.)	Graphic Log	Strata	Material Description	Remarks
0	SS	S-1	24	1 1 2 3	7				Dry, very loose, brown-orange, fine SAND, some silt, trace fine gavel	
	SS	S-2	24	5 7 6 8	15				Dry, medium dense, brown-orange, fine to medium SAND, little silt	
5	SS	S-3	24	5 9 10 10	16				Dry, medium dense, brown-orange, fine to medium SAND, trace fine gravel, trace silt	
	SS	S-4	24	7 9 12 11	13				Dry, medium dense, brown-orange, fine to medium SAND, trace silt	
	SS	S-5	24	11 12 10 12	7				Dry, medium dense, brown-orange, fine to coarse SAND, little fine gravel, trace silt	
10	SS	S-6	24	8 12 10 10	15				Dry, medium dense, brown-orange, fine to coarse SAND, trace fine gravel, trace silt	
	SS	S-7	24	8 9 11 12	16				Dry, medium dense, light brown, fine to medium SAND, trace silt	
15	SS	S-8	24	7 8 11 14	11				Dry, medium dense, light brown, fine to medium SAND, trace silt	
	SS	S-9	24	9 12 10 11	12				Dry, medium dense, light brown, fine to coarse SAND, little fine gravel, trace silt	
	SS	S-10	24	9 12 11 14	11				Dry, medium dense, light brown, fine to coarse SAND, some fine gravel, trace silt	

Sample Types

AS - Auger/Grab Sample
CS - California Sampler
BQ - 1.5" Rock Core
NQ - 2" Rock Core
HP - Hydro Punch
SS - Split Spoon
ST - Shelby Tube
WS - Wash Sample
GP - Geoprobe

Consistency vs Blowcount/Foot

Granular (Sand):

V. Loose:	0-4	Dense:	30-50
Loose:	4-10	V. Dense:	>50
M. Dense:	10-30		

Fine Grained (Clay):

V. Soft:	<2	Stiff:	8-15
Soft:	2-4	V. Stiff:	15-30
M. Stiff:	4-8	Hard:	>30

Burmister Classification

and	35-50%
some	20-35%
little	10-20%
trace	<10%

moisture, density, color

Reviewed by: **Date:** **Boring Number: CDM-6**

CAMP DRESSER & McKEE

CDM

Boring Number: CDM-6

Client: Town of Harwich
Project Name: Hydrogeology Evaluation
Project Location: Harwich, Massachusetts
Project Number: 0324-60650

Elev. Depth (ft)	Sample Type	Sample Number	Sample Length (in)	Blows per 6 inches	Sample Recovery (in)	Split Spoon Size (O.D.)	Graphic Log	Strata	Material Description	Remarks
20	SS	S-11	24	10 12 13 14	13				Dry, medium dense, light brown, fine to medium SAND, trace silt	
	SS	S-12	24	12 13 12 17	6				Dry, medium dense, light brown, fine to medium SAND, trace fine gravel, trace silt	
25	SS	S-13	24	12 14 16 19	14				Moist, dense, light brown, fine to coarse SAND, trace fine gravel	
▼	SS	S-14	25	5 6 6 6	8				Wet, medium dense, light brown, fine to medium SAND, little silt, trace fine gravel	
	SS	S-15	26	6 7 8 9	6				Wet, medium dense, light brown, fine to medium SAND, little silt, trace fine gravel	
30										
35	SS	S-16	27	8 11 13 14	10				Wet, medium dense, light brown, fine coarse SAND, trace fine gravel, trace silt	
40	SS	S-17	28	8 10 13 17	9				Wet, medium dense, light brown, fine coarse SAND, trace fine gravel, trace silt	
45	SS	S-18	29	9 12 23 27	9				Wet, dense, light brown, fine coarse SAND, trace fine gravel, trace silt	

BL HARWICH BORING LOGS.GPJ - 8/24/11

CAMP DRESSER & McKEE

CDM

Boring Number: CDM-6

Client: Town of Harwich
Project Location: Harwich, Massachusetts
Project Name: Hydrogeology Evaluation
Project Number: 0324-60650

Elev. Depth (ft)	Sample Type	Sample Number	Sample Length (in)	Blows per 6 inches	Sample Recovery (in)	Split Spoon Size (O.D.)	Graphic Log	Strata	Material Description	Remarks
50	SS	S-19	30	10 21 23 22	13				Wet, dense, light brown, fine coarse SAND, trace fine gravel, trace silt	
55	SS	S-20	31	13 13 24 32	17				A: Wet, brown, hard, SILT and CLAY	A: (0"-10")
									B: Wet, gray, hard, silty CLAY	B: (10"-17")
60	SS	S-21	32	7 9 11 13	10				Wet, medium dense, light brown, fine to coarse SAND, trace fine gravel, trace silt	
65									END OF BORING = 61.0'	
70										

BL HARWICH BORING LOGS.GPJ - 8/24/11

CAMP DRESSER & McKEE

CDM

Boring Number: CDM-7

Client: Town of Harwich
Project Name: Hydrogeology Evaluation
Project Location: Harwich, Massachusetts
Project Number: 0324-60650

Drilling Contractor/Driller: New Hampshire Boring, Inc. / Jason Stokes
Drilling Method/Casing/Core Barrel Size: Drive and Wash / 4-in/
Hammer Weight/Drop Height/ Spoon Size: 140-lbs lb / 30-in in /2-in
Bore Hole Location: See Boring Location Plan
N: E:
Drilling Date: Start: 8/11/2011 **End:** 8/12/2011

Surface Elevation (ft.):
Total Depth (ft.): 81
Depth to Initial Water Level (ft):

Depth	Date	Time
38.0	8/12/2011	3:30 P.M.

Abandonment Method: Fill with Cuttings
Logged By: J. Morency

Elev. Depth (ft)	Sample Type	Sample Number	Sample Length (in)	Blows per 6 inches	Sample Recovery (in)	Split Spoon Size (O.D.)	Graphic Log	Strata	Material Description	Remarks
0	SS	S-1	24	1 2 2 3	10				Dry, loose, brown-orange, fine to medium SAND, little silt, trace fine gravel	
5	SS	S-2	24	15 17 13 14	6				Dry, dense, brown-orange, fine to coarse SAND, some fine gravel, trace silt	
10	SS	S-3	24	10 7 7 12	12				Dry, medium dense, brown-orange, fine to coarse SAND, trace fine grave, trace silt	
15	SS	S-4	24	10 10 11 11	5				Dry, medium dense, brown-orange, fine to coarse SAND, trace fine grave, trace silt	
	SS	S-5	24	6 7	6				Dry, medium dense, brown-orange, fine to medium SAND, little silt	

Sample Types

AS - Auger/Grab Sample
CS - California Sampler
BQ - 1.5" Rock Core
NQ - 2" Rock Core
HP - Hydro Punch
SS - Split Spoon
ST - Shelby Tube
WS - Wash Sample
GP - Geoprobe

Consistency vs Blowcount/Foot

Granular (Sand):

V. Loose:	0-4	Dense:	30-50
Loose:	4-10	V. Dense:	>50
M. Dense:	10-30		

Fine Grained (Clay):

V. Soft:	<2	Stiff:	8-15
Soft:	2-4	V. Stiff:	15-30
M. Stiff:	4-8	Hard:	>30

Burmister Classification

and	35-50%
some	20-35%
little	10-20%
trace	<10%

moisture, density, color

Reviewed by: **Date:** **Boring Number: CDM-7**

CAMP DRESSER & McKEE

CDM

Boring Number: CDM-7

Client: Town of Harwich
Project Location: Harwich, Massachusetts
Project Name: Hydrogeology Evaluation
Project Number: 0324-60650

Elev. Depth (ft)	Sample Type	Sample Number	Sample Length (in)	Blows per 6 inches	Sample Recovery (in)	Split Spoon Size (O.D.)	Graphic Log	Strata	Material Description	Remarks
20	SS	S-5	24	6 7	6					
25	SS	S-6	24	7 7 8 11	9				Dry, medium dense, light brown, fine to coarse SAND, little fine to coarse gravel, trace silt	
30	SS	S-7	24	8 10 12 15	13				Dry, medium dense, light brown, fine to coarse SAND, trace fine gravel, trace silt	
35	SS	S-8	24	7 9 10 11	11				Dry, medium dense, light brown, fine to coarse SAND, little silt	
▼										
40	SS	S-9	24	7 10 11 15	9				Wet, medium dense, light brown, fine to coarse SAND, little silt	
45	SS	S-10	24	12 15 25 29	10				Wet, dense, light brown, fine to coarse SAND, little silt	

BL HARWICH BORING LOGS.GPJ - 8/24/11

CAMP DRESSER & McKEE

CDM

Boring Number: CDM-7

Client: Town of Harwich
Project Location: Harwich, Massachusetts
Project Name: Hydrogeology Evaluation
Project Number: 0324-60650

Elev. Depth (ft)	Sample Type	Sample Number	Sample Length (in)	Blows per 6 inches	Sample Recovery (in)	Split Spoon Size (O.D.)	Graphic Log	Strata	Material Description	Remarks
50	SS	S-11	24	15 27 61 71	19				Wet, very dense, light brown, fine to coarse SAND, some fine gravel, trace silt	
55	SS	S-12	24	15 31 41 56	9				Wet, very dense, light brown, fine to coarse SAND, some fine gravel, trace silt	
60	SS	S-13	24	13 15 16 17	17				Wet, dense, light brown, fine to medium SAND, little silt	
65	SS	S-14	24	12 14 15 14	19				Wet, medium dense, light brown, fine to medium SAND, little silt	
70	SS	S-15	24	21 32 36 41	16				Wet, very dense, light brown, fine SAND, little silt, trace fine gravel	

BL HARWICH BORING LOGS.GPJ - 8/24/11

CAMP DRESSER & McKEE

CDM

Boring Number: CDM-7

Client: Town of Harwich
Project Location: Harwich, Massachusetts
Project Name: Hydrogeology Evaluation
Project Number: 0324-60650

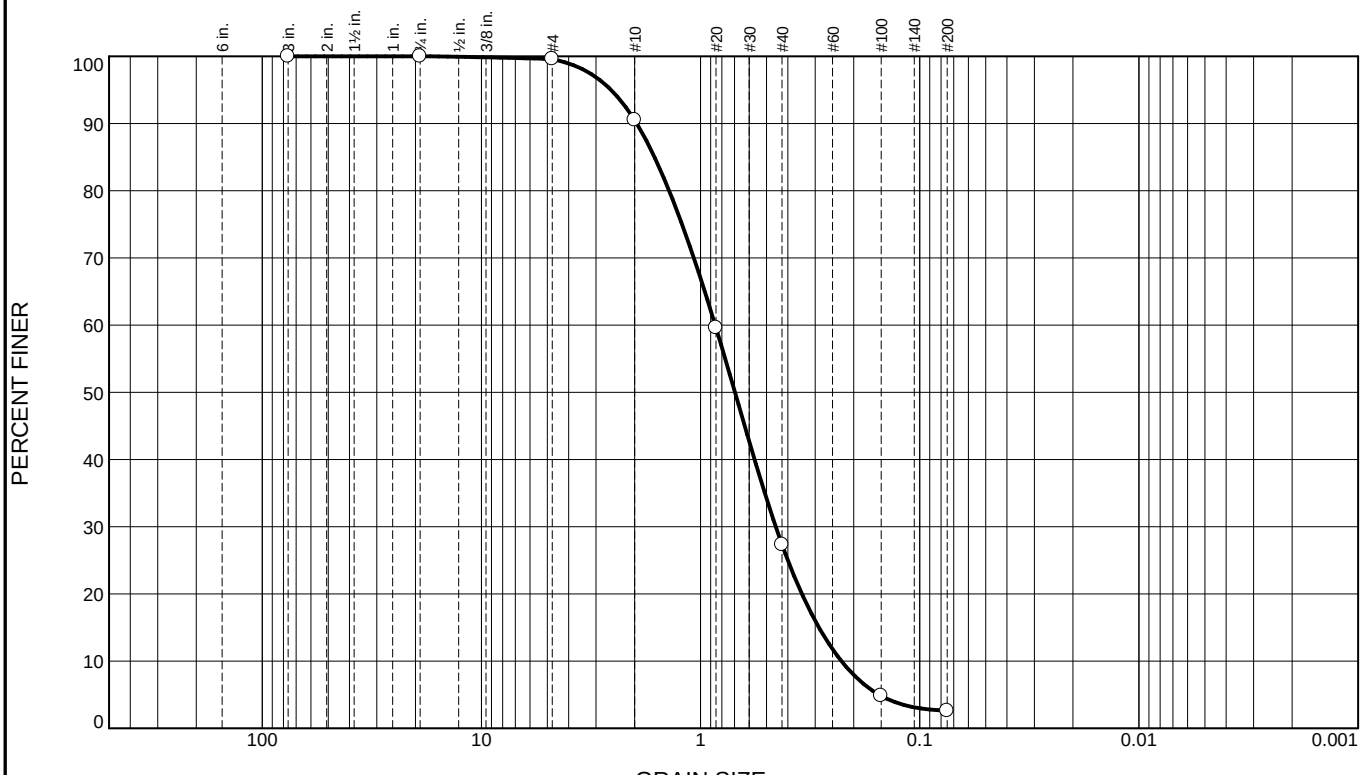
Elev. Depth (ft)	Sample Type	Sample Number	Sample Length (in)	Blows per 6 inches	Sample Recovery (in)	Split Spoon Size (O.D.)	Graphic Log	Strata	Material Description	Remarks
75	SS	S-16	24	22 31 41 40	24				Wet, very dense, light brown, fine SAND, little silt, trace fine gravel	
80	SS	S-17	24	9 12 15 21	24				Wet, very stiff, gray CLAY	
									END OF BORING = 81.0'	
85										
90										
95										
100										

BL HARWICH BORING LOGS.GPJ - 8/24/11

Hydrogeological Report

Appendix B

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.4	9.1	63.2	24.7	2.6	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3	100.0		
3/4	100.0		
#4	99.6		
#10	90.5		
#20	59.6		
#40	27.3		
#100	4.8		
#200	2.6		

* (no specification provided)

Material Description

poorly graded sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 1.9564 D_{85}= 1.6230 D_{60}= 0.8576
D_{50}= 0.6969 D_{30}= 0.4541 D_{15}= 0.2885
D_{10}= 0.2278 C_u= 3.76 C_c= 1.06

Classification

USCS= SP AASHTO=

Remarks

As received moisture content = 15.0%

Source of Sample: CDM-2 **Depth:** 8-10
Sample Number: S-5 **Date:** 8/3/2011

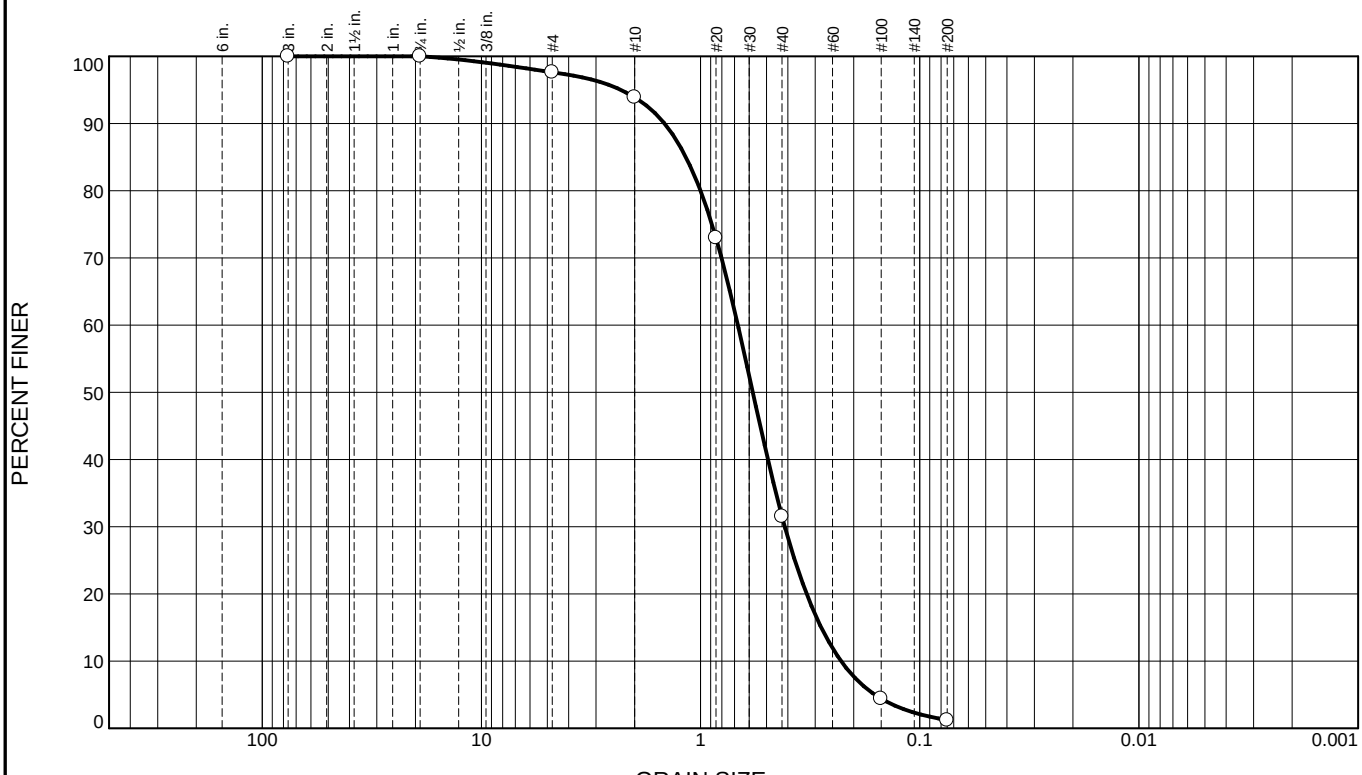
CDM

Cambridge, Massachusetts

Client: Town of Harwich
Project: Hydrogeology Evaluation
Project No: 324-60650 **Figure**

Tested By: MR

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	2.4	3.7	62.4	30.3	1.2	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3	100.0		
3/4	100.0		
#4	97.6		
#10	93.9		
#20	73.0		
#40	31.5		
#100	4.4		
#200	1.2		

* (no specification provided)

Material Description

poorly graded sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 1.4606 D_{85}= 1.1668 D_{60}= 0.6763
D_{50}= 0.5778 D_{30}= 0.4129 D_{15}= 0.2816
D_{10}= 0.2286 C_u= 2.96 C_c= 1.10

Classification

USCS= SP AASHTO=

Remarks

As received moisture content = 3.6%

Source of Sample: CDM-3 **Depth:** 12-14
Sample Number: S-7 **Date:** 8/4/2011

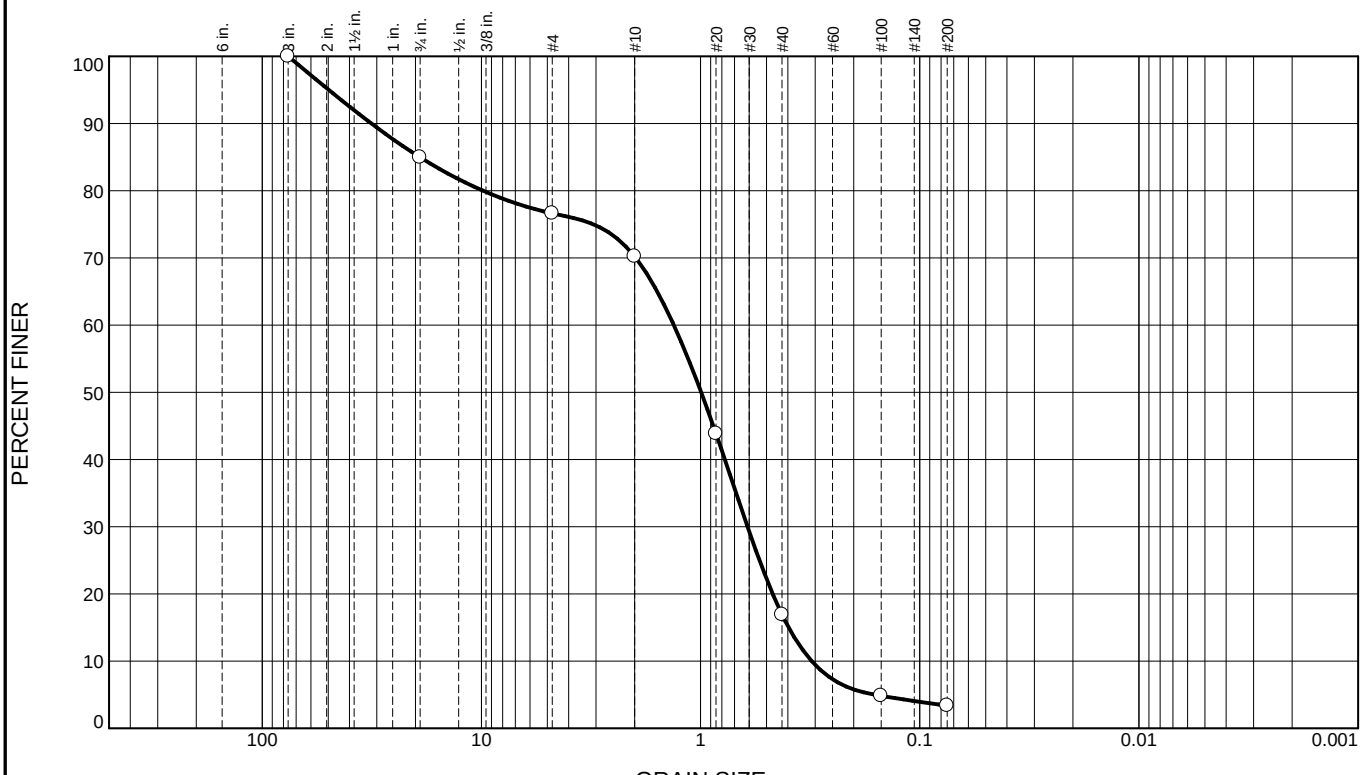
CDM

Cambridge, Massachusetts

Client: Town of Harwich
Project: Hydrogeology Evaluation
Project No: 324-60650 **Figure**

Tested By: MR

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	15.0	8.4	6.4	53.3	13.5	3.4	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3	100.0		
3/4	85.0		
#4	76.6		
#10	70.2		
#20	43.8		
#40	16.9		
#100	4.8		
#200	3.4		

* (no specification provided)

Material Description

poorly graded sand with gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 31.7679 D_{85}= 19.1238 D_{60}= 1.3247
D_{50}= 0.9936 D_{30}= 0.6106 D_{15}= 0.3966
D_{10}= 0.3112 C_u= 4.26 C_c= 0.90

Classification

USCS= SP AASHTO=

Remarks

As received moisture content = 3.1%

Source of Sample: CDM-5 **Depth:** 4-6
Sample Number: S-3 **Date:** 8/9/2011

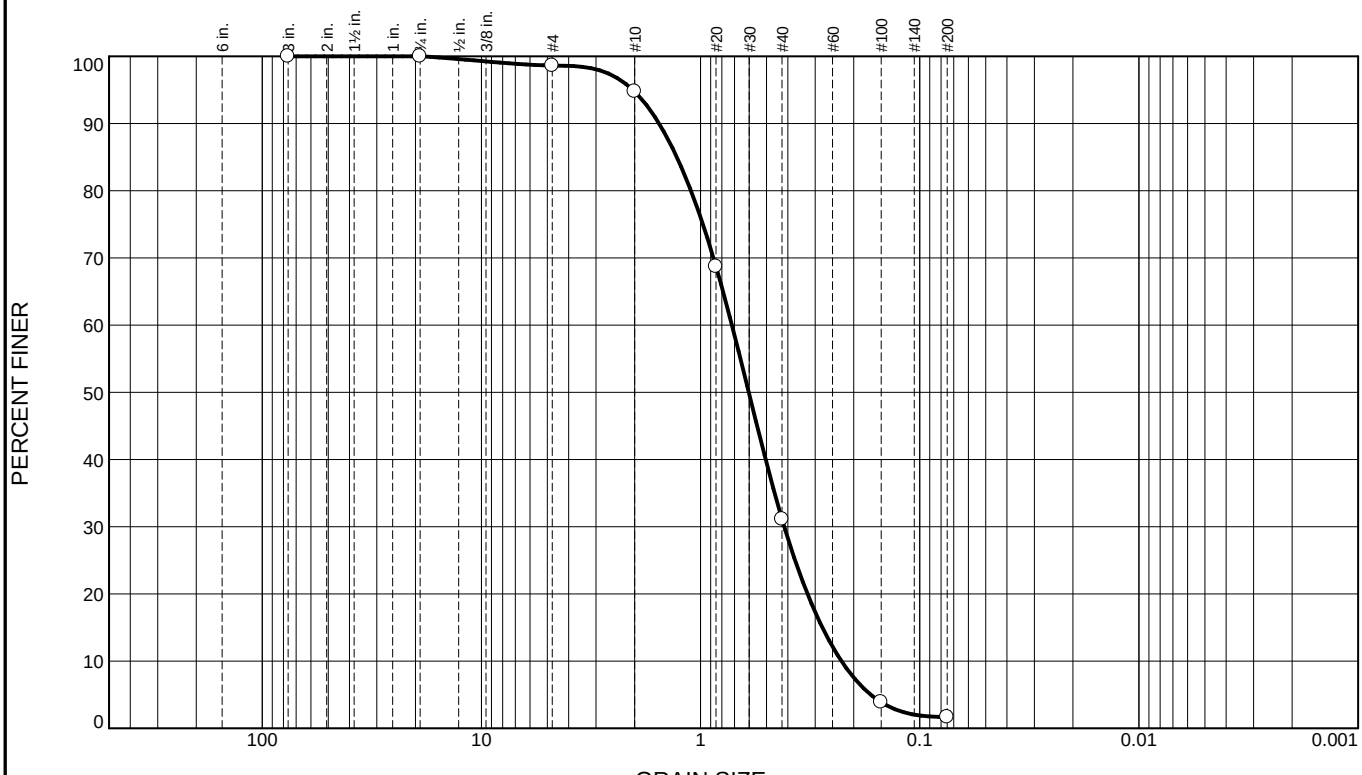
CDM

Cambridge, Massachusetts

Client: Town of Harwich
Project: Hydrogeology Evaluation
Project No: 324-60650 **Figure**

Tested By: MR

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	1.4	3.9	63.6	29.4	1.7	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3	100.0		
3/4	100.0		
#4	98.6		
#10	94.7		
#20	68.7		
#40	31.1		
#100	3.9		
#200	1.7		

* (no specification provided)

Material Description

poorly graded sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 1.5466 D_{85}= 1.2835 D_{60}= 0.7198
D_{50}= 0.6029 D_{30}= 0.4152 D_{15}= 0.2783
D_{10}= 0.2277 C_u= 3.16 C_c= 1.05

Classification

USCS= SP AASHTO=

Remarks

As received moisture content = 2.3%

Source of Sample: CDM-6 **Depth:** 6-8
Sample Number: S-4 **Date:** 8/10/2011

CDM

Cambridge, Massachusetts

Client: Town of Harwich
Project: Hydrogeology Evaluation
Project No: 324-60650 **Figure**

Tested By: MR

Hydrogeological Report

Appendix C

Town of Harwich
Harwich, MA
Hidrogeology Evaluation

Table 1
Infiltration Test - Summary of Results

Exploration No.	Depth (ft)	Strata	USDA Classification	Peak Infiltration Velocity -Inner Ring (gpm)	Peak Infiltration Rate -Inner Ring (gpd/sf)	Design Loading Rates Based on Infiltration Rate (gpd/sf)[2]	
						2%	4%
DRI-1	3	Sand	C	0.100	180.57	3.61	7.22
DRI-2[1]	3	Sand	C	-	-	-	-
DRI-3[1]	3	Sand	C	-	-	-	-

Notes

1-At Locations DRI-2 and 3, Infiltration Velocity was too high and test could not be performed. Infiltration Velocity was estimated in the field to be 1-3gal/min

2-USEPA, "EPA 625/1-81-013 - Process Design Manual for Land Treatment of Municipal Wastewater", USEPA Center of Environmental Research Information, Cincinnati-OH, 1981; USEPA, "EPA 625 R00 008 Onsite Wastewater Treatment System Manual", USEPA Center of Environmental Research Information, Cincinnati-OH, 2000;

DRIT-1

Project:
Test Location: Harwich, MA
Liquid Used: Water
Tested By: Dan Nyanjom; Max Rolandi
Depth to Water Table: Not Encounter

Constants:	**Area (cm^2)**	**Area (ft^2)**
Inner Ring	740	0.7992
Annular Space	2219	2.39652

Penetration of Ring (in): 6 (Inner), 10 (Annular)

Trial Number		Time	Elapsed Time (min.)	Water Level (in)		Change in Water Level (in)		Infiltration Velocity(cm/hr)		Infiltration Velocity(gpm)		Infiltration Rate (gpd/sf)	
				Inner Ring	Annular Space	Inner Ring	Annular Space	Inner Ring	Annular Space	Inner Ring	Annular Space	Inner Ring	Annular Space
1	Start	9:55		0.00	0.00								
	End	10:10	15.0	3.00	4.00	3.00	4.00	30.48	40.64	0.1002	0.1336	180.57	240.76
2	Start	10:11		0.00	0.00								
	End	10:26	30.0	2.25	4.00	2.25	4.00	22.86	40.64	0.0752	0.1336	135.43	240.76
3	Start	10:27		0.00	0.00								
	End	10:42	45.0	2.25	4.00	2.25	4.00	22.86	40.64	0.0752	0.1336	135.43	240.76
4	End	10:43		0.00	0.00								
	Start	10:58	60.0	2.00	4.00	2.00	4.00	20.32	40.64	0.0668	0.1336	120.38	240.76
5	End	11:00		0.00	0.00								
	Start	11:15	75.0	2.00	4.00	2.00	4.00	20.32	40.64	0.0668	0.1336	120.38	240.76
6	Start	11:16		0.00	0.00								
	End	11:31	90.0	1.75	3.50	1.75	3.50	17.78	35.56	0.0585	0.1169	105.33	210.66
7	Start	11:32		0.00	0.00								
	End	11:47	105.0	1.75	3.00	1.75	3.00	17.78	30.48	0.0585	0.1002	105.33	180.57
8	Start	11:48		0.00	0.00								
	End	12:03	120.0	1.75	3.50	1.75	3.50	17.78	35.56	0.0585	0.1169	105.33	210.66

Notes:

1- A 5 ft wide trench was excavated to remove topsoil. Test was performed at approximately 4 ft of depth, in the Harwich outwash plain deposit; inner and outer ring were pushed 6 to 10 inches into the Harwich outwash plain deposit. Water level in inner ring and annular space were maintained manually

DRIT-2

Project:
Test Location: Harwich, MA
Liquid Used: Water
Tested By: Dan Nyanjom; Max Rolandi
Depth to Water Table: Not Encounter

Constants:	**Area (cm^2)**	**Area (ft^2)**
Inner Ring	740	0.7992
Annular Space	2219	2.39652

Penetration of Ring (in): 6 (Inner), 10 (Annular)

Trial Number		Time	Elapsed Time (min.)	Water Level (in)		Change in Water Level (in)		Infiltration Rate (cm/hr)		Infiltration Velocity(gpm)(2)	Infiltration Rate (gpd/sf)	
				Inner Ring	Annular Space	Inner Ring	Annular Space	Inner Ring	Annular Space		Inner Ring	Annular Space
1			2.0							1.5		
2			2.0							2.5		

Notes:

1- A 5 ft wide trench was excavated to remove topsoil. Test was performed at approximately 4 ft of depth, in the Harwich outwash plain deposit; inner and outer ring were pushed 6 to 10 inches into the Harwich outwash plain deposit. Water level in inner ring and annular space were maintained manually

2 - Infiltration Velocity was too high and test could not be performed. Approximate reedings of change in volume in water tank over time were taken in the field; Infiltration Velocity was estimated in the field to be 1-3gal/min - Test duration was approximately 2 hours.

DRIT-3

Project:
Test Location: Harwich, MA
Liquid Used: Water
Tested By: Dan Nyanjom; Max Rolandi
Depth to Water Table: Not Encounter

Constants:	**Area (cm^2)**	**Area (ft^2)**
Inner Ring	740	0.7992
Annular Space	2219	2.39652

Penetration of Ring (in): 6 (Inner)
10 (Annular)

Trial Number		Time	Elapsed Time (min.)	Water Level (in)		Change in Water Level (in)		Infiltration Rate (cm/hr)		Infiltration Velocity(gpm)(2)	Infiltration Rate (gpd/sf)	
				Inner Ring	Annular Space	Inner Ring	Annular Space	Inner Ring	Annular Space		Inner Ring	Annular Space
1			2.0							1.5		
2			2.0							3.0		

Notes:
1- A 5 ft wide trench was excavated to remove topsoil. Test was performed at approximately 4 ft of depth, in the Harwich outwash plain deposit; inner and outer ring were pushed 6 to 10 inches into the Harwich outwash plain deposit. Water level in inner ring and annular space were maintained manually
2 - Infiltration Velocity was too high and test could not be performed. Approximate reedings of change in volume in water tank over time were taken in the field; Infiltration Velocity was estimated in the field to be 1-3gal/min - Test duration was approximately 1.5 hours.

NOTES:

1. BORING LOCATIONS AND PATHS ARE ESTIMATED. IT IS PLANNED TO SURVEY THE SITE'S EXISTING FEATURES AND BORING LOCATIONS AT A LATER DATE.

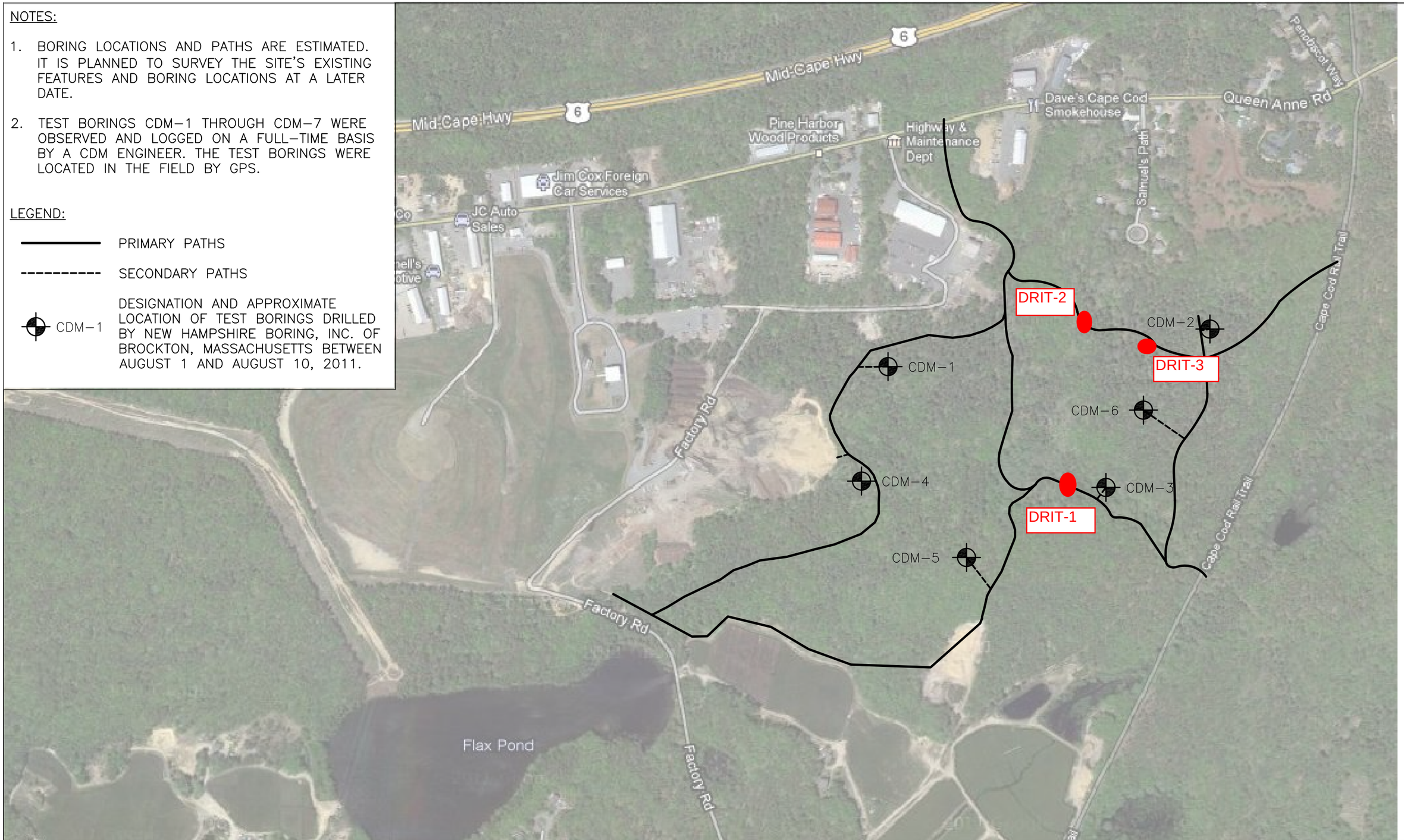
2. TEST BORINGS CDM–1 THROUGH CDM–7 WERE OBSERVED AND LOGGED ON A FULL–TIME BASIS BY A CDM ENGINEER. THE TEST BORINGS WERE LOCATED IN THE FIELD BY GPS.

LEGEND:

PRIMARY PATHS

SECONDARY PATHS

CDM–1 DESIGNATION AND APPROXIMATE LOCATION OF TEST BORINGS DRILLED BY NEW HAMPSHIRE BORING, INC. OF BROCKTON, MASSACHUSETTS BETWEEN AUGUST 1 AND AUGUST 10, 2011.



CDM
consulting • engineering • construction • operations

TOWN OF HARWICH
HARWICH, MASSACHUSETTS
HYDROGEOLOGY EVALUATION

BORING LOCATION PLAN
SITE HR–12

FIGURE 1

Commonwealth of Massachusetts
City/Town of

Form 11 - Soil Suitability Assessment for On-Site Sewage Disposal

A. Facility Information

HIGHWAY AND MAINTENANCE DPT. - TOWN OF HARWICH
Owner Name

273 QUEEN ANN ROAD
Street Address

Map/Lot #

HARWICH
City

MA
State

02645
Zip Code

B. Site Information

1. (Check one) ☒ New Construction ☐ Upgrade ☐ Repair

2. Published Soil Survey Available? ☒ Yes ☐ No If yes: 1969 (Year Published) 1:24000 (Publication Scale) 6Q-786 (Soil Map Unit)

   HARWICH OUTWASH PLAIN DEPOSIT
   Soil Name

   Soil Limitations

3. Surficial Geological Report Available? ☐ Yes ☒ No If yes: Year Published / Publication Scale / Map Unit

   Geologic Material

   Landform

4. Flood Rate Insurance Map

   Above the 500-year flood boundary? ☒ Yes ☐ No Within the 100-year flood boundary? ☐ Yes ☒ No

   Within the 500-year flood boundary? ☐ Yes ☒ No Within a velocity zone? ☐ Yes ☐ No

5. Wetland Area: National Wetland Inventory Map — Map Unit: — Name: —

   Wetlands Conservancy Program Map — Map Unit: — Name: —

6. Current Water Resource Conditions (USGS): 11/2011 (Month/Year) Range: ☐ Above Normal ☐ Normal ☐ Below Normal NOT RANKED

7. Other references reviewed: BORING TEST LOGS FROM HWH Inc. (1990) AND FROM CDM (2011)

Commonwealth of Massachusetts
City/Town of
Form 11 - Soil Suitability Assessment for On-Site Sewage Disposal

C. On-Site Review (*minimum of two holes required at every proposed primary and reserved disposal area*)

Deep Observation Hole Number: 1 | Date: 11/10/2011 | Time: 9.30 | Weather: SUNNY / DRY

1. Location

Ground Elevation at Surface of Hole: / Location (identify on plan): DRIT-1

2. Land Use: WOODLAND (e.g., woodland, agricultural field, vacant lot, etc.) | Surface Stones: NOT PRESENT | Slope (%): 0%

Vegetation: ABUNDANT | Landform: HILL | Position on Landscape (attach sheet):

3. Distances from:

Open Water Body	3000 feet	Drainage Way	100 feet	Possible Wet Area	/ feet
Property Line	/ feet	Drinking Water Well	/ feet	Other	/ feet

4. Parent Material: SANDWICH MARINE DEPOSIT | Unsuitable Materials Present: ☐ Yes ☒ No

If Yes: ☐ Disturbed Soil ☐ Fill Material ☐ Impervious Layer(s) ☐ Weathered/Fractured Rock ☐ Bedrock

5. Groundwater Observed: ☐ Yes ☒ No | If yes: Depth Weeping from Pit | Depth Standing Water in Hole

Estimated Depth to High Groundwater: / inches / elevation

Commonwealth of Massachusetts
City/Town of
Form 11 - Soil Suitability Assessment for On-Site Sewage Disposal

C. On-Site Review (continued)

Deep Observation Hole Number: 1

Depth (in.)	Soil Horizon/ Layer	Soil Matrix: Color-Moist (Munsell)	Redoximorphic Features (mottles)			Soil Texture (USDA)	Coarse Fragments % by Volume		Soil Structure	Soil Consistence (Moist)	Other
			Depth	Color	Percent		Gravel	Cobbles & Stones			
12	(A) TOPSOIL					MEDIUM					
36	(C) SAND	LOOSE; RED/ BROWN	30"	RED	< 5%	FINE	0%	0%	LOOSE SAND/ ROUNDED GRAINS	LOOSE	/

Additional Notes:

Commonwealth of Massachusetts
City/Town of
Form 11 - Soil Suitability Assessment for On-Site Sewage Disposal

C. On-Site Review (continued)

Deep Observation Hole Number: 2 | Date: 11/10/2011 | Time: 12.30 | Weather: SUNNY/DRY

1. Location

Ground Elevation at Surface of Hole: / Location (identify on plan): D.R.I.T.-2

2. Land Use: WOODLAND (e.g., woodland, agricultural field, vacant lot, etc.) | Surface Stones: NOT PRESENT | Slope (%): 1-3%

Vegetation: WOODED AREA | Landform: HILL | Position on Landscape (attach sheet):

3. Distances from:

Open Water Body	3000 feet	Drainage Way	10 feet	Possible Wet Area	/ feet
Property Line	/ feet	Drinking Water Well	/ feet	Other	/ feet

4. Parent Material: SANDWICH MARINE DEPOSIT Unsuitable Materials Present: ☐ Yes ☒ No

If Yes: ☐ Disturbed Soil ☐ Fill Material ☐ Impervious Layer(s) ☐ Weathered/Fractured Rock ☐ Bedrock

5. Groundwater Observed: ☐ Yes ☒ No If yes: Depth Weeping from Pit | Depth Standing Water in Hole

Estimated Depth to High Groundwater: / inches / elevation

Commonwealth of Massachusetts
City/Town of
Form 11 - Soil Suitability Assessment for On-Site Sewage Disposal

C. On-Site Review (continued)

Deep Observation Hole Number: 2

Depth (in.)	Soil Horizon/ Layer	Soil Matrix: Color-Moist (Munsell)	Redoximorphic Features (mottles)			Soil Texture (USDA)	Coarse Fragments % by Volume		Soil Structure	Soil Consistence (Moist)	Other
			Depth	Color	Percent		Gravel	Cobbles & Stones			
12	(A) TOPSOIL					FINE					
40	(C) SAND	LOOSE; RED/ BROWN				FINE	0%	0%	LOOSE SAND ROUND GRAIN	LOOSE	—

Additional Notes:

TEST WAS NOT CONDUCTED AT THIS LOCATION DUE TO HIGH WATER INFILTRATION RATE (1-3 gal/MIN)

Commonwealth of Massachusetts
City/Town of
Form 11 - Soil Suitability Assessment for On-Site Sewage Disposal

C. On-Site Review (*minimum of two holes required at every proposed primary and reserved disposal area)*

Deep Observation Hole Number: 3 | Date: 11/10/2011 | Time: 15.00 | Weather: SUNNY / DRY

1. Location

Ground Elevation at Surface of Hole: / Location (identify on plan): D.R.I.T. 3

2. Land Use: WOODLAND (e.g., woodland, agricultural field, vacant lot, etc.) | Surface Stones: NOT PRESENT | Slope (%): 1-3 %

Vegetation: WOODED AREA | Landform: HILL | Position on Landscape (attach sheet)

3. Distances from:

Open Water Body	3000 feet	Drainage Way	10 feet	Possible Wet Area	/ feet
Property Line	– feet	Drinking Water Well	– feet	Other	/ feet

4. Parent Material: SANDWICH MARINE DEPOSIT | Unsuitable Materials Present: ☐ Yes ☒ No

If Yes: ☐ Disturbed Soil ☐ Fill Material ☐ Impervious Layer(s) ☐ Weathered/Fractured Rock ☐ Bedrock

5. Groundwater Observed: ☐ Yes ☐ No | If yes: Depth Weeping from Pit | Depth Standing Water in Hole

Estimated Depth to High Groundwater: / inches | – elevation

Commonwealth of Massachusetts
City/Town of

Form 11 - Soil Suitability Assessment for On-Site Sewage Disposal

C. On-Site Review (continued)

Deep Observation Hole Number: 3

Depth (in.)	Soil Horizon/ Layer	Soil Matrix: Color-Moist (Munsell)	Redoximorphic Features (mottles)			Soil Texture (USDA)	Coarse Fragments % by Volume		Soil Structure	Soil Consistence (Moist)	Other
			Depth	Color	Percent		Gravel	Cobbles & Stones			
12	(A) TOPSOIL					FINE					
40	(C) SAND	LOOSE; RED/ BROWN				MEDIUM	0%	0%	LOOSE SAND; ROUND GRAIN	LOOSE	✓

Additional Notes:

SEE NOTE - TEST 2

Commonwealth of Massachusetts
City/Town of

Form 11 - Soil Suitability Assessment for On-Site Sewage Disposal

D. Determination of High Groundwater Elevation

1. Method Used:

☐ Depth observed standing water in observation hole	A. _____ inches	B. _____ inches
☐ Depth weeping from side of observation hole	A. _____ inches	B. _____ inches
☐ Depth to soil redoximorphic features (mottles)	A. _____ inches	B. _____ inches
☐ Groundwater adjustment (USGS methodology)	A. _____ inches	B. _____ inches

2. _____ Index Well Number _____ Reading Date _____ Index Well Level

_____ Adjustment Factor _____ Adjusted Groundwater Level

E. Depth of Pervious Material

1. Depth of Naturally Occurring Pervious Material
   a. Does at least four feet of naturally occurring pervious material exist in all areas observed throughout the area proposed for the soil absorption system?

      ☐ Yes ☐ No

   b. If yes, at what depth was it observed? Upper boundary: _____ inches Lower boundary: _____ inches

Commonwealth of Massachusetts
City/Town of

Form 11 - Soil Suitability Assessment for On-Site Sewage Disposal

F. Certification

I certify that I am currently approved by the Department of Environmental Protection pursuant to 310 CMR 15.017 to conduct soil evaluations and that the above analysis has been performed by me consistent with the required training, expertise and experience described in 310 CMR 15.017. I further certify that the results of my soil evaluation, as indicated in the attached Soil Evaluation Form, are accurate and in accordance with 310 CMR 15.100 through 15.107.

Signature of Soil Evaluator	Date
Typed or Printed Name of Soil Evaluator / License #	Date of Soil Evaluator Exam
Name of Board of Health Witness	Board of Health

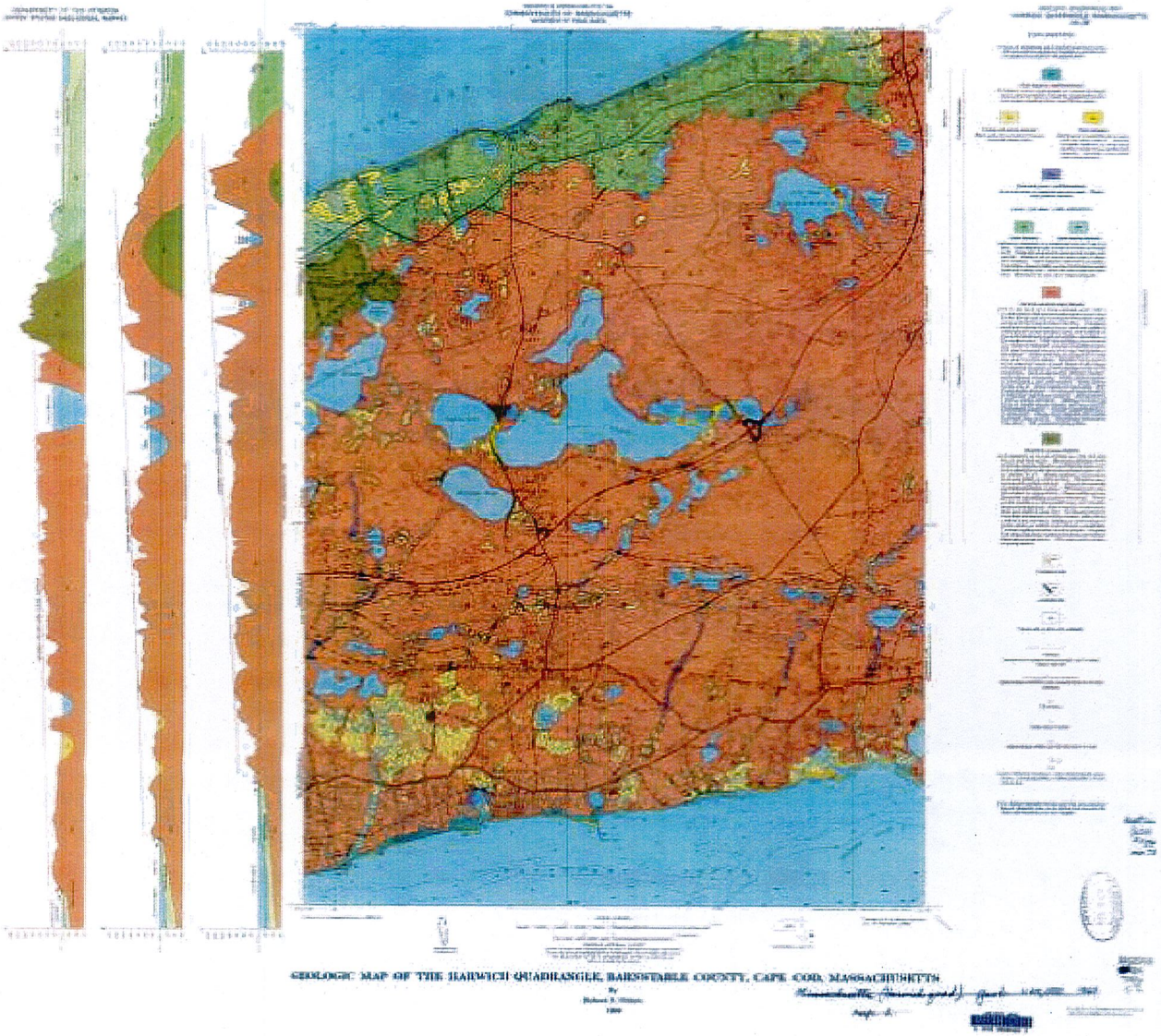
Note: In accordance with 310 CMR 15.018(2) this form must be submitted to the approving authority within 60 days of the date of field testing, and to the designer and the property owner with Percolation Test Form 12.

Commonwealth of Massachusetts
City/Town of

Form 11 - Soil Suitability Assessment for On-Site Sewage Disposal

Field Diagrams

Use this sheet for field diagrams:



GEOLOGIC MAP OF THE HARWICH QUADRANGLE, BARNSTABLE COUNTY, CAPE COD, MASSACHUSETTS

By

Qhw

Harwich outwash plain deposits

Drift in the form of a large outwash plain with a graded surface that slopes gently south toward Nantucket Sound and an ice-contact head that slopes steeply north toward Cape Cod Bay. Composed mostly of medium to very coarse sand and pebble to cobble gravel in the northern part, and medium to fine sand containing scattered pebbles and cobbles in the southern part. Till, and boulders up to several tens of feet in diameter common in northern part. Till most commonly occurs at or near the surface of the deposit. Lenses and beds of clayey silt or silty clay occur in some places. Boulders up to several feet in diameter occur in some places in the clayey silt deposits exposed in the southwest part of the quadrangle. Sand mostly quartz; feldspar and glauconite common accessories. Grains mostly angular to subrounded, a few well rounded. Stones mostly granite (fig. 2). Stones angular to subrounded. Beds mostly gently dipping. In collapsed deposits gentle to steep dips and normal faulting. Beds generally a foot to several feet thick. Bedding in sand and gravel is mostly planar, tabular and scour and fill crossbedding common. Current rippled beds occur in some places. Clayey silt or silty clay beds mostly laminated, some massive. Laminations deformed in some places. Till massive to poorly bedded

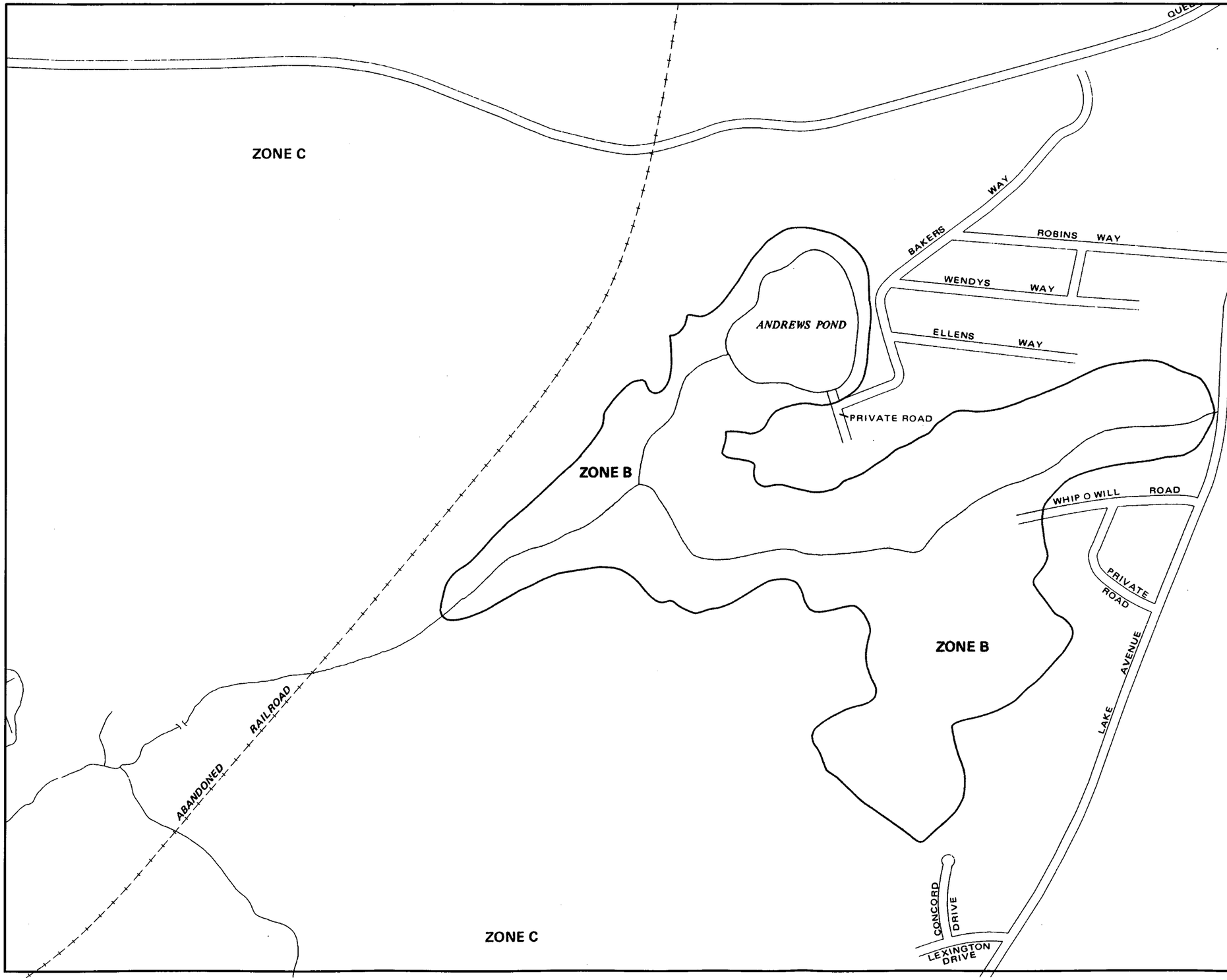
Qsm

Sandwich moraine deposits

Drift deposited as an end moraine by Cape Cod Bay lobe ice and melt water. Maximum altitudes on the sandwich moraine deposits are distinctly above maximum altitudes on the Harwich outwash plain nearby (Section A-A'). Mostly medium to very coarse sand and pebble to cobble gravel. Boulders up to several tens of feet common. Clayey silt and silty sand beds and lenses common. Till occurs at or near the surface in many places. Sand mostly quartz; glauconite and feldspar common accessories. Grains mostly angular to subrounded, some well rounded. Stones mostly granites. Stones angular to subrounded. Beds have gentle to steep dips. In collapsed deposits steep dips and normal faulting common. Beds mostly a foot to a few feet thick. Bedding in sand and gravel mostly planar or tabular and lenticular crossbedded. Current ripples common in some places. Clay silt and silty sand beds mostly laminated, laminations deformed in some places. Till ranges from massive to poorly bedded

*EXPLANATION OF ZONE DESIGNATIONS

ZONE	EXPLANATION
A	Areas of 100-year flood; base flood elevations and flood hazard factors not determined.
A0	Areas of 100-year shallow flooding where depths are between one (1) and three (3) feet; average depths of inundation are shown, but no flood hazard factors are determined.
AH	Areas of 100-year shallow flooding where depths are between one (1) and three (3) feet; base flood elevations are shown, but no flood hazard factors are determined.
A1-A30	Areas of 100-year flood; base flood elevations and flood hazard factors determined.
A99	Areas of 100-year flood to be protected by flood protection system under construction; base flood elevations and flood hazard factors not determined.
B	Areas between limits of the 100-year flood and 500-year flood; or certain areas subject to 100-year flooding with average depths less than one (1) foot or where the contributing drainage area is less than one square mile; or areas protected by levees from the base flood. (Medium shading)
C	Areas of minimal flooding. (No shading)
D	Areas of undetermined, but possible, flood hazards.
V	Areas of 100-year coastal flood with velocity (wave action); base flood elevations and flood hazard factors not determined.
V1-V30	Areas of 100-year coastal flood with velocity (wave action); base flood elevations and flood hazard factors determined.



APPROXIMATE SCALE

400 0 400 FEI

NATIONAL FLOOD INSURANCE PROGRAM

FIRM
FLOOD INSURANCE RATE MAP

TOWN OF
HARWICH,
MASSACHUSETTS
BARNSTABLE COUNTY

PANEL 6 OF 11
(SEE MAP INDEX FOR PANELS NOT PRINTED)

COMMUNITY-PANEL NUMBER
250008 0006 B

EFFECTIVE DATE:
SEPTEMBER 30, 1980

U.S. DEPARTMENT OF HOUSING
AND URBAN DEVELOPMENT
FEDERAL INSURANCE ADMINISTRATION

This is an official copy of a portion of the above referenced flood map. It was extracted using F-MIT On-Line. This map does not reflect changes or amendments which may have been made subsequent to the date on the title block. For the latest product information about National Flood Insurance Program flood maps check the FEMA Flood Map Store at www.msc.fema.gov

Hydrogeological Report

Appendix D

	CDM ID	**CDM-5-11-11-16**	**CDM-3-11-11-16**	**FB-11-11-16**	Trip Blank
	Lab ID	1165744-01	1165744-02	1165744-03	1165744-04
	Date	11/16/2011	11/16/2011	11/17/2011	11/16/2011
VOCs					
Chloroform	ug/L	1.4	4.8	4.6	ND
Test Parameters					
Surfactants	mg/L	--	--	--	NA
Chlorides	mg/L	12	14	14	NA
Fluoride	mg/L	--	--	--	NA
Nitrate as Nitrogen	mg/L	--	--	--	NA
Sulfate	mg/L	4.1	4.5	4.2	NA
Nitrite as Nitrogen	mg/L	--	--	--	NA
Nitrogen, total	mg/L	--	--	--	NA
Phosphorus, total	mg/L	--	0.11	0.067	NA
TKN	mg/L	--	--	--	NA
Total Dissolved Solids	mg/L	34	37	36	NA
Metals - Total					
Arsenic	mg/L	--	--	--	NA
Barium	mg/L	0.02	0.02	0.02	NA
Cadmium	mg/L	--	--	--	NA
Chromium	mg/L	--	--	--	NA
Copper	mg/L	--	--	--	NA
Iron	mg/L	0.02	0.4	0.048	NA
Lead	mg/L	--	--	--	NA
Manganese	mg/L	0.039	0.074	0.074	NA
Mercury	mg/L	--	--	--	NA
Selenium	mg/L	--	--	--	NA
Silver	mg/L	--	--	--	NA
Sodium	mg/L	7.2	9.3	10	NA
Zinc	mg/L	0.005	0.009	0.01	NA
Metals - Dissolved					
Arsenic	mg/L	--	--	--	NA
Barium	mg/L	0.02	0.011	0.012	NA
Cadmium	mg/L	--	--	--	NA
Chromium	mg/L	--	--	--	NA
Copper	mg/L	--	--	--	NA
Iron	mg/L	--	--	--	NA
Lead	mg/L	--	--	--	NA
Manganese	mg/L	0.032	0.042	0.042	NA
Mercury	mg/L	--	--	--	NA
Selenium	mg/L	--	--	--	NA
Silver	mg/L	--	--	--	NA
Sodium	mg/L	8.1	9.6	7.3	NA
Zinc	mg/L	--	--	--	NA

NA - Not Analyzed
-- Non-detect

Hydrogeological Report

Appendix E

Appendix E

Visits with Cranberry Bog Owners Downgradient from Effluent Recharge Site HR-12

January 27, 2012

Visits conducted by Heinz Proft, Harwich; and Dave Young and Bob Schreiber, CDM Smith.

Following notes summarized by Bob Schreiber

Site Visit No. 1 – Bogs Owned by Leo Cakounes

1. He has plans with elevations of the flow control structure he installed a few years ago on the shore of Flax Pond. He will provide a copy of what he can find.

2. He can control the Flax Pond water level with the flow control structure

3. He reported that Wayne Coulson (bog owner to east of Flax Pond) brings water to his bogs by damming Coy Brook to fill from it.

4. He reported Wayne Coulson has his own flow and thus does not depend on Flax Pond.

5. He reported Mr. Sarkes (bog owner adjacent to eastern edge of Flax Pond) pumps from Flax Pond for his water source, and does not put it back into the pond, rather the flow then goes through ditches/into Coy Brook.

6. Mr. Cakounes' bogs are approximately 1.0 to 1.5 feet higher than Flax Pond, and thus he sometimes pumps water up to that elevation from Flax Pond. In addition, he can put water back into the pond. He estimates that about 70% is put back into the pond and 30% flow out and away/downstream. He puts the flow back into the pond by pulling boards on the structure at the west end of the pond where his pumping system is located.

7. He reported his flow structure can drop Flax Pond 8 to 9 inches in a few hours, and 2 feet within 24 hours.

8. During the summertime, in general and during typical seasonal conditions, Flax Pond is lower than the water level in his bogs. During flood conditions (in the springtime?), the pond may have water levels close to or higher than in the bogs. If the pond's water level gets too high, he can lower the water level

9. Having the Flax Pond water level rise by one foot is better than going down. For instance: To design the pumping system at his Flax Pond pumping/ flow control structure, Mr. Cakounes had to select a minimum Flax Pond water level. Thus, a higher Flax Pond water level would be a benefit to him.

10. Mr. Cakounes can provide us with the maximum Flax Pond water level that he has witnessed. He estimates it to be approximately 14 to 16 inches below the top of the pumping inlet structure (metal).

11. A sand bar separates the eastern small lobe of Flax Pond from the western, much larger lobe. The eastern lobe has gone dry at times (also see comment 15).

12. If Flax Pond rises during higher recharge times, the area southeast (SE) from Mr. Cakounes' property gets wet (some surface ponding and general wetness due to high water table). When this happens, he works with Linc Thacher to move the water down along the water course south of their properties. Mr. Cakounes' southern bog will experience a water level rise in this situation, also; but, his northeast (NE) bog doesn't rise. He believes that there is probably seepage/leakage occurring along a short shoreline stretch in the SW (7:30 o'clock) position of Flax Pond's footprint. The residential homes to the south and S/SW of Flax Pond are up on much higher ground and thus their basements do not flood.

13. In regard to high water levels in Flax Pond and associated impacts, Mr. Cakounes upon questioning indicated that he would be willing to try running an "experiment" in which he would use the hydraulic controls on his property (and perhaps any that his neighbor and fellow bog-owner, Linc Thacher, may be willing to modify as well in cooperation).

14. Regarding water use, Mr. Cakounes noted the following "water use months" in typical years: September, January, and May. September's use is via withdrawal for irrigation purposes.

15. Back on the subject of the Flax Pond sand bar, Mr. Cakounes indicated that he believes that someone probably broke through the sand bar, to ensure that the pond's stored water would extend into the eastern small lobe, while also providing sufficient flow area for pulling in pond water stored in the bigger western/main lobe.

16. Mr. Cakounes indicated that he has probably seen the eastern lobe's sand bar exposed only 2 times in the last 11 years.

17. Mr. Cakounes also indicated that Flax Pond varies by about 2 to 3 feet during the year.

18. When asked about the presence of a shallow clay unit, Mr. Cakounes stated that there was clay found at his bog system's culvert (southern) outlet when the bog was created back in the 1900s.

19. Mr. Cakounes said that the Crapo Family owned the property back in the 1880s, and agricultural operation of the bog(s) was conducted by that family.

20. Mr. Cakounes indicated he would make copies of his design drawings and pumping records available.

21. Mr. Cakounes indicated that the USDA/NRCS (Natural Resource Conservation Service, formerly the SCS, or Soil Conservation Service) set the vertical survey datum. He believes the datum system utilized is noted on his drawings. According to Mr. Cakounes, Mr. Sarkes has complained about Flax Pond being too low; therefore, it would be better for him if the pond were maintained at a generally higher elevation.

22. Regarding the well just beyond the NE corner of Flax Pond, labeled as a USGS installation, Mr. Cakounes recommended contacting Paula Champagne at the Harwich Health Department to see

if they have any records for it. Also in reference to monitoring of water conditions, Mr. Cakounes noted that Mr. Sarkes was close to bringing suit against the Town due to the "sewerage issue".

23. Discussion then focused on Mr. Cakounes' observations of clay, during such activities as construction excavation and well/borehole drilling. He said that excavation and/or drilling encountered clay at various depths below ground surface (BGS) Regarding Mr. Cakounes' fellow bog-owner, Linc Thacher, Mr. Cakounes provided the following information:

    a. Mr. Thacher supplies most of his bogs' agricultural needs with water pumped out of Sand Pond, as well as from a groundwater well that is located within (or immediately adjacent to the pump house on his property.

    b. The Thacher-owned bog system has at least one flow control structure. In the wet season, Mr. Cakounes warned that Sand Pond's water level should not be raised, due to the beaches along part of the pond's shoreline. This was noted as being in significant contrast with the situation along the Flax Pond residential shoreline (generally the southern shore), where the homes were built on much higher-elevation land.

24. Mr. Cakounes told us that he is licensed to use 11 million gallons He went on to say that he typically comes close to using the full amount.

25. Concerning his agricultural operations, Mr. Cakounes conducts wet cultivation/harvesting in his northern two bogs, and dry cultivation/harvesting in the southern bog. He floods the bogs in the springtime, and went on to say that Mr. Thacher does not conduct a spring flooding, whereas Mr. Coulson has started doing this.

26. In addition to the hydraulic/hydrologic considerations cited above, Mr. Cakounes emphasized that he uses organic farming techniques, and thus he must control bugs by flooding even in the wintertime now due to the exceptionally warm weather.

27. Mr. Cakounes stressed that his most pressing concern relates to water quality. Therefore, he has water samples collected and analyzed for a suite of water quality parameters, including E. coli, total coliform, and fecal coliform.

28. Discussion of water quality testing then centered on the sampling & analysis efforts of the Town, related to Flax Pond water quality improvements.

29. On the subject of water quality in Flax Pond, Mr. Cakounes cited how the pond's water quality has changed for the better by a significant amount, with the change starting in earnest about 11 to 12 years ago. He also noted that aerators had been placed in the pond but were removed (as another sign of water quality improvement). He believes the main reasons for the water quality improvements are related to the landfill capping and removal of the septage pits from just north of the pond near the landfill.

Site Visit No. 2 with Bog Owner Wayne Coulson

1. Mr. Coulson has owned and cultivated his bogs since 1974Types of cultivation:

    a. North bog – wet method; "black" fruit for juice.

    b. South bogs (2 of them) – dry method; for the fresh fruit market.

2. Mr. Sarkes' outflow is diverted and carried away, alongside the SW side of Mr. Coulson's southern bogs. The outflow comes in through a pipe that discharges into the ditch that runs alongside Mr. Coulson's bog until it connects to Coy Brook on the south side.

3. Mr. Coulson's operation is not "certified" as organic.

4. Mr. Coulson's operation does not have the ability to supply Mr. Sarkes' bogs with water. (Thus, Mr. Coulson confirms Mr. Cakounes' indication that Mr. Sarkes' operation depends on Flax Pond for all his water.)

5. Mr. Coulson indicated that if the water table rises, due to natural conditions or in the future due to artificially applied recharge, his system could drain it off effectively. As evidence of this capacity, he cited the proven ability to drain down his flooded bogs by 2-ft in 10 hours, overnight, from a maximum water level at only 1 to 1.5 ft below the top level of the bogs (as defined by the ground surface elevation of the land at the edges of the bogs).

6. Mr. Coulson noted that the culvert that carries Coy Brook under Great Western Road has had problems carrying the brook's flow. He also noted that recently Town DPW signs had been posted on Great Western Road in that vicinity, warning of upcoming bridge work – he speculated that the Town might be conducting upgrades to the Road's Coy Brook culvert/bridge [but subsequent windshield-survey checking demonstrated that the work is being done on a bridge further downstream on Lothrop Road].

7. Mr. Coulson indicated that the bogs he now owns were originally constructed in the 1800s.

8. When questioned further about the bog system's hydraulic capacity, Mr. Coulson cited the big rainstorm last summer. He also said that there have only been 3 or 4 times that the bogs' hydraulic capacity and that of the downstream culvert have been stressed and that vegetation blocking the meandering stream could be the main cause.

9. Regarding surveyed or relative elevations, water depths, and operating water levels, as well as surficial geologic conditions affecting subsurface flow-connection, here are several statements and indications from Mr. Coulson:

    a. He does not have surveyed elevations or related topographic mapping for his property.

    b. The two northeast ponds have a bottom elevation that is the same as in the northern bog.

    c. The northern bog has a bottom elevation that is roughly 0.5 ft above the bottom of the southern 2 bogs.

d. When asked what he thinks allows the ponds to be maintained several feet higher than the bogs immediately to the south, he indicated that believes the berm between the ponds and the northern bog has "hardpan" inside it.

e. The pond to the NW is much deeper than the NE pond and the bogs. He said that the bottom of the NW pond is approximately 12 feet below the current water level. That pond is used for irrigation source water.

10. Regarding hydraulic controls, Mr. Coulson provided the following information:

    a. He controls the structure that is located on the eastern side of the bike trail (former RR track alignment).

    b. He controls the flow using that structure as well as the other structures in his bog system in the springtime, for achieving appropriate flow rates to allow for effective bug control..

11. In regard to the history of his property and the cranberry cultivation there, Mr. Coulson offered the following:

    a. Before the RR tracks were placed, the bogs spanned across the RR track alignment, thus connecting the bog area (now uncultivated) with the bogs to the W/SW (currently cultivated or used for water storage).

    b. The bogs were constructed in the 1835-37 time-period.

    c. The historic record indicates that the bogs were constructed in a zone labeled "upland" or "rough swamp", circa 1835; and, by 1837, the historic record calls the property "bogs".

    d. The record also cites "Leonard Underwood" as the owner, and subsequently "Nathaniel Underwood".

12. Regarding flow rates, Mr. Coulson said that his bog system is fed solely by "runoff water". He does not conduct any tracking or measurement of flow rates or volumes.

13. Mr. Coulson noted that there was "a whole chain of bogs upstream (northeast) of his property and bog-system, but many or all of them are now uncultivated.

14. With respect to the presence of clay, Mr. Coulson cited these observations:

    a. He has seen "some veins of clay – such as under the pine trees east of the berm" that separates the ponds and his northern bog.

    b. Near his pump house, the shallowest sediments are "beautiful sands". But, there is a blue clay layer below that top sand layer.

15. Mr. Coulson reiterated that if the water table was to rise 1 ft, his bog system could handle it (without undue/unwanted flooding of the bogs) without any problems. From the other perspective of the potential for insufficient flow for good cultivation, Mr. Coulson cited time-periods – "back in the 1990s, maybe 1995 or so" – when he had some trouble getting enough water due to drought or near-drought conditions. In regard to agricultural practice and required water quality, Mr. Coulson noted the following:

a. He follows "GAP", or "Good Agricultural Practice" as defined by the Cranberry Growers Association.

b. Because he cultivates fresh fruit cranberries, the bogs' water quality must have no coliform bacteria.

16. Back on the subject of historical changes, Mr. Coulson cited the following:

    a. There used to be a series of bogs and flumes, in a sort of "step-down" arrangement running from upstream to downstream.

    b. Many of these old bogs are now defunct or uncultivated.

17. Further on the subject of the storage ponds on his property, Mr. Coulson noted again that the NW pond is roughly 12 feet deep. In summer, it drops 5 feet from its winter/springtime filled condition, so that its water level is lowered to approximately 1 foot below the bottom, or ground surface elevation of the northern bog – which is the same elevation roughly of the bottom of the NE pond

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Appendix F

Figure F-1
Simulation 3 Clay Extent Layer 6: 10 to 20 feet elevation

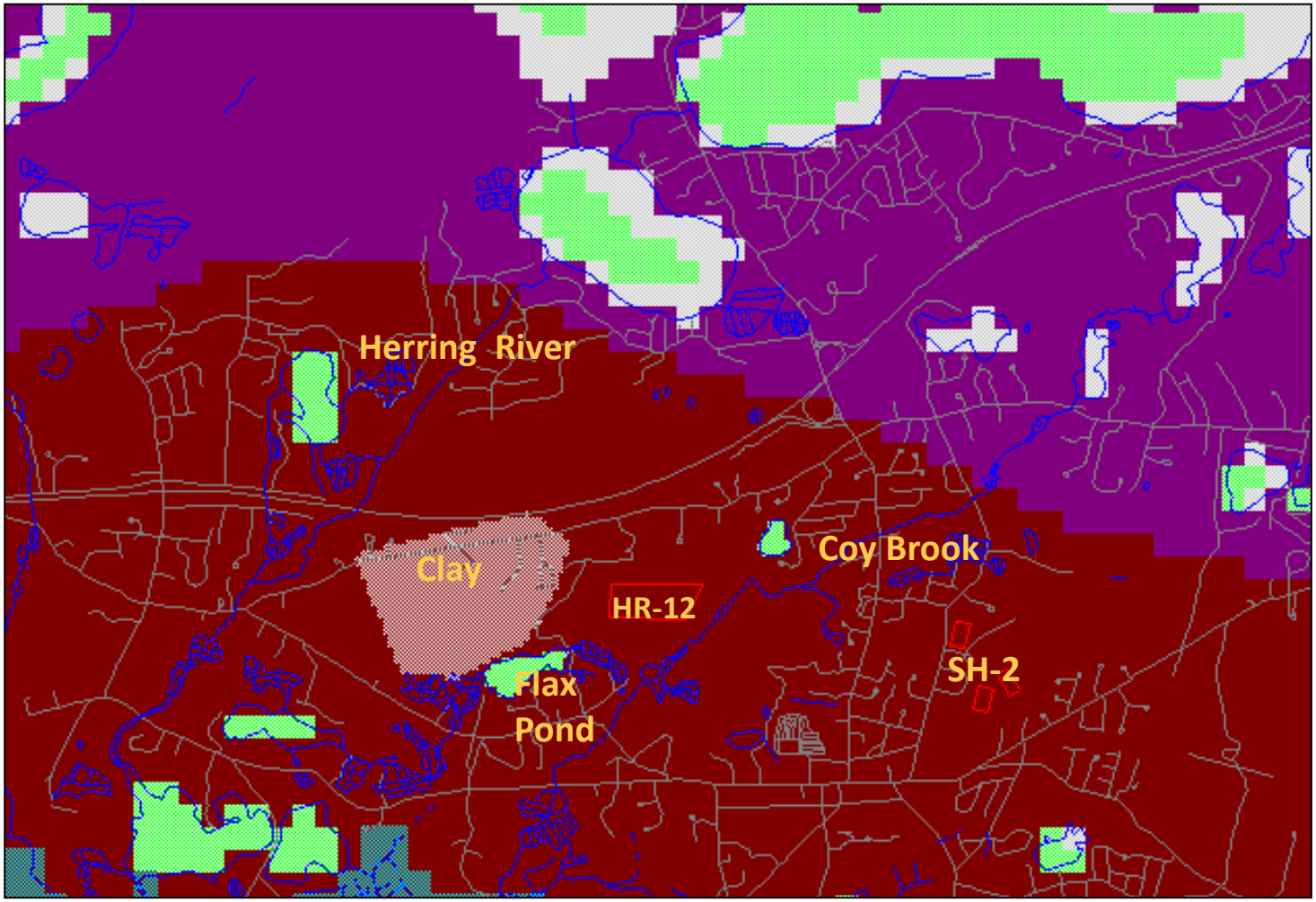

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Figure F-2
Simulation 3 Clay Extent Layer 7: -1 to 10 feet elevation

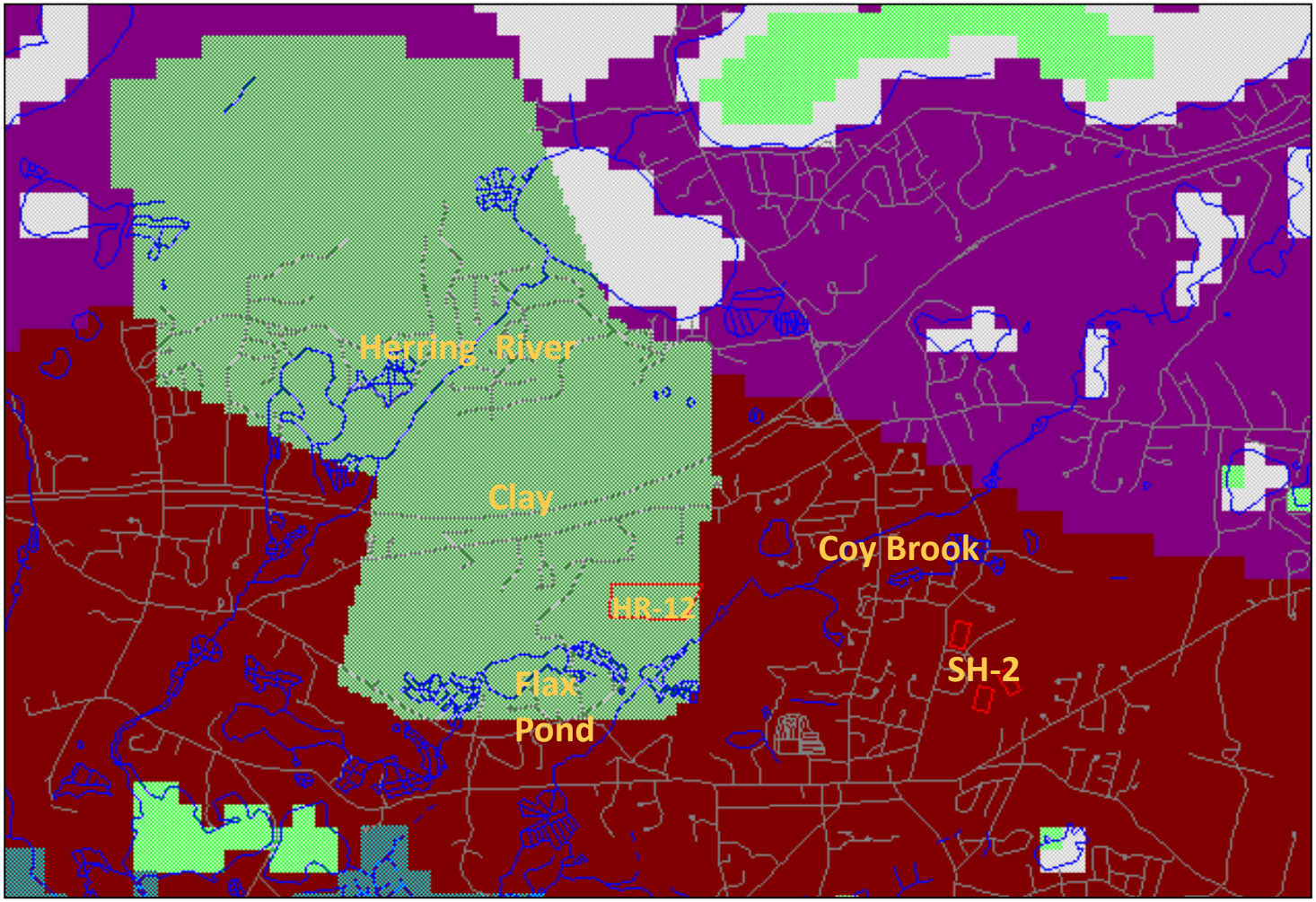

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Figure F-3
Simulation 3 Clay Extent Layer 8: -10 to -1 feet elevation

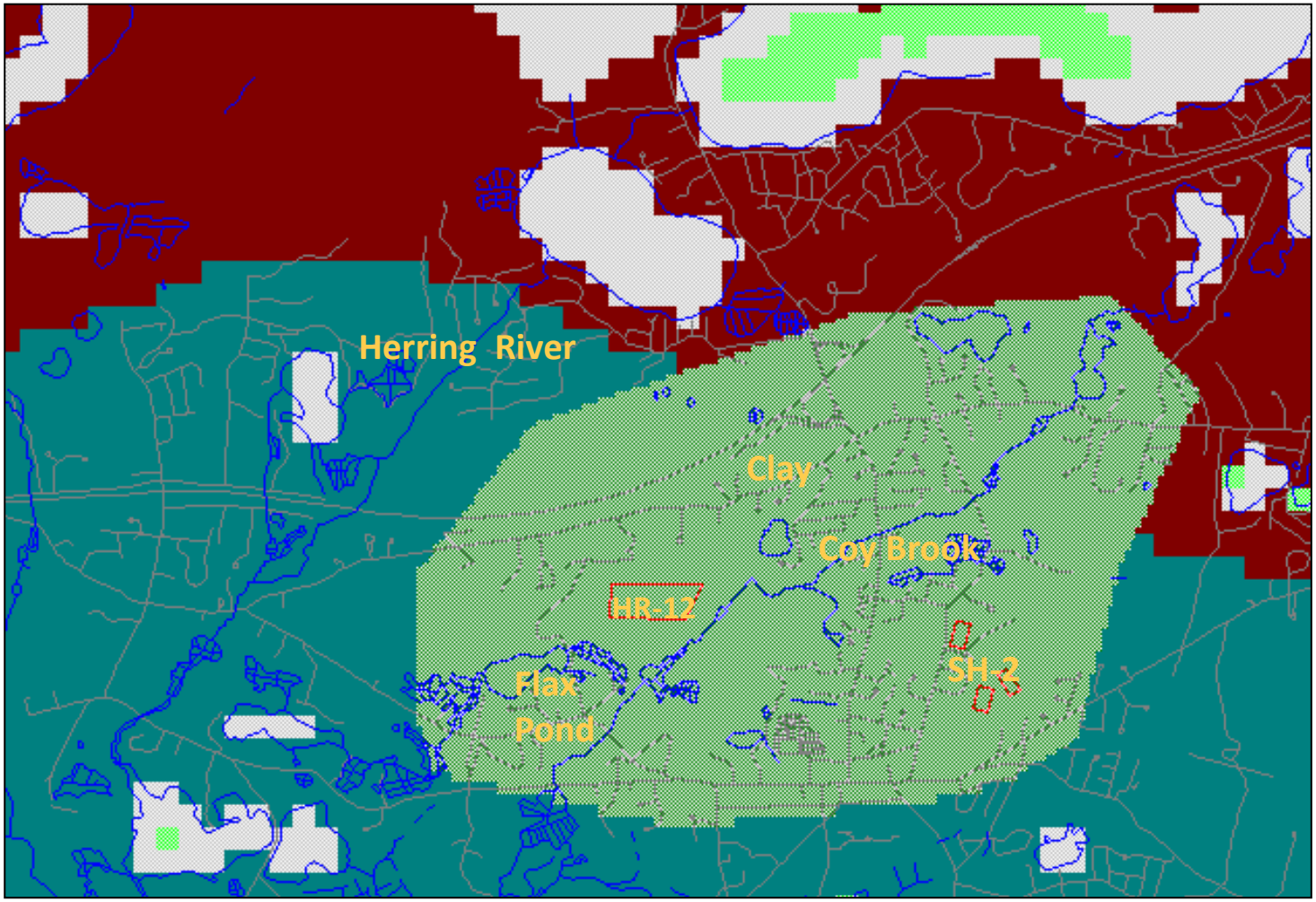

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Figure F-4
Simulation 3 Modeled Surface Water Features near HR-12

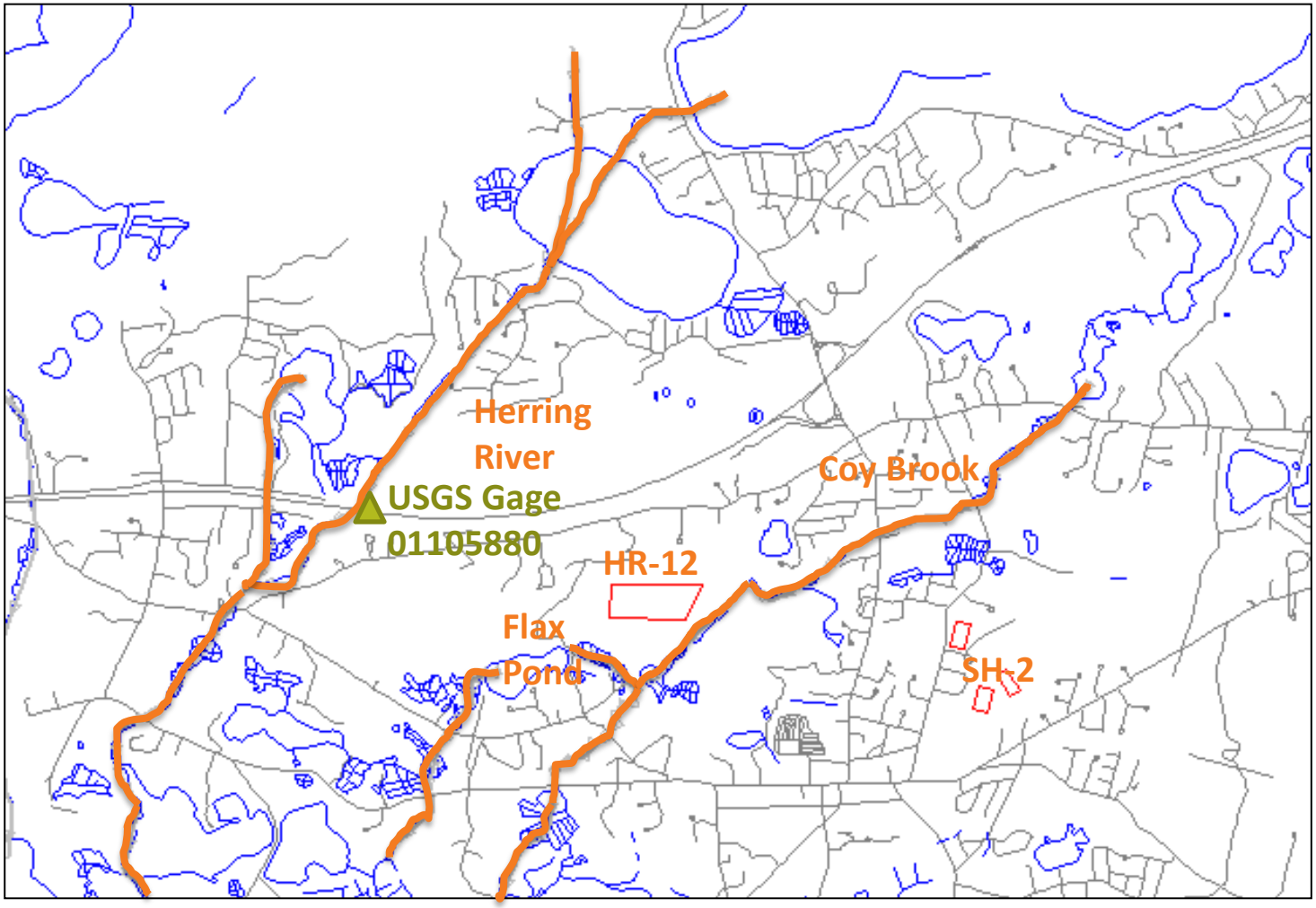

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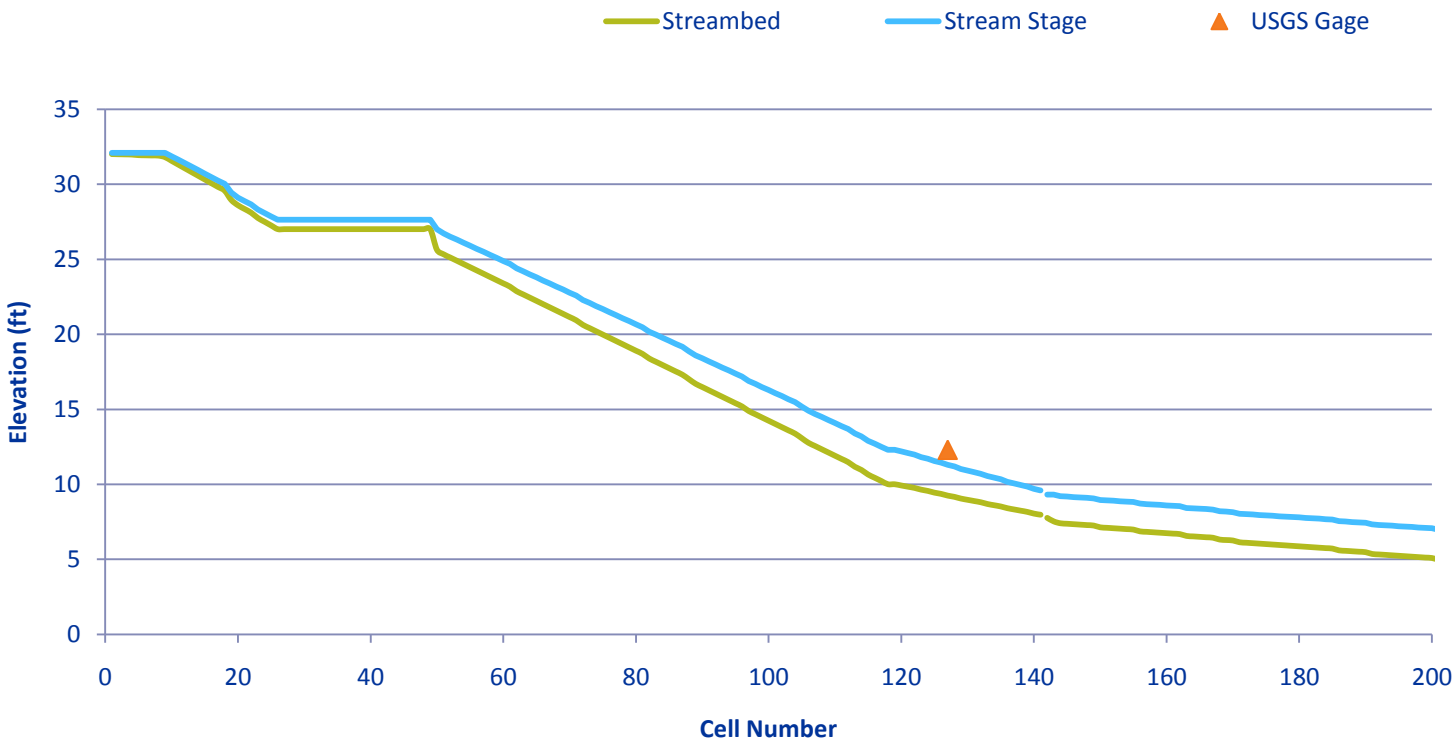
Figure F-5
Simulation 3 Herring River Modeled Streambed and Stage



X axis shows the number of model cells from the start of the stream.
Length of stream varies within each cell.

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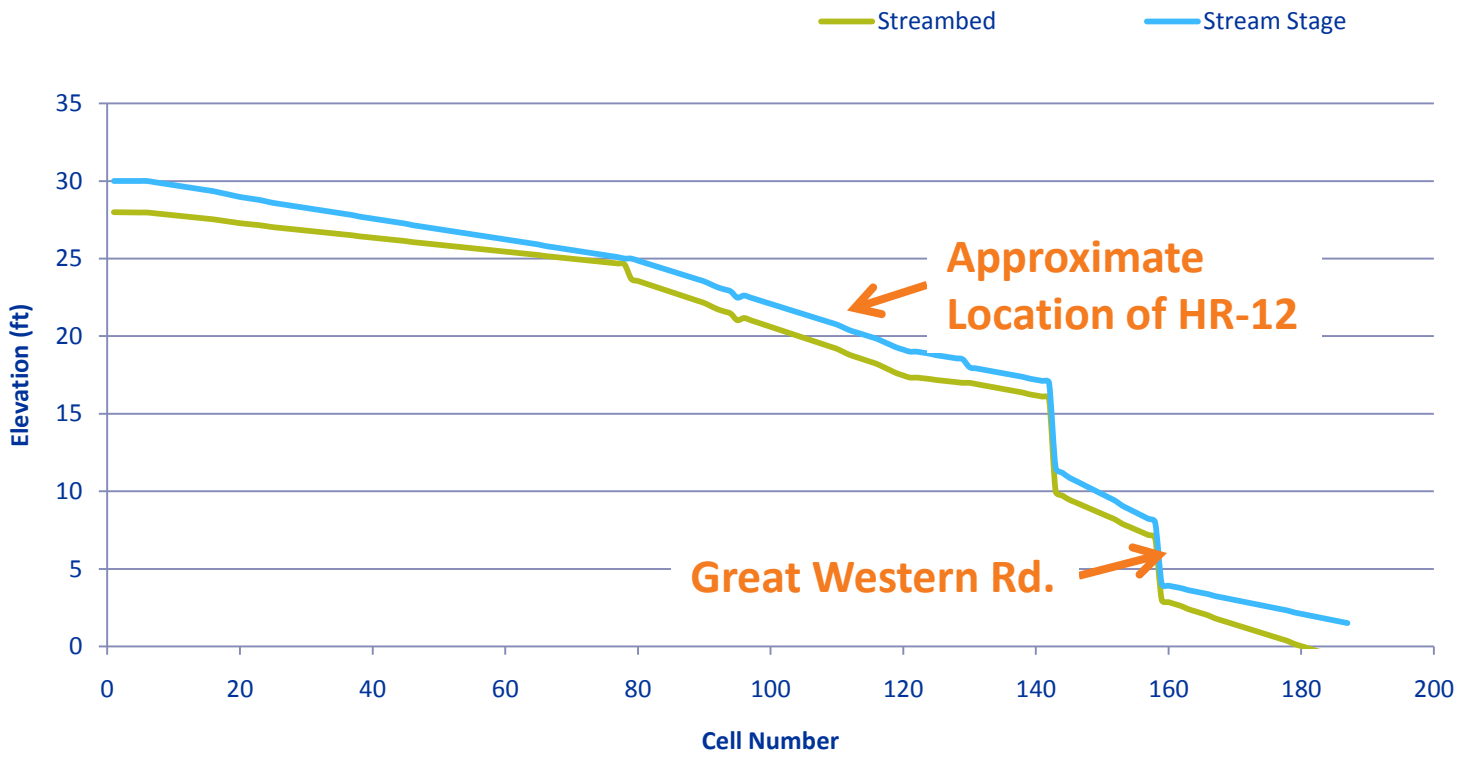
Figure F-6
Simulation 3 Coy Brook Modeled Streambed and Stage



X axis shows the number of model cells from the start of the stream.
Length of stream varies within each cell.

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Figure F-7
Simulation 3 Model Calibration Check: USGS Regional Wells

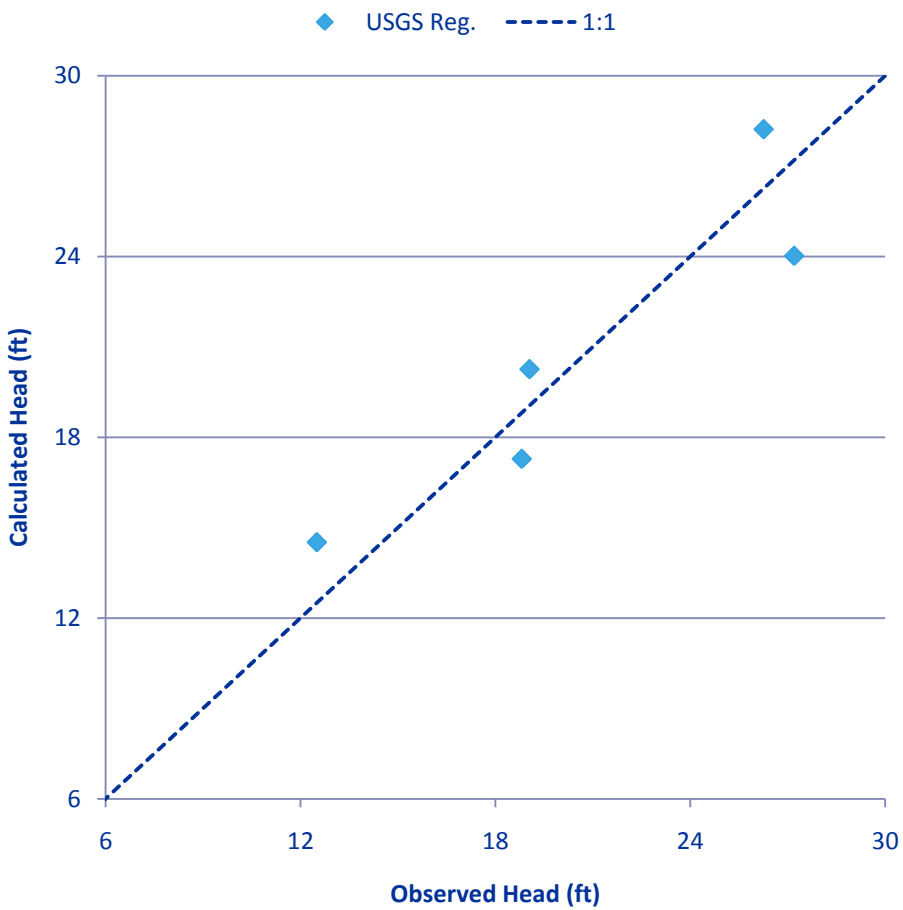

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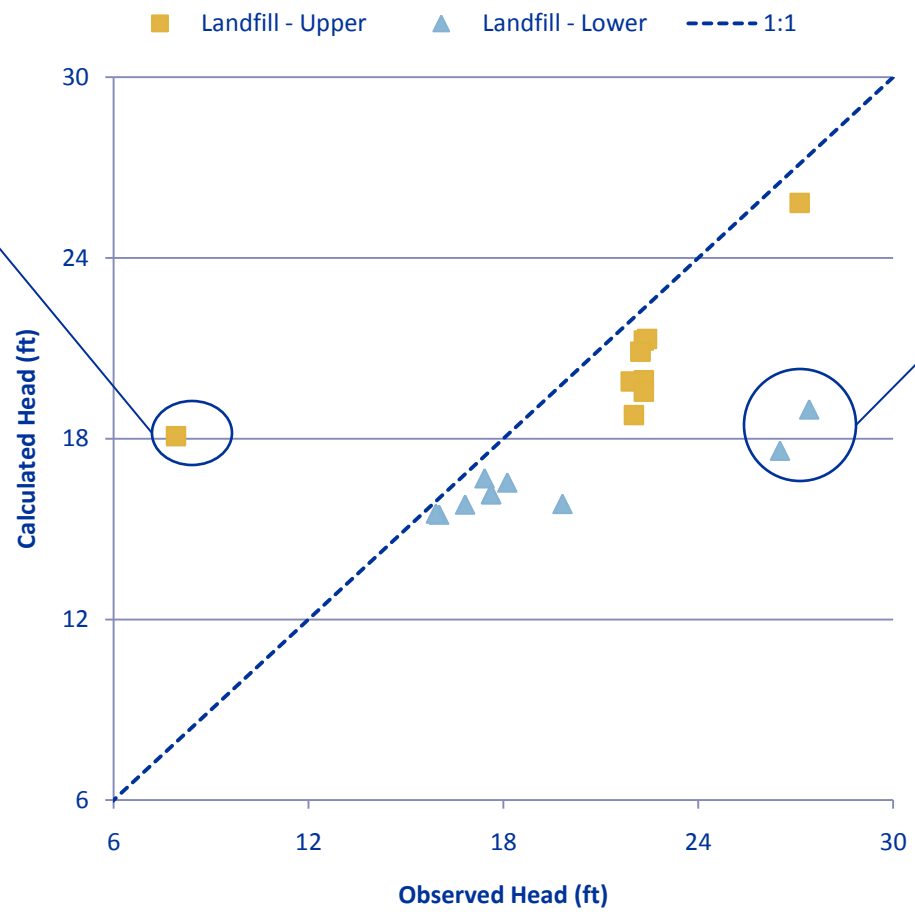
Figure F-8
Simulation 3 Model Calibration Check: Landfill Wells

Review of the boring logs suggests that this well (HWH-19) may not be connected to the upper aquifer due to heaving sand.



Review of the boring logs suggests that these wells (HWH-1 and HWH-8D) may be connected hydraulically to the upper aquifer.

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Table F-1
Simulation 3 Model Calibration Check

Well	Aquifer	Measured Head (feet)	Modeled Head (feet)	Modeled Head – Cranberry Bogs Added (feet)
BMW-21	USGS well	26.3	29.2	28.2
BMW-44	USGS well	27.2	24.0	24.0
CGW-138	USGS well	12.5	14.6	14.5
HJW-141	USGS well	19.1	20.4	20.3
OSW-24	USGS well	18.8	17.7	17.3
HWH-1	Lower	27.4 *	20.4	19
HWH-2 S	Upper	21.9	23.6	19.9
HWH-2 M	Upper	22.0	22.0	18.8
HWH-2 D	Lower	19.8	17.5	15.8
HWH-3 S	Upper	22.2	24.2	20.9
HWH-3 M	Upper	22.3	22.4	19.6
HWH-3 D	Lower	17.6	17.8	16.2
HWH-3 DD	Lower	17.6	17.8	16.2
HWH-4 S	Upper	NM	--	--
HWH-4 D	Lower	16.8	17.4	15.8
HWH-8 S	Upper	27.1	28.4	25.8
HWH-8 D	Lower	26.5 *	19.1	17.6
HWH-11	Lower	16.0	17.0	15.5
HWH-14	Lower	15.9	17.2	15.5
HWH-17 S	Upper	22.3	24.5	21.3
HWH-17 M	Upper	22.3	22.7	19.9
HWH-17 D	Lower	18.1	18.2	16.5
HWH-18 S	Upper	22.4	24.5	21.3
HWH-18 D	Lower	17.4	18.3	16.7
HWH-19	Upper	7.9 *	21.6	18.1