



Hague Stormwater Evaluation and Improvement Concepts Report

Presented to:

City of Norfolk

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1. Executive Summary

Moffatt & Nichol (M&N) was retained by the City of Norfolk to assess the existing stormwater outfalls along the Hague water body, evaluate the need for dredging and outfall maintenance, and identify alternatives for enhancing water quality within the Hague Area.

1.1. Data Collection and Findings

In order to evaluate and assess the Hague stormwater outfalls and to determine opportunities for water quality improvement a number of site investigations were performed, including:

- Existing Conditions Surveys - generally “bank to bank” within the approximately 19 acres of the Hague water body, including locating visible outfalls and shoreline features.
- Outfall Inspection – visually inspected and noted the conditions of 40 storm drain outfalls that discharge into the Hague.
- Sediment Sampling and Testing – collected 10 core samples for determining characteristics of bottom sediments, and prepared five composite samples for environmental testing.
- Baseline Water Quality Monitoring – campaign of regular monitoring of water quality indicators within the Hague, from April 2013 to April 2014.

1.2. Outfall Improvements

Of the 40 stormwater outfalls discharging into the Hague, eight (8) are recommended for additional investigations and/or repair. The recommendations are summarized in Table 3 found in Chapter 3 of this report.

Note that two large outfalls (referred to as E143250 and E143699 in this report) entering the Hague in the east canal, in front of the Chrysler Museum, discharge stormwater collected along Monticello Avenue and its tributary subbasins. These culverts and their outfalls are being inspected under a separate work order. Existing conditions assessments and recommended repairs to the Monticello Avenue culvert outfalls will be provided in a separate report under that separate work order.

1.3. In-Water Improvement Projects

In-water projects are evaluated that have the potential to improve or restore the environment within the Hague. This approach aims to improve water quality and enhance the habitat through alternatives including wetland creation and restoration, sediment restoration (combination of dredging and capping) and restoring oyster reefs. The alternatives include:

- Dredging - Removal of sediment by outfalls
- Dredging - Restore to 1970s project
- Oyster reef creation/restoration
- Living shoreline along Brambleton Avenue
- Living cap adjacent to Chrysler Museum

Projects that directly improve in-water conditions (e.g. contaminated sediment removal and wetland creation) generally receive recognition (i.e. credit) under different regulatory programs than projects that seek to improve the quality of stormwater discharges. Projects not appropriately defined in the context of regulations are at risk of not being counted towards stormwater improvement mandates placed upon the City. Thus, despite sharing the overall objective of improving water quality in the Hague (and thus the Elizabeth River into the Chesapeake Bay), care should be taken to align projects with specific regulatory objectives.

Although in-water improvement efforts have traditionally aligned with regulations that require mitigation efforts for projects impacting the in-water environment, such as construction of a new pier or channel, credit for water quality improvement through these efforts is a viable option worth developing and discussing with regulatory agencies.

1.4. Stormwater Treatment BMPs

Stormwater treatment improvements considered are those generally associated with mitigating stormwater quality impacts from development, as established by the Clean Water Act and administered through the National Pollution Discharge Elimination System (NPDES) permit program. For this report, the alternatives considered include:

- Retention Pond
- Constructed Wetland
- Hydrodynamic Separator
- Bioretention Area
- Biofilter (Filterterra)
- Biofilter (Site Design)
- Permeable Pavement

1.5. Recommendations

This report details each of the in-water improvements and stormwater treatment alternatives. Each alternative is discussed in terms of the establishment of the Chesapeake Bay Total Maximum Daily Load (TMDL). TMDLs as dictated by the EPA introduce an additional program (above the NPDES) for which water quality improvements will be necessary to demonstrate compliance. Under this program, each contributing watershed is assigned pollutant limits and improvement goals for further reduction. Numerous water quality improvement strategies are identified, including both stormwater treatment improvements and in-water improvements. The consensus on the effectiveness of each strategy has not been achieved, nor has the system to track implementation been finalized.

As the EPA creates and clarifies TMDL requirements the City needs to consider cost effective methods to meet the requirements. Following is a summary of the alternatives considered for the report. Comments on the likely credits/benefits for TMDL calculations, approximate cost and effectiveness is summarized below –additional details follow in the report.

Table 1: Summary of conceptual water quality improvement project elements

Concept Project / Element	Order-of-Magnitude Cost	Likely TMDL Credit	Benefits/Effectiveness
Dredging - removal of sediment by outfalls	\$600,000 to \$800,000	See Note 1	Open Flow from outfalls. Restore sedimentation bays.
Dredging - restore to 1970s project template	\$1.1M to \$1.6M	See Note 1	Open flow from outfalls, allow for sedimentation, and increase volume which may have water temperature, DO, and pathogen dilution benefits.
Oysters - create approx. 1.3 acres total oyster reef	\$820,000	See Note 1	Water quality, nutrient uptake, reduced turbidity, habitat enhancement
Living Shoreline - approx. 1,100 LF parallel to Brambleton Ave	\$1.7M	See Note 1	Water quality, reduced turbidity, nutrient uptake, habitat enhancement. Eliminates structure in need of maintenance.
Living Cap - adjacent to Chrysler Museum	\$820,000	See Note 1	Clean subsurface for habitat enhancement, water quality
Retention Pond - parallel to Brambleton Ave.	\$550,000	Yes	Treating 18 acres, removes 18 lbs/yr TP; 70 lbs/yr TN; 5 tons/yr TSS.
Constructed Upland Wetland - parallel to Brambleton Ave.	\$500,000	Yes	Treating 12 acres, removes 11 lbs/yr TP; 42 lbs/yr TN; 3 tons/yr TSS.
Hydrodynamic Separator (Maury High School)	\$730,000	Yes	Treating 18 acres, removes 8 lbs/yr TP; 65 lbs/yr TN; 5 tons/yr TSS.
Bioretention Area (various sites)	\$60,000	Yes	Treating 1 acre, removes 1 lb/yr TP; 6 lbs/yr TN; < 1 ton/yr TSS.
Biofilter (Filterra Inlet Retrofit) (various sites)	\$60,000	Yes	Treating 0.5 acre, removes 0.5 lb/yr TP; 2 lbs/yr TN; < 1 ton/yr TSS.
Biofilter (Site Design) (various sites)	\$60,000	Yes	Treating 1 acre, removes 0.8 lb/yr TP; 4 lbs/yr TN; < 1 ton/yr TSS.
Permeable Pavement (various sites)	\$320,000	Yes	Treating 2 acres, removes 2 lbs/yr TP; 7 lbs/yr TN; < 1 ton/yr TSS.

Note 1: Unlike more conventional stormwater treatment alternatives, in-water mitigation credits would require additional discussion with stormwater regulators to calculate appropriate credit. Guidance for TMDL credits for these alternatives, if any, is still under development by the Chesapeake Bay TMDL program.

2. Existing Conditions

The Hague, formally known as Smith Creek, is the receiving body of water from the Hague watershed. The Hague flows into the Elizabeth River, and it is tidally influenced and subject to storm surges. The Hague cove shoreline has been modified by land reclamation and construction activities since the late 1800s. Figure 1 shows the present day extents of water (blue lines and hatching) over a NOAA chart from 1894. The present-day shoreline indicated in the figure is defined primarily by vertical retaining walls and vertical-faced concrete relieving platforms. Approximately 40 stormwater outfalls discharge through the retaining walls and relieving platform faces.

The outlet from the Hague to the Elizabeth River is spanned by Brambleton Avenue Bridge and The Tide light rail bridge. On the upstream side of the bridges, the outlet is approximately 500 feet wide from shore-to-shore. On the downstream side, the opening is narrower and is approximately 375 feet wide from shore-to-shore. Although The Hague is not a defined, maintained navigation channel, the bridge openings and the existing water depths are navigable by small craft, and there is a history of incidental usage of the Hague by small power boats and canoes/kayaks. The Hague was dredged by the Norfolk Housing & Redevelopment Authority in the 1970s for navigation and water quality improvement.

The Hague watershed includes the Ghent residential/commercial community, portions of the Freemason area, and northwestern portions of the downtown Norfolk business district. The watershed includes 2,373 parcels within the 894 acres of land in the watershed. Approximately 9,000 residents live within the watershed, according to one estimate by the City's Planning Department.

The Hague and the residential community along its shoreline are within the City-designated Ghent Local Historical District, with distinctive architecture dating back to the 1890s. Development activities within Local Historical Districts are regulated to ensure the historical aesthetics of the neighborhood are retained.

The density of development, characterized by on-street parking, narrow (1 to 2 ft wide) green spaces with mature trees, sidewalks, and shallow front yards, also presents challenges to implementing many commonly used stormwater quality BMPs.

In order to evaluate and assess the present condition of the Hague stormwater outfalls and to determine opportunities for water quality improvement, a number of site investigations were performed. The following is a summary of those investigations; additional details of the investigations are contained in appendices to this report.

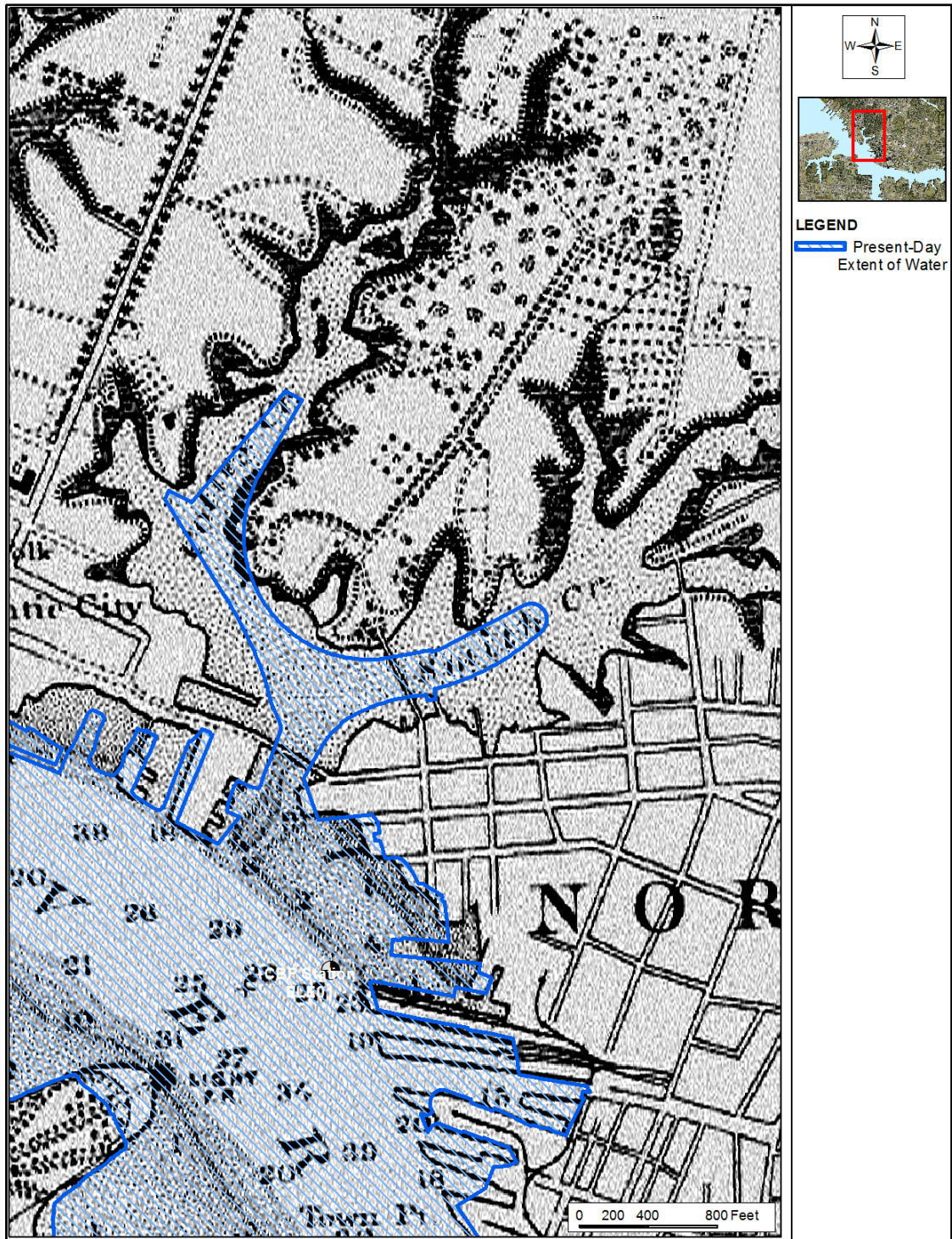


Figure 1: Present-day Hague shoreline over 1894 chart of Smith Creek and Colley Creek (ref: NOAA chart BIC-45 Hampton Roads, 1894)

2.1. Survey of Existing Outfalls, Bulkhead, and Hydrography

Existing condition surveys for this project were performed by Precision Measurements, Inc. (PMI) in February and April 2013. Surveys were completed in feet with vertical datum NAVD88 (92) City of Norfolk 2000 and horizontal datum NAD 83/93 HARN. “Bank to bank” sections within the Hague, landward of the Brambleton Avenue bridge, were generally taken every 100 feet. At each visible outfall the size and invert and elevations are noted. In addition, the survey includes the location and elevations of the top of retaining wall (bulkhead) caps and/or relieving platforms. Appendix A includes figures showing existing conditions based on the completed survey. General information from the survey of the Hague (refer to Figure 2) includes:

- Mudline elevation varies from approximately -6 feet to -10 feet NAVD88 in the main canals.
- Bank to bank area of the Hague is approximately 19 acres.
- Average dimension of the Hague is 200 feet wide by 3,400 feet long.
- Typical tide range (MLW to MHW) is approximately 2.5 feet.
- 1,800 linear feet (LF) of relieving platform
- 5,200 LF of bulkhead / retaining wall

2.2. Outfall Inspection

In addition to surveying in the invert and size of all visible outfalls, a log including photos of the existing stormwater outfalls into the Hague is included in Appendix B. The exposed or partially exposed outfalls were observed via kayak during low tide on November 11, 2013 to assess if there was any obvious clogging or other condition impacting their performance. A summary of the outfalls:

- 40 storm drain systems discharge into the Hague north of the Brambleton Avenue bridge
- 32 pipes, 8-inch to 48-inch diameter
- 8 square culverts
- Typically inverts ranged between elevations -4.0 feet and -1.5 feet NAVD88.
- Most outfalls exposed/semi-exposed during low tide and fully submerged at high tide.
- 3 outfalls are noted for repairs; 5 outfalls are recommended for further investigation

Since most development of the area pre-dates requirements to treat stormwater, there are no existing treatment measures in place for stormwater discharge into the Hague.

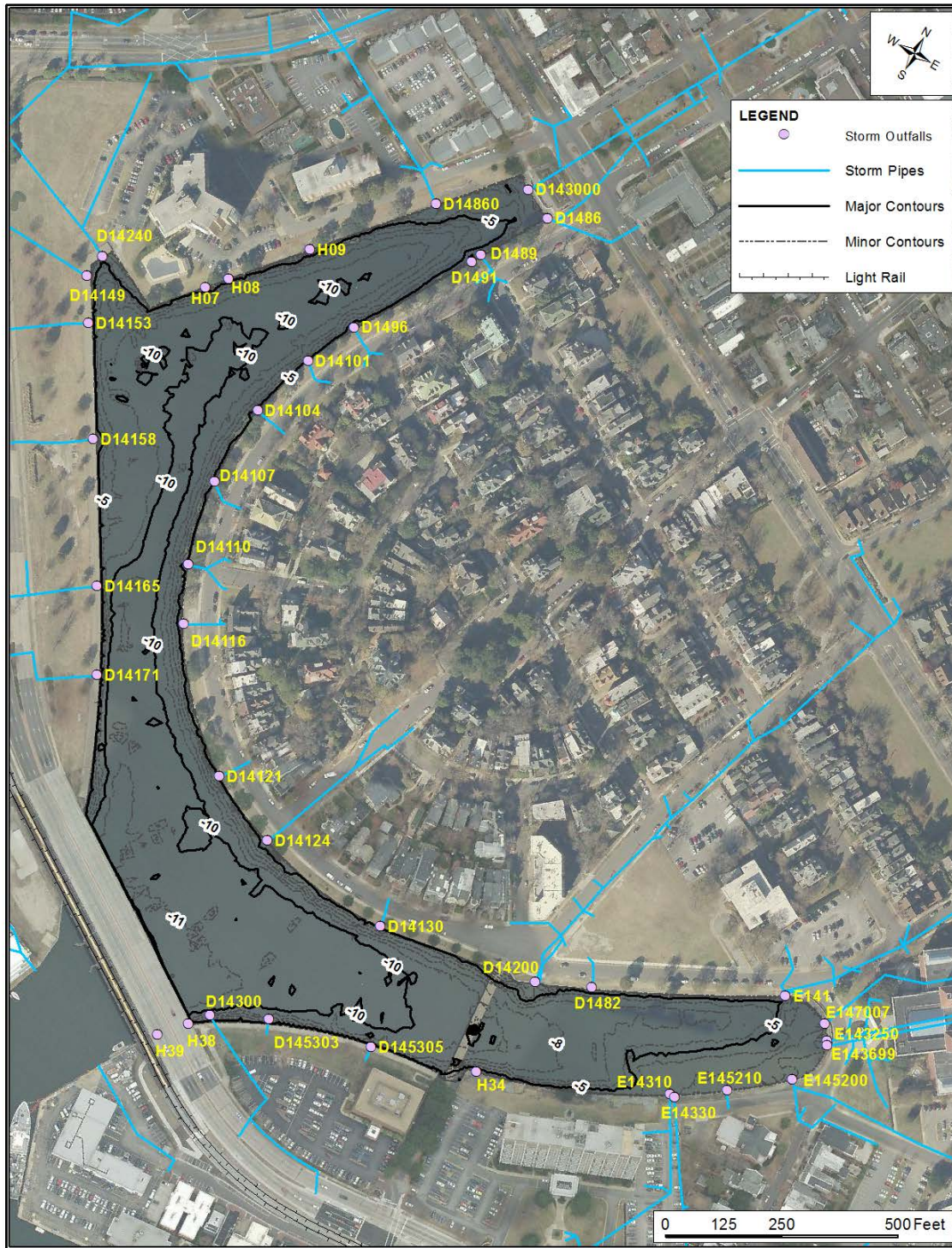


Figure 2: Survey contours and outfalls

2.3. Sediment Sampling and Testing

GET Solutions, Inc. obtained 10 core samples from the Hague (see Figure 3). Sampling was conducted August 2013. From the 10 sampling locations, five composite samples were prepared for environmental testing. Representative samples were also obtained for classification. Classification testing results indicate the upper 4 to 6 feet sampled consist of silts and clays.

The composited soil samples collected for environmental testing were analyzed for TCLP Volatile Organic Compounds (TCLP-VOCs), TCLP Semi-Volatile Organic Compounds (TCLP-SVOCs), TCLP RCRA Metals, TCLP Polychlorinated Biphenyls (TCLP-PCBs), Extractable Organic Halides (EOX), and Total Petroleum Hydrocarbons (TPH) using EPA-approved Methods.

Details can be found in the attached geotechnical report in Appendix C and as discussed under the dredging alternatives in Chapter 4.3.

2.4. Baseline Water Quality Monitoring

A campaign of regular monitoring of water quality indicators within the Hague was initiated in April 2013. Electronic measurements and bottle samples were collected, and the bottle samples were analyzed by EnviroCompliance Laboratories (ECL). Appendix D contains detailed results from the water quality sampling.

Water quality sampling locations are shown in Figure 3. Three sample locations are within the Hague, and a fourth is outside of the Hague between the NOAA and PETA facilities. The fourth location provides data for comparison of measurements in the Hague to an area intended to be less influenced directly by stormwater discharges into the Hague. Data were also obtained from the data archives of the Chesapeake Bay Program (CBP) for a nearby monitoring station in the Elizabeth River. (CBP data can be accessed at the web address <http://www.chesapeakebay.net/data>.)

The monitoring includes the measurement of temperature, salinity, conductivity, dissolved oxygen, and pH via portable YSI 556 multi-parameter meter, in conjunction with laboratory tests of nutrient series (N, P), chlorophyll-a, organic carbon, suspended sediments, and bacterial pathogen indicators. Field measurements and/or samples have been collected on four dates, including a wet-weather event. Table 2 summarizes the range of water quality parameter values sampled from the Hague and the Elizabeth River over the course of the monitoring program (April 2013 – April 2014).

Table 2: Summary of sampling results

Parameter	Range Sampled within the Hague	Range Sampled Between NOAA and PETA	Range from CBP Elizabeth River Station ELE01
Temperature (°F)	50 – 81	50 – 80	41 – 79
Salinity (ppt)	4.3 – 22.1	14.9 – 22.0	14.3 – 22.5
Dissolved Oxygen (mg/L)	2.5 – 12.5	3.8 – 10.5	3.7 – 10.6
Dissolved Oxygen Saturation ¹ (%)	36 – 125	54 – 110	77 – 102
pH	6.3 – 8.2	7.5 – 8.1	7.4 – 8.0
Total Nitrogen (mg/L)	0.7 – 6.9	0.9 – 3.5	0.44 – 0.94
Total Phosphorus (mg/L)	0.03 – 0.14	0.04 – 0.10	0.04 – 0.13
Total Organic Carbon (mg/L)	BQL – 31.6	4.7 – 18.9	5.11
Suspended Sediments (mg/L)	2.9 – 26.2	3.4 – 15.5	9.5 – 36.0
Bacterial pathogen indicators (CFU/100 mL) ²	1 – 4200	2 – 1000	25 – 125

¹Dissolved oxygen saturation percentage is calculated from the M&N sampled or CBP reported data.

²Colony Forming Units per 100 mL.

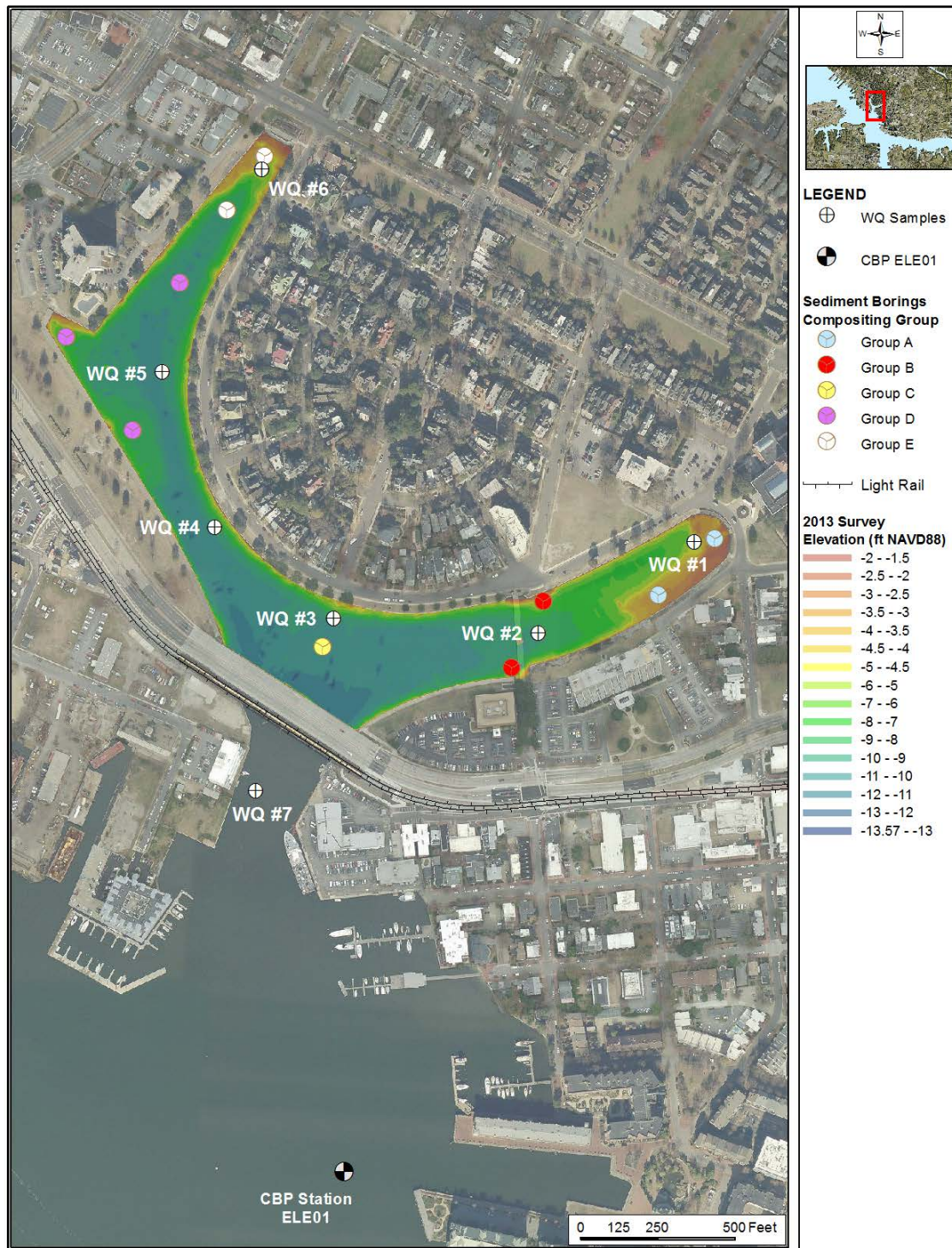


Figure 3: Sediment and water quality sampling locations

3. Maintenance of Existing Outfalls

Periodic maintenance ensures outfalls are performing adequately and have no structural deficiencies, are stable along the shoreline/bulkhead, and are not blocked by sediment.

In addition to the information provided from PMI's February 2013 survey of outfall inverts and pipe sizes, Moffatt & Nichol performed visual inspection of the outfalls discharging to the Hague. Photos of the outfall pipe and of the topside area immediately landward of the existing bulkhead were taken, and these are shown in Appendix B. Moffatt & Nichol noted any areas above the outfall from point of discharge to the upstream stormwater structure (i.e. yard basin, manhole) that showed evidence of outfall deficiencies. Indications noted in the field include areas of settlement or evidence that fill has been used to fill in settled areas in the upland area behind the bulkhead. Settlement along outfall pipe is evidence that there is a gap or void in the outfall which is washing away surrounding soil. Where the inspector was unsure if settlement is from the outfall pipe or due to an unrelated cause, the need for further investigation is noted. Where strong evidence exists that the outfall or a section of the discharge pipe has deficiencies, repairs to the outfall or culvert have been recommended. Based on the site inspections of the visible outfalls, those listed in Table 3 require follow-up.

Table 3: Outfalls Recommended for Repairs or Further Investigation

Outfall	Size	Deficiencies Noted
D14240	5 ft x 3 ft culvert	Further investigation needed: CCTV pipe to verify no joint separation or failure.
D14860	15" pipe	
H34 ¹	24" pipe	
D1496	12" pipe	
D14110	15" pipe	
D1486(A)	4 ft x 8.5 ft culvert	Repairs needed: Pipe appears to be collapsed and should be replaced.
D1486(B)		
D1482	15" pipe	Repairs needed at outfall: Excavate, realign, wrap pipe and backfill.
E14330	5 ft x 3.5 ft culvert	Repairs needed: Separated joint – excavate, realign, wrap pipe, and backfill.
Outfalls at west canal end (D14860, D143000, D1486, D2489, D1491) and east canal end (D141, E147007, E143250, E143699, E145200, E145210, E14330, E14310)	Various pipes and box culverts	Removal of sediment in front of each outfall is advisable to improve discharge capacity.

¹Outfall structure not documented in City's GIS database.

²CCTV pipe to verify no joint separation or failure.

For purposes of later sections of this report, storm drain systems are subdivided into Local, Minor, and Major storm drain systems.

- *Localized Area Drains.* Localized area drains are those with characterized by having relatively few inlets and which are fairly close to the outfall location. This allows the pipe profiles to support generally shallow inverts. The drainage basins for these systems are likewise small.
- *Minor Storm Drain Systems.* Minor storm drain systems convey runoff from larger area, though still typically within several hundred feet of the associated outfall.
- *Major Storm Drain Systems.* Major storm drain systems are those which drain large basins with pipe networks extending several thousand feet and necessitate the use of large diameter pipes or culverts with deep invert elevations.

Appendix B contains a summary of the outfalls and their associated systems. As much of the discussion for treatment retrofit opportunities will focus on locations near the Hague, information for the upstream structures near each outfall is also listed. The outfall designations used in the tables are provided on the survey drawing (Appendix A) and in Figure 2.

4. Water Quality Improvement via In-Water Mitigation

4.1. Overview

In-water mitigation can consist of enhancing or restoring an area to historic conditions, for example creating or restoring fringe wetlands, oyster reefs and sediment restoration. Similar effort is underway to restore an area of the Southern Branch of the Elizabeth River as a compensation project to the Eastward Expansion of Craney Island. The restoration includes a landscape approach to improve water quality and enhance the habitat through a combination of wetland creation and restoration, sediment restoration (combination of dredging and capping) and restoring oyster reefs. On a smaller scale, this landscape approach concept can be applied to the Hague. However, unlike some of stormwater treatment alternatives discussed later in the report, in-water mitigation credits would require some additional discussion with stormwater regulators to ensure appropriate credit as there is no clear guidance for TMDL credits for these alternatives.

4.2. Existing Conditions

The Hague is a relatively shallow basin ranging from the mudline being exposed at low tide to -13 feet MLLW at the Brambleton Avenue Bridge. Much of the shoreline is hardened with concrete and stone bulkheads and/or relieving platforms. There is no significant wetland vegetation along the shoreline. Limited sediment sampling was completed to determine the physical and chemical characteristics of the sediments for alternatives involving dredging. In September 2013 (see Appendix C) 10 sediment core samples were taken within the Hague area. The physical characteristics indicate the bottom sediments are predominately silts and clays. Visual observations indicate material adjacent to outfalls contains some sandy material. Testing for chemical constituents in the sediments is based on protocols to determine alternatives for upland placement of dredged material. Samples for chemical testing involved compositing sediment samples into 5 groups based on areas within the Hague. Each composited sample was then tested for selected organic compounds and metals. This limited testing does indicate special handling may be required for dredged material for petroleum hydrocarbons in some areas, and is discussed in more detail below, with the data presented in Appendix C.



Photo 1: Typical hardened shoreline along the Hague

4.3. Dredging Overview and Alternatives

Dredging can have many benefits including:

- Removing sediment built up from runoff through outfalls and overland
- Improving bottom habitat by removing impacted sediments
- In some cases, providing increased circulation/water exchange and recreational opportunities for boaters. In the case of the Hague – due to its shape with two long, narrow canals – dredging is not expected to significantly improve circulation.



Photo 2: Small mechanical dredging operation.

Placement of dredged material is an important component of each of the dredging alternatives. As discussed above, sediment sampling was performed to assist in determining conceptual placement alternatives. The reported values from the environmental sediment testing include total values for petroleum hydrocarbons, Extractable Organic Halides (EOX) and PCBs. The Toxicity Characteristic Leachate Procedure (TCLP) test criteria are used for other metals (ex. arsenic, lead, mercury, etc.) to represent constituents that could leach from the material with an acidic leachate. Results from this testing methodology is used by landfill operators to determine the acceptability of the material to be used as general fill or landfill cover, as well as tipping fees.

Landfills set tipping fees dependent on the type of material and testing results, as well as the landfill's need for cover material. These local landfills would require truck hauling the material to the landfills. The local landfills that could be considered include:

- WM, Bethel, Hampton
- SPSA, Suffolk
- City of Portsmouth
- Holland Enterprises, Suffolk

Moffatt & Nichol obtained quantitative thresholds for the analytes identified from three of the four area landfills. The thresholds, as compared to the test results on the composited samples, are summarized below in Table 4 for those chemical analytes above a non-detect limit. Testing frequency and requirements for these sites may vary, but have the basis for acceptance on the testing protocols discussed above.

Table 4: Detected Analyte Concentration Ranges and Surveyed Landfill Thresholds

Analyte	¹ Concentration Units	² Concentration Range in Sediments	Landfill Threshold Range
TPH-DRO	mg/kg (ppm)	16.4 - 876.4	50+
TPH-GRO	mg/kg (ppm)	BQL - 66.8	50+
PCB-1254	mg/kg (ppm)	BQL - 2.30	1 – 50
PCB-1260	mg/kg (ppm)	BQL - 3.40	1 – 50
Barium	mg/L	BQL - 0.61	100
Lead	mg/L	BQL - 1.95	5.0

¹Mass concentration units of mg/kg are totals, while volume concentration units of mg/L are TCLP results

²BQL: Below Quantitation Level

Being located within the Hampton Roads harbor, material removed from the Hague for navigation can be considered for placement at the Corps of Engineers' (Corps) Craney Island Dredged Material Management Area (CIDMMA). Dredged material from other City navigation projects, such as Broad Creek and the Lafayette River have been placed at CIDMMA. The Corps charges a tipping fee to dump the material (currently \$6.81 per cubic yard to bottom dump a barge into the re-handling basin), but may be less than that of an upland landfill. The advantage to using CIDMMA is the material can be barged and unloaded in the re-handling basin.

Note that the Norfolk District has adopted 500 parts per million (ppm) as the interim threshold for total petroleum hydrocarbon (TPH) that can be placed in CIDMMA (Navy, 2009). There is a single composited sample where the value was above 500 ppm that would require further delineation if CIDMMA is considered.

In addition to the above sites, the Port Weanak site on the James River has been used to accept dredged material for local dredging projects, and can be considered for this project. Material can be barged to the site, avoiding trucking fees. If necessary, Port Weanak also has the ability to stabilize impacted sediment and transfer to appropriate upland placement areas / landfill.

4.3.1. Localized dredging adjacent to outfalls

Removing sediment built up from runoff through outfalls and overland is akin to maintenance activities in an upland stormwater detention basin or pond. In this case, areas adjacent to outfalls have provided an area for soil to settle out. This alternative will remove this sediment in the areas of outfalls and provide additional capacity for future settlement of solids.



Photo 3: Sediments (sandy) exposed at low tide adjacent to an outfall.

This alternative would also remove impacted bottom sediments (ex. areas that may have elevated petroleum hydrocarbons), thereby improving bottom habitat. At this time, with the limited sediment composite test results, there is not sufficient data to support and delineate the necessity of dredging for remediating sediments, but is included in concepts for future consideration.

4.3.2. Large-scale dredging to previous (1970s) depth template

This alternative is based on a dredging project performed by the Norfolk Redevelopment and Housing Authority in 1974 to 1975 (VMRC, 1973). The project purpose was noted as improving water quality (mitigating odor) and providing small boat access. The project dredged the basin to a uniform depth of -8 feet MLW (approximately -10 feet NAVD88) except for the area between the pedestrian bridge and the Chrysler Museum; that canal end was dredged to -6 feet MLW (approximately -8 feet NAVD88). The lateral limits of the dredge template were offset at least 25 feet from the then-existing shoreline. Approximately 50,000 cubic yards were removed and placed at CIDMMA.

Present mudline elevations within the main portion of the Hague average between -6 to -8 feet NAVD88 (approximately -4 to -6 feet MLW). There remains sufficient depth for small recreational

boats that would be able to access the area through the bridges, but the basin is significantly shoaled since the 1970s project.



Photo 4: Boat moored in the Hague (ref: Bing Maps, 2013)

The water exchange within the Hague is limited by the relatively small daily tide range and the long, narrow shape of the canals that isolates the far ends of the canals. From results of a hydrodynamic computer model of tidal exchange in the Hague, it is estimated that the time to flush a non-specific conservative tracer from 100% to 10% of its initial concentration – near the far ends of the east and west canals – is approximately 3 to 6 days. Flushing occurs more swiftly in the southern arc of the Hague, i.e. between Pembroke Towers and the pedestrian bridge at Hague Towers.

It is expected that dredging, alone, would not provide a significant increase in water exchange and flushing times. However, deepening the presently shoaled ends of the canals would help to dilute nutrients and other pollutants in stormwater discharges, and could mitigate water temperature increases observed in those areas. The lower temperatures would allow for a higher dissolved oxygen saturation level in the ends of the canals.

4.4. Oyster Reefs

Oyster reef creation and restoration in the Elizabeth River and surrounding area has become a recognized means to improve water quality and mitigate for the areas with historically lost oyster reefs. For example, created/restored oyster reefs exist near the Portsmouth Marine Terminal, Fort Norfolk, and in the Lafayette River. This concept for the Hague considers constructing oyster reefs using similar methods with the purpose of benefiting water quality and habitat.

Oyster reefs are shown to improve water quality by their ability to remove suspended particles from the water through filtration. Oysters also enhance the ecosystem by providing habitat, for crabs and fish. The Virginia Institute of Marine Science (VIMS) has studied and concluded that oyster reefs, in

addition to reducing turbidity, improves water quality many ways including removing significant nitrogen (Kellogg, 2013).

Construction would involve use of oyster shell to build a 12 to 18-inch layer of shell on the exiting mudline. Alternative materials (such as stone or welk shell) have also been used to minimize the volume of required oyster shell. After shell placement the reefs are seeded with oyster spat (the larval stage of the oyster when it begins to develop a shell) on shell typically produced at a local hatchery. Best practice is to restore an oyster reef where there is evidence of prior reef and shell, or where the bottom is stable (sandy) so the shell does not settle into the bottom. In addition, oysters prefer high water circulation.



Photo 5: Oyster reef construction on the Lafayette River (Picture taken from Chesapeake Bay Foundation website, cbf.org)

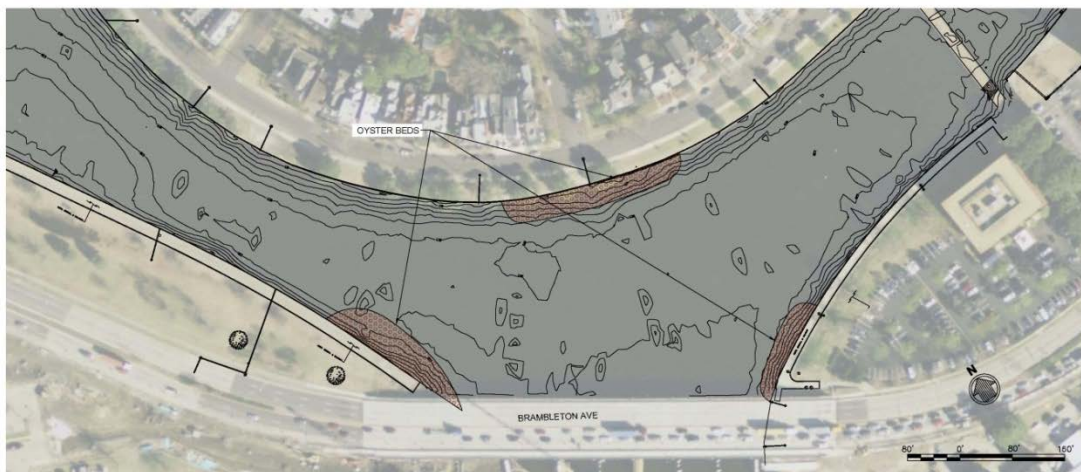


Figure 4: Concept layout of oyster reef restoration within the Hague near Brambleton Ave.

4.5. Wetlands

Creating or restoring wetlands improves water quality and provides ecosystem habitat. From observations of a historical chart, Smith Creek appears to have contained some fringe wetlands (see Photo 6 and Figure 1) prior to construction of the relieving platform that hardened the southwest Hague shoreline. Two concepts have been developed to create tidal wetlands within the Hague:

- Living Shoreline – restore wetlands to a reach of approximately 1,100 linear feet along the Hague’s southwest shoreline, paralleling Brambleton Avenue
- Living Cap – create wetlands by placing clean bottom sediment and planting tidal wetland species on top of capped impacted sediments, at the end of the east canal near the Chrysler Museum



Photo 6: Circa 1964 Aerial showing probable wetland fringe along southwestern shoreline of the Hague (source: Google Earth Professional)

4.6. Living Shoreline

Living shorelines use plants and sand fill, sometimes with stone or other structures to stabilize a shoreline while leaving a natural connection from upland to the water. This provides for shoreline erosion control, improved habitat for animals and fish, and beneficial filtration of stormwater as it passes through the wetlands. Wetlands provide for pollutant removal and nutrient uptake, and they reduce flow rates into the receiving body (refer to <http://ccrm.vims.edu/livingshorelines/index.html>). The concept developed for this project option would include a living shoreline adjacent to the shoreline along Brambleton Avenue, the area shown in Photo 7.



Photo 7: Potential site for living shoreline fronting promenade west of the Brambleton Ave bridge

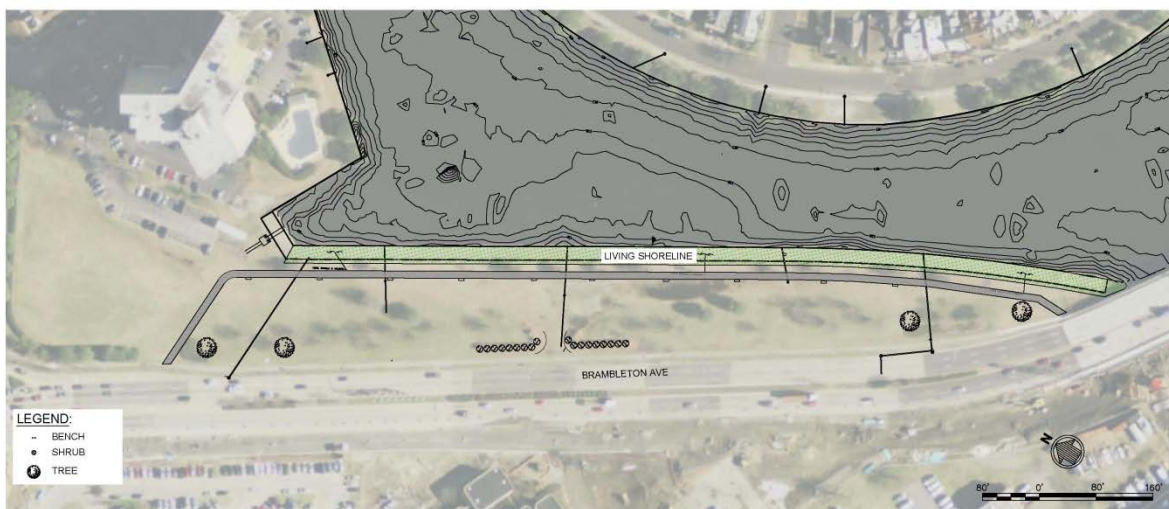


Figure 5: Concept living shoreline plan along present relieving platform line near Brambleton Ave.

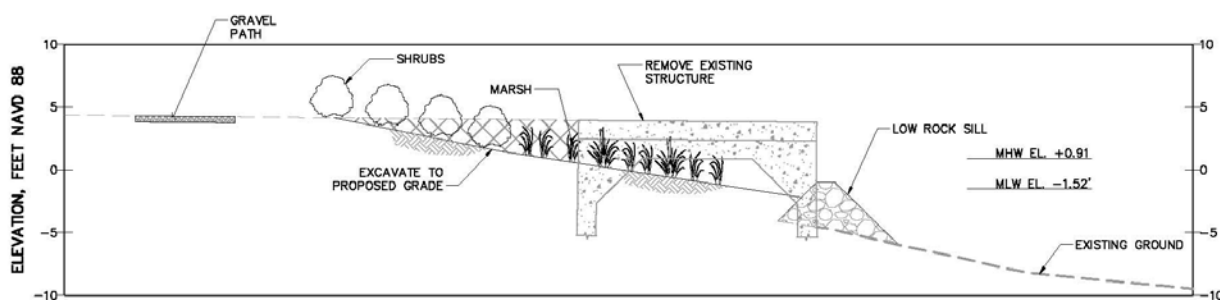


Figure 6: Concept section of living shoreline replacing existing relieving platform

4.7. Living Cap

Placing clean material over contaminated sediments is a method to cap contaminated sediments. The cap is generally constructed of granular material such as suitable/clean sand, silts, clays or gravel or mixtures thereof. More complex caps may include geomembranes, layers of treatment materials (carbon) or liners as deemed necessary. The purpose of the cap is to separate contaminated sediment from organisms living at the sediment – water interface to include burrowing organisms, prevent migration of contaminants, isolate the chemical contaminants from the overlying water and provide protection from breaching as a result of cap erosion or disturbance.

Capping of contaminated material in open-water sites began in the 1970's, and as of 2004, in-situ capping has been selected as a component of the remedy for contaminated sediment at approximately fifteen Superfund sites (USEPA, 2005). At some sites, in-situ capping has served as the primary approach for sediment, and at other sites it has been combined with sediment removal (i.e., dredging or excavation) and/or monitored natural recovery of other sediment areas (USEPA, 2005; USEPA, 2007).

Concept Description. A nominal 2 feet thick sand cap would be placed in areas where sediment testing verifies contamination at levels determined to be above some pre-determined effects range, such as NOAA's Sediment Quality Guidelines (NOAA, 1999). Wetlands could then be created on top of a portion of the sand cap that is placed for sediment remediation purposes. A low stone sill would be considered, along the channelward edge, to protect the sand cap from wave action. In addition, stone may be placed to provide adequate channel section for stormwater outfalls that would pass through the cap area. The area considered in this concept is shown in Figure 7.

Benefits. The sand cap provides a clean surface which benthic organisms could populate as natural river sedimentation improves the habitat. Wetlands provide the benefits described above: pollutant removal, nutrient uptake, and reduced flow rates.

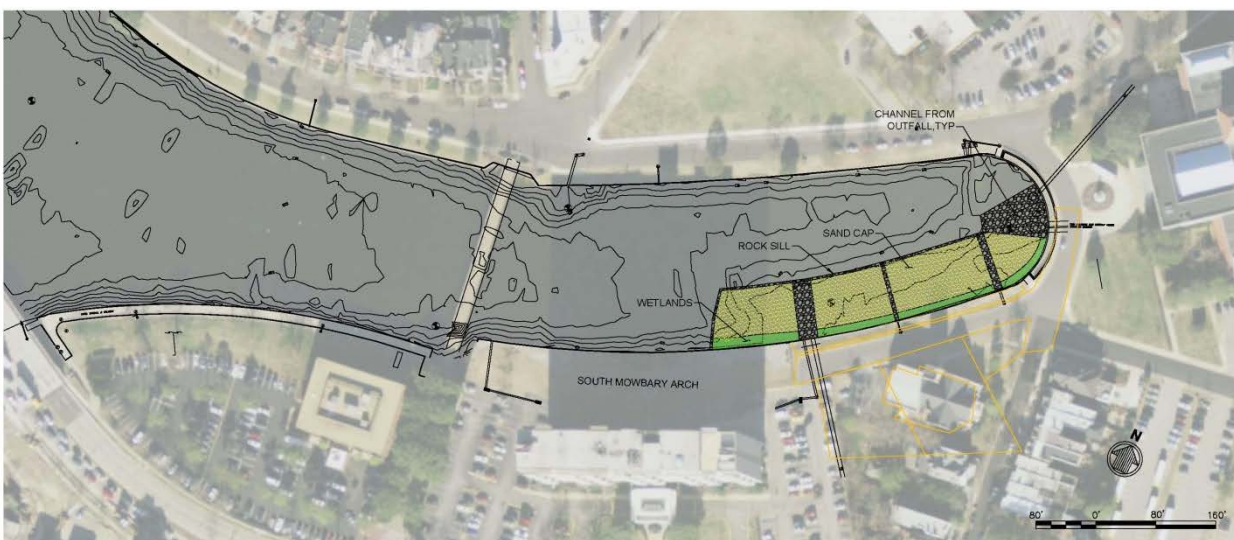


Figure 7: Concept living cap with wetlands in east canal near Chrysler Museum

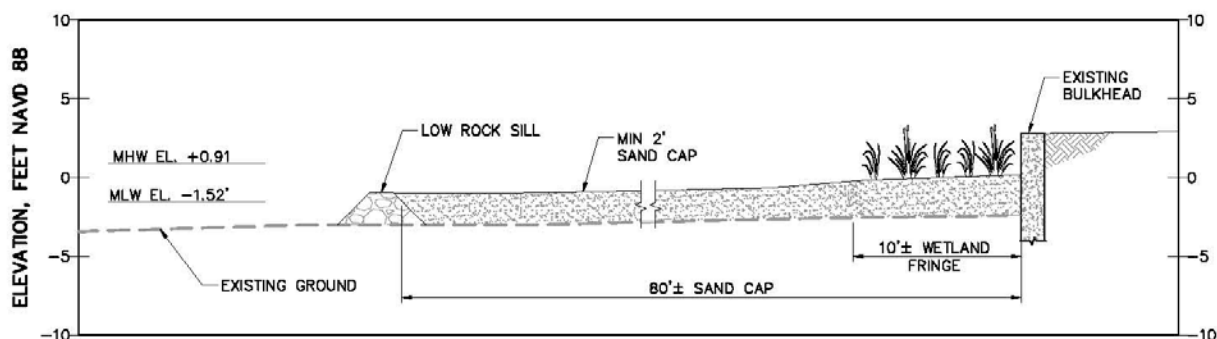


Figure 8: Concept section of living cap

4.8. Permitting Considerations

The in-water concepts discussed above will require coordination with the Virginia Marine Resources Commission (MRC), US Army Corps of Engineers (Corps), The Virginia Department of Environmental Quality (DEQ) and local review committees and civic league groups. A Joint Permit Application would be submitted to the MRC and be forwarded to all applicable agencies that would require review and issuance of permits based on the areas of impacts of each specific concept.

4.9. In-Water Conclusions and Recommendations

Unfortunately, determination of the effectiveness of the in-water best management practices to reduce TMDLS for the Chesapeake Bay Program is still being established. Coordination is required with the Chesapeake Bay Program's Water Quality Goal Implementation Team (Chesapeake Bay Program, 2010). In addition, because some or all of these projects are in the water, the state has apparently suggested that in-water BMPs would be a state credit, as opposed to the City – this requires further discussion with the state to negotiate that effort by the City for these project would count as credit to the City.

Table 5: In-Water Improvement Summary

Concept	Order-of-Magnitude Cost	Benefits
Dredging Removal of sediment by outfalls	\$0.6M to \$0.8M \$80 to \$102/CY	Open flow from outfalls. Restore sedimentation bays at outfalls.
Dredging Restore to 1970s project	\$1.1M to \$1.6M \$58 to \$81/CY	Open flow from outfalls, allow for sedimentation, and increase volume which may have water temperature, DO, and pathogen dilution benefits.
Oysters	\$820,000 for 1.3 acres	Water quality improvement from nutrient uptake, reduced turbidity; habitat enhancement
Living Shoreline Along Brambleton Ave	\$1.7M for 1,100LF (\$1,500/LF)	Water quality improvement from nutrient uptake, reduced turbidity; habitat enhancement
Living Cap Adjacent to Chrysler Museum	\$820,000	Water quality improvement from nutrient uptake; clean substrate for habitat enhancement

5. Water Quality Improvement via Stormwater BMPs

In addition to determining required maintenance of outfalls discharging to the Hague, the City is looking for opportunities to improve the quality of stormwater entering the Hague from the collection systems.

This chapter focuses on opportunities to treat stormwater before it is discharged into the Hague, as opposed to the in-water opportunities described above. The chapter begins with a brief discussion of existing regulations and requirements for stormwater pollutant reduction. Alternative BMPs are presented with specific examples of how each type of BMP could be implemented within the Hague watershed; the BMP discussions include concept-level opinions of probable cost, estimated pollutant removal efficiencies, and qualitative discussions of required maintenance.

5.1. Overview of Regulations and Need

Establishment of the Chesapeake Bay Total Maximum Daily Load (TMDL) by the EPA in December 2010 introduces an additional program for which water quality improvements will be necessary to demonstrate compliance. Under this program, each contributing watershed is assigned pollutant limits and improvement goals for further reduction. Numerous water quality improvement strategies have been identified, including both stormwater treatment improvements and in-water improvements. However, the consensus on the effectiveness of each strategy has not been achieved, nor has the system to track implementation been finalized.

Each watershed state must develop a Watershed Implementation Plan (WIP) to identify how these limits will be adhered to and improvements achieved. The WIPs are being developed in phases with Virginia having most recently published the Phase II WIP in March 2012. This 2012 WIP reflects ongoing development of the Phase I WIP following substantial stakeholder interaction.

Within Virginia's Phase II WIP, the state has identified numerous strategies for improving water quality in urban environments, including promotion of bioretention and other low impact development practices, improved erosion and sediment control practices, stormwater facility retrofit programs, and shoreline restoration and outfall improvements. While not specifically identified as a strategy in Virginia's WIP, EPA's watershed model being developed to track TMDLs will also account for the beneficial impacts of filter feeders such as oysters to water quality.

However, the TMDL program is still under development. At the time of this report, task forces are still developing uniform criteria for determining the effectiveness of the various strategies in the context of pollutant load reductions, as well as the system that will be used by local watersheds to report and track their efforts.

In Virginia, the intent is to develop the Virginia ePermitting System to track proposed water quality improvement projects. Data collected by this system will be shared with the National Environmental Information Exchange Network (NEIEN), from which the Chesapeake Bay TMDL model will retrieve its input data for tracking watershed progress. A planning tool, the Virginia Assessment and Scenario Tool (VAST), is available (with ongoing development as the TMDL model develops) to assist stakeholders with identifying which strategies may be most effective.

Appendix E includes details and references to the development of the stormwater regulations and programs and provides an overview of stormwater treatment.

The following sections provide an overview of concepts of alternatives that can be considered for assisting the City to meet TMDL targets, and they provide material for discussing these alternatives with state regulators.

5.2. BMP Alternatives for Treatment Prior to Entering the Hague

The following BMPs are presented as typical applications which may, on a case-by-case basis, be a feasible alternative to providing stormwater treatment to runoff prior to discharging into the Hague.

- Retention Pond
- Constructed Wetland
- Hydrodynamic Separator
- Bioretention Area
- Biofilter (Filterra)
- Biofilter (Site Design)
- Permeable Pavement

5.2.1. Retention Pond

Concept Description

Retention ponds (wet ponds) are designed to provide a permanent pool of water, which acts as a calming mechanism to promote settlement of suspended solids as stormwater is routed into the pond. The basins are typically landscaped and planted to promote biological uptake as well.

Critical features of a retention pond include:

- 15 – 20 acre minimum watershed to ensure a permanent pool of water is maintained unless groundwater can be shown to support smaller basins.
- 20-foot wide vegetated buffer and other pretreatment features to filter out pollutants prior to introduction to the main water body.
- Attention to attractiveness and safety features commensurate with its level of public exposure.

Concept Placement

Candidate sites for a retention pond would be limited to the open areas near the Hague (Figure 9). Other locations may work from a hydraulic standpoint, but aesthetic and safety concerns would likely keep such concepts from being selected.

A proposed pond in some or all of the area indicated would likewise need to address public safety and aesthetic concerns, but since it is within an open area away from developed residential areas, there would be greater opportunity to incorporate attractive elements such as a walking trail, benches, and decorative landscaping into the design.

This area is also immediately adjacent to and partially disturbed by ongoing improvements to Brambleton Avenue.

Treatment Effectiveness

Excess storage capacity further increases the residence time of the stormwater to enhance treatment effectiveness. The Virginia Stormwater Management Handbook provides three design levels (Retention Basin I – III) to achieve different removal rates, ranging from 40% to 65% reductions, based on the size of the designed basin relative to the design rain volume (i.e. water quality volume).

The concept pond would receive runoff primarily from minor Brambleton Avenue drainage systems (D14171, D14165, D14158, D14153, D14149). Based on preliminary calculations, a Retention Basin I could be achieved, which is based on providing a storage volume of 3 times the calculated water quality volume associated with the 17.89 acre total basin size.

Using the CBP pollutant removal rate protocol for retrofit BMPs, this achieves 57%, 37%, and 74% reductions in Total Phosphorus, Total Nitrogen, and Total Suspended Solids, respectively. This corresponds to annual reductions of 17.80 lbs/yr TP, 69.99 lbs/yr TN, and 5.05 tons/year TSS.

Maintenance

Routine maintenance of retention ponds generally consists of annual visual inspections and general landscape maintenance. Sediment removal frequency is based on the design sediment storage volume. Typical designs are based on removing sediment every 5 to 10 years. Permits and sediment testing are typically necessary prior to removing the sediment.

Order-of-Magnitude Cost

A conceptual opinion of probable construction cost for the footprint shown on Figure 9, including incorporation of pedestrian walkway, amenities, and landscaping is \$550,000.

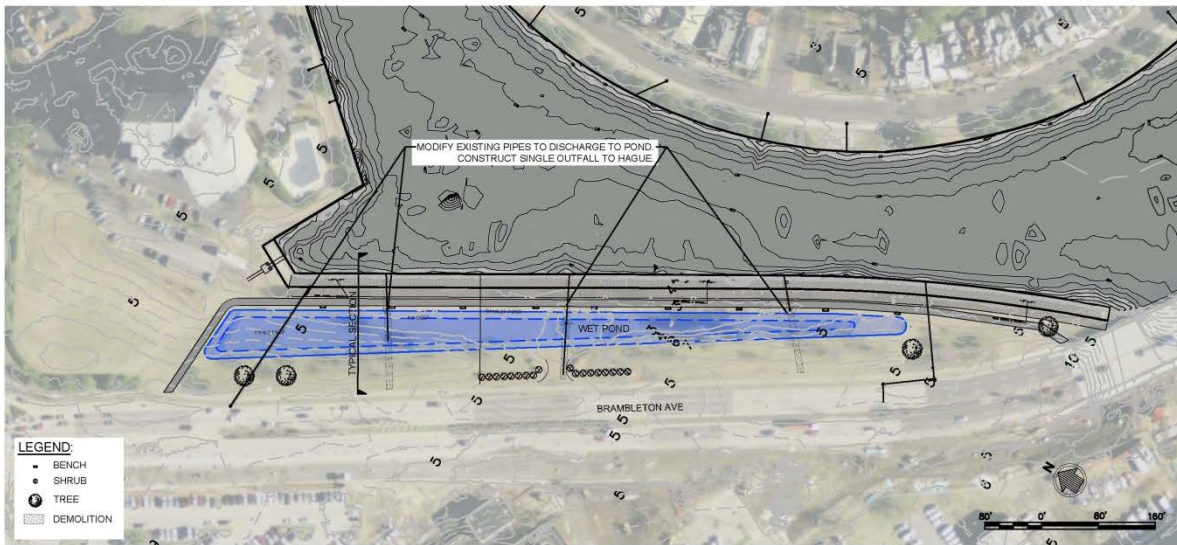


Figure 9: Retention pond concept

Table 6: Retention pond concept summary

Order-of-Magnitude Cost	Drainage Area Treated (Acres)	TP Reduction (lbs/yr)	TN Removal (lbs/yr)	TSS Removal (tons/yr)
\$550,000	17.89	17.80	69.99	5.05

5.2.2. Constructed Wetlands

Concept Description

Constructed wetlands are similar to retention ponds, but are shallower and incorporate a greater density of vegetation. The dense vegetation promotes settlement of solids and biological uptake.

Critical features of a constructed wetland include:

- 15 – 20 acre minimum watershed to ensure a permanent pool of water is maintained unless groundwater can be shown to support smaller basins. A clay liner to inhibit infiltration may also be necessary.
- Pretreatment features such as a forebay to filter out heavy sediments prior to introduction to the main wetland body.
- Four depth zones to support diversity of vegetation and animal life.
- Attention to attractiveness and safety features commensurate with its level of public exposure.

Concept Placement

As with the retention pond, potential siting of a wetland is limited to the open space between the Hague and Brambleton Avenue within the same conceptual footprint and with the intent to treat the some or all of the same storm drain systems (D14171, D14165, D14158, D14153, D14149).

However, the dense wetland vegetation does not lend itself to deliberate landscaping and is more prone to stagnation, which introduce greater challenges to adopting the BMP to a more formal and attractive public space consistent with the adjacent landscaping. One approach to addressing these concerns is to develop the wetland as an educational exhibit.

Treatment Effectiveness

Due to wetlands being shallower than retention ponds, the storage volume is smaller. For a given BMP footprint, the retention pond will be capable of treating a larger drainage area than the wetland. Preliminary concept calculations suggest that a constructed wetland in the selected location may only be able to effectively treat approximately 12.4 acres (D14165, D14158, D14153). Per the CBP removal rate protocol, this translates to 50% (10.85 lbs/yr) TP, 32% (42.03 lbs/yr) TN, and 65% (3.02 tons/yr) TSS reductions.

Maintenance

Routine maintenance of constructed wetlands typically consists of periodic visual inspections for flow obstructions, sediment buildup, vegetative health, and invasive plant species. More frequent inspections and corrective actions will likely be necessary for the first few years until the desired vegetation is well-established. Removal of sediment from the forebay should occur every 3 to 5 years, or when excessive sediment build up is observed. This maintenance, unlike sediment removal from a retention pond, can be performed with the need for state or federal permits. Sediment testing is still recommended, however, to ensure proper disposal.

Order-of-Magnitude Cost

It is anticipated that the wetland concept pictured in Figure 10 could be constructed for a cost of approximately \$500,000, including public access amenities and related improvements.

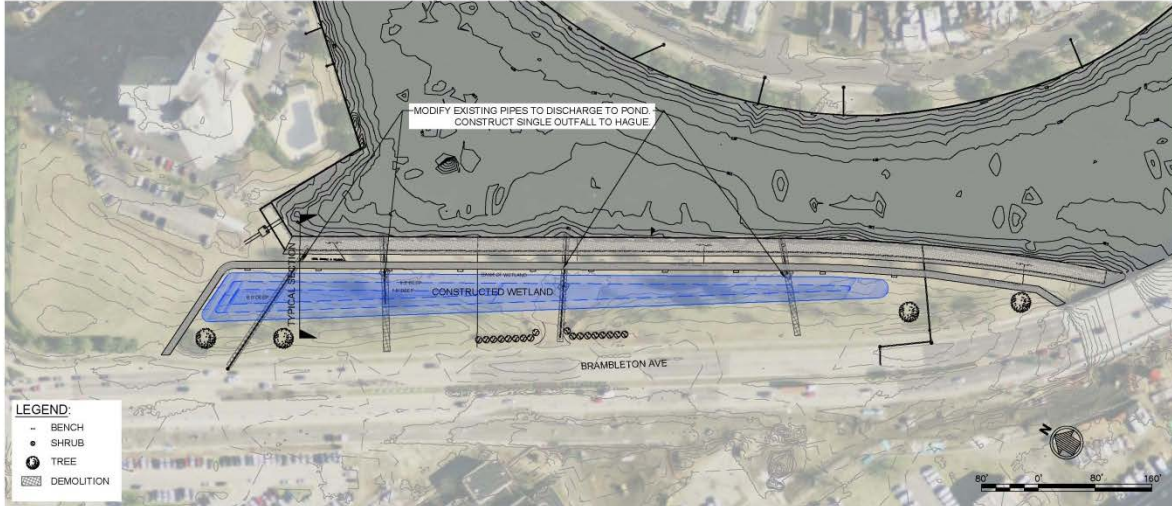


Figure 10: Constructed wetland concept

Table 7: Constructed wetland concept summary

Order-of-Magnitude Cost	Drainage Area Treated (Acres)	TP Removal (lbs/yr)	TN Removal (lbs/yr)	TSS Removal (tons/yr)
\$500,000	12.42	10.85	42.03	3.09

5.2.3. Hydrodynamic Separator

Concept Description

Several manufactured systems are available to treat stormwater via hydrodynamic separation and are typically in the form of a manhole or underground vault structure. Design of these structures are based on treating a specified flow rate and are substantially smaller than wet vaults, which are designed based on achieving a specified volume. Popular systems include the Contech CDS unit, Contech Vortechs system, Rinker Stormceptor, BaySaver Technologies BaySeparator, and the Hydro International Downstream Defender.

Critical features of hydrodynamic separators include:

- Typically direct flow structures that require consideration of peak system flow rather than just treatment flows. Diversion structures may be added to control treatment structure size.
- Relatively low headloss across structure
- May need additional anchoring features to address buoyance issues in areas with high ground water.

Concept Placement

Site suitability is dependent on being able to accommodate the size of underground structure necessary to handle to peak flow of the upstream system being treated. Candidate sites include:

- The open space between the Hague and Brambleton Avenue to treat one or more minor systems (D14171, D14165, D14158, D14153).
- System E143000 (partial) - Within the ball fields and other open areas surrounding Maury High School and Ghent Elementary School
- System D14240 (Brambleton Ave / Colley Ave)
- System D14860 (Colley Ave / Eastern Virginia Medical School)
- System E14200 (Botetourt Street system).
- System E145200 (Grace St. and Duke St.)

Concept Example – Maury High School w/ Rinker Stormceptor unit

This concept constructs an underground Rinker Stormceptor hydrodynamic separator BMP in the baseball field area north of Maury High School to treat runoff from approximately 17.9 acres dense development (93% impervious) prior to its eventual discharge through outfall D143000. See Figure 11 and Figure 12 for concept plan and details.

Based on the drainage size, the structure needs to be sized to provide treatment to 10.47 cfs with the ability to handle (i.e. bypass) up to approximately 75 cfs (10-year peak flow rate). This corresponds to 3 Stormceptor STC 16000s units. [Each STC 16000s unit is capable of treating 7 acres of developed urban land (CN=93)].

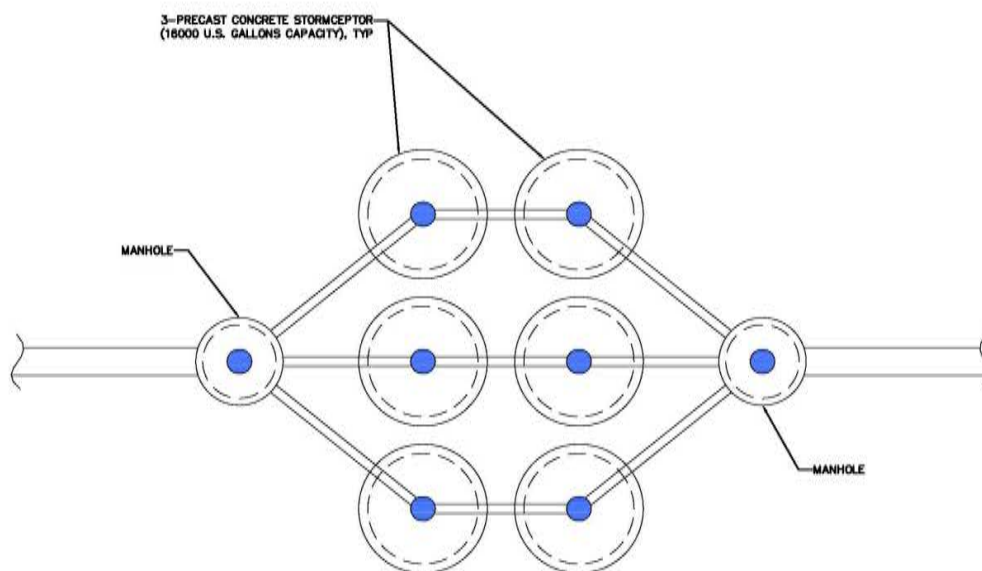


Figure 11: Concept example – Maury High School



Figure 12: Typical Stormceptor 16000s unit

Treatment Effectiveness

Effectiveness of hydrodynamic separators remains under some debate. While each respective manufacturer will advertise relatively high removal rates (primarily for suspended solids), regulatory agencies appear to be reluctant to concur. Virginia has established a presumptive removal rate for total Phosphorus of 15% to 20%, with indications that it may be adjusted in the future as further testing is carried out. Other states have relegated hydrodynamic separators to be pretreatment structures intended to replace the presettlement bays of volume-based BMPs.

Based on Virginia's average presumptive removal rate is 17.5%, which is based on monitoring efforts, the concept example would remove 6.07 lbs/year of total Phosphorus (using 34.70 lbs/year baseline concentration).

Specific guidance for determining removal rates with hydrodynamic separation BMPs has not been published for the CBP. Use of the retrofit protocol results in substantially higher removal rates. However, it is likely that as the program develops, additional guidance will be issued and credit for standalone hydrodynamic separators will be reduced, particularly for Phosphorus and nitrogen components.

Maintenance

Biannual inspection is recommended to ensure proper functioning and structural integrity. If frequent debris build up is observed, inspection frequency should be increased accordingly. The frequency of sediment removal will be governed by the typical influent quality and effective removal rates, but is typically done on a quarterly basis. Sediment removal is most often performed by a vacuum truck. Based on the baseline sediment levels (7.75 tons/year), projected removal rates (65%), and sediment

storage capacity of the concept Stormceptor model, sediment removal would be necessary approximately once per year.

Order-of-Magnitude Cost

The order-of-magnitude cost for the example concept is \$730,000 which includes site demolition, excavation, construction, and site restoration efforts.

Table 8: Hydrodynamic separator concept summary

Order-of-Magnitude Cost	Drainage Area Treated (Acres)	TP Removal¹ (lbs/yr)	TN Removal¹ (lbs/yr)	TSS Removal¹ (tons/yr)
\$730,000	17.91	8.39	64.48	5.04

¹Based on current CBP protocol. M&N anticipates future reductions to credit granted for hydrodynamic separators.

5.2.4. Bioretention Areas

Concept Description

Bioretention areas are shallow landscaped depressions designed to restore natural infiltration processes in developed areas. These functions include promoting infiltration of captured runoff into the groundwater and, where exceeds infiltration rates, provide treatment and detention.

Bioretention areas are typically designed to store between 6 to 12-inches of stormwater (depending on local standards) and which is subsequently infiltrated through a designed soil bed over a short period following the rain event (typically 24 hours). Where subgrade conditions do not support long term infiltration, underdrain pipes can be provided to convey the treated stormwater to a storm drain.

As a landscaped area, care should be taken to design a bioretention area to be compatible with the character of its surroundings. Construction should also not be proposed near mature trees where root damage could occur.

Critical components of a bioretention area include:

- Buffer features to allow pretreatment and spreading of incoming stormwater to prolong soil bed life.
- A shallow storage volume.
- Ground cover / mulch to reduce weed establishment.
- Plants selected for the climate and varying soil moisture conditions
- Designed soil bed including amendments and mulch to promote filtration and vegetation growth.
- Drainage layer with or without an underdrain
- Overflow feature to bypass runoff exceeding the design limits.

Concept Placement

Bioretention areas are typically placed adjacent to impervious surfaces such as parking lots, roads, and roofs to capture and store runoff. Their effectiveness is further enhanced if they are integrated into a site design such that runoff patterns are dispersed (as opposed to concentrated at one or two outlet locations).

Candidate locations within the study area include, but are not limited to:

- Boulevard areas adjacent to De Bree Avenue in vicinity of Maury High School (system D143000)
- Boulevard areas along Stockley Gardens (system D143000)
- South side of Mowbray Arch (systems D1489, D1491, D1496, D14101, etc)
- South side of Dundaff Street (systems H07-H08, D14860)
- Private landscape and lawn areas adjacent to parking lots (case-by-case basis)

Concept Example – South Mowbray Arch

Construction of a bioretention area indicated in Figure 13 would provide stormwater treatment to approximately 1.09-acres of urban development. The proposed locations coincide with existing storm drain inlets to make use of existing drainage patterns to convey the surface runoff to the bioretention areas. The existing storm drain infrastructure would likewise be used to receive treated runoff above the infiltration capacity of the subgrade, as well as be part of the overflow system. A typical section is shown in Figure 14.

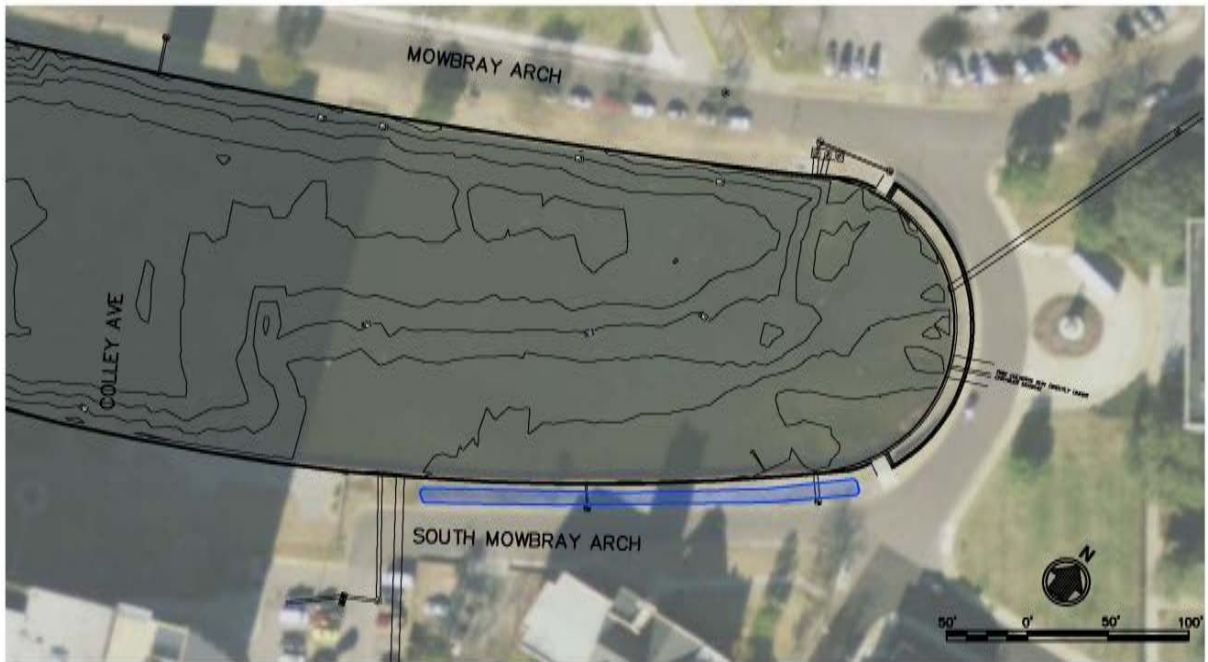


Figure 13: South Mowbray Arch bioretention area concept plan

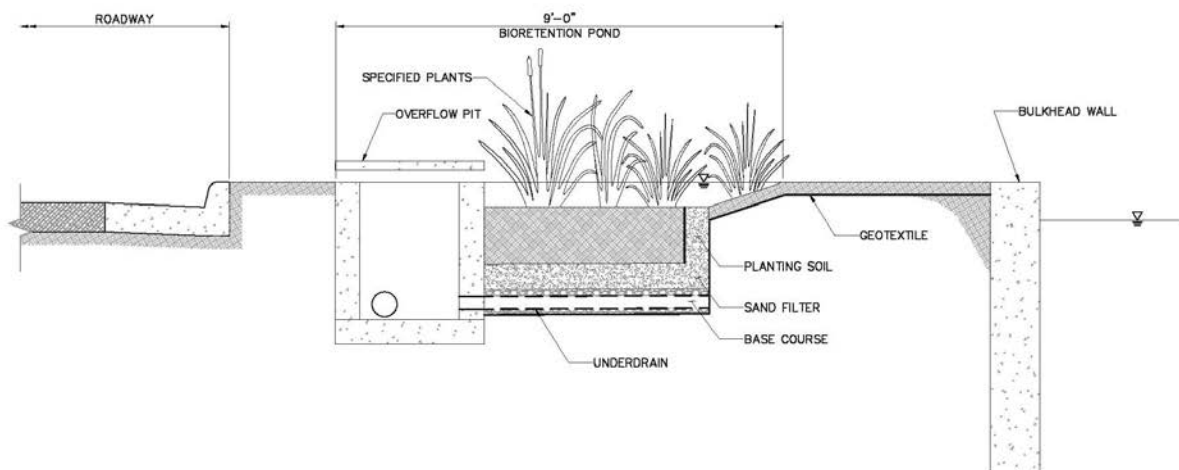


Figure 14: South Mowbray Arch bioretention area typical section

Treatment Effectiveness

State-approved removal rates for bioretention areas are based on the design runoff capture volume, expressed in inches of rainfall. An area designed to capture 0.5-inches of rainfall is presumed to remove 50% of total Phosphorus. An area designed to capture 1.0-inches is presumed to remove 65%.

The concept example design was based on state guidelines (which specify the basin area to be a percentage of the contributing impervious area) to capture the 1.0-inch event. However, using the CBP protocol, the storage volume was calculated to store 0.61-inches of stormwater. This equates to reductions of 0.87 lbs/year (57%) TP, 5.67 lbs/year (47%) TN, and 0.18 tons/year (60%) TSS.

Maintenance

Bioretention area maintenance activities primarily consist of those typical to landscaping. The Virginia Stormwater Management Handbook recommends monthly inspections, 6-month pruning, annual mulch additions with full mulch replacement every two to three years.

Order-of-Magnitude Cost

The cost to construct the bioretention areas in the concept example are projected to be \$60,000 assuming no major utility improvements are necessary.

Table 9: Bioretention area concept summary

Order-of-Magnitude Cost	Drainage Area Treated (Acres)	TP Removal (lbs/yr)	TN Removal (lbs/yr)	TSS Removal (tons/yr)
\$60,000	1.09	0.87	5.67	0.18

5.2.5. Biofilter Systems

Concept Description

This report regards bioretention and biofilters as different systems, though product literature and regulatory descriptions may treat them as the same category and use the terms interchangeably.

Biofilter systems, in this report, refer to BMPs that use filtration as the primary treatment mechanism, with vegetation providing additional mechanical filtration and long-term maintenance of the filter media (e.g. the continual, albeit slow, disruption of the filter bed by developing root system and attracted microfauna). Biofilter BMP alternatives include both manufactured units contained within in-ground structures like planter boxes, and site-developed alternatives such as specially constructed landscape areas. Example manufactured products are the Contech Biofilter, Americast Filterra System, and Modular Wetlands Systems.

Unlike bioretention BMPs, biofilters do not provide a significant storage volume, prolonged drawdown following a storm, and significant infiltration. Treated effluent from biofilters is collected by underdrains connected to a traditional storm drain (or ditch) system for subsequent conveyance. Infiltration features may be included in the design, but are not the primary mechanism for discharging treated runoff.

Critical features of biofilter systems include:

- Amended soil filter media
- Vegetation
- Erosion control and flow spreading features as necessary
- Underdrain w/ connection to storm drain system.
- Overflow/bypass structures to prevent adverse local flooding

Concept Placement

Filtration as the primary mechanism necessitates the presence of a hydraulic gradient to move the runoff through the filter media. Combined with the vegetative element, which must receive sunlight, practical placement of biofilter BMPs is at surface inlet locations such as inlet retrofits (in the case of manufactured biofilter units), or where runoff can be allowed to sheet flow in open landscape areas. The vegetative element also introduces the need to consider site aesthetics (e.g. a small shrub or tree may be inappropriate for an residential street lined with well-maintained lawn and carefully spaced mature trees).

Manufactured units typically replace conventional storm drain inlet structures and feature small trees, shrubs, and other landscape vegetation. Candidate locations within the study area are upstream inlet structures, which would need to be evaluated on a case-by-case basis.

Site-developed biofilter BMPs are typically landscape or lawn areas adjacent to paved areas that can be graded to convey sheet flow to the BMP. Curbed sites may be considered if curb cuts and flow

spreading features are provided. Impacts to other infrastructure such as sidewalks would need to be evaluated in these cases. Within the study area, candidate locations are:

- South side of Mowbray Arch (systems H13 thru H25)
- South side of Dundaff Street (systems H07-H10)
- Private landscape and lawn areas adjacent to parking lots (case-by-case basis)

Concept Example #1 – Inlet Retrofit with Filterra system (1/2 acre treatment area)

Treatment effectiveness and cost projection is based on replacement of inlet structure that drains a 1/2-acre urban area with a Filterra System. State guidelines establish a minimum required Filterra bed size as a percentage (0.33%) of the contributing impervious area. Therefore, for a 1/2 urban drainage area, the minimum required Filterra area would be approximately 72 ft², could be 2 standard 6-ft by 6-ft units, or a custom unit designed for specific site constraints. See Figure 15 for typical detail.



Figure 15: Typical Filterra retrofit

Concept Example #2 – Site-developed biofilter adjacent to Dundaff Street

Biofilters may also be designed as landscape areas where space permits but temporary storage of runoff is not desired (i.e. bioretention). Concept Example #2 is based on construction of a biofilter area adjacent to Dundaff Street and is intended to capture runoff that discharges through systems H09 and D14860. See Figure 16 and Figure 17 for concept plan and typical section.

Sizing guidelines for generic, flow-based biofilters have not yet been identified by DEQ beyond those of the Filterra unit. For this concept example, a design developed by the Washington State Department of Transportation was used. This design (referred to by WSDOT as a media filter drain) is intended to be a very low maintenance BMP suitable for linear placement along roadways. The system consists of a suitable grass planted in an amended soil material designed to maintain high long-term infiltration rates. Under the amended soil is a drainage layer with underdrains to convey the treated runoff to its discharge point.

Based on WSDOT guidelines and using the TR-55 peak runoff for a 1" storm event, a 10-ft wide strip along the full length of the 205-ft site would be able to treat the incoming runoff.



Figure 16: Concept plan for Dundaff Street biofilter



Figure 17: Sample site-developed biofilter concept

Treatment Effectiveness

Concept Example #1 – Inlet retrofit: DEQ design guidelines for Filterra units are based on treating a 1” storm event. While not having a significant storage volume, the 1” volume was used to estimate removal rates. Further clarification from the Chesapeake Bay Program may be necessary. For the 1/2-acre site, the 1” volume equates to reductions of 0.54 lbs/yr (53%) TP, 1.85 lbs/yr (34%) TN, and 0.15 tons/year (65%) TSS.

Concept Example #2 – Site-developed biofilter: As with the Filterra unit, estimation of the storage volume for flow-based treatment for determining the CBP removal rates is left somewhat open to interpretation. Using the same removal rates as the Filterra unit (as both concepts are based on the 1” storm event), the treatment of the 1.04-acre drainage area yields reductions of 0.78 lbs/yr TP, 3.62 lbs/yr TN, and 0.20 tons/year TSS.

Maintenance

Maintenance activities for biofilters are consistent with maintained landscaping, including periodic inspections, removal of debris, replacement of mulch (if used), and pruning (as applicable).

Order-of-Magnitude Cost

Concept Example #1 – Replacement of an inlet structure with a biofilter structure in an urban environment will typically cost approximately \$60,000 assuming no utility relocations or significant modifications to the receiving storm drain.

Concept Example #2 – Construction of a site-developed biofilter in the example provided is projected to be \$60,000 based on the necessary curb alterations, site grading, and biofilter construction.

Table 10: Biofilter concept summary

Concept	Order-of-Magnitude Cost	Drainage Area Treated (Acres)	TP Removal (lbs/yr)	TN Removal (lbs/yr)	TSS Removal (tons/yr)
#1 Inlet Retrofit with Filterra Units	\$60,000	0.50	0.54	1.85	0.15
#2 Site-Developed Filter	\$60,000	1.04	0.78	3.62	0.20

5.2.6. Permeable Pavement

Concept Description

Permeable pavement (also referred to as porous or pervious pavement) is the general term for any pavement system designed to allow runoff to infiltrate through it. Concrete, asphaltic concrete, and unit paver systems have all been successfully implemented.

The permeable wearing layer of concrete or asphaltic concrete pavement systems is achieved by selecting a mix design using a very low percentage of fine aggregate that results in 12 to 20 percent interconnected void space by volume. Unit paver systems use shapes with full depth holes that are filled with aggregate.

Under the wearing layer is a filter or choker course of 3/8" to 5/8" aggregate, intended to provide a stable surface for the pavement above. Beneath the filter course is a base reservoir layer of larger aggregate (1.5" to 2.5" stone). Runoff in the base reservoir can either be allowed to infiltrate into the subgrade (if conditions allow), or be collected by an underdrain system.

For retrofit applications, as being considered in this report, the existing storm drains are used to convey the treated runoff to outfalls. Existing inlet structures are retained to serve as overflow structures in the event of large storm events or surface clogging.

Treatment is primarily accomplished through filtration, settlement, and infiltration, though biological uptake by microorganisms has also been observed.

Concept Placement

Permeable pavement performs optimally in relative flat locations where it is not subject to heavy traffic. Its life is further prolonged in designs that avoid exposure to sediment and debris-laden runoff that may accelerate clogging.

Within the study area, the numerous residential streets and parking lots with little to no truck traffic are candidates, though each proposed site would need to be evaluated for ultimate suitability. The impact of location within flood zones, if such a location was considered, would likewise need to be evaluated. Use of permeable pavement for driveways and walkways is also beneficial.

Concept Example – Stockley Gardens

Stockley Gardens is a candidate location for permeable pavement construction due to its relatively light and truck-free traffic exposure. Within this example, a 270-foot long block, plus two 100-foot long cross segments are converted to pervious pavement (both directions of travel – approximately 25-feet wide each way), resulting in .39-acres of roadway plus 1.00-acre and 0.45-acres contributing impervious and pervious area, respectively (total drainage area 1.84-acres). Figure 18 and Figure 19 illustrate the concept plan and pavement section.



Figure 18: Stockley Gardens permeable pavement concept plan

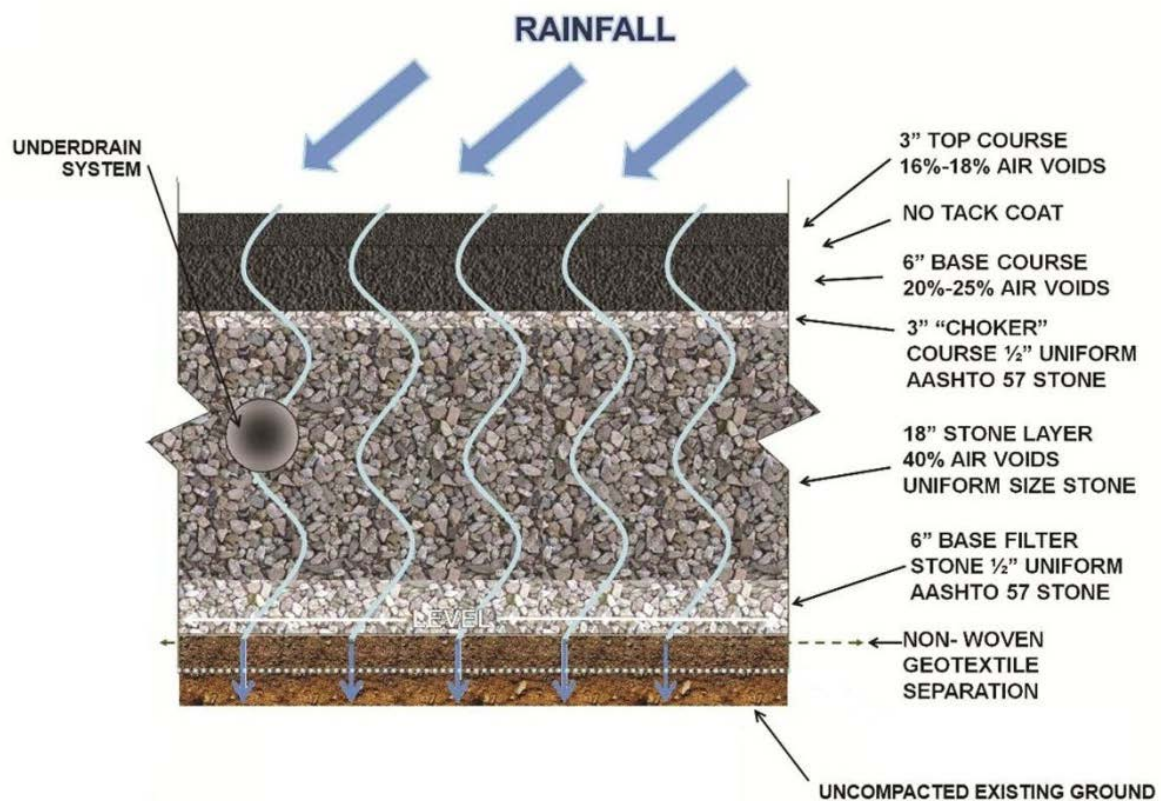


Figure 19: Stockley Gardens permeable pavement concept pavement section

Treatment Effectiveness

Based on the CBP protocol, installation of permeable pavement based on a 1” treatment flow without infiltration (i.e. the storage layer will discharge to existing storm drains via an underdrain pipe) will provide reductions of 53% (1.63 lbs/yr) TP, 34% (6.55 lbs/yr) TN, and 65% (0.43 tons/yr) TSS.

Maintenance

Frequency of maintenance is impacted by the runoff conditions and incorporation of mitigating design elements. The primary maintenance tasks are efforts to maintain the porosity of the pavement. This is typically accomplished with a semi-annual street sweeping using a vacuum cleaning sweeper truck, followed by a high pressure washing. Application of sand or other abrasive material during winter months should be minimized.

No practical measures exist to unclog pavement other than total replacement. However, if clogging is contained to localized areas only, the pavement as a whole should have sufficient capacity to drain the runoff.

Order-of-Magnitude Cost

Cost to remove the existing pavement and construct the indicated pervious pavement system is projected to cost \$320,000 and assumes no major utility work will be necessary.

Table 11: Pervious pavement concept summary

Order-of-Magnitude Cost	Drainage Area Treated (Acres)	TP Removal (lbs/yr)	TN Removal (lbs/yr)	TSS Removal (tons/yr)
\$320,000	1.84	1.63	6.55	0.43

6. Stormwater Treatment BMP Implementation Strategies

Successful implementation of widespread stormwater treatment improvements typically relies on a strategy that incorporates careful planning of projects supported by outreach and policy efforts, which altogether can comprise a “Stormwater Master Plan”. The City’s development of its general master plan (*PlaNorfolk2030*) includes development of a Stormwater Master Plan as an action item. A program to implement stormwater treatment upgrades to the Hague watershed would be a subset of this plan.

The following is a brief discussion of elements of a master plan that could be considered.

6.1. Programmatic Approach

Two approaches to defining a stormwater treatment retrofit to the Hague watershed are available, with the final program likely to benefit from incorporating both.

Street Planning: Street planning identifies both the location and type of BMP, typically along one or more streets. Identifying feasible BMPs and defining the plan provides the opportunity for it to be implemented incrementally in conjunction with other projects, or as a standalone project. This flexibility can be useful for pursuing grant opportunities or as a negotiating tool for approval of proffers or private development.

Another key component of street planning is communicating a vision of the final condition, particularly for areas with distinctive aesthetics such as the Hague.

Examples of this approach for the Hague could include:

Green Streets: An overall program to construct permeable pavement with biofilters (where appropriate) along suitable streets. Stockley Gardens, Botetourt Gardens, Warren Crescent, Pembroke Avenue, and Fairfax Avenue would be typical candidate locations to consider.

Brambleton Storm Gardens: An overall program to implement stormwater treatment BMPs such as a wet pond, bioretention areas, and biofilter areas along the Hague in conjunction with pedestrian improvements (e.g. a trail around the pond) and educational features such as placards that communicate the various aspects of stormwater management. This could also be integrated with living shoreline and oyster reef improvements.

Opportunistic Improvements: An opportunistic approach recognizes that there are BMP retrofits available that don’t require significant planning or coordination with other projects to successfully implement. These opportunities can be pursued as a specific item within the City’s budget or when smaller scale proffers or private developments are being negotiated. Community programs may also assist with such projects. Examples of opportunistic improvements include:

Incremental Filterra Retrofits: Establish funding within the Public Works budget to replace a target number of inlets with Filterra or other small scale structures each budget cycle. Inlets

may be selected from a prioritized list, or as opportunities to piggyback on other projects present themselves.

Community Bioretention: Work with community groups to identify opportunities to construct bioretention or biofilter areas with volunteer labor. Consider providing technical assistance, funding grants, and ‘final connection’ support.

6.2. Demonstration Projects

Adoption of low impact development BMPs such as permeable pavement and biofilter/retention BMPs continues at steady but relatively slow pace due to the sensitivity of the designs to local conditions. Designs that work in one region may not be suitable for implementation in other regions.

A valuable approach for encouraging broader use of low impact BMPs in a given area is to construct demonstration projects. Demonstration projects also provide the opportunity to evaluate different designs while providing experience to local contractors and engineers, as well as City personnel responsible for maintaining the BMPs.

These observations and experiences can then be documented and incorporated into City design standards.

Demonstration projects also support both public and internal stakeholder outreach by providing physical sites that interested parties can visit and react to.

Permeable pavement is a specific BMP that benefits greatly from demonstration projects, as its performance is very sensitive to its design, quality of construction, and site environment (e.g. traffic exposure, contributing runoff, flooding).

6.3. Public Outreach

Public outreach is a critical component of successfully implementing stormwater retrofit improvements, both in terms of generating support for the projects, as well as educating the public on how the BMPs function and what the public can do to assist with maintenance (e.g. collect yard waste rather than push to the gutter).

6.4. Internal Stakeholder Outreach/Coordination

Also critical to successful implementation are outreach and coordination efforts with internal stakeholders to reach consensus on preferred BMPs and execution of the various program elements.

6.5. Development Policy and Incentive Programs

The rate at which stormwater treatment retrofits are implemented may be further increased by developing policies that incentivize private development to construct stormwater treatment improvements. Such policies may include reduced development review fees, expedited reviews, and grant programs. (Note: The extent to which these policies are implemented or pursued would

necessarily have to consider political ramifications, budgetary needs, and other aspects beyond the scope of this document.)

7. Stormwater Treatment Conclusions and Recommendations

Table 12 provides a summary of the stormwater BMP concept examples considered in this report.

Table 12: BMP Alternatives summary

BMP	Treatment Area (acres)	Order of Magnitude Cost	Cost / TP reduction (\$1000/lbs/yr)	Total Phosphorus Reduction (lbs/yr)	Total Nitrogen Reduction (lbs/yr)	Total Suspended Solids Reduction (tons/yr)
Retention Pond	17.89	\$550,000	30.9	17.80	69.99	5.05
Constructed Wetland	12.42	\$500,000	46.1	10.85	42.03	3.09
Hydrodynamic Separator	17.91	\$730,000	87.0	8.39	64.48	5.04
Bioretention Area	1.09	\$60,000	68.9	0.87	5.67	0.18
Biofilter (Filterra)	0.50	\$60,000	111.0	0.54	1.85	0.15
Biofilter (Site Design)	1.04	\$60,000	76.9	0.78	3.62	0.20
Permeable Pavement	2.04	\$320,000	198.8	1.61	7.17	0.42

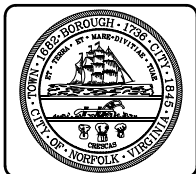
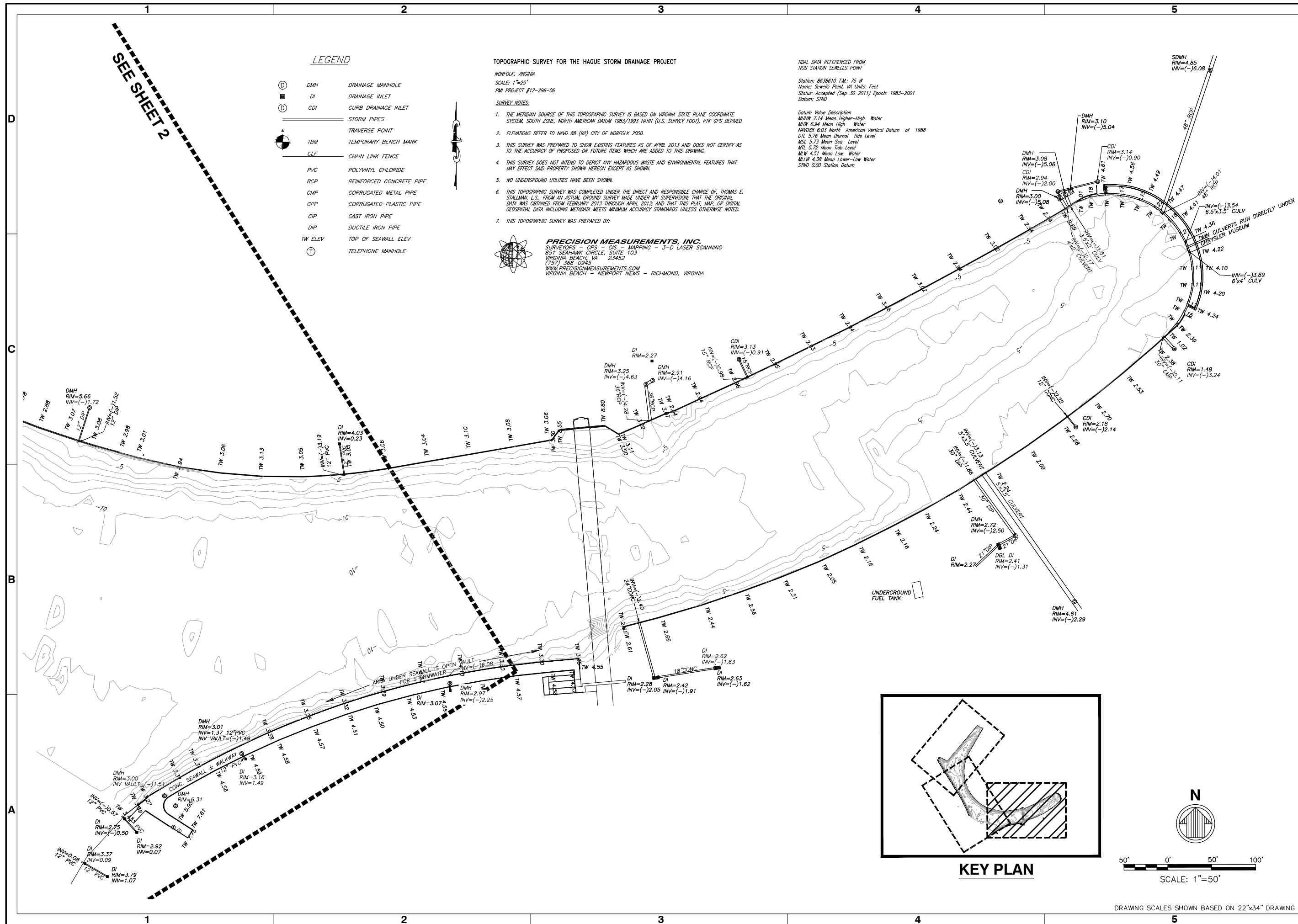
The concept examples are intended to illustrate approaches to implementing stormwater treatment facilities in an urban area. Each candidate improvement must be evaluated on a case-by-case basis to assess actual impacts and costs. Extrapolating results found in this table to other locations is discouraged due to the unique conditions likely to be encountered at each project site.

8. References

- Chesapeake Bay Program (2010) Water Quality Goal Implementation Team, *Protocol for the Development, Review, and Approval of Loading and Effectiveness Estimates for Nutrient and Sediment Controls in the Chesapeake Bay Watershed Model*, March 15, 2010
http://www.chesapeakebay.net/documents/Nutrient-Sediment_Control_Review_Protocol_07162013.pdf
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- NOAA, 1999. “*Sediment Quality Guidelines developed for the National Status and Trends Program*” 6/12/1999. http://archive.orr.noaa.gov/book_shelf/121_sedi_qual_guide.pdf
- USEPA. 2005. Contaminated Sediment Remediation Guidance for Hazardous Waste Sites, EPA-540-R-05-012, OSWER 93555.0-85. December 2005. (<http://www.epa.gov/uscep/ordering.html>).
- USEPA. 2007. Great Lakes Protection Fund – Deciding About Sediment Remediation – A Step-by-Step Guide to Making Decisions. Great Lakes National Program Office, Chicago, IL. March 8, 1996. (<http://www.epa.gov/glnpo/sediment/isemain>).
- VMRC, 1973. Virginia Marine Resources Commission Application Permit No. MRC 73-499, October 1, 1973.

APPENDIX A

Topographic / Hydrographic Survey



DRAFT REPORT

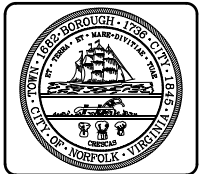
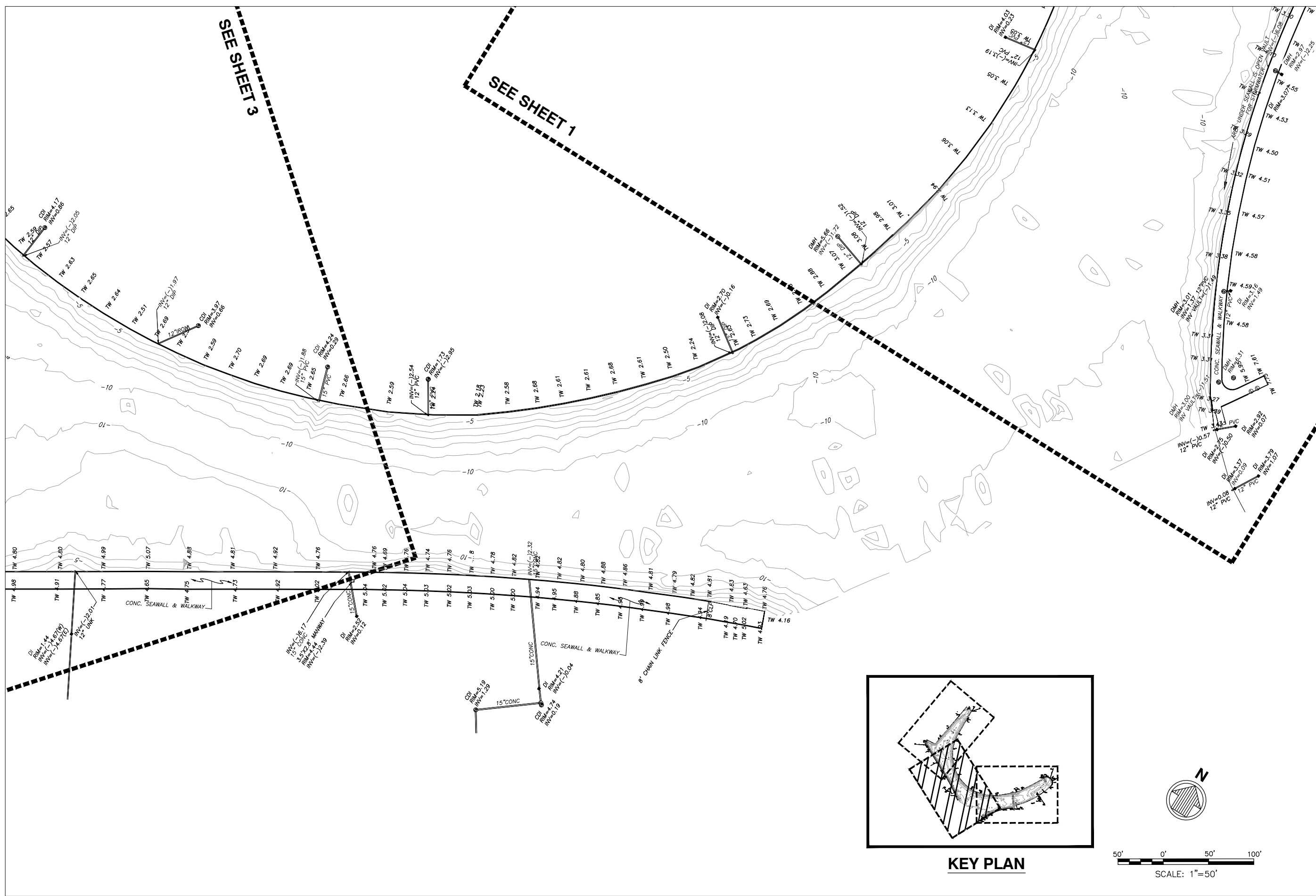
**THE HAGUE STORMWATER EVALUATION
& IMPROVEMENT CONCEPTS
NORFOLK, VA**

TOPOGRAPHIC SURVEY
SHEET 1 OF 3

 moffatt & nichol	800 WORLD TRADE CENTER NORFOLK, VA 23510 757-628-8722		Designed by:	Date: 02/5/2014	Rev. -
			Dwn by:	M&N Project No. 7970-03	
			Reviewed by:	Drawing code:	
PREPARED FOR: CITY OF NORFOLK DEPARTMENT OF PUBLIC WORKS		Submitted by: MOFFATT & NICHOL		Drawing Scale: Plot scale:	

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Number:

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**THE HAGUE STORMWATER EVALUATION
& IMPROVEMENT CONCEPTS
NORFOLK, VA**

TOPOGRAPHIC SURVEY
SHEET 2 OF 3

 moffatt & nichol	800 WORLD TRADE CENTER NORFOLK, VA 23510 757-628-8222		Designed by:	Date: 02/5/2014 Rev. —
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			Reviewed by:	Drawing code:
			Submitted by: MOFFATT & NICHOL	Drawing Scale: Plot scale:

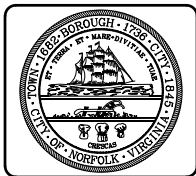
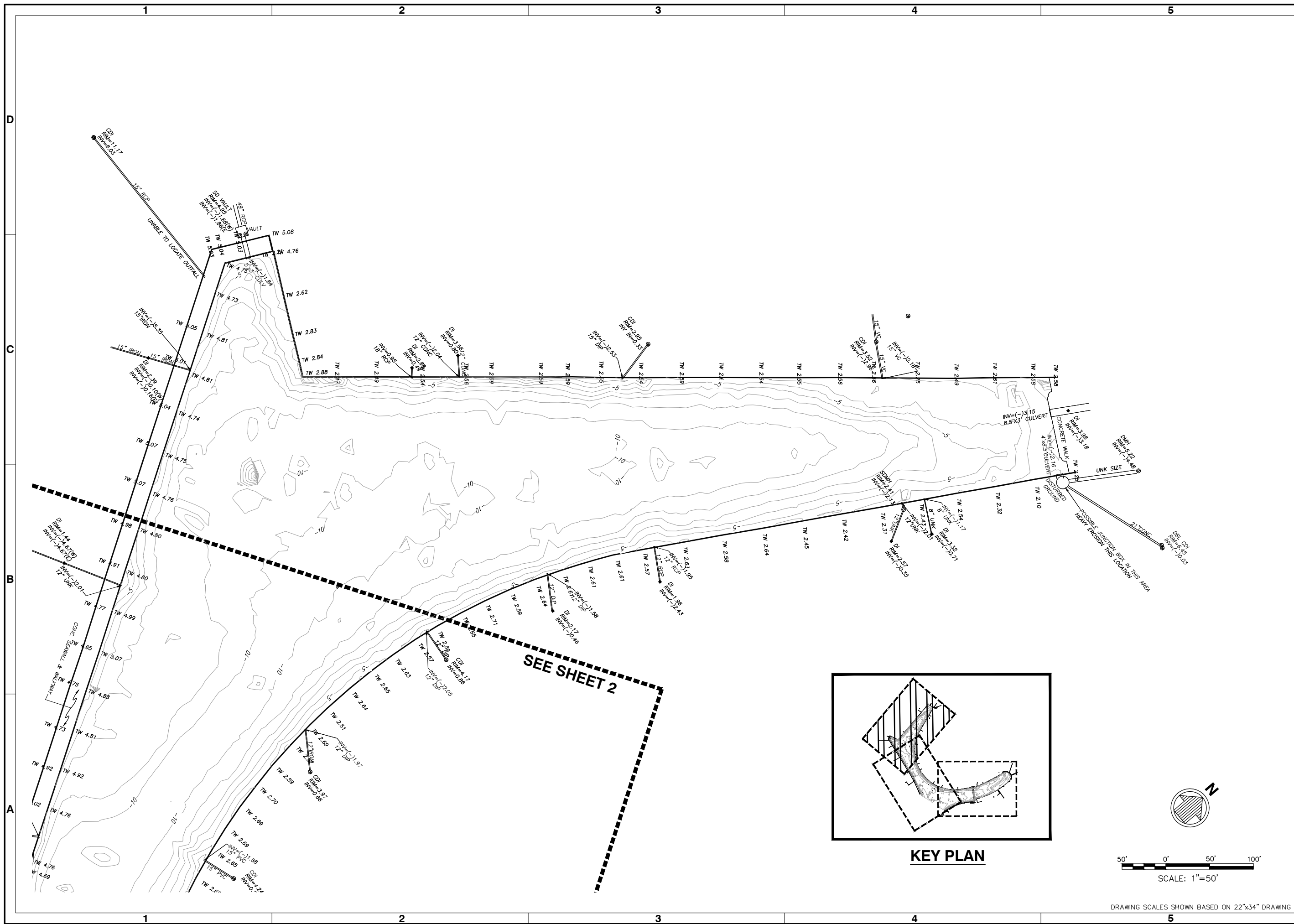


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DEPARTMENT OF PUBLIC WORKS

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**THE HAGUE STORMWATER EVALUATION
& IMPROVEMENT CONCEPTS
NORFOLK, VA**

TOPOGRAPHIC SURVEY
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						Dwn by:	Cdd by:	M&N Project No. 7970-03		Reviewed by:	Drawing code:	

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DRAWING SCALES SHOWN BASED ON 22"x34" DRAWING

File: P:\7970-03\400 Reports\2014-01-28 Conceptual Design Report DRAFT\Figures\The Hague Overall Topographic 4; Plotted: 2/5/2014 3:20 PM by VARTABEDIAN; BEV; Saved: 2/5/2014 2:56 PM by BVARTABEDIAN

APPENDIX B

Outfall Inventory and Photo Log

Table B-1: Outfall Inventory

Outfall	Size	Outfall Invert Elevation (ft, NAVD88)	Upstream Structure Invert Elevation (ft, NAVD88)	Upstream Structure Rim Elevation (ft, NAVD88)	System Size	Drainage Basin ² (Acres)
D14171	15"	-2.32	-0.04	+4.21	Minor	2.60
D14165	15"	-6.17	+0.12	+2.52	Minor	3.90
D14158	12"	-2.01	-4.67	+1.44	Minor	7.23
D14153	15"	-5.35	-0.16	+2.39	Minor	1.29
D14149	15"	Unavailable	+6.03	+11.17	Minor	2.87
D14240	5'x3' Culvert	-1.84	-1.86	+4.95	Major	19.78
H07 ¹	18"	+0.95	+0.49	+2.89	Local	0.44
H08 ¹	12"	-2.04	+0.80	+3.56	Local	1.70
H09 ¹	15"	-2.53	+0.33	+2.95	Local	1.22
D14860	15"	-2.18	-2.96	+3.52	Minor	3.62
D143000	8.5'x3' Culvert	-3.15	-3.18	+3.98	Major	195.34
D1486(A)	4'x8.5' Culvert	-2.16	-4.48	+5.22	Minor	2.23
D1486(B)			-0.03	+6.45	Local	4.59
D1489	8"	-1.17	-0.71	+3.32	Local	0.18
D1491	12"	-2.01	-0.35	+2.57	Local	3.34
D1496	12"	-1.95	-2.43	+1.96	Local	3.66
D14101	12"	-1.58	-0.46	+2.17	Local	0.62
D14104	12"	-2.05	+0.86	+4.17	Local	1.43
D14107	12"	-1.97	+0.66	+3.97	Local	1.30
D14110	15"	-1.88	+0.29	+4.24	Local	1.08
D14116	12"	-2.54	-2.95	+1.73	Local	1.82
D14121	12"	-2.08	-0.16	+2.70	Local	0.79
D14124	12"	-1.52	-1.72	+5.66	Minor	4.67
D14130	12"	-3.19	+0.23	+4.03	Local	1.52
E14200	36"	-4.28	-4.63	+3.25	Major	22.16
D1482	15"	-0.98	-0.91	+3.13	Local	0.59
E141	3.5'x2' Culvert 4'x2' Culvert	-2.17	-0.90	+3.14	Major	64.16
E147007	48"	-4.01	-6.08	+4.85	Minor	1.82
E143250	6.5'x3.5' Culvert	-3.54	Unavailable	Unavailable	Major	307.95
E143699	6'x4' Culvert	-3.89	Unavailable	Unavailable	Major	140.04
E145200	30"	-2.11	-3.24	+1.48	Minor	5.23
E145211	12"	-2.22	-2.14	+2.18	Local	0.51
E14330	5'x3.5' Culvert	-3.13	-2.29	+4.61	Major	16.24
E14310	30"	-1.86	-1.31	+2.41	Minor	5.31
H34 ¹	24"	-2.40	-2.05	+2.42	Local	2.49
D145305	Unavailable	-6.08	Unavailable	+3.07	Local	0.66
D145303	12"	+1.37	+1.49	+3.16	Local	0.25
D14300	Unavailable	-1.51	Unavailable	+6.31	Minor	4.64
H38 ¹	12"	-0.57	+0.07	+2.92	Local	0.34
H39 ¹	12"	+0.09	+1.07	+3.79	Local	0.38

¹Outfall structure not documented in City's GIS database.²Drainage Basins approximated using available GIS contour data and other physical features.

	Photo No.: B-1 Location: Outfall E141-View at Top of Outfall Description: No Deficiencies Noted 1/13/2014
	Photo No.: B-2 Location: Outfall E141-Elevation View Description: 3.5'x2' Box Culvert(L) 4'x2' Box Culvert(R) 11/11/2013

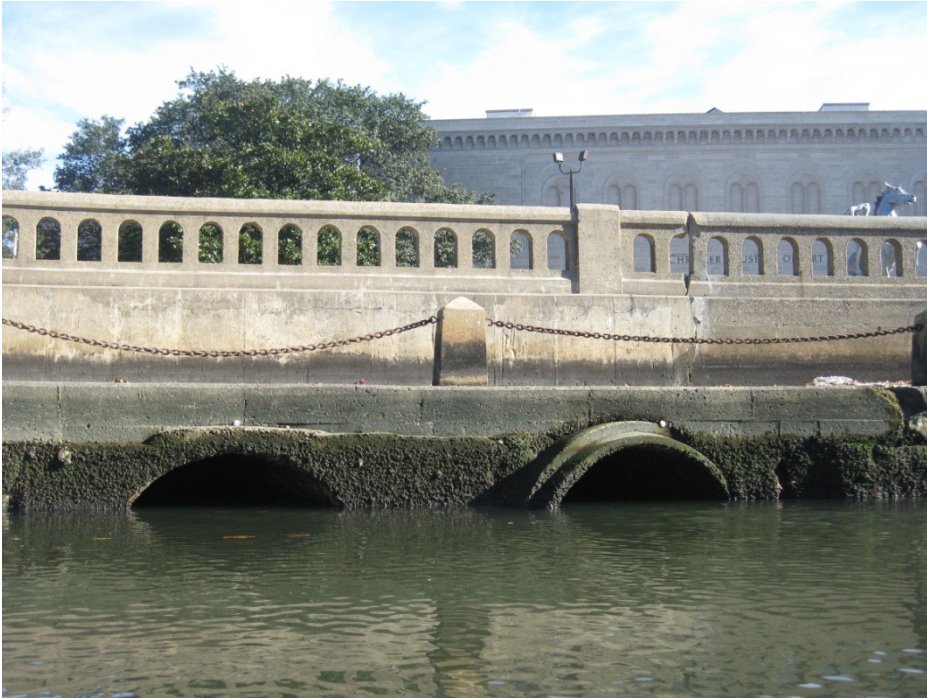
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	Location: Outfall E147007-View at Top of Outfall
	Description: No Deficiencies Noted
	1/13/2014
	Photo No.: B-4
	Location: Outfall E147007- Elevation View
	Description: 48" RCP
	11/11/2013

	Photo No.: B-5
	Location: Outfall E143250 (L) & E143699 (R) -View at Top of Outfall
	Description: No Deficiencies Noted
	1/13/2014
	Photo No.: B-6
	Location: Outfall E143250 (L) & E143699 (R) -Elevation View
	Description: 6.5'x3.5' Culvert(L) 6'x4' Culvert (R)
	11/11/2013

	Photo No.: B-7
	Location: Outfall E145200-View at Top of Outfall
	Description: No Deficiencies Noted
	1/13/2014
	Photo No.: B-8
	Location: Outfall E145200- Elevation View
	Description: 30" CMP
	11/11/2013

	Photo No.: B-9
	Location: Outfall E145211-View at Top of Outfall
	Description: No Deficiencies Noted
	1/13/2014
	Photo No.: B-10
	Location: Outfall E145211- Elevation View
	Description: 12" Conc.
	11/11/2013

	Photo No.: B-11
	Location: Unknown outfall west of E145211-Elevation View
	Description: Unknown if Pipe is in service.
	11/11/2013

	Photo No.: B-12
	Location: Outfall E14330-View at Top of Outfall
	Description: Settlement of 1'Dia. x 1'D along length of culvert
	1/13/2014
	Photo No.: B-13
	Location: Outfall E14330-Elevation View
	Description: 5'x3.5' Culvert
	11/11/2013

	Photo No.: B-14
	Location: Outfall E14310- Elevation View
	Description: 30" DIP
	11/11/2013

	Photo No.: B-15 Location: Unnumbered Outfall (Report Designation H34), west of E14310-View at Top of Outfall Description: -Rip Rap placed behind Retaining wall <i>Not in Picture:</i> -Settlement of 4'W x 2'L x up to 4"D along length of pipe. -Settlement behind structure 8'W x up to 4'L x 8"D likely from vehicles. 1/13/2014
	Photo No.: B-16 Location: Outfall H34 Description: 24" Conc. 11/11/2013

**Photo No.: B-17****Location:**

Unnumbered Outfall
(Report Designation
H38), under westbound
Brambleton Ave
Bridge-Elevation View

Description:

No Deficiencies Noted
(12" PVC)

11/11/2013

	Photo No.: B-18
	Location: Unnumbered Outfall (Report Designation H39), under eastbound Brambleton Ave Bridge-Elevation View
	Description: No Deficiencies Noted (12" PVC)
	11/11/2013

	Photo No.: B-19
	Location: Outfall D14171-View at Top of Outfall (Outfall is under relieving platform and is not visible.)
	Description: No Deficiencies Noted (15" Conc. Pipe)
	1/13/2014

	Photo No.: B-20
	Location: Outfall D14165-View at Top of Outfall (Outfall is under relieving platform and is not visible.)
	Description: Non Observed (15" Conc. Pipe)
	1/13/2014

	Photo No.: B-21
	Location: Outfall D14158-View at Top of Outfall (Outfall is under relieving platform and is not visible.)
	Description: No Deficiencies Noted (12" Pipe)
	1/13/2014

	Photo No.: B-22
	Location: Outfall D14153-View at Top of Outfall (Outfall is under relieving platform and is not visible.)
	Description: No Deficiencies Noted (15" Iron Pipe)
	1/13/2014

	Photo No.: B-23
	Location: Outfall D14149-View at Top of Outfall (Outfall is under relieving platform and is not visible.)
	Description: No Deficiencies Noted (18" RCP)
	1/13/2014

	Photo No.: B-24 Location: Outfall D14240-View at Top of Outfall Looking west (Outfall is under relieving platform and is not visible.) Description: -Settlement east of Structure 12'W x 4'L x up to 1'D <i>Not in Picture:</i> -Pipe Joist Disc. at Structure 1/13/2014
	Photo No.: B-25 Location: Outfall D14240-Elevation View Description: 5'x3' Culvert 11/11/2013

	Photo No.: B-26 Location: Unnumbered Outfall (Report Designation H07), east of D14240- View at Top of Outfall Description: No Deficiencies Noted 1/13/2014
	Photo No.: B-27 Location: Outfall H07-Elevation View Description: 18" RCP 11/11/2013

	Photo No.: B-28
	Location: Unnumbered Outfall (Report Designation H08), east of H07-View at Top of Outfall
	Description: 12" Conc. Pipe
	1/13/2014

	Photo No.: B-29 Location: Unnumbered Outfall (Report Designation H09), east of H08-View at Top of Outfall Description: No Deficiencies Noted 1/13/2014
	Photo No.: B-30 Location: Outfall H09-Elevation View Description: 15" DIP 11/11/2013

	Photo No.: B-31
	Location: Outfall D14860-View at Top of Outfall
	Description: Stone Fill Placed Along Length of Pipe 15' Lx6'W
	1/13/2014
	Photo No.: B-32
	Location: Outfall D14860- Elevation View
	Description: 15" VC
	11/11/2013

	Photo No.: B-33
	Location: Outfall D143000-View at Top of Outfall
	Description: No Deficiencies Noted
	1/13/2014
	Photo No.: B-34
	Location: Outfall D143000- Elevation View
	Description: 8.5'x3' Conc. Culvert
	11/11/2013

	Photo No.: B-35 Location: Outfall D1486-View at Top of Outfall Description: 2- Areas of settlement along length of pipe- 8" Dia x 1'D & 4"Dia x 6"D 1/13/2014
	Photo No.: B-36 Location: Outfall D1486- Elevation View Description: 4'x8.5' Culvert 11/11/2013

	Photo No.: B-37
	Location: Outfall D1489-View at Top of Outfall
	Description: No Deficiencies Noted
	1/13/2014
	Photo No.: B-38
	Location: Outfall D1489-Elevation View
	Description: 8" Pipe
	11/11/2013

	Photo No.: B-39
	Location: Outfall D1491-View at Top of Outfall
	Description: No Deficiencies Noted
	1/13/2014
	Photo No.: B-40
	Location: Outfall D1491-Elevation View
	Description: 12" Pipe (appears to be sealed)
	11/11/2013

	Photo No.: B-41
	Location: Outfall D1496-View at Top of Outfall
	Description: -Fill along bulkhead at pipe. <i>Not in Picture:</i> -Settlement 10" Dia x up to 3"D -Erosion on either side of sidewalk along pipe Approx. 10SF
	1/13/2014
	Photo No.: B-42
	Location: Outfall D1496-Elevation View
	Description: 12" RCP
	11/11/2013

	Photo No.: B-43
	Location: Outfall D14101-View at Top of Outfall
	Description: No Deficiencies Noted
	1/13/2014
	Photo No.: B-44
	Location: Outfall D14101- Elevation View
	Description: 12" DIP
	11/11/2013

	Photo No.: B-45
	Location: Outfall D14104-View at Top of Outfall
	Description: Erosion on west side of sidewalk 4'wx3"D
	1/13/2014
	Photo No.: B-46
	Location: Outfall D14104- Elevation View
	Description: 12" DIP
	11/11/2013

	Photo No.: B-47 Location: Outfall D14107-View at Top of Outfall Description: No Deficiencies Noted 1/13/2014
	Photo No.: B-48 Location: Outfall D14107- Elevation View Description: 12" Iron 11/11/2013

	Photo No.: B-49
	Location: Outfall D14110-View at Top of Outfall
	Description: <i>Not in Picture:</i> 10'L x 4"W area along pipe where stone has been placed
	1/13/2014
	Photo No.: B-50
	Location: Outfall D14110- Elevation View
	Description: 15" PVC
	11/11/2013

	Photo No.: B-51
	Location: Outfall D14116-View at Top of Outfall
	Description: No Deficiencies Noted
	1/13/2014
	Photo No.: B-52
	Location: Outfall D14116- Elevation View
	Description: 12" PVC
	11/11/2013

	Photo No.: B-53
	Location: Outfall D14121-View at Top of Outfall
	Description: No Deficiencies Noted
	1/13/2014
	Photo No.: B-54
	Location: Outfall D14121- Elevation View
	Description: 12" DIP
	11/11/2013

	Photo No.: B-55
	Location: Outfall D14124-View at Top of Outfall
	Description: No Deficiencies Noted
	1/13/2014
	Photo No.: B-56
	Location: Outfall D14124- Elevation View
	Description: 12" DIP
	11/11/2013

**Photo No.: B-57****Location:**

Outfall D14130-View
at Top of Outfall

Description:

Settlement
6'Lx3.5'Wx3"D East
of pipe(12" PVC)

1/13/2014

	Photo No.: B-58
	Location: Outfall D14200-View at Top of Outfall
	Description: No Deficiencies Noted (36" RCP)
	1/13/2014

	Photo No.: B-59 Location: Outfall D1482-View at Top of Outfall Description: No Deficiencies Noted 1/13/2014
	Photo No.: B-60 Location: Outfall D1482-Elevation View Description: 15"RCP 11/11/2013

**Photo No.: B-61****Location:**

Outfall D1482-
Elevation View

Description:

End of outfall(invert
misalignment)

11/11/2013

APPENDIX C

Sediment Sampling and Testing



REPORT OF SUBSURFACE EXPLORATION
AND
LABORATORY TESTING SERVICES

**The Hague Dredging
Norfolk, Virginia**

**G E T Project No: VB13-184G
September 27, 2013**

Prepared for:

Moffatt & Nichol
800 World Trade Center
Norfolk, Virginia 23510

204 Grayson Road, Virginia Beach, VA 23462
Phone 757-518-1703 ♦ Fax 757-518-1704 ♦ www.getsolutionsinc.com



September 27, 2013

TO: **Moffatt and Nichol**
800 World Trade Center
Norfolk, VA 23510

Attn: Mr. Brian Joyner, P. E.

RE: Report of Subsurface Exploration and Laboratory Testing Services
The Hague Dredging
Norfolk, Virginia
G E T Project No: VB13-184G

Dear Mr. Joyner:

G E T Solutions, Inc. has completed our subsurface exploration and laboratory testing services for the proposed Hague Dredging project located in the City of Norfolk, Virginia. The subsurface exploration services were conducted in general accordance with the scope presented in **G E T** Proposal No. PVB12-574G. Authorization to proceed with our services was obtained in the form of an electronic mail dated July 22, 2013 from Mr. Brian Joyner with Moffatt & Nichol. The purpose of this study was to obtain information regarding the general nature and condition of the soils within the proposed dredging cut.

Project Location and Description

The project site, designated as The Hague, is located south of Olney Road and north of Brambleton Avenue in Norfolk, Virginia. The body of water, which is roughly 220 feet wide (average), approximately 3,400 linear feet long (total) and approximately 2 to 14 feet deep is bordered by residential properties to the north, east and west and by the Elizabeth River to the south. The proposed construction will consist of dredging the body of water to an approximate depth of 2 to 20 feet deep requiring cuts of up to 6 feet. Site vicinity and location maps are provided in Appendix I.

Field Exploration

In order to explore the general subsurface soil types, ten (10) 3-inch diameter sediment samples, designated as H-1 through H-10, were advanced within the existing body of water with the use of a Vibecore-D sediment sampler. The tube samples were obtained at depths ranging from approximately 2 to 12 feet below the current water elevation (from the mud line elevation to depths of approximately 6 feet below the mud line). A composite sample was created in the field at each of the boring locations. The composite soil samples were sealed in glass jars to prevent moisture loss and returned to the laboratory for classification and environmental testing.

The sample locations were established by the client and located in the field by a representative of **G E T Solutions, Inc.** with use of a handheld GPS Unit. The approximate boring locations are shown on the attached "Boring Location Plan" (Appendix II).

Laboratory Testing

Soil Classification Testing

Composite portions of all soil samples collected during drilling were sealed in glass jars, labeled and transferred to our laboratory for classification and analysis. A Geotechnical Engineer performed the soil classification in general accordance with ASTM Specification D 2487. A summary of the soil classification system is provided in Appendix III. The records of the subsurface exploration are included in Appendix IV (Boring Logs) and in Appendix V (Generalized Soil Profile), which should be reviewed for specific information as to the individual borings. The approximate stratifications shown on the records of the subsurface exploration represent the conditions only at the actual boring locations. Variations may occur and should be expected between boring locations. The stratifications represent the approximate boundary between subsurface materials and the transition may be gradual.

Ten (10) composite soil samples were selected and subjected to natural moisture, Atterberg limits, #200 sieve wash, grain size distribution, organic content and hydrometer testing and analysis in order to corroborate the visual classification. These test results are presented below (Table I) and on the "Particle Size Distribution Report" sheets (Appendix VI).

Table I - Laboratory Test Results

Boring No.	Water Depth (ft)*	Natural Moisture (%)	Percent Passing #200	Percent Silt**	Percent Clay**	Organic Content (%)	Atterberg Limits (LL/PL/PI)	USCS
H-1	1.75	91.3	67.6	49.4	18.2	17.7	44/37/7	ML
H-2	4.0	119.7	69.2	54.9	14.3	17.3	44/37/7	ML
H-3	5.5	121.0	84.3	66.9	17.4	18.9	52/35/17	MH
H-4	7.0	110.7	91.8	56.8	35.0	7.2	29/25/4	ML
H-5	12.0	121.1	97.3	47.6	49.7	4.3	57/30/27	CH
H-6	7.0	143.1	97.7	48.8	48.9	7.3	65/31/34	CH
H-7	7.0	131.9	92.3	57.2	35.1	8.9	58/33/25	MH
H-8	8.5	133.7	95.2	51.3	43.9	6.9	58/35/23	MH
H-9	8.5	133.5	97.2	64.3	32.9	15.5	58/47/11	MH
H-10	5.0	168.9	61.4	46.5	14.9	21.6	57/48/9	MH

Laboratory test results are indicative of the composite samples at each sample location, from a depth of 0.0 to 6.0 feet below the mud line at sample locations H-1 through H-10. The above noted laboratory test results are not indicative to a specific depth.

* Approximate water depth.

** Determined by hydrometer analysis.

The Hague Dredging

Norfolk, Virginia

GET Project No: VB13-184G*Environmental Testing*

The ten (10) field composite samples that were obtained from boring locations H-1 through H-10 were collected and placed in glass jars and shipped under chain of custody to EnviroCompliance Laboratories, Inc. located in Hampton, Virginia. Five (5) representative laboratory composite samples were created from the ten (10) field composite samples at EnviroCompliance Laboratories in accordance with the composite group identification legend as shown on the boring location plan provided by the client. The laboratory composite sample identifications and corresponding sample locations are presented below in (Table II).

Table II – Laboratory Composite Soil Sample Schedule

Composite Sample Identification	Boring Locations
Group A	H-1 and H-2
Group B	H-3 and H-4
Group C	H-5
Group D	H-6, H-7 and H-8
Group E	H-9 and H-10

The laboratory composite samples (Group A through Group E) were analyzed for TCLP Volatile Organic Compounds (TCLP-VOCs), TCLP Semi-Volatile Organic Compounds (TCLP-SVOCs), TCLP RCRA Metals, TCLP Polychlorinated Biphenyls (TCLP-PCBs), Extractable Organic Halides (EOX), and Total Petroleum Hydrocarbons (TPH) using EPA-approved Methods at EnviroCompliance Laboratories. The “Analytical Summary” is provided in Appendix VII.

Based on the laboratory reports, detectable concentrations of the analyzed chemicals were identified in all of the soils samples (Group A through Group E). Barium, Lead, Polychlorinated Biphenyls (PCB as Arochlor 1254 & PCB as Arochlor 1260), Mercury, TPH-Diesel Range Organics (TPH-DRO), and TPH-Gasoline Range Organics (TPH-GRO) were detected in the laboratory group composite samples. These results should be compared to the published regulatory levels presented in “Table I - Maximum Concentrations of Contaminants For The Toxicity Characteristic” in 40 CFR (Code of Federal Regulations) 261.30 and Department of Environmental Quality (DEQ) regulations. A summary of the detectable concentrations is provided in Table III in Appendix VII. The contractor is responsible for analyzing material prior to disposal.

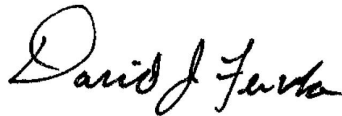
REPORT LIMITATIONS

The data submitted is based on the available soil information obtained by **GET Solutions, Inc.** and the information supplied by the client and their consultants for the proposed project.

The Geotechnical Engineer warrants that the findings, recommendations, specifications or professional advice contained herein have been made in accordance with generally accepted professional geotechnical engineering practices in the local area. No other warranties are implied or expressed.

We appreciate the opportunity to work with you on this project. We trust that the information contained herein meets your immediate need, and should you have any questions or if we could be of further assistance, please do not hesitate to contact us.

Respectfully Submitted,
GET Solutions, Inc.



David J. Ferko
Staff Engineer



Bruce R. Spiro, P.E.
Principal Engineer

Copies: (1) Client

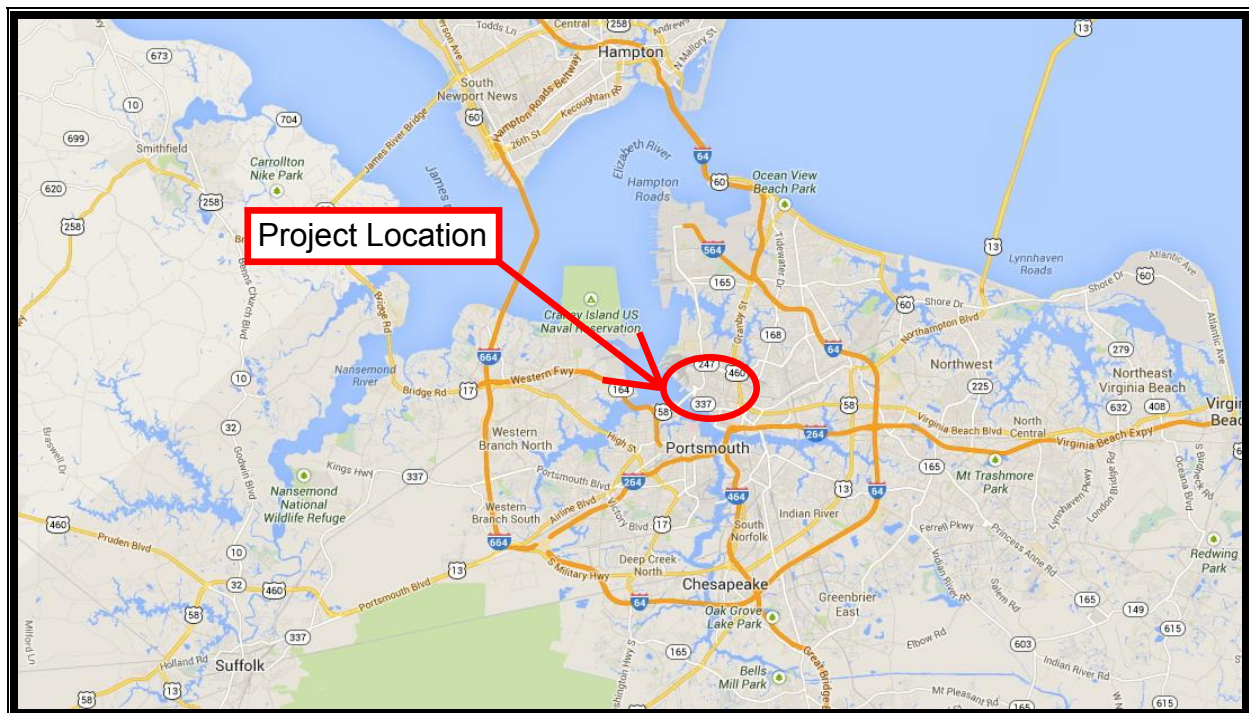


APPENDICES

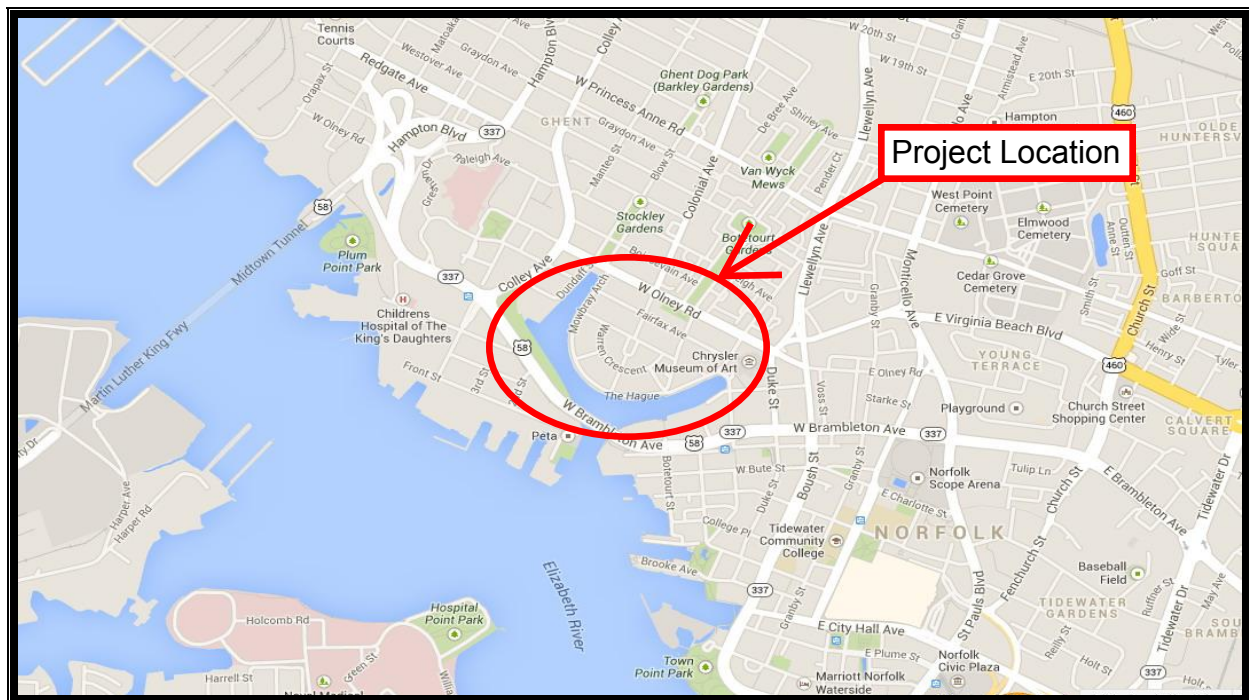
- I SITE VICINITY AND LOCATION MAPS**
- II BORING LOCATION PLAN**
- III SUMMARY OF SOIL CLASSIFICATION**
- IV BORING LOGS**
- V GENERALIZED SOIL PROFILE**
- VI PARTICLE SIZE DISTRIBUTION REPORTS**
- VII REPORT OF LABORATORY ANALYSES**

APPENDIX I

SITE VICINITY AND LOCATION MAPS



SITE VICINITY MAP



SITE LOCATION MAP

SITE VICINITY AND LOCATION MAPS

PROJECT: The Hague Dredging
PROJECT LOCATION: Norfolk, Virginia
PROJECT NO: VB13-184G
CLIENT: Moffatt & Nichol
DATE: 9/13/2013
PLOT BY: D. Ferko



APPENDIX II
BORING LOCATION PLAN



LEGEND

Sediment Boring Locations
Compositing Group

- Group A (light blue circle)
- Group B (red circle)
- Group C (yellow circle)
- Group D (purple circle)
- Group E (white circle)

Major Contours (thick line)
Minor Contours (thin line)
Light Rail (line with cross-ticks)

Hydro TIN
Elevation (ft NAVD88)

Red	-2 - -1.5
Dark Orange	-2.5 - -2
Orange	-3 - -2.5
Light Orange	-3.5 - -3
Yellow-Orange	-4 - -3.5
Yellow	-4.5 - -4
Light Yellow	-5 - -4.5
Light Green	-6 - -5
Green	-7 - -6
Dark Green	-8 - -7
Teal	-9 - -8
Blue-Teal	-10 - -9
Blue	-11 - -10
Dark Blue	-12 - -11
Very Dark Blue	-13 - -12
Dark Purple	-13.57 - -13



0 70 140 280 Feet

NAVD88 is 1.65 feet above MLLW



Boring Location Plan
The Hague Dredging
GET Project No: VB13-184G
Norfolk, Virginia
Client: Moffatt & Nichol
09/08/13

APPENDIX III

SUMMARY OF SOIL CLASSIFICATION

CLASSIFICATION SYSTEM FOR SOIL EXPLORATION

Standard Penetration Test (SPT), N-value

Standard Penetration Tests (SPT) were performed in the field in general accordance with ASTM D 1586. The soil samples were obtained with a standard 1.4" I.D., 2" O.D., 30" long split-spoon sampler. The sampler was driven with blows of a 140 lb. hammer falling 30 inches. The number of blows required to drive the sampler each 6-inch increment (4 increments for each soil sample) of penetration was recorded and is shown on the boring logs. The sum of the second and third penetration increments is termed the SPT N-value.

NON COHESIVE SOILS

(SILT, SAND, GRAVEL and Combinations)

Relative Density

Very Loose	4 blows/ft. or less
Loose	5 to 10 blows/ft.
Medium Dense	11 to 30 blows/ft.
Dense	31 to 50 blows/ft.
Very Dense	51 blows/ft. or more

Particle Size Identification

Boulders	8 inch diameter or more
Cobbles	3 to 8 inch diameter
Gravel	Coarse 1 to 3 inch diameter
	Medium $1/2$ to 1 inch diameter
	Fine $1/4$ to $1/2$ inch diameter
Sand	Coarse 2.00 mm to $1/4$ inch (diameter of pencil lead)
	Medium 0.42 to 2.00 mm (diameter of broom straw)
	Fine 0.074 to 0.42 mm (diameter of human hair)
Silt	0.002 to 0.074 mm (cannot see particles)

COHESIVE SOILS

(CLAY, SILT and Combinations)

Consistency

Very Soft	2 blows/ft. or less
Soft	3 to 4 blows/ft.
Medium Stiff	5 to 8 blows/ft.
Stiff	9 to 15 blows/ft.
Very Stiff	16 to 30 blows/ft.
Hard	31 blows/ft. or more

Relative Proportions

<u>Descriptive Term</u>	<u>Percent</u>
Trace	0-5
Few	5-10
Little	15-25
Some	30-45
Mostly	50-100

Strata Changes

In the column "Description" on the boring log, the horizontal lines represent approximate strata changes.

Groundwater Readings

Groundwater conditions will vary with environmental variations and seasonal conditions, such as the frequency and magnitude of rainfall patterns, as well as tidal influences and man-made influences, such as existing swales, drainage ponds, underdrains and areas of covered soil (paved parking lots, side walks, etc.).

CLASSIFICATION SYMBOLS (ASTM D 2487 and D 2488)

Coarse Grained Soils

More than 50% retained on No. 200 sieve

GW - Well-graded Gravel
GP - Poorly graded Gravel
GW-GM - Well-graded Gravel w/Silt
GW-GC - Well-graded Gravel w/Clay
GP-GM - Poorly graded Gravel w/Silt
GP-GC - Poorly graded Gravel w/Clay
GM - Silty Gravel
GC - Clayey Gravel
GC-GM - Silty, Clayey Gravel
SW - Well-graded Sand
SP - Poorly graded Sand
SW-SM - Well-graded Sand w/Silt
SW-SC - Well-graded Sand w/Clay
SP-SM - Poorly graded Sand w/Silt
SP-SC - Poorly graded Sand w/Clay
SM - Silty Sand
SC - Clayey Sand
SC-SM - Silty, Clayey Sand

Fine-Grained Soils

50% or more passes the No. 200 sieve

CL - Lean Clay
CL-ML - Silty Clay
ML - Silt
OL - Organic Clay/Silt
 Liquid Limit 50% or greater
CH - Fat Clay
MH - Elastic Silt
OH - Organic Clay/Silt

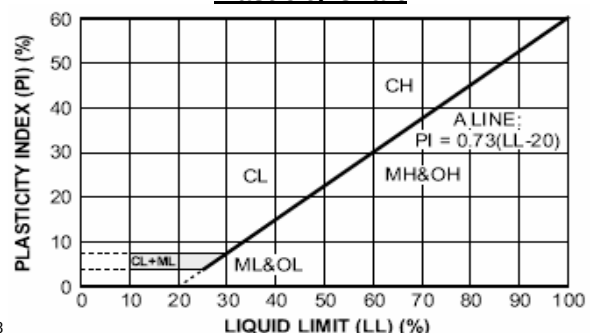
Highly Organic Soils

PT - Peat

Depending on percentage of fines (fraction smaller than No. 200 sieve size), coarse-grained soils are classified as follows:

Less than 5 percent	GW, GP, SW, SP
More than 12 percent	GM, GC, SM, SC
5 to 12 percent	Borderline cases requiring dual symbols

Plasticity Chart



APPENDIX IV
BORING LOGS



DEPTH TO WATER - INITIAL*: 0' **AFTER 24 HOURS:**

CAVING> C

Notes:

SS = Split Spoon Sample
ST = Shelby Tube Sample
HA = Hand Auger Sample
BS = Bulk Sample
WOH = Weight of Hammer

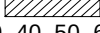
**The initial groundwater reading may not be indicative of the static groundwater level.*



BORING LOG H-2

PROJECT: The Hague Dredging
CLIENT: Moffatt & Nichol
PROJECT LOCATION: Norfolk, VA PROJECT NO.: VB13-184G
BORING LOCATION: See attached boring location plan SURFACE ELEVATION: Existing
DRILLER: GET Solutions, Inc. LOGGED BY: D. Ferko
DRILLING METHOD: Vibecore DATE: 08/27/13
DEPTH TO WATER - INITIAL*: 0' AFTER 24 HOURS: 0' CAVING> C

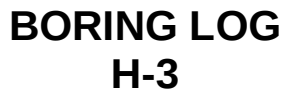
This information pertains only to this boring and should not be interpreted as being indicative of the site.

Elevation (MSL) (ft)	Depth (meters)	Depth (feet)	Description	Graphic	Sample No.	Sample Recovery	Sample Type	Blows per 6"	N-Value	% < #200	TEST RESULTS	
											Plastic Limit	Liquid Limit
	0	0	4.0' Water								Moisture Content - ●	
											N-Value - 	
											10	20
											30	40
											50	60
											70	
	1.6	4	Gray-Black, Wet, Sandy SILT (ML) with varying amounts of Clay, organics (leaf and wood) fragments and hydrocarbon odor									
		8										
	3.2		Gray, Wet, Fat CLAY (CH) with varying amounts of fine Sand, Silt and hydrocarbon odor									
			Boring terminated at 10 ft.									
		12										
	4.8	16										
		20										
	6.4											
		24										
	8											
		28										

Notes:

*The initial groundwater reading may not be indicative of the static groundwater level.

SS = Split Spoon Sample
ST = Shelby Tube Sample
HA = Hand Auger Sample
BS = Bulk Sample
WOH = Weight of Hammer



DEPTH TO WATER - INITIAL*: 0' **AFTER 24 HOURS:**

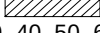
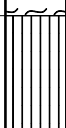
CAVING> C



BORING LOG H-4

PROJECT: The Hague Dredging
CLIENT: Moffatt & Nichol
PROJECT LOCATION: Norfolk, VA PROJECT NO.: VB13-184G
BORING LOCATION: See attached boring location plan SURFACE ELEVATION: Existing
DRILLER: GET Solutions, Inc. LOGGED BY: D. Ferko
DRILLING METHOD: Vibecore DATE: 08/27/13
DEPTH TO WATER - INITIAL*: 0' AFTER 24 HOURS: 0' CAVING> C

This information pertains only to this boring and should not be interpreted as being indicative of the site.

Elevation (MSL) (ft)	Depth (meters)	Depth (feet)	Description	Graphic	Sample No.	Sample Recovery	Sample Type	Blows per 6"	N-Value	% < #200	TEST RESULTS	
											Plastic Limit	Liquid Limit
	0	0	7.0' Water								Moisture Content - ●	
											N-Value - 	
											10	20
											30	40
											50	60
											70	
	4											
	1.6											
		8	Gray-Black, Wet, SILT (ML) with varying amount of Sand, Clay, organics (leaf and wood) fragments and hydrocarbon odor									
	3.2		Gray, Wet, Fat CLAY (CH) with varying amounts of Sand, Silt and hydrocarbon odor									
		12	Boring terminated at 12 ft.									
	4.8	16										
		20										
	6.4											
		24										
	8											
		28										

Notes:

*The initial groundwater reading may not be indicative of the static groundwater level.

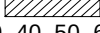
SS = Split Spoon Sample
ST = Shelby Tube Sample
HA = Hand Auger Sample
BS = Bulk Sample
WOH = Weight of Hammer



BORING LOG H-5

PROJECT: The Hague Dredging
CLIENT: Moffatt & Nichol
PROJECT LOCATION: Norfolk, VA PROJECT NO.: VB13-184G
BORING LOCATION: See attached boring location plan SURFACE ELEVATION: Existing
DRILLER: GET Solutions, Inc. LOGGED BY: D. Ferko
DRILLING METHOD: Vibecore DATE: 08/27/13
DEPTH TO WATER - INITIAL*: 0' AFTER 24 HOURS: 0' CAVING> C

This information pertains only to this boring and should not be interpreted as being indicative of the site.

Elevation (MSL) (ft)	Depth (meters)	Depth (feet)	Description	Graphic	Sample No.	Sample Recovery	Sample Type	Blows per 6"	N-Value	% < #200	TEST RESULTS	
											Plastic Limit	Liquid Limit
	0	0	12.0' Water								Moisture Content - ●	
											N-Value - 	
											10	20
											30	40
											50	60
											70	
	4											
	1.6											
		8										
	3.2											
		12										
			Gray-Black, Wet, Silt (ML) with varying amounts of Sand, Clay, organics (leaf and wood) fragments and hydrocarbon odor									
			Gray, Wet, Fat CLAY (CH) with varying amounts of fine Sand, Silt and hydrocarbon odor									
	4.8	16										
			Boring terminated at 18 ft.									
		20										
	6.4											
		24										
	8											
		28										

Notes:

*The initial groundwater reading may not be indicative of the static groundwater level.

SS = Split Spoon Sample
ST = Shelby Tube Sample
HA = Hand Auger Sample
BS = Bulk Sample
WOH = Weight of Hammer



DEPTH TO WATER - INITIAL*: 0' **AFTER 24 HOURS:**

CAVING> C

Notes:

SS = Split Spoon Sample
ST = Shelby Tube Sample
HA = Hand Auger Sample
BS = Bulk Sample
WOH = Weight of Hammer

**The initial groundwater reading may not be indicative of the static groundwater level.*



BORING LOG H-7

PROJECT: The Hague Dredging

CLIENT: Moffatt & Nichol

PROJECT LOCATION: Norfolk, VA

BORING LOCATION: See attached boring location plan

DRILLER: GET Solutions, Inc.

DRILLING METHOD: Vibecore

DEPTH TO WATER - INITIAL*: 0' AFTER 24 HOURS: 0'

PROJECT NO.: VB13-184G

SURFACE ELEVATION: Existing

LOGGED BY: D. Ferko

DATE: 08/27/13

CAVING> C

Elevation (MSL) (ft)	Depth (meters)	Depth (feet)	Description	Graphic	Sample No.	Sample Recovery	Sample Type	Blows per 6"	N-Value	% < #200	TEST RESULTS	
											Plastic Limit	Liquid Limit
	0	0	7.0' Water								Moisture Content -	
											N-Value -	
											10 20 30 40 50 60 70	
	4											
	1.6											
		8	Gray-Black, Wet, Elastic Silt (MH) with varying amounts of Sand, Clay, organics (leaf and wood) fragments and hydrocarbon odor									
	3.2											
		12	Gray, Wet, Fat CLAY (CH) with varying amounts of fine Sand, Silt and hydrocarbon odor									
			Boring terminated at 13 ft.									
	4.8	16										
		20										
	6.4											
		24										
	8											
		28										

Notes:

*The initial groundwater reading may not be indicative of the static groundwater level.

SS = Split Spoon Sample
ST = Shelby Tube Sample
HA = Hand Auger Sample
BS = Bulk Sample
WOH = Weight of Hammer



BORING LOG H-8

PROJECT: The Hague Dredging
CLIENT: Moffatt & Nichol
PROJECT LOCATION: Norfolk, VA PROJECT NO.: VB13-184G
BORING LOCATION: See attached boring location plan SURFACE ELEVATION: Existing
DRILLER: GET Solutions, Inc. LOGGED BY: D. Ferko
DRILLING METHOD: Vibecore DATE: 08/27/13
DEPTH TO WATER - INITIAL*: 0' AFTER 24 HOURS: 0' CAVING> C

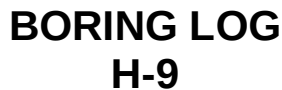
This information pertains only to this boring and should not be interpreted as being indicative of the site.

Elevation (MSL) (ft)	Depth (meters)	Depth (feet)	Description	Graphic	Sample No.	Sample Recovery	Sample Type	Blows per 6"	N-Value	% < #200	TEST RESULTS	
	0	0	8.5' Water								Plastic Limit	— Liquid Limit
											Moisture Content -	●
											N-Value -	
											10 20 30 40 50 60 70	
		4	Gray-Black, Wet, Elastic SILT (MH) with varying amounts of Sand, Clay and hydrocarbon odor									
	1.6											
		8										
	3.2											
		12	Boring terminated at 14.5 ft.									
	4.8	16										
		20										
	6.4											
		24										
	8											
		28										

Notes:

*The initial groundwater reading may not be indicative of the static groundwater level.

SS = Split Spoon Sample
ST = Shelby Tube Sample
HA = Hand Auger Sample
BS = Bulk Sample
WOH = Weight of Hammer



DEPTH TO WATER - INITIAL*: 0' **AFTER 24 HOURS:**

CAVING> C



DEPTH TO WATER - INITIAL*: 0' **AFTER 24 HOURS:**

CAVING> C

Elevation (MSL) (ft)	Depth (meters)	Depth (feet)	Description	Graphic	Sample No.	Sample Recovery	Sample Type	Blows per 6"	N-Value	% < #200	TEST RESULTS										
											Plastic Limit					Liquid Limit					
											Moisture Content -										
											N-Value -										
	0	0	5.0' Water								10	20	30	40	50	60	70				

Notes:

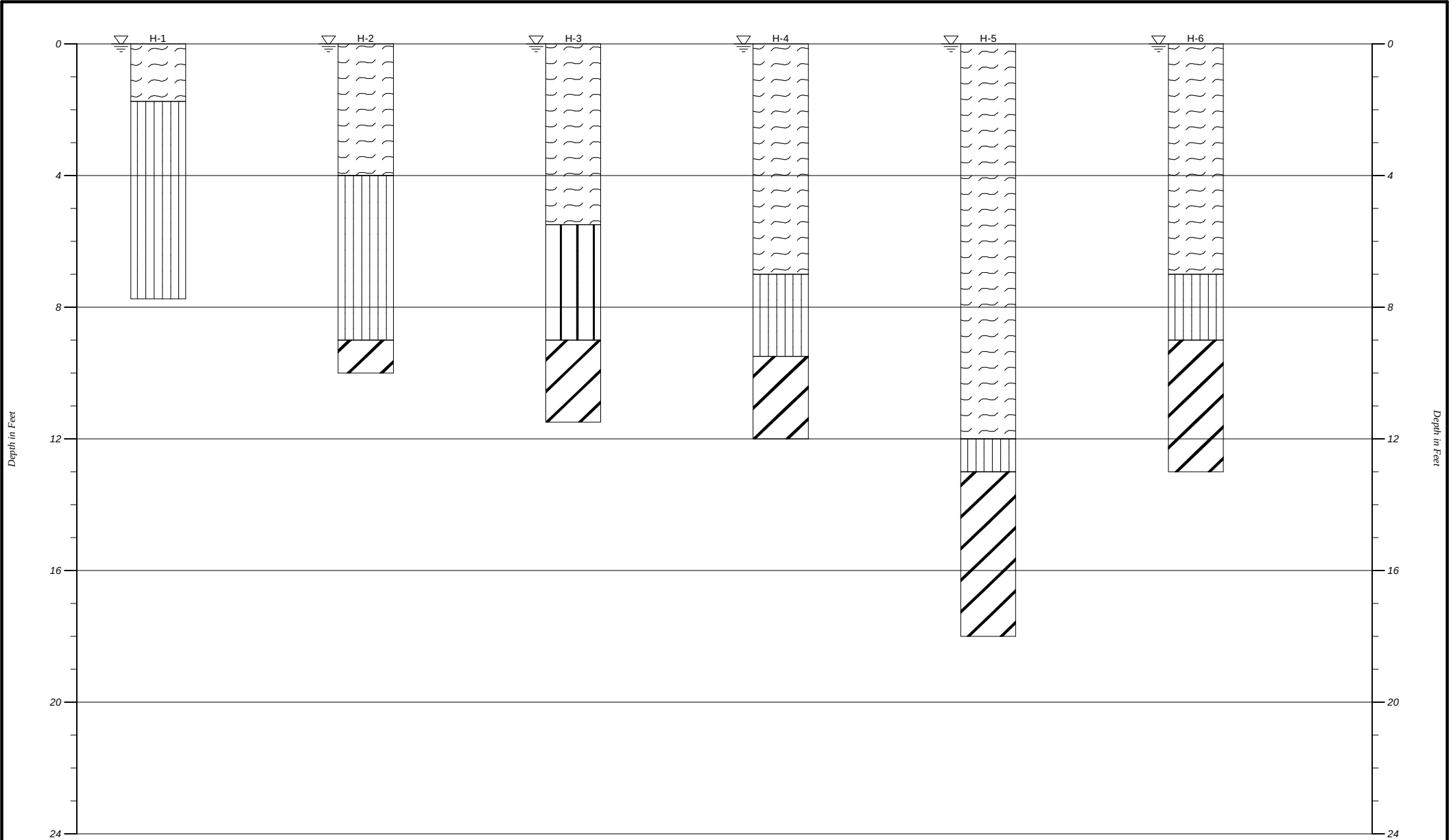
SS = Split Spoon Sample
ST = Shelby Tube Sample
HA = Hand Auger Sample
BS = Bulk Sample
WOH = Weight of Hammer

**The initial groundwater reading may not be indicative of the static groundwater level.*

This information pertains only to this boring and should not be interpreted as being indicative of the site.

APPENDIX V

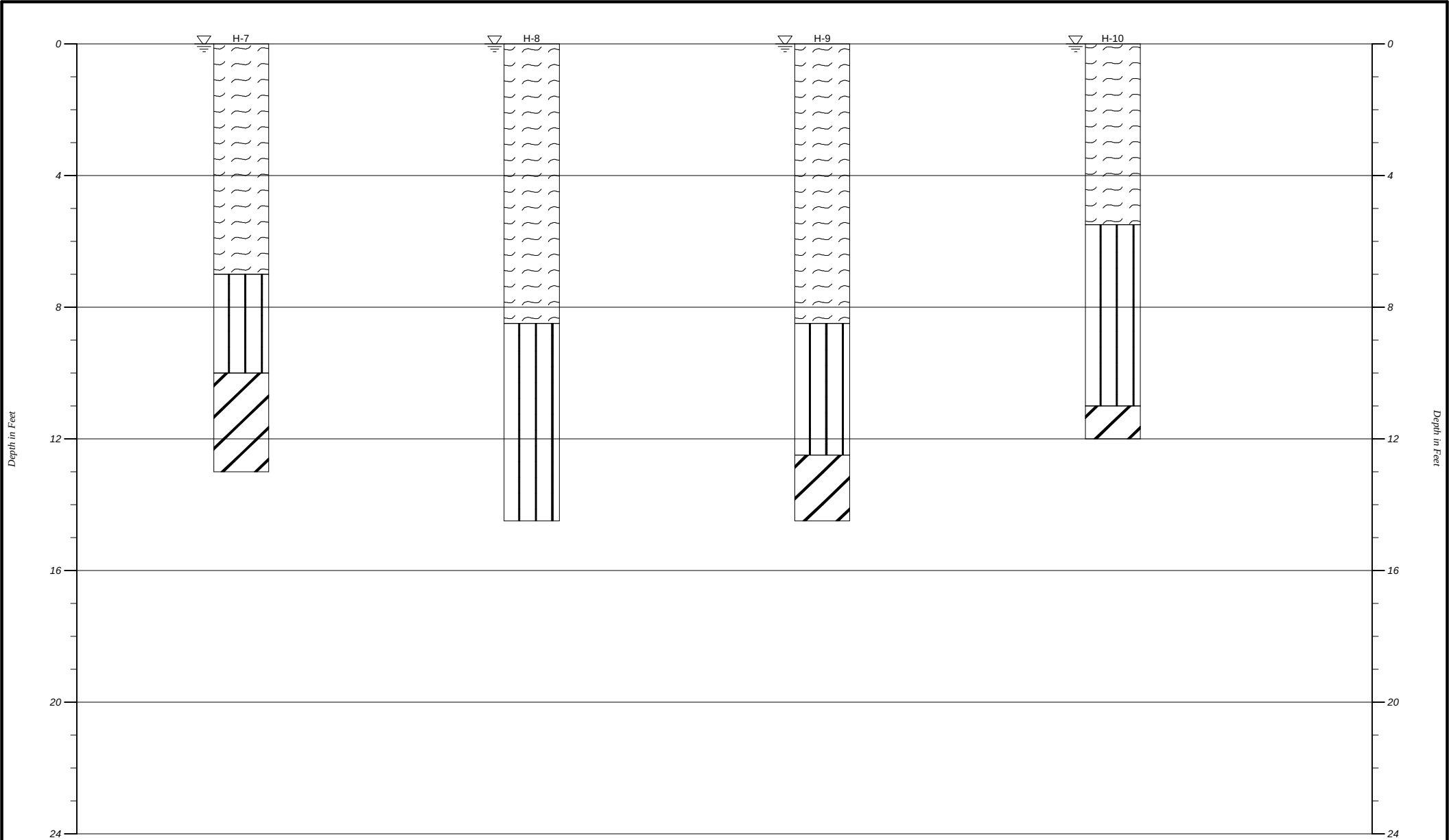
GENERALIZED SOIL PROFILE



Strata symbols

-  Water
-  Silt
-  Fat Clay
-  Elastic Silt

GET Solutions, Inc.		
GENERALIZED SOIL PROFILE		
HORIZONTAL SCALE:	DRAWN BY/APPROVED BY	DATE DRAWN
VERTICAL SCALE: 1"=4'	DF/BS	9/26/2013
The Hague Dredging		
PROJECT NO. VB13-184G		FIGURE NUMBER



Strata symbols

-  Water
-  Silt
-  Fat Clay
-  Elastic Silt

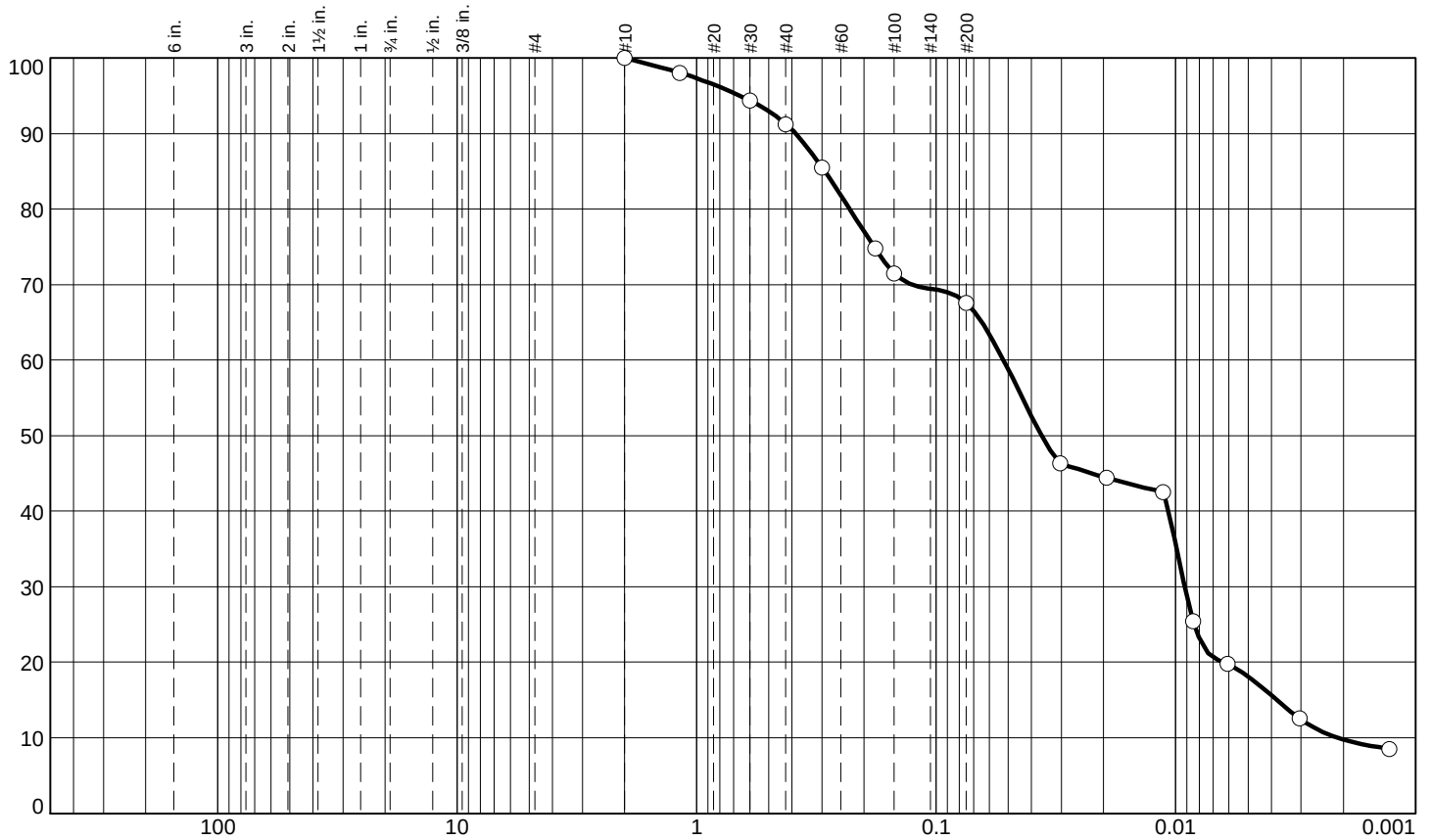
GET Solutions, Inc.		
GENERALIZED SOIL PROFILE		
HORIZONTAL SCALE:	DRAWN BY/APPROVED BY	DATE DRAWN
VERTICAL SCALE: 1"=4'	DF/BS	9/26/2013
The Hague Dredging		
PROJECT NO. VB13-184G		FIGURE NUMBER

APPENDIX VI

PARTICLE SIZE DISTRIBUTION REPORTS

Particle Size Distribution Report

PERCENT FINER



GRAIN SIZE - mm.

% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	8.7	23.7	49.4	18.2

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#10	100.0		
#16	98.1		
#30	94.4		
#40	91.3		
#50	85.5		
#80	74.8		
#100	71.5		
#200	67.6		

* (no specification provided)

Material Description

Gray, Sandy SILT

Atterberg Limits

PL= 37

LL= 44

PI= 7

Coefficients

D₉₀= 0.3875

D₈₅= 0.2920

D₆₀= 0.0524

D₅₀= 0.0363

D₃₀= 0.0092

D₁₅= 0.0038

D₁₀= 0.0021

C_u= 24.83

C_c= 0.76

Classification

USCS= ML

AASHTO= A-5(6)

Remarks

H-1

Natural Moisture = 91.3%

Organic Content = 17.7%

Location: H-1
Sample Number: H-1

Date: 8/27/13

**GET
SOLUTIONS, INC.**

Client: Moffatt & Nichol
Project: The Hague Dredging

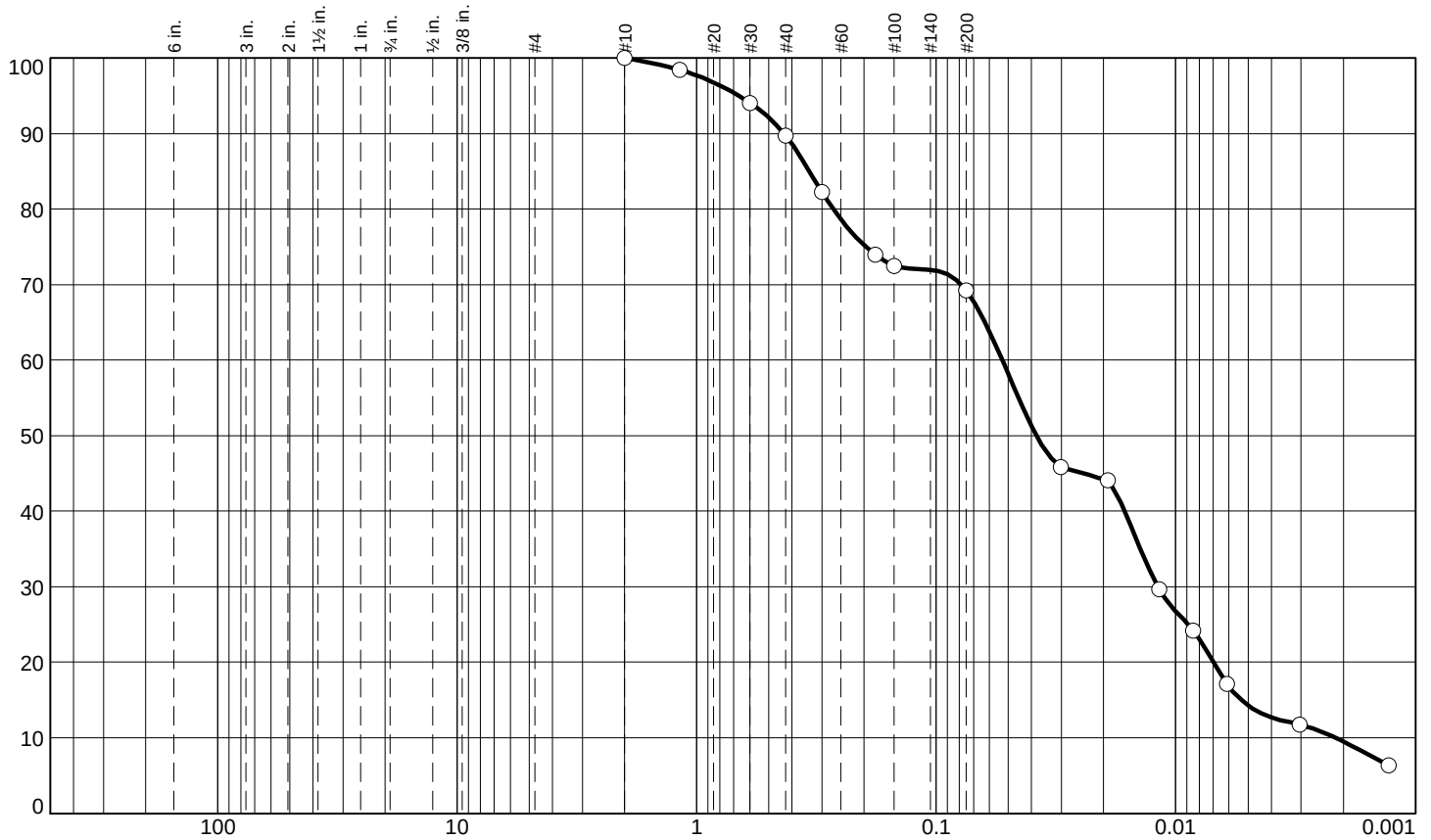
Project No: VB13-184G

Figure

1

Particle Size Distribution Report

PERCENT FINER



GRAIN SIZE - mm.

% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	10.3	20.5	54.9	14.3

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#10	100.0		
#16	98.5		
#30	94.1		
#40	89.7		
#50	82.2		
#80	74.0		
#100	72.5		
#200	69.2		

* (no specification provided)

Material Description

Gray, Sandy SILT

Atterberg Limits

PL= 37

LL= 44

PI= 7

Coefficients

D₉₀= 0.4324

D₈₅= 0.3397

D₆₀= 0.0530

D₅₀= 0.0381

D₃₀= 0.0119

D₁₅= 0.0053

D₁₀= 0.0022

C_u= 24.56

C_c= 1.24

Classification

USCS= ML

AASHTO= A-5(6)

Remarks

H-2

Natural Moisture = 119.7%

Organic Content = 17.3%

Location: H-2
Sample Number: H-2

Date: 8/27/13

**GET
SOLUTIONS, INC.**

Client: Moffatt & Nichol
Project: The Hague Dredging

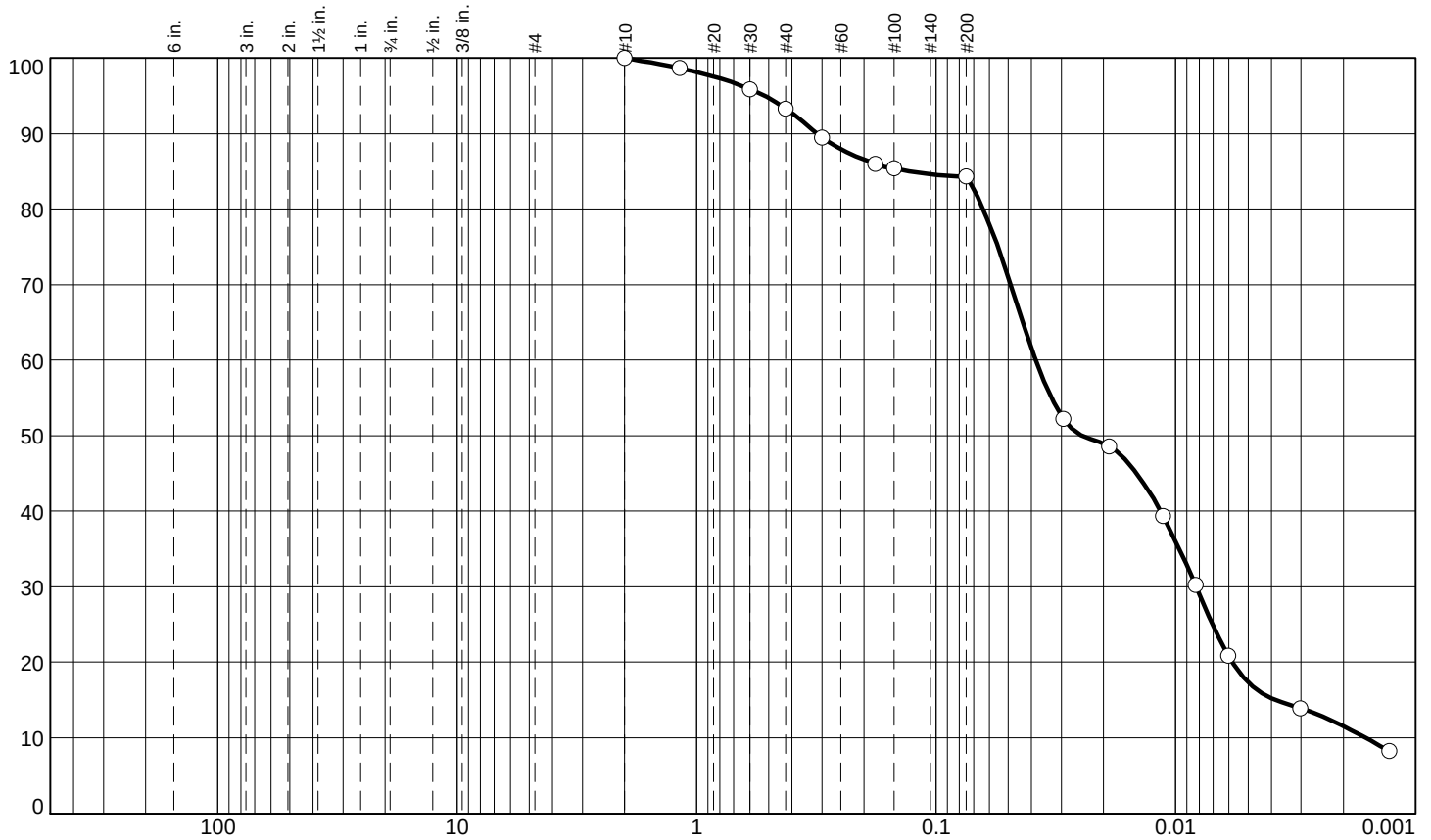
Project No: VB13-184G

Figure

2

Particle Size Distribution Report

PERCENT FINER



GRAIN SIZE - mm.

% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	6.7	9.0	66.9	17.4

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#10	100.0		
#16	98.7		
#30	95.9		
#40	93.3		
#50	89.5		
#80	86.0		
#100	85.4		
#200	84.3		

* (no specification provided)

Material Description

Gray, Elastic SILT with Sand

Atterberg Limits

PL= 35

LL= 52

PI= 17

Coefficients

D₉₀= 0.3149

D₈₅= 0.1292

D₆₀= 0.0384

D₅₀= 0.0246

D₃₀= 0.0082

D₁₅= 0.0038

D₁₀= 0.0016

C_u= 23.76

C_c= 1.09

Classification

USCS= MH

AASHTO= A-7-5(18)

Remarks

H-3

Natural Moisture = 121.0%

Organic Content = 18.9%

Location: H-3
Sample Number: H-3

Date: 8/27/13

**GET
SOLUTIONS, INC.**

Client: Moffatt & Nichol
Project: The Hague Dredging

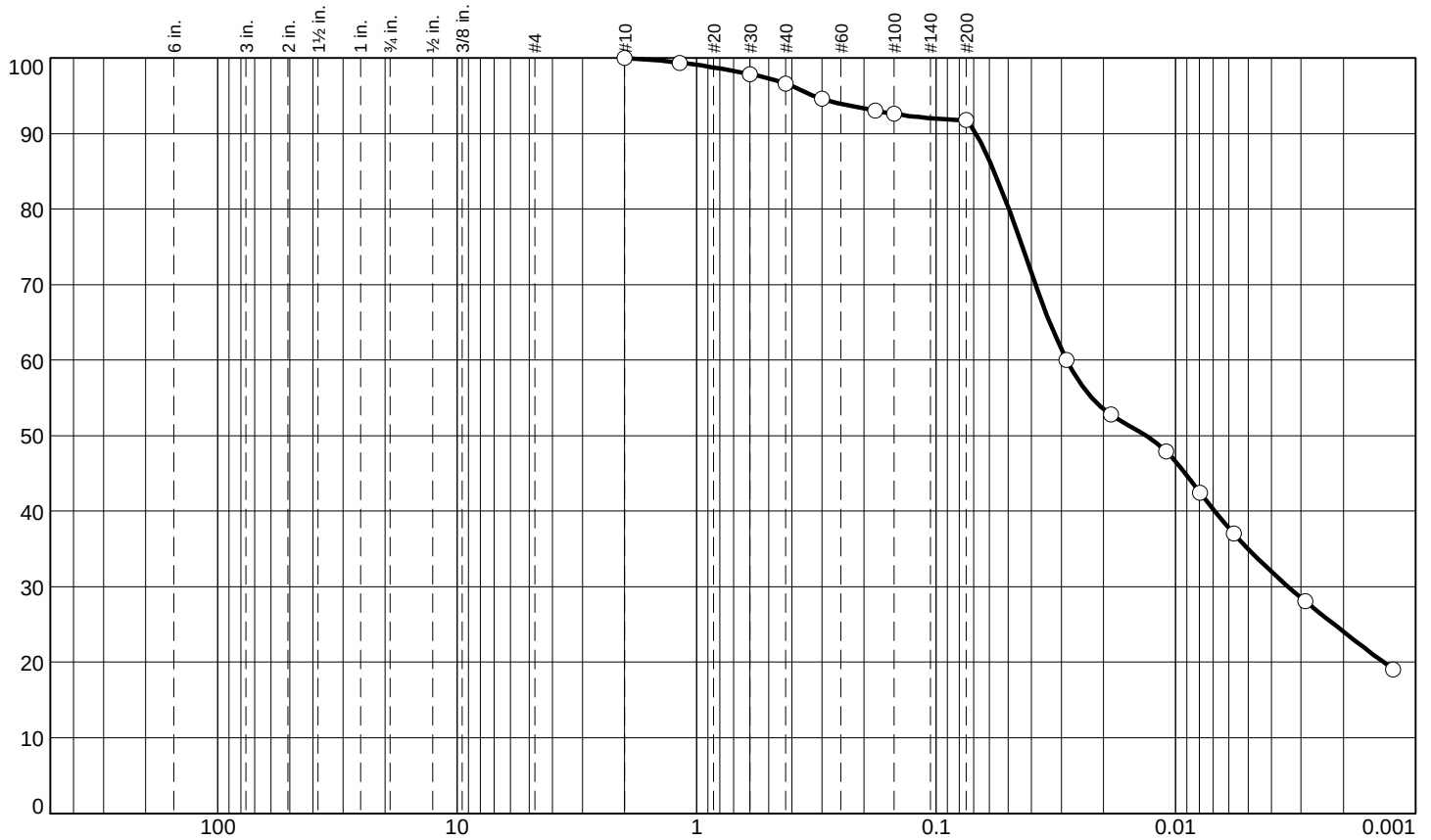
Project No: VB13-184G

Figure

3

Particle Size Distribution Report

PERCENT FINER



GRAIN SIZE - mm.

% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	3.4	4.8	56.8	35.0

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#10	100.0		
#16	99.4		
#30	97.9		
#40	96.6		
#50	94.6		
#80	93.1		
#100	92.6		
#200	91.8		

* (no specification provided)

Material Description

Gray SILT

Atterberg Limits

PL= 25

LL= 29

PI= 4

Coefficients

D₉₀= 0.0684

D₈₅= 0.0573

D₆₀= 0.0286

D₅₀= 0.0133

D₃₀= 0.0034

D₁₅=

D₁₀=

C_u=

C_c=

Classification

USCS= ML

AASHTO= A-4(4)

Remarks

H-4

Natural Moisture = 110.7%

Organic Content = 7.2%

Location: H-4
Sample Number: H-4

Date: 8/27/13

**GET
SOLUTIONS, INC.**

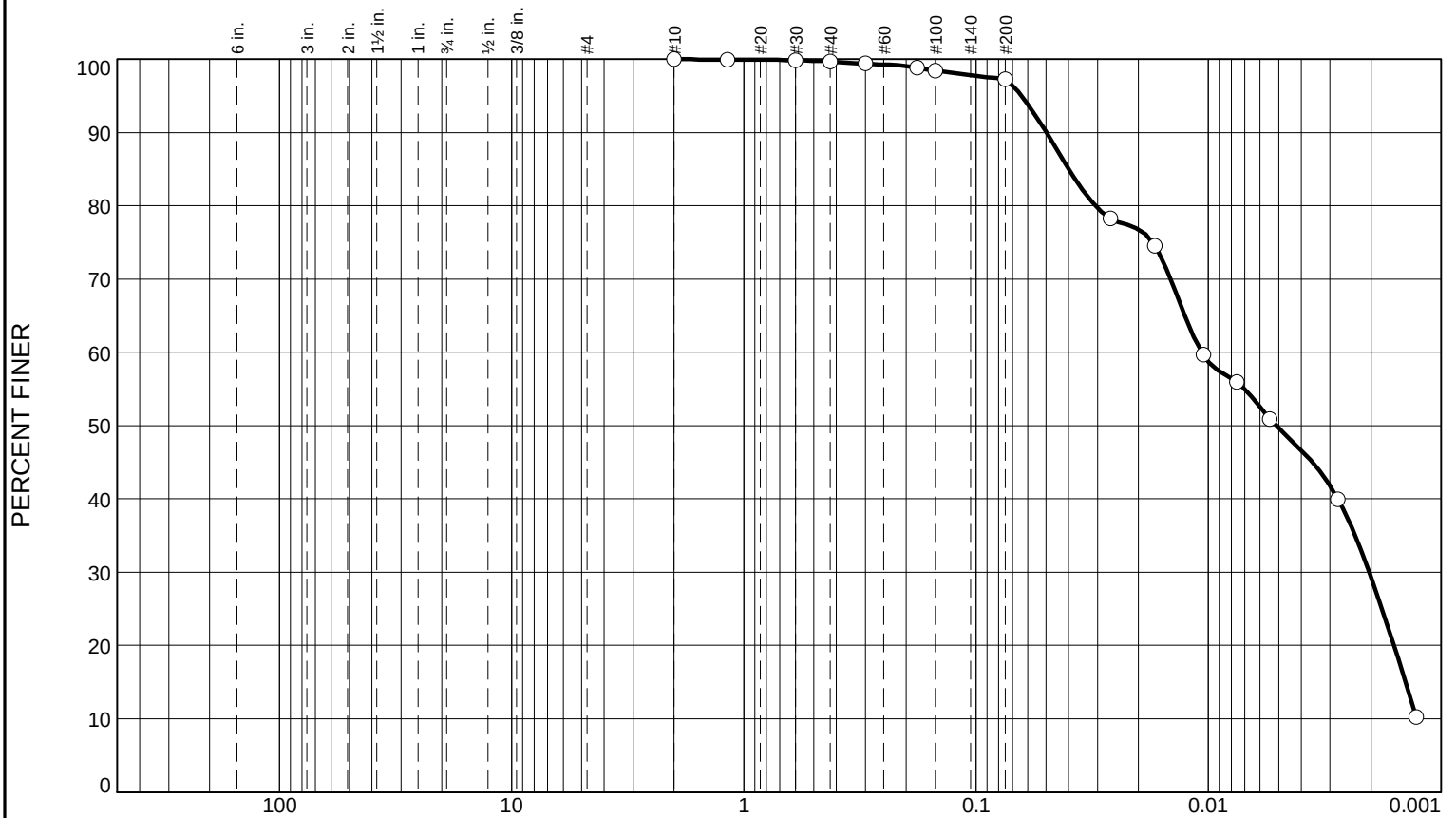
Client: Moffatt & Nichol
Project: The Hague Dredging

Project No: VB13-184G

Figure

4

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	0.3	2.4	47.6	49.7

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#10	100.0		
#16	99.9		
#30	99.9		
#40	99.7		
#50	99.4		
#80	98.9		
#100	98.5		
#200	97.3		

* (no specification provided)

<u>Material Description</u>		
Gray, Fat CLAY		
<u>Atterberg Limits</u>		
PL= 30	LL= 57	PI= 27
<u>Coefficients</u>		
D ₉₀ = 0.0499	D ₈₅ = 0.0400	D ₆₀ = 0.0107
D ₅₀ = 0.0051	D ₃₀ = 0.0020	D ₁₅ = 0.0014
D ₁₀ =	C _u =	C _c =
<u>Classification</u>		
USCS= CH	AASHTO= A-7-5(32)	
<u>Remarks</u>		
H-5		
Natural Moisture = 121.1%		
Organic Content = 4.3%		

Location: H-5
Sample Number: H-5

Date: 8/27/13

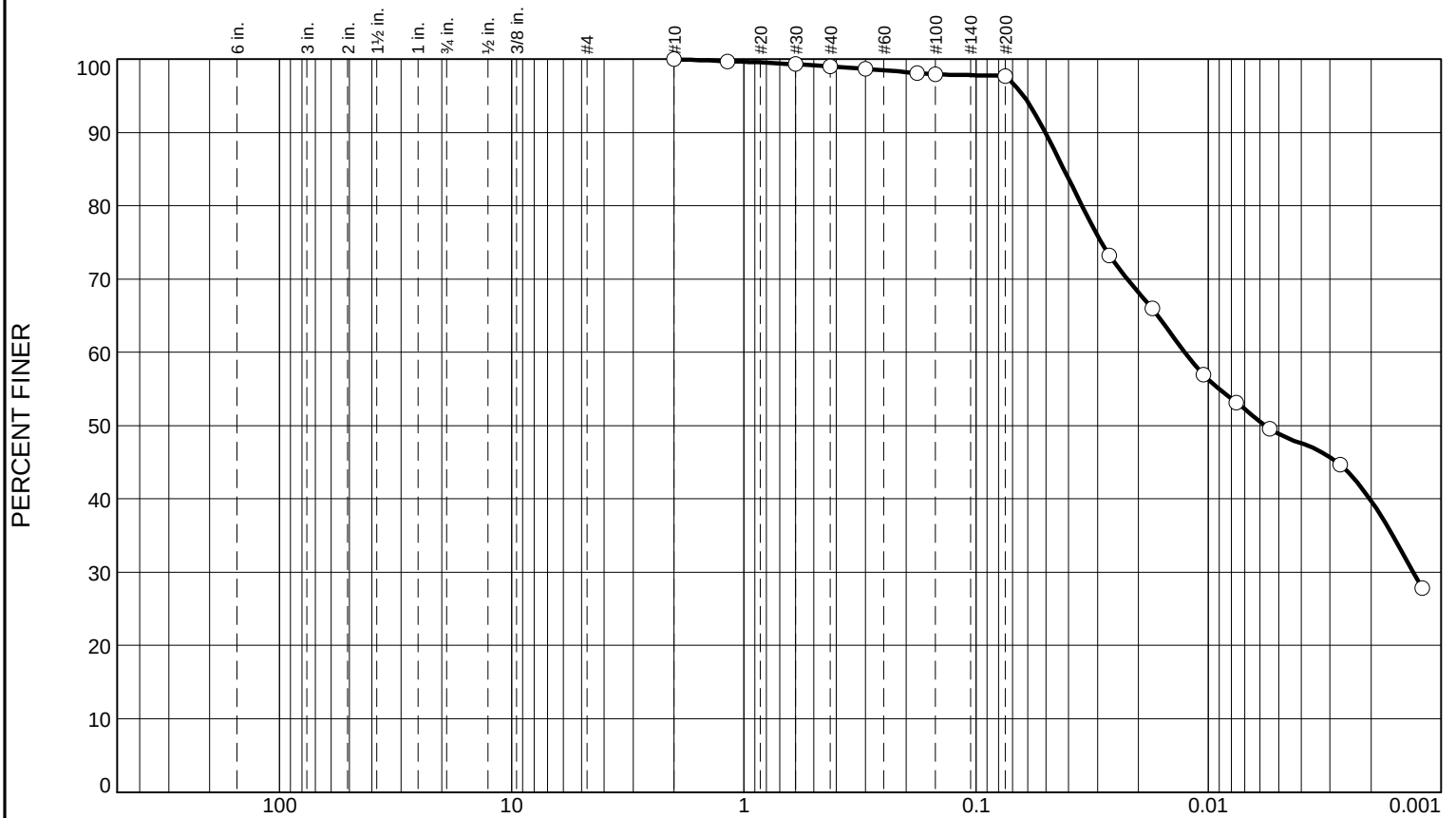
GET SOLUTIONS, INC.

Client: Moffatt & Nichol
Project: The Hague Dredging

Project No: VB13-184G

Figure 5

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	1.0	1.3	48.8	48.9

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#10	100.0		
#16	99.7		
#30	99.3		
#40	99.0		
#50	98.7		
#80	98.1		
#100	97.9		
#200	97.7		

* (no specification provided)

<u>Material Description</u>		
Gray, Fat CLAY		
<u>Atterberg Limits</u>		
PL= 31	LL= 65	PI= 34
<u>Coefficients</u>		
D ₉₀ = 0.0504	D ₈₅ = 0.0419	D ₆₀ = 0.0127
D ₅₀ = 0.0057	D ₃₀ = 0.0013	D ₁₅ =
D ₁₀ =	C _u =	C _c =
<u>Classification</u>		
USCS= CH	AASHTO= A-7-5(40)	
<u>Remarks</u>		
H-6		
Natural Moisture = 143.1%		
Organic Content = 7.3%		

Location: H-6
Sample Number: H-6

Date: 8/27/13

**GET
SOLUTIONS, INC.**

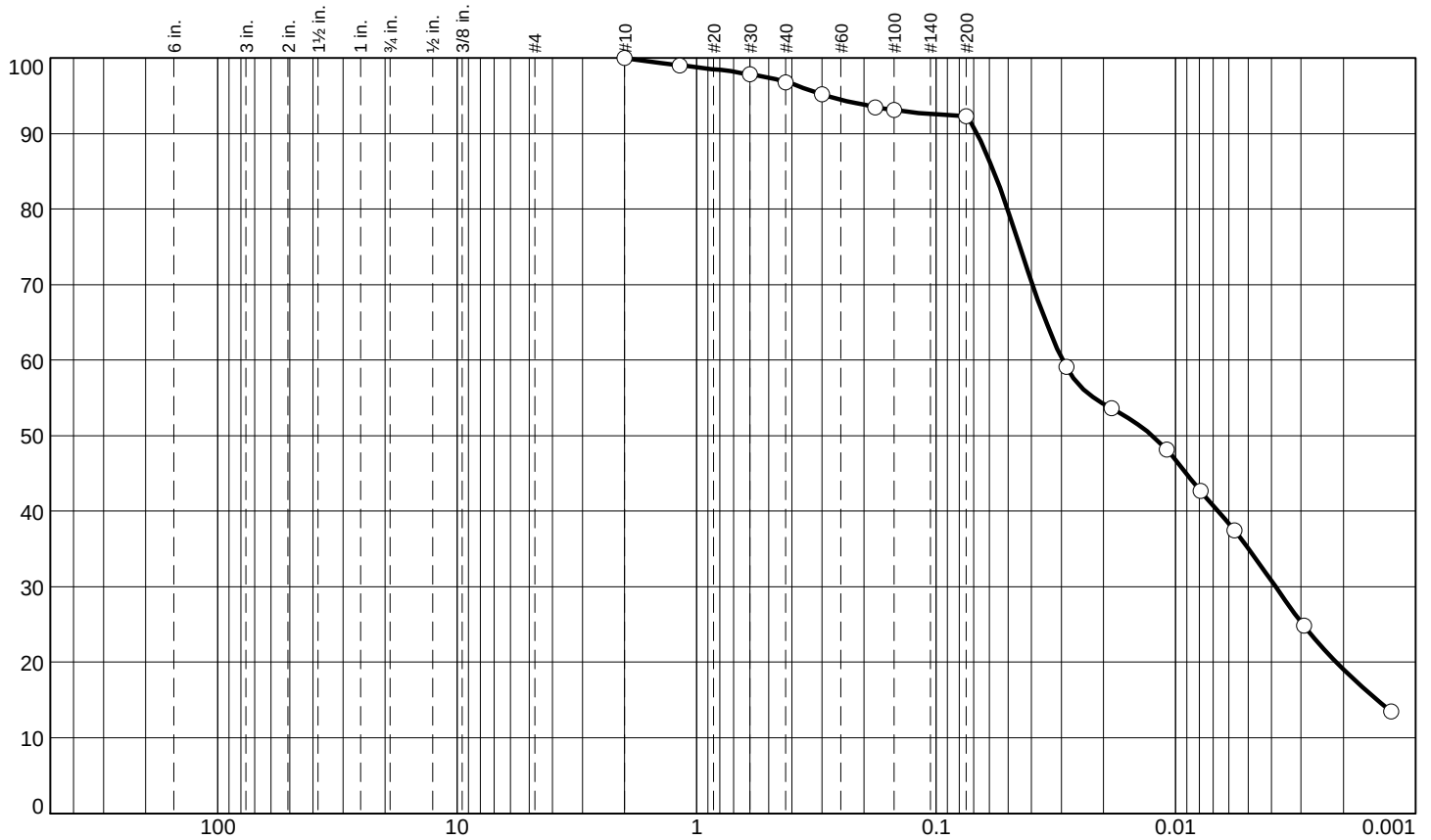
Client: Moffatt & Nichol
Project: The Hague Dredging

Project No: VB13-184G

Figure 6

Particle Size Distribution Report

PERCENT FINER



GRAIN SIZE - mm.

% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	3.2	4.5	57.2	35.1

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#10	100.0		
#16	99.1		
#30	97.9		
#40	96.8		
#50	95.2		
#80	93.5		
#100	93.1		
#200	92.3		

* (no specification provided)

Material Description

Gray, Elastic SILT

Atterberg Limits

PL= 33

LL= 58

PI= 25

Coefficients

D₉₀= 0.0676

D₈₅= 0.0576

D₆₀= 0.0297

D₅₀= 0.0125

D₃₀= 0.0038

D₁₅= 0.0014

D₁₀=

C_u=

C_c=

Classification

USCS= MH

AASHTO= A-7-5(28)

Remarks

H-7

Natural Moisture = 131.9%

Organic Content = 8.9%

Location: H-7
Sample Number: H-7

Date: 8/27/13

**GET
SOLUTIONS, INC.**

Client: Moffatt & Nichol
Project: The Hague Dredging

Project No: VB13-184G

Figure

7

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	0.7	4.1	51.3	43.9

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#10	100.0		
#16	100.0		
#30	99.7		
#40	99.3		
#50	98.4		
#80	96.7		
#100	96.3		
#200	95.2		

* (no specification provided)

<u>Material Description</u>		
Gray, Elastic SILT		
<u>Atterberg Limits</u>		
PL= 35	LL= 58	PI= 23
<u>Coefficients</u>		
D ₉₀ = 0.0561	D ₈₅ = 0.0460	D ₆₀ = 0.0119
D ₅₀ = 0.0067	D ₃₀ = 0.0022	D ₁₅ =
D ₁₀ =	C _u =	C _c =
<u>Classification</u>		
USCS= MH	AASHTO= A-7-5(28)	
<u>Remarks</u>		
H-8		
Natural Moisture = 133.7%		
Organic Content = 6.9%		

Location: H-8
Sample Number: H-8

Date: 8/27/13

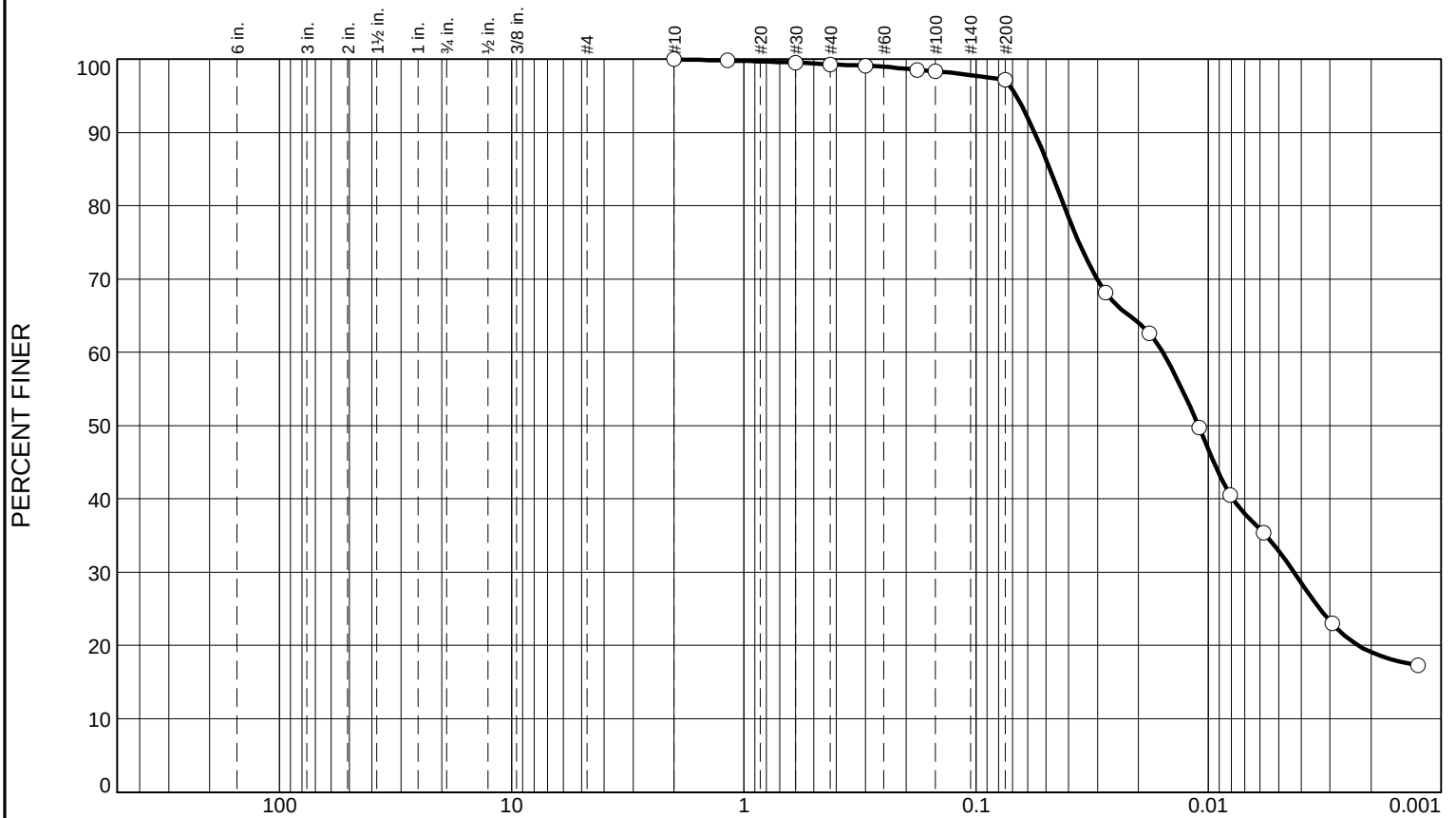
**GET
SOLUTIONS, INC.**

Client: Moffatt & Nichol
Project: The Hague Dredging

Project No: VB13-184G

Figure 8

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	0.7	2.1	64.3	32.9

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#10	100.0		
#16	99.8		
#30	99.5		
#40	99.3		
#50	99.1		
#80	98.5		
#100	98.3		
#200	97.2		

* (no specification provided)

<u>Material Description</u>		
Gray, Elastic SILT		
<u>Atterberg Limits</u>		
PL= 47	LL= 58	PI= 11
<u>Coefficients</u>		
D ₉₀ = 0.0561	D ₈₅ = 0.0483	D ₆₀ = 0.0157
D ₅₀ = 0.0111	D ₃₀ = 0.0043	D ₁₅ =
D ₁₀ =	C _u =	C _c =
<u>Classification</u>		
USCS= MH	AASHTO= A-7-5(19)	
<u>Remarks</u>		
H-9		
Natural Moisture = 133.5%		
Organic Content = 15.5%		

Location: H-9
Sample Number: H-9

Date: 8/27/13

**GET
SOLUTIONS, INC.**

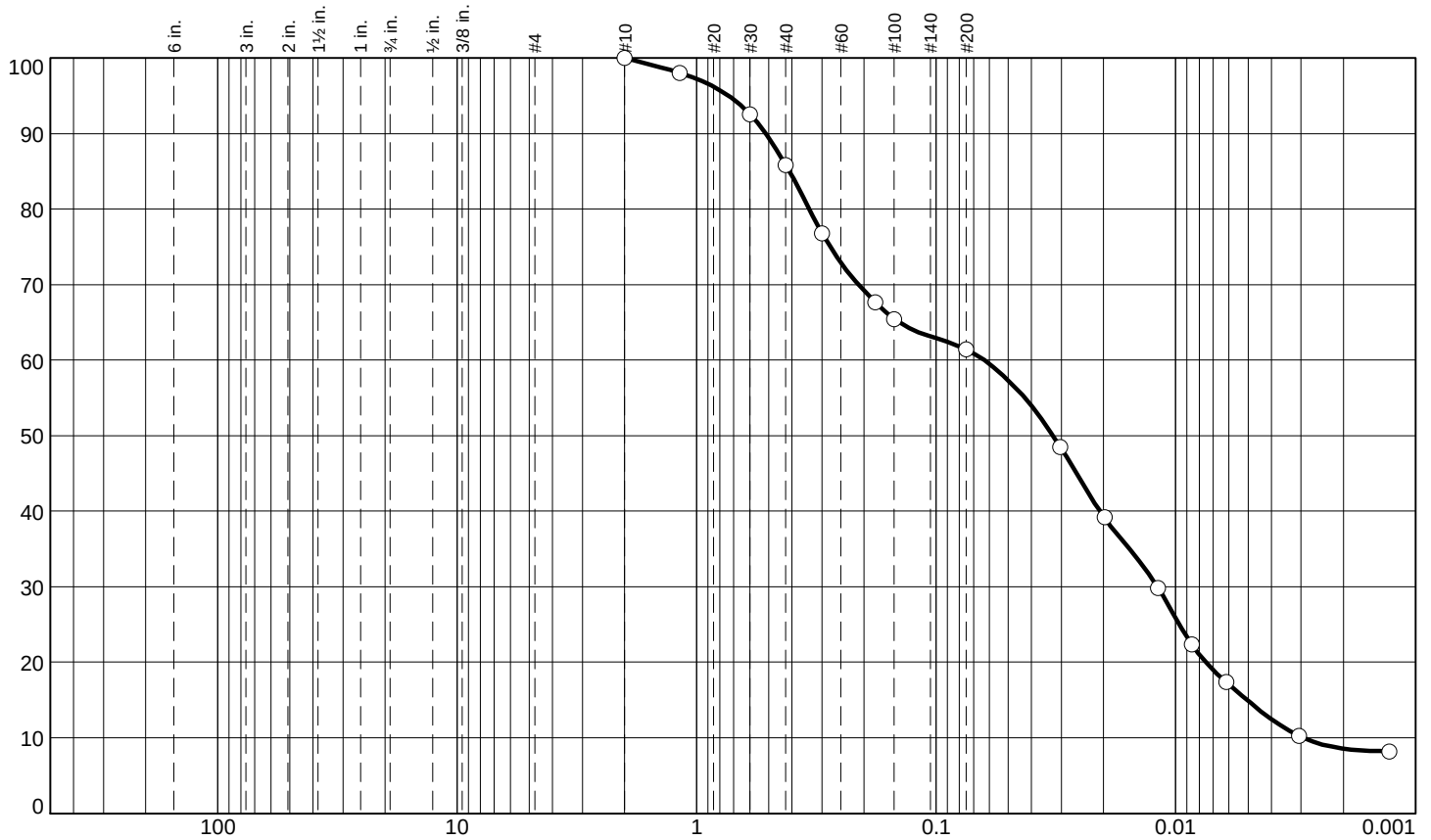
Client: Moffatt & Nichol
Project: The Hague Dredging

Project No: VB13-184G

Figure 9

Particle Size Distribution Report

PERCENT FINER



GRAIN SIZE - mm.

% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	14.2	24.4	46.5	14.9

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#10	100.0		
#16	98.0		
#30	92.5		
#40	85.8		
#50	76.8		
#80	67.7		
#100	65.5		
#200	61.4		

* (no specification provided)

Material Description

Gray, Sandy Elastic SILT

Atterberg Limits

PL= 48

LL= 57

PI= 9

Coefficients

D₉₀= 0.5155

D₈₅= 0.4108

D₆₀= 0.0631

D₅₀= 0.0325

D₃₀= 0.0119

D₁₅= 0.0050

D₁₀= 0.0029

C_u= 21.47

C_c= 0.77

Classification

USCS= MH

AASHTO= A-5(7)

Remarks

H-10

Natural Moisture = 168.9%

Organic Content = 21.6%

Location: H-10
Sample Number: H-10

Date: 8/27/13

**GET
SOLUTIONS, INC.**

Client: Moffatt & Nichol
Project: The Hague Dredging

Project No: VB13-184G

Figure 10

APPENDIX VII

REPORT OF LABORATORY ANALYSES

Table III
Detectable Concentrations of Analyzed Chemicals

Sample	Parameter	Result
Group A	TPH-DRO	876.4 mg/kg
Group A	TPH-GRO	66.8 mg/kg
Group A	PCB as Arochlor 1254	2.30 mg/kg
Group A	PCB as Arochlor 1260	3.40 mg/kg
Group A	Lead	1.77 mg/l
Group B	TPH-DRO	392.8 mg/kg
Group B	Barium	0.61 mg/l
Group B	Lead	1.70 mg/l
Group C	TPH-DRO	16.4 mg/kg
Group D	TPH-DRO	234.0 mg/kg
Group D	Barium	0.57 mg/l
Group D	Lead	1.95 mg/l
Group E	TPH-DRO	20.8 mg/kg
Group E	Lead	1.03 mg/l



Analytical Summary

Enviro Compliance Laboratories, Inc.
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Hampton, Virginia 23661
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www.envirocompliance.com
ec1hampton@envirocompliance.com

GET Solutions, Inc.
Attn: David Ferko
204B Grayson Road
Virginia Beach, Virginia 23462

Project No. : VB13184G
Project Name : The Hague Dredging
Date Received: August 29, 2013
Date Sampled : August 28, 2013
Time Sampled : 12:00
Date Reissued: September 25, 2013

Lab # 1(A-F)/Sample ID : Group A (1-2)

Date/Time	Date/Time						
Parameter	Result	Units	QL	Prepared	Analyzed	Method	Analyst
TPH-DRO	876.4	mg/kg	.5	09-06/1818	09-06/1818	8015C	AEM
TPH-GRO	66.8	mg/kg	5.0	09-17/0858	09-17/0858	8015C	AEM
EOX	BQL	mg/kg	10.0	09-05/1300	09-05/1600	9023	*ECL-R
PCB as Arochlor 1221	BQL	mg/kg	.33	09-11/0900	09-12/0900	8082	*EMSL
PCB as Arochlor 1232	BQL	mg/kg	.33	09-11/0900	09-12/0900	8082	*EMSL
PCB as Arochlor 1242	BQL	mg/kg	.33	09-11/0900	09-12/0900	8082	*EMSL
PCB as Arochlor 1016	BQL	mg/kg	.33	09-11/0900	09-12/0900	8082	*EMSL
PCB as Arochlor 1248	BQL	mg/kg	.33	09-11/0900	09-12/0900	8082	*EMSL
PCB as Arochlor 1254	2.30	mg/kg	.33	09-11/0900	09-12/0900	8082	*EMSL
PCB as Arochlor 1260	3.40	mg/kg	.33	09-11/0900	09-12/0900	8082	*EMSL
TCLP Metals:						1311	
Arsenic	BQL	mg/l	.05	09-06/0600	09-06/1146	6020A	*ECL-R
Barium	BQL	mg/l	.50	09-06/0600	09-06/1146	6020A	*ECL-R
Cadmium	BQL	mg/l	.05	09-06/0600	09-06/1146	6020A	*ECL-R
Chromium	BQL	mg/l	.50	09-06/0600	09-06/1146	6020A	*ECL-R
Lead	1.77	mg/l	.50	09-06/0600	09-06/1146	6020A	*ECL-R
Mercury	BQL	mg/l	.02	09-06/1420	09-08/1400	7471B	*ECL-R
Selenium	BQL	mg/l	.05	09-06/0600	09-06/1146	6020A	*ECL-R
Silver	BQL	mg/l	.10	09-06/0600	09-06/1146	6020A	*ECL-R
TCLP Volatiles						1311	
Vinyl chloride	BQL	ug/l	100	09-11/0900	09-12/0900	8260B	*EMSL
1,1-Dichloroethene	BQL	ug/l	100	09-11/0900	09-12/0900	8260B	*EMSL
Chloroform	BQL	ug/l	100	09-11/0900	09-12/0900	8260B	*EMSL
1,2-Dichloroethane	BQL	ug/l	100	09-11/0900	09-12/0900	8260B	*EMSL
Carbon tetrachloride	BQL	ug/l	100	09-11/0900	09-12/0900	8260B	*EMSL
Trichloroethene	BQL	ug/l	100	09-11/0900	09-12/0900	8260B	*EMSL
Benzene	BQL	ug/l	100	09-11/0900	09-12/0900	8260B	*EMSL
Tetrachloroethene	BQL	ug/l	100	09-11/0900	09-12/0900	8260B	*EMSL
Chlorobenzene	BQL	ug/l	100	09-11/0900	09-12/0900	8260B	*EMSL
1,4-Dichlorobenzene	BQL	ug/l	100	09-11/0900	09-12/0900	8260B	*EMSL
Methyl ethyl ketone	BQL	ug/l	200	09-11/0900	09-12/0900	8260B	*EMSL
TCLP Semi-volatiles						1311	

BQL = Below Quantitation Level (Result is less than stated QL)

All data meets NELAC requirements unless otherwise noted.

* = Analysis was sub-contracted.

Report #: H3830070 Page 1 of 11 Rev.1





Analytical Summary

Enviro Compliance Laboratories, Inc.
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GET Solutions, Inc.
Attn: David Ferko
204B Grayson Road
Virginia Beach, Virginia 23462

Project No. : VB13184G
Project Name : The Hague Dredging
Date Received: August 29, 2013
Date Sampled : August 28, 2013
Time Sampled : 12:00
Date Reissued: September 25, 2013

Lab # 1(A-F)/Sample ID : Group A (1-2)

Date/Time								Date/Time
Parameter	Result	Units	QL	Prepared	Analyzed	Method	Analyst	
2,4,6-Trichlorophenol	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
Pentachlorophenol	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
o-Cresol	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
m-Cresol	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
p-Cresol	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
2,4,5-Trichlorophenol	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
Pyridine	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
Hexachloroethane	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
Nitrobenzene	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
Hexachlorobutadiene	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
2,4-Dinitrotoluene	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
Hexachlorbenzene	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	

BQL = Below Quantitation Level (Result is less than stated QL)

All data meets NELAC requirements unless otherwise noted.

* = Analysis was sub-contracted.

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Analytical Summary

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GET Solutions, Inc.
Attn: David Ferko
204B Grayson Road
Virginia Beach, Virginia 23462

Project No. : VB13184G
Project Name : The Hague Dredging
Date Received: August 29, 2013
Date Sampled : August 28, 2013
Time Sampled : 13:30
Date Reissued: September 25, 2013

Lab # 2(A-F)/Sample ID : Group B (3-4)

Date/Time							Date/Time
Parameter	Result	Units	QL	Prepared	Analyzed	Method	Analyst
TPH-DRO	392.8	mg/kg	.5	09-06/1818	09-06/1818	8015C	AEM
TPH-GRO	BQL	mg/kg	5.0	09-17/0858	09-17/0858	8015C	AEM
EOX	BQL	mg/kg	10.0	09-05/1300	09-05/1600	9023	*ECL-R
PCB as Arochlor 1221	BQL	mg/kg	.33	09-11/0900	09-12/0900	8082	*EMSL
PCB as Arochlor 1232	BQL	mg/kg	.33	09-11/0900	09-12/0900	8082	*EMSL
PCB as Arochlor 1242	BQL	mg/kg	.33	09-11/0900	09-12/0900	8082	*EMSL
PCB as Arochlor 1016	BQL	mg/kg	.33	09-11/0900	09-12/0900	8082	*EMSL
PCB as Arochlor 1248	BQL	mg/kg	.33	09-11/0900	09-12/0900	8082	*EMSL
PCB as Arochlor 1254	BQL	mg/kg	.33	09-11/0900	09-12/0900	8082	*EMSL
PCB as Arochlor 1260	BQL	mg/kg	.33	09-11/0900	09-12/0900	8082	*EMSL
TCLP Metals:						1311	
Arsenic	BQL	mg/l	.05	09-06/0600	09-06/1146	6020A	*ECL-R
Barium	0.61	mg/l	.50	09-06/0600	09-06/1146	6020A	*ECL-R
Cadmium	BQL	mg/l	.05	09-06/0600	09-06/1146	6020A	*ECL-R
Chromium	BQL	mg/l	.50	09-06/0600	09-06/1146	6020A	*ECL-R
Lead	1.70	mg/l	.50	09-06/0600	09-06/1146	6020A	*ECL-R
Mercury	BQL	mg/l	.02	09-06/1420	09-08/1400	7471B	*ECL-R
Selenium	BQL	mg/l	.05	09-06/0600	09-06/1146	6020A	*ECL-R
Silver	BQL	mg/l	.10	09-06/0600	09-06/1146	6020A	*ECL-R
TCLP Volatiles						1311	
Vinyl chloride	BQL	ug/l	100	09-11/0900	09-12/0900	8260B	*EMSL
1,1-Dichloroethene	BQL	ug/l	100	09-11/0900	09-12/0900	8260B	*EMSL
Chloroform	BQL	ug/l	100	09-11/0900	09-12/0900	8260B	*EMSL
1,2-Dichloroethane	BQL	ug/l	100	09-11/0900	09-12/0900	8260B	*EMSL
Carbon tetrachloride	BQL	ug/l	100	09-11/0900	09-12/0900	8260B	*EMSL
Trichloroethene	BQL	ug/l	100	09-11/0900	09-12/0900	8260B	*EMSL
Benzene	BQL	ug/l	100	09-11/0900	09-12/0900	8260B	*EMSL
Tetrachloroethene	BQL	ug/l	100	09-11/0900	09-12/0900	8260B	*EMSL
Chlorobenzene	BQL	ug/l	100	09-11/0900	09-12/0900	8260B	*EMSL
1,4-Dichlorobenzene	BQL	ug/l	100	09-11/0900	09-12/0900	8260B	*EMSL
Methyl ethyl ketone	BQL	ug/l	200	09-11/0900	09-12/0900	8260B	*EMSL
TCLP Semi-volatiles						1311	

BQL = Below Quantitation Level (Result is less than stated QL)

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Report #: H3830070 Page 3 of 11 Rev.1





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GET Solutions, Inc.
Attn: David Ferko
204B Grayson Road
Virginia Beach, Virginia 23462

Project No. : VB13184G
Project Name : The Hague Dredging
Date Received: August 29, 2013
Date Sampled : August 28, 2013
Time Sampled : 13:30
Date Reissued: September 25, 2013

Lab # 2(A-F)/Sample ID : Group B (3-4)

Date/Time								Date/Time
Parameter	Result	Units	QL	Prepared	Analyzed	Method	Analyst	
2,4,6-Trichlorophenol	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
Pentachlorophenol	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
o-Cresol	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
m-Cresol	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
p-Cresol	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
2,4,5-Trichlorophenol	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
Pyridine	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
Hexachloroethane	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
Nitrobenzene	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
Hexachlorobutadiene	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
2,4-Dinitrotoluene	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
Hexachlorbenzene	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	

BQL = Below Quantitation Level (Result is less than stated QL)

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Project No. : VB13184G
Project Name : The Hague Dredging
Date Received: August 29, 2013
Date Sampled : August 28, 2013
Time Sampled : 14:00
Date Reissued: September 25, 2013

Lab # 3(A-C)/Sample ID : Group C (5)

Date/Time								Date/Time
Parameter	Result	Units	QL	Prepared	Analyzed	Method	Analyst	
TPH-DRO	16.4	mg/kg	.5	09-06/1818	09-06/1818	8015C	AEM	
TPH-GRO	BQL	mg/kg	5.0	09-17/0858	09-17/0858	8015C	AEM	
EOX	BQL	mg/kg	10.0	09-05/1300	09-05/1600	9023	*ECL-R	
PCB as Arochlor 1221	BQL	mg/kg	.33	09-11/0900	09-12/0900	8082	*EMSL	
PCB as Arochlor 1232	BQL	mg/kg	.33	09-11/0900	09-12/0900	8082	*EMSL	
PCB as Arochlor 1242	BQL	mg/kg	.33	09-11/0900	09-12/0900	8082	*EMSL	
PCB as Arochlor 1016	BQL	mg/kg	.33	09-11/0900	09-12/0900	8082	*EMSL	
PCB as Arochlor 1248	BQL	mg/kg	.33	09-11/0900	09-12/0900	8082	*EMSL	
PCB as Arochlor 1254	BQL	mg/kg	.33	09-11/0900	09-12/0900	8082	*EMSL	
PCB as Arochlor 1260	BQL	mg/kg	.33	09-11/0900	09-12/0900	8082	*EMSL	
TCLP Metals:						1311		
Arsenic	BQL	mg/l	.05	09-06/0600	09-06/1146	6020A	*ECL-R	
Barium	BQL	mg/l	.50	09-06/0600	09-06/1146	6020A	*ECL-R	
Cadmium	BQL	mg/l	.05	09-06/0600	09-06/1146	6020A	*ECL-R	
Chromium	BQL	mg/l	.50	09-06/0600	09-06/1146	6020A	*ECL-R	
Lead	BQL	mg/l	.50	09-06/0600	09-06/1146	6020A	*ECL-R	
Mercury	BQL	mg/l	.02	09-06/1420	09-08/1400	7471B	*ECL-R	
Selenium	BQL	mg/l	.05	09-06/0600	09-06/1146	6020A	*ECL-R	
Silver	BQL	mg/l	.10	09-06/0600	09-06/1146	6020A	*ECL-R	
TCLP Volatiles						1311		
Vinyl chloride	BQL	ug/l	100	09-11/0900	09-12/0900	8260B	*EMSL	
1,1-Dichloroethene	BQL	ug/l	100	09-11/0900	09-12/0900	8260B	*EMSL	
Chloroform	BQL	ug/l	100	09-11/0900	09-12/0900	8260B	*EMSL	
1,2-Dichloroethane	BQL	ug/l	100	09-11/0900	09-12/0900	8260B	*EMSL	
Carbon tetrachloride	BQL	ug/l	100	09-11/0900	09-12/0900	8260B	*EMSL	
Trichloroethene	BQL	ug/l	100	09-11/0900	09-12/0900	8260B	*EMSL	
Benzene	BQL	ug/l	100	09-11/0900	09-12/0900	8260B	*EMSL	
Tetrachloroethene	BQL	ug/l	100	09-11/0900	09-12/0900	8260B	*EMSL	
Chlorobenzene	BQL	ug/l	100	09-11/0900	09-12/0900	8260B	*EMSL	
1,4-Dichlorobenzene	BQL	ug/l	100	09-11/0900	09-12/0900	8260B	*EMSL	
Methyl ethyl ketone	BQL	ug/l	200	09-11/0900	09-12/0900	8260B	*EMSL	
TCLP Semi-volatiles						1311		

BQL = Below Quantitation Level (Result is less than stated QL)

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GET Solutions, Inc.
Attn: David Ferko
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Virginia Beach, Virginia 23462

Project No. : VB13184G
Project Name : The Hague Dredging
Date Received: August 29, 2013
Date Sampled : August 28, 2013
Time Sampled : 14:00
Date Reissued: September 25, 2013

Lab # 3(A-C)/Sample ID : Group C (5)

Date/Time								Date/Time
Parameter	Result	Units	QL	Prepared	Analyzed	Method	Analyst	
2,4,6-Trichlorophenol	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
Pentachlorophenol	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
o-Cresol	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
m-Cresol	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
p-Cresol	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
2,4,5-Trichlorophenol	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
Pyridine	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
Hexachloroethane	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
Nitrobenzene	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
Hexachlorobutadiene	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
2,4-Dinitrotoluene	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
Hexachlorbenzene	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	

BQL = Below Quantitation Level (Result is less than stated QL)

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Project No. : VB13184G
Project Name : The Hague Dredging
Date Received: August 29, 2013
Date Sampled : August 28, 2013
Time Sampled : 15:30
Date Reissued: September 25, 2013

Lab # 4(A-F)/Sample ID : Group D (6, 7, 8)

Date/Time							Date/Time
Parameter	Result	Units	QL	Prepared	Analyzed	Method	Analyst
TPH-DRO	234.0	mg/kg	.5	09-06/1818	09-06/1818	8015C	AEM
TPH-GRO	BQL	mg/kg	5.0	09-17/0858	09-17/0858	8015C	AEM
EOX	BQL	mg/kg	10.0	09-05/1300	09-05/1600	9023	*ECL-R
PCB as Arochlor 1221	BQL	mg/kg	.33	09-11/0900	09-12/0900	8082	*EMSL
PCB as Arochlor 1232	BQL	mg/kg	.33	09-11/0900	09-12/0900	8082	*EMSL
PCB as Arochlor 1242	BQL	mg/kg	.33	09-11/0900	09-12/0900	8082	*EMSL
PCB as Arochlor 1016	BQL	mg/kg	.33	09-11/0900	09-12/0900	8082	*EMSL
PCB as Arochlor 1248	BQL	mg/kg	.33	09-11/0900	09-12/0900	8082	*EMSL
PCB as Arochlor 1254	BQL	mg/kg	.33	09-11/0900	09-12/0900	8082	*EMSL
PCB as Arochlor 1260	BQL	mg/kg	.33	09-11/0900	09-12/0900	8082	*EMSL
TCLP Metals:						1311	
Arsenic	BQL	mg/l	.05	09-06/0600	09-06/1146	6020A	*ECL-R
Barium	0.57	mg/l	.50	09-06/0600	09-06/1146	6020A	*ECL-R
Cadmium	BQL	mg/l	.05	09-06/0600	09-06/1146	6020A	*ECL-R
Chromium	BQL	mg/l	.50	09-06/0600	09-06/1146	6020A	*ECL-R
Lead	1.95	mg/l	.50	09-06/0600	09-06/1146	6020A	*ECL-R
Mercury	BQL	mg/l	.02	09-06/1420	09-08/1400	7471B	*ECL-R
Selenium	BQL	mg/l	.05	09-06/0600	09-06/1146	6020A	*ECL-R
Silver	BQL	mg/l	.10	09-06/0600	09-06/1146	6020A	*ECL-R
TCLP Volatiles						1311	
Vinyl chloride	BQL	ug/l	100	09-11/0900	09-12/0900	8260B	*EMSL
1,1-Dichloroethene	BQL	ug/l	100	09-11/0900	09-12/0900	8260B	*EMSL
Chloroform	BQL	ug/l	100	09-11/0900	09-12/0900	8260B	*EMSL
1,2-Dichloroethane	BQL	ug/l	100	09-11/0900	09-12/0900	8260B	*EMSL
Carbon tetrachloride	BQL	ug/l	100	09-11/0900	09-12/0900	8260B	*EMSL
Trichloroethene	BQL	ug/l	100	09-11/0900	09-12/0900	8260B	*EMSL
Benzene	BQL	ug/l	100	09-11/0900	09-12/0900	8260B	*EMSL
Tetrachloroethene	BQL	ug/l	100	09-11/0900	09-12/0900	8260B	*EMSL
Chlorobenzene	BQL	ug/l	100	09-11/0900	09-12/0900	8260B	*EMSL
1,4-Dichlorobenzene	BQL	ug/l	100	09-11/0900	09-12/0900	8260B	*EMSL
Methyl ethyl ketone	BQL	ug/l	200	09-11/0900	09-12/0900	8260B	*EMSL
TCLP Semi-volatiles						1311	

BQL = Below Quantitation Level (Result is less than stated QL)

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Report #: H3830070 Page 7 of 11 Rev.1





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Attn: David Ferko
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Project No. : VB13184G
Project Name : The Hague Dredging
Date Received: August 29, 2013
Date Sampled : August 28, 2013
Time Sampled : 15:30
Date Reissued: September 25, 2013

Lab # 4(A-F)/Sample ID : Group D (6, 7, 8)

Date/Time								Date/Time
Parameter	Result	Units	QL	Prepared	Analyzed	Method	Analyst	
2,4,6-Trichlorophenol	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
Pentachlorophenol	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
o-Cresol	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
m-Cresol	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
p-Cresol	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
2,4,5-Trichlorophenol	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
Pyridine	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
Hexachloroethane	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
Nitrobenzene	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
Hexachlorobutadiene	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
2,4-Dinitrotoluene	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
Hexachlorbenzene	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	

BQL = Below Quantitation Level (Result is less than stated QL)

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Attn: David Ferko
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Virginia Beach, Virginia 23462

Project No. : VB13184G
Project Name : The Hague Dredging
Date Received: August 29, 2013
Date Sampled : August 28, 2013
Time Sampled : 17:00
Date Reissued: September 25, 2013

Lab # 5(A-F)/Sample ID : Group E (9-10)

Date/Time								Date/Time
Parameter	Result	Units	QL	Prepared	Analyzed	Method	Analyst	
TPH-DRO	20.8	mg/kg	.5	09-06/1818	09-06/1818	8015C	AEM	
TPH-GRO	BQL	mg/kg	5.0	09-17/0858	09-17/0858	8015C	AEM	
EOX	BQL	mg/kg	10.0	09-05/1300	09-05/1600	9023	*ECL-R	
PCB as Arochlor 1221	BQL	mg/kg	.33	09-11/0900	09-12/0900	8082	*EMSL	
PCB as Arochlor 1232	BQL	mg/kg	.33	09-11/0900	09-12/0900	8082	*EMSL	
PCB as Arochlor 1242	BQL	mg/kg	.33	09-11/0900	09-12/0900	8082	*EMSL	
PCB as Arochlor 1016	BQL	mg/kg	.33	09-11/0900	09-12/0900	8082	*EMSL	
PCB as Arochlor 1248	BQL	mg/kg	.33	09-11/0900	09-12/0900	8082	*EMSL	
PCB as Arochlor 1254	BQL	mg/kg	.33	09-11/0900	09-12/0900	8082	*EMSL	
PCB as Arochlor 1260	BQL	mg/kg	.33	09-11/0900	09-12/0900	8082	*EMSL	
TCLP Metals:						1311		
Arsenic	BQL	mg/l	.05	09-06/0600	09-06/1146	6020A	*ECL-R	
Barium	BQL	mg/l	.50	09-06/0600	09-06/1146	6020A	*ECL-R	
Cadmium	BQL	mg/l	.05	09-06/0600	09-06/1146	6020A	*ECL-R	
Chromium	BQL	mg/l	.50	09-06/0600	09-06/1146	6020A	*ECL-R	
Lead	1.03	mg/l	.50	09-06/0600	09-06/1146	6020A	*ECL-R	
Mercury	BQL	mg/l	.02	09-06/1420	09-08/1400	7471B	*ECL-R	
Selenium	BQL	mg/l	.05	09-06/0600	09-06/1146	6020A	*ECL-R	
Silver	BQL	mg/l	.10	09-06/0600	09-06/1146	6020A	*ECL-R	
TCLP Volatiles						1311		
Vinyl chloride	BQL	ug/l	100	09-11/0900	09-12/0900	8260B	*EMSL	
1,1-Dichloroethene	BQL	ug/l	100	09-11/0900	09-12/0900	8260B	*EMSL	
Chloroform	BQL	ug/l	100	09-11/0900	09-12/0900	8260B	*EMSL	
1,2-Dichloroethane	BQL	ug/l	100	09-11/0900	09-12/0900	8260B	*EMSL	
Carbon tetrachloride	BQL	ug/l	100	09-11/0900	09-12/0900	8260B	*EMSL	
Trichloroethene	BQL	ug/l	100	09-11/0900	09-12/0900	8260B	*EMSL	
Benzene	BQL	ug/l	100	09-11/0900	09-12/0900	8260B	*EMSL	
Tetrachloroethene	BQL	ug/l	100	09-11/0900	09-12/0900	8260B	*EMSL	
Chlorobenzene	BQL	ug/l	100	09-11/0900	09-12/0900	8260B	*EMSL	
1,4-Dichlorobenzene	BQL	ug/l	100	09-11/0900	09-12/0900	8260B	*EMSL	
Methyl ethyl ketone	BQL	ug/l	200	09-11/0900	09-12/0900	8260B	*EMSL	
TCLP Semi-volatiles						1311		

BQL = Below Quantitation Level (Result is less than stated QL)

All data meets NELAC requirements unless otherwise noted.

* = Analysis was sub-contracted.

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Analytical Summary

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GET Solutions, Inc.
Attn: David Ferko
204B Grayson Road
Virginia Beach, Virginia 23462

Project No. : VB13184G
Project Name : The Hague Dredging
Date Received: August 29, 2013
Date Sampled : August 28, 2013
Time Sampled : 17:00
Date Reissued: September 25, 2013

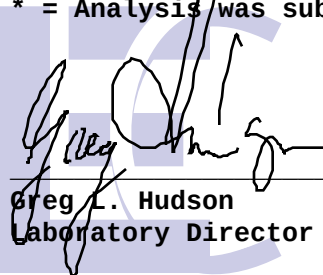
Lab # 5(A-F)/Sample ID : Group E (9-10)

Date/Time								Date/Time
Parameter	Result	Units	QL	Prepared	Analyzed	Method	Analyst	
2,4,6-Trichlorophenol	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
Pentachlorophenol	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
o-Cresol	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
m-Cresol	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
p-Cresol	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
2,4,5-Trichlorophenol	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
Pyridine	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
Hexachloroethane	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
Nitrobenzene	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
Hexachlorobutadiene	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
2,4-Dinitrotoluene	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	
Hexachlorbenzene	BQL	mg/l	.05	09-13/0900	09-16/0900	8270C	*EMSL	

BQL = Below Quantitation Level (Result is less than stated QL)

All data meets NELAC requirements unless otherwise noted.

* = Analysis was sub-contracted.


Greg L. Hudson
Laboratory Director

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VELAP ID#: 460130





Report Annex

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Abbreviations:

NR = Not Reported

ND = Not Detected

BQL = Below Quantitation Level (Result is less than stated QL)

< = Result is less than Quantitation Limit

Quality Assurance Flags:

L = LCS did not meet method criteria.

H/B = Blank did not meet QC criteria

HT = Sample was not analyzed within holding times.

SR = Surrogate Recovery not available due to dilution.

R = Corr Coef <.995

C = Initial Instrument Calibration (Second Source) did not meet criteria

V = Continuing Calibration Verification did not meet criteria

S = Matrix Spike did not meet criteria

D = Duplicate did not meet criteria

OVr = Overrange- Sample was outside of calibration range

UnR = Underrange w/Diln.- Sample was below low standard because of dilution

TOX = Toxicity exhibited in BOD

G = GGA/Int. QC was not 198.5+/-30.5

Y = Yield not within 10-200mg

* = Analysis was subcontracted

** = Non-accreditable/non-accredited parameter

Subcontractor Information:

Information for subcontracted analytical data.

ECL-R=EnviroCompliance Laboratories:460032

EMSL=EMSL-Beltsville :460184

Analysis was performed in accordance to NELAC requirements unless otherwise noted.

All methods are 40 CFR 136 March 12, 2007, Table IB approved.

Reference to Standard Methods is 18th ed.

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APPENDIX D

Water Quality Sampling and Results

D 1. Monitoring Approach

A campaign of regular monitoring of water quality indicators within the Hague was initiated in April 2013. Electronic measurements and bottle samples were collected, and the bottle samples were analyzed by EnviroCompliance Laboratories (ECL), at various dates between April 18, 2013 and November 11, 2013. (The first sampling event on April 11 did not include bottle samples.) This section presents the methods and results of the sampling to date.

The study includes the measurement of temperature, salinity, conductivity, dissolved oxygen, and pH via portable YSI 556 multi-parameter meter, in conjunction with laboratory tests of nutrient series (N, P), chlorophyll-a, organic carbon, suspended sediments, and bacterial pathogen indicators. Field measurements and/or samples have been collected on 4 dates, including two wet-weather dates, at four of locations shown on Figure 3. Bottle samples and instrument data were collected at locations #1, #3, #6, and #7; instrument data only was collected at locations #2, #4, and #5. Table D-1 summarizes the field work dates with types of measurements and sampling conducted.

Table D-1: Summary of sampling dates

Date	Wet-Weather?	YSI 556 Instrument: pH, DO, T, S	Bottle Samples with ECL Lab Tests: N, P, chlorophyll-a, organic carbon, suspended sediments, pathogen indicators
04/11/2013	no	yes	no
04/18/2013	yes	yes	yes
07/26/2013	no	yes	yes
10/08/2013	yes	yes	yes
11/11/2013	no	yes	yes
04/02/2014	no	yes	yes
04/08/2014	yes	yes	yes

Location #7 is outside of the Hague between the NOAA and PETA facilities, and it provides data for comparison of measurements in the Hague to an area intended to be less influenced directly by stormwater discharges into the Hague. Data were also obtained from the data archives of the Chesapeake Bay Program (CBP) for a nearby monitoring station in the Elizabeth River. (CBP data can be accessed at the web address <http://www.chesapeakebay.net/data>.)

D 2. Sampling Results

Table D-2 summarizes the range of water quality parameter values sampled from within the Hague and from location #7 between NOAA and PETA facilities, and values reported by CBP in the Elizabeth River over the course of the monitoring program (April 2013 – April 2014).

Table D-2: Summary of selected sampling results

Parameter	Range Sampled within the Hague	Range Sampled Between NOAA and PETA	Range from CBP Elizabeth River Station ELE01
Temperature (°F)	50 – 81	50 – 80	41 – 79
Salinity (ppt)	4.3 – 22.1	14.9 – 22.0	14.3 – 22.5
Dissolved Oxygen (mg/L)	2.5 – 12.5	3.8 – 10.5	3.7 – 10.6
Dissolved Oxygen Saturation ¹ (%)	36 – 125	54 – 110	77 – 102
pH	6.3 – 8.2	7.5 – 8.1	7.4 – 8.0
Total Nitrogen (mg/L)	0.7 – 6.9	0.9 – 3.5	0.44 – 0.94
Total Phosphorus (mg/L)	0.03 – 0.14	0.04 – 0.10	0.04 – 0.13
Total Organic Carbon (mg/L)	BQL – 31.6	4.7 – 18.9	5.11
Suspended Sediments (mg/L)	2.9 – 26.2	3.4 – 15.5	9.5 – 36.0
Bacterial pathogen indicators (CFU/100mL) ²	1 – 4200	2 – 1000	25 – 125

¹Dissolved oxygen saturation percentage is calculated from the M&N sampled or CBP reported data.

²Colony Forming Units per 100 mL.

For a view of the variation in the data over time, Figure D-1 through Figure D-12 display results for each field sampling event at the four locations with both instrument and bottle samples, with each figure representing a single water quality parameter. Each vertical shaded bar in the figures indicates the value of the parameter at a different sampling location, identified in the figure legend. The y-axis indicates the parameter value, and the x-axis indicates the sampling date for each group of bars.

The paragraphs below briefly discuss the charted results, making reference where applicable to water quality standards referenced from the Virginia Department of Environmental Quality (VDEQ) website. The standards are defined in the Virginia Administrative Code (VAC) under Title 9 Environment, of the State Water Control Board (Agency 25), Chapter 260 Water Quality Standards.

D 2.1. Salinity, Temperature, and Dissolved Oxygen

Figure D-1 shows the variation in salinity within the Hague. Very little variation in salinity was observed from location to location on most sampling dates, and salinity within the Hague was generally similar to salinity reported at CBP station ELE01. The exception was on 4/8/2014, when salinity was significantly lower in the east and west arms of the Hague, following a rainfall of 0.91 inches in the previous 24 hours.

Water temperature is shown in Figure D-2. On both April 2013 dates, the temperature in the upper reaches of the east and west canals was 5 to 10 degrees Fahrenheit higher than the temperature in the middle reaches of the Hague and at location #7 outside the Hague. This may be due to poor circulation of water between the canal ends and the middle reaches, or it may reflect the shallower water depths in the canal ends. Water temperature showed little variation between locations on the summer and fall sampling dates. Though the CBP Elizabeth River data were recorded on different dates than the Hague sampling events, the range of temperatures reported by CBP indicate that water temperature in the Hague may trend several degrees higher than the simultaneous temperature in the Elizabeth River.

Dissolved oxygen (DO) did not vary significantly from location to location (Figure D-3). DO levels in April were generally between 8 to 10 mg/L, with DO of approximately 8 mg/L in November. In July and early October, the DO levels and the DO saturation percentage decreased significantly. Higher water temperatures lower the DO saturation concentration (i.e. warmer water can hold a lower level of DO than cooler water).

The Virginia Administrative Code 9VAC25-260-185 discusses DO standards in the Chesapeake Bay and its tidal tributaries. The standard specifies the following for open waters, year round:

- 30 day mean ≥ 5 mg/l (tidal habitats with > 0.5 ppt salinity)
- 7 day mean ≥ 4 mg/l
- instantaneous minimum ≥ 3.2 mg/l at temperatures $< 29^{\circ}\text{C}$ (84°F)

The samples in the Hague best represent instantaneous values. DO concentrations in the east and west canal ends were less than the instantaneous minimum criteria of 3.2 mg/L on July 26, 2013, with DO concentrations less than 4 mg/L at the other sampling locations. Concentrations near 5 mg/l were sampled on October 26, 2013. The July 26 and October 8 sampling indicate the system is stressed in terms of DO these times.

D 2.2. Nutrients: Nitrogen and Phosphorus Forms

Nitrogen and phosphorus are the primary nutrients required for algal growth, and either can limit growth. Nitrogen is usually the limiting nutrient in saline systems such as the Hague. These two nutrients are generally not harmful alone; rather it is their stimulation of excessive algal production that causes problems (eutrophication). Each of these two nutrients can exist in inorganic and organic forms. From organic matter, such as algal detritus, mineralizes, organic N and P are transformed into inorganic forms (ammonium and phosphate). Subsequently, ammonium undergoes nitrification leading to formation of nitrate. Algae require these inorganic nutrients for growth, thus ammonium, nitrate, and phosphate are utilized within the algal biomass fulfilling the nutrient cycle (organic to inorganic and return to organic).

Nitrogen and phosphorus samples captured as part of this study are intended to form a baseline understanding of nutrient levels in the Hague. As water quality improvement projects are undertaken within the Hague or in the watershed draining to the Hague, future measurements of N and P forms

will assist the City to assess the effectiveness of the various BMPs and in-water mitigation projects for removing nutrients from the overall system.

Total nitrogen (TN, Figure D-5) is a measure of all nitrogen forms, including TKN and nitrate.

Total Kjeldahl nitrogen (TKN, Figure D-6) is a common N measurement and consists of particulate and dissolved organic N plus ammonium (NH₄). If ammonium concentrations are low, as is the case most of the time in the Hague (Figure D-7), then TKN is mostly organic nitrogen.

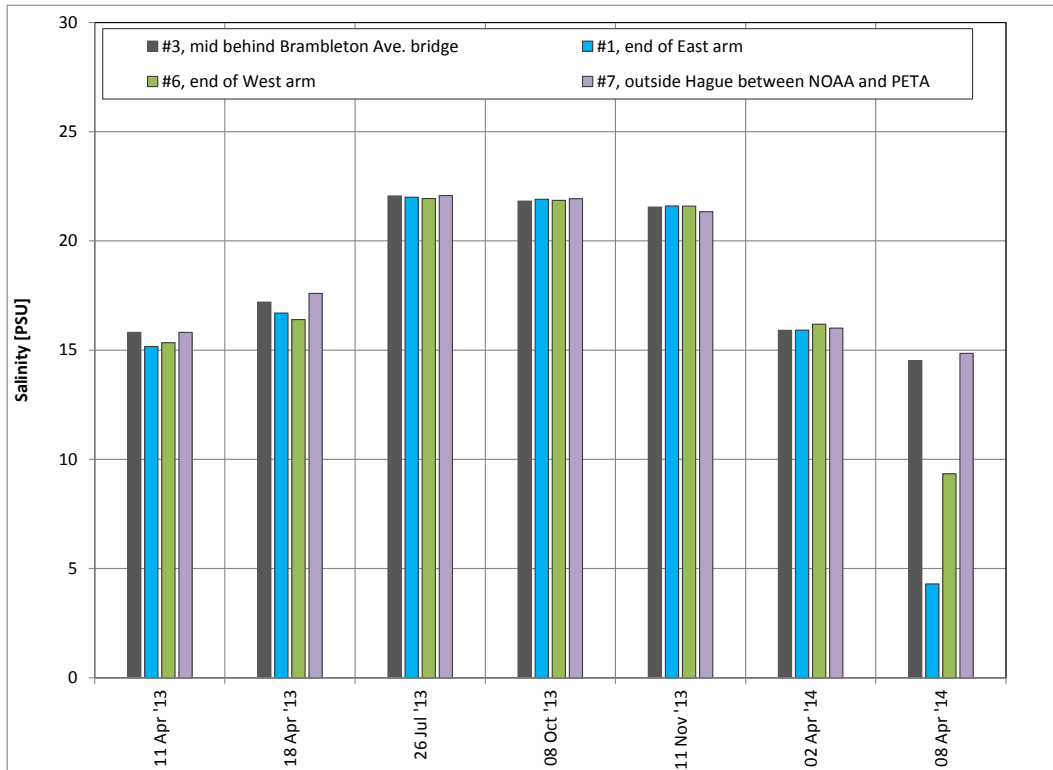
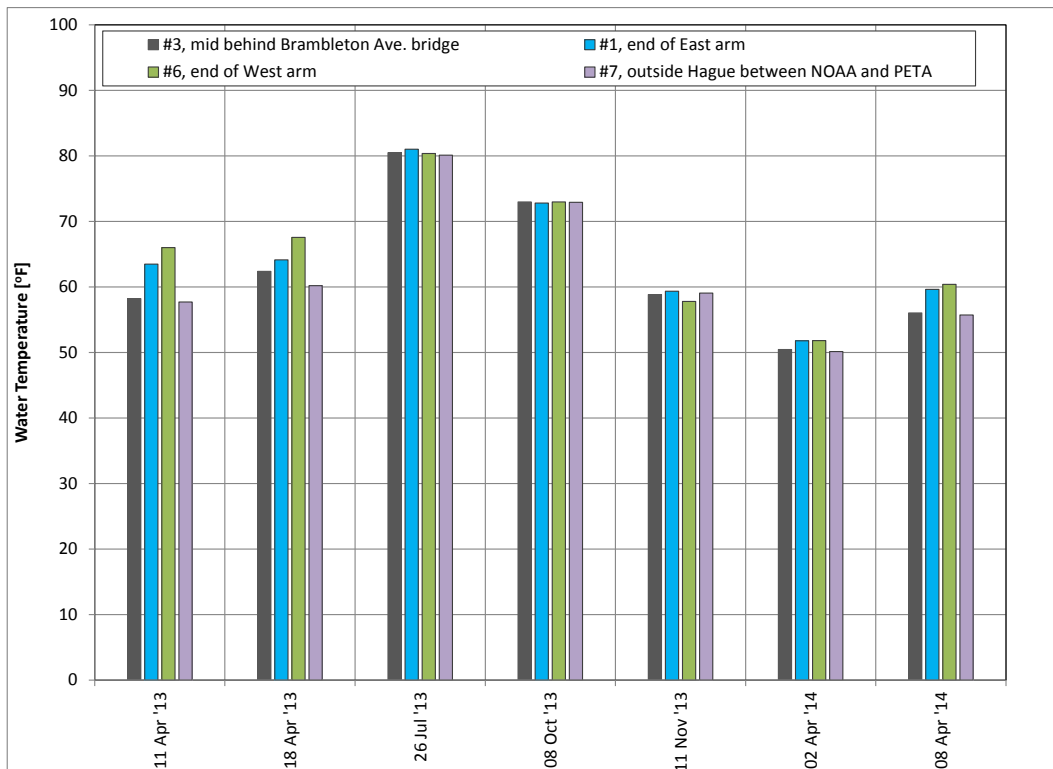
Total phosphorus (TP, Figure D-9) consists of total (particulate and dissolved) organic P and total inorganic P. Total inorganic P includes various particulate and dissolved forms including the dissolved orthophosphate ion (PO₄³⁻), referred to as simply phosphate (Figure D-10). Phosphate is required by algae for growth, thus it is often a key indicator of potentially eutrophic conditions.

D 2.3. Pathogen Indicators

Figure D-11 and Figure D-12 display concentrations of fecal coliform presence indicators *Enterococcus* and *E. coli*. Virginia Administrative Code 9VAC25-260-170 lists several state standards for *E. coli* and *Enterococcus* in primary contact recreational uses in surface waters (i.e. swimming):

- If there are insufficient data to calculate monthly geometric means in transition and saltwater (as is the case in Mason Creek), no more than 10% of the total samples in the assessment period shall exceed enterococci 104 CFU/100 ml.
- For beach advisories or closures, a single sample maximum of 235 *E. coli* CFU/100 ml in freshwater and a single sample maximum of 104 enterococci CFU/100 ml in saltwater and transition zones shall apply.

The dashed black horizontal line in Figure D-11 and Figure D-12 indicates the single sample maximum values from 9VAC25-260-170. The charts show that the *E. coli* and *Enterococcus* levels in the creek exceeded the VAC single sample limits in April, July, and October 2013, and on April 8, 2014. The highest levels were recorded in the upper canal ends and between NOAA and PETA.

*Figure D-1: Salinity**Figure D-2: Water temperature*

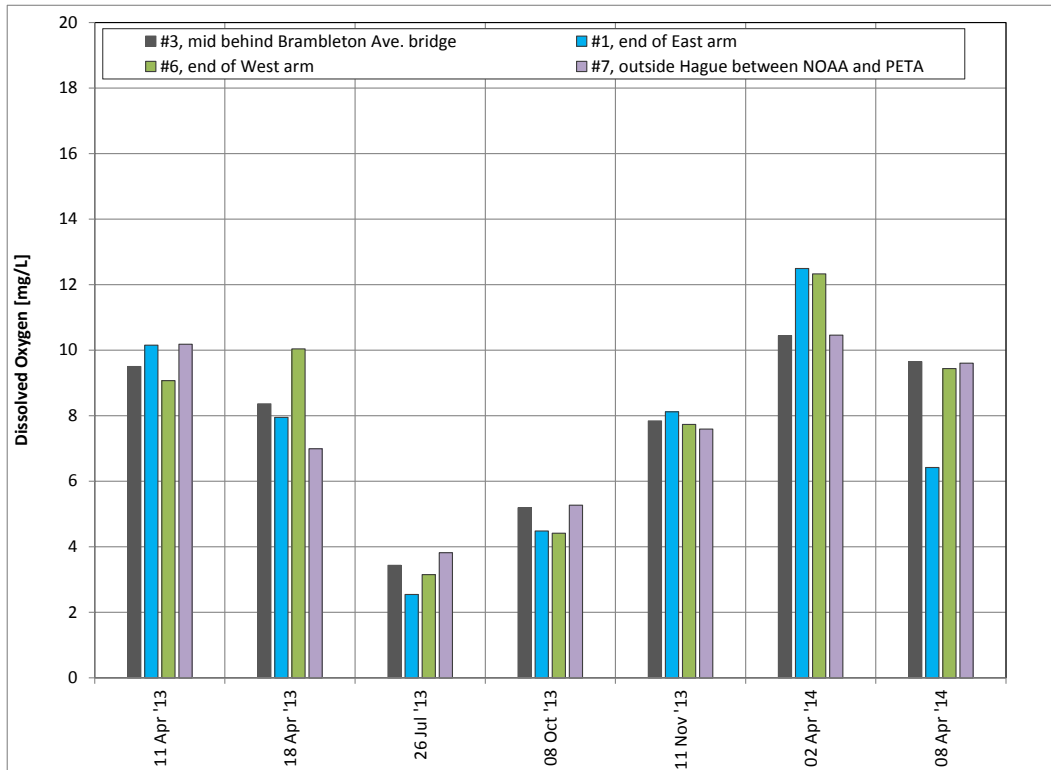


Figure D-3: Dissolved oxygen concentration

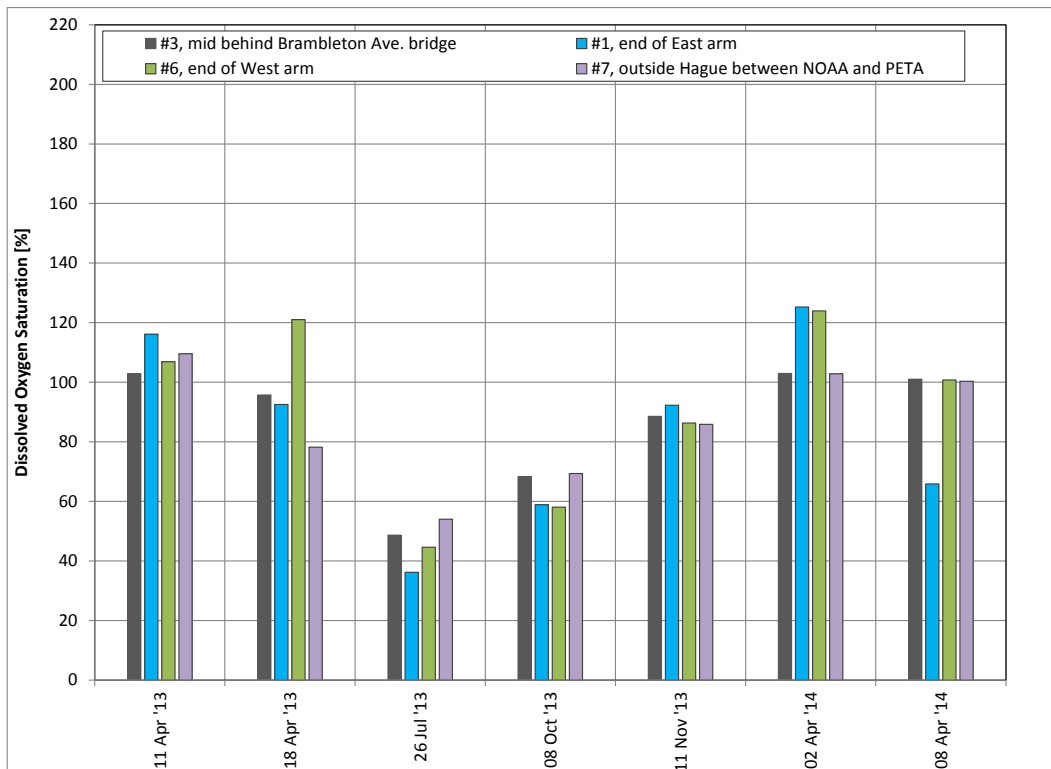


Figure D-4: Dissolved oxygen saturation (calculated)

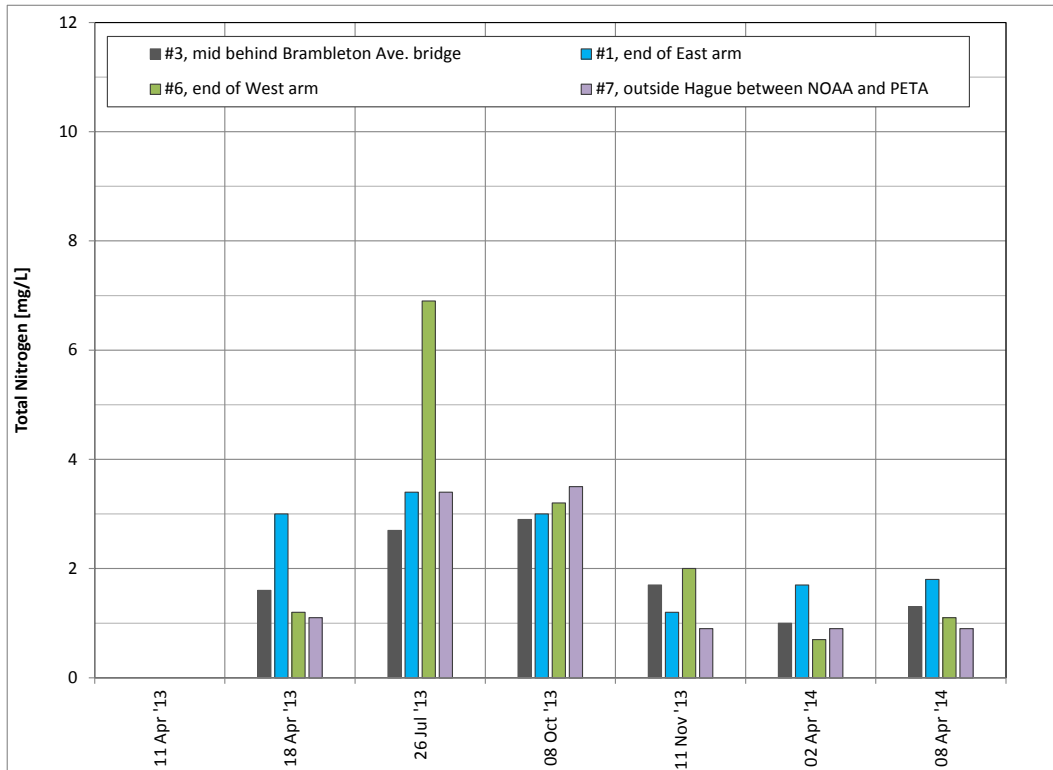


Figure D-5: Total nitrogen concentration

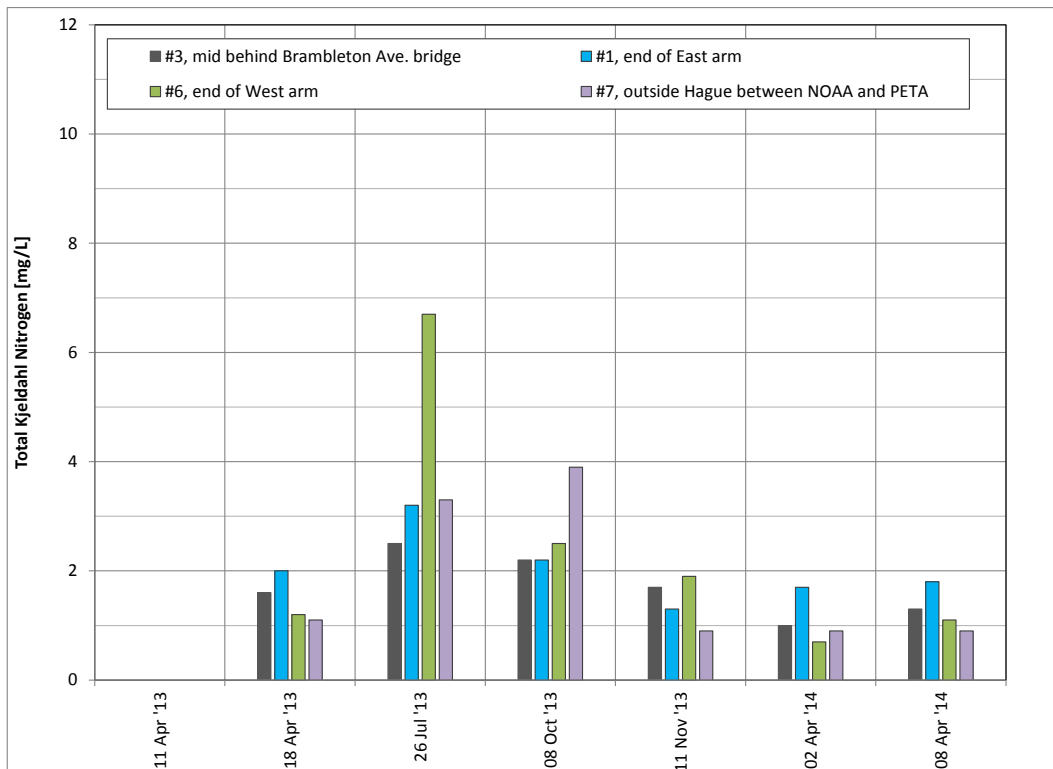


Figure D-6: Total Kjeldahl nitrogen concentration

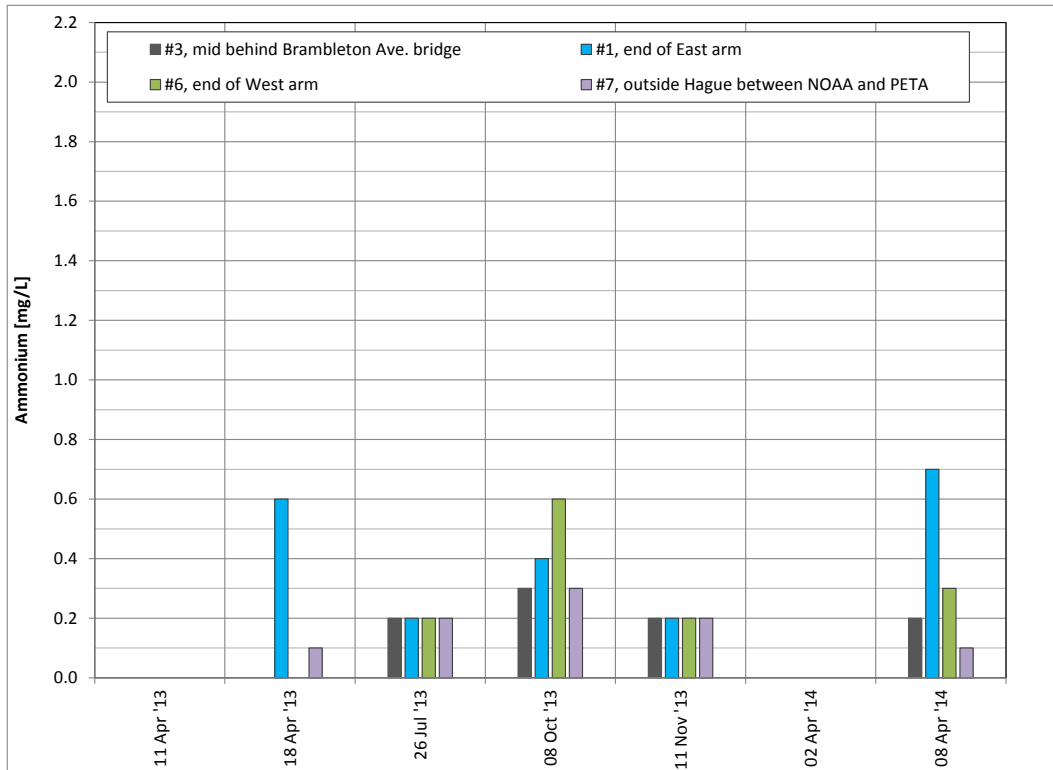


Figure D-7: Ammonium concentration

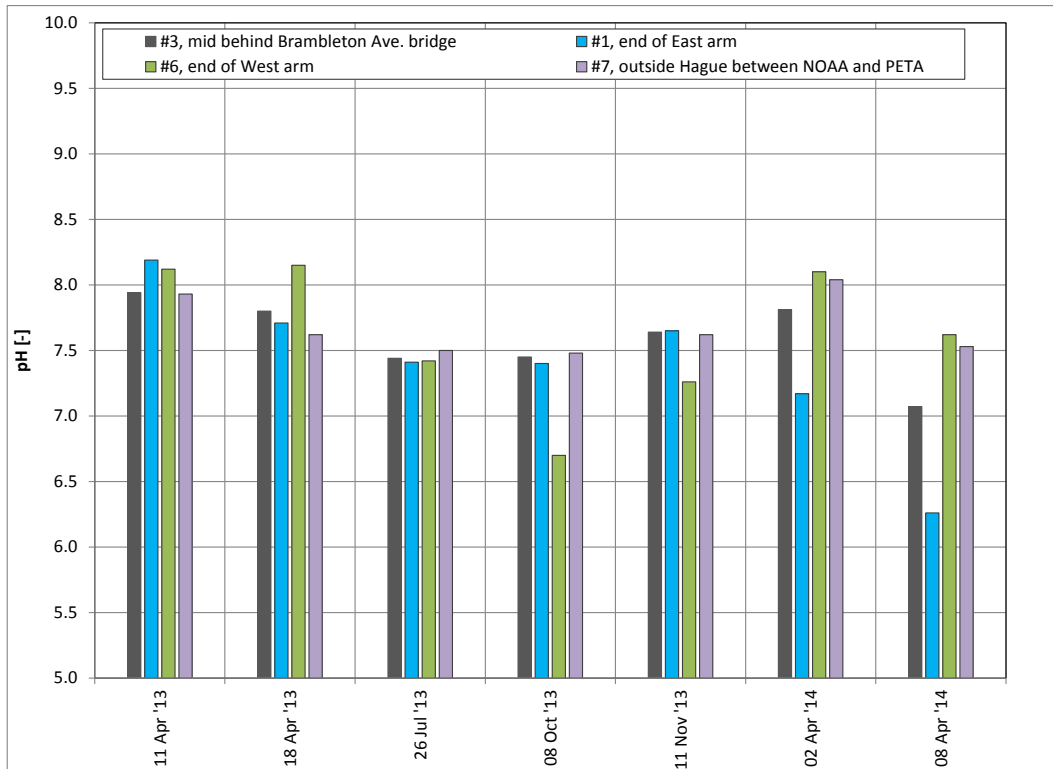


Figure D-8: pH

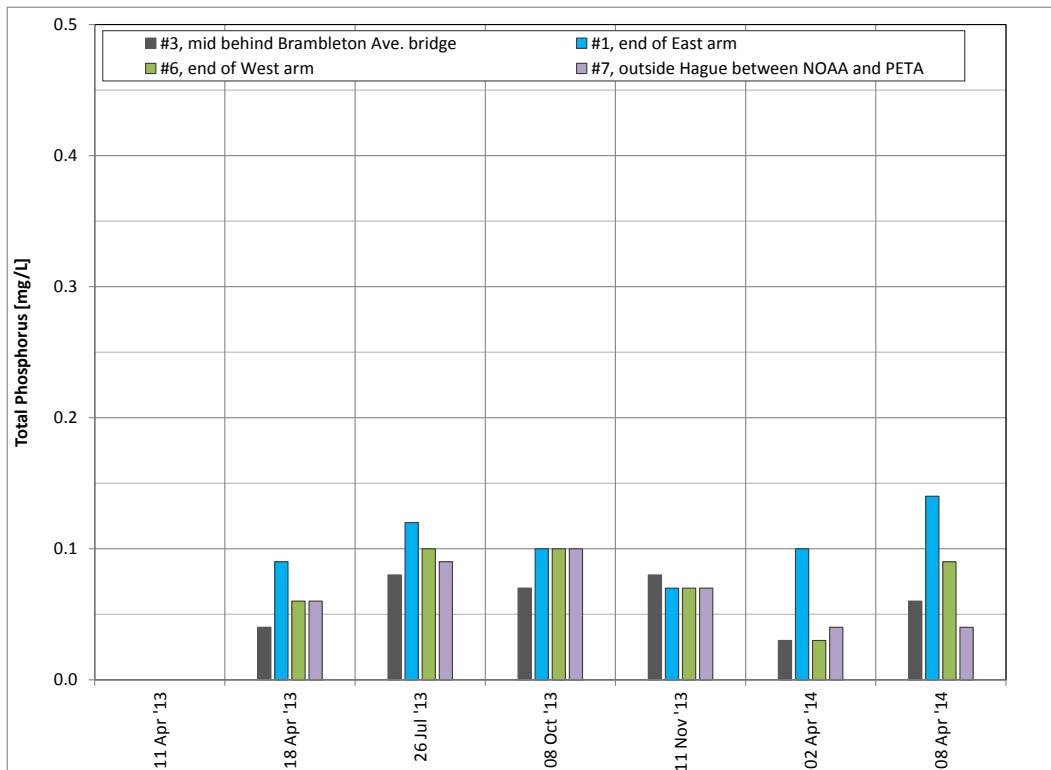


Figure D-9: Total phosphorus concentration

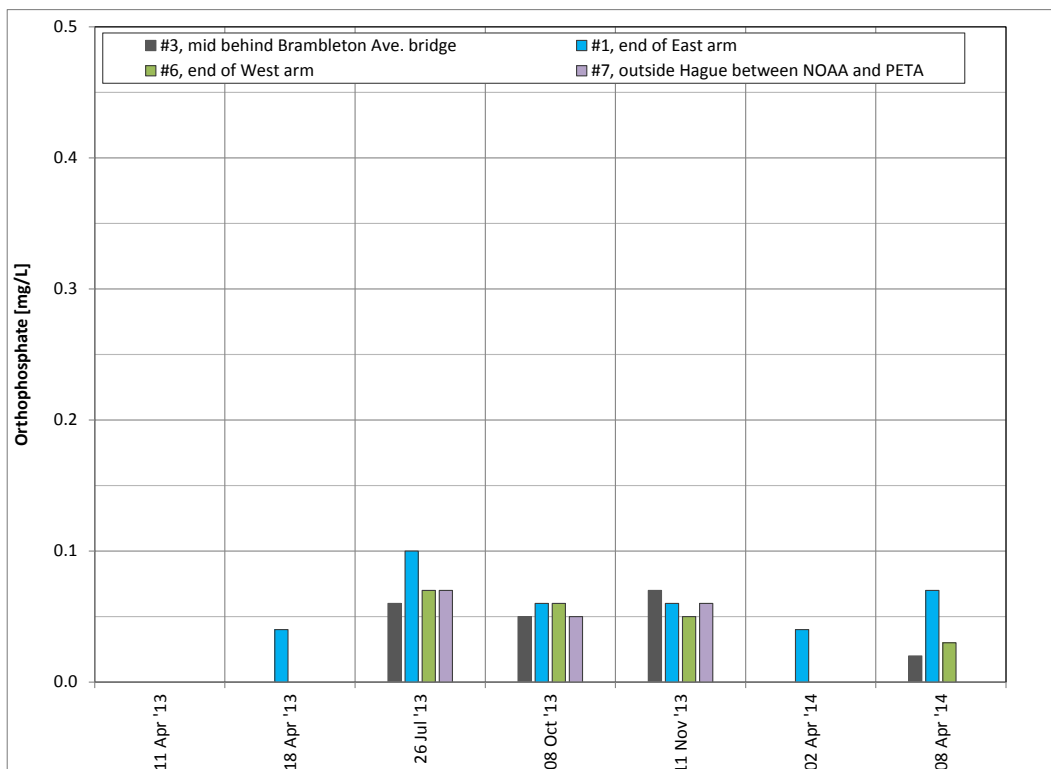


Figure D-10: Orthophosphate concentration

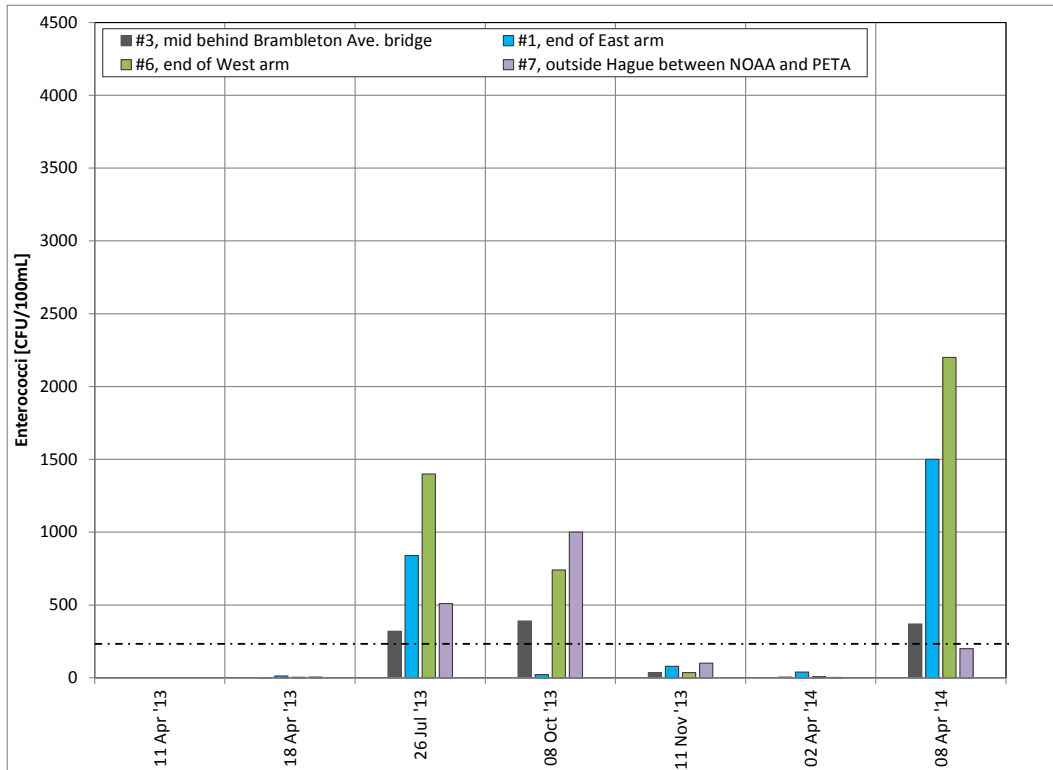


Figure D-11: Enterococcus concentration

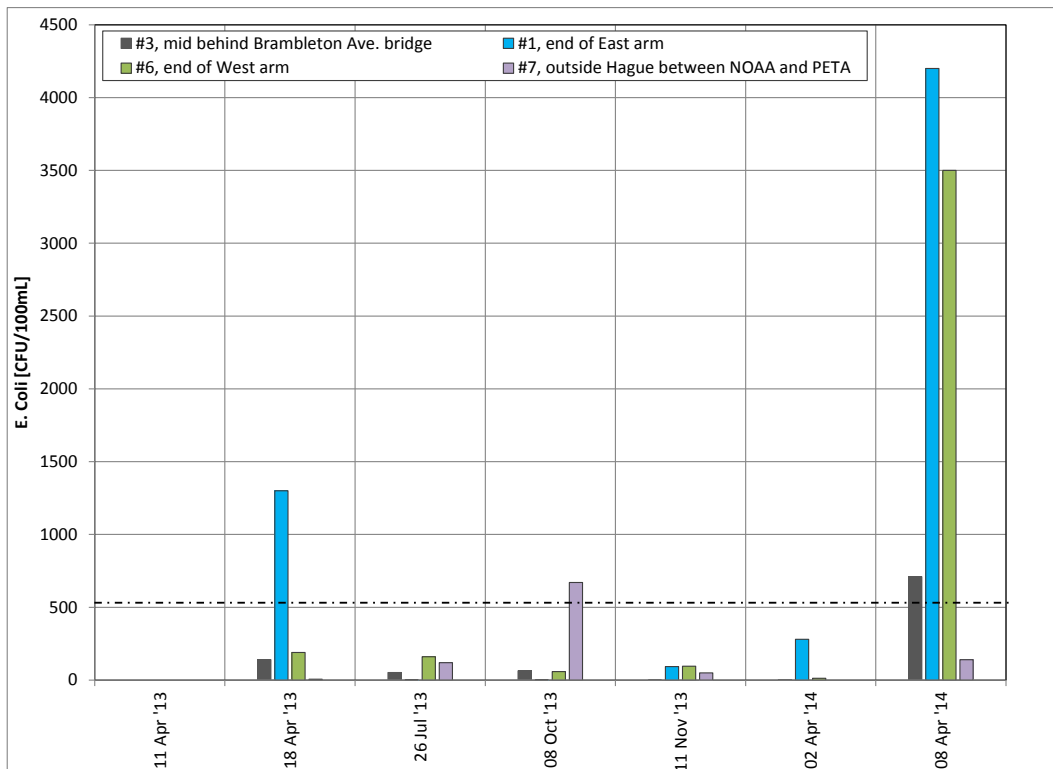


Figure D-12: E. coli concentration

APPENDIX E

Stormwater Regulations and Stormwater Treatment Overview

E 1. Stormwater Regulations

The term “stormwater regulations” in this report refers to the series of federal, state, and local regulations and programs that have been established to limit the amount of pollutants that get discharged into the Waters of the United States. A common means for pollutants to reach U.S. waters is through exposure to stormwater runoff.

E 1.1. Clean Water Act

The need for state stormwater management programs, including treatment, is established primarily by the 1972 Clean Water Act (CWA). This act gave the EPA authority to regulate water quality by establishing the National Pollutant Discharge Elimination Permit (NPDES) program. The law further authorizes EPA to delegate responsibility to a state after the state establishes a CWA-compliant stormwater program.

E 1.2. Virginia Stormwater Management Act

Virginia’s NPDES-compliant stormwater program, codified by the Virginia Stormwater Management Act, establishes several state stormwater management permits. Management of municipal separate storm sewer systems (MS4) is delegated to larger cities (population over 100,000) such as the City of Norfolk, via Virginia Stormwater Management Program Permits (VSMP), which are issued to cities after they develop a state-compliant stormwater management program. This is the primary program that applies to the stormwater issues in the vicinity of the Hague.

Under Norfolk’s stormwater management program (and consistent with most locations), the need to construct MS4 stormwater treatment facilities is generally linked to development or redevelopment efforts only, where such improvements can be included in the overall design. Existing facilities (excluding businesses governed by a VPDES permit) are not compelled to construct treatment facilities unless land disturbing activities above specified thresholds are undertaken.

Construction activities are regulated by requiring land-disturbing activities to register for coverage under the state’s General Permit for Discharges from Construction Activities. Construction activities at project sites discharging to the Chesapeake Bay (e.g. the Hague) are considered to be within the Chesapeake Bay Preservation Area and subject to requirements.

Industrial activities and other point sources of pollution are regulated directly by the state via Virginia Pollutant Discharge Elimination System (VPDES) permits. This program is unlikely to govern improvements covered in this report.

E 1.3. Chesapeake Bay TMDL Program

Establishment of the Chesapeake Bay Total Maximum Daily Load (TMDL) by the EPA in December 2010 introduces an additional program for which water quality improvements will be necessary to demonstrate compliance. Under this program, each contributing watershed is assigned pollutant limits (total Phosphorus, total nitrogen, total suspended solids) and improvement goals for further reduction.

Each watershed state must develop a Watershed Implementation Plan (WIP) to identify how these limits will be adhered to and improvements achieved. The WIPs are being developed in phases with Virginia having most recently published the Phase II WIP in March 2012. This WIP reflects ongoing development of the Phase I WIP following substantial stakeholder interaction.

Within Virginia's Phase II WIP, the state has identified numerous strategies for improving water quality in urban environments, including promotion of bioretention and other low impact development practices, improved erosion and sediment control practices, stormwater facility retrofit programs, and shoreline restoration and outfall improvements. While not specifically identified as a strategy in Virginia's WIP, EPA's watershed model being developed to track TMDLs will also account for the beneficial impacts of filter feeders such as oysters to water quality.

However, the TMDL program is still under development. At the time of this report, task forces are still developing uniform criteria for determining the effectiveness of the various strategies in the context of pollutant load reductions, as well as the system that will be used by local watersheds to report and track their efforts.

In Virginia, the intent is to develop the Virginia ePermitting System to track proposed water quality improvement projects. Data collected by this system will be shared with the National Environmental Information Exchange Network (NEIEN), from which the Chesapeake Bay TMDL model will retrieve its input data for tracking watershed progress. A planning tool, the Virginia Assessment and Scenario Tool (VAST), is available (with ongoing development as the TMDL model develops) to assist stakeholders with identifying which strategies may be most effective.

E 2. Stormwater Treatment Overview

Pollutant transfer to stormwater runoff is typically classified as either a point or nonpoint source. A pollutant is considered a point source when there is an identifiable source that is primarily associated with commercial and industrial activities. Point sources are regulated differently than non-point sources.

Stormwater pollution stemming from runoff generated by a developed area, such as the Hague, cannot be isolated to a single source, and the pollution is considered to originate from a nonpoint source. It may consist of multiple pollutants including fertilizer constituents, dissolved metals, hydrocarbons, and harmful bacteria.

Pollutant concentrations from nonpoint sources are highly variable in both magnitude and type of pollutants, as their presence is dependent on variable activity (e.g. traffic levels) and climate (e.g. season, frequency and duration of rainfall). Monitoring is likewise difficult due to the sheer number of individual outfall locations.

Therefore, treatment of nonpoint sources such as municipal stormwater is generally approached on a *presumptive* basis wherein the governing entity establishes design standards and an associated removal rate for each treatment approach or Best Management Practice (BMP). When a BMP is constructed and maintained in accordance with the governing design standard, it is presumed to

provide the associated removal rate without the need for the owner to actually monitor its effectiveness.

For simplicity, Virginia uses phosphorus as the indicator pollutant in MS4 permits, and BMP effectiveness is expressed in terms of total Phosphorus (TP) removal efficiency. If the selected BMPs for a given project provide the necessary Phosphorus removal, all other pollutants regulated by the CWA are presumed to be satisfactorily treated. As part of the Chesapeake Bay TMDL, baselines and reduction rates for total nitrogen (TN) and total suspended solids (TSS) will be further developed and established for existing conditions and BMPs.

Practical treatment measures must use gravity flow of runoff to drive the treatment process to avoid the need for pump systems or other complex mechanisms susceptible to failure. For facilities near the Hague, overcoming tidal back pressure and saltwater intrusion is also a challenge.

Treatment facilities must also address the realities of municipal infrastructure, including public safety, risks and impacts of failure, and ability to be maintained in the face of perpetually-constrained maintenance budgets.

Several treatment mechanisms have been incorporated into BMP designs, each with their own limitations. There is no mechanism that is universally effective under all conditions and thus selection of treatment BMPs must be done on a case-by-case basis.

Note: Another major component of stormwater management is flow control in which the objective is to manage runoff rates to reduce or eliminate adverse impacts relating to downstream flooding and channel erosion. In the case of the Hague, the stormwater systems discharge directly into a large water body (i.e. a receiving body) such that peak discharge rates do not need to be limited. Flow control measures are therefore not discussed further in this report.

E 2.1. Pollutant Reduction Mechanisms

Settlement

Treatment via settlement is an approach wherein incoming runoff is allowed to reduce its velocity to allow suspended solids to settle out of the water. Suspended solids often has other pollutants adhered to the particles, thus removal of these particles also removes part of the total load of the other pollutants as well. This is typically accomplished by constructing large retention ponds, wetlands, or vaults with permanent pools of water that act to slow down any incoming runoff.

A subset of settlement treatment is hydrodynamic separation, which uses directional velocity changes to extract suspended solids for settlement.

Effectiveness of settlement is typically a function of the suspended solids particle size, the extent to which velocity can be reduced, and the duration of the retention (residence time).

Settlement treatment begins to lose effectiveness as the settled material accumulates and becomes exposed to areas of higher velocity, at which time it may re-suspend. Performance can be restored by removing the accumulated material.

Filtration

Filtration removes pollutants by physically impeding their passage through a filter material such as sand. Chemical binding may also be provided. Common BMPs employing filtration include sand filters, commercially-sold (patented) stormwater filter modules, and pervious pavement.

Filtration is often very effective at removing pollutants, but as the captured material accumulates, overall flow becomes impeded and flow will either back up or seek alternative routes based on the facility. Re-suspension of pollutants may also occur if there is significant accumulation or if flow through the filter is reversed (as may occur during tidal fluctuations or storm surges).

Maintenance typically consists of replacing or otherwise cleaning the filter media. Required frequency of the maintenance is a function of the runoff pollutant load vs. the effective surface area of the filter.

Infiltration

Infiltration is the approach wherein the quantity of runoff is reduced by being directed to pervious surfaces to soak in and disperse into the groundwater (and thus no longer reaching a discharge point). Bioretention, infiltration swales, dry wells, pervious pavement, and dispersion techniques are common approaches that use infiltration.

Similar to filtration, certain configurations can be prone to long-term clogging due to the soil acting as a filter material. Maintenance may consist of tilling and amending the soil, depending on the specific design. Incorporation of plants assists with infiltration by providing a growing root system and fauna to constantly disturb the soil.

Biological Uptake

Biological uptake are the processes by which plants and bacteria absorb and break down pollutants. These processes include oxidation, denitrification, and ion exchange. BMPs which support plant life, such as wetlands, ponds, and bioretention areas typically use this treatment mechanism (in addition to other mechanisms).

Selected processes can be reproduced with chemical agents, though these practices are rarely employed for treating urban stormwater due to the ongoing maintenance costs.

E 2.2. Treatment Trains

Many BMPs use several of the aforementioned treatment mechanisms, either concurrently or in series, to achieve the desired effectiveness.

E 2.3. Treatment Placement

Application of the above treatment mechanisms must define the necessary hydraulic characteristics of incoming runoff under which that application will be effective. This in turn influences where in the storm drain system each application will be most effective.

Settlement applications are generally more effective when treating a relatively large volume of water. Therefore, they are often most effectively location at a downstream position on a storm drain system capturing runoff from a large drainage basin.

In contrast, filtration mechanisms rely on runoff overcoming the head loss of flowing through a filtration medium, as well as the flow being uniformly dispersed over said medium. In areas with flat topography, it is often advantageous to position these applications upstream to treat smaller subbasins and use the head generated by runoff moving vertically from the surface to the underground pipes.

Similarly, applications that seek to mimic natural processes, such as bioretention areas and pervious pavement, are more effective when they receive sheet flow rather than concentrated runoff. This again encourages use upstream of concentrated conveyances such as storm drains and ditches.

E 2.4. Treatment Credit

Treatment credit for the BMP concepts discussed in the next section is based on the Recommendations of the Expert Panel to Define Removal Rates for Urban Stormwater Retrofit Projects, which received final approval by the Chesapeake Bay Program Water Quality Goal Implementation Team on October 9, 2012.

That report establishes a protocol for calculating target pollutant removal rates wherein the removal rate is calculated based on the quantity of treated runoff and degree of runoff reduction provided (if applicable). In the calculation, a normalized “inches of treated runoff” is calculated, for which removal rates can be read from published charts for Phosphorus, nitrogen, and suspended solids.

The underlying assumption in CBP reduction calculation is that the BMP retrofits are designed in general accordance with their respective design standards and are routinely maintained. Furthermore, the treatment credit for a BMP must be renewed every 10 years through a positive BMP restoration action (i.e. a documented major maintenance activity that is reported to the CBP).

It is important to note that that the CBP approach differs from Virginia’s Runoff Reduction Method used to comply with NPDES permit requirements.

Per version 5.3.0 of the CBP model, the calculated reductions were applied to the following baseline values:

Table E-1: CBP annual urban runoff loads per acre (CBP Model 5.3.0)

Pollutant	Urban Impervious Average	Urban Pervious Average
Total Phosphorus (lbs/acre/yr)	2.04	0.57
Total Nitrogen (lbs/acre/yr)	10.85	9.43
Total Suspended Solids (tons/acre/yr)	0.46	0.07

As the program is implemented, Virginia may issue more guidance as to how the baseline is applied (e.g. based on actual impervious/pervious areas or per a simplified weighted average). The baseline loads are also subject to change as the CBP model evolves.

APPENDIX F

Opinions of Probable Cost for Conceptual Alternative Project Elements

 OPINION OF PROBABLE COST		DATE PREPARED 1/31/2014		SHEET 1		OF 1	
ACTIVITY AND LOCATION City of Norfolk Dept of Public Works		CONSTRUCTION CONTRACT NO.		IDENTIFICATION NUMBER			
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Dredging: Removal of Sediment by Smaller Outfalls

<u>Dredging</u>					
	Mob/Demob	1	LS	\$125,000.00	\$125,000
	Erosion and Sediment Controls	1	LS	\$30,000.00	\$30,000
	Dredging	7,000	CY	\$15.81	\$110,670
 <u>Placment Areas: Transporation & Tipping Fee</u>					
	Alt 1: CIDMMA bareg to Re-handling	7,000	CY	\$15.00	\$105,000
	Alt 2: Port Weanak	7,000	CY	\$30.00	\$210,000
				Subtotal (CIDDMA)	\$370,670
				Subtotal (Weanak)	\$475,670
	Engineering and Permitting	10.00%		\$47,567	
	Contract Administration	6.00%		\$28,540	
	Profit	8.00%		\$38,054	
	Contingency	25.00%		\$118,918	
	Bond	1.50%		\$7,135	
					<u>\$/CY:</u>
				Total Estimated Construction Cost (CIDDMA):	\$557,858
				Total Estimated Construction Cost (Weanak):	\$715,883
					\$79.69
					\$102.27

Notes:
 No special handling.
 Dredge production 40 CY/hr - 1.25 CY bucket, 70% full, 75% eff., 1 cycle/min.

SAY \$600,000
SAY \$800,000

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Dredging: Removal of Sediment to 1970s Dredge Template

<u>Dredging</u>					
	Mob/Demob	1	LS	\$125,000.00	\$125,000
	Erosion and Sediment Controls	1	LS	\$30,000.00	\$30,000
	Dredging	19,728	CY	\$15.81	\$311,900
 <u>Placment Areas: Transporation & Tipping Fee</u>					
	Alt 1: CIDMMA barge to Re-handling	19,728	CY	\$15.00	\$295,920
	Alt 2: Port Weanak	19,728	CY	\$30.00	\$591,840
				Subtotal (CIDDMA)	\$762,820
				Subtotal (Weanak)	\$1,058,740
	Engineering and Permitting	10.00%		\$105,874	
	Contract Administration	6.00%		\$63,524	
	Profit	8.00%		\$84,699	
	Contingency	25.00%		\$264,685	
	Bond	1.50%		\$15,881	
					<u>\$/CY:</u>
Total Estimated Construction Cost (CIDDMA):					\$1,148,044 \$58.19
Total Estimated Construction Cost (Weanak):					\$1,593,403 \$80.77

Notes:
 No special handling.
 Volume shown is to neat line dredging, 1 foot of allowable overdepth would add 18,784 CY.

	SAY	\$1,200,000
	SAY	\$1,600,000

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Oysters

Mob/Demob	1	LS	\$200,000.00	\$200,000
Based on 3 areas (250' * 75') = 1.3 acres				
Base Layer Shell (12 inches)	2,100	CY	\$59.00	\$123,900
Top Layer Shell (12 inches)	2,100	CY	\$100.00	\$210,000
Seeding	1	LS	\$25,000.00	\$25,000

Subtotal \$558,900

Engineering and Permitting	10.00%	\$55,890
Contract Administration	6.00%	\$33,534
Profit	8.00%	\$44,712
Contingency	20.00%	\$111,780
Bond	1.50%	\$8,384

Total Estimated Construction Cost:

\$813,200

\$/sf:
\$14.46

Notes:

SAY \$820,000

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Living Shoreline: 1,100 LF along Brambleton

Mob/Demob	1	LS	\$150,000.00	\$150,000
Demolition of Concrete Relieving Platform (20 ft wide)	22,000	SF	\$20.00	\$440,000
Site Clean-up, Clearing and Grubbing	1	LS	\$25,000.00	\$25,000
Erosion and Sediment Control Measures	1	LS	\$10,000.00	\$10,000
Geotextile	4,889	SY	\$5.00	\$24,444
Riprap / Blanket Stone	3,080	TON	\$60.00	\$184,800
Sand Fill	4,889	CY	\$25.00	\$122,222
Planting (Spartina Alterniflora, 12" O.C.)	22,000	SF	\$2.00	\$44,000
Upland Planting	22,000	SF	\$4.00	\$88,000
Landscaping	1,178	SY	\$50.00	\$58,900

Subtotal \$1,147,367

Engineering and Permitting	10.00%	\$114,737
Contract Administration	6.00%	\$68,842
Profit	8.00%	\$91,789
Contingency	20.00%	\$229,473
Bond	1.50%	\$17,211

Total Estimated Construction Cost:

\$1,669,419 \$/LF: \$1,518

Notes:

1.8 multiplier for converting CY to Tons.

SAY \$1,700,000

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Living Cap: Adjacent to Chrysler Museum

Mob/Demob	1	LS	\$150,000	\$150,000
Site Clean-up	1	LS	\$10,000	\$10,000
Erosion and Sediment Control Measures	1	LS	\$10,000	\$10,000
Geotextile	4,000	SY	\$5.00	\$20,000
Low Sill: Riprap / Blanket Stone	1,067	TON	\$60.00	\$64,000
Sand Fill (3')	8,000	CY	\$25.00	\$200,000
Stone blanket at outfalls	1,600	TON	\$60.00	\$96,000
Planting (Spartina Alterniflora, 12" O.C.)	4,500	SF	\$2.00	\$9,000
Subtotal				\$559,000
Engineering and Permitting	10.00%		\$55,900	
Contract Administration	6.00%		\$33,540	
Profit	8.00%		\$44,720	
Contingency	20.00%		\$111,800	
Bond	1.50%		\$8,385	

Total Estimated Construction Cost:

\$813,345 \$/SF: \$10,167

Notes:

1.8 multiplier for converting CY to Tons.

SAY \$820,000

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Wetland along Brambelton Ave

Mob/Demob	1	LS	\$20,000	\$20,000
Erosion and Sediment Control Measures	1	LS	\$10,000	\$10,000
Excavation& Grading	1,870	CY	\$30	\$56,104
Demo Drop Inlet	3	LS	\$1,000	\$3,000
Demo Storm Pipe	560	LF	\$25	\$14,000
Storm Structure	2	EA	\$5,000	\$10,000
Stormwater Pipe(12")	70	LF	\$40	\$2,800
Stormwater Pipe(15")	195	LF	\$60	\$11,700
Zone 2 Vegetation	41,437	SF	\$2	\$82,874
Path (1325 ft long x 8ft wide)	1,178	SY	\$36	\$42,408
Benches	9	EA	\$1,000	\$9,000
Landscaping	1	LS	\$30,000	\$30,000
Zone 1 Vegetation	4,780	SF	\$2	\$9,560
Subtotal				\$301,446
Engineering and Permitting	10.00%		\$30,145	
Contract Administration	6.00%		\$18,087	
Profit	8.00%		\$24,116	
Contingency	30.00%		\$90,434	
Bond	1.50%		\$4,522	
Total Estimated Construction Cost:				\$468,748

Notes:

Excavation: Pond and Sidewalk (8' wide x 10" deep).
 New pipe running from street to wetland.

SAY \$500,000



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Wet Pond along Brambelton Ave

Mob/Demob	1	LS	\$20,000	\$20,000
Erosion and Sediment Control Measures	1	LS	\$10,000	\$10,000
Excavation	4,967	CY	\$25	\$124,166
Demo Drop Inlet	3	LS	\$1,000	\$3,000
Demo Storm Pipe	560	LF	\$25	\$14,000
Storm Structure	2	EA	2000	\$4,000
Stormwater Pipe(12")	70	LF	\$40	\$2,800
Stormwater Pipe(15")	195	LF	\$60	\$11,700
Path (1325 ft long x 8ft wide)	1,178	SY	\$36	\$42,408
Benches	7	EA	\$1,000	\$7,000
Landscaping	1	LS	\$30,000	\$30,000
Zone 1 Vegetation	26,272	SF	\$2	\$52,544
			Subtotal	\$321,618
Engineering and Permitting	10.00%		\$32,162	
Contract Administration	6.00%		\$19,297	
Profit	8.00%		\$25,729	
Contingency	30.00%		\$96,485	
Bond	1.50%		\$4,824	

Total Estimated Construction Cost:

\$500,116

Notes:

Excavation: Pond and Sidewalk.

SAY \$550,000

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Hydrodynamic Separator: StormCeptor at Maury High School Sports Field

Mob/Demob	1	LS	\$20,000	\$20,000
Site Clean-up	1	LS	\$10,000	\$10,000
Silt Fence	4,500	LS	\$2.50	\$11,250
Excavation (18.5' deep) w/ shoring	1,692	CY	\$35.00	\$59,221
Demo Storm Pipe	70	LS	\$28.00	\$1,960
Stormceptor	3	EA	\$103,500	\$310,500
12" RCP Pipe	163	LF	\$90	\$14,669
Manhole	2	EA	\$1,000	\$2,000
Bedding	126	TON	\$22	\$2,765
Backfill	1,018	CY	\$26	\$26,462
Seeding	3,770	SF	\$1.5	\$5,655
Subtotal				\$464,482
Engineering and Permitting	10.00%		\$46,448	
Contract Administration	6.00%		\$27,869	
Profit	8.00%		\$37,159	
Contingency	30.00%		\$139,345	
Bond	1.50%		\$6,967	
Total Estimated Construction Cost:				\$722,270
			SAY	\$730,000

Notes:

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Pervious Pavement: Stockley Gardens

Mob/Demob	1	LS	\$10,000	\$10,000
Traffic Control	1	LS	\$5,000	\$5,000
Erosion and Sediment Control Measures	1	LS	\$8,000	\$8,000
Excavation (1'8")	1037.5	CY	\$25.00	\$25,938
Pavement Demo (6")	311	CY	\$15.00	\$4,659
Geotextile	2,143	SY	\$4.00	\$8,573
Underdrain	740	LF	\$18.00	\$13,320
Porous Asphalt (5")	507.2	TON	\$150	\$76,080
Crushed Stone Base (4")	363.4	TON	\$30.00	\$10,903
Drainage Layer Aggregate (1'4")	1346.2	TON	\$35.00	\$47,115
			Subtotal	\$209,589
Engineering and Permitting	10.00%		\$20,959	
Contract Administration	6.00%		\$12,575	
Profit	8.00%		\$16,767	
Contingency	25.00%		\$52,397	
Bond	1.50%		\$3,144	

Total Estimated Construction Cost: \$315,431

Notes: **SAY \$320,000**

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Bioretention Filter: Mowbray Arch

Mob/Demob	1	LS	\$2,000	\$2,000
Erosion and Sediment Control Measures	1	LS	\$3,000	\$3,000
Excavation(2'-2)	182.0	CY	\$25.00	\$4,550
Sand(6")	36	CY	\$35.00	\$1,251
Planting Soil(1'-2")	98	CY	\$35.00	\$3,430
Drainage Layer	75	TON	\$35.00	\$2,625
Geotextile	363	SY	\$4.00	\$1,451
Underdrain	280	LF	\$18.00	\$5,040
Landscaping	2268.0	SF	\$3.00	\$6,804
			Subtotal	\$30,151
Engineering and Permitting			\$12,000	
Contract Administration	6.00%		\$1,809	
Profit	8.00%		\$2,412	
Contingency	20.00%		\$6,030	
Bond	1.50%		\$452	
Total Estimated Construction Cost:				\$52,854

Notes:

Underdrain- 1-4" dia running lengthwise of roadway.
Aggregate density used 130 lbs/ft³.

SAY \$60,000

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Biofiltration: Site Designed at Dundaff Street

Mob/Demob	1 LS	\$2,000	\$2,000
Erosion and Sediment Control Measures	1 LS	\$3,000	\$3,000
Curb Demolition	215 LF	\$10	\$2,150
CDI Modification	1 LS	\$1,500	\$1,500
Excavation	236.0 CY	\$25.00	\$5,900
Engineered Soil Mix (2')	157 CY	\$35.00	\$5,496
Drainage Stone Pretreatment (2' wide x 2' deep)	65 TON	\$35.00	\$2,275
Geotextile	350 SY	\$4.00	\$1,400
Underdrain	250 LF	\$18.00	\$4,500
Seeding	2.1 MSF	\$100.00	\$212
Subtotal			\$28,433
Engineering and Permitting		\$15,000	
Contract Administration	6.00%	\$1,706	
Profit	8.00%	\$2,275	
Contingency	20.00%	\$5,687	
Bond	1.50%	\$426	
Total Estimated Construction Cost:			\$53,527

Notes:

Underdrain- 1-4" dia running lengthwise of roadway.

SAY \$60,000

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Biofiltration: Inlet Retrofit with Filterra Units

Mob/Demob	1 LS	\$3,000	\$3,000
Erosion and Sediment Control Measures	1 LS	\$1,000	\$1,000
Misc. Site Demolition	1 LS	\$500	\$500
Excavation	25 CY	\$25.00	\$625
Filterra units (2 units, each 6' x 6' square)	2 EA	\$13,800	\$27,600
Site Restoration	1 LS	\$1,000	\$1,000
Stormdrain Connections	3 EA	\$250.00	\$750
		Subtotal	\$34,475
Engineering and Permitting		\$12,000	
Contract Administration	6.00%	\$2,069	
Profit	8.00%	\$2,758	
Contingency	20.00%	\$6,895	
Bond	1.50%	\$517	
Total Estimated Construction Cost:			\$58,714

Notes:

SAY \$60,000