United States Army Corps of Engineers, New England District
Stratford Army Engine Plant, Stratford, CT
DRAFT FINAL Focused Feasibility Study

APPENDIX G

Dredging Alternatives Evaluation

STRATFORD ARMY ENGINE PLANT, STRATFORD, CONNECTICUT DREDGING ALTERNATIVES EVALUATION FEASIBILITY STUDY

FINAL DRAFT

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1.0 Introduction

Lally Consulting LLC (Lally) was tasked by Wood PLC dba AMEC Foster Wheeler (AMEC FW) to conduct a feasibility-level alternatives evaluation of dredging technologies for remediation of the Stratford Army Engine Plant (SAEP) site. The findings of these analyses, including proposed suitable alternative dredging technologies, are provided in this report.

2.0 Site Assessment and Data Review

To become familiar with site conditions and constraints, a site visit was conducted by John Lally at the SAEP property in Stratford, Connecticut on October 6, 2017, along with AMEC FW representatives Tony Delano and Danielle Ahern. After an introduction of the SAEP's historical activities and current operations by site representative Richard Barlow, Tikigao Construction LLC, shoreside visual assessment was made of the areas targeted for sediment remediation, including the Intertidal Flats (tidal flats), and, to a lesser degree, the Outfall 008 Drainage Ditch. The tidal flats shoreline and intertidal areas were viewed from the Causeway and central shoreline during mid- and low tide. A portion of the Outfall 008 Drainage Ditch was viewed at its west end through a chain link fence. Also viewed were the site's upland features including parking lots, roadways and buildings, that can potentially be employed for project access, staging areas, dredged material transport, dewatering and water treatment activities, cap material storage, and dredged material placement/beneficial use. Several photographs taken during the site visit are provided in Appendix A.

Further assessment was made through review of available site information. Several data sets were provided by AMEC FW or accessed through the additional efforts of Lally. These data and information include;

- *Geotechnical Investigation Summary Causeway Non-time Critical Removal Action Design* (Harding, 2000);
- Preliminary chemical analytical data and mapping of contaminants across the SAEP tidal flats;
- Preliminary geotechnical testing results for samples collected August and October 2017;
- Preliminary treatability study results;
- Preliminary dredge area delineation across the SAEP tidal flats and Outfall-008 Drainage Ditch remediation areas;
- National Oceanic and Atmospheric Administration (NOAA) tide data;
- Housatonic River Federal Navigation Project, Draft Environmental Assessment. (USACE, 2012);
- Historical aerial photography.

2.1 Proposed Remediation Plan

To address the sediment in the tidal flats, which has been determined to contain varying concentrations of primarily mercury, metals and PCBs, AMEC FW has developed a preliminary remediation plan. The plan currently involves the removal by dredging of approximately 58 acres of tidal flats sediment to depths of 1 ft. to 4 ft. below mudline. This would represent approximately 140,000 cy of dredged material to neatline elevation. Following dredging to target elevations, the dredged areas are proposed to be backfilled with clean material (i.e. sand) to original grades.

2.2 Shoreline Structures

The SAEP tidal flats site extends approximately 2,700 ft. along the right descending bank of the Housatonic River, with the downstream boundary roughly 7,700 ft. from the terminus of the outer breakwater at the river's entrance.

To protect the plant and property from wave-induced erosion and flooding, a dike and armor rock revetment approximately 2,300 ft. in length was installed along the facility's boundary with the tidal flats.

In the 2000s, an erosion control cover system consisting of geogrid marine mattresses was placed over the Causeway to prevent possible receptor contact with contaminated soil and overland transport of contaminated soil into the tidal flats.

Where the west tidal flats meet the Housatonic River, a quarrystone jetty extends approximately 1,200 ft. parallel with channel. The crest elevation of the jetty is set at approximately 0 ft. MSL.

Photos of the site setting, including these structures, are provided in Appendix A.

2.3 Sediment Characteristics

The physical characteristics of the surface sediments in the east and west tidal flats were observed from shore during the site visit to be dark brown silt with some sand and organic content. The sediments are generally very soft, exhibiting high water content and low bearing strength.

The report *Geotechnical Investigation Summary, Causeway Non-Time Critical Removal Action Design Stratford Army Engine Plant, Stratford, Connecticut* (Harding, 2000) documented the subsurface geotechnical characteristics of the Causeway for the purposes of designing the aforementioned erosion control cover system. Accordingly, most of the borings driven for the investigation were on the Causeway. Five (5) borings, however, GB-00-05, GB-00-06, GB-00-07, GB-00-08 and GB-00-09 were collected off the Causeway and provide an indication of the physical characteristics of the surface sediment to be encountered in the dredge prism. For this dredging evaluation, relevant physical characteristics were extracted from the report and boring logs and summarized in Table 1.

Table 1
Off-the-Causeway Sediment Physical Characteristics (from Harding, 2000)

Sample	Bed Surface Elevation (ft, MSL)	Field Description			USCS Group Symbol	SPT - N Value (Blows / Foot)
		0 - 2 ft. Below Surface	2 - 4 ft. Below Surface	4 - 6 ft. Below Surface		
GB-00-05	-1.9	Black mud flat muck, gritty w/ trace sand, trace silt, trace fiber, distinct hydrocarbon odors, non-plastic, very sticky, non-draining. PID=3	Black organic silt, trace fibers, trace shells, Sulphur odor, w/ slight organic odor, non-plastic, non-dilating, non-draining. PID=2.6	Vane Shear	MH	<1
GB-00-06	-1.7	Black organic silt. High Sulphur odor, very soft, some fibers - muck. PID=7	Blackish brown organic silt. Muck, high Sulphur odor, very soft, micaceous, w/ some plant fibers. PID=31	Vane Shear	OL	<1
GB-00-07	-2.7	Black silt, soft, non-plastic	Black silt, loose fine sand, non-plastic	Vane Shear		<1
GB-00-08	-1.3	Black muck, silt, very soft	Black to very gray silt, fine sand, muck, very soft	Fine sandy silt, wood, soft, trace peat, micaceous brown to gray	ML / OL	<1
GB-00-09	-2.1	No recovery	Black muck and silt. Very high Sulphur odor, very soft and sticky. PID =2	Black to very dark gray organic silt, micaceous - does not stick to fingers when squeezed, strong Sulphur odor. PID=7	OL	<1

As seen in the upper core intervals (0-2 ft., 2-4 ft., and 4-6 ft.), the surface layers of the tidal flats on either side of the Causeway are generally characterized as very soft, black to very dark gray organic silt, often with some sand, shell and fiber content.

Standard Penetration Test (SPT) sampling was performed with blow counts recorded for each 6-inch interval. At the 5 samples of interest off the Causeway, the blow counts where all weight of rod (N<1) in the upper core segments.

Vane shear testing (VST) was also performed on some of these samples in the field to characterize the shear strength of near surface sediments. For the off the Causeway samples, VST was undertaken at sample locations GB-00-05, GB-00-06, GB-00-07, at the 4-6 ft. interval. Based on VST results and analysis, the average undrained shear strength for the off the Causeway sediment was estimated to be 180 psf, while the saturated unit weight was estimated at 94 pcf, 0 - 10 ft. below mudline.

Based on the field sampling results and lab testing, strengths for the organic sediments were seen to increase with depth. Water contents are also reported to increase with depth. This is likely due to the increased organic contents observed with depth. (Harding, 2000)

As reported, the tidal flats sediment exhibits a high Sulphur odor. Photoionization detector (PID) testing was conducted on many samples, which registered readings as high as 31 ppm in GB-00-06, for example.

More recent field investigations and laboratory testing were initiated by AMEC FW in summer 2017 to yield a greater understanding of the physical properties of the contaminated sediment inventory in support of feasibility study development. Two sampling events, on August 22nd and October 19th, 2017 were undertaken.

For the August event, sampling was focused in four (4) discrete areas associated with some of the highest contaminant concentrations on the tidal flats. These areas were selected primarily for treatability testing and waste characterization analysis. From several of the coring locations, samples were collected to develop a treatability composite sediment sample. Of this master composite sample, 59.9% was silt and clay, with 38.4% sand, and 1.7% gravel, with a description of sandy silt (MH). LL was 72, PL was 43, and the PI was 29. Bulk (wet) density was 90.3 pcf and dry density was 50.1 pcf. Specific gravity was 2.61. Percent solids was 55.5%. (AMEC FW, 2018)

In the October event, ten (10) additional samples were collected from locations across the site. Samples were collected from borings advanced to the proposed depth of dredging (either 1, 2, 3, or 4 ft. below mudline) and composited across the depth of the recovered core. The October site-wide samples are more useful in assessing variability spatially and vertically across the site. A summary of the site-wide results is provided in Table 2.

For the ten (10) site-wide samples, silt content ranges from 17 to 66% and clay content ranges from 4 to 20%. Sand content ranges from 16.5 to 71.9% and descriptions include silt, silt with sand, sandy silt, and silty sand (MH, SM, and SM/ML). One sample was non-plastic. For plastic samples, LL ranged from 36 to 82, PL ranged from 33 to 41, and the PI ranged from 3 to 41. Bulk (wet) densities range from 81.5 to 112.5 pounds per cubic foot (pcf) and dry density ranges from 34.8 to 85.4 pcf. Specific gravity ranges from 2.5 to 2.68. Percent solids range from 50.4 to 75.9% and organic carbon ranges from 0.3 to 1.98%. (AMEC FW, 2018)

The results for the site-wide samples averaged 61.3% silt and clay, with 35.6% sand, and 0.9% gravel, with a description of sandy silt (MH). LL was 59.9, PL was 36.9, and the PI was 23. Bulk (wet) density was 101.1 pcf and dry density was 62.8 pcf. Specific gravity was 2.65. Percent solids was 61.6%. These results appear to provide a reasonable representation of overall geotechnical conditions at the site.

Table 2

Summary of Geotechnical Laboratory Testing Data

October 2017 Site-wide Samples

Sample Designation	Composite Depth Intervals (ft. bgs)	USCS Description	USCS Group Symbol	Moisture Content (%)	Total Unit Weight (pcf)	Dry Unit Weight (pcf)	% Solids	Specific Gravity	Particle Size Analysis				Atterberg Limits			
									% Gravel	% Sand	% Silt	% Clay	LL	PL	PI	LI
SDT-501-0003	0 -3	Dark gray silt with sand	MH	98.4	92.6	46.7	50.4%	2.62	0.0	16.5	83..5		82	41	41	1.4
SDT-502-0001	0 - 1	Dark gray silt with sand	MH	89.5	92.0	48.6	52.8%	2.62	0.0	23.1	76.9		78	39	39	1.3
SDT-503-0002	0 - 2	Dark gray sandy silt	MH	72.8	96.7	56.0	57.9%	2.67	0.0	38.4	61.6		60	33	27	1.5
SDT-504-0001	0 - 1	Dark gray sandy silt	MH	61.8	100.8	62.3	61.8%	2.64	0.0	43.3	56.7		51	35	16	1.7
SDT-505-0002	0 - 2	Dark gray silt with sand	MH	59.9	101.4	63.4	62.5%	2.63	0.0	28.6	71.4		54	36	18	1.3
SDT-506-0001	0 - 1	Dark gray silt with sand	MH	71.0	96.4	56.4	58.5%	2.65	0.0	26.1	73.9		64	37	27	1.3
SDT-507-0004	0 - 4	Dark gray silty sand	SM	31.8	112.5	85.4	75.9%	2.63	6.7	71.9	21.4		Non - Plastic			
SDT-508-0001	0 - 1	Dark gray silt with sand	MH	66.3	101.8	61.2	60.1%	2.64	1.2	29.5	69.3		59	39	20	1.4
SDT-509-0002	0 - 2	Dark gray silt with sand	MH	53.9	104.8	68.1	65.0%	2.68	0.0	25.7	74.3		55	39	16	0.9
SDT-510-0001	0 - 1	Dark gray silty sand / sandy silt	SM/ML	40.4	111.6	79.5	71.2%	2.68	1.2	53.0	45.8		36	33	3	2.5

Data extracted from Preliminary Summary of Geotechnical Laboratory Testing Data (AMEC FW, 2018)

pcf = pounds per cubic foot, LL = liquid Limit; PL = plastic limit; PI = plasticity index; LI = liquidity index

ASTM clay size particles are 0.005 mm or smaller and silt sized particles are 0.075 mm to 0.005 mm.

Hydrometer results have not yet been provided by the laboratory.

Debris, shellfish, organic matter, marsh grasses, etc. should also be characterized and accounted for in dredge and processing system design. Based on initial visual assessment, debris potentially to be encountered consists of loose riprap near the toe of the revetment and jetty, marsh grasses located along the western and southeastern shorelines of the tidal flat, and bivalves and mollusks within the sediment matrix. Anthropogenic debris from SAEP operations is unlikely to be encountered according to site personnel familiar with historic operations, but possible. One isolated pile of riprap was observed at roughly the - 3.5 ft. MSL contour in the east tide flat just off the Causeway that may require removal.

2.4 Bathymetry

The bathymetry of the tidal flats remediation area ranges from approximately 0.0 ft. MSL near the toe of the rock revetment, to -10 ft. MSL just channelward of the Causeway. The slope is gently sloping to flat across most of the tidal flats, with an average depth of roughly -2.0 ft. MSL on the west flat, and -3.0 ft. MSL on the east flat. Three primary rivulets (on the west flat) and many smaller rivulets drain the marshes and tidal flats.

2.5 Water Levels

Tides at the site are semi-diurnal, that is with two nearly equal high tides and low tides every lunar day (roughly 24 hours and 50 minutes). Tidal datums applicable to the project site were obtained from NOAA Tide Station 8467150, Bridgeport, the closest harmonic station to the project site. The tidal datums, with elevations converted from the station datum (NAVD88) to MLLW and MSL (project vertical datum), are provided in Table 3. Historic extreme water levels are also provided in Table 3.

Table 3

Water Level Data based on NOAA Tide Station 8467150

Water Level Data: NOAA Station 8467150 Bridgeport, CT	Elevation (ft., NAVD88)	Elevation (ft., MLLW)	Elevation (ft., MSL)
Mean Higher High Water (MHHW)	9.30	7.32	3.70
Mean High Water (MHW)	8.97	6.99	3.37
Mean Tide Level (MTL)	5.59	3.61	-0.01
Mean Sea Level (MSL)	5.6	3.62	0.00
Mean Low Water (MLW)	2.22	0.24	-3.38
Mean Lower-Low Water (MLLW)	1.98	0.00	-3.62
North American Vertical Datum of 1988 (NAVD88)	0.00	-1.98	-5.60
Highest Observed Water Level (Oct. 30, 2012)	15.02	13.04	9.42
Lowest Observed Water Level (Feb. 2, 1976)	-2.60	-4.58	-8.20

2.6 Wave Climate

The lower Housatonic River estuary near its confluence with Long Island Sound is generally protected from long period swell. The longest fetch distance over which wind-waves incident to the SAEP tide flats can form is slightly over a mile. Vessel wakes from heavy boat traffic in the adjacent navigation channel can generate wave energy across the tidal flats as well. In either case, it is unlikely that wave heights exceed 1.5 ft. and wavelengths exceed 10 ft.

3.0 Dredging Alternatives Evaluation

Informed by the site visit, preliminary geotechnical characterization, and initial physical processes evaluation, a shortlist of dredging technologies are proposed and evaluated in this section.

3.1 Key Considerations

3.1.1 Dredgeability

With regards to the dredgeability of the tidal flats surface sediments, the following observations are made based on the initial characterization information and prior experience;

- The material is diggable using hydraulic or mechanical dredging technology,
- The material is transportable by both hydraulic slurry pipeline or barge,
- The presence of clay provides for possible impacts to hydraulic slurry transport and mechanical dewatering processes,
- The potential for resuspension and residuals generation is considerable,
- The material does not have adequate bearing capacity to support terrestrial excavation/hauling equipment with or without matting, in *situ* conditions,
- The sediments do not appear suitable for in-place dewatering and excavation “in the dry”.

3.1.2 Production

The shallowness and expansiveness of the tidal flats site will limit access, and the size and production capacity of the dredging equipment to be employed. The site’s tidal regime will greatly influence remedial design decisions and the dredge production rates and cleanup efficiency to be achieved during construction implementation.

Based on the existing bathymetry, 0.0 ft. MSL provides an approximate elevation at which shallow draft dredging plant will be able to begin productively working the tidal flats. A tides analysis was developed to provide an idea of the time available above 0.0 ft MSL. The analysis was run for a typical construction window of 0600 hrs. - 1800 hrs. The percentage of time and average available hours per day above specific tide elevations is summarized in Table 4.

Table 4
Floating Plant Working Tides Analysis (based on NOAA Station Bridgeport, CT)

Tide Elevation (ft., MSL)	Average Hours above / Day	% Time above / Day
4.0	0.2	2%
3.0	1.7	15%
2.0	3.4	29%
1.0	4.3	36%
0.0	4.9	41%

Based on the analysis, for approximately 5 hours per day tide elevations will provide adequate flotation for dredging with shallow draft equipment (<3 ft.). While much of the time these working high tides would be continuous within a 12-hr work day, oftentimes they are split between early morning and late afternoon, which would further impact production efficiency. During lower tides the dredging equipment could be productive in deeper areas along the northern slopes of the tidal flats.

3.1.3 Accuracy

Measured at approximately 58 acres, the tidal flats site would significantly benefit from the application of precision dredging equipment, to minimize the unnecessary removal, transportation and processing of clean underlying sediments. To underscore the importance of dredging accuracy, Table 5 was developed to provide a simple estimate of realistic overdredge performance values for the SAEP tidal flats site, and associated volume and cost implications. The estimate assumes a total unit cost of $400/CY for dredging, processing and T&D, based on recent experience at other remedial dredging sites.

Table 5

Implications of Dredging Accuracy on Volume and Cost

SAEP Tide Flats Dredge Area (Acres)	SAEP Tide Flats Dredge Area (ft^2)	Overdredge (ft)	Overdredge Volume (ft^3)	Overdredge Volume (CY)	$/CY	Cost
58	2,526,000	0.1	252,600	9,000	$400	$3,600,000
		0.2	505,200	19,000		$7,600,000
		0.5	1,263,000	47,000		$18,800,000
		1.0	2,526,000	94,000		$37,600,000

As can be seen from these order of magnitude examples, there are significant cost and schedule implications driven by dredging accuracy performance. Accordingly, precision variants of both hydraulic and mechanical dredges are proposed for this project, as discussed below.

3.1.4 Resuspension and Residuals

To achieve cleanup goals cost effectively, dredging plant, support equipment and approaches should be applied to the SAEP site that minimize the generation of residual contamination. Both generated residuals and undredged inventory can lead to excessive, and expensive, returns to areas not meeting cleanup criteria. There can be many causes of generated residuals, including loss at the cutterhead / clamshell bucket, propwash, and sloughing. Undredged inventory is often a function of how accurately the contaminated inventory was sampled and delineated in the horizontal and vertical extent, modeled, and how effectively the dredge prism was designed.

Similarly, to meet project water quality requirements, and possibly allow for expanded construction windows, dredging plant, support equipment and approaches should be applied to the SAEP site that create minimal resuspension.

Table 6 was developed to summarize the resuspension and residuals generation ‘footprint’ of the proposed dredging alternatives, by operation.

3.1.5 Engineering Controls

It is appropriate to consider the need for engineering controls at this stage as they relate to the evaluation of dredging alternatives and project planning.

3.1.5.1 Cofferdam

A steel sheet pile cellular cofferdam extending from the shore connection of the jetty to the eastern boundary of east tidal flat could effectively isolate the tidal flats dredging areas from the Housatonic River during construction. Isolation of the dredging area by cofferdam allows for consideration of;

- Performing sediment removal in-the-dry, or
- Performing dredging with constant flotation, and
- Preventing water quality impacts outside the project.

As reported in the *Geotechnical Investigation Summary* (Harding, 2000), the water contents in the sediments increase with depth, which makes the prospect of in-place dewatering and excavation in-the-dry difficult. Possibly more feasible through construction of the cofferdam would be maintaining a constant water surface elevation over the dredge areas to provide adequate flotation at all times. This would allow for optimal dredging production, accuracy and residuals management by the floating dredge operation. Lastly, a cofferdam would allow for the isolation of the dredging project, and consequential water quality impacts during construction, from the Housatonic River estuary. This could open the possibility of dredging year-round and not being subject to environmental windows.

The potential advantages of the cofferdam described above are worth considering during the feasibility and remedial design stages and will need to be balanced against the cost of the installation and any impacts during and following construction. One other consideration would be the increase in flooding potential along adjacent shoreline properties caused by an ongoing high water surface elevation and storm-induced wind-waves. Accordingly, and based on detailed analysis of tidal flats shoreline topography, the cofferdam engineering control should not create a pool elevation exceeding a typical high tide elevation (i.e. MHW, or MHHW).

3.1.5.2 Wave Attenuator

To reduce potential impacts incident wind-waves and vessel wakes may have on dredging operations while underway in the tidal flats, a floating wave attenuator could be installed at strategic segments of the opening between the jetty and Causeway, and Causeway and eastern project shoreline. Again, the potential benefits in terms of production gains would need to be compared to the costs of installation and maintenance. It would also be important to consider that the larger, heavier dredge platforms would be less impacted by waves than the smaller plant.

3.1.5.3 Turbidity Curtain

The use of silt curtains and turbidity curtains to manage water quality impacts from dredging and support operations is common at contaminated sediment sites. For the SAEP tidal flats site it is anticipated that a Type II or Type III full length curtain could be required to contain plumes and manage water quality and release to adjacent waters. The alignment and depth of the curtain will need to be determined to meet agency requirements and accommodate dredging operations. It's possible the curtain would need to enclose a large area, i.e. between the jetty and eastern project shoreline, and accommodate a large tidal flux. A solid understanding of the tidal regime, including velocities, is suggested.

3.2 Alternative Dredging Technologies

Informed by an initial understanding of site conditions, likely processing and disposal scenarios, and experience, a shortlist of five (5) dredging technologies are proposed as likely suitable alternatives to complete the SAEP dredging work;

- Hydraulic Swinging Ladder Cutterhead Dredge
- Precision (Mechanical) Excavator Dredge - Hydraulic Transport
- Precision (Mechanical) Excavator Dredge - Shallow Draft Barge Transport
- Amphibious Dredge (Mechanical / Hydraulic)
- Long Reach (Terrestrial) Excavator

Most of these dredging technologies have been demonstrated to be effective on other contaminated sediment sites and show potential for successful application on the conditions the SAEP tide flats site presents, to a degree they are evaluated here. Photos of each technology are provided in Appendix B.

3.2.1 Alternative 1 - Hydraulic Swinging Ladder Cutterhead Dredge

A hydraulic swinging ladder cutter suction dredge in the 8-in class is proposed as an appropriately sized and functioning shallow draft hydraulic pipeline dredge for the SAEP tidal flats.

The Dredge Supply Company (DSC) Moray SL and Ellicott 360 SL are versions of swinging ladder dredge, both 8-in discharge, with similar pumping characteristics, that are suitable for a shallow dredge cuts, pipeline conveyance over long distances, and feeding mechanical dewatering systems. The Moray has been used on more sediment remediation projects than the 360SL, in part likely due to customizations to their base model dredges for specific applications (i.e. shallow draft, precision cutting, and higher % solids). That said, the Ellicott 360 swinging ladder dredge has also been adapting to the needs of environmental dredging projects.

The swinging ladder dredge spuds down to stabilize the dredge platform while dredging, for improved accuracy, steadier state cutting and slurry concentrations, and consistent lane advance. Horizontal positioning is good, better than +/- 2 ft. typically, in using the walking spud system to advance in small increments (generally about one cutterhead width), before lowering the spuds again, to create a stable platform from which to swing the ladder and cutterhead. Both the Moray and 360SL can be operated in either swinging ladder mode, which swings that ladder and cutterhead into the bank whilst the barge is held stationary; or in conventional mode, where the entire dredge platform pivots off its stern spud. Conventional mode allows for wider swing widths, to about 40 ft., while swinging ladder provides closer to a 20 ft. swing width depending on pontoon configuration and ladder length and depth.

The dredges' cutterheads are designed to agitate and draw the targeted bank material closer to the influence of the suction intake immediately behind the cutter on the ladder. Options in cutterhead design, for improved accuracy, higher % solids, and reduced residuals, have been developed for the Moray dredge. Also, to orient the cutterhead and suction level with the cut bank to promote improved accuracy and higher solids, articulated ladders are available for both the Moray SL and 360 SL.

On a recent visit to the Lower Fox River project in Green Bay, Wisconsin the performance of swinging ladder dredge operations was observed. Three hydraulic dredges, including one (1) 12-in and two (2) 8-in swinging ladder dredges were being employed on the project to remove and transport PCB-contaminated sediment up to 10 miles to the project's sediment processing facility. System capacity is 6,500 GPM, with typical operating discharge of 5,000-6,000 GPM combined from the three dredges. The 8-in DSC Moray dredges, was producing on the order 25-30 cy/hr in high bank material, and as low as 5 cy/hr or less in thin face - cleanup pass mode. Corresponding slurry concentrations are reported to range from 8%-12% solids by weight for thick faces down to 2%-4% solids by weight for thin faces – cleanup passes. Dredging efficiencies (effective time) was reportedly maintained at 80% - 90%.

The Moray dredges can draw as little 1.5-2.0 ft and use both conventional and modified pontoons for shallow water operations. The contractor on the Fox River employs, and in some cases developed, several different cutter attachments, including the conventional rotating basket cutter for denser and thicker material, an environmental disk cutter, as well as a specialized straight vacuum for unconsolidated, high water content material removal overlying stiffer substrates. The Moray dredge is essentially self-propelled in lane advances through use of the kicker (traveling) spud. Project-averaged vertical dredging accuracies are reported to be 0.4-0.5 ft. using installed RTK-GPS and electronic dredge positioning system.

Conceptually, for the SAEP tidal flat project, one (1) or two (2) 8-in swinging ladder dredge systems, which are truckable, could be transported to the project site, and lifted or floated into the Housatonic or possibly mobilized off the Causeway. Depending on the required feed characteristics of the project dewatering system, and to optimize production, accuracy, and residuals management performance, it may be advisable to include automation controls (i.e. swing speed, cutter speed, flow rate) and a site-specific cutterhead design to minimize spillage and resuspension. The dredge would also be instrumented with RTK-GPS and dredge positioning and guidance system to implement a final, potentially tighter tolerance dredging plan. Shallower draft pontoons, articulated ladders, and advanced spud systems would also be considered as potential cost savings measures on a swinging ladder dredging alternative. Developing an operations plan that would leverage the swinging ladder's dredge pattern, to achieve cleanup with the greatest efficiency, would be done at the design phase.

3.2.2 Alternative 2 - Precision (Mechanical) Excavator Dredge - Shallow Draft Barge Transport

Based on prior experience with both hydraulic and mechanical dredge types, precision excavator dredges coupled with a latest generation level-cut sealed environmental clamshell bucket can offer the best available performance on contaminated sediment remediation sites in most key categories, including dredging accuracy, production, solids concentrations, and residuals management. These platforms are also versatile in their ability to easily convert to capping operations.

For shallower sites like the SAEP tide flats, the precision excavator dredges can be constructed on site by fabricating a barge platform, typically of modular barges (i.e. Flexifloat), lifting on deck plant (spud and winches/drums, genset, control rooms, etc.) with a shore-based crane, then rolling on the excavator.

The excavator is instrumented with RTK-DGPS and a dredge and bucket positioning system (DBPS), using a series of angle sensors (inclinometers) and rotation sensors mounted on the machine, boom, stick, and bucket for precise location and monitoring of the dredge and bucket. Operating from a relatively stable platform with 2-4 spuds, precision dredging, to better than 2-in. vertically, is achieved by placing the cutting edge of the bucket to target elevations monitored via a real-time heads-up display. For sites with high cost for T&D, use of the +/- 1-in. variance or better level-cut clamshell buckets is warranted to minimize further 'scallop' cuts into non-target sediments. Dredging progresses in defined set patterns, with consistent grab thicknesses and overlap to manage residuals and maintain planned production rates. For optimal solids concentrations and production rates, bucket grabs with consistently high fill efficiency are made. Barges provide the ability to transport dredge materials at highest possible solids concentrations, with the only water added that which is entrained in the bucket. To a large degree, clamshell buckets can also contend with debris better than hydraulic dredging systems.

Another potential advantage of mechanical dredging is the ability to leverage a 'visual' dredging approach. Developed on New Bedford Harbor during the Pre-Design Field Test in 2000, with the first excavator- mounted level-cut clamshell bucket used in the United States, this is the ability to make real time visual assessments of the material being dredged, to inform and tune core-based dredge target elevations. This approach is feasible where the contact between the contaminated inventory and 'clean' native material can be distinguished, either by color or consistency. Based on review of initial core logs from the east and west flat, the surface layers are predominantly homogenous black to dark gray organic silt (muck), very soft, with no distinguishing contact with native. The ability to apply the aforementioned approach in this case thus far appears limited.

For either the mechanical excavator with barge transport approach, or hybrid mechanical excavator – hydraulic transport approach, described in the next section, it is conceptualized that one (1) or two (2) shallow draft precision excavator dredges, would be employed to be able to work the tides efficiently, i.e. one working the east flat and one the west flat, or two working the west flat. These would use something like a CAT 3049MH long reach material handler or similar class excavator to operate an approximate 3.0 cy sealed level-cut environmental clamshell bucket. Deck barge platforms would be configured to provide greater flotation for optimal dredging production in the shallow conditions the tidal flats present. It is envisioned Flexifloat S-50 modular barges, which are 5 ft. high, would be used in the deck barge fabrication. Lane advances (stepping) and moves between areas would be accomplished using either an anchor and wire system or shallow draft push boat. These determinations would be based on balancing access, production, and residuals management on the tidal flats, while not sacrificing realized dredging accuracy.

To accommodate anticipated dredge production rates, depth limitations, and transport the mechanically dredge sediments from the point of dredging to shore, shallow draft barges would be needed for the mechanical dredging operations. Conceptually the barges would have capacities of roughly 60 cy, and not draw more than about 3 ft. To move the barges, shallow draft, truckable push boats would be employed. It is recognized that the push boats would be sources of resuspension, and their design and operations will need to be planned and managed carefully to keep water quality and residuals generation within acceptable ranges.

Another component that would need to be addressed with a mechanical dredging alternative (no hydraulic pipeline) at the SAEP, is transloading of dredged sediments to the presumed mechanical dewatering facility (i.e. east parking lot.). A likely scenario to transload dredged sediments under precision excavator and barge alternative would be to build a barge offloading area (BOA) on either the northwest or northeast corner of the Causeway, or, near the channelside shore connection of the jetty. This would require construction of a pier-trestle capable of supporting a hydraulic offloader system and/or material offloading crane. Once installed, the BOA could be used for other site activities, including potentially residual cover and capping material conveyance to capping barges.

3.2.3 Alternative 3 - Precision (Mechanical) Excavator Dredge - Hydraulic Transport

This alternative combines the benefits of precision excavator dredging and hydraulic pipeline transport. Advantages and limitations are essentially the same as described for the precision excavator in the prior section. By the hybrid dredging approach, mechanical excavation removes material with a high degree of accuracy, typically better that 2-in below target elevation on average, at close to *in situ* concentrations, and places it in a hopper on board the dredge for initial screening of larger debris. Material that passes the debris screen, or grizzly, is slurried via a high efficiency, automated pump, with just enough makeup water to transport the material at maximum practical and steady-state concentrations. The makeup water can be sourced from a seachest along the dredge rail, or recirculated. The dredge material slurry would be received and processed in the same manner as hydraulically dredged sediment, at a presumed mechanical dewatering facility at the SAEP east parking lot.

During a pilot study in New Bedford Harbor in 2000, production averaged approximately 80 cy/hr, in deeper water, vertical dredging accuracy exceeded +/- 0.4 ft. with an average overdredge of -0.1 to -0.2 ft. below target elevation for the test area, and the visual dredging method was developed and applied to make real-time adjustments to the dredge plan. A similar system and approach has recently been setup at New Bedford and starting to achieve similar results, with improved accuracies. Additional details on the hybrid dredge system, can be reviewed in the Pre-Design Field Test study report, https://www3.epa.gov/region1/superfund/sites/newbedford/23751.pdf.

3.2.4 Alternative 4 - Amphibious Excavator

There are many variants of amphibious dredges, both mechanical and hydraulic. Mechanical models such as the Wilco marsh buggy are conventional excavator machines mounted on custom floating or low ground pressure (LGP) tracked pontoons. Hydraulic amphibious dredges such as the Amphibex or Waterking, use large sponsons and kicking spuds to traverse over ground. These platforms are also convertible to mechanical dredging mode.

While the production rates and accuracy of these dredges are not as high as Alternatives 1-3, the concept of employing amphibious dredges from floating to emergent conditions, to remain productive in the intertidal areas over the full tidal cycle, is attractive for this site. What would present a distinct disadvantage for these dredge types, however, is the problem of residuals generation and recontamination. Interaction of the tracks in the case of the marsh buggy and its support equipment (i.e. LGP trucks), or of the barge and sponsons in the case of the Amphibex type, would significantly disturb the bed surface, and cause mixing such that a ‘clean’ and organized removal sequencing would be difficult to achieve.

Examples of amphibious dredge types are provided in Figures 7 and 8 of Appendix B.

3.2.5 Alternative 5 - Long Reach (Terrestrial) Excavator

A long-reach excavator operated from stable ground close to the water's edge for the mechanical removal of near shore sediments is likely a suitable approach and cost effective for much of SAEP sediment site. Mechanically dredged material removed at close to *in situ* concentrations can provide savings in processing and disposal costs. Elimination of some of the shallowest areas, or areas where shoreline debris content may be high would also yield savings versus applying floating plant. Given the preliminary design slopes, a long reach excavator would also be a preferred technology for sediment removal and basin contouring in the Outfall 008 Drainage Ditch.

Long reach excavators are available from several manufacturers with various boom and stick configurations and aftermarket attachments. Reaches can extent to about 70 ft. from kingpin along the digging envelope. Smooth lipped, open faced buckets are typically used, however, with proper lifting capacity calculations, a sealed, level-cut clamshell bucket may be better applied, particularly if removing soft, high water content sediments, and on the tidal flats. An open bucket may be required in the Outfall 008 Drainage Ditch to accomplish slope sculpting. In either case, the dredged materials could be placed in dump trucks and presumably hauled to an onsite stabilization or processing facility.

Examples of long reach excavators working on shoreline and canal projects are provided in Figures 9 and 10 of Appendix B.

3.3 Summary

Specifications and estimated performance characteristics for the five alternative dredging technologies evaluated for this site are summarized in Table 6. Table 7 has been developed to provide the resuspension and residuals generation 'footprint' of each alternative, by operation. Table 7 does not yet attempt to quantify the various source mechanisms, nor propose mitigation measures or best management practices, of which there are many.

Based on the evaluations conducted, recommendation is made to retain Alternatives 1, 2, 3 and 5 for possible application on the SAEP project. To make a final determination on which technology or combination of technologies would be most effective in achieving project goals, detailed production and cost estimates for each system should be developed, cleanup goals better understood (i.e. backfilling to be carried out or not), and the site's dredged material disposal / beneficial use alternatives assessed further.

The estimates should incorporate reasonable performance value assumptions for production rates, dredging accuracy, equipment costs, added water, as well as construction schedules to assess the overall project cost for each dredging alternative. With this knowledge, determination of the most cost-effective dredging approach can be made, and developed during the remedial design phase.

TABLE 6
ALTERNATIVE DREDGING TECHNOLOGIES

Dredge Performance Parameter	Alternative 1 8-In. CUTTER SUCTION DREDGE , SWINGING LADDER, HYDRAULIC TRANSPORT	Alternative 2 PRECISION MECHANICAL DREDGE - SHALLOW DRAFT BARGE TRANSPORT	Alternative 3 HYBRID - PRECISION MECHANICAL DREDGE / HYDRAULIC TRANSPORT	Alternative 4 AMPHIBIOUS DREDGE (MECHANICAL / HYDRAULIC)	Alternative 5 LONG REACH TERRESTRIAL EXCAVATOR
Examples	DSC 8-In Moray	Hudson River Precision Excavator	New Bedford Harbor Hybrid Dredge	Wilco Marsh Buggy / Amphibex, Waterking	CAT 345D, CAT 352F, Komatsu PC200
Removal Method	Basket, Horizontal Disk or Viscous Cutterhead	Sealed, Level Cut Clamshell bucket, w/ Rotator	Sealed, Level Cut Clamshell bucket, w/ Rotator	Sealed Clamshell bucket, Open smooth bucket, or cutterhead	Sealed, Level Cut Clamshell bucket, w/ Rotator, or Open smooth edge bucket
Propulsion, lane advance	Traveling (Kicker) Spud	Winch & Wire Rope - Anchor, Skiff/Tug Assist	Winch & Wire Rope - Anchor, Skiff/Tug Assist	Tracks on ground, Sponson/kicking spud, Z-drive propeller	N/A
Propulsion, between areas	Skiff / Tug assist	Skiff / Tug assist	Skiff / Tug assist	Self Propelled	Self Propelled
Draft (ft.)	~2.5	~3.0	~3.0	~2.5	N/A
Weight (lbs.)	42,000 lbs	+ 200,000 lbs	+ 200,000 lbs	100,000 - 200,000 lbs	100,000 - 150,000 lbs
Positioning Method	Three-Four (3-4) 8-in Spuds	Two-Three (2-3) 20-in Spuds	Two-Three (2-3) 20-in Spuds	Two-Four Spuds, Sponson	N/A
Accuracy - Horizontal (ft.)	1.0 - 2.0	0.3 - 1.0	0.3 - 1.0	1.0 - 3.0	0.2 - 0.5
Accuracy - Vertical (ft.)	0.4 - 0.7	0.2 - 0.5	0.2 - 0.5	0.5 - 1.0	0.1 - 0.5
Visual Dredging Approach	No	Yes	Yes	Yes / No	Yes
Lane Width (ft.)	17 - 40	30 - 50	30 - 50	20 - 40	N/A
% Solids by Weight (Dry Solids)	2% - 12%	30% - 70%	10% - 20%	2% - 70%	30% - 70%
Production Rate (per dredge)	15 - 50 cy/hr	20 - 80 cy/hr	20 - 80 cy/hr	20 - 40 cy/hr	30 - 60 cy/hr
Operating Depth Range (ft.)	0 ft - 18 ft.	0 ft. - 25 ft.	0 ft. - 25 ft.	0 ft. - 15 ft.	0 ft. - 25 ft.
Convertible to Debris Removal Operations	No	Yes	Yes	Yes	Yes
Convertible to Capping Operations	No	Yes	Yes	Yes	Yes
Impact of Debris on Production	High	Low	Medium	High	Low
Residuals Footprint (See Table 7)	Medium	Medium	Medium	High	Low
Material Transport	HDPE Pipeline	Shallow Draft Hopper Barge	HDPE Pipeline	Shallow Draft Hopper Barge, LGP Truck, HDPE Pipeline	Dump Truck, LGP Truck
Barge Offloading Area Required	No	Yes	No	Yes / No	No
Adaptable to Mechanical Dewatering	Yes	No	Yes	Yes / No	No
Adaptable to Geotube Dewatering	Yes	No	Yes	Yes / No	No
Adaptable to Stabilization	No	Yes	No	Yes / No	Yes
Adaptable to Pneumatic Flow Tube Mixing	No	Yes	No	Yes / No	Yes

TABLE 7
RESUSPENSION AND RESIDUALS GENERATION PROCESSES

Potential Sources of Residuals and/or Resuspension	Alternative 1 8-In. CUTTER SUCTION DREDGE , SWINGING LADDER, HYDRAULIC TRANSPORT	Alternative 2 PRECISION MECHANICAL DREDGE - SHALLOW DRAFT BARGE TRANSPORT	Alternative 3 HYBRID - PRECISION MECHANICAL DREDGE / HYDRAULIC TRANSPORT	Alternative 4 AMPHIBIOUS DREDGE (MECHANICAL / HYDRAULIC)	Alternative 5 LONG REACH TERRESTRIAL EXCAVATOR
Anchor System	No anchor system required in swinging ladder mode. When dredging in conventional mode, to achieve wider cuts, an anchor and wire system is used to swing entire dredge. On SAEP a 3- or 4- wire system deployed up to 500 ft fore-aft and side-side of dredge, using shore connections when possible. Anchor setting and removal, with propwash and potential groundings of work boat and A-frame, and interaction of wires with bed, can cause resuspension and residuals.	No anchor system required for mechanical dredging operations, howver may be used to optimize access and production in shallow tide dependent areas of the SAEP. Likely a 3- or 4-point wire system could make use of shore anchors when possible. Anchor setting and removal, with propwash and potential groundings of work boat and A-frame, and interaction of wires with bed, can cause resuspension and residuals.	Anchor and wire system may be advisable for hybrid dredge to optimize access and production in shallows tidal dependent areas of the SAEP, likely a 4- or 5-point wire system could make use of shore anchors when possible. Anchor setting and removal, with propwash and potential groundings of work boat and A-frame, and interaction of wires with bed, can cause resuspension and residuals.	Anchor and wire system not suitable for amphibious dredge types.	N/A, land-based
Point of Dredging	Overloading of pump suction results in plowing, loss, and generated residuals. Overpenetration and mixing generates residuals and disturbed inventory. Evacuation of sediment slurry in discharge pipeline back to harbor to clear pump of debris, backflushing, and clearing plugged pipelines generates resuspension and residual contamination. Potential for grounding.	Resuspension with pressure wave as bucket approaches bed. Resuspension and residuals due to loss from grab closure through cycle to barge placement when bucket not sealed completely, or overfilled. Potential to cause generated residuals and undredged inventory if proper bucket overlap not achieved. Potential for grounding.	Resuspension with pressure wave as bucket approaches bed. Resuspension and residuals due to loss from grab closure through cycle to barge placement when bucket not sealed completely, or overfilled. Potential to cause generated residuals and undredged inventory if proper bucket overlap not achieved. Potential for grounding.	Grounding and traversing over bed surface is inherent in these dredge types. Significant residuals and resuspension likely. In addition, overloading of pump suction results in plowing, loss, and generated residuals. Overpenetration and mixing generates residuals and disturbed inventory. Evacuation of sediment slurry in discharge pipeline back to harbor to clear pump of debris, backflushing, and clearing plugged pipelines generates resuspension and residual contamination. In mechanical mode resuspension with pressure wave as bucket approaches bed. Resuspension and residuals due to loss from grab closure or open face bucket.	Resuspension with pressure wave as bucket approaches bed. Resuspension and residuals due to loss from grab closure or open face bucket.
Material Transport	Submerged and floating discharge pipeline interaction with bed surface. Periodic barge transits needed to transfer debris to shore.	Propwash and potential groundings from shallow draft barge operations. Barge transits from the dredges to the barge offloading area (BOA), oftentimes working the tides and with possibly less than 1 ft unkeel clearance.	Submerged and floating discharge pipeline interaction with bed surface. Periodic barge transits needed to transfer debris to shore.	By hydraulic method, submerged and floating discharge pipeline interaction with bed surface. Periodic barge transits needed to transfer debris to shore. By mechanical method LGP truck may be required, which would cause significant residuals. Propwash and potential groundings from shallow draft barge operations. Barge transits from the dredges to the barge offloading area (BOA).	N/A, land-based
Positioning and Lane Advance	Typically 1-2 passes required per 1 ft bank of material to remove. Uses traveling (kicker) spud to step forward in uniform increments, typically one cutterhead width. Each step requires resetting of the three (3) 8-in square spuds.	Typically 1 pass required per 1-2 ft bank of material to remove. Uses two (2) 20-in spuds to position dredge. Lane advance can be achieved by traveling spud, push boat assist, or anchor/wire, each with potential to generate resuspension and residual generation potential.	Typically 1 pass required per 1-2 ft bank of material to remove. Uses two (2) 20-in spuds to position dredge. Lane advance can be achieved by traveling spud, push boat assist, or anchor/wire, each with potential to generate resuspension and residual generation potential.	Typically 1 pass required per 1-2 ft bank of material to remove. Uses two (2) 8-10 in. spuds to position. Lane advance can be achieved by traveling spud, outboards, push boat assist, or tracking over bed surface, each generate resuspension and residuals.	N/A, land-based
Move between Areas	Moving dredges between areas upon completing an area, to accomodote bathy surveys and verfication sampling, or working the tides. Propeller wash from work boats and pipeline moves creates resuspension and potentially residuals.	Moving dredges between areas upon completing an area, to accomodate bathy surveys and verfication sampling, or working the tides. Propeller wash from work boats create resuspension and potentially residuals.	Moving dredges between areas upon completing an area, to accomodate bathy surveys and verfication sampling, or working the tides. Propeller wash from work boats and pipeline moves creates resuspension and potentially residuals.	Movements achieved by traveling spud, outboards, push boat assist, or tracking over bed surface, each generate resuspension and residuals.	N/A, land-based
Debris Management	Separate debris removal operation may be required, but not foreseen on SAEP.	Separate debris removal step not anticipated.	Separate debris removal step not anticipated.	Separate debris removal step not anticipated.	Separate debris removal step not anticipated.

4.0 References

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APPENDIX A

October 6, 2017 Site Visit Photographs

Photo 1. West end of Outfall 008 Drainage Ditch looking east from east parking lot. October 6, 2017.

Photo 2. East of Outfall 008 Drainage Ditch confluence with tidal lagoon, looking northwest. October 6, 2017.


Photo 3. South Causeway, looking north, mid-tide. October 6, 2017.


Photo 4. Head of Causeway looking east across east tide flat, dike and revetment, mid-tide. October 6, 2017.

Photo 5. Head of Causeway looking west across west tide flat, dike and revetment, mid-tide. October 6, 2017.

Photo 6. North Causeway looking east at Housatonic River confluence with Long Island Sound, mid-tide. October 6, 2017.

Photo 7. North Causeway looking north across Housatonic River at Nells Island, mid-tide. October 6, 2017.

Photo 8. North Causeway looking northwest across west tide flat boundary with Housatonic River and jetty light. Note jetty is submerged at mid-tide. Note USCG buoy tender managing vessel traffic. October 6, 2017.


Photo 9. Mid - Causeway looking northwest. Note vessel wake propagating into western tide flat, mid-tide. October 6, 2017.


Photo 10. Mid - Causeway on marine mattress erosion control cover system looking west across west tide flat, mid-tide. Note vessel wake has approximate 6 ft. wavelength, 0.5 ft. amplitude. October 6, 2017.

Photo 11. Mid - Causeway looking southeast across east tide flat to eastern end of dike and revetment, mid-tide. October 6, 2017.

Photo 12. South Causeway on rock revetment looking west across west tide flat, near low-tide. October 6, 2017.


Photo 13. Mid - Causeway looking east across east tide flat, near low-tide. Note isolated debris pile (riprap). October 6, 2017.


Photo 14. Mid - Causeway looking southeast across east tide flat, near low-tide. October 6, 2017.

Photo 15. Mid - Causeway on marine mattress erosion control cover system looking west across west tide flat, near low-tide. Note subtidal zone. Note emergent jetty. October 6, 2017.

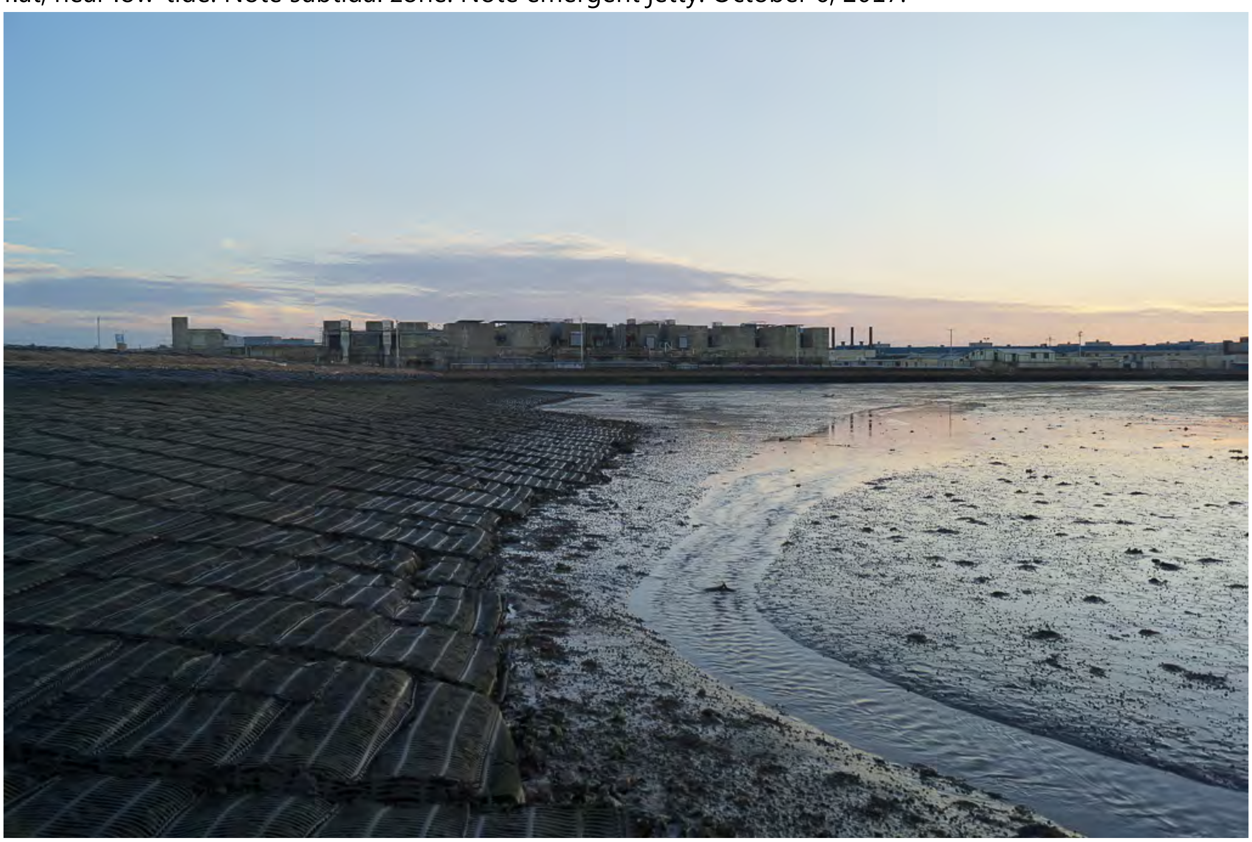

Photo 16. North Causeway on marine mattress erosion control cover system looking south with Building 19 in background, near low-tide. Note toe of marine mattress erosion control cover system. Note tidal rivulet running through surface sediment. October 6, 2017.


Photo 17. North Causeway looking north across Housatonic River towards Nells Island, near low-tide. Note shallow slope of marine mattress erosion control cover system extending to subtidal. October 6, 2017.


Photo 18. North Causeway looking south along east tide flat, near low-tide. October 6, 2017.


Photo 19. North Causeway looking west across entrance to west tide flat, near low-tide. Note subtidal area. Note fishermen practicing riparian rights. October 6, 2017.


Photo 20. South Causeway looking north. October 6, 2017.

APPENDIX B
Alternative Dredging Approaches

Figure 1. Alternative 1 - Swinging Ladder Dredge. Source: Dredge Supply Company

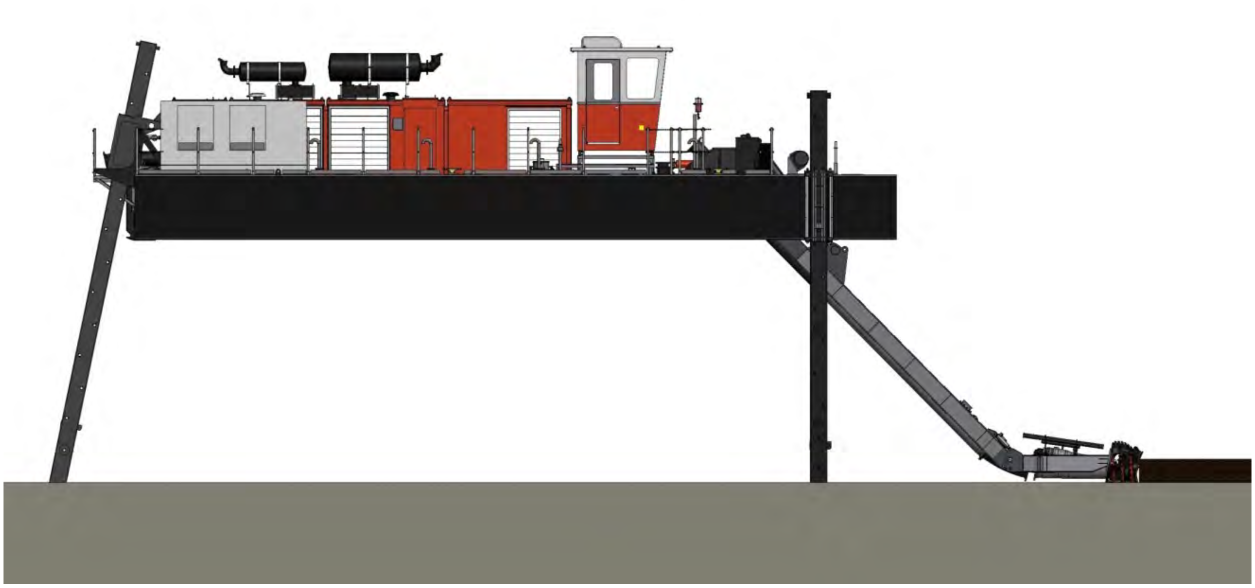

Figure 2. Alternative 1 - Swinging Ladder Dredge with Articulated Ladder. Source: Dredge Supply Co.

Figure 3. Alternative 2 - Precision Excavator Dredge, Shallow Draft Barge, Hudson River, NY, 2009.

Figure 4. Alternative 2 - Precision Excavator Dredge, Shallow Draft Barge, Push Boat, Hudson River, 2013

Figure 5. Alternative 3 - Hybrid Precision Excavator Hydraulic Transport Dredge, New Bedford, MA, 2000

Figure 6. Alternative 3 - Precision Excavator - Hydraulic Transport Dredge with 4.6 cy (3.5 m^3) Horizontal Profile Grab Level-Cut Environmental Clamshell Bucket, New Bedford, MA, 2000.

Figure 7. Alternative 4 – Amphibious Dredge - Mechanical. Source: BIG Dredging

Figure 8. Alternative 4 – Amphibious Dredge - Mechanical. Source: Amphibex

Figure 9. Alternative 5 – Long Reach Excavator. CAT 345B. Source: Pierce Pacific

Figure 10. Alternative 5 – Long Reach Excavator. CAT 352F. Source: CAT

Figure 11. Engineering Control - Cofferdam. Source: Pilebuck

Figure 12. Engineering Control – Wave Attenuator. Source: Kropf

Figure 13. Engineering Control – Silt Curtain, Type III. Source: Elastec


Figure 14. Engineering Control – Turbidity Barrier. Source: Layfield

APPENDIX H

Alternative Cost Estimate Summary

Amec Foster Wheeler, Inc.
271 Mill Road
Chelmsford, MA 01824

Project: Stratford Army Engine Plant
Project No: Focused Feasibility Study Cost Estimate
Date: 10/26/2018
Calc. By JR
Checked By: TD

DESCRIPTION	Alternative 2				Alternative 3		Alternative 4				Alternative 5	Alternative 6
	Hydraulic Belt Off-Site	Hydraulic Belt On-Site	Hydraulic Geotube Off-Site	Hydraulic Geotube On-Site	Mechanical Stabilization Off-Site	Mechanical Stabilization On-Site	Mechanical Hydraulic/Belt Off-Site	Mechanical Hydraulic/Belt On-Site	Mechanical Hydraulic/Geotube Off-Site	Mechanical Hydraulic/Geotube On-Site	Mechanical PFTM On-Site	Mechanical Barge Off-Site
Work Plans and Submittals	$ 130,429	$ 130,429	$ 112,914	$ 112,914	$ 108,508	$ 108,508	$ 120,621	$ 120,621	$ 108,257	$ 108,257	$ 75,638	$ 75,288
Mobilization	$ 7,064,300	$ 7,064,300	$ 4,975,753	$ 4,975,753	$ 3,502,081	$ 3,502,081	$ 3,743,658	$ 3,743,658	$ 2,564,219	$ 2,564,219	$ 2,527,270	$ 2,520,456
North Processing Area	$ 1,431,632	$ 1,431,632	$ 1,431,632	$ 1,431,632	$ -	$ -	$ 1,431,632	$ 1,431,632	$ 1,431,632	$ 1,431,632	$ -	$ 1,431,632
South Processing Area	$ 2,400,704	$ 2,400,704	$ 2,400,704	$ 2,400,704	$ 2,400,704	$ 2,400,704	$ 2,400,704	$ 2,400,704	$ 2,400,704	$ 2,400,704	$ 2,400,704	$ -
Temporary Access Road on Causeway	$ -	$ -	$ -	$ -	$ 129,807	$ 129,807	$ -	$ -	$ -	$ -	$ -	$ -
Surveys	$ 356,819	$ 356,819	$ 356,819	$ 356,819	$ 356,819	$ 356,819	$ 356,819	$ 356,819	$ 356,819	$ 356,819	$ 356,819	$ 356,819
Environmental Protection and Monitoring	$ 847,626	$ 847,626	$ 847,626	$ 847,626	$ 847,626	$ 847,626	$ 847,626	$ 847,626	$ 847,626	$ 847,626	$ 847,626	$ 847,626
Debris Removal	$ 212,237	$ 212,237	$ 212,237	$ 212,237	$ 212,237	$ 212,237	$ 212,237	$ 212,237	$ 212,237	$ 212,237	$ 212,237	$ 212,237
Dredging - Mechanical	$ -	$ -	$ -	$ -	$ 9,297,799	$ 9,297,799	$ -	$ -	$ -	$ -	$ 9,297,799	$ 9,297,799
Dredging - Mechanical - Hybrid	$ -	$ -	$ -	$ -	$ -	$ -	$ 8,841,713	$ 8,841,713	$ 8,841,713	$ 8,841,713	$ -	$ -
Dredging and Offloading - Hydraulic	$ 14,840,290	$ 14,840,290	$ 14,840,290	$ 14,840,290	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Offloading - Mechanical	$ -	$ -	$ -	$ -	$ 4,337,471	$ 4,337,471	$ -	$ -	$ -	$ -	$ -	$ -
Offloading - Hydraulic - Hybrid	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,623,085	$ 2,623,085	$ 2,623,085	$ 2,623,085	$ -	$ -
Offloading and Processing - Mechanical/PFTM	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 13,027,314	$ -
Processing	$ 10,034,681	$ 10,034,681	$ 5,668,433	$ 5,668,433	$ 4,152,228	$ 4,152,228	$ 7,083,447	$ 7,083,447	$ 4,889,062	$ 4,889,062	$ -	$ -
Backfill Material Procurement and Delivery	$ 5,145,149	$ 5,145,149	$ 5,145,149	$ 5,145,149	$ 4,490,955	$ 4,490,955	$ 4,490,955	$ 4,490,955	$ 4,490,955	$ 4,490,955	$ 4,490,955	$ 4,490,955
Backfill Material Loading - Mechanical - Crane	$ -	$ -	$ -	$ -	$ 2,472,749	$ 2,472,749	$ -	$ -	$ -	$ -	$ -	$ -
Backfill Material Loading - Mechanical - Telebelt	$ 1,724,439	$ 1,724,439	$ 1,724,439	$ 1,724,439	$ -	$ -	$ 1,724,439	$ 1,724,439	$ 1,724,439	$ 1,724,439	$ 1,724,439	$ 1,724,439
Backfill Material Placement - Mechanical	$ -	$ -	$ -	$ -	$ 5,300,582	$ 5,300,582	$ -	$ -	$ -	$ -	$ 5,300,582	$ 5,300,582
Backfill Material Placement - Mechanical - Hybrid	$ -	$ -	$ -	$ -	$ -	$ -	$ 5,300,582	$ 5,300,582	$ 5,300,582	$ 5,300,582	$ -	$ -
Backfill Material Placement - Mechanical - Hydraulic	$ 6,072,713	$ 6,072,713	$ 6,072,713	$ 6,072,713	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Onsite Non-TSCA Disposal	$ -	$ 691,544	$ -	$ 691,544	$ -	$ 671,779	$ -	$ 633,754	$ -	$ 633,754	$ 671,779	$ -
Offsite TSCA Disposal - Truck	$ 468,489	$ 468,489	$ 468,489	$ 468,489	$ 306,792	$ 306,792	$ 289,426	$ 289,426	$ 289,426	$ 289,426	$ -	$ -
Offsite RCRA Disposal - Truck	$ 1,980,790	$ 1,980,790	$ 1,980,790	$ 1,980,790	$ 1,920,531	$ 1,920,531	$ 1,811,822	$ 1,811,822	$ 1,811,822	$ 1,811,822	$ -	$ -
Offsite Non-TSCA Disposal - Barge	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 30,477,187
Offsite TSCA Disposal - Barge	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 366,306	$ 366,306
Offsite RCRA Disposal - Barge	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,888,701	$ 1,888,701
Offsite Non-TSCA Disposal - Truck	$ 30,329,155	$ -	$ 30,329,155	$ -	$ 29,462,309	$ -	$ 27,794,632	$ -	$ 27,794,632	$ -	$ -	$ -
Water Treatment	$ 2,697,116	$ 2,697,116	$ 2,697,116	$ 2,697,116	$ 428,408	$ 428,408	$ 2,697,116	$ 2,697,116	$ 2,697,116	$ 2,697,116	$ 428,408	$ 428,408
Site Restoration	$ 1,078,452	$ 1,078,452	$ 1,078,452	$ 1,078,452	$ 1,078,452	$ 1,078,452	$ 1,078,452	$ 1,078,452	$ 1,078,452	$ 1,078,452	$ 1,078,452	$ 1,078,452
Demobilization	$ 7,064,300	$ 7,064,300	$ 4,975,753	$ 4,975,753	$ 3,502,081	$ 3,502,081	$ 3,743,658	$ 3,743,658	$ 2,564,219	$ 2,564,219	$ 2,527,270	$ 2,520,456
Subtotal Tidal Flats	***$ 93,879,322***	***$ 64,241,710***	***$ 85,318,463***	***$ 55,680,852***	***$ 74,308,137***	***$ 45,517,607***	***$ 76,592,622***	***$ 49,431,744***	***$ 72,026,995***	***$ 44,866,118***	***$ 47,222,298***	***$ 63,017,341***
Outfall - 008												
Work Plans and Submittals	$ 6,879	$ 8,611	$ 6,879	$ 8,611	$ 6,879	$ 8,611	$ 6,879	$ 8,611	$ 6,879	$ 8,611	$ 8,611	$ 8,611
Mobilization	$ 35,374	$ 42,972	$ 35,374	$ 42,972	$ 35,374	$ 42,972	$ 35,374	$ 42,972	$ 35,374	$ 42,972	$ 42,972	$ 42,972
Temporary Construction and Access Roads	$ 154,092	$ 154,092	$ 154,092	$ 154,092	$ 154,092	$ 154,092	$ 154,092	$ 154,092	$ 154,092	$ 154,092	$ 154,092	$ 154,092
Surveys	$ 48,608	$ 48,608	$ 48,608	$ 48,608	$ 48,608	$ 48,608	$ 48,608	$ 48,608	$ 48,608	$ 48,608	$ 48,608	$ 48,608
Debris Removal	$ 15,409	$ 15,409	$ 15,409	$ 15,409	$ 15,409	$ 15,409	$ 15,409	$ 15,409	$ 15,409	$ 15,409	$ 15,409	$ 15,409
Sheet Pile Installation for Water Diversion	$ 1,975,050	$ 1,975,050	$ 1,975,050	$ 1,975,050	$ 1,975,050	$ 1,975,050	$ 1,975,050	$ 1,975,050	$ 1,975,050	$ 1,975,050	$ 1,975,050	$ 1,975,050
Excavation	$ 432,740	$ 432,740	$ 432,740	$ 432,740	$ 432,740	$ 432,740	$ 432,740	$ 432,740	$ 432,740	$ 432,740	$ 432,740	$ 432,740
Processing	$ 341,679	$ 341,679	$ 341,679	$ 341,679	$ 341,679	$ 341,679	$ 341,679	$ 341,679	$ 341,679	$ 341,679	$ 341,679	$ 341,679
Backfill Material Procurement and Delivery	$ 185,344	$ 185,344	$ 185,344	$ 185,344	$ 185,344	$ 185,344	$ 185,344	$ 185,344	$ 185,344	$ 185,344	$ 185,344	$ 185,344
Backfill	$ 382,790	$ 382,790	$ 382,790	$ 382,790	$ 382,790	$ 382,790	$ 382,790	$ 382,790	$ 382,790	$ 382,790	$ 382,790	$ 382,790
Onsite Non-TSCA Disposal	$ -	$ 338,067	$ -	$ 338,067	$ -	$ 338,067	$ -	$ 338,067	$ -	$ 338,067	$ 338,067	$ 338,067
Offsite Non-TSCA Disposal - Truck	$ 1,017,311	$ -	$ 1,017,311	$ -	$ 1,017,311	$ -	$ 1,017,311	$ -	$ 1,017,311	$ -	$ -	$ -
Offsite RCRA Disposal - Truck	$ 296,213	$ 296,213	$ 296,213	$ 296,213	$ 296,213	$ 296,213	$ 296,213	$ 296,213	$ 296,213	$ 296,213	$ 296,213	$ 296,213
Water Treatment	$ 428,408	$ 428,408	$ 428,408	$ 428,408	$ 428,408	$ 428,408	$ 428,408	$ 428,408	$ 428,408	$ 428,408	$ 428,408	$ 428,408
Site Restoration	$ 318,292	$ 318,292	$ 318,292	$ 318,292	$ 318,292	$ 318,292	$ 318,292	$ 318,292	$ 318,292	$ 318,292	$ 318,292	$ 318,292
Demobilization	$ 35,374	$ 42,972	$ 35,374	$ 42,972	$ 35,374	$ 42,972	$ 35,374	$ 42,972	$ 35,374	$ 42,972	$ 42,972	$ 42,972
Subtotal Outfall 008	***$ 5,673,563***	***$ 5,011,248***	***$ 5,673,563***	***$ 5,011,248***	***$ 5,673,563***	***$ 5,011,248***	***$ 5,673,563***	***$ 5,011,248***	***$ 5,673,563***	***$ 5,011,248***	***$ 5,011,248***	***$ 5,011,248***
Total Costs												
Subtotal	$ 99,552,885	$ 69,252,958	$ 90,992,026	$ 60,692,099	$ 79,981,700	$ 50,528,855	$ 82,266,185	$ 54,442,992	$ 77,700,559	$ 49,877,365	$ 52,233,546	$ 68,028,589
20% Contingency	$ 13,844,746	$ 13,850,592	$ 12,132,574	$ 12,138,420	$ 10,103,878	$ 10,105,771	$ 10,894,311	$ 10,888,598	$ 9,981,185	$ 9,975,473	$ 10,446,709	$ 7,510,280
Total with Contingency	$ 113,397,631	$ 83,103,550	$ 103,124,600	$ 72,830,519	$ 90,085,579	$ 60,634,626	$ 93,160,495	$ 65,331,590	$ 87,681,744	$ 59,852,838	$ 62,680,255	$ 75,538,869
Pre-Design Investigation	$ 200,000	$ 200,000	$ 200,000	$ 200,000	$ 200,000	$ 200,000	$ 200,000	$ 200,000	$ 200,000	$ 200,000	$ 200,000	$ 200,000
Project Management (5%)	$ 4,153,424	$ 4,155,177	$ 3,639,772	$ 3,641,526	$ 3,031,163	$ 3,031,731	$ 3,268,293	$ 3,266,579	$ 2,994,356	$ 2,992,642	$ 3,134,013	$ 2,253,084
Remedial Design (5%)	$ 4,153,424	$ 4,155,177	$ 3,639,772	$ 3,641,526	$ 3,031,163	$ 3,031,731	$ 3,268,293	$ 3,266,579	$ 2,994,356	$ 2,992,642	$ 3,134,013	$ 2,253,084
Construction Management (6%)	$ 4,984,109	$ 4,986,213	$ 4,367,727	$ 4,369,831	$ 3,637,396	$ 3,638,078	$ 3,921,952	$ 3,919,895	$ 3,593,227	$ 3,591,170	$ 3,760,815	$ 2,703,701
Total	$ 126,888,587	$ 96,600,118	$ 114,971,871	$ 84,683,402	$ 99,985,302	$ 70,536,166	$ 103,819,034	$ 75,984,644	$ 97,463,682	$ 69,629,293	$ 72,909,096	$ 82,948,738
Annual Inspection (Years 1-5)	$ 25,000	$ 25,000	$ 25,000	$ 25,000	$ 25,000	$ 25,000	$ 25,000	$ 25,000	$ 25,000	$ 25,000	$ 25,000	$ 25,000
Escalation to 2022	$ 15,921,413	$ 12,119,882	$ 14,428,129	$ 10,626,598	$ 12,544,698	$ 8,853,834	$ 13,030,966	$ 9,535,356	$ 12,236,318	$ 8,740,707	$ 9,150,904	$ 10,411,262
Total with Escalation (Capital Cost - 2022)	**$ 142,810,000**	**$ 108,720,000**	**$ 129,400,000**	**$ 95,310,000**	**$ 112,530,000**	**$ 79,390,000**	**$ 116,850,000**	**$ 85,520,000**	**$ 109,700,000**	**$ 78,370,000**	**$ 82,060,000**	**$ 93,360,000**
Total Cost with Escalation -30%	$ 99,967,000	$ 76,104,000	$ 90,580,000	$ 66,717,000	$ 78,771,000	$ 55,573,000	$ 81,795,000	$ 59,864,000	$ 76,790,000	$ 54,859,000	$ 57,442,000	$ 65,352,000
Total Cost with Escalation +50%	$ 214,215,000	$ 163,080,000	$ 194,100,000	$ 142,965,000	$ 168,795,000	$ 119,085,000	$ 175,275,000	$ 128,280,000	$ 164,550,000	$ 117,555,000	$ 123,090,000	$ 140,040,000

Notes: See Alternative Summary's Attached

Amec Foster Wheeler, Inc. 271 Mill Road Chelmsford, MA 01942	Project: Stratford Army Engine Plant Date: 10/26/2018 Calc. By JR Checked By: TD

ALTERNATIVE 2 - HYDRAULIC DREDGE WITH BELT FILTER PRESS AND OFF-SITE DISPOSAL

Description	Units of Meas.	Quantity on Proposal	Unit Price (Includes Taxes, OH, Profit)	Total Cost
Performance and Payment Bond				
Work Plans and Submittals (Assumed 1% of Total Labor)	LS	1	$130,429	**$140,000**
Mobilization (Assumed 10% of Total Equipment)	LS	1	$7,064,300	**$7,070,000**
Temporary Construction (North Processing Area)	LS	1	$1,431,632	**$1,440,000**
Temporary Construction (South Processing Area)	LS	1	$2,400,704	**$2,410,000**
Conditions Surveys	LS	1	$2,313	**$3,000**
Topographic Surveys	LS	1	$49,961	**$50,000**
Hydrographic Surveys	LS	1	$176,122	**$180,000**
Utilities Surveys	LS	1	$75,468	**$76,000**
Debris Surveys	LS	1	$52,954	**$53,000**
Environmental Protection	LS	1	$479,272	**$480,000**
Environmental Monitoring	LS	1	$368,354	**$370,000**
Debris Removal	CY	3,487	$61	**$220,000**
Dredging and Offloading - Hydraulic	CY	170,281	$87	**$14,850,000**
Processing - Hydraulic - Belt Press	CY	170,281	$59	**$10,040,000**
Backfill Material Procurement and Delivery - Hydraulic (Alt 2)	CY	127,240	$40	**$5,150,000**
Backfill Material Loading - Mechanical - Telebelt	CY	111,062	$16	**$1,730,000**
Backfill Material Placement - Mechanical (Alt 2)	CY	127,240	$48	**$6,080,000**
Characterize, Transport, and Dispose TSCA (>=50 PPM) wo/PC - Hydraulic	Ton	2,078	$225	**$470,000**
Characterize, Transport, and Dispose RCRA (>=1 to <50 PPM) wo/PC - Hydraulic	Ton	13,966	$141.83	**$1,990,000**
Characterize, Transport, and Dispose Non-TSCA (<1 PPM) wo/PC - Hydraulic	Ton	213,836	$141.83	**$30,330,000**
Water Treatment - Hydraulic Transport	LS	1	$2,697,116	**$2,700,000**
Site Restoration	LS	1	$1,078,452	**$1,080,000**
Demobilization (Assumed 10% of Total Equipment)	LS	1	$7,064,300	**$7,070,000**
		TOTALS	**$23,072,198**	**$93,980,000**

Amec Foster Wheeler, Inc. 271 Mill Road Chelmsford, MA 01942	Project: Stratford Army Engine Plant Date: 10/26/2018 Calc. By JR Checked By: TD

ALTERNATIVE 2 - HYDRAULIC DREDGE WITH BELT FILTER PRESS AND ON-SITE BENEFICIAL REUSE

Description	Units of Meas.	Quantity	Unit Price (Includes Taxes, OH, Profit)	Total Cost
Work Plans and Submittals (Assumed 1% of Total Labor)	LS	1	$ 130,429	$ 140,000
Mobilization (Assumed 10% of Total Equipment)	LS	1	$ 7,064,300	$ 7,070,000
Temporary Construction (North Processing Area)	LS	1	$ 1,431,632	$ 1,440,000
Temporary Construction (South Processing Area)	LS	1	$ 2,400,704	$ 2,410,000
Conditions Surveys	LS	1	$ 2,313	$ 3,000
Topographic Surveys	LS	1	$ 49,961	$ 50,000
Hydrographic Surveys	LS	1	$ 176,122	$ 180,000
Utilities Surveys	LS	1	$ 75,468	$ 76,000
Debris Surveys	LS	1	$ 52,954	$ 53,000
Environmental Protection	LS	1	$ 479,272	$ 480,000
Environmental Monitoring	LS	1	$ 368,354	$ 370,000
Debris Removal	CY	3,487	$ 61	$ 220,000
Dredging and Offloading - Hydraulic	CY	170,281	$ 87	$ 14,850,000
Processing - Hydraulic - Belt Press	CY	170,281	$ 59	$ 10,040,000
Backfill Material Procurement and Delivery - Hydraulic (Alt 2)	CY	127,240	$ 40	$ 5,150,000
Backfill Material Loading - Mechanical - Telebelt	CY	111,062	$ 16	$ 1,730,000
Backfill Material Placement - Mechanical (Alt 2)	CY	127,240	$ 48	$ 6,080,000
Characterize and Handle for Onsite Disposal wo/PC - Hydraulic	Ton	213,836	$ 3	$ 700,000
Characterize, Transport, and Dispose TSCA (>=50 PPM) wo/PC - Hydraulic	Ton	2,078	$ 225	$ 470,000
Characterize, Transport, and Dispose RCRA (>=1 to <50 PPM) wo/PC - Hydraulic	Ton	13,966	$ 142	$ 1,990,000
Water Treatment - Hydraulic Transport	LS	1	$ 2,697,116	$ 2,700,000
Site Restoration	LS	1	$ 1,078,452	$ 1,080,000
Demobilization (Assumed 10% of Total Equipment)	LS	1	$ 7,064,300	$ 7,070,000
			TOTAL	**$ 64,350,000**

Amec Foster Wheeler, Inc. 271 Mill Road Chelmsford, MA 01942	Project: Stratford Army Engine Plant Date: 10/26/2018 Calc. By JR Checked By: TD

ALTERNATIVE 2 - HYDRAULIC DREDGE WITH GEOTUBES AND OFF-SITE DISPOSAL

Description	Units of Meas.	Quantity	Unit Price (Includes Taxes, OH, Profit)	Total Cost
Work Plans and Submittals (Assumed 1% of Total Labor)	LS	1	$ 112,914	$ 120,000
Mobilization (Assumed 10% of Total Equipment)	LS	1	$ 4,975,753	$ 4,980,000
Temporary Construction (North Processing Area)	LS	1	$ 1,431,632	$ 1,440,000
Temporary Construction (South Processing Area)	LS	1	$ 2,400,704	$ 2,410,000
Conditions Surveys	LS	1	$ 2,313	$ 3,000
Topographic Surveys	LS	1	$ 49,961	$ 50,000
Hydrographic Surveys	LS	1	$ 176,122	$ 180,000
Utilities Surveys	LS	1	$ 75,468	$ 76,000
Debris Surveys	LS	1	$ 52,954	$ 53,000
Environmental Protection	LS	1	$ 479,272	$ 480,000
Environmental Monitoring	LS	1	$ 368,354	$ 370,000
Debris Removal	CY	3,487	$ 61	$ 220,000
Dredging and Offloading - Hydraulic	CY	170,281	$ 87	$ 14,850,000
Processing - Hydraulic - Geotube	CY	170,281	$ 33	$ 5,670,000
Backfill Material Procurement and Delivery - Hydraulic (Alt 2)	CY	127,240	$ 40	$ 5,150,000
Backfill Material Loading - Mechanical - Telebelt	CY	111,062	$ 16	$ 1,730,000
Backfill Material Placement - Mechanical (Alt 2)	CY	127,240	$ 48	$ 6,080,000
Characterize, Transport, and Dispose TSCA (>=50 PPM) wo/PC - Hydraulic	Ton	2,078	$ 225	$ 470,000
Characterize, Transport, and Dispose RCRA (>=1 to <50 PPM) wo/PC - Hydraulic	Ton	13,966	$ 142	$ 1,990,000
Characterize, Transport, and Dispose Non-TSCA (<1 PPM) wo/PC - Mechcnical	Ton	213,836	$ 142	$ 30,330,000
Water Treatment - Hydraulic Transport	LS	1	$ 2,697,116	$ 2,700,000
Site Restoration	LS	1	$ 1,078,452	$ 1,080,000
Demobilization (Assumed 10% of Total Equipment)	LS	1	$ 4,975,753	$ 4,980,000
			TOTAL	**$ 85,410,000**

Amec Foster Wheeler, Inc. 271 Mill Road Chelmsford, MA 01942	Project: Stratford Army Engine Plant Date: 10/26/2018 Calc. By JR Checked By: TD

ALTERNATIVE 2 - HYDRAULIC DREDGE WITH GEOTUBES AND ON-SITE BENEFICIAL REUSE

Description	Units of Meas.	Quantity	Unit Price (Includes Taxes, OH, Profit)	Total Cost
Work Plans and Submittals (Assumed 1% of Total Labor)	LS	1	$ 112,914	$ 120,000
Mobilization (Assumed 10% of Total Equipment)	LS	1	$ 4,975,753	$ 4,980,000
Temporary Construction (North Processing Area)	LS	1	$ 1,431,632	$ 1,440,000
Temporary Construction (South Processing Area)	LS	1	$ 2,400,704	$ 2,410,000
Conditions Surveys	LS	1	$ 2,313	$ 3,000
Topographic Surveys	LS	1	$ 49,961	$ 50,000
Hydrographic Surveys	LS	1	$ 176,122	$ 180,000
Utilities Surveys	LS	1	$ 75,468	$ 76,000
Debris Surveys	LS	1	$ 52,954	$ 53,000
Environmental Protection	LS	1	$ 479,272	$ 480,000
Environmental Monitoring	LS	1	$ 368,354	$ 370,000
Debris Removal	CY	3,487	$ 61	$ 220,000
Dredging and Offloading - Hydraulic	CY	170,281	$ 87	$ 14,850,000
Processing - Hydraulic - Geotube	CY	170,281	$ 33	$ 5,670,000
Backfill Material Procurement and Delivery - Hydraulic (Alt 2)	CY	127,240	$ 40	$ 5,150,000
Backfill Material Loading - Mechanical - Telebelt	CY	111,062	$ 16	$ 1,730,000
Backfill Material Placement - Mechanical (Alt 2)	CY	127,240	$ 48	$ 6,080,000
Characterize and Handle for Onsite Disposal wo/PC - Hydraulic	Ton	213,836	$ 3	$ 700,000
Characterize, Transport, and Dispose TSCA (>=50 PPM) wo/PC - Hydraulic	Ton	2,078	$ 225	$ 470,000
Characterize, Transport, and Dispose RCRA (>=1 to <50 PPM) wo/PC - Hydraulic	Ton	13,966	$ 142	$ 1,990,000
Water Treatment - Hydraulic Transport	LS	1	$ 2,697,116	$ 2,700,000
Site Restoration	LS	1	$ 1,078,452	$ 1,080,000
Demobilization (Assumed 10% of Total Equipment)	LS	1	$ 4,975,753	$ 4,980,000
			TOTAL	**$ 55,780,000**

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ALTERNATIVE 3 - MECHANICAL DREDGE WITH STABILIZATION AND OFF-SITE DISPOSAL

Description	Units of Meas.	Quantity	Unit Price (Includes Taxes, OH, Profit)	Total Cost
Work Plans and Submittals (Assumed 1% of Total Labor)	LS	1	$ 108,508	$ 110,000
Mobilization (Assumed 10% of Total Equipment)	LS	1	$ 3,502,081	$ 3,510,000
Temporary Construction (South Processing Area)	LS	1	$ 2,400,704	$ 2,410,000
Temporary Construction (Causeway Access Road)	LS	1	$ 129,807	$ 130,000
Conditions Surveys	LS	1	$ 2,313	$ 3,000
Topographic Surveys	LS	1	$ 49,961	$ 50,000
Hydrographic Surveys	LS	1	$ 176,122	$ 180,000
Utilities Surveys	LS	1	$ 75,468	$ 76,000
Debris Surveys	LS	1	$ 52,954	$ 53,000
Environmental Protection	LS	1	$ 479,272	$ 480,000
Environmental Monitoring	LS	1	$ 368,354	$ 370,000
Debris Removal	CY	3,487	$ 61	$ 220,000
Dredging - Mechanical	CY	155,573	$ 60	$ 9,300,000
Offloading - Mechanical (Crane)	CY	155,573	$ 28	$ 4,340,000
Processing - Stabilization/Solidification	CY	155,573	$ 27	$ 4,160,000
Backfill Material Procurement and Delivery - Mechanical	CY	111,062	$ 40	$ 4,500,000
Backfill Material Loading - Mechanical - Crane (Alt 3)	CY	111,062	$ 22	$ 2,480,000
Backfill Material Placement - Mechanical	CY	111,062	$ 48	$ 5,310,000
Characterize, Transport, and Dispose TSCA (>=50 PPM) w/PC	Ton	1,361	$ 225	$ 310,000
Characterize, Transport, and Dispose RCRA (>=1 to <50 PPM) w/PC	Ton	13,541	$ 142	$ 1,930,000
Characterize, Transport, and Dispose Non-TSCA (<1 PPM) w/PC	Ton	207,724	$ 142	$ 29,470,000
Water Treatment - Mechanically Dredged	LS	1	$ 428,408	$ 430,000
Site Restoration	LS	1	$ 1,078,452	$ 1,080,000
Demobilization (Assumed 10% of Total Equipment)	LS	1	$ 3,502,081	$ 3,510,000
			TOTAL	**$ 74,410,000**

Amec Foster Wheeler, Inc. 271 Mill Road Chelmsford, MA 01942	Project: Stratford Army Engine Plant Date: 10/26/2018 Calc. By JR Checked By: TD

ALTERNATIVE 3 - MECHANICAL DREDGE WITH STABILIZATION AND ON-SITE BENEFICIAL REUSE

Description	Units of Meas.	Quantity	Unit Price (Includes Taxes, OH, Profit)	Total Cost
Work Plans and Submittals (Assumed 1% of Total Labor)	LS	1	$ 108,508	$ 110,000
Mobilization (Assumed 10% of Total Equipment)	LS	1	$ 3,502,081	$ 3,510,000
Temporary Construction (South Processing Area)	LS	1	$ 2,400,704	$ 2,410,000
Temporary Construction (Causeway Access Road)	LS	1	$ 129,807	$ 130,000
Conditions Surveys	LS	1	$ 2,313	$ 3,000
Topographic Surveys	LS	1	$ 49,961	$ 50,000
Hydrographic Surveys	LS	1	$ 176,122	$ 180,000
Utilities Surveys	LS	1	$ 75,468	$ 76,000
Debris Surveys	LS	1	$ 52,954	$ 53,000
Environmental Protection	LS	1	$ 479,272	$ 480,000
Environmental Monitoring	LS	1	$ 368,354	$ 370,000
Debris Removal	CY	3,487	$ 61	$ 220,000
Dredging - Mechanical	CY	155,573	$ 60	$ 9,300,000
Offloading - Mechanical (Crane)	CY	155,573	$ 28	$ 4,340,000
Processing - Stabilization/Solidification	CY	155,573	$ 27	$ 4,160,000
Backfill Material Procurement and Delivery - Mechanical	CY	111,062	$ 40	$ 4,500,000
Backfill Material Loading - Mechanical - Crane (Alt 3)	CY	111,062	$ 22	$ 2,480,000
Backfill Material Placement - Mechanical	CY	111,062	$ 48	$ 5,310,000
Characterize and Handle for Onsite Disposal w/PC	Ton	207,724	$ 3	$ 680,000
Characterize, Transport, and Dispose TSCA (>=50 PPM) w/PC	Ton	1,361	$ 225	$ 310,000
Characterize, Transport, and Dispose RCRA (>=1 to <50 PPM) w/PC	Ton	13,541	$ 142	$ 1,930,000
Water Treatment - Mechanically Dredged	LS	1	$ 428,408	$ 430,000
Site Restoration	LS	1	$ 1,078,452	$ 1,080,000
Demobilization (Assumed 10% of Total Equipment)	LS	1	$ 3,502,081	$ 3,510,000
			TOTAL	**$ 45,620,000**

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ALTERNATIVE 4 - MECHANICAL DREDGE WITH HYDRAULIC TRANSPORT, BELT FILTER PRESS AND OFF-SITE DISPOSAL

Description	Units of Meas.	Quantity	Unit Price (Includes Taxes, OH, Profit)	Total Cost
Work Plans and Submittals (Assumed 1% of Total Labor)	LS	1	$ 120,621	$ 130,000
Mobilization (Assumed 10% of Total Equipment)	LS	1	$ 3,743,658	$ 3,750,000
Temporary Construction (North Processing Area)	LS	1	$ 1,431,632	$ 1,440,000
Temporary Construction (South Processing Area)	LS	1	$ 2,400,704	$ 2,410,000
Conditions Surveys	LS	1	$ 2,313	$ 3,000
Topographic Surveys	LS	1	$ 49,961	$ 50,000
Hydrographic Surveys	LS	1	$ 176,122	$ 180,000
Utilities Surveys	LS	1	$ 75,468	$ 76,000
Debris Surveys	LS	1	$ 52,954	$ 53,000
Environmental Protection	LS	1	$ 479,272	$ 480,000
Environmental Monitoring	LS	1	$ 368,354	$ 370,000
Debris Removal	CY	3,487	$ 61	$ 220,000
Dredging - Mechanical - Hybrid	CY	155,573	$ 57	$ 8,850,000
Offloading - Hydraulic - Hybrid	CY	155,573	$ 17	$ 2,630,000
Processing - Hybrid - Belt Press	CY	155,573	$ 46	$ 7,090,000
Backfill Material Procurement and Delivery - Mechanical	CY	111,062	$ 40	$ 4,500,000
Backfill Material Loading - Mechanical - Telebelt	CY	111,062	$ 16	$ 1,730,000
Backfill Material Placement - Hybrid	CY	111,062	$ 48	$ 5,310,000
Characterize, Transport, and Dispose TSCA (>=50 PPM) wo/PC - Mechanical (Alt 4)	Ton	1,284	$ 225	$ 290,000
Characterize, Transport, and Dispose RCRA wo/PC - Mechanical (Alt 4)	Ton	12,774	$ 142	$ 1,820,000
Characterize, Transport, and Dispose Non-TSCA (<1 PPM) wo/PC - Mechcnical	Ton	195,966	$ 142	$ 27,800,000
Water Treatment - Hydraulic Transport	LS	1	$ 2,697,116	$ 2,700,000
Site Restoration	LS	1	$ 1,078,452	$ 1,080,000
Demobilization (Assumed 10% of Total Equipment)	LS	1	$ 3,743,658	$ 3,750,000
			TOTAL	**$ 76,710,000**

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ALTERNATIVE 4 - MECHANICAL DREDGE WITH HYDRAULIC TRANSPORT, BELT FILTER PRESS AND ON-SITE BENEFICIAL REUSE

Description	Units of Meas.	Quantity	Unit Price (Includes Taxes, OH, Profit)	Total Cost
Work Plans and Submittals (Assumed 1% of Total Labor)	LS	1	$ 120,621	$ 130,000
Mobilization (Assumed 10% of Total Equipment)	LS	1	$ 3,743,658	$ 3,750,000
Temporary Construction (North Processing Area)	LS	1	$ 1,431,632	$ 1,440,000
Temporary Construction (South Processing Area)	LS	1	$ 2,400,704	$ 2,410,000
Conditions Surveys	LS	1	$ 2,313	$ 3,000
Topographic Surveys	LS	1	$ 49,961	$ 50,000
Hydrographic Surveys	LS	1	$ 176,122	$ 180,000
Utilities Surveys	LS	1	$ 75,468	$ 76,000
Debris Surveys	LS	1	$ 52,954	$ 53,000
Environmental Protection	LS	1	$ 479,272	$ 480,000
Environmental Monitoring	LS	1	$ 368,354	$ 370,000
Debris Removal	CY	3,487	$ 61	$ 220,000
Dredging - Mechanical - Hybrid	CY	155,573	$ 57	$ 8,850,000
Offloading - Hydraulic - Hybrid	CY	155,573	$ 17	$ 2,630,000
Processing - Hybrid - Belt Press	CY	155,573	$ 46	$ 7,090,000
Backfill Material Procurement and Delivery - Mechanical	CY	111,062	$ 40	$ 4,500,000
Backfill Material Loading - Mechanical - Telebelt	CY	111,062	$ 16	$ 1,730,000
Backfill Material Placement - Hybrid	CY	111,062	$ 48	$ 5,310,000
Characterize and Handle for Onsite Disposal wo/PC - Mechancial (Alt 4)	Ton	195,966	$ 3	$ 640,000
Characterize, Transport, and Dispose TSCA (>=50 PPM) wo/PC - Mechanical (Alt 4)	Ton	1,284	$ 225	$ 290,000
Characterize, Transport, and Dispose RCRA wo/PC - Mechanical (Alt 4)	Ton	12,774	$ 142	$ 1,820,000
Water Treatment - Hydraulic Transport	LS	1	$ 2,697,116	$ 2,700,000
Site Restoration	LS	1	$ 1,078,452	$ 1,080,000
Demobilization (Assumed 10% of Total Equipment)	LS	1	$ 3,743,658	$ 3,750,000
			TOTAL	**$ 49,550,000**

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ALTERNATIVE 4 - MECHANICAL DREDGE WITH HYDRAULIC TRANSPORT, GEOTUBE AND OFF-SITE DISPOSAL

Description	Units of Meas.	Quantity	Unit Price (Includes Taxes, OH, Profit)	Total Cost
Work Plans and Submittals (Assumed 1% of Total Labor)	LS	1	$ 108,257	$ 110,000
Mobilization (Assumed 10% of Total Equipment)	LS	1	$ 2,564,219	$ 2,570,000
Temporary Construction (North Processing Area)	LS	1	$ 1,431,632	$ 1,440,000
Temporary Construction (South Processing Area)	LS	1	$ 2,400,704	$ 2,410,000
Conditions Surveys	LS	1	$ 2,313	$ 3,000
Topographic Surveys	LS	1	$ 49,961	$ 50,000
Hydrographic Surveys	LS	1	$ 176,122	$ 180,000
Utilities Surveys	LS	1	$ 75,468	$ 76,000
Debris Surveys	LS	1	$ 52,954	$ 53,000
Environmental Protection	LS	1	$ 479,272	$ 480,000
Environmental Monitoring	LS	1	$ 368,354	$ 370,000
Debris Removal	CY	3,487	$ 61	$ 220,000
Dredging - Mechanical - Hybrid	CY	155,573	$ 57	$ 8,850,000
Offloading - Hydraulic - Hybrid	CY	155,573	$ 17	$ 2,630,000
Processing - Hybrid - Geotube	CY	155,573	$ 31	$ 4,890,000
Backfill Material Procurement and Delivery - Mechanical	CY	111,062	$ 40	$ 4,500,000
Backfill Material Loading - Mechanical - Telebelt	CY	111,062	$ 16	$ 1,730,000
Backfill Material Placement - Hybrid	CY	111,062	$ 48	$ 5,310,000
Characterize, Transport, and Dispose TSCA (>=50 PPM) wo/PC - Mechanical (Alt 4)	Ton	1,284	$ 225	$ 290,000
Characterize, Transport, and Dispose RCRA wo/PC - Mechanical (Alt 4)	Ton	12,774	$ 142	$ 1,820,000
Characterize, Transport, and Dispose Non-TSCA (<1 PPM) wo/PC - Mechcnical	Ton	195,966	$ 142	$ 27,800,000
Water Treatment - Hydraulic Transport	LS	1	$ 2,697,116	$ 2,700,000
Site Restoration	LS	1	$ 1,078,452	$ 1,080,000
Demobilization (Assumed 10% of Total Equipment)	LS	1	$ 2,564,219	$ 2,570,000
			TOTAL	**$ 72,130,000**

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ALTERNATIVE 4 - MECHANICAL DREDGE WITH HYDRAULIC TRANSPORT, BELT FILTER PRESS AND ON-SITE BENEFICIAL REUSE

Description	Units of Meas.	Quantity	Unit Price (Includes Taxes, OH, Profit)	Total Cost
Work Plans and Submittals (Assumed 1% of Total Labor)	LS	1	$ 108,257	$ 110,000
Mobilization (Assumed 10% of Total Equipment)	LS	1	$ 2,564,219	$ 2,570,000
Temporary Construction (North Processing Area)	LS	1	$ 1,431,632	$ 1,440,000
Temporary Construction (South Processing Area)	LS	1	$ 2,400,704	$ 2,410,000
Conditions Surveys	LS	1	$ 2,313	$ 3,000
Topographic Surveys	LS	1	$ 49,961	$ 50,000
Hydrographic Surveys	LS	1	$ 176,122	$ 180,000
Utilities Surveys	LS	1	$ 75,468	$ 76,000
Debris Surveys	LS	1	$ 52,954	$ 53,000
Environmental Protection	LS	1	$ 479,272	$ 480,000
Environmental Monitoring	LS	1	$ 368,354	$ 370,000
Debris Removal	CY	3,487	$ 61	$ 220,000
Dredging - Mechanical - Hybrid	CY	155,573	$ 57	$ 8,850,000
Offloading - Hydraulic - Hybrid	CY	155,573	$ 17	$ 2,630,000
Processing - Hybrid - Geotube	CY	155,573	$ 31	$ 4,890,000
Backfill Material Procurement and Delivery - Mechanical	CY	111,062	$ 40	$ 4,500,000
Backfill Material Loading - Mechanical - Telebelt	CY	111,062	$ 16	$ 1,730,000
Backfill Material Placement - Hybrid	CY	111,062	$ 48	$ 5,310,000
Characterize and Handle for Onsite Disposal wo/PC - Mechancial (Alt 4)	Ton	195,966	$ 3	$ 640,000
Characterize, Transport, and Dispose TSCA (>=50 PPM) wo/PC - Mechanical (Alt 4)	Ton	1,284	$ 225	$ 290,000
Characterize, Transport, and Dispose RCRA wo/PC - Mechanical (Alt 4)	Ton	12,774	$ 142	$ 1,820,000
Water Treatment - Hydraulic Transport	LS	1	$ 2,697,116	$ 2,700,000
Site Restoration	LS	1	$ 1,078,452	$ 1,080,000
Demobilization (Assumed 10% of Total Equipment)	LS	1	$ 2,564,219	$ 2,570,000
			TOTAL	**$ 44,970,000**

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ALTERNATIVE 5 - MECHANICAL DREDGE WITH PTFM AND OFF-SITE DISPOSAL

Description	Units of Meas.	Quantity	Unit Price (Includes Taxes, OH, Profit)	Total Cost
Work Plans and Submittals (Assumed 1% of Total Labor)	LS	1	$ 75,638	$ 80,000
Mobilization (Assumed 10% of Total Equipment)	LS	1	$ 2,527,270	$ 2,530,000
Temporary Construction (South Processing Area)	LS	1	$ 2,400,704	$ 2,410,000
Conditions Surveys	LS	1	$ 2,313	$ 3,000
Topographic Surveys	LS	1	$ 49,961	$ 50,000
Hydrographic Surveys	LS	1	$ 176,122	$ 180,000
Utilities Surveys	LS	1	$ 75,468	$ 76,000
Debris Surveys	LS	1	$ 52,954	$ 53,000
Environmental Protection	LS	1	$ 479,272	$ 480,000
Environmental Monitoring	LS	1	$ 368,354	$ 370,000
Debris Removal	CY	3,487	$ 61	$ 220,000
Dredging - Mechanical	CY	155,573	$ 60	$ 9,300,000
Offloading and Processing - Mechanical/PFTM	CY	155,573	$ 84	$ 13,030,000
Backfill Material Procurement and Delivery - Mechanical	CY	111,062	$ 40	$ 4,500,000
Backfill Material Loading - Mechanical - Telebelt	CY	111,062	$ 16	$ 1,730,000
Backfill Material Placement - Mechanical	CY	111,062	$ 48	$ 5,310,000
Characterize and Handle for Onsite Disposal w/PC	Ton	207,724	$ 3	$ 680,000
Characterize and Barge Transport for Offsite TSCA (>=50 PPM) Disposal	Ton	1,284	$ 285	$ 370,000
Characterize and Barge Transport for Offsite RCRA (>=1 to <50 PPM) Disposal	Ton	12,774	$ 148	$ 1,890,000
Water Treatment - Mechanically Dredged	LS	1	$ 428,408	$ 430,000
Site Restoration	LS	1	$ 1,078,452	$ 1,080,000
Demobilization (Assumed 10% of Total Equipment)	LS	1	$ 2,527,270	$ 2,530,000
			TOTAL	**$ 47,300,000**

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ALTERNATIVE 6 - MECHANICAL DREDGE WITH OFF-SITE PROCESSING AND DISPOSAL

Description	Units of Meas.	Quantity	Unit Price (Includes Taxes, OH, Profit)	Total Cost
Work Plans and Submittals (Assumed 1% of Total Labor)	LS	1	$ 75,288	$ 80,000
Mobilization (Assumed 10% of Total Equipment)	LS	1	$ 2,520,456	$ 2,530,000
Temporary Construction (North Processing Area)	LS	1	$ 1,431,632	$ 1,440,000
Conditions Surveys	LS	1	$ 2,313	$ 3,000
Topographic Surveys	LS	1	$ 49,961	$ 50,000
Hydrographic Surveys	LS	1	$ 176,122	$ 180,000
Utilities Surveys	LS	1	$ 75,468	$ 76,000
Debris Surveys	LS	1	$ 52,954	$ 53,000
Environmental Protection	LS	1	$ 479,272	$ 480,000
Environmental Monitoring	LS	1	$ 368,354	$ 370,000
Debris Removal	CY	3,487	$ 61	$ 220,000
Dredging - Mechanical	CY	155,573	$ 60	$ 9,300,000
Backfill Material Procurement and Delivery - Mechanical	CY	111,062	$ 40	$ 4,500,000
Backfill Material Loading - Mechanical - Telebelt	CY	111,062	$ 16	$ 1,730,000
Backfill Material Placement - Mechanical	CY	111,062	$ 48	$ 5,310,000
Characterize and Barge Transport for Offsite Non-TSCA (<1 PPM) Disposal	Ton	195,966	$ 156	$ 30,480,000
Characterize and Barge Transport for Offsite TSCA (>=50 PPM) Disposal	Ton	1,284	$ 285	$ 370,000
Characterize and Barge Transport for Offsite RCRA (>=1 to <50 PPM) Disposal	Ton	12,774	$ 148	$ 1,890,000
Water Treatment - Mechanically Dredged	LS	1	$ 428,408	$ 430,000
Site Restoration	LS	1	$ 1,078,452	$ 1,080,000
Demobilization (Assumed 10% of Total Equipment)	LS	1	$ 2,520,456	$ 2,530,000
			TOTALS	**$ 63,100,000**

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OUTFALL-008 - Excavation, Solidification and Off-Site disposal

Description	Units of Meas.	Quanity	Unit Price	Total Cost
Work Plans and Submittals (Assumed 2% of Total Labor)	LS	1	$ 6,879	$ 7,000
Mobilization (Assumed 10% of Total Equipment)	LS	1	$ 35,374	$ 36,000
Temporary Construction	LS	1	$ 154,092	$ 160,000
Surveys	LS	1	$ 48,608	$ 49,000
Debris Removal	CY	245	$ 63	$ 16,000
Sheet Pile Installation for Water Diversion	LS	33,000	$ 60	$ 1,980,000
Excavation	CY	6,370	$ 68	$ 440,000
Processing	CY	6,125	$ 56	$ 350,000
Backfill Material Procurement and Delivery	Ton	7,802	$ 24	$ 190,000
Backfill	CY	5,779	$ 66	$ 390,000
Characterize and Transport for Non-TSCA (< 1PPM) Disposal	Ton	7,173	$ 142	$ 1,020,000
Characterize and Transport for RCRA (>=1 to <50 PPM) Disposal	Ton	2,088	$ 142	$ 300,000
Water Treatment - Mechanically Dredged	LS	1	$ 428,408	$ 430,000
Site Restoration	LS	1	$ 318,292	$ 320,000
Demobilization (Assumed 10% of Total Equipment)	LS	1	$ 35,374	$ 36,000
			TOTALS	**$ 5,720,000**

Amec Foster Wheeler, Inc. 271 Mill Road Chelmsford, MA 01942	Project: Stratford Army Engine Plant Date: 10/26/2018 Calc. By JR Checked By: TD

OUTFALL-008 - Excavation, Solidification and On-Site Beneficial Reuse

Description	Units of Meas.	Quantity	Unit Price (Includes Taxes, OH, Profit)	Total Cost
Work Plans and Submittals (Assumed 2% of Total Labor)	LS	1	$ 8,611	$ 9,000
Mobilization (Assumed 10% of Total Equipment)	LS	1	$ 42,972	$ 43,000
Temporary Construction	LS	1	$ 154,092	$ 160,000
Surveys	LS	1	$ 48,608	$ 49,000
Debris Removal	CY	245	$ 63	$ 16,000
Sheet Pile Installation for Water Diversion	LS	33,000	$ 60	$ 1,980,000
Excavation	CY	6,370	$ 68	$ 440,000
Processing	CY	6,125	$ 56	$ 350,000
Backfill Material Procurement and Delivery	Ton	7,802	$ 24	$ 190,000
Backfill	CY	5,779	$ 66	$ 390,000
Characterize and Handle for Onsite Disposal	Ton	7,173	$ 47	$ 340,000
Characterize and Transport for RCRA (>=1 to <50 PPM) Disposal	Ton	2,088	$ 142	$ 300,000
Water Treatment - Mechanically Dredged	LS	1	$ 428,408	$ 430,000
Site Restoration	LS	1	$ 318,292	$ 320,000
Demobilization (Assumed 10% of Total Equipment)	LS	1	$ 42,972	$ 43,000
			TOTALS	**$ 5,020,000**