CITY OF WEST HAVEN
WATER POLLUTION CONTROL FACILITY
OUTFALL LINE STUDY

PREPARED FOR

City of West Haven, CT

19 MAY 2017

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Executive Summary

The City of West Haven, Connecticut Water Pollution Control Facility's (WPCF) outfall line is approaching 50 years of age, has reached the end of its useful life and is in poor condition. The pipeline is highly vulnerable to damage from storms such as hurricanes, tropical storms and strong Nor'easters. Recent storms such as Irene and Sandy have damaged the pipe, requiring emergency repairs. The natural movement of the tides continuously shifts the sand, requiring maintenance activities by the City to cover the exposed pipeline with a protective sand layer to abate further erosion. Sea level rise will reduce the conveyance capacity of the pipeline especially during storms, and extreme high tides in New Haven Harbor. On this basis, the City is planning to replace the outfall pipe, thus greatly increasing its resiliency to handle sea level rise and storms and to improve its conveyance capacity.

Hydraulic calculations show a 72 inch pipe diameter is necessary to discharge the WPCF design flows at future sea levels during the 100 year storm. Both cut and cover and deep tunneling construction alternatives were examined for the new pipeline. The cut and cover alternatives are much more economical. Additionally a pumped discharge alternative was investigated and a 48 inch pipe diameter is sufficient to discharge the WPCF design flows for this alternative.

Budget level costs were estimated for each alternative. Based on the limited development of each alternative, a construction contingency of 40% is used in this preliminary study. Table ES-1 below shows a summary of the costs for the three base alternatives.

Table ES- 1 Summary of Opinion of Probable Construction Costs

ITEM	NEW PIPELINE ON SOUTH SIDE OF EXISTING LINE (72" PIPE)	TUNNEL ALTERNATIVE	NEW PIPELINE ON SOUTH SIDE WITH PUMP STATION (48" PIPE)
Construction Cost[1]	$16,450,000	$54,200,000	$15,800,000
Engineering Design/Construction Support[2]	$3,300,000	$10,850,000	$3,150,000
Additional Studies and Permitting[3]	$1,750,000	$1,750,000	$1,750,000
Total Project Cost (2017 dollars)	**$21,500,000**	**$66,800,000**	**$20,700,000**

Notes:

1. **Includes 40% Construction Contingency**
2. **Engineering Design/Construction support is based on 20% of Construction Costs**
3. **Allowance estimate does not include environmental remediation**

While the new pipeline can be implemented technically, there are numerous Federal, State, and local agencies in addition to non-governmental organizations and commercial interests which will make permitting a unique challenge. Initial inquiries/analyses, indicate that it may take two to two and a half years to complete all environmental permitting and approvals for this project.

The cut and cover alternatives are preferred over the tunneling alternative based on lower overall cost. Final alignment of the cut and cover alternative will be determined once environmental agency input is obtained prior to commencing design. Additionally, the decision on pumped versus gravity discharge will be determined after environmental agency input is obtained and after an outfall diffuser/water quality study is completed.

1 Introduction

The City of West Haven, Connecticut Water Pollution Control Facility (WPCF) was originally built in two stages; the primary treatment facilities, including the plant effluent outfall line was constructed in the late 1960s and became operational by 1972, and construction of the secondary treatment facilities commenced in 1972. The outfall line discharges treated effluent into New Haven Harbor approximately 5,600 feet from where it begins at the effluent structure of the Chlorine Contact Tank. A section of the line, approximately 3,300 feet long is situated on Sandy Point in the inter-tidal zone. The 2,300 feet long section of the line after the inter-tidal zone section is located in the deeper waters of New Haven Harbor and ends at the bank of the shipping channel. Figure 1 shows the existing outfall line. The original planned location for the outfall pipeline was several hundred feet north of the installed location and had several feet of cover. During construction, the pipeline was moved to its currently installed location and cover was reduced as part of a cost saving measure. The existing outfall line is in poor condition and, based on a limited dive inspection performed in 2003, it is believed that effluent no longer reaches the end of the outfall pipe but is discharged through several holes which appear to have been cut on an exposed section of the outfall line, roughly 4,000 feet from the beginning point of the line.

Figure 1 Existing West Haven WPCF Outfall Alignment

On several occasions since its installation, the outfall pipeline has seen vertical/upward displacements and has required maintenance and repairs to return it to its original position. In 1980, approximately 380 feet of pipe "blew out" and was repaired. Between 1980 and 1984, additional vertical displacements occurred. In 1985, approximately 3,300 feet of the pipeline, the section located in the inter-tidal zone, was replaced because of damage resulting from continuous erosion due to sand movement. In 1994, the US Army Corp of Engineers (ACOE) covered approximately 1,000 feet of the pipe with concrete articulated mats to further help stabilize the pipe and protect it from erosion. Over the years, because of the natural movement of the tides and resulting shifting sand, the City has had to cover the pipe numerous times with sand in an effort to further protect it from erosion. This maintenance requires many truckloads of sand and requires permits from both the ACOE and the CT Office of Long Island Sound Project (OLISP).

Over time, the original channel for Old Field Creek has completely shifted from flowing east to flowing northeast to New Haven Harbor. The main reason for this is that the outfall pipe acts as a dam to the creek outlet resulting in its migration to the north as well as the sand shifting northward. The new channel erodes the sand cover around the outfall line and has exposed it to daily movement of water and sand, which if allowed to continue, will cause the pipe bedding and support to erode further resulting in pipe failure. The City is aware of this and regularly maintains the pipe by covering it with sand. Two recent storms, Irene and Sandy, caused erosion and damage to a 200 foot section of pipe which required emergency repairs at a cost of $200,000 and $50,000 respectively for each storm. A partial summary of the repairs and maintenance that have been performed over the years on the outfall pipe is listed in Table 1-1. As sand drifting north from Savin Rock beach continues to encroach on the Old Field Creek outlet, the flow will continue to be directed over the outfall pipe which will result in even greater erosion and scour problem along and over the pipe.

Table 1-1 Partial Summary of Outfall Line Maintenance and Repairs

YEAR	MAINTENANCE PERFORMED	COST (UNADJUSTED)
1980	Repair 380 feet of pipe that "blew out"	Not Available
1985	Replace 3300 feet of damaged pipe	$1,100,000
1994	Cover 1,000 feet of pipe with articulated mats	$1,400,000
2011	Repair 200 foot section of pipe	$200,000
2012	Replace eroded sand and repair pipe	$50,000

Since the outfall line in the inter-tidal zone is shallow, it is always subject to erosion and failure unless protected by sand cover which is a regular and expensive maintenance activity. There are other critical issues as well. The Old Field Creek has to flow over the top of the pipe and this has caused the channel bottom to rise to roughly the middle of the pipe. Thus Old Field Creek backs up and never empty out, prompting flooding of upstream properties and siltation of the channel bottom which further restricts flow. Lowering the outfall pipe will not only protect the pipeline, but will also help reduce flooding of upstream properties and may eventually restore the marshland with better tidal flow characteristics. It is also noted that the sand spit where the pipeline is located is a breeding ground for several shore bird species, including the piping plover, protected as threatened under the Endangered Species Act.

In the future, the existing pipeline will not be able to convey high flows from the WPCF during storm events by gravity flow because of sea level rise. This will require increasing the pipe size or adding effluent pumping. Therefore, in addition to the erosion problems of the pipeline, sea level rise is also reducing the discharge capacity of the pipe particularly during storm events.

In summary, storms will continue to damage the outfall pipeline as recent tropical and extra-tropical storms have demonstrated. Sea level rise will slowly cause a decrease in outfall pipeline capacity as the gravity flow will have a gradual reduction in head to move the discharge through the outfall pipeline. A long term solution to the existing outfall line must be implemented.

Considering all of these issues, the City is planning to replace the outfall pipe in its entirety with a new larger pipeline. If feasible, the City would like to construct the new pipeline at a depth of roughly 4 feet lower than the existing pipeline; this would minimize the risk of the above described problems from continuing. The new pipeline would extend to the edge of the shipping channel and have the diffuser located at a depth of approximately 16 feet (at low tide) on the sloped portion of the shipping channel. Based on the description from the Port Authority, City of New Haven, the Port of New Haven has a federally authorized channel depth of 35 feet and a width of 400 feet. Based on the sandy bottom of the New Haven Harbor, the existing side is assumed to be sloped at approximately a 4H:1V for a stable configuration as no bathymetry is available for this report. This arrangement would keep the diffuser out of the main shipping channel to avoid interference with shipping.

2 Purpose

Following the coastal flooding in the northeast United States by Irene and Sandy, the federal government began issuing grants to improve coastal resiliency in the region. The U.S. Department of Housing and Urban Development (HUD) has provided a grant to the City of West Haven to develop a community-wide coastal resiliency plan. The coastal resiliency study will develop a plan to improve the City's resiliency against storms, sea level rise, coastal erosion, public safety during storms, and repeated losses to property. The study will also evaluate alternatives for replacing the WPCF effluent outfall line.

The outfall line study will review the pipeline corridor, analyze pipeline hydraulics, review geotechnical conditions, compare open cut shallow profile installation vs deep profile alternatives for the new pipe using Horizontal Directional Drilling (HDD) and tunneling construction methods and prepare budget level cost opinions. The study will also provide a brief assessment of the more prominent environmental and permitting requirements for the new outfall line. Finally, a preliminary recommendation for the new outfall line will be identified.

The information presented in this report is briefly summarized below.

- Analysis of hydraulics for discharge during storm events
- Alternative route analysis for the new outfall pipe
- Evaluation of alternatives for outfall pipe installation
- Opinion of Probable Construction Cost for the outfall pipe alternatives
- New Haven Harbor construction access/shipping channel restrictions
- Outfall pipe environmental and wildlife considerations
- Conclusions and Recommendation

3 Outfall Pipe Hydraulic Analysis

The main purpose of the hydraulic analysis is to establish a preliminary size of the new outfall line. The hydraulic modeling requires basic inputs of the flow, outlet depth, pipe diameter, length, diffuser outlet configuration, sea level (normal and Stillwater during storms) and pipe roughness. Based on a previous hydraulic study performed for the WPCF, this study started by using the same annual average flows, maximum month flows and future peak hour flows summarized in the Table 3-1 below:

Table 3-1 Summary of Flows for Hydraulic Analysis

FLOW CONDITION	FUTURE PEAK HOUR	EXISTING PEAK HOUR	PEAK DAY	MAX MONTH	ANNUAL AVERAGE
Units	**mgd(cfs)**	**mgd(cfs)**	**mgd(cfs)**	**mgd(cfs)**	**mgd(cfs)**
Flow	33 (51)	25.4 (39.3)	17.2 (26.6)	10.4 (16.1)	9.7 (15)

The pipe length is kept at 5,600 feet to maintain the current location of the outfall diffuser. Since this will be new pipe, a future pipe roughness value of C=100 was used. This will allow for some normal deterioration in the flow coefficient as the pipe ages. The pipe will have a new connection to the existing Chlorine Contact Tank effluent structure, thus it was modeled as a bell mouth entrance to provide a hydraulically efficient inlet. Based on the description of the shipping channel from the Port Authority of the City of New Haven, and the USGS quad map, the diffuser at the end of the outfall pipe is estimated to be at an elevation of -17.3 ft NAVD88 (84.9 ft City of West Haven Datum) or about 14-16 feet of water (at low tide) but was not located during the dive inspection of 2003. A depth of 16 feet was used to calculate the effect of the sea water density on the pipeline hydraulics.

Since the outfall line is discharging treated wastewater effluent into New Haven Harbor, there are several variables which need to be selected.

1. Available Hydraulic driving head under various states of the tide
2. Allowance for sea level rise
3. Difference in density between treated effluent and receiving water
4. Required dilution / dispersion
5. Marine environment – waves, tides, currents, still water elevation during storms

Available Hydraulic driving head under various states of the tide

Based on available information, the existing weir in the Chlorine Contact Tank is at an elevation of 113.12 feet on the City of West Haven Datum (10.92 ft NAVD88). The tidal range is from a mean low tide elevation of 97.32 to a mean high tide elevation of 105.7. The available head for gravity discharge therefore varies from 7.42 feet at high tide to 15.8 feet at low tide. Based on the peak hour flows, the normal tidal fluctuations do not control the size of the outfall pipe. The storm surge associated with the 1% annual chance storm event will control the outfall pipe size to provide the necessary capacity to pass the peak hour flow.

Since the sea level changes regularly with storms it was necessary to investigate the outfall line hydraulics for still water elevations corresponding to different annual storm probabilities. Table 3-2 below summarizes the annual probability of each storm and the corresponding still water elevation. Stillwater elevations in the table are based on the FEMA flood elevation data published on Flood Insurance Rate Maps (FIRMs) as part of the National Flood Insurance Program.

Table 3-2 Summary of Stillwater Elevations During Storms

PERCENT ANNUAL CHANCE STORM	10%	2%	1%	0.2%
Stillwater elevation (NAVD88)	6.9	8.3	8.9	10.2
Stillwater elevation (City of West Haven Datum)	108.5	110	110.7	112.4

Allowance for sea level rise

The second variable is the estimated sea level elevation at the end of the design life of the new pipeline and outfall diffuser. Using a design life of 50 to 60 years, the sea level rise provided by NOAA for the year 2075 is the closest year available to the end of the design life. NOAA publishes several different scenarios for sea level rise. The first is the NOAA Low Sea Level change which is based on simple extrapolation of historical sea level rise. This was not selected as the climate warming may accelerate sea level rise in the future. The second is the NOAA Intermediate Low Sea Level change which is based on climate projections for ocean warming (warm water expansion) and intended to be on the low side of sea level rise. The third is the NOAA Intermediate High Sea Level change which is also based on climate projections for ocean warming and recent ice sheet loss and is intended to be on the high side of the computer model climate scenarios. The fourth is the NOAA High Sea Level change which is based on maximum plausible contribution from glaciers melting. In evaluating the likely future conditions, it was considered that simple extrapolation of historical trends would be un-conservative and was not used. Likewise, the high projection is extreme as NOAA indicates this is for situations where there is little tolerance for risk and the nearly 4 feet of projected sea level rise would turn the WPCF into an island; such a scenario would probably require more than just changes to the outfall line to remain functional. The two remaining intermediate projections both seem reasonable as starting points, and based on recent political actions to limit climate change, it was considered appropriate to use an average of the two NOAA intermediate projections. For the year 2075, the average of the NOAA projections (1.04 ft. and 2.28 ft.) is a sea level rise of 1.66 ft.

Difference in density between treated effluent and receiving water

To account for the difference in density of the fresh water (i.e. treated wastewater effluent) from the outfall line to the sea water, a factor of 1.025 was used to account for the approximate 2.5% greater density of the sea water multiplied by the approximate still water depth at the diffuser port.

Required dilution / dispersion

The outlet configuration of the diffuser has one main purpose – to disperse flow into the channel area of New Haven Harbor, thereby achieving adequate dilution. Water quality modelling was outside the scope of this study; hence the primary focus has been on hydraulic capacity rather than dilution/dispersion. A detailed diffuser study should be performed prior to preliminary design to determine the best configuration of the diffuser to achieve required dispersion of the effluent into the harbor.

The diffusion of the plant's treated effluent involves a 'freshwater' discharge with lower density into the salt water environment of New Haven Harbor. Generally slower outlet conditions would favor better diffusion, particularly for this condition where density driven currents would potentially cause the discharge water to create a plume reaching the surface where it could then spread horizontally on top of the higher density sea water and not mix successfully unless turbulence was present at the surface. Tideflex check valves have been used on past diffuser systems with the primary purposes of increasing mixing energy and preventing foreign objects from entering the diffuser. The tideflex valves generally induce around 5 feet of headloss and cause a higher velocity jet to extend from the diffuser. This may be advantageous in some mixing situations, but in this case for relatively shallow water depth and density difference, the higher velocity jets may cause poor mixing. Nevertheless, a conceptual diffuser layout with two outlet ports (reportedly, the same as the original outfall line design), but with tideflex valves on each port was analyzed. Initial investigations of headloss indicated the existing Chlorine Contact Tank would have the effluent weir overtopped with a minimum flow of 5 mgd during all of the storms listed in the table above.

After an initial round of hydraulic analyses on the new outfall line, Black & Veatch had a conference call with the City of West Haven. During the meeting it was agreed that the outfall line and diffuser would be based on a conceptual diffuser arrangement with up to four (4) openings, each 24 inches in diameter (to match the original ports) to pass the existing peak hour flows during the 1% annual chance storm. The City representative noted that significant improvements to the Main Pumping Station would need to be performed to increase the discharge capacity to the future peak hour flow identified in Table 3-1 above. It was also noted that the future flows identified above were developed as part of a study completed more than 10 years ago; however, currently, the City does not envision that flows to the WPCF will increase beyond the current flow baseline. It was also noted that flows to the plant have been slightly decreasing. Therefore, based on these discussions, an additional outlet configuration was investigated which has four (4) 24 inch outfall diffuser ports and no Tide Flex check valves. Table 3-3 and Table 3-4, provided below, summarize the pipe diameters needed to discharge the flow at the corresponding still water elevation for the two outfall line diffuser configurations analyzed as part of the hydraulic modeling. Note that the pipe size listed as NA indicates that there is no pipe, regardless of size, which can pass the flow at the specified still water elevation (storm Stillwater elevations account for sea level rise added to the current estimated Stillwater elevation).

Table 3-3 Outfall Pipe Sizes Required to Pass Flow with Duckbill Check Valves on Two Outlet Diffusers

REQUIRED PIPE SIZES TO PASS FLOWS WITH OUTFALL DIFFUSER HAVING TWO 24" DIAMETER TIDEFLEX (DUCKBILL) CHECK VALVES					
Percent annual chance storm	Normal high tide	10%	2%	1%	0.2%
Future Peak Hour (required pipe size)	66"	NA	NA	NA	NA
Existing Peak Hour (required pipe size)	60"	NA	NA	NA	NA
Peak Day (Required Pipe Size)	48"	NA	NA	NA	NA
Max Month (Required Pipe Size)	48"	NA	NA	NA	NA
Annual Average (Required Pipe Size)	48"	NA	NA	NA	NA

Table 3-4 Outfall Pipe Size Required to Pass Flow with Four Outlet Diffusers

REQUIRED PIPE SIZES TO PASS FLOWS WITH OUTFALL DIFFUSER HAVING FOUR 24" DIAMETER OPENINGS					
Percent annual chance storm	Normal high tide	10%	2%	1%	0.2%
Future Peak Hour (required pipe size)	48"[1]	60"[1]	66"[1]	78"[1]	NA
Existing Peak Hour (required pipe size)	48"	60"	66"	72"[1]	NA
Peak Day (Required Pipe Size)	48"	54"	66"	72"[1]	NA
Max Month (Required Pipe Size)	48"	48"	54"	60"[1]	NA
Annual Average (Required Pipe Size)	48"	48"	48"	54"[1]	NA

Note:

1. Pipe diameters listed will submerge the effluent weir but not overflow the Chlorine Contact Tank.

Note that none of the alternatives can pass the annual average flows at the future sea level and 0.2% annual chance storm still water elevation. The reason for this is the incredibly small allowable headloss from the Chlorine Contact Tank effluent weir to the outlet WSEL (the still water elevation is 0.86 ft. above the effluent weir). If the future peak hour flows must be passed during the 0.2% annual chance storm for the selected sea level rise, additional work must be done in the Chlorine Contact Tank and upstream structures, or effluent pumping must be added. For the future peak hour conditions, pipe sizes were selected which allowed the weir to be submerged, but with no calculated overflow of the Chlorine Contact Tank. This was allowed because of the small number of hours (probably 12-24 hours every 10 to 100 years) for such occurrences. As long as the effluent is still passed through the outfall pipe, the system is conveying the treated effluent into the harbor. Additional costs to provide the freeboard below an unsubmerged weir are unlikely to be economical compared to installing a pump station for the 1% annual chance storm.

Based on the hydraulic calculations:

- A 72 inch diameter line was selected for additional analysis
- A 72 inch line will pass all flows up to the existing peak hour flows at the 1% annual chance storm and design sea level rise

- A 72 inch line will not pass the WPCF discharge during a 0.2% storm and future sea level rise; however, there will be other serious flooding issues affecting the plant under these conditions which make the effluent pipe capacity a lesser issue during this extreme event.

Since the 72 inch diameter outfall line diameter covers the required design criteria for discharge of the current peak hour flow during a 1% annual chance storm at future sea levels, it was selected for additional engineering analysis for this study.

4 Pipeline Corridor Analysis

The new pipeline is planned to be located in general proximity to the existing outfall line, with the section in the inter-tidal zone at or in the area of Sandy Point and the subaqueous zone section in the general alignment of the existing outfall line terminating at the shipping channel in New Haven harbor. Two basic construction methods were considered for implementing the new outfall line in the inter-tidal zone section as identified below. These will be described in a later section of this report.

1) A cut and cover alternative which features a relatively shallow vertical profile depth for this section of the pipeline, and
2) A tunneling or horizontal directional drilling (HDD) alternative with a much deeper corresponding vertical profile for the outfall line as compared to the cut and cover alternative.

Regardless of construction alternative, the new pipeline must be located a certain distance away from the existing outfall line such that the existing line is not disturbed or compromised while the new line is being constructed. The existing outfall line must remain in operation during this time, thus a minimum of 50 to 100 feet clear distance should be maintained between the existing outfall line and the new pipeline.

The actual location of the outfall line in the inter-tidal zone is more important for the cut and cover alternative as the relatively shallow pipeline depth for this alternative makes it more amenable to being maintained and/or repaired if that is required during its lifetime. Therefore, because large areas of the Sandy Point are underwater during high tides, then locating the new pipeline on higher ground would be preferred.

Possible alignments will need to parallel the existing pipe to various degrees to allow the existing pipe to remain in service as long as possible and provide as short a period of bypass pumping as is feasible. The alignments analyzed parallel the existing pipeline with roughly 50 feet clear spacing between the two pipelines to avoid interferences between the existing erosion control and the new pipeline. Locating the new pipeline on the north side and the south side of the existing line, and parallel to it, was studied for the cut and cover alternative. An alignment along that of the existing line was also considered. A second south side alignment was considered; this alignment would cross over to Morse Point for a ways before crossing back to Sandy Point prior to joining up to the subaqueous zone section at its near land terminus. Table 4-1 summarizes the advantages and disadvantages of each alignment and these are further discussed here. Figure 2 depicts the alignments.

As table 4-1 shows, the first two alignments, the one on the north of the existing outfall line and the one re-using the alignment of the existing outfall line, both have more disadvantages than providing a parallel alignment to the south of the existing outfall line. By installing the new pipeline south of the existing pipeline, the new pipeline would be installed in the higher ground and provide somewhat easier access for any future inspections or maintenance/repairs. However, while the ground is higher here, it is not much above the high tide line and may in the future be below the high tide line depending on the rate of sea level rise and the rate at which the Sandy Point is built up by new deposits. The Morse Point is higher ground and crossing over to it would provide better protection against sea level rise and erosion. The primary issue with Morse Point is the presence of endangered species habitat for plovers and other nesting bird species. The permitting of construction near this habitat may be subject to seasonal and spatial restrictions such as staying a certain minimum distance away from the plover habitat or working only when the plover have migrated south for the winter. It is also possible that any future access to the pipeline buried on Morse Point could have access restricted to certain seasons and/or require access to always be via Sandy Point and crossing Old Field Creek beyond the plover habitat. Provided the alignment with a cross over to Morse Point can be permitted without excessive restrictions for construction and future access, this would be the preferred alignment for the cut and cover alternative. If excessive permit restrictions are placed on this alignment, the next best cut and cover alternative would be parallel to the existing pipeline on the south side.

Table 4-1 Comparison of Alignments

ALIGNMENT	ADVANTAGES	DISADVANTAGES
Parallel to existing pipeline on north side	-Keeps existing outfall line active during part of the construction -Completely bypasses nesting ground of endangered plover	-All construction below high tide level -Increased cost of construction -Difficult access for future inspection and/or repair
Re-use existing alignment	May have fewer permitting challenges	-Extensive bypass pumping required -Increased cost of demolishing existing pipe -Difficult access for future inspection and/or repair
Parallel to existing pipeline on south side	-Keeps existing outfall line active during part of the construction -Completely bypasses nesting ground of endangered plover -Provides pipeline access as this alignment is on slightly higher ground than the alignments on the north side	-Difficult access for future inspection and/or repair; however, less so than the alignments on the north side
Parallel to existing pipeline on south side with crossover to Morse point	-Keeps existing outfall line active during construction -Provides pipeline access on higher ground (as compared to the other alignments) -easiest access for future inspections and/or repair	-Crossover to Morse Point must bypass plover habitat by amount required in permit. -Construction access to Morse Point may be limited to crossing creek outlet in tidal zone to avoid damage to plover habitat.

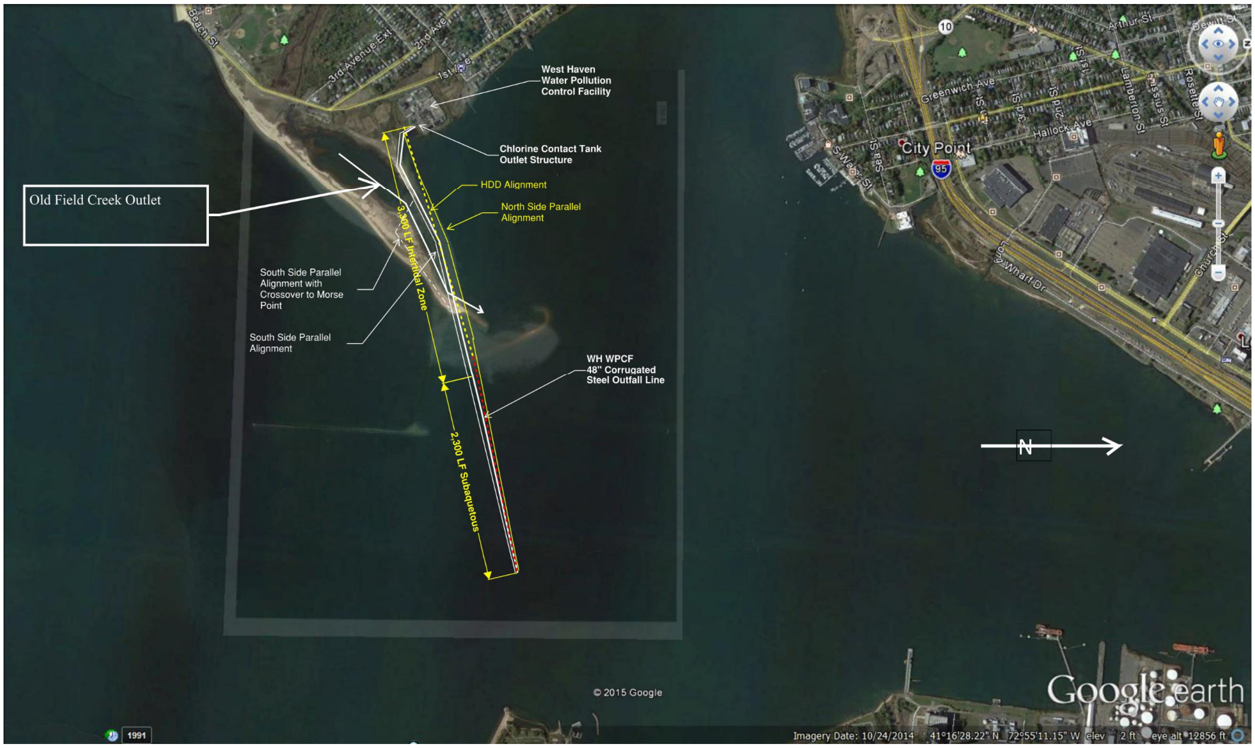

Figure 2 Outfall Alignments

The tunnel and HDD alternatives are not as dependent on alignment in the inter-tidal zone as the cut and cover alternatives discussed above. This is because of the significantly greater depth at which the tunnel or HDD alternative would be constructed. Both the tunnel and HDD alternatives would begin near the Chlorine Contact Tank and would be constructed beneath the extensive peat layer in the sand layer to provide the necessary strength of the soil for construction. Thus the tunnel and/or HDD alignment would be a straight line beginning from near the chlorine contact tank, then generally parallel to the harbor floor until close to the end of Morse Point where the subaqueous zone section begins. The actual transition is described later in this report. The alignment of the tunnel and HDD alternatives is envisioned to be the same and is shown on Figure 6.

5 Evaluation of Construction Alternatives

As noted previously, two basic construction methods were considered for installation of the new outfall line in the inter-tidal zone section as noted below. This section provides a brief description of these construction alternatives.

1) A cut and cover alternative with shallow vertical profile depth, and
2) A tunneling or horizontal directional drilling (HDD) alternative with a deep vertical profile.

5.1 CUT AND COVER OUTFALL PIPE ALTERNATIVE

As stated earlier, the original design of the outfall line showed a deeper vertical alignment than was eventually constructed. Thus the pipe section in the inter-tidal zone is quite shallow; some portions of it are above ground and exposed during tide cycles. This has accelerated the corrosion of the pipe which has weakened it and has resulted in damage requiring repeated emergency repairs and regular maintenance of this asset over the years. The shallow vertical profile also makes the pipe vulnerable to even more catastrophic damage associated with strong winds, waves and ocean currents brought on by powerful storms. The shallow alignment of the pipe also restricts the outlet of Old Field Creek causing property flooding, shifting sands and erosion, which also exacerbates damage to the pipeline.

The design of the new pipeline in the inter-tidal zone must address the limitations of the existing line as summarized above and elsewhere. The new pipe must have a deeper vertical profile such that it will not require frequent sand replacement to mitigate ongoing erosion as occurs with the existing line. The new line must be deep enough such that the outlet to Old Field Creek is no longer restricted. The new line, similar to the existing line will need to be supported by a system of piles and concrete caps which are designed to minimize vertical uplift of the pipeline as well as settlement of the pipe.

Figure 3 shows the new pipeline parallel to the existing line on the south side and Figure 4 also shows the new pipeline on the south side of the existing line, but this alignment utilizes the higher ground on Morse Point for a portion of the overall length of the pipe in the inter-tidal zone.

Figure 3 Outfall alignment, south of existing alignment.

Figure 4 Outfall alignment with crossover to Morse Point

Both of these alignments would have a similar profile so only a single representative profile is shown in Figure 5. The depth of the pipeline was chosen to provide adequate cover and sufficiently sound invert of the pipe trench. In general, the soil profile along the inter-tidal zone corridor consists of a layer of sand near the surface, underlain by a layer of organic silt with a thick layer of sand beneath the organic layer. The upper layer probably migrated north from Savin Rock and overlays the original organic silt which was deposited from the rivers that enter New Haven Harbor. Because the soil borings performed by GZA show loose sand as the surface and weak organic silt, the best support for the pipe would be to excavate to the bottom of the organic silt layer when it is less than 12 feet below the surface. Where the organic silt layer is deeper, the outfall pipe will be installed above the organic silt layer where possible. Because of the low strength of the soils, pipe piles will be required to provide sufficient support for the outfall pipe.

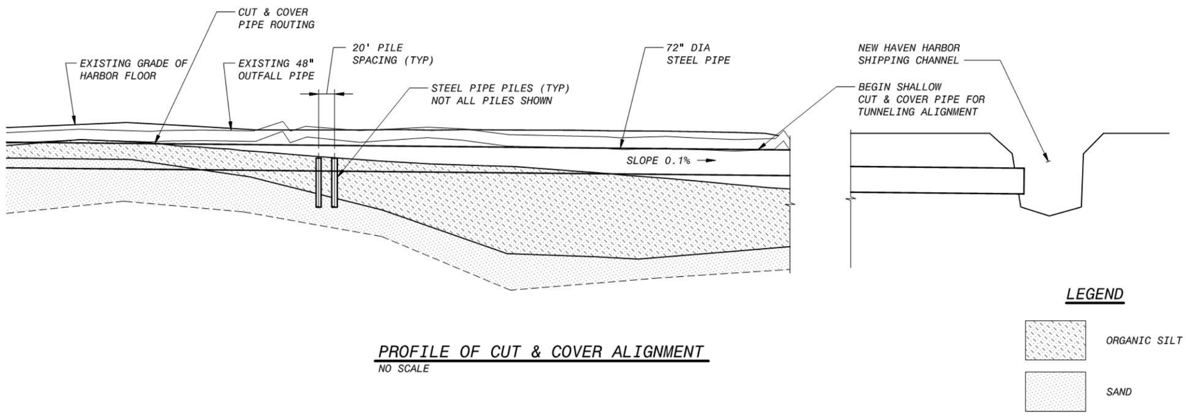

Figure 5 Profile of Cut and Cover Alignment

5.2 DEEP OUTFALL PIPE ALTERNATIVES

In looking at the deep outfall pipe alternatives, the most cost effective method of installation is to construct the deep outfall pipe only in the inter-tidal zone up to the location where it becomes subaqueous (approximately 3,300 feet in length). At this location, the deep outfall line is connected to the subaqueous zone section. The subaqueous zone section of the outfall line would be constructed as a shallow cut and cover pipeline from the edge of the intertidal zone to the outfall diffuser. Two deep outfall construction technology alternatives were analyzed: Horizontal Directional Drilling (HDD) and soft ground tunneling. The horizontal alignment itself is the same for both of these technologies. The primary difference between the HDD and the soft ground tunnel is in the technology for installing the pipeline, control of the vertical alignment, and the pipe size limitations for each. In addition, for the HDD option, the completed pipe section would either require a large laydown area on the land or be floated on the water and pulled back toward the land through the excavated hole. Pipe materials chosen will also affect the construction method. The horizontal alignment, as shown in Figure 6, would be straight from near the Chlorine Contact Tank to the connection of the shallow cut and cover section of the pipeline in the subaqueous zone.

Figure 6 Outfall alignment for HDD or Tunneling Alternatives

The HDD alternative would begin near the Chlorine Contact Tank and go down at a 12-16 degree angle to a suitable depth to provide the necessary strength of the soil for drilling and installing the pipeline. The pipeline would then generally parallel the harbor floor until nearing the end of the drilled portion where it would then come back up at an angle to reach a receiving pit where it would connect to the shallow cut and cover pipeline (i.e., the subaqueous zone section). This would minimize bends as the pipeline would have an essentially straight horizontal alignment and have just two sets of bends to create the change in elevation. Possible challenges with the alignment include soft sediment, lack of access for inspection or maintenance, and environmental permitting. Inadvertent returns of the drilling slurry due to hydrofracturing of the subsurface are also a typical risk with HDD construction. To pass the required flow by gravity under high tide and storm surge conditions, it would be necessary to either provide a pipe larger than a feasible diameter for HDD installations (roughly 42 to 48-inches in diameter), or provide multiple parallel pipes. This would make the HDD alternative either technically infeasible, or uneconomical. Additionally, the isolated low spot could be a location which traps sediment over time given the very low velocities of the pipeline to meet the headloss requirements. If sediment did get into the pipe, it is unlikely that it will be self-flushing, and could increase headloss significantly. The availability of qualified specialty subcontractors for the HDD portion of this project with these requirements is limited. Due to the large size required for the outfall line, environmental sensitivity and the likely possible entrapment of debris in the low spots of the HDD vertical profile, the HDD deep pipeline alternative is eliminated from further viable consideration.

The soft ground tunneling alternative would begin near the Chlorine Contact Tank and have an access construction shaft (later used as a drop shaft for the treated plant effluent) extending down to a suitable depth below the organic silt layer. The soft ground tunneling would be performed by an earth pressure balance tunnel boring machine (EPBM) designed to possibly use pre-excavation grouting ahead of the boring machine. This would improve and stabilize the soil to allow tunneling and placement of a segmental concrete liner as it bores through the soil. With the segmental concrete liner, no additional pipe is needed as a carrier for the treated effluent, and the smallest practical ID of the tunnel would be approximately 78 inches. Figure 7 shows the proposed tunnel profile view for construction. The soft ground tunnel profile would slope gently upwards for proper drainage during construction until it reaches a cofferdam at the marine recovery shaft where it connects to the shallow cut and cover pipeline constructed in the subaqueous zone. The marine recovery shaft would be used as a riser shaft for the treated effluent once construction is complete. This would minimize bends as the soft ground tunnel would have an essentially straight horizontal alignment and have just two shafts to change elevation. Possible challenges with the alignment include soft sediment, hydrostatic pressure, a marine shaft, and lack of access for inspection or maintenance. If inspections are desired, gates could be used at the drop shaft and recovery shaft to isolate the tunnel and dewater it to facilitate inspections. Additionally, the isolated low spot could be a location which traps sediment over time given the very low velocities of the tunnel to meet the headloss requirements. If sediment did get into the tunnel, it is unlikely that it will be self-flushing, and could increase headloss significantly.

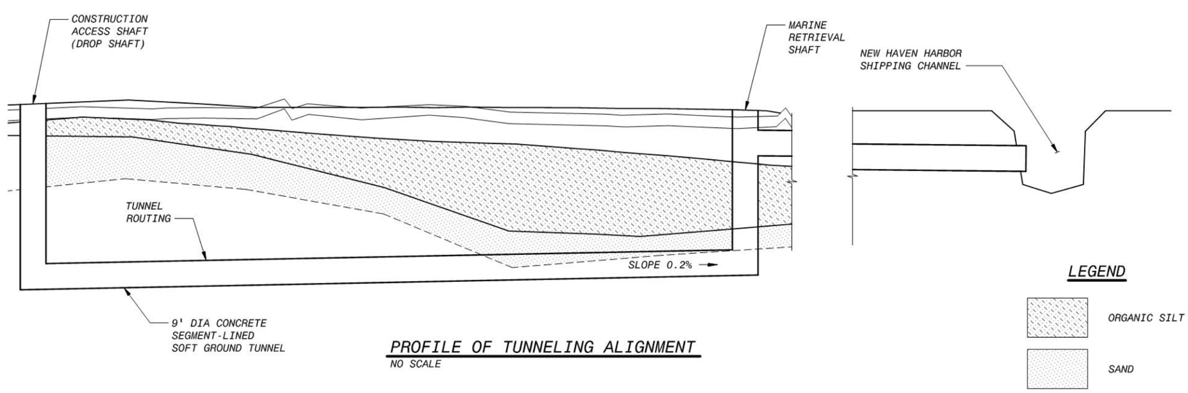

Figure 7 Profile of Tunneling Alternative.

5.3 PUMPED EFFLUENT ALTERNATIVE

In Table 3-4 the required size of outfall pipe for the max month condition and 10% annual chance storm is 48 inches. Note that this is a full two feet diameter smaller than the pipe size necessary to pass the existing peak hour flow at the 100 year storm. Additionally, the 48 inch diameter pipe can pass the existing peak hour flows at normal high tide levels for the estimated future sea level rise. Therefore, for the full range of flows, pumping would only be needed during a relatively few hours during large storm events and possibly during the highest tide cycles. Given the low estimated frequency for pumping, the associated operating costs range from a low of $6,000 per year to $23,000 per year for the energy costs. Normal maintenance costs such as seal replacment and excercising the pumps are not estimated at this time. On this basis, for a relative comparison to the other pipeline alternatives, only the capital cost needs to be considered for evaluating a pumped effluent alternative. The alignment of the pipeline for this pumped effluent alternative is proposed as a shallow cut and cover as previously described.

The addition of the pump station would require a new structure and a pair of diversion gates to either bypass the pump station when pumping is not required, or to force all flow through the pump station when pumping is required. Because the pumps can be sized for greater heads, the addition of the pump station provides the greatest resiliency against future changes in storm intensity and sea level rise. Additionally if an outfall diffuser study determines an outfall configuration with greater headloss (perhaps up to 5 feet of headloss) is necessary, then the pumped effluent alternative may become the only technically feasible option. The pump station would be called on to operate typically during severe weather conditions of a tropical storm or Nor'easter storm and therefore redundant pumping equipment is considered necessary. A conceptual level layout of the pump station is shown in Figure 8.

Figure 8 considers submersible pumps with three duty units and one standby pump. Variable speed operation based on level control in the pump station wetwell is envisioned. Additionally, consideration should be made for connecting the effluent pumps to the existing backup emergency generator if capacity is available there. If the existing emergency generator does not have adequate spare capacity, then a new emergency backup generator which can supply power to the effluent pumping station would be required. The new effluent pump station would be located near the south and east fenceline of the plant boundary. The entire WPCF plant site is very constrained, including the area near the existing Chlorine Contact Tank. Preliminary layout indicates that the site boundary will need to be enlarged to fit the new pump station and allow for operation and maintenance access. The design would strive to minimize any encroachment on adjacent wetlands. The addition of an effluent pumping station to handle WPCF effluent flows during extreme wet weather conditions where receiving water levels are too high to discharge via gravity is not unusual.

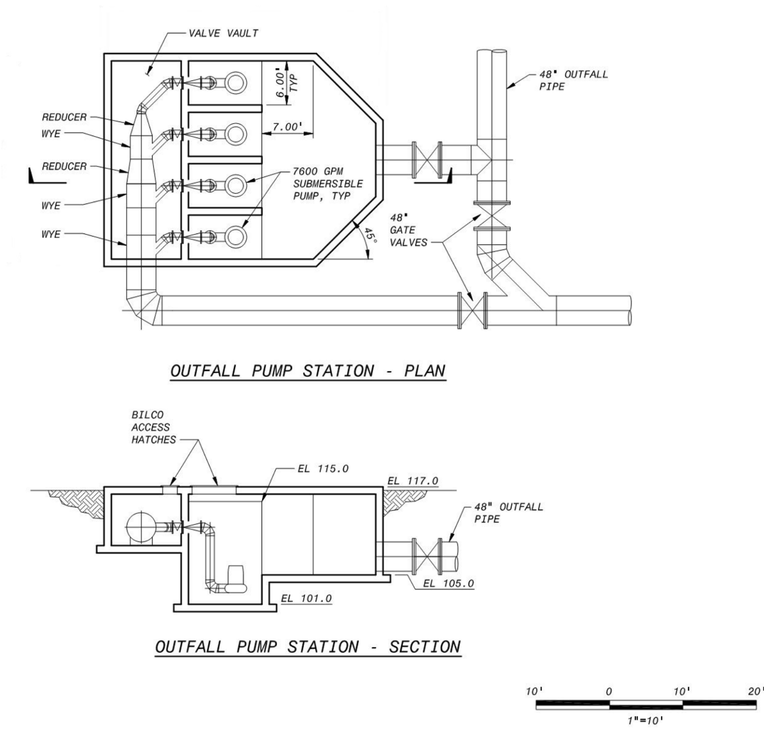

Figure 8 Effluent Pump Station conceptual layout

The addition of the pump station provides less benefit for the soft ground tunnel outfall line alternative since the minimum tunnel diameter is large enough to pass the effluent by gravity. The shallow (cut and cover) alternative would benefit from the greatly reduced pipe size as the trench, pipe, backfill, anchorage, and cathodic protection systems would all decrease.

6 Opinion of Probable Construction Cost and Preliminary Schedule

6.1 ASSUMPTIONS USED IN THE COST OPINIONS

The conceptual level opinion of probable construction cost for each alternative should be used for comparative purposes only. The cost opinions include a high-level breakdown of expected costs associated with implementation of the alternatives considered. Unit priced items were included where sufficient detail was available to estimate quantities. Unit prices were developed using a combination of manufacturer supplied data, estimates and known construction costs for other similar projects, and judgment. In some instances, lump sum allowance values were used when an item was clearly required yet insufficient information was available to develop greater detail. Costs for items such as mobilization, engineering and construction management, and other indirect costs were based on percentages of the total direct construction costs with contingency, and were assigned based on experience and judgment. Assumptions used in the conceptual level cost opinion are briefly identified below:

- Excavation is performed from a barge using a clamshell
- Intertidal zone tide changes would cause some regular re-filling of excavated trenches due to movement of the sand from tidal action
- Cost differences between the two parallel cut and cover alignments are minor and only the alignment south of the existing outfall line is presented
- Above ground work within outside of the WPCF fence is restricted between April and October because of the plover habitat
- Erosion and sedimentation control, tubidity monitoring and wetlands protection are required for 16 months (extends beyond end of construction)
- Existing organic silt has low strength and must be removed where possible to prevent settlement issues with the pipe
- Spoils are assumed to be dumped at sea within 20 miles of the excavation site
- Pipe material is steel to span between piles in the event of subgrade settlement or movement
- An internal lining of up to 40 mils of epoxy and an external coating of three-layer polyethlyne sheathing suitable for sea water exposure is assumed for corrosion protection.
- Piles are concrete filled pipe piles, driven a minimum of 20 ft below the bottom of the existing organic silt layer, thus overall average depth of piles is 60 ft.
- Pile spacing is 20 ft along the entire length of the pipe, two piles per support
- Concrete pile caps are used to anchor the pipe to the piles
- Mass of the concrete pile caps is equal to the buoyant force of the pipe during construction and in case air enters the pipe
- Concrete erosion control mats (articulating mats similar to what USACE has used during the 1990s upgrade) are placed on approximately 1,000 ft of pipe in the intertidal zone
- Temporary bypass pumping is based on rental of diesel driven pumps
- Diffuser is simple pipe with four outlet ports
- Tunneling requires a concrete lined tunnel with ground stabilization ahead of tunneling operations for soft ground tunneling. Two access shafts are required, one on land to start

the tunnel, one in the harbor to retrieve the tunnel boring machine. Access shaft on land will later serve as drop shaft for treated effluent to enter the tunnel and the marine recovery shaft will serve as the riser for treated effluent to exit the tunnel and enter the subaqueous zone section of the outfall line.

- No steel pipe liner is required in the tunnel
- Existing outfall pipe is removed to a distance from shore where the water depth at low tide is at 72 inches or greater (approximately 4,800 ft from the shore).
- Costs are in 2017 dollars.

The Association for the Advancement of Cost Engineering (AACE) International is an international non-profit professional educational association that provides services related to cost estimating, cost/schedule control, and project management to a wide range of professions and industries. The AACE provides standard ranges of expected accuracy for the opinions of probably construction cost based on level of effort in developing the project. Based on the conceptual nature of this study, we are providing a class 4 estimate which has an expected accuracy of -30% to +50% of the opinion of probable construction costs listed in the following table.

Table 6-1 Opinions of Probable Construction Cost for Outfall Alternatives

ITEM	PARALLEL TO EXISTING PIPELINE ON SOUTH SIDE (72" Pipe)[1]	DEEP SOFT GROUND TUNNEL ALTERNATIVE	PARALLEL ALIGNMENT WITH PUMP STATION (48" PIPE)
Construction Costs			
Base Construction Costs of Alternative	$11,750,000	$38,700,000	$11,300,000
Construction Contingency (40%)	$4,700,000	$15,500,000	$4,500,000
Total Construction Cost	**$16,450,000**	**$54,200,000**	**$15,800,000**
Engineering Design & Construction Phase Engineering Services (20% of Costs)	$3,300,000	10,850,000	3,150,000
Additional Studies & Environmental/Permitting Costs			
Environmental, Regulatory and Permitting (allowance)	$800,000	$800,000	$800,000
Bathymetric Survey and Mapping	$150,000	$150,000	$150,000
Geotechnical Investigations and Environmental Sampling (allowance)	$500,000	$500,000	$500,000
Environmental Sampling of Dredged materials (allowance)	$100,000	$100,000	$100,000
Diffuser Study (allowance)	$200,000	$200,000	$200,000
Subtotal Construction and Study Costs	**$21,500,000**	**$66,800,000**	**$20,700,000**
ESTIMATED TOTAL PROJECT COST (2017 dollars)	**$21,500,000**	**$66,800,000**	**$20,700,000**

Note:

1. **At this conceptual level of study, the cost presented above for the south side alignment reflects that of either the alignment parallel to the existing pipe or the alignment which crosses over to Morse Point. These two slightly different alignments are considered to have approximately the same cost at this preliminary stage.**
2. **Construction costs do not include any remediation of environmental contamination.**

6.2 PRELIMINARY SCHEDULE

A preliminary schedule is shown below in Figure 9. The assumed duration of activities used in the preliminary schedule are based on the current understanding of the project and the discussions with local authorities. Based on the single pipeline design, the engineering phase of the project schedule is based on design time for similar outfall pipeline projects. Because of the large number of permits required from different agencies and the overall complexity of the permit related efforts, the permitting period is projected to take approximately two to two and a half (2.5) years. This period may be shorter; however, this time requirement will be more realistically determined after the initial pre-application meetings with the agencies is held at the onset of the engineering design phase.

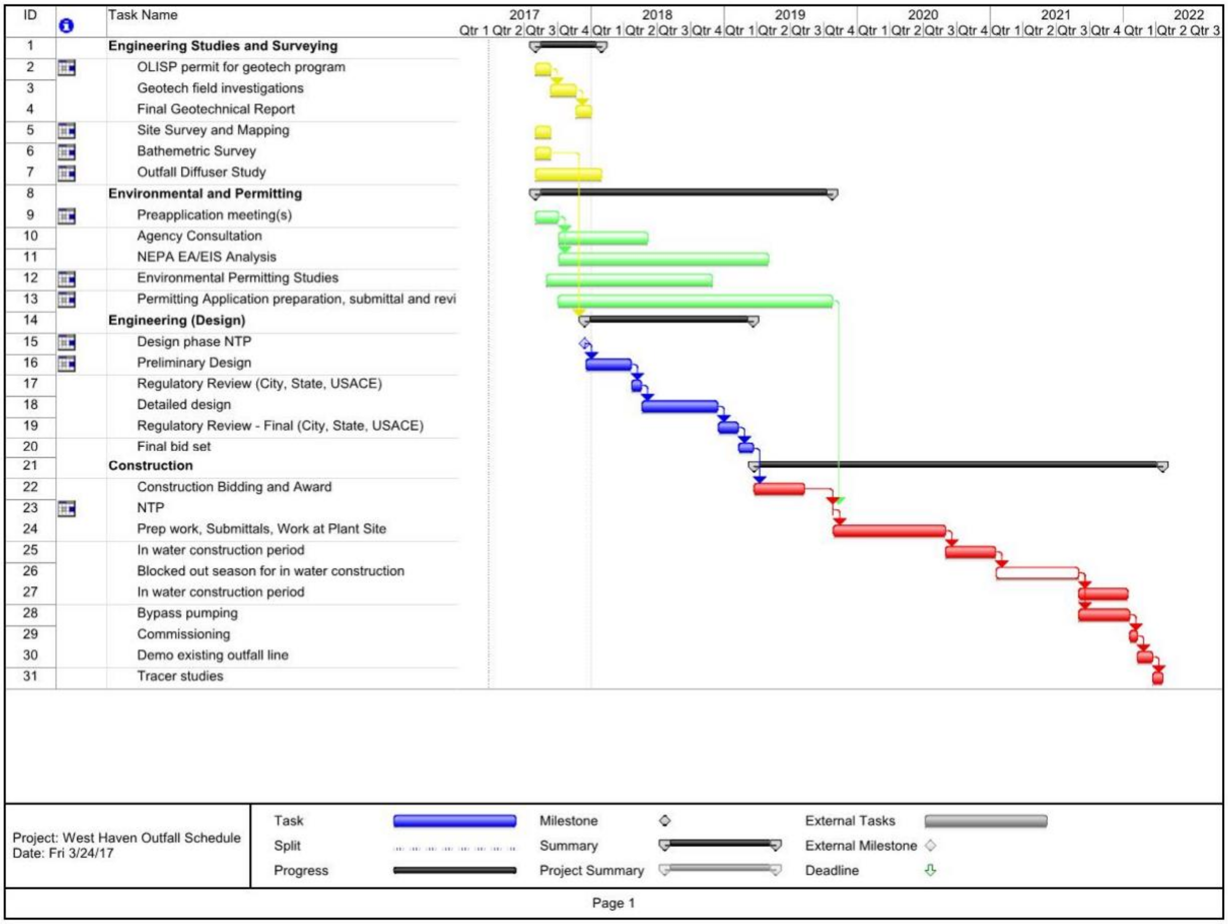

Figure 9 Preliminary Schedule for West Haven WPCF Outfall Replacement

7 Environmental, Permitting and Regulatory Requirements

The proposed outfall pipeline alternatives to discharge effluent from the WPCF will be located within the waters of New Haven Harbor which is under the regulatory jurisdiction of the United States Coast Guard (USCG), United States Army Corps of Engineers (USACE), Connecticut Department of Energy and Environmental Protection (DEEP), the New Haven and West Haven Harbormasters among others. The presence of federally listed threatened and endangered species, commercial shellfish beds and an active shipping channel presents additional environmental challenges for the implementation of any of the alternatives to the outfall pipeline discussed in previous sections. The following subsections outline the potential requirements to successfully obtain the currently known permits/approvals from the regulatory agencies and/or interested stakeholders.

7.1 NATIONAL ENVIRONMENTAL POLICY ACT

The National Environmental Policy Act (NEPA) *42 U.S.C. §4321 et seq. (1969)* may be applicable for the pipeline project. NEPA only applies to federal agency proposals for "actions", which include direct agency undertakings (i.e., federal projects), funding, permitting and proposals for legislation.

Permitting under the Clean Water Act which will be required for this project is exempt from NEPA; however, should any federal funding be involved in this project, a NEPA analysis would be required. This would result in the agency providing the funding being required to develop an Environmental Assessment (EA) or Environmental Impact Statement (EIS) according to the Council of Environmental Quality (CEQ) guidelines and the agency's specific guidelines to evaluate potential impacts to the natural and human environment and identify mitigation options as applicable.

7.2 AGENCY CONSULTATION

Consultation with the United States Fish & Wildlife Service (USFWS), Connecticut DEEP Natural Diversity Database (NDDB) and National Marine Fisheries Service will be necessary due to the commercial shellfish beds, piping plover nesting habitat on the sand spit, and the terrestrial and aquatic habitat with the potential to support numerous shore and fish species, including colonial nesting birds, located in and within close proximity to each of the pipeline alternatives. In addition, the Audubon Society should be consulted in conjunction with USFWS as an interested stakeholder due to the piping plover nesting habitat and other shore birds because their organization is directly involved with conservation efforts and can provide best management practices to not cause adverse impacts during construction and ongoing maintenance.

Although cultural resources are not anticipated to be impacted as a result of the pipeline alternatives, consultation with the Connecticut Department of Economic and Community Development – State Historic Preservation Office is required to satisfy USACE and Connecticut DEEP permitting requirements.

As part of agency consultation, pre-application meetings should be scheduled with all permitting agencies, and/or other regulatory agencies at the onset of the project to present project details, discuss the schedule and determine each agencies' requirements for permit application submission. For the purposes of this feasibility study and preliminary scheduling it is assumed that current information associated with threatened and endangered species, cultural resources or other sensitive resources is sufficient and additional studies/surveys will not need to be performed.

7.3 AGENCY APPROVALS/PERMITTING

There are numerous permits/approvals or coordination/notification that will be required for the construction of the new outfall pipeline. The following subsections discuss each of the agencies that will require a permit/approval or coordination/notification to advance the project. It should be noted that this list of agencies is based on a review of the current scope of the project, informal discussions with USACE, Connecticut DEEP and the West Haven and New Haven Harbormasters. It is possible that other agencies or stakeholders that need to be involved will be identified during the consultation process and agency pre-application meetings as discussed below.

7.3.1 United States Army Corps of Engineers

The USACE regulates work and structures that are located in, under or over any navigable water of the U.S. as defined in 33 CFR 329 that affect the course, location, condition or capacity of such waters; or the excavating from or depositing of material in navigable waters according to Section 10 of the Rivers and Harbors Act of 1899. All of the pipeline alternatives will involve construction activity in and placement of a pipeline under the navigable water of New Haven Harbor and associated tributaries.

The USACE also regulates the discharge of dredged or fill material into waters of the U.S. as defined in 33 CFR 328 according to Section 404 of the Clean Water Act. New Haven Harbor, while a Section 10 jurisdictional water of the U.S., is also a Section 404 water of the U.S. and any discharge of dredge or fill material is subject to the requirements under the Clean Water Act.

As part of the design, dredged material from the harbor is currently proposed to be transported and ultimately dumped offshore. The USACE regulates the transportation of dredged material for the purpose of disposal at sea under Section 103 of the Marine Protection, Research and Sanctuaries Act.

Various general permits are available for all of these activities in regulated waters of the U.S.; however, the typical threshold for total disturbance is capped at ½ acre. Given the length of the pipeline from the WPCF, a total of more than ½ acre of disturbance is anticipated. As a result, an individual permit review would likely be required.

Additionally, total volume of anticipated dredge material will require review and must be sampled and tested to demonstrate that the material is "clean" free from toxic pollutants in toxic amounts to be disposed of at sea. It was noted by the New Haven Harbormaster that PCB contaminants have previously been found in some areas of the harbor and its tributaries and contaminants may be present in the area of the pipeline alignments.

7.3.2 United States Coast Guard

The United States Coast Guard (USCG) regulates navigable waters and reviews all projects that have the potential to affect navigability through Executive Order 10173, the Magnuson Act (50 USC §191), the Ports and Waterways Safety Act of 1972, as amended (33 USC §1221, et seq.) and the Maritime Transportation Security Act of 2002 (46 USC Section 701). The USCG is responsible for all matters related to navigational safety, vessel engineering and safety standards.

As detailed in this report, the new pipeline will be constructed under the existing New Haven Harbor bottom and terminate at the edge of the harbor shipping channel which would not permanently affect navigability or safety standards; however, construction of the pipeline from the aforementioned barges has the potential to temporarily affect navigability and safety standards. As a result, the USCG would need to review the overall project. It is anticipated that the USCG would provide comments and input to the USACE on issuance of the Section 10 of the Rivers and Harbor Act/Section 404 of the Clean Water Act permit approval and not a separate approval from USCG. For construction, USCG will need all the information submitted to them necessary to issue a Notice to Mariners regarding construction and presence of the construction barges installing the new pipeline.

7.3.3 Connecticut Department of Energy and Environmental Protection

Connecticut DEEP's Land and Water Resource Division (LWRD) and Office of Long Island Sound Programs (OLISP) regulates all activities conducted within tidal wetlands and in tidal, coastal or navigable waters in Connecticut as outlined in the Structures, Dredging and Fill Act (Connecticut General Statues [CGS] Sec. 22a-359 – 22a-363f, inclusive) and the Tidal Wetlands Act (CGS Sec. 22a-28 – 22a-35, inclusive). Under this review three permit processes are available:

- Certificates of Permission – authorization for minor activities related to previously authorized work and could include maintenance dredging and substantial maintenance of existing structures.
- General Permits – authorize specific minor activities such as small residential docks, boat moorings, swim floats, pump-out facilities at marinas among others where the environmental impacts are generally well understood or documented and do not require detailed review.
- Individual Permit – authorization for new construction and other work for which the environmental impacts are not well understood or documented and require a detailed review. This process provides the public with an opportunity to comment.

Based on these review processes, it is anticipated that constructing one of the new pipeline alternatives and disposing of dredge material at sea will require an individual permit review as the potential environmental impact is not known and could potentially be significant. Similar to USACE requirements, approval to dispose of dredge material at sea requires sampling of the material to demonstrate that it is free from toxic pollutants in toxic amounts.

7.3.4 West Haven and New Haven Harbormasters

The powers and duties of the Harbormasters and Deputy Harbormasters are established in the CGS, including Sections 15-1 through 15-9 among other sections. The primary responsibility is keeping navigation channels and established fairways clear of temporary and permanent obstructions. Harbormasters and Deputy Harbormasters are also empowered to enforce the provisions of the CGS concerning removal of abandoned and derelict vessels, including Sec. 15-11a and 15-140c.

Although the USACE is the primary agency for granting Federal approval of mooring locations the USACE has delegated to the Harbormaster approval authority for the installation of individual, noncommercial moorings. Section 15-8 of the CGS gives the Harbormaster authority to assign mooring locations and require all mooring users to apply for mooring permits.

The tidal waters, navigable waterways, submerged lands, and intertidal areas adjacent to Connecticut's shores are held in trust for the general public by the State of Connecticut. The Harbormaster's local knowledge is a valuable resource for assisting the various State and Federal regulatory agencies, including the USACE and Connecticut DEEP, in ensuring that these Public Trust waters are managed for the benefit of the general public. In this regard, Harbormasters are provided the opportunity to review applications for state and federally regulated activities within their jurisdictional waters, including applications for docks, piers, dredging, and other work affecting navigable waters. Harbormasters are asked by the regulatory agencies to evaluate what effect the proposed activity may have on navigation and to provide a written recommendation for approval, disapproval, or modification of the proposed activities presented in the application. Although Harbormasters are involved in the review of a project through the state permitting process, both the New Haven and West Haven Harbormasters should be coordinated with directly to ensure their input is incorporated into overall project design, schedule and construction.

7.3.5 Commercial Shellfish Beds

Numerous municipal jurisdictional commercial shellfish beds occur within New Haven Harbor and any of the potential pipeline routes will need to be constructed through these harvesting beds. Any impact to shellfish beds will need to be minimized to the greatest extent practicable and require coordination with the local Shellfish Commission and harvesting entity of the beds.

7.3.6 Southwest Soil and Water Conservation District

The soil and water conservation district provides erosion control and stormwater plan review. Erosion control will be necessary for both the terrestrial and aquatic components of constructing the new pipeline. On the terrestrial side, erosion of soils into the nearby New Haven Harbor will need to be minimized through Best Management Practices (BMPs) such as silt fence or filter sock from pipeline installation and any on-shore construction staging areas. In-water work would require a turbidity barrier to prevent any siltation of adjacent waters, particularly to prevent indirect impact to adjacent shellfish harvesting beds. The total project area will exceed 1 acre in size and would require a General Permit for the Discharge of Stormwater from Construction Activities from Connecticut DEEP.

7.4 TIMING RESTRICTIONS

Timing restrictions are required to protect sensitive species from harm during times when they are most vulnerable to anthropogenic impacts, typically during migrations, nesting/brooding/spawning or other critical activities in their life cycle. Given the known presence of piping plover, commercial shellfish beds and important fisheries; timing restrictions that will likely apply to this project may include, but are not limited to the following:

- In-water Construction work – restricted January 15 through May 31 for winter flounder, or as directed by NMFS.
- Construction work in or near the piping plover nesting areas – may require a timing restriction between March 15 and August 31 (nesting/brooding season). This is based on New Jersey's requirements since Connecticut DEEP and USFWS have not published a timing restriction range for Connecticut piping plover populations.

8 Conclusions and Recommendations

Three main alternatives were analyzed for the replacement of the West Haven WPCF outfall line. The cut and cover alternative is a shallow pipe flowing by gravity from the Chlorine Contact Tank to the Outfall Diffuser, the deep outfall (tunnel) alternative is a tunnel from the Chlorine Contact Tank to marine recovery shaft in the subaqueous zone and a shallow pipe from the marine recovery shaft to the Outfall diffuser. This alternative also flows by gravity. The pumped alternative utilizes a shallow pipe which flows by gravity during most of the year and is pumped only during periods of storms when gravity discharge is incapable of passing the entire WPCF effluent discharge or during occurances of higher flows and certain high tide cycles. This alternative follows the same pipeline alignment as the cut and cover alternative(s).

Environmental impacts for the alternatives are slightly different. The tunnel alternative is anticipated to have the lowest impact as it is beneath the harbor floor for more than half the alignment and essentially minimizes impacts to shellfish, fish, and birds for the first part of the overall route. However, for the subaqueous zone section of the alignment, the tunnel alternative will have the same environmental issues as the cut and cover alternative(s). For the cut and cover alternatives, the alignments parallel to the existing pipe (both north and south) would have greater environmental impact than the tunnel alternative because of the increased disturbance to the harbor floor and excavation in the vicinity of the piping plover habitat. The alignment which re-uses the existing outfall alignment is anticipated to have greater environmental impact than the parallel lines because of the increased length of the construction time, and the greater duration of bypass pumping. The cut and cover alternative which crosses over to Morse Point is anticipated to have the same environmental impact as the two parallel alignments as it disturbs approximately the same area. The cross over to Morse Point may have less risk of environmental impact to marine life as it is easier to control sediment when working on land; however, this alternative may be seen as more disruptive to the bird nesting and brooding sites.

In comparing the alternatives, all of the cut and cover alignments in either gravity or pumped discharge are very similar in cost. The tunnel alternative has a significantly greater cost than any of the other alternatives. The pumped discharge alternative is currently estimated to have a slightly lower cost as compared to the gravity cut and cover alternative(s). The difference in overall cost between the pumped outfall alternative and the gravity cut and cover outfall alternatives is less than 4%, which at this preliminary stage of development for each alternative should be considered as similar costs.

Permitting/environmental reviews and agency consultations will need to be conducted to verify that no additional concerns which are presently unknown would either preclude one or more of the outfall line alternatives under consideration or potentially extend the permitting schedule and increase the project costs associated with the new outfall pipeline. To confirm the location, arrangement, and headloss required for the outfall diffuser, water quality modeling and localized dilution/dispersion modelling may need to be completed. Further information on the marine environment (e.g. waves, currents) is also required for the structural design of the outfall line. Advanced testing of soils for toxic pollutants should be performed to determine if the excavated materials may be disposed of at sea or if more costly disposal of contaminated materials needs to be included in the design. Bathymetric surveys should be completed to determine the current topography of the harbor floor along the alignment and geotechnical investigations to confirm the soils present along the exact alignment will be required.

Based on the analysis above, the cut and cover alternatives are preferred over the tunneling alternative mainly based on lower overall cost. As the cut and cover alternatives are very similar in costs at this time, final selection of an alternative alignment will be made once further agency input has been made which would take place prior to starting design development. Selection of the pumped versus gravity discharge will be determined at a later date as well, and will be based on the outcome of additional environmental/permitting reviews, agency meetings, and completion of an outfall diffuser study. It is noted that the pumped outfall line alternative may be the only feasible solution if dispersion/water quality studies conclude that the diffuser system requires smaller/jet port type openings in lieu of the open port style diffuser that has been assumed for the gravity pipeline option.