SHELTER ISLAND YACHT BASIN TIDAL FLUSHING PROJECT

ENGINEERING FEASIBILITY AND CONSTRUCTABILITY REPORT

August 5, 2016

Prepared for:
Unified Port of San Diego

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Table of Contents

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1. Introduction

1.1. Project Summary and Background

The Shelter Island Yacht Basin (SIYB) is a recreational marina located at the northern end of San Diego Bay. SIYB was placed on the 1996 Clean Water Act Section 303(d) List of Water Quality Limited Segments for dissolved copper. The elevated levels of dissolved copper in the harbor are correlated to the use of copper-based coatings applied to ship hulls and limited tidal flushing of the harbor. The Port of San Diego has authorized this more detailed study by the Rick Engineering Company Team which includes Moffat & Nichol and TerraCosta Consulting Group. This study will address feasibility, constructability, and opinion of probable cost estimates for a submerged culvert connection between SIYB and America's Cup Harbor to increase tidal flushing, which should reduce dissolved copper concentrations.

1.2. Initial Study and Alignment Selection

In February 2013, Weston Solutions prepared a preliminary report titled "Shelter Island Yacht Basin Tidal Flushing Modeling and Engineering Feasibility Study." The study evaluated the potential effectiveness of reducing dissolved copper levels in SIYB by a tidal flushing system, performing modeling simulations of enhanced flushing scenarios and provided preliminary engineering feasibility assessments and cost estimates. Two potential flushing locations were studied: an approximately 750' long connection between SIYB and San Diego Bay (SDB), and an approximately 340' long connection between SIYB and America's Cup Harbor (ACH). Modeling of the flushing scenarios using a 12' wide x 8' high reinforced concrete box (RCB) culvert and a 54" reinforced concrete pipe (RCP) connection at both locations was compared to a baseline scenario with no enhanced flushing. The results of the simulations showed that a connection between SIYB and ACH produced the greatest amount dissolved copper reduction in SIYB, along with having a lower construction cost. The study also found that the RCB connection had a higher potential of reducing copper concentrations than a single 54" RCP, and that five parallel 54" RCP's would be required to have equivalent flushing capabilities as the box culvert. This report will address the feasibility of constructing the SIYB to ACH connection, using both the RCB option and the five parallel RCP options.

1.3. Existing Site Conditions

The proposed SIYB to ACH connection crosses Shelter Island Drive, approximately 1000' south of the entrance to Shelter Island (See Figure 1):

Figure 1: Vicinity Map

(While Shelter Island Drive runs in a northwest/southeast direction, for the purposes of this study, we will reference the road running in a north/south direction)

Existing utilities and as-built drawings along Shelter Island Drive were provided by the Port and used to locate existing utilities. In addition to as-built drawings and CAD files, field verifications and supplemental design surveys were completed to identify utility locations and invert elevations of existing sewer manholes.

RICK Engineering has performed supplemental field survey and developed an existing topographic base map locating building footprints, docks and slips, surface improvements, traffic striping, and utilities in the vicinity of the proposed culvert. Pothole and utility markings present at the time of the survey were also used to locate existing utilities in and adjacent to the roadway. A bathymetric survey was performed to generate topography underwater on both the SIYB and ACH sides of the culvert.

Through field investigations, record document review, and field surveys, the existing utilities and infrastructure that will be affected by the construction of the culvert can be summarized by the following:

1. An SDGE transformer in the parking lot west of Shelter Island Drive.
2. Street light conduits run underneath the west sidewalk of Shelter Island Drive. A joint utility trench containing cable TV conduits and a gas line run along the south side of the roadway.

3. A 12” water line and 20” sewer line are also located along the west side of the roadway. The sewer line is approximately 10.5’ deep.
4. Electrical/telephone conduits run along the east side of the roadway.
5. A stormwater runoff collection tank in the Shelter Island Boatyard (See Figure 2)
6. An existing sheet pile bulkhead in the Shelter Island Boatyard (See Figure 3)
7. Roadway, sidewalk, and landscape impacts
8. Parking lot for the Silver Seas Yacht and S.C. Yacht Brokerage (See Figure 4)
9. Rock protected slope at the America’s Cup Harbor (See Figure 5)
10. Shelter Island Boatyard and Maintenance Facility
11. Existing Docks located in the America’s Cup Harbor

Figure 2: View along the culvert alignment, facing east towards Shelter Island Boatyard and ACH. Note adjacent office building with exterior staircase. Also note the large stormwater collection tank inside the boatyard.

Figure 3: View of the sheet pile bulkhead at the Shelter Island Boatyard, at the proposed culvert outfall location

Figure 4: View along the culvert alignment, facing west towards parking lot and Shelter Island Yacht Basin. Note existing transformer in background.

Figure 5: View of the outfall location and riprap protected slope at Shelter Island Yacht Basin, facing the Silver Seas Yacht building.

2. Horizontal and Vertical Alignment

The proposed tidal flushing system crosses through a parking lot between 2385 and 2353 Shelter Island Drive on the west side (which are boat sales/repair and supply shops), and through the Shelter Island Boatyard at 2330 Shelter Island Drive on the east side. An office building at 2390 Shelter Island Drive lies north of the culvert. The horizontal alignment of both the RCB and five RCP options would need to be laid out such so that the culverts would not be in the zone of influence of the adjacent buildings (see Figure 6 below).

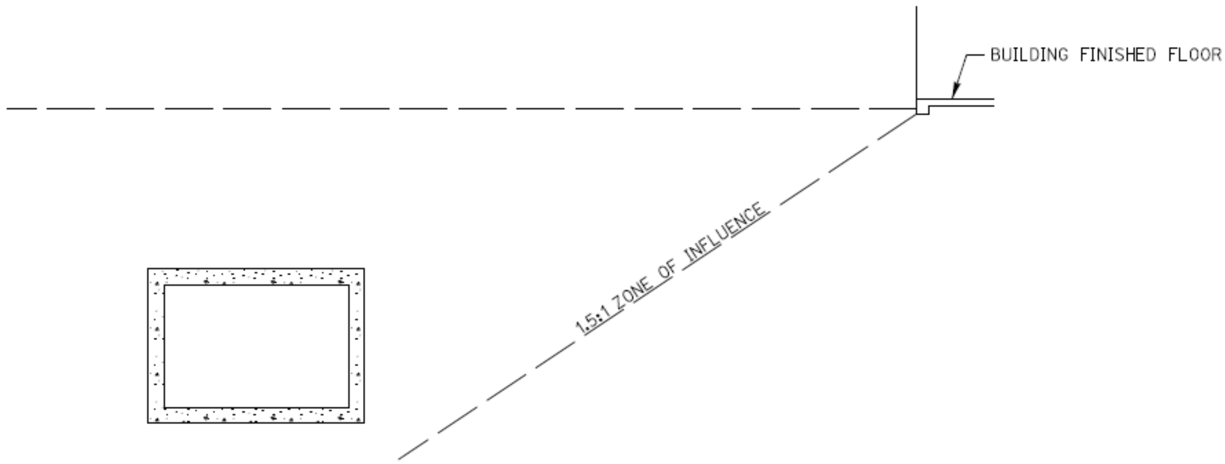


Figure 6: Typical Building Influence Zone

The culverts would need to pass underneath the existing utility lines in Shelter Island Drive. The deepest utility line in the roadway is an existing 20" sewer, which is approximately 10.5' deep. The flowline of the flushing system will be level across the culvert. The culverts would be set to provide at least 1' clearance (2.5' clear for microtunneling) below the sewer line.

See Appendix A for 30% improvement plans for the RCB and 5-RCP culvert alternatives.

3. Construction Methods/Issues

3.1. Excavation – RCB Alternative

A trench would need to be excavated to facilitate the construction of the RCB culvert. A preliminary geotechnical assessment performed by TerraCosta Consulting Group anticipates the site to primarily consist of sands with variable silt and clay contents. A sheet-pile shoring system for the trench excavation would need to be utilized in order to stabilize adjacent soils, minimize impacts to adjacent structures, and reduce the footprint of the excavation. Analysis of the soil pressures indicated that the sheet piles would need to extend approximately 30' below the bottom of excavation. Because of the low cohesion of the soils, overexcavation and recompaction at the bottom of the shoring will be required to support the proposed culverts as well.

The trench required for construction would need to accommodate 5'on each side of the culvert. For the 12'x8' RCB, the trench would need to be 24' wide (assuming a 1' box thickness). The bottom of the trench would need to be outside of the adjacent building's zone of influence. The finished floor elevation of the office building fronting the boatyard is at approximate elevation 11.6, and the bottom of the RCB trench would be at elevation -9.5. Assuming a 1.5:1 zone of influence, the trench would need to be set a minimum 31' away from the adjacent building. The buildings across the street from the boatyard also have an approximate finished floor elevation of 11.6 and would require the same separation to the culvert (See Figure 7 below).

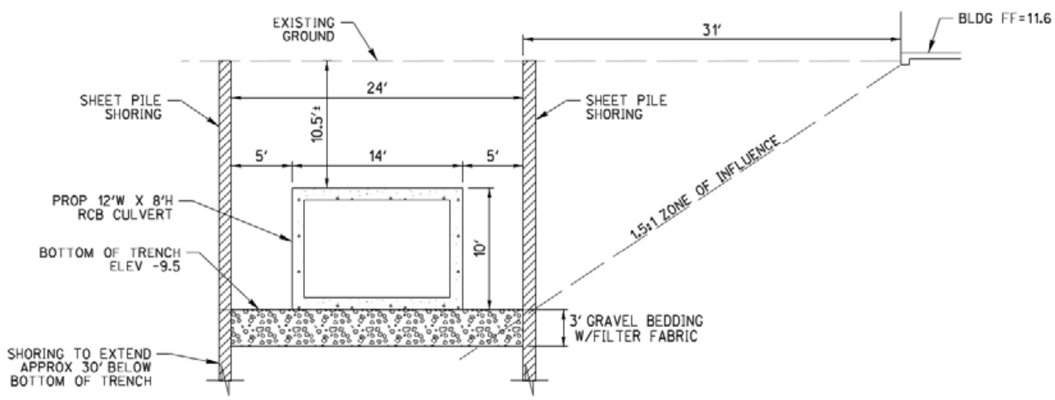


Figure 7: Typical Section for 12'x8' RCB Alternative

The depth of the proposed culvert is below the existing mudline at each end of the culvert, so dredging of the harbor within the vicinity of both outfalls will be required to allow the passage of flow through the crossing. The dredging should extend 10' minimum past the sides of the culvert opening at both basins in order to minimize sediment buildup within the crossing, and will need to extend approximately 100' into SIYB and ACH to daylight at both outfalls. Dredging of the harbor would require permitting through the U.S. Army Corps of Engineers

See Appendix A for a 30% improvement plan for the RCB crossing

3.2. Microtunneling – RCP Alternative

Preliminary structural and geotechnical assessments have found that the use of trenchless methods for the construction of the multiple 54" RCP option underneath Shelter Island Drive is feasible. The geotechnical study concluded that microtunneling is the most viable trenchless method for constructing the 54" RCP culverts underneath the roadway. The pipes could be microtunneled through almost the entire length of the crossing, which would eliminate the need to temporarily relocate utilities in the roadway during construction and minimize impacts to traffic and access to the impacted businesses. Launch and receiving pits will need to be excavated, shored, and dewatered at both ends of the culvert, but the amount of excavation and impact to properties will be significantly less than the cut and cover construction method.

As with the RCB alternative, dredging of the SIYB and ACH will be required in the vicinity of the outfalls in order to allow flow through the pipes. The length of dredging into the harbors at either end of the culverts will be less than that required for the RCB alternative since the pipes are shallower (approx. 50' at both outfalls), although the dredging quantity is roughly the same due to a wider trench.

To facilitate microtunneling, the horizontal spacing between the RCPs will need to be on the order of 2.5' apart, as would be the required vertical separation from any existing utilities. The total width of the crossing would be approximately 37.5' (assuming a 6" pipe thickness), and the flowline of the culverts would need to be set at elevation -6 to allow for 2.5' minimum clear from the existing sewer, see Figure 8 below:

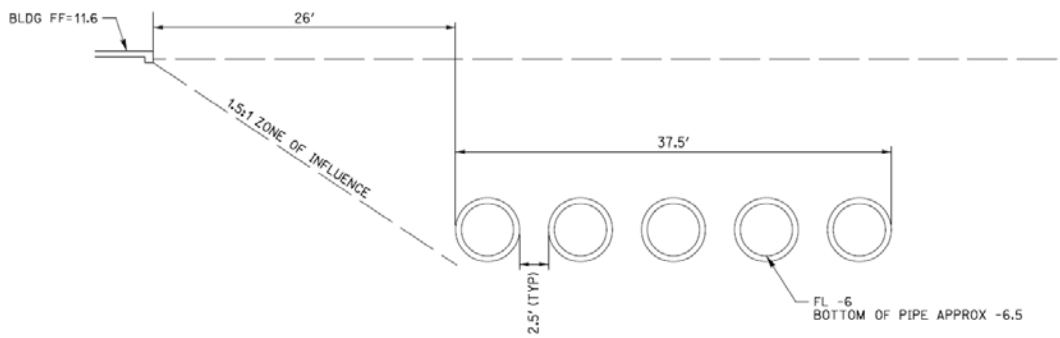


Figure 8: Typical Section for 54" RCP Alternative

As shown in the figure, given the floor elevations of the adjacent buildings and the flowline of the culverts, the pipes would need to be approximately 26' away from the buildings in order to be located outside of the structure's 1.5:1 zone of influence. The spacing between the adjacent buildings allows for the total microtunneled culvert width to be just outside of that influence zone. However, as stated previously, additional excavation is required near either end of the culverts to allow for the launching and receiving pits for the microtunneling operation, and construction of the proposed headwalls. This means that the shoring required for the excavation would encroach into the zone of influence. Keeping out of a 1.5:1 zone of influence is a "rule of thumb" that is used to determine whether a more detailed assessment would be required, in regards to excavations. The zone of influence represents the horizontal limits at the ground surface where ground settlements may occur. Encroaching into the zone of influence or even in close proximity to a building does not necessarily preclude microtunneling. However, a more detailed analysis of the site's soils and the adjacent building's foundation would be warranted to determine possible needs for a stiffer shoring system if or any structural impacts to the affected buildings will be encountered.

See Appendix A for a 30% improvement plan for the 5-54" RCP crossing

3.3. Dewatering

Because the tidal flushing culvert is submerged, groundwater will be encountered during excavation and dewatering will need to be accounted for during construction. Cofferdams will also need to be constructed in SIYB and ACH at the outfall locations. The sheet piles would only be able to slow groundwater seepage into the trench, unless they penetrate an impermeable layer of soil (which is unlikely according to the existing soils information). Because of this, the bottom of excavations will need to be designed with a filter-wrapped gravel blanket to collect groundwater seepage, which would then be removed by a series of pumps. Excavated soil would need to be dewatered before storage or transported offsite. The culvert joints would need to be watertight as well.

4. Construction Impacts

4.1. Property Impacts

Portions of the parking lots serving 2385 and 2353 Shelter Island Drive in the SIYB will be impacted during the construction of the culvert. The culvert alignment crosses under a 50' commercial driveway approach which straddles both parking lots, but there are additional driveway approaches to the north and south which will still allow access to both properties. The rip-rap protecting the existing slope at the SIYB outfall would need to be temporarily removed and replaced to allow for the headwall construction.

The Shelter Island Boatyard will be significantly impacted during construction, as the culvert alignment crosses under the boatyard and through the existing sheet pile bulkhead that supports it. The existing concrete slab will need to be cut and removed to excavate the trench or tunneling pit, and an additional 15' of the slab beyond the excavation limits will need to be removed and reconstructed after the culvert is completed. If a trench were to be excavated through the boatyard, access to the repair shops on 2390 Shelter Island Drive fronting the yard will be cut off during construction as well. Regardless of which the culvert alternative is chosen, one of the boatyard's docks would need to be temporarily removed and access to the boat docks reconfigured during the construction of the culvert. Dredging will be required in both SIYB and ACH within the vicinity of the culvert openings, to accommodate flow through the crossing. The amount of harbor dredging of the five 54" RCP option will be less than for the RCB option due to their shallower depth. A portion of the existing sheet pile bulkhead at the east end of the boatyard will need to be demolished and reconstructed to accommodate the culvert outlet. See Section 5 for conceptual details of the bulkhead reconstruction.

A staircase leading up to the 2nd floor of 2390 Shelter Island Drive may either need to be temporarily relocated, or its foundation will need to be underpinned during construction if possible (See Figure 11).

At the time of this study, there is another project which proposes to replace the boatyard's existing crane with a new 150MT gantry crane. The project would also add two concrete runways adjacent to the existing piers to support the use of the new crane, with new floating docks underneath the runways. Portions of existing floating docks would be removed as well to facilitate the movement of boats between the piers. The limits of this crane replacement project are outside of the limits of work of the proposed tidal flushing construction, and the projects do not impact each other.

Figure 9: View of existing Shelter Island Boatyard docks, which would need to be temporarily removed during the culvert construction and harbor dredging.

Figure 10: Inside Shelter Island Boatyard. Note repair shops fronting boatyard which would be inaccessible during construction.

Figure 11: Staircase at 2390 Shelter Island Drive

Figure 12: Plank leading from boatyard to docks

4.2. Roadway and Utility Impacts

The roadway, sidewalk, and other surface improvements will need to be removed and reconstructed to facilitate the trench excavation for the RCB culvert. The construction of the RCB culvert within the roadway will need to be constructed in stages in order to keep access to Shelter Island open, as Shelter Island Drive is the only connection to the mainland. Existing curb popout/planter areas within the roadway will need to be demolished and reconstructed to allow traffic to be redirected around the construction zone during each stage. The utility lines within the roadway will need to be relocated prior to construction of the box culvert, due to the sheet pile shoring. An SDGE transformer in the parking lot on the west side, and a stormwater collection tank inside the boatyard will also need to be relocated. Due to the culvert location, no public storm drain or inlets will be impacted with the project. See Appendix C for proposed construction staging, utility relocation and traffic control for the RCB alternative.

Because the 5-54” RCP option could allow for microtunneling underneath the roadway and utilities for the length of the crossing, the utilities could be protected in place and the crossing could be constructed in one stage. If a final engineering assessment finds that trenchless construction for the 5-54” RCP is not viable and cut/cover was required, excavation and utility relocation costs would be comparable to the cost of constructing the RCB.

5. Structural Engineering/Constructability Assessment

From a structural engineering evaluation, both options of the culvert connection are feasible. With proper shoring systems and cofferdams, the facilities can be constructed in place as an open cut excavation or microtunneling. The bulkhead on each end of the culverts will need to be reconstructed.

In the SIYB, the box culvert or 5-54” RCP option will exit into the basin and a structural headwall will be constructed to retain the bay floor soils (see Figure B and Figure D on the next page).

In the ACH, the existing sheet pile bulkhead will need to be modified to accommodate the culvert outfall to the ACH bay floor (See Figure A and Figure C on the next page for cross sections of the two alternative and the bulkhead retrofit requirements). As the as-built plans for the bulkhead were not available at the time of this study, additional field explorations will be needed to refine the design of the bulkhead retrofit. The Shelter Island Boatyard will be significantly impacted during construction, as the leasing areas and impacted dock areas would need to be temporarily relocated in order to facilitate the reconstruction of the bulkhead and harbor dredging.

The following is a construction sequence for the two culvert systems:

<u>RCB Culvert Alternative With Open Cut Excavation</u>

Prior to constructing the box culvert, the existing utilities in Shelter Island Drive will need to be relocated outside of the construction work area. The box culvert can then be constructed using a cut and cover method after driving sheet piles on each side of the new box. The box under the roadway will have to be constructed in phases to maintain traffic above.

A detailed construction sequence of the box culvert and headwalls follow:

1. Relocate existing utilities outside of proposed work area
2. Shift traffic to one side of roadway, drive sheet piles, and construct the gravel bed and box culvert under approximately one half of Shelter Island Drive.
3. Shift traffic to the other side of the roadway, drive sheet piles, and construct the remaining portion of the gravel bed and box culvert underneath the roadway.
4. Drive sheet piles and construct the gravel bed and box culvert through the properties adjacent to Shelter Island Drive.
5. Prepare bay floor by dredging the harbor to accommodate the culvert outlet elevations.

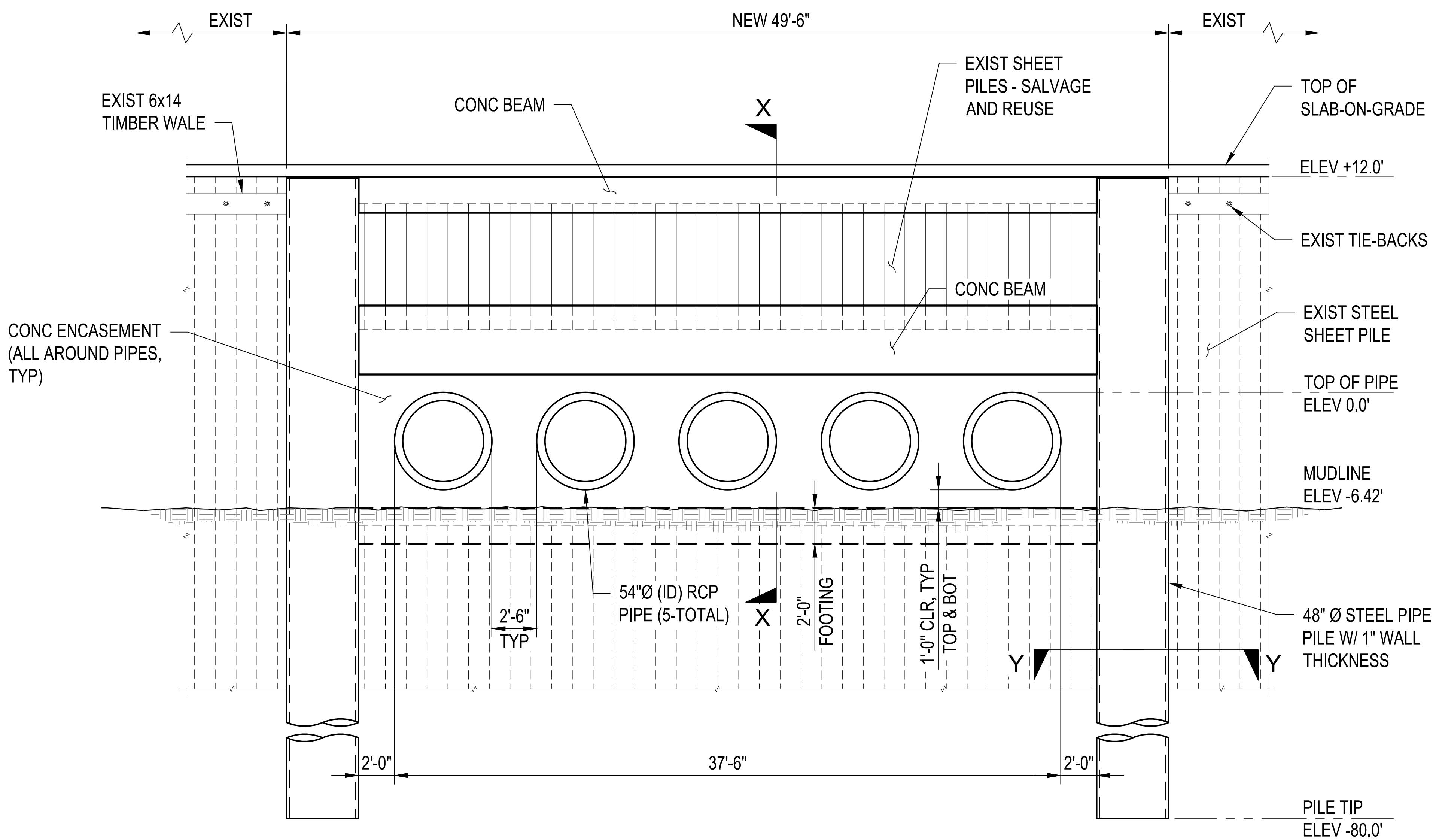
6. Construct cofferdams, and dewater for reconstruction of the existing bulkhead at ACH and the proposed headwall at SIYB.
7. Reconstruct the existing bulkhead and construct the new headwall.
8. Construct gravel bed and 12'x8' box culvert ends, and connect to reconstructed bulkhead and newly constructed headwall.
9. Remove sheet piles and backfill
10. Place slope protection.
11. Reconstruct surface treatments and landscaping.

RCP Option With Microtunneling and Open Cut Excavation at Ends of Culvert Only

Utilizing microtunneling construction techniques, the pipes can be constructed without relocation of utilities or interruption to traffic on Shelter Island Drive. A launch pit can be constructed near the SIYB and a receiving pit constructed near ACH. The distance between the pits would be approximately 225'.

A detailed construction sequence of the five pipes and headwalls follow:

1. Drive sheet piles and excavate for launch and receiving pits. Dewater pits.
2. Microtunnel approximately 225' between the two pits.
3. Construct cofferdams beyond the launch and receiving pits and dewater for reconstruction of the existing bulkhead at ACH, and the new headwall at SIYB.
4. Prepare bay floor by dredging the harbor to accommodate the culvert outlet elevations.
5. Reconstruct the existing bulkhead and construct the new headwall.
6. Excavate and place 3' gravel bed for remainder of 5-54" RCPs.
7. Place remainder of 5-54" RCPs and connect to reconstructed bulkhead and newly constructed headwall.
8. Remove sheet piles and backfill.
9. Place slope protection.
10. Reconstruct surface treatments.



ELEVATION

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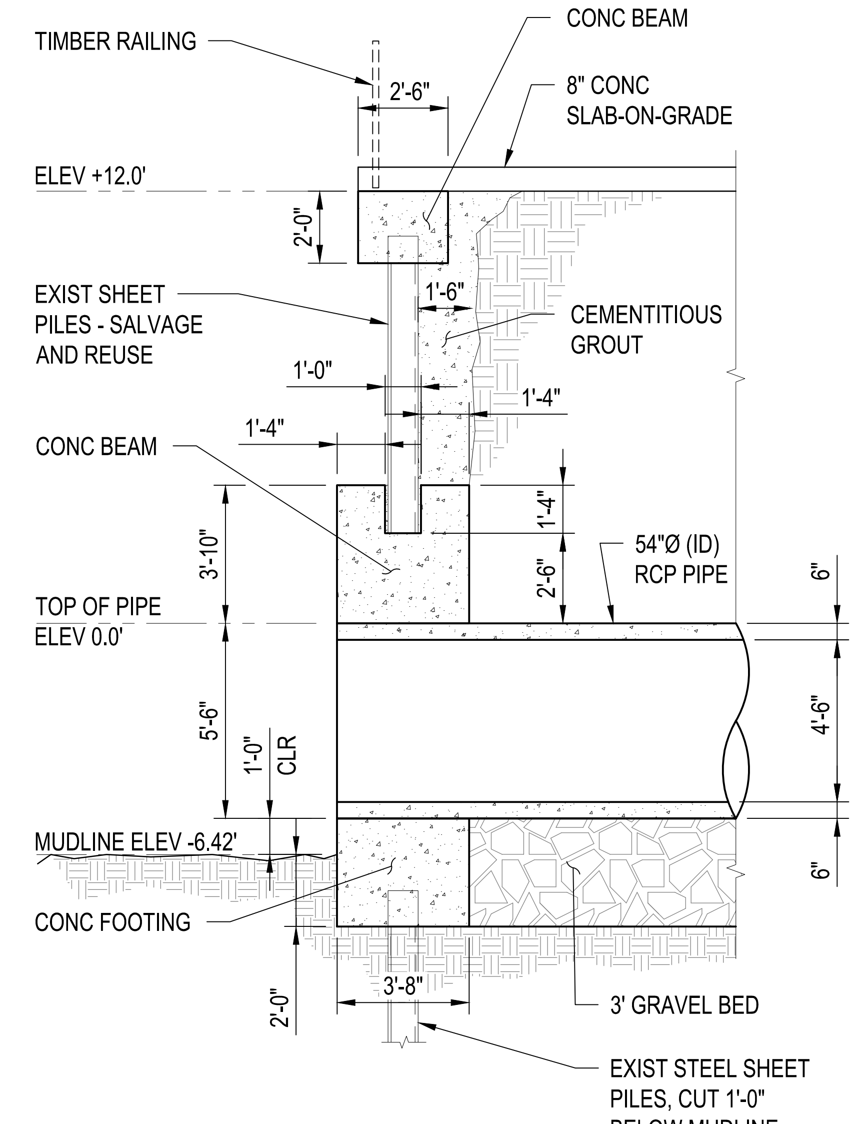

SECTION X-X

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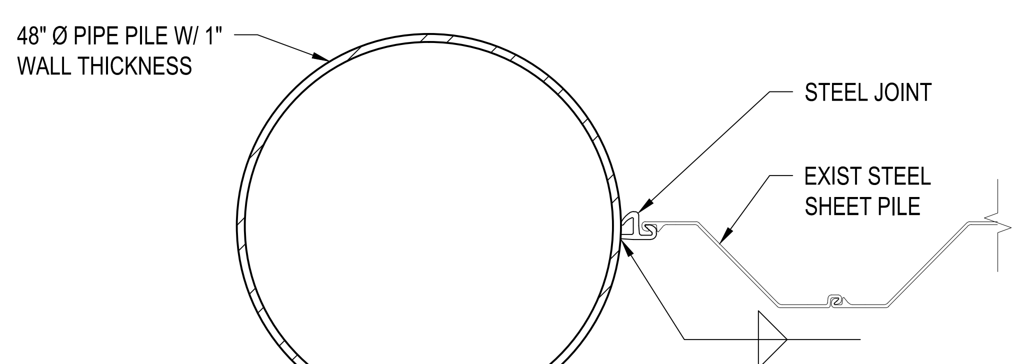


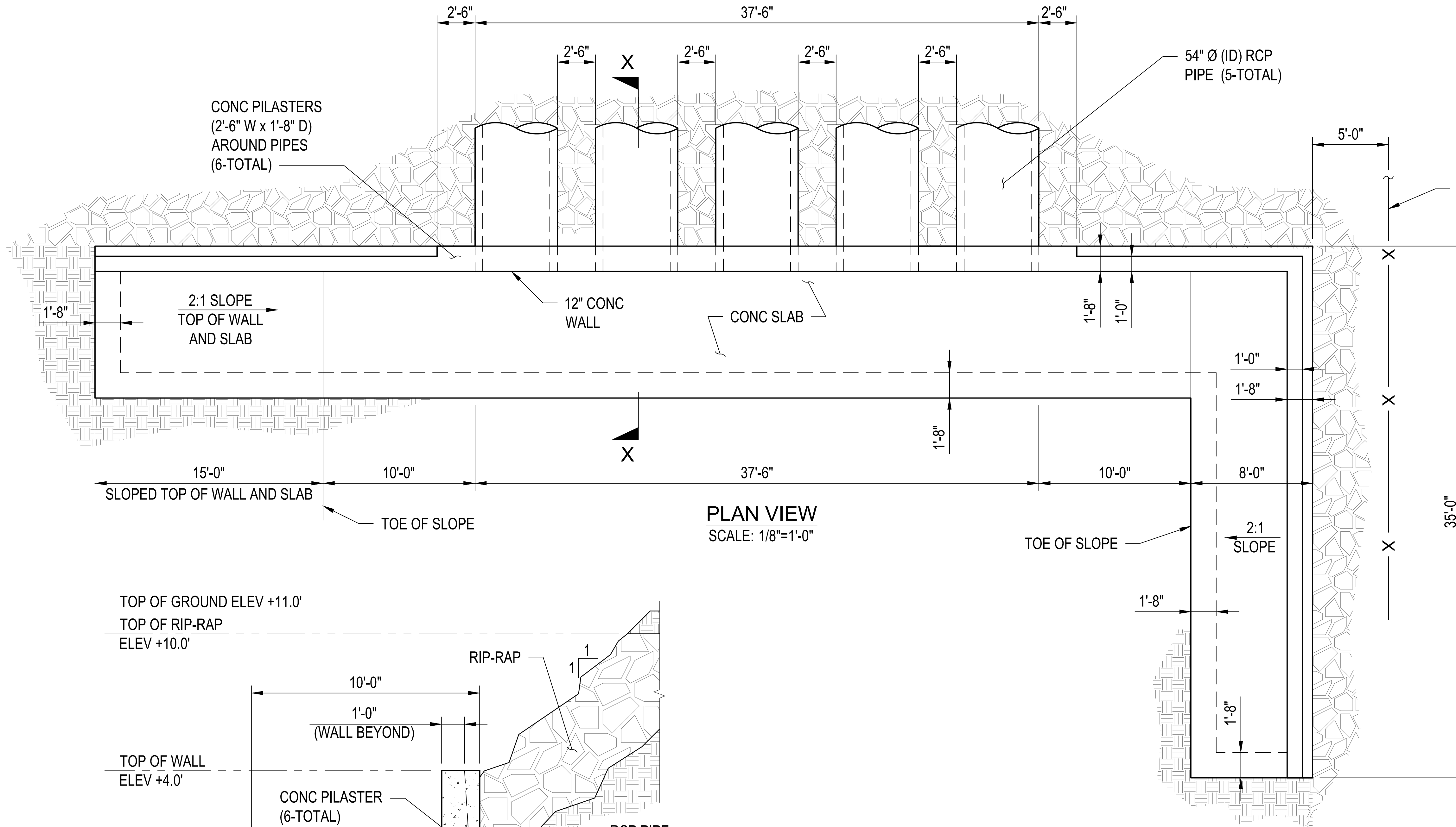
PLAN VIEW Y-Y

SCALE: 1/2"=1'-0"

NOTE:
ALL INFORMATION SHOWN IS FOR CONCEPT LEVEL PLANNING.
THESE PLANS ARE NOT FOR CONSTRUCTION

Unified Port of San Diego

DATE	moffatt & nichol	SHELTER ISLAND YACHT BASIN CULVERT	
AUGUST 2016	1660 HOTEL CIRCLE NORTH, SUITE 500 SAN DIEGO, CALIFORNIA 92108	EXIST BULKHEAD RETROFIT RCP PIPES OPTION	FIG. No. A



PLAN VIEW

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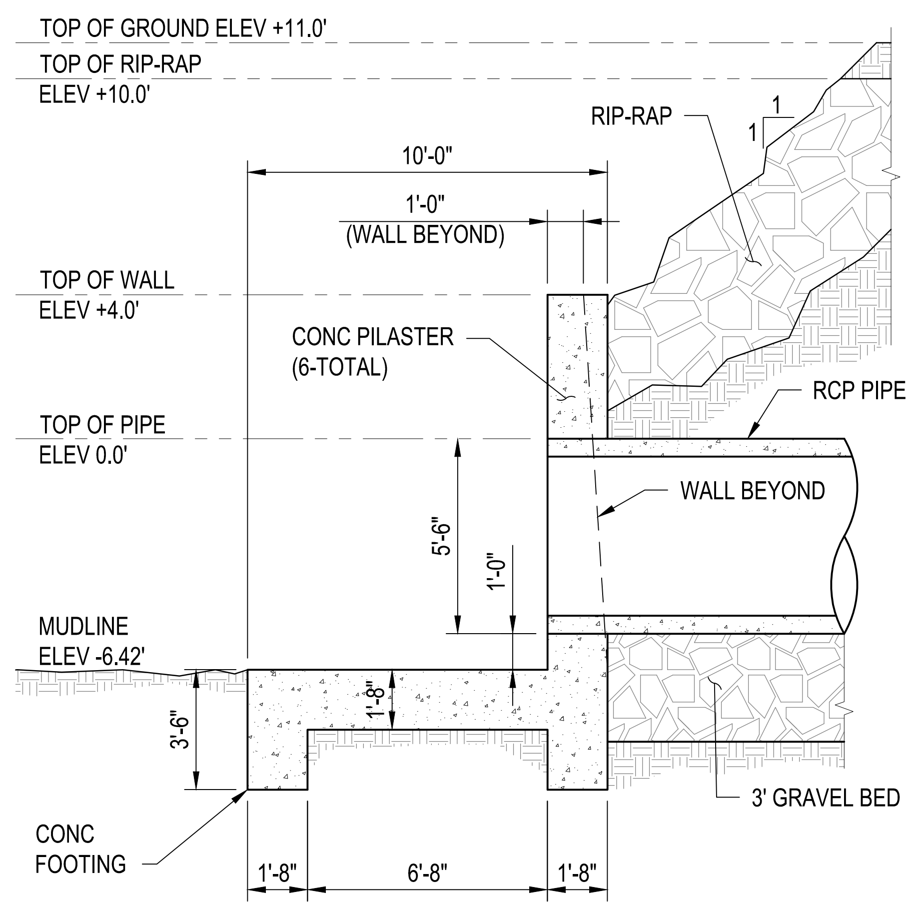

SECTION X-X

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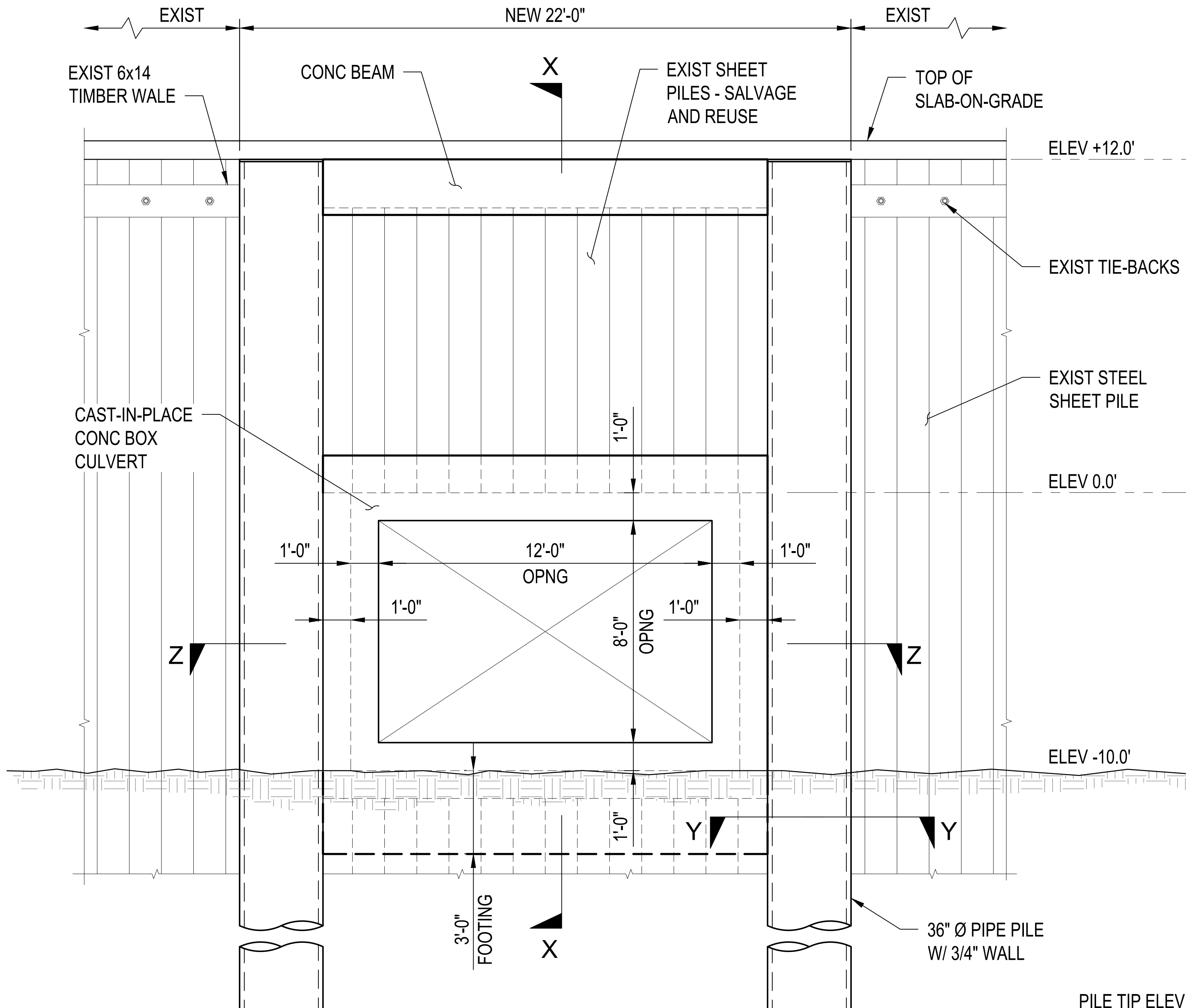
DATE	moffatt & nichol	SHELTER ISLAND YACHT BASIN CULVERT	
AUGUST 2016	1660 HOTEL CIRCLE NORTH, SUITE 500 SAN DIEGO, CALIFORNIA 92108	NEW HEADWALL RCP PIPES OPTION	FIG. No. B



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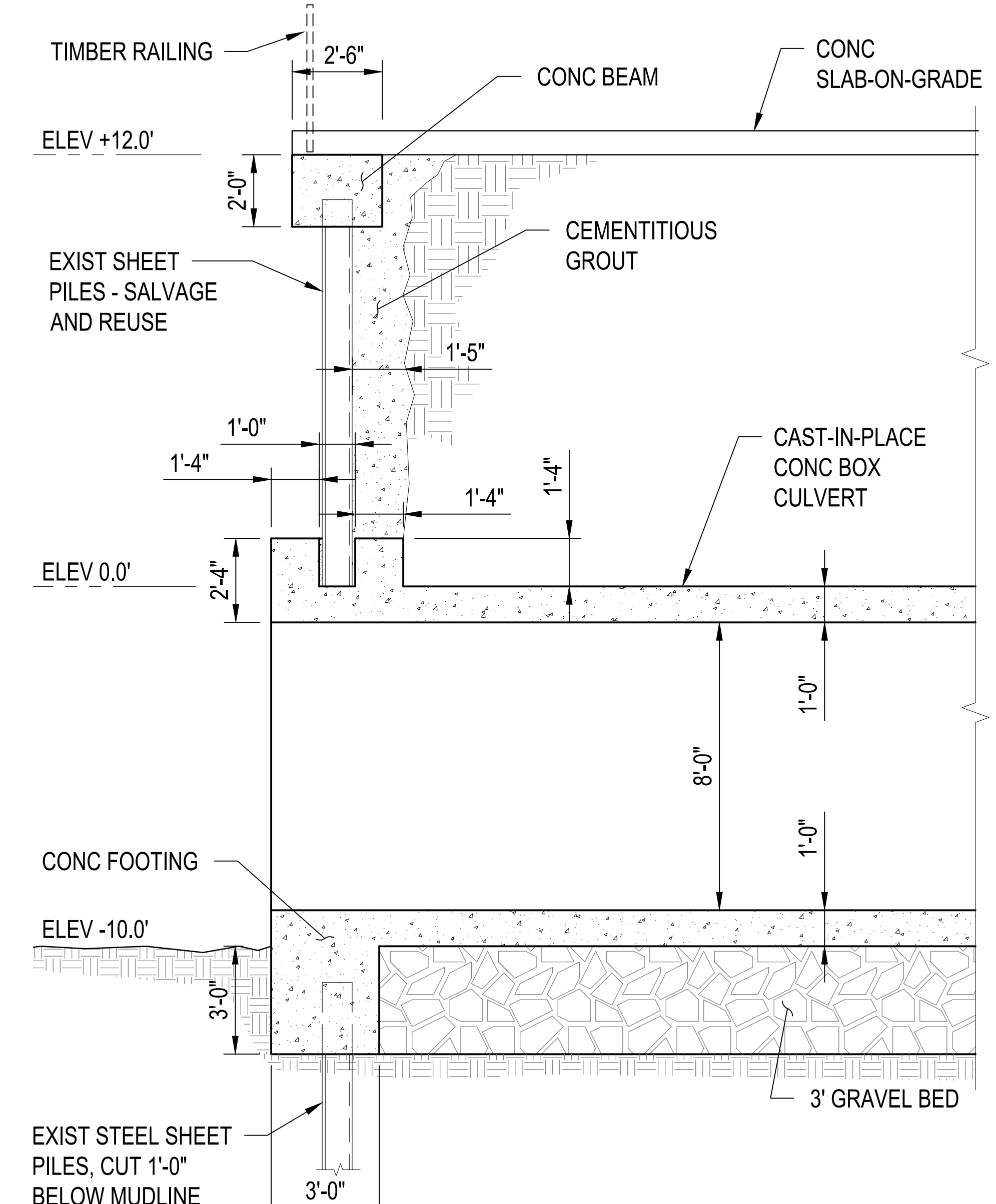

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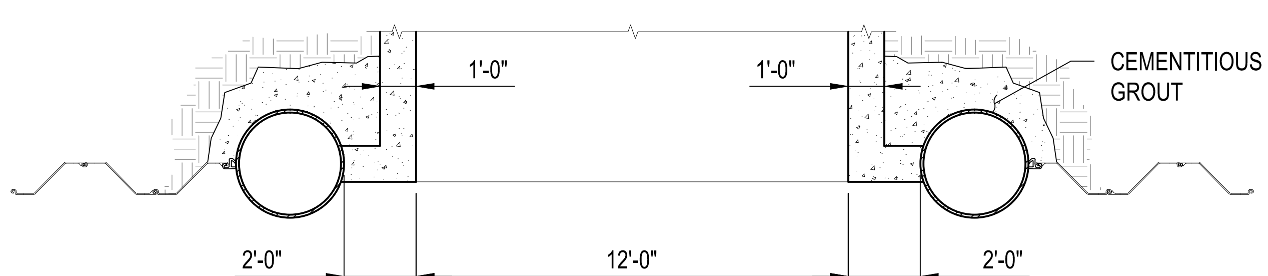

PLAN VIEW Z-Z
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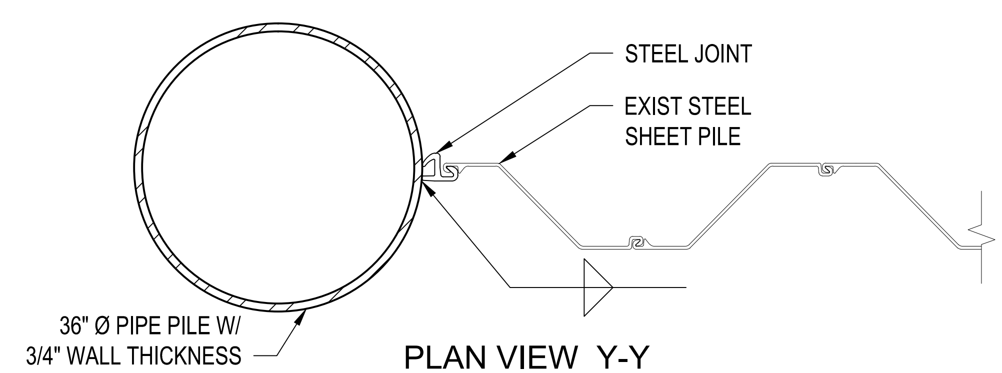

PLAN VIEW Y-Y
SCALE: 1/2"=1'-0"

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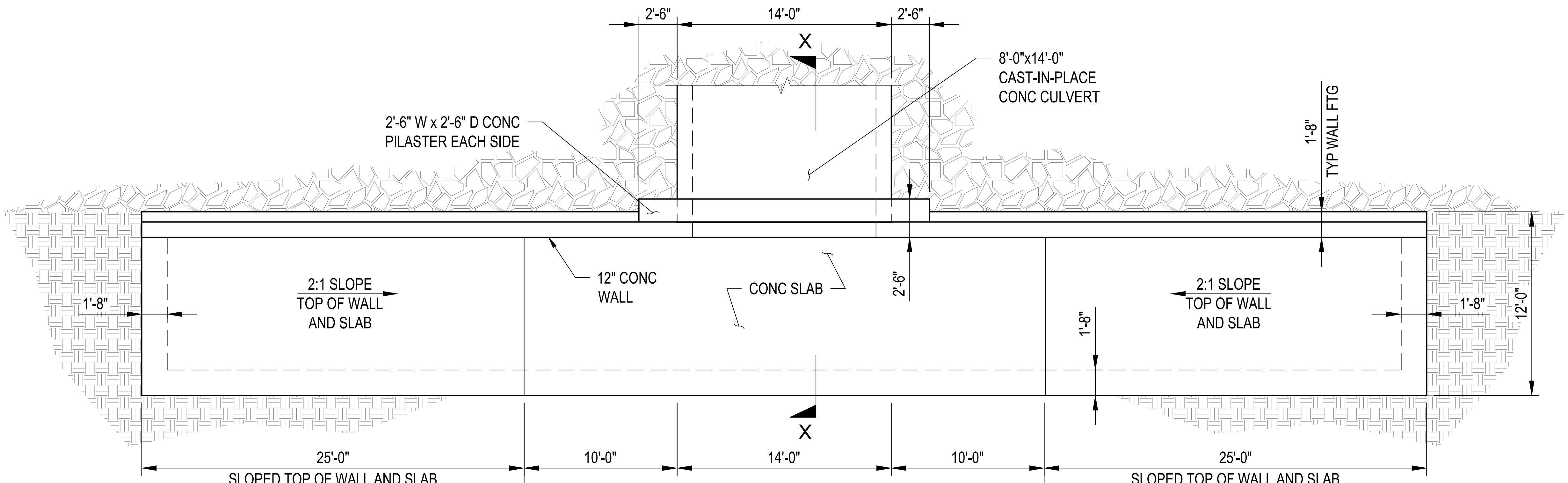
AUGUST 2016	1660 HOTEL CIRCLE NORTH, SUITE 500 SAN DIEGO, CALIFORNIA 92108	EXIST BULKHEAD RETROFIT BOX CULVERT OPTION	FIG. No. C

DWG INFO: P:\9398 - SHELTER ISLAND YACHT BASIN CULVERT\CADD_ACTIVE_EXHIBITS\9398-FIGURE 3.DWG - 9398-FIGURE 3 - LAYOUT1 | (c) MOFFATT AND NICHOL ENGINEERS



PLAN VIEW
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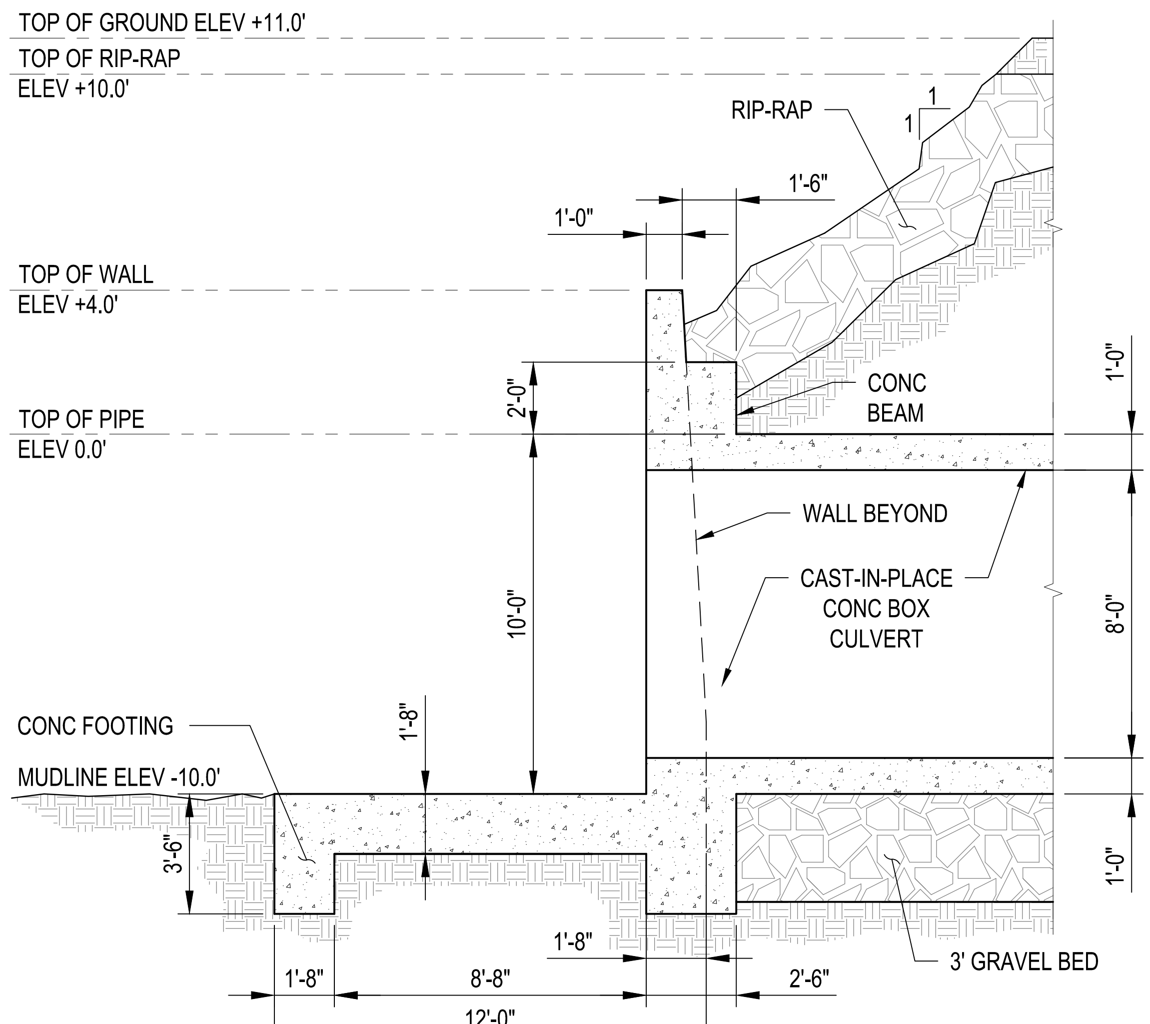

SECTION X-X
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DWG INFO: P:\9398 - SHELTER ISLAND YACHT BASIN CULVERT\CADD_ACTIVE_EXHIBITS\9398-FIGURE 4.DWG -- 9398-FIGURE 4 - LAYOUT1 | (c) MOFFATT AND NICHOL ENGINEERS

6. Geotechnical Evaluation

The two culvert options will be excavated into, and placed within, the Shelter Island access causeway. This causeway was constructed by placing hydraulic fill from the mainland onto the man-made island known as Shelter Island. This fill closed off the historic natural nearshore coastwise channel which had provided natural flushing behind the island prior to fill placement.

From a geotechnical perspective the excavations for the improvements will be performed in hydraulically placed fill soils generally comprised of sands and silty sands likely containing some debris. Depending upon the depth of the excavations, recent bay deposits of limited thickness likely comprised of very loose to loose silts and soft clays, as well as and possibly formational soils consisting of interbedded stiff to very stiff sand and silty clays and medium dense to dense silty sands, may be encountered. In addition the majority of the excavations will extend below the groundwater table which is controlled and recharged by the bay.

RCB Culvert Alternative

Our review of the proposed alignments and invert elevations of the two alternatives suggests that the proposed 12’ x 8’ concrete box culvert system will likely be constructed using cut and cover methods. The excavation will need to be shored and dewatered. We anticipate that internally braced continuous sheet-pile wall systems embedded sufficiently to reduce seepage into the excavation, will be employed. In addition, we anticipate that a three-foot filter fabric wrapped gravel mat will need to be placed at the bottom of the excavation in order to provide a firm subgrade, and to permit the collection and removal of groundwater that will be seeping into the excavations. The depth of embedment of the sheet-pile walls will need to be sufficient to maintain stability of the bottom of the excavation and to reduce seepage forces in order to mitigate impacts to the design of the shoring system. Lastly, the utilities that are located within the right-of-way of Shelter Island Drive will likely need to be relocated in order to permit the construction of the culvert across the roadway. Refer to Figure 13 for a detail of the required shoring and dewatering for the box culvert construction.

RCP Option

If selected, the five proposed 54-inch RCP conduits would likely be constructed using microtunneling techniques. The jacking pit would likely be located at the western end of the conduit alignment with the receiving pit located near the eastern outlet structure. The access pits would likely be comprised of rectangular sheet-pile structures that are internally braced. In addition to the three-foot gravel mat, the pits would likely have a concrete slab placed in the bottom of the pits in order to handle the mircrotunneling machinery and operations. In the jacking pit a thrusting slab would be required. The design of the slab may require special features to permit the transfer of the thrust forces generated by the microtunneling operations due to the location near the proposed western outfall structure. Refer to Figure 14 for a detail of the microtunneling launch/receiving pit. The soils underlying the utilities located within Shelter Island Drive would likely need to be grouted in order to protect them from potential damage associated with the microtunneling operations.

Geotechnically related construction issues associated with the project include the generation of ground displacements due to the installation of the sheet-piles, ground settlement induced by excavations, dewatering of excavations and microtunneling access pits, and the processing and stockpiling of excavated materials. In addition, a closer evaluation of impacts to the adjacent building structures would need to be performed to make sure that building structural impacts would be minimized.

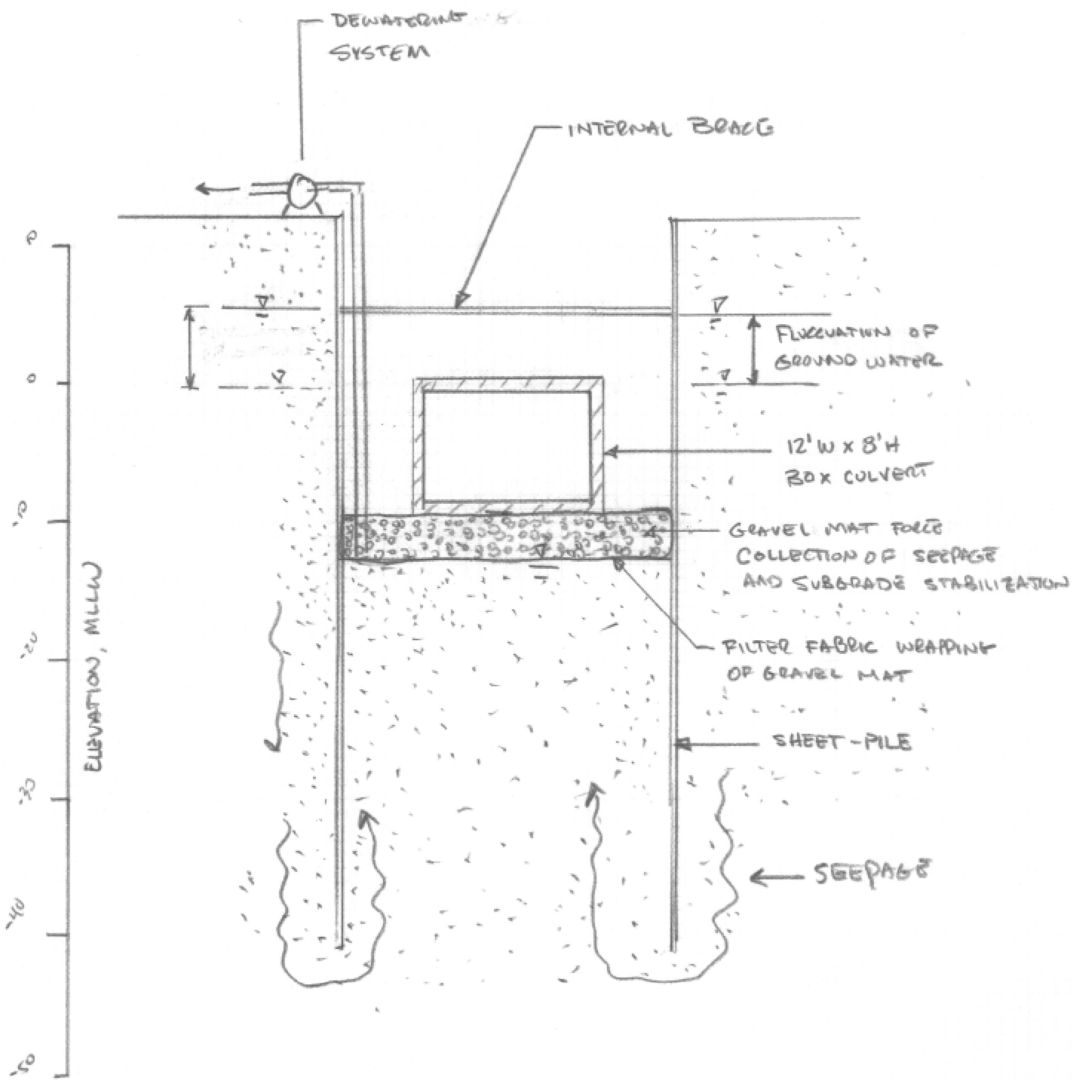


Figure 13: Box Culvert Shoring and Dewatering

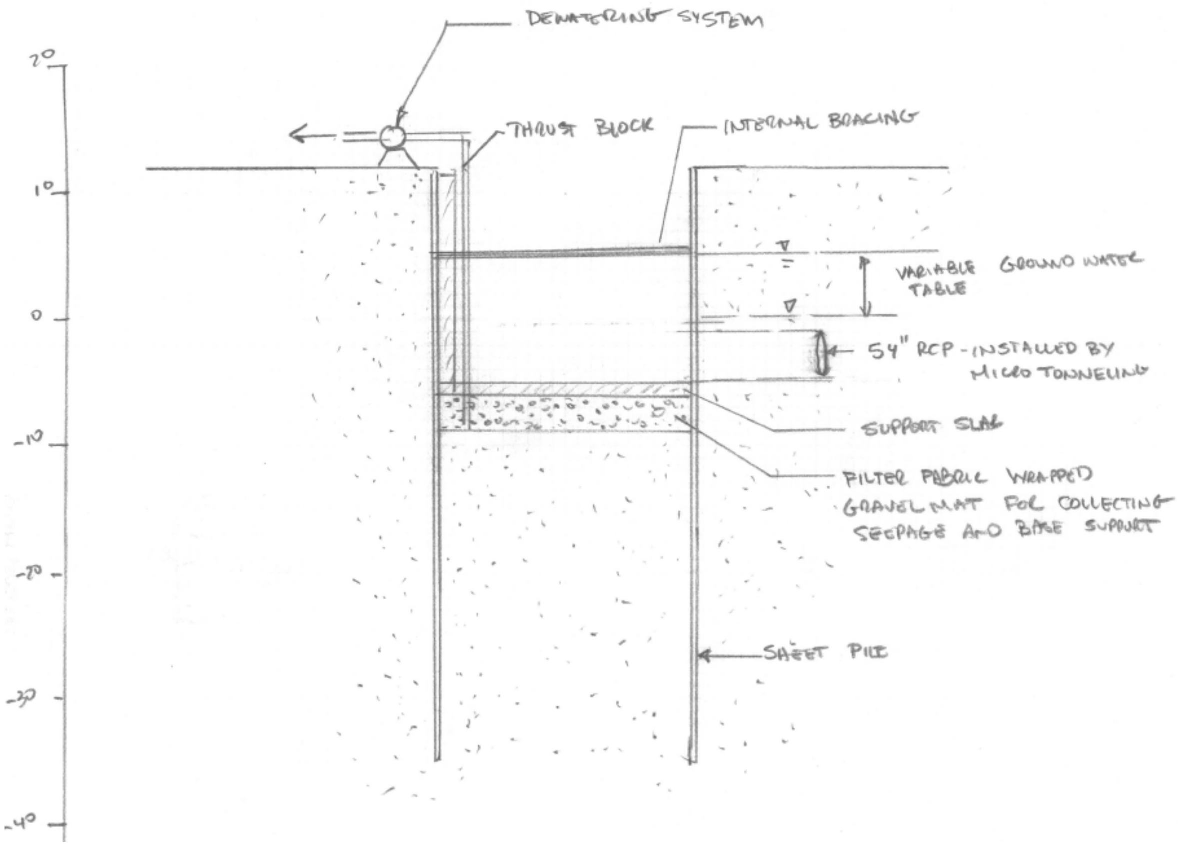


Figure 14: Schematic Microtunneling Launch/Receiving Pit

7. Schedule

The following is a project schedule for the two culvert alternatives:

RCB Culvert Alternative

- Design – **6 months**
- Bid & Award – **3 months**
- Phase 1 – Demolition and reconstruction of existing bulkhead in the Shelter Island Boatyard, construction of the RCB inside of the boatyard, and dredging in the ACH – **7 months**
- Phases 2 and 3 – Utility relocation and two stage construction of the RCB within Shelter Island Drive – **11 months**
- Phase 4 – Construction of RCB in parking lot between 2385 and 2353 Shelter Island Drive, construction of the new headwall and dredging in the SIYB – **6 months**
- Project Closeout – **1 month**

Because Phases 1 and 4 could potentially occur simultaneously, the total project time for the RCB alternative would approximately be **28 months**.

RCP Alternative

- Design – **6 months**
- Bid & Award – **3 months**
- Construction of launching and receiving pits – **2 months**
- Microtunneling operation for 5-54” RCPs - **2 months**
- Demolition and reconstruction of existing bulkhead in the Shelter Island Boatyard, construction of the RCB inside of the boatyard, and dredging in the ACH – **7 months**
- Construction of RCB in parking lot between 2385 and 2353 Shelter Island Drive, construction of the new headwall and dredging in the SIYB – **6 months**
- Project Closeout – **1 month**

As stated previously, the work in the SIYB and ACH can occur simultaneously, after the launching and receiving pits are constructed. Therefore, the total project time for the RCP alternative would approximately be **21 months**.

See Appendix E for a detailed scheduling exhibit for both alternatives.

8. Next Steps

Additional geotechnical studies are required to assess and confirm site and subsurface conditions including parameters for the design of shoring, microtunneling, earthquake operations, and the design of the outlet structures. Investigation of the integrity of the existing utilities in the roadway would be required as well to help determine the feasibility of microtunneling.

An assessment of the presence of hazardous materials will be needed for both the landside operations and the dredging operations for the outfalls. Because of the culvert flushing system's proximity to operating marinas, boatyards, and repair shops, excavated soils may have become contaminated with hazardous materials. A Phase I environmental site assessment will need to be prepared to identify potential issues related to hazardous substances. In addition, soil testing may be required to assess proper handling and disposal.

Environmentally sensitive habitat (such as eel grass) needs to be evaluated in future studies to determine if any sensitive/protected habitat is present and the mitigation requirements that may be needed. The project will require permitting through the U.S. Army Corps of Engineers, NPDES, and the U.S. Fish and Wildlife Service.

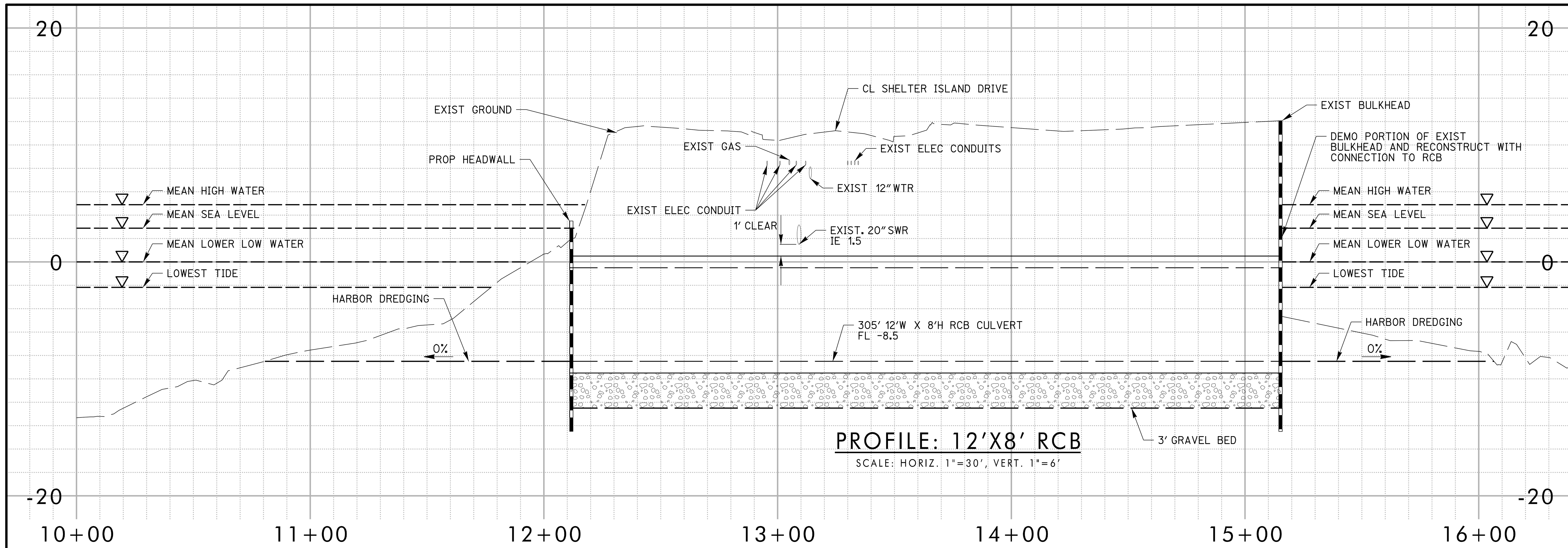
9. Conclusion

After preliminary research, geotechnical and structural assessments, the construction of the enhanced flushing system is physically feasible, however may be significantly impactful to the adjacent properties and traffic leading to and from Shelter Island. The cost associated with constructing the 12'x8' RCB culvert alternative would be approximately $9,667,000, and the cost associated with the five 54" RCP alternative with microtunneling would be approximately $6,638,000 . See Appendix D for construction cost estimates for both alternatives. Note that the costs do not include project cost escalation; any environmental impacts, permitting, or mitigation costs; hazardous materials/contaminated soils costs; costs associated to impacted business operations, leases; temporary dock impacts and dock/slip removal and reconstruction.

The 5-54" RCP option with microtunneling would be our recommended alternative due to cost savings, and reduced overall impacts to existing businesses and vehicular/pedestrian traffic along Shelter Island Drive. If it were determined that microtunneling was not possible, the cost of constructing the 5 RCP's via excavation would be comparable to the cost of constructing the RCB. In this case, however, the RCB would be the preferable alternative due to the narrower trench width required.

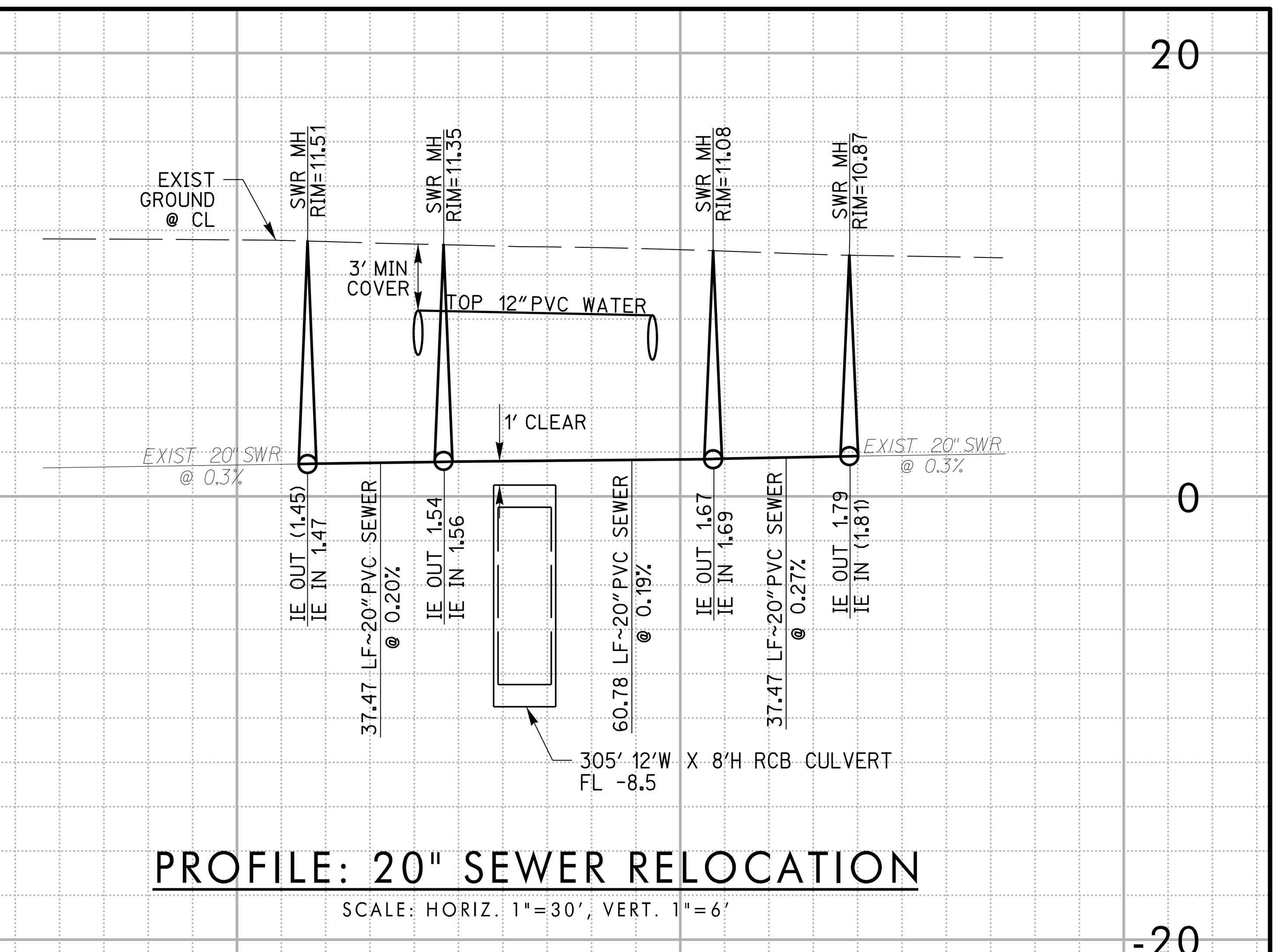
Appendix A

30% Improvement Plans



PROFILE: 12'X8' RCB

SCALE: HORIZ. 1"=30', VERT. 1"=6'

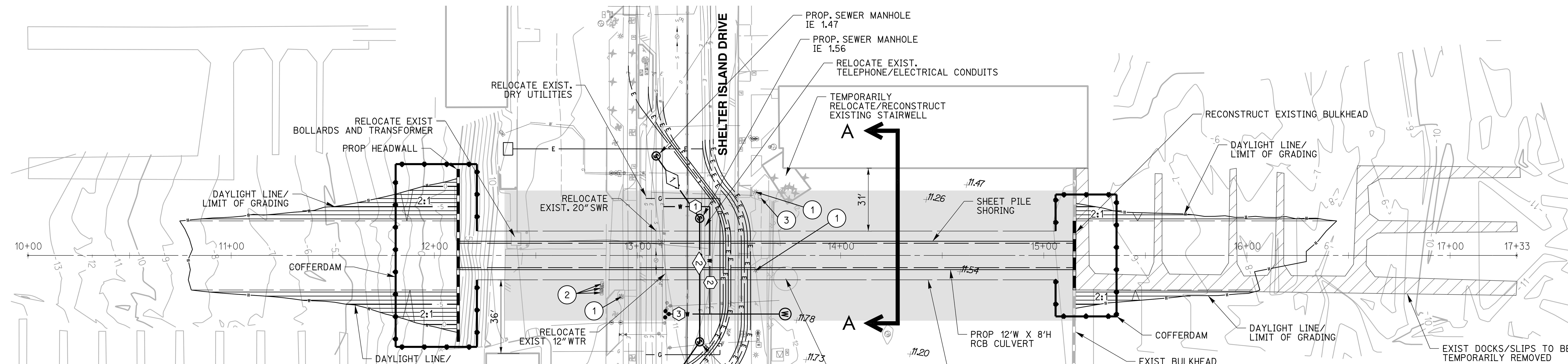


PROFILE: 20" SEWER RELOCATION

SCALE: HORIZ. 1"=30', VERT. 1"=6'

SEWER DATA				
NO.	BEARING	RADIUS	LENGTH	REMARKS
1	N88°39'32"W		37.47'	20" PVC SWR
2	N53°43'59"W		60.78'	20" PVC SWR
3	N18°48'09"W		37.47'	20" PVC SWR

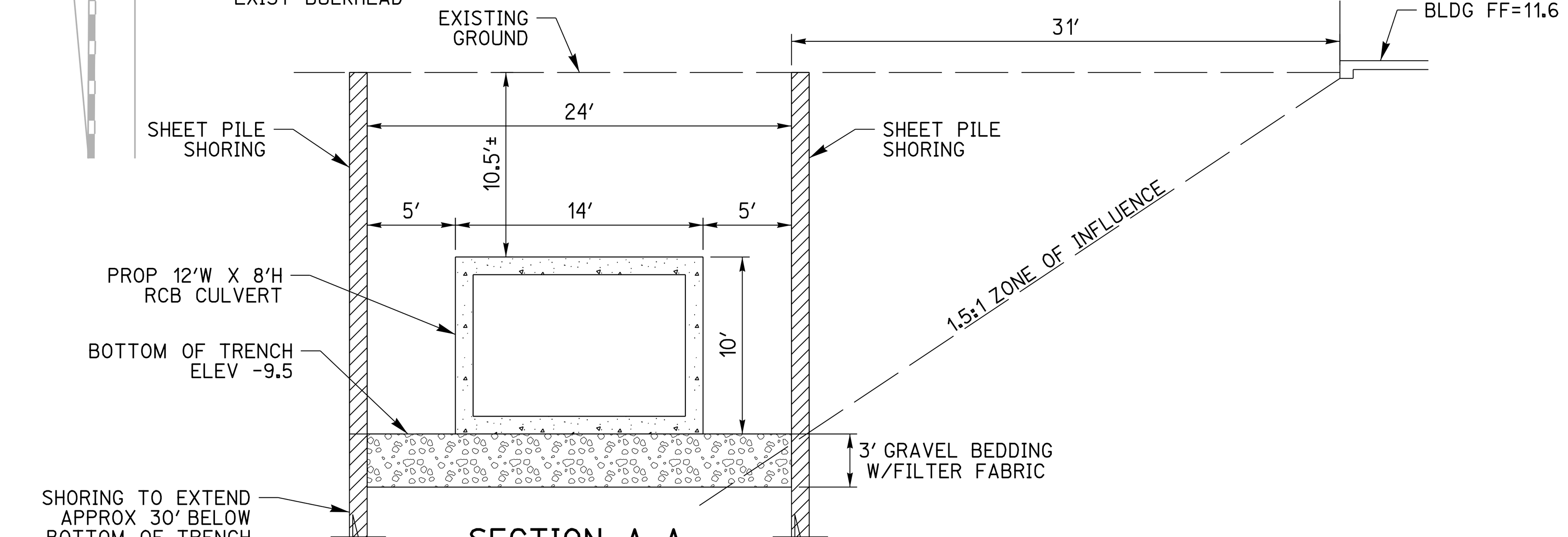
WATER DATA				
NO.	BEARING	RADIUS	LENGTH	REMARKS
1	N36°16'01"E		22.82'	12" PVC WTR
2	N53°43'59"W		52.86'	12" PVC WTR
3	N36°16'01"E		21.54'	12" PVC WTR



UTILITY RELOCATION NOTES

1. EXISTING STREET LIGHT TO BE REMOVED, SALVAGED, AND RECONSTRUCTED
2. EXISTING ELECTRICAL PULLBOX TO BE REMOVED, SALVAGED, AND RECONSTRUCTED
3. EXISTING TELEPHONE PULLBOX TO BE REMOVED, SALVAGED, AND RECONSTRUCTED

AREA TO BE DEMOLISHED AND NEW PAVING, CURB, GUTTER, SIDEWALK, DRIVEWAYS, PARKING AREAS, AND LANDSCAPING TO BE RECONSTRUCTED



SECTION A-A

NOT TO SCALE

30% IMPROVEMENT PLANS

AS BUILT

Date ____ SIGNATURE ____ P.E. No. ____ Printed Name ____ My Registration Expires ____ Discipline ____

UTILITY NOTE

ALL EXISTING UTILITIES SHOWN ON THESE PLANS ARE PLOTTED FROM RECORD DATA AT THEIR APPROXIMATE LOCATIONS. UNDERGROUND FACILITIES MAY EXIST WHICH HAVE NOT BEEN REPORTED OR ARE NOT OF RECORD. CONTRACTOR SHALL VERIFY THE LOCATION OF ALL PERTINENT UTILITIES IN THE FIELD PRIOR TO THE START OF CONSTRUCTION.

Submitted: ____ By: ____ Planning: ____ Landscape: ____

Approved: ____ For the City Engineer

J-17780

RICK ENGINEERING COMPANY

San Diego

5620 FRIARS ROAD
SAN DIEGO, CA 92110
619-291-0707
(FAX) 619-291-4165

rickengineering.com

Riverside - Orange - Sacramento - San Luis Obispo - Phoenix - Tucson - Denver

RECORD DRAWING

REVIEWED BY: ____ ENGINEER OF RECORD ____ DATE:

NOTE: THIS DRAWING MAY BE A REDUCED SCALE PRINT OF THE ORIGINAL DRAWING. UTILIZE GRAPHIC SCALES TO VERIFY IF DRAWING IS A REDUCTION, AND ADJUST SCALES ACCORDINGLY TO THE GRAPHIC SCALES SHOWN.

SPEC NO. ____ WBS NO. ____
REFERENCES
PROJECT ENGINEER
CONTRACTOR
CONSTRUCTION STARTED
CONSTRUCTION COMPLETED
COST ____ INSPECTOR

REVISIONS ____ DATE / APPROVED

San Diego Unified Port District

San Diego • California

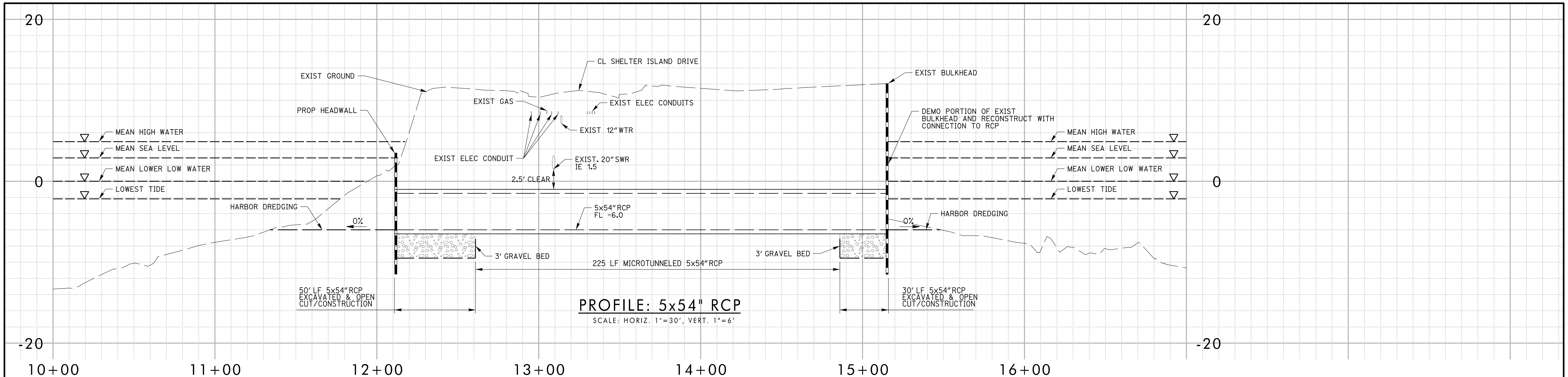
DESIGNED JY
DRAWN JY
CHECKED TWG

APPROVAL RECOMMENDED ____ DISTRICT PROJECT MANAGER
APPROVED ____ DISTRICT MANAGER-DESIGN

SHELTER ISLAND YACHT BASIN
TIDAL FLUSHING PROJECT

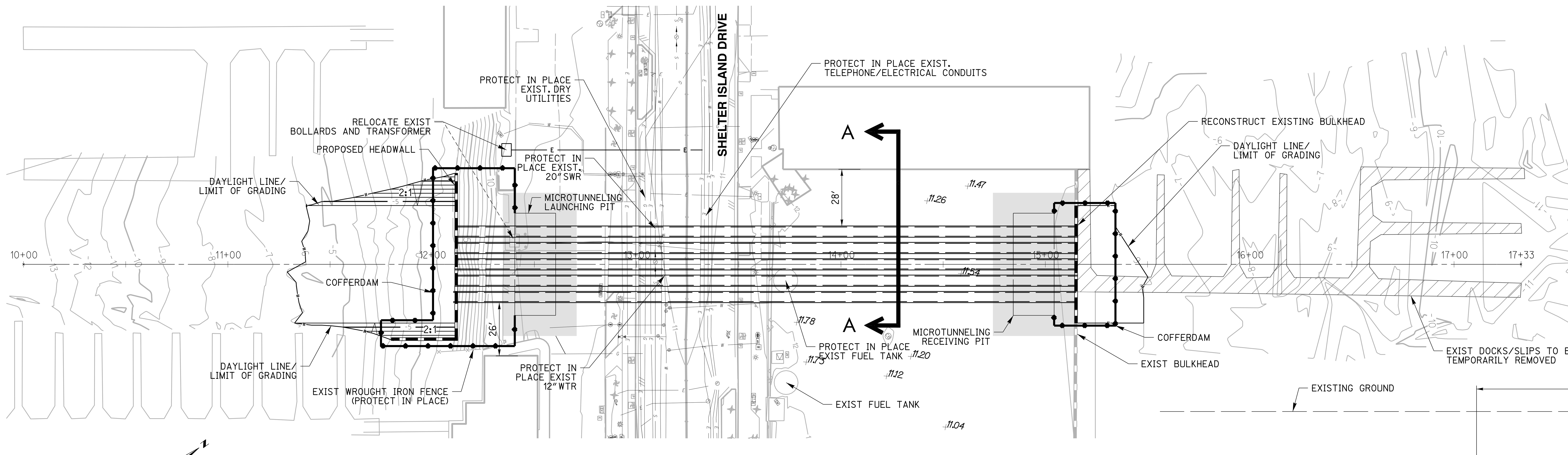
DATE 8/5/2016
A/E NO.
SHEET 1 OF 2
DRAWING NO. XX-XXXX-
REV. -

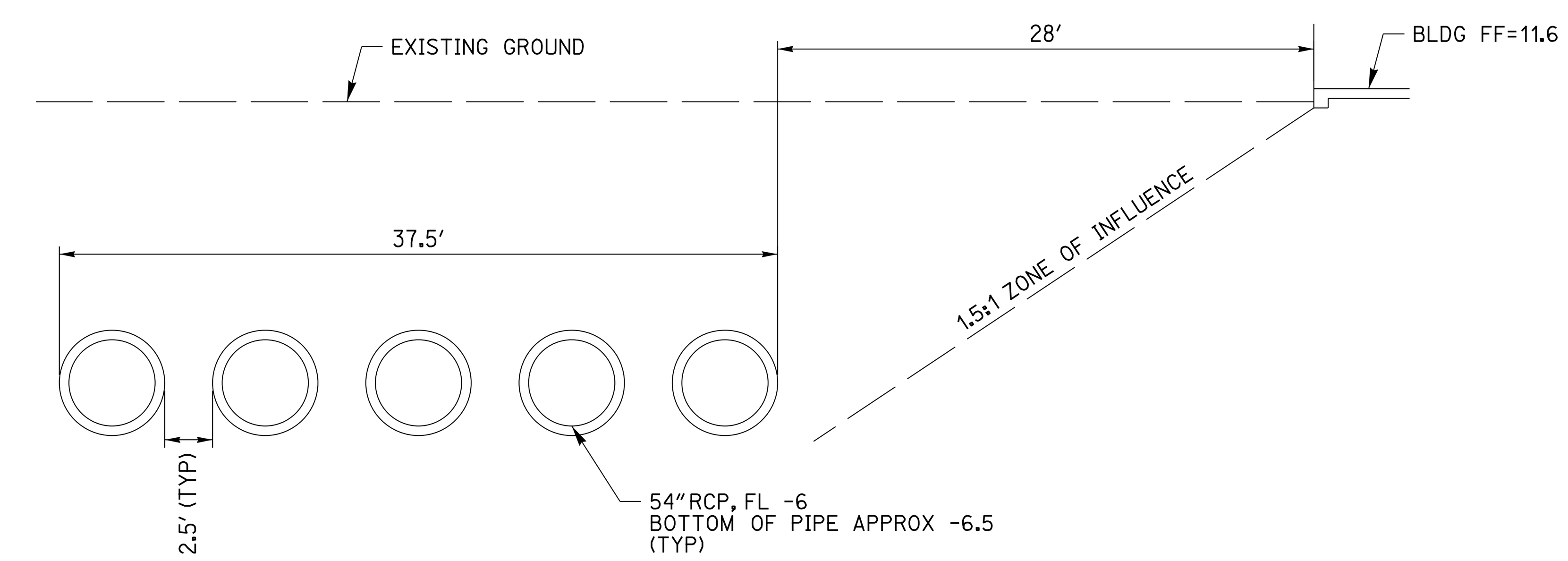
CONCEPTUAL - NOT FOR CONSTRUCTION



PROFILE: 5x54" RCP

SCALE: HORIZ. 1"=30', VERT. 1"=6'





SECTION A-A

NOT TO SCALE

30% IMPROVEMENT PLANS

AS BUILT	UTILITY NOTE
Signature / Date Printed Name / P.E. No. My Registration Expires / Discipline	ALL EXISTING UTILITIES SHOWN ON THESE PLANS ARE PLOTTED FROM RECORD DATA AT THEIR APPROXIMATE LOCATIONS. UNDERGROUND FACILITIES MAY EXIST WHICH HAVE NOT BEEN REPORTED OR ARE NOT OF RECORD. CONTRACTOR SHALL VERIFY THE LOCATION OF ALL PERTINENT UTILITIES IN THE FIELD PRIOR TO THE START OF CONSTRUCTION.

Submitted:
By:
Planning: Landscape:

Approved:
For the City Engineer

RICK ENGINEERING COMPANY
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Riverside - Orange - Sacramento - San Luis Obispo - Phoenix - Tucson - Denver

J-17780

RECORD DRAWING

REVIEWED BY:

ENGINEER OF RECORD

DATE:

NOTE: THIS DRAWING MAY BE A REDUCED SCALE PRINT OF THE ORIGINAL DRAWING. UTILIZE GRAPHIC SCALES TO VERIFY IF DRAWING IS A REDUCTION, AND ADJUST SCALES ACCORDINGLY TO THE GRAPHIC SCALES SHOWN.

SPEC NO. / WBS NO.
REFERENCES
PROJECT ENGINEER
CONTRACTOR
CONSTRUCTION STARTED
CONSTRUCTION COMPLETED
COST / INSPECTOR

REVISIONS / DATE / APPROVED

San Diego Unified Port District
San Diego • California

DESIGNED	JY
DRAWN	JY
CHECKED	TWG

APPROVAL RECOMMENDED — DISTRICT PROJECT MANAGER

APPROVED — DISTRICT MANAGER-DESIGN

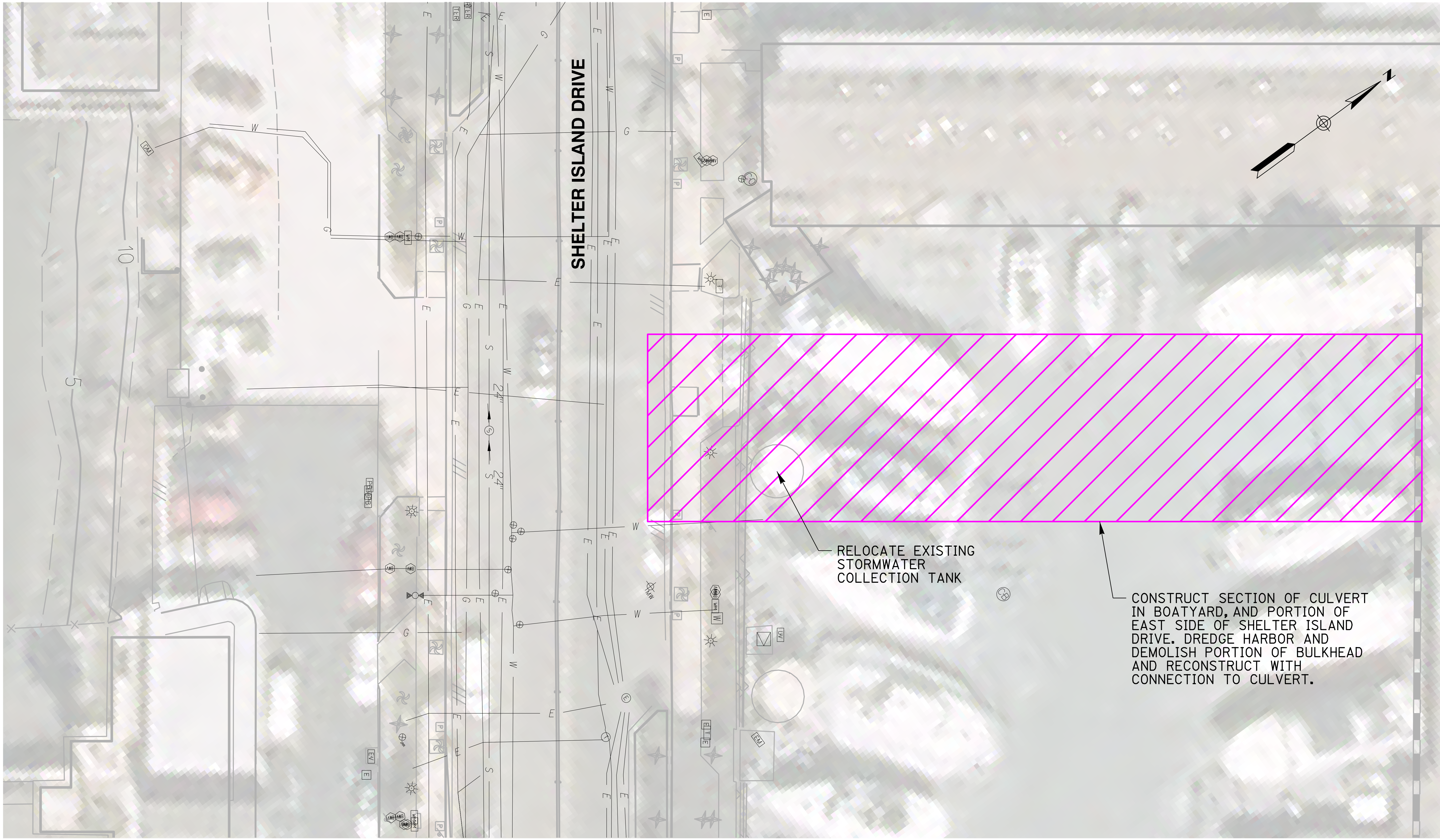
SHELTER ISLAND YACHT BASIN
TIDAL FLUSHING PROJECT

DATE	8/5/2016
A/E NO.	
SHEET	2 OF 2
DRAWING NO.	XX-XXXX-
REV.	-

CONCEPTUAL - NOT FOR CONSTRUCTION

Appendix B

Construction Staging – RCB Alternative



08-05-16

RICK ENGINEERING COMPANY

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20 10 0 20 40 60

GRAPHIC SCALE 1" = 20'

SHELTER ISLAND YACHT BASIN TO AMERICA'S CUP HARBOR TIDAL FLUSHING STAGE CONSTRUCTION - PHASE 1

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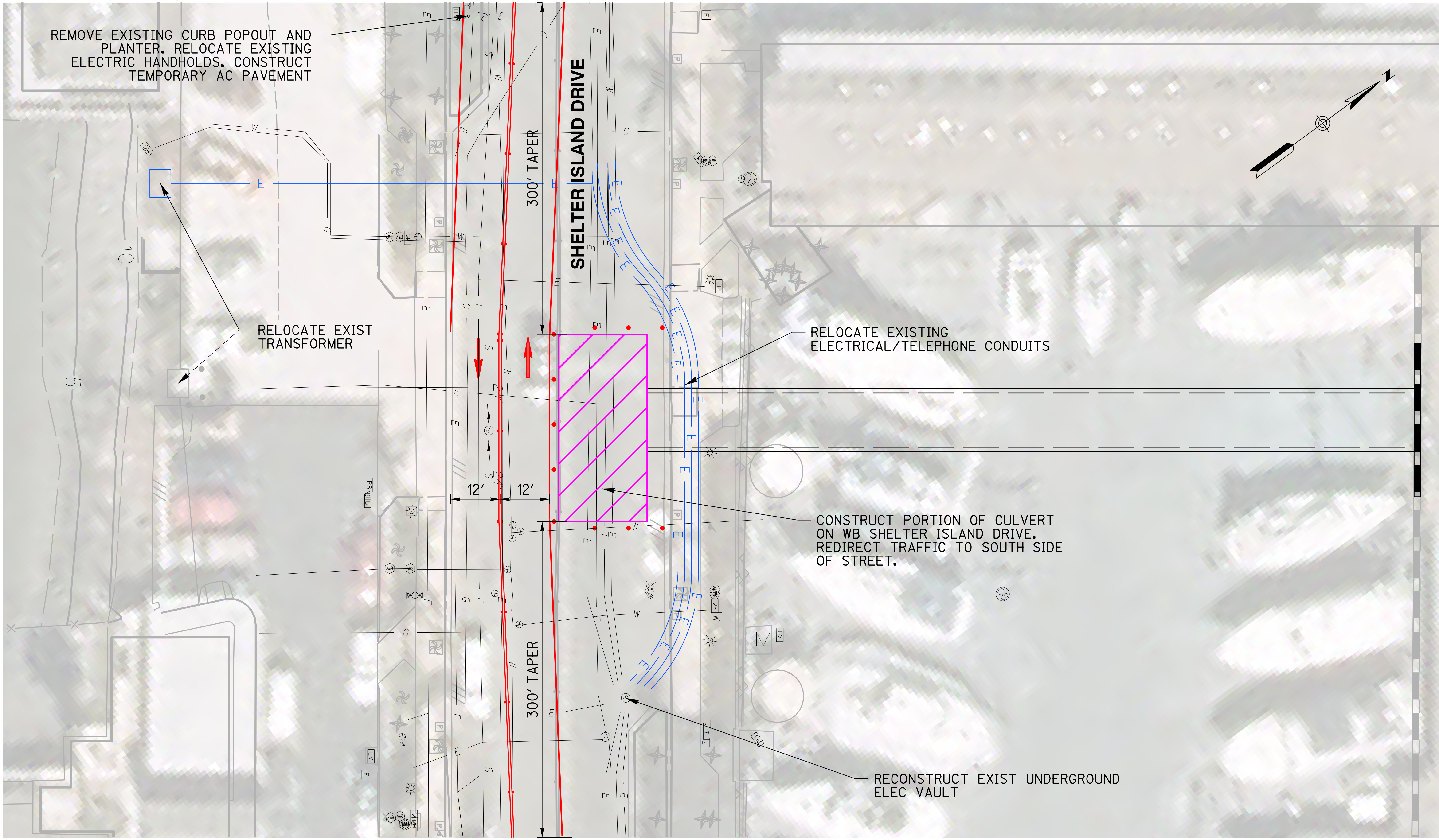

08-05-16

RICK ENGINEERING COMPANY

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(FAX) 619-291-4165

20 10 0 20 40 60

GRAPHIC SCALE 1" = 20'

SHELTER ISLAND YACHT BASIN TO AMERICA'S CUP HARBOR TIDAL FLUSHING

STAGE CONSTRUCTION - PHASE 2

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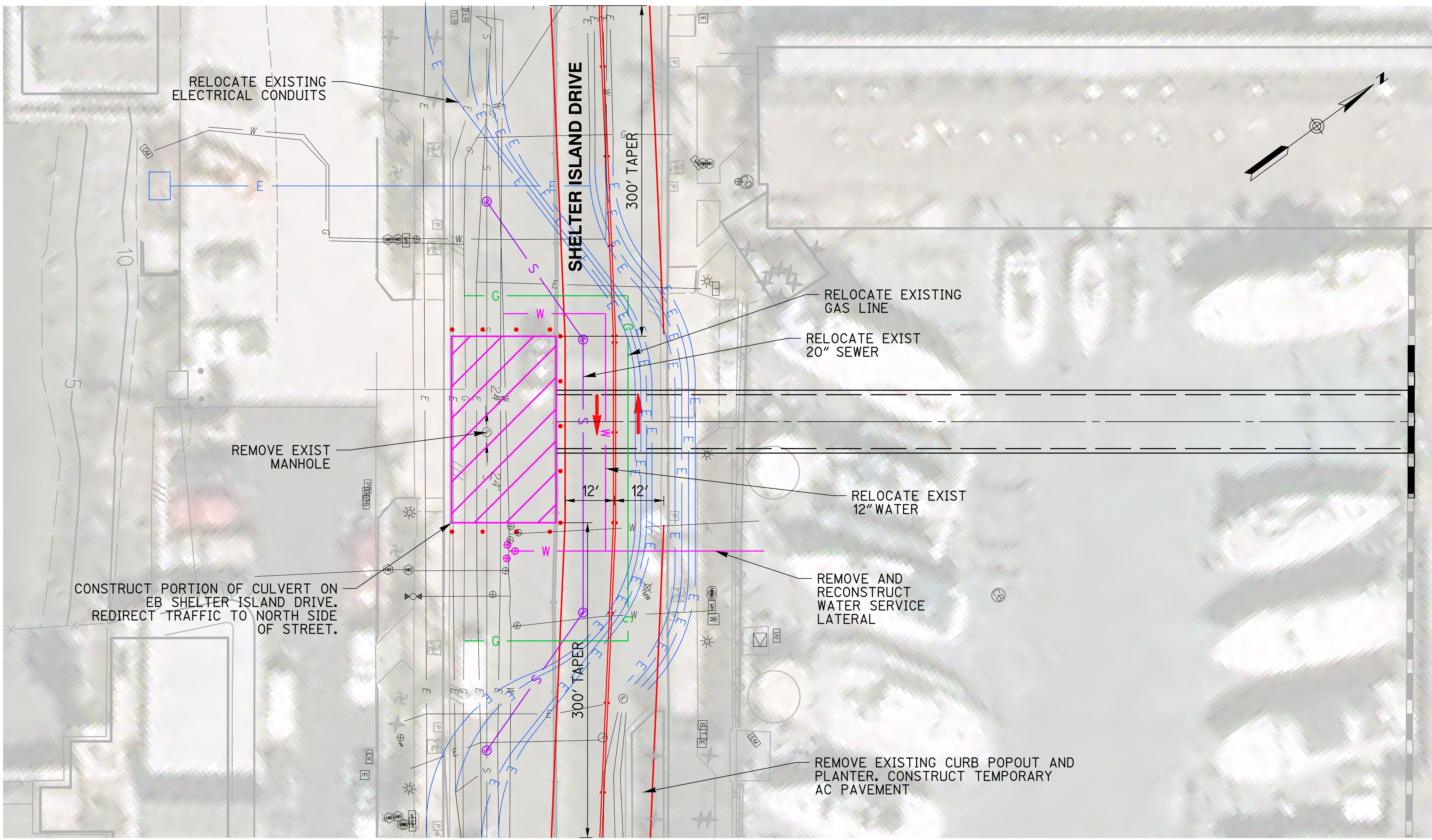

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GRAPHIC SCALE 1" = 20'

SHELTER ISLAND YACHT BASIN TO AMERICA'S CUP HARBOR TIDAL FLUSHING STAGE CONSTRUCTION - PHASE 3

08-05-16
RICK ENGINEERING COMPANY
5620 FRIARS ROAD
SAN DIEGO, CA 92110
619-291-0707
(FAX) 619-291-4165

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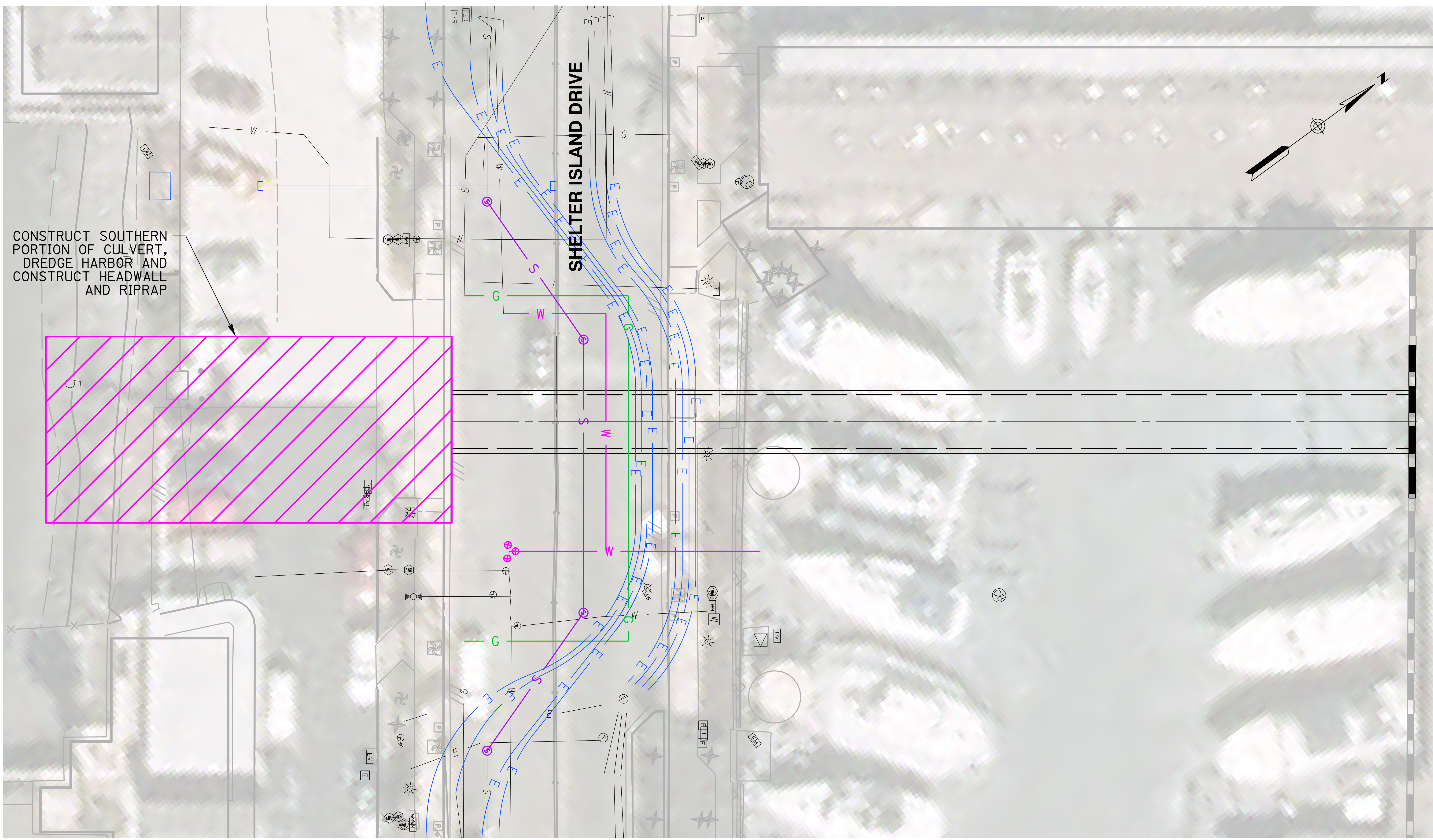

08-05-16
RICK ENGINEERING COMPANY
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619-291-0707
(FAX) 619-291-4165

20 10 0 20 40 60

GRAPHIC SCALE 1" = 20'

SHELTER ISLAND YACHT BASIN TO AMERICA'S CUP HARBOR TIDAL FLUSHING STAGE CONSTRUCTION - PHASE 4

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Appendix C

Preliminary Summary of Geotechnical Findings

Appendix D

Opinion of Probable Cost Estimates

Cost Estimate for
12’x8’ Box Culvert Option

Box Culvert
Opinion of Probable Cost
Estimate Summary

- **Roadside Improvements - $1,471,000**
- **Excavation, Dewatering, Culvert and Headwall Construction, Backfill - $8,196,000**
- **Total - $9,667,000**

OPINION OF PROBABLE COST
SHELTER ISLAND YACHT BASIN TO AMERICA'S CUP HARBOR TIDAL FLUSHING
12'x8' RCB ALTERNATIVE
ROADSIDE IMPROVEMENTS

Item	Phase 1 Quantity	Phase 2 Quantity	Phase 3 Quantity	Phase 4 Quantity	Total Quantity	Unit	Unit Cost	Cost
MOBILIZATION	10,000	10,000	10,000	10,000	40,000	LS		$40,000.00
DEMO EXIST PCC CONCRETE (PARKING LOT)				3,300	3,300	SF	$5.00	$16,500.00
DEMO EXISTING ROADWAY PAVEMENT		1,500	1,500		3,000	SF	$3.50	$10,500.00
DEMO EXISTING PCC SIDEWALK		450	450		900	SF	$2.00	$1,800.00
DEMO EXISTING PCC CURB AND GUTTER		65	65		130	LF	$10.00	$1,300.00
RELOCATE EXISTING ELECTRICAL/TELEPHONE CONDUITS		200,000	100,000		300,000	LS		$300,000.00
RELOCATE EXISTING GAS			50,000		50,000	LS		$50,000.00
RELOCATE EXISTING FUEL TANK	50,000				50,000	LS		$50,000.00
RELOCATE EXISTING SDGE TRANSFORMER IN WEST PARKING AREA			50,000		50,000	LS		$50,000.00
TEMPORARY HILINE EXISTING WATER LINE/CONNECTIONS			30,000		30,000	LS		$30,000.00
RELOCATE EXISTING 12" WATER			98		98	LF	$90.00	$8,820.00
RELOCATE EXISTING WATER SERVICE			1		1	EA	$2,400.00	$2,400.00
BACKFLOW PREVENTION ASSEMBLY			1		1	EA	$2,400.00	$2,400.00
12" GATE VALVE			3		3	EA	$3,700.00	$11,100.00
RELOCATE EXISTING CATV CONDUITS			50000		50,000	LS		$50,000.00
TEMPORARY BYPASS EXISTING SEWER LINE/CONNECTIONS			20000		20,000	LS		$20,000.00
RELOCATE EXISTING 20" SEWER			135		135	LF	$120.00	$16,200.00
CONSTRUCT SEWER MANHOLE			4		4	EA	$5,000.00	$20,000.00
RECONSTRUCT PCC CONCRETE (PARKING LOT)				3,300	3,300	SF	$8.40	$27,720.00
RECONSTRUCT LANDSCAPING					15,000	LS		$15,000.00
HARBOR DREDGING					625	CY	$300.00	$187,500.00
MISCELLANEOUS IMPROVEMENTS					75,000	LS		$75,000.00
SWPPP					10,000	LS		$10,000.00
WATER QUALITY/LID IMPROVEMENTS					25,000	LS		$25,000.00

Subtotal	$1,021,240
10% Design	$102,124
10% Construction Administration	$102,124
20% Contingency	$245,098
Total:	**$1,470,586**

ASSUMPTIONS AND LIMITATIONS

1) Estimates do not include any costs for business interruptions or lost lease revenue.
2) Estimates assume existing bulkhead in the America's Cup Harbor is not degraded and can be modified.
3) Unit costs are from projects of similar nature, experience of project team or City of San Diego Unit Price List.
4) Costs do not include any hazardous material handling and permitting.
5) Estimates do not include any environmental assessments, mitigation, and permitting.
6) Project Assumes that all existing dry utilties can be relocated in the stages proposed.
7) Estaimtes do not include public agency fees or permitting costs.
8) Estimates do not include costs for dock removals and dock improvements.
9) Dredging costs assume that a barge will be utilized. Price includes dredging and disposal.
10) Unit costs assume prevailing wage.

Owner: Port of San Diego
Location: Shelter Island

Project Title: Shelter Island Yacht Basin Culvert

Estimated By
Firm: M & N
Est Name: MOD

A-E Firm Name
Moffatt and Nichol
Checked By: FM
Status of Design: Conceptual

Date 08/02/16

Alternative B - 8' x 14' Reinforced Concrete Box (RCB) Culvert - Estimate Summary

ITEM NO.	ITEM DESCRIPTION					UNIT	QUANTITY	UNIT PRICE	AMOUNT
	RCB - Cofferdams					LS	1	$1,513,460	$1,513,460
	RCB - Earthwork					LS	1	$4,176,150	$4,176,150
	Construct RCB, New Headwall, & Bulkhead Repairs					LS	1	$1,123,250	$1,123,250
	RCB - Remove and Re-Use Rock Slope Protection (RSP)					LS	1	$17,460	$17,460
	NOTES:								
	The provided lump sum (LS) costs include the following:								
	10% Markup for Mobilization/Demobilization/Field Overhead, Bond, and Insurance								
	15% Markup for Contractro Profit and Central Office Overhead								
	15% for Contingency								
	Estimate Does Not Include Costs For:								
	Permitting, Environmental, Escalation,								
		SUBTOTAL							$6,830,320
					10%	Design Costs			$683,032
					10%	Construction Management			$683,032
						SHEET TOTAL			$8,196,384

Notes: THIS COST ESTIMATE IS AN OPINION OF CONSTRUCTION COST MADE BY THE CONSULTANT. IN PROVIDING OPINIONS OF CONSTRUCTION COST, IT IS RECOGNIZED THAT NEITHER THE CLIENT NOR THE CONSULTANT HAS CONTROL OVER THE COSTS OF LABOR, EQUIPMENT, AND MATERIALS, OR OVER CONTRACTORS' METHODS OF DETERMINING PRICES OR BIDDING. THIS OPINION OF CONSTRUCTION COST IS BASED ON THE CONSULTANT'S REASONABLE PROFESSIONAL JUDGMENT AND EXPERIENCE AND DOES NOT CONSTITUTE A WARRANTY, EXPRESSED OR IMPLIED, THAT CONTRACTORS' BIDS OR NEGOTIATED PRICES OF THE WORK WILL NOT VARY FROM THE CLIENT'S BUDGET OR FROM ANY OPINION OF COST PREPARED BY THE CONSULTANT.
THE INTENT OF THIS ESTIMATE IS TO REFLECT FAIR MARKET VALUE FOR THE CONSTRUCTION OF THIS PROJECT. IT IS NOT A PREDICTION OF LOW BID. PRICING IS BASED UPON COMPETETIVE BIDDING, A MINIMUM OF FOUR BIDS FROM PRIME CONTRACTORS. IF FEWER BIDS ARE RECEIVED BID RESULTS CAN BE EXPECTED TO VARY.

Owner: Port of San Diego
Location: Shelter Island

Project Title: Shelter Island Yacht Basin Culvert

Estimated By
Firm: M & N
Est Name: MOD

A-E Firm Name
Moffatt and Nichol
Checked By: FM
Status of Design: Conceptual

Date 08/02/16

RCB - Cofferdams

				LABOR COST		EQUIPMENT COST		MATERIAL COST		SUB QUOTE COST		TOTAL COST	
ITEM NO.	ITEM DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	AMOUNT	UNIT PRICE	AMOUNT	UNIT PRICE	AMOUNT	UNIT PRICE	AMOUNT	UNIT PRICE	AMOUNT
	Furnish PZ40 Sheet Piles (Wt =40lb/lf, H=53', L=328')	LB	695,360		$0		$0	$1.00	$695,360		$0	$1.00	$695,360
	Install Sheet Piles - Ea = number of pairs	EA	100	$1,300.00	$130,000	$1,000.00	$100,000		$0		$0	$2,300.00	$230,000
	Remove Sheet Piles	EA	100	$650.00	$65,000	$500.00	$50,000		$0		$0	$1,150.00	$115,000
	SUBTOTAL	LS	1		$195,000		$150,000		$695,360		$0		$1,040,360
									10%	Mobilization/Demobilization/Field Overhead			$104,036
									15%	Contractor Profit/Central Office Overhead			$171,659
									15%	Contingency			$197,408
										TOTAL			$1,513,460

Notes:

Owner: Port of San Diego
Location: Shelter Island

Project Title: Shelter Island Yacht Basin Culvert

Estimated By
Firm: M & N
Est Name: MOD

A-E Firm Name
Moffatt and Nichol
Checked By: FM
Status of Design: Conceptual

Date 08/02/16

RCB - Earthwork

				LABOR COST		EQUIPMENT COST		MATERIAL COST		SUB QUOTE COST		TOTAL COST	
ITEM NO	ITEM DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	AMOUNT	UNIT PRICE	AMOUNT	UNIT PRICE	AMOUNT	UNIT PRICE	AMOUNT	UNIT PRICE	AMOUNT
	Remove Existing Concrete Slab (45'x45'x1' & 60'x50'x1')	CY	187	$50.00	$9,350	$75.00	$14,025		$0		$0	$125.00	$23,375
	Furnish PZ40 Sheet Piles (Wt =40lb/lf, H=53', L=610')	LB	1,293,200		$0		$0	$1.00	$1,293,200		$0	$1.00	$1,293,200
	Install Sheet Piles - Ea = number of pairs)	EA	186	$1,300.00	$241,768	$1,000.00	$185,976		$0		$0	$2,300.00	$427,744
	Excavate Trench and Haul to Stockpile (Assume 5 mile haul)	CY	6,755	$7.00	$47,286	$15.00	$101,328		$0		$0	$22.00	$148,614
	Install and Maintain Dewatering System (Assume 2 Pumps, Baker Tanks, 24 hr maintaining, and testing water; No treatement required	DAY	90	$2,000.00	$180,000	$500.00	$45,000	$500.00	$45,000		$0	$3,000.00	$270,000
	Furnish and Install 3' Gravel Bed	CY	881	$5.00	$4,406	$4.00	$3,524	$30.00	$26,433		$0	$39.00	$34,363
	Backfill RCB (Incl Hauling From Stockpile Location)	CY	4,360	$22.00	$95,928	$27.00	$117,730		$0		$0	$49.00	$213,658
	Remove Sheet Piles	EA	186	$650.00	$120,884	$500.00	$92,988		$0		$0	$1,150.00	$213,872
	Traffic Control and Temporary Striping	LS	1	$4,800.00	$4,800	$1,000.00	$1,000		$0	$2,000.00	$2,000	$7,800.00	$7,800
	Install and Remove K-Rail	LF	200	$6.00	$1,200	$3.00	$600	$10.00	$2,000		$0	$19.00	$3,800
	Repave, Replace S/W, C&G, Restripe Harbor Drive	LS	1	$15,000.00	$15,000	$5,000.00	$5,000	$50,000.00	$50,000	$1,000.00	$1,000	$71,000.00	$71,000
	Replace Concrete Slabs	CY	187	$150.00	$28,050	$25.00	$4,675	$150.00	$28,050		$0	$325.00	$60,775
	Construct Timber Rail	LF	50		$0		$0		$0	$50.00	$2,500	$50.00	$2,500
	Stage the earthwork (2 -stages)	LS	1	$100,000.00	$100,000		$0		$0		$0	$100,000.00	$100,000
	SUBTOTAL	LS	1		$848,672		$571,846		$1,444,683		$5,500		$2,870,701
									10%	Mobilization/Demobilization/Field Overhead			$287,070
									15%	Contractor Profit/Central Office Overhead			$473,666
									15%	Contingency			$544,716
										TOTAL			$4,176,150

Notes:

Owner: Port of San Diego
Location: Shelter Island

Project Title: Shelter Island Yacht Basin Culvert

Estimated By
Firm: M & N
Est Name: MOD

A-E Firm Name
Moffatt and Nichol **Date** **08/02/16**
Checked By: FM
Status of Design: **Conceptual**

Construct RCB, New Headwall, & Bulkhead Repairs

				LABOR COST		EQUIPMENT COST		MATERIAL COST		SUB QUOTE COST		TOTAL COST	
ITEM NO.	ITEM DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	AMOUNT	UNIT PRICE	AMOUNT	UNIT PRICE	AMOUNT	UNIT PRICE	AMOUNT	UNIT PRICE	AMOUNT
	Furnish Pre-Cast RCB Sections	CY	317		$0		$0	$1,100.00	$348,578		$0	$1,100.00	$348,578
	Install RCB Sections	LF	305	$150.00	$45,750	$60.00	$18,300		$0		$0	$210.00	$64,050
	Construct End Sections for RCB -CIP (Sheet Pile Bulkhead End)	CY	14	$450.00	$6,300	$150.00	$2,100	$350.00	$4,900		$0	$950.00	$13,300
	Construct Cast-In-Place Concrete Headwall for RCB	CY	193	$450.00	$86,850	$150.00	$28,950	$350.00	$67,550		$0	$950.00	$183,350
	Remove and Salvage Sheet Piles, Construct Grout	LS	1	$3,000.00	$3,000	$1,500.00	$1,500	$1,500.00	$1,500		$0	$6,000.00	$6,000
	Furnish 2 ea Pipe Piles D=36", T=0.75", L=85' (282.62 lb/lf)	LB	48,045		$0		$0	$1.00	$48,045		$0	$1.00	$48,045
	Install Pipe Piles	EA	2	$2,400.00	$4,800	$2,000.00	$4,000		$0		$0	$4,400.00	$8,800
	Stage the RCB Construction (2-stages)	LS	1	$100,000.00	$100,000		$0		$0		$0	$100,000.00	$100,000
	SUBTOTAL	LS	1		$246,700		$54,850		$470,573		$0		$772,123

10%	Mobilization/Demobilization/Field Overhead	$77,212
15%	Contractor Profit/Central Office Overhead	$127,400
15%	Contingency	$146,510
	TOTAL	$1,123,250

Notes:

Owner: Port of San Diego
Location: Shelter Island

Project Title: Shelter Island Yacht Basin Culvert

Estimated By
Firm: M & N
Est Name: MOD

A-E Firm Name
Moffatt and Nichol
Checked By: FM
Status of Design: Conceptual

Date 08/02/16

RCB - Remove and Re-Use Rock Slope Protection (RSP)

				LABOR COST		EQUIPMENT COST		MATERIAL COST		SUB QUOTE COST		TOTAL COST	
ITEM NO.	ITEM DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	AMOUNT	UNIT PRICE	AMOUNT	UNIT PRICE	AMOUNT	UNIT PRICE	AMOUNT	UNIT PRICE	AMOUNT
	Remove and Re-Use RSP	CY	120	$50.00	$6,000	$25.00	$3,000	$25.00	$3,000		$0	$100.00	$12,000
	SUBTOTAL	LS	1		$6,000		$3,000		$3,000		$0		$12,000

10%	Mobilization/Demobilization/Field Overhead	$1,200
15%	Contractor Profit/Central Office Overhead	$1,980
15%	Contingency	$2,277
	TOTAL	$17,460

Notes:

Cost Estimate for
5-54” RCP’s with Microtunneling Option

5-54" RCP's
Opinion of Probable Cost
Estimate Summary

- **Roadside Improvements - $449,000**
- **Excavation, Dewatering, Culvert and Headwall Construction, Backfill - $6,189,000**
- **Total - $6,638,000**

OPINION OF PROBABLE COST
SHELTER ISLAND YACHT BASIN TO AMERICA'S CUP HARBOR TIDAL FLUSHING
5'-54" RCP ALTERNATIVE WITH MICROTUNNELING

Item	Quantity	Unit	Unit Cost	Cost
MOBILIZATION	1	LS	$50,000.00	$50,000.00
DEMO EXIST WEST PARKING LOT	2,500	SF	$5.00	$12,500.00
RELOCATE EXISTING SDGE TRANSFORMER IN WEST PARKING AREA	1	LS	$5,000.00	$5,000.00
RECONSTRUCT EXIST WEST PARKING LOT	2,500	SF	$10.00	$25,000.00
SWPPP	1	LS	$10,000.00	$10,000.00
WATER QUALITY/LID IMPROVEMENTS	1	LS	$25,000.00	$25,000.00
HARBOR DREDGING	615	CY	$300.00	$184,500.00
			Subtotal	$312,000
			10% Design	$31,200
			10% Construction Administration	$31,200
			20% Contingency	$74,880
			Total:	**$449,280**

ASSUMPTIONS AND LIMITATIONS

1) Estimates do not include any costs for business interruptions or lost lease revenue.
2) Estimates assume existing bulkhead in the America's Cup Harbor is not degraded and can be modified.
3) Unit costs are from projects of similar nature, experience of project team or City of San Diego Unit Price List.
4) Costs do not include any hazardous material handling and permitting.
5) Estimates do not include any environmental assessments, mitigation, and permitting.
6) Project Assumes that all existing dry utilties can be relocated in the stages proposed.
7) Estaimtes do not include public agency fees or permitting costs.
8) Estimates do not include costs for dock removals and dock improvements.
9) Dredging costs assume that a barge will be utilized. Price includes dredging and disposal.
10) Unit costs assume prevailing wage.

Owner: Port of San Diego
Location: Shelter Island

Project Title: Shelter Island Yacht Basin Culvert

Estimated By
Firm: M & N
Est Name: MOD

A-E Firm Name
Moffatt and Nichol
Checked By: FM
Status of Design: Conceptual

Date 08/02/16

Alternative A - Five 54" Reinforced Concrete Pipes (RCP) Culvert - Estimate Summary

ITEM NO.	ITEM DESCRIPTION					UNIT	QUANTITY	UNIT PRICE	AMOUNT
	RCP - Jacking Pits					LS	1	$1,820,900	$1,820,900
	Install RCP, New Headwall & Bulkhead Repairs					LS	1	$1,589,200	$1,589,200
	RCP - Cofferdams					LS	1	$1,708,240	$1,708,240
	RCP - Remove and Re-Use Rock Slope Protection (RSP)					LS	1	$29,100	$29,100
	NOTES:								
	The provided lump sum (LS) costs include the following:								
	10% Markup for Mobilization/Demobilization/Field Overhead, Bond, and Insurance								
	15% Markup for Contractro Profit and Central Office Overhead								
	15% for Contingency								
	Estimate Does Not Include Costs For:								
	Permitting, Environmental, Escalation,								
		SUBTOTAL							$5,147,440
					10%	Design Costs			$514,744
					10%	Construction Management			$514,744
						SHEET TOTAL			$6,176,928

Notes: THIS COST ESTIMATE IS AN OPINION OF CONSTRUCTION COST MADE BY THE CONSULTANT. IN PROVIDING OPINIONS OF CONSTRUCTION COST, IT IS RECOGNIZED THAT NEITHER THE CLIENT NOR THE CONSULTANT HAS CONTROL OVER THE COSTS OF LABOR, EQUIPMENT, AND MATERIALS, OR OVER CONTRACTORS' METHODS OF DETERMINING PRICES OR BIDDING. THIS OPINION OF CONSTRUCTION COST IS BASED ON THE CONSULTANT'S REASONABLE PROFESSIONAL JUDGMENT AND EXPERIENCE AND DOES NOT CONSTITUTE A WARRANTY, EXPRESSED OR IMPLIED, THAT CONTRACTORS' BIDS OR NEGOTIATED PRICES OF THE WORK WILL NOT VARY FROM THE CLIENT'S BUDGET OR FROM ANY OPINION OF COST PREPARED BY THE CONSULTANT.
THE INTENT OF THIS ESTIMATE IS TO REFLECT FAIR MARKET VALUE FOR THE CONSTRUCTION OF THIS PROJECT. IT IS NOT A PREDICTION OF LOW BID. PRICING IS BASED UPON COMPETETIVE BIDDING, A MINIMUM OF FOUR BIDS FROM PRIME CONTRACTORS. IF FEWER BIDS ARE RECEIVED BID RESULTS CAN BE EXPECTED TO VARY.

Owner: Port of San Diego
Location: Shelter Island

Project Title: Shelter Island Yacht Basin Culvert

Estimated By
Firm: M & N
Est Name: MOD

A-E Firm Name
Moffatt and Nichol
Checked By: FM
Status of Design: Conceptual

Date 07/07/16

RCP - Jacking Pits

				LABOR COST		EQUIPMENT COST		MATERIAL COST		SUB QUOTE COST		TOTAL COST	
ITEM NO	ITEM DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	AMOUNT	UNIT PRICE	AMOUNT	UNIT PRICE	AMOUNT	UNIT PRICE	AMOUNT	UNIT PRICE	AMOUNT
	Remove Existing Concrete Slab (20'x50'x1' & 20'x50'x1')	CY	75	$50.00	$3,750	$75.00	$5,625		$0		$0	$125.00	$9,375
	Furnish PZ40 Sheet Piles (Wt =40lb/lf, H=53', L=280')	LB	593,600		$0		$0	$1.00	$593,600		$0	$1.00	$593,600
	Install Sheet Piles - Ea = number of pairs)	EA	85	$1,300.00	$110,976	$1,000.00	$85,366		$0		$0	$2,300.00	$196,341
	Excavate Pits (2130 cy West & 1363 cy East)	CY	3,493	$7.00	$24,451	$15.00	$52,395		$0		$0	$22.00	$76,846
	Install and Maintain Dewatering System (Assume 2 Pumps, Baker Tanks, 24 hr maintaining, and testing water: No treatement required	DAY	60	$2,000.00	$120,000	$500.00	$30,000	$500.00	$30,000		$0	$3,000.00	$180,000
	Remove Sheet Piles	EA	85		$0		$0		$0		$0	$0.00	$0
	Replace Concrete Slabs	CY	75	$150.00	$11,250	$25.00	$1,875	$150.00	$11,250		$0	$325.00	$24,375
	Backfill Pits	CY	3,493	$22.00	$76,846	$27.00	$94,311		$0		$0	$49.00	$171,157
					$0		$0		$0		$0	$0.00	$0
					$0		$0		$0		$0	$0.00	$0
					$0		$0		$0		$0	$0.00	$0
	SUBTOTAL	CY	75		$347,273		$269,572		$634,850		$0		$1,251,694

10%	Mobilization/Demobilization/Field Overhead	$125,169
15%	Contractor Profit/Central Office Overhead	$206,530
15%	Contingency	$237,509
	TOTAL	$1,820,900

Notes:

Owner: Port of San Diego
Location: Shelter Island

Project Title: Shelter Island Yacht Basin Culvert

Estimated By
Firm: M & N
Est Name: MOD

A-E Firm Name
Moffatt and Nichol
Checked By: FM
Status of Design: Conceptual

Date 08/02/16

Install RCP, New Headwall & Bulkhead Repairs

				LABOR COST		EQUIPMENT COST		MATERIAL COST		SUB QUOTE COST		TOTAL COST	
ITEM NO	ITEM DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	AMOUNT	UNIT PRICE	AMOUNT	UNIT PRICE	AMOUNT	UNIT PRICE	AMOUNT	UNIT PRICE	AMOUNT
	Furnish 54" RCP	LF	1,525		$0		$0	$120.00	$183,000		$0	$120.00	$183,000
	Microtunneling work (5- 54" Reinforced Concrete Pipes)	LF	1,050	$300.00	$315,000	$143.00	$150,150		$0		$0	$443.00	$465,150
	Excavate, Lay, and Backfill 54" RCP (Assume excavated material is hauled to a stockpile and hauled back as backfill- 5 mile haul)	LF	475	$50.00	$23,750	$20.00	$9,500	$175.00	$83,125		$0	$245.00	$116,375
	Construct Cast-in-Place Concrete for Bulkhead Repairs	CY	74	$450.00	$33,300	$150.00	$11,100	$350.00	$25,900		$0	$950.00	$70,300
	Construct Cast-in-Place Concrete Headwall for RCP	CY	157	$450.00	$70,650	$150.00	$23,550	$350.00	$54,950		$0	$950.00	$149,150
	Remove and Salvage Sheet Piles, Construct Grout	LS	1	$3,000.00	$3,000	$1,500.00	$1,500	$1,500.00	$1,500		$0	$6,000.00	$6,000
	Furnish 2 ea Pipe Piles D=48", T=1.0", L=92' (502.44 lb/lf)	LB	92,449		$0		$0	$1.00	$92,449		$0	$1.00	$92,449
	Install Pipe Piles	EA	2	$2,750.00	$5,500	$2,250.00	$4,500		$0		$0	$5,000.00	$10,000
	SUBTOTAL	LS	1		$451,200		$200,300		$440,924		$0		$1,092,424
									10%	Mobilization/Demobilization/Field Overhead			$109,242
									15%	Contractor Profit/Central Office Overhead			$180,250
									15%	Contingency			$207,287
										TOTAL			$1,589,200

Notes:

Owner: Port of San Diego
Location: Shelter Island

Project Title: Shelter Island Yacht Basin Culvert

Estimated By
Firm: M & N
Est Name: MOD

A-E Firm Name
Moffatt and Nichol
Checked By: FM
Status of Design: **Conceptual**

Date **08/02/16**

RCP - Cofferdams

				LABOR COST		EQUIPMENT COST		MATERIAL COST		SUB QUOTE COST		TOTAL COST	
ITEM NO.	ITEM DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	AMOUNT	UNIT PRICE	AMOUNT	UNIT PRICE	AMOUNT	UNIT PRICE	AMOUNT	UNIT PRICE	AMOUNT
	Furnish PZ40 Sheet Piles (Wt =40lb/lf, H=53', L=370')	LB	784,400		$0		$0	$1.00	$784,400		$0	$1.00	$784,400
	Install Sheet Piles - Ea = number of pairs	EA	113	$1,300.00	$146,900	$1,000.00	$113,000		$0		$0	$2,300.00	$259,900
	Remove Sheet Piles	EA	113	$650.00	$73,450	$500.00	$56,500		$0		$0	$1,150.00	$129,950
	SUBTOTAL	LS	1		$220,350		$169,500		$784,400		$0		$1,174,250
									10%	Mobilization/Demobilization/Field Overhead			$117,425
									15%	Contractor Profit/Central Office Overhead			$193,751
									15%	Contingency			$222,814
										TOTAL			$1,708,240

Notes:

Owner: Port of San Diego
Location: Shelter Island

Project Title: Shelter Island Yacht Basin Culvert

Estimated By
Firm: M & N
Est Name: MOD

A-E Firm Name
Moffatt and Nichol **Date** **08/02/16**
Checked By: FM
Status of Design: **Conceptual**

RCP - Remove and Re-Use Rock Slope Protection (RSP)

				LABOR COST		EQUIPMENT COST		MATERIAL COST		SUB QUOTE COST		TOTAL COST	
ITEM NO.	ITEM DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	AMOUNT	UNIT PRICE	AMOUNT	UNIT PRICE	AMOUNT	UNIT PRICE	AMOUNT	UNIT PRICE	AMOUNT
	Remove and reinstall RSP (Re-use the removed RSP)	CY	200	$50.00	$10,000	$25.00	$5,000	$25.00	$5,000		$0	$100.00	$20,000
	SUBTOTAL	LS	1		$10,000		$5,000		$5,000		$0		$20,000

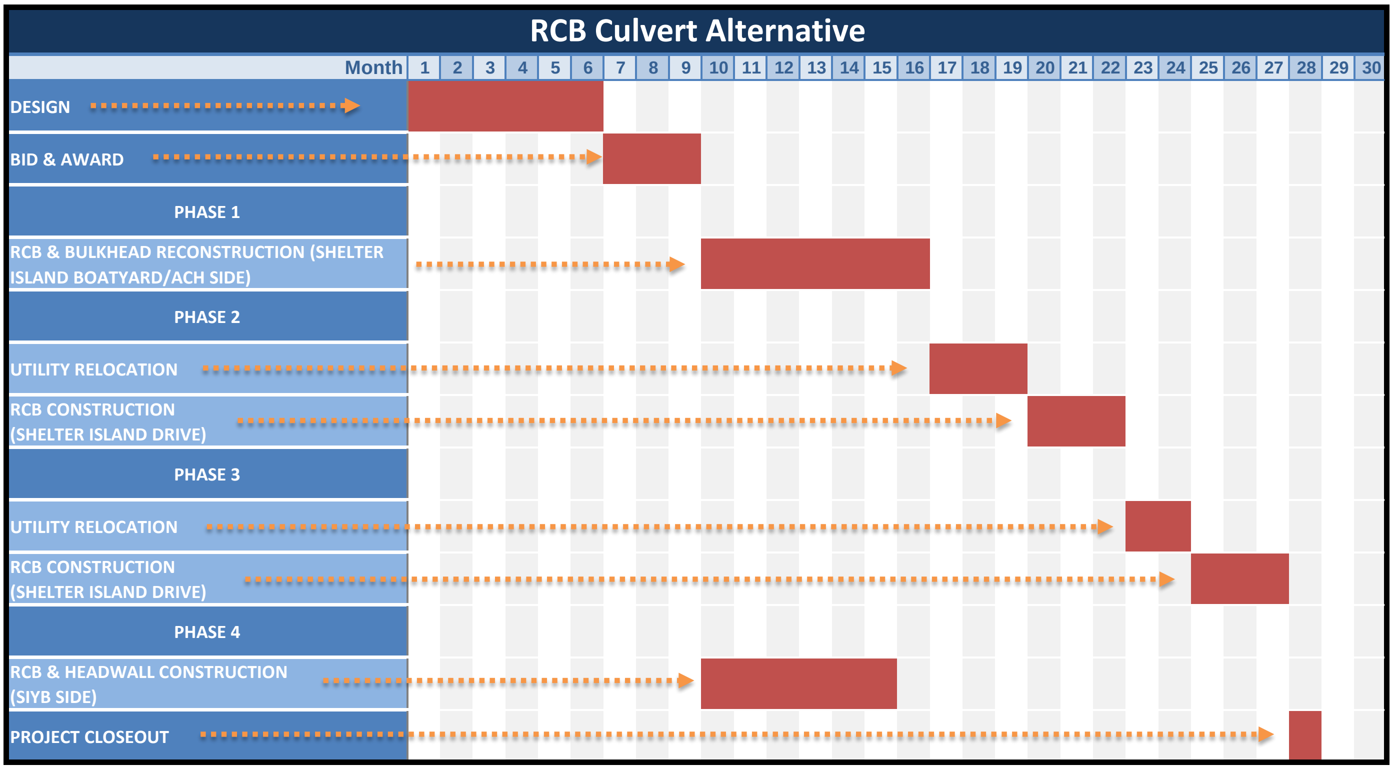
10%	Mobilization/Demobilization/Field Overhead	$2,000
15%	Contractor Profit/Central Office Overhead	$3,300
15%	Contingency	$3,795
	TOTAL	$29,100

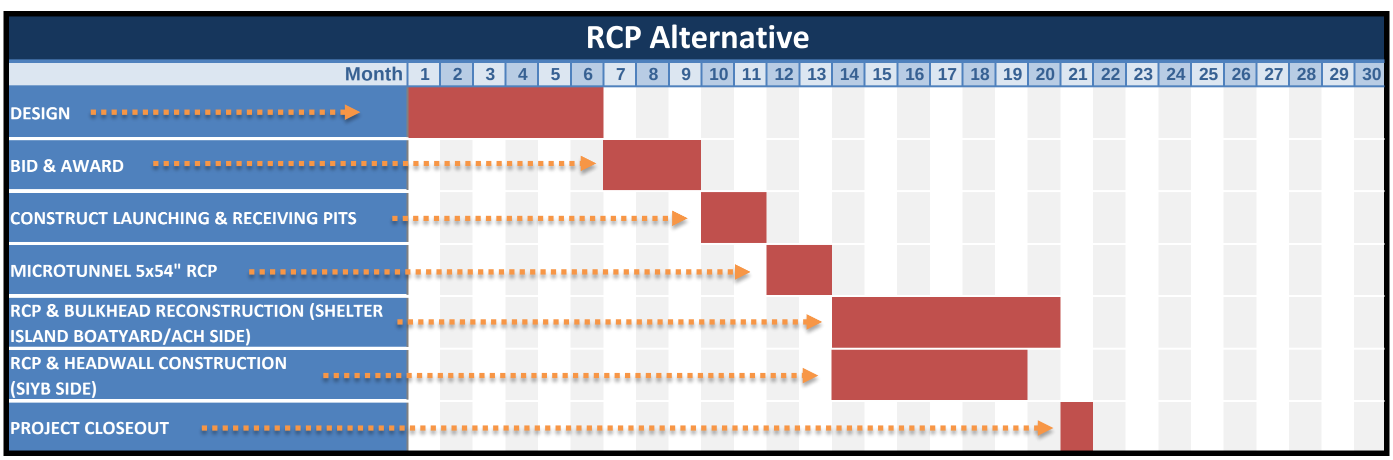
Notes:

Appendix E

Project Schedule

Shelter Island Yacht Basin Tidal Flushing - Project Schedule





Appendix F

"Shelter Island Yacht Basin Tidal Flushing Modeling and Engineering Feasibility Study" – Prepared by Weston Solutions, dated February 2013

Shelter Island Yacht Basin Tidal Flushing Modeling and Engineering Feasibility Study

Final Report

Prepared For:

Port of San Diego
3165 Pacific Highway
San Diego, California

February 2013

Shelter Island Yacht Basin Tidal Flushing Modeling and Engineering Feasibility Study

Prepared For:

Port of San Diego
3165 Pacific Highway
San Diego, California

Prepared By:

Weston Solutions, Inc.
5817 Dryden Place, Suite 101
Carlsbad, California 92008

February 2013

TABLE OF CONTENTS

APPENDIX

LIST OF FIGURES

LIST OF TABLES

ACRONYMS AND ABBREVIATIONS

ACH	America's Cup Harbor
Basin Plan	*Water Quality Control Plan for the San Diego Basin – Region 9*
BMP	best management practice
CWA	Clean Water Act
CMA	Coastal Monitoring Associates, LLC
Implementation Plan	SIYB Dissolved Copper TMDL Implementation Plan
Investigative Order	Investigative Order No. R9-2011-0036
MAR	marine habitat
OAL	Office of Administrative Law
Port	San Diego Unified Port District
RCB	reinforced concrete box
RCP	reinforced concrete pipe
Regional Board	San Diego Regional Water Quality Control Board
SIYB	Shelter Island Yacht Basin
SDB	San Diego Bay
TMDL	Total Maximum Daily Load
Weston	Weston Solutions, Inc.
WILD	wildlife habitat
WQO	water quality objectives

UNITS OF MEASURE

µg/L	microgram per liter
%	percent

1.0 INTRODUCTION

1.1 TMDL Summary & Background

In 1996, the Shelter Island Yacht Basin (SIYB) was placed on the Clean Water Act (CWA) Section 303(d) list of impaired waters due to elevated levels of dissolved copper in the water column. The CWA requires that the Regional Board implement a TMDL for 303(d)-listed waters of SIYB since the existing water quality did not meet numeric water quality standards for dissolved copper or narrative water quality objectives (WQOs) for toxicity and pesticides. As a result, the Regional Board developed a TMDL for SIYB, with the purpose of achieving applicable WQOs as well as the restoration of marine habitat (MAR) and wildlife habitat (WILD) beneficial uses within the basin. The San Diego Regional Water Quality Control Board (Regional Board) incorporated the dissolved copper TMDL into the *Water Quality Control Plan for the San Diego Basin – Region 9* (Basin Plan)(Regional Board, 2005) through Resolution No. R9-2005-0019. The Office of Administrative Law (OAL) reviewed and approved the dissolved copper TMDL on December 2, 2005.

1.2 TMDL Implementation Plan

Named Parties (i.e., Dischargers) prepared a TMDL Implementation Plan (Implementation Plan) that describes the collective approach to achieving reductions in copper loading into SIYB in order to preserve and restore beneficial uses. The Implementation Plan takes a solutions-oriented approach of establishing and implementing Best Management Practices (BMPs) that directly and indirectly facilitate reductions in copper loading into the basin to meet the SIYB TMDL interim and final dissolved copper loading compliance thresholds. The Implementation Plan was prepared in response to Resolution No. R9-2005-0019 (Weston, 2011).

This Implementation Plan incorporates an adaptive management model of planning, implementation, and assessment. The first step in the planning phase is to develop a BMP implementation strategy by which the Named Parties will work independently and collectively to reduce copper loading into SIYB. It is recognized that the current primary source of dissolved copper to the water column originates from copper-based antifouling paints. A potential strategy to reduce dissolve copper in the water column is to increase tidal flushing (i.e., reduce the average time that water remains in SIYB) resulting in the more rapid removal of dissolve copper and thus lower concentrations of dissolved copper in the water column.

1.3 Study Purpose

The purpose of this Tidal Flushing Modeling and Engineering Feasibility Study (Study) is to utilize a predictive model to simulate the processes that regulate copper concentrations in SIYB under current and modified conditions. The modified conditions evaluated for this Study include the potential strategies of constructing a submersed connection (pipe or culvert) between SIYB and the San Diego Bay (SDB) or a connection between SIYB and the America's Cup Harbor (ACH). In support of the modeling effort the cost and construction feasibility of each potential strategy was evaluated. The results of this Study may be used by planners to facilitate future decisions regarding the best implementation strategies to achieve TMDL interim and final dissolved copper loading compliance thresholds.

2.0 ENGINEERING FEASIBILITY ASSESSMENT

The feasibility, considering the engineering and construction involved, of providing a submersed connection (culvert or pipe) between SIYB and SDB or between SIYB and ACH was evaluated. This included an evaluation of existing underground utilities and providing rough order of magnitude cost estimates. Potential conflicts with existing underground utilities were evaluated. Depending on size, location, and type of utility, conflicts may impact the constructability of the proposed scenarios (e.g., a large gravity sewer line in the path of a culvert or pipe may cause the project to not be constructible).

In order to assess the engineering feasibility of the modeling enhanced flushing scenarios, conceptual drawings of the potential improvements (connections) were prepared. Research of the existing underground utilities was conducted at the City of San Development Services Department and included a review of Shelter Island Drive sewer as-built drawings, which also show other existing utilities. The topographic elevations for the conceptual drawings were estimated by City of San Diego SanGIS 2-foot contour data, and elevations data obtained from as-built drawings of the Shelter Island Drive. Street centerline and right-of-way as well as property lines were estimated by combining SanGIS data, information from as-built drawings, and aerial photographs.

Profiles of the proposed culverts (or pipes) were prepared in order to compare the locations of the proposed connections to those of the existing utilities. No direct conflict with underground utilities for any of the scenarios is indicated on these profiles. Various utilities are located beneath Shelter Island Drive that would require additional attention during construction activities to ensure that they remain protected-in-place (e.g., hand excavation around them, shoring, etc. or employing horizontal construction). Additionally, dewatering would be required for the entire project excavation and may include constructing temporary coffer dams in SYIB and SDB or ACH.

The preparation of the conceptual drawings was based on limited data in order to identify potential obvious and major conflicts and issues. If one or more of these scenarios is proposed for potential implementation, additional assessment shall be conducted early in the project planning phase in order to refine the design and further assess the feasibility and cost of the scenario.

2.1 Shelter Island Yacht Basin to San Diego Bay Connection

Connecting SIYB to SDB would require about 750 feet of underground culvert or pipe. Figure 2-1 shows SYIB connected to SDB utilizing a reinforced concrete box (RCB) culvert (12 feet wide by 8 feet height). Table 2-1 provides the rough cost estimate associate with constructing the RCB culvert. Unit prices in the cost estimate are based on the City of San Diego Development Services Department *Unit Price List* (San Diego, 2009), if applicable. In cases where items are not listed in this reference, reasonable assumptions regarding costs were made. Figure 2-2 shows SYIB connected to SDB utilizing a 54-inch diameter reinforce concrete pipe (RCP), and Table 2-2 provides the rough cost estimate associate with constructing the RCP.

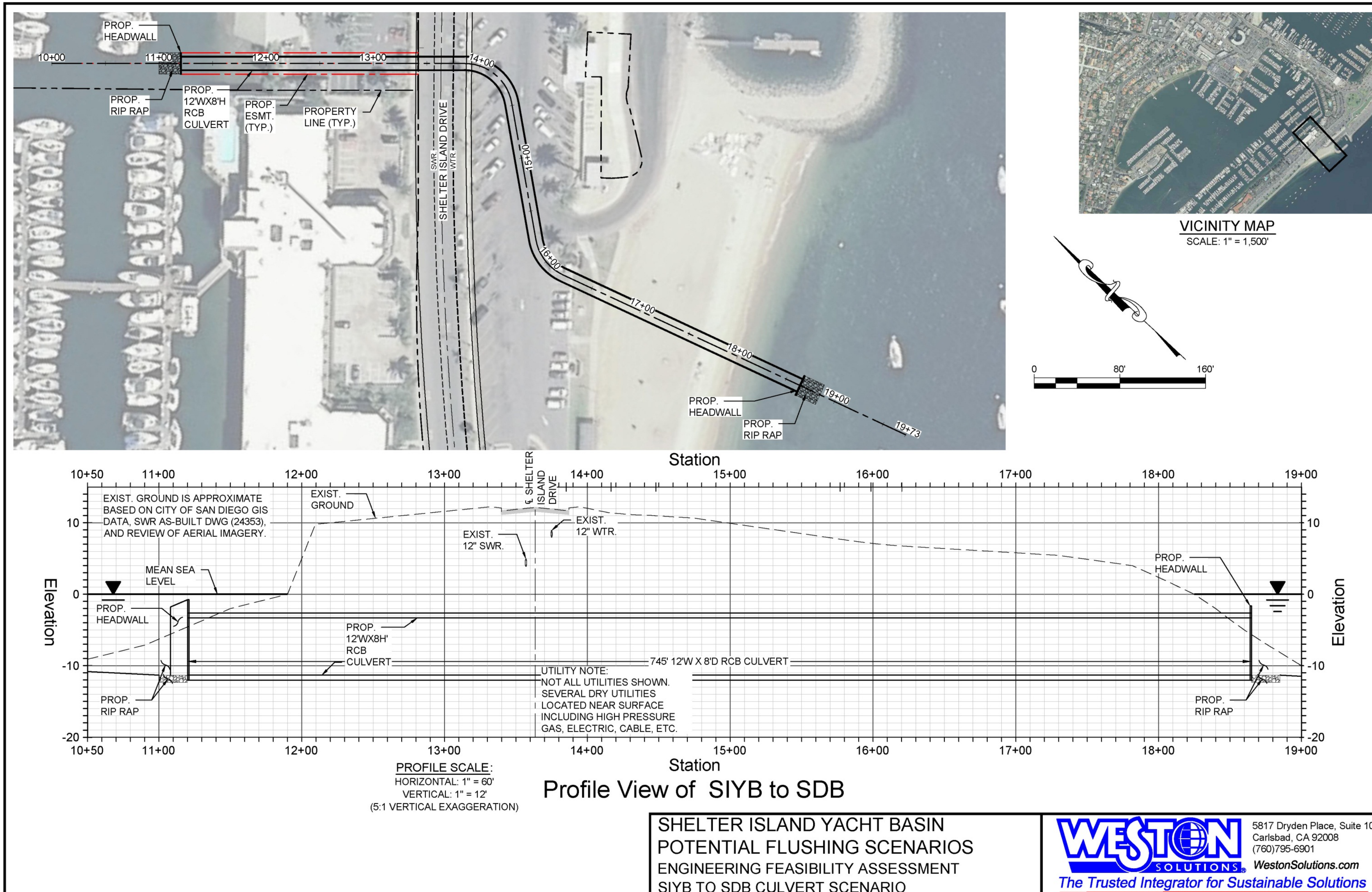


Figure 2-1. Shelter Island Yacht Basin to San Diego Bay Box Culvert Connection Conceptual Plan Drawing

Table 2-1. Cost Estimate for SIYB to SDB Culvert Connection Scenario

ITEM	QUANTITY	UNIT	UNIT PRICE	COST
Demo Existing Asphalt Parking Lot	4,900	SF	$3.50	$17,150
Demo Existing Roadway Asphalt Concrete	658	SF	$4.00	$2,632
Demo Existing Roadway Sidewalk	140	SF	$2.50	$350
Demo Existing Roadway Curb & Gutter	56	LF	$8.00	$448
Grading (Excavate, Stockpile, Backfill)	7,073	CY	$25.00	$176,825
Storm Darin Pipe - 12' X 8' RCB (Caltrans D-80)	745	LF	$988.00	$736,060
Storm Drain Structure - Headwall	2	EA	$7,000.00	$14,000
Construct Type A Cleanout (Per D-9)	3	EA	$6,368.00	$19,104
Rip Rap	46	CY	$125.00	$5,750
Dredge Area of Storm Drain Pipe & Rip Rap	400	CY	$45.00	$18,000
Repair Asphalt Concrete Parking Lot	4,900	LF	$6.00	$29,400
Repair Asphalt Concrete Roadway	658	SF	$9.00	$5,922
Repair Curb & Gutter in Roadway	56	LF	$30.00	$1,680
Repair Sidewalk in Roadway	140	SF	$16.00	$2,240
Trench Shoring	620	LF	$32.00	$19,840
Construct Cofferdam	2	LS	$15,000.00	$30,000
Traffic Control	1	LS	$8,000.00	$8,000
Protect-in-place existing utilities	1	LS	$5,000.00	$5,000
Concrete Washout	1	EA	$825.00	$825
Construction Fence	1,200	LF	$4.00	$4,800
Gravel Bag	1,200	EA	$1.82	$2,184
			Construction Subtotal	**$1,100,210**
			Environmental Permitting	$60,000
			Engineering Design - 20% of construction subtotal	$220,042
			Mobilization - 10% of construction subtotal	$110,021
			Construction Bond - 5% of construction subtotal	$55,011
			Contingency - 20% of construction subtotal	$220,042
			Construction Total	**$1,765,326**

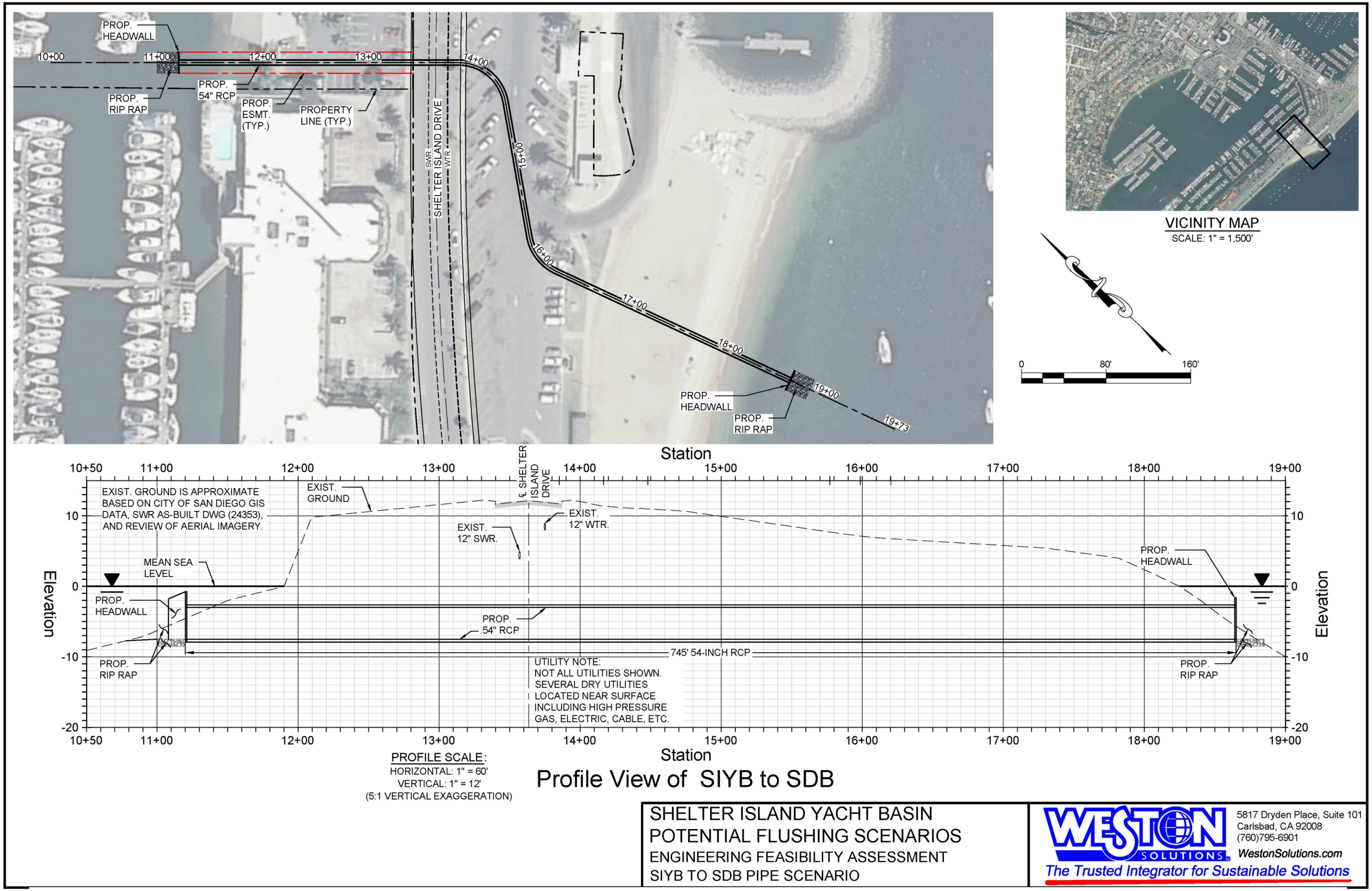


Figure 2-2. Shelter Island Yacht Basin to San Diego Bay Pipe Connection Conceptual Plan Drawing

Table 2-2. Cost Estimate for SIYB to SDB Pipe Connection Scenario

ITEM	QUANTITY	UNIT	UNIT PRICE	COST
Demo Existing Asphalt Parking Lot	2,800	SF	$3.50	$9,800
Demo Existing Roadway Asphalt Concrete	376	SF	$4.00	$1,504
Demo Existing Roadway Sidewalk	80	SF	$2.50	$200
Demo Existing Roadway Curb & Gutter	32	LF	$8.00	$256
Grading (Excavate, Stockpile, Backfill)	3,307	CY	$32.20	$106,485
Storm Darin Pipe - 54" RCP	745	LF	$273.00	$203,385
Storm Drain Structure - Headwall	2	EA	$7,000.00	$14,000
Construct Type A Cleanout (Per D-9)	3	EA	$6,368.00	$19,104
Rip Rap	46	CY	$125.00	$5,750
Dredge Area of Storm Drain Pipe & Rip Rap	400	CY	$45.00	$18,000
Repair Asphalt Concrete Parking Lot	2,800	LF	$6.00	$16,800
Repair Asphalt Concrete Roadway	376	SF	$9.00	$3,384
Repair Curb & Gutter in Roadway	32	LF	$30.00	$960
Repair Sidewalk in Roadway	80	SF	$16.00	$1,280
Trench Shoring	620	LF	$32.00	$19,840
Construct Cofferdam	2	LS	$15,000.00	$30,000
Traffic Control	1	LS	$8,000.00	$8,000
Protect-in-place existing utilities	1	LS	$5,000.00	$5,000
Concrete Washout	1	EA	$825.00	$825
Construction Fence	1,200	LF	$4.00	$4,800
Gravel Bag	1,200	EA	$1.82	$2,184
			Construction Subtotal	**$471,557**
			Environmental Permitting	$60,000
			Engineering Design - 20% of construction subtotal	$94,311
			Mobilization - 10% of construction subtotal	$47,156
			Construction Bond - 5% of construction subtotal	$23,578
			Contingency - 20% of construction subtotal	$94,311
			Construction Total	**$790,914**

The cost associated with constructing a single 54-inch RCP is much less than the cost associated with constructing a 12 feet wide by 8 feet in height RCB culvert. The 54-inch pipe has a much smaller cross section area (about 16 square feet) compared to the RCB (96 square feet), and therefore will provide less enhanced flushing (exactly how much less is determined by modeling). In order to get the same approximate cross sectional area, and similar flushing, 5 pipes could be constructed in parallel in with an alignment and profile shown in Figure 2-2. Although not modeled, there may be advantages to constructing multiple pipes rather than a large RCB culvert (e.g., shorter construction schedule and easier to perform horizontal boring and placement). Table 2-3 shows the cost associated with constructing 5 pipes to connect SIYB to SDB.

Table 2-3. Cost Estimate for SIYB to SDB 5-Pipe Connection Scenario				
ITEM	**QUANTITY**	**UNIT**	**UNIT PRICE**	**COST**
Demo Existing Asphalt Parking Lot	11,375	SF	$3.50	$39,813
Demo Existing Roadway Asphalt Concrete	1,528	SF	$4.00	$6,110
Demo Existing Roadway Sidewalk	350	SF	$2.50	$875
Demo Existing Roadway Curb & Gutter	70	LF	$8.00	$560
Grading (Excavate, Stockpile, Backfill)	13,434	CY	$25.00	$335,850
Storm Darin Pipe - 54" RCP	3,725	LF	$273.00	$1,016,925
Storm Drain Structure - Headwall	4	EA	$7,000.00	$28,000
Construct Type A Cleanout (Per D-9)	15	EA	$6,368.00	$95,520
Rip Rap	90	CY	$125.00	$11,250
Dredge Area of Storm Drain Pipe & Rip Rap	400	CY	$45.00	$18,000
Repair Asphalt Concrete Parking Lot	11,375	LF	$6.00	$68,250
Repair Asphalt Concrete Roadway	1,528	SF	$9.00	$13,748
Repair Curb & Gutter in Roadway	70	LF	$30.00	$2,100
Repair Sidewalk in Roadway	350	SF	$16.00	$5,600
Trench Shoring	620	LF	$32.00	$19,840
Construct Cofferdam	2	LS	$15,000.00	$30,000
Traffic Control	1	LS	$8,000.00	$8,000
Protect-in-place existing utilities	1	LS	$5,000.00	$5,000
Concrete Washout	1	EA	$825.00	$825
Construction Fence	1,200	LF	$4.00	$4,800
Gravel Bag	1,200	EA	$1.82	$2,184
			Construction Subtotal	**$1,713,249**
			Environmental Permitting	$60,000
			Engineering Design - 20% of construction subtotal	$342,650
			Mobilization - 10% of construction subtotal	$171,325
			Construction Bond - 5% of construction subtotal	$85,662
			Contingency - 20% of construction subtotal	$342,650
			Construction Total	**$2,715,536**

2.2 Shelter Island Yacht Basin to America's Cup Harbor Connection

Connecting SIYB to ACH would require about 340 feet of underground box culvert or pipe. Figure 2-3 shows SYIB connected to ACH utilizing a RCB culvert (12 feet wide by 8 feet height). Table 2-4 provides the rough cost estimate associate with constructing the RCB culvert. Similarly, Figure 2-4 shows SYIB connected to ACH utilizing a 54-inch diameter RCP, and Table 2-5 provides the rough cost estimate associate with constructing the RCP.

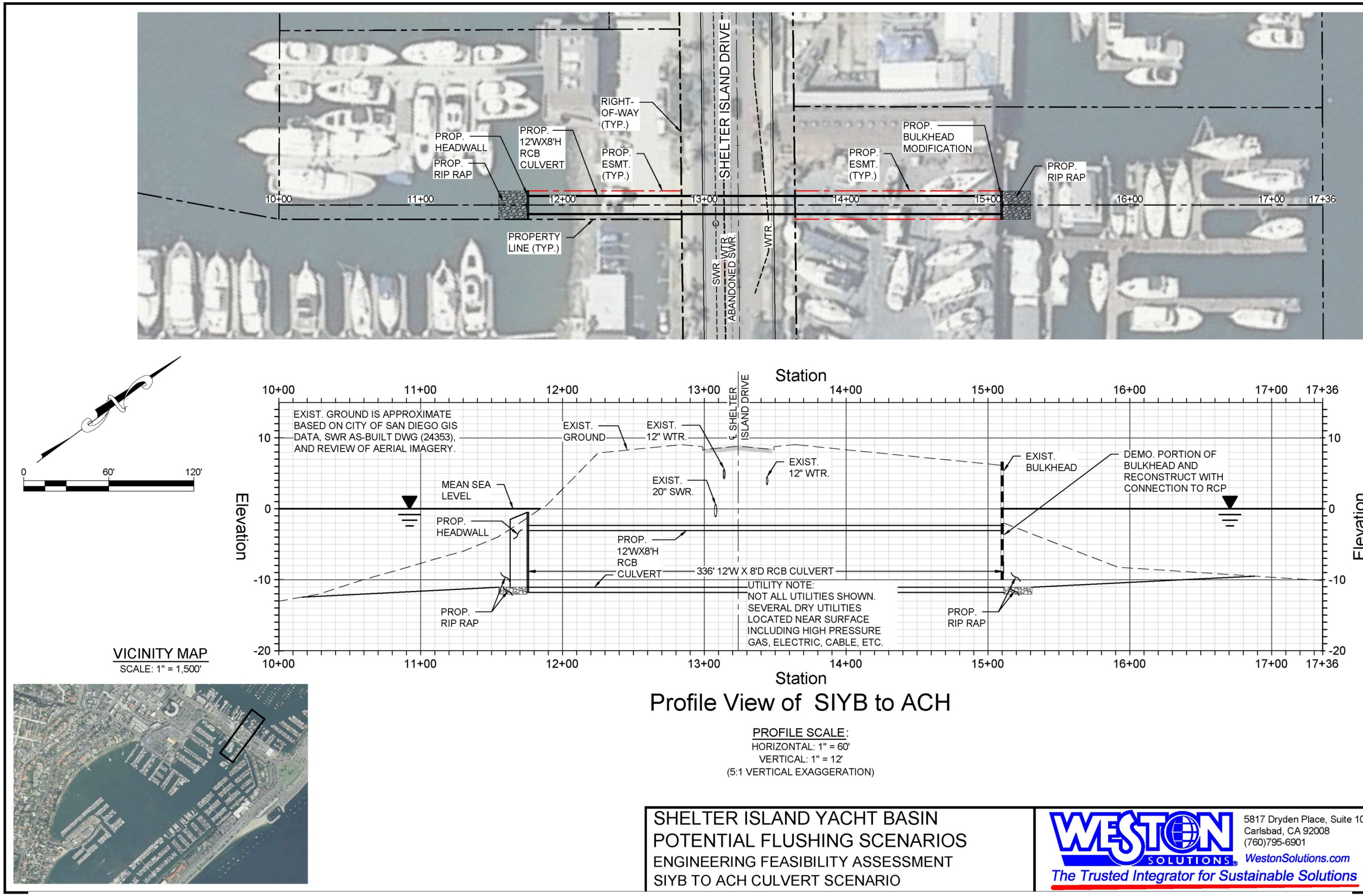


Figure 2-3. Shelter Island Yacht Basin to America's Cup Harbor Box Culvert Connection Conceptual Plan Drawing

Table 2-4. Cost Estimate for SIYB to ACH Culvert Connection Scenario

ITEM	QUANTITY	UNIT	UNIT PRICE	COST
Demo Existing Asphalt Parking Lot	2,800	SF	$3.50	$9,800
Demo Existing Roadway Asphalt Concrete	658	SF	$4.00	$2,632
Demo Existing Roadway Sidewalk	140	SF	$2.50	$350
Demo Existing Roadway Curb & Gutter	28	LF	$8.00	$224
Grading (Excavate, Stockpile, Backfill)	2,562	CY	$25.00	$64,050
Storm Darin Pipe - 12' X 8' RCB (Caltrans D-80)	336	LF	$988.00	$331,968
Storm Drain Structure - Headwall	1	EA	$10,500.00	$10,500
Connection / Reconstruct Bulkhead	280	SF	$50.00	$14,000
Construct Type A Cleanout (Per D-9)	1	EA	$6,368.00	$6,368
Rip Rap	46	CY	$125.00	$5,750
Dredge Area of Storm Drain Pipe & Rip Rap	200	CY	$45.00	$9,000
Repair Asphalt Concrete Parking Lot	2,800	LF	$6.00	$16,800
Repair Asphalt Concrete Roadway	658	SF	$9.00	$5,922
Repair Curb & Gutter in Roadway	28	LF	$30.00	$840
Repair Sidewalk in Roadway	140	SF	$16.00	$2,240
Trench Shoring	260	LF	$32.00	$8,320
Construct Cofferdam	2	LS	$15,000.00	$30,000
Traffic Control	1	LS	$8,000.00	$8,000
Protect-in-place existing utilities	1	LS	$5,000.00	$5,000
Concrete Washout	1	EA	$825.00	$825
Construction Fence	600	LF	$4.00	$2,400
Gravel Bag	1,200	EA	$1.82	$2,184
			Construction Subtotal	**$537,173**
			Environmental Permitting	$60,000
			Engineering Design - 20% of construction subtotal	$161,152
			Mobilization - 10% of construction subtotal	$53,717
			Construction Bond - 5% of construction subtotal	$26,859
			Contingency - 20% of construction subtotal	$107,435
			Construction Total	**$946,336**

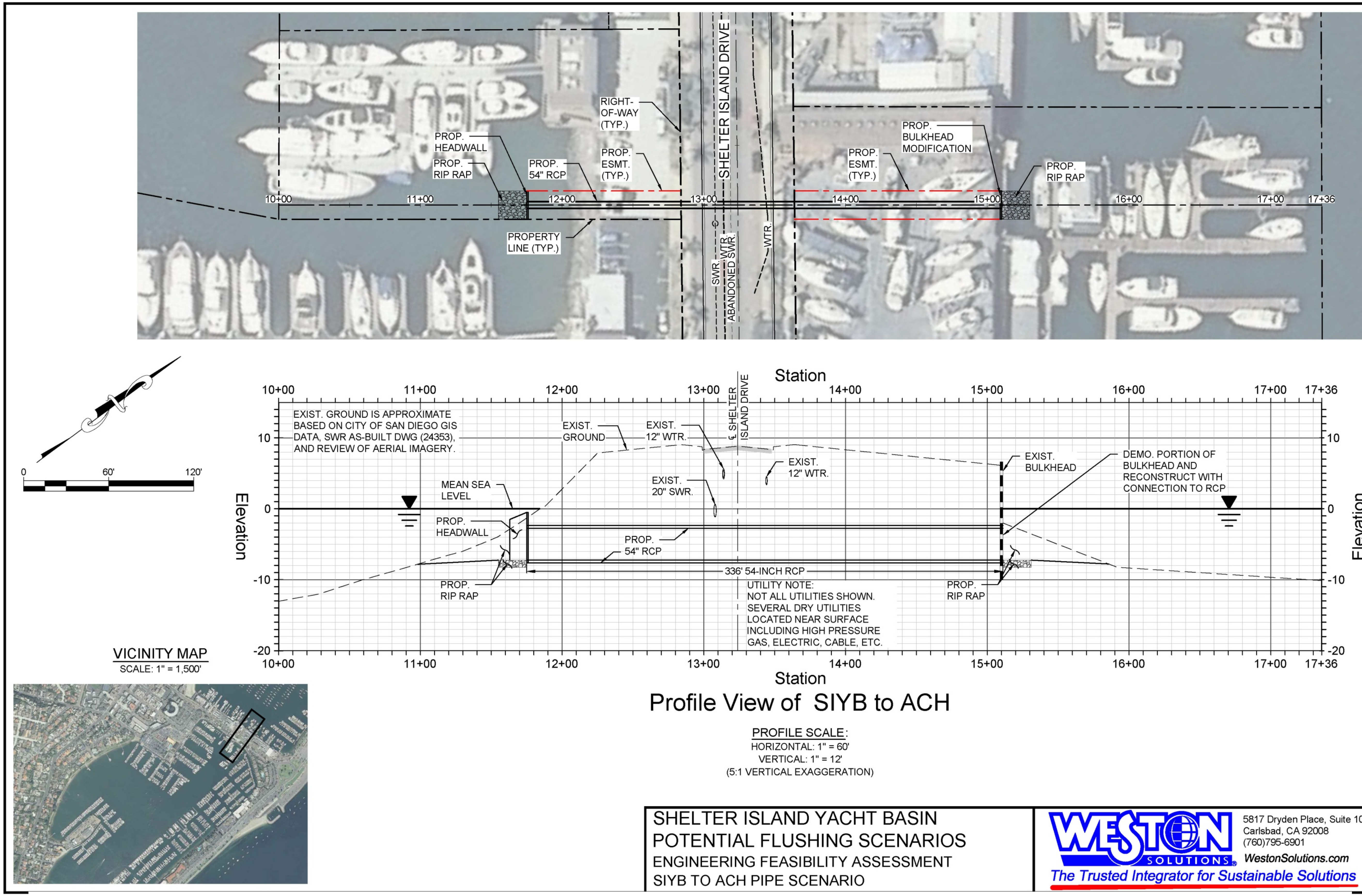


Figure 2-4. Shelter Island Yacht Basin to America's Cup Harbor Pipe Connection Conceptual Plan Drawing

Table 2-5. Cost Estimate for SIYB to ACH Pipe Connection Scenario

ITEM	QUANTITY	UNIT	UNIT PRICE	COST
Demo Existing Asphalt Parking Lot	1,600	SF	$3.50	$5,600
Demo Existing Roadway Asphalt Concrete	376	SF	$4.00	$1,504
Demo Existing Roadway Sidewalk	80	SF	$2.50	$200
Demo Existing Roadway Curb & Gutter	16	LF	$8.00	$128
Grading (Excavate, Stockpile, Backfill)	1,156	CY	$32.20	$37,223
Storm Darin Pipe - 54" RCP	336	LF	$273.00	$91,728
Storm Drain Structure - Headwall	1	EA	$7,000.00	$7,000
Connection / Reconstruct Bulkhead	128	SF	$50.00	$6,400
Construct Type A Cleanout (Per D-9)	1	EA	$6,368.00	$6,368
Rip Rap	46	CY	$125.00	$5,750
Dredge Area of Storm Drain Pipe & Rip Rap	200	CY	$45.00	$9,000
Repair Asphalt Concrete Parking Lot	1,600	LF	$6.00	$9,600
Repair Asphalt Concrete Roadway	376	SF	$9.00	$3,384
Repair Curb & Gutter in Roadway	16	LF	$30.00	$480
Repair Sidewalk in Roadway	80	SF	$16.00	$1,280
Trench Shoring	260	LF	$32.00	$8,320
Construct Cofferdam	2	LS	$15,000.00	$30,000
Traffic Control	1	LS	$8,000.00	$8,000
Protect-in-place existing utilities	1	LS	$5,000.00	$5,000
Concrete Washout	1	EA	$825.00	$825
Construction Fence	600	LF	$4.00	$2,400
Gravel Bag	1,200	EA	$1.82	$2,184
			Construction Subtotal	**$242,374**
			Environmental Permitting	$60,000
			Engineering Design - 20% of construction subtotal	$72,712
			Mobilization - 10% of construction subtotal	$24,237
			Construction Bond - 5% of construction subtotal	$12,119
			Contingency - 20% of construction subtotal	$48,475
			Construction Total	**$459,918**

The cost associated with constructing a single 54-inch RCP is much less than the cost associated with constructing a 12 feet wide by 8 feet in height RCB culvert. The 54-inch pipe has a much smaller cross section area (about 16 square feet) compared to the RCB (96 square feet), and therefore will provide less enhanced flushing (exactly how much less is determined by modeling). In order to get the same approximate cross sectional area, and similar flushing, 5 pipes could be constructed in parallel in with an alignment and profile shown in Figure 2-4. Although not modeled, there may be advantages to constructing multiple pipes rather than a large RCB culvert (e.g., shorter construction schedule and easier to perform horizontal boring and placement). Table 2-6 shows the cost associated with constructing 5 pipes to connect SIYB to SDB.

Table 2-6. Cost Estimate for SIYB to ACH 5-Pipe Connection Scenario

ITEM	QUANTITY	UNIT	UNIT PRICE	COST
Demo Existing Asphalt Parking Lot	6,500	SF	$3.50	$22,750
Demo Existing Roadway Asphalt Concrete	1,528	SF	$4.00	$6,110
Demo Existing Roadway Sidewalk	350	SF	$2.50	$875
Demo Existing Roadway Curb & Gutter	70	LF	$8.00	$560
Grading (Excavate, Stockpile, Backfill)	4,695	CY	$25.00	$117,375
Storm Darin Pipe - 54" RCP	1,680	LF	$273.00	$458,640
Storm Drain Structure - Headwall	2	EA	$7,000.00	$14,000
Connection / Reconstruct Bulkhead	520	SF	$50.00	$26,000
Construct Type A Cleanout (Per D-9)	5	EA	$6,368.00	$31,840
Rip Rap	90	CY	$125.00	$11,250
Dredge Area of Storm Drain Pipe & Rip Rap	200	CY	$45.00	$9,000
Repair Asphalt Concrete Parking Lot	6,500	LF	$6.00	$39,000
Repair Asphalt Concrete Roadway	1,528	SF	$9.00	$13,748
Repair Curb & Gutter in Roadway	70	LF	$30.00	$2,100
Repair Sidewalk in Roadway	350	SF	$16.00	$5,600
Trench Shoring	260	LF	$32.00	$8,320
Construct Cofferdam	2	LS	$15,000.00	$30,000
Traffic Control	1	LS	$8,000.00	$8,000
Protect-in-place existing utilities	1	LS	$5,000.00	$5,000
Concrete Washout	1	EA	$825.00	$825
Construction Fence	600	LF	$4.00	$2,400
Gravel Bag	1,200	EA	$1.82	$2,184
			Construction Subtotal	**$815,577**
			Environmental Permitting	$60,000
			Engineering Design - 20% of construction subtotal	$244,673
			Mobilization - 10% of construction subtotal	$81,558
			Construction Bond - 5% of construction subtotal	$40,779
			Contingency - 20% of construction subtotal	$163,115
			Construction Total	**$1,405,702**

3.0 TIDAL FLUSHING MODELING

Weston contracted Coastal Monitoring Associates, LLC (CMA) to perform Curvilinear Hydrodynamics in Three Dimensions (CH3D) modeling simulations of the existing condition and tidal flushing enhancement modification scenarios. The objective of the modeling was to evaluate the potential for enhanced flushing of SIYB through the placement of engineered culverts (or pipes) between the head of SIYB and SDB, and between the heads of SIYB and ACH. Flushing and associated total copper concentrations were modeled under five scenarios, including:

1. Baseline with no enhanced flushing.
2. Culvert connecting SIYB to SDB.
3. Culvert connecting SIYB to ACH.
4. Pipe[1] connecting SIYB to SDB.
5. Pipe[1] connecting SIYB to ACH.

Note 1: The modeling of the potential enhanced flushing scenarios as result of implementing pipe connections was conducted utilizing a 52-inch diameter pipe. The purposed of performing modeling for both a large geometry RCB culvert and a smaller geometry pipe was to provide data for comparison (large versus small connections). Available precast RCP sizes are limited to 3-inch increments that include 51-inch and 54-inch diameters, but not the modeled 52-inch diameter. The conceptual drawings for the pipe connections assumed 54-inch diameter pipes, which have a very similar, but slightly larger, geometry compared to 52-inch diameter pipes. The discrepancy between the different pipe sizes noted (2 inches) is considered insignificant and does not deduct from the overall modeling purpose or results.

Enhanced flushing configuration (connection to either SDB or ACH) model results were compared to the baseline condition with no enhanced flushing as well as to each other. The complete modeling report is provided in the Appendix A of this report and provides additional details on the modeling methods, approach, and simulation results.

4.0 RESULTS

The results showed that the CH3D Model provided a reasonable prediction of total copper concentrations in SIYB under baseline conditions (i.e., no enhanced flushing). In assessing the enhanced flushing scenarios, establishing a connection between SIYB and ACH was modeled to be much more effective in enhancing flushing and reducing copper concentrations than a connection between SIYB and SDB for both culvert and pipe scenarios. Installation of a submerged culvert between SIYB and ACH was modeled to provide the greatest benefit in terms of reducing total copper concentrations in SIYB, since it reduced concentrations by 17% on average throughout the basin and by 21% at the head (or enclosed end) of the basin. The single pipe connection between SIYB-ACH was modeled to reduce total copper concentrations by approximately 10% at the head and by approximately 9% basin-wide.

Based on the modeling study, it can be concluded that placement of a culvert connection between SIYB and ACH has the greatest potential to enhance flushing and reduce copper concentrations. Based on 2011 TMDL monitoring, the average dissolved copper concentration in SIYB was 8.3 µg/L; a 17% reduction in dissolved copper concentration would equate to an average concentration of roughly 6.9 µg/L. Based on the modeled results, enhancement of flushing alone would not result in compliance with the current water quality objective of 3.1 µg/L.

The engineering feasibility assessment, which included a review of the existing on-land infrastructure between SIYB and ACH, indicated that a standard 12 feet wide by 8 feet in height box culvert could be placed below the existing sewer and water lines that run parallel to Shelter Island Drive. Alternatively, multiple 54-inch diameter pipes could also be used to enhance flushing between the basins. The SIYB-ACH culvert connection was estimated to cost about $950,000, including permitting, design, and construction costs. Construction of pipe connections varied in cost from about $460,000 for a single 54-inch pipe to about $1,400,000 for five 54-inch pipes. Engineering feasibility and cost assessments were also performed for pipe and culvert connections between SIYB and SDB; however, the modeling shows lower efficacy of this connection in conjunction with the higher estimated costs indicates that the SIYB-ACH connection would be preferable.

5.0 REFERENCES

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City of San Diego Development Services Department (San Diego). 2009. *Unit Price List*. January 2009.

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APPENDIX A

Modeling Analysis of Enhanced Flushing of Shelter Island Yacht Basin, San Diego Bay, California

Final Report

Modeling Analysis of Enhanced Flushing of Shelter Island Yacht Basin, San Diego Bay, California

September 2012

Submitted to:

Port of San Diego.

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San Diego, CA 92101

Submitted by:

Coastal Monitoring Associates, LLC

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TABLE OF CONTENTS

LIST OF ACRONYMS

ACH	America's Cup Harbor
CH3D	Curvilinear Hydrodynamics in Three Dimensions
RWQCB	Regional Water Quality Control Board
SDB	San Diego Bay
SD1D	One-Dimensional Steady State Box Model
SIYB	Shelter Island Yacht Basin
TMDL	Total Maximum Daily Load
WSL	Water Surface Elevation

UNITS

cm	centimeters
cm/s	centimeters per second
degrees	degrees
in	inches
kg	kilograms
km^2	square kilometers
ft	feet
ft^2	square feet
m	meters
ppb	parts per billion
ug/L	micrograms per liter
%	percent

LIST OF TABLES

LIST OF FIGURES

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1 INTRODUCTION AND BACKGROUND

Shelter Island Yacht Basin (SIYB) is an enclosed recreational marina located in northern San Diego Bay (SDB) and connected to the Bay by a single entrance at the southern extent of Shelter Island. The basin contains a large number of recreational vessels (~2,300) that are typically painted with copper-based antifouling paints that are designed to leach into the environment to prevent marine fouling (Regional Water Quality Control Board [RWQCB, 2005]). The combination of the large number of vessels in the basin, and the limited hydrodynamic flushing has led to previously documented elevated concentrations of copper (Katz, 1998; VanderWeele, 1996; McPherson and Peters, 1995; Valkirs et al., 1994), placement on the State 303(d) List of Water Quality Limited Segments in 1996, and the subsequent development and initial implementation phases of a total maximum daily load (TMDL) for dissolved copper starting in 2005 (RWQCB, 2005).

The majority of the copper loading (~93%) is believed to come from passive leaching from antifouling coatings, and thus the TMDL has focused on reduction of this source (RWQCB, 2005). While the focus of the TMDL implementation phase has been on load reduction, the other primary factor driving elevated concentrations in the basin is the poor tidal flushing. To date, there has been no analysis of the potential to increase the flushing of SIYB and thus reduce the buildup of elevated copper concentrations. While Shelter Island was originally a sand-spit with open circulation between the island and the shore of SDB, subsequent modifications of SIYB and construction of the causeway connecting the island to the shoreline have significantly limited the flushing of the basin. Thus an alternative or supplemental management strategy for the TMDL could be to improve the flushing of SIYB by improving the connection of the basin with the main body of SDB or the adjacent America's Cup Harbor (ACH).

In order to evaluate the potential to improve flushing of SIYB, an accurate predictive model is required that can capture the processes that regulate copper concentrations in the basin under current and modified conditions. Copper fate and transport in SDB has been extensively modeled in previous mass balance modeling studies by Chadwick et al. 2004 using a one-dimensional, steady-state box model (SD1D), and in full 3-D numerical modeling simulations using the Curvilinear Hydrodynamics in Three Dimensions (CH3D) model by Chadwick et al. 2008 and Wang et al. 2006. In these studies, extensive measurements were made throughout SDB, and models were calibrated and validated for use in simulating copper concentrations, mass balance among the loads, hydrodynamic advection and dispersion, partitioning and settling of particulate copper. Results from these studies showed that these models could accurately predict copper concentrations and these associated processes, and thus provide the best available tool for predicting future conditions in SDB, including those associated with changes in loading or other potential management strategies.

2 OBJECTIVE

The objective of this study was to evaluate the potential for enhanced flushing of SIYB through the placement of engineered culverts (or pipes) between the head of SIYB and SDB, and between the heads of SIYB and ACH. Flushing and associated total copper concentrations were modeled under five scenarios, including (1) baseline with no enhanced flushing, and enhanced flushing via (2) a culvert connecting SIYB to SDB, (3) a culvert connecting SIYB to ACH, (4) a pipe connecting SIYB to SDB, and (5) a pipe connecting SIYB to ACH. Enhanced flushing configurations were compared to the baseline condition with no enhanced flushing, as well as to each other, using the existing CH3D model that was modified to account for the connections and their effects on flows and copper concentrations in SIYB, ACH and SDB.

To achieve this, the specific technical objectives of this study included the following:

1) Simulate baseline total copper concentrations in SIYB with no added connectivity;
2) Simulate total copper concentrations in SIYB with an added culvert or pipe between SIYB and SDB, and between SIYB and ACH, respectively; and
3) Assess potential reductions in total copper concentrations under enhanced flushing scenarios as compared to baseline conditions.

3 METHODS AND APPROACH

3.1 FATE AND TRANSPORT MODELING

The numerical hydrodynamic fate and transport model applied for this study is the CH3D. This model is a boundary-fitted finite difference, Z-coordinate model developed at the U.S. Army Corps of Engineers Waterways Experiment Station (Johnson *et al*., 1991) to simulate physical processes in bays, rivers, lakes and estuaries (Wang and Martin, 1991; Wang, 1992; Wang and McCutcheon, 1993; Wang *et al*., 1997, 1998; Johnson *et al*., 1995). The model simulates hydrodynamic currents in four dimensions (x, y, z and time) and allows for the prediction of the fate and/or transport of metals, fecal coliforms and other contaminants in estuaries and coastal environments under the forcing of tides, wind and freshwater inflows (Sheng *et al*., 1990; Wang and Richter, 1999). The grid of the existing CH3D model for SDB covers an area of approximately 215 km^2, with about 7,000 grid elements, and a resolution of approximately 100 meters (Figure 3-1).

The CH3D model was implemented to simulate copper and other antifouling biocide concentrations from hull paint in San Diego Bay (Wang et al., 2006), and concentrations of copper and its species (Chadwick et al., 2008). In these two studies, mean annual copper loads from all the known sources, including Navy and non-Navy sources, were estimated (Chadwick et al., 2004; Johnson et al., 1998), and distributed over the model domain in accordance with their known source locations. The same copper model and copper load are used to support this study. In order to simulate culvert flows, the CH3D hydrodynamic model was implemented and a new modeling approach was developed to accommodate the addition of the culverts and their effects on hydrodynamics and copper fate and transport as described below.

3.2 MODEL SIMULATIONS

The CH3D model simulates advection processes due to water currents and tides in San Diego Bay. The effect of tides is driven by tidal harmonic constants, which were obtained by calibration, and are prescribed at the open ocean boundaries (Figure 3-1; Wang *et al.*, 1998). The sequence for the model simulation starts from quiescent initial conditions (zero water surface level for the entire Bay), with tidal forcing at the model's ocean boundaries starting with the simulation (t≥0). The water surface elevation and tidal currents at every grid cell is simulated at a time-step of 2 minutes, reaching simulated steady state hydrodynamic conditions within 4 days. From the end of the 4th day, steady-state copper loading from various sources are introduced into the model from the various loading source locations. Simulation of fate and transport of copper, which is driven by the hydrodynamics simulation in CH3D, continues for 320 days so that copper concentration and its fate and transport patterns in the Bay reach steady state.

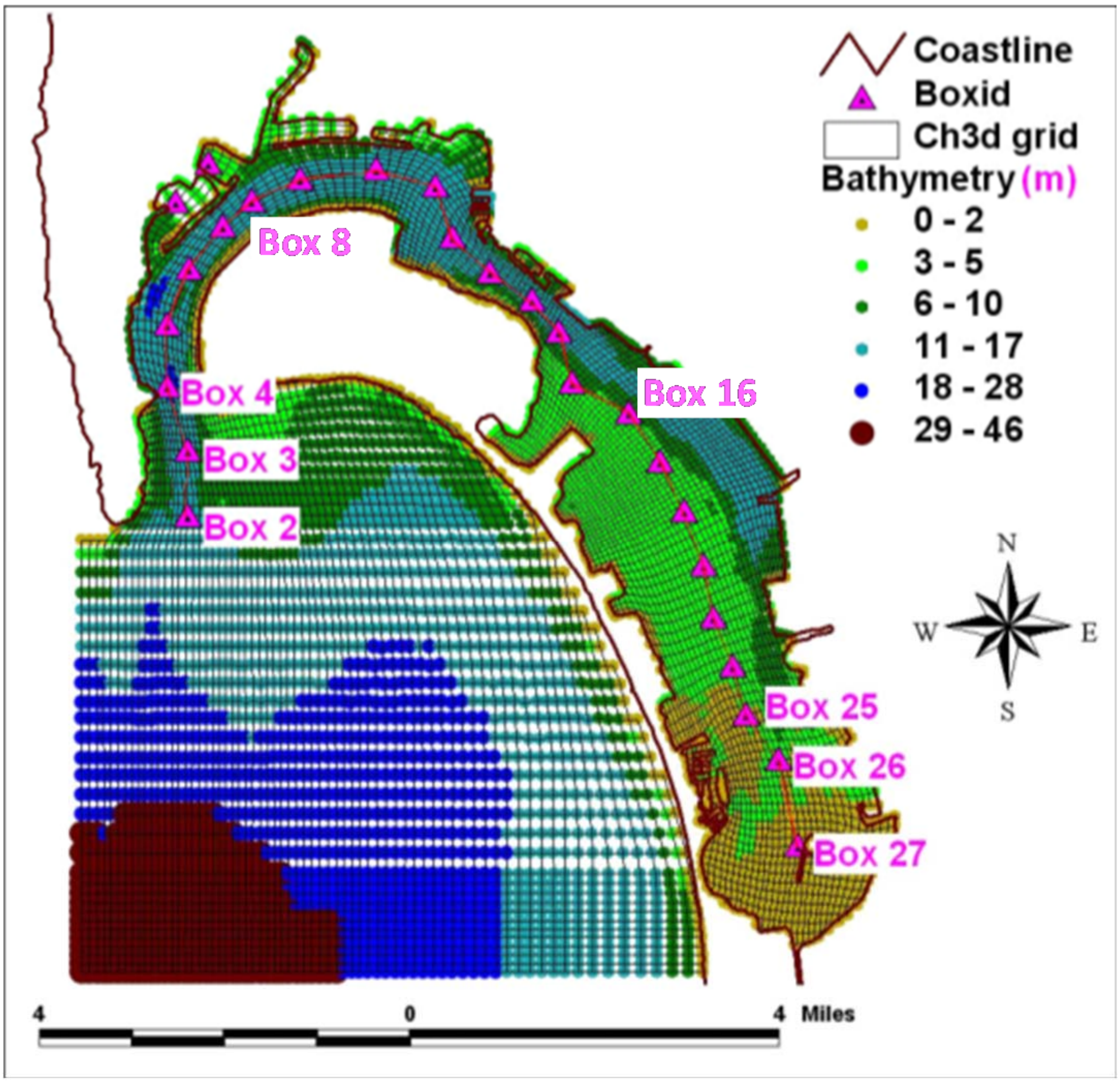

Figure 3-1. Grid for the Curvilinear Hydrodynamics in Three Dimensions (CH3D) model for San Diego Bay, California.

For the present study, the existing CH3D model configuration for SDB was modified to account for the addition of the connections between SIYB-SDB and SIYB-ACH, respectively. All the other assumptions and parameterization, including copper loads, of the existing CH3D model remained unchanged. Table 3-1 lists the major assumptions and the parameterization for the model.

Table 3-1. CH3D model assumptions/parameterization for copper loads and settling velocity.

Model Condition	**Assumption/Parameterization**
Copper Load	Total copper load to Shelter Island was estimated as 2,983 kg/year per Chadwick et al. 2004 and was initially distributed over the water column
Dissolved/Particulate Copper Partitioning	Partitioning coefficient based on field data from Chadwick et al. 2008 of 0.27 L/mg
Settling Velocity for Particulate Copper	Empirical net settling rate 4.3 cm/hr from SDB mouth (Box2) to south SDB (Box24), 2.1 cm/hr at the head of SDB (Box27), and linear decrease from Box24 to Box 26 (per Chadwick et al., 2008)
Model output	Water column averaged total copper concentrations in ug/L (ppb)

3.3 CULVERT CONFIGURATIONS AND SIMULATIONS

Figure 3-2 shows the modeling approach, which includes simulations of the culvert flows for culverts connecting between SIYB and SDB and between SIYB and ACH, respectively. The culverts were assumed to be a rectangular channel with a size of 12ft (width) by 8ft (depth, relative to mean sea level) in cross section. The addition of the culvert into the model grid severely restricts the model time-step to less than 20 seconds, compared to the normal time-step of 120-150 seconds for the original model. The small model time-step for the culvert model makes it impractical to perform the normal simulation period of 320 days, which is required for the model to reach steady state. Therefore, instead of simulating for 320 days to reach steady state, flow velocities through the culvert were simulated for two weeks, covering the full spring/neap tidal cycle. Flow velocity (speed and direction) was found to be a direct function of gradient of water surface elevation between the two waterbodies (e.g., SIYB and SDB, and SIYB and ACH). When the water surface elevation gradient was positive between SIYB and SDB (or ACH), flow was in the direction from SIYB to SDB (or ACH) and vice versa.

Simulated flow velocities through the culverts were functionally related to the water surface elevation gradients between the connecting water bodies.

Next we used the CH3D model to simulate copper concentrations with the culvert flows, previously simulated and quantified as a function of water elevation gradient, specified as fictitious river flows. During positive water surface elevation gradient between SIYB and SDB (or ACH), water flows out of SIYB and into SDB (or ACH) at the fictitious culvert (river) mouth locations. When the gradient is negative between SIYB and SDB (or ACH), water flows out of SDB channel (or ACH) and into SIYB at the fictitious culvert (river) mouth locations. This allowed for a relaxation of the time-step to the normal 120-150 seconds for the original model, and thus allowed the simulations to be run for the full 320 days required for steady state model output, which was then stored and analyzed to characterize the changes in flushing.

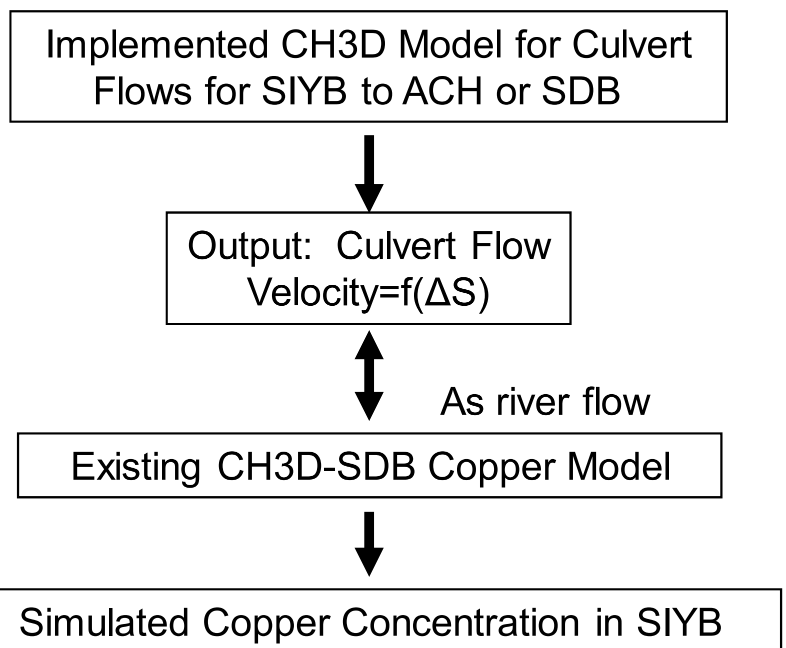

Figure 3-2. Modeling approach for the Shelter Island enhanced flushing analysis.

4 RESULTS AND DISCUSSION

4.1 GENERAL FLOW PATTERNS

In general currents in San Diego Bay are driven by tides from the Pacific Ocean, which are assigned as the tidal forcing at the model's ocean boundaries. Tides in San Diego Bay are predominantly driven by diurnal (K1) and semi-diurnal (M2) components. Simulated water surface elevations range from ±70 cm during the neap tides to ±100 cm during the spring tides relative to mean sea level (*Figure 4-1*). Tidal flows enter into the Bay through the mouth, where water is deep (~15-20 meters), and as the tidal flow propagates along the Bay's axis, water depth decreases to ~10 meters in mid-Bay and <5 meters in south Bay. The range of water surface elevation also grows slightly (~ 5 cm) from the mouth (Box 4) toward the head (Box 27) of the Bay, consistent with previously reported measurements and simulations (Wang *et al*., 1998).

There is a marked gradient in the magnitude of tidal currents within the Bay. Tidal currents are governed by multiple factors, including bathymetry, geometry (shape) of the Bay, bottom friction, etc. As a result, tidal current distributions differ from location to location in the Bay; but, in general, current directions are restricted and follow the geometry of the Bay. The speeds of the tidal current range from ~15-50 cm s^{-1} near the mouth, to over 65 cm s^{-1} in the channel bends and constrictions, and to less than 10 cm s^{-1} in the inner Bay (Figure 4-2).

In general the simulated current direction follows the shape of the Bay (Figure 4-3). Currents near the mouth are bi-directional, flowing north (~360°) and south (~180°) alternately, depending on the tidal stage. The direction of the current is dominated by the geometry of the Bay, and while simulated currents at box 4 and box 8 are going in or out of the Bay, the direction of the flow follows the direction of the axis of the Bay. While the direction in box 4 is North (or South), the corresponding direction in box 8 is rotated toward East and West. With the calibrated tidal harmonic constants assigned at the model's ocean boundaries, CH3D predicts both water surface elevations and tidal currents (both speed and direction) consistent with the results of Wang *et al*. (1998).

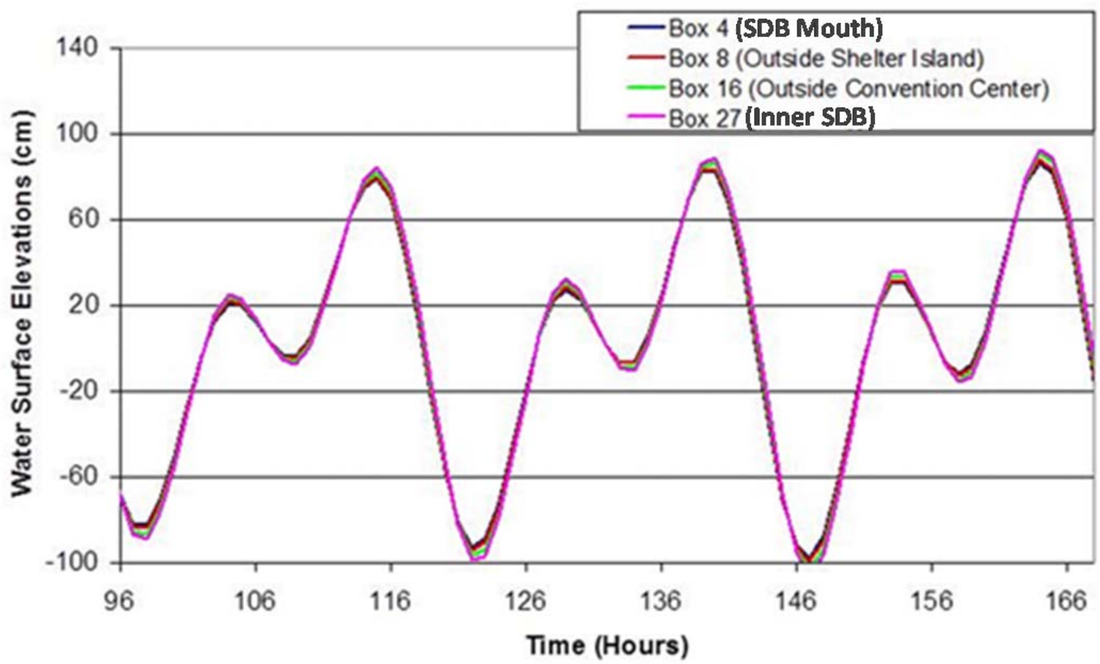

Figure 4-1. Simulated water surface elevations at several locations within San Diego Bay. The boxes are those designed in Figure 3-1.

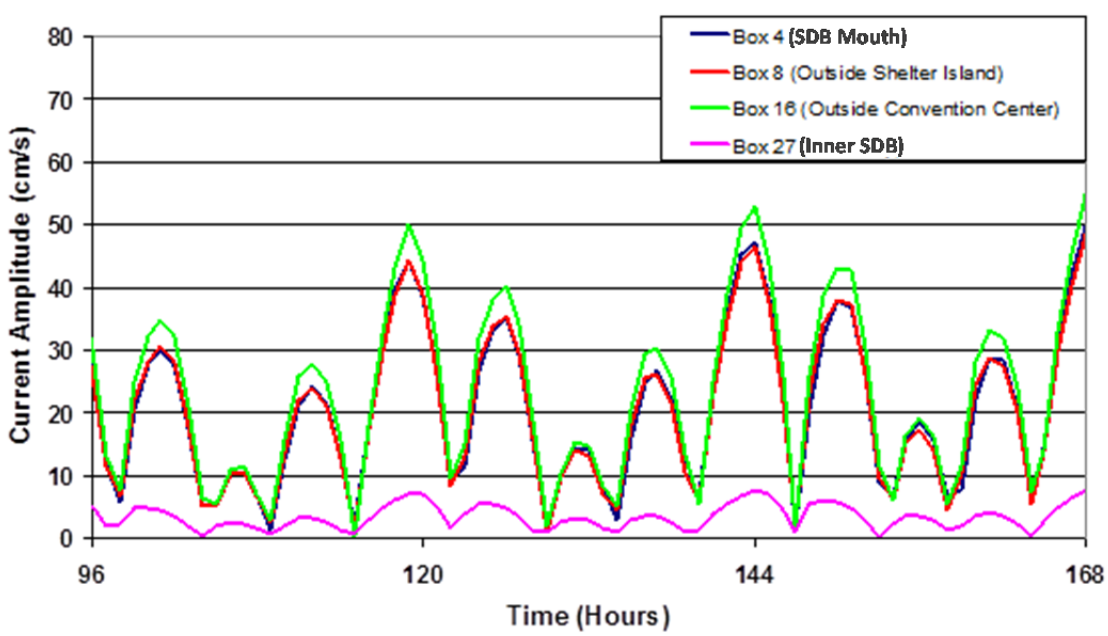

Figure 4-2. Simulated current amplitudes at four locations in San Diego Bay.

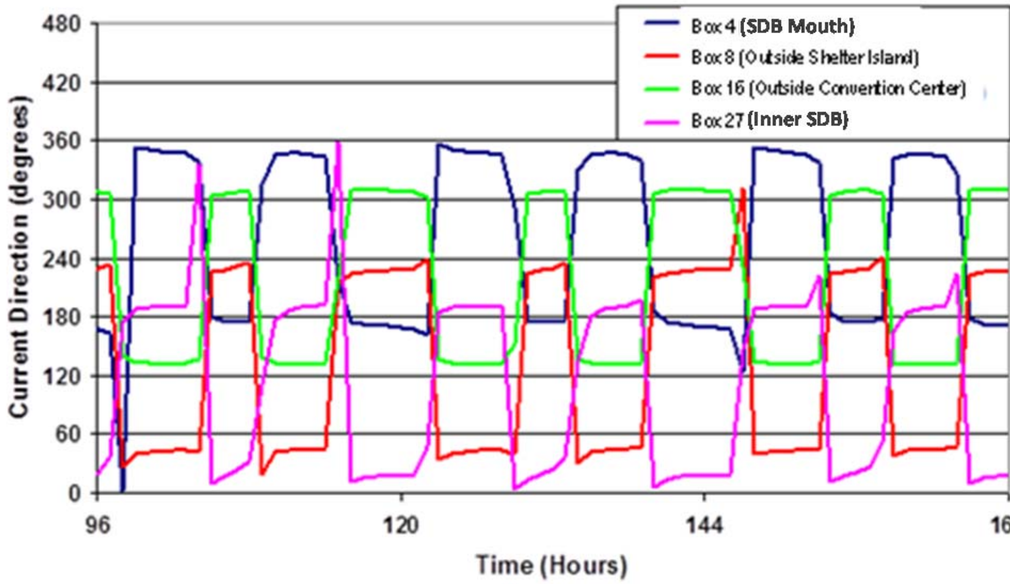

Figure 4-3. Simulated current direction at four locations in San Diego Bay. The angle is defined clockwise with 0° and 360° indicating North and 90° East.

4.2 CULVERT BETWEEN SIYB AND SDB

Figure 4-4 shows the modified CH3D model grid with the culvert added to connect SIYB and SDB channel. In order to accommodate the small size of the culvert (12ft x 8ft), the model grids near the culvert needed to be reduced and gradually increased to the sizes of the ambient grid cells. CH3D was run with the grid at a time step of 20 seconds, which is not efficient to run copper model, since it takes 320 days for the copper model to reach steady state. Instead, we ran the culvert model and quantified the flow through the culvert as a function of the difference of water surface elevations between SIYB and SDB.

CH3D was simulated for 20 days, covering the spring/neap tidal cycle (Figure 4-5). Flow through culvert is induced by difference in water surface elevations between SIYB and SDB. The relationship between flow velocity and water surface elevation difference is not linear, nor is it conservative with loss of momentum through bottom friction. Therefore, we hypothesized that culvert flow velocity is a fraction of the idealized conservative system, which dictates velocity is completely driven by difference of water surface elevations between the two water bodies such that

$$\vec{V}_{Ideal} = \mathrm{sgn}(\Delta S)\sqrt{2g|\Delta S|} \qquad (1)$$

where g is gravity acceleration constant, and vector V_{Ideal} is the idealized velocity (speed and direction) driven by the difference of water surface elevations between SIYB and SDB (ΔS), with direction determined by the sign of ΔS. Culvert flow velocity is positive, flowing from SIYB to SDB for ΔS > 0, and flow velocity is negative, flowing from SDB to SIYB for ΔS < 0.

Model results show that culvert flow velocity can be approximated by multiplying a constant of 0.42 and 0.36 to the idealized velocity (Eq.(1)) during the flooding and ebbing tides (ΔS > 0, and < 0, respectively). Figure 4-5 and Figure 4-6 show time series of the simulated culvert flow velocity, which correlates with the difference of simulated water surface elevation, as expected. Simulated culvert velocity can also be regenerated by multiplying the 0.42 and 0.36 constants to the idealized velocity (Eq.(1)), as shown by line in yellow in Figure 4-5 and Figure 4-6.

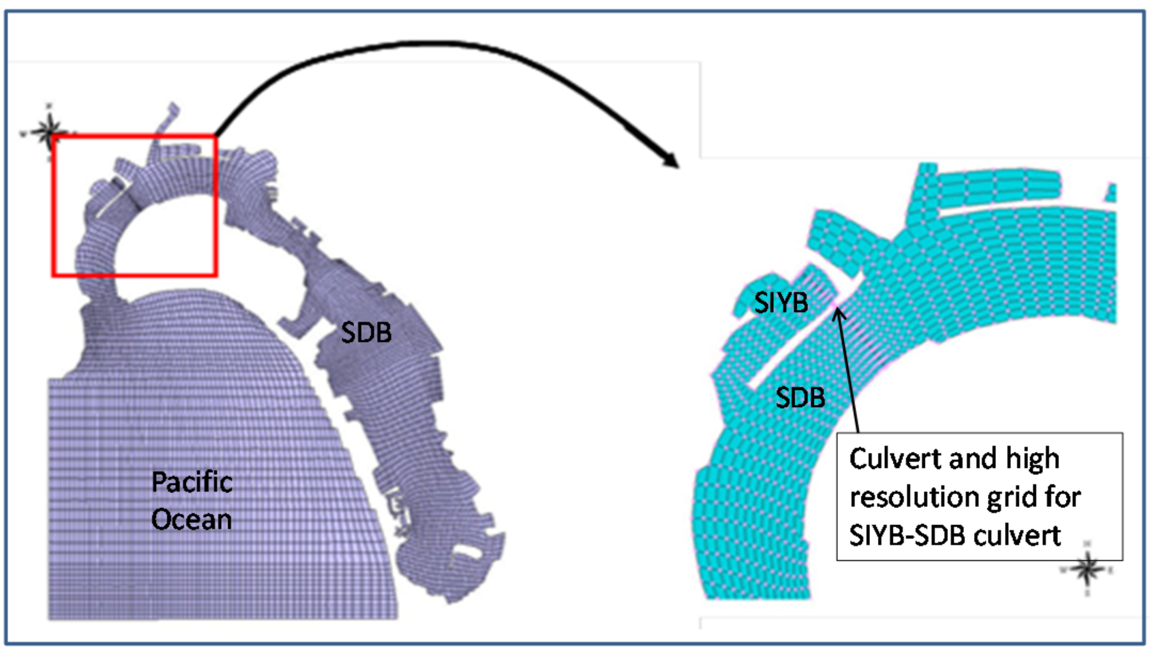

Figure 4-4. CH3D model grid with a culvert connecting SIYB and SDB.

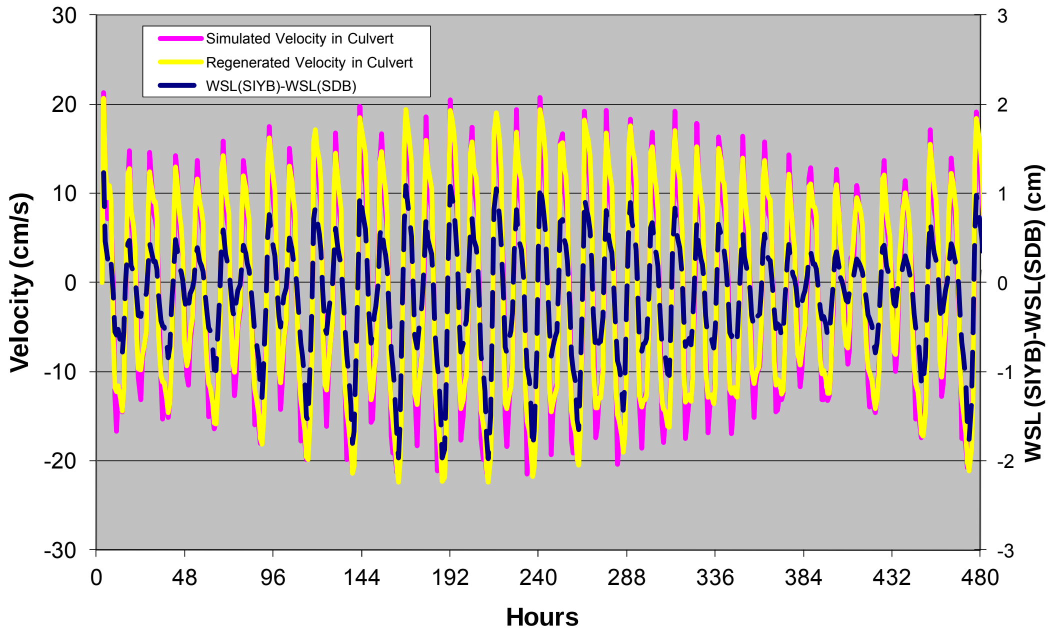

Figure 4-5. Simulated culvert flow velocity (pink) and difference of water surface elevations (WSLs) between SIYB and SDB (blue), reproduced culvert flow velocity by multiplying constants to the idealized velocity during flooding and ebbing tides.

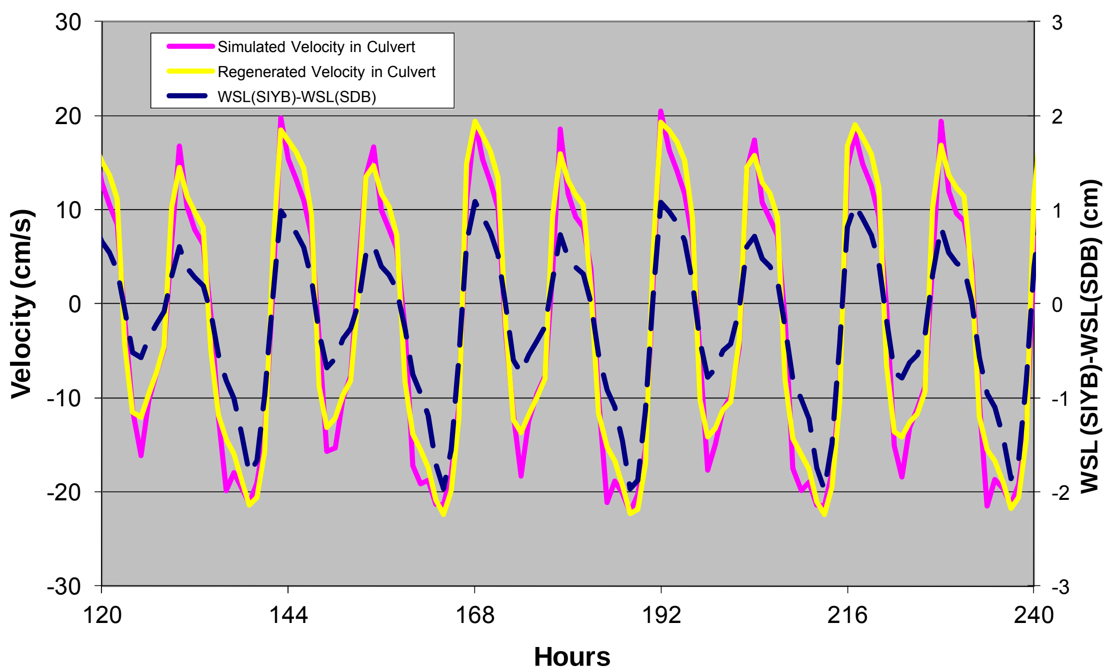

Figure 4-6. Close-up time series between 120-240 hours.

4.3 CULVERT BETWEEN SIYB AND ACH

Figure 4-7 shows the close-up look of the CH3D grid between SIYB and ACH. The culvert is of the same size (12ft x 8ft), for which re-gridding of the local regions near the culvert is required. The CH3D model runs with the grid at a time step of 20 seconds.

Following the SIYB-SDB analysis approach from the previous section, we reproduced the culvert flow velocities between SIYB and ACH by multiplying a constant of 0.6 to the idealized velocity which is generated by Eq.(1) with the difference of water surface elevations between SIYB and ACH (ΔS). The multiplicative constants for culverts between SIYB and SDB (case 1), and between SIYB and ACH (case 2) are summarized in Table 4-1.

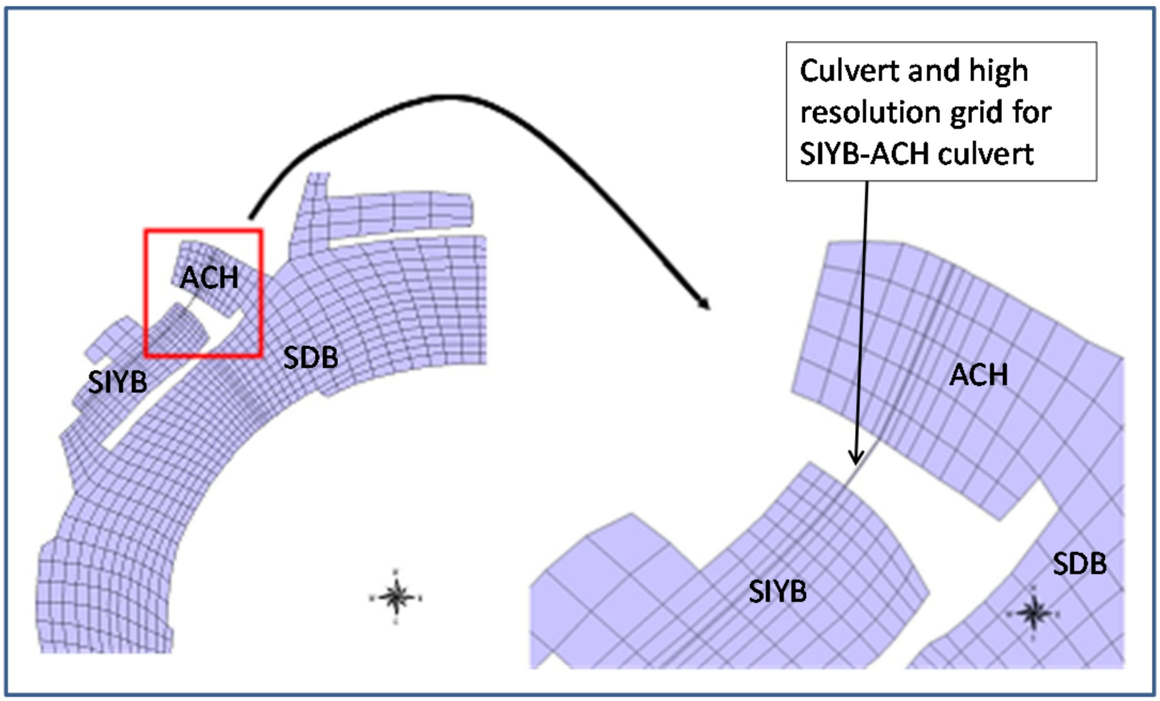

Figure 4-7. CH3D model grid with a culvert connecting SIYB and ACH.

Similar to the SIYB-SDB culvert analysis, culvert flow velocities can be reproduced from the difference of simulated water surface elevations between SIYB and ACH. A multiplicative constant of 0.6 was found to work well for the SIYB-ACH culvert flow. In general, these constants are functions of detailed circulation patterns, bathymetry, and nonlinear advection, which only can be adequately simulated by the model.

However, these two examples indicate that culvert flow velocities can be obtained from the difference of water surface elevations between the two water bodies, SIYB-SDB and SIYB-ACH, by way of an idealized velocity multiplied by a constant. In general, culvert flow velocities for SIYB-ACH are higher than those for SIYB-SDB. This is reflected in Figure 4-8 and Figure 4-9.

Table 4-1. Multiplicative constants for the regenerated culvert flow velocities from the idealized velocity (Eq.(1)).

Condition	SIYB-SDB	SIYB-ACH
$\Delta S > 0$ (e.g., flooding tide)	0.36	0.6
$\Delta S < 0$ (e.g., ebbing tide)	0.42	0.6

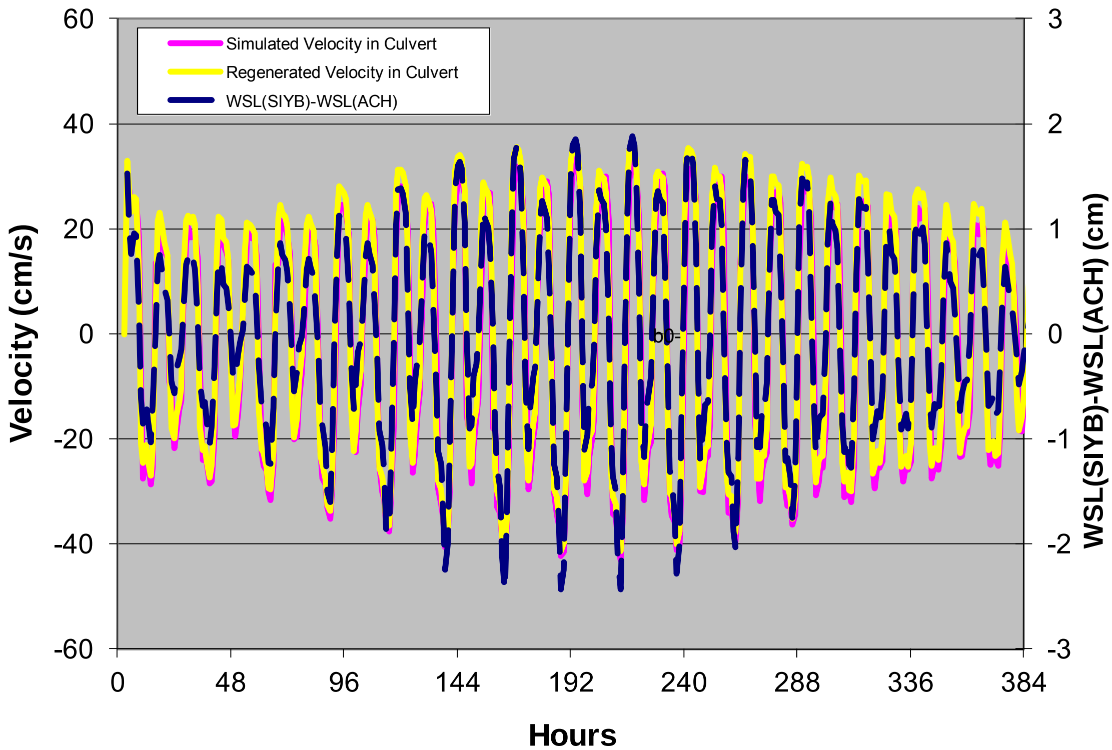

Figure 4-8. Simulated culvert flow velocity (pink) and difference of water surface elevations (WSLs) between SIYB and ACH (blue), reproduced culvert flow velocity by multiplying constants to the idealized velocity during flooding and ebbing tides.

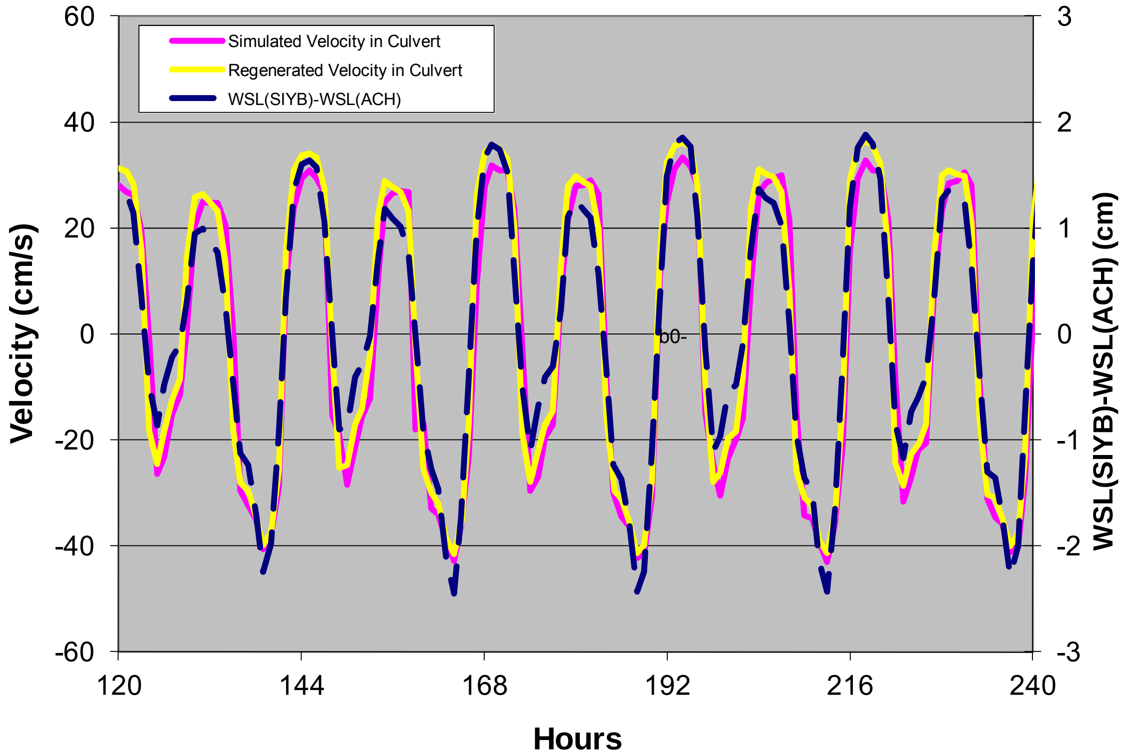

Figure 4-9. Close-up time series between 120-240 hours.

4.4 SUBMERGED PIPE FLOW SIMULATIONS

In addition to the open culvert flow scenarios, enhanced flushing was simulated for two scenarios – (1) placement of one 52”-diameter submerged pipe between SIYB and SDB, and (2) one 52”-diameter submerged pipe between SIYB and ACH. Flows through the submerged pipes are driven primarily by the differences of water surface elevations between the corresponding pairs of water bodies. The potential energy is compensated by the energy-dissipating processes, including pipe flow velocity, pipe friction and head losses due to pipe connectivity and/or pipe configuration. For this study, we assumed that pipe friction and head losses are minor and can be neglected. The potential energy from water surface elevation difference drives the pipe flow, which is a conservative assumption in that the pipe flows are optimally maximized. Therefore, the idealized flow, as depicted in Eq.(1), was used for the pipe flow scenario:

$$\vec{V}_{Ideal} = \operatorname{sgn}(\Delta S)\sqrt{2g|\Delta S|}$$

4.5 SIMULATED TOTAL COPPER CONCENTRATIONS IN SIYB WITH AND WITHOUT THE CULVERTS/SUBMERGED PIPES

Culvert flows implemented and simulated by the short-term CH3D hydrodynamic model runs were assigned as the riverine/withdrawal boundary conditions for the steady state copper modeling simulations. To accommodate the culvert flows between SIYB/SDB and SIYB/ACH, respectively, the regenerated culvert flow formulation (described above) was added to the model, which allowed culvert flows to be calculated at every time step as a function of difference of water surface elevation. The CH3D model was then used to simulate culvert flows as boundary condition at the culvert mouths in each water body. For example, when culvert flows were in the positive direction, flowing from SIYB to SDB (or SIYB to ACH), the culvert flow rates were treated as withdrawal from SIYB and as riverine input to SDB or ACH. When culvert flows were in negative direction, flowing from SDB or ACH to SIYB, the culvert flow rates were treated as withdrawal from SDB or ACH and as riverine input to SIYB. These input and withdrawal flows are a standard capability of the CH3D model that were customized to accommodate the specific conditions developed for the culvert flows.

The CH3D model was also configured to accommodate the additional river/withdrawal boundary conditions for copper concentrations. When water flows from SDB or ACH to SIYB, the culvert flows through the riverine mouths in SIYB carry concentrations from SDB or ACH into SIYB. The same flow conditions were treated as withdrawals for SDB or ACH and no additional adjustment was needed for boundary condition for copper. Conversely, when water flows from SIYB to SDB or ACH, the culvert flows through the riverine mouths in SDB or ACH carry the copper concentration of SIYB. The same flow conditions were treated as withdrawal for SIYB and no additional adjustment was needed for boundary condition for copper.

CH3D-simulated total copper concentrations in SIYB were compared for the five scenarios: (1) no culvert, (2) culvert between SIYB and SDB, (3) culvert between SIYB and ACH, (4) a submerged pipe with 52” diameter between SIYB and SDB, and (5) a submerged pipe with 52” diameter between SIYB and ACH.

Figure 4-10 shows three representative locations, including inner SDB, ACH, and SIYB, for model output. Figure 4-11 shows the time series of depth-averaged copper concentrations at the three locations. Simulation results indicate that total copper concentrations reach steady state relatively quickly at SIYB and ACH which are closer to the SDB mouth, and slower for the inner SDB. Figure 4-12 shows the time series of total copper concentrations at SIYB for the five scenarios: baseline scenario (no connection), culvert for SIYB-ACH and for SIYB-SDB, and pipe flow for SIYB-ACH and for SIYB-SDB, respectively. Reduction of total copper concentrations in SIYB is greatest for the SIYB-ACH culvert, followed by the SIYB-ACH submerged pipe scenario, and then the SIYB-SDB culvert and submerged pipe scenarios.

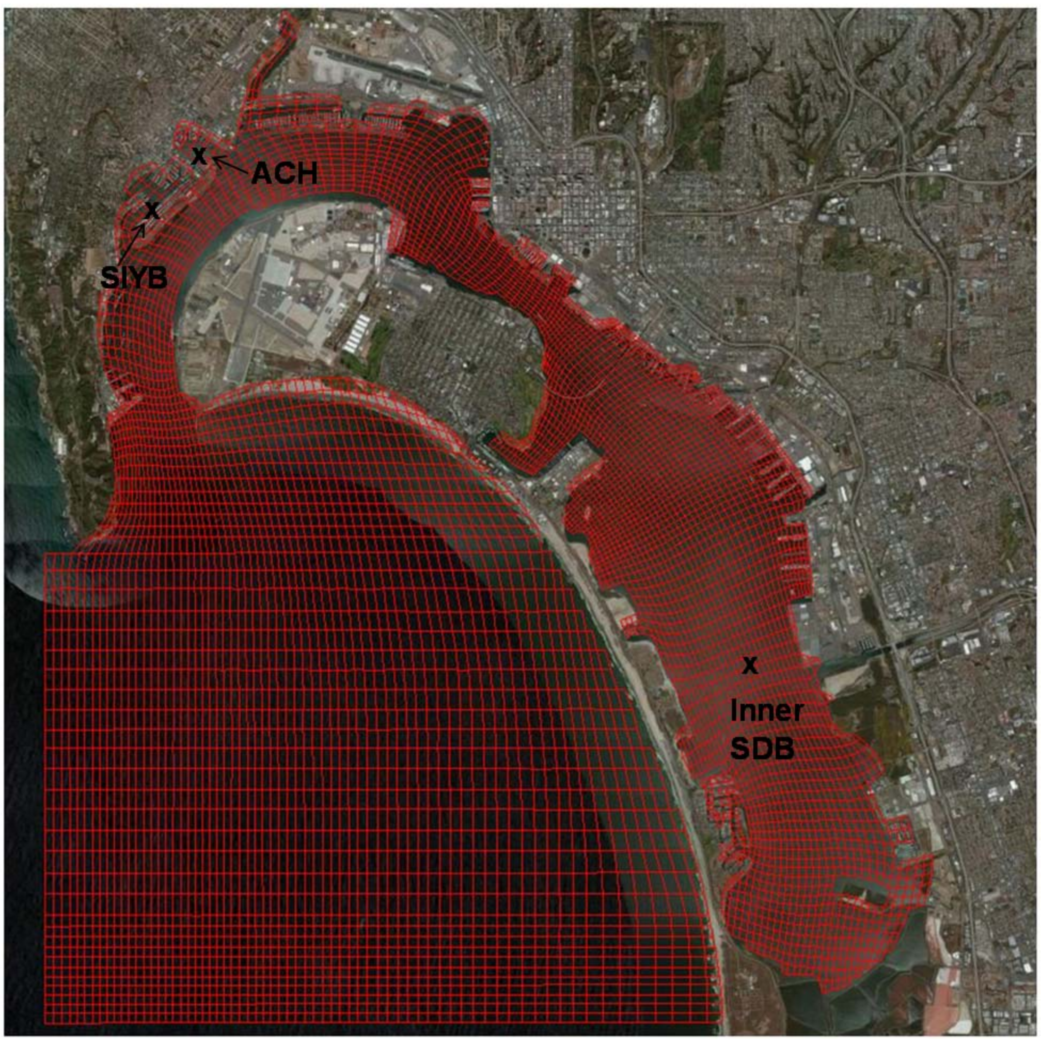

Figure 4-10. Representative locations of San Diego Bay model domain: Inner SDB, ACH and SIYB.

Figure 4-13 shows total copper concentrations in ACH for the baseline, and the two culvert scenarios. Simulated total copper concentrations in ACH are comparable for the baseline case and the SIYB-SDB culvert scenario, whereas, the culvert between SIYB and ACH reduces total copper concentrations in ACH slightly, due to enhanced flushing. As shown in Figure 4-11 through Figure 4-13, total copper concentrations in SIYB, and ACH are strongly influenced by tidal actions. Significant diurnal and spring/neap tidal cycle effects are reflected in these results, with differences of total copper concentrations at different tidal stages reaching up to ~3.5ppb near the head and ~7 ppb near the mouth regions of SIYB.

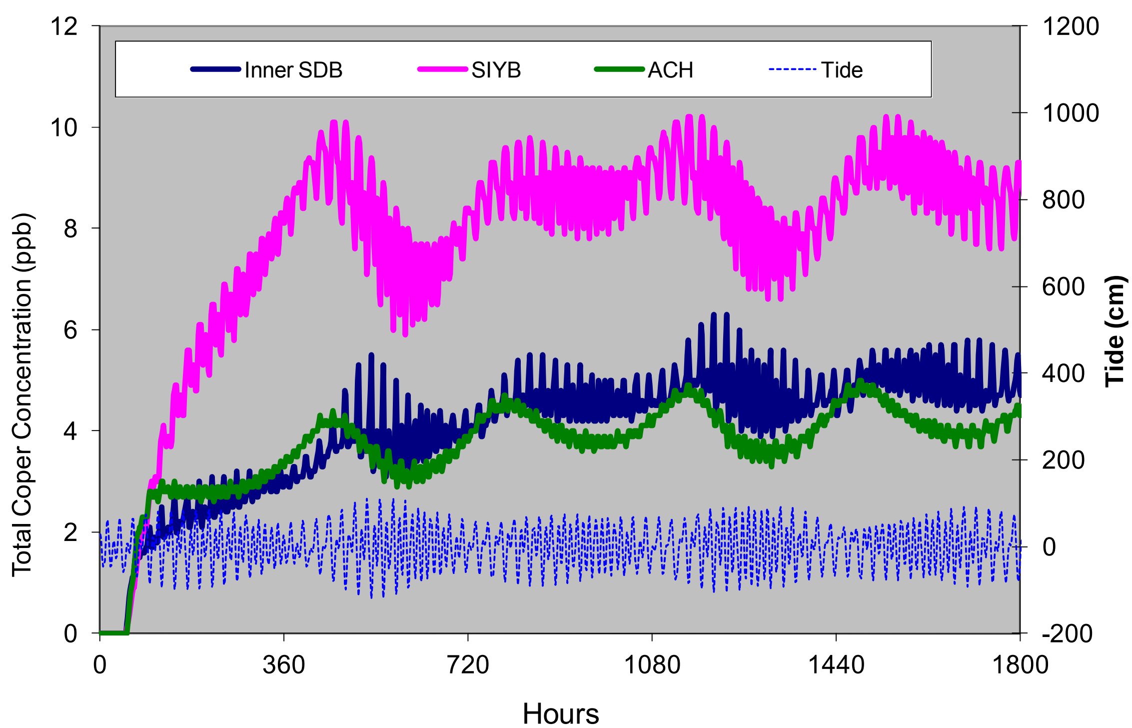

Figure 4-11. Simulated total copper concentration time series at three locations in SDB including a location in inner SDB, SIYB, and ACH. The tidal forcing is also shown relative to the scale on the right.

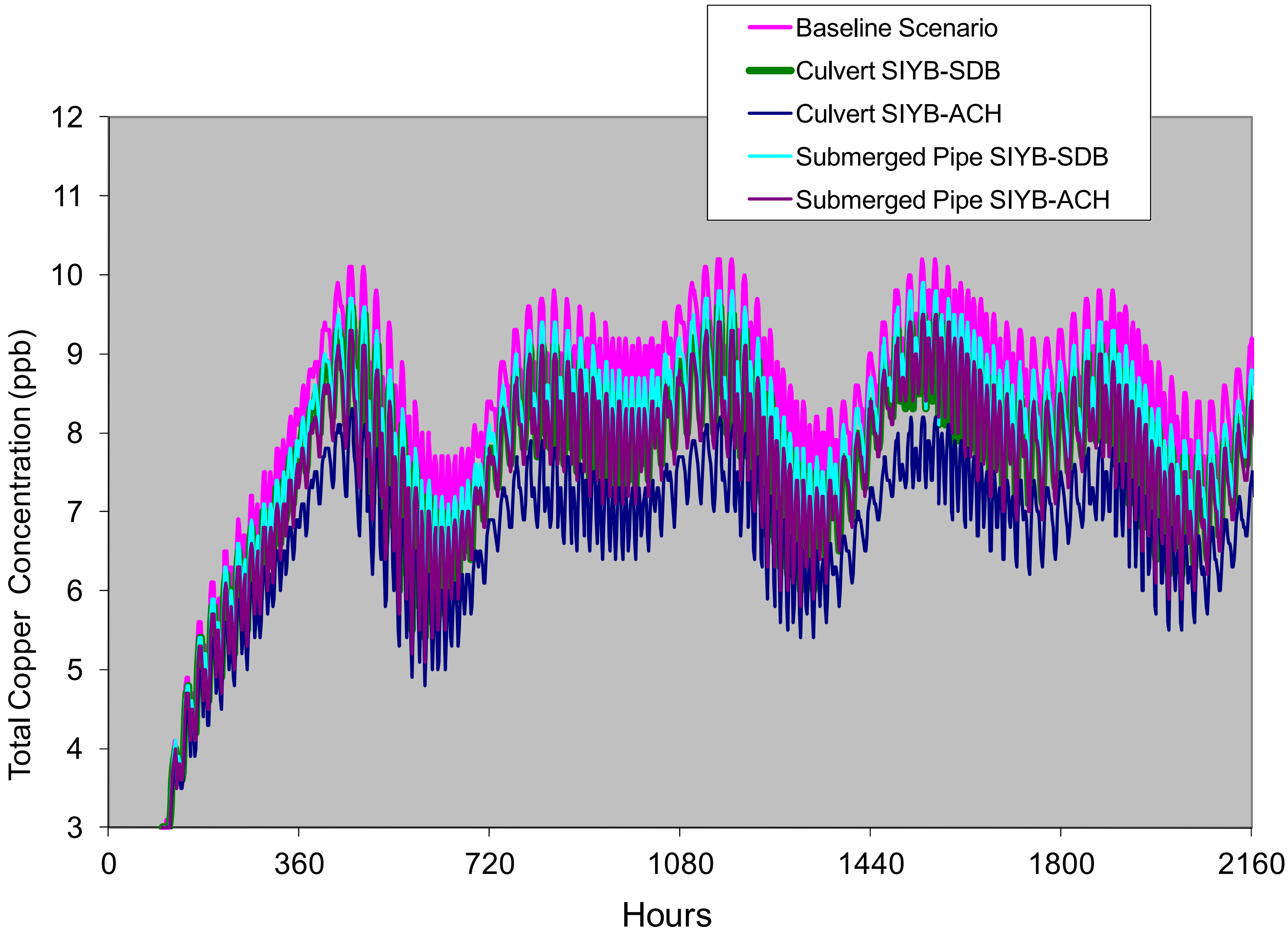

Figure 4-12. Total copper concentrations at SIYB for the five scenarios.

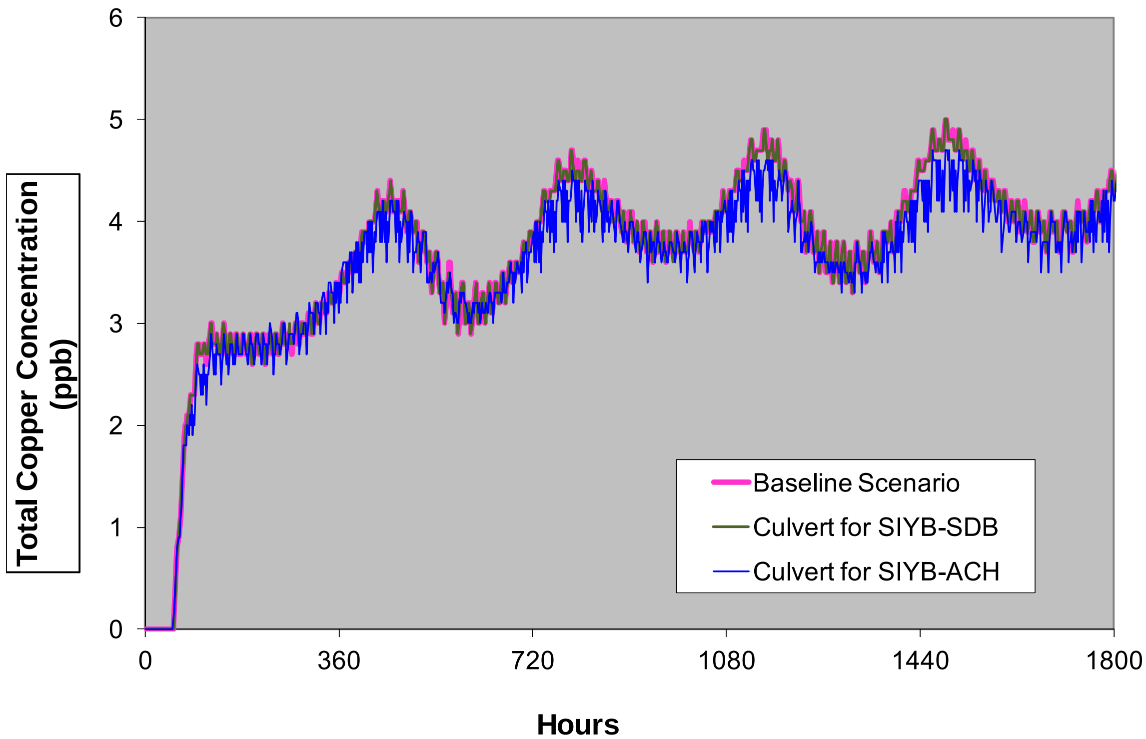

Figure 4-13.Copper concentrations in ACH for the base, SIYB-SDB and SIYB-ACH culvert scenarios.

In SIYB, concentrations tend to increase from the mouth toward the head of the basin. This is also primarily due to the flushing effect of the SDB water, which is strongest at the mouth. Simulated copper concentrations in ACH are at about half of those in SIYB. These concentration levels are obtained based on the best knowledge of copper loads, including those in ACH and the hydrodynamics of the Bay.

Figure 4-14 shows the three sub-divided regions of SIYB for model comparison and analysis: the inner, middle and mouth regions. Model results were averaged over a 15-day period to obtain mean values. Figure 4-15 shows simulated mean total copper concentrations for these three regions, and Figure 4-16 shows the corresponding percentage of reduction in copper concentrations compared to the baseline scenario. For the SIYB-ACH culvert scenario, simulated total copper concentrations were reduced by 21% in the head region, 15% in the middle region and 12% near the mouth of SIYB with an average reduction of 17% for the entire basin. For the SIYB-SDB culvert scenario, simulated total copper concentrations were reduced by 8% in the head region, 6% in the middle region and 5% near the mouth with an average reduction of 7% for the entire basin, approximately half of the reduction predicted for the SIYB-ACH culvert.

The reduction of copper concentration for the culvert scenarios depends on both the flow rate through the connecting culvert, and the relative copper concentrations in SDB and ACH compared to SIYB when inflow from these two water bodies takes place. Although copper concentrations are higher in ACH than SDB (~4 ppb vs. ~1.5 ppb), the flow rate for the SIYB/ACH culvert scenario is ~50% more than that for the SIYB/SDB culvert scenario. These higher flushing results in the greater reduction in total copper concentrations for the SIYB/ACH culvert scenario compared to the SIYB/SDB culvert scenario.

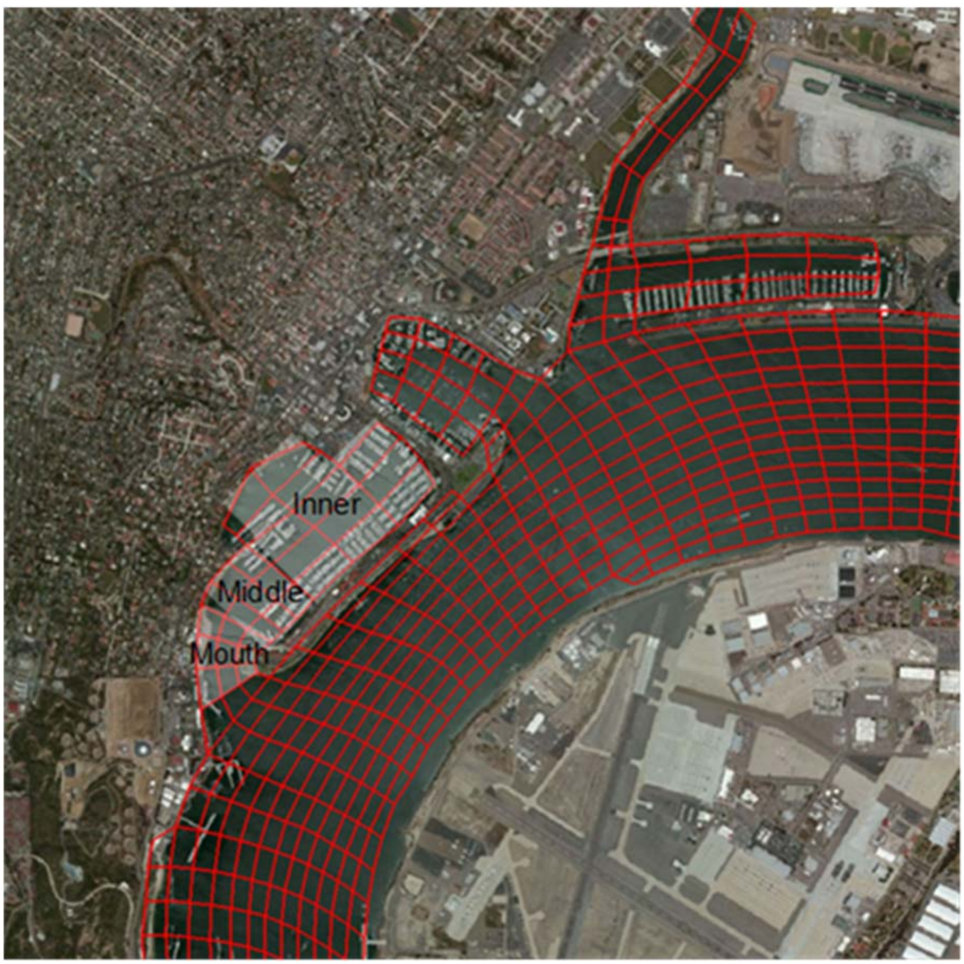

Figure 4-14. Sub-divided SIYB regions for model result analysis: Inner (Head), Middle and Mouth regions of SIYB.

It was also observed that reductions of copper in SIYB were similar between culvert and submerged pipe connection scenarios for the SIYB-SDB location. This indicates a higher exchange efficiency for the pipe, since the cross section of culvert is about 96 ft^2, whereas cross section area of the pipe is 14.8 ft^2, only 1/6 of the culvert. The flow velocity in the culvert was only half that of the pipe. The higher efficiency may be related to the assumption that the discharge from the pipe was fully mixed vertically, while the culvert flow was constrained to the surface layer (top ~2.5 m) of the water column by the channel geometry.

Overall, culvert and pipe flow rates were higher between SIYB and ACH than between SIYB and SDB. However, due to the elevated copper concentration in ACH, reduction through water exchange is more efficient between SIYB-SDB than SIYB-ACH. Combination of these factors results in reduction at the same level for these culvert or submerged pipe scenarios.

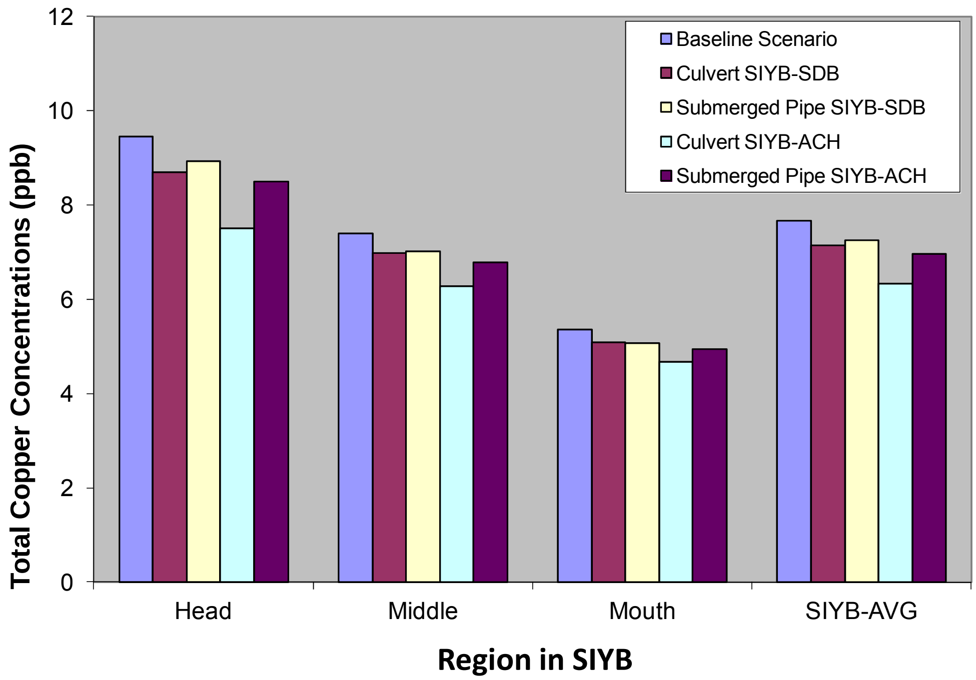

Figure 4-15. Total copper concentrations in inner, middle and mouth of SIYB for the baseline, culvert and pipe scenarios.

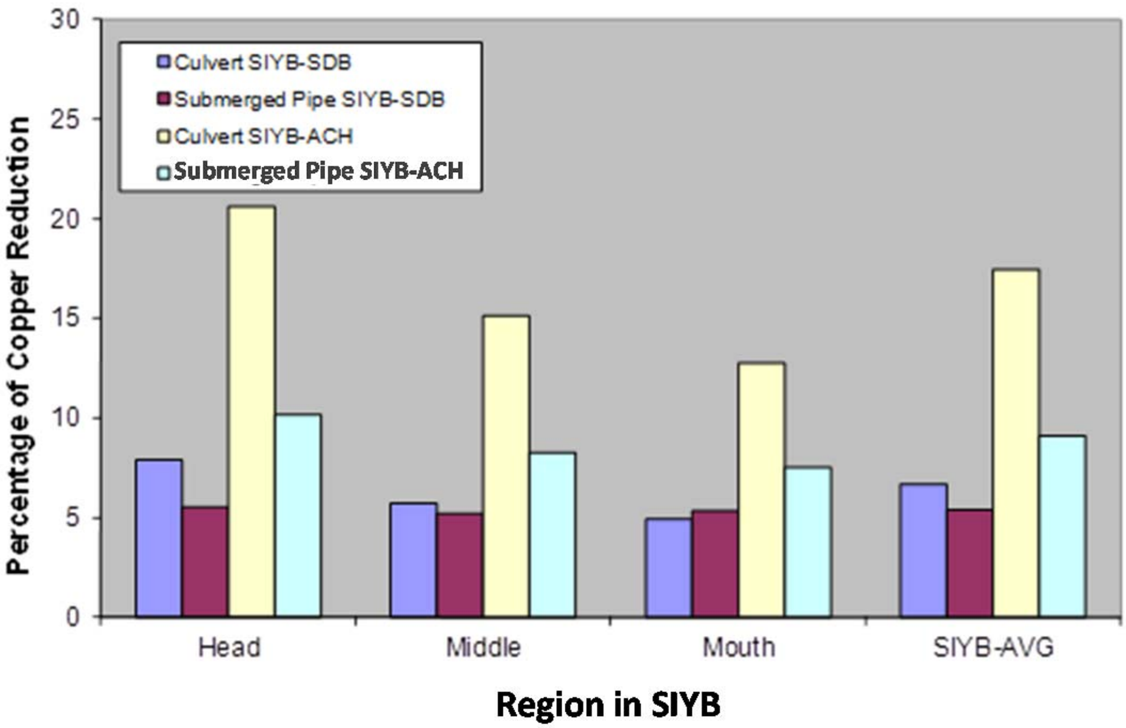

Figure 4-16. Percentage of copper reduction for SIYB for the two culvert/pipe scenarios.

Reduction of total copper concentrations were analyzed along the axis of SIYB in more detail. Model output of total copper concentration was laterally-averaged across the width of SIYB for 10 transect locations along the axis (Figure 4-17). The mean, minimum and maximum of simulated total copper concentrations at the 10 axis locations during a 15-day steady state period are shown in Table 4-2. Based on this analysis, copper reduction from the design scenarios were calculated and results shown in Figure 4-18. The culverts and pipes are located at north-eastern corner grid cell of SIYB, which corresponds with Station 1. A reduction of 25% was achieved at Station 1 for the SIYB-ACH culvert scenario, followed by 12% for SIYB-ACH submerged pipe, and 10% for SIYB-SDB culvert scenario. The SIYB-SDB submerged pipe scenario produced the lowest reduction (6.7%) at Station 1.

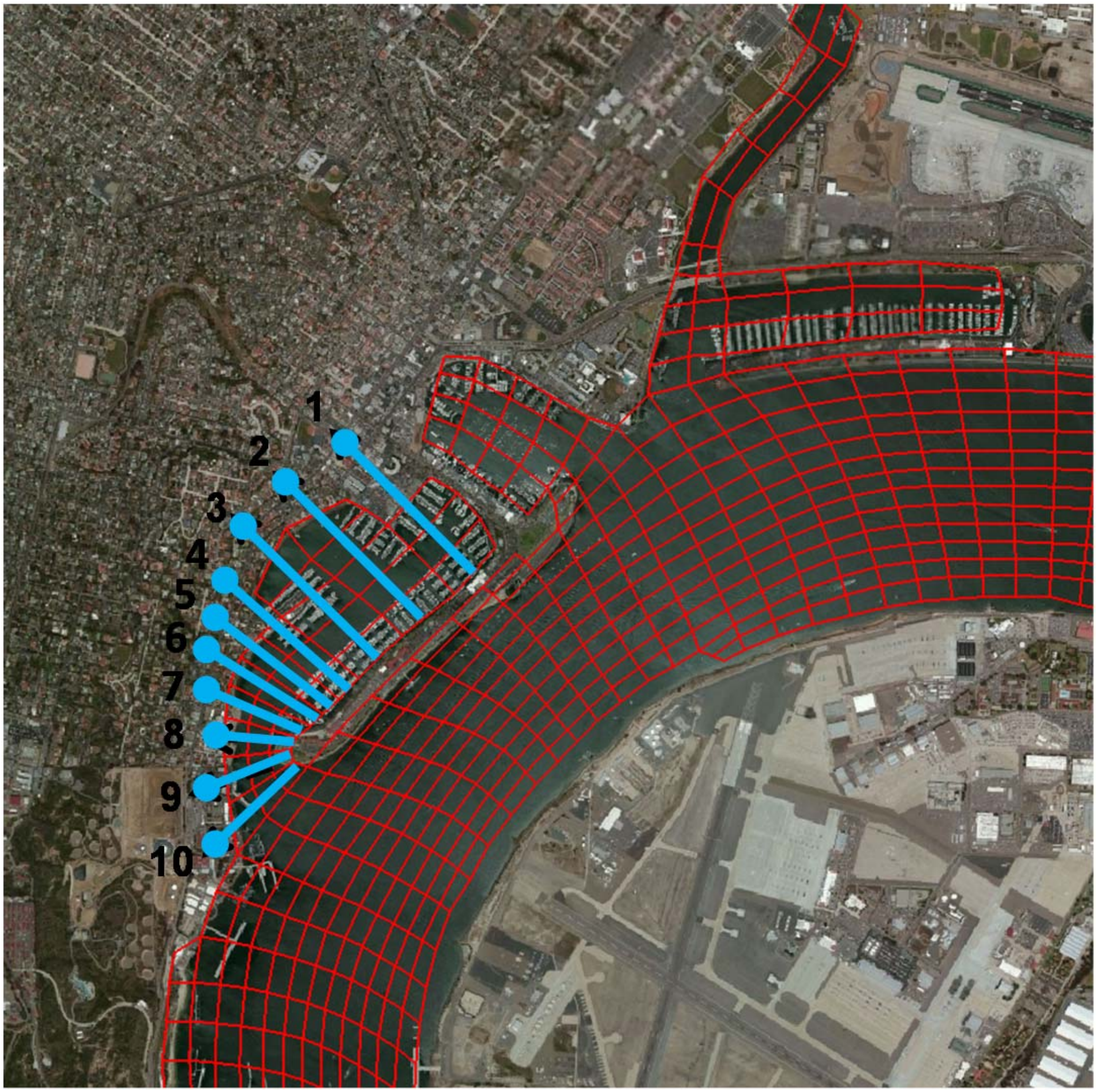

Figure 4-17. Ten transect locations along the axis of the SIYB model grid where total copper concentrations were spatially averaged laterally across the width of SIYB.

Table 4-2. Mean, minimum maximum of simulated total copper concentrations during 15-day period.

	Baseline			SIYB-SDB Culvert			SIYB-ACH Culvert			SIYB-SDB Pipe			SIYB-ACH Pipe		
SIYB Axis Box	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
1.0	10.3	8.8	12.2	9.2	7.9	11.0	7.6	5.1	9.5	9.6	8.1	11.9	9.0	7.7	10.8
2.0	9.5	7.6	11.8	8.8	6.9	10.9	7.6	6.1	9.2	9.0	7.0	11.4	8.6	6.7	10.6
3.0	8.9	5.7	11.2	8.3	5.3	10.6	7.4	4.8	9.3	8.4	5.1	10.9	8.1	5.0	10.4
4.0	7.9	3.3	11.3	7.5	3.1	10.7	6.6	2.9	9.5	7.5	2.9	10.9	7.3	2.9	10.5
5.0	7.4	2.9	10.9	7.0	2.7	10.4	6.3	2.5	9.3	7.0	2.5	10.6	6.8	2.5	10.2
6.0	6.8	2.2	9.7	6.5	2.1	9.4	5.9	1.9	8.5	6.5	1.9	9.4	6.3	1.9	9.1
7.0	6.3	1.7	9.1	6.0	1.7	8.8	5.5	1.6	8.0	6.0	1.6	8.8	5.8	1.5	8.6
8.0	5.5	1.3	8.0	5.3	1.2	7.6	4.8	1.2	7.0	5.2	1.2	7.6	5.1	1.2	7.5
9.0	4.2	0.6	7.2	4.0	0.6	7.0	3.7	0.6	6.4	4.0	0.6	6.9	3.9	0.5	6.8
10.0	2.9	0.4	7.1	2.8	0.4	6.7	2.6	0.4	6.2	2.8	0.4	7.1	2.7	0.4	6.9

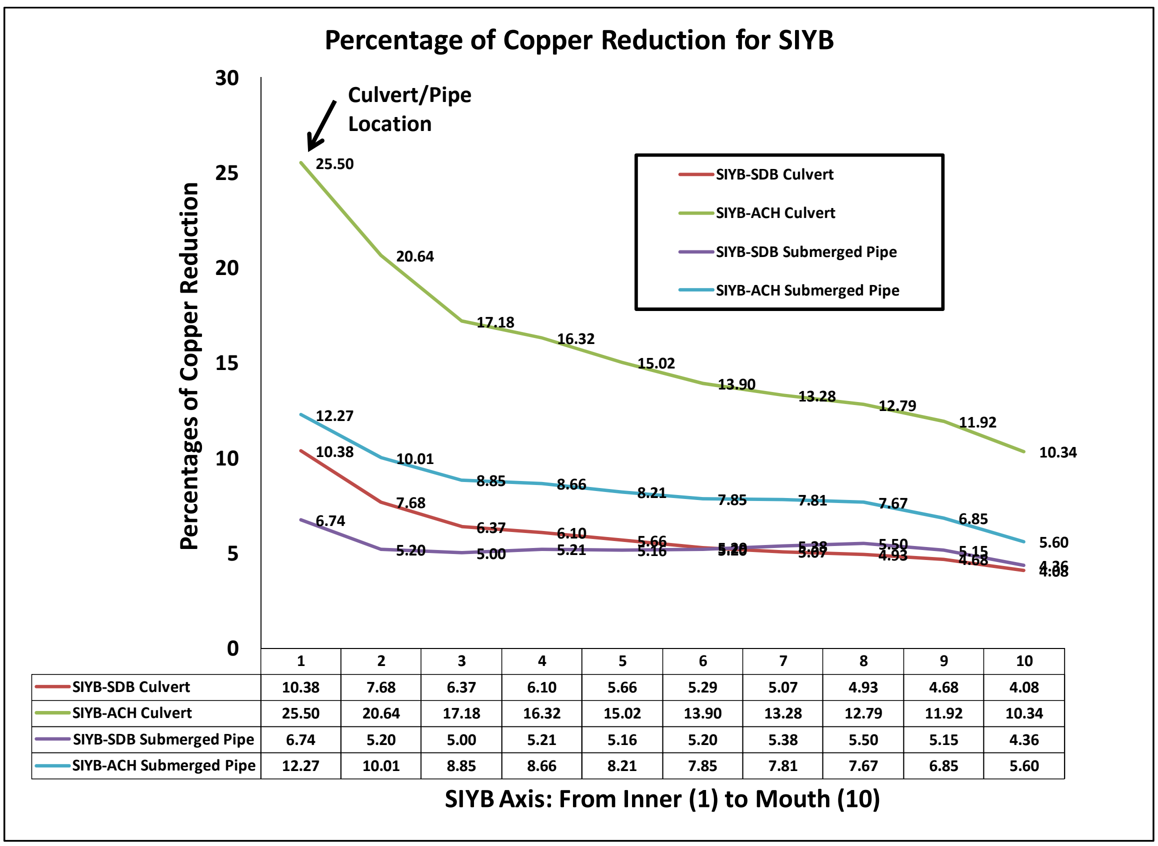

Figure 4-18. Percentages of reduction of width-averaged mean total copper concentrations along the axis of SIYB from the head (Station 1) toward the mouth (Station 10).

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