SHORE-BASED BALLAST WATER TREATMENT IN CALIFORNIA

TASK 4: SHORE-BASED BWT AND STORAGE

PREPARED FOR

DELTA STEWARDSHIP COUNCIL
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Revision History

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References

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Executive Summary

This report is part of an overall coordinated study evaluating the feasibility of using shore-based mobile or permanent ballast water treatment facilities to meet California's Interim Ballast Water Discharge Performance Standards (CA Interim Standards). Tasks 2 through 5 are submitted together to discuss the practical necessities for shore-based treatment system implementation, from the modifications onboard vessels through to the treatment technologies used in the facilities.

This Task 4 report assesses alternatives for ballast water conveyance, storage, and treatment locations for the five case study facilities listed in Table 18. The overall study uses the location-specific case studies to reflect the range of ports and terminals within California impacted by the new standards and to ensure that a range of feasibility challenges are considered, including: vessel types; ballast water conveyance and storage; and ballast water treatment approaches.

The work in this report has been closely coordinated with development of the Task 3 report (Reference 2) and applies several wastewater treatment plant (WWTP) unit processes identified the Task 5 report which evaluates ballast water treatment technologies (Reference 3).

1.1 Report Scope

This report is intended to identify the technical and engineering challenges associated with shore-based ballast water treatment and to estimate costs for construction and ongoing operation and maintenance of ballast water pump stations, pipelines, and new stationary, barge-based and truck-based WWTPs. The technical and economic feasibility of using existing municipal Publicly Owned Treatment Works (POTWs) for treatment of ballast water, and the modifications estimated to be necessary to achieve the CA Interim Standards are also assessed for one of the case studies.

1.2 Methods

Preferred ballast water storage and treatment system layouts, with associated rough order of magnitude (ROM) construction costs for ballast water conveyance, storage, and treatment were developed considering available facility footprints identified under the Task 3 report (Reference 2), ballast water discharge rates and frequencies, and the case study-specific goals identified previously.

In general, the evaluation included:

- Assessment of instantaneous ballast water discharge flow rates necessary to size pump stations and pipelines required to meet facility and vessel-specific operational needs.
- Consideration of daily maximum discharge rates for each facility to size ballast water equalization tanks and treatment equipment.
- Consideration of facility-specific operational areas dictating the space available for storage and treatment equipment.
- Assessment of the adequacy of the Port of Stockton regional municipal wastewater treatment plant for treatment of ballast water flows and to achieve specified water quality goals.

- Development of rough order of magnitude (ROM) cost estimates for ballast water conveyance, storage, treatment, discharge, and anticipated ongoing operation and maintenance (O&M).

Table 1 Vessel interface particulars for each case study

Port/Terminal	Disch. Rate (m3/hr)	Connection Flange (mm)	Connection Hose (mm)	Volume Period (days)	Volume Total (m3)	Vessel Types
Port of Stockton	2,800	600	300	1	34,000	*Bulk carriers.*
Port of Oakland/Trapac	750	300	200	1	7,500	*Containerships. Basis for reception facility.*
Adjacent terminals	1,500	400		1	14,000	*Basis for piping works to treatment plant.*
Total for processing plant.	2,400	500		1	22,500	*Basis for treatment plant sizing.*
Port Hueneme	350	200	150	20	4,000	*Various. Base ship connection on car carriers.*
El Segundo Marine Terminal	3,400	600	300	1	32,000	*Tankers.*
PoLA/SA Recycling	1,400	400	200	5	24,000	*Bulk carriers.*
PoLB/Cruise Terminal	400	200	150	1	2,400	*Cruise ships.*

Description of particulars basis is provided in Task 2 report.

1.2.1 Ballast Water Storage and Treatment Approaches

As described in detail in the Task 5 report, the CA Interim Standards for discharged ballast water quality require removal of 100% of organisms greater than 50 µm in minimum dimension, eliminate organisms between 10 µm and 50 µm in minimum diameter to concentrations ≤ 1 organism per 100 ml, and removal of bacteria below 103 per 100 ml and viruses below 104 per 100 ml. A treatment approach for shore-based systems that can potentially meet these limits is coagulation, flocculation, and sedimentation followed by membrane filtration and UV or chemical disinfection. A description of each treatment technology and its efficacy for microorganism removal is provided in Task 5 report.

Two ballast water treatment approaches were evaluated for construction of new facilities; the first approach applicable at the Port of Oakland TraPac facility and the ballast water facility serving SA Recycling and the Long Beach Cruise Terminal would employ permanent shore-based tanks for ballast water flow equalization and a centralized ballast water treatment facility equipped with coagulation, flocculation, sedimentation, UF membrane filtration, and chlorine contact basins. The second approach utilizes smaller truck- and barge-based treatment systems using membrane filtration and UV disinfection as the primary unit treatment processes. At Port of Hueneme, shore-based permanent storage tanks serviced by truck-based treatment would be employed and at El Segundo flow equalization and storage would be provided on a barge also housing treatment equipment.

A third treatment approach including modification of a POTW adding necessary equipment to meet the CA Interim Standards was considered for the Port of Stockton.

1.2.2 Sizing Storage and Treatment Facilities

Wastewater treatment plants use storage to manage surges in influent flow (e.g. while ballast water is being discharged) and maintaining treatment during interim lower flow periods (e.g. between discharge events). As a general rule, assuming adequate space is available, increasing storage capacity and reducing the size of treatment equipment reduces cost and the total area needed for treatment. To evaluate if increasing storage resulted in lower cost and smaller footprints for ballast water treatment, the storage volume, footprint, and capital costs were assessed over a range of treatment times (defined as time needed to treat a port's daily ballast water discharge volume). The results from this analysis for the Port of Oakland TraPac terminal are shown in Figure 1 to Figure 3. Results for the other ports are not shown, but were similar to those illustrated below.

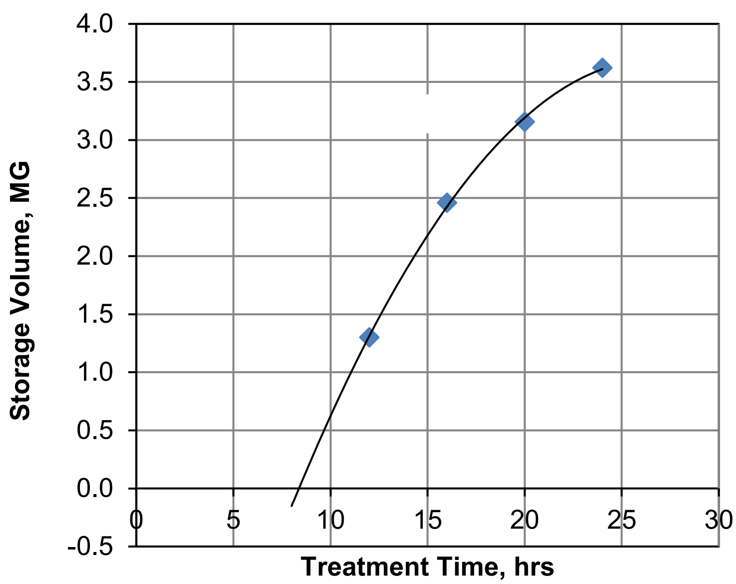


Figure 1 Storage tank volume vs. treatment flowrate relationship

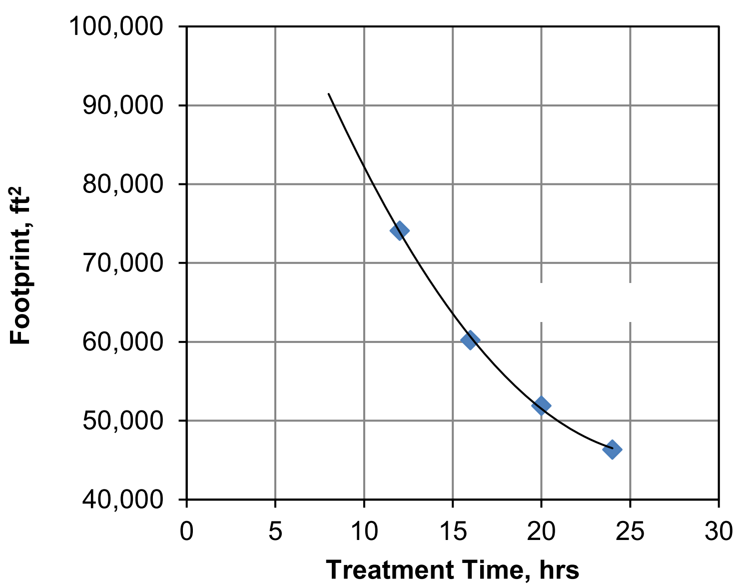


Figure 2 Overall facility footprint vs. treatment flowrate relationship

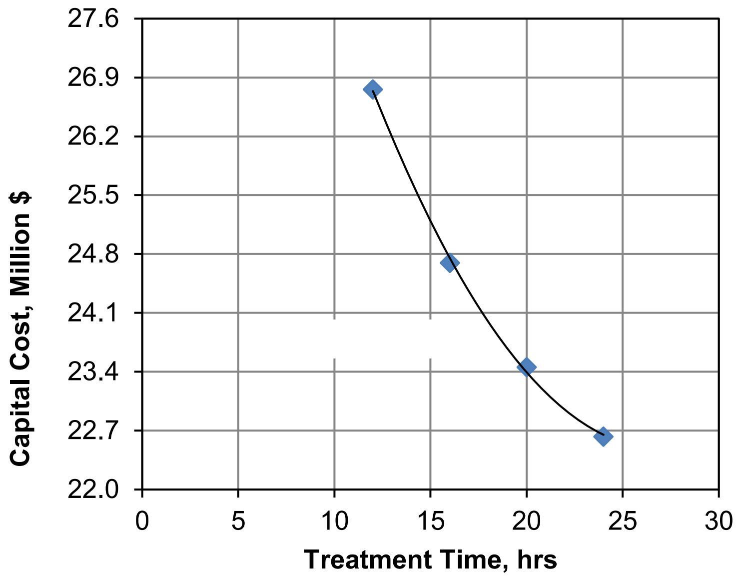


Figure 3 Overall facility capital cost vs. treatment flowrate relationship

As illustrated in the above figures, the footprint and capital cost decrease with increasing storage and treatment time. The smallest footprint and capital cost for all ports studied is based on this finding of a 24-hour treatment cycle, rather than sizing for treating on a 12-hour daily work schedule. Thus, the storage and treatment equipment capacities for each shore-based case study were selected to treat the maximum daily discharge over a 24-hour period unless described otherwise.

1.2.3 Reuse and Recycling of Ballast Water

It may feasible in some locations to reuse and recycle ballast water. This is generally applicable in cases where there is mass balance between ballast water that is taken up and discharged in the same location.

An example of this would be a container terminal where the first ship needed to discharge 2,000 tons of ballast water. This could be transferred to a holding tank. A second ship, either at the same berth or one nearby where the water would be plumbed to, might then need to take on that same 2,000 tons of ballast water.

This operation has some practical applications in a limited set of locations where this can be practiced. This study has not developed an estimate of how frequently this could take place as the result will not significant alter the findings due to:

- The cost of the reception will remain, with cost of treatment as secondary.
- The mass transfer will rarely be equal, same to be received as discharged. This means that in general a treatment plant will be required to make-up the difference.
- Vessels that are taking up ballast water have no current requirement. In order for the transfer to take place, they would now be burdened with having to have a ballast transfer station and making such a connection.

Reuse and recycling should remain a consideration, but would not likely result in a significant state-wide reduction in costs and would require an impact on more vessels.

1.3 Summary of Findings

The Task 5 report identifies standardized treatment approaches which may be able to achieve the CA Interim Standards, though it is noted that additional bench-scale and in-field testing would be required to verify the validity, performance, and reliability of the treatment approaches described above.

This Task 4 report provides ROM estimated costs for construction of conveyance, storage, and treatment in Table 3 below. Additional details supporting ballast water storage and treatment system sizing and costs for each of the case studies evaluated are provided in the sections that follow. Additional detail supporting ballast water storage and treatment system sizing and costs are included in Appendix A.

Table 2 Ballast water conveyance, storage, and treatment summary

Case Study	Port Terminal	Conveyance & Treatment Approach	Design Max Daily Discharge (m^3)	Design Ballast Discharge Rate (m^3/hr)	Storage Volume Required (MG)[1]	Overall Facility Footprint (acre)[2]	Total ROM Initial Capital Cost ($M)[3]
1	Port of Stockton East Complex	New pipeline to POTW & new onsite or offsite tank	34,000	2,800	NA	NA	>$50M
2	Port of Oakland TraPac Terminal	New pipeline to new onsite WWTP	22,500	2,400	3.6	1.06	$28.4
3	Port Hueneme South Terminal Wharf 1	Onsite storage & mobile shore-based treatment	4,000	350	1.06	0.11[4]	$10.0
4	El Segundo Marine Terminal	Offload to mobile, marine vessel-based storage & treatment	32,000	3,400	5.1	NA[5]	$29.4[6]
5	Port of LA/LB SA Recycling & Cruise Terminal	Offload to mobile marine vessel & new offsite WWTP	26,400	1,800	1.8	0.45	$12.7[7]

The limitations listed below are also applicable to cost estimate summary tables provided in Section 2.

[1] Storage volume required to treat maximum daily discharge over 24-hr. period unless otherwise noted. Costs based on aboveground steel tank and site preparation. Pile-supports not included.
[2] Footprint includes space required for storage and treatment equipment.
[3] Conveyance costs are included from Task 3 delivery point to lift station wet well. Costs for improvements required to receive ballast water from vessel and for wharf piping improvements are not included. Costs for land

acquisition costs, right-of-way, and the impacts due to the loss of leasable land necessary for storage and treatment are not included. Costs for O&M, depreciation, escalation, etc are not included.
[4] Footprint for one storage tank at one location only.
[5] Footprint calculations do not include storage which is assumed to be provided on barge.
[6] $8M estimated cost for retrofit of barge based treatment system are included.
[7] Costs for upgrading mooring systems are not included.

Section 2 Case Study Conveyance, Storage, and Treatment Methodology

This section describes the site conditions, assumptions, and methodology applied during the evaluation of ballast water conveyance, storage, and treatment at each of the case study port facilities under consideration.

2.1 Port of Stockton/East Complex

2.1.1 Summary of Port

Located along the San Joaquin Delta, approximately 75 miles from San Francisco Bay, the Port of Stockton is an important California port for the import and export of bulk products by sea. In 2014, the Port handled nearly 4.1 million metric tons in waterborne tonnage, setting it apart as the leading bulk/break-bulk port in the State. It now exports more than 2.3 million tons of American products annually, and imports more than 1.8 million tons of products with an estimated cargo value of $1.5 billion.

Figure 4 Location of the Port of Stockton

Encompassing an area of nearly 4,000 acres, and with over seven million square feet of covered storage, the Port of Stockton is the second largest inland freshwater port in the western United States. The Port possesses more than 60 miles of railroad track and 12,000 linear feet of dock space. It has multiple storage and handling facilities for dry and liquid bulk materials, as well as facilities and equipment to handle a wide variety of break-bulk, project, and containerized cargoes.

The Port's marine terminals are divided into two primary berthing "complexes" –the East Complex and West Complex– offering 15 deepwater ship berths, collectively, many of which are equipped with on-dock rail for cargo load and discharge operations (Reference 7). Also located within the broader port district are a number of independently-owned and operated terminals, including the Penny-Newman bulk cargo terminal which handles liquid and dry feed (grain) products.

The Port of Stockton is called primarily by Panamax-size bulkers and tankers. In 2014, port-wide discharge volumes at the Port of Stockton totaled 1.7 million metric tons. Figure 5 indicates ballast water discharges at the Port of Stockton.

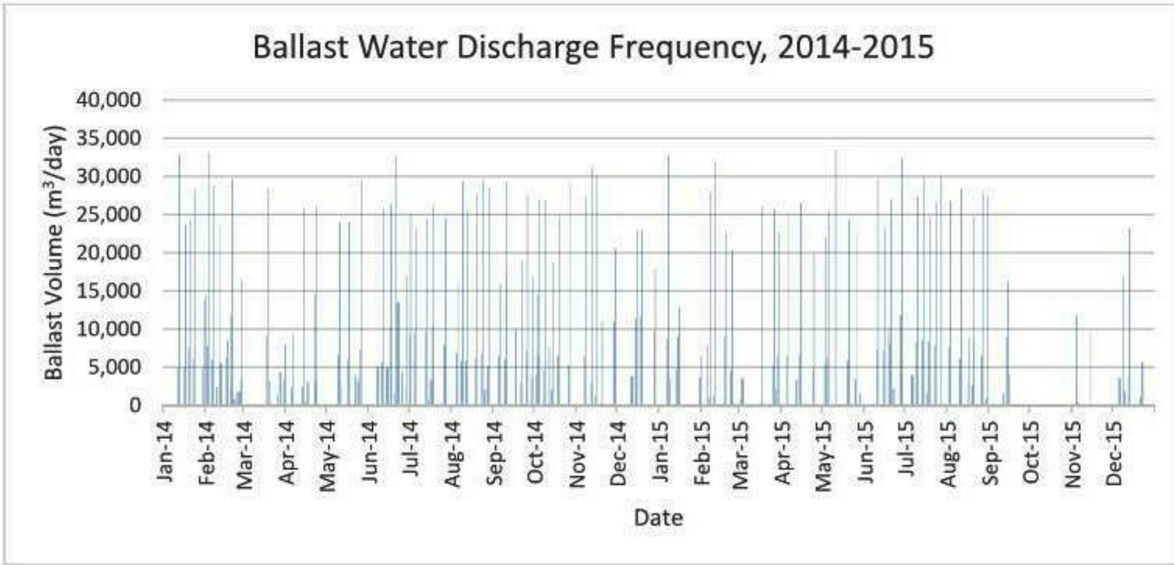


Figure 5 Ballast water discharges, 2014-2015 at Port of Stockton

The Port of Stockton was selected as a case study for this project because it represents a California bulk cargo port with a diverse suite of terminals and cargo operations. The bulk carrier vessel type, which the study was required to evaluate, calls the Port of Stockton most frequently, though many other vessel types call this port as well. They are one of the few facilities located relatively near to a POTW (existing WWTP), which satisfied a project goal to evaluate the potential for discharge of ballast water to local POTWs for potential treatment. The Port of Stockton is also located in a unique estuarine environment with a fresh/brackish water mix, and receives significant annual discharge volumes of both fresh and marine (salt) ballast water. It sees some of the largest ballast water discharge flowrates of any facility in the State of California. Table 3 provides the case study characteristics and approach.

Table 3 Port of Stockton case study summary

Case Study	Port/Terminal	Vessel Type	Conveyance Approach	Storage Approach	Treatment Approach
1	Port of Stockton/East Complex	Bulk Carriers	Rail & Pipeline	New onsite tank	Existing WWTP

The design basis assumed for the Port of Stockton is provided in Table 4. Port of Stockton ballast water discharges are tightly linked to cargo load rates, which occur daily and in high volumes. Due to this tight pattern of frequent and consistantly high volumes, the design basis is set at the maximum rates with a small margin added. Often, there are multiple consecutive days with high volume discharges, resulting in as much as 98,000 tons in a single seven-day period.

Table 4 Port of Stockton design basis

Discharge Rate	Max. (m3/hr)	90% (m3/hr)	Design (m3/hr)	Flange (mm)
	2,819	2,600	2,800	600

Discharge Volume	Period (days)	Max. (m3)	90% (m3)	Design (m3)	Vessel Types
	1	33,570	29,500	34,000	Bulk carriers

2.1.2 Ballast Water Conveyance

This case study includes evaluation of two different options for conveyance of ballast water from shore-side reception facilities to the City of Stockton Sewage Treatment Plant (referred to as SPOTW throughout). The SPOTW is located at 2500 Navy Drive, approximately 1.5 miles from the Port's ballast water discharge locations. The first option considered loading ballast water onto tank cars and conveyance by rail to a sanitary sewer inlet close to the SPOTW. The second option considered construction of a new pipeline connecting a new lift station receiving ballast water near the wharf directly to the SPOTW. The adequacy of the SPOTW's treatment capacity to accommodate the addition of ballast water influent and its capability to achieve the discharge water quality goals of the CA Interim Standards are also evaluated.

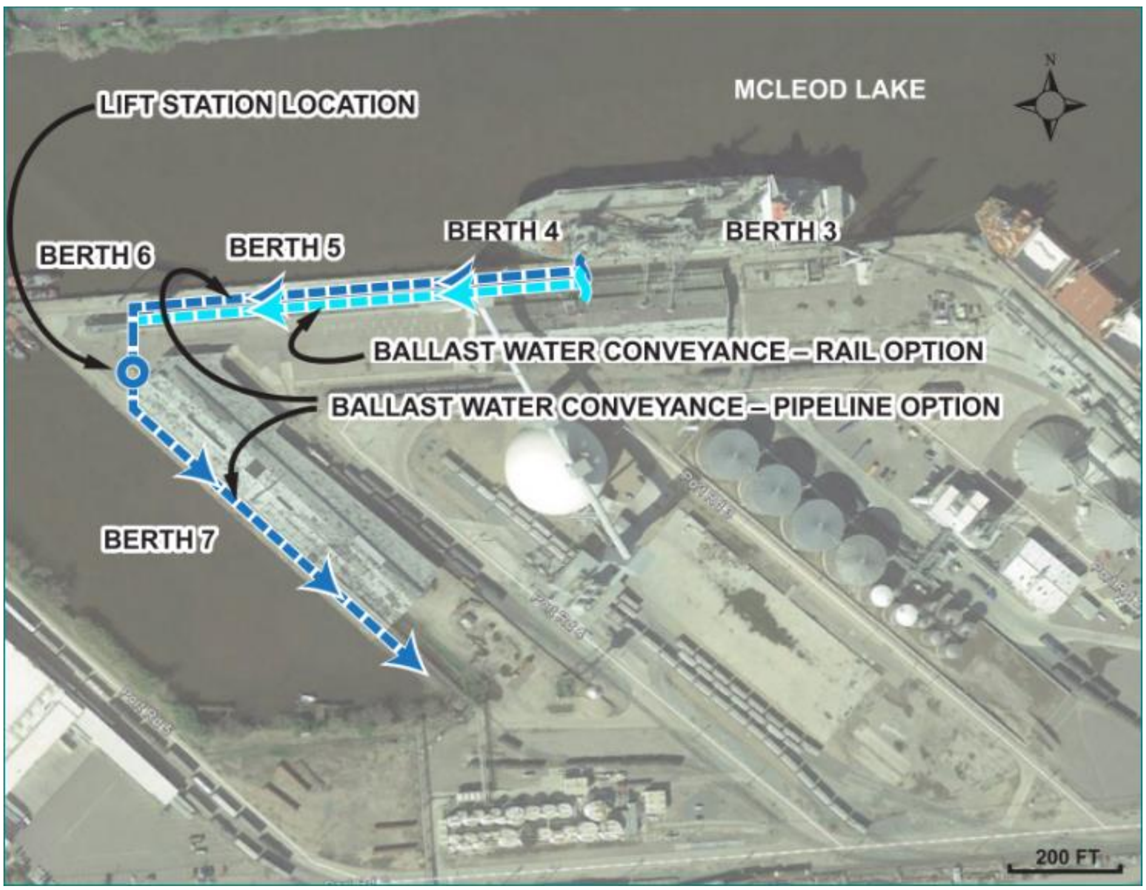


Figure 6 Port of Stockton/east complex general conveyance approaches

A landside lift station will be required to convey ballast water from shore-side reception facilities to either to rail cars or a new pressurized force main pipeline that will deliver the ballast water to the SPOTW.

2.1.2.1 Conveyance by Rail

Two existing rail yard storage areas were identified for loading and unloading of ballast water as shown below. The study considered the proximity of the rail yard to the terminal, the length of piping needed to convey the ballast water to the loading area of the railroad tank cars, the location of the unloading rail yard storage area and the length of pipe required to transfer the ballast water from the unloading area to the SPOTW.

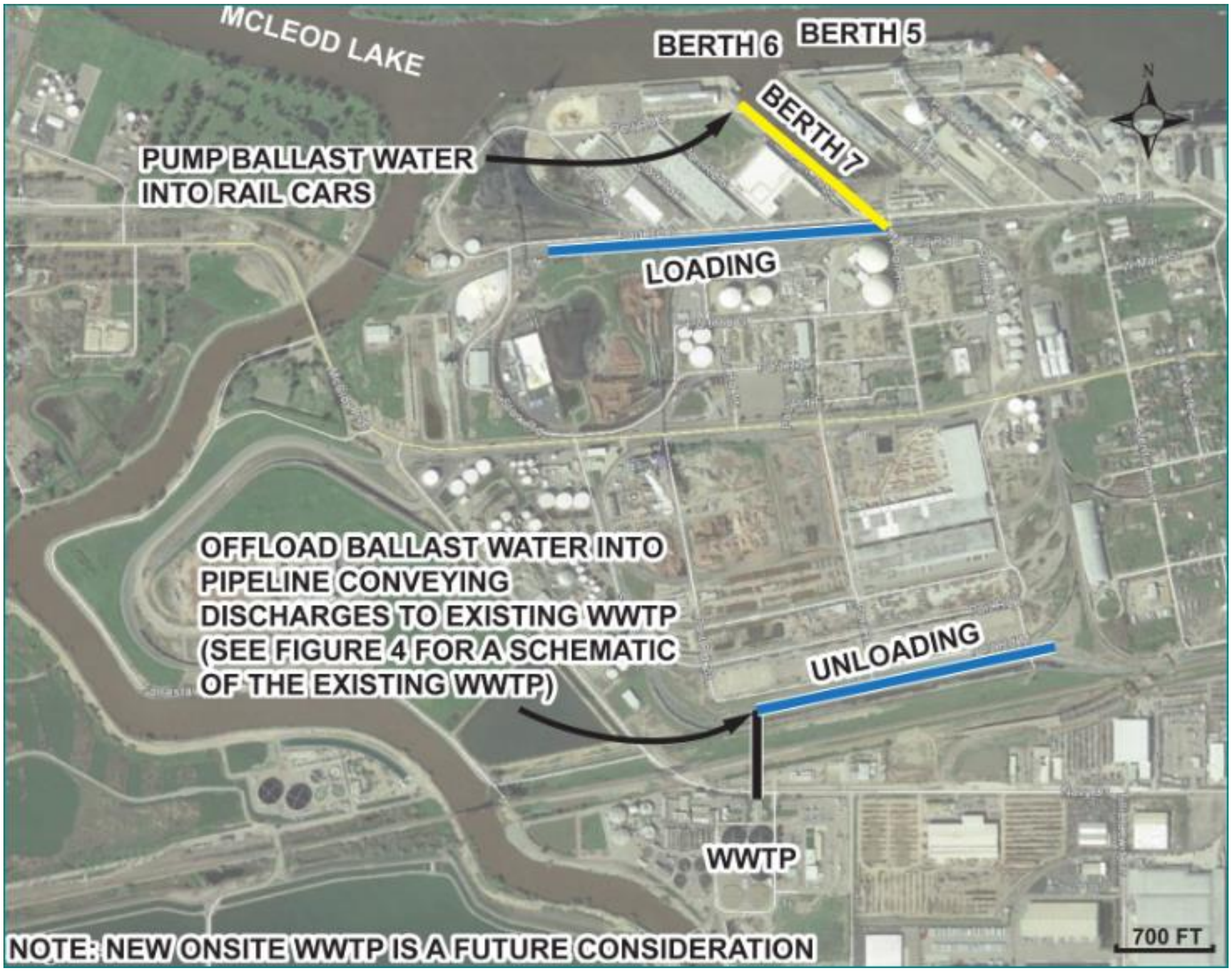


Figure 7 Port of Stockton/east complex rail car conveyance conceptual approach

The instantaneous ballast water discharge rate (2,800 m^3/hr) and daily maximum volume (34,000 m^3) generated by the facility are extreme and would require approximately 300 rail car loads per day to convey the volume. The total length of rail cars would be approximately 3.5 miles. The required length of train essentially exceeds the length of available storage track both at the loading yard and at the unloading yard. Moreover, using the tracks to convey ballast water would preclude the use of the rail yards for their intended purposes. Rail operations support the Port's tenants and business mission. Using the rail for tank cars to convey ballast water to the SPOTW would adversely affect the Port's business operations to such extent that this solution is not feasible.

2.1.2.2 Conveyance by New Pipeline

As an alternative to transporting ballast water from the wharf to the SPOTW by rail car, the option of installing a new 24-inch diameter pipeline along the alignment depicted in Figure 9 was considered. The estimated costs for installation of the new lift station and pipeline to the SPOTW are included in Table 3.

Figure 8 Port of Stockton/east complex pipeline conveyance conceptual approach

2.1.3 Ballast Water Treatment

The primary ballast water disposal and treatment option considered in this study for the Port of Stockton is to blend the ballast water with municipal wastewater and treat the blended stream at the SPOTW. For this to be a feasible option, the WWTP must be able to remove ballast water microorganisms below the CA Interim Standards and the blended wastewater must not have any concentration of pollutants exceeding the plant's discharge permit. A schematic drawing of the SPOTW's treatment processes is provided in Figure 9.

The main treatment processes at the WWTP include primary and secondary clarification, bio-towers (nitrifying and non-nitrifying), pond and wetland treatment, and dissolved air floatation. Bio-towers typically contain very porous media used as attachment sites for fixed-film bacteria that are responsible for carbon and nutrient removal. Bio-towers do remove some influent solids; however, removal of ballast water microorganisms would likely be low. As discussed in the Task 5 report, low removals of ballast water microorganisms would be expected through clarification/ sedimentation processes such as the primary and secondary clarifiers. The pond and wetland systems will remove/inactivate some microorganisms due to the UV radiation from sunlight and settling. Guastalli et al. (Reference 4) demonstrated 60% removal of seawater bacteria using dissolved air floatation combined with dual media filtration; removal at the

SPOTW would be expected to be lower without media filtration. Bacteria and viruses could be removed in the chlorine contactor; however, the chlorination dose would have to be substantially increased to achieve the necessary virus and bacteria removals and chlorination is not as effective as filtration for removal of larger marine microorganisms (organisms > 10 µm). Although it may be possible to modify the SPOTW with membrane filters and higher chlorine doses to accept ballast water, the additional cost and potential negative impacts on the receiving streams from disinfection byproducts formed in the presence of high concentrations of chlorine makes this inadvisable.

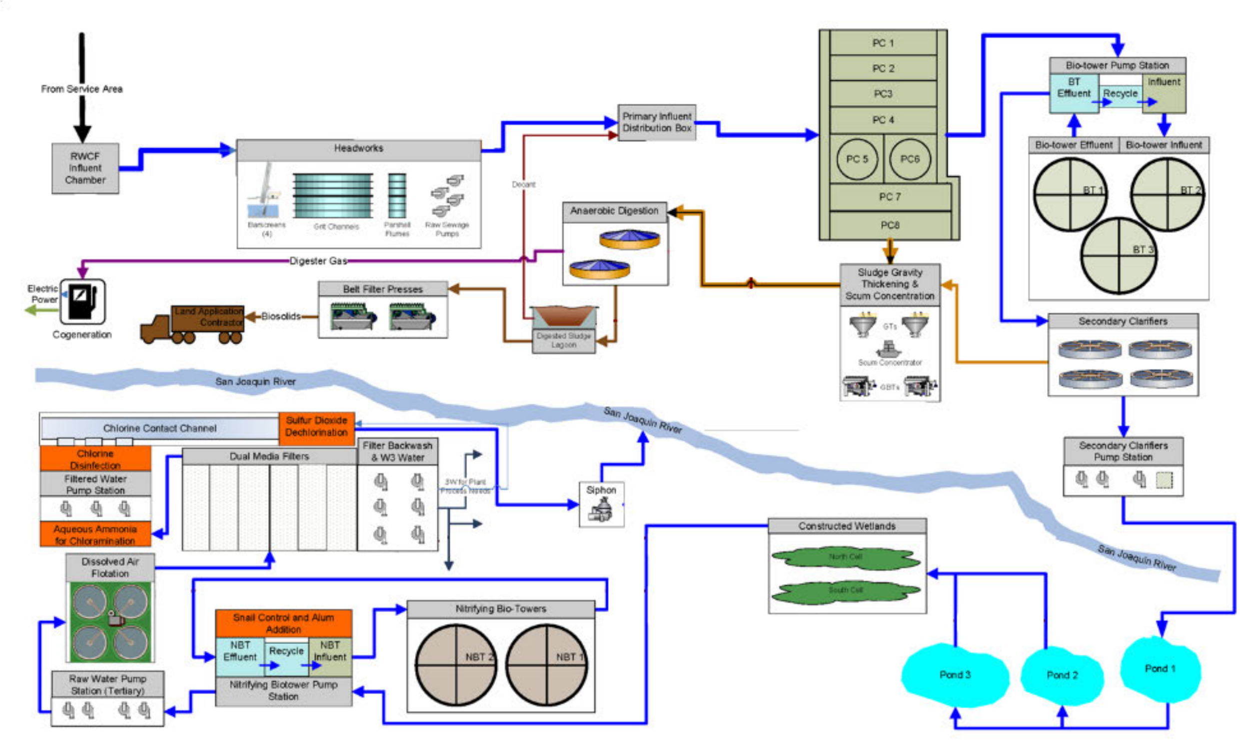


Figure 9 Process diagram of City of Stockton's regional wastewater control facility (adapted from the City of Stockton)

The required effluent quality from the SPOTW is defined in the facility's National Pollution Discharge Elimination System (NPDES) permit. The NPDES permit sets limits for the allowable concentration of nutrients, organic chemicals, suspended solids, and total dissolved solids (TDS) in the SPOTW's effluent.

Three blending analyses were conducted under the Task 5 study to determine if ballast water blending was a viable treatment and disposal option. The TDS of the full SPOTW and ballast water blend (7,100 mg/L) far exceeds the allowable effluent concentration (830 mg/L). Considering this limitation, the second blending analysis was conducted to determine how much ballast water could be blended per day without exceeding the permit limit. The second blending analysis was done assuming the full wastewater flow, a wastewater TDS equal to 670 mg/L, and a ballast water concentration of 30,000 mg/L. The maximum amount of ballast water that can be blended per day without exceeding a blended concentration of 830 mg/L was estimated under Task 5 to be 167,000 gallons per day, approximately 8.8 MGD short of the total ballast water flow estimated to require treatment under the design scenario.

The third blending analysis was conducted to determine how much wastewater flow would be required to achieve a specified allowable blended TDS concentration. A range of blended TDS concentrations was evaluated because not all POTWs will have the same TDS limits as the SPOTW. The results from the third blending analysis performed under Task 5 estimated that approximately 1,600 MGD of wastewater flow would be required to dilute the volume of ballast water received by the Port of Stockton to meet the SPOTW's NPDES allowable concentration. In summary, it is very unlikely that blending municipal wastewater with ballast water will be a viable option under most ballast water discharge scenarios unless the port facility under consideration has very low ballast water disposal needs and is located near a very large POTW, or the POTW is permitted to discharge very high TDS effluent, which is typically uncommon. Additional challenges with treatment of ballast water at municipal POTW's include:

1. Conveyance of large volumes of ballast water to POTWs, typically located in urbanized areas, will require acquisition of conveyance corridors and rights-of-way that are assumed to be very difficult to acquire
2. Ballast water is generated at flows and volumes comparable to a large city, is saline by nature, corrosive, and generally not conducive to existing pipeline and POTW infrastructure designed to convey and manage typical municipal wastewater
3. Most POTWs are limited in capacity, operate applying biological approaches not conducive to high chloride influent
4. Specific to discharges from the Port of Stockton, The Water Quality Control Plan for the Sacramento and San Joaquin River Basin, Revised April 2016, includes discussion of saline water discharges that would be expected to complicate permitting of ballast water discharges under the SPOTW's NPDES permit.

In consideration of all of the listed challenges and specific evaluation performed, it is assumed that use of municipal POTWs for treatment and disposal of ballast water will not be a feasible option for most port facilities in California. ROM costs for a new WWTP based on preliminary concepts are included below.

Table 5 Port of Stockton storage and treatment costs

Location/Details	Modification	Cost
Port of Stockton East Complex	Treatment Equipment (New WWTP)	$24,321,000
	Lift Station	$2,695,000
	Conveyance	$4,100,000
	Engineering (25%)	$1,699,000
	Contingency 25%	$8,204,000
	Total	**$41,019,000**

2.2 Port of Oakland/TraPac Terminal

2.2.1 Summary of Port

TraPac, Oakland is a dedicated container-only terminal located in the Port of Oakland, Outer Harbor Channel at Berth 30 and 32. Presently, TraPac handles four to five vessel calls per week (Reference 8), mostly Panamax-sized.

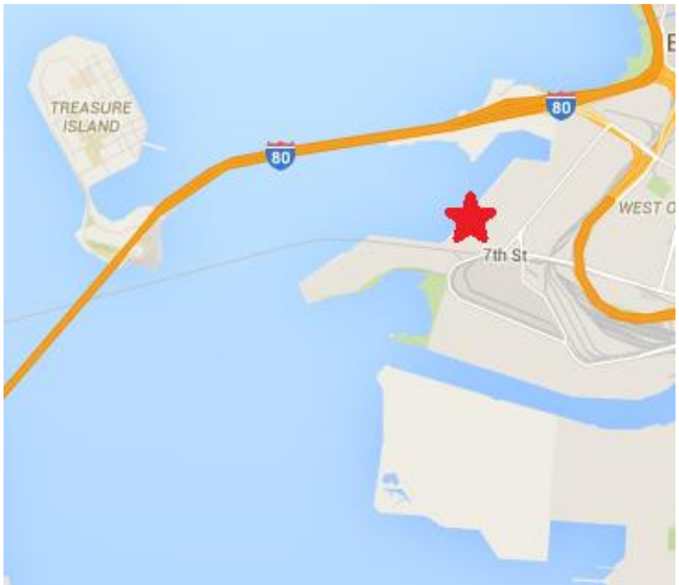


Figure 10 Location of TraPac Terminal

The terminal area encompasses approximately 66 acres. The berth area is 2,100 feet long and has six working lanes beneath four post-Panamax container gantry cranes. Currently, the yard is set up to accommodate a combination of wheeled and grounded operations, but is designed to allow for conversion to higher density grounding if required.

Ballasting operations at TraPac are typical of container terminals that see a net import of cargo. The vessel offloads cargo, and takes on ballast water to compensate for weight changes. In the TraPac case, there were only five ballast water discharges over a 24-month period that saw an estimated 500 vessel calls (one ballast discharge per 100 vessel calls). Discharges are indicated by Figure 11 below.

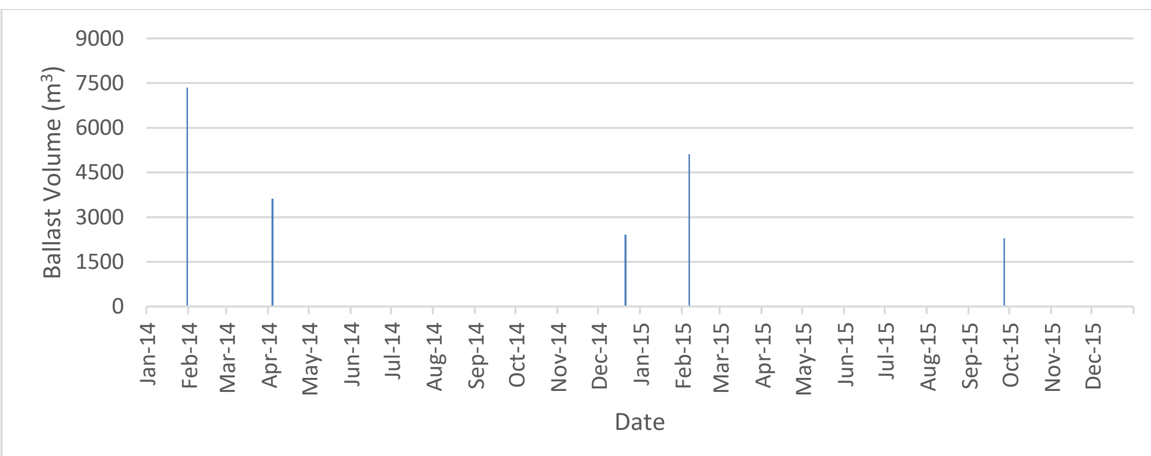


Figure 11 Ballast water discharges, 2014-2015 TraPac Terminal

TraPac Terminal was selected as a case study for this project because it represents a major California container import/export terminal that, in contrast to the other case study ports, receives regular and frequent calls from a single vessel type (i.e. containerships). Despite the frequency of vessel calls and the size of the vessels themselves, ballast water discharge events at TraPac are sporadic and the volumes relatively small. TraPac is also centrally located with available space to accommodate storage and treatment facilities with the potential to serve adjacent terminals. Table 6 gives the case study characteristics and approach.

Table 6 TraPac Terminal case study matrix

Case Study	Port/Terminal	Vessel Type	Conveyance Approach	Storage Approach	Treatment Approach
2	Port of Oakland/TraPac Terminal	Containerships	New pipeline	New onsite tank	New onsite WWTP

The design basis assumed for TraPac Terminal is given in Table 7. The TraPac, Oakland facility case study is being used to design reception from ship to shore and make use of intermediate ballast water storage. The adjoining facility details are included for sizing transfer station pumps and piping. The total for processing plant design basis considers the rate and total of ballast water discharged from Trapac and Adjoining facilites to the centralized processing plant. The totals provided use Trapac specific as well as port wide historic ballast water discharge volumes and rates.

Table 7 TraPac Terminal design basis

Discharge Rate	**Max.** (m^3/hr)	**90%** (m^3/hr)	**Design** (m^3/hr)	**Flange** (mm)	
Port of Oakland/Trapac	750	750	750	300	
Adjoining facilities reception	2,400	1,500	1,500	400	
Total for processing plant	3,150	2,400	2,400	500	
Discharge Volume	**Period** (days)	**Max.** (m^3)	**90%** (m^3)	**Design** (m^3)	**Vessel Types**
Port of Oakland/Trapac	1	7,500	7,500	7,500	Containerships. Basis for reception facility.
Adjoining facilities reception	1	15,000	13,500	14,000	Basis for piping works to treatment plant.
Total for processing plant	1	22,500	21,000	22,500	Basis for treatment plant sizing.

2.2.2 Ballast Water Conveyance

This alternative includes collection of ballast water at potentially multiple locations along the wharf draining to a single lift station used to convey ballast water via 12-inch force main to an approximately 8-acre centrally located, infrequently used portion of the TraPac terminal depicted below. Conveyance elements assume ductile iron piping and appurtenances buried at least 3 feet below structural subgrade and aircraft rated pavement sections.

Figure 12 Port of Oakland TraPac Terminal conceptual conveyance approach

2.2.3 Ballast Water Treatment

The footprint identified to potentially be available at the Trapac terminal is estimated to be adequate for the storage and treatment equipment necessary to support the ballasting needs of Trapac and adjacent terminals. The figure below depicts moderately sized storage and treatment facilities applying the treatment methodology recommended in Task 5 (coagulation, flocculation, sedimentation, membrane filtration, and chlorine disinfection) and the flow and volume requirements identified in Table 7. Specific storage and treatment system sizing calculations and criteria are included in Appendix B.

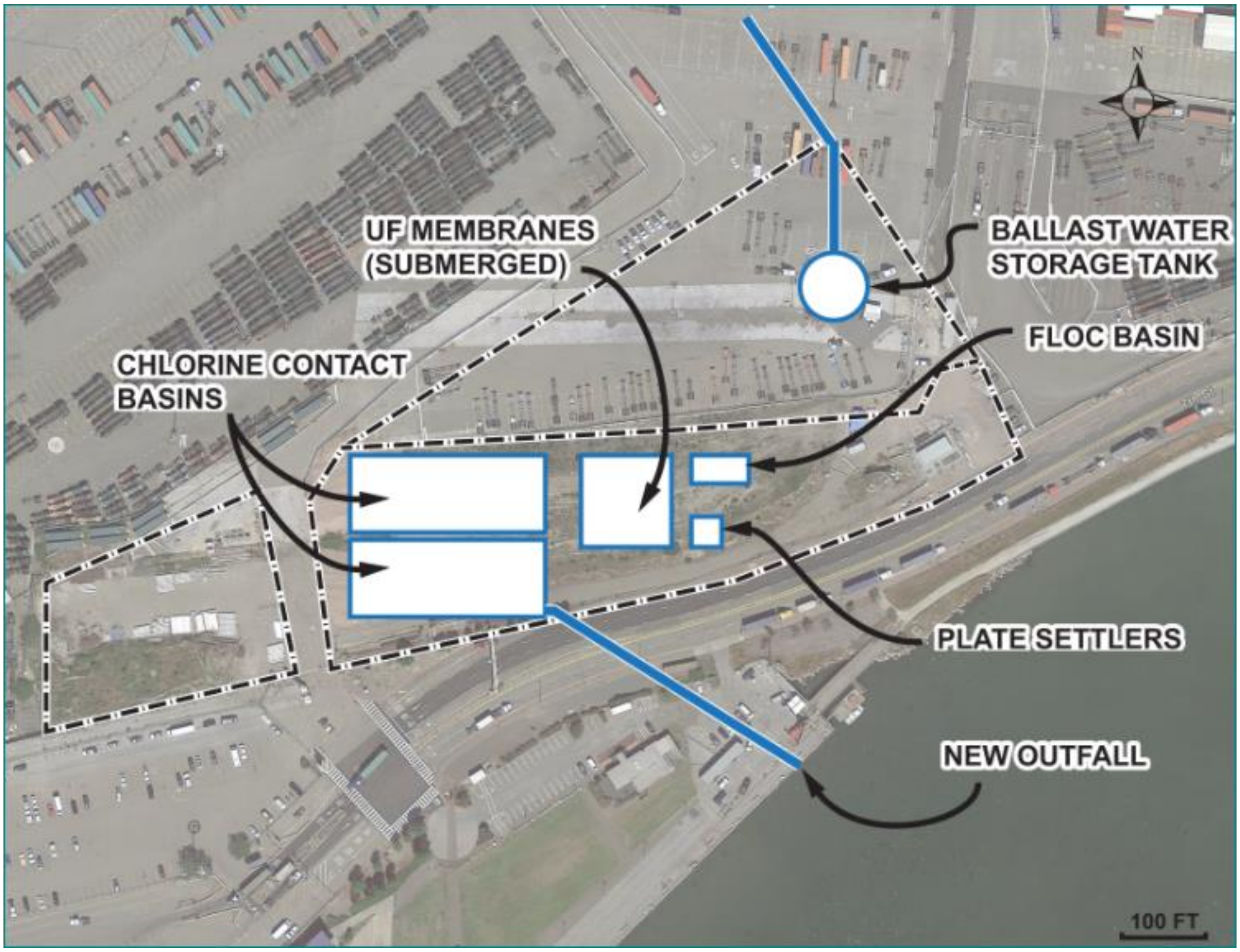


Figure 13 Port of Oakland TraPac Terminal conceptual treatment approach

Table 8 Port of Oakland storage and treatment costs

Location/Details	Modification	Cost
Port of Oakland TraPac Terminal	Treatment Equipment	$22,630,000
	Lift Station	$1,783,000
	Conveyance	$1,900,000
	Engineering (25%)	$921,000
	Contingency 25%	$6,809,000
	Total	**$34,043,000**

2.3 Port of Hueneme – South Terminal Wharf 1

2.3.1 Summary of Port

The Port of Hueneme is located approximately 60 miles north of Los Angeles, near the city of Oxnard. Port of Hueneme handles approximately $9 billion in cargo annually, mainly from Ro-Ro vessels, refrigerated cargo and general cargo ships, and small containerships. The port has ~120 acres of available land area, as well as a ~30-acre Naval facility, and six wharves (Reference 9).

Figure 14 Port of Hueneme

The Port of Hueneme received nearly 1,500 ship calls over the four-year period between June 2012 and June 2016. During this same period, there were 34 ballast water discharge events totaling 40,280 metric tons. These discharges ranged from 75 tons to 6,972 tons per ship call, with discharge rates estimated between 150 and 2,000 metric tons per hour. The majority of the discharges in this four-year period were from containerships (12 discharges totaling 10,097 metric tons), followed by tankers (7 discharges totaling 7,178 metric tons). This constitutes a broad range of ballast water discharge volumes and flow rates. Additionally, ballast water discharges at the Port of Hueneme are sporadic. Discharges over 2,000 metric tons in volume have only occurred three times in the past four years.

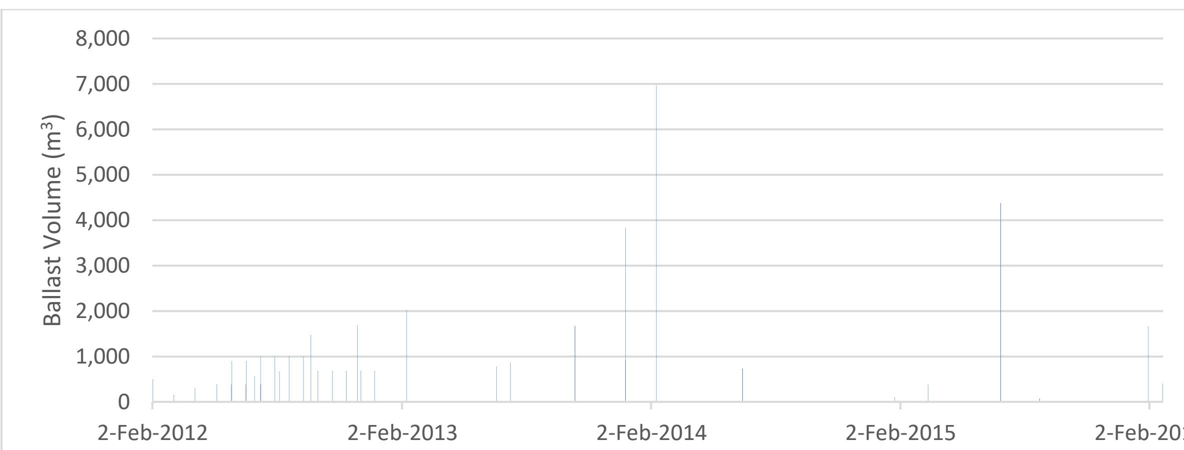


Figure 15 Ballast water discharges, 2012-2015 at Port of Hueneme

The Port of Hueneme was selected as a case study for this project because it represents a smaller scale California port with regular but (comparatively) less frequent calls from multiple vessel types, including Ro-Ro ships. Due to its limited land area, the Port of Hueneme also faces terminal space constraints that merit consideration in this study, in addition to the variability in ballast water discharge frequency and volumes, described above. The comparatively low ballast water treatment requirements at this terminal make it well suited to mobile truck-based treatment. For the purposes of the evaluation, it is assumed that storage capacity would be provided at one location to accommodate the design flow rate and volume.

Table 9 Port of Hueneme case study matrix

Case Study	Port/Terminal	Vessel Type	Conveyance Approach	Storage Approach	Treatment Approach
3	Port of Hueneme/South Terminal Wharf 1	Automobile Carriers	Onsite storage	New onsite tank	Mobile shore-based treatment

The design basis assumed for the Port of Hueneme is given in Table 10. Hueneme sees discharges from multiple vessel types, but car carriers provide a reasonable design basis for presentation flange pressure and dimensions. The discharge rates and volumes vary significantly, and there is more than one approach. The design rate is based on slowing down some of the larger vessels discharge rates, but allowing typical discharge volumes to be offloaded in less than eight hours. There are various ways to consider the volume period and amounts. The design basis here assumes a 20-day period for the ballasting cycle, i.e. how many vessels and ballast discharge volumes per 20-day period. This approach is based on 12 years dataof data, showing that such a 20-day period will typically seeing see no more than 4,000 tons of ballast discharge . For the rare, every five years, higher volumes, an additional barge or other means would be required.

Table 10 Port of Hueneme design basis

Discharge Rate	Max. (m^3/hr)	90% (m^3/hr)	Design (m^3/hr)	Flange (mm)	
	900	250	350	200	
Discharge Volume	**Period** (days)	**Max.** (m^3)	**90%** (m^3)	**Design** (m^3)	**Vessel Types**
	20	11,000	4,000	4,000	Various. Base ship connection on car carriers

2.3.2 Ballast Water Conveyance

The scenario depicted on the figure below assumes that ballast water can be collected at multiple locations at Port Hueneme's North and South wharves. Two landside lift stations would convey ballast water from reception locations to a single 4,000 m^3 storage tank. The exact location of this tank is not yet identified, assumed to be located in the yard behind the wharf.

Figure 16 Port of Hueneme Terminal conceptual conveyance approach

2.3.3 Ballast Water Treatment

Treatment would be provided by a standard tractor-trailer equipped with membrane filtration modular equipment applying ultraviolet light disinfection as described in Task 5. For the purposes of evaluating treatment costs, we have assumed that one truck-based system would be capable of treating the maximum daily discharge of 4,000 m^3 over multiple days available between historically documented discharge events.

The membrane and UV disinfection technologies available are thought to be capable of achieving the CA Interim Standards, though the concept has yet to be proven. Bench-scale and in-field pilot testing will be required to verify the approach. The truck-based systems should also be expected to require more frequent maintenance than the full-scale approach recommended at the Port of Oakland, a tradeoff for the lack of coagulation, flocculation, and sedimentation processes preceding membrane filtration. A comprehensive listing of advantages and disadvantages of the different treatment technologies considered is included in the Task 5 report.

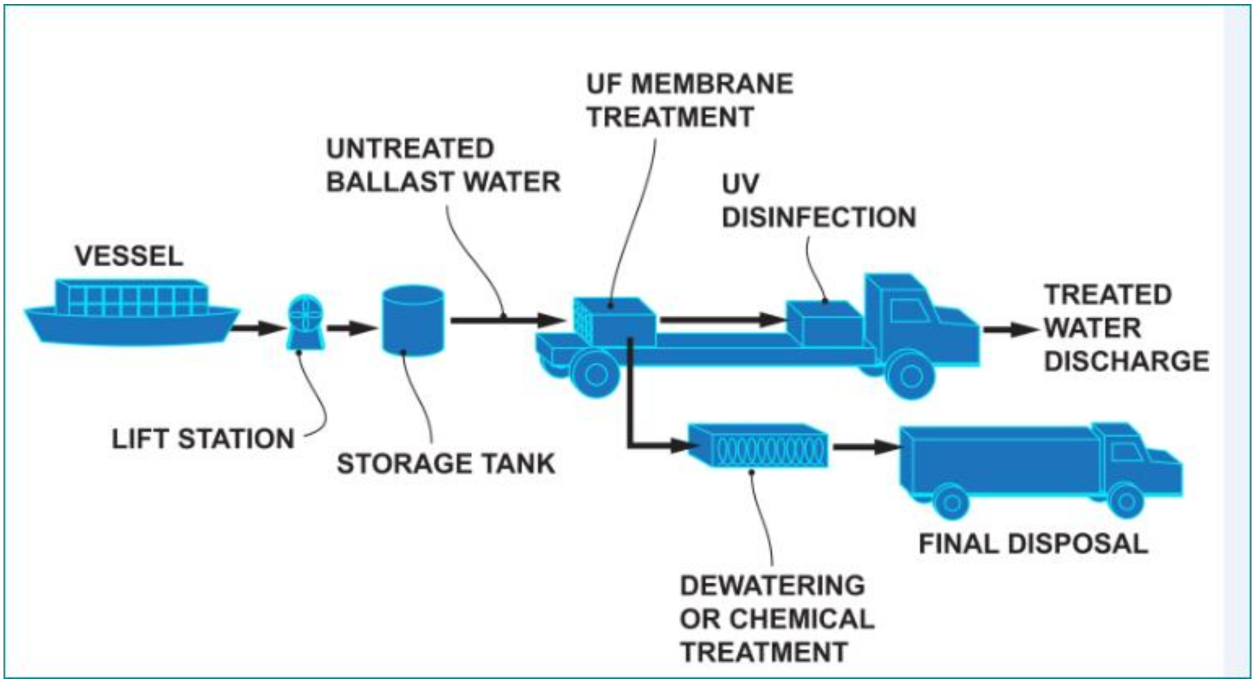


Figure 17 Port of Hueneme truck-based treatment approach

Table 11 Port of Hueneme storage and treatment costs

Location		Modification	Cost
Port of Hueneme	One Truck (0.25 MGD)	Treatment Equipment	$6,663,000
		Lift Stations (2)	$636,000
	2,000 LF Assumed	Conveyance	$1,500,000
		Engineering (25%)	$534,000
		Contingency 25%	$2,333,000
		Total	**$11,666,000**

2.4 El Segundo Marine Terminal

2.4.1 Summary of Port

El Segundo Marine Terminal facility is an offshore import/export facility for liquid bulk petroleum products, operated by Chevron U.S.A. Products Company. The terminal is located in an open, unsheltered mooring in Santa Monica Bay, directly offshore of Dockweiler State Beach in El Segundo.

Figure 18 Location of El Segundo Marine Terminal

The Terminal has two berths, defined by two seven-point conventional buoy moorings systems. Berth No. 3 is approximately 7,200 feet offshore, and Berth No. 4 is approximately 8,100 feet offshore (Reference 3). Cargo is transferred to and from the onshore facility through a network of submarine hoses and pipelines. The terminal is maintained and operated 24 hours a day, 7 days a week.

El Segundo Terminal sees approximately 214 tank vessel calls annually (2014 and 2015 data). The vessels are generally Handymax, Aframax, and Suezmax size tankers; but less frequent calls by articulated tug-barge units (ATBs) and very large crude carriers (VLCCs) also occur. Vessels discharged ballast water 95 times over a 24-month period (1/1/2014 – 12/31/2015), averaging less than one (1) discharge per week. The discharge volumes range from 122 to 53,819 m^3, with 95% of discharge volumes being less than 18,250 m^3 and 75% less than 9,250 m^3.

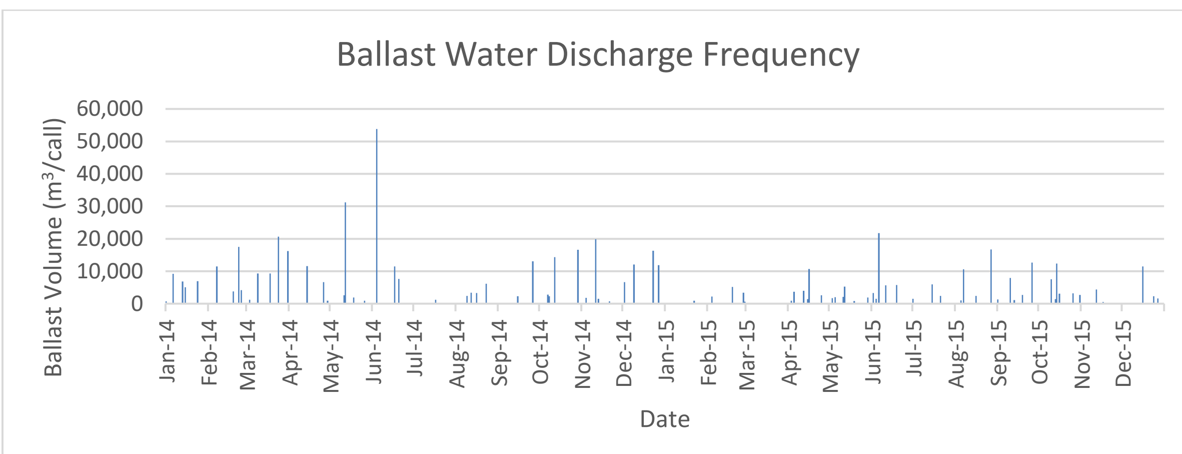


Figure 19 Ballast water discharges, 2014-2015 at El Segundo Terminal

The El Segundo Marine Terminal was selected as a case study for this project because it represents a California liquid bulk import/export terminal with regular calls from two vessel types (tankers and ATBs) that vary considerably in size and carrying capacity. This terminal is unique in that it is an offshore mooring with no dock infrastructure, and thus no direct access to the facility ashore. The El Segundo Marine Terminal is also the site of some of California's largest ballast water discharges, in terms of discrete discharge events by a single vessel. Table 12 gives the case study characteristics and approach.

Table 12 El Segundo case study matrix

Case Study	Port/Terminal	Vessel Type	Conveyance Approach	Storage Approach	Treatment Approach
4	El Segundo Marine Terminal	Tank Ships; ATBs	Offload to mobile marine vessel	Mobile marine vessel	Mobile, marine vessel-based treatment

The design basis assumed for the El Segundo Marine Terminal is given in Table 13. El Segundo vessel discharges are strictly governed by cargo loading rates, which are impractical to slow for all but extreme cases. The discharge volumes and rates are based on typical highest discharges, noting that only one vessel called in the last several years with higher rates and volumes. That case will require additional time, split discharge, or other special accomodation.

Table 13 El Segundo design basis

Discharge Rate	Max. (m^3/hr)	90% (m^3/hr)	Design (m^3/hr)	Flange (mm)	Hose (mm)
	5,000	3,400	3,400	600	300
Discharge Volume	**Period** (days)	**Max.** (m^3)	**90%** (m^3)	**Design** (m^3)	**Vessel Types**
	1	53,819	32,000	32,000	Tankers.

2.4.2 Ballast Water Conveyance

This facility was selected for evaluation of barge or vessel based treatment of ballast water where the vessel would provide temporary storage and act as a mobile treatment plant. Discharges occur frequently and extreme treatment flowrates must be satisfied to accommodate optimal ship schedules. Though volumes of ballast water generated from tanker vessels calling at the El Segundo Terminal are measured in the tens of thousands of tons per vessel, the volume of ballast is no greater than that already carried on board the ships, so building storage and treatment facilities onboard retrofitted tanker vessels is conceivable.

For the purposes of this evaluation and in consideration of deck space limitations on conceived retrofit vessels, it is assumed that the same treatment approach applied at Port Hueneme (membrane filtration and UV disinfection) would be provided on a modified barge or similar vessel with adequate storage capacity meeting the requirements listed in Table 13. In this case a booster pump, rather than lift station, is used to ensure that the transfer rate is adequate to keep up with cargo weight shifts.

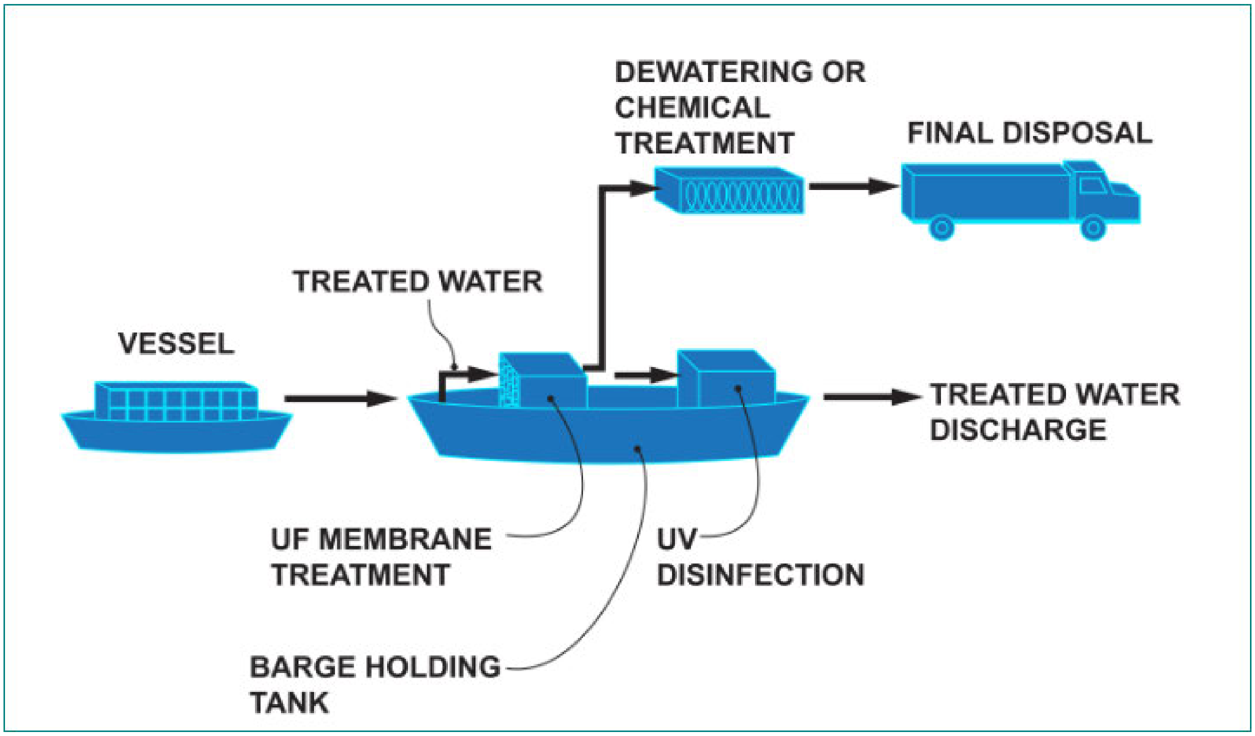


Figure 20 Port of El Segundo vessel-based conceptual storage and treatment approach

Table 14 Port of El Segundo storage and treatment costs

Location	Details	Modification	Cost
Port of El Segundo		Barge & Retrofit	$8,000,000
		Treatment Equipment	$10,324,000
		Booster Pump	$2,536,000
		Engineering (25%)	$2,634,000
		Contingency 25%	$5,874,000
		Total	**$29,368,000**

2.5 Port of Long Beach/SA Recycling and Cruise Terminal

2.5.1 Summary of Port

Taken together, the twin ports of Los Angeles and Long Beach constitute the busiest port complex in the US. Two separate terminals were examined in this study – the SA Recycling facility in the Port of Los Angeles (Terminal Island, Berth T118), and the Long Beach Cruise Terminal in the Port of Long Beach.

SA Recycling is a full-service ferrous and non-ferrous metal recycler and processor operating multiple facilities in California and six other states. The Terminal Island facility in Los Angeles is both a processing facility and export terminal, servicing one or two vessel arrivals per month, on average.

Figure 21 Location of SA Recycling Terminal

Vessel sizes are typically Panamax in the 50-60k deadweight ton range. Cargo operations normally occur over a consecutive five-day period, with export volumes around 45k metric tons per vessel call (see Figure 22). There were 27 ballast water discharges at this terminal in a 24-month period from 2014 – 2015.

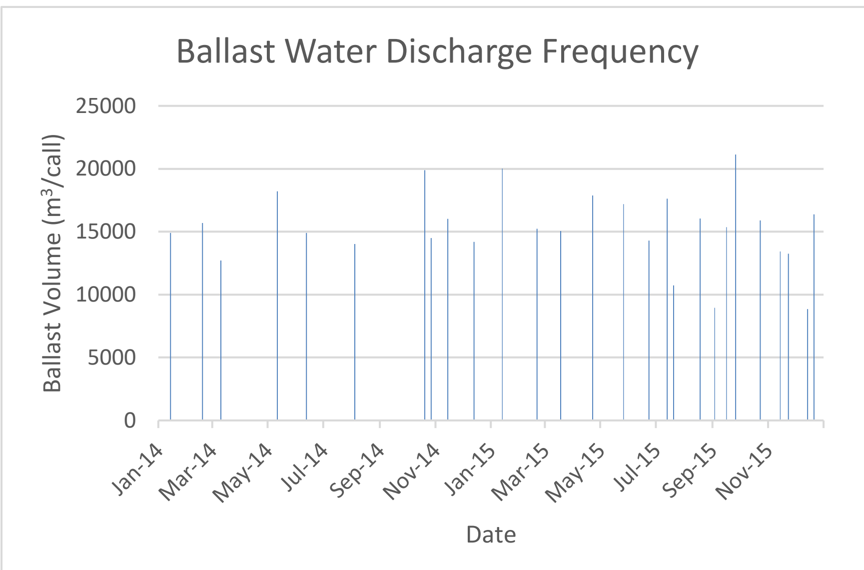


Figure 22 Ballast water discharges, 2014-2015 at SA Recycling Terminal

Owned and operated by Carnival Corporation, the Long Beach Cruise Terminal is located at the head of Queensway Bay in the Port of Long Beach. It features a single ship berth at the end of a T-shaped pier, approximately 50 meters from shore.

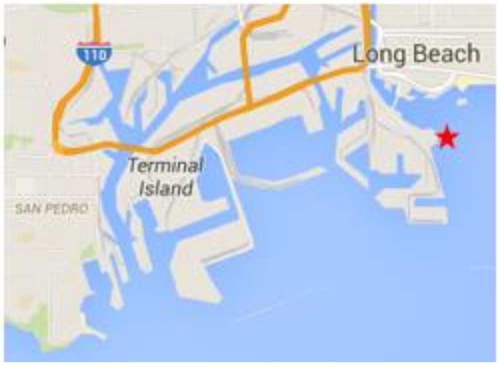


Figure 23 Location of the Long Beach Cruise Terminal

The Cruise Terminal receives roughly 250 vessel arrivals per year - generally one per day, excepting Tuesdays and Wednesdays. The duration of ballasting events on cruise ships is closely related to the duration of fuel oil bunkering operations rather than the duration of cargo operations as with bulk carrying marine vessels. The average ballast water discharge per event is 783 m^3, and the total annual ballast water discharge is 158,000m^3 (see Figure 24). In a 24-month period from 2014-2015, this terminal saw 483 discharge events.

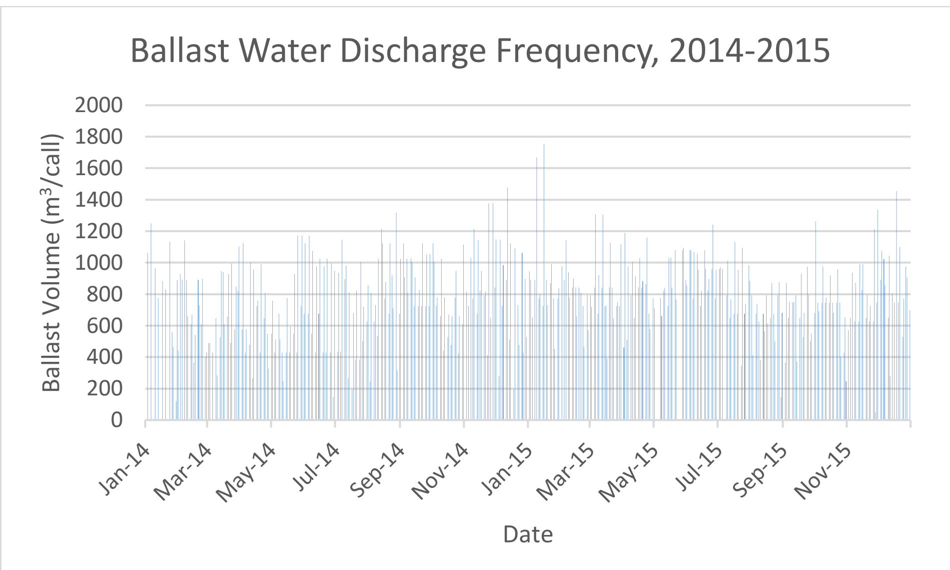


Figure 24 Ballast water discharges, 2014-2015 at Long Beach Cruise Terminal

These two terminals at LA/ Long Beach were selected as a case study for this project because they represent two dissimilar terminals in a busy port district, serving two very different vessel types – bulk carriers and passenger cruise ships. They are also physically distant from one another within the port complex, which highlights the challenges associated with conveying water to a shared WWTP. The Long Beach Cruise Terminal sees frequent -almost daily- discharge events characterized by relatively small volumes and lower flow rates. This terminal also represents a unique case in that it sees seasonal fluctuations in vessel activity. In comparison, the SA Recycling facility sees infrequent -monthly- discharge events characterized by relatively large volumes and higher flow rates. Together, these two terminals illustrate the variability in ballast water discharge practices within the LA/Long Beach port district. A ballast water conveyance approach must accommodate the ballast water needs of both terminals. Table 15 gives the case study characteristics and approach.

Note: a large-scale container terminal was intentionally not selected for evaluation in LA/Long Beach since a similar terminal is evaluated in the Port of Oakland case study.

Table 15 Port of Long Beach case study matrix

Case Study	Port/Terminal	Vessel Type	Conveyance Approach	Storage Approach	Treatment Approach
5	Port of Long Beach/SA Recycling and Cruise Terminal	Bulk Carriers and Passenger Cruise Ships	Offload to mobile marine vessel	New offsite tank	New offsite WWTP

The design basis assumed for the Port of Long Beach is given in Table 16. SA Recycling Terminal processes cargo on weekly basis, seeing ballast discharges of as much as 22,000 tons per week. Although ship discharge rates are as high as 2,800 m^3/hr, it is reasonable to slow this rate significantly during port collection, as the amount of ballast water to be discharged on a daily basis is no more than 6,000 metric tons. This reduced rate, over an eight-hour period would be only 750 m^3/hr. However, it is important to not stress ship's pumps by running at too slow of a rate, i.e. less than 50% of rated. As such, design rate for port reception is 1,400 m^3/hr, 50% of ship pumps.

The Cruise Terminal has seen only three vessels routinely discharging over the last several years. That noted, these vessels are typical of the industry in terms of volume discharges and rates, discharging less than 2,000 tons of ballast water in around of four hour period. The design basis provides some margin to holding capacity, to account for some growth given newer cruise ships having larger capacities, based on analysis of other cruiseship discharges at other ports. The rate is increased to 400 m^3/hr to correspond to six-hour processing of larger volumes.

Table 16 Port of Long Beach/Los Angeles design basis

Discharge Rate	Max. (m^3/hr)	90% (m^3/hr)	Design (m^3/hr)	Flange (mm)	
SA Recycling	2,800	2,500	1,400	400	
Cruise Terminal	500	350	400	200	
Discharge Volume	**Period** (days)	**Max.** (m^3)	**90%** (m^3)	**Design** (m^3)	**Vessel Types**
SA Recycling	5	21,672	18,000	24,000	Bulk carriers
Cruise Terminal	1	1,800	1,500	2,400	Cruise ships

2.5.2 Ballast Water Conveyance

The 3.60 acre PoLB Navy Mole site was selected as the centralized location for study of an approach where ballast water would be collected and conveyed by carrier vessels to a new off-site treatment plant.

This alternative assumes that barges would collect ballast water from the LA and Long Beach facilities, moor adjacent to the Navy Mole facility, and discharge to a lift station located onshore.

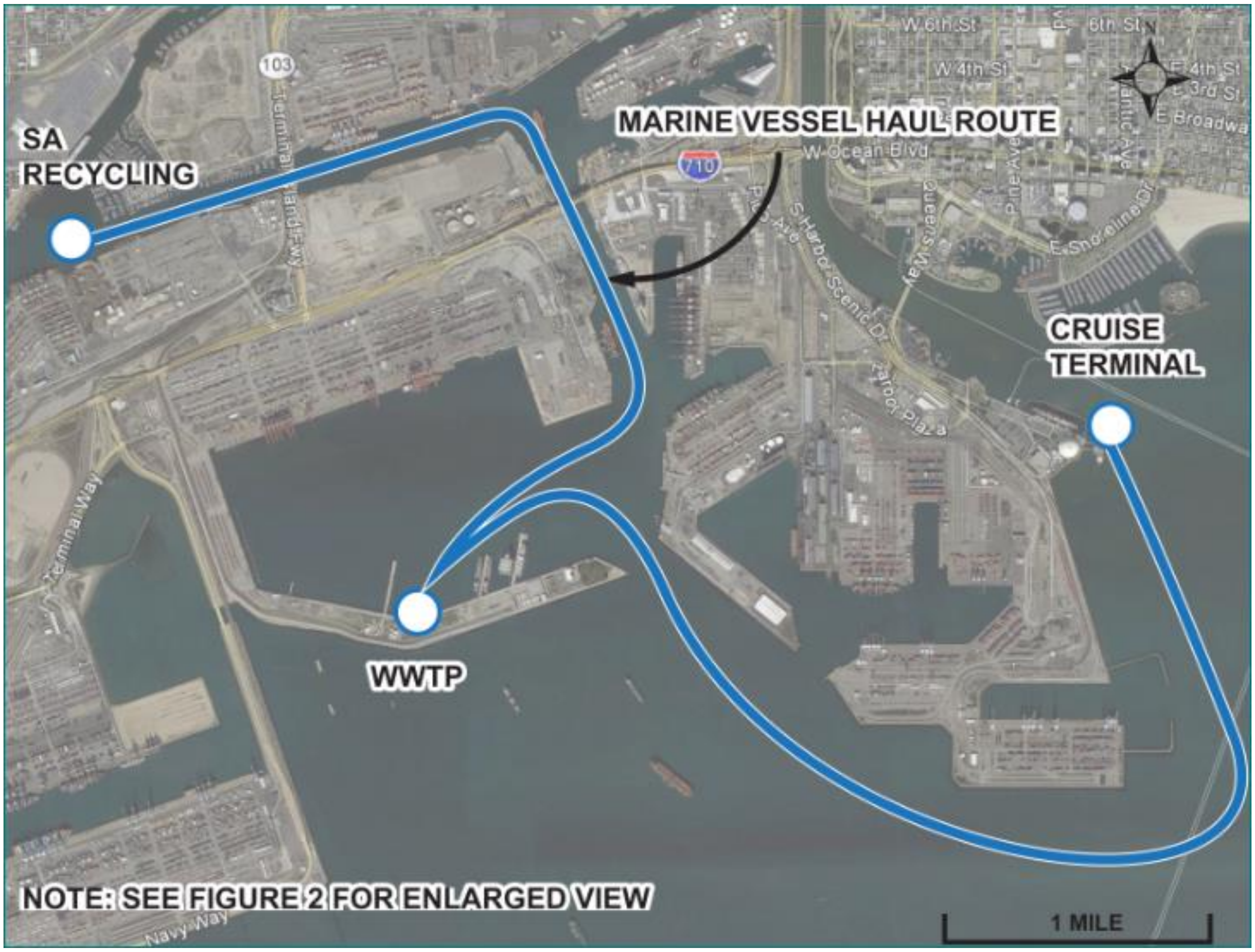


Figure 25 PoLA SA recycling & PoLB cruise terminal conveyance approach

2.5.3 Ballast Water Treatment

Ballast water will be conveyed via force main from the shoreside lift station to the onsite storage tank discharging via short force main to an upland storage and treatment location applying the same general approach as described or the Port of Oakland TraPac terminal. Treatment methodologies recommended in Task 5 (coagulation, flocculation, sedimentation, membrane filtration, and chlorine disinfection) would be employed to accommodate the flow and volume requirements identified in Table 16 as depicted below. Storage and treatment sizes and costs are listed in Table 17. Detailed calculations supporting facility equipment sizing and construction cost estimates are provided in Appendix B.

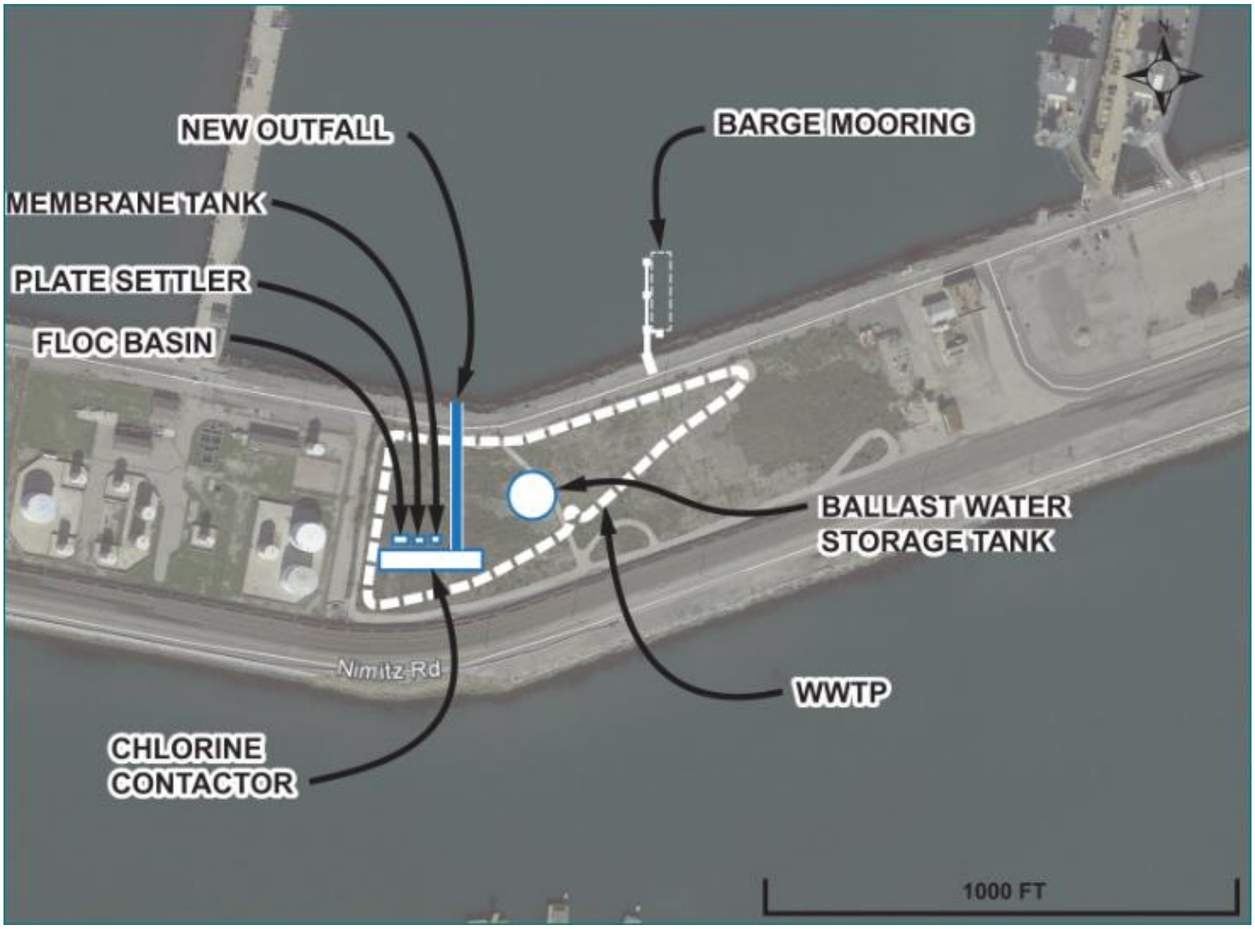


Figure 26 Port of LA, SA recycling & Port of LB cruise terminal storage, treatment, and disposal layout

Table 17 PoLA SA recycling/PoLB cruise terminal storage and treatment costs

Location	Details	Modification	Cost
PoLA – SA Recycling & PoLB Cruise Terminal		Treatment /Storage Equipment	$6,498,000
		Lift Station	$666,000
		Conveyance	$975,000
		Engineering (25%)	$2,035,000
		Contingency (25%)	$2,543,000
		Total	**$12,717,000**

Section 3 Further Considerations

These considerations consider the interactions between Tasks 2, 3, and 4. These are considered in the next series of Task Reports 6 through 13.

1. Costs for land acquisition, right-of-way, and the impacts due to the loss of leasable land necessary for storage and treatment are not included. Costs for O&M, depreciation, escalation, etc. are still under development and will be provided in the final Task 4 report.
2. Based on the infeasibility of using the SPOTW for ballast water treatment, conceptual costs have been developed for construction of a new WWTP which is considered to be a much more practical and cost effective approach. The Port owns land adjacent to the San Joaquin River where storage and treatment facilities could potentially be sited.
3. Outfall and receiving water evaluation.
4. Design, permitting, and construction schedules are currently under development based on the following general criteria common for similar shore based treatment projects:

Phase 1 - Preliminary Evaluation – Basis of Design	Date
Draft and Final Alternatives Evaluation	Year 01
Draft and Final Engineering Reporting for Authorizing Agencies	Year 01
Bench Scale and Pilot Testing	Year 01 – Year 02
Development of Basis of Design	Year 02

Phase 2 Preliminary Design – Final Design, Bidding	Date
Conceptual Design	Year 03
Complete 30% Design / Submit Long Lead Environmental Permit Applications	Year 03
Complete 60% Design	Year 03 – Year 04
Complete 90% Design / Submit Construction Permit Applications	Year 04
Complete 100% Design and Issue Design Documents for Bid	Year 04
Review Contractor Bids, Contractor Selection	Year 04

Phase 3 Permitting	Date
State Fish & Wildlife	Year 03 – Year 04
Federal US Army Corps of Engineers	Year 04 – Year 06
Local Shoreline Substantial Development	Year 06
Local Grading & Construction	Year 06
Local Building Department	Year 06

Phase 4 Construction	Date
Award Contractor	Year 06
Permits Acquired and Transferred to Contractor	Year 06
Begin Construction	Year 06
Substantial Construction Complete	Year 07
Final Construction/Project Closeout Complete	Year 08
Treatment System Commissioning/Startup	Year 08 – Year 09

Appendix A Study Overview and Definitions

This report is part of an overall coordinated study evaluating the feasibility of using shore-based mobile or permanent ballast water treatment facilities to meet the CA Interim Standards.

Study Overview

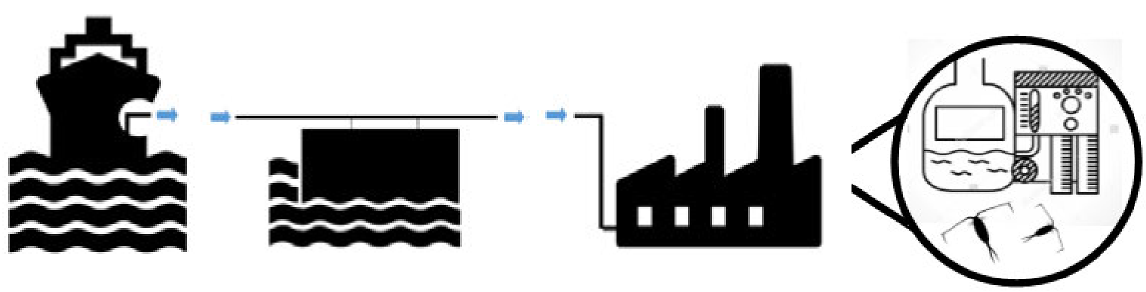
Marine vessels routinely uptake ambient sea or harbor water as ballast, transit to another port, and then discharge that ballast water. Unfortunately, the resulting ballast water discharges have been linked to the introduction of aquatic invasive species and harmful pathogens. In an effort to reduce or possibly eliminate further introductions, marine vessels are being required to manage ballast water discharges by a myriad of international, federal, and regional guidelines and rules. Vessels discharging in California will be required to meet an interim standard that is more stringent than international and U.S. federal standards.

In response, there has been significant development work and commercial installations of treatment systems located on board marine vessels themselves. However, there is a lack of data to determine if the treatment systems that are being installed on board marine vessels are capable of meeting the CA Interim Standards. Shore-based ballast water reception and treatment is under consideration as an approach to meet the CA Interim Standards.

This overall study evaluates the feasibility of such shore-based treatment systems in ten separate tasks, beginning with a review of shore-based treatment research and assessing potential all the way to cost estimates and an implementation timeline.

Tasks Overview

Tasks 2 through 5 are submitted together to discuss the practical necessities for shore-based treatment system implementation, from the modifications onboard vessels through to the treatment technologies used in the facilities (see Figure 27).



Task 2	Task 3	Task 4	Task 5
Vessel Outfitting	Port Retrofitting	Shore Facilities	Treatment Technologies

Figure 27 Scope of Tasks 2 through 5

Task 2 of the larger study assesses the retrofitting and outfitting of marine vessels calling California ports. This report considers the feasibility and required modifications so that vessels can pump ballast water out of the ship to a new exterior piping manifold where shore facilities can receive and process the ballast water in accordance with California requirements.

Task 3 of the larger study discusses retrofitting of ports and wharves to receive ballast water from the vessels that need to transfer to on-site reception and treatment facilities, minimizing the disruption of normal port and vessel operations.

This Task 4 report assesses the needed shore facilities to transfer, store and treat the ballast water once it leaves the marine vessel, determining the most cost-effective approach to meet performance standards and capacity requirements.

Task 5 of the larger study assesses applicable types of treatment technologies available for shore-based reception facilities that show promise in the ability to meet the CA Interim Standards and how the efficacy of such systems can be measured.

Case Studies Overview

The overall study uses location-specific case studies to cover the range of ports and terminals within California. A case study approach allowed the study team to develop a specific solution for each case, based on actual berth locations, estimated piping distances, specific water transfer rates and volumes, and applicable regulations, among other tangible aspects. After examining these cases, the estimated costs, timelines, and considerations discovered in the case study process will be scaled up to inform stakeholders and policymakers about statewide implementation.

Collectively, the five selected port districts constitute a rough cross-section of commercial shipping activity in California. The case studies were structured to ensure that a range of feasibility challenges are considered, including: vessel types; ballast water reception and conveyance; and ballast water storage and treatment approaches. For each case study, actual vessels and feasible methods of ballast water conveyance were combined with the three storage approaches and five treatment approaches that the study was required to asses. These approaches were assigned according to what approach promised to be feasible for each case study port. Table 18 summarizes the case studies and assigned approaches.

Table 18 Summary of case studies

Case Study	Port/Terminal	Vessel Type	Conveyance Approach	Storage Approach	Treatment Approach
1	Port of Stockton/East Complex	Bulk Carriers	Rail & Pipeline	New onsite tank	Existing WWTP[1]
2	Port of Oakland/TraPac Terminal	Containerships	New pipeline	New onsite tank	New onsite WWTP
3	Port of Hueneme/South Terminal Wharf 1	Automobile Carriers	Onsite storage	New onsite tank	Mobile shore-based treatment
4	El Segundo Marine Terminal	Tank Ships; ATBs	Offload to mobile marine vessel	Mobile marine vessel	Mobile, marine vessel-based treatment
5	Port of Long Beach/Cruise Terminal, Los Angeles/SA Recycling	Bulk Carriers & Passenger Cruise Ships	Offload to mobile marine vessel	New offsite tank	New offsite WWTP

Definitions

ABS	American Bureau of Shipping
ANSI	American National Standards Institute
ASTM	An international standards organization.
ATB	Articulated Tug Barge
AWL	Height Above Waterline
AWWA	American Water Works Association
Ballast Water	Water taken on by a ship to maintain stability in transit.
Ballast Water Exchange	The process of exchanging a vessel's coastal ballast water with mid-ocean water to reduce concentration of non-native species in accordance with regulatory guidelines.
Ballast Water Management	The entire process of treatment and handling of a ship's ballast water to meet regulatory requirements and prevent spread of non-native species.
BMPF	Ballast Manifold Presentation Flange
Booster Pump	Pump, typically centrifugal, that adds additional pumping force to a line that is already being pumped.
BWDS	Ballast Water Discharge Standards
BWE	Ballast Water Exchange
BWM	Ballast Water Management
BWMS	Ballast Water Management System
BWTP	Ballast Water Treatment Plant
BWTB, BWT Barge	Ballast Water Treatment Barge
BWTS	Ballast Water Treatment System
Capture	Capture is the method by which ballast water is transferred onto or off a marine vessel.
CD	Chart Datum
CFU	Colony Forming Units
CMSA	California Marine Sanitation Agency
DAF	Dissolved Air Floatation
DIN	Deutches Institut für Normung (German Institute for Standardization)
Discharge	Discharge of ballast water is the method by which post-treatment ballast water is disposed of in compliance with applicable standards and regulations.
DOC	Dissolved Organic Carbon
DWT	Deadweight Tonnage
EPA	Environmental Protection Agency (US, unless otherwise noted)
Filtrate	Water that has been separated from any particulate matter (used to clean ballast water treatment filters).

GA	General Arrangement
GM	Metacentric height (a measure of a ship's stability).
gpm	Gallons per minute. Any measurements quoted in gallons of ballast water per minute will also be shown in MT of ballast water per hour, or MT/h.
HDPE	High-density Polyethylene
IMO	International Maritime Organization
ISO	International Organization for Standardization
JIS	Japanese Industrial Standards (organization)
L	Liter
Lift Station	Means of receiving a liquid, typically from a drain or low-pressure piping, and 'lifting' it with pump(s) to a different location such as a remote tank.
Lightering	Cargo transfer between vessels, commonly practiced to reduce a vessel's draft before entering port.
LT2ESWTR	Long Term 2 Enhanced Surface Water Treatment Rule
MARPOL	International Convention for the Prevention of Pollution from Ships
MF	Microfiltration
mg	Milligram
MG	Millions of gallons. Any measurements quoted in MG of ballast water will also be shown in MT of ballast water.
MGD	Millions of Gallons/Day
MHHW	Mean Higher High Water
MLLW	Mean Lower Low Water
MPA	Megapascal (unit of pressure)
MSL	Mean Sea Level
MT	Metric tons. One cubic meter of seawater is roughly equivalent to 1.025 MT, but this value varies depending on temperature and salinity of the water. In this report, conversions between volume and weight of seawater are merely approximate and assume 1 m3 of seawater has a mass of roughly 1 MT, for convenience.
Navy Mole	A man-made peninsula in the Port of Long Beach that flanks entrance to the middle and inner harbor
NBIC	National Ballast Information Clearinghouse
NOM	Natural Organic Matter
Non-native Species	Species that are not indigenous to a particular region. Non-native species can be introduced to marine ecosystems through a ship's ballast water. "Invasive" species are non-native species with the potential to cause harm to the environment or human health.
NPDES	National Pollution Discharge Elimination System
NTU	Nephelometric Turbidity Unit

NYSERDA	New York State Energy Research and Development Authority
O&M	Operations and Maintenance (cost)
OCIMF	Oil Companies International Marine Forum
POTW	Publicly Owned [Wastewater] Treatment Works
PSU	Practical salinity units.
Residuals	Particulate matter collected from cleaning ballast water treatment filters.
ROM	Rough Order of Magnitude (cost)
Ro-ro	Roll-on/roll-off (vessels designed to carry wheeled cargo such as car, trucks, trailers, and equipment)
RWCF	Regional Wastewater Control Facility (e.g. City of Stockton, CA)
Shipboard Ballast Water Treatment	Ballast water management approaches that do not require support from shore-based infrastructure and are conducted entirely by a vessel's crew.
Shore-Based Ballast Water Management	Ballast water management approaches that require support from shore-based infrastructure in order to meet ballast water management requirements. Such infrastructure may include: means of transferring ballast water to a land-based or another marine vessel facility for storage and/or processing, deployment of shore-based equipment and personnel for onboard treatment approaches, etc.
Slurry	Mixture of filtrate and filter residuals resulting from cleaning ballast water treatment filters.
Slurry Handling	Slurry handling includes activities related to the storage, treatment, and discharge of filtrate and residuals collected from cleaning ballast water treatment filters.
SOLAS	International Convention for Safety of Life at Sea
Storage	Storage of ballast water includes provision of space and containment for ballast water, either pre-or post-treatment.
STS	Ship-to-Ship. Transfer from one marine vessel to another.
TDS	Total Dissolved Solids
TEU	Twenty-foot Equivalent Unit
TOC	Total Organic Carbon
Transfer	Ballast water transfer considers the logistics and equipment required to capture the ballast water from the marine vessel and transport to a reception and treatment facility.
Transport	Transport is the method by which ballast water is moved post-capture from marine vessels to remote, non-mobile reception and treatment facilities – either land-based or otherwise.
Treatment	Treatment includes the various methods to process ballast water such that it is suitable for discharge in compliance with applicable standards and regulations.

Treatment Approach	A general method for implementing ballast water treatment. Treatment approaches may include mobile systems, land-based facilities, shipboard systems, etc.
Treatment Technology	Specific techniques for removal or inactivation of organisms in ballast water (e.g., UV disinfection, filtration, ozonation, etc.)
TRO	Total Residual Oxidant
TSS	Total Suspended Solids
UF	Ultrafiltration
UKC	Underkeel Clearance
UL	A global independent safety consulting and certification company (formerly Underwriters Laboratories).
USCG	United States Coast Guard
UV	Ultraviolet Light
UVT	UV Transmittance
VLCC	Very Large Crude Carrier
WWTF	Waste Water Treatment Facility
WWTP	Waste Water Treatment Plant

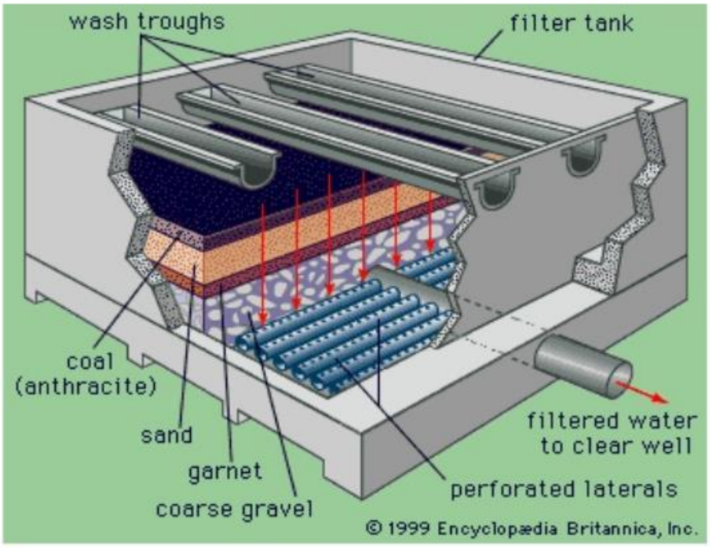
Appendix B Water Treatment Unit Process Examples

Coagulation/Flocculation/Sedimentation

Combined Flocculation and Plate Settler

Plate Settlers

Multi-Media Filtration



Fixed Shore Based Submerged UF Membrane Filtration (Not for Trucks)

Truck and Barge Based UF Membrane Filtration Pressure Vessels

UV System for Truck and Barge Based Disinfection

Fixed Shore Based Chlorine Disinfection Contact Basin