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WEST BASIN MUNICIPAL WATER DISTRICT

OCEAN WATER DESALINATION DISCHARGE FEASIBILITY STUDY

FINAL
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OCEAN WATER DESALINATION DISCHARGE FEASIBILITY STUDY

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1.0 INTRODUCTION

The purpose of this study is to evaluate commingling high salinity brine from the proposed West Basin Ocean Water Desalination Facility (OWDF) with treated secondary effluent from the Hyperion Water Reclamation Plant (HWRP). The feasibility evaluation analyzes five areas of technical feasibility, described in detail in subsequent sections. Results from the evaluation are used to develop discharge alternatives, which are then subjected to an initial screening analysis. Any alternatives surviving the screening analysis are further analyzed for non-technical considerations, including social, environmental, and economic factors.

The approach that was used to complete the study is shown in Figure 1.

The *Ocean Water Desalination Program Master Plan* (PMP) provides conceptual design for the OWDF and helps define key project components for seawater desalination, including concentrate (brine) discharge location and setting.[1] The PMP considered four different brine discharge alternatives, as follows:

1. Utilizing the existing El Segundo Generating Station (ESGS) Unit 3 or 4 discharge tunnel.
2. Discharge to the HWRP outfall (commingled with effluent).
3. Construct a new tunnel that would house both intake and discharge pipelines.
4. Construct a new discharge pipeline using Horizontal Directional Drilling (HDD).

The focus of this study is to evaluate the feasibility of the second alternative, commingling brine with HWRP effluent and discharging through the existing HWRP outfall system.

1.1 Study Location

The HWRP is located in southwest Los Angeles, next to the Dockweiler State Beach on the Santa Monica Bay. The ESGS (location of proposed OWDF as discussed in the next section) is a natural gas fired electrical power plant located in the southernmost limit of El Segundo approximately 2 miles south of HWRP. Locations of both facilities are shown in Figure 2.

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[1] Arcadis, Ocean Water Desalination Program Master Plan (PMP), January 2013.

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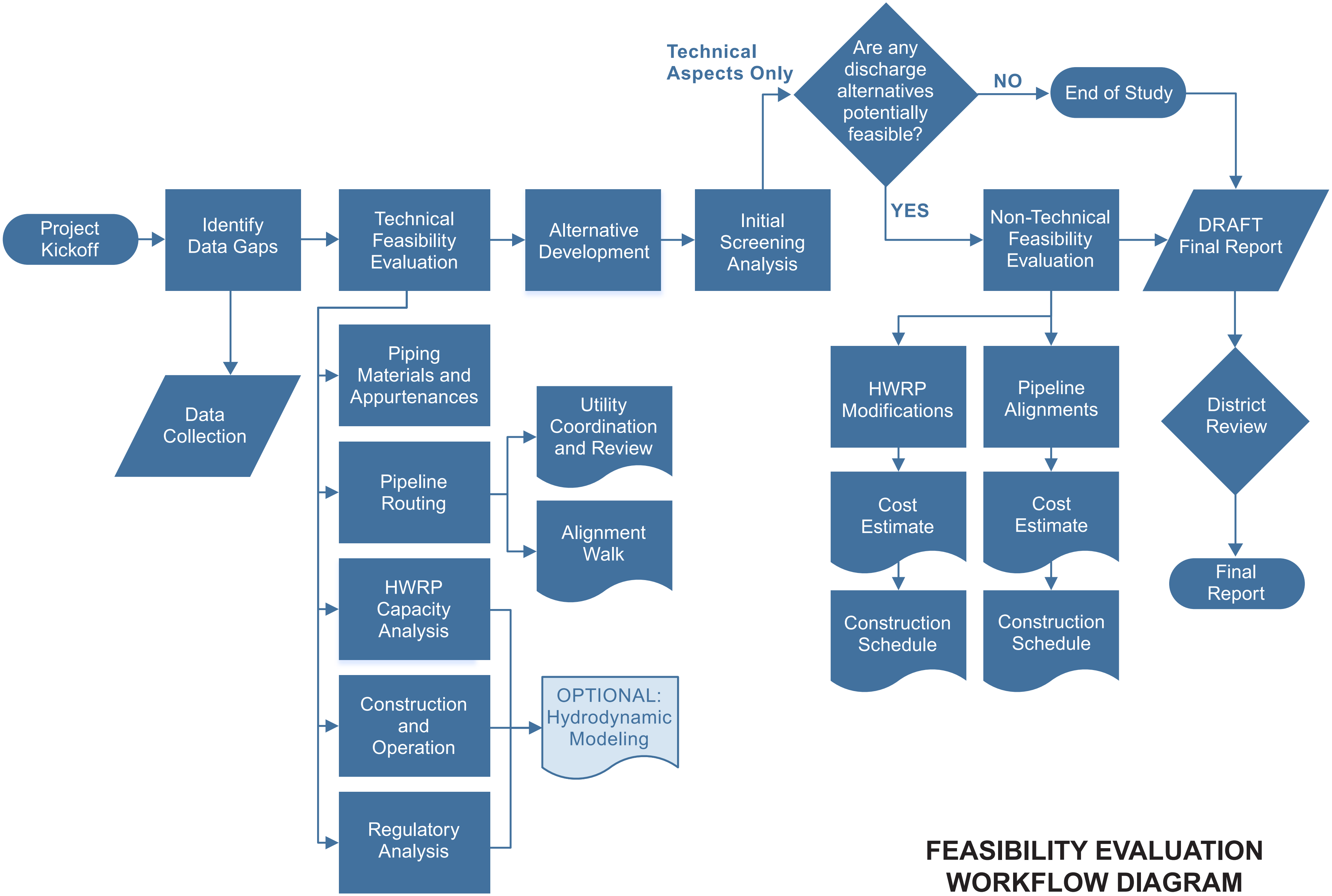

FEASIBILITY EVALUATION WORKFLOW DIAGRAM

FIGURE 1

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HWRP AND ESGS LOCATIONS

FIGURE 2

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The study location encompasses the entire area from the northern ESGS property line to the HWRP, as shown in Figure 3.

2.0 BACKGROUND

Water conservation in California has become increasingly important with the occurrence of two sustained and severe droughts within the last decade. To provide a more reliable and diversified water portfolio, West Basin Municipal Water District (West Basin) is proposing the Ocean Water Desalination Program, which includes the construction of the new OWDF at the existing ESGS to provide a safe and reliable potable water supply source. As mentioned previously, the program is the subject of the *Ocean Water Desalination PMP*; refer to this document for additional information.[1]

2.1 Ocean Water Desalination Facility

The proposed OWDF incorporates seawater reverse osmosis (RO) as the major process to desalinate the source ocean water. The project has been split into two phases, initial and build-out. The 20 million gallons per day (mgd) initial OWDF project would be located within the ESGS property boundaries, as shown in Figure 4. Future expansion would increase the capacity of the facility to 60 mgd. Based upon anticipated recovery of the seawater RO process, the brine discharge is 20.9 mgd with a salinity of 68 parts per thousand (ppt) for the 20 mgd facility. Future expansion to the 60 mgd facility would increase brine discharge 62.7 mgd at the same salinity.

2.2 Hyperion Water Reclamation Plant

HWRP is a high purity oxygen activated sludge plant that processes an average of 275 mgd of wastewater on a dry weather day; however, during wet weather flows, the plant can handle a maximum daily flow 450 mgd and a peak daily flow of 850 mgd. HWRP has the capability to discharge secondary effluent to the ocean through:

- A one-mile outfall (Emergency Use Only).
- A five-mile outfall (Routine Operations).

Under current routine operations, secondary effluent is gravity fed to HWRP's five-mile outfall and discharged to the ocean. In certain scenarios of flow and sea level, the effluent must be pumped through the five-mile outfall. Under current operational strategies, the effluent pump station is required when flows reach 320 mgd, and also when head in the secondary effluent pump station wetwell reaches 22.5 feet. Typically, only under emergency circumstances, such as extremely high flows, power failures, storm conditions, or testing of emergency bypass gates, HWRP discharges chlorinated secondary effluent via the one-mile outfall.

STUDY AREA

FIGURE 3

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OWDF PROJECT LOCATION MAP

FIGURE 4

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Consistent with goals of this study, it was necessary to perform a capacity analysis on the existing HWRP outfalls to assess feasibility of commingling OWDF brine with HWRP effluent and discharging through the existing HWRP outfall system.

2.2.1 HWRP Capacity Analysis

The HWRP is one of the largest wastewater treatment plants in the world with a design capacity of 450 mgd and a peak wet weather flow of 850 mgd. The ability of the outfall to operate effectively and safely under all flow conditions is crucial for determining the feasibility of commingling brine with the HWRP secondary effluent.

2.2.1.1 Current Outfall Capacity

Both the five-mile and one-mile outfalls are 12-foot in diameter and are utilized independently. Figure 5 represents the increase in velocity in the current 12-foot diameter outfall piping due to the proposed brine flows of 20.9 mgd and 62.7 mgd. Five years of historical daily flow data measured at the five-mile outfall was used to determine these velocities.

In the figure, the current highest secondary effluent flow is considered in conjunction with the highest possible brine flow to analyze the impact of the additional flow volume. Therefore, when HWRP is experiencing an average daily flow of 435.22 mgd, the addition of 62.7 mgd of brine will increase the velocity in the outfall by approximately 0.36 fps. This slight increase is negligible and is not likely to cause substantial impacts to the functionality of the outfall.

Ultimately, sufficiency of the HWRP outfall capacity is dependent on the wet weather peak instantaneous flow (PIF) of 850 mgd. Under these conditions, which could happen only during a very significant storm event, greater than 100-year flood[2], the velocity in the outfall piping is approximately 12 fps. Although that velocity is high, it would be acceptable for an intermittent occurrence. Additionally, it's possible that during such an event HWRP could send a portion of the flow to the one-mile outfall. One-mile outfall has peak capacity of 600 mgd. During very significant storm events, if needed, OWDF brine flow could be sent to one-mile outfall if 850 mgd capacity of five-mile outfall is being utilized for very significant storm event. Since 2010 the maximum flow experienced at HWRP has been about 440 mgd, refer to Figure 6 for additional information.

For these reasons the current HWRP outfall capacity is considered sufficient to accept brine flows from the proposed ODWF.

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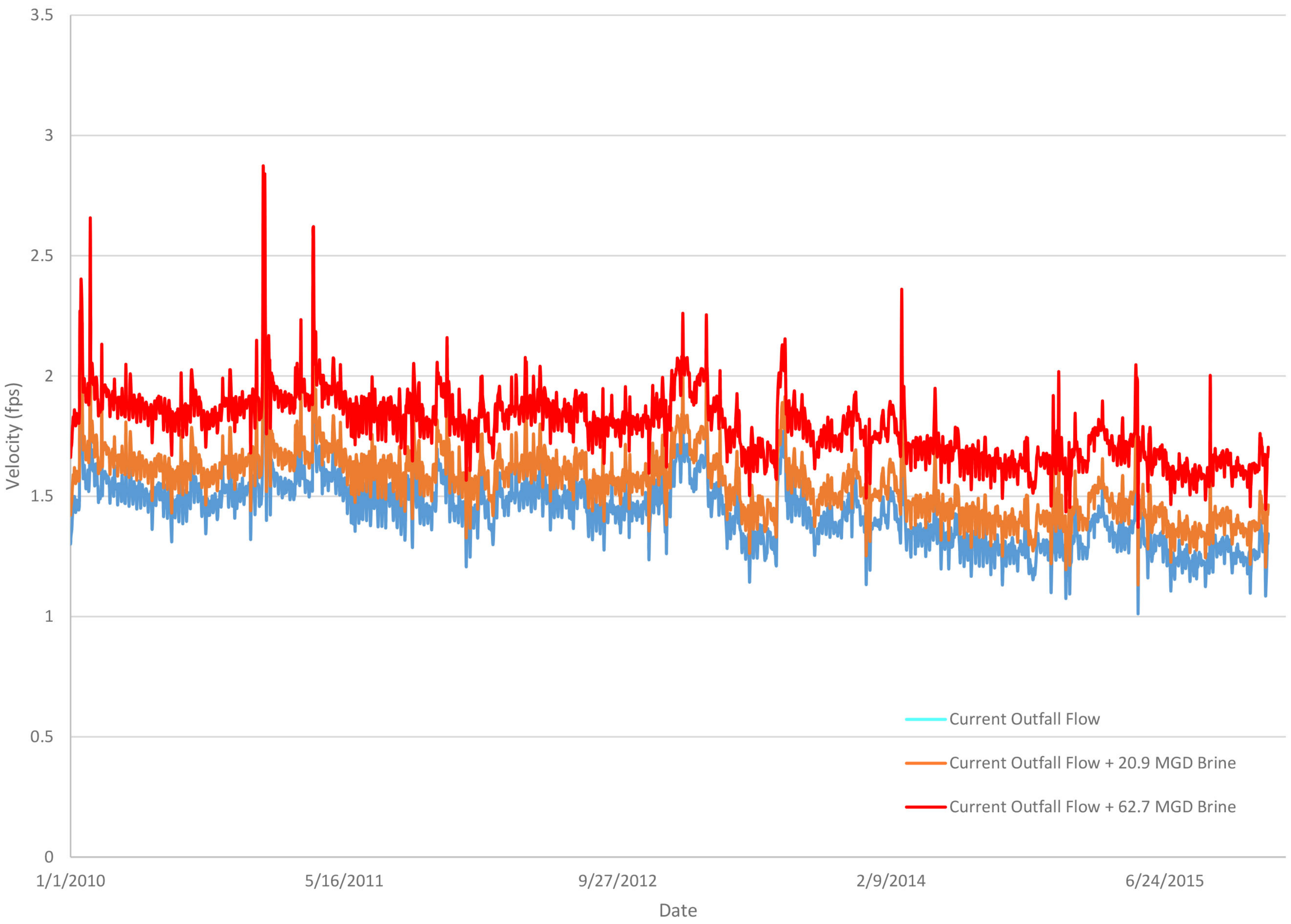
[2] A 100-year flood is a design condition used to describe a flood event with an annual exceedance probability of 1 percent. By definition, in any given year, this flood event has a probability of occurrence of 1 percent.



OUTFALL VELOCITIES

FIGURE 5

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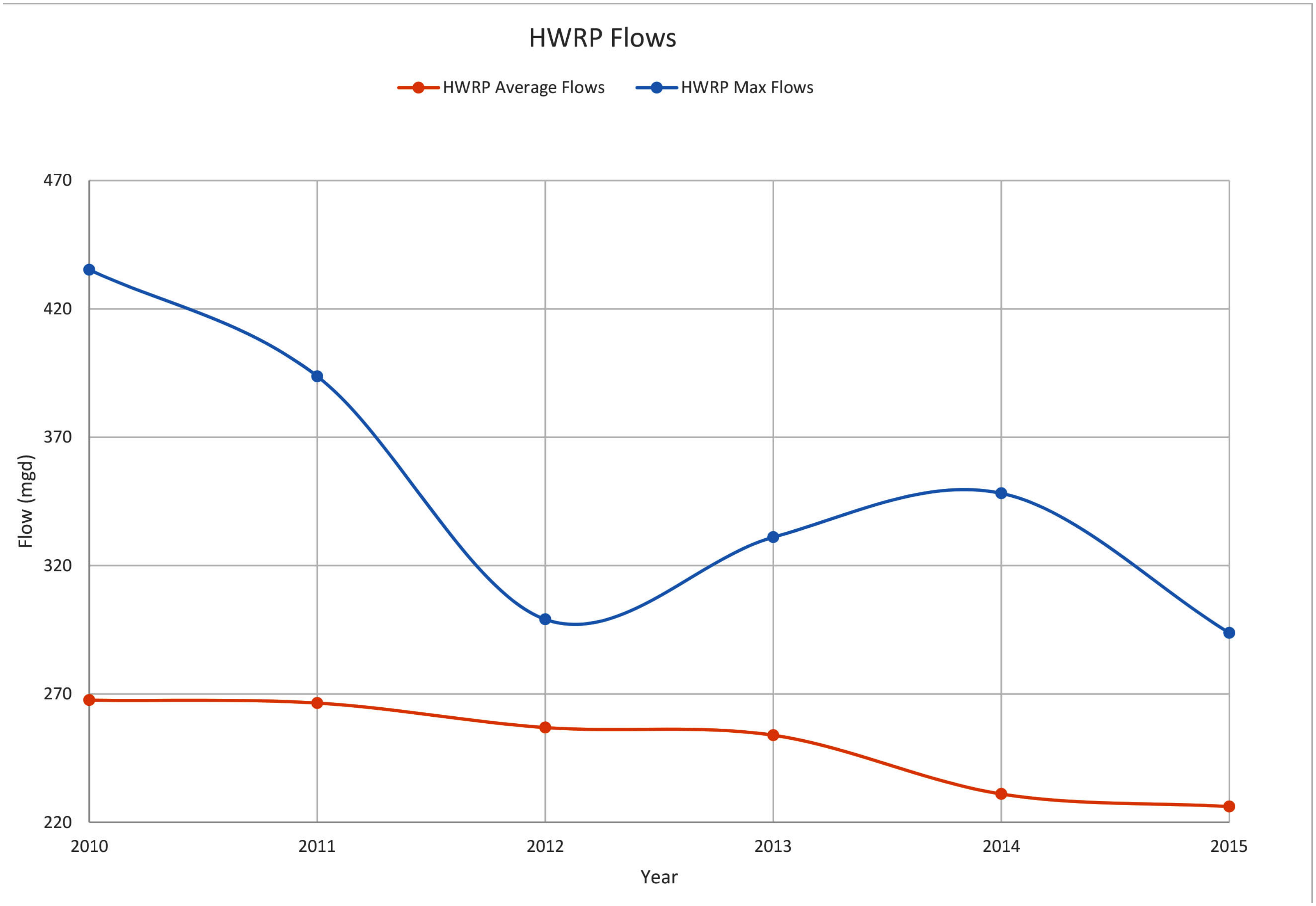

HWRP AVERAGE AND MAXIMUM DAILY FLOWS

FIGURE 6

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2.2.1.2 Future Outfall Flows

The trend of water conservation and recycling in California is resulting in a clear reduction of secondary effluent flows at HWRP, per the data of the average and maximum daily flows shown Figure 6. This figure presents a clear reduction in recent years of the average flows at the HWRP. It is likely that these trends will continue as initiatives to grow these efforts increase. In fact, current preliminary planning efforts are considering using all HWRP low flow for reuse purposes. Current HWRP low flow is about 90 mgd as shown in Figure 7 below. Of this 90 mgd, 20 mgd is planned for onsite reuse purposes using tertiary filtration, 30 mgd is planned of offsite reuse purposes using advanced treatment including RO, and 40 mgd is planned for offsite reuse purposes for the West Basin Municipal Water District using membrane bioreactor (MBR) process. The combination of these future reuse flows are expected to produce 10 mgd of brackish brine to be discharged to the ocean via HWRP's existing outfall systems. This 10 mgd brackish brine flow represents potential future HWRP outfall flow during low flow conditions as all other secondary effluent may be repurposed as described above.

Based on current plans for future water recycling expansion at HWRP, there is potential for 10 mgd of brackish water brine to be discharged to the outfall, which would increase the salinity concentration of the commingled plume.[3] However, based on the steady decline of flows to the HWRP due to water conservation and recycling, it is projected that the available capacity of the outfall will continue to increase, even with the addition of possible future recycle flows described above. However, impacts to the water quality of the commingled plume will result as the secondary effluent flows decrease over time (i.e., density increase of the resulting plume). These impacts can be predicted using hydrodynamic modeling, which is the subject of future sections.

2.2.2 Existing HWRP Infrastructure

The following subsections evaluate existing infrastructure at the HWRP and their ability to accept seawater desalination brine from the proposed OWDF.

2.2.2.1 Existing Outfall Diffuser System

Typically, diffuser systems in outfall systems are specifically designed to provide adequate mixing for specific types of plumes (i.e., buoyant or dense). The current secondary effluent discharged from the HWRP to the existing outfalls is a buoyant plume. However, the additional salinity from the ODWF brine will impact the density of the commingled discharge plume. Because the brine from seawater desalination processes at the OWDF is a dense plume (i.e., higher density than surrounding seawater to be discharged in), plume density will increase. Hydrodynamic modeling is used to evaluate the efficient of mixing at the existing diffuser system at the HWRP with discharge including the additional 20.9 or

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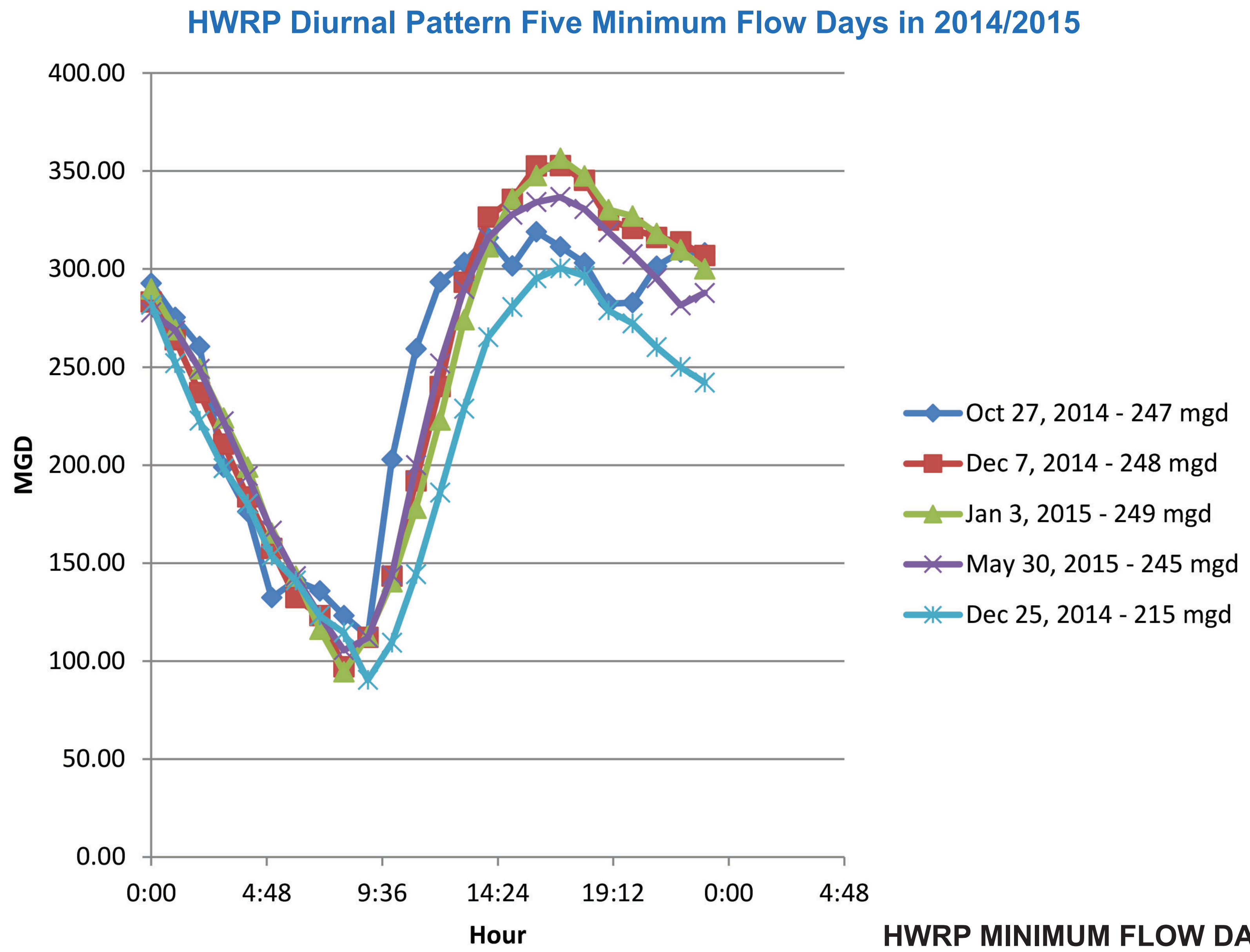
[3] Density of concentrate from reverse osmosis (RO) processes used for water recycling is higher than secondary effluent.



HWRP MINIMUM FLOW DAYS

FIGURE 7

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62.7 mgd of seawater desalination brine. This will be discussed in further detail in the Hydrodynamic modeling section of this study.

There are a total of six diffuser ports located in the one-mile outfall. Each 100-foot length of discharge section, which is defined as the final 300-feet of the outfall, includes two identical ports. The ports are centered in each 100-foot length of the discharge section and located in the lower half of the piping with one on each side of the outfall. Each port measures 3-feet 4-inches long by 1-foot 6-inches high.

The five mile outfall has two diffuser legs that wye off of the main 12-foot diameter outfall pipe, each diffuser leg is approximately 3,800 feet long with 85 ports per leg with each port measuring 7.26 in. in diameter.

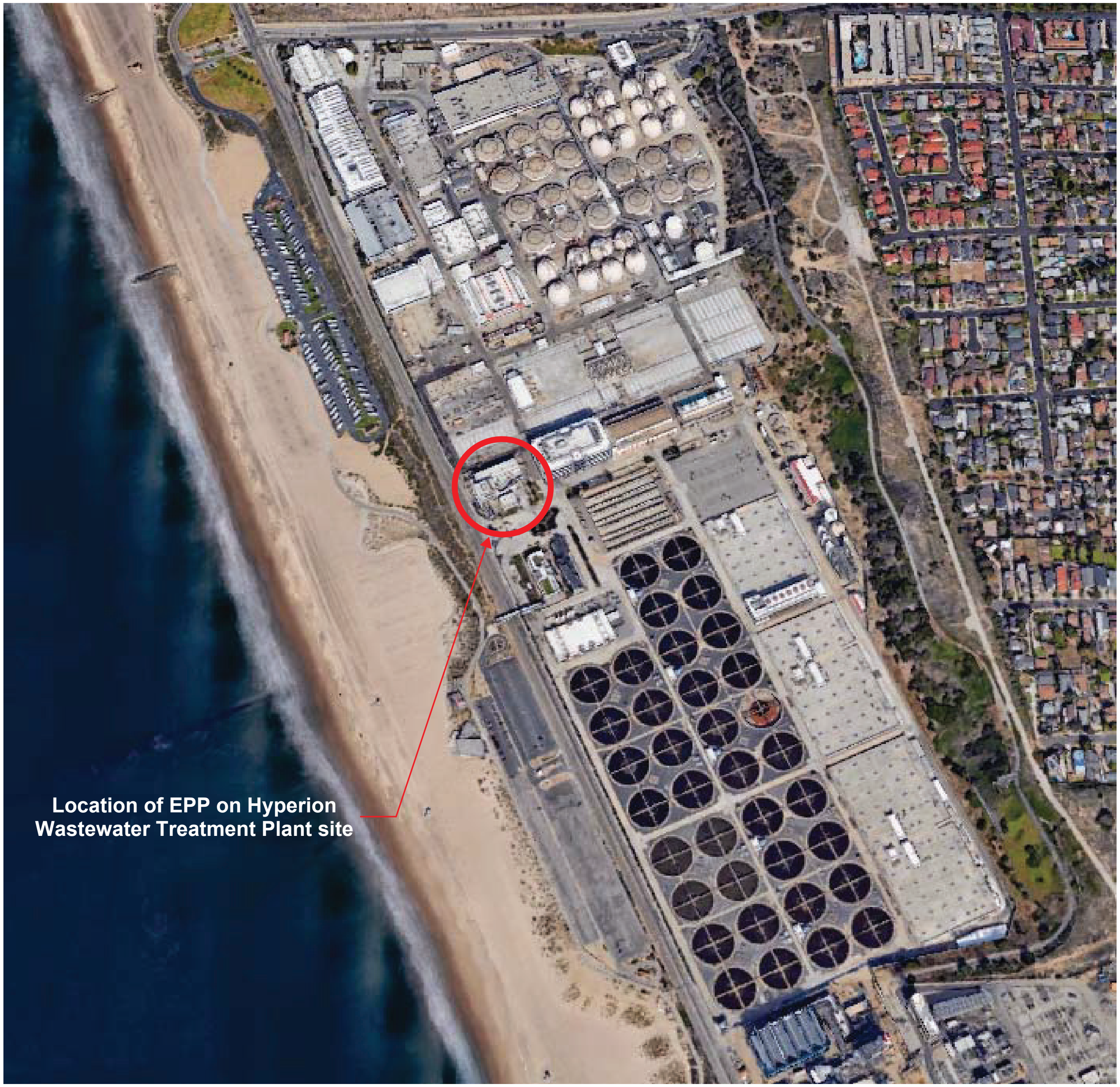
2.2.2.2 HWRP Connection Locations

Commingling HWRP secondary effluent with the OWDF brine requires existing facilities and/or discharge elements at HWRP to be modified to provide a location for joining the flows. Connection locations at HWRP were selected based on the following criteria:

- Minimal disturbances to unrelated facilities.
- No disruption to existing HWRP treatment processes/does not produce process upsets.
- Access to either the one mile, five mile, or both outfalls.
- Sufficient mixing residence time prior to discharge into ocean.

The HWRP secondary effluent is combined at the Effluent Pumping Plant (EPP), as shown in Figure 8. The majority of the connection locations that comply with the above selection criteria are located in or around the EPP as shown in Figure 9. The following connection point locations were defined and evaluated for their feasibility:

- EPP wetwell.
- Effluent junction box.
- Gravity line valve structure.
- EPP discharge piping cleanout.
- Five-mile outfall.
- One-mile outfall.
- Five-mile and one-mile outfalls (i.e., connect to both locations directly to provide operational flexibility).



EFFLUENT PUMPING PLANT LOCATION

FIGURE 8

OVERVIEW OF POTENTIAL CONNECTION LOCATIONS

FIGURE 9

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Technical considerations for commingling the constant brine flow from the RO process at the OWDF with the diurnal and seasonal fluctuation of HWRP secondary effluent flows are presented in the following sections during the technical feasibility evaluation. Major assessment areas include the evaluation of the following infrastructure:

- Pipeline from proposed OWDF to connection locations.
- Connection location.
- Existing outfall and appurtenances.

3.0 TECHNICAL FEASIBILITY EVALUATION

The feasibility evaluation analyzes five areas of technical feasibility selected to consider the range of criteria that are used to develop discharge alternatives, as follows:

1. HWRP connection locations.
2. Piping materials and appurtenances.
3. Pipeline routing.
4. Construction and operation.
5. Regulatory analysis.

These areas are further discussed in the following subsections.

3.1 HWRP Connection Locations

Options for each connection point location are discussed further in the following subsections and are defined as follows:

- Option 1: EPP Wetwell.
- Option 2: Effluent Junction Box.
- Option 3: Gravity Line Valve Structure.
- Option 4: EPP Discharge Piping Cleanout.
- Option 5: One-Mile Outfall:
  - Option 5a: Existing Manhole.
  - Option 5b: New Manhole.
  - Option 5c: Core Drill.

- Option 6: Five-Mile Outfall:
  - Option 6a: Existing Manhole.
  - Option 6b: New Manhole.
  - Option 6c: Core Drill.
- Option 7: Combined Outfalls (i.e., any combination of Options 6 and 7).

3.1.1 Option 1: EPP Wetwell

The majority of the secondary effluent at HWRP is collected in a 0.35 million gallon (MG) wetwell located at the EPP. The EPP consists of five large, 2,500 horsepower, dry-pit, centrifugal pumps, which are used in situations where the secondary effluent must be pumped to be discharged through the outfall (i.e., gravity discharge is insufficient). However, under normal operation, the secondary effluent flows by gravity out of the wetwell, through a gravity line valve structure, and discharges to the ocean via the five-mile outfall and corresponding diffuser system.

A schematic of the connection location at the EPP Wetwell is located in Figure 10. The north wall of the wetwell is approximately 125-feet long and 14-feet tall and does not contain any large obstructions or penetrations on either the interior or exterior. Connecting into the EPP wetwell provides access to the five-mile outfall during both pumped and gravity conditions.

Table 1 presents the design criteria of the existing effluent pumps. A review of the design criteria indicates the maximum pumping capacity with all pumps in service is 900 mgd (720 mgd with one standby pump assumed). After performing the capacity analysis of the outfall (subject of Section 2.2.1), it was determined that the effluent pumps have sufficient capacity to accept additional flows from the OWDF brine. However, the materials of construction of these existing pumps may not be compatible with corrosive nature of such flows, as discussed below.

Table 1 Existing Effluent Pumps Design Criteria
Ocean Water Desalination Discharge Feasibility Study
West Basin Municipal Water District

Description	Units	Criteria
Number of Pumps(1)	No.	5
Flow, each pump	mgd	180
Head	feet	64
Motor Size	horsepower	2,500

Notes:
(1) Total number of pumps (i.e., does not include a redundant pump)

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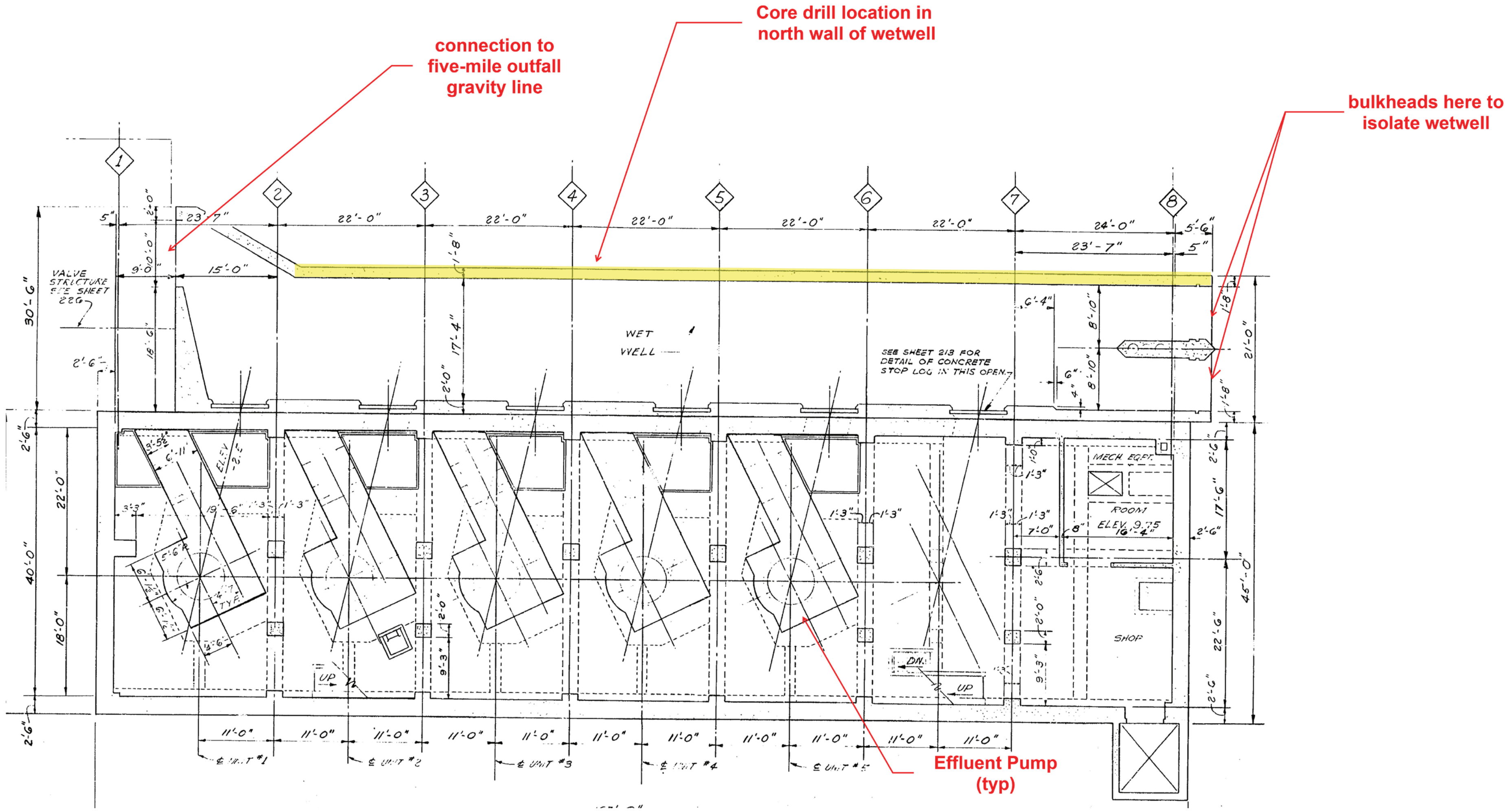

EPP WETWELL CONNECTION ALTERNATIVE

FIGURE 10

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Because of the corrosion potential of high salinity brine, modifications to the pump materials, piping materials, and ancillary equipment will likely be required to avoid corrosion of the existing pumps. Table 2 describes the existing materials within the pump station, and their compatibility with brine service.

Table 2 EPP Existing Materials and Brine Compatibility
Ocean Water Desalination Discharge Feasibility Study
West Basin Municipal Water District

Description	Existing Material	Compatible with Brine?
Effluent Pumps		
Pump Body	NA(1)	No(2)
Impeller	NA(1)	No(2)
Discharge Piping		
Suction	Unlined Welded Steel	No(2)(3)
Discharge	Unlined Welded Steel	No(2)(3)
Wetwell		
Interior	Concrete	No(4)

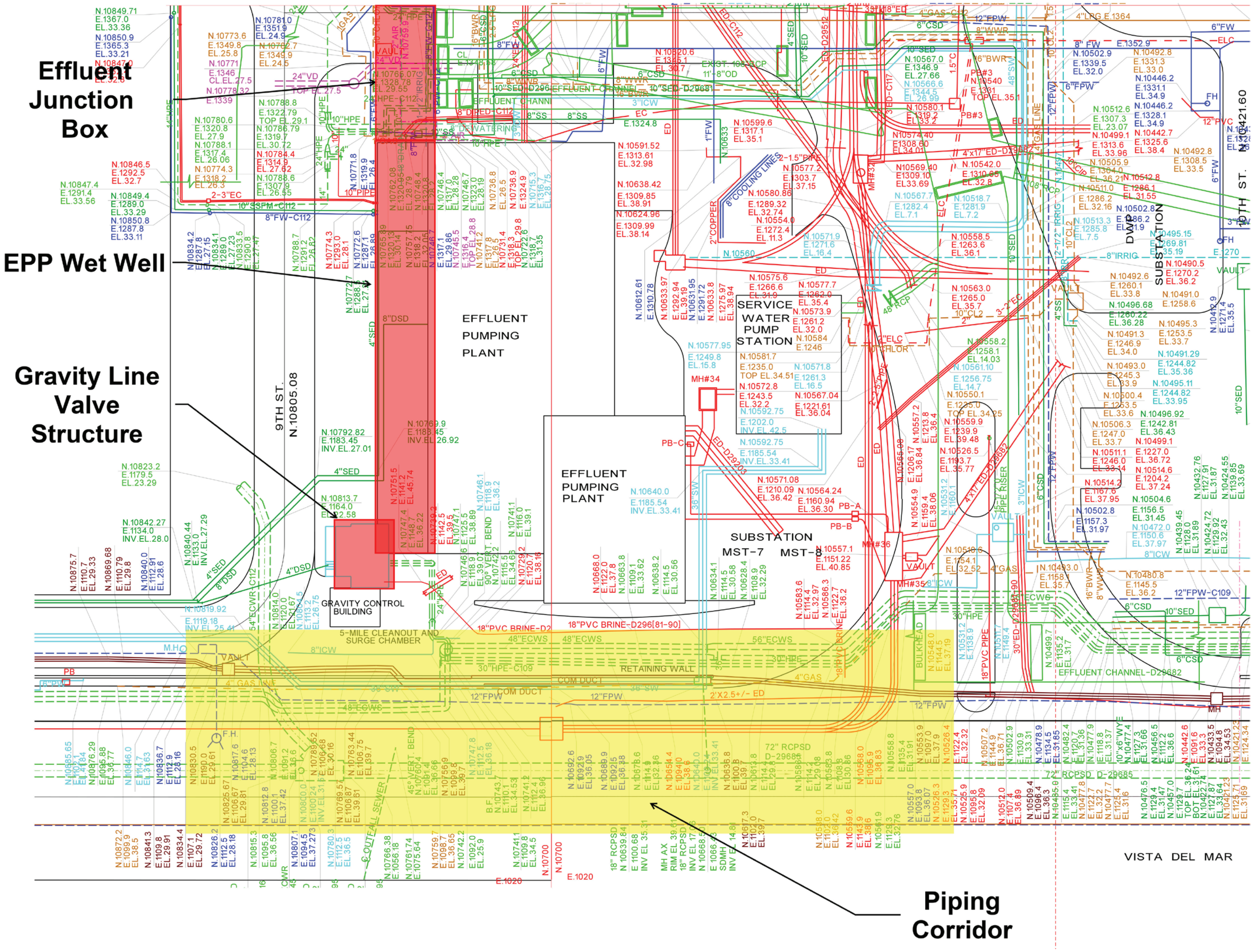
Notes:

(1) Not available at time of this draft.
(2) Cast iron, steel, or conventional 316 stainless steel will require cathodic protection to prevent corrosion. Alternatively, a high grade super duplex or other marine grade metal could be used, but at higher cost.
(3) FRP can be used in applications because pump discharge pressure requirements are low per Table 1.
(4) Lined concrete recommended for brine services.

Additionally, connecting to the EPP wetwell would require bypass pumping and/or a temporary shutdown of the EPP and five-mile outfall. Magnitude and duration of the shutdown is dependent on the construction method selected.

A crowded piping corridor located underneath the east side of Vista Del Mar Boulevard presents a challenge for routing the brine pipe to the EPP; however, with careful coordination and unconventional construction methods it is possible to cross the piping corridor. Figure 11 shows the extent of piping in the corridor.

Further exploration of the piping corridor is required to determine the best practice for navigating the large diameter brine pipe across, however, it is likely that an advanced technique, such as conventional tunneling will be required. Figure 12 shows the general extent and location for the excavation of the asphalt area located on the north side of the EPP for placement of the new brine pipeline. This excavation will then require the appropriate bedding, fill, and new asphalt surface upon completion of construction.



YARD PIPING CORRIDOR LAYOUT

FIGURE 11

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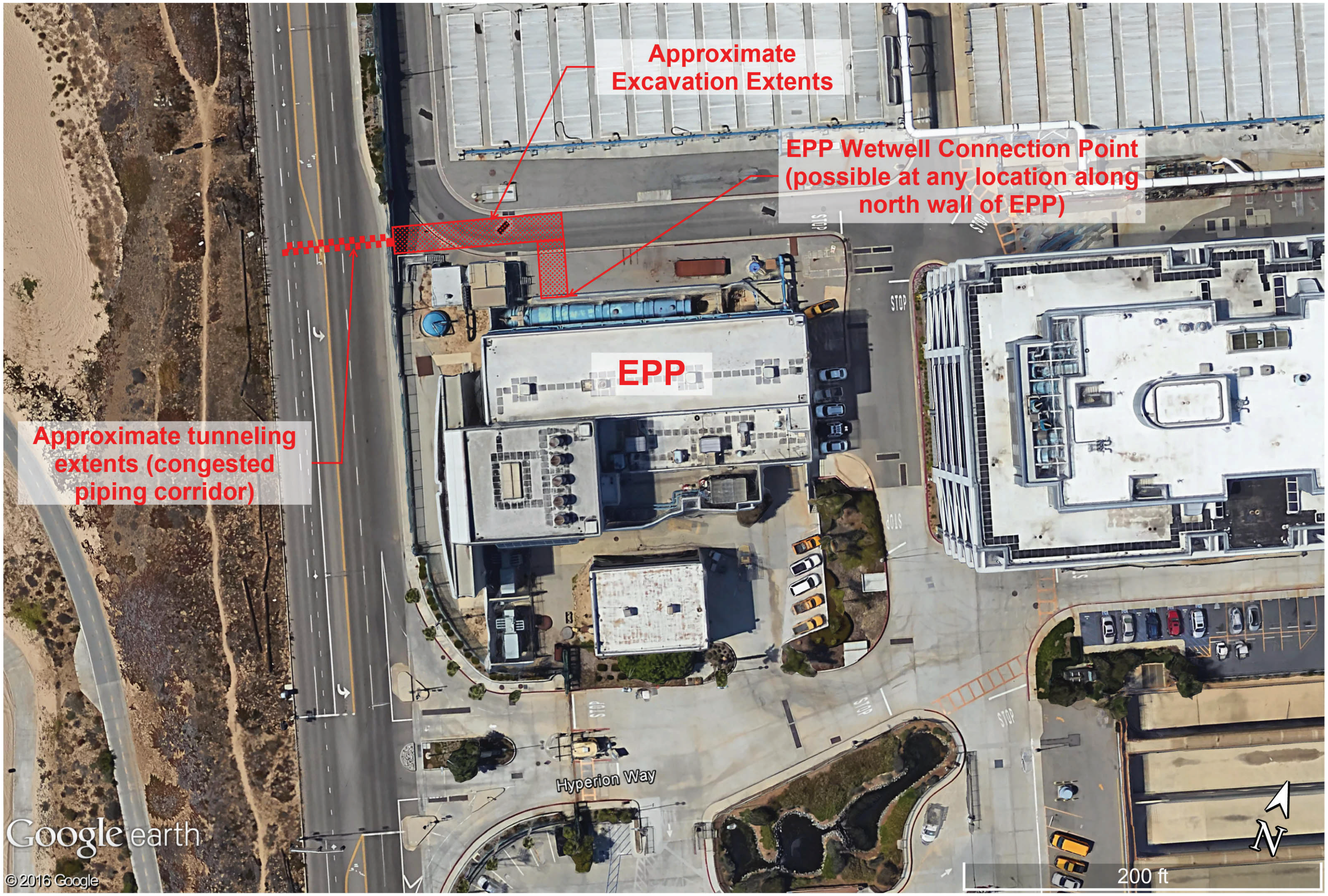

EXTENT OF EXCAVATION FOR EPP WETWELL CONNECTION ALTERNATIVE

FIGURE 12

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Secondary effluent flows through the EPP wetwell under routine operations, whether pumped or discharged via gravity. Isolation of the EPP wetwell is required during construction for connection of the new brine piping. Two bulkheads at the northeast corner of the wetwell can be inserted to isolate the wetwell; however, secondary effluent flows must be diverted to either the one-mile outfall or a temporary bypass arrangement (i.e., passive channel/pipe or bypass pumps).

To minimize the EPP wetwell shutdown time, a temporary bulkhead structure can be constructed inside the wetwell to isolate only the area around where the new piping connection will be made within the wetwell. Proper design of the temporary bulkhead structure is critical to ensure reliability and safety while construction activities are in progress.

Penetration through the existing 18-inch thick wetwell wall will include core drilling and installing a specially fabricated weep ring and spool piece. Additionally, the wall area will be developed around the new penetration to allow for proper doweling and anchoring needed to establish a watertight penetration. To safeguard against backflow of the secondary effluent into the new brine pipeline should it ever be taken out of service, installation of a duckbill style check valve on the brine pipe within the wetwell is suggested.

Replacement of the effluent pumps and piping (both suction and discharge) is required to overcome the issues due to material compatibility with high salinity brine. Construction sequencing can be employed to minimize the out of service time for the pumps. The majority of the costs associated with this option are due to the replacement of elements inside the EPP.

As a requirement from the State Water Resources Control Board (SWRCB) when updating the NPDES discharge permit for HWRP to include the desalination brine discharge, composite sampling of the effluent before and after commingling with brine will be necessary. An existing sample location downstream of the EPP wetwell is located within the five-mile outfall piping and would provide a sampling point after commingling. An additional sampling location would be required upstream of the EPP wetwell to provide a sample prior to commingling with brine.

3.1.2 Option 2: Effluent Junction Box

The north east corner of the EPP wetwell, referred to as the effluent junction box, can be isolated using bulkheads to divert flows to the one-mile outfall. The bulkheads are manually inserted during emergency conditions or when maintenance is required in the EPP wetwell and/or the five-mile outfall piping. Connecting brine discharge piping to this location and commingling within the junction box provides access to both the five-mile and one-mile outfalls. Additionally, the commingled flow can be pumped during high tide events that require pumping.

Connecting to the effluent junction box provides the greatest amount of flexibility for discharging the commingled effluent as it provides access to both of the outfalls, the EPP, and the gravity line. However, tying into this location would require extensive sequencing and bypass requirements to achieve.

The least complicated location for access to the effluent junction box is along the north wall making this the optimum location for the brine piping to penetrate, as shown in Figure 13. In order to tie into this location, a temporary shutdown of the effluent junction box is required, which would require temporary bypass pumping of the secondary effluent to the EPP wetwell and/or one-mile outfall while construction proceeds.

Similar considerations exist for the EPP wetwell and this location; these include crossing the crowded piping corridor to the west and potential modifications to the EPP pumps and wetwell to accept high salinity brine. Refer to Section 3.1.1 for additional information regarding these considerations.

Connection of the new brine piping to the effluent junction box will include all of the same excavation and fill requirements as for connecting to the EPP wetwell, however the location of the excavation is shifted slightly further east as shown in Figure 14.

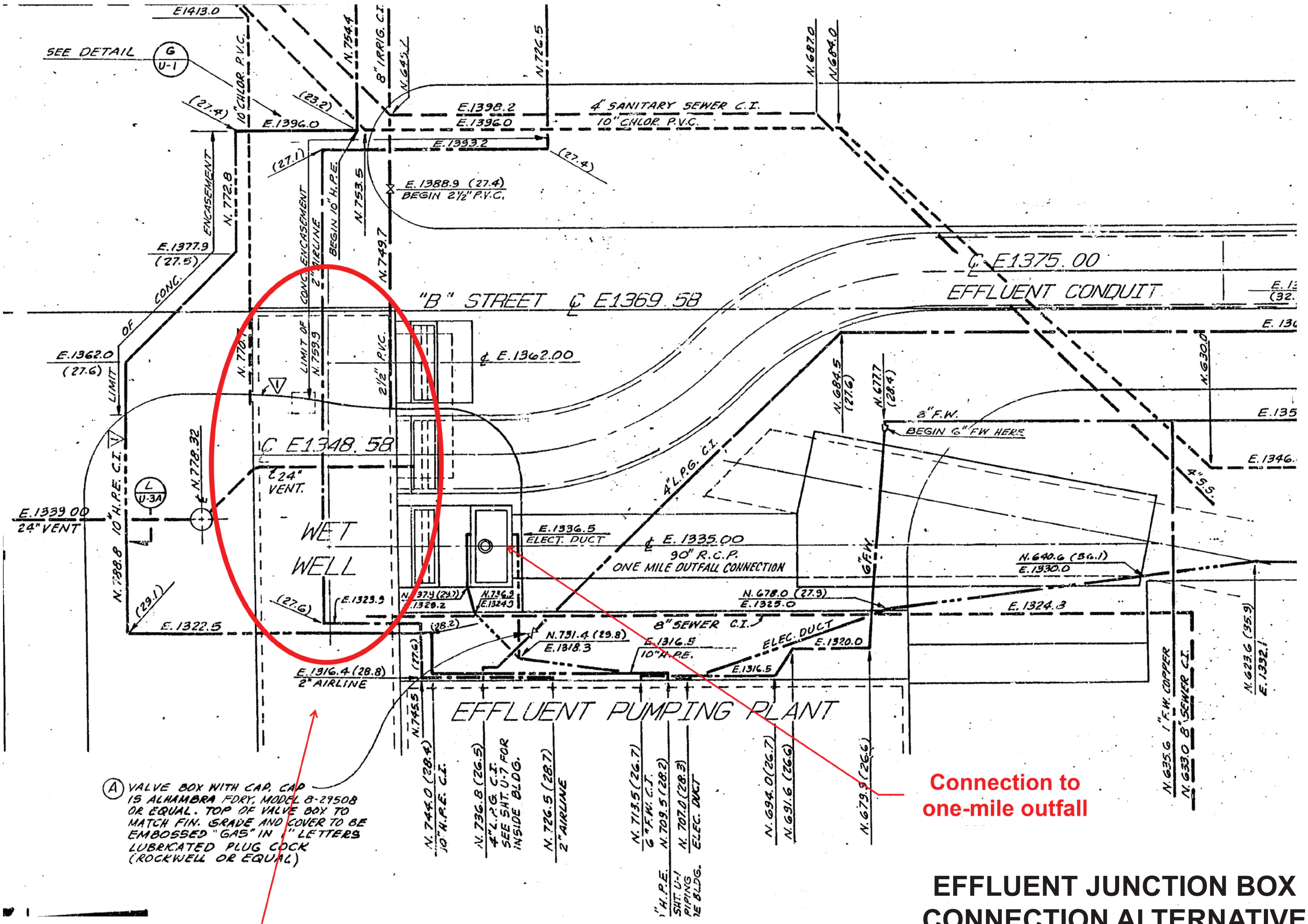
All of the secondary effluent flows combine in the effluent junction box before continuing to the EPP wetwell for discharge via the five-mile outfall. Connecting to the junction box will require a temporary shutdown of the effluent junction box to construct bulkheads which isolate the construction area within the box. During this short time (approximately 4 days), secondary flow can be bypassed to the one or five-mile outfalls with passive or active system.

Penetration through the existing 18-inch thick junction box wall will include the same elements as described for penetrating the EPP wetwell wall. Additionally, the majority of the elements within the EPP will require replacement to accommodate material compatibility with the brine. Replacement of these items is the bulk expense involved in this option.

As with the connection location to the EPP wetwell, samples of the commingled secondary effluent can be obtained from the existing composite sampler located within the five-mile outfall piping. A new sampling location would be required upstream of the effluent junction box to obtain samples of the secondary effluent prior to commingling.

3.1.3 Option 3: Gravity Line Valve Structure

As mentioned previously, secondary effluent can be discharged through the five-mile outfall by gravity or in certain cases, using the effluent pumps. When flow is discharged via the effluent pumps, the gravity flow pipe is isolated using the 120-inch butterfly valve (BFV) located inside the gravity line valve structure located downstream of the EPP, as shown in Figure 15. The structure is a large concrete vault, approximately 46-feet deep, that provides access to the 10-foot diameter secondary effluent gravity flow piping and valve.



Connection to
one-mile outfall

EPP Wetwell

EFFLUENT JUNCTION BOX CONNECTION ALTERNATIVE

FIGURE 13

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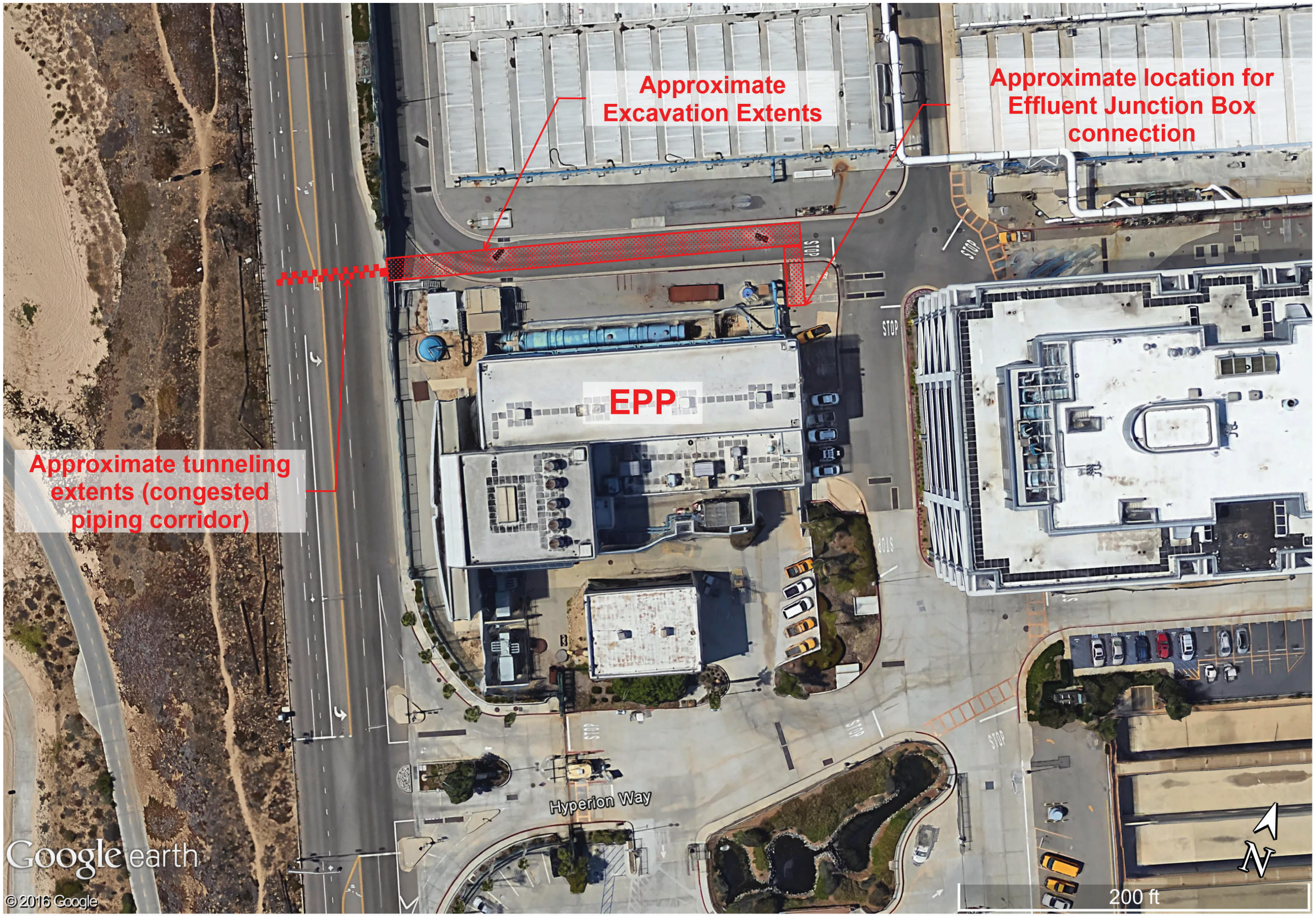
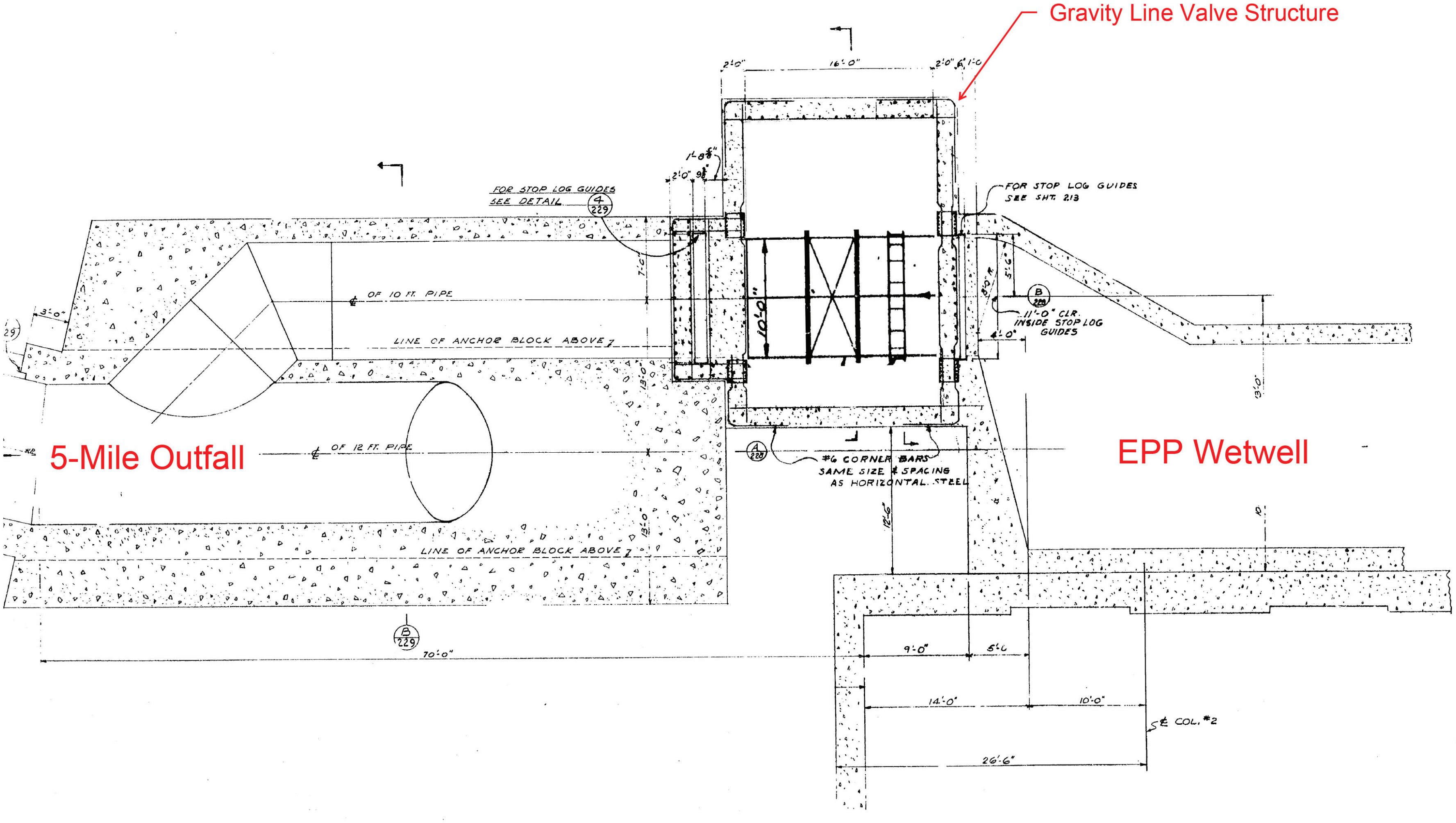


EXTENT OF EXCAVATION FOR EFFLUENT JUNCTION BOX CONNECTION ALTERNATIVE

FIGURE 14



PLAN. OF GRAVITY VALVE STRUCT.
(ELEV. = 5.39) SCALE: ¼"=1'-0"

GRAVITY LINE VALVE STRUCTURE CONNECTION ALTERNATIVE

FIGURE 15

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Access to the structure is limited due to congestion in the yard, as described in previous sections; however, a large hatch in the top of the structure provides access at grade.

The gravity line valve structure provides an access point for connection of the brine with HWRP secondary effluent to be discharged through the five-mile outfall. If the brine piping is connected downstream of the BFV, then it will commingle whether the secondary effluent is pumped or discharged via gravity; however, this connection location does not provide access to the one-mile outfall and will likely require additional connection to the one mile outfall to provide required operational flexibility.

Because the new brine piping can be tied into the effluent gravity piping either at grade or without requiring a deep excavation, the volume and duration of civil site work is less than the previous two options; however, similar to the previous two options, navigation of the new brine pipe through the existing piping corridor west of the EPP is required.

The existing butterfly valve inside the valve structure can be closed to isolate the gravity line; however, currently there is no existing infrastructure for isolation between the pumped discharge and the gravity line. Therefore, temporary bulkheads in the 102-inch gravity line are required to achieve temporary isolation of the piping within the valve structure so as not to necessitate a full bypass of the five-mile outfall.

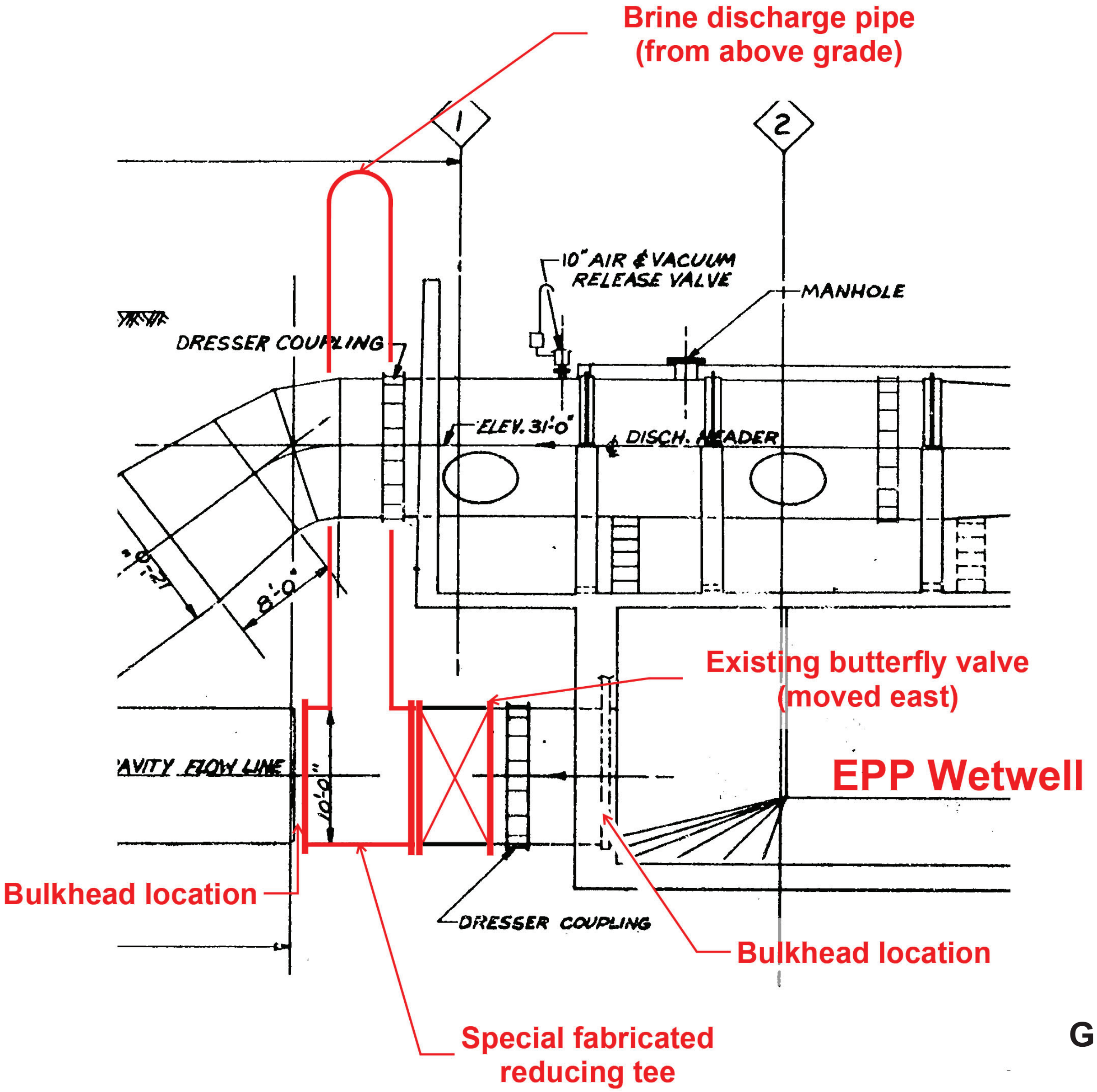
Additionally, secondary effluent flows will need to be pumped or diverted during the time period in which the new tee is being installed. Figure 16 shows the temporary bulkhead location and new piping arrangement within the gravity line valve structure.

Sampling of the commingled secondary effluent can be obtained by using the existing sampler in the five-mile outfall piping, described previously. Another sampling location is currently located in the gravity line valve structure, but the exact location is unknown. The connection of the new brine discharge piping should be coordinated to agree with the sample location to provide a sample prior to commingling.

3.1.4 Option 4: EPP Discharge Piping Cleanout

The effluent pumps discharge into a header located above the EPP wetwell. The header drops below grade to connect with the gravity line, where there is a 12-foot diameter access port for cleanout, as shown in Figure 17. This port may also be used for pigging. The use of this location as a connection point provides access to the five-mile outfall via gravity and during pumping events; however, it does not provide access to the one-mile outfall.

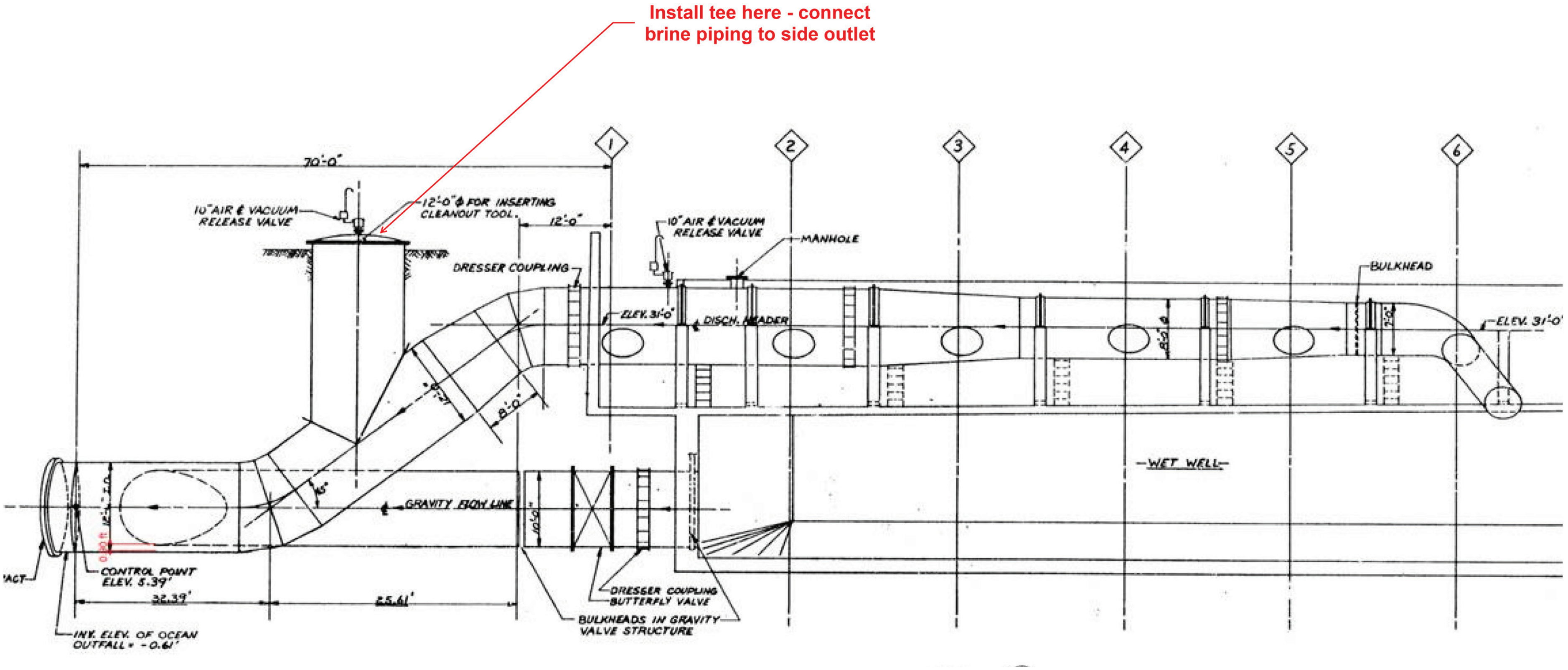
A method for commingling at this location is to install a 144-inch tee on top of the existing access port with the branch facing to the south. The new brine piping could then connect to the side branch at or above grade. This method would only require a brief shutdown of the five-mile outfall and EPP to complete.



GRAVITY LINE VALVE BOX CONNECTION DETAILS

FIGURE 16

WEST BASIN
MUNICIPAL WATER DISTRICT


Install tee here - connect brine piping to side outlet

EPP DISCHARGE PIPING CLEANOUT CONNECTION ALTERNATIVE

FIGURE 17

WEST BASIN
MUNICIPAL WATER DISTRICT

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As with the other connection alternatives discussed previously, this connection location requires the brine piping to cross the crowded yard to the west of the EPP, but may not be as challenging depending on the location where the piping is brought above grade. If piping can be brought above grade in a location west of the crowded piping corridor, challenges associated with crossing that pipe corridor are diminished.

Sampling of the commingled secondary effluent can be obtained by using the existing sampler in the five-mile outfall piping. Coordination of the secondary effluent sampling that exists in the gravity line valve structure should be used to provide a sample prior to commingling.

3.1.5 Option 5: One-Mile Outfall

The one-mile outfall is a 12-foot diameter discharge for the secondary effluent that is located south of the five-mile outfall piping. It terminates approximately one mile west-southwest of HWRP at a depth of approximately 50 feet below the ocean surface, and is permitted for emergency discharge of chlorinated secondary effluent.[4]

The outfall piping is reinforced concrete pipe (RCP) that was constructed prior to the 1950s. Portions of the outfall underwent repairs approximately fifteen years ago. Prior to any construction on a pipe of this material and age, a detailed condition assessment is typically performed to ensure success and safety of the project, which would be recommended for any modifications to this outfall if it were to be used to discharge brine.[5]

A passive bypass pipe system will be required during construction to allow HWRP to discharge during emergency high flow events or maintenance procedures. Sampling of the commingled secondary effluent is required and a new sampling device and sample line would be required for the one-mile outfall. Sampling of the secondary effluent prior to commingling is also required and can be accomplished using the existing sampling station in the gravity line valve box.

Unfortunately, connection at this location may not be a reliable long-term solution. In September of 2015, HWRP discharged all of the treated secondary effluent via the one-mile outfall for a period of approximately 6 weeks while repairs were made to the five-mile outfall. Although bacteria and phytoplankton counts were in compliance with health and safety regulations, trash and debris were observed along the shoreline, resulting in multiple beach closures. The relatively short length and shallow discharge into the bay may make this an undesirable location for continuous discharge.

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[4] California Regional Water Quality Control Board and U.S. Environmental Protection Agency Region IX, Order No. R4-2005-0020, NPDES Permit No. CA0109991

[5] Although likely recommended for other alternatives, condition assessment for this alternative is required due to modifications performed directly on the pipe of this material and age.

Therefore, a connection point to the five-mile outfall must be made in conjunction with a connection to the one-mile outfall in order for any of these connection points to be deemed feasible.

Potential connection locations for the one-mile outfall include the existing manhole hatches, construction of a new manhole structure, and core drilling into the existing pipe for direct connection of the brine piping.

3.1.6 Option 5a: One-Mile Outfall - Existing Manhole

As shown in Figure 18, the outfall piping crosses Dockweiler State Beach. The entire stretch of the one-mile outfall pipeline contains eight manhole hatches spaced at 500 feet on center, also shown in Figure 18. Potential connection locations for the one-mile outfall include any of the existing manhole hatches (with preference being closer to shore).

The existing manhole hatches are 36 inches in diameter, which is likely smaller than the diameter of the brine piping required to convey the proposed desalination brine. To use the smaller diameter manhole without cutting into the existing RCP outfall piping, the brine discharge could be split between two manholes. However, this alternative increases construction and operational complexity. A single discharge at an existing manhole could be provided, but the high velocity at the confluence point would likely erode the existing RCP pipe, resulting in reliability issues. This alternative is not recommended.

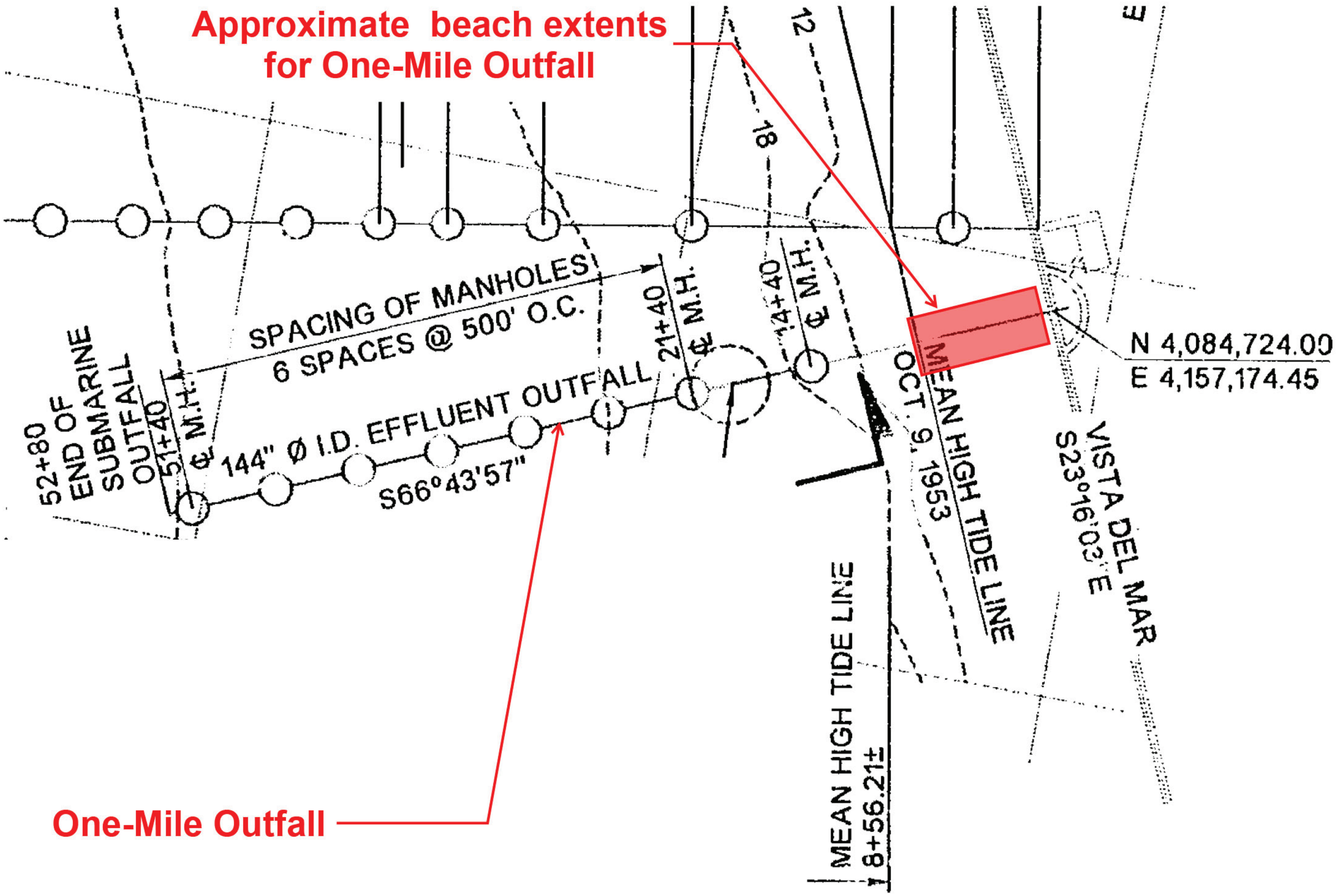
Construction activities for this option include dewatering of the construction area and the use of heavy duty equipment for excavation.

For the one-mile outfall, the closest existing manhole to the beach is located west of the mean high tide (MHT) line approximately 3-feet below MSL. Connection to the existing manhole within the ocean requires extensive shoring and dewatering activities to complete.

3.1.7 Option 5b: One-Mile Outfall - New Manhole

A new manhole structure can be constructed around the one-mile outfall piping on the beach. These are typically referred to as "doghouse" manholes, and are cast in place concrete structures that are constructed around the existing piping. Construction of a doghouse manhole would entail some risk for supporting and modifying the aging RCP as the structure is constructed below.

Construction activities for this option include the use of heavy equipment for excavation and to provide support of the existing outfall piping during excavation and installation of the new manhole structure underneath. In addition, extensive dewatering of the construction area will be required.



ONE-MILE OUTFALL CONNECTION ALTERNATIVE

FIGURE 18

WEST BASIN
MUNICIPAL WATER DISTRICT

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Once the new manhole is fully constructed, sealed around the existing outfall, and new brine piping tied in, the segment of the existing RCP within the doghouse manhole is cut and removed. Typically, "flow lines" within the manhole are constructed to provide hydraulic routing through the structure. The completed manhole structure is covered and buried. The cover would be water tight, but is not typically built to withstand pressurized conditions.

Figure 19 shows the potential new manhole locations for the one -mile outfall.

3.1.8 Option 5c: One-Mile Outfall - Core Drill

Lastly, core drilling into the top of the existing one-mile outfall pipeline is a potential option for connecting the new brine pipeline to the outfall piping. Specialized construction techniques may be required to mitigate pipe collapsing, which can result from a reduction in hoop strength from the removal of portions of an RCP pipe. A possible method is to build a concrete encasement that encompasses the entire segment of outfall piping that is compromised and overlapping it onto the adjacent segments on each side. The age and material of the outfall present considerable risks for modifications such as cutting and tying into the existing piping, but it can be achieved using costly, and potentially timely, construction techniques.

Construction activities for this option include dewatering of the construction area and the use of heavy equipment for excavation of the existing RCP outfall piping. An advantage of core drilling is that there are many locations that can be considered, as long as they are not connecting into an existing joint. The primary concern when cutting or drilling into an RCP pipe of this size and age, is the reduction in hoop stresses associated with cutting rebar. A potential way to mitigate this issue is to fully encase the segment of RCP piping that is compromised from the core drilling process.

3.1.9 Option 6: Five-Mile Outfall

The five-mile outfall is a 12-foot diameter outfall terminating approximately five miles west-southwest of HWRP at a depth of approximately 187 feet below the ocean surface.[6] The RCP outfall piping was put into service 55 years ago.[7] Portions of the outfall underwent repairs approximately fifteen years ago. As with the one-mile outfall, a condition assessment is recommended to ensure success and safety of the project for any modifications to this outfall if it were to be used to discharge brine. The analysis presented in future sections assumes the condition of the pipeline is sufficient for use and modification (e.g., in direct connection alternatives).

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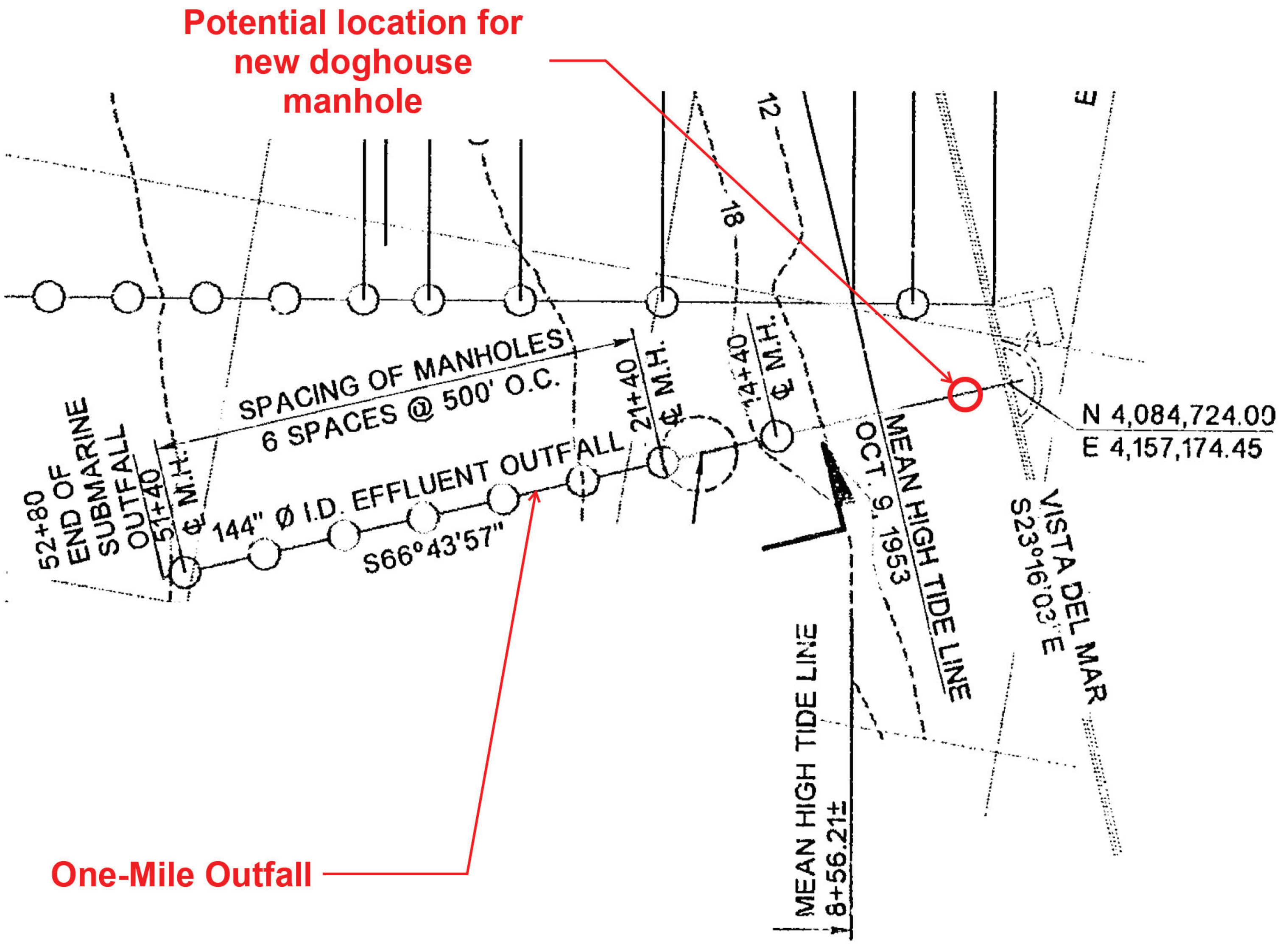
[6] California Regional Water Quality Control Board and U.S. Environmental Protection Agency Region IX, Order No. R4-2005-0020, NPDES Permit No. CA0109991

[7] Los Angeles Citywide General Plan Framework EIR



ONE-MILE OUTFALL POTENTIAL MANHOLE LOCATION

FIGURE 19

Any bypass requirements that are needed to discharge effluent while the five-mile outfall is in use can be obtained by using the one-mile outfall. However, it is not possible to use the EPP to discharge to the one-mile outfall, which ultimately means the bypass system must be designed and/or modified to accommodate any high flow and high tide events without the use of the EPP. Conditions requiring the use of the EPP for pumping effluent discharge were discussed in previous sections.

Additionally, the ODWF operations will require shutdown if the five-mile outfall is taken out of service for maintenance activities. Therefore, a connection point to the one-mile outfall must be made in conjunction with a connection to the five-mile outfall.

Depending on the location, sampling of the commingled secondary effluent can be obtained using the existing sampling system that pulls samples from the five-mile outfall piping. Sampling of the secondary effluent prior to commingling can be acquired using the sample station already in use in the gravity line valve box.

Potential connection locations for the five-mile outfall include the existing manhole hatch on the beach, construction of a new manhole structure, and core drilling into the existing pipe for direct connection of the brine piping.

3.1.10 Option 6a: Five-Mile Outfall - Existing Manhole

As shown in Figure 20, the outfall piping crosses Dockweiler State Beach and contains many manhole hatches, one of which is located on the beach.

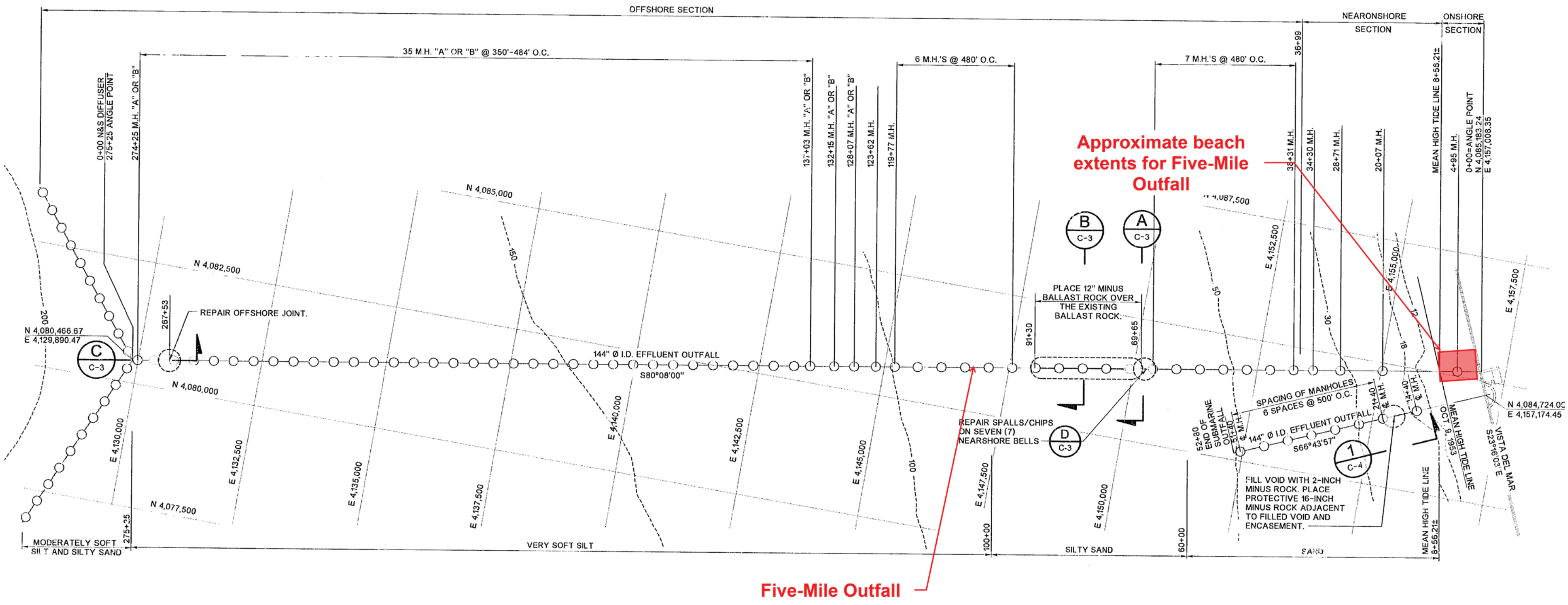
As discussed in the previous section for the one-mile outfall, the diameter of the existing manhole hatch is smaller than the proposed desalination brine piping. Therefore, whether gravity or pumped, the brine piping discharge must be designed to accommodate the reduction in diameter.

Construction activities for this option include dewatering of the construction area and the use of heavy duty equipment for excavation. Figure 21 provides a section view through one of the existing manholes. Figure 22 shows locations of the existing manholes.

3.1.11 Option 6b: Five-Mile Outfall - New Manhole

A new manhole structure can be constructed around the five-mile outfall piping on the beach. As with the one-mile outfall, construction of a doghouse manhole would entail some risk for supporting and modifying the aging RCP as the structure is constructed below.

Constructing a doghouse manhole at the five-mile outfall involves a significant risk for supporting the piping during construction. The outfall will need to be taken out of service at some point during construction which will require the one-mile outfall to discharge all of the secondary effluent flows. The completed manhole structure is covered and buried. The cover would be water tight, but is not typically built to withstand pressurized conditions. During high tide events when the EPP is operating and discharging pressurized secondary



ONE-MILE AND FIVE-MILE OUTFALL PLAN

SCALE: 1" = 1000'-0"

FIVE-MILE OUTFALL CONNECTION ALTERNATIVE

FIGURE 20

WEST BASIN
MUNICIPAL WATER DISTRICT

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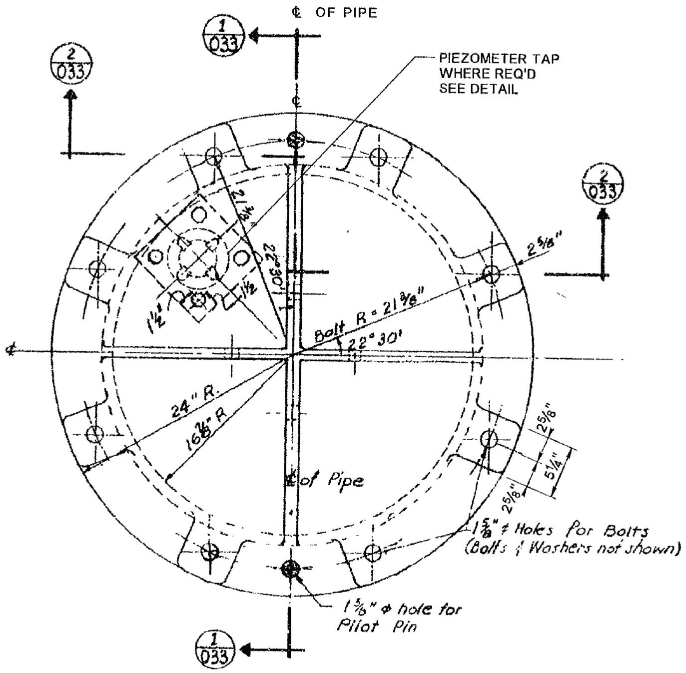
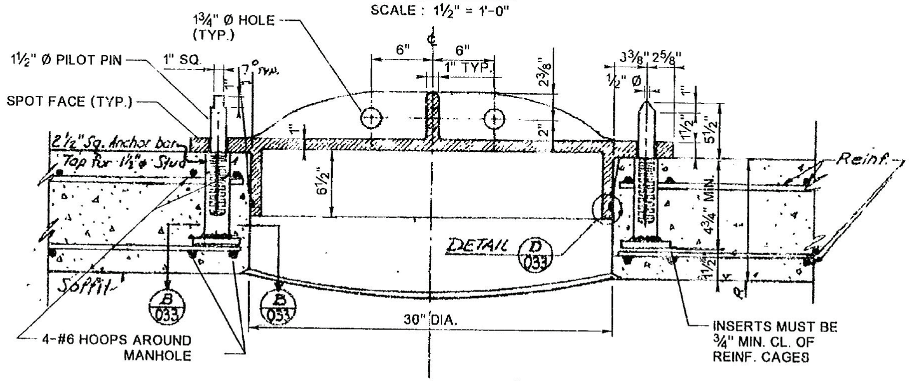


PLAN

SCALE : 1½" = 1'-0"



SECTION 1 033

SCALE: 1½" = 1'-0"

DETAILS OF MANHOLE A 033

FIVE-MILE OUTFALL
EXISTING MANHOLE

FIGURE 21

WEST BASIN
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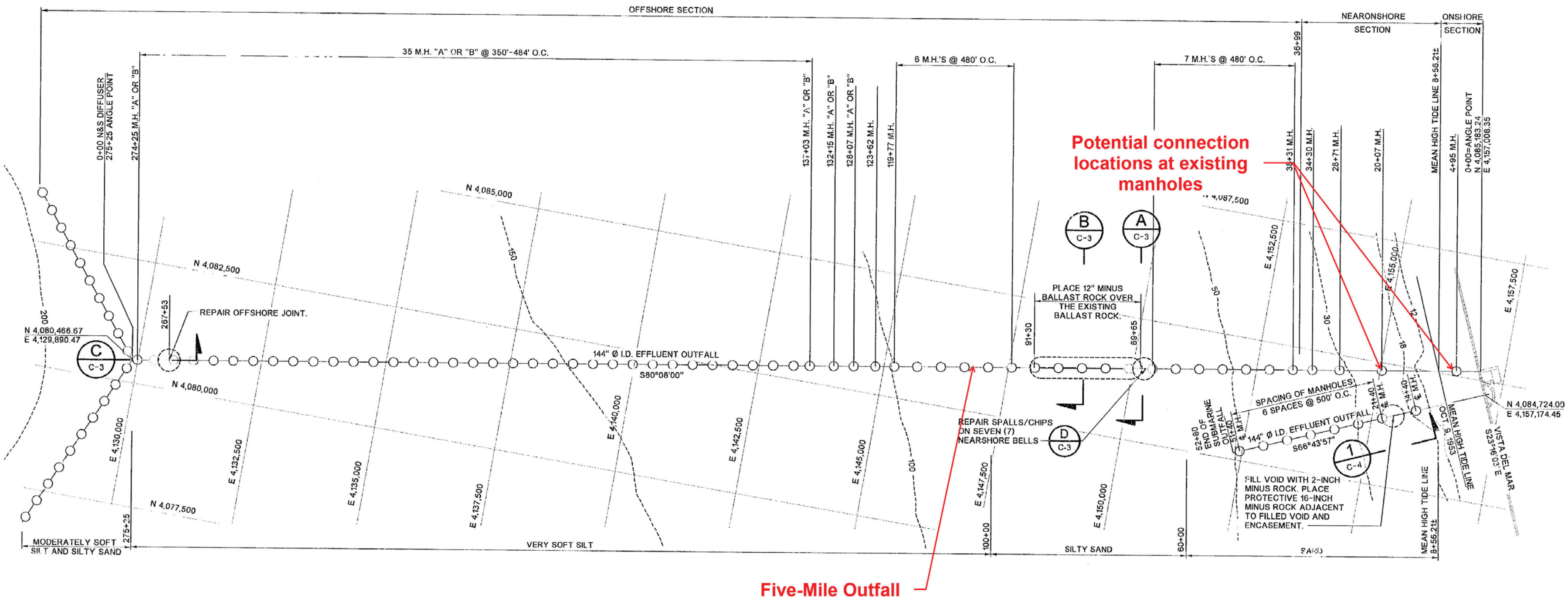

ONE-MILE AND FIVE-MILE OUTFALL PLAN

SCALE : 1" = 1000'-0"

FIVE-MILE OUTFALL EXISTING MANHOLE LOCATIONS

FIGURE 22

WEST BASIN
MUNICIPAL WATER DISTRICT

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effluent, a doghouse style manhole is not feasible for the five-mile outfall.[8] Since the five-mile outfall periodically operates under a pressurized condition from pumping, this connection alternative is not recommended.

3.1.12 Option 6c: Five-Mile Outfall - Core Drill

Lastly, core drilling into the existing five-mile outfall pipeline presents the same advantages and challenges discussed for the one-mile outfall.

3.1.13 Option 7: Combined Outfalls

Brine cannot be discharged to only one of the outfalls due to inadequate mixing if the outfall is out of service. The five-mile outfall is used under routine operations, however, it is taken out of service periodically when maintenance is required. The one-mile outfall only provides the necessary flows for mixing under emergency conditions when it is utilized.

Therefore, for this option to be feasible a connection must be made to both outfalls, which increases the construction schedule and cost. Any one feasible connection options for the one-mile outfall combined with any one feasible connection option for the five-mile option will create a feasible combination for connection to the outfalls.

3.2 Piping Materials and Appurtenances

Proper material selection is critical for applications involving high salinity brine from seawater desalination processes, which is highly corrosive. Section 3.1 above described the material compatibility considerations associated with existing materials at HWRP (i.e., connection locations, pumps, etc.). The following subsections evaluate piping materials and appurtenances for new infrastructure required for the various connection alternatives.

3.2.1 New Pipeline Materials and Appurtenances

Due to the highly corrosive nature of brine, the materials of construction must possess a high degree of corrosion resistance. Application of nonmetallic materials, such as plastic and fiberglass, are commonly used for brine piping due to their high corrosion resistance, chemical inertness, lighter weight, resistance to galvanic attack, and lower unit costs. While these materials offer many advantages, they are typically not suited for high pressure systems (i.e., greater than 100 psi of discharge pressure) and can present some constructability challenges in buried applications. For higher pressure solutions (e.g., concentrate piping before pressure is reduced in an energy recovery device [ERD]), typically carbon steel or stainless steel (SST) piping is used. Carbon and low alloy steels will require a liner and cathodic protection to combat the harmful effects of the corrosivity of the brine. SST is generally corrosion resistant, but must be carefully selected to avoid

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[8] A doghouse style manhole is not recommended for application in pressurized pipe flow. As mentioned in previous sections, there are scenarios where the five-mile outfall is operated under a pressurized condition, and this style of manhole would not be recommended.

damage due to pitting. A general 316 SST will likely require cathodic protection for use in the high salinity brine application. The following subsections further evaluate the four most prevalent types of pipe materials used for brine.

3.2.1.1 High Density Polyethylene Pipe

High density polyethylene (HDPE) piping has a high resistance to corrosion and is often less costly than other similar types of piping such as steel or stainless steel. HDPE is available in a variety of diameters up to 78 inches, however at large diameters (>48 inches) a profile type wall is often required. Additionally, HDPE can tolerate high fluid velocities making it desirable for applications requiring a wide range of flow conditions.

3.2.1.2 Fiberglass Reinforced Plastic Pipe

Fiberglass reinforced plastic (FRP) piping plays an important role in desalination plants because the material properties are very compatible with highly corrosive fluids. FRP is widely used in desalination plants throughout the world, largely in above ground, low pressure piping applications. FRP is not recommended for high pressure piping systems.

Additionally, FRP is positively buoyant in water and fractures more easily than HDPE. If outfall pipe is located in a beach area that is exposed to accelerated erosion or wave action, it must be buried and installed in a trench on special bedding.

3.2.1.3 Lined Steel Pipe

Carbon and low alloy steel piping systems provide the structural integrity required for high pressure systems, however the piping must be lined to gain compatibility with high salinity brine flows. Typical liners for steel piping are cement mortar, polyurethanes, and epoxies. As mentioned previously, a cathodic protection system is also required to reduce corrosion potential.

3.2.1.4 Stainless Steel Pipe

The primary advantage of stainless steel is that it is resistant to corrosion. There are special types of stainless steel that are usually required for marine construction, such as superduplex. Specialty stainless steels can be costly and scarce, which could impact budget and construction schedule, but would be the only type of stainless steel suited for duty use in this application. Other types of more readily available stainless steel (i.e., 316L, 304L, etc) can be used for this application, however they will likely still require cathodic protection to prevent corrosion.

Table 3 provides a comparison of the pipe materials discussed above.

Table 3 Pipe Materials Comparison
Ocean Water Desalination Discharge Feasibility Study
West Basin Municipal Water District

	Compatibility Criteria		
Pipe Material	**Corrosion Resistant?**	**Pressure**	**Typical Installation**
HDPE	Y	N	Buried
FRP	Y	N	Buried or Exposed
Stainless Steel(1)(2)	Y	Y	Buried or Exposed
Lined Steel(1)	Y	Y	Buried or Exposed

Notes:

(1) Requires robust cathodic protection to prevent corrosion of piping.
(2) Alternatively, a specialized stainless steel for this application can be used (e.g., superduplex), but at higher cost and potential schedule affects for procurement/installation.

3.2.1.5 Brine Piping Capacity

Pipe capacity is typically based on the minimum and maximum allowable velocities. Minimum velocities are chosen to prevent solids from settling out of the fluid or scale from forming. Brine produced from desalination processes has low solids and scaling potential, which makes the minimum velocity less important for pipe sizing.

The maximum velocity is based on several factors including pipe material, allowable head loss (pumped system), and the outfall size (gravity system). For West Basin's projected flows of 20.9 mgd and 62.7 mgd, Table 4 illustrates the resulting velocities for different pipe diameters.

Table 4 Pipe Velocities
Ocean Water Desalination Discharge Feasibility Study
West Basin Municipal Water District

	Velocity (fps)								
Brine Flow	**I.D. (in)**								
(mgd)	**24**	**30**	**36**	**42**	**48**	**54**	**60**	**66**	**72**
20.9	10.3	6.6	4.6	3.4	2.6	2.0	1.6	1.4	1.1
62.7	30.9	19.8	13.7	10.0	7.7	6.1	4.9	4.1	3.4

As shown in the table above, the fluid velocities for the brine piping vary drastically for the two different flow rates. As such, there is a range of pipe sizes that are acceptable for this application (shaded cells in table indicate acceptable velocities); however, for the purposes of this study the pipeline will be sized to accommodate the regional flow capacity of 62.7 mgd and conveyed through a 54-inch pipe.

3.2.2 Additional Modifications to Existing Materials

Lined concrete is typically recommended to reduce the risk of corrosion that may occur on any exposed rebar. Due to the age and unknown condition of the existing RCP outfall, it is preferable to install a liner for protection. The extent of lining required depends on the water chemistry, commingled salinity, and RCP condition which would be confirmed during a condition assessment of the outfall(s).

3.3 Pipeline Routing

Various pipeline alignments could be considered from the proposed OWDF to the connection locations at the HWRP. The purpose of this pipeline is to transfer brine (i.e., membrane concentrate) from the seawater RO process at the OWDF to the connection location, and ultimately to be discharged commingled with the HWRP effluent. The conceptual placement of the proposed pipeline routes were determined using utility as-built drawings from each respective utility owner within Vista Del Mar Boulevard from the ESGS to the HWRP outfalls. Substructure utility maps were also used to gain a general idea of existing utility locations within the project limits. It is noted that this study does not consider exiting the NRG site, and only includes the pipeline alignment beginning outside the property line.

Three potential pipeline routes for a large diameter brine transmission pipeline were identified using the methods described above and a field walk of the general study area to be evaluated as part of this study:

1. Vista Del Mar Boulevard alignment.
2. Dockweiler State Beach alignment.
3. Parking areas alignment.

Figure 23 and Figure 24 show the potential pipeline routes which are described in more detail in the following subsections. Appendix A includes field walk photographs.

CONCEPTUAL ALIGNMENTS
FOR LARGE-DIAMETER HIGH SALINITY BRINE TRANSMISSION PIPELINE
(WITHIN CITY OF LOS ANGELES)

— **OPTION 1: PLACEMENT IN VISTA DEL MAR BLVD**

— **OPTION 2: PLACEMENT ON BEACH. BURIED CONDITION**

— **OPTION 3: PLACEMENT IN DOCKWEILER STATE BEACH, PARKING AREAS**

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POTENTIAL PIPELINE ALIGNMENTS

FIGURE 23

WEST BASIN
MUNICIPAL WATER DISTRICT

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CONCEPTUAL ALIGNMENTS
FOR LARGE-DIAMETER HIGH SALINITY BRINE TRANSMISSION PIPELINE
(WITHIN CITY OF EL SEGUNDO)

N

NTS

- OPTION 1: PLACEMENT IN VISTA DEL MAR BLVD
- OPTION 2: PLACEMENT ON BEACH. BURIED CONDITION
- OPTION 3: PLACEMENT IN DOCKWEILER STATE BEACH, PARKING AREAS

POTENTIAL PIPELINE ALIGNMENTS

FIGURE 24

WEST BASIN
MUNICIPAL WATER DISTRICT

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24-WBMWD12-16F24-10240A00.AI

3.3.1 Alignment 1: Vista Del Mar Boulevard

Refer to Appendix B for the full pipeline alignment for the Vista Del Mar alternative. The horizontal locations of subsurface wet utilities (city owned) and dry utilities (city owned and privately owned) were evaluated to determine the feasibility of installing a large diameter, one mile long, underground pipeline beneath the roadway of Vista Del Mar Boulevard or within right-of-way limits. In addition to the record drawings and utility maps collected for this study, a field walk (refer to Appendix A for photographs of the field walk) of Vista Del Mar and the right-of-way areas to the east and west was performed on October 14, 2016, to assess site conditions and verify potential obstacles.

The following potential obstacles were observed:

- Subsurface utility congestion within the Los Angeles city limits.
- A vehicle tunnel crossing below the road surface from the Scattergood Power Generating Station.
- Several large diameter water lines perpendicular to the roadway associated with power generating facilities and a large cooling water intake structure (CWIS).
- Street lights.
- Powerline poles.
- Unknown subsurface utilities (i.e., not shown in drawings, maps, or detectable during field walk.

Horizontal placement of the pipeline may be possible at approximately 25-feet west of the Vista Del Mar centerline; however, it must be placed to avoid conflict with an existing 6-inch gas line within the limits of the City of Los Angeles.[9] A design exception from the gas line owner may be required to install the brine pipeline within the proximity of the gas line. Additionally, the vehicle tunnel and large diameter water lines serve to provide access and utilities to a large CWIS for the Scattergood Generation Station. Considering the depths of utilities and vehicle tunnel it may be necessary to utilize non-traditional construction methods, such as tunneling, to navigate the large diameter brine pipeline past these obstacles. It is noted that vertical investigation of this tunnel and large diameter water pipelines was beyond the scope of this feasibility study.

Subsurface utility records indicate storm and sewer located between the curb and right-of-way on the east side of Vista Del Mar Boulevard. Subsurface utilities on the west side appear limited, which may also be considered within beach limits.

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[9] Special considerations and spacing may be necessary to place pipeline in vicinity of high pressure gas pipeline.

Placement of the pipeline within Vista Del Mar is the least environmentally invasive option, due to the absence of sensitive habitats and beach and ocean disturbances; however the following permits and approvals are required for construction of the pipeline in Vista Del Mar Boulevard:

- California Environmental Quality Act (CEQA)/National Environmental Policy Act (NEPA): Clearance document to amend current environmental impact report (EIR) to address pipeline.
- Coordination and/or permits with local utilities to mitigate potential for buried utility lines and/or hazmat plumes to be encountered with deep trenching.
- Coordination and/or permits with local utilities to mitigate potential conflicts with perpendicular oil and telecom industry conduits running under the beach.

3.3.2 Alignment 2: Dockweiler State Beach

Beach areas are not shown on substructure maps. Therefore, it was assumed that no utilities are located within the beach areas other than outfall pipes. A field walk (refer to Appendix A for photographs of the field walk) of the beach area was performed on October 14, 2016 to assess site conditions and verify potential obstacles.

The following potential obstacles were observed:

- Existing easements for the beachfront.
- A large diameter outlet pipe from the ocean to the CWIS.
- Chevron ocean outlet pipe.
- Lifeguard stands, fire pits, and a paved bike path.
- Unknown subsurface utilities.

In addition to these physical obstacles, there are local, county, state, and federal regulations that must be addressed for this option to be feasible. The following list of permits and approvals is required for beach construction:

- California Environmental Quality Act (CEQA)/National Environmental Policy Act (NEPA): Clearance document to amend current EIR to address pipeline.
- Dockweiler State Beach: encroachment permits for beach construction and temporary disruption to beach users.
- City of El Segundo: encroachment permit(s) and/or Coastal Development Permit (CDP) for any construction above MHT.

- City of Los Angeles: encroachment permit(s) and/or CDP for any construction above MHT.
- State Land Commission: lease for any construction below MHT.
- California Coastal Commission: CDP for any construction below MHT (or in the event the City CDP is appealed as a major Public Works Project).
- Army Corps of Engineers: Section 404 Permit for dredge/fill below MHT.
- U.S. Fish and Wildlife Service (USFWS): Section 7 consultation and seasonal restriction due to snowy plover critical habitat Subunit CA 45C.
- California Department of Fish and Wildlife (CDFW): consultation due to snowy plover critical habitat Subunit CA 45C.
- Regional Water Quality Control Board (RWQCB): National Pollutant Discharge Elimination System (NPDES)/Waste Discharge Requirement (WDR) permit for beach construction/dewatering - special construction.
- Coordination and/or permits with local utilities to mitigate potential for buried utility lines and/or hazmat plumes to be encountered with deep trenching.
- Coordination and/or permits with local utilities to mitigate potential conflicts with perpendicular oil and telecom industry conduits running under the beach.
- Long-term coastal erosion hazards would require the pipe to be buried well below the 2100 scour depth based on current SLR/Coastal Erosion guidance from Coastal Commission and State Lands.

It is noted that although the technical constraints with this alignment are minimal compared to the Vista Del Mar alternative, this alternative has many environmental constraints that were outside the scope of this technical feasibility evaluation.

3.3.3 Alignment 3: Parking Areas

Placement of the pipeline under the existing parking lots of Dockweiler State Beach, operated by Los Angeles County, was considered as an additional route. The Los Angeles County Department of Public Works provided the locations of several pump stations and force mains within Dockweiler State Beach; however, as-builts and substructure maps were not available at the time of this report. A field walk (refer to Appendix A for photographs of the field walk) of the parking areas was performed on October 14, 2016, to assess site conditions and verify potential obstacles.

The following potential obstacles were observed:

- The Scattergood Generation Station CWIS.
- Two large parking lots.
- Concession stand, aquatic center, lifeguard station, restrooms, and a parking booth.
- Paved bike path.
- Unknown subsurface utilities.

Further investigation, such as potholing and utility mark-outs, is warranted to determine the technical feasibility and final layout for this pipeline alignment. Also, given that portions of this alignment are within beach limits, the above permits and approval listing for the beach alignment would apply to this pipeline alignment alternative as follows:

- California Environmental Quality Act (CEQA)/National Environmental Policy Act (NEPA): Clearance document to amend current EIR to address pipeline.
- Dockweiler State Beach: encroachment permits for beach construction and temporary disruption to beach users.
- City of El Segundo: encroachment permit(s) and/or Coastal Development Permit (CDP) for any construction above MHT.
- City of Los Angeles: encroachment permit(s) and/or CDP for any construction above MHT.
- State Land Commission: lease for any construction below MHT.
- California Coastal Commission: CDP for any construction below MHT (or in the event the City CDP is appealed as a major Public Works Project).
- Army Corps of Engineers: Section 404 Permit for dredge/fill below MHT.
- U.S. Fish and Wildlife Service (USFWS): Section 7 consultation and seasonal restriction due to snowy plover critical habitat Subunit CA 45C.
- California Department of Fish and Wildlife (CDFW): consultation due to snowy plover critical habitat Subunit CA 45C.
- Regional Water Quality Control Board (RWQCB): National Pollutant Discharge Elimination System (NPDES)/Waste Discharge Requirement (WDR) permit for beach construction/dewatering - special construction.

- Coordination and/or permits with local utilities to mitigate potential for buried utility lines and/or hazmat plumes to be encountered with deep trenching.
- Coordination and/or permits with local utilities to mitigate potential conflicts with perpendicular oil and telecom industry conduits running under the beach.
- Long-term coastal erosion hazards would require the pipe to be buried well below the 2100 scour depth based on current SLR/Coastal Erosion guidance from Coastal Commission and State Lands.

Consistent with the beach alignment, it is also noted that although the technical constraints with this alignment are minimal compared to other alternatives, this alternative has many environmental constraints that were outside the scope of this technical feasibility evaluation.

3.4 Construction and Operation

Construction and operational challenges associated with commingling high salinity brine with HWRP's existing secondary effluent were evaluated to determine the technical feasibility of the connection points, pipeline routes, HWRP modifications, and pumping alternatives. This section expands on the material presented in sections above. Additionally, the material presented in this section was used as the basis for the construction cost estimates presented in future sections during the non-technical analysis performed in this study. Although cost is not considered a grounds to deem alternatives "technically infeasible," it is important to understand the magnitude of cost implications for technically feasible alternatives.

Additional construction and operational considerations included in this study are grouped in the subsections as follows:

1. Connection Point Locations: Provides additional construction and operational methodology in addition to the general descriptions presented in Section 3.1.
2. Modifications to HWRP: Provides an overview of construction needed to upgrade existing HWRP to be compatible with brine.
3. Feasible Pipeline Alignments to HWRP: Provides description of the challenges and methods needed to construct pipeline routes.
4. Pumping Alternatives: Provides an overview on modifications that would be necessary to pump brine from OWDF to connection location.
5. Additional Construction/Operational Challenges: Provides any additional considerations.

3.4.1 Connection Locations

The following potential connection point locations were identified and described in Section 3.1:

- Option 1: EPP Wetwell.
- Option 2: Effluent Junction Box.
- Option 3: Gravity Line Valve Structure.
- Option 4: EPP Discharge Piping Cleanout.
- Option 5: One-Mile Outfall:
  - Option 5a: Existing Manhole.
  - Option 5b: New Manhole.
  - Option 5c: Core Drill.
- Option 6: Five-Mile Outfall:
  - Option 6a: Existing Manhole.
  - Option 6b: New Manhole.
  - Option 6c: Core Drill.
- Option 7: Combined Outfalls (i.e., any combination of Options 6 and 7).

The following subsections describe additional construction considerations of potential construction elements for each connection point location. It is noted that Section 3.1 includes some construction methodology for connection locations. For the purposes of the cost estimates, a 54-inch brine pipe was assumed. Construction considerations for Options 5, 6, and 7 were similar and grouped accordingly for discussion in the following subsections.

Option 1: EPP Wetwell

The following construction procedures are presented to provide a general overview of the methodology that may be used to connect the new brine piping to the EPP wetwell:

- Tunnel underneath existing utilities in Vista Del Mar roadway.
- Excavation of soil and asphalt on north side of the EPP.
- Shutdown of EPP wetwell.
- Construct temporary bulkheads within EPP wetwell.
  - Once temporary bulkheads are erected, wetwell can be brought back into service.

- Core drill through existing 18-inch wall.
- Tie-in new brine piping to existing wall.
- Install duckbill style check valve on new brine pipe.
- Remove bulkheads within wetwell.
- Replace soil and asphalt in yard.
- Replace effluent pumps and associated suction and discharge piping.
- Install new sample location.

Option 2: Effluent Junction Box

To connect the new brine piping to the effluent junction box, the following construction elements are required:

- Tunnel underneath existing utilities in Vista Del Mar roadway.
- Excavation of soil and asphalt on north side of the EPP.
- Shutdown and/or bypass of effluent junction box.
- Construct temporary bulkheads within effluent junction box.
    - Once temporary bulkheads are erected, junction box can be brought back into service.
- Core drill through existing 18-inch wall.
- Tie-in new brine piping to existing wall.
- Install duckbill style check valve on new brine pipe.
- Remove bulkheads within junction box.
- Replace soil and asphalt in yard.
- Replace effluent pumps and associated suction and discharge piping.
- Install new sample location.

Option 3: Gravity Line Valve Structure

Connecting the new brine piping within the existing gravity line valve structure involves the following construction elements:

- Tunnel underneath existing utilities in Vista Del Mar roadway.

- Excavation of soil and asphalt on north side of the gravity line valve structure.
- Shutdown and/or bypass of gravity line to the five-mile outfall.
- Install reducing tee into existing 102-inch secondary effluent gravity piping to mate with new brine piping.
- Replace soil and asphalt in yard.

Option 4: EPP Discharge Piping Cleanout

As mentioned previously, connecting at this location would require installation a 144-inch tee on top of the existing access port with the branch facing to the south. The new brine piping could then connect to the side branch at or above grade. This method would only require a brief shutdown of the five-mile outfall and EPP to complete. It also requires the least complex construction methods to complete.

Option 5, 6, and 7: One and/or Five-Mile Outfalls

The following three options for tying into the existing one and five-mile outfalls require significant beach excavation. The sub-options for the one and five-mile outfalls are grouped together as discussion is similar for both. Additionally, it is noted that discussion for Option 7 is identical, as it is a combination of any of the sub-options for Option 5 and 6 (e.g., 5a, 5b, etc.).

Both outfalls are 12-foot diameter, RCP, buried approximately 35-feet below the surface of the beach. The outfall piping must be taken out of service for a condition assessment prior to commencement of construction. Because of the age and material of the outfalls, taking it out of service during construction is suggested to reduce risk. As noted in previous sections, this analysis assumes the existing outfall piping is in good condition. Significant risk including cost, schedule, and overall technical feasibility is encountered without a detailed condition assessment of the outfalls, which is beyond the scope of this study.

As described in previous sections, excavation and construction on Dockweiler State Beach has substantial permitting requirements and must be started and completed within a dedicated time period to reduce environmental impacts.

Option 5a and 6a: Existing Manhole

Both outfalls include several existing 36-inch manhole hatches that can be removed to provide a connection location for the new brine piping. As discussed previously, it may be necessary to split the brine flow to two existing manholes locations which would require an additional excavation location, possibly within the ocean.

As stated above, the one mile outfall does not have a manhole within the beach (i.e., closest manhole is west of MHT). In addition to construction challenges, continued operational challenges would result as this location is difficult to access.

__Option 5b: Doghouse Manhole__

The following construction elements should be considered when evaluating this option:

- This connection is applicable to the one-mile outfall only.
- Heavy regulatory presence for beach construction could significantly impact schedule and costs.
- Deep excavation on the beach will require extensive dewatering efforts and shoring.
- Outfall piping must be taken out of service during construction.
- Supporting underneath existing outfall piping involves high risk.

As noted in Section 3.1, this alternative is not feasible for the pumped five-mile outfall, which would produce pressures greater than recommended for the doghouse manhole.

Option 5c and 6c: Core Drill

As discussed in Section 3.1, construction activities for this option include dewatering the location and core drilling into the existing pipe. Core drilling involves the use of a special drill to remove a cylinder of the existing RCP pipe to connect the propose pipeline to. The primary concern when cutting or drilling into an RCP pipe of this size and age, is the reduction in hoop stresses associated with cutting rebar, which could cause catastrophic failure of the existing outfall. Engineered solutions, such as full concrete encasement of the affected areas, can be used to mitigate this risk.

3.4.2 Modifications to HWRP

Depending on the chosen connection point and construction method, the following existing HWRP elements will require modification to achieve compatibility with high salinity brine:

- EPP Wetwell: Install liner within wetwell to preserve integrity of concrete.
  - For Options 1 and 2.
- EPP: Replace EPP pumps, suction and discharge piping, and all associated valves and appurtenances.
  - For Options 1 and 2.
- Effluent Junction Box: Install liner within junction box to preserve integrity of concrete; install new SST sluice gates.
  - For Option 2.

- Five-mile outfall: New manhole, new tee, or modifications to existing manhole.
  - For Options 5, 6, and 7.
- One-mile outfall: New manhole, new tee, or modifications to existing manhole.
  - For Options 5, 6, and 7.

Additionally, substantial site construction north of the EPP is required to route the brine piping to the connection location for Options 1, 2, 3 and 4. This site construction is needed to cross the crowded piping corridor that was described in previous sections.

3.4.3 Feasible Pipeline Alignments to HWRP

Three potential pipeline routes were identified and described in section 3.2; Vista Del Mar Boulevard alignment, Dockweiler State Beach alignment, and parking area alignment.

Due to congested utilities in the roadway, advanced construction techniques such as conventional tunneling will be required to install the large diameter brine pipeline from ESGS to HWRP via the Vista Del Mar Boulevard alignment option. Conventional tunneling is a method for excavating a tunnel using a tunnel boring machine (TBM). It is a two pass process; first a 60-inch to 72-inch diameter steel casing is installed; second, a 54-inch carrier pipe is installed within the casing. Challenges for tunneling include:

- Traffic control measures and location restrictions for location of sending/receiving pits.
- Risk associated with tunneling underneath high pressure gas line. Special safety precautions must be used to ensure no rupture of the high pressure line.
- Significant tunnel depth needed for adequate clearance of vehicle tunnel and large diameter water pipes.

Further investigation of subsurface utilities and substantial permitting controls are required for the Dockweiler State Beach alignment. These stipulations can cause an increase in the overall design and construction complexity for this alignment option; however, this would not affect overall technically feasibility. Similarly, the parking area alignment also requires further investigation of subsurface utilities, but is likely a technically feasible pipeline route.

3.4.4 Pumping Alternatives

Depending on the location of the desalination facility (ESGS south or ESGS north), the PMP noted that brine pumping may be required. Additionally, the connection and configuration of the brine piping could impact pumping requirements. To determine the extent of that impact, the head loss in the pipeline would require further analysis.

3.4.5 Additional Construction/Operational Challenges

As described in previous subsections, construction activities for all of the connection locations and pipeline routes that have been presented will require a high degree of skill, specialized methods, and construction sequencing to achieve; this is particularly true for connection locations involving altering the existing outfall pipelines, as the material and age involves significant risk.

Beach construction is subject to many regulations and permits, may have seasonal construction restrictions due to protected wildlife, and has high public awareness due to beach closures affecting the community. Construction and routine maintenance activities may need to work around certain restrictions, which could increase construction and maintenance duration and cost.

3.5 Regulatory Analysis

The requirements for construction and operations and maintenance of the brine disposal pipeline from ESGS to HWRP involves obtaining permits from several different agencies, as described in previous sections.

Additionally, the discharge of brine to the ocean through the existing HWRP ocean outfall would be subject to requirements of HWRP's permitting program, (e.g., amended NPDES permit) and the California Ocean Plan Amendments (OPA). HWRP is subject to the following NPDES permit: Order No. R4-2010-0200, NPDES No. CA0109991. The OPA is further discussed in the following sections, and NPDES dilution requirements are discussed under regulatory compliance below.

Further discussions with HWRP representatives would be needed to confirm whether the programs and permits in place could accept the brine without requiring further detailed studies and permitting.

3.5.1 California Ocean Plan Amendments

The California SWRCB and the nine RWQCB are delegated the responsibility for administering permitted discharge into the coastal marine waters of California under the federal Clean Water Act. As guidance to their discharge permitting authority, the SWRCB prepares and adopts the Quality Control Plan for Waters of California (Ocean Plan), which establishes water quality standards that apply to ocean waters within the State's jurisdiction.

The SWRCB adopted Amendments to the Ocean Plan Addressing Desalination Facility Intakes, Brine Discharges, and the Incorporation of Other Non-substantive Changes (OPA) on May 6, 2015.

The process for the RWQCB to make a Water Code Section 13142.5(b) determination first includes analyzing a range of feasible alternatives for the best site, design, technology, and mitigation measures as separate factors. Then all four of these factors are considered collectively to determine the best combination of feasible alternatives to minimize the mortality of all forms of marine life.

Technology is referred to by the OPA as the type of equipment, materials, and methods used to construct and operate the design components of a desalination facility. The OPA requires an evaluation to determine the “best available technology feasible” to minimize mortality of all forms of marine life. The OPA specifies particular criteria for determining the best available technology feasible for desalination facility brine discharges as described in the following section.

3.5.1.1 Brine Discharge Requirements

The brine discharge must be designed so that the brine mixing zone does not adversely affect sensitive habitat, the discharge does not result in negatively-buoyant plumes, and minimizes the suspension of benthic sediments. The OPA first requires an analysis of the potential to commingle the brine discharge with existing wastewater discharge if there is adequate wastewater flow for sufficient salinity dilution and it would not preclude future recycling of the wastewater. It should also be noted that the OPA requires that brine discharges not exceed a daily maximum of 2.0 ppt above natural background salinity at 100 meters horizontally from each discharge point.

3.5.1.2 Mitigation Measures

Mitigation is the replacement of all forms of marine life or habitat lost due to construction and operation of a desalination facility. The OPA requires that the best available mitigation measures feasible to minimize mortality of all forms of marine life after utilizing the best available site, design, and technology feasible. The level of mitigation required is determined by submitting a Marine Life Mortality Report to the RWQCB for construction (e.g., disturbance of habitat) and operation (e.g., entrainment and elevated salinity) of the desalination facility brine discharge. The Marine Life Mortality Report will translate the mitigation requirement to the area of production foregone (APF) and will mitigate these impacts through a mitigation project of fee-based mitigation program.

3.5.1.3 Monitoring and Reporting Programs

Under the OPA, a Monitoring and Reporting Plan must be submitted to the RWQCB to determine the baseline biological conditions before and after construction and operation of the desalination facility. The Monitoring and Reporting Plan must include monitoring for benthic health, aquatic life toxicity, hypoxia, and receiving water characteristics to demonstrate compliance with receiving water limitations (including for salinity).

3.5.2 Water Quality Evaluation

Brine from a RO desalination process typically contains monovalent ions that do not scale or deposit; however, the concentrated brine is highly saline. High salinity brine is very corrosive, as discussed in previous sections of this report. Considerations for commingling a high-salinity flow with a low salinity flow (i.e., wastewater effluent) include providing adequate mixing for proper dilution and a full analysis on the complex mixing chemistry of the resulting water. A mixing analysis is recommended to provide additional detail on the potential water quality issues that may result.

3.5.3 Buoyant vs Dense Plumes

Plume density is a key consideration for discharge of brine into the ocean and is discussed in the OPA requirements for brine disposal. Most of the Pacific Ocean has a salinity between 34 ppt and 36 ppt. The salinity of the brine is significantly more dense than seawater and is anticipated to be approximately 68 ppt. Dense plumes sink to the ocean floor where there is less mixing from ocean currents and wave action, thereby posing environmental hazards to marine life.

Sufficient mixing of the wastewater effluent and the brine is critical to produce a homogenous plume that will mix thoroughly with seawater. This will be discussed further based on the results of the Hydrodynamic modeling which were not complete at the time of this draft report.

3.5.4 Future HWRP Regulations

The severe droughts are pushing California to move aggressively toward a more sustainable water future. The SWRCB issued a policy to mandate the use of recycled water in California by 200,000 afy by 2020 and by an additional 300,000 afy by 2030[10]. This policy will impact the availability of wastewater flows for the purpose of commingling brine from desalination plants; the increase in recycled water will decrease the amount of wastewater needed to be discharged, thus decreasing the amount available for brine dilution.

3.5.5 Regulatory Compliance

According to the NPDES permit (No. CA-0109991, Order No. 94-021), the required minimum initial dilution of the five-mile outfall is 84 to 1, (CRWQCB, 1994). During the period 1980-2004, the maximum wastewater discharge rate from the five-mile outfall was 566 mgd; and the minimum was 203 mgd, with an average discharge rate of 352 mgd.

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[10] State Water Resources Control Board, Policy for Water Quality Control for Recycled Water (Recycled Water Policy), April 25, 2013.

4.0 HYDRODYNAMIC MODELING

Critical study objectives to be evaluated through hydrodynamic modeling are:

1. The initial dilution rates of the present outfall diffuser design and its ability under normal operating conditions to accept additional brine effluent and combine it with highly variable waste water flow rates and still satisfy the initial dilution requirements of the existing NPDES permit;

2. The ability of the existing outfall diffuser design to satisfy under emergency conditions the new water quality objectives for brine discharges under the amended California Ocean Plan.

Hydrodynamic modeling considered a range of flows from HWRP and the proposed desalination brine. Ocean water desalination brine was considered at 21 mgd and 63 mgd for 20 mgd and 60 mgd OWDFs, respectively, for each HWRP flow scenario. HWRP flow scenarios are defined as follows:

- Scenario No. 1 (future low flow) - 10 mgd brackish brine from advanced water treatment facilities (AWTFs).
- Scenario No. 2 (current low flow) - 90 mgd secondary effluent.
- Scenario No. 3 (current average flow) - 203 mgd secondary effluent.
- Scenario No. 4 (historical average flow) - 250 mgd secondary effluent.
- Scenario No. 5 (peak flow under storm condition) - 657 mgd secondary effluent.

The above HWRP flow scenarios were selected to cover the full spectrum of anticipated flows at HWRP, from future low flow to peak flow conditions. Future low flow condition is described in section 2.2.1.2 above.

Hydrodynamic modeling scenarios are summarized in Table 5.

Table 5 Hydrodynamic Modeling Scenarios
Ocean Water Desalination Discharge Feasibility Study
West Basin Municipal Water District

Discharge Location	Brine Flow (mgd)	Brine Concentration (ppt)	Wastewater Flow (mgd)
Five-mile Outfall			
Scenario No. 1 (future low flow)	21 63	67.84	10
Scenario No. 2 (current low flow)	21 63	67.84	90
Scenario No. 3 (current average flow)	21 63	67.84	203
Scenario No. 4 (historical average flow)	21 63	67.84	250
Scenario No. 5 (peak flow)	21 63	67.84	657
One-mile Outfall			
Scenario No. 1 (future low flow)	21 63	67.84	10
Scenario No. 2 (current low flow)	21 63	67.84	90
Scenario No. 3 (current average flow)	21 63	67.84	203
Scenario No. 4 (historical average flow)	21 63	67.84	250
Scenario No. 5 (peak flow)	21 63	67.84	657

Refer to Appendix C for full results of the hydrodynamic modeling performed for this study. Results of the hydrodynamic modeling are summarized in the following subsections.

4.1 Five-Mile Outfall Hydrodynamic Modeling Results

For the five-mile outfall all hydrodynamic modeling scenarios defined in Table 5 above satisfy discharge limits set forth under both the brine amendment of the Ocean Plan and the present NPDES permit for HWRP, with the exception of co-mingling OWDF brine with 10 mgd of brackish brine effluent from the Hyperion Water Reclamation Plant (Scenario No. 1). When either 21 mgd or 63 mgd of West Basin brine is added to the

10 mgd of brackish brine from the Hyperion Water Reclamation Plant, the combined effluent becomes negatively buoyant. In either case, the combined brine effluent will not dilute to within 2 ppt of natural background salinity within 100 m from the point of discharge, in violation of the provisions of the amended Ocean Plan (SWRCB 2015). However, dilution continues beyond 100 m from the discharge point and reaches the value of Dm = 84 to 1 required by the present NPDES permit at distances between 213 m and 340 m. Therefore, a determination of consistency with both new and existing discharge standards is uncertain for this anticipated future low-flow condition.

4.2 One-Mile Outfall Hydrodynamic Modeling Results

For the one-mile outfall, all hydrodynamic modeling scenarios defined in Table 5 above satisfy discharge limits set forth under both the brine amendment of the Ocean Plan and the present NPDES permit for HWRP, with the exception of commingling OWDF brine with 10 mgd of brackish brine effluent from the HWRP (Scenario No. 1). When either 21 mgd or 63 mgd of West Basin brine is added to the 10 mgd of brackish brine from the HWRP, the combined effluent becomes negatively buoyant. In either case, the combined brine effluent will not dilute to within 2 ppt of natural background salinity within 100 m from the point of discharge, in violation of the amended Ocean Plan (SWRCB 2015). However, dilution continues beyond 100 m from the discharge point and reaches the value of Dm = 13 to 1 required by the present NPDES permit at distances between 214 m and 513 m from the point of discharge. Therefore, a determination of consistency with both new and existing discharge standards is uncertain for this anticipated future low-flow condition.

5.0 ALTERNATIVE DEVELOPMENT

Based on the findings presented in this study, the majority of the connection points, with the exception of the doghouse manhole at the five-mile outfall, were carried forward to initial screening analysis.[11] The following list indicates the connection locations brought to initial screening:

- Option 1: EPP wetwell.
- Option 2: Effluent junction box.
- Option 3: Gravity line valve structure.
- Option 4: EPP discharge cleanout.

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[11] As discussed in previous sections, the intermittent pressurized operation of the five-mile outfall made it not technically feasible to use a doghouse style manhole.

- Option 5a: One-mile outfall - Existing manhole.
- Option 5b: One-mile outfall - New doghouse manhole.
- Option 5c: One-mile outfall - Core drill.
- Option 6a: Five-mile outfall - Existing manhole.
- Option 6c: Five-mile outfall - Core drill.
- Option 7: Combined Outfalls (i.e., one- and five mile outfalls).[12]

Additionally, the following pipeline alignments were evaluated and subjected to an initial screening analysis considering technical feasibility:

- Alignment 1: Vista Del Mar Boulevard alignment.
- Alignment 2: Dockweiler State Beach alignment.
- Alignment 3: Parking area alignment.

For the purposes of this study, it is assumed that any one of the technically feasible connection alternatives can be combined with any of the technically feasible pipeline route alternatives to generate a technically feasible discharge alternative. All of the above pipeline routes and connection locations were brought to the initial screening analysis.

6.0 INITIAL SCREENING ANALYSIS

The initial screening analysis provides a structured methodology to evaluate technical feasibility such that only technical feasible alternatives are further developed. Any alternatives surviving the screening analysis are subject to a non-technical analysis, considering social, environmental, and economic factors. While the design basis is developed for alternatives, initial screening criteria (i.e., based upon technical criteria) are considered. For this project, "feasibility" will be defined by industry standard procedures in California, as documented in the 2012 CEQA Statute and Guidelines. The act provides the following definition:

> *"Feasible" means capable of being accomplished in a successful manner within a reasonable period of time, taking into account economic, environmental, social, and technological factors."*

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[12] Option 7 not formally carried into initial screening. However, for the purposes of this study, any technically feasible option using the one-mile outfall (i.e., Option 5) can be combined with any technically feasible option using the five-mile outfall (i.e., Option 6) to produce a technically feasible combined outfall option (i.e., Option 7).

The technical factors are the starting point to determine if each discharge alternative should be further considered for evaluation - e.g., before economic, environmental, and social factors are considered in this study. Desalination plant discharge alternatives that are judged to have technical feasibility criteria in conflict with the project objectives were not considered further in this study. Therefore, each discharge alternative was categorized as:

1. Not feasible (NF),
2. Potentially feasible (PF).

For the purposes of this study, "Initial Screening Criteria" was defined as follows:

> Initial Screening Criteria: *Those technical factors that would not allow a full-scale system to be successfully constructed or operated, would result in a high risk of failure or unacceptable performance, per Study goals.*

For the purposes of this study, it was assumed that any combination of technically feasible alternatives could be combined with another technically feasible alternative to provide operational flexibility (i.e., provide access to both one- and five-mile outfalls using two connection options). Thus, alternatives were not deemed technically infeasible if they did not allow access to both outfalls.

6.1 Initial Screening Results

Table 6 and Table 7 present the initial screening criteria definitions and results for the connection locations and pipeline route alternatives, respectively:

As indicated by the results of the initial screening analysis, that are summarized in Table 6 and Table 7, all of the connection points and two of the pipeline routes considered in this study were determined to be infeasible based upon the study objectives.. These findings are the result of the analysis of key technical factors and hydrodynamic modeling presented previously in Sections 3.0, 4.0, and 5.0.

Failure to pass initial screening for connection alternatives and alignments is explained further in the following subsections.

Table 6 **Initial Screening Results for Ocean Water Desalination Connection Location Alternatives**
Ocean Water Desalination Discharge Feasibility Study
West Basin Municipal Water District

		Ocean Water Desalination Connection Location Alternative								
		Option 1	**Option 2**	**Option 3**	**Option 4**	**Option 5a**	**Option 5b**	**Option 5c**	**Option 6a**	**Option 6c**
	Initial Screening Criteria	**EPP Wetwell**	**Effluent Junction Box**	**Gravity Line Valve Structure**	**EPP Discharge Piping Cleanout**	**One-Mile Existing Manhole**	**One-Mile New Manhole**	**One-Mile Core Drill**	**Five-Mile Existing Manhole**	**Five-Mile Core Drill**
1	**Piping Material and Appurtenances**									
a.	Piping and appurtenances for transporting high salinity brine can be designed.	PF	PF	PF	PF	PF	PF	PF	PF	PF
b.	Existing infrastructure at HWRP and connection location are compatible with high salinity brine and do not require significant modification to perform reliably.	NF	NF	PF	PF	PF(1)	PF(1)	PF(1)	PF(1)	PF(1)
2	**HWRP Capacity**									
a.	HWRP existing outfall capacity is sufficient to receive 20 mgd (or 60 mgd at build-out) of brine.	PF	PF	PF	PF	PF	PF	PF	PF	PF
b.	HWRP existing outfall diffuser system provides enough mixing to be used with desalination brine (low- vs. high-density plumes).	PF	PF	PF	PF	PF	PF	PF	PF	PF
c.	Tie-in point at HWRP existing infrastructure results in undesired consequences, such as salting out at the confluence, corrosion, and/or congestion.	PF	PF	PF	PF	PF	PF	PF	PF	PF
3	**Construction and Operation**									
a.	Construction at the connection point and modifications to HWRP existing infrastructure are constructible.	PF	PF	PF	PF	PF(1)	PF(1)	PF(1)	PF(1)	PF(1)
b.	Operation and maintenance of the brine and HWRP secondary effluent discharge is sustainable.	PF	PF	PF	PF	PF(1)	PF(1)	PF(1)	PF(1)	PF(1)
4	**Regulatory Aspects**									
a.	Current regulations would not allow discharge alternative to be permitted and/or operated under current HWRP flow conditions.	PF	PF	PF	PF	PF	PF	PF	PF	PF
b.	Future regulations or modifications to HWRP would not allow alternative to be permitted and/or operated under current HWRP flow conditions.	PF	PF	PF	PF	PF	PF	PF	PF	PF
c.	Current regulations would not allow discharge alternative to be permitted and/or operated under future HWRP flow conditions.	NF	NF	NF	NF	NF	NF	NF	NF	NF
d.	Future regulations or modifications to HWRP would not allow alternative to be permitted and/or operated under future HWRP flow conditions.	NF	NF	NF	NF	NF	NF	NF	NF	NF
Passes Initial Screening? Yes (Y) or No (N)		**N**	**N**	**N**	**N**	**N**	**N**	**N**	**N**	**N**

Notes:

(1) Potentially feasible assuming good condition of existing outfall. Alternative may not be feasible with results from a detailed condition assessment.

Table 7	**Initial Screening Results for Ocean Water Desalination Pipeline Alignment Alternatives Ocean Water Desalination Discharge Feasibility Study West Basin Municipal Water District**		

		Ocean Water Desalination Pipeline Alignment Alternative		
	Initial Screening Criteria	**Alignment 1: Vista Del Mar**	**Alignment 2: Dockweiler State Beach**	**Alignment 3: Parking Area**
1	**Pipeline Routing**			
a.	Sufficient horizontal space for new brine piping.	PF	PF	PF
b.	Pipeline shall not encroach on easements, sensitive habitat(s), or other factors.	PF	PF(1)	PF(1)
2	**Construction and Operation**			
a.	Constructing around existing utilities is achievable.	PF	PF	PF
b.	Additional construction/operational challenges: Permits for construction can be obtained in a manner in which predictability of the outcome is successful.	PF	NF	NF
Passes Initial Screening? Yes (Y) or No (N)		**Y**	**N**	**N**

Notes:

(1) Potentially feasible using information given at time of study. As presented in Section 3.3, additional permitting, potholing, restrictions, etc. may result in this alternative being deemed not feasible under this initial screening criteria.

6.1.1 Connection Alternatives

All connection alternatives were determined to be "not feasible" based upon this study's initial screening criteria. Information supporting the determination of connection alternatives to be “not feasible” (NF) during initial screening is presented in Table 8 below.

Table 8 **Initial Screening Supporting Information: Connection Alternatives**
Ocean Water Desalination Discharge Feasibility Study
West Basin Municipal Water District

No.(1)	**Description**	**Discussion**(2)
4c, 4d	Regulatory Aspects	• As presented in Sections 4.1 and 4.2, comingling OWDF brine with future HWRP low flows does not meet NPDES and Ocean Plan Amendment permit requirements.

Notes:

(1) Corresponds to initial screening criteria number listed in Table 6.
(2) Definitions of initial screening criteria are present in Table 6.

Where a pipeline alignment alternative was determined to be "not feasible" based upon this study's initial screening criteria, this failure to pass initial screening is explained further in Tables 9 and 10, below. Discussion is grouped by the alignment alternative and the initial screening criteria presented in Table 7.

6.1.2 Alignment 2: Dockweiler State Beach

Information supporting the determination of this alignment to be “not feasible” (NF) during initial screening is presented in Table 9 below.

Table 9 **Initial Screening Supporting Information: Dockweiler State Beach Alignment**
Ocean Water Desalination Discharge Feasibility Study
West Basin Municipal Water District

No.(1)	**Description**	**Discussion**(2)
2b	Construction and Operation	• As presented in Section 3.3 and 3.5, there are many permitting procedures involved with this option that do not have predictable results. The permitting process must predictably result in a permit that allows the project to be constructed in the time frame necessary to complete the construction.

Notes:

(1) Corresponds to initial screening criteria number listed in Table 7.
(2) Definitions of initial screening criteria are present in Table 7.

6.1.3 Alignment 3: Parking Area Alignment

Information supporting the determination of this alignment to be "not feasible" (NF) during initial screening is presented in Table 10 below.

Table 10 **Initial Screening Supporting Information: Parking Area Alignment**
Ocean Water Desalination Discharge Feasibility Study
West Basin Municipal Water District

No.[1]	Description	Discussion[2]
2b	Construction and Operation	• As presented in Section 3.3 and 3.5, there are many permitting procedures involved with this option that do not have predictable results. The permitting process must predictably result in a permit that allows the project to be constructed in the time frame necessary to complete the construction.

Notes:
(1) Corresponds to initial screening criteria number listed in Table 7.
(2) Definitions of initial screening criteria are present in Table 7.

7.0 NON TECHNICAL FEASIBILITY EVALUATION

Considering that no combination of connection alternatives and pipeline alignments was determined to be potentially feasible, non-technical feasibility evaluation was not performed.

8.0 CONCLUSION

This report summarized a technical feasibility analysis performed for commingling brine from the proposed OWDF with secondary effluent from HWRP and using one (or both) of the existing ocean outfalls. Various connection locations and pipeline route alternatives were proposed and analyzed in areas of technical feasibility. Hydrodynamic modeling was used to assess the mixing and dilution in the outfall, and in the ocean waters within close proximity to the discharge nozzles. Results of the analysis were used to inform an initial screening analysis, which deemed alternatives potentially feasible or not feasible.

Overall, all of the connection locations and two of the pipeline routes were found to be infeasible considering regulatory requirements associated with future HWRP low flow conditions. Several of the connection alternatives only were able to use one of the two outfalls at HWRP. Since HWRP currently operates both intakes (one-mile only intermittently during maintenance and emergencies as described previously), it would be necessary to combine certain alternatives to provide operational flexibility to discharge to both intakes. Since the proposed OWDF is a base loaded facility, it could not be shut down during times where the five-mile intake was unavailable. As described in this study, connection to these locations is technically infeasible, considering regulatory requirements associated with future flows.

It is further noted that one pipeline alignment was determined to be technically feasible. This feasible pipeline alternative would, however, need to be combined with a technically feasible connection alternative in order to provide an overall technically feasible HWRP discharge alternative for OWDF brine. Considering that no connection alternatives were determined to be feasible given regulatory requirements, an overall technically feasible HWRP discharge alternative for OWDF brine has not been identified. This study concludes that comingling brine with HWRP effluent to be technically infeasible given regulatory requirements, future HWRP low flows, and current outfall diffuser configuration.

APPENDIX A – FIELD WALK PHOTOGRAPHS

BA, Inc.
MBE/DBE/SBE

800 W. 6th Street, Ste. 400
Los Angeles, CA 90017
T. 213.622.2100 F: 213.622.7330

www.baincorp.com

EXHIBIT C:
WEST BASIN OCEAN WATER DESALINATION DISCHARGE FEASIBILITY STUDY
FIELD WALK PHOTOS

Photo 1: Chevron Storage, South of NRG Energy, Looking North

Photo 2: North side of NRG Energy meets South end of Dockweiler State Beach Looking North

Photo 3: Chevron Entrance
Looking South

Photo 4: Vista Del Mar Boulevard from Chevron Entrance
Looking South

Photo 5: Vista Del Mar Boulevard from Chevron Entrance
Looking North

Photo 6: Department of Water and Power, Scattergood Steam Plant
Looking South

Photo 7: Dockweiler State Beach
Looking South

Photo 8: Dockweiler State Beach Parking Lot
Looking North

Photo 9: Dockweiler State Beach Community Center
Looking North

Photo 10: Dockweiler State Beach, from the Community Center
Looking South

Photo 11: Dockweiler State Beach
Looking South

Photo 12: Hyperion Ocean Outfall
Looking West

Photo 13: Dockweiler State Beach Parking Lot
Looking South

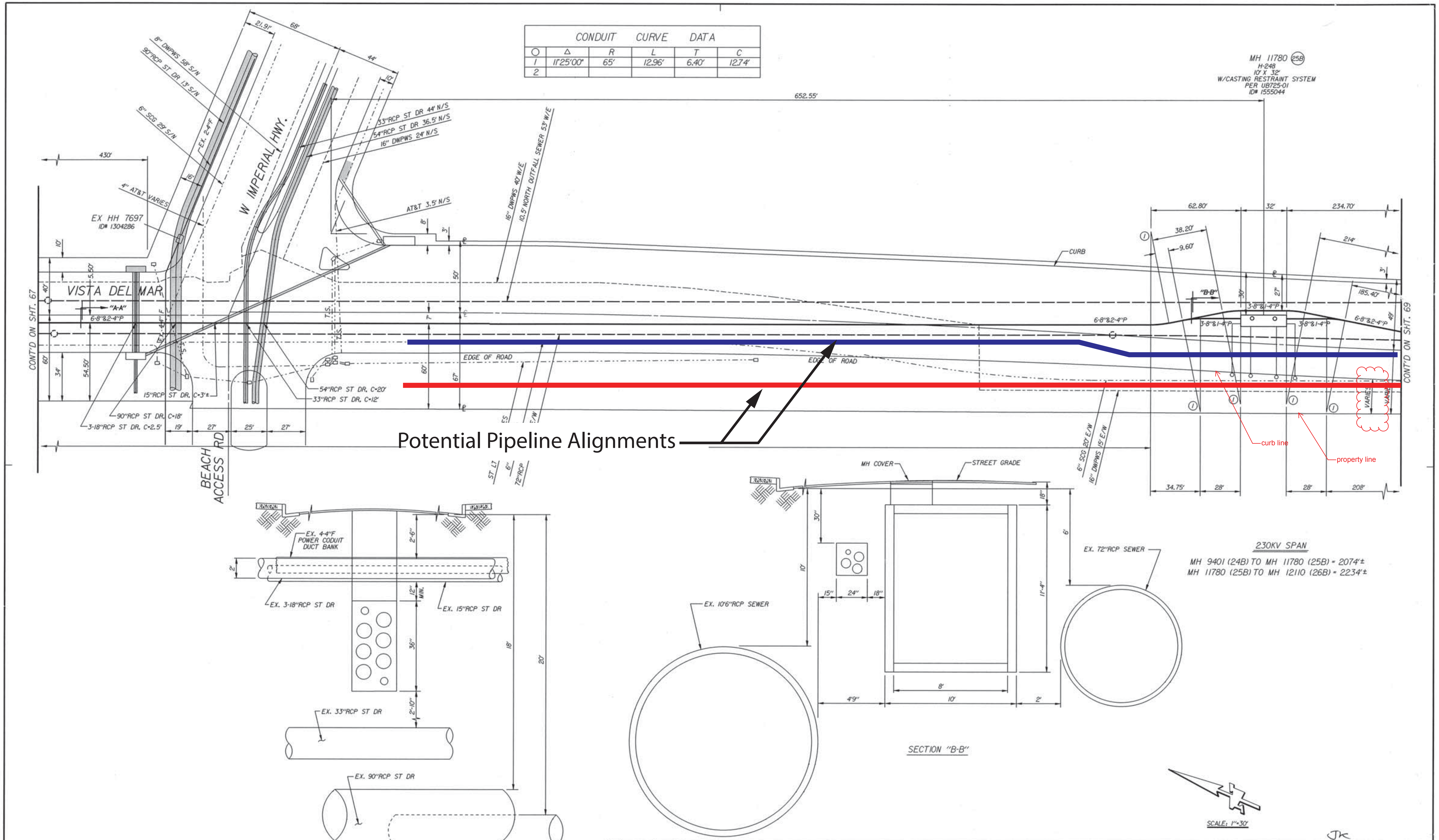
Photo 14: Vista Del Mar Boulevard,
from Dockweiler Community Center Parking Entrance
Looking South

Photo 15: Vista Del Mar Boulevard,
From Dockweiler Community Center Parking Entrance
Looking North

Photo 16: Hyperion Water Reclamation Plant,
From Dockweiler Community Center
Looking North East

APPENDIX B – VISTA DEL MAR ALIGNMENT SUPPORTING INFORMATION

CONDUIT CURVE DATA					
○	Δ	R	L	T	C
1	11°25'00"	65'	12.96'	6.40'	12.74'
2					



230KV SPAN
MH 9401 (24B) TO MH 11780 (25B) = 2074'±
MH 11780 (25B) TO MH 12110 (26B) = 2234'±

SCALE: 1"=30'

JK

REV. NO.	REV. DATE	INIT'L.	REVISION DESCRIPTION	APPV.	TAT NO.

DRAWING CIRCULATION					
PRELIM.			FINAL		
ENG'R 4	WOD	1	ENG'R 2	VGS	1
SP(MW) 2			SP(MW) 5	WOD	1
D(WL) 2			D(WL) 6		
DSP 1			COE 1		
EP 5			DDFT 1		
MFGR 2			DSP 1		
VGS 1			LSMS 2		

Darrell Kalani Tom
No. C035571
Exp. 9/30/13
CIVIL

SERVICE CENTER JOB LOCATION WLA
SERVICE CENTER CONSTRUCTION WLA

CITY OF LOS ANGELES
DEPARTMENT OF
WATER AND POWER
DISTRIBUTION ENGINEERING SECTION

DESIGN D. PALMER
DRAFTING AOS/PV
CHECKER D. PALMER
OK
APPROVED Darrell K.
DATE 8/30/12

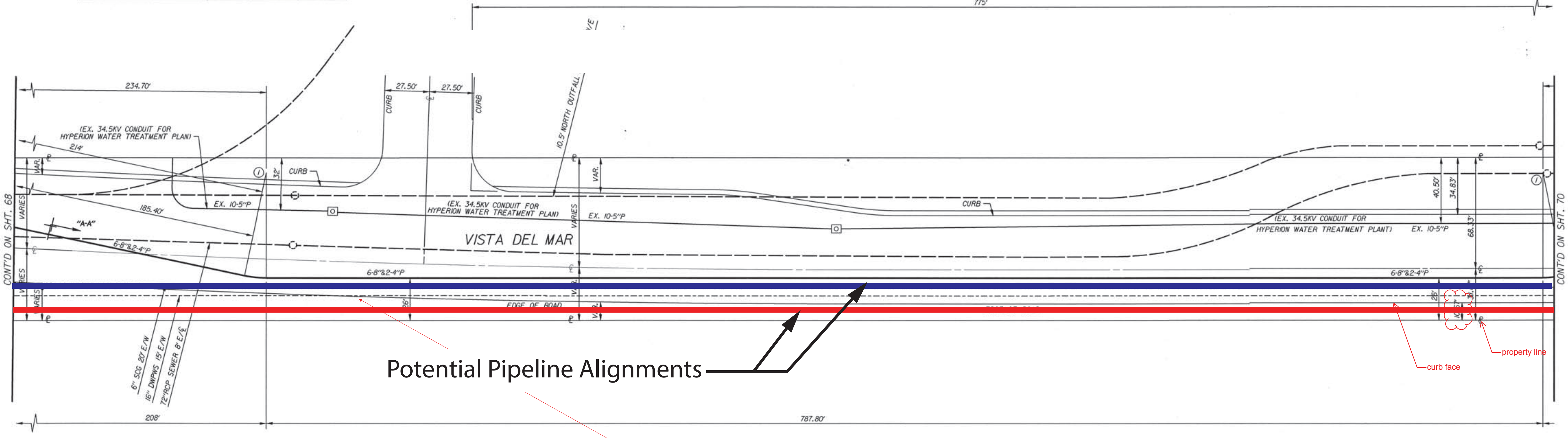
WR #:	CONST #:	PROJECT #:	NON-CONST #:
822768	KYV99	P240974	KYV86

230KV CONDUIT REQUIREMENT
1840 CENTINELA AV.
RS "K"
FROM RS "K" TO SCATTERGOOD

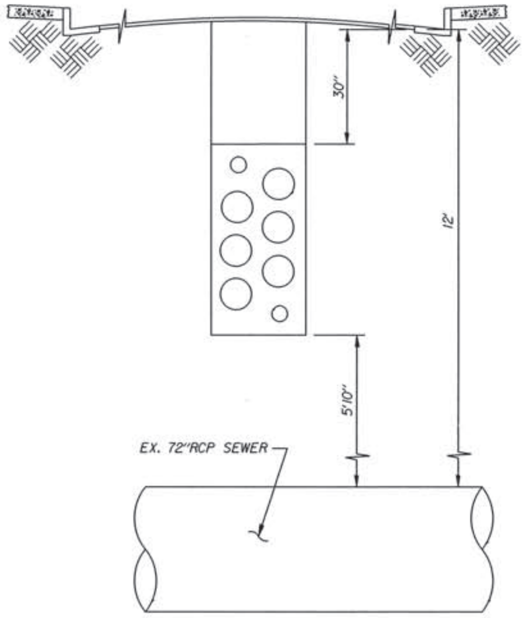
08H5039 SHEET 68 OF 77

CONDUIT CURVE DATA

○	Δ	R	L	T	C
1	11°15'00"	65'	12.96'	6.40'	12.74'
2					



Potential Pipeline Alignments



SECTION "A-A"
6-8" & 2-4"P

Looking North

this could be the trench for the existing 16-inch waterline (DWP)

About 10' of right-of-way beyond the curb

SCALE: 1"=30'

JK

REV. NO.	REV. DATE	INIT'L.	REVISION DESCRIPTION	APPV.	TAT NO.

DRAWING CIRCULATION

PRELIM.				FINAL			
ENG'R	4	WOD	1	ENG'R	2	VGS	1
SP(MW)	2			SP(MW)	5	WOD	1
D(WL)	2			D(WL)	6		
DSP	1			COE	1		
EP	5			DDFT	1		
MFGR	2			DSP	1		
VGS	1			LSMS	2		

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SERVICE CENTER CONSTRUCTION WLA

CITY OF LOS ANGELES
DEPARTMENT OF
WATER AND POWER
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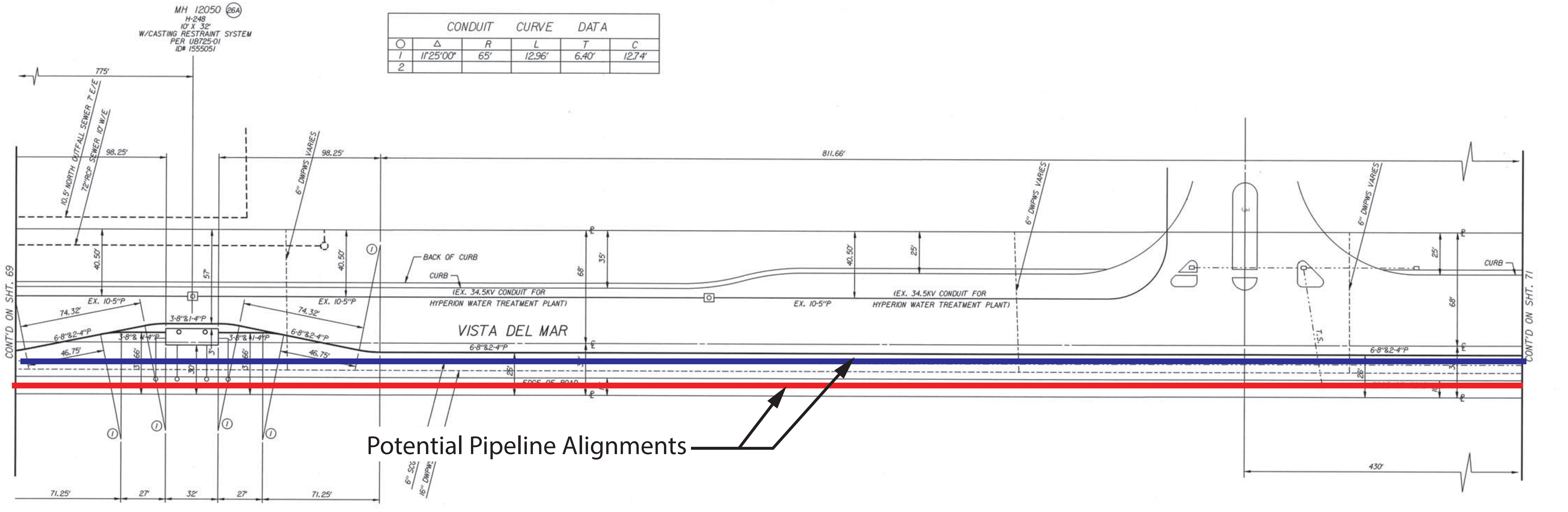
DRAFTING AOS/PV
CHECKER D. PALMER
OK
APPROVED
DATE 8/30/12

WR #	CONST #	PROJECT #	NON-CONST #
822768	KYV99	P240974	KYV86

230KV CONDUIT REQUIREMENT
1840 CENTINELA AV.
RS "K"
FROM RS "K" TO SCATTERGOOD

08H5039 SHEET 69 OF 77

CONDUIT CURVE DATA					
○	Δ	R	L	T	C
1	11°25'00"	65'	12.96'	6.40'	12.74'
2					



230KV SPAN
MH 9575 (25A) TO MH 12050 (26A) = 2376'±
MH 12050 (26A) TO MH 12400 (27A) = 2136'±

SCALE: 1"=30'

JK

REV. NO.	REV. DATE	INIT'L.	REVISION DESCRIPTION	APPV.	TAT NO.

DRAWING CIRCULATION							
PRELIM.				FINAL			
ENG'R	4	WOD	1	ENG'R	2	VGS	1
SP(MW)	2			SP(MW)	5	WOD	1
D(WL)	2			D(WL)	6		
DSP	1			COE	1		
EP	5			DDFT	1		
MFGR	2			DSP	1		
VGS	1			LSMS	2		

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No. C035571
Exp. 9/30/13
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SERVICE CENTER JOB LOCATION WLA	SERVICE CENTER CONSTRUCTION WLA
CITY OF LOS ANGELES DEPARTMENT OF WATER AND POWER DISTRIBUTION ENGINEERING SECTION	
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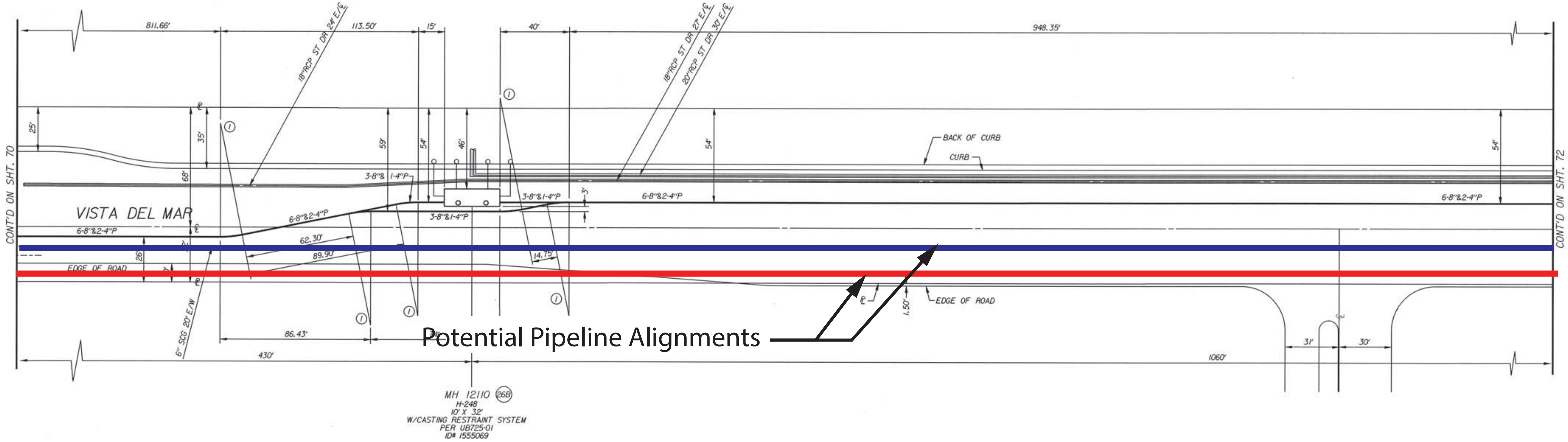
OK	CHECKER D. PALMER
APPROVED DarrellKL	DATE 8/30/12

WR #	CONST #	PROJECT #	NON-CONST #
822768	KYV99	P240974	KYV86

230KV CONDUIT REQUIREMENT
1840 CENTINELA AV.
RS "K"
FROM RS "K" TO SCATTERGOOD

08H5039 SHEET 70 OF 77

CONDUIT CURVE DATA					
○	Δ	R	L	T	C
1	11°15'00"	65'	12.96'	6.40'	12.74'
2					



230KV SPAN

MH 1178 (25B) TO MH 12110 (26B) = 2234'±
MH 12110 (26B) TO MH 12740 (27B) = 2182'±

SCALE: 1"=30'

JK

REV. NO.	REV. DATE	INIT'L.	REVISION DESCRIPTION	APPV.	TAT NO.

DRAWING CIRCULATION							
PRELIM.				FINAL			
ENG'R	4	WOD	1	ENG'R	2	VGS	1
SP(MW)	2			SP(MW)	5	WOD	1
D(WL)	2			D(WL)	6		
DSP	1			COE	1		
EP	5			DDFT	1		
MFGR	2			DSP	1		
VGS	1			LSMS	2		

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No. C035571
Exp. 9/30/13
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SERVICE CENTER CONSTRUCTION WLA

CITY OF LOS ANGELES
DEPARTMENT OF
WATER AND POWER
DISTRIBUTION ENGINEERING SECTION

DESIGN D. PALMER
DRAFTING AOS/PV
CHECKER D. PALMER
OK
APPROVED Darrell K T
DATE 8/30/12

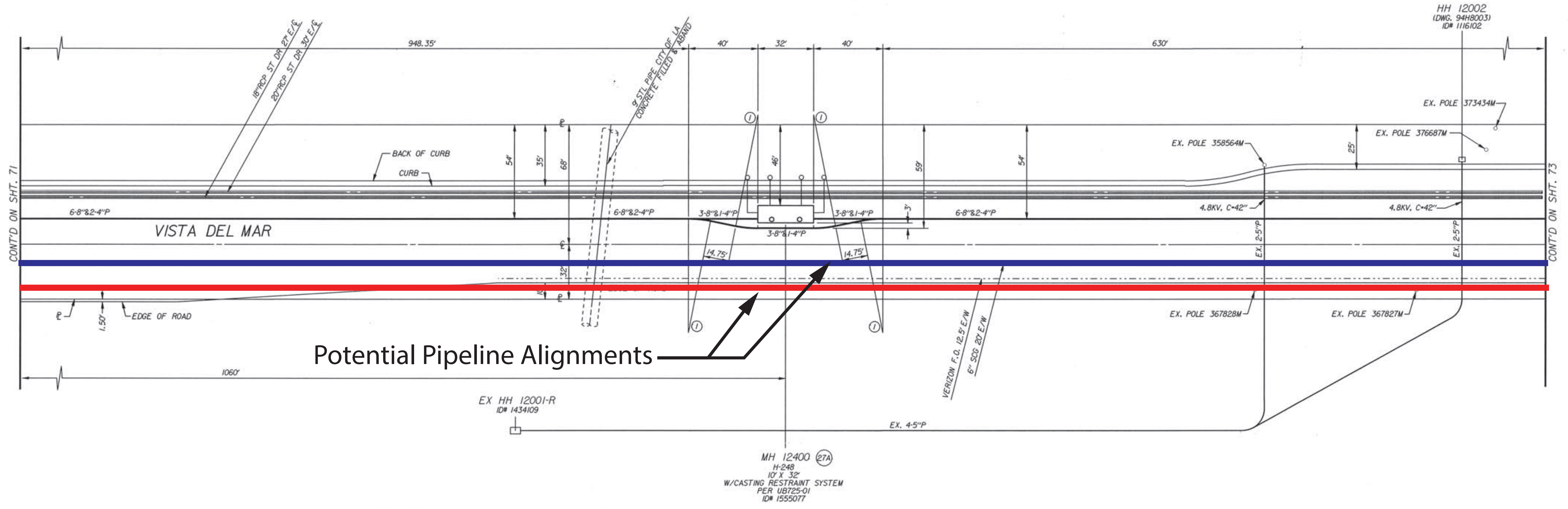
WR #: 822768
CONST #: KYV99
PROJECT #: P240974
NON-CONST #: KYV86

230KV CONDUIT REQUIREMENT
1840 CENTINELA AV.
RS "K"
FROM RS "K" TO SCATTERGOOD

08H5039

SHEET 71 OF 77

CONDUIT	CURVE	DATA			
○	Δ	R	L	T	C
1	11°25'00"	65'	12.96'	6.40'	12.74'
2					



230KV SPAN

MH 12050 (26A) TO MH 12400 (27A) = 2136'±
MH 12400 (27A) TO MH 7540 (28A) = 2153'±

SCALE: 1"=30'

JK

REV. NO.	REV. DATE	INIT'L.	REVISION DESCRIPTION	APPV.	TAT NO.

DRAWING CIRCULATION							
PRELIM.				FINAL			
ENG'R	4	WOD	1	ENG'R	2	VGS	1
SP(MW)	2			SP(MW)	5	WOD	1
D(WL)	2			D(WL)	6		
DSP	1			COE	1		
EP	5			DDFT	1		
MFGR	2			DSP	1		
VGS	1			LSMS	2		

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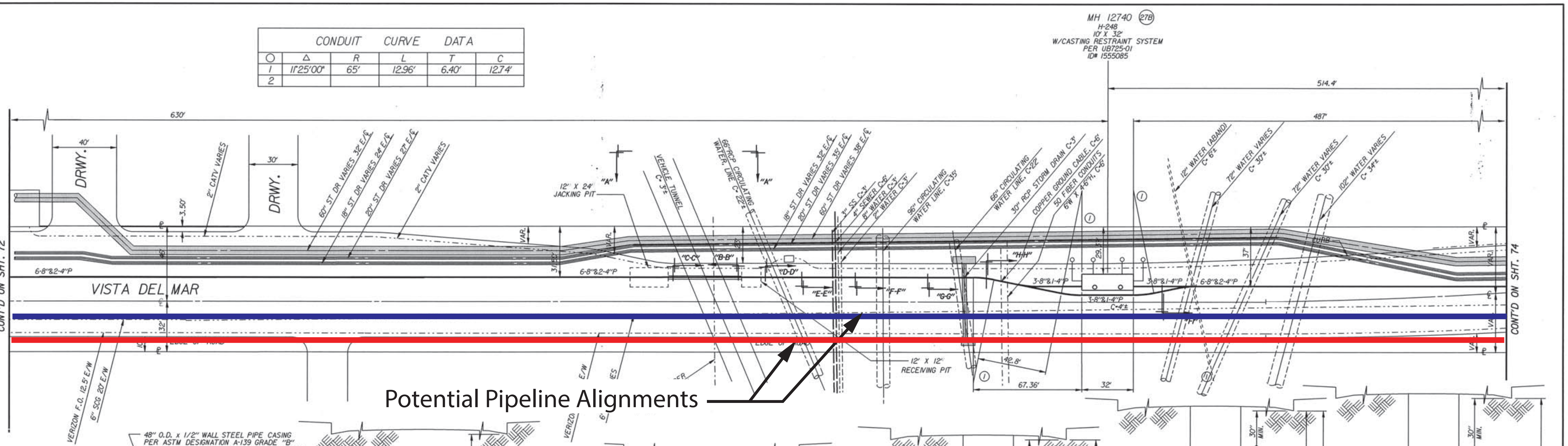
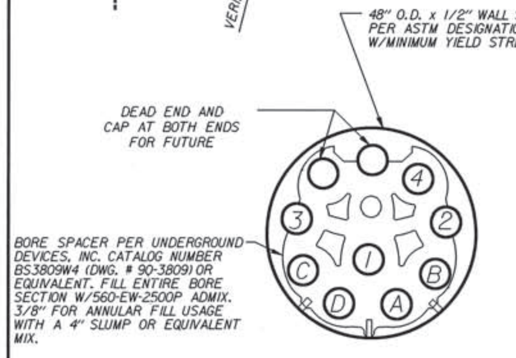
No. C035571
Exp. 9/30/13
CIVIL

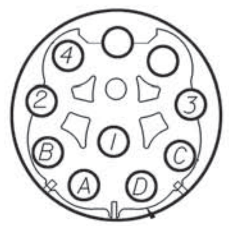
SERVICE CENTER JOB LOCATION WLA	SERVICE CENTER CONSTRUCTION WLA	WR #: 822768	CONST #: KYV99	PROJECT #: P240974	NON-CONST #: KYV86
CITY OF LOS ANGELES DEPARTMENT OF WATER AND POWER DISTRIBUTION ENGINEERING SECTION		230KV CONDUIT REQUIREMENT 1840 CENTINELA AV. RS "K" FROM RS "K" TO SCATTERGOOD			
DESIGN D. PALMER	DRAFTING AOS/PV				
OK	CHECKER D. PALMER	08H5039		SHEET 72 OF 77	
APPROVED Darrell KL	DATE 8/30/12				

CONDUIT CURVE DATA					
○	Δ	R	L	T	C
1	11°25'00"	65'	12.96'	6.40'	12.74'
2					

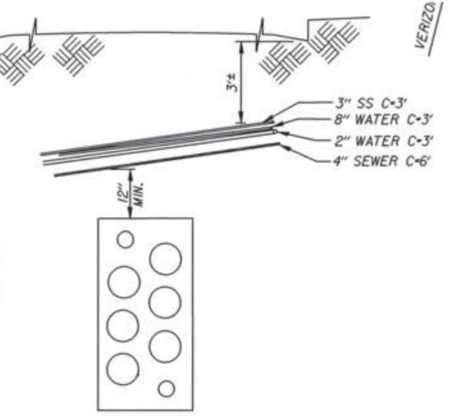




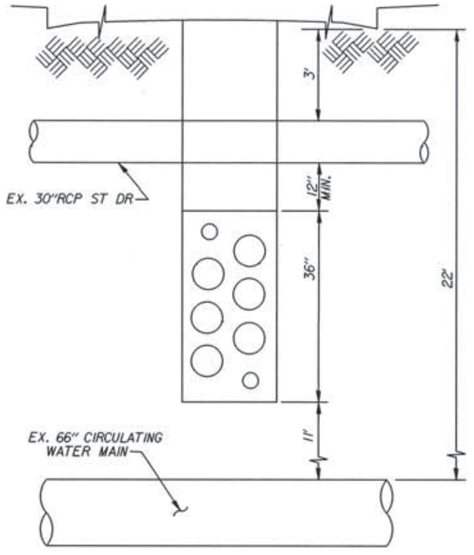
SECTION "B-B"
10-8"P



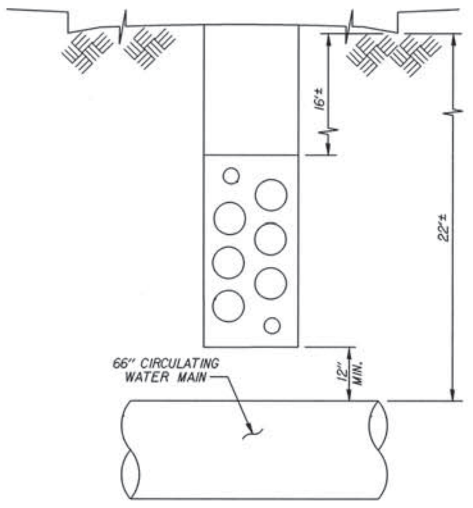
SECTION "C-C"
10-8"P



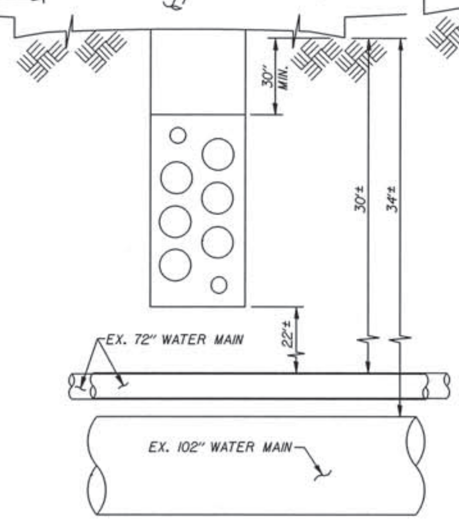
SECTION "E-E"
6-8" & 2-4"P



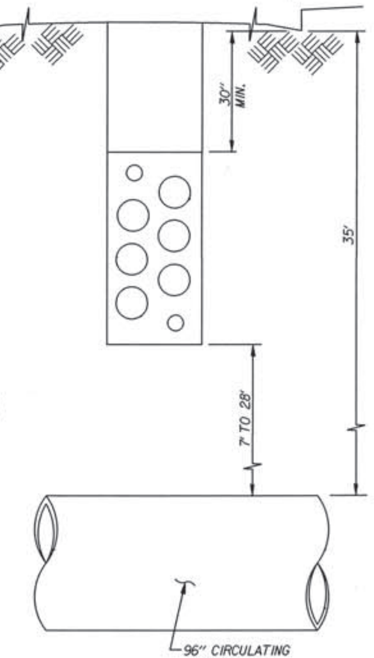
SECTION "G-G"
6-8" & 2-4"P



SECTION "D-D"
6-8" & 2-4"P



SECTION "I-I"
6-8" & 2-4"P



SECTION "F-F"
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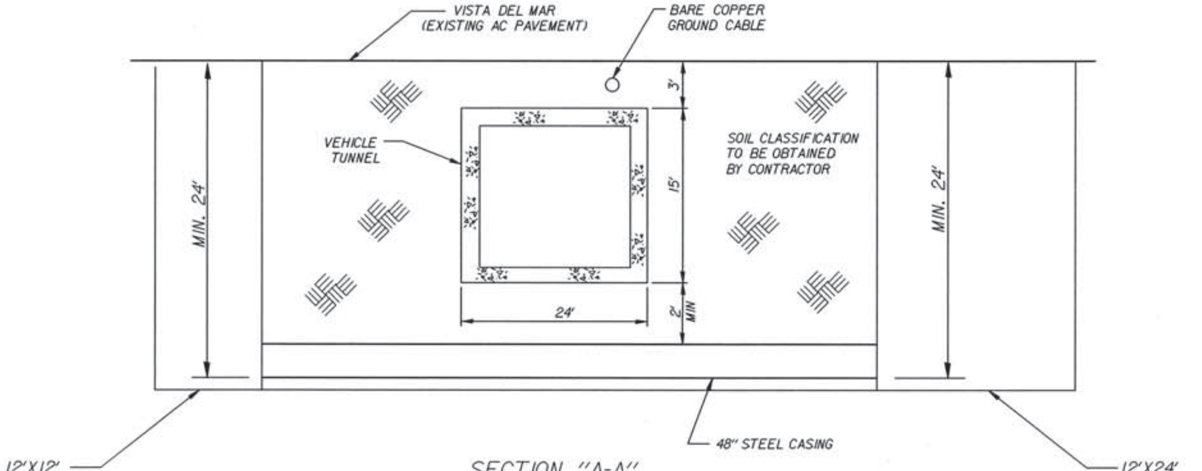
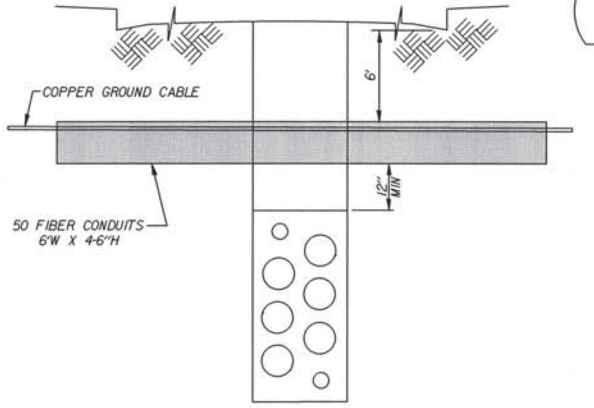


SECTION "A-A"
NTS

230KV SPAN

MH 12400 TO MH 12740 = 1062'±

MH 12740 @ VISTA DEL MAR TO
MH 7540 @ GRAND AV = 1082'±



SECTION "H-H"
6-8" & 2-4"P

SCALE: 1"=30'

JK

REV. NO.	REV. DATE	INIT'L.	REVISION DESCRIPTION	APPV.	TAT NO.

DRAWING CIRCULATION							
PRELIM.				FINAL			
ENG'R	4	WOD	1	ENG'R	2	VGS	1
SP(MW)	2			SP(MW)	5	WOD	1
D(WL)	2			D(WL)	6		
DSP	1			COE	1		
EP	5			DDFT	1		
MFGR	2			DSP	1		
VGS	1			LSMS	2		

DARRELL KALANI TOM
No. C035571
Exp. 9/30/13
CIVIL

SERVICE CENTER JOB LOCATION	WLA	SERVICE CENTER CONSTRUCTION	WLA

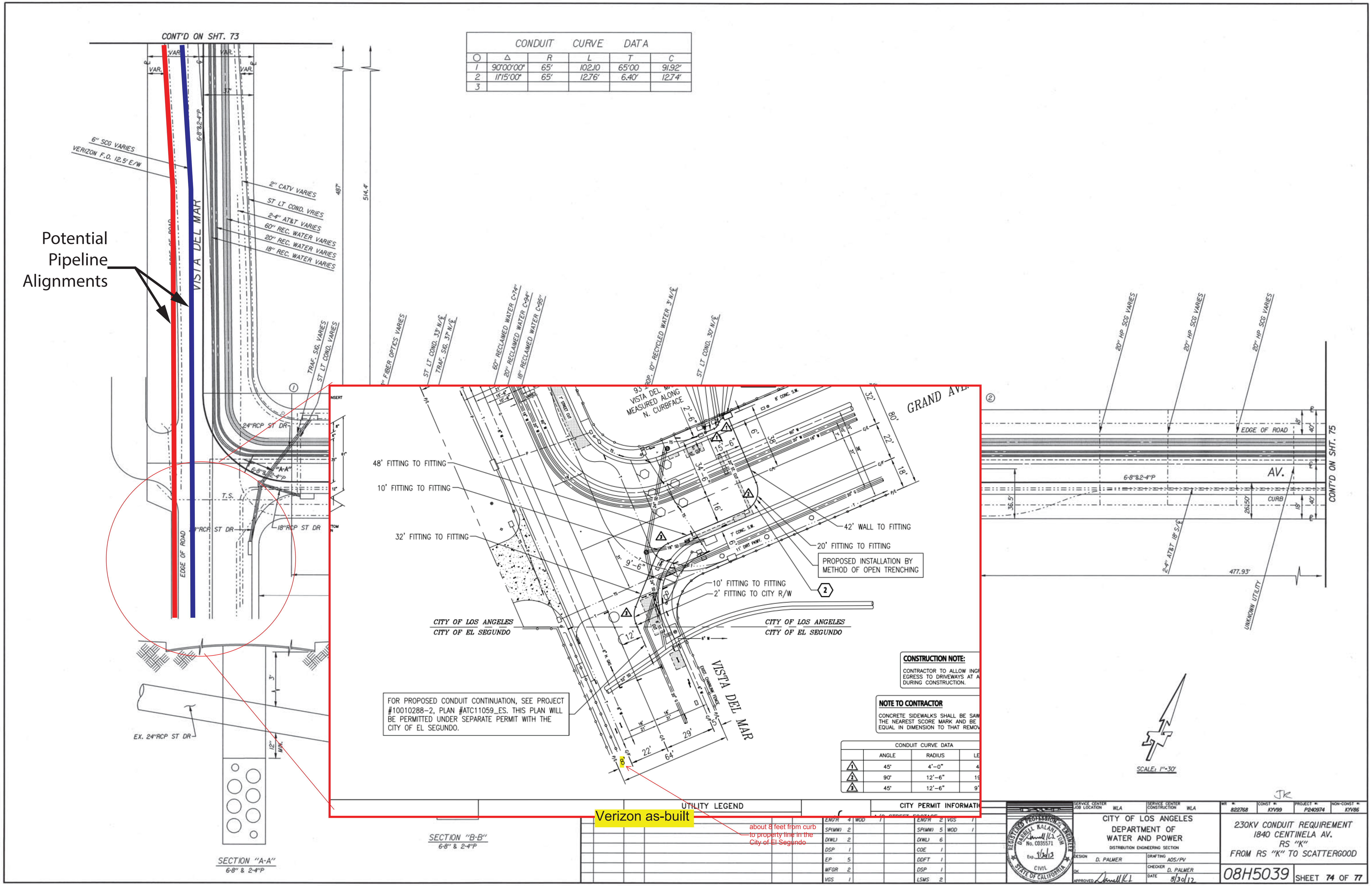
CITY OF LOS ANGELES
DEPARTMENT OF
WATER AND POWER
DISTRIBUTION ENGINEERING SECTION

DESIGN	D. PALMER	DRAFTING	AOS/PV
OK		CHECKER	D. PALMER
APPROVED	Darrell K	DATE	8/30/12

WR #	CONST #	PROJECT #	NON-CONST #
822768	KYV99	P240974	KYV86

230KV CONDUIT REQUIREMENT
1840 CENTINELA AV.
RS "K"
FROM RS "K" TO SCATTERGOOD

08H5039 SHEET 73 OF 77



CONDUIT CURVE DATA					
○	Δ	R	L	T	C
1	90°00'00"	65'	102.10	65'00	91.92'
2	11°15'00"	65'	12.76'	6.40'	12.74'
3					

ENG'R	4	WOD	1	ENG'R	2	VGS	1
SP(MW)	2			SP(MW)	5	WOD	1
D(WL)	2			D(WL)	6		
DSP	1			COE	1		
EP	5			DDFT	1		
MFGR	2			DSP	1		
VGS	1			LSMS	2		

JK

SERVICE CENTER JOB LOCATION WLA
SERVICE CENTER CONSTRUCTION WLA
WR #: 822768
CONST #: KYV99
PROJECT #: P240974
NON-CONST #: KYV86

CITY OF LOS ANGELES
DEPARTMENT OF
WATER AND POWER
DISTRIBUTION ENGINEERING SECTION

DARRELL KALANI TOM
No. C035571
Exp. 9/30/13
CIVIL

DESIGN D. PALMER
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CHECKER D. PALMER
APPROVED Darrell KL
DATE 8/30/12

230KV CONDUIT REQUIREMENT
1840 CENTINELA AV.
RS "K"
FROM RS "K" TO SCATTERGOOD

08H5039
SHEET 74 OF 77

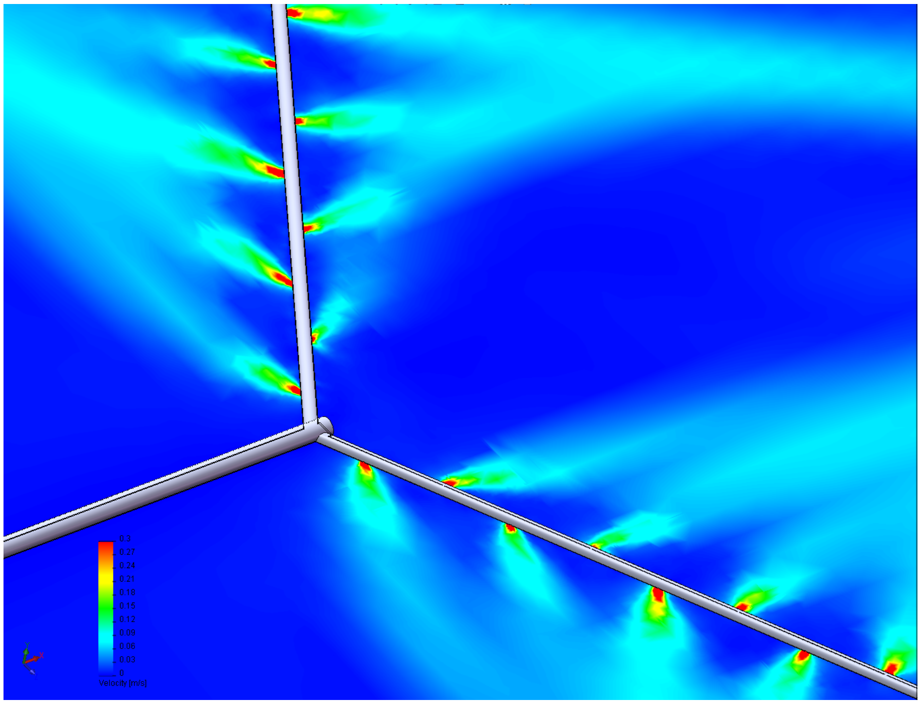
APPENDIX C – HYDRODYNAMIC MODELING REPORTS

Hydrodynamic Modeling of Dilution of Brine from the West Basin Municipal Water District Sea Water Desalination Project Discharged from the Hyperion 5-mile Outfall, Los Angeles, CA

(By Scott A. Jenkins, Ph.D., Draft: 7 December 2016)

Hydrodynamic Modeling of Dilution of Brine from the West Basin Municipal Water District Sea Water Desalination Project Discharged from the Hyperion 5-mile Outfall, Los Angeles, CA

By Scott A. Jenkins, Ph.D.



Submitted by:

Scott A. Jenkins,
Michael Baker International
9755 Clairmont Mesa Blvd
San Diego, CA 92124

Submitted to:

Roland Pilemalm, P.E.
Associate Vice President
Carollo Engineers, Inc.
707 Wilshire Boulevard, Suite 3920
Los Angeles, CA 90017

Draft: 7 December 2016

ABSTRACT:

This is a dilution study to examine the feasibility of using the Hyperion 5-Mile Outfall to discharge brine by-product from the *West Basin Municipal Water District Sea Water Desalination Project* after it has been blended with effluent from the *Hyperion Water Reclamation Plant*. The study looks at two different scales for West Basin brine conveyance (21 mgd & 63 mgd) to be blended with reclamation plant effluent that varies across an envelope from present to future operating conditions, up to and including combined conveyance equal to the maximum certified hydraulic capacity of the outfall (720 mgd).

Feasibility is judged in terms of the ability of the existing diffuser of the 5-Mile Outfall to achieve sufficient dilution performance to satisfy *both* minimum initial dilution requirements of 84 to 1 set forth in the existing NPDES permit (No. CA-0109991, Order No. R4-2010-0200), as well as the discharge limits set forth in the Appendix-A *brine amendment* to the California Ocean Plan. The dilution study invokes the EPA certified Visual Plumes (UM3) mixing zone model and the same reclamation plant effluent properties and environmental parameters assumed by the recently updated dilution study for the Hyperion 5-Mile Outfall performed by Walker (2016), who used the alternative EPA dilution model, CORMIX version 9.0.

The first step in the analysis was to reproduce the Walker (2016) results for the same Hyperion Water Reclamation Plant effluent conveyance rates. The coefficient of determination between the two model prediction was rather good, (R-squared = 0.83), with Visual Plumes slightly underestimating the minimum initial dilution predictions of the CORMIX model. A future discharge scenario being planned for the Hyperion Water Reclamation Plant (a scenario not evaluated by Walker, 2016) was found to be problematic. Brackish brine-only discharges from the reclamation plant of 10 mgd at 6.8 ppt will only achieve a minimum initial dilution of Dm = 59.6 to 1, in violation of the dilution credit presently issued to the Hyperion 5-Mile Outfall under the NPDES permit. This problematic result is due to *diffuser stall* since the densimetric Froude number becomes sub- critical at discharges as little as 10 mgd, (where $F_r = u / \sqrt{g' d}$ = 0.49). At these ultra-low discharge flows, there are simply too many discharge ports with too much discharge cross-sectional area in the Hyperion 5-Mile diffuser, resulting in failure of the discharge streams to become turbulent jets. To correct this condition without physical modification of the diffuser, the brackish brine-only conveyance from the reclamation plant must be increased to at least 24.2 mgd. It should be noted that the 10 mgd brackish brine-only scenario will dilute at the trapping level to within 2ppt of natural background salinity within a horizontal distance 100 m from the point of discharge, thereby satisfying the Ocean Plan brine amendment, (SWRCB, 2015).

The feasibility results of co-mingling West Basin brine with Hyperion Reclamation Plant effluent are summarized in Table A-1. Most of the modeled outcomes satisfy discharge limits set forth under both the Appendix- A brine amendment of the Ocean Plan and the present NPDES permit. The only failures resulted from co-mingling West Basin brine with 10 mgd of brackish brine effluent from the Hyperion Water Reclamation Plant (projected as the ultimate low-flow conveyance once the reclamation plant is expanded to final design capacity). When either 21 mgd or 63 mgd of West Basin brine is added to the 10 mg of brackish brine from the Hyperion Water Reclamation Plant, the combined effluent becomes negatively buoyant. In either case, the combined brine effluent will not dilute to within 2ppt of natural background salinity within 100 m from the point of discharge, in violation of the Appendix-A provisions of the amended Ocean Plan (SWRCB 2015). However, dilution continues beyond 100 m from the discharge point and

Table A-1: Summary of Dilution of Brine from the West Basin Desalination Project Discharged from the Hyperion 5-mile Outfall

Discharge Scenario Wastewater + Brine = Total Flow Rate (MGD)	Combined Discharge Salinity (ppt)	Discharge Velocity m/sec	Densimetric Froude Number $F_r = u / \sqrt{g' d}$	Distance horizontally to within 2ppt of Natural Background (BMZ, m)	Initial Dilution at BMZ	Initial Dilution (Dm) at lowest monthly trapping level **(ZID)	Meet OPA/ NPDES Limits?
***10 + 0 = 10	6.8	0.096	0.49	8.5	12.35	59.6	Maybe/No
***10 + 21 = 31	48.15	0.30	2.06	144	6.33	N/A	No/Maybe
***10 + 63 = 73	59.48	0.70	3.64	110	11.99	N/A	No/Maybe
90 + 21 =110	12.95	1.06	6.17	1.7	9.28	135.8	Yes/Yes
90 + 63 = 153	27.93	1.48	16.57	0.7	1.78	130.4	Yes/Yes
177 + 21 = 198	7.19	1.91	9.80	2.5	12.15	124.8	Yes/Yes
177 + 63 = 240	17.80	2.32	15.37	1.7	6.85	119.6	Yes/ Yes
203 + 21 = 224	6.36	2.16	10.91	2.8	12.57	121.6	Yes/ Yes
203 + 63 = 266	16.06	2.57	16.22	2.1	7.72	118.4	Yes/ Yes
250 + 21 = 271	5.26	2.68	13.12	3.0	13.1	115.8	Yes/ Yes
250 + 63 = 313	13.65	3.02	17.82	2.8	8.92	110.6	Yes/ Yes
699 + 21 = 720	1.98	6.94	32.52	10.7	14.76	84.2	Yes/ Yes
657 + 63 = 720	5.94	6.94	34.81	10.3	12.78	84.0	Yes/ Yes

Red = future low wastewater flow; **Yellow** = present low wastewater flow; **Blue** = average wastewater flow

Green = combined discharge at maximum certified hydraulic capacity

* Trapping Levels (ZID) are measured in terms of height above the point of discharge (vertical distance from discharge ports)

** ZID boundary defaults to minimum trapping level for buoyant discharges.

***Wastewater for these scenarios is brackish brine from Hyperion Water Reclamation Plant at 6.8 ppt

OPA = Ocean Plan Appendix-A brine amendment, SWRCB, (2015).

reaches the value of Dm = 84 to 1 required by the present NPDES permit at distances between 213 m and 340 m. Therefore, a determination of consistency with both new and existing discharge standards is uncertain for these anticipated future low-flow conditions.

For all other combinations of West Basin brine and Hyperion effluent in Table A-1, the combined effluent produces buoyant discharges, which rise in the water column until reaching the trapping layer at the pycnocline interface. For these buoyant discharge cases, the present NPDES permit and Requirements III.C.4(b-d) of the Ocean Plan are the critical regulatory discharge standards, although we will still pay attention to the 100 m brine mixing zone (BMZ) discharge limits set under the Appendix-A provisions of the amended Ocean Plan (SWRCB 2015). Inspection of Table A-1 reveals that dilution performance of the 5-Mile Outfall diffuser was better for buoyant discharges at low-flow conditions than high flow conditions, because smaller volumes of effluent at smaller discharge rates are more rapidly diluted in the limited volume of receiving water available beneath the pycnocline and trapping layer. The best dilution performance was achieved for the low-flow condition that blended 90 mgd of effluent from the Hyperion Water Reclamation Plant with 21 mgd of Wes Basin brine, for which minimum initial dilution reached Dm = 135.8 to 1 at a trapping layer z = 42.6 m above the discharge point. Because the primary motion of the plume is vertically upward through the water column, the horizontal spreading of the plume was only x = 10.1 m at the pycnocline trapping level. With this limited horizontal spreading, the BMZ limits of the amended Ocean Plan were easily satisfied, and the discharge salinity rose to within 2 ppt of natural background at a horizontal distance of only x =1.7 m from the point of discharge. Additional increases in effluent from the Hyperion Water Reclamation Plant resulted in continual declines in the minimum initial dilution, but always remaining above the dilution credit of Dm = 84 required by the present NPDES permit; and increases in the horizontal plume spreading that resulted in *the 2ppt above natural background threshold* being achieved at greater horizontal distances from the point of discharge, but always well within the 100 m BMZ requirement of the amended Ocean Plan (SWRCB, 2015). Worst-case dilution occurred for combined discharges at maximum certified hydraulic capacity, 720 mgd. Here, minimum initial dilution was Dm = 84.2 to 1 with 21 mgd of West Basin brine loading, and Dm = 84.0 to 1 with 63 mgd of West Basin brine loading; both results marginally satisfying the certified minimum initial dilution for the 5-Mile Outfall under the existing NPDES permit. At these high flow rates, the densimetric Froude number was in the range of $F_r = u / \sqrt{g' d}$ = 32.5 to 34.8, and the maximum horizontal spreading of the plume at the pycnocline trapping level increased to x = 28.8 m. Nonetheless, the discharge salinity came within 2 ppt of natural background at horizontal distances in the range of x = 10.3 m to 10.7 m from the point of discharge, easily satisfying the Appendix-A brine amendment of the Ocean Plan (SWRCB, 2015).

Hydrodynamic Modeling of Dilution of Brine from the West Basin Municipal Water District Sea Water Desalination Project Discharged from the Hyperion 5-mile Outfall, Los Angeles, CA

by Scott A. Jenkins, Ph.D.

1) Introduction:

This is a dilution modeling study of the brine by-product from the *West Basin Municipal Water District Sea Water Desalination Project* after it has been blended with effluent from the Hyperion Water Reclamation Plant and subsequently discharged through the *Hyperion 5-mile Outfall*. The 5-mile Hyperion outfall was put into service in 1960 and has a certified flow rate of 720 million gallons per day (mgd), Parsons, (2008). The outfall is located approximately 26,500 feet from shore at a depth of -61 m MSL, (Figure 1), and the diffuser is comprised of two legs, each approximately 3,800 feet long with 85 ports per leg with each port measuring 7.26 in. in diameter. According to the NPDES permit (No. CA-0109991, Order No. R4-2010-0200), the required minimum initial dilution of the 5-mile outfall is 84 to 1, (CRWQCB, 2010). An updated dilution study was recently completed and established a worst-month minimum initial dilution of 86.5 to 1 at maximum certified hydraulic capacity (720 mgd) for Hyperion effluent temperatures and ocean conditions for the period January 2010- March 2015, (Walker, 2016). During this period the actual maximum operational wastewater discharge rate was 435.22 mgd; and the minimum was 176.67 mgd, with an average discharge rate of 250.33 mgd (Table-1). However, plans for expanded capacity of the Hyperion Water Reclamation Plant, (combined with projected future water conservation efforts in Los Angeles) are expected to reduce future annual conveyance rates to as little as 90 mgd with an ultimate minimum of 10 mgd consisting of brine from the reclamation plant at 6.8 ppt TDS.

Table 1: Hyperion 5-mile Outfall Historic Wastewater Conveyance Rates (2010-2016)

Absolute Maximum = 435.22 mgd
Average Annual Maximum = 350.15 mgd
Long-term Average = 250.33 mgd
Average Annual Minimum = 202.62 mgd
Absolute Minimum = 176.67 mgd
Future Annual Minimum = 90 mgd
Future Absolute Minimum = 10 mgd @ 6.8 ppt

West Basin is considering two different scales for its desalination project: 1) a 20 mgd project discharging 20.9 mgd of brine at 68 ppt from the R.O facilities of the desalination plant and 0.1 mgd of West Basin recycled blowdown water at 35 ppt, resulting in a total discharge rate of 21 mgd with 67.84 ppt salinity end of pipe; 2) a 60 mgd project discharging 62.7 mgd of brine at 68 ppt from the R.O facilities of the desalination plant and 0.3 mgd of West Basin recycled blowdown water at 35 ppt, resulting in a total discharge rate of 63 mgd with 67.84 ppt salinity end of pipe. Based on the possible envelope of combinations of Hyperion and West Basin operating conditions, Table-2 summarizes the modeling scenarios to be evaluated in this study. We chose to bracket the upper end of the envelope of combined Hyperion and West Basin discharges using the maximum hydraulic capacity of the Hyperion 5-mile Outfall because these

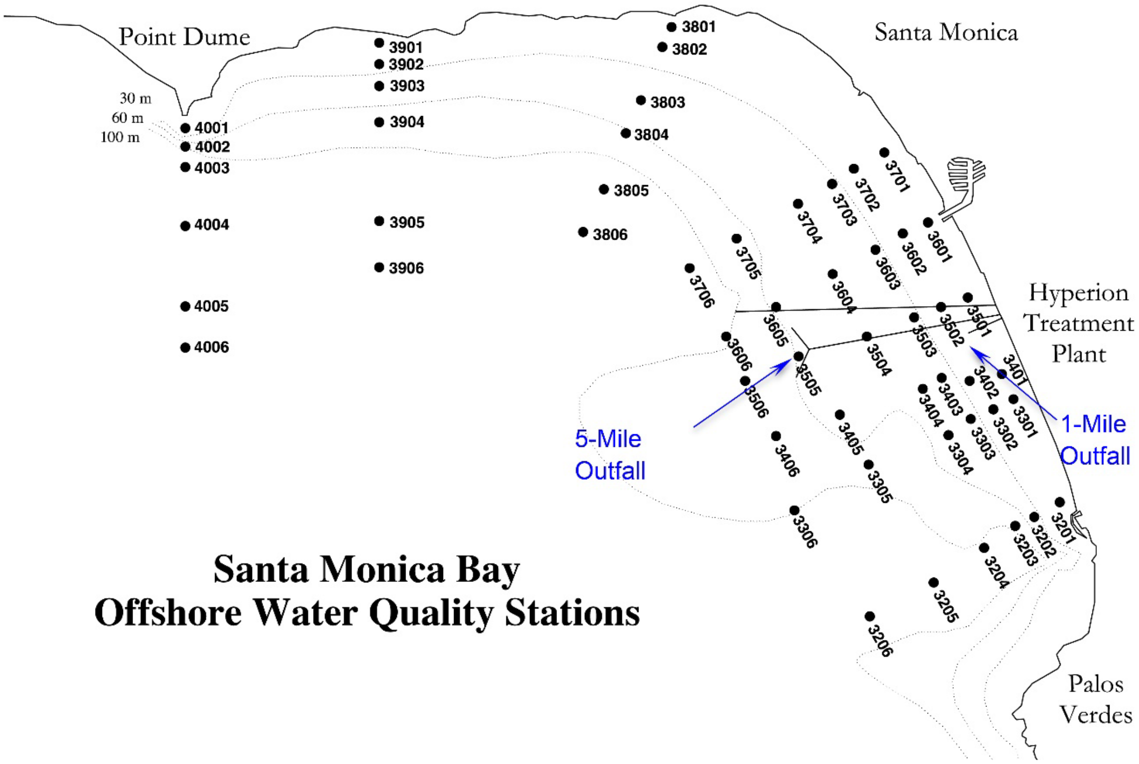


Figure 1: Location map with water quality monitoring stations showing the 12 ft diameter Hyperion emergency outfall (blue) located 5,384 ft offshore in Santa Monica Bay (often referred to as the "*1-mile outfall*"), and the 12 ft diameter Hyperion deep outfall (red) located 27,539 ft offshore (referred to as the " *5-mile outfall*"). From Walker (2016).

Table 2: Envelope of operating conditions for the West Basin Desalination Project at Hyperion 5-mile Outfall

Hyperion Wastewater Flow Rates (MGD)	Brine Discharge Rate (MGD)	Combined Discharge Rate (MGD)	Combined Discharge Salinity (ppt)	*Density Anomaly $\Delta \rho / \rho$
10 @ 6.8 ppt	**0**	**10**	**6.8**	**+0.0214**
10 @ 6.8 ppt	**21**	**31**	**48.15**	**-0.0117**
10 @ 6.8 ppt	**63**	**73**	**59.48**	**-0.0208**
90	**21**	**110**	**12.95**	**+0.0164**
90	**63**	**153**	**27.93**	**+0.0044**
177	**21**	**198**	**7.19**	**+0.0210**
177	**63**	**240**	**17.80**	**+0.0126**
203	**21**	**224**	**6.36**	**+0.0217**
203	**63**	**266**	**16.06**	**+0.0139**
250	**21**	**271**	**5.26**	**+0.0226**
250	**63**	**313**	**13.65**	**+0.0159**
699	**21**	**720**	**1.98**	**+0.0252**
657	**63**	**720**	**5.94**	**+0.0220**

Red = future low wastewater flow
Orange = present low wastewater flow
Blue = average wastewater flow
Green = maximum wastewater flow at maximum certified hydraulic capacity = 720 mgd

conveyance rates produced the worst-case minimum initial dilution results in the updated dilution study by Walker (2016). The red entries represent projections of future low flow conditions and bracket the lower end of the operating envelope. The first red entry represents discharge of only the brine from the Hyperion Water Reclamation Plant which was included because it is a case that has never been studied, and is required to understand low-flow limitations of the present diffuser design. The orange entries represent present historic low flow conditions while the blue entries represent present average wastewater flows in combination with the brine from 21 mgd and 63 mgd West Basin projects. The green entries in Table-3 represent the maximum possible conveyance of combinations of brine from West Basin and wastewater from the Hyperion Water Reclamation Plant, whereby all available conveyance capacity is utilized and the combined discharge is at the maximum certified hydraulic capacity of the 5-mile outfall pipeline. Note most of the values of the density anomaly are positive, indicating the combined wastewater/brine effluent is buoyant in ocean receiving waters, (i.e., $\Delta \rho / \rho > 0$). However the density anomaly turns negative for the ultimate low-flow combination of West Basin brine and brine from the Hyperion Water Reclamation Plant, indicating that these scenarios will involve dilution of dense (negatively buoyant) combined effluent in ocean receiving waters, (i.e., $\Delta \rho / \rho < 0$). Having the physical nature of the combined effluent switch between a buoyant and a dense discharge across the operational envelope creates a dual set of regulatory requirements for discharge compliance which we consider in the following section.

2) Compliance Issues:

Amendments specific to brine discharges have recently been approved for the California Ocean Plan (SWRCB, 2015). Appendix-A of this document, "Ocean Plan with the May 6, 2015 Final Desalination Amendment," establishes two distinct set of discharge limits on brine discharges, one for buoyant discharges, and the other for dense (negatively buoyant) discharges. Based on the brine concentrations listed above, most of the West Basin/Hyperion combined wastewater/brine discharges will be buoyant in seawater (those entries in Table 2 where $\Delta \rho / \rho > 0$); and accordingly will be regulated under Requirement III.C.4(b) of the present version of the California Ocean Plan as it would apply to a Zone of Initial Dilution (ZID). The California Ocean Plan defines the ZID as the zone in which the process of initial dilution is completed. Initial dilution is defined within Appendix I of the *California Ocean Plan* as follows: "*Initial Dilution is the process which results in the rapid and irreversible turbulent mixing of wastewater with ocean water around the point of discharge. For a submerged buoyant discharge, characteristic of most municipal and industrial wastes that are released from the submarine outfalls, the momentum of the discharge and its initial buoyancy act together to produce turbulent mixing"*… Provision III.C.4(d) of the Ocean Plan requires that minimum initial dilution be determined in a specific manner: "*For the purpose of this Plan, minimum initial dilution is the lowest average initial dilution within any single month of the year. Dilution estimates shall be based on observed waste characteristics, observed receiving water density structure, and the assumption that no currents, of sufficient strength to influence the initial dilution process, flow across the discharge structure".*

Under the present NPDES permit for the Hyperion 5-mile Outfall (No. CA-0109991, Order No. R4-2010-0200), the Los Angeles Regional Water Quality Control Board has interpreted these provisions such that minimum initial dilution has been determined to be 84 to 1 at the *trapping level* during the month of December, (Walker, 2016). To understand how this interpretation of the Ocean Plan was made, consider the dynamics of a buoyant plume as shown schematically in Figure 2. The effluent is initially discharged at high velocity from, in this case, 170 small diameter discharge ports creating as many turbulent jets. The large eddies produced by these turbulent jets dilute the jet momentum, at which point the buoyancy of the effluent causes the turbulent eddies to rise as a convective plume in the water column. As the eddies and convective circulation entrain more and more of the surrounding water mass, the plume becomes diluted and the buoyancy declines until the plume no longer rises further in the water column. This typically occurs at a density interface in the water column referred to as the *pycnocline*,

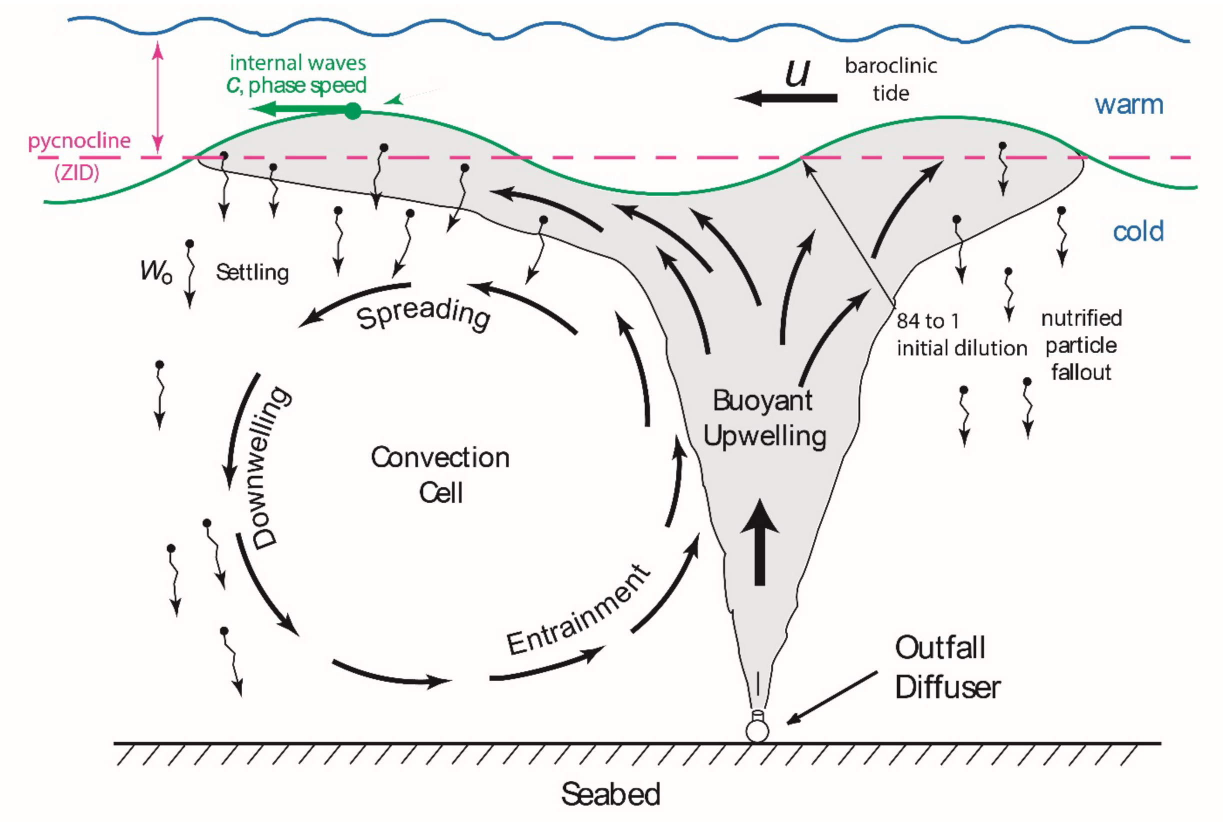


FIGURE 2: Schematic diagram of the rising buoyant plume ascending to the trapping level for a combined effluent of wastewater and brine discharged from the Hyperion 5-mile deep outfall diffuser.

usually formed between two water masses, namely the warm surface mixed layer and the colder bottom water. The pycnocline forms a *trapping layer*, and the residual turbulent momentum of the plume causes it to spread out horizontally. If the receiving waters are only weakly stratified, i.e., there is only a small temperature difference between surface mixed layer and the bottom water, then the plume can rise to the sea surface (sometimes referred to as the *second trapping layer*). The plume will spread out horizontally along the trapping layer interface until all of its turbulent kinetic energy and buoyant potential energy is dissipated, at which dilution ceases to change. The dilution at this point is referred to as *initial dilution*. In the natural ocean environment, the pycnocline (or trapping layer) is dynamic, rising and falling in the water column with the seasons, and with internal (baroclinic) tides that propagate along the pycnocline interface. While seasonal effects on pycnocline heights and trapping levels were included in the updated dilution study for the Hyperion 5-Mile Outfall (Walker, 2016), the effects of baraocliinic tides and the sweeping velocities they create across the diffuser are excluded under Provision III.C.4(d) of the Ocean Plan

However, a second set of discharge limits specific to brine must also be considered under the newly amended California Ocean Plan (SWRCB, 2015). This amendment found in Appendix-A of SWRCB (2015) establishes a water quality objective for brine discharges under the following requirements:

"*Discharges shall not exceed a daily maximum of 2.0 ppt above natural background salinity to be measured as total dissolved solids (mg/L) measured no further than 100 meters (328 feet)* *horizontally from the discharge. There is no vertical limit to this zone. Natural background salinity is defined as the salinity at a location that results from naturally occurring processes and is without apparent human influence. Natural background salinity shall be determined by averaging 20 years of historical salinity data at a location unless the actual salinity measured at the facility intake is greater than the 20 year average salinity, in which case, the natural background salinity shall be the lower of the actual salinity measured at the intake and the maximum salinity level measured in the 20 years of historical salinity data. When historical data are not available, natural background salinity shall be determined by measuring salinity at depth of proposed discharge for three years, on a weekly basis prior to a desalination facility discharging brine, and the average salinity shall be used to determine natural background salinity unless the actual salinity measured at the facility intake is greater than the average salinity, in which case, the natural background salinity shall be the lower of the actual salinity measured at the intake and the maximum salinity level measured in the salinity data. Facilities shall establish a reference location with similar natural background salinity to be used for comparison in ongoing monitoring of brine discharges. The fixed distance referenced in the initial dilution definition shall be no more than 100 meters (328 feet). In addition, the owner or operator shall develop a dilution factor (Dm) based on the distance of 100 meters (328 feet) or initial dilution, whichever is smaller".*

There is no vertical dimension in this new water quality objective; i.e. no consideration of trapping levels or restrictions on a brine plume broaching the sea surface. Therefore there is some uncertainty regarding how the Regional Water Quality Control Boards will reconcile this water quality objective with the antecedent Requirement III.C.4(b) of the previous version of the California Ocean Plan when the brine plume is buoyant. One thing is clear however, and that is an initial dilution analysis is required to determine the dilution credit the outfall will receive once brine is added to the effluent from the Hyperion Water Reclamation Plant. It is our belief that if brine additions from West Basin can simultaneously satisfy both the minimum initial dilution requirements of the existing NPDES permit and the new brine amendment requirements of Appendix A of SWRCB (2015), then from a regulatory compliance standpoint, the Hyperion 5-Mile outfall is a viable discharge option for the *West Basin Municipal Water District Sea Water Desalination Project.*

3) Technical Approach:

A minimum initial dilution analysis was performed using the EPA certified Visual Plumes (UM3) model, supplemented by verification using a commercially available computational fluid dynamics (CFD) model, *COSMOS/ FLoWorks.* Both models were initialized for quiescent ocean receiving waters with worst-month temperature/salinity (density) profiles, as required for an initial dilution analyses under Provision III.C.4.d of the Ocean Plan. For purposes of analytic fidelity, both models were initialized using the same receiving water and effluent data bases as used in the recently updated dilution study by Walker, (2016). A set baseline dilution simulations was first performed to reproduce the results from Walker (2016) for wastewater only discharges before proceeding to add West Basin brine and evaluate dilution of the combined effluent. Comparisons with the baseline results then makes it possible to isolate the effects of brine additions on the dilution performance of the diffuser.

The recently updated dilution study of the Hyperion 5-Mile Outfall was performed using the EPA certified mixing model CORMIX version 9.0, (Walker, 2016). CORMIX is an empirically based *expert systems model*, that takes accumulated laboratory and field experience to compile a set of rule-based predictions. CORMIX is most effective when the real-world prototype conditions and model variables match closely. When they do not, the CORMIX predictions can degrade substantially (Frick, et al., 2003). CORMIX models were developed to investigate the plume behavior and dilution from one discharge port, and predictions for discharges emanating from multiple discharge ports become valid only after the point where the plumes from the individual ports merge to form the whole plume. The model implicitly assumes the discharged flow is equally split between each discharge port and plume evolution occurs identically for each port and for each row of ports. Clearly simplistic assumptions impair CORMIX at the transition sections of the north and south legs of the y-shaped Hyperion 5-Mile diffuser, where the diffuser legs transition from 102 in. diameter pipe to 72 in. diameter pipe, as well as at the Y-junction of the two legs where the geometry of the diffuser diverges from the implicit linear assumptions made by CORMIX.

To circumvent these shortcomings, we selected the alternative EPA model mixing model, Visual Plumes (UM3). This is a robust process-based model, based on the Projected Area Entrainment (PAE) hypothesis (Winiarski and Frick, 1976; Frick, 1984). The most current version of this model, Visual Plumes UM3, is the most commonly used model to provide initial dilution analysis in NPDES permits for ocean outfalls. It accepts inputs for multiple ports with arbitrary size, spacing, angle and elevation above the bottom, but can not directly resolve opposing rows of discharge ports on opposite faces of the diffuser manifold, nor rows of ports that are not co-linear, as is found on either side of the Y-junction of the 5-Mile Outfall diffuser. However, because of it is a process-based architecture, Visual Plumes UM3 can be coupled with a computational fluid dynamics (CFD) models that will specify opposing multi-plume and ono-linear inputs to the Visual Plumes UM3 model prior to plume merging, thereby resolving the complex flow patterns around the Y-junction, transition sections and terminal ends of the two legs to the diffuser.

The CFD model chosen for these complex geometric solutions was the commercially available COSMOS/FloWORKS codes that were originally developed by the French aerospace company Dassault Systems, and are presently marketed in the United States by its US subsidiary SolidWorks as an add-on to the SolidWorks Professional computer-aided design (CAD) software package under the name “FlowSimulation”. In general, CFD models do not make simplifying assumptions in the way the Visual Plumes UM3 model does with its Projected Area Entrainment (PAE) approximation, or CORMIX with its empirical rule-based processing. Instead CFD models use the brute force of modern high-speed computers to perform enormous numbers of iterations that converge on exact solutions to the equations of motion (Navier Stokes Equations). The unique ability of COSMOS/FloWorks is that it provides CFD simulation capability inside a 3-dimensional CAD system. The CAD embedded CFD codes of COSMOS/FloWORKS and SOLIDWORKS Flow Simulation have been substantially validated in the peer reviewed literature (Balakin, et al., 2004; Oberkampf, W.L. and Trucano, 2002; Melnik, et al., 2015). As with all novel technologies, considerable attention is paid to Validation and Verification (V&V). It is these capabilities and pedigree which makes the embedded COSMOS/FloWORKS and SolidWorks Professional technology the best available technology for resolving the discharge streams and entrainment flows in the geometrically complex sections of the Hyperion 5-Mile Outfall diffuser.

4) Model Initialization:

The Hyperion wastewater effluent is essentially fresh water, with the density determined through the temperature. Over the period of January 2010 to March 2015, averages of temperatures from each month were determined for use in the scenarios. The monthly average temperatures are presented in Figure 3.

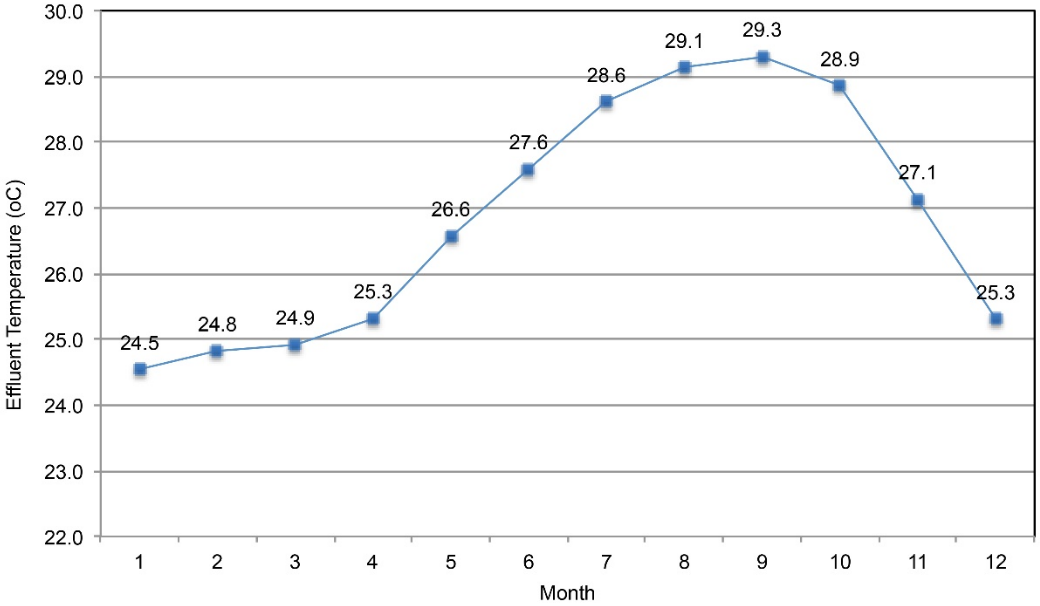


Figure 3: Inter-annual Hyperion wastewater effluent temperature variation; (from Walker, 2016).

N*atural background salinity* according to the amended Ocean Plan is a reference location that is representative of the *natural background salinity* of the discharge location. For the purposes of this evaluation, we have adopted the period of record at the Santa Monica Bay monitoring stations, (Figure 1) archived at:

http://www-mlrg.ucsd.edu/shoresta/mnSIOMain/siomain.htm

Figure 4 plots the full 33 year period of record at NPDES monitoring Station 3505. The period of record, 1980 to 2013 contains 12,055 verified daily measurements. Monthly averages for each individual month in a 20-year reference period and the full 33-year period of record are given. The long-term mean for both the 20 and 30 year time frames are the same, 33.52 ppt; and monthly means vary by no more than 0.2 ppt about the long-term mean.

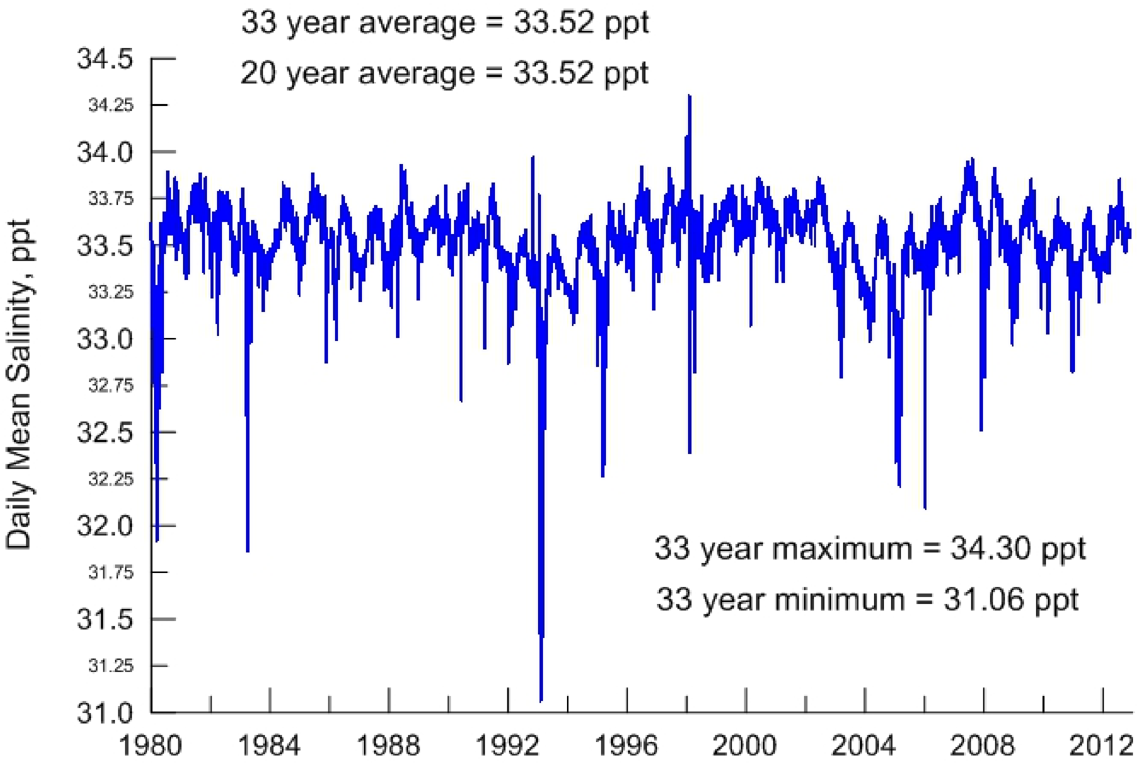


Figure 4: Period of record for N*atural background salinity* at Santa Monica Bay monitoring Stations (Figure 1). Data archived at:

http://www-mlrg.ucsd.edu/shoresta/mnSIOMain/siomain.htm

To evaluate worst-month density profiles in the receiving waters, NPDES water quality monitoring data (temperature/salinity profiles) were compiled quarterly and a rolling 4-point density change over depth was calculated for each spatially averaged quarterly monitoring events. Profiles were segregated into two categories: those events with the smallest maximum change were selected as the least stratified and those with the largest maximum change were selected as the most stratified. Pycnocline heights were then extracted from the two sets of density profiles and plotted according to monthly variation in Figures 5 & 6.

A 3-dimensional CAD model was built of the Hyperion 5-Mile Outfall diffuser was constructed using SolidWorks Professional CAD software. For the diffuser section, the first 2,400 feet is 8.5 feet in diameter and then tapers to a diameter of 6 feet for the remaining 1,400 feet. Each leg has 83 ports along the length at an interval of 48 feet, with the first 50 ports (counted from the “Y”) measuring 6.75 inches in diameter, followed by 21 ports of 7.75 inches in diameter, with the last 12 ports 8.35 inches in diameter (Parsons 2008). The weighted average of port areas yields an equivalent diameter of 7.26 inches (0.6 feet). The ports are located on alternating sides of the diffuser, 48 feet between sequential ports so there is 96 feet between ports on one side of the diffuser. Odd numbered ports are on the shore side of the diffuser and even numbered ports are located on the ocean side. The discharge ports are aligned to be parallel to the bottom and normal to the diffuser as shown in Figure 7. There are two gas vent ports on the

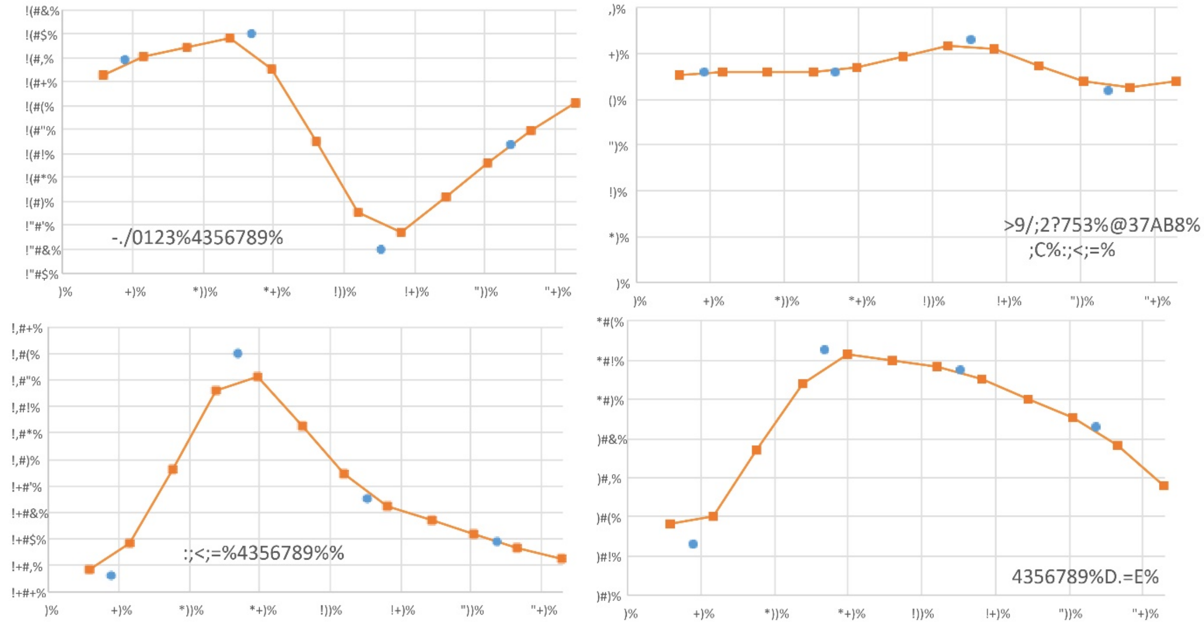


Figure 5: Inter-annual variation in density and pycnocline heights from most stratified density profiles after Walker (2016)

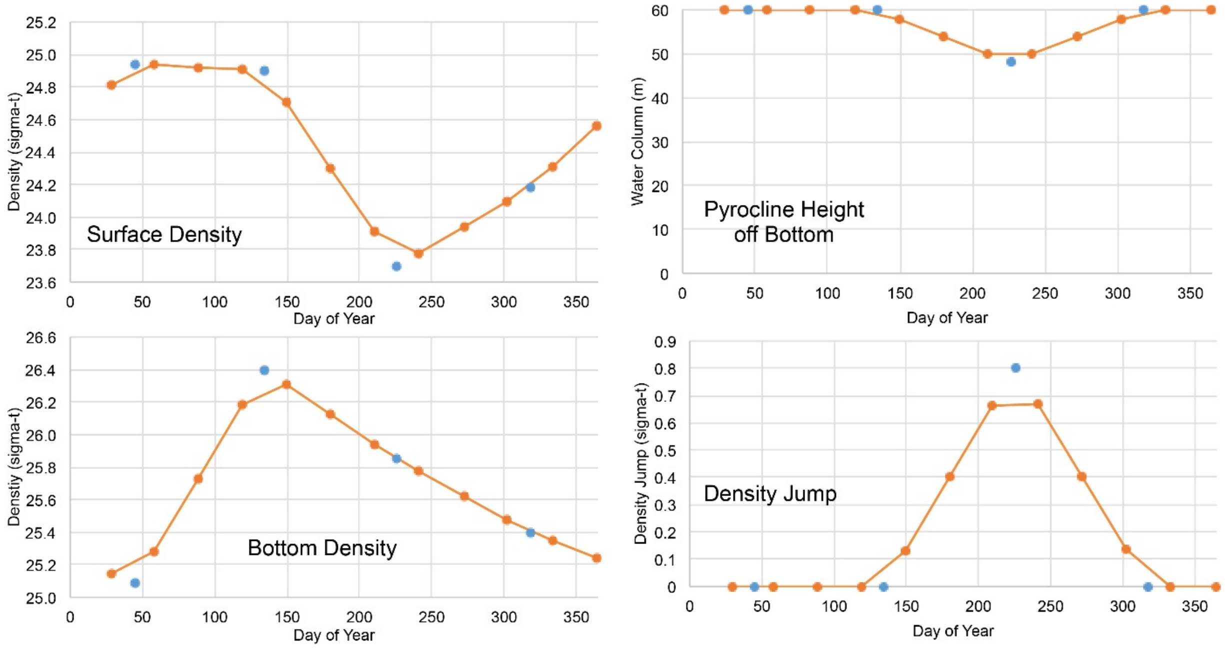


Figure 6: Inter-annual variation in density and pycnocline heights from least stratified density profiles after Walker (2016)

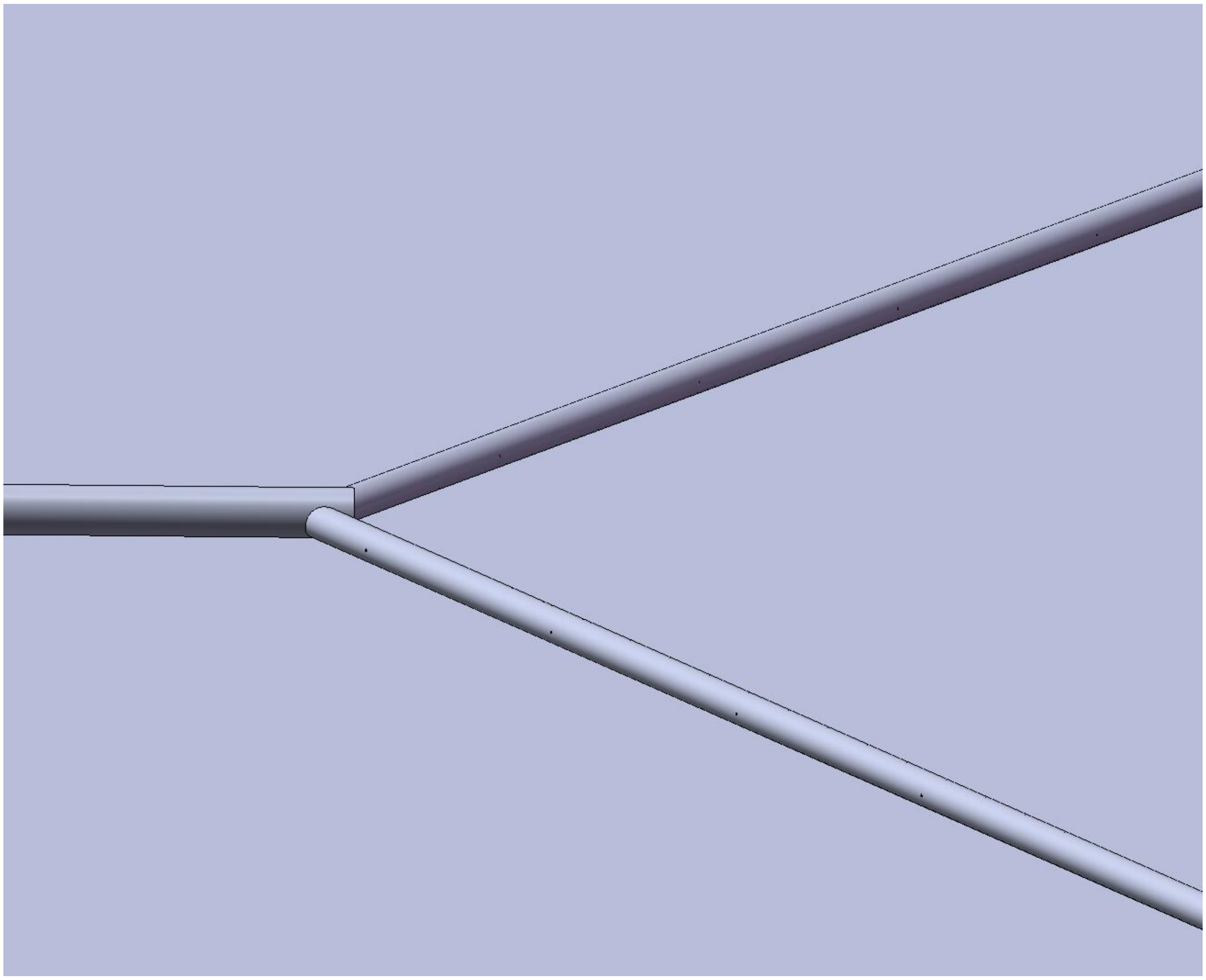


Figure 7: SolidWorks 3-dimensional CAD model of the Y-junction of the Hyperion 5-Mole Outfall diffuser.

top of each leg for a total of 85 ports. The gas vents are located at the transition structure between the 8.5 foot and 6 foot sections and the end structure of the diffuser (Ballard 2014).

5) Baseline Simulations:

Using the initialization parameters described in Section 4, the Visual Plumes (UM3) mixing model was run for the exact same discharge scenarios studied previously in the updated dilution study by Walker (2016). These scenarios included conveyance of 250 mgd, 450 mgd and 720 mgd of effluent from the Hyperion Water Reclamation Plant that was subsequently discharged from the Hyperion 5-Mile Outfall for 24 separate density stratification/pycnocline combinations. A comparison of the results from CORMIX v-9 used in Walker (2016) vs the Visual Plumes (UM3) model is shown in Figure 8. The coefficient of determination between the two model prediction was rather good, R-squared = 0.83, with Visual Plumes slightly underestimating minimum initial dilution for worst-case month (December). At maximum

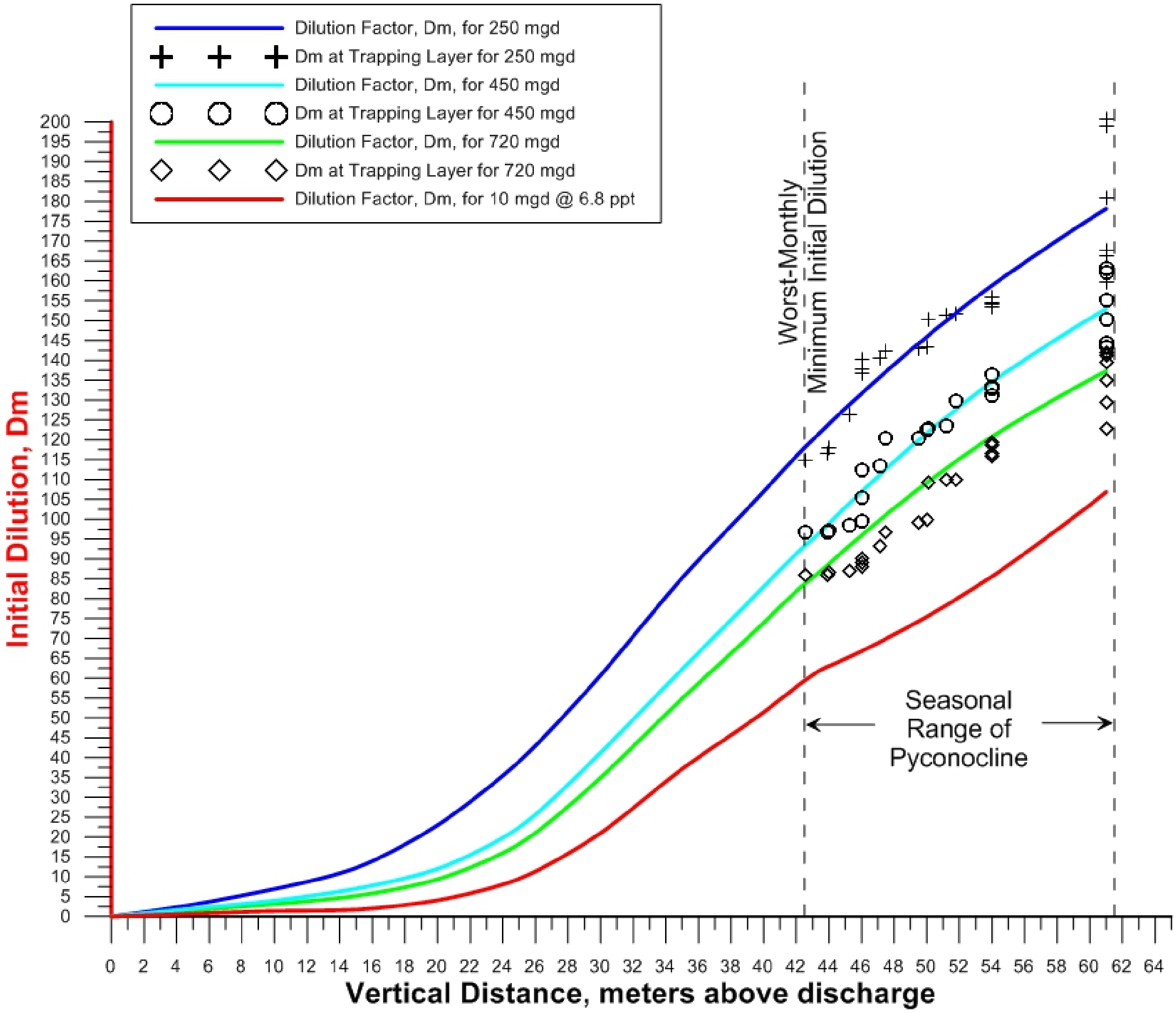


Figure 8: Baseline simulations of initial dilution of effluent from only the Hyperion Water Reclamation Plant after discharge from the Hyperion 5-Mile Outfall. Comparison are made of monthly initial dilution results from Walker (2016) shown as points versus Visual Plumes (UM3) results shown solid lines. Minimum initial dilution results found along the dashed vertical line as labeled, corresponding to worst-case month. Independent solution for initial dilution of 10 mgd have Hyperion Water Reclamation brine at 6.8 ppt shown as solid red line.

certified hydraulic capacity, (720 mgd), CORMIX from Walker (2016) predicts Dm = 86.5 whereas Visual Plumes (UM3) predicts Dm = 84.3. At historic average discharge rates (250 mgd), CORMIX predicts Dm = 114.9 whereas Visual Plumes (UM3) predicts Dm = 118.4; and for the historic maximum conveyance during the 2010-2015 period of record, (450 mgd), CORMIX predicts Dm = 96.8 whereas Visual Plumes (UM3) predicts Dm = 93.6. Therefore, the initial dilution results of the updated Hyperion 5-Mile Outfall dilution study by Walker (2016) have been verified for wastewater-only discharges by a second EPA model; and in general, those results show the minimum initial dilution increases with decreasing discharge rate. Intuitively this occurs because smaller volumes of effluent at smaller discharge rates are being loaded into the limited dilution volume available beneath the pycnocline (trapping layer). However, Figure 8 shows that a future discharge scenario being planned for the Hyperion Water Reclamation Plant (a scenario not evaluated by Walker, 2016) appears to be problematic. Figure 8 indicates that brine-only discharges from the reclamation plant of 10 mgd at 6.8 ppt will only achieve a minimum initial dilution of Dm = 59.6, in violation of the dilution credit presently issued to the Hyperion 5-Mile Outfall under NPDES permit (No. CA-0109991, Order No. R4-2010-0200). This problematic result is due to *diffuser stall* since the densimetric Froude number becomes sub-critical at discharges as little as 10 mgd, (where $F_r = u / \sqrt{g' d}$ = 0.49). At these ultra-low discharge flows, there are simply too many discharge ports with too much discharge cross-sectional area in the Hyperion 5-Mile diffuser, resulting in failure of the discharge streams to become turbulent jets. In this case, the maximum discharge velocity is only u = 9.6 cm/s. To correct this condition without physical modification of the diffuser, the brackish brine-only conveyance must be increased to at least 24.3 mgd. Otherwise, many of the existing discharge ports are likely to become flooded by ambient seawater. If diffuser ports flood, a salt wedge forms inside the diffuser and beneath the brackish brine, resulting in high rates of internal bio-fouling of the diffuser.

6) Dilution Results for Blended West Basin Brine Discharges

The results of the dilution modeling analysis are summarized in Table 3. Most of the modeled outcomes satisfy discharge limits set forth under both the Appendix- A brine amendment of the Ocean Plan and Requirement III.C.4(b) specific to buoyant discharges. The only failures resulted from co-mingling West Basin brine with 10 mgd of brackish brine effluent from the Hyperion Water Reclamation Plant (projected as the ultimate low-flow conveyance once the reclamation plant is expanded to final design capacity). As discussed in Section 5, the 10 mgd brackish brine discharges from the 5-Mile Outfall will not satisfy NPDES discharge permit limits even as a stand-alone scenario. When either 21 mgd or 63 mgd of West Basin brine is added to the 10 mg of brackish brine from the Hyperion Water Reclamation Plant, the combined effluent becomes negatively buoyant (those scenarios in Table 2 where the density anomaly is negative). The effluent limits will be governed by the new brine amendments to the Ocean Plan per Appendix-A of SWRCB (2015). The discharge plume consists of an initial fully developed turbulent jet with rapid initial dilution caused by entrainment of the surrounding water mass, followed by a more gradual subsequent dilution phase where the brine plume disperses as a turbulent bottom spreading layer, (Figure 9). During the entire dilution process, the dense plume remains in close proximity to the seabed. The pycnocline remains well above the plume and there is no trapping layer to limit dilution and define the boundaries of a ZID. The Visual Plumes simulation in Figure 10 indicates that the salinity (red curve) progressively declines as

Table 3: Summary of results for Dilution of Brine from the West Basin Desalination Project Discharged from the Hyperion 5-mile Outfall

Discharge Scenario Wastewater + Brine = Total Flow Rate (MGD)	Combined Discharge Salinity (ppt)	Discharge Velocity m/sec	Densimetric Froude Number $F_r = u / \sqrt{g' d}$	Distance horizontally to within 2ppt of Natural Background (BMZ, m)	Initial Dilution at BMZ	Initial Dilution (Dm) at lowest monthly trapping level **(ZID)	Meet OPA/ NPDES Limits?
*****10 + 0 = 10**	**6.8**	**0.096**	**0.49**	**8.5**	**12.35**	**59.6**	**Maybe/No**
*****10 + 21 = 31**	**48.15**	**0.30**	**2.06**	**144**	**6.33**	**N/A**	**No/Maybe**
*****10 + 63 = 73**	**59.48**	**0.70**	**3.64**	**110**	**11.99**	**N/A**	**No/Maybe**
90 + 21 =110	**12.95**	**1.06**	**6.17**	**1.7**	**9.28**	**135.8**	**Yes/Yes**
90 + 63 = 153	**27.93**	**1.48**	**16.57**	**0.7**	**1.78**	**130.4**	**Yes/Yes**
177 + 21 = 198	**7.19**	**1.91**	**9.80**	**2.5**	**12.15**	**124.8**	**Yes/Yes**
177 + 63 = 240	**17.80**	**2.32**	**15.37**	**1.7**	**6.85**	**119.6**	**Yes/ Yes**
203 + 21 = 224	**6.36**	**2.16**	**10.91**	**2.8**	**12.57**	**121.6**	**Yes/ Yes**
203 + 63 = 266	**16.06**	**2.57**	**16.22**	**2.1**	**7.72**	**118.4**	**Yes/ Yes**
250 + 21 = 271	**5.26**	**2.68**	**13.12**	**3.0**	**13.1**	**115.8**	**Yes/ Yes**
250 + 63 = 313	**13.65**	**3.02**	**17.82**	**2.8**	**8.92**	**110.6**	**Yes/ Yes**
699 + 21 = 720	**1.98**	**6.94**	**32.52**	**10.7**	**14.76**	**84.2**	**Yes/ Yes**
657 + 63 = 720	**5.94**	**6.94**	**34.81**	**10.3**	**12.78**	**84.0**	**Yes/ Yes**

Red = future low wastewater flow; **Yellow** = present low wastewater flow; **Blue** = average wastewater flow

Green = combined discharge at maximum certified hydraulic capacity

* Trapping Levels (ZID) are measured in terms of height above the point of discharge (vertical distance from discharge ports)

** ZID boundary defaults to minimum trapping level for buoyant discharges.

***Wastewater for these scenarios is brackish brine from Hyperion Water Reclamation Plant at 6.8 ppt

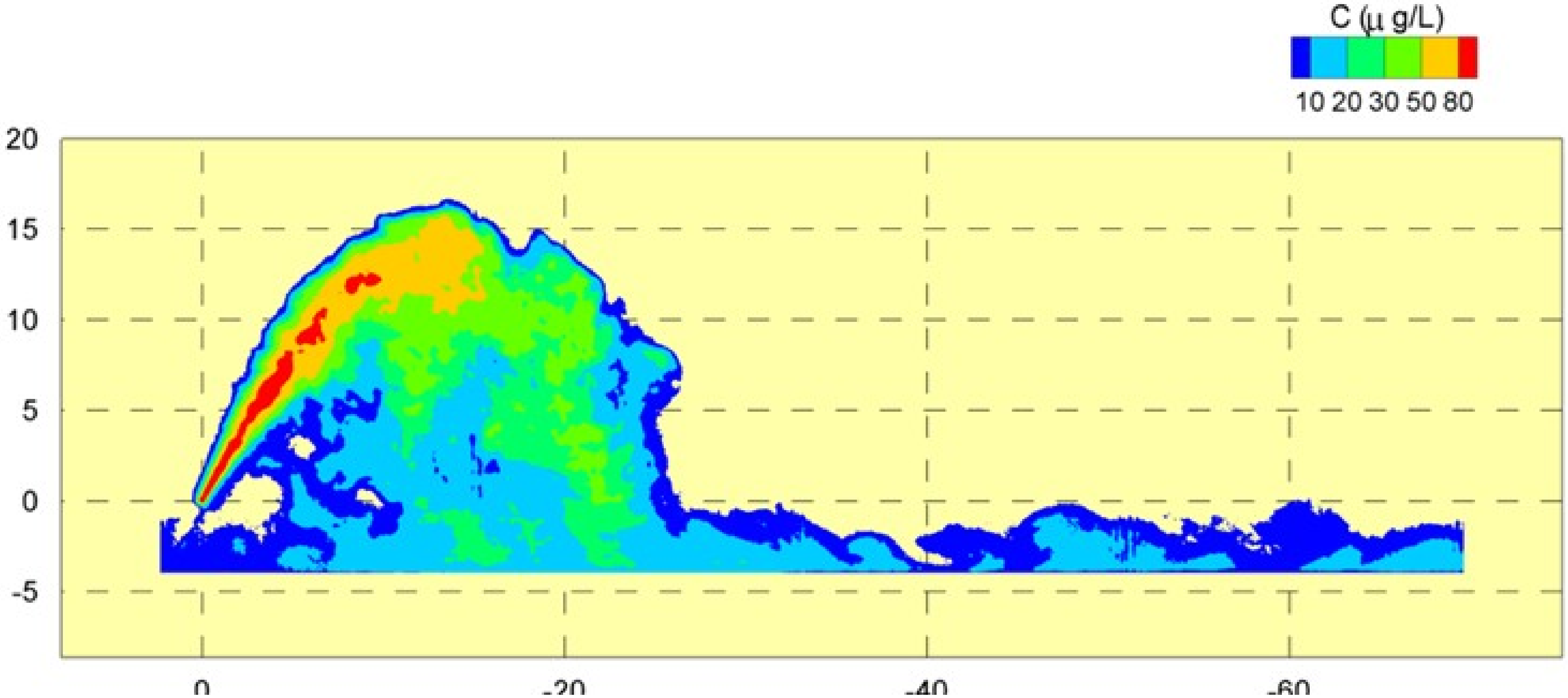


Figure 9: Brine plume and subsequent bottom spreading layer after discharge from a diffuser. The turbulent bottom spreading layer appears between horizontal reference points -25 m and -70 m on the right hand portion of the figure, (from Roberts, 2012, cf. Jenkins et al., 2012)

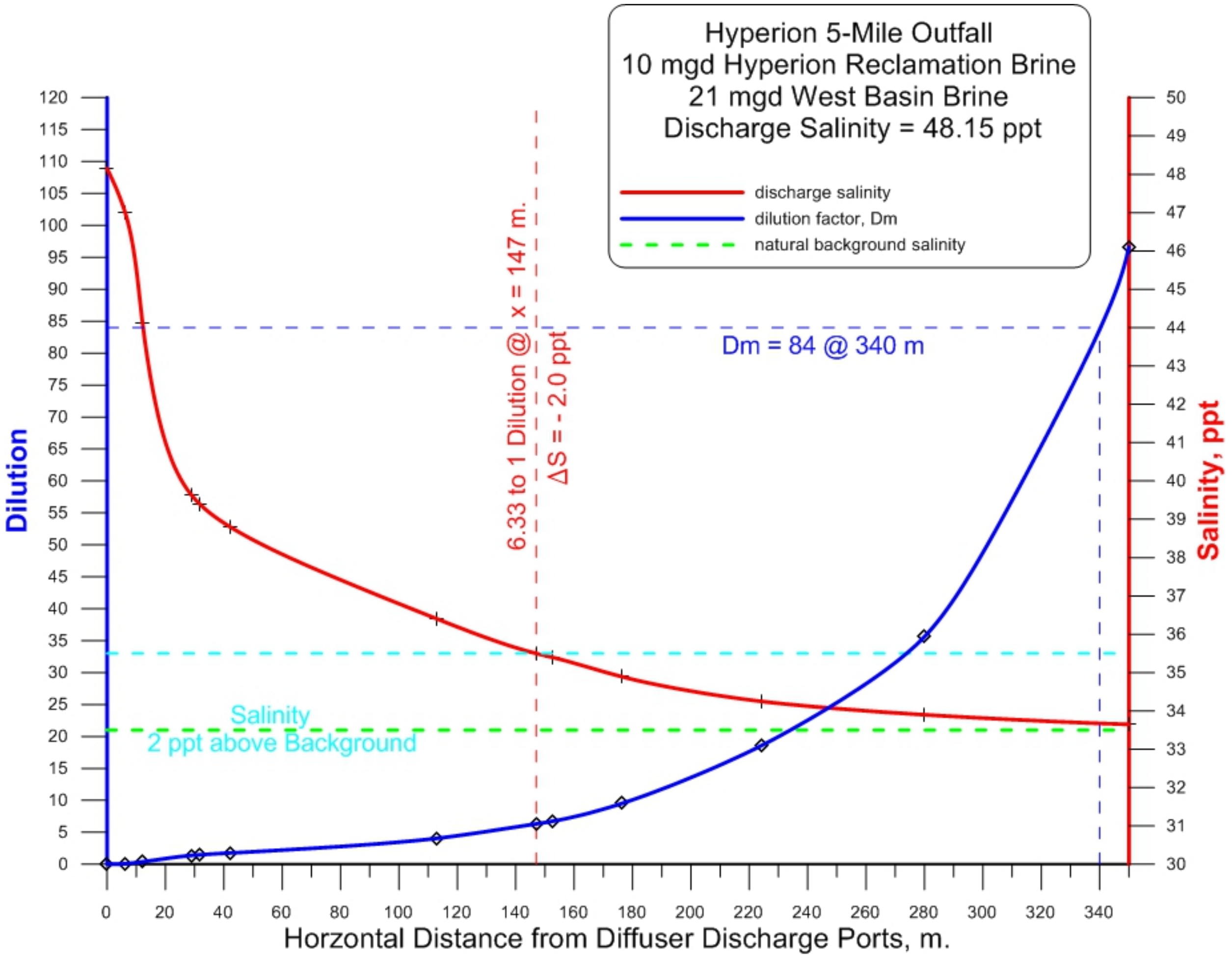


Figure 10: Visual Plumes (UM3) simulation of still water dilution of 21 mgd of West Basin brine blended with 10 mgd of Hyperion water reclamation brine discharged at a combined end-of-pipe of 48.15 ppt. Discharge salinity (red, right hand axis) as a function of distance vertically (upper panel) and horizontally (lower panel) from the Hyperion 5-mile outfall diffuser. Dilution factor (blue, left hand axis) as a function of distance vertically (upper panel) and horizontally (lower panel).

plume spreads horizontally across the seafloor, but does not reach to within 2ppt of natural background salinity until 147 m from the point of discharge. This is result does not satisfy the 100 m BMZ discharge limits set under the Appendix-A provisions of the amended Ocean Plan (SWRCB 2015). However, dilution continues beyond 147 m from the discharge point and reaches the value of Dm = 84 required by the present NPDES permit (No. CA-0109991, Order No. R4-2010-0200) at 340 m (cf. blue curve in Figure 10). The fact that the dilution curve continues to increase beyond x = 340 m suggests that dilution is still not yet complete; so that the minimum initial dilution may be even greater than Dm =84. Therefore it can be argued that blending 21 mgd of West Basin Brine with 10 mgd of brackish brine from the Hyperion Water Reclamation Plant will result in a dilution performance at the 5-Mile Outfall that satisfies the present NPDES permit, but is non-compliant with the brine amendment of the Ocean Plan. Similarly, the addition of 63 mgd of West Basin Brine with 10 mgd of brackish brine from the Hyperion Water Reclamation Plant (Figure 11) will achieve sufficient dilution, Dm = 84 at x = 213 m, which satisfies the present NPDES permit, but discharge salinity will not reach within 2 ppt of natural background until x = 110 m from the point of discharge; and hence is non-compliant with the brine amendment of the Ocean Plan. The reason why dilution is faster with the addition of 63 mgd of West Basin brine vs. 21 mgd is that the higher resulting combined discharge rate increases the densimetric Froude number by 77%, producing larger turbulent eddies in the discharge jet streams that accelerate dilution rates.

For all other combinations of West Basin brine and Hyperion effluent that result in buoyant discharges, (those scenarios in Table 2 where the density anomaly is positive), the discharge plumes will rise in the water column until reaching the trapping layer at the pycnocline interface, as represented in Figure 2. For these buoyant discharge cases, the present NPDES permit (No. CA-0109991, Order No. R4-2010-0200) and Requirements III.C.4(b-d) of the Ocean Plan are the critical regulatory discharge standards, although we will still pay attention to the 100 m BMZ discharge limits set under the Appendix-A provisions of the amended Ocean Plan (SWRCB 2015). Inspection of Table 3 reveals that dilution performance of the 5-Mile Outfall diffuser was better for buoyant discharges at low-flow conditions than high flow conditions, because, again, smaller volumes of effluent at smaller discharge rates are more rapidly diluted in the limited volume of receiving water available beneath the pycnocline and trapping layer. The best dilution performance was achieved for the low-flow condition that blended 90 mgd of effluent from the Hyperion Water Reclamation Plant with 21 mgd of Wes Basin brine, (Figure 12), where minimum initial dilution (blue curve) reached Dm = 135.8 to 1 at the worst-month trapping layer z = 42.6 m above the discharge point. Because the primary motion of the plume is vertically upward through the water column, the horizontal spreading of the plume was only x = 10.1 m at the pycnocline trapping level. Because of this limited horizontal spreading, the BMZ limits of the amended Ocean Plan were easily satisfied, and the discharge salinity (red curve) rose to within 2 ppt of natural background at a horizontal distance of only x =1.7 m from the point of discharge. However, the diffuser jets in the vicinity of the Y-junction of the diffuser legs produce horizontal entrainment streams that bend the angle of the jet streams, (Figure 13); as well as significant flanking streams at the ends of the north and south legs of the diffuser (Figure 14 & 15). These flow features were resolved with the CFD model and used to adjust jet angles in the initialization of the Visual Plumes (UM3) mixing zone model.

When the West Basin brine loading was increased to 63 mgd and blended with 90 mgd of effluent from the Hyperion Water Reclamation Plant, (Figure 16), the minimum initial dilution (blue curve) declined slightly to Dm = 135.8 to 1 at the pycnocline trapping level, well

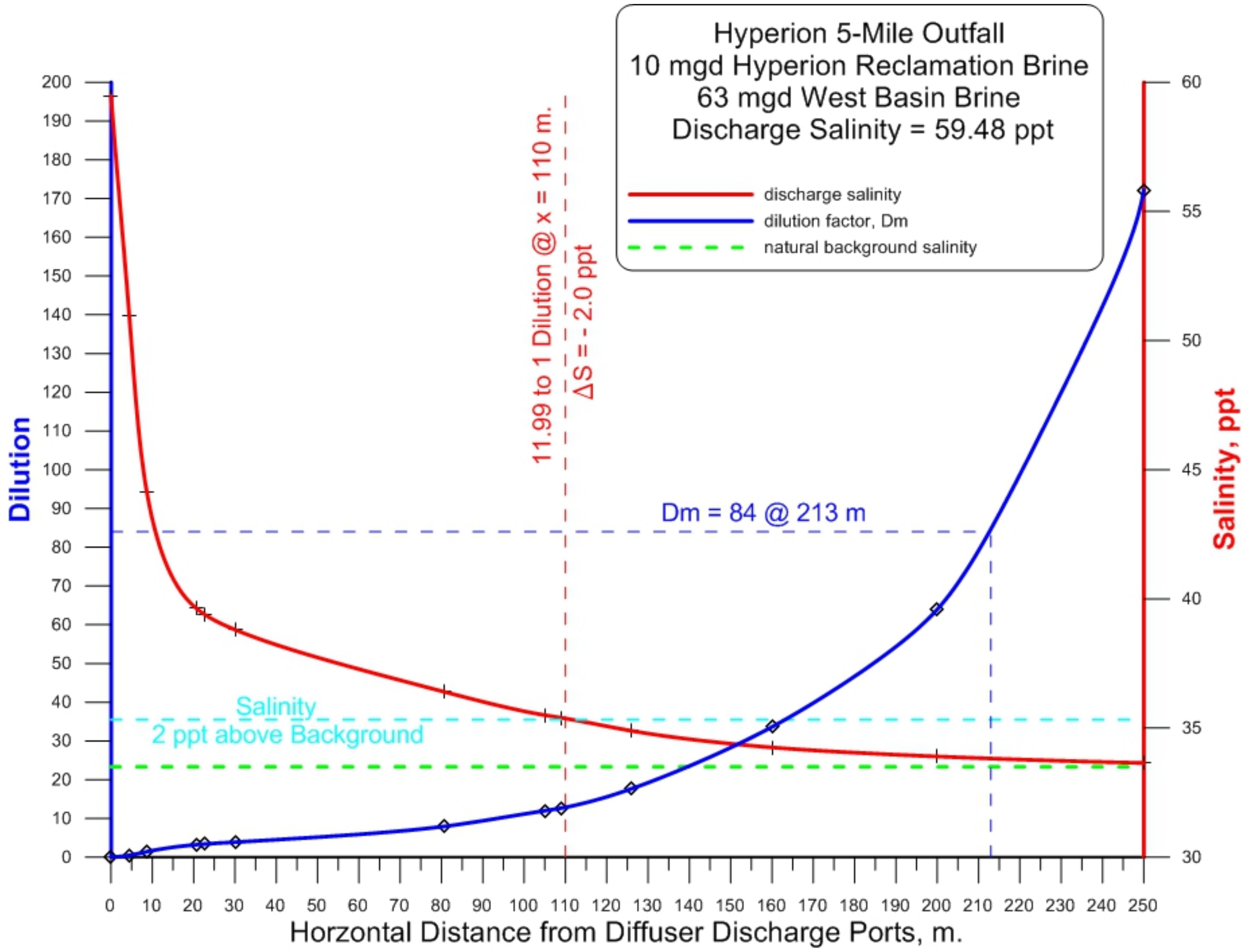


Figure 11: Visual Plumes (UM3) simulation of still water dilution of 63 mgd of West Basin brine blended with 10 mgd of Hyperion water reclamation brine discharged at a combined end-of-pipe of 59.148 ppt. Discharge salinity (red, right hand axis) as a function of distance vertically (upper panel) and horizontally (lower panel) from the Hyperion 5-mile outfall diffuser. Dilution factor (blue, left hand axis) as a function of distance vertically (upper panel) and horizontally (lower panel).

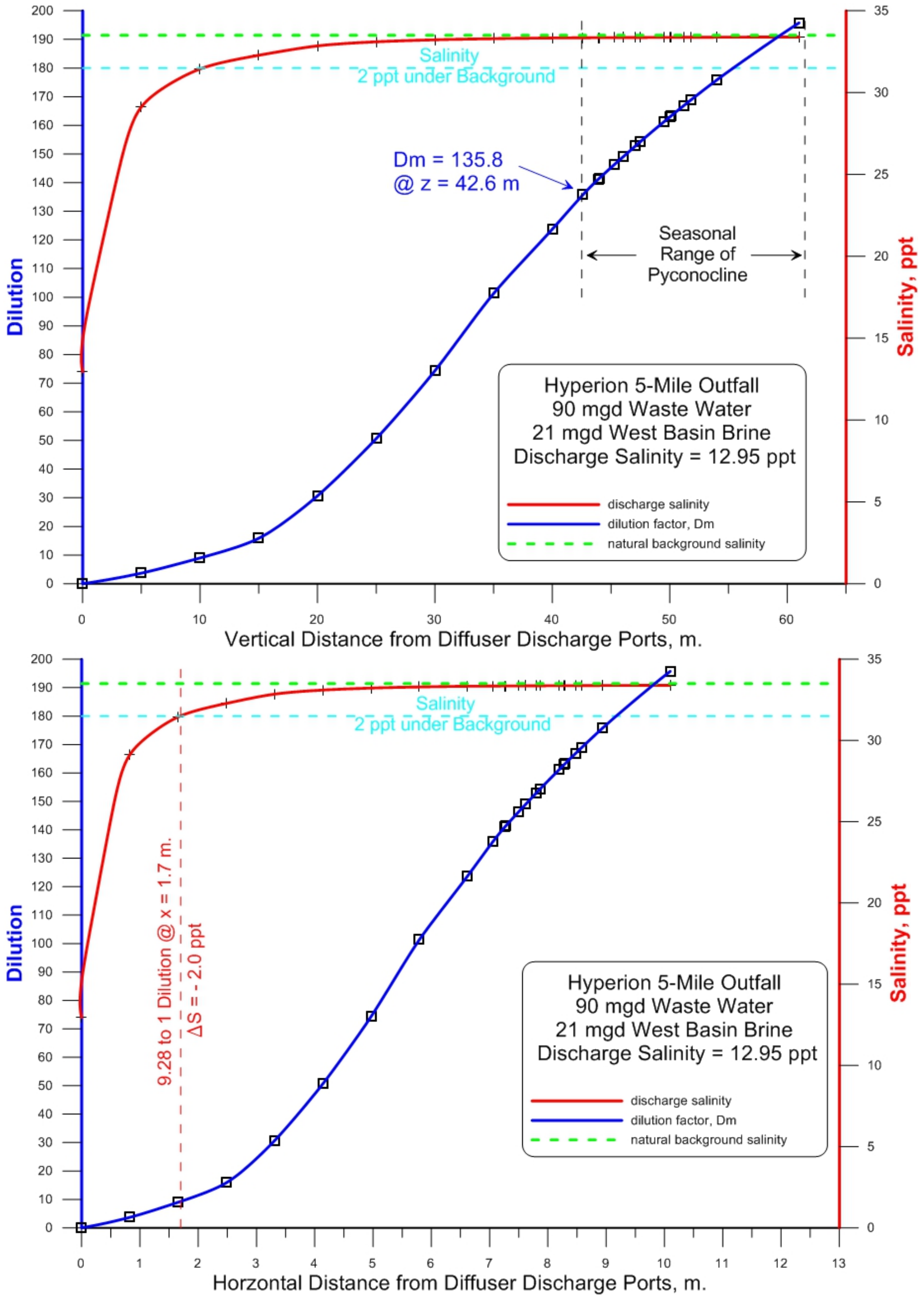


Figure 12: Visual Plumes (UM3) simulation of still water dilution of 21 mgd of West Basin brine blended with 90 mgd of Hyperion wastewater discharged at 12.95 ppt end-of-pipe. Discharge salinity (red, right hand axis) as a function of distance vertically (upper panel) and horizontally (lower panel) from the Hyperion 5-mile outfall diffuser. Dilution factor (blue, left hand axis) as a function of distance vertically (upper panel) and horizontally (lower panel).

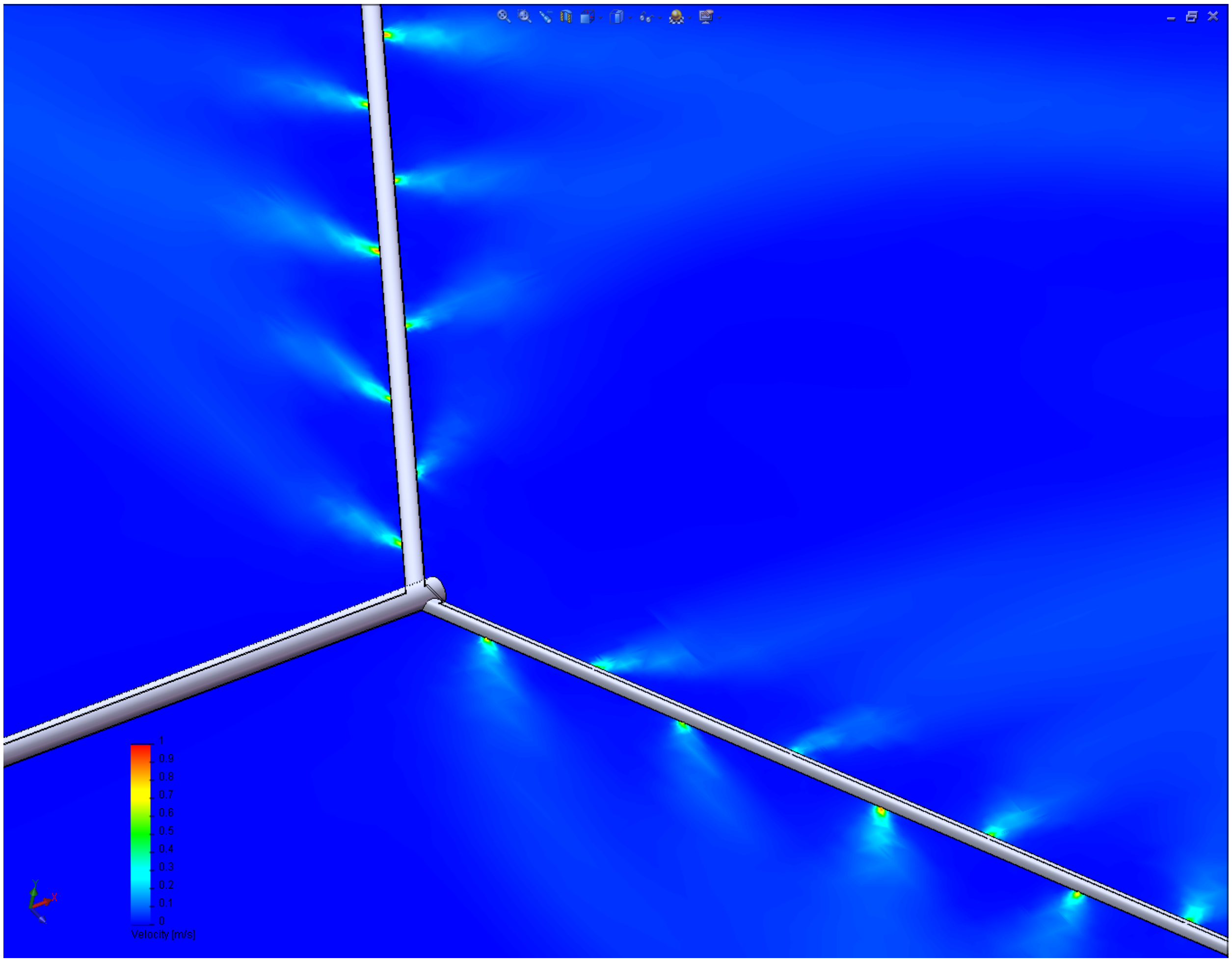


Figure 13: Contour cut-plot in a horizontal plane through the jet nozzles discharge velocity field in the neighborhood of the Y-junction of the Hyperion 5-Mile Outfall diffuser. COSMOS/FloWORKS simulation of still water dilution of 21 mgd of West Basin brine blended with 90 mgd of Hyperion wastewater discharged at u = 1.06 m/s, $F_r = u / \sqrt{g' d} = 6.17$. Note horizontal angles of jets due to entrainment streams.

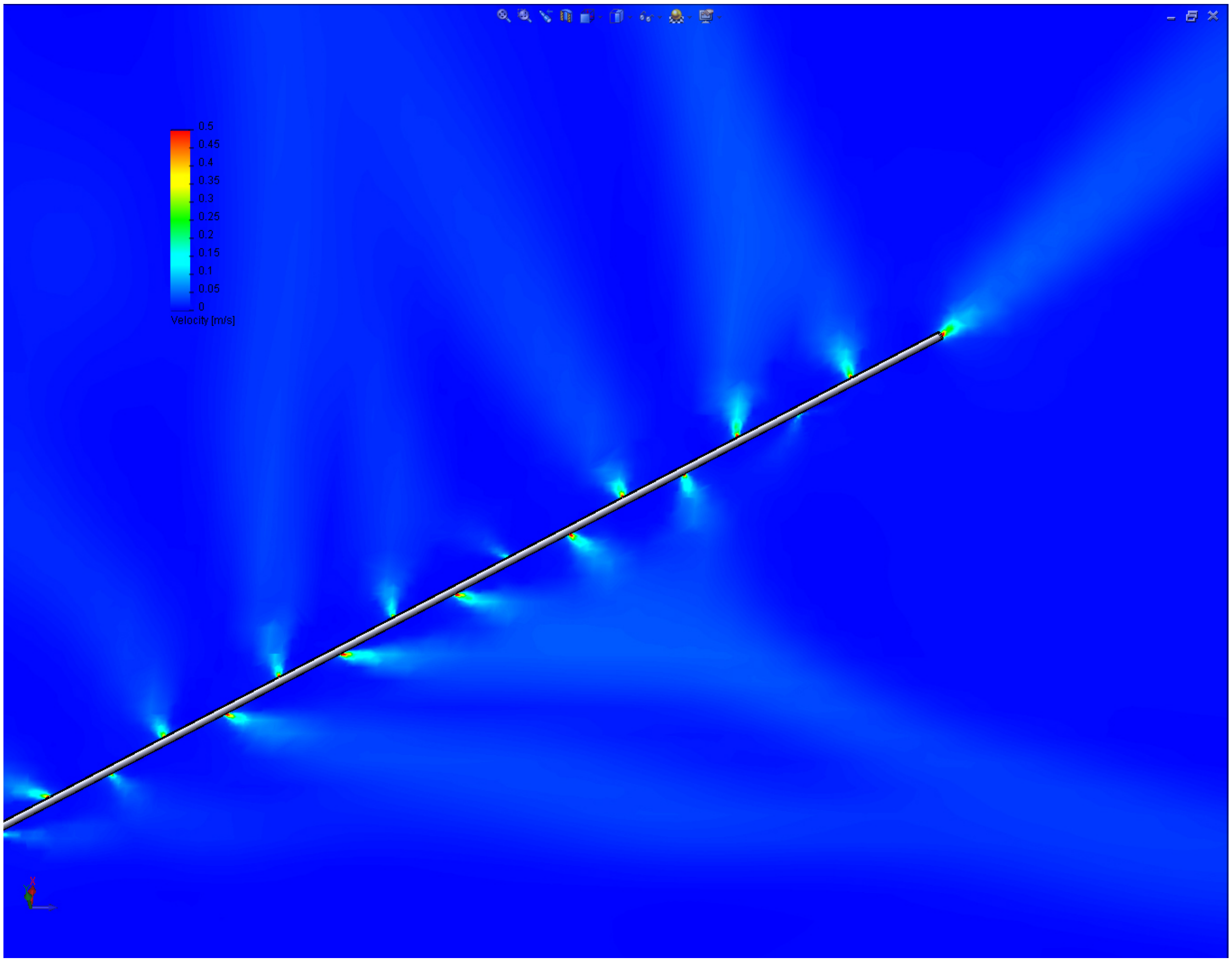


Figure 14: Contour cut-plot in a horizontal plane through the jet nozzles discharge velocity field in the neighborhood of the north end of the north leg of the Hyperion 5-Mile Outfall diffuser. COSMOS/FloWORKS simulation of still water dilution of 21 mgd of West Basin brine blended with 90 mgd of Hyperion wastewater discharged at u = 1.06 m/s, $F_r = u / \sqrt{g' d} = 6.17$. Note horizontal angles of jets due to entrainment streams and end-effects due to terminal end jets.

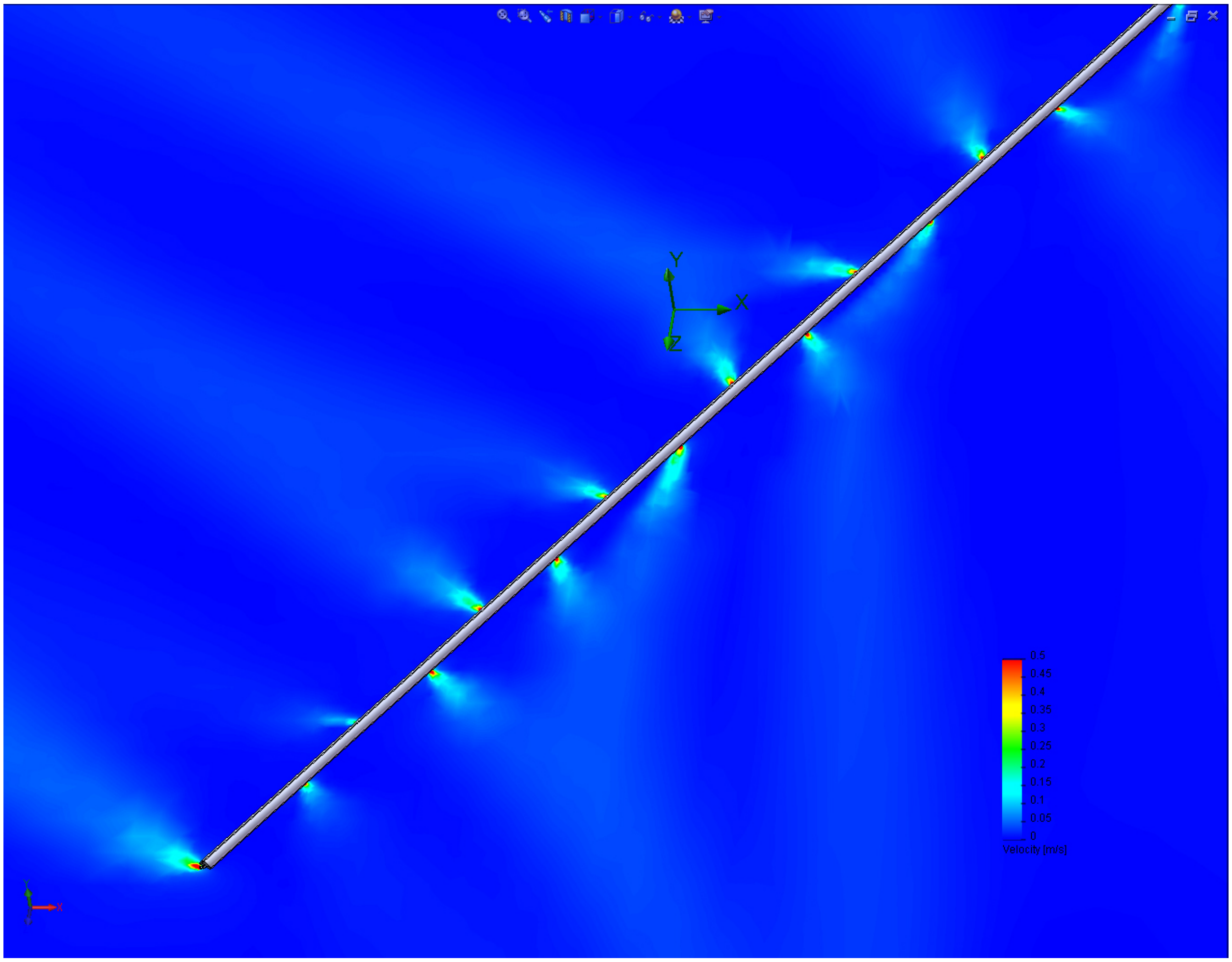


Figure 15: Contour cut-plot in a horizontal plane through the jet nozzles discharge velocity field in the neighborhood of the south end of the Hyperion 5-Mile Outfall diffuser. COSMOS/FloWORKS simulation of still water dilution of 21 mgd of West Basin brine blended with 90 mgd of Hyperion wastewater discharged at u = 1.06 m/s, $F_r = u / \sqrt{g' d}$ = 6.17. Note horizontal angles of jets due to entrainment streams and end-effects due to terminal end jets.

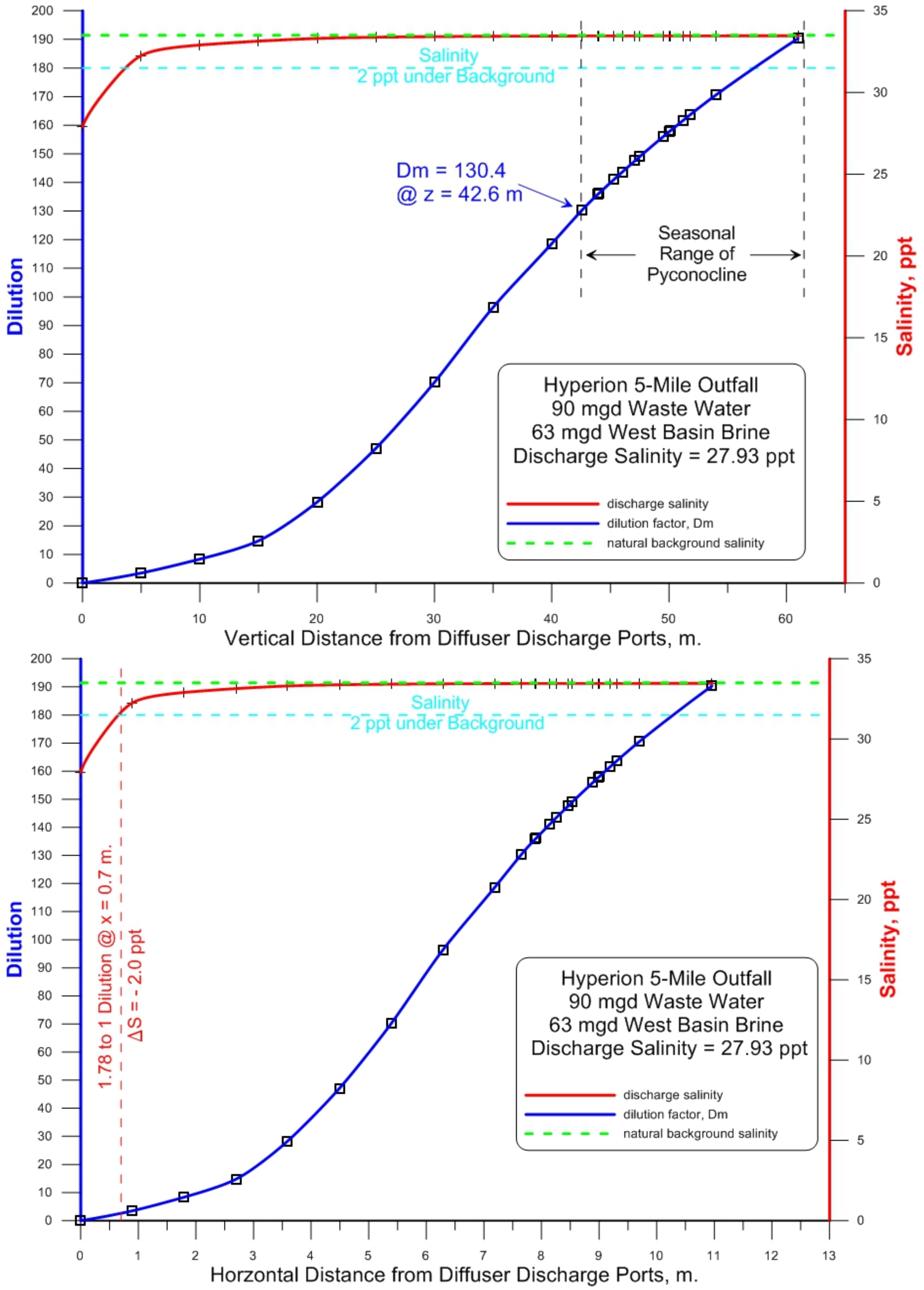


Figure 16: Visual Plumes (UM3) simulation of still water dilution of 63 mgd of West Basin brine blended with 90 mgd of Hyperion wastewater discharged at 27.93 ppt end-of-pipe. Discharge salinity (red, right hand axis) as a function of distance vertically (upper panel) and horizontally (lower panel) from the Hyperion 5-mile outfall diffuser. Dilution factor (blue, left hand axis) as a function of distance vertically (upper panel) and horizontally (lower panel).

above the 84 to 1 dilution credit required by the present NPDES permit.. Discharge salinity (red curve) rose to within 2 ppt of natural background at a horizontal distance of only $x = 0.7$ m from the point of discharge, again easily satisfying the Appendix-A brine amendment to the Ocean Plan. When the Hyperion Water Reclamation Plant effluent conveyance is increased to the historic absolute minimum of 177 mgd and blended with 21 mgd of Wes Basin brine, (Figure 17), minimum initial dilution (blue curve) declined further to Dm = 124.8, while discharge salinity came within 2 ppt of natural background at a horizontal distance of only x =2.5 m from the point of discharge as horizontal spreading of the plume increased to x = 10.96 m. But, increasing West Basin brine loading to 63 mgd and blending it with 177 mgd of effluent from the Hyperion Water Reclamation Plant, (Figure 18), produced further declines in the minimum initial dilution to Dm = 119.6, while discharge salinity (red curve) rose to within 2 ppt of natural background at a horizontal distance of only $x = 1.7$ m from the point of discharge. And so these trends continued in Figures 19-24 with additional increases in effluent from the Hyperion Water Reclamation Plant resulting in continual declines in the minimum initial dilution, but always remaining above the dilution credit of Dm = 84 required by the present NPDES permit; and increases in the horizontal plume spreading that resulted in *the 2ppt above natural background threshold* being achieved at greater horizontal distances from the point of discharge, but always well within the 100 m BMZ requirement of the amended Ocean Plan (SWRCB, 2015). Worst-case dilution occurred for combined discharges at maximum certified hydraulic capacity, 720 mgd (Figures 23 & 24). Here minimum initial dilution was Dm = 84.2 with 21 mgd of West Basin brine loading, and Dm = 84.0 with 63 mgd of West Basin brine loading; both results marginally satisfying the certified minimum initial dilution for the 5-Mile Outfall under NPDES permit No. CA-0109991, Order No. R4-2010-0200. At these high flow rates, the densimetric Froude number was in the range of $F_r = u / \sqrt{g' d}$ = 32.5 to 34.8, and the maximum horizontal spreading of the plume at the pycnocline trapping level increased to x = 28.8 m. Nonetheless, the discharge salinity came within 2 ppt of natural background at horizontal distances in the range of x = 10.3 m to 10.7 m from the point of discharge, easily satisfying the Appendix-A brine amendment of the Ocean Plan (SWRCB, 2015).

The addition of West Basin brine to the Hyperion effluent has multiple dynamic effects which may or may not reduce the minimum initial dilution that would have otherwise been achieved with a wastewater-only discharges of comparable flow rate. On the one hand, brine additions to buoyant effluent reduce the net buoyancy and rate of rise of the discharge plume in the water column; and that reduction in rise rate reduces the rate of entrainment of the surrounding water mass that ultimately produces dilution. On the other hand, the reduction in net buoyancy due to brine additions increases the densimetric Froude number of the discharge jets, which enhances the initial dilution due to turbulent eddy entrainment. However, the results in Table 3 generally show that the addition of West Basin brine has reduced the minimum initial dilution that would have otherwise been achieved with a wastewater-only discharge of comparable flow rate from the Hyperion Water Reclamation Plant; and that the suppression of initial dilution is less for brine additions from the 21 mgd West Basin Desalination Project than for the 63 mgd project. This suggests that the degradation of convective entrainment caused by brine additions has a stronger influence on initial dilution than the enhancement of jet turbulence due to increased densemetric Froude numbers.

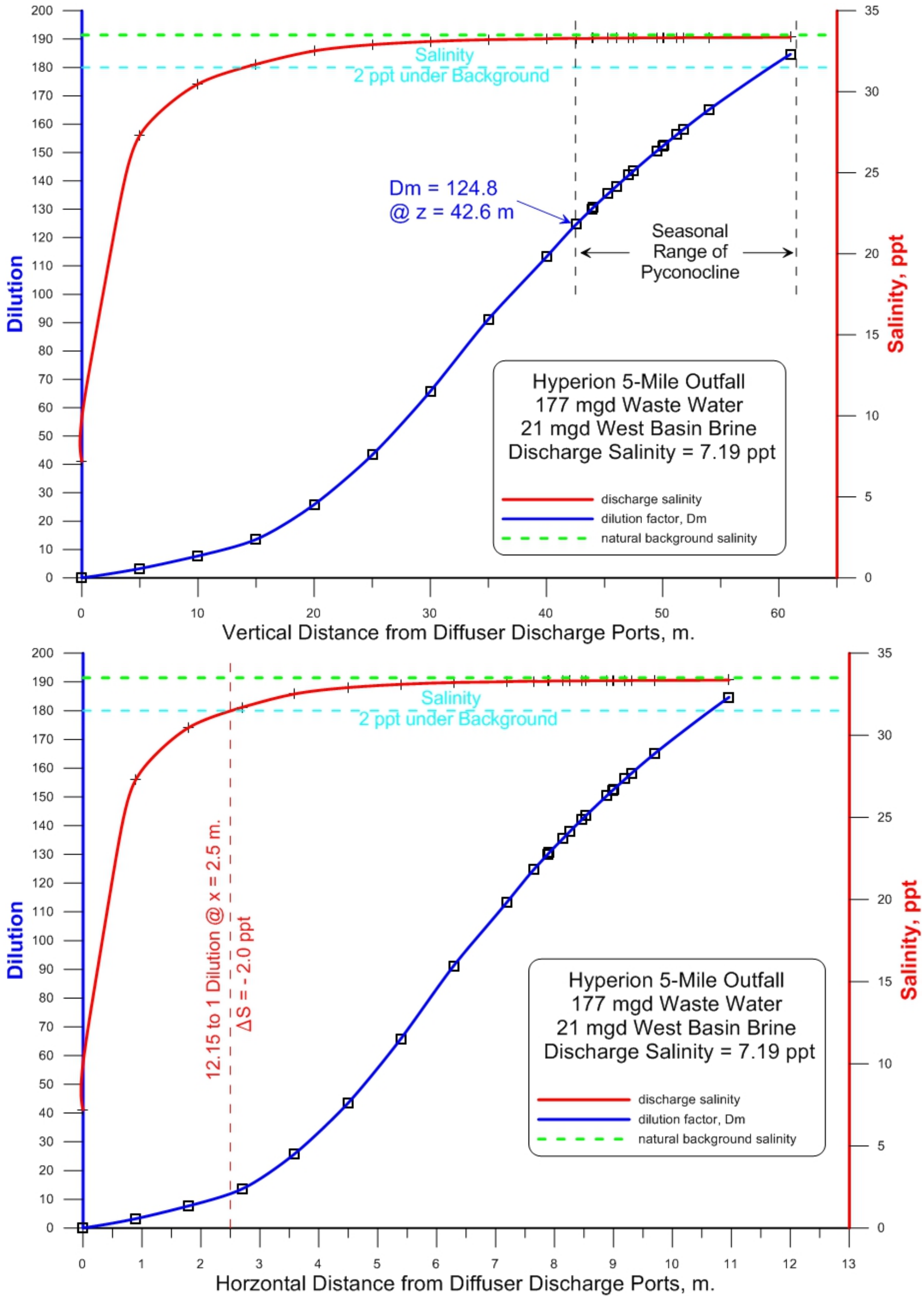


Figure 17: Visual Plumes (UM3) simulation of still water dilution of 21 mgd of West Basin brine blended with 177 mgd of Hyperion wastewater discharged at 7.19 ppt end-of-pipe. Discharge salinity (red, right hand axis) as a function of distance vertically (upper panel) and horizontally (lower panel) from the Hyperion 5-mile outfall diffuser. Dilution factor (blue, left hand axis) as a function of distance vertically (upper panel) and horizontally (lower panel).

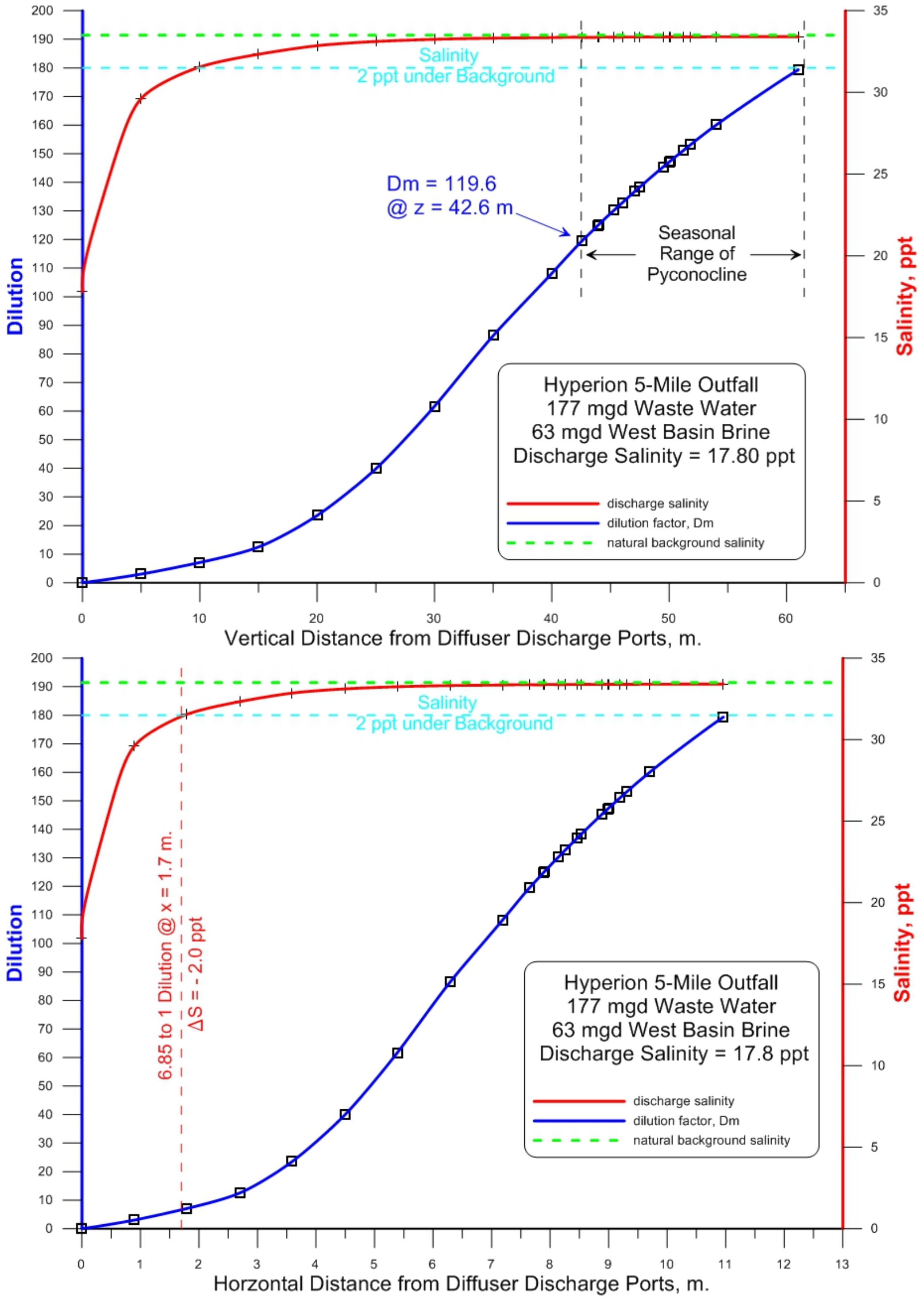


Figure 18: Visual Plumes (UM3) simulation of still water dilution of 63 mgd of West Basin brine blended with 177 mgd of Hyperion wastewater discharged at 17.8 ppt end-of-pipe. Discharge salinity (red, right hand axis) as a function of distance vertically (upper panel) and horizontally (lower panel) from the Hyperion 5-mile outfall diffuser. Dilution factor (blue, left hand axis) as a function of distance vertically (upper panel) and horizontally (lower panel).

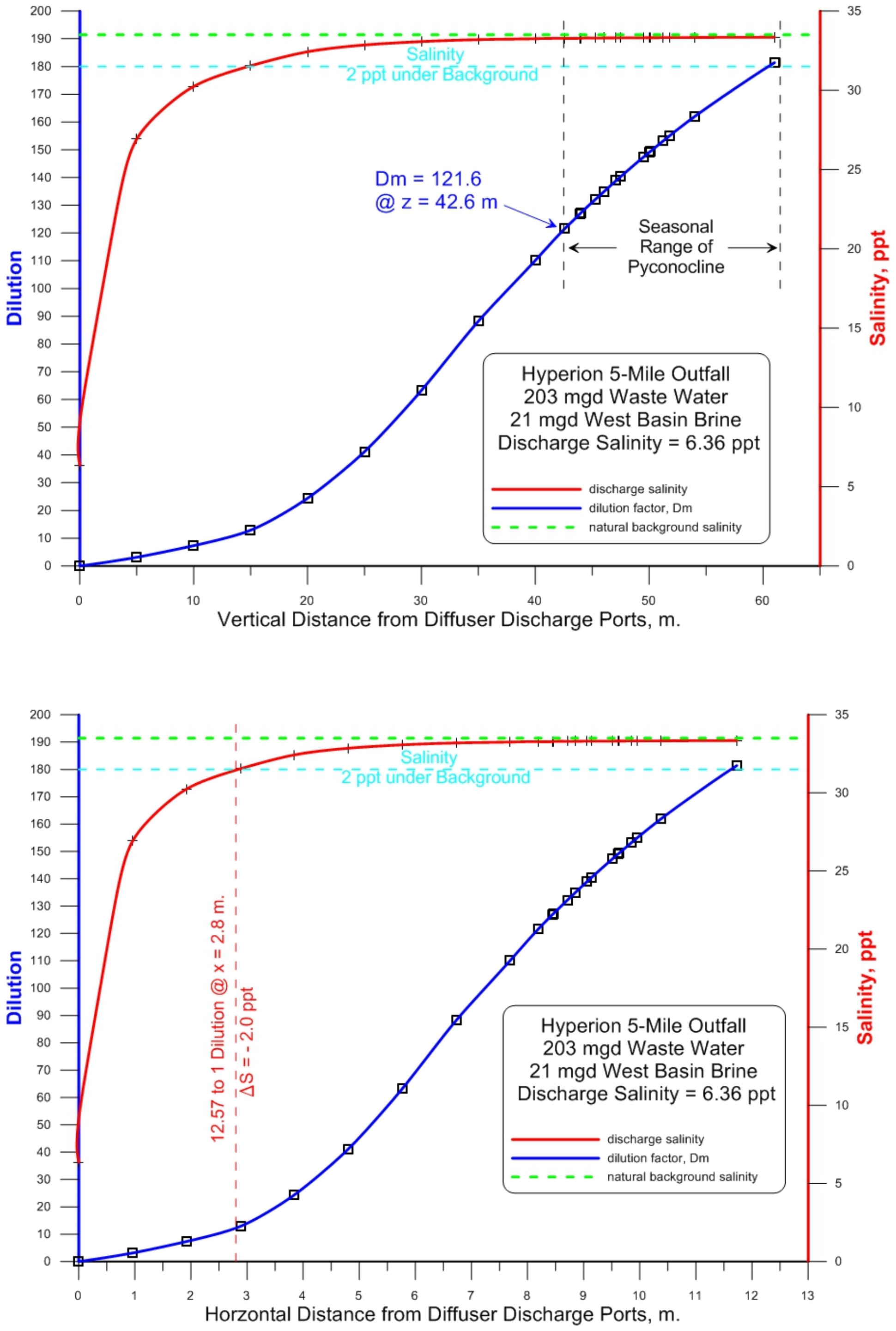


Figure 19: Visual Plumes (UM3) simulation of still water dilution of 21 mgd of West Basin brine blended with 203 mgd of Hyperion wastewater discharged at 6.36 ppt end-of-pipe. Discharge salinity (red, right hand axis) as a function of distance vertically (upper panel) and horizontally (lower panel) from the Hyperion 5-mile outfall diffuser. Dilution factor (blue, left hand axis) as a function of distance vertically (upper panel) and horizontally (lower panel).

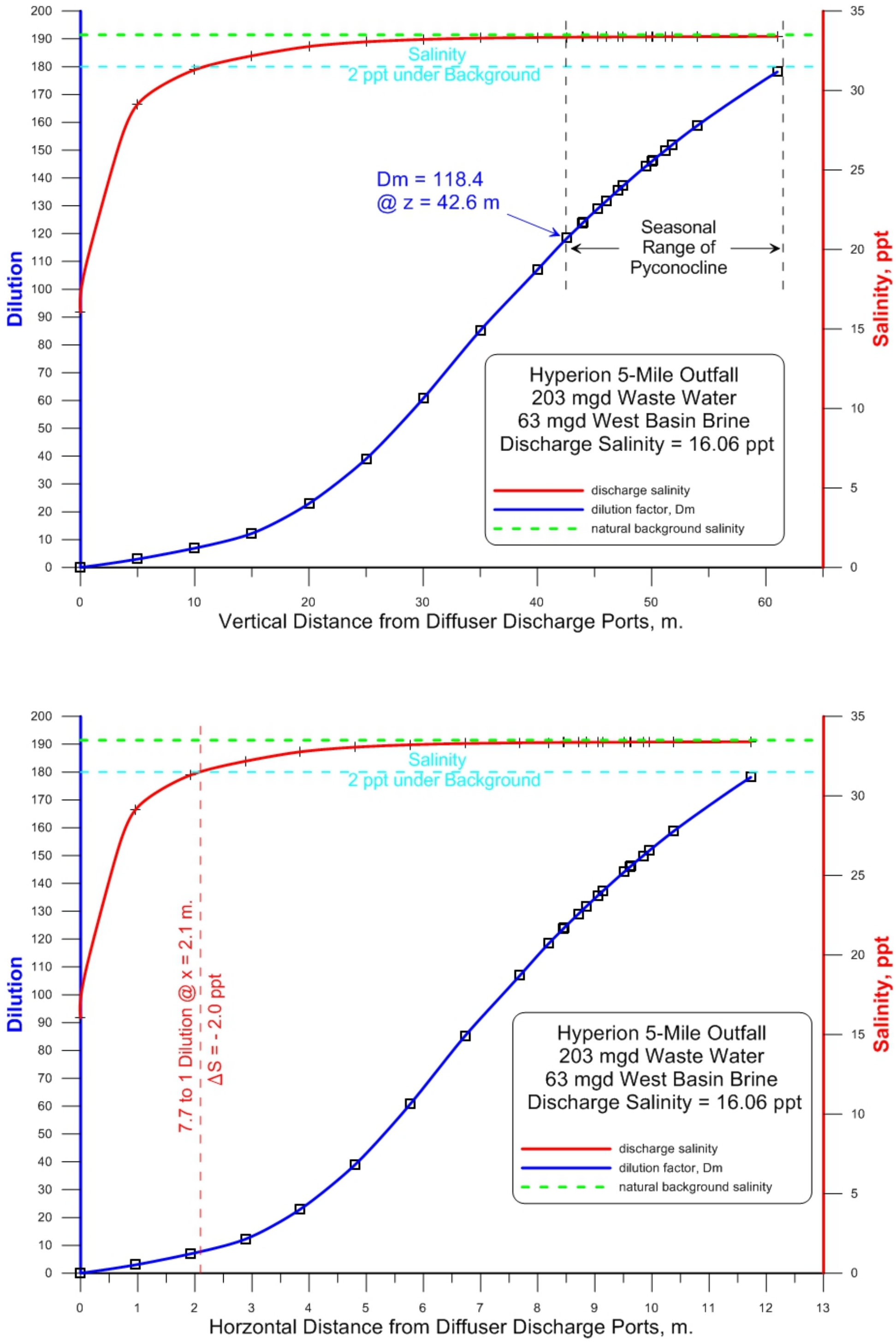


Figure 20: Visual Plumes (UM3) simulation of still water dilution of 63 mgd of West Basin brine blended with 203 mgd of Hyperion wastewater discharged at 16.06 ppt end-of-pipe. Discharge salinity (red, right hand axis) as a function of distance vertically (upper panel) and horizontally (lower panel) from the Hyperion 5-mile outfall diffuser. Dilution factor (blue, left hand axis) as a function of distance vertically (upper panel) and horizontally (lower panel).

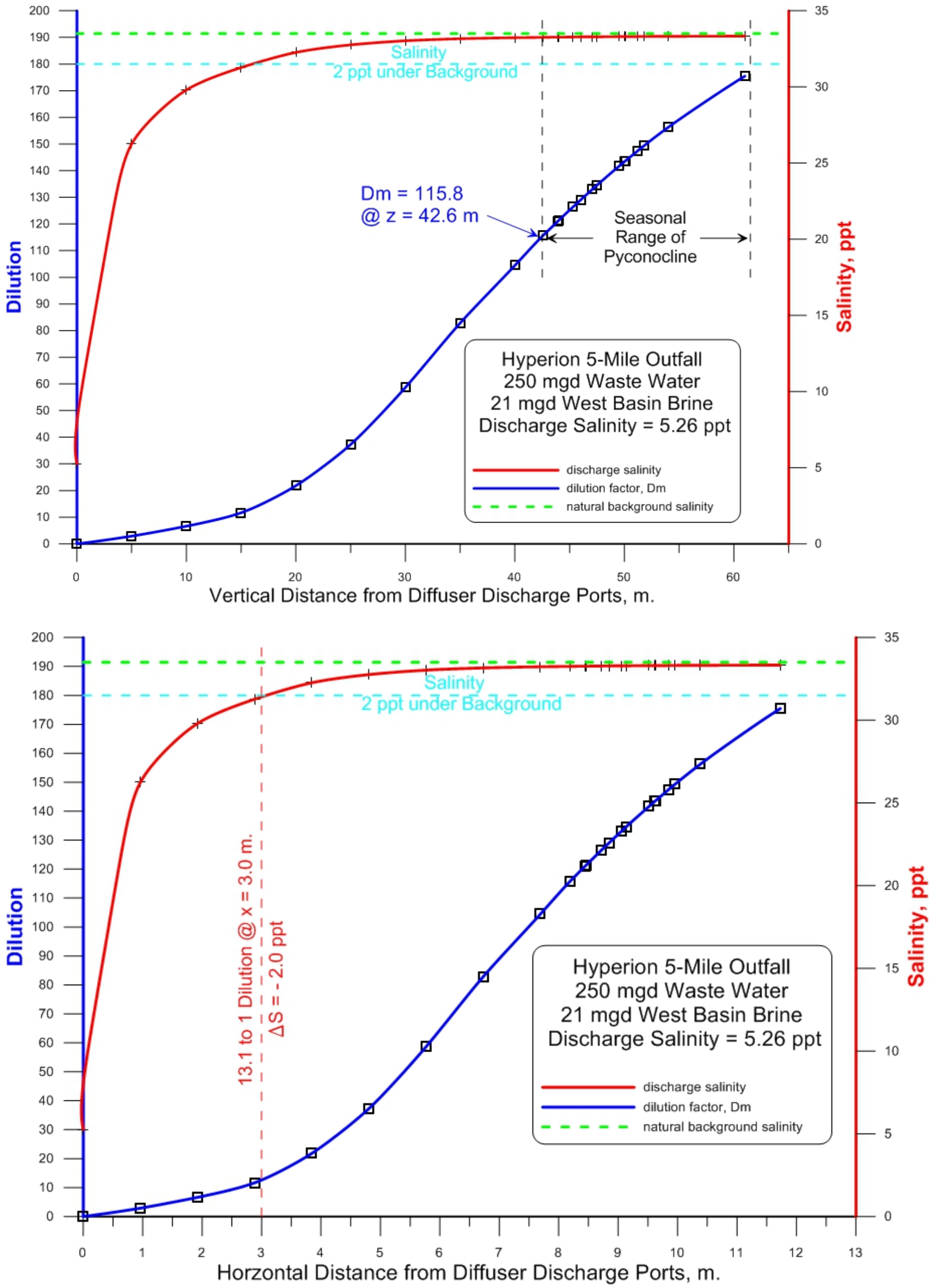


Figure 21: Visual Plumes (UM3) simulation of still water dilution of 21 mgd of West Basin brine blended with 250 mgd of Hyperion wastewater discharged at 5.26 ppt end-of-pipe. Discharge salinity (red, right hand axis) as a function of distance vertically (upper panel) and horizontally (lower panel) from the Hyperion 5-mile outfall diffuser. Dilution factor (blue, left hand axis) as a function of distance vertically (upper panel) and horizontally (lower panel).

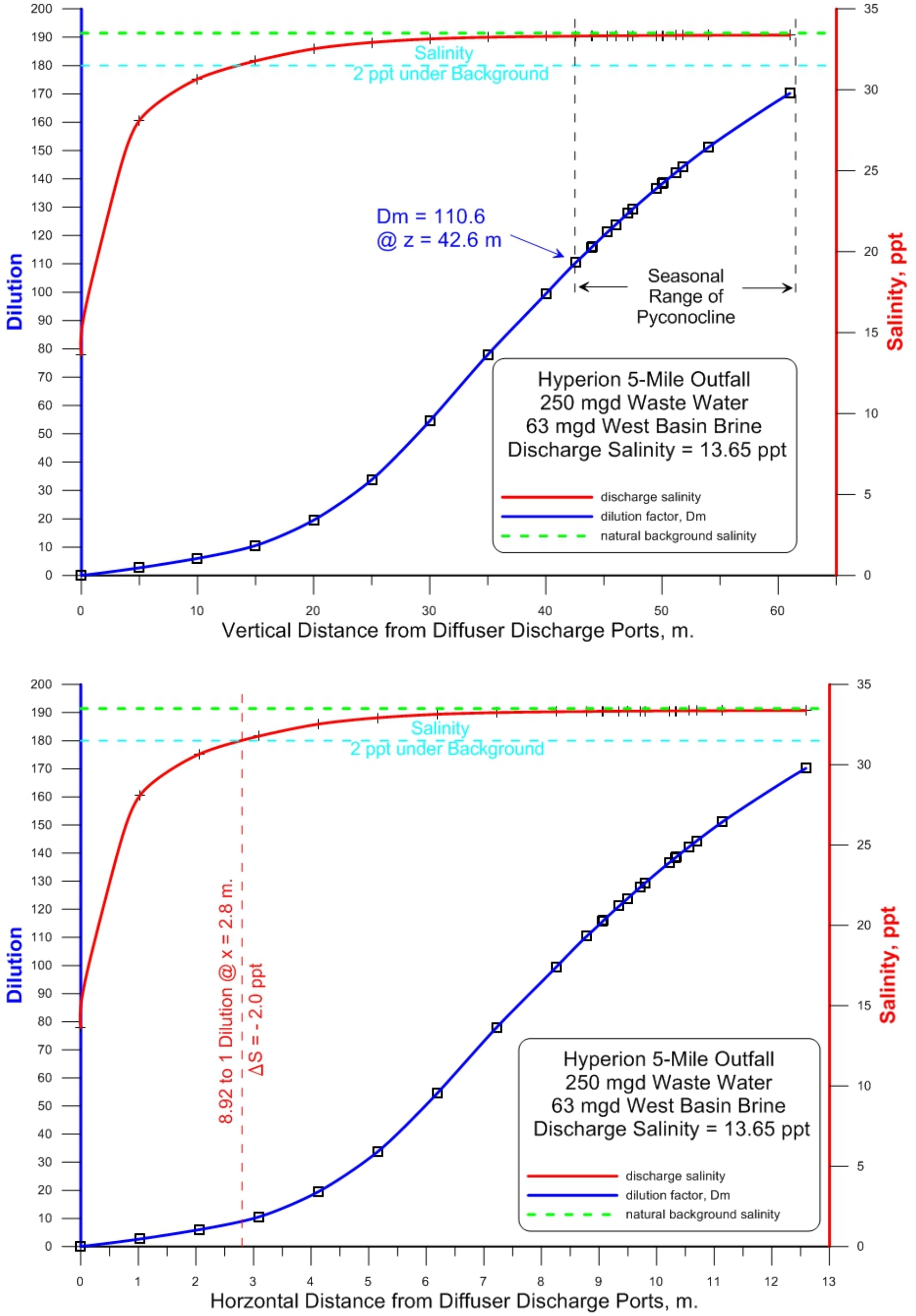


Figure 22: Visual Plumes (UM3) simulation of still water dilution of 63 mgd of West Basin brine blended with 250 mgd of Hyperion wastewater discharged at 13.65 ppt end-of-pipe. Discharge salinity (red, right hand axis) as a function of distance vertically (upper panel) and horizontally (lower panel) from the Hyperion 5-mile outfall diffuser. Dilution factor (blue, left hand axis) as a function of distance vertically (upper panel) and horizontally (lower panel).

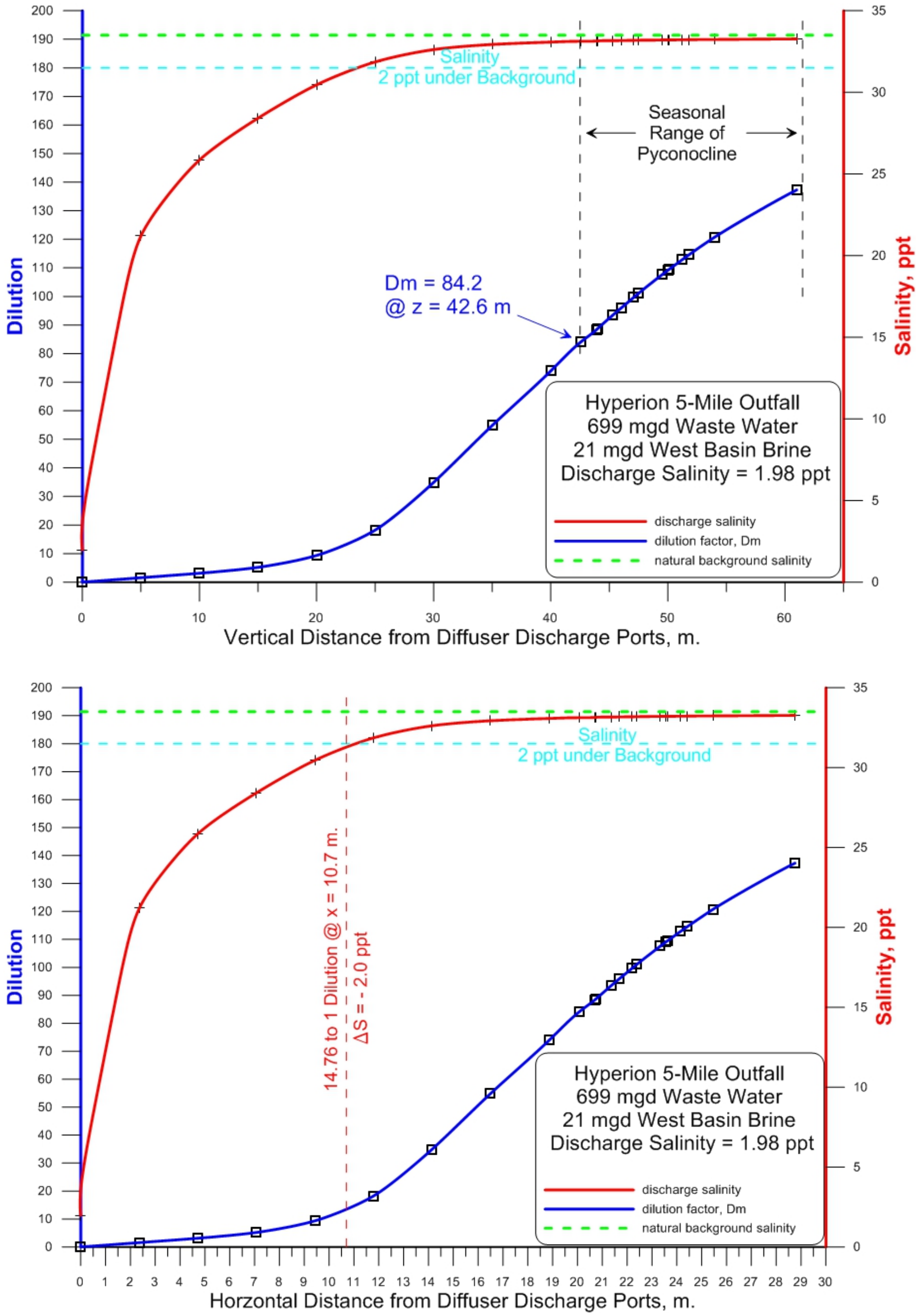


Figure 23: Visual Plumes (UM3) simulation of still water dilution of 21 mgd of West Basin brine blended with 699 mgd of Hyperion wastewater discharged at 1.98 ppt end-of-pipe. Discharge salinity (red, right hand axis) as a function of distance vertically (upper panel) and horizontally (lower panel) from the Hyperion 5-mile outfall diffuser. Dilution factor (blue, left hand axis) as a function of distance vertically (upper panel) and horizontally (lower panel).

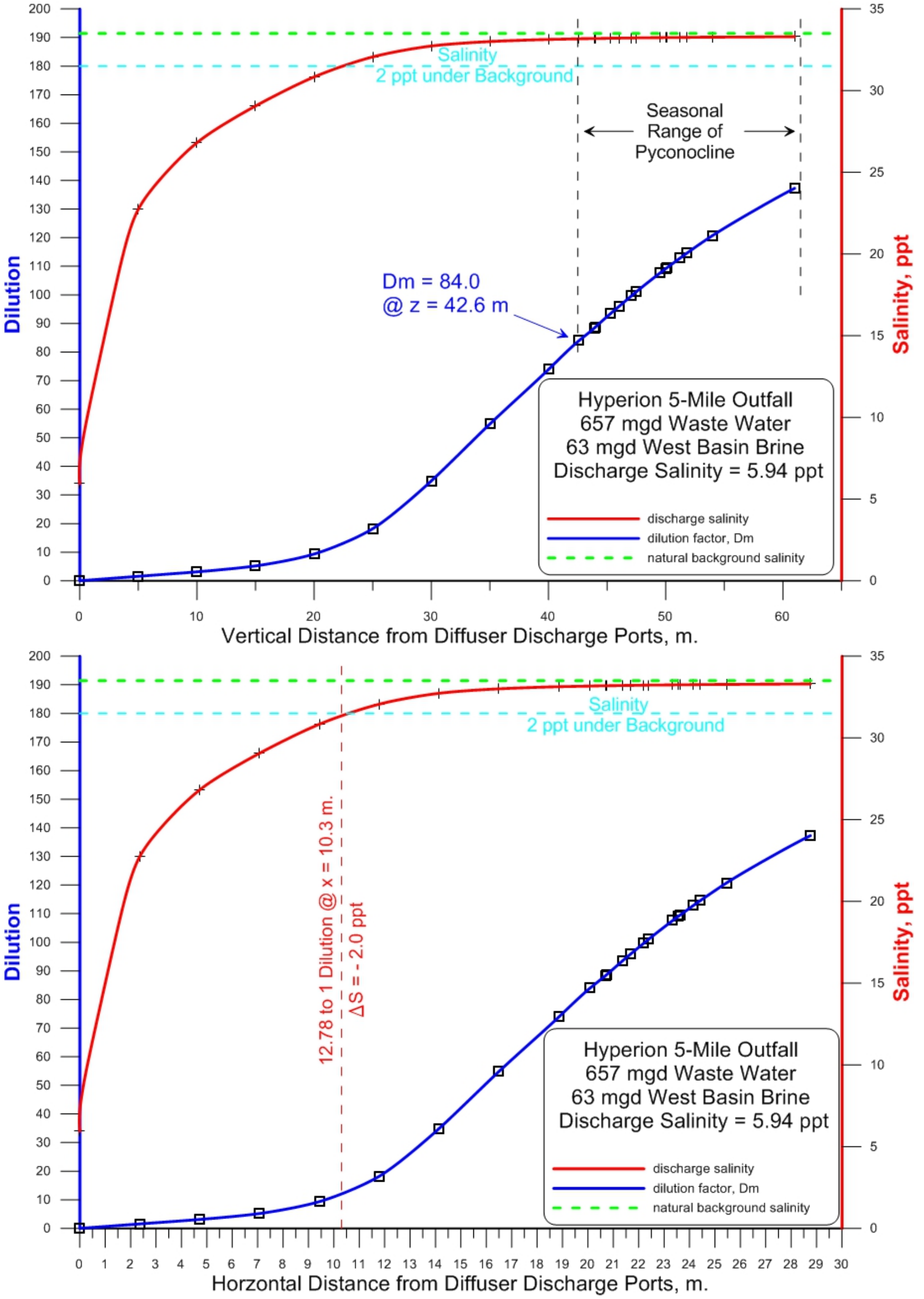


Figure 24: Visual Plumes (UM3) simulation of still water dilution of 63 mgd of West Basin brine blended with 657 mgd of Hyperion wastewater discharged at 5.94 ppt end-of-pipe. Discharge salinity (red, right hand axis) as a function of distance vertically (upper panel) and horizontally (lower panel) from the Hyperion 5-mile outfall diffuser. Dilution factor (blue, left hand axis) as a function of distance vertically (upper panel) and horizontally (lower panel).

7) Conclusions:

This is a dilution study to examine the feasibility of using the Hyperion 5-Mile Outfall to discharge brine by-product from the *West Basin Municipal Water District Sea Water Desalination Project* after it has been blended with effluent from the *Hyperion Water Reclamation Plant*. The study looks at two different scales for West Basin brine conveyance (21 mgd & 63 mgd) to be blended with reclamation plant effluent that varies across an envelope present and future operating conditions, up to and including combined conveyance equal to the maximum certified hydraulic capacity of the outfall (720 mgd).

Feasibility is judged in terms of the ability of the existing diffuser of the 5-Mile Outfall to achieve sufficient dilution performance to satisfy *both* minimum initial dilution requirements of 84 to 1 set forth in the existing NPDES permit (No. CA-0109991, Order No. R4-2010-0200), as well as the discharge limits set forth in the Appendix-A *brine amendment* to the California Ocean Plan. The dilution study invokes the EPA certified Visual Plumes (UM3) mixing zone model and the same reclamation plant effluent properties and environmental parameters assumed by the recently updated dilution study for the Hyperion 5-Mile Outfall performed by Walker (2016), who used the alternative EPA dilution model, CORMIX version 9.0.

The first step in the analysis was to reproduce the Walker (2016) results for the same Hyperion Water Reclamation Plant effluent conveyance rates. The coefficient of determination between the two model prediction was rather good, (R-squared = 0.83), with Visual Plumes slightly underestimating the minimum initial dilution predictions of the CORMIX model. A future discharge scenario being planned for the Hyperion Water Reclamation Plant (a scenario not evaluated by Walker, 2016) was found to be problematic. Brackish brine-only discharges from the reclamation plant of 10 mgd at 6.8 ppt will only achieve a minimum initial dilution of Dm = 59.6 to 1, in violation of the dilution credit presently issued to the Hyperion 5-Mile Outfall under the NPDES permit. This problematic result is due to *diffuser stall* since the densimetric Froude number becomes sub- critical at discharges as little as 10 mgd, (where $F_r = u / \sqrt{g' d} =$ 0.49). At these ultra-low discharge flows, there are simply too many discharge ports with too much discharge cross-sectional area in the Hyperion 5-Mile diffuser, resulting in failure of the discharge streams to become turbulent jets. To correct this condition without physical modification of the diffuser, the brackish brine-only conveyance from the reclamation plant must be increased to at least 24.2 mgd. It should be noted that the 10 mgd brackish brine-only scenario will dilute on the trapping level to within 2ppt of natural background salinity within a horizontal distance 100 m from the point of discharge, thereby satisfying the Ocean Plan brine amendment, (SWRCB, 2015).

The feasibility results of co-mingling West Basin brine with Hyperion Reclamation Plant effluent are summarized in Table 3. Most of the modeled outcomes satisfy discharge limits set forth under both the Appendix- A brine amendment of the Ocean Plan and the present NPDES permit. The only failures resulted from co-mingling West Basin brine with 10 mgd of brackish brine effluent from the Hyperion Water Reclamation Plant (projected as the ultimate low-flow conveyance once the reclamation plant is expanded to final design capacity). When either 21 mgd or 63 mgd of West Basin brine is added to the 10 mg of brackish brine from the Hyperion Water Reclamation Plant, the combined effluent becomes negatively buoyant. In either case, the combined brine effluent will not dilute to within 2ppt of natural background salinity within 100 m from the point of discharge, in violation of the Appendix-A provisions of the amended Ocean Plan (SWRCB 2015). However, dilution continues beyond 100 m from the discharge point and reaches the value of Dm = 84 to 1 required by the present NPDES permit at distances between 213 m and 340 m. Therefore, a determination of consistency with both new and existing discharge standards is uncertain for these anticipated future low-flow conditions.

For all other combinations of West Basin brine and Hyperion effluent in Table 3, the combined effluent produces buoyant discharges, which rise in the water column until reaching the trapping layer at the pycnocline interface. For these buoyant discharge cases, the present NPDES permit and Requirements III.C.4(b-d) of the Ocean Plan are the critical regulatory discharge standards, although we will still pay attention to the 100 m brine mixing zone (BMZ) discharge limits set under the Appendix-A provisions of the amended Ocean Plan (SWRCB 2015). Inspection of Table 3 reveals that dilution performance of the 5-Mile Outfall diffuser was better for buoyant discharges at low-flow conditions than high flow conditions, because smaller volumes of effluent at smaller discharge rates are more rapidly diluted in the limited volume of receiving water available beneath the pycnocline and trapping layer. The best dilution performance was achieved for the low-flow condition that blended 90 mgd of effluent from the Hyperion Water Reclamation Plant with 21 mgd of Wes Basin brine, for which minimum initial dilution reached Dm = 135.8 to 1 at a trapping layer z = 42.6 m above the discharge point. Because the primary motion of the plume is vertically upward through the water column, the horizontal spreading of the plume was only x = 10.1 m at the pycnocline trapping level. With this limited horizontal spreading, the BMZ limits of the amended Ocean Plan were easily satisfied, and the discharge salinity rose to within 2 ppt of natural background at a horizontal distance of only x =1.7 m from the point of discharge. Additional increases in effluent from the Hyperion Water Reclamation Plant resulted in continual declines in the minimum initial dilution, but always remaining above the dilution credit of Dm = 84 required by the present NPDES permit; and increases in the horizontal plume spreading that resulted in *the 2ppt above natural background threshold* being achieved at greater horizontal distances from the point of discharge, but always well within the 100 m BMZ requirement of the amended Ocean Plan (SWRCB, 2015). Worst-case dilution occurred for combined discharges at maximum certified hydraulic capacity, 720 mgd. Here, minimum initial dilution was Dm = 84.2 to 1 with 21 mgd of West Basin brine loading, and Dm = 84.0 to 1 with 63 mgd of West Basin brine loading; both results marginally satisfying the certified minimum initial dilution for the 5-Mile Outfall under the existing NPDES permit. At these high flow rates, the densimetric Froude number was in the range of $F_r = u / \sqrt{g' d}$ = 32.5 to 34.8, and the maximum horizontal spreading of the plume at the pycnocline trapping level increased to x = 28.8 m. Nonetheless, the discharge salinity came within 2 ppt of natural background at horizontal distances in the range of x = 10.3 m to 10.7 m from the point of discharge, easily satisfying the Appendix-A brine amendment of the Ocean Plan (SWRCB, 2015).

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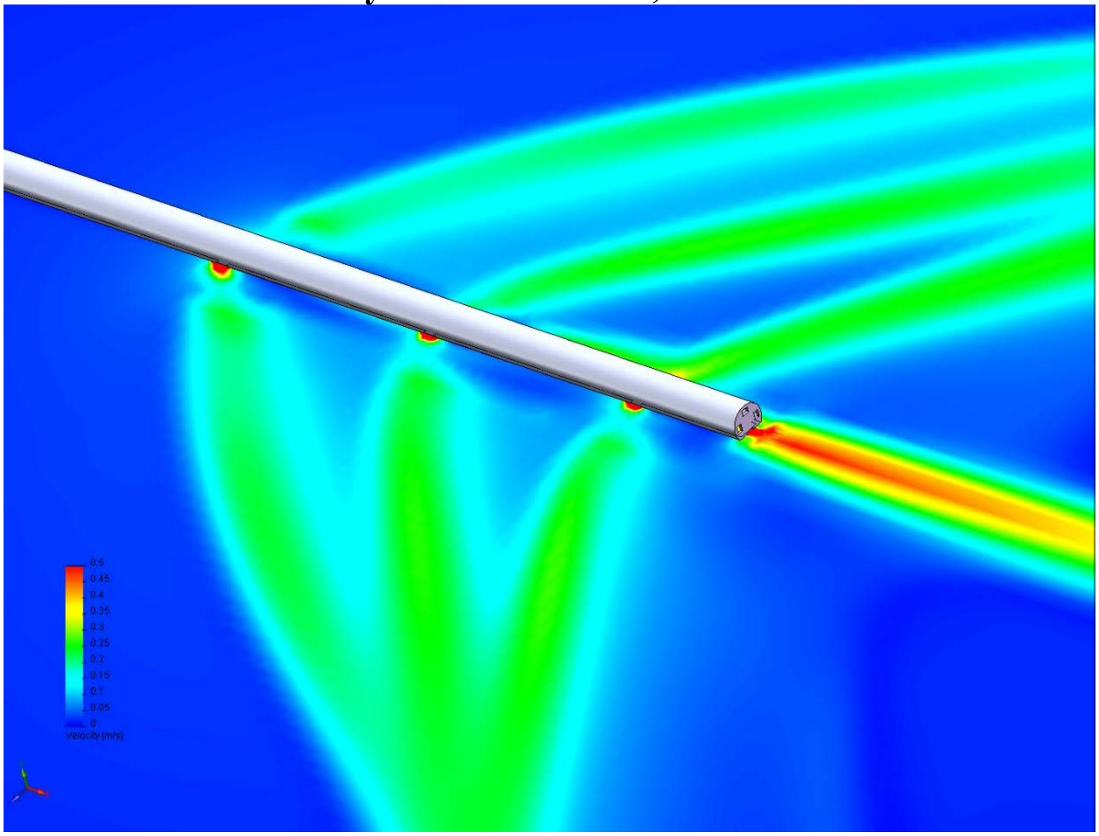
Hydrodynamic Modeling of Dilution of Brine from the
West Basin Municipal Water District
Sea Water Desalination Project
Discharged from the Hyperion 1-mile Emergency Outfall, Los Angeles, CA
(By Scott A. Jenkins, Ph.D., Draft: 8 December 2016)

Hydrodynamic Modeling of Dilution of Brine from the West Basin Municipal Water District Sea Water Desalination Project Discharged from the Hyperion 1-mile Emergency Outfall, Los Angeles, CA

By Scott A. Jenkins, Ph.D.



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ABSTRACT:

This is a dilution study to examine the feasibility of using the Hyperion 1-Mile Outfall to discharge brine by-product from the *West Basin Municipal Water District Sea Water Desalination Project* after it has been blended with effluent from the *Hyperion Water Reclamation Plant*, (HWRP). The study looks at two different scales for West Basin brine conveyance (21 mgd & 63 mgd) to be blended with reclamation plant effluent that varies across an envelope present and future operating conditions, up to and including combined conveyance equal to the maximum certified hydraulic capacity of the outfall (850 mgd).

Feasibility is judged in terms of the ability of the existing diffuser of the 1-Mile Outfall to achieve sufficient dilution performance to satisfy *both* minimum initial dilution requirements of 13 to 1 set forth in the existing NPDES permit (No. CA-0109991, Order No. R4-2010-0200), as well as the discharge limits set forth in the Appendix-A *brine amendment* to the California Ocean Plan. The dilution study invokes the EPA certified Visual Plumes (UM3) mixing zone model and the same reclamation plant effluent properties and environmental parameters assumed by the recently updated dilution study for the Hyperion 1-Mile Outfall performed by Walker (2016), who used the alternative EPA dilution model, CORMIX version 9.0.

The first step in the analysis was to reproduce the Walker (2016) results for the same Hyperion Water Reclamation Plant effluent conveyance rates. The coefficient of determination between the two model prediction was rather good, (R-squared = 0.83), with Visual Plumes slightly underestimating the minimum initial dilution predictions of the CORMIX model. A future discharge scenario being planned for the Hyperion Water Reclamation Plant (a scenario not evaluated by Walker, 2016) was found to be problematic. Brackish brine-only discharges from the reclamation plant of 10 mgd at 6.8 ppt will only achieve a minimum initial dilution of Dm = 59.6 to 1, in violation of the dilution credit presently issued to the Hyperion 1-Mile Outfall under the NPDES permit. This problematic result is due to *diffuser stall* since the densimetric Froude number becomes sub- critical at discharges as little as 10 mgd, (where $F_r = u/\sqrt{g'd} =$ 0.16). At these ultra-low discharge flows, there are simply too many discharge ports with too much discharge cross-sectional area in the Hyperion 1-Mile diffuser, resulting in failure of the discharge streams to become turbulent jets. To correct this condition without physical modification of the diffuser, the brackish brine-only conveyance from the reclamation plant must be increased to at least 63 mgd. It should be noted that the 10 mgd brackish brine-only scenario will dilute by spreading across the sea surface to within 2ppt of natural background salinity in a horizontal distance of less than 100 m from the point of discharge, thereby satisfying the Ocean Plan brine amendment, (SWRCB, 2015).

The feasibility results of co-mingling West Basin brine with Hyperion Reclamation Plant effluent are summarized in Table A-1. Most of the modeled outcomes satisfy discharge limits set forth under both the Appendix- A brine amendment of the Ocean Plan and the present NPDES permit. The only failures resulted from co-mingling West Basin brine with 10 mgd of brackish brine effluent from the Hyperion Water Reclamation Plant (projected as the ultimate low-flow conveyance once the reclamation plant is expanded to final design capacity). When either 21 mgd or 63 mgd of West Basin brine is added to the 10 mg of brackish brine from the Hyperion Water Reclamation Plant, the combined effluent becomes negatively buoyant. In either case, the combined brine effluent will not dilute to within 2ppt of natural background salinity within 100 m from the point of discharge, in violation of the Appendix-A provisions of the amended Ocean Plan (SWRCB 2015). However, dilution continues beyond 100 m from the discharge point and

Table A-1: Summary of results for Dilution of Brine from the West Basin Desalination Project Discharged from the Hyperion 1-Mile Outfall

Discharge Scenario Wastewater + Brine = Total Flow Rate (MGD)	Combined Discharge Salinity (ppt)	Discharge Velocity m/sec	Densimetric Froude Number $F_r = u / \sqrt{g' d}$	Distance horizontally to within 2ppt of Natural Background (BMZ, m)	Initial Dilution at BMZ	Initial Dilution (Dm) at lowest monthly trapping level **(ZID)	Meet OPA/ NPDES Limits?
***10 + 0 = 10	6.8	0.069	0.16	17.2	12.35	8.9	Maybe/No
***10 + 21 = 31	48.15	0.22	0.68	390	6.33	N/A	No/Maybe
***10 + 63 = 73	59.48	0.51	1.19	207	11.99	N/A	No/Maybe
90 + 21 =110	12.95	0.76	2.03	23.5	9.28	29.2	Yes/Yes
90 + 63 = 153	27.93	1.07	5.45	10.7	1.78	27.2	Yes/Yes
203 + 21 = 224	6.36	1.56	3.59	51.0	12.57	23.8	Yes/ Yes
203 + 63 = 266	16.06	1.85	5.33	45.0	7.72	21.8	Yes/ Yes
250 + 21 = 271	5.26	1.89	4.25	66.0	13.1	21.5	Yes/ Yes
250 + 63 = 313	13.65	2.19	4.98	61.0	8.92	19.5	Yes/ Yes

Red = future low wastewater flow; **Yellow** = present low wastewater flow; **Blue** = average wastewater flow

* Trapping Levels (ZID) are measured in terms of height above the point of discharge (vertical distance from discharge ports)

** ZID boundary defaults to minimum trapping level for buoyant discharges.

***Wastewater for these scenarios is brackish brine from Hyperion Water Reclamation Plant at 6.8 ppt

OPA = Ocean Plan Appendix-A brine amendment, SWRCB, (2015).

reaches the value of Dm = 13 to 1 required by the present NPDES permit at distances between 214 m and 513 m from the point of discharge. Therefore, a determination of consistency with both new and existing discharge standards is uncertain for these anticipated future low-flow conditions.

For all other combinations of West Basin brine and Hyperion effluent in Table A-1, the combined effluent produces buoyant discharges, which rise in the water column until reaching the trapping layer at the pycnocline interface. For these buoyant discharge cases, the present NPDES permit and Requirements III.C.4(b-d) of the Ocean Plan are the critical regulatory discharge standards, although we also pay attention to the 100 m brine mixing zone (BMZ) discharge limits set under the Appendix-A provisions of the amended Ocean Plan (SWRCB 2015). Inspection of Table A-1 reveals that dilution performance of the 1-Mile Outfall diffuser was better for buoyant discharges at low-flow conditions than high flow conditions, because smaller volumes of effluent at smaller discharge rates are more rapidly diluted in the limited volume of receiving water available beneath the pycnocline and sea surface. The best dilution performance was achieved for the low-flow condition that blended 90 mgd of effluent from the Hyperion Water Reclamation Plant with 21 mgd of West Basin brine, where minimum initial dilution (blue curve) reached Dm = 29.2 to 1 at the worst-month trapping layer $z = 6.1$ m above the discharge point. The primary motion of the plume is vertically upward through the water column until reaching the trapping layer, whence the plume spreads horizontally along the pycnocline interface and continues until dilution is complete at $x = 127$ m. In spite of this horizontal spreading, the BMZ limits of the amended Ocean Plan were satisfied, and the discharge salinity (red curve in Figure 13) rose to within 2 ppt of natural background at a horizontal distance of only $x = 23.5$ m from the point of discharge. Additional increases in effluent from the Hyperion Water Reclamation Plant resulted in continual declines in the minimum initial dilution, but always remaining above the dilution credit of Dm = 13 required by the present NPDES permit; and increases in the horizontal plume spreading that resulted in *the 2ppt above natural background threshold* being achieved at greater horizontal distances from the point of discharge, but always well within the 100 m BMZ requirement of the amended Ocean Plan (SWRCB, 2015). Worst-case dilution occurred for combined discharges with the long term average HWRP conveyance of 250 mgd. Here minimum initial dilution was Dm = 21.5 with 21 mgd of West Basin brine loading, and Dm = 19.5 with 63 mgd of West Basin brine loading; both results satisfying the certified minimum initial dilution of Dm = 13 for the 1-Mile Outfall under the NPDES permit. At these higher flow rates, the densimetric Froude number was in the range of $F_r = u / \sqrt{g' d}$ = 4.25 to 4.98, and the maximum horizontal spreading of the plume at the pycnocline trapping level increased to x = 297 m and was deflected away from the shoreline by end-effects of the diffuser design. Nonetheless, the discharge salinity came within 2 ppt of natural background at horizontal distances in the range of $x = 61$ m to 66 m from the point of discharge, easily satisfying the Appendix-A brine amendment of the Ocean Plan (SWRCB, 2015).

Hydrodynamic Modeling of Dilution of Brine from the West Basin Municipal Water District Sea Water Desalination Project Discharged from the Hyperion 1-Mile Outfall, Los Angeles, CA

by Scott A. Jenkins, Ph.D.

1) Introduction:

This is a dilution modeling study of the brine by-product from the *West Basin Municipal Water District Sea Water Desalination Project* after it has been blended with effluent from the Hyperion Water Reclamation Plant and subsequently discharged through the *Hyperion 1-Mile Outfall*. The 1-mile diffuser, is located approximately 5,400 feet from shore, at a depth of -15 m MSL, (Figure 1), and is one section of 300 feet long with 6 ports along the length and 4 end ports. Routine discharge is limited to the 5-mile outfall by the permit. Generally, the 1-mile outfall is utilized for additional capacity during storm events, emergency situation, power outages, and during periods of maintenance on the 5-mile outfall. Additionally, short-interval effluent discharges from the 1-mile outfall occur on an approximate quarterly frequency for testing of gate valves. Effluent discharged through the 1-mile outfall typically receives disinfection. Under high flows into the HWRP induced by intense storms or when plant power outages occur, un-disinfected storm water overflows from the HWRP are also permitted through the 1-mile outfall. The locations of the two outfalls within Santa Monica Bay are presented in Figure 1. According to the NPDES permit (No. CA-0109991, Order No. R4-2010-0200), the required minimum initial dilution of the 1-Mile outfall is 13 to 1, (CRWQCB, 2010). An updated dilution study was recently completed and established a worst-month minimum initial dilution of Dm = 14.1 to 1 at maximum certified hydraulic capacity (850 mgd) for Hyperion effluent temperatures and ocean conditions for the period January 2010- March 2015, (Walker, 2016).

Operational wastewater discharge rates from the Hyperion Water Reclamation Plant (HWRP) that could be diverted to the Hyperion 1-Mile outfall average 250.33 mgd (Table-1). However, plans for expanded capacity of the Hyperion Water Reclamation Plant, (combined with projected future water conservation efforts in Los Angeles) are expected to reduce future annual conveyance rates to as little as 90 mgd with an ultimate minimum of 10 mgd consisting of brine from the reclamation plant at 6.8 ppt TDS.

Table 1: Hyperion Water Reclamation Plant Conveyance Rates (2010-2016)

Long-term Average = 250.33 mgd
Average Annual Minimum = 202.62 mgd
Absolute Minimum = 176.67 mgd
Future Annual Minimum = 90 mgd
Future Absolute Minimum = 10 mgd @ 6.8 ppt

West Basin is considering two different scales for its desalination project: 1) a 20 mgd project discharging 20.9 mgd of brine at 68 ppt from the R.O facilities of the desalination plant and 0.1 mgd of West Basin recycled blowdown water at 35 ppt, resulting in a total discharge rate of 21 mgd with 67.84 ppt salinity end of pipe; 2) a 60 mgd project discharging 62.7 mgd of brine at 68 ppt from the R.O facilities of the desalination plant and 0.3 mgd of West Basin recycled blowdown water at 35 ppt, resulting in a total discharge rate of 63 mgd with 67.84 ppt salinity

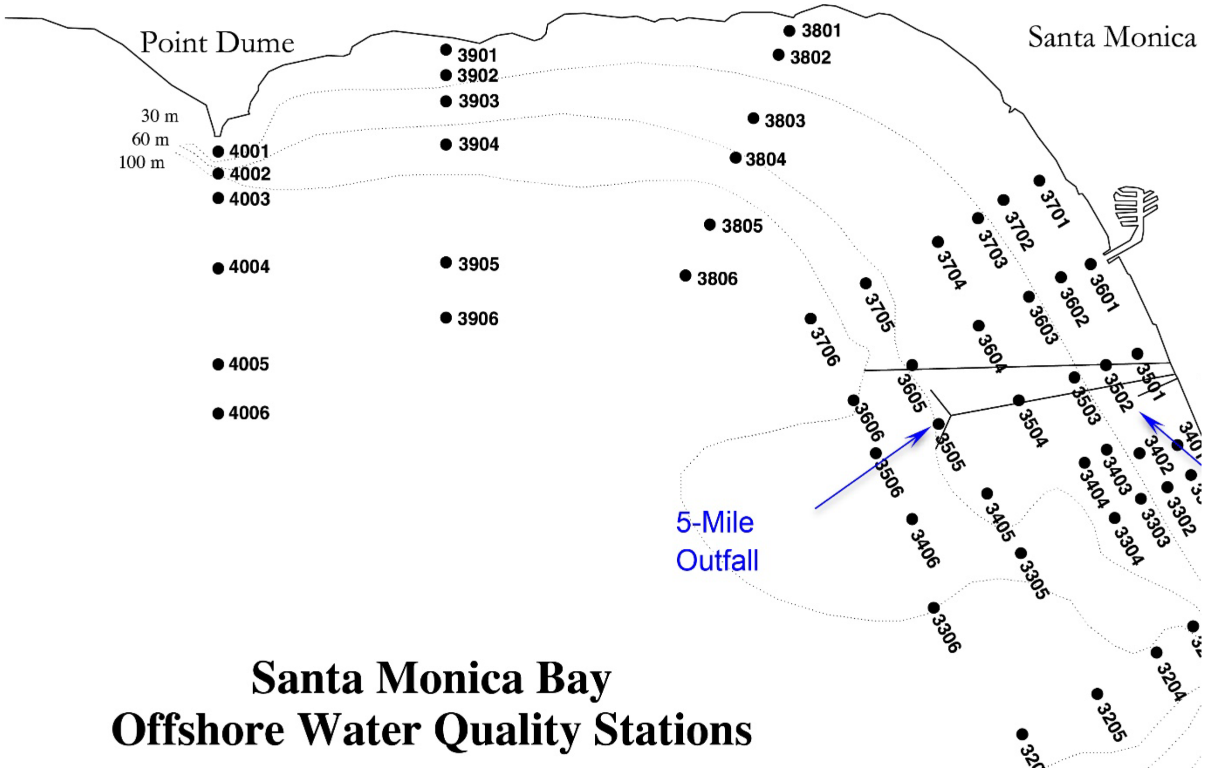

Figure 1: Location map with water quality monitoring stations showing the 12 ft diameter Hyperion emergency outfall (blue) located 5,384 ft offshore in Santa Monica Bay (often referred to as the "*1-mile outfall*"), and the 12 ft diameter Hyperion deep outfall (red) located 27,539 ft offshore (referred to as the " *1-Mile outfall*"). From Walker, (2016)

Table 2: Envelope of operating conditions for the West Basin Desalination Project at Hyperion 1-Mile Outfall

Hyperion Wastewater Flow Rates (MGD)	Brine Discharge Rate (MGD)	Combined Discharge Rate (MGD)	Combined Discharge Salinity (ppt)	*Density Anomaly $\Delta\rho/\rho$
10 @ 6.8 ppt	**0**	**10**	**6.8**	**+0.0214**
10 @ 6.8 ppt	**21**	**31**	**48.15**	**-0.0117**
10 @ 6.8 ppt	**63**	**73**	**59.48**	**-0.0208**
90	**21**	**110**	**12.95**	**+0.0164**
90	**63**	**153**	**27.93**	**+0.0044**
203	**21**	**224**	**6.36**	**+0.0217**
203	**63**	**266**	**16.06**	**+0.0139**
250	**21**	**271**	**5.25**	**+0.0226**
250	**63**	**313**	**13.65**	**+0.0159**

Red = future low wastewater flow
Orange = present low wastewater flow
Blue = average wastewater flow

end of pipe. Based on the possible envelope of combinations of Hyperion (HWRP) and West Basin operating conditions, Table-2 summarizes the modeling scenarios to be evaluated in this study. The red entries represent projections of future low flow conditions and bracket the lower end of the operating envelope. The first red entry represents discharge of only the brine from the Hyperion Water Reclamation Plant which was included because it is a case that has never been studied, and is required to understand low-flow limitations of the present diffuser design. The orange entries represent present historic low flow conditions while the blue entries represent present average wastewater flows in combination with the brine from 21 mgd and 63 mgd West Basin projects. Note most of the values of the density anomaly are positive, indicating the combined wastewater/brine effluent is buoyant in ocean receiving waters, (i.e., $\Delta\rho/\rho > 0$). However the density anomaly turns negative for the ultimate low-flow combination of West Basin brine and brine from the Hyperion Water Reclamation Plant, indicating that these scenarios will involve dilution of dense (negatively buoyant) combined effluent in ocean receiving waters, (i.e., $\Delta\rho/\rho < 0$). Having the physical nature of the combined effluent switch between a buoyant and a dense discharge across the operational envelope creates a dual set of regulatory requirements for discharge compliance which we consider in the following section.

2) Compliance Issues:

Amendments specific to brine discharges have recently been approved for the California Ocean Plan (SWRCB, 2015). Appendix-A of this document, "Ocean Plan with the May 6, 2015 Final Desalination Amendment," establishes two distinct set of discharge limits on brine discharges, one for buoyant discharges, and the other for dense (negatively buoyant) discharges. Based on the brine concentrations listed above, most of the West Basin/Hyperion combined wastewater/brine discharges will be buoyant in seawater (those entries in Table 2 where $\Delta\rho/\rho > 0$); and accordingly will be regulated under Requirement III.C.4(b) of the present version of the California Ocean Plan as it would apply to a Zone of Initial Dilution (ZID). The California Ocean Plan defines the ZID as the zone in which the process of initial dilution is completed. Initial dilution is defined within Appendix I of the *California Ocean Plan* as follows:

"*Initial Dilution is the process which results in the rapid and irreversible turbulent mixing of wastewater with ocean water around the point of discharge. For a submerged buoyant discharge, characteristic of most municipal and industrial wastes that are released from the submarine outfalls, the momentum of the discharge and its initial buoyancy act together to produce turbulent mixing"*

Provision III.C.4(d) of the Ocean Plan requires that minimum initial dilution be determined in a specific manner:

"*For the purpose of this Plan, minimum initial dilution is the lowest average initial dilution within any single month of the year. Dilution estimates shall be based on observed waste characteristics, observed receiving water density structure, and the assumption that no currents, of sufficient strength to influence the initial dilution process, flow across the discharge structure"*.

Under the present NPDES permit for the Hyperion 1-Mile Outfall (No. CA-0109991, Order No. R4-2010-0200), the Los Angeles Regional Water Quality Control Board has interpreted these provisions such that minimum initial dilution has been determined to be 13 to 1 at the *trapping level* during the month of December, (Walker, 2016). To understand how this interpretation of the Ocean Plan was made, consider the dynamics of a buoyant plume as shown schematically in Figure 2. The effluent is initially discharged at high velocity from, in this case, 170 small diameter discharge ports creating as many turbulent jets. The large eddies produced by these turbulent jets dilute the jet momentum, at which point the buoyancy of the effluent causes the turbulent eddies to rise as a convective plume in the water column. As the eddies and convective circulation entrain more and more of the surrounding water mass, the plume becomes diluted and the buoyancy declines until the plume no longer rises further in the water column. This typically occurs at a density interface in the water column referred to as the *pycnocline*,

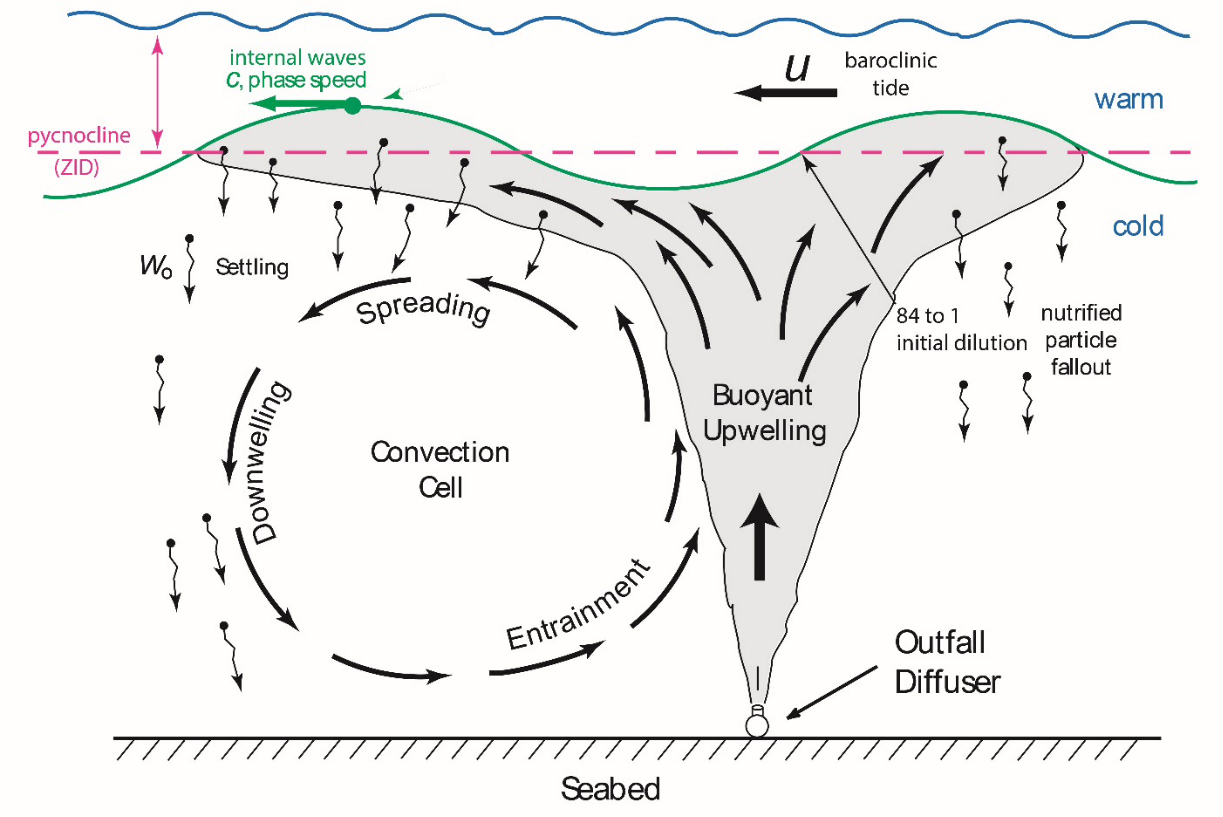

FIGURE 2: Schematic diagram of the rising buoyant plume ascending to the trapping level for a combined effluent of wastewater and brine discharged from the Hyperion 5-mile deep outfall diffuser.

usually formed between two water masses, namely the warm surface mixed layer and the colder bottom water. The pycnocline forms a *trapping layer*, and the residual turbulent momentum of the plume causes it to spread out horizontally. If the receiving waters are only weakly stratified, i.e., there is only a small temperature difference between surface mixed layer and the bottom water, then the plume can rise to the sea surface (sometimes referred to as the *second trapping layer*). The plume will spread out horizontally along the trapping layer interface until all of its turbulent kinetic energy and buoyant potential energy is dissipated, at which dilution ceases to change. The dilution at this point is referred to as *initial dilution*. In the natural ocean environment, the pycnocline (or trapping layer) is dynamic, rising and falling in the water column with the seasons, and with internal (baroclinic) tides that propagate along the pycnocline interface. While seasonal effects on pycnocline heights and trapping levels were included in the updated dilution study for the Hyperion 1-Mile Outfall (Walker, 2016), the effects of baraocliinic tides and the sweeping velocities they create across the diffuser are excluded under Provision III.C.4(d) of the Ocean Plan

However, a second set of discharge limits specific to brine must also be considered under the newly amended California Ocean Plan (SWRCB, 2015). This amendment found in Appendix-A of SWRCB (2015) establishes a water quality objective for brine discharges under the following requirements:

“*Discharges shall not exceed a daily maximum of 2.0 ppt above natural background salinity to be measured as total dissolved solids (mg/L) measured no further than 100 meters (328 feet)* *horizontally from the discharge. There is no vertical limit to this zone._Natural background salinity is defined as the salinity at a location that results from naturally occurring processes and is without apparent human influence. Natural background salinity shall be determined by averaging 20 years of historical salinity data at a location unless the actual salinity measured at the facility intake is greater than the 20 year average salinity, in which case, the natural background salinity shall be the lower of the actual salinity measured at the intake and the maximum salinity level measured in the 20 years of historical salinity data. When historical data are not available, natural background salinity shall be determined by measuring salinity at depth of proposed discharge for three years, on a weekly basis prior to a desalination facility discharging brine, and the average salinity shall be used to determine natural background salinity unless the actual salinity measured at the facility intake is greater than the average salinity, in which case, the natural background salinity shall be the lower of the actual salinity measured at the intake and the maximum salinity level measured in the salinity data. Facilities shall establish a reference location with similar natural background salinity to be used for comparison in ongoing monitoring of brine discharges. The fixed distance referenced in the initial dilution definition shall be no more than 100 meters (328 feet). In addition, the owner or operator shall develop a dilution factor (Dm) based on the distance of 100 meters (328 feet) or initial dilution, whichever is smaller".*

There is no vertical dimension in this new water quality objective; i.e. no consideration of trapping levels or restrictions on a brine plume broaching the sea surface. Therefore there is some uncertainty regarding how the Regional Water Quality Control Boards will reconcile this water quality objective with the antecedent Requirement III.C.4(b) of the previous version of the California Ocean Plan when the brine plume is buoyant. One thing is clear however, and that is an initial dilution analysis is required to determine the dilution credit the outfall will receive once brine is added to the effluent from the Hyperion Water Reclamation Plant. It is our belief that if brine additions from West Basin can simultaneously satisfy both the minimum initial dilution requirements of the existing NPDES permit and the new brine amendment requirements of Appendix A of SWRCB (2015), then from a regulatory compliance standpoint, the Hyperion 1-Mile outfall is a viable discharge option for the *West Basin Municipal Water District Sea Water Desalination Project.*

3) Technical Approach:

A minimum initial dilution analysis was performed using the EPA certified Visual Plumes (UM3) model, supplemented by verification using a commercially available computational fluid dynamics (CFD) model, *COSMOS/ FLoWorks.* Both models were initialized for quiescent ocean receiving waters with worst-month temperature/salinity (density) profiles, as required for an initial dilution analyses under Provision III.C.4.d of the Ocean Plan. For purposes of analytic fidelity, both models were initialized using the same receiving water and effluent data bases as used in the recently updated dilution study by Walker, (2016). A set baseline dilution simulations was first performed to reproduce the results from Walker (2016) for wastewater only discharges before proceeding to add West Basin brine and evaluate dilution of the combined effluent. Comparisons with the baseline results then makes it possible to isolate the effects of brine additions on the dilution performance of the diffuser.

The recently updated dilution study of the Hyperion 1-Mile Outfall was performed using the EPA certified mixing model CORMIX version 9.0, (Walker, 2016). CORMIX is an empirically based *expert systems model*, that takes accumulated laboratory and field experience to compile a set of rule-based predictions. CORMIX is most effective when the real-world prototype conditions and model variables match closely. When they do not, the CORMIX predictions can degrade substantially (Frick, et al., 2003). CORMIX models were developed to investigate the plume behavior and dilution from one discharge port, and predictions for discharges emanating from multiple discharge ports become valid only after the point where the plumes from the individual ports merge to form the whole plume. The model implicitly assumes the discharged flow is equally split between each discharge port and plume evolution occurs identically for each port and for each row of ports. Clearly simplistic assumptions impair CORMIX at the transition sections of the north and south legs of the y-shaped Hyperion 1-Mile diffuser, where the diffuser legs transition from 102 in. diameter pipe to 72 in. diameter pipe, as well as at the Y-junction of the two legs where the geometry of the diffuser diverges from the implicit linear assumptions made by CORMIX.

To circumvent these shortcomings, we selected the alternative EPA model mixing model, Visual Plumes (UM3). This is a robust process-based model, based on the Projected Area Entrainment (PAE) hypothesis (Winiarski and Frick, 1976; Frick, 1984). The most current version of this model, Visual Plumes UM3, is the most commonly used model to provide initial dilution analysis in NPDES permits for ocean outfalls. It accepts inputs for multiple ports with arbitrary size, spacing, angle and elevation above the bottom, but cannot directly resolve opposing rows of discharge ports on opposite faces of the diffuser manifold, nor rows of ports that are not co-linear, as is found on either side of the Y-junction of the 1-Mile Outfall diffuser. However, because of it is a process-based architecture, Visual Plumes UM3 can be coupled with a computational fluid dynamics (CFD) models that will specify opposing multi-plume and ono-linear inputs to the Visual Plumes UM3 model prior to plume merging, thereby resolving the complex flow patterns around the Y-junction, transition sections and terminal ends of the two legs to the diffuser.

The CFD model chosen for these complex geometric solutions was the commercially available COSMOS/FloWORKS codes that were originally developed by the French aerospace company Dassault Systems, and are presently marketed in the United States by its US subsidiary SolidWorks as an add-on to the SolidWorks Professional computer-aided design (CAD) software package under the name “FlowSimulation”. In general, CFD models do not make simplifying assumptions in the way the Visual Plumes UM3 model does with its Projected Area Entrainment (PAE) approximation, or CORMIX with its empirical rule-based processing. Instead CFD models use the brute force of modern high-speed computers to perform enormous numbers of iterations that converge on exact solutions to the equations of motion (Navier Stokes Equations). The unique ability of COSMOS/FloWorks is that it provides CFD simulation capability inside a 3-dimensional CAD system. The CAD embedded CFD codes of COSMOS/FloWORKS and SOLIDWORKS Flow Simulation have been substantially validated in the peer reviewed literature (Balakin, et al., 2004; Oberkampf, W.L. and Trucano, 2002; Melnik, et al., 2015). As with all novel technologies, considerable attention is paid to Validation and Verification (V&V). It is these capabilities and pedigree which makes the embedded COSMOS/FloWORKS and SolidWorks Professional technology the best available technology for resolving the discharge streams and entrainment flows in the geometrically complex sections of the Hyperion 1-Mile Outfall diffuser.

4) Model Initialization:

The Hyperion wastewater effluent is essentially fresh water, with the density determined through the temperature. Over the period of January 2010 to March 2015, averages of temperatures from each month were determined for use in the scenarios. The monthly average temperatures are presented in Figure 3.

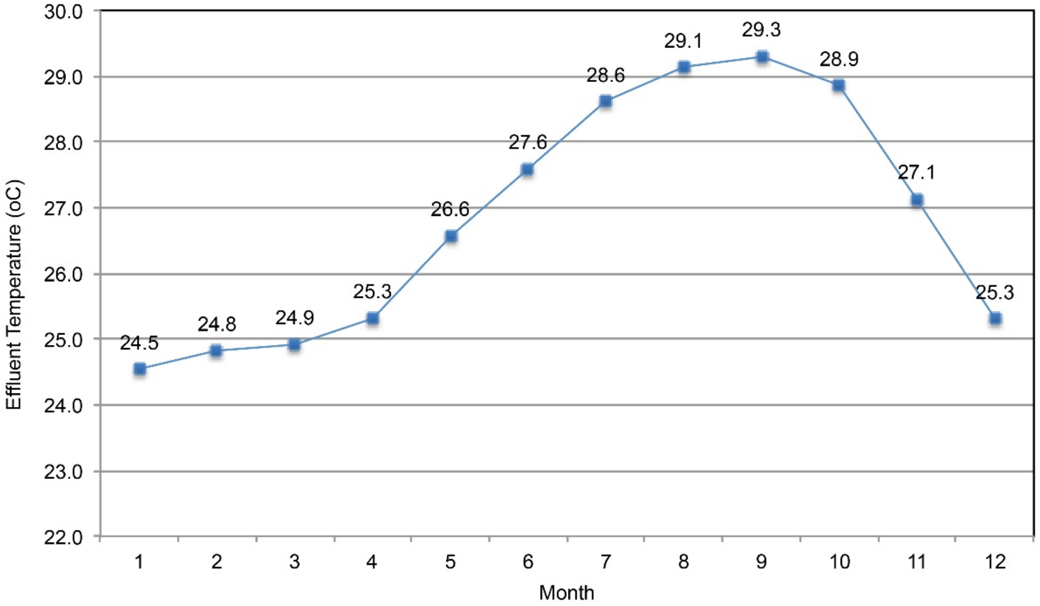

Figure 3: Inter-annual Hyperion wastewater effluent temperature variation; (from Walker, 2016).

N*atural background salinity* according to the amended Ocean Plan is a reference location that is representative of the *natural background salinity* of the discharge location. For the purposes of this evaluation, we have adopted the period of record at derived from the Santa Monica Bay monitoring stations, (Figure-1) archived at:

http://www-mlrg.ucsd.edu/shoresta/mnSIOMain/siomain.htm

Figure 4 plots the full 33 year period of record at NPDES monitoring Station 3505. The period of record, 1980 to 2013 contains 12,055 verified daily measurements. Monthly averages for each individual month in a 20-year reference period and the full 33-year period of record are given. The long-term mean for both the 20 and 30 year time frames are the same, 33.52 ppt; and monthly means vary by no more than 0.2 ppt about the long-term mean.

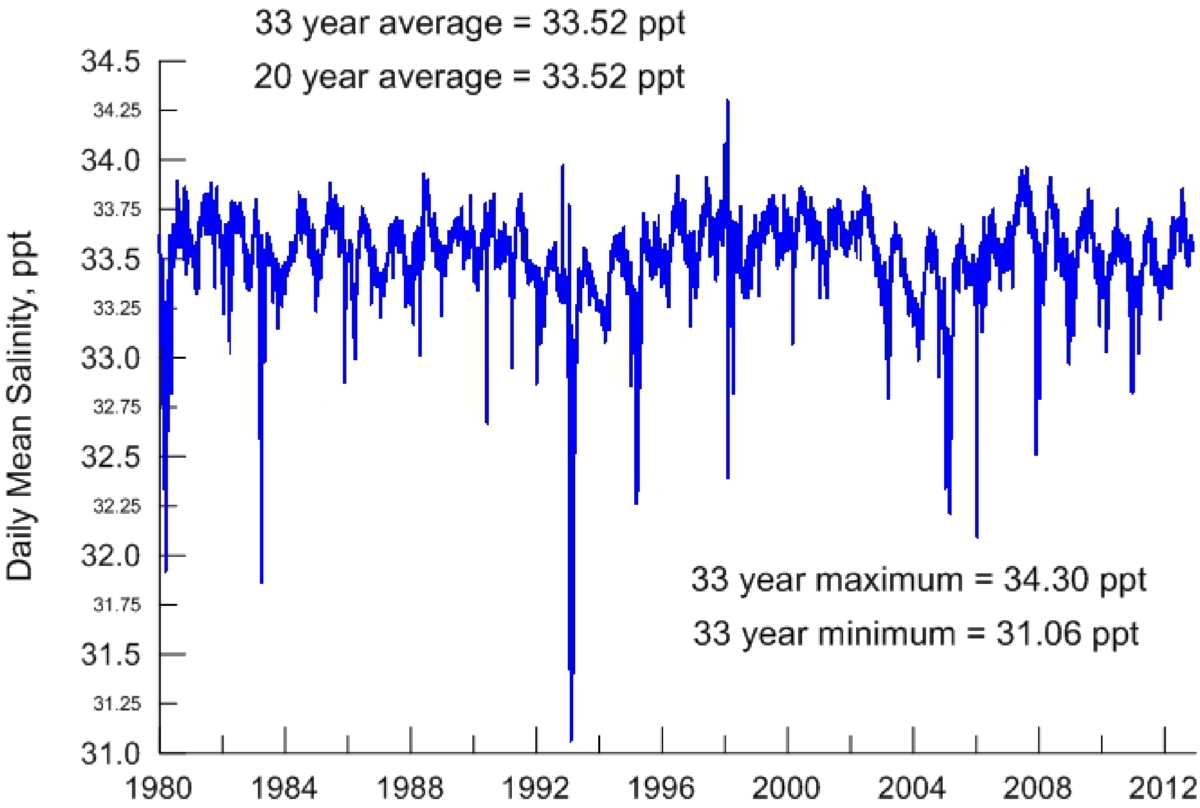

Figure 4: Period of record for N*atural background salinity* at Santa Monica Bay monitoring Stations (Figure 1). Data archived at:

http://www-mlrg.ucsd.edu/shoresta/mnSIOMain/siomain.htm

To evaluate worst-month density profiles in the receiving waters, water quality monitoring data (temperature/salinity profiles) were compiled quarterly and a rolling 4-point density change over depth was calculated for each spatially averaged quarterly monitoring events. Profiles were segregated into two categories: those events with the smallest maximum change were selected as the least stratified and those with the largest maximum change were selected as the most stratified. This approach was adopted in the recently updated dilution study by Walker (2016) and produced two sets of density profiles and plotted according to monthly variation in Figures 5 & 6.

A 3-dimensional CAD model was built of the Hyperion 1-Mile Outfall diffuser was constructed using SolidWorks Professional CAD software. The 1-mile outfall is a 12-foot diameter reinforced concrete pipe, approximately 5,400 feet long. A 300 foot diffuser section at the end of the outfall is in approximately 50 feet of water, with the location displayed on Figure 1. There is one 18-inch by 54-inch slot on each side of each 100-foot section of pipe forming the diffuser, and three upper ports and one lower grill on the end cap (Figure 7). Each of the end ports measures 27 inches by 36 inches. Each of the side ports and end ports measures 972 square inches. The discharge elevation above the bottom is determined through the nominal height of the diffuser, 5 feet, and the discharge slots centered 2.75 feet above the pipe bottom, for a discharge height of 7.75 feet as shown in Figure 7.

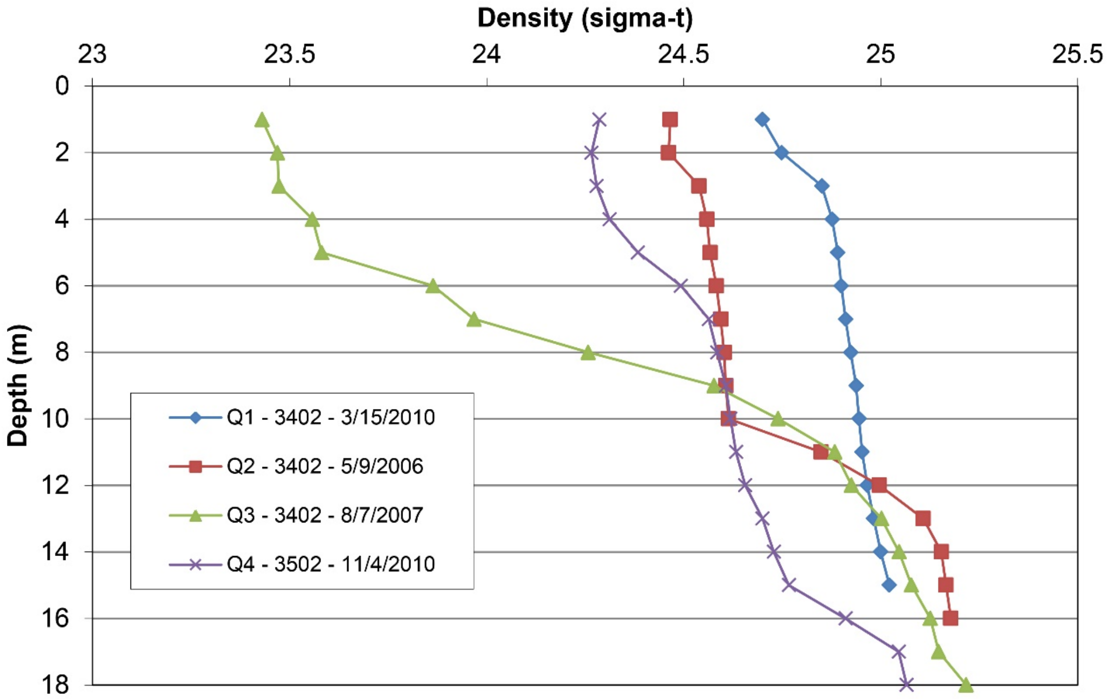

Figure 5: Inter-annual variation in density profiles for most stratified months after Walker (2016)

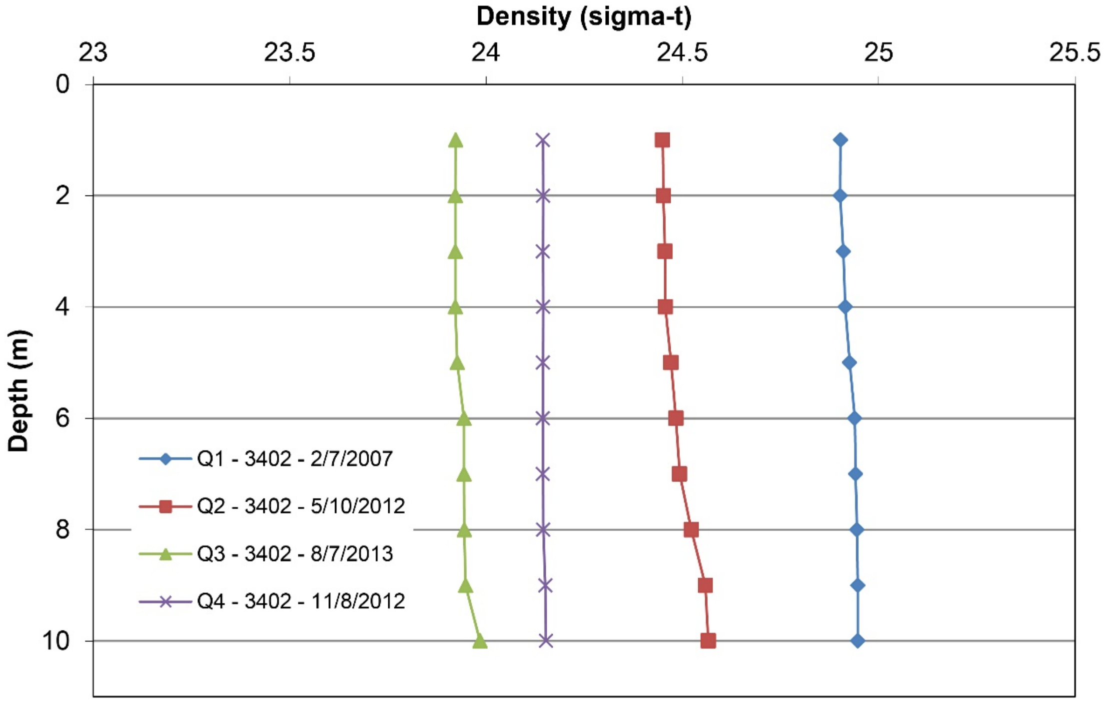

Figure 6: Inter-annual variation in density profiles for least stratified months after Walker (2016)

Figure 7: SolidWorks 3-dimensional CAD model of the Y-junction of the Hyperion 1-Mile Outfall diffuser.

5) Baseline Simulations:

Using the initialization parameters described in Section 4, the Visual Plumes (UM3) mixing model was run for the discharge scenarios studied previously in the updated dilution study by Walker (2016). These scenarios included conveyance of 250 mgd, and 450 mgd from the Hyperion Water Reclamation Plant that was subsequently discharged from the Hyperion 1-Mile Outfall for 8 separate density profile combinations. A comparison of the results from CORMIX v-9 used in Walker (2016) vs the Visual Plumes (UM3) model is shown in Figure 8. The coefficient of determination between the two model prediction was rather good, R-squared = 0.95, with Visual Plumes slightly underestimating minimum initial dilution for worst-case month (January).

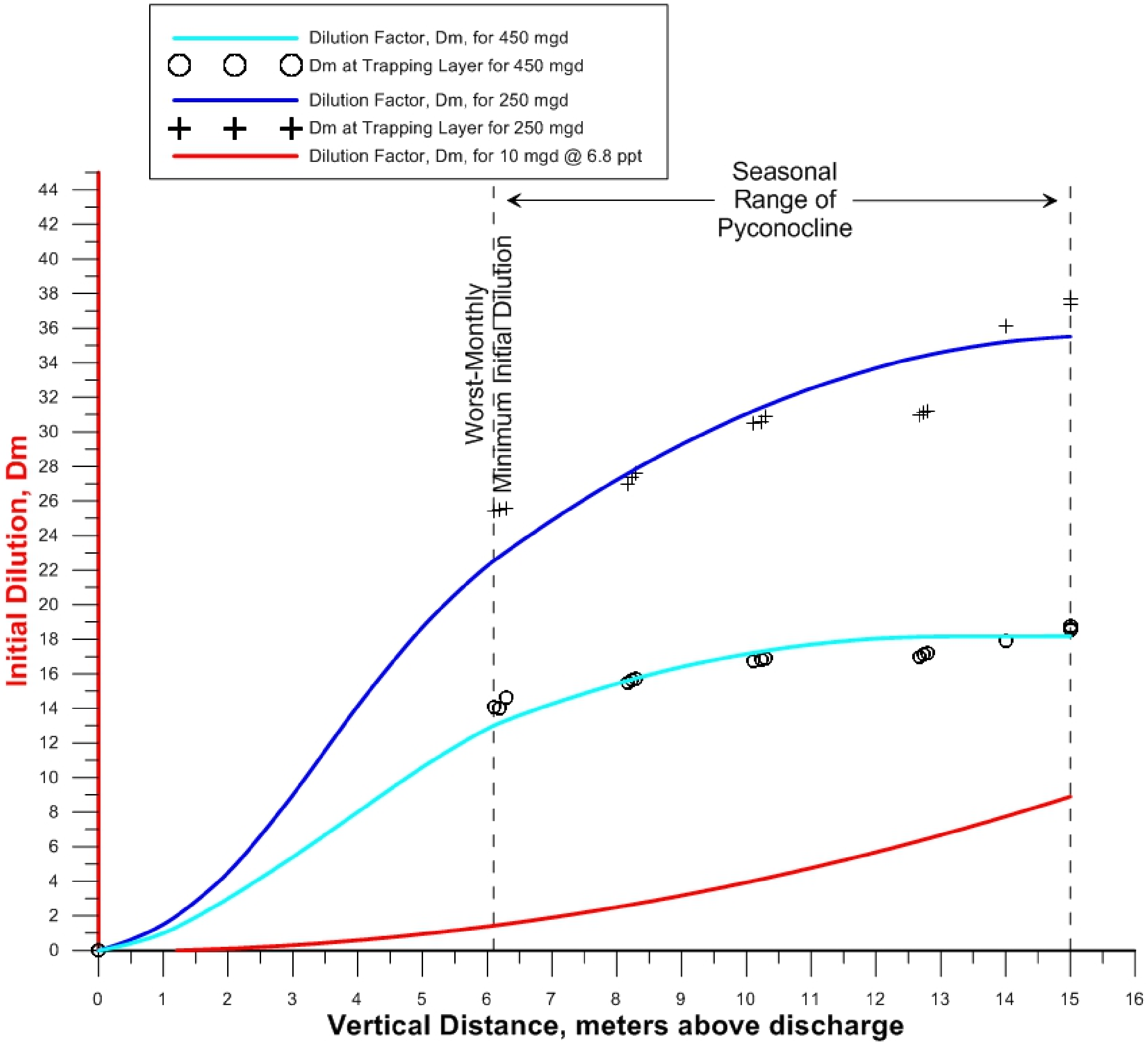

Figure 8: Baseline simulations of initial dilution of effluent from only the Hyperion Water Reclamation Plant after discharge from the Hyperion 1-Mile Outfall. Comparison are made of monthly initial dilution results from Walker (2016) shown as points versus Visual Plumes (UM3) results shown solid lines. Minimum initial dilution results found along the dashed vertical line as labeled, corresponding to worst-case month. Independent solution for initial dilution of 10 mgd have Hyperion Water Reclamation brine at 6.8 ppt shown as solid red line.

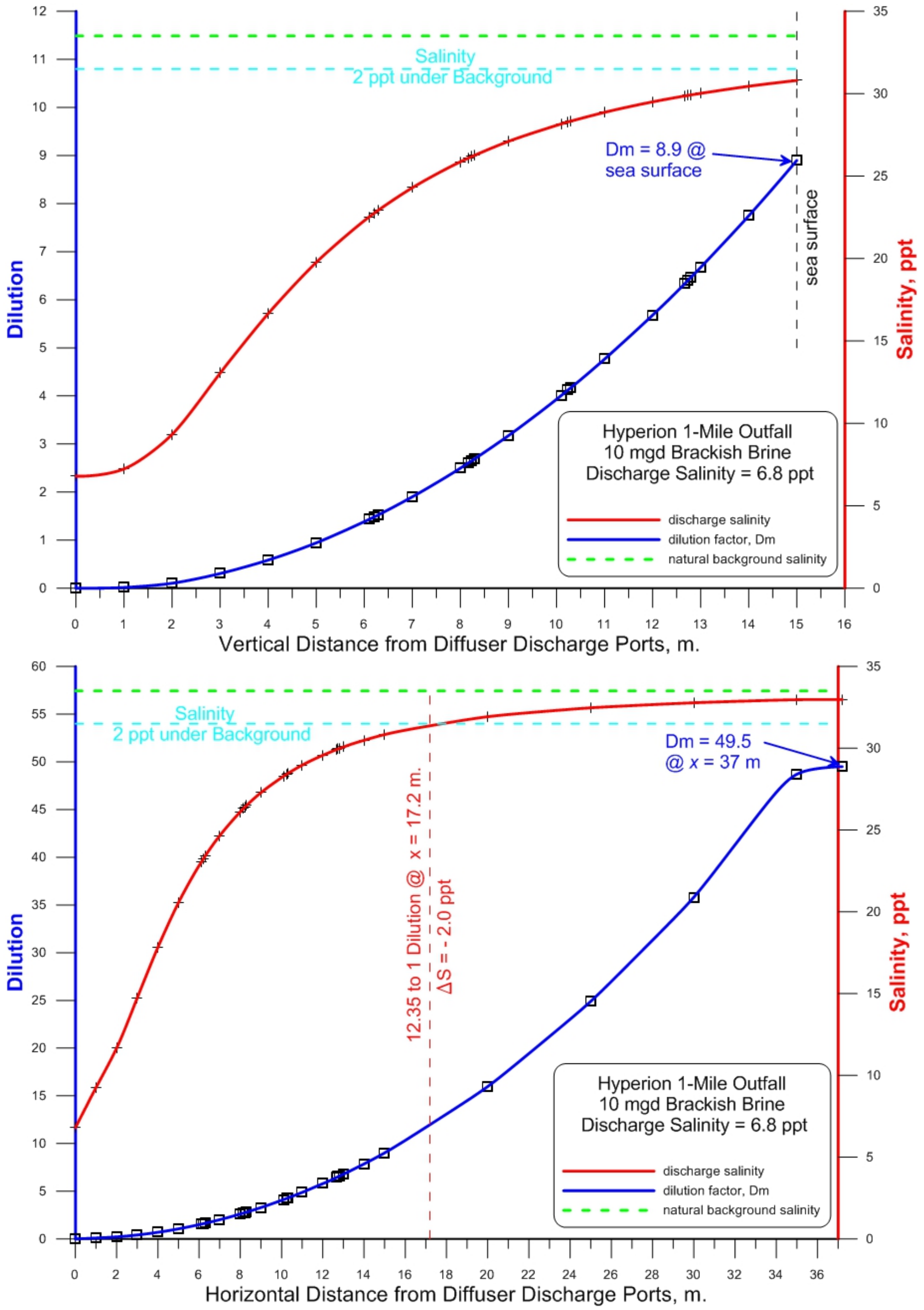

Figure 9: Visual Plumes (UM3) simulation of still water dilution of 10 mgd of Hyperion water reclamation brine discharged at end-of-pipe of 6.8 ppt. Discharge salinity (red, right hand axis) as a function of distance vertically (upper panel) and horizontally (lower panel) from the Hyperion 1-Mile outfall diffuser. Dilution factor (blue, left hand axis) as a function of distance vertically (upper panel) and horizontally (lower panel).

At historic average discharge rates (250 mgd), CORMIX predicts Dm = 25.5 whereas Visual Plumes (UM3) predicts Dm = 22.4; and for the historic maximum conveyance during the 2010-2015 period of record, (450 mgd), CORMIX predicts Dm = 14.1 whereas Visual Plumes (UM3) predicts Dm = 13.0. Therefore, the initial dilution results of the updated Hyperion 1-Mile Outfall dilution study by Walker (2016) have been verified for wastewater-only discharges by a second EPA model; and in general, those results show the minimum initial dilution increases with decreasing discharge rate. Intuitively this occurs because smaller volumes of effluent at smaller discharge rates are being loaded into the limited dilution volume available beneath the pycnocline (trapping layer). However, Figure 8 shows that a future discharge scenario being planned for the Hyperion Water Reclamation Plant (a scenario not evaluated by Walker, 2016) appears to be problematic. Figure 9 indicates that brine-only discharges from the reclamation plant of 10 mgd at 6.8 ppt will only achieve a minimum initial dilution of Dm = 8.9, in violation of the dilution credit presently issued to the Hyperion 1-Mile Outfall under NPDES permit (No. CA-0109991, Order No. R4-2010-0200). This problematic result is due to *diffuser stall* since the densimetric Froude number becomes sub- critical at discharges as little as 10 mgd, (where $F_r = u / \sqrt{g' d}$ = 0.16). At these ultra-low discharge flows, there are simply too many discharge ports with too much discharge cross-sectional area in the Hyperion 1-Mile diffuser, resulting in failure of the discharge streams to become turbulent jets. In this case, the maximum discharge velocity is only u = 6.9 cm/s. To correct this condition without physical modification of the diffuser, the brackish brine-only conveyance must be increased to at least 63 mgd. Otherwise, many of the existing discharge ports are likely to become flooded by ambient seawater. If diffuser ports flood, a salt wedge forms inside the diffuser and beneath the brackish brine, resulting in high rates of internal bio-fouling of the diffuser.

6) Dilution Results for Blended West Basin Brine Discharges

The results of the dilution modeling analysis are summarized in Table 3. Most of the modeled outcomes satisfy discharge limits set forth under both the Appendix- A brine amendment of the Ocean Plan and Requirement III.C.4(b) specific to buoyant discharges. The only failures resulted from co-mingling West Basin brine with 10 mgd of brackish brine effluent from the Hyperion Water Reclamation Plant (projected as the ultimate low-flow conveyance once the reclamation plant is expanded to final design capacity). As discussed in Section 5, the 10 mgd brackish brine discharges from the 1-Mile Outfall will not satisfy NPDES discharge permit limits even as a stand-alone scenario, (but it will dilute on the sea surface to within 2ppt of natural background salinity within a horizontal distance 100 m from the point of discharge, cf. Ocean Plan amendment, SWRCB, 2015). When either 21 mgd or 63 mgd of West Basin brine is added to the 10 mg of brackish brine from the Hyperion Water Reclamation Plant, the combined effluent becomes negatively buoyant (those scenarios in Table 2 where the density anomaly is negative). The effluent limits will be governed by the new brine amendments to the Ocean Plan per Appendix-A of SWRCB (2015). The discharge plume consists of an initial fully developed turbulent jet with rapid initial dilution caused by entrainment of the surrounding water mass, followed by a more gradual subsequent dilution phase where the brine plume disperses as a turbulent bottom spreading layer, (Figure 10). During the entire dilution process, the dense plume remains in close proximity to the seabed. The pycnocline remains well above the plume and there is no trapping layer to limit dilution and define the boundaries of a ZID. The Visual Plumes simulation in Figure 11 indicates that the salinity (red curve) progressively declines as

Table 3: Summary of results for Dilution of Brine from the West Basin Desalination Project Discharged from the Hyperion 1-Mile Outfall

Discharge Scenario Wastewater + Brine = Total Flow Rate (MGD)	Combined Discharge Salinity (ppt)	Discharge Velocity m/sec	Densimetric Froude Number $F_r = u/\sqrt{g' d}$	Distance horizontally to within 2ppt of Natural Background (BMZ, m)	Initial Dilution at BMZ	Initial Dilution (Dm) at lowest monthly trapping level **(ZID)	Meet OPA/ NPDES Limits?
*****10 + 0 = 10**	**6.8**	**0.069**	**0.16**	**17.2**	**12.35**	**8.9**	**Maybe/No**
*****10 + 21 = 31**	**48.15**	**0.22**	**0.68**	**390**	**6.33**	**N/A**	**No/Maybe**
*****10 + 63 = 73**	**59.48**	**0.51**	**1.19**	**207**	**11.99**	**N/A**	**No/Maybe**
90 + 21 =110	**12.95**	**0.76**	**2.03**	**23.5**	**9.28**	**29.2**	**Yes/Yes**
90 + 63 = 153	**27.93**	**1.07**	**5.45**	**10.7**	**1.78**	**27.2**	**Yes/Yes**
203 + 21 = 224	**6.36**	**1.56**	**3.59**	**51**	**12.57**	**23.8**	**Yes/ Yes**
203 + 63 = 266	**16.06**	**1.85**	**5.33**	**45**	**7.72**	**21.8**	**Yes/ Yes**
250 + 21 = 271	**5.26**	**1.89**	**4.25**	**66.0**	**13.1**	**21.5**	**Yes/ Yes**
250 + 63 = 313	**13.65**	**2.19**	**4.98**	**61.0**	**8.92**	**19.5**	**Yes/ Yes**

Red = future low wastewater flow; **Yellow** = present low wastewater flow; **Blue** = average wastewater flow

* Trapping Levels (ZID) are measured in terms of height above the point of discharge (vertical distance from discharge ports)

** ZID boundary defaults to minimum trapping level for buoyant discharges.

***Wastewater for these scenarios is brackish brine from Hyperion Water Reclamation Plant at 6.8 ppt

OPA = Ocean Plan Appendix-A brine amendment, SWRCB, (2015).

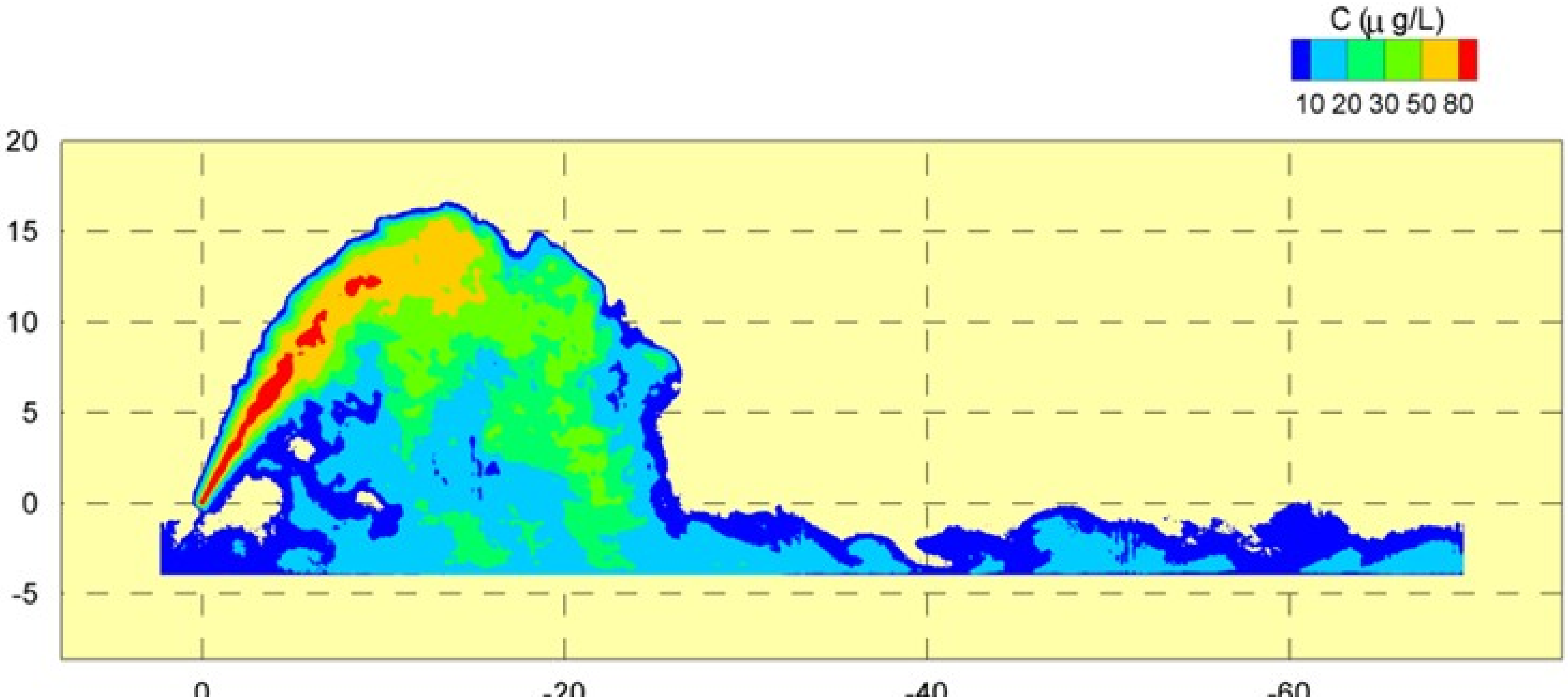

Figure 10: Brine plume and subsequent bottom spreading layer after discharge from a diffuser. The turbulent bottom spreading layer appears between horizontal reference points -25 m and -70 m on the right hand portion of the figure, (from Roberts, 2012, cf. Jenkins et al., 2012)

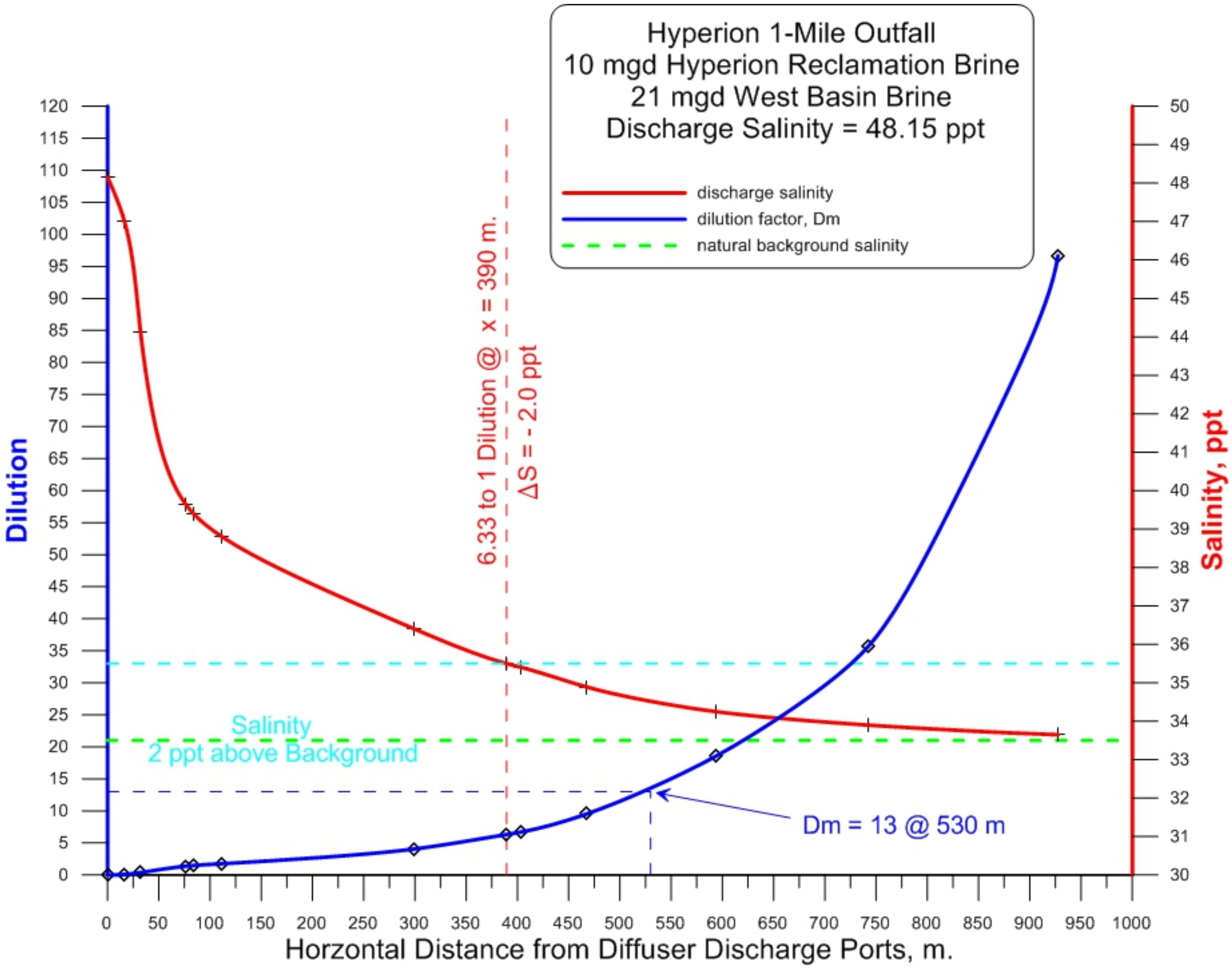

Figure 11: Visual Plumes (UM3) simulation of still water dilution of 21 mgd of West Basin brine blended with 10 mgd of Hyperion water reclamation brine discharged at a combined end-of-pipe of 48.15 ppt. Discharge salinity (red, right hand axis) as a function of distance vertically (upper panel) and horizontally (lower panel) from the Hyperion 1-Mile outfall diffuser. Dilution factor (blue, left hand axis) as a function of distance vertically (upper panel) and horizontally (lower panel).

plume spreads horizontally across the seafloor, but does not reach to within 2ppt of natural background salinity until 390 m from the point of discharge. This is result does not satisfy the 100 m BMZ discharge limits set under the Appendix-A provisions of the amended Ocean Plan (SWRCB 2015). However, dilution continues beyond 390 m from the discharge point and reaches the value of Dm = 13 required by the present NPDES permit (No. CA-0109991, Order No. R4-2010-0200) at 530 m (cf. blue curve in Figure 11). The fact that the dilution curve continues to increase beyond $x = 530$ m suggests that dilution is still not yet complete; so that the minimum initial dilution may be even greater than Dm =13. Therefore it can be argued that blending 21 mgd of West Basin Brine with 10 mgd of brackish brine from the Hyperion Water Reclamation Plant will result in a dilution performance at the 1-Mile Outfall that satisfies the present NPDES permit, but is non-compliant with the brine amendment of the Ocean Plan. Similarly, the addition of 63 mgd of West Basin Brine with 10 mgd of brackish brine from the Hyperion Water Reclamation Plant (Figure 12) will achieve sufficient dilution, Dm = 13 at $x =$ 214 m, which satisfies the present NPDES permit, but discharge salinity will not reach within 2 ppt of natural background until $x = 207$ m from the point of discharge; and hence is non-compliant with the brine amendment of the Ocean Plan. The reason why dilution is faster with the addition of 63 mgd of West Basin brine vs. 21 mgd is that the higher resulting combined discharge rate increases the densimetric Froude number by 75%, causing it to go super-critical and produce large turbulent eddies in the discharge jet streams that accelerate dilution rates.

For all other combinations of West Basin brine and Hyperion effluent that result in buoyant discharges, (those scenarios in Table 2 where the density anomaly is positive), the discharge plumes will rise in the water column until reaching the trapping layer at the pycnocline interface, as represented in Figure 2. For these buoyant discharge cases, the present NPDES permit (No. CA-0109991, Order No. R4-2010-0200) and Requirements III.C.4(b-d) of the Ocean Plan are the critical regulatory discharge standards, although we will still pay attention to the 100 m BMZ discharge limits set under the Appendix-A provisions of the amended Ocean Plan (SWRCB 2015). Inspection of Table 3 reveals that dilution performance of the 1-Mile Outfall diffuser was better for buoyant discharges at low-flow conditions than high flow conditions, because, again, smaller volumes of effluent at smaller discharge rates are more rapidly diluted in the limited volume of receiving water available beneath the pycnocline or sea surface. The best dilution performance was achieved for the low-flow condition that blended 90 mgd of effluent from the Hyperion Water Reclamation Plant with 21 mgd of Wes Basin brine, (Figure 13), where minimum initial dilution (blue curve) reached Dm = 29.2 to 1 at the worst-month trapping layer $z = 6.1$ m above the discharge point. The primary motion of the plume is vertically upward through the water column until reaching the trapping layer, whence the plume spreads horizontally along the pycnocline interface and continues until dilution is complete at $x = 127$ m. In spite of this horizontal spreading, the BMZ limits of the amended Ocean Plan were satisfied, and the discharge salinity (red curve in Figure 13) rose to within 2 ppt of natural background at a horizontal distance of only $x = 23.5$ m from the point of discharge. However, the diffuser jets at the end the diffuser legs produce horizontal entrainment streams that bend the angle of the jet streams, (Figure 14); causing the discharge streams from the side ports to be deflected seaward, away from the shoreline, (consistent with plume CORMIX v9 simulations by Walker 2016). These flow features were resolved with the CFD model and used to adjust jet angles in the initialization of the Visual Plumes (UM3) mixing zone model.

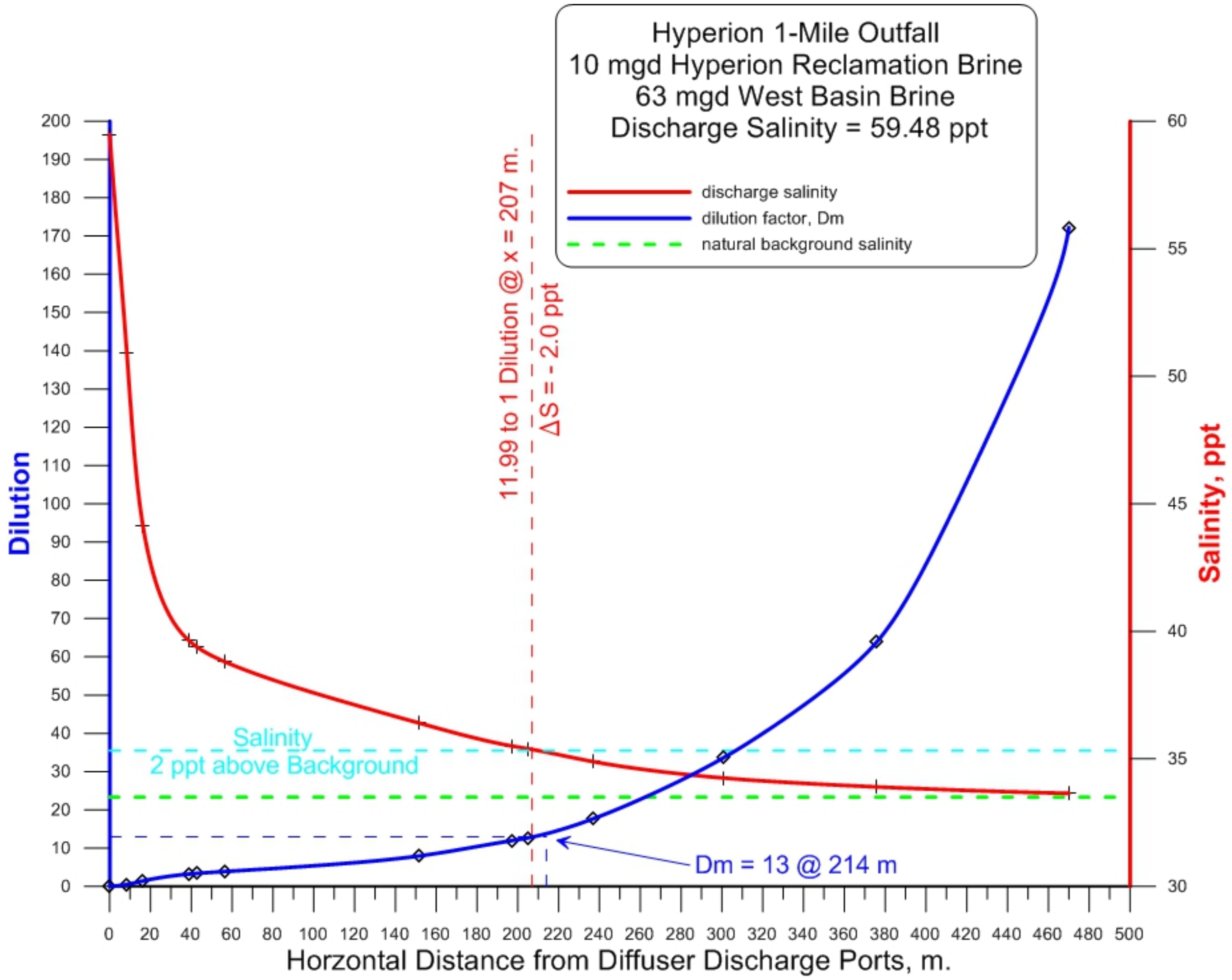

Figure 12: Visual Plumes (UM3) simulation of still water dilution of 63 mgd of West Basin brine blended with 10 mgd of Hyperion water reclamation brine discharged at a combined end-of-pipe of 59.148 ppt. Discharge salinity (red, right hand axis) as a function of distance vertically (upper panel) and horizontally (lower panel) from the Hyperion 1-Mile outfall diffuser. Dilution factor (blue, left hand axis) as a function of distance vertically (upper panel) and horizontally (lower panel).

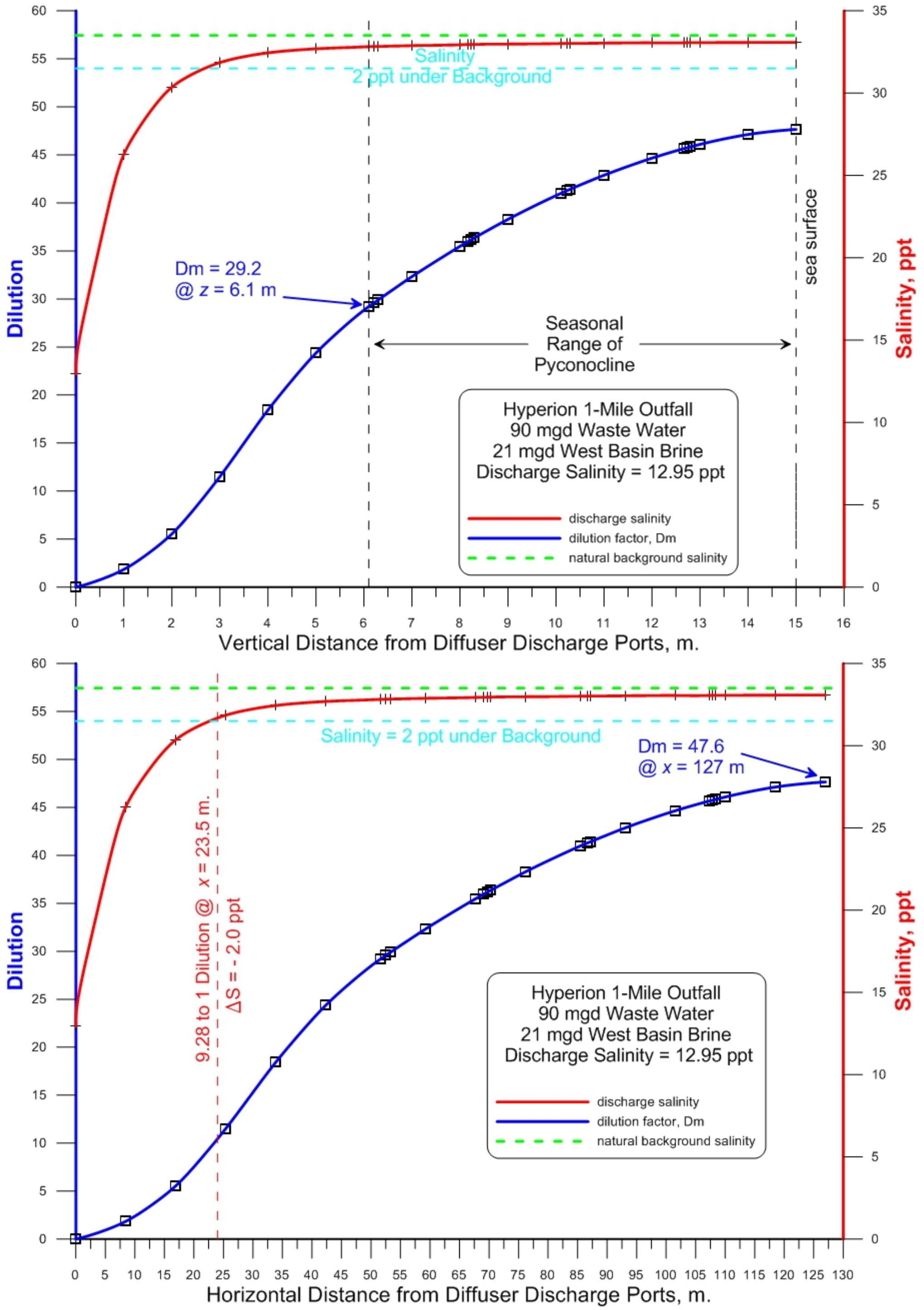

Figure 13: Visual Plumes (UM3) simulation of still water dilution of 21 mgd of West Basin brine blended with 90 mgd of Hyperion wastewater discharged at 12.95 ppt end-of-pipe. Discharge salinity (red, right hand axis) as a function of distance vertically (upper panel) and horizontally (lower panel) from the Hyperion 1-Mile outfall diffuser. Dilution factor (blue, left hand axis) as a function of distance vertically (upper panel) and horizontally (lower panel).

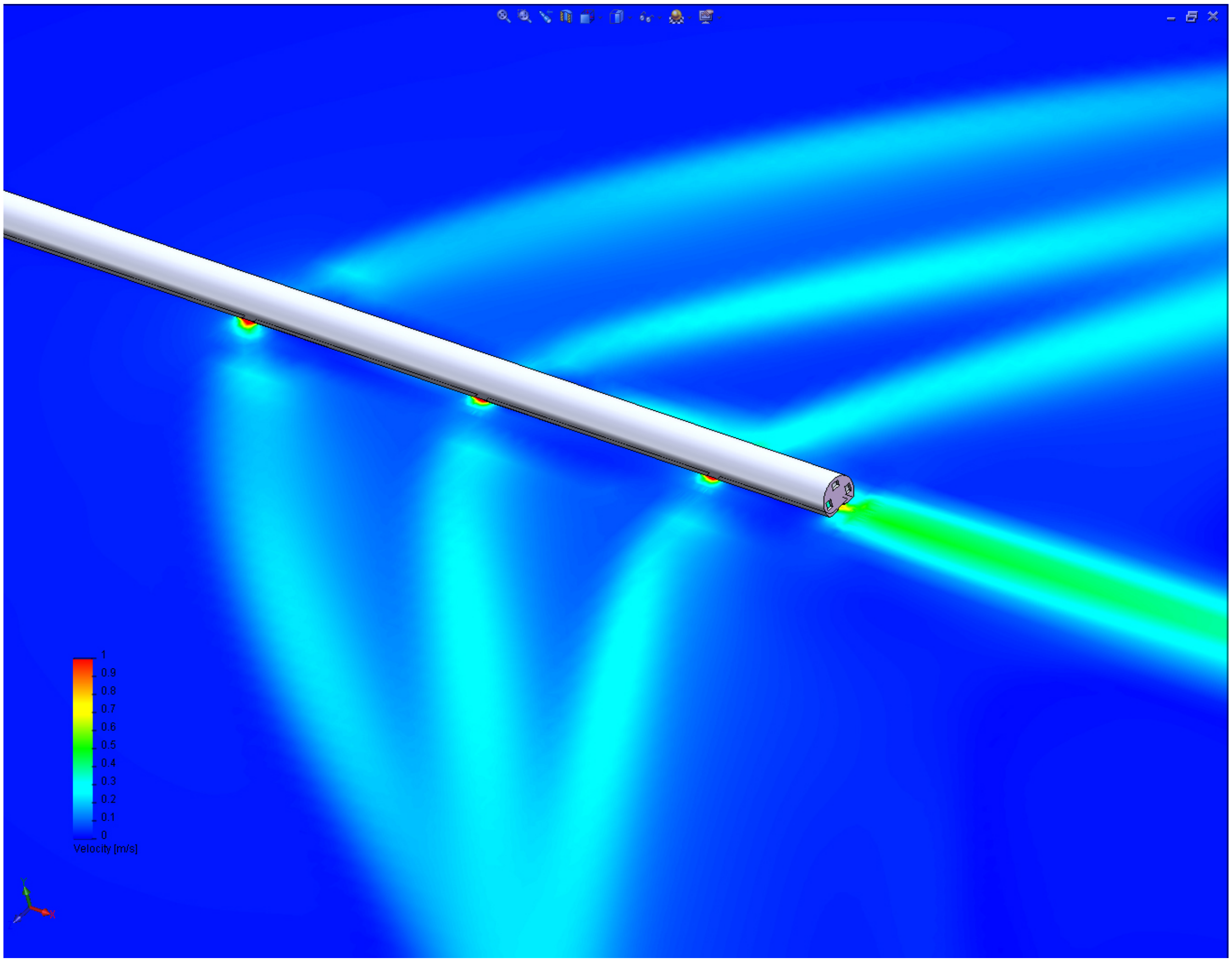

Figure 14: Contour cut-plot in a horizontal plane through the diffuser jet nozzles and discharge velocity field of the Hyperion 1-Mile Outfall diffuser. COSMOS/FloWORKS simulation of still water dilution of 63 mgd of West Basin brine blended with 90 mgd of Hyperion wastewater discharged at u = 1.07 m/s, $F_r = u / \sqrt{g' d}$ = 5.45. Note horizontal angles of jets due to entrainment streams by terminal end jets.

When the West Basin brine loading was increased to 63 mgd and blended with 90 mgd of effluent from the Hyperion Water Reclamation Plant, (Figure 15), the minimum initial dilution (blue curve) declined slightly to Dm = 27.2 to 1 at the pycnocline trapping level, well above the 13 to 1 dilution credit required by the present NPDES permit. Discharge salinity (red curve) rose to within 2 ppt of natural background at a horizontal distance of x = 10.7 m from the point of discharge, again easily satisfying the Appendix-A brine amendment to the Ocean Plan. When the Hyperion Water Reclamation Plant effluent conveyance is increased to the average annual minimum of 203 mgd and blended with 21 mgd of Wes Basin brine, (Figure 16), minimum initial dilution (blue curve) declined further to Dm = 23.8, while discharge salinity came within 2 ppt of natural background at a horizontal distance of only x = 51 m from the point of discharge as horizontal spreading of the plume increased to x = 224 m. But, increasing West Basin brine loading to 63 mgd and blending it with 203 mgd of effluent from the Hyperion Water Reclamation Plant, (Figure 17), produced further declines in the minimum initial dilution to Dm = 21.8, while discharge salinity (red curve) rose to within 2 ppt of natural background at a horizontal distance of only x = 45 m from the point of discharge. And so these trends continued in Figures 19-24 with additional increases in effluent from the Hyperion Water Reclamation Plant resulting in continual declines in the minimum initial dilution, but always remaining above the dilution credit of Dm = 13 required by the present NPDES permit; and increases in the horizontal plume spreading that resulted in *the 2ppt above natural background threshold* being achieved at greater horizontal distances from the point of discharge, but always well within the 100 m BMZ requirement of the amended Ocean Plan (SWRCB, 2015). Worst-case dilution occurred for combined discharges with the long term average HWRP conveyance of 250 mgd (Figures 18 & 19). Here minimum initial dilution was Dm = 21.5 with 21 mgd of West Basin brine loading, and Dm = 19.5 with 63 mgd of West Basin brine loading; both results satisfying the certified minimum initial dilution of Dm = 13 for the 1-Mile Outfall under NPDES permit No. CA-0109991, Order No. R4-2010-0200. At these higher flow rates, the densimetric Froude number was in the range of $F_r = u / \sqrt{g' d}$ = 4.25 to 4.98, and the maximum horizontal spreading of the plume at the pycnocline trapping level increased to x = 297 m. Nonetheless, the discharge salinity came within 2 ppt of natural background at horizontal distances in the range of x = 61 m to 66 m from the point of discharge, easily satisfying the Appendix-A brine amendment of the Ocean Plan (SWRCB, 2015).

The addition of West Basin brine to the Hyperion effluent has multiple dynamic effects which may or may not reduce the minimum initial dilution that would have otherwise been achieved with a wastewater-only discharges of comparable flow rate. On the one hand, brine additions to buoyant effluent reduce the net buoyancy and rate of rise of the discharge plume in the water column; and that reduction in rise rate reduces the rate of entrainment of the surrounding water mass that ultimately produces dilution. On the other hand, the reduction in net buoyancy due to brine additions increases the densimetric Froude number of the discharge jets, which enhances the initial dilution due to turbulent eddy entrainment. However, the results in Table 3 generally show that the addition of West Basin brine has reduced the minimum initial dilution that would have otherwise been achieved with a wastewater-only discharge of comparable flow rate from the Hyperion Water Reclamation Plant; and that the suppression of initial dilution is less for brine additions from the 21 mgd West Basin Desalination Project than for the 63 mgd project. This suggests that the degradation of convective entrainment caused by brine additions has a stronger influence on initial dilution than the enhancement of jet turbulence due to increased densemetric Froude numbers.

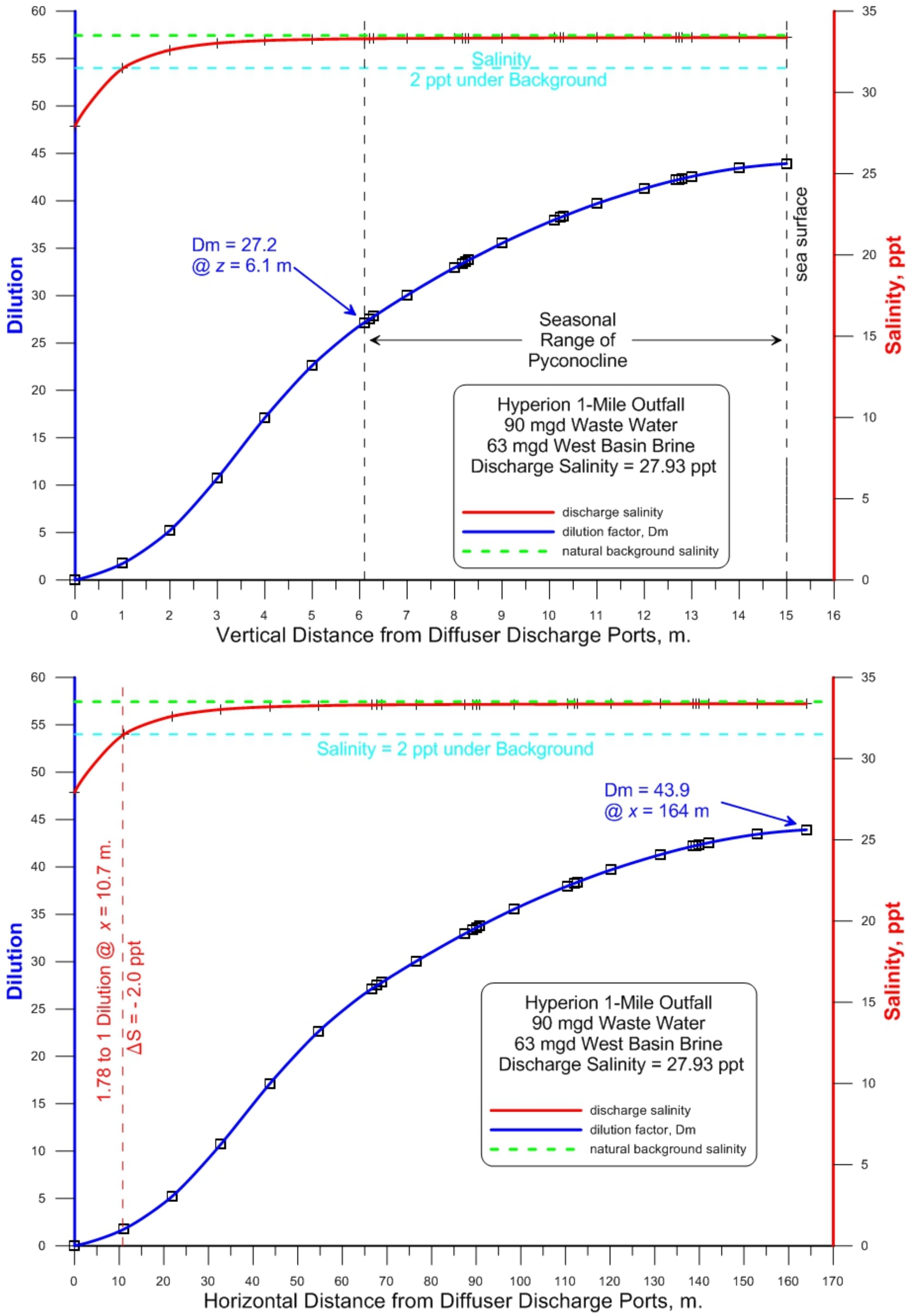

Figure 15: Visual Plumes (UM3) simulation of still water dilution of 63 mgd of West Basin brine blended with 90 mgd of Hyperion wastewater discharged at 27.93 ppt end-of-pipe. Discharge salinity (red, right hand axis) as a function of distance vertically (upper panel) and horizontally (lower panel) from the Hyperion 1-Mile outfall diffuser. Dilution factor (blue, left hand axis) as a function of distance vertically (upper panel) and horizontally (lower panel).

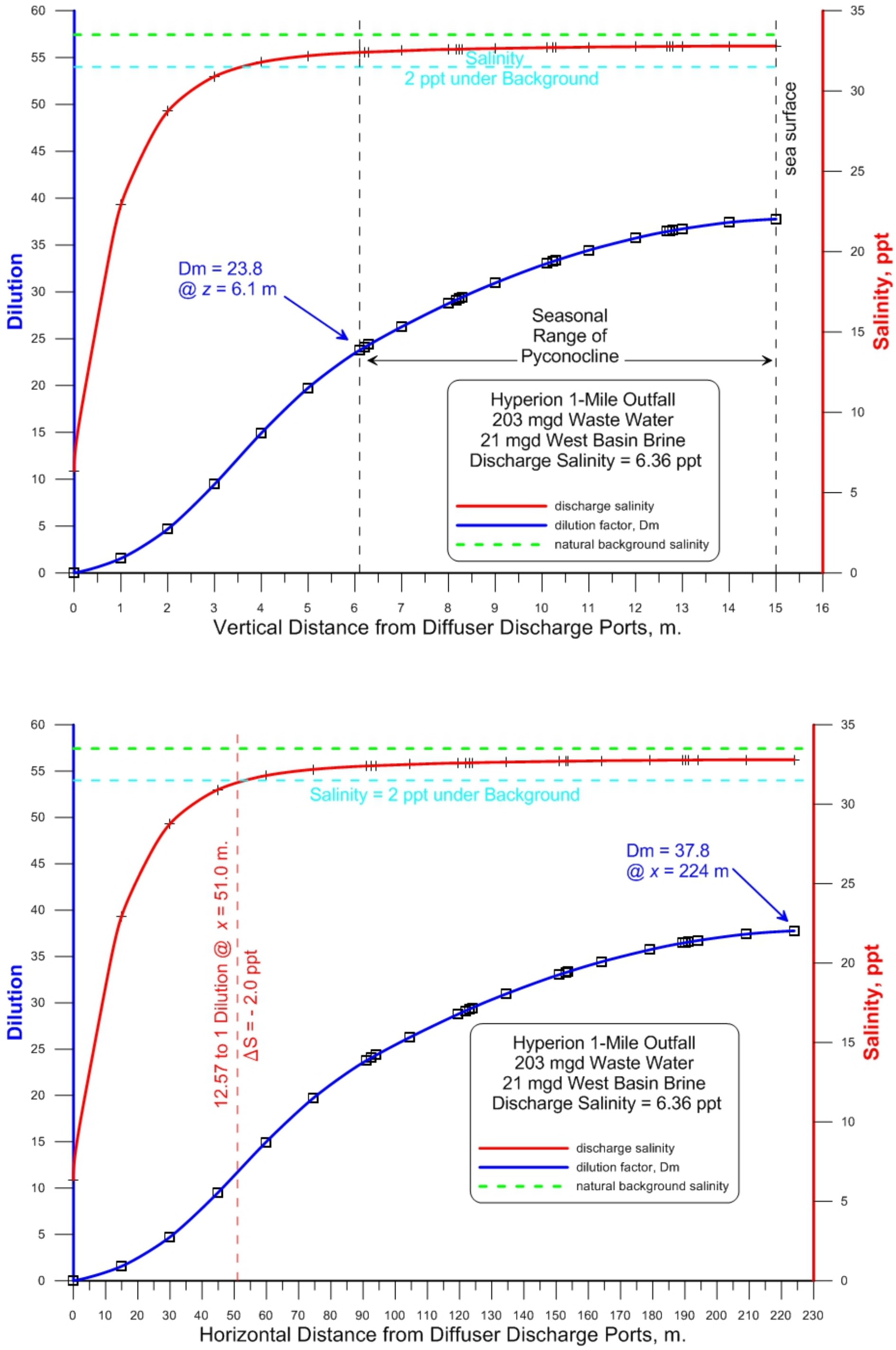

Figure 16: Visual Plumes (UM3) simulation of still water dilution of 21 mgd of West Basin brine blended with 203 mgd of Hyperion wastewater discharged at 6.36 ppt end-of-pipe. Discharge salinity (red, right hand axis) as a function of distance vertically (upper panel) and horizontally (lower panel) from the Hyperion 1-Mile outfall diffuser. Dilution factor (blue, left hand axis) as a function of distance vertically (upper panel) and horizontally (lower panel).

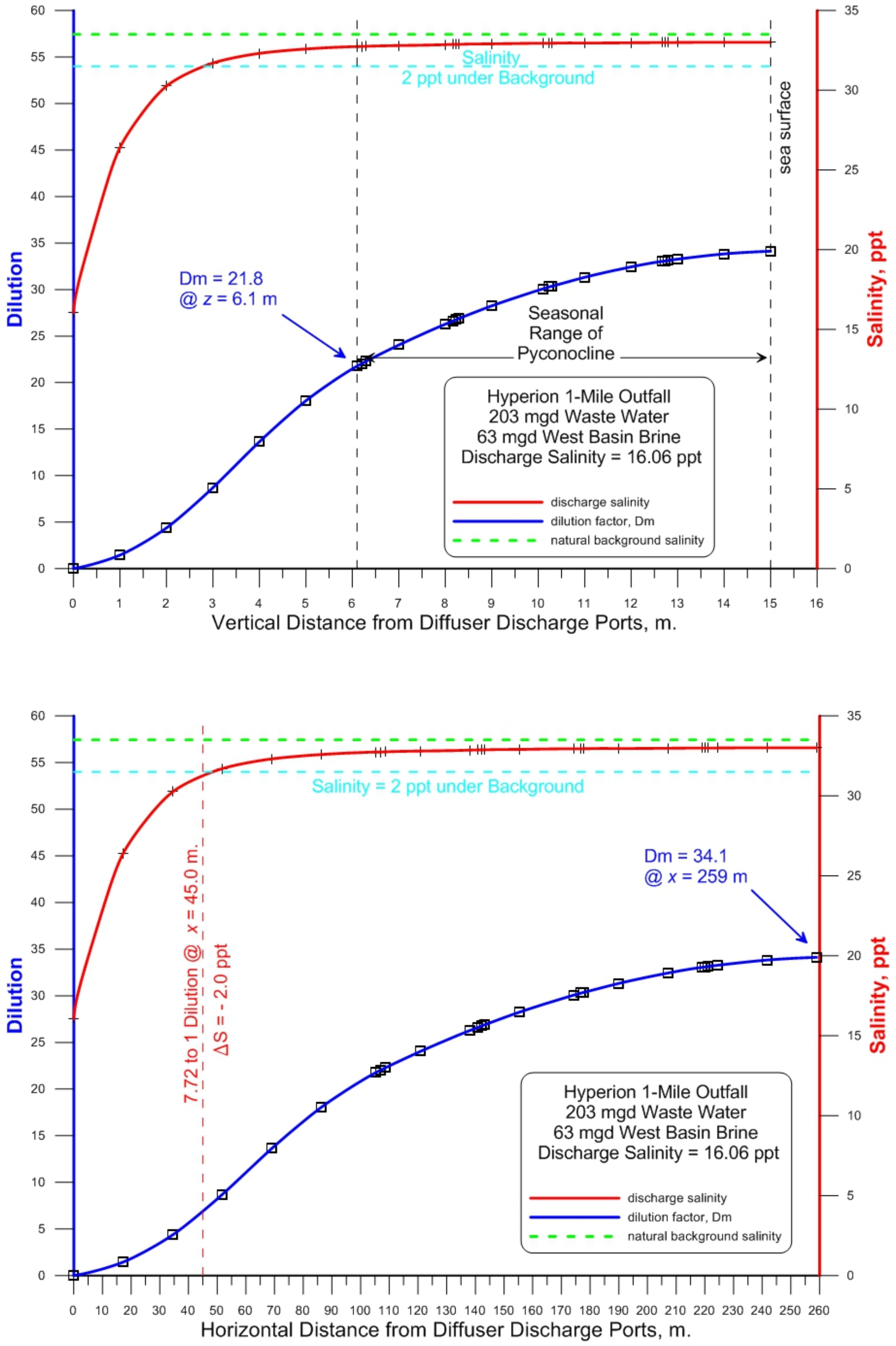

Figure 17: Visual Plumes (UM3) simulation of still water dilution of 63 mgd of West Basin brine blended with 203 mgd of Hyperion wastewater discharged at 16.06 ppt end-of-pipe. Discharge salinity (red, right hand axis) as a function of distance vertically (upper panel) and horizontally (lower panel) from the Hyperion 1-Mile outfall diffuser. Dilution factor (blue, left hand axis) as a function of distance vertically (upper panel) and horizontally (lower panel).
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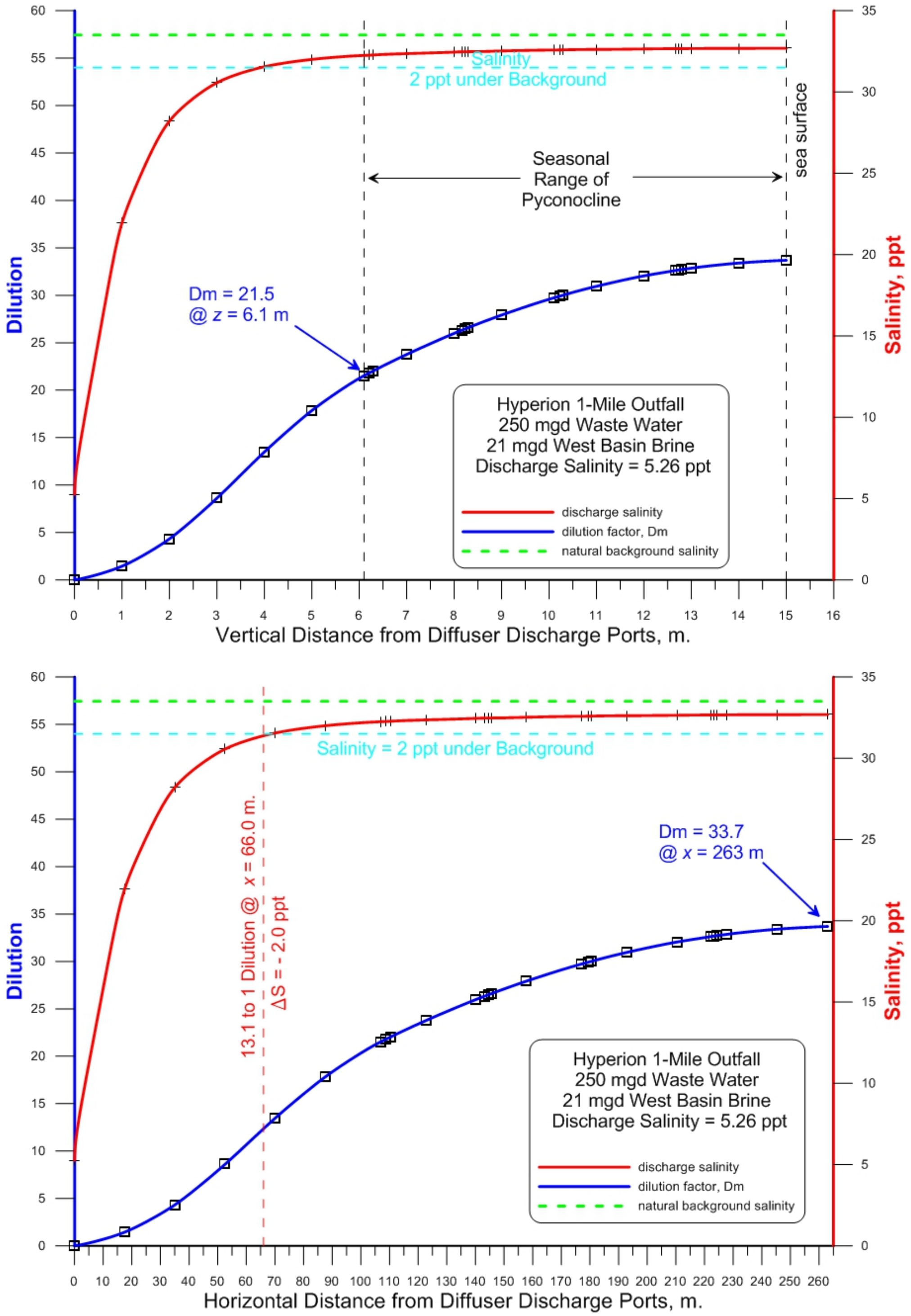

Figure 18: Visual Plumes (UM3) simulation of still water dilution of 21 mgd of West Basin brine blended with 250 mgd of Hyperion wastewater discharged at 5.26 ppt end-of-pipe. Discharge salinity (red, right hand axis) as a function of distance vertically (upper panel) and horizontally (lower panel) from the Hyperion 1-Mile outfall diffuser. Dilution factor (blue, left hand axis) as a function of distance vertically (upper panel) and horizontally (lower panel).

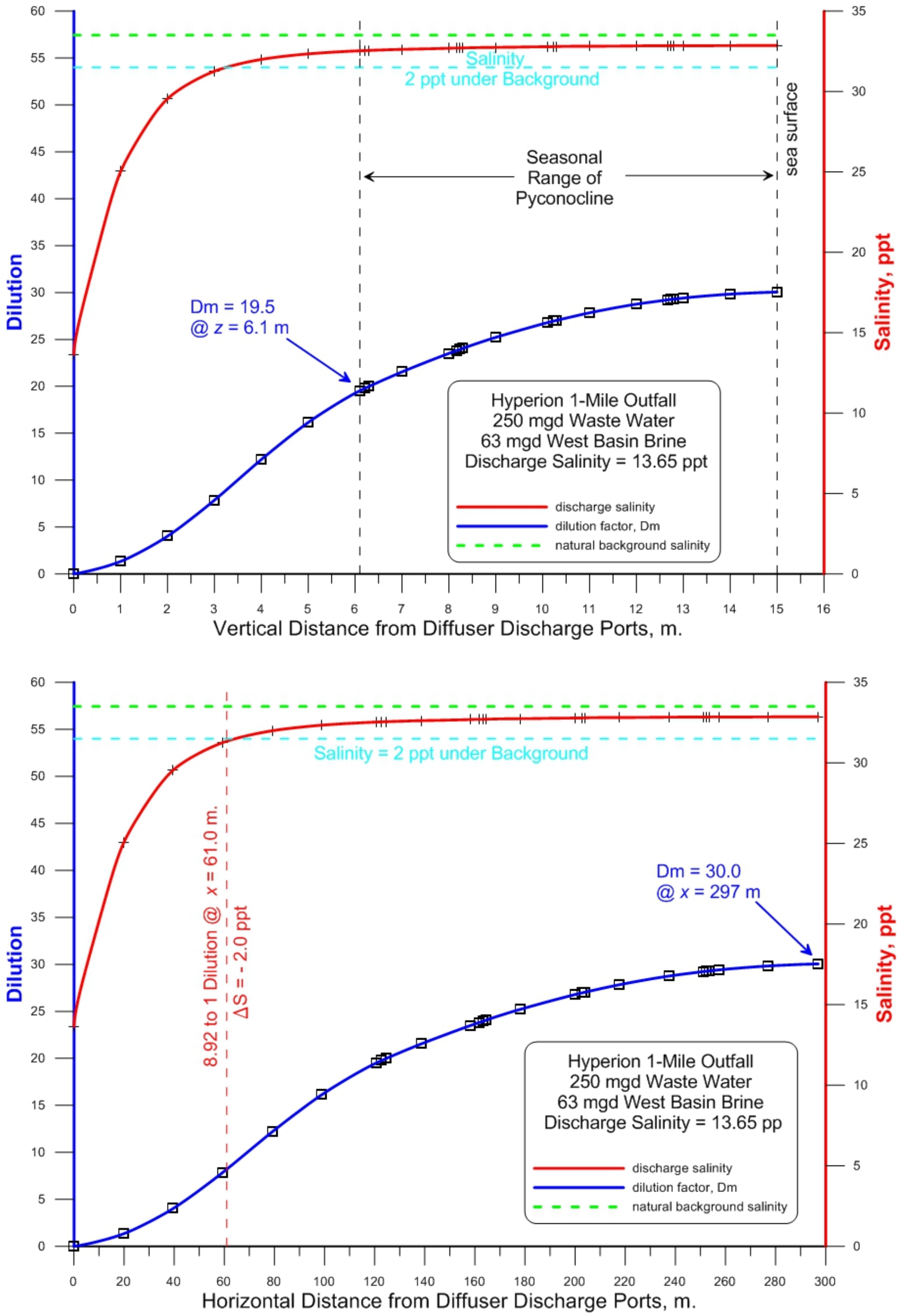

Figure 19: Visual Plumes (UM3) simulation of still water dilution of 63 mgd of West Basin brine blended with 250 mgd of Hyperion wastewater discharged at 13.65 ppt end-of-pipe. Discharge salinity (red, right hand axis) as a function of distance vertically (upper panel) and horizontally (lower panel) from the Hyperion 1-Mile outfall diffuser. Dilution factor (blue, left hand axis) as a function of distance vertically (upper panel) and horizontally (lower panel).

7) Conclusions:

This is a dilution study to examine the feasibility of using the Hyperion 1-Mile Outfall to discharge brine by-product from the *West Basin Municipal Water District Sea Water Desalination Project* after it has been blended with effluent from the *Hyperion Water Reclamation Plant*, (HWRP). The study looks at two different scales for West Basin brine conveyance (21 mgd & 63 mgd) to be blended with reclamation plant effluent that varies across an envelope present and future operating conditions, up to and including combined conveyance equal to the maximum certified hydraulic capacity of the outfall (850 mgd).

Feasibility is judged in terms of the ability of the existing diffuser of the 1-Mile Outfall to achieve sufficient dilution performance to satisfy *both* minimum initial dilution requirements of 13 to 1 set forth in the existing NPDES permit (No. CA-0109991, Order No. R4-2010-0200), as well as the discharge limits set forth in the Appendix-A *brine amendment* to the California Ocean Plan. The dilution study invokes the EPA certified Visual Plumes (UM3) mixing zone model and the same reclamation plant effluent properties and environmental parameters assumed by the recently updated dilution study for the Hyperion 1-Mile Outfall performed by Walker (2016), who used the alternative EPA dilution model, CORMIX version 9.0.

The first step in the analysis was to reproduce the Walker (2016) results for the same Hyperion Water Reclamation Plant effluent conveyance rates. The coefficient of determination between the two model prediction was rather good, (R-squared = 0.83), with Visual Plumes slightly underestimating the minimum initial dilution predictions of the CORMIX model. A future discharge scenario being planned for the Hyperion Water Reclamation Plant (a scenario not evaluated by Walker, 2016) was found to be problematic. Brackish brine-only discharges from the reclamation plant of 10 mgd at 6.8 ppt will only achieve a minimum initial dilution of Dm = 59.6 to 1, in violation of the dilution credit presently issued to the Hyperion 1-Mile Outfall under the NPDES permit. This problematic result is due to *diffuser stall* since the densimetric Froude number becomes sub- critical at discharges as little as 10 mgd, (where $F_r = u / \sqrt{g' d}$ = 0.16). At these ultra-low discharge flows, there are simply too many discharge ports with too much discharge cross-sectional area in the Hyperion 1-Mile diffuser, resulting in failure of the discharge streams to become turbulent jets. To correct this condition without physical modification of the diffuser, the brackish brine-only conveyance from the reclamation plant must be increased to at least 63 mgd. It should be noted that the 10 mgd brackish brine-only scenario will dilute by spreading across the sea surface to within 2ppt of natural background salinity in a horizontal distance of less than 100 m from the point of discharge, thereby satisfying the Ocean Plan brine amendment, (SWRCB, 2015).

The feasibility results of co-mingling West Basin brine with Hyperion Reclamation Plant effluent are summarized in Table 3. Most of the modeled outcomes satisfy discharge limits set forth under both the Appendix- A brine amendment of the Ocean Plan and the present NPDES permit. The only failures resulted from co-mingling West Basin brine with 10 mgd of brackish brine effluent from the Hyperion Water Reclamation Plant (projected as the ultimate low-flow conveyance once the reclamation plant is expanded to final design capacity). When either 21 mgd or 63 mgd of West Basin brine is added to the 10 mg of brackish brine from the Hyperion Water Reclamation Plant, the combined effluent becomes negatively buoyant. In either case, the combined brine effluent will not dilute to within 2ppt of natural background salinity within 100 m from the point of discharge, in violation of the Appendix-A provisions of the amended Ocean

Plan (SWRCB 2015). However, dilution continues beyond 100 m from the discharge point and reaches the value of Dm = 13 to 1 required by the present NPDES permit at distances between 214 m and 513 m from the point of discharge. Therefore, a determination of consistency with both new and existing discharge standards is uncertain for these anticipated future low-flow conditions.

For all other combinations of West Basin brine and Hyperion effluent in Table 3, the combined effluent produces buoyant discharges, which rise in the water column until reaching the trapping layer at the pycnocline interface. For these buoyant discharge cases, the present NPDES permit and Requirements III.C.4(b-d) of the Ocean Plan are the critical regulatory discharge standards, although we also pay attention to the 100 m brine mixing zone (BMZ) discharge limits set under the Appendix-A provisions of the amended Ocean Plan (SWRCB 2015). Inspection of Table A-1 reveals that dilution performance of the 1-Mile Outfall diffuser was better for buoyant discharges at low-flow conditions than high flow conditions, because smaller volumes of effluent at smaller discharge rates are more rapidly diluted in the limited volume of receiving water available beneath the pycnocline and sea surface. The best dilution performance was achieved for the low-flow condition that blended 90 mgd of effluent from the Hyperion Water Reclamation Plant with 21 mgd of West Basin brine, where minimum initial dilution (blue curve) reached Dm = 29.2 to 1 at the worst-month trapping layer z = 6.1 m above the discharge point. The primary motion of the plume is vertically upward through the water column until reaching the trapping layer, whence the plume spreads horizontally along the pycnocline interface and continues until dilution is complete at x = 127 m. In spite of this horizontal spreading, the BMZ limits of the amended Ocean Plan were satisfied, and the discharge salinity (red curve in Figure 13) rose to within 2 ppt of natural background at a horizontal distance of only x =23.5 m from the point of discharge. Additional increases in effluent from the Hyperion Water Reclamation Plant resulted in continual declines in the minimum initial dilution, but always remaining above the dilution credit of Dm = 13 required by the present NPDES permit; and increases in the horizontal plume spreading that resulted in *the 2ppt above natural background threshold* being achieved at greater horizontal distances from the point of discharge, but always well within the 100 m BMZ requirement of the amended Ocean Plan (SWRCB, 2015). Worst-case dilution occurred for combined discharges with the long term average HWRP conveyance of 250 mgd. Here minimum initial dilution was Dm = 21.5 with 21 mgd of West Basin brine loading, and Dm = 19.5 with 63 mgd of West Basin brine loading; both results satisfying the certified minimum initial dilution of Dm = 13 for the 1-Mile Outfall under the NPDES permit. At these higher flow rates, the densimetric Froude number was in the range of $F_r = u / \sqrt{g' d}$ = 4.25 to 4.98, and the maximum horizontal spreading of the plume at the pycnocline trapping level increased to x = 297 m and was deflected away from the shoreline by end-effects of the diffuser design. Nonetheless, the discharge salinity came within 2 ppt of natural background at horizontal distances in the range of x = 61 m to 66 m from the point of discharge, easily satisfying the Appendix-A brine amendment of the Ocean Plan (SWRCB, 2015).

8) References:

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