A CONCEPTUAL DESIGN OF SEAWATER PIPELINES FOR THE DEEP WATER DESAL PROJECT

Prepared For

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1. **INTRODUCTION**

This report summarizes work carried out by Makai Ocean Engineering, Inc. (“Makai”) on an engineering and conceptual design analysis of a seawater supply system for a desalination system at Moss Landing, California. The seawater supply and discharge system planned by DWD is intended to supply seawater to a new desalination plant to be located in the vicinity of Moss Landing on Monterey Bay, California. A secondary use of this water is to supply continuous cooling water to data center also located near the desalination plant. This work was conducted under contract to DeepWater Desal, LLC (‘‘DWD’’).

The purpose of this report is to provide a summary of the construction methods and impacts associated with the DWD conceptual pipeline. The report includes:

- Purpose and description of the pipeline alignment with potential wet well locations.
- Planned flow rates and the basis of design for two intake pipes and a single discharge pipeline.
- Description of HDPE for the pipe material for all offshore conduits.
- Description of the wave environment and anchoring needs for installation of intake/discharge pipes in deeper water.
- Description of Horizontal Directional Drilling and why this is the best construction method for the selected alignment.
- Description of the constructability of the proposed pipeline.
- Conceptual-level description of the anticipated construction activities for the pipeline fabrication and installation including estimates based on information provided by experienced marine and HDD contractors, including:
  - Type and duration of various construction phases
  - Number of vessels required
  - Area required for pipe fabrication
  - Potential impacts of marine construction (i.e., drilling mud, installing anchors, etc.)
2. CONCEPTUAL DESIGN

This chapter describes the pipeline alignment and wet-well locations, planned flow rates, and environmental wave loading and anchoring methods.

2.1. PIPELINE ALIGNMENT

The seawater supply and discharge system planned by DWD is shown below in Figure 2-1. The drawing shows locations of the planned intake and discharge seawater pipelines, the wet-well in which seawater pumps are located, and the DWD desalination facility.

2.1.1. Preferred Intake Route

The preferred intake route is described by two 42” OD HDPE pipes with DR13.5 wall thickness. The conceptual design shows the pipelines tunneled under the harbor from the preferred wet well to water depth of 45 meters offshore of Moss Landing Harbor. The pipe is shown in the drawing as the solid green line labeled “Intake - Preferred”. Tunneling from the wet well to the intake location is proposed using HDD (Horizontal Directional Drilling) technology. HDD and tunneling methods are described in more detail in Section 3.2.

An intake screen structure and any section of pipe beyond the HDD breakout will be anchored to the seafloor. Details on wave loading and anchoring methods for exposed pipe sections are described further in Section 2.4.

The wet well location will house pumps required for the suction intake pipes. From the wet well location another (pressurized) intake pipe will supply the seawater to the desalination plant.

The total distance of the intake alignment from the preferred wet well location to the 45m deep intake is 1.67 km.

2.1.2. Alternate Intake Route

The alternate intake route is described by two 42” OD HDPE pipes with DR13.5 wall thickness. The pipes will be tunneled under the harbor from the alternate wet well location to the 45m deep intake. The pipe route is shown in the drawing as the solid green line labeled “Intake - Alternate”. Similar to the preferred intake route, an intake screen structure will be anchored to the seafloor beyond the HDD breakout. Similar to the preferred intake route, any length of pipe and intake structure offshore of the HDD breakout will be anchored to the seafloor.

The wet well location will house pumps required for the suction intake pipes. From the wet well location another (pressurized) intake pipe will supply the seawater to the desalination plant.

The total distance of the intake alignment from the preferred wet well location to the 45m deep intake is 1.23 km.

2.1.3. Discharge Route

A single discharge pipe is proposed which extends from the desalination plant, along the existing pipeline easement, and out to two possible discharge locations. The pipe will be buried under the harbor using HDD, tie into the existing pipeline structure on the shoreline north of the harbor.
entrance, and discharge in 35m water depth. The discharge route is shown in Figure 2-1 as a black line with dashed sections where the pipeline will be tunneled with HDD and solid sections where the concept will utilize the existing pipeline and easement.

A length of HDPE with diffusers will be anchored on the seafloor beyond the HDD tunnel breakout. More details on anchoring methods for this segment of pipe are included in Section 2.4.

The total distance of the discharge alignment from the preferred wet well location to the 35m deep discharge is 3.34km; with 761m of pipe tunneled under the harbor. The total distance of the discharge alignment from the alternate wet well location is 3.00km; with 413m of pipe tunneled under the harbor.
Figure 2-1. Plan view of the location of the preferred and alternate intake and discharge pipeline alignments for Deep Water Desal in Moss Landing. The dashed black lines are tunneled discharge pipes across the harbor to the existing pipeline and easement. The solid black line follows the alignment of the existing pipeline within the easement, with two potential discharge locations shown as black dots. The solid green lines are the intake pipelines from both wet well locations with a red dot showing the intake location. The yellow dashed line demarcates the approximate limit of horizontal directional drilling (HDD) capabilities (6,000' or 1.8km) under satisfactory geological conditions, measured from the preferred wet well location. The dark bathymetry contours are in meters (10m intervals) and the lighter numbers and contours are in fathom from NOAA nautical charts. An existing power and communications cable buried under the seafloor using HDD and belonging to MBARI is shown in pink.
2.2. PIPELINE DESIGN

This Basis of Design (BOD) for the conceptual design of intake and discharge pipelines is as shown:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Input Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intake Flow</td>
<td>34,000 gpm @ 10C</td>
</tr>
<tr>
<td>Intake Pipes Dimensions</td>
<td>Two intake pipelines at 42-inch diameter each</td>
</tr>
<tr>
<td>Intake Depth</td>
<td>~45m</td>
</tr>
<tr>
<td>Discharge Flow</td>
<td>18,200 gpm @ 10C-11C</td>
</tr>
<tr>
<td>Discharge Pipe Dimensions</td>
<td>Single 36-inch diameter line (maintain velocity &lt;6 fps.)</td>
</tr>
<tr>
<td>Discharge Depth</td>
<td>~25-35m</td>
</tr>
<tr>
<td>Intake Pump Station Location</td>
<td>Wet-well location Identified in Figure 2-1</td>
</tr>
</tbody>
</table>

2.3. HDPE PIPE MATERIAL

High Density Polyethylene (HDPE) has been selected for the primary pipe material. HDPE has several advantages over FRP and concrete pipes for this marine pipeline:

- Readily Available Commercial Product
- High Flexibility/Strain Capability
- High Strength/Rugged
- Strong Fusion Joints
- Corrosion/UV/Biofouling Resistant
- Excellent Hydraulic Characteristics
- Low Cost

HDPE’s unique characteristics of high flexibility, high strength, high strain capability, strong fusion joints, no corrosion, and buoyancy provide for fast and low-cost deployment using the controlled submergence deployment method. HDPE pipe is also a favorite for HDD installation, as its strength and flexibility make it highly suitable for installation in tunnel borings.
2.4. SITE CONDITIONS AND PIPE ANCHORING

Intake structures and lengths of the discharge pipe beyond the HDD breakout locations will need to be anchored to the seafloor. Most HDPE pipelines installed on the seafloor are ballasted with concrete gravity anchors. The anchors are typically installed on long segments of the pipe at a staging site, the segments flanged together, and the entire length of pipe towed into position and sunk precisely along the alignment in one continuous process called controlled submergence. In deeper water gravity weights retain the advantage of not requiring diver assistance for installation, so deep water does not greatly increase installation difficulty. A typical design of the concrete gravity anchors is shown below in Figure 2-2. The holding power of a gravity anchor is a function of the friction force between the anchor and the seabed.

![Figure 2-2 Gravity Concrete Anchors for an HDPE pipe at Keahole Pt., Hawaii.](image)

In shallow water (typically <50m) the required anchoring for wave loads can exceed the maximum deployable weight. Site conditions for offshore Moss Landing obtained from the U.S. Army Corps of Engineer’s Wave Information Studies (WIS) reveal design waves of 8.4 meters and 18 second period. Figure 2-3, below, shows the WIS data used for this study. Makai performed hydrodynamic calculations and found the forces exceed the frictional holding power of the concrete gravity anchors. Additional anchoring will be required such as rock bolts or driven piles.
2.4.1. Additional Anchoring

In diver depths, in which the proposed DWD intake and discharge pipes are installed, the options and methods for installation of post-deployment anchors include hollow bar or rock-bolt anchors, manta-ray embedment anchors, or pile anchors. The type of anchor selected will depend on exact bottom conditions at the anchoring site.
Both hollow bar and rock bolt anchors are installed by drilling an oversized hole into the seabed, inserting a threaded steel bar anchor of prescribed length and then filling the annular hole with grout to form a corrosion resistant and structurally strong connection to the seafloor. An illustration showing the use of hollow bar anchors is shown in Figure 2-4. These anchors obtain the greatest holding power in hard bottoms made up of rock or limestone.

Manta Ray anchors are one type of sand embedment anchor. They are installed by driving the anchor into the seabed using a jack hammer, removing the driving rod and then pulling up on the attached anchor rod to rotate and set the anchor deep in the seafloor. Often Manta Rays are installed by first pre-drilling a hole to reduce the anchor installation loads. A hydraulic loading unit is used to pull up on and set the anchor. The anchor is set when it has rotated into a horizontal orientation. Manta Ray anchors are shown in Figure 2-5.

A last anchoring method considered was the use of driven steel pipe piles to hold the pipeline in place in the shallow zone. One way of attaching piles to the pipe weights to obtain additional anchoring is shown in Figure 2-6. Driven piles are installed on either side of the weight and connected with chain and turnbuckles to pipe. The piles are heavy steel pipes of at least 20’ length that are driven into the seafloor from a moored or jack-up barge. Once mobilized at the site, pile anchors can be quickly installed if no adverse sub-bottom condition (rock) is encountered. Pile anchor installation is limited to diver depths as all connections between the pipes and the pipe are made up by divers.
There are other types of post-deployment anchors available such as large concrete mats that are placed over the pipe after deployment. However, any system that depends upon gravity and the weight of concrete for anchoring is usually much less effective in terms of anchoring per unit cost than the methods described here.

The above anchoring methods can be used on both the exposed pipe on the seafloor after it leaves the HDD tunnel and securely anchor the intake structure and discharge diffuser pipe section in place.
3. CONSTRUCTION METHODS AND IMPACTS

This chapter describes the construction methods for the conceptual pipe design with focus on the environmental impacts of the construction and installation operations. Makai Ocean Engineering contacted two experienced contractors (Triton Marine Construction and Environmental Crossings) to obtain additional data on the type of equipment likely to be needed, duration of construction operations, and environmental impacts. The contractor feedback has been included throughout. Where applicable Makai has provided construction methodology based on our own experience.

3.1. SHORE CROSSING METHODS

During a conceptual design process, Makai considered two possible shore crossing methods for the seawater intake and return pipes. Based on our experience in past marine pipeline projects and on our understanding of the current design, Makai has performed a conceptual, qualitative comparison of these two pipeline installation methods below for the DWD project:

<table>
<thead>
<tr>
<th>Pipe Shoreline Crossing Method</th>
<th>Economic preference</th>
<th>Environmental preference</th>
<th>Brief description, example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trenched</td>
<td>High.</td>
<td>Low.</td>
<td>Containing the displaced earth from dispersing into the ocean is difficult. Construction is visible directly on the shoreline. It may be necessary to construct an offshore trestle during the excavation.</td>
</tr>
<tr>
<td></td>
<td>Least expensive pipeline shore crossing method.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tunneled: Horizontal Directional Drill (HDD)</td>
<td>Low.</td>
<td>High.</td>
<td>There are no visible signs of the pipeline, and it is possible to contain the dispersion of the displaced earth and drill mud.</td>
</tr>
<tr>
<td></td>
<td>HDD is significantly more expensive than trenching due in part to the specialized equipment required.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A trench is excavated from onshore to a certain depth offshore. The pipe is laid in the trench and backfill and/or concrete is used to cover the trench.

A tunnel starts onshore and travels below ground to emerge at the desired depth offshore. Multiple passes of a drill ream the hole to the desired size.
Due to the much higher environmental preference for HDD tunneling, Makai recommends this pipe installation method and exclusively discusses this method for the remainder of the report.

3.2. HORIZONTAL DIRECTIONALLY DRILLED SHORE CROSSING

HDD technology is being used for pipeline (water, wastewater) and cable crossings for airports, highways, waterways, and elsewhere around the world. A recently installed (2007) MBARI power and communications cable going to a deep sea observatory was installed using HDD from the southern side of the Moss Landing Harbor. Environmental Crossings Inc., the contractor responsible for tunneling the MBARI cable, quotes their state-of-the-art capabilities for HDD at 1800m tunnel lengths under satisfactory geological conditions. Based on their experience at this location, they stated that 1.8km lengths of HDD should be possible; although detailed geotechnical borings are needed to confirm.

An HDD crossing can be broken into multiple steps:

1. The first stage involves drilling a pilot hole of 3” to 10” in diameter from the shoreline along the design centerline of the proposed pipeline. The pilot hole is drilled while bentonite drilling-mud is pumped down the center of the drill rod. The bentonite also functions as a coolant and facilitates spoil removal.

2. The second stage involves enlarging the pilot hole by ‘reaming out’ the hole during several passes until it reaches the desired diameter. For this project, the drilling would start with a 9” or 10” pilot hole, then step-up the diameter size for each successive pass (e.g., 20”, 30”, 38”, 44”, 50”, 55”, etc). Each successive step will be a small increase in diameter because the total volume of earth that can be removed at a given time is limited. For a 42” HDPE intake pipe the hole may have to be reamed to as much as 60”diameter depending on soil conditions and the driller’s evaluation of risk. It would take an HDD contractor at least 6 or 7 passes to get to about 60’’ diameter hole that is necessary for a 42’’ pipe (some buffer room is required between the tunnel wall and the pipe). Makai consulted with Environmental Crossings Inc. who provided Makai with an informal estimate that it would take an HDD crew 60 to 70 days of drilling to complete the HDD tunnel for a single 42’’ pipe. It may take as long as 6 months to complete the HDD tunnels for all three pipes.

3. Prior to the pipeline pullback operation, the HDPE pipeline has to be fused together in one full length. The most likely way that the pipeline would be installed into the tunnel is as follows: The pipeline would be fused into one long section of HDPE, filled with air, floated out, and then submerged onto the bottom in-line with the drilled hole. The HDPE pipeline is then pulled back through the HDD tunnel until it pops out on the shore end.

Examples of a drill rig, reaming device, and other heavy equipment used in HDD are shown in Figure 3-1.
Use of HDD technology will require an onshore area of at least 150’ by 100’ and a source of freshwater for mixing the drill mud. In addition to the drilling rig, this space is used to house a drilling fluid cleaning and recirculation unit, drill pipe trailer, water truck, hoses, pumps, driller’s van, excavator and vacuum pump truck. An aerial view of a site performing HDD, illustrating the space requirements, is shown in Figure 3-2.

Ideally, the tunnel would breakout as deep as is possible – as close to the required intake and discharge depths as possible. The breakout depth for tunneling will be deeper than for a trenched pipeline as there is only a small additional cost to extend the tunnel to a deeper depth, and the added depth will provide the advantages of smaller hydrodynamic loads and thus reduced anchoring requirements.
3.3. HDD ENVIRONMENTAL CONCERNS

Drilling fluid (bentonite) handling and disposal are important considerations in an HDD operation.

1. When the pilot hole is drilled, bentonite will be pumped to the drill head until the drill head is about 30’ or more away from breaking out on the seabed. Then the contractor will suck out all the bentonite from the tunnel and fill the hole with fresh water so that no drill mud escapes into the ocean after the drill breaks out on the seabed.

2. There have been documented cases of the pressurized bentonite leaking out of the drilled bore through cracks and fissures in the ground while the bore is in progress. This very fine clay is known to be harmful to some marine organisms. A method that HDD contractors use to mitigate this risk is to drill the tunnel deeper than the breakout depth, and then angle the tunnel upwards when they approach the breakout. This reduces the risk of bentonite escaping through cracks in the seafloor. Some form of special plug has to be fitted over the end of the bored hole at the offshore end of the tunnel to avoid bentonite escaping into the ocean.

3. An HDD contractor has suggested to Makai that a reasonable method for containing the bentonite is to dig a large pit (for example 30’ x 20’ x 6’ deep) on the seafloor just down the slope from the offshore end of the tunnel mouth. The bentonite is denser than seawater, and it wants to sink, so when bentonite exits the hole, it will want to flow down the slope and collect in the excavated pit. Divers will use a suction hose to suck the bentonite into tanks on the barge for disposal. An alternative to a simple excavated pit is to construct a steel walled cofferdam in the same location to collect the bentonite.

4. To perform HDD, a land area of roughly 100’ x 150’ is needed during construction.

5. An HDD contractor has suggested that during HDD operations an offshore barge would be required to provide tension for the HDD tunnel reaming process. This barge will be moored using a 4 point anchor spread.

3.4. BOTTOM-ANCHORED PIPE

The bottom-mounted segments of pipe located offshore from the breakout location of the tunnelled pipe will be installed using a controlled submergence method. This involves ballasting a section of air-filled pipeline with concrete anchors clamped around the pipe at set intervals (see Section 2.4). For longer sections of pipe, the pipe is towed into position, anchored on the shoreward end, and is slowly flooded with water as it is tensioned in the offshore direction. The proposed alignments for the DWD concept routes are mostly tunnelled pipes with limited exposure to the seafloor. The limited lengths of pipe that will be installed on the seafloor will use a simpler submergence process, such that the entire pipe sections would be sunk into place at the same rate with no anchoring or large offshore pulls required.

As described in Section 2.4, the wave loading for this location exceeds the friction capacity of the concrete gravity anchors that can be mounted on the pipe. The pipe design will require installation of post-deployment anchoring as described in Section 2.4.1.

During a controlled submergence deployment, mitered HDPE bends cannot be used; a fabricated mitered bend cannot take the deployment loads. The offshore bend in the discharge pipe segment
would need to be a gradual bend in the pipe itself, and it would be installed with the help of restraint bridles. A set of bridles will be designed to hold the pipe in a safe bend radius and distribute the loads associated with bending over a long section of pipe. Bridles extend back to a common point which is attached to a preset anchor line offset from the pipe. This preset anchor is designed to hold the deployment loads without slipping. The anchor and bridles can be removed after the pipe is in place on the seafloor. The deployment process is likely to require two tug boats, and two to three tenders. A dive team of at least four commercial divers operating form a devoted dive vessel will be required to install the post-deployment anchoring. Once staged and towed on-site, the controlled submergence deployment process could occur within 12 to 24 hours. The length of time required to install the additional post-deployment anchoring would require several days to weeks, depending on the dive crew mobilized to complete the work.

A calm water staging area would have to be available to the marine contractor. This is where the intake pipe and discharge pipe would be fully assembled each into one continuous length. Each pipe would be fused into one long segment. This site would be used for both the pipes that pulled into the HDD bored tunnels and for the exposed pipes on the seafloor. For the latter, concrete gravity anchors would be installed on the air filled floating pipes. Makai has seen harbors, lagoons and rivers used as quiet water staging sites.
4. CONCLUSIONS

Makai has conducted a preliminary feasibility study of two routes for the seawater intake and discharge pipelines for planned Deepwater Desalination system development at Moss Landing, Monterey Bay, California. The investigation included a summary of the general methods for shoreline crossing and offshore installation of HDPE pipe, collection of detailed environmental site data, and preliminary assessment of the constructability of the two route concepts. This is a summary report on our analysis.

Makai’s major findings include the following:

- It is proposed that all pipes be installed across the shoreline interface to the maximum depth possible by HDD tunneling to provide a very direct and practical installation method that minimizes contractor exposure to offshore sea conditions.

- The recommendation to use HDD tunneling as an installation method is based on the following:
  - Laying exposed pipe on the seafloor of the harbor is not feasible. The harbor is too shallow for the height of the HDPE pipe in concrete collar weights.
  - Trenching in the surf zone is technically feasible, but will be difficult to accomplish given the known sea state conditions at the site. Environmental permits for a trenched shore crossing will be more difficult to obtain than for an HDD tunneled crossing.
  - HDD is likely to be more cost effective than micro-tunneling. HDD does not require multiple vertical shafts to acts as drive shafts and receiving pits.

- For an exposed HDPE pipe on the seafloor, based on the dimension, thickness, rigidity, and positioning of the pipe with respect to wave currents, the wave loading could exceed the holding power of the maximum deployable ballast weights. For the pipe dimensions and type modeled, this is most likely to occur. Smaller diameter pipes of varying material, if laid on the seafloor, may lessen this risk. However, in virtually all situations and in particular along this area of the bay, additional post-deployment anchors would be needed to stabilize the pipe against expected large, long period swell events. Wave loading on the pipe and anchoring requirements are sensitive to the pipe alignment, and the final anchoring requirements will need to be analyzed in detail once a final path is selected. The primary effect of additional anchoring is not technical risk but additional installation costs and long term maintenance costs.