ENGINEERING CONCEPTS AND PRELIMINARY COSTS FOR OCEAN WATER INTAKE AND OUTFALL INFRASTRUCTURE TO FACILITATE ECONOMIC DEVELOPMENT ACTIVITIES ON FORMER GEORGIA PACIFIC MILL SITE

FINAL REPORT

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EXECUTIVE SUMMARY

The City of Fort Bragg (City or Fort Bragg) is assessing opportunities to drive regional economic development using ocean water. This report provides a screening evaluation of ocean water withdrawal (intake) and treated wastewater return (discharge) options, along with preliminary costs.

This project has many technical challenges, but the benefits of successful implementation would be significant. Determining the type and location of the intake is non-trivial, and needs to be identified with regulatory/agency input and environmental data. Regulatory input will help determine the type of project that may be permitted once it is designed. Water quality, water depth, ambient water current directions and speed, geotechnical conditions, benthic and habitat data, etc. will help determine the location of the project that will provide water with requisite quality. Various studies would be needed as the project achieves greater definition to overcome uncertainties and project risks.This report provides recommendations for such studies.

Key regulatory criteria and permits are discussed in Section 3. The anticipated intake and discharge have many constraints and challenges, such as location, topography, geotechnical conditions, and water depth. These are discussed in Section 4.

Intakes for seawater desalintation plants in California need to first demonstrate that a subsurface intake would be infeasible before considering a surface water intake. It is unlikely that this requirement would apply to the City’s intake since it will not be serving a seawater desalination plant. Regardless, typical subsurface intake types are discussed in Section 5, potential additional studies to assess the feasibility of subsurface intakes are discussed in Section 8, and an order of magnitude cost of a subsurface intake is presented in Section 10.1.

There are two types of surface water intakes – those with traveling water screens and those with passive wedgewire screens. Intakes with traveling water screens need to be onshore or nearshore. As discussed in Section 6.3, a shoreline intake with neither wedgewire screens nor traveling water screens would be feasible. Three different locations for wedgewire screens are also discussed in Section 6. Each location poses different challenges and risks. Section 7 discusses key risks and potential mitigation measures and Section 8 discusses studies that may be undertaken at different phases of planning to assess the feasibility of the project. Section 9 presents a relative schedule for implementing a surface water intake. Sections 10.2 and 10.3 provide cost estimates for two surface water intakes – one with the intake pipe drilled through the bluffs and one with the intake pipe installed on the bluffs.

Based on information presently available, the Association for the Advancement of Cost Engineering (AACE) Class 5 estimate for a surface water intake could be bewteen $19 and 43 million, and for a subsurface water intake over $70 million.

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ABBREVIATIONS

AACE	Association for the Advancement of Cost Engineering
CA	California
CESA	CA Endangered Species Act
CEQA	CA Environmental Quality Act
CDP	Coastal Development Permit
CCI	Construction Cost Index
cf	cubic feet
DO	dissolved oxygen
ENR	Engineering News Records
EIR	Environmental Impact Report
ft	feet
fps	feet per second
HDD	horizontal directionally drilled
in	inch
MTJ	Mendocino Triple Junction
m	meter
MGD	million gallons per day
mm	millimeter
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
OTC	Once-Through Cooling
O&M	Operation and Maintenance
OP	The California Ocean Plan
Project	The City ocean water intake and discharge project
City or Fort Bragg	The City of Fort Bragg
TWS	traveling water screens
WWFT	Wastewater Treatment Facility
WWS	wedgewire screens

1. PROJECT NEED

The City of Fort Bragg (City or Fort Bragg) is assessing opportunities within the "Blue Economy" to drive the regional economy - improving livelihoods and wages – primarily by revitalizing the City's economy and employment base while also nurturing healthy marine ecosystems. To support the Blue Economy objectives, the City is evaluating solutions to withdraw ocean water (intake) and return treated wastewater back to the ocean (discharge) for the following uses:

- The Blue Economy Innovation Center for small, land-based aquaculture facilities and blue technology businesses.
- The Noyo Marine Science Center future Noyo Headlands facility (aquariums, research, etc.).

At this time, the water intake is expected to have a capacity of approximately 1 million gallons per day (MGD).

2. PROJECT CRITERIA

The City ocean water intake and discharge project (“Project”) has many needs; some of the needs are competing. This section groups these project needs as either required or preferred criteria. Required project criteria must be met; preferred project criteria may be met if possible.

2.1 REQUIRED PROJECT CRITERIA

Required project criteria include the following.

- Water quality appropriate for land-base aquaculture facilities, blue technology businesses, marine research and aquaria. Ocean water withdrawn via the new intake would be used to support marine life; therefore, water quality must be compatible with marine life. The water needs to be devoid of toxin, viruses, etc. or be treatable/treated to remove such pollutants.

- Meet regulatory requirements. The California Ocean Plan (OP) does not include requirements specific to ocean water intakes that would support Blue Economy activities, but has requirements for intakes associated with seawater desalination plants. Some of these requirements may be applicable at the Fort Bragg intake. The OP has specific requirements for ocean discharges. A summary of the OP is provided in Section 3.

- Availability of adequate quantities of ocean water. The water source(s) need to provide sufficient quantities of water based on long-term (daily or monthly scales) even if not at the instantaneous scale. Fluctuations in water availability may be addressed by having sufficient water storage onshore. The larger the storage, the higher the costs.

- The system needs to be constructibile. The design needs to accommodate geotechnical constraints, avoid damaging the bluffs during construction and operations, and be constructible with available construction methods.

- Intake technology needs to be presently available and avoid a first-in-class installation that would add to the risk of the Project.

- Ability to modify the design as-needed to accommodate funding requirements. This Project will be funded by public grants; likely a combination of grants. Each grant has its constraints and requirements. A project design that is malleable to the grant requirements may be funded more easily.

- Minimum impact to surrounding resources such as freshwater aquifers, ocean, and wetlands. The project needs to be constructed and operated with minimal impact on surroundings resources. The intake should not draw freshwater – freshwater is already scarce, and it would not support marine life or the other Blue Economy activities planned. The project needs to use marine/ocean water without causing irreversible adverse impacts to the ocean floor, water, organisms, or habitat. In addition, the project needs to preserve the existing wetlands, an invaluable resource, which act as a buffer between some parts of the Noyo Headlands Park and the City.

- Ability to locate the onshore portion of infrastructure on City-owned property. If the onshore infrastructure cannot be located within City-owned property, it is likely that the intake and discharge to support Blue Economy activities could not be constructed at all. Alternate lands and locations are not available elsewhere along the Noyo Headlands Park and acquisition of additional real estate would be costly and potentially infeasible.

2.2 PREFERRED PROJECT CRITERIA

- Consistent water quality. Dependent on the Blue Economy end use activities (i.e., organisms being cultured) the raw water may need to be treated prior to use. The design of the treatment system can be streamlined when the raw water has consistent quality. If the raw water quality fluctuates significantly, then the treatment system needs to be designed and built at greater cost to treat a broader range of pollutants and constituents.

- Reliable water quantities. The system would have raw water storage to accommodate fluctuations in user needs. If the supply is less reliable, then the raw water storage needs to be larger to accommodate both demand- and supply-side fluctuations.

- Low cost. This system would be funded by public grants; likely a combination of grants. A lower cost system that meets the above needs would be preferable.

3. THE CALIFORNIA OCEAN PLAN AND PERMITTING APPROACH

While the Project would need many permits and approvals, requirements within the OP are likely to be the key driver for many of the design criteria. This section provides a summary of the OP and the general approach for permitting the Project.

3.1 BACKGROUND

The OP is one of five California-wide water quality control plans established by the State Water Resources Control Board to preserve and enhance California's territorial ocean waters for the use and enjoyment of the public. This is achieved by controlling the discharge of wastes (such as stormwater, treated sewage effluent, and other industrial discharges) into the ocean and seawater intakes (such as for power plant cooling and desalination plants). The OP was adopted by the State Water Board on July 6, 1972, and has been amended five times since it was last reviewed in 2011. The amendments more relevant to the Project are the 2012 State Water Quality Protection Areas and Marine Protected Areas Amendment, which established new criteria for designating State Water Quality Protection Areas, and the 2019 Bacteria Amendment, which revised statewide bacteria water quality objectives and implementation options to protect recreational users from the effects of pathogens (bacteria). Some elements of the 2015 Desalination Amendment, which instituted requirements to protect ocean waters during the construction and operation of seawater desalination facilities may also be relevant to the Project.

3.2 PERMITTING APPROACH

The Project will require the construction of a new ocean water intake and a connection to the existing wastewater treatment facility discharge. The intake would be located within coastal state waters and would draw water from the Pacific Ocean. The discharge would be pre-mixed with treated wastewater effluent and would be discharged to the Pacific Ocean through existing infrastructure. The City's Project would therefore require permits and approvals from the relevant federal, state, and local agencies with jurisdiction over the construction and operation of such facilities in California.

Explicit regulations exist for ocean intake and discharge structures associated with once-through cooled power plants and seawater desalination plants. Those requirements do not strictly apply to the intake and discharge flows or structures proposed for the Blue Economy activites. However, it is possible that the requirements for the City may be informed by those requirements applicable to power and desalination plants.

California's Once-Through Cooling (OTC) Policy and the CA OP (and its associated amendments such as the Desalination Amendment) were reviewed for applicability to this Project. Each of these includes standards and requirements for the design and operation of intake and discharge structures. Beyond these state-level requirements, various federal and local permits/approvals would also be required. Table 3-1 lists the suite of permits and approvals that would likely be required for constructing and operating an intake and discharge for the City's Project. Note that coordination among the agencies is typical, but can also result in long durations for securing all required permits/approvals. All consultations with regulatory agencies should be streamlined by a clear communication plan such that all potential delays can be minimized. To the extent practicable, agencies should be engaged concurrently as sequential engagement could cause delays.

Per the CA OP, the State Water Resources Control Board may also grant exceptions to the CA OP requirements in cases where it "*will not compromise protection of ocean waters for beneficial uses*" and where "*the public interest will be served*". Of the exceptions that have been granted to date, a number of them (listed below) are for marine research and aquarium-related facilities which would be similar to the proposed uses for the Blue Economy activities. The City will explore the applicability of an exception for this Project.

- US Navy San Nicholas Island
- US Scripps Institution of Oceanography
- USC Wrigley Marine Science Center
- UC Davis Bodega Marine Laboratory
- HSU Telonicher Marine lab
- Monterey Bay Aquarium
- Stanford Hopkins Marine Station
- Hubbs Sea World Research Institute

The City expects that many of the regulatory standards developed for these industries will be applicable to some degree; however, the specific nature of the above projects are different from those proposed as part of the Blue Economy Project.

Table 3-1. Potential Permits and Approvals Required for the Proposed Blue Economy Innovation Center.

Agency/Regulator	Permit/Approval Required	Reason
Federal		
National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service (NMFS)	Consultation	To assure consistency with the Endangered Species Act and Marine Mammal Protection Act. To assess potential impacts to federally-list (threatened and endangered) marine life
U.S. Fish and Wildlife Service	Consultation	To assure consistency with the Endangered Species Act and assess potential impacts to federally-list (threatened and endangered) marine life
U.S. Army Corps of Engineers	Section 404 of the Clean Water Act	Required for the placement of fill in navigable waters of the U.S.
State		
State Water Resources Control Board	Consultation	To assure consistency with the CA OP; State Board also coordinates with the Regional Water Quality Control Board and other state agencies
Regional Water Quality Control Board (North Coast)	National Pollutant Discharge Elimination System (NPDES) permit	Required for point source discharge of effluent to waters of the U.S.; would have to be coordinated with the Fort Bragg Wastewater Treatment Facility (WWTF)

Agency/Regulator	Permit/Approval Required	Reason
	Water Quality Certification (Section 401 of the Clean Water Act)	Required in order for U.S. Army Corps of Engineers to act on a Section 404 permit
CA State Lands Commission	Submerged Land Lease	Required for lease of submerged lands where the intake structure would be constructed
CA Coastal Commission	Coastal Development Permit (CDP) and consultation regarding Coastal Zone Management Act (CZMA)	Required per the CA Coastal Act for all facilities being constructed in the coastal zone
CA Department of Fish and Wildlife	Consultation	To assure consistency with the CA Endangered Species Act (CESA)
State Historic Preservation Office (CA Department of Parks and Recreation)	Consultation	To assess potential impacts to historic land/artifacts
First Nations/Tribes	Consultation	To assess potential impacts to historic tribal land/artifacts
Local		
Lead Agency - *TBD*	CA Environmental Quality Act (CEQA)	Required for certification of Environmental Impact Report (EIR) which assess all potential impacts of the proposed project and project alternatives
City of Fort Bragg Public Works Department	Consultation	To assure new infrastructure will not conflict with existing public facilities
City of Fort Bragg Planning Commission	Consultation	To review land use and development permits (use permits, coastal development permits, design review permits, subdivisions, etc.) for consistency with the goals and policies of the Fort Bragg General Plan, and the development standards of the Fort Bragg Municipal Code
City of Fort Bragg WWTF	Consultation	To reach agreement regarding the connection of the Blue Economy Innovation Center discharge to the existing WWTF discharge (NPDES NO. CA0023078)

4. PRELIMINARY PROJECT CONSTRAINTS

This section discusses construction and operations period constraints that need to be incorporated into the design.

4.1 EXISTING WASTEWWATER TREATMENT FACILITY

The existing City of Fort Bragg Wastewater Treatment Facility (WWTF) is located along the shoreline on the western part of the Noyo Headlands Park, which sits approximately 50 feet above sea level immediately inland of bluffs that demarcate the Fort Bragg coastline. The WWTF provides sanitary sewage treatment with aeration, clarification and disinfection. The WWTF was originally constructed in 1970 and has undergone multiple expansions and upgrades (HDR 2016). The space to the north of the WWTF site is ear-marked for potential expansion of the facility and space used for the now-demolished treatment units is available for repurposing (including the former trickling filters). Figure 4-1 shows the WWTF fenceline and the green circles show the former trickling filters which are now filled in with rock.

The WWTF is the only real-estate that the City presently owns within the Noyo Headlands Park and acquisition of additional real-estate would be costly and potentially infeasible. Therefore the onshore portion of the intake and discharge system needs to be located within the existing WWTF property.

Source: Google Earth 2018[1].

Figure 4-1. Extent of the City of Fort Bragg Wastewater Treatment Facility Before Recent Upgrades.

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[1] This image does not show the latest treatment units. Newer images show parts of latest treatment units but clouds and fog obscure view of the site.

4.2 EXISTING WWTF OUTFALL

The original WWTF discharged through a 30-inch outfall that emptied nearshore into shallow water. In order to meet CA OP requirements, the City evaluated the performance and biological community near the outfall in 1973 and extended it by approximately 650 ft offshore in 1977 (Underwater Resources 2020). The existing WWTF is designed for peak daily wet weather flow of 4.9 MGD (California Water Boards, 2019), therefore the capacity of the outfall is expected to exceed 4.9 MGD. The existing outfall consists of a 14-port linear diffuser spanning approximatley 100-130 ft in 25-30 ft deep water.

At a later date, duckbill-type TideFlex check valves were installed on each of the diffuser ports (Figure 4-2). The valves begin to open when the pressure inside the discharge pipe reaches a pre-determined pressure and open wider as the pressure increases. The valves close when the pressure in the pipe falls below the pre-determined threshold. This mechanism prevents ambient water from entering the system.

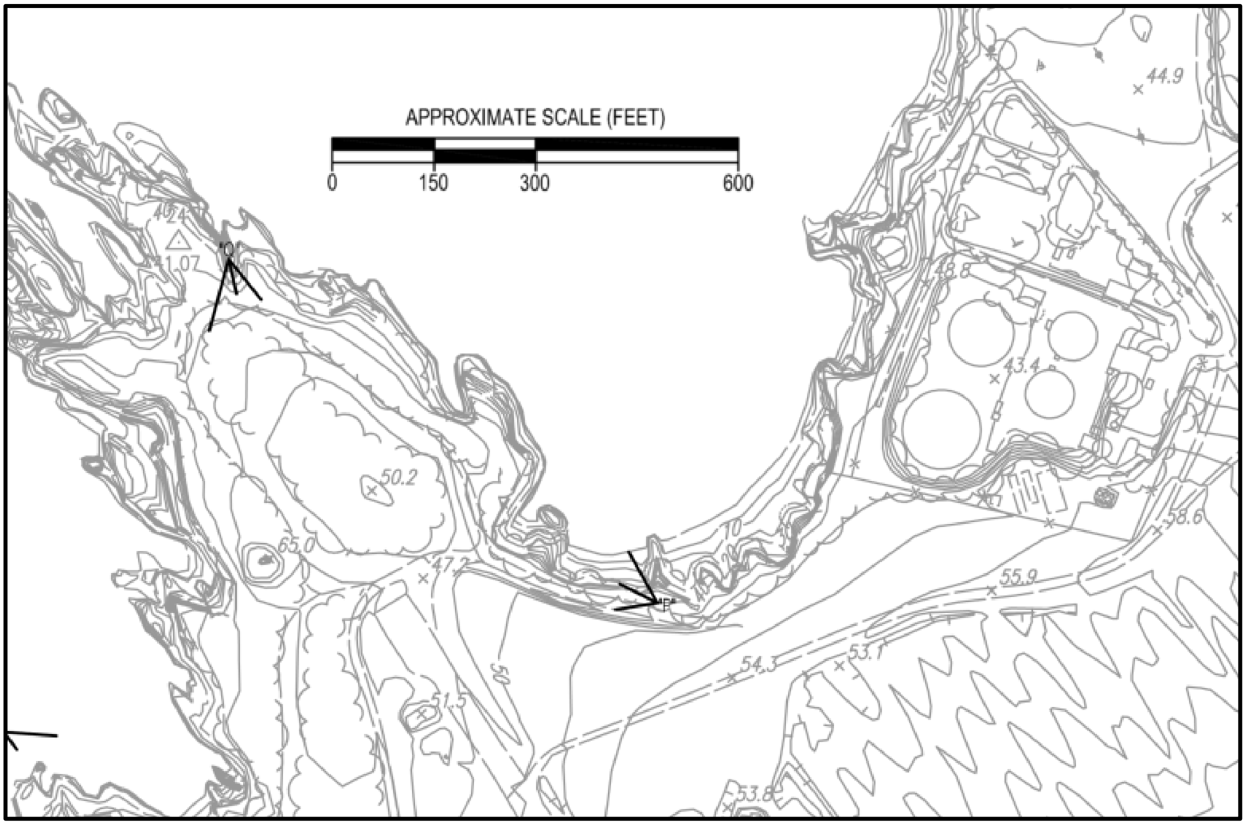
Source: Underwater Resources 2020

Figure 4-2. A Diffuser Port with TideFlex Check Valve.

4.3 TOPOGRAPHY

The 50-ft drop from the edge of the WWTF to water is shown in the 1-ft interval topographical map of and around the WWTF (Figure 4-3). The bluffs have an average slope of approximatley one-quarter horizontal to one vertical with local areas that are near vertical (BACE Geotechnical 2004).

This topography and the weathered rock pose key challenges to construction.



Source: BACE Geotechnical 2004, Plate 3

Figure 4-3. Topography Surrounding the City of Fort Bragg Wastewater Treatment Facility.

Routing (i.e., drilling) the intake pipe through the rock would be challenging and potentially disruptive to the bluffs, as the vibration from drilling could cause weathered rock to move and crumble. Crumbling rock would pose a major safety issue to construction workers and potentially damage and disrupt operations at the WWTF.

Routing the intake pipe along the bluffs would also be challenging. The intake pipe would need to be tethered to the outer face of rock. Installing anchors to hold the pipe in place would pose some of the same challenges faced with drilling the pipe through rock. The pipe would need to be installed from the bottom to the top of the WWTF site. During the operations period, the entire pipe would be exposed to the sun, wind and rain; the lower sections of pipe would be exposed to waves as well. The pipe would need to be secure enough to withstand these forces, but also be designed to break in a planned/controlled manner when stressed beyond a certain threshold.

4.4 BLUFFS

The bluffs are the primary topographical feature of the Noyo Headlands Park. Weathered rock extends from the seabed to the top of the bluffs. The integrity of rock at each location is unknown. Owing to shallow rock at the WWTF, the former trickling filters at the WWTF were approximatley 4 feet deep (typically approximately 8-10 feet deep) and were aboveground. The hardness of the rock would challenge excavation, yet the weathered nature could cause rock to crumble, disallowing tunneling and drilling.

BACE Geotechnical (2004) noted erosion of bluffs, with most of the upper bluff errosion stemming from runoff from the hard surfaces. Using aerial photographs spanning 25 years, BACE Geotechnical (2004) estimated that hard rock areas of the bluffs to be retreating at an average rate of approximately 1.5 to 2 inches per year, and bluffs containing large fill deposits to be eroding at an average rate of approximately 2.5 to 3 inches per year. BACE Geotechnical (2004) also recommended diverting draininage away from near-vertical bluff areas to reduce the erosion rate.

HDR (2016) describes soil liquefaction as a phenomenon in which saturated (submerged), cohesionless soil experiences a temporary loss of strength due to buildup of excess pore water pressure during cyclic loading induced by an earthquake. Soils most susceptible to liquefaction are loose, clean, saturated, poorly graded sand and non- to low-plasticity silt and silty sand. HDR (2016) noted that hazards such as slope instability, lurching or fault rupture were unlikely where the WWTF upgrades were planned. The HDR (2016) study did not specifically study the bluffs immediately west of the chlorine contact tank.

4.5 GEOTECHNICAL CONDITIONS

Several geotechnocal studies have been performed over the last several decades to support the various expansions and upgrades of the WWTF. These include the four borings drilled to depths of 21.3 ft, 15.7 ft, 15 ft and 15 ft by Clear Heart Drilling to support the HDR (2016) investigation; two borings drilled to depths of 14.9 ft and 24.1 ft by Kleinfelder (2001); and the three test borings drilled to depths of 16.5 ft, 12 ft and 8.5 ft by Harding, Lawson and Associates in 1987. A summary of the findings from these three studies is provided in Figure 4-4.

These prior studies found that fill extends to depths of about 8 to 9.5 ft and consists of loose to medium dense silty sand with varying amounts of gravel, and that loose poorly-graded sand with silt lie under the fill (HDR 2016). Borings suggest that the depth to bedrock generally increases to the north and west. Bedrock encountered consisted of slightly weathered to decomposed, weak to moderately strong sandstone and shale.

Owing to proximity of existing WWTF structures, blasting should be avoided during construction.

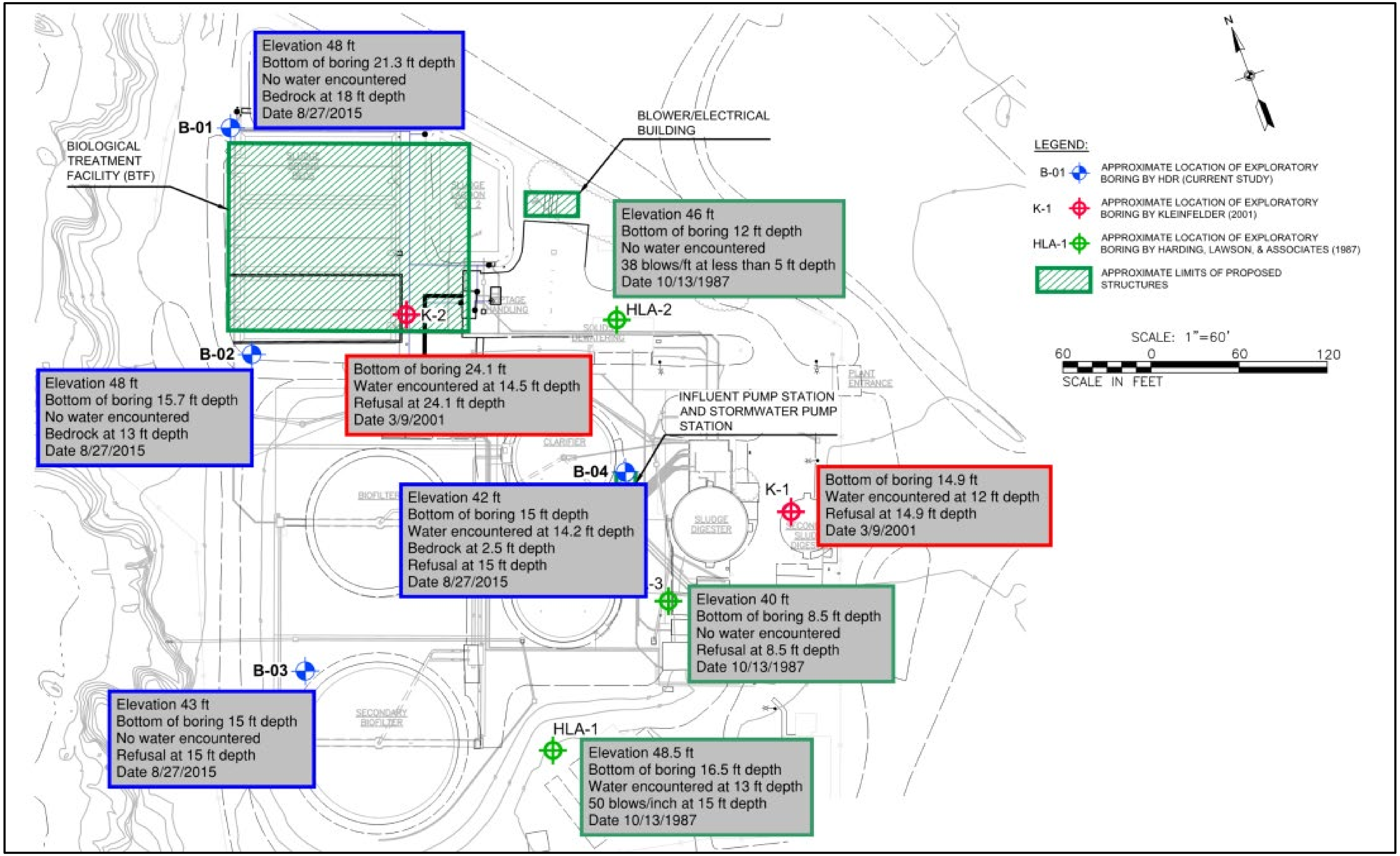
Owing to spatial constraints and to reduce the amount of excavation, the contractor may need to install temporary shoring during excavations. Areas with shallow bedrock and areas with rock outcroppings would challenge driving sheetpile or drilling through rock.

Figure 4-5 is a geologic map of the existing pipeline location and the seabed material that would be encountered during construction.

4.6 DEPTH TO GROUNDWATER

Depth to groundwater changes with season and year, thererfore whether groundwater is encountered or not during discrete days of drilling does not indicate long-term trends. The depth to groundwater under general conditions impacts the design. If groundwater is shallow during excavation and construction, then the work needs to plan for constant dewatering and disposal. If groundwater is expected to be shallow under all conditions, then the structures need to be sufficiently heavy to overcome the bouyancy and be designed and constructed to resist lateral hydrostatic pressures.

The design, permitting and construction would need to anticipate construction dewatering.



Source: Adapted from HDR 2016

Figure 4-4. Summary of Geotechnical Borings at the City of Fort Bragg Wastewater Treatment Facility.

4.7 OCEAN WATER DEPTH

The intake must be located in sufficienty deep water to facilitate proper operation of the intake and to reduce navigation risks, but not too deep as to pose construction and maintenance challenges. Figure 4-6 provides bathymetric information around the existing pipeline from 1977. While the bathymetic information may have changed, the figure still provides a general sense of water depth.

Even though the specific location of the intake is presently unknown, it is likely that the intake would extend beyond the existing outfall into waters with depths greater than 35 feet.

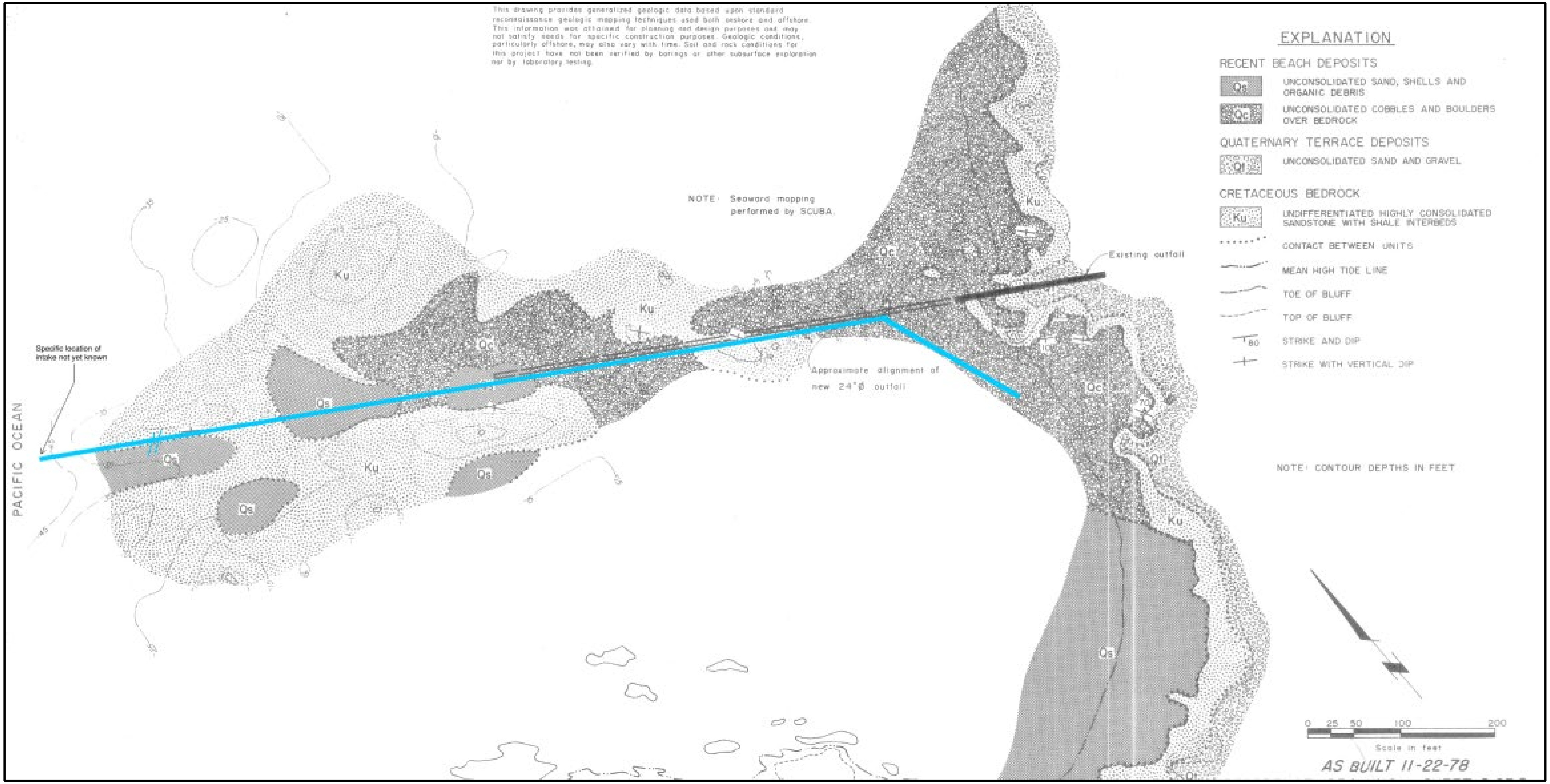
4.8 NAVIGATION

There is commercial and recreational boating in the general vicinity of the outfall and proposed intake. As such, appropriate signage would need to demarcate the locations to protect infrastructure.

4.9 SEISMIC ACTIVITY

Coastal areas along California experience seismic activity that damages natural and built structures. The seismically active Mendocino Triple Junction (MTJ) occurs about 70 miles northwest of Fort Bragg (HDR 2016). MTJ is where the Pacific, North American and Gorda plates meet, and includes the northern-most terminus of the San Andreas fault, the Mendocino Fault, and the Cascadia Subduction Zone.

The design needs to be informed by potential seismic activity and accommodate the additional challenges and forces it presents. The system needs to be constructed to withstand certain forces, but be designed to fail in a controllable/systematic form when those forces exceed a pre-determined thresold.



This drawing provides generalized geologic data based upon standard reconnaissance geologic mapping techniques used both onshore and offshore. This information was attained for planning and design purposes and may not satisfy needs for specific construction purposes. Geologic conditions, particularly offshore, may also vary with time. Soil and rock conditions for this project have not been verified by borings or other subsurface exploration nor by laboratory testing.

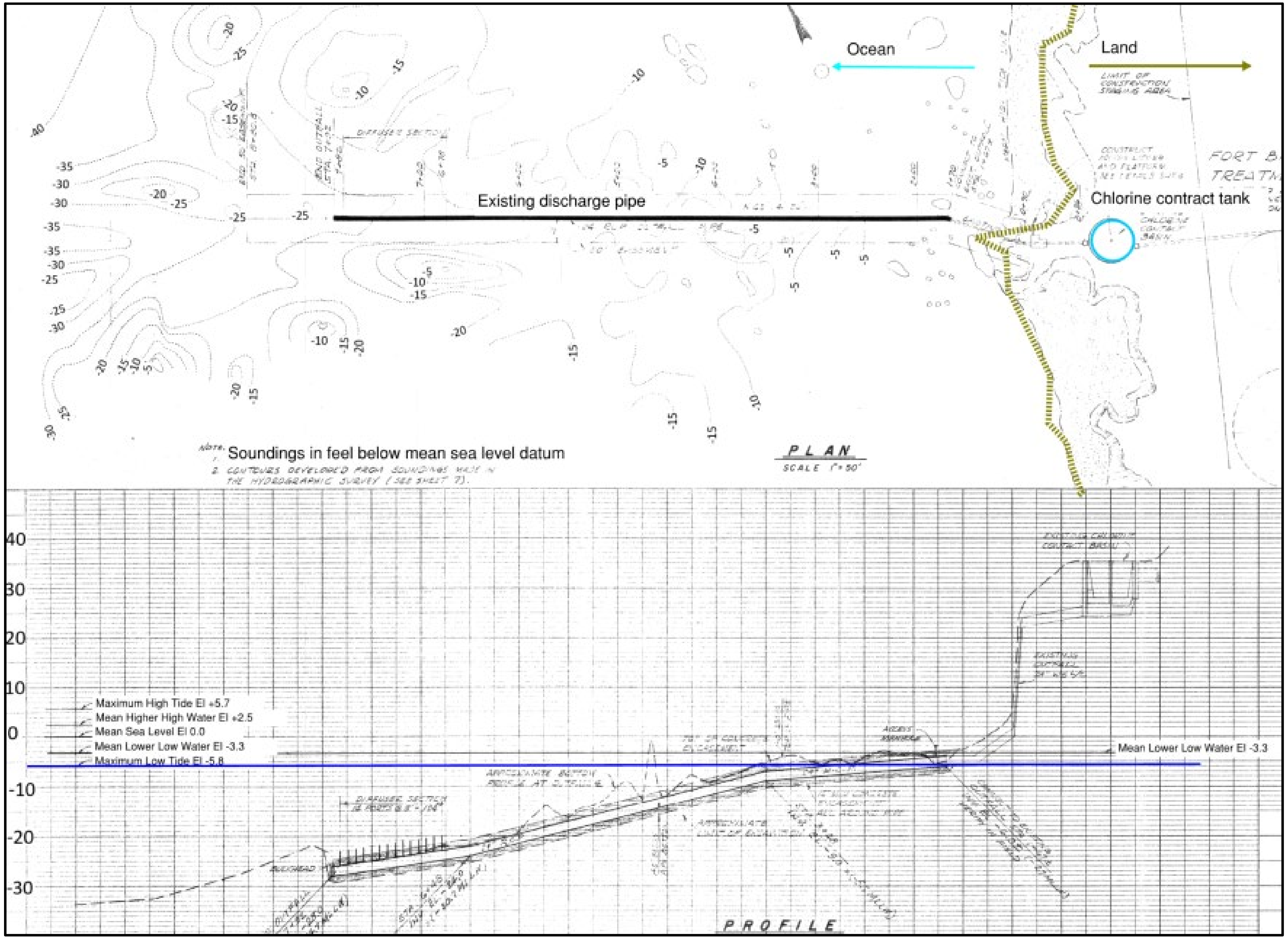
NOTE: Seaward mapping performed by SCUBA.

NOTE: CONTOUR DEPTHS IN FEET

AS BUILT 11-22-78

Source: HLA 1978

Figure 4-5. Geologic Map of Pipeline Locations.



Source: HLA 1978

Figure 4-6. Bathymetric Map of Existing Pipeline Location.

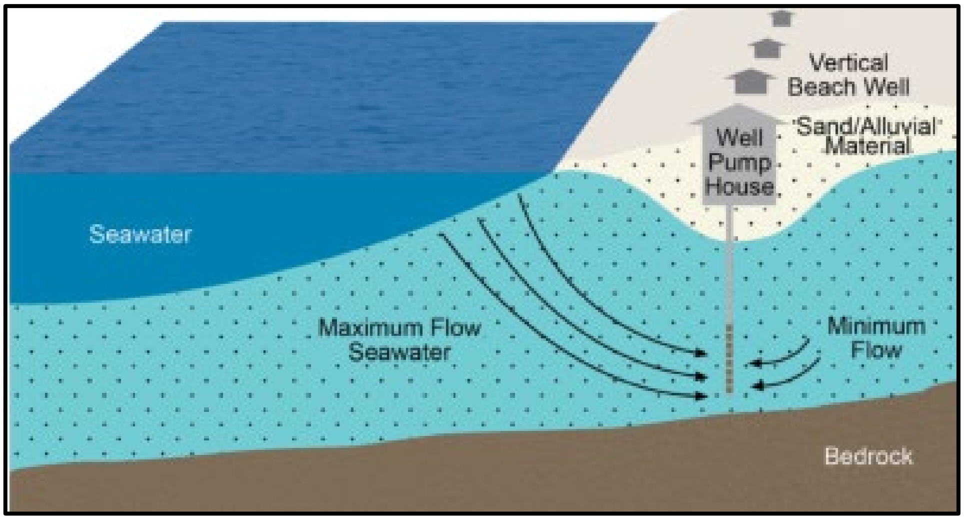
5. SUBSURFACE INTAKE

The Desalination Amendment to the CA OP requires desalination plants to first assess the feasibility of subsurface intakes and consider surface water intakes only if subsurface intakes are determined to be infeasible. The proposed intake would not serve a desalination plant and therefore the requirement to assess subsurface intakes is unlikely to apply here. Nevertheless, this section provides an overview of the different types of subsurface intakes and their relative advantages. Much of the information summarized below is from intake research and studies conducted in support of desalination plants. No known studies of subsurface intakes have been conducted in support of aquaria, marine research, aquaculture facilities, or Blue Economy development projects.

Review of literature suggests that subsurface intakes would be costlier than surface water intakes. Given that this Project would be funded with public grants, a high-cost intake may be looked upon less favorably.

5.1 VERTICAL BEACH WELL

A vertical beach well consists of a well drilled vertically down near the seashore. These wells can draw a mix of seawater and freshwater (Boerlage et al. 2017). The pumphouse and the well would be onshore, therefore maintenance would be reasonably easy (Figure 5-1). Because these wells can draw freshwater as well, there could be a potential impact to freshwater resources and other onshore resources such as wetlands. Salinity levels can fluctuate over the course of the year. As with any groundwater source, this water could have low levels of dissolved oxygen (DO). If a single well is used then the well may need to be drilled deeper to yield sufficient quantities of water. Alternatively, a well field consisting of several shallow vertical wells may be developed.

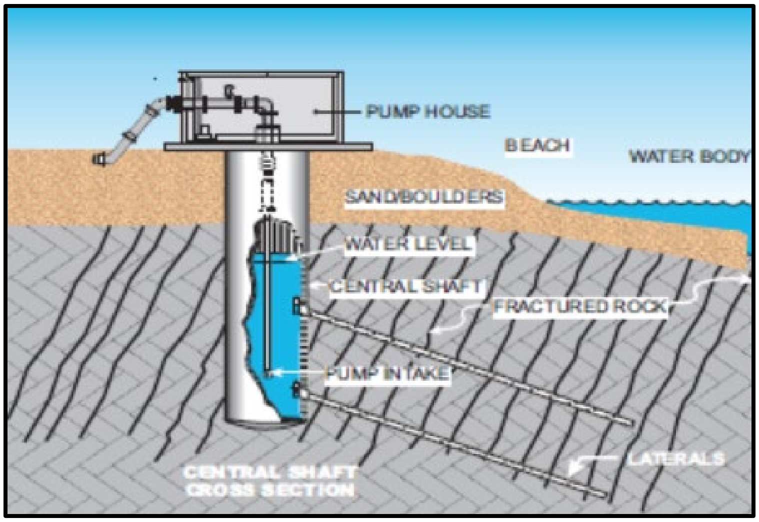


Source: Boerlage *et al*. 2017

Figure 5-1. Schematic of a Vertical Well.

5.2 RANNEY WELL

Ranney wells consist of a vertical shaft installed onshore with multiple lateral wells drilled horizontally out from the shaft (Boerlage et al. 2017). The direction and locations of the laterals induce a preferential flow direction (Figure 5-2). The pumphouse and well would be onshore; the laterals have the capability to draw water from farther away. Because multiple laterals can draw from a larger area, this system may be reasonably shallow.

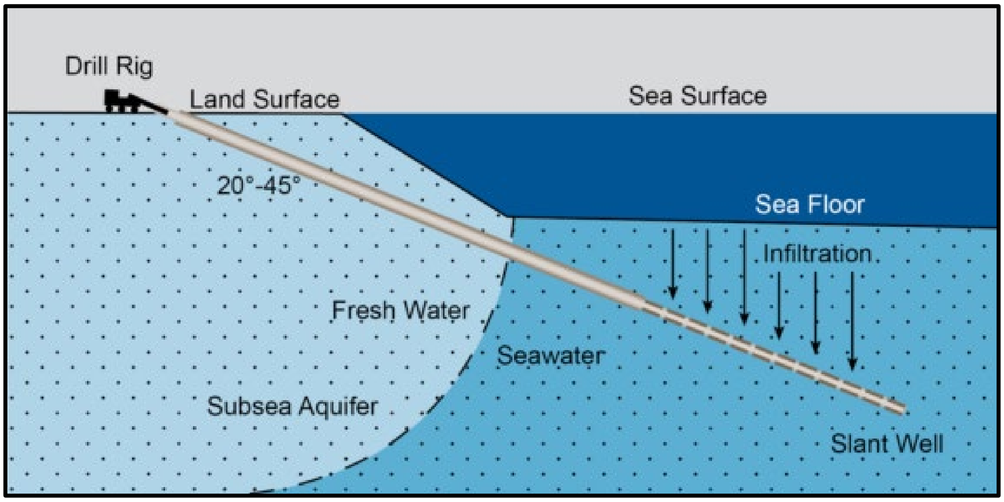


Source: Boerlage *et al*. 2017

Figure 5-2. Schematic of a Ranney Well.

5.3 SLANT WELL

Slant wells are similar to a vertical well in that they consist of a single pipe, but unlike a vertical well, the slant well is drilled at an angle (California American Water 2019). The system could include multiple slant wells. The perforations along the pipe can preferentially draw from predetermined locations. The pumphouse for these systems would be onshore with the wellfield located offshore and under the seabed (Figure 5-3).

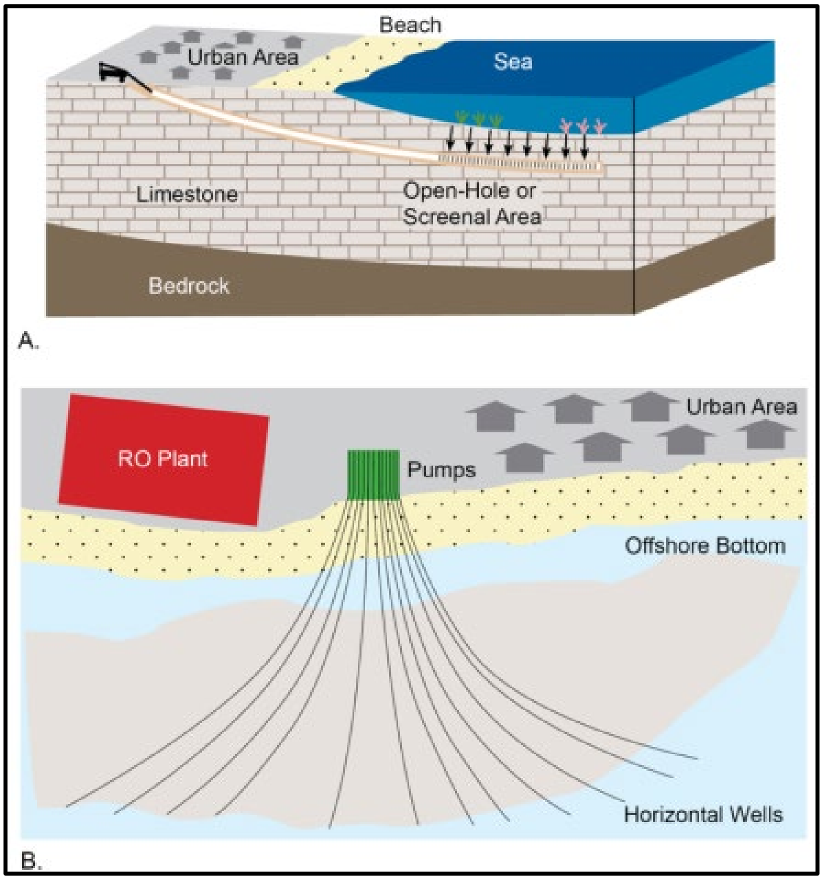


Source: California American Water 2019

Figure 5-3. Schematic of a Slant Well.

5.4 HORIZONTAL WELL

Horizontal well technology (aka horizontal directionally drilled or HDD) was developed primarily for and by the oil and gas industry to facilitate horizontal fracturing and gas retrieval. Horizontal wells consist of a single well that starts out vertical and then turns horizontal and runs parallel to the sea floor (Boerlage et al. 2017). The system could consist of multiple horizontal wells. Here too, the pumphouse would be onshore with the perforated section lying under the seabed (Figure 5-4).



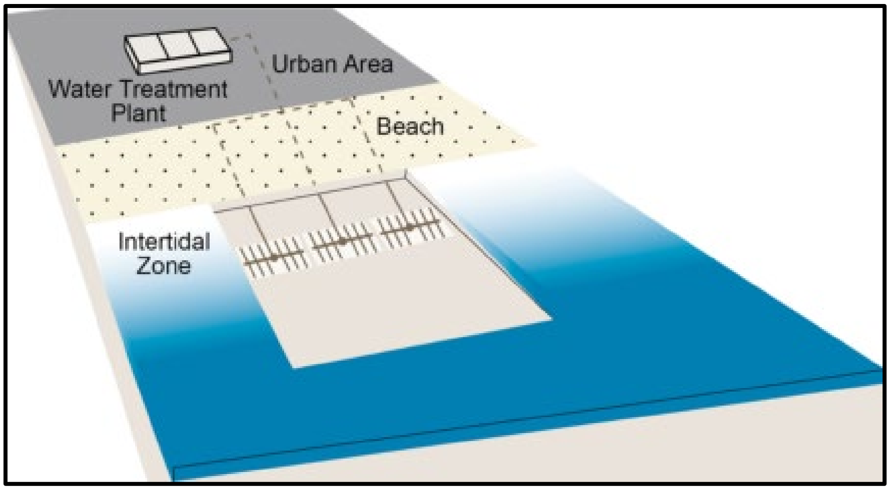
Source: Boerlage *et al*. 2017

Figure 5-4. Schematic of a Horizontal Well.

5.5 INFILTRATION GALLERY

Infiltration galleries may be installed nearshore or offshore and require the initial removal of the natural seafloor material and replacement with engineered fill material that is highly permeable (Boerlage et al. 2017). Seawater infiltrates through the highly permeable material into a collection system and gets routed to a pumphouse onshore (Figure 5-5).

Infiltration galleries require a substantial offshore construction effort. Nearshore infiltration galleries could exacerbate beach erosion. Offshore infiltration gallery locations may be limited by water depths in which coffer dams can be constructed.



Source: Boerlage *et al*. 2017

Figure 5-5. Schematic of a Near-Shore Infiltration Gallery.

Table 5-1 provides a brief comparison of these subsurface intakes types. Much of the information summarized below is from intake research and studies conducted in support of desalination plants.

5.6 SUMMARY

Two key characteristics associated with subsurface intakes make them impractical and potentially infeasible for supporting the City's Blue Economy activities:

1. Higher cost compared to surface water intakes.
2. Incompatibility with requisite water quality –
    a) Samples collected at a few offshore subsurface intakes found high concentrations of iron and manganese, which could be toxic to organisms (Boerlage *et al*., 2017).
    b) Nearly all subsurface intakes have low levels of dissolved oxygen. If a subsurface intake were used, water would likely need to be aerated onshore prior to use.

This evaluation performed only a cursory review of subsurface intakes. If the CA OP were amended to necessitate detailed evaluations of subsurface intakes for all marine withdrawals, then additional focused studies near the City would be needed.

Table 5-1. Comparison of Subsurface Intakes

Subsurface Intake Type	Potential Impact on Freshwater Aquifer	Potential for Clogging	Water Quality	Performance Uncertainty	Construction Period Impacts	Limitations	Key performance Risk
Vertical Well	Moderate	Moderate	Potential for low DO	Low	Low	Geotechnical conditions; soil permeability	Freshwater aquifer drawdown; mobilizing freshwater.
Ranney Well	Moderate to low because shallow well	Moderate to low	Potential for low DO	Moderate	Low	Geotechnical conditions; soil permeability	Geologic conditions; lack of hydraulic connectivity
Slant Well	Low	Moderate	Potential to draw anoxic water; potential for high dissolved iron and manganese	Moderate to high	Low when conditions are favorable.	Geotechnical conditions; soil permeability; aquifer quality	Impact on bluffs, potential for collapse from drilling and vibration
Horizontal Directionally Drilled Well	Low	Moderate; cleaning and maintenance for water production purposes is less well known	Uncertain potential for low DO	High	Low when conditions are favorable	Geotechnical conditions; soil permeability; aquifer quality; greater directional flexibility	Impact on bluffs, potential for collapse from drilling and vibration
Nearshore Infiltration Gallery	Low	Moderate to high	Potential for low DO	Moderate to high	Could be high – exacerbate beach erosion	Space availability	Geologic conditions
Offshore Infiltration Gallery	Low	Moderate	Potential for low DO	Moderate to high	Could be high – impacts to benthic organisms, exacerbate scouring	Depth at which coffer dam can be constructed.	Geologic conditions

6. SURFACE WATER INTAKE CONCEPTS

6.1 GENERAL CONCEPT

The general concept for a surface water intake is to withdraw surface water and route it to a raw water wet well on the WWTF site. A pumphouse located at the WWTF ground level would withdraw water from the raw water wet well and distribute to the various Blue Economy end users. Effluent from the various Blue Economy activities, once treated as appropriate and ready for discharge, would be sent to a second wet well (effluent wet well). Water from the effluent wet well would be pumped to the existing chlorine contact tank bypass line. The Blue Economy effluent and discharge from the chlorine contact tank would mix immediately downstream of the chlorine contact tank and get routed via the former outfall to the existing 24-inch discharge pipe and the existing 14-port linear diffuser.[2]

The proposed raw water wet well and proposed effluent wet well would be located on the site of the former trickling filters (see Figure 4-1). When they were in operation each former trickling filter was about 4 feet deep and were located aboveground. When the trickling filters were taken out of service, their media was removed, filled with rock, and covered with a layer of concrete. These two spaces are not readily available now. To use these spaces for wet wells, the concrete and rock would need to be removed, excavated down to the appropriate depth, and lined with concrete. Reusing these spaces would reduce the need for new real estate. Figure 6-1 shows the former trickling filter locations. The former trickling filter on the left is expected to serve as the potential effluent wet well, and the former trickling filter in the middle of the picture is expected to serve as the potential raw water wet well.

An interconnection between the two wet wells could add flexibility to system operation and allow for backwashing.

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[2] Mixing of the treated Blue Economy effluent and the WWTF influent (prior to treatment) is not recommended due to the difference in salinity. The WWTF was designed to treat freshwater-based influent. Blue Economy effluent could potentially kill the microbes that treat the sewage.

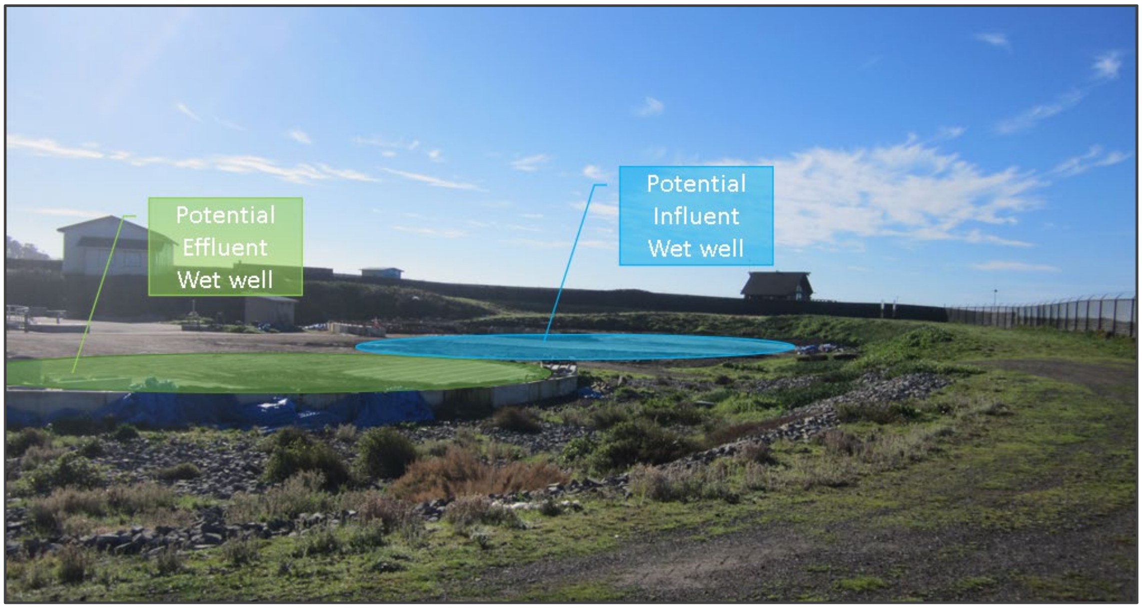


Figure 6-1. Former Trickling Filters at the City of Fort Bragg Wastewater Treatment Facility.

6.2 POTENTIAL INTAKE AND OUTFALL OPTIONS

This evaluation considered a few surface water intake concepts, all of which may be grouped as follows:

1. A shoreline surface water intake that feeds the raw water wet well. There may be a few variations to this system (all of which are generally shown in Figure 6-3).
    a. The type of screens – either passive wedgewire screens or traveling water screens.
    b. Pipeline route – a pipeline that is drilled through the bluffs into the wet well, or a pipeline that is installed on the bluff.
2. An offshore surface water intake in a 'new' area. There may be a few variations of this alternative as well (shown in Figure 6-5 and Figure 6-6).
    a. Whether or not to reuse the existing easement – the intake located within an extension of the current easement, or the intake located in a completely separate area. Either option would provide sufficient separation between the intake and outfall to avoid recirculation of discharge into the intake.
    b. Pipeline route – a pipeline that is drilled through the bluffs into the wet well, or a pipeline that is installed on the bluff.
3. A new dedicated marine water intake pipe and outfall in a 'new' area away from the existing easement, shown in Figure 6-7.

Each of these is discussed below.

6.3 SHORELINE SURFACE WATER INTAKE

6.3.1 Concept

A surface water intake at the shoreline would consist of screens, either cylindrical wedgewire or traveling water screens with a fish return, installed at the shoreline near the WWTF. Either option would need to be able to withdraw 1 MGD. Figure 6-3 shows a potential configuration.

The intake may be immediately north or south of the former nearshore outfall (Figure 6-8). The intake pipe would originate at the screens, and traverse through the rock into the wet well or along the rock and up the bluffs, and discharge to the wet well. Because the discharge to the wet well would be approximately 50 ft above sea level, both pipeline configurations would necessitate pumping of raw water.

A more detailed description of the wedgewire and traveling water screen shoreline intake options is provided in the following subsections.

6.3.2 Wedgewire Screen Option

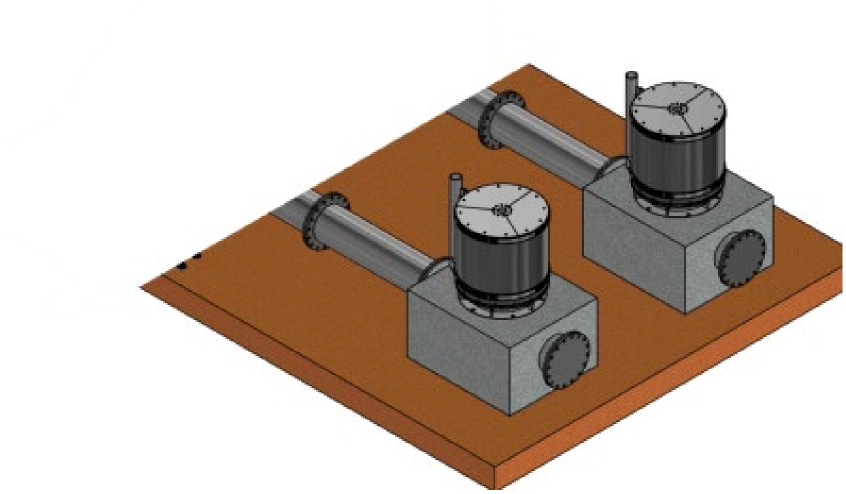
The evaluation assumed that two vertical drum-type wedgewire screens (WWS), each 1.5 ft tall and 2 ft in diameter, with 1-mm slot openings would be installed near the shore. When both WWS are in operation, the through-slot velocity would be approximatley 0.23 feet per second (fps) when the screens are clean. If one WWS were taken out of service for maintenance, then the through-screen velocity would increase to 0.46 fps.

The two WWS would be designed and constructed to operate independently. Each screen would be connected to its dedicated pipe that would route water to the raw water wet well. The pipes would be interconnected as well, but the interconnecting valve would be normally closed, and opened only during an emergency.

The WWS would be surrounded by underwater bollards and signage to prevent swimmers and recreational users from damaging the screens or getting hurt by the screens.

Biofouling would be significant in this marine environment and therefore both the WWS and the pipes would need an automated cleaning system. The WWS would be electrically actuated and rotate on their axes for the wedgewire slots to be cleaned by brushes on the inside and outside of the screens. The pipes would need to have the ability to be pigged as needed. Pig launch or exit chambers would be directly under the drum-type WWS.

The evaluation assumed that the WWS and pig launch or exit chambers would be installed on a pre-cast concrete slab (Figure 6-2). The concrete pad, pig launch or exit chamber and drum-type WWS together would be about 54 inches tall. The WWS need to be submerged at all times to achieve the low through-slot velocity calculated above. It is preferable to have the WWS submerged by about another one-half height of screen.



Source: Intake Screens, Inc., 2022

Figure 6-2. Drum-type Wedgewire Screens Mounted on a Pre-cast Concrete Pad.

As shown in Figure 4-6, the water depth nearshore is insufficient to accommodate the height of the concrete pad, pig launch or exit chambers and WWS. The screens would be out of water most of the time and completely out of water during low tide, and unable to provide sufficient quantities of water to the system. The potential for damage of the system is high in shallow water. Given the steep bluffs along the shoreline, construction activities would need to be performed from water. The water depth near the shore may be too shallow for a barge; a tressle may need to be built to provide construction access. Providing foundational support on rocks for a tressle that can support heavy equipment would be very challenging.

6.3.3 Traveling Water Screen Option

For the purposes of this evaluation, it was assumed that a traveling water screen system would include two traveling water screens (TWS). Both TWS would operate whenever the system is in operation under normal conditions, providing 100 percent redundancy.

For screens with 1-mm square mesh and a 5-foot width, the TWS would need about 2 feet of water depth when clean to maintain 0.5 fps through-screen velocity. The system would have two fish-friendly TWS and a fish return to protect organisms. The TWS would be installed in a newly constructed concrete structure. Organisms collected off the TWS would be returned to a location that would preclude organism recirculation. Debris collected on the TWS would be sent for offsite disposal. As with the wedgewire screens system, each TWS would feed a dedicated pipeline that would route water to the wet well. This would allow for maintenance and pigging of pipelines. The water would need to be pumped regardless of whether the pipeline is routed through the bluffs or over the face of the bluffs. In order to maintain a low profile, the pumps would be installed within the WWTF site and not near the TWS. The intake would have a bar rack and a mechanical rake to manage larger debris. Water would pass through the bar rack and through the screens before entering the raw water pipes that would convey the water to the raw water wet well.

Biofouling would be significant for this configuration as well. It is assumed that the TWS would be rotated near-continuously and washed with a low-pressure wash to remove organisms, followed by a high-pressure wash to remove debris. Use of chemicals to clean screens would be based on regulatory input. The screens and washwater pumps would need electrical power.

The system would need a mechanism to dissipate energy from wave action and provide quiescent conditions at the face of the screens.

This system would need a robust foundation, which would necessitate excavation and shoring. About one-half of traveling water screen structure would rise up out of the water. Excavation and shoring in the rocky terrain would be challenging. Similar to the challenges with a wedgewire screens sytem, construction activities would need to be performed from water. The water depth near the shore may be too shallow for a barge and may necessitate a tressle. But providing foundational support on rocks for a tressle that can support heavy equipment would be very challenging.

6.3.4 Feasibility

A shoreline intake with wedgewire screens or traveling water screens is infeasible due to the key reasons listed below. Brief discussions about each is provided above.

- Difficulty with supporting construction equipment.
- Challenges with excavation and shoring.
- Permitting challenges due to disturbance during construction period and visual impact during the operations period.
- Operational challenges due to shallow water; inability to withdraw sufficient quantities of water.

For the reasons and challenges listed above the shoreline surface water intake option should not be evaluated further.

6.4 OFFSHORE SURFACE WATER INTAKE WITHIN THE EXISTING EASEMENT

6.4.1 Concept

This option would locate the intake infrastructure within the existing easement, at a location in between the existing diffuser and the former shoreline outfall. Water withdrawn would be pumped via two pipes to the raw water wet well within the WWTF. Water for Blue Economy activities would be withdrawn from the raw water wet well. Figure 6-4 shows a schematic of this configuration.

6.4.2 Description of the Intake

Similar to the configuration described in Section 6.3.2, this system would be comprised of two 2-foot diameter 1.5-foot tall WWS with 1-mm slot openings. The WWS would be automatically cleaned on the inside and outside with brushes; the brushes would be stationary and the WWS would rotate to clean the wedgewire slots. When clean, they would have 36 percent open area. When both WWS are in operation and withdrawing 1 MGD, the through-slot velocity would be approximately 0.23 fps. The screen configuration would be similar to that presented for the shoreline WWS option (Figure 6-2). Here too, each screen would feed its dedicated raw water pipe. The pipes would be cross-connected for use in an emergency. The pipes are expected to be installed within the existing easement, and have the ability to be pigged. Electrical conduit for rotating the WWS would be tethered to the outside of a raw water pipe.

The water depth at this location is expected to be between 20-30 ft; therefore, construction would be performed from barges. A pre-cast concrete slab would be installed on the seabed, and the WWS assembly mounted on it. Underwater bollards and signage would alert the public of this system.

Material selection would be critical for the success of this configuation. Screen and pipe material would need to resist corrosion and biofouling, perform reliably and have long life.

6.4.3 Feasibility

Based on information available thus far, this offshore WWS system is feasible from an engineering standpoint. However, its performance is still uncertain. Ambient ocean current directions need to be better understood to confirm that the WWTF discharge would not recirculate into the intake and potenitally introduce bacteria and viruses to organisms being cultured in the various Blue Economy activities. Subsequent phases of this project will evaluate ambient currents.

6.5 OFFSHORE SURFACE WATER INTAKE OUTSIDE THE EXISTING EASEMENT

6.5.1 Concept

A surface water intake outside the existing easement could be located within an extension of the existing easement or in a completely ‘new’ area. Such a system would withdraw water through wedgewire screens and route it to the raw water wet well at the WWTF. Figure 6-5 and Figure 6-7 show a configuration that places the intake in a ‘new’ area within a new intake easement. The specific withdrawal location would be determined during the next phase of the project. Figure 6-6 shows the intake within an extended section of the existing easement.

The intake pipes would originate at the screens, be laid on the seafloor with concrete anchors holding the pipes in place. The pipes would traverse through the rock into the raw water wet well or along the rock and up the bluffs, and discharge to the wet well. As with all options, because the discharge to the wet well would be approximately 50 ft above sea level, both pipeline configurations would necessitate pumping of raw water from the intake to the raw water wet well. The intake pumps would be located within the WWTF site.

6.5.2 Description of the Intake

This system would consist of two vertical drum-type WWS, each 1.5 feet tall and 2 feet in diameter, with 1-mm slot openings (Figure 6-2). When both WWS are in operation, the through-slot velocity would be approximatley 0.23 fps when the screens are clean. If one WWS were taken out of service for maintenance, then the through-screen velocity would increase to 0.46 fps. As with the shoreline intake configuration, the two WWS would be designed and constructed to operate independently. Each screen would be connected to its dedicated pipe that would route water to the raw water wet well. The pipes would be interconnected as well, but the interconnecting valve would be normally closed, and used only during an emergency.

To construct the system, the pre-cast concrete slab would be lowered from a barge to the intake location. The slab would have provision to tether the WWS assemblies and pipes, all of which would be transported to the location on barges and installed by divers. The design of the foundation support for the slab would be evaluated during the next phases of the project.

Appropriate signage would alert of the presence of WWS at the withdrawal location, but the likelihood of damage would be low in deeper water.

The specific location for the intake would be determined based on several criteria. Key among these would be:

- Sufficient water depth – both for the operation of the screens and protection of the screens. Based on information presently available, a minimum water depth greater than 12 feet would be beneficial.

- Sufficient ambient current – the location must have sufficient ambient current to 'sweep' debris and organisms away from the WWS.

- Minimal safety concerns – the location should not be impacted by navigation.

- Away from sensitive/essential habitats – the construction and operation of the system should have minimal impact on habitats or organisms.

- Adequate access for construction and maintenance. The intake location should be accessible for construction and periodic maintenance. Any offshore location would pose health and safety challenges, especially during inclement weather.

- Avoid interference with existing infrastructure. The location and raw water pipeline route should be clear of existing infrastructure or the locations of existing infrastructure should be well understood so as to avoid damaging or interfering with existing infrastructure.

- Minimize disturbance to the extent practical.

- Minimize recirculation of discharge from the WWTF.

Biofouling would be significant in this marine environment and therefore both the screens and the pipes would need an automated cleaning system. Brushes on the inside and outside of the screens will automatically clean the WWS regularly as they rotate on their axes. The pipes would need to have the ability to be pigged as needed. Pig launch or exit chambers would be directly under the drum-type WWS.

6.5.3 Feasibility

The feasibility of this system would depend on identifying an intake location that meets the criteria listed in Section 6.5.2.

6.6 NEW INTAKE AND NEW OUTFALL OUTSIDE THE EXISTING EASEMENT

6.6.1 Concept

This configuration would install the Blue Economy related intake and outfall in a completely separate area from the existing linear diffuser and existing easement. The new intake and outfall would have sufficient separation to avoid recirculation. Figure 6-7 show a schematic of this configuration with both the intake and discharge in 'new' areas within new easements.

6.6.2 Description of the Intake

The intake configuration would be similar to that described in Sections 6.4 and Section 6.5, and could look like the configuration shown in Figure 6-2. The outfall would be installed within another new easement. Blue Economy activities would have minimal interaction with the existing WWTF.

6.6.3 Feasibility

The feasibility of this configuration is also contingent on identifying appropriate intake and outfall locations, and pipline routes.

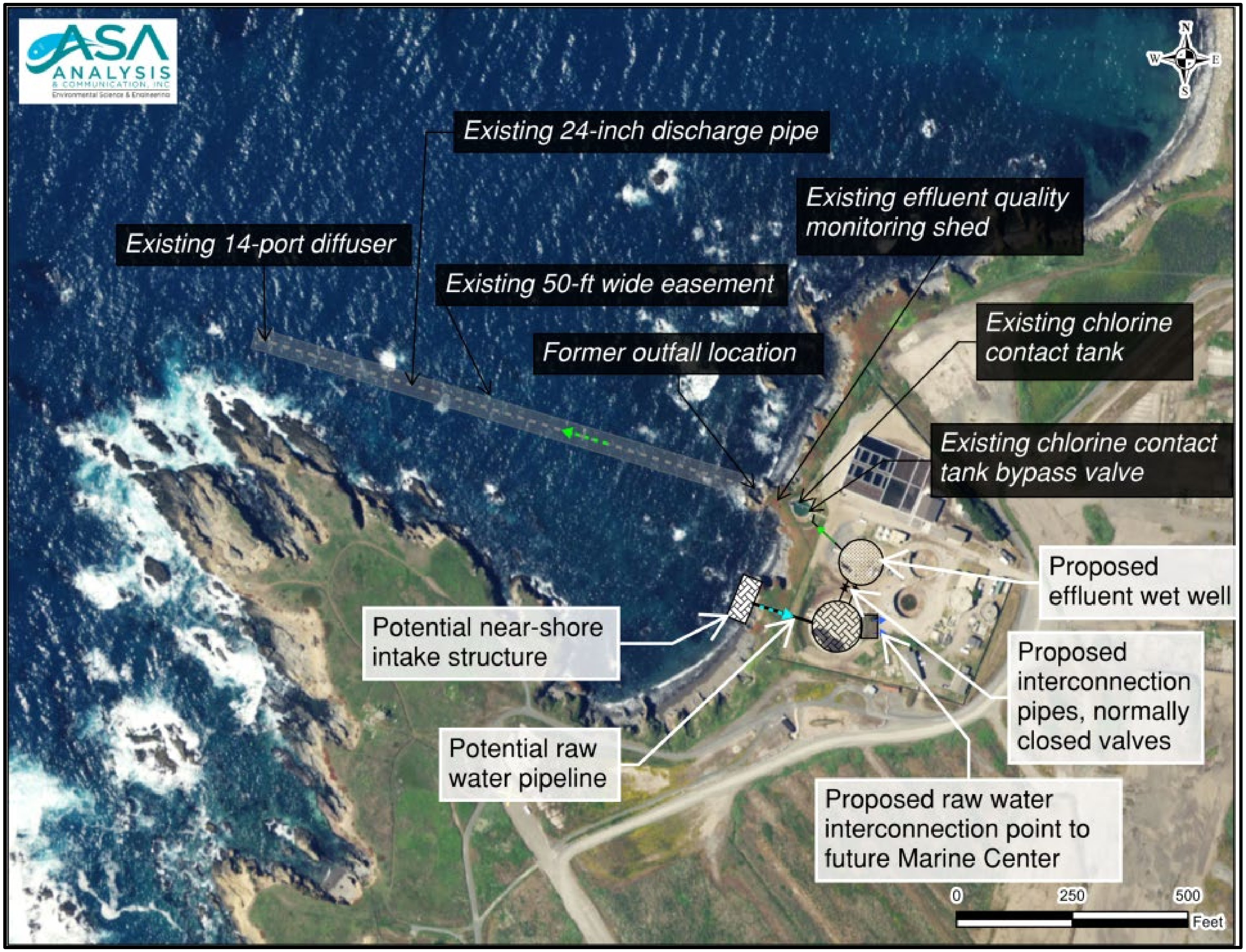


Figure 6-3. Potential Shoreline Intake Structure.

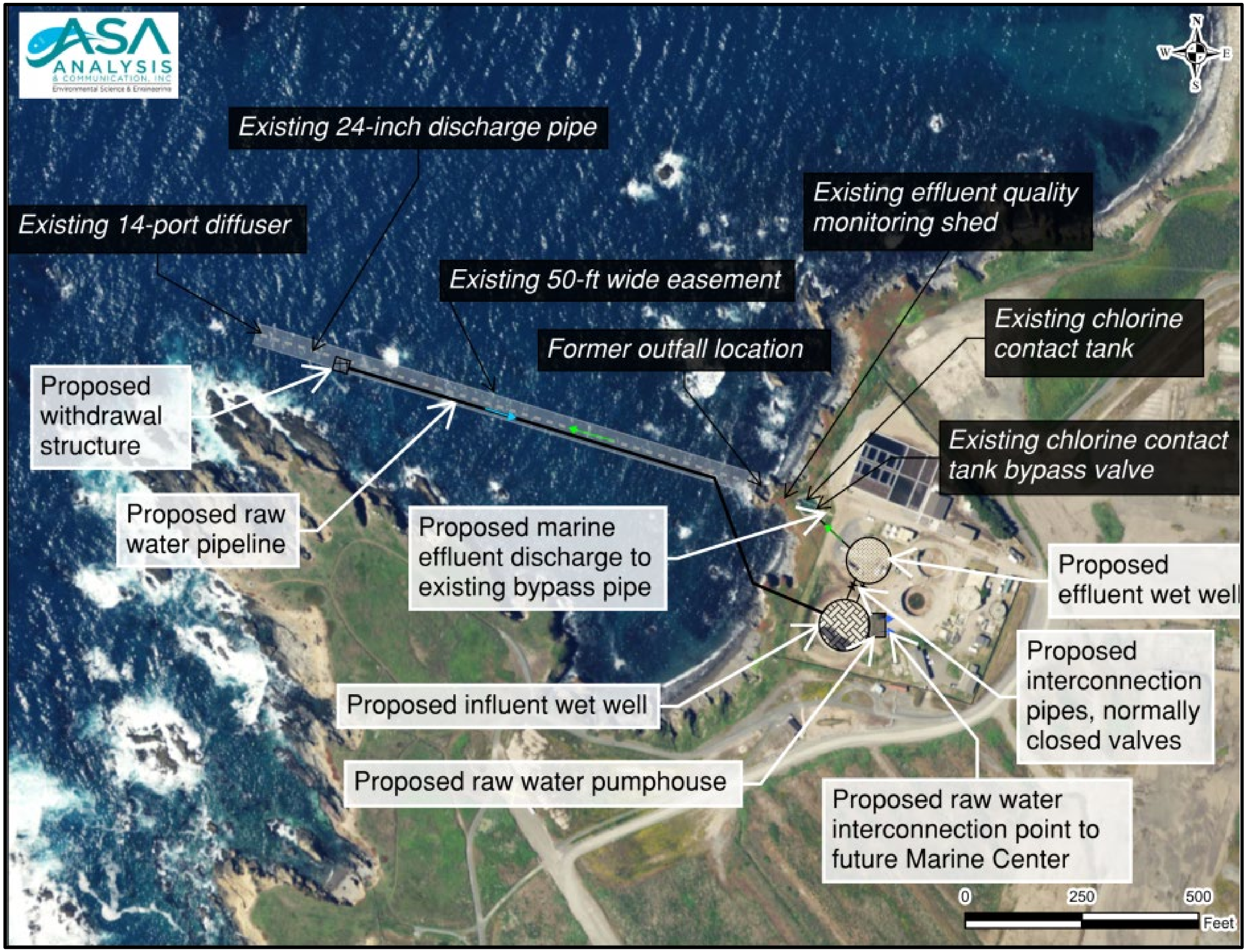


Figure 6-4. Potential Offshore Surface Water Intake Within the Existing Easement.

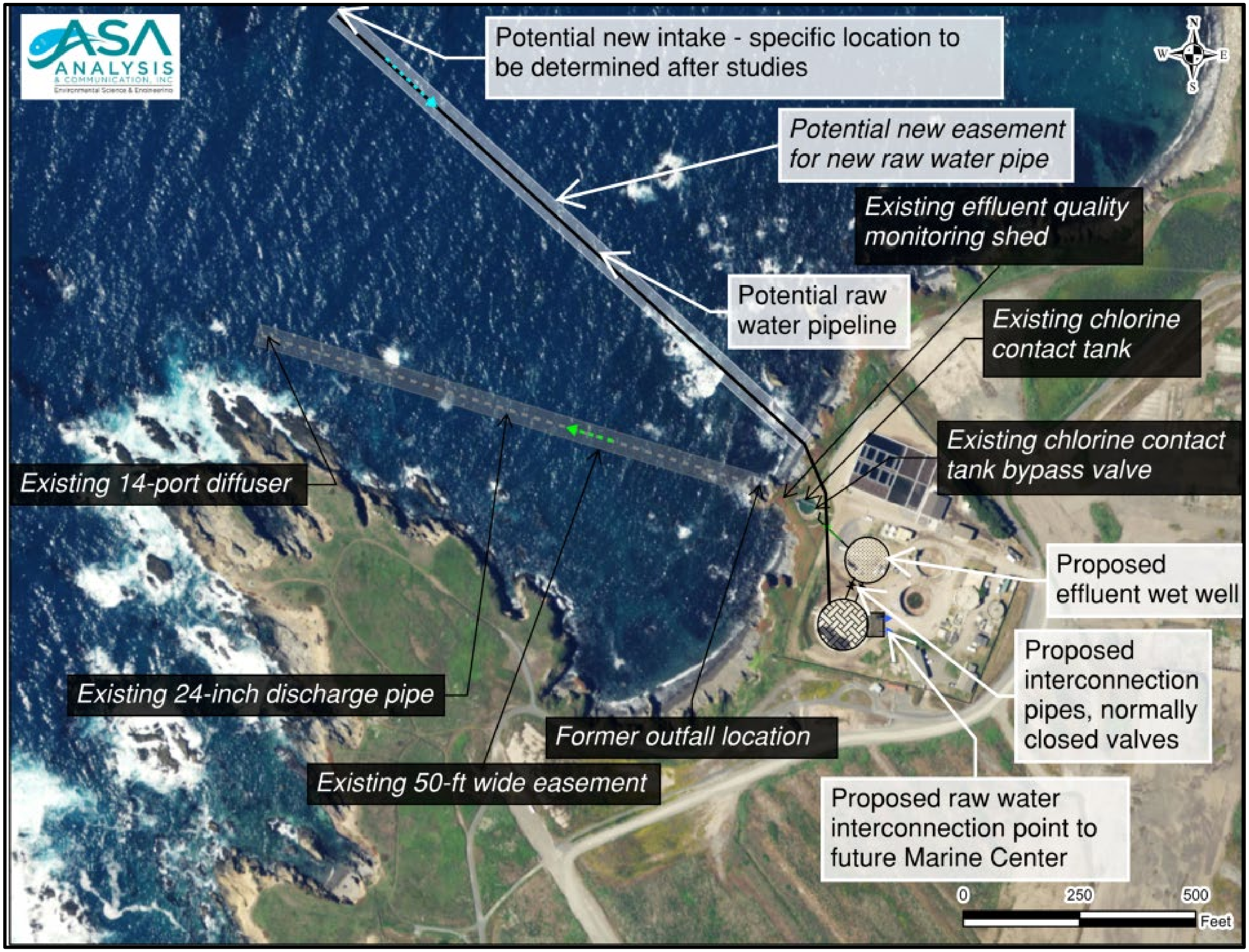


Figure 6-5. Potential Offshore Separate Intake Structure and Current Outfall.

Figure 6-6. Potential Offshore Separate Intake Structure and Current Outfall.

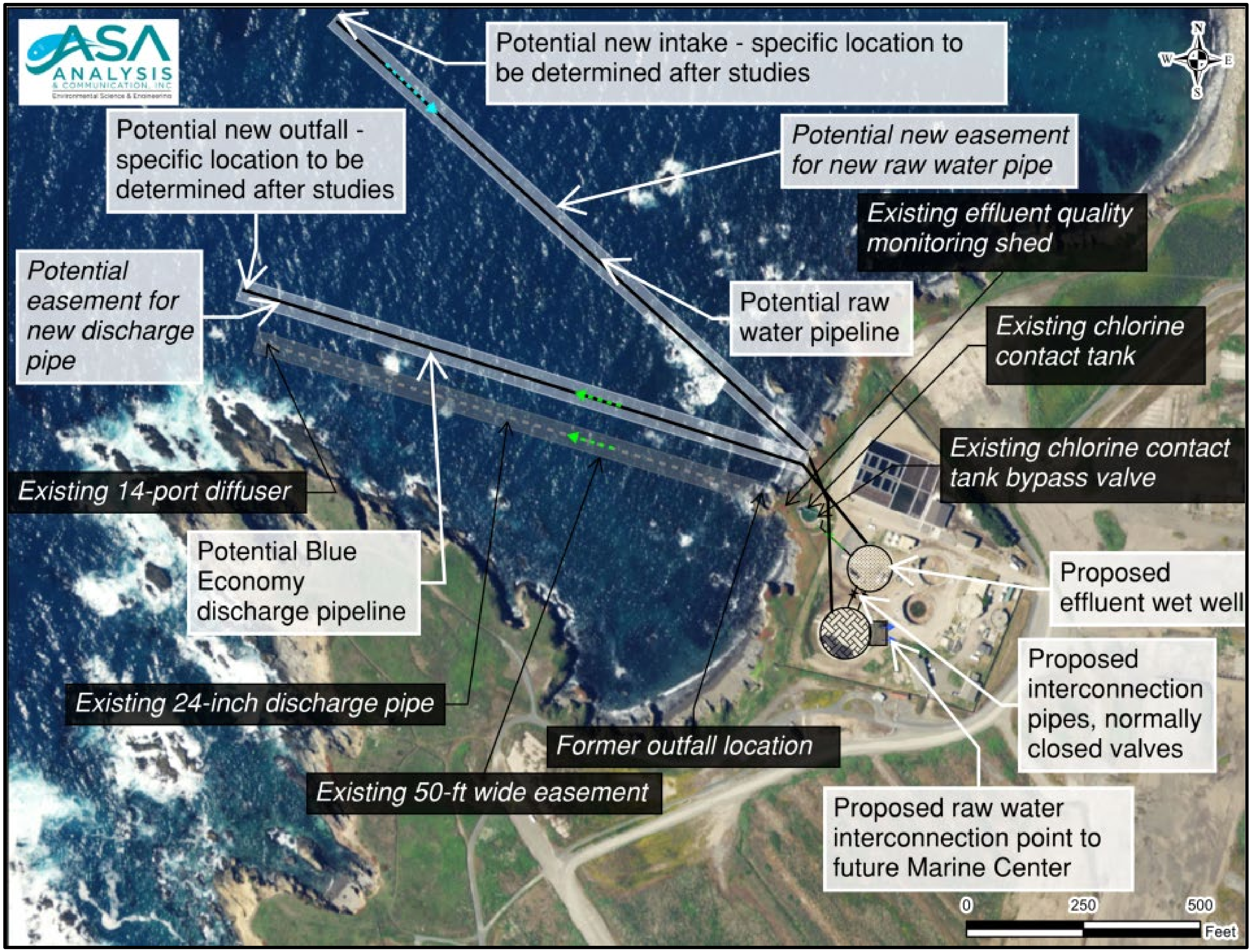


Figure 6-7. Potential Offshore Separate Intake Structure and Separate Offshore Outfall.

Figure 6-8. Photographs of the Shoreline to the South (Left) and North (Right) of the Former WWTF Outfall.

7. OVERVIEW OF RISKS AND POTENTIAL MITIGATION MEASURES

Key risks associated with the design, construction and operation of the Project are discussed below.

7.1 ROUTING AND TETHERING THE RAW WATER PIPE

Regardless of the type or location of the intake, the raw water pipe needs to convey water from the intake to the raw water wet well. The evaluation considered two raw water pipeline routes – one through the bluffs and one tethered on the bluffs. Both options pose challenges.

The pipeline route through the bluffs would necessitate drilling down from the WWTF site, penetrating out near the base of the bluffs, and then traversing on or under the seabed to the intake location. The bluffs consist of weathered hard rock. Because the rock is hard, it is difficult to drill through and because the rock is fragmented, its rigidity and integrity is not uniform throughout. The vibration of drilling could cause the bluffs to collapse. Additional studies are needed to assess appropriate drilling techniques to drill through bluffs.

A pipeline route along/on the bluffs would need to be tethered to withstand some movement of rock and forces of wind and rain. The very motion of drilling anchors/collars into the rock to tether the pipe could loosen the rock. Geotechnical conditions and alternate pipe anchoring methods would need to be evaluated during the next phase of the project.

7.2 FOUNDATIONAL SUPPORT FOR THE CONCRETE PAD THAT WOULD SUPPORT THE SCREENS

The wedgewire screens would be mounted on a concrete pad. The screens may be mounted onshore and the entire slab and screen assembly lowered into water, or the slab could first be placed on the seabed followed by the screen installation. Both options are challenging. If the screens are mounted onshore, then the overall assembly would be heavier to handle. The screens could get damaged when the unit is handled by a crane. Achieving the requisite precision would be challenging if the screens are installed underwater by divers. Both options have been performed successfully, albeit with difficulty.

Tethering the concrete slab to the seabed would also be challenging. It is important that the concrete slab resist movement. Wave action could cause the slab to move over time. Movement beyond a certain threshold could cause the pipes to crack. The nature of the seabed would determine tethering options. The next phase of the project would evaluate the best seafloor locations and geotechnical features to assess options for tethering the concrete slab to the seabed to avoid movement of the slab due to wave action.

7.3 WATER QUALITY

Suitable water quality is critical for the success of Blue Economy activities. Water quality issues can stem from anthropogenic or natural causes, but the outcome would be the same – hindering Blue Economy activities. Some of the water quality risks can be planned for and mitigated; mitigating for others would be more difficult.

This evaluation recommends that the new intake be at sufficient distance from the existing WWTF diffuser to avoid recirculation of treated WWTF effluent.

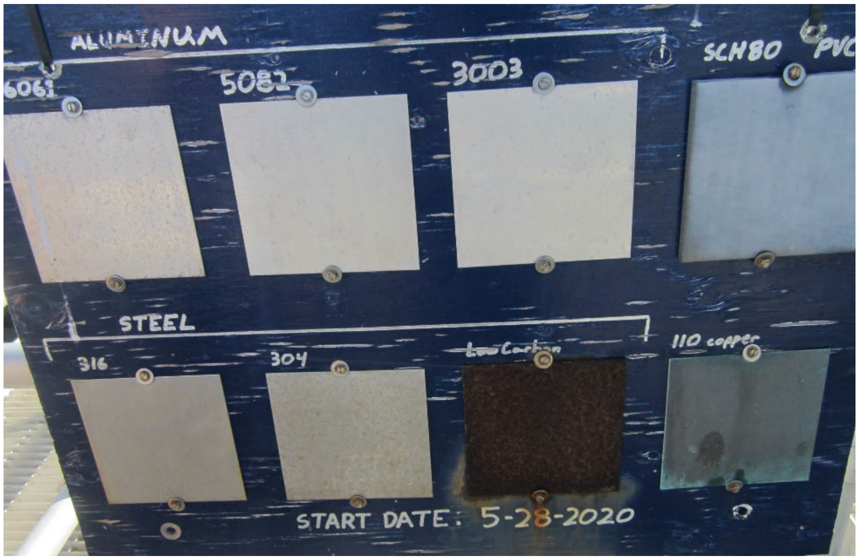
Several stormwater outfalls discharge through the bluffs. Any of these could introduce a pathogen. Existing and future stormwater outfall locations and their impacts on the intake need to be evaluated.

An offshore oil spill could render ocean water unsuitable for a period of time.

A change in long-distance ocean transport currents due to weather or climate change could have a longer and more deleterious effect by changing the nutrient composition and temperature of the ocean water near the intake.

7.4 CORROSION

High moisture and salinity in the air makes the City's terrestrial environment highly corrosive to all types of metals (Figure 7-1). In order to achieve sufficient strength and avoid excessive corrosion in the marine environment, the screens would likely need to be fabricated with superduplex stainless steel.



Source: Corrosion potential experiment by Mr. Alden at the WWTF

Figure 7-1. Corrosion Potential Coupon Testing at the WWTF.

7.5 BIOFOUING

The marine environment is highly productive. If not propoerly controlled, various organisms would grow on the inside and outside of the screens and the pipelines. Both the screens and the pipelines therefore need to be cleaned regularly – the specific interval would be determined during the operations period. However, it is expected that the screens would be cleaned automatically on a daily scale and the pipe would be pigged on an annual scale.

7.6 MAINTENANCE CHALLENGES DURING SEVERE WEATHER

The electrical supply to the WWS cleaning system could get damaged during severe weather. Sending a boat and divers to perform repairs at the intake during severe weather may not be practical. During potential power losses, the WWS would still be able to pass flow, however extended periods of outage could lead to excessive biofouling.

The raw water wet well is meant to provide several hours of residency to account for occasional loss of the intake.

7.7 PERMITTING CHALLENGES

The environmental footprint and impact associated with construction and operation would need to be minimized to the extent practical in order to permit a new intake (and potentially a new outfall).

7.8 SEA-LEVEL RISE AND CLIMATE CHANGE

Constant sea-level rise would have minimal impact on the construction and operation of this system. However climate change, which often manifests itself in more extreme weather patterns could cause the water levels to fluctuate more often and over a larger range; could increase wave action and forces on the pipe; could change the intake water temperature and the ultimate suitability of the withdrawn flow for organisms at the Blue Economy facilitiy.

The design of the system would need to be cognizant of these impacts and be flexible to these varying conditions.

8. RECOMMENDED STUDIES FOR THE FEASIBILITY EVALUATION PHASE

Several additional studies would need to be undertaken as the project moves forward. These studies may be performed progressively. Key uncertainties, potential required studies, and their relative urgency are discussed below.

8.1 SUBSURFACE WATER QUALITY

A subsurface intake would cost more than a surface water intake, but it has the potential to provide consistent quality water. However, that water quality may not be compatible with Blue Economy activities.

This study recommends collecting several representative subsurface water samples and assessing compatibility with target/representative organisms to be cultured. Assessing subsurface water quality may be undertaken early in the planning process.

8.2 SURFACE WATER QUALITY

A surface water quality study in the early stages of evaluation would also be beneficial. The study would assess compatibility with Blue Economy activities and target/representative marine organisms that would be cultured.

A modeling study that asseses entrainment of stormwater and WWTF effluent would also be beneficial.

8.3 OCEAN CURRENTS SURVEY

Ocean currents play an important role in carrying debris and marine life away from screens and avoiding recirculation of WWTF or Blue Economy effluent. An early-stage study needs to assess ocean currents when evaluating the specific location for the intake and any new discharge infrastructure.

8.4 GEOTECHNICAL ANALYSES

Geotechnical conditions need to be evaluated in several locations.

Using previous mapping efforts and studies, this study recommends performing an initial geotechnical assessment of the seabed to identify suitable locations for the intake (and possibly the new outfall). Such a preliminary assessment should be undertaken in the early phases of the project. Once the potential intake location is identified, specific geotechnical studies would be needed to assess methods to anchor the concrete slab to avoid movement associated with wave action.

Constructing the raw water pipeline is one of the most challenging aspects of this project, and the challenge is posed by the bluffs. This study therefore recommends identifying high integrity areas of the bluffs where the pipeline may be drilled through or the pipeline could be supported on. Such an assessment should be undertaken early in the planning process.

8.5 BENTHIC AND HABITAT SURVEYS

Locating the intake in an area with low biological activity and habitat would provide many benefits. In particular, given local kelp restoration efforts, areas suitable for kelp establishment should be avoided.The intake location selection should incorporate such habitat information.

8.6 CONSTRUCTION METHODS

The City is remote and thus there are few specialty contractors readily available from within the City or from the immediate surroundings. This study therefore recommends evaluating construction methods for intalling the raw water pipe, installing the intake, and developing the raw water and effluent wet wells with consideration for availability of appropriate contractors and costs.

This would be a medium-term evaluation.

8.7 BATHYMETRIC SURVEY

Construction and operation of the intake becomes challenging when the water is too shallow or too deep. Existing bathymetric information may be used for the initial evaluations. Once an intake location is identified, a site-specific bathymetric survey would need to be undertaken in the medium term to confirm prior information.

8.8 ENTRAINMENT STUDIES

Once regulators have provided feedback about the intake system that is permissible, the City would likely need to study organism entrainment associated with the intake structure to assess the need for potential mitigation.

8.9 SYSTEM MAINTENANCE METHODS

Protecting the system from corrosion and biofouling is critically important for the successful operation of the system. Prior to detailed design, the City would need to evaluate raw water pipeline pigging methods and screen cleaning sufficiency and subsequently incorporate any constraints and requirements into the design (such as allowable bends in the pipe, pipe size, pipe material, etc.).

8.10 DEPTH TO GROUNDWATER

Construction methods for the raw water and effluent wet wells would be impacted by the depth to groundwater at the WWTF site and the fluctuations in the depth to groundwater. Assessing the depth to groundwater over a period of a few years would benefit the design and construction methods.

9. RELATIVE SCHEDULE FOR THE SURFACE WATER INTAKE

A relative schedule by project phase and activity is provided in Table 9-1. This schedule assumes that the Blue Economy effluent would be discharged via the existing outfall and that the existing easement would be extended out to locate the new intake. That configuration would reuse much of the existing footprint. Other surface water intake options would need more planning and permitting time; the subsurface intake would likely need significantly more planning and permitting time.

Table 9-1. Relative Schedule of Project Phases and Activities for a Surface Water Intake Option at Fort Bragg.

Timeline for Completing the Task	Project Phases and Activities
2022	Concept Screening • Develop preliminary concepts • Identify key permitting constraints • Identify preliminary financial, access, O&M constraints • Prepare Class 4 or 5 cost estimates • Identify key risks • Recommend key studies to reduce uncertainties
One year after Concept Screening	Feasibility Evaluation • Implement initial studies • Refine intake/outfall size and location • Refine permitting constraints • Evaluate feasibility • Prepare preliminary design basis document • Prepare Class 3 cost estimate
One to 1.5 years after Feasibility Evaluation	Budget Authorization • Develop 30 percent design and develop 30 percent drawings • Refine design basis document • Confer with regulatory agencies • Perform any other studies that may be required in permit applications • Update regulatory agencies • Prepare Class 2 cost estimate • Prepare project schedule

Timeline for Completing the Task	Project Phases and Activities
	• Prepare and submit long-lead permit applications • Identify construction specifications applicable to the project • Begin to identify vendors and contractors • Procure funding
One year following Budget Authorization	Detailed Design • Develop 60 percent design and develop 60 percent drawings • Refine design basis document • Apply for remaining permits • Prequalify vendors and contractors • Perform constructability review • Begin to receive long-lead permits • Develop 90 percent drawings incorporating any additional permit conditions and input from constructability review • Prepare Class 1 cost estimate • Refine project schedule • Prepare final specifications
Six to 9 months following Detailed Design	Bidding and Construction • Receive all permits • Prepare 100 percent drawings, specifications and bid package • Bid equipment and construction together or separately • Select vendors and contractor • Refine costs and schedule as needed • Construction, commissioning and construction management

10. COST ESTIMATES

This section presents three cost estimates. An order of magnitude cost for a subsurface water intake, and the Association for the Advancement of Cost Engineering (AACE) Class 5 costs for two surface water intakes (one with the raw water pipe drilled through the bluffs and the other for the raw water pipe installed on the bluffs).

As shown in Table 10-1, a Class 5 estimate is based on up to 2 percent design of the system and is typically used for concept screening evaluations such as this. A Class 5 estimate does not need to assess all costs in detail; capacity factoring, parametric estimates, professional judgment, and analogous pricing that apply to the system are acceptable. Such an estimate is expected to be accurate to -20 percent and -50 percent on the lower end to 30 percent and +100 percent on the upper end. Additional information about cost estimating accuracy may be found at AACE (2016).

Table 10-1. Association for the Advancement of Cost Engineering Costing Categories.

Estimate Class	Primary Characteristic	Secondary Characteristic			
	Level Of Project Definition (expressed as percentage of complete definition)	End Usage (typical purpose of estimate)	Methodology (typical estimating method)	Expected Accuracy Range (typical variation in low [L] and high [H] ranges)	Preparation Effort (typical degree of effort relative to least cost index of 1)
Class 5	0% to 2%	Concept screening	Capacity factored, parametric models, judgment, or analogy	L: -20% to -50% H: +30% to +100%	1
Class 4	1% to 15%	Study of feasibility	Equipment factored or parametric models	L: -15% to -30% H: +20% to +50%	2 to 4
Class 3	10% to 40%	Budget, authorization, or control	Semi-detailed unit costs with assembly-level line items	L: -10% to -20% H: +10% to +30%	3 to 10
Class 2	30% to 70%	Control or bid/Tender	Detailed unit cost with forced detailed take-off	L: -5% to -15% H: +5% to +20%	4 to 20
Class 1	50% to 100%	Check estimate or bid/Tender	Detailed unit cost with detailed take-off	L: -3% to -10% H: +3% to +15%	5 to 100

Source: AACE (2016)

10.1 ORDER OF MAGNITIDUE COST OF A SUBSURFACE WATER INTAKE

There are no industry standard unit costs for subsurface water intakes; nor are there numerous subsurface water intakes similar in size or location to the City's to apply component costs to develop an accurate estimate. The order of magnitude cost of constructing a subsurface intake for the City's Blue Economy activities was developed by scaling costs for the Monterey Peninsula Water Supply Projects (a 9.6 MGD project and a 6.4 MGD project) and presented at Caldesal, in Palm Springs, CA, in February 2019 (California American Water 2019).

Monterey Peninsula is a coastal location, similar to the City. It also has geological sedimentary formations, although not to the same extent as the WWTF site. Because the two facilities evaluated for the Monterey Peninsula have intake flow rates of 15.5 MGD (for the 6.4 MGD plant) and 24.1 MGD (for the 9.6 MGD plant), which are larger than the 1 MGD system contemplated for the City, all other conditions being the same, the unit costs for the Monterey Peninsula project would be lower than for the City. The City is more remote than the Monterey Peninsula, therefore labor and material costs at the City would likely be higher than in the Monterey area.

Scaling intake costs developed for Monterey Peninsula's intake flow rates in 2018 to a 1 MGD City intake, and adjusting by Engineering News Records (ENR) Construction Cost Index (CCI)[3] results in an approximate cost of $71 million (in 2022 dollars) for the City's subsurface intake. Given site conditions discussed above, the actual cost for a subsurface system for the City would likely be higher than this estimate.

This estimate does not account for the bluffs, the type of rock, the specific locations of the well heads or terminals.

The effluent from Blue Economy activities, treated to meet water quality standards, is assumed to be discharged with the WWTF effluent and the existing discharge pipe is assumed to be used as-is.

10.2 SURFACE WATER INTAKE WITH RAW WATER PIPE THROUGH THE BLUFFS

The Class 5 estimate for a surface water intake with the raw water pipes drilled through the bluffs and discharging into the raw water wet well is over $40 million (in 2022 dollars).

As presented in the cost breakout in Table 10-2, the cost is driven by civil work (pipe installation, raw water and effluent wet well excavation, loading and hauling excavated rock). Key assumptions include the following.

- The existing easement would be extended out so that the WWTF effluent would not recirculate to the intake. The intake would be constructed on the new section of easement. The cost of the easement is assumed to be negligible.
- The system would have dual raw water pipes so that the two screens can operate independently (100% redundancy). Each 10-inch diameter raw water pipe would consist of 800 feet installed on the seabed, 500 feet installed under the seabed, and 320 feet installed through the bluffs. A single pigging system is expected to be used for both raw water pipes.
- The raw water wet well would be 72 feet in diameter and 80 feet deep, yielding 326,000 cf of volume and 48 hours of residence time for a 1 MGD system. The raw water wet well will be lined with concrete.
- The effluent wet well would be 96 feet in diameter and 34 feet deep, yielding 246,000 cf of volume and 36 hours of residence time for a 1 MGD system. If the discharge rate is lower than the withdrawal rate, then the residence time would be longer. The effluent wet well will also be lined with concrete.

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[3] The average 2018 ENR CCI was 11,062. The August 2022 CCI was 13,171

- The system would have two brush-cleaned WWS with 1-mm slot openings and 1.75-mm wire width creating a 36 percent open area (ISI 2022). The cleaning system would be electrically driven. Screens would be constructed of 2507 super duplex stainless steel, except for the nylon brush bristles and electric motor and gearbox which would be contained in a 2507 super duplex stainless steel canister (ISI 2022). A California-approved, non-toxic foul-release coating would be applied to the internal suction pipe on each screen to reduce marine fouling (ISI 2022). Each screen motor would need 0.8 amperes and 460 volts, and is expected to operate/clean for 10 minutes each day.

- The system would have two raw water pumps to withdraw water; two more raw water pumps to pump water from the wet well to Blue Economy activities; and two effluent pumps to pump water from the effluent wet well to the discharge pipe. Each pump would be rated for 400 gpm.

- The pre-cast concrete slab that would support the screens and all offshore pipe would be installed using a barge-mounted crane and divers.

- The existing WWTF discharge pipe and diffuser would be used to discharge Blue Economy effluent. Therefore there would be minimal additional cost associated with the discharge.

- Depending on depth to rock at the intake location, pile supports may be needed.

- A new power distribution center would be needed for the intake/discharge system. Electrical wire encased in conduit would need to be run out to the intake to power the screens. A monitoring and logic system would initiate a cleaning cycle based on a timed sequence or based on exceeding a threshold pressure drop across the WWS.

- Owner's direct costs were assumed to be 10 percent.

- Given the Class 5 estimate, contingency was added at 25 percent.

- This cost estimate assumes that it is possible to install the pipelines through the bluffs, but that has not yet been determined.

Table 10-2. Surface Water Intake with Raw Water Pipe Drilled Through Bluffs.

Cost Component	2022 $M
Construction Direct Costs	
Demolition	$0.29
Civil/Sitework	$16.85
Mechanical	$0.79
Structural	$1.00
Architectural	$0.20
Electrical instrumentation and controls	$0.96
Subtotal	$20.09

Cost Component	2022 $M
Construction Indirect Costs	
Contractor site supervision	$1.27
General conditions	$1.71
General administration and profit*	$3.46
Subtotal	$6.44
Total Construction Cost	**$26.53**
Design engineering	$2.41
Permitting	$2.00
Project management (engineering)	$0.57
Owner’s costs	$3.15
Contingency	$8.66
Total Capital Cost	**$43.32**

Note: $M = millions of dollars.

10.3 SURFACE WATER INTAKE WITH RAW WATER PIPE INSTALLED ON THE BLUFFS

The Class 5 estimate for a surface water intake with the raw water pipe installed on the bluffs and discharges to the raw water wet well is approximately $18 million (in 2022 dollars). The breakout is provided in Table 10-3. Key assumptions include the following.

- The existing easement would be extended out so that the WWTF effluent would not recirculate to the intake. The intake would be constructed on the new section of easement. The cost of the easement is assumed to be negligible.

- The system would have dual raw water pipes so that the two WWS can operate independently (100% redundancy). Each 10-inch diameter raw water pipe would consist of 1,300 feet installed on the seabed, and 320 feet installed on and tethered to the bluffs. A single pigging system is expected to be used for both raw water pipes.

- The raw water wet well would be 72 feet in diameter and 20 feet deep, yielding approximately 80,000 cf of volume and 12 hours of residence time for a 1 MGD system. The raw water wet well will be lined with concrete.

- The effluent wet well would be 96 feet in diameter and 10 feet deep, yielding approximately 72,000 cf of volume and 10 hours of residence time for a 1 MGD system. If the discharge rate is lower than the withdrawal rate, then the residence time would be longer. The effluent wet well will also be lined with concrete.

- The system would have two brush-cleaned WWS with 1-mm slot openings and 1.75-mm wire width creating a 36 percent open area (ISI 2022). The cleaning system would be electrically powered and actuate automatically. Screens would be constructed of 2507 super duplex stainless steel, except for the nylon brush bristles and electric motor and gearbox which would be contained in 2507 super duplex stainless steel canister (ISI

2022). A California-approved, non-toxic foul-release coating would be applied to the internal suction pipe on each screen to reduce marine fouling (ISI 2022). Each screen motor would need 0.8 amperes and 460 volts, and is expected to operate/clean for 10 minutes each day.

- The system would have two raw water pumps to withdraw water; two more raw water pumps to pump water from the wet well to Blue Economy activities; and two effluent pumps to pump water from the wastewater wet well to the discharge pipe. Each pump would be rated for 400 gpm.
- The pre-cast concrete slab that would support the screens and all offshore pipe would be installed using a barge-mounted crane and divers.
- The existing WWTF discharge pipe and diffuser would be used to discharge Blue Economy effluent. Therefore there would be minimal additional cost associated with the discharge.
- Depending on depth to rock at the intake location, pile supports may be needed.
- A new power distribution center would be needed for the intake/discharge system. Electrical wire encased in conduit would need to be run out to the intake to power the screens. A monitoring and logic system would initiate a cleaning cycle based on a timed sequence or based on exceeding a threshold pressure drop across the WWS.
- Owner’s direct costs were assumed to be 10 percent.
- Given the Class 5 estimate, contingency was added at 25 percent.
- This cost estimate assumes that it is possible to install the pipelines on the bluffs, but that has not yet been determined.

Table 10-3. Surface Water Intake with Raw Water Pipe Installed On Bluffs.

Cost Component	2022 $M
Construction Direct Costs	
Demolition	$0.29
Civil/Sitework	$4.72
Mechanical	$0.79
Structural	$0.80
Architectural	$0.20
Electrical instrumentation and controls	$0.96
Subtotal	**$7.76**

Cost Component	2022 $M
Construction Indirect Costs	
Contractor site supervision	$0.88
General conditions	$0.98
General administration and profit*	$1.92
Subtotal	**$3.78**
Total Construction Cost	**$11.54**
Design engineering	$0.93
Permitting	$2.20
Project management (engineering)	$0.27
Owner’s costs	$1.27
Contingency	$3.51
Total Capital Cost	**$19.73**

Note: $M = millions of dollars.

11. SUMMARY

The summary of findings from this screening evaluation of intake and outfall options for the Fort Bragg Blue Economy activities is provided in Table 11-1.

Table 11-1. Summary of Findings from Screening Evaluation of Intake and Outfall Options.

Technology Option	Finding	Primary Reason
Intake Options		
Subsurface intake (any type)	To be determined	Significant uncertainty regarding water quality, ability to drill through bluffs, conductivity
Surface water shoreline intake with wedgewire screens	Infeasible	Insufficient water depth
Surface water shoreline intake with traveling water screens and fish return	Infeasible	Insufficient water depth
Surface water offshore intake within the existing easement	Likely infeasible	Potential to recirculate WWTF effluent into the intake
Surface water offshore intake within and extension of the existing easement	To be determined; likely feasible	Need to identify suitable location for intake that meets requisite criteria and avoids/minimizes recirculation of effluent
Surface water offshore intake within a new easement	To be determined; likely feasible	Need to identify suitable location for intake that meets requisite criteria and avoids/minimizes recirculation of effluent
Outfall Options		
Use of existing WWTF discharge pipe and linear diffuser	Likely feasible	Continue to monitor WWTF discharge rate and confirm capacity. Confirm that the discharge rate is trending down.
New discharge pipe and outfall within a new easement	Likely feasible	Need to identify an appropriate outfall location and easement; need to avoid recirculation of discharge into the intake.
Raw Water Pipeline Options		
Pipeline drilled through bluffs	To be determined	Need to evaluate integrity of rock and construction methods.
Pipeline installed on and tethered to bluffs	To be determined	Need to evaluate construction methods and ways to protect pipeline from the elements.

12. REFERENCES

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