Appendix 2 - AVOIDING OR MINIMIZING POTENTIAL IMPACTS OF RO DESALINATION IN SAN JUAN COUNTY[1]

by Richard R. Strathmann 24 Apr 2009

RO (Reverse Osmosis) plants pump seawater or other feed water at high pressure through permeable membranes that allow the passage of water molecules while blocking the passage of salt, other dissolved minerals, and contaminants.

Demand for desalinization plants will likely continue to grow in San Juan County. Few coastal areas in the Pacific NW have the limited supply of freshwater and proximity to seawater that occur in San Juan County.

Several potential sources of impacts on sea life from desalination plants have been identified. Minimizing those impacts will protect marine resources.

POTENTIAL SOURCES OF IMPACTS ON SEA LIFE FROM RO DESALINATION PLANTS

Potential sources of impacts from RO desal plants have been noted (Tularum & Ilahee 2007; Einav et al. 2002; Lattemann and Höpner 2008). These include:

- **Discharge of brine to receiving waters.** Water of greater density because of its greater salinity sinks below water of lower salinity. If denser, more saline water sinks to the seafloor, the denser water can, in some circumstances, form a stable pool on the seafloor that resists mixing. Decrease in oxygen and associated changes then kill marine animals and plants. Also, increased salinity affects some marine animals and plants in some circumstances.

- **Chemicals used in pre- and post-treatment of water.** Most or all future desal plants in San Juan County will not be using these chemicals (D. Drahn, A. Evers, personal communications). Here are examples of chemicals that have been used in RO desal plants (not necessarily in the County) to overcome chemical scaling from impurities in the water and biological growth and clogging of the membranes in an RO plant. Chemicals such as sodium hypochlorite or chlorine prevents growth of organisms; ferric or aluminum chloride may be added for flocculation to form larger masses that are easier to remove by filters and removal of suspended matter; sulfuric or

[1] This footnote was provided by Mike Kaill of Friday Harbor: *Richard has addressed the issues that are of concern to me. The only thing I might add is to assure that permit review, including consistent and knowledgeable application of such policy as may develop out of this effort be carefully done. -MK*

hydrochloric acid may be added for pH adjustment; sodium bisulfite to neutralize remaining chlorine; polymaleic acid and phosphonates are typical scale inhibitors. Chemicals are also used in cleaning membranes (which can be enzymes to remove bacterial slimes, detergents, biocides to kill bacteria, chelators such as EDTA to remove scale, acids to dissolve inorganics, and caustics to dissolve organic material and silica). With on site cleaning, most of the cleaning chemicals are washed into the brine that is discharged into the marine environment. **Discharge of brine to receiving waters.** Water of greater density because of its greater salinity sinks below water of lower salinity. If denser, more saline water sinks to the seafloor, the denser water can, in some circumstances, form a stable pool on the seafloor that resists mixing. Decrease in oxygen and associated changes then kill marine animals and plants. Also, increased salinity affects some marine animals and plants in some circumstances.

- I**mpingement (**marine animals killed or injured as they collide with screens at the intake)

- **Entrainment** (marine life sucked into the system with seawater)

- **Noise from pumps**

- **Energy** required for generating the pressure differences required for desalination by reverse osmosis

- **Leaking of brine from pipes or other spills on land into groundwater**

- I**nstallation of the desal plant near the shoreline**, including potential impacts from impervious surfaces and removal of vegetation near the shoreline for a building housing equipment or a road to access the site

- **Other impacts of development or water intensive uses** in areas that otherwise could not support them

EXAMPLES OF OBSERVED IMPACTS AND NON-IMPACTS OF RO DESALINATION PLANTS ON SEA LIFE

Large desal plants elsewhere

The studies of marine impacts found in a literature search were for RO desalination plants that discharge larger volumes of brine at higher salinities than those in San Juan County. A study in Spain tracked substitution of an assemblage of animals characterized by Polychaeta, Crustacea, and Mollusca for another dominated by nematodes (Del Pilar Ruso et al. 2007). The plant was large with initially a high salinity (68 parts per thousand) and discharge of 65,000 m^3 per day. The changes were correlated with greater salinities near the discharge and also with differences in organic matter, depth, and sediment sizes. They also found changes in abundances of polychaetes (a group of animals living in and on the sea floor sediments) (Del Pilar Ruso et al. 2008). At the site of another large plant in the Canary Islands (discharge of 17,000 m^3/day of water of 90 parts per thousand salinity), a seagrass was less abundant near the outfall (Pérez Talavera and Quesada Ruiz 2001).

However, at another site in Spain with discharge of high salinity (60 parts per thousand) water, there was no detectable effect on benthic animals or fishes, and the lack of detectable effect was attributed to rapid dilution of discharged brine and high variability of abundances in the habitat (Raventos et al. 2006).

Limited information from sites and RO plants like those in San Juan County

Studies for a marine biota more similar to that in San Juan County and for smaller desalination plants with discharges at lower salinity, like those presently in San Juan County, would be useful. A literature search has thus far revealed no similarly detailed studies from desalination plants in California or from small desalination plants. Ideally such studies would include before and after sampling at control and impact sites. Megan Dethier (unpublished observation) found no apparent change in sea life on rocks near a desalination plant outfall on Haro Strait, where tidal currents are fast and mixing is rapid.

Two studies in the San Juan Islands, following installation of desalination plants, indicated rapid mixing of water near the discharge pipes. In each case salinities were reduced to concentrations near or not detectably different from that of the surrounding water within a few feet of the discharge pipe. A discharge into Griffin Bay near San Juan Island is described in Mayo (2009, Appendix 4, communicated by Dan Drahn and Chris Betcher). The mixing occurred in slow currents (speeds of 0 to 3 feet per minute). The volume flow of discharged water was unstated. At a discharge into Lopez Sound, measurements indicated rapid mixing to salinities near that of the receiving water but the volume flow of effluent and the current velocities in the receiving water were unstated (Andrew Evers, personal communication).

Ongoing modeling of mixing of discharged water may provide improved predictions of mixing of discharged water under a range of conditions (Dan Drahn and Tom Boydston, personal communication).

The sites expected to be most vulnerable to impacts from small desalination plants are sheltered bays in which currents and mixing are slow, especially those with basins that could accumulate sinking effluent water. In such cases the effect of denser (higher salinity) water on mixing of water near the seafloor would be the possible source of impacts on sea life. Small bays with low flushing would also be the sites where volume pumped could remove a greater proportion of slow swimming planktonic animals.

No studies of effects or lack of effects of desalination plant discharges on juvenile salmon or other fish moving along shore were found in a literature search. In the study by Raventos et al. (2006), some fish, instead of avoiding the discharge site, aggregated near the discharge pipe, as can happen at artificial reefs where there are no natural rock reefs. In a laboratory study with artificial seawater, Iso et al. (1994) observed that juvenile sea bream spent less time in water at high salinities, but the salinities with this effect were very high, with avoidance at 45 ppt salinity.

AVOIDING OR MINIMIZING IMPACTS IN THE SAN JUAN ISLANDS

Mixing at outfalls:

Impacts from effluent water from desalination plants are expected to be reduced where the brine is rapidly dispersed by currents or waves and greater in environments where mixing is slow (Höpner and Windelberg 1996; Höpner 1999; Lattemann and Höpner 2008).

The plants and animals in the San Juan Islands are likely to tolerate the increased salinities observed near outfalls of small desalination plants after some mixing has occurred. Salinities in the waters of the San Juan Islands commonly vary by several parts per thousand.

Pooling of denser water at the seafloor is most likely to occur where discharges are into sheltered bays where currents are often slow and into basins that would retain denser water. If, even with mixing, the water was dense enough to sink to the sea floor and form a stable layer that retards further mixing, then the impacts on sea life would be substantial. Bottom water and sediments would become hypoxic or anoxic. This situation occurs naturally in some basins, such as Saanich Inlet, where less saline water overlies more saline water.

However, for a small desal plant, pumping about 50,000 gallons per day and with brine mixed to within one part per thousand close to the outfall, under most circumstances the currents from tides and winds are expected to be adequate to further mix the water. A total capacity of 50,000 gallons per day is a small fraction of the volume at low tide in many of the bays. The vertical salinity difference would be within the range that commonly occurs with lowered surface salinities from freshwater runoff. Impacts may be more substantial in small bays in which discharged water could enter a basin. For such situations, additional useful studies would include direct observations of the movement of the discharged plume of mixing water under a variety of current conditions, with known rates of discharge and measured salinities of discharged and receiving water. The discharged water could be marked by a dye such as fluorescein mixed with the brine. This dyed discharge plume would indicate whether or not the mixing effluent water was sinking to the seafloor.

There may be information on currents sufficient to overcome density gradients by mixing in the kinds of small bays in the San Juan Islands with the kinds of salinity differences that have been observed near outfalls. Additional information may be available because common sources of density stratification are freshwater in flow and surface warming.

Where accumulation of denser, more saline water near the seafloor is suspected, monitoring of oxygen and pH (acidity) are indications of impacts from reduced mixing. Monitoring sulfide in sediments could reveal a history of low oxygen. Sediment cores could show the level at which black anoxic sediment occurs.

Design of effluent pipes varies. In some plants the intake and discharge pipes are designed with intake screened to exclude organisms and discharge pipe configured solely to enhance mixing. In other systems, intake and discharge are switched at intervals to avoid fouling of pipes, and both then have similar screens. A comparison of mixing with these two arrangements and demonstration of best design for each will help to minimize impacts.

While uncertainty about mixing and sinking of water remains, impacts could be avoided by not sitting outfalls in waters with slow currents and with basins in which denser water could accumulate. Such sites could be identified and listed. Locating an outfall in such an area could require demonstration that mixing effluent water does not sink even when currents are slowest and mixing least.

Impingement and entrainment of marine animals:

Slow moving marine animals are killed when they are sucked against a filtering screen at the intake or sucked into a desalination plant with the seawater. A present standard for an intake is a screen size less than 1/8” to exclude larger organisms (D. Drahn, personal communication). A screen of this size excludes juvenile fish but not small larvae, like those of clams, mussels, oysters, and sea urchins.

The capacity of 12 desalination plants in San Juan County is 124,000 gallons per day (Mayo 2009, Table 5). That amount of freshwater is expected to require a 4 to 1 ratio of seawater to freshwater (Mayo, personal communication) and thus pumping of about 496,000 gallons per day of seawater (2456 cubic yards). Measured face velocities at several intake screens were approximately 0.1 feet per second (Mayo 2009), which is about 3 centimeters per second. Many small larvae (of sea urchins, clams, mussels, oysters, some crustaceans, etc.) do not swim that fast. (F.-S. Chia, et al. 1984). If this face velocity is representative, at full capacity slow swimming animals would be removed from a volume equal to about 1.4 miles by 1 square yard each day. Average production is about 1/5 of this volume flow (R. Mayo, personal communication).

However, as a proportion of a local population, losses from impingement and entrainment are expected to be low if the volume pumped is a small fraction of the volume of a bay. For many bays, the proportion of water pumped is low, even with a low rate of flushing. As an example, 50,000 gallons per day is about 250 cubic yards per day; soundings and area from a chart indicate about 500,000 cubic yards at low tide in Mitchell Bay. In three weeks, the volume of water pumped would be equivalent to about 1% of the volume of the bay. The small expected effect depends on scale. If desalination capacity were greatly increased within a small bay in which larvae were retained, then losses from impingement and entrainment could impact animals within that bay.

Intakes below the sediment surface have been recommended as a means of avoiding impingement and entrainment of animals, but mussels have settled within a system supplied by in this manner (Andrew Evers, personal communication), which indicates that larvae were drawn into the gravel used as a filter.

The first stage filters in an RO desalination plant are back flushed to clear the filter (D. Drahn and Tom Boydston, personal communication). A filter of 20 to 25 microns excludes animal embryos and larvae. Few planktonic eggs are less than 50 microns. Those that survive the impingement between flushings of the filter would be returned to the plankton. A study could demonstrate survival and mortality of small animals caught on the filter and then washed away when the filter is flushed. Survival presumably depends on the type of filter, frequency of back flushing, and swimming speeds and vulnerability of small animals.

Inclusion in permit applications of face velocity at filters and a calculation of volume pumped at capacity relative to volume of an embayment would give one indication of probable losses from impingement and entrainment.

Energy use:

Ron Mayo (personal communication) gives the energy requirements for three desalination plants on San Juan Island as 38, 29, and 26 gallons per kilowatt hour. If production were at the current capacity of 124,000 gallons per day for the 12 desalination plants in San Juan County and at 30 gallons/kWh, then production would require 4133 kilowatt hours daily, which is about 0.7% of the 560,000 kWh per day average energy consumption in San Juan County. The average production is much less than full capacity: 23,500 gallons per day with an energy requirement of about 800 kWh per day. Additional desalination capacity will increase energy demand, as will other development in the County. Ron Mayo (pers. comm.) estimates the present energy use for desalination in the County as equivalent to the energy use of 15 housing units. Another way of estimating energy for desalination is from the 16 connections, 5500 gal/day (summer), 3000 gal/day (other seasons), and 38 gal/kWh for desalination at Cattle Point, and the 50.7 kWh/day per average household in the County (Ron Mayo 2009, Table 6, and personal communication). From these estimates, desalination would be 4.8% of an average household's energy use. These estimates could be improved for accuracy, by including other desalination plants, and by comparison with costs for water from other sources, such as wells, cisterns, or hauling.

Chemicals used in operation:

Lattemann and Höpner (2008) say that various metals from corrosion are in low concentrations and that dechlorination with sodium bisulfite is done to protect membranes. They nevertheless mention discharge of chemicals used in cleaning as potentially harmful to aquatic life.

Information from the operators of desalination plants in San Juan County is that most, possibly all, future desal plants in the County will not be using these chemicals. Most small RO plant operators replace membranes or send them away to be cleaned.
There are several procedures that can minimize impacts of cleaning chemicals.
(1) Off-site cleaning of membranes could be required.
(2) If there is on-site cleaning, a requirement for chemicals used in cleaning to be known to be harmless.

Of chemicals used for cleaning membranes, acid and alkaline treatments (low and high pH) can be rendered not toxic from pH effects if pH is subsequently adjusted before the cleaners are discharged, but some cleaners are proprietary mixes of unknown composition. The second requirement would eliminate on site use of proprietary cleaners of unknown composition. Operators prefer hydrochoric acid to sulfuric acid because it is gentler on equipment and because the chloride present after neutralizing the acid is already present in seawater at a high concentration (D. Drahn, personal communication).

The MSDS (material safety data sheet) for polymaleic acid (a scale inhibitor) says that it is no more than slightly toxic if absorbed or swallowed, that it is moderately irritating to eyes and skin, and that significant health effects are not expected if less than a mouthful is swallowed (indicating low toxicity for this scale inhibitor).

Some cleaners also occur in household products. These are enzymes that remove bacterial slimes, biocides that kill bacteria, and detergents. These cleaners are therefore part of a more extensive environmental and regulatory issue. Quantities used in desal plants could be evaluated in relation to quantities entering the sea from other sources and any effects from those other sources.

The EDTA that removes scale occurs in household products. It is a chelator of divalent positive ions. EDTA is a component of algal culture medium and thus is introduced to cultures of marine larvae at low concentrations with no known ill effects. The MSDS indicates (for health effects) that EDTA is a mild irritant.

Flocculents are generally used in very large plants that remove the material and dispose of it in land fills (D. Drahn, personal communication).

(3) Latteman and Höpner (2008) suggest prefiltration, and UV disinfection as means of reducing the need for chemical treatments.

Subsurface sources of water, such a beach wells, have also been recommended as means of reducing chemical treatments (Campbell and Jones 2005). However, beach wells are not a possibility on all shores and require more extensive disturbance to the sea floor during construction.

There is also a "pickling" process for keeping membranes when they are not in use. The chemical is sodium metabisulfite and may not present problems of toxicity in the concentrations discharged. The MSDS for sodium metabisulfite indicates irritation to eyes or skin and recommends dilution as the treatment, with no known or anticipated mutagenic effect. Toxicity at low concentrations is not expected.

Operators and installers of desalination plants in San Juan County can provide advice on practical means of minimizing impacts from chemicals used with desalination plants. A recommendation for minimizing marine impacts is that sodium metabisulfite solutions be allowed as a membrane preservative and that no other chemical additions be allowed without submittals and evaluation (D. Drahn, personal communication). A potential problem with permitting on-site cleaning is the difficulty of assuring proper disposal of cleaning chemicals.

Salt-water leaks on land:

Leaks of seawater on land can be prevented by
(1) use of pipes unlikely to fail, such as high density polyethylene pipes and
(2) a design for buildings so that overflows or spills within the building goes into a drain that leads to the effluent outflow pipe.
The polyethylene pipe for the FHL seawater system has been in use for many years without a break in the pipe. The spills that have occurred were because of design features that can be avoided in desal plants. Also, RO desalination is often installed where it is intended to halt the intrusion of freshwater into groundwater that can be associated with withdrawal of water from wells.

Impervious surfaces and other impacts of construction near shorelines:

Design, siting, and construction are or can be under the regulations for other shoreline development.

Noise from pumps:

If standards for acceptable sound levels exist in the county, they presumably apply to desalination plants as they do to other facilities.

Cumulative impacts

One difficulty in detecting impacts of desal plants in San Juan County is that the plants are small but will likely be numerous. Thus impacts may be cumulative but not large at any one site. Minimizing reliance on desalination for water supplies until more experience is gained on impacts (or lack of impacts) for sea life is one way to avoid undesired impacts.

Also, this discussion has addressed potential impacts of small desalination plants, not larger desalination plants, as might be anticipated for towns like Friday Harbor or East Sound.

Permit review:

Marine impacts could be reduced by changes in the criteria for permit review.

Permit applications in San Juan County have included data on currents distant from and quite different from the site of the desalination plant outfall. The County review process does not appear to consider the impacts that could occur where currents are slow and where basins could accumulate denser water. Also, developments in the County may still be permitted where water supplies are uncertain and later application for RO desalination likely.

Criteria for sites of outfalls and other best practices that would guide applicants for desal plants and review of applications would be useful. Such information is available for other kinds of shoreline development. Criteria for best practices could minimize impacts by guiding design, construction, and operation.

Threshold volumes could be stated such that above a given capacity and recovery rate of the desal plant additional analysis of marine impacts would be required to inform a decision on the permit application.

Also, sites in bays with slow currents and basins could be identified as sites at which a permit would not be issued before a site-specific study indicated that there would be adequate mixing and no accumulation of denser water at the sea floor.

Characteristics of existing desal plants in the county that are in Table 5 of Mayo (2009) include
on or off-site membrane cleaning,
type of intake, capacity,
type of effluent discharge.

This information on proposed plants may already be required for permits, but in any case this information should be included along with
volume of brine to be discharged per time,
salinity of the brine produced at the outfall,
useful detail on the characteristics of intake screens or filters and their flushing,
the type and position of the diffuser at the outfall,
so far as available, information on bottom topography and currents at the outfall.
Reported currents should be relevant to the outfall site and include currents at times of slack water on calm days.

A general requirement after installation could be measurement of salinities at and near the outfall when currents in the receiving water are minimal to assess mixing of discharged water. That would create a data base that would aid improved design for outfalls from future desal plants.

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LOPEZ WATER LLC

This facility went into service in the summer of 2007, initially serving 2 connections. The RO system has a nominal capacity of 14,400 gpd (10 gpm). The current service area is property owned by the Bumstead family. Planning is based on the eventual expansion to surrounding properties.

The system consists of two (2) 2" HDPE pipes constructed in the Lopez Sound tidal zone for seawater intake and salt water reject. Each of the HDPE pipes is 450 feet long extending to the marine water. A 2" perforated HDPE pipe is provided at the ends of the 2" HDPE pipes for seawater intake and salt water reject dispersion in the sea. The perforated pipe (a 4 foot length of a 3"+ well screen) is elevated 30 inches above the sea bottom.

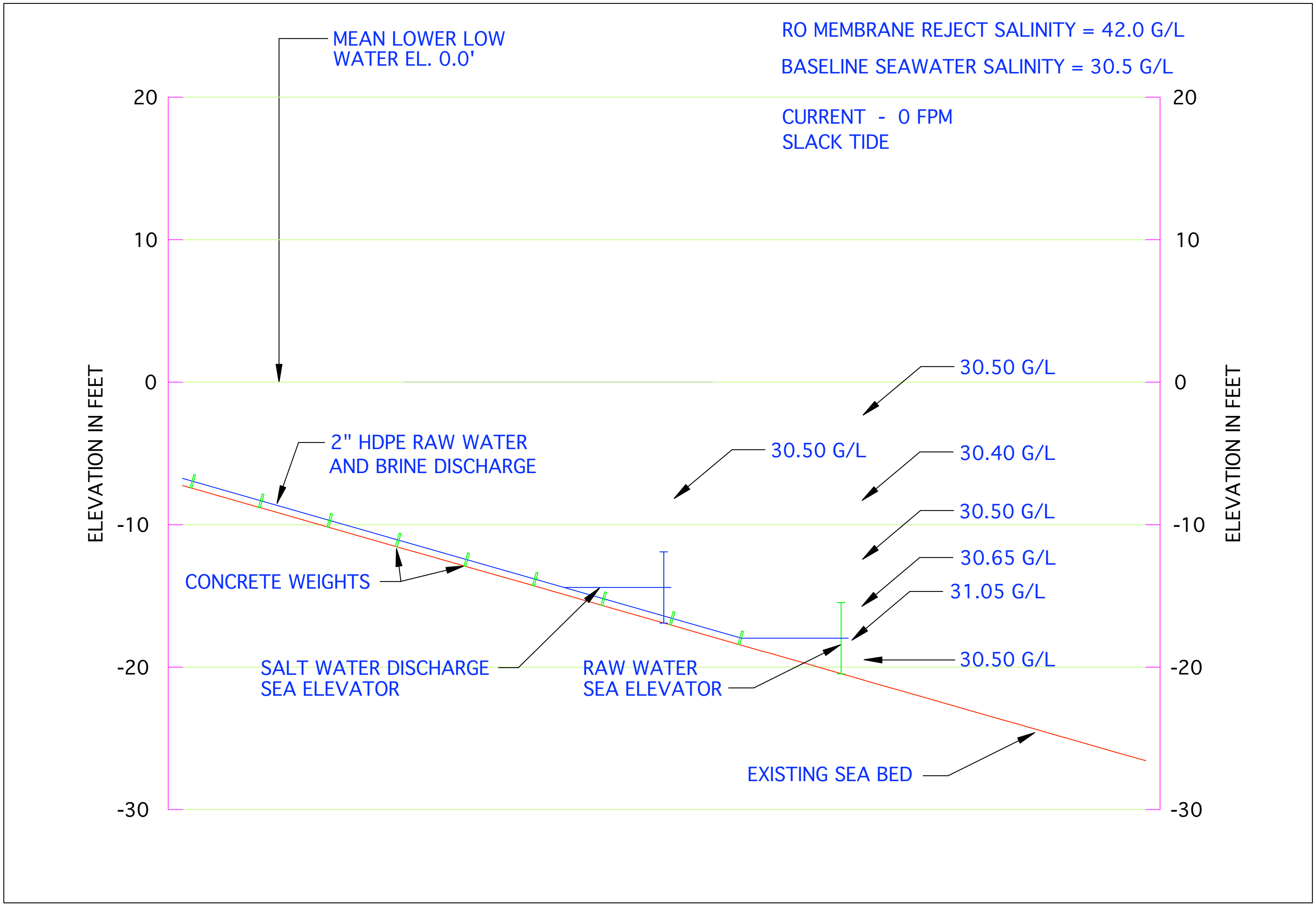
Seawater is pumped to an upland building in which the RO desalination water system is installed. The seawater pump is in a dry pit on shore. 40 gpm of seawater is pumped to the RO desalination water system, 10 gpm of potable water is produced from the seawater, and 30 gpm of salty reject water is returned to Lopez Sound via the 2" HDPE discharge pipe.

A recent series of test produced these measurements: (see following attached drawing)

Salinity of water column (ave. 4 samples)	30.5 g/L
Salinity of reject flow at RO Plant (1 sample)	42.0 g/L
Salinity at outfall screen of reject (ave. 4 samples)	31.05 g/L
Salinity of reject 18" down current (ave. 4 samples)	30.65 g/L

The RO plant operates year around. It is the only source of water for the family compound.

The Approximate Capital Cost of RO Plant is $300,000 includes construction, design and permitting costs - built 2006.



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By: evers

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Watek
4489 Mud Bay Rd
Lopez, WA U.S.A.
98261
Tel. 360.468.4272
Fax. 360.468.4272
www.watekwater.com

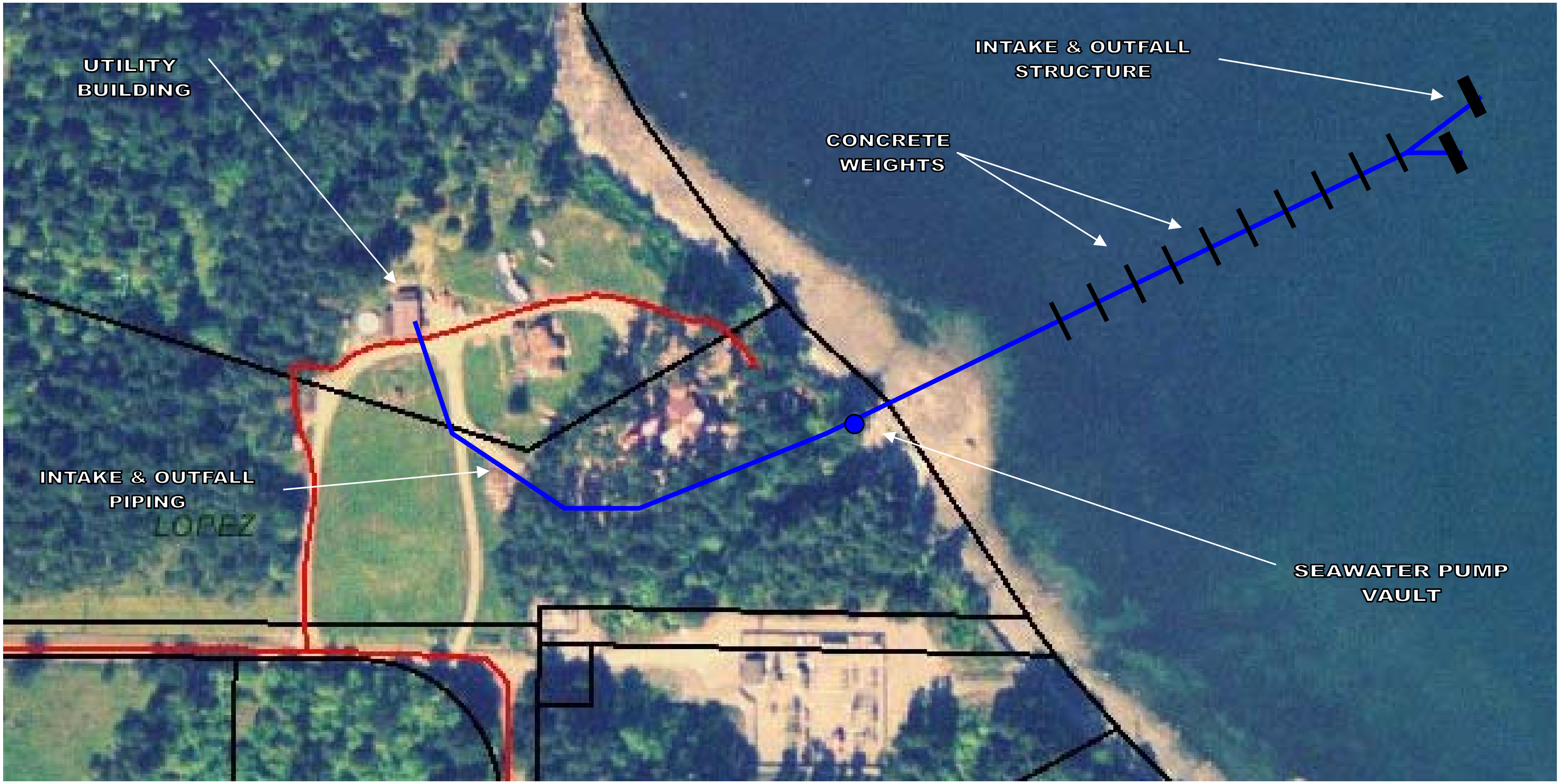
Client / Project
LOPEZ WATER
LOPEZ ISLAND
RO DESALINATION PROJECT

Figure No.
FIGURE 1 OF 1

Title
LOPEZ WATER
OUTFALL

WATEK

LOPEZ WATER DESALINATION SCHEMATIC



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