3 Zero Liquid Discharge

Zero Liquid Discharge refers to processes that fully removes water from the concentrate stream (in other words, no liquid is left in the discharge). The end product of a ZLD system is a solid residue of precipitate salts that needs to be transferred to an appropriate solid waste disposal facility, such as a landfill. Toxicity tests and other applicable tests will determine the type of the landfill (municipal solids waste landfill versus hazardous waste landfill) that can handle the ultimate disposal of the solid residue. ZLD systems range from less complex/technological (that is, natural treatment systems) to highly complex/technological (that is, complex mechanical processes) solutions.

ZLD systems include:

- Combination Thermal Process with Zero Liquid Discharge
- Mechanical and Thermal Evaporation ZLD
- Enhanced Membrane and Thermal ZLD
- Evaporation Ponds
- Wind-Aided Intensified Evaporation (WAIV)
- Dewvaporation
- Salt Solidification and Sequestration

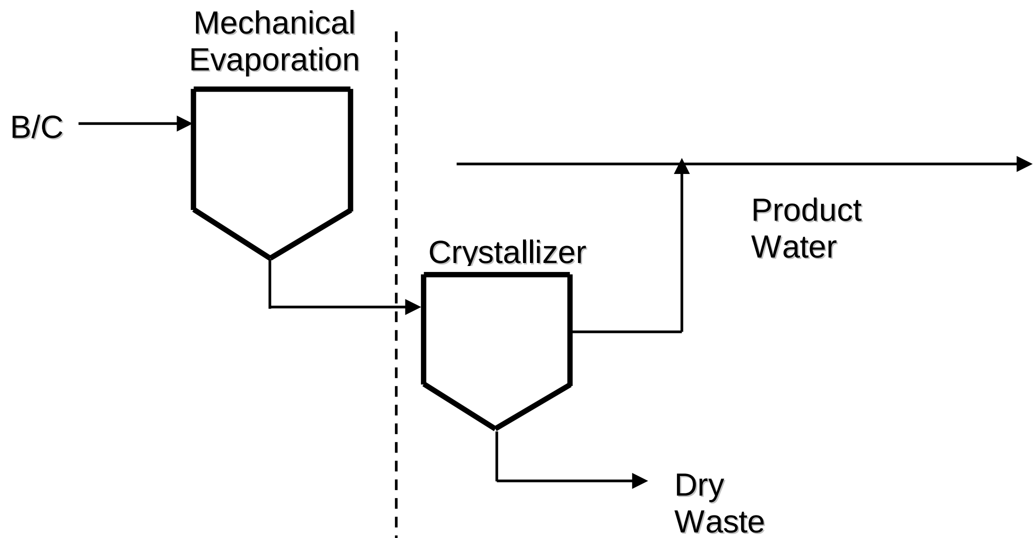
Technologies used in conventional ZLD systems include the use of evaporators and brine crystallizers to completely separate dissolved salts from the water. These technologies are relatively complex and energy intensive. Several ZLD technologies have been successfully implemented for industrial water treatment; however, the ZLD concept is new when applied to treatment and disposal of concentrate from large-scale RO systems. WAIV, Dewvaporation, and Salt Solidification and Sequestration are developmental ZLD technologies.

Permit requirements are minimal for operation of solids residual-producing process equipment for membrane concentrate disposal and are similar to requirements for implementing wastewater treatment processes. However, some public health and ecosystem health concerns exist for regulations governing brine concentrate management using solids residual producing processes. Public health concerns include protection of groundwater and other potable water supply sources. Ecosystem health concerns include protection of wildlife from constituents of concern at evaporation ponds.

3.1 Combination Thermal Process with Zero Liquid Discharge

Combination thermal process ZLD systems combine mechanical or thermal evaporation for volume reduction with crystallization to produce a dry waste. Figure 3.1 presents a schematic of a combination thermal ZLD process. This section will describe the different components of a combination thermal ZLD system.

FIGURE 3.1 COMBINATION THERMAL PROCESS WITH ZERO LIQUID DISCHARGE SYSTEM SCHEMATIC



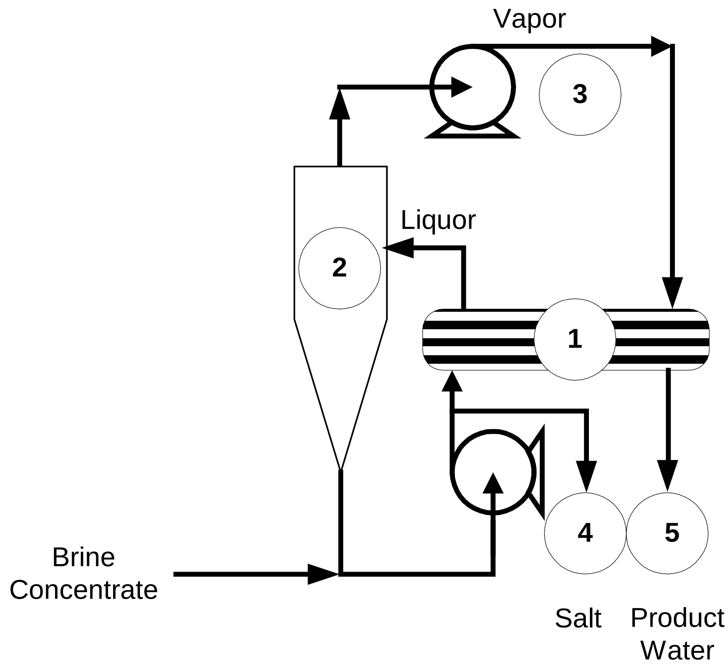
3.1.1 Mechanical and Thermal Evaporation

MTE portion of Combination Thermal Process ZLD was covered in Section 2.5.

3.1.2 Crystallizer

Crystallization is a mechanical evaporation process that uses heat to transform the concentrate waste slurry from the evaporator into purified distillate and a solid product. Crystallizer feed is typically a concentrate stream, which has undergone volume reduction and has a Total Solids (TS) concentration of about 200,000 to 300,000 mg/L. Figure 3.2 displays the process flow diagram for a typical forced circulation crystallizer (FCC).

FIGURE 3.2 FORCED CIRCULATION CRYSTALLIZER PROCESS FLOW DIAGRAM



Note: Numbers correspond with descriptions in text.

The following steps correspond to the numbers in the figure and describe the process flow steps.

1. The 20 to 30 percent concentrate is recirculated through a heat exchanger, where compressed and desuperheated steam heats the brine above its boiling point at atmospheric pressure as the steam condenses on the outsides of the tubes.
2. The heated concentrate then enters a separator chamber (vapor body or flash tank), operating at a slightly lower pressure, resulting in flash evaporation of water, and formation of insoluble salt crystals in the concentrate.
3. The vapor passes through mist eliminators and enters the vapor compressor, which heats the vapor. Compressed vapor is desuperheated with hot distillate and flows to the outside of the heat-transfer tubes, heating the recirculated concentrate that flows inside the heat-transfer tubes. Mechanical compressors are used in most wastewater crystallizer applications. The mechanical vapor compressor is responsible for about 80 percent of the ~250-kWh energy usage per 1,000 gallons of FCC feed.
4. From 1 to 5 percent of the concentrate/crystal liquor is wasted to separate the insoluble salt from the liquor. Typically, salt crystals are separated from the liquor with a centrifuge or filter press. Salt can be disposed of in a landfill, and concentrate or filtrate can be returned to the FCC feed tank.
5. Total recovery of product water across the crystallizer is between 95 and 99 percent. The condensate can be delivered as distillate water, make-up water, or a blend with RO product water.

FCCs are used directly with high recovery RO reject or in combination with brine concentrators to create a dry salt waste and a high-quality product water. Crystallizers are a proven technology for commercial production of salt. They have more recently been applied to mixed salt waste streams from RO and mechanical evaporation systems and in this application, have a small site footprint. However, crystallizers are mechanically complex and have high capital and O&M costs (primarily energy costs). In addition, crystallizers could pose aesthetic issues associated with the vertical profile, although they are shorter than vertical tube, falling film evaporators.

Advantages associated with FCCs include:

- Proven history of use in industrial applications
- High-quality product water
- Small site footprint when used for waste stream applications

Disadvantages associated with FCCs include:

- High capital and O&M costs (primarily energy costs)
- May require frequent cleaning when used for complex salt waste streams.
- Mechanically complex
- Potential aesthetic issues associated with vertical profile

Estimated capital costs for an FCC unit are summarized in Table 3.1. Capital cost estimates are based on vendor data for the FCC produced by GE-Ionics. Capital costs for a 1-mgd FCC unit are approximately $17.7 million.

TABLE 3.1
FCC CAPITAL COST MATRIX

	0.2 mgd	1.0 mgd	5.0 mgd
Total Capital Cost Including Equipment Installation , $	**$6,170,000**	**$20,681,000**	**$59,826,000**

Note:

Capital costs for 0.2-mgd system is according to BBARWA, 2006. Cost for other flow rates were estimated using the following formula:

Cost 2=(Flow 2/Flow 1)^0.66*Cost 1. (Flow 1 is 0.2 mgd).

Table 3.2 provides O&M cost estimates for FCC. O&M costs include power, labor, chemicals, maintenance and replacement costs for key equipment components (i.e., vapor compressor). These estimates were provided by GE-Ionics and are based on a 1-mgd feed flow.

TABLE 3.2
FCC OPERATION AND MAINTENANCE COSTS

Component	O&M Cost, $/year
Power	$4,844,000
Parts	$1,035,000
Chemicals	$282,000
Maintenance	$621,000
Labor	$225,000
Total O&M Cost, $/year	**$7,007,000**

3.1.3 Combination Thermal Process ZLD Systems

The most common ZLD setup is a vertical-tube falling-film with vapor compression evaporation followed by an FCC. The salt waste or dry concentrate from the process is ultimately transferred to a landfill for final disposal. Advantages and disadvantages of combined thermal ZLD systems are similar to those discussed for mechanical evaporation and crystallizers. Combined thermal ZLD systems can handle a wide range of feedwater compositions while producing high-quality product water. Combined thermal ZLD systems commonly have been used in industrial applications. Major disadvantages of these systems are high capital and O&M costs, the mechanical complexity associated with the combined systems, and the need for more frequent cleaning of the FCC unit. The high O&M costs are driven by the amount of energy required to run a combined thermal ZLD system. Other disadvantages include the height of the separator chamber (flash tank or vapor body) profile, which might be limited by local regulations or aesthetics.

Capital costs for combined thermal ZLD were provided by Ionics and are tabulated in Table 3.3. Capital costs for a combined thermal ZLD unit are approximately $21 million. This cost is based on a system with a 1-mgd evaporator and a 0.05-mgd crystallizer.

TABLE 3.3
CONVENTIONAL ZLD CAPITAL COST

	Cost
MTE Capital Cost (1 mgd), $	17,698,000
FCC Capital Cost (0.05 mgd), $	2,864,000
Total Capital Cost for Conventional ZLD, $	**20,562,000**

O&M costs for combination thermal process ZLD are high due the energy usage of the systems components. Table 3.4 summarizes the O&M costs for a combined thermal ZLD facility with 1-mgd of feedwater flow to the evaporator and 0.05-mgd flow of concentrate slurry to crystallizer. The projected annual O&M costs are approximately $6.3 million and are predominantly energy costs.

TABLE 3.4
FCC OPERATION AND MAINTENANCE COSTS

Component	MTE O&M Cost, $/year	FCC O&M Cost, $/year	Conventional ZLD O&M Cost, $/year
Power	$4,000,000	$243,000	$4,243,000
Parts	$885,000	$144,000	$1,029,000
Chemicals	$250,000	$15,000	$265,000
Maintenance	$531,000	$86,000	$617,000
Labor	$180,000		$180,000
Total O&M Cost, $/year	**$5,846,000**	**$488,000**	**$6,334,000**

3.2 Enhanced Membrane and Thermal System ZLD

The Enhanced Membrane and Thermal System ZLD system combines EMS with thermal-driven crystallization to produce a dry waste. The EMS utilizes IX softening of membrane reject to prevent scaling and operates a three-stage RO system at a high pH to reduce the amount of concentrate produced. Following the EMS process, a thermal-driven crystallizer is used to produce a dry waste for disposal.

Advantages and disadvantages of the Enhanced Membrane and Thermal System ZLD are similar to EMS and crystallizers. This type of ZLD system is a proven technology for industrial brine concentrate management high in silica that requires high-quality product water. However, this system is complex to operate and has high capital and O&M costs. In addition, this technology may require a precipitative process to be used in place of IX for some waters.

Cost data are not available. However, the capital costs are expected to be similar to the combined thermal ZLD.

3.3 Evaporation Ponds

Evaporation ponds rely on solar energy to evaporate water from the concentrate, leaving behind precipitated salts, which are periodically collected and disposed of in landfills. Evaporation ponds are most efficient in arid and semi-arid climates where high net evaporation rates are the norm. Evaporation rates can be enhanced by providing a larger evaporative surface. One option is to include mechanical misting equipment that sprays the concentrate into the air in tiny droplets. However, misting is controversial because fine mist and dry salt particles can leave the site as drift, creating a secondary nuisance.

Evaporation ponds rely on solar energy to evaporate water from the membrane concentrate stream, leaving behind precipitated salts, which ultimately are disposed of in a landfill. Evaporation ponds are optimal in arid climates with high net evaporation rates, which decreases the pond area required, compared to humid climates with low net evaporation rates. The practicality of evaporation ponds is not limited by concentrate quality.

In the most common case, concentrate is conveyed to evaporation ponds where it is spread over a large area and allowed to evaporate. Multiple ponds are constructed to allow continued receipt of concentrate when a pond is taken offline for periodic maintenance. Periodic maintenance includes allowing the evaporation pond to be idle to desiccate the precipitated salts. When the precipitated salts have reached a satisfactory consistency, the precipitated salts are removed from the ponds and transported to a landfill for ultimate disposal.

The evaporation ponds must be lined appropriately to prevent percolation of reject water into the groundwater table, which could affect a USDW. The material and thickness of the liner must be selected appropriately because increased salt content could cause the liners to deteriorate.

Factors affecting the feasibility of implementing evaporation ponds for disposal of RO concentrate include the flow rate of the RO concentrate, and the geographical location and specific site location of a prospective evaporation pond. The flow rate of the RO concentrate is the primary factor affecting the area required for the evaporation ponds. The greater the flow rate of RO concentrates, the larger the area required for evaporation ponds. An estimate of the pond area required should take into account the reduced evaporation rate of a brine solution compared to typical lower-TDS water and the lower “lake” evaporation rate compared to the “pan” evaporation rate. A general guideline is to apply a factor of 0.7 to the pan evaporation rates shown in Table 3.5.

For example, an evaporation pond for 1 mgd of concentrate flow with a TDS concentration of 8,000 mg/L constructed at a site with a net evaporation rate of 90 inches per year is about 220 acres. The actual pond area constructed should be greater than the 220 acre minimum pond area required to allow for standby area that would be put into service when other ponds are being cleaned and to accommodate reduced evaporation as salinity increases. As a general guideline, an allowance of 20 percent should be added for construction of dikes to contain the brine concentrate and service roads.

TABLE 3.5
AVERAGE SEASONAL AND ANNUAL CLASS-A PAN EVAPORATION

Station	May-Oct	Nov-Apr	Annual	Beginning of Record	Latest Data
	in	in	in	mo/yr	mo/yr
Arvin-Edison Water Storage District	66.2	21.3	87.5	Mar-67	Dec-77
Backus Ranch	85.6	30.5	116.1	Jun-36	Jun-62
Baldwin Park	40.9	18.5	59.5	Jul-32	Dec-53
Beaumont Pumping Plant	49.7	23.0	73.0	Jan-55	Sep-75
Casitas Dam	40.2	20.3	60.5	Sep-59	Sep-77
Castaic Dam Headquarters	51.8	29.0	81.0	Jun-68	Dec-78
Chula Vista	39.7	23.6	63.4	18-Sep	Dec-79
Fullerton Airport	41.9	21.9	63.9	Jan-35	May-77
Henshaw Reservoir	49.4	18.5	67.9	Jul-59	Apr-79
Huntington Beach – Heil	39.6	18.1	57.6	Sep-34	Dec-45
Irvine Co Automatic	38.0	20.9	58.8	Feb-46	Jun-72
Lake Bard	49.0	33.0	82.0	Mar-67	Sep-77
Mockingbird Reservoir	34.3	20.8	55.0	Jul-41	Feb-79
Perris Reservoir Evaporation	60.4	27.0	87.4	Dec-63	Jan-79
Prado Dam	50.6	25.4	76.0	30-Jul	Jan-69
Riverside Citrus Experimental Station	46.7	22.7	69.4	25-Jan	Apr-78
San Bernardino Flood Control	52.2	23.8	76.0	Jun-59	Oct-73
San Jacinto Reservoir Municipal Water District	58.4	23.7	82.1	Jul-39	Sep-71
Silver Lake Reservoir	42.8	23.0	65.8	Jan-52	Dec-67
Tujunga Spreading Grounds – Evaporation	48.6	26.2	74.8	Dec-32	Dec-44
Vail Lake – United States Geographical Survey	54.6	25.9	80.5	Apr-52	Jun-76
Van Nuys Flood Control 15B	25.9	11.8	37.7	Jan-30	Jul-48

Notes:
These values represent the sum of the monthly means.

Advantages associated with evaporation ponds include:

- Proven in industrial and wastewater applications
- Simple, low-technology solution
- Insensitive to energy costs (not withstanding cost of conveyance to ponds)

Disadvantages associated with evaporation ponds include:

- Implementation of evaporation ponds is sensitive to land costs.
- Liners are required to prevent seepage.
- Evaporation ponds are sensitive to climate (that is, they are most effective in arid climates with high evaporation rates).
- Potential regulatory and environmental/habitat issues exist due to accumulation and concentration of micropollutants
- Residuals have to be disposed of in landfills during periodic maintenance

Evaporation ponds must be lined to prevent seepage into the groundwater, or the ponds would be considered a Class V injection well; permitting an evaporation pond as a Class V injection well would be extremely difficult. To permit a Class V injection well, the project proponent has to show that all constituents in the water are at lower concentrations than those found in the native groundwater. However, installing a double liner with leachate collection system should remove the Class V requirements.

Another major concern with installation of evaporation ponds is the control of habitat, including that for waterfowl. Large evaporation ponds are attractive to many birds. In some cases, high concentrations of selenium in evaporation ponds have caused birth defects in waterfowl; however, waterfowl control can be successfully accomplished by broadcasting the sound of the natural predators of the fowl over a loud-speaker system. This type of control is in use at fruit orchards across the country and has been proven to be quite effective.

Evaporation pond costs are highly specific to project location and depend on:

- Concentrate volume
- Geographic location (i.e., evaporation rates and rain falls)
- Storage requirements
- Land cost

For example, the capital and O&M costs for treating 1.0-mgd concentrate flow via an evaporation pond are approximately $43,000,000 and $390,000 per year, respectively. This estimate is based on evaporation and rainfall data for Irvine, California. This estimate does not include land acquisition.

3.3.1 Enhanced Evaporation

Evaporation can be enhanced by using mechanical misting equipment, which decreases the required pond surface area by increasing the evaporation rate. Mechanical misting equipment (for example, the Slimline Evaporator, also known as the Turbo-Mist Evaporator) works by spraying the brine concentrate into the atmosphere in tiny droplets, thereby increasing the liquid surface area and substantially increasing the rate of evaporation. Depending on the atmospheric conditions, large amounts of water can be evaporated leaving only precipitated salts. A photograph of an evaporation pond utilizing misting equipment is shown in Figure 3.3.

FIGURE 3.3 TYPICAL EVAPORATION POND CONFIGURATION OF MECHANICAL MIST EVAPORATOR

Evaporation ponds and mechanical misters are proven industrial and wastewater technologies that provide a simple, reliable solution to brine concentrate management. However, evaporation ponds have a large footprint and are climate sensitive. In addition, evaporation ponds could pose regulatory, aesthetic, environmental, and ecological issues; additionally, mechanical misters could pose noise and air quality issues. Precipitated salts have to be transferred to a landfill for final disposal.

A major concern about mist-enhanced evaporation is that the mist and small salt particulate matter can to drift away from the evaporation pond at very low wind velocities, and negate the purpose of zero discharge.

Similar to the evaporation ponds, capital cost is sensitive to project location and location specific evaporation and rainfall data which determines surface area requirement for evaporation pond. Mister type and size have impact on both capital and operating costs.

For example; the capital and O&M costs for treating 1.0-mgd concentrate flow via an evaporation pond located in Irvine are approximately $26,000,000 and $1,060,000/year, respectively. Mister use can dramatically reduce foot-print and hence capital cost for the project but it nearly triples the O&M cost. Capital cost estimates for the enhanced evaporation ponds were provided by CH2M HILL and Slimline Manufacturing, Inc.

3.4 Wind-Aided Intensified Evaporation

Wind-Aided Intensified Evaporation is an enhanced evaporation process that uses wind energy to reduce the land area required for brine-concentrate disposal. The WAIV process sprays brine concentrate over vertically mounted and continuously wetted evaporation surfaces that have a high packing density footprint (20 m2/m2 footprint or larger) (Gilron, 2003). This concept is based on exploiting wind energy to enhance evaporation rates.

Three different evaporation surfaces have been tested for use in the WAIV process, they are:

- Woven nettings
- Nonwoven geotextiles
- Tuff (volcanic rock)

Pilot testing has found that materials with less internal surface areas, such as nonwoven geotextiles are less susceptible to clogging of the surface compared to materials with large internal surface areas (that is, woven nettings).

Figure 3.4 shows the configuration of a WAIV pilot unit. The WAIV unit has vertically mounted evaporation surfaces placed in arrays. Deploying the evaporation surfaces in arrays with large lateral dimensions significantly increases the height and depth across which the wind passes. This results in the wind coming into contact with a greater surface area prior to saturation with vapor. The pilot study found that this resulted in a tenfold increase in evaporative capacity per footprint area (Gilron, 2003).

FIGURE 3.4 WAIV PILOT UNIT

The WAIV process works best in a climate with high evaporation rates. Another important component of implementing the WAIV process is the selection of suitable materials for evaporation surfaces. Suitable materials should have a packing density high enough to enhance evaporation while not causing unnecessary wind blockage. Prior to implementation of this technology a detailed pilot testing program should be undertaken to ensure this technology is feasible for brine concentrate management at a specific site.

The potential advantages of the WAIV technology include:

- Land requirement is reduced in comparison to evaporation ponds due to enhanced evaporation rates.
- Natural energy sources (solar and wind) are used resulting in lower O&M costs.
- Operation is less complex compared to MTE and RO based concentrate management options.

The disadvantages of this technology are:

- Technology is still under development.
- Surface material and packing density need to be optimized.
- No full-scale performance and capital and O&M data exist.
- Technology is ineffective in climates with low evaporation rates.
- Periodic rinsing and acid wash are required for cleaning of woven surfaces.
- Residuals need to be disposed of in landfills.

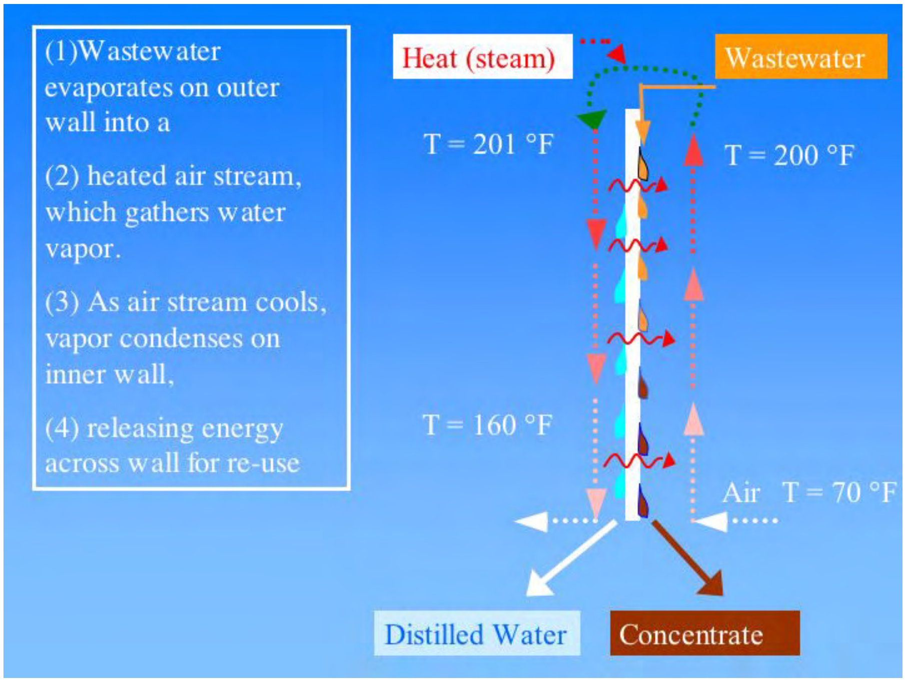
3.5 Dewvaporation

Dewvaporation is a process that combines dew formation and evaporation processes to purify water. The concept was developed at Arizona State University in conjunction with L'Eau LLC, the company that owns the patent rights to the process. Dewvaporation works by using heated air to evaporate water from brackish water. Each Dewvaporation tower contains a heat transfer wall made of plastic material. The wall divides the module into two compartments, one for evaporation and one for dew formation. The tower unit is built of thin plastic materials to avoid corrosion and to minimize equipment costs. Using this tower configuration lowers the cost because the tower operates at atmospheric pressure.

The process works by introducing wastewater or salty water down the evaporation side of the heat transfer wall; then an external blower is used to move the stream upward. Heat coming through the heat transfer wall causes most of the water to evaporate. Evaporation occurs at the liquid-air interface and not at the heat transfer wall, which minimizes scaling problems. The remainder of the water, which will have concentrated salts, exits from the bottom of the module.

At the top of the tower, humid air mixes with a stream of steam and flows into the dew formation module. Heat flows through the heat transfer wall into the evaporation module, cooling the warm air and allowing dew (distilled water) to form. The distilled water flows out the bottom of the module as shown in Figure 3.5. Heat sources for dewvaporation can be combustible fuel, solar, or waste heat. Dewvaporation has been pilot tested extensively; however, no full-scale application of this process for desalination and RO concentrate treatment exists.

FIGURE 3.5 A SIMPLIFIED PROCESS SCHEMATIC OF DEWVAPORATION



Source: L'Eau LLC, 2009

The potential advantages of Dewvaporation include:

- Dewvaporation produces high-quality (distilled) water.
- Solar or waste heat can be used to power the unit.
- Operation is less complex than MTE and RO based concentrate management options.
- Operation cost is low due to moderate operating temperature and atmospheric pressure.
- Plastics heat transfer walls reduce capital cost and eliminate corrosion concerns.

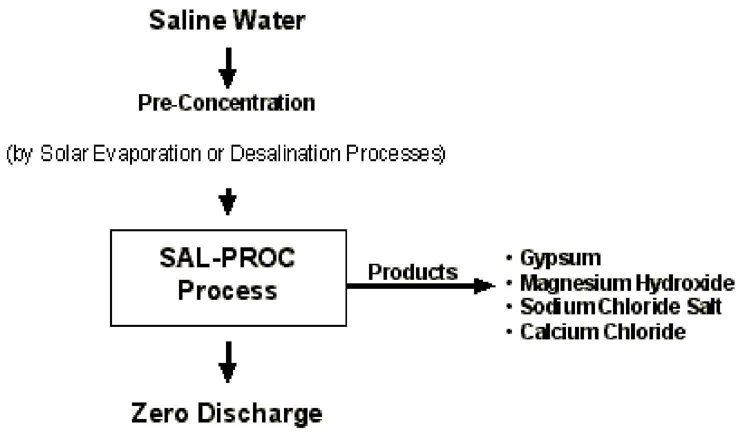
The potential advantages of this technology include:

- No full-scale units are in service,
- No data exist on full-scale performance or on capital and O&M costs.
- Dewvaporation results in lower water recovery (30 to 40 percent).

3.6 Salt Solidification and Sequestration (SAL-PROC)

SAL-PROC™ is a patented process of Geo-Processors USA, Inc. (Glendale, California). It is an integrated process for the sequential or selective extraction of dissolved elements from saline waters in the form of valuable salts and chemical compounds (mineral, slurry, and liquid forms). The process involves multiple evaporation and/or cooling steps supplemented by conventional mineral and chemical processing. This technology is based on simple closed-loop processing and fluid flow circuits, which enable the partial or comprehensive treatment of inorganic saline streams for recovery of valuable by-products. Field trials and pilot testing indicated that a number of saline waste streams can be converted into marketable products (precipitated salts) while achieving zero liquid discharge. The chemicals typically recovered from saline streams include gypsum-magnesium hydroxide, magnesium hydroxide, sodium chlorite, calcium carbonate, sodium sulfate, and calcium chloride. A simplified SAL-PROC process schematic is illustrated in Figure 3.6.

FIGURE 3.6 A SIMPLIFIED PROCESS SCHEMATIC OF SAL-PROC™



Geo-Processor has developed a model that consists of two subsystems, including one or more selective salt recovery steps that are linked with RO desalination, thermo-mechanical brine concentration, and crystallization steps. The desktop modeling exercise enables the selection of an appropriate ZLD process scheme. The selected ZLD systems utilize multiple reaction steps using lime and soda ash to produce carbonated magnesium, calcium carbonate, and a mixed salt. The overall system recovers the entire flow and can generate high-quality water. However, SAL-PROC requires incorporation of one or more desalting technologies to reduce volume significantly while highly concentrating water entering the SAL-PROC.

SAL-PROC is not a stand-alone brine concentrate treatment technology. This process acts as a product recovery process. The suitability of using SAL-PROC depends upon the water quality and type of application. RO concentrate from water reuse facilities might not be permitted to recover products because wastewaters contain organic, toxic, and hazardous material. The major advantage of implementing this process is that it can recover marketable products. Cost data for SAL-PROC is not available.

4 Final Disposal Options

Final disposal options are concentrate management technologies that require no additional management technology. The following final disposal options result in the concentrate being discharged into the ocean, a nonpotable groundwater location, or disposed in a landfill. These options are: deep well injection, ocean discharge (existing and new), downstream discharge to wastewater treatment plant or disposal station, and disposal to landfills. Each of these concentrate management technologies requires regulatory approval prior to discharge. The following subsection will discuss each of the technologies including the regulatory approvals required prior to disposal.

4.1 Deep Well Injection

Deep well injection (DWI) is a concentrate management technology that uses subsurface geologic formations that are not otherwise drawn on for beneficial purposes (that is, nonpotable groundwater sources, such as areas where oil and/or gas have been extracted) to store liquid concentrate. A well is used to convey the liquid concentrate some distance below the ground surface where it is released into a geologic formation. The depth of the well is typically less than 8,000 feet, depending on the class of well used, the existing geologic strata, and the depth to groundwater aquifers. In particular, injection of concentrate into abandoned oil or gas wells could be a disposal option if the well complies with regulatory standards to protect the USDW.

Implementation issues for concentrate disposal by DWI include site availability, well classification, concentrate compatibility, and public perception. The site must have favorable underground geology conducive to DWI, with a porous injection zone capable of sustaining adequate injection rates over the life of the membrane facility. In addition, an impermeable layer is required to prevent the migration of the injected concentrate into a USDW. The site should be a sufficient distance from any wells going through the impermeable layer that could serve as a pathway to a USDW.

DWI has a proven history in municipal and industrial applications. For example, Laguna County Sanitation District disposes of concentrate from an RO membrane into a Class I nonhazardous injection well. The major advantage of using DWI is that it requires minimal land area and can utilize abandoned well sites, which would reduce costs for infrastructure. However, DWI is feasible only in specific geological and site conditions. One important consideration regarding the use of DWI is proximity to faults because injecting concentrate could increase water pressure on fault lines resulting in earth movement. Figures 4.1 to 4.5 show the locations of faults in southern California. In addition, DWI requires extensive O&M because fluid confinement must be proven and maintained, capacity reduction due to plugging could occur over time, repairing leaks or abandoning wells could be difficult, and treatment plant complexity could add more manpower time. Existing DWI wells in southern California achieve injection rates of approximately 60 to 100 gpm, with decreasing injection rates over time. Reduction in injection rate over time is caused by clogging and can be reversed with periodic well redevelopment.

Capital and O&M costs for DWI are site specific. Capital costs to retrofit abandoned oil and gas wells for DWI in California vary from $600,000 to $1,000,000 per well, including permitting. Capital costs to install a new DWI site are approximately $800,000 to $2,160,000 per well, including permitting. These estimates for capital costs do not include well testing, which will vary based on the well. Well testing could include pump testing, mechanical integrity testing, geophysical surveys, and geochemistry analyses. Table 4.1 summarizes capital costs based on the size of the well.

TABLE 4.1
WELL INJECTION CAPITAL COST MATRIX

Type of DWI Well	Capital Cost[a] ($)
Abandoned Oil and Gas Well Retrofit	$1,00,000
Install New DWI Well	$2,160,000

Note:
Capital Cost based on 1 well.

Well testing costs can vary greatly depending on the age and location of the well, and well rehabilitation could be required on a periodic basis due to loss of injection capacity. Additional factors that could affect the cost are high-pressure injections, quality of injection water, and the quality of the receiving aquifer matrix and water. Table 4.2 provides the O&M costs for retrofitting an abandoned well to a DWI.

TABLE 4.2
DEEP WELL INJECTION OPERATION AND MAINTENANCE COSTS

Component	Cost[a] $/yr
Power	$432,000
Parts and Maintenance	$317,000[b]
Chemicals and Other	$190,000
Total	$939,000

Note:
[a] O&M costs are for a 1-mgd flow.
[b] For a new well Parts and Maintenance costs would be $557,000, which increases the total O&M cost for a new well to $1,179,000.

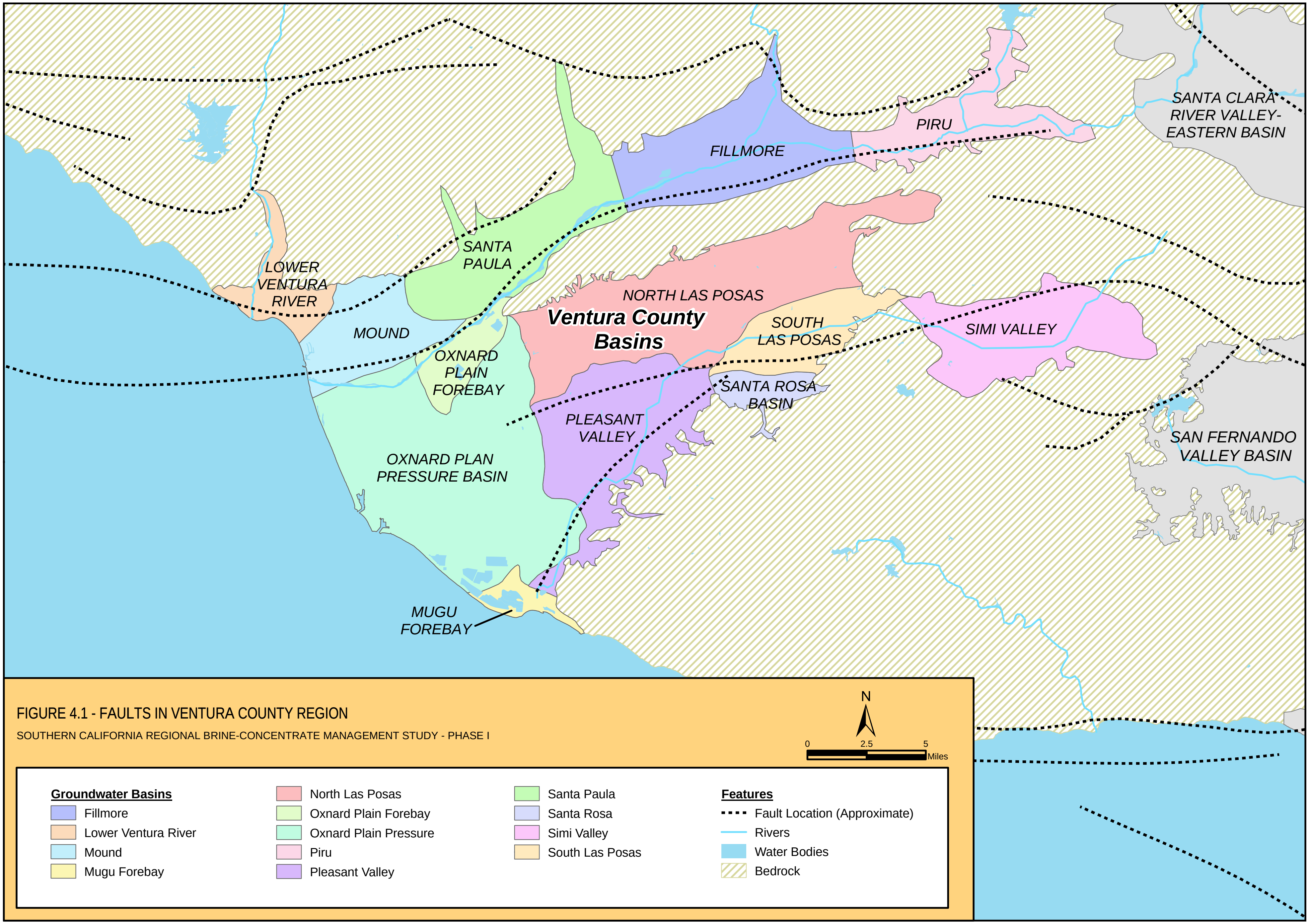


FIGURE 4.1 - FAULTS IN VENTURA COUNTY REGION

SOUTHERN CALIFORNIA REGIONAL BRINE-CONCENTRATE MANAGEMENT STUDY - PHASE I

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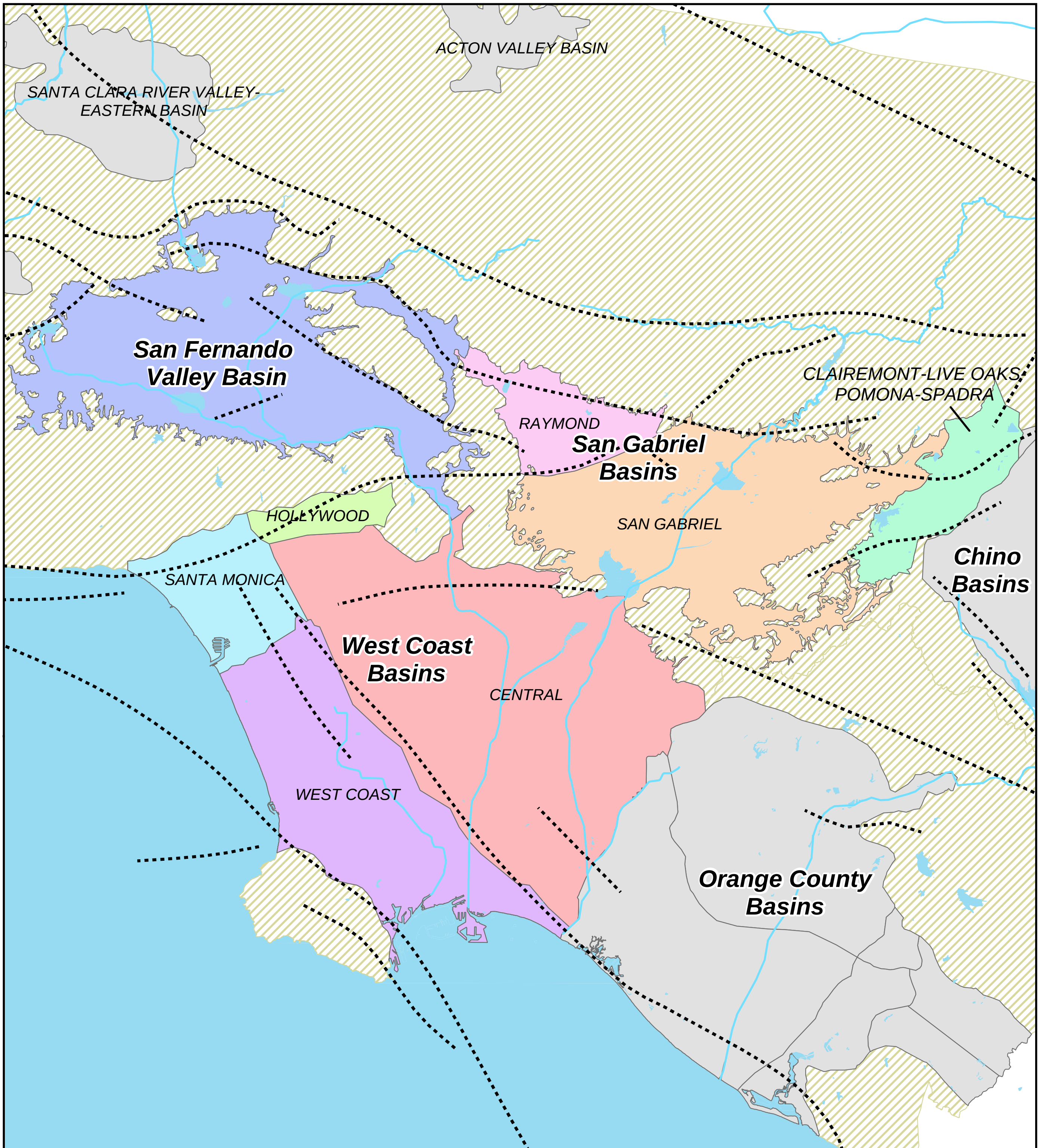

FIGURE 4.2 - FAULTS IN LOS ANGELES COUNTY REGION

SOUTHERN CALIFORNIA REGIONAL BRINE-CONCENTRATE MANAGEMENT STUDY - PHASE 1

Groundwater Basins

- Central
- Claremont-Live Oaks-Pomona-Spadra
- Hollywood
- Raymond
- San Fernando Valley
- San Gabriel
- Santa Monica
- West Coast

Features

- Fault Location (Approximate)
- Rivers
- Water Bodies
- Bedrock

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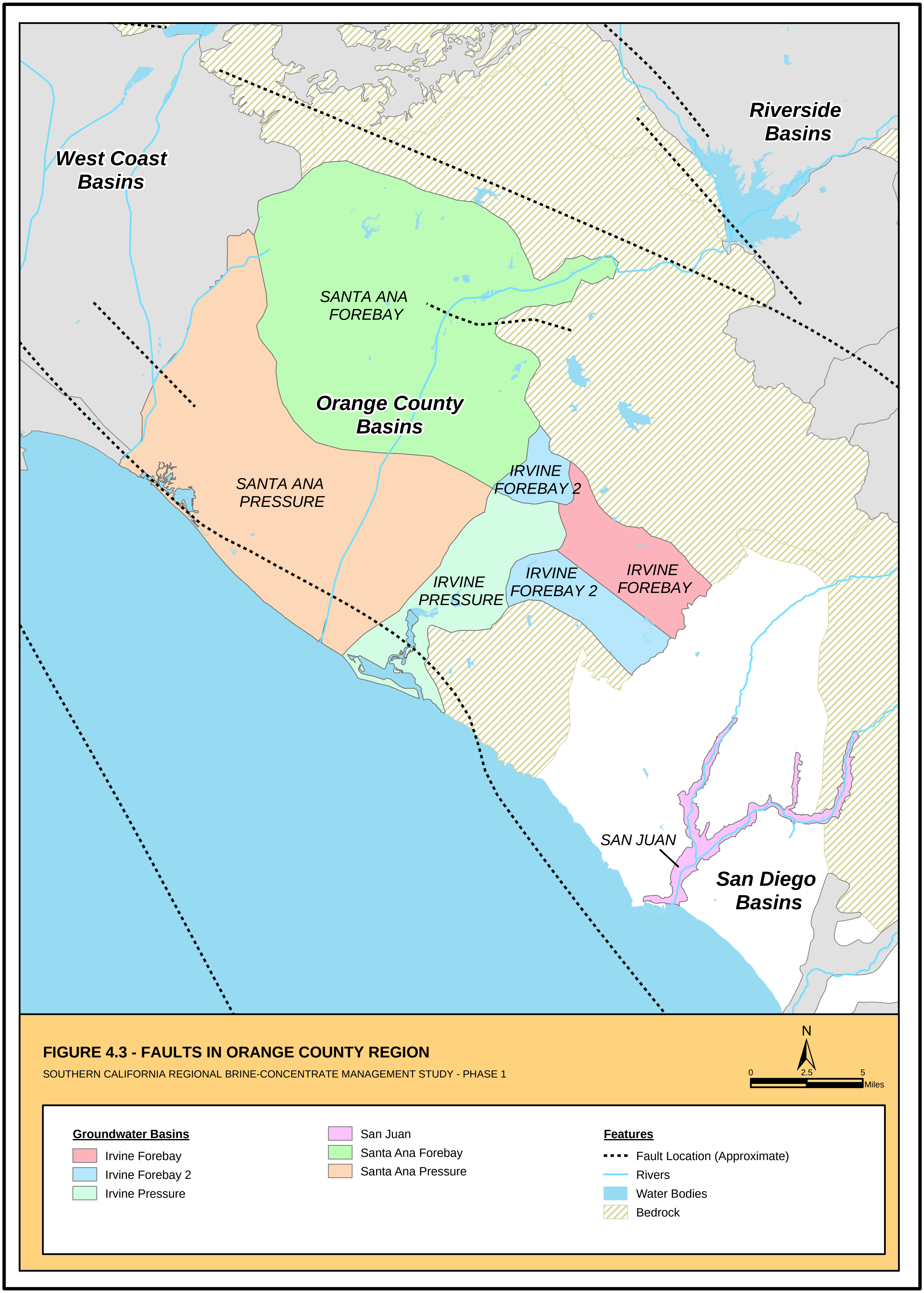

FIGURE 4.3 - FAULTS IN ORANGE COUNTY REGION

SOUTHERN CALIFORNIA REGIONAL BRINE-CONCENTRATE MANAGEMENT STUDY - PHASE 1

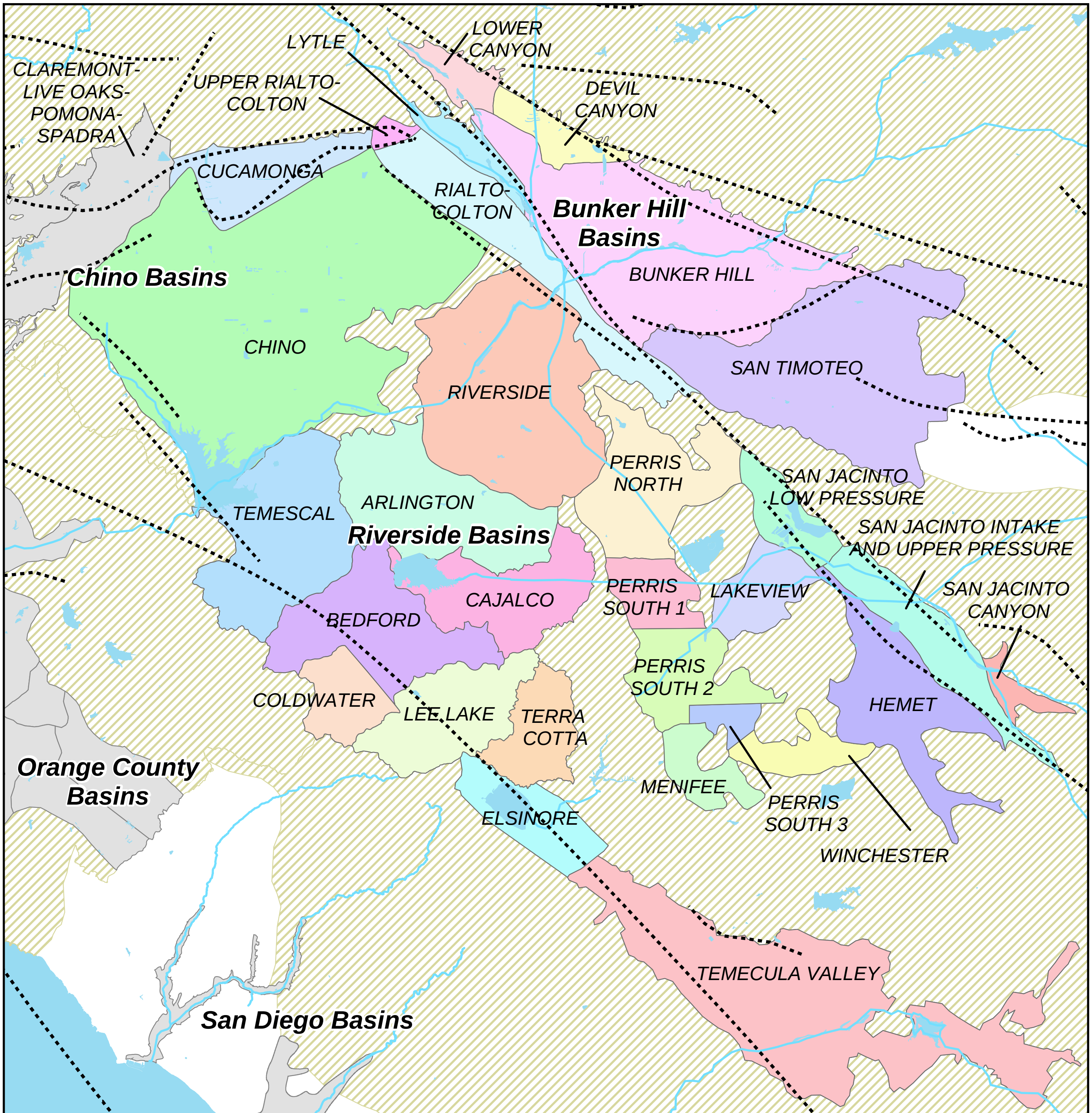

FIGURE 4.4 - FAULTS IN INLAND EMPIRE REGION

SOUTHERN CALIFORNIA REGIONAL BRINE-CONCENTRATE MANAGEMENT STUDY - PHASE 1

N

0 4 8 Miles

Groundwater Basins

- Arlington
- Bedford
- Bunker Hill
- Cajalco
- Chino
- Claremont-Live Oaks-Pomona-Spadra
- Coldwater
- Cucamonga
- Devil Canyon
- Elsinore
- Hemet
- Lakeview
- Lee Lake
- Lower Canyon
- Lytle
- Menifee
- Perris North
- Perris South 1
- Perris South 2
- Perris South 3
- Rialto-Colton
- Riverside
- San Jacinto Canyon
- San Jacinto Intake and Upper Pressure
- San Jacinto Low Pressure
- San Timoteo
- Temecula Valley
- Temescal
- Terra Cotta
- Upper Rialto-Colton
- Winchester

Features

- Fault Location (Approximate)
- Rivers
- Water Bodies
- Bedrock

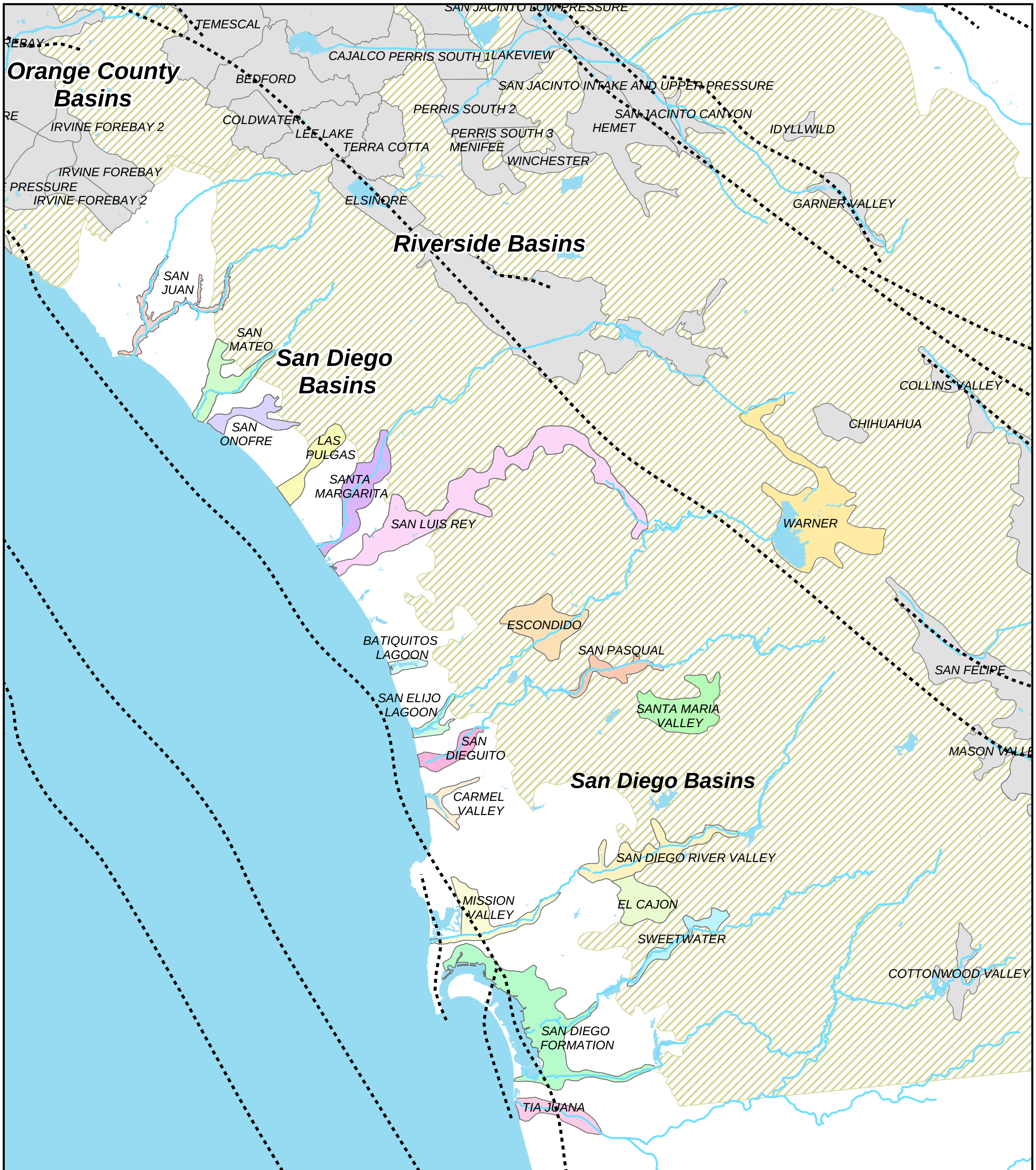

FIGURE 4.5 - FAULTS IN SAN DIEGO COUNTY REGION

SOUTHERN CALIFORNIA REGIONAL BRINE-CONCENTRATE MANAGEMENT STUDY - PHASE 1

Groundwater Basins
- Batiquitos Lagoon
- Carmel Valley
- El Cajon
- Escondido
- Las Pulgas
- Mission Valley
- San Diego Formation
- San Diego River Valley
- San Dieguito
- San Elijo Lagoon
- San Juan
- San Luis Rey
- San Mateo
- San Onofre
- San Pasqual
- Santa Margarita
- Santa Maria Valley
- Sweetwater
- Tia Juana
- Warner

Features
- Fault Location (Approximate)
- Rivers
- Water Bodies
- Bedrock

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The primary driver for regulation of concentrate discharged through DWI is public health. Groundwater is or could be used as a drinking water source, and drinking water standards often are applied to concentrate when it is discharged through DWI.

The Underground Injection Control (UIC) program was developed to protect USDW and is administered by the United States Environmental Protection Agency (USEPA) and the California Regional Water Quality Control Boards (RWQCBs). In Title 40 of the Code of Federal Regulations (CFR) Part 146 of the UIC program lays out a classification system for injection wells. The UIC provides standards, technical assistance, and grants to state governments to regulate injection wells to prevent contamination of drinking water sources. Five classes of wells are described in Table 4.3 and illustrated in Figure 4.6. The different classes of wells are categorized by the origin and characteristics of the liquid waste.

Class I, II, and III wells must comply with the following:

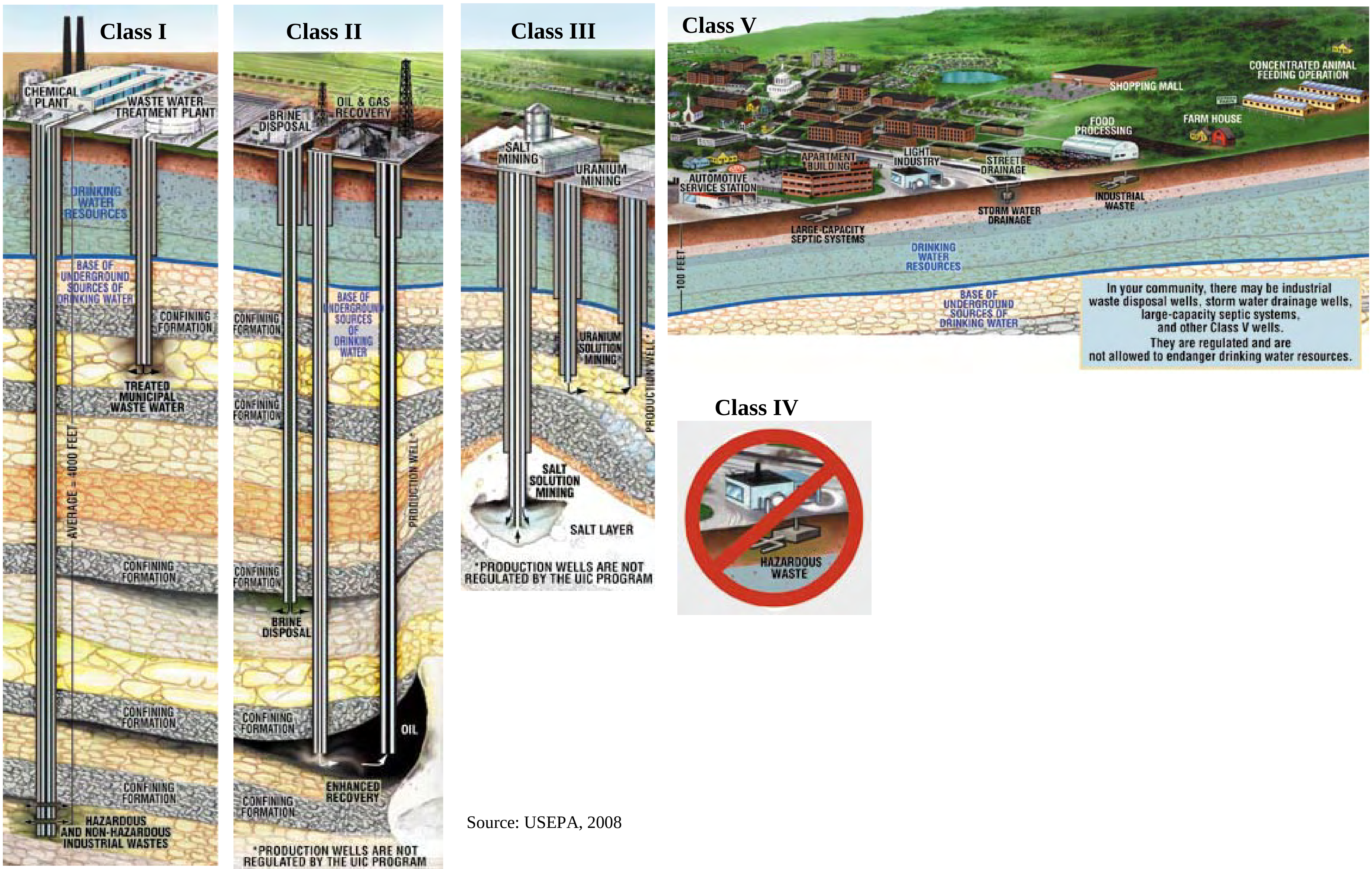
- Be in a location that is free of faults or other adverse geologic features
- Be drilled to depths so that injected fluids do not affect a potential USDW and be confined from any formation that potentially could be a USDW
- Be tested for integrity of the well at the time of completion and every 5 years thereafter
- Be monitored continuously to assure well integrity

TABLE 4.3
CLASSES OF INJECTION WELLS

Class	Description
I	Injectate equal to or greater than 10,000 mg/L TDS Geologic confining layer present to prevent contamination of upper level USDW Injectate could have a poorer quality than the USDW into which it is being injected
II	Wells used in the recovery of natural gas or oil
III	Wells used to inject super-heated steam, water, or other fluids into formation to extract minerals
IV	Wells used to dispose of radioactive waste (banned under UIC Program)
V	Wells used to inject fluids not classified in other well classes (for example, advanced wastewater disposal systems, disposal of septic systems, or stormwater, agricultural, and industrial drainage wells) Injectate is of greater quality than the water into which it is being injected Injectate is less than 10,000 mg/L TDS

In California, the California Department of Conservation, Division of Oil, and Geothermal Resources regulates Class II wells, and USEPA regulates Classes I, III, IV, and V wells. Concentrate disposal can use Class I or V wells; however, permitting a Class V well could be difficult because these are typically low-technology wells and use gravity to supply the well. In addition, it is unlikely that in southern California a Class V well would be permitted because concentrate would contaminate a potential USDW. A USDW is defined as any underground aquifer containing water with TDS less than 10,000 mg/L.

FIGURE 4.6 CLASSES OF INJECTION WELLS



Source: USEPA, 2008

To permit a Class I well, the project proponent must show, through extensive geologic testing and modeling, that injected water quality will not degrade the USDW. Class I injection wells must have special protection against contamination of the USDW. The permitting process for an injection well can be a labor-intensive process. The permitting process involves drilling a test well that is completed to Class I standards. Permit requirements for a Class I injection well as stipulated under Subpart B, Section 146.12, of the UIC regulations state:

> *All Class I wells shall be sited in such a fashion that they inject into a formation which is beneath the lowermost formation containing, within 0.25 mile of the well bore, an underground source of drinking water.*

In addition, an impermeable geologic stratum must be located above the injection zone to prevent the migration of the injectate into an overlying USDW. Extensive geologic modeling might be required to demonstrate the effectiveness of the impermeable strata in preventing migration. In many cases, geologic investigations are required to collect data used for modeling purposes.

USEPA requires that Class I wells be placed in areas free of vertically transmissive faults and fissures and that the region be characterized by low seismicity and a low probability of earthquakes. In California, locating a site that could be shown to have no faults or fissures and a low probability of earthquakes would be difficult. In other regions, DWI has resulted in a rise in pore pressures and activation of faults, causing increased seismicity. Proving that seismicity would not increase as a result of any given project would be difficult. Figures 4.7 to 4.11 show the locations of oil and gas wells. These wells can potentially be used for DWI if site-specific hydrogeological conditions comply with regulatory requirements.

If suitable geology is determined to be present, a test well is drilled, completed, and used to confirm adequate injection capacity. The test well typically is completed to Class I standards, but initially permitted as a Class II well to expedite the permit process.

A typical Class I injection well consists of concentric pipes that extend several thousand feet below the ground surface into a highly saline, permeable, injection zone that is vertically confined by impermeable strata. The outermost pipe or surface casing extends below the base of any USDW and is cemented to the surface to prevent contamination of the USDW. Directly inside the surface casing is a long, string casing that extends to and sometimes into the injection zone. This casing is cemented to the surface to seal the injected waste from the formations above the injection zone. If the well is determined suitable for DWI, it can be reclassified as a Class I well. Figure 4.12 is a schematic of a deep injection well.

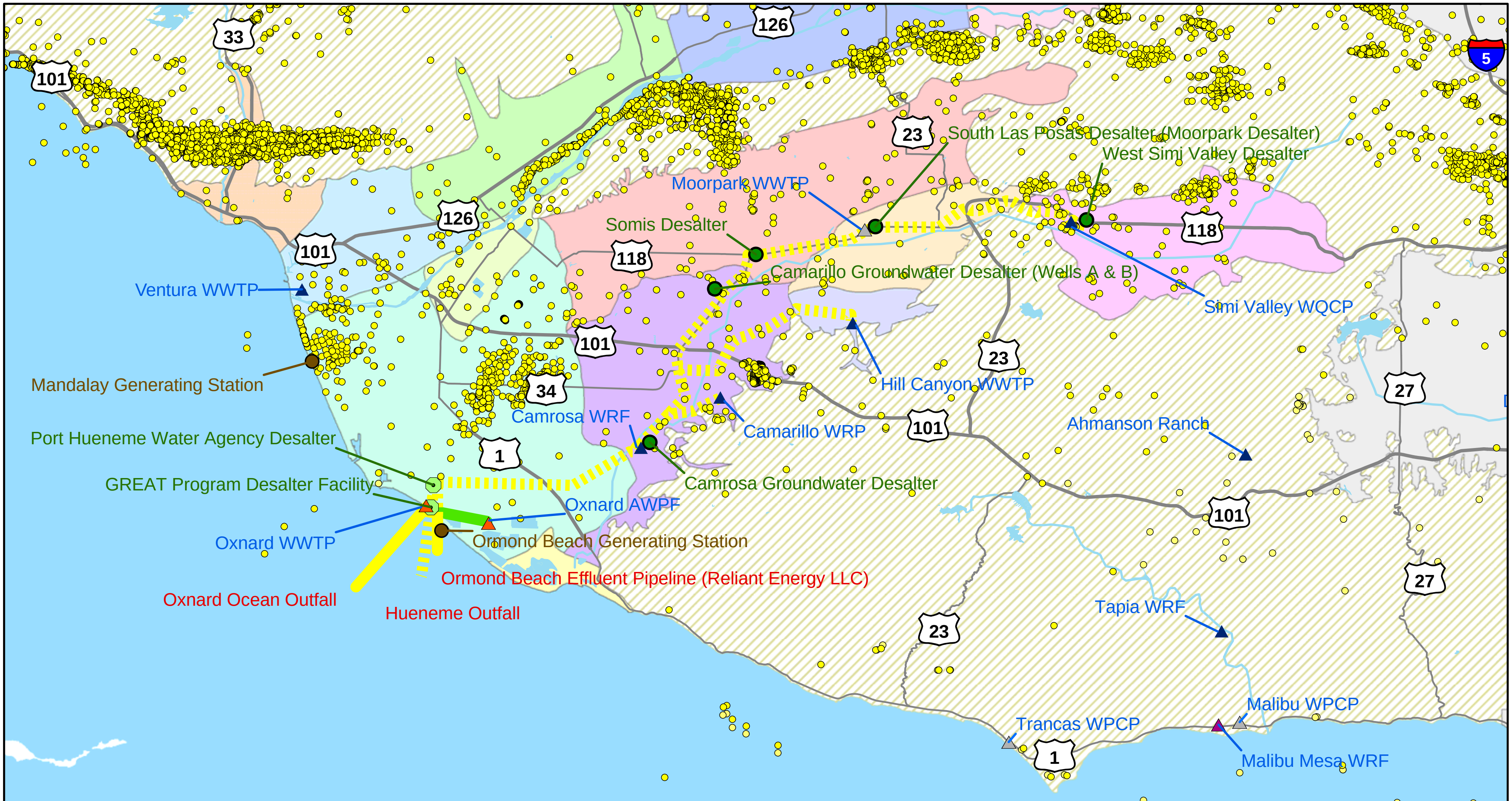


FIGURE 4.7 - OIL AND GAS WELLS IN VENTURA COUNTY REGION

SOUTHERN CALIFORNIA REGIONAL BRINE-CONCENTRATE MANAGEMENT STUDY - PHASE I

N

0 2.5 5 Miles

Wastewater Treatment Plants
- Land Discharge
- Recycled Water Only
- Stream Discharge
- Ocean Discharge
- Other

Oil and Gas Wells
- Oil and Gas Wells

Desalination Facilities
- Existing Groundwater Desalter
- Planned Groundwater Desalter
- Proposed Seawater Desalination Plant

Industrial Ocean Outfalls
- Power Plants
- Industrial/Others

Wastewater Outfalls
- Wastewater Outfalls
- Planned or Potential Ocean Outfall
- Existing Brineline or Interconnector Sewer
- Planned or Potential Brineline or Interconnector Sewer

Features
- Highways
- Rivers
- Water Bodies

Groundwater Basins
- Fillmore
- Lower Ventura River
- Mound
- Mugu Forebay
- North Las Posas
- Oxnard Plain Forebay
- Oxnard Plain Pressure
- Piru
- Pleasant Valley
- Santa Paula
- Santa Rosa
- Simi Valley
- South Las Posas

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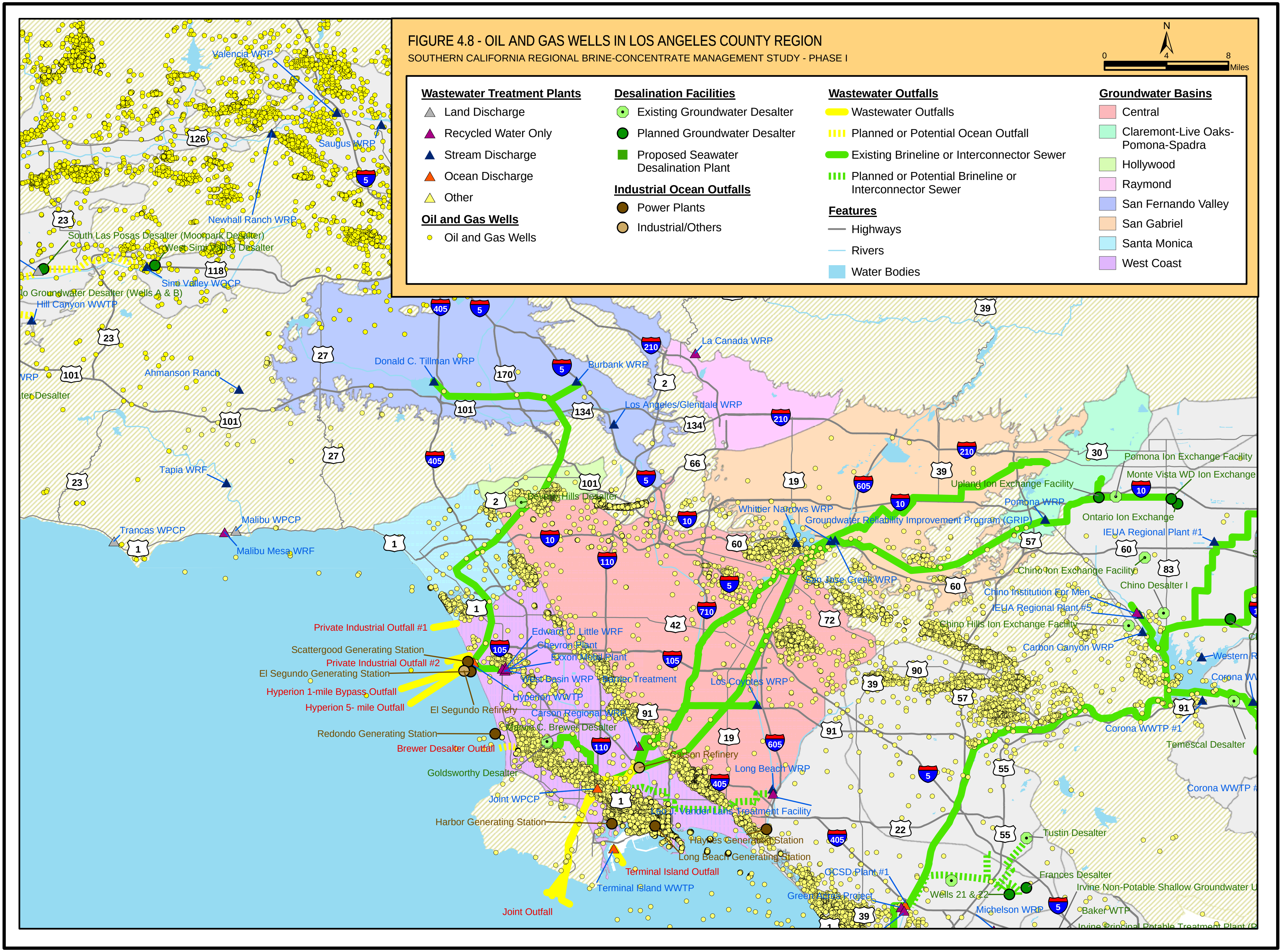

FIGURE 4.8 - OIL AND GAS WELLS IN LOS ANGELES COUNTY REGION
SOUTHERN CALIFORNIA REGIONAL BRINE-CONCENTRATE MANAGEMENT STUDY - PHASE I

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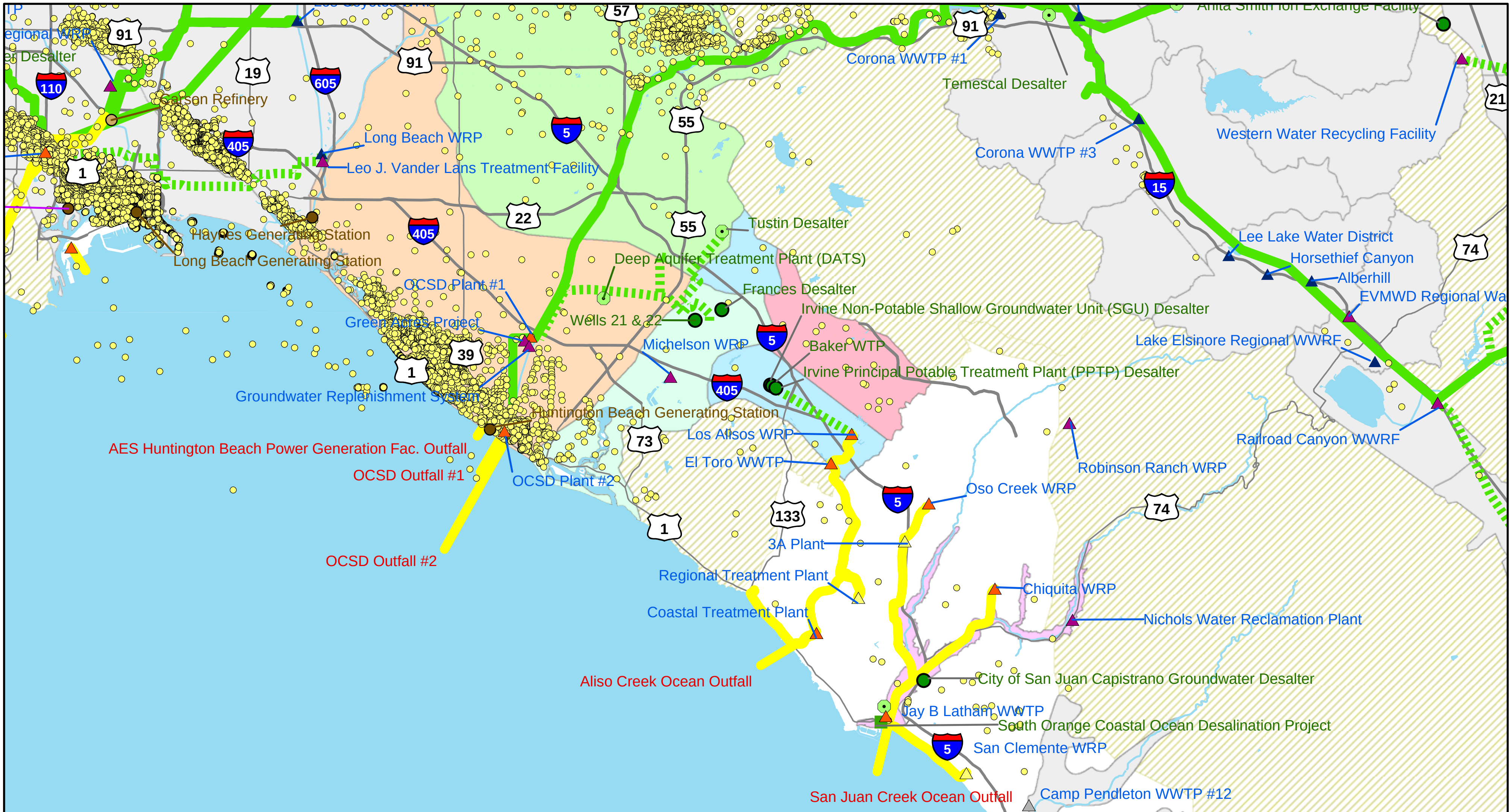

FIGURE 4.9 - OIL AND GAS WELLS IN ORANGE COUNTY REGION

SOUTHERN CALIFORNIA REGIONAL BRINE-CONCENTRATE MANAGEMENT STUDY - PHASE I

Wastewater Treatment Plants
- Land Discharge
- Recycled Water Only
- Stream Discharge
- Ocean Discharge
- Other

Oil and Gas Wells
- Oil and Gas Wells

Desalination Facilities
- Existing Groundwater Desalter
- Planned Groundwater Desalter
- Proposed Seawater Desalination Plant

Industrial Ocean Outfalls
- Power Plants
- Industrial/Others

Wastewater Outfalls
- Wastewater Outfalls
- Planned or Potential Ocean Outfall
- Existing Brineline or Interconnector Sewer
- Planned or Potential Brineline or Interconnector Sewer

Features
- Highways
- Rivers
- Water Bodies

Groundwater Basins
- Irvine Forebay
- Irvine Forebay 2
- Irvine Pressure
- San Juan
- Santa Ana Forebay
- Santa Ana Pressure

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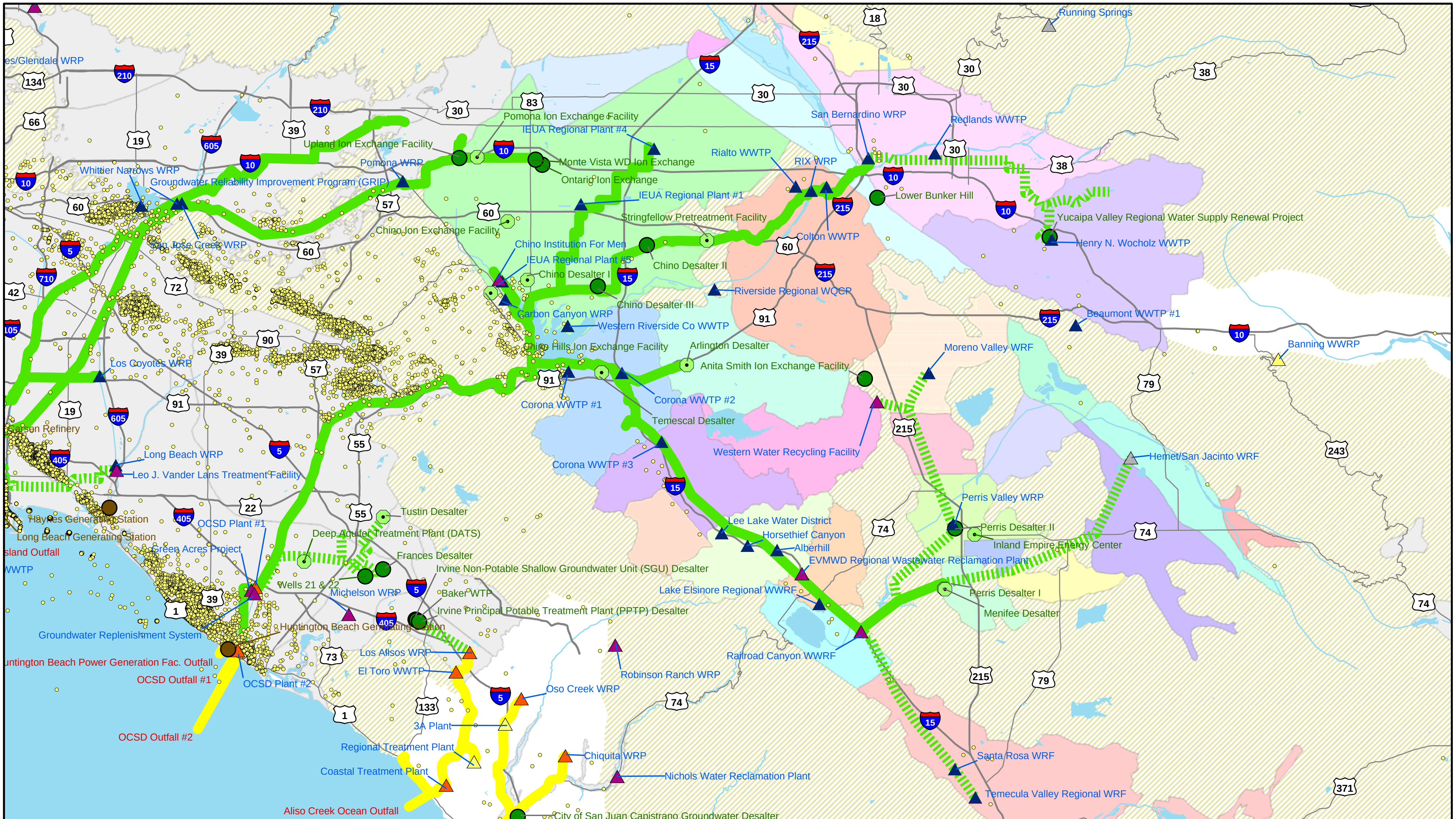

FIGURE 4.10 - OIL AND GAS WELLS IN INLAND EMPIRE REGION

SOUTHERN CALIFORNIA REGIONAL BRINE-CONCENTRATE MANAGEMENT STUDY - PHASE I

Wastewater Treatment Plants
- Land Discharge
- Recycled Water Only
- Stream Discharge
- Ocean Discharge
- Other

Oil and Gas Wells
- Oil and Gas Wells

Desalination Facilities
- Existing Groundwater Desalter
- Planned Groundwater Desalter
- Proposed Seawater Desalination Plant

Industrial Ocean Outfalls
- Power Plants
- Industrial/Others

Wastewater Outfalls
- Wastewater Outfalls
- Planned or Potential Ocean Outfall
- Existing Brineline or Interconnector Sewer
- Planned or Potential Brineline or Interconnector Sewer

Features
- Highways
- Rivers
- Water Bodies

Groundwater Basins
- Arlington
- Bedford
- Bunker Hill
- Cajalco
- Chino
- Claremont-Live Oaks -Pomona-Spadra
- Coldwater
- Cucamonga
- Devil Canyon
- Elsinore
- Hemet
- Lakeview
- Lee Lake
- Lower Canyon
- Lytle
- Menifee
- Perris North
- Perris South 1
- Perris South 2
- Perris South 3
- Rialto-Colton
- Riverside
- San Jacinto Canyon
- San Jacinto Intake and Upper Pressure
- San Jacinto Low Pressure
- San Timoteo
- Temecula Valley
- Temescal
- Terra Cotta
- Upper Rialto-Colton
- Winchester

FIGURE 4.11 - OIL AND GAS WELLS IN SAN DIEGO COUNTY REGION

SOUTHERN CALIFORNIA REGIONAL BRINE-CONCENTRATE MANAGEMENT STUDY - PHASE I

N

0 4 8 Miles

Wastewater Treatment Plants
- Land Discharge
- Recycled Water Only
- Stream Discharge
- Ocean Discharge
- Other

Oil and Gas Wells
- Oil and Gas Wells

Desalination Facilities
- Existing Groundwater Desalter
- Planned Groundwater Desalter
- Proposed Seawater Desalination Plant

Industrial Ocean Outfalls
- Power Plants
- Industrial/Others

Wastewater Outfalls
- Wastewater Outfalls
- Planned or Potential Ocean Outfall
- Existing Brineline or Interconnector Sewer
- Planned or Potential Brineline or Interconnector Sewer

Features
- Highways
- Rivers
- Water Bodies

Groundwater Basins
- Batiquitos Lagoon
- Carmel Valley
- El Cajon
- Escondido
- Las Pulgas
- Mission Valley
- San Diego Formation
- San Diego River Valley
- San Dieguito
- San Elijo Lagoon
- San Juan
- San Luis Rey
- San Mateo
- San Onofre
- San Pasqual
- Santa Margarita
- Santa Maria Valley
- Sweetwater
- Tia Juana
- Warner

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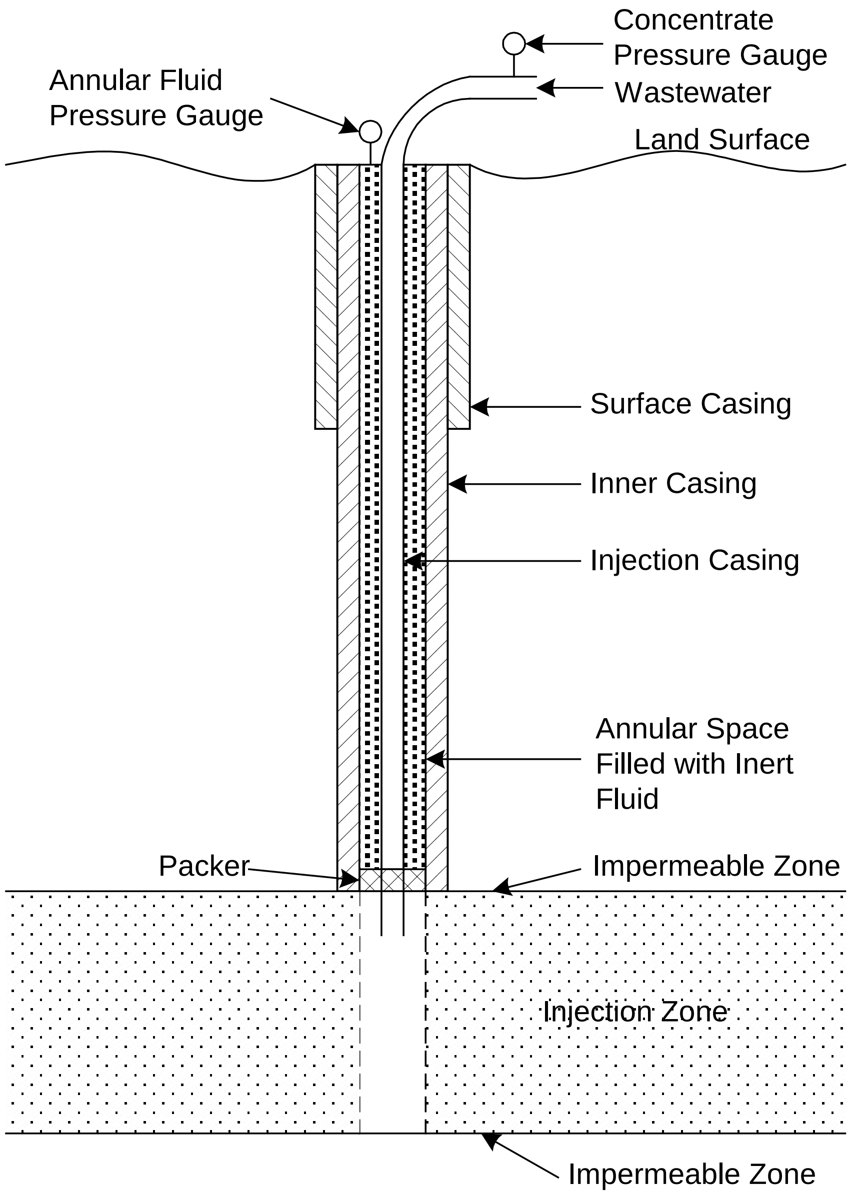
FIGURE 4.12 SCHEMATIC OF A DEEP INJECTION WELL



Some constraints when using DWI include:

- Injection might not be feasible in areas where seismic activity could occur and cause seepage at faults.
- Injected wastes must be compatible with the mechanical components of the injection well system and the natural formation water. Pretreatment of injectate could be required to ensure compatibility with geologic formation and the receiving water.
- High concentrations of suspended solids (typically more than 2 ppm) can lead to plugging of the injection area of the well.
- Organic carbon could serve as an energy source for indigenous or injected bacteria, which could result in rapid population growth and subsequent fouling.

- Concentrate streams containing sparingly soluble salts including silica, above their respective solubility limits, could require pretreatment before injection into a well.

4.2 Disposal via Wastewater Treatment Facility

In California, concentrate can be disposed of into a sewer system. However, concentrate disposal might be limited at local sewage systems because of potential detrimental effects on the ability of wastewater plants to comply with requirements of the National Pollutant Discharge Elimination System (NPDES).

4.2.1 Concentrate Blending

Blending some or all of the RO concentrate with wastewater influent is a common RO concentrate disposal method. Blending reduces or eliminates treatment needs, as long as wastewater treatment plant (WWTP) NPDES permit limits are fully satisfied. The amount of RO concentrate flow that can be blended with secondary effluent or WWTP flow depends upon the RO concentrate flow and quality, as well as WWTP flows, wastewater quality and permit limits.

Capital cost for concentrate blending is highly project specific. For small applications, the facility cost may include construction of a small pipe-line that is connected to the secondary effluent for blending.

4.3 Ocean Disposal

Southern California has over 80 facilities that discharge to the ocean, as seen in Figure 4.13. In addition, six facilities discharge to other WWTPs via interceptors. A majority of these facilities discharge a mixture of wastewater effluent and/or brine concentrate (for example, the Orange County Sanitation District outfall). All ocean outfalls are permitted under NPDES permits. NPDES permit requirements for ocean discharges are focused primarily on habitat effects on marine organisms and most commonly include requirements for total suspended solids (TSS), biochemical oxygen demand (BOD), toxicity, and residual chlorine.

The NPDES limits for refineries and power plants have more stringent requirements for metals and other constituents because these outfalls are typically short, shallow, and do not have diffusers as seen in Figure 4.14. For this reason, this type of outfall has more stringent water quality objectives in the outfall NPDES permit because the permit uses standards based on the Ocean Plan. For example, several metal parameters (i.e., Chromium, Copper, Silver and Mercury) have water quality objectives in the Ocean Plan which are more stringent and well below drinking water quality standards. Table 4-4 provides concentrate water quality examples for a brackish water RO and wastewater RO facility. The water quality data are based on water quality projections for Menifee Desalter and GWRS RO concentrate.
Table 4-4 also presents Ocean Plan water quality objectives along with Federal Drinking Water Standards.

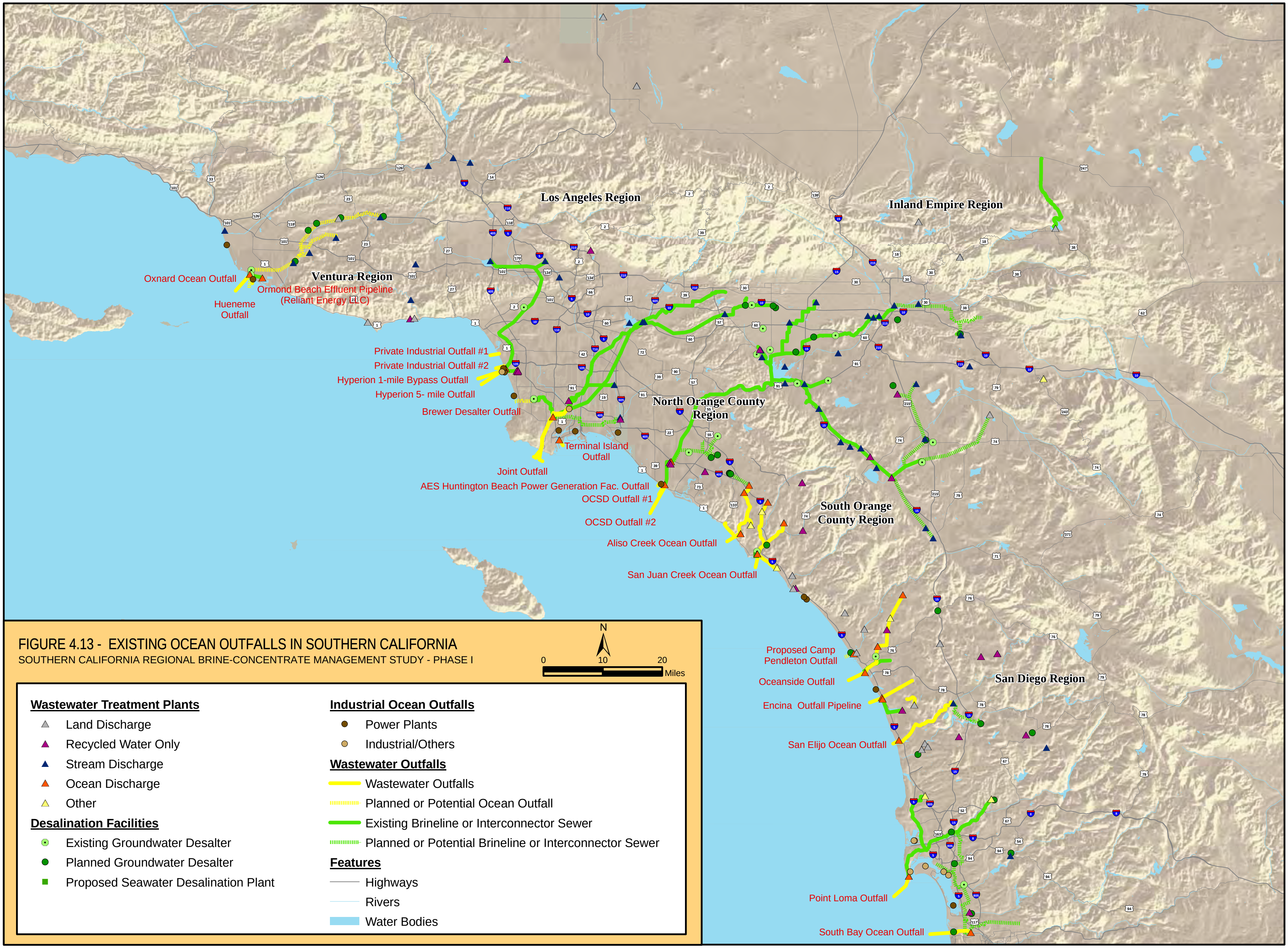


FIGURE 4.13 - EXISTING OCEAN OUTFALLS IN SOUTHERN CALIFORNIA
SOUTHERN CALIFORNIA REGIONAL BRINE-CONCENTRATE MANAGEMENT STUDY - PHASE I

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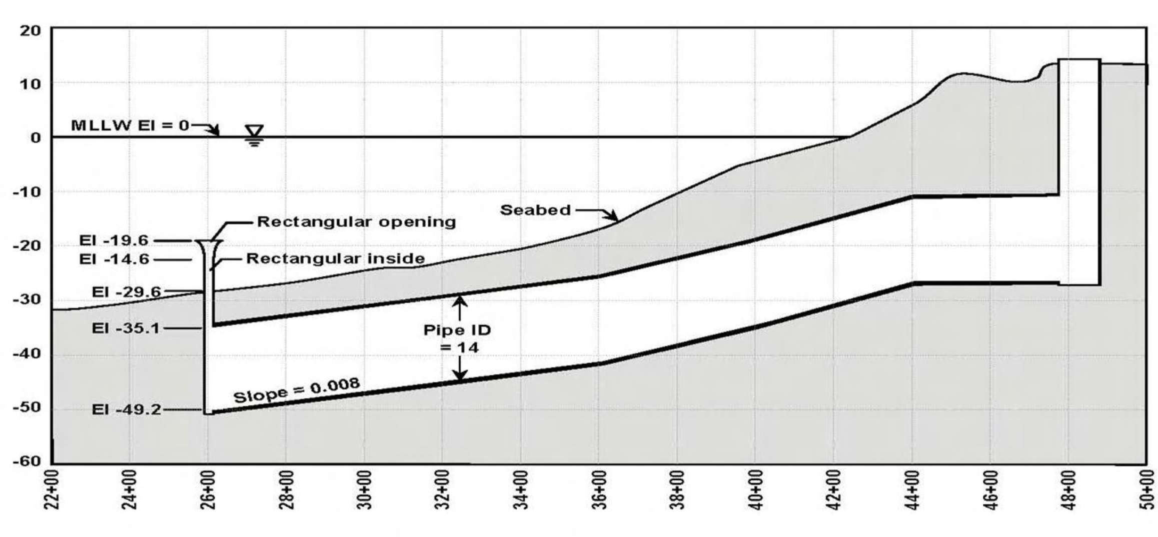
FIGURE 4.14 TYPICAL POWER PLANT OUTFALL CONFIGURATION



Source: Calleguas Municipal Water District, 2008

TABLE 4.4
RO CONCENTRATE WATER QUALITY EXAMPLES, OCEAN PLAN OBJECTIVES AND FEDERAL DRINKING WATER STANDARDS

Parameter	Unit	Brackish Water RO Concentrate Water Quality[a]	Wastewater RO Concentrate Water Quality[b]	Ocean Plan Water Quality Objectives	National Drinking Water Regulations
Total Organic Carbon (TOC)	mg/L	1.5	69		
Total Hardness ($CaCO_3$)	mg/L	3,500	1,920	-	-
Calcium (Ca)	mg/L	990	513	-	-
Magnesium (Mg)	mg/L	234	154	-	-
Sodium (Na)	mg/L	890	1,380	-	-
Potassium (K)	mg/L	26	91	-	-
Total Alkalinity ($CaCO_3$)	mg/L	650	910	-	-
Sulfate (SO_4)	mg/L	470	1,660	-	-
Chloride (Cl)	mg/L	2,440	1,425	-	250,000 [c]
Nitrate (as NO_3)	mg/L	88	22	-	-
Fluoride (F)	mg/L	0.1	5.0	-	-
pH	-	7.2-7.4	7.9	-	6.5-8.5 [c]
Total Dissolved Solids (TDS)	mg/L	5,700	6,200	-	-
Aluminum	µg/L	NA	184	-	200 [c]

TABLE 4.4
RO CONCENTRATE WATER QUALITY EXAMPLES, OCEAN PLAN OBJECTIVES AND FEDERAL DRINKING WATER STANDARDS

Parameter	Unit	Brackish Water RO Concentrate Water Quality[a]	Wastewater RO Concentrate Water Quality[b]	Ocean Plan Water Quality Objectives	National Drinking Water Regulations
Antimony	µg/L	NA	1.0	-	6
Arsenic	µg/L	NA	3.0	80.0	10
Barium	µg/L	660	273	-	2,000
Cadmium	µg/L	NA	8.1	10.0	5
Chromium (Hexavalent)	µg/L	NA	10.0	20.0	100
Copper	µg/L	NA	13.2	30.0	1,300[b]
Iron	µg/L	26	710	-	300 [c]
Manganese	µg/L	8	5	-	50
Mercury	µg/L	NA	0.12	0.4	2
Nickel	µg/L	NA	133	50.0	-
Selenium	µg/L	NA	7.0	150.0	50
Silica	mg/L	180	145	-	-
Silver	µg/L	NA	1.0	7	100 [c]
Nitrite-N	µg/L	100	200-500	-	1,000
Cyanide	µg/L	NA	35	10	-
Ammonia-N	µg/L	1,000	75,000-100,000	6,000	-

Notes:

[a] Based on Eastern Municipal Water District Menifee Desalter RO Concentrate Water Quality Projections

[b] Based on OCWD GWRS RO Concentrate Water Quality Projections
[c] Data obtained from National Drinking Water Regulation

Sources: California Ocean Plan and National Drinking Water Regulations

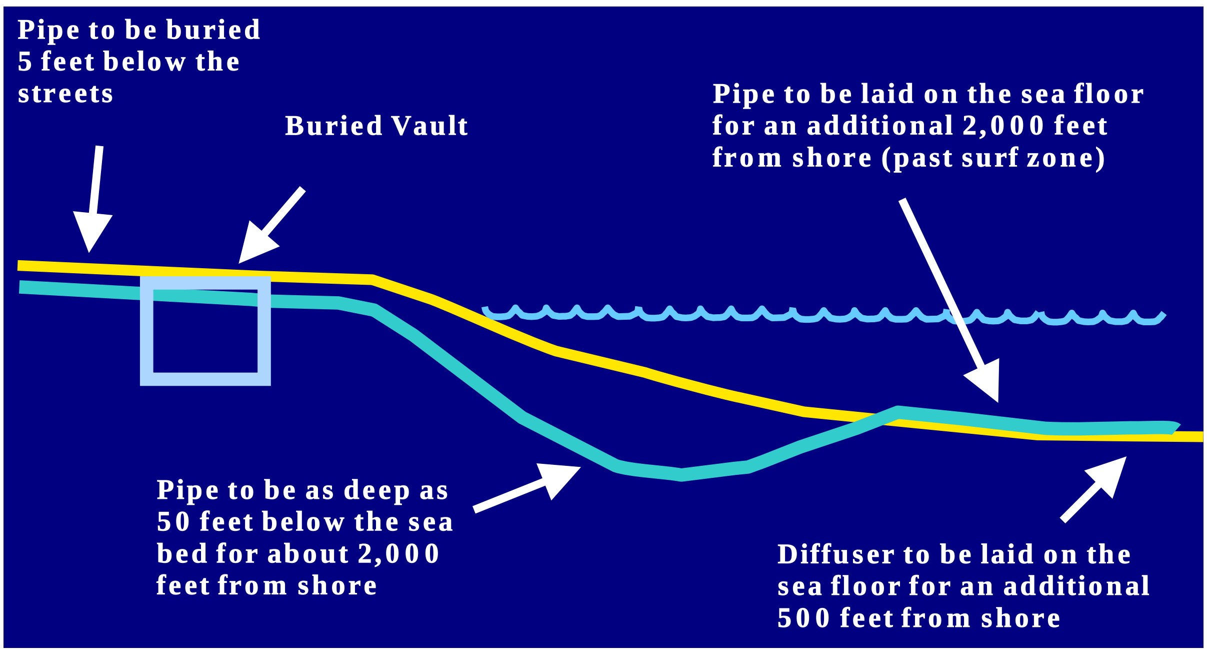
According to Table 4-4, with the exception of iron, nickel and ammonia-N, GWRS RO concentrate water quality data fully satisfies Ocean Plan Water Quality Objectives. However, RO concentrate water quality data in Table 4-4 reflect projections in which very conservative assumptions were made (i.e., no removal of metals via microfiltration and 100 percent rejections of metals via RO). Therefore, actual metal concentrations in RO concentrate stream may be lower than the values presented in Table 4-4 and those metals can potentially meet Ocean Plan objectives without further relying on ocean mixing and dilution.

Many coastal wastewater treatment facilities in California were designed and operated for BOD removal only which results in very high concentration of ammonia-N (i.e., >20 mg/L) in ocean outfalls (e.g., City of Oxnard, Orange County outfalls, etc.). Although such ammonia concentration does not satisfy Ocean Plan objectives, ocean discharge can be permitted if adequate dilution and mixing are provided as discussed in Section 4.3.3.

4.3.1 New Ocean Outfall

Construction of a new ocean outfall can be complicated due to coastal preserves and endangered or sensitive species located in areas along the coast, such as Marine Protected Areas, coastal preserves, or State Water Quality Management Plans (SWQMP). The best location for an ocean outfall would be in an urban area because impacts to species have already occurred, and the area would likely be disturbed. Figure 4.15 provides a typical ocean outfall configuration.

FIGURE 4.15 TYPICAL OCEAN OUTFALL CONFIGURATION



Source: Calleguas Municipal Water District, 2008

4.3.2 Disposal Costs

Capital and O&M costs for ocean outfalls vary based on location (i.e., existing infrastructure conflicts, topography, and population density) whether the outfall is a new or existing facility, stakeholder groups in the area, and environmental issues in the area. To include the new outfall costs, an estimated unit cost value was obtained from Calleguas Municipal Water District (MWD) Salt Management Project (Calleguas Municipal Water District, 2008). Table 4.5 lists the estimated outfall costs.

TABLE 4.5
ESTIMATED OUTFALL COSTS

Outfall Length (feet)	Outfall Diameter (inches)	Estimated Cost ($)
10,000	54	11,000,000
15,000	60	29,000,000
33,000	66	55,000,000

Source: SAWPA, 2004.

Capital requirements for the new brine lines were calculated based on the cost information obtained from the Calleguas MWD Salt Management Project (SMP) Phase I, which is under construction, as well as SARIS system costs. Phase I of the SMP project has a unit price of $16.5 per pipe diameter in inches per linear foot for the pipeline, along with other project costs and permitting. The overall estimated project cost for a new brine line/outfall system was estimated by adding the brine line and ocean outfall cost together.

Connectivity and user fees are project or site specific. For example SAWPA applies the fees summarized in Table 4.6 for brine discharges to the Santa Ana River Interceptor (SARI) System for 2009:

TABLE 4.6
SAWPA RATES FOR TREATMENT AND DISPOSAL OF NON-RECLAIMABLE AND TEMPORARY DOMESTIC WASTEWATER

Fiscal Year	Flow/ MGD[a]	BOD/ 1000 lbs[b]	TSS/ 1000 lbs[c]	Fixed Pipe[d]	Fixed Treatment[e]
2009-2010	$850	$283	$420	$2,581	$6,452

Notes:

[a] This component shall be calculated and assessed per gallon of discharge (flow) to the SARI System each month.

[b] This component shall be calculated and assessed per gallon of dry weight of BOD calculated from the average of sample results each month.

[c] This component shall be calculated and assessed per gallon of dry weight of TSS calculated from the average of sample results each month.

[d] This component for fixed costs (also known as Readiness to Serve) shall be assessed per MGWD of owned pipeline/connection capacity per month.

[e] This component for fixed costs shall be assessed per MGWD of owned treatment and disposal capacity per month.

Additional fees applied by SAWPA for discharges to the SARI system include:

- An annual permit fee of no less than $500
- Discharge of non-reclaimable wastewater from sources within the Santa Ana River watershed shall be charged truck rates for $0.010 per gallon of brine discharge (less than 100 mg/L of BOD and TSS) or $0.029 per gallon of non-brine discharges (greater than or equal to 100 mg/Lo of BOD and TSS). Discharges from outside the watershed shall be charged $0.14 per gallon of waste.
- A fixed cost of $0.0915 per gallon per month for leases of SARI connection capacity.

The connection fees shown above may be somewhat inflated due to capital cost recovery, so lower connection fees may be expected in some other projects locations. Average connection fees are subject to infrastructure pricing structures of operating agencies.

Conveyance infrastructure required to transport the concentrate to the discharge point is usually comprised of closed pipelines. Design of the conveyance system should address materials of construction, time required for transportation, and pumping costs. The materials used to construct the conveyance system are an important consideration due to the corrosivity of the concentrate resulting from high TDS concentrations. The time required for conveyance of the concentrate to the discharge point is also a key consideration in applications where sparingly soluble salts (such as carbonates, sulfates, and silicates) are supersaturated. Given a sufficient amount of time, precipitation of these salts could occur in the conveyance system resulting in scaling of infrastructure surfaces. The shorter the time concentrate resides in the conveyance system, the smaller the chance sparingly soluble salts will precipitate and cause operational difficulties. Finally, the pumping system is a critical consideration during the design of a concentrate conveyance system. Depending on the energy of the concentrate exiting membrane treatment and the energy requirements for conveyance of the concentrate to the discharge point, a pumping system might be required.

4.3.3 Considerations for Regulatory Approval

Construction of a new outfall would require completion of technical and environmental analyses. These studies would serve as the basis for application to obtain construction and operation permits from the State Water Resources Control Board (SWRCB), RWQCB, United States Army Corps of Engineers (USACE), California Coastal Commission (CCC), California Department of Fish and Game (CDFG), United States Fish and Wildlife Service (USFWS), National Marine Service Fisheries—a Division of the Department of Commerce (NOAA Fisheries Service), and local agencies.

For any new outfall or structural changes to an existing outfall, the California Environmental Quality Act (CEQA) process will be initiated, and a USACE Section 404 permit most will likely be required. In addition, Section 7 of the Endangered Species Act will be triggered, requiring consultation from the resource agencies on the CEQA documentation, as well as the NPDES permit. Also, coordination with the State Lands Commission (SLC) could be required for a lease of coastal lands under their ownership, as well as for any stream crossings. For a new outfall to be eligible to receive a permit, from an RWQCB perspective, as well as a California Coastal Commission (CCC) perspective, it must be a sufficient distance from any sensitive areas, including State Water Quality Protection Areas.

Given a satisfactory environmental impact study, a temporary permit could be issued during design and construction of the outfall based on acceptable water quality and quantity, and suitable outfall design. However, the permanent discharge permit generally will not be issued until the full-scale facility has passed rigorous water quality tests to determine constituent concentrations. In addition, the effluent must pass a bioassay test prior to issuance of an ocean discharge permit. Instances have occurred where a permanent permit was not issued for an ocean outfall based on results from the bioassay tests.

Regulatory issues involved with discharging membrane concentrate to surface water primarily involve obtaining an NPDES permit and any permits associated with conveyance to the discharge site. In some cases, individual states have implemented their own NPDES guidelines that must be followed. Requirements for obtaining an NPDES permit include determination of quality and quantity of membrane concentrate. In addition, reporting guidelines to the regulating agency are to be determined prior to issuance of an NPDES permit. An NPDES permit will be issued only if requirements imposed by national and state authorities are satisfied. These requirements are dependent on the body of water being discharged into, as well as secondary treatment standards. Additional information regarding the application process for an NPDES permit is provided in the USEPA *NPDES Permit Writers' Manual* (1996).

One key issue associated with obtaining an NPDES permit is the ability to provide an adequate visual mixing zone for the concentrate to protect the marine habitat. At existing refinery and power plant outfalls, updating the NPDES permit might be difficult if the existing outfall does not provide adequate mixing and if existing water quality limits preclude the discharge of non-ocean water sources. Limits on metals are of particular concern as NPDES limits are often below drinking water quality because they are based on the Ocean Plan. For the Calleguas Municipal Water District Salt Management Project new ocean outfall, the RWQCB set a dilution ratio of 72 to 1. This ratio is more than sufficient for compliance with the Ocean Plan objectives.

Qualifications for obtaining a permit to discharge concentrate to an ocean outfall are slightly more stringent. Given a satisfactory environmental impact study, a temporary permit could be issued during design and construction of the treatment facility based on acceptable membrane concentrate quality and quantity, and on suitable outfall design. However, the permanent discharge permit generally will not be issued until the full-scale facility has passed rigorous concentrate quality tests to determine constituent concentrations. The permit application process will require:

- Outfall diffuser modeling
- Water quality modeling
- Sampling of anticipated flows

The Coastal Zone Management Act (CZMA) requires all federal permittees that affect a state coastal zone to comply with state guidelines regarding coastal zone management. These guidelines could affect any ocean discharge requiring one or more federal permits. The coastal zone includes states adjacent to the Great Lakes, and all East, West, and Gulf Coast states.

4.4 Landfill Disposal Option

4.4.1 Introduction

For a majority of the concentrate management alternatives, the end disposal mechanism is disposal of either the liquid/slurry or concentrate-precipitated solid to a landfill. The amount of material disposed of into a landfill depends upon which reduction/disposal alternative is used, as well as its efficacy. Concentrate is designated by USEPA as an industrial waste, which is significant because this designation limits disposal to a Class I landfill.

Class I landfills are facilities that can accept industrial wastes as defined in the California Code of Regulations (23 CCR 2531, Municipal Solid Waste, Construction Debris, and Yard Waste). The designation of concentrate by USEPA as an industrial waste occurred because USEPA has only two waste designation categories—domestic discharge and industrial discharge (everything else). A number of factors must be taken into account when identifying potential disposal sites including:

- Disposal of liquid waste might not be permitted at every facility and could be significantly more expensive because liquid waste is most commonly required to be in drums prior to disposal.
- Landfills have restrictions regarding the acceptance of liquid waste. Some landfills cannot accept any liquid waste. Landfills that accept liquid waste must be lined. For Class III landfills the waste-to-liquid ratio is typically 5:1 or 20 percent moisture content.
- Not all Class I landfills have the same permit requirements, and at this time, most RWQCBs do not allow disposal of materials that have high TDS content.

- High transport and disposal costs are associated with disposing material in landfills. Also, disposal fees can vary dramatically by landfill facility. Transportation fees will vary based on the location and could be costly.

Table 4.7 provides a list of potential industrial waste management facilities in the region.

TABLE 4.7
CALIFORNIA COMMERCIAL OFFSITE INDUSTRIAL WASTE MANAGEMENT FACILITIES

Facility Name	Location	Type of Waste Streams Permitted
Waste Management Kettleman Hills	Kettleman City	Wide range
Clean Harbors Buttonwillow	Buttonwillow	Wide range
Clean Harbors Westmoreland	Westmoreland	Wide range
Clean Harbors Wilmington	Wilmington	Wide range (Wastewater)

Note:

This list includes commercial hazardous-waste-permitted recycling, treatment, storage, and disposal facilities that accept offsite waste for a fee and perform treatment and/or disposal at the facility.

4.4.2 Classification of a Waste

Concentrate has to be disposed of at a Class I landfill. This class of landfill can take hazardous and nonhazardous wastes. Nonhazardous wastes are defined as:

> *. . . all putrescible and non-putrescible solid, semi-solid, and liquid wastes including garbage, trash, refuse, paper, rubbish, ashes, industrial wastes, demolition and construction wastes, abandoned vehicles and parts thereof, discarded home and industrial appliances, manure, vegetable or animal solid and semi solid wastes and other discarded waste (whether of solid or semi solid consistency); provided that such wastes do not contain wastes which must be managed as hazardous wastes, or wastes which contain soluble pollutants in concentrations which exceed applicable water quality objectives, or could cause degradation of waters of the state (i.e., designated waste). . .*

For hazardous wastes, Title 22 Division 4.5 sets criteria for defining the characteristics of a hazardous waste. The waste designation classification is important because different waste designations incur different disposal fees.

There are two hazardous waste classifications—listed and characteristic. Listed wastes are specific wastes that can be from specific or nonspecific sources. Listed wastes are identified in the California Code of Regulations (CCR) and CFR. Because listed wastes are considered hazardous despite their respective characteristics, dilution does not change a listed waste classification to a hazardous waste; dilution simply creates a larger amount of listed hazardous waste. Because of this characteristic of listed wastes, the concentrate waste discussed in this report is not likely to consist of listed wastes.

A waste is considered a characteristic hazardous waste if it exhibits any one of four characteristics—toxicity, corrosivity, reactivity, or ignitability. Classification of the concentrate is site specific and is based on the waste characteristics. From initial comparisons of brine/concentrate constituents from the West Basin Municipal Water District (MWD) West Basin Barrier Project, brine/concentrate would not appear to be classified as a hazardous waste. However, this classification will be site specific and dependent upon the discharges to the wastewater or recycled water treatment plant and will need to be determined on a case-by-case basis. For this reason, each of these waste characteristics is described in detail below.

Toxicity

The toxicity characteristic is determined by a series of analytical tests. If the waste will be disposed of in California, the CCR applies, and total threshold-limit concentrations (TTLC) and soluble threshold-limit concentrations (STLC) are used to determine if a waste has the toxicity characteristic. If the waste will be disposed of outside California, the CFR applies, and the TTLC and the toxicity characteristic leaching procedure (TCLP) are used to determine if a waste has the toxicity characteristic. Figure 4.16 is a process flow diagram of how to determine if a waste has a toxicity characteristic.

The TTLC test is performed first. If the results of the TTLC test are less than 10 times the TTLC or 20 times the TCLP limits, the waste does not exhibit the toxicity characteristic. If the results exceed 10 times the TTLC or 20 times the TCLP limits, the STLC or the TCLP test is performed. If the results of the STLC or the TCLP test exceed their respective limits, the waste is considered hazardous per the toxicity characteristic. Based on current concentrations provided by the West Basin MWD West Basin Barrier Project and accounting for brine/concentrate concentration related to the technologies discussed in this report, the brine/concentrate is not expected to be classified as hazardous based on the toxicity characteristic (see the determination process in Figure 4.16 and the information in Table 4.8 from the West Basin MWD).

FIGURE 4.16 FLOW PROCESS DIAGRAM FOR TOXICITY CHARACTERISTIC

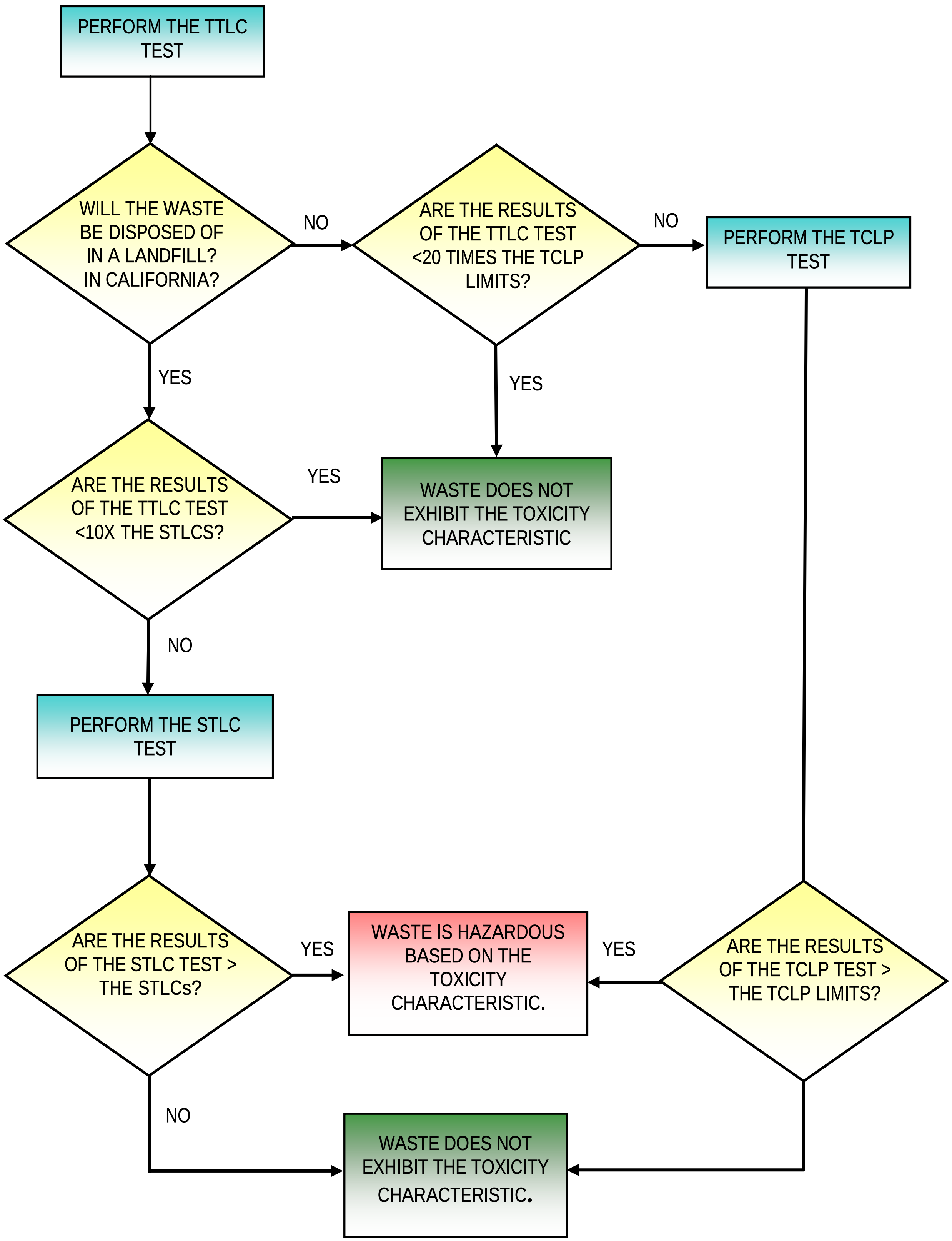


TABLE 4.8
SUMMARY OF WEST BASIN MUNICIPAL WATER DISTRICT BARRIER PROJECT BRINE CONCENTRATIONS

Constituent	Units	TCLP Limit[a]	STLC	TTLC	Maximum Concentration 2000	2001	2002	2003	2004
pH					6.8	7	7.1	7.5	7.2
Arsenic	µg/L	5,000	5,000	500,000	14.9	28.8	30	36.5	31
Antimony	µg/L	-	15,000	500,000	6.57	5.77	6.37	6.8	6.68
Beryllium	µg/L	-	750	75,000	<1	0.1	0.1	0.14	0.2
Cadmium	µg/L	1,000	1,000	100,000	<1	5.6	0.95	1.47	1.12
Chromium III	µg/L		5,000	250,000	45	29	47.2	95	87
Chromium IV	µg/L	-	5,000	500,000	<5	0.25	2.9	1.5	1.4
Total Chromium	µg/L	5,000	5,000	2,500,000	44.9	51.7	87.1	111	122
Copper	µg/L	-	25,000	2,500,000	158	95	45.2	51.5	98.4
Lead	µg/L	5,000	5,000	1,000,000	34.2	19	2.1	1.52	1.33
Mercury	µg/L	200	200	20,000	1.27	1.31	1.24	1.09	1.12
Nickel	µg/L	-	20,000	2,000,000	123	96	78	99.9	59.3
Selenium	µg/L	1,000	1,000	100,000	23.2	23	22.8	38.3	32.4
Silver	µg/L	5,000	5,000	500,000	<5	2.1	1.66	2.27	2.96
Thallium	µg/L	-	7,000	700,000	<1	<0.11	-	<0.18	<0.18
Zinc	µg/L	-	250,000	5,000,000	144	160	90.6	123	249
Lindane	µg/L	400	400	4,000	0.04	<0.063	<0.063	<0.063	<0.063
Endrin	µg/L	20	20	200	0.05	<0.031	<0.031	<0.031	<0.031
Heptachlor	µg/L	8b	470	4,700	<0.01	<0.03	<0.03	<0.03	<0.03
Heptachlor Epoxide	µg/L	8[b]	-	-	-	<0.03	<0.03	<0.03	<0.03
Total PCBs	µg/L	-	5,000	50,000	0.25	-	-	-	-
1,1-Dichloroethene	µg/L	700	-	-	<1	<0.32	<0.32	<0.32	<0.32
1,2-Dichloroethane	µg/L	500	-	-	<1	<0.35	<0.35	<0.35	<0.35
1,4-Dichlorobenzene	µg/L	7,500	-	-	3	9.7	12	10.5	9.9
Benzene	µg/L	500	-	-	<1	<0.09	<0.09	<0.09	<0.09
Trichloromethane	µg/L	6,000	-	-	13	25	30	33	29
Carbon Tetrachloride	µg/L	500	-	-	<1	<0.29	<0.29	<0.29	<0.29
Chlorobenzene	µg/L	100,000	-	-	<1	<0.14	<0.14	<0.14	<0.14
Tetrachloroethene	µg/L	700	-	-	10	7.8	12	14	33
Trichloroethene	µg/L	500	20,400	204,000	<1	0.46	<0.26	0.5	1.2

TABLE 4.8
SUMMARY OF WEST BASIN MUNICIPAL WATER DISTRICT BARRIER PROJECT BRINE CONCENTRATIONS

Constituent	Units	TCLP Limit[a]	STLC	TTLC	Maximum Concentration				
					2000	2001	2002	2003	2004
Vinyl Chloride	µg/L	200	-	-	<5	<0.24	<0.24	<0.24	<0.24
2,4,6-Trichlorophenol	µg/L	2,000	-	-	<1	<2.2	<2.2	1.9	1.3
2,4-Dinitrotoluene	µg/L	130	-	-	<1	<2.2	<2.2	<0.4	<0.4
Hexachlorobutadiene	µg/L	500	-	-	<1	<1.2	<1.2	<0.48	<0.48
Hexachloroethane	µg/L	3,000	-	-	<1	-	-	-	<0.51
Nitrobenzene	µg/L	2,000	-	-	<1	<1.3	<1.3	<0.46	<0.46

Note:

[a]TCLP limits apply where California-specific concentration limits are not identified.

[b]Concentration limit applies to the total concentration of heptachlor and its epoxide.

< Indicates that the parameter was not detected and the given value is the method detection limit.

- Indicates that the parameter was not analyzed.

Corrosivity

The corrosivity characteristic generally is determined by a pH less than 2 or greater than 12.5. Based on the pH data of concentrate provided from the West Basin MWD West Basin Barrier Project, the pH of the concentrate is expected to be between 2 and 12.5. Therefore, the concentrate is not expected to be classified as hazardous waste based on the corrosivity characteristic.

Reactivity

The reactivity characteristic generally applies to wastes that are unstable, react violently, create explosive mixtures, or generate toxic gases or fumes when mixed with water, or are capable of detonation. Based on the aqueous and stable nature of the concentrate, the concentrate is not expected to be classified as hazardous due to a reactivity characteristic.

Ignitability

The ignitability characteristic generally applies to wastes with flashpoints less than 60°C. Because concentrate does not exhibit the ignitability characteristic and the concentration processes discussed in this report are not expected to increase the ignitability of the concentrate, the concentrate is not expected to exhibit the ignitability characteristic. Therefore, the brine concentrate is not expected to be classified as hazardous waste based on the ignitability characteristic.

O&M costs for landfill depend on waste quality and the type of landfill to be utilized. The disposal costs in Los Angeles area vary between $50 and $150 per dry ton disposed. Another cost factor is the hauling and annual permit fees.

5 Energy Generation and Recovery

5.1 Energy Generation and Recovery from Brine Concentrate

Most of the brine-concentrate technologies require a significant amount of energy to operate to overcome thermodynamic barriers such as boiling point rise, heat of dilution and parasitic energy losses and inefficiencies. In general there are few opportunities to generate or recover power in these processes. Two types of energy recovery concepts are currently employed in specific situations to help reduce the power demand on some technologies.

The first concept is sometimes used with systems treating high TDS feed water, especially seawater systems employing a second pass RO unit to further purify permeate from the primary RO system. In such cases, a turbine or turbocharger can be used to recover energy from the primary RO high pressure reject stream to help drive the second RO system. This typically works best when the brine-concentrate has a TDS between 10,000 and 40,000 mg/L, where recovery is relatively low and the pressurized reject stream has a significant amount of recoverable potential energy. Marginal recovery rates can also occur when TDS levels are between 5,000 and 10,000 mg/L or between 50,000 and 70,000 mg/L, on a site-specific basis.

The second concept is to utilize the waste heat from one process to generate energy or steam to power another process unit(s). This has been done in wastewater digesters and membrane distillation processes; however, whether such technology can be economically employed on brine-concentration technologies is unknown.

5.2 Co-Siting of Facilities

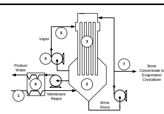
Co-siting of facilities has two primary potential advantages—cost savings due to reduced or eliminated utility conveyance and reduced environmental impacts. Power and water conveyance are the typical utilities that benefit the most from co-siting facilities. Savings are realized as a result of lower capital costs for conveyance facilities and from improved energy efficiencies resulting from shorter conveyance distances. An example of this arrangement includes power plants that are located near large power users, such as a brine-concentrate system and multiple discharges located adjacent an outfall system. Co-siting of brine-concentrate generating facilities and disposal facilities such as a wastewater treatment plant, brineline, or outfall could reduce costs and maximize collateral efficiencies. Facilities that can share outfall capacities can also reduce capital and operation costs if they are optimized to work integrated. Co-siting could also reduce the overall footprint of the facilities if the site plan designs are integrated. Careful site layout and visual barriers that combine aesthetic and noise abatement functions have been adopted in some desalination projects that are located in urban areas.

For some brine-concentrate projects, renewable energy facilities such as solar power can be included as part the overall facility. In many cases, these power sources might not be as cost-effective as traditional power sources. However, in more remote areas, such power options could be more attractive because of the reduced population density and lower land costs. For solar evaporation or brine ponds that are often located away from urbanized areas and in sunnier climates, co-siting of solar power units could be attractive.

6 Summary of Technologies

Figure 6.1 presents a summary of the brine-concentrate treatment technologies and disposal options. In addition, a general assessment of their applicability to wastewater and groundwater sources is summarized in the figure. The relative performance of the treatment and disposal options is rated based on the evaluation criteria discussed in the above sections. These criteria were used to summarize the advantages and disadvantages associated with each technology.

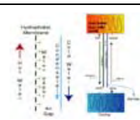
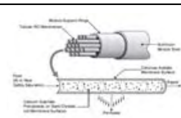
FIGURE 6.1
SUMMARY OF BRINE-CONCENTRATE TECHNOLOGY APPLICABILITY AND EVALUATION CRITERIA

Technology	Illustration	Applicability		Evaluation Criteria												
		Groundwater	Recycled Water	Performance	Amount of Water Recovered	Water Quality Produced	Design Flexibility and Implementability	Technology Footprint	Amount of Waste Minimization	Hazardous Wastes/ Environmental Concerns	Chemical Usage/ Handling and Safety	Proven Technology	Regulatory Complexity	Maintenance and Labor Requirements	Aesthetics and Public Acceptance	Ease of Use
VOLUME REDUCTION TECHNOLOGIES																
Electrodialysis (ED) / Electrodialysis Reversal (EDR)		Good	Good	Good	Average	Poor	Good	Good	Average	Good	Average	Good	Good	Average	Good	Average
Vibratory Shear-Enhanced Processing (VSEP)		Good	Average	Good	Average	Average	Average	Good	Average	Average	Average	Poor	Average	Poor	Average	Average
Precipitative Softening and Reverse Osmosis (PS/RO)		Good	Average	Good	Good	Good	Average	Average	Average	Average	Poor	Good	Good	Average	Average	Poor
Enhanced Membrane Systems (EMS)		Good	Average	Good	Good	Good	Good	Average	Average	Average	Average	Good	Good	Average	Average	Poor
Mechanical and Thermal Evaporation (MTE)		Good	Good	Good	Good	Good	Average	Average	Average	Average	Average	Good	Good	Poor	Poor	Poor
Constructed Wetlands (CW)		Good	Average	Average	Poor	Poor	Poor	Poor	Good	Average	Good	Average	Average	Good	Good	Good
Two-Pass Nanofiltration		Good	Average	Average	Average	Average	Average	Good	Average	Average	Average	Poor	Good	Average	Good	Poor

LEGEND

Good Average Poor NA - Not Applicable Unk. - Unknown

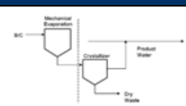
FIGURE 6.1
SUMMARY OF BRINE-CONCENTRATE TECHNOLOGY APPLICABILITY AND EVALUATION CRITERIA

Technology	Illustration	Applicability		Evaluation Criteria												
		Groundwater	Recycled Water	Performance	Amount of Water Recovered	Water Quality Produced	Design Flexibility and Implementability	Technology Footprint	Amount of Waste Minimization	Hazardous Wastes/ Environmental Concerns	Chemical Usage/ Handling and Safety	Proven Technology	Regulatory Complexity	Maintenance and Labor Requirements	Aesthetics and Public Acceptance	Ease of Use
VOLUME REDUCTION TECHNOLOGIES																
Forward Osmosis (FO)		Unk.	Unk.	Unk.	Unk.	Unk.	Unk.	Unk.	Unk.	Unk.	Unk.	Unk.	Unk.	Unk.	Unk.	Unk.
Membrane Distillation (MD)		Good	Average	Average	Average	Average	Average	Average	Average	Average	Average	Poor	Good	Average	Good	Poor
Natural Treatment Systems (NTS)		Good	Average	Average	Poor	Poor	Poor	Poor	Good	Average	Good	Average	Average	Good	Good	Good
Slurry Precipitation and Reverse Osmosis (SPARRO)		Good	Average	Average	Good	Average	Average	Average	Average	Average	Average	Poor	Average	Average	Good	Poor
Advanced Reject Recovery of Water (ARROW)		Good	Average	Good	Good	Good	Average	Average	Average	Average	Poor	Poor	Average	Average	Average	Poor
Capacitive Deionization (CDI)		Good	Average	Average	Average	Poor	Average	Average	Good	Good	Average	Average	Average	Average	Good	Average

LEGEND

Good   Average   Poor   NA - Not Applicable   Unk. - Unknown

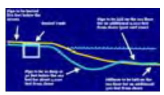
FIGURE 6.1
SUMMARY OF BRINE-CONCENTRATE TECHNOLOGY APPLICABILITY AND EVALUATION CRITERIA

Technology	Illustration	Applicability		Evaluation Criteria												
		Groundwater	Recycled Water	Performance	Amount of Water Recovered	Water Quality Produced	Design Flexibility and Implementability	Technology Footprint	Amount of Waste Minimization	Hazardous Wastes/ Environmental Concerns	Chemical Usage/ Handling and Safety	Proven Technology	Regulatory Complexity	Maintenance and Labor Requirements	Aesthetics and Public Acceptance	Ease of Use
ZERO LIQUID DISCHARGE																
Combination Thermal Process with Zero Liquid Discharge (ZLD)		Good	Good	Good	Good	Good	Average	Average	Average	Average	Average	Good	Good	Poor	Poor	Poor
Enhanced Membrane and Thermal System ZLD		Good	Good	Good	Good	Good	Average	Average	Average	Average	Average	Good	Good	Poor	Poor	Poor
Evaporation Ponds (EP)		Good	Good	Good	Poor	Poor	Average	Poor	Average	Average	Good	Good	Good	Good	Poor	Good
Wind-Aided Intensified Evaporation (WAIV)		Good	Average	Average	Poor	Poor	Good	Good	Good	Average	Average	Poor	Average	Average	Poor	Good
Dewvaporation		Good	Good	Average	Good	Good	Average	Good	Good	Good	Good	Poor	Average	Average	Average	Average

LEGEND

Good Average Poor NA - Not Applicable Unk. - Unknown

FIGURE 6.1
SUMMARY OF BRINE-CONCENTRATE TECHNOLOGY APPLICABILITY AND EVALUATION CRITERIA

Technology	Illustration	Applicability		Evaluation Criteria												
		Groundwater	Recycled Water	Performance	Amount of Water Recovered	Water Quality Produced	Design Flexibility and Implementability	Technology Footprint	Amount of Waste Minimization	Hazardous Wastes/ Environmental Concerns	Chemical Usage/ Handling and Safety	Proven Technology	Regulatory Complexity	Maintenance and Labor Requirements	Aesthetics and Public Acceptance	Ease of Use
FINAL DISPOSAL OPTIONS																
Deep Well Injection (DWI)		Good	Good	Good	NA	NA	Average	Good	Good	Good	Good	Good	Average	Good	Good	Good
WWTP Effluent Blending		Good	Good	NA	NA	NA	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good
Ocean Outfall		Good	Good	NA	NA	NA	Poor	Average	Poor	Poor	Good	Good	Poor	Good	Poor	Good
Landfill		Good	Good	Good	NA	NA	Poor	Poor	Good	Good	Good	Good	Good	Average	Average	Average

LEGEND

Good Average Poor NA - Not Applicable Unk. - Unknown

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Attachment A
Halophyte Land Requirements

Irrigation Water Requirements Calculator - Irvine, California

Month	ETo (in)	Kc [-]	P (in)	Etc (in)	Peff (in)	NIWR Halophyte (in)	GIWR w/o LF (in)	GIWR w/ LF (in)
Jan	2.294	0.000	2.15	0.00	0.00	0.00	0.00	0.00
Feb	2.418	0.005	3.44	0.01	0.01	0.00	0.00	0.00
Mar	3.755	0.032	1.61	0.12	0.12	0.00	0.00	0.00
Apr	4.737	0.147	0.87	0.70	0.51	0.19	0.22	0.22
May	5.372	0.423	0.30	2.27	0.16	2.11	2.48	2.48
Jun	5.589	0.766	0.08	4.28	0.00	4.28	5.04	5.04
Jul	6.489	0.872	0.03	5.66	0.00	5.66	6.66	6.66
Aug	6.199	0.619	0.01	3.84	0.00	3.84	4.51	4.51
Sep	4.752	0.276	0.29	1.31	0.15	1.17	1.37	1.37
Oct	3.602	0.078	0.80	0.28	0.28	0.00	0.00	0.00
Nov	2.511	0.014	1.05	0.04	0.04	0.00	0.00	0.00
Dec	2.137	0.002	1.89	0.00	0.00	0.00	0.00	0.00
Total	49.86		12.53	18.51	1.27	17.24	20.28	20.28

Vegetation Type	Irrigated Area (acres)
Saltgrass	663

Normal Depth of Soil Moisture Depletion (in)	2.28
LF	0%
Total Leaching Requirement (in)	0.00
Combined Irrigation Efficiency	85%

Annual Irrigation Demand

1,121 ac-ft
365 MG
1.000444 MGD

<u>*Notes and Definitions:*</u>
Kc - crop coefficient
ETo - reference grass evapotranspiration
ETc - crop evapotranspiration (ETo x Kc halophyte)
P - average precipitation
Peff - effective precipitation (calculated using SCS method w/ monthly P, ETc, and effective soil water storage)
NIWR - net irrigation water requirements (ETc - Peff)
GIWR w/o LF - gross irrigation water requirements without leaching fraction (NIWR / (combined irrigation efficiency))
LF - leaching fraction (assumed no leaching fraction)
Total Leaching Requirement = GIWR w/ LF - GIWR w/o LF
GIWR w/ LF = GIWR w/o LF / (1 - LF)
Normal Depth of Soil Moisture Depletion is 50% of AWHC over the rooting zone depth; assumed for Sorrento soils with 0.19 in/in available water and a 24-inch rooting depth

Irrigation Water Requirements Calculator - Riverside, California

Month	ETo (in)	Kc [-]	P (in)	Etc (in)	Peff (in)	NIWR Halophytes (in)	GIWR w/o LF (in)	GIWR w/ LF (in)
Jan	2.49	0.000	2.05	0.00	0.00	0.00	0.00	0.00
Feb	2.72	0.005	2.48	0.01	0.01	0.00	0.00	0.00
Mar	4.35	0.032	1.18	0.14	0.14	0.00	0.00	0.00
Apr	5.33	0.147	0.59	0.78	0.29	0.49	0.58	0.58
May	6.19	0.423	0.20	2.62	0.07	2.55	3.00	3.00
Jun	6.65	0.766	0.09	5.09	0.00	5.09	5.99	5.99
Jul	7.53	0.872	0.02	6.56	0.00	6.56	7.72	7.72
Aug	7.19	0.619	0.02	4.45	0.00	4.45	5.24	5.24
Sep	5.49	0.276	0.22	1.52	0.08	1.44	1.69	1.69
Oct	4.00	0.078	0.49	0.31	0.23	0.08	0.10	0.10
Nov	2.82	0.014	0.63	0.04	0.04	0.00	0.00	0.00
Dec	2.39	0.002	0.77	0.00	0.00	0.00	0.00	0.00
Total	57.14		8.74	21.54	0.87	20.67	24.32	24.32

Vegetation Type	Irrigated Area (acres)
Saltgrass	553

Normal Depth of Soil Moisture Depletion (in)	1.2
LF	0%
Total Leaching Requirement (in)	0.00
Combined Irrigation Efficiency	85%

Annual Irrigation Demand

1,121 ac-ft

365 MG

1.0003954 MGD

<u>*Notes and Definitions:*</u>

Kc - crop coefficient

ETo - reference grass evapotranspiration

ETc - crop evapotranspiration (ETo x Kc halophyte)

P - average precipitation

Peff - effective precipitation (calculated using SCS method w/ monthly P, ETc, and effective soil water storage)

NIWR - net irrigation water requirements (ETc - Peff)

GIWR w/o LF - gross irrigation water requirements without leaching fraction (NIWR / (combined irrigation efficiency))

LF - leaching fraction (assumed no leaching fraction)

Total Leaching Requirement = GIWR w/ LF - GIWR w/o LF

GIWR w/ LF = GIWR w/o LF / (1 - LF)

Normal Depth of Soil Moisture Depletion is 50% of AWHC over the rooting zone depth; assumed for Willows soils with 0.10 in/in available water and plant rooting depth of 24 inches