Salton Sea Funding and Feasibility Action Plan

Benchmark 2: Review and Update Existing Condition Data

May 2016

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Revision Record

Revisions to this document will be reviewed and approved through the same level of authority as the original document. All changes to the Benchmark 2 Report must be authorized by the Principal in Charge.

Date	Version	Changes
January 2015	Working Draft	Posted on Salton Sea Authority website. Included changes from draft review by Salton Sea TCT.
June 2015	First Complete Document	Updated hydrology section and inflow projections including Figures 81-84, along with editorial revisions.
September 2015	Revision 1	Added this Revision Record. Editorial revisions to Future Inflows Section 4.1.2. Added Section 3.6 Biota. Corrected title of California Department of Fish and Wildlife and other minor editorial revisions. Updated discussion on 2003-2017 inflows in the context of known changes.
May 2016	Revision 2	Corrected call outs to Figures 79-83. Updated Salton Sea Authority address on previous page.

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Executive Summary

This report presents an overview of historical and current hydrology and water quality of the Sea and its tributaries, projected inflows and salinity, dust mitigation alternatives from areas of exposed playa, and future data needs for management. The report is intended to inform those who are engaged in designing options for the restoration and management of the Sea. Because many of the topics addressed in this report have been considered in prior efforts, the particular focus here is recent data and trends in the Salton Sea, the New, Alamo and Whitewater Rivers and several major agricultural drains. New data have been analyzed and compiled in a way that emphasizes these near-term changes. Trends in hydrology and water quality are important for modeling future conditions that can be used to evaluate alternatives and restoration options.

Major findings from each of the topic areas are summarized below.

Hydrology

- The elevation of the Salton Sea is now -233.7 feet below National Geodetic Vertical Datum of 1929 (NGVD 29) as of February 2015.
- The elevation of the Sea declined at an accelerated rate after 1995 and has decreased by 5.5 feet since 1987.
- New River inflows to the Sea averaged 411,760 acre feet/year (2004-2014). Daily discharge averaged 568 cubic feet per second (cfs) from 2004-2014.
- Flows from Mexico have decreased over the past 10-20 years, reducing flows into the New River and the Sea.
- Alamo River inflows to the Sea averaged 592,500 acre feet/year (2004-2014). Daily discharge averaged 829 cubic feet per second (cfs) from 2004-2014.
- Flows from the Alamo River have decreased at the border but flows to the Sea have remained fairly consistent.
- New and Alamo Rivers reach their highest flows during the months of March to May during peak irrigation season.
- Whitewater River/Coachella Valley Stormwater Channel (CVSC) inflows to the Sea averaged 39,600 acre feet/year (2004-2014). Daily discharge averaged 55 cubic feet per second (cfs) from 2004-2014.

- Whitewater River/CVSC flow showed the sharpest decline among the rivers and the hydrograph has levelled off considerably.
- Other drains and channels that flow directly to the Sea averaged 128,000 acre feet/year (2004-2014).
- Total Salton Sea inflows averaged 1,221,000 acre feet/year (2004-2014).

Salinity

- Salinity in the Sea has increased steadily since 2004 to an average of 55.7 g/L total dissolved solids (TDS) in 2014.
- Average salinity concentrations over the past decade were lowest in the Whitewater River/CSVC, followed by the Alamo River and New River, which averaged 1.2, 2.1, and 2.7 g/L TDS, respectively.
- Annual average salt load to the Sea was about 3.2 million metric tons/year. The Alamo River contributed 47%, the New River 42%, 2% was from the Whitewater River/CVSC and 10% was from other drains and small watercourses.

Water Quality

- Nutrient levels (nitrogen, N, and phosphorus, P) remain high in the Sea and rivers.
- Annual average P load (mostly as ortho-phosphorus) to the Sea was about 1,130 metric tons, with the New and Alamo Rivers contributing 43% and 42%, respectively, and the Whitewater River and other drains contributed 7% and 10%, respectively of the Total P load.
- Annual average N load (mostly as ammonia and organic-N) to the Sea was 11,550 metric tons; the Alamo River added 47%, the New River contributed 36%, the Whitewater River contributed 7% and other drains accounted for 10%.
- Dissolved selenium (Se) levels in the Sea water column are considered to be below the level of concern for aquatic life within the Sea, generally below 2 micrograms per liter (µg/L), but sediment concentrations are a concern for toxicity.
- Higher concentrations of dissolved Se were found in the source Rivers, averaging 6 and 6.8 µg/L at the New and Alamo Rivers, respectively.
- Oxygen depletion in the Sea coincided with temperature and pH stratification, which occurred for a substantial fraction of each year.
- Total suspended solids (TSS) concentrations were elevated in the Sea (42 miligrams per liter (mg/L) from 2003 and 2007) but dramatically

decreased thereafter (21 mg/L from 2007-2014) and was much lower than in the New (218 mg/L from 2004-2014) and Alamo (259 mg/L from 2004-2014) Rivers.

Inflow Projections

Hydrology is projected based on the best available estimates of inflows in Chapter 4. Historical data were used as a baseline for future inflows predicted for the Salton Sea by the Salton Sea Accounting Model (SSAM). The reduction of flows due to Mexicali's plans to reclaim treated effluent and agriculture drainage that would typically flow from the New River into the Sea were identified as the major causes for declining inflows. This analysis focused on the transition period of 2014-2025 which includes the end of Quantification Settlement Agreement (QSA) mitigation flows in 2018. Less flow from Mexico, agricultural efficiency, urban water demand, climate change, drought and less groundwater inflow are additional factors that will contribute to lower elevations at the Sea. The future inflows to the Sea are discussed as components of flow from the Imperial Valley, Coachella Valley and Mexico.

Under the most recent projected inflows to the Sea by Imperial Irrigation District (IID), two conditions were examined utilizing a similar methodology to previous reports: California Environmental Quality Act (CEQA) conditions and variability conditions. CEQA conditions yielded higher estimated annual inflows that were based solely on known inflows, and the effects of the QSA transfer agreements. Under variability conditions, anticipated conditions and projects will result in a somewhat lower inflow estimate; the result of many factors as discussed in this document. Since the future contains uncertainty regarding water supply and availability, these two conditions provide a range of possibilities for future inflows. The range of estimated flows is useful for engineering design considerations.

- Imperial Valley will contribute 558,000 – 667,000 acre feet/year (AFY), or 76 - 78% of the total inflow.
- Coachella Valley flows to the Sea will be an estimated 61,000 – 98,000 AFY or 9 - 11% of total inflow. This estimate is much lower than previous estimates because Coachella Valley Water District (CVWD) intends to recycle more water, desalinate and use more water for recharging aquifers, and comply with new water conservation mandates due to the drought.
- Flows from Mexico will average 40,390 - 96,834 AFY, contributing about 6 - 11% of total inflow to the Sea. This is due to a 30% reduction in flows relative to 2010 as Mexico intends to reuse its dry weather flows and agricultural water use efficiency increases.

- Groundwater flows to the Sea have not been adequately characterized and contribute a relatively minor quantity of flow.
- Due to the severe and potentially long-term drought, flows from the watershed (minor channels and washes) will be increasingly allocated and decreasing in reliability.
- Therefore the estimated "Other" flow contribution is likely 20,000 AFY or 2-3% of the total inflow.

All estimates of future flows contain a certain amount of uncertainty but will provide a design criteria in order to progress with alternative planning and evaluation. It is still a reasonable assumption that inflows to the Sea can vary by up to 200,000 AFY. Evaporation will be much larger than total inflows by 2020, and the inflows will also need to be used for air quality management and habitat creation. Habitat flows will be returned to the Sea after evaporation and transpiration losses occur.

Salinity and Elevation Forecasts

Using hydrology inflow projections and current plans for shallow habitat development, anticipated changes in the area of the Sea, exposed playa area and in-Sea salinity is evaluated over the 21st century in Chapter 5. SSAM, a one-dimensional salt and water balance accounting model was used to project future Salton Sea elevation, volume and salinity based on the current inflow projections and assuming that the Species Conservation Habitat (SCH) project would come on line over 2015-2020. Updated bathymetry data for the Salton Sea was used in this analysis to obtain a more accurate area-volume-depth relationship that is essential for siting future habitat and potential barriers and dikes. The US Bureau of Reclamation's (Reclamation) SSAM, originally developed in 2000, was used for this evaluation with several modifications to represent current inflows and bathymetry. The model shows a continued drop in elevation, with a major change in 2018 following the end of mitigation flows to the Sea, and accompanying decreases in area and increasing salinity.

Air Quality and Dust Mitigation Review

Air quality conditions and dust mitigation strategies for exposed playa that are essential for any restoration alternative are evaluated in Chapter 6. Significant data disparities exist regarding the extent and variability of Salton Sea playa emissivity (dust-emitting), future emissivity, and dust loading of particulate matter less than 10 microns (PM_{10}) in the region. Exposed playa is expected to increase substantially over the next 15 years (2015-2030), creating a significant health risk that has yet to be fully characterized. The Imperial Irrigation District's JPA Dust Mitigation Plan includes an adaptive management framework to monitor ambient air quality, research and monitoring efforts to identify and map playa surface characteristics related to erosion and emission potential. Pollutants of concern include PM_{10}, particulate matter less than 2.5 microns ($PM_{2.5}$), ozone, hydrogen sulfide, arsenic, Se and others.

Future Data Needs

A summary of the current conditions and key areas for future data collection are discussed in Chapter 7. Key aspects of the additional data that might be required are divided into three general categories: water quality processes, biological uptake processes, and air emission and dust control processes. The most important areas to focus on include mixing and nutrient dynamics in a shrinking Sea, especially ammonia and hydrogen sulfide production and release, quantification and transport of dust emitted from the exposed playa surfaces, and Se fate, transport, and potential biological uptake.

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Acronyms and Abbreviations

Acronyms and abbreviations used in the document are listed below.

AF	Acre-Feet
AFY	Acre-Feet/Year
AQM	Air Quality Management
Authority	Salton Sea Authority
BMP	Best Management Practice
CARB	California Air Resources Board
CCAA	California Clean Air Act
CEDEN	California Environmental Data Exchange Network
CDFW	California Department of Fish and Wildlife
CEQA	California Environmental Quality Act
CFS	Cubic feet per second
CNRA	California Natural Resources Agency
CRBRWQCB	Colorado River Basin Regional Water Quality Control Board
CVSC	Coachella Valley Stormwater Channel
CVWD	Coachella Valley Water District
DCM	Dust Control Measure
DDT	Dichlorodiphenyltrichloroethane
DFG	California Department of Fish and Game, now CDFW
DWR	California Department of Water Resources
EAC	Elevation, Area, Capacity curve
EIR/EIS	Environmental Impact Report/Statement
EPA	Environmental Protection Agency
g/L	Grams per liter
IBWC	International Boundary and Water Commission
IID	Imperial Irrigation District
IRWMP	Integrated Regional Water Management Plan
MAP	Monitoring And Assessment Plan
µg/L	Micrograms per liter
mg/L	Milligrams per liter
MPN/100mL	Most Probable Number per 100 milliliters
N	Nitrogen
NAAQS	National Ambient Air Quality Standards
NGVD 29	National Geodetic Vertical Datum of 1929
NO_x	Nitrous oxides
NWIS	National Water Information System
OCPs	Organochlorine pesticides

P	Phosphorous
$PM_{2.5}$	Particulate matter less than 2.5 microns
PM_{10}	Particulate matter less than 10 microns
PEIR	Programmatic Environmental Impact Report
ppt	Parts per thousand
QSA	Quantification Settlement Agreement
Reclamation	US Bureau of Reclamation
SCAQMD	South Coast Air Quality Management District
SCH	Species Conservation Habitat (Project)
Se	Selenium
SSAM	Salton Sea Accounting Model
SIP	State Implementation Plan
SWRCB	California State Water Resources Control Board
TMDL	Total Maximum Daily Load
TSS	Total Suspended Solids
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WMP	Water Management Plan

Table of Contents

List of Figures

List of Tables

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1.0 Introduction

This document was prepared in partial completion of Benchmark 2 of the Salton Sea Funding and Feasibility Grant that was awarded to the Salton Sea Authority (Authority) from the California Natural Resources Agency in early 2014. The document provides an overview of existing data on hydrology, water quality, flow, salinity and elevation projections, and air emissions in the Salton Sea region.

1.1 Background

The Salton Sea is located in a closed portion of the Colorado River basin in Riverside and Imperial Counties within the Colorado River Basin Regional Water Quality Control Board (CRBRWQCB). The Sea is currently at about 233 feet below mean sea level (msl) and has no natural outlet. The Salton Basin is part of the Lower Colorado River Delta system. Lakes have historically existed in the basin as the course of the Colorado River shifted, most recently, several hundred years ago.

The climate in the Salton Basin is one of great extremes. The local rainfall is about 2.5 inches per year while the temperatures can often reach above 110° F in the summer and below freezing in the winter (DWR and CDFW 2011). The presence of the Sea has a micro-climate effect in the Imperial Valley which provides some regulation of extremes in temperature and humidity which is beneficial to agriculture. However, the temperature extremes can have an adverse effect on the fish population in the Sea (DWR and CDFW 2011). Low temperatures in the winter can result in fish mortality while high temperatures in the summer can suppress oxygen levels in the water which can also lead to fish mortality.

Water temperature stratification occurs annually and sometimes more frequently, causing oxygen depletion in the lower portion (hypolimnion). When the Sea mixes, oxygen can be depleted throughout the water column, causing fish die offs and releasing toxic ammonia and hydrogen sulfide. On the other hand, reducing conditions in the bottom of the lake appears to be an important mechanism that enables selenium (Se) sequestration in sediments. Due to Se concerns, research has been conducted to quantify the release of Se from sediments. Water quality data indicate that there will be an initial, temporary flush of Se released but the effects can be mitigated (DWR and CDFW 2011). These factors need to be considered in habitat expansion design and operation.

The Sea and its adjacent areas have supported a diverse wildlife habitat for over 400 bird species (Shuford *et al.* 2000, 2002 and 2004). The Sea also serves as a critical link on the 5,000 mile international Pacific Flyway for bird migration as most of the remaining rest stops for birds--such as the Colorado River delta in Mexico—have dried up (Hurlbert *et al.* 2007, Cohen and Hyun 2006, Detwiler *et al.* 2002, and Cohen 2014).

Even though the Sea was relatively stable in size and elevation over the last 40 years, the dissolved salts present in the inflow water (about 2.5 tons per acre-foot) have been continuously accumulating in the water (except for the amount that precipitates and settles to the bottom). Declines in the inflow discharge have caused the Sea's water surface elevation to drop by about 5 feet over the past 10 years. Consequently, salt concentrations are rising even faster than before and are currently about 55 grams per liter (g/L). This is about 50% saltier than ocean water. If no remedial actions are taken, the Sea will become so saline within 2 years (over 60 g/L salt) that the remaining fish that serve as a food source for piscivorous birds may be effectively eliminated. If the current inflow projections are correct, the Sea will evolve into a hypersaline water body (over 120 g/L salt) within 15 years, similar to Mono Lake in Inyo County. Some have suggested an even more rapid deterioration in habitat values (Pacific Institute, 2006). As inflows are reduced by water transfers and other factors as discussed below, the Sea will eventually become a semi-solid brine pool (over 200 g/L salt) surrounded by hard-surface salt flats similar to the Great Salt Lake in Utah and the Laguna Salada basin southwest of Mexicali.

In addition to high salinity, the Sea is also highly eutrophic, meaning that it has high levels of phosphorus (P) and nitrogen (N) compounds that result from agricultural (fertilizer) drainage and municipal wastewater, a significant fraction of which, until 2007, was discharged without treatment into the New River from Mexicali south of the border. These nutrients stimulate algal growth which settles to the bottom of the Sea, and upon decay, creates oxygen deficiencies in the water. The near absence of oxygen in the deep bottom-water of the Sea leads to the formation and accumulation of substances such as hydrogen sulfide and ammonia that have unpleasant odors and can be toxic to fish in water and to humans when inhaled. When wind events overturn the Sea's natural stratification, these harmful gases rise to the surface and have caused sudden fish kills involving millions of fish. The Sea's eutrophic state also causes the unpleasant odors that permeate the residential areas surrounding the Sea (and occasionally as far away as Los Angeles and the San Fernando Valley) in certain months of the year (Salton Sea Authority 2006).

Projected inflow reductions in the upcoming years will shrink the Sea's wetted surface area and further concentrate salinity and possibly increase eutrophication problems. There are two primary reasons for the projected inflow reductions. First, the Quantification Settlement Agreement (QSA) was signed in October 2003 by Imperial Irrigation District (IID), Coachella Valley Water District (CVWD), other California Colorado River water users, the U.S. Department of Interior, and the California Department of Water Resources (DWR). Under this landmark agreement, about 300,000 acre feet/year (AFY) of Colorado River water (counting both contractual transfers and other reductions) that previously flowed into the Salton Sea will be supplied instead to other users outside the Salton Sea basin. Second, New River inflows from Mexico, recently estimated at about 61,600 AFY, have been estimated to decline as a result of plans by Mexicali to reclaim treated-effluent and farm-drainage flows. Some of this decline has already occurred.

There have been numerous attempts to address the water quality, biology, recreational and economic issues at the Salton Sea over the past five decades. Many investigations have sought to control the salinity and elevation with large engineering projects but recently a shift in thinking has renewed focus on achievable, incremental progress toward avoiding the imminent human health and ecological disaster caused by the shrinking Sea. One of the first reports on the subject was authored by the Colorado River Basin Regional Water Pollution Control Board in 1963 and recommended a partial Sea concept with a concentration pond for removing salts. Two years later the California State Water Quality Control Board concluded that the fishing and recreational values of the Sea would decline sooner than anticipated without immediate measures of action and also recommended a partial Sea (Pomeroy, Johnston and Bailey Engineers, 1965). A wider range of alternatives was proposed by the US Department of the Interior, Aerospace Corporation, and the California Natural Resources Agency from 1969-1971. During this time, controlling nutrients, salinity and sediment were identified as the highest priority, and eutrophication was seen as the most insurmountable issue (DOI and The California Resources Agency, 1969). The idea to incorporate geothermal energy was evaluated in 1976 and 1978 by the Lawrence Livermore Laboratory and the California Institute of Technology (Layton *et al.* 1976 and 1978). In 1983 the California Department of Fish and Game (now the California Department of Fish and Wildlife) evaluated the potential to expand geothermal development and put in a large solar pond (DFG 1983). The California Resources Agency (now the California Natural Resources Agency) in 1988 evaluated three main solutions to the problems of salinity and flood control at the Sea, including evaporation ponds, solar ponds and a canal to the Gulf of California (that was written off as unfeasible). Previous alternatives were evaluated in 1994 by the newly-created Authority.

Components included a smaller diked Sea, solar ponds, constructed wetlands, import-export to the Gulf of California with energy generation, desalination plants to reduce salinity for freshwater wetlands, and called for studies on Se toxicity. Other restoration alternatives continued to be proposed and evaluated based on maintaining elevation and salinity throughout the 1990's and 2000's.

In 2005 the US Bureau of Reclamation (Reclamation) and the United States Geological Survey (USGS) reviewed the Authority's 2004 preferred project report and identified several issues that were not recognized in the report: dust control, Se management and the accommodation of seasonal and annual inflow fluctuations. The Programmatic Environmental Impact Report (PEIR) completed by the Department of Water Resources (DWR) and the Department of Fish and Game (DFG), now California Department of Fish and Wildlife (CDFW), in 2007 evaluated and analyzed potential environmental impacts of alternatives developed for the restoration of the Salton Sea. Reclamation produced a study in 2007 that determined a preferred alternative action for restoring the Salton Sea. In 2013 the Environmental Impact Report/Environmental Impact Statement (PEIR/EIS) was completed to evaluate the impacts of alternative methods of implementing the Species Conservation Habitat Project (SCH Project), which is a proof of concept for restoring shallow water habitat that supports fish and wildlife dependent upon the Sea. Key restoration alternatives are described in detail in the Benchmark 3 document. As a result of the most recent environmental impact studies, extensive water quality analysis and modeling was performed. Local and state agencies have conducted pilot projects to control salinity, establish habitat ponds (fresh, saline and in between), and to control dust. Academic studies have characterized the Sea's salinity, biological communities, nutrient dynamics, Se dynamics, and other water quality parameters. Even though there have been advances in those research areas, major gaps in knowledge still exist that prevent a complete understanding of the consequences of the proposed alternatives or even the future under the status quo.

1.2 Scope of the Document

This report presents an overview of historical and current hydrology and water quality of the Sea and its tributaries (Chapters 2 and 3). It is intended to inform those who are engaged in designing options for the restoration and management of the Sea. New data has been analyzed and compiled in a way that emphasizes near-term changes. Trends in hydrology and water quality are important for modeling future conditions that can be used to evaluate alternatives and options. The Salton Sea, and the New, Alamo and Whitewater Rivers and several major agricultural drains are examined in detail. Following this section is the projected hydrology based on the best available estimates of inflows (Chapter 4). Using these projections and current plans for shallow habitat development, anticipated changes in the area of the Sea, exposed playa area and in-Sea salinity is evaluated over the 21st century (Chapter 5). Air quality conditions and dust mitigation strategies that are essential for any restoration alternative are also evaluated (Chapter 6). A summary of the current conditions and key areas for future data collection are discussed in Chapter 7.

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2.0 Hydrology and Salinity in the Salton Sea Basin

Hydrologic data including Salton Sea elevation and New, Alamo and Whitewater River gaged flows were analyzed over the past four decades. Salinity, which is closely related to the hydrologic regime, is also analyzed over the last decade. The resulting temporal and spatial trends are discussed.

Stream flow observations provide insight into the changes in the hydrology of Salton Sea basin. Recent changes include reductions in flows from Mexico, and with the full implementation of the Quantification Settlement Agreement in the near future, stream flows are expected to decrease further. Historical flow and salinity data from the Alamo, New and Whitewater River Basins, focusing on the last two decades, are summarized to provide a general understanding of the flow contributions in the basin, and to provide a baseline for this work. Associated salinity data in the inflows are also summarized in this chapter because the hydrology and resulting salinity in the Salton Sea are closely intertwined. Sources of data included state and federal government agencies, specifically the California Environmental Data Exchange Network (CEDEN), the United States Geological Survey (USGS; http://waterdata.usgs.gov/nwis), Reclamation's Salton Sea division and the International Boundary and Water Commission (IBWC; http://www.ibwc.state.gov/wad/histflo3.htm). Data were compiled for key locations in each river basin. These locations included multiple sites on each of the rivers, major and minor agricultural drains, and the Salton Sea itself. The major locations referred to in this chapter are shown in Figure 1, Figure 2 and Figure 3. Figure 4 shows a simplified hydrologic cycle for the Sea. Water from the Colorado River flows into the Alamo River, New River and Whitewater River (via the Coachella Canal into the Coachella Valley Stormwater Channel). Precipitation and groundwater also feed the Sea directly and through other sources.

Figure 1 Major sampling locations referred to in this section.

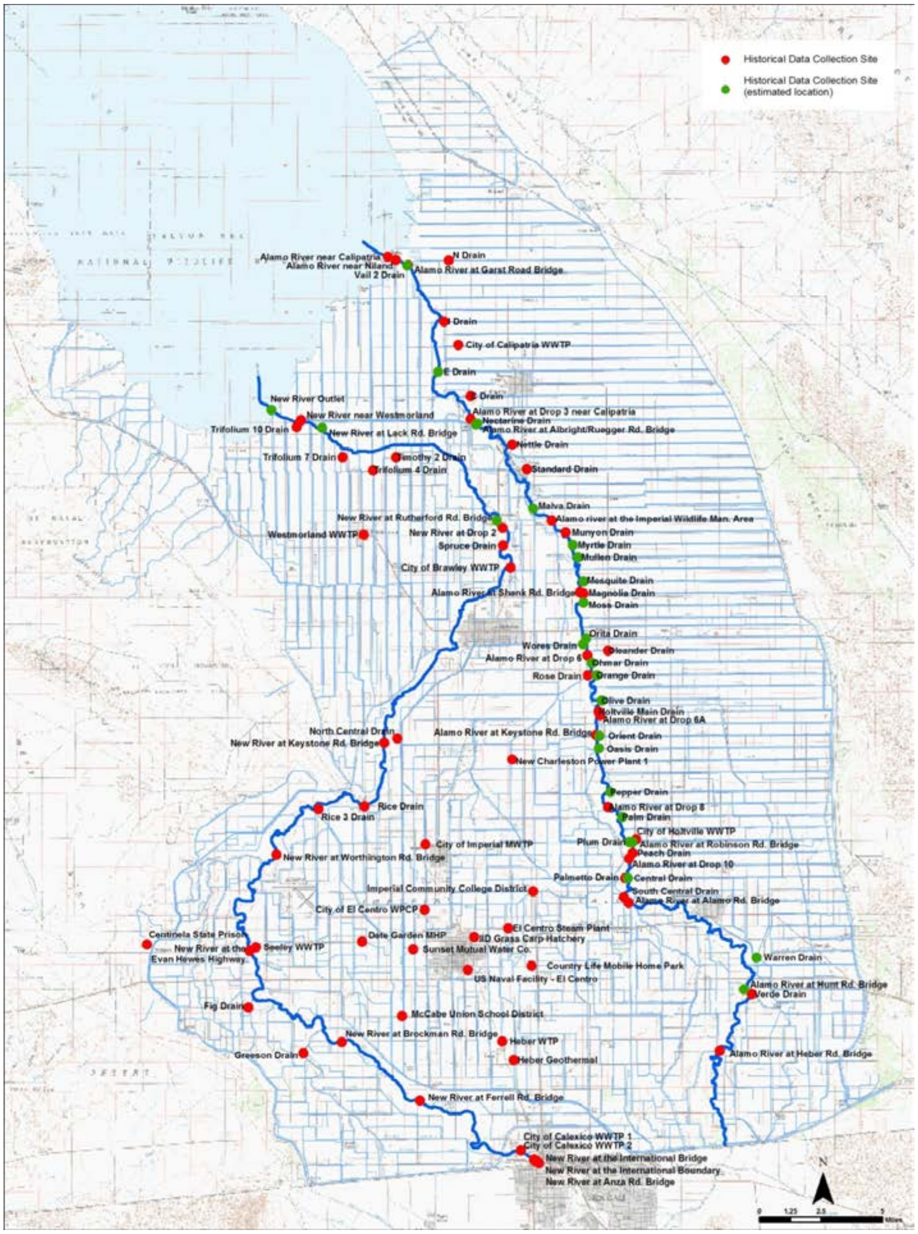

Figure 2 **Map of the historical water quality data sampling locations for the New and Alamo Rivers. Coordinates of some locations were available from the original data sources used. Other coordinate locations were estimated based on station descriptions. The two types of stations are shown in the map legend.**

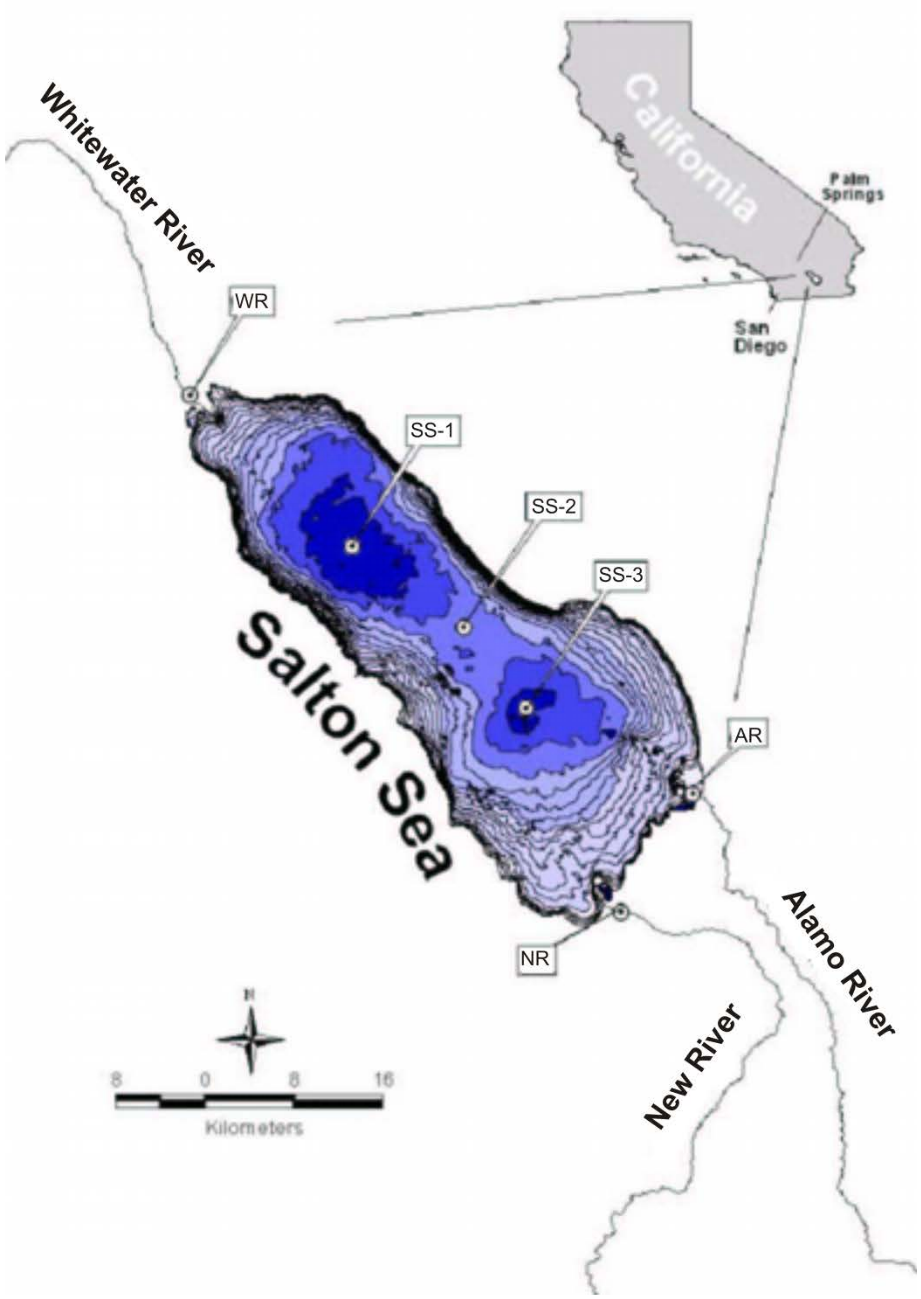

Figure 3 Reclamation sampling locations (Source: Holdren and Montaño 2002). WR is the Whitewater River sampling location, AR is the Alamo River sampling location, NR is the New River location, and SS-1, 2 and 3 are in-Sea sampling locations.

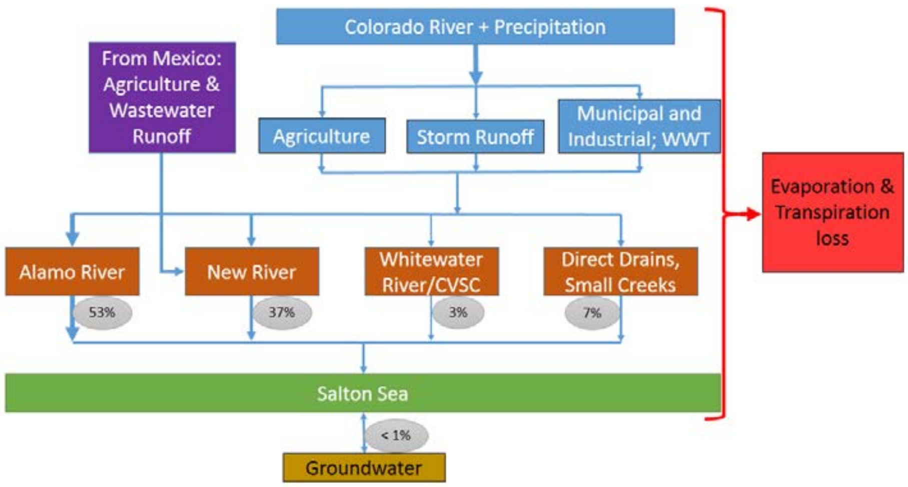

Figure 4 **Conceptual diagram showing simplified hydrological pathways to and from the Salton Sea. Grey circles show the relative percent contribution of the total inflow from each source to the Sea in 2013. WWT= waste water treatment.**

2.1 Elevation – Salton Sea

Daily surface elevation data for the Salton Sea station near Westmorland, CA were available from October 1987 to February 28, 2015. During the entire period of record, the average daily surface water elevation has decreased by 5.5 ft. (Figure 5). The elevation peaked in 1995 but declined at an accelerated rate thereafter. A precipitous drop in water level occurred in 2014, bringing the Sea level down to -234 feet below the National Geodetic Vertical Datum of 1929 (NGVD 29, Figure 5). The downward trend in the Sea surface elevation is related to a long-term decrease of inflows due to drought and diminishing flows from Mexico into the New River and from Coachella Valley into the Whitewater River. These conditions are further analyzed in Section 4.0, Salton Sea Inflow Projections. Reducing the Sea elevation exposes shoreline soils or playa, which has the potential to emit harmful fine particulate matter less than 10 microns (PM_{10}) and is discussed further in Section 6.0, Air Quality and Dust Mitigation Review.

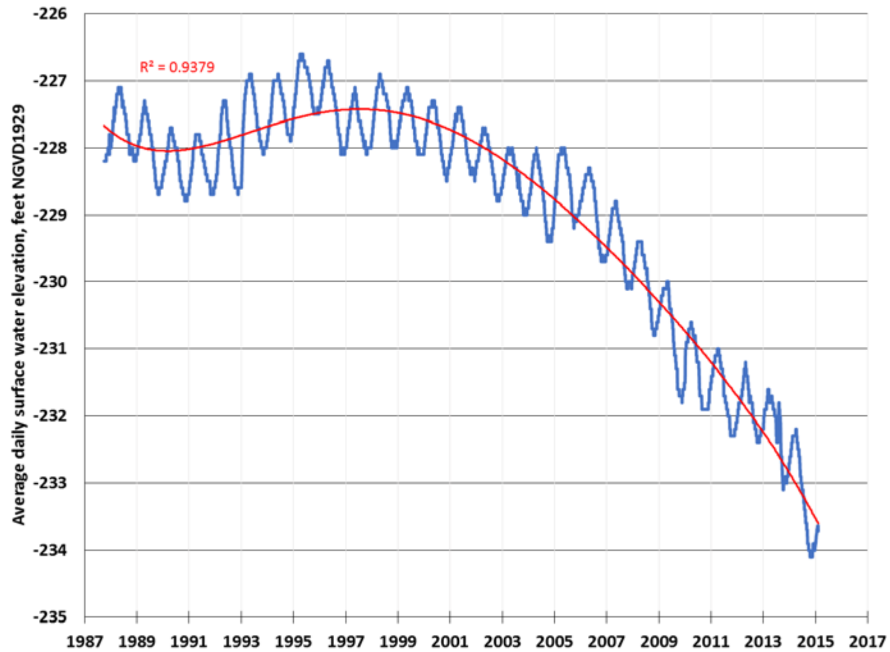

Figure 5 Daily surface water elevation above NGVD 29 for Station 10254005 located along Salton Sea near Westmorland, CA from October 1987 to February 28, 2015 (USGS). Trend line (5th order polynomial) with R^2 shown in red.

2.2 Flow

2.2.1 New River

The New River originates in northern Mexico and terminates at the southern end of the Salton Sea. It receives runoff from agricultural drainage conveyed by a network of surface and subsurface tile drains, wastewater treatment effluent, industrial effluent and stormwater runoff. The New River watershed is at or below sea level and receives up to 10 inches of precipitation from northern Mexico. Prior to March 2005, IID and USGS independently measured flow on the New River; only USGS data is presented here for consistency. Since that time they have cooperatively measured streamflow data for the river. Two USGS gaging stations are located on the New River with available flow data: the international boundary and Westmorland (Figure 1). Data were obtained from the USGS National Water Information System (NWIS) website. Daily mean flow data for the New River at the international boundary were available from 1979 to February 2015; the average flow over the period of record was 204 cfs. Flow from Mexico increased slightly in the 1980's, after which flows have decreased. Flow from Mexico in 2014, averaged over the last 5 years, and averaged over the last 10 years are shown in Table 1. The average daily discharge from February 2004 to February 2015 was 126 cfs (Figure 6). Flow has decreased from an annual 183,800 acre-feet (AF) in 1999 to 73,500 AF in 2014, a decrease of 60%.

Daily flow data for the New River at Westmorland near its discharge to the Salton Sea is shown for 1980-2015. Flow has remained fairly regular but has slightly declined over the past 20 years (Figure 7). Higher flows are typically observed in the river from August to March, and are likely attributed to the higher flows in agricultural drains feeding into the river during this period. The average flow at Westmorland in the past decade was 568 cfs, which is 22% higher than flow at the boundary due to the addition of agricultural drain water that flows into the New River between the international boundary and the Salton Sea. Average daily flow to the Sea was 384,300 AF in 2014, a decrease of 21% from the average daily flow in 1999 (489,300 AF).

Table 1
Average annual Inflows to the Salton Sea.

	Imperial Valley	Coachella Valley	Mexico	Total Inflow to Sea
2014	953,132	63,088	73,499	1,138,861
% of Total	84%	6%	7%	
5-year average	1,022,831	56,374	79,887	1,208,234
% of Total	85%	5%	7%	
10-year average	1,013,687	65,355	89,887	1,218,070
% of Total	83%	5%	7%	

Notes

Values in acre-feet

Groundwater inflows conservatively estimated at 1,000 from Imperial Valley and 1,470 from Coachella Valley (DWR 2007 and Coachella Valley WMP 2013)

Imperial Valley includes flow from the New River, Alamo River, Drains and estimated groundwater contribution (see note above).

Coachella Valley includes flow from the Whitewater River/CVSC, Direct Drains, estimated groundwater contribution (see note above), and Salt Creek.

San Felipe Creek and other smaller tributaries are not included due to lack of current monitoring.

Total Inflow to Sea includes estimated precipitation.

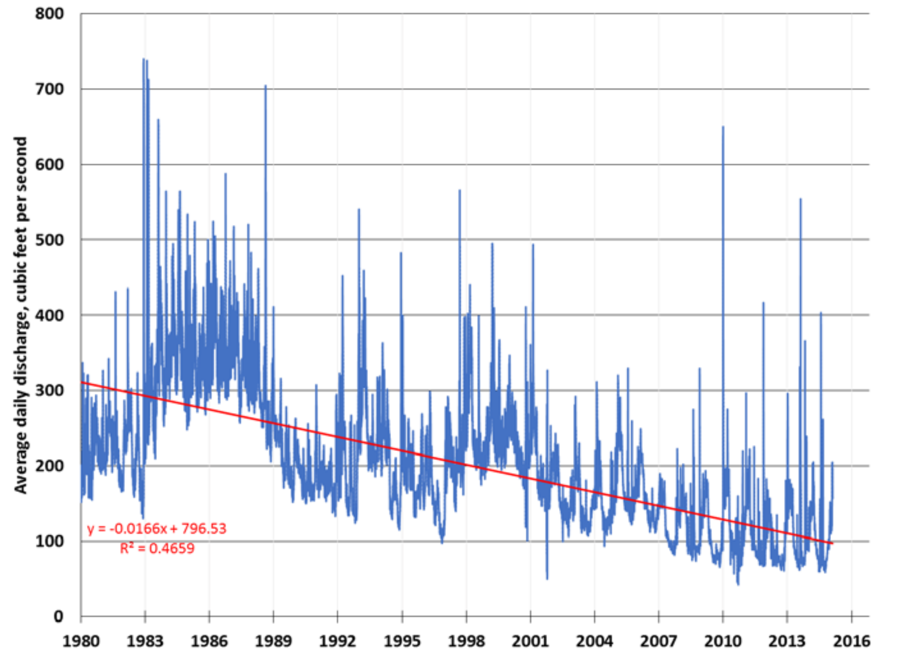

Figure 6 Daily mean discharge along New River @ International Boundary near Calexico, CA from 1980 to February 28, 2015 (USGS Station 10254970, data obtained from NWIS). Linear trend line with equation of fit and R^2 shown in red.

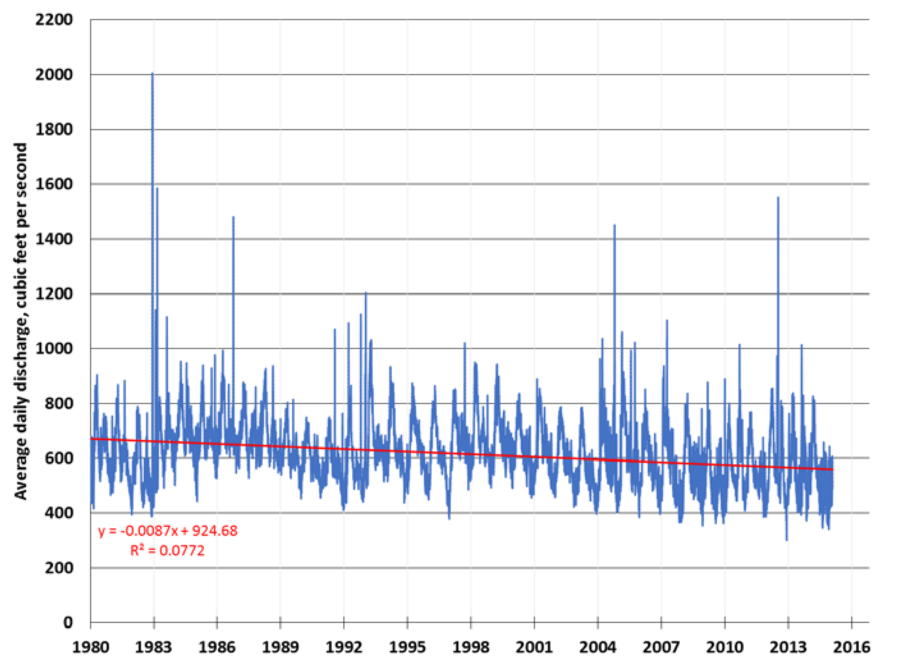

Figure 7 Daily mean discharge for Station 10255550 located along New River near Westmorland, CA from 1980 to February 28, 2015 (USGS). Linear trend line with equation of fit and R^2 shown in red.

Average monthly flows from the New River over two periods are presented in Figure 8 (1980-2002 and 2003-2013). The New River reaches its highest flow during the month of April during peak irrigation (Figure 8). Flows have decreased fairly consistently over the annual hydrograph but the largest reduction in flows compared with historical values occurs during August. Flows may have reduced mainly because of California and Mexico's implementation of nonpoint pollution control, TMDL compliance and improvements to wastewater treatment plants.

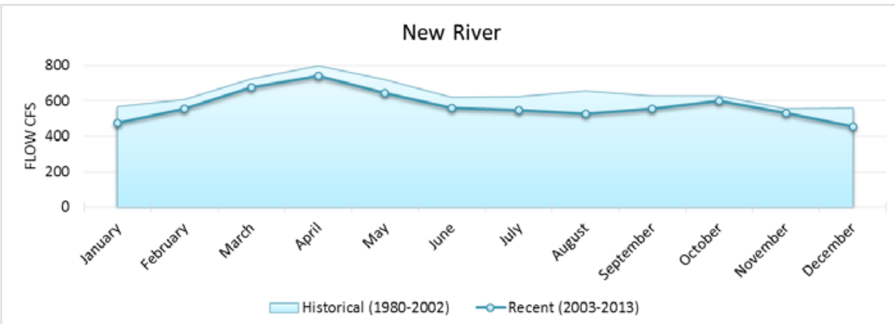

Figure 8 **New River discharge in cubic feet per second (CFS) by month and averaged over the last 10 years and a historic period of record (1980-2002).**

San Felipe Creek watershed drains about 1,693 square miles in the south west Salton Sea watershed. Flows generally consist of desert summer storms and heavy winter storms, and have not been measured since 1991. Average flow to the Sea from 1961 to 1991 was 4,532 AFY with a minimum of 60 AF in 1973 and a maximum flow of 40,638 AF in 1976 (DWR and DFG 2007). Flows from the New River and San Felipe Creek are two surface water components of Imperial Valley flows, shown in Table 1.

2.2.2 Alamo River

The Alamo River originates at the south side of the All-American Canal on the eastern boundary of Calexico and terminates at the Salton Sea. Source waters include seepage from the All-American Canal, runoff from the Chocolate Mountains, agricultural drain flows, and stormwater runoff. Three stations on the Alamo River provided flow data: the international boundary, near the Salton Sea at Niland, and Drop 3 near Calipatria (Figure 1). The Niland and Calipatria stations are USGS gaging stations, and the data were obtained electronically from the NWIS website. Prior to October 1, 2004, IID and USGS independently collected Alamo River flow data. Minor differences in measurements occurred and only USGS and IBWC flows are reported here. The data for the Alamo River at the international boundary were obtained from the IBWC website. Figure 9, Figure 10 and Figure 11 show the flow data for these three sites from January 1, 1980 to the last available data record.

Daily mean flow data for the Niland station were available from 1960 to February 2015. The average daily discharge from 1980 to January 2004 was 829 cfs, and about the same from February 2004 to February 28, 2015 (816 cfs; Figure 9). For the Calipatria site, daily flow data were available from 1979 to October 2003, averaging 719 cfs. Flows were very consistent over this period, increasing seasonally in response to agricultural discharges (Figure 11).

Average annual inflow to the Sea from the Alamo River was 617,569 AF in 1999. In 2014, flow to the Sea was 548,100 AF, which is within typical inter-annual variability (Figure 9). There is no decreasing flow trend for the Alamo River. Flows from the Alamo River contribute about 60% of the total flow to the Sea from Imperial Valley shown in Table 1.

Average monthly flows from the Alamo River over two time periods, 1980-2002 and 2003-2013, are presented in Figure 12. Like the New River, the Alamo River reaches its highest flows during the months of March to May during peak irrigation (Figure 12). Recent monthly flows have not increased or decreased significantly compared with historical values.

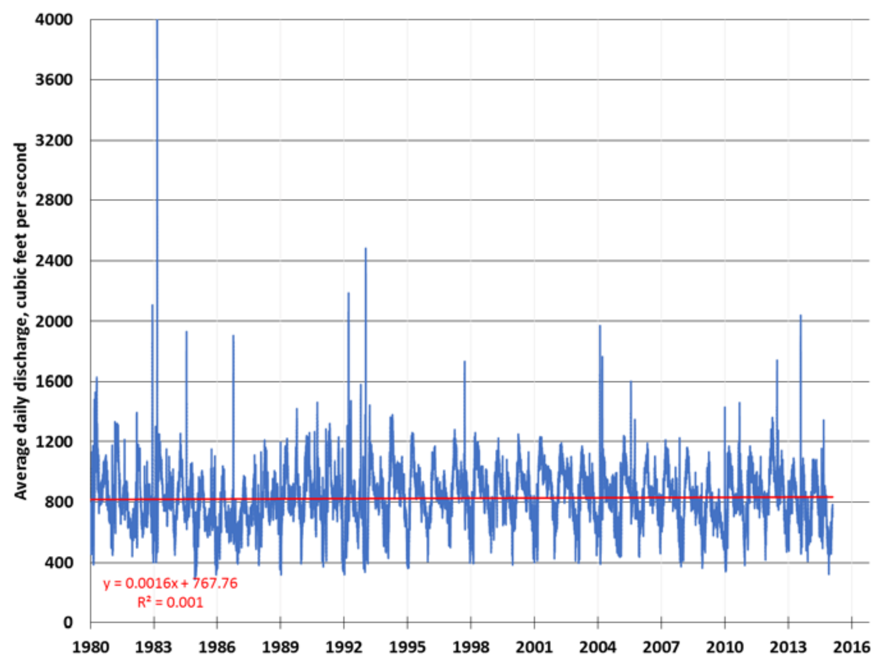

Figure 9 **Daily mean discharge for Station 10254730 located along the Alamo River near Niland, CA from 1980 to February 28, 2015 (USGS). Linear trend line with equation of fit and R^2 shown in red.**

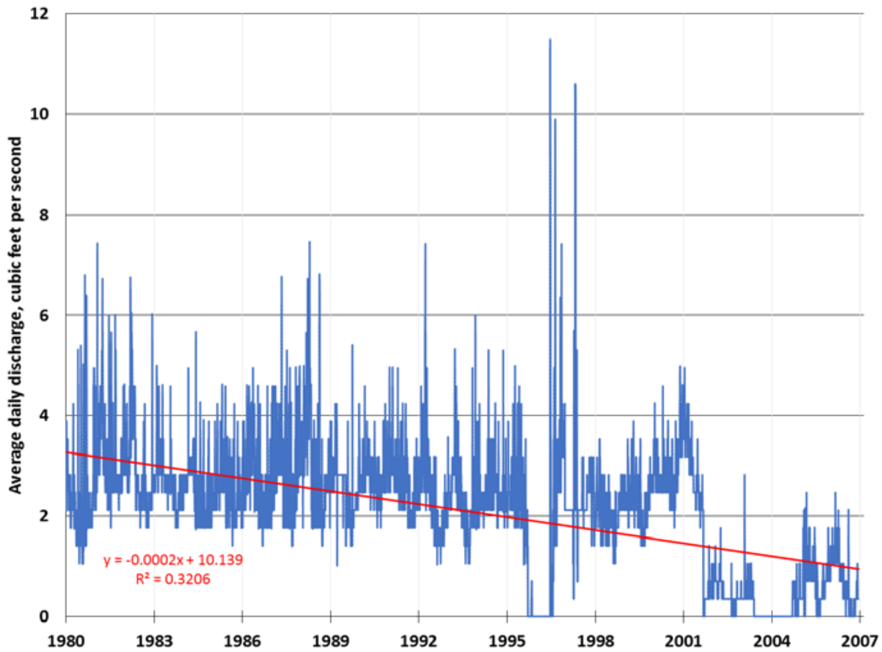

Figure 10 **Daily mean discharge along the Alamo River @ International Boundary from 1980 to December 31, 2006 (IBWC). Linear trend line with equation of fit and R^2 shown in red.**

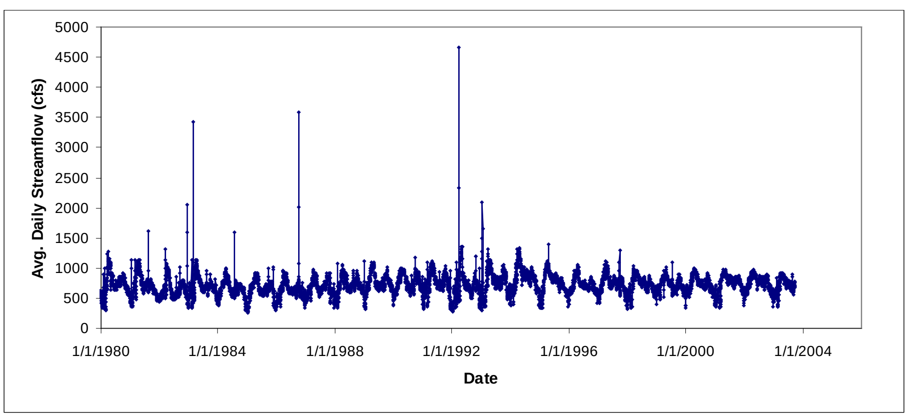

Figure 11 **Average daily flow from the Alamo River at Drop 3 near Calipatria.**

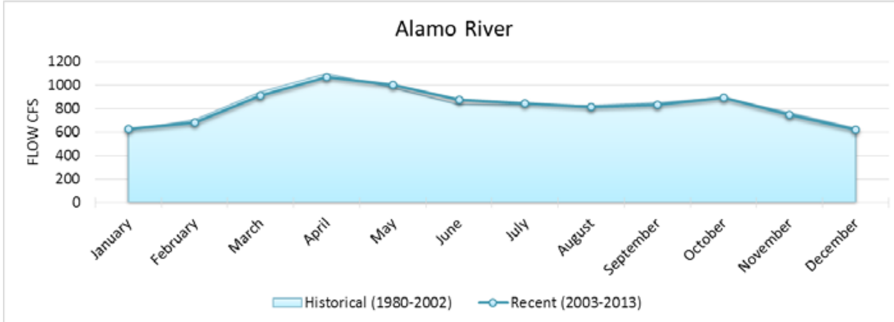

Figure 12 **Alamo River discharge in cubic feet per second (CFS) by month and averaged over the last 10 years and a historic period of record (1980-2002).**

Daily stream flow discharge data for the International Boundary station were available from 1947 to 2007. The site has much lower flows than the Niland or Calipatria sites; the average daily discharge from 1980 to 2007 was 2.1 cfs. Stream flow generally increased in the 1980's until 1995 when flows dropped to zero. Flows recovered slightly but declined and became irregular after 2001 (Figure 10). At the international border location, flow solely consists of seepage from the All American Canal (DWR and CDFW 2013).

2.2.3 Whitewater River/CVSC

The Whitewater River/Coachella Valley Stormwater Channel (CVSC) originates in the San Bernardino Mountains and collects stormwater runoff, Colorado River water and agricultural drainage flows in the Coachella Valley and terminates at the Salton Sea. The waterway is mostly channelized and it is considered fully appropriated by the State Water Resources Control Board (SWRCB) (DWR and CDFW 2013). The upper reaches convey natural runoff and State Water Project exchange water to agricultural fields and to the Whitewater Spreading Facility for groundwater recharge (CVWD 2002). Lower reaches of the river/CVSC consist of unlined conveyance of stormwater and agricultural runoff (CVWD 2012). The Whitewater River has two stations with available stream flow data: near Mecca and Indio (Figure 1). The Indio station is about 18 miles further upstream than the Mecca station. These stations are run by the USGS and data were obtained from the NWIS website. Daily stream flow discharge data for the Whitewater River station at Indio, CA were available from 1960 to 2015. The average daily discharge from January 1, 1980 to January 31, 2004 was 3.7 cfs. The average daily discharge from February 2004 to February 2015 was 3 cfs. Flows are very small in comparison to the Mecca station, with occasional large flash flows from storm runoff (Figure 13; CVWD 2002).

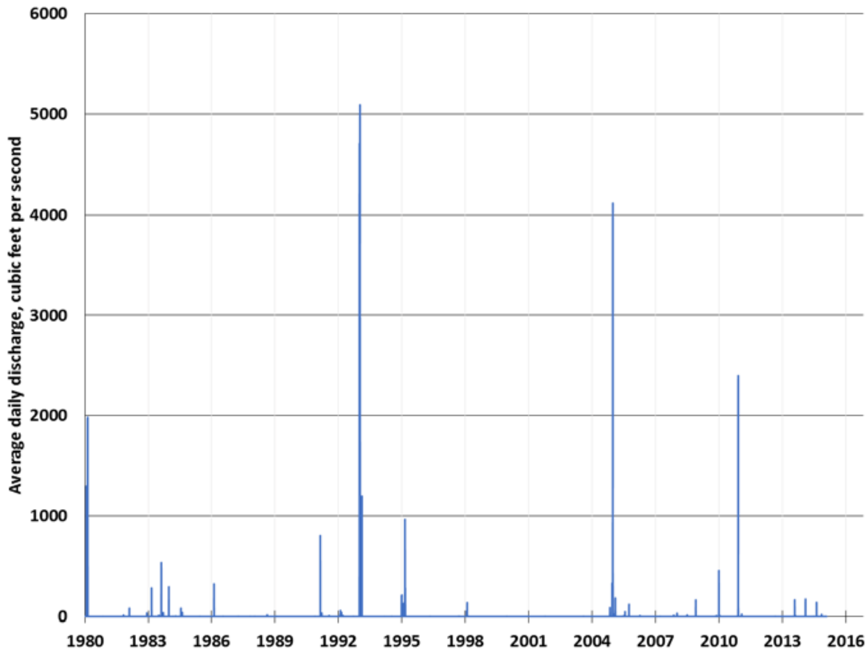

Figure 13 Daily mean discharge for Station 10259300 located along Whitewater River @ Indio, CA from 1980 to February 28, 2015 (USGS).

Daily stream flow discharge data for the Mecca Station were available from 1960 to December 17, 2014. The average daily discharge from January 1, 1980 to January 31, 2004 was 90.4 cfs (Figure 14). The average daily discharge from February 2004 to January 6, 2014 was 55 cfs. Flows have decreased since the early 1980s and large short-term discharge events have become less frequent (Figure 14). Annual inflow to the Sea has decreased by 27% from 1999 to 2014 at about 38,460 AF. Direct drains that collect subsurface agricultural drainage have been estimated at an additional 40% of Coachella Valley flows (CVWD 2002), although this estimate may be conservatively high and outdated. Including estimated flows, the total inflow from Coachella Valley was 63,088 AF in 2014.

The surface water supply has decreased due to increased water use efficiency, drought, Delta environmental needs, decreased supply reliability, and climate change. Groundwater overdraft, or the condition of the groundwater basin created by the pumping of groundwater greater than is replenished over a period of average water supply years, has resulted from the increased demand of population growth and agriculture. Groundwater overdraft in the Coachella Valley means that less water is discharged to the Sea because it is needed for groundwater replenishment. Coachella Valley has agreed to continue drain flows to the Sea at their current levels even if some drainage flows are diverted for desalination (CVWD 2012). Chronic overdraft has reversed historically perched water tables and created a downward pressure gradient. Therefore groundwater inflow to the Sea is very small, estimated at 1,100-1,470 AFY by the Coachella Valley Water Management Plan (CVWD 2012).

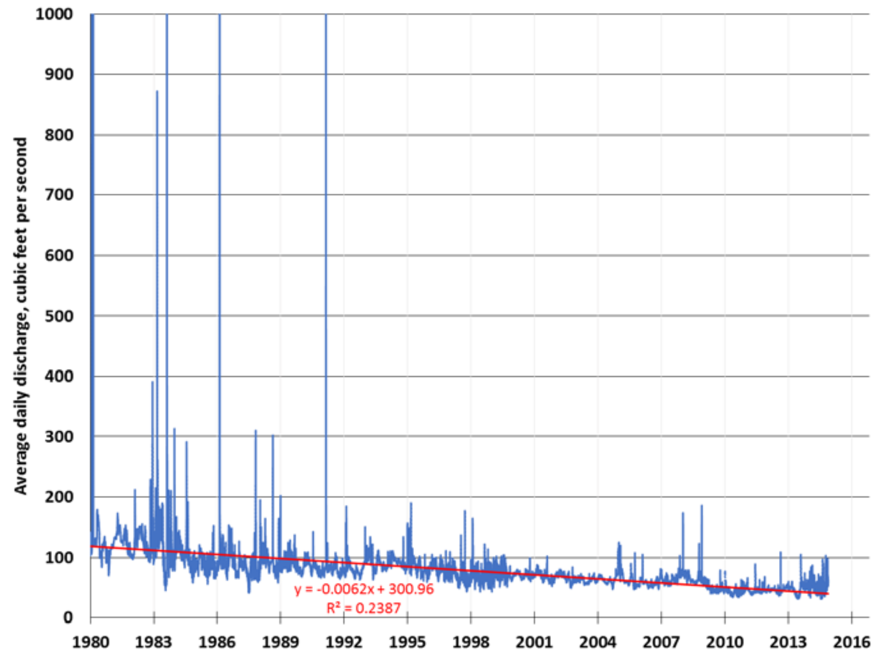

Figure 14 **Daily mean discharge for Station 10259540 located along Whitewater River near Mecca, CA from 1980 to December 17, 2014 (USGS). Flows greater than 1,000 cfs are not shown. Linear trend line with equation of fit and R^2 shown in red.**

Average monthly flows from the Whitewater River/CVSC are presented in Figure 15 over two periods: 1980-2002 and 2003-2013. The Whitewater River/CVSV has shown a decline in flow and the hydrograph has levelled off considerably (Figure 15). The flow reaches its highest point in February, due to less of an agricultural drain input compared with the New and Alamo Rivers.

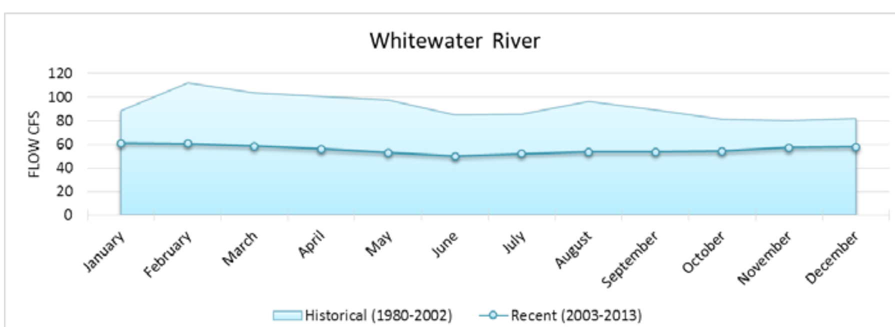

Figure 15 **Whitewater River/CVSV discharge in cubic feet per second (CFS) by month and averaged over the last 10 years and a historic period of record (1980-2002).**

Salt Creek is another inflow to the Salton Sea, located in the northern portion of the Salton Sea watershed and draining about 269 square miles. Annual flows averaged 564 AFY over the past 5 years but have historically varied considerably. Additional unmetered runoff not associated with Salt Creek or San Felipe Creek was estimated to be 2,031 AFY (DWR and DFG 2007). The Whitewater River/CVSC and Salt Creek contribute to Coachella Valley flows in Table 1.

2.2.4 Hydrologic Summary

Inflows to the Salton Sea have been decreasing, leading to a decrease in the elevation of the Sea. As a consequence, the playa is being exposed at a faster rate which may have air quality effects (See Section 6.0 Air Quality and Dust Mitigation Review). The relative contribution from each source has remained fairly consistent. However a decreasing trend is evident from all regions. Total inflow to the Sea has averaged 1,278,600 AFY and varied by 76,000 AF or 6% from 1991-2014. The only outflow for Salton Sea water is evaporation, at about 64-75 inches/year or about 1,194,000 AFY to 1,400,000 AFY. Since 2008, inflows to the Sea have been consistently less than the higher evaporation estimate and less than the lower estimate in three of the last seven years. The Sea volume decreases due to this imbalance, lowering the water level and concentrating water quality constituents like salts in the Sea.

2.3 Salinity and Specific Conductivity

2.3.1 Salton Sea

Based on CEDEN data within the Salton Sea, salinity has slightly increased over the last decade. The salinity at the Salton Sea ranged from 30 to 58 parts per thousand (ppt) from 2002-2011 (Figure 16). While other sources have reported higher salinity in the Salton Sea (DWR and CDFW 2013), the increasing trend is consistent. It is also widely understood that the Colorado River Basin Regional Water Quality Control Board’s 2006 water quality objective for total dissolved solids (TDS, or salinity) of 35 g/L or 35 ppt will not be met without an engineering solution with federal, State and local cooperation (CRBRWQCB 2006). At the Salton Sea TDS increased steadily from 2004 at an average of 45 g/L to an average of 55.7 g/L in 2014, classifying the Sea’s water as brine 54% saltier than ocean water. Over time the Sea’s salt content has concentrated by about 1 ppb per year. Average salinity in 2013 was 51.5 ppt or 54 g/L TDS (Figure 17). Reclamation reported in 2007 that without further definitive information, the majority of the fishery is projected to be lost at a salinity of 60 g/L. Indeed, the Species Conservation Habitat EIR cited a laboratory study by Schlenk and Lorenzi of UCR that showed that most tilapia strains and species had moderately good survival in 45 ppt and 60 ppt conditions at warm (23-28°C) temperatures, all species showed poor survival in hot (33-38°C) high-salinity (60 ppt) conditions (DWR and CDFW 2011).

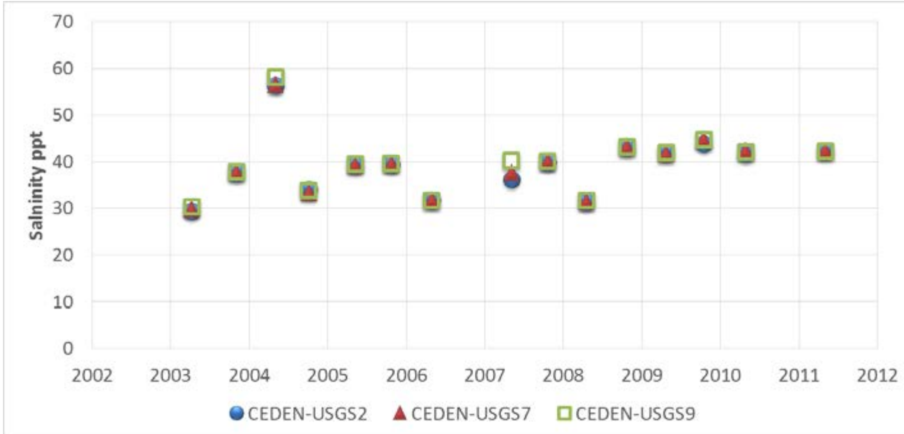

Figure 16 CEDEN data for total salinity of Salton Sea stations in ppt.

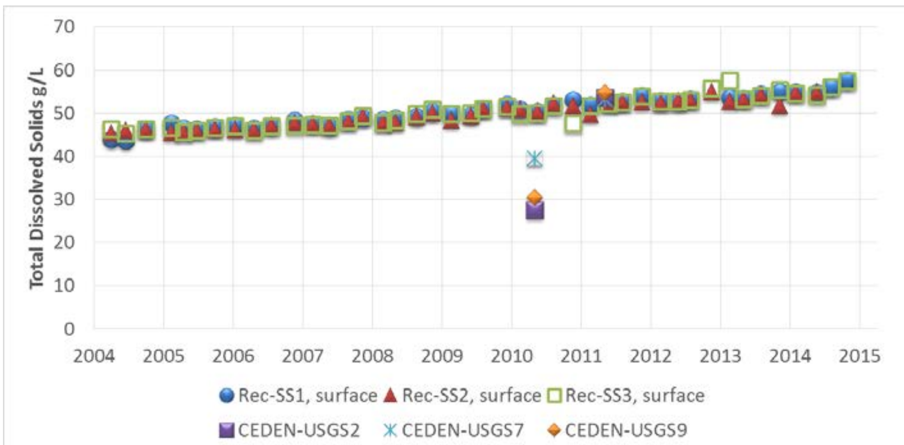

Figure 17 Salinity as total dissolved solids (TDS; g/L or ppt) of Salton Sea Stations. CEDEN data stations and Reclamation (Rec) stations.

The ions mostly responsible for the TDS increase are chloride, magnesium, sulfate and sodium. Some have reported that the Sea has become oversaturated with regard to calcite and gypsum, leading to considerable percentage (estimated up to 1/3) of the salt load to precipitate out of solution (Amrhein *et al.* 2001).

Salinity is also reported in terms of specific conductivity, or electrical conductivity measured and corrected to 25°C using sensors rather than total dissolved solids. Specific conductivity data are more easily continuously monitored and are included here because these sensors may be implemented in the Salton Sea basin more widely in future. Specific conductivity levels of 81 mS/cm were reached in 2004, correlating to an increase in salinity (Figure 16 and Figure 18). Higher levels of salinity typically occur toward the Sea's center due to local heating, evaporative concentration and influence from the river inflows (Amrhein *et al.* 2001 and DWR and CDFW 2013). Spatial variation in salinity within the Sea can result from measurement location and calibration. Salinity originates from imported Colorado River water that is used to irrigate agricultural fields where salt is concentrated via evaporation and subsequently leached from soils. The water is routed through surface and subsurface drains to the major rivers or directly to the Sea. Imperial Valley contributes the majority of flows and salt to the Salton Sea (DWR and CDFW 2013).

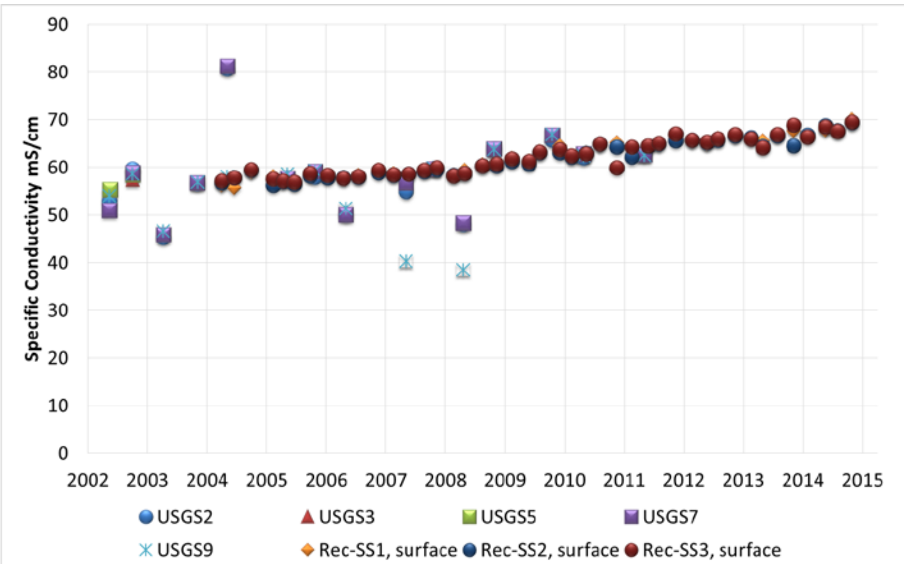

Figure 18 Specific conductivity of Salton Sea Stations (mS/cm @ 25°C). CEDEN (USGS) data stations and Reclamation (Rec) stations.

Salt Load

In 2002, Holdren and Montaño calculated total dissolved salt loading of 3,434,000 tonnes/year, consistent with other calculated salt loads to the Sea (Holdren and Moñtano 2002; Amrhein *et al.* 2001). Average flow from the Alamo, New and Whitewater Rivers was multiplied by the corresponding average TDS concentration to obtain annual dissolved salt loads. Direct drain flow loads were calculated by multiplying measured TDS in 2010 by typical drain flow (10% of combined Alamo River and New River flow; DWR and DFG 2007). The average annual TDS load from 2004-2014 was 3,236,000 metric tons, varying annually by 287,000 tonnes (Table 2). Agricultural drains from Imperial Valley that discharge directly into the Sea accounted for 10% of the salt load at 312,000 metric tons per year from 2004-2014 (Table 2). The load calculated may be an underestimate because some flows and/or salt concentrations were not available (local watershed, groundwater, small creeks, Coachella Valley direct drains) and could not be included. Salt loads from the Imperial Valley may be lower due to QSA mitigation water delivered directly to the Sea via the Alamo River and drains without leaching any fields, therefore diluting the salt content of the surface waters. Lower flows are likely the cause of decreased salt loading from the New River.

Table 2
Salt Load (metric tons/year) using total dissolved solid data by source in 2014 and an average from 2004-2014.

	2014		2004-2014 Average	
	Load (metric ton/year)	Percent Total	Load (metric ton/year)	Percent Total
Alamo River	1,263,000	45%	1,518,000	47%
New River	1,159,000	41%	1,348,000	42%
Whitewater River	52,000	2%	58,000	2%
Direct Drains	321,000	11%	312,000	10%
Total	**2,795,000**		**3,236,000**	

2.3.2 New River

The salinity of the New River at the international boundary increased from 2002 to 2012 (Figure 19). Salinity decreases spatially from the international boarder toward the Salton Sea outlet due to dilution from lower salinity agricultural drain flows (Figure 19). Salinity measured at the border ranged from 2.4 to 3.8 ppt except for an outlier of 7.7 ppt in December 2004. At the outlet salinity ranged from 1.2 to 2.9 ppt. Specific conductivity was also higher at the at the international boundary than the outlet, as the two parameters are closely related (Figure 20). Salinity and specific conductivity remained fairly level from 2002 to 2012 at the outlet to the Salton Sea. A large fraction of the New River water consists of agricultural drain flows, so salinities in major drains flowing into the New River are similar to levels in the river (Figure 19 and Figure 21). Specific conductivity trends were similar to salinity levels in the rivers and drains (Figure 19- Figure 22).

The average TDS concentrations calculated using all the data were lower at the outlet than the international boundary, consistent with salinity and specific conductivity data. The average TDS concentrations from these sites were 3.4 g/L and 4.4 g/L, respectively. Overall, TDS concentrations increased at the international boundary from 2004 to 2012. Since the 1960's, TDS has declined in the New River at all locations with the boundary as a possible exception (Figure 23). More data is needed at the boundary to confirm a trend. At these TDS concentrations, the New River water is considered brackish. Salt loads were calculated using TDS concentrations from 2004 to 2014 for the New River. The average annual TDS load from 2004-2014 was

1,348,000 metric tons, approximately 42% of the total contribution of salt to the Sea (Table 2).

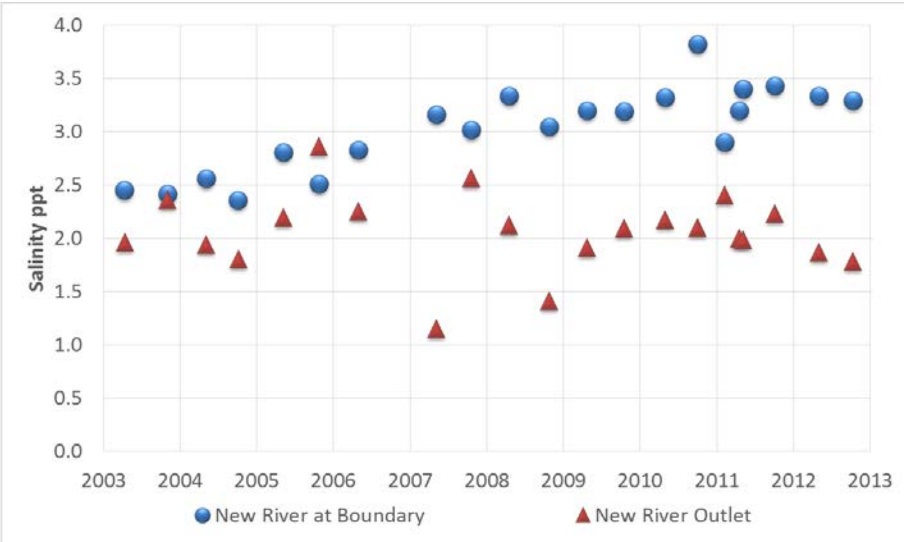

Figure 19 New River at the International Boundary and the Outlet. CEDEN data for total salinity (ppt). One data point greater than 4 ppt was omitted for easier visual representation, measured at the boundary on 12/28/2004 (7.65 ppt).

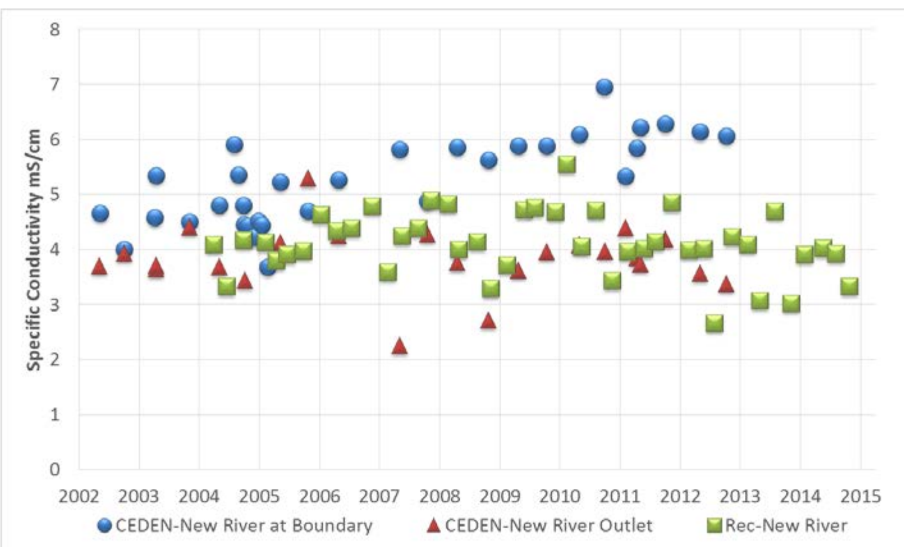

Figure 20 New River at the International Boundary and the Outlet. CEDEN and Reclamation (Rec) data for total specific conductivity (mS/cm @ 25°C).

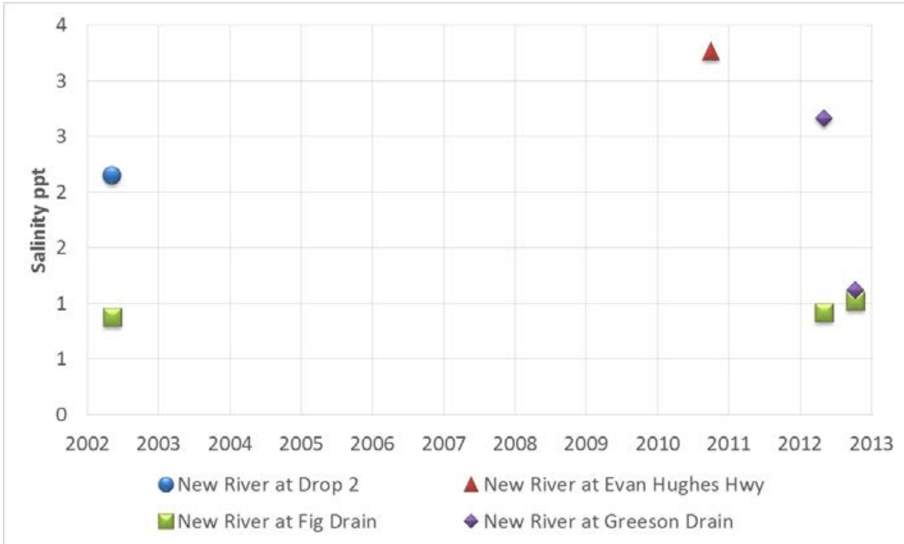

Figure 21 New River agricultural drains. CEDEN data for total salinity (ppt).

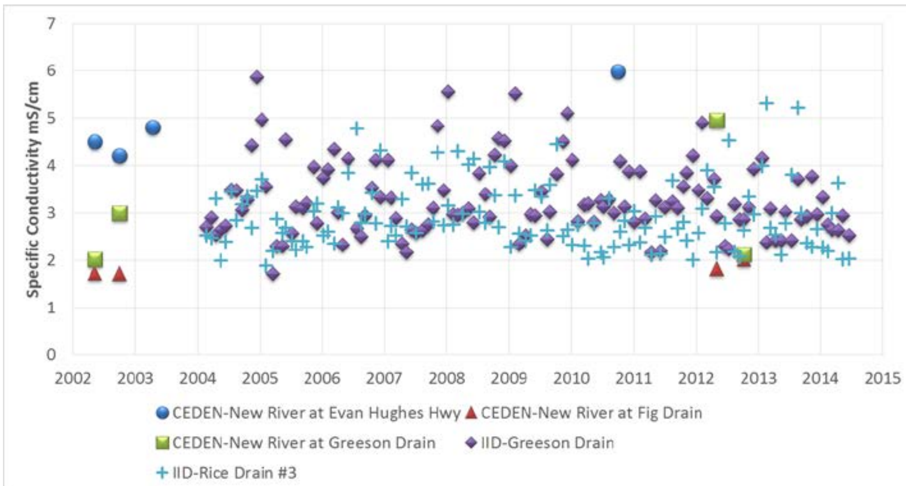

Figure 22 New River agricultural drains. CEDEN and IID data for specific conductivity (mS/cm @ 25°C).

Figure 23 **New River at International Boundary and the Outlet. CEDEN and Reclamation data for total dissolved solids (mg/L).**

2.3.3 Alamo River

The salinity of the Alamo River at the international boundary varied but was generally below 3 ppt (Figure 24). Salinity concentrations decreased slightly from the international boarder toward the Salton Sea outlet due to dilution with agricultural flows. At the border, salinity ranged from 0 to 3.1 ppt and averaged about 2 ppt (Figure 24). At the Salton Sea outlet salinity ranged from 1.4 to 2.1 ppt and averaged 1.6 ppt (Figure 24). Along the river and within agricultural drains, salinity ranged from 1 to 2.5 ppt (Figure 25). Specific conductivity was also higher at the international boundary than the outlet (Figure 24), corresponding with salinity data (Figure 26). Salinity and specific conductivity was mostly unchanged from 2002 to 2014 at the outlet to the Salton Sea.

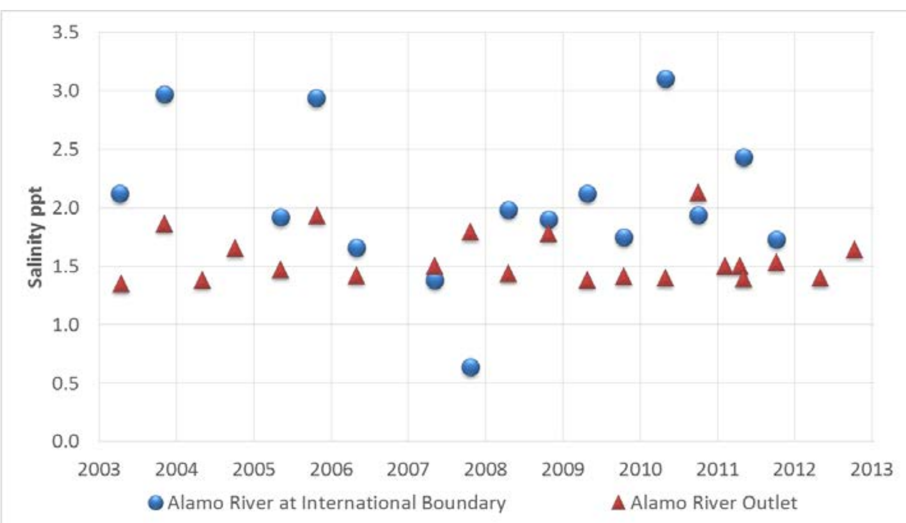

Figure 24 **Alamo River at International Boundary and the Outlet. CEDEN data for total salinity (ppt).**

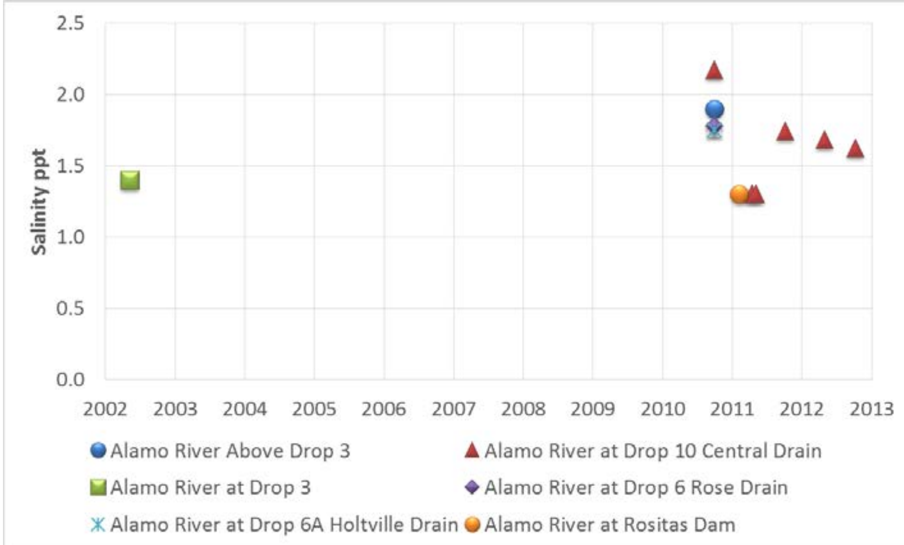

Figure 25 **Alamo River agricultural drains. CEDEN data for total salinity (ppt).**

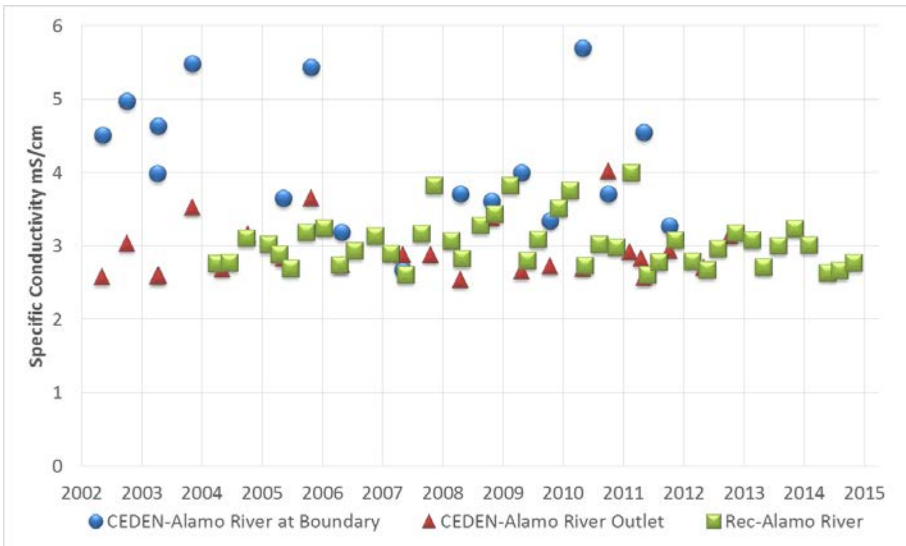

Figure 26 **Alamo River at International Boundary and the Outlet. CEDEN and Reclamation (Rec) data for specific conductivity (mS/cm @ 25°C).**

Specific conductivity values measured at Calipatria and Niland in 2005 were 3.2 and 3.16 mS/cm, respectively. The results are consistent with recent CEDEN data (Figure 26). Alamo River drain specific conductivity was stable over time and averaged about 3.5 mS/cm (Figure 27).

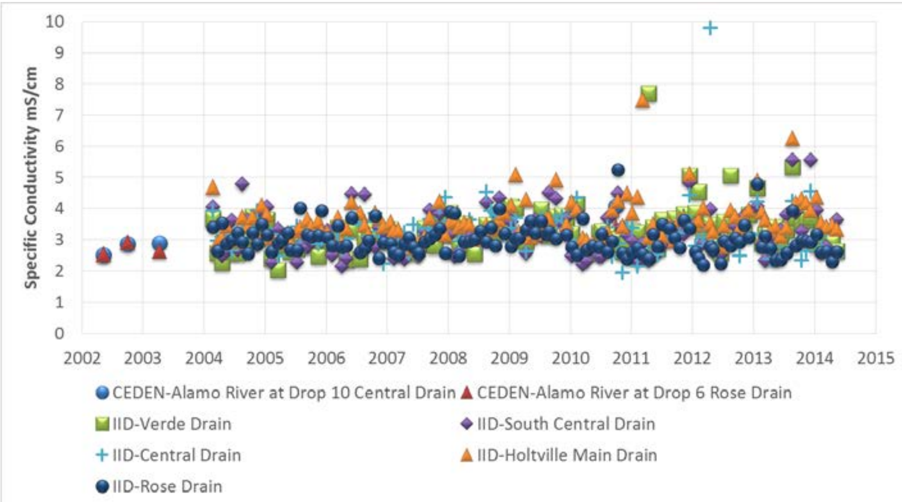

Figure 27 Alamo River agricultural drains. CEDEN and IID data for specific conductivity (mS/cm @ 25°C).

There was less total dissolved solid data than most other parameters at the border, but the average TDS concentrations calculated using all the data were lower at the outlet than the international boundary. The average TDS concentrations from these sites were about 2.4 g/L and 3.0 g/L, respectively (Figure 28). In four agricultural drains, TDS ranged from 2.0 to 2.6 g/L but was only measured on one date in 2010. Overall, TDS concentrations remained fairly constant at the international boundary and at the outlet. At these measured TDS concentrations, the Alamo River water is considered brackish. Average annual salt load from the Alamo River from 2004 to 2014 was 1,518,000 metric tons, or 47% of the total load to the Sea (Table 2).

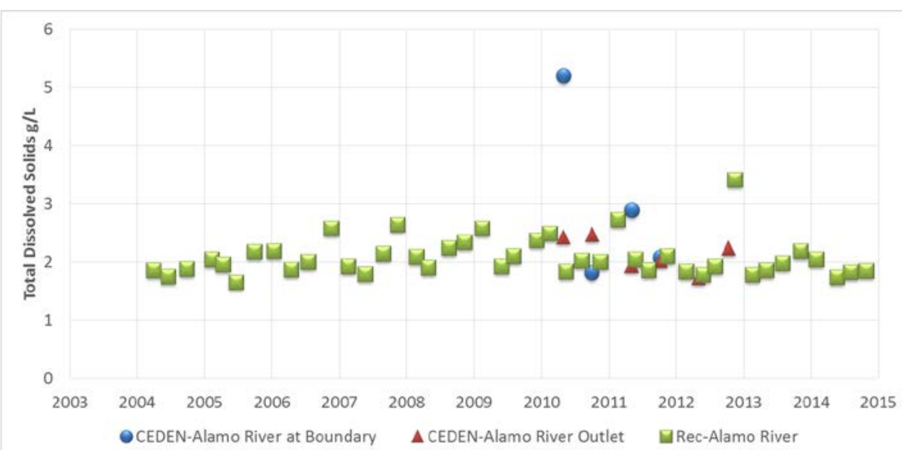

Figure 28 Alamo River at International Boundary and the outlet. CEDEN and Reclamation data for total dissolved solids (g/L).

2.3.4 Whitewater River/CVSC

A lower reach of the Whitewater River was channelized downstream of Point Happy in La Quinta to provide flood protection, it is referred to as the

Coachella Valley Stormwater Channel (CVSC; Whitewater River WQMP 2009). The salinity of the Whitewater River was fairly constant over time, ranging from 0.5 ppt in May 2004 to 1.9 ppt in October 2004 and averaged 0.9 ppt (Figure 29). Salinity and specific conductivity decreased from 2003 to 2011 at the outlet to the Salton Sea.

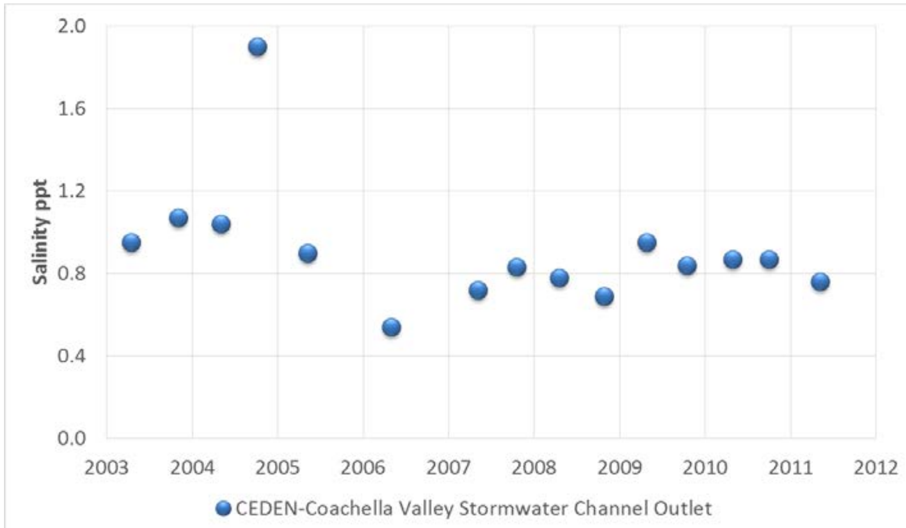

Figure 29 Whitewater River (also called Coachella Valley Stormwater Channel (CVSC) at the outlet to the Salton Sea) salinity (ppt) data from CEDEN.

Specific conductivity from USGS is consistent with recent CEDEN data and show a slight decreasing trend (Figure 30). The average TDS concentration was 2.26 mS/cm from 1963 to 1967 and has decreased to an average of 1.19 mS/cm in the past decade (pre-2001 data not shown; Figure 31). At these measured TDS and salinity concentrations, the Whitewater River water has become less brackish over time and can almost be classified as fresh water. Average annual salt load from the Whitewater River from 2004 to 2014 was 58,000 metric tons, or about 2% of the total load to the Sea (Table 2).

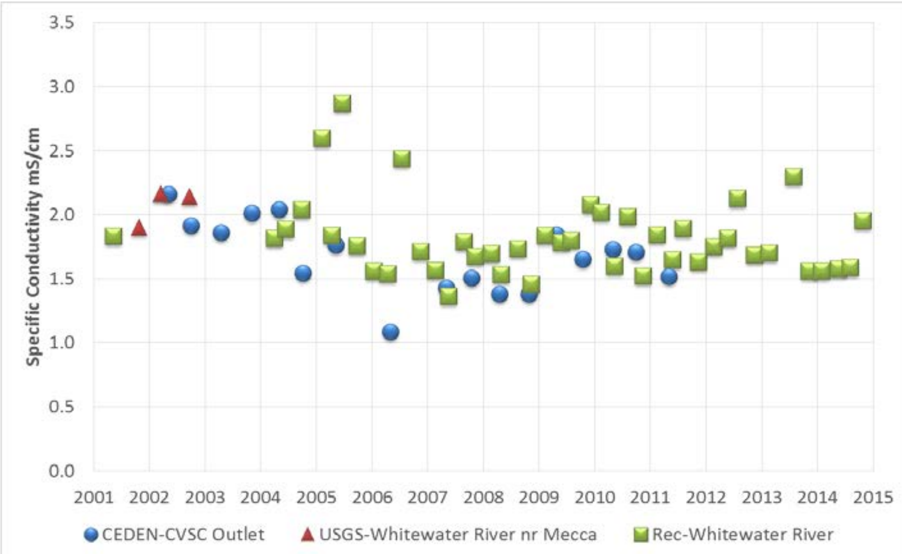

Figure 30 **Whitewater River near the outlet to the Salton Sea specific conductivity (mS/cm @ 25°C) data from CEDEN, USGS and Reclamation (Rec).**

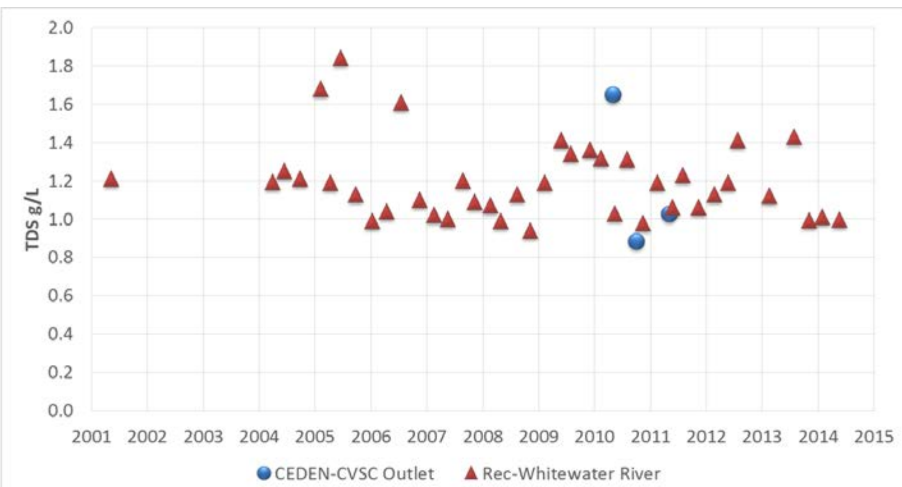

Figure 31 **Whitewater River near the outlet to the Salton Sea total dissolved solids (TDS; g/L) data from CEDEN and Reclamation.**

2.4 Summary

Given the large evaporative loss of water from the Salton Sea, the reduction of the Sea's volume directly increases salinity. This chapter presents an overview of the hydrologic conditions over the past two to three decades using available observations from individual inflows and in the Sea. Although more extreme changes are anticipated in the future with diminishing flows into the Sea, the following changes stand out over the past decade: a small decrease in New River inflows into the Sea, an increase of salinity in the Sea, and a decrease in the in water elevation at the Sea. There is little change in the salinity of inflows, or of the volume of inflows from the Alamo and

Whitewater Rivers. Therefore, changes in salinity and water level in the Sea may be related to a longer-term imbalance between inflows and evaporation, with a smaller effect due to reductions in New River flows.

3.0 Water Quality in the Salton Sea Basin

Water quality—besides salinity—in the Salton Sea basin is affected by a variety of sources, and is managed by the Colorado River Basin Regional Water Board (Regional Board 7 in California), such that the different beneficial uses of the rivers and the Salton are met. Pollutants associated with impairment are identified through a process called the 303(d) list (governed by the Federal Clean Water Act). The sources of most concern are various chemicals related to the agricultural activities in the watershed and Se, which originates in the source waters from the Colorado River, but is concentrated to higher levels as part of the agricultural practices in the Salton Sea watershed. Typically, total maximum daily load (TMDL) analyses are performed to develop approaches to reduce the pollutant levels, although non-TMDL actions are also possible. At this time, the most recent 303(d) list is for 2010, and includes the water body and pollutants, and some have TMDLs completed (Table 3; CRBRWQCB 2010).

Recognizing the unique present-day condition of the Salton Sea the Regional Board states that: "TMDL development will not be effective in addressing this problem, which will require an engineering solution with federal, local, and state cooperation," (CRBRWQCB 2006). This statement refers only to salinity at the Salton Sea and does not apply to the rivers and drains in the watershed contributing to the problem. Looking forward, it is important to recognize that management of existing levels of contamination in the Sea as well as in the watershed will need to be addressed through non-point source control in addition to restoration actions. First, this is because some environmental concerns in the Sea occur in the watershed. For example, nutrients in the inflows result in eutrophic conditions that lead to the listing for low dissolved oxygen. Second, the primary river waters are listed for toxicity as well as Se, and their use for restoration purposes must ameliorate potential ecological risks.

Table 3
EPA 303(d) list by water body and pollutant/stressor

Water Body	Pollutant/Stressor																						
	Arsenic	Chlordane	Chlorpyrifos	Copper	Dichlorodiphenyltrichloroethane (DDT)	Diazinon	Dieldrin	Endosulfan	Enterococcus	Escherichia coli (E. coli)	Hexachlorobenzene	Mercury	Nutrients	Organic Enrichment/Low Dissolved Oxygen	Polychlorinated biphenyls (PCBs)	Pathogens	Salinity	Sedimentation/Siltation	Selenium	Toxaphene	Toxicity	Trash	Zinc
New River		1	1	1	1	1	1				1	1	1	1	1	2		2	1	1	1	2	1
Alamo River		1	1		1	1	1	1	1	1		1			1			2	1	1			
Imperial Valley Drains		1			1		1	1							1			2	1	1			
Salton Sea	1		1		1				1				1				3		1				
Coachella Valley Stormwater Channel*					1		1								1	2				1			

Notes

1 On 303(d) list (TMDL required or in place)

2 Completed TMDL

3 TMDL development will not be effective in addressing this problem, which will require an engineering solution with Federal, local, and state cooperation (CRBRWQCB 2010)

*Coachella Valley Stormwater Channel is the channelized portion of the Whitewater River from Lincoln Street to the Salton Sea

Historical water quality data from the Alamo and New River Basins were compiled and summarized for this study. Sources of data included State and Federal government agencies, international agencies, and universities. Data were compiled for several key locations in each river basin. These locations included multiple sites on each of the rivers, major agricultural drains, and the Salton Sea itself. For each of these sites, available data for nutrients, suspended solids, or key parameters of concern (e.g., total coliforms and Se) were compiled. A detailed discussion of the historical data collected from the rivers and agricultural drains is provided in the following sections. Figure 2 shows the various sampling locations in the Imperial Valley where the historical water quality data discussed in this chapter were collected.

Historical water quality data collected within the Salton Sea and the Alamo, New and Whitewater Rivers were compiled from USGS's NWIS database, the Imperial Irrigation District (IID), the Reclamation Salton Sea website, and the SWRCB's CEDEN website. The CEDEN website contained water quality data collected as part of the Surface Water Ambient Monitoring Program (SWAMP) that assesses water quality in California's surface waters to fulfill the requirements of the federal Clean Water Act, i.e. TMDL development. The period of record and number of analysis varied depending on the parameter. The following parameters were consistently analyzed at the Sea: Total N, Total P and Se. Temperature, dissolved oxygen and total suspended solids (TSS) and coliform data are also examined for the Salton Sea.

The majority of the historical water quality data for the New and Alamo Rivers came from the Reclamation and SWRCB CEDEN website. The Reclamation sampling sites are in close proximity to USGS gage site near the outlet to the Sea (Figure 3). The USGS NWIS database included two sites on the New River: the international boundary and near Westmorland, two sites on the Alamo River: Drop 3 near Calipatria and near Niland, and one site on the Whitewater River near Mecca.

Data were obtained from the Imperial Irrigation District (IID) in several electronic databases (Excel spreadsheets). The IID data were collected from agricultural drains in the area on a monthly basis from 2004-2014. The parameters of interest included in this data set were: total N, Total P, and TSS. In 2005 water quality data on suspended solids, nutrients, coliforms, and Se, were analyzed at river, drain, and pilot wetland stations in the Imperial Valley. The results of the synoptic study are presented for the New River and drain stations.

More recent data from the Alamo River at the international boarder, Drop 3, Niland, numerous agricultural drains and up to 5 USGS sampling locations within the Salton Sea were obtained from the SWRCB's CEDEN website. Data for New River at the international boundary and the outlet, along with major and minor agricultural drains were obtained from CEDEN. Data were also obtained from the Whitewater River, Salt Creek and agricultural drains from CEDEN. Similar to other water quality databases in the region, the period of record and number of analysis varied depending on the parameter. The following parameters were analyzed in this study: total salinity, specific conductivity, Total N, Total P, ortho-P, dissolved Se and TSS. Several agricultural drains located along the New and Alamo Rivers between the international boundary and outlet were also sampled in 2002, 2010 and salinity, Se and specific conductivity in 2012.

A consistent set of data collected on a monthly basis from 2004 to 2014 was provided on http://www.usbr.gov/lc/region/programs/saltonsea.html, Reclamation's Salton Sea website. Some of the measured constituents include salinity (TDS and specific conductivity), TSS, Se, N, and P. Measuring locations are shown on the map in Figure 3.

3.1 Temperature, Dissolved Oxygen and Transparency

Water temperature is mainly influenced by the climate and affects many physical, chemical and biological processes. As temperature increases, biological and chemical reaction rates increase and oxygen solubility decreases. Hypersalinity also contributes to anoxia in the water as oxygen solubility decreases under higher salinities. Temperature and dissolved oxygen (DO) data were collected approximately quarterly by Reclamation from 2004-2014 along depth profiles at three locations within the Sea (Figure 3; Figure 32 to Figure 35). Average monthly temperature and stratification typically occurred during the months of March, May, and June to August. During the summer months of May to August, stratified conditions led to temperature differences of up to 9°C between surface waters and the hypolimnion (Figure 32-Figure 34). Well-mixed conditions led to temperature differences less than 4°C along the depth profile (Figure 32-Figure 34). High temperatures in summer reached up to 33.3°C near the surface at station SS-3 in August 2012. The lowest observed temperature was 13.3°C on February 21, 2007 at station SS-1, 13 meters deep. Temperature averaged over the previous 10 years by stratified (June-August) and well-mixed (November-February) conditions confirms other reports of ongoing seasonal temperature stratification (Holdren and Montaño 2002, Setmire *et al.* 2000).

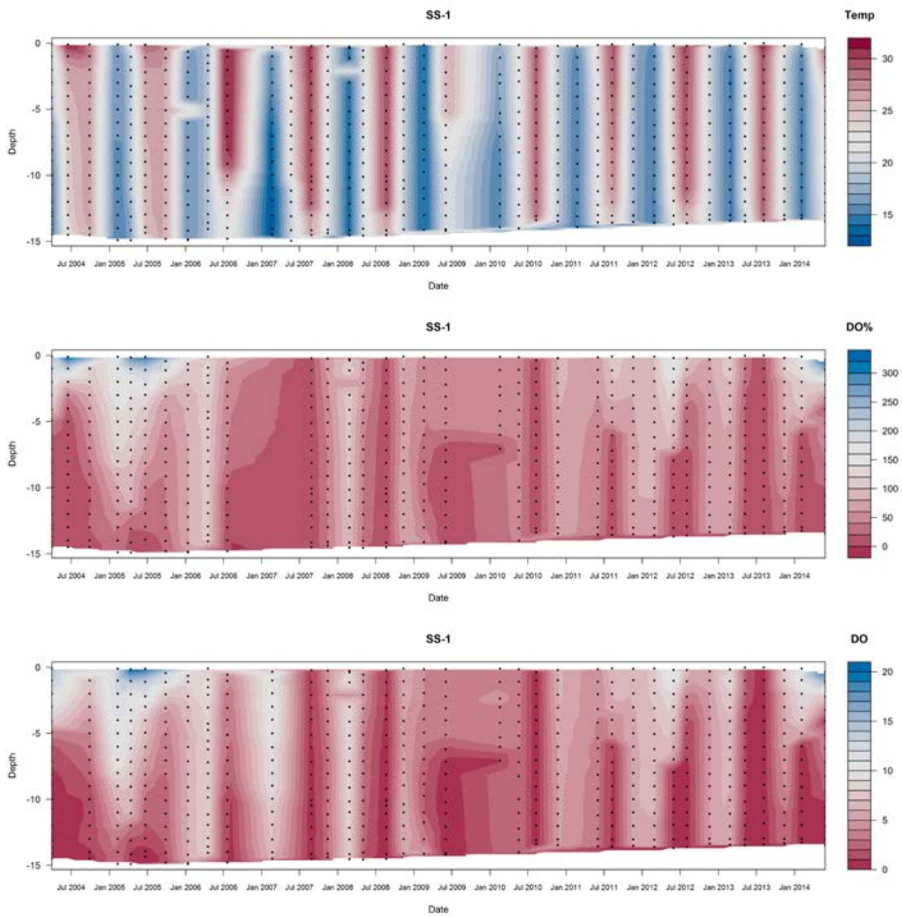

Figure 32 Temperature, DO Saturation (%) and DO concentration at Salton Sea station SS-1.

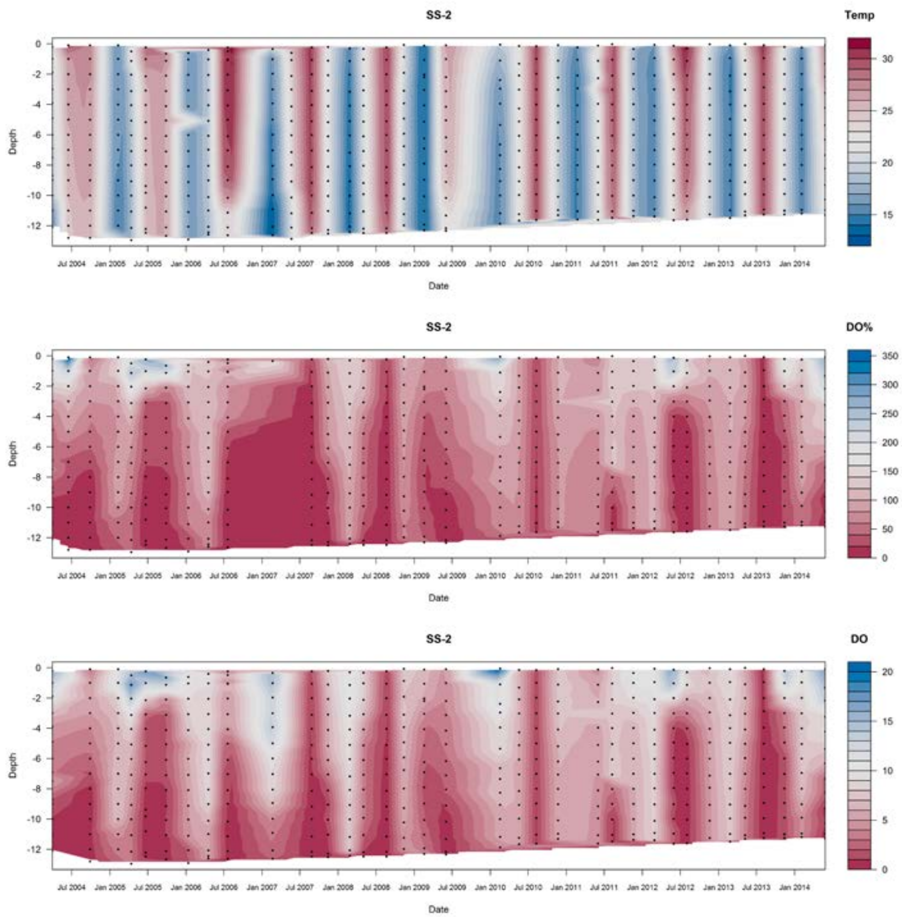

Figure 33 **Temperature, DO Saturation (%) and DO concentration at Salton Sea station SS-2.**

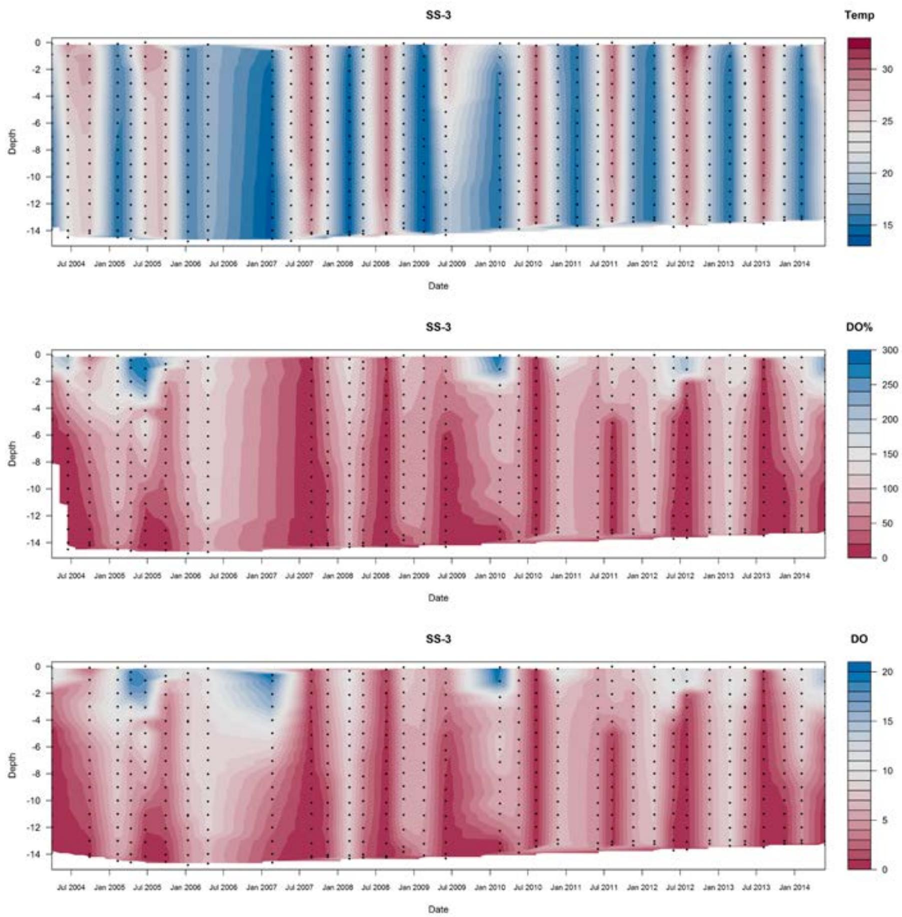

Figure 34 Temperature, DO Saturation (%) and DO concentration at Salton Sea station SS-3.

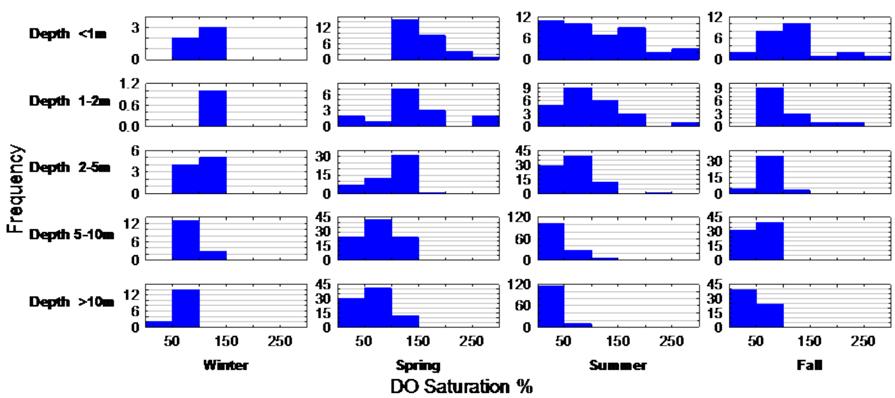

Figure 35 Histogram of dissolved oxygen (% saturation) by season along the depth gradient at three water quality monitoring stations in the Salton Sea. Winter includes January (no data for December), spring includes February-April, summer includes May-August, and fall includes September-November (no data for October).

Oxygen depletion at depth coincided with temperature, pH, and ORP stratification. Differences in pH were as high as 1.6 pH units from the top to the bottom, decreasing pH with depth. ORP decreased dramatically (maximum change was 520 mV in August 2012) with depth during stratification, corresponding to oxygen levels. During the summer months the average DO concentration was 2.15 mg/L, less than the threshold of 4 mg/L recommended for aquatic organism survival. Tilapia can survive in oxygen concentrations less than 1 mg/L and can migrate upward when oxygen is low (DWR and CDFW 2011). Thus, low dissolved oxygen concentrations are a bigger concern for relatively immobile benthic organisms that form the basis of the food web (DWR and CDFW 2011; Anderson *et al.* 2007). As algae photosynthesize during the day, oxygen saturates the epilimnion (upper layer). The abundance of nutrients, warm temperatures, and an available carbon source encourages rapid, short-lived algal growth. The warm summer temperatures and algal production increases oxygen depletion during the night when algal respiration and algal decay demands oxygen in already low DO water (Figure 35 shows the Seasonal DO trend by depth). When oxygen depletion occurs along the entire depth profile, it typically corresponds to an algal bloom and often immense fish kills. Overall clarity in the Sea has been low over the past 10 years, peaking at 2.4 m in 2011 (Figure 36). Clarity was greater and more variable in the Sea compared to the stable, low secchi depth measured in the rivers (average 0.1 m, 0.13 m and 0.36 m for the Alamo, New and Whitewater River, respectively, in 2011-2014).

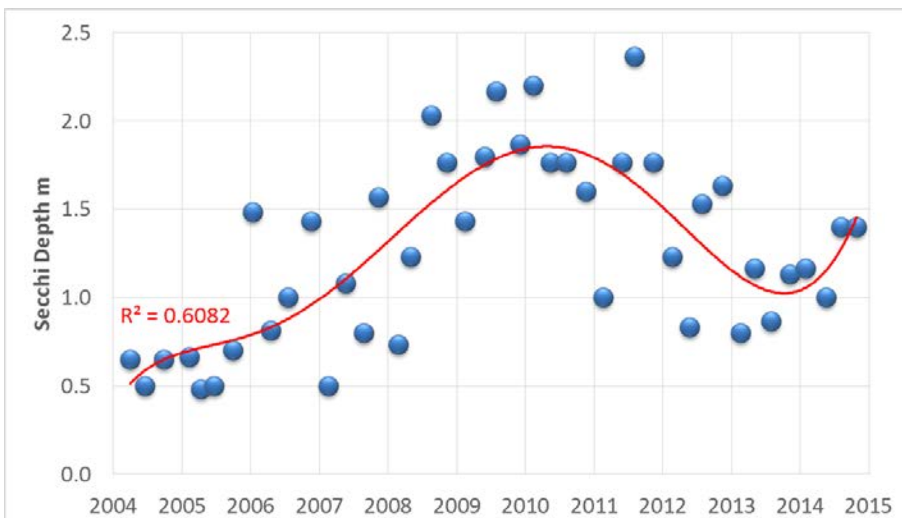

Figure 36 Average Secchi depth (meters) at three Salton Sea stations from 2004 to 2014.

During the Sea turnover event in February 2007, pheopigment and Chlorophyll-a concentrations increased significantly while secchi depth decreased (Figure 36). High Chlorophyll-a concentrations corresponded temporally to high TSS concentrations in the Sea, demonstrating the algal cell contribution to TSS. However Swan *et al.* (2007) determined that light attenuation was not caused by Chlorophyll-a in the Sea, phaeopigments or plankton, but mostly caused by inorganic particles. Tiffany *et al.* (2007) determined that gypsum crystal precipitation causes the frequent "green tides." Eutrophication leads to algal blooms and an abundance of algal cells. This organic matter decomposes, followed by anoxia that produces hydrogen sulfide via sulfate-reducing bacteria deep in the Sea. During wind overturning events, hydrogen sulfide is oxidized to sulfate and gypsum is precipitated which causes the green colored water (Tiffany *et al.* 2007).

Major shifts in wind also cause the Sea to turnover, disturbing anaerobic sediments and creating additional oxygen demand that further depletes DO (Setmire *et al.* 2000). Sea turnover also releases toxic gasses formed under the anaerobic conditions at the bottom of the Sea. Figure 32-Figure 35 show a sharp decline in DO saturation within 2 to 4 meters of the surface when stratification occurs. Generally well-mixed conditions during the winter months allows for oxygen saturation of the epilimnion and significant saturation below (Figure 32-Figure 35).

3.2 Nutrients

Excess nutrients in the Salton Sea is a major issue affecting many physical and biological processes. Untreated wastewater was a significant portion of flows from Mexico into the New River and delivered nutrients to the Sea until 2007 when wastewater treatment improved in Mexico and was routed away from the New River (DWR and CDFW 2011). After that time a substantial decrease in flow (and associated nutrients) is evident by declining elevation in the Sea (Figure 5) and less flow in the New River at the border (Figure 6). Untreated and partially treated wastewater remains a part of the New River flow. Two important nutrients are nitrogen (as Total N) and phosphorus (as Total P). In excess amounts, nutrients stimulate exponential algal growth. Algal respiration and decay reduces oxygen in the water to levels toxic for fish. This process is known as eutrophication. Massive fish kills have occurred many times in the Sea as a result, causing noxious odors.

3.2.1 Salton Sea

In the recent data shown in Figure 37, Salton Sea Total P concentrations were high, typically about 0.1 mg/L after 2007 (Figure 37). This is greater than the EPA eutrophic criterion of 0.03 mg/L (U.S. EPA 1980) and the Salton Sea has been characterized as eutrophic and phosphorus-limited (DWR and CDFW 2013; Holdren and Moñtano 2002; Setmire *et al.* 2000; Schroeder *et al.* 2002). These data also show even higher values in the 2001-2006 period (>0.3 mg/l), are larger than previously reported for the Salton Sea. The numeric TMDL target for Total P in the Salton Sea is an annual average of 0.035 mg/L; this target has been exceeded every year. However Total P concentrations have declined over the past decade. Data in Figure 37 show Total P data and demonstrates that the Salton Sea is potentially eutrophic, depending upon the nitrogen concentrations. The eutrophic state of the Sea has been reported by others (DWR and CDFW 2013; Holdren and Moñtano 2002; Setmire *et al.* 2000). Soluble orthophosphate was the major species contributing to Total P (>70%) in the Sea, especially during the winter months when biological activity is low. This leaves very little inorganic P available for uptake and contributes to a P limitation in the Sea and biological oxygen demand (BOD) leading to low DO, as discussed in Section 3.1. Other sources of BOD include untreated wastewater effluent and stormwater runoff.

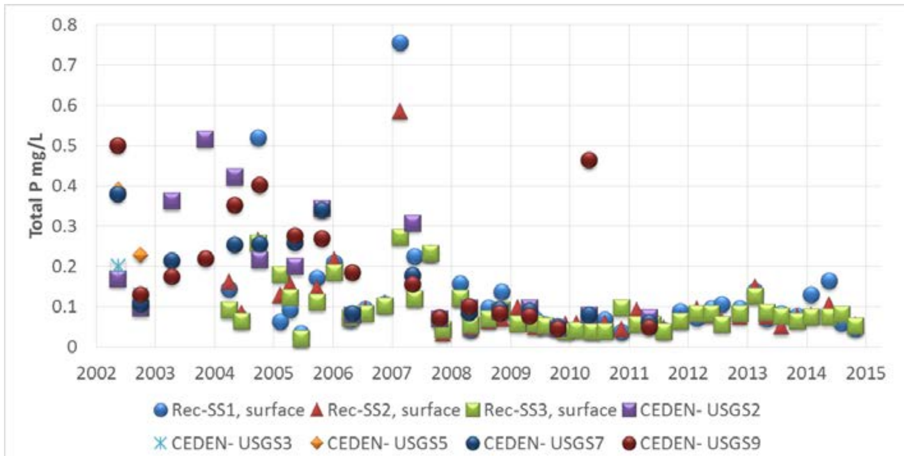

Figure 37 **CEDEN and Reclamation data for Total P (mg/L) in the Salton Sea. One data point greater than 1 mg/L has been omitted.**

The calculated P load was similar to previous estimates (Table 4). Over the last decade, an average of 1,130 metric tons of P has been added to the Sea annually. The Alamo and New Rivers contributed 43% and 42% of the P load, respectively, while the Whitewater River averaged 7% and minor drains contributed an average of 8% of the Total P load. Compared with previous studies, the average annual P load has decreased while the concentration in the Sea has increased (Table 4). Total P concentrations were much higher in the Whitewater River than the other sources, and all the Rivers had significantly higher Total P concentrations than the Sea (Figure 38).

Table 4
Comparison of Total P and Total N concentrations and loads from other studies.

	Total P		Total N		
Dates	**Concentration (mg/L)**	**Annual Load (tonnes/year)**	**Concentration (mg/L)**	**Annual Load (tonnes/year)**	**Source**
1967-68	0.095	663	2.1	11,400	Watts *et al.* 1999
1980-92	--	1,135	--	12,500	Cagle 1998
1996-97	0.091	1,515	5	11,400	Watts *et al.* 1999
1999	0.069	1,358	3.6	14,300	Holdren and Montaño 2002
2004-2014	0.105	1,129	4.7	11,550	This study

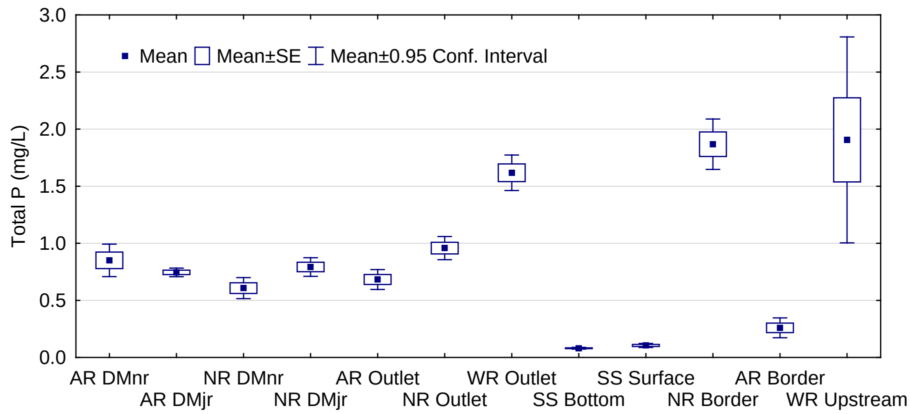

Figure 38 Box plot of Total P data by measurement location from 2002-2014. (AR=Alamo River, NR=New River, WR=Whitewater River, SS=Salton Sea, Upstream=Avenue 52 location, DMjr= Major Drain, DMnr=Minor Drain, Border = Mexico International border, Outlet=outlet to Salton Sea)

Within the Salton Sea, total N increased from 2002 to 2005 and decreased from 2007 to 2012. Maximum total N in the Sea was 14.5 mg/L and has decreased to a maximum of 6 mg/L after 2007 (Figure 39). Ammonia concentrations ranged from 0.02 mg/L (in February 2011) to 2.9 mg/L (in November 2006) and averaged 0.83 mg/L over the past decade. Total N in the Salton Sea was mostly Total Kjeldahl Nitrogen (TKN; ammonia and organic N) due to periodic reducing conditions and the decay of biomass. Total nitrogen has not decreased below concentrations observed in 2002 and remains quite high. The amount of Total N loading to the Sea was 11,550 metric tons annually over the past decade (Table 4). The Alamo River contributed the most total N with 47% of the total, the New River added 36%, and the Whitewater River contributed 7%, and the minor drains 10%. Similar to spatial trends seen with Total P, Total N was highest in the Whitewater River, lower in the other Rivers, lowest at the Alamo River Mexico border, and low in the Sea (Figure 40). The majority of nitrogen species within the Sea were typically ammonia due to the reduced conditions, and up to 25% as nitrate + nitrite. The Redfield ratios (Total N: Total P) calculated for the Sea were very high, as reported in Holdren and Montaño (2002) and others. Ratios greater than 7 represent a limitation of phosphorus on algal growth. All calculated ratios were greater than the healthy algal growth ratio of 7. N:P ratios were highest in the 2005-2006 period (up to 265; Figure 41). Holdren and Montaño (2002) found that ratios were highest in the summer, however Reclamation data typically miss that period. Phytoplankton biomass measured as Chlorophyll-a concentration was typically below 100 µg/L except in 2005 and 2007 when concentrations reached up to 265 µg/L in June 2005 and 737 µg/L in February 2007 (Figure 42). Reclamation began measuring phaeopigment, a degradation product of algal chlorophyll pigments, in early 2007. Typically below 5 µg/L, phaeopigment reached 104 µg/L coinciding with the spike in Chlorophyll-a. Concentrations of phaeopigment have remained very low (less than 5 µg/L) from 2007 to present.

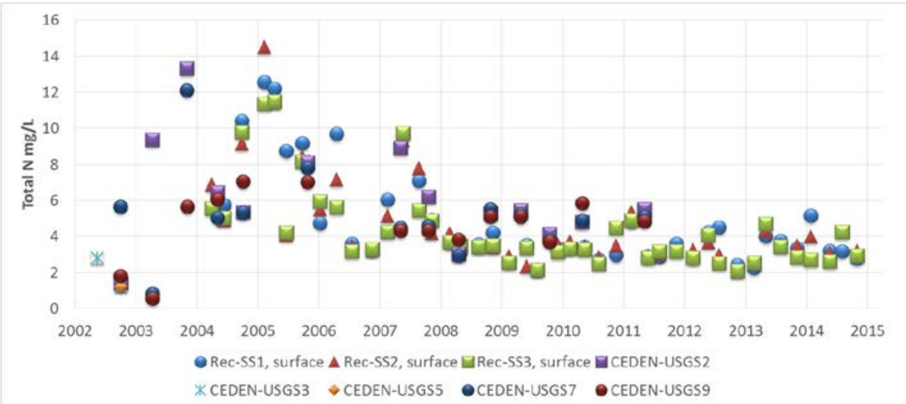

Figure 39 **Stations located throughout the Salton Sea. CEDEN and Reclamation data for Total N (mg/L) in the Salton Sea.**

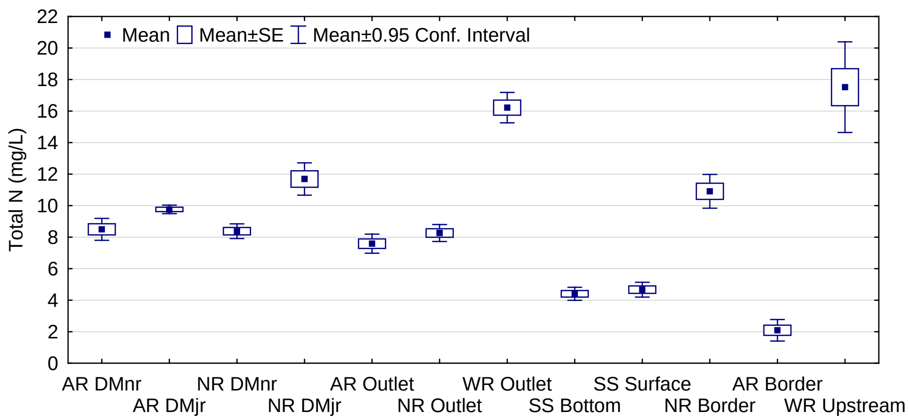

Figure 40 **Box plot of total N data by measurement location from 2002-2014.**

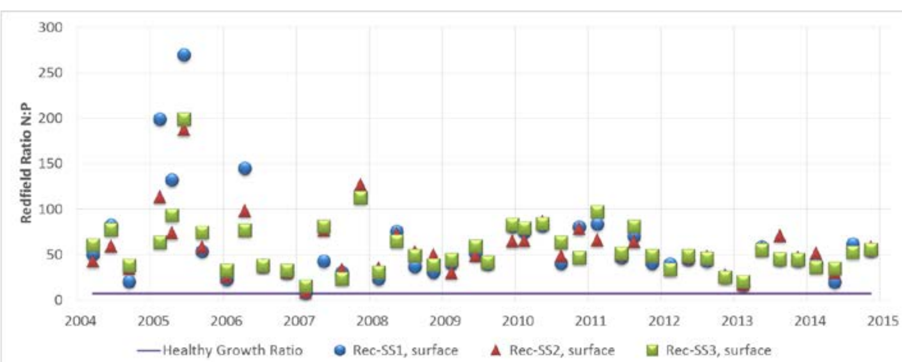

Figure 41 **Reclamation data used to calculate N:P ratios at three Salton Sea surface water monitoring locations.**

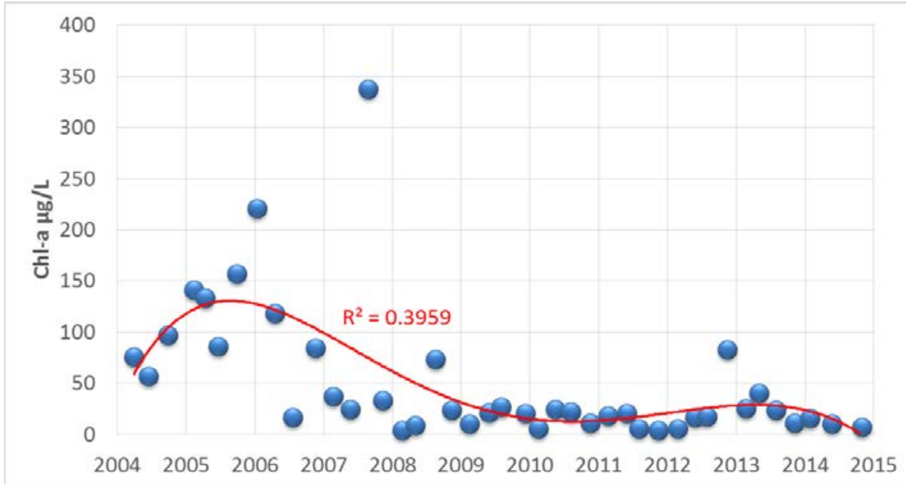

Figure 42 Average Chlorophyll-a concentrations near the surface (1.1m max) of the Salton Sea at three sample locations. Reclamation data.

3.2.2 Sources

New River

The highest Total P concentrations for the New River was about 2.97 mg/L at the international boundary and 1.62 mg/L at the outlet, occurring in October 2005 (Figure 43). Average Total P was almost twice as high at the border (1.9 mg/L) than at the outlet (1.06 mg/L) and an order of magnitude higher than the Salton Sea (0.1 mg/L; Figure 38). Higher concentrations at the border may be due to effluent water that is discharged into the New River from a wastewater treatment plant in Mexico located near the border. Concentrations of Total P decreased after 2007, notably at the outlet (Figure 43). Orthophosphate varied temporally and accounted for an average of 57% of Total P concentrations in the New River. Total P concentrations were typically lower during the low flow and low rainfall months of April to July.

Agricultural drain data from CEDEN measured in 2002 and 2010 ranged from 0.25 to 3 mg/L (Figure 44). The results are consistent with historical agricultural drain concentrations averaging 0.54 mg/L to 1.4 mg/L (Tetra Tech and Wetlands Management Services 2007). IID data for agricultural drains was more variable, ranging from 0.07 mg/L to 5.9 mg/L in October 2010 and averaged 0.69 mg/L (Figure 44).

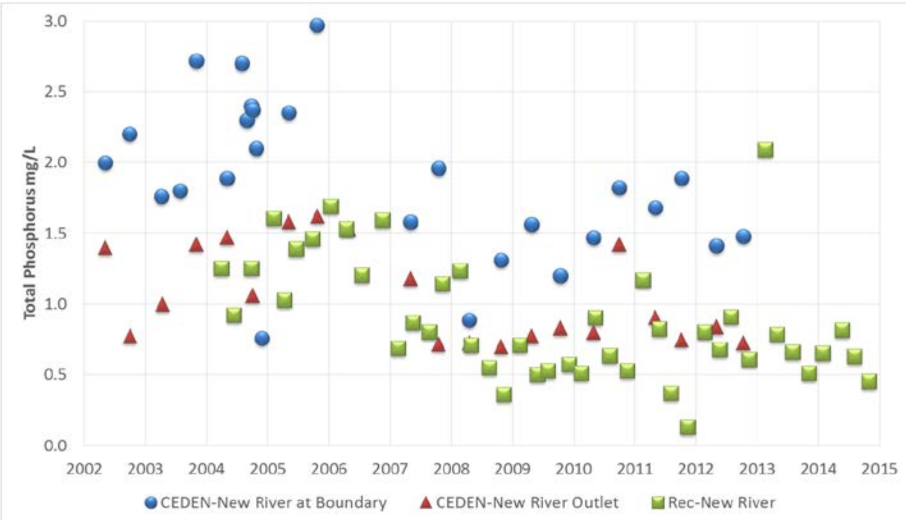

Figure 43 **New River at the International Boundary and the Outlet to the Salton Sea. CEDEN and Reclamation (Rec) data for Total P (mg/L). One outlier greater than 3.5 mg/L was removed.**

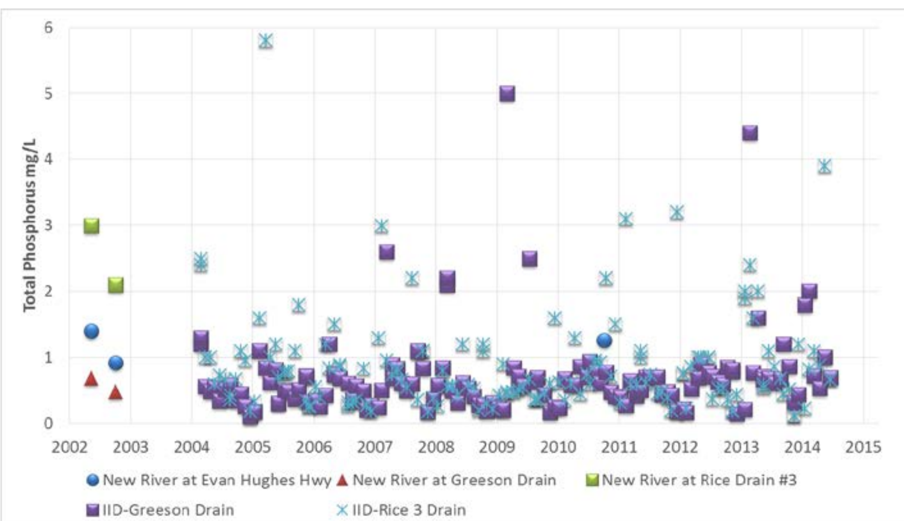

Figure 44 **Major agricultural drains near the New River. CEDEN and IID data for Total P (mg/L).**

Average Total N concentrations over the past decade were higher at the international boundary than at the outlet and drain locations (Figure 45). The average Total N concentrations from these sites were 10.2 mg/L and 6.4 mg/L, respectively. The maximum total N concentration was 21 mg/L at the international boundary on November 18, 1975.

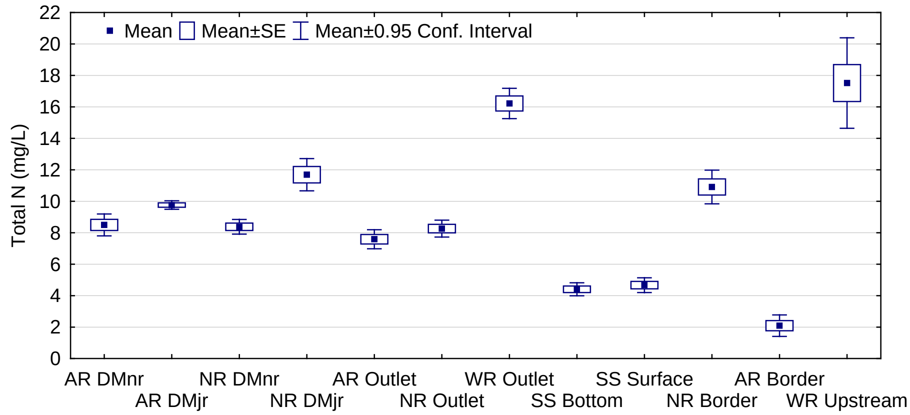

Figure 45 **Box plot of total N data by measurement location from 2002-2014. (AR=Alamo River, NR=New River, WR=Whitewater River, SS=Salton Sea, Upstream=Avenue 52 location, DMjr= Major Drain, DMnr=Minor Drain, Border = Mexico International border, Outlet=outlet to Salton Sea)**

Data since 2002 show that Total N concentrations have declined at the boundary and the outlet. Average Total N concentrations from the boundary, CEDEN outlet and Reclamation site were 10.9 mg/L, 8.6 mg/L and 8.1 mg/L, respectively (Figure 46). The majority of Total N was Kjeldahl (organic and ammonia/ammonium) nitrogen, composing 56-85% of Total N. This is likely due to high algal production and biomass decomposition. The synoptic study in 2005 confirmed that average Total N at the international boundary was higher than at the outlet and were 13 mg/L and 5.6 mg/L, respectively.

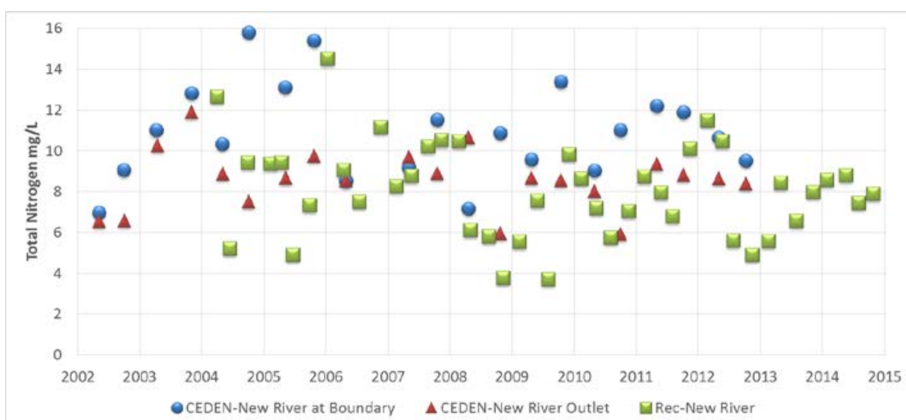

Figure 46 **New River at the International Boundary and the Outlet. CEDEN and Reclamation (Rec) data for Total N (mg/L).**

Agricultural drain Total N concentrations ranged from 3.9 to 11.2 mg/L in 2002 (Figure 47). Total N data were available for the major agricultural drains from the past decade. The Rice Drain #3 had the highest Total N concentration (29 mg/L in 2005) followed by the Greeson Drain (24 mg/L in

2007). The average Total N concentration in the major agricultural drains was 8.3 mg/L.

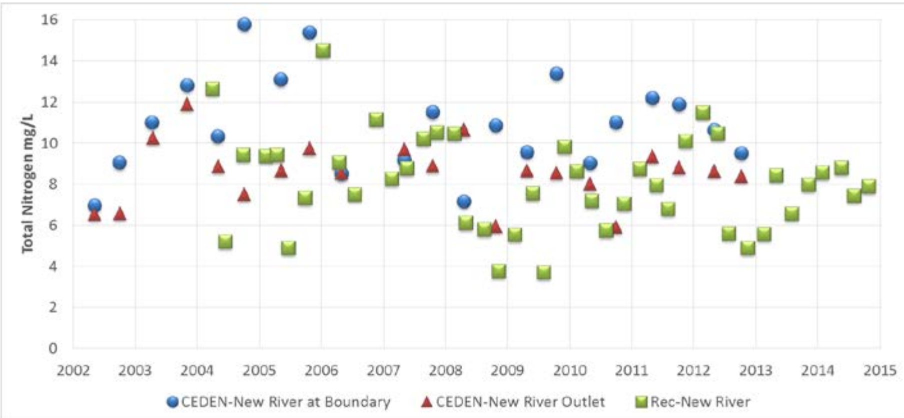

Figure 47 Major agricultural drains near the New River. CEDEN, IID, and Reclamation (Rec) data for Total N (mg/L).

Alamo River

Total P concentrations were moderate to high at the international boundary from 2002-2013, ranging from 0.08 to 0.9 mg/L and averaging about 0.3 mg/L (Figure 48). Agricultural drains contributed significant concentrations of Total P to the Alamo River: 0.4-1.5 mg/L (Figure 48). At the outlet concentrations were higher than the boundary, averaging about 0.7 mg/L and remained fairly constant from 2002-2014 (Figure 48). CEDEN data collected at the outlet were consistent with Reclamation data. The synoptic study in 2005 measured similar concentrations at Niland and Calipatria of 0.7 mg/L Total P. A seasonal trend analysis conducted on various sites in the Alamo River showed that Total P concentrations are typically lower during the low flow and low rainfall months from April to July.

Total P was measured in all four of the major agricultural drains. The Rose Drain had the highest average Total P concentration (1 mg/L) followed by the Central Drain (0.9 mg/L). The maximum detected Total P concentration from the major drains was 4.3 mg/L for the Rose Drain on February 7, 2006 (Figure 49).

In the Alamo River, the average concentration of total N over the past decade was highest in agricultural drains, then the outlet, and the international border was the lowest (Figure 45). At the Alamo River international boundary site, Total N concentrations ranged from 0.6 to 5.8 mg/L and averaged about 2.1 mg/L from 2002 to 2012 (Figure 50). Concentrations of Total N were higher at the outlet than the boundary, ranging from 3.3 to 17.3 mg/L and averaging 9 mg/L at the outlet from 2004-2014 (Figure 50). Agricultural drain concentrations of total N ranged from 0.7 to 2.7 mg/L in 2002 but there is not enough data to infer a temporal trend (Figure 50). Nitrate accounted for most of the nitrogen, about 88% of Total N, due to significant fertilizer N contribution in agricultural water. There was no increasing or decreasing trend over time observed with Total N concentrations.

A seasonal trend analysis conducted on various sites showed that the concentrations of total N are typically lower during the low flow and low rainfall months of April to July. However, this trend was not as strong as the one observed for Total P.

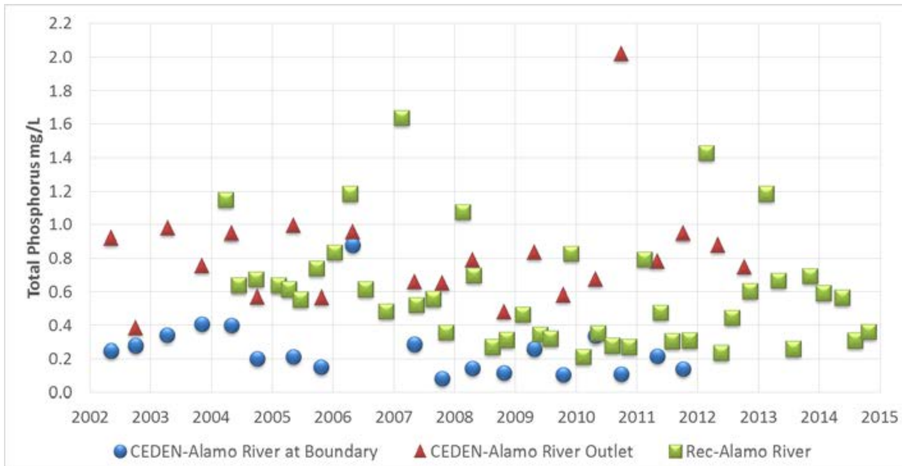

Figure 48 Alamo River at the International Boundary, Outlet to Salton Sea. CEDEN and Reclamation (Rec) data for Total P (mg/L).

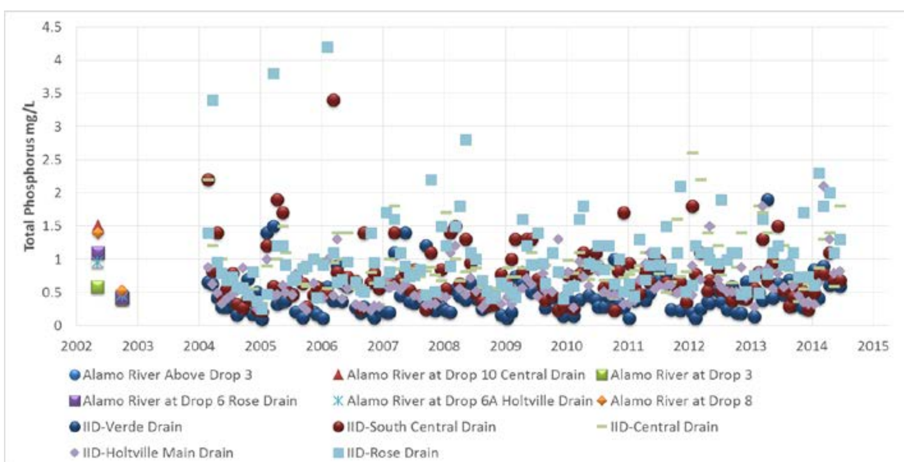

Figure 49 Major agricultural drains near the Alamo River. CEDEN and IID data for Total P (mg/L).

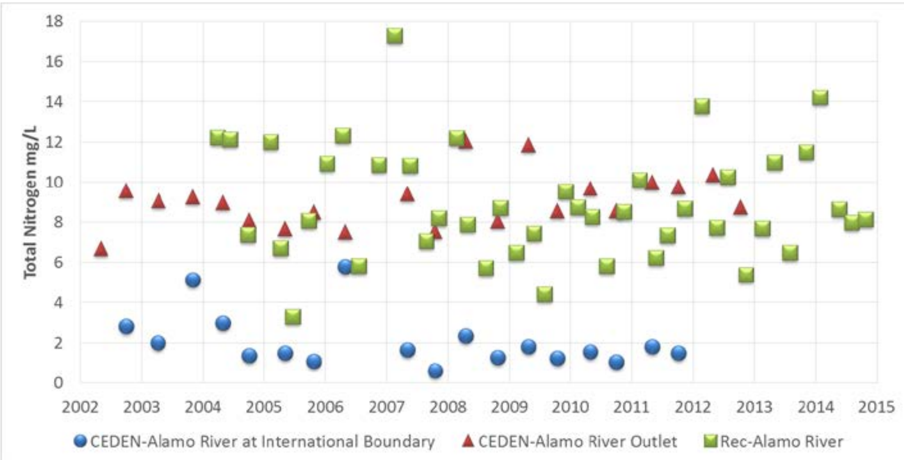

Figure 50 Stations along Alamo River at the Outlet and International Boundary. CEDEN and Reclamation (Rec) data for Total N (mg/L). One data point greater than 25 mg/L was omitted.

Total N data were available for all five of the major agricultural drains. The South Central Drain had the highest average total N concentration (11.7 mg/L) followed by the Holtville Drain (10.75 mg/L). The maximum total N concentration from the major drains was 26 mg/L at the Verde Drain on March 20, 2013 (Figure 51).

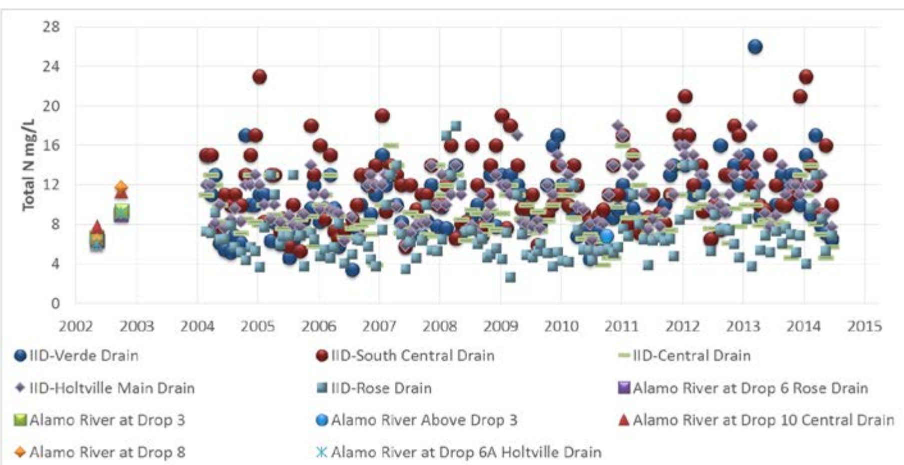

Figure 51 Major agricultural drains near the Alamo River. CEDEN and IID data for Total N (mg/L).

Whitewater River/CVSC

Recent data show significantly elevated Total P in the Whitewater River (Coachella Valley Stormwater Channel), above concentrations in the New and Alamo Rivers (Figure 38). The maximum concentration of Total P in the river was 4.3 mg/L at the Coachella Valley Stormwater Channel outlet in May 2004. Average Total P concentrations in the river from 2001-2014 was 1.6 mg/L. The channelized river upstream of the Salton Sea outlet (at Avenue 52) had similar concentrations to the outlet (Figure 52). Orthophosphate was a significant proportion of Total P, averaging 69% in the river. CEDEN data were consistent with Reclamation data.

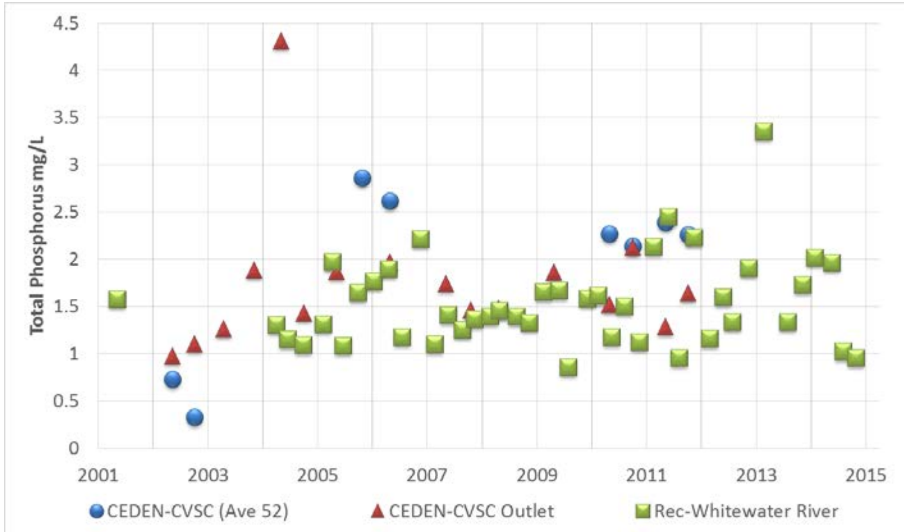

Figure 52 Whitewater River/CSVC at Avenue 52 and at the outlet to the Sea. CEDEN and Reclamation (Rec) data for Total P (mg/L).

Total P was measured in four major agricultural drains. Drain Total P concentrations remained lower than the Whitewater River, less than 0.5 mg/L (Figure 53). Total P concentrations in agricultural drains were sparsely collected but in 2002 and 2006 drain concentrations averaged about 0.2 mg/L.

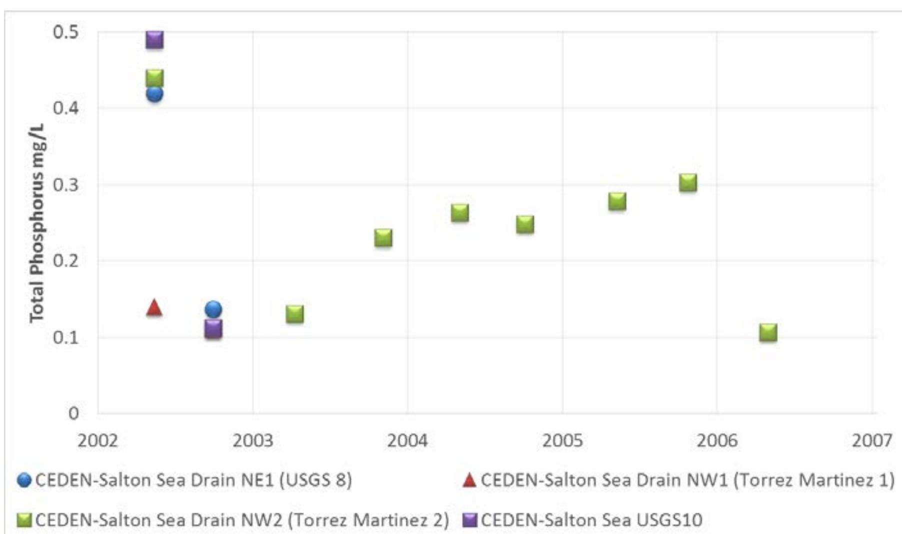

Figure 53 Four drains in the North Sea. CEDEN data for Total P (mg/L).

The average concentration of Total N from the outlet samples was 22.6 mg/L from 2001 to 2014. The maximum concentration of total N in the river samples was 32.4 mg/L measured by Reclamation on May 7, 2001 (Figure 54; omitted). Reclamation data agreed well with average Total N measurements than CEDEN data (Figure 54).

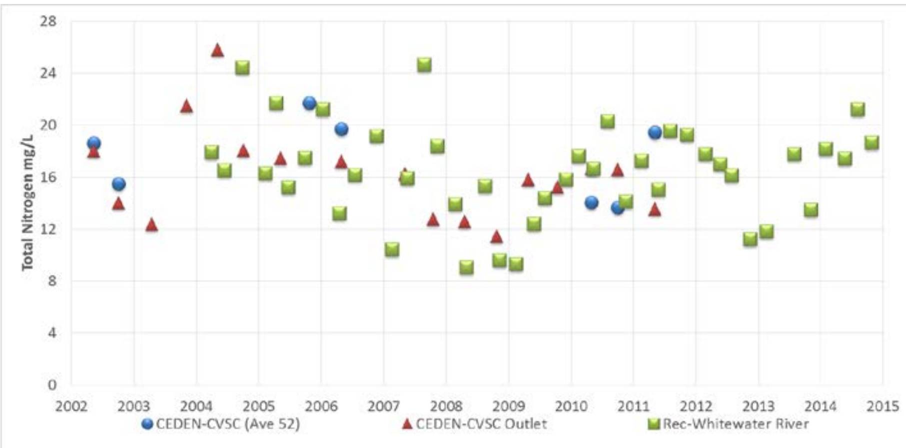

Figure 54 **Stations along the Whitewater River/CVSC at the Salton Sea outlet and at Avenue 52. CEDEN and Reclamation (Rec) data for Total N (mg/L).**

Five agricultural drains near the Whitewater River/CVSC were measured for Total N between 2002 and 2006. Figure 55 shows that agricultural drains typically had lower Total N than the river, ranging from 1.2 mg/L to 20 mg/L and averaging 10.1 mg/L.

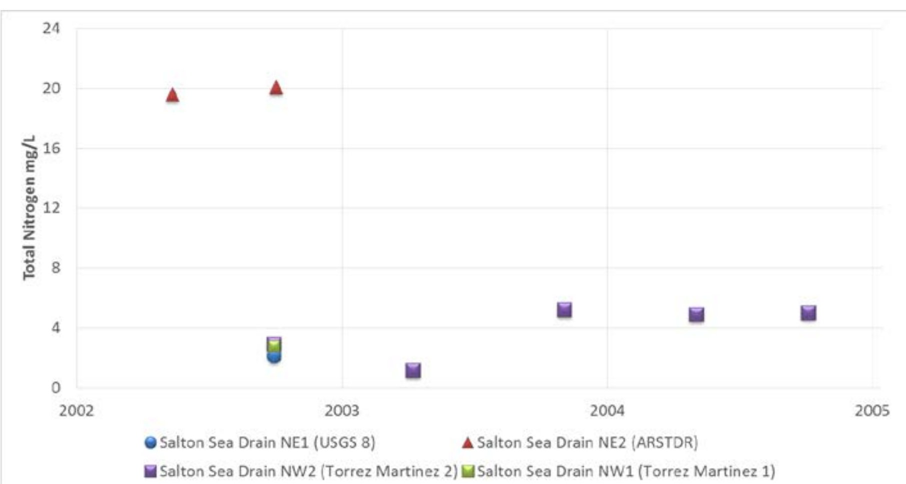

Figure 55 **Agricultural drains near the North of the Sea: CEDEN data for Total N (mg/L).**

3.2.3 Discussion

Temperature dynamics in the Sea are characterized by seasonal thermal and dissolved oxygen stratification, followed by periods of mixing by wind-driven upwelling. This phenomenon occurs due to the large size of the Sea, wind fetch and air temperature range. While the Sea is stratified, oxygen concentrations decrease at the bottom (hypolimnion) of the Sea and bacterial decomposition reduces oxidized species to reduced forms (i.e. nitrate/nitrite to ammonia and sulfate to hydrogen sulfide). As algae photosynthesizes during the day, oxygen saturates the epilimnion (upper layer). The warm summer temperatures and algal production causes oxygen depletion during the night when algal respiration demands oxygen in already low DO water. Mixing of the layers releases the accumulated ammonia and hydrogen sulfide, along with a substantial oxygen demand that strips the water of its remaining oxygen. This often results in massive fish kills and die offs of smaller benthic organisms that are an important base of the food chain. Clarity is low in the Sea, typically less than 2.8 meters and was less than 0.8 meters during 2004-2005.

The Salton Sea is eutrophic and phosphorus-limited, with average Total P concentrations of about 0.1 mg/L (2007-2014), which is greater than the EPA eutrophic criterion of 0.03 mg/L. The numeric TMDL target for Total P in the Salton Sea is an annual average of 0.035 mg/L; this target has been exceeded every year but overall Total P concentrations have decreased over the past decade. An average of 1,130 metric tons per year of P has been added to the Sea annually. The New and Alamo Rivers contributed 43% and 42%, respectively, and the Whitewater River/CVSC and other drains contributed 7% and 10%, respectively, of the Total P load. Phosphorus concentrations at the Alamo River were moderate to high due to agricultural drain influences and concentrations were even higher in the Whitewater River where the drains did not contribute substantial P. The New River also had high Total P concentrations that decreased spatially from the border to the Sea and temporally (previous 10 years). In the Alamo and New Rivers, Total P concentrations were typically lower during the low flow and low rainfall months of April to July.

Total N concentrations were the lowest in the Sea, followed by the Alamo and New Rivers. The Whitewater River had the highest total N concentrations but contributed the smallest total N load (7% of 11,550 metric tons). The Alamo River contributed the most total N with 47% of the total, the New River added 36%, and the minor drains 10%. At the Salton Sea and the New and Whitewater Rivers, total N concentrations increased from 2002 and 2005 and decreased from 2007 to 2012. Total N in the Salton Sea mostly consisted of Total Kjeldahl Nitrogen (TKN; ammonia and organic N) due to periodic reducing conditions and the decay of biomass. Total nitrogen has not decreased below concentrations observed in 2002 and remains quite high.

The Redfield ratios calculated for the Sea were very high, greater than the healthy algal growth ratio of 7. N:P ratios and highest in the 2005-2006 period (up to 265) and typically higher in the late summer. Phytoplankton biomass (as Chlorophyll-a concentration) was typically below 100 µg/L except for two spikes in June 2005 and in February 2007, coinciding with Sea turnover events. Phaeopigment, a degradation product of algal chlorophyll pigments, was typically below 5 µg/L, except when phaeopigment reached 104 µg/L corresponding with the spike in Chlorophyll-a. The majority of nitrogen species within the Sea were typically ammonia due to the reduced conditions, and up to 25% as nitrate + nitrite.

3.3 Selenium

Selenium (Se) is a naturally occurring element found in seleniferous rocks in the Colorado River Valley. Selenium enters waterways as selenate via weathering and erosion of rock and soil in the region. It is an essential nutrient for organisms but becomes toxic at elevated concentrations that are very near ideal concentrations.

The biogeochemistry of Se in aquatic systems is complex and controlled by several factors. Similar to sulfur, Se can exist in four different oxidation states (6 species): organo-Se (Se-II), elemental Se (Se 0), selenite (Se 4+ or SeO_3 2-), and selenate (Se 6+ or SeO4 2-; Presser and Luoma 2010). The oxidation state of Se affects solubility and plays a major role in the mobility, transport, fate, and effects of Se species in the environment (Figure 56; Presser and Luoma 2010; Masscheleyn and Patrick 1993; Lemly 2002). The dissolved species that are present will determine the type of phase transformation reaction that creates particulate Se. Uptake of particulate Se is the main pathway for bioaccumulation. Examples of types of reactions include 1) uptake by plants and phytoplankton; 2) sequestration of selenate into sediments as particulate elemental Se; 3) adsorption through reactions with particle surfaces; and 4) recycling of particulate phases back into water as detritus after organisms die and decay (Presser and Luoma 2010).

Inorganic forms of Se (selenate and selenite) usually predominate in water, but inorganic and organic forms of Se occur in water, sediment, and biological tissues. In an aquatic system, most Se is associated with sediments in the form of elemental and organic selenides (acting as a sink and reservoir) or plants and animals (Hamilton 2004). The most dominant species in agricultural drainage is selenate, whereas a combination of selenite and organo-Se are most common in pond-treated agricultural drainage and the oceans (Presser and Luoma 2010). Selenate is reduced to selenite and removed from the aqueous phase into sediment. Once in sediment, selenite is reduced to insoluble organic, mineral, elemental (makes up 99 percent of the sediment Se), or adsorbed Se (DWR and CDFW 2011; Lemly 2002). Particulate matter including planktonic organisms, bacteria, protozoa, phytoplankton, and zooplankton forms the basis for detrital matter that is the food source for sediment organisms such as benthic macroinvertebrates. Selenium of different oxidation states can be further biotransformed by sediment organisms and transferred up the food chain (Figure 56; Fan *et al.* 2002; Hamilton 2004).

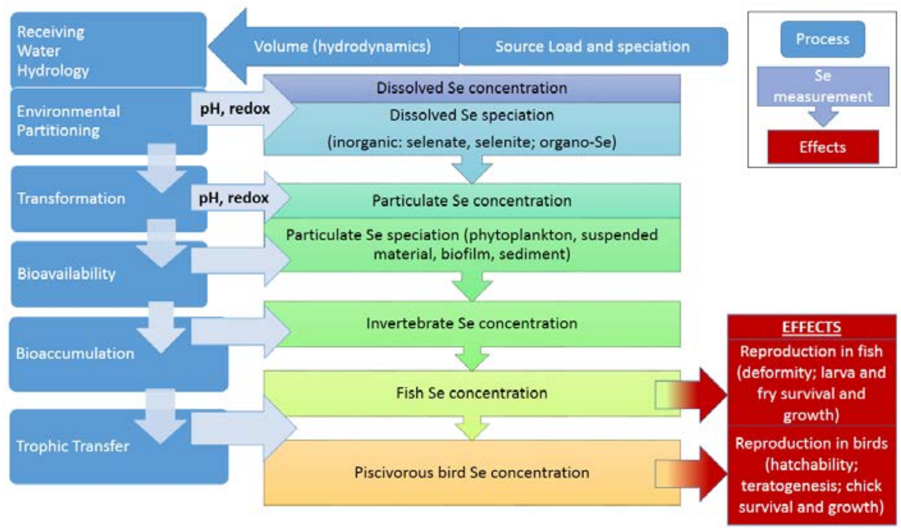

Figure 56 Ecosystem-scale Se (Se) cycle, adapted from Presser and Luoma (2010).

The conceptual model (Figure 56) shows the processes and parameters important for understanding Se fate and transport in the environment. Redox is a measurement of the oxidation/reduction state or transfer of electron potential. Higher redox indicates higher oxidation states and generally more soluble/bioavailable species of Se. Selenium speciation depends on pH and redox conditions in the environment and the source load and speciation. Plant uptake is another pathway but fish and birds are the most important end points.

Sediment may serve as only a temporary repository for Se because many processes can transfer Se into or out of sediment (Masscheleyn and Patrick 1993). Transport and partitioning of Se in soils is highly influenced by pH (measure of the acidity or alkalinity of a substance) and Eh (oxidation/reduction conditions). Elemental Se is essentially insoluble and stable in soils when anaerobic conditions occur. Under low pH or with high organic matter sediments, heavy metal selenides and Se sulfides are insoluble and will remain in sediments (Kabata-Pendias 2001, as cited in DWR and DFG

2007). Selenates are highly soluble, have a low adsorption potential to soil particles, are very mobile and easily taken up by plants or leached through the soil. Selenates dominate in alkaline, well-oxidized soil environments such as the source rivers. Under alkaline and oxidizing conditions, plants can accumulate the soluble forms of Se, although selenate seems to be the preferred form for uptake (DWR and DFG 2007). Plants are not abundant in the Sea, so plant uptake is not the largest concern. Microbially mediated selenate reduction was found to be a very significant mechanism that reduced Se concentrations (VillaRomero *et al.* 2013)

The California Toxics Rule (CTR) (May 2000) provides the appropriate standards for total Se when the Basin Plan does not provide one. The CTR provides a long-term, or chronic, exposure standard of 5.0 µg/L for the protection of aquatic life in freshwater. For saltwater, the criteria maximum concentration is 290 µg/L and continuous concentration is 71 µg/L, but it is noted that the status of the fish community should be monitored if Se concentrations exceed 5.0 µg/L because the criteria does not take into account uptake via the food chain (USEPA 2015). In addition, EPA is in the process of updating the freshwater criterion to reflect the latest scientific information. In sediment, a Se concentration of greater than 4.0 µg/g is a suggested toxicity threshold, and concentrations from 1 to 4 µg/g are considered elevated above background concentrations (Reclamation 1998, Hamilton 2004 and Reclamation 2009).

3.3.1 Salton Sea

Dissolved Se was collected more frequently than total recoverable Se, and represented 61-100% of total Se concentrations. Dissolved Se measured at the Salton Sea ranged from 0.3 to 4.3 micrograms per liter (µg/L) between 2002 and 2014. Two large spikes of dissolved Se was observed in 2005-2007, coinciding with observed nutrient concentrations spikes (see Section 3.2 Nutrients). Average Se was about 1.2 µg/L over the past 12 years at the Salton Sea (Figure 57). Total Se measured in sediment samples ranged from 1.5-11.8 µg/g and averaged 5.37 µg/g between 2005 and 2014 (Figure 58). Therefore Se levels in the Sea water column are considered below the level of concern for aquatic life within the Sea but sediment concentrations are a concern for toxicity, as other researchers have shown (DWR and CDFW 2013).

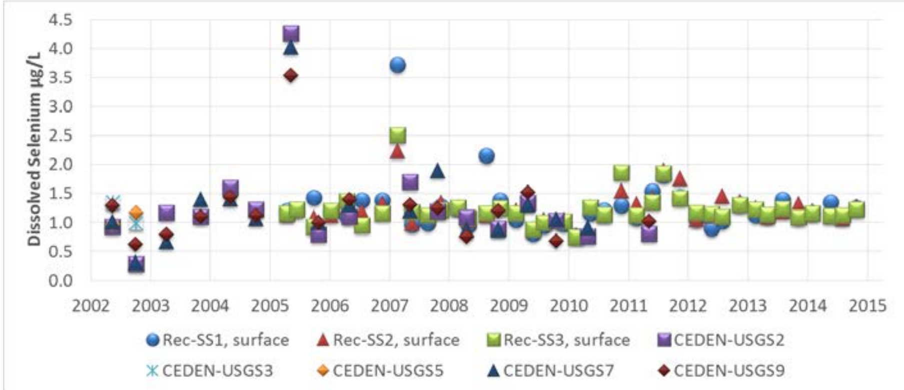

Figure 57 **Stations located throughout the Salton Sea. CEDEN and Reclamation data for total dissolved Selenium (µg/L) in the Salton Sea.**

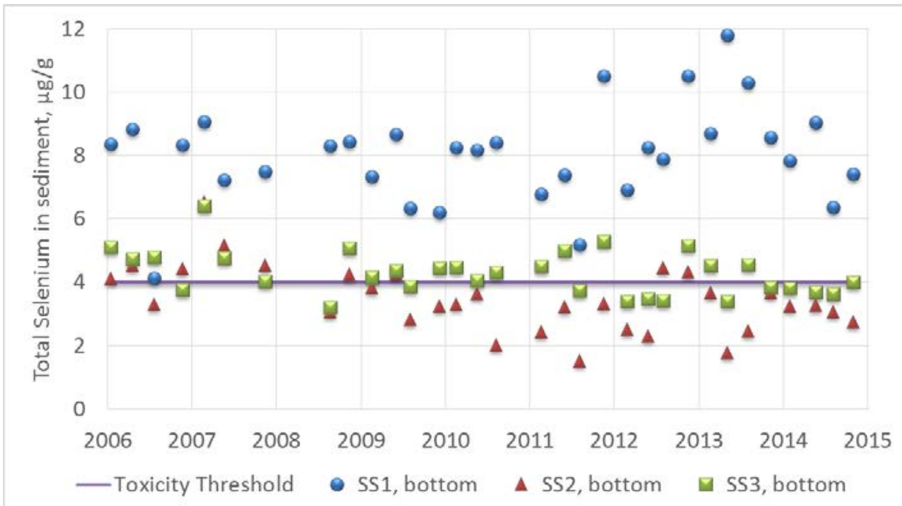

Figure 58 **Three sampling stations in the Salton Sea, Reclamation data for total Se in sediment, µg/g.**

3.3.2 Sources

New River

Much higher concentrations of dissolved Se were found in the source Rivers (averaging 6 and 6.8 µg/L at the outlets of the New and Alamo Rivers, respectively), indicating Se partitions to sediment and is stable under anaerobic conditions but can be mobilized in alkaline, well-oxidized waters (Setmire and Schroeder 1998, DWR and CDFW 2013). Typical pH within the Sea and rivers ranges from neutral to alkaline. Sea turnover causes such a transition and is a major concern as a mechanism for Se mobilization. Selenium is also taken up by biota and bioaccumulated in the food chain when Se enters the Sea (DWR and CDFW 2013, Tetra Tech and Wetlands Management Services 2007, Setmire and Schroeder 1998). During the synoptic study in 2005, total Se concentrations in the New River sites were typically below the 5 µg/L criterion set by the CTR except at four locations.

Between 2002 and 2012, dissolved Se was measured more regularly at the international boundary and the outlet. Dissolved Se was collected more frequently than total recoverable Se, and represented 82-100% of total Se concentrations. The average total dissolved Se concentrations at the New River international boundary and the outlet calculated using historic data were 12.5 µg/L and 6.0 µg/L, respectively. If Reclamation data are excluded, the average outlet concentration is 12.3 µg/L. Selenium concentrations measured in agricultural drains near the New River during 2010 and 2012 ranged from 3 to 11 µg/L. However, from 2005 to 2009, dissolved Se concentrations were much higher at all river sites (Figure 59, Figure 61 and Figure 62). For example, at the New River international boundary, dissolved Se concentrations increased from 7 µg/L or less to 38 µg/L (Figure 59). From 2010 to 2012 the dissolved Se concentrations decreased to 4 µg/L or less. Similarly at the outlet, concentrations increased from less than 10 µg/L up to 46 µg/L at the outlet and subsequently declined until 2009 (Figure 59). Average total Se measured during the synoptic study in 2005 resulted in much lower concentrations, averaging 0.99 and 2.46 µg/L at the international boundary and outlet, respectively. Reclamation data from the New River site were extremely consistent and low compared with CEDEN data. In fact, CEDEN data indicate that the CTR was exceeded 94% of the time, while Reclamation data show only one exceedance. This could be due to differences in analysis and/or collection methods.

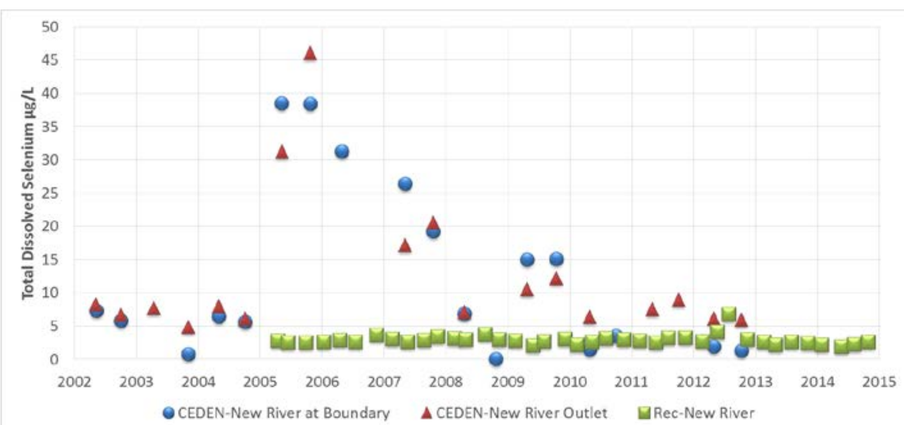

Figure 59 New River at the International Boundary and Outlet. CEDEN and Reclamation (Rec) data for total dissolved Se (µg/L).

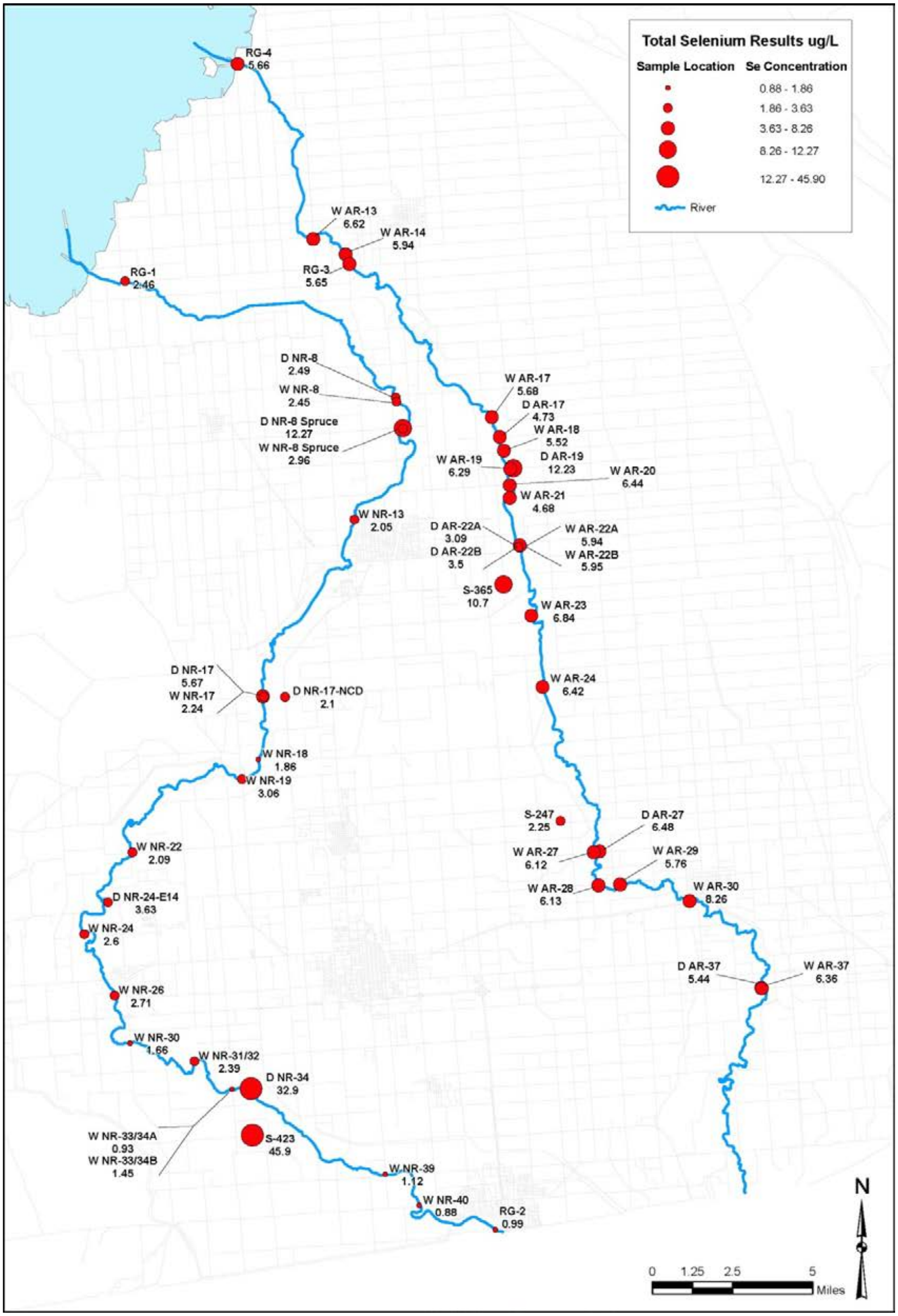

Figure 60 Synoptic Study Field Sample Locations and Total Selenium Results (µg/L)

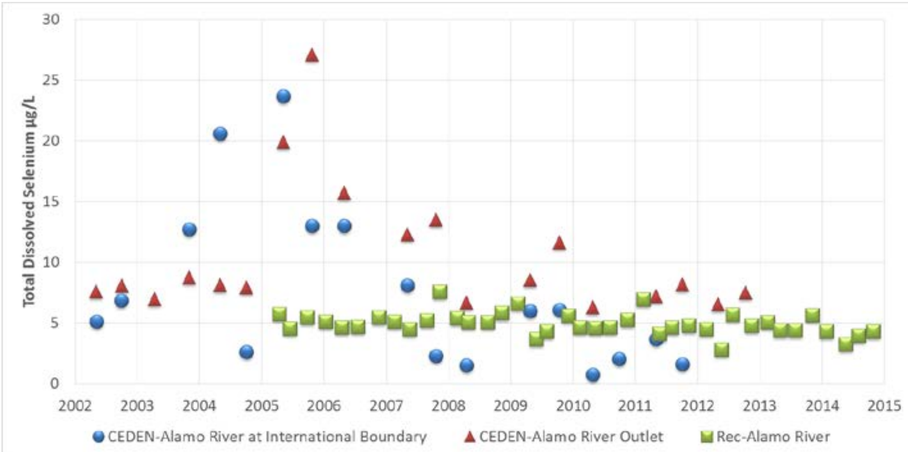

Figure 61 **Alamo River at the International Boundary and the Outlet. CEDEN and Reclamation data for total dissolved Se (µg/L).**

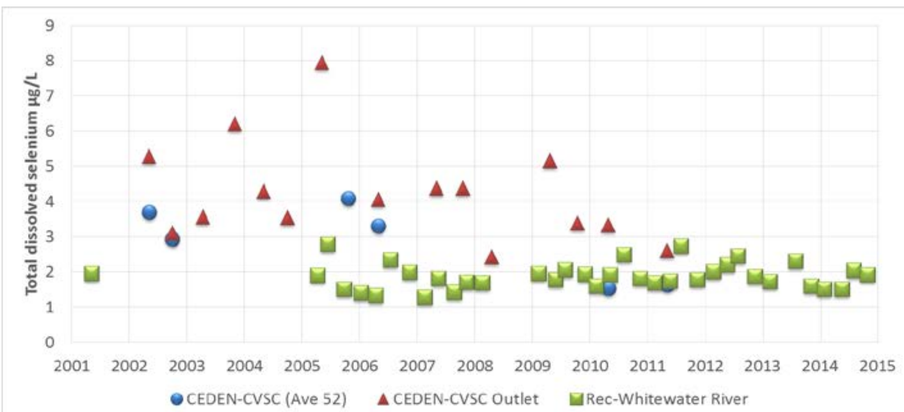

Figure 62 **Whitewater River at the Outlet and at Avenue 52. CEDEN and Reclamation (Rec) data for total dissolved Se (µg/L).**

Total dissolved Se data were measured in three major drains on the New River for a total of five samples in the CEDEN data set. Average dissolved Se was equal to the 5 µg/L toxic criterion and ranged from 3.2 to 10.6 µg/L. In the synoptic study, the Greeson Drain had 18 samples analyzed for total Se, averaging 4.8 µg/L. The maximum detected concentration of total Se from the major drains in the synoptic study was 33 µg/L for the Rice Drain on March 31, 1999.

Alamo River

In the Alamo River, the average total Se concentrations calculated using all the historical data were similar for the international boundary (5.8 µg/L) and the outlet (7.0 µg/L) (Figure 61). Dissolved Se was collected more frequently than total recoverable Se, and represented 86-100% of total Se concentrations in the river. The maximum concentration of total dissolved Se measured in the river was 27 µg/L at the outlet on October 26, 2005 (Figure

61). Total dissolved Se concentrations in the Alamo River sites were above the 5 µg/L criterion set by the CTR 65% of the time at the international boundary and 100% of the time at the outlet. The average dissolved Se concentration was 6.8 µg/L if Reclamation data are included. When excluded, the average concentration is much higher at 10.4 µg/L. Again, Reclamation data from the Alamo River site were extremely consistent and low compared with CEDEN data.

During the 2005 synoptic study, Alamo River Se concentrations near the outlet averaged 5.7 µg/L. Figure 60 shows hot spots of total Se concentrations measured during the study. Hot spots varied spatially, and the minimum and maximum Se concentrations were located within 10 miles and ranged from 0.88 to 45.9 µg/L (Figure 60). Sparsely collected dissolved Se concentration data from CEDEN at agricultural drains ranged from 0.6 to 9.3 µg/L and averaged 7.5 µg/L.

Whitewater River/CVSC

At the Whitewater River, the average total dissolved Se concentrations calculated using all data from 2001 to 2014 was 2.6 µg/L. The maximum concentration of total dissolved Se measured in the river was 10 µg/L near Mecca on May 24, 2005 (Figure 62). Total dissolved Se concentrations in the Whitewater River sites were below the 5 µg/l criterion set by the CTR except at the outlet, which exceeded the limit 27% of the time, excluding Reclamation data. Overall, dissolved Se has decreased slightly over the past decade and increased spatially from the Avenue 52 location to the outlet (Figure 62). Similar to New and Alamo River sites, Reclamation data from the Whitewater River site were extremely consistent and low compared with CEDEN data.

Total Se data were measured in six major agricultural drains. However, in five of the major drains sampling only occurred in 2002. The average total dissolved Se concentrations from these drains was 1.1 µg/L (Figure 63). The maximum detected concentration of total dissolved Se from the major drains was 4 µg/L at the Torrez Martinez 2 drain on May 11, 2005.

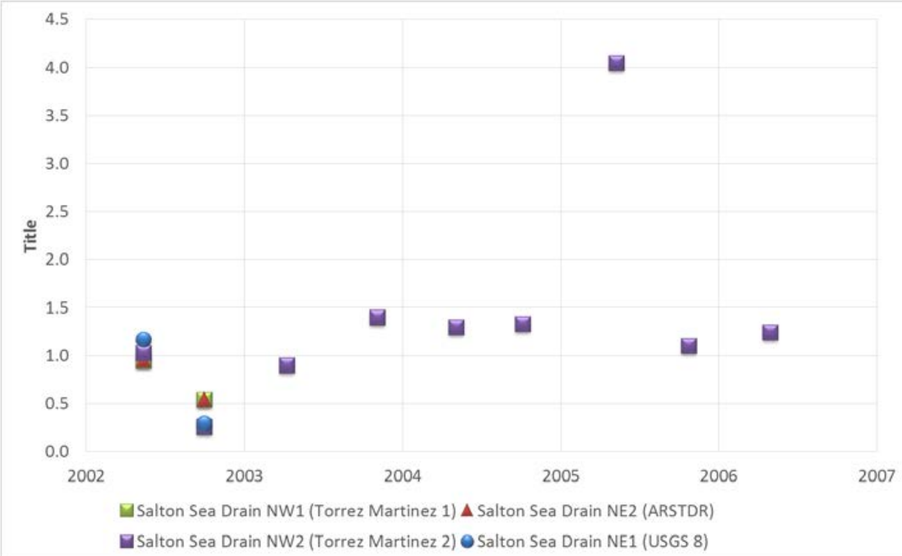

Figure 63 Agricultural drains near the North of the Sea: CEDEN data for total dissolved Se, µg/L.

3.3.3 Discussion

Dissolved Se measured at the Salton Sea was fairly low (about 1.2 µg/L over the past 12 years) in comparison to the source River concentrations (6 and 6.8 µg/L) and less than the CTR (5 µg/L). The CTR was exceeded at the Alamo River 65% of the time at the international boundary and 100% of the time at the outlet. Dissolved Se data in the rivers from Reclamation was quite different from CEDEN data. Discrepancies with the New River Se data show a 3% or 94% exceedance rate at the outlet, depending on the data set. The CTR was exceeded at the New River border 67% of the time from 2002-2012 and 25% of the time in the Whitewater River/CVSC.

A large spike of dissolved Se was observed in 2005-2007, coinciding with an elevated N:P ratio in the Sea. Total Se measured in sediment samples ranged from 1.5-11.8 µg/g and averaged 5.37 µg/g between 2005 and 2014, which is above the recommended toxicity threshold in sediments. The low aquatic concentration in the Sea and high inflow concentration indicate that Se is partitioned readily to sediment and is sequestered under anaerobic conditions.

Many unknowns still exist about the Se dynamics (characterization of inorganic/organic, different oxidative states, elemental species and their distributions), biogeochemical cycling in the Sea and the effect of Se concentrations on local species. These knowledge gaps need to be addressed in order to attain some certainty about future restoration actions.

3.4 Total Suspended Solids

TSS is an indicator of water clarity and overall water quality. The measurement includes organic matter like algae and plant material, and inorganic matter including sand, silt and clay particles. TSS is generally usually associated with flow, increasing with higher flows.

3.4.1 Salton Sea

TSS concentrations decreased in the Sea from 2003 to 2014 but rose sharply in November 2014 (Figure 64). Samples collected toward the bottom of the Sea were very similar to surface samples. Average TSS was 42 mg/L between 2003 and 2007 with a high of 132 mg/L. TSS decreased to an average of 31 mg/L until November 2014, when TSS reached levels similar to pre-2007 levels, likely the result of a sea turnover event. Annual average TSS ranged from 15-39 mg/L during 2008-2014. From 2004 to 2008, annual average TSS ranged from 25-69 mg/L. These concentrations are all lower than the 200 mg/L TMDL target set for two of the Sea's source rivers.

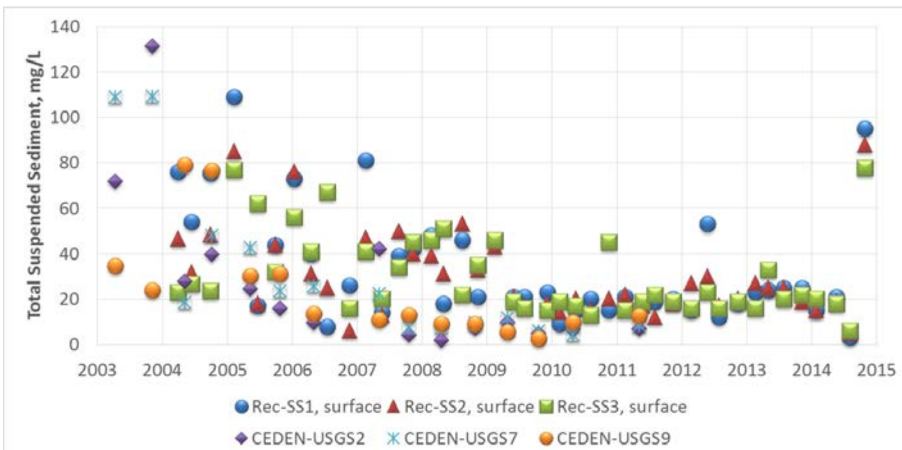

Figure 64 Stations located throughout the Salton Sea. CEDEN and Reclamation data for TSS (TSS; mg/L) in the Salton Sea.

3.4.2 Sources

New River

The average TSS concentrations calculated using all the historic data were much lower at the international boundary compared to the outlet. The average TSS concentrations from these sites were 50.7 mg/L and 213 mg/L, respectively (Figure 65). This difference can likely be attributed to the fact that the agricultural return flows entering the river contain high concentrations of suspended solids leading to an increase in suspended solids along the New River toward the Salton Sea. Data from the 2005 study also show that TSS concentrations were much higher at the outlet (160 mg/L) than the international boundary (34 mg/L). The New River TMDL target for silt with compliance by 2014 is 200 mg/L. Average TSS from 2011 to 2014 was

211 mg/L and the TMDL target at the outlet has been exceeded 8 out of 10 previous years.

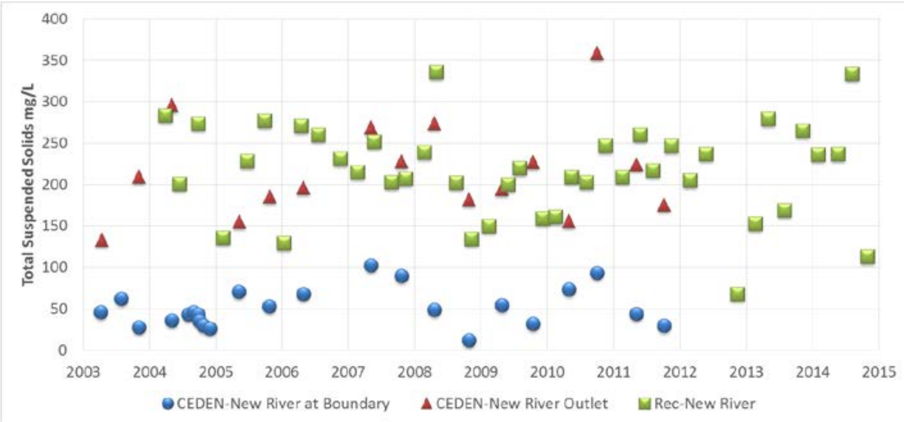

Figure 65 **TSS at the New River International Boundary and Outlet. CEDEN and Reclamation data for TSS (mg/L).**

There is a slight decline in TSS concentration over time. A seasonal trend analysis conducted on various sites in the New River showed that higher concentrations of TSS generally occur during late spring and throughout the summer months.

TSS measured in agricultural drains was higher than at the international boundary and similar to the outlet (Figure 65 and Figure 66). The agricultural drains measured for TSS exceeded the implemented silt TMDL of 200 mg/L at times but annual averages were below 200 mg/L except at the Rice 3 Drain in 2004 (237 mg/L), and 2007 (238 mg/L) and at the Greeson Drain in 2010 (204 mg/L).

Alamo River

Similar to the New River, the average TSS concentrations in the Alamo River calculated using all the historical data was much lower at the international boundary (59.4 mg/L) than at the outlet (381.2 mg/L). Figure 67 shows that there is a significant increase in the TSS concentration between the international boundary and the Salton Sea, and that there is typically an increase in suspended sediments as you move downstream. It also shows that the agricultural drains contain significant amounts of suspended sediments. The Alamo River TMDL target for silt with compliance by 2014 is 200 mg/L. Average TSS from 2011 to 2014 was 267 mg/L. The maximum concentration of TSS measured in the river was 3,040 mg/L at the outlet site on March 1, 1983.

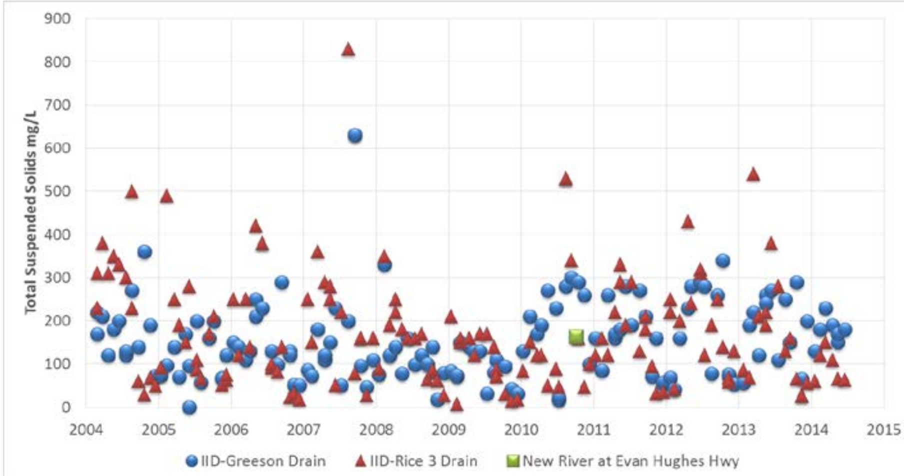

Figure 66 **Agricultural drains near the New River. CEDEN and IID data for TTS (TSS; mg/L).**

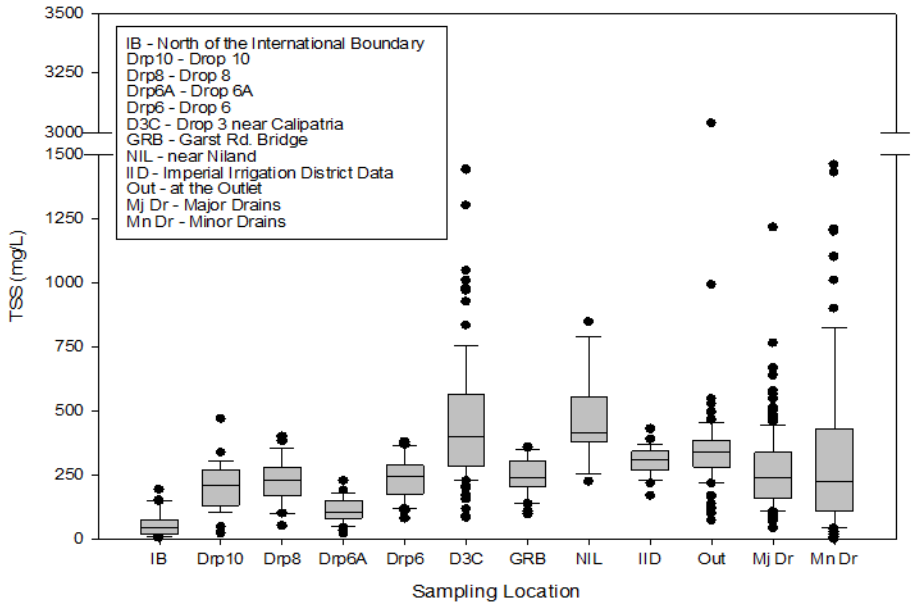

Figure 67 **Box plot of TSS data for various locations in the Alamo River and for the agricultural drains flowing into the river (Tetra Tech and Wetlands Management Services 2007).**

The TSS data revealed changes in the concentration over time and a seasonal trend. There has been a decline in the TSS concentration over the last 25 to 30 years (Tetra Tech and Wetlands Management Services 2007). Average TSS measured in the river at Calipatria and Niland in the 2005 synoptic study was 220 and 240 mg/L, respectively. This further demonstrates the declining trend in TSS concentrations. A seasonal trend analysis conducted on various sites showed that higher concentrations of TSS generally occur during late spring and throughout the summer months.

Data collected since 2003 show that TSS has remained fairly stable over time at each location, and that TSS is much higher at the Sea outlet than at the international boarder due to TSS input from agricultural drains (Figure 68).

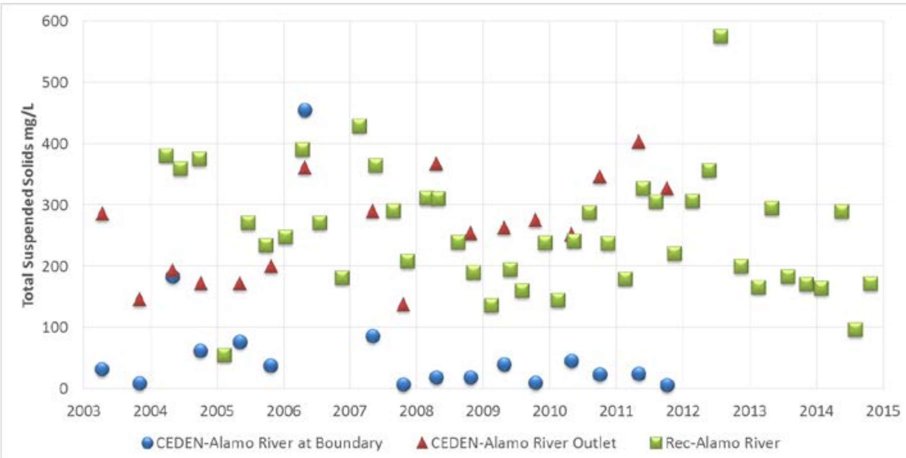

Figure 68 Alamo River at the International Boundary and Outlet. CEDEN and Reclamation (Rec) data for TTS (mg/L).

TSS data was measured in four of the major agricultural drains and five major drains were analyzed by IID. The Rose Drain had the highest average TSS concentration (295 mg/L) followed by the South Central Drain (251 mg/L). The maximum detected concentration of TSS from the major drains was 1,216 mg/L from the Central Drain on March 1, 1987. From the past decade the maximum TSS concentration measured in the major agricultural drains was 700 mg/L on April 23, 2014 (Figure 69).

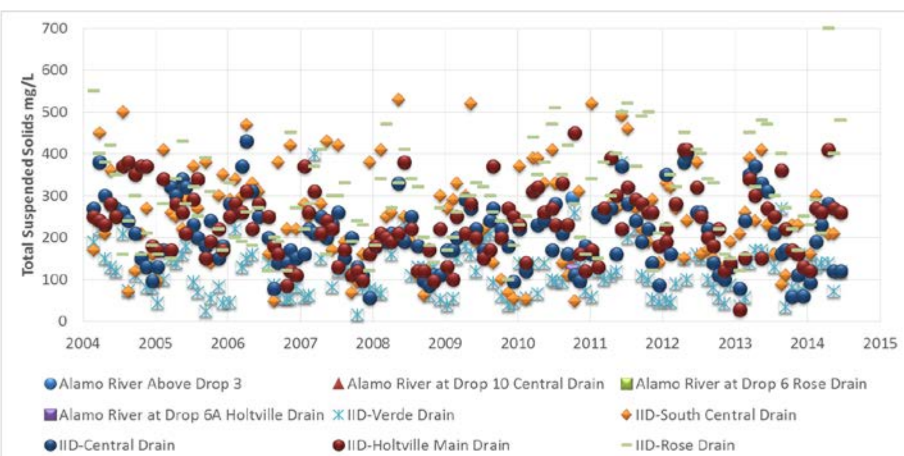

Figure 69 Major agricultural drains near the Alamo River. CEDEN and IID data for TTS (mg/L).

TSS was measured in thirty out of sixty-eight minor agricultural drains. The Mullen Drain had the highest TSS concentration (1,460 mg/L) followed by the

Mesquite Drain (1,207 mg/L) (Figure 67). However, the Mullen Drain and the Mesquite Drain only had one sample each. This was also the case for fifteen of the thirty minor drains with measured TSS data. The maximum detected concentration of TSS from the minor drains was 1,460 mg/L from the Mullen Drain on March 3, 2000. The minor drains had a higher average concentration of TSS compared to the major drains (Figure 67). IID data from 8 minor drains averaged 290 mg/L from 2004-2014. The highest measured concentration was 2,300 mg/L at the I Drain on September 1, 2009.

Whitewater River/CVSC

Total suspended solids concentrations were lower in the Whitewater River than the New and Alamo Rivers, averaging 83 mg/L from 2011 to 2014. TSS increased spatially from the channel at Avenue 52 to the Salton Sea outlet (Figure 70). The TSS data were not sufficient to show changes in the concentration over time or a seasonal trend.

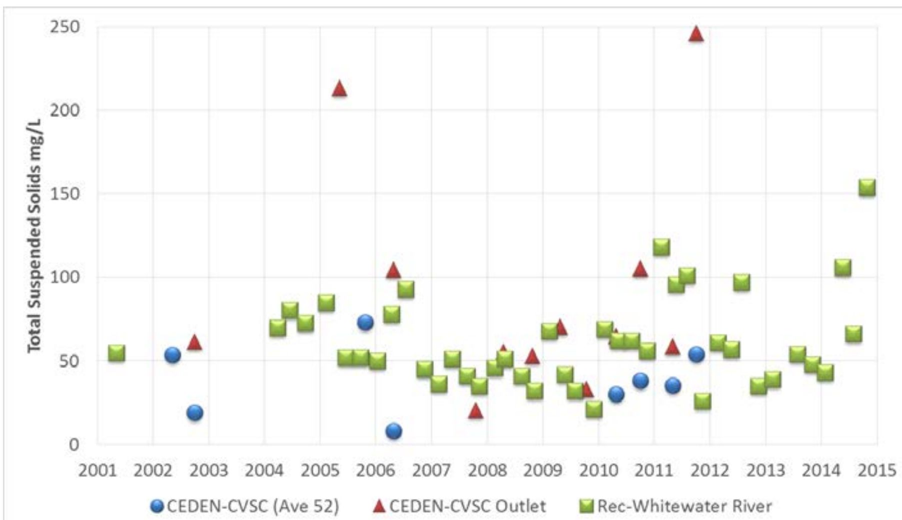

Figure 70 **Whitewater River/CSVC at the Outlet and at Avenue 52. CEDEN and Reclamation (Rec) data for TTS (mg/L).**

TSS data was measured in all five of the major agricultural drains. Concentrations were very low in all drains during 2002 (less than 10 mg/L), but TSS was much higher in 2005 and closer to concentrations measured at the outlet (Figure 71).

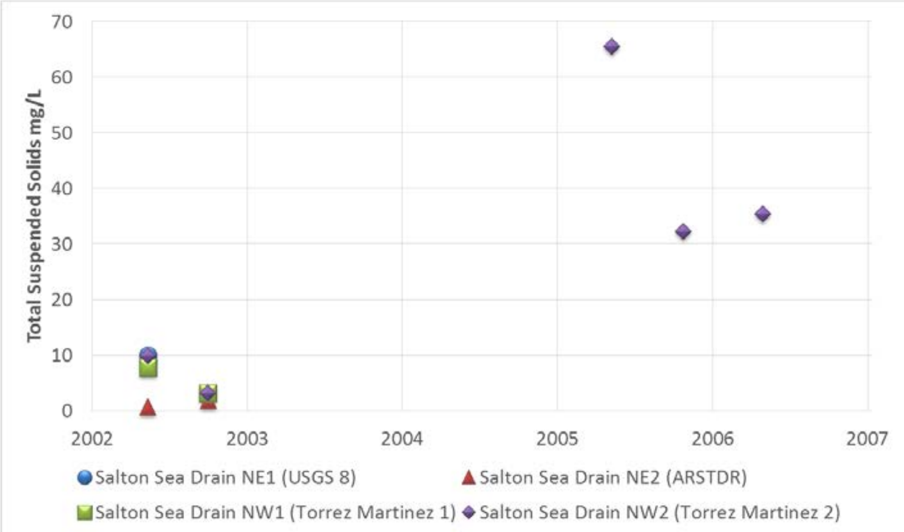

Figure 71 Agricultural drains near the North of the Sea: CEDEN data for TSS, mg/L.

3.4.3 Discussion

Total Suspended Solids (TSS) concentrations decreased dramatically in the Sea from 2003 to 2014. This trend corresponds with nutrient and Se concentration declines over the past decade. TSS was much lower in the Sea than in the New and Alamo Rivers, confirming that suspended sediment readily settles upon entering the Sea as suggested by Holdren and Montaño (2002). Unlike in the Sea, the source rivers exhibit a fairly stable TSS concentration over time. At the New and Alamo Rivers, TSS concentrations were four to six times lower at the Mexico border than at the outlet, due to agricultural return flows containing high concentrations of suspended solids entering the river. TSS concentrations were higher at the outlet than the TMDL target of 200 mg/L. The target was exceeded 80% of the time in the New River and 65% of the time in the Alamo River. TSS was less of a concern in the Whitewater River and concentrations increased spatially from upstream to the Sea.

3.5 Coliforms

The Mexican-American Water Treaty, Minute No. 264, "Recommendation for Solution of the New River Border Sanitation Problem at Calexico, California – Mexicali, Baja California Norte" (RWQCB-7 Basin Plan) provides the following quantitative standards for coliforms:

New River Upstream of Discharge Canal: 30,000 Colonies per 100 mL, with no single sample to exceed 60,000 colonies per 100 mL. The Colorado River Basin Plan provides the following "not to exceed" fecal coliform objectives: Rec 1 = 400 colonies/100 mL and Rec II = 2,000 colonies/100 mL.

3.5.1 Salton Sea

Fecal coliform data were only available through CEDEN and was collected infrequently at the Salton Sea. The few data collected indicate relatively low levels of fecal coliform, averaging 10 Most Probable Number per 100 Milliliters (MPN/100mL). Total coliforms were higher, ranging from 20 to 2,400 MPN/100mL. Thus, coliforms in the Sea are not a major concern.

3.5.2 Sources

New and Alamo Rivers

Seventy-nine percent of the historic samples collected from the New and Alamo Rivers contained total coliform levels that exceeded the 60,000 colonies/100 mL limit set by the Mexican-American Water Treaty, with concentrations that reached greater than 2.4 million colonies/100 mL (Figure 72). Current beneficial uses for the New and Alamo Rivers include contact and non-contact recreation, even though those uses are prohibited.

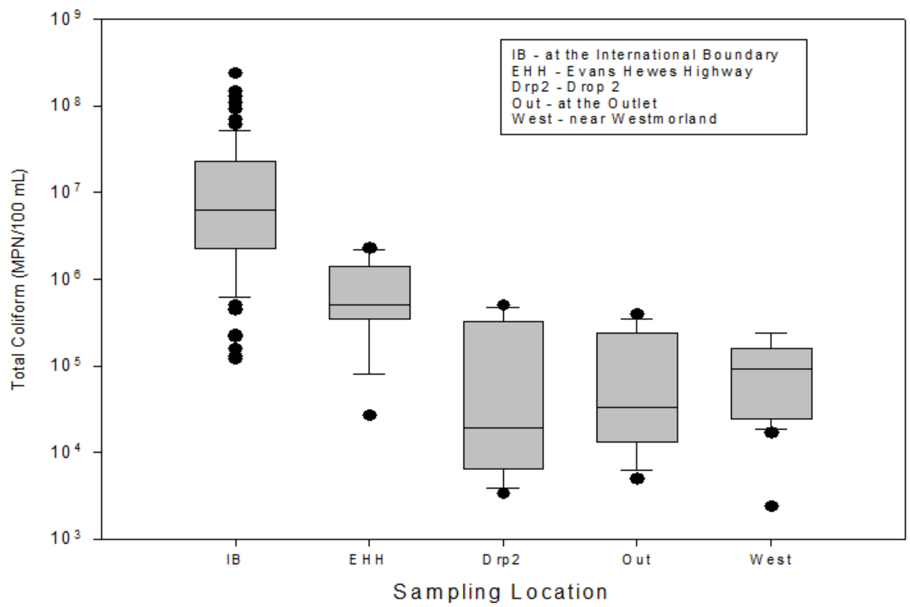

Figure 72 Box plot of total coliforms data for various locations in the New River (Tetra Tech and Wetlands Management Services 2007).

The average total coliform concentrations calculated using all the historical data were much higher at the international boundary compared to the outlet (Figure 72). The average total coliform concentrations from these sites were 1.7×10^7 MPN/100 mL and 1.0×10^5 MPN/100 mL, respectively. The higher concentrations occurring at the international boundary may be the result of sewage effluent water discharged into the New River from a treatment plant in Mexico located near the border. The maximum concentration of total coliforms measured in the river was 2.4×10^8 MPN/100 mL at the international boundary on three dates in late 1977. Total coliforms measured during the synoptic study in 2005 were lower than the historical average, reaching greater than $2.4x10^5$ MPN/100 mL at the international boundary and $3.9x10^5$ MPN/100 mL at the outlet.

Fecal coliform from CEDEN were collected in 2002 and 2006 at the international boundary and the outlet. Again concentrations were higher at the boundary, with an average of $5.5x10^5$ MPN/100 mL, than the outlet, with an average of $1x10^4$ MPN/100 mL (Figure 73). Total coliforms were much higher, averaging $2.18x10^6$ MPN/100 mL at the boundary and $2.0x10^5$ MPN/100mL at the outlet. Fecal coliform measured in drains near the New River averaged $1.65x10^5$ MPN/100 mL and reached a maximum of $9x10^4$ MPN/100 mL at the Rice Drain in May 2002.

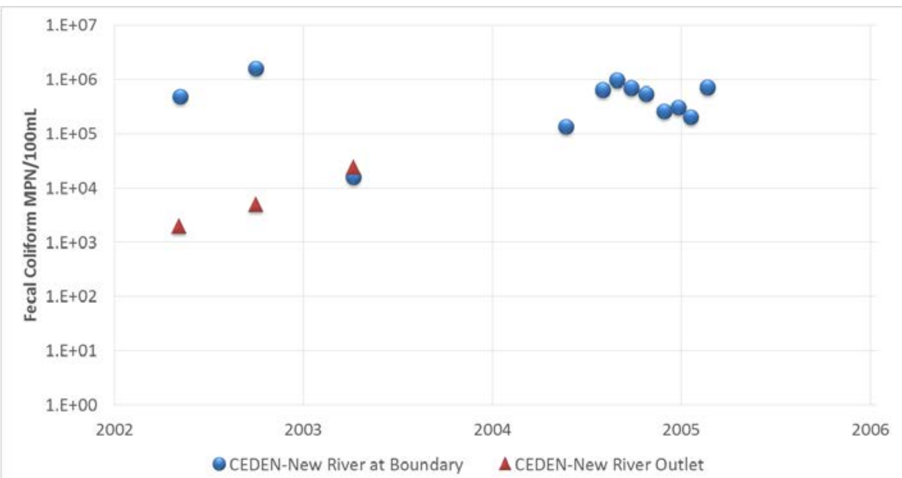

Figure 73 New River at the International Boundary and Outlet. CEDEN data for fecal coliform (MPN/100mL). Note logarithmic scale on y-axis.

At the Alamo River, fecal coliform data were collected at the international boundary and at Drop 3. The average fecal coliform concentrations calculated using all the data from these two sites were $2.6x10^3$ MPN/100 mL and $1.9x10^4$ MPN/100 mL, respectively. The maximum concentration of fecal coliforms measured in the river was $3.0x10^5$ MPN/100 mL at Drop 3 on October 23, 1979.

The fecal coliform data from Drop 3 were used to evaluate changes in concentration over time. Figure 74 shows a sharp decline in the fecal coliform concentrations in the late 70's and early 80's. Sparsely collected fecal coliform data indicate further reductions in bacteria may have occurred, for example 1.1×10^3 MPN/100 mL was measured at Drop 3 in 2002. At the outlet concentrations were found be very low, 110 to 800 MPN/100 mL in 2002-2003. A seasonal trend analysis showed that lower concentrations of fecal coliforms generally occur during low flow/low rainfall months of April to July.

Results of the 2005 synoptic study total coliform concentrations similar to historic concentrations in the 1990's at Drop 3 of $2.0x10^5$ MPN/100 mL. At the station near Niland concentrations averaged $1.2x10^5$ MPN/100 mL.

Whitewater River

Fecal coliform data were collected in the Whitewater River at the outlet to the Sea and upstream at Avenue 52. Concentrations of fecal coliforms were higher at the outlet to the Sea, indicating significant fecal coliform contribution occurred between the two sites. Bacteria sources include avian, human, rodents and other mammals, and livestock (CRBRWQCB 2007). The TMDL target for bacterial indicators in the Coachella Valley Stormwater channel is 200 MPN/100 mL fecal coliform per sample. In the 1980's fecal coliform concentrations varied significantly but reached as high as 1,700 MPN/100mL and averaged 300 MPN/100mL. Recent data are sparse and end in 2003 but average fecal coliform concentration at the outlet was 270 MPN/100 mL. However the concentrations have decreased significantly since 1999, when fecal coliform concentrations were reported to be 900,000 MPN/100 mL at Avenue 52 (CRBRWQCB 2007). Levels of total coliforms were high, reaching 24,000 MPN/100mL in 2002 and 198,600 MPN/100mL in 2005.

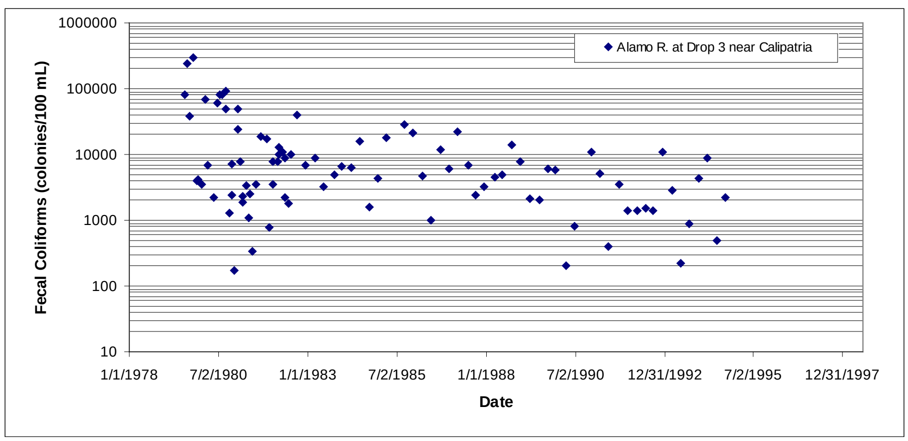

Figure 74 Historic fecal coliforms between 1979 and 1994 from Alamo River outlet samples (Tetra Tech and Wetlands Management Services 2007).

3.5.3 Discussion

Coliform concentrations in the Salton Sea were generally below levels of concern. However total coliform from the New and Alamo Rivers exceeded the Colorado River Basin Plan "not to exceed" coliform objectives of 60,000 colonies/100 mL limit set by the Mexican-American Water Treaty 79% of the time (from 2002-2005), with concentrations that reached greater than 2.4 million colonies/100 mL. Sources of coliform include agricultural drains, fecal matter from livestock and humans, and stormwater runoff. Progress has been made through the TMDL process, and coliforms may have decreased over the past two decades in the Alamo and Whitewater Rivers. However more data needs to be collected in order to definitively confirm this trend.

3.6 Biota

3.6.1 Recent Food Web

Since the Sea became hypersaline in 1990, the ecosystem has become less diverse and fish became less abundant, which may have negatively influenced bird populations. The food web is a simple one: single-celled algae are the base, invertebrates feed on algae and detritus which are the food supply for fish and birds (DWR and DFG 2007). Pileworms (*Neanthes succinea*: Polychaeta) dominated the macroinvertebrates until a decline of abundance in 2004-2005, thought to be related to sea turnover and increased hydrogen sulfide releases (Detwiler *et al.* 2002; Dexter *et al.* 2007). The increasing salinity of the Sea may be a significant factor as well, reaching 57 g/L TDS in November 2014. Other invertebrates include flies (diptera), water boatmen (corixids), amphipods (*Gammarus mucronatus* and *Corophium louisianum*), seed shrimp (ostracods), a spionid worm (*Streblospio benedicti*), and a barnacle (*Balanus Amphitrite*; Detwiler *et al.* 2002; Miles *et al.* 2009). Marine zooplankton is composed mainly of copepods (Miles *et al.* 2009).

Fish species in the Sea are dominated by tilapia (*Tilapia sp.*) and the native desert pupfish. Other fish include common carp (*Cyprinus carpio*), channel catfish (*Ictalurus punctatus*), flathead catfish (*Pylodictis olivaris*), mosquitofish (*Gambusia affinis*), grass carp (*Ctenopharyngodon idella*), and sailfin molly (*Poecilia latipinna*) although these are limited mostly to the river habitat and near the outlet (Schlenk *et al.* 2014; Moreau *et al.* 2007). Three species that were common 10 years ago became effectively eliminated in 2003 as salinity rose, including sargo, corvina and bairdiella (DWR and CDFW 2011; Anderson *et al.* 2007).

The bird species most at risk at the Sea are those that are present almost year-round and breed at the Sea, including egrets and herons (of the Ardeidae Family: Great Blue Heron (*Ardea herodias* Ridgway), Great Egret (*Egretta alba* Gmelin), Snowy Egret (*Egretta thula* (Molina)), Cattle Egret (*Bubulcus ibis* (Linnaeus)), Black-crowned Night Heron (*Nycticorax* (Gmelin)), Northern Shoveler (*Anas clypeata* Linnaeus), Lesser Scaup (*Aythya affinis* (Eyton)), and Ruddy Duck (*Oxyura jamaicensis* (Wilson)) and the Double-brested Cormorant (*Phalacrocorax auritus* Ridgway). Ospreys (*Pandion haliaetus* (Gmelin)) are found most of the year at the Sea but are not known to breed there (Patten *et al.* 2003). Breeding season migrants travel to the Sea during spring. These species include Caspian Terns (*Hydroprogne caspia* Pallas), Black Skimmers (*Rynchops niger* Linnaeus) and Gull-billed Terns (*Gelochelidon nilotica* Bancroft). Brown Pelicans (*Pelecanus occidentalis*

Ridgway) occasionally nest at the Sea but are mostly present during late summer. American White Pelicans (*Pelecanus erythrorhynchos* (Gmelin)) use the Sea as a wintering refuge. During winter as much as 30% of the entire North American breeding population migrates to the Sea—and has been documented at 30,000 or more individuals (Shuford *et al.* 2002). Population trends for fish species are mirrored by populations of breeding and wintering piscivorous birds, which have declined with the decrease in fish availability (Hulbert *et al.* 2007; Henny *et al.* 2008). Anderson *et al.* (2007) proposed that changes in primary productivity, brought about during El Niño Southern Oscillation (ENSO), caused a drop in pileworm population that subsequently starved the Eared Grebe population. This link can be explored in more detail, as a strong El Niño signal is developing for 2015-2016 in the region (>90% chance; National Oceanic and Atmospheric Administration and National Weather Service 2015), which could devastate already diminished populations.

Complex physical dynamics and biological response at the bottom of the food chain have contributed to the boom and bust of fish populations, which has a direct effect on piscivorous bird populations and influences populations of birds that rely upon macroinvertebrates. Multiple stressors are acting to reduce Salton Sea fish populations. While water temperature, oxygen, stratification/mixing (and subsequent hydrogen sulfide release) and salinity are the biggest drivers of aquatic species' suitability and response (Hulbert *et al.* 2007; Lorenzi and Schlenk 2014), toxicity from legacy and inorganic contaminants are a threat to the biological species in the Salton Sea. Other stressors include pathogens and microbial ectoparasites; to date no study has addressed all stressors and their interactions at the Sea (Moreau *et al.* 2007).

3.6.2 Persistent Legacy and Inorganic Contaminants

Biotic toxicity thresholds for Se vary depending on the species. Since uptake that leads to bioaccumulation occurs mostly via particle ingestion rather than from the water column, Selenium concentrations of sediment and fish are critical to assessing overall health and ecological risk. Lemly (2002) proposed 3 µg/g dry weight (dw) to avoid toxicity to piscivorous wildlife, and 4 µg/g dw to avoid toxicity to the fish. This corresponds to 0.6 µg/g ww and 0.8 µg/g ww (assuming 80% moisture), respectively (Hinck *et al.* 2004). The thresholds represent Se concentrations at which toxic effects first begin to occur in sensitive fish species and not the point at which all species die from Se toxicity (Saiki *et al.* 2010). From low to very high concentrations, Se causes a range of effects from reduced hatching success to teratogenic deformities (CNRA 2015). Sensitivity to Se varies among bird species, and risk of impaired reproduction can start to occur at egg concentrations of 6-12 µg/g dw. The risk of teratogenesis starts to occur above 12 µg/g dw for sensitive species, and above 20 µg/g dw for moderately sensitive species (Ohlendorf and Heinz 2011 as cited in CNRA 2015).

Recently Schlenk *et al.* (2014) found that persistent legacy and inorganic contaminants are still prevalent in fish and sediments of the Salton Sea and the New and Alamo Rivers (Schlenk *et al.* 2014). Higher levels of contamination were found at the international border and the outlets to the Sea for each river. Within the Sea, concentrations of Se in sediment have increased since 2007. Metals in water and sediment that were consistently above criteria thresholds included Se and copper, and occasionally above the thresholds were chromium, silver and mercury. Organic contaminants such as DDT isomers and metabolites (total DDT; tDDT) were found to exceed thresholds in sediment at both river outlets and the Salton Sea (Schlenk *et al.* 2014).

High concentrations of tDDT and Se in water and sediment translated to fish tissue concentrations. From 2004-2012, fish tissues exceeded tDDT criteria 81% of the time across 31 sampling events, ranging from 30-132 ng/g ww in 2012. These values have remained high over time and at times above the predator threshold of 14 ng/g ww but below the threshold for fish health (600 ng/g ww; Environment Canada 1997 and Beckvar *et al.* 2005). For Se, fish tissues exceeded the criteria for piscivorous wildlife at 78% of the 32 sites. Selenium concentrations in fish from the Sea ranged from 1.9-2.8 mg/kg ww in 2001 and was 2.24-3.52 mg/kg ww in 2007 (Schlenk *et al.* 2014). In addition, the threshold for PCBs of 0.1 ng/g ww was exceeded in every sample, ranging from 1.5-49 ng/g ww (Jarvinen and Ankley 1999).

Selenium concentrations in fish samples collected from the Brawley and Imperial Pilot Wetlands on the New River in 2005-2006 ranged from 2.74 mg/kg dw at BW-3 to 6.46 mg/kg dw (Tetra Tech and Wetlands Management Services 2007). Concentrations of Se in fish tissues collected from both the Brawley and Imperial Wetlands exceeded the lower bound of the NIWQP criterion of 4-6 mg/kg dw. This criterion is the estimated threshold range (LC10) for reproductive impairment in sensitive species (Tetra Tech and Wetlands Management Services 2007). In addition, concentrations of Se in fish tissues collected from both the Brawley and Imperial Wetlands exceeded the lower bound of the NIWQP criterion of 3-8 mg/kg dw for reproductive effects in bids. However, none of the measured concentrations exceeded 8 mg/kg dw, the upper bound of this criterion.

Eight organochlorine pesticides (OCPs) were detected in fish samples collected from the Brawley and Imperial Pilot Wetlands however none of the OCPs were detected at concentrations exceeding screening criteria protective of fish (Tetra Tech and Wetlands Management Services 2007). It is important to note that screening criteria were not available for aldrin and alpha-chlordane or for the protection of piscivorous birds, which would likely be lower than screening criteria protective of fish. The exception is tDDT, which has a criteria for the protection of predators of 14 ng/g ww. Concentrations of tDDT in fish from the pilot wetlands exceeded this threshold in 2005-2006 and ranged from 147.5-554.4 ng/g ww (Tetra Tech and Wetlands Management Services 2007).

Concentrations of Se, OCPs and other contaminants vary spatially and temporally. Selenium decreased since the 1980's for night herons and great egrets on the north end of the Sea; in fact all egg concentrations were below 5.03 µg/g in 2004 and the lowest reported Se effect in bird eggs occurs at 6-7 µg/g. Stilt egg Se concentrations in the south end of the Sea continued to have a 4.5-7.65% impairment rate (Henny *et al.* 2008). Henny *et al.* (2008) demonstrated a promising decline of DDE concentrations in night herons and great egrets at the northern end of the Sea and for Stilt eggs at the southern end of the Sea since the 1980's and 1990's. Those concentration decreases correspond to a significant increase in egg shell thickness (Henny *et al.* 2008). However eggs from white-faced ibis contained very high levels of DDE (geometric mean of 11 µg/g; effect level is < 4 µg/g). A portion of the population winters in the Imperial Valley and eats earthworms that concentrate DDE and therefore continues to be a concern for DDE toxicity. PCBs in eggs measured in 2004 from around the Sea ranged from 2.1 ng/g ww in Stilt to 180.3 ng/g in Heron species. The typical effect threshold for reproductive problems is an order of magnitude higher. Concentrations of metals and trace elements were also below thresholds of concern.

3.7 Summary

Due to the desert environment in the watershed of the Salton Sea, the intensity of imported water use, and the extent of agricultural cultivation, a variety of pollutants are observed in all water bodies in the basin, including the agricultural drains, the rivers, and ultimately in the Salton Sea. Designated as an agricultural drainage repository, the Salton Sea will continue to receive polluted waters. An understanding of water quality in different areas is of interest to the feasibility study because these waters may be considered for restoration and habitat creation, and pollutant concerns will need to be fully considered before actions can move forward. In the case of the Species Conservation Habitat project, an important goal is to address the ecological risks from the waters and lake sediments that are to be used (DWR and CDFW 2013). In addition to the habitat restoration, some basic beneficial uses of the Salton Sea cannot be attained without the inflowing water quality improving significantly. The eutrophic conditions in the lake, low dissolved oxygen and high ammonia concentrations are a direct consequence of the large nutrient loads that enter the Sea, a lack of an outlet, and the environment, so reduction of the nutrient loads is essential if these concentrations are to be managed. Since the Sea is phosphorus-limited, it will be important to study phosphorus dynamics further and continue to monitor concentrations among the various source waters. Complex interactions between selenium dynamics, temperature stratification and redox conditions are also very important to research, especially as the Sea recedes and exposed playa undergoes oxidation.

Based on these considerations, any future analysis performed for the feasibility study must consider how water quality flowing into the Sea and into newly created restoration projects will change, and whether the quality can be managed through various control techniques such as modifying agricultural practices, treatment wetlands, settling basins, or more engineered approaches.

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4.0 Salton Sea Inflow Projections

This chapter describes the recent history and development of future hydrology projections of the Salton Sea based on data on existing commitments and water transfers, particularly over the next decade where mitigation flows will taper off. Over the recent period, regional inflows are shown on an annual and monthly basis to allow comparison against flow requirements for new habitat creation.

4.1 Historic and Projected Inflows

4.1.1 Historic Inflows

Historical data were collected and analyzed as discussed in Section 2.2. The majority of historical flows were measured by the U.S. Geological Survey (USGS), Imperial Irrigation District (IID) and Coachella Valley Water District (CVWD). When actual flows could not be obtained for the water budget, they were estimated using the best available information. Groundwater contributions have been estimated by IID and CVWD. Over the entire period of record, monthly and annual flows have decreased from the New and Whitewater River/Coachella Valley Stormwater Channel (CVSV) and remained fairly constant in the Alamo River. While the future of inflows to the Sea are somewhat uncertain, this study used established modeling tools and new information to estimate inflows.

4.1.2 Future Inflows

Many studies have attempted to characterize future inflows to the Sea using modeling techniques. Quantifying these flows allows a design criteria to be reached, which is essential for determining solutions to the impending crisis. Here we build off previous efforts and re-examine past modeling assumptions in light of new information. Annual total flows, evaporation, other water requirements, and projected flow for 2020 are presented in Table 10. A review of previous inflow estimates and their source follows, including quotes from the document and a table showing the results.

Authority (2006)

Projections generated by the Authority in 2006 suggested that inflows to the Salton Sea would remain above 800,000 AFY over the 75-year restoration project evaluation period. The estimates were based upon several key assumptions including a review of area regional water management plans. The quantity projected assumed full utilization of IID's and CVWD's contractual Colorado River Entitlements over the 75-year QSA term with return flow percentages nearly equivalent to current irrigation and water use practices.

More information on the Authority's projections can be accessed in *Salton Sea Revitalization & Restoration, Salton Sea Authority Plan for Multi-Purpose Project.* Table 5 provides a summary of inflow projections provided in that report. The total inflow shown in Table 5 includes a deduction of 56,856 AFY for the Inadvertent Overrun and Payback Policy (IOPP), based on the assumption that IID will overrun its net Priority 3a quantified entitlement periodically. Sometimes IID has to order additional water to meet unplanned early fall irrigation demands, causing IID to exceed its annual water year (October 1st to September 31st) entitlement. Under the QSA operating rules, IID is required to deduct any prior year's overrun from its next year's entitlement. "Other" flows include groundwater and minor channels and washes. Imperial Valley flows do not include flow originating from Mexico.

Table 5
Projected inflows by region from the Authority (2006).

Source	"CEQA-baseline case" Projected Inflows: 2018-2077 AFY	"Probabilistic Uncertainty Case" Projected Inflows: 2018-2075 AFY
Imperial Valley	723,944	614,856
Coachella Valley	138,446	98,043
Mexico	97,044	40,446
Other	18,984	18,984
Total Inflow*	921,503	715,473

State of California (prepared by DWR and DFG in 2006)

The PEIR prepared by the State of California utilized the QSA baseline which was obtained from the IID Water Conservation and Transfer Project EIR/EIS (IID and Reclamation, 2002)

These same numbers have been used in the Species Conservation Habitat Environmental Impact Statement/Report (SCH EIR/EIS) in 2011 and used/updated by IID in 2015. The logic presented in the PEIR is presented in the following two paragraphs.

In the past, inflows have surpassed 1.2 million AFY. As a result of the IID Water Conservation and Transfer program, a portion of these inflows are projected to be reduced after 2017. IID is currently supplying additional inflows as a mitigation measure to maintain the salinity at less than 60,000 mg/L until

2017 which is when the salinity was projected to exceed this concentration without the transfer.

Inflows may also decline due to the following reasons: water recycling in Mexico, changes in agricultural practices to meet projected Total Maximum Daily Loads, and changes to municipal wastewater disposal practices to meet discharge regulations. Similar changes have occurred in other areas of California. In addition, global climate change models have predicted increased evaporation rates which could further reduce inflows and increase evaporation from the Salton Sea, Saline Habitat Complex, or Brine Sink. Due to these reasons, the Draft PEIR included risk-based analyses of inflows considering the various water sources (variability scenario). The results of the analyses showed the average annual inflow for the period 2018 through 2078 (the period after IID ceases to divert mitigation water) as 717,000 acre-feet.

More information on the State of California's projections can be accessed in the *Salton Sea Ecosystem Restoration Programmatic Environmental Impact Report (PEIR, 2006).* Table 6 provides a summary of inflow projections provided in that report. "Other" flows shown in the table include groundwater and minor channels and washes. Imperial Valley flows do not include flow originating from Mexico.

Table 6
Projected inflows by region from the State of California (prepared by DWR and DFG in 2006).

Source	"No Action-Variability" Projected Inflows: 2018-2078 AFY	"No Action-CEQA" Projected Inflows: 2018-2078 AFY
Imperial Valley	615,000	724,000
Coachella Valley	98,000	138,000
Mexico	40,000	97,000
Other	19,000	19,000
Total Inflow	717,000	922,000

Reclamation (2007)

The risk-based approach implemented by Reclamation acknowledged that alternative concepts are subject to risk due to potential water conservation that could occur in response to non-specific reasons. For example, the Salton Sea could be subject to responses due to economic conditions, competing water demands, or water market conditions.

Uncertain responses may occur in Mexico, IID, or CVWD. When something is uncertain, it is possible to describe potential variability in the form of a distribution that explains the range in possible values that might be expected. The implementation of a risk-based method involved the development of distributions of the possibilities that represent full ranges in uncertainty of responses from Mexico, IID, or CVWD and resulting uncertainty of Coachella Valley surface water and groundwater interactions. These distributions do not depict probability of occurrence but, instead, describe the full range of possibilities. The approach was applied within the Salton Sea Accounting Model (SSAM), starting with QSA level inflows and the implementation of the CVWD groundwater management program. More information on the Reclamation's projections can be accessed in *Bureau of Reclamation, Reclamation: Managing Water in the West. Restoration of the Salton Sea. Volume 1: Evaluation of Alternatives*.

In Table 7 Imperial Valley flows do not include flow originating from Mexico.

Table 7
Projected inflows by region from Reclamation (2007).

Source	Risk-based Future Inflows: 2018-2077
Imperial Valley	620,000
Coachella Valley	113,000
Mexico	29,000
Other	--
Total Inflow	**727,000**

IID (2015) and Other Regional Reports

IID provided inflow projections used in their project in 2015 as shown in table 8. "Other" flows shown in table 8 include groundwater and minor channels and washes. Imperial Valley flows do not include flow originating from Mexico.

Table 8
Projected inflows by region from IID (2015).

Source	"No Action-Variability" Projected Inflows: 2018-2077 AFY	"No Action-CEQA" Projected Inflows: 2018-2077 AFY
Imperial Valley	557,945	667,073
Coachella Valley	98,042	98,042
Mexico	40,390	96,834
Other	20,002	20,002
Total Inflow	716,380	881,952

In addition to large-scale government reports, regional reports yielded important information regarding future flows and uncertainty:

- IID QSA 2010-2013 Implementation Report, 2014.
- CVWD Water Management Plan Update, 2012.
- Strategic Plan: New River Improvement Project, California-Mexico Border Relations Council, 2011.

Projects, agreements and plans with the potential to significantly affect flows to the Salton Sea are discussed in detail in the following section and include the following:

- QSA Projects
  - IID Water Conservation and Transfer Agreement
- TMDL Implementation
- Coachella Valley Water District Water Management Plan
- New River Strategic Plan

This analysis focused on the transition period of 2014-2025 which includes the end of QSA mitigation flows in 2018.

Imperial Valley

In Imperial Valley, IID has committed to delivering conserved water transfers obligated under the QSA and related agreements to San Diego, Coachella Valley, Metropolitan Water District, and mitigation water to the Salton Sea. Table 9 shows the annual volumes transferred to each entity. Conserved water is achieved with fallowing and water efficiency programs implemented throughout the Imperial Valley.

Table 9
Imperial Irrigation District water transfer to SDCWA and CVWD, Salton Sea Mitigation water and net water loss to the Salton Sea by year.

Year	SDCWA Transfer	CVWD Transfer	Salton Sea Mitigation Water created by fallowing
2003	3,445	0	0
2004	20,000	0	30,239
2005	30,000	0	21,476
2006	40,000	0	0
2007	50,000	0	23,306
2008	50,000	4,000	26,085
2009	60,000	8,000	30,158
2010	70,000	12,000	80,282
2011	63,278	16,000	0
2012	106,722	21,000	15,110
2013	100,000	26,000	71,470
2014	100,000	31,000	90,000
2015	100,000	36,000	110,000
2016	100,000	41,000	130,000
2017	100,000	45,000	150,000
2018	130,000	63,000	0
2019	160,000	68,000	0
2020	190,000	73,000	0
2021	200,000	78,000	0
2022	200,000	83,000	0
2023	200,000	88,000	0
2024	200,000	93,000	0
2025	200,000	98,000	0
2026-2047	200,000	103,000	0

Notes

1) SWRCB approvals for mitigation water were not obtained until early 2004. Therefore, IID deferred the delivery of mitigation water scheduled for 2003 until 2004. As a result, IID delivered a total of 15,000 AF of mitigation water in 2004.

2) Table does not include a transfer of "Early Transfer Water" under the Revised Fourth Amendment to the IID/SDCWA Transfer Agreement, which requires the transfer of an additional 2,500 AF to SDCWA in 2020, 5,000 AF in 2021, and 2,500 AF in 2022 at a price of $125/AF, adjusted by changes in a defined price index from January 1, 1999 to the year of delivery.

Volumes prior to 2014 are actual amounts, after 2013 the volumes are estimated/scheduled.

Source: IID QSA 2010-2013 QSA Implementation Report and 2009 QSA Annual Implementation Report

Lining 23 miles of the All American Canal was completed in 2009 and conserved an estimated 67,700 AFY (IID 2010). IID, assisted by Water

Authority staff, have also implemented habitat creation for 44 acres of wetlands and 30 acres of sand dunes, alternative water sources for deer, and acquired over 1,025 acres of habitat for the flat-tailed horned lizard. In 2011 and 2012 IID significantly exceeded its Colorado River entitlement, partially due to high commodity markets and lack of rainfall, but it is on track to complete the payback by 2014 (IID 2014). The effect of this was slightly higher agricultural return flows to the Sea than would otherwise occur during those two years and subsequent lower agricultural return flows during payback. Mitigation water delivered to the Sea through the Alamo River and eastern Imperial Valley drains will end in 2017 (Table 9). This will dramatically reduce inflows by 150,000 AF in 2018 and increasing up to a maximum of 303,000 AF in 2026 (Table 9).

The fallowing program is a temporary means to create water for transfers and mitigation water. The program is anticipated to end in 2017, at which time the on-farm water efficiency program, the Temporary Land Conversion Fallowing Policy (TLCFP) and delivery system improvements conserved water will be the only sources of transfer water. In the near term, a combination of fallowing and efficiency are being used for mitigation and conservation water. Fallowing takes land out of production, so water that the crop would have consumed is made available for transfer and the field return flows to the Sea (surface and subsurface) can continue to be used for environmental mitigation. In contrast, the on-farm efficiency program targets only field runoff (tile and/or tail water) for transfer purposes and therefore has a larger direct impact on the Sea (IID 2014). The sedimentation/siltation Total Maximum Daily Loads (TMDLs) for the New and Alamo Rivers have been implemented under the Imperial County Farm Bureau (ICFB) Voluntary Watershed Program that provides assistance to farmers for reducing TSS concentrations. The Best Management Practices (BMPs) involved in this process improve water use efficiency, reduce silt loads and moderately reduce drain flows (New River TAC 2011).

While IID and farmers reduce water use, urban populations are expected to increase dramatically in Imperial Valley (Imperial IRWMP 2012). Municipal water demand is already below the required target for water demand set forth by the 20x2020 Water Conservation Plan for the Colorado River Hydrologic Region. Recent water conservation mandates will require an additional 32% reduction in residential water use for the City of Imperial (SWRCB 2015). Transitioning from agricultural land uses to urban land uses is expected to increase at a steady rate to accommodate population growth, potentially freeing up some water for transfers and mitigation. The Imperial IRWMP estimates that municipal land use area is expected to increase by 450% by the year 2050 within the IID service area. Renewable energy development, including geothermal and solar thermal, could increase water use substantially. Environmental resources water demand will increase to 12,020 AFY by 2050 as a result of the QSA and Related Agreements for the Habitat Conservation Plan and other mitigation efforts (7,930 AFY was projected for 2015).

Previously estimated flow projections for Imperial Valley into the Sea by 2020 are 723,940 AFY (DWR and DFG 2007), 673,179 AFY (Authority 2006) and 620,000 (Reclamation 2007). Based on updated information regarding QSA implementation and recent flow data, inflows from Imperial Valley are very similar to previous estimates and are assumed to be between about 557,945 AFY under variability conditions and 667,073 AFY under California Environmental Quality Act (CEQA) conditions (IID 2015; Table 8). The long term drought could further decrease delivered water to Imperial County via the Colorado River entitlements and therefore reduce inflows to the Sea but it is unknown if and to what extent this would occur.

Coachella Valley

Flows from Coachella Valley to the Sea are lower than previously estimated, due to an updated water management plan and modifications to the timing and location of programs used to reduce overdraft. The QSA agreements assumed that the IID/CVWD transfer water will have no impact to the Sea since the CVSC also drains to the Sea. Unrelated to the QSA actions, the CVWD, in compliance with the Coachella Valley Water Management Plan, intends to recycle water, desalinate and use water for recharge of the aquifer, which could lead to reduced flows to the Sea. Under new water conservation mandates, residential water use must be reduced by 24% for the City of Coachella and 36% for CVWD (SWRCB 2015). This will decrease future wastewater flows entering the Whitewater River/CVSC.

Lining of the Coachella Canal began in 2004 and was completed in 2008. A net of 26,000 acre-feet of conserved water is transferred to San Diego County, who funded the project (CVWD 2006).

The Water Management Plan (WMP) of 2010 was created to update the earlier WMP in 2002 and to address population growth, the associated water demand, and water supply issues, especially groundwater overdraft. The plan indicates that flows to the Sea could increase or decrease based on land use and water use patterns (CVWD 2012). The potential desalination of drain water and tertiary treatment of wastewater projects could reduce freshwater flows from the Coachella Valley to the Salton Sea. As the WMP predicted, flows from Coachella Valley have decreased (Figure 14). The lowest annual flow from the Whitewater River/CVSC was 50,300 AF in 2010, which was predicted to increase to 55,000-65,000 AF in 2020 and reach 41,000-125,000 AF by 2045, depending on the extent of desalination used in the model (no desalination, minimum desalination or maximum desalination). Model results show drain and CVSC flows declining slightly until about 2015. After 2015, flows to the drains and the CVSC are projected to increase steadily during the planning period in the absence of drain water desalination projects. Under the implementation of the minimum amount of drain water desalination, flows to the Sea from Coachella Valley would increase to about 70,000 AF by 2045 (CVWD 2012). If maximum drain water desalination occurs, flows to the Sea could decrease to 40,000 AF by 2045 (CVWD 2012). These factors result in an estimated annual average Coachella Valley contribution to the Sea of 61,000 AFY from 2018-2077 under variable conditions and 98,042 AFY under CEQA conditions (IID 2015; Table 8); the variable conditions estimate is much lower than flow projections done by others (DWR and DFG 2007, Reclamation 2007, Authority 2006).

Mexico

Future inflow projections from Mexico have ranged from 29,000 AFY to 97,044 AFY (DWR and DFG 2007; Authority 2006; Reclamation 2007). Between 1980 and 2006, flows have remained within approximately 109,000 AFY to 190,000 AFY. In 2007, flows from Mexico decreased by about 22,000 AFY due to wastewater treatment plant diversions and power plant consumption. Since 2007, flows from Mexico have diminished further, ranging from about 69,900 AFY to 90,000 AFY. Lower flows from Mexico are also due to lining of water supply canals, resulting in less seepage as a water supply and therefore fallowed fields and the elimination of agricultural runoff from those fields (Reclamation 2007). Also, drought conditions and groundwater overdraft are causing water supply issues in the region. The New River Strategic Plan anticipates a decrease in New River flows, mostly dry weather flows originating from Mexico, by 30% in the future, citing a U.S. IBWC report that describes alternative plans for Mexico to recycle and reuse New River flows (New River TAC 2011). Relative to flow from Mexico in 2011, this would be about 57,000 AFY and may occur as soon as 2020. Due to significant uncertainty with funding and other logistics of water reuse projects, the low estimate due to variability conditions is 40,390 AFY and the CEQA conditions flow estimate is 96,834 AFY (Table 8). This range encompasses the Authority's Preferred Plan projected inflow from Mexico of 60,000 AFY (Authority 2006).

Summary

Water transfers out of Imperial Valley are expected to ramp up over the next 11-33 years and mitigation water created by IID fallowing and efficiency improvements will increase until 2017 and then cease, as shown in Table 9. The Coachella Valley Water Management Plan of 2002 anticipated increased flows to the Sea as a result of conservation measures, acquisition of other water supplies, and groundwater recharge (CVWD 2002). The 2010 update to the plan curtailed estimated inflows significantly to account for planned drain water reuse and desalination (CVWD 2012). Due to those factors, uncertainty with economic conditions, competing water demands and water market conditions, the mean of all future inflows was calculated by Reclamation to be 727,000 AF per year (AFY; Table 7; Reclamation 2007). A Monte-Carlo analysis predicted that the variability of inflows could be up to 200,000 AF in any year (DFG and DWR 2006). The Authority' preferred plan report (2006) includes an analysis of future inflows to the Sea as well. Assuming the full utilization of Colorado River Entitlements over the 75-year QSA term with return flow percentages similar to current agricultural and urban water use, the Salton Sea inflows were calculated at 927,474 AFY (Authority 2006; Table 5). Under a scenario allowing for uncertainty, the mean inflows to the Sea were 715,000 AFY. While the models have predicted the actual flows with a fair amount of accuracy and under significant uncertainty up until this point, it is important to consider whether the modeling assumptions are still valid, considering incentivized water efficient irrigation techniques, increasing urban water demand, long-term drought conditions, climate change, and other factors.

Under the most recent projected inflows to the Sea by IID, two conditions were examined utilizing a similar methodology to previous reports: CEQA conditions and variability conditions. CEQA conditions yielded higher estimated annual inflows that were based solely on known inflows, and the effects of the QSA transfer agreements. Under variability conditions, anticipated conditions and projects will result in a somewhat lower inflow estimate; the result of many factors as discussed in this document. Since the future contains uncertainty regarding water supply and availability, these two conditions provide a range of possibilities for future inflows. The range of estimated flows for 2018-2077 is useful for engineering design considerations. Imperial Valley will contribute 558,000 – 667,000 AFY, or 76-78% of the total inflow. Coachella Valley flows to the Sea will be an estimated 61,000 – 98,000 AFY or 9 - 11% of total inflow (Table 8). This estimate is much lower than previous estimates because CVWD intends to recycle more water, desalinate and use more water for recharging aquifers, and comply with new water conservation mandates due to the drought. Flows from Mexico will average 40,390 - 96,834 AFY, contributing about 6 - 11% of total inflow to the Sea (Table 8). This is based on a 30% reduction in flows relative to 2010 as Mexico intends to reuse its dry weather flows and agricultural water use efficiency increases. Groundwater flows to the Sea have not been adequately characterized and contribute a relatively minor quantity of flow. Due to the serious and potentially long-term drought, flows from the watershed (minor channels and washes) will be increasingly allocated and decreasing in reliability. Therefore the estimated “Other” flow contribution is likely 20,000 AFY or 2-3% of the total inflow.

All estimates of future flows contain a certain amount of uncertainty but will provide design criteria to enable alternative planning and evaluation. It is still a reasonable assumption that inflows to the Sea can vary by up to 200,000 AFY. Table 10 shows that evaporation will be much larger than total inflows by 2020, and that the inflows will also need to be used for air quality management and habitat creation. Habitat flows will be returned to the Sea after evaporation and transpiration losses occur. By 2020, about 57% of SCH and Air Quality Management (AQM) water or 18,600 AF will go toward AQM and be lost. Sea water will also be used for habitat and AQM but this is not included in Table 10. The water budget will continue to be unbalanced and will shrink the Sea volume until inflows are equivalent to or larger than evaporation and other losses. Detailed modelling of these changes are in Section 5.0, Salinity and Elevation Forecasts.

Table 10
Current and projected water balance for the Salton Sea, AFY.

	Total Inflow to Sea	Evaporation Loss	SCH and AQM Fresh Water Use
2014	1,089,700	1,243,000	-
% of Total	100%	114%	-
2020	878,069	1,175,000	32,400
% of Total	100%	134%	4%

Notes
Values are in acre-feet; projected inflow assumes baseline flow (IID 2014)
SCH is Species Conservation Habitat; AQM is Air Quality Management.
Evaporation is estimated at 5.5 feet/year.

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5.0 Salinity and Elevation Forecasts

Using our best estimates of inflows in the coming years, and detailed knowledge of the bathymetry of the Sea, a salt and water balance model is used to compute the changes in Salton Sea volume, area, and salinity over the 21st century.

5.1 Modeling

SSAM, a one-dimensional salt and water balance accounting model was used to project future Salton Sea elevation, volume and salinity based on the current inflow projections and assuming that the Species Conservation Habitat (SCH) project will come on line over 2015-2020. Additional details of the SCH and other alternatives for restoration are presented in the Benchmark 3 report. Updated bathymetry data for the Salton Sea was used in this analysis to obtain a more accurate area-volume-depth relationship that is essential for siting future habitat and potential barriers and dikes. Reclamation's SSAM, developed in 2000, was used for this evaluation with several modifications to represent current inflows and bathymetry. This model was chosen over similar hydrologic models governed by the same principles of operation due to the flexibility to model different sea configurations. Flow requirements for new habitat development and for air emission mitigation in the exposed playa were also added to the modeling framework.

5.2 Bathymetry data

We used the new bathymetry data provided by IID (the data are a compilation of multiple sources, and referred to as IID, 2014 here) to calculate an updated Elevation, Area, Capacity (EAC) curve. The updated EAC curve, interpolated to tenths of a foot NGVD 29, was used to replace the previous lookup tables inside SSAM.

Figure 75 compares the EAC curve of Reclamation (2000) with the one calculated from the new IID bathymetry data (IID, 2014). The relationship between surface and volume is very similar in both curves, but the new bathymetry data predict higher sea areas for surface elevations above -230 feet. Because exposed area is calculated from the larger initial Salton Sea area, water requirements for air quality management may be larger.

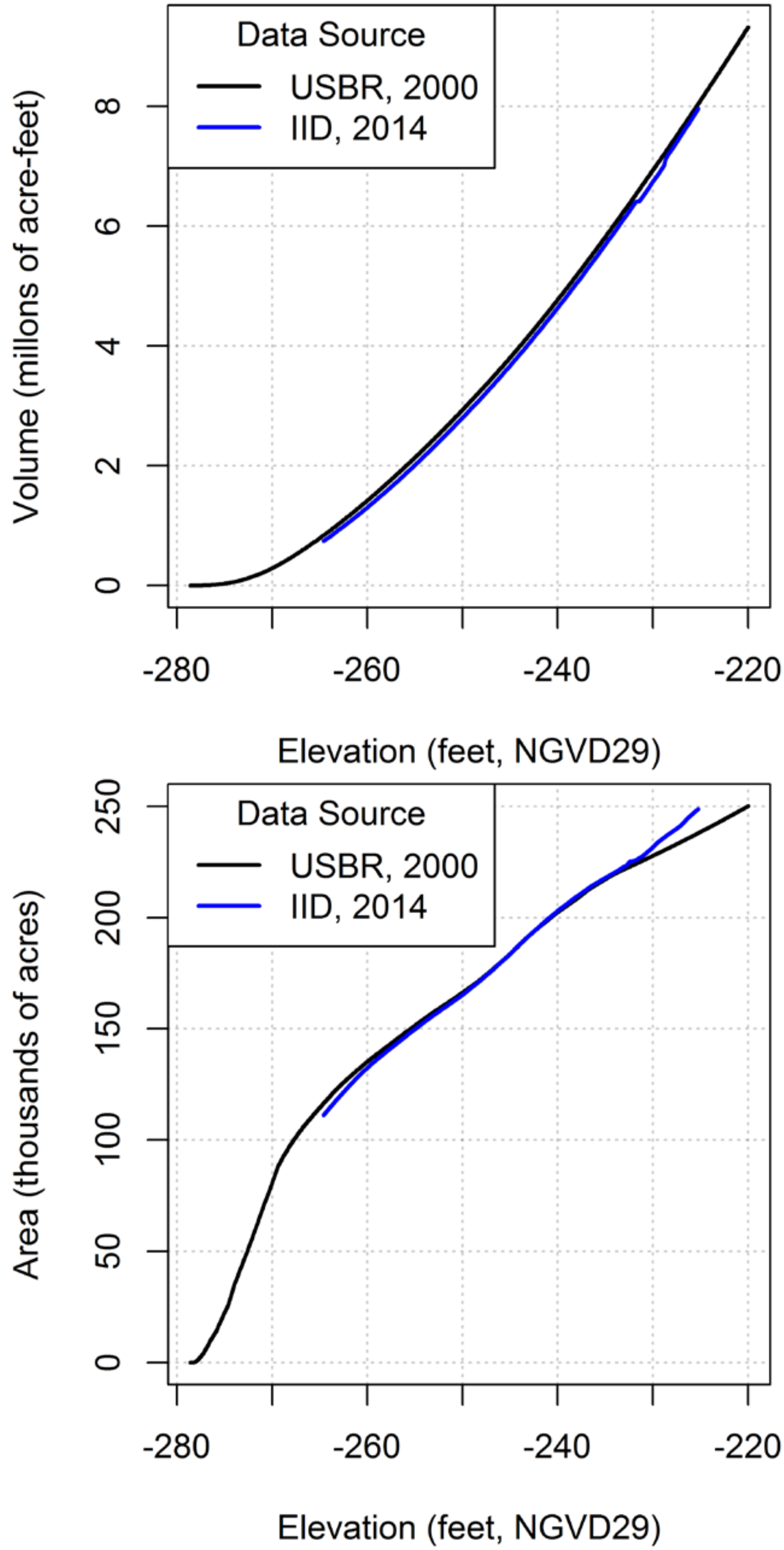


Figure 75 Comparison of volume and area as a function of elevation, original Reclamation (USBR) data and recent IID data.

5.3 Water uses for mitigation scenarios

The SSAM was modified to account for consumptive use of water for species conservation habitat (SCH) and AQM. Water use is modelled similarly for both components as an evaporative loss proportional to area. Currently, AQM requirements are 1 foot of water per acre of exposed area, modelled as the difference in modelled Sea area between the first and current time step. Habitat area follows a user specification—we used 700 acres starting in 2017, increasing to 3,800 acres in 2020—and requires 6 feet of water per acre. Mitigation water for each purpose can be modelled with or without a target salinity, which is met by mixing relatively fresh inflow water with sea water. If a target salinity is not used, the entire required volume is take from the Sea. With a target salinity, the amount of water used is governed by two equations:

$$e_w = Q_{sea} + Q_{fresh} \text{ (water balance)}$$

$$e_w \cdot S_{target} = Q_{sea} \cdot S_{sea} + S_{fresh} \cdot Q_{fresh} \text{ (salt balance)}$$

where e_w is the evaporative water requirement, S are the relevant salt concentrations and Q are the relevant water amounts. The fresh water requirement is then:

$$Q_{fresh} = e_w \cdot \frac{S_{sea} - S_{target}}{S_{sea} - S_{fresh}}$$

The target salinities of both components are set to 20,000 ppm. The salt ending up in the habitat area is placed into the Sea at the beginning of the following time step. Salt from the air quality area is not recirculated.

5.4 Model Validation

As a first step the modified SSAM was validated against recent daily elevation data. The model was operated using actual inflows and actual precipitation and a starting point of the elevation in the year 2000 was used. As shown in Figure 76, the model, which runs on an annual time step, provides a good representation of the near-term changes in elevation. The same model parameters and an initial TDS of 42,000 mg/l in 2000 was used to compute the evolution of salinity (Figure 77). For both of these metrics, the model performed well at representing near term changes. This validation step is important in building model confidence for changes projected with significant changes of inflows over the coming decades.

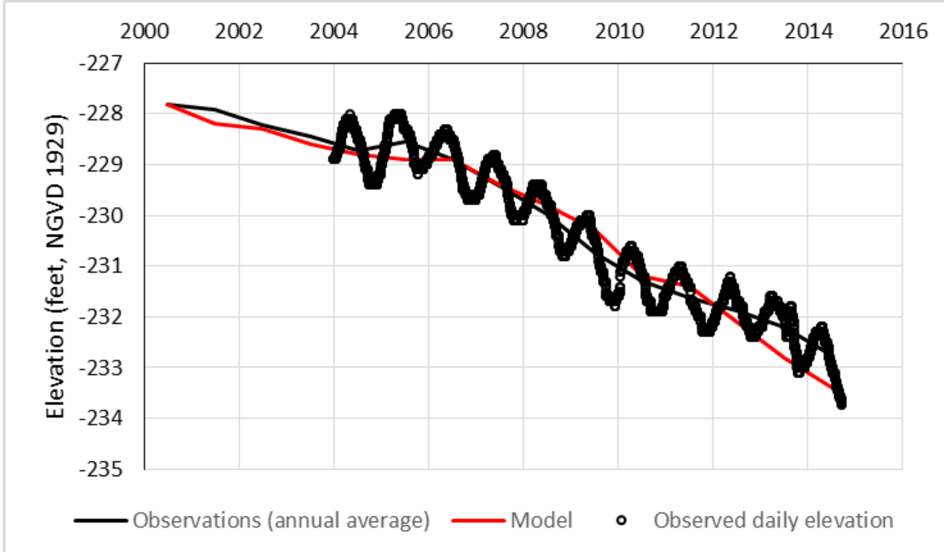


Figure 76 **Modeled and observed elevation in the Salton Sea, using annual precipitation data and baseline evaporation of 66.0 inches (before salinity adjustment). Open circles show daily elevation data; solid lines are annual averages for each calendar year.**

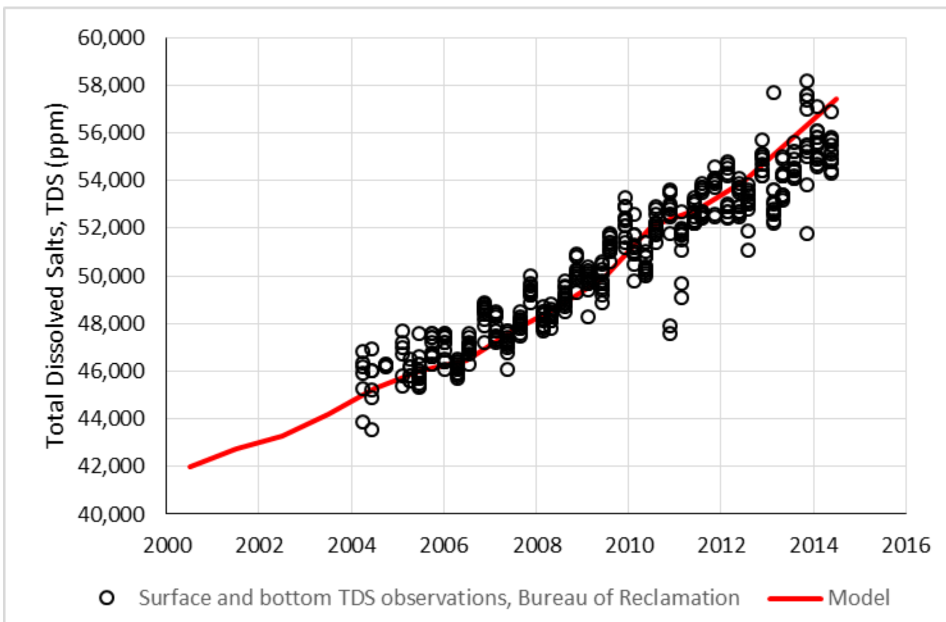


Figure 77 **Starting with an initial TDS level of 42,000 ppm in 2000, the modeled evolution of salinity using the same model parameters as used in Figure 76.**

5.5 Model Application

Using the inflow projections for the next decade, which incorporate the effects of IID mitigation flows as well as longer term flow projections (Figure 78), the model was used to compute changes in salinity and elevation. The modeling framework accounted for the presence of SCH (700 acres constructed by 2017 and 3,800 acres constructed by 2020) and the water needs for dust mitigation. At this time the model did not include any other restoration alternatives.

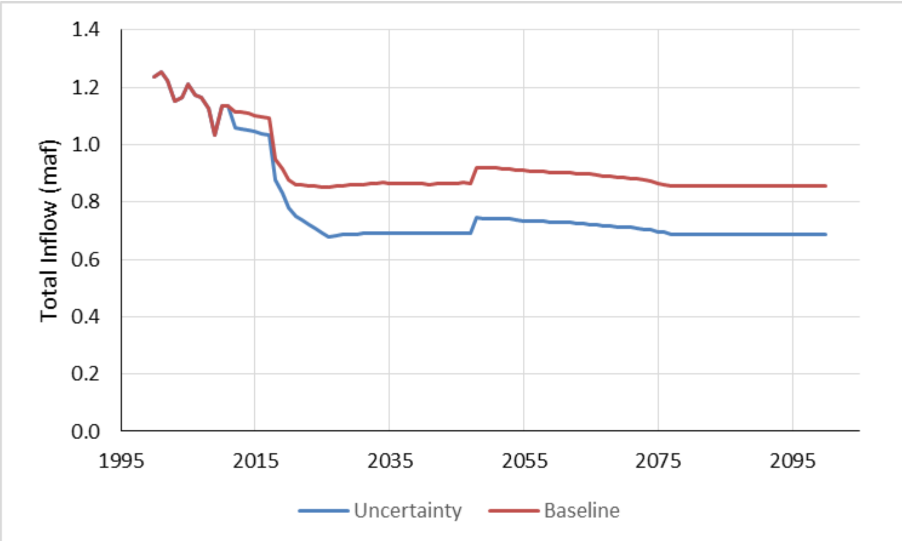


Figure 78 Inflows used in SSAM implementation: baseline flow scenario (red) and uncertainty flow scenario (blue)

Elevation, area, and salinity changes are shown in Figure 79 through Figure 81. The model shows a continued drop in elevation, with a major change in 2018 following the end of mitigation flows to the sea, and accompanying decreases in area and increases in salinity in accordance with inflow projections. The volume of water used for SCH and AQM is also shown on an annual and cumulative basis in Figure 82 and Figure 83 under the bassline flow scenario and in Figure 84 and Figure 85 under the uncertainty flow scenario. After 2020, the water requirements for AQM begin to exceed that for SCH.

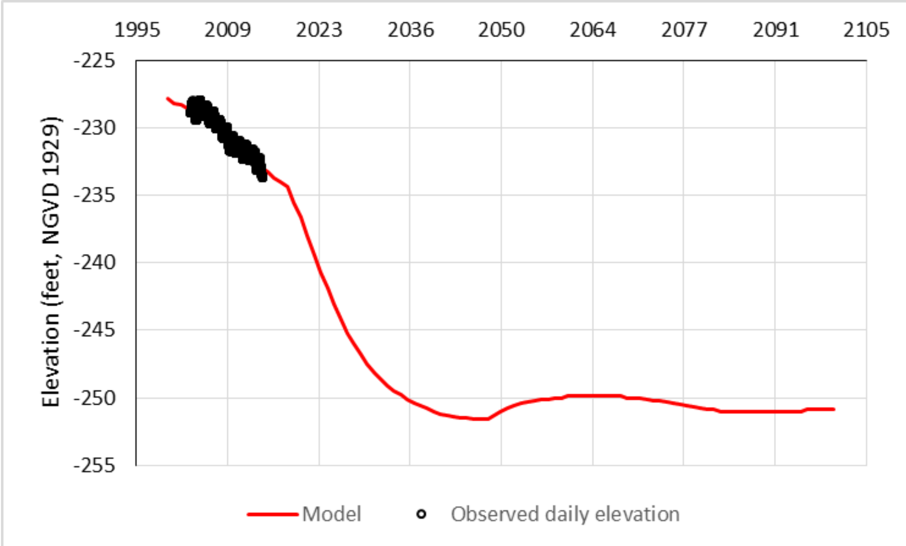


Figure 79 **Elevation change over time predicted by the SSAM utilizing implementation: baseline flow scenario.**

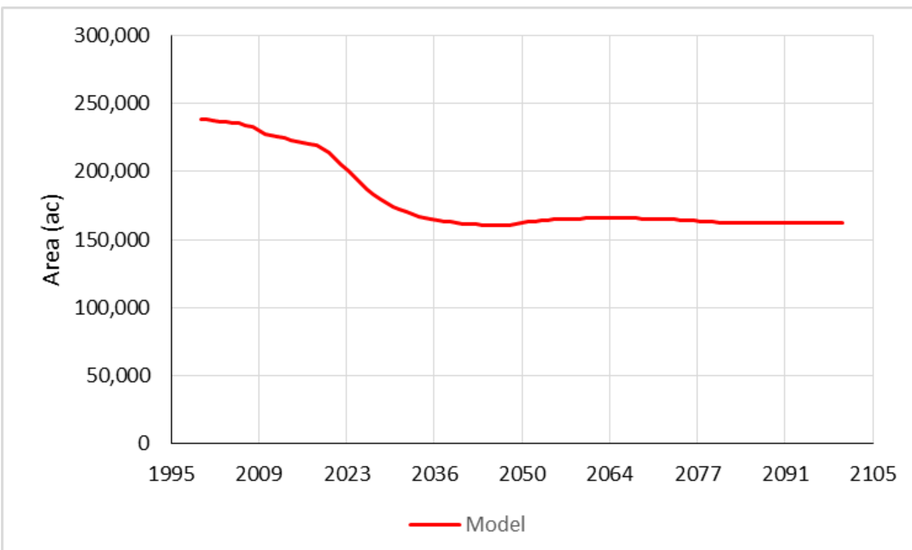


Figure 80 **Salton Sea water surface area change over time predicted by the SSAM utilizing implementation: baseline flow scenario.**

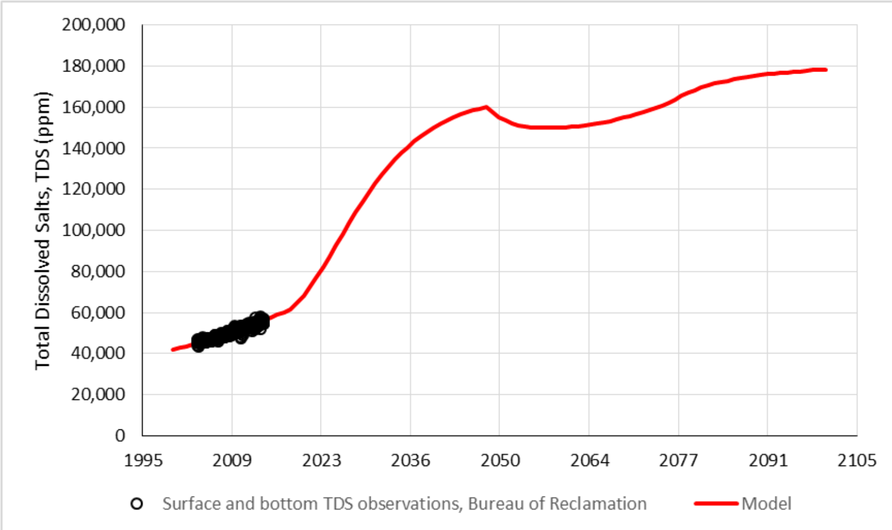


Figure 81 **Salinity change over time predicted by the SSAM utilizing implementation: baseline flow scenario.**

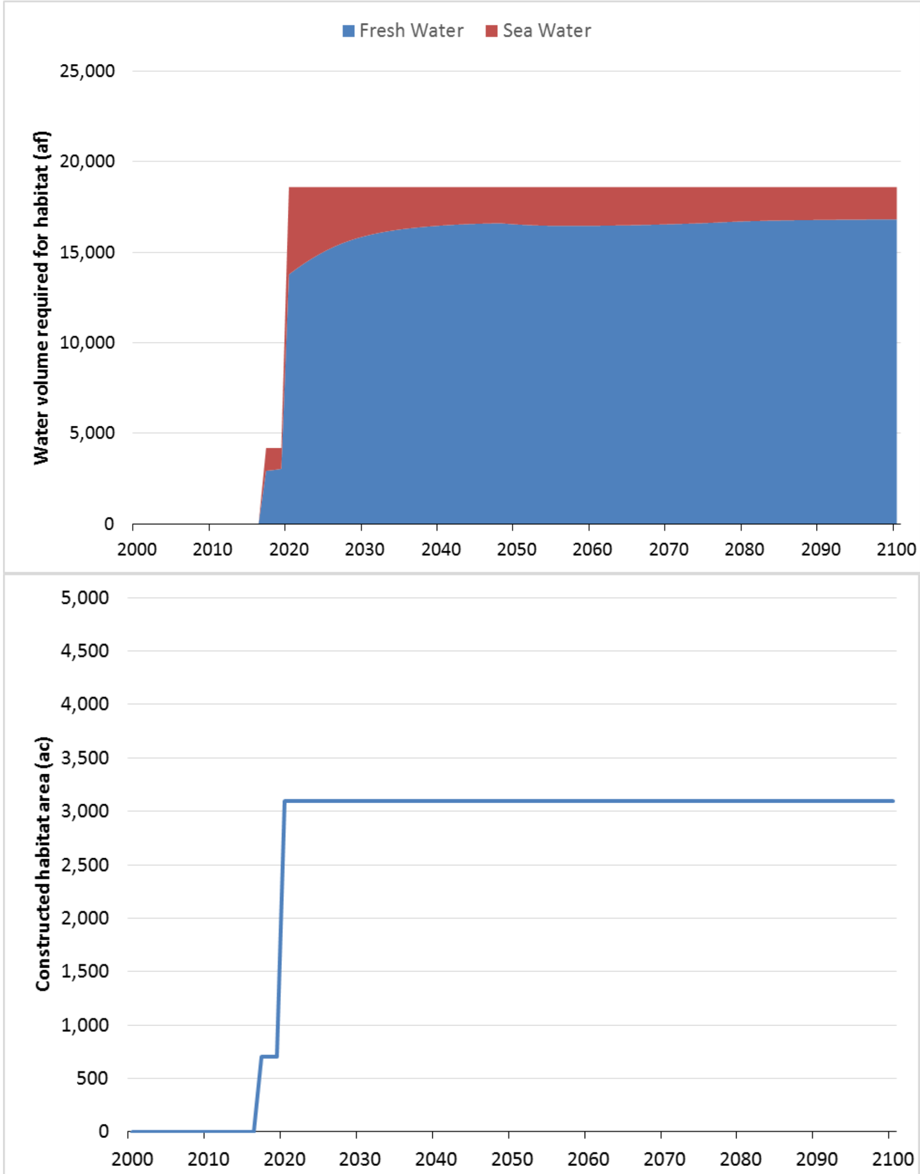


Figure 82 **Water volume applied for SCH (top graph) and corresponding area (bottom graph; baseline flow scenario).**

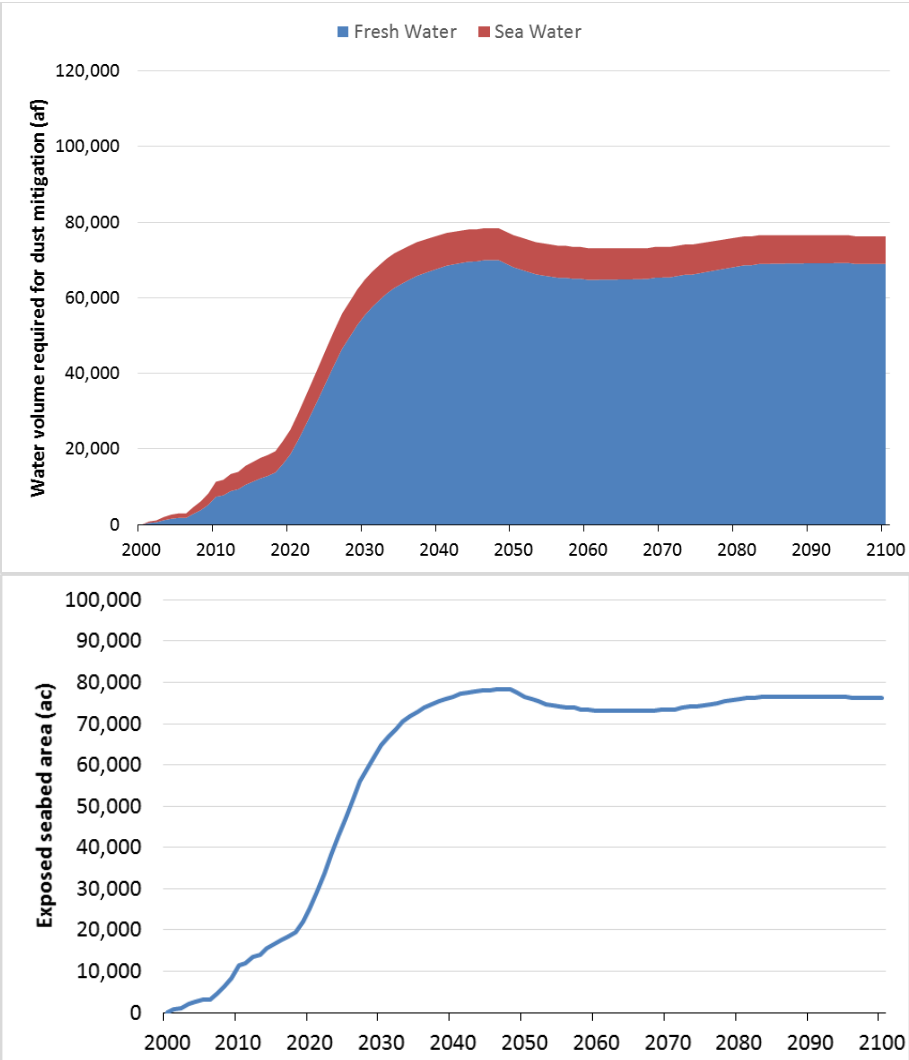


Figure 83 **Water volume applied for AQM and corresponding area (baseline flow scenario).**

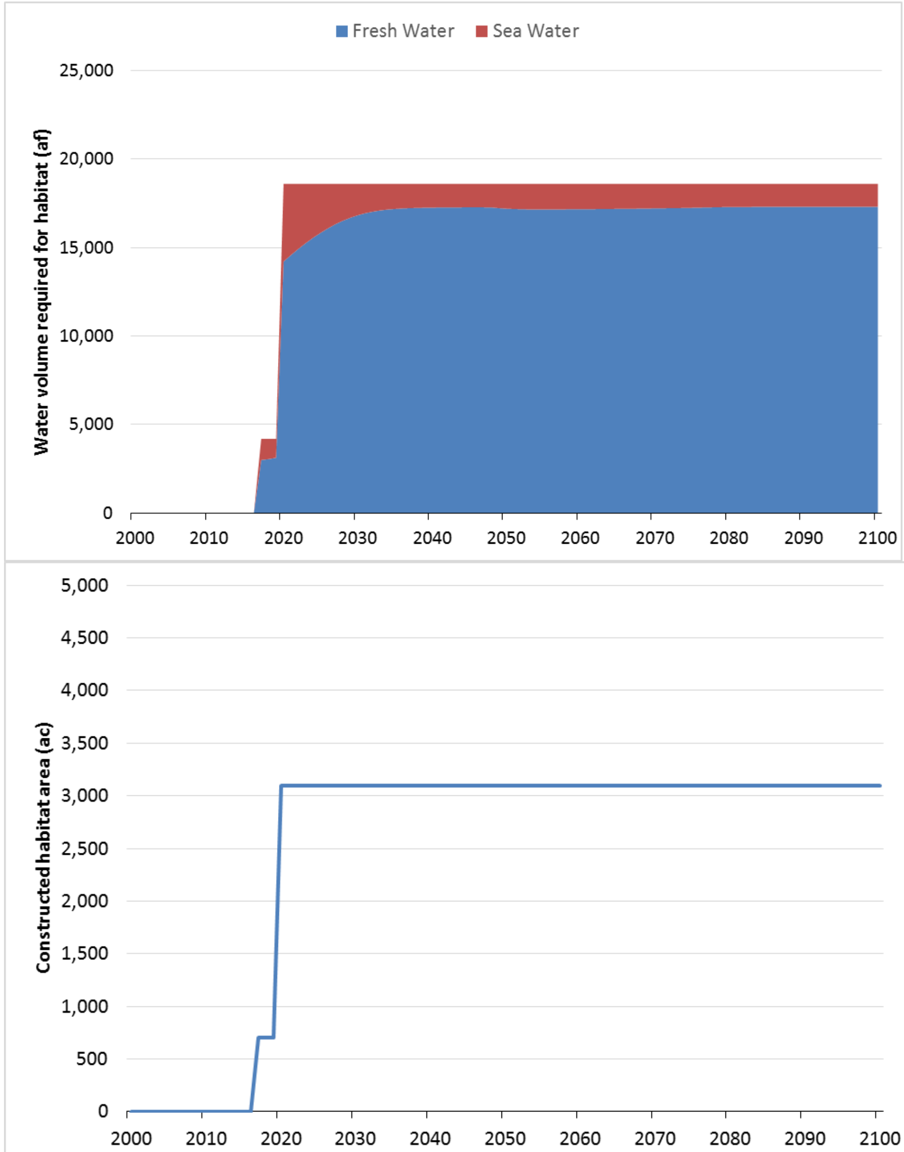
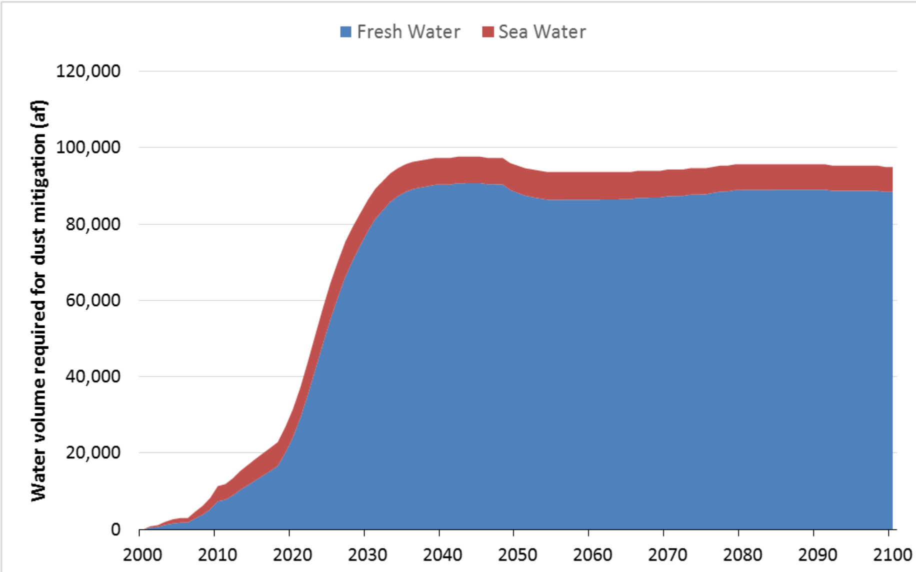


Figure 84 Water volume applied for SCH and corresponding area (uncertainty flow scenario).



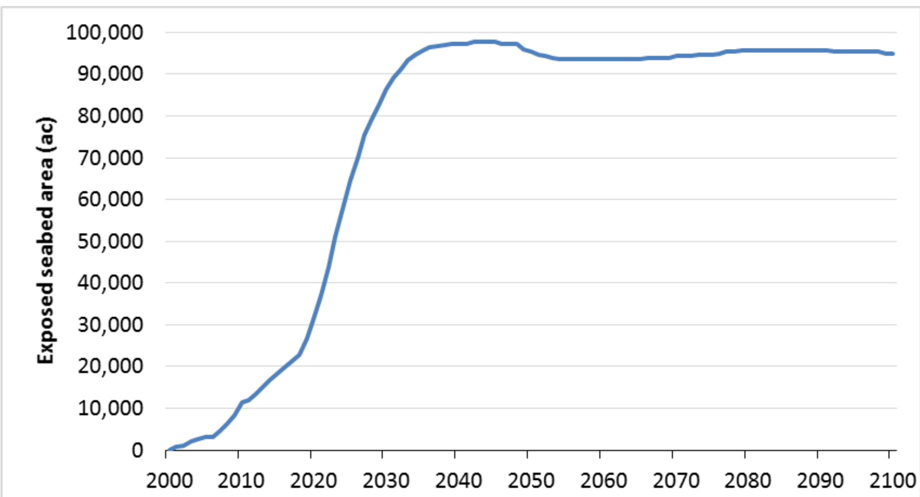


Figure 85 Water volume applied for AQM and corresponding area (uncertainty flow scenario).

This information is also presented graphically, as the shoreline along the northern and southern portion of the Sea in Figure 86 and Figure 87.

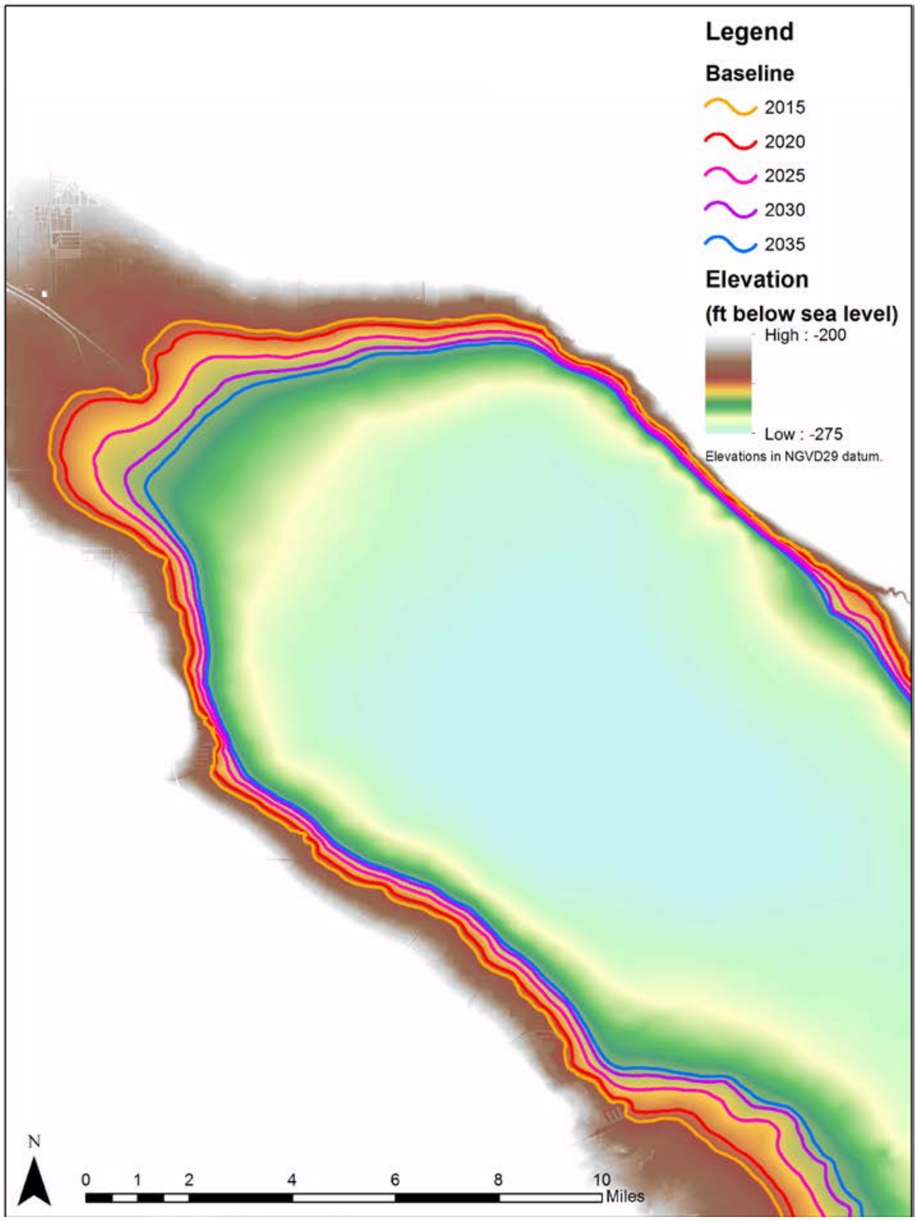


Figure 86 Projected changes in shoreline between 2015 and 2035 in the northern portion of the Salton Sea (baseline inflow scenario). Projected using SSAM and assuming that the SCH project is constructed between 2017 and 2020.

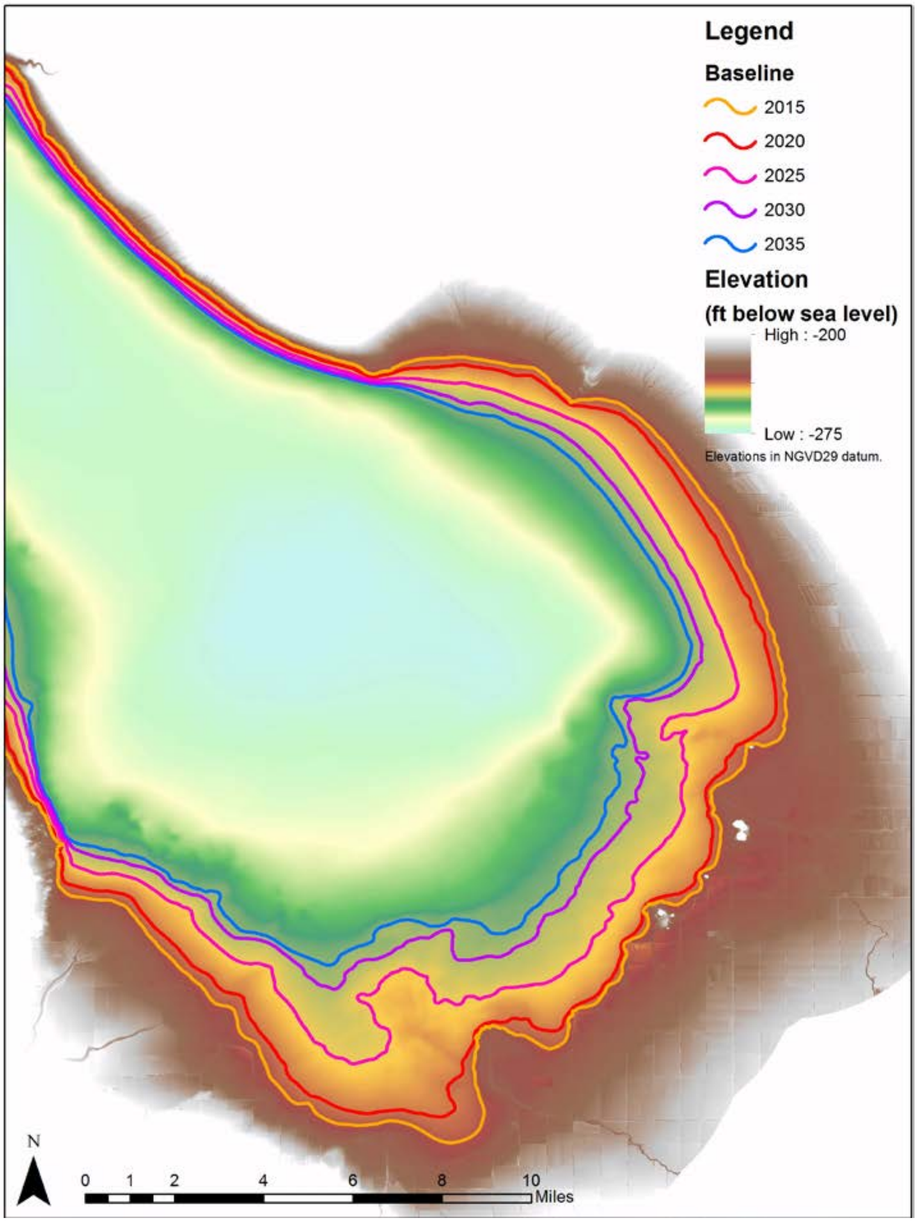


Figure 87 Projected changes in shoreline between 2015 and 2035 in the southern portion of the Salton Sea (baseline inflow scenario). Projected using SSAM and assuming that the SCH project is constructed between 2017 and 2020.

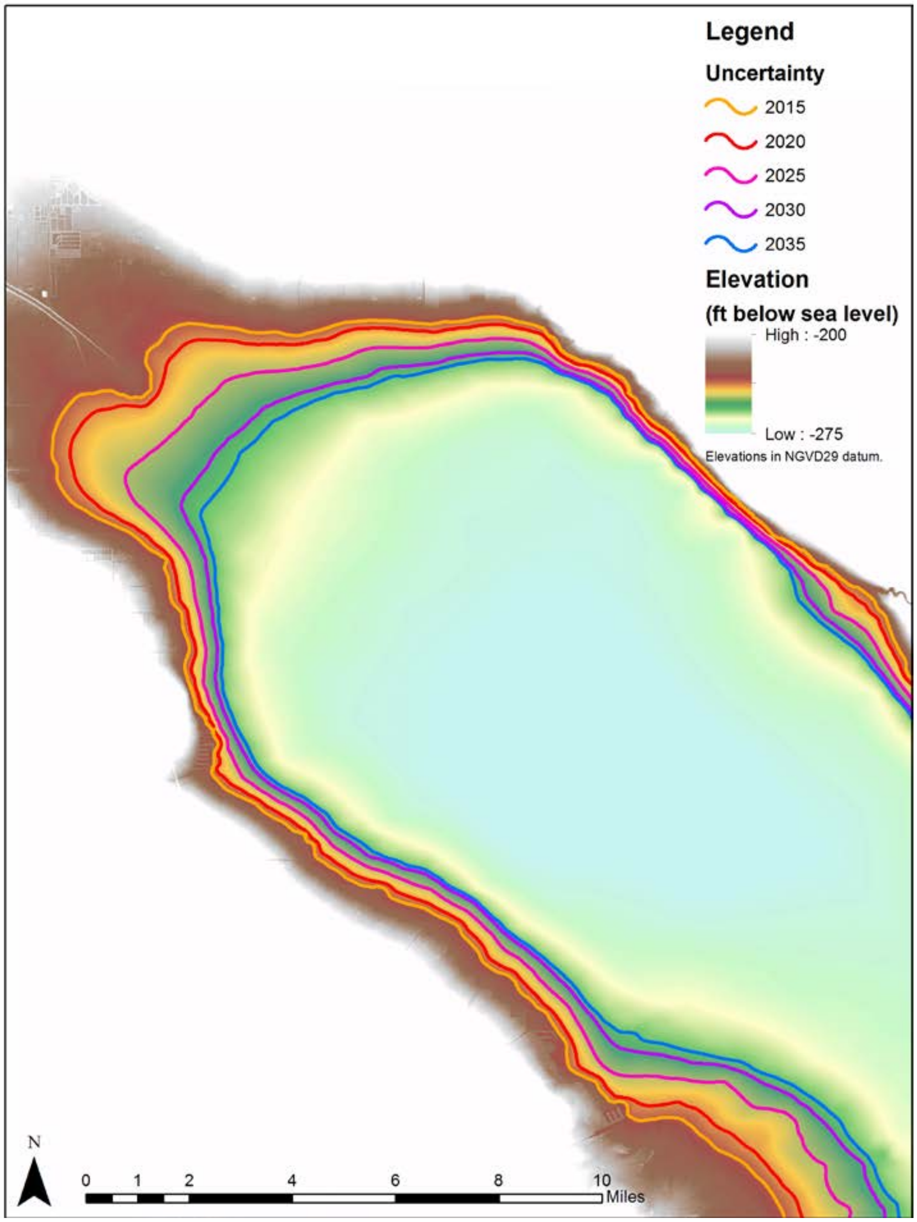


Figure 88 **Projected changes in shoreline between 2015 and 2035 in the northern portion of the Salton Sea (uncertainty inflow scenario). Projected using SSAM and assuming that the SCH project is constructed between 2017 and 2020.**

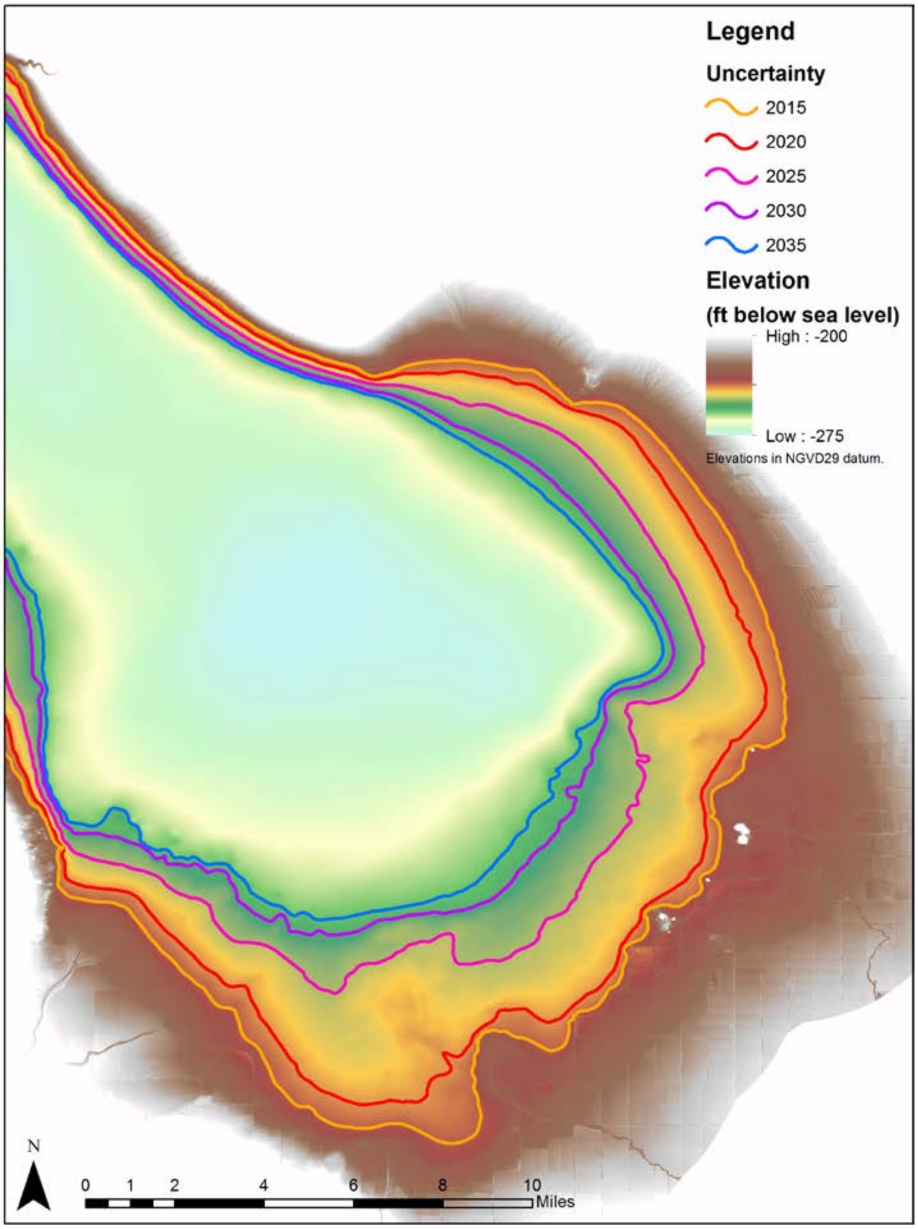


Figure 89 Projected changes in shoreline between 2015 and 2035 in the southern portion of the Salton Sea (uncertainty inflow scenario). Projected using SSAM and assuming that the SCH project is constructed between 2017 and 2020.

5.6 Summary

SSAM, a one-dimensional salt and water balance accounting model, was used to project future Salton Sea elevation, volume and salinity based on the current inflow projections and assuming that the Species Conservation Habitat (SCH) project would come on line over the 2015-2020 period. Updated bathymetry data for the Salton Sea was used in this analysis to obtain a more accurate area-volume-depth relationship. The new data is important information for siting future habitat and potential barriers and dikes. The updated bathymetry data predict larger sea areas for surface elevations above -230 feet than the older data, potentially requiring more water than previously thought for air quality management purposes.

Reclamation's SSAM was used for this evaluation with several modifications to represent current inflows, bathymetry, and consumptive use of water for SCH and AQM. Water use is modelled as an evaporative loss proportional to area. For both of these metrics, the model performed well at representing near-term changes.

Flow requirements for new habitat development and for air emission mitigation in the exposed playa were added to the existing modeling framework.

Results of the model show that elevation will continue to decline, with a major decrease in 2018 following the end of mitigation flows to the Sea, and a corresponding decrease in area and increase in salinity. Without intervention, the elevation will not stabilize until the 2040s, 18 feet lower. Salinity is predicted to increase rapidly, reaching 120 g/L TDS by 2030 and 160 g/L by 2049. The shrinking sea will expose 64,800 acres by 2030 and 80,000 acres by 2049. After 2020 the water requirements for AQM begin to exceed that for SCH.

6.0 Air Quality and Dust Mitigation Review

An inventory and evaluation of on-going dust mitigation planning efforts is provided in this chapter. Information from specific plans regarding spatial variations in sediment characteristics and soil erodibility or temporal variations in factors contributing to the formation and erodibility of salt crusts will be reviewed and updated as part of the mitigation process. An analysis of how restoration efforts may affect dust mitigation emissions under forecasted scenarios is included.

6.1 Dust Mitigation Review

6.1.1 Regulatory Setting

The Salton Sea's location encompasses the Salton Sea Air Basin (Basin), under the jurisdiction of two districts: Imperial County air Pollution Control District (ICAPCD), southern Basin, and South Coast Air Quality Management District (SCAQMD), northern Basin. The Basin is subject to regulations under the Federal Clean Air Act and Clean Air Act Amendments (CAAA). In 1970 the United States Environmental Protection Agency (EPA) established National Ambient Air Quality Standards (NAAQS) for six "criteria" pollutants, listed in Table 11. Primary standards are established to protect human health, whereas secondary standards are established to protect degradation of the environment. The US EPA classifies regions as "attainment" or "non-attainment" depending on whether ambient air quality data collected from permanent monitoring stations meet requirements stated in the primary standards. The CAAA of 1990 requires states with nonattainment areas to achieve NAAQS by developing an EPA-approved State Implementation Plan (SIP) and calls for specific emission reduction goals.

Table 11
Ambient Air Quality Standards

Pollutant	Averaging Time	California Standards		National Standards	
		ppmv	µg/m³	ppmv	µg/m³
Ozone (O3)	1-hour	0.09	177		
	8-hour	0.07	137	0.075	147
Nitrogen Dioxide (NO2)	1-hour	0.18	339	0.1	188
	Annual	0.03	57	0.053	100
Sulfur Dioxide (SO2)	1-hour	0.25	655	0.075	196
	3-hour (secondary)			0.5	1,300
	24-hour	0.04	105		
	Annual			0.03	79
Carbon Monoxide (CO)	1-hour	20	22,898	35	40,071
	8-hour	9	10,304	9	10,304
	Lake Tahoe (8-hr)	6	6,869		
Particulates (as PM_{10})	24-hour		50		150
	Annual		20		
Particulates (as $PM_{2.5}$)	24-hour				35
	Annual		12		12
Lead (Pb)	30-day		1.5		
	3-month (rolling)*				0.15
Sulfates (as SO4)	24-hour		25		
Hydrogen Sulfide (H2S)	1-hour	0.03	42		
Vinyl Chloride (C2H3Cl)	24-hour	0.01	26		
Visibility Reducing Particulates	8-hour	Extinction coefficient of 0.23 per kilometer; visibility of 10 miles or more (0.07 to 30 miles or more for Lake Tahoe) due to particles when relative humidity is less than 70 percent)			

Sources: adapted from SCH Final EIR/EIS; CARB 2010; USEPA 2010

Notes
ppmv= part(s) per million by volume
µg/m³=microgram(s) per cubic meter

*The 1.5 µg/m³ Federal quarterly lead standard applied until 2008; 0.15 µg/m³ rolling 3-month average thereafter

For gases, µg/m³ calculated from ppmv based on molecular weight and standard conditions (Temperature 25°C, molar volume 24.465 liter/g-mole)

The General Conformity Rule (Section 176(c)(1) of the CAAA (42 USC section 7506(c))) prohibits the Federal government from "engag[ing] in, support[ing] in any way, or provid[ing] financial assistance for, licens[ing] or permit[ing] or approv[ing] any activity" that does not conform to an EPA-approved SIP. Thus any Federal agency involved in the restoration activities must not undermine SIP efforts in the area. A conformity review may be required if the Federal action will take place in a Federal non-attainment or maintenance area, and if the action would result in significant emissions of an air pollutant that is regulated due to the non-attainment or maintenance status of the region. If the emissions are expected to be significant, then it must be determined if the threshold levels would be exceeded. A conformity review is required if the threshold levels would be met or exceeded (40CFR section 93.153(b)).

States have the right to establish and enforce their own air quality standards, provided they are equal to or more stringent than the Federal standards. The California Clean Air Act (CCAA) of 1988 (California Health and Safety Code 25 section 39600 et seq.) called for similar designations of areas as attainment or non-attainment based on California standards and requires air quality plans with a range of control measures to reach attainment for ozone, carbon monoxide, nitrogen oxides (NO_x), and sulfur dioxide (SO_2) (Table 11). The California Air Resources Board (CARB) is the agency tasked with regulating air quality by setting standards for emissions and regulations for mobile emission sources (i.e. autos, trucks).

The pollutants of greatest concern in the Basin are: PM_{10}, particulate matter less than 2.5 microns ($PM_{2.5}$) from wind erosion (fugitive dust), soil disturbance and fuel combustion, ozone and ozone precursors, NO_x, and volatile organic carbons (VOCs), primarily from vehicle and equipment exhaust. Agriculture and transported pollutants from Mexico contribute to the air quality problems in the area (USGS 2013).

As the Salton Sea recedes due to declining inflows, windblown dust emissions from the exposed dry lakebed (the playa) will increase in some areas. This will lead to a potential human health risk, since a significant portion of this windblown dust is PM_{10}; particulate matter with an aerodynamic diameter of 10 micrometers or less that are small enough to be inhaled. Imperial County is designated as a serious non-attainment area for PM_{10} (i.e., the area does not attain federal or state air quality standards) and non-attainment for $PM_{2.5}$ NAAQS. Imperial Valley is designated as a state non-attainment area for ozone and PM_{10}. As such, the potential for creating sources of PM_{10} is a public health concern (IID 2013). Part of the 2009 PM_{10} SIP revision contains requirements for an air quality assessment, an emission inventory, Best

Available Control Measures (BACM) and Best Available Control Technologies (BACT), and transportation conformity budgets (CARB 2010).

As a consequence of the QSA water transfers, CEQA guidelines sections 15091[d] and 15097 require that an agency adopt a program for reporting or monitoring mitigation measures that were adopted or made conditions of approval for a project. Such a program ensures that the mitigation measures identified in an EIR are implemented, and the mitigation, monitoring and reporting plan (MMRP) was created by IID in 2003. According to the SWRCB Order and IID's Water Conservation and Transfer Project MMRP (IID, 2003; SWRCB, 2002), potential air quality impacts from exposed Salton Sea playa must be monitored and mitigated by implementing the following four steps:

1. Restrict public access. Minimize disturbance of natural crusts and soil surfaces in exposed shoreline areas;
2. Research and monitoring. Conduct research to find effective and efficient dust control measures for the Exposed Playa, develop information to define the potential problem over time, and monitor the surrounding air quality;
3. Emission reduction credits. If monitoring results indicate exposed areas are emissive, create or purchase offsetting emissions reductions as part of a negotiated long-term program; and
4. Dust control measures. To the extent that offsets are not available, implement dust control measures (with feasible dust control measures and/or supplying water to re-wet emissive areas) on the emissive parts of the exposed playa.

The term "emissive" indicates that the land surface has a tendency to release enough dust to constitute or contribute to an air quality violation. "Non-emissive" is used to describe surfaces that do not emit sufficient dust to cause or contribute to air quality violations. All restoration alternatives must contain Air Quality Management actions related to this four-step process.

Access to exposed playa will be controlled in coordination with landowners and stakeholders to avoid disturbance and resulting emissions. In concert with the MMRP, a research program focusing on the development of cost effective, water efficient, and adaptive Air Quality Management has been initiated and will continue. In the long run, results of this effort will guide the Air Quality Management approaches implemented at the Salton Sea (IID 2013).

The SWRCB Order approving the water transfer (Order WRO-2002-0013) requires IID to evaluate dust control measures to determine feasibility in consultation with the Imperial County Air Pollution Control District, the South Coast Air Pollution Control District and the California Air Resources Board (IID 2013).

6.1.2 Air Quality Studies

Ongoing efforts to characterize the air quality at the Salton Sea are briefly discussed in this sub section. Significant data disparities exist regarding the extent and variability of Salton Sea playa emissivity (dust-emitting), future emissivity, and dust loading of PM_{10} in the region (Cohen 2014). Exposed playa is expected to increase exponentially over the next 15 years, creating a significant health risk that has yet to be fully characterized.

IID Dust Mitigation Plan

IID's JPA Dust Mitigation Plan includes an adaptive management framework to monitor ambient air quality, research and monitoring efforts to identify and map playa surface characteristics related to erosion and emission potential. Pollutants of concern include PM_{10}, $PM_{2.5}$, ozone, hydrogen sulfide, arsenic, Se and others.

The IID Air Quality Mitigation Program contains four components that contribute toward the implementation of a science-based adaptive management plan to detect, locate, assess and mitigate PM_{10} emissions associated with the Water Transfer Project. Each component of the Air Quality Program will attempt to answer a set of questions or achieve a goal. The **Air Quality and Playa Characterization** component seeks to differentiate the emissions sources, whether they are a direct consequence of the Water Transfer Project or not by analyzing data from an extensive ambient air quality monitoring network. In order to capture intermittent dust events, PM_{10} and $PM_{2.5}$ will be measured with continuous monitors (i.e. Tapered Element Oscillating Microbalance Monitor (TEOM) or a Beta Attenuation Monitor (BAM)) and verified with filter-based federal reference method monitors (i.e. BGI or Partisol). The filters could initially be analyzed for contaminants (i.e. arsenic, Se, pesticides) at regular intervals to characterize the problem of contaminated dust particle transport (IID 2013). Permanent and portable air quality stations will be used as necessary to document the spatial heterogeneity of dust emissions.

In the future, ambient air quality data will be used to assess the occurrence and magnitude of emissions from newly exposed playa and existing emission sources. This information will aid the development of a dust identification methodology to identify playa emission source areas, estimate emission characteristics and determine downwind impacts. Drawing from existing dust identification programs such as Owens Lake and forming new methodologies as necessary, the program will integrate information from research and monitoring efforts (IID 2013).

Hydrologic modeling will use the hydrologic analysis from the Water Transfer EIR/EIS and high-resolution bathymetry data to yield the estimated extent and time frame for additional playa exposure. The result will be planning level information about the location of projected playa exposure and ownership information. Research and monitoring will aid the understanding of salt crust formation, vulnerability to erosion and overall emission potential of various salt crust surfaces. The potential sources of PM_{10} emissions include playa salt crusts, sand sheets, beach deposits and soil surfaces. The main focus of research will be assessing the vulnerability of each potential emission source to erosion. This component also aims to identify specific areas of exposed playa that are emissive and source areas associated with erosion events. Properties to be mapped include crust type, crust thickness, soil moisture, crust relief, crust hardness, penetration resistance, surface erosion, free surface sand, percent vegetation, overflow and other features. Meteorological conditions, such as wind, precipitation, temperature and relative humidity, will be monitored and analyzed to determine environmental and climatic events that affect emission potential seasonally (IID 2013).

The **Dust Control Measure (DCM) Research and Monitoring** component will test and evaluate DCMs for feasibility and cost-effectiveness. Existing DCMs will be derived from a literature review, modeling studies and screening-level tests. Novel and untested measures will be incorporated into the DCM research via pilot field testing. The performance of DCMs will be monitored at the pilot project scale for overall performance and sensitive parameters such as habitat quality. DCM selection will be guided by the following principles:

1. Effective dust control is achieved by a combination of:
    a. Physical stabilization of the playa surface
    b. Reduction in wind velocity at the playa surface
    c. Enhanced net-sand capture rates
2. DCMs should enable constant dust control
3. Dust control should be based on achieving target level of emission control on a preventative, macro scale (not reactive, micro scale)
4. Water-based DCMs are effective, but are generally inefficient from a cost, water supply and water-use standpoint

5. DCMs that are designed to interrupt fetch and saltation protect downwind surfaces and capture sand.
6. DCMs with salt- and drought- tolerant vegetation can be challenging to establish and sustain, but are more water efficient and provide effective dust control.

Potential DCMs in Imperial County are discussed below and include surface stabilizers, vegetated swales, plant community enhancement, moat and row, water-efficient vegetation, tillage, alternative land use, species conservation habitat and other habitat-based uses (IID 2013).

Surface stabilizers are commonly used to suppress dust on disturbed lands including unpaved roads and construction sites. They are usually applied topically and can consist of water, salts and brines, organic non-petroleum products, synthetic polymers, organic petroleum products, or mulch and fiber mixtures. Surface stabilizers change the physical properties of the soil surface to reduce dust by forming crusts or protective surfaces on the soil, causing particles to agglomerate, or attracting moisture to the soil particles. Surface stabilizer efficacy varies with the stabilizer type, environmental conditions, soil type, weather, application rate, and application frequency.

Habitat swales are earthen channels with vegetation constructed by raising pairs of parallel berms, with adjacent pairs of berms. Habitat swales interrupt wind fetch (the distance that wind has traveled over an unobstructed area) on the playa, which reduces wind velocity at the soil surface and suppresses sand flux and dust emissions in downwind areas. Vegetated swales capture sand beneath the plant community's canopy. Regional dust suppression results due to periodic surface wetting, natural crusting, reduced sand motion, and reduced surface wind velocities due to sheltering of areas downwind of the swales.

With habitat swales, existing vegetation can be leveraged as the Sea recedes to enhance dust suppression. Plant communities will follow successional patterns as the shoreline is exposed. Favorable growing conditions will exist where freshwater inflows create fresher, shallow groundwater and/or leach salts from newly exposed playa. Sedges, rushes, and similar wetland vegetation will likely appear near the wet shoreline; grasses and other herbaceous species near the middle of the landscape; and shrub species in drier areas near and above the historic shoreline. These plant communities can achieve plant cover densities that postpone or eliminate the need for more resource-intensive DCMs.

Moat and row consists of an array of earthen berms (rows) flanked on either side by ditches (moats). Moats capture moving soil particles and the rows physically shelter the downwind playa by lifting wind velocity profiles above the soil surface. Moats and rows are designed to run perpendicular to primary wind vectors. The efficacy of this DCM can be enhanced by reducing the distance between rows, increasing the height of the rows, vegetating rows, or using gravel, sand fences, etc. to enhance sand capture.

Water-efficient vegetation stabilizes and suppresses soil and sand movement beneath the canopy of salt- and drought tolerant species on playa surfaces. Similar to a habitat swale, vegetation is seeded or planted on raised beds spaced 5-15 ft. apart. Findings from the literature indicate the most desirable species for dust control are salt- and drought-tolerant, may be rhizomatous (growth by the spread of underground roots and shoots), and must provide adequate cover even during dormant periods.

Native shrubs such as salt bushes (*Atriplex* spp.) and seepweed (*Sueada moquinii*) may be used alone or in combination with the common Saltgrass (*Distichlis spicata*). A mix of native species will provide the needed diversity to maintain adequate cover levels, reduce water demand, and suppress invasive species. Research is necessary to assess the dust control and economic efficiency of different levels of infrastructure, vegetation density, and vegetation uniformity.

Tillage involves roughening the land surface, which creates furrows that capture sand and lifts the boundary layer of moving air further above the land surface, thereby reducing erosion. Tillage may need to be repeated periodically to reverse land smoothing by erosion, sedimentation, and settling.

Tillage can be optimized to minimize turning and avoid traffic on untilled areas by tilling in blocks or strips. Tillage has some significant cost and operational advantages over other dust control approaches. Relative to other DCMs, it can be designed and installed at a fairly low cost with common implements used in agricultural production. However tillage needs to be conducted in a way that minimizes dust production. Tillage configurations are currently being evaluated for dust control at Owens Lake, and the results will be useful for implementation at the Salton Sea.

Alternative land use practices can cover exposed playa and eliminate or significantly mitigate the potential for emissions. Some relevant land use practices include the following:

- **Agricultural land.** Portions of exposed playa may be reclaimed for more conventional agricultural activities, including graminoid forage crops typically grown in the Imperial Valley, or aquaculture crops, such as algae. These crops may be harvested for protein (food) or used as biomass for energy conversion.

- Constraints on expanding agriculture onto exposed playa include irrigation infrastructure, irrigation water availability, and agricultural markets. Soil types are a major consideration: non-hydric and moderately to well drained soils found west of the New River delta are suitable for farming and less suitable soil types can be used for aquaculture farming (i.e. algae and other aquatic vegetation). IID is evaluating areas around the Sea for potential agricultural activity.
- IID is also evaluating several halophytic plants that might be suitable for crop use in playa areas with high salt content soils.

- **Energy Generation Projects.** Energy generation projects including geothermal and solar may also be located on exposed playa and could also, with prior planning and design modification, be co-located with habitat projects.
  - **Geothermal:** The Refined Conceptual Modeling and a New Resource Estimate for the Salton Sea Geothermal Field, Imperial Valley, California (Hulen, et al. 2002 as cited in IID 2013) estimated a more extensive geothermal resource at the Salton Sea than previously thought. The "Salton Sea Shallow Thermal Anomaly" is mapped from east of the New River delta, through the Alamo River delta area and the Morton Bay/Mullet Island area and along the east side of the Salton Sea to the Imperial Wildlife Area-Wister Unit. The potential geothermal area extends out into the Sea up to three miles in some areas.
  - **Solar:** Two types of solar energy recovery are being considered for installation on exposed playa: photovoltaic panel technology and solar gradient ponds.
    - **Photovoltaic panel** technology is a relatively well proven technology, but it has not been tested in the extreme environment of the Sea playa.
    - **Solar gradient ponds** extract energy by using solar rays to heat the lower water layer in a stratified impoundment. This technology has been moderately successful in other areas, but it has not been tested in the Imperial Valley.

Biological habitat can also cover exposed playa and eliminate or significantly mitigate the potential for emissions. Many habitat restoration projects are proposed in the Salton Sea area in an effort to sustain the fish and wildlife currently dependent on the Sea. Some of these projects will extend onto areas of the playa that would otherwise be exposed. These projects include, but are not limited to, the following:

- The Species Conservation Habitat Project will be located at the southern end of the Sea and will create up to 3,770 acres of relatively shallow water habitat. Ponds to support fish and wildlife species will be constructed and operated by the CA Department of Fish and Wildlife and supplied with a combination of New River (brackish) and Sea (saline) water, blended to maintain a salinity range of 20-40 ppt.
- The US Fish and Wildlife Service (USFWS) has proposed developing approximately 700 acres of wading and shore bird habitat in Red Hill Bay in an effort to maintain wetland habitat values on this part of the National Wildlife Refuge.
- The Wister Unit of the Imperial Wildlife Area or the Sonny Bono Salton Sea National Wildlife Refuge Complex may expand the current habitat onto exposed playa (IID 2013).

The **Dust Prevention and Mitigation** component will answer the question: how can dust emissions including from off-highway vehicle (OHV) use be prevented or mitigated? Off-highway vehicles cause considerable surface disturbance and erodibility. An adaptive management framework will be in place to prevent dust emissions from OHVs. Dust mitigation strategies include creating or purchasing off-setting emission reduction credits, similar to a cap-and-trade program and direct emissions reductions at the Sea. IID would negotiate with the local air pollution control districts to create a long-term program that would enable the creation or purchase of off-setting PM_{10} emission reduction credits (IID 2013).

Plan Implementation will occur throughout the duration of the Water Transfer Project. In fact, ambient air quality and DCM pilot projects have already begun. IID will coordinate with regulatory agencies and provide periodic updates on the implementation of the Air Quality Program. As of 3013, IID has installed six ambient air quality stations in 2009, playa exposure modeling, playa shoreline monitoring, playa surface characterization, and playa emission characteristics have been underway. Pilot projects including a surface stabilizer product evaluation, shallow flooding at the New River and plant community enhancement at the New River have been completed. In addition, a vegetation swale pilot project is being planned (IID 2013). Remote sensing and advanced satellite-based radar techniques have been employed to characterize active OHV traffic areas on the playa.

Other Studies

Ambient air quality monitoring is critical to establish a baseline for the comparison to future actions and conditions. The USGS Ecosystem Monitoring and Assessment Plan report (2013) recommends focusing air quality studies to address the following:

- Measurements of upper air meteorological conditions.
- Use of remote sensing and satellite imagery to track changes in exposed Salton Sea shoreline areas.
- Back-trajectory analysis to predict the sources of monitored particulate matter.
- Development and pilot testing of a "toolbox" of possible dust control measures.
- Investigations of potential odorous emissions.
- Identification of needed tools and models to support future studies.
- Estimation of greenhouse gas emissions from restoration activities.
- Evaluation of potential effects of global climate change on the Salton Sea and the Salton Sea Air Basin.

Findings from Buck *et al.* (2011) indicate that areas where the hydrous/anhydrous minerals are dominant were the most likely to result in highly emissive surfaces and is exacerbated by high water tables. However King *et al.* (2011) did not find a significant correlation between salt content and emissivity but determined that dry washes (sand-sized particles with little silt/clay crust) were the largest source of PM_{10} emissions compared with any other playa type. More studies are necessary to determine a causal relationship between existing and future playa characteristics and emissivity.

6.2 Restoration Scenarios and Dust Mitigation

In addition to air quality emissions from the Sea area reduction, air quality may be effected by the construction and operation of ecosystem restoration program elements, as a result of equipment exhaust and fugitive dust emissions. Habitat restoration will reduce dust emissions in the long term by covering exposed playa. Ecosystem restoration activities could also affect the levels of hydrogen sulfide released from geothermic and biogenic sources in the Salton Sea (USGS 2013).

Locally, ICAPCD is responsible for regulating air quality within the southern Basin and has established Regulation VIII, Fugitive Dust Control Measures. It specifies standard measures required at all construction sites to reduce PM_{10} emissions. Every restoration scenario will be subject to ICAPCD's Fugitive Dust Control Measures, in addition to the measures required by the ICAPCD's CEQA Air Quality Handbook and the ICAPCD's Policy 5 to further minimize impacts from NO_x and PM_{10} emissions. Rules and other regulation requirements can be found in the Imperial County 2009 PM_{10} SIP. Relevant measures identified by the SCH Final EIR/EIS include:

6.2.1 Fugitive Dust (PM_{10}) Control Measures

- Water exposed soil with adequate frequency to keep it continually moist for continued moist soil so that visible dust emissions would be limited to 20 percent opacity for dust emissions at all times (at least twice daily and as indicated by soil and air conditions).
- Replace ground cover in disturbed areas as quickly as possible.
- Limit vehicle speed for all construction vehicles to 15 miles per hour on any unpaved surface at the construction site.
- Develop a trip reduction plan to achieve a 1.5 average vehicle ridership for construction employees.

6.2.2 Implement diesel control measures (to reduce PM_{10} and NO_x emissions from diesel engines)

- A schedule of low-emissions tune-ups will be developed and such tune-ups will be performed on all equipment, particularly for haul and delivery trucks.
- Low-sulfur (≤ 15 ppmw S) fuels will be used in all stationary and mobile equipment.
- Curtail construction during periods of high ambient pollutant concentrations as directed by the ICAPCD.
- Reschedule activities to reduce short-term impacts to the extent feasible.

6.2.3 Applicable Mitigation Measures from the Water Transfer EIR/EIS

Mitigation Measure AQ-2: Implementation of BMPs during construction and operation would help to minimize PM_{10} emissions. BMPs could include, but are not limited to, the following (IID 2002):

- Equip diesel powered construction equipment with particulate matter emission control systems, where feasible.
- Use paved roads to access the construction sites when possible.

- Minimize the amount of disturbed area, and apply water or soil stabilization chemicals periodically to areas undergoing ground-disturbing activities. Limit vehicular access to disturbed areas, and minimize vehicle speeds.
- Reduce ground disturbing activities as wind speeds increase. Suspend grading and excavation activities during windy periods (i.e., surface winds in excess of 20 miles per hour).
- Limit vehicle speeds to 10 mph on unpaved roads.
- Cover trucks that haul soils or fine aggregate materials.
- Enclose, cover, or water excavated soil as necessary.
- Replant vegetation in disturbed areas where water is available, following the completion of grading and/or construction activities.
- Designate personnel to monitor dust control measures to ensure effectiveness in minimizing fugitive dust emissions.

6.3 Summary

The air pollutants of greatest concern in the Basin are: particulate matter (PM_{10} and $PM_{2.5}$) from wind erosion (fugitive dust), soil disturbance and fuel combustion, ozone and ozone precursors, nitrogen oxides (NO_x) and volatile organic carbons (VOCs), primarily from vehicle and equipment exhaust. Agriculture and transported pollutants from Mexico contribute to the air quality problems in the area but the declining inflows and associated elevation decrease will increase windblown dust emissions from the exposed dry lakebed (the playa) in some areas. The PM_{10} emissions from exposed playa are a considerable human health hazard, and could also affect crop production and solar energy generation.

IID's JPA Dust Mitigation Plan includes an adaptive management framework to monitor ambient air quality, research and monitoring efforts to identify and map playa surface characteristics related to erosion and emission potential. While some studies have advanced the knowledge base about the playa, more studies are necessary to determine the potential for salt crust formation and a causal relationship between existing and future playa characteristics and emissivity.

In addition to air quality emissions from Sea area reduction, air quality may be effected by the construction and operation of ecosystem restoration program elements, as a result of equipment exhaust and fugitive dust emissions. While habitat restoration will reduce dust emissions in the long term by covering exposed playa, detailed mitigation measures are recommended to reduce the potential impacts of construction activities.

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7.0 Summary and Future Data Needs

The Salton Sea has been the subject of routine monitoring for various flows and constituents that are the foundation of this report. Moving forward, however, there is a need to further characterize various physical, chemical, and biological processes in support of different restoration alternatives. Key aspects of the additional data that might be required are presented in this chapter. These are divided into three general categories: water quality processes, biological uptake processes, and air emission and dust control processes.

7.1 Water quality processes

There is a need to continue the monitoring in the Sea as well as in the new habitats that are created as part of any restoration plan.

For newly created shallow habitat, both saltwater and brackish, an extensive effort at characterization is needed. The most important water quality concerns identified in the SCH final EIS/EIR are salinity, temperature, dissolved oxygen, nutrients, and Se (also a concern in sediment, bird eggs and other biota). These key indicators will be monitored within the SCH habitat in order to determine the effects of various operational scenarios under an adaptive management framework (DWR and CDFW 2013; CNRA 2015). The water quality science panel created by the Salton Sea PEIR process in 2007 identified Se, hydrogen sulfide, water temperature and dissolved oxygen as a potential problem for birds and fish (DWR and DFG 2007). A similar protocol of monitoring and analysis needs to be developed for brackish water and lower salinity habitats, some of which are already in existence.

Monitoring in the Sea needs to be continued so that changes associated with increasing salinity, and reduced area and depth can be evaluated. The annual loading of nutrients, proportional to the volume of the Sea, may increase over time and change the eutrophication characteristics. Numerous gaps in knowledge create uncertainty for restoration. Important areas to focus on include:

- Selenium dynamics (characterization of inorganic/organic, different oxidative states, elemental species and their distributions) and biogeochemical cycling in the Sea, including sediment settling, re-suspension and volatilization
- Projected Se concentrations in brine sink under declining inflows

- Phosphorus in sediment and re-suspension: effect on internal cycling and water column concentrations
- Temperature and dissolved oxygen dynamics related to mixing and the effects on nutrient cycling and ammonia and hydrogen sulfide production.

7.2 Biological uptake processes

Because of the terminal character of the Sea, all contaminants that flow into it accumulate in water or sediments, unless there is a volatilization pathway. This last pathway has not been quantified for many contaminants in the Sea, and a conservative assumption is that all inflowing contaminants will continue to add to the sediment and water concentrations over time. Given the ecological importance of the Sea, it is very important to understand the transfer and uptake of the contaminants into the food web, from plankton to fish to bird eggs. To date, the characterization of contaminants in tissues has been limited, and a more systematic approach is needed. A recent U.S. Geological Survey Monitoring and Assessment Plan (MAP) provides a strong foundation for the data needs for the Sea (Case III *et al.*, 2013). The full scope of the MAP is broad, and includes characterization of biological resources (bird, fish, and algae species), water column concentrations, and tissue concentrations. The characterization is focused on the Sea as well as the different created habitats. Some of the key data requirements identified in that report include:

- Algal and zooplankton species composition
- Fish type and abundance
- Endangered desert pupfish abundance in Sea and inflowing waters, as well as created habitats
- Avian use of different habitats, both existing and created
- Selenium transfer into particulate matter and bioaccumulation/effects in piscivorous birds at the Salton Sea

7.3 Air emission and dust control processes

The changing volume and elevation of the Sea over the next 15 years is expected to result in tens of thousands of acres of newly exposed playa. Managing the emission of PM_{10} from these areas effectively is a high priority component of any planned restoration. Some of the key data needs associated include:

- Playa surface mineralogy dynamics including crust formation, erodibility and potential to contribute fine particulate matter
- Evaluation and design of multiple dust control measures
- Plant community optimization for dust control
- Water availability and requirements for dust control measures

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