

---

**SUSTAINABILITY OF THE SALTON SEA:  
A REVIEW OF THE ENVIRONMENTAL, ECONOMIC, AND SOCIAL CLIMATE  
AROUND CALIFORNIA'S LARGEST SALINE LAKE**

---

*Prepared as part of a First Year Experience Course  
BE100: Crisis in the Salton Sea  
Fall 2016*

Emilie Gray, Associate Professor  
Colorado College

Edited by Jenna Wu, Senior, Block researcher and Student mentor

Contributors (FYE students):

Carly Bonwell, Jordan K. Schrage, Madison E. Sternitzky, Monica H. Nelson, Mia K. Hsu, Joseph Gutstadt, Wilson Kaplan, Ben E. Murphy, Silas J. Farwell Mead, Lily E. Clouse, Benjamin B. Hall, Virginia G. Thom, Natalie Gubbay, Evan M. Doherty

## Introduction

Jenna Wu  
Colorado College

The Salton Sea and its surrounding region have historically held a variety of roles including ecological haven, agricultural utopia, chemical outlet, resort area, and desert wasteland. The Sea was originally formed as part of a tragic accident in the Imperial Valley in 1905: the Colorado River inundated flimsy dikes, flooding into what was a void, desert basin. Over one hundred years later, an ecological dependency on the Salton Sea has formed. Multiple types of residents inhabit this region, including people who work the land, farming date palms and alfalfa, and over four hundred species of birds that stop to feed during their long migration known as the Pacific Flyway. This increasingly briny, shallow lake covers a surface area of 30 by 15 miles. This is as small of an area as the Sea has ever occupied, currently holding a volume of 7.5 million acre feet and shrinking fast (Barringer, 2014). If the region's hot climate causes it to fully evaporate, the Sea will see the disappearance of tilapia, the only species of fish left in the lake. This will, in turn, decrease the number of migrating visitors like brown pelicans and grebes.

As the surrounding Imperial and Coachella Valleys have grown, a great challenge has formed over time due to the manifold needs of the environment and agricultural development. Getting the government to take preventive measures proves an incredibly difficult task since the Salton Sea is not a naturally formed body of water. Thus, agricultural runoff flowing into the Sea remains unmonitored. In fifteen years, water volume may decrease by 60 percent, exposing an additional 100 square miles of toxic playa dust that circulates the air above the shore and in people's homes (Pacific Institute, 2006). The objective of this report is to evaluate the current state of the Salton Sea through environmental, economic, and social lenses, ultimately presenting information that can assist with restoration, and to analyze the complex issues that challenge this region of the United States.

The Salton Sea exists in one of the most arid regions in North America, nearly touching the northern border of Mexico, and represents the largest inland body of water in California (Cohen and Hyun, 2006). The Colorado River provides water for regional agriculture via canals, which in turn feed agricultural runoff into the New, Whitewater, and Alamo Rivers. These three tributaries flow into the Salton Sea, greatly affecting its water quality year to year. Supplemented minimally by precipitation and other municipal and industrial emissions, this influx culminates to a yearly addition of ~85,000 acre-feet to the Salton Sea (Cohen and Hyun, 2006).

Prior to the human-caused accidental filling in 1905, multiple natural changes in course of the Colorado River resulted in the filling and refilling of the basin, creating instances of Lake Cahuilla at least five times over the last million years (Redlands Institute, 2016). Lake Cahuilla was a terminal lake 26 times the size of the Salton Sea, but evaporated completely for the last time in 1500. Nine billion tons of salt, calcium carbonate marine fossil shells, and sediment beds were left after these multiple evaporation events, cumulatively forming a dry, residual layer more than two miles deep (Cohen and Hyun, 2006).

Construction of the Alamo Canal was finished in 1901 to bring water from the Colorado River to

the dry lakebed leftover by Lake Cahuilla, after George Chaffey invested \$150,000 in the California Development Company (CDC) (Cohen and Hyun, 2006). Chaffey soon renamed the basin the Imperial Valley in order to attract investors and tourists. Alongside its upcoming popularity, however, the Alamo Canal had accumulated enough silt build up by 1905 to flood and breach a dike, unintentionally and artificially forming the Salton Sea (Redlands Institute, 2016). This breach was a catastrophe to the area, creating an inland sea that held no water rights due to its artificial formation. Post-1905, after multiple legal agreements and regulations came together to help form a course of action for the Imperial Valley, the Salton Sea finally saw its heyday in the 1950s when it became the second most popular recreation locale in California (Redlands Institute, 2016). The valley sold over 15,000 lots on ~12,000 acres of land, which eventually became a hub for golfing, boating, and fishing (Cohen and Hyun, 2006). Presently, the Salton Sea subsists with a surface area of 376 square miles at ~226 feet below sea level and sits between the Imperial and Coachella Valleys (Case and Douglas, 2007). Maximum depth is currently 51 feet with a maximum width of 15 miles. The regional climate of southern California is characterized by drastically high temperatures and a lack of precipitation; therefore, temperatures commonly surpass 100° F for approximately one third of the year, sometimes even exceeding 110°F (Cohen and Hyun, 2006). Annual evaporation rates range between 5.5-6 feet per year.

Without better monitoring of water deficit and salinity levels, the loss of wildlife in the Salton Sea will become imminent. The Sea at present has a salinity of 44 parts per thousand (ppt), 25% saltier than ocean water at approximately 35 ppt; however, it still supports vital habitat for over 400 species of bird and fish (Case and Douglas, 2007). Although millions of birds used to frequent the Salton Sea, the basin is no longer an ideal resting place for birds along the Pacific Flyway due to exceedingly high salinity. For example, yearly numbers now dwindle around a few hundred thousand for eared grebe populations at the Sea, when they used to be just above one million. Agricultural runoff and the resultant eutrophication of the Sea is currently a major factor that has lowered dissolved oxygen levels over time, affecting all game fish species and leaving only tilapia (Cohen and Hyun, 2006). Comparatively, populations nationwide have become dependent on the surrounding agricultural land— the main source of harmful runoff— for mass food production. As the water crisis rises, so do human health crises. Toxic dust exposure resulting from Salton Sea shrinkage is a major cause of severe asthma in Imperial County, with the number of emergency room visits on average three times higher than anywhere else in California. This report will later evaluate the local and national dependency on Imperial Valley agriculture whose runoff is ironically also detrimental to the health of both humans and animals.

Despite deteriorating water quality and its adverse ecological effects, the Salton Basin holds promise for renewable energy production, including geothermal power. The Sea sits atop the Salton Trough, a rift valley formed adjacent to the San Andreas Fault (Brothers et al., 2009). Over millions of years, a zone of crustal spreading was formed within a series of mountain ranges in Southern California. Currently, the basin is made up of alluvial deposits saturated by highly saline water. Fifteen earthquakes reaching at least 6.0 on Richter scale have occurred since the year 1900, in addition to another 45 earthquakes of 5.0+ in or near the basin (Brothers et al., 2009). In this year, 2016, almost 200 smaller earthquakes have hit the Salton Sea within the span of two days (Grad, 2016). Due to recently elevated seismic activity and hot brine near the surface of the Sea, this report will discuss the basin as an area of great potential for geothermal power moving

forward.

Understanding the development of water rights and water distribution in the Salton basin is necessary in order to address current sociopolitical and economic challenges. Although the Kamia, Quechan, Cucupa, and Desert Cahuilla Indians occupied the northern part of the basin long before the basin was irrigated, their right to water in the valley has been a source of controversy to this day. This report uses the Torres-Martinez tribe as a case study to examine the technical and ethical decisions involved in the development of specific water distribution policies. In order to face the ecological and economic challenges met by the Salton Sea and Imperial County over the last 30 years, the Torres Martinez General Membership and state agencies have proposed several restoration plans, many of which have not yet fully come to fruition. One proposed plan, for example, attempts to restore the Sea's previous water quality and also compensate for agricultural runoff by building peripheral wetland around the Sea (Redlands Institute, 2016). Creating a successful, well-defined restoration strategy, however, proves difficult when a clear "previous" environmental baseline for the Sea has yet to be established. Unfortunately, a single all-encompassing restoration plan is not realistic because of the complexity and interconnectedness of various issues broached in this introduction. Rise in salinity is not the only problem that needs to be addressed; anthropogenic factors such as land use, and policy establishment throughout the entire state of California must also be a part of the discussion.

The various groups of people relying on the Salton Sea as means of agricultural production and even drinking water on Native American reservation land represents one of the most complex networks in water distribution. Interdependency between the diverse aspects discussed above will only be reconciled with efforts from varied groups of people. The need to address both economic and environmental concerns in the region represents an incredibly complex task for not only Native Americans, but also farmers, conservationists, and the local government. It is imperative that the residents of the Salton Basin area address the many challenges encountered in the attempt to preserve and reinforce the diverse values of the area, especially in such a rapidly changing climatic environment. By analyzing the sustainability of the Salton Sea, this report hopes to offer direction in order to uphold environmental, social, and economic equity in the valley.

## References

- Barringer, F., 2014. Preserving an Accident, the Salton Sea in California, for the Good of Nature. *The New York Times: Environment*, Nov. 10: 1-4
- Brothers, D. S., Driscoll, N. W., Kent, G. M., Harding, A. J., Babcock, J. M., Baskin, R. L., 2009. Tectonic evolution of the Salton Sea inferred from seismic reflection data. *Nature Geoscience* 2, 581-584.
- Case III, H. L., Barnum, D. A., 2007. The USGS Salton Sea Science Office Fact Sheet 2007-3097. U.S. Geological Survey, 2p.
- Cohen, M. J., Hyun, K. H., 2006. Hazard: The Future of the Salton Sea With No Restoration Project. Pacific Institute. 60p.
- Grad, S., 2016. Nearly 200 earthquakes hit Salton Sea amid quake swarm. *Los Angeles Times* Sept. 27 issue.
- Redlands Institute, 2016. The Salton Sea Database Program. University of Redlands. <http://www.spatial.redlands.edu/salton/about/default.aspx>

## Additional Sources

- Carmichael, W. W., RenHui, L., 2006. Cyanobacteria toxins in the Salton Sea. *Saline Systems* 2(5), 5-17.
- Chattopadhyay, J., Bairagi, N., 2001. Pelicans at risk in Salton sea – an eco-epidemiological model. *Ecological Modelling* 136(2-3), 103-112.
- de Koff, J. P., Anderson, M. A., Amrhein, C., 2008. Geochemistry of iron in the Salton Sea, California. *Hydrobiologia* 604(1) 111-121.
- Goodyear, D., 2015. The Dying Sea: What will California sacrifice to survive the drought? *The New Yorker: Letter From the Imperial Valley*. May 4 issue.
- Reidel, R., Schlenk, D., Frank, D., Costa-Pierce, B., 2002. Analyses of organic and inorganic contaminants in Salton Sea fish. *Marine Pollution Bulletin* 44, 403-411.
- Sapozhnikova, Y., Bawardi, O., Schlenk, D., 2003. Pesticides and PCBs in sediments and fish from the Salton Sea, California, USA. *Chemosphere* 55, 797-809.

## Table of Contents

<b>1: The effect of water chemistry on the ecology of the Salton Sea and its future implications - <i>Carly Bonwell</i></b>	<b>1</b>
1. Introduction	
2. Water Chemistry of the Salton Sea	
3. The Effect of the Salton Sea Water Chemistry on the Ecosystem	
4. The Future of the Salton Sea	
5. Conclusions	
<b>2: The Salton Sea’s Migratory Birds Mass-Mortality and Those Impacts Along the Pacific Flyway - <i>Jordan K. Schrage</i></b>	<b>7</b>
1. Introduction	
2. Changes in fish and bird populations due to salinity, agricultural runoff, and chemicals	
3. Eared grebe, gull-billed tern, and white pelican	
4. How mass mortalities may be changing the Pacific Flyway	
5. Conclusion	
<b>3: Salton Sea Restoration and its Impacts on Migratory Birds of the Pacific Flyway – <i>Madison E. Sternitzky</i></b>	<b>12</b>
1. Introduction	
2. Organizations Involved	
3. Red Hill Bay Restoration	
4. Peripheral Sea restoration plan	
5. The Future Without Restoration	
6. The Salton Sea in comparison to Mono Lake	
7. Conclusion	
<b>4: The Health Implications of Toxic Dust in the Salton Sea - <i>Monica H. Nelson</i></b>	<b>18</b>
1. Introduction	
2. Toxic Dust and Health Implications	
3. Possible Solutions in the Imperial Valley	
4. Learning from Mono Lake and the Aral Sea	
5. Conclusions	
<b>5: Geothermal Energy in the Salton Sea: The mechanics of geothermal energy and its risks and benefits - <i>Mia K. Hsu</i></b>	<b>22</b>
1. Introduction	
2. The mechanics and geology of geothermal energy	
3. Current and future geothermal energy development in the Salton Sea	
4. Pros and benefits of geothermal energy	
5. Cons and risks of geothermal energy	
6. Conclusion	

<b>6: Diverting our Attention: A lack of evolution of water rights systems in the west and the ramifications of lack of change on water and the Salton Sea - <i>Joseph Gutstadt</i></b>	<b>28</b>
1. Introduction	
2. History of Water Rights	
3. Ecological Ramifications of Water Transfers, namely in the Salton Sea	
4. Problems Within the Water Rights System	
5. Other Models for Water Rights Systems	
6. Conclusion	
<b>7: Consequences of Water Use and Diversion in the American West - <i>Wilson Kaplan</i></b>	<b>33</b>
1. Introduction	
2. Manifest Destiny and Water in the West	
3. Negative Consequences of Water Diversion on the Environment	
4. Restoration	
5. Salton Sea Restoration	
6. Conclusion	
<b>8: Native Americans and Water in the Western United States with a Focus on the Torres Martinez Cahuilla Desert Indians and the Salton Sea - <i>Ben E. Murphy</i></b>	<b>38</b>
1. Introduction	
2. Native American Water Rights in the Colorado River Basin	
3. History of Native Americans in the Salton Basin	
4. Torres Martinez Desert Cahuilla Indian Tribe	
5. Salton Sea Restoration	
6. Conclusion	
<b>9: A Green Oasis in the Desert: The History of Immigration in the Imperial Valley – <i>Silas J. Farwell Mead</i></b>	<b>43</b>
1. Introduction	
2. Early History of the Imperial Valley	
3. Strikes, Population Growth, and Demographic Shifting	
4. The Current State of the Imperial Valley	
5. Conclusion	
<b>10: The History, Current State, and Future of Tourism at the Salton Sea, California, USA - <i>Lily E. Clouse</i></b>	<b>48</b>
1. Introduction	
2. The Rise of the Salton Sea as a Popular Tourist Destination	
3. The Downfall of the Salton Sea Tourist Industry	
4. The Current State of Tourism at the Salton Sea	
5. The Correlation Between Health Hazards and Salton Sea Tourism	
6. The Three Main Alternates for the Future of the Salton Sea	
7. Conclusion	

<b>11: Agriculture Production and Water Use in the Imperial Valley - <i>Benjamin B. Hall</i></b>	<b>56</b>
1. Introduction	
2. Climatic Effects on Agriculture	
3. Water Use	
4. Water Source	
5. Agricultural Production and Feasibility	
6. Irrigation	
7. Effects on the Salton Sea and the QSA	
8. Conclusion	
<b>12: The Truth Behind Organic Farming and Food - <i>Virginia G. Thom</i></b>	<b>62</b>
1. Introduction	
2. The History and Agriculture of Food Activism	
3. Regulations on Organic Farming	
4. Pros and Cons Analysis	
5. Conclusion	
<b>13: The Clash Between Labor and Economic Advocates in Agricultural Policy: Dissecting the Farm Subsidy System - <i>Natalie Gubbay</i></b>	<b>67</b>
1. Introduction	
2. The Two Sides	
3. The U.S. Agricultural Subsidy System Over Time	
4. Alternatives: An Overview of Other Subsidy Options	
4.1. No Subsidies – New Zealand	
4.2. Price Control – Venezuela	
4.3. Wage Subsidies	
4.4. Reform	
5. Conclusion	
<b>14: Wetland restoration project analysis for the Salton Sea - <i>Evan M. Doherty</i></b>	<b>75</b>
1. Introduction	
2. The Importance of Wetlands	
3. Other Wetland Restoration Projects can Help Inform Salton Sea Plans	
3.1. Lake Urmia, Iran	
3.2. Grasslands Ecological Area, California, USA	
3.3. San Dieguito Lagoon, CA, USA	
4. A Current Project Proposal for the Salton Sea: Red Hill Bay Restoration Project	
5. Conclusion	



# The effect of water chemistry on the ecology of the Salton Sea and its future implications

Carly Bonwell  
Colorado College

---

## Abstract

The Salton Sea was formed between 1905 and 1907 when the Colorado River broke through an improperly made canal and flooded parts of the Coachella and Imperial valleys. The agricultural runoff that has sustained the Salton Sea since its creation has caused the water quality of the Sea to deteriorate. The agricultural runoff contains relatively large amounts of salts, nutrients, minerals, and other contaminants. Because the Salton Sea is a terminal lake with no outlet, the contaminants accumulate and the evaporation of water concentrates them. These contaminants have varying effects on the water chemistry and ecosystem of the Salton Sea. The Sea's increase in salinity dictates which organisms, such as tilapia, are able to survive within it. Nutrients, such as phosphorus and nitrogen, within the Sea cause it to become highly eutrophic with anoxic zones that kill fish and lead to hydrogen sulfide and ammonia production. The amplifying cycle between nutrients, eutrophication, and toxins has large effects on the ecosystem as it leads to fish die-offs, which in turn decrease the availability of food for birds. Birds are also affected by disease and toxins cultivated within the waters of the Sea. Because of the large impacts of the water chemistry of the Salton Sea on the Sea's ecological health, it is imperative that an effort be made to improve the Sea's water chemistry.

---

## 1. Introduction

In 1905, a breach of an improperly made canal, which was meant to transport Colorado River water to the Coachella and Imperial Valleys, resulted in the formation of California's largest lake, the Salton Sea. The large body of water in the desert of southern California seems to be unnatural, but in fact the Salton Trough has a history of being under water. Millions of years ago the Salton Trough was once a part of the Sea of Cortez. Eventually, sediments from the Colorado River delta built up, changed the course of the Colorado River, and formed the valleys. Periodically, the Colorado River would flood the valleys and create Lake Cahuilla, which would then eventually evaporate. Today the Salton Sea resides within the basin that was once submerged by the irregular occurrence of Lake Cahuilla. Like Lake Cahuilla, the Salton Sea is a terminal lake, meaning there are no outlets, and without sufficient input, the lake will eventually evaporate.

After the breach in the canal was stopped in 1907, the Salton Sea was expected to evaporate like Lake Cahuilla had done intermittently for thousands of years. However, runoff from agriculture within the Imperial Valley was enough to sustain the Salton Sea. This agricultural runoff is mainly brought into the Salton Sea by two rivers, the New River and the Alamo River,

which run north from Mexicali and flow into the Sea's southern end. However, being terminal, the Salton Sea became concentrated with salt, nutrients, and other contaminants that were held within the runoff. Through out the years, as the water quality of the Salton Sea changed, so too has the Sea's ecosystem. The water chemistry of the Salton Sea is extremely important, as it is the root of the ecological crisis that the Salton Sea faces.

## **2. Water Chemistry of the Salton Sea**

The water in the Salton Sea has been studied since its creation in 1907. Over the years, the monitoring of the Sea has increased as problems with its composition, such as the salinity, have also increased. Substances, including minerals, metals, and nutrients, are brought into the Salton Sea through the agricultural runoff ditches, the New River, and the Alamo River. These substances accumulate in the Sea, and as water evaporates they become more concentrated. Substances of concern include salts, selenium, sulfate, nitrogen, and phosphorus. These contaminants are linked to the declining health of the Salton Sea's ecosystem.

When the Salton Sea formed its salinity was 3.55ppt, however the Colorado River water, which flowed into the Salton Trough creating the Sea, was fresh water with a salinity of 0.7ppt. This increase in salinity from the river water to the Sea was due to the high salt content in the basin's soil from when it was once a part of the Sea of Cortez (Carpelan, 1958). Since 1907, the salinity of the water has increased dramatically. In 1955 it was 33ppt, and today is around 55ppt. This increase is due to the acculturation and condensation of salts brought in by the agricultural runoff. On average, the Salton Sea receives 3.2 million metric tons of salt per year, with 47% of that load coming from the Alamo River and 42% from the New River (Salton Sea Authority, 2016). However, the rate at which the salinity increases is slowed by the annual precipitation of .33 to 1.5 million metric tons of salt held within the Sea. This salt precipitates mostly in the form of calcite and gypsum (Amrhein et al., 2001). Because the salt compounds are precipitating and becoming incorporated into the settlements on the bottom of the lake, they are no longer accounted for in the salinity of the Sea, as the salinity measures the dissolved salts within the water. Also, since 2003, mitigation water has been put into the Sea by the Imperial Irrigation District (IID) in an attempt to stabilize the Sea's salinity. However, this is only a temporary solution to combat the raising salinity of the Salton Sea.

Selenium is another element of concern in the Salton Sea. In the Sea's water column, the levels of dissolved selenium are below 2 micrograms per liter ( $\mu\text{g/L}$ ), which are considered to be below the level of concern for aquatic life within the Sea. However, the amount of selenium held in sediments is of more concern for toxicity as it ranges from 1.5-11.8  $\mu\text{g/g}$  (Salton Sea Authority, 2016). It is possible for this selenium to leech out of the sediments, but periods of oxygen depletion and deteriorating conditions in the water allow for selenium sequestration in sediments. The selenium in the Salton Sea mainly comes from the input rivers. The Alamo River averages 6.8  $\mu\text{g/L}$ , while the New River averages 6  $\mu\text{g/L}$ . The selenium is brought into these rivers from the erosion and weathering of seleniferous rocks that are naturally occurring in the Colorado River Valley.

Hydrogen sulfite and ammonia concentrations are also of great concern in the Salton Sea. These substances are produced through biological and chemical processes involving the decay of organic matter and the depletion of oxygen. Therefore, there are high amounts of hydrogen sulfide and ammonia within the anoxic zones of the Sea. The Salton Sea has a large amount of

sulfate reduction and hydrogen sulfide production because of the high temperatures, algal productivity and sulfate concentrations (Salton Sea Authority, 2007). Sulfate enters the Sea primarily through the input of the Colorado River water. Sulfate concentrations in the Salton Sea are about 4 times higher than in ocean water (Cohen and Hyun, 2006). In anoxic conditions, sulfate-reducing bacteria produce hydrogen sulfide through anaerobic respiration. In 2005 it was estimated that as much as 78,000 metric tons of hydrogen sulfide are produced each year by sulfate-reducing bacteria (Amrhein, 2005). Ammonia is also a byproduct of this process. Additionally, ammonia is added to the Sea through external loading from the input water. Ammonia is the most common form in which nitrogen is discharged into the Sea. The concentration of ammonia in the water is high enough to lead to unionized ammonia concentrations above regulatory limits (Holdren, 2002). During mixing events, hydrogen sulfide and ammonia are carried into surface waters, which lead to a rotten egg smell that can sometimes travel as far as San Diego and Los Angeles (Cohen, 2014). The hydrogen sulfide released during these events tends to further strip the lower water column of its remaining oxygen (Cohen and Hyun, 2006).

### **3. The Effect of the Salton Sea Water Chemistry on the Ecosystem**

The water chemistry of the Salton Sea greatly affects the ecosystem of the Salton Sea. For example, the salinity of the Salton Sea has a significant impact on the organisms that can survive in it. In the 1950s, sport fishing was introduced into the Salton Sea, but today only tilapia are able to survive in the high salinity of the waters. Studies have found that as long as the temperature is 23–28°C, the tilapia can tolerate salinities up to 60ppt (Lorenzi, 2014). However, it is estimated that the tilapia will no longer be able to reproduce and survive in the Salton Sea when its salinity passes this mark. The lake is estimated to reach this level within the next 15 years (Salton Sea Authority, 2016). With the death of the fish populations, the piscivorous birds that currently frequent the Salton Sea will no longer be able to use it as a stop along the Pacific Flyway.

Not only is the tilapia population affected by the rise in salinity, it is also greatly affected by the minerals that flow into the sea from the agricultural runoff. The runoff contains large amounts of pesticides, nutrients, and metals. This, along with the high temperatures of the sea, leads to large amounts of algal productivity. It has been found that the algal production within the Salton Sea is phosphorus limited, as there is a smaller amount of phosphorus coming into the system than nitrogen. Phosphorus is also limited because of the uptake by biota and the precipitation of apatite minerals (Holdren and Montano, 2002). However, there is still a relatively large amount of phosphorus brought into the Salton Sea from the agricultural runoff and input rivers. This makes the sea highly eutrophic. Large algal blooms lead to anoxic zones within the water. Because the dissolved oxygen content of the water decreases so drastically, severe fish die-offs occur. Fish die-offs may also be related to ammonia toxicity.

Fish die offs and bioaccumulation of toxins pose serious threats to the populations of birds that rely on the Salton Sea. As the majority of wetlands in California have been destroyed, the Salton Sea had become an invaluable resource to the more than 400 species of birds that live in the area of the Salton Sea or use it as a stop along the Pacific Flyway. Fish die-offs, caused by the eutrophication of the sea and high hydrogen sulfide and ammonia concentrations, have a large effect on the piscivorous birds that currently frequent the Salton Sea. Not only do the fish die-offs limit an important food source for these birds, but also they are also associated with

diseases, such as botulism in birds (Cohen and Hyun, 2006). Birds, including species that don't eat fish, are still at risk for health problems even when a fish die-off is not occurring. That is because the fish, invertebrates, and algae within the sea contain small amounts of ammonia and selenium. The tissue of fish from the Salton Sea consistently exceed selenium thresholds for potential risk on the ecosystem (Bui et al., 2016). This is particularly concerning for bird species. That is because toxins, such as selenium, increase in concentration up the food chain leading to their bioaccumulation and magnification in the top consumer, which in this case are the birds. Selenium toxicity has devastating effects on bird populations as it can cause birth defects, decrease reproductive success, and can compromise birds' immune systems (Cohen and Hyun, 2006). Because so many species of birds rely on the Salton Sea to survive, it is imperative that the water quality of the Sea be improved.

#### **4. The Future of the Salton Sea**

In upcoming years, the Salton Sea will greatly decrease in area largely because of the decrease in inflow to the Sea. After 2017, the Salton Sea will no longer receive mitigation water from the IID as was required by the Quantification Settlement Agreement. About 300,000 acre feet per year of Colorado River water that would have entered the Salton Sea will instead be transferred to users outside of the Salton Sea basin (Salton Sea Authority, 2016). Additionally, water input from the Alamo River, the New River, and other agricultural drains, is expected to decrease as more of an effort is being put into preserving and limiting water used on agriculture.

Because of the impending decrease in the water input, and consequently in the area of the Salton Sea, the water chemistry of the Sea is also destined to change dramatically. It is estimated that within the next 20 years the lake will become hypersaline with a salinity of over 120ppt if no remedial actions are taken (Salton Sea Authority, 2016). Since tilapia are not expected to survive past a salinity 60ppt, this increase will have a large effect on the ecosystem. Without the predation from the fish, algae populations will increase. Piscivorous birds will no longer be able to rely on the Salton Sea for food. The hypersaline environment may allow for other organisms to live in the Salton Sea, which could be new food sources for the birds. One such organism is the brine shrimp which is able to survive in the hypersaline waters of Mono Lake. However, it is unknown if they would be able to survive in the Salton Sea because of its high concentrations of nutrients. While Mono Lake has an alkaline, carbonate system, the Salton Sea is expected to have a sulfate-dominated system (Cohen and Hyun, 2006).

Because of the Salton Sea's unique water chemistry, including its high concentration of nutrients, it is hard to use other lakes, such as Mono Lake, as an example for how to deal with the problem it faces. It is extremely important that possible restoration projects of the Salton Sea look at the nutrients and other contaminants in the water, and not just its salinity.

If nothing is done to improve the water quality of the Salton Sea, the nutrients within the Sea will cause large disturbances in its ecosystem and water chemistry. Although delivery of nitrogen and phosphorus to the Sea will decrease as the amount of irrigation runoff to the sea decreases, the amount that is in the Sea will still continue to cause greater eutrophication of the Sea. That is because the decrease in volume of the Salton Sea will cause it to become even more polymictic, meaning that the sea will not stratify and will almost always be in a state of mixing (Chung, 2008). Nutrients currently in the lower anoxic zones of the sea will be released from the sediments and become suspended within the water, also increasing nutrient cycling. This will

cause more productivity within the sea, which will lead to further depletion of dissolved oxygen and will increase in hydrogen sulfide and ammonia production. As hydrogen sulfide and ammonia will be mixed throughout the water column, they will be released into the air more continuously, and therefore the periods of strong odor that occur today will become infrequent.

## 5. Conclusions

The water chemistry of the Salton Sea is extremely important to the health of its ecosystem. As less water flows into the Salton Sea, its water quality will deteriorate at a faster rate if no action is taken to restore it. Fish will die off, eutrophication will increase, and birds will no longer be able to use it as feeding and nesting grounds. In order for the Salton Sea to have a bright future, the quality of its water must be improved. Today, most restoration projects focus on improving the Sea's salinity. This is important, as keeping the salinity below 60ppt will allow for the continuation of the survival of tilapia within the lake. However, much more needs to be considered in order to insure the health of Salton Sea's ecosystem. Remediation strategies for nutrients, particularly phosphorus and nitrogen, will be required in order to limit the eutrophication of the Sea. Other contaminants, such as selenium, will need to be further monitored and their input into the sea restricted in order to ensure the health of birds. Although many possible Salton Sea restoration projects have been proposed, none fully address the Sea's complicated water chemistry. More research needs to be done on the interactions of the chemicals within the water, their precipitation, and their ecological impacts, especially in regards to the possible engineered alternatives.

## References

- Amrhein, C., Anderson, M., and Matsumoto, M. 2005. Final Report for Reducing Eutrophic Conditions at the Salton Sea. Prepared for California Regional Water Quality Control Board, Colorado River Basin Region. 23p.
- Amrhein, C., Crowley, D., Holdren, G. C., Kharaka, Y. K., Parkhurst, D. L., Pyles, J., Schroeder, R. A., Tostrud, M. B., Webhorst, P. A. 2001. Effect of Salt Precipitation and Historical and Projected Salinities of the Salton Sea: Summary Comments from Workshop at the University of California, Riverside. January 30-31, 2001. 31p.
- Bui, C., Lamerdin, C., Schlenk, D., Xu, E.G. 2016. Spatial and temporal assessment of environmental contaminants in water, sediments and fish of the Salton Sea and its two primary tributaries, California, USA, from 2002 to 2012. *Science of the Total Environment* (599).
- Carpelan, L. H., 1958. The Salton Sea. Physical and Chemical Characteristics. *Limnol. Oceanogr.* 3: 373-386.
- Chung, E. G., Perez-Losada, J., Robertson, D.M., Schladow, G. 2008. A linked hydrodynamic and water quality model for the Salton Sea. *Hydrobiologia* 604:57-75.
- Cohen, M. and Hyun, K. H. 2006. Hazard: The future of the Salton Sea with No Restoration Project. Pacific Institute.
- Cohen, M. 2014. Hazard's Toll: The Costs of Inaction at the Salton Sea. Pacific Institute.
- Holdren, G. C. and Montano, A. Chemical and physical characteristics

of the Salton Sea, California. *Hydrobiologia* 473: 1-21, 2002.

Salton Sea Authority. 2007. Water Quality Studies in Support of Salton Sea Restoration: Final Report. Tetra Tech.

Salton Sea Authority. 2016. Salton Sea Funding and Feasibility Action Plan Benchmark 7: Project Summary. Tetra Tech

# The Salton Sea's Migratory Birds Mass-Mortality and Those Impacts Along the Pacific Flyway

Jordan K. Schrage  
Colorado College

---

## Abstract

The Salton Sea was formed as a result of an engineering mishap, filling the Salton Sink with hundreds of tons of water. With settlers developing over the California wetlands, the Salton Sea served as an appropriate alternative for birds to use along the Pacific Flyway. The Sea started out fresh but gradually became toxic and saltier as it filled with more runoff. Mass-mortalities in both fish and bird populations began happening more and more often, eventually leading to the question of whether these mortalities affect populations and thus affect other areas along the Pacific Flyway. This paper looks at the populations of the eared grebe (*Podiceps nigricollis*), the gull-billed tern (*Gelochelidon nilotica*), and the white pelican (*Pelecanus erythrorhynchos*) to infer whether the bird populations around the Salton Sea will affect other stops along the Pacific Flyway.

*Keywords:* Salton Sea; population dynamics; Pacific Flyway; selenium; fish; birds; mass-mortality

---

## 1. Introduction

The Salton Sea was formed by an accidental levee break in 1905 and became an instant draw for migratory birds along the Pacific Flyway, the North-South migration route from Alaska to Patagonia. California was losing its wetlands due to development, so the birds needed this as an alternative. Over the last 100 years, the Salton Sea has served as a sanctuary for migrating birds, whether it is a stopover, wintering, or breeding location, it functions just as a natural lake would. Unfortunately, however, fish were introduced, the agriculture industry began in the area, and tourism boomed; the water soon became more saline and loaded with toxic material. Mass mortalities increased in certain bird species and many factors contribute to these deaths. Population dynamics in fish and bird species fluctuated over time, posing a question: Do these fluctuations and mass deaths impact other areas along the Pacific Flyway?

## 2. Changes in fish and bird populations due to salinity, agricultural runoff, and chemicals

During the earliest years of the Salton Sea's existence, the salinity of the Sea was a low 3.5 g/L. Over time, agricultural runoff bringing chemicals such as salts, nitrogen, phosphorus and many others into the Sea and high evaporation rates relative to the freshwater inflow, have increased the salinity of the Sea to about 50% saltier than the ocean (Ponce, 2005). With changes in the salinity of the Salton Sea, the amount of nutrients present in the sea, and the amount of evaporation occurring, change in fish populations have become a concern. Salinity is the easiest excuse for cause of death, as fish reproduction is generally reduced in bodies of water with salinity over 40-45 g/L and survival becomes a concern at 50-60 g/L (DWR, 2004). Fish diversity

in the Salton Sea is already low, so salinity can have damaging impacts on the populations. The Salton Sea is the third most saline lake along the Pacific Flyway, at a current salinity of about 49 g/L. Soon the tilapia, one of the only remaining fish in the Sea, will be at risk of not reproducing as often or at all. The California Department of Fish and Wildlife began introducing new fish species between 1929 and 1956. These were in addition to the species that came in on the Colorado River during the flooding, to try to bring sport fishing to the area (Ponce, 2005). These species did not survive long due to sensitivity to changing salinities.

Owen's Lake was once in a similar situation as the Salton Sea is currently. Owen's lake was a saline environment for brine shrimp and flies and water was diverted from it for human use. Owen's Valley was dried up and left behind a dry, lifeless area that birds no longer visited, a dry, exposed playa. It is unclear what happened to the birds that once thrived at Owen's Lake, but it seems that the Salton Sea would have the same fate. Populations will shift in both fish and birds, if the Salton Sea dries up.

Agricultural runoff and other chemicals that have entered the Sea are also a possible cause of death for fish. Selenium, a concern for both fish and bird populations, is at very high concentrations in the Salton Sea (*A Sea in Trouble*, 1992). Selenium is naturally found in ancient rock sediment, so when farmers put Colorado River water on their fields, Selenium levels increase in the soil, sometimes negatively affecting crops. Farmers leach their fields before planting at the beginning of a season, which floods their fields, moving the selenium in large quantities into the Colorado River. In the 1990's the levels of selenium before the water reached the sea was 300 parts per billion (ppb) which is 150 times greater than the amount the Fish and Wildlife Service mark as the level threatening reproductive health in fish and birds (*A Sea in Trouble*, 1992). Before selenium enters the Sea, microbes eat the selenium and other contaminants, greatly reducing the levels to a safe zone; however, the microbes die and settle in the sediments where birds and fish are still at risk of ingesting the sediments in the Salton Sea. Some sediment samples have shown an outrageously toxic 3,300 ppb of selenium – enough to scoop up and transport to a hazardous waste dump (*A Sea in Trouble*, 1992).

As a result of chemicals, agricultural runoff, and increasing salinity, fish populations are at a decline, and with declining fish populations, fish-eating bird populations are negatively impacted. The most recent fish species to reside in the Salton Sea include the Orange mouth Corvina (*Cynoscion xanthulus*), croaker (*Genyonemus lineatus*), tilapia (*Oreochromis mossambicus*), and the endangered native desert pupfish (*Cyprinodon macularius*). *C. xanthulus* and *G. lineatus* disappeared from the Sea by 2002, reducing the variety and numbers of fish available for birds to eat, according to Chris Schoneman, project leader of the Sonny Bono Salton Sea National Wildlife Refuge. The decline of fish diversity and numbers negatively impacts the bird populations, as food sources become less prominent and competition arises between bird populations. While mass bird die-offs are not uncommon around the world, the magnitude of the die-offs around the Salton Sea are rare (Jehl, Jr., 1996). Causes of these mass deaths are undetermined, as there are many factors that could influence large-scale mortality in the Salton Sea area.



### 3. Eared grebe, gull-billed tern, and white pelican

The eared grebe (*Podiceps nigricollis*) is just one out of over 400 species of birds that use the Salton Sea at any given time. The *P. nigricollis* is a small duck-like bird that seeks out highly saline habitats. Their populations are vulnerable because of their popular use of Great Salt Lake, Mono Lake, and the Salton Sea, all of which are highly saline terminal lakes at risk of decline. The *P. nigricollis*'s diet consists mainly of brine shrimp, brine flies and sometimes other aquatic invertebrates, which is why the three saline lakes are a fitting habitat for these birds (Kaufman, 2016).

The *P. nigricollis* has faced population threats for a very long time, even when the Salton Sea was newly formed, mass deaths were occurring. In January of 1992, the largest known *P. nigricollis* mass-death occurred at the Salton Sea, killing 150,000. While cause of death is unknown for many mass deaths around the Salton Sea, it is speculated that the 1992 death was due to either chemical toxicity or disease, as avian botulism and cholera are common around the area. However, even with that one die-off wiping out 8% of the *P. nigricollis* population (2 mill) in North America, die-offs have not shown to have any consequences towards bird populations (*For the Birds, It's an Attractive Threat*, 1992). *P. nigricollis* spends many months of the year unable to fly, as they increase their weight and the size of several organs. It is estimated that the *P. nigricollis* spends ten months of the year flightless (The Cornell Lab of Ornithology, 2015). This could present a possible problem for the eared grebe were a food source to decline or a disease outbreak to occur, as their bodies will not respond quickly enough to leave the area in search of a better habitat.

The gull-billed tern (*Gelochelidon nilotica*) is among the rarest of terns found in the United States, with a small population of about 600-700 pairs in the *vanrossemei* subspecies. The population by the Salton Sea, estimated by J. R. Pemberton in 1927, was at around 500 pairs, but the population was at a rapid decline, reaching only 17 pairs by 1976, but then rebounding to 240-259 pairs in 2005 (Molina and Erwin, 2006). The *G. n. vanrossemei*, as its English name tells, has a thick bill and feasts mostly on small terrestrial organisms, insects, and aquatic invertebrates. This subspecies breeds mainly at the southern end of the Salton Sea and therefore is a species of special concern in California because of the Salton Sea's reputation for random mass-mortalities (The Cornell Lab of Ornithology, 2015). Without the Salton Sea, the *G. n. vanrossemei* population would likely die off, as the area is the only inland breeding location left for the terns. According to Bob McKernan, biologist at the San Bernardino County Museum, there will be no place left for the *G. n. vanrossemei* to breed if the Sea were to dry up (*For the Birds, It's an Attractive Threat*, 1992). While the *G. n. vanrossemei* population has not yet experienced a mass-mortality it is certainly vulnerable to one due to its breeding habitat.

The White Pelican (*Pelecanus erythrorhynchos*) is a large, stocky bird with a large wingspan and a thick bill and neck. For feeding, the *P. erythrorhynchos* works together with both its own species and with the Double-crested cormorant (*Phalacrocorax auritus*), and changes its feeding behavior depending on prey availability. Mainly, it includes small, shallow wetlands fish. In the mid-twentieth century, *P. erythrorhynchos* populations were dwindling, but over the last years, the population has increased to an estimated 120,000 individuals. The *P. erythrorhynchos* has a status of "Moderate Concern", as the population is still recovering from small numbers (The Cornell Lab of Ornithology, 2015). The water birds around the Salton Sea died from a botulism infection spreading through the fish in 1996. Up to 14,000 bird mortalities were recorded, most

of which were the *P. erythrorhynchos* (Chattopadhyay et al., 2003). Over half of North America's breeding populations spends its winter at the Salton Sea, so those who winter at the Salton Sea are at a higher risk of health issues arising (*For the Birds, It's an Attractive Threat*, 1992).

Without the Salton Sea where it is today, many bird species would suffer from longer migration distances. The species that currently winter in the Gulf of California and the Salton Sea would have to all winter in the Gulf of California and then make the long haul to Mono Lake on the way back north. This long leg of the migration trip would easily exhaust and kill many of the birds attempting the trip (*For the Birds, It's an Attractive Threat*, 1992). Populations would not do well without such an important stopover or wintering site as the Salton Sea.

#### **4. How mass-mortalities may be changing the Pacific Flyway**

The Pacific Flyway has three similar saline habitats that are popular for migrating birds in the spring and fall. This includes the Great Salt Lake, Mono Lake, and the Salton Sea. Both Mono Lake and the Great Salt Lake are too salty to host fish anymore, so they support a high production of brine shrimp and brine fly populations. All three are large terminal lakes that are important stopovers for water birds, as they're very productive habitats. The Salton Sea is the only of the three that can support fish-eating birds for long periods of time (DWR, 2004). Also, of the three lakes, and other terminal lakes along the Pacific Flyway, the Salton Sea is the only one to host wintering birds.

With these three lakes hosting thousands of migratory birds each year, at least one of them is going to eventually feel the weight of change if the Salton Sea were to consistently cause large-scale mass-mortalities in birds. While current studies have shown that mass-mortalities do not greatly impact population sizes, they likely will in the future. More impactful mortalities are on the way because the Sea is shrinking and will not be able to provide the food or habitat for these many migratory birds.

Were this to actually happen, areas up and down the Pacific coast, from Patagonia to Alaska, will likely see ecological changes occur. A possible outcome of diminishing bird populations along the Pacific coast is the population increase of fish or other organisms during the season the birds spend their summer elsewhere. This could alter entire ecosystems over time, so it is of international concern between the Americas.

#### **5. Conclusion**

While it's now been noted that the mass deaths of the past involving the Salton Sea area do not have significant impacts on individual populations, it can be assumed that one day it will. Change will be obvious. The Salton Sea has become a mecca for migratory birds, hosting over 400 different species throughout a single year. However, being responsible for so many birds has been a challenge for the Salton Sea. The salinity has been slowly increasing since the Sea first formed, agriculture has added pesticides and fertilizers into the water that drains into the Sea, and chemicals such as selenium have made their way into the Sea in large quantities. The Sea started out well below oceanic salinity levels but surpassed that quickly, working its way up to unsustainable levels for some fish and birds.. Many birds are affected by changes in the Salton Sea, so touching on the specifics of the eared grebe, gull-billed tern, and white pelican is important. These three species have had or will have to face mass deaths of their own kind, which

shows how unsustainable the Salton Sea is at this time. As the likelihood of mass deaths increases, there will be big changes along the Pacific Flyway in the future.

### **Acknowledgements**

This research was supported by the Sonny Bono Salton Sea National Wildlife Refuge (SBSSNWR) and Chris Schoneman, the project leader of the SBSSNWR.

### **References**

- The Cornell Lab of Ornithology, 2015. American White Pelican. Cornell University.
- The Cornell Lab of Ornithology, 2015. Eared Grebe. Cornell University.
- The Cornell Lab of Ornithology, 2015. Gull-Billed Tern. Cornell University.
- Molina, Kathy C., Michael Erwin, 2006. The Distribution and Conservation Status of the Gull-billed Tern (*Gelochelidon nilotica*) in North America. The Waterbird Society. 29 (3), 271-295.
- Polakovic, G., 1992. For the Birds, It's an Attractive Threat. The Press-Enterprise.
- Chattopadhyay, J., P.D.N. Srinivasu, N. Bairagi, 2003, Pelicans at risk in Salton Sea – and eco-epidemiological model-II. Ecological Modelling. 167 (1-2), 199-211.
- Kaufman, K., 2016. Eared Grebe. National Audubon Society.
- Jehl, Jr., J.R., 1996. Mass Mortality Events of Eared Grebes in North America. Journal of Field Ornithology. 67 (3), 471-476.
- Ponce, V.M., 2005. The Salton Sea: An Assessment. SDSU.
- California Department of Water Resources (DWR), 2004. The Importance of the Salton Sea and Other Terminal Lakes in Supporting Birds of the Pacific Flyway.
- Polakovic, G., 1992. A Sea in Trouble. The Press-Enterprise.

# Salton Sea Restoration and its Impacts on Migratory Birds of the Pacific Flyway

Madison E. Sternitzky  
Colorado College

---

## Abstract

This paper provides an exploration into the positive and negatives of restoring the Salton Sea to benefit migratory bird populations. Species such as the American White Pelican, Brown Pelican, Yuma Clapper Rail, Double-crested Cormorants and Eared Grebes are explored in the contexts of habitat preferences and environmental needs. The Red Hill Bay project is providing shallow wetlands that benefit non diving birds. The bigger more extreme Peripheral Sea, examines restoration of the whole lake and provides both deep water and shallow wetland habitats. If no restoration action is taken the future of piscivorous birds is at stake but invertebrate populations might allow certain birds to survive, possibly creating an environment comparable to Mono Lake.

---

## 1. Introduction

Most might consider a saline lake in the middle of the desert an unlikely setting for one of the most diverse avian habitats in North America, but the Salton Sea is habitat to over 400 different bird species (Riesz, 2016). One of the most diverse bird habitats in North America, the Salton Sea provides many necessities to birds of the Pacific flyway. Over the years' urbanization and development of California has led to a ninety percent decrease in wetland habitat (Paige, 2016). Therefore, the man-made sea provides a vital ecological niche for migratory birds. Birds rely on the sea as a stop during migration and use the area for breeding, overwintering and feeding. The sea also provides habitat to some currently endangered species, such as the Yuma Clapper Rail. Each bird species has slightly different specificities needed in an ecosystem. For example, the American White Pelican relies on fish and prefers shallower water while the Brown Pelican, also relies on fish, but needs deep water habitats for diving. The feeding behavior of birds greatly influences which environments they thrive in. The sea which used to attract more visitors a year than Yosemite is now on the brink of an ecological crisis (Iovenko, 2016). The salinity has reached the critical 60 parts per thousand (ppt) this is believed to be the number at which the Tilapia stop breeding. This could have staggering effects on the Pelican populations and other migratory birds that rely on the fish. Restoration plans in the works include both preserving the depth of the sea and creating and maintaining wetlands. Exploring the possible outcomes of the sea, both involving restoration and the prospect of no restoration, provides a lens into the future complications that the birds of the Pacific Flyway will face.

## 2. Organizations Involved

Red Hill Bay, which 10 years ago was covered in water is the site of dry playa in the process of being restored to wetlands. The United States Fish and Wild Life services has been working with the Imperial Irrigation District to fund and start the project. The Peripheral Sea is being explored by the Salton Sea Authority, an organization that is responsible for overseeing the

restoration of the sea. They are responsible for understanding environmental and economic sustainability of restoration plans.

### **3. Red Hill Bay Restoration**

The first restoration project, Red Hill Bay, is now in the process of construction. 420 acres of dry exposed playa will be covered with shallow water pumped from both the Salton Sea and the Alamo River. The goal is that the water will blend to create a salinity of 20ppt in the first cell and increase as water moves through the system due to evaporation (Red Hill Bay). The project includes two wetlands that will be separated by a levee. The goal of the project is to provide habitat for birds that rely on wetland environments. They plan on pumping water into the sea through a specialized pump that will allow fish and other organisms in the water to go through and fill the new environments. Although this is not a long term plan for the whole sea, it is still an effort to create wetland habitat and reduce the amount of toxic dust due to dry playa. The Red Hill Bay project acts as a “Band-Aid” to address the actual problem, but it is a project that is moving forward and therefore bringing attention to the sea and the need to preserve habitat for migratory birds.

The maintained wetlands could provide valuable habitat for birds that thrive in shallow waters and do not rely on diving for feeding. A study conducted in the Redfish Bay in Texas investigated the preferences of different bird species in terms of habitat. Although the environment in Redfish Bay may differ from that of the Salton Sea, the research still provides valuable information into habitat preference. They looked at total of 4,232 different birds, including 478 American Coots, 659 American White Pelicans, 436 Eared Grebes and 1,920 Double-Crested Cormorants, all of which are also present at the Salton Sea (Gibbons, 2008). The study found that the American White Pelican and the American Coot preferred shallower estuaries with seagrass beds. Double-Crested Cormorants and Eared Grebes preferred deeper estuaries with un vegetated bottoms. These preferences are likely due to feeding habits. Both Eared Grebes and Double-Crested Cormorants are surface divers. The Eared Grebe feed on invertebrates and the Double-Crested Cormorant feed on small fish. American White Pelicans scoop fish off the surface and often work in groups ranging from two to six individuals, herding the fish into shallow waters. The American Coot feeds on plants by surface diving. Although the American Coot feeds by diving, it still prefers the shallower wetlands as long as it is deep enough to permit surface diving. The Red Hill Bay restoration will likely benefit birds such as the White Pelicans and American Coots that thrive in shallower wetland habitats. For Pelicans it will be vital that the Tilapia survive, otherwise they will have no food source. Considering the water of the Salton Sea will be mixed with water from the Alamo river, the salinity will be lower in the wetlands than in the sea. Therefore, if the pumping system works properly the White Pelicans will be attracted to the wetlands. This plan fails to benefit bird species that rely on deep waters for diving, such as Eared Grebes or Brown Pelicans.

#### 4. Peripheral Sea restoration plan

The Salton Sea Authority's current restoration plan involves dealing with the decreasing water by drastically reducing the size of the sea. The plan calls for a peripheral sea; the outer rim of the lake would be cut off from the center with a barrier that would go all the way around the sea. Deep navigable water, surrounding the original sea, would support recreation and environmental needs. The middle of the lake will be allowed to dry up and playa will be exposed. This is in an effort to maintain the beach-front properties and recreational use of the sea while creating a habit of manageable size for migratory birds. The lake is expected to be 36 square miles and reach depth up to 25 feet, currently the average depth is 31 feet. The plan also includes 130 square miles of wetland along the shore of the sea. The sea would be split into different habitats. The marine sea, which would extend from the north end of the lake and stop at the southern end, would hopefully have a maintained salinity between 30 to 40ppt. The Early Start habitat will be at the southern end of the lake and is expected to be 2,000 acres of shallow saline habitat. The Early Start habitat would be divided into cells by berms, and the depth of the water in each cell will be less than 4 feet deep. Saline water from the sea will be pumped into these cells and mixed with fresh water to provide a salinity between 20ppt and 60ppt (Benchmark, 2016).

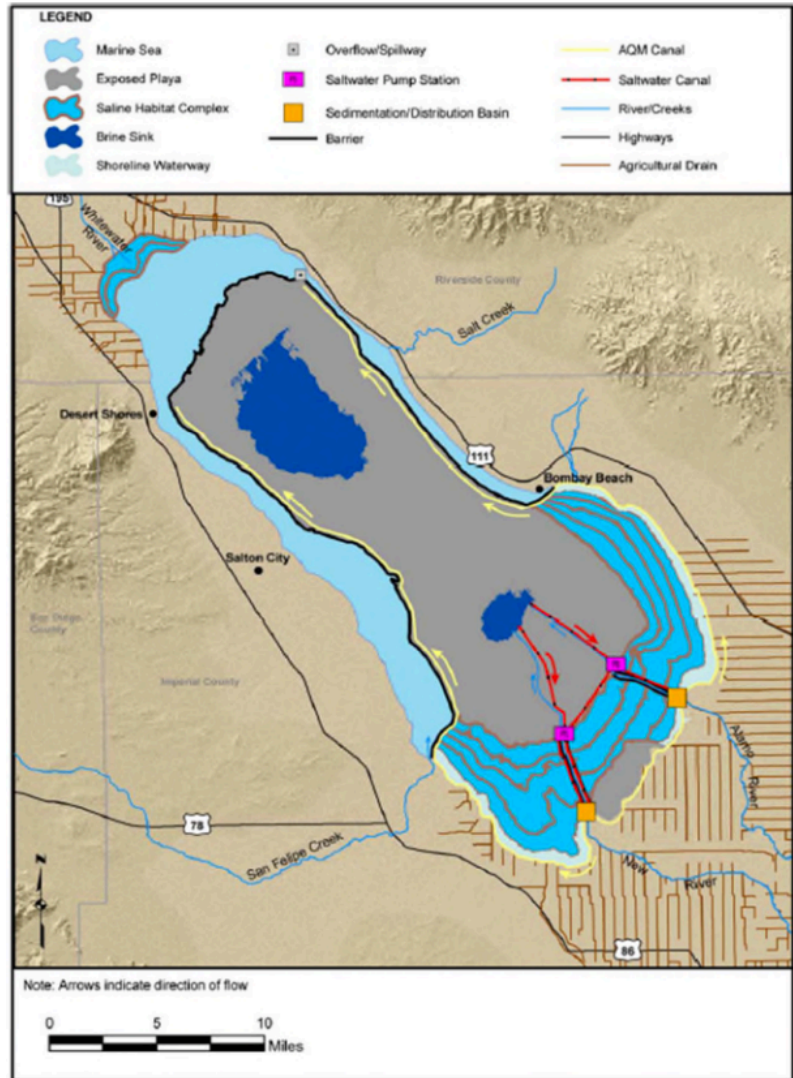


Fig. 1. Diagram of plan for the Peripheral Sea showing the marine sea and the wetland cells at the Southern end of the sea. (Benchmark, 2016).

The Red Hill Bay, which basically acts as a small scale experiment compared to the peripheral sea, only took into consideration birds that thrive in shallow wetlands. This restoration plan would benefit a much more diverse bird population due to differing habitats. The deep marine sea would allow birds like the Brown Pelican and Eared Grebes, which rely on deep waters for diving, to thrive. This plan also promises extensive wetland habitat for birds such as the Yuma Clapper Rail, which rely on shallow waters. The Yuma Clapper Rail uses its beak to probe the ground eating both invertebrates and plants. A study published in 2002 found that 40% of the

Yuma Clapper Rails in the United States rely on the Salton Sea for breeding grounds (Shufors, 2002). Considering that the Yuma Clapper Rail was listed as endangered in 1967 due to habitat loss, all plans to increase habitat should be explored. This plan, unlike Red Hill Bay, would take many years to achieve and is not yet underway. It is a seventy-year plan that has many benefits but it is drastic and there is doubt it will never actually be built. With predicted costs of 1.8 billion, the actual feasibility of the plan is low (Benchmark, 2016). Even if the funding is provided the engineering needed to do something like this is complicated and not commonly done. The Peripheral sea seems like a brilliant solution that takes into consideration the habitat needs for a variety of bird species. It is true that it would take into attention significantly more species than the Red Hill Bay, but there are the possibilities for major downsides. The most obvious of which is size, because the sea would shrink significantly. The competition for space and resources might cause some species of birds to be out competed, forcing species to find new migratory stops. Many bird species that breed at the sea rely on islands to protect their nests from land predators. The peripheral sea would from land bridges to those islands and either force birds to look for new breeding grounds or cause populations to decline due to higher levels of predation. The Double-crested Cormorant has a large breeding population on Mullet island, which is one of the largest colonies in western north America (Hulbert, 2007). The Yuma Clapper rail also has a small breeding population at the Salton Sea. Considering they are endangered, loss of this habitat could greatly influence their population.

## **5. The Future Without Restoration**

There is the likely possibility that nothing will be done in order to restore the sea. The playas will continue to dry up as mitigation water from agreements with the San Diego Water District stop in the upcoming year. Toxic dust will become an increasing problem, and the salinity of the sea will continue to rise. The Tilapia will most likely die and they are key players in the Salton Sea's food web, causing major shifts amongst the birds relying on the sea. The Tilapia feed on algae and other aquatic plants, therefore keeping those populations down even in a highly nutrient rich environment. Few studies have been done to understand exactly what salinity the Tilapia will die, but it has been believed that once the sea reached 60ppt the fish would no longer be able to breed and that would soon be the end of their populations. One study using fish collected from the sea looked at both temperature and salinity, which is valuable because temperature influences salinity. The warmer is the faster evaporation, and therefore higher levels of salinity. The study found that in a temperature between 23 to 28 degrees Celsius and 60ppt salinity showed rapid decreases in population, with only a 20 percent survival rate by day 30. In temperatures between 32 and 38 degrees Celsius the survival rate for 60ppt salinity was 0% by day 20 (Lorenzi, 2014). This data shows that higher temperatures combined with the negative effects of salinity on fish survival, eventually result in their demise. This is noteworthy because as the rate at which water going into the sea decreases, the size of the sea will decrease, making it both warmer and more saline. With the Tilapia dead, the piscivorous birds will either die or be forced to find new migratory routes.

The Double-crested Cormorants and White and Brown Pelicans are both piscivorous fish that rely on the Tilapia populations. Without their food sources they will be forced to find different stop over grounds. Birds have a history with the sea, the Salton basin has provided bird habitat longer than the Salton Sea has existed. In April 1908 a California naturalist, Joseph

Grinnell, recorded 908 American White Pelican nests and 147 Double-crested Cormorant nests on Echo island alone. At that point the lake was filled with freshwater fish brought in with the Colorado river. Those species peaked in 1910 and then rising salinity greatly diminished their populations. In the 1950s marine fish were introduced and then Tilapia in the 60's and their populations increased until rising salinity caused physiological stress and their populations decreased in the 80's (Hurlbert, 2007). The reason this history is important is because it shows the fluctuations in both fish species and population sizes mainly influenced by salinity. The migratory bird populations have experienced fish shortages and changes in species but never in the history of the sea have there been no fish. This is not to say that the end of the Tilapia means the end of all birds. There is a possibility that birds that rely on plants or invertebrates might still inhabit the sea.

## **6. The Salton Sea in comparison to Mono Lake**

The Salton Sea and Mono lake, in northern California, have similarities in terms of high salinities and migratory bird population which make them comparable in understanding the future of the Salton Sea. Mono Lake is three times as saline as the ocean, while the Salton Sea is 50% more Saline than the ocean (Benchmark, 2016). Mono lake maintains a population of brine shrimp and brine flies allowing it to provide habitat for non piscivorous birds. The Eared Grebe is one of the most prominent species at Mono lake with numbers reaching 1.8 million (Boyd, 1995). It is also a popular species at the Salton Sea. Although the Eared Grebe breeds in fresh water wetlands and lakes across western United States and southern Canada, it is also a species often found in highly saline habitats. Eared Grebes mainly feed on invertebrates and therefore it is possible they will still thrive at the Salton Sea even after the Tilapia are gone. Eared Grebes were one of the first species documented at the sea but it was not until the 1970's that we really began to see their populations increasing.

Scientists believe this is due to the introduction of pile worms to the Salton Sea in the 1930's, once their populations began to increase so did the Eared Grebes and by the 1960's they were noted as very abundant by scientist in the area. One study found that from January to April pile worm made up 95% of the Eared Grebe diet (Jehl, 2002). Food sources greatly influence where the birds will go after breeding. In late July they migrate directly to Mono lake or the Great Salt Lake, they thrive off the abundance of brine shrimp and brine flies and stay there until resources begin to diminish and they leave. They fly straight to their wintering grounds Sothern California or Mexico. Tens of thousands utilize the Salton Sea as wintering grounds, the Salton Sea is believed to have the highest concentration of Eared Grebes in the world. The increasing Salinity of the sea will not negatively impact the Eared Grebe considering it already survives in the more Saline Mono lake. What could have an impact on the Eared Grebes is if loss of Tilapia and increasing salinity affects the invertebrates in the sea. A study looking into invertebrates and increasing salinity suspects that there will be rapid changes in invertebrate populations. It predicts that the biggest changes will be seen in an increase in Trichocorixa and a loss of Gammarus (Hart, 1998). Gammarus is a food source for Eared Grebes and other species that feed in shallow waters. It's impossible to predict exactly what invertebrates will thrive and which will not, but that will greatly influence the lakes ability to continue to host migratory birds. The birds that do not eat fish and do not mind the Salinity can continue to use the sea considering it has



similar characteristics as Mono lake, but only time will tell which invertebrates will survive and how the bird's species will acclimate.

## **7. Conclusion**

The trepid future of the Salton Sea lies in the uncertain possibility of restoration. The bird species that are reliant on the sea as a migratory stopover or breeding grounds have an uncertain future. The Red Hill Bay restoration project will act as a "Band-Aid" as the sea continues to shrink and salinity increases. As a result of this the Tilapia will die off and the ecology will change. This could benefit some species like the Eared Grebes that rely on invertebrates but the sea will become inadequate to the pelicans and other piscivorous birds that rely on the sea. The peripheral sea project would have benefits and it is a step toward restoration and addressing the whole sea but that details of the plans are complicated and will take decades to complete. The uncertain future of the sea means that over 400 different bird species could be impacted and each of those species affects different ecosystems along the migratory routes. Restoration plans must fully consider their impacts on bird species looking into the habitat, behavior and food sources in order to predict the best possible outcome.

## **References**

- Benchmark 7: Project Summary. May 2016. Salton Sea Funding and Feasibility Action Plan.
- Tetra Tech Boyd, S. 1995. Eared Grebes Survey on Mono Lake. Pacific Wildlife Research Center.
- Gibbons, R. E., Withers, K. Southwestern Association of Naturalists. 2008. Habitat Preferences of Surface Diving Water Birds and American White Pelicans Wintering in Redfish Bay, Texas. *The Southwestern Naturalist*. 51(1), 103-107.
- Hart, C. M., and González, M. R., San Diego State University, 1998. Salinity and Fish Effects on Salton Sea Micro ecosystems: Zooplankton and Nekton. *Kluwer Academic Publishers*. 381 (1), 129-152.
- Hurlbert, A. H., Thomas A. W., Kenneth S. K., and Hulbert, S. A., 2007. Fish and Fish-eating Birds at the Salton Sea: A Century of Boom and Bust. *Land and Reservoir Management*. 469-499.
- Jehl, J. R., McKernan R. L., 2002. Biology and Migration of Eared Grebes at the Salton Sea. *Developments in Hydrobiology*. Kluwer Academic Publishers 161, 245-253.
- Lorenzi, V., Schlenk D., 2014. Impacts of Combined Salinity and Temperature Extremes on Different Strains and Species of Tilapia Inhabiting the Watershed of the Salton Sea. *North American Journal of Aquaculture* 79, 221- 231.
- Red Hill Bay Restoration project. Imperial Irrigation District.
- Riesz, K., 2016. Salton Sea Birds. California Department of Fish and Wildlife.
- Shufors, D. W., Warnock N., 2002. The Salton Sea as Critical Habitat to Migratory and Resident Water birds. *Developments in Hydrobiology*. Kluwer Academic Publishers 161, 255-274.

# The Health Implications of Toxic Dust in the Salton Sea

Monica H. Nelson  
Colorado College

---

## Abstract

Nicknamed the “toxic dust bowl,” the Imperial Valley in California suffers from poor air quality due to the drying up of the Salton Sea. As water disappears from the Salton Sea, the receding shoreline reveals miles of exposed lakebed filled with toxic dust. Toxic dust is dust that contains heavy metals and pesticides due to agricultural runoff into the Salton Sea. This dust blows over all of Southern California, including large cities such as San Diego and Los Angeles, causing respiratory illnesses. Restoration of the Salton Sea would improve air quality by decreasing the amount of airborne toxic dust and thus improve people’s health in Southern California.

*Keywords:* Toxic Dust; Salton Sea; Health; Respiratory Illness; Asthma; Mono Lake

---

## 1. Introduction

The Salton Sea, an inland saline lake in California’s Imperial Valley, is a natural phenomenon formed by a flood from the Colorado River. Since before the year 1200, the Salton basin would alternate between being occupied by a freshwater lake known as Lake Cahuilla, and being a dry, empty desert basin (Singer). Yet this time around, due to human activities, the Salton Sea has suffered unnatural consequences since its formation in 1907.

Around 1927, developers saw potential in the sea and turned it into a resort town rivaling that of Palm Springs. Meanwhile, farmers took advantage of the fertile riverbeds and began farming what is today the Imperial Valley, which provides 90% of the United States’ winter vegetables and is a major producer of alfalfa (Miller, 2015). All of the agricultural runoff from the Imperial Valley flows into the Salton Sea resulting in algal blooms that create an anoxic environment that which causes the fish die-offs that the Sea is infamous for. The shores, once lined with palm trees and sunbathers, are now littered with sludge and decomposing fish. At the same time, the salinity in the Salton Sea has increased to 50% higher than ocean water mainly due to evaporation (Ponce, 2005). Consequently, by the late 1970s, the ecosystem was deteriorating rapidly and the sea became a distant memory for most. However, the saying “ignorance is bliss” does not apply to the Salton Sea because its evaporation allows tons of toxic dust, a health hazard, to blow over Southern California and beyond causing respiratory illnesses.

## 2. Toxic Dust and Health Implications

Nicknamed the “toxic dust bowl,” the Imperial Valley suffers from poor air quality due to the drying up of the Salton Sea. As water disappears from the Salton Sea, the receding shoreline reveals miles of exposed lakebed filled with toxic dust. Toxic dust is dust that contains heavy metals, fertilizers pesticides, such as DDT, due to agricultural runoff into the Salton Sea (Dudley, 2015). In fact, Salton Sea mud contains enough enough arsenic and selenium to qualify for

disposal in a dump for the most toxic of society's trash (Polakovic). This dust blows over all of Southern California, including large cities such as San Diego and Los Angeles, causing respiratory illnesses. Michael Cohen, senior associate for the Pacific Institute, says "The dry lakebed could emit as much as 100 tons of microscopic dust each day." This particulate matter ("PM") dust is 100 times thinner than a strand of human hair and is easily inhaled and absorbed into the bloodstream, in which children are particularly susceptible (Gottberg, Cichocki, 2016). In fact, all heavy metals that one inhales is absorbed into the body whereas only 20% to 70% is absorbed if ingested. According to Timothy Krantz, an environmental studies professor at the University of Redlands, "once this toxic particulate matter is inhaled, it cannot be expelled, and heads into our bloodstream, affecting our organs, brain and even DNA." Health studies show that this level of exposure will increase the number and severity of asthma attacks, lung and cardiovascular diseases, and weaken the body's immune system (Gottberg, Cichocki, 2016). The most common respiratory illnesses associated with toxic dust are lung cancer in adults and asthma in children.

While these illnesses are most prominent in the Imperial Valley, this growing problem is not restricted to solely the Salton Sea. Wind can cause the toxic dust to become airborne, allowing it to travel hundreds of miles, reaching beyond Los Angeles. For example, Barrio Logan, a neighborhood in San Diego, has the highest rates of asthma in California. Even closer to the Salton Sea, in the Imperial County, particulate matter levels are four times higher than in San Diego. In fact, one in five children aged 5 to 17 living in the Imperial County has a chronic respiratory disease possibly due to toxic dust from the Salton Sea (Gorman 2012). Whipping winds, lack of health insurance, farmland dust and even tires burning in Mexico, are commonly blamed, but the toxic dust from the Salton Sea is rarely mentioned. As it continues to shrink, it becomes increasingly imperative that the Salton Sea gets recognized as a public health problem. By allowing the Salton Sea to (literally) turn to dust, we are also allowing our children to develop respiratory illnesses.

### **3. Possible Solutions in the Imperial Valley**

On the positive side, there have been efforts to prevent toxic dust from spreading. Some farmers in the Imperial Valley are implementing mounds of dirt that interfere with the course of the wind carrying toxic dust. There has also been talk of building dust-proof fences, as seen on construction sites, on the perimeter of the Salton Sea. However, unfortunately, there have not been many solutions implemented to deal with toxic dust. As knowledge is power, an organization called IVAN (Identifying Violations Affecting Neighborhoods) Imperial, allows anyone to easily access daily data from air quality monitors around the Imperial Valley. These air quality monitors rate areas as either low risk, moderate, unhealthy for sensitive groups (children, pregnant women, people who already suffer from asthma/lung cancer), and unhealthy, and cite a corresponding health recommendation. Currently, most areas in the Imperial Valley are rated as either low risk or moderate, with some unhealthy for sensitive groups. In the summer, these ratings tend to go up, and are relatively low in the fall and winter. Air quality monitors in the San Diego and Los Angeles Areas report similar conditions to the Imperial Valley (Ivan Imperial, 2016).

#### **4. Learning from Mono Lake and the Aral Sea**

Other drying up bodies of water that have struggled with dust include Mono Lake and the Aral Sea. Between 1852 and 1941, Euro-American settlers began diverting streams to irrigate ranches, flowing eventually into Mono Lake. At the same time, sheep and cattle grazing damaged streambanks and vegetation, causing erosion. However the major damage occurred in 1941 with the extension of the Los Angeles Aqueduct to the Mono Basin. Four creeks were diverted into the aqueduct, wreaking havoc on the environment below the diversion dams and depriving Mono Lake of most of its inflow. By 1982, Mono Lake dropped 45 vertical feet, lost half its volume, and doubled in salinity. Consequently, islands where California Gulls nested became peninsulas accessible to predators, toxic alkali dust arose from the exposed Mono Basin, and the duck and geese population fell by 99%. Today, Mono Lake restoration is focused on raising the level of the lake, which will lower its salinity, reduce dust storms, and reconnect the lake to springs and deltas. A major component of the Mono Lake restoration is re-establishing stream flows that mimic natural flows, which will rebuild deep stream channels, re-grow riparian forests, and reestablish healthy floodplains (The Mono Lake Committee, 2016).

Perhaps beating out the Salton Sea as one of the largest ecological catastrophes in recent history, the Aral Sea has also struggled with the issue of toxic dust. In less than half a century, its surface area has shrunk by more than 75% and its volume by 90%. This was largely due to the fact that the Soviet Union diverted water from the Aral Sea for the cultivation of cotton. As a result, toxic dust from the exposed lakebed has impaired human health, contaminated water sources, decreased crop production and killed off 200 species of plants and animals. Furthermore, the respiratory-related mortality rate among communities near the Aral Sea ranks as one of the world's highest, with 250 tons of toxic dust and salt deposited per acre of land, each year, in areas downwind. Similar to the Salton Sea, the Aral Sea shrunk gradually and incrementally. It was described as a 'creeping environmental problem' that failed to generate political concern or action. Competing interests further postponed actions until it was too late and the cumulative interests generated a crisis. This sounds eerily similar to the present state of the Salton Sea. Today, the focus of restoration efforts for the Aral Sea is on revitalizing the small, individual seas that are left (Pacific Institute, 2006).

#### **5. Conclusions**

Of all the problems the Salton Sea faces, toxic dust is the most dangerous of them all and will have the largest consequences if the shrinking sea does not get addressed. Toxic dust alone should provide enough incentive to restore the Salton Sea, because restoration costs would only be a fraction of the costs the state would have to pay in health care if nothing is done. The Aral Sea serves as a cautionary tale of what will happen if this 'creeping environmental problem' is not addressed soon.

## References

- Singer, E.,. Ancient Lake Cahuilla. Geology of the Imperial Valley. San Diego State University.
- Miller, C. , 2015. Imperial County Alfalfa - Critical for California, Essential for the World. The Desert Review.
- Ponce, V. M., 2005. The Salton Sea: An Assessment. San Diego State University.
- Dudley, S., 2015. Agriculture in the Imperial Valley: A Tale of Two Seas. Salton Sea Sense.
- Polakovic, G.,. A Shrinking Sea Means Toxic Dust. San Diego State University.
- Gottberg, K., Cichocki, C., 2016. Saving the Salton Sea. The Desert Sun.
- Gorman, A., 2012. In California's Imperial County, asthma takes severe toll on children. The Washington Post.
- Ivan Imperial, 2016. List of Air Monitors. Comite Civico Del Valle, Inc.
- The Mono Lake Committee, 2016. Restoration of the Mono Basin. Mono Lake.
- Pacific Institute, 2006. The Future of the Salton Sea with No Restoration Project. Pacific Institute.

# Geothermal Energy in the Salton Sea: The mechanics of geothermal energy and its risks and benefits

Mia K. Hsu  
Colorado College

---

## Abstract

With the Salton Sea's health depleting, California and the Imperial Valley are currently trying to find a solution to sustainably restore the sea. One of the more popular strategies is to provide restoration money through geothermal energy. This study focuses on why the Salton Sea area has such great geothermal potential, the risks and benefits of its development, and how it can aid in the restoration of the Salton Sea. The Imperial Valley area is positioned on an area called the Pacific Ring of Fire: an area along the edges of the Pacific Ocean that contains strings of volcanoes and experiences increased seismic activity (National Geographic, 2016). The Salton Sea region is a prime spot for geothermal energy production as a result of the Ring of Fire, which creates "hotbeds" or underground reservoirs of heat. The production of geothermal energy would provide a source of revenue for the community to help aid the rebuilding of the sea.

---

## 1. Introduction

The implementation of geothermal energy in the Salton Sea area is becoming an increasingly popular strategy to aid the sea's restoration due to the high potential for geothermal production found there. The Salton Sea, California's largest lake, is in dire need of assistance. With California's current drought and the increase in restrictions on water use, the lake, which receives most of its water from agricultural runoff from the booming farming business there, is quickly receding. As the body of water shrinks, hundreds of acres of lake bed are exposed allowing for toxic dust to be picked up and swept across southern California. This crisis is reaching alarming levels and California and the Imperial valley are currently trying to formulate strategies to help rebuild the sea, one of them being the development of geothermal energy.

One of the biggest obstacles in restoring the sea is the lack of funding. Geothermal production would provide a sustainable and economically stable revenue for the regions community to use toward restoration. Geothermal facilities need very specific geological conditions in order to function and the Salton Sea area fulfill those conditions. Geothermal energy is generated from the heat found within the earth's crust as a result of radioactively decaying minerals, such as uranium (Lund, 2015). There is an abundance of this resource due to the Pacific Ring of Fire: an area along the edge of the pacific where reservoirs of heat can be found beneath the earth's surface (Fig 1). A portion of the ring goes through the Salton Sea, which means that there are hotbeds, making the sea an ideal place for the establishment of geothermal facilities.

This resource has many benefits but it is hard to implement due to its high upfront cost and lengthy construction. It is also important to take into account the high rate of seismic activity that occurs in the Salton Sea region and the risks of increasing geothermal production, which has

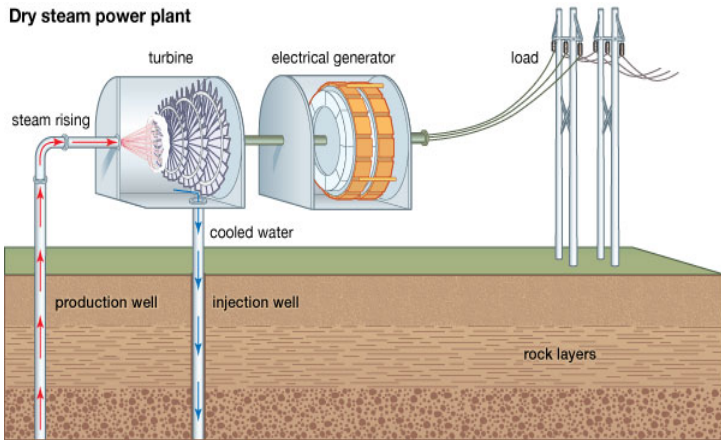
been proven to increase earthquake activity in some areas around the country. It is important for the Salton Sea community to facilitate research so they prove that geothermal energy would be more beneficial than harmful to their community in order to gain funding. Although there are many obstacles for the community to pass before they can comfortably rely on geothermal energy to aid in restoring the sea, there is no doubt that, if successful, this strategy will help to change the fate of the Salton Sea.

**2. The mechanics and geology of geothermal energy**

Geothermal energy is a product of the capturing of heat from within the crust of the earth and the conversion of that heat into usable energy such as electricity, space heating, etc. The heat that is used in the production of geothermal energy is created from the radioactive decay of minerals such as uranium, potassium, and thorium. This heat often contributes to the creation of lava flows, hot springs, and geysers and you will find that geothermal facilities are only found near these spectacles because they are good indicators of hotbeds (Lund, 2015). The region where geothermal energy is found around the sea is called the “Salton Sea Known Geothermal Resource Area” (SSKGRA).

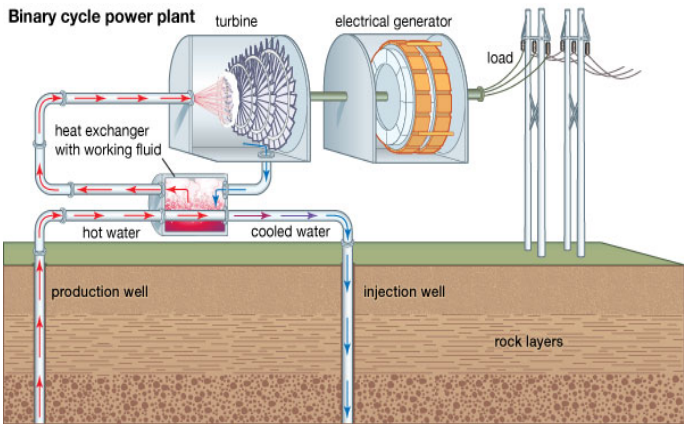
There are three major techniques in producing geothermal energy: dry steam, binary steam, and flash steam.

Dry steam plants directly extract steam from underground heated aquifers and pump it to turbines (Fig 2.). This process is extremely rare in the U.S. since there are only two known sources of steam: Yellowstone and The Geysers in northern California. Since Yellowstone is a national park, construction is prohibited so The Geysers is the only dry steam plant in the U.S. (National Renewable Energy Laboratory, 2016).



© 2011 Encyclopædia Britannica, Inc.

Fig 2. Diagram of the process of a dry steam geothermal plant (Encyclopedia Britannica, 2015)



© 2011 Encyclopædia Britannica, Inc.

Fig 3. Diagram of the process of a binary steam geothermal plant (Encyclopedia Britannica, 2015)

Binary steam plants use water found in underground heated aquifers to boil a “working fluid” (Fig 3.). A working fluid can be an organic compound with a lower boiling point than water. A lower boiling point increases the rate at which steam is created thus increasing the rate at which the turbines can spin. The water found within the ground ranges from temperatures between 225°-360°F and is used to turn the working fluid into steam but never actually comes in contact with the fluid. The water is then injected back into the ground to be reheated and used again (National Renewable Energy Laboratory, 2016).

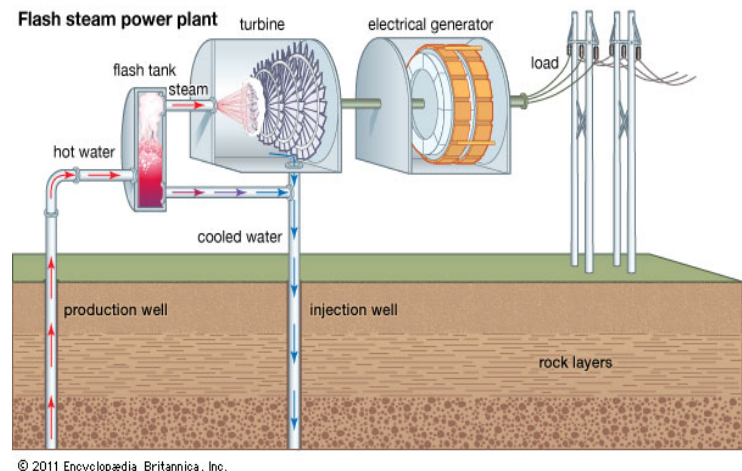


Fig 4. Diagram of the process of a binary steam geothermal plant (Encyclopedia Britannica, 2015)

Flash steam plants also use water from heated underground aquifers and are the most common of all the plants (Fig 4.). This water can be above 360°F and is circulated through pipes that go from underground to the above ground facility. The hot water is piped up to the facility and the sudden decrease in pressure causes it to vaporize, or “flash,” into steam (Encyclopedia Britannica, 2015). The leftover water and steam are then separated. The steam goes through turbines to produce electricity and is condensed back into water and returned to the reservoir to be heated and used again. The recycling of water and the continual heat from the earth is what makes geothermal such a sustainable resource (National Renewable Energy Laboratory, 2016). The majority of the Salton Sea geothermal power plants are flash steam plants but there are binary plants too. There are current plans to produce more geothermal facilities.

### 3. Current and future geothermal energy development in the Salton Sea

There are currently eleven geothermal facilities in operation, ten are owned by CalEnergy, one is owned by Berkshire Hathaway, and one is currently in the process of being constructed by Controlled Thermal Resources (CTR). Most of these plants were built in the late 80’s and early 90’s with construction slowing in the late 90’s. CTR is a geothermal development corporation founded by Rod Colwell, an Australian property developer (Imperial Valley Press, 2016). CTR’s plant will only be the second facility built in the Salton Sea since 2000. Energy Source built a plant in 2012 (Imperial Valley Press, 2016). Expansion of geothermal energy has slowed in the last decade because any plant that produces more than 50 Megawatts must get approval from the California Energy Commission which can take many years and producing 49.9 MW a year is not economically sustainable for most companies. The Imperial Irrigation District (IID) plans on leasing 1,880 acres of its land to CTR for 50 years to develop a geothermal plant. Of those 50 years, the first 8 will be the initial drilling, welling, and construction of the plant and during the rest of the 42 years, the facility is aimed to be fully operational. During stage one, CTR’s plant is estimated to generate 250 MW and in later stages, the hope is to produce 375 MW at full



capacity, five times as much as the current eleven plants in the area combined (Roth, 2016). CTR decided to build a facility in the Salton Sea because according to Rod Colwell, CEO and founder of CTR, “We found the Salton Sea area to be the most desirable and best geothermal field in California and maybe the US, it’s just a great proven resource.”

This is good news for the Salton Sea because an increase in geothermal development would provide a viable funding source for Salton Sea restoration. For example, just for this power plant the IID, who is leasing the land to CTR, is receiving \$21 an acre per year during the exploration period (this will rise to \$100 for the rest of the development process), \$600 per year for surface rent of power plants and well sites, and will also receive 3.2%-4% in royalties from the electricity produced by the plant. Graeme Donaldson, the Salton Sea Program Manager for the IID said that this could generate a revenue of \$421 million over the entire lease period. Most of this money will hopefully be used in Salton Sea restoration projects but there is some concern that CTR will not cooperate with the Salton Sea Restoration and Renewable Energy Initiative (Imperial Valley, 2016). The development of CTR’s plant is giving the IID and Salton Sea some hope for the future but there are still many doubters who believe that geothermal will not be able to save them and their homes.

#### **4. Pros and benefits of geothermal energy**

Geothermal energy could change the tide for the Salton Sea community and California by providing a renewable resource and steady flow of revenue. The Salton Sea area’s land has about 2,500 megawatts of undeveloped geothermal potential, the largest in the United States (Geothermal Energy Association, 2016). This means that there is plenty of room for developers to expand and establish facilities. If that were to happen, the Salton Sea would be able to garner a steady income to focus on sea restoration and California would be able to work toward its renewable energy goals. This type of energy resource is becoming more prominent in California since the state aims to receive 33% of its electricity from renewable sources by 2020 and 50% by 2030. California is already a major power house for geothermal energy and actually comprises “40 percent of the total world-wide geothermal plant production” (US Department of the Interior Bureau of Land Management and US Department of Agriculture United States Forest, 2009). There is a lot of hope and support going into geothermal since it is a reliable and sustainable resource that has proven benefits and is 100% renewable.

The resources geothermal plants use are very versatile and can be used to create a number of energy sources. For example, since the water used in geothermal plants is very briny, many geothermal plants extract valuable minerals such as lithium from it to create batteries. In 2014 the eleven facilities currently at the sea were generating a total of 400 MW a year and it was estimated that 2,000 more MW of energy would be available in the future as the sea receded. This kind of energy potential could help generate a massive amount of money, and with the price of restoration projects ranging from \$3-\$9 billion, it would be a great strategy to provide funding. According to The Desert Sun, a local daily newspaper in Southern California, the IID estimated “that geothermal development could generate \$2 billion in royalty payments over the next 30 years” which would go toward efforts for restoring the sea (Roth, 2016). This would aid in fund raising and proves that geothermal energy pays off its high upfront costs while being a completely renewable and carbon neutral energy source.

Geothermal is a highly viable energy source for a couple of reasons. First, and perhaps most importantly, it can operate 24/7 unlike solar and wind which must rely on specific weather conditions and times of day. Wind and solar energy operates about one-third of the time geothermal does (Encyclopedia Britannica, 2015). Second, geothermal energy production is completely carbon and pollution neutral since there is no need for any sort of burning or dumping of waste. They are completely reusing their resources (water and, in some cases, working fluids) without creating any emissions. Based on this information, geothermal energy is clearly an efficient and sustainable resource to use, especially in the Salton Sea area.

## 5. Cons and risks of geothermal energy

Although there are many advantages to geothermal production there are also some disadvantages and many obstacles to go through before you can establish a geothermal facility. One of the biggest issues pertaining to this resource is the high upfront cost. It is extremely expensive to conduct the exploration period (the period before construction when the developer determines where the most geothermal potential is, often by drilling). This exploration period is important because it helps to determine if the site where the facility is to be built will be cost efficient. Often times developers will find “dry holes,” which are holes that have steam, but not enough to be economical for the company (Encyclopedia Britannica, 2015). It is also very expensive and time consuming to construct the actual geothermal facility. So it is very important that the end result will produce enough energy to offset the initial expenses of construction.

A possible risk that comes with creating geothermal facilities is an increase in seismic activity. The development of geothermal facilities and their movement of water from reservoirs has been linked to increases in seismic activity around the Salton Sea. According to Emily Brodsky, a geophysicist at the University of California, Santa Cruz, “earthquake rate in the Salton Sea tracks a combination of the volume of fluid removed from the ground power generation and the volume of wastewater injected.” What Brodsky is essentially saying, is that there is a correlation between when a geothermal plant pumps water to and from its facility and increases in earthquake rates around the sea (Stephens, 2013). If it is in fact true that geothermal production can cause earthquakes there may be a huge obstacle for future geothermal developer’s that want to establish facilities on the receding sea’s playa. There was a recently discovered fault located in the sea named the Salton Trough Fault. The fault lies parallel to the San Andreas and runs from just north of the sea toward the south end near Bombay Beach (Fig. 5) (Muckenfuss, 2016). This fault could hinder the planned construction of future geothermal facilities on the exposed lake bed, where there is a huge amount of geothermal potential. Based off of this information we know that, although geothermal is extremely efficient and seemingly sustainable, it is important

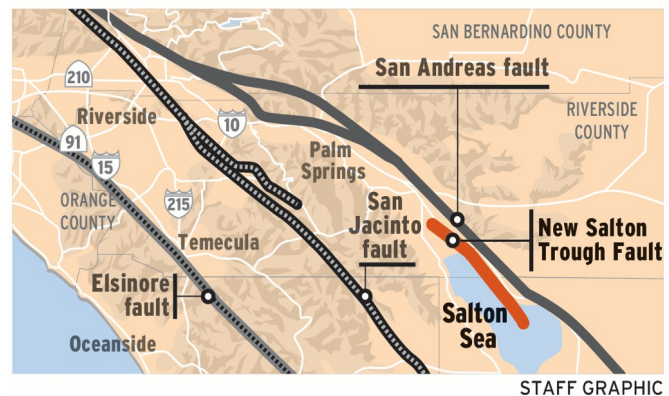


Fig 5. Diagram of the faults found in and around the Salton Sea (Muckenfuss, 2016)

to take into account the pay-off time to make sure it is cost efficient and to recognize the geological risks of geothermal production.

## 6. Conclusion

The Salton Sea is in dire need of assistance and geothermal energy seems to be able to aid the sea in overcoming many of its current obstacles. The land surrounding the sea has a plethora of geothermal energy that, if utilized, could potentially create a source of funding for Salton Sea restoration projects. The region has prime geological conditions as a result of being located on the Pacific Ring of Fire, which provides the area with geothermal hotspots and makes the Salton Sea area one of the richest renewable energy landscapes in the United States. The only major hindrance to increasing geothermal expansion is the high initial cost of development. Most development companies are deterred from building geothermal plants because of the cost of construction but many don't realize that it is paid off after the plant is fully operational for a few years since it is a renewable and efficient resource. Even though geothermal production may have some obstacles, they are minimal compared to the benefits. Geothermal production could change the Salton Sea's dreary present and future if implemented correctly. The community has all the right conditions and tools to make geothermal energy the answer to their problems, they just need to have the right support and knowledge to implement it.

## References

- Encyclopedia Britannica, Accessed 5 Sept. 2016. Geothermal Energy. *Encyclopedia Britannica Online*
- Geothermal Energy Association, Accessed 18 Oct. 2016. Major Companies. Geothermal Energy Association.
- Imperial Valley Press, Accessed 17 Oct. 2016. IID Approves Agreement to Bring in Another Geothermal Plant to Salton Sea Area. *Salton Sea Now!*
- Lund, J. W., 20 Apr. 2015. Geothermal Energy. Britannica.
- Muckenfuss, M., 6 Oct. 2016. Why the discovery of a new fault near the Salton Sea earthquake swarm could be important. *The Press Enterprise*.
- National Geographic, Accessed 16 Oct. 2016. Ring of Fire. National Geographic.
- National Renewable Energy Laboratory, Accessed 17 Oct. 2016. Geothermal Electricity Productions Basics. National Renewable Energy Laboratory.
- Roth, S., Accessed 18 Oct. 2016. Report: Don't Count on Geothermal to save Salton Sea. *USA Today*.
- Stephens, T., 11 July 2013. Geothermal Power Facility Induces Earthquakes. *University of California Santa Cruz*.

# ***Diverting our Attention: A lack of evolution of water rights systems in the west and the ramifications of lack of change on water and the Salton Sea***

Joseph Gutstadt  
Colorado College

---

## **Abstract**

Recent severe droughts in California and all across the West have strained the water rights system, increasing tensions between the agricultural industry and urban water districts. This paper seeks to show how lack of attentiveness to the water rights system, after its conception in the mid- 19<sup>th</sup> century, has ultimately led to its downfall. It follows the water rights system from its creation through its effect on development. Through the study of the evolution of the water rights the flawed wastage on an individual farmer level, and on system-wide efficiency have become more apparent, and so too the actions necessary to create a more viable and efficient system.

Keywords: Water rights; prior appropriation; drought; California; water waste

---

## **1. Introduction**

During the mid-19<sup>th</sup> Century, the Western US had little in the way of settlement, and much less centralized government control. This theme also applied to the creation of water rights, which were made in order to benefit those who first settled the land. The US government created these rights on a first come first serve basis, soon called “prior appropriation”. These same rights created in a period of chaos and free-for-all, are still what generally govern who receives water on an individual scale today. Some water rights stretch back generations into family lineage because families have lived on the same land for over a century and retained the same water rights created under prior appropriation. Though allowing those who claim water to be entitled to it may have worked in the 19th and even 20th centuries, with the high water use in the west and extreme droughts today we must be sure we are using water as efficiently as possible. A system founded on settlement, which can be effected by so many other factors, doesn’t logically seem as if it would come together to form the most efficient or practical system of distributing water.

## **2. History of Water Rights**

Western Water Rights were most heavily influenced by where the early settlers lived. When they first moved into an area, they needed water a larger amount of water than what was readily available to them so that they could till the land to survive. This led to the creation of prior appropriation, eastern water rights, called Riparian rights, allowed any property abutting a water source to have access to that water. This worked because the east’s agriculture industry was able to be supported by the large number of rivers (California Environmental Protection Agency, 2016). However, the West had so few rivers that a new way of distributing water had to

be created. This led to the transferring of water miles away from a river, and consequently those settlers exerting the energy to divert the water wanted to make sure this water was entitled to them presently and for all time. Thus, prior appropriation was written into law with the Supreme Court case *Matthew W. Irwin V. Robert Phillips* in 1855. This ensured that anyone using water for 'beneficial use', which is defined as anything that benefits the individual, other people, or society (Produced Water Treatment and Beneficial use information center, 2001). These laws remain very much the same today with Western states, providing water to those who originally settled and used water.

Delph Carpenter proposed similar litigation on a multi-state level to divide up the water from the Colorado river into two large areas, the upper and lower basin. The upper including Utah, Colorado, Wyoming, and New Mexico, and the lower California, Arizona, and Nevada each receiving 7.5 MAF with 1.5 MAF going to Mexico. To further distinguish where water goes first, some states like California have senior water rights, meaning, like prior appropriation, they are guaranteed their water before a Junior state like Arizona gets theirs. This is because in 1968, in exchange for the Central Arizona Project, Arizona agreed to be last to receive water if a drought struck (Hiltzik, 2014). In years of drought, this means that Arizona can be short of water with no legal way of obtaining it, further the Colorado River was measured by the Reclamation Bureau to flow at about 16 MAF when in reality it is more around 13 MAF further restricting the compact, which was built around the larger approximation (Gelt, 1997). You can see that the current Western water rights system is largely just a more complex version of the original historic rights that allowed the land to develop as quickly as possible.

### **3. Ecological Ramifications of Water Transfers namely the Salton Sea**

The Imperial Valley is an archetypical example of the pull between agricultural and metropolitan uses of water in the divvying up of water rights. In 1928 the local irrigation authority completed the larger All-American canal and in the same year Calvin Coolidge designated the Salton Sea as an agricultural sump for the Colorado River water that was now being sent there (Polakovic). This, paralleling the larger consequences of diversions on the water rights system, both saved the Sea and doomed it in the long term if nothing was done.

The early settlement of the valley for agriculture, a water intensive activity ensured a large water appointment to the Imperial Valley, which currently stands at 3.1 MAF out of the 4.4 MAF California receives for the entire state. With the low levels of water in the Salton Sea and the arid climate it was due to dry up in a few decades, but the agricultural runoff, made possible from the high entitlement of water, draining into the terminal lake from the surround Imperial Valley farms has sustained it for the past century. At the same time this runoff carrying large amounts of nutrients has turned the Sea into a looming ecological disaster, building up more nutrients and salinity every day.

The tightening restrictions on water rights and overall amount of available water have led California to have to actually decrease its water usage beginning in the early 2000's. When Arizona began to use its full entitlement California was no longer able to usurp its excess and the cities suffered greatly. This led to the selling of the Imperial Valley water to the Metropolitan Water District of Southern California in what is known as the Quantification Settlement Agreement, or QSA(San Diego Water Authority, 2016). This was necessary in order to cope with the water shortage while still providing it to places and people that needed it. The decrease in

water in the Imperial Valley has brought in revenue, but had disastrous effects on the already dying Salton Sea's water level and net evaporation rates. The Salton Sea requires immediate action in order to save it from disaster, whether that comes from more water being delivered to the Valley in water rights, a complete overhaul of the water rights system, or using the current amounts of water in different and more beneficial ways.

Furthermore, it is illustrative of how the agricultural industry and urbanized areas are too busy fighting to consider the ecological impacts of their actions. This problem isn't confined to the Salton Sea either, it keeps recurring- Mono Lake, Owens Lake, the Aral Sea- their thirst for progress has blinded them to the consequences of their actions.

#### **4. Problems within the water rights system**

Even with all the laws, entitlements, and appropriations that control water rights, the main flaws arise from a lack of organization and accountability within the governing. A lot of water is wasted in the process of getting what from where it is being diverted from to where it is being diverted to. When it rains in the Imperial Valley many farmers close their irrigation canals, when enough of them do this there is a buildup of water up-canal. The all American Canal continues to flow and the water has nowhere to go once it reaches the Imperial Valley, so it spills out of the canal wasting whatever the flow rate of the canal is at that moment multiplied by the amount of time the farmers don't use water for. The Imperial Irrigation District (IID) has addressed this by making plans to build a small reservoir at the end of the All American Canal in order to store overflow water, but this and many other problems plague the Valley's precious water supply. These wastes included about 400,000 MAF acre feet of waste per year and this was only in the Imperial Valley's system alone. Wastage like this occurs all across the West and has been overlooked until now because water wasn't so scarce.

Another problem with the water rights system is it encourages farmer to use their full water allotment even in years they don't need it. This is because if farmers don't use their full water right the government is allowed to decrease it, so farmers out of self-interest and self-preservation are using their full allotment even just to overwater fields that have already received enough water. If even 30% of farmers in just the Imperial Valley were wasting 10% of their water this way that would come out to almost 100,000 AF of waste a year, or one third of the QSA at its highest transfer rate. In reality, it is extremely hard to estimate these figures as we don't know when the farmers are using the water rightfully or just trying to keep their allotments (Obegi, 2016).

#### **5. Other Models for Water Rights Systems**

Water rights were created in a time of chaos in order to appropriate water to whoever claimed it first. By piggybacking off those rights instead of creating new ones to match a more complex and restrictive system we are wasting water. The water rights system allows those who first settled the west to abuse their rights and with no accountability or punishment, they will continue to use as much water as they can. In my opinion a complete overhaul of the water rights system is necessary, and we can look to Australia for guidance. Australia is very similar to California in many ways: high coast population, arid climate, and extreme heat, the only difference is their drought began all the way back in 1997 and lasted a full 13 years. This forced

them to revamp their water rights in a way California might have to do if their drought continues like Australia's did.

Australia operates differently than the US in that their water rights are part of a fully connected system. This means that instead of water being divided up on federal, state, and local levels, like it is in the US, which makes it hard to change the course of water once it is allocated, in the Australian system anyone can trade water with any other member of the system leading to less waste. This is a much more advanced version of the trade houses the IID is setting up, but the beginnings of this new system seem to be there in the US. Furthermore, they promise water first to those who need it most like orchards and vineyards, then to all other crops that only receive 30 to 80% reliability on their allotment (Simonetti, 2015). This seems to work a lot better than using time as a measure for higher guarantee. Lastly, Australia has meters in place that account for every drop, this keeps people honest and helps them to realize where their water is going further eliminating waste. Looking to Australia's system is not a perfect solution, because Australia does not have the property rights protection the US does, which makes the US's system far more entrenched and hard to change than theirs was (Boxall, 2015). Though California's system would face much more opposition than Australia's did, it could save a lot of water and time to look to Australia for a remodeling of California's water system.

## **6. Conclusion**

It seems counterintuitive at first glance to grow food in a desert, and though it was harder to question after feeling the sheer magnitude of farming in the Imperial Valley and other areas in the west, growing food in a desert is not sustainable or efficient. For example, the desert that is Arizona plans to phase out farming in the long term. This is because the desert was never meant to support agriculture especially when cities need that water, and that water will only become more vital in the coming years (Fresh air, 2015). The water rights system in the Western United States was created in a time of when we weren't thinking about US population of 319 million, today with extreme droughts, and such high water needs it is more important than ever that we fix the system. Through accountability, system-wide efficiency measures, and laws that allow trade of water instead of encouraging waste, the US can ease the tensions of the drought. Though these efficiency measures would actually only directly hurt the Salton Sea, currently it is hard for California to even worry about the Sea because of other water priorities. By easing the tension, we would not only save water that could be allocated to a place like the Salton Sea, but also make it easier to focus on the Sea and other ecological disasters that in the future will cost the state even more money.

## References

- Fresh air, 2015. How a historical blunder helped create the water crisis in the west. NPR.
- San Diego Water Authority, 2016. Quantification Settlement Agreement. San Diego Water Authority. 1-2.
- California Environmental Protection Agency, 2016. The water rights process. California Environmental Protection Agency.
- Bettina Boxall, 2015. Lawsuits over California water rights are a century in the making. Los Angeles Times.
- Carson Bruno, August 2015. Australia can teach us about drought. The Mercury News.
- Jeff Simonetti, May 2015. Australia's Water Rights System - A look of things to come in the state of California post-drought. Hydrowonk Blog.
- Delph E. Carpenter, November 1922. Colorado River Compact. United States Congress. The Water Information Program. Colorado Water Rights. The Water Information Program.
- Gary Polakovic. Farm Runoff: It's an ongoing Challenge. The Press-Enterprise
- Doug Obegi, July 2016. Accounting and accountability in California Water. NDRC.
- Kurtis Alexander, September 2015. 5 fixes for California's age-old water-rights system. San Francisco Chronicle
- Produced Water Treatment and Beneficial use information center, 2001. What are 'beneficial' uses?. Produced Water Treatment and Beneficial use information center
- Michael Hiltzik, June 2014. Water war bubbling up between California and Arizona. Los Angeles times.



# Consequences of Water Use and Diversion in the American West

Wilson Kaplan  
Colorado College

---

## Abstract

The West is struggling with water scarcity and allocation. Today's water problems can be traced to historic American attitudes on water, which often led to irrational water policies. In the West, water was diverted away from rivers and apportioned to distant cities and farms. Mono Lake and the Salton Sea are two examples of the damaging environmental consequences in diverting water from its natural path. Restoring these two ecosystems is a difficult task that both takes time and money. To avoid future ecosystem collapses and the costly restoration projects, water conservation has become a major consideration when providing water to agriculture and population centers.

---

## 1. Introduction

The sprawling cities on the California coast and lush green farms of the Imperial Valley all started as desert. The major diversion of water from the Colorado River that has transformed these deserts can either be viewed as a great success or a great mistake of American capitalism. Recently, the West has been plagued by droughts that have caused water deficits. As a result, water must be conserved to meet the water demands of a growing population and maintain an extensive agriculture industry. Water-saving legislation must be passed if any of these goals are to be achieved. Before that can happen, there will have to be changes in the way people think about water.

## 2. Manifest Destiny and Water in the West

As Americans spread westward during the 1800s and early 1900s they felt that they were the rightful owners of the land and water around them. Farmers were lured into going west with promises of flat land with good soil and a longer growing season (Reisner, 1986). Propaganda from land developers led settlers to believe that there would be enough rainfall to farm the land. In fact, many believed the preposterous claim that "the rain follows the plow" (Reisner, 1986). But after years of drought across the West in the early 1890s, the government realized that rainfall in most western states was not adequate to grow crops. To make farming work, both the state and federal governments invested in enormous irrigation projects to bring river water to dry fields. In 1902 the Bureau of Reclamation was formed to "reclaim" the deserts of the West through water diversion and irrigation. The Bureau spent billions to construct canals across the west.

This practice turned out to be economically viable in California's Imperial Valley, where gravity carried water from the Colorado River all the way to the valley's farms. Also, the valley's warm climate allowed for high value crops like fruits and vegetables to be grown year round. But, not all areas of the west are as ideal for farming. In colder, higher elevation areas the farms

are substantially less productive because the growing season is much shorter (Reisner, 1986). Therefore, virtually all crops grown in Utah, Wyoming, or Colorado can be considered a waste of irrigation water and government money. But the 1928 Colorado River Compact protected the water of upper basin states, ruling that lower and upper basin states are both entitled to 7.5 million acre feet of water per year. So even though it did not make economic sense for farmers to grow in the upper basin they were legally entitled to the water and subsidized by the government. This is only one example of politically driven western water policy that was not based on a rational or economic division of water rights. In Cadillac Desert, Marc Reisner attributes the absurd uses of water to the “blind ambition” of the Bureau of Reclamation and the pressure applied by business interests. But in another sense, irrational water use can be tied to the underlying American belief that people have a sacrosanct right to water.

Once water was diverted to western cities, populations soared. And with skyrocketing populations cities needed more and more water. By the early 1900s, the city of Los Angeles was facing water shortages. To satisfy its need for a greater share of the water allotment, the city diverted almost all of the Owen’s Valley water by buying up the water rights to the Owens River. As a result, Los Angeles had excess water for decades and the Owen’s Valley farms dried up were. The diversion of water from farms to cities has become a common trend. Most recently, San Diego has paid for 200,000 acre feet a year of Imperial Valley water to sustain the city’s ever-increasing population in a 2007 deal called the Quantitative Settlement Agreement ([www.sdcwa.org](http://www.sdcwa.org)). Agriculture and growing population are competing for finite water allotments. An additional concern is the effect of water diversion on the environment.

### **3. Negative Consequences of Water Diversion on the Environment**

Unfortunately, the massive western water diversion has had and continues to have many negative impacts. Wasteful water practices eventually led to water shortages in expanding cities and environmental disasters in wetlands and rivers. Dams are one example of a manmade water control that has many negative environmental consequences. Because dams stop the natural spring flooding in rivers, the downstream ecosystem is negatively affected. Sediment is not carried down the river which causes river banks to shrink and hurts the ecosystem of the riparian zone. Dams also act as a physical barrier for fish, so certain species can no longer swim up or downstream. The Hoover and Glen Canyon Dams have also significantly limited the amount of water that drains into the Gulf of California (Sanchez, 1999). Factors ranging from salinity to amount of uplifting in the area near the Colorado River delta have dramatically changed with the decreased outflow, which has affected the gulf’s ecosystem (Sanchez, 1999). Along with the vast environmental consequences, dams actually worsen the West’s water shortage. Glen Canyon Dam created Lake Powell which currently has an area of 254 square miles; the lake loses approximately 160 billion gallons of water to evaporation every year which is a waste of a limited resource. These findings have called into question whether dams cause more harm than good from both environmental and water conservation perspectives.

Along with taking water from the Owens River in the early 1900s, Los Angeles also diverted water from Mono Lake starting in 1940 (Cantor, 2016). By the 1990s the water level of the lake dropped over 40 feet because evaporation rates remained constant as less stream water flowed into the lake. This caused the lake’s fragile ecosystem to fall into a sharp decline (Little, 1997). One example of animals hurt by the water diversion is the birds who nested on Negit

Island. Historically, the island's isolation had protected birds from predators but by the late 1970s the water level had dropped substantially, forming a land bridge which predators could cross. Because of the increase in predation, species diversity dropped on Negit Island. The ecosystem collapse on the island is only one example of the environmental consequences from diverting water from its natural path.

#### **4. Restoration**

Eventually the State of California intervened at Mono Lake and stopped the water diversion. One of the major reasons the state could legally conserve Mono Lake was the lake's "rights" under the Public Trust Doctrine, which became Federal law in 1892 (Cantor, 2016). The doctrine entrusts every state to protect their "navigable bodies of water". Therefore, California was legally bound to protect Mono Lake for "human and environmental uses" (State Water Board Decision-1631, 1994). The State Water Board's ruling in 1994 dictated that water levels would need to rise 17 feet before the city could begin diverting water again (Cantor, 2016).

One of the major difficulties in protecting the Salton Sea is that the Public Trust Doctrine does not protect the sea. The law cannot be applied to the sea for two major reasons: First, the sea is a temporary lake that did not exist when California became a state in 1850 (Cantor, 2016). The new state acquired the rights to all bodies of water which did not include the Salton Sea. Therefore, the Sea was never formally recognized as a protectable body of water. Second, the lake is considered an agricultural sump, not a natural body of water, because it was created by accident in 1905 (Goodyear, 2015). The second point is contentious because the sea would have eventually formed naturally had the Colorado River not been damned.

#### **5. Salton Sea Restoration**

Even though it is not, legally, California's job to protect the Salton Sea, measures should be taken soon to fix the sea because of the vast human and environmental impacts of a smaller and saltier sea. Since 2007, San Diego has pulled 200,000 acre feet per year of water from the Imperial Valley and by 2018 mitigation water provided by the QSA will stop flowing into the sea. That means that after 2018 water levels will drop even faster if no action is taken to replenish the sea. Less water in the Salton Sea is detrimental to the health of people in the valley. The area already has the highest rate of asthma related hospitalizations in all of California and as the lake's decreasing depth exposes playa, more dust is blown toward population centers (Goodyear, 2015). It is estimated that wind could pick up a hundred tons of toxic dust a day if the lake dries up completely, which would cause a health disaster in the surrounding area (Iovenko 2015). The dust would also hurt the farms of the Imperial Valley which are some of the most productive in America and provide the majority of the nation's winter produce. The sea is also home to 426 species of migratory birds (Schuford, 2002). If the sea shrinks the salinity will increase which will make it hard for birds to find a food source.

To make matters even worse for the sea, Imperial Valley farms are conserving more and more water by lining canals and using less water intensive means of irrigation, so less irrigation runoff and ground water is flowing into the lake. Farms are trying to use less water because if they waste water, cities could claim that the farms are not putting their water allotment to beneficial use. If beneficial use is not met, then farmers could lose a portion of their water right (Tina Shields).

Many conservation solutions have been proposed for the sea. All would use a combination of federal, state, and local funds. One idea is to build a “peripheral sea” with restored wetland ecosystems around the outside of the current sea ([www.sdcwa.org](http://www.sdcwa.org)). The inside of the lake would become a brine sink. Dust could be controlled by furrowing the exposed playa or planting local plants (Salton Sea Funding and Feasibility Action Plan, 2016). The plan would cost approximately three billion dollars to implement. Some more far flung ideas include “sea to sea” restoration which would involve pumping water out of the Salton Sea to the Sea of Cortez, while also pumping water from the ocean to the lake. Unfortunately, the project is expensive and it would take years for the lake to reach ocean-like salinity. To test the peripheral sea solution, a relatively small project is currently being built in Red Hill Bay near the Sony Bono wildlife preserve. Exposed playa will be flooded with water of varying salinities to encourage a wetland that will help aquatic animals and migratory birds.

## **7. Conclusion**

To avoid future environmental disasters like Mono Lake and the Salton Sea, water use must be decreased, not simply diverted. The reality is that the West’s population is expanding faster than ever. Therefore, water conservation in households, cities, and farms is crucial. The average Californian uses 196 gallons of water a day and approximately 75% of household water use is used in landscaping (Warner, 2016). Americans should be educated about water as a finite resource to change the common mindset that unlimited water use is a god-given right. Also, new technology in household appliances could minimize water use. On a larger scale, industrial farmers are finding ways to minimize water use. In the Imperial Valley, canals are lined to reduce water lost to ground seepage and farms are beginning to use more advanced irrigation techniques that conserve water. Some farmers are using drip irrigation to minimize water lost to evaporation. And, western cities have put water restrictions in place, in Los Angeles residents are actually paid to replace their “water inefficient grass” with native plants ([dpw.lacounty.gov/Conservation](http://dpw.lacounty.gov/Conservation)). That program alone has converted over 2 million square feet of lawn. But even with conservation, there will have to be tough choices for water distribution. It seems impossible for an objective bystander to decide between the environment, farms, and cities. Farmers in the Imperial Valley seem to believe that cities will continue to gain water rights because the metropolitan areas have the strongest lobbying powers. One farmer admits: “I know that we’ll lose eventually”. His bleak outlook reflects the potential consequences of lawmakers controlling water in the American West. It remains unclear whether lawmakers can create water policy that rationally balances agriculture, population centers, and the environment.

## References

- Cantor, Alida. "The public trust doctrine and critical legal geographies of water in California." *Geoforum*, vol. 72, June 2016, pp. 49-57. *Web of Science*. Accessed 18 Oct. 2016.
- Goodyear, Dana. "The Dying Sea." *The New Yorker*. N.p., 4 May 2014. Web. 10 Sept. 2016.
- Iovenko, Chris. "Toxic Dust from a Dying California Lake." *Atlantic* 9 Nov. 2015: n. pag. Print.
- Lavin, Salvador. "On how the Colorado River Affected the Hydrography of the Upper Gulf of California." *Continental Shelf Research*, vol. 19, no. 12, Sept. 1999, pp. 1545-50. *Web of Science*, [www.sciencedirect.com/science/article/pii/S0278434399000308](http://www.sciencedirect.com/science/article/pii/S0278434399000308). Accessed 18 Oct. 2016.
- Little, Jane. "Mono Lake: Victory over Los Angeles turns into local Controversy." *High Country News*, 8 Dec. 1997, [www.hcn.org/issues/120/3820](http://www.hcn.org/issues/120/3820). Accessed 18 Oct. 2016.
- Reisner, Marc. *Cadillac Desert*. Penguin, 1986.
- Sanchez, Salvador. "On how the colorado river affected the hydrography of the upper Gulf of California." *Continental Shelf Research*, vol. 19, no. 12, Sept. 1999, pp. 1545-60. *Web of Science*.
- Shuford, David. "The Salton Sea as critical habitat to migratory and resident waterbirds." *Hydrobiologia*, vol. 473, no. 1, 2002, pp. 255-74. *Web of Science*. Accessed 18 Oct. 2016.
- Warner, Laura. "Classifying Residents who use Landscape Irrigation: Implications for Encouraging Water Conservation Behavior." *Environmental Management*, vol. 58, no. 2, 13 May 2016, pp. 238-53. *Web of Science*, doi:10.1007/s00267-016-0706-2. Accessed 18 Oct. 2016.
- White, David. "Sedimentation and the Economics of Selecting Reservoir Size." *Water Resources Research*, vol. 23, no. 8, Aug. 1987, pp. 1443-48. *Web of Science*, [onlinelibrary.wiley.com/doi/10.1029/WR023i008p01443/epdf](http://onlinelibrary.wiley.com/doi/10.1029/WR023i008p01443/epdf). Accessed 18 Oct. 2016.
- "The Quantification Agreement." San Diego Water Authority. N.p., n.d. Web. 16 Sept. 2016.

# **Native Americans and Water in the Western United States with a focus on the Torres Martinez Cahuilla Desert Indians and the Salton Sea**

Ben E. Murphy  
Colorado College

---

## **Abstract:**

The purpose of this paper is to inform the reader on the complex relationship between Native Americans and water management and allocation United States, including both the historic and contemporary aspects of this issue. The paper also analyzes the history of the Torres Martinez tribe and the current dynamic between the tribe and the Salton Sea. The paper also delves into the legal aspect of Native American water rights.

*Keywords:* Native Americans; Torres Martinez; *Winters v. United States*; Debi Livesay; arsenic; Colorado River

---

## **1. Introduction**

Water has been, and always will be, a central component of survival and it is therefore important to understand this facet of human life. The ways in which people have managed water has both permitted the existence of societies and has instigated their demise. In the western United States water is a scarcity, and the Colorado River serves as the lifeblood of the region. Indigenous North American people have been manipulating the Colorado River for a very long time. In fact, the most dated archeological evidence of irrigation structures in the western U.S. is from 2,000 years ago. These structures were built by the Hohokam tribe in what is now Phoenix, Arizona (Singer). Once Americans began to settle the West, the Bureau of Reclamation initiated programs and projects that would make the desert bloom. Access to water became synonymous with progress. Unfortunately, as infrastructure was being built to make agriculture possible, many Native American tribes were neglected when it came to water access. Furthermore, some of the irrigation projects initiated by the U.S. government and private companies resulted in disasters. One such disaster was the unintentional flooding of the Salton Basin in 1905, which inundated much of the Torres Martinez reservation. Since the creation of the Salton Sea, water has been an issue for this tribe. In essence, since the early 1900's, the management of water in the West has either been life-sustaining or life-threatening for Native American tribes.

## **2. Native American Water Rights in the Colorado River Basin**

The Colorado River is a heavily managed river in the United States: there are two interstate compacts, an international treaty, many state and federal statutes, and many Indian water rights settlements that revolve around the management and allocation of water from the Colorado River (Cordalis A., Cordalis D., 2015). Yet, of the 277 federally recognized tribes in the West, many of them are in need of reliable sources of water today. In order to fully comprehend the relationship between Native American in the river basin and water, one must understand the

history of Native American water rights and litigation. Potentially the most significant litigation for Native American water rights was the Supreme Court cases: *Winters v. United States*. In 1905, a conflict arose between American settlers and Gros Ventre and Assiniboine Indians. The Native Americans relied on the Milk River for water and had for many years. However in the early 1900's, white settlers built an irrigation project that left little water downstream for the Native American tribes. Due to overuse by the settlers and a drought in 1905, the Native Americans did not have enough water resulting in dead crops and empty stomachs the following winter. The United States filed suit on behalf of the tribe, and ultimately the Supreme Court came to the conclusion that when the federal government gave the tribes land for a reservation water was also being given to the tribes, at least enough to "reasonably... irrigate their lands" (Cordalis A. and Cordalis D., 2015). Therefore, the Native Americans were legally promised an appropriate amount of water. This case laid the foundation for all other litigation that revolved around Native American water rights.

Today, the state of the West is such that water is over-allocated according to a study completed by the Bureau of Reclamation in 2012 (Cordalis A., Cordalis D., 2015). Even though Native American tribes are legally promised the correct amount of water many tribes run into the issue of quantification of the tribe's water right. Essentially, the amount of water these tribes deserve is unknown because it has not been calculated which is an expensive legal process. However, of the 28 tribes in the Colorado River basin today, 16 have managed to quantify their deserved amount of water resulting in nearly 2.9 million acre-feet of water for the tribes each year (Cordalis A., Cordalis D., 2015).

### **3. History of Native American in the Salton Basin**

Long before the era of water litigation, indigenous peoples existed and thrived in the arid environment of the southwest United States. Human existence in the desert was made possible by the meandering Colorado River which slowly built its delta for more than three million years. Once the river reached southern California, the topography of the region created a natural dam near the Salton Basin. The direction of the delta fluctuated from north to south over thousands of years, and with each switch, the basin would fill with water or slowly dry up. The last major lake to exist in the Salton Basin was Lake Cahuilla, a 2,000 square mile expanse of fresh water that originated about 900 years ago (Singer).

The abundance of water and nutrients that Lake Cahuilla provided permitted Native Americans to create societies surrounding the massive body of water. Slightly after the creation of Lake Cahuilla it is believed that a tribe of people, connected to the Aztecs by language, migrated to the lake. However, by the time Spanish explorers discovered the region in the 16th century the lake had dried up, but the people who lived in the basin told legends of a massive lake full of fish that once existed in the middle of the desert. Inevitably, ancient Lake Cahuilla had slowly dried up as the Colorado River changed its course. This event is thought to have occurred by the year 1600 (Singer).

During the height of ancient Lake Cahuilla's approximately 300 years of existence, Native American tribes flourished from an abundance of fish and water for irrigation. The Cahuilla peoples diet consisted of fish, acorns, mesquite beans, seeds, fruits, agave and yucca. Today, there is archeological evidence of Indian fish traps made of stone on the periphery of what once was Lake Cahuilla. The indigenous people had a well developed trading system with neighboring

tribes in which they would trade food, shells, animal products, and mineral. The number of people living around Lake Cahuilla during this time fluctuated with the river. Today, tribes still inhabit the area, including the Torres Martinez Desert Cahuilla Indians.

#### **4. Torres Martinez Desert Cahuilla Indian Tribe**

In 1876, an executive order given by President Ulysses S. Grant created both the Torres and the Martinez reservations for the Cahuilla people that had inhabited the area north of the Salton Sink since the early 1800's. Then, in 1891, the two reservations were combined and expanded by 12,000 acres under the Relief of Mission Indians Act of 1891. Fourteen years later, an engineering mistake on an irrigation project directed by California Development Company created an influx of water into the Salton Sink for two years, inundating 2,000 acres of the land originally designated to the tribe in 1891 and creating the Salton Sea ("U.S.C. Title 25 - INDIANS," 2007). In 1909, the tribe was given an additional 12,000 acres of land. However, 9,000 of those acres were located in the Salton Sea. The the US government gave the tribe the inundated land because it was believed that this new sea would dry up in 25 short years. Because the Salton Sea has the New River, the Alamo River, and the Whitewater River flowing into it the 25 year figure was an underestimate to say the least. Of the 22,000 acres of land belonging to the Torres Martinez Desert Cahuilla Indians today, half is still submerged in water (Dirmann, 2002).

The Torres Martinez tribe is one of the poorest in California. Many in the tribe do not have access to electricity and running water. The drinking water that the tribe does have access to comes from a very full aquifer that is polluted with the arsenic. The EPA investigated the public water system which provides water for about 260 people in the tribe through the tribal clinic, administrative building, and residential homes. The EPA found that the system had been "out of compliance" since 2009 (Marx, 2015). In March of 2015, the arsenic levels reached 16 parts per billion; the federal regulation limit of arsenic in drinking water is 10 parts per billion (Marx, 2015). Skin cancer and skin lesions are the most common long term effects that one would experience from drinking groundwater with a concentration of arsenic higher than 10 parts per billion (World Health Organization). There have not been cases of cancer clusters in the Torres Martinez tribe, but the exposure to higher levels of arsenic in the communities drinking water has occurred for only 7 years. Also, it is impossible to differentiate cases of cancer caused by arsenic from cancers caused by other factors (World Health Organization).

Unsurprisingly, the tribe does not have the financial means to buy arsenic filtration equipment. The current plan for the Torres Martinez tribe is to access the Coachella Valley Water District's water supply by building a pipeline which was originally planned to be completed in June of 2015. This pipeline would cost \$750,000 to build and administer, but the tribe has asked for a grant from the EPA to complete the project (Marx, 2015). Arsenic also occurs in the Coachella Water District's water supply, and in some areas in dangerous levels because arsenic contamination is widespread, but the water from Coachella is generally safer than the groundwater the tribe currently has access to.

Despite the poverty and poisonous water supply the Torres Martinez tribe has been drinking for potentially a decade, they are grasping onto the hope of accepting a \$14 million settlement check from the water districts and the US government after 15 years of litigation (Dirmann, 2002). This \$14 million is purportedly being paid to the Torres Martinez tribe as an



amends for the initial flooding of the Salton Sea more than 100 years ago. The money is essentially a compensation for the 11,000 acres of reservation land that is currently underwater.

## **5. Salton Sea Restoration**

The Torres Martinez tribe is in a unique position when it comes to preserving the Salton Sea habitat. The tribe is the largest private owner of lands in and around the Salton Sea. Furthermore, embedded into the morals of the tribe is the ideology of planning 7 generations into the future (Torres Martinez Desert Cahuilla Indians, 2016). The tribe has the land and the moral obligation to preserve and restore the ecosystems around the sea that are slowly degrading as more pollutants enter the sea from agricultural runoff and as the salinity rises. As the water level continues to decline, the tribe is increasingly at risk of the 100 years of selenium and pesticides that have accumulated in the water.

To mitigate these problems the tribe completed a pilot project in which they have created an 85 acre wetland at the mouth of the Whitewater River. This project aims to provide water treatment, dust stabilization, and habitat restoration through the implementation of seven water quality cells and four habitat ponds (Mayton, 2015). This project was initiated in large part by a woman named Debi Livesay who is the head of water resources for the Torres Martinez tribe. Livesay received a \$2.3 million dollar fund from state and federal agencies and began working on the small scale project in 2005 (Kelly, 2008). Since then the project has been finished and is a thriving ecosystem for birds and fish. The Torres Martinez tribe will play a vital role in the preservation of the Salton Sea ecosystem. Because the tribe owns the land, they can work on wetland projects without the consent of others. Livesay has the ambitious goal of creating 10,000 acres of preserved wetland around the northern reaches of the sea. Livesays advisor, a biologist named Monica Swartz told L.A. Times in 2008: “The Torres Martinez are the only group taking responsibility for it (the sea). Everyone else is talking, but they are the only ones doing anything about it” (Kelly, 2008).

## **6. Conclusion**

The ecological restoration the Torres Martinez tribe has accomplished in the Salton Sea is remarkable given the strange paradox they face. The tribe is attempting to alleviate a problem that was imposed upon them even though they do not have the financial means to do so. Debi Livesay’s example is a symbol of hope for Native Americans all throughout the West that face ecological crises regarding water that they did not necessarily create. Livesay exemplifies the determination and leadership that one must have when fighting for the integrity of ecosystems and the equality of water.

Water in the western United States will continue be a contentious issue for Native Americans. Native Americans being neglected in water allocation is an injustice; the ways in which the government and individuals manage water in the future must be equitable for everyone, especially for the indigenous people in the West that have been using the water for thousands of years. Ultimately, the management of water needs to prioritize human health and the local ecology.

## References

World Health Organization, 2016, Arsenic.

Cordalis, A., Cordalis, D., 2015, Indian Water Rights: How Arizona v. California left an unwanted cloud over the Colorado River basin.

Dirmann, T., 2002, Tribe Impoverished by Salton Sea Gets Windfall, Los Angeles Times.

Kelly, D., 2008, Throwing Salton Sea a Lifeline, Los Angeles Times.

Marx, J., 2015, Torres Martinez Tribe, EPA Work out Deal on Arsenic, The Desert Sun.

Mayton, H., 2015, The Torres-Martinez Band of Desert Cahuilla Indians, Wordpress.com.

Singer, E., Ancient Lake Cahuilla, San Diego State University.

Torres Martinez Desert Cahuilla Indians, 2016, Water Resources, Torres Martinez Tribe.

U.S. Government Printing Office, 2007, U.S.C. Title 25 - INDIANS.

# **A Green Oasis in the Desert: The History of Immigration in the Imperial Valley**

Silas J. Farwell Mead  
Colorado College

---

## **Abstract**

The Imperial Valley is one of the most important agricultural zones in the world. Cleft out of the desert by amazing feats of human engineering, this tucked away corner of California is often forgotten yet is very important. The Salton Sea is important for bird life of the western flyway but is also potentially dangerous to humans. The history of this region is important because it places the current situation in context.

---

## **1. Introduction**

The story of the Imperial Valley is a story of migration and water. How has this arid valley below sea level been transformed into one of the most productive swaths of farmland in the world? Before 1907, Imperial County did not even exist. Today, the population is about 180,000 and the food produced from the valley is essential for the United States and the world. Directly to the North lies the Salton Sea, a saline sea that collects agricultural runoff from the Imperial Valley and supports huge numbers of migratory birds. The Salton Sea and the Imperial Valley interact in an interwoven existence; the story of the Imperial Valley is the story of the Salton Sea. Humans have been calling this area home for thousands of years. Native Americans migrated around the valley when there was water; farmers flocked in when the valley received Colorado river water; Okies fled here during the dust bowl; and Hispanic immigrants call this valley home because of the work opportunities it offers. In order to look at the current state and the future of the Imperial Valley, first we have to examine its past.

## **2. Early History of the Imperial Valley**

The Salton Sea region and the Imperial Valley have been explored by humans for millennia. The low elevation of the region allowed a large inland lake called Lake Cahuilla to form in the Salton Sink at various times as the Colorado River flooded. This natural occurrence happened every few hundred years. This occurred because the Colorado River naturally changes course as it carries tons of sediment to its mouth, which eventually causes certain channels to silt up, changing the course of the river (Ponce, 2005). When the course of the Colorado River would shift towards the Salton sink, the water would naturally flow downhill and fill up the entire valley in a terminal lake. The river would then change course again and flow towards the Gulf of California, leaving Lake Cahuilla to slowly dry up over time until the next flood occurred. Lake Cahuilla was six times the size of the current Salton Sea; its massive size is evident on the bathtub line on the side of hills near the sea. Native Americans lived near the lake and grew crops and fished for about the last 900 years. When the lake would dry up, the Native Americans would retreat into the mountains to find food and other sources of life. The impact of Lake Cahuilla on

the region is evident in the deposits from salt and other minerals and the vast flatness of the old lakebed (Singer).

The Imperial Valley had been explored by the Spanish in the 16<sup>th</sup> century, who proclaimed that the lake was a barren wasteland as there was no Lake Cahuilla at the time. Later, in the 19<sup>th</sup> century, American explorers came to the region and heard Native American tales of the ancient lake (Singer). It was clear that there had been water in the region at one time from the Colorado River. The idea to bring water to the Imperial Valley began in the 1850s. Water shapes the landscape and dictates survival in the desert. In 1901, the California Development Company started to build a canal from the Colorado River which was called the Alamo Canal (“All-American Canal”). However, this diversion that fed the thirsty Imperial Valley led to the flooding that unintentionally created the Salton Sea. In 1905, an unexpected flood breached the levees on the diversion and led a slow moving river full of sediment to creep towards the Salton Sink, the natural low point in the area. By the time the river was brought under control in 1907, the water had collected to form the current iteration of Lake Cahuilla, or the Salton Sea (Ponce, 2005). This single human mistake has led to many debates and headaches about what to do with the Salton Sea.

American settlers had traveled through the Imperial Valley during the 19<sup>th</sup> century via the Southern Emigrant Trail. However, the valley was just a barren walk through region at this time and its agricultural potential was not considered. In the 1890s, water engineers started to bring in water and irrigate the desert. They renamed the valley the Imperial Valley in order to entice settlers. Settlers were allowed to come and take land via the Desert Land Act, which allowed settlers to settle an area with the promise that they would irrigate it and try to “reclaim” the arid land (Heuberger, 1993). The introduction of the Alamo Canal allowed more land to be irrigated and the promise of cheap land, the American dream, and the idea of reclaiming the desert enticed settlers to arrive. By 1907, the area had 15,000 residents, leading to the incorporation of Imperial County as the last county in California. The difficult task of bringing life to the desert was alive and running (Heuberger, 1993).

Imperial County was formed and settled by white Americans. These white settlers founded many farms and some of the same families run the 400-odd farms that exist in the Imperial Valley today (Lippert, 2015). Over time, the demographics of the Imperial Valley have shifted. While the valley is mostly Hispanic today, it has always been a home to immigrants of all shapes and sizes over the past century. During the history of the Imperial Valley, Koreans, Swiss, Greeks, Chinese, Italians, Portuguese, Mexicans, Filipinos, French, Lebanese, Japanese, East Indians and African Americans have called the valley home (Perry, 2009). All of these different groups came to the valley with the idea of the American dream strongly in mind; they all wanted to live the rags to riches story and saw farming as the best way to do so.

Over time, different ethnic groups have been prominent in the Imperial Valley based on who is emigrating to the US. For example, Asians and Asian-Americans were very present in the valley during the early 1900s. Similarly, “Okies” became a huge part of the farm labor force during the dust bowl of the 1930s. One group that has been important in the Imperial Valley’s history since the beginning is Mexicans. Due to the valley’s proximity to the border, Mexicans have worked on the farms and called the valley home for over 100 years. The issues with immigration, racism, and abuse of power have existed during this entire time. Over time, however, the

Hispanic population has risen to a point where whites have gone from the majority to the vast minority (Taylor, 2001).

### **3. Strikes, Population Growth, and Demographic Shifting**

Farm owners in the Imperial Valley, as well as elsewhere, have historically held a lot of power over their workers. This imbalance in power has led to resentment and eventually violent or nonviolent protest. In the late 1920s and early 30s there were many strikes by Hispanic farm laborers. In 1928, Mexican farm workers tried to start a union that would allow them to make a decent wage, have access to ice for drinking water, have outhouses, and have legal compensation for injured workers (“What were the Imperial Valley Strikes?” 2011). These demands were made in response to long days in 110-degree weather, low wages, and abusive bosses. In May 1928 the union sent out these requests and refused to work until they were met. The workers occupied the fields and refused to work, leading to 36 arrests in that month. Many laborers returned to work, but still the bosses feared of a large scale uprising and started to make unfair arrests. This led to a state official investigating the situation, and, along with support from officials in Mexicali, led to the workers getting most of their requests met. In the early 30s, during the depression, thousands of workers left their jobs in protest, which led to violent altercations between Hispanic workers and the police. Eventually more fair wages and bonuses were put into place and relative peace was maintained (“What were the Imperial Valley Strikes?” 2011).

The history of the Imperial Valley is mostly composed of non-white farm laborers. However, the 1930s brought in a new and different kind of immigrant: “Okies”. During the 1930s, a period of severe drought coupled with reckless depletion of the soil led to the Dust Bowl in the once prosperous farmland in the middle of the country. Winds picked up the parched soils and created massive dust storms that coated everything in dirt and made life impossible. People from Oklahoma were traditionally used to living nomadically, so heading to the greener pastures of California seemed to be a natural step. Between 1935 and 1940, 250,000 Okies immigrated to California (Mullins, 2009). The natural course of action for these Okies was to work as farmers, which led to displacement of Japanese, Filipino, and Mexican laborers. In the Imperial and San Joaquin valleys, Okies congregated in the tens of thousands and formed tent cities on the edges of farms. The influx of workers reduced wages, allowing farmers to pay the Okies less than their previous foreign laborers. Okies were viewed as dirty, stupid, inferior people, despite their whiteness. This relationship is very interesting to observe; white people were discriminated against just as much as non-white people because they were unskilled farm workers (Mullins, 2009).

In the early 1900s, it was clear that the population of the Imperial Valley was growing and the limiting factor, as with anywhere in the desert, was water. The Imperial Valley receives 2.3 inches of precipitation annually, so the importation of water is essential for life (Ponce, 2005). In the 1910s and 20s many people lobbied statewide and nationally to get a larger water system to the Imperial Valley. In addition to adding water to the Imperial Valley, having a new canal would allow the United States to have control of the water from the Colorado River. Previously, the Alamo Canal crisscrossed the border and thus was not controlled entirely by the United States or Mexico. Thus the need for an “All-American Canal” became more apparent. After years of work, the canal was ready to use in 1942. Today, the Imperial Valley receives 3.1 million acre feet of Colorado River water, which is a massive allotment. The All-American Canal is 80 miles long, drops

175 feet, and carries all the water for the Imperial Valley. The canal system from the All-American Canal encompasses 1,675 miles of irrigation canals and the reservoirs hold 3,300 acre feet at one time. This life giving canal has transformed the Imperial Valley from a small, dusty settlement of a few thousand into one of the most productive agricultural areas in the world (“All-American Canal”).

#### 4. The Current State of the Imperial Valley

Over time, the Imperial Valley has been getting significantly more and more Hispanic. The population started out mostly white, and then experienced periods of influx from many different ethnic groups (Table 1).

Table 1: Change in the relative proportion of White and Hispanic people in the Imperial Valley over time (data from Taylor 2001)

Year	Percent White	Percent Hispanic
1970	57.1 %	35.6 %
1980	38.6 %	56.1 %
1990	28.9 %	66.0 %
2000	21.7 %	72.1 %
2010	20.1 %	74.0 %

So what is the Imperial Valley like today? The population is currently about 180,000 people living in 4,000 square miles, which is about 43 people per square mile. The median age is 32.6, which is five years younger than the average of 37.8 in the US, indicating that there are many young people looking for work. The valley is currently 83% Hispanic, 12% white, 2% black, and the rest are Native American, Asian, and others. This county is the most Hispanic in the nation because of the massive number of migrant farmworkers. The per capita income of \$15,000 is about half of the US average and less than half of the California average. The most arresting statistic is perhaps the 25.1% of people who live below the poverty line, which is far higher than the national average of 14.7%. The percent of people who hold a high school diploma is only 66.6%, which is significantly lower than the 87.1% of the nationwide average. Additionally, the foreign born population sits at 31.9%, which is more than double the 13.5%% national average (“Imperial County, CA”). These statistics indicate that Imperial County is mostly poor, young, and Hispanic, which makes sense given the nature of the farm labor job.

#### 5. Conclusion

The Imperial Valley is one of the most fertile agricultural areas in the world. This has occurred in the short span of 100 years via a massive amount of Colorado River water that gives life to the desert. Driving through the valley is a surreal site; bright, verdant beds of green form a sharp juxtaposition with the dry hills in the background. The valley is home to a huge number of migrant farmworkers and also daily commuters from Mexico. The opinions on the treatment of these farmworkers differ. The farmers that were interviewed during the Salton Sea trip said that their workers were treated very well and enjoyed their jobs, including long shifts and difficult work. These farmers said that their Hispanic laborers often work just as much as they need to

live off of and have good working conditions. Historically, the relationship between white farm owners and their workers have not always been great and have resulted in low pay and bad working conditions. Indeed, this is still evident today in the strategy that some farmers employ of going to Mexico to utilize cheap labor and less strict laws. This relationship between farm owner and laborer could take an interesting turn after new California laws require a \$15 an hour minimum wage and 8-hour work days. Given that harvesting produce often takes longer than 8 hours, new laws could make some jobs extraneous and make it more difficult for migrant laborers to hold steady jobs. Over all, the relationship between farm workers and farm owners has been strained at times and will continue to be an interesting problem to navigate.

How does the Imperial Valley affect the Salton Sea? The Salton Sea relies entirely on agricultural runoff water from the Imperial Valley. Without the valley, the Salton Sea would be dried up years ago. This water is both a blessing and a curse: while giving the sea longevity, it also pumps it full of chemicals and pesticides. The Salton Sea also affects the Imperial Valley. As the state continues to experience a crippling drought and the Salton Sea dries up further, the Imperial Valley will experience more and more harmful wind from the dry playas of the sea. This wind carries harmful toxins that cause asthma and other respiratory illnesses, creating massive health issues in the region. Imperial County already has the highest rates of childhood asthma in the country and this will only get worse as more playa is exposed. If the Salton Sea continues to dry at the same rate and nothing is done, the population of the Imperial Valley could drop. This could affect the farms of the valley because they need laborers and also because the playa dust could hurt the crops. This could cause the farms of the Imperial Valley to produce less food, which would in turn affect the entire nation and parts of the world. Essentially, if the Salton Sea dries up, the repercussions will be felt throughout the country.

## References

- "All-American Canal." 2016. *Imperial Irrigation District*. IID.
- Heuberger, Jurg., 1993. "Imperial County General Plan Overview." *Planning & Development Services Department*.
- "Imperial County, CA." 2015. *Census Reporter*.
- Lippert, John., 2015. "A Few California Farmers Have Lots of Water. Can They Keep it?". *Bloomberg*.
- Mullins, William H., 2009. "Okie Migrations." *Oklahoma Historical Society*.
- Perry, Tony., 2009. "Deepening Woes for the Imperial Valley." *Los Angeles Times*.
- Ponce, Victor M., 2005. "The Salton Sea: An Assessment." San Diego State University.
- Singer, Eugene. "Ancient Lake Cahuilla." *Ancient Lake Cahuilla*.
- Taylor, Edward J., 2001. "Immigration, Employment, Poverty, and Welfare in the Imperial Valley." *Changing Face*. UC Davis.
- "What Were the Imperial Valley Strikes?" 2011. *San Diego Mexican and Chicano History*.

# **The History, Current State, and Future of Tourism at the Salton Sea, California, USA**

Lily E. Clouse  
Colorado College

---

## **Abstract**

The Salton Sea, a saltwater lake in the Imperial Valley, California, is in a state of ecological crisis; deterring tourists from visiting. The salinity levels of the lake are consistently rising as the sea is disappearing, in part causing fish to die, birds to vanish, and people to leave. This has contributed to an economic collapse surrounding the Sea. The purpose of this report is to discuss the reasons why the lake has oscillated from a national tourist attraction to an abandoned desert, the current state of human interaction with the Sea, and the possibility of the return of tourism.

*Keywords:* Salton Sea; Imperial Valley; Tourism; Salinity; Fish

---

## **1. Introduction**

Sixty miles southeast of Palm Springs lives the Salton Sea, California's largest lake. Although the government considers the body of saltwater an accidental and man-made lake, a sea has naturally filled and depleted every three hundred years or so there for the past 14,000 years. Interestingly enough, in the last 1,300 years there has been a lake present in the Imperial Valley more often than not. Every few hundred years when the Colorado River flooded, the Salton Sink, or basin, would fill. In 1905, after Anglo-American settlers had arrived to the area, the lake began to form again. The unknowing settlers were alarmed by the flooding of the Colorado River, and after a year and half dammed the Colorado River, pausing the filling of the lake before the basin was full. This resulted in the formation of the Salton Sea, a body of water five times smaller than the original ephemeral lake. Although the Sea is only a fraction of the size it could be, during the mid to late 1900s the lake fluctuated from a national tourist destination to an abandoned wasteland. This report will ultimately explore the challenges and potential outcomes of a currently unstable visitor attraction.

## **2. The Rise of the Salton Sea as a Popular Tourist Destination**

After the initial flooding of the Colorado River, the Salton Sink formed a freshwater lake. By 1920 freshwater fish were introduced to the lake and sport fishing and speed boating became major tourist draws. During this time, pipes were built to irrigate the Imperial Valley, kick starting the Valley as a national leader in agriculture. The leftover water from this irrigation was returned to the Salton Sea, contributing salts, pesticides, and fertilizer residue to the freshwater. As lake water evaporates in an endorheic basin, salts and pesticides are left behind, resulting in rising salinity levels. This process is intensified by extreme heat, such as the triple digit temperature averages in the Imperial Valley. Approximately 1,300,000 acre feet of water evaporate from the



Salton Sea annually, causing salinity levels to consistently increase. For this reason, the Salton Sea transitioned from freshwater to saltwater during the early to mid 1900s (Bellows, 2006).

The salinity of the Salton Sea has affected tourism throughout the years, causing tourism to spike and crash. There was a slight decrease in tourism during the 1930s and 1940s because as the freshwater fish died out, fewer people came for fishing. In June of 1951, the California Department of fish and Game introduced thousands of salt-tolerant fish from the Gulf of California by San Felipe, Mexico. By 1957 sport fishing became a tourist attraction again, and fishermen came from all over to catch the big game fish in the Sea, such as orangemouth corvina and halibut (Paiva, 2016).

During the 1950s and early 1960s the Salton Sea rose to become one of the top tourist destinations in California. The Sea was a beautiful oasis in stark contrast to the surrounding desert. People would travel from all over to the go to the yacht club, boat, fish, kayak, waterski, swim, golf, and party (Bellows, 2006). Thousands of people visited the lake to watch the Salton Sea 500, a powerboat endurance race, and even more watched it televised nationally (Paiva, 2016). Around 500,000 people visited a year, more annual visitors than Yosemite at the time (Big Boy Travel, 2016). Celebrities such as Sonny Bono, Frank Sinatra, the Beach Boys, and Jerry Lewis vacationed at the “desert Lake Tahoe” (Raoul Rañoa, 2014). In the early 1960s the Salton Sea was recognized as a crucial stop for migratory birds along the Pacific Flyway, acknowledging the over 400 bird species around the Sea enhancing the desert beauty (Paiva, 2016). Thousands of lake side resident plots in Salton City were made readily available for sale. During this economic boom, more canals were built for farms in the Imperial Valley, attracting more farmers (Bellows, 2006). The Salton Sea was so popular it was predicted to become the next Palm Springs (Raoul Rañoa, 2014).

### **3. The Downfall of the Salton Sea Tourist Industry**

However, by the mid to late 1960s tourism began to decrease. Instead of the Salton Sea shrinking due to an imbalance of water intake verses water outtake, the size of the lake remained constant. This was because the Imperial Valley farms were dumping 6 feet of agricultural runoff into the Sea, the same rate as evaporation. This caused the Sea to become muddier and filled with chemicals. The Salton Sea was no longer as visually pleasing, or lavish as before.

During the 1970s multiple tropical storms affected the Imperial Valley, flooding the Salton Sea. Floodwaters consumed houses and halted the use of tourist attractions such as yacht clubs and golf courses (Paiva, 2016). By the 1980s the local economy had crashed, causing many people to sell what they could and leave the Imperial Valley. The tourist cities surrounding the Salton Sea became ghost towns, and people never returned (Kim Stringfellow, 2013). Furthermore, the floods caused eutrophication of the waters and algal blooms took off. When the algae decomposed they added a “rotten egg” smell to the lake. The algae also depleted the water of oxygen, killing the fish in enormous numbers. Rotten fish carcasses covered the once sandy beaches. The birds consumed the diseased fish and contracted the same infections. During the 1990s tens of thousands of dead birds and fish washed ashore, adding to the rotten smell of the Salton Sea. For ten years, animal carcasses rimmed sections of the lake (Paiva, 2016).

Throughout this time, the once cherished sea had begun to shrink. With California in an intense drought, the evaporation rate is currently greater than the agricultural runoff rate of the Imperial Valley farms (Raoul Rañoa, 2014). Vacation houses that used to be lakeside are slowly

becoming farther and farther from the Sea. Once nicely watered golf courses are now dusty land plots surrounded by ghost towns. All of the fish that used to attract sport fishers are now gone except for the tilapia, and even they are dying out. The beautiful white beaches are now covered with tilapia carcasses and dead barnacles. This crucial stop for birds along the Pacific Flyway is now in jeopardy because the marshlands are disappearing and the bird's main food source of fish is almost gone (Paiva, 2016).

#### **4. The Current State of Tourism at the Salton Sea**

Undoubtedly, Salton City is not the national tourist destination people had once hoped for. Tourism today consists mostly of kayaking in extremely salty, but technically safe, waters, visiting an artist's work, Salvation Mountain, birdwatching, and gambling at nearby casinos. In 2008 the Native American Torres Martinez tribe opened the Red Earth Casino, and although this does draw some tourists, the majority of people seeking a gambling getaway tend to visit the famous Palm Springs (Kim Stringfellow, 2013). The recreation area's district average annual revenue in 2011 and 2012 was only around \$118,000 dollars, or less than one dollar per visitor day (Fig. 1). In 2013 the average tourist spent \$117 dollars per day, however, by 2014 they spent \$92.50 dollars per day. Bird-watchers at the Sonny Bono Salton Sea National Wildlife Refuge spent \$30 dollars a day in 2013, \$11 dollars more per day than in 2014.

The recreation area's district average annual revenue is expected to consistently decrease in coming years. The Salton Sea is losing roughly \$6 million dollars per year relative to estimated historic rates (Cohen, 2014). In the past, tourists were attracted to the lush vacation life that is no longer present.

Instead of vacation goers, most people at the Salton Sea are permanent residents looking for isolation and a low cost of living (Paiva, 2016). Only around 400 tourists visit the Salton Sea annually (T. Bradley, pers.com). Approximately 250 people live in Bombay Beach, a neighborhood next to the Sea (Ella Morton, 2014). The land plots that were once predicted to house custom-built vacation homes in the Salton City are now for sale for an unbelievably low price of \$1400 dollars for a fourth of an acre. All in all, living around the Salton Sea is inexpensive for a multitude of reasons, including health.

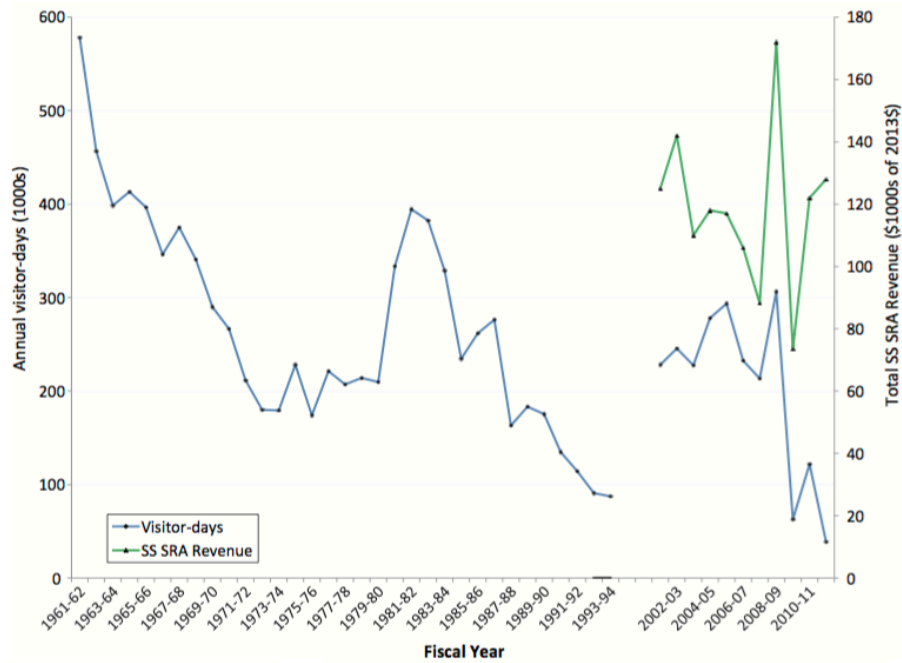


Fig. 1 Number of annual visitor-days and annual park revenue at the Salton Sea State Recreation Area (SS SRA) from 2002 to 2011. Visitation records for the mid to late 1990s are not available. (Cohen, 2014)

### 5. The Correlation Between Health Hazards and Salton Sea Tourism

The Imperial County has the highest asthma-hospitalization rates in all of California, in part due to toxic dust from the Salton Sea. As the Sea shrinks, every foot drop in sea level results in thousands of feet of exposed horizontal dry lake bed. Winds blow up this dust, dispersing pesticides and toxic heavy metals into the air (Iovenko, 2015). The levels of arsenic and selenium in the dust are high enough to qualify for disposal in toxic waste dumps. The Sea is expected to drop 3 to 20 more feet in upcoming years, resulting in even more toxic dust. The Imperial Valley population is breathing in this dust, which is causing respiratory issues to increase. Ecologist and Assistant Secretary for Salton Sea Policy, Bruce Wilcox, is urging the government to import more water into the Salton Sea in order to maintain the safety of the nearby community (Wilcox, 2016). Some residents of the Valley are considering relocating to other areas of California to ensure better health. Unfortunately, visiting a destination that is detrimental to one’s health is not desirable, and therefore, as toxic dust increases, the chances of the Salton Sea becoming a national, or even local, attraction decrease.

Another consequence of toxic dust is cancer risk. Although no studies have been conducted on how cancer risk relates to the Salton Sea specifically, a similar shrinking sea in central California has been connected with an increase in respiratory cancers. Mono Lake has comparable issues to the Salton Sea, with less water input and evaporation, leaving the lake’s salinity levels 3 times higher than the ocean’s. The salts in the toxic dust at Mono Lake pose a

cancer risk 100 times more dangerous than the toxic emissions from a large factory (Polakovic, 2007). The Salton Sea is expected to have even higher cancer risks.

Additionally, the future of the Salton Sea could also reflect the present situation of the Aral Sea. Once one of the largest lakes in the world, the Aral Sea in Eurasia has shrunk by 40 percent due to river dams. This results in 11,000 square miles of exposed lake bed, with 40 million tons of toxic dust annually. The nearby population of five million people is stricken with cases of mouth and respiratory cancers (Thompson, 2008).

One might think this health hazard is dangerous enough that the government would be forced to address it; however, because the Salton Sea is considered an accident, it has no natural lake water rights. As a part of the Quantification Settlement Agreement, in 2017 the Salton Sea will no longer receive any agricultural runoff from the Imperial Valley farms. The Sea is shrinking and there will be no water replacing any of the lake lost by evaporation. Not only is the Salton Sea no longer a large tourist draw, it is actually unhealthy to visit the area (San Diego County Water Authority, 2016).

## **6. The Three Main Alternates for the Future of the Salton Sea**

The Salton Sea Authority has proposed three main options for the future of the lake, and only one would potentially result in the Sea gaining tourism value. This plan is to spend \$3 billion dollars building trenches around the rim of the Sea so that the lake becomes concentrated around the edges (Fig. 2). This would maintain the value of the lakeside houses and nearby plots for resident development, while keeping enough sea present to still have boating and other tourist attractions. The levels of salinity would go down from around 45 parts per thousand to around 30 parts per thousand, approximately the same as the ocean. This is possible via brine sinks, or small, concentrated pools of salts and pesticides, in the middle of the Salton Sea basin. The southeast section of the Peripheral Sea would become wildlife wetlands to maintain the integrity of the Salton Sea as a stop along the Pacific Flyway. The Sonny Bono Salton Sea National Wildlife Refuge has already begun the process of creating these marshlands through the Red Hill Project. The center of the Sea would become exposed dry lakebed, a potential danger to the tourists; however, dust fences and other air quality modifiers could be put in place. Although expensive, the goal of this plan is to bring back tourism and boost the economy. Nonetheless, this idea does take a considerable amount of money. The progress would be slow and the steps would be paid for incrementally. The plan is estimated to take fifty to seventy-five years to complete (Salton Sea Authority, 2016).

The other two alternatives include pumping saltwater in and out of the Sea or dividing the Sea into two smaller lakes, both of which are also extremely expensive. The pipes would have to transfer water to and from the Pacific Ocean off the coast of San Diego, the Sea of Cortez in Mexico, or the Laguna Salada in Mexico. The Laguna Salada is the closest to the Salton Sea; however, it would still require moving the water 45 miles one way. According to the U.S. Bureau of Reclamation, this plan would cost at least \$95 million dollars, and would have an annual operation maintenance fee of \$5 million dollars. Although, this plan could save the Salton Sea. Pumping water in and out of the Sea provides the lake with an outlet, and in effect, a way to desalinate. Separating the Salton Sea into two smaller lakes also provides this outlet, only this time through concentrated pools of salts adjacent to the Sea. The smaller lakes would provide areas of fresher, less polluted water. The U.S. Bureau of Reclamation estimates the cost of

creating the two lakes at \$188 million dollars, and it would have an annual operation maintenance cost of \$4 million dollars (McClurg, 1994). In spite of the fact that these alternatives are less expensive than the \$3-billion-dollar Peripheral Sea, these options do not result in the Salton Sea gaining tourism value again.

Some believe there is not enough money in California to be able to fix the Sea, and therefore, the return of tourism is not attainable. If nothing is done to stop the rising rates of salinity in the Salton Sea, by 2030 the lake would have lost 500,000 acre-feet. This means there would be 500,000 acre feet of exposed dry lake bed, haunting the Imperial Valley. The northern edge could recede nearly 4 miles. The Salton Sea State Recreation Area could recede a mile by the park, a once popular fishing destination. By this date, the fish population would have died off. The western shore could recede 4 miles as well, exposing Salton City to the biggest dust bowl

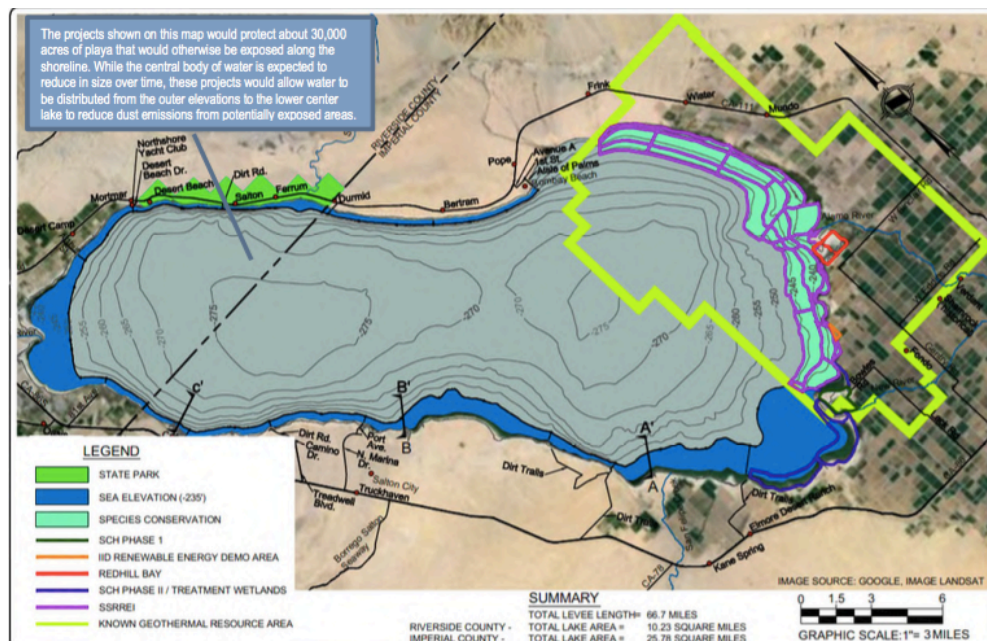


Fig. 2 Diagram of the Salton Sea Authority Peripheral Sea Plan. (Salton Sea Authority, 2016)

in the Western Hemisphere. The Sonny Bono Salton Sea National Wildlife Refuge that helps to protect over 400 bird species would be mostly dry and the fish-eating birds will be forced to find other sources of food. The southern shore, near the Wildlife Refuge, could recede up to 6 miles (Raoul Rañoa, 2014). The Salton Sea would become even more harmful to the surrounding populations and the tourism industry would be completely gone, and it would be nearly impossible to bring back.

## 7. Conclusions

If California waits too long, tourism may never return to the Salton Sea. Unfortunately, this is currently the most likely outcome. The future of tourism and the economy of the Salton Sea depend heavily on creating a safe and entertaining environment for visitors. Before attempting to attract more people and tourists to the area, California should address the health

hazards of the Salton Sea in order to provide its residents with reasonable living conditions. However, the most effective way to revitalize the Salton Sea is to boost the economy, and a valid method to do so is tourism. My recommendation based on this study would be to mitigate the effects of toxic dust through dust fences as well as begin the process of creating the Peripheral Sea.

### **Acknowledgements**

This information was supported by Tim Bradley from the University of California Irvine. Thank you for giving us a tour of the Salton Sea.

## References

- Bellows, J., 2006. Sordid History of the Salton Sea. Dam Interesting. <https://www.daminteresting.com/sordid-history-of-the-salton-sea/>
- Salton Sea Action Committee, 2016. FAQ's. SSAC. <http://www.saltonseaactioncommittee.org/faqs>
- Big Boy Travel, 2016. Salton Sea History. Big Boy Travel.com Your Adventure Awaits. <http://www.bigboytravel.com/california/saltonsea/history/>
- Rañoa, R., 2014. Drought, drawdowns and death of the Salton Sea. Los Angeles Times. <http://www.latimes.com/local/california/la-me-g-drought-drawdowns-and-death-of-the-salton-sea-20141021-htmlstory.html>
- Paiva, T., 2016. The Salton Sea. Lost America Night Photography of the Abandoned West. <http://lostamerica.com/photo-items/the-salton-sea/>
- San Diego County Water Authority, 2016. Quantification Settlement Agreement. San Diego County Water Authority. <http://www.sdcwa.org/quantification-settlement-agreement>
- Stringfellow, K., 2013. Salton City. Greetings from the Salton Sea. <http://www.greetingsfromsaltonsea.com/salton101.html>
- Morton, E., 2014. Salton Sea: From Relaxing Resort to Skeleton-Filled Wasteland. Slate. [http://www.slate.com/blogs/atlas\\_obscura/2014/02/04/the\\_salton\\_sea\\_in\\_california\\_turned\\_from\\_a\\_relaxing\\_resort\\_to\\_an\\_apocalyptic.html](http://www.slate.com/blogs/atlas_obscura/2014/02/04/the_salton_sea_in_california_turned_from_a_relaxing_resort_to_an_apocalyptic.html)
- McClurg, S., 1994. The environmental and economic values of this vast inland lake prompt local officials to launch a new restoration effort. The Salton Sea. <http://www.sci.sdsu.edu/salton/EnvirnEconValueSaltonSea.html>
- Cohen, M., J., 2014. Hazard's Toll: The Costs of Inaction at the Salton Sea. Pacific Institute.
- Iovenko, C., 2015. Toxic Dust from a Dying California Lake. The Atlantic. <http://www.theatlantic.com/science/archive/2015/11/the-airborne-toxic-lake-event/414888/>
- Polakovic, G., 2007. Shrinking Sea Mean Toxic Dust. The Salton Sea. <http://www.sci.sdsu.edu/salton/ShrinkingSeaNToxicDust.html>
- Thompson, U., 2008. Introduction. The Aral Sea Crisis. <http://www.columbia.edu/~tmt2120/introduction.htm>
- Wilcox, B., 2016. Bruce Wilcox, CA's Assistant Secretary for Salton Sea Policy. The Desert Sun. <http://www.desertsun.com/videos/news/2016/02/25/80931468/>
- Cohen, M., J., 2014. Hazard's Toll: The Costs of Inaction at the Salton Sea. Pacific Institute. <http://pacinst.org/publication/hazards-toll/>
- Salton Sea Authority, 2016. Benchmark 7: Project Summary. Salton Sea Funding and Feasibility Action Plan. [http://saltonsea.ca.gov/Portals/0/News%20Archive/SS%20Benchmark%207\\_5-11-16r.pdf?ver=2016-05-18-102017-660](http://saltonsea.ca.gov/Portals/0/News%20Archive/SS%20Benchmark%207_5-11-16r.pdf?ver=2016-05-18-102017-660)

# Agricultural Production and Water Use in the Imperial Valley

Benjamin B. Hall  
Colorado College

---

## Abstract

California's Imperial Valley has an extremely hot and dry climate that seems uninviting to agricultural endeavors. However, the half a million acres of farmland in the Valley are some of the most productive in the country. Sustaining a one-billion-dollar agricultural industry in a desert requires extraordinary amounts of water—Imperial Valley farms use 3.5 times as much water per acre annually than the average American farm. This is necessary both to combat high evaporation and to leach salt out of the Valley's highly saline soil. All of the Valley's 3.1 million-acre-foot water allowance comes from the Colorado River via the 80-mile long All-American Canal. Over 100 different crops from around the world are grown in the Valley each year, ranging widely in the amounts of water they require to grow. Farmers are often able to grow for 365 days a year, and can plant three of four rotations of crops annually. Overall irrigation trends are beginning to shift from flood and sprinkler irrigation to newer, more efficient drip irrigation systems. This bodes well for water conservation and the region's Quantification Settlement Agreement, which orchestrates large-scale water transfers from the Imperial Irrigation District to other parts of the region; but poorly for the health of the nearby Salton Sea, which receives 100% of its inflow from agricultural runoff.

---

## 1. Introduction

In southern California, just outside of Palm Springs, lies over 500,000 acres of land, formerly a continuation of the dry, cracked ground of the surrounding Anza Borrego Desert adjacent to the Salton Sea. That region, known now as the Imperial Valley, has been transformed into half a million acres of the most productive farmland in the United States. Agriculture in the Imperial Valley region is a billion-dollar industry that accounts for a huge percentage of the United States' production of an impressively wide variety of crops despite its location in one of the hottest and driest corners of the country. High agricultural yields in an extreme climate come at a steep price in terms of water, which is a precious commodity in the Western United States; as a result, the farms of the Imperial Valley have a complicated relationship with the water they use, and with others in the state who want to get their hands on it.

## 2. Climatic Effects on Agriculture

The Imperial Valley's climate is unapologetically arid. The region boasts warm and dry winters with daily maximum temperatures of up to 75°F, and scorching with daily maximum temperatures of up to 115°F. A majority of the 3 inches (7.5 cm) of annual rainfall comes in late summer or midwinter (University of California Cooperative Extension [UCCE]). Some months average no rainfall at all. Strangely enough, the farmers prefer it this way; any water that falls from the sky only creates a nuisance, causing flash floods and making a mucky mess in the fields.



To an outsider, it seems impossible, even laughable, that so much can be grown here, a desert where the only water around is saltier than the ocean. Crops can be grown nearly anywhere with good enough soil; the question is, how much water is needed? In this part of the country, the numbers are staggering: 3.5 times as much water as the average American farm.

### **3. Water Use**

On average, an irrigated farm in the United States will apply 1.6 acre-feet of water per acre of land per year (Midwar, 2015). For reference, one acre-foot of water is approximately what two American families of four use annually. According to the Imperial County Farm Bureau (ICFB), that number is 3.5 times higher in the Imperial Valley (ICFB Water Fact Sheet). This figure is, of course, attributable in part to the miniscule amount of rain the Valley receives each year. The average figures for the country account only for water applied to crops via irrigation, and not from the sky. Nonetheless, there is still a substantial gap in the amount of water needed to grow crops in the desert. The 5.6 acre-feet of water per year on 500,000 acres adds up; the farms in the Valley use every drop of the Imperial Irrigation Districts 3.1 million acre-foot allotment each year. To anyone familiar with the geography of the region, a glaring question emerges: where does all that water come from, and how does it get to the Valley? The answer lies right at the point where the Colorado River creates the border between Arizona and California.

### **4. Water Source**

One hundred percent of the water used to irrigate the Valley comes from the Colorado River. Straddling the river between the California and Arizona is the Imperial Dam, an 85-foot tall hydroelectric dam that creates the Imperial Reservoir, a lake with capacity to hold 160,000 acre feet of water. Each year, 3.1 million acre feet of water travels from the Imperial Reservoir to the Imperial Valley via the 80-mile long All-American Canal. In ironic juxtaposition to the life the canal brings to this barren landscape, it has been called the most dangerous body of water in the United States as a result of the more than 550 drownings that occurred in it between 1997-2010 (Pelley, 2010). The Imperial Valley does not fall within the boundaries of the Colorado River drainage basin; however, water rights laws from dating back well over a century ago allowed the people of the Valley to stake their claim to this far-away water source.

### **5. Agricultural Production and Feasibility**

The Imperial Valley's 450 farms (Census of Agriculture, 2012) grow more than one hundred different types of crops worth more than one billion dollars each year. The agricultural variety of the Valley includes large yields of grasses, vegetables, grains, nut and fruit trees, cattle, and even honey. The Valley is the largest growing region in the world for alfalfa, which is the number one crop in the county: 100,000 acres' worth were produced in 2009, part of the 1.8 billion tons of hay produced in the Valley in total. Other major field crops include 34,000 acres of Sudan grass, 18,000 acres of sugar beets (which produced over 800,000 tons of beets), and 110,000 acres of wheat. In total in 2009, the Valley produced 353,128 acres of field crops valued at \$312,554,000. The region even boasts a booming cattle industry with feedlots containing over 370,000 head of cattle valued around \$350 million.

The Valley's most lucrative type of crop are vegetables. In 2009 the Valley produced 114,099 acres of vegetables valued at \$690.3 million. Vegetables grown in the area vary based

on the time of year; the winter is ideal for vegetables such as crisp head lettuce, leaf lettuce, cauliflower, broccoli, cabbage, asparagus, and carrots growing in the winter, while the warmer months bring Sweet Imperial onions, sweet corn, bell peppers, chili peppers, cantaloupes, mixed melons and watermelons. Plants from around the world can be grown in the Valley, and the diversity of growth is astounding: bamboo, sugar cane, flax, corn, artichokes, cilantro, water lilies, and dozens of other varieties of plants are commercially harvested each year (UCCE). The volume and diversity of the harvest is especially remarkable when you look at the land surrounding the farms and see only cacti and tamarisks dotting the bone-dry earth.

Some of these crops aren't terribly difficult to grow in the region in terms of water application; safflower and grapes require a depth of just 1.4 feet and 1.6 feet (respectively) of water annually on average in the state of California. Comparatively, however, California's average for growing alfalfa is 4.9 feet (Cooley, 2015). This number is undoubtedly even higher in the Imperial Valley, one of the hottest and driest regions in the state. The Imperial Valley's emphasis on growing crops that are highly water-dependent in large amounts is one reason that their water usage is so immense. Alfalfa, potatoes, sugar beets, onions, grazing pastures, and the notoriously water-intensive almond are all grown in large amounts throughout the Valley. One commonly cited statistic in the media during the height of California's recent drought was that one gallon of water is required to produce one almond; the Imperial Valley has around 5,750 acres of fruit and nut trees (UCCE). Many crops grown in the region would be less water-intensive if grown in other parts of the world. The reason such a huge variety of crops are economically feasible in such inhospitable conditions is their domesticity; the Imperial Valley is the only region in the US where many crops can be grown, especially during the winter time—more than two thirds of vegetables consumed in the United States in the wintertime are estimated to have been produced in this relatively small region (ICFB Agriculture Fact Sheet). The Imperial Valley gives the US access to crops throughout the year that would otherwise need to be imported from other countries. That's not the only advantage to growing in a region where the temperature almost never drops below freezing, though; another benefit lies in the number of times farmers can harvest each year.

## **6. Irrigation**

The Imperial Valley is so productive in part because farmers can, and often do, grow three to four different crops in one field each year. The heat of the ecosystem allows for a nearly endless cycle of growing seasons without seeing a frost. This also helps to explain the, at first glance, inane high irrigation figures. A farm in a different part of the country with a shorter growing season may only be able to harvest crops once or twice in the year. This necessitates irrigating fields for only a portion of the year. In a place where the growing season effectively never ends, however, fields are potentially being irrigated for twelve months of the year, giving some perspective to the necessity of the immense amounts of water being diverted from the Colorado. Adding to the economic sensibility of agriculture in the Valley is fact that costs for growing a crop for a full year on one farm is less expensive than growing for half a year on two separate farms.

The near-constant irrigation does not, however, level the field in terms of how much can be produced from a certain amount of water in the Valley versus the rest of the country. The high temperatures and very dry air mean that irrigation methods like sprinklers and flood irrigation

lose a significant amount of water to evaporation. More water, therefore, must be applied to fields using such methods. Less than half of the fields in the Valley use drip irrigation, a more modern and efficient irrigation system; farmers can use up to two-thirds less water with drip irrigation than with flood irrigation. Even with drip irrigation, however, above-average amounts of water are required to sufficiently drain the soil of salts. Each acre foot of water that flows into the region brings one ton of salt with it. Overwatering of the soil, working in conjunction with advanced tile drainage systems beneath the fields, is necessary to keep soil salinity at levels where the potential productivity of the land can be harnessed and exploited. With around three million acre feet of water entering the Valley, three million tons of salt need to go somewhere once they are leached out of the soil. Those hundreds of millions of tons of salt drain into the lowest elevation in the area: the bed of the Salton Sea.

## **7. Effects on the Salton Sea and the QSA**

Agricultural runoff is the sole source of water flowing into the Salton Sea. The Sea is a terminal body of water, and becomes increasingly saline over time as water evaporates and the salt flowing into the Sea remains there. The roughly three million acre feet of water used in agriculture in the Valley each year feed the Sea, though more water is lost annually through evaporation, causing the Sea to shrink and salinity to increase even more rapidly. The ecological repercussions caused by this salinization are far reaching, extending far past the Imperial Valley and the people who live there. The fate of the Sea is inextricably tied to the Valley's agriculture in a paradoxical way; the deterioration of the Sea will be an environmental nightmare, and the only way to slow that deterioration is through the addition of more water from agriculture. However, environmentally responsible irrigation methods will lead to more efficient water use and a decline in the Valley's demand for water use, and result in a decline in the Sea's health. It seems that no matter what, there's no good option environmentally. All of this is exacerbated by the new strain being put on the Valley to conserve more water in order to meet the demands laid out in the Quantification Settlement Agreement (QSA).

The Quantification Settlement Agreement is an agreement drawn up in 2003 between the state of California, the US Department of Interior, the San Diego County Water Authority (SDCWA), and three southern Californian water districts. Southern California's urban population has continued to swell, and needs more water to sustain growth. So the SDCWA and southern California's Metropolitan Water District (MWD) struck an agreement with the Imperial Irrigation District to transfer a combined 305,000 acre feet each year (about 10% of the Imperial Valley's total water allotment) from the Valley (SDCWA). In theory, the agreement could have been a win-win for everybody; San Diego gets the water that it needs, and gives the Imperial Valley money that farmers can use to invest in more efficient types of irrigation, negating the need for the water they lost. The major catch, however, is the Salton Sea. In 2017, when the SDWA stops sending mitigation water to the Sea to combat the ill effects of having taken water eventually destined for the Sea, the Sea will begin to bear the full brunt of the agreement, and receive 10% less water than it historically has. Part of the agreement required a plan to be drawn up to deal with the fallout from the under-watering of the Sea, and many plans have been proposed. To date, however, no single holistic plan to save the Sea has been enacted due to lack of funding and lack of political motivation to deal with the potential crisis at this point in time.

## 8. Conclusion

The Imperial Valley of southern California is an unlikely oasis, hundreds of thousands of acres of green in the middle of a dry desert, where some months average 0 mm of total precipitation. Against all logic, the Valley provides huge amounts of food for people across the country, and for livestock and dairy animals both foreign and domestic. The region marks the final diversion of the Colorado river, the point where the often river dries up before (sometimes) making it out of the country. The production in the Valley requires as much the water as it can get, and thus takes it all. The Valley's agricultural runoff serves as the single source of inflow for the ecologically crumbling Salton Sea. As the amount of water being fed into the Sea decreases, the Sea's health will decrease in turn, potentially setting off a nightmarish chain of events: fish die-offs, a tumultuous spiral of global bird populations, and toxic alkaline dust storms that will blow into highly populated areas in southern California. The fate of the Sea is tied inextricably to the agricultural productions surrounding it. The promises of restoration funds continue to come from all levels of government, yet little progress is being made. Efforts will become even more complicated in 2017, when mitigation water flowing into the Sea as part of the QSA will stop, a move that will increase the rate at which the Sea is shrinking, and the rate at which its salinity increases. The economics of the Valley itself are volatile; agriculture keeps over half of Imperial County employed; however, poverty and unemployment rates are still high—the Imperial Valley boasts a 23.6% poverty rate—because apart from agriculture, there's almost no way to make a living in the area. A drive to reclaim the desert and turn wasteland into farmland created the Salton Sea, and has kept it alive ever since. The Valley's fields have changed to fill a higher purpose than they were intended for. They don't just provide food for millions of Americans; they hold together a fragile ecosystem.

## References

- Census of Agriculture, 2012, Printed October 18, 2016. County Profile: Imperial County, California. 1-2.
- Cooley, Heather, 2015. California Agricultural Water Use: Key Background Information. Pacific Institute. 1-9.
- Imperial County Farm Bureau (ICFB), Printed October 18, 2016. Quick Facts About Imperial County Agriculture. 1-2.
- Imperial County Farm Bureau (ICFB), Printed October 18, 2016. Water. 1-2.
- Midwar, David, April 20, 2015. Acres and Acre-Feet; A Look at Irrigation Trends in the US. Agricultural Economic Insights. 1-5.
- Pelley, Scott, April 30, 2010. The Deadly Passage of the All-American Canal. CBS News. 1-4.
- Round, Phillip H., 2008. The Impossible Land. Impossible Land. 19-20.
- San Diego County Water Authority (SDCWA), Printed October 18, 2016. Quantification Settlement Agreement for the Colorado River. 1-2.
- Schlenker, Wolfram, Hanemann, W. Michael, Fisher, Anthony C., March 2007. Water Availability, Degree Days, and the Potential Impact of Climate Change on Irrigated Agriculture in California. Climate Change. Vol. 81 Issue 1, p19-38. 20p.
- University of California Cooperative Extension [UCCE], Printed October 18, 2016. Imperial County Agriculture. 1-3.

# The Truth Behind Organic Farming and Food

Virginia G Thom  
Colorado College

---

## Abstract

Organic food has gained huge popularity over the years. However, as it increases in popularity growing amounts of people question the relative pros and cons. Concerns regarding organic food production become especially relevant when combined with our rapidly growing population, and our ability to feed the world. The goal of this paper is to provide up to date analysis on the health differences between organic and conventional food, the economics behind both organic and conventional farming, the different cultivation methods for both organic and conventionally grown crops and the history of food activism.

*Keywords:* Organic food; organic growing; nutrition; food advocacy; population growth; economics

---

## 1. Introduction

Eat organic! That's what health advocates left and right always tell you. It's better for you, it's better for the environment and it supports small businesses. Organic food, as defined by the USDA must be "produced without excluded methods, (e.g., genetic engineering, ionizing radiation, or sewage sludge), produced using allowed substances and overseen by a USDA National Organic Program authorized certifying agent, following all USDA organic regulations" (Agricultural, USDA). This definition is not to be confused with the terms "free-range", "hormone free" or "natural" (Zelma, WebMD). These terms are not regulated by the government, thus while they may sound better they do not hold the produce to any specifically regulated standards.

## 2. The History and Agriculture of Food Activism

America has a long history of food activism. Significant movements began in the 1830's, particularly among Northern middle class evangelists, headed by the protestant minister Sylvester Graham. Graham called for significant changes in the nation's fundamental diet, citing meat, alcohol, coffee, spices and store bought bread as the worst offenders. Graham encouraged a more natural vegetarian diet, because it was in line with what God wanted. Graham believed that by increasing the physical health of the community, he was also increasing the community morality. This period led to an increase in vegetarianism (Haydu et al, 2016).

The next period of food advocacy occurred from the 1890's to the 1900's. The main argument in this time said that food was impure. Food in America was unsafe due to chemical additives. According to food advocates, food was also mislabeled to confuse consumers (Haydu et al, 2016). While the food at this time was not unsafe, this movement did lead to the creation of the Food and Drug Administration (FDA) in 1906 (Lal, 2009). In contrast to earlier times, progressives in this time period championed legislative measures to ban adulterants, require

accurate labeling and monitor food additives. They sought, as well, to educate consumers to make their food purchases more wisely (Haydu et al, 2016).

After World War 2, the agricultural technology skyrocketed. Many new advances in technology made chemical fertilizers, pesticides and herbicides much more accessible. As widespread use of synthetic chemicals increased, the food yield jumped significantly, easily outpacing crop production of the past (Moseley, 2015). However, Rachel Carson, the author of *Silent Springs* started a huge movement towards organic food. Her novel questioned the widespread use of DDT and pesticides in general. This started a huge push for closer chemical regulation that continued into the more recent period (Funk, Carson).

The latest period began in the 1960's and continues to this day. This is the era of organic food. Advocates of organic foods raised alarms about the safety of conventional food, claiming that it carried unsafe chemical residues. Organic advocates also raised the alarm over the environmental concerns from the use of artificial fertilizers, pesticides, energy-intensive meat production and crop monoculture. They furthered this attack to food processing, claiming that it turned fruits, vegetables and many ingredients into "precooked, instantized [products that] can be taken right out of the box and eaten" (Organic Gardening and Farming July 1965, p. 20). The activists cultivated their efforts in the creation of the Organic Foods Production Act of 1990 (Haydu et al, 2016). This act in turn created the National Organic Program and gave it the authority to regulate agricultural products sold, labeled or depicted as organic within the US (Agricultural, USDA).

As of today, organic food continues to increase in popularity, accounting for 8 billion of the grocery market sales in 2001 (Marcus, 2001), and a whopping 39 billion in 2016 (Kell, 2016). Additionally, 78% of families report buying organic foods at least once (Forbes, 2012). This upward trend continues even though customers pay on average 47% more for organic foods (Lazarus, 2015).

### **3. Regulations on Organic Farming**

Because of all the regulations on organic farming, it is much more expensive than conventional farming. Organic farming requires the farmers to follow a highly regulated set of conditions. One of the most significant is the National List of Allowed and Prohibited Substances. This distinguishes between the nonsynthetic (natural) and synthetic (unnatural) substances that are prohibited in organic crop and livestock production. There are many differences in the farming practices between organic and conventional crops. For example, in conventional farming, farmers would add chemical fertilizers to the soil. To be organic, farmers must add purely nonsynthetic compost, animal manure or green manure to the soil. They are strictly prohibited from adding sewage sludge or biosolids to soil. Farmers must also plant organic seeds. They are only permitted to use conventionally grown seeds if there are no suitable organic alternatives, but the seeds must also be produced in a manner that does not violate any chemical rules (Agricultural, USDA).

Farmers must also practice different crop management systems when they grow organic crops. Crop rotation is a strategy already practiced by both conventional and organic farmers. It is a practice of rotating the crops grown in a field with the goals of interrupting insect life cycles, suppressing soil borne plant diseases, preventing soil erosion, building organic material, fixing nitrogen and increasing farm biodiversity. However, crop rotation is required for organic farms

due to the lack of alternative methods available to them (Agricultural, USDA). While crop rotation is a highly effective method, some farmers choose not to practice it and instead practice monocropping—planting massive amounts of the same crop in the same spot, year after year. This not only degrades the soil quality, but makes the risk of a widespread disease or pest outbreak much more likely (Lal, 2009). Pest management on organic farms must also follow the PAMS strategy: prevention, avoidance, monitoring and suppression. If pest suppression becomes necessary, farmers first turn to mechanical and physical practices such as releasing predatory insects to reduce pest populations or by laying down a thick layer of mulch to smother weeds. The last resort is for farmers to work with their organic certifier to find an approved pesticide (Agricultural, USDA).

Organic farms are also responsible for making sure that there is no contact between the organically and conventionally grown crops. This includes ensuring that none of the prohibited substances used on the conventional crops come into contact with the organic crops. Furthermore, these prohibited substances cannot be applied to land set aside for organic growing 3 years prior to harvesting organic crops (Agricultural, USDA).

There are also strict rules regarding the labeling of organic products. To be labeled organic, processors must use certified organic ingredients for a minimum of 95% of the product. The processors also follow strict rules, they must prevent comingling of organic and non-organic products and prevent contact between organic ingredients and non-organic substances, including prohibited sanitizers. They must also clean and sanitize processing equipment when changing from non-organic to organic products (Agricultural, USDA).

#### **4. Pros and Cons Analysis**

The sheer number of regulations farmers must follow to be considered organic is overwhelming, to the point where many farmers wonder if it is worth it anymore. Organic farming is much more expensive than conventional farming. Because of the more expensive alternatives farmers have to invest in and the smaller yield, the crops produced are more expensive. All of these factors lead to 50%-100% more expensive prices for organic crops (Zelma, WebMD). Farmers are forced to spend more money on approved fertilizers and other alternatives. Furthermore, the crop yield for organic crops is between 19%-25% less (Kniss et al, 2016). This becomes a much severer issue when the future population growth is taken into account. With the world's population projected to grow from 7.2 billion people to 9.6 billion by 2050 there are massive concerns about how this will impact the agriculture industry (Liu et al, 2016). As organic food continues to grow in popularity, the food yields remain small. It is estimated that if all US wheat production was grown organically, an additional 12.4 million hectares (30.6 million acres) would be needed in order to match the 2014 wheat production levels in the US (Kniss et al, 2016). The higher prices can also lead to social issues, as not everyone can afford to buy premium organic food, and consequently, large groups of Americans feel trivial.

However, there are multiple benefits to organic farming. Ecologically, species richness (the number of different species) was found to be 34% higher on organic farms versus conventional farms (Tuck et al, 2014). Furthermore, organic farms held a significantly higher number of rare or declining species (Hole et al, 2005). Mycorrhizae, which improve plant mineral nutrition, contribute to atmospheric nitrogen fixation and to soil aggregate formation were 40% higher in organic systems versus conventional. Additionally, the biomass and abundance of



earthworms and other arthropods, which contribute to soil quality, was between 1.3 to 3.2 times higher (Maeder et al, 2002).

It is important to understand that organic foods contain natural chemicals from the nonsynthetic alternatives that farmers use. In addition to these pesticides, more can enter the food chain via 4 different routes. Pesticide use on the farm, post-harvest pesticide use, pesticide use on imported food and cancelled pesticides that persist in the environment can all end up in organic food. Thus, it is possible for organic foods to be contaminated with illegal pesticide residue (Liu et al, 2016).

Nutritionally, there are not significant differences between organic produce and conventional produce (Maeder et al, 2002). Both organic and conventionally grown produce contain trace amounts of pesticides, yet both of them are far below the level set by the FDA. However, there have not been enough studies to determine whether long term exposure to conventionally grown produce would be dangerous. Scientists have determined several foods that, when grown conventionally, contain significantly more pesticide residue than organically grown ones. The list includes spinach, green peas, green beans, green onions, summer and winter squash, apples, peaches, pears, strawberries, raspberries and blackberries (Zelma, WebMD).

## **5. Conclusions**

After doing extensive research, I do not support wide-scale organic food. The amount of pesticides in conventional food is so low, it's almost completely negligible. Furthermore, the nutritional quality is no different, and I would be paying anywhere from 50-100% more for organic food. Currently organic fields do have a higher biodiversity than conventional fields, yet conventional field biodiversity could be much higher if the government were to implement stricter growing policies or provide subsidies.

I would recommend that if you are going to buy organic food, you should buy food from the list mentioned earlier, where the pesticide residue is higher in conventionally grown crops. I also recommend legislative action from the government. One particularly relevant example is the Imperial Valley. As of right now, farming in the Imperial Valley is not sustainable if farmers continue to grow all 3 growing seasons, using conventional crop technique managements. This can be fixed if the government were to encourage techniques such as fallowing, crop rotation and up to date technology, such as drip irrigation. The solution is to implement organic food practices to conventional food. That keeps the prices low for everyone, the yield high and maintains ecological biodiversity.

The future of agriculture is hugely important for the Salton Sea. The way things are progressing right now there are 2 potential issues. If agriculture does become more efficient, and rely on drip irrigation, there will be massive reductions in the amount of water going to the Sea. However, if they do not, and continue flood and spray irrigation, the runoff to the Sea will be nutrient-filled. While neither situation is ideal, it is important to understand the possible outcomes of the farming overhaul occurring in the Imperial Valley.

## Acknowledgements

Thanks to Professor Emilie Gray for the opportunity to visit the Salton Sea and collect firsthand research, as well as provide a bevy of information. Thanks also to Jenna Wu, senior, for the extensive information on how to properly write, format and organize a research paper.

## References

- Agricultural Marketing Services. "National Organic Program." USDA.
- Haydu, Jeffrey, and Tad Scotticki. 2016. "Three Layers of History in Recurrent Social Movements: The Case of Food Reform." Taylor&Francis Online, 345-60.
- Hole, D. G., A. J. Perkins, J. D. Wilson, I. H. Alexander, P. V. Grice, and A. D. Evans. 2005. "Does Organic Farming Benefit Biodiversity?" *ScienceDirect* 122, no. 1: 113-30.
- Kell, John. 2016. "SHOPPERS LIKE ORGANIC FOOD A LOT MORE THAN SCIENTISTS." *Fortune* 173, no. 5: 12. *Business Source Complete*
- Kniss, Andrew R., Steven D. Savage, and Randa Jabbour. 2016. "Commercial Crop Yields Reveal Strengths and Weaknesses for Organic Agriculture in the United States." *Plos ONE* 11, no. 8: 1-16.
- Lal, R. 2009. "The Plow and Agricultural Sustainability." *Journal of Sustainable Agriculture*, 66-84.
- Lazarus, David. 2015. "Is Organic Food worth the Higher Price? Many Experts Say No." *Los Angeles Times*.
- LearnVest. 2012. "Study Says Organic Isn't Healthier? Here's Why It Still May Be Worth The Cost." *Forbes*.
- Liu, X. B., and S. Y. Gu. 2016. "A brief discussion on energy use and greenhouse gas emmission in organic farming." *International Journal Of Plant Production* 10, no. 1: 85-95.
- Maeder, Paul, Andreas Fliessbach, David Dubois, Lucie Gunst, Padruot Fried, and Urs Niggli. 2002. "Soil Fertility and Biodiversity in Organic Farming." *Web of Science* 296, no. 5573: 1694-697.
- Marcus, Mary Brophy. 2001. "Organic foods offer peace of mind--at a price." *U.S. News & World Report* 130, no. 2: 48.
- Moseley, William G. 2015. "Food Security and 'Green Revolution'" *International Encyclopedia of the Social&Behavioral Sciences* 8: 307-10.
- Tuck, Sean L., Camilla Winqvist, Flávia Mota, Johan Ahnström, Lindsay A. Turnbull, and Janne Bengtsson. 2014. "Land-use intensity and the effects of organic farming on biodiversity: a hierarchical meta-analysis." *Journal Of Applied Ecology* 51, no. 3: 746-755.
- Zelma, Kathleen M. "Organic Food-- Is "Natural" Worth the Extra Cost?" *WebMD*.
2016. "Carson, Rachel Louise." *Funk & Wagnalls New World Encyclopedia* 1p. 1. *Funk & Wagnalls New World Encyclopedia*.
2016. "Organic food." *Funk & Wagnalls New World Encyclopedia* 1p. 1. *Funk & Wagnalls New World Encyclopedia*.

# The Clash Between Labor and Economic Advocates in Agricultural Policy: Dissecting the Farm Subsidy System

Natalie Gubbay  
Colorado College

---

## Abstract

Recent California legislation to offer farmworkers standard overtime has ignited tensions between the state's labor and agricultural communities, which have long disagreed on the relationship between farmworker wages and the employing farm's profitability. The purpose of this paper is to address and contextualize that division. Tracing it through the evolution of the farm subsidy system showed that today's federal policy is largely out of line with both perspectives. Moreover, applying the same framework to theoretical subsidy alternatives highlighted the potential for a wage subsidy, along with farm subsidy cuts, to reconcile the two sides of the argument.

*Keywords:* AB 1066; overtime; farmworkers; subsidies; labor

---

## 1. Introduction

On September 12, 2016, California governor Jerry Brown signed into law Assembly Bill 1066, and emerged as either a hero of the working class or the gravedigger of Imperial Valley agriculture, but most certainly nothing in between. The bill calls for a phasing in of overtime protection for farmworkers: by 2020, farmworkers must, by state mandate, be paid 1.5 times their salary for every hour worked beyond eight per day, and twice their salary for hours worked beyond twelve per day. Registered supporters of the bill, which was sponsored by the United Farm Workers of America, include the California Employment Lawyers Association, the California Immigration Policy Center, the California Labor Federation, Human Rights Watch, and Hillary Clinton. Opponents include the Agricultural Council of California, the California Chamber of Commerce, the California Farm Bureau Federation, and associations of growers representing most of the state's staple crops (Senate Committee on Labor and Industrial Relations, 2016). In concert with the state's minimum wage increase (from \$10 to \$15/hour by 2021), AB 1066 does no less than secure farmworkers a shot at the American Dream—or guarantee the decline of an industry responsible for producing huge proportions of the nation's food, depending on who you ask.

The two sides of the controversy represent two schools of thought—which I'll call the labor perspective and economic perspective—that have clashed over agricultural policy since the early 1900's. And perhaps what makes the argument so fiery is the fact that both are valid. This paper will examine the ever-dynamic interaction between the labor and economic perspectives in U.S. agricultural policy, focusing on their representation—or lack thereof—within the farm subsidy system over time. It reveals a subsidy system that was founded within the rhetoric of the labor perspective, yet that no longer claims to defend the rights of farm laborers

and that only vaguely caters to the economic perspective. Ultimately, the paper seeks to identify areas of policy where the labor and economic perspectives may align—for if both are valid, then they both must be addressed; if they must coexist, they cannot be mutually exclusive.

## **2. The Two Sides**

The fundamental difference between the labor and economic perspectives is the focus of their analysis. The labor perspective focuses, of course, on laborers themselves; as is indicated by the list of the bill's registered supporters, this group sees labor protection laws as integral to the just treatment of farmworkers. On the economic side are those who focus on the success of farms as a whole, contending that just treatment of laborers is contingent on the success of the business that receives the labor.

The labor perspective can draw from history for support: the majority of the 1900's were characterized by minimal protection for California farmworkers, who as a result endured extremely low wages and harsh working conditions. The 1938 Fair Labor Standards Act—the cornerstone of labor policy over the past century—exempted farmworkers from minimum wage and overtime pay protections, allowing wages to be determined solely by the market. Meanwhile, proximity to Mexico ensured a labor oversupply, as immigrants, attracted by the promise of agricultural labor, migrated across the border, causing income to plummet and unemployment to rise. Welfare use, once established, served to attract even larger numbers of immigrants, exacerbating the cycle further (Martin and Taylor, 1998). Racial prejudice fed rural poverty, by acting as a justification for farm owners who pocketed worker's wages, ignored labor regulations, failed to provide sanitary housing, and withheld salaries at the end of the season (Andrés, 2010: 108). In combination and left unchecked, these factors led to an industry that, for farm laborers, could only have been described as utterly inhumane.

Thus, the past century, from the labor perspective, foreshadows—grimly—the consequences of a deregulated agricultural labor system. Today, though the 1938 FLSA remains federal policy, state law insists that farmworkers in California be compensated at least up to minimum wage, currently \$10/hour, and paid overtime for work beyond ten hours a day (State of California Department of Industrial Relations, 2016). Good, but not enough, says the labor perspective: still, the average full-time salary of agricultural workers in the Imperial Valley sits just under \$20,000 (U.S. Census, 2014). Therefore, increasing the minimum wage and providing overtime benefits seems positive, a reasonable protection for those who engage in one of the country's most dangerous jobs. As the president of the United Farm Workers of America put it: "For 78 years, a Jim Crow-era law discriminated against farm workers by denying us the same overtime rights that other workers benefit from. Here in the U.S. today, Governor Brown corrected a historic wrong and set an example for other states to follow." (Rodriguez, 2016).

In theory, the economic perspective responds, but not in practice. In reality, they argue, AB 1066 will actually lower farmworker's incomes, while hindering farm production and California's economy. The bill's opposition coalition, an impressive conglomerate of California grower's associations, base their argument on research put together by Highland Economics, an independent economics consulting firm. The study found that labor costs under the new overtime and minimum wage regulations would increase dramatically, from 46% of operating costs to 55% in vegetable crops and from 58 to 73% in fruit crops (field crops remained relatively stable). Farm employers, attempting to minimize labor costs, would likely try to compensate by

either reducing production or expanding the labor force, hiring a larger number of farmworkers for fewer hours. Both scenarios would lead to a roughly 16% decrease in farmworkers' income. The study also predicts:

- The removal of 1.25 million acres of farm land from production,
- A \$5.4 billion loss in crop production,
- A \$2.5 billion loss in dairy production,
- Up to 78,000 lost farm, processing, transportation, and support industry jobs,
- \$4.9 billion to \$7.8 billion in lost income statewide,
- \$587 million in lost farm investment,
- Reduced farm investment resulting in 2,100 lost farm jobs, and
- A \$474 million reduction in farm income (Agricultural Council of California, 2016).

It should be noted that the Highland Economics study was commissioned by the opposition coalition. Few comparable analyses of the bill have been performed. Still, the evidence is persuasive that AB 1066, combined with California's minimum wage increase, will limit the economic productivity of the state's farms. Given that they must compete with Mexican farms, where labor costs far less, such impacts have serious implications for the viability of Californian agriculture in an internationally influenced market.

The challenge that arises, then, is to reconcile the very real need for labor protection, on the one hand, with the very real need to keep California farms competitive, on the other. An effective agricultural policy would place checks and balance on the two; an ideal agricultural policy would find a way to benefit both at once. The agricultural policy of the past century, dominated by the farm subsidy system, has done neither: it has sought to protect farm owners and excluded farmworkers; it was founded on the notion of relieving poverty yet allowed farm work to remain one of the country's lowest-paying jobs. It is aimed at promoting economic viability yet fails to help non-commodity farms compete globally. Still, the farm subsidy system remains central to the nation's agricultural system; it is essential in the production of wheat, corn, and other grains and cannot be discounted. If ever there is a war of ideology in agricultural policy, then the subsidy system must be its battleground—and thus is an importance place to look in an attempt to identify common ground between the two perspectives.

### **3. The U.S. Agricultural Subsidy System Over Time**

Though the U.S. government has influenced agricultural production since the 1800's, it was the first hundred days of the New Deal that established the framework and precedent for the modern subsidy system, through FDR's Agricultural Adjustment Act of 1933 (known as the AAA). The AAA sought to alleviate farms from the stresses of the Great Depression by setting supply controls, parity pricing, and income supports to counteract plummeting commodity prices and the associated rural poverty (Sumner, 2007). In theory, these programs worked by keeping crop prices artificially high. By paying farmers for fallowed land, the government reduced the supply of agricultural goods (hence the title "supply control"), driving prices up without farmers suffering from leaving land unused. Parity pricing set prices for commodities that kept a farm's "purchasing power" constant even through market fluctuations: while the actual price of a good changes, parity pricing attempts to ensure that a fixed amount of one thing produces enough money to buy a comparable fixed amount of another from year to year (USDA & National

Agricultural Statistics Service, 2008). For example, a farmer producing 2000 acres of wheat should spend the same proportion of what he makes selling it on what he needs to produce it every season. Parity and supply control sought to insulate farmers from the depression's worst effects while keeping U.S. agriculture from collapse.

The AAA's main problem was that it funded the subsidy with an excise tax on the processing of agricultural goods, raising prices dramatically for the consumer. Moreover, many farmers chose not to harvest crops already growing, deciding that a subsidy for their underproduction would be more profitable than actually selling the food. Fields were burned, livestock slaughtered, and crops plowed under, even as citizens lined the streets waiting for soup kitchens. Thus, many criticize the act for making food less accessible at a time when much of the population lived in hunger. Others argue that the act failed in its goal regardless; though farm incomes did increase in the early thirties, many believe the effects of the AAA were negligible (Sumner, 2007; Lotterman, 1996; Hardman, 1999).

Ultimately, the AAA of 1933 was replaced by the AAA of 1938 and the Agricultural Act of 1949. These two acts remain the basis of today's legislation, and were essentially intended to be more effective versions of the AAA of 1933. Still seeking to protect farms from variability in crop prices—and from the poverty that follows—they establish crop insurance and continue parity pricing programs, while adapting the calculation of parity prices to better reflect an evolving economy. The Agricultural Act of 1949 remains “permanent legislation”: all farm bills since take the form of amendments and adjustments to the 1949 act, rather than standalone laws (Sumner, 2007).

Together, these early programs suggest a responsibility of the government to regulate agricultural production for the benefit of farmers. For almost a century, it has been an expectation that federal policy step in when farmers' incomes drop—that the government alleviate poverty associated with agriculture. These original policies strove to “give agriculture a fair share in the national income” at a time when farming was relatively unprofitable: per capita farm income was less than 40% of per capita non-farm income in 1933-40, and remained significantly lower until at least the seventies (Gardener, 1992). At their core, the AAA and the following 1949 act suggest that farmer prosperity is tied to national economic prosperity—that ensuring fair payment for farmers accompanies success for farms, which in turn creates success for the nation's economy.

This would seem to stand in contrast to the logic of the opponents of AB 1066, who contend that government intervention in farm income hinders economic prosperity. A closer look at who exactly receives “farm income”, though, tells a different story: farm income is calculated as the per capita income of people who live on farms. “Farmers”, therefore, are really farm owners; farm workers, often hired for short periods of time by several farms, are left out of the first subsidy acts in theory as well as in practice (Gardner, 1992). Thus, even if farm families found relief from federal subsidies, little of this relief translated to payment for those they hired. The early subsidy system, therefore, caters to the labor perspective only in part: while aiding struggling farm owners does fall within the labor perspective, large swaths of farm laborers were excluded from the effects of subsidies entirely. The economic perspective, on the other hand, is well represented in the program's logic, if not satisfied by its results.

The distinction between farm owners and farmworkers remains central to the debate on today's subsidy program. As farms grow in size but diminish in number, farm owners, be they

individuals or corporations, reap more profit—unlike those of the twentieth century, they are now often wealthier than their non-farm counterparts (Gardner, 1992; Sumner, 2007; USDA, 2016). Yet today’s subsidy programs, despite some reform, continue to aid those at the top of the farm hierarchy. Until 2014, direct payments compensated farmers each year with fixed rates based on historical production, maximizing benefits for those with high production levels in the past. Subsidies focused on a small number of commodity crops—corn, wheat, rice, soybeans, peanuts, and cotton—that tend to be grown on large, industrial farms; small and intermediate sized vegetable and fruit farms did not receive compensation (USDA, 2016; Goodwin et al., 2005). In such a system, subsidy payments, which Daniel A. Sumner defines in his analysis of farm subsidy history as “roughly proportional to production of program crops”, accrue to the largest producers, who need assistance the least. Indeed, farm owners with gross incomes up to 900,000 a year could qualify; in addition, a government audit found millions of dollars each year flowing to farmers who have died since enrolling in subsidy programs, and undetected fraud claimed over \$100 million from the program (Nixon, 2013; Nixon, 2014). It is for this reason that opposition to agricultural subsidies is so violent: a google search for “U.S. farm subsidy system” yields titles such as “Our Crazy Farm Subsidies, Explained”, “Farm Bill 2014: it’s even worse than the old farm bill”, and “Taxpayers turn U.S. Farmers into Fat Cats with Subsidies”. And though the 2014 farm bill nodded at reform, repealing direct and countercyclical payments in favor of more variable, market-based programs, there is general consensus in the agricultural community that little has changed.

If the subsidy system has failed to adapt to changes in farm ownership, it has most definitely failed to identify the true source of the rural poverty it sought to uproot. Even as farm jobs outpay non-farm ones at the upper levels, the median weekly income of hired crop workers totaled, in 2010, only 60 percent of those in comparable non-farm jobs. Farmworkers are twice as likely to live below the federal poverty line than non-farm households (Martin & Jackson-Smith, 2013). Though some states have adopted minimum wage legislation for farmworkers, even in such states wages sit just above the lower limit; in California, for example, the National Agricultural Workers Survey shows incomes consistently at about minimum wage since the legislation was enacted (National Agricultural Workers Survey, 2015). Researchers Philip Martin and Douglas Jackson-Smith, who crafted a policy brief on the subject in 2013, point out that 18 percent of crop workers have health insurance benefits despite consistent exposure to pesticides, poor sanitary conditions, and long workdays. In sum, though living in working conditions have improved for farmworkers since the early 1900’s, they remain far from ideal. To truly address the issue of rural poverty, the subsidy system would need to benefit this class of hired workers—and to argue that large-scale commodity payments address the needs of the farmworker class would, quite simply, be irrational. Sumner concludes: “Even strong program advocates no longer claim a significant link from farm subsidies to poverty reduction.”

The goal of poverty alleviation, then, has become completely dissociated from the subsidy system, which today does not even pretend to represent the labor perspective. Its main merits—providing stability for industrial, commodity farms—speak to an economic motive but do not totally match with the economic perspective, which seeks to protect the profitability of all Californian (or American) agriculture, not just that of program crops. In short, the farm subsidy system is ripe for reform, even as farm bills continue to pass with minimal changes.

## 4. Alternatives: An Overview of Other Subsidy Options

### 4.1. *No Subsidies – New Zealand*

There are those who argue that, given its inequity and inefficiency, the farm subsidy program should be eliminated altogether. New Zealand offers a prime example: in the 1980s, in the midst of an economic crisis, the country cut more or less cold-turkey an agricultural subsidy program totaling 4% of the nation's GDP (the U.S.'s currently totals .42%) and providing over 30 programs to the nation's farmers. From 1983 to 1985, the Effective Rate of Assistance to farmers dropped from 123% of gross farm receipts to 40%; by 1990, that number was almost 0. Removing subsidies did, at first, drop farm prices; however, they have since recovered to over 100% of their value pre-reform. To economists, this offers evidence against farm subsidies, which proved to have indeed distorted farm prices and also proved less effective than allowing them to be determined by the market (Vitalis, 2007).

The economic impact of New Zealand's reform was generally positive, yielding huge increases in the export of horticultural products and allowing the sector to better respond to market price signals. Socially, its effects were mixed: initially, farm price drops lessened rural incomes, which in turn forced farmers to cut spending. Many rural companies selling farm equipment closed, and unemployment rose as farmers hired fewer laborers. Rural populations did decline slightly. However, fears of rural collapse proved unfounded, as New Zealand's rural population actually rose within two decades of the subsidy cuts (Vitalis, 2007).

New Zealand's example suggests that cutting—or perhaps more realistically, reducing—agricultural subsidies could bolster the economic viability of the U.S.'s farms with some, albeit not dramatic, harm to farmworkers. The money freed from subsidy cuts could potentially, though, be used to redress that harm, making the reform process more sustainable from the labor perspective.

### 4.2. *Price Control: Venezuela*

On the opposite end would be those who argue for even stricter regulation of agriculture and the foundation of price controls that ensure profitability for farmers. But price control only exacerbates the divide between the economic and labor perspectives: keeping prices artificially high aids farmers but increases poverty when consumers can't afford food (recall the effects of the AAA), and keeping prices artificially low, as in modern Venezuela, creates food shortages and drives the agricultural sector out of business (Sumner, 2007; Otis, 2015).

### 4.3. *Wage Subsidies*

Wage subsidies provides federal money to companies for the explicit purpose of funding worker compensation. Within agriculture, it could essentially compensate for difference between what farmworkers should fairly earn, determined by the labor perspective, and what farmers can feasibly pay them, determined by the economic. Oren Cass explains in a U.S. News article (2015):

“A wage subsidy adds dollars-per-hour to the worker's wage, on a sliding scale that pays the highest subsidy for the lowest wage and phases out to no subsidy as the wage increases. A worker earning \$8 per hour might, for instance, receive an additional \$2 per hour in his paycheck. And he would receive that for every hour worked, no matter how many hours he worked or how



much he eventually earned. For him, the policy appears like the minimum wage has been raised to \$10 per hour. But for his employer and co-workers and customers the cost is still \$8 per hour.”

Wage subsidy programs that do exist have been small in scale, so little information is available on their actual implementation, but the rationale behind it certainly brings some resolution to the disparity between the two sides (MDRC, 2013).

#### *4.4. Reform*

There remains, of course, the option of subsidy reform, which would attempt to redirect the benefits of the subsidy program away from large farm owners and toward smaller, non-commodity farms. This is perhaps the most commonly cited alternative to the current subsidy system and does have key ties to the discussion of labor and economic contradiction. However, it is not addressed here, as the body of literature regarding it is large and deserves to be examined as its own entity.

### **5. Conclusion**

The debate highlighted by AB 1066 runs far deeper than the act itself or even the California legislature. Agricultural policy over the past decade has reflected pushes and pulls from the labor and economic perspectives in both its rhetoric and its ultimate impact. Today’s subsidy system, however, serves to alienate both. Thus the present offers a unique opportunity to attempt to ease the dichotomy between the two perspectives; most notably, a wage subsidy program, if combined with other agricultural reform, has the potential to satisfy both sides of the argument—to reap the benefits of AB 1066 without its consequences.

### **References**

- Senate Committee on Labor and Industrial Relations, 2016. Bill Analysis: AB 1066. State of California Legislative Council.
- Martin, P., & Taylor, J, 1998. Poverty Amid Prosperity: Farm Employment, Immigration, and Poverty in California. *American Journal of Agricultural Economics* 80(5), 1008-1014.
- Andrés, B. J., 2015. *Power and Control in the Imperial Valley: Nature, Agribusiness, and Workers on the California Borderland, 1900-1940*. Texas A&M University Press, 102-108.
- U.S. Census Bureau. 2014. American Community Survey 5-year estimates. Retrieved from Census Reporter Profile page for Imperial County, CA.
- Vangelis V., 2007. Agricultural subsidy reform and its implications for sustainable development: the New Zealand experience. *Environmental Sciences*, 4(1), 21-40
- State of California Department of Industrial Relations, 2016. Overtime. From State of California Department of Industrial Relations website.
- Office of Asm. Lorena Gonzalez, 2016. AB 1066—Phase In Overtime for Agricultural Workers Act of 2016. California State Assembly. Retrieved from United Farmworkers of America website, Key Campaigns.
- United Farmworkers of America, 2016. Overtime bill a precedent. Victory for farm workers. United Farmworkers of America, Key Campaigns.
- Agricultural Council of California, 2016. Gov. Brown Signs New Ag Overtime Requirements into Law. Agricultural Council of California.

Lotterman, E., 1996. Farm Bills and Farmers: The effects of subsidies over time. Federal Reserve Bank of Minneapolis, The Region: The December 1996 Issue.

Hardman, J., 1999. The Great Depression and the New Deal. Retrieved from Stanford University website.

Gardner, B. L., 1992. Changing Economic Perspectives on the Farm Problem. *Journal of Economic Literature*, 30(1), 62-101.

Sumner, D. A., 2007. Farm Subsidy Tradition and Modern Agricultural Realities. Paper prepared for American Enterprise Institute project on Agricultural Policy for the 2007 Farm Bill and Beyond. Retrieved from University of California Agricultural Issues Center.

USDA & National Agricultural Statistics Service. Chapter Four. Parity Prices, Parity Ratio, and Feed Price Ratio. Retrieved from USDA website.

Goodwin, Barry K., Ashok K. Mishra, and François Ortalo-Magné. 2005. "Landowners' Riches: The Distribution of Agricultural Subsidies." University of Wisconsin-Madison School of Business, Department of Real Estate and Urban Land Economics.

Nixon, R., 2014. House Approves Farm Bill, Ending a 2-Year Impasse. *The New York Times*, January 30, 2014, pA14.

Nixon, R., 2013. Millions in U.S. Subsidies Go to Dead Farmers. *The New York Times*, July 31, 2013, pA10.

Martin, P. & Jackson-Smith, D., 2013. An Overview of Farm Labor in the United States. *RuralCONNECTIONS*, 8(1), 21.

Otis, J., 2015. The Nightmare of Grocery Shopping in Venezuela. All Things Considered, National Public Radio, October 29, 2015.

Mrdc, 2013. Subsidized Employment: A Strategy for Bad Economic Times and for the Hard-to-Employ. Mrdc.

Cass, O., 2015. A Better Wage Hike. *U.S. News and World Report*, August 19, 2016.

National Agricultural Workers Survey, 2015. Table 14: California Employment Characteristics. Retrieved from the USDA Employment and Training Administration website.

USDA, 2016. Agricultural Act of 2014: Highlights and Implications. Overview. Retrieved from USDA website.

USDA, 2016. Ag and Food Statistics: Charting the Essentials. Farming and Food Income. Retrieved from USDA website.

**Additional Sources:**

BO WON, SUH, ANITA EVES, and MARGARET LUMBERS. 2015. "DEVELOPING A MODEL OF ORGANIC FOOD CHOICE BEHAVIOR." *Social Behavior & Personality: An International Journal* 43, no. 2: 217-230.

Trewaves, Anthony. 2001. "Urban myths of organic farming." *Nature* 410, no. 6827: 409.

Worthington, Virginia. 2001. "Nutritional Quality of Organic Versus Conventional Fruits, Vegetables, and Grains." *Journal Of Alternative & Complementary Medicine* 7, no. 2: 161-173.

# Wetland restoration project analysis for the Salton Sea

Evan M. Doherty  
Colorado College

---

## Abstract

The Salton Sea in California is evaporating quickly, and it is imperative that restoration projects for bird and fish habitats be explored. This paper analyzes three wetland restoration projects in other areas in order to better understand what should be done in the Imperial Valley. Iran's Lake Urmia, Merced County's Grasslands Wildlife Management Area and San Diego's San Dieguito Lagoon all provide helpful insights into restoration projects for the shrinking Salton Sea. The Red Hill Bay restoration project is an example of a current restoration project for the sea. As a wetland project, it can provide habitat for endangered fish and bird species as well as mitigate toxic dust pollution. Both present and past wetland restoration projects can inform future solutions for the Salton Sea.

*Keywords:* Wetlands, Lake Urmia, Grasslands Wildlife Management Area, San Dieguito Lagoon, Red Hill Bay, Salton Sea

---

## 1. Introduction

Who would have thought that a huge sea surrounded by miles of lush farmland could exist in the middle of Southern California's desert? The Salton Sea was somewhat of a human error, and only exists now because it is filled with extra farm runoff water. However, the 35-mile long, 15-mile wide sea is evaporating quickly, which poses many environmental and health threats. Toxic dust gets released into the air when the sandy playa becomes exposed, and this is harmful to breathe. The Imperial Valley has the highest childhood asthma rate in all of California due to the amount of toxic selenium that residents breathe every day (Iovenko, 2015). The Salton Sea's evaporation and increasing salinity also affect bird, fish and animal populations. The Salton Sea is a significant stop on the Pacific Flyway for migratory birds, and is one of the most diverse bird habitats in North and Latin America. The 400 species of birds that live or stop here also include 80% of the western population of American white pelicans (Case and Barnum, 2016).

Tilapia populations are also suffering due to increasing salinity in the sea. In 2006, the tilapia population decreased to about 1% of what it was in 1999 when over 100 million fish lived in the sea (Cohen and Hyun, 2006). Studies show that tilapia may not be breeding anymore, which could quickly lead to their extinction in the Imperial Valley (Bradley, 2016). This would be detrimental for fish-eating birds, because they do not have another source of food. Brine shrimp and small invertebrate populations would also be affected by the disappearance of tilapia, as the ecosystem of the sea depends on the balance of all species.

Ideas for Salton Sea restoration abound, and many large-scale projects have been evaluated. However, many of these projects require significant funding and have proven to be difficult to initiate. Kay Pricola of the Imperial Valley Vegetable Growers Association notes,

“everything easy has already been done. We’ve tried all of the inexpensive quick-fixes, so now the remaining solutions are the expensive ones.” (Pricola, 2016). One potential solution to improve water quality is a desalination plant that would be powered by geothermal energy. This project is estimated to cost millions of dollars and research suggests that it may not be viable because it would require significant maintenance and may disrupt the communities in shoreline towns (“Salton Sea Funding,” 2016). Another expensive option is the “Sea to Sea” water transfer from the Sea of Cortez to the Salton Sea. For this option, pipelines would bring water from the Sea of Cortez to the Salton Sea to maintain the depth of the sea. However, the transferred water may in fact raise salinity levels because it is more saline than the current agricultural runoff that fills the sea.

While many large-scale projects are being explored, there are also some side components to these plans. Wetland restoration is a smaller-scale, less expensive option that is often tacked onto grandiose project proposals. This idea is important because before 1850, California used to have 5 million acres of wetlands, but now less than 6% of those wetlands are still intact (Hartmann and Goldstein, 1994). Birds and animals are quickly losing important habitat areas in the Imperial Valley and wetland restoration may help keep some of those areas intact.

## **2. The Importance of Wetlands**

Wetlands are extremely important to sustaining plant and animal life in many different climates. There are different types of wetlands that are categorized under the Cowardin system: palustrine, lacustrine, riverine, estuarine, and marine (“Wetlands and Their Importance,” 2010). The types of wetlands that would best suit the Salton Sea are most likely palustrine, which are playas, ponds and wet meadows, or estuarine wetlands, which are saline and brackish estuaries. Wetlands provide a habitat for both land and water dwellers, as they incorporate both marshland areas and drier, shallower places where plants can grow.

Not only are wetlands important because they are a habitat for various species, but they also have other ecological advantages. Introducing wetlands in dry areas can mitigate dust pollution from dry playa beds. Additionally, they can control pollution by trapping sediments that filter bacteria and break down pollutants in the water. Some cattails in wetlands have bacterial biofilms that suck up bacteria and store it until the gravel is removed from the area and disposed of by wetland restoration groups (“Wetlands and Their Importance,” 2010). This also helps cycle nutrients, because both plants and animals can absorb and excrete different chemicals in the water.

The most beneficial uses for wetlands in the Salton Sea would be to mitigate toxic dust pollution and to restore endangered habitats for birds and fish. If no restoration projects are pursued, the tilapia will die, bird species will lose food sources and habitats, and toxic dust will dominate the Imperial Valley. Tina Shields of the Imperial Irrigation District notes the importance of beginning a project—any project—and says, “something is better than nothing” (Shields, 2016).

### **3. Other Wetland Restoration Projects can Help Inform Salton Sea Plans**

Other areas of the world have also explored wetland restoration in ecological crises. Various scenarios and solutions can help Salton Sea officials make decisions on which wetlands to build and how to construct them. Lake Urmia, Grasslands Ecological Area and the San Dieguito Lagoon are all slightly different projects and each offer unique insights into potential wetland restoration near the Salton Sea.

#### *3.1. Lake Urmia, Iran*

Iran launched a wetlands restoration project in 2013 to address the weakening ecosystem around Lake Urmia. Lake Urmia is near Iran's border with Turkey. The volume of the lake has significantly decreased over time due to the damming of rivers that feed into it. The surrounding wetlands have suffered as well because people have also been pumping groundwater out of the area. Due to the decreasing water supply, Lake Urmia has become hypersaline and no longer supports fish life.

With the financial help of Japan and Iran's governments, The United Nations Development Program restored multiple areas of wetlands in East Azerbaijan, Kordestan, and twelve other provinces ("Conservation of Iranian Wetlands," 2016). This project focuses on community engagement to encourage sustainable agriculture and to conserve water usage. This approach recognizes the interconnectedness of wetlands and their surrounding communities and farms by educating farmers on water usage at a field farm school. Here, the farmers learn about efficient irrigation systems, such as covering fields with plastic to minimize evaporation and other fertilizing techniques in order to conserve water (Kummer). These practices were implemented in over 74,000 acres in Iran, and the project has made significant strides in wetland restoration ("Conservation of Iranian Wetlands," 2016). Various wetlands around the country have been refurbished with the help of extra water flow that local farms have conserved.

Even though this example of wetland restoration may seem like a stretch to relate to the Salton Sea because it is halfway across the world, it is in fact quite helpful in informing future Salton Sea restoration. Because it recognizes the interconnectedness of farming and wetlands through water usage, it can be used as a model for integrating sustainable farming methods and habitat conservation in the Imperial Valley. However, conserving agricultural runoff water is contributing to the crisis in the Salton Sea, not improving wetlands like it is in Iran. Even though the strategies are not quite the same, the Iranian wetland model may be helpful in terms of connecting farmers with their surrounding environments through education. Additionally, the water that is not used for agriculture potentially could be pumped separately to wetland areas. This may provide wetland areas with cleaner water without extra chemicals. Lake Urmia is also very salty, so scientists could examine the specific water chemistry of each lake in order to make a more informed decision on what to do in the Salton Sea.

#### *3.2. Grasslands Ecological Area, California, USA*

The Grasslands Wildlife Management Area, established in 1979, is located east of San Jose in Merced County, and is part of the San Joaquin River Basin. These 80,000 acres of wetlands provide 30% of California's remaining wetlands in the Central Valley ("Grasslands Wildlife Management," 2013). There are many different kinds of wetlands and habitat restoration projects here, including flooded marshlands, wet meadows, riparian habitats, pastures, native

grasslands and vernal pools. It is beneficial to have multiple types of habitats in order to support animal and bird diversity in the area because certain species thrive in different environments. For example, shorebirds prefer habitats in flooded rice fields and California quails prefer to live in sagebrush or chaparral, so the varying habitats in this area can help both species.

This area also uses a seasonal wetland strategy. This means that a depression is dug in the ground with two shallow parts on either end and a deeper part in the middle. Water is then filled in the wide, trench-like depressions and plants such as cattails or bulrush are planted in the shallower parts on the edges. The wetlands are filled up to the reed vegetation levels during the colder months and then dry up during the summer so that only the deeper part of the area is filled with water. Even though the vegetation does not have water to grow in the summer, the root systems remain intact, allowing the plants to regrow when water levels rise again.

To sustain some seasonal wetlands in the Grasslands Wildlife Management Area, water is taken from the San Joaquin River and diverted to the wetlands via streams. However, the salinity of the river introduces a challenge to the sustainability of the wetlands. Scientists must monitor the salinity of the river in order to ensure that the wetlands are not receiving water that is too saline for the animals that rely on those habitats. 30% of the San Joaquin River's annual salt load flows through the wetlands in the Grasslands Basin, which could harm the plant and animal life there (Parrot and Quinn, 2016). So, options are being explored to help improve the water quality. One potential solution is shifting the wetland water drawdown period, which may change the inflow of salt to the wetlands because of seasonal salinity changes in the San Joaquin River.

The Grasslands Ecological Area also incorporates vernal pools. They look similar to seasonal wetlands, but they have a few differences. Vernal pools are depressions in soils that fill with rainwater and fluctuate depths depending on the season. Flowers and other types of vegetation grow around the vernal pools in wet seasons and their seeds remain dormant in dry seasons when they cannot grow. The water remains in the pools during wet seasons because the soils are hard and impermeable at the bottom. These habitats best suit animals that are adapted to alternating wet and dry seasons, such as certain crustaceans, amphibians and insects ("California's Vernal Pools," 2013). Vernal Pools are an important type of wetland in areas that receive enough rainfall to sustain them. They differ from the seasonal wetlands because their water source is typically rainfall, not diverted water from other rivers.

This specific type of wetland may not work in the Salton Sea because the area does not receive enough rainfall. An average of about two inches of rain fall each year in the Imperial Valley, so the pools would evaporate very quickly. However, this example is still pertinent to the sea because it is an example of a wetland strategy that would not work well. Any wetland in the Imperial Valley will need to be maintained and have an outside water source other than rainfall. Additionally, vernal pools tend to become very salty because when the water evaporates in dry seasons, salts get left behind. This would be an issue at the Salton Sea because the water flowing into the pools would already be quite salty and may not be a hospitable environment for fish or invertebrate life. However, any wetland solution will require significant maintenance, so perhaps maintaining vernal pools could be an option.

The Grasslands Ecological Area method of wetland restoration addresses the need for habitat diversity. It incorporates multiple types of wetlands as well as grassland and forest restoration. Although the climate around the Salton Sea is slightly different from the Grasslands

Ecological Area, it can still benefit from variation in different habitats and can use desert wetland strategies.

### *3.3. San Dieguito Lagoon, CA, USA*

The San Dieguito Lagoon is located on the coast of California, north of San Diego. In the beginning of the restoration project in the early 2000s, this area mainly focused on dredging to restore wetlands and getting rid of excess sand. Wet sand was pumped out of the area into other canals where the water seeped out of the sand and back into other marshland areas. This was beneficial for plant life, because an imbalanced sand and soil ratio limits the available nutrients for vegetation growth. In the past, the San Dieguito Lagoon covered 1,000 acres and the surrounding marsh area covered over 600 acres (“San Dieguito Lagoon Wetland Restoration,” 2003). Much of this natural wetland area has been destroyed due to construction of highways and city development. Now, the project is focused on reviving 400 acres of wetlands (“San Diego Lagoon Wetland Acquisition”). This restoration is a tidal exchange wetland project, which means that water flows from the ocean into the wetlands. This salty water flow also creates seasonal salt marshes near the shore. California least tern birds thrive in this habitat because they like to nest in the ground in sandy beach areas and they eat small, salt-tolerant fish and some invertebrates. This habitat is also good for western snowy plover birds because they too make nests in the ground on barren sandy beaches and salt-evaporation ponds. They eat terrestrial and aquatic invertebrates that live in salty waters.

Approximately 2.3 million cubic yards of dredge material were excavated from the San Dieguito area and disposed of (“San Dieguito Lagoon Wetland Restoration,” 2003). This helped with the productivity of the area, allowed more plants to grow, and may have contributed to the appearance of a new bird species, the wood stork. It was found in August of 2016, approximately four years after the completion of the wetland restoration project (“August 2016 San Dieguito Lagoon Bird Survey,” 2016). The wood stork is also seen at the Salton Sea, and is well-suited to the environment on the coast of California. This is hopeful news for the wetlands because it indicates that new species can thrive in the improving conditions.

While this exact method would not work in the Salton Sea because it is not near the ocean, the overall strategy is applicable. Similar bird species are found in the coastal wetlands and Salton Sea because of high salinity levels in both places. For example, the least tern and snowy plover both thrive in saline habitats, and therefore those birds at the Salton Sea may benefit from similar habitats to the coastal wetlands.

## **4. A Current Project Proposal for the Salton Sea: Red Hill Bay Restoration Project**

Wetland restoration project plans in the Salton Sea are typically small parts of larger initiatives. For example, the Red Hill Bay Restoration project focuses on 420 acres of exposed playa around the Salton Sea and is a side component of other ideas, such as the peripheral sea. The goal of the project is to mitigate toxic dust pollution and provide wetland habitats for birds, fish and small invertebrates. The area will be divided into two different cells filled with water from the Salton Sea as well as the Alamo River. This mixing of hypersaline and freshwater will result in a salinity of about 20 ppt (Red Hill Bay Restoration Project). These different cells will provide habitats for different animal species, because the depths and salinities will be different in each cell. The water will be pumped into the wetland areas via special tubes that can transport

fish and other small invertebrate life from the Salton Sea. Through regular monitoring, the wetland areas will maintain their individual depth and salinity levels. However, this project will require significant maintenance and the wetlands will not be completely self-sufficient.

## 5. Conclusion

Before beginning construction of any restoration plans, it may be helpful to consult other wetland projects. For example, the three projects mentioned above each have certain qualities that could work well in the Imperial Valley. Perhaps a project such as the Red Hill Bay project could benefit from certain aspects of the three examples. First, the Lake Urmia project integrated farms and the environment by educating farmers on water usage. By educating farmers in the Imperial Valley on the current state of the Salton Sea, ecologists and farm companies may be able to work in harmony in order to save the Salton Sea. Education can only help in this situation: the more the farmers know about their environment, the more they can make conscious decisions to help their surrounding environment.

Second, the Grasslands Ecological Area provides research on many different types of wetlands, and this broad overview of habitat diversity can help inform which type of wetland the Salton Sea would most benefit from. If water levels could be manually regulated season by season, the seasonal wetland strategy may work. Although the Imperial Valley does not experience drastic seasonal changes, a controlled version of the fluctuating wetland depths may allow plants to cycle through phases of blooming and dormant seeds. This area is also conducting studies on when the best time is to bring water to the wetlands to avoid dragging too much salt with the water. Perhaps scientists in the Imperial Valley can gain valuable knowledge from salinity studies in wetlands in the Grasslands Ecological Area.

Lastly, the coastal wetlands provide insights into saline wetlands. Although the Salton Sea does not have ocean water easily accessible for creating marshes or wetlands, the Salton Sea water is quite salty and somewhat mimics coastal wetlands. For example, similar bird species live in the Salton Sea and the San Dieguito Lagoon. The wood stork has been found in both locations and indicates that they could be somewhat similar in food availability and water quality.

Tim Bradley of UC Irvine believes that although the Red Hill Bay project— or a similar wetland project—is currently the best option, this restoration is still an idealistic solution. Critics can bash the desalination plant or “Sea to Sea” option for being too expensive or labor intensive, but even small wetland projects are far from perfect. Every current option will cost money and will require significant effort, but the sea is running out of time. It has reached the point where the “no action” plan is worse than any other potential solution. Trying a restoration project can only help. At the very least, if a plan fails, it will inform an iteration of the next one. Wetland restoration is a good place to start at the Salton Sea because it does not require as much money or labor as some other plans do. Since small wetlands can be built in individual squares, they can be used as test areas before larger ones are built. Other places have effectively implemented wetland projects, so it is possible that they may work at the Salton Sea. However, it is also possible that they may not. The first step is to start building small areas with slightly different strategies to discover what works and what does not.



## Acknowledgements

Emilie Gray made the Salton Sea field trip possible. Without her, none of this research would be conducted. Thanks to Jenna Wu for organizing the structure of the final research reports and compiling scientific papers into a larger book.

## References

- "August 2016 San Dieguito Lagoon Bird Survey Results -- New Species!" *San Dieguito River Park*, 23 Aug. 2016, [www.sdrp.org/wordpress/2016/08/august-2016-san-dieguito-lagoon-bird-survey-results-new-species/](http://www.sdrp.org/wordpress/2016/08/august-2016-san-dieguito-lagoon-bird-survey-results-new-species/). Accessed 13 Oct. 2016.
- Bradley, Tim. Lecture. 3 Oct. 2016.
- "California's Vernal Pools." 17 June 2013, *California Department of Fish and Wildlife*, State of California, [www.wildlife.ca.gov/Conservation/Plants/Vernal-Pools](http://www.wildlife.ca.gov/Conservation/Plants/Vernal-Pools). Accessed 13 Oct. 2016.
- Case, Harvey Lee, and Douglas A. Barnum. "The USGS Salton Sea Science Office." *U.S. Geological Survey*, [pubs.usgs.gov/fs/2007/3097/](http://pubs.usgs.gov/fs/2007/3097/). Accessed 13 Oct. 2016.
- Cohen, Michael J., and Karen H. Hyun. May 2006. "Hazard: The Future of the Salton Sea with No Restoration Project." *Pacific Institute*, [pacinst.org/app/uploads/2014/04/hazard.pdf](http://pacinst.org/app/uploads/2014/04/hazard.pdf). Accessed 13 Oct. 2016.
- "Conservation of Iranian Wetlands Project – Phase II (Scale-up)." Mar. 2016, *United Nations Development Program*, [www.ir.undp.org/content/dam/iran/docs/Publications/UNDP-Iran-One-Pagers/CurrentProjects/Project%20One%20Pager%2C%20Environment%20-%20Wetlands%2001%20%20English.pdf](http://www.ir.undp.org/content/dam/iran/docs/Publications/UNDP-Iran-One-Pagers/CurrentProjects/Project%20One%20Pager%2C%20Environment%20-%20Wetlands%2001%20%20English.pdf) Accessed 12 Oct. 2016.
- "Grasslands Wildlife Management Area." 9 Apr. 2013, *U.S. Fish and Wildlife Service*, [www.fws.gov/refuge/Merced/grasslands.html](http://www.fws.gov/refuge/Merced/grasslands.html). Accessed 13 Oct. 2016.
- Hartmann, J. R., and J. H. Goldstein. 1994. The impact of federal programs on wetlands: a report to congress by the secretary of the interior: Vol. II: The Everglades, Coastal Louisiana, Galveston Bay, Puerto Rico, California's Central Valley, Western Riparian Areas, Southeastern and Western Alaska, the Delmarva Peninsula, North Carolina, Northeastern New Jersey, Michigan, and New Jersey. The Department, 333 pages.
- Iovenko, Chris. 9 Nov. 2015, "Toxic Dust From a Dying California Lake." *The Atlantic*, [www.theatlantic.com/science/archive/2015/11/the-airborne-toxic-lake-event/414888/](http://www.theatlantic.com/science/archive/2015/11/the-airborne-toxic-lake-event/414888/). Accessed 13 Oct. 2016.
- Kummer, Tamara. "Sustainable Agriculture around Lake Parishan." *United Nations Development Program*, [www.ir.undp.org/content/iran/en/home/ourwork/Environment\\_sustainable\\_development/impacting\\_lives/env\\_success.html](http://www.ir.undp.org/content/iran/en/home/ourwork/Environment_sustainable_development/impacting_lives/env_success.html). Accessed 12 Oct. 2016.
- Parrot, Lael and Nigel Quinn. 27 Jun 2016. "A complex systems approach for multiobjective water quality reugulation on managed wetland landscapes." <http://tinyurl.com/gq4u2fu>. Accessed 15 Oct. 2016.
- Pricola, Kay. Lecture. 6 Oct. 2016.
- "Red Hill Bay Restoration Project." *Imperial Irrigation District*, [www.iid.com/home/showdocument?id=11699](http://www.iid.com/home/showdocument?id=11699). Accessed 14 Oct. 2016.
- "Salton Sea Funding and Feasibility Action Plan Benchmark 7: Project Summary." May 2016. *Tetra Tech*. Accessed 13 Oct. 2016.

"San Dieguito Lagoon Wetland Acquisition." *Southern California Wetlands Recovery Project*, [scwrp.org/projects/san-dieguito-lagoon-wetland-acquisition/](http://scwrp.org/projects/san-dieguito-lagoon-wetland-acquisition/). Accessed 13 Oct. 2016.

"San Dieguito Lagoon Wetland Restoration Project." 2003, *San Dieguito River Park*, [www.sdrp.org/projects/coastal.htm](http://www.sdrp.org/projects/coastal.htm). Accessed 13 Oct. 2016.

Shields, Tina. Lecture. 6 Oct. 2016. "Wetlands and Their Importance." 2010, *Southern California Wetlands Recovery Project*, [scwrp.org/general-wetlands-information/](http://scwrp.org/general-wetlands-information/). Accessed 13 Oct. 2016.

### **Additional Sources**

"California Quail." *All About Birds*, The Cornell Lab of Ornithology, [www.allaboutbirds.org/guide/California\\_Quail/id](http://www.allaboutbirds.org/guide/California_Quail/id). Accessed 13 Oct. 2016.

"Conservation of Iranian Wetlands Project Phase II (Scale-Up)." 2013, *United Nations Development Program*, [www.ir.undp.org/content/iran/en/home/operations/projects/environment\\_and\\_sustainable\\_development/Wetlands\\_II.html](http://www.ir.undp.org/content/iran/en/home/operations/projects/environment_and_sustainable_development/Wetlands_II.html). Accessed 12 Oct. 2016.

"Cowardin U.S. Fish and Wildlife Service Wetland Classification System." *Water Shedss Wetlands Classification System*, NCSU Water Quality Group, [www.water.ncsu.edu/watershedss/info/wetlands/class.html](http://www.water.ncsu.edu/watershedss/info/wetlands/class.html). Accessed 13 Oct. 2016.

"eBirders Help Identify Critical Shoreline Habitat in California's Central Valley." 23 Oct. 2014, *eBird*, Cornell Lab of Ornithology, [tinyurl.com/zq8vxkk](http://tinyurl.com/zq8vxkk). Accessed 13 Oct. 2016.

"Least Tern." *All About Birds*, Cornell Lab of Ornithology, [www.allaboutbirds.org/guide/Least\\_Tern/lifehistory](http://www.allaboutbirds.org/guide/Least_Tern/lifehistory). Accessed 13 Oct. 2016.

"Planning a Wetland Restoration Project." 2002, *Wisconsin Wetlands Association*, [wisconsinwetlands.org/restorationplan.htm](http://wisconsinwetlands.org/restorationplan.htm). Accessed 12 Oct. 2016.

"Salton Sea Ecosystem Restoration Program Preferred Alternative Report and Funding Plan." May 2007. *California Department of Water Sources and California Department of Fish and Game*. Accessed 13 Oct. 2016.

"Saving a Corner of the Aral Sea." 1 Sept. 2005, *The World Bank*, [www.worldbank.org/en/results/2005/09/01/saving-a-corner-of-the-aral-sea](http://www.worldbank.org/en/results/2005/09/01/saving-a-corner-of-the-aral-sea). Accessed 12 Oct. 2016.

Smail, Stephanie. 13 June 2016. "Great Barrier Reef Water Quality Improved by Wetlands Restoration, Scientist Says." *ABC News*, *ABC News*, [www.abc.net.au/news/2016-06-14/wetlands-restoration-critical-to-improving-barrier-reef-water/7507452](http://www.abc.net.au/news/2016-06-14/wetlands-restoration-critical-to-improving-barrier-reef-water/7507452). Accessed 12 Oct. 2016.

"Snowy Plover." *All About Birds*, Cornell Lab of Ornithology, [www.allaboutbirds.org/guide/Snowy\\_Plover/lifehistory](http://www.allaboutbirds.org/guide/Snowy_Plover/lifehistory). Accessed 13 Oct. 2016.

"Wetlands Restoration Definitions and Distinctions." 6 Oct. 2016, *US Environmental Protection Agency*, [www.epa.gov/wetlands/wetlands-restoration-definitions-and-distinctions](http://www.epa.gov/wetlands/wetlands-restoration-definitions-and-distinctions). Accessed 12 Oct. 2016.

"Wildlife & Habitat." *U.S. Fish and Wildlife Service*, [www.fws.gov/Refuge/Merced/wildlife\\_and\\_habitat/index.html](http://www.fws.gov/Refuge/Merced/wildlife_and_habitat/index.html). Accessed 13 Oct. 2016.