RECLAMATION

Managing Water in the West

San Justo Reservoir Zebra Mussel Eradication

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San Justo Reservoir Zebra Mussel Eradication

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Acronyms and Abbreviations

TSC	Technical Service Center
MOP	Muriate of Potash (potassium chloride)
ROV	Remotely Operated Vehicle
LiDAR	Light Detection and Ranging
IFSAR	Interferometric Synthetic Aperture RADAR

Executive Summary

San Justo Reservoir has been known to be infested with invasive exotic zebra mussels (*Dreissena polymorpha*) since 2008, prompting a quarantine and closure of the area to public access in order to further prevent their potential spread. There is no direct connectivity between San Justo Reservoir and other water bodies, effectively isolating the zebra mussel population and presenting a relatively unique opportunity for eradication.

A group of personnel from the Bureau of Reclamation Mid Pacific Region, California Department of Fish and Wildlife, San Benito County, and the San Benito County Water District, have proposed and developed environmental compliance documentation towards an eradication effort using potassium provided in the form of muriate of potash (MOP).

Previous work has demonstrated the efficacy of MOP in treating invasive mussels and the potential for use in eradication. However, a suitable eradication strategy at San Justo faces some inherent complexities such as the scale of the treatment and costs, the time window available for treatment (water storage and delivery obligations), the seasonal changes in water quality parameters, and risks of mussels escaping treatment potentially leading to re-infestation.

This report covers several tasks accomplished towards developing a technically and logistically sound mussel eradication plan for San Justo Reservoir, including a site-specific dose-exposure study, bathymetry analysis, creation of a draft eradication plan, and a feasibility level cost estimate.

Ex-situ studies conducted at San Justo Reservoir measured the response of zebra mussels to various concentrations of MOP at average high (22° C) and low (12° C) temperatures. Results of the study indicated a considerable effect of water temperature on mussel die-off, and evidence to support eradication may be achievable in less than 30 days even at low temperatures.

Bathymetric data was collected from the San Justo Reservoir to more accurately estimate the volume of water that would need to be treated at various reservoir elevations.

The draft eradication plan has four fundamental components:

- Drawing down the reservoir to expose shoreline mussels to desiccation as well as reducing the total volume of water to be treated.
- Appling potash solution to San Justo Reservoir to achieve a homogenous concentration of 100 ppm potassium.
- Flushing the distribution system with treated water from the reservoir and holding all treated waters in place for at least 30 days.
- Monitoring water quality and zebra mussel metrics to ensure appropriate treatment conditions and evaluation of mussel mortality, as well as to inform into any necessary adaptive management measures.

The plan to eradicate zebra mussels from San Justo Reservoir currently remains in draft form awaiting further response and input from the working group. It is not presented in its entirety in this report, but the general strategy and potential risks for eradication failure are discussed. Likewise, the feasibility level cost estimate is also not presented but general inputs and cost drivers are illustrated.

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Introduction

San Justo Reservoir

San Justo Reservoir is an off-stream storage facility of the San Felipe Division of the Central Valley Project. The reservoir is located approximately three miles southwest of Hollister, California and consists of a 151 foot high dam and a companion dike 79 feet high; total capacity is roughly 9,785 acre-feet. The reservoir was built and is owned by the Bureau of Reclamation and operated by the San Benito County Water District. San Justo receives water from San Luis Reservoir by way of the Pacheco Bifurcation and Hollister Conduit. Water is delivered out of San Justo by way of the Hollister Conduit and the San Benito County Water District distribution system and subsystems (distribution system) for irrigation and municipal uses, with a service area of 23,700 acres. The distribution system includes more than 90 miles of total piping with various turnouts, flow control structures, booster pumps, and other features.

The invasive exotic zebra mussel (*Dreissena polymorpha*) was detected at San Justo Reservoir in 2008, and the reservoir has since been closed to public access to prevent potential spread. Adult zebra mussels were also found to infest the Hollister Conduit at multiple locations downstream of San Justo Reservoir in 2009.

Because San Justo is essentially a terminal water body and does not discharge into connective waters, it presents a relatively unique prospect for potentially eradicating zebra mussels in the reservoir and distribution system. A group of personnel from various agencies including Bureau of Reclamation Mid Pacific Region, California Department of Fish and Wildlife, San Benito County, and the San Benito County Water District, has proposed an eradication effort by treating the reservoir and distribution system with potassium in the form of muriate of potash (MOP).

Open-Water Mussel Eradication

Mussel control or eradication treatments in large water bodies are inherently difficult and costly due to the scale of the treatment and volume of treatment materials necessary, as well as potential impacts to beneficial organisms, downstream use limitations, and other factors. Various alternatives for eradicating invasive mussels at San Justo Reservoir are discussed in the Draft Finding of No Significant Impact (Reclamation 2015). Alternatives eliminated from further analysis included the use of copper based pesticides, *Pseudomonas* bacterial derived biocide products, as well as a complete drawdown of the reservoir (desiccation) and programmatic mussel management (containment).

Previous work by others, such as the successful mussel eradication at Millbrook Quarry, Virginia, established that water treated with MOP at 100 ppm potassium can be lethal to mussels (USFWS 2005). A suitable treatment for achieving 100% kill at San Justo reservoir may be constrained by time available for treating the reservoir (water storage and delivery obligations) and the seasonal changes in water quality parameters.

The selected alternative takes advantage of seasonal fluctuations in reservoir elevation, weather conditions, and utilizes MOP (a form of potassium chloride) to treat the reservoir and distribution system. Properties of MOP such as toxicity and environmental impacts are reviewed and summarized in the draft FONSI (Reclamation 2015).

San Justo Mussel Eradication

The scale of the effort to completely eliminate invasive mussels from San Justo Reservoir and the distribution system will be one of the largest yet conducted. With a drawdown target of 455 feet elevation, 3,000 acre-feet of water will need to be treated, as well as over 90 miles of piped systems.

Successful mussel eradication at San Justo faces several complexities, including a substantial volume of water to be treated, extensive invasive zebra mussel populations, and a multifaceted pipeline system. These aspects present a level of risk for eradication failure that is difficult to accurately quantify; primarily the ability to fully expose all mussels to water with sufficient potassium concentrations throughout the prescribed treatment period to cause complete mortality is unknown. Mussels will have the potential to "escape" treatment in various ways, including non-homogenous mixing and dispersal of the potassium solution, refugia areas within the drawdown zone, or incomplete charging of the distribution system.

Very small populations of surviving mussels would have the potential to completely re-infest the entire system in a relatively short period. For the eradication to succeed, treatments must ensure best possible concentration and contact times of treated water throughout the reservoir and connected systems. This includes San Justo Reservoir, the Hollister Conduit and distribution system as well as shoreline areas.

In addition to the risks associated with the scale and complexity of the systems to be treated, a feasible eradication effort must mesh logistically with ongoing water delivery and storage operations at San Justo Reservoir, which may necessitate sub-optimal timing and conditions in which to conduct the eradication treatments.

Eradication Planning and Studies

Several data collection efforts were conducted in order to inform the best possible methods for successful eradication of zebra mussels at San Justo Reservoir, and are the primary focus for this report. These include:

- Dose-exposure tests to determine mortality rates of mussels at different potassium concentrations and water temperatures.
- Bathymetric surveys to more accurately estimate reservoir water volumes.
- Draft analysis for eradication implementation.

Dose-Exposure Testing

Because of the scale, cost, and risks involved in an effort to eradicate mussels in San Justo reservoir, as well as the logistical timing with ongoing reservoir operations, an evaluation of the site-specific dose and temperature effects on mussel mortality over time was necessary. This study was conducted as a proof-of-concept for a MOP treatment to kill zebra mussels at San Justo reservoir, and to provide data to help refine the final eradication plan.

Methods

This study was conducted on-site at San Justo using both mussels and water from the reservoir. The experiment was a 2-factor design with water temperature and potassium dose as main factors. There were two levels for water temperature (12 °C and 22 °C) and five levels for potassium dose (0, 25, 50, 100, and 200 ppm). The 12 °C and 22 °C temperature treatments were created via a water bath using flow-through chillers, aquarium heaters, and plastic wading pools. We used 0 ppm potassium as a negative control and

200 ppm potassium as a positive control, expecting little to no mortality over the experiment at the 0 ppm dose and relatively fast and complete mortality at the 200 ppm dose. There were five replicates for each treatment combination (total of 50 experimental units).

Each replicate was a mason jar containing ten zebra mussels and aerated with aquarium bubblers. Mussels were collected from the infested reservoir, examined and confirmed live, then sorted into one of 3 size classes. Mussels were assigned at random to each replicate at the ratio of 7 large: 2 medium: to 1 small mussel, and each replicate was in turn assigned at random to a treatment combination.

For the first 3 weeks of the experiment, the number of mussels in each replicate that were dead and the number that were alive were recorded daily. The water in each replicate was replaced daily with fresh reservoir stock solutions of water dosed with the appropriate amount of MOP. Each mussel in each replicate was observed to determine whether they were dead or alive. If a mussel exhibited symptoms characteristic of a dead mussel (e.g., gaping and unresponsive), it was removed from the treatment jar and placed into a separate jar supplied with untreated reservoir water (i.e., no MOP, 0 ppm potassium), allowing it to recover. A recovery jar was created for each experimental unit that yielded mussels that appeared dead on a given day. Mussel(s) that appeared dead were allowed to recover for 3 days and then were then observed again to verify their status (dead or alive). Any mussel(s) that had failed to recover (i.e., exhibit symptoms of a living mussel) after 3 days in the recovery conditions were recorded as dead (on the date it was removed from the treatment jar and placed in the recovery jar) and they were removed from the experiment. If a mussel recovered, it was deemed an inaccurate mortality assessment and removed from the experiment. Mussels exhibit levels of "intoxication" when exposed to potassium, where their shells gape and are unresponsive, but will return to normal after being placed in untreated water. Two of the experimental treatments were initially suspected to be dead but recovered after 24 hours. These treatments were re-created with new mussels from the reservoir, and the protocol modified for determination of live vs. dead mussels. None of the mussels recovered after being assessed as dead following the initial misclassification.

In addition to the number of dead and live mussels in each jar, water temperature, dissolved oxygen content, and the pH at the time of the observation were recorded. Also, the length of the shell for mussels that were confirmed to be dead was either measured directly, or the shell was photographed for later size measurement.

After three weeks of daily observations, the time between observations of the remaining live mussels was increased from daily to 1 to 4 days through the duration of the study (total of 45 days). Observations were continued in order to gather information on mortality of mussels subjected to treatments with live mussels remaining (lower temperatures and lower doses), where effects were expected to be delayed.

Results and Discussion

Both concentration of potassium and water temperature had considerable effects on mussel mortality. Dose-exposure curves for MOP treatments are presented in Figure 1, and days required to reach complete mortality by treatment are presented in Table 1. Control treatments (0 ppm) at both temperatures did not exhibit any effects on mussel, confirming treatment jar mortality was caused by the MOP treatment and not an artifact of jar confinement, low oxygen/nutrient levels, etc. The 25 ppm treatments at both temperatures reached nominal mortality (2%) by the end of the 45 day trial.

At concentrations at and above 50 ppm the effects of water temperature were more apparent, with lower temperatures exhibiting slower mortality, likely the result of a slower metabolic rate and less-frequent feeding by the mussels, as they were observed to be generally more tightly shut in their shells at 12° C vs. 22° C. The 50 ppm treatment reached 100% mortality in 36 days at 22° C, whereas the 12° C/50 ppm treatments topped out at 42% mortality at the end of the 45 day trial. All mussels treated with 100 or 200 ppm potassium attained 100% mortality within the study period. Both concentrations in the warmer water treatments died off more quickly than the cooler water treatments.

These results suggest that eradication of zebra mussels at San Justo reservoir is feasible at 100 ppm potassium concentrations, and should be able to eradicate mussels within the reservoir in less than 30 days, even in the later part of the season when temperatures are low. However, these tests were conducted in artificial environment and may not translate directly to reservoir-scale treatments. Water currents, thermal stratifications, and varying depths may prevent complete mixing of the applied MOP and cause a much longer holding period necessary to achieve the desired concentration throughout the reservoir and result in mussel eradication. Treatment with MOP when water temperatures are higher (late summer-early fall) will likely distribute throughout the reservoir more quickly and hit the mussels while they are more active metabolically, resulting in quicker eradication and potentially less risk of escapes (eradication failure).

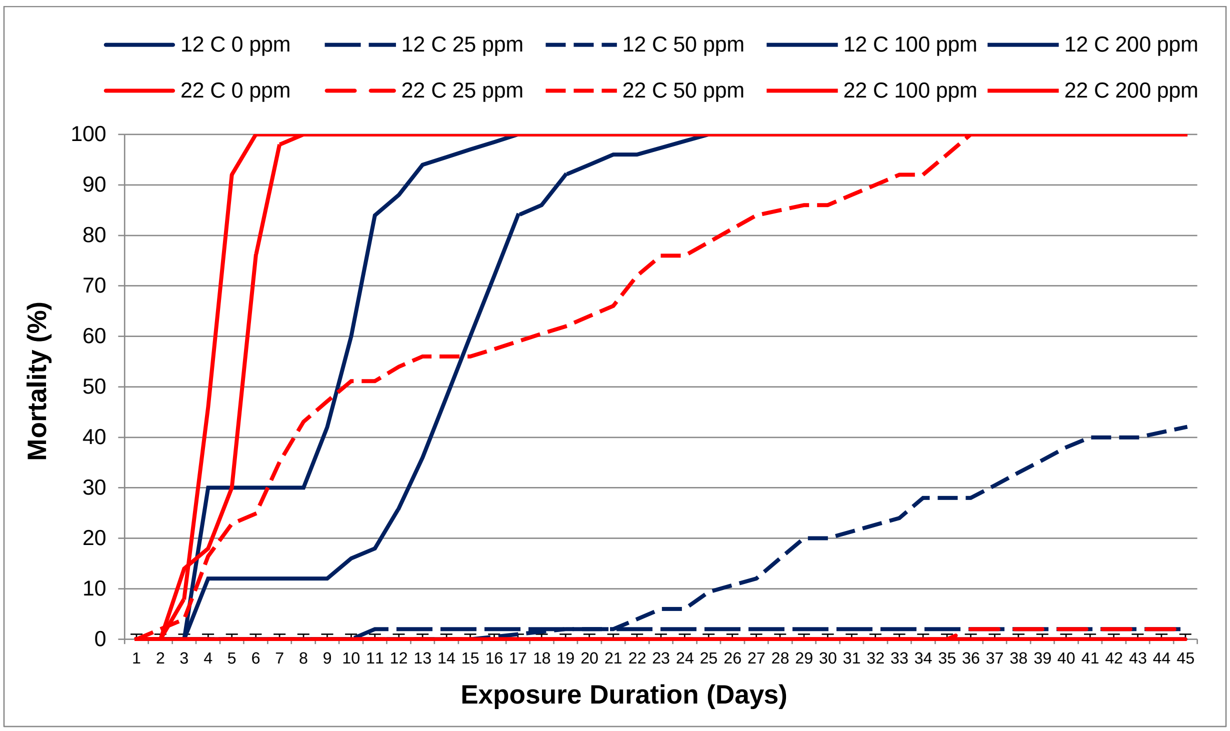

Figure 1. Mean dose-exposure curves for mussels treated with potassium at 12° C and 22° C.

Table 1. Time in days to achieve 100% mussel mortality by water temperature and potassium concentration.

Treatment Temperature (°C)	Treatment Concentration (ppm K)	Days to 100% Mortality
12	0	-
	25	-
	50	-
	100	25
	200	17
22	0	-
	25	-
	50	36
	100	8
	200	6

Treatments with missing values did not reach 100% mortality within the study period.

Bathymetric Survey

Methods

A bathymetric survey was conducted at San Justo Reservoir the week of November 13th, 2017 by TSC Sedimentation and River Hydraulics group. San Justo Dam was constructed in 1987 and the reservoir has never been resurveyed. Ideally surveys are conducted when the reservoir is at its fullest operating elevation (typically in the spring). Higher water levels allow the survey vessel access to a larger portion of the reservoir and overlap with any aerial data that may exist.

Following the bathymetric survey, collected data was processed to generate topographic maps of the reservoir area and to compute updated area-capacity relationships for potash dosage calculations and dam operations. No known recent aerial data has been collected at San Justo to combine with bathymetry for generation of a continuous map. In above water areas where no LiDAR is available, IFSAR data may be used to complete the topographic maps up to the full capacity elevation.

Bathymetric survey data covering the San Justo Reservoir area of interest was processed, filtered, and combined into a single set of coordinates and bottom elevations. This data was the basis for developing current bathymetric charts and area-capacity tables.

Results

The reservoir elevation at the time of the survey was approximately 480 feet; bathymetric mapping and analyses was considered accurate below 472 feet elevation. The elevation-capacity relationship of San Justo Reservoir is presented in Figure 2, and the topographic representation is presented in Figure 3. Area-capacity by elevation tables at 0.1 foot increments are presented in Appendix A.

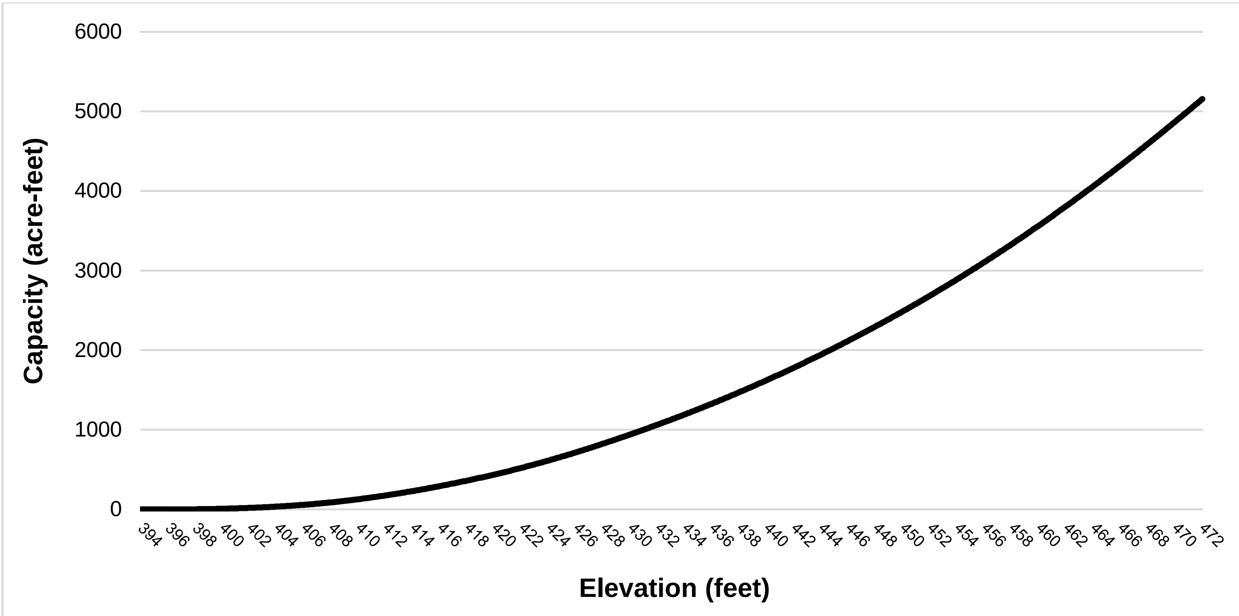

Figure 2. San Justo Reservoir capacity by elevation from 2017 bathymetry.

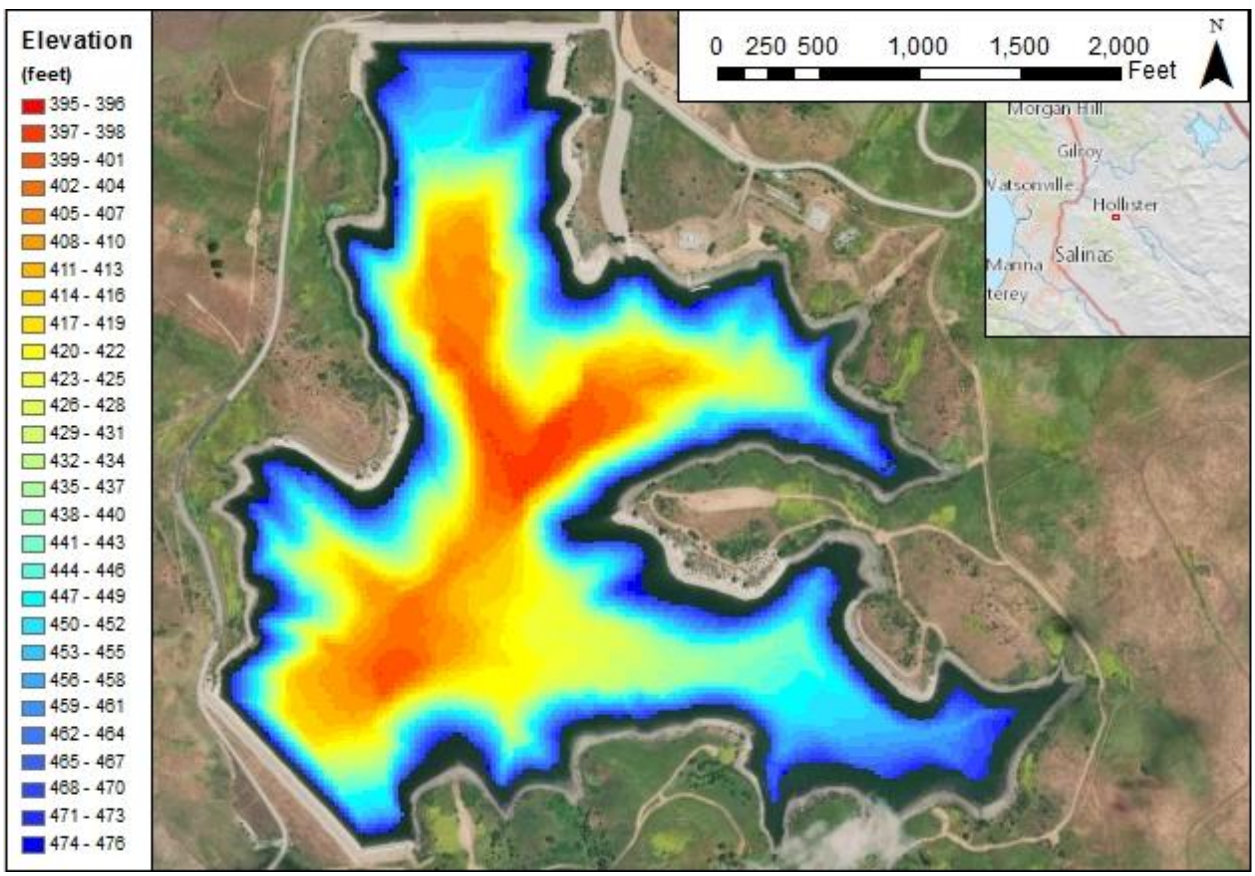

Figure 3. San Justo Reservoir bathymetric chart from 2017 survey.

Zebra Mussel Eradication Plan

The objectives of the eradication plan are to provide the best feasible strategy for complete elimination of zebra mussels within San Justo Reservoir, the Hollister Conduit, and all distribution system components, and to fully inform and describe known inherent risks for eradication failure and means available to minimize risks to inform considerations in decision-making.

Reservoir Drawdown

Drawing down the reservoir to reduce the total volume of water to be treated creates a more economically realistic, although still significant, amount of potash necessary for mussel eradication.

Several drawdown scenarios for San Justo Reservoir were examined, and indicated 455 feet as the minimum elevation below which adverse impacts would likely be seen by water users and stakeholders (Reclamation 2015). Since January 2014 the reservoir elevation has fluctuated between 441 and 500 feet (Appendix B). Much of this history includes drought years where water was delivered out of San Justo from early spring through late fall/early winter, and then refilled during the winter off-season with water from San Luis Reservoir. High-water conditions such as seen in the 2016/2017 season may create challenges to drawing down San Justo reservoir for the mussel eradication effort as alternative storage may be limited.

A drawdown can be accomplished by delivering water to customers from San Justo and delaying inflows from San Luis Reservoir; water would not discharge from San Justo Reservoir to rivers, creeks, or other open waters per the discontinued use of these turnouts (in effect since the discovery of invasive mussels at San Justo). Scheduling and implementation of the drawdown and reservoir refill should be conducted in coordination with San Benito County Water District and stakeholders so as to minimize the impacts to water users, costs of the eradication effort, and the risk of eradication failure.

Shoreline Treatment

The reservoir drawdown will expose shoreline-established mussel populations. Desiccation is expected to cause mortality to the majority of the exposed mussels, but wet areas, particularly pockets within the reservoir armoring and along the perimeter of the immediate shoreline may be able to support viable mussels. These refugia areas have the potential to be more prevalent and able to sustain viable mussels in the presence of cooler temperatures and/or precipitation, and the current treatment window would coincide with the start of the historical wet season (November through March, Appendix C).

The shoreline area will require regular monitoring as the drawdown progresses to assess the presence and extent of potentially live mussels or viable refugia, and continue until complete mortality is confirmed. In the event of inadequate desiccation or incomplete mortality, contingency practices for treating shoreline mussels should be enacted. Best practices for shoreline treatments will depend on the topography of the exposed shoreline, weather conditions, and extent of observed presence/absence of live mussels or potential habitats.

Reservoir Treatment

The current selected alternative for zebra mussel eradication at San Justo Reservoir includes the application of MOP. On a global level, potash is mined in significant quality and quantity in only a few countries. The continental U.S. is believed to contain one percent of the world's potash. In 2015, U.S. production was estimated at 740,000 metric tons, compared to global production of 40,600,000 metric tons. The largest known potash reserves are found in Canada (46% of global supply), with most mines located in central to south-central Saskatchewan (USGS 2017).

Fertilizer suppliers commonly deliver potassium for agricultural use in the form of potash solution, and various sources are available in the Central Valley of California. Off-site mixing and tanker-truck deliveries are services readily available in the vicinity of the San Justo. However, due to the scale of product necessary for the eradication, acquisition of potash may require pre-planning and need to be initiated one or more years prior to conducting the treatment. For reference of scale, treating San Justo at 455 feet elevation would require approximately 759 metric tons of potash, which equates to 0.1% of U.S. production in 2015 (0.002% of 2015 global production).

Various options are available for application of MOP to the reservoir, in principle a relatively simple process but with some logistical nuances due to the scale of the project. Transport, storage, spill containment, and MOP application and should be attainable using commonly available equipment (storage tanks, pumps, hoses, etc.). The primary unknown and potential risk factor in the reservoir treatment is in achieving a homogenous mixing of the MOP throughout the water column.

The ability to attain and maintain uniformly distributed concentrations of potassium throughout San Justo Reservoir is unknown. Previous eradication efforts using potash have seen variable results: At Millbrook Quarry, complete mixing was verified within 24 hours of the treatment completion using only surface applications and distribution hoses less than 3 meters long (ASI 1996).

Winter potash treatments were conducted at Christmas Lake by pumping potash slurry under surface ice. Monitoring results indicated vertical and horizontal stratifications of potassium concentrations, with “hot spots” accumulating at the deepest depths, attributed to the higher density of the potash solution and low water temperatures. Efforts to mechanically mix the product under the ice were unsuccessful, and ultimately control of mussels was poor (Lund et al. 2017).

The timing of the MOP treatment at San Justo may coincide with cold but above freezing water temperatures, typically as low as 12ºC (Appendix D). Spreading the application over a large portion of the reservoir surface and throughout the water column may not fully achieve target concentration of MOP at deeper parts of the reservoir, as was seen at Christmas Lake. Further investigation into mitigation measures to adequately mix potash solution into colder temperature waters may be warranted.

Conducting the treatment earlier in the season would present warmer water temperatures, and additionally the summer/fall temperature inversion could aid in mixing the potash throughout the reservoir. However, the added risk of eradication failure due to improper mixing of MOP caused by low water temperatures must be weighed against the logistics, costs, and other impacts of conducting the treatment earlier in the season when delivery operations are typically conducted.

Distribution System Treatment

Once San Justo Reservoir is confirmed to be consistently within the target concentration range for potassium, the distribution system can be flushed with treated water by opening the inlet/outlet valve. Untreated water within the distribution system will need to be bled from multiple turnout locations to move full-concentration treated water to all wetted surfaces, and should be conducted so as not to cause any adverse impacts to water users or the environment.

The San Benito County Water District estimates that charging the distribution system from 455 feet reservoir elevation would fully wet all but two of the subsystems. The remaining 2 subsystems will require injections of potash solution at several locations. The total volume of water to be treated with potash injection is in the subsystems is unknown, but assumed to be very minor in comparison to the overall effort.

Smaller features of the distribution system such as residential “blue meters” and piping are extensive, and may be very difficult if not impossible to fully charge with treated water for the duration of the treatment. These systems should be verified to be kept at positive pressure or equipped with backflow preventers to safeguard against re-infestation. These would be preventative measures and the systems may continue to harbor live mussels for many years, potentially indefinitely after the conclusion of the eradication treatment. This presents an unknown level risk to re-infest the distribution system and consequently San Justo Reservoir with invasive mussels, as mussels are motile to some extent, as well as the possibility of system outages or malfunctions that would move or allow live mussels into the distribution system. Mitigation of this risk would require inspection, treatment, and/or removal of all mussels from thousands of small-diameter (~2”) piping systems, and is assumed to be impractical or unattainable to conduct at this time. This risk is therefore inherent to the eradication effort and should be weighed accordingly.

Monitoring

Monitoring for water quality and mussel mortality/survival should be conducted at various sites and depths throughout the reservoir and distribution system on a weekly basis, before, during, and after the potash treatment. Short-term monitoring will evaluate the eradication effort at San Justo Reservoir and provide input for any necessary strategic modifications, and should be conducted prior-to, during, and immediately after the eradication treatments. The duration of short-term should generally extend from within one year prior to treatment, transitioning to long-term protocols after the conclusion of the eradication.

Reservoir

Water quality monitoring should be conducted before (baseline), during, and after MOP treatments to confirm adequate potassium concentrations and record potential changes in other water quality parameters that may affect the dose-exposure necessary for eradication or any potential undesirable effects. Water samples should be collected from various locations and depths within the reservoir at minimum on a weekly basis. More intensive sampling may be necessary dependent on deviations from expected levels through the treatment process.

Potassium concentrations will need to be monitored closely from multiple locations and depths to determine concentration levels and consistency of distribution. Samples will be collected at least once prior to treatment, then weekly during the application of potash to the reservoir and the holding period. Monitoring results should provide rapid feedback to guide any necessary corrective modifications to the application process.

Other water quality parameters including temperature, dissolved oxygen, conductivity, pH, and turbidity should also be regularly monitored with field instrumentation in coordination with sample collection for potassium concentration analysis.

Mussels of all life stages will be monitored regularly at various locations within the reservoir as well over the course of the eradication treatment. Specific methods for monitoring mortality include live mussel bioassays, plankton tows, visual inspection, and artificial settlement substrates. Mussel bioassays are live adult mussels placed in mesh bags and exposed to treated water. Live mussels would need to be collected from San Justo prior to MOP dosing. Sufficient quantities of live mussels may be acquired more easily if collected during the drawdown process as mussels settled at deeper depths become accessible from shallows over time. Live mussels can be kept in aerated reservoir water for several months if water is changed regularly. Using chilled water in insulated aquaria will slow mussel metabolism and may extend viable retention times and may reduce necessary frequency of water changes.

Plankton tows are high-volume filtered water samples that concentrate particulates and can be used to detect the presence of larval mussels. Tows are collected vertically from just off the bottom substrate to the surface, taken in sets to acquire a standard total volume. Filtered samples are transferred to sample bottles, preserved, and sent for laboratory analysis.

Artificial substrates deployed from docks or buoys can be used to assess mussel settlement within the reservoir. Substrates are to be deployed within one week of the initiation of the potash application and monitored every two weeks. Mussel settlement observations will transition into the long-term monitoring phase, at which point they will emphasize efforts during the typical June through October peak settlement window at San Justo.

At the completion of the eradication treatment, provided all other monitoring results indicate complete mortality of mussels, visual surveys conducted by divers or Remotely Operated Vehicle (ROV) video should be used to further validate the eradication effort.

Final determination of eradication success or failure will require at least 2 full consecutive seasons of monitoring for presence of live mussels at various life stages. A preliminary determination should be made at the conclusion of the visual mussel inspections, and if favorable may initiate monitoring strategies to shift from short-term to long-term protocols. Long-term monitoring should largely mimic short-term protocols but with efforts focused during the peak mussel settlement period at San Justo (June to October).

Distribution System

Various taps and hose bibs are available for collecting water samples throughout the distribution system. Monitoring parameters and protocols should mimic that of the reservoir. It will be important to closely monitor potassium concentrations will be important to closely monitor at as many points as possible to verify full charging of the system with sufficient concentrations of treated water. Any deviations from expected levels noted within the system should initiate corrective application of MOP solution to the nearest upstream (towards San Justo) injection point, to be bled off through all potassium-deficient upstream terminal ends of the system until acceptable concentrations are reached.

The Hollister Conduit can be monitored using bioboxes, which are essentially flow-through aquaria plumbed directly into the system. Inflow and outflow valves are installed to regulate flow and allow enough retention time for mussels to settle. Both mussel settlement monitoring and live mussel assays can be conducted in the bioboxes. Settlement is monitored by placing substrate plates (plastic or PVC) within the biobox, and live mussel assays for the distribution system consists of adult mussels in mesh bags placed in bioboxes. Biobox outflow should be considered to be contaminated with viable mussels and must be discharged so as not to spread to water bodies, streams or other open waters.

A final visual inspection of the conduit will be conducted at manholes and by remotely operated cameras for presence of live mussels.

Quarantine

All vehicles and equipment used for the eradication effort that come into contact with water from the reservoir or the distribution system, regardless of whether it has been treated with potash, will require inspection and decontamination before moving off site. Inspection/decontamination should follow procedures presented in the Bureau of Reclamation Inspection and Cleaning Manual for Equipment and

Vehicles to Prevent the Spread of Invasive Species, and the California Department of Fish and Wildlife Aquatic Invasive Species Decontamination Protocol, available at:

https://www.usbr.gov/mussels/prevention/docs/EquipmentInspectionandCleaningManual2012.pdf.

https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=43333&inline

Use of a high-pressure hot-water decontamination equipment will likely be necessary. A trailer-mounted mobile unit for on-site use is preferred; alternatively all equipment and vehicles may be transported directly to the nearest decontamination station. Care should be taken to either avoid contact with water or decontamination of all sampling equipment, boats, waders, or any other equipment for the duration of the eradication effort until data confirm the complete absence of invasive mussels. This will likely include an extended timeframe after the eradication effort is complete, the extent of which will be determined by the outcome of the monitoring effort and a consensus from all stakeholders.

Reclamation and San Benito have also committed to prepare a zebra mussel re-infestation prevention program, consistent with Bay Area Consortium's Zebra and Quagga Mussel Coordinated Prevention Plan.

Eradication Cost Estimate

A feasibility- level cost estimate for eradicating zebra mussels from San Justo Reservoir was conducted by Bureau of Reclamation Technical Service Center Construction Engineering, Specifications, & Construction Management Group. The assumptions for the cost estimate are as follows:

- MOP delivered to the project site as a pre-mixed solution via tanker truck at 12% potassium concentration by weight. Total estimated product is 755,000 gallons.
- A total of four Workboats with chemical distribution/diffuser systems connected to land-based storage tanks and delivery pumps will be used to distribute the MOP solution.
- The reservoir will be treated at approximately 455 feet elevation and will achieve target concentration of 100 ppm potassium homogenously mixed.
- The MOP treatment of both the reservoir and distribution system, including the holding period (45 day minimum) will be conducted between October 1 and December 31.
- A mussel decontamination station will be available on site.
- Monitoring activities will be coordinated between various State and Federal agencies.

Total costs for the eradication were estimated between $2.1 and $3.1 million. Of the total, the cost for the MOP product accounts for between 18-27%; potash is a publicly traded commodity and prices will vary over time. Mobilization, labor and equipment were calculated as a lump-sum for the remainder of the costs.

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Appendix A – San Justo Reservoir, Area and Capacity by Elevation tables.

Table A-1. San Justo Reservoir Surface Area (acres) by Elevation.

Elevation (feet)		0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
394		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
395		0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1
396		0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.4	0.5
397		0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4
398		1.5	1.7	1.9	2.0	2.2	2.4	2.5	2.7	2.9	3.0
399		3.2	3.3	3.5	3.6	3.7	3.8	4.0	4.1	4.2	4.4
400		4.5	4.6	4.7	4.8	4.9	5.0	5.1	5.2	5.3	5.4
401		5.5	5.7	5.8	5.9	6.0	6.1	6.3	6.4	6.5	6.6
402		6.7	6.9	7.0	7.2	7.3	7.5	7.6	7.7	7.9	8.0
403		8.2	8.3	8.5	8.6	8.8	8.9	9.1	9.2	9.4	9.5
404		9.7	9.8	10.0	10.1	10.3	10.4	10.6	10.7	10.9	11.0
405		11.2	11.4	11.5	11.7	11.8	12.0	12.2	12.3	12.5	12.6
406		12.8	13.1	13.3	13.6	13.8	14.0	14.3	14.5	14.8	15.0
407		15.3	15.5	15.7	16.0	16.2	16.4	16.6	16.8	17.1	17.3
408		17.5	17.7	18.0	18.2	18.4	18.7	18.9	19.1	19.4	19.6
409		19.8	20.1	20.3	20.5	20.7	20.9	21.1	21.3	21.5	21.7
410		22.0	22.2	22.3	22.5	22.7	22.9	23.1	23.3	23.5	23.7
411		23.9	24.1	24.2	24.4	24.6	24.8	25.0	25.2	25.3	25.5
412		25.7	25.9	26.1	26.3	26.5	26.7	26.8	27.0	27.2	27.4
413		27.6	27.8	28.0	28.2	28.4	28.6	28.8	29.0	29.2	29.4
414		29.6	29.8	29.9	30.1	30.3	30.5	30.6	30.8	31.0	31.2
415		31.3	31.5	31.7	31.8	32.0	32.2	32.3	32.5	32.7	32.9
416		33.0	33.2	33.3	33.5	33.6	33.8	34.0	34.1	34.3	34.4
417		34.6	34.8	34.9	35.1	35.2	35.4	35.5	35.7	35.9	36.0
418		36.2	36.4	36.5	36.7	36.9	37.0	37.2	37.4	37.6	37.7
419		37.9	38.1	38.3	38.5	38.7	38.9	39.1	39.4	39.6	39.8
420		40.0	40.2	40.5	40.7	40.9	41.2	41.4	41.7	41.9	42.2
421		42.4	42.6	42.8	43.0	43.3	43.5	43.7	43.9	44.1	44.3
422		44.6	44.8	45.0	45.2	45.4	45.6	45.8	46.0	46.2	46.4
423		46.7	46.9	47.1	47.3	47.5	47.7	47.9	48.2	48.4	48.6
424		48.8	49.0	49.2	49.4	49.6	49.9	50.1	50.3	50.5	50.7
425		50.9	51.1	51.3	51.5	51.7	51.9	52.1	52.3	52.5	52.7
426		52.9	53.1	53.3	53.5	53.6	53.8	54.0	54.2	54.3	54.5
427		54.7	54.9	55.0	55.2	55.4	55.6	55.7	55.9	56.1	56.2
428		56.4	56.6	56.7	56.9	57.1	57.2	57.4	57.5	57.7	57.9
429		58.0	58.2	58.4	58.5	58.7	58.9	59.0	59.2	59.3	59.5
430		59.7	59.8	60.0	60.2	60.3	60.5	60.6	60.8	61.0	61.1
431		61.3	61.5	61.6	61.8	61.9	62.1	62.2	62.4	62.6	62.7
432		62.9	63.0	63.2	63.4	63.5	63.7	63.8	64.0	64.2	64.3
433		64.5	64.7	64.8	65.0	65.2	65.4	65.5	65.7	65.9	66.0
434		66.2	66.4	66.5	66.7	66.9	67.1	67.2	67.4	67.6	67.7
435		67.9	68.1	68.2	68.4	68.6	68.8	68.9	69.1	69.3	69.5
436		69.6	69.8	70.0	70.2	70.4	70.6	70.7	70.9	71.1	71.3
437		71.5	71.6	71.8	72.0	72.2	72.4	72.5	72.7	72.9	73.1

Elevation (feet)		0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
438		73.3	73.4	73.6	73.8	74.0	74.2	74.4	74.5	74.7	74.9
439		75.1	75.3	75.5	75.7	75.8	76.0	76.2	76.4	76.6	76.8
440		77.0	77.2	77.3	77.5	77.7	77.9	78.1	78.3	78.5	78.7
441		78.9	79.1	79.2	79.4	79.6	79.8	80.0	80.2	80.4	80.6
442		80.7	80.9	81.1	81.3	81.5	81.7	81.9	82.1	82.3	82.5
443		82.6	82.8	83.0	83.2	83.4	83.6	83.8	84.0	84.2	84.3
444		84.5	84.7	84.9	85.1	85.3	85.5	85.7	85.9	86.1	86.3
445		86.4	86.6	86.8	87.0	87.2	87.4	87.5	87.7	87.9	88.1
446		88.3	88.5	88.6	88.8	89.0	89.2	89.4	89.6	89.8	90.0
447		90.2	90.4	90.6	90.8	91.0	91.2	91.4	91.6	91.8	92.0
448		92.3	92.5	92.7	92.9	93.1	93.3	93.5	93.7	94.0	94.2
449		94.4	94.6	94.8	95.0	95.2	95.5	95.7	95.9	96.1	96.3
450		96.5	96.8	97.0	97.2	97.4	97.7	97.9	98.1	98.4	98.6
451		98.8	99.0	99.3	99.5	99.7	99.9	100.2	100.4	100.6	100.8
452		101.0	101.3	101.5	101.7	101.9	102.2	102.4	102.6	102.8	103.1
453		103.3	103.5	103.7	104.0	104.2	104.4	104.6	104.8	105.1	105.3
454		105.5	105.7	106.0	106.2	106.4	106.6	106.9	107.1	107.3	107.5
455		107.8	108.0	108.2	108.4	108.7	108.9	109.1	109.3	109.6	109.8
456		110.0	110.2	110.5	110.7	110.9	111.2	111.4	111.6	111.9	112.1
457		112.3	112.6	112.8	113.1	113.3	113.5	113.8	114.0	114.2	114.5
458		114.7	115.0	115.2	115.5	115.7	116.0	116.2	116.4	116.7	116.9
459		117.2	117.4	117.6	117.9	118.1	118.3	118.6	118.8	119.0	119.2
460		119.5	119.7	119.9	120.1	120.3	120.6	120.8	121.0	121.2	121.4
461		121.7	121.9	122.1	122.3	122.5	122.7	122.9	123.2	123.4	123.6
462		123.8	124.0	124.2	124.4	124.6	124.8	125.1	125.3	125.5	125.7
463		125.9	126.1	126.3	126.6	126.8	127.0	127.2	127.4	127.7	127.9
464		128.1	128.3	128.6	128.8	129.0	129.3	129.5	129.7	130.0	130.2
465		130.4	130.6	130.9	131.1	131.3	131.5	131.7	132.0	132.2	132.4
466		132.6	132.8	133.1	133.3	133.5	133.7	133.9	134.1	134.3	134.6
467		134.8	135.0	135.2	135.4	135.7	135.9	136.1	136.3	136.5	136.7
468		137.0	137.2	137.4	137.6	137.8	138.0	138.2	138.4	138.6	138.8
469		139.0	139.2	139.4	139.6	139.8	140.0	140.1	140.3	140.5	140.7
470		140.9	141.0	141.2	141.3	141.5	141.7	141.8	142.0	142.1	142.3
471		142.4	142.6	142.7	142.8	142.9	143.0	143.1	143.2	143.3	143.5
472		143.6	-	-	-	-	-	-	-	-	-

Table A-2. San Justo Reservoir Capacity (acre-feet) by Elevation.

Elevation (feet)	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
394	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
395	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
396	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.3
397	0.4	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2
398	1.4	1.6	1.7	1.9	2.1	2.4	2.6	2.9	3.2	3.5
399	3.8	4.1	4.4	4.8	5.2	5.5	5.9	6.3	6.8	7.2
400	7.6	8.1	8.5	9.0	9.5	10.0	10.5	11.0	11.6	12.1
401	12.6	13.2	13.8	14.4	15.0	15.6	16.2	16.8	17.5	18.1
402	18.8	19.5	20.2	20.9	21.6	22.3	23.1	23.8	24.6	25.4
403	26.2	27.1	27.9	28.8	29.6	30.5	31.4	32.3	33.3	34.2
404	35.2	36.2	37.1	38.2	39.2	40.2	41.3	42.3	43.4	44.5
405	45.6	46.8	47.9	49.1	50.2	51.4	52.6	53.9	55.1	56.4
406	57.6	58.9	60.2	61.6	63.0	64.3	65.8	67.2	68.7	70.2
407	71.7	73.2	74.8	76.4	78.0	79.6	81.2	82.9	84.6	86.3
408	88.1	89.8	91.6	93.4	95.3	97.1	99.0	100.9	102.8	104.8
409	106.7	108.7	110.7	112.8	114.8	116.9	119.0	121.1	123.3	125.5
410	127.6	129.8	132.1	134.3	136.6	138.9	141.2	143.5	145.8	148.2
411	150.6	153.0	155.4	157.8	160.3	162.7	165.2	167.7	170.3	172.8
412	175.4	177.9	180.5	183.2	185.8	188.4	191.1	193.8	196.5	199.3
413	202	204.8	207.6	210.4	213.2	216.1	218.9	221.8	224.7	227.7
414	230.6	233.6	236.6	239.6	242.6	245.6	248.7	251.7	254.8	257.9
415	261.1	264.2	267.4	270.5	273.7	276.9	280.2	283.4	286.7	289.9
416	293.2	296.6	299.9	303.2	306.6	309.9	313.3	316.7	320.2	323.6
417	327	330.5	334.0	337.5	341.0	344.5	348.1	351.7	355.2	358.8
418	362.4	366.1	369.7	373.4	377.0	380.7	384.5	388.2	391.9	395.7
419	399.5	403.3	407.1	410.9	414.8	418.7	422.6	426.5	430.5	434.4
420	438.4	442.4	446.5	450.5	454.6	458.7	462.8	467.0	471.2	475.4
421	479.6	483.8	488.1	492.4	496.7	501.1	505.4	509.8	514.2	518.6
422	523.1	527.5	532.0	536.5	541.1	545.6	550.2	554.8	559.4	564.0
423	568.7	573.4	578.1	582.8	587.5	592.3	597.1	601.9	606.7	611.5
424	616.4	621.3	626.2	631.1	636.1	641.1	646.1	651.1	656.1	661.2
425	666.3	671.4	676.5	681.6	686.8	692.0	697.2	702.4	707.6	712.9
426	718.2	723.5	728.8	734.1	739.5	744.9	750.3	755.7	761.1	766.5
427	772	777.5	783.0	788.5	794.0	799.6	805.1	810.7	816.3	821.9
428	827.6	833.2	838.9	844.6	850.3	856.0	861.7	867.4	873.2	879.0
429	884.8	890.6	896.4	902.3	908.1	914.0	919.9	925.8	931.7	937.7
430	943.6	949.6	955.6	961.6	967.6	973.7	979.7	985.8	991.9	998.0
431	1004.1	1010.3	1016.4	1022.6	1028.8	1035.0	1041.2	1047.4	1053.7	1059.9
432	1066.2	1072.5	1078.8	1085.1	1091.5	1097.8	1104.2	1110.6	1117.0	1123.4
433	1129.9	1136.3	1142.8	1149.3	1155.8	1162.3	1168.9	1175.5	1182.0	1188.6
434	1195.2	1201.9	1208.5	1215.2	1221.9	1228.6	1235.3	1242.0	1248.7	1255.5
435	1262.3	1269.1	1275.9	1282.7	1289.6	1296.5	1303.3	1310.2	1317.2	1324.1
436	1331.1	1338.0	1345.0	1352.0	1359.1	1366.1	1373.2	1380.2	1387.3	1394.5
437	1401.6	1408.8	1415.9	1423.1	1430.3	1437.6	1444.8	1452.1	1459.3	1466.6
438	1474	1481.3	1488.6	1496.0	1503.4	1510.8	1518.2	1525.7	1533.2	1540.6

Elevation (feet)	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
439	1548.1	1555.7	1563.2	1570.7	1578.3	1585.9	1593.5	1601.2	1608.8	1616.5
440	1624.2	1631.9	1639.6	1647.3	1655.1	1662.9	1670.7	1678.5	1686.3	1694.2
441	1702.1	1710.0	1717.9	1725.8	1733.8	1741.7	1749.7	1757.7	1765.8	1773.8
442	1781.9	1790.0	1798.1	1806.2	1814.3	1822.5	1830.7	1838.9	1847.1	1855.3
443	1863.6	1871.8	1880.1	1888.5	1896.8	1905.1	1913.5	1921.9	1930.3	1938.7
444	1947.2	1955.6	1964.1	1972.6	1981.1	1989.7	1998.2	2006.8	2015.4	2024.0
445	2032.7	2041.3	2050.0	2058.7	2067.4	2076.1	2084.9	2093.6	2102.4	2111.2
446	2120	2128.8	2137.7	2146.6	2155.5	2164.4	2173.3	2182.3	2191.2	2200.2
447	2209.2	2218.3	2227.3	2236.4	2245.5	2254.6	2263.7	2272.9	2282.1	2291.3
448	2300.5	2309.7	2319.0	2328.2	2337.5	2346.9	2356.2	2365.6	2375.0	2384.4
449	2393.8	2403.2	2412.7	2422.2	2431.7	2441.2	2450.8	2460.4	2470.0	2479.6
450	2489.2	2498.9	2508.6	2518.3	2528.0	2537.8	2547.6	2557.4	2567.2	2577.0
451	2586.9	2596.8	2606.7	2616.7	2626.6	2636.6	2646.6	2656.6	2666.7	2676.7
452	2686.8	2697.0	2707.1	2717.3	2727.4	2737.6	2747.9	2758.1	2768.4	2778.7
453	2789	2799.3	2809.7	2820.1	2830.5	2840.9	2851.4	2861.9	2872.3	2882.9
454	2893.4	2904.0	2914.6	2925.2	2935.8	2946.4	2957.1	2967.8	2978.5	2989.3
455	3000	3010.8	3021.6	3032.5	3043.3	3054.2	3065.1	3076.0	3087.0	3097.9
456	3108.9	3120.0	3131.0	3142.0	3153.1	3164.2	3175.4	3186.5	3197.7	3208.9
457	3220.1	3231.4	3242.6	3253.9	3265.2	3276.6	3287.9	3299.3	3310.7	3322.2
458	3333.6	3345.1	3356.6	3368.2	3379.7	3391.3	3402.9	3414.5	3426.2	3437.9
459	3449.6	3461.3	3473.1	3484.9	3496.7	3508.5	3520.3	3532.2	3544.1	3556.0
460	3567.9	3579.9	3591.9	3603.9	3615.9	3627.9	3640.0	3652.1	3664.2	3676.3
461	3688.5	3700.7	3712.9	3725.1	3737.3	3749.6	3761.9	3774.2	3786.5	3798.8
462	3811.2	3823.6	3836.0	3848.4	3860.9	3873.4	3885.9	3898.4	3910.9	3923.5
463	3936	3948.6	3961.3	3973.9	3986.6	3999.3	4012.0	4024.7	4037.5	4050.2
464	4063	4075.9	4088.7	4101.6	4114.5	4127.4	4140.3	4153.3	4166.3	4179.3
465	4192.3	4205.4	4218.4	4231.5	4244.7	4257.8	4271.0	4284.2	4297.4	4310.6
466	4323.8	4337.1	4350.4	4363.7	4377.1	4390.4	4403.8	4417.2	4430.6	4444.1
467	4457.5	4471.0	4484.5	4498.1	4511.6	4525.2	4538.8	4552.4	4566.1	4579.7
468	4593.4	4607.1	4620.8	4634.6	4648.4	4662.2	4676.0	4689.8	4703.6	4717.5
469	4731.4	4745.3	4759.3	4773.2	4787.2	4801.2	4815.2	4829.2	4843.2	4857.3
470	4871.4	4885.5	4899.6	4913.7	4927.8	4942.0	4956.2	4970.4	4984.6	4998.8
471	5013	5027.3	5041.5	5055.8	5070.1	5084.4	5098.7	5113.0	5127.3	5141.7
472	5156	-	-	-	-	-	-	-	-	-

Appendix B – San Justo Reservoir Elevations

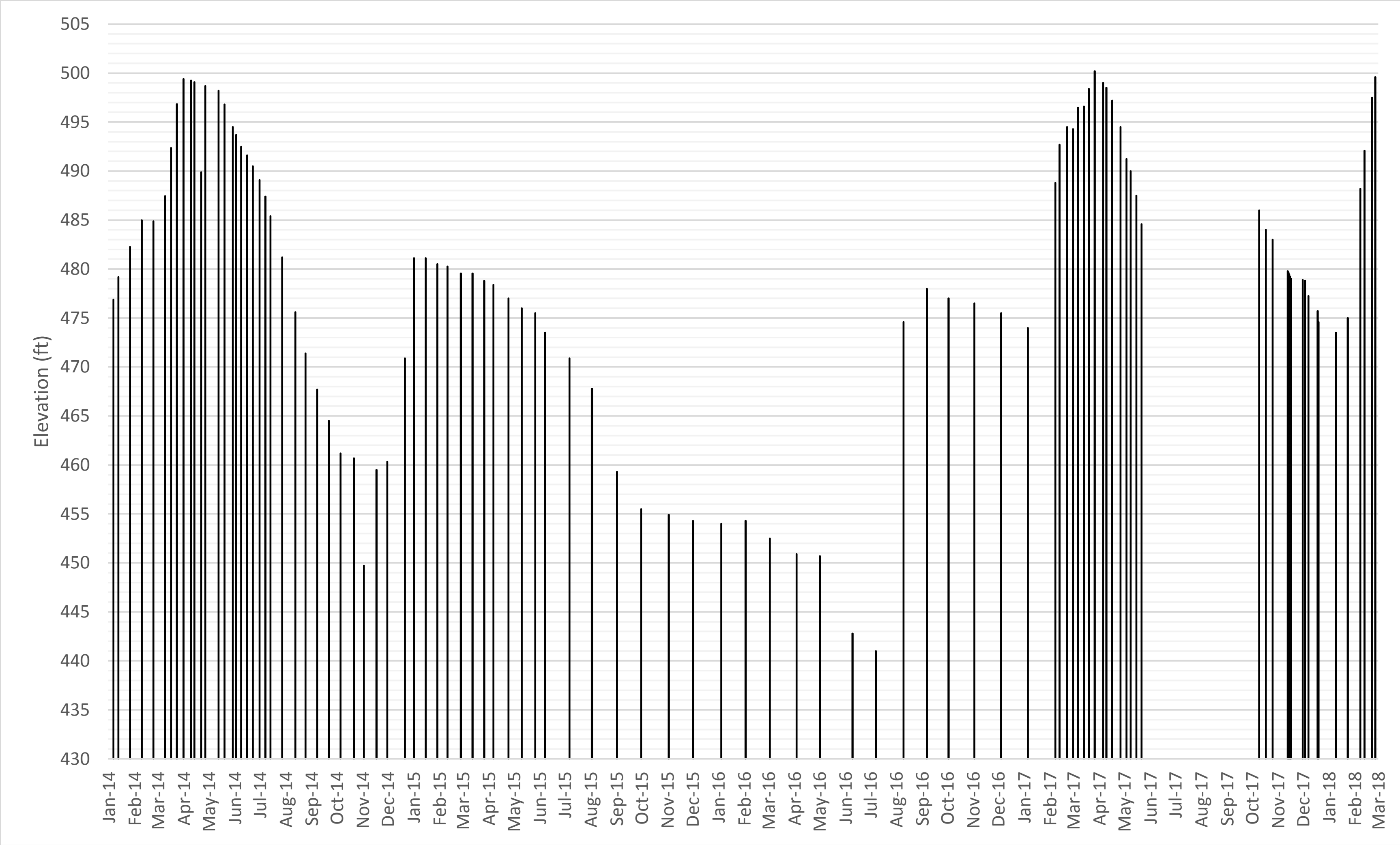

Figure B 1. San Justo Reservoir, available historic elevation data (Jan. 2014 - Mar. 2018).

Appendix C – Historical Climate Data Summary, Hollister California.

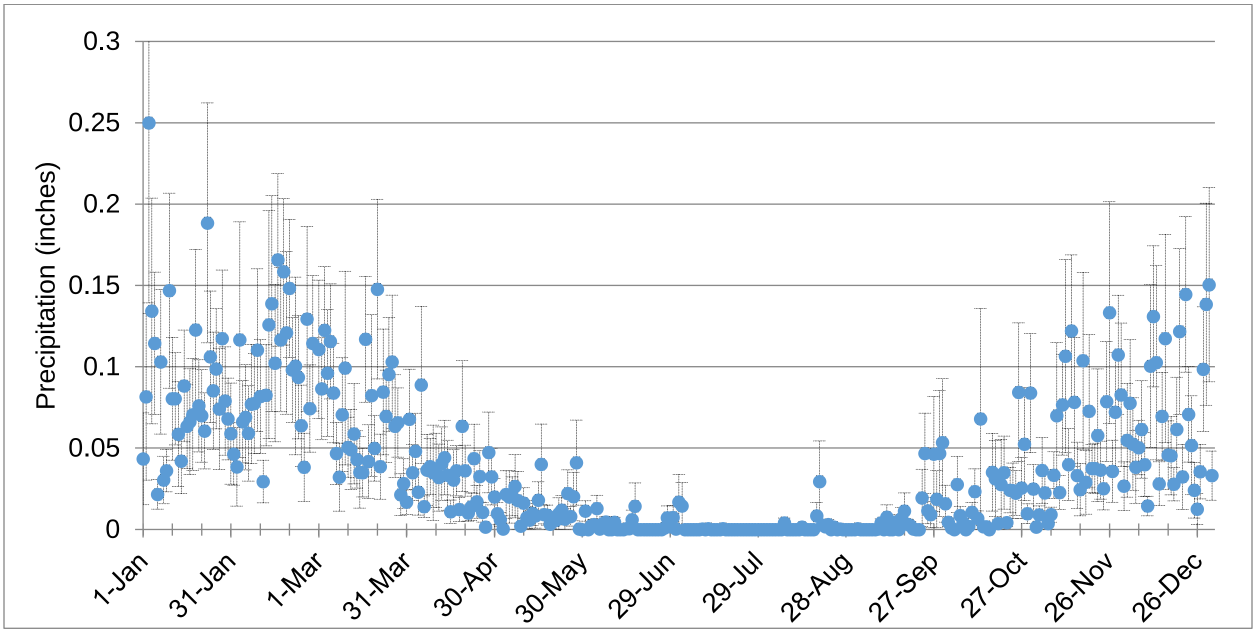

Figure C 1. 35 year daily precipitation means and standard deviations, Hollister weather station.

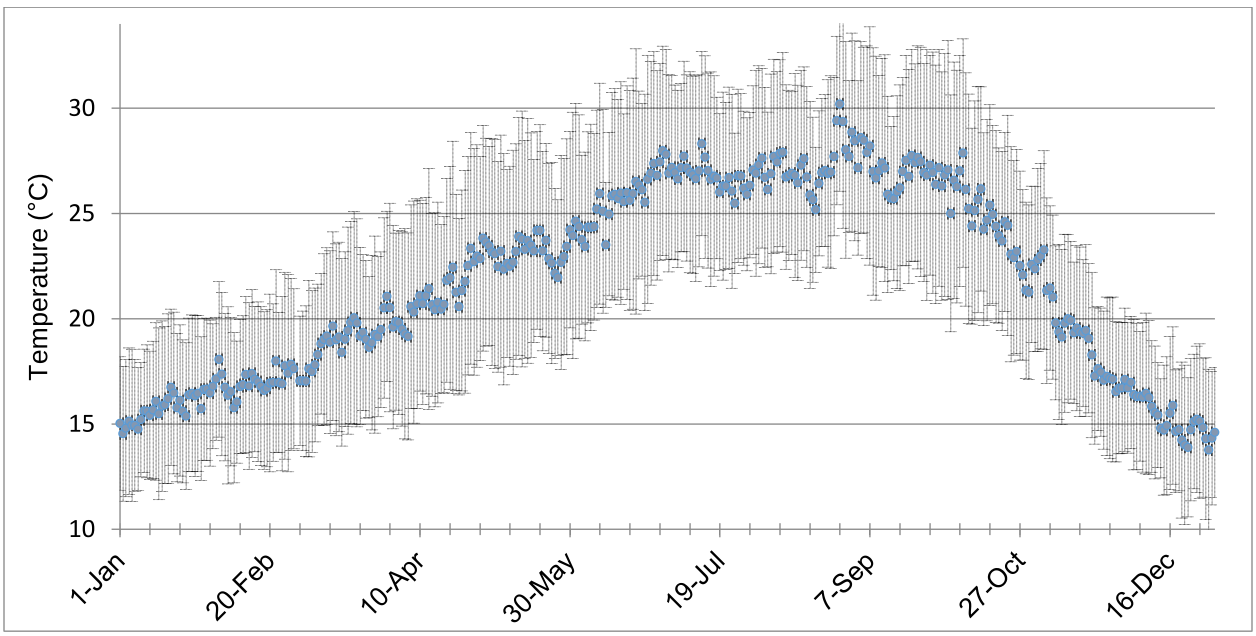

Figure C 2. 35 year daily daily air temperature means and standard deviations, Hollister weather station.