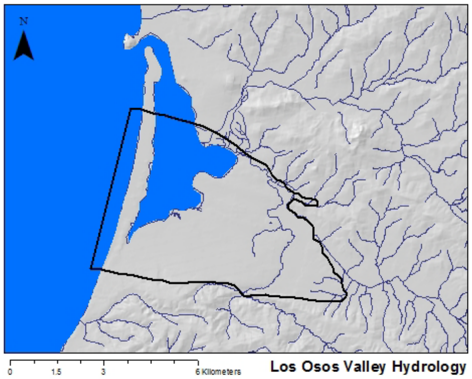

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Can Los Osos Valley Groundwater Basin Provide a Sustainable Water Supply?

CSUMB Class ENVS 660

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Executive Summary

The aquifers underlying the community of Los Osos in California are impaired by nitrate pollution from septic systems (shallow aquifers) and saltwater intrusion from overdraft (lower aquifers). The development of a centralized waste water system, now in the final pre-construction stages, is proceeding concurrently with an adjudicated basin planning process involving local water purveyors in an effort to develop a management plan for a sustainable basin and water supply. Development of the wastewater system aimed at protecting the shallow aquifer has highlighted the need for a comprehensive groundwater basin management plan that focuses the County, the local water purveyors, the residents, and resource agencies on a common set of actions to stop seawater intrusion and protect the entire basin. The final basin management plan will be scrutinized and critiqued as a potential model for myriad other hydrologically independent communities that are, or will soon be, undergoing the similar quest for reliable water. Stakeholders in the Los Osos Valley Water Basin have the opportunity to lead coastal California on the difficult path toward sustainable water supply through creative local solutions that do not presume the long-term viability of imported water or desalination.

While there are a number of detailed analyses and suggested actions in this report, the overarching conclusions/recommendations include:

- The saltwater intrusion models used in the draft EIR and technical memoranda (TMs) recently developed for the purveyor basin planning process attempt to balance saltwater intrusion against inputs and outputs to and from the aquifers. The net groundwater extraction amounts simulated in the models (corresponding to the purported safe yields) are considered aggressive (too much extraction) because they do not stabilize, or result in seaward migration, of the saltwater/freshwater interface (toward the northwest). In fact, the TM safe yield may allow the saltwater to move inland, especially if California climate becomes drier, as projected by State Government. Modeling results presented in our report indicate that if rainfall patterns persist as they have in the past, there is a reasonable chance that saltwater intrusion will progress farther, rather than remain stable, under anticipated pumping conditions. Further investigation is recommended to resolve uncertainties associated with the TM safe yields, including permeability of the regional (AT2) aquitard, how the AT2 affects lower aquifer recharge, and whether sufficient recharge will occur to prevent seawater intrusion in the upper aquifer. These uncertainties are under-appreciated in the EIR and TMs.
- We recommend the development of a “contingency plan” that allows flexible adaptive management to address unintended consequences that may occur following the implementation of the Los Osos Valley Wastewater Plan. Contingency plans identify mission-critical sections of the plan that have uncertainties, recommend

monitoring to ascertain progress of the plan, and define remedial actions that will mitigate various unintended consequences, including divergence from, or failure of the plan. Several mission-critical arenas are discussed in the report.

- Rooftop rainwater harvesting and low impact development (LID) options could produce a substantial amount of water for local irrigation, reducing potable water use, while also augmenting groundwater recharge. Some LID alternatives, e.g., rain gardens and vegetated swales, can also provide attractive low-water using landscape features that may also help Los Osos residents adapt to the potential changes in groundwater levels and soil moisture content resulting from project implementation that may affect landscaping. Both on-site and community LID features will also reduce pollution of surface waters in the area. While the method used to calculate potential basin recharge from rainwater and LID features in this report is inconclusive, it suggests that the benefits of these measures may be considerable. Rainwater harvesting and LID are proven technologies that should be considered on a broad basis in the Los Osos Valley to help balance the basin and adapt to potential impacts from the project.
- Treatment wetlands can provide economical, efficient waste water treatment systems and/or the means to provide additional treatment, storage, and recharge of the groundwater basin. They also provide habitat and quality of life benefits (open space and passive recreational opportunities, such as hiking trails). Nitrate removal in wetlands has been studied in small scale experiments in Monterey County, has been implemented in large scale applications with positive success. Wetlands to treat surface water and wastewater have been used successfully in many communities around the world.
- We recommend an emphasis on agricultural exchange to maximize its benefits on seawater intrusion and help balance the basin. Tertiary-treated waste water is safe for irrigation and can reduce groundwater pumping, as well as energy and fertilizer use for farmers, with related costs savings. When well water from farms is exchanged for recycled water, potable water can be used to offset pumping causing seawater intrusion. While it is best to balance the hydrologic budget using resources within the basin, there is also an option to trade agricultural-grade treated water to regional farms in exchange for drinking grade water from wells outside the basin if ample water reserves are developed in the future.
- The draft Los Osos Valley sustainable water basin management plan, “Achieving a sustainable Los Osos Valley Water Basin: Framework for a 21st century basin management plan” (Wimer 2009) presents realistic, well-supported solutions for addressing the water needs of the Los Osos Community using sustainable, water saving and LID methods while preserving the basin for future use. The plan integrates methods reviewed in this report (rainwater harvesting, LID, and agriculture exchange), with urban reuse and intensive indoor and outdoor conservation to

balance the basin and provide flows to sensitive ecosystems, with margins of safety that also address current and future uncertainties. We recommend that the plan is further developed, possibly with the help of water use efficiency expert, and considered for implementation.

To answer the question posed by the title--yes, Los Osos can become a model of sustainable water use for coastal California *if* stakeholders implement reasonable conservation measures to complement an appropriate waste water treatment strategy and an adaptive management plan. The great number of uncertainties in the system makes any plan "experimental." Given the uncertainties, due diligence will include erring on the side of caution (being conservative, not aggressive, in planned groundwater production), and devising a realistic contingency plan that includes adaptive management strategies.

The Advanced Watershed Science and Policy (ENVS 660) graduate course at California State University Monterey Bay produced this report. It presents the results of extensive literature review, synthesis, and new analyses. The breadth of the report spans many of the key water supply issues facing the people of the Los Osos Valley. It provides information that can help this region move toward a sustainable water supply through innovative waste water management and sound conservation measures.

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- Keith Wimer
- Michael Taraszki

Abbreviations used in this document

AF	Acre-feet
AFY	Acre-feet per year
CDEC	California Data Exchange Center
CRWQCB	California Regional Water Quality Control Board
CSLOPBD	County of San Luis Obispo Planning and Building Department
EIR	environmental impact report
gpd/ft^2	gallons/day/square foot
I_h	horizontal hydraulic gradient
IPCC	Intergovernmental Panel on Climate Change
ISJ	Interlocutory Stipulated Judgment
K_b	hydraulic connectivity
LID	low impact development
LOCV	Los Osos Creek Valley
LOSG	Los Osos Sustainability Group
LOWMPU	Los Osos Wastewater Management Plan update
LOWWP	Los Osos Wastewater Program
LP3	Log-Pearson Type 3
MBFD	Morrow Bay Fire Department
MCRP	Monterey County Recycling Project
MCWD	Marina Coast Water District
NH_4^+	Ammonium Ion
SBMP	sustainable basin management plan
SLO	San Luis Obispo
STEG	septic tank effluent gravity
STEP	septic tank effluent pumps
SWI	seawater intrusion
TM	technical memoranda
WRCC	Western Regional Climate Center

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1 Introduction

The development of long-term, dependable, and sustainable water supplies is a growing challenge for California communities. Recent drought years (CDWR, 2009), growing demand, and better groundwater basin characterization (e.g., Yates et al., 2005) have led to the realization that California's water demands are locally out of balance with long-term supply. Of special concern is the central California coast where communities isolated from large Central Valley water projects must locally balance their water needs with finite supplies. These communities must strive to quantify the long-term local hydrologic cycle in order to fully understand and manage their water supply and groundwater budget (e.g., Yates et al. 2005, SLOC 2007). Many factors complicate that hydrologic work including significant uncertainties in climate, physical and chemical groundwater basin characteristics, ineffective or non-existent conservation programs, assumptions about water quality, time to equilibrium, and realistic alternatives for adaptive management once a plan is implemented. For coastal aquifers faced with saltwater intrusion, there is also the unquantified impact of gradually rising sea level.

Los Osos, an unincorporated coastal community in San Luis Obispo County (Fig. 1), depends on a system of wells tapping into the regional Los Osos Valley ground water basin for drinking water (SLOC 2007). Currently without a community-scale sewer and waste water system, residents rely on individual septic systems for waste water disposal. As the community has grown, the need for a community-wide waste water collection and treatment system has become increasingly evident by nitrate contamination of the upper aquifer (Brown and Caldwell 1983). The water supply problem is further aggravated by overdraft of the lower freshwater aquifer resulting in considerable salt water intrusion (Cleath and Associates 2005). In 1983, the California Regional Water Quality Control Board (CRWQCB) of the Central Coast (Region 3) ordered a prohibition of discharge from new or additional individual and community septic systems to protect the drinking water quality (CRWQCB 1983). This discharge prohibition effectively halted new construction or major expansions of existing development and the community has since had several unsuccessful attempts to develop a centralized waste water facility for various reasons. San Luis Obispo County assumed responsibility for the Los Osos Wastewater Program (LOWWP) with passage of AB 2701, and has been in the process of an alternatives analysis since 2007. Stakeholders including local water purveyors and the County of San Luis Obispo have also not yet succeeded in formulating and implementing a feasible and comprehensive plan to stop seawater intrusion and balance the basin despite a long history of attempts. In the meantime, seawater intrusion has progressed inland contaminating more of the basin.

An adjudicated basin planning process is underway with the County and three other water purveyors participating. The process is currently proceeding under a cooperative agreement known as an interlocutory stipulated judgment (or ISJ). The lack of a single authority over all water and wastewater management in the basin complicates basin management although the County is granted special rights to manage seawater intrusion under the ISJ, and it has broad authority over the basin as administering agency of the local Resource Management System and Flood Control and Conservation District.

This report provides analyses and discussion of a few key issues important to the sustainability of the Los Osos Valley Water Basin. The report also provides a review of a water-use efficiency plan framework, integrating rainwater harvesting, graywater reuse, and low impact development strategies presented to us in draft form by Keith Wimer of the Los Osos Sustainability Group. In the spirit of fostering sustainable water supplies, the report offers specific and general recommendations for managing the Los Osos groundwater basin and for adaptive management/mitigation strategies.

1.1 Los Osos Valley Groundwater Basin

The Los Osos aquifer system is a fault bounded, east/west trending sedimentary basin located directly beneath the city of Los Osos. The aquifer comprises porous Tertiary and Quaternary age geologic units overlying significantly less porous bedrock (CDWR 2004) that rises in elevation gradually toward the west. The aquifer and aquitard units are probably intercepted by strands of the Quaternary Los Osos fault zone that project into the basin (Fig. 1). The aquifer has been vertically subdivided into 5 parts (A-E) separated by a range of low permeability layers (Fig. 2).

Three-fourths of the municipal and agricultural groundwater is currently drawn from the lower aquifers (Zone D and E), while about one-third is drawn from one of the upper aquifers (Zone C). The upper-most zones (Zones A and B) are tapped only by a few private wells, despite elevated nitrate levels. However, Zones A and B, the perched and transitional aquifers, are important sources of groundwater flows to environmentally sensitive habitat in the area and to the main production aquifers below.

The County of SLO has recently submitted a Coastal Development Permit (CDP) to the Coastal Commission as the last step in the wastewater project's review and approval process. The project will result in decommissioning about 5000 individual septic systems in the prohibition zone (about 85% of the properties in the urban area), and connecting the homes to a centralized wastewater system. Decommissioning septic systems will remove one of the largest sources of ground water recharge into basin aquifers. In order to compensate for the loss of the inputs from the septic tanks, the EIR presents various water management scenarios, which it indicates will mitigate for project impacts (maintain the status quo of the basin or slightly improve water balance with the project).

The post-sewerage basin management plan has been the focus of a long political and scientific discussion in the Los Osos Valley. Since the draft EIR was published (January 2009), technical memoranda have been developed as part of the ISJ basin planning process (Cleath-Harris 2009). These provide scenarios the TMs indicate will create a sustainable basin, which recommend pumping more water from the upper aquifer and less from the lower than recommended in the EIR management scenarios. The TMs base the recommendations on updated "safe yields" developed using a dual-density model, rather than the equivalent freshwater head (EFH) models used earlier. TM recommendations are to shift 900 AFY of pumping from the lower aquifer to the upper doubling its current pumping levels (800 AFY to 1670 AFY). The safe yields (pumping levels) in the lower aquifer would be reduced from about 1300 AFY to about 650 AFY (Cleath-Harris, 2009). The EIR and TM scenarios and management strategies raise several concerns related to the uncertainties of hydrologic modeling and adequate project mitigations, which are considered in sections of this report.

1.2 Implications of Groundwater Velocity

1.2.1 Rates and Time

Public discussion and management of groundwater often de-emphasize the timescales involved, as the rates and processes of groundwater movement are not intuitive. Groundwater moves differently from surface water, with hydraulic conductivity of the base material, hydraulic gradient, and pressure being the most important factors controlling water velocity. The range of flow rates are extremely large, with one variable in the equation, conductivity, ranging through five orders of magnitude in just sand and gravel (Ward and Trimble 2004). The ability to pump water from deep wells is very recent, starting in California in 1907 with the multi-stage turbine pump, which allowed pumping from several hundred meters below ground (Narasimhan 2009). Before this technology, centrifugal pumps were limited to 8m depths, and other wells had to be situated over pressurized artesian aquifers, which were often rapidly depleted (Narasimhan 2009). As recharge to aquifers can take many decades and residence times or average age of water in aquifers is often hundreds to thousands of years, the 103-year period of access to these resources is very small, and societies have not yet seen many effects of continuous pumping. In the Los Osos basin (Figs 1 and 2), radiocarbon dating of water returned an average age in Zone C of 870 years, Zone D of 3200 years, and Zone E of 7300 years (Cleath 2005). Due to modern water extraction, the current residence time for the lower aquifer is now estimated at 268 years, compared to thousands of years prior to development (Yates and Williams 2003, Cleath 2005).

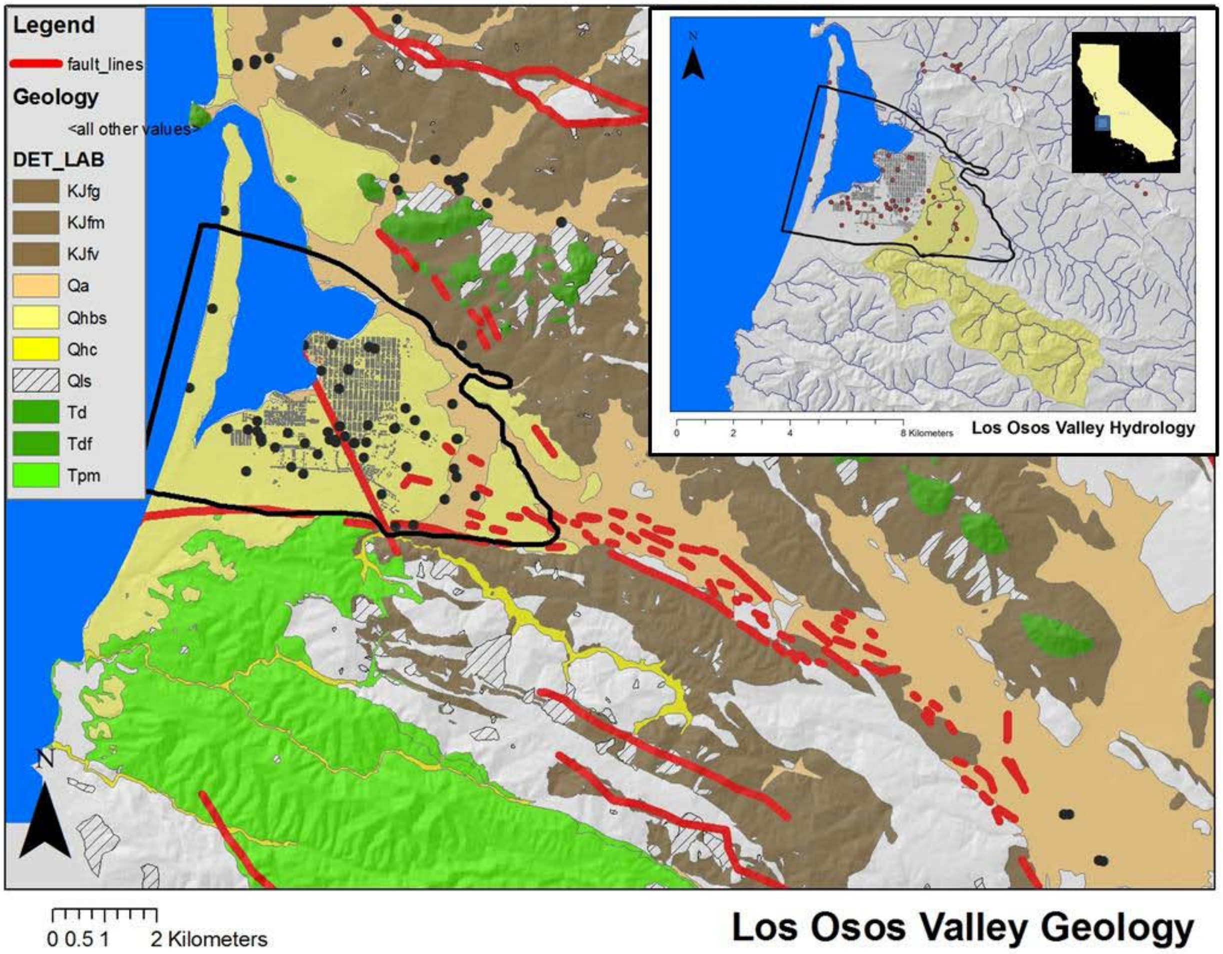


Figure 1: Location and geology of the Los Osos Valley groundwater basin (black line). Red lines show outcrops of the Los Osos fault zone. Yellow area of inset map shows the Los Osos Creek watershed.

The groundwater hydrology of the Los Osos Basin has been characterized by many studies and technical papers (Yates and Williams 2003, Cleath 2005 Michael Brandman Associates 2008), but presenting the implications of slow vertical and horizontal groundwater velocities to policymakers and the public was not their primary goal. Therefore, this paper highlights the timescales of groundwater movement within the basin as a resource for decision making upon policy options, public discussion, and monitoring efforts. We will estimate times of travel between parts of the basin in the upper and lower aquifer zones using values found in the existing literature from the area.

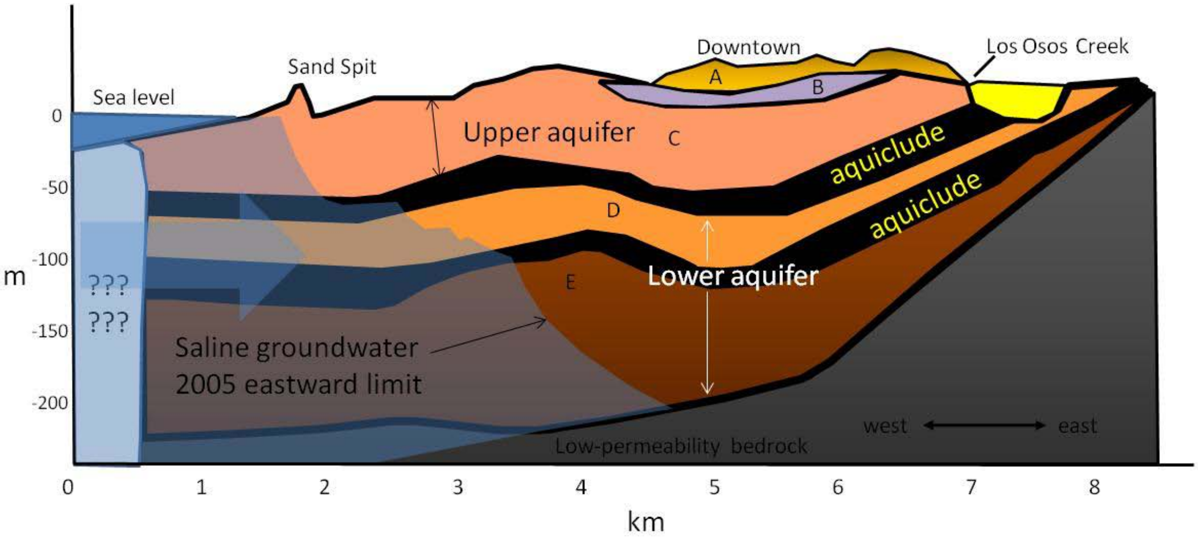


Figure 2: Schematic east-west cross section of the Los Osos aquifer system. Letters refer to aquifer zones discussed in the text. Figure after Heath and Associates (2005).

1.3 Rain and Drought

The only freshwater input to the hydrologic cycle of the Los Osos Valley is precipitation. It is important therefore to quantify that resource in a variety of ways, considering long-term trends and drought probabilities. It is not just the historic and pre-historic record that can influence management decisions, future climate change may provide a moving target for planners. If average precipitation significantly climbs or falls in coming decades, then an assumption underpinning all the recent hydrologic models will be violated. Analysis of credible precipitation variability influences the probability of saltwater intrusion (Section 1.8) and rainwater harvesting (Section 1.4).

Climate change is evident as numerous studies and analyses show an overall increasing trend in global temperatures (e.g., Le Treut et. al. 2007). As a result of increased global temperatures, variations in the local climate may occur. Increases in global temperatures result in increases in atmospheric moisture holding capacity which, in turn, affect precipitation characteristics (magnitude, frequency, intensity, extremes) (Trenberth et. al. 2003). The 2007 report from the Intergovernmental Panel on Climate Change (IPCC) (Trenberth et. al. 2007) reported a decreasing trend in precipitation for western North America from 1901 -2005. Although the scale used in the 2007 IPCC report is regional, the same patterns may be experienced on a local scale. Changes in precipitation can have a direct effect on the recharge rates of coastal aquifers and the communities that rely solely on coastal aquifers for drinking water. Climate change and precipitation trends and patterns must be considered when planning for future management of coastal aquifers, especially coastal, closed hydrologic systems like Los Osos.

Given the uncertainty in future rainfall input, it is worth investigating the uncertainties surrounding historic rainfall records. If a single average rainfall value were selected for modeling aquifer recharge, the output would be generally wrong, since the true average value is not known with certainty. Modeling that uses rainfall as an input should be run with the full range of possible average values as derived from statistical analysis. The short record available for the Los Osos region carries significant error bars, which we assess below.

1.4 Rainwater Harvesting

As Los Osos evolves from septic to sewer, it is critical to evaluate all potential sources of groundwater recharge to ensure sufficient future drinking water supply and support of environmentally sensitive habitat. To encourage water conservation and a sustainable development, it has been proposed that the upper aquifer could be partially recharged by water obtained from rain catchment. In the past, during heavy rainfall, water would flow from the impervious areas to the low zones and cause flooding, prompting pumping of the water into Morro Bay or Los Osos Valley Creek (Yates and Williams 2003). Some of the rainwater was also conveyed via storm drains to these water bodies. In both instances, an un-estimated amount of rain water is lost to the bay. Capture and storage of this water would allow for slow release and percolation into the aquifer, which would potentially aid in balancing the water budget for the area.

Current septic flow into the perched aquifer is estimated at 631 acre-feet/yr (AFY) (Michael Brandman Associates 2008 Appendix D), and septic flow into the upper aquifer is estimated at 606 AFY. Transition from septic systems to a centralized wastewater system will result in the loss of the input from the septic flow to the perched and upper aquifers. It is also estimated that total recharge to the upper aquifer from the perched aquifer is 698 acre-feet-per year (374 from leakage, and 324 from subsurface cross flow (Michael Brandman Associates 2008 Appendix D). The LOWWP condition of approval that recommends voluntary redirection of rainwater into the septic fields, in addition to other rainwater harvesting strategies, may help to recharge the upper aquifer, which may become the main source of water for Los Osos community (Michael Brandman Associates 2008). The goal of this section is to quantify the amount of water that might be available for recharge through rooftop rain harvesting and to analyze whether or not the amount of groundwater recharge is a significant volume when compared to other components of the water budget for the Los Osos Valley. This information will be useful for future decision making regarding rainwater harvesting/LID strategies in Los Osos, including the cost-effectiveness of such options for management the groundwater basin.

For the analysis, rain data were obtained from Morro Bay Fire Dept (MBFD); rooftop areas were obtained from the County of San Luis Obispo Planning & Building Department (CSLOPBD) building footprints AutoCAD files; and 1 m orthoimagery was obtained from SLO Data Finder. The total amount of possible rain water harvesting e.g., from other impervious surfaces on site and in public spaces, is not calculated, nor is soil moisture content or other factors to determine the actual recharge benefit of this options. Here we present one component of the calculation as a starting point for more thorough calculations.

1.5 Wetlands and Wastewater Treatment

Since the 1950s, environmental engineers have used wetland biogeochemical processes as a cost effective means to remove excess nutrients from wastewater (Kadlec and Knight 1996; Mitsch and Gosselink 2000). However, excess loading of nitrogen into US waters still consistently ranks as one of the top three causes of water impairment (USEPA 2006). Specifically, effluent from on-site sewage treatment systems, i.e. septic systems, has been noted as a prominent source of groundwater contamination (USEPA 1998). Other sources of nitrogen, including agricultural and urban fertilizer use, and natural sources such as native vegetation, contribute to nitrate pollution of ground and surface waters (Yates & Williams, 2003). The Los Osos groundwater basin on the central coast of California is currently experiencing groundwater contamination from nitrate, assumed to originate from septic system effluent (Michael Brandman Associates 2008). The basin also has relatively high levels of nitrates from other sources currently entering groundwater and surface waters. Finally, the project will produce about 800 acre feet of recycled water which would require additional treatment (e.g., in wetlands) prior to some types of applications, such as stream flow support.

Twenty percent of all U.S. household use septic systems (USEPA 2008). Many of these households are located in rural areas, such as the Los Osos community. Additionally, in these rural areas, the main source of drinking water is generally obtained from groundwater sources (Solley et al. 1993), representing a need for high water quality resources. Although using septic systems for residential sewage treatment works well in many situations, when these systems fail, are too densely grouped, or installed close to the groundwater table, problems of contamination can occur and result in degradation of drinking water resources (USEPA 2002). In Los Osos, all households currently use septic systems for sewage treatment, with many of these households in densely grouped neighborhoods. The resulting groundwater contamination has led to the need for the Los Osos community to decommission all septic systems and install a wastewater treatment plant.

The purpose of this section is to explore whether treatment wetlands could effectively treat the wastewater estimated to be produced by the Los Osos community. As nitrate is one of the primary concerns in the basin, nitrate removal estimates from an experimental treatment wetland (Molera Wetland) located in Monterey County will serve as the basis for inference in regards to the ability and amount of wetland required to service the Los Osos community.

1.6 The Role of Agriculture in Groundwater Management

The Los Osos community has a deep agricultural history. Row crops started shortly after development of irrigation technologies in the late 1800's. Factors such a climate, soil and availability of water have made the Los Osos Valley a highly desirable location for vegetable production (Michael Brandman Associates 2008). Much of the agricultural lands in the Los Osos Valley are recognized as Prime Farmland, Farmland of State Importance, Farmland of Local Importance, Farmland of Potential Local Importance and Grazing Land (Michael Brandman Associates 2008).

Currently there are several wastewater disposal options being reviewed for the LOWWP, none of which fully mitigate SWI. One proposed disposal option is to use recycled water from the LOWWP for agricultural irrigation in the Los Osos Creek Valley. The modeled impact for this option would be continued SWI (Michael Brandman Associates 2008, Appendix D). However, utilizing recycled water for agricultural irrigation to its full potential in the Los Osos Creek Valley could help halt SWI.

1.7 Los Osos Sustainable basin management plan (draft)

Beginning in the 1970s, studies of the basin have warned about the serious threat of seawater intrusion to the basin and recommended ways to address the problem (RCS 1992). On going over-extraction can lead to nearly irreversible damage to water quality and storage capacity (Kinzelback et al. 2003). However, management of the basin has not been effective in stopping seawater intrusion, resulting in seawater contaminating a growing percentage of the large freshwater lower aquifers in the basin now supplying three-fourths of the community's drinking water. Since 2000, Los Osos Community Services District (in charge of developing the wastewater project before AB 2701 turned the responsibility over to the County) sponsored three management plans (in 2000, 2002, and 2005). The first plan in 2000 relied largely on conservation cooperatively implemented by water purveyors. It was never fully implemented. The other two relied mostly on shifting pumping to the upper aquifer, with some urban reuse and imported water.

In response to growing concerns about seawater intrusion, the cost and impacts of imported water and desalination, and trends state-wide and world-wide for less resource intensive water management solutions, the Los Osos Sustainability Group (LOSG) drafted a sustainable basin management plan, "Achieving a sustainable Los Osos

Valley Water Basin Framework for a 21st century basin management plan" (Wimer 2009). This sustainable basin management plan (SBMP) offers an integrated approach to solutions for addressing the water needs of the Los Osos Community using water-use efficiency technologies and methods, rainwater harvesting, low impact development (LID), and graywater reuse. The plan also integrates urban and agricultural reuse, maximizing the benefits of recycled water for seawater intrusion mitigation and ecosystem support. By reducing potable water use, it balances the needs of the community with the physical limitations of the freshwater basin's hydrologic systems. Mitigating for the impacts of the LOWWP the plan aims to reduce, stop and perhaps reverse seawater intrusion (Wimer 2009). It also calls for a basin-wide implementation concurrent with the LOWWP to assure maximum effectiveness and cost savings.

The SBMP's focus on sustainability and preserving the basin for the future is consistent with the basin management plan guidelines laid out in the Interlocutory Stipulated Judgement (ISJ) (ISJ 2008) and the requirements to protect drinking water as described in the Porter-Cologne Act (SWRCB 2009). We present an evaluation of the SBMP, using references from the literature, reports and case studies on the topic of sustainable design, LID and conservation and case studies.

1.8 Modeling the Effect of Variable Precipitation on Saltwater Intrusion

The basin management scenarios presented in the draft EIR estimate the Los Osos basin will remain in a state of dynamic equilibrium with respect to saltwater intrusion in the lower aquifer with seawater intrusion continuing to replace freshwater at a rate of about 450 AFY (Michael Brandman Associates 2008). The ISJ TM scenarios do not stop seawater intrusion completely allowing it to continue at a rate of 55 AFY, despite radical shifts in pumping to the upper aquifer (900 AFY). Under the ISJ scenarios, saltwater is apparently assumed to continue to infiltrate into the lower aquifer at a rate comparable to fresh water recharge, such that the saltwater is diluted and there is no annual net loss of potential potable water (Cleath Harris Geologists 2009). This exactly balanced condition may be hard to achieve given the large uncertainties in model inputs. Under the proposed balanced conditions, a drop in average precipitation would put the lower aquifers at a high risk of significant continued saltwater intrusion.

The draft EIR states that under any of the water management scenarios the loss of recharge from the septic systems will be mitigated such that there is no loss in annual freshwater recharge. However, the risk associated with the condition of dynamic equilibrium was not accurately described. The recharge, loss and extraction rates for all of the wastewater treatment plans are represented as constants with no clear definition of the range of maximum or minimum annual rates. In all of the hydrologic budgets for the management scenarios the single largest source of fresh water recharge is from precipitation. However, rain and drought patterns are currently variable, and they will change in the future. At a minimum the known uncertainties associated with the historic rainfall record should be honored as a variable, rather than a constant.

The goal of this section is to introduce a simple model for stakeholder use in visualizing a variety of climate-change scenarios. The model illustrates the sensitivity of the Los Osos basin's hydrologic budget to historic precipitation variability and to potential shifts in precipitation patterns due to climate change.

1.9 Los Osos Wastewater Project Contingency Plan

The purpose of a contingency plan is to prepare for the feasible range of outcomes that may arise after implementing a wastewater project. Planned outcomes might not be achieved due to changing conditions, inaccuracy of model assumptions, or the use of incorrect models to formulate water management scenarios for the LOWWP. A model is by definition a simplification of reality and is often built on assumptions and uncertainties. A contingency plan highlights uncertainties in parameters used in a modeling or planning effort, and includes a sensitivity analysis of the range of variance that is likely for each key input variable. The sensitivity analysis would present a range of outcomes that are possible based on the most likely range in these key input variables. It also includes likely management responses to these potential outcomes, i.e. remedial measures that would be taken. The LOWWP is a large investment for the community, which has the potential to offset or delay future investments in a desalination facility or other water sourcing that may become necessary if sustainability goals are not met. Due to both its cost to the community and its potential to offset or delay solutions to water resource needs, it is advisable to develop a contingency plan in concert with further LOWWP planning. Examples of contingency plans are presented in this report.

2 Methods

This report provides recommendations to improve the likelihood of achieving a sustainable water supply in the Los Osos Valley. Specific methods in our analysis are detailed in the following sections. In general, much of the analysis is based upon a review of the ISJ TMs, draft EIR, consulting reports, primary literature, and the Los Osos Sustainability Group's SBMP (Wimer, 2009). We obtained geological GIS data from USGS seamless server, SLO County, and CalPoly San Luis Obispo. Maps were created to relate the topography, surface hydrology, geology, to the well locations and groundwater basin boundaries. We reviewed cross sectional data provided in consulting reports and PowerPoint presentations available at the SLO County web site. These data were assessed in the context of standard geologic knowledge and depositional models.

2.1 Timescales of Groundwater Movement in the Los Osos Basin

We gathered parameter values used to calculate groundwater flow rates from recent literature. Ranges of horizontal hydraulic conductivity (K_h) for each basin zone (Fig. 2) were then averaged. Where the average of specific yields was greater than average estimated porosity, it was substituted, as the specific yield of a substrate is always less than its porosity (Ward and Trimble 2004). Substitution only occurred in Zone A. Hydraulic conductivity values often referenced in literature are in units of gallons/day/square foot (gpd/ft^2). We converted to feet/days using 1 gallon = 0.133681 cubic feet. Note that K values are based on well screen footage, and generally overestimate average values for the aquifer (Cleath 2005). Thus, our results overestimates the rates for groundwater travel, and the resulting times for travel from place to place are conservatively low. We used Google Earth™ to approximate the distances between selected locations (Figure 3). We obtained gradients from specific values given in Cleath (2005) or Yates and Williams (2003), calculating them using plate E1 of Brandman (2008) for Zone C and Figure 5 in Cleath (2005) for Zones D and E.

The horizontal flow rate equation used was

$$v = (K_h \times I_h) \div n$$

where v is average linear velocity in feet/day, K_h is horizontal hydraulic conductivity in feet/day, I_h is horizontal hydraulic gradient, and n is effective porosity (Driscoll 1986; Ward and Trimble 2004).

The approximate amount of time associated with vertical migration in the unsaturated zone was calculated as

$$t = b \div K_v = b \div (K_h/10)$$

where t is time in days, K_v is vertical hydraulic conductivity in feet/day, and b is vadose zone thickness in feet (based upon pers. comm. With Mike Taraszki).

The vertical migration rates in the saturated zone were calculated as

$$v = (K_v \times I_v) \div n$$

where v is average linear velocity in feet/day, K_v is vertical hydraulic conductivity in feet/day, I_v is vertical hydraulic gradient, and n is effective porosity (Driscoll 1986).

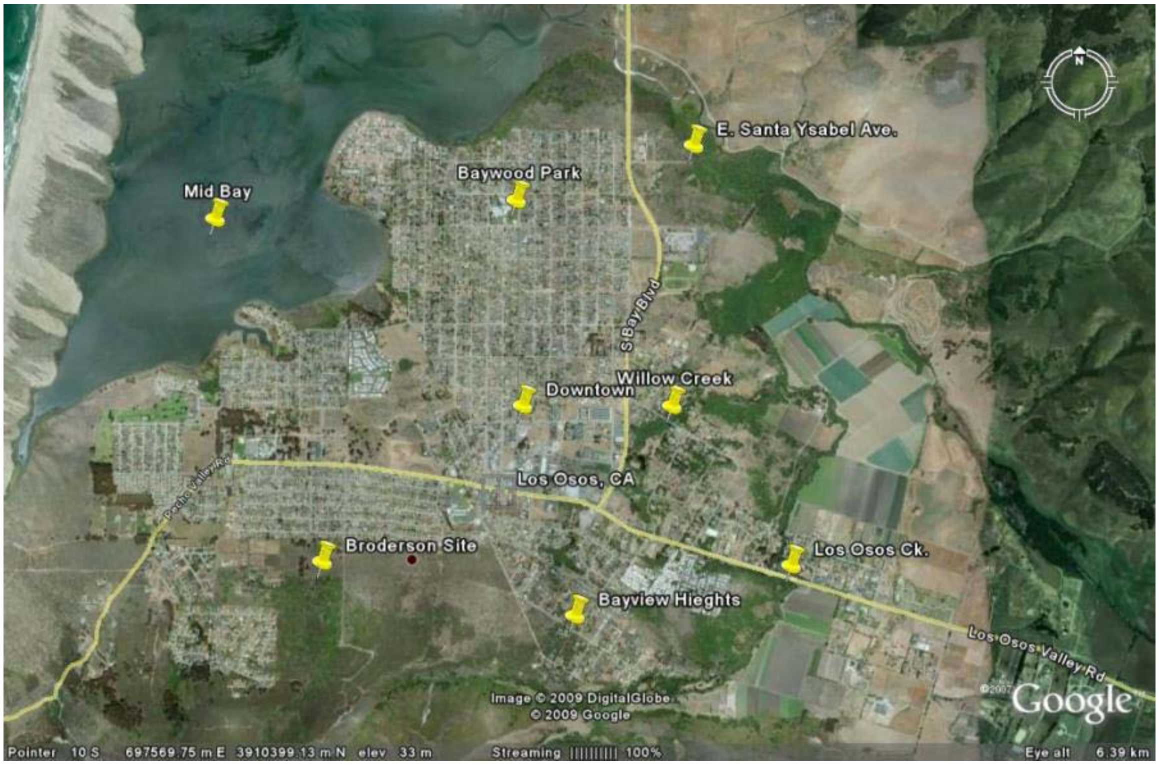


Figure 3: Map of locations used in travel times of groundwater.

2.2 Rain Harvesting

Footprint data for homes in the prohibition zone were obtained from San Luis Obispo County Department of Planning. These data were used to calculate rooftop areas in ArcMap 9.2 (ESRI 2009). However, data were not available for all buildings in the prohibition zone so roof top areas were estimated in several locations. Estimations were made by counting roofs on aerial photographs for houses between West Woodland and Butterfly Lanes (32 houses), Monarch Lane and Pecho Valley Road (56 houses), houses on Montana Way, Los Abbles Way, Los Padres Court, and Vista Court (72 houses), houses on Rodman Drive, Madera Street, San Dominico Avenue, San Ricardo Lane, and San Sebastian Lane (56), houses off of and between Travis Drive and Rodman Drive (150 houses), between Woodland Drive, Highland Drive, and east of Broderson Avenue (300 houses), between Woodland Drive, Highland Drive, and west of Broderson Avenue to Ravenna Avenue (80 houses), between Los Osos Valley Road, Highland Drive, Ravenna

Avenue, and Palisades Avenue (110 houses), and between Las Encinas Drive, and Bay Oaks Drive (67 houses). The above calculations/estimations did not include all rooftops in the prohibition zone. Areas with low density development, as well as high density were not counted (e.g., mobile home not for which building footprints are not shown). Figure 1 represents the extent of available rooftop data and the areas where estimations were necessary. Estimation of rooftop areas was made by multiplying the number of houses by the mean rooftop area obtained from building footprints. This is a conservative estimate, since 706 building footprints out of 5118 had an area less than 400 square feet, not included in the count.

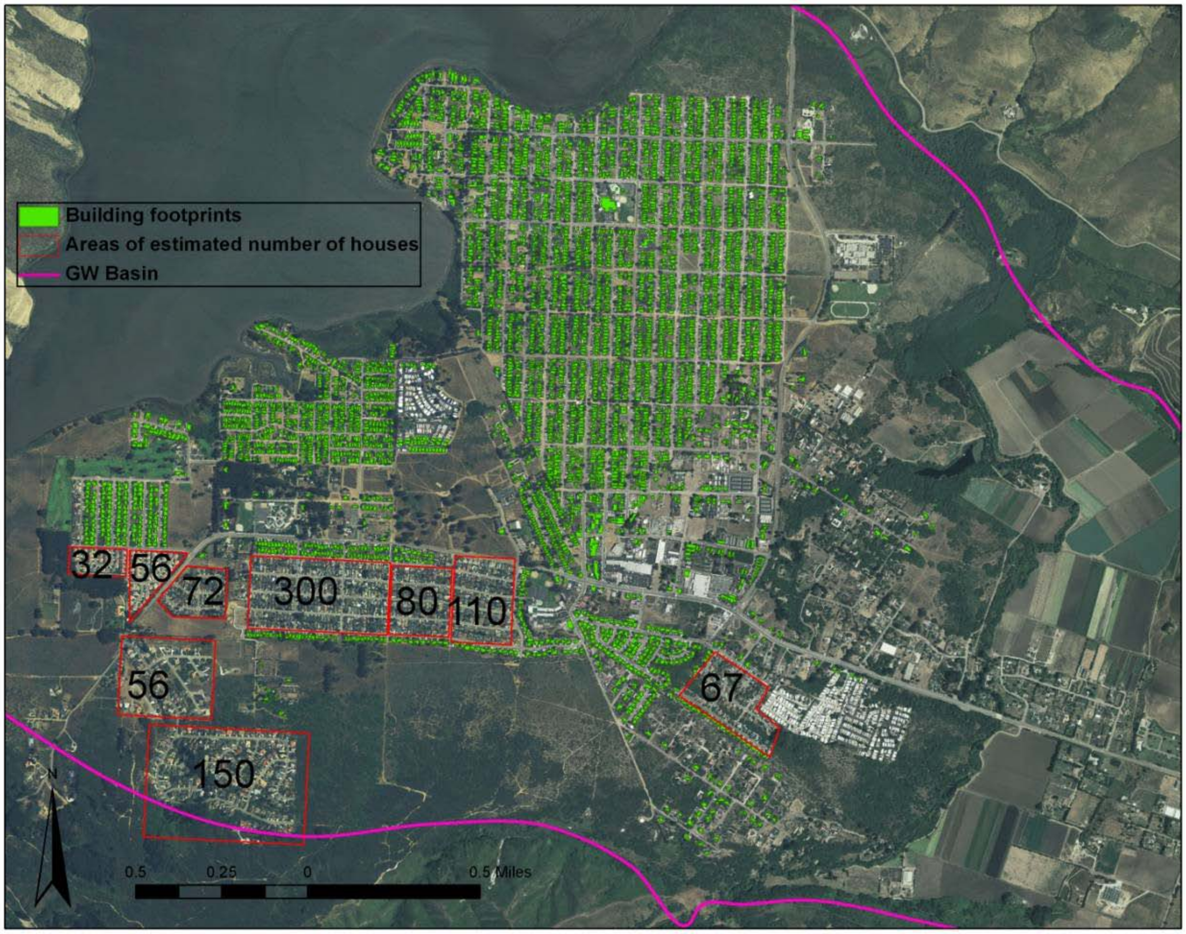


Figure 3: Areas covered by building footprint data, and areas where the number of houses was estimated. The numbers within the red polygons represent the number of buildings estimated.

2.3 Water Treatment Wetlands

To estimate the removal of nitrogen using treatment wetlands, we obtained data from an experimental offstream treatment wetland, Molera Wetland. The wetland has two delineated sections; upper and lower (Figure 4). The upper section is approximately 1.3

acres in size with a channel length and width of 925 and 20 feet respectively. It is a sinuous engineered channel with a maximum depth of 1.3 feet, volume of 28,500 cubic feet, and has emergent wetland vegetation along side berms that form the channel. The lower section has an average depth of 0.5 feet, is approximately 1.2 acres in area, and has a maximum volume of approximately 14,100 cubic feet. The wetland was monitored to evaluate nutrient removal from June of 2006 to January of 2007. Eight different experimental flow rates were monitored to determine the effect of retention time on nitrate removal. Influent, primarily composed of agricultural and urban drainage, was mechanically pumped into the wetland from Tembladero Slough, a nutrient enriched waterway bordering the site.

Figure 4: Site map of the Molera Wetland located near the city of Castroville in Monterey County, California. Relative elevation is represented as color, with green representing low spots that typically hold water and yellow representing earthen berms that confine channels in the upper section of the wetland. Sampling location used to estimate nitrate removal, water pump location, and water distribution piping is also shown.

We estimated the load of nitrogen generated at the current population (15,000) and expected build out population (18,000) for the Los Osos community using information provided in the draft EIR and other literature sources. Average nitrogen concentrations produced from septic systems (45 to 35 mg(N)/L) were acquired from Hantzsche and Finnemore (1992). These estimates were used to calculate the total nitrogen load produced by the Los Osos community using the wastewater generation rate per capita provided in the draft EIR (66 gallons/day/capita).

Using nitrate removal rates from Molera Wetland and expected nitrate generation rates, we calculated the amount of treatment wetland required to remove the total nitrate load generated at the current and expected build out populations of prohibition zone in Los Osos. The amount of treatment wetland required to service the Los Osos community was estimated in terms of both the area and channel length of treatment wetlands required to adequately treat the Los Osos wastewater.

2.4 Precipitation and Drought

A literature review and rainfall probability analysis provides perspectives on the long-term and medium-term risk of drought conditions that could violate explicit or implicit assumptions used in the ISJ and EIR water management scenarios for the Los Osos groundwater basin. We obtained local precipitation records for San Luis Obispo from the California Data Exchange Center (CDEC) web site and Morro Bay from the Western Regional Climate Center (WRCC). Exploratory data analyses were used to look for precipitation trends and Log Pearson Type III analyses were used to generate drought risk probabilities.

2.5 Modeling the Effect of Variable Precipitation on Saltwater Intrusion

There are many variables used as “inputs” to computer modeling of groundwater, and many of those variables have a range of values that are equally defensible. While it may be difficult to re-run models with the full range input values, it is certainly reasonable to change the values of one or two key variables to determine if the model output changes significantly. We chose to model the impact of changing one variable—precipitation. The model should not be used for planning, but simply illustrates the potential value in running saltwater intrusion models with a reasonable range of rainfall, rather than a single average value.

We created a simulation model of for the Los Osos aquifer system using STELLA (i-see systems 2009) modeling software (Fig 5). The model simulated the movement of water within the different layers of the Los Osos aquifer using randomly selected annual precipitation values from the historic record for the Valley. We used the inflow and outflow rates presented by Michael Brandman Associates (2008) in the LOWWP draft EIR (Appendix D of the EIR) except where noted. The precipitation data were based on a distribution of historical precipitation data from the Morro Bay Fire Department gage (WRCC #045866), but other local and regional records could be used in future modeling scenarios. The chief reason for developing this new model is to simulate the impact of realistically-varied rainfall rather than assuming a constant average occurring each year.

The model output assumes that the natural variability of rainfall propagates through the groundwater system, and is not internally muted by processes in the aquifer.

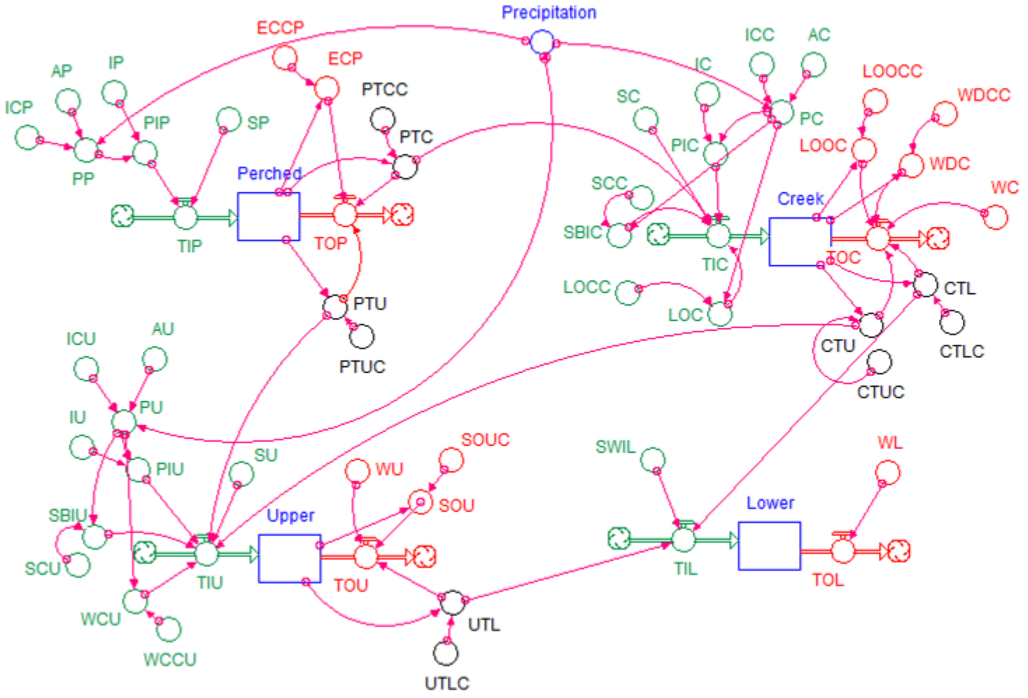


Figure 5. The green converters represent sources of recharge. Red converters are sources of outflow that leave the aquifer. Black converters are sources of outflow for one aquifer level and recharge for another.

The perched and transitional zones (Zones A & B), Creek (Creek Compartment), upper aquifer (Zone C) and lower aquifers (Zones D & E) are represented as state variables in Acre Feet of water (AF). The complete list of model outputs can be seen in Table 1, and the complete list of inputs can be seen in Table 2. The material flows (AF) are represented as total inputs perched (TIP), total outputs perched (TOP), total inputs creek (TIC), total outputs creek (TOC), total inputs upper (TIU), total outputs upper (TOU), total inputs lower (TIL) and total outputs lower (TOL) and the units are acre feet of water (AF) (Table 3). The model ran on an annual time step for 100 years, starting in 2008 and running through 2108. The year 2008 was chosen as the starting point, the year cited in the ISJ TMs (CHG, 2009) when total basin inflows and outflows are equal (although seawater intrusion continues due to too much pumping of the lower aquifer).

Table 1. The majority of the annual output rates came from the Yates and Williams (2003) and Cleath (2008) studies. The process for calculating coefficients is described in text.

Parameter	Value	Unit	Source
Evapotranspriation Creek Coefficent Perched (ECCP)	0.403804	AFY	Cleath & Associates 2008 (from LOWWP Draft EIR), Yates and Williams 2003 (zone 105 - 128)
Evapotranspiration Creek Perched (ECP)	ECP = Perched × ECCP	AFY	Derived from Model
Los Osos Creek Outflow Coefficent (LOOCC)	0.054649	AFY	Cleath & Associates 2008 (from LOWWP Draft EIR)
Los Osos Creek Outflow Creek (LOOC)	LOOC = Creek × LOOCC	AFY	Derived from Model
Warden Drain Coefficent Creek (WDCC)	0.004258	AFY	Cleath & Associates 2008 (from LOWWP Draft EIR)
Warden Drain Creek (WDC)	WDC = Creek × WDCC	AFY	Derived from Model
Subsurface Outflow Coefficent Upper (SOCU)	0.437396	AFY	Cleath & Associates 2008 (from LOWWP Draft EIR)
Subsurface Outflow Upper (SOU)	SOU = Upper × SOCU	AFY	Derived from Model
Well Extraction Creek (WC)	870	AFY	Cleath & Associates 2008 (from LOWWP Draft EIR)
Well Extraction Upper (WU)	803	AFY	Cleath & Associates 2008 (from LOWWP Draft EIR)
Well Extraction Lower (WL)	1717	AFY	Cleath & Associates 2008 (from LOWWP Draft EIR)
Perched to Creek Coefficent (PTCC)	0.085589	AFY	Cleath & Associates 2008 (from LOWWP Draft EIR)
Perched to Creek (PTC)	PTC = Perched × PTCC	AFY	Derived from Model
Perched to Upper Coefficent (PTUC)	0.510607	AFY	Cleath & Associates 2008 (from LOWWP Draft EIR)
Perched to Upper (PTU)	PTU = Perched × PTUC	AFY	Derived from Model
Creek to Upper Coefficent (CTUC)	0.063875	AFY	Cleath & Associates 2008 (from LOWWP Draft EIR)
Creek to Upper (CTU)	CTU = Creek × CTUC	AFY	Derived from Model
Creek to Lower Coefficent (CTLC)	0.259759	AFY	Cleath & Associates 2008 (from LOWWP Draft EIR)
Creek to Lower (CTL)	CTL = Creek × CTLC	AFY	Derived from Model
Upper to Lower Coefficent (UTLC)	0.294491	AFY	Cleath & Associates 2008 (from LOWWP Draft EIR)
Upper to Lower (UTL)	UTL = Lower × UTLC	AFY	Derived from Model

Table 2. The majority of the annual input rates came from the Yates and Williams (2003) and Cleath (2008) studies.

Parameter	Value	Unit	Source
Precipitation (P)	variable	feet/yr	Morro Bay Fire Department
Acres Perched (AP)	1340	acres	Yates and Williams 2003 (zone 105 - 128)
Acres Creek (AC)	427	acres	Yates and Williams 2003 (zones 20, 24, 25, 220, 229)
Acres Upper (AU)	2891	acres	Yates and Williams 2003 (total area minus AC & AP)
Infiltration Coefficent Perched (ICP)	0.2995	feet/yr	Derived from Model
Infiltration Coefficent Creek (ICC)	0.55	feet/yr	Derived from Model
Infilitration Coefficent Upper (ICU)	0.281	feet/yr	Derived from Model
Precipitation Perched (PP)	PP = AP × P	AFY	Derived from Model
Precipitation Creek (PC)	PC = AC × P	AFY	Derived from Model
Precipitation Upper (PU)	PU = AU × P	AFY	Derived from Model
Irrigation Perched (IP)	178	AFY	Yates and Williams 2003 (zone 105 - 128)
Irrigation Creek (IC)	104	AFY	Yates and Williams 2003 (zones 20, 24, 25, 220, 229)
Irrigation Upper (IU)	360	AFY	Yates and Williams 2003 (total Irrigation Inputs minus AC & AP)
Precipitation Irrigation Input Perched (PIP)	PIP = PP + IP	AFY	Derived from Model
Precipitation Irrigation Input Creek (PIC)	PIC = PC + IC	AFY	Derived from Model
Precipitation Irrigation Input Upper (PIU)	PIU = PU + IU	AFY	Derived from Model
Septic Perched (SP)	631	AFY	Yates and Williams 2003 (zone 105 - 128)
Septic Creek (SC)	30	AFY	Yates and Williams 2003 (zones 20, 24, 25, 220, 229)
Septic Upper (SU)	606	AFY	Yates and Williams 2003 (total septic inputs minus AC & AP)
Subsurface Inflow Coefficent Creek (SCC)	0.51227	AFY	Cleath & Associates 2008 (from LOWWP Draft EIR) Yates and Williams 2003 (zones 20, 24, 25, 220, 229)
Subsurface Inflow Coefficent Upper (SCU)	0.099203	AFY	Cleath & Associates 2008 (from LOWWP Draft EIR) Yates and Williams 2003 (total septic inputs minus AC & AP)
Subsurface Inflow Creek (SBIC)	SBIC = SCC × PC	AFY	Derived from Model
Subsurface Inflow Upper (SBIU)	SBIU = SCU × PU	AFY	Derived from Model
Los Osos Creek Coefficent (LOCC)	2.03988	AFY	Cleath & Associates 2008 (from LOWWP Draft EIR) Yates and Williams 2003 (zones 20, 24, 25, 220, 229)
Los Osos Creek Inputs Creek (LOC)	LOC = LOCC × PC	AFY	Derived from Model
Willow Creek Inputs Coefficent (WCCU)	0.079717	AFY	Cleath & Associates 2008 (from LOWWP Draft EIR) Yates and Williams 2003 (zones 20, 24, 25, 220, 229)
Willow Creek Inputs Upper (WCU)	WCU = WCCU × PU	AFY	Derived from Model
Salt Water Intrusion Lower (SWIL)	469	AFY	Cleath & Associates 2008 (from LOWWP Draft EIR)

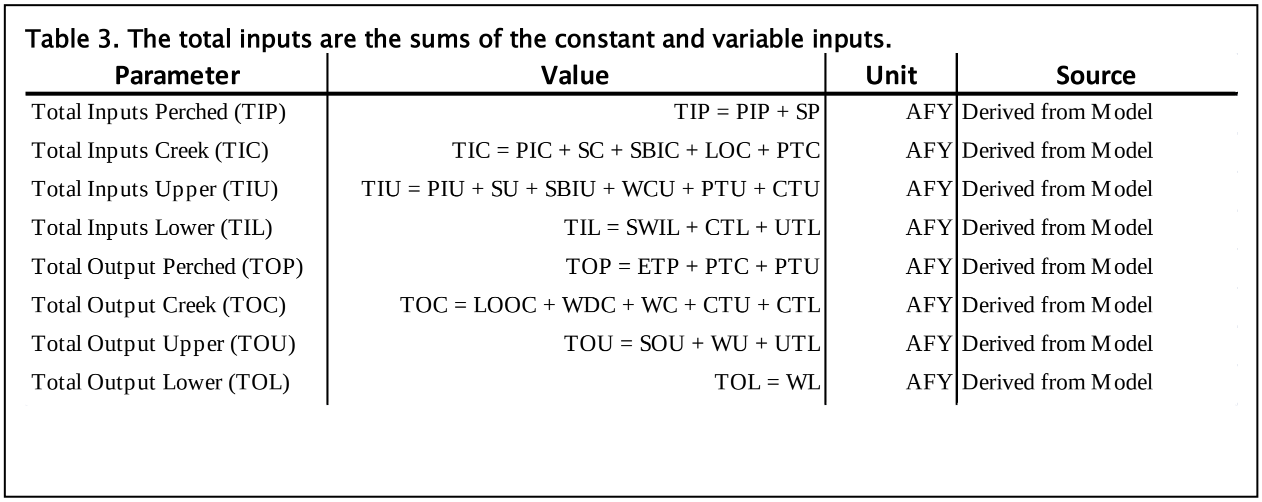


Table 3. The total inputs are the sums of the constant and variable inputs.

Parameter	Value	Unit	Source
Total Inputs Perched (TIP)	TIP = PIP + SP	AFY	Derived from Model
Total Inputs Creek (TIC)	TIC = PIC + SC + SBIC + LOC + PTC	AFY	Derived from Model
Total Inputs Upper (TIU)	TIU = PIU + SU + SBIU + WCU + PTU + CTU	AFY	Derived from Model
Total Inputs Lower (TIL)	TIL = SWIL + CTL + UTL	AFY	Derived from Model
Total Output Perched (TOP)	TOP = ETP + PTC + PTU	AFY	Derived from Model
Total Output Creek (TOC)	TOC = LOOC + WDC + WC + CTU + CTL	AFY	Derived from Model
Total Output Upper (TOU)	TOU = SOU + WU + UTL	AFY	Derived from Model
Total Output Lower (TOL)	TOL = WL	AFY	Derived from Model

Recharge from precipitation to the perched (PP), creek (PC) and upper aquifers (PU) was modeled using the equation:

$$PR = P \times A \times I$$

PR represents the respective precipitation recharge rates (PP, PC and PU), *P* is the randomly generated precipitation, *A* is the respective ground surface areas (AP, AC and AU) and *I* is the infiltration coefficients (IP, IC and IU). The infiltration coefficient was calculated by taking the average annual rainfall total from the gage data and multiplying it by the respective area and infiltration coefficient. The coefficient was then adjusted such that *PR was* equal to the recharge rates given in Cleath & Associates (2008). The model was then run using the randomly selected data from the real rain gage data.

Inflows from irrigation (IP, IC and IU), septic systems (SP, SC and SU) and seawater intrusion (SWI) were represented as constants, as it was assumed their rates would not change with changes in precipitation. Recharge from subsurface inflow (SBIC and SBIU), Los Osos Creek (LOOC) and Willow Creek (WCU) were dependent on precipitation. This was shown with coefficients (ICP, ICC, ICU, SCC, SCU and WCCU). The coefficients were calculated by taking the given respective rates of recharge and dividing them by respective rates of balanced recharge from precipitation from the Cleath (2008) groundwater budget. Thus, when the there was more or less precipitation than required for balance, there was a proportional amount of inflow from respective variables. These coefficients are assumptions about the more complex behavior of precipitation recharging groundwater from creeks and subsurface flow. We assumed the ratio of inputs to precipitation would remain 1:1 regardless of precipitation rates.

The outflow rates for wells were modeled as constants. This assumes that well extraction from the groundwater basin will remain constant over time. Outflow rates from creek outflow (ECP and LOOC), subsurface outflow (SOU), drains (WDC) and outflow to other aquifers (PTC, PTU, CTU, CTL and UTL) were dependent on aquifer levels (Perched, Creek and Upper respectively). This was done by the use of coefficients

(LOOCC, ECCP, SOUC, WDCC, PTCC, PTUC, CTUC, CTLC and UTLC). The coefficients were calculated by taking the given rates of recharge and dividing them by balanced level of inputs from the Cleath (2008) budget. Thus, when the input levels varied there was a proportional change (1:1 ratio) in the amount of outflow from the respective variables. These coefficients are assumptions on more complex behavior of groundwater movement within the aquifer.

Each time we ran the model, we simulated 100 time steps, starting at 2008. For each time-step of each run we selected an annual rainfall amount at random from the historic Morro Bay record. We ran the model 50 times using historic annual precipitation to see if modeling natural rainfall variability can lead to insights about the likelihood of success under the proposed basin management plan. The historic data set has an average annual rainfall of 16.7 inches. We then ran the model 50 more times for each of three rainfall distributions having a slightly lower average values to simulate the impact of variable rainfall and slightly stronger drought conditions. These three subsequent rainfall distributions had averages of 16.5 inches, 15.9 inches, and 15.1 inches respectively.

3 Results and Discussion

3.1 Geology

3.2 Timescales of Groundwater Movement in the Los Osos Basin

Results of the characterization of each groundwater zone are described below and summarized in Table 4. Zones are shown in Figure 2. While these results are based upon the best descriptions of aquifer character available in the literature, we recognize that the actual values may be significantly different. Aquifer parameters are very difficult to determine with high precision, and some are simply unknown. It is not our goal to do a sensitivity analysis; we make the same assumptions that are present in the literature.

ZONE A: This upper, unconfined aquifer has hydraulic conductivity ranging from 9.4 to 30.7 ft /day with specific yield ranging from 0.20 to 0.25 (Cleath 2005), and flow moving from NW to NE with a hydraulic gradient of 0.06 between Bayview Heights and downtown with less gradient elsewhere (Michael Brandman Associates 2008).

AT1: AT1 is an aquitard layer between A and B with clay/clayey sand up to 30 feet thick that creates the perched Zone A (Cleath 2005). No values are given in the literature for this aquitard.

ZONE B: Zone B is a transitional aquifer that is partially saturated (Weber Hayes and Associates 2001), lying within the Paso Robles Formation. No specific hydraulic conductivity values are available (Cleath 2005).

ZONE C: This main upper aquifer used for groundwater extraction is primarily in the Paso Robles formation and confined where under AT1, has hydraulic conductivity of 20 ft /day and specific yield of 0.13 to 0.20 or much less where unconfined (Cleath 2005). Porosity in Zone C is estimated at 15 to 20 percent (Yates and Williams 2003). Flow in Zone C moves North to West with an average gradient of 0.09 (range of 0.004 to 0.025) (Cleath 2005).

AT2: AT2 is the main aquitard in the basin with an average thickness of 50 feet, values have not been measured but the flow model uses 0.1 ft /day horizontal and 0.002 ft /day vertical conductivity (Cleath 2005).

ZONE D: This lower confined aquifer lies in the Paso Robles formation with average thickness of 100 feet and conductivity of 8 to 24 ft /day (Cleath 2005). Hydraulic gradient in Zone D is 0.03 ft /day between the upper creek valley and downtown and less than that elsewhere (Cleath 2005, Michael Brandman Associates 2008).

AT3: This is a thin and likely discontinuous aquitard between Zones D and E (Cleath 2005).

ZONE E: This lower confined aquifer has both Paso Robles and Careaga formations with a large range of conductivity from 0.95 ft /day to 10 ft /day (Cleath 2005). Specific yield is estimated at 0.10 to 0.15 and thickness at 90 feet, while the gradient is generally 0.01 or less (Cleath 2005). The values for conductivity and specific yield of the Paso Robles Formation in Los Osos generally match values found for the same formation in nearby areas. In the Santa Maria valley conductivity was 13 to 52 ft /day or 2 to 15 ft /day depending on location, with specific yields 0.08 to 0.13 (Luhdorff & Scalamanini 2000).

Table 4. Summary of parameter values used gathered from literature.

Zone	Low Kh (ft/d)	High Kh (ft/d)	Avg. K	Low Specific Yield	High Specific Yield	Estimated Porosity
A	9.4	30.75	20.1	0.2	0.25	0.175
B	na	na	na	na	na	0.175
C	18.7	20	19.4	0.13	0.2	0.175
D	8	24	16.0	0.13	0.2	0.300
E	0.94	10	5.5	0.1	0.15	0.300

Rates of horizontal groundwater movement in the basin ranged from 0.05 ft /day to 5.4 ft /day, and travel time between the locations selected ranged from 1.6 to 302.5 years (Table 4).

Table 5. Rates and times of horizontal travel between selected locations.

From	To	Zone	Distance	Avg. K (ft/d)	Hydraulic Gradient (i)	Porosity (n)	Horizontal Rate (ft/d)	Travel Time (yr)
Bayview Hts.	Willow Ck.	A	4760	20.1	0.06	0.225	5.4	2.4
Downtown	Willow Ck.	A	3130	20.1	0.06	0.225	5.4	1.6
Broderson Site	Downtown	C	5300	19.4	0.006	0.175	0.67	21.8
Bayview Hts.	Downtown	C	4427	19.4	0.009	0.175	1.0	12.2
Los Osos Ck/Los Osos Valley Rd	Downtown	C	6546	19.4	0.009	0.175	1.0	18.0
E. Santa Ysabel Ave.	Baywood Park	D	3917	16	0.009	0.3	0.48	22.4
Mid Bay	Downtown	D	7540	16	0.0013	0.3	0.07	297.9
Los Osos Ck/Los Osos Valley Rd	Downtown	D	6546	16	0.01	0.3	0.5	33.6
Los Osos Ck/Los Osos Valley Rd	Downtown	D	6546	16	0.0046	0.3	0.2	73.1
Broderson Site	Downtown	D	5300	16	0.0009	0.3	0.05	302.5
Bayview Hts.	Downtown	D	4427	16	0.0023	0.3	0.1	98.9
Los Osos Ck/Los Osos Valley Rd	Downtown	E	6546	5.5	0.01	0.3	0.2	97.8

The water table at the Broderson site is on average 180 feet below ground surface (Michael Brandman Assoc. 2008) and located in Zone C, so it would take 93 days for a parcel of water to percolate down to the water table. At the Tonini Ranch sprayfield site groundwater is 7 to 42 feet below the ground (Cleath 2008a) so percolation would take 3.6 to 21 days. The current model uses vertical hydraulic conductivity of 0.002 ft/day for the 50 foot thick AT2 clay aquitard and the assumed vertical gradient is 0.4, with no porosity value available (Cleath 2005). This results in a vertical rate of 0.0008 ft /day and a travel time of 171 years for water moving through the AT2 clay.

3.2.1 Implications of Groundwater Velocity

The primary implications of groundwater movement rates in Los Osos Basin are for efforts to monitor and discern effects of current policy actions. It must be recognized that terms such as recharge, equilibrium, and balance are not immediate, but happen over the long term. On some scales such as the average ages of water in the main aquifers from 870 to 7300 years, there is no feasible way of monitoring the true effects of recent actions so far in the future. However, setting up monitoring on the timescale of movement between and within the aquifers is possible.

According to our groundwater velocity results, the Impacts of changes in water-use practices in Zone A such as LID or recycled water (e.g., in percolation ponds or wetlands) could manifest as changes in Willow Creek hydrology in as few as 2 years (Table 5), or sooner depending on how close measures are to the site. The effects of changing recharge regimes on many parts of Zone C would take much longer, about 20 years (Table 5). If a drought were to reduce recharge from Los Osos Creek, the attendant reduced recharge of the current water table depression below downtown in Zone C might not be realized for 18 years. In Zones D and E the same drought could take more than 100 years to impact water tables (and seawater intrusion), depending on the evolving hydraulic gradients (Table 5). This lag time is important in terms of understanding how nitrate levels in the aquifers may change with the project. The reduction in nitrates from the project will take thirty years in the upper aquifer according to the models and about 268 years in the lower if assumptions about aquitard permeability are correct (Yates and Williams 2003). The effect of current actions designed to reduce nitrate concentrations will not be testable for many years, and nitrate levels will continue to rise in the near term (Yates and Williams 2003).

Vertical percolation rates down to the water table are rapid compared to lateral water movement, except where the flow is impeded by aquitards. This may have implications for management. At the proposed Broderson site, percolation to the water table is estimated to be three months but then travel time to downtown takes twenty years (Table 5), so there will be lag time between current geographically dispersed septic recharge and planned point recharge in the system. The transition period, when the recharge system is equilibrating may be a time of saltwater intrusion in the upper aquifer.

The primary impediment to vertical movement in the Los Osos basin is the AT2 aquitard. The time of 171 years for water to move vertically through the aquitard implies that any post-development recharge moving between the upper and lower aquifers is from well leakage between these zones, or natural holes in the clay layer although studies characterize the aquitard as continuous. The Late Quaternary Los Osos fault zone (Fig. 1) cuts through the layers in the groundwater basin, raising the possibility that the AT2 aquitard is not a continuous barrier. Further, the “hydraulic parameters of the clay have not been measured directly” (Cleath 2005, pg 8). Testing should be done to resolve this question as the vertical permeability of the aquitard is key to estimating recharge potential and safe yields for the lower aquifer. It is worth noting that conservation and other water management strategies that reduce the pumping from the lower aquifer will have the most direct and immediate benefits on the lower aquifer, as recharge from the surface is very slow and the benefits are uncertain.

The long timelines involved in most groundwater basins, as in the Los Osos basin, pose problems for realistic monitoring programs by public agencies. Over periods of twenty or thirty years, most personnel in public agencies, private consulting firms, and politics will have retired, so the transfer of knowledge crucial to effective program implementation may not occur. Similarly, budgets do not often earmark expenses on those timelines, and the political will to fund monitoring programs requested decades earlier may disappear. The timescales described in this paper, with more detailed analysis by consultants, can be used to provide perspective on the most effective groundwater management solutions.

3.3 Rain and Drought

Precipitation data were acquired from two gages, one located in Morro Bay and one located just east of Los Osos in San Luis Obispo. The Morro Bay gage record (MBFD) ranged from 1959 to 2005 and San Luis Obispo gage (CDEC) record ranged from 1905 to 2007.

We first explored the San Luis Obispo record since it contains more years of data and might reveal longer term regional trends (Fig. 6). This gage is located in the San Luis Obispo Creek river basin at 35.3000°N 120.6670°W at 315ft elevation. These annual precipitation data were plotted to look for trends and cycles in a 102 year time frame.

Plots of decadal running averages of precipitation and standard deviations were made to reveal decadal-scale trends, important for drought assessment (Figs. 7 and 8). The plot of decadal precipitation averages shows that the average rainfall in any given decade can have a fairly large range, from 19 inches to 30 inches, if past trends continue. The decadal scale standard deviation shows a visual correlation with decadal precipitation, revealing that higher decadal average rainfall occurs because of a few unusually high rainfall years, rather than a series of above average years. Of importance is that extreme storms have precipitation rates that exceed infiltration rates, leading to a disproportionate amount of runoff instead of infiltration to the groundwater resource.

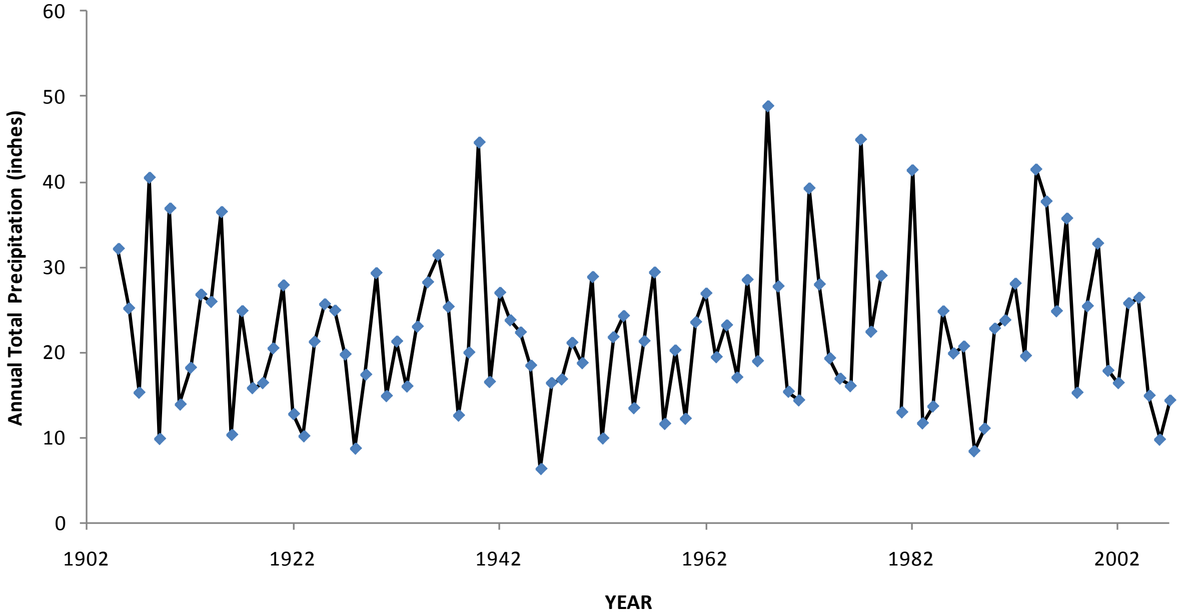


Figure 6. Annual precipitation (inches) vs. year. San Luis Obispo CDEC gage.

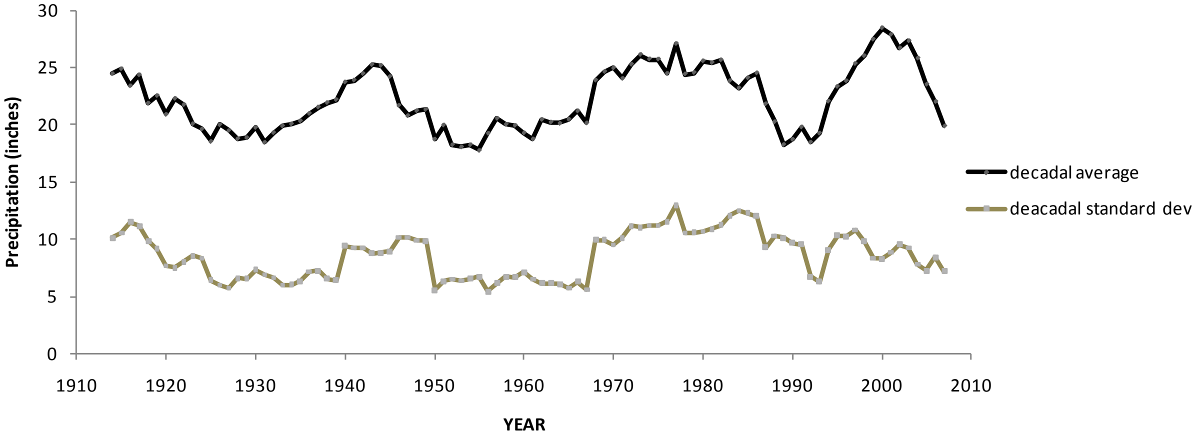


Figure 7. Decadal precipitation average and standard deviation. Each point on the upper plot is the average of the previous decade of annual rainfall. Each point on the lower plot is the standard deviation of the previous 10 years of rainfall. San Luis Obispo Poly CDEC gage.

The local precipitation record from the Morro Bay fire department gage 045866 is located in Morro Bay at 35.22°N 120.51°W at 120ft elevation. This location is optimal for precipitation analysis for Los Osos, but is probably too short to capture important trends and patterns. The Morro Bay fire department gage data are also used in recent hydrologic models (Michael Brandman Associates 2008), so the short record may have implications for model accuracy and management decisions. Figure 8 shows a plot of the gage record.

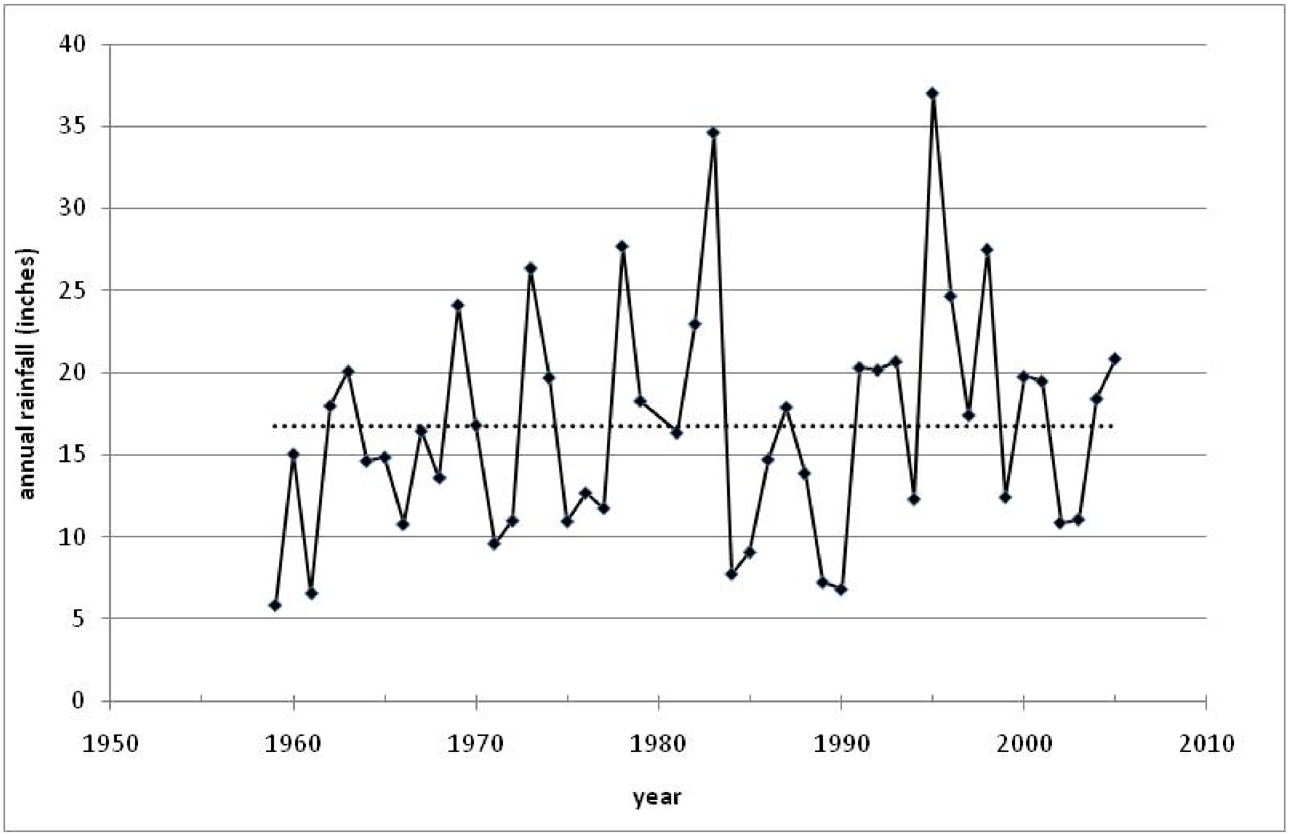


Figure 8. Los Osos annual precipitation record. Dashed line is average value. Morro Bay Fire Department gage.

Visual inspection of the plots of decadal precipitation averages and decadal precipitation standard deviations (Fig. 9) shows patterns that are comparable to the same time range of the SLO record (Fig. 7). The range in decadal average is less than for San Luis Obispo, with an anticipated range between approximately 14 and 22 inches (Fig. 9). Decadal standard deviation shows the same correlation with precipitation present in the SLO record. The observation that the mean (16.7 in) is 5 inches below the high end of the range, but only 2 inches above the low end of the range further underscores the idea that the climate structure comprises consistently low annual rainfall values, balanced by sporadic, very high values (Fig. 8). An histogram of annual rainfall frequency illustrates the presence of sporadic high years as well (Fig. 10).

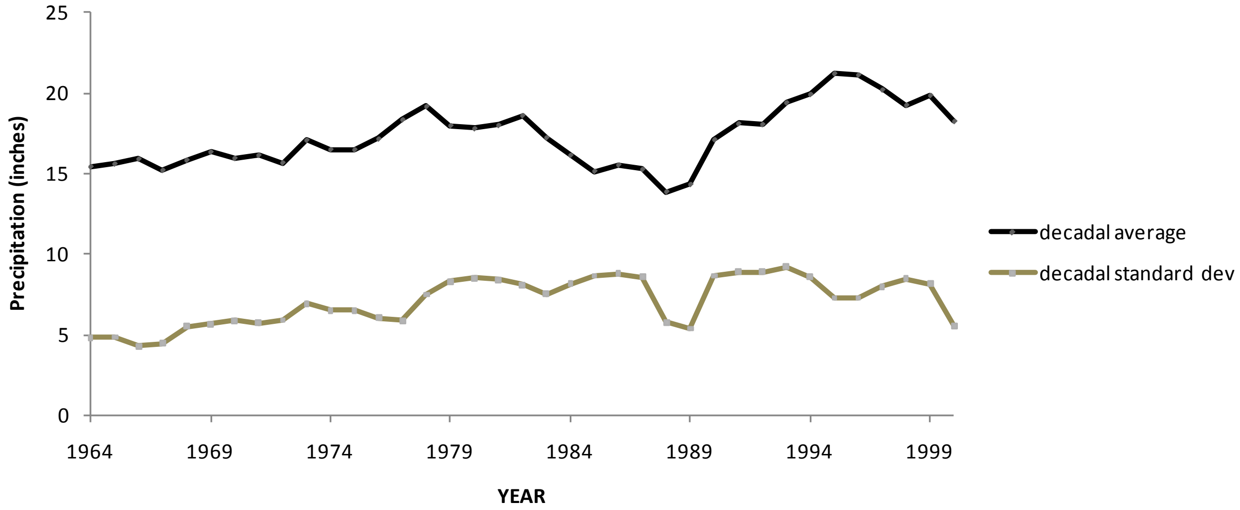


Figure 9. Decadal precipitation average and standard deviation. Each point on the upper plot is the average of the previous decade of annual rainfall. Each point on the lower plot is the standard deviation of the previous 10 years of rainfall. Morro Bay Fire Department gage.

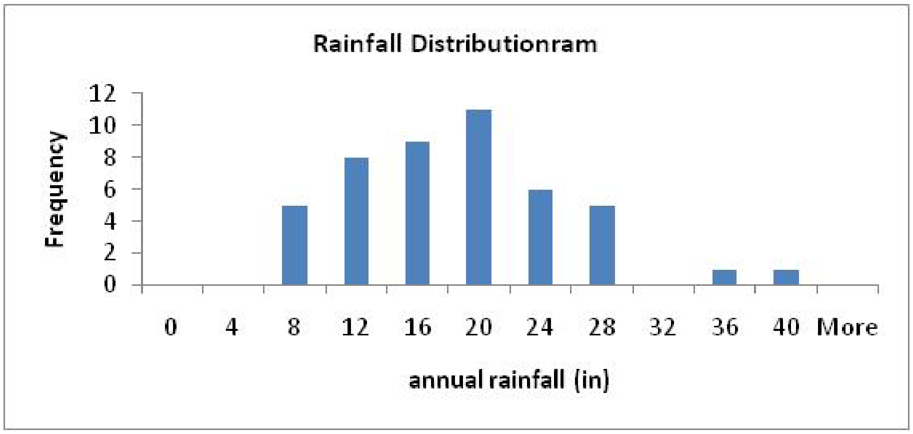


Figure 10: Histogram of annual rainfall frequency in Los Osos. Morro Bay fire Department gage. The rare high rainfall years give the distribution a positive (0.8) skew.

3.3.1 Log Pearson Type 3 Frequency Analysis

Log-Pearson Type 3 (LP3) analysis was used to quantify uncertainty in average rainfall value, and other rainfall amounts, and to provide insight into the probability of various drought conditions. An LP3 analysis uses the mean, standard deviation, and skew of the logarithms of annual rainfall values to create confidence intervals for any specified rain year. This approach is widely used to assess hydrologic data because the raw data are typically too skewed for statistical treatments that assume a normal population. The Los Osos LP3 model is plotted along with the data in figure 11. The LP3 model line is only slightly curved, fits the data very well, and the 95% confidence lines form a narrow uncertainty band. These results show that LP3 analyses removed most of the skew and provides strong confidence in statistical inferences, given that future conditions contain the same average and variance in precipitation present in the Los Osos data. These assumptions may be violated in the context of a longer record and regional long-term climate variability.

The sample mean annual precipitation in Los Osos is approximately 16.5 inches, but LP3 analysis shows that the true average value could lie anywhere between 14.7 and 18.4 inches with 95% confidence (Table 5.5).

Given the good fit of the LP3 models, extrapolation and prediction of non-exceedance probability scenarios for a set of precipitation values were completed. Figure 12 shows the likelihood and frequency of below average rainfall. The arrows in Figure 12 illustrate the chances of not exceeding 7 inches of rain in any one year is approximately 4% (red line). In other words, annual average rainfall will be less than 7 inches once in approximately 25 years (blue line).

The arithmetic mean precipitation value (16.7 in) and a drought rainfall of one standard deviation below the mean (9.8 in) were chosen to illustrate more rainfall statistics. The mean was chosen because recent hydrologic models were based off mean precipitation values (Michael Brandman Associates 2008), while the lower value was chosen to represent a critical low precipitation year, but not a rare event.

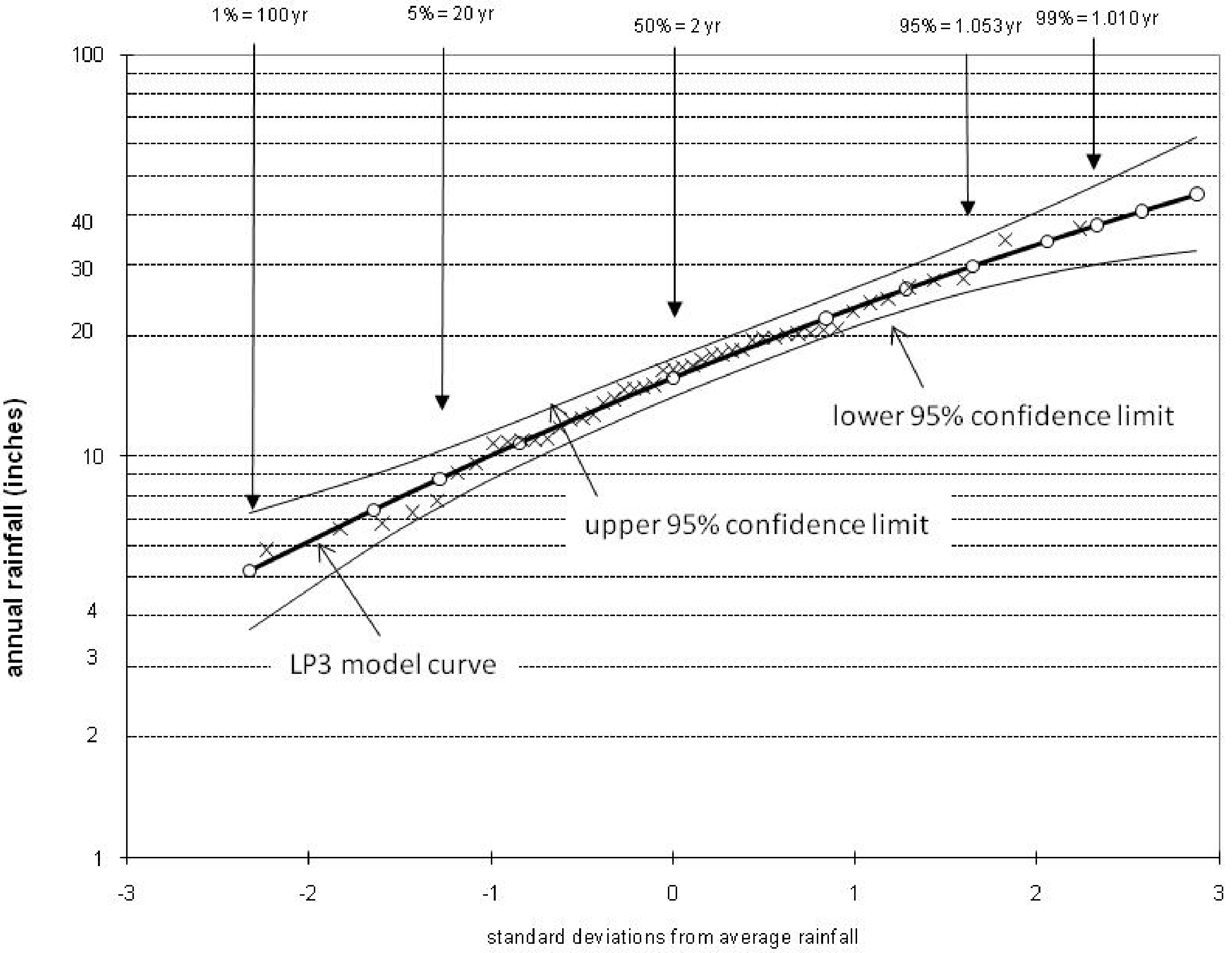


Figure 11: LP3 model of annual precipitation from the Morro Bay Fire Department gage. Raw data are plotted as x-symbol. The percent chance and recurrence intervals along the top axis are non-exceedance (drought) values.

Table 5.5: Central values and limits of 95% confidence range for annual rainfall amounts with non-exceedance recurrence intervals of 2.2, 10, 20, and 100 years.

Recurrence interval (yr)	Rainfall (in)	lower 95% (in)	upper 95% (in)
2.2	16.5	14.7	18.4
10	8.7	7.5	10
20	7.3	5.9	8.9
100	5.2	3.7	7.2

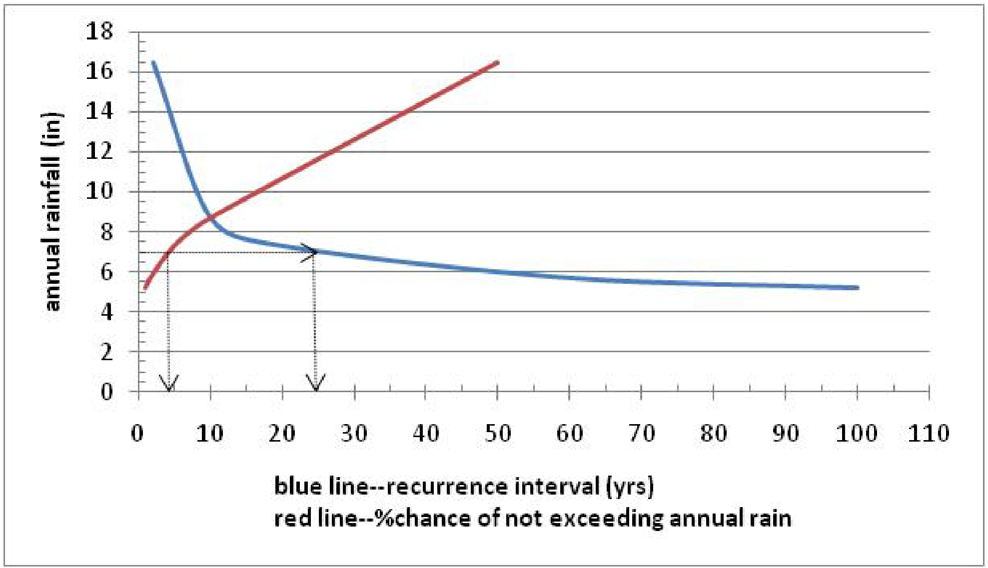


Figure 12: Non-exceedance recurrence interval and % chance of low values of annual rainfall. Thin arrows provide an example for an annual rainfall of 7 inches.

Figure 13 shows the risk (percent chance) of experiencing below average rainfall for several years running. For example there is a 10 percent chance that annual precipitation will be below average 4 years in a row in any random 4 year sequence. During the first few serial years, we see an exponential decrease in the probability.

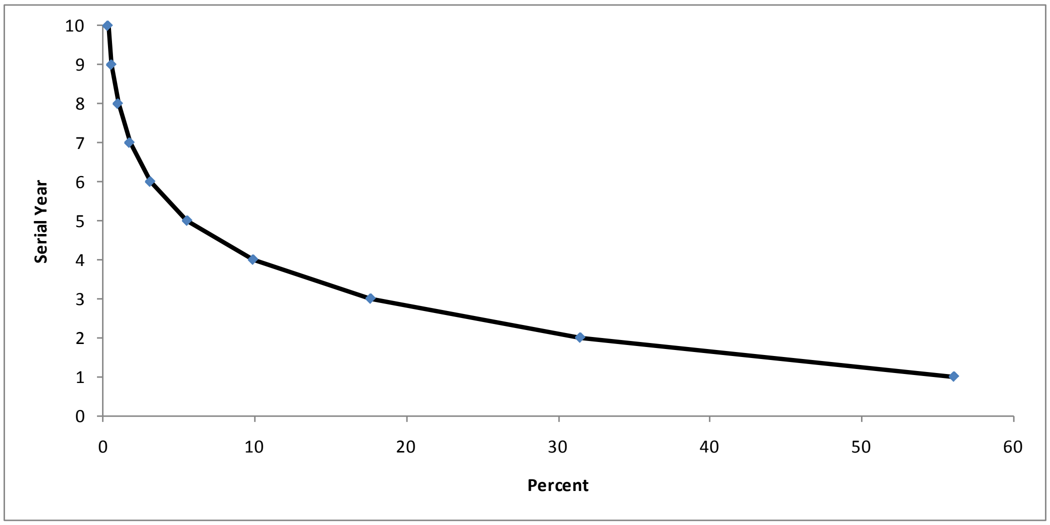


Figure 13: Percent chance of annual rainfall falling below average rainfall in serial years. (Morro Bay Fire Dept data mean).

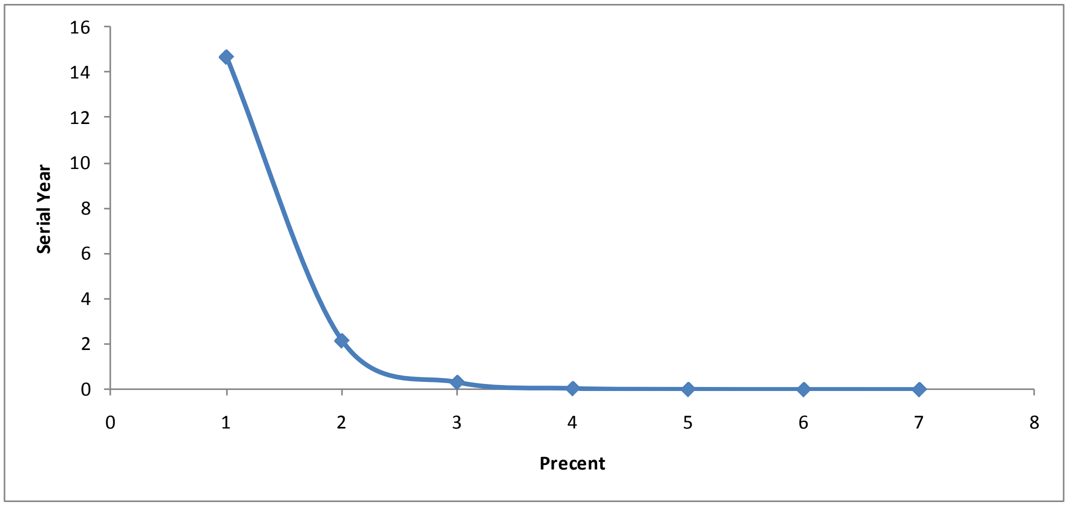


Figure 14: Percent chance of annual rainfall falling below 9.8 in rainfall in serial years. Morro Bay Fire Dept gage.

Figure 14 provides the risk (percent chance) of annual rainfall falling below 9.8 for several years in a row. For example there is only a 1.5 % chance of rainfall dropping below 9.8 inches for 6 years in a row. Figure 12 shows that there is a 16% chance of annual rainfall dropping below 9.8 inches in any single year. Figure 14 confirms that there is a high probability of exceeding 9.8 inches of rain in any sequence of years. Similar quick analyses can be performed on other rainfall amounts if they become important to the development of sustainable water supplies in the Los Osos groundwater basin.

3.3.2 Long-term Drought in California

While the regional rain gage record provides a basis for understanding drought risk, events with recurrence intervals longer than about 50 years are probably not represented in the data. Assessment of rarer, longer, and more severe drought conditions must be derived from other sources. Fritts and Gordon (1980) used extensive tree-ring records to deduce that California has experienced six decade-long droughts since the mid 1500s. These occurred in the following time periods: 1560-1580, 1600-1625, 1665-1670, 1720-1730, 1760-1780, and 1865-1885. Accordingly, the period from 1885 to the present has had a surplus of rain when compared with their 360 year proxy record. Meko and Woodhouse (2005) further document decadal-scale droughts in central California. Looking to the future is less accurate, but recent models convincingly depict a warmer and drier California (e.g., Moser et al. 2009; Hughes and Diaz 2008). The weight of evidence suggests that the recent gage records in California are wetter than average, so there is clear merit in erring on the side of caution in water resource planning. The region might realistically anticipate less rain than the recent record promises.

3.4 Rainwater Harvesting

Results of the analysis are presented in table 6. The total rooftop area was estimated at 241 acres. Multiplying roof top area by the mean annual precipitation we obtain an estimated average of 336 acre feet of rain water per year that could be collected and used to recharge the perched aquifer through the leach fields.

Table 6. Rooftop area calculations and possible rain catchment in Los Osos, CA.

	Total	Min	Mean	Max
Rooftop Area from Building Footprints (acres)	205		0.04	
Estimated number of housing units not covered by the building footprints	923			
Estimated rooftop area housing units not covered by the building footprints (acres)	37			
Rooftop Area from Building Footprints and estimated areas (acres)	241			
Possible Rain Catchment from Building Footprints and estimated rooftop areas (acre feet)		118	**336**	745

This calculation shows the potential of rainwater harvesting as a source of recharge for the basin. This calculation does not include how much can be harvested from other impervious surfaces in the area, including driveways, patios, and public spaces, such as streets. There are several limitations to the assumption that water collected from roof tops can be percolated to the groundwater, as in the proposed Condition 87. First, it is unlikely that all of the rooftops would be retrofitted for rainwater catchment because Condition 87 proposes a voluntary program. Further, catchment systems would only be placed in locations where depth to groundwater prevents pollutants from leaching to the groundwater (LOWWP CDP) Also, a large percentage of the rainwater that falls onto rooftops flows onto sandy soils and already percolates into the ground.

A more detailed analysis would take into account the storage capacity of the top groundwater aquifer, an estimate of the soil moisture storage capacity and the rate of groundwater recharge from rainfall, to determine the amount of rainwater that could realistically be captured and percolated to support groundwater recharge.

3.5 Wetlands and Wastewater Treatment

Strong evidence for nitrate removal, in units of load and concentration, from Molera Wetland has been documented, but the removal rate was dependent on the flow rate and thus retention time of the system. The relationship between flow rate and estimated nitrate load removal rate (g/day/foot) was such that higher removal rates occurred at high flow rates and low retention times (Figure 16). The inverse was observed for nitrate concentration reduction. At the highest flow rate (~210 thousand gallons/day) and lowest retention time (~1 day), the estimated maximum and minimum removal rate for nitrate load was 4.95 and 3.59 g/day/foot respectively.

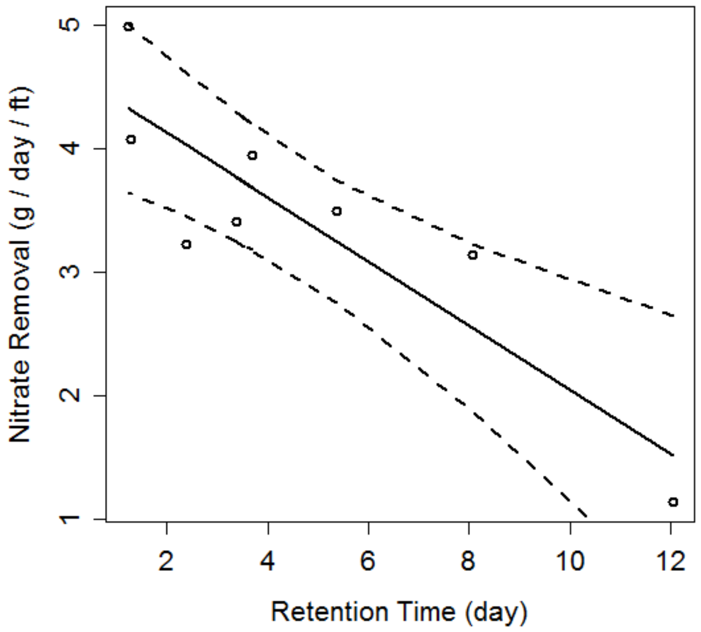


Figure 16: Linear relationship (R^2 = 0.77) between retention time (days) of the Molera Wetland and the nitrate removal rate (g/day/foot), with dashed lines representing the 95 % confidence intervals of the linear relationship. Notice that lower retention time, i.e. higher flow rates (gallons/day), resulted in higher total nitrate removal.

The current population of the Los Osos community is approximately 15,000, with an expected build out population size of 18,000. The expected wastewater generation rate per capita is assumed to be 66 gallons/day, resulting in 0.9 million gallons/day at the current population size and 1.2 million gallons/day after build out. Assuming a range of septic tank effluent concentration of 45 – 35 mg/L N (Hantzsche and Finnemore 1992), this equates to a minimum and maximum nitrogen load between 131 and 202 kg/day N respectively at current and build out conditions.

Using the estimated volume of wastewater generated by the Los Osos community at the current and build out population size and the flow rate estimated to remove the highest load of nitrate at the Molera Wetland, we estimated that 5 – 6 wetlands would be required to handle the expected volume of wastewater. Therefore, each wetland would receive between 22 and 41 kg/day N depending on population size and septic tank effluent nitrogen concentration.

If these wetlands were constructed with the same cross-sectional geometry and removed nitrate at the maximum removal rate estimated at the Molera Wetland, each wetland would require a channel length between 5,500 feet and 7,200 feet depending on nitrogen load. If the wetlands functioned at the lower end of nitrate removal estimated at Molera, the length of wetland channel would increase to between 7,700 feet and 9,900 feet. These channel lengths would correspond to an area ranging from 4.9 to 8.6 acres per wetland, assuming 20 foot wide berms separating wetland channels. Figure 17 is an example of the area and channel morphology of a treatment wetland that could be used to remove nitrate.

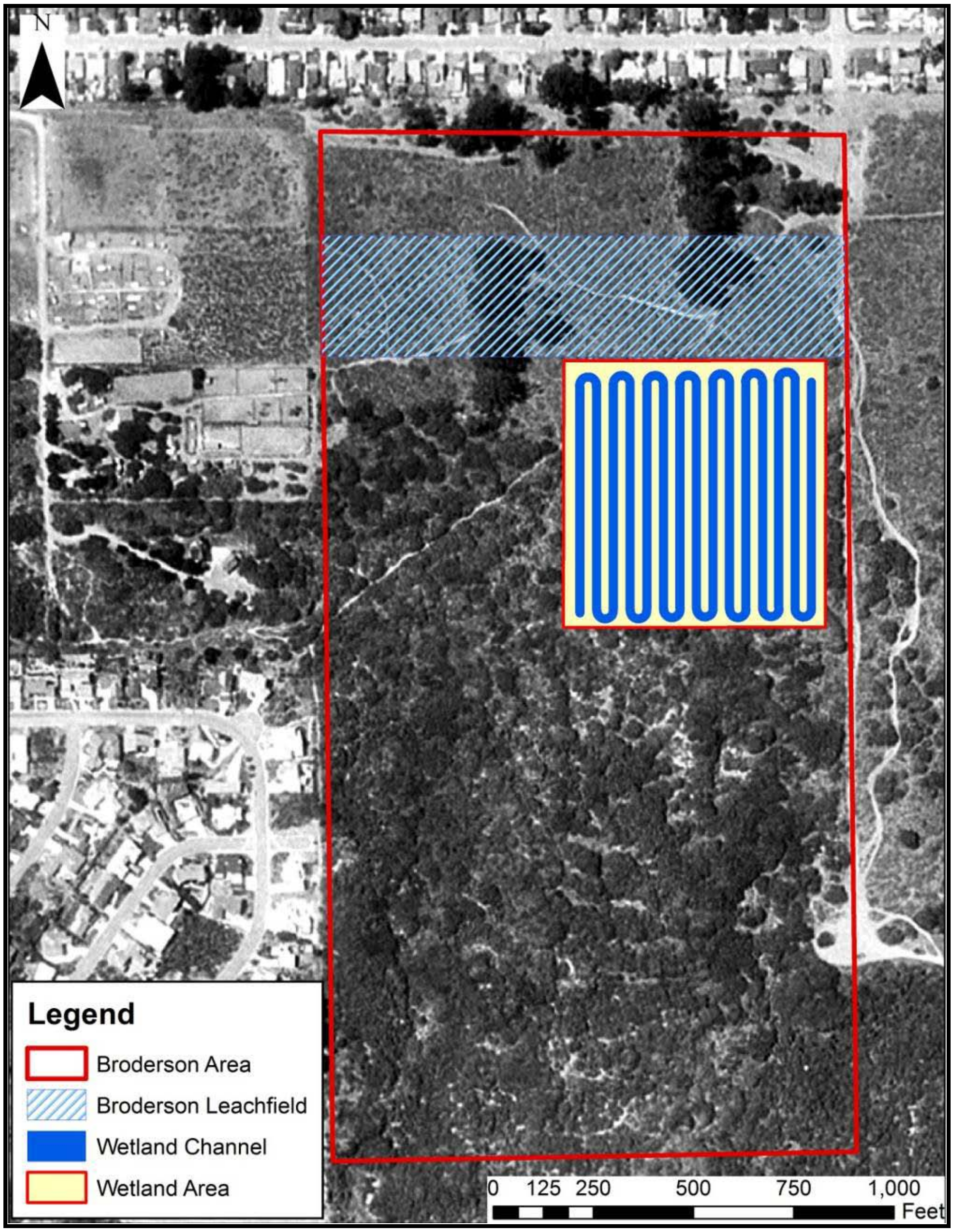


Figure 17: Map of Los Osos at the proposed land parcel for the Broderson leachfields. An example treatment wetland layout is shown to give perspective of the required land area and channel morphology. The wetland channel is approximately 9,900 feet long and 20 feet wide, with 20 foot wide earthen berms separating the water channels. The total area of this wetland is approximately 9 acres.

3.5.1 Discussion of Treatment Wetlands

Using treatment wetlands as a means to reduce nitrate concentrations from wastewater may be suitable for the needs of the Los Osos community. Results reveal that to remove the total load of nitrate expected to be generated in Los Osos, approximately 30 - 50 acres of treatment wetlands would be required. In two of the proposed wastewater projects, approximately 40 acres of land is designated for use by facultative ponds to improve water quality, but not expected to remove nitrate until the addition of methanol as a carbon source to fuel microbial activity. If treatment wetlands in Los Osos functioned at the average rate determined at the Molera Wetland, these 40 acres could be developed with constructed wetlands that followed the Molera design and remove nitrate without requiring additional treatment to remove nitrate.

Results of this section, however, were derived by making assumptions that may be violated and reduce the nitrate removal rates estimated to occur when using treatment wetlands.

First, the results assumed that wetlands constructed in Los Osos would perform similarly to the Molera wetland. Studies have shown that wetlands function differently in different settings and therefore remove pollutants at different rates (Kadlec and Knight 1996). However, since the two areas are within the same geographic area, i.e. both sharing a Mediterranean climate and within the coastal zone, and since geographic location has been shown to have important influences on wetland functioning (Kadlec and Knight 1996) there is support that wetlands in Los Osos would remove nitrate at the same rate as the Molera wetland.

Second, the sampling at Molera Wetland occurred approximately 5 months after the wetland was constructed. Previous studies have cautioned when using results from wetlands that have not had adequate time to adjust and equilibrate to the various environmental conditions affecting wetland performance in regards to pollutant removal (Kadlec and Knight 1996). Studies, however, have indicated that nutrient removal rates should increase after the start-up stages of a wetland as the wetland equilibrates and develops a microbial community capable for transforming harmful pollutants to less harmful compounds (Kadlec and Knight 1996). Therefore, the results may not be representative of the long term functioning of the system, either under or over-estimating nitrate removal, and should be considered when extrapolating results from one wetland to another.

Third, a more important point is that the majority of septic effluent is commonly in the form of ammonium (NH4+), with studies finding that the majority of total N from these systems is composed of ammonium and not nitrate (Wakida and Lerner 2005). Since ammonium concentrations observed at Molera Wetland were near two orders of magnitude smaller than expected to occur from Los Osos septic effluent, due to different pollution sources, removal rate estimates are not easily transferred to Los Osos region in regards to the ability of treatment wetlands to remove this species of nitrogen. Therefore, these findings assume the implementation of trickling filters or other means of transforming ammonium-nitrogen to nitrate-nitrogen prior to being applied to treatment wetlands.

Accounting for the assumptions listed above, if the acreage proposed for facultative ponds were developed with treatment wetlands using the design of Molera Wetland, community and state resources may be put towards a wastewater treatment system that not only effectively improves water quality, but supports wetland associated and dependent species. Specifically, if the edges of the wetlands channels were planted with native emergent vegetation and berms planted with a mixture of wetland and upland plant species, as done at the Molera Wetland, the diversity and complexity of habitat may provide valuable refuge and territory for numerous species as well as providing a means to treat wastewater.

3.6 The role of Agriculture in Groundwater Management

3.6.1 Recycled Water Safety

One concern of using recycled water for agricultural irrigation is food safety. There are many programs in commercial use today; one such example is Monterey County located just 140 miles north of Los Osos. Monterey County had been experiencing SWI along the coast in the early 1970's because of overdraft of the freshwater aquifer (Engineering Science, 1987). As a response, in 1974, the CRWQCB recommended that wastewater be utilized for agricultural irrigation (Engineering-Science 1987). This began the initial water quality safety studies that led to the Monterey County Recycling Project (MCRP).

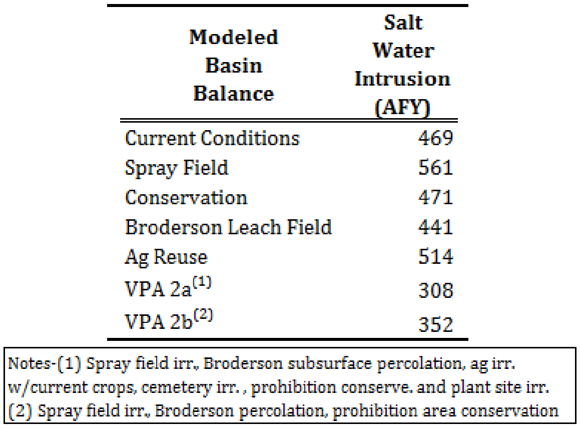
Monterey Regional Water Pollution Control Agency conducted the first water safety study in Monterey County. The resulting Monterey Wastewater Reclamation Study for Agriculture produced an 11-year project, including 5 years of field studies (Engineering-Science 1987). For the field studies, fresh vegetables were grown using three water treatments: tertiary treated wastewater (recycled), secondary treated wastewater and well water (control). This study concluded that at no time were there any food safety issues from the use of the recycled water for irrigation. Interestingly, researchers stated they often found that the recycled water was safer than the well water used as a control (Engineering-Science 1987).

A second study was conducted from October through December, 1997, several months before the MCRP was to begin deliveries for agricultural irrigation. The Recycled Water Food Safety Study focused on several pathogens--Salmonella, Cyclopora, E. coli 0157:H7 and viable Giardia (Shiekh et al., 1998). The study purpose was to address concerns that these pathogens may be present in the recycled water after treatment. The study never recorded any Salmonella, Cyclopora, E. coli 0157:H7 or viable Giardia in the treated water even when high counts of the pathogens were found in the wastewater before treatment. The researchers concluded that the recycled water was safe for fresh vegetable production (Shiekh et al. 1998).

The MCRP has been delivering recycled water for agricultural irrigation since 1998. Currently it delivers recycled water to 12,000 acres of agricultural land which produce fresh fruits and vegetables. In MCRP's 11 years of operation, there has never been a food safety incident.

3.6.2 Agriculture and Los Osos Aquifer Balance

Cleath & Associates modeled the Los Osos aquifers to estimate the water budget for the proposed wastewater disposal options suggested in the draft EIR. Modeled outcomes varied in saltwater intrusion yields (table 7). Recycled wastewater for agricultural use has the second highest saltwater intrusion yields compared to all the modeled outcomes. Current and Agricultural reuse model diagrams are illustrated in figure 18.



Modeled Basin Balance	**Salt Water Intrusion (AFY)**
Current Conditions	469
Spray Field	561
Conservation	471
Broderson Leach Field	441
Ag Reuse	514
VPA 2a(1)	308
VPA 2b(2)	352

Notes-(1) Spray field irr., Broderson subsurface percolation, ag irr. w/current crops, cemetery irr. , prohibition conserve. and plant site irr.
(2) Spray field irr., Broderson percolation, prohibition area conservation

Table 7 Modeled saltwater intrusion for different wastewater deposal proposals for the Los Osos wastewater treatment facility (Michael Brandman Associates 2008).

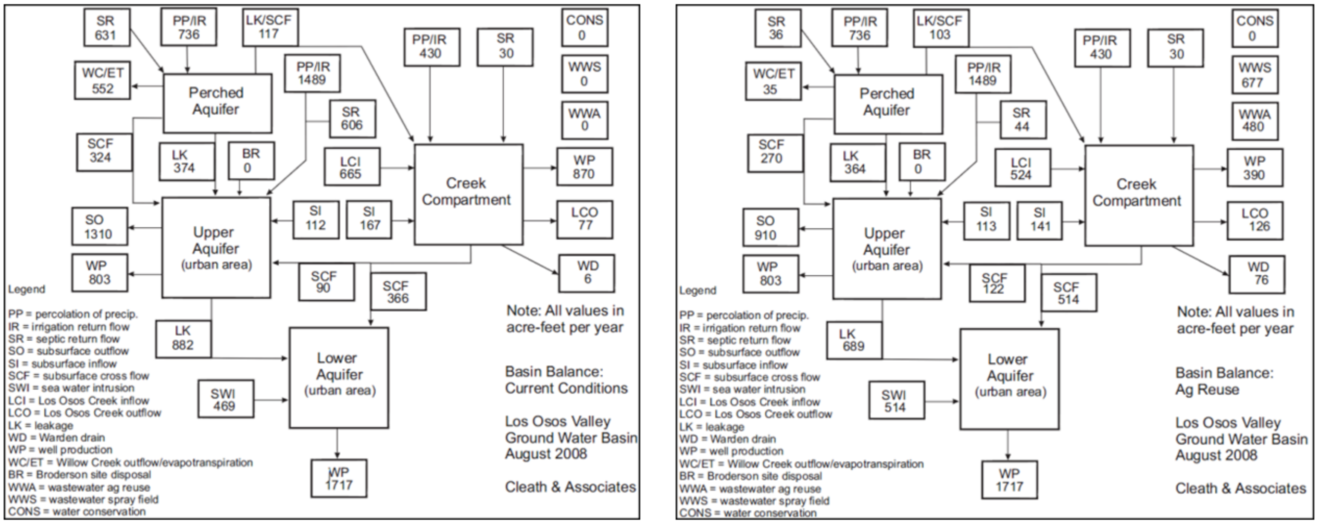


Figure 18: Los Osos modeled aquifer water balance for current conditions and the agricultural re-use option. Note that both water balances assume that saltwater intrusion will occur (Michael Brandman Associates, 2008).

Current conditions estimate SWI to be 469 acre-ft/yr (AFY) (Michael Brandman Associates, 2008). Agriculture reuse proposed in the draft EIR would increase the SWI to 514 AFY, an increase of 45 AFY. The model assumes that 480 AFY would be delivered to 230 agricultural acres in the Los Osos Creek Valley from the LOWWP, thus reducing agricultural well extraction from the lower aquifer by 480 AFY (Michael Brandman Associates 2008). For the Agriculture reuse model, the LOWWP is estimated to yield 1,157 AFY of wastewater. The difference between agricultural deliveries and facility yield is 677 AFY (Michael Brandman Associates 2008). This is a severe underutilization of this recycled resource.

3.6.3 Projected Agriculture Water Use

Modeled outcomes for agricultural reuse in the draft EIR fail to utilize the full potential for recycled wastewater for agricultural reuse over the Los Osos Creek Valley (LOCV). The modeled area of 230 acres is significantly less than the 400 acres of agricultural and cemetery lands available (375 irrigated and 25 fallow) identified in the Cleath-Harris Geologists, Inc. technical memorandum, “Water use estimate for Los Osos Creek Valley irrigation wells,” of July 29, 2009 (figure 19). This memorandum calculated well extraction for irrigation, primarily agriculture and a small quantity for a cemetery, to be 800 AFY using current crops grown in the LOCV (Cleath Harris Geologists 2009). This is the same agricultural extraction rate used for the current conditions modeling in the draft EIR. The agriculture reuse modeled well extraction of only 480 AFY, a difference of 320 AFY between modeled and potential if delivered for irrigation, would have a direct, positive, impact on SWI. If the agriculture reuse model assumed 800 AFY of irrigation water delivery from the LOWWP, SWI could be as low as 221 AFY, significantly lower than all wastewater disposal options modeled (table 7).

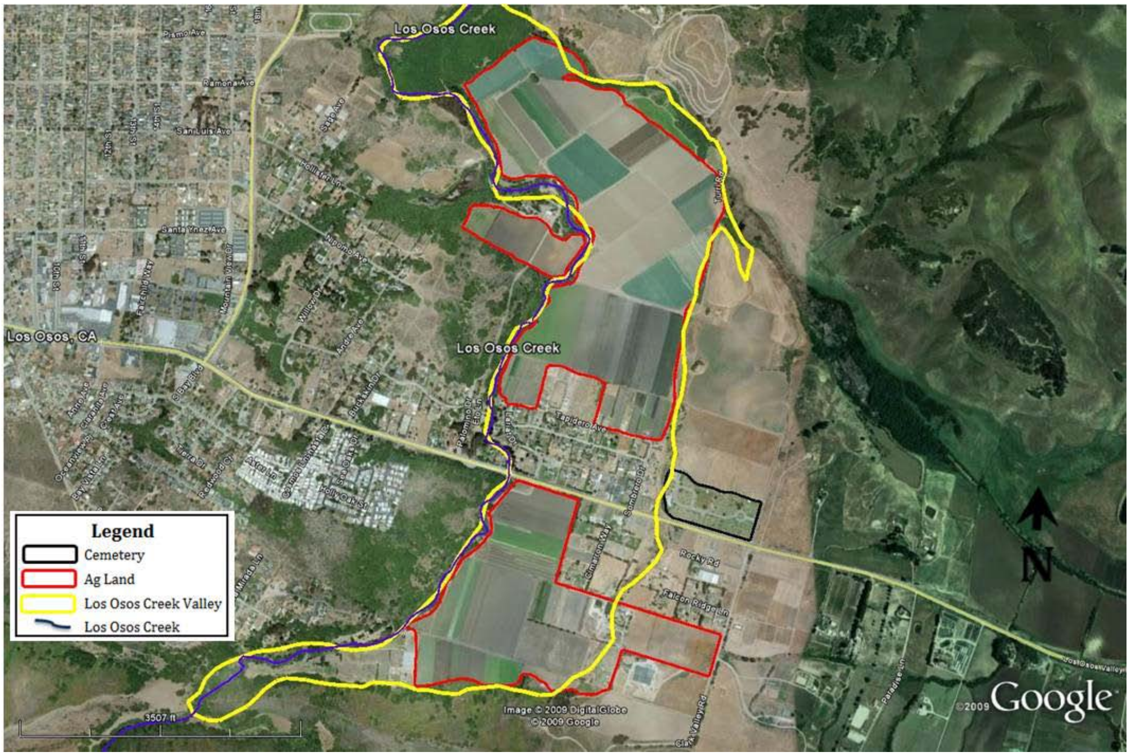


Figure 19 Los Osos Creek Valley agriculture and cemetery lands used to calculate annual aquifer extraction for irrigation (CHG, 2009)

3.6.4 Projected Recycled Wastewater Yields

One question is whether the LOWWP is capable of meeting all the demands for agricultural irrigation in the LOCV. On July 28, 2006, the Los Osos Wastewater Management Plan Update (LOWMPU) calculated potential recycled water production yields for the LOWWP (table 8)(Ripley Pacific Company, 2006). Recycled wastewater yields vary with total connections, however 1,157 AFY used in the draft EIR modeling is obtainable (table 8).

	2006			At Buildout		
	Low	Medium	High	Low	Medium	High
Connected Population	5,000	10,000	15,000	7,000	15,000	20,590
Recycled Water Production (AFY)	280	672	1,176	392	1,008	1,614

Table 8 Projected Los Osos Wastewater Recycled Water Production study for reuse at six different connection levels (Ripley Pacific Company 2006).

At full buildout, when all residential connections are completed, there is more than enough recycled water production for farming. Agricultural exchange has multiple benefits for the basin and is a key component of total watershed management for the area. Farmers have many reasons to participate, including reduce pumping of their groundwater and cost savings from reduce groundwater pumping. Likely the most effective implementation would be with a basin-wide management plan that provides incentives to encourage the participation of all stakeholders, as occurred in Monterey County.

3.7 Evaluating the Los Osos Valley Sustainable Basin Management Plan

3.7.1 Support for the Los Osos Valley SBMP in the Literature

Sustainable groundwater management is essential because of the limitations of basin-scale anthropogenic aquifer recharge and the slow rate of natural recharge in comparison with high rate of extraction (Kinzelbach et al. 2003; Section 3.2 above). While many studies propose improvements in conservation, efficiency, recycling and LID for reducing water demands, studies evaluating such plans on a community or basin scale are scarce. Even so, the methodology and technology for reducing water demand described in the SBMP are taken from reliable sources and are supported by the existing literature on sustainable development and conservation approaches (Fiske 2001). Likewise the reductions described in the SBMP are consistent with those described in similar projects (Dietz and Clausen 2008, SWRCB 2009a, USEPA 2000). Further, the Waste water recycling options in the study (agricultural exchange and urban reuse) has been reported as key to sustainable basin management because effluent remains the only water resource that actually increases with population growth (Gardner et al. 2000). Grey water use in combination with rainwater collection has been shown to decrease some residential water use by 80% and is seen as the greatest residential source of water savings (Dixon et al. 1999, Al-Jayyosusi 2003). The longer flow paths implement in many LID plans effectively reduce the amount of polluted runoff and limit polluted runoff from reaching sensitive aquatic ecosystems or groundwater recharge areas (USEPA 2000). Water retention from LID methods also can mimic natural hydrologic processes resulting in increased water retention times, effective nutrient sequestration by soils and cleaner water for aquifer recharge (Dietz 2007, Dietz and Clausen 2008).

Besides reducing water usage, studies also demonstrate monetary savings associated with sustainable water use approaches (Fiske 2001, USEPA 2000). Water for both residential and class II water consumers, installation of water conserving fixtures and appliances can result in lower water bills and reduced wastewater charges and costs for chemicals and water purification (NRDC 2009). LID infrastructure can save $3500 - $4500 per lot compared to development with conventional stormwater controls in a recently implemented sustainable subdivision in North Carolina (Kloss 2006)

Communities throughout the United States and the world increasingly report success in reducing water demand, making current usage more efficient and reducing contaminated effluent through the implementation of sustainable water management practices. (USEPA 2000). Water recycling programs on both the community and individual home scale in a suburb of near Brisbane, Australia demonstrated decreased extracted water usage by nearly 50% (Gardner 2000). The City of Olympia, Washington successfully implemented a *mandatory* LID strategy to protect the freshwater resources of the watershed and demonstrated reductions of wastewater effluent (Haub 2002). Based solely on implementation of moderate in-home water use efficiency improvements and education, residents of the Marina Coast Water District (MCWD), another California Central Coast community experiencing groundwater aquifer overdraft, demonstrated a 27% decrease in demand between 1989 and 2005. MCWD affirms that improvements in water use technology (installation of flow controlling devices) alongside rate and education-driven behavior changes successfully reduce water use and demand (MCWD 2005).

3.7.2 SBMP Implementation Challenges:

3.7.2.1 Funding

The Los Osos valley SBMP makes a very good case for conservation, increasing water use efficiency, water recycling, rainwater capture and LID methods for reducing the demands on the lower freshwater aquifer and by extension reducing sea water intrusion, and provides guidance on to implement sustainable practices on a community-wide scale. The community-wide scale implementation is very important in order to capture the water draw reductions projected by the plan. The plan also does a very good job of highlighting the associated costs of particular measures, and outlines a reasonable funding strategy that includes fees from water users supplemented by external sources. It is unclear whether the costs associated with implementation of the SBMP would be covered by bond funds going towards paying for the waste water treatment project. To increase the likelihood that the County of San Luis Obispo in conjunction with the community of Los Osos adopts and then implements a SBMP, a specific and detailed funding plan would be helpful. Perhaps the SBMP could be implemented in conjunction with the state as a demonstration project for other communities facing similar threats and challenges to their water supply in coastal zones.

3.7.2.2 Community Perception/ Acceptance of Sustainable Water Management

Fostering community acceptance of community-wide conservation and LID plans is essential because community perception of such methods may hinder successful implementation. In terms of LID, many homeowners want large-lots and wide streets and may view reduction of these features as undesirable or even unsafe. While unsubstantiated by modern practices and standards, many people believe that without conventional water management and controls, they will be required to contend with basement flooding and subsurface structural damage (USEPA 2000). Those concerns may not be relevant to Los Osos where basements are not common. The maintenance responsibilities associated with implementation of LID and conservation approaches must also be explained and embraced by the community members for proper compliance and to gain the intended benefits (PGCDER 1999). These issues must be addressed through outreach and education that extend beyond information on the benefits and facts of water conservation (Gardner et al. 2000). The water auditors described in the SBMP are key to successful implementation of community-wide participation.

3.7.2.3 External contingencies

While decreasing water demand can result in reduced water extraction from the lower aquifer, it is unclear whether this will be enough to prevent further sea water intrusion because of the low permeability rate across the regional aquitard, the rate at which the aquifer recharges from other natural sources, potentially reduced rainfall and rising sea levels. The slow rate of aquifer recharge and diffusion across the aquitard may lead to such a long time span for reversal of SWI that the basin cannot be used for drinking water for several generations (Kinzelbach et al. 2003). The SBMP addresses this point by focusing on reducing pumping from the lower aquifer, and providing a “margin of safety” as a contingency for unexpected negative results, such as extended drought. Effective modeling for possible drought and sea level scenarios must also be considered before adopting any basin management plan. Some of these external contingencies are addressed in other sections of this report.

3.8 Modeling the Effect of Variable Precipitation on Saltwater Intrusion

Using the hydrologic budget described in section 2.5, and the gage record of annual rainfall from Morro Bay as inputs, there is a 26% chance the lower aquifer will experience a net gain in saltwater over time (Table 9; Fig. 20). With a slight reduction in the mean of the precipitation distribution to simulate a small drop in annual rainfall, the likelihood of increased saltwater intrusion remained the same. However, with a larger drop in precipitation the likelihood of a net increase in saltwater increased (Table 9; Fig. 21).

Table 9: Impacts of serial rainfall on chance of saltwater intrusion

				Percent chance of	
Mean	**AF in lower aquifer**			**Net increase**	**Net increase**
Precipitation	**Max**	**Min**	**Average**	**freshwater**	**saltwater**
16.7	53400	15500	30000	74%	26%
16.5	46000	12400	30000	74%	26%
15.9	37000	86000	20900	38%	62%
15.1	27500	1800	16400	4%	96%

In all of the simulations saltwater continues to intrude the lower aquifer. The current hydrologic budget for the Los Osos aquifer system allows for 469 AFY of saltwater intrusion into the lower aquifer. When this value is extrapolated over 100 time steps there is a resulting input of 46,900 AF of saltwater into the lower aquifer. The ISJ management goal is to allow for 55 AFY of inputs from salt water to the lower aquifer.

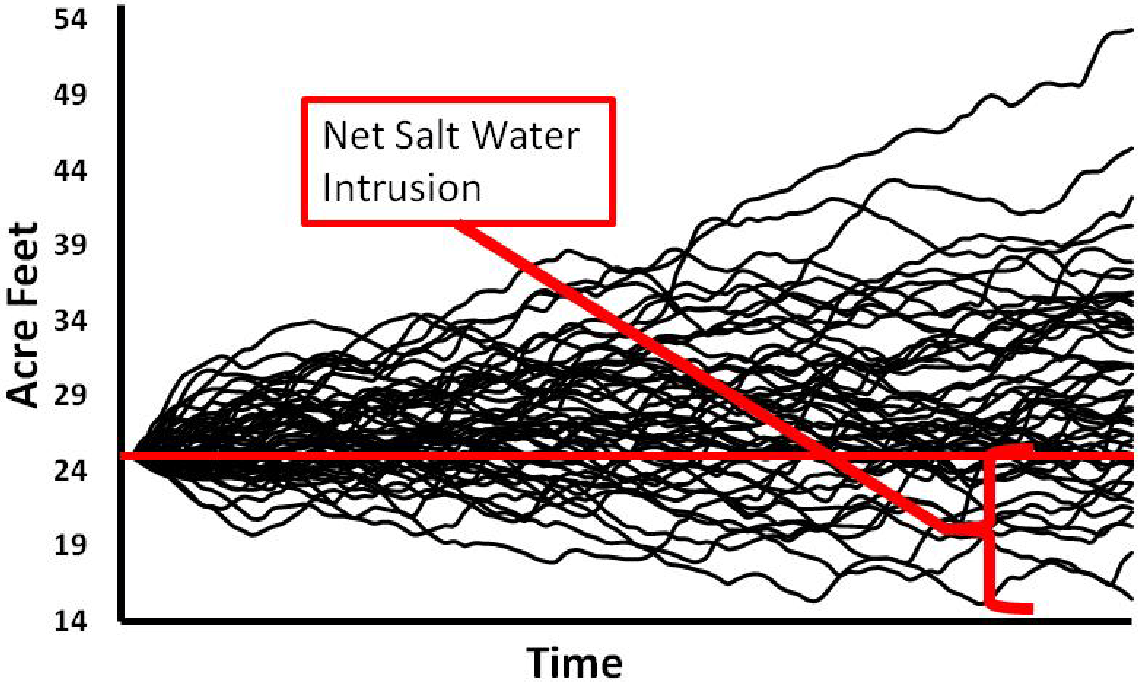


Figure 20. The simulations predict the variability in the lower aquifer based on variations in precipitation rates. The redline represents the level of inputs needed to maintain the 2008 amount of potable fresh water in the lower aquifer. Vertical axis is thousands of acre feet.

Achieve that goal, there would need to be the equivalent increase in the inputs from fresh water sources or equivalent reduction in extraction of fresh water from the aquifer.

Under the best simulation result (highest increase in the storage of the lower aquifer), when the gross inputs from salt water intrusion are removed from the total increase in the storage of the aquifer, there is a deficit of 18,500 AF (Fig. 20). Therefore, under the best case scenario there will 18,500 AF more of saltwater over time. Under the inputs of the average unchanged precipitation there will be a total of 41,900 AF of saltwater intrusion into the lower aquifer. Under the reduced rainfall conditions shown in Figure

21 (B, C, and D), there would be a total of 41,900 AF, 51,000 AF and 55,500 AF gross saltwater intrusion respectively over time.

Given these results, there is a need to factor uncertainty into the basin management plan. If the plan is designed to exactly balance the hydrologic budget, there is a reasonable chance of failing to meet that goal. Rather, the plan should be conservative in extraction rates, leaving more fresh water in the aquifer than is needed in an average year. While the cost of leaving more water in the ground may seem high, it must be compared to the cost of failing to develop a long-term water supply. A "positive pressure" of fresh groundwater to counter SWI is an essential part of long-term resource management (e.g., Yates et al. 2005).

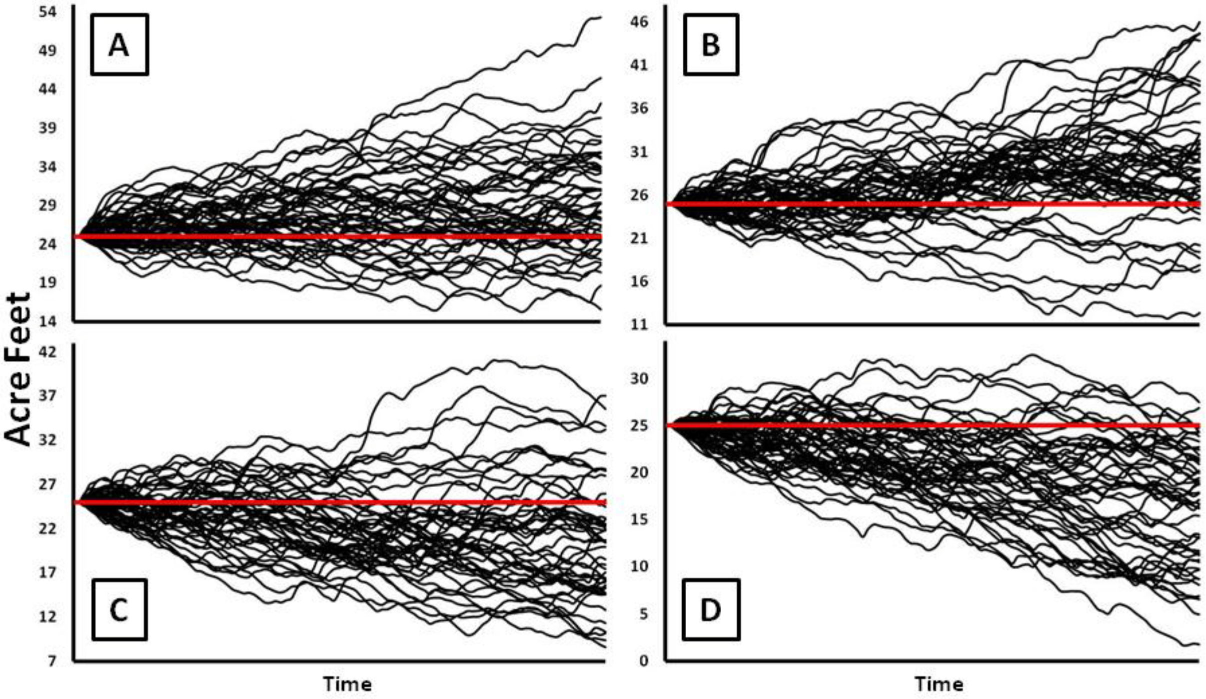


Figure 21. Each line represents the freshwater storage of the lower aquifer over time. Plot A is the unchanged precipitation data. Plot B, C and D are the results when subtracting 0.01, 0.05 and 0.1 from the mean in the precipitation distribution. The simulations accurately predict the variability in the storage of the aquifer based on variations in precipitation rates. The redline represents the balanced 2008 storage of potable fresh water in the lower aquifer based on the Cleath & Associates hydrologic budget. Vertical axes are thousands of acre feet.

3.9 Los Osos Wastewater Project Contingency Plan

3.9.1 Mitigation

A contingency plan for the wastewater project should address three key elements:

- Uncertainty in plan elements
- Essential monitoring that can determine if the basin plan is working
- Mitigation activities that will bring the project back in line with desired goals.

Money should be budgeted to perform the required monitoring, periodic assessment of the monitoring data, and appropriate mitigation activities.

Although each contingency plan is unique to a project and a region, there are common elements that are often included in a ground water contingency plan. An example of the outline of a contingency plan is shown in Figure 22 (Taraszki et al. 1997). The purpose of an LOWWP contingency plan is to describe actions that should be taken to monitor effects from the implementation of the LOWWP, and to determine actions that could be taken to mitigate potential adverse groundwater impacts related to either salt water intrusion or the implementation of the LOWWP (DRC2008-00103). Additionally, the plan should provide the means to respond to contingencies. The stated primary purpose of the Los Osos Wastewater Project is to comply with the CRWQCB's directive to reduce groundwater contamination (primarily of nitrate) caused by ineffective septic treatment systems. The secondary objective is to address current water resource issues in Los Osos and the problem of salt water intrusion into the lower aquifer. Because there is likely to be a time delay between project implementation and its potential impacts to some basin groundwater systems and because management options, such as strategies to supply water to wetlands and respond to seawater intrusion in the upper aquifer, require considerable lead time—it is advisable to take the following actions:

a) Be conservative in mitigation plans and err on the side of doing too much rather than too little to prevent, rather than respond to, impacts such as increased seawater intrusion,
b) Set up monitoring protocols for early detection, and
c) Develop a range of options that provide maximum flexibility (including a full range or water conservation and water re-use options) to respond early to signs of groundwater contamination by salt water or other project/management plan impacts.

Contingency Plan Outline

I. Introduction
    a. Purpose and Objectives
II. Background
    a. Project Description
    b. Regulatory and EIR Framework
    c. Regional Geological and Hydrological Conditions
III. Monitoring Well Network
    a. Rational for needed well network
    b. Review of Wells and Site Selection Process
    c. Well Installation Recommendations
IV. Groundwater Sampling Program and Data Analysis
    a. Sampling Program
    b. Procedures
    c. Data Management and Analysis
    d. Hydrologic Balance Evaluation
V. Remedial Contingency Plan
    a. Priority Zone A
        i. Performance Criteria
        ii. Benchmarks

Figure 22: Example of a contingency plan outline extracted from plans developed by Taraszki et al. 1997 and 2007.

A contingency plan identifies areas where there are significant uncertainties and defines remedial plans for responding to outcomes that might occur. In the case of the LOWWP, the primary uncertainties of this project relate to the performance of the Broderson leachfield, salt water intrusion in the upper aquifer, increased salt water intrusion in the lower aquifer and the environmental impact on wetlands, creeks and environmental resources. A contingency plan should be developed for each of these four arenas (called "Priority Zones" in the outline) as well as any other arenas where there is a substantial risk that might arise due to uncertain outcomes. The purpose of this paper is to recommend that contingency plans are developed for these arenas, so that Los Osos can be well prepared to respond if necessary, to a reasonable range of outcomes. Other objectives are to stress the need for preventative measures and to highlight some of the questions that should be addressed in regard to each of the four arenas where we believe contingency plans should be developed. As the LOWWP contingency plans are further defined and clarified, someone or some group with understanding of the final plans and the required hydrological expertise to develop a contingency plan should be assigned to develop such a plan. It is also advisable the plan is an integrated plan detailing integrated and coordinated responses to potential impacts, with the appropriate administration and funding spelled out in a basin management program or plan.

3.9.2 Priority Zone 1: The Broderson Leachfield Disposal Capacity

Approximately 1130 AFY (1.4 million m3/yr) of septic effluent that is currently dispersed throughout the Los Osos basin will be reduced in stages. Thus, the water that previously leached into the upper aquifer from these septic systems will be redirected to a treatment plant (Hopkins Groundwater Consultants 2008 EIR p. 30). The Broderson leach fields will discharge 448 AFY (550,000 m3/yr) of treated effluent to a single location if this level can be achieved without developing adverse conditions (Hopkins Groundwater Consultants EIR p. 30). Note that this level of discharge to Broderson leach field is half that assumed by Yates in the 2003 modeling effort, but the previous project used “harvest” wells to keep water from day-lighting downhill (Yates and Williams 2003). The EIR speaks to setting up a monitoring program for the Broderson leach field but does not address the need for a contingency plan in the event that this location cannot achieve the desired level of infiltration without adverse impacts.

Below is a list of questions that might reveal where uncertainties exist:

1) Broderson Site: Can the Broderson site dispose of 448 acre feet per year without adverse impact?
2) Can the site provide the desired recharge benefits to the groundwater (upper and lower aquifers, and to wetlands, etc.)

<u>Monitoring Requirements:</u>

The EIR discusses the use of a series of monitoring wells to ensure there is no liquefaction and that day lighting of water does not occur downhill.

Are these impacts likely to be seasonal or weather dependent and is this accounted for in the monitoring plan?

Are there sufficient monitoring wells.

<u>Benchmarks:</u>

How will current conditions be adequately measure and monitor?

Can performance assessment occur at stages through the timeline of septic system removal so that if adverse impacts are detected, the remainder can be delayed until contingency plans are implemented?

Contingency Measures:

Are there other disposal locations that could supplement the Broderson site if it is unable to handle the load requirements?

What are the best alternative locations and why are these preferred?

Could more recycled water be directed to urban reuse, agricultural reuse, and wetlands to reduce the need to dispose of recycled water at the Broderson site?

How much conservation should be in place prior to project start up to allow reduced pumping of the upper aquifer if Broderson fails to recharge the upper aquifer? (This would be designed to prevent/reduce the need for a response.)

Contingency Decision Making Process and Reporting:

Who will be responsible for developing, approving, implementing, and maintaining plans/program initially and over time?

How will plans be funded initially and over time.?

Who should be informed of the results of the monitoring and assessment?

Who should be involved in decision making regarding the need to resort to a contingency plan?

Figure 23 depicts the beginning draft of a decision tree regarding the Broderson site contingency plan. As the contingency plan is further developed and questions like those outlined above are addressed, this decision tree can be added to, refined, and modified.

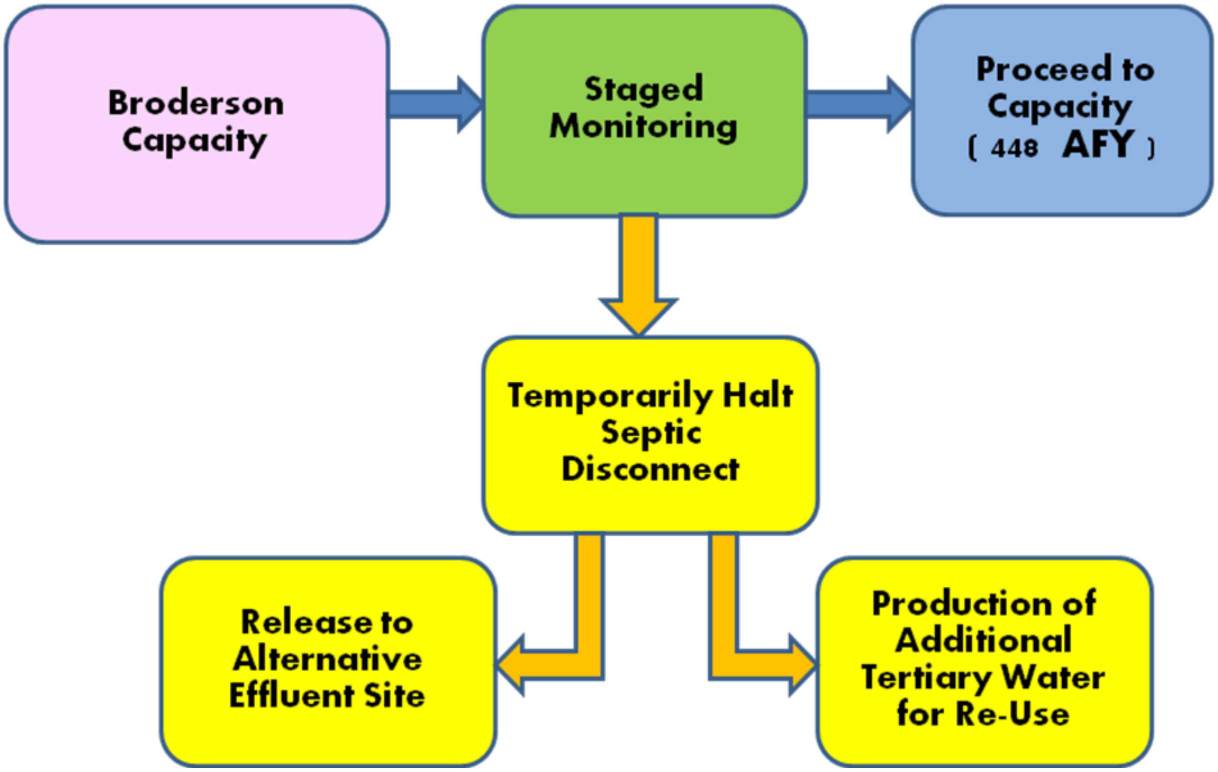


Figure 23:The draft of a decision tree for the contingency plan needed to address the uncertainty of the Broderson site capacity to infiltrate 448 AFY (550,000 m3/yr) without adverse impact.

3.9.3 Priority Zone 2: Capacity of the Upper Aquifer to Resist Salt Water Intrusion

The capacity of the upper aquifer to resist sea water intrusion across the face of the sea water- aquifer interface under the conditions that will exist when the LOWWP is implemented are uncertain. One source of uncertainty is how lateral water flow in the upper aquifer will be impacted when it receives a greater portion of water from a single location (the Broderson site) rather than from dispersed sites (septic systems). It is feasible that a change in flow dynamics could cause more outflow along part of the interface and less outflow along other parts, thereby increasing the possibility of salt water intrusion in reduced flow areas.

Safe yield of the upper aquifer is unknown and is estimated in the Resource Capacity Study to be 1150 AFY (1.4 million m^3/yr) (SLOCDPBD 2007). Current production from the upper aquifer is 800 AFY (985,000 m^3/yr) and safe yield estimates go as high as 1670 AFY (2 million m^3/yr) according to purveyors (Cleath-Harris, 2009). The accuracy of these yield estimates is uncertain. Under average rainfall conditions, it is currently assumed that the Los Osos upper aquifer discharges approximately 1300 AFY to the bay with a portion of that supplied by septic return flows (based on basin balance charts in the EIR; Cleath & Associates, 2008). The Sea Water Intrusion Assessment states that the upper aquifer is "relatively stable with the potential for onshore sea water intrusion" during extended droughts (Hopkins Groundwater Consultants 2005, p 27). This assessment of the possibility of salt water intrusion was made under current conditions, prior to removing the septic discharge or increasing supply pumping of the aquifer as is proposed by water purveyors. Under the project scenario with only Broderson in the draft EIR the outflow to the bay is estimated to drop by 200 AFY, and with increased pumping from the upper aquifer, outflow will drop by about 200 AFY (from about 1300 to about 1100 AFY) (Brandman Associates, 2009, Cleath-Harris, 2009)

Given the uncertainties associated with Broderson leach fields and project impacts, it is advisable to err on the side of caution by assuming a worse case and providing preventative mitigation programs. The Planning Commission added several conditions to the project to help ensure it would mitigate for potential impacts on seawater mitigation, including Condition 99 which augmented the project's conservation program (SLO Planning Commission, "Findings and Conditions of Approval" August 13, 2009). If the conservation program and other mitigation programs and plans err on the side of caution, they will reduce the possibility of having to resort to a contingency plan. Some of the main project conditions added to mitigate for the project's potential impacts on groundwater include:.

- Condition 97 specifies the need to return treated effluent to the groundwater basin, to use reserved capacity to satisfy environmental and agricultural needs in Los Osos Valley and to avoid using water to satisfy non-agricultural development outside the community.
- Condition 99 outlines a plan for a household conservation effort and specifies a dollar amount of funding to go toward this water conservation program.
- Condition 86 prevents growth until there is evidence for available water to support development without harm to wetlands and habitats.
- Condition 88 agrees the County will assist property owners in the implementation of using existing septic systems for percolating storm water runoff where appropriate.

Even with preventative measures in place, a contingency plan is needed to detect and respond to the possible occurrence of salt water intrusion into the upper aquifer (Fig.

24). If a plan has not yet been developed, a qualified hydrologist should develop a monitoring plan regarding SWI in the upper aquifer, and should include in this plan the needed frequency of monitoring and assessment to make such a determination. A hydrologist should be consulted to determine whether further wells will be required to make this determination. Budgeted money and a contract with the hydrologist for developing a monitoring plan, for needed additional wells and for implementing the monitoring and assessment should be a condition of approval of the LOWWP.

Questions regarding the upper aquifer's Safe Yield and capacity to resist salt water intrusion:

Monitoring Wells:
Is there a sufficient set of monitoring wells to detect salt water intrusion that might result from the LOWWP?
Are additional wells needed as an early indicator so that appropriate response can be taken and responsiveness can be as timely as possible?

Sampling Program:
How frequently should samples be taken at each well?
How should this data be managed and analyzed?
How will the hydrologic balance and current models for this balance be updated and refined based on findings from monitoring?

Contingency Plan:
What are the performance criteria that will be used to evaluate whether the project is having negative impacts on salt water intrusion?
What are the benchmarks that will be used to determine the safe yield of the upper aquifer and to flag the beginning signs of salt water intrusion?
What contingency measures can be taken if there are signs of salt water intrusion into the upper aquifer?
How many AFY can an LID system provide to infiltrate rain water into the upper and/or lower aquifer? How much water can be collected water from hillside runoff, roof tops or impervious surfaces? How many AFY would grey water systems for recharge or outdoor watering save?

Decision Making and Reporting:
Who will pay for the ongoing monitoring and assessment of the condition of the upper aquifer?

Who will receive information and reports from monitoring, assessment and the hydrological balance developed from these studies?

What decision making process will be used to decide on the appropriateness of implementing contingency measures?

How will decisions be made regarding amounts and limits of purveyor pumping from the upper aquifer?

Can the plans be codified with an ordinance?

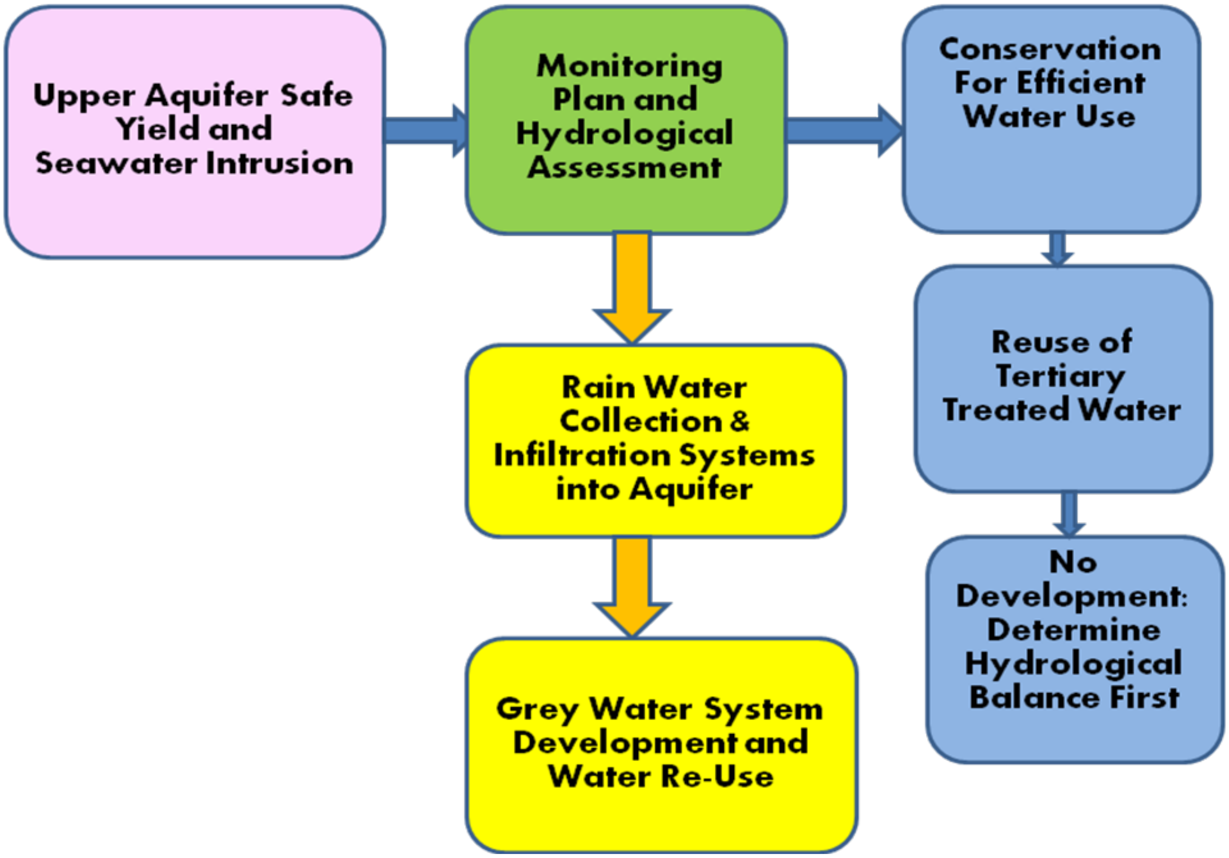


Figure 24. The beginning draft of a decision tree regarding the upper aquifer safe yield and saltwater intrusion contingency plan. As the contingency plan is further developed and questions like those outlined above are addressed, this decision tree can be added to, refined, and modified.

3.9.4 Priority Zone 3: Reversing Salt Water Intrusion in the Lower Aquifer

The current rate of SWI into the lower aquifer estimated in the Los Osos CSD is an advance of 60 feet inland per year between 1985 and 2005. There is uncertainty regarding the recharge rate from the upper aquifer to the lower aquifer through the aquitards and leaking wells. The SWI report (Hopkins Groundwater Consultants 2005) states that the clay aquitard between the upper and lower aquifers is one of the most regionally significant geological features of the groundwater basin; however the report admits “the hydraulic parameters of the clay have not been measured directly (Hopkins Groundwater Consultants 2005, p8).” The flow model used to quantify recharge of the lower aquifer adopted a horizontal conductivity of 0.1 feet per day (0.75 gpd/ft2) and vertical conductivity of 0.002 feet per day (0.015 gpd/ft2), with no range of probability given for these parameters. The USGS 1988 report claimed the predominant source of recharge of the lower aquifer is by water conveyed from the upper aquifer through this aquitard (1988 USGS p.50 referenced by Hopkins 2005 p13). The range of permeability of clay aquitards varies by several orders of magnitude and in general can be between 0.05 gpd/ft2 and 0.000001 gpd/ft2 (Driscoll 1986). The outline for a contingency plan (Fig. 22) can be used to develop additional questions regarding what the contingency plan for this aquifer needs to address. Note that conservation and LID are added here as part of a contingency plan; however, preventative programs and measures using these options that err on the side of caution, implemented prior to or concurrent with project construction, will minimize or eliminate the need to resort to contingency plans in the future.

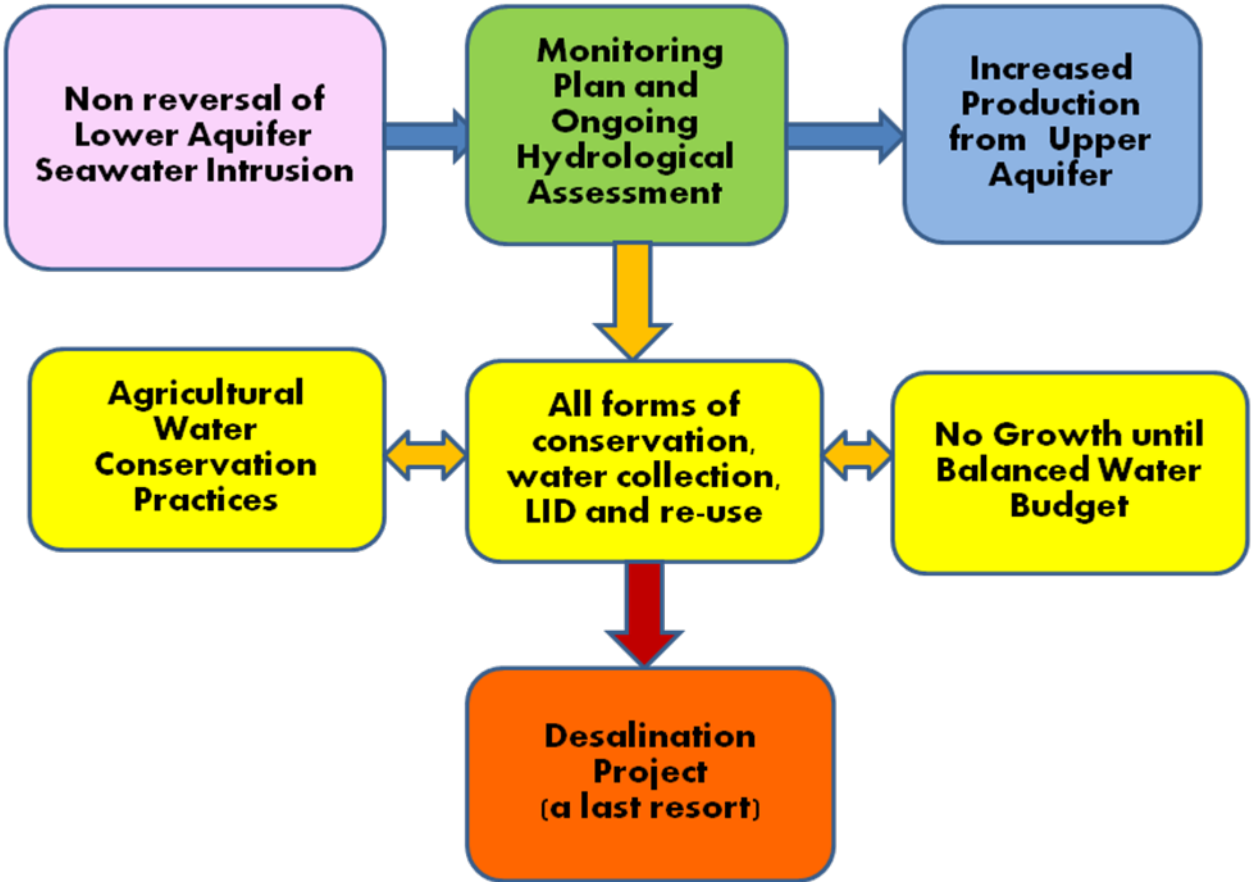


Figure 25. The beginning draft of a decision tree regarding the lower aquifer Safe Yield and the need for a contingency plan if salt water intrusion is not reversed.

3.9.5 *Priority Zone 4: Environmental Conditions – Willow Creek, Los Osos Valley Creek, Los Osos Valley Creek Estuary, and Morro Bay National Estuary and State Marine*

All creeks and wetlands that might be affected by changes in the water regime should be monitored and surveyed prior to the project, then during and after project implementation for changing hydrological conditions affecting plant and animal species. It is very important to maintain stream flows in Los Osos Valley Creek because it is a protected watershed for steelhead. When the LOWWP is implemented, water that is currently going to wetlands will be reduced by several hundred acre feet. (Harris at a Planning Commission hearing on 6/30/09). Project Condition 97 specifies that no less than 10% of the effluent will be reserved for the environment. Appeal Condition 20 from the Coastal Commission hearing (Los Osos Wastewater Treatment Facility Groundwater Level Monitoring and Management Plan Coastal Development Permit condition 20) lays out a monitoring and contingency plan to protect these resources. The detail of this plan should be revisited as a condition of approval. A more abbreviated condition of approval from the 8/13/09 meeting of the Planning Commission (Condition 87) specified the need for monitoring groundwater levels, surveying wetlands plants and animals, monitoring wetland hydrology and water quality. This same condition provides for general plan components, i.e. annual reporting and an education program encouraging property owners to direct rain gutters to abandoned septic systems to recharge groundwater.

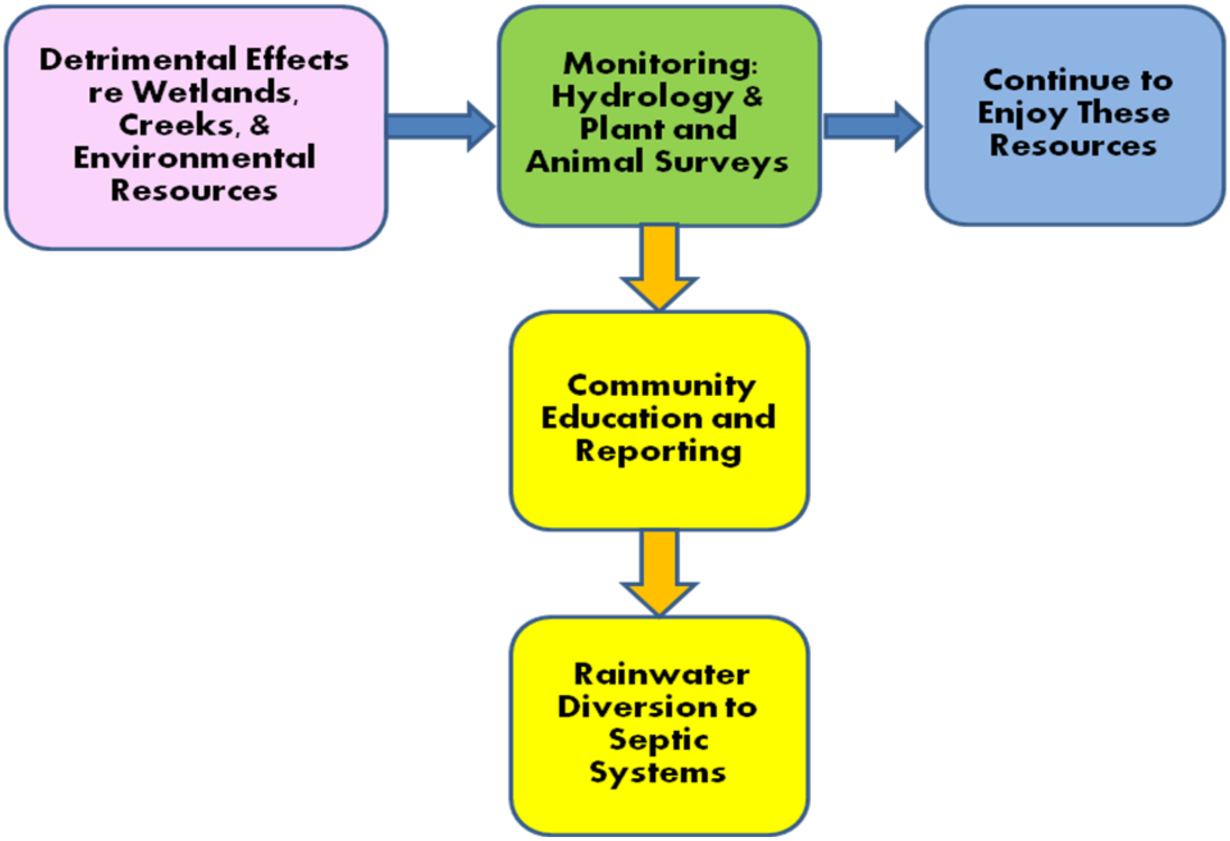


Figure 26. The beginning draft of a decision tree regarding the Environmental Resources, Creeks and Wetlands. There is a need for a monitoring and contingency plan to protect these resources from changes that may occur due to the LOWWP.

4 Recommendations

The challenge of developing a sustainable water supply for the community of Los Osos has been triggered, in part, by development of a waste water project in the area. Planning for the Los Osos Wastewater Project (LOWWP) has included the investigation of several opportunities to avoiding the impacts of the project on the groundwater, and this has highlighted the need to reverse salt water intrusion into the lower aquifers, while protecting the upper drinking water aquifer, and the environmentally sensitive ecosystems in the area that depend on groundwater flows. Community members, water purveyors, San Luis Obispo Public County officials, and other stakeholders, are investigating a range of options to accomplish these water management goals—including shifting pumping locations, intensive conservation, rainwater harvesting and LID strategies, and beneficial reuse of recycled water once the wastewater project goes on line. We recommend that a management plan for the basin, maximize cost-effective water sources (conservation, LID, and recycled water) developed concurrently with the LOWWP, also that the plan err on the said of caution to prevent, rather than respond, to problems, stop or reverse seawater intrusion as soon as possible, and establish a sustainable basin.

Pursuing outside sources of water or a desalination facility to achieve a balanced water budget should be considered last resorts, as these alternatives are expensive, have questionable sustainability, and may bring unintended consequences. For example, desalination facilities are energy intensive and create environmental problems that are difficult to mitigate (Cooley et at. 2006).

4.1 Recommended Actions

For each topic of study, we recommended potential actions that could be taken by the Los Osos community, water purveyors, the County and other governing agencies, with input from the public as plans are developed. We hope that the suggestions will spark creative ideas amongst those who read and discuss them, and stimulate further investigation of possible means for creating a balanced hydrologic budget in the Los Osos basin. The goal of achieving a water balance is an important one, and we credit the community for seeking alternative strategies and outside perspectives toward achieving this goal.

4.2 Pursue a Balanced Hydrological Budget, Monitor to Improve Basin Understanding, and Update Models

Water in deep aquifers has been called “fossil water” because it is ancient water that has slowly accumulated over several millennia and is replenished by gradual processes that occur on a geological timescale rather than a human timescale. The reservoir of fossil water for Los Osos is stored in the lower aquifers and has been depleted at accelerated rates far exceeding the recharge rate. This practice must be stopped for a sustainable water supply. It is anticipated that water use will transition to the upper aquifer as a primary source; however increased pumping from the upper aquifer may be limited by nitrate contamination, and may have adverse impacts on the upper aquifer, reported to be only “relatively” stable and subject to seawater intrusion during extended droughts (Cleath & Associates, 2005). Due to the many factors and unknowns associated with groundwater hydrology and achieving a balanced Los Osos water basin, we recommend project mitigation measures that err on the side of caution. We also recommend well-thought-out adaptive management strategies and contingency plans that take into account the time scales involved in groundwater movement and the need to act now to head off problems in the future. To successfully balance the Los Osos Valley Water Basin and maintain the water independence of the Los Osos community, we also recommend maximizing use of sustainable options for augmenting the water supply—water-use efficiency strategies, agricultural and urban reuse strategies, and LID recharge.

4.3 Rainwater Harvesting from Roof Top Collection

Rainwater harvesting and LID strategies represent a potential water source which can reduce outdoor water use and help recharge the aquifers supporting basin balance. While our calculation and analysis of the amount of water that can be collected from roof-tops deals with only one factor associated with this potential water source—and our findings were inclusive—the investigation suggests very significant volumes of water may be available from this source to help balance the basin. We recommend further analysis and consideration of t rainwater harvesting/LID options to help balance the basin and mitigate for the project. The option also has several co-benefits, including prevention of stormwater pollution and creation of attractive community features and on-site landscaping features.

4.4 Wetlands as an Alternative for Nitrate Reduction, Water Purification, Tourism, and Ecosystem Values

Wetlands are a relatively inexpensive means for water purification when compared with mechanical treatment systems because they are powered by the natural energies of sunlight, wind and bio-geological interactions (Kadlec and Knight 1996). The relative disadvantage of wetland treatment systems is that they require more land than some other treatment options; However wetlands can be integrated into a community plan that achieves other community goals. Wetlands can become parks, centers for education, and a draw for tourism into an area. They provide quality of life benefits and ecotourism opportunities by attracting wildlife, providing beautiful open space, and creating sites for outdoor recreation and enjoyment.

We have estimated a total wetland area between 30 and 50 acres would be needed to provide the treatment capacity required for the Los Osos waste water facility. The Cal Poly San Luis Obispo Department of Landscape Architecture has previously developed project plans and provided renditions of community parks incorporating wetland spaces. This group or other similar programs might be asked to propose a wetland park for Los Osos. Investigation of treatment wetlands that provide many simultaneous values (water purification, open space, recreation, education and habitat) could enhance the Los Osos community and become an example for other communities. We recommend visiting the Arcata, California wetland to see an outstanding example of a wetland sewage treatment system that is simultaneously a park space, recreational and educational facility, source of community pride, as well as a tourist destination. If a site can be found to accommodate the development of a wetlands and park in the Los Osos and if these goals and values are consistent those of the Los Osos community, then a wetland treatment system should be further investigated.

4.5 Rain and Drought

Developing a sustainable water supply includes evaluating climate records, and accounting for uncertainties in planning, so that droughts do not pose a risk to the resource. Planning for “average” rainfall conditions based only upon local gage records is risky when the values come from records that are short and positively skewed, like the Los Osos gage. The local rainfall average has quantifiable uncertainty, and typical droughts might not be adequately represented in previous analyses.

Statistical estimates of average rainfall can be stated as a range of values that are equally likely to be the true average with 95% confidence. One conservative approach to sustainable water planning is to model the hydrologic budget of the basin using the lower limit of the 95% confidence range rather than the central value. There are other ways to employ conservative values as inputs to the model. We recommend using the most conservative methods for the Los Osos Valley Water Basin due to the serious seawater intrusion problem.

The literature shows periods of long term historical drought and predictions of increased drought in the future. We recommend that this information be considered in the planning process. The uncertainty of future drought is a strong motivation to base hydrologic models on conservative rainfall estimates. The rainfall analysis addresses only one factor affecting the uncertainty of basin hydrology and modeling basin groundwater processes. Analyses in the future should address all sources of uncertainty, so they can be accounted for in basin management scenarios and solutions.

4.6 Agricultural Recommendations

4.6.1 Recycled Water Surplus Options

Using tertiary treated recycled water for agricultural irrigation is safe for fresh vegetable production. In the Los Osos basin, treated water from the LOWWP can be used for agricultural irrigation. If this water is exchanged with farmers for some lesser amount of potable well water, this management strategy could reduce pumping of the lower aquifer by about 700 AFY. This would go a long ways toward stopping seawater intrusion in the basin and establishing a sustainable water supply.

Improved water conservation practices for farms in the basin could extend the benefit of the agricultural reuse option. Implementing water conservation practices developed by the University of California Cooperative Extension and the National Resource Conservation Service would increase the number of agricultural participants to receive water from the LOWWP. This would secure a future for the agricultural industry for the Los Osos region.

4.7 Recommendations for the SBMP

Considerable effort and thought has gone into the development of the Los Osos SBMP. We commend the efforts of the LOSG regarding both their ambition and on the effectiveness of their efforts in developing and communicating the Los Osos SBMP. The range of conservation approaches they recommend and their diligence in terms of community education and government intervention are compelling examples of the achievements a small motivated group can have on community perceptions and project outcomes. We recommend that the plan is further developed, possibly by an expert in water use efficiency, and considered for implementation.

4.7.1 Quantifiable results

One of the most common challenges to the evaluation of water use efficiency and conservation models/plans is the question of quantifiable results. Many SBMPs are not designed with quantifiable analysis and evaluation in mind, and therefore limit the extent and value of assessments that can be made such as before/after comparisons, estimations of resources saved and cost/benefit analyses (Fiske 2001). The availability of quantifiable results of such projects significantly affects acceptance of such projects (Pekelney et al. 1996). Quantification provides a baseline for monitoring and analyzing the achievement of projected conservation goals, for evaluating project costs and benefits, and for determining whether the programs represent savings and values over standard practices (PGCDER 1999, NRDC 2009). The Los Osos SBMP would benefit from including more quantifiable measures which would provide a means for predicting and monitoring results as well as for evaluating the costs and benefits of their proposals over standard methods and previous management practices (PGCDER 1999). If this plan includes implementation as part of a state-funded demonstration project, quantifiable results will be all the more important for monitoring success and ongoing funding.

4.7.2 Tiered Rate Schedule

The SBMP discusses incentives such as rebates and grants to cover some of the costs, and it also mentions tiered rates (Wimer 2009). While the rebates and grants will most likely come from outside the community, the tiered rate schedule, as a local funding source, is important for the goals of sustainability and reducing costs. Because the community members and businesses share in some of the costs for the development of the infrastructure as well as the real costs of water extraction and production, they have more incentive to reduce usage, make usage more efficient and seek alternatives to water extraction. (Rogers et al. 2002). Also, when recycled water is priced lower than extracted/potable water, residents often turn towards the recycled water and actively implement methods to reduce potable/extracted water demand (Gardner et al. 2000).

Water use volumes are non-uniform across the region. Because there are some major water users extracting well above the mean water usage across the basin, these major users should have to face a disincentive in the form of price penalties, unless alternate sources are seriously entertained. A tiered rate structure also helps the issue of community perception and motivation; community members understand that all water users are paying in proportion to their use but those who use progressively larger shares than others pay a disproportionate share of the total cost of water.

4.7.3 Further Research

GIS data with current landscaping patterns and water usage would be helpful to determine how much water use reductions would be associated with xeriscaping efforts. Irrigation for non-residential and non-agricultural landscaping typically can consume over 30% of sector II water demand in urban areas throughout California. The vast luxury apartment community of Avalon at Mission Bay in San Diego decreased irrigation water use by 67% by implementing xeriscaping alongside smart irrigation controls and sensors tied into national weather service data (NRDC 2009). Los Osos may have opportunities for transitioning current water intensive landscaping to xeriscaping and for including xeriscaping in future home and commercial development projects.

4.7.4 Sustainability conclusions

The Los Osos Valley water budget has been seriously out of balance for the past 25 years and this imbalance is not a sustainable practice (Michael Brandman Associates 2008). It is in the best interest of all users of the groundwater aquifer to establish a SBMP where extraction rates are significantly less than recharge as soon as possible. Sustainable groundwater management is essential because of the limitations of wide scale artificial aquifer renewal and the slow rate of natural recharge in comparison with high rate of extraction. Also, a conservatively managed basin will more safely endure the short term over-pumping that will be done in response to exceptional drought conditions. (Kinzelbach et al. 2003). The LOSG plan provides a conservative approach that errs on the side of balancing the budget, moving seawater intrusion back, and creating reserves and flexible options for future basin management. We recommend the plan for further review and consideration.

4.8 Contingency Plan

We recommend the development of a contingency plan to address the water resources issues of Los Osos Valley and to respond to changes that may occur following the implementation of the LOWWP. We have highlighted priority arenas where we believe contingency plans are required and have shown an outline of what a contingency plan should include. These priority arenas include the Broderson leachfield, the upper aquifer, the lower aquifer, natural resources including streams and wetlands, endangered species such as steelhead, and any other arenas the community feels should receive consideration due to either its significance or uncertainty. Because groundwater hydrology has many unknowns associated with it—and because the Los Osos Valley Water Basin is in serious overdraft—we recommend strong preventative measures to avoid the need of resort to contingency plans; but, well thought out contingency plans should be developed to further assure a sustainable water supply. We recommend engaging knowledgeable community members and trained hydrologists to develop a complete and comprehensive contingency plan as part of a basin management plan, to prepare for adjustments that may be needed as the project and management plan is implemented to protect and preserve the resource.

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