Indian Wells Valley Resource Opportunity Plan

Water Availability and Conservation Report

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Executive Summary

Public concern over the adequacy of local water supplies has reached a new high in Indian Wells Valley. At the direction of the Kern County Board of Supervisors, the Kern County Planning and Community Development Department convened a public visioning process in 2011 to encourage local residents to participate in shaping the future of the community. Water emerged as the number one issue, fueled in part by recent expansion of irrigated cropland. Groundwater is the sole source of water in the area, and most scientific studies since 1973 have concluded that the groundwater basin is in overdraft. A few studies dissented, however, casting doubt among some citizens about the severity of the problem. Also, because the impacts of overdraft can take decades to occur, it seemed more of a theoretical issue than an immediate problem. But the increase in irrigation renewed public awareness of chronic declines in groundwater levels and the uncertainty of their future water supply.

This concern prompted the Board of Supervisors to initiate a two-part effort to address the problem. The first element of the program is an independent technical review and update on groundwater conditions, including a preliminary inventory of potential solutions to local water supply problems. That element is the topic of this report. The second element is a stakeholder process that allows local water users and members of the public to engage with County staff and the technical experts to reach broad agreement on the condition of the basin, the amount of overdraft, and viable options for improving the water supply situation. This report is the first product of that collaborative effort.

This report describes groundwater conditions in Indian Wells Valley, including groundwater levels and groundwater quality. The water balance is presented, along with discussion of basin yield and overdraft. Water use is documented for historical, current and potential future conditions. The institutional framework for land use planning and water resource planning in Indian Wells Valley also is summarized. Water resource goals and objectives are presented, followed by presentation of water supply alternatives. Each section is concluded with a brief summary of major conclusions, including next steps, which are also presented below.

Major Findings

- The Indian Wells Valley groundwater basin is in overdraft and has been since the 1960s, and the severity meets the definition of a "critical condition of overdraft".
- Groundwater pumping is now three to five times greater than basin yield.
- Indian Wells Valley is a "closed" basin, meaning that subsurface inflows from outside the watershed (for example, from the Kern River Plateau) and subsurface outflows are both negligibly small.
- The magnitude of the overdraft indicates that recovery cannot be achieved with conservation or water recycling alone without jeopardizing beneficial uses; importation of supplemental water is needed.
- The majority of wells with long-term data show increasing TDS trends, which suggest that long-term groundwater level decline is adversely impacting groundwater quality.
- The consequences of overdraft (including increased pumping costs, loss of well yield, degraded water quality, and land subsidence) affect everyone in the basin, albeit in varying ways and to different degrees. By the same token, all pumpers contribute to overdraft and could reasonably be expected to contribute toward a solution to overdraft.

- Current total groundwater production is about 25 times greater than it was prior to 1940.
- Current groundwater use categories include military (China Lake NAWS), municipal, Searles Valley Minerals, private domestic, and agricultural.
- Municipal and agricultural uses are the two largest uses and are similar in magnitude (36-40 percent of total groundwater pumping).
- The tui chub, an endangered species, currently is dependent on wastewater disposal from the City of Ridgecrest and NAWS, and thus depends indirectly on groundwater pumping.
- Military and Searles Valley Minerals pumping is estimated to remain steady, while municipal and domestic pumping increase slowly.
- Agricultural water demand will increase as newly planted trees mature; in addition, new acreage may be planted, representing a potential substantial increase in pumping.
- Land use planning is provided by an array of agencies—from federal to local—with objectives, policies, plans, and programs that are supportive of long-term sustainable water supply for Indian Wells Valley.
- Two important themes in the Kern County General Plan are the economical, equitable and efficient delivery of public services, including water supply, and the importance of agriculture to the Kern County economy. These two themes intertwine in terms of development of major water projects to provide water for agriculture.
- Water resource planning is provided by overlapping County and local agencies with different objectives, authorities, powers, and jurisdictions.
- Kern, Inyo, and San Bernardino counties have groundwater ordinances; the Kern and Inyo ordinances limit out-of-county exports while the San Bernardino ordinance (applicable to areas beyond Indian Wells Valley groundwater basin) requires a permit for a new production well.
- While organized under different legislation, the Kern County Water Agency and Indian Wells Valley Water District each have authority and powers to provide water supply and manage groundwater.
- Water management—including conduct of investigations, monitoring and reporting, water conservation, and some pumping management—has occurred through collaborative but non-binding plans with voluntary financial contributions.
- The Kern County General Plan goal for water management is to ensure that adequate supplies of high-quality water are available to meet present and future needs.
- Water management objectives to attain that goal are to optimize the existing groundwater supply, develop one or more supplemental supplies, manage water demand, and develop an institutional framework for management.
- Numerous water management alternatives exist including physical measures, land use planning options, and institutional options.
- Seven physical measures appear to be technically and financially feasible: redistribution of municipal pumping, urban water conservation, agricultural water conservation, wastewater recycling, groundwater demineralization, water importation, and groundwater banking. The physical measures generally are additive; some may be redundant but few are mutually exclusive.
- Importation of water is essential to the elimination of overdraft while retaining the existing land uses.

- If the water budget imbalance is to be addressed primarily by importing water, then multiple sources will be needed, including at least some water from remote sources such as the State Water Project, Central Valley Project, spot market, and/or distant private sources.
- A pipeline and water treatment plant would be the best means of conveying any identified imported water through use of the Los Angeles Aqueduct to municipal users in Indian Wells Valley in terms of reliability, water quality and energy (gravity flow). Percolation of aqueduct releases along Little Dixie Wash merits consideration for supplemental groundwater recharge in wet years or months when the supply of relatively low-cost imported water exceeds local municipal demand.
- Local demand reduction or supply augmentation projects are worth pursuing in addition to imports if they are reasonably comparable in terms of cost-effectiveness for reducing overdraft. Funding to support a water importation project may be easier to obtain if all reasonable local water resource options have already been implemented.
- Development of a specific plan for Indian Wells Valley is the logical vehicle for implementing changes in land use and limiting future water demands in unincorporated areas.
- Up-zoning of inactive agricultural parcels to large lot residential, low impact industrial or use for solar energy could reduce the potential for exacerbating future overdraft with minimal risk of takings issues.
- Land trusts to maintain open space may be applicable to Indian Wells Valley for specific parcels, but are unlikely to conserve sufficient land to make a difference to future water demand.
- Necessary characteristics of a water agency to achieve the water management objectives include the authority to develop supplemental supply, ability to manage water demand, capability to fund or finance programs and projects, local and equitable representation of stakeholders in the formation and governance of the district, and sufficient geographic extent of jurisdiction.
- A variety of agency options exist; of these, formation of a new Special Act District has the greatest potential to achieve all of the characteristics needed for effective water management.
- While adjudication provides water rights certainty and can compel a physical solution, it is costly and time-consuming; application to Indian Wells Valley would result in draconian reductions in pumping by all users.
- A Kern County urgency ordinance would prevent overdraft from becoming worse while a water management agency is being established and a water importation project is planned, designed and constructed, but has legal implications and potential for lawsuits.

Next Steps

- Consider an urgency ordinance and evaluate legal issues
- Develop a water management agency
- Acquire imported water
- Pursue local conservation and supply projects
- Complete a Specific Plan and related Environmental Impact Report for Indian Wells Valley
- Strengthen current water management planning
- Obtain funding

1. Introduction

1.1 Background

In 2011, the Kern County Planning & Community Development Department conducted a public visioning process to guide land use planning in the Indian Wells Valley area. Two public workshops attracted 52 participants who articulated their desires and concerns regarding the character of Indian Wells Valley and use of its resources. Water supply was identified as a high priority issue requiring immediate action. This concern reflects the community's complete reliance on local groundwater supplies, documented groundwater level declines, and recent changes in land use that entail increased groundwater pumping and consumption.

Groundwater in Indian Wells Valley Groundwater Basin is being managed through the Indian Wells Valley Cooperative Groundwater Management Plan, among other efforts. This groundwater management has included definition of basin management objectives, regular water resource monitoring and reporting, acquisition of grant funding for and sponsorship of numerous investigations, redistribution of pumping to minimize impacts, promotion of water conservation, ongoing collaboration among agencies and organizations, and regular outreach to the public.

Nonetheless, the community remains divided on fundamental issues, including the existence of a basin-wide groundwater supply problem (in other words, overdraft), much less its magnitude. Consequently, it follows that the community also is divided on the objectives for groundwater management and the actions that should be undertaken.

1.2 Purpose

The purpose of the Water Availability and Conservation Plan is to provide a foundation for effective and collaborative groundwater management action. The goal is to ensure that adequate supplies of high-quality water are available to meet present and future needs in Indian Wells Valley. To succeed with such management, the community needs broad agreement to move forward with planning and actions.

Such agreement needs to be based on technically-sound knowledge of land use and water resource planning, groundwater basin hydrogeology, water supply sources and groundwater basin yield, governance options, and water supply alternatives. This Water Availability and Conservation Plan report provides an independent and science-based perspective on how the groundwater system works, an understanding of how land use and water resources are managed, and a recommended array of water management alternatives. Agreement also needs to be based on a collaborative process that ensures consideration of all available information and provides a forum to discuss technical findings and recommended next steps.

1.3 Process

The Water Availability and Conservation Plan process has included a comprehensive compilation and review of existing information and independent analysis of the current state of the Indian Wells Valley Groundwater Basin. It also has involved a series of meetings and workshops with stakeholders and the public. The stakeholder process began in July 2013 with a public presentation at a meeting of the Indian Wells Valley Cooperative Groundwater Management Group (CGMG). A second public workshop was held in late August in Inyokern. In addition, interviews have been held with public agency staff and local residents with water expertise. The resulting information obtained from stakeholders, previous groundwater studies and ongoing monitoring programs has been integrated to reach conclusions regarding water use, basin yield and overdraft. In addition, a broad range of land use and water management options to improve the water supply situation have been evaluated.

1.4 Study Area

This report describes groundwater conditions in Indian Wells Valley in eastern Kern County, shown in **Figure 1**. Although the focus is groundwater, the overall hydrologic system includes surface watersheds that extend west to the crest of the Sierra Nevada Mountains and north and east to mountains in Inyo and San Bernardino counties. Development in the valley includes the City of Ridgecrest, the China Lake Naval Air Weapons Station (NAWS), the communities of Inyokern and Pearsonville, and numerous rural residences. Agricultural development consists of alfalfa fields and pistachio orchards, most of which are located along Brown Road north of Inyokern. Most of the land area in the valley is undeveloped and managed by federal agencies.

1.5 Acknowledgments

This Water Availability and Conservation Plan has been prepared by Eugene (Gus) Yates, PG, CHG, Senior Hydrologist, and Iris Priestaf, PhD, President of Todd Engineers with the assistance of Phyllis Stanin, PG, CHG, CEG, Vice President, and Amber Ritchie, Staff Geologist. We appreciate the support of Kern County Planning & Community Development Department staff including Lorelei Oviatt, Craig Murphy, John George, and Ross Fehrman.

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2. Groundwater Conditions

2.1 Basin Description

The hydrogeology, water balance and yield of Indian Wells Valley groundwater basin have been studied for over a century. Over 25 technical reports describing Indian Wells Valley geology, hydrology and water use were reviewed for this project. In addition, recent data for land use, groundwater levels, water quality and water use data were obtained from local agencies. This report presents only key information necessary to understand the current water supply situation. The text includes references to prior reports for those who desire additional information.

Hydrogeologic Setting

The boundaries of the basin are shown in **Figure 2**. The groundwater basin is located at the western edge of the Basin and Range geologic province. It is bounded to the west by the Sierra Nevada Mountains, to the north by the Coso Range, to the east by the Argus Range and to the south by the El Paso Mountains. These all consists of granitic bedrock, with some volcanic deposits in the Coso Range. Adjacent and nearby basins include Rose Valley, Coso Valley, Salt Wells Valley, and Searles Valley (see Figure 2). The basin underlies 597 square miles of land area and is filled with unconsolidated clays, sands, silts and gravels extending to depths of over 2,000 feet throughout most of the basin area. The deposits thin and pinch out against bedrock around the basin perimeter.

Several faults are present within the basin, and some studies have asserted that the faults obstruct groundwater flow and create distinct storage units (for example, Bloyd and Robson, 1971; St.-Amand, 1986). However, other studies including recent groundwater flow models (Berenbrock and Martin, 1991; Tetra Tech EM, 2003; Brown and Caldwell, 2009) and water-level trend and contouring exercises (this study) have not identified effects of internal faults on groundwater levels and flow within the basin. In several locations, clay and/or silt deposits are known to affect groundwater flow. First, an extensive buried lakebed clay deposit separates the shallow aquifer from the primary aquifer beneath China Lake playa. In addition, the steep water-level gradient between the El Paso subarea and main part of the basin appears to be associated with relatively fine-grained deposits and possibly also a fault. Finally, a thick subsurface clay deposit near the north end of Brown Road (possibly derived from Pleistocene lakeshore deposits) creates a zone of low permeability in the groundwater system.

Groundwater Levels and Flow

Under predevelopment conditions—more than a century ago—groundwater flowed radially from recharge areas at the base of surrounding mountains toward China Lake playa, where groundwater was discharged to the atmosphere by evaporation and plant transpiration. Groundwater recharge and discharge were balanced, and there was no long-term trend in groundwater storage. The general pattern of water levels today resembles the predevelopment pattern, but with noticeable changes in the western and southern parts of the basin due to groundwater pumping. **Figure 3** shows contours of groundwater elevation in spring 2012 delineated by Kern County Water Agency (Casterline, 2013). Groundwater flows perpendicular to the contours, from high elevations to low elevations. Decades of groundwater pumping have lowered water levels throughout the area and created two pumping troughs: one extending west from the Ridgecrest area and one extending north from the Inyokern area. Together, these pumping troughs capture essentially all mountain front recharge originating from the

Sierra Nevada and El Paso Mountains that would otherwise have flowed to China Lake playa and discharged to the atmosphere.

The overall lowering of water levels can be seen most easily in hydrographs of groundwater elevation. Historical water-level data are available for 178 wells in the basin. Most have data only since the early 1990s, but a few have data from as far back as 1946. A sample of hydrographs is shown in **Figure 4**; these illustrate the widespread declines that have been occurring in groundwater levels.

Water-level declines are occurring throughout the basin, not just near pumping centers. **Figure 5** shows the distribution of water-level trends across the basin, as measured from the hydrographs. Eighty-six percent of the wells have declining trends, compared with 8 percent that have rising trends (and 6 percent with no trend). The only area with consistently stable or rising water levels is the El Paso subarea in the southwestern corner of the basin. That region is partially isolated from the rest of the basin by a zone of low permeability (clay deposits or a fault). The ubiquitous, long-term and ongoing decline in water levels is the most definitive evidence of groundwater overdraft.

Figure 6 shows hydrogeologic cross sections of the basin from three previous reports. They all indicate the discontinuous layers of varying texture within the alluvial deposits that fill the basin. One indicates horizontal and vertical components of flow from mountain front recharge areas toward China Lake playa, which is a universally accepted conceptual model of the groundwater flow system. Groundwater that flows via shallow aquifers moves relatively quickly, while flow via deep aquifers can take thousands of years. These studies considered bedrock as impermeable, with no subsurface flow entering or leaving the basin via bedrock fractures. Some studies in the 1980s and 1990s asserted a contrary hypothesis that substantial amounts of water enter the basin via fractured bedrock from regions of the Sierra Nevada that are outside the local watershed (Austin, 1988; Ostdick, 1997; Thyne and others, 1999). However, subsequent studies and water-level data convincingly refute that hypothesis. A detailed discussion of the topic is included in Appendix A, "Water Balance and Safe Yield."

Groundwater Quality

Many aspects of groundwater quality have been studied, but the most important from a water supply standpoint is its salinity, or total dissolved solids (TDS) concentration. Salinity in the primary aquifer generally increases from west to east, as shown in **Figure 7**. Elevated concentrations are largely the result of evaporative concentration of salts over many centuries at China Lake playa. Two of the TDS contour lines in the figure correspond to the lower and upper secondary drinking water standards (500 and 1000 milligrams per liter or mg/L). The map shows that about two-thirds of the main basin area (excluding the El Paso subarea in the southwestern corner of the basin) has a TDS concentration that exceeds the lower drinking water standard.

There are also TDS variations with depth. For example, six of ten multiple-completion deep monitoring wells drilled in the early 1990s had slight to pronounced patterns of increasing TDS with depth (U.S. Bureau of Reclamation, 1993). Thus, even within the low-TDS region of the basin, a portion of the basin thickness can have high TDS as a result of variations among individual sediment layers. It is common for TDS to be higher in finer-grained deposits than coarser ones (Stone, 2003). Consequently, TDS can increase even within low-TDS aquifers if groundwater pumping lowers the pressure in aquifers and induces seepage out of clay layers between the aquifers. Thus, there are three pathways by which high-TDS groundwater can reach a water supply well that initially had low TDS: laterally from the China Lake area, vertically from below, and internally from clay deposits

Historical TDS trends in water supply wells were compiled to determine whether TDS is increasing and whether the locations of the wells with increasing trends indicate the source of salinity. Historical water quality data were obtained for IWVWD and NAWS production wells and also from a previous study that investigated trends (Berenbrock and Martin, 1991). The average annual rate of change in TDS concentration was calculated for each well and plotted as color-coded dots on the TDS map (Figure 7). The data show increasing trends at 13 of the 19 wells with data. The annual rates of increase range from 0.5 to 67 mg/L per year. Almost all of the wells with increasing trends—especially the ones with steep increases—are located in or near areas of elevated salinity, suggesting that lateral inflow of saline groundwater from the adjacent high-TDS zone could have caused the increase. There is some local variability in the trends, which could mean saline water is reaching the affected well screen from confining layers adjacent to the screened interval or from greater depth within the basin. The fact that the majority of wells with long-term data show increasing TDS trends confirms that long-term declines in groundwater levels (and associated changes in local groundwater flow) can adversely impact the quality of local water supplies.

Arsenic is also a water quality concern in Indian Wells Valley. It occurs naturally in basin sediments and can potentially be mobilized by changes in groundwater levels. A discussion of arsenic in groundwater is presented in Appendix B "Arsenic Data and Issues".

2.2 Water Balance and Basin Yield

Indian Wells Valley groundwater basin has been in a state of overdraft since the 1960s (Dutcher and Moyle (1973). Groundwater pumping began exceeding the yield of the basin at that time, and the imbalance has continued ever since. Excess pumping has simply "mined" groundwater storage, which cannot be sustained indefinitely.

The "safe" yield of a basin is the average quantity of water that can be extracted annually over a period of years without causing undesirable results (Bachman and others, 2005). Variations of the term such as "safe yield", "perennial yield" or "sustainable yield" all have essentially the same meaning. The safe yield of the groundwater basin depends on the basin water balance, which is a tabulation of all inflows and outflows. The water balance can be expressed by the following equation, which reflects the principal of conservation of mass: Inflows – Outflows = Change in Storage. Groundwater overdraft occurs when outflows chronically exceed inflows. It becomes apparent when water levels decline over a period of time that includes a complete climate cycle of wet and dry years, typically 10-20 years.

It is important to note that the yield of a basin is not necessarily a fixed quantity. It can be affected by the location of pumping and by interactions between groundwater and surface water. The simplest way to understand yield is to consider what happens when pumping is introduced into a basin or is subsequently increased. There are three possible effects: increased inflows, decreased outflows and depletion of storage. Pumping can increase inflows if it induces seepage from perennial surface-water bodies such as lakes or rivers. However, there are no such water bodies in Indian Wells Valley. Pumping can decrease outflows by intercepting groundwater that would otherwise flow to China Lake playa and be lost to evaporation. Pumping also causes storage depletion, as evidenced in Indian Wells Valley by chronically declining water levels.

Numerous previous studies have estimated the water balance of Indian Wells Valley groundwater basin. An updated, itemized estimate of the current water balance and safe yield is documented in **Appendix A** based on a critical review of prior studies and recent data. The bar chart in **Figure 8** shows average annual inflows and outflows by category under 2013 conditions. The range of uncertainty associated with each item is also indicated. In the case of agricultural pumping, the range also indicates total pumping when recently-planted young orchards reach maturity (around 2025). The bar at the right shows average annual storage change, with a range reflecting two methods of calculating storage change (see Appendix A for details). The annual storage change equals the amount of overdraft, which is about 16,500 acre feet per year (AFY) in 2013. The magnitude of the overdraft indicates that recovery cannot be achieved with conservation or water recycling alone without jeopardizing beneficial uses; importation of supplemental water is needed.

The safe yield of the basin with current well locations can be roughly estimated as the difference between annual pumping and annual storage depletion in 2010, which was 7,300 AFY. Safe yield is not a fixed number and is influenced by pumping locations and human activities that increase or decrease recharge. Additional discussion of basin yield is presented in Appendix A.

Indian Wells Valley meets the definition of a basin with a "critical condition of overdraft". This term was developed by the California Department of Water Resources (1980) to identify basins where "continuation of present water management practices would probably result in significant adverse overdraft-related environmental, social, or economic impacts." All of the consequences of overdraft described below would probably occur or be accelerated even in the absence of further agricultural expansion. Well replacement, demineralization and subsidence mitigation would collectively represent a significant economic impact on local residents. Agricultural expansion is currently a water management practice (as cited above) because lands zoned for agriculture are allowed to commence cultivation, and all agriculture in Indian Wells Valley presently requires irrigation with groundwater. Irrigation of all parcels presently zoned for agriculture would lower groundwater levels by up to 300 feet by 2057 (see Section 3.3 "Future Water Demand" below); this would unquestionably result in significant adverse economic impacts.

2.3 Consequences of Overdraft

Overdraft has serious long-term consequences. In this basin, chronic declines in groundwater levels and storage are likely to increase pumping costs, cause shallow wells to go dry, degrade water quality, and trigger land subsidence. Some of the impacts are already occurring. As described below, overdraft affects everyone in the basin, albeit in varying ways and to different degrees.

Members of the public frequently ask, "If we don't do anything, when will we run out of water?" The answer is that the basin is not like a jug of water that abruptly runs out. Instead, the impacts of overdraft become progressively worse and more expensive to mitigate. For example, demineralization of groundwater would greatly increase the volume of storage that could be mined and used, but demineralization is quite expensive and obtaining permits for disposal of the waste brine can be very difficult. Similarly, domestic wells that go dry will have to be replaced with deeper (and more expensive) ones to accommodate not only historical groundwater declines but anticipated declines over the next 50 years.

Increased Pumping Costs

It requires 1.02 kilowatt hours (kWh) to lift one acre-foot of water one foot. For a typical rural residence using 0.52 AFY of water where the depth to water is 250 feet, the annual electricity cost for pumping is approximately $42 per year and increasing at 11-22 cents per year.[1] This increase is probably insignificant relative to household budgets. In contrast, the energy cost to irrigate all of the existing

[1] Assumptions for residential cost: pumping drawdown = 0 ft, pressure = 50 psi, wire-to-water efficiency = 0.60, electricity cost = $0.13/kWh, water-level decline = 1-2 ft/yr. Assumptions for agricultural pumping are the same except pumping drawdown = 50 ft. One psi of pressure is equivalent to 2.31 feet of lift.

alfalfa fields (approximately 7,600 AFY) is about $700,000 per year and increasing at $1,700-$3,400 per year.

Dewatering of Shallow Wells

Private domestic wells are generally much shallower than municipal or agricultural wells, because the required pumping rate is much smaller and cost is a greater constraint. The impact of long-term water-level declines on domestic wells was investigated by compiling well construction information from well completion reports and comparing the depth to water at the time of drilling to current depth to water. Information was tabulated for 52 wells distributed over the region where most rural residences are located (approximately one sample well per section). The dates of construction ranged from 1971 to 2006, and the average age of the sampled wells is 23 years. Water levels have declined on average 32 feet since the time of construction. In nearly one-third of the sampled wells, the water level is below the top of the well screen, which creates a risk of corrosion and pump cavitation due to air entrainment in the water. The average water level is 78 feet above the bottom of the screen, which provides a maximum of 20-40 years of useful life assuming water-level declines of 1-2 feet per year (ft/yr). In one well, the water level is only 10 feet above the bottom of the screen. As the water level declines, the pump typically needs to be set deeper in the well, which entails some expense. The greater pumping lift will decrease the pump output, which in typical domestic wells will be compensated by an automatic increase in pump run time.

Water levels were already declining at the time all of the sampled wells were drilled. While that might not have been common knowledge when the oldest well was drilled, it should have been when most of the wells were drilled (after 1990). However, the data do not indicate that drillers provided extra well depth as time went by. The life expectancy of a water supply well is typically 30-50 years. It appears that most domestic wells will still be functional by the time they reach that age, although water-level declines will probably shorten the useful life of some of them.

Water Quality Degradation

The discussion of groundwater quality in the “Basin Characteristics” section, above, noted that groundwater salinity (TDS concentration) is increasing at the majority of wells in the Ridgecrest area for which long-term water-quality data are available. Salinity in aquifers commonly increases as water levels decline because decreased pressure in the aquifer causes water to leak out of the confining layers between aquifers. Confining layers consist of clays and silts and commonly contain more saline pore water than is present in the intervening aquifers. Salinity increases have raised the TDS concentration in four of IWVWD’s twelve wells to near or above the recommended secondary maximum contaminant level (MCL) of 500 mg/L. This does not pose a health hazard, but it renders the water less palatable. To continue meeting customer acceptance, IWVWD could eventually have to demineralize the pumped water or replace the impacted wells with ones in different locations. Domestic users, NAWS and Searles Valley Minerals similarly would face decreasing water quality.

Subsidence

Land subsidence has not yet been reported in Indian Wells Valley, but it is certainly a possibility as water levels continue to decline. Groundwater declines in Antelope Valley—a similar desert basin located 65 miles southwest of Indian Wells Valley—caused as much as 6 feet of land subsidence and created large cracks in runways at Edwards Air Force Base (Galloway and others, 1998). Like water-quality degradation, subsidence results when reduced water pressure in aquifers bleeds water out of intervening clay confining layers, causing those layers to compact. The compaction is permanent and lowers the overlying land surface. Subsidence commonly alters flooding patterns in flat terrain, such as is present near China Lake. If compaction is uneven, subsidence can damage buildings and pipelines. At NAWS in particular, there is a 4-mile-long test track that is leveled to within 0.030 inch along its entire length; it obviously would be impacted by even a tiny amount of subsidence (Boggs, 2013).

2.4 Major Findings

- The Indian Wells Valley groundwater basin is in overdraft and has been since the 1960s.
- Groundwater pumping is now three to five times greater than basin yield.
- The severity of overdraft meets the State of California's definition of a "critical condition of overdraft".
- Indian Wells Valley is a "closed" basin, meaning that subsurface inflows from outside the watershed (for example, from the Kern River Plateau) and subsurface outflows are both negligibly small.
- The majority of wells with long-term data show increasing TDS trends, which suggest that long-term groundwater level declines are adversely impacting groundwater quality.
- The consequences of overdraft (including increased pumping costs, loss of well yield, degraded water quality, and land subsidence) affect everyone in the basin, albeit in varying ways and to different degrees.
- The magnitude of the overdraft indicates that recovery cannot be achieved with conservation or water recycling alone without jeopardizing beneficial uses; importation of supplemental water is needed.

3. Water Use

Overdraft in Indian Wells Valley groundwater basin is not a result of decreased recharge. Natural recharge today is nearly the same as it was prior to development a century ago. Overdraft is caused by the large amount of groundwater extracted and used in the valley. Accordingly, it is worth characterizing the types and amounts of water use in some detail. The purpose of this water use inventory is not to find culprits but rather to begin identifying opportunities for management. All of the pumpers contribute to overdraft, and all of the current water uses would be considered "reasonable and beneficial" under the California Constitution.

The description of water use presented below is in chronological order, from historical to future. The intent is not to suggest that water use return to some particular date in the past, but rather to illustrate how various categories of water use can and do change over time. Estimates of current water use are documented in detail so that assumptions and uncertainty are clear. Future water use is unknown and will likely be affected by this report and the associated stakeholder planning process. However, land use zoning and population projections reveal the potential for water demand to increase in the future.

3.1 Historical Water Use

Annual groundwater pumping during 1920-2012 reported by previous investigators is shown in **Figure 9** broken down by user category. The values for 1920-1974 were estimated by the U.S. Geological Survey (Berenbrock and Martin, 1991), and the subsequent years were estimated by IWVWD. Several patterns are notable in the figure. Total groundwater production began increasing rapidly when NAWS was established in the early 1940s and has increased nearly continuously since then. Current total groundwater production is about 25 times greater than it was prior to 1940. Private domestic production is relatively small and has increased at a slow, steady rate. Production for export to the community of Trona and mining operations in Searles Valley (presently operated by Searles Valley Minerals) increased fairly quickly until the late 1970s and has remained steady at that level since then. Municipal production has fluctuated with changes in population, which are driven primarily by employment at NAWS. Growth was rapid during 1970-1990 and has been more gradual since then. Much of the increase in municipal pumping resulted from a shift in personnel and residential water use from NAWS to Ridgecrest. NAWS pumping has decreased rapidly and steadily over the past four decades and is presently less than one-fourth of its peak use in 1970. The decrease resulted from substantial reduction in irrigated landscape area on the base, in addition to the population exodus. Agricultural water use has fluctuated substantially due to changes in cropping patterns and irrigation practices. For example, one major alfalfa grower decreased per-acre water applications by one-third from the 1960s to 1990s but increased irrigated acreage about eight-fold (Mead, 2013).

The uncertainty in estimating non-metered pumping (such as by agricultural and private domestic wells) is revealed by discrepancies between the historical data sets during periods where they overlap. The U.S. Geological Survey and IWVWD data sets overlapped during 1975-1985, and the two estimates differed substantially in some years. The municipal and private domestic pumping estimates differed by up to 23 percent, NAWS pumping estimates differed by up to 34 percent, and agricultural pumping estimates differed by as much as a factor of two. Similarly, estimates of private domestic and agricultural pumping developed in this report for 2010-2012 differ from the estimates in IWVWD's database. Rather than attempt to explain the cause of historical discrepancies, this report focuses on thoroughly documenting its own methods used to estimate current water use in each category, so that the assumptions and calculations are clear and the results can be evaluated accordingly.

3.2 Current Water Use

Water use as of 2013 is estimated in this section for six categories: military (China Lake NAWS), municipal, Searles Valley Minerals, private domestic, agricultural and environmental. **Figure 10** compares current water use for the first five of those categories, which are the ones supplied by groundwater. Environmental uses are presently supplied by recycled water. The estimates shown in the figure represent average annual use under current population, land use and water use factors. However, all water uses fluctuate somewhat from year to year due to weather patterns and other transient factors.

Municipal and agricultural uses are the two largest uses and are similar in magnitude (36-40 percent of total groundwater pumping). However, current agricultural land use will require increasing amounts of water over the next 10-12 years as recently-planted pistachio orchards grow to maturity. That latent demand will increase agricultural groundwater demand by about 70 percent, as indicated by the dashed box on the agricultural water use bar in the figure. The approximate range of uncertainty is indicated by error bars in the figure. Details regarding data, assumptions and uncertainty for each category of water use are presented below.

Table 1 lists estimated groundwater demand by user category for 2010, 2013 and 2025. These three dates were selected to reveal the effects of recent agricultural expansion on water demand over that 15-year period. Agricultural water demand is broken down by crop type and growth stage: alfalfa, young pistachios and mature pistachios. The sources of the acreage tabulations and water use factors are explained below.

The location of groundwater pumping is important to understanding water level patterns, water quality trends, potential conflicts among users, and overdraft. The map in **Figure 11** shows the current locations of groundwater pumping in Indian Wells Valley. The points labeled as private domestic wells are actually the locations of residences mapped from aerial photographs and that are presumed to have on-site domestic wells. Similarly, one agricultural well is shown at the center of each alfalfa field and pistachio orchard on the assumption that each field and orchard is served by a local well. The area of each circle is proportional to the annual pumping volume (except for private domestic wells, which would be too small to see easily if they were displayed proportionally). Groundwater pumping is distributed fairly uniformly along the south and west sides of NAWS. Agricultural pumping dominates on the west side of NAWS, and municipal, NAWS and SVM pumping dominate on the south side. A comparison with Figure 7 shows that pumping is concentrated in areas of relatively good water quality, although the southern area has generally lower TDS than the western area.

China Lake NAWS

NAWS produces water from six wells located on the base to supply on-base water needs. These needs are essentially municipal in character, and include two schools, office and laboratory buildings, some residences, and a small amount of landscape irrigation. The golf course is irrigated with recycled water, not groundwater. All of the wells are metered, and average annual production during 2008-2012 was 1,800 AFY.

Table 1. Indian Wells Valley Groundwater Demand in 2010, 2013 and 2025

User	2010 Conditions[2]			2013 Conditions			Estimated 2025 Conditions		
	Acres	Applied Water ft/yr	Water Use AFY[1]	Acres	Applied Water ft/yr	Water Use AFY[1]	Acres	Applied Water ft/yr	Water Use AFY[1]
Private Domestic			1,000			1,000			1,100
IWVWD + Inyokern CSD			8,000			8,000			8,200
NAWS			1,800			1,800			1,800
SVM			2,600			2,600			2,600
Ridgcrest park irrigation			350			350			350
Alfalfa	870	8.0	7,000	990	8.0	7,900	990	8.0	7,900
Pistachios									
Young trees	0	0.25	0	2,200	0.25	550	0.0	0.25	0
Mature trees	300	5.0	1,500	300	5.0	1,500	2,500	5.0	12,500
Subtotal of current uses			22,300			23,700			34,500
Potential increase in irrigated cropland[3]							25,530	5.0	130,000
Potential total									165,000

Notes:

[1] All water use entries rounded to two significant digits.

[2] Water use except for new alfalfa fields and pistachio orchards was approximately the same in 2010 as in 2013.

[3] Potential future agricultural water demand assumes additional cropland consists of mature pistachios.

IWVWD = Indian Wells Valley Water District CSD = Community Services District NAWS = Naval Air Weapons Station China Lake SVM = Searles Valley Minerals AFY = acre-feet per year

Municipal

IWVWD provides the municipal water supply for the City of Ridgecrest and China Lake Acres. Eleven wells were active during 2008-2012, most of which are within the IWVWD service area but a few of which are in outlying areas southwest of Ridgecrest. Production from the wells is metered, and total production averaged 8,000 AFY during 2008-2012. The City of Ridgecrest operates five wells to irrigate a total of 41 acres of turf (measured from Google Earth imagery) at City Hall, Pearson Park, Jackson Park, and the Kerr-McGee Sports Facility. Using an estimated annual irrigation rate of 7.8 ft/yr (Provost and Pritchard, 2011) total irrigation use is 320 AFY. The IWVWD database shows an average of 370 AFY for 2008-2012, but the basis for the estimate is not documented. Given the relatively small magnitude of this use, an intermediate value of 350 AFY was used for this analysis. Inyokern CSD supplies municipal uses in Inyokern from a single well. Average annual production during 2008-2012 was 120 AFY. The sum of these three municipal uses was 8,350 AFY.

Characteristics of municipal water use that help guide management programs include per-capita water use and the proportions of indoor and outdoor use. Per-capita water use within the IWVWD service area decreased from 269 gallons per person per day (gpcd) in 1990 to 219 gpcd in 2010 (IWVWD, 2011; Morquecho, 2013). This 19 percent decrease was the result of local water conservation efforts. The proportions of indoor and outdoor water use were estimated by comparing monthly groundwater production with WWTP inflows, as shown in **Figure 12**. The lower line in the plot is inflow to the WWTP, which represents indoor use and has remained fairly constant seasonally and from year to year. The upper line shows municipal groundwater production, which has large seasonal fluctuations due to irrigation in summer. The difference between the upper and lower curves represents outdoor use. Beginning around 2008, outdoor use decreased by 16 percent relative to prior years. Outdoor use during 2009-2012 accounted for 67 percent of total IWVWD water use.[2]

Searles Valley Minerals

Searles Valley Minerals (SVM) pumps groundwater from wells in the eastern part of Ridgecrest and exports the water to Searles Valley for municipal and industrial uses. Production is metered and routinely compiled by IWVWD. Annual groundwater pumping averaged 2,570 AFY during 2008-2012 and has varied by only +/- 9 percent since 1985.

Private Domestic

A new estimate of private domestic groundwater use was developed for this analysis because prior estimates were not sufficiently documented to evaluate their accuracy. Google Earth air photo imagery and a digital parcel map obtained from Kern County were used in GIS (Geographic Information Systems) to locate all parcels outside the IWVWD, NSWS and Inyokern CSD service areas that contained at least one structure that appeared to be a residence. A total of 1,235 developed residential parcels were identified (locations shown on Figure 10). All of these were assumed to be served by on-site domestic wells. In addition, numerous homes in the western part of Ridgecrest and China Lake Acres reportedly have wells that pre-dated annexation to the IWVWD service area and that are still in use, at least for irrigation. The maximum number of such residences was estimated by counting all existing residences on parcels greater than 2.25 acres in size located west of Mahan Road. There were 353 parcels that fit this description, bringing the total number of residences supplied by on-site wells to as much as 1,588.

Based on field reconnaissance and inspection of aerial imagery, average per-residence water use on parcels with private domestic wells is probably similar to average water use per single-family home in Ridgecrest, which was 0.528 AFY (IWVWD, 2011). Swimming pools and lawns are both noticeably more common in town than in outlying areas. However, IWVWD customers pay more for each additional unit of water than well owners, and they are the focus of IWVWD's water conservation program. In contrast, rural residential parcels appear to have more tree canopy area per house on average than homes in town. About 50 homes in the area between Mahan Road and Jacks Ranch Road have exceptionally large amounts of vegetation, but those are offset by numerous rural residences that have almost none. Also, the trees and shrubs at rural residences are almost always drought-tolerant varieties such as mesquite, eucalyptus, pine and oleander. In light of these counterbalancing considerations, an assumption of equal water use by urban and rural single-family homes appears reasonable.

Multiplying the per-residence water use factor by the number of parcels with domestic wells obtains an estimated 838 AFY of private domestic groundwater use. A small water system and possibly some small parcels in China Lake Acres also reportedly use wells, which could push the estimate closer to 900 AFY. On the other hand, many of the large-lot residences within the IWVWD service area might not have wells, and some might use wells only for irrigation, which would shift the estimate of private domestic pumping down toward 800 AFY.

The estimate of private well pumping in the IWVWD database is much larger: 2,800 AFY. However, that number includes some agricultural pumping. A groundwater study in 2003 determined that only 1,730 AFY of the total was rural residential use (Tetra Tech EM, Inc., 2003). The estimate of private well

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[2] These calculations exclude park irrigation by City of Ridgecrest wells. The indoor/outdoor proportions were calculated at the customer's point of use by adjusting well production for estimated water pipe leaks and adjusting WWTP inflow for estimated sewer pipe leaks.

pumping was reportedly developed by spectral analysis of color-infrared aerial photography that measured the area of irrigated vegetation. The photos were taken in the late 1980s, and the number of residences was not reported. All irrigated areas were assigned a water use factor equivalent to that of alfalfa, including rural residential landscaping. That methodology produced an estimate that was probably too high by about one-third (Decker, 2013). A reasonable adjustment of the previous estimate might thus be more like 1,150 AFY.

Even with downward adjustments, the IWVWD estimate and the one developed for this study still differ, but the difference is quite small in the context of the overall basin water balance. Accordingly, averaging the two estimates to 1,000 AFY is reasonable for the purposes of this study.

Agricultural

Agricultural water use has been changing rapidly in the past two years, and independent estimates of current and future agricultural water use were developed for this study so that planning can be based on a clear and consistent set of data, assumptions and methods. The amount of irrigation water applied to a crop equals the crop area (in acres) multiplied by its annual irrigation demand (in feet per year). Net agricultural water use is the amount of applied water minus deep percolation beneath the root zone, which in most locations returns to the principal aquifer and which was assumed to be a fixed percentage of applied water. Each of these factors is explored in detail below.

A map of irrigated cropland as of 2013 was compiled through a combination of air photo inspection (Google Earth imagery dated May 2013) and on-the-ground site inspections. This resulted in the map of currently irrigated cropland shown in **Figure 13**. The only two crops grown commercially in the valley are alfalfa and pistachios. Cropland under cultivation prior to 2011 is indicated with different colors, to emphasize the large increase that has occurred since then. Since 2010, alfalfa acreage has increased from 870 to 990 acres, and pistachio plantings have increased from 300 to 2,500 acres. All of the new alfalfa and most of the new pistachio plantings have been in the Brown Road area north of Highway 395 and Inyokern. Crop area was measured in GIS and corresponds to the actual planted area, not the gross parcel area.

Alfalfa fields are irrigated by center-pivot overhead sprinkler systems. When alfalfa farming commenced in the 1960s, 10-11 feet of water were customarily applied per year. That amount was gradually reduced to about 7 ft/yr by the early 2000s by switching sprinkler heads and pressures and by managing irrigation more carefully (Mead, 2013). The reduced amount was reportedly sufficient to prevent salt buildup in the soil and therefore must have included a leaching fraction (deep percolation beneath the root zone). The amount of water use reported by the two current alfalfa growers was about 10,800 AFY in 2011 and 2012, which corresponds to 10.9 ft/yr of applied water on the current alfalfa acreage. A study of alfalfa irrigation requirements in other arid California locations (Shafter and Brawley) found that average annual crop ET was about 7 ft/yr (Hansen and others, 2008). Allowing for an irrigation inefficiency of 20 percent (10 percent spray evaporation and 10 percent deep percolation), the irrigation requirement would be 8.8 ft/yr. Thus, estimates of applied water range from 7 to 11 feet. A value of 8 feet is used for the water balance and overdraft calculations in this report, recognizing that it might be slightly low. Application of this irrigation rate to the alfalfa acreage in 2013 provides an estimated use of 7,900 AFY of groundwater for alfalfa irrigation.

Recycled water from the City of Ridgecrest wastewater treatment plant is used to irrigate approximately 30 acres of alfalfa at a former WWTP site in eastern Ridgecrest. An average of 220 AFY is used for that purpose. Because the source of water is recycled water, this use is not included in the tabulation of groundwater demand.

Pistachio trees take about 12 years to reach maturity, and the per-acre irrigation requirement parallels the growth of the trees. Water is delivered by drip irrigation, initially with one emitter per seedling and with additional lines and emitters introduced as the trees grow. According to one grower new to the area, annual irrigation starts at around 0.25 ft/yr (averaged over the full area of the orchard) and is expected to reach 4 ft/yr when the trees reach full size (Stiefvater, 2013). A University of California study of pistachio irrigation under drought conditions measured 4.4 ft/yr of crop ET during the mid-April to mid-November growing season, after adjusting by the ratio of reference ET in Barstow to reference ET in the San Joaquin Valley study area (Goldhamer, 2005). Assuming a minimum 10 percent leaching requirement, the crop ET estimate translates to 4.9 ft/yr of applied water. Irrigation requirements in the Brown Road area could be higher than this due to the reportedly windy conditions, which would increase reference ET above the amount measured in Barstow (Mead, 2013; Decker 2013). In addition, the trees may need some winter irrigation to prevent root desiccation in the desert environment. Another local grower who has farmed pistachios for many years reported a use of 750 AFY on a 125-acre orchard of mature trees, which equals an annual application rate of 6 ft/yr (Quist, 2012). The three estimates of irrigation rate for mature pistachios range from 4 to 6 ft/yr. An average value of 5 ft/yr is used in this study for quantifying overdraft and the basin water balance. Multiplying the 5 ft/yr and 0.25 ft/yr irrigation rates by the areas of mature and young trees, respectively, obtains an estimated 2,050 AFY of groundwater used for pistachio irrigation in 2013 (Table 1).

Environmental

The most well-known environmental water use in Indian Wells Valley—for the tui chub—does not draw directly on groundwater from the principal aquifer and accordingly is not shown as a groundwater demand (Table 1). The environmental use is supported entirely by WWTP pond percolation and irrigation return flow on NAWS. Those sources of recharge flow a short distance through the shallow aquifer and emerge at the land surface to create Lark Seep, which discharges into a series of channels and wetlands in the direction of China Lake playa. Lark Seep and a short channel that feeds into it support a healthy population of tui chub, an endangered fish species. The tui chub, an endangered species, currently is dependent on wastewater disposal from the City of Ridgecrest and NAWS, and thus depends indirectly on groundwater pumping.

Annual evapotranspiration from open water and cattail marsh at Lark Seep has been estimated to equal 390 AFY (Bilhorn and Feldmeth, 1991). An additional 420 AFY evaporates from downstream areas, but those areas support few fish. These two evaporative losses combined approximately equal the amount of WWTP pond percolation (estimated to equal 630 AFY in 2010) and irrigation deep percolation at the golf course (75 AFY). This suggests that the local sources of percolation do not support phreatophytic plants farther north toward the China Lake playa.

China Lake playa was historically ringed by various types of phreatophytic vegetation supported by shallow groundwater near the playa discharge area. Kunkel and Chase (1969) measured over 12,000 acres of sparse saltgrass and pickleweed growth around the perimeter of China Lake playa on aerial photographs taken in 1953. The vegetated area presumably decreased since then as groundwater pumping has intercepted increasing amounts of groundwater that otherwise would have discharged at the playa.

3.3 Future Water Demand

All sectors of water use in Indian Wells Valley are difficult to forecast because they hinge on uncertain economic factors, including defense research spending, agricultural and mineral commodity prices, and potential new industries such as solar energy. The only water demand certain to increase over the next few years is the irrigation demand for recently-planted pistachio orchards, which will increase from 0.25 ft/yr of applied water (on a gross acre basis) to approximately 5 ft/yr as the trees mature over the next 12 years. Estimated water demand in 2025 is described below for each user category, along with a discussion of uncertainty in the estimate. A map of projected groundwater pumping locations and amounts is shown in **Figure 14**. It assumes the same well locations and crop acreage as the map for 2013 (Figure 11) but increases the pumping amounts to reflect projected increases in water use.

China Lake NAWS

NAWS recently prepared an Environmental Impact Statement for renewal of its land withdrawal, which is the formal process in which the Department of Defense "borrows" land from the U.S. Bureau of Land Management (U.S. Department of the Navy, 2012). This document provides the most current forecast of Navy activities and population on the base. It projected a 25 percent increase in the number of test events at NAWS, but without any appreciable increase in military staff or civilian contractors. This apparent paradox reflects current trends toward improved labor utilization (longer work shifts; improved scheduling) and increased automation of fabrication, deployment, data collection and data analysis (Boggs, pers. comm., 2013). Although activities and employment at NAWS can change unexpectedly due to world events and Congressional budget priorities, a reasonable estimate is that NAWS water use in 2025 will be the same as it is in 2013. It assumes no further expansion of irrigated cropland.

Municipal

The population of Ridgecrest has historically been closely tied to the number of jobs at NAWS. It decreased by 10 percent from 1990 to 2000, but increased 6 percent from 2000 to 2007 (Matrix Design Group, 2008). Future population growth scenarios in the general plan update range from 1 to 3 percent per year. Given the flat projected trend for NAWS employment, a reasonable estimate is 1 percent annual growth.

Municipal water use will probably increase more slowly than population because of the ongoing trend toward lower per-capita water use. During 1998-2010, per-capita water use decreased by an average of 0.84 percent per year. Combining the population and per-capita water use trends provides an estimate of 0.2 percent annual growth in water use. Estimated water use in 2025 is 8,240 AFY, which is 2.6 percent greater than water use in 2012. Irrigation of parks by the City of Ridgecrest is assumed to remain unchanged.

Searles Valley Minerals

Although output and employment at SVM's mineral processing facilities in Searles Valley is affected by commodity prices for those minerals, there is no reliable forecast for those prices. Given that SVM groundwater production has been quite steady in recent decades, it is reasonable to assume that production will remain at current levels over the next 12 years.

Private Domestic

For water supply planning purposes, rural population is assumed to grow at the same rate as the Ridgecrest population (1 percent per year), but with no decrease in per-capita water consumption. The resulting estimate of private domestic groundwater use in 2025 is 1,100 AFY.

Agricultural

Estimates of future agricultural water use cover a vast range, depending on the number of new acres assumed to come under cultivation. The recent surge in irrigation use associated with new pistachio plantings justifies a reevaluation of any previous assumptions about agricultural expansion. The surge may be continuing, as evidenced by a recent land swap in which the company that has planted almost all of the new pistachio orchards obtained the 434-acre Neal Ranch property on Brown Road (Ridgecrest Daily Independent, October 19, 2013).

A new map of potentially irrigated lands was developed by overlaying maps of parcels, zoning, land ownership and currently-irrigated fields in a geographic information system. The groundwater basin includes 125,000 acres of land in agricultural zoning categories (A, A-1, A-1 MH, etc.). The following lands were subtracted from that area:

- Parcels owned by public agencies
- Fields that are already irrigated
- Parcels 5 acres or smaller in size with an existing residence, which are unlikely to be commercially farmed.

The result was 25,500 acres of potentially irrigated land, which is shown in **Figure 15**. Most of the acreage is between Highway 14 and the west boundary of NAWS, from the Inyo County line to south of Inyokern. However, isolated parcels of various sizes are present in the El Paso subarea and south of Ridgecrest and China Lake Acres.

Local growers suggested that the map probably overstates the potential expansion of irrigated lands for the following reasons (Stiefvater, 2013; Mead, 2013):

- Remote, isolated parcels in the El Paso subarea are not served by roads or electricity.
- A substantial amount of the potentially irrigated area is in small parcels, which would have to be consolidated to create blocks large enough to farm efficiently.
- Known limitations on groundwater availability are a disincentive to new farming operations.
- Growing conditions in this desert basin are considerably different from conditions in California's primary agricultural areas, which poses a risk to farmers relocating from those areas to Indian Wells Valley.
- Given the above impediments, it could be difficult for growers from other regions to obtain financing to start new operations in Indian Wells Valley.

However, the San Joaquin Valley farming operation that planted the recent pistachio orchards did so in spite of the above obstacles. In addition, the uncertainties faced by future newcomers will be reduced by the efforts of this pioneering firm. Lastly, current pistachio orchards include parcels as small as 10 acres in size, and a few are quite remote from other orchards.

If all of the potentially irrigated land were planted with pistachios, the irrigation demand when the trees reach maturity would be 130,000 AFY, or more than five times greater than the amount of groundwater pumping for all uses in 2013 (Table 1). The magnitude of this potential increase in agricultural pumping is shown in the context of historical pumping in **Figure 16**. The figure assumes that pistachios continue to be planted at the 2011-2013 rate until all 25,500 acres of potentially irrigated cropland are under cultivation, which occurs in 2033 in this scenario. Municipal, domestic and SVM pumping are projected using the growth rates discussed above. If the potentially irrigated cropland were planted to alfalfa, groundwater pumping would increase by a factor of eight. Even a relatively small increase in irrigated area can substantially increase basin-wide pumping and overdraft. For example, when the 2,200 acres of pistachios planted over the past two years reach maturity, their water demand will represent a 50 percent increase compared to total groundwater pumping in 2010.

The effects of future increases in agricultural pumping on groundwater levels were simulated using the regional groundwater flow model developed by Brown and Caldwell (2009). The analysis was concurrent with but independent of this Water Availability and Conservation Report. The existing groundwater model was updated with historical pumping data for 2007-2012 but apparently not recalibrated. Two scenarios of future agricultural expansion were simulated from 2012 through 2057 and compared with a baseline scenario that had no expansion (Brown and Caldwell, 2013). In the first scenario, agricultural expansion was limited to the 3,000 acres of new pistachios that had already been planted between 2010 and 2013. The scenario assumed an annual irrigation rate of 4.5 ft/yr, of which 20 percent was assumed to percolate back to the water table. At the end of the simulation, water levels in the north Brown Road area were 50-60 feet lower than without the pistachio irrigation. The second scenario assumed that all of the remaining undeveloped agricultural parcels in Indian Wells Valley (22,000 acres) were also planted with pistachios in 2012. Simulated water levels in 2057 under that scenario were 200-300 feet lower than under the no-agricultural-expansion scenario, with the maximum decrease located west of Inyokern.

Although a technical review of the model was not completed for this study, the results are a reasonable estimate of the range of water-level declines that could be expected with agricultural expansion. At the upper end of the range, many domestic wells would certainly go dry and saltwater would displace fresh groundwater throughout broad areas in the southwestern part of the basin. Land subsidence of several feet would be very likely.

Environmental

Preliminary plans to enhance and consolidate tui chub habitat in the Lark Seep area are under development (Campbell, 2013). Tui chub prefer deep open channels, which also resist encroachment by cattails. The existing narrow, shallow channels require frequent cattail removal, which is expensive and disruptive to the fish. The G-1 channel and seep downstream of Lark Seep would no longer be maintained or considered tui chub habitat. The reconfiguration of the habitat areas would probably not alter total consumptive use of percolation from the WWTP ponds and golf course.

3.4 Major Findings

- Current total groundwater production is about 25 times greater than it was prior to 1940.
- Current groundwater use categories include military (China Lake NAWS), municipal, Searles Valley Minerals, private domestic, and agricultural.
- Municipal and agricultural uses currently are the two largest uses and are similar in magnitude (36-40 percent of total groundwater pumping).
- The tui chub, an endangered species, currently is dependent on wastewater disposal from the City of Ridgecrest and NAWS, and thus depends indirectly on groundwater pumping.
- Military and Searles Valley Minerals pumping is estimated to remain steady into the future, while municipal and domestic pumping increase slowly.
- Agricultural water demand will increase as newly planted trees mature; in addition, new acreage may be planted, representing a potential substantial increase in pumping.

4. Institutional and Planning Framework

This section describes the institutional framework for land use planning and water resource planning. In brief, land use planning is provided by an array of agencies—from federal to local—with objectives, policies, plans, and programs that are generally supportive of long-term sustainable water supply for Indian Wells Valley. Water resource planning similarly is provided by overlapping County and local agencies with different objectives, authorities, powers, and jurisdictions. Water management—including conduct of investigations, monitoring and reporting, water conservation, and some pumping management—has occurred through non-binding plans with voluntary financial contributions.

4.1 Land Use Planning

Land use planning in the Kern County portion of Indian Wells Valley is provided by the federal government through the Bureau of Land Management (BLM) and China Lake Naval Air Weapons Station (NAWS), by the County of Kern, and by the City of Ridgecrest in their respective jurisdictions. A portion of Indian Wells Valley groundwater basin also extends into Inyo and San Bernardino counties. Given the potential for collaborative water management with Inyo County (for example, through the Inyo-Mono Integrated Regional Water Management Plan), Inyo County land use planning also is presented.

Bureau of Land Management

The US Department of Interior Bureau of Land Management is responsible for land use planning for extensive Federal public lands. BLM prepares Resource Management Plans (RMPs) as the basis for all actions and approved uses of the public lands. The Indian Wells Valley is in the California Desert Conservation Area (CDCA), which encompasses much of Southern California. The CDCA Plan (BLM, 1980) establishes goals for protection and for use, designates multiple use classes, and establishes a framework for managing resources within the classes. The multiple use classes are wilderness, limited use, moderate use, and intensive use. Most of the BLM land in Indian Wells Valley is open space managed for natural and economic resources, including mineral resources, rights-of-way for powerlines and pipelines, and some livestock grazing (although much land has been retired from grazing). BLM land use planning is conducted in collaboration with local, state, and tribal governments; the public; industry and user groups. For example, BLM may exchange federal land for private land when it results in improved compatibility with existing and proposed uses and plans.

China Lake Naval Air Weapons Station

China Lake NAWS is one of several lands withdrawn from the Bureau of Land Management (BLM) for military use, most recently under the 1994 California Desert Protection Act (CDPA). Renewal of this land withdrawal (anticipated by October 2014) currently is underway, including plans for increased testing and training with environmental review of proposed activities. The renewal also involves update of the May 2005 Comprehensive Land Use Management Plan (CLUMP), the long-term, strategic plan for land use planning and management at NAWS China Lake. The CLUMP provides an integrated framework for the management of military operations, public health and safety process, and environmental resource conservation and management programs (NAWS China Lake and BLM, 2005).

With regard to environmental management, CLUMP Goal No. 3 is to ensure compliance with statutes and regulations to protect and conserve sensitive natural and cultural resources, to maintain environmental quality, and to exercise responsible stewardship of Navy administered lands.

Objective 3-4 is to continue the management of groundwater resources through the implementation of the goals and guidelines in the IWV Cooperative Groundwater Management Plan (discussed later) to ensure the availability of high-quality potable water to meet NAWS' long-term needs.

Consistent with the above is Goal No. 5 to maintain and enhance coordination and cooperation with neighboring communities, agencies, and organizations, and Objective 5-1, to continue to coordinate land-management initiatives with off-Station land-management agencies to ensure compatible land use development on adjacent lands.

The land withdrawal renewal entails Navy administration of China Lake NAWS for an additional 25 years. This includes some planned increases in testing and training; environmental assessment of the proposed activities is currently underway. The draft Environmental Impact Statement/Legislative Impact Statement (EIS/LEIS), published in July 2013, indicates no significant impacts on groundwater resources (Dept. of the Navy, 2013).

Kern County General Plan

The Kern County General Plan is a policy document that guides the growth, development, and resource management for the unincorporated areas under County jurisdiction. It is prepared, administered, and updated by the Kern County Planning and Community Development Department, which also implements programs to effect its goals and policies (Kern County Planning and Community Development, 2009). The General Plan addresses seven elements (Circulation, Noise, Safety, Energy, Kern River, Housing, and Land Use, Open Space, and Conservation); of these, the Land Use, Open Space, and Conservation Element is most relevant to water supply issues. This element addresses the following: public facilities and services, residential, commercial, industrial, and resource (e.g., agriculture and mining) land uses. Water-related policies are dispersed throughout the General Plan.

Summarized below are the specific planning areas in Indian Wells Valley, water supply-related issues, goals, policies, and implementation measures.

Planning Areas

Most of the groundwater basin in Kern County is addressed in the Ridgecrest Priority Area Map, except the southwestern portion. This southwest area is predominantly land under the jurisdiction of State and Federal agencies, but includes small areas of agriculture, residential, and service industrial land uses along Highway 14.

The Ridgecrest Priority Area includes the Inyokern Specific Plan area, South Inyokern Specific Plan area, and Ridgecrest Ranchos Specific Plan area. Also encompassed in the Priority Area is land under the respective jurisdictions of the City of Ridgecrest, and Federal agencies, including BLM and China Lake Naval Air Weapons Station.

Water Supply Availability Issues

With regard to Public Facilities and Services (including water supply systems), the Land Use, Open Space, and Conservation Element states that the economical and efficient delivery of public services is one of the main purposes and benefits of effective land use planning. This is an important theme guiding water-related planning throughout the General Plan.

Another important theme concerns agriculture. The Resource section of the Land Use, Open Space, and Conservation Element states that:

- Agriculture has been, and will continue to be, vital to the economy of Kern County. The development of major water projects has greatly increased the amount of land in agricultural production during the last two decades.
- Conflicts over the use of agricultural land frequently occur. As is the case for other urbanizing regions, the loss of valuable agricultural lands to urban development is a prime concern.
- Land division, even where actual development does not take place, can also adversely affect the County's agricultural resource base. This is particularly a problem in extensive agriculture areas, such as rangeland, where land values can be significantly increased beyond values based on agricultural productivity.

The two themes combine in the first bullet, which refers to development of major water projects to increase agriculture. The statements on conflicts between agriculture and urban land uses clearly are applicable to the San Joaquin Valley portions of Kern County. In contrast, the local Indian Wells Valley economy has focused historically on China Lake Naval Air Weapons Station and the City of Ridgecrest in the eastern portions of the valley, while agriculture has been located primarily in the northwest. Conflicts over the use of agricultural land have not focused on loss of agricultural land to urban uses; instead, conflict is focusing on expansion of agricultural land and competition for groundwater supply.

Water Supply Availability Goals

The Land Use, Open Space, and Conservation Element provides for a variety of land uses for future economic growth while also assuring the conservation of the County's agricultural, natural, and resource attributes. Relevant goals are summarized below:

- Residents and business should receive adequate and cost effective public services and facilities.
- Promote an urban growth pattern in areas where adequate public service infrastructure exists or can be provided.
- Distribute the cost of new services or facilities equitably among the beneficiaries.
- Ensure that adequate supplies of quality (appropriate for intended use) water are available to residential, industrial, and agricultural users.
- Discourage scattered urban density development that is not supported by adequate infrastructure.
- Promote the conservation of water quantity and quality in Kern County.
- Ensure that adequate infrastructure and public services are available for all proposed commercial projects.

Inyo County General Plan

With regard to land use planning in Inyo County, the Federal government owns 92 percent of all land in Inyo County, while the State of California and City of Los Angeles own another 6 percent. This general pattern holds for the portions of the county overlying Indian Wells Valley groundwater basin. Most of the basin is federal land (NAWS China Lake) with residential, industrial, and natural resources (i.e., open space) lands clustered along Highway 395 in Pearsonville.

The County is working on updating the General Plan from 2001; the Draft General Plan and elements are available online (Inyo County Planning Dept., 2013). The Draft Conservation/Open Space Element is organized into discrete sections focused on key topics; one of these is agriculture. Goal AG-1 is to provide and maintain a viable and diverse agricultural industry in Inyo County. Related policies include (among others) to support and encourage continued agricultural production activities, discourage conversion of productive agricultural lands for urban development, and support the continued use and expansion of public lands for agricultural operations. Policy AG-1.8, Sustainable Agriculture, promotes sustainable agricultural activities to lessen environmental impacts, including encouragement of reclaimed water use and efficiency with irrigation water in order to conserve potable water.

The Draft Conservation/Open Space Element also has a specific section on water resources, with three goals (and supporting policies) that are relevant to Indian Wells Valley water availability and conservation:

Goal WR-1 Provide an adequate and high quality water supply to all users within the County

- Policy WR-1.1 Water Provisions - Review development proposals to ensure adequate water is available to accommodate projected growth, and that water resources are used with conservation and efficiency in mind.
- Policy WR-1.2 Domestic Groundwater - Support sustainable groundwater extraction for domestic use in rural areas
- Policy WR-1.3 Water Reclamation - Encourage the use of reclaimed wastewater, where feasible, to augment groundwater supplies and to conserve potable water for domestic purposes
- Policy WR-1.6 Water for Agriculture - Support existing and expanded sources of water for use in agriculture.

Goal WR-2 Protect and preserve water resources for the maintenance, enhancement, and restoration of environmental resources

- Policy WR-2.1 Restoration - Encourage and support the restoration of degraded water surface and groundwater resources.

Goal WR-3 Protect and restore environmental resources from the effects of export and withdrawal of water resources

- Policy WR-3.2 Sustainable Groundwater Withdrawal - The County shall manage the groundwater resources within the County through ordinances, project approvals and agreements, ensure an adequate, safe and economically viable groundwater supply for existing and future development within the County, protect existing groundwater users, maintain and enhance the natural environment, protect the overall economy of the County, and protect groundwater and surface water quality and quantity.

A relevant implementation measure states that Inyo County shall review any new development proposals that involve a withdrawal of groundwater that is not regulated by the County's Groundwater Ordinance (Ordinance 1004) or the Inyo County/Los Angeles Water Agreement. The purpose of this review is to ensure that with the proposed use, there will be an adequate, safe and economically viable supply of groundwater to supply all existing users of the groundwater as well as the future users under the proposed development.

City of Ridgecrest General Plan

The City of Ridgecrest has direct land use jurisdiction over about 21 square miles in the incorporated city limits, excepting about nine square miles within NAWS China Lake. Although within the City limits, that area is managed by the Navy. The overall Planning Area for the City, covering about 40 square miles, also includes land outside its boundary that bears relation to its planning. This Planning Area includes lands held by NAWS China Lake and by BLM. The General Plan includes elements on Land Use, Community Design, Circulation, Open Space and Conservation, Health and Safety, and Military

Sustainability. The last element reflects the City's objective to achieve growth while protecting the military missions of China Lake.

Evaluation of land use within the City (excluding Federal lands), indicates that about 50 percent of land in the Planning Area was vacant as of 2007. Analysis of undeveloped land indicated substantial potential for single family residential land use. Population in the community is strongly linked to employment changes at NAWS China Lake.

The Open Space and Conservation Element recognizes the finite limits of natural resources and presents policies and measures for development, utilization and conservation. Goal OSC-4 encourages energy and water conservation, and Policy OSC-4.2, Water Conservation Programs, states that the City shall develop programs to encourage water conservation in conjunction with IWVWD and other agencies.

Goal OSC-6, Groundwater and Water Resources, is to ensure that a supply of acceptable quality water is available to meet the present and future needs of the City and Indian Wells Valley. This goal is supported by sixteen specific water-related policies, summarized briefly below:

- Reduction of impervious surface and runoff
- Prevention of groundwater contamination
- Establishment of population limits to reflect the sustainable yield of groundwater
- Investigation of water recycling for industrial use, landscape irrigation, or recharge
- Discouragement of water intensive landscaping or crops
- Encouragement of water conservation city-wide
- Investigation and implementation of water conservation for municipal buildings
- Investigation and correction of unnecessary water losses
- Encouragement of water efficient practices for City landscaping
- Encouragement of recycled or grey water use for landscaping
- Support for the Urban Water Management Plan
- Support for investigation of the groundwater basin
- Support IWVWD and NAWS research into alternative sources of water
- Support IWVWD, NAWS and other purveyors in development of sound pumping patterns
- Support IWVWD in a valley wide water policy to control water export
- Identify potential recharge areas as open space to aid groundwater recharge

For implementation, the City shall:

- Investigate the establishment of a land trust for open space lands and consider opportunities for acquiring natural habitat and agricultural areas for permanent open space and natural parks
- Develop and periodically update a groundwater management plan to protect local aquifers in cooperation with local water districts
- Develop and administer a long-term water quantity carrying capacity model for the Indian Wells Valley
- Participate in regional water resource planning
- Participate in developing a comprehensive groundwater recharge program
- Participate in groundwater monitoring partnerships with local groundwater users and stakeholders.

4.2 Water Resource Planning and Management

Water resource planning and management occurs at federal, state and local levels. The California Department of Water Resources' California Groundwater (DWR, 2003) and the Groundwater Resources Association's California Groundwater Management (Bachman, 2005) provide comprehensive descriptions of federal and state agencies and their respective roles. For the sake of brevity and focus, this section summarizes local agencies and their roles. The Indian Wells Valley groundwater basin extends across portions of Kern, Inyo and San Bernardino counties; accordingly, each of the county groundwater management ordinances was examined. This section also summarizes the respective authority, role and activities of the primary water management agencies: Kern County Water Agency and Indian Wells Valley Water District. Two major water resource management plans are discussed: the Indian Wells Valley Cooperative Groundwater Management Plan and the Inyo-Mono Integrated Regional Water Management Plan.

Kern, Inyo and San Bernardino Counties

Counties (and cities) can undertake groundwater management pursuant to their police powers in order to promote the health, safety and welfare of their citizens (Bachman, 2005). At least 27 counties have adopted groundwater ordinances, typically to limit out-of-county exports, including Kern County and Inyo County (DWR, 2003). San Bernardino County has a Desert Groundwater Management Ordinance.

Kern County Ordinance No. G-6502 (adopted by the Board of Supervisors on May 12, 1998) applies only to transfers of native groundwater from or taking place in the unincorporated areas of the county within the southeastern drainage of the Sierra Nevada and Tehachapi mountain ranges; this area includes Indian Wells Valley. The ordinance also pertains only to "native groundwater," which does not include water that is originated outside Kern County and recharged artificially (or banked) in the county. With some exemptions[3], the ordinance requires a conditional use permit prior to any such water transfer. Approval of such a conditional use permit is predicated on documented findings and a site specific Environmental Impact Report for compliance with the California Environmental Quality Act (CEQA). The findings must show that the transfer will not unreasonably affect the economy or environment; this includes causing overdraft. The ordinance also includes extensive notification requirements for all parcels in the basin for native water extraction, documentation of amount of water in basin area, monitoring e and reporting requirements, provides for modification and revocation of the permit, and a civil penalty for violations. No Conditional Use Permits for native water exportation have been processed or approved.

The Inyo County Board of Supervisors adopted Resolution No. 1004 in 1998. The resolution governs sales and transfers of groundwater from one groundwater basin to another groundwater basin or to outside of the County. While sales and transfers to Los Angeles by another party are included, Los Angeles Department of Water and Power operations are exempt. The Inyo County resolution requires a conditional use permit that is evaluated by the Inyo County Water Department and Water Commission, and submitted to the Planning Commission for approval.

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[3] One exemption is for historical use likely applicable to Searles Valley Minerals Corporation's use of Indian Wells Valley groundwater in San Bernardino County: "the transport or transfer of water to the extent of the highest historical average annual quantity prior to December 15, 1997, by means of substantially similar transport facilities as established by claim of exemption determination and to the extent the transfer is to substantially the same areas as was done historically."

The San Bernardino County's Desert Groundwater Management Ordinance 3872 (passed in 2002) focuses on protection of groundwater resources in desert groundwater basins within a certain geographic area, specifically un-adjudicated basins or those without a suitable groundwater management plan. The ordinance does not apply to Indian Wells Valley, which is outside the geographic area; nonetheless, the ordinance is an example of a potential management measure. The ordinance requires a permit for a new production well. Exemptions are provided; for example, for wells in specific jurisdictions, wells for mining operations with mining reclamation plans, replacement wells, onsite wells for agricultural operations of a defined size, and small non-agricultural wells. Documentation of the well must be provided along with description of the aquifer and groundwater quality, and estimation of natural recharge. Permit approval is based on a finding that the well operation will not result in overdraft.

Kern County Water Agency

The Kern County Water Agency (KCWA) was created in 1961 by a special act of the California State Legislature. The primary purpose for creating the Agency was the establishment of a single entity in Kern County to negotiate and administer a water supply contract with the State of California for its State Water Project (SWP) supply (KCWA, 2012). Nonetheless, KCWA's jurisdiction encompasses the entire county and it has general powers to acquire water supplies, construct facilities (such as distribution systems) and enter into activities such as flood control, drainage, and generation of hydroelectric energy (DWR, 1963). Its authority and powers for groundwater management have been expanded by the State Legislature and currently KCWA participates in a broad scope of water management activities, including serving as a wholesaler for SWP water, construction and operation of conveyance facilities, flood control, and groundwater operations including monitoring in San Joaquin Valley and Indian Wells Valley groundwater basins. KCWA also provides supplemental water to the Bakersfield area through Improvement District No. 4 (ID4).

While ID4 has no authority or activities in Indian Wells Valley, it represents a potential model for a water district that secures supplemental water supply. Improvement District No. 4 was formed by the KCWA Board of Directors to provide a supplemental water supply for the urban Bakersfield area through importation of SWP water (KCWA, 2012). Creation of ID4 was initiated in 1970 by the KCWA Board through adoption of Resolution No. 25-70, which outlined the need for such an improvement district. Subsequently, ID4 was formed and its boundaries established by Resolutions Nos. 16-71 and 17-71 adopted by the Board in December 1971 for the purpose of financing the construction of a water purification plant and related water conveyance facilities, including a portion of the Cross Valley Canal, the major conveyance from the SWP to KCWA. An election held within ID4 on September 12, 1972 authorized $17.5 million of general obligation bonds for construction of the treatment and conveyance facilities. Later in 1982, KCWA established a groundwater charge for all wells in ID4.

While KCWA has jurisdiction across the entire County, plus broad authority and powers for management of groundwater and development of supplemental water supply, it has not established an improvement district in Indian Wells Valley and to date has limited its role mostly to monitoring.

Indian Wells Valley Water District

Indian Wells Valley Water District (IWVWD) was organized in 1953 in accordance with the State of California County Water District Law (IWVWD, 2011). As described on their website (IWVWD, 2013), the District exists for the primary purpose of owning, operating, maintaining, constructing, and improving works for the acquisition, storage, transmission, distribution and sale of domestic water for public and private uses within the District (IWVWD, 2013). The District is empowered to manage water resources and to construct, operate, maintain, repair, and replace water system facilities as needed to provide water service in compliance with applicable standards and regulations. As the primary water provider of public water supply in the Ridgecrest area, IVWD has shouldered significant responsibility for managing the area's limited water resources (IWVWD, 2011). However, the District's jurisdiction is limited; the District's service area overlaps the City of Ridgecrest and includes several small noncontiguous areas, but encompasses only about 38 square miles in Indian Wells Valley.

The sole source of potable water supply to IWVWD is groundwater; no imported water or recycled water supply currently is available to IWVWD. IWVWD participates in several water resource planning and management activities including the Indian Wells Valley Cooperative Groundwater Management Group and its Groundwater Management Plan and the Inyo-Mono Integrated Regional Water Management Plan, which are summarized below. Two water management plans prepared by IWVWD are the Urban Water Management Plan and Water Supply Enhancement Plan.

Urban Water Management Plan

An Urban Water Management Plan (UWMP) is prepared every five years by an urban water purveyor to provide a comparison of historical, current, and future water supply and demand, and thereby promote sustainable water supply for current and planned land uses. Additional objectives are to reduce reliance on imported supplies and encourage local supplies, especially recycled water. Effective water demand management (i.e., water conservation) and readiness for water shortages also are important UWMP objectives. UWMPs are required by the State's Water Code for all urban water providers having 3,000 or more connections (as does IWVWD); non-compliance results in loss of eligibility for certain State funds. Moreover, the State's Water Conservation Act of 2009 established water conservation goals to be achieved; in the simplest form, these are a 20% reduction by 2020.

In brief, the 2010 UWMP documented a service area population of 31,120 in 2010 and projected an increase to 36,720 in 2035. The population projections were provided by the Kern Council of Governments (KCOG). IWVWD serves single-family residential, multi-family residential, and commercial/institutional connections; of these single-family homes account for the preponderance of water demand. Total water demand in 2010 (including system losses) was 7,570 acre-feet per year (AFY) and projected to increase to 8,685 AFY in 2035. The sole source for existing and projected water demand is groundwater.

The projections include planned water conservation. Consistent with the State's Water Conservation Act, the IWVWD 2010 UWMP documents current, baseline water demand on a per capita basis and defines water use targets to be achieved by 2020. The baseline water use is 264 gallons per capita per day (gpcpd) and the target is 214 gpcpd. The UWMP presents water conservation measures implemented and planned by IWVWD and the City of Ridgecrest, which participated in development of the UWMP. The City of Ridgecrest also has adopted a Water Efficient Landscaping Ordinance.

The UWMP acknowledges the long-term overdraft condition in the groundwater basin and describes IWVWD's efforts to eliminate overdraft as part of the Water Supply Enhancement Program. However, the UWMP itself is limited to the State-mandated minimum projection of 20 years out to 2035. Within this immediate period, the UWMP considers the groundwater supply to be reliable. In other words, given the arid climate and reliance on groundwater, the groundwater supply is not affected by drought.

Accordingly, the UWMP focuses on water shortages caused by natural disaster (e.g., earthquake) or equipment failure (e.g., power outage). The UWMP documents the measured taken to improve reliability, such as availability of backup pumps and interconnections with the NAWS and Searles Valley Mineral water systems. It also defines actions to be undertaken with different stages (ranging from Stage 1 voluntary reductions to Stage 3 and 4 mandatory rationing) and recommends that groundwater production capacity be increased to maintain a 20% redundancy factor.

Water Supply Enhancement General Plan

In 2007, IWVWD adopted the Water Supply Enhancement General Plan (WSEP) in response to chronically declining groundwater levels and the realization that groundwater demands had exceeded recharge. The goals of the WSEP are twofold:

- To further IWVWD's ongoing efforts to optimize the existing groundwater supply
- To evaluate the feasibility of obtaining or developing one or more supplemental supplies

Implementation was planned through various studies addressing:

1. Optimization of existing groundwater supply through water conservation
2. Development of supplemental water supplies potentially within the Indian Wells Valley and outside the valley
3. Site selection and source evaluation in analyzing supplemental supplies
4. Consideration of water characteristics, including quantity, quality and treatment requirements
5. Working with local communities
6. Institutional considerations such as regulatory approvals and permitting
7. Conveyance and storage requirements
8. Environmental considerations
9. Cost comparison and alternatives
10. Financing alternatives such as bonds, cash, grants and loans
11. Historic efforts such as participation in the Indian Wells Valley Cooperative Groundwater Management Group

Also in 2007, IWVWD proposed a Water Supply Improvement Project to increase IWVWD pumping capacity in order to provide increased system redundancy and provide for projected growth. The project involved Phase 1 improvements to existing wells and possible Phase 2 construction of a new well. However, the project was the subject of intense controversy. Phase 1 has not been funded.

Indian Wells Valley Cooperative Groundwater Management Plan

The major groundwater pumping organizations in Indian Wells Valley include IWVWD, NAWS China Lake, and Searles Valley Minerals, plus City of Ridgecrest and Inyokern Community Services District. In addition, there are numerous agricultural and domestic groundwater users. In 1995, the Indian Wells Valley Cooperative Groundwater Management Group was formed as a public water data-sharing group to coordinate efforts, share data, and avoid the redundancy of effort. Members are defined as:

- A government agency with offices and/or representatives in the Indian Wells Valley,
- An entity or company representing domestic water systems or users that pump a minimum of 250 acre-feet of water per year in the aggregate
- An agriculture interest that pumps a minimum of 250 acre-feet per year of water.

The Groundwater Management Group has a standing Technical Advisory Committee (TAC) established by the group's bylaws. Membership is limited to technical experts representing the signatory members. Currently the committee consists of representatives from the U. S. Navy, IWVWD, Kern County Water Agency, Searles Valley Minerals and BLM. The TAC coordinates a variety of activities including monitoring, dissemination of information, compliance with State regulations (e.g., CASGEM) and acquisition of funding (e.g., AB 303 grants). The TAC generally holds monthly working sessions that are not open to the public. The public forum is the Groundwater Management Group meeting, which is held monthly (agenda and meeting notes are posted online). Agency reports and TAC reports are regular agenda items at that meeting. Subcommittees are established as needed, for example to review goals and objectives, or to investigate issues such as groundwater sampling protocols.

In September 1995, the group (including IWVWD, NAWS China Lake, Searles Valley Minerals, City of Ridgecrest, Inyokern Community Services District, BLM, Kern County Water Agency, East Kern County Resources Conservation District, Indian Wells Valley Airport District, and Quist Farms) signed the Indian Wells Valley Cooperative Groundwater Management Plan. The Groundwater Management Plan, which remains in effect for six years, was revised and accepted again in March 2006 and in 2012. Kern County became a signatory in 2006 and Quist Farms resigned from the Plan in April 2013.

The Groundwater Management Plan is a brief document that acknowledges limited information on the local groundwater resources and expresses an interest in extending the usefulness of groundwater resources to meet current and foreseeable water needs in Indian Wells Valley. Purposes of the Plan are:

- Set forth guidelines and management principles for the production, distribution, and use of groundwater within the purview of the participants
- Further develop technical data and analytical capabilities to better understand the watershed and aquifer system
- Apply these guidelines toward sound conservation and management practices to extend the useful life of the groundwater resources
- Coordinate interested local agencies and water producers into a cooperative planning effort to develop objectives and share information and management practices to maintain the resource
- Develop and refine criteria for the selection, collection, sampling, and monitoring protocol of groundwater and groundwater production and/or monitoring wells

The Plan also defines seven Planning Objectives:

1. Limit additional large-scale pumping in areas that appear to be adversely impacted
2. Distribute new groundwater extraction within IWV in a manner that would minimize adverse effects to existing groundwater conditions (levels and quality), and maximize the long-term supply within IWV
3. Aggressively pursue the development and implementation of water conservation and education programs
4. Encourage the use of treated water, reclaimed water, recycled , gray and lower quality water where appropriate and economically feasible
5. Explore the potential for other types of water management programs that are beneficial to the Indian Wells Valley
6. Continue cooperate efforts to develop information and data which contributes to further defining and better understanding the groundwater resource
7. Develop an interagency management framework to implement objectives of the Plan

The IWV Cooperative Groundwater Management Group has been working actively in carrying out purposes of the Plan. The group meets monthly and maintains a website with background information on the Group, current agenda and discussion notes, conservation tips, reference documents, and data. The Planning Objectives are updated regularly with accomplishments noted and new tasks defined.

Nonetheless, a salient fact is that the Plan is voluntary and non-binding. Funding is through the donated in-kind services of the members or through grants. The management of groundwater to meet each producer's needs remains at the discretion of the individual water producer. Accordingly, the Plan does not provide the authority or funding mechanisms for major projects, such as development of supplemental supply.

Inyo-Mono Integrated Regional Water Management Plan (IRWMP)

Integrated regional water management is a collaborative effort to manage all aspects of water resources in a region. Initiated by the State Senate in 2002 and supported by voter-approved water bonds, IRWM plans and programs have been established over most of California, including the Inyo-Mono region, which includes Indian Wells Valley groundwater basin.

Indian Wells Valley Water District is signatory to the Memorandum of Understanding (MOU) governing the Inyo-Mono IRWM Plan. At time of adoption in December 2010, there were 26 signatory members including Inyo County, Mono County, BLM, water purveyors, tribes, and other local agencies and non-governmental agencies. The MOU was developed in order to form an IRWMP Group to (1) develop, implement and periodically update the Plan, and (2) coordinate planning and actions with connected Regions. The purpose is to provide stability and consistency in the planning, management, and coordination of water resources within the watershed of the Inyo-Mono Region. This includes identifying projects, establishing the priority of projects and seeking funds to implement water-related projects. As explained in the IRWMP, the MOU does not impose legally binding requirements on its Members and is not an enforceable contract or agreement. It is a statement of principles, including consensus-based decision making.

The Inyo-Mono IRWMP (Inyo-Mono Regional Water Management Group, 2011) provides a comprehensive regional description, including geography, hydrology, water quality, objectives and conflicts, plus climate change. The discussion addresses Indian Wells Valley groundwater and concerns about its sustainability. It also describes Indian Wells Valley projections of population growth and groundwater pumping.

The Inyo-Mono IRWMP defines six major objectives:

1. Protect, conserve, optimize, and/or augment water supply
2. Protect, restore, and/or enhance water quality
3. Provide stewardship of our natural resources
4. Maintain and enhance water, wastewater, and power generation infrastructure efficiency and reliability
5. Address climate variability and reduce greenhouse gas emissions
6. Increase participation of small and disadvantaged communities in IRWM process

It also provides management strategies or each objective. One management strategy relevant to Indian Wells Valley is Strategy 1.4 - Address local water supply issues through various techniques, including, but not limited to: groundwater recharge projects, conjunctive use of water supplies, water recycling, water conservation, water transfers, and precipitation enhancement.

The IRWMP also identifies and prioritizes projects for potential funding. In the first round of Proposition 84 Implementation funding, the Inyo-Mono Group submitted a suite of projects to be considered for funding; included was a Brackish Water Resource Study for Indian Wells Valley Water District that would have identified brackish sources for possible treatment and potable use. However, the study did not receive funding.

4.3 Major Findings

- Land use planning is provided by an array of agencies—from federal to local—with objectives, policies, plans, and programs that are supportive of long-term sustainable water supply for Indian Wells Valley.
- Two important themes in the Kern County General Plan are the economical, equitable and efficient delivery of public services, including water supply, and the importance of agriculture to the Kern County economy. These two themes intertwine in terms of development of major water projects to provide water for agriculture.
- Water resource planning is provided by overlapping County and local agencies with different objectives, authorities, powers, and jurisdictions.
- Kern, Inyo, and San Bernardino counties have groundwater ordinances; the Kern and Inyo ordinances limit out-of-county exports while the San Bernardino ordinance (applicable to limited areas) requires a permit for a new production well.
- While organized under different legislation, the Kern County Water Agency and Indian Wells Valley Water District each have authority and powers to provide water supply and manage groundwater.
- Water management—including conduct of investigations, monitoring and reporting, water conservation, and some pumping management—has occurred through collaborative but non-binding plans with voluntary financial contributions.

5. Water Resource Goals and Objectives

Goals and objectives are needed to guide any planning process. A goal is a general purpose, and objectives are specific and measurable actions directed toward attainment of the goal. For this Water Availability and Conservation Plan, definition of goals and objectives has been based on reviewing written goal statements and hearing the verbal statements of stakeholders at meetings and workshops.

5.1 Goals

A clear statement and mutual acceptance of a goal is fundamental. Review of various documents prepared by involved agencies reveals a fairly consistent primary goal. Four local examples, each distilled to its essence, are listed below without attribution to an agency:

- Ensure that adequate supplies of quality water are available to residential, industrial, and agricultural users.
- Ensure the availability of high-quality water to meet long-term needs
- Ensure that a supply of acceptable quality water is available to meet present and future needs
- Provide for self-sustaining water resources now and for generations to come.

These all communicate a goal of ensuring adequate water supplies with appropriate water quality. While each goal (as originally expressed by an agency) might refer specifically to its particular role in Indian Wells Valley, the sum of the goals encompasses provision of water supply for various beneficial uses, including residential, industrial, agricultural, and environmental. Two of the four goals specifically state an intention to ensure water supply for existing and future, long-term needs, one does not address time, and one refers to sustainability, which implies a groundwater balance in perpetuity. For the purposes of this Water Availability and Conservation Plan, the goal is restated below:

Ensure that adequate supplies of high-quality water are available
to meet present and future needs.

This restated goal affirms sustainability. For the purposes of this Water Availability and Conservation Plan, the goal includes provision of water supply over the long term, including cessation of overdraft.

5.2 Objectives

Numerous specific objectives have been identified by local agencies that are applicable to attainment of the above goal for the Water Availability and Conservation Plan. For the purposes of this Plan, the objectives can be grouped in terms of optimizing the existing groundwater supply, obtaining or developing one or more supplemental supplies, managing water demand (conservation), and developing an institutional framework for management. For this Plan, some similar or related objectives have been combined for brevity. The statement of some objectives has been strengthened for clarity; for example, objectives that apparently stop at research/investigation/identification are extended to actions.

Optimization of Existing Groundwater Supply

- Distribute groundwater pumping to minimize adverse effects (levels and quality) and maximize the long-term supply
- Reduce impervious surfaces and runoff, encourage recharge

- Prevent groundwater contamination
- Develop information that contributes to better understanding the groundwater resource
- Identify potential recharge areas and protect as open space to aid groundwater recharge

Development of Supplemental Supplies

- Encourage the use of recycled water, gray and lower quality water where appropriate, economically feasible and beneficial to the basin water balance
- Identify and evaluate alternative sources of water, and develop sources that are technically and economically feasible

Water Demand Management

- Develop and implement water conservation and education programs
- Establish population limits to reflect the sustainable yield of groundwater
- Discourage water intensive landscaping or crops and encourage water efficient practices
- Investigate and implement water conservation for municipal buildings
- Investigate and correct unnecessary water losses

Development of Institutional Framework

- Develop an interagency management framework to implement objectives of the Groundwater Management Plan

Objectives are intended to be measurable, so that progress toward the attainment of the goal can be assessed on a regular basis. The above objectives (plus others yet to be defined) should result collectively in provision of adequate, high-quality water supplies on a sustainable basis to meet present and future needs.

5.3 Major Findings

- Review of documents prepared by involved agencies reveals a common goal: Ensure that adequate supplies of high-quality water are available to meet present and future needs.
- Objectives to achieve that goal can be summarized in terms of: optimizing the existing groundwater supply, obtaining or developing one or more supplemental supplies, managing water demand (conservation), and developing an institutional framework for management.

6. Water Management Alternatives

Many physical, planning, and legal measures can help decrease overdraft in Indian Wells Valley. They vary in terms of uncertainty and logistical, institutional and financial feasibility. Some could address at most a small part of the imbalance between supply and demand, while others could theoretically solve the entire problem. Some of the options might be redundant if combined, but few are mutually exclusive.

6.1 Physical Measures

Expected consumptive use of groundwater in 2025—when existing pistachio orchards are all mature—equals total groundwater withdrawals of 34,500 AFY (Table 1) minus irrigation deep percolation of 2,600-3,100 AFY (Table A-2), or about 31,700 AFY. Safe yield of the groundwater basin is probably less than 7,000 AFY (Appendix A), resulting in an imbalance of about 25,000 AFY. Physical measures are necessary to address the existing imbalance between groundwater supply and demand. These measures need to increase supply or decrease demand until the existing imbalance of about 25,000 AFY has been offset.

This section describes a lengthy list of water management alternatives. They are described in most cases at a conceptual level sufficient to support preliminary discussions among land use and water planners and members of the community. Preliminary engineering design, feasibility and cost evaluations are beyond the scope of the present effort but would be the next step for alternatives carried forward for further consideration. For example, cost-effectiveness is certain to be an important factor in selecting preferred alternatives. In a few cases, reasonably accurate cost estimates were available from previous studies, but in most cases only a qualitative indication of relatively high, medium or low cost is provided.

Seven physical management measures are described below, including:

- Redistribution of Municipal Pumping
- Urban Water Conservation
- Agricultural Water Conservation
- Wastewater Recycling
- Groundwater Demineralization
- Water Importation
- Groundwater Banking

Others might be theoretically feasible, but the ones included here are considered plausible from the standpoint of technical and financial feasibility. An example of a water source not included is the Fremont Valley Preservation Project, which would bank and export groundwater from the Fremont Valley groundwater basin about 25 miles south of Indian Wells Valley. The project is in the process of design and permitting, and availability of water from that source is considered speculative.

Redistribution of Municipal Pumping

Description

New municipal wells would be installed so that groundwater pumping by IWVWD, NAWS and SVM would be distributed more uniformly throughout the low-TDS region in the southwestern part of the basin. This would have the potential benefits of intercepting any remaining Sierra Nevada mountain front recharge that is still lost to evaporation at China Lake playa and allow more complete mining of available low-TDS groundwater storage.

Examples

IWVWD is studying the possibility of installing new municipal wells along the southwest boundary of NAWS, where there presently is relatively low density of pumping stress (see Figure11).

Yield

This measure would not increase basin yield. It would delay some impacts of overdraft, but by an amount that cannot be estimated with any certainty.

Impacts and Mitigation

Any large well that pumps at hundreds or even thousands of gallons per minute substantially lowers groundwater levels in the vicinity of the well, creating a "cone of depression". This drawdown is highly localized but much larger than regional water-level declines. Consequently, domestic wells located near a new large well can suddenly experience much lower water levels and various associated operational problems, such as pumps breaking suction, well screen corrosion, or even complete loss of yield.

Drawdown decreases rapidly with distance from a well, but increases with pumping rate and duration. For example, simulated drawdown around existing and proposed IWVWD municipal wells southwest of Ridgecrest pumping at rates of 1,200-2,300 gpm was as much as 6 feet at distances of 1 mile after 10 years of operation (Layne-Western Hydro, Inc., 2011), although drawdown of 1-2 feet at that distance was typical of most of the scenarios.

A second illustration of local drawdown impacts can be seen in **Figure 17**, which shows depth to water at a domestic well on Siebenthal Road near Avenida del Sol, between new plantings of pistachio and alfalfa. There had been a net water-level decline of only 1 foot during 2009-2011, but from February 2012 through September 2013, water levels declined 4.5 feet, with no recovery during the winter of 2013. The increased rate of water-level decline is very likely the result of increased agricultural pumping in the vicinity.

A reasonable mitigation approach for new municipal wells would be to connect impacted nearby residences to the municipal water delivery system. The cost could reasonably be borne by all IWVWD customers, given that the entire water system benefits from the new well. Mitigation for impacts of new irrigation wells is less obvious, because farms and rural residences have equal priority with respect to water-rights context, and installation of an irrigation well is not a "project" that requires CEQA compliance.

Cost and Options for Funding

For its long-range capital improvement plan, IWVWD currently estimates that a new municipal well would cost approximately $1.8 million (not including any unusual engineering or permitting costs, and not including any connecting pipeline costs). The cost of installing pipeline depends partly on diameter, material and right-of-way. For pipelines ranging from 12-inch to 30-inch, the cost per linear foot would be roughly $125-$250, including engineering, contracting, mitigation and contingency (Zdeba, 2013; City of Dallas, 2012).

Data and Analysis Needs

If the Brown and Caldwell groundwater model were enhanced to include solute transport, it could be used to test well locations and pumping rates that optimize storage depletion. Additional test wells with vertical salinity distribution data could be needed to achieve a reliable calibration.

Preliminary Assessment

- This measure does not improve the basin water balance. It simply delays the onset of overdraft impacts.
- This is a reasonable near-term strategy if water imports are deferred.

Urban Water Conservation

Description

IWVWD, SVM and Inyokern CSD would increase outreach efforts and incentives to further reduce per-capita water consumption. IWVWD has successfully decreased per-capita water use by about 16 percent since 1998 (see Figure 12). However, additional reduction is feasible, as illustrated by the following examples:

- Residential per-capita water use decreased by half in the San Diego Country Estates residential development near Ramona (in central San Diego County) beginning in 2009. This is illustrated the monthly water use and WWTP inflow data in **Figure 18**, which can be compared to the graph for Ridgecrest shown in Figure 12. The reduction primarily involved a decrease in residential irrigated area and was motivated by a drought-related Stage 2 water shortage declaration and an increase in water rates.
- Per-capita water use in Ridgecrest remains high compared to other communities in southeastern California, as shown in **Figure 19**.

Elements of an expanded urban water conservation program could include:

- Technical assistance to homeowners for converting to xeriscape. IWVWD has planted attractive xeriscape vegetation as a demonstration garden at its headquarters building, but that type of landscaping is relatively rare in Ridgecrest residential areas. More commonly, people simply let their lawns die. This measure could make water conservation more palatable by making it more visually appealing.
- Turf removal rebates. Some southern California water retailers offer rebates to customers who remove turf, with rebates starting at about $0.30 per square foot (http://socalwatersmart.com/index.php/qualifyingproducts/turfremoval).
- Irrigation at existing residences could be reduced by requiring that irrigation demand targets be implemented when the house is sold. The Maximum Applied Water Allowance method recommended by the California Department of Water Resources' Model Water Efficient Landscape Ordinance would be an appropriate approach. Information is available at (http://www.water.ca.gov/wateruseefficiency/landscapeordinance/) including an Excel Water Budget Calculator workbook. Water use factors for landscape plants are available in the Water Use Classification of Landscape Species (WUCOLS) on-line at www.water.ca.gov/wateruseefficiency/docs/wucols00.pdf. Landscape conversion could be funded by means of a refundable title transfer tax, which is how the City of Berkeley promotes seismic safety retrofits of existing homes. A fee equal to a percentage of the sale price is refunded if the new owner implements the retrofit within one year.

- Rebates for high-efficiency toilets and clothes washers could accelerate plumbing retrofits in existing residences. Rebates for these fixtures are currently offered by many Metropolitan Water District of Southern California customers through the SoCal Water Smart program *(http://socalwatersmart.com/index.php/home/?p=res).*
- Raising the current water rates and implementing a steeply tiered rate structure provides a strong incentive for homeowners to implement water conservation measures and also provides a source of funding for rebates and other elements of the water conservation program. The monthly water bill for single-family homes in Ridgecrest using a typical amount of water was $40.54 in 2011 (Raftelis Financial Consultants, Inc. and American Water Works Association, 2011). This is less than the average rate across California and near the middle of the range of water rates in other desert communities.
- Conservation efforts could be extended to SVM, Inyokern CSD and rural residences. It appears that NAWS and IWVWD have implemented most of the urban water conservations efforts to date.

Examples

See discussion above.

Yield

If residents of Ridgecrest achieved a 50 percent decrease in outdoor water use relative to the 2005-2008 period—equaling the reduction achieved by San Diego Country Estates—groundwater pumping could be decreased by an additional 1,700 AFY. This amounts to a 34 percent decrease from 2012 outdoor use, which has already been lowered by 16 percent. If Ridgecrest were able to match the per-capita water use in Twentynine Palms (a decrease of 42 percent from 2012 Ridgecrest usage), municipal groundwater pumping would be reduced by about 3,300 AFY.

Impacts and Mitigation

No adverse environmental impacts are anticipated from this measure. There could be aesthetic impacts if residents simply let their landscape plants die rather than actively re-landscape to use less water. IWVWD (and Inyokern, NAWS and SVM) might need to restructure their rates to avoid revenue shortfalls as water usage declines.

Cost and Options for Funding

No information yet available.

Data and Analysis Needs

A survey of "penetration" rates for low-flow fixtures in existing homes might be needed. A cost-benefit analysis of various rebates and programs based on experience in other cities could be useful.

Agricultural Water Conservation

Description

Options for decreasing water use on existing irrigated cropland include the following:

- Modify nozzles and reduce pressure to minimize spray losses from alfalfa sprinklers. Visible losses are still occurring.
- Meter and record well pumping so that amounts of applied water are accurately known and managed.

- Convert alfalfa fields to pistachio orchards, which would decrease per-acre irrigation demand on those fields by approximately one-third.

Examples

No information yet available.

Yield

If spray losses on alfalfa fields were reduced by 10 percent of the applied water, basin-wide irrigation pumping would decrease by about 800 AFY. If the 990 acres of existing alfalfa were converted to pistachios, basin-wide irrigation pumping would decrease by about 3,000 AFY (when the trees are mature).

Impacts and Mitigation

No adverse impacts are anticipated as a result of increased irrigation efficiency or crop conversion.

Cost and Options for Funding

No information yet available.

Data and Analysis Needs

No information yet available.

Wastewater Recycling

Description

Water that is presently lost to evaporation from ponds at the Ridgecrest WWTP and from channels and seeps downstream of the tui chub habitat area would be intercepted prior to evaporation and piped to the former WWTP site in Ridgecrest, where additional alfalfa acreage would be grown with the recycled water. Through an agreement with a local alfalfa grower, the new alfalfa field would replace an equal number of acres of alfalfa presently irrigated along north Brown Road.

This measure would substantially decrease the total area of ponds at the WWTP to the minimum area needed for treatment and seasonal storage. Sufficient percolation to maintain existing inflows to the tui chub habitat area could be guaranteed, if necessary, by piping treated wastewater to a small percolation area or wetland closer to the habitat area. The seeps and channels that collect and convey WWTP pond percolation and shallow groundwater are shown in **Figure 20.** Tui chub habitat would be consolidated and enhanced in Lark Seep, North Channel and the "Bologna Pool". Enhancements would consist of excavating deeper and wider channels that resist cattail encroachment and that are preferred by tui chub. These types of enhancements have been proposed in the past (Bilhorn and Feldmeth, 1991) and are currently under renewed consideration (Campbell, 2013). All of the water flowing out of the habitat area would be collected near George Road and pumped back to the WWTP through a new pipeline and from there to the former WWTP site through an existing 20-inch recycled water pipeline. George Channel downstream of the diversion point and G-1 channel and G-1 seep would probably continue to receive some inflow from groundwater seepage, but total inflow would be much less than under existing conditions.

Wastewater could also be recycled for irrigation of urban landscaping. However, that use would require a higher (tertiary) level of treatment and a much more extensive distribution system. It would certainly cost more than the irrigation of alfalfa with secondary-treated effluent proposed in this alternative. The lower-cost option is presumably more feasible and is described here.

Examples
Some of the treated effluent from the Ridgecrest WWTP is already recycled for alfalfa irrigation at the former WWTP site. North Channel is already routinely excavated to remove cattails.

Yield
As much as 800 AFY of wastewater presently lost to evaporation could be recycled to irrigate an additional 100 acres of alfalfa. Basin yield would be increased by the same amount, assuming an equivalent number of existing alfalfa acres along Brown Road are retired. **Table 2** shows the disposition of WWTP outflows under existing and alternative conditions.

Impacts and Mitigation
The reduction in WWTP pond area, reconfiguration of the tui chub habitat area and diversion of water from G-1 channel downstream of the habitat area would all be predicated on avoiding adverse impact to the tui chub population. Aquatic plants and animals living in G-1 channel and seep would face a large reduction in habitat area due to the flow diversion, but no sensitive species have been reported in those water bodies.

Cost and Options for Funding
No information yet available.

Data and Analysis Needs
Various feasibility studies are needed to identify the minimum WWTP pond area that meets treatment and seasonal storage needs. A detailed biological and engineering plan for tui chub habitat reconfiguration is needed. Land availability and grower interest in increased alfalfa acreage near the former WWTP site needs to be ascertained.

Groundwater Demineralization

Description
Demineralization removes salt from water and can lower the TDS concentration of slightly brackish water to meet primary and secondary drinking water standards. Reverse osmosis is the most common method of demineralization. The process produces a waste stream of concentrated brine that requires disposal. Demineralization is typically expensive, partly because it requires a substantial amount of energy and partly because the brine disposal is usually expensive (zero liquid discharge or long-distance hauling costs).

IWVWD commissioned a pilot study of groundwater demineralization in Ridgecrest (Carollo Engineers, 2010). The objective was zero liquid discharge. In the 60month pilot study, groundwater from IWVWD well 1 was treated by a four-step process: pretreatment, reverse osmosis, electrodialysis reversal and brine concentration. The supply TDS concentration ranged from 1,400-2,300 mg/L. The reverse osmosis and electrodialysis stages achieved 92 percent efficiency, and the brine concentration step brought overall recovery up to 99.6 percent.

The brine concentration step is expensive and was only included to meet the objective of zero liquid discharge. That step accounted for 65 percent of overall cost. Discharging liquid brine to China Lake playa or the G-1 seep would appear to be plausible alternatives because both of those sites naturally and currently evaporate brines. Whatever impacts might result from brine evaporation are already occurring.

Table 2. Disposition of Outflows from Ridgecrest Wastewater Treatment Plant

Water Balance Item	Existing Conditions			Enhanced Habitat and Recycling		
	Acres	ft/yr	AFY	Acres	ft/yr	AFY
Inflows						
WWTP Inflow			2,936			2,936
Outflows						
WWTP pond evaporation						
Facultative ponds	57[a]	7.3[b]	416	57[f]	7.3[b]	416
Evaporation/percolation ponds	125[a]	7.3[b]	912	55[h]	7.3[b]	401
Seasonal storage ponds[i]	0	0.7[g]	0	0.7[g]	0.7	45
Golf course irrigation ET[c]	70	10.7	673	70	10.7	673
ET from Lark Seep, North Channel and Bologna Pool[d]			386			386
ET from George Channel and G-1 channel and seep[d]			421			0
Existing alfalfa irrigation[e]	33	6.8	224	33	6.8	224
New alfalfa irrigation	0	8	0	100	8	800
Total consumptive use of outflow			3,032			2,945
Discrepancy (outflows/inflow)			3.3%			0.3%

Notes:

a Total pond area is 239 acres (Provost & Pritchard, 2011), of which 182 were wetted in 2012. 57 acres of facultative pond are wetted at any one time.

b Pan evaporation at Trona (9.2 ft/yr) multiplied by 0.8 pan-to-lake coefficient.

c Golf course area and applied water (748 AFY) from Provost & Pritchard (2011). Irrigation rate = 748 AFY/70 ac. ET loss assumes 10% of applied water percolates to shallow aquifer and flows to the seeps and channels.

d ET losses in habitat areas from Bilhorn and Feldmeth (1991)

e Existing alfalfa area from Provost & Pritchard (2011) and volume from IWVWD (2011). Irrigation rate = 224 AFY/33 ac.

f Area of facultative ponds on-line at any time (unit A or B) (Provost & Pritchard, 2011).

g 90 days of seasonal storage required for irrigation uses (Provost & Pritchard, 2011). December-February evaporation = 9.9% of annual evaporation.

h Equals habitat ET volume (386 AFY) divided by average pond percolation rate of 7 ft/yr (Provost & Pritchard, 2012).

i Seasonal storage requirement = 40-45 acres per mgd of irrigation (Provost & Pritchard, 2011).

Examples

The Sweetwater Authority that supplies water for San Diego has operated the Reynolds Groundwater Desalination Facility since 1999. It processes up to 4 million gallons per day (mgd) of brackish groundwater from the San Diego Formation by reverse osmosis, and the waste brine is discharged to the ocean. The San Antonio Water System in Texas is about to construct an 11 mgd reverse osmosis plant to demineralize groundwater from the Wilcox Aquifer (1,300-1,500 mg/L). Waste brine will be disposed of by deep well injection.

Yield

This measure would not change the basin water balance and thus would not increase basin yield. It would increase the amount of groundwater in storage that can be "mined" for potable supply.

Impacts and Mitigation

Demineralization uses a lot of energy. If that energy is obtained from traditional fossil fuel sources, there would be adverse global warming impacts. Brine disposal by evaporation at G-1 seep or China Lake playa would probably have less than significant impacts.

Cost and Options for Funding

Carollo Engineers estimated that a full-scale plant treating 3,000 AFY would require a capital investment of $46 million and produce potable water at a cost of $2,350/AF. However, if the brine concentration and evaporation steps were eliminated, the cost would drop to $814/AF. Accordingly, it would be worth investigating the feasibility of obtaining a permit from the Lahontan Regional Water Quality Control Board to discharge the reverse osmosis/electrodialysis brine to G-1 seep or China Lake playa.

For comparison, the demineralization plant in San Antonio, Texas is expected to produce drinking water at a cost of $1,000 per acre-foot.

Data and Analysis Needs

Permitting and operation of alternative brine disposal methods need to be studied.

Water Importation

Description

Water would be imported to Indian Wells Valley from somewhere outside the basin. Various sources of water are possible (see below), and available capacity in the Los Angeles Aqueduct would be the logical means of bringing to water to Indian Wells Valley, as directed by Water Code sections 1810-1814. Except for water originating farther up the aqueduct (from Mono or Inyo Counties), delivering or "wheeling" the water to Indian Wells Valley would require reoperation of LADWP's system of sources, conveyance facilities and storage reservoirs. That is, LADWP would exchange water from Mono or Inyo County with water that arrives to Southern California from some other region such as the Delta or the Colorado River.

Indian Wells Valley would have the strategic advantage of being able to manage local and imported water conjunctively. It could import water in wet and normal years when external sources are relatively abundant and inexpensive, then revert to using local groundwater in dry years. Local groundwater storage capacity would absorb seasonal and year-to-year variations in imports. The reduction in overdraft would depend on the long-term average annual amount of imported water.

Options for Water Delivery

The imported water would need to be delivered from the Los Angeles Aqueduct to Ridgecrest. The shortest distance between the aqueduct and the IWVWD distribution system is about 6 miles. There are two conceptual delivery options:

- Pipeline and Treatment Plant

This option is conceptually straightforward and is currently preferred by IWVWD. The pipeline would probably follow road rights-of-way, and a treatment plant located somewhere along the pipeline would bring the water up to drinking water standards. Advantages of this option are the avoidance of pumping costs (treated water could be conveyed and introduced at suitable pressure into the distribution system by gravity flow) and the high quality of the delivered water. Potential disadvantages are the construction and operating costs of the pipeline and treatment plant, the lack of storage to accommodate variations in delivery rate, and possible flow capacity constraints where the water is introduced into the distribution system.

- Groundwater Recharge
  This option would percolate water diverted from the aqueduct into the groundwater basin, where it would subsequently be recovered by existing municipal wells. For example, Little Dixie Wash might have sufficient percolation capacity to infiltrate water at the necessary rate. Advantages of this option include low construction cost and avoiding the need for a long pipeline and treatment plant. It could also be used as a low-cost means of importing and storing water in wet years, when external supplies are cheaper and more abundant. Disadvantages include: the energy required to pump the water out of the ground and up to distribution system pressure (just like existing groundwater), deterioration of water quality as the aquifer water comingles with groundwater (the recovered water would have the same quality as existing well water), delays in access to the water as it percolates down to the water table and then horizontally to municipal wells, and alteration of habitat conditions along Little Dixie Wash.

Options for Water Source

Sources of imported water are potentially available. Because the Los Angeles Aqueduct provides water to the City of Los Angeles, which also is served by MWD's overall water supply system, it is theoretically possible to obtain water by transfer from parties anywhere in a region that includes the entire Colorado River basin and most of California up to the Oregon border. Water rights can be leased or purchased from users within that region, and the water can be "wheeled" to Indian Wells Valley subject to operational constraints related to canal and reservoir capacities, environmental flow requirements, etc. For example, the applicant-proposed Fremont Valley Preservation Water Bank and Solar project by AquaHelio Resources, LLC, includes a proposed water bank involving the Los Angeles Aqueduct. This proposal is being processed for consideration by the Board of Supervisors, and its feasibility is still being investigated. Consequently, it is still considered speculative as a potential source of supply for Indian Wells Valley. Additional sources and water rights are likely to be identified and to become available in the foreseeable future.

Butterworth Ranch (Inyo County)

IWVWD owns an alfalfa farm located just upstream of Haiwee Reservoir in Inyo County, 44 miles northwest of Ridgecrest. To transfer water to Indian Wells Valley, farming would be discontinued and water would be piped about 1,700 feet from existing wells to the Los Angeles Aqueduct, which would convey it to Indian Wells Valley. Irrigation pumping averaged 907 AFY during 2008-20012, and that is roughly the amount that would be transferred. Advantages of this source are that IWVWD already owns it and that no reoperation of the LADWP or MWD water supply systems would be necessary. The reach of the Los Angeles Aqueduct that would convey the water is presently underutilized because of releases upstream to Owens Lake bed for dust control. The disadvantages are institutional and philosophical. This source of water constitutes an export from Inyo County, and requires compliance with the Inyo County Water Export Ordinance and ultimate approval by the Inyo County Board of Supervisors. This could be politically unpopular and therefore difficult to permit. However, Ridgecrest is within the Inyo-Mono Integrated Regional Water Management Plan area (and has most of its population), so the transfer would not constitute an export with respect to the planning area. This source also involves retirement of active farmland. If farmland is going to be retired, why not retire it in Indian Wells Valley rather than export the economic impacts to another county and go to the trouble and expense of obtaining permits, paying LADWP to wheel the water and building a pipeline and treatment plant?

The yield of this supply is too small to be cost-effective as the sole source of imported water. It would only be reasonable to add it to a portfolio that includes larger sources.

Antelope Valley Water Bank

The relatively new Antelope Valley Water Bank is located near Rosamond in southeastern Kern County approximately 60 miles south of Indian Wells Valley. The bank is capable of storing up to 500,000 AF of water and is operated by Antelope Valley East Kern Water Agency (AVEK), a major State Water Project contractor. The water bank increases the overall storage capacity of the State Water Project system and thereby creates additional, reliable yield. Indian Wells Valley could potentially become a customer for some of the available yield (AVEK, 2010).

LADWP/MWD Water Transfer or SWP/CVP Purchase

Various sources of imports are potentially available, including:

- State Water Project (SWP) "Table A" contract water. Indian Wells Valley would become a SWP contractor by buying an entitlement from an existing contractor. For example, Mojave Water Agency has purchased Table A entitlements from Berrenda Mesa and Dudley Ridge Water Districts in the past. The amount purchased would need to be considerably greater than the amount actually needed. Due to hydrologic and Delta export constraints, SWP is expected to be able to deliver only 60 percent of the Table A contract amounts on average (DWR, 2011).
- Spot market water. California has an ongoing, active mechanism for transferring current-year water between willing sellers and buyers. Prices are relatively low during wet years and high during dry years—especially multi-year droughts. During 2000-2010, the median price was $135 per acre-foot, and the range was $25-$500 per acre-foot. The average annual volume of water transferred on the spot market was 403,500 AF.
- Central Valley Project (CVP) contract water. Similar to obtaining SWP water, Indian Wells Valley would purchase a long-term contract amount from an existing CVP contractor. The seller would need to be another south-of-Delta municipal user.
- Other water districts and private sellers. Various other individuals and local agencies hold rights to water within the Central Valley watershed, and their water can be wheeled to Indian Wells Valley via the SWP/CVP and Los Angeles Aqueduct. For example, Yuba County Water Agency regularly sells water from its New Bullards Bar Reservoir.

Examples

See "Description", above.

Yield

The Butterworth Ranch source could potentially supply about 900 AFY. For practical purposes, there is no limit to the amount of water that could be transferred from the spot market or external water users connected to the SWP or CVP; however, there are delivery limitations each year in the total amount of water available. Total annual groundwater pumping in Indian Wells Valley presently equals only four percent of the annual flow in the Los Angeles Aqueduct, so delivering aqueduct water to Indian Wells Valley would probably have only minor impacts on LADWP flow operations.

Impacts and Mitigation

Adverse impacts of imported water would be almost entirely in the source area, where some other entity would use less water. In many cases this would involve a decrease in agricultural water use by fallowing land, changing crops or changing irrigation practices.

Cost and Options for Funding

The cost of constructing a 30-inch pipeline from the Los Angeles Aqueduct to the IWVWD distribution system was estimated in 2000. Allowing for subsequent price inflation, that estimate would be approximately $7.5 million in 2013. A 10 mgd water treatment plant might cost on the order of $25 million to construct. If both projects are financed for 30 years at 5 percent interest, loan payments would be $2.1 million per year. The cost per acre-foot of water varies inversely with the amount of water imported: $350/AF for 6,000 AFY, decreasing linearly to $190/AF for 11,000 AFY (10 mgd). For reference, present combined use by IWVWD, NAWS and SVM is 12,400 AFY.

The typical price for Table A SWP water has been around $2,500 per AFY of yield, although Mojave Water Agency has paid as much as $5,250/AFY. Because the yield continues in future years, the purchase price can be amortized. Allowing for the 60 percent average delivery rate for Table A water and assuming a 30-year loan repayment at 5 percent interest, the water would cost $270/AF.

Spot market water prices ranged from $25 to $500/AF during 2000-2010, and the median price was $135/AF.

The cost of water from Butterworth Ranch in Inyo County would be small because IWVWD already owns the source. There would be one-time costs to negotiate an export permit, potentially pay for agricultural and environmental mitigation measures, and construct a short pipeline to connect the ranch wells to the Los Angeles Aqueduct.

In addition to the above purchase costs for imported water, there would be additional costs to pay LADWP to wheel the water and for operation and maintenance of pipelines and treatment plants.

The cost of water obtained from local agencies or private sellers could depend substantially on the years and seasons of delivery. For planning purposes, it would be reasonable to assume prices similar to spot market prices.

Data and Analysis Needs

Feasibility and engineering studies are needed for pipelines, percolation facilities and a treatment plant in Indian Wells Valley. An up-to-date inventory of potential water sellers and prices would be necessary to evaluate cost and availability. Indian Wells Valley will be competing with other agencies such as MWD that are also perennially shopping for water. LADWP and possibly MWD would need to conduct reoperation studies to integrate the new supply and delivery into their overall system operation.

Groundwater Banking

Description

Groundwater storage capacity is a valuable commodity in California, and Indian Wells Valley has plenty. Cumulative overdraft since the 1960s has vacated on the order of 600,000 AF of storage capacity. Under this option, an external agency would store water in Indian Wells Valley during wet years and pump it back out during dry years. Several methods could be used to store water transported from the Los

Angeles Aqueduct in Indian Wells Valley groundwater basin: in-lieu recharge by delivering aqueduct water to local urban users, injection, or percolation.

By way of illustration, suppose a Southern California water district wanted to use 200,000 AF of storage capacity on a 25-year cycle: 20 years of adding water for every 5 years of withdrawal. If water were available continuously during the 20-year "put" period, about seven 1,000-gpm injection wells would be needed to store the water (more likely double that number to allow for the need to operate wells cyclically). About thirty 1000-gpm wells would be needed to recover the stored water during the 5-year "take" cycle.

The main part of Indian Wells Valley basin could be unfavorable for groundwater banking for two reasons. First, its water levels are too low. Groundwater would have to be pumped approximately 1,400 feet uphill to return it to the Los Angeles Aqueduct (including allowances for drawdown in the wells and pressure head in the aqueduct). Second, the water quality is slightly suboptimal because groundwater TDS is higher than average TDS in the aqueduct. The State Water Project readily accepts groundwater pump-ins to the California Aqueduct if water quality is better than the water quality at the upstream end of the aqueduct. Pump-ins of poorer-quality water are accepted only on a case-by-case basis. If those same standards were applied to the Los Angeles Aqueduct, pumped-in groundwater would be readily accepted only if its TDS concentration were less than 231 mg/L (the average TDS during 2012). Most wells in the southwestern part of the basin have 250-400 mg/L TDS.

Both of these drawbacks to banking in the main part of the basin might be overcome by banking in the El Paso subarea, which presently is almost completely unutilized. There is a large amount of storage capacity above the current water table (in excess of 1 million acre-feet), water levels are 700-1,000 feet higher than in the main basin, and TDS is reportedly low because the area was always higher than the lakes during the Pleistocene (Berenbrock and Schroeder, 1994). The only local benefit of groundwater banking in the El Paso subarea is that some of the stored water would leak into the main part of the basin.

Examples

Kern County is home to the largest water banks in California, with twelve or more water districts actively operating up to 10 million acre-feet of storage capacity in the Tulare basin (Water Association of Kern County, 2013). Kern Water Bank is the largest of those operations, with a capacity to store up to 72,000 AF per month by percolation and extract up to 240,000 AFY using 85 high-capacity wells. The Antelope Valley Water Bank is approved and operational in southeastern Kern County. It has capacity for up to 500,000 acre feet of storage and has connectivity to AVEK (Antelope Valley East Kern Water Agency) a wholesaler of State Water Project water.

Yield

If all of the stored water were pumped back out, there would be no water supply benefit to local users. Groundwater levels would on average be higher, however, which would confer several benefits: reduced pumping costs, delayed onset of subsidence, and reductions in the rates at which shallow wells go dry and high-TDS groundwater flows toward municipal wells. In all banking agreements, however, an allowance is made for "losses", some of which accrue to local groundwater yield. For example, the Kern Water Bank allows for 6 percent evapotranspiration losses, 5 percent "export compensation" and 6 percent in-basin purchase options. The latter two items amount to 11 percent and represent additional local water supply yield. The Arvin-Edison water bank similarly assumes a 10 percent loss factor (no breakdown available).

In the 200,000-acre-foot storage example described earlier, a 10-percent loss allowance accruing to Indian Wells Valley would equal 20,000 AF over the 25-year put-and-take cycle, or only 800 AFY. This yield benefit is negligible in the context of the basin water balance. Thus, water banking by itself would do little to solve the overdraft problem.

Impacts and Mitigation

The environmental impacts of groundwater storage projects are small relative to surface water diversion and storage projects. Water is stored during wet periods, when associated reductions in surface water flows have minimal impacts. There are no evaporative losses, and impacts on other basin users are mostly beneficial due to higher average groundwater levels.

Cost and Options for Funding

The cost of constructing the recharge and extraction facilities would presumably be borne by LADWP. If a "storage fee" is charged, local water users could benefit financially from the banking operation.

Data and Analysis Needs

Additional hydrogeologic characterization of the El Paso subarea would be needed to confirm the physical viability of groundwater banking. A characterization study would likely include:

- New monitoring wells at a few locations to provide a more complete picture of geologic materials, water levels and water quality across the subarea.
- Aquifer tests at one or two locations to measure aquifer transmissivity and short-term storativity.
- Measurements of percolation losses and nearby water-table response along the upper reach of Little Dixie Wash to determine the feasibility of banking water by stream percolation.
- Estimation of groundwater leakage from the El Paso subarea into the main Indian Wells Valley basin by groundwater modeling or groundwater flow equations.
- Sampling of water quality to determine its suitability for potable use, its compliance with Los Angeles Aqueduct pump-in criteria and the potential for dissolution/precipitation reactions if banking is implemented using aquifer-storage-and-recovery wells.
- Calculation of the storage volume available for use in a banking operation and estimation of maximum potential rates of recharge and withdrawal.

6.2 Planning and Legal Measures

As described above, physical solutions have the potential to resolve the current overdraft by existing groundwater pumpers. However, a substantial potential also exists for land use changes involving additional pumping that would exacerbate overdraft. Accordingly, land use planning, groundwater ordinances, and legal measures are considered here as means of regulating future land uses and limiting future water demands.

Planning Options

Two planning options are presented: rezoning and land trusts.

Rezoning and Specific Plan

It has been suggested that agricultural lands—as-yet undeveloped with irrigated crops—be rezoned by the County to another, lower-water-demand land use such as estate residential. **Table 3** lists the number and size of parcels that were mapped in Figure 15 as potentially irrigated cropland. The

Table 3. Potentially Irrigated Cropland Parcels

A. Number of Parcels

Zoning Code	Zoning Description	Number of Parcels – Parcel Size Category (Acres)						
		<3	3-5	6-10	11-20	21-40	>40	Total
A	EXCLUSIVE AGRICULTURE	2	2	5	1	2	3	15
A FP	EXCLUSIVE AGRICULTURE, FLOODPLAIN COMBINING	0	0	0	0	0	0	0
A FPS	EXCLUSIVE AGRICULTURE, FLOODPLAIN SECONDARY COMBINING	0	0	0	1	2	3	6
A GH	EXCLUSIVE AGRICULTURE, GEOLOGIC HAZARD COMBINING	0	1	0	0	0	0	1
A-1	LIMITED AGRICULTURE	205	128	70	36	36	19	494
A-1 FPS	LIMITED AGRICULTURE, FLOODPLAIN SECONDARY COMBINING	20	2	0	0	0	0	22
A-1 MH	LIMITED AGRICULTURE, MOBILEHOME COMBINING	987	388	238	97	75	52	1837
A-1 MH FPS	LIMITED AGRICULTURE, MOBILEHOME COMBINING, FLOODPLAIN SECONDARY COMBINING	51	14	5	1	1	0	72
A-1 MH H	LIMITED AGRICULTURE, MOBILEHOME COMBINING, AIRPORT APPROACH HEIGHT COMBINING	140	56	39	33	15	16	299
A-1 MH H FPS	LIMITED AGRICULTURE, MOBILEHOME & AIRPORT APPROACH HEIGHT & FLOODPLAIN SECONDARY	2	0	0	0	0	0	2
	Total	1,407	591	357	169	131	93	2,748
	Percent of total	51%	22%	13%	6%	5%	3%	100%

B. Parcel Area

Zoning Code	Zoning Description	Parcel Area (Acres) – Parcel Size Category (Acres)						
		<3	3-5	6-10	11-20	21-40	>40	Total
A	EXCLUSIVE AGRICULTURE	3	9	42	15	70	539	678
A FP	EXCLUSIVE AGRICULTURE, FLOODPLAIN COMBINING	0	0	0	0	0	0	0
A FPS	EXCLUSIVE AGRICULTURE, FLOODPLAIN SECONDARY COMBINING	0	0	0	13	57	199	269
A GH	EXCLUSIVE AGRICULTURE, GEOLOGIC HAZARD COMBINING	0	5	0	0	0	0	5
A-1	LIMITED AGRICULTURE	457	622	646	652	1,208	2,038	5,623
A-1 FPS	LIMITED AGRICULTURE, FLOODPLAIN SECONDARY COMBINING	45	10	0	0	0	0	55
A-1 MH	LIMITED AGRICULTURE, MOBILEHOME COMBINING	2,282	1,864	2,336	1,759	2,384	5,577	16,202
A-1 MH FPS	LIMITED AGRICULTURE, MOBILEHOME COMBINING, FLOODPLAIN SECONDARY COMBINING	123	63	45	20	39	0	290
A-1 MH H	LIMITED AGRICULTURE, MOBILEHOME COMBINING, AIRPORT APPROACH HEIGHT COMBINING	357	233	378	621	534	2,010	4,135
A-1 MH H FPS	LIMITED AGRICULTURE, MOBILEHOME & AIRPORT APPROACH HEIGHT & FLOODPLAIN SECONDARY	5	0	0	0	0	0	5
	Total	3,273	2,806	3,447	3,080	4,291	10,364	27,261
	Percent of total	12%	10%	13%	11%	16%	38%	100%

Notes:

1. See Figure 15 for map of the region that includes these parcels.
2. In this table the full area of parcels that contain existing fields is omitted from the tabulation of potentially irrigated cropland. In the text, only the actual existing field area was subtracted.
3. The 25,500 acre estimate of potentially irrigated cropland presented in the text omitted agricultural parcels less than 5 acres in size with an existing house. No parcels are omitted in this table.

potential cropland area includes 2,748 parcels in ten subcategories of agricultural zoning. The three most common categories in terms of number of parcels and total area are A-1 Limited Agriculture, A-1 MH Limited Agriculture Mobile Home Combining, and A-1 MH H Limited Agriculture Mobile Home Combining, Airport Approach Height Combining. Parcels range in size from 0.1 to 598 acres. Parcels that are 5 acres or less account for 73 percent of the number of parcels but only 22 percent of the area. Conversely, parcels greater than 40 acres in size account for only 3 percent of the number of parcels but 38 percent of the total area. Re-zoning could apply across the board to all parcels, or be limited to certain zoning subcategories, parcel sizes or geographic areas.

In any event, land use planning and re-zoning must be consistent with the General Plan, which addresses many issues and has multiple objectives and policies. As a general rule, "an action, program, or project is consistent with the General Plan if, considering all its aspects, it will further the objectives and policies of the general plan and not obstruct their attainment" (Governor's Office of Planning and Research, 1998). For example, as summarized in Section 3, General Plan goals include that Kern County "ensure that adequate supplies of quality (appropriate for intended use) water are available to residential, industrial, and agricultural users." Stopping overdraft is basic to attainment of this goal. However, another goal mandates that the County "discourage scattered urban density development that is not supported by adequate infrastructure." Re-zoning all of the potentially irrigated cropland parcels to Estate Residential, for example, could be inconsistent with that policy unless urban infrastructure and services were extended to the scattered estates. Accordingly, provision of adequate infrastructure of all types needs to be considered.

The point here is not to cherry-pick General Plan goals and policies to argue for or against such a rezoning, but to illustrate the systematic reasoning that needs to be its basis. This Water Supply Availability and Conservation Report is part of that reasoning process, beginning with the County's 2012 Indian Wells visioning process and now including the finding of overdraft.

Continuation of the County's area or specific planning process for Indian Wells Valley is an appropriate means of land use planning in light of the overdraft situation. A specific plan may be developed in response to a single policy issue (e.g., overdraft), to address each applicable policy of the general plan, or to include other subjects viewed by the community as relevant. The specific plan process provides an important forum for resolving land use conflicts among local competing interests. The resulting specific plan then provides details on:

- The distribution, location, and extent of the uses of land, including open space, within the area covered by the plan
- The proposed distribution, location, and extent and intensity of major components of public and private transportation, sewage, water, drainage, solid waste disposal, energy, and other essential facilities proposed to be located within the area covered by the plan and needed to support the land uses described in the plan
- Standards and criteria by which development will proceed, and standards for the conservation, development, and utilization of natural resources, where applicable
- A program of implementation measures including regulations, programs, public works projects, and financing measures

Subsequent subdivisions and developments, public works projects and zoning regulations must be consistent with the specific plan.

For Indian Wells Valley, a specific plan supports long-term implementation of the visioning process, including regulation of land uses, limitation of future water demands and acquisition of a long-term sustainable supply. While the specific planning process can be lengthy (two years or more) and compliance with CEQA is needed, continuation of this process supports resolution of the linked land use and water resource issues.

Land Trusts

The goal of land conservation trusts is to preserve sensitive natural areas, open space, farmland, ranchland, water sources, or cultural resources. Conservation trusts, such as the Eastern Sierra Land Trust, have a precise process to evaluate lands for protection. Trusts often target lands adjacent to or within existing protected areas, or areas that are particularly valuable (e.g., critical habitat for endangered species). Trusts may protect land through a conservation easement to prevent development; this typically is a voluntary land protection agreement between a private landowner and the land trust. Land acquisition may be used in cases of significant and valuable resources on the land and a clear pubic benefit. In these cases, the land trust works closely with public agencies and seeks funding.

The use of land trusts to maintain open space is applicable to Indian Wells Valley and has been recognized in the Open Space and Conservation Element of the City of Ridgecrest's General Plan. One implementation measure of the City's General Plan is to "investigate the establishment of a land trust for open space lands and consider opportunities for acquiring natural habitat and agricultural areas for permanent open space and natural parks."

Other cities in California have established open space protection programs; for example, the City of Davis in Yolo County established an Open Space and Habitat Commission, whose purpose is to advise the City Council on all open space issues, including natural areas, wildlife and wildlife habitat, agricultural land conservation, land acquisition, trail systems, environmental education and interpretation, project site design and project operations and maintenance (City of Davis, 2014). These open space areas are not the same as City Parks, and the City prohibits open space land from being developed. The City collaborates with the US Department of Agriculture Natural Resource Conservation Service, California Department of Conservation, and local organizations (including Yolo Land Trust) in acquiring and managing open space lands. The open space land acquisition program was funded through passage of a ballot measure in 2000, which increased property taxes by $24/year, providing the City with funds for acquisition and management of open space. A similar measure was passed in 2006.

For Indian Wells Valley, a similarly sustained, regional and multi-purpose program would involve acquiring parcels with value for open space, trails systems, wildlife habitat (e.g., Mohave ground squirrel), and water conservation. This would likely entail acquisition of parcels of varying size; for example, land conservation projects of the Eastern Sierra Land Trust range in area from 15 to 3,748 acres, with a total of about 6,500 acres. It should be recognized that land conservation agreements take time; while some high priority land conservation agreements (especially donations) are quickly arranged in 6 to 18 months, other agreements may take years to accomplish. Lastly, keeping the land under private ownership may be an issue, as it maintains the land on local property tax rolls; in the case of Indian Wells Valley, the potential loss of tax revenue would most likely fall affect the County.

Groundwater Management Ordinances

At least 27 counties have adopted groundwater management ordinances pursuant to their police powers, through which they protect the public health, safety and general welfare of the people. These ordinances have been developed to limit groundwater export or to regulate groundwater pumping, and such an ordinance may be useful in Indian Wells Valley to regulate future pumping. Ordinances are prepared to address local objectives and conditions, and therefore are very diverse. Several examples are briefly summarized here, recognizing that any consideration of an ordinance for Indian Wells Valley would be tailored to its unique needs; it also would need to be evaluated for litigation potential and costs for such defense.

San Bernardino County Desert Groundwater Ordinance

The San Bernardino County Desert Groundwater ordinance requires application for a production well permit that includes documentation of groundwater supply. The application is not approved unless the well does not result in the safe yield being exceeded. For Indian Wells Valley, overdraft already exists, so such an ordinance could effectively prohibit all new wells for the near future, recognizing that an ordinance would likely include specified applications, limitations, and exemptions (e.g., for replacement wells). This likely would be subject to legal challenge.

Imperial County Groundwater Management Ordinance

In 1998, Imperial County adopted its Groundwater Management Ordinance (Imperial County, 1998) for the purpose of preserving, protecting and managing the groundwater within the County. The ordinance specifically addresses groundwater extraction, export, and management, including artificial recharge. It is implemented by the Planning Commission with recommendations to the Board of Supervisors. At the request of the Planning Commission, the Planning Director may be charged with the conduct of studies, investigations and reports; determination whether sufficient groundwater is available for a proposed development project (defined to include agricultural uses); and other responsibilities.

With regard to groundwater management, the Planning Commission can recommend to the Board of Supervisors a range of groundwater management activities:

- Acquisition, purchase, sale, exchange, conditioning, importation, recapture, conservation, reclamation or storage of water or water rights.
- Requirement of conservation practices and measures.
- Regulation of groundwater replenishment programs and recapture of supplemental groundwater resulting from such programs.
- Determination of the amount of groundwater basin storage space available and allocation of groundwater basin storage space.
- Limitation or suspension of extractions from extraction facilities, the construction of new extraction facilities, the expansion of existing facilities, or the reactivation of abandoned or closed extraction facilities.

The ordinance provides for registration of existing extraction facilities, permitting of new extraction facilities, and metering and reporting of pumping amounts.

The ordinance specifically addresses overdraft, establishing priority among groundwater users. It provides for the Planning Commission, after notice to the public and a hearing that discloses competent evidence of overdraft or threat of overdraft in a groundwater basin, to reduce or suspend extraction and/or exportation. Limitations would be allocated primarily on the basis of the users' proportional use. The ordinance also provides for levy of charges for the purpose of groundwater resource management, and provides procedures for the Planning Commission to resolve well interference disputes.

The Imperial County Groundwater Management Ordinance has not been implemented to a significant extent; nonetheless, it is comprehensive and detailed in addressing extraction of groundwater, exportation, and artificial recharge.

San Luis Obispo County Urgency Ordinance

Another example is the August 2013 Urgency Ordinance for the Paso Robles groundwater basin in San Luis Obispo County (San Luis Obispo County Planning and Building, August 2013). This basin, while within the county-wide jurisdiction of the San Luis Obispo County Flood Control and Water Conservation District, lacks a local district to provide supplemental supply to agricultural and rural uses. The Urgency Ordinance responds to persistent groundwater level declines, wells going dry, and a significant increase in new irrigated acreage. Unlike the San Bernardino County ordinance that regulates well drilling, the San Luis Obispo county ordinance addresses land use, requiring a permit for new or expanded irrigated crop production dependent on a well in the groundwater basin. This ordinance requires that the demand on the groundwater basin be offset at least 1:1 before pumping starts (an "offset clearance"). The Ordinance also requires metering and monitoring of new wells associated with the offset clearance, prohibits the creation of new parcels in the basin and requires changes to the County General Plan to be water neutral. The Ordinance does not affect local cities or towns, the drilling of wells, or the building of single family home. The Ordinance was deemed exempt from CEQA.

Consideration of this ordinance prompted a "race to the pumphouse," as would-be pumpers rushed to file well drilling applications with the County before the ordinance went into effect. Nonetheless, the ordinance—recently extended from 45 days to two years—gives local water managers time to plan for supplemental supplies. Currently, the local community is discussing options of general act and special act districts to serve the Paso Robles basin, and seeking grant funding for an evaluation of governance options. In addition, two significant lawsuits have been filed against the County and local municipal water purveyors; one of these was filed by property owners suing to seek quiet title to their groundwater rights as a potential prelude to an adjudication. All costs for these lawsuits, in the possible event that the County and municipal providers lose, would be borne by the County taxpayers and local purveyor taxpayers/rate payers.

Napa County Groundwater Ordinance

The 1996 Napa County Groundwater Ordinance regulates the extraction, use, and preservation of the County's groundwater resources. This ordinance applies to new water systems or improvements for water systems for agricultural land development or re-development activities in five designated groundwater deficient areas. The ordinance identifies issuance of groundwater permits based on three types of applications (exempt, ministerial, and required). Exempt projects are very small agricultural developments. Ministerial permits are provided for residential and agricultural land re-development projects that comply with specified water demands (e.g., 0.6 AFY for a residence and 0.3 AFY per acre for agriculture). Required groundwater permits are issued based on compliance with "no net increase" and "fair share" standards. Applications for a groundwater permit require identification of existing and future uses of any existing water system which is supplied by groundwater, potential alternative water sources, number of existing and future connections, intent of groundwater use, and an assessment of the potential impacts to the affected groundwater basin. Most new wells require metering.

Such ordinances typically do not provide the means to develop supplemental supply or to conserve or replenish groundwater. In the Napa County example, the ordinance has regulated local groundwater pumping, providing time to plan for supplemental supply (i.e., recycled water pipeline). In the Napa example, this supply is being developed through a newly created Community Facilities District (CFD). Property owners along the pipeline route voluntarily request annexation into the CFD, pay an assessment for pipeline construction and pay for recycled water.

Legal Measures

Water rights are fundamental to a discussion of groundwater management. The scope of this report does not include description of water rights law in California; the reader is referred to California Groundwater Management (Bachman et al., 2005). Nonetheless, the basic water right of overlying landowners establishes a baseline condition: overlying landowners have the right to pump groundwater for beneficial uses on their properties. This represents a correlative share of the groundwater yield, which is not defined unless a basin is adjudicated. Cities and special districts can divert water through an appropriative right or purchase water; in Indian Wells Valley, municipalities and water agencies pump groundwater through appropriative rights for use in the basin. In addition, Searles Minerals pumps groundwater and exports it for use in the Searles Valley groundwater basin, which also constitutes an appropriative use.

Injunction

If a groundwater user with a prior or higher water right suffers material injury from someone else's pumping, the user might be able to obtain injunctive relief that would force the other party to reduce their pumping. The material injury needs to be substantial, such as an appreciable decrease in the amount or quality of water available to the impacted user. For example, this concept could theoretically be applied if a private domestic well is dewatered by a large new irrigation well installed nearby.

The prescriptive water rights of existing pumpers in an overdrafted basin might also serve as the basis for injunction. In the context of Indian Well Valley, the threat of an injunction lawsuit could serve as a deterrent to others who might be contemplating new irrigated cropland. This is an untested concept and could run a risk of triggering adjudication.

Adjudication

Adjudication is a legal proceeding that quantifies the rights of all users in an overdrafted groundwater basin. It can be initiated by any user, and all users automatically become part of the proceeding. You cannot opt out. Adjudication proceedings typically require 5-20 years. After adjudication, management of the groundwater basin is undertaken by a court-appointed Watermaster, who has powers similar to a management district. The Watermaster often has the power to levy special assessments on the groundwater pumpers to administer the judgment or to purchase supplemental water. Adjudication provides certainty in terms of water rights, and can compel participation in the management process or development of a solution.

Two aspects of adjudication have serious implications for Indian Wells Valley:

- Adjudication will cost millions of dollars in legal fees. Those costs are paid directly by basin users. For example, the recent Santa Maria Groundwater Basin adjudication was estimated to cost all parties over $11 million. As a matter of perspective, the proposed project to import water was estimated to cost $25 million (San Luis Obispo Planning, 2013).
- Historical adjudications have brought the basin back into balance, with pumping by all users reduced by more or less equal percentages until total withdrawals are equal to or less than basin yield. However, imported water has been part of the physical solution emerging from the

adjudication proceeding. In the case of Indian Wells Valley in 2013, every user would have to get by on one-third of their current water use, or possibly less.

Given that Indian Wells Valley does not presently have access to imported water, adjudication at this time would likely result in draconian reductions in pumping by all users. If imported water is going to be part of the solution to local water supply shortages, it would be far more cost-effective to proceed directly with that option rather than to wait until after the tremendous delay and expense of adjudication.

6.3 Institutional Options

Indian Wells Valley has a mosaic of federal and local agencies—some overlapping—with distinct responsibilities and powers for land use management and for water resource management. These were described in the section, Institutional and Planning Framework.

The major groundwater-pumping agencies along with other resource management and planning agencies have collaborated on groundwater basin management, with many achievements. However, the benefits have been constrained by the limited power, funding, and/or geographic jurisdiction of different agencies. Accordingly, the development of supplemental supplies, which is needed to achieve the goal of adequate supply, has not progressed beyond studies.

Issues and Options

In considering agency options, the necessary characteristics are the:

- Authority to acquire or develop supplemental supply
- Ability to manage water demand (e.g., regulate pumping)
- Capability and means to fund or finance programs and projects
- Local and equable representation of stakeholders in the formation and governance of the district (e.g., voting)
- Geographic extent of jurisdiction

The agency selected for Indian Wells Valley should provide all the needed authority and capabilities, plus equable representation and financial responsibility. The areal jurisdiction should encompass Indian Wells Valley groundwater basin and also Salt Wells Valley and Searles Valley basins. This geographic extent covers parts of three counties and allows unified management of water resources in all areas that rely on the Indian Wells Valley groundwater basin. The selected institutional option(s) should support collaboration among all stakeholders, allow equable representation, and provide a broad funding base.

The California Water Code provides a variety of General Act districts to manage water, while other Special Act Districts may be established directly by the State Legislature. Some aspects of groundwater management also can occur through county ordinance, AB3030 management plans, and adjudication. Relevant to Indian Wells Valley, **Table 4** provides descriptions of three General Act water districts (California Water District, County Water District, Water Replenishment District, several Special Act water management agencies.

LAFCo

At this point, a brief discussion is warranted about how agencies are formed; Table 4 provides brief summaries and mentions LAFCo, namely Local Agency Formation Commissions.

(LAFCos) were created by the State Legislature in 1963 to promote orderly growth and development in California. LAFCos (organized on a county-by county basis) have broad powers to regulate the

Table 4. Water Agency Options

	California Water District	County Water District	Water Replenishment District	Kern County Water Agency	Improvement District No. 4
Location	Various	Various	Various	Coincides with Kern County	Kern County
Enabling Legislation	California Water District Law	County Water District Law	Water Replenishment District Act	1961 Special Legislation	1971 KCWA Board Resolution
Formation Process	1) Holders of title to a majority of land within boundaries of proposed district submit formation petition to LAFCo; 2) Holders in proposed boundary can seek exclusion and holders outside of but adjacent to proposed boundary can seek inclusion; 3) LAFCo holds hearing and enters order establishing boundaries and naming the district; 4)Election proceeds based on one vote for each dollar's worth of land or based on one vote for each acre; 5) May be divided into divisions upon resolution of board of directors or upon petition signed by a majority of eligible voters within the district (one director from each division who must hold land title in division)	1) Assuming municipalities excluded, formation petition shall be signed by voters equal in number to at least 10 percent of the voters registered within the boundaries of the proposed district and submitted to LAFCo (must be a resident of the proposed district to be a voter); 2) Persons may seek inclusion of land adjacent to the proposed boundary; 3) LAFCo holds hearing to consider approving boundaries and whether to have formation vote; 4) Formation election proceeds based on one vote for each voter residing in district area.	1) Assuming municipalities excluded, formation petition shall be signed by voters residing within proposed boundaries equal in number to at least 10 percent of voters residing within proposed boundaries and submitted to LAFCo and DWR; 2) Persons may seek inclusion of land adjacent to the proposed boundary; 3) DWR holds hearing to consider approving boundaries 4) Board of Supervisors or LAFCo divides district into five divisions based on population; 5) Formation election proceeds based on one vote for each voter residing in district area. Only one exists: Water Replenishment District of Southern California, formed 1959.	Legislator Sponsorship	Initiated by KCWA Board of Directors with adoption of Resolution No. 25-70, outlining need. ID4 formed by KCWA Board of Directors resolution in 1971.
Purpose and Powers	Acquire, plan, construct, maintain, improve, operate, and keep in repair the necessary works for the production, storage, transmission, and distribution of water for irrigation, domestic, industrial, and municipal purposes	Furnish water; store water; appropriate, acquire, conserve water; operate water rights, works, property, rights, and privileges to convey, supply, store, or make use of water; sell water; establish rules and regulations for the sale, distribution, and use of water; restrict the use of water during water shortages; fix and collect water rates; and issue bonds.	Replenish groundwater supplies within the district: Buy and sell water; Exchange water; Distribute water to persons in exchange for ceasing or reducing extractions; Spread, sink and inject water into the underground; Store, transport, recapture, recycle, purify, treat or otherwise manage and control water for the beneficial use of persons or property within the district; Build the necessary works to achieve groundwater replenishment.	Contract with the US, State of CA and other entities for purchase, sale, acquisition of water supply. Acquire water supplies and enter into allied activities such as flood control, drainage, and generation of hydroelectric energy. Construct works including distribution systems. Contract with member units.	Provide supplemental water supply for urban Bakersfield area. Contract with KCWA for SWP water and provide to retail water purveyors; water conveyance, recovery, treatment, monitoring.
Monitoring	Generally for the purpose of managing water operations, accounting and charges	Generally for the purpose of managing water operations, accounting and charges	Generally for the purpose of managing water operations, accounting and charges and monitoring groundwater	Collects, interprets and reports groundwater data for San Joaquin Valley and Indian Wells Valley basins	Groundwater level monitoring and reporting; usage reported; annual report on water conditions
Demand Management	No express extraction limitation powers within the enabling legislation.	No express extraction limitation powers within the enabling legislation.	May levy a groundwater replenishment assessment upon the production of groundwater to fund replenishment programs; conservation programs	Education and outreach, including water conservation	Education and outreach
Projects	Typically conveyance, storage, supplemental water	Typically conveyance, storage, supplemental water	Projects aimed at preserving and/or replenishing groundwater	Conveyance facilities, flood control; also see ID4	Conveyance, water treatment, groundwater recovery, facilities, associated energy facilities
Fee	Charges/standby charges allowed	Charges/standby charges ($10/acre) allowed	Charges and replenishment assessments	Ad valorum tax, special assessments in zones of benefit, contracts with member units for surface water	Zone of Benefit No. 7 tax; groundwater charges: ag ($18/AF), other ($36/AF), small ($36 flat rate)
Governance	5-13 directors; divisions can be considered post formation	5 Directors; divisions can be considered post formation	5 Directors/5 Divisions	7 Directors/7 Divisions	KCWA- 7 Directors/7 Divisions
Link	http://leginfo.legislature.ca.gov/faces/codes California Water Code Section 34000	http://leginfo.legislature.ca.gov/faces/codes California Water Code Section 30000	http://leginfo.legislature.ca.gov/faces/codes California Water Code Section 60000	http://www.kcwa.com	http://www.kcwa.com

Table 4. Water Agency Options, continued

	Fox Canyon Groundwater Management Agency	Orange County Water Agency	Pajaro Valley Water Management Agency
Location	Ventura County	Orange County	Santa Clara, Monterey, San Benito Counties
Enabling Legislation	1982 Special Legislation	1933 Special Legislation	1984 Special Legislation
Formation Process	Legislator Sponsorship	Legislator Sponsorship	Legislator Sponsorship
Purpose and Powers	Groundwater conservation through well extraction management; Ordinance and Resolutions establishing programs/rules and regulations for various basins within agency area	Purchase supplemental water for groundwater recharge; to construct, operate and maintain water production facilities; to acquire water rights and spreading facilities to replenish and protect the groundwater supply	Formed to efficiently and economically manage existing and supplemental water supplies in order to prevent further increase in, and continuing reduction of, long-term overdraft.
Monitoring	All extraction facilities registered, metered and reported on semi- annually	Extensively monitored and metered	Water Metering Program requires meters on all water extraction facilities pumping more than 10 afy. Presently, approx. 800 extraction facilities are metered.
Demand Management	Extraction limitation and reduction schedule are calculated and established; Non-compliance: fees and/or petition court to prohibit use of well (injunction).	A basin production percentage is calculated for major producers (see annual Engineer's reports); equity assessments charged if exceeded; smaller (less than 25 AFY) exempt; Conservation programs	Conservation programs
Projects	Limited to scientific/ hydrogeological to manage basin; no major capital facilities/projects	Imported water, recharge, recycled water projects; reservoirs	Managed aquifer recharge and recovery facility; recycled water; storage and conveyance
Fees	$4.00 per acre foot per well; no fee for permit	Combination of ad valorem taxes and water use assessments; replenishment assessment based on amount of overdraft (varies for each major producer)	Metered Users - Outside Delivered Water Zone $170/AF, Inside Delivered Water Zone $205/AF Unmetered Users (Rural Residential)
Governance	5 member Board: County rep, Farm rep, United Water Conservation District rep, one rep for the 5 cities, one rep for 7 small water districts	10 member Board/divisions: 7 elected, 3 are appointed by the city councils of Anaheim, Fullerton and Santa Ana	Seven-member Board of Directors
Link	www.fcgma.org AB-2995 – FCGMA Act, Uncodified (Water Code Appendix) (not found online)	www.ocwd.com http://www.ocwd.com/Portals/0/Pdf/ocwd_district_act.pdf	http://www.pvwma.dst.ca.us/ http://www.pvwma.dst.ca.us/about-pvwma/assets/agency_act_assets/Agency%20Act%20-%202009_Act%20760.PVWMA.pdf

Source: Revised from San Luis Obispo County Flood Control & Water Conservation District, 2013 "Special District Comparison," boundaries of cities and local agencies, incorporation of new cities, and formation of special districts (CALAFCo, 2013). With the exception of Improvement Districts, the expansion and creation of water districts are regulated by LAFCo. Proponents of a proposed district submit an application to LAFCo; requirements may include a:

- Fiscal study
- Financial plan
- CEQA environmental study
- Water management plan
- Infrastructure capacity study
- Negotiation with other agencies

LAFCo's consideration of the application will include:

- Consistency with general plan or specific plan
- Performance of the same or similar functions in a common territory (duplication)
- Economic feasibility of the formation
- Present needs
- Territory shall be annexed only if agency has or soon will have the capability to provide the requested service
- Change in sphere of influence
- Proposal shall document present and planned land uses
- Present and probably need for public facilities and services in the area
- Present capacity of facilities and adequacy of public services agency provides
- Existence of social or economic communities of interest
- Projected capital facilities and needs of capacities
- No hearing until compliance with CEQA
- Whether annexation or incorporation would allow or lead to conversion of prime agricultural land or other open space land.

General Act Districts

The State Water Code does not provide for a generic district for the purpose of groundwater management. However, it does provide for about 20 types of local agencies with authority to provide water, and many of these have some authority to manage groundwater. For example, a Water Replenishment District is authorized to establish groundwater replenishment programs and collect fees for that service, including importation and use of surface water in lieu of groundwater to enable groundwater storage to be replenished by natural recharge. Water Conservation Districts can levy groundwater extraction fees. These General Act Districts are limited to respective authorities granted to them under the applicable act. The lack of authority to regulate groundwater pumping is recognized as a shortcoming of such districts in addressing overdraft (Bachman, 2005), as is their typical limited jurisdiction in a geographic sense.

Review of the purpose and powers of the California Water District, County Water District, and Water Replenishment District in Table 4 indicates that each would have broad powers to bring water supply to Indian Wells Valley. The Replenishment District, intended for recovery of overdrafted basins, has an explicit goal of replenishing groundwater. Only one has been established, namely the Water

Replenishment District of Southern California in 1959. Among the three General Act Districts, a major difference concerns the definition of qualified voters for the formation of a district and selection of directors. County Water Districts and Replenishment Districts are based on registered voters within the boundaries (i.e., one vote per voter). California Water District elections are based on one vote for each dollar's worth of land, and thus are most applicable to agricultural areas.

IWVWD is a County Water District, established pursuant to the County Water District Law with the purposes and powers summarized in the Table 4. IWVWD has the authority to establish an Improvement District to undertake projects, including financing, which may involve charges and taxes levied in the Improvement District. As a County Water District, IWVWD does not have express powers to regulate groundwater extraction. However, because IWVWD adopted the AB3030 Management Plan, it may exercise many of the powers of a Groundwater Replenishment District. These powers include the power to levy a groundwater replenishment assessment on the production of groundwater in order to fund a groundwater replenishment program.

With regard to governance and community representation, IWVWD directors are local residents, voted to four-year terms by registered voters within IWVWD. While having broad water management powers, IWVWD encompasses only 38 of the 597 square miles of the basin (6 percent), providing water to the City but not to NAWS, Searles Valley Minerals, or most of the basin agriculture or domestic wells. If IWVWD were to undertake a supplemental water supply project, its current limited jurisdiction and service area represent a significant limitation on the size of a project, the distribution of benefits across the basin, and equable funding ability. While IWVWD has expanded in the past, acquiring small water systems, expansion sufficient to manage a major supply project would likely entail major reorganization and extension of boundaries. LAFCo review and approval would be needed.

Special Act Districts

Local circumstances may not be served adequately by a general act district. In such a case, the State legislature can create a Special Act District tailored to the specific needs of an area. Such districts typically are regional, with special governing requirements, unique services or special financing. The Legislature has created (through specific legislation) approximately 13 Special Act Districts with substantial authority to manage groundwater. Most of these agencies have the authority to limit export and to control some in-basin extraction upon evidence of overdraft or threat of overdraft.

As summarized in Table 4, KCWA is a Special Act agency. It was not formed initially for groundwater management (its major purpose was to contract for State Water Project water); however it has obtained significant groundwater management authority directly from the Legislature. With seven elected directors representing seven respective districts, KCWA has jurisdiction throughout Kern County. Based on its special enabling legislation, it has the ability to contract with the US, State of CA and other entities for purchase, sale, or acquisition of water supply; acquire water supplies and enter into allied activities such as flood control, drainage, and generation of hydroelectric energy; construct works including distribution systems; and contract with member units. It has the capability for funding through water sales, levy of taxes, and special assessments in zones of benefit that it establishes, such as Zone 7 in Improvement District No. 4.

Table 4 also summarizes Improvement District No. 4, which was established by KCWA. Although not having any authority in Indian Wells Valley, it represents a potential template for groundwater management and development of supplemental supply, with capabilities for funding. Its powers include levying and collecting groundwater charges for water-related benefits, use of those funds for water import and recharge, registration of wells, and collection of groundwater production data. It was formed by a resolution of the KCWA Board. Such a resolution is a detailed document that represents significant planning and community discussion. It not only states the intent to form an improvement district, but also defines its boundaries (parcel by parcel), describes the purpose (i.e., the water project) for which the district is formed, provides an estimate of costs, identifies means of financing, and sets the time, date and place for a public hearing. The improvement district is subject to approval by voters. Its directors are the KCWA Board, advised by an appointed committee of water purveyor representatives.

The representation of a KCWA Improvement District is important to consider for Indian Wells Valley, because six of the seven KCWA directors represent divisions that are distant and quite different from Indian Wells Valley. Moreover, the KCWA Board meetings are held in Bakersfield, a two-hundred-mile round trip from Ridgecrest. Should the Indian Wells Valley community wish to consider a KCWA improvement district, its initiation would involve a resolution of the KCWA Board of Directors. Given the limited representation of Indian Wells Valley on the KCWA Board, such a resolution is at best uncertain.

A new independent and local Special Act District could be established. Special Act Districts are formed by action of the Legislature, which extends to the agency the specific powers expressed in its authorizing act. Some Special Act water agencies have the authority to control in-basin groundwater extraction upon evidence of overdraft or the threat of overdraft. These agencies generally can levy fees for groundwater management activities and replenishment. Typically, these agencies are governed by an independent board of directors with 5 to 7 members. The selection method of the board members varies; they may be appointed, elected, or a combination of the two. The powers and organization of Special Act Agencies are customized to the local area; examples of several Special Act Districts are provided in Table 4.

For Indian Wells Valley, formation of a Special Act District provides several important advantages: the likelihood of having the needed powers to develop supplemental supply, manage water demand, and fund or finance projects; local and equable representation of stakeholders; and the possibility of defining a district extent that encompasses Indian Wells Valley groundwater basin and also Salt Wells Valley and Searles Valley basins.

Role of AB3030 Management Plan

The Water Code (Section 10750 et seq., known as AB3030) authorizes local water agencies to adopt a Groundwater Management Plan plus rules and regulations to enforce such a plan. The Indian Wells Valley Cooperative Groundwater Management Plan was prepared and signed by multiple organizations (including IWVWD) in 1995 with subsequent revisions. An agency that adopts a Groundwater Management Plan pursuant to AB 3030 has some of the powers of a Water Replenishment District; it may impose equitable annual fees and assessments for groundwater management based on the amount of groundwater extracted from the groundwater basin within the area included in the plan. However, before a local agency can impose fees and assessments, the local agency must hold an election on the matter and a majority of votes cast must be in favor. An agency that adopts a Groundwater Management Plan pursuant to AB 3030 also has the authority to limit or suspend extractions if it is determined through study and investigation that the groundwater replenishment programs or other alternative sources of water supply have proved insufficient or infeasible to lessen the demand for groundwater.

With limited exceptions, an agency cannot engage in groundwater management planning pursuant to AB 3030 within the service area of another local agency. Accordingly, basin-wide management through an AB3030 Plan would involve development of a Memorandum of Understanding (MOU) among organizations or a Joint Powers Agreement (JPA) among local agencies. It is noted that Joint Powers Authorities can only exercise powers that are common to the member agencies. Accordingly, JPAs are commonly used in basins with multiple water districts with similar powers and a need for close coordination.

Indian Wells Valley has long had an active, collaborative groundwater management plan. While its voluntary basis is inadequate in itself to support major water supply projects, the groundwater management plan should continue to be a central element of local water resource planning and an inclusive forum. It should be strengthened and updated as an AB3030/SB1938 plan, including compliance with the 2011 Assembly Bill 359, requiring delineation of recharge areas. The Groundwater Management Plan document should be updated with the current understanding of the basin hydrogeology, water balance, and current conditions. This should form the basis for review of basin management objectives, prioritization of actions, and development of an implementation plan. While the role of the Technical Advisory Committee is recognized, a policy or steering committee should be considered to promote the inclusion of stakeholder groups, including agriculture and domestic well owners.

7. Evaluation of Alternatives

Solving the overdraft problem in Indian Wells Valley will require items from each of three categories: physical measures to eliminate the imbalance between existing demand and supply, management measures to minimize future increases in agricultural water demand, and an agency with the appropriate powers and local focus to implement those measures. All of the measures explored in the previous section could contribute toward a solution, and each one has uncertainties regarding yield, logistical feasibility, institutional feasibility and cost. Based on limited available information, some appear more promising than others and are described below.

7.1 Physical Measures

Imported water is essential if overdraft is to be eliminated while retaining existing land uses. Even if all of the local conservation and supply options were implemented, a substantial imbalance between supply and demand would remain. This can be seen from the numbers in **Table 5**, which summarizes the yields, costs, advantages and disadvantages of each of the physical management measures. If the water budget imbalance is to be addressed primarily by importing water, then the sources of imported water will need to include more than the Butterworth Ranch in Inyo County. Local demand reduction or supply augmentation projects are worth pursuing in addition to imports if they are reasonably comparable in terms of cost-effectiveness for reducing overdraft. Funding to support a water importation project may be easier to obtain if all reasonable local water resource options have already been implemented.

A pipeline and water treatment plant would be the most reliable way to deliver imported water for municipal use in Indian Wells Valley. They would retain the high quality of aqueduct water and be able to deliver the water almost entirely by gravity. Percolation of aqueduct releases along Little Dixie Wash merits consideration for supplemental groundwater recharge in wet years or months when the supply of relatively low-cost imported water exceeds local municipal demand.

Table 5. Comparison of Physical Management Measures

Management Measure	Yield (AFY) Increase Current Supply	Yield (AFY) Decrease Current Demand	Capital Cost ($ million)	Unit cost ($/AFY)	Advantages	Disadvantages and Uncertainties	Additional Information Needed
Redistribute pumping	0	0	Med	Med	Delays overdraft impacts.	Does not improve water balance.	
Groundwater demineralization	0	0	24[a]	900[a]	Delays overdraft impacts.	Does not improve water balance.	Permissability of brine disposal at G-1 Seep or China Lake playa.
Urban water conservation	0	2000	Low	Med	Can be implemented incrementally. Increases public awareness of water scarcity. Possible prerequisite for obtaining imports or funding assistance.		Cost-effectiveness of conservation options, particularly for urban irrigation use.
Agricultural water conservation	0	800-3,000	Low	Low	Potentially large savings for modest investment.	Grower cooperation is necessary but presently uncertain.	Grower interest/concerns.
Wastewater recycling	800		Med	Med-High	Recovers local water presently lost to evaporation.	Requires integrated and concurrent modification of WWTP pond operations, tui chub habitat and alfalfa fields near former City WWTP site.	An approved design for tui chub habitat enhancement. WWTP reoperations analysis. Cost estimates for all elements.
Imported Water							
Butterworth Ranch	900	0	Low	Low	IWVWD already owns the ranch. Wheeling the water would not degrade Los Angeles Aqueduct water quality.	Export from Owens Valley likely to face political opposition. Not a large enough yield to be a stand-alone import project.	Willingness of Inyo County to approve the export. Willingness of LADWP to wheel the water.
Antelope Valley Water Bank	25,000	0	?	?	AVWB is the nearest large, existing water bank. Antelope Valley East Kern Water Agency already sells raw water to other agencies.	To wheel the water to IWV using the Los Angeles Aqueduct, an intertie between the LAA and AVEK's facilities would need to be constructed.	Yield and availability of AVWB water. Cost and feasibility of wheeling the water to IWV.
SWP/CVP/spot market/private	25,000+	0	30	350[b]	Very large potential source. IWV could take advantage of its own storage capacity to purchase water in wet and normal years when it is cheaper and more available.	Competition with many other buyers shopping for water. Unknown future price and total cost.	Willingness of LADWP to wheel the water. Cost and availability of water from various external sources.
Groundwater banking	800	0	Low	Low	The cost would be borne entirely by external entities operating the bank.	Little yield benefit. Main basin banking problematic due to water quality and pumping lift. El Paso subarea banking feasibility uncertain and benefit to main basin users would be delayed.	LADWP preliminary assessment of IWV banking potential.

Notes:
[a] Assume discharge of RO/EDR brine to G-1 seep is permitted. Brine concentration and evaporation pond not needed.
[b] Median spot market price (about $150/AF) plus amortized pipeline and treatment plant in IWV ($200/AF).

7.2 Planning and Legal Measures

Management measures that restrict land use and/or well construction are the most appropriate strategy for minimizing the risk of large future increases in agricultural water use. Each of the zoning/planning/ordinance/legal management measures explored in the previous section would theoretically be capable of eliminating the entire 130,000 AFY risk. However, some are relatively untested concepts and others could raise takings issues. The recommended measures are:

- Consider the adoption of an urgency ordinance to prevent overdraft from becoming worse while a management agency is being established and a water importation project is planned, designed and constructed. The ordinance could either limit new irrigated acreage (the San Luis Obispo County approach) or limit installation of large new wells (the San Bernardino County approach). After 50 years, overdraft might not seem like an "emergency", but it is a serious problem that has not been widely recognized by decision-makers. The duration of the ordinance would need to be at least two years, and probably longer. Any such ordinance would need legal advice from County Counsel on the feasibility, parameters and legal exposure.
- Continue with the development of a specific plan for Indian Wells Valley. The planning process commenced with the community visioning exercise in 2011. A specific plan is the logical vehicle for implementing changes in land use management.
- Up-zone some or all parcels in the area of potential irrigated cropland expansion from an agricultural category to large lot residential, low impact industrial or use for solar energy. . Up-zoning could reduce the potential for exacerbating future overdraft with minimal risk of takings issues.

Basin adjudication is not recommended. It would add tremendous delay and expense and probably end up with an outcome similar to the recommendations in this report. Legal injunction against large new wells based on prior prescriptive water rights could be explored as an interim measure.

7.3 Institutional Options

The agency selected to perform the physical measures and collaborate for the management measures needs to have certain basic characteristics. These are summarized in **Table 6** along with the types of agencies considered for Indian Wells Valley. As noted, most of the agencies have at least one limitation in terms of its powers or its representation. A water replenishment agency may be a possibility, but it is noteworthy that only one has been created (in the Los Angeles metropolitan area) and may not be a good model. A special act district—not yet defined—does not have limitations; this indicates the greatest potential to achieve all of the characteristics needed for effective water management in Indian Wells Valley.

Table 6. Evaluation of Agency Options

	Authority to acquire supplemental supply[1]	Authority to regulate groundwater pumping[2]	Authority to fund and finance projects[3]	Provides equable local governance and representation	Comments
County Water District	√		√	√	A new, areally-extensive district could be formed with LAFCo review; potential duplication of functions with IWVWD would be an issue.
Indian Wells Valley Water District	√		√	√	Existing County Water District, with limited service area. Expansion would entail major reorganization and would need approval of LAFCos.
California Water District	√		√		Representation is not appropriate for urban/rural basin; based on land value, not one vote per voter.
Water Replenishment District	√	√	√	√	Has a specific purpose of groundwater replenishment; only one exists- WRD of Southern California
Special Act District	√	(√)	√	√	Formed through Legislative sponsorship, powers and representation to be defined
KCWA Improvement District	√		√		Formed and governed by KCWA Board of Directors in Bakersfield. Local representation is limited to advisory committee.

1 Generally the powers to acquire, plan, construct, maintain, improve, and operate the necessary works for the production, storage, transmission, and distribution of water for irrigation, domestic, industrial, and municipal purposes.

2 Powers to permit and/or meter production wells, levy groundwater assessments and/or limit extraction; adoption of an AB3030 Groundwater Management Plan provides authority to limit extractions under specific circumstances.

3 Various powers to fund and finance projects and programs; e.g., charges/standby charges, taxes, assessments.

8. Next Steps

The following tasks should be initiated and to the extent possible completed within the next two years. They can be worked on concurrently in a coordinated effort. The primary leadership during this phase will need to come from the Board of Supervisors, the Kern County Planning & Community Development Department, Kern County Water Agency, and Indian Wells Valley Cooperative Groundwater Management Group (CGMG). CGMG can also serve as an open forum for local stakeholder participation during the planning process. The local water management agency established during this phase can provide most of the leadership needed in subsequent years.

Consider Preparation of an Urgency Ordinance

The Kern County Board of Supervisors should direct its staff in the Planning & Community Development Department and County Counsel to prepare a feasibility report for consideration of a draft urgency ordinance capable of preventing large increases in groundwater pumping until long-term management measures are put into place.

Develop a Water Management Agency

The Kern County Planning & Community Development Department—working collaboratively with legal counsel, LAFCo, Kern County Water Agency, Indian Wells Valley Water District, Inyo and San Bernardino Counties, and local stakeholders—should identify the preferred type of agency for managing groundwater, imported water and water demand in Indian Wells Valley. Whether the preferred option is a new agency or expansion of jurisdiction and authority of an existing agency, the general steps for creating the agency include the following:

- Investigate the need for a new agency and evaluate options
- Define the boundaries, authorities and services of the agency
- Define agency governance and financing
- Obtain approval from LAFCo, County Supervisors and State legislators
- Obtain approval from voters and ratepayers
- Complete LAFCo procedures to start the new district

Acquire Imported Water

The Kern County Board of Supervisors should apply its influence to initiate a regional interagency effort to plan and implement a water importation project. This process will certainly involve LADWP and probably involve MWD, the State Water Project, Central Valley Project and state-level elected officials, in addition to a local team consisting of the Planning & Community Development Department, Kern County Water Agency and Indian Wells Valley CGMG.

Pursue Local Conservation and Supply Projects

The Indian Wells Valley CGMG should evaluate the cost-effectiveness and feasibility of additional local measures to reduce water demand and supplement water supply. Additional studies needed for those projects were roughly outlined in the section on "Management Alternatives". CGMG members should begin implementing measures identified by those studies as cost-effective in conjunction with water imports.

Complete a Specific Plan for Indian Wells Valley

The Kern County Planning & Community Development Department should continue the Indian Wells Valley Resource Opportunity Planning process, and to regulate land use to reduce future water demand within the context of a specific plan.

Strengthen Current Water Management Planning

The CGMG, or other such cooperative group formed and supported by the Kern County Board of Supervisors, needs to continue its functions of monitoring and reporting, promoting water conservation, and optimizing local groundwater pumping. The Group needs to maintain its forum for discussion of water management issues; this is vital to community agreement on the state of the groundwater basin and on the institutional, physical and management measures needed to resolve overdraft. Establishment is advised of a policy or steering committee that represents all major stakeholder groups. Topics of discussion will need to include the findings of this report. Update of the Groundwater Management Plan is advised; this is not only an important planning process, but compliance with the water code supports eligibility for funding. As representatives for local water management, the Group should provide its input to the Board of Supervisors.

Obtain Funding

Funding possibilities, including grants and loans, should be investigated to support the above actions. For example, the California Department of Public Health (CDPH) has a Pre-Planning and Legal Entity Formation Assistance Program, which provides grant funds to assist with the formation of a legal entity (e.g., water agency). Other grant and loan programs are available at least periodically for planning, design and construction of water projects. CGMG may need to update the groundwater management plan to qualify for some sources of State funding.

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A. Water Balance Details

This appendix presents the average annual water balance of Indian Wells Valley groundwater basin as of 2013. A water balance is an itemized tabulation of all inflows and outflows to and from a basin. Any difference between total inflows and total outflows is balanced by a change in groundwater storage. Previous estimates of each item are critically reviewed and new or updated information is introduced in a few instances to obtain the best current estimate. The amount of uncertainty in the estimates varies from item to item. Accordingly, some estimates are presented as a range of values that is considered most likely.

The inflows, outflows and storage changes described below reflect a “closed basin” conceptual model. Previous studies have used that term to refer to the assumption that all inflows to the basin derive ultimately from precipitation falling on watersheds tributary to Indian Wells Valley. By the same token, there are assumed to be no significant flows of water out of the basin into adjoining ones. An alternative concept termed the “open basin” hypothesis was proposed in the 1980s and 1990s which asserted that substantial amounts of additional inflow enters the groundwater basin from west of the Sierra Nevada crest (that is, from outside the local watershed). Subsequent studies discredited the data and analysis used to support the hypothesis. A critical review of the open-basin hypothesis and subsequent studies follows the water balance section below, along with a description of recent data that are also inconsistent with the open basin hypothesis.

A.1 Inflows

A comparison of estimated water balances from previous studies is complicated by the fact that those studies lumped and split inflows and outflows differently. **Table A-1** summarizes estimates of groundwater recharge to the principal aquifer in Indian Wells Valley presented in previous studies. Most of the estimates are for predevelopment conditions, and natural sources of recharge have generally been assumed to remain the same as under predevelopment conditions. At the bottom of the table are estimates of each source of recharge that reflect current basin conditions and critical review of prior estimates.

Rainfall Recharge on Valley Floor

Average annual rainfall on the valley floor in Indian Wells Valley is less than 5 inches (Tetra Tech, 2003). All previous studies have concluded that deep percolation of rainfall through the soil zone on the valley floor is zero or negligible, and that item is not included in the table.

Table A-1. Previous Estimates of Recharge to the Principal Aquifer in Indian Wells Valley

Data Source	Surface Drainage from Sierra Nevada	Surface Drainage from Coso Range	Surface Drainage from Argus Range	Surface Drainage from El Paso Mountains	Geothermal Leakage (upwelling)	Subsurface Inflow from Sierra Nevada Bedrock	Inflow from Rose Valley	Leakage from Los Angeles Aqueduct	Leakage from IWVWD Water Distribution System	Irrigation Deep Percolation (agric. and muni.)	Wastewater Pond Percolation	Total Recharge
Lee (1913)[a]	27,000				----	----	----	----	----	----	----	----
Thompson (1929)	39,000				----	----	10,000	----	----	----	----	49,000
Kunkel and Chase (1969)	----	----	----	----	----	----	----	----	----	----	----	11,000 to 15,000
Bloyd and Robson (1971)	6,235	3,160		400	----	----	45	----	----	----	----	9,850
Dutcher and Moyle (1973)	----	----	----	----	----	----	----	----	----	----	----	11,000
St. Amand (1986)	----	----	----	----	----	----	----	----	----	----	----	11,000
Austin (1988)	at least 30,000	----	----	----	1,000 to 10,000	----	----	4,000	----	----	----	----
Bean (1989)	6,300	2,000	1,000	400	100	2,500	400	900	500	----	1,000	15,100
Berenbrock and Martin (1991)	6,236	3,170		400	----	----	46	----	----	100	1,001	10,996
Watt (1993)	8,876	975		0	----	----	----	----	----	----	----	----
Thyne and others (1999)	8,026	----	----	----	----	34,100	1,297	----	----	----	----	----
Bauer (2002)	----	----	----	----	----	----	3,300	----	----	----	----	----
Brown and Caldwell (2009)[c]	5,890	300	1600	50	----	----	1,000	----	----	----	----	8,521
This report[d]	3,090 to 5,890	300	1,600	50	0	0	1,000	0	80	1,600 to 2,100	0	7,700 to 11,000

Notes:

--- Recharge component was not evaluated or specifically presented in report.

a Recharge estimates by Lee (1913) as reported in Bean (1989).

b Sierran mountain front recharge and inflow from Coso Range adjusted downward from 9,500 AFY and 500 AFY, respectively, during model calibration.

c The sum of the items reported in the text (8,840 AfY) is 319 AFY greater than the total listed in Table 5-1 of the report.

d If the only remaining playa discharge from the principal aquifer originates from the Coso and Argus Ranges, simulated playa ET in the Brown & Caldwell model (4,700 AFY as of 2006) is too high by 2,800 AFY and recharge from the Sierra Nevadas would need to be decreased by the same amount to recalibrate the model. Irrigation deep percolation and wastewater pond percolation are estimated only for areas beyond the extent of the shallow aquifer.

Mountain Front Recharge from Sierra Nevada Watersheds Tributary to Indian Wells Valley

The southern tip of the Sierra Nevada adjoins the western edge of IWV basin from Rose Valley to the southwestern lobe of the basin known as the El Paso subarea. The conceptual model of mountain front recharge is that direct runoff and infiltration occur at high elevations, where precipitation is greater and evapotranspiration (ET) is smaller than at lower elevations. For example, one recent study selected an elevation of 4,500 feet above sea level as the threshold at which significant amounts of rainfall recharge begin to appear. Above the threshold elevation, Infiltrated rainwater or snowmelt flows through relatively shallow subsurface pathways and mostly discharges as base flow in streams that flow out of the mountains into the basin. After leaving the steep bedrock canyons, all of the base flow percolates and recharges the groundwater basin. Direct subsurface inflow to the basin via subsurface fractures might occur but is probably much smaller than stream base flow. There are some losses to ET by vegetation along the creek channels, but those are small compared to total stream flow and groundwater recharge. Occasional large storm events generate surface runoff that flows all the way to China Lake playa (and the nearby, smaller Satellite Lake and Mirror Lake playas), where the water evaporates. These flows are not gauged, however.

Most previous studies estimated mountain front recharge by assuming that it was equal to playa ET under predevelopment conditions. This approach implicitly assumes that other sources of recharge are negligible and that mountain front recharge has not changed significantly since predevelopment times. The most detailed calculation of playa ET was developed by Kunkel and Chase (1969) based on historical vegetation maps, plant-specific ET factors, historical water table contours and functions relating ET to water table depth. Their estimate for predevelopment conditions (1912) was 11,000 AFY. Their estimate for 1953 was 8,000 AFY, and the decrease was attributed to interception of discharge by wells. A groundwater model developed shortly thereafter cited the Kunkel and Chase study as the source of the mountain front recharge estimate (Bloyd and Robson, 1971). However, for reasons that were not stated, predevelopment recharge in the model was only 9,850 AFY. Two subsequent groundwater models retained the same estimate of recharge, but the more recent one decreased it to 7,500 AFY to improve model calibration (Berenbrock and Martin, 1991; Brown and Caldwell, 2009).

Playa ET equals the sum of mountain front recharge from all of the surrounding mountains. Kunkel and Chase (1969) did not subdivide their recharge estimate, but 4,000 AFY (37 percent) of their tabulated predevelopment playa ET was in vegetation zones on the north and east sides of the playa. Those regions would presumably be supplied by mountain front recharge from the Coso and Argus Ranges, while the remainder of playa ET (approximately 7,000 AFY) would be supplied by Sierra Nevada recharge. Bean (1989) and Berenbrock and Martin (1991) respectively assigned 6,300 AFY (67 percent) and 6,236 AFY (64 percent) of total mountain front recharge to the Sierra Nevada. The most recent groundwater model estimated that mountain front recharge from the Sierra averages 5,890 AFY and recharge from the Coso and Argus Ranges averages 1,900 AFY. These amounts and proportions were obtained in part by model calibration.

The Brown & Caldwell groundwater model might overestimate mountain front recharge from the Sierra. A more recent study revealed consistently downward water-level gradients between the shallow aquifer and principal aquifer along the south and southwestern sides of China Lake playa (TriEcoTt Joint Venture, 2012). This implies that wells now intercept all recharge originating from those directions. A pumping trough associated with irrigation wells along Brown Road probably similarly intercepts any remaining mountain front recharge from the Sierra. The only remaining source of playa ET would be the 1,900 AFY of mountain front recharge from the Coso and Argus Ranges. Note that WWTP pond percolation and irrigation deep percolation on NAWS accrue to the shallow aquifer and support some additional playa ET. However, that flow does not pass through the principal aquifer, which is the focus of the recharge estimates in the table. Simulated discharge of groundwater from the principal aquifer steadily decreased throughout the calibration simulation, but it was still 4,700 AFY in the final year of the simulation (2006). If playa ET is actually only 1,900 AFY, then the simulated rate in the model is 2,800 AFY too high. Because models maintain conservation of mass, recharge would also be too high by the same amount. Revising the model to decrease playa ET and recharge by 2,800 AFY would decrease the estimate of Sierra Nevada mountain front recharge to 3,090 AFY. This alternative water balance is reasonable but uncertain, and it has not been tested using the model. Accordingly, the current best estimate of Sierra Nevada mountain front is shown as a range: 3,090 to 5,890 AFY.

Inflow from Rose Valley

Rose Valley is a small basin northwest of Indian Wells Valley that—under wetter conditions over 10,000 years ago—was part of a river system that flowed from Owens Valley through Rose Valley and Indian Wells Valley to Salt Wells Valley, Searles Valley and ultimately Death Valley. Surface flow between the basins now occurs rarely, if ever. However, there is the possibility of some groundwater flow from Rose Valley to Indian Wells Valley. This subsurface flow is obstructed by geologically recent basalts, which force most of the groundwater to the surface as it crosses between basins. This rising groundwater forms Little Lake, a perennial lake on the north (upgradient) side of the basalt barrier. The most completely documented study of groundwater flow from Rose Valley to Indian Wells Valley was by Bauer (2002), who equated the flow to the maximum surface flow he recorded in a series of road culverts that cross the outlet stream of Little Lake. However, his estimated average annual outflow of 3,300 AFY is probably too high for the following reasons:

- His measurements were all made during 1997 and 1998, which were wet years. In fact, 1998 annual rainfall was in the 80th percentile at Haiwee Reservoir, the 88th percentile at Independence, and the 92nd percentile in the upper Kern River watershed. A longer study period that includes a representative selection of year types would be needed to accurately estimate average annual stream base flow.
- He calculated annual discharge assuming the flow on each measurement date continued all year. Six of the seven measurements were in mid-winter to early summer, which is the season of maximum stream flow. Those values are higher than the average for all seasons.
- He omitted the smallest measured flow when calculating the average.
- The method of stream gauging was not described. Given that the flow was measured at culverts and was slightly larger than could be measured with a bucket and stopwatch, it is plausible that the centerline surface velocity of the flow was taken as the average velocity. Because of boundary friction effects, the centerline surface velocity is the maximum velocity and generally much larger than the average velocity.
- The flow at North Culvert decreased by two-thirds from June 1 to July 2, 1997. That percentage of decrease over the span of one month is unlikely for spring base flow recession and very improbable for groundwater discharge from an entire basin. This

raises questions regarding the accuracy of the flow measurements and certainly the assumption that each measurement is representative of average annual flow.

Further evidence that inflow from Rose Valley is not appreciably different from recharge along the rest of the western basin boundary is that water levels in a monitoring well close to Rose Valley (USBR MW-10) have been declining at a rate similar to other wells in the western part of the basin. If there were a large amount of localized inflow from Rose Valley, MW-10 would decline by a smaller amount or not at all.

Other previous estimates of inflow from Rose Valley have mostly been in the range of 45-1,300 AFY (Table A-1). Although the basis and accuracy of those estimates are vague, the range of values is at least plausible given that Bauer's estimate appears high. The estimate of 1,000 AFY used in the Brown and Caldwell model is retained as the current best estimate of inflow.

Mountain Front Recharge from Coso, Argus and El Paso Ranges

The Coso and Argus Ranges abut the northern and eastern boundaries of Indian Wells Valley basin, respectively. Many previous studies reported a single estimate of recharge from both ranges combined. Based on the smaller amount of rainfall in those mountains (compared to the Sierra Nevada) and on model calibration, recharge estimates were 32-51 percent as large as estimated mountain front recharge from the Sierra Nevada. The most recent estimate of 1,900 AFY is from the Brown and Caldwell groundwater model and is retained here as the best current estimate. Several reports noted that recharge from the Coso and Argus Ranges is inaccessible to wells near Ridgecrest because of the intervening clay deposits and saline groundwater beneath the China Lake playa.

All previous studies have agreed that any mountain front recharge originating from the El Paso Mountains is relatively small, with estimates ranging from 0 to 400 AFY. The estimate of 50 AFY used in the Brown and Caldwell model is retained as the best current estimate.

Recharge from Percolation of Wastewater and Applied Irrigation Water

Ridgecrest and NAWS share a wastewater treatment plant (WWTP) that was designed to dispose of water by evaporation and percolation from approximately 200 acres of storage ponds located on NAWS south of the China Lake playa. Inflow to the WWTP was 2,600-2,900 AFY during 2005-2012. Multiplying pan evaporation in Trona (9.2 ft/yr) by a pan-to-lake coefficient of 0.8 and the wetted area of WWTP ponds in 2012 (182 acres) yields an estimate of 1,350 AFY of pond evaporation. Recycled water from the WWTP is used for irrigation: 748 AFY on the NAWS golf course and 224 AFY on an alfalfa at the former WWTP site in Ridgecrest (Provost and Pritchard, 2011). WWTP pond percolation can be estimated by difference; in 2010 it was 630 AFY. Some of the percolated water emerges as seepage into Lark Seep and nearby drainage channels downgradient of the WWTP ponds, where additional water is lost to evapotranspiration. The remainder flows through the shallow groundwater system to China Lake playa and is consumed by evaporation. Because of the thick clay layers separating the shallow aquifer from the principal aquifer between the WWTP and China Lake playa, essentially none of the percolated water contributes to the yield of the principal aquifer.

Deep percolation beneath the root zone of crops is necessary to flush salts that accumulate from the evaporation of irrigation water. Because rainfall in Indian Wells Valley is insufficient to generate deep percolation, additional irrigation water must be applied for that purpose. A minimum of 10% applied over and above the amount needed for crop ET is probably needed to prevent excessive soil salinity (Ayers and Westcot, 1985). Also, a certain amount of applied irrigation water tends to percolate past the root zone due to non-uniformity of application, unless the crop is under-irrigated. Estimated average annual recharge to the principal aquifer from deep percolation of irrigation water is itemized in **Table A-2**. The center-pivot irrigation systems used to irrigate alfalfa fields and the drip systems used for pistachio orchards both provide relatively high uniformity. Landscaping at rural residences consists almost entirely of drought-tolerant shrubs and trees with fairly deep root systems. Air photos of parks irrigated by City of Ridgecrest wells reveal turf that appears slightly under-irrigated. For each of these irrigation situations, deep percolation is estimated for this analysis to equal 10 percent of applied water. In residential areas of Ridgecrest, lawns are common, though not universal. Irrigation uniformity is generally low on residential lawns because of their small size and irregular shapes relative to sprinkler spray patterns. Deep percolation is more likely to approach 20 percent of applied water in those situations. Total irrigation return flow to the primary aquifer is 1,600 to 2,100 AFY.

Table A-2. Recharge to the Principal Aquifer by Deep Percolation of Irrigation Water in 2013

Irrigation Location	Average Annual Applied Water (AFY)	Percent Deep Percolation	Estimated Deep Percolation (AFY)[1]
Alfalfa[2]	7,900	10%	790
Pistachios[3]			
Young trees	300	10%	30
Mature trees	2,200	10%	220
Rural residences[4]	620	10%	60
IWVWD and Inyokern CSD	5,000	10% to 20%	500 to 1,000
Ridgecrest parks	350	10%	40
NAWS[5]	---	---	0
Searles Valley Minerals[6]	---	---	0
Total			1,600 to 2,100

AFY = acre-feet per year CSD = Community Services District IWVWD = Indian Wells Valley Water District NAWS = Naval Air Weapons Station China Lake

Notes:

1 All values rounded to two significant digits.

2 Assuming 8 feet per year of water applied on the 990 acres of irrigated alfalfa present in 2013.

3 The irrigation demand at maturity of trees that were planted as of 2013 equals 12,400 AFY (5 feet/year x 2,480 acres). Most of the trees are 0-2 years old and will reach maturity at age 12.

4 Outdoor water use at rural residences is assumed to be the same percentage of total water use as for single-family homes in Ridgecrest: 62 percent.

5 Deep percolation from irrigation on NAWS accrues to the shallow aquifer and is eventually lost to evaporation at China Lake playa. It does not contribute to yield of the principal aquifer.

6 All water pumped by Searles Valley Minerals is used in Searles Valley. None of it returns to Indian Wells Valley.

A.2 Outflows

Outflow to Wells

Groundwater supplies over 95 percent of water use in Indian Wells Valley, and groundwater pumping has been the largest outflow from the basin since the 1960s. Estimated groundwater pumping for each user category is described in the section on "Water Use".

Outflow to China Lake Playa Evapotranspiration

The most thoroughly documented estimate of ET from China Lake playa under predevelopment conditions was by Kunkel and Chase (1969). Using detailed vegetation maps from 1912, published values of ET rates for each type of vegetation, mapped depth to the water table, and a function relating ET to water table depth, they estimated total playa ET of 11,000 AFY. Estimates of playa ET have decreased over time from about 11,300 AFY in 1912 to 4,700 AFY in 2006, as shown in **Figure A-1**. Some of the decrease is attributable to revised estimates of recharge based on model calibration, but most of it reflects the interception of playa outflow by wells. The estimate of 4,700 AFY of outflow in 2006 (from the Brown and Caldwell groundwater model) is less than half of the 1912 high. A recent study found that vertical water-level gradients from the shallow aquifer to the principal aquifer are consistently downward along the southern and southwestern edges of the playa (TriEcoTt, 2012). Those are the directions from which most recharge is thought to originate, and the remaining discharge from the principal aquifer would only occur on the northern and eastern sides of the playa and consist of mountain front recharge from the Coso and Argus Ranges. Those sources amount to 1,900 AFY in the Brown and Caldwell model. Thus, the estimate of playa ET in the model could be too high by 2,800 AFY (4,700 – 1,900 = 2,800).

Some playa ET derives from local recharge to the shallow aquifer, including percolation at the City of Ridgecrest WWTP disposal ponds and to a lesser extent from irrigation deep percolation at the NAWS golf course and residential areas. This water does not pass through the principal aquifer, which is the focus of the basin recharge estimates and currently the sole source of usable groundwater supply.

Subsurface Outflow to Salt Wells Valley and Searles Valley Basins

Most previous studies have considered subsurface outflow to Salt Wells Valley to be negligible. Kunkel and Chase (1969) applied Darcy's Law to estimate that 20 AFY of groundwater could flow through the former surface outlet channel of China Lake, which is now filled with sand. This estimate was subsequently used by Dutcher and Moyle (1973). All three groundwater models that have been developed for the basin have assumed no subsurface outflow to Salt Wells Valley (Bloyd and Robson, 1971; Berenbrock and Martin, 1991; Brown and Caldwell, 2009).

Groundwater levels are higher on the China Lake side of the buried bedrock ridge that separates the basins; this could indicate groundwater flow from China Lake to Salt Wells Valley. In addition, some investigators have noted a similarity in water quality between the China Lake playa area and the western end of Salt Wells Valley.. These factors have been advanced as evidence of groundwater outflow (Tetra Tech EM, 2003; TriEcoTt, 2012; Stoner, 2013). However, one must be careful when drawing conclusions about flow based on groundwater quality. Similar groundwater qualities would likely have developed during the Pleistocene, when the climate was much wetter and Indian Wells Valley and Salt Wells Valley were intermittently connected by surface flow (or even covered by one large lake). As the climate became drier during the past 10,000 years, the rate of groundwater movement decreased dramatically, preserving a "snapshot" of Pleistocene water quality.

A recent study of Salt Wells Valley groundwater included a cross section labeled with "potential fracture flow" through bedrock from eastern Indian Wells Valley into Salt Wells Valley (TriEcoTt, 2012, Figure 2-3). The 175-foot abrupt decrease in groundwater level across the buried bedrock ridge suggests that the flow must be small. However, the 70-foot decrease in groundwater elevation along the 6-mile length of Salt Wells Valley suggests that there is eastward groundwater flow in that basin, some of which could originate from inflow through bedrock fractures (in addition to local mountain front recharge).

Austin (1988) and Thyne and others (1999) suggested that groundwater might flow from Indian Wells Valley directly to Searles Lake Valley (beyond Salt Wells Valley). Erskine (1989) mentioned that there are substantial upward gradients in groundwater levels beneath Searles Lake. However, none of those studies presented any data supporting a conclusion that substantial amounts of groundwater flow occurs through 10 miles of bedrock from Indian Wells Valley to Searles Lake Valley.

On balance, it appears that the estimate of 50 AFY or less of outflow to Salt Wells Valley is probably the right order of magnitude. This means that there is no large subsurface outflow from Indian Wells Valley basin that could be intercepted by wells to increase the yield of the basin.

A.3 Storage Change

A chronic imbalance between inflows and outflows results in a long-term change in groundwater storage. Change in storage can be estimated by two methods: by the difference between total inflows and total outflows, and by the observed change in groundwater levels. Both methods are subject to considerable uncertainty, and it is prudent to apply both of them and compare the results.

Estimated by Water Balance

Annual inflows to the principal aquifer under 2010 conditions average 7,600 to 10,900 AFY (see Table A-1). Those conditions correspond more closely to the period for which water-level trends were calculated than 2013 conditions. Average annual outflows to wells (21,500 AFY), playa ET (1,900 to 4,700 AFY), and subsurface outflow to Salt Wells Valley (50 AFY) total 23,450 to 26,250 AFY. The ranges given for inflows and outflows are correlated because both stem primarily from uncertainty in playa ET. That is, the low estimate of total inflows should be matched with the low estimate of outflows. This produces estimates of average annual decrease in basin storage of 15,330 to 15,830 AFY, or roughly 15,600 AFY.

Estimated by Change in Water Levels

Estimating storage change by changes in water levels involved a two-step process. First, average annual rates of change in groundwater levels were calculated for 152 wells with sufficient hydrograph data. Those rates were posted on a map and contoured, resulting in the map of average annual water-level change shown in **Figure A-2**. Integrating those rates over the areal extent of contouring produced the average annual change in total saturated aquifer volume. The second step was to multiply that volume by a storage factor (specific yield) representing the percent of total aquifer volume filled by water that can drain freely from it. Calibrated parameter zones from the most recent groundwater model were used to obtain estimates of specific yield (Brown and Caldwell, 2009). Most of the volumetric change fell within the zone with a specific yield of 0.15, and a small part fell within the 0.12 zone. An area-weighted average of the two values produced an estimated average annual storage decrease of 14,600 AFY. This excludes the El Paso subarea, where water level trends were increasing, but data were sparse, specific yield values were smaller, and storage is relatively inaccessible to wells in the main part of the basin due to an intervening zone of low permeability.

The two estimates of average annual storage change under 2010 conditions (15,600 AFY and 14,600 AFY) are quite similar, given the very different methods used to obtain them and the considerable uncertainty in both methods. Overdraft has been increasing since 2010 because of increased water use for new plantings of alfalfa and pistachios. That increase is not yet reflected in long-term water-level changes because trends are calculated over 5-20 years. The water balance calculations indicate that pumping increased by 1,400 AFY between 2010 and 2013. Allowing for 10 percent deep percolation of applied irrigation water, overdraft increased by 1,260 AFY, or to approximately 16,400 AFY. When currently-planted pistachios reach maturity (around 2025), overdraft will increase by an additional 5,800 AFY even if no other changes in basin water use occur.

A.4 Summary of Water Balance and Yield

The average annual rate of storage decline was approximately 15,000 AFY as of 2010, and will increase fairly rapidly to roughly 27,000 AFY as newly-planted pistachio orchards grow to maturity and urban population grows. The rate of storage depletion could easily increase more rapidly if additional cropland is brought into cultivation. The annual storage decline is the amount of annual overdraft. Eliminating overdraft would require an increase in recharge or decrease in pumping (or combination thereof) equal to that amount.

Basin yield is not a fixed number. It is affected by the location of pumping, changes in recharge, and the presence of head-dependent boundaries such as rivers, lakes or adjacent basins. For example, a ballpark estimate of yield would simply be the difference between pumping and overdraft in 2010, which was 7,300 AFY (22,300 AFY of pumping minus 15,000 AFY of annual storage depletion). However, it might be possible to increase basin-wide pumping without increasing the rate of storage depletion if new pumping were located on the northern or eastern sides of China Lake Playa and intercepted groundwater that presently discharges to the playa. Similarly, the yield of the principal aquifer could be increased by adding recharge. Hypothetical examples of additional recharge might include relocation of Ridgecrest WWTP facilities to a location where pond percolation would accrue to the principal aquifer instead of the shallow aquifer, or percolation of imported water in the southwestern part of the basin.

The interaction of pumping with head-dependent boundaries means that the relationship between pumping and overdraft is usually not one-to-one. In the case of Indian Wells Valley, decreasing pumping to 7,300 AFY would probably increase the amount of groundwater discharging at China Lake playa, so the effect of the pumping change would be divided between storage depletion and boundary flow in some proportion. Most of the effect would go toward a reduction in overdraft, but some overdraft would likely remain even if pumping were decreased to 7,300 AFY.

There are numerous ways in which groundwater pumping can be decreased or recharge increased. A comprehensive list of options relevant to Indian Wells Valley is presented in the section on “Water Supply and Management Alternatives”.

A.5 Additional Recharge: the Open-Basin Hypothesis

The above water balance tabulation assumes that all recharge to the Indian Wells Valley groundwater basin derives from precipitation on watersheds tributary to the basin, with no inflow from external areas. This has been the conceptual model used in the majority of previous groundwater studies. Between the late 1980s and early 2000s, several studies advanced an alternative conceptual model that has been referred to as the "open basin" hypothesis (Austin, 1988; Ostdick, 1997; Thyne and others, 2002). This hypothesis asserts that substantial amounts of groundwater recharge enter the groundwater basin via bedrock fracture flow from the upper Kern River watershed west of the Sierra crest. Three lines of evidence were presented to support the hypothesis: groundwater flow calculations using Darcy's Law, stable isotopes, and groundwater age dating. To resolve the issue, the Indian Wells Valley Cooperative Groundwater Management Group conducted additional hydrogeologic and water quality studies to verify the data and calculations (CGMG and Geochemical Technologies Corporation, 2008). That study—funded by an AB303 grant—found flaws in the data and calculations for all three lines of evidence, as follows:

- **Groundwater Flow Calculations**
  Thyne and others (1999) estimated groundwater flow entering the main part of Indian Wells Valley groundwater basin from the El Paso subarea in the southwestern corner of the basin (see Figure 2). Calculated flow is the product of cross-sectional area, hydraulic conductivity and water-level gradient. The 2008 AB303 study drilled new monitoring wells at eight locations in the region where the groundwater flow calculations were applied. The lower half of the basin thickness contained predominantly fine-grained deposits of low permeability, so the cross-sectional area that Thyne and others (1999) had used was too large by a factor of about two. The new wells also revealed that the pair of wells used by Thyne and others (1999) to estimate the water-level gradient overestimated the average gradient by about an order of magnitude. Thus, the overall flow calculation was probably high by a factor of around 20.
- **Stable Isotope Analysis**
  Groundwater in Indian Wells Valley is isotopically light, which means it contains a relatively high proportion of light isotopes of oxygen and hydrogen. The isotopes are all naturally occurring, and there are two mechanisms that could have caused the "light" signature: precipitation at high elevation—such as the Kern River Plateau—or precipitation under cooler climatic conditions—such as were present in Indian Wells Valley during the Pleistocene epoch (more than 12,000 years ago). Thyne and others (1999) used groundwater age dating (see next bullet) to conclude that the groundwater in the basin is less than 70 years old and therefore must have come from the Kern River Plateau.
- **Groundwater Age Dating**
  Thyne and others (1999) sampled 13 wells near the location of the purported Sierran inflow and found that they all had elevated tritium. Tritium is a radioactive residue of atmospheric nuclear testing in the 1950s to 1960s and is commonly used in groundwater age dating studies. The 2008 AB303 study re-sampled those wells plus 26 additional wells, all of which had very low (pre-bomb) tritium concentrations. Upon further investigation, the AB303 study discovered that the laboratory used in the earlier study used equipment and methods incapable of detecting low concentrations and that the reported values were simply the detection limit of the laboratory's method.

The AB303 study used carbon-14 age dating and geochemical reaction modeling to demonstrate that groundwater in the basin is of Pleistocene age. The AB303 also noted three previous studies had independently applied carbon-14 dating and concluded that most of the groundwater was of Pleistocene age.

Thyne and others (1999) and the 2008 AB303 report were carefully reviewed for this study; in brief, the AB303 data and analysis appear sound and compelling. This study found additional weaknesses in the Thyne and others (1999) report and compiled more recent data that further refute the open-basin hypothesis, as follows:

- The hydraulic conductivity values used by Thyne and others (1999) for the groundwater flow calculation were values reported from pumping tests of the monitoring well cluster BR-1. The four wells all had short screen intervals placed in sandy layers of the aquifer system, which are much more permeable than the intervening clay and silt layers. However, the permeability of the coarse layers was applied to the full thickness of the cross section, which inevitably overestimates total groundwater flow.
- The text and Table 1 of Thyne and others (1999) report inflow along three segments of the Sierra Nevada mountain front that total 42,000 AFY. Inexplicably, the conclusions section of the paper gives a value of only 30,000 AFY. Perhaps coincidentally, Austin (1988) had estimated Sierra Nevada recharge as “at least 30,000 AFY”.
- Long-distance flow through bedrock fractures is highly improbable. The path of least resistance for infiltrated rainfall and snowmelt high in the mountains is to flow through the subsurface only as far as the nearest creek channel, seep into the creek as base flow, travel down the mountain as surface water, then percolate into the groundwater basin as soon as the creek transitions from a bedrock canyon onto the alluvial fan at the margin of the basin.
- The ongoing and widespread decline in groundwater levels since Thyne and others (1999) did their study is inconsistent with the presence of a large source of recharge. Water levels around a pumping well continue to decline only until the cone of depression intercepts enough recharge to supply the water pumped by the well. In wells located near rivers or lakes, water levels typically level out fairly rapidly, while wells located farther from those sources of recharge continue declining for a longer period. If the open-basin hypothesis were correct, one would expect water levels in wells in the southwestern part of the basin to have leveled out by now, while more distant wells continue to decline. The observed pattern is that water levels are continuing to decline at similar rates throughout the basin, which is an indication that the total amount of recharge from all sources is less than the amount being pumped.
- There is no plausible explanation for where all the Sierra Nevada recharge went prior to modern development. Thyne and others (1999) did not address this issue. Evaporation at China Lake playa is not a possibility, because there would have been a large body of open water at China Lake when the area was first settled a century ago. Groundwater outflow to Salt Wells Valley is also not a plausible option for several reasons. The shallow bedrock block separating the China Lake playa area from the west end of Salt Wells Valley has low permeability, as demonstrated by the large water-level drop from west to east across it (Tetra Tech EM, 2003; TriEcoTt, 2012). While some investigators have noted a similarity in groundwater quality between the eastern

part of Indian Wells Valley basin and the western part of Salt Wells Valley basin (Tetra Tech EM, 2003; TriEcoTt, 2012; Stoner, 2013), that could easily be a relic of surface water connection between the two valleys during the wetter Pleistocene epoch; it does not necessarily imply a large amount of current groundwater flow. Finally, if there were substantial groundwater flow through Argus Range bedrock from Indian Wells Valley direct to Searles Lake Valley, fresh groundwater would be abundant in that basin and the mining operations and town of Trona would not have needed to import water from Indian Wells Valley via pipeline.

- Current long-term decreases in groundwater storage are consistent with a water balance that does not include interbasin flow. If there were 30,000-42,000 AFY of groundwater recharge from the Kern River Plateau entering the basin, it would sustain current amounts of pumping without long-term storage depletion.

In summary, all of the evidence advanced to support the open-basin hypothesis has been discredited and a larger body of evidence convincingly supports the traditional “closed-basin” hypothesis. To the extent that any groundwater enters or leaves the Indian Wells Valley watershed via flow through fractured bedrock, the amounts are negligibly small compared to current amounts of pumping and overdraft.

B. Arsenic Data and Issues

Naturally-occurring arsenic is one of the most common groundwater contaminants in groundwater basins in the southwestern United States (Welch and others, 1988). Arsenic occurs naturally in the sediments that compose the Indian Wells Valley groundwater basin. In some wells the arsenic concentration in groundwater exceeds the primary drinking water standard of 10 µg/L (lowered from 50 µg/L about 10 years ago). In fact, IWVWD Wells 9, 10 and 13 did not meet the new standard and were retrofitted with wellhead treatment equipment in 2011 at a cost of $12 million. The solubility and mobility of arsenic in groundwater are affected by its oxidation state as well as by the co-occurrence of iron and manganese. Consequently, groundwater pumping that alters groundwater levels and flow in a way that changes oxygen availability can theoretically mobilize arsenic and increase its concentration in groundwater. This occurred in Bangaladesh, for example, with severe public health impacts (Bridge and Husain, 2000). In the context of Indian Wells Valley, a plausible scenario that could be causing increased arsenic concentrations is as follows. Minerals containing arsenic (for example, arsenic oxyhydroxide or arsenopyrite) were deposited along with organic matter, such as might have occurred on the bottom of China Lake during the Pleistocene epoch. Thousands of years later, after those sediments had become buried within the basin, they were exposed to oxygen as a result of chronically declining groundwater levels. The oxygen converted sulfur in the pyrites to sulfate, which promptly formed sulfuric acid, which in turn lowered the pH and mobilized the arsenic. This scenario is chemically and geologically plausible. However, the oxidized form of arsenic (arsenate) tends to adsorb or co-precipitate with iron under neutral to high pH and is consequently less common in groundwater (Paul and others, 2010). The hypothesis that oxidation is mobilizing arsenic is testable: if it is true, measured arsenic concentrations in groundwater should be increasing.

Arsenic data for IWVWD wells from 1990 to the present were compiled and examined for trends. Samples for 10 wells collected every 1-2 years during the 1990s revealed only one well with increasing arsenic concentration. Six wells had no trend and three wells had decreasing trends. In general, wells that initially had high concentrations stayed high, and vice versa. Data from quarterly sampling during 2005-2013 for four wells with relatively high concentration (Wells 9A, 10, 11 and 13) showed a possible upward trend in one well (9A) and a level trend in the other three.

The lack of increasing arsenic concentrations in IWVWD wells does not necessarily mean that arsenic is not being mobilized by declining groundwater levels. IWVWD's wells are screened far below the water table, where the expected oxidation would be occurring. Private domestic wells are shallower than municipal wells, and many are screened at or near the water table. Data from those wells are more likely to reveal a long-term increase in arsenic, if any is occurring. Water quality is not routinely monitored at private domestic wells, but all of them were tested for water quality—including arsenic—at the time of construction. If a number of domestic wells were resampled now, the changes in arsenic concentration since the time of construction would reveal whether concentrations are generally increasing and whether they commonly pose a health risk. Testing for arsenic is inexpensive, and a one-time resampling effort is recommended to investigate the issue.