

**EXHIBIT A**

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## ***The Antelope Valley Accord***

### **A Statement of Agreed Principles for Settlement of the Antelope Valley Groundwater Adjudication**

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#### **Introduction**

This *Antelope Valley Accord -- A Statement of Agreed Principles for Settlement* represents a comprehensive set of agreements establishing a physical solution for Antelope Valley groundwater management and providing a basis for final resolution of pending litigation over the amount and allocation of groundwater pumping rights in the Antelope Valley Area of Adjudication.

Litigation over groundwater rights has clouded the use of groundwater in the Antelope Valley for more than ten years. Known as the Antelope Valley Groundwater Cases (JCCP 4408, Superior Court of California, Santa Clara County), an initial dispute in 1999 between some urban and agricultural interests grew through filing of related lawsuits into a general adjudication of all groundwater rights in the basin. In addition to the original municipal and industrial purveyors (*i.e.*, urban and industrial water systems operated by cities and local water and community service districts – generally referred to as “purveyors” or “appropriators”) and active agricultural pumpers, the cases also involve local water recycling districts, Edwards Air Force Base (“EAFB”), the City of Los Angeles, an industrial user, and State Water Contractors. Two court-certified classes of groundwater rights holders are also litigants – a class including small landowners who pump relatively small amounts of groundwater, and a class including landowners who are not currently pumping but currently possess rights to do so. Under California law, landowners whose land holdings overlie an aquifer suitable for pumping groundwater but who are not yet pumping hold inchoate, equal rights with other landowners to pump available groundwater and put it to reasonable beneficial use on their land (“overlyers’ rights”).

In the *Antelope Valley Accord*, landowners who are pumping groundwater are generally referred to as “overlyers.” Landowners who have not yet pumped groundwater are generally referred to as “dormant overlyers” or “dormant landowners,” and by court order belong to the certified class known as the “Willis Class” unless they have separate representation before the Court.

In the first two phases of trial, the Court defined the geographic area of the basin being adjudicated (the Antelope Valley Adjudication Area; the “AVAA”), and determined that the

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AVAA contains no discrete sub-basins (*i.e.*, the basin is a single hydrogeologic unit) for the purposes of defining the groundwater adjudication area. Phase III of the trial, currently scheduled for September, 2010, would determine the Total Sustainable Yield<sup>1</sup> of the AVAA; *i.e.*, whether recharge and pumping are in balance or whether the aquifer is in a state of overdraft requiring a reduction in pumping.

Most of the litigants want to settle the litigation, and began mediation in earnest this spring to reach a comprehensive settlement and avoid litigating Phase III of the trial, and other subsequent litigation to resolve further issues in the adjudication. The parties to the *Antelope Valley Accord* have engaged in serious negotiations as a group, meeting in two-day sessions every other week starting in March, 2010. Virtually all major landowners have participated, including the two certified landowner classes and most of the mutual water companies, along with a representative of EAFB (which is not a signatory of the *Antelope Valley Accord*, however), the Cities of Lancaster and Palmdale, Los Angeles County Sanitation District Nos. 14 and 20, Tejon Ranch, Rio Tinto/U.S. Borax, and most of the water purveyors participating in the litigation: Palmdale Water District, Phelan-Piñon Hills Community Services District, Quartz Hill Water District, and Rosamond Community Services District, as well as the Antelope Valley-East Kern Water Agency.

Jim Waldo, a mediator experienced in complex negotiations and resolving water conflicts, led the mediation team and effort. Mr. Waldo has successfully mediated a number of complex, multi-party water rights disputes in California, including the milestone *Monterey Agreement* among State Water Contractors. The negotiation sessions have consumed more than 70 hours since March, 2010, in addition to several hundred hours in breakout sessions, work team assignments, and preparation for negotiation sessions.

A technical analysis effort was the primary assignment of Bill West, one of the mediation team members. Bill's 25-year background as a natural resources scientist prior to becoming a lawyer was valuable in developing a quality product. Five technical papers intended to inform the group's decisions were prepared by a working group composed of mediation principals. These reports and associated documents are being reviewed by two independent experts in hydrogeology.

The *Antelope Valley Accord* settles all claims to native groundwater by and between the settling parties. It also serves as a basis for fair settlement of claims with non-participating parties, thereby providing a basis for a comprehensive settlement as required by the McCarran Amendment, 43 U.S.C. § 666, a statute allowing the United States to be joined as a defendant in certain suits concerning the adjudication of water rights.

The *Antelope Valley Accord* represents a comprehensive physical solution to the AVAA's groundwater management challenges. It includes an agreed initial Total Sustainable Yield based on sound science, agreed reductions in current groundwater pumping in the AVAA, and agreed application of available groundwater management tools in designated management areas to reach

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<sup>1</sup> Total Sustainable Yield = native recharge plus return flows from both native and imported water.

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and sustain the Total Sustainable Yield target. The pumping reductions, applied groundwater management tools, and resulting groundwater levels will be studied and monitored over an initial 10-year period, at the end of which the Total Sustainable Yield target will be re-evaluated and additional pumping adjustments and application of new or other combinations of water management tools will be pursued as advisable. The plan includes “Special Emphasis Areas” in which more acute groundwater management concerns have been raised, and in which the plan authorizes flexible, proactive management to address those concerns.

The pumping adjustments and water management tools set forth in the *Antelope Valley Accord* will improve groundwater conditions in the basin, while offering water users real opportunities to secure adequate water supplies for urban needs and economic development, and irrigated agriculture. The *Antelope Valley Accord* will benefit the environment and all water users, and will provide a sound basis for moving forward toward sustainable groundwater management in the AVAA.

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**Statement of Agreed Principles for Settlement**

- I. **Settlement Goals** – The agreed-upon goals provide a foundation for the comprehensive settlement. They include:
- A. determination of the initial Total Sustainable Yield of groundwater in the AVAA based on sound science and informed by the history of groundwater use and levels, where Total Sustainable Yield represents the native recharge plus return flows from both native and imported water; Total Sustainable Yield as initially agreed and as modified after the 10-year monitoring period will prevent long-term substantial negative impacts to the basin’s groundwater resource and avoid jeopardy to the basin’s aquifer;
  - B. allocation of Total Sustainable Yield among current and future groundwater users in the AVAA;
  - C. establishment of a system for managing groundwater resources in the AVAA that will include the structure, responsibilities, funding, and authority of a Watermaster to administer the groundwater management system according to the Settlement Agreement and Court decrees;
  - D. achievement of certainty and stability in groundwater management necessary for the water users to act now to enhance the Basin’s water supplies for the future;
  - E. creation of transition mechanisms by which the participants can move from present practices in an orderly, predictable, and manageable fashion towards a long-term sustainable water management system for the Basin while minimizing negative socioeconomic impacts to the Antelope Valley community in the interim; and

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- F. settlement of all claims to native groundwater by and between the settling parties, including but not limited to claims that have been asserted in this litigation, and to serve as a basis for settling claims with non-participating parties.

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**Agreed Settlement Provisions**

**II. Total Sustainable Yield**

- A. A Total Sustainable Yield value of 150,000 acre-feet per year (“AF/yr”) will be in place for the first ten years following settlement, during which the Watermaster will oversee compliance with groundwater management rules in the AVAA as provided in the Settlement Agreement.
- B. During this first ten years, also known as the 10-year verification and monitoring period, a monitoring and research plan will be carried out that will feature systematic tracking of groundwater levels, measurement of pumping volumes, and performance of targeted applied research in key subject areas.
- C. The Settlement Agreement includes provisions for incorporating these results into the groundwater management system for subsequent years following the 10-year verification and monitoring period.
- D. At the end of the 10-year verification and monitoring period, the Total Sustainable Yield will be adjusted as necessary according to sound scientific principles and provisions to be set forth in the Settlement Agreement. [See Section XI.]

**III. Allocation of Total Sustainable Yield of Groundwater**

- A. Allocations of groundwater rights and certain groundwater management provisions set forth in the *Antelope Valley Accord* shall be based on current pumping rates. For these purposes, the current pumping rate for a party will be determined by identifying the average of that party’s pumping between 2006 and 2010 (unless agreed and provided otherwise in the documents implementing the Settlement Agreement), and adjusted as necessary for special circumstances as set forth in the documents implementing the Settlement Agreement. The methods of verifying pumping shall be specified in the documents implementing the Settlement Agreement.

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- B. The current pumping rate is estimated to be approximately 173,000 AF/yr<sup>2</sup> creating a need for a reduction of approximately 23,000 AF/yr to achieve the 150,000 AF/yr initial Total Sustainable Yield.<sup>3</sup> The current estimate of groundwater pumping by the purveyors is approximately 43,500 AF/yr, by overlyers is 125,500, and is 4,000 AF/yr at Edwards Air Force Base (“EAFB”).
- C. EAFB will hold a federal reserved right of 8,000 AF/yr, although in recent years it has been pumping half of this volume or less.

This agreement assumes EAFB will manage its pumping to a target of 4,000 AF/yr during the initial 10-year period (*i.e.*, management target will be roughly equal to current pumping). If EAFB needs more water above its management target it would notify the Watermaster, who will determine whether it will be necessary to make an adjustment to the overall pumping volumes available to other users within the AVAA. EAFB’s management target will be subtracted from the total 150,000 AF/yr Total Sustainable Yield.

- D. To achieve total pumping equal to the 150,000 AF/yr Total Sustainable Yield (less an assumed EAFB management target of 4,000 AF/yr) the current ratio of pumping by each separately-identified class of pumpers to total pumping will be applied to the adjusted Total Sustainable Yield of 146,000 AF/yr. Applying the ratios resulting from the estimated pumping rates referenced in Paragraph III.A to the adjusted Total Sustainable Yield allocates 36,500 AF/yr to purveyors and 109,500 AF/yr to overlyers. To achieve these allocations, settling parties agree to reductions from current pumping levels of approximately 7,000 AF/yr for the purveyors and 16,000 AF/yr for the overlyers.

E. Small Pumpers Class (Wood Class)

1. It is understood and agreed that the proposed settlement with the Wood Class is subject to Court approval following notice to the Class and a fairness hearing.
2. The parties agree to mediate the issue of fees and costs claimed by Wood Class counsel. If mediation fails the parties agree to petition the Court for an award of fees and costs.
3. The current estimate of the number of members in the Small Pumpers Class is approximately 3,800;<sup>4</sup> each member is typically identified with a single household or farming operation. On the basis of that estimate the Small Pumpers Class’s initial allocation, prior to any reduction, would be 11,400 AF/yr. Unlike the reductions required of the other overlyers and appropriators, the reduction for the Class would be fixed at 500 AF/yr for a total of 10,900 AF/yr. Pumping by this Class shall be the subject of a study by the Watermaster to verify the total of the Class members’

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<sup>2</sup> This estimate includes pumping numbers reported by the Mediation Participants, individual communications, published numbers, and estimates where necessary.

<sup>3</sup> Actual current pumping rates will be disclosed by signatories in the course of finalizing this agreement. Actual pumping rates as disclosed at that time shall form the basis for allocations and other groundwater management provisions as set forth in this Antelope Valley Accord.

<sup>4</sup> This is a preliminary figure and is subject to revision.

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current, average actual use per year during the initial verification and monitoring period, and the total allocated to the Class shall then be adjusted downward if appropriate. However, no Class member found to be currently pumping more than 3 AF/yr will be compelled to reduce pumping below 3 AF/yr. The total water available following the verification study and adjustment shall continue to be available in a pool for the benefit of the Small Pumpers Class. This quantity of water shall not be transferable. Any water reserved for this purpose but unused shall be available for use by others as specified in the Settlement and at no charge.

4. Future allocations of groundwater rights accruing to dormant landowners (referenced in Paragraph III.G) when they develop their properties shall not be deducted from the allocation for the Small Pumpers Class.

F. A.V. United Mutual Group

1. The mutual water companies belonging to A.V. United Mutual Group shall reduce their current pumping by the percentage required in the Settlement for overlyers generally.
2. A reserved groundwater right will be created for the use and benefit of the A.V. United Mutual Group. The initial quantity of this reserved right shall be 2,100 AF/yr. To the extent that the verification for the Small Pumpers Class as provided in Paragraph III.E demonstrates that the Class's needs can be met with less than the initial allocation then the members of the A.V. United Mutual Group mutual water companies shall have first priority access to that unused quantity up to a maximum of 900 AF/yr, for a total reserved right of 3,000 AF/yr. This total reserved right shall not be subject to further reduction.
3. To the extent that the verification for the Small Pumpers Class as provided in Paragraph III.E demonstrates that the Class's needs can be met with less than the initial allocation, and after the members of the A.V. United Mutual Group mutual water companies have exercised their first priority access to that unused quantity up to a maximum of 900 AF/yr, any other mutual water companies not parties to this *Antelope Valley Accord* shall have second priority access to that unused quantity up to a maximum of 100 AF/yr for actual reasonable beneficial use.
4. Members of the A.V. United Mutual Group will be allocated groundwater rights from this reserved right for actual reasonable beneficial use by a member mutual water company. The use of water by a member mutual water company, or by any member of any mutual water company, shall be presumed to be reasonable and beneficial, unless questioned or challenged in the same manner as the reasonableness and beneficial nature of the use of water by any other party to this Agreement is questioned or challenged. Increased actual reasonable beneficial use under this provision shall be reported to the Watermaster, to the same extent that the demonstration of actual reasonable beneficial use is required of all other overlyers generally. The Watermaster will determine when, as a consequence of such increased use, it will be necessary to make an adjustment to the pumping volumes available to other users within the AVAA.
5. The entire allocation of the mutual water companies' native groundwater rights shall not be transferable outside the mutual water companies, but can be transferred among them.

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6. Any water reserved for this purpose but unused shall be available for use by others as specified in the Settlement at no charge. The mutual water companies will receive no water credit from the allocation for the Dormant Landowners Class when a dormant landowner connects to a mutual water company system.
7. Groundwater rights allocated to the mutual water companies shall remain constant whether there is a downwards or an upwards adjustment of Total Sustainable Yield, and such companies shall not be assessed costs for replacement water if the estimated Total Sustainable Yield is reduced.

**G. Dormant Landowners Class (Willis Class)**

1. It is understood and agreed that the proposed settlement with the Willis Class is subject to Court approval following notice to the Class and a fairness hearing.
2. The parties agree to mediate the issue of fees and costs claimed by Willis Class counsel. If mediation fails the parties agree to petition the Court for an award of fees and costs.
3. Class rules will govern access to benefits for Class members when they begin to make actual reasonable beneficial use of groundwater. The administrative and ministerial implementation of the Class rules will be managed by the Watermaster, with the costs for such work covered via assessments.
4. Qualifying parcels of 20 acres or less shall be assigned groundwater rights according to the following principles:
  - a. For parcels that are being developed for a single family residence -
    - i. parcels located within, adjacent to, or in close proximity to the service area of a municipal water supplier or water district, such that they may be provided service by that district at nominal cost, will be entitled to a quantity of water free of a replacement assessment equal to the average use for a residence within that district, and if that supplier provides service to such parcels then that entitlement is transferred to the district;
    - ii. non-adjacent or distant parcels will be entitled to one acre-foot per single-family residence for domestic use free of any replacement assessment; and
    - iii. owners of parcels of 20 acres or less may divide such parcels to the extent consistent with applicable zoning requirements, except that an owner may not combine more than one such contiguous parcel to effectively form a project area exceeding 20 acres - such projects will be subject to the provisions in Paragraph III.G.5 below. Subject to that exception, each parcel of 20 acres or less shall be entitled to exercise the above right.
  - b. Parcels of 20 acres or less shall also receive an allocation of 0.1 AF/yr under the same terms as set forth in Paragraph III.G.5 below.
  - c. The expected quantities of groundwater involved in this category will be considered de minimis and will not adversely affect the Basin as a whole. The Watermaster will account for them but they will not be counted against the Class reserved right or reduce the allocation of any other party. Such rights will remain constant whether Total Sustainable Yield is adjusted downward or upward.
5. For qualifying Class parcels greater than 20 acres, a reserved groundwater right will be created for the use and benefit of members of the Class. Individual Class members will be allocated groundwater rights free of replacement assessment from this reserved



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right for actual reasonable beneficial use on the parcels that qualify them for Class membership.

- a. Each qualifying Class parcel of a size greater than 20 acres will be entitled to an allocation of groundwater rights from the Class reserved right when the owner begins to make actual reasonable beneficial use of groundwater on that parcel. 0.1 AF/yr per acre will be assigned to that parcel from the Class reserved right.
- b. One single family residence on one of these parcels will also receive 1.0 AF/yr as described in Paragraph III.G.4 above.
- c. Such rights will remain constant whether Total Sustainable Yield is adjusted downward or upward.
- d. Any requirements on that parcel for water in excess of these allocations must be accommodated through purchase or other acquisition of water from other sources.
6. To the extent that the quantities of groundwater allocated to the Class reserved right have not been allocated according to Paragraph III.G.5 above, such quantities will be available for use by purveyors and other overlying landowners that are not members of a mutual water company or the Small Pumpers Class.
7. The impacts of the perfection of Class rights, thereby reducing the portion of Total Sustainable Yield available to other users, will be accommodated as follows:
  - a. Such reductions will be borne pro rata (based on pumping rights) by appropriators and overlyers, but not members of the A.V. United Mutual Group, the Small Pumpers Class, or Edwards Air Force Base; and
  - b. A “leave-behind” percentage of 5% for the benefit of the Basin will be imposed on any transfer of water rights or contracts for the delivery of water by an overlyer to a location other than the overlying parcel per the provisions of Paragraph VII.C.3 below.
8. All groundwater rights assigned to a qualifying Class parcel per Paragraph III.G above will run with the land and will not be transferable.
9. Water put to actual reasonable beneficial use by Class members is transferable to the other Class members for use only on lands within the Class, and such transfers shall be exempt from leave-behind requirements.

**IV. Groundwater Management Areas**

The Watermaster will establish and use groundwater management areas to manage the AVAA groundwater resource in accordance with the physical realities of the Basin. The sub-basins identified by the United States Geological Survey will provide a starting point for development of the management area system, recognizing that the Watermaster may need to perform studies in the field to identify the actual boundaries and characteristics of some of the different regions of the AVAA and the physical interrelationships between them.

- A. Groundwater management areas within the AVAA will be identified and used in the future management of groundwater in the Basin.
- B. Groundwater management practices will be tailored to manage use of native groundwater within each management area on a sustainable basis, and on a basis that does not negatively impact groundwater resources in down-gradient management areas.

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**V. Transition and Phase-in of Settlement Provisions**

- A. There shall be a four-year phase-in period, applying 25% of the agreed pumping reductions in each year.
- B. Recycled water provisions

The California Water Code identifies the treatment plant operator as holding the exclusive right to the treated water. However, since it is anticipated that recycled water will be a key source of water to meet both existing demands and economic growth, the supply of recycled water is addressed here.

The majority of the recycled water will be receiving additional treatment (i.e., tertiary treatment) allowing for a greater range of reuse options.

The majority of recycled water within the valley has been committed by contract to municipalities and municipal water suppliers.

- 1. Over the long term, recycled water will generally be used to supplement supplies for urban needs;
- 2. During the four-year phase-in of pumping reductions, pursuant to existing contracts and commitments, opportunities exist to use recycled water to help:
  - a. overliers achieve their reductions with less impact to farming operations, including by leveraging recycled water in transactions of groundwater rights from agricultural to urban users, and to help provide for continued farming for a period of years before the agricultural water rights are finally transferred to urban use;
  - b. purveyors will have options to provide additional flexibility in meeting urban demands;
  - c. leverage imported water and groundwater transfers for banking through blending with recycled water; and
  - d. enhance groundwater recharge programs.

**VI. Permanent Transfers of Groundwater from Agricultural Users (“Ag”) to Urban Users**

- A. It is estimated that there could be between 5,000 and 10,000 AF/yr available for transfer from Ag to Urban users within the first five years following the settlement.
- B. The transfer agreements can be negotiated in the near term but be effectuated at a specified time in the future.
  - 1. Each transfer agreement shall include the quantity of water subject to the transfer agreement. The consideration in the form of price to be paid for the transferred water and quantities of “leave behind” obligations (i.e., 5% to the benefit of the Basin) shall be reflected in the transfer agreements.
  - 2. Purveyors who receive the Ag water shall receive three benefits: a net quantity of water to be used annually; the ability to have periodic peak annual capacity equal to

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the transferred quantity plus the percentage reduction required in the settlement; and the amount of the reduction related to the transfer should be the first rights “rehydrated” to the purchaser if additional water becomes available in the Basin, or if the Total Sustainable Yield is adjusted upward.

3. Cities and purveyors that are signatories to this agreement shall all have fair access to participate in all Ag to Urban transfers.
4. In addition to transfers of groundwater pumping rights, settlement provisions will create a category of “pumping forbearance” agreements by which a party will contract with a holder of a groundwater right to permanently abstain from pumping some defined quantity of groundwater, by means of covenants that will attach to and run with a designated parcel. The effect will be to permanently “retire” that portion of the groundwater rights associated with that parcel. The groundwater quantity associated with each such pumping forbearance will accrue to the account of the party contracting for the forbearance and may be used to offset mandatory reductions in that party’s right to pump groundwater. Such forbearance agreements will only be allowed when the effects of the forbearance will be realized in the same management area as the party contracting for the forbearance.

**VII. Transfers**

**A. General Policies:**

1. Water transfers should do no harm: no physical impairment of other rights or significant long-term damage to the groundwater resource; and
2. No native groundwater shall be exported from the AVAA. (Limited exceptions to address historical usage patterns or AVAA boundary issues are described in Section XIII.)
3. Water rights in the AVAA will be quantified so that the Watermaster will have a master list of all holders of rights to native groundwater in the Basin and the amount of each such water right.
4. Groundwater rights in the AVAA will be severed from the land and freely transferable, except for the limitations on groundwater rights assigned to members of the Small Pumpers and Dormant Landowners Classes and the mutual water companies as provided elsewhere in this *Antelope Valley Accord*.

**B. The transfer provisions will address the following categories of transfers:**

1. permanent transfers in the first five years of the initial 10-year monitoring period when the basin is transitioning down to pumping at the 150,000 AF/yr Total Sustainable Yield target;
2. other transfers during and after the initial 10-year monitoring period;
3. short-term transfers in the spot market, or water exchange; and
4. transfers within and between management areas.

**C. Basic transfer mechanics:**

1. All proposed transfers would require written notice to the Watermaster that would include all material terms, including price. No transfer would become operable until the Watermaster has posted notice of approval. Transfers within a management area

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should not require the same level of Watermaster review and approval as transfers between management areas.

2. The Watermaster shall review proposed transfers between management areas to determine whether they create a need for replacement water in the source management area.
3. All transfers within the AVAA shall be subject to a “leave-behind” percentage of 5% for the benefit of the Basin. This requirement shall not apply to transfers among mutual water companies or within the Willis Class, nor shall they apply to the pumping forbearance agreements described in Paragraph VI.B. 4 above.

*[Details of the permanent transfer and forbearance programs outlined in Sections VI and VII will be developed following the settling parties’ approval of this Antelope Valley Accord while the legal and other documents implementing the Settlement Agreement are being prepared. It is anticipated that contracts or other commitments sufficient to meet the purveyors’ needs to offset initial cutbacks will be negotiated during this period, and will be a condition of their final approval of the Settlement Agreement.]*

**VIII. Tejon Ranch**

- A. Tejon Ranch will settle all legal claims to groundwater as against the other parties to the current Antelope Valley groundwater rights adjudication, including but not limited to any claims asserted under the Treaty of Guadalupe Hidalgo and any claims related to currently unexercised overlyer’s groundwater rights.
- B. Tejon Ranch will have a post-settlement right to pump groundwater of up to 5,500 AF/yr, unless the monitoring during the 10-year verification and monitoring period establishes that this level of pumping would in the future jeopardize the groundwater resources of the underlying management area(s) and the Antelope Valley Basin as a whole.
- C. During the initial 10-year verification and monitoring period, Tejon Ranch will cut back its current pumping volume<sup>5</sup> for its own uses by the same percentage as defined in the Settlement Agreement for current pumpers (other than members of the Small Pumpers Class, mutual water companies, and EAFB). If that percentage is more than 16%, the percentage above 16% will be first taken from the “surplus,” if any, as provided in Paragraph VIII.D.
- D. Tejon Ranch has pumped a historic high of 12,500 AF/yr with no observable decrease in groundwater levels. The difference between Tejon Ranch’s historic high pumping levels and Tejon Ranch’s 5,500 AF/yr right under the Settlement Agreement, or “surplus,” is 7,000 AF/yr. In order to facilitate the settlement, Tejon Ranch agrees that any “surplus” (estimated to be 7,000 AF/yr) can be pumped from its wells, as a second priority use after Tejon Ranch’s uses as allowed under the Settlement Agreement, for the purpose of meeting other settlement goals during the initial 10-year period. The recipient of such

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<sup>5</sup> Presently estimated at around 2,500 AF/yr, subject to verification at the time of final settlement.

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water from the Tejon Ranch “surplus” shall bear the costs of pumping, including well maintenance due to the increased pumping, and conveyance of the water from Tejon Ranch to its destination, and shall forgo pumping from its own wells in an equal quantity. If Tejon Ranch’s wells cannot support that level of pumping, Tejon Ranch will cooperate with the user(s) to facilitate additional pumping, if additional pumping does not jeopardize the groundwater resources of the underlying management area(s) and the Antelope Valley Basin as a whole. In order to be eligible to receive such water, the requesting entity’s wells must be physically located in an area with declining groundwater levels and the entity must also be taking practical steps to otherwise reduce its long-term impacts on the local groundwater resource.

- E. The water levels in the management area(s) where the “surplus” pumping occurs during the initial 10-year period will be monitored to verify whether the “surplus” pumping can continue at the same rate, or should be adjusted, and if so to what level. No such reduction in pumping of “surplus” water will impact Tejon Ranch’s current pumping levels for its own uses during the initial 10-year period, as provided in Paragraph VIII.C, or Tejon Ranch’s 5,500 AF/yr post-settlement right after the initial 10-year period, as provided in Paragraphs VIII.B and VIII.F.
- F. After the 10-year verification and monitoring period, Tejon Ranch will have the right to pump up to 5,500 AF/yr, unless the monitoring during the 10-year verification and monitoring period has established that this level of pumping would in the future jeopardize the groundwater resources of the underlying management area(s) and the Antelope Valley Basin as a whole, in which case Tejon Ranch will reduce its pumping accordingly until a determination is made that such reduction is no longer necessary.
- G. After the 10-year verification and monitoring period, any amount above the 5,500 AF/yr that monitoring verifies can be pumped without harm will be available for use by others, subject to second priority use, agreements for cost reimbursements, and qualification for this use, as addressed in Paragraph VIII.D.

**IX. Special Emphasis Areas (SEAs)**

- A. Special Emphasis Areas will initially involve three primary geographic areas: the Lancaster-Palmdale SEA, the North Muroc SEA, and the EAFB-Rogers Dry Lake SEA (to be more specifically identified for depiction on a map showing, among other things, agreed initial management areas).
  - 1. Issues to be addressed: water levels, water quality, subsidence.
- B. Goals:
  - 1. for the Lancaster-Palmdale SEA, to improve water levels and minimize water quality issues;
  - 2. for the North Muroc SEA to improve water levels; and
  - 3. for EAFB-Rogers Dry Lake SEA, to improve water levels and eliminate the risk of further subsidence.

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C. Objectives

1. identify practicable recovery activities and tools for each SEA;
2. determine benchmarks for each activity that will reliably measure progress toward recovery;
3. determine which recovery activities should be included in the action plan document, and which should be managed by local entities outside of the settlement; and
4. establish agreements that apply the best tools to perform the recovery activities and achieve the recovery goals.

D. Potential tools:

1. collect groundwater improvement fees from water users;
2. reduce pumping in the SEAs;
3. water transfers;
4. design and construct additional water conveyance infrastructure;
5. develop the City of Palmdale's Amargosa Creek Recharge Project;
6. pumping forbearance payments to farmers in the SEAs;
7. recycled water exchange for potable groundwater;
8. acquire additional imported surface water as available, and within conveyance and treatment limitations, use imported surface water to reduce groundwater pumping in the SEAs;
9. use only recycled water for farming east of Plant 42;
10. establish additional recycled water recharge areas and blending facilities;
11. encourage urban and on-farm conservation and efficiency measures in order to reduce pumping in the SEAs or shift the location of pumping;
12. use pumped water in SEAs as much as practicable to meet needs at times of peak demand;
13. utilize water storage and banking; and
14. use Tejon Ranch "surplus" water during the initial 10-year period per the provisions of Section VIII.

X. Watermaster

A. The Watermaster will manage native groundwater in the AVAA.

B. Creation of Watermaster - The Watermaster will be established through a combination of court action and state legislation.

1. The Court would approve the Settlement Agreement subject to adoption of state legislation, creating a California Water District, and the Court would then approve the legislatively created body as the Watermaster and retain jurisdiction to oversee water rights and associated issues outside the authority of the Watermaster;
2. The legislation would provide the authorization for establishing, funding and implementing the Settlement Agreement by establishing and authorizing funding for the Watermaster through the imposition and collection of fees assessed against all tax parcels in the AVAA, as provided below; and

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3. The Court would implement the Watermaster and the Groundwater Management System based on the combined authority of the state legislation and the Court's continuing jurisdiction.
- C. Watermaster Rules and Regulations - The Watermaster will create rules and regulations that can be periodically updated. Samples of rules and regulations from other watermaster districts in the state will be reviewed for guidance.
- D. Governance by Board - The Watermaster will be governed by a voluntary (non-paid) seven member Board, each with a designated alternate, made up of representatives of the following interest groups:<sup>6</sup>
  1. Agricultural overlyers;
  2. Appropriators;
  3. The City of Lancaster;
  4. The City of Palmdale;
  5. Mutual water companies;
  6. Rosamond Community Services District; and
  7. Small pumpers.

The intent is to have a balanced Board, represented by the diverse interests in the Antelope Valley, and specifically including Board representation from each management area and SEA in order to best achieve Basin-wide solutions.

If additional seats are necessary in order to effectuate the intent of this *Antelope Valley Accord*, such seats will be created.

If certain entities, such as EAFB, do not participate in a voting or representative capacity under applicable law, or such as State Water Project Contractors who do not have a direct groundwater connection (e.g., AVEK) but who will play a critical role in a physical solution, the Board may add additional ex-officio, non-voting Board representatives.

Terms will be three years (or as otherwise decided), and staggered for continuity of changing Board representatives.

Voting will be equal by representative (that is seven votes). Specified "major" decisions will be by super majority vote of the Board (that is, 5/2 vote); routine decisions will be by majority vote of the Board (that is, 4/3). Samples of Board bylaws from other watermaster districts in the state will be reviewed for guidance.

- E. Initial priorities to accomplish native groundwater management goals:
  1. implement the 10-year verification and monitoring program;

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<sup>6</sup> Discussions will be held with the United States concerning its participation in the Watermaster Board. AVEK has also raised a question about its participation on the Board.

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2. conduct a program of targeted applied research on key issues for establishing a scientifically-sound basis for groundwater management, including quantifying Total Sustainable Yield;
3. analyze and establish groundwater management zones/areas;
4. conduct a study to determine the average native groundwater use by the small pumpers;
5. after notice and hearing, establish rules adjusting pumping in special emphasis areas as needed;
6. establish a native groundwater exchange program;
7. establish a replacement water program (make up water);
8. prescribe by rules and regulations the carryover provisions for native groundwater not pumped within a water year; and
9. establish and implement significant milestones for Watermaster -
  - a. End of Year 1 - develop and finalize the 10-year verification and monitoring plan.
  - b. End of Year 2 - have meters installed on all wells that will be metered.
  - c. End of Year 3 - fully implement the 10-year verification and monitoring plan.
  - d. Year 5 - assess value of instituting a groundwater replenishment program (see Paragraph X.F.20 below).

F. General powers and duties:

1. adopt rules and regulations, including for individual water meters;
2. employ necessary personnel;
3. promote and coordinate groundwater management efforts in the AVAA;
4. collect and analyze hydrologic data, report on conditions, plan and coordinate additional applied research relevant to key water management issues;
5. set, levy, and collect assessments and fees;
6. maintain notice list of affected persons or properties;
7. prepare and administer budget;
8. prepare and disseminate annual report to Court;
9. hold, borrow and invest funds;
10. report and maintain records of water and water right transfers;
11. report and maintain records of imports of water by management area;
12. determine annual allowable groundwater production per terms of the Settlement Agreement;
13. collect pumping reports from pumpers;
14. enjoin unauthorized pumping;
15. notice public meetings and maintain public records;
16. rely on and use best available records and data;
17. maintain historical information;
18. prohibit export of native groundwater (subject to Settlement Agreement provisions);
19. after notice and hearing, establish rules adjusting pumping in management zones as needed (including in SEAs during the initial 10-year period if necessary);
20. receive and report on groundwater data resulting from conjunctive use and groundwater storage;
21. coordinate with local governments and State Water Contractors;



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22. at Year Five following settlement, initiate and oversee a one- to two-year process to assess the value of instituting a groundwater replenishment program, including identifying sources and costs for the water needed, and identifying and evaluating means for funding the program;
23. reconcile and address water management issues that arise in connection with parcel boundaries, boundaries of the AVAA, and boundaries of hydrogeologic sub-basins and/or management areas (See Section XIII);
24. develop or assist in development of groundwater conservation policies and implementation procedures; and
25. develop alternative dispute resolution provisions for the Watermaster to hear disputes between pumpers, or disputes with proposed pumping adjustments, or similar disputes that do not need to rise to the level of oversight by or hearing by the Court.

G. Funding – The administrative costs of the Watermaster and Groundwater Management System will be funded by fees assessed on tax parcels lying within the AVAA. Based on review of budgets from other watermaster districts in the state, it is estimated that the initial annual budget will be in the range of \$1,200,000. Since there are approximately 200,000 tax parcels within the AVAA, it is anticipated that the fee structure will be based on approximately \$6.00 per tax parcel or portion thereof within the boundaries of the AVAA, subject to special fee structures for landowners, such as Tejon Ranch, that have large landholdings but a small number of tax parcels, or in other special situations. Funding for the start-up and transition period will be addressed in the documents implementing the Settlement Agreement.

If it is determined that alternative funding mechanisms will be necessary to fund these costs, such mechanisms will be developed and implemented as prescribed in the documents implementing the Settlement Agreement.

**XI. Adjustment of Total Sustainable Yield Following the 10-year Verification and Monitoring Period**

- A. The Watermaster shall make necessary adjustments to Total Sustainable Yield, tailoring such adjustments to the management areas to achieve optimum outcomes within and across the management areas including the ability of higher recharge areas to contribute to areas with lower water levels. (The procedures by which the Watermaster will make these determinations will be specified in Watermaster rules.)
- B. Any downward adjustments in groundwater pumping rights to accommodate a reduction in Total Sustainable Yield within one or more management areas shall be implemented over a five-year period, at 20% per year.
- C. Provisions to accommodate upward adjustments in Total Sustainable Yield will be developed in the Watermaster rules as guided by the Settlement Agreement.
- D. Groundwater rights allocated to the United States (Edwards AFB), members of the Small Pumpers Class, and the mutual water companies shall remain constant whether there is a

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downwards or an upwards adjustment of Total Sustainable Yield, and such persons shall not be assessed costs for replacement water even if the estimated Total Sustainable Yield is reduced.

- E. Groundwater rights allocated to members of the Dormant Landowners Class per the provisions in Paragraph III.G above shall remain constant whether there is a downward or an upward adjustment of Total Sustainable Yield, and such members shall not be assessed costs for replacement water even if the estimated Total Sustainable Yield is reduced.
- F. For all other holders of groundwater rights, the groundwater rights each holds at the end of the 10-year verification and monitoring period will serve as the basis for the allocation of adjustments to that user's allocation of pumping rights if adjustments to Total Sustainable Yield are needed in that management area for the following period.
- G. The management areas will frame the analysis and context for adjustments upward or downward within the overall Basin context.
- H. Credit for imported water: The policy objective of this section is to promote the use of imported water within the Basin, which will benefit all users and the Basin as a whole.
  - 1. Included in the adjustment of each groundwater pumper's allocation of groundwater pumping rights will be a credit for water imported by that pumper and applied within its management area during the 10-year verification and monitoring period. This credit will only operate as to the allocation of upwards or downwards adjustments to pumping among all other groundwater pumpers within that management area.
  - 2. A credit based on a percentage of the quantity of water imported by the groundwater pumper purchasing that water shall accrue to that pumper's account. The accounts will be maintained by the Watermaster and the pumper will report its imports to the Watermaster.
    - a. The credit percentage will be set at a minimum of 10% of the amount of water imported during the 10-year verification and monitoring period. The Watermaster can adjust the percentage upward in a management area, as appropriate, based on the results of analysis of the geology, hydrology, water levels within the management area, and related issues, to a maximum of 15%.
  - 3. At the end of the 10-year verification and monitoring period a groundwater pumper that has purchased imported water can use the credits in its account to affect the impact on that pumper of upward or downward adjustments of Total Sustainable Yield within its management area, as follows:
    - a. If allowable groundwater pumping is adjusted upward, credits may be used to provide for additional pumping allowed in the groundwater pumper's management area. Pumpers wishing to redeem their credits will be granted first priority access to such additional pumping, as against pumpers that have imported no water and have thus accrued no credits.
    - b. If allowable groundwater pumping is adjusted downward, credits may be used to offset a portion of the pumping reduction assigned by the Watermaster to that pumper.

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4. If a public water supplier imports water as a participant in an integrated, multi-entity program, the Watermaster will allocate credits to that supplier's account according to the supplier's participation in the program or the individual purchase.
5. Notwithstanding the provisions above, at the end of the initial 10-year period in each water management area, if:
  - o public water suppliers have not purchased imported water in a quantity equal to total imports during the ten years immediately preceding this *Antelope Valley Accord*; and
  - o the Watermaster is ordering reductions in pumping in that Water Management Area, and makes a determination that the public water suppliers' reduced water imports have substantially caused the need for reductions;

then import credits will apply as between public water suppliers, but Overlyers will not be assigned reductions resulting from reduced return flows from imports. Calculation of reductions shall apply the percentage of return flows from imported water stated in the Problem Statement Report unless the Watermaster has identified (based on sound science) a different percentage. Going forward after the adjustments made at the end of the initial ten-year period, the Watermaster shall use this general approach applying reasonable base periods for determining whether imports in a water management area are up or down.

- I. Future Adjustments – After the initial 10-year review and decisions, the Watermaster will establish a schedule for periodic future reviews and adjustments with a maximum of a ten-year period between such reviews and adjustments.

**XII. Groundwater Banking**

The Antelope Valley currently has several successful groundwater banks in operation, and others are in the planning and permitting stages. The parties to the Antelope Valley Accord agree that present and future groundwater banks operated in the manner set forth in Exhibit B make a positive contribution to the status of the groundwater resources in the AVAA, and provide opportunities for facilitating the prudent, sustainable management of those resources.

- A. Information about water stored in and withdrawn from groundwater banks, and information about water left in the aquifer as a result of leave-behind provisions in the banking agreement, shall be reported to the Watermaster in a timely manner.

**XIII. Boundary Issues Related to Implementation of the Settlement**

In many cases, parcel boundaries, political boundaries, the boundaries of the AVAA, and the boundaries of hydrogeological sub-basins do not coincide. There are also historic pumping facilities, water delivery patterns, and service area delineations that overlap one or more sets of such boundaries.

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- A. Phelan-Piñon Hills Community Services District (“PPHCSD”) will maintain its current pumping level of groundwater from within the AVAA, as determined by current metered deliveries and notwithstanding the provisions of Paragraph III.A, for use within its service area under terms and conditions that will not set a precedent for other water users.
- B. Rio Tinto/U.S. Borax and Tejon Ranch own and conduct their business operations on lands that overlap the AVAA boundary. To the extent these operations and lands may be located outside the AVAA boundary, the related water needs of those operations and lands will not be subject to or inhibited by the general policy of no export of native groundwater.
- C. The Watermaster shall have the authority in future to reconcile and address other such boundary-related issues as they arise. In doing so, factors and policies that should be taken into account include:
  - 1. the general policy of no export of native groundwater from the Antelope Valley;
  - 2. no physical harm to neighbors;
  - 3. taking account of the particular circumstances, all Antelope Valley users should receive comparable benefits and opportunities; and
  - 4. provide flexibility to promote administrative efficiency where potential adverse impacts are negligible.

**XIV. Miscellaneous**

**A. Purpose and Intent Regarding Implementation of the *Antelope Valley Accord***

The settling parties expressly intend that this *Antelope Valley Accord* will require development of additional documents and agreements to effectuate their intent, purpose and understanding, and each pledges to use its best-faith efforts to develop, obtain ratification and approval of, and execute such documents as promptly as practicable.

- 1. **Settlement Agreement:** The settling parties intend that a separate Settlement Agreement will be developed and executed. The Settlement Agreement will be narrowly drawn to settle the issues in dispute in the Antelope Valley Groundwater Cases, including the establishment of Total Sustainable Yield for the AVAA, and the agreed groundwater pumping rights and allocations set forth in the *Antelope Valley Accord*. The Settlement Agreement shall specify the information needed and the steps required to verify the settling parties’ current groundwater pumping rates and volumes. To the extent that Watermaster activities and the use of certain water management tools contained in the *Antelope Valley Accord* pertain to resolution of the disputed issues in the litigation, such matters should be included in the Settlement Agreement and thereby subjected to the continuing jurisdiction and authority of the Court. The settling parties specifically intend, however, that all matters contained in the *Antelope Valley Accord* that are not essential to resolving the litigation should be effectuated in a manner that allows water users in the AVAA to engage in arrangements and activities separate from and outside of the Court’s continuing jurisdiction and authority. It is the settling parties’ express desire that the Court not be involved in day-to-day management of AVAA groundwater, and that the application

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of management tools, Watermaster activities, and water user arrangements that are not directly related to the groundwater rights adjudication not be subject to Court review and approval.

2. **Legislation:** The settling parties contemplate that because, among other reasons, the Groundwater cases are *in personam* actions and not *in rem* actions, establishing jurisdiction and legal authority to fully implement the *Antelope Valley Accord* and make it binding on all water users within the AVAA will require a combination of state legislation and a Court Order in the Groundwater Cases.
3. **Drafting Committee:** To ensure that a Settlement Agreement and other appropriate documents implementing the *Antelope Valley Accord* are prepared and presented to the parties for execution and to the Court and state legislature for action, the settling parties will form a drafting committee of attorneys and, if appropriate, some principals, to begin work on these tasks immediately after execution of the *Antelope Valley Accord*. The committee will be fairly representative of the settling parties, and will be charged with producing a package of documents for their review, approval and execution.
4. **Equal Treatment:** To the greatest extent practicable, as the *Antelope Valley Accord*, Settlement Agreement, Court orders, and other actions and agreements are implemented across the AVAA, landowners and groundwater users who have not been parties to either the *Antelope Valley Accord* and Settlement Agreement or the Groundwater Cases litigation shall be treated substantially the same as other parties in the AVAA who have agreed to the *Antelope Valley Accord* and Settlement Agreement and who are similarly situated regarding groundwater rights and use. Terms and conditions applying to new parties shall be established in the documents implementing the Settlement Agreement, or by the Watermaster.

**B. No Precedent; No Waiver:** If the settling parties do not subsequently enter into a Settlement Agreement, and/or there is no corresponding Settlement Order issued by the Court, each party agrees to abide by the privilege and confidentiality requirements of the California mediation law and not use the *Antelope Valley Accord* or any other mediation materials against any party in the litigation, and nothing in this *Antelope Valley Accord – A Statement of Agreed Principles for Settlement*, shall be interpreted as a waiver of any signatory's rights in law or in equity.

**C. Technical Analysis:** Technical and scientific data and information related to the AVAA's hydrogeology, hydrology, and historical groundwater pumping were analyzed in a series of technical reports, which were used to inform the agreements in the *Antelope Valley Accord* concerning Total Sustainable Yield, pumping amounts, and pumping allocations. The settling parties engaged two qualified experts to independently review this information and the parties' use of it. The technical reports and the independent experts' conclusions are attached to the *Antelope Valley Accord* as Exhibit A.

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**Exhibit A – Technical Reports**

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**Exhibit B - Groundwater Banking**

**Groundwater Banking**

- A. Goal: The design, operation, and monitoring for groundwater banks shall be conducted and coordinated in a manner that ensures that the benefits of the banking operations are realized by participants without causing significant adverse impacts to water levels, water quality, or land subsidence.
  
- B. Key objectives:
  - 1. No significant impairment of recharge from native run-off;
  - 2. No significant degradation of groundwater quality outside of the project boundaries;  
and
  - 3. No significant impairment or increase in the pumping costs of neighboring pumpers.

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**AGREED:**

**[signature blocks for settling parties]**



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**TECHNICAL CONSIDERATIONS IN CONSTRUCTING THE SETTLEMENT FRAMEWORK**

by the Mediators for the  
Antelope Valley Groundwater Mediation Principals

### **Abstract**

A Technical Working Group was tasked by the Mediation Principals to examine the existing body of technical and scientific reports on the status of the Antelope Valley groundwater resource in an effort to develop a common understanding of these assessments and reports and how the different reports could reach substantially different conclusions. The Technical Working Group prepared four reports on its analyses, and these are presented here. Informed by these reports, the Mediation Principals agreed that the evidence demonstrated that the AVAA groundwater resource could sustain a pumping rate of 150,000 AF/yr over a ten-year period without risking substantial harm to the resource. Two independent, qualified experts were retained to review these reports and this conclusion, and they substantially concurred.

### **Mediators' Introduction and Summary**

At an early stage in the Mediators' efforts to assist the Antelope Valley Groundwater Mediation Principals ("Principals") in negotiating a settlement agreement it became clear that the status and trends involving the groundwater resource in the Antelope Valley Area of Adjudication ("AVAA" or "Valley") were central to many issues that must be resolved. For example, understanding the resource's characteristics and physical processes was essential in order to develop an agreement on whether the current level of pumping could continue. It was also essential for one of the Principals' goals: to develop a groundwater management system that ensures long-term sustainable use of the resource, while allowing continued use for economic purposes to the extent possible that is consistent with preventing harm to the resource and avoiding related impacts such as subsidence. While many reports and assessments of the resource have already been done, they did not reach identical conclusions and there was no consensus among the Principals regarding which were more reliable or why they had reached different conclusions.

At their meeting on March 31-April 1, 2010, the Principals tasked a small working group (the "Technical Working Group") from among the Principals to oversee the preparation of summary reports on selected technical topics related to the Valley's groundwater resource. The purposes of these summary reports were:

- to establish a shared understanding among the Principals of particular technical issues related to recent assessments of the status of the groundwater resources within the Valley;
- to evaluate and discuss recent trends in the status of those resources to the extent that the available data allowed; and
- to identify areas where additional information or analysis would be needed to provide a basis for moving forward or for responsibly managing the resource in the future.

Most of the members of the Technical Working Group were selected on the basis of their working experience as professional groundwater resource managers or their technical training in relevant subjects. Members were also selected to represent various interests within the larger group of Principals: municipal water purveyors, agriculture, residential development, and water banking. Bill

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West, one of the members of the mediation team, coordinated the Technical Working Group's efforts. Bill's background includes his 25-year pre-law career as a research scientist dealing with complex, difficult-to-study, natural resource management issues.

This compilation presents the reports on technical issues that were produced by the Technical Working Group or as a result of their efforts. This Introduction and Summary describes the goals and processes by which the reports were produced, and discusses their significance to the Principals' evolving understanding of how an acceptable settlement agreement could be structured to ensure sound stewardship of the Valley's groundwater resource while allowing sustainable use of that resource to both address current needs and accommodate future economic growth.

**The Technical Working Group Reports**

The Technical Working Group completed four reports ("Reports") and presented them to the Principals.<sup>1</sup> The Reports are included in this compilation. Each Report was prepared in the following manner: One member of the Technical Working Group, selected on the basis of experience or interests, served as lead author for each paper. The draft was then circulated among the entire Technical Working Group for review, editing, and comments. The edits and comments were addressed or incorporated into a new draft, which then was redistributed to the Group for the next round of edits. Mr. West coordinated the editing and reconciled the contributions from the various Group members. Only when a Report had been approved by the entire Technical Working Group was it considered final.

**Report #1 - trends in standing groundwater levels**

Report #1 describes trends in standing groundwater levels across the Valley. The analysis reviewed data, updated where possible, from the 19 U.S. Geological Survey ("USGS") monitoring wells that were used in the Problem Statement Report.<sup>2</sup> The results revealed various long-term trends in groundwater levels in the Valley: the water table was dropping in the central Valley and around Edwards Air Force Base; however, the water table in other parts of the Valley appeared stable over the period examined. While the information from this review was valuable, it raised a concern that the number and location of these 19 wells did not provide adequate information for a rigorous program of water management.

**Report #2 - trends in groundwater pumping for agriculture**

Report #2 analyzed estimates of historical pumping rates for agricultural purposes in the Valley. The report started with the premise that estimates of historical agricultural pumping are an important component in many groundwater assessment methodologies, e.g., water balance analyses that examine the total volume pumped vs. the amount in storage; and the contributions of pumped and applied water to estimates of return flow. Estimates of agricultural pumping were used in this manner in the Problem Statement Report and in other Reports produced by the Technical Working Group.

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<sup>1</sup> Some additional analyses are currently underway, but have not yet been reviewed by the Technical Working Group.

<sup>2</sup> The Problem Statement Report is a comprehensive technical study that was commissioned by the Mediation Principals at an earlier point in this proceeding.

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One way to estimate agricultural pumping is to multiply known acreages under cultivation by crop-specific water requirements (crop coefficients). However, the crop coefficients used in the Problem Statement Report may not have reflected conditions found in the Antelope Valley. Consultation with agriculture experts from the University of California and Antelope Valley growers produced revised estimates of crop coefficients specific to the Valley, which are now used by the California Water Resources Board for estimating groundwater pumping for agriculture in the Valley. Report #2 employed these revised crop coefficients and found that agricultural pumping may have been higher than the estimates used in the Problem Statement Report.

Report #2 also discussed the importance of estimates of irrigation efficiency, i.e., the proportion of water applied vs. the amount required to meet the plants' needs, noted that there is controversy regarding the correct values for these parameters and the forms of the equations relating crop requirements to estimates of total applied water, and that University of California experts recommended a form for these equations that differs from that used in some previous estimates.

Finally, Report #2 presented a sensitivity analysis intended to indicate which factors drive the differences between alternative estimates of agricultural pumping in the various reports.

**Report #3 - analysis and discussion of critical factors in groundwater assessments**

Report #3 was a discussion of the key factors (formulas, estimates, assumptions) that went into the various assessments of and reports on groundwater status in the Valley. This analysis clarified how these key factors lead to the differences in the outcomes of these assessments and reports. This was motivated by the Principals' realization that it was important for the progress of the mediation process to establish:

- a common technical language;
- a common understanding of the variety of analytical tools and assumptions that have been used in assessing the condition of AVAA groundwater resources, together with the strengths and weaknesses of each of these tools and assumptions;
- and a common understanding of the sources of data used as inputs to those assessments.

This came from the Principals' recognition that several alternative assessments of AVAA groundwater status exist, and that these alternative assessments do not reach the same conclusions about total sustainable yield,<sup>3</sup> or "TSY," and the overall current health of AVAA groundwater resources. The Principals also recognized that the interests of the various Principals, their positions within the mediation process, their perceptions of the risks associated with various approaches to AVAA groundwater management and thus their willingness to consider alternative approaches, were all affected by how much they individually rely on various alternative assessment(s).

Accordingly, the Principals' Group asked the Technical Working Group to review and discuss the important factors and assumptions affecting and driving the range of groundwater assessments that have been presented to or relied upon by members of this group, looking at areas of difference and areas of concurrence. Recognizing that different assessment techniques relying on different data

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<sup>3</sup> Total Sustainable Yield represents the native groundwater recharge plus return flows from both native and imported water.

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inputs and key assumptions will necessarily yield different outcomes, the Technical Working Group was specifically instructed not to debate the value of the various assessments but to analyze and explain how each report addressed the issues. The Technical Working Group's goal was to summarize information by which the individual Principals could reach their own conclusions about, and interpretations of, the alternative assessments that have been prepared and circulated during the course of this adjudication.

Report #3 concluded that estimates of historic pumping and native recharge were important drivers of the different outcomes. The report compared some empirical indicators of groundwater status with the outcomes of the various analyses, and noted that storage volumes in many parts of the Valley have been relatively stable in recent years, suggesting that current pumping volumes may be sustainable in those areas. The report also noted a corollary to this observation: the water table across the Valley is not dropping at the rates that would be expected if severe overdrafting were occurring.

**Report #4 - estimate of TSY as a function of changes in storage vs. pumping volumes**

Report # 4 was an estimate of TSY as a function of changes in storage vs. pumping volumes, using data found in the Problem Statement Report as presented there and as adjusted using the revised Valley-specific crop coefficients discussed in Report #2. The procedure involved identifying a period when the volume of groundwater in storage was stable, indicating that withdrawals were equal to inputs, as a way to estimate TSY if withdrawals during that period are known. The report noted that there was a roughly 20-year period starting in the late 1970's where the data indicated storage was stable. Estimates of groundwater pumping during that same period ranged from roughly 145,000 AF/yr to 164,000 AF/yr, suggesting that TSY would fall within that same range. The report noted that such estimates are sensitive to the period selected for the analysis, the estimated volume of pumping during that period, and the magnitude and lag time of return flows.

**Technical Memorandum #2 - updated estimate of agricultural pumping<sup>4</sup>**

During the mediation a question arose concerning the actual volumes of agricultural pumping at the present time, or as close to the present time as reasonably possible. This question arose out of three concerns: the substantial volumes of agricultural pumping, or approximately 60% of all groundwater pumping in the Valley; the dynamic nature of agricultural pumping rates, which can swing up or down markedly from year to year in response to market considerations, other economic factors, and growing conditions; and the lack of convenient access to reliable, independent and verifiable data on agricultural pumping.

In response to these concerns, Mr. West prepared an independent estimate of agricultural pumping using the method employed in the Problem Statement Report and in the Technical Working Group's Report #2. He obtained records from the Agricultural Commissioners for Los Angeles and Kern Counties of the acreages planted in various crops (or crop categories) for 2007, 2008, and 2009, for parcels located within the Antelope Valley Area of Adjudication. He multiplied the reported acreages for each crop by the applied water requirement specific to that crop to obtain the total amount of water applied for irrigation, then scaled these results upwards by 5% to account for unreported farms, as was done in the Problem Statement Report. Finally, he subtracted the recorded volumes of

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<sup>4</sup> Technical Memorandum #2 ("Tech Memo #2") was not a product of the Technical Working Group but is included in this section because it addressed similar issues using similar analyses.

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surface water and reclaimed water used for irrigation from the total volume of water applied for agricultural irrigation, with the remainder thus representing the total groundwater pumped for irrigation.

Tech Memo #2 compared the results obtained through this procedure with other estimates of agricultural pumping, including an estimate produced from self-reports from farmers, and concluded that current agricultural pumping in the Valley was approximately 105,000 AF/yr.

**The Expert Reviews**

The Principals found these reports useful in informing their decisions. However, given the importance of these analyses, the Principals believed that the reports' value would be enhanced by a review by recognized, independent specialists in the relevant technical and scientific fields. The Principals believed that such a review would be valuable in order to provide more certainty about the range of annual groundwater pumping volumes that the AVAA groundwater resources can support during a ten-year period during which targeted, applied research will be conducted in order to define total sustainable yield with greater precision, and during which a comprehensive program for monitoring the status of the groundwater resource will be coupled with proactive management of the resource.

Accordingly, the Principals authorized Mr. West to retain two qualified experts to take the Technical Working Group's summary reports and other existing information and reports as a starting point to evaluate the existing analyses in light of recent understandings of the relevant scientific and technical information and assessment methods, and using the best presently-available data to produce an assessment of the range of annual groundwater pumping volumes within which total sustainable yield would be expected to occur.

Mr. West sent requests for proposals to a number of hydrogeologists, some in private consulting practice and some from academia. Two experts were selected on the basis of their qualifications, ability to work within the time constraints, and absence of potential conflicts of interest. These were: Mr. David Abbott of Todd Engineers, 2490 Mariner Square Loop, Suite 215, Alameda, CA 94501-1080; and Mr. Ken Schmidt of Kenneth D. Schmidt and Associates, 3701 Pegasus Drive, Bakersfield, CA 93308.

The experts were asked to respond to the following questions:

- Is it reasonable to conclude that the range identified in the summary reports bounds the actual total sustainable yield in light of the data available?
- Did the summary reports correctly identify and assess the operation and significance of the critical factors (methodologies, key assumptions, and values of critical parameters) that drive the range of outcomes of the assessments considered?
- Are there other key factors that either were not considered in the underlying assessments, or were not identified or examined in the summary reports, and if so what is their significance in terms of influencing assessment outcomes?

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- Based on the data and analyses presently available, did the Principals reasonably conclude that the AVAA groundwater resource could sustain a pumping rate of 150,000 AF/yr over a ten-year period without risking substantial harm to the resource?

The experts were asked to consider and answer these questions based on available current information and reports. In order to not influence their analyses, the groundwater protection and management measures that the Principals were considering for incorporation into their settlement agreement were not shared with the experts. These include: applied research aimed at identifying total sustainable yield with greater precision; a comprehensive program for monitoring the status of the groundwater resource; adaptive management of the groundwater resource; and the identification of management zones or sub-areas within the Valley, within which groundwater management practices will be tailored to manage use within each management area on a sustainable basis, and on a basis that does not negatively impact groundwater resources in down-gradient management areas.

**Mr. Schmidt's report**

After reviewing the reports and documents described above, and in light of his own knowledge and experience, Mr. Schmidt concluded that the actual range of groundwater TSY in the Valley is "probably about 160,000 to 180,000 acre-feet per year." He took issue with some of the data selected for analysis in the reports, some of their assumptions, and details of some of their conclusions, but did not find any of them clearly erroneous. He strongly endorsed the work presented in Report #2, which discussed estimates of agricultural pumping in view of Valley-specific crop requirements. Mr. Schmidt expressed concerns about the 19 USGS monitoring wells chosen for analysis in the Problem Statement Report and Report #1, noting that information was lacking about their characteristics that would allow better interpretation of data from them, and that data from 50 to 70 wells should be examined instead of 19. He also concurred with Report #4 that TSY estimates are sensitive to the lag times of return flows. Mr. Schmidt concluded his report with the opinion that "150,000 acre-feet per year of pumping over a 10-year period is a reasonable pumping volume to be used" as long as an average of 70,000 AF/yr of water is imported into the Valley, as is presently being done.

**Mr. Abbott's report**

Mr. Abbott concluded that the answer to question four from the terms of reference was a qualified yes: "the Principals reasonably concluded that the AVAA groundwater basin could sustain a pumping volume of 150,000 AF/yr over a 10 year period (total of 1,500,000 AF) without risking substantial harm to the groundwater resources under average or above-average operating conditions including climatologic conditions and water imports." Not surprisingly, he did note that a pumping volume of 110,000 AF/yr for 10 years posed "a lower risk of harming the groundwater resources under current conditions." However, he noted that while the range of TSY estimates in the reports bounds the actual TSY, "It is my opinion that the actual TSY is closer to 110,000 AF/yr rather than to 170,000 AF/yr; the TSY is likely between 110,000 and 130,000 AF/yr..." In reaching this conclusion he cited uncertainty and bias in basic hydrologic data (precipitation and stream flows) and other elements (return flows, pumping estimates, and evapotranspiration) of the water balance; low predicted lag times and overestimates of return flows; his belief that native recharge, native sustainable yield, and bedrock infiltration values are at the low end of the ranges discussed in previous assessments.

July 12, 2010

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Mr. Abbott approved of the Reports' analyses of critical factors and the inherent uncertainties of the components of water balance calculations, and agreed that these components need to be further developed. He also stated, "The summary reports, especially Report #3, recognize that a common language with associated technical definitions is important for proper communication between stakeholders. The summary reports recognized also, and identified correctly, that additional work (including ongoing and additional monitoring) is essential to improve the hydrologic understanding of the AVAA and to refine the water balance and TSY."

Mr. Abbott noted that TSY is a dynamic quantity on both annual and decadal time scales, and went on to state, "Not only is the value of the TSY dynamic but accurate measurements of the critical elements of the water balance are difficult (and in some cases, impossible) to achieve, and can be imprecise." Mr. Abbott noted that precipitation records during the period 1979 to 1997, i.e., the period of stable water tables examined in Report #4, were high relative to the period 1950-2005, and that this could lead to an overestimate of TSY based on the method used in Report #4 if the longer period were a better predictor of future trends.

**Conclusions**

In view of the range of opinions previously expressed by other experts, and the acknowledged difficulty of obtaining adequate data or verifying key assumptions, it was not a surprise that these two experts could reach different conclusions about TSY in the Valley. Mr. Schmidt's estimate of TSY was a range of 160,000 AF/yr to 180,000 AF/yr. Mr. Abbott's range was 110,000 AF/yr to 130,000 AF/yr, although he did express a qualified conclusion that 150,000 AF/yr could be sustainable under the right circumstances. A mid-point of their ranges is approximately 145,000 AF/yr, which is close to the proposed level of 150,000 AF/yr. Both reports support a conclusion that a pumping rate of 150,000 AF/yr can be sustained for ten years without risking substantial harm to the aquifer. Mr. Schmidt's report would lead one to a somewhat higher number and Mr. Abbott's conclusion would point to a somewhat lower number.

Both experts reached their conclusions without taking into consideration the water management measures that the Principals have incorporated into their proposed settlement agreement. These include: initial cuts from current pumping levels; identifying and employing management areas to manage groundwater pumping; further real-time adjustments to pumping in management areas as needed; encouraging and facilitating use of water from management areas where it is relatively abundant into areas where it is not; and encouraging increased use of imported water and recycled water. These measures would be expected to increase the margin of safety around the proposed level of 150,000 AF/yr of groundwater pumping during a ten year verification and monitoring period.

In their reports, both experts provided valuable advice on how to focus and refine future research and monitoring efforts regarding the Valley's groundwater resource. In addition to the research and monitoring activities already planned by the Principals, the new efforts the experts recommended include: expanding the number of monitoring wells that are routinely sampled and observed, plus gaining more information about the structure of these wells and the geotechnical properties of the strata they penetrate; studies of soil moisture and other soil properties; and monitoring the water quality at sampling wells. Taken together with the program that the Principals have already endorsed, this should provide a sound scientific and technical foundation for sustainable management of the Valley groundwater resource.



July 12, 2010

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**Appendix**

An additional document, **CHANGE IN GROUNDWATER LEVELS 1997-2009**, was prepared by members of the Technical Working Group too late to be considered by the two independent experts. Nonetheless, the information presented in this report could be of value to persons considering the status of the Antelope Valley groundwater resource. Accordingly it has been appended to this document together with its exhibits.

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**REPORT # 1: SUMMARY AND SYNTHESIS OF AVAILABLE INFORMATION ON STANDING  
GROUNDWATER LEVELS AND SIGNIFICANT TRENDS**

Technical Working Group, Antelope Valley Groundwater Mediation Principals  
April 14, 2010

**INTRODUCTION**

At the meeting of the Antelope Valley Groundwater Mediation Principals on March 31-April 1, 2010, the Principals agreed to task a small working group of volunteers from within the Principals' Group to draft short summary reports on selected topics. The general purpose of these summary reports is to establish a shared understanding within the Principals' Group of particular technical issues related to recent assessments of the status of the groundwater resources within the Antelope Valley Area of Adjudication (AVAA), to evaluate and discuss recent trends in the status of those resources to the extent that the available data permit, and to identify areas where additional information or analysis is needed to provide a basis for moving forward.

**STANDING GROUNDWATER LEVELS WITHIN THE ANTELOPE VALLEY**

As discussed by the Technical Working Group on April 6, 2010, it is important to understand how well the groundwater levels in the Antelope Valley Area of Adjudication (AVAA) are able to reflect any change in groundwater storage. There is general agreement on the historic groundwater level declines and loss of groundwater storage in the mid-1900's. However, there is less agreement concerning changes within the last twenty to thirty years, especially over the last ten years.

The authors of the Problem Statement Report (PSR) analyzed a large amount of data, developed several computer models, and presented analyses and figures in the PSR estimating groundwater storage since the 1950's. PSR Figures 4.3-9, 4.3-10, and 4.3-11, which summarize and illustrate these findings, are attached for reference as Exhibit A. In general, they show a relatively constant groundwater storage volume from 1980 to 2000 and then an apparent decline from 2000 to 2005. At the time the PSR was drafted, no data were available for the years following 2005 so neither the 2005 level of groundwater storage nor the apparent declining trend could be verified.

Figure 4.3-9 of the PSR shows the location and hydrographs of nineteen wells that were used to help calibrate the computer modeling used in the PSR. Data from these wells from the time since 2005, if available, can provide a starting point to understand how the groundwater levels and storage have changed since 2005.

The United States Geological Survey (USGS), in association with local agencies, has monitored static groundwater levels and water quality in numerous (over 200) wells across the AVAA since early in the 1900's. The nineteen wells shown in PSR Figure 4.3-9 are included in the USGS monitoring program. Results from the monitoring program are now available through a publicly accessible web site maintained by the USGS, with monitoring information for California available at [http://ca.water.usgs.gov/gmaps/gw\\_map.html](http://ca.water.usgs.gov/gmaps/gw_map.html). The counties of Los Angeles and Kern can then be mapped to show the wells involved in the monitoring program in those counties. The attached screen shots from the USGS website depict the locations of groundwater monitoring wells in Los Angeles and Kern Counties. See Exhibit B.

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Updated hydrographs from the nineteen wells used in the PSR's analysis were copied from the USGS web site and are attached in groupings of similar areas and types of use. See Exhibit C. For the purpose of this summary, the groupings are: West & East Agricultural (AG) Areas, Lancaster-Palmdale Area, Rosamond Area, the Edwards Air Force Base (EAFB) Area, the Poppy Reserve Area, the Butte Subunit, and the Pearland Subunit. The information from most of these wells is fairly complete through the present date, although updated groundwater levels are not available for three well sites. The remaining well sites help give a picture of general trends in the AVAA.

The updated groundwater levels show a downward trend in the central areas of the AVAA and the Edwards Air Force Base area. Areas in Rosamond, in the western part of the AVAA near the fault zones, and along the eastern AVAA boundary show relatively stable groundwater levels. The map attached as Exhibit D, "AV Groundwater Areas and Trends," was adapted from PSR Figure 4.3-9 to show the area groupings and includes arrows showing the trends from 2000 to a time as close to the present as the data will permit.

**CONCLUSION**

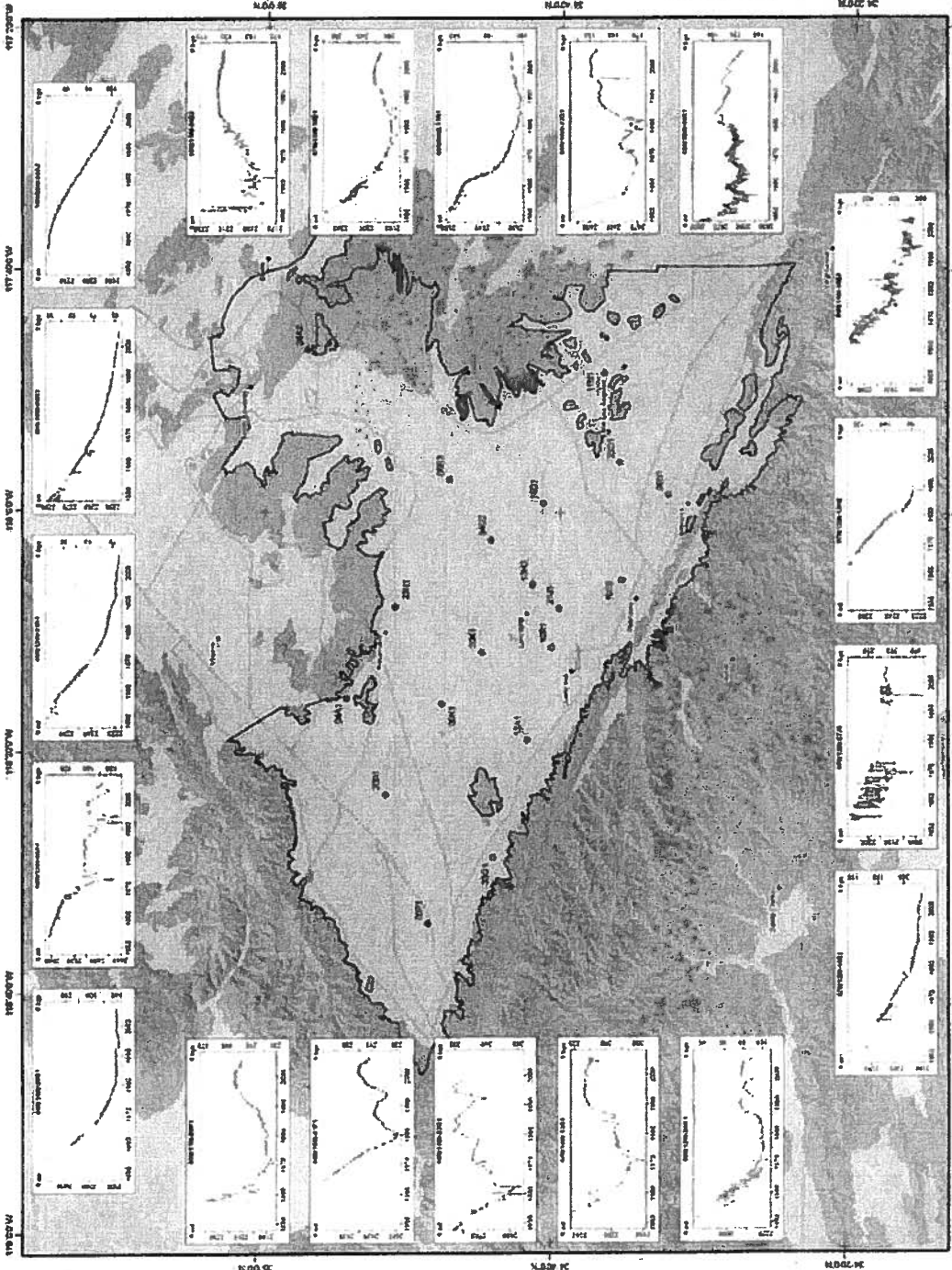
In conclusion, the updated information shows declining static groundwater levels in a large portion of the AVAA, suggesting an apparent declining trend in groundwater storage in those areas but not in others. If this is correct it would provide an important tool for guiding groundwater management in the AVAA. However, the limited number of wells originally selected for the analysis in the PSR, complicated by the lack of recent data for three of the 19 selected, raises concerns about the reliability of conclusions drawn from such a limited sample.

Further work to verify and quantify these findings should incorporate additional well sites within all the areas of the AVAA, including wells not presently being monitored by USGS, verification of monitoring protocols, and updated, calibrated, computer modeling. Adding additional monitoring wells to the analysis, instituting quality control measures on the data, and adopting more robust analytical techniques will allow the development of a more reliable picture of spatial and temporal patterns in groundwater storage in the AVAA.

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## Exhibit A.

Figures 4.3-9, 4.3-10, and 4.3-11 from the Problem Statement Report

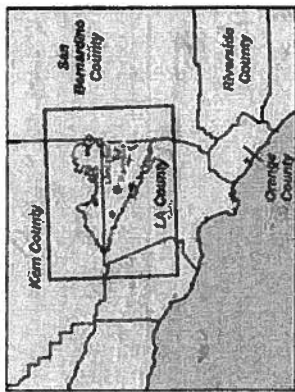


- Main Features**
- West Antelope Valley
  - East Antelope Valley
  - North Antelope Valley
  - South Antelope Valley

- Antelope Valley Groundwater Basin - Adjusted
- Antelope Valley Groundwater Sub-basins

**Geologic Features**

- Water-Bearing Sediments
- Pliocene to Holocene Alluvium
- Consolidated Bedrock
- Undifferentiated Pre-Tertiary to Early Pleistocene igneous, metamorphic, and sedimentary rocks



**Groundwater Elevation Trends  
Antelope Valley Groundwater Basin**

**Figure 4.3-9**

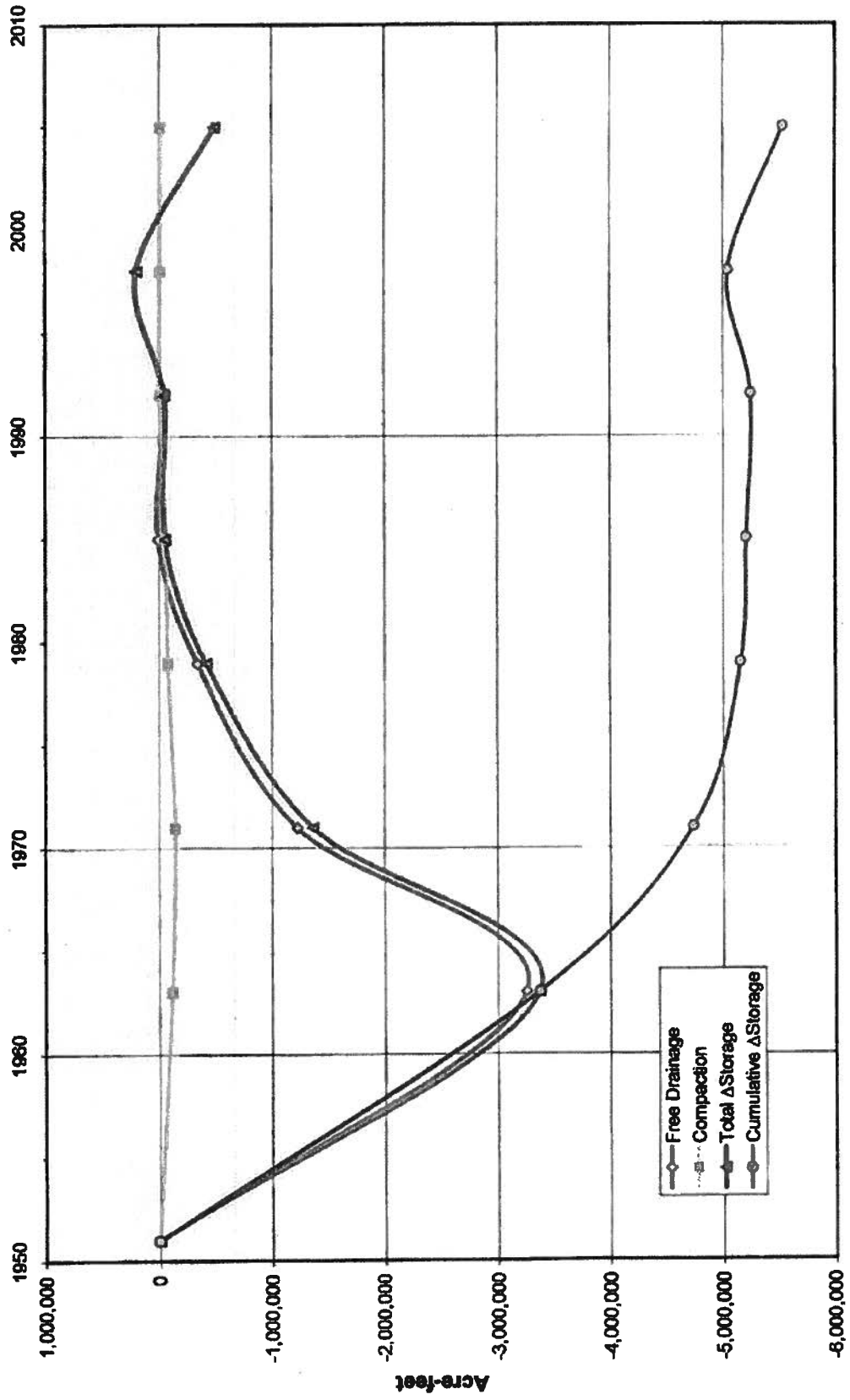
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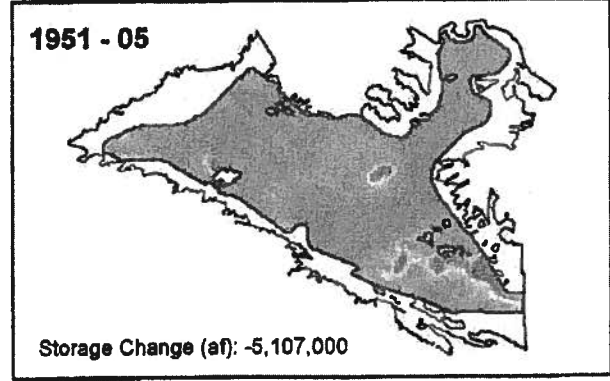
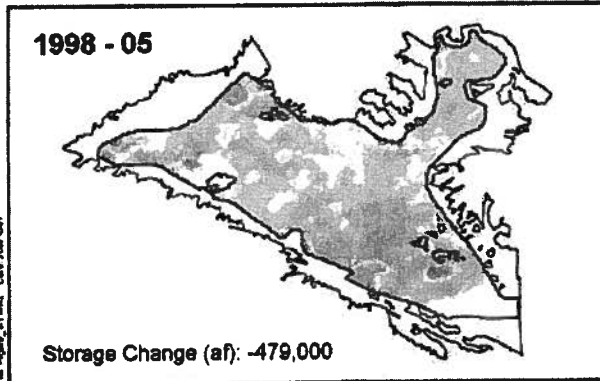
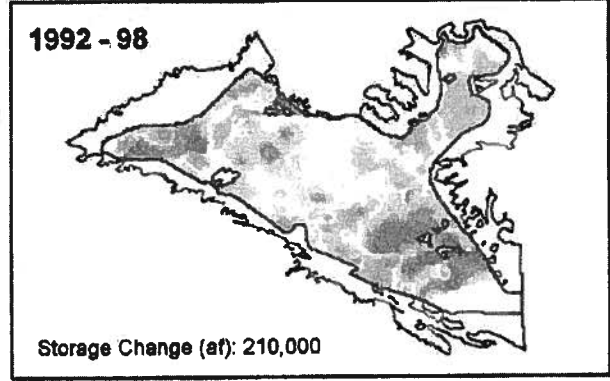
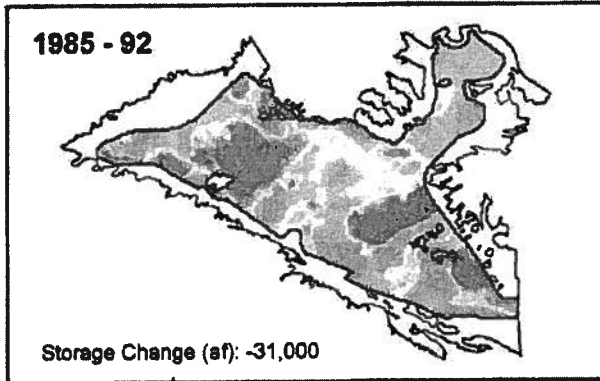
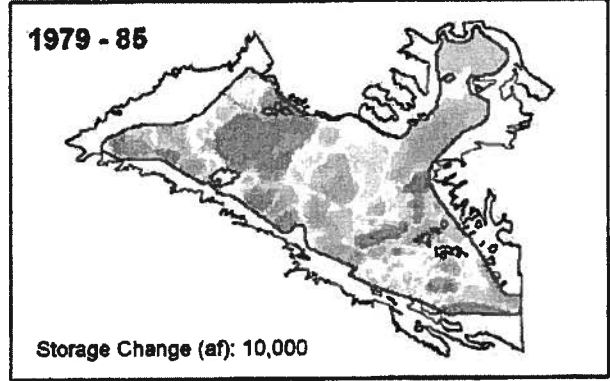
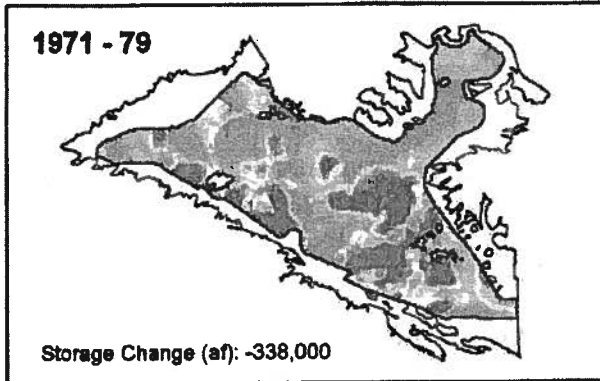
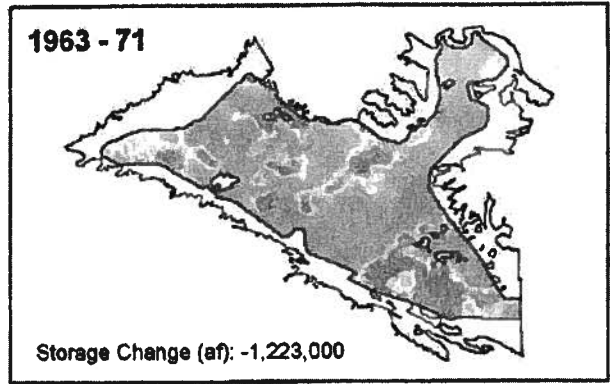
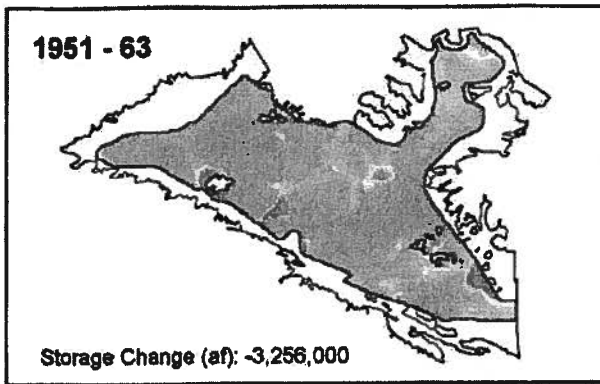
Prepared by:
   
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Author: WCL
   
 Date: 2008010
   
 File: AntelopeValley\_elevations\_fig4.3-9.mxd

687-001
   
 001

Figure 4.3-10: Storage Change and Storage Change Components 1951 - 2005





File: 43g98\_51.mxd Date: 2007-06-01

Storage Change (acre-feet) / 400 x 400 meters

11 - 50   51 - 100   101 - 300   301 - 500   > 500   No Change   -50 - -11   -100 - -51   -300 - -101   -500 - -301   < -500

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0 10 20 30 40 Miles

**Groundwater Storage Change**

Antelope Valley, CA

Figure 4.3-11

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## Exhibit B.

Locations of wells in the Antelope Valley that are monitored by the United States Geological Survey



http://ca.water.usgs.gov/gmaps/gw\_map.html

USGS California Water Science Center Groundwater L...

**access to CA hydrologic monitoring data**

- [Precipitation](#)
- [Streamflow](#)
- [Ground water Levels](#)
- [Water Quality](#)
- [Lakes](#)

**Water Data Made ( )**

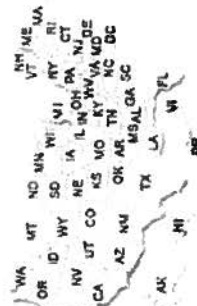
- [NWISWeb \( \)](#)
- [Real-time data \( \)](#)
- [Site Information \( \)](#)
- [Streamflow \( \)](#)
- [Ground water \( \)](#)
- [Water quality \( \)](#)
- [Precipitation \( \)](#)

**Historical data**

- [Streamflow \( \)](#)
- [Ground water \( \)](#)
- [Water quality \( \)](#)
- [Annual Data Reports \( \)](#)
- [WaterWatch \( \)](#)
- [Floods/High flows \( \)](#)
- [DroughtWatch \( \)](#)
- [Ground water \( \)](#)
- [2006 Streamflow Summary \( \)](#)

**USGS IN YOUR STATE**

USGS Water Science Centers are located in each state.

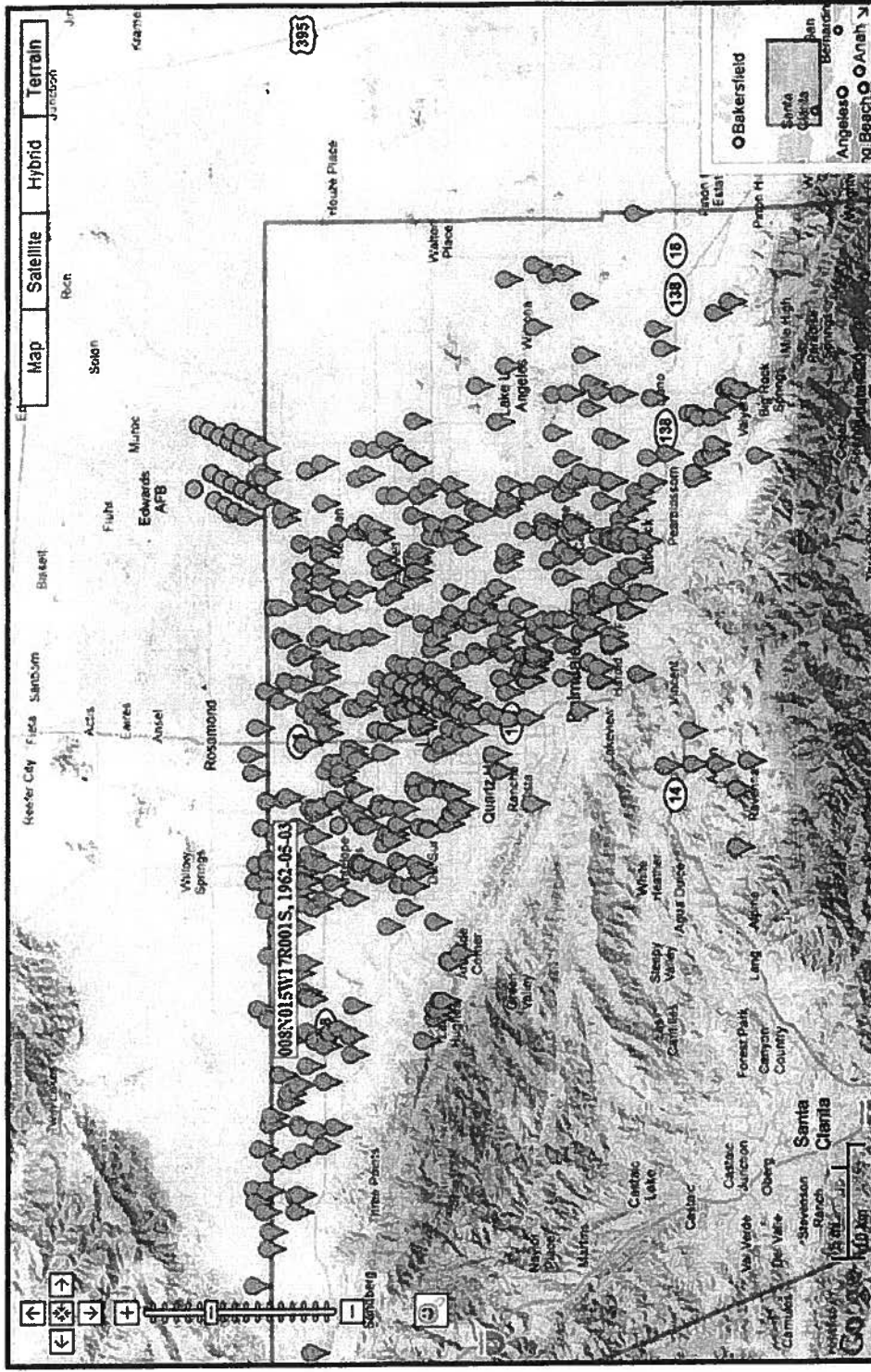


Show Sites in County: Los Angeles

Map it

**Groundwater Sites in Los Angeles County**

Use the map's zoom tool below ( ) to focus on your area of interest. Click on an individual site marker to view additional information about that site. Data are provisional and subject to revision.



This site contains multiple monitoring wells, each at differing depths.

Data Portals

- access to CA
- hydrologic monitoring data
- Precipitation
- Streamflow
- GROUNDWATER
- Lakes
- Water Quality
- Lakes

Show Sites in County: Kern

Map it

### Groundwater Sites in Kern County

Use the map's zoom tool below ( ) to focus on your area of interest. Click on an individual site marker to view additional information about that site. Data are provided and updated as revisions.

#### Water Data Maps ( )

- Rest-frame data ( )
- Site Information ( )
- Streamflow ( )
- Ground water ( )
- Water quality ( )
- Precipitation ( )

#### Historical data

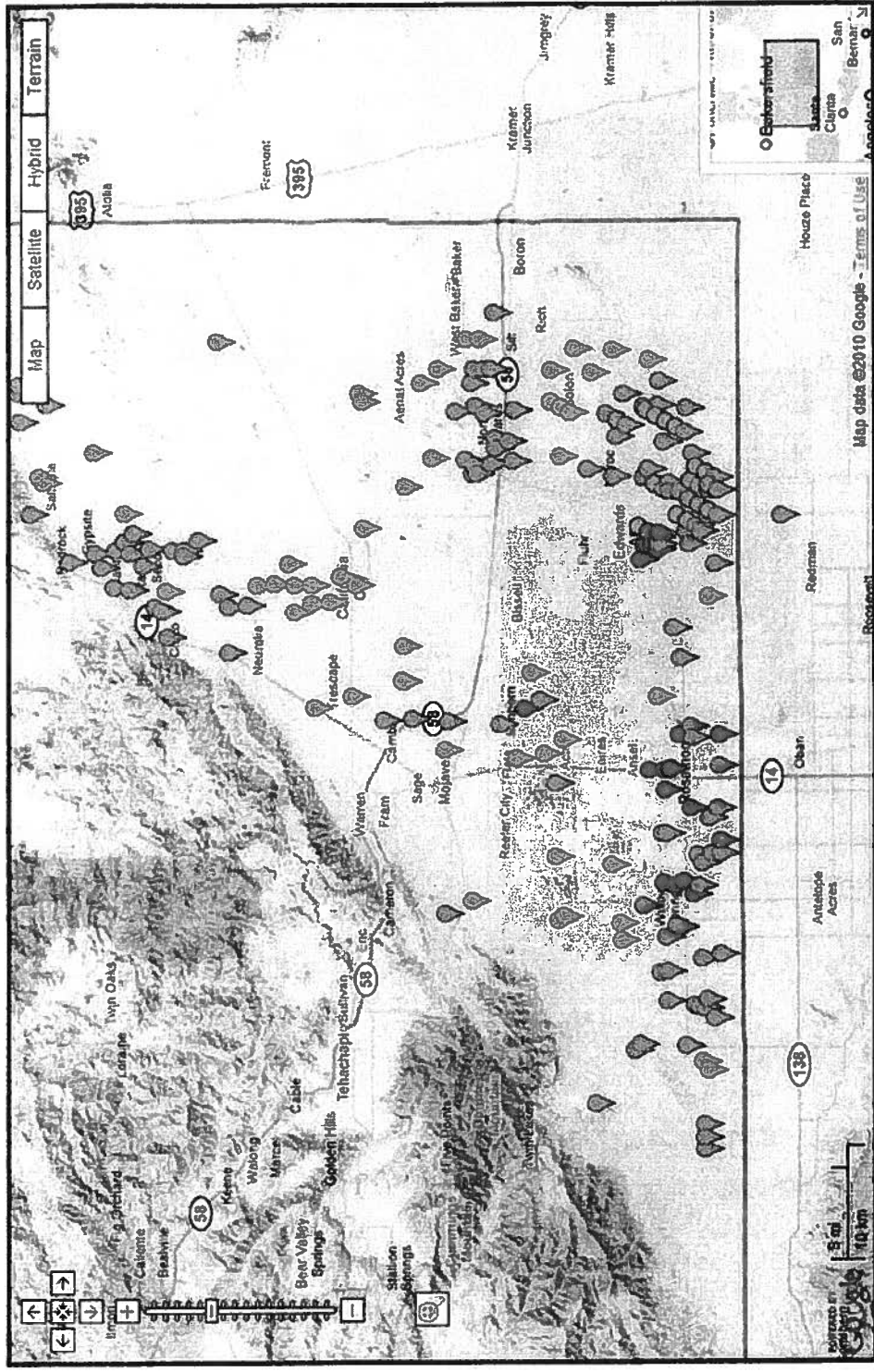
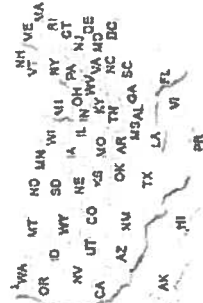
- Streamflow ( )
- Ground water ( )
- Water quality ( )
- Annual Data Reports ( )

#### WaterWatch ( )

- Floods/High flows ( )
- Droughtwatch ( )
- Ground water ( )
- 2006 Streamflow Summary ( )

#### USGS IN YOUR STATE

USGS Water Science Centers are located in each state.



This site contains multiple monitoring wells, each at differing depths.

#### Data Portals

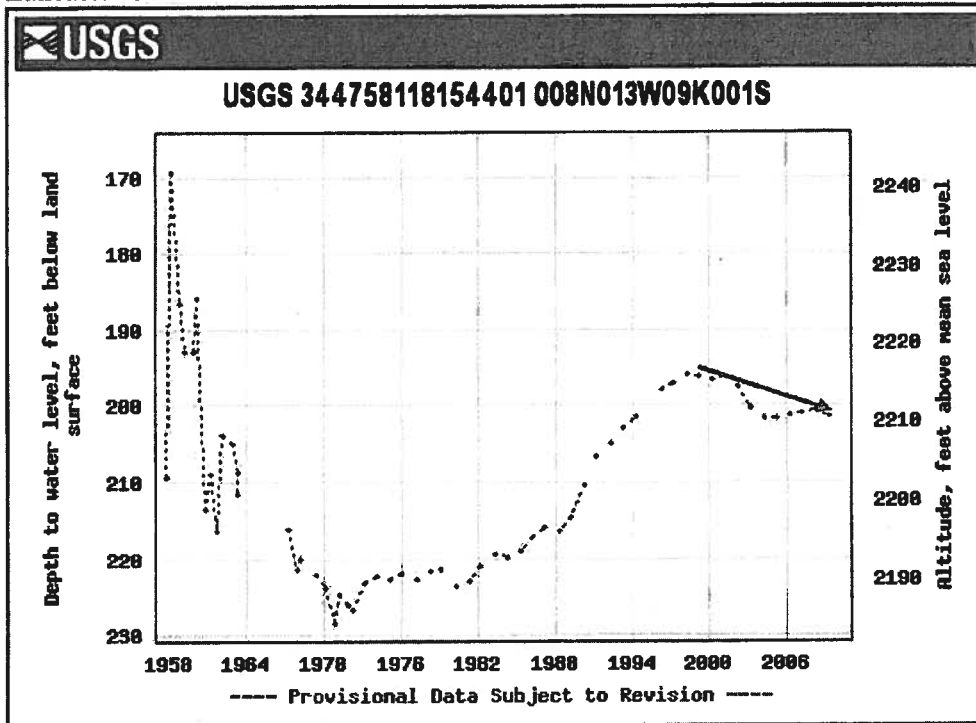
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## Exhibit C.

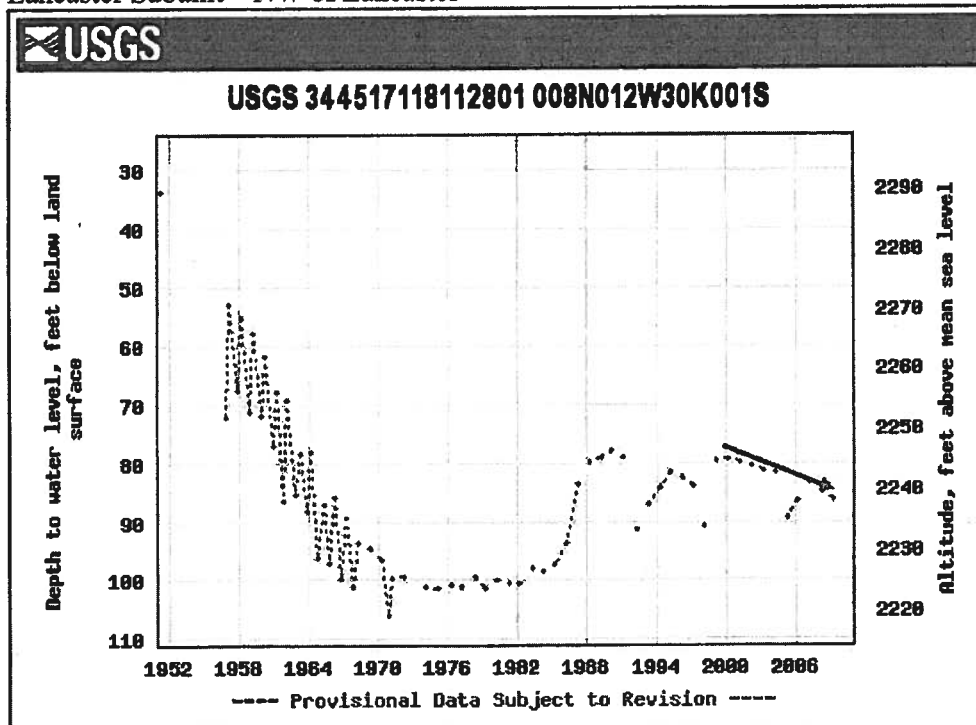
Updated hydrographs for nineteen monitoring wells that were used in the groundwater storage analysis in the Problem Statement Report

WEST & EAST AG AREAS

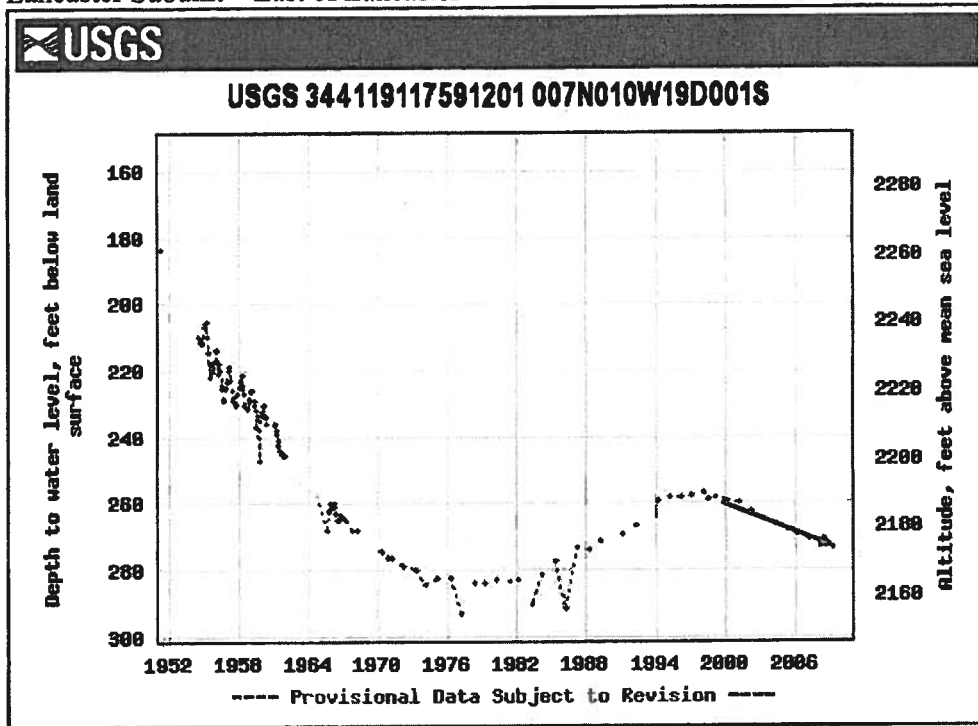
Lancaster Subunit – NW of Lancaster



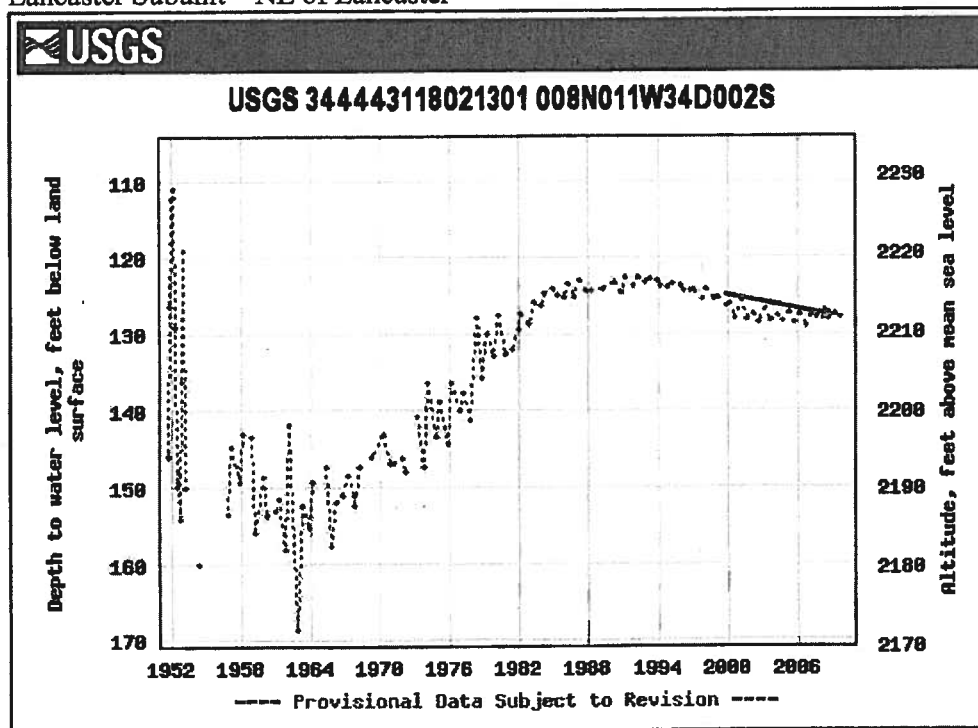
Lancaster Subunit – NW of Lancaster



Lancaster Subunit – East of Lancaster

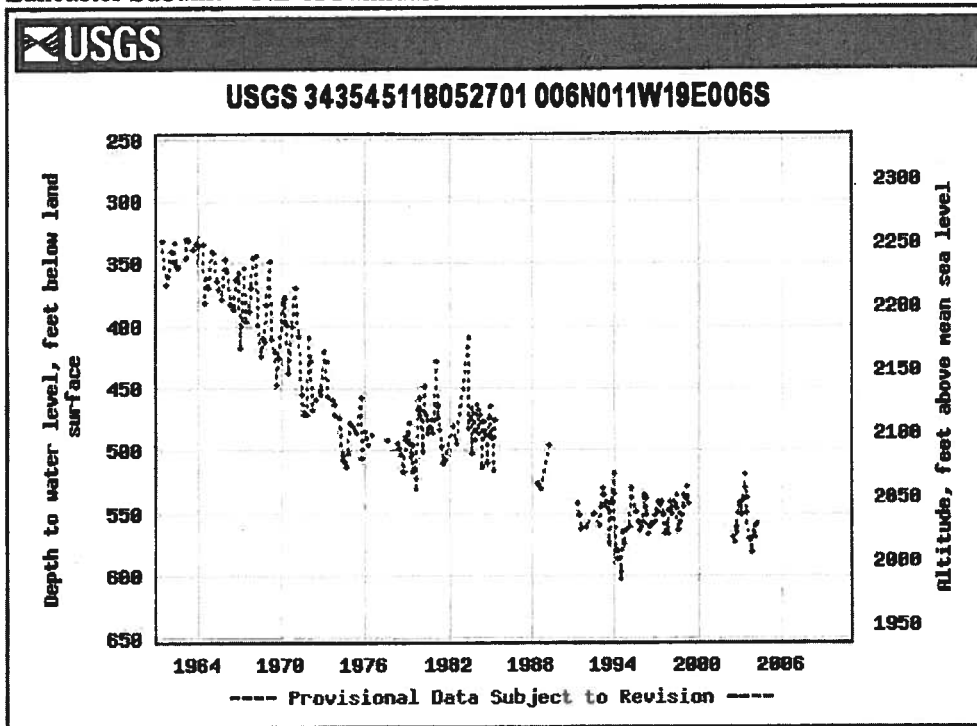


Lancaster Subunit – NE of Lancaster

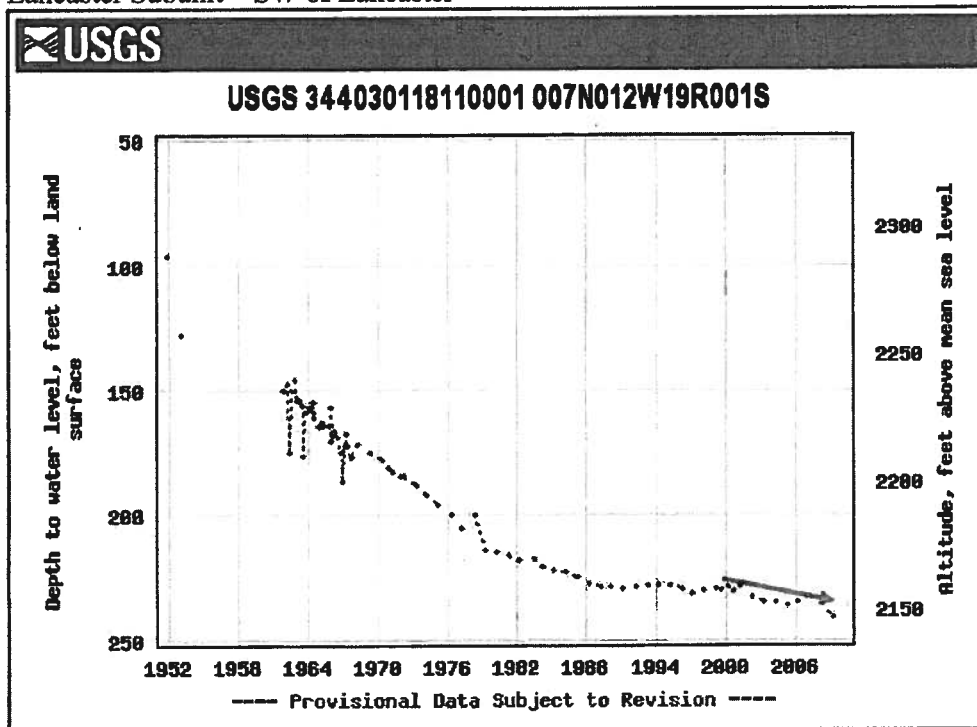


# LANCASTER - PALMDALE AREA

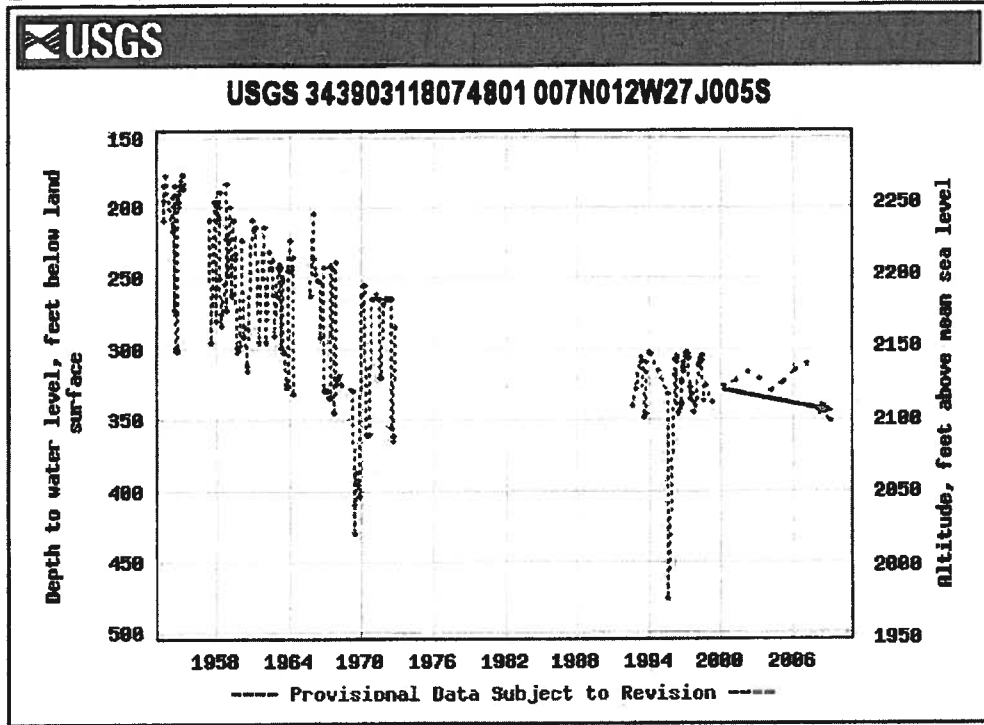
Lancaster Subunit - NE of Palmdale



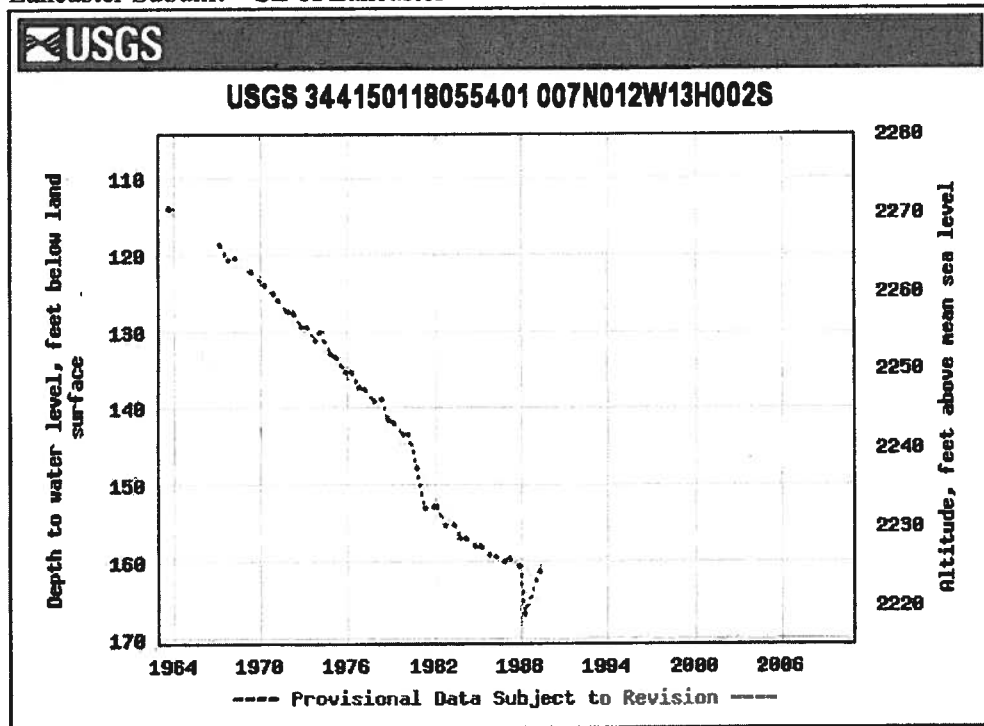
Lancaster Subunit - SW of Lancaster



Lancaster Subunit – South of Lancaster

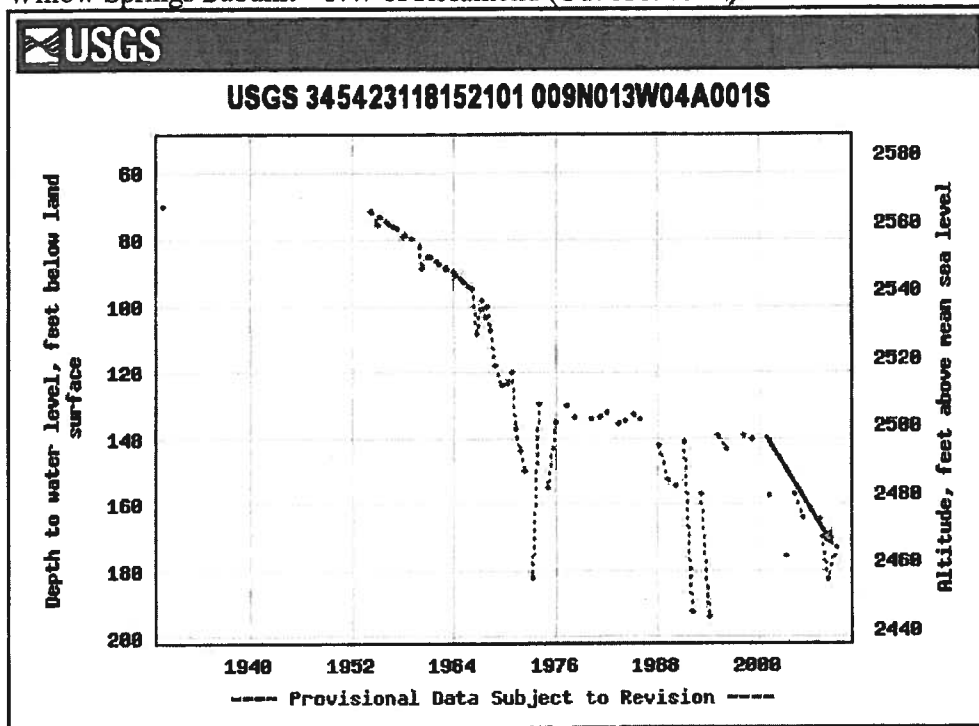


Lancaster Subunit – SE of Lancaster

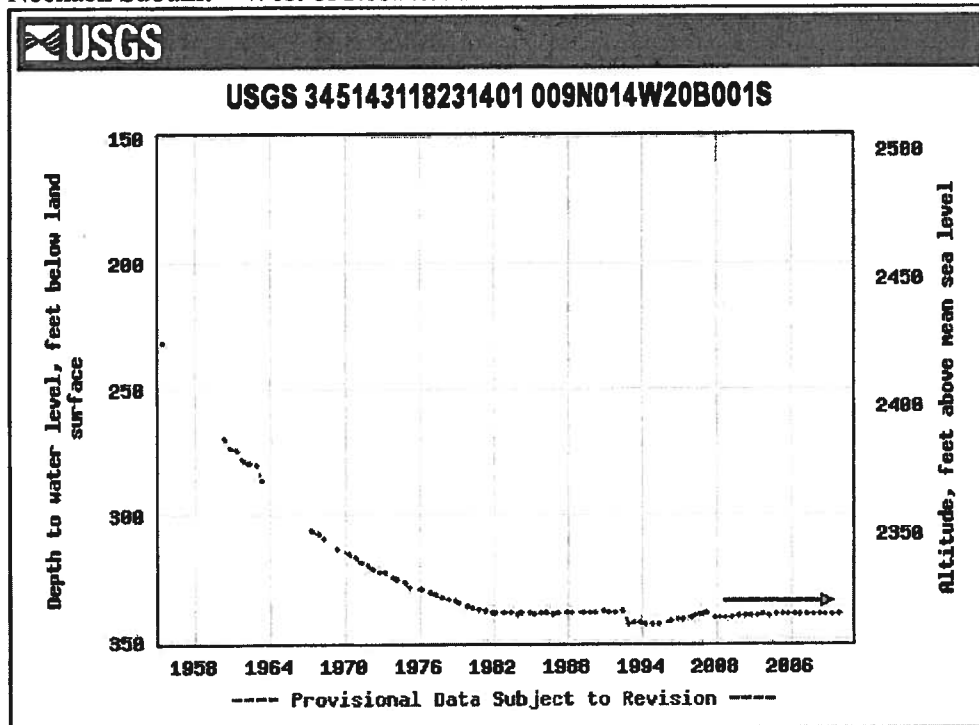


## ROSAMOND AREA

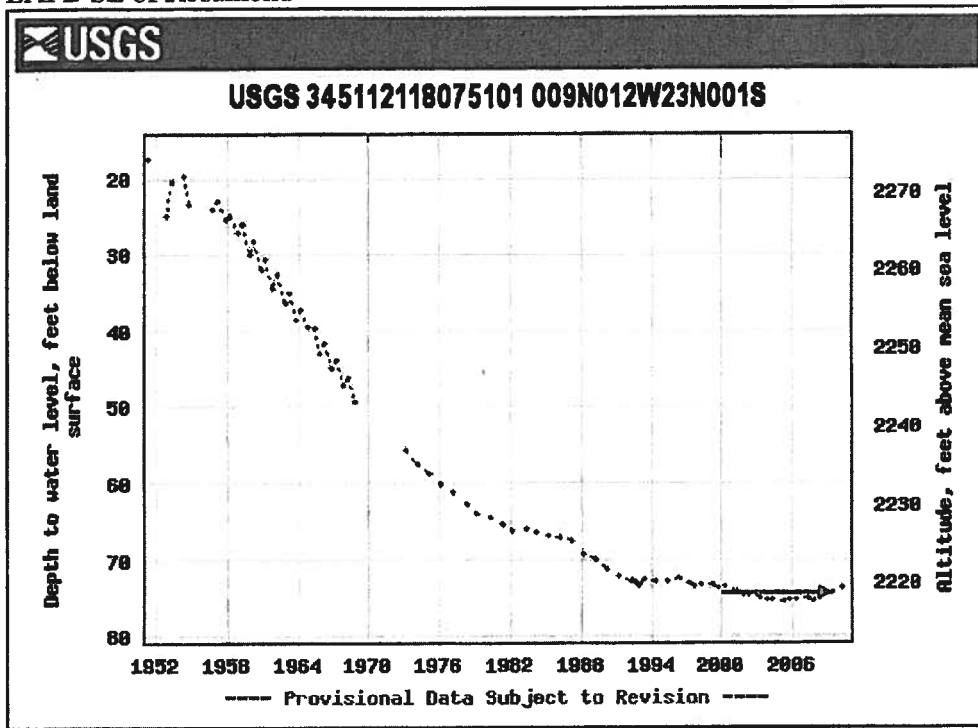
Willow Springs Subunit – NW of Rosamond (Out of AVAA)



Neenach Subunit – West of Rosamond

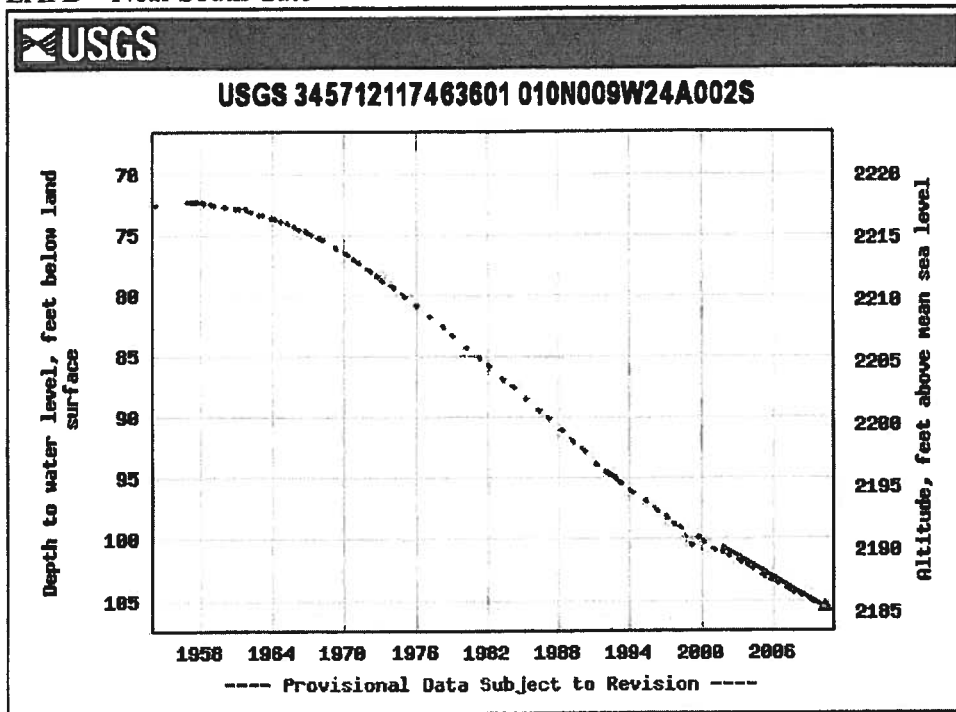




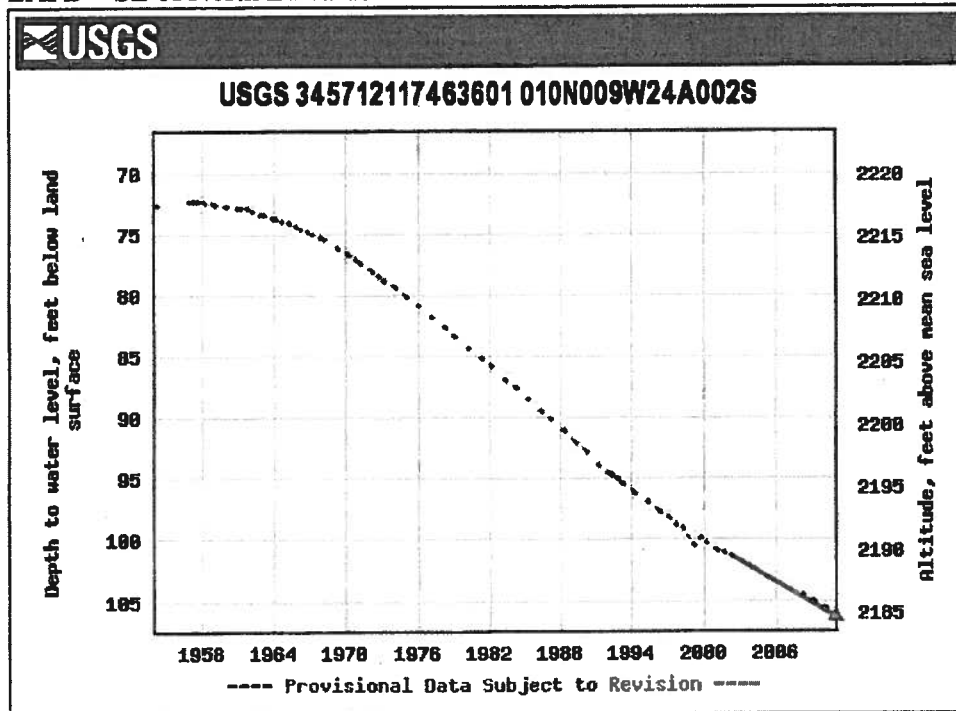


EAFB AREA

EAFB – Near South Gate

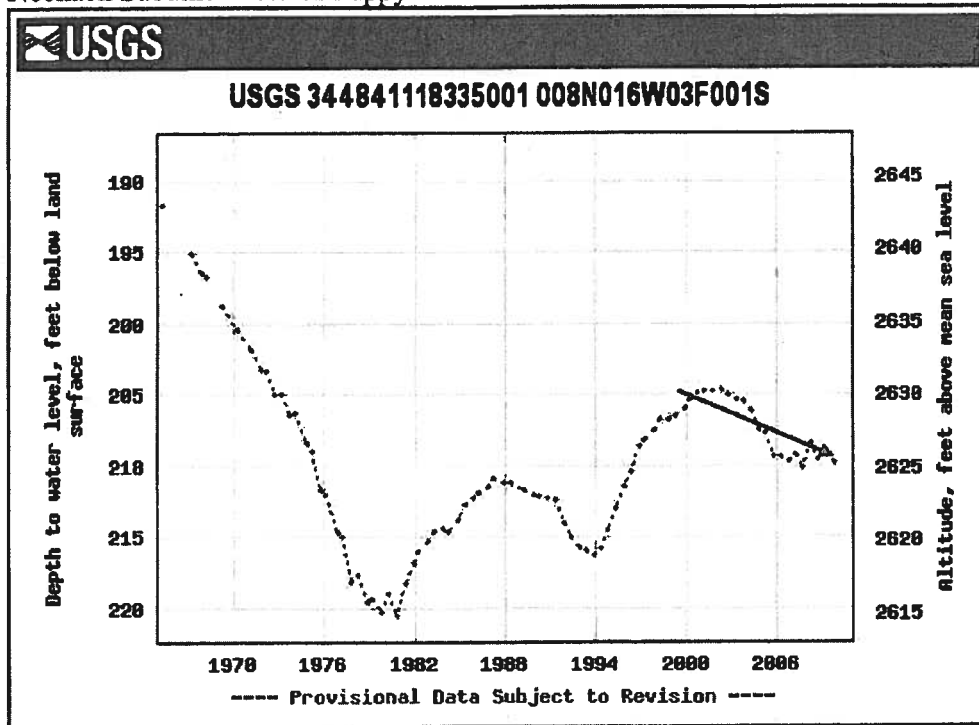


EAFB – SE of North Edwards

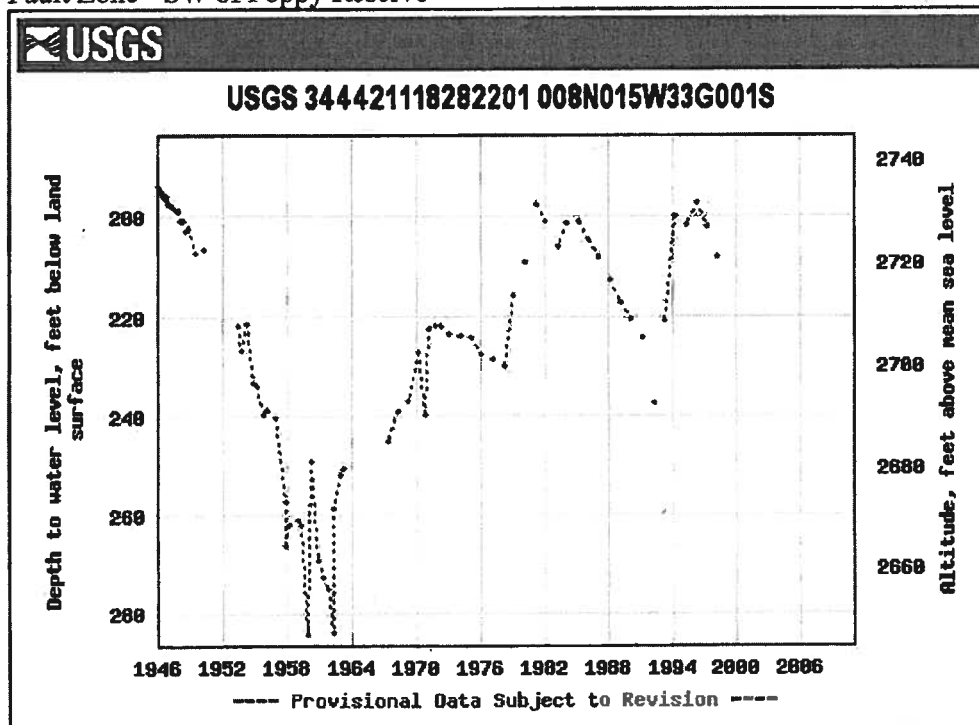


# POPPY RESERVE AREA

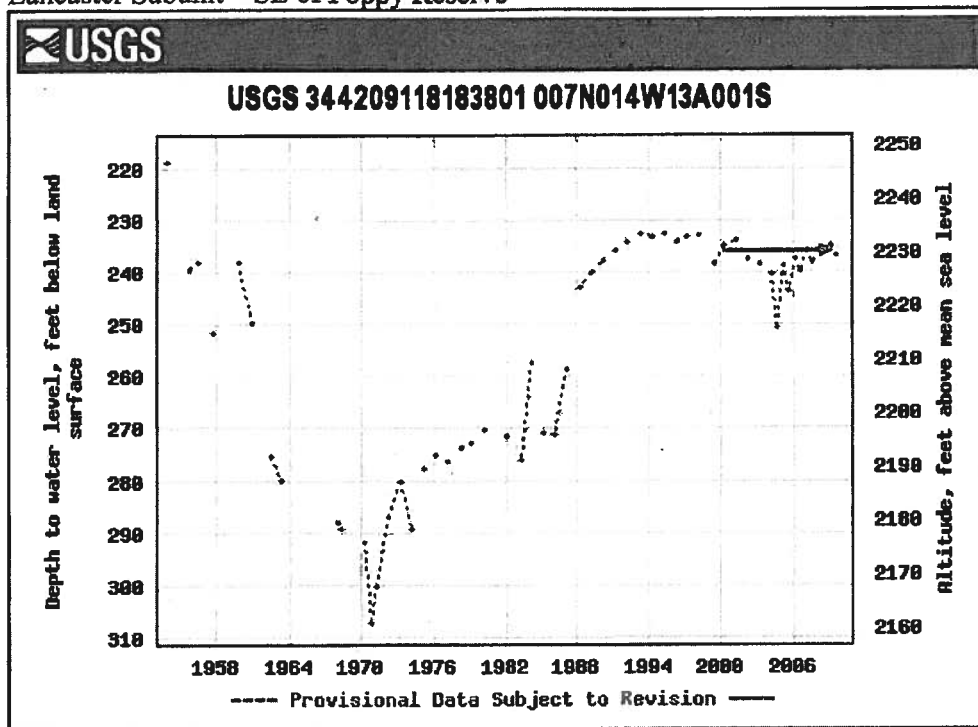
Neenach Subunit – NW of Poppy Reserve



Fault Zone - SW of Poppy Reserve

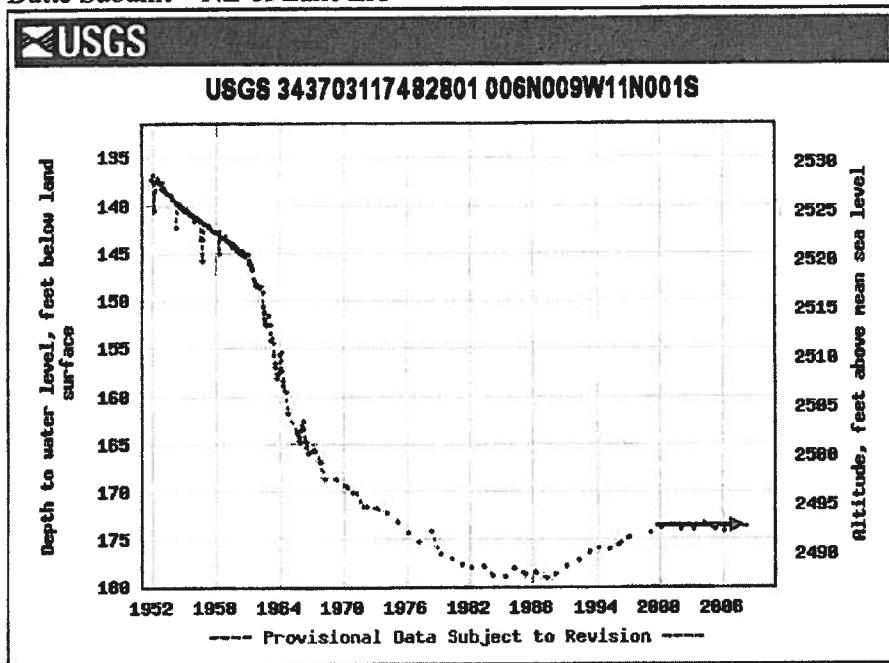


Lancaster Subunit – SE of Poppy Reserve

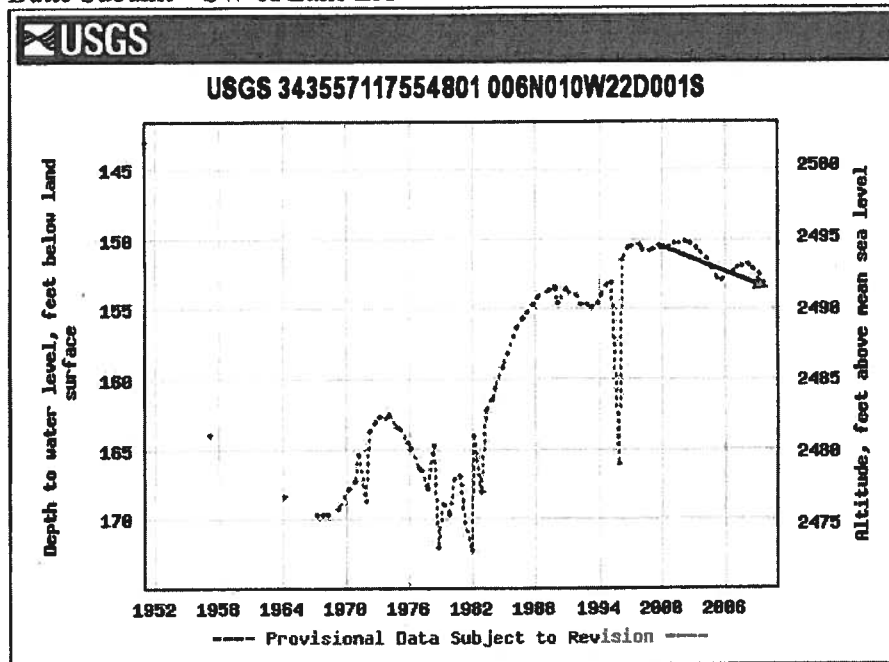


**BUTTE SUBUNIT**

Butte Subunit – NE of Lake LA

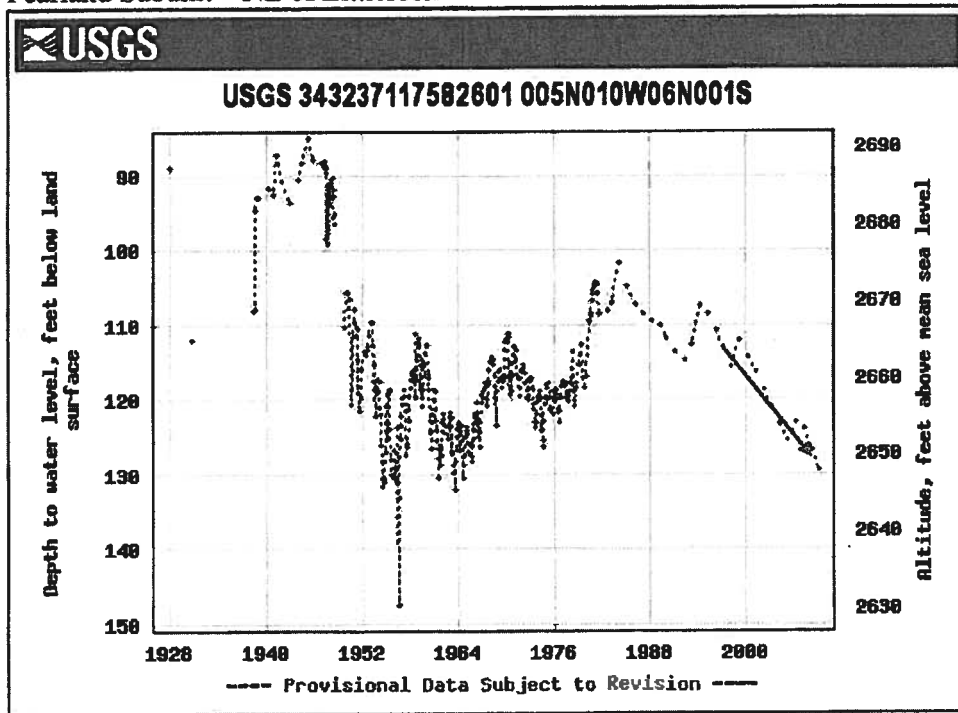


Butte Subunit – SW of Lake LA



PEARLAND SUBUNIT

Pearland Subunit – NE of Littlerock



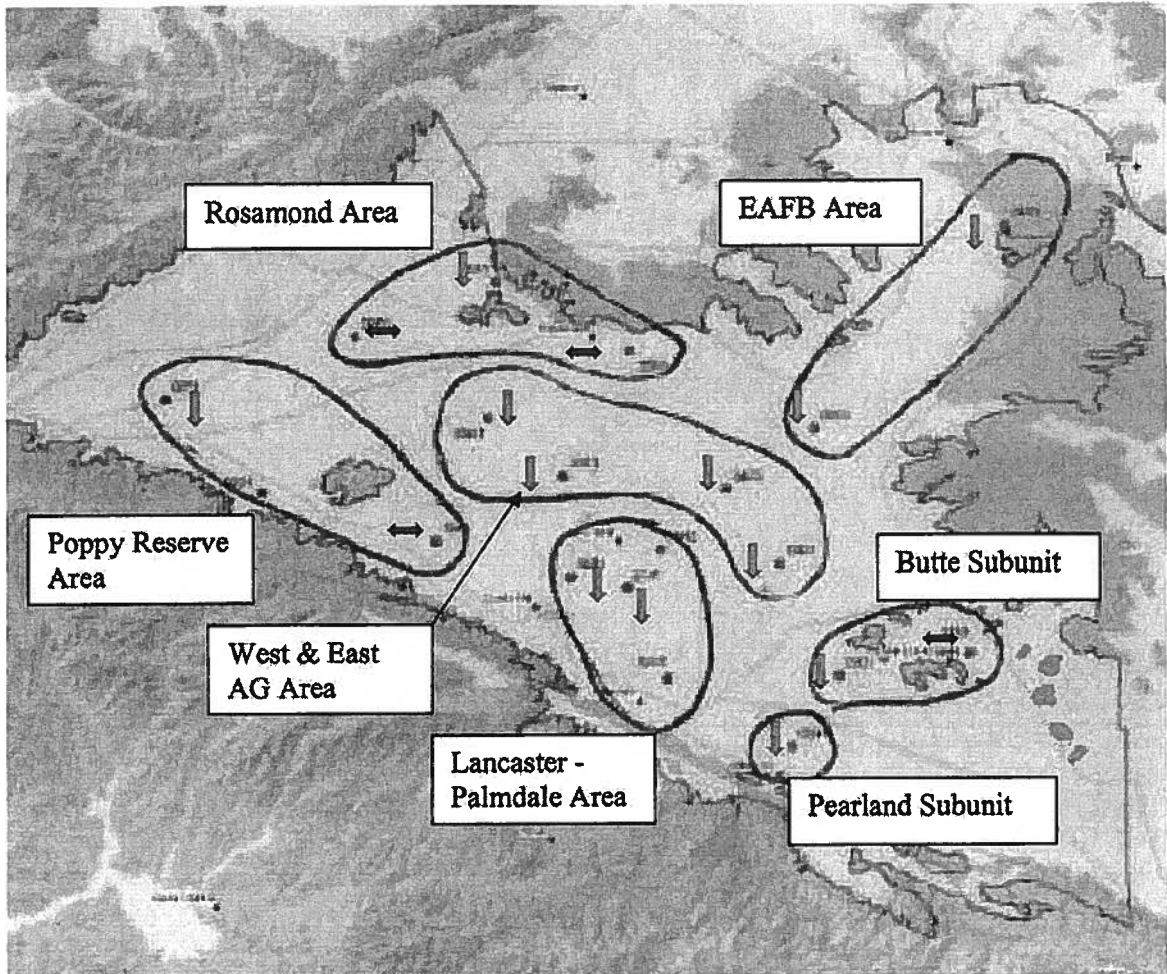
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## Exhibit D.

Map illustrating Antelope Valley groundwater areas and trends, adapted from Problem Statement  
Report Figure 4.3-9

APRIL 9, 2010

**AV GROUNDWATER AREAS & TRENDS\***



\* Note: Arrows indicate groundwater level change after 2000 and, when available, after 2006 as shown in USGS data included on the following pages.



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**REPORT # 2: Summary and Synthesis of Available Information on Historical  
Groundwater Pumping in the Antelope Valley**

Technical Working Group, Antelope Valley Groundwater Mediation Principals

April 14, 2010

**Introduction**

This report provides and compares estimates of historical groundwater pumping in the Antelope Valley between 1995 and 2006, and discusses the differences between estimation procedures. References to the data are provided within. Estimated values for Agricultural (“AG”) pumping volumes and data compiled from records of Municipal and Industrial (“M&I”) pumping were taken from the Problem Statement Report, Antelope Valley Area of Adjudication (Antelope Valley Technical Committee, 6/6/08). Additionally, AG pumping estimates were taken from An Estimate of Crop Water Requirements in the Antelope Valley (“Revised Crop Requirements”) (April, 2007) and are supported by correspondence from Blaine Hanson (Extension Irrigation and Drainage Specialist, UC Davis) and Steve Orloff (former Farm Advisor, Los Angeles County, UC Cooperative Extension) (4/22/08). A summary of these records and estimates is tabulated below. At the time of writing no comparable data are available for the years after 2006.

Year	Problem Statement			Revised Crop Requirements			Delta (AF)
	M&I (AF)	AG (AF)	TOTAL (AF)	M&I (AF)	AG (AF)	TOTAL (AF)	
<b>1995</b>	49,321	69,299	<b>118,620</b>	49,321	82,771	<b>132,091</b>	<b>13,471</b>
<b>1996</b>	50,511	74,570	<b>125,081</b>	50,511	89,880	<b>140,391</b>	<b>15,311</b>
<b>1997</b>	50,471	79,408	<b>129,879</b>	50,471	96,512	<b>146,983</b>	<b>17,104</b>
<b>1998</b>	43,670	92,535	<b>136,206</b>	43,670	110,675	<b>154,345</b>	<b>18,139</b>
<b>1999</b>	48,608	90,215	<b>138,824</b>	48,608	109,361	<b>157,969</b>	<b>19,145</b>
<b>2000</b>	48,822	106,748	<b>155,570</b>	48,822	128,997	<b>177,819</b>	<b>22,249</b>
<b>2001</b>	57,818	101,412	<b>159,230</b>	57,818	121,399	<b>179,217</b>	<b>19,987</b>
<b>2002</b>	53,599	120,699	<b>174,298</b>	53,599	143,139	<b>196,738</b>	<b>22,440</b>
<b>2003</b>	48,001	116,460	<b>164,461</b>	48,001	137,583	<b>185,584</b>	<b>21,124</b>
<b>2004</b>	54,380	111,876	<b>166,257</b>	54,380	132,526	<b>186,907</b>	<b>20,650</b>
<b>2005</b>	50,902	102,295	<b>153,197</b>	50,902	121,937	<b>172,839</b>	<b>19,642</b>
<b>2006</b>	43,960	89,484	<b>133,444</b>	43,960	107,710	<b>151,670</b>	<b>18,226</b>
<b>High</b>	<b>57,818</b>	<b>120,699</b>	<b>174,298</b>	<b>57,818</b>	<b>143,139</b>	<b>196,738</b>	<b>22,440</b>
<b>Low</b>	<b>43,670</b>	<b>69,299</b>	<b>118,620</b>	<b>43,670</b>	<b>82,771</b>	<b>132,091</b>	<b>13,471</b>
<b>AVG</b>	<b>50,005</b>	<b>96,250</b>	<b>146,255</b>	<b>50,005</b>	<b>115,208</b>	<b>165,213</b>	<b>18,957</b>

In calculating historical M&I pumping, the Problem Statement Report relied on pumping records kept by public water suppliers, not estimates, so these components of M&I pumping are not in dispute. On the other hand, the Problem Statement Report’s value for M&I pumping does include estimated pumping for “rural residential” uses (a/k/a “small pumpers” or the “Wood Class”), along with estimates of pumping by “mutual and small private water companies.” The Problem Statement Report estimated rural residential pumping at 8,200 AF/yr, and at 3,200 AF/yr of pumping by mutual and small private water companies.<sup>1</sup> Recent opinions offered in the meditation sessions indicate that the Problem Statement Report’s estimates for both of these categories may be low by several thousand acre-feet per year, but no quantitative

<sup>1</sup> Problem Statement Report Appendix D-7, Table 4.

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corrections have been offered to date. Thus, other than to recognize that the Problem Statement Report's estimate of total M&I pumping may be low to the extent that it underestimated these components, its figures for M&I pumping will be accepted for this analysis and will not be discussed further here.

**Difference Between AG Pumping Estimations in the Problem Statement Report and the Revised Crop Requirements Report**

In comparing the historical pumping estimates in the two reports, the most significant differences are attributable to: a) a different equation used to convert net water requirements to gross or applied water requirements, b) the Problem Statement Report used Distribution Uniformity ("DU") to convert from net water to applied water requirements while the Revised Crop Requirements used a different factor, Irrigation Efficiency, and c) different estimates of crop-specific evapotranspiration (ET) rates.

***Net Water and Applied or Gross Water***

University of California Publication 3366 states: "... *The amount of water [applied] in an irrigation [operation] must supply crop water requirements as well as compensate for inefficiencies in the irrigation system. Irrigation water can be lost from runoff; deep percolation; and, in the case of sprinklers, spray evaporation and drift. Most irrigation water losses are attributable to nonuniformity of water application.*"

Net water is the amount of water that is necessary to furnish the evapotranspiration needs of the plant, protect against wind erosion, and provide for field preparation and pre-irrigation. Applied or gross water is the amount of water that actually has to be applied to take care of these needs, given the natural inefficiencies of any irrigation system.

***Different Equations***

Both reports use the Total Applied Water ( $AW_T$ ) as a surrogate for historical groundwater pumping for agriculture. The Problem Statement Report describes Total Applied Water in Appendix D-3 (page 2) as the sum of evapotranspiration of net water (ET) divided by the Distribution Uniformity (DU) as defined below, plus water applied for erosion control ( $AW_{er}$ ), plus water applied for field preparation and pre-irrigation ( $AW_{pr}$ ). This is represented by the following formula:

$$AW_T = (ET/DU) + AW_{er} + AW_{pr}$$

where

$AW_T$	= Total Applied Water (also referred to as "total applied crop water duty")
ET	= Net evapotranspiration of the plants
DU	= "catch-can" distribution uniformity of irrigation system
$AW_{er}$	= applied water for erosion control
$AW_{pr}$	= applied water for field preparation and pre-irrigation

When the above equation was evaluated in the Problem Statement Report, the net amount of water for erosion control and field preparation and pre-irrigation was used and not the applied water as called for in the above equation.

University of California Publication 3366 states " *To avoid under-irrigation of large areas of the field, use the equation that follows to calculate the gross irrigation requirement – that is, the amount of water needed to meet plant needs (crop water requirements) and compensate for irrigation inefficiency.*

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*Gross Irrigation Requirement = Net Irrigation Requirement/Irrigation System Efficiency*

University of California experts employed a different calculation for Total Applied Water ( $AW_T$ ) by applying the irrigation efficiency parameter to the sum of evapotranspiration (ET), net water for erosion control ( $NW_{er}$ ), and net water for field preparation ( $NW_{pr}$ ).

$$AW_T = (ET + NW_{er} + NW_{pr}) / \text{Irrigation Efficiency}$$

In Hanson and Orloff's letter to Nebeker (4/22/2008), they support dividing all three variables by the Irrigation Efficiency with the following statement:

*"We agree that the [Numerator] in the above equation is the sum of all beneficial uses of water not simply water for evapotranspiration. Other beneficial uses include water to control soil erosion when the plants are small and all water used during the non-growing time periods that include water preceding field preparation, fumigation and water capping."*

***Definition of Distribution Uniformity***

Distribution Uniformity in irrigation is a measure of how uniformly water is applied to the area being watered, expressed as a percentage. This is measured by placing straight-sided containers ("catch can") throughout the area and measuring the water collected in each container after irrigation. A common measure of "catch-can" DU is the **Low Quarter DU**, which is a measure of the average of the lowest quarter of samples, divided by the average of all samples.

$$DU = \frac{\text{Low Quarter depth of water applied to plants in a field}}{\text{Average amount of water applied to plants}} \times 100$$

The higher the DU, the more uniformly water is applied to the field and, therefore, the better the performance of the irrigation system. If all samples are equal, the DU is 100%.

***Use of Distribution Uniformity Values***

As noted above, Distribution Uniformity (DU) is a measure of how evenly water is applied across a field during irrigation. The Problem Statement Report uses 80% and explains this choice in the following statement in Appendix D-3 (page 3):

*"For all crops, there are no known data on DU values; anecdotal information suggests that there have been widespread efforts to utilize irrigation equipment and practices to increase DU values into the range of 80 percent."*

In the Hanson and Orloff letter, they state:

*"A reasonable estimate of the field-wide DU of portable solid set sprinkler systems is about 75% under low wind conditions... However, as the wind speed increases above about 5 miles per hour, the catch can DU decreases rapidly, as does the field wide DU."*

***Use of Irrigation Efficiency***

Publication 3366 states "Numerous field studies show, however, that an irrigation efficiency of 75 percent can be used to calculate gross irrigation requirement when irrigating with wheel-line or hand-move

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*sprinkler systems.*” Historically, these types of irrigation systems have been most prevalent in the Antelope Valley.

***Difference in Calculated Crop Evapotranspiration (ET<sub>AW</sub>)***

The final difference between the Problem Statement Report and the Revised Crop Requirements Report is a difference in the values calculated for evapotranspiration of water applied to support crop growth (ET<sub>AW</sub>). The table below shows the ET<sub>AW</sub> estimates from each report.

<b>ET<sub>AW</sub></b>			
	<b>Crop</b>	<b>Problem Statement (AF) (1)</b>	<b>Revised Crop Requirements (AF) (2)</b>
			<b>Difference as % of Problem Statement</b>
	<b>Alfalfa</b>	5.03	5.57
	<b>Carrots</b>	2.29	2.26
	<b>Grain</b>	1.79	1.93
	<b>Melons and Squash</b>	1.99	2.00
	<b>Onions</b>	3.13	3.12
	<b>Orchard</b>	3.95	4.02
	<b>Pasture</b>	5.37	5.59
	<b>Potatoes</b>	2.00	2.02
	<b>Sugar Beets</b>	3.38	3.38
	<b>Vineyard</b>	2.94	N/A
(1) Problem Statement Appendix D-3, Table 4			
(2) Revised Crop Requirements, Table 4 (2007)			

Regarding the estimates in the Problem Statement Report, the text indicates:

*“The daily reference evapotranspiration (ET<sub>o</sub>) data reported for the nearest CIMIS station, at Victorville, shows only small fluctuation from year to year, so they were utilized to develop average ET<sub>o</sub> values for each bimonthly and monthly period of the growth stages for each crop grown in the Antelope Valley.*

*Crop coefficients (K<sub>c</sub>) specific to the high desert of California for each of the growth stage periods of each crop category were derived from the University of California Cooperative Extension as listed in Appendix D-3: Table 5. Those crop coefficients were then combined with the corresponding average ET<sub>o</sub> values to estimate crop water requirements in the Antelope Valley.”*

Data in Problem Statement Report Appendix D-3, Table 5 were preliminary estimates from Grant Poole, Farm Advisor. The committee that prepared the “An Estimate of Crop Water Requirements in the Antelope Valley” modified these values to reflect more recent research results.

Regarding the estimates in the Revised Crop Requirements Report, Hanson and Orloff write:

*“You assembled the document ‘An Estimate of Crop Water Requirements in the Antelope Valley’ dated April 19, 2007 with assistance from University of California farm advisors or former advisors and UC specialists working in crop ET. The document lists estimates of crop coefficients of crops grown in the area in question and historical reference crop ET. After*

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*reviewing these data, in our opinion, they are the best available information on this matter and are as accurate as possible for your area."*

**Sensitivity Analysis**

A sensitivity analysis was performed to see how responsive the crop water requirement estimates are to the choice of the model used (Problem Statement Report versus Revised Crop Requirements Report) and to changes in the coefficients used in the estimation formulas. In short, the sensitivity analysis indicated that in all cases except for carrots and alfalfa, the use of distribution uniformity parameter (DU) versus Irrigation Efficiency is the largest driver of change between the Problem Statement Report and Revised Crop Requirements values for Applied Water. In the case of alfalfa, the largest driver is the different crop coefficient for evapotranspiration (ET<sub>AW</sub>). In the case of carrots, the change in the equation was the largest driver due to the significant amount of water applied for erosion control and pre-irrigation (AW<sub>er</sub> and AW<sub>pr</sub>).

The calculations below demonstrate how much impact each of the three different approaches and values described above has on the estimated value for Total Applied Water.

Below, again, are the two alternative equations for Total Applied Water:

*Problem Statement Report*  
 $AW_T = (ET/DU) + AW_{er} + AW_{pr}$

*Revised Crop Requirements*  
 $AW_T = (ET + NW_{er} + NW_{pr}) / \text{Irrigation Efficiency}$

We will use the example of alfalfa to illustrate the changes in the equation using the following values for the variables above:

*Problem Statement Report*  
ET<sub>AW</sub> = 5.03 AF  
DU = 80%  
AW<sub>er</sub> = 0 AF  
AW<sub>pr</sub> = 0.17 AF

*Revised Crop Requirements*  
ET<sub>AW</sub> = 5.57 AF  
Irrigation Efficiency = 75%  
NW<sub>er</sub> = 0 AF  
NW<sub>pr</sub> = 0.17 AF

Recall that:

ET = evapotranspiration of applied water  
DU = distribution uniformity of irrigation system  
AW<sub>er</sub> = applied water for erosion control  
AW<sub>pr</sub> = applied water for field preparation and pre-irrigation  
NW<sub>er</sub> = net water for erosion control  
NW<sub>pr</sub> = net water for field preparation and pre-irrigation

First, we start with the equation and values from the Problem Statement:

$$AW_T = (5.03/80\%) + 0 + 0.17 = 6.5 \text{ AF}$$

Note that the equation shows applied water for field preparation and pre-irrigation but uses net water for these purposes. If you assume 80% in the denominator, 0.17 becomes  $0.17/0.80 = 0.21$

By changing *only* the form of equation from the Problem Statement form to the Revised Crop Requirements form, while keeping the Problem Statement values yields:

$$AW_T = (5.03 + 0 + 0.17)/80\% = 6.5 \text{ AF (no difference)}$$

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By changing *only* the DU from 80% to 75%, the equation yields:

$$AW_T = (5.03/75\%) + 0 + 0.17 = 6.9 \text{ AF (5.7\% change compared to 6.5)}$$

By changing *only* the  $ET_{AW}$  from 5.03 AF to 5.57 AF, the equation yields:

$$AW_T = (5.57/80\%) + 0 + 0.17 = 7.1 \text{ AF (a 9.8\% change compared to 6.5)}$$

Finally, using the Revised Crop Requirements equation and values yield:

$$AW_T = (5.57 + 0 + 0.17)/75\% = 7.65: \text{ (a 17.7\% change compared to 6.5)}$$

The following table runs through these iterations for all the crops considered and shows the resulting percent change for each factor.

<b>Applied Water Calculations - Problem Statement vs. Revised Crop Requirements</b>								
<b>Crop</b>	<b>Problem Statement (AF) (1)</b>	<b>Revised Crop Rqmnts. (AF) (2)</b>	<b>Total Δ%</b>	<b>Aw<sub>er</sub> (1)</b>	<b>Aw<sub>pr</sub> (1)</b>	<b>Δ% Eqtn.</b>	<b>Δ% DU</b>	<b>Δ% ET<sub>AW</sub></b>
<b>Alfalfa</b>	6.5	7.7	17.7%	0.00	0.17	0%	5.7%	9.8%
<b>Carrots</b>	3.9	4.6	17.9%	0.50	0.54	6.8%	5.0%	-0.7%
<b>Grain</b>	2.6	3.1	17.3%	0.00	0.33	2.2%	4.8%	5.4%
<b>Melons and Squash</b>	2.8	3.1	11.1%	0.00	0.33	3.8%	6.8%	1.2%
<b>Onions</b>	4.5	5.2	16.0%	0.25	0.33	3.2%	5.7%	-0.3%
<b>Orchard</b>	4.9	5.4	9.4%	0.00	0.00	0.0%	7.4%	2.6%
<b>Pasture</b>	6.7	7.5	11.2%	0.00	0.00	0.0%	6.8%	4.3%
<b>Potatoes</b>	2.8	3.4	19.6%	0.00	0.33	4.3%	7.3%	1.9%
<b>Sugar Beets</b>	4.6	5.0	7.8%	0.00	0.33	0.9%	5.2%	-0.8%
<b>Vineyard</b>	3.7			0.00	0.00			

(1) Problem Statement Appendix D-3, Table 4  
(2) Revised Crop Requirements, Table 4 (2007)

Please note that the changes presented individually, above, for the Equation, DU, and  $ET_{AW}$  are not additive, meaning that the sum of the percent changes does *not* equal the total change. It only helps indicate how significant the changes are when compared to one another.

Note also that the water requirements for individual crops used in the Problem Statement Report are from about 8% to nearly 20% below those presented in the Revised Crop Requirements. Applied across the large areas under cultivation in the Antelope Valley this can lead to a substantial difference in the estimated volume of groundwater pumping for agriculture.

**REFERENCES**

*An Estimate of Crop Water Requirements in the Antelope Valley*, Nebeker, Poole, Sanden, Orloff, Hansen, Hays. (April 2007) (Presented to the Principals Group in 2009)

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*Correspondence*, Blaine Hanson (Extension Irrigation and Drainage Specialist, UC Davis) and Steve Orloff (former Farm Advisor, Los Angeles County, UC Cooperative Extension) to Gene Nebeker, 4/22/08

*Problem Statement Report, Antelope Valley Area of Adjudication*, Antelope Valley Technical Committee, 6/6/08

Orloff, S. B. & Carlson, H. L., Intermountain Alfalfa Management, University of California. Division of Agriculture and Natural Resources, Publication 3366, 1995.

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**REPORT # 3: CRITICAL FACTORS AFFECTING ASSESSMENTS OF GROUNDWATER YIELD AND  
RESOURCE STATUS IN THE ANTELOPE VALLEY**

Technical Working Group, Antelope Valley Groundwater Mediation Principals  
April 28-29, 2010

**INTRODUCTION**

At the meeting of the Antelope Valley Groundwater Mediation Principals on March 31-April 1, 2010, the Principals agreed to task a small working group of volunteers from within the Principals' Group to draft short summary reports on selected topics. The general purpose of these summary reports is to establish a shared understanding within the Principals' Group of particular technical issues related to recent assessments of the status of the groundwater resources within the Antelope Valley Area of Adjudication (AVAA), to evaluate and discuss recent trends in the status of those resources to the extent that the available data permit, and to identify areas where additional information or analysis is needed to provide a basis for moving forward.

Among these technical issues, the Principals determined that it was important for the progress of the mediation process to establish a common technical language, a common understanding of the variety of analytical tools and assumptions that have been used in assessing the condition of AVAA groundwater resources, together with the strengths and weaknesses of each of these tools and assumptions, and a common understanding of the sources of data used as inputs to those assessments. This came out of the Principals' recognition that several alternative assessments of AVAA groundwater status exist, and that these alternative assessments do not reach the same conclusions about total sustainable yield and the overall current health of AVAA groundwater resources. The Principals also recognized that the interests of the various Principals, their positions within the mediation process, their perceptions of the risks associated with various approaches to AVAA groundwater management and thus their willingness to consider alternative approaches, are all affected by how much they individually rely on various alternative assessment(s).

Accordingly, the Principals' Group asked the Technical Working Group to review and discuss the important factors and assumptions affecting and driving the range of groundwater assessments that have been presented to or relied upon by members of this group, looking at areas of difference and areas of concurrence. Recognizing that different assessment techniques relying on different data inputs and key assumptions will necessarily yield different outcomes, the Technical Working Group was specifically instructed to not try to determine which assessment technique was superior or gave a more accurate result. Instead, the Technical Working Group's goal was to summarize information by which the individual Principals could reach their own conclusions about, and interpretations of, the alternative assessments that have been prepared and circulated during the course of this litigation.

This report presents the Technical Working Group's efforts to achieve that goal. It assumes that the reader is generally familiar with groundwater management issues and terminology, although not at the level of a groundwater specialist. Reference materials cited in this report are numbered and listed at the end.



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**KEY DEFINITIONS USED IN THIS REPORT**

**Native Recharge**

The amount of natural replenishment of groundwater within the basin from infiltration of rainfall and snowmelt, primarily in the mountains.

**Native Sustainable Yield**

Native recharge plus return flows from the application of water derived from native recharge.

**Total Sustainable Yield**

Native sustainable yield plus return flows from the application of imported water.

**Specific Yield**

The ratio, relative to one unit volume of soil or rock, of the volume of water that, after saturation, can be drained by gravity from that unit volume of soil or rock. (Ref. 5).

**Return Flow**

Water that leaves the ground surface after application and percolates down to the water table.

**CRITICAL ANALYTICAL PROCEDURES AND ASSUMPTIONS IN ASSESSMENTS OF YIELD**

Certain standard analytical methods have been used in preparing the various overall assessments of Antelope Valley groundwater resources that have been presented in the course of this litigation. These methods will be discussed in this section in general terms; the next section will address details of their application in the various assessments.

**Change in Storage Analysis**

The quantity of groundwater in storage depends on the standing water levels within the aquifer, the volume of aquifer materials, and the pore space in the aquifer material that can drain water under gravity. (Specific yield as defined above is another measure of aquifer porosity and/or the storage capacity of an aquifer.) Storage change can be caused by draining or filling aquifer materials. Also, depending on the nature of the aquifer materials, lowering the water levels in the aquifer below a "pre-consolidation" head can cause irreversible compaction of aquifer materials, thereby causing a permanent loss in storage capacity and potentially resulting in subsidence visible at ground level.

The effect on stored water volumes of draining or filling for a time period can be calculated by multiplying the water level change by the specific yield of the aquifer materials over which the water level change occurred per unit area of the aquifer. The effect of compaction can be estimated by knowing the volume of subsidence that occurred during the relevant time frame.

Storage change calculations are often referenced to a particular time. The Problem Statement Report ("PSR") (Ref. 1) uses 1951 as the starting reference point. Results of the PSR's analysis of change between 1951 and 2005 in the volume of water stored in the Antelope Valley aquifer are presented in Figure 1 (attached), which was presented in the PSR as Figure 4.3-10 and discussed in PSR Section 4.3.2.4.

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**Mountain-Front Recharge Analysis**

This technique, used in the PSR (Ref. 1) and the Sheahan analysis (Ref. 8), assumes all native recharge occurs at the mountain fronts surrounding the Basin, and is the amount of replenishment of the Basin from infiltration of precipitation, snowmelt, and runoff. It is calculated by:

$$\text{Precip} = R_o + BI + ET_{nv} \quad \text{Equation 1}$$

Where:

Precip = precipitation in the mountains surrounding the Valley;

$R_o$  = runoff from the mountains;

BI = bedrock infiltration; and

$ET_{nv}$  = evapotranspiration of native vegetation.

All values are expressed as rates, i.e., acre-feet per year.

Therefore,

$$BI = \text{Precip} - R_o - ET_{nv} \quad \text{Equation 2}$$

Having defined BI, it can be inserted into the formula for native recharge (NR) in Equation 3 below:

$$NR = MFR = R_o + BI - \text{Playa Evaporation} \quad \text{Equation 3}$$

Where:

NR = native recharge;

MFR = mountain front recharge; and

Playa Evaporation = evaporation of the runoff on the valley floor.

**Water Balance Analysis**

A Water Balance Analysis considers the entire basin in calculating native recharge and is therefore preferred by many as more comprehensive. It is calculated by:

$$NR = \text{Pumping} - RF_v - \Delta\text{STOR} + \text{SUB} - \text{AR} \quad \text{Equation 4}$$

Where

NR = native recharge;

Pumping = all groundwater pumping;

$RF_v$  = return flow over the entire Valley;

$\Delta\text{STOR}$  = change in volume of stored groundwater;

SUB = water produced from subsidence; and

AR = artificial recharge.

All values are expressed as rates, i.e., acre-feet per year.

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**Crop Water Requirements**

Agricultural groundwater pumping is usually not metered. There are several methods for estimating the total volume of such pumping, including: a) multiplying the acreage under cultivation of the various crops by the average amount of water needed to grow each such crop, then summing across crops; b) using power consumption records from pumps powered by electricity, calibrated to each pump's pumping efficiency; or c) performing the same energy-to-pumping conversion on diesel or natural gas fuel consumption records for engine-driven pumps. While records of electricity and fuel consumption are not generally available to the public, data on cultivated acreage and crop water requirement estimates can be found, making this a useful tool for estimating agricultural pumping.

At the time the PSR was drafted no values for crop water requirements were available that specifically addressed the physical and climatological conditions within the Antelope Valley. Addressing this lack, an assessment entitled the "Estimate of Crop Water Requirements in the Antelope Valley" ("Revised Crop Requirements") (Ref. 7) was prepared by a group of experts in irrigation practices generally and under Antelope Valley conditions in particular.<sup>1</sup> The values presented in the Revised Crop Requirements were also discussed with Antelope Valley growers of alfalfa, onions, carrots, grain, sudan, and other crops, and those values compare closely with these growers' experiences.<sup>2</sup>

The coefficients developed and presented in the Revised Crop Requirements report are substantially higher than those reported in the Problem Statement Report and employed in its analyses, as shown in the table below:

Crop Water Requirements (acre-feet of applied water per acre planted of crop)		
Crop	Problem Statement Report (Ref. 1)	Revised Crop Requirements (Ref. 7)
Alfalfa	6.5	7.65
Carrots	3.9	4.60
Grain	2.6	3.05
Melons and Squash	2.8	3.11
Onions	4.5	5.22
Orchard	4.9	5.36
Pasture	6.7	7.45
Potatoes	2.8	3.35
Sugar Beets	4.6	4.96

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<sup>1</sup> These included: Eugene B. Nebeker, Ph.D., grower in Antelope Valley and licensed Professional Engineer in Chemical and Agricultural Engineering; Grant Poole, University of California Cooperative Extension (UCCE) Farm Advisor for Los Angeles County from 2001 through 2006; Blake Sanden, UCCE Farm Advisor for Kern County; Steve Orloff, UCCE Farm Advisor for Los Angeles County from 1984 to 1992 and currently the UCCE County Director and Farm Advisor for Siskiyou County, and Blaine Hansen, Ph.D., Irrigation and Drainage Specialist at the University of California at Davis. Tim Hays, Agricultural Consultant and California Licensed Pest Control Advisor, also provided significant inputs. All these individuals participated in drafting this document, and reviewed and approved the final copy.

<sup>2</sup> For the purposes of preparing the Annual Notice of Extraction and Diversion of Water, the California Water Resources Control Board, Division of Water Rights, adopted the coefficients developed and presented in the Revised Crop Requirements (Ref. 7) for crops grown in Antelope Valley.

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**Selection of Period of Analysis**

The time period chosen for analysis can affect the calculated value of natural recharge in the water balance analysis. The chosen time period should provide adequate historical hydrological data and representative precipitation figures, with the goal of avoiding extreme or anomalous values that might significantly affect the results.

**Existence and Magnitude of Return Flows**

Return flow refers to water that is deposited on the surface of the ground and gradually makes its way to the aquifer. It is often assumed that all water applied for agricultural irrigation that does not provide the evapotranspiration requirement of the crop goes to return flow. However, no study has been done to demonstrate or quantify return flows in Antelope Valley. For example, if 75% represents the proportion of applied water that provides the evapotranspiration needs of the plant (sometimes referred to as the "irrigation efficiency") then the other 25% of the applied water must be accounted for. In the climatic conditions of Antelope Valley, unknown components of the other 25% are consumed by such factors as: evaporation in the wind, a particular concern during the hot, dry summers in the Valley; wicking of water back to the surface of the soil (Hillel, 1980, Ref. 4); leaks in the irrigation system; ponding; runoff; and excess water applied due to scheduling problems, leaving whatever is left to go to return flow.

The Problem Statement Report did not consider these losses or attempt to quantify them. Discussions with the four UC experts that contributed to the Revised Crop Requirements analysis (Ref. 7), as well as Dr. Howard Neibling, P.E., Extension Water Management Engineer, University of Idaho, disclose a consensus that under conditions typical of Antelope Valley much of this hypothetical 25% would be lost to evaporation and other sinks and would therefore not be available for return flow. (See Hanson and Orloff letter, Ref. 3.) While no firm figures are presently available, ongoing water balance simulations, backhoe pits, and experimental soil moisture measurements beneath the root zone at various depths support a conclusion that return flows are likely to be low relative to the total water applied.

**Lag Time of Return Flows**

"Lag time" refers to the time required for water to reach the aquifer once the water has been applied to the surface of the land, i.e., how long does it take for potential return flows to actually make a contribution to groundwater stored within the underlying aquifer. Estimates of lag times in the literature range from one year to several decades, and are highly dependent on local geology and other factors. Sheahan (Ref. 8) discusses the significance of varying estimates of lag times, and notes that estimates of lag time have ranged between 1 to 15 years in analyses of Antelope Valley groundwater. Where return flow rates are substantial, lag times are significant computational factors in groundwater models employing a water balance analysis and can have a strong influence on the resulting assessments of total sustainable yield. In general, where above average water was applied to the ground in earlier years, a long lag time will decrease the natural recharge estimate resulting from the Water Balance Method and vice versa. (Note that if return flows are small, then lag times are not a significant factor in groundwater assessments.)

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**Consumptive Use**

The consumptive use of water is the applied water less any return flow that may make its way back to the aquifer. If return flow is small, consumptive use is roughly equal to the amount of water applied.

**Elements and Assumptions Found in Typical Assessments of Native Recharge, Native Sustainable Yield, and Total Sustainable Yield**

The elements making up native recharge are shown in Equation 3 for the Mountain-Front Recharge Analysis approach. The most controversial element is bedrock infiltration (BI), which is found in Equations 1 and 2. Another controversial component is the evapotranspiration of precipitated water by native vegetation ( $ET_{nv}$ ) before the water reach the aquifer. A low estimate of BI or a high estimate of ( $ET_{nv}$ ) will reduce the estimated values of Native Sustainable Yield and Total Sustainable Yield.

Equation 4 shows the key elements in the Water Balance Analysis. If groundwater levels remain nearly constant over an extended period of years, the values for the change in storage volume ( $\Delta STOR$ ) and water produced from subsidence (SUB) would be essentially zero. In the Antelope Valley the actual amount of artificial recharge (AR) historically applied is small, and can be considered zero for purposes of water balance estimates. Hence, the key elements remaining in Equation 4 (and the most controversial) are total groundwater pumping (Pumping) and the return flow of water ( $RF_v$ ) over the entire Antelope Valley.

As shown in the Definitions section above, Native Sustainable Yield and Total Sustainable Yield are both related to return flows from application of native and imported water. Again, note that the actual magnitude of return flows is unknown.

**ASSESSMENTS OF YIELD**

This section will discuss various assessments that have been produced using the analytical methods described above. It will describe how the assessments varied in their approaches, key assumptions, and choice of critical coefficients, with the goal of helping clarify how they reached different conclusions about the status of Antelope Valley groundwater resources.

**Problem Statement Report**

The PSR calculated storage change with time in the manner described in the section above entitled "Change in Storage" over the time period 1951-2005. Results are shown in Figure 1. The PSR assumed that the agricultural return flow rate was 25% of the applied water, the municipal return flow rate was 28.1% plus 500 AF/yr, and the average lag time for return flow over the Valley was 15 to 20 years.

The PSR estimated that the average native annual recharge of groundwater by the Mountain-Front Recharge analysis was about 56,000 AF/yr. In its Mountain-Front Recharge analysis the PSR assumed that the bedrock infiltration (BI) component was around 4% of precipitation in the mountains, a relatively low value compared to other authorities [Sheahan (Ref. 8), Wilson & Guan (Ref. 10)], which would result in a low estimate of native recharge.

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Applying the Water Balance method the PSR estimated that the average native annual recharge of groundwater was around 57,000 AF/yr. An estimate produced by this method will be affected by the estimate of total pumping, with a high estimate of pumping contributing to an increased estimate of native recharge, and a low estimate of pumping leading to a lower estimate of native recharge. Note that the PSR's estimate of agricultural pumping, the largest component in its estimate of total pumping (PSR Appdx. D Table D.4-2), is not based on currently-accepted values for crop water requirements in the Antelope Valley. Compare PSR (Ref. 1) to Revised Crop Requirements (Ref. 7). Note also that the PSR used an estimate of around 5,200 AF/yr for mutual and small private water companies,<sup>3</sup> which is several thousand AF/yr lower than estimates offered by representatives of those entities. (John Ukkestad, personal communication.) Had the PSR used higher values for either of these components in its assessment using the Water Balance method, its estimate of native recharge would presumably have been correspondingly higher.

**Revisions to Pumping Values in Problem Statement Report (Ref. 2)**

Steve Dassler, Andrew Werner, and Gene Nebeker, at the direction of the participants in the Principal's Settlement Meetings facilitated by Randy Williams, revised the agricultural pumping values found in the Problem Statement Report to reflect additional knowledge about Crop Water Requirements under conditions found in the Antelope Valley. Ref. 2. This was accomplished by multiplying the crop acreages presented in the Problem Statement Report by the crop coefficients specific to the Antelope Valley that were presented in the Revised Crop Requirements (Ref. 7) and subsequently adopted for the Valley by the State Water Resources Control Board.

In addition, 5,000 AF/yr was added to estimates of total annual pumping on the basis of reports from representatives of the mutual and small private water companies indicating that the Problem Statement Report underestimated their historical pumping by that amount.

Increasing the estimates of agricultural pumping as described above, and adding in the higher estimates of pumping by the mutual water companies, produced an estimate of average annual groundwater pumping at about 170,000 AF/yr from 1995 through 2006, compared to the approximate 146,000 AF/yr estimate derived from the PSR. This has the effect of increasing the TSY by about 20,000 AF/yr using the Water Balance approach.

**Assessment of Native Recharge by N. Thomas Sheahan (Ref. 8)**

Sheahan used two different, independent techniques for assessing native recharge, mountain-front recharge analysis and water balance analysis, and obtained estimates of native recharge that were quite similar. Both techniques were also used in the PSR but applied different assumptions, which led to different outcomes. He did not estimate native sustainable yield or total sustainable yield.

Water Balance Analysis - Starting from the Problem Statement Report, Sheahan made only two substantive changes in the water balance analysis: the base period for the analysis and the lag time for return flows. Sheahan chose a base period of 27 years, from 1971 through 1998 since the PSR's analysis indicated that groundwater storage levels in the Basin were relatively stable during this

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<sup>3</sup> See PSR App. D § D.3.3 at page D-22. Elsewhere the PSR estimated pumping in this category between 1994 and 2006 at 2,200 to 3,600 AF/yr. PSR App. D-7, Table 3.

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period. He also assumed a seven-year lag time for return flows, which falls at the midpoint of the range of 1 to 15 years found in other sources. Sheahan did not adjust for any other issues such as crop water requirements or magnitude of return flows. After making these changes he calculated a value of 107,000 AF/yr for native recharge.

Mountain-Front Recharge Analysis - Sheahan also performed an independent mountain-front recharge analysis. Departing from the approach taken in the Problem Statement Report Sheahan used native vegetation evapotranspiration (ET<sub>nv</sub>) values prepared by personnel at the State of California Department of Water Resources and the United States Department of Agriculture, and used a higher value of bedrock infiltration, based on calculations from Equation 3 and consistent with values of bedrock infiltration as a percentage of precipitation published in Wilson & Guan (Ref. 10). By this method he obtained an estimated value of native recharge of 106,000 AF/yr, which is close to the 107,000 AF/yr estimate for native recharge obtained with the water balance analysis.

**Comparison of Values of Factors in the Problem Statement Report's Mountain Front Recharge Analysis with Values Typically Found in the Technical Literature**

Factors as a percentage of mountain front precipitation:

Factor	Sheahan (Ref. 8)	Magruder, Woessner, & Running (Ref. 5)	Wilson & Guan (Ref. 10)	Problem Statement Report (Ref. 1)
MFR	39%	38%		21%
BI	22%		14-38%	7%
ET <sub>nv</sub>	62% <sup>4</sup>	63%		

Low estimates of mountain-front recharge (MFR) and bedrock infiltration (BI) and high estimates of evapotranspiration of native vegetation (ET<sub>nv</sub>) will depress the native recharge, native sustainable yield, and total sustainable yield, and visa versa.

**Initial Approach to Quantifying Yield by Nebeker (Ref. 6)**

It is intuitive that if groundwater storage remains stable during a period when pumping is occurring then the extractions must roughly equal the inputs during that period. Accordingly, if the volumes pumped are known this provides an estimate of total sustainable yield.

The basis of this approach is to select a time period during which the groundwater levels remained nearly constant over an extended period of time, and then estimate the annual pumping volumes during that period. As shown in Figure 1 (attached), numerous time periods are available that would satisfy this criterion.

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<sup>4</sup> The values in this column are not expected to add up to 1. As shown in Equation 1, the sum of Runoff, Bedrock Infiltration, and Evapotranspiration of Native Vegetation as a percentage of precipitation should add up to 1. Equations 2 and 3 demonstrate that too high an estimate of evapotranspiration of native vegetation and too low an estimate of bedrock infiltration will depress the estimated value for native recharge and vice versa. There is close agreement of these elements of the Sheahan analysis with the published values found in Magruder et al. and Wilson & Guan.

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The methodology used in this approach tends to minimize the effect of controversial and hard-to-quantify factors such as the magnitude of return flows, lag time, and consumptive use.

Using this approach, the period of 1995 through 2006 produces a value of about 160,000 AF/yr for Native Sustainable Yield Valley-wide and about 170,000 AF/yr for Total Sustainable Yield. Note that this approach is dependent on the period selected, and is not sensitive to localized variations in stored groundwater levels, which may depart substantially from results integrated across the entire Valley. For example, according to the PSR, the period of 1995 to 2006 exhibited a relatively large negative change in groundwater storage when compared to the period of 1971 to 2005 and, therefore, this period may not provide the most reliable estimate of Total Sustainable Yield.

**SIGNIFICANT EMPIRICAL OBSERVATIONS**

**Average Yearly Pumping During Times of Constant Groundwater Storage**

Figure 1 (PSR Figure 4.3-10) shows that the storage in the Basin remained essentially unchanged from 1975 through 2001. The Problem Statement Report estimated the average annual pumping over this 27-year time period to be about 160,000 AF/yr. PSR Table D.4-4. Since storage remained essentially constant during this period this suggests that the Total Sustainable Yield of the Basin was around 160,000 AF/yr under conditions prevailing during that time. Revising the PSR's pumping estimate to incorporate the crop water requirements specific to Antelope Valley that were reported in the Revised Crop Requirements, and increasing the estimate of pumping by mutual and small private water companies, would raise the estimate of the pumping volume over this period of time to 175,000 to 180,000 AF/yr. This would indicate that Total Sustainable Yield is around 175,000 to 180,000 AF/yr.

**Using Specific Yield to Cross-check Total Sustainable Yield Estimates**

Specific yield of a soil or rock is the ratio of volume of water in a unit volume of the soil or rock that, after saturation, can be drained by gravity. Todd et al. 2005 (Ref. 9). Therefore, specific yield can be calculated by dividing the volume of drained water by the volume of the soil sample. Specific yield indicates the volumetric fraction of the aquifer volume that a given soil will yield when all the water is allowed to drain out by gravity.

Using "round numbers" of an average specific yield of 10%<sup>5</sup> over a basin of 1,000 square miles, similar in nature to the Antelope Valley, it would be necessary to overpump the basin by about 64,000 AF to reduce the average static or standing water level by one foot. As noted above, estimated recent total pumping values have gone as high as 175,000 to 180,000 AF/yr, while the Problem Statement Report suggests a Total Sustainable Yield of 110,000 AF/yr, a difference of more than 60,000 AF/yr. If 110,000 AF/yr is the correct value for Total Sustainable Yield, then the average standing water level of the Basin should have been declining about 1 foot per year, i.e., it would have dropped about 27 feet over the last 27 years. The data in the record, as reported in the PSR and elsewhere, do not demonstrate a Basin-wide drop of such magnitude.

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<sup>5</sup> This value was chosen for ease of computation and is within the range of specific yield values claimed for the Antelope Valley.



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**CONCLUSIONS**

Alternative assessments of the status of the groundwater resources in Antelope Valley reach significantly different conclusions about total sustainable yield and the overall current health of those resources. The following table illustrates some of the key values and assumptions that were incorporated in different assessments, and presents selected results. The text of the assessments do not always make it clear how the authors defined the concepts presented here, or how the quantities were measured or calculated, and not all the assessments used or reported the same variables. Accordingly this table should only be viewed as illustrative of the different approaches taken.

<u>Comparison of Values, Assumptions, and Results from Selected Assessments</u>									
(all values in AF/yr unless otherwise indicated)									
<u>Assessment</u>	<u>Native Recharge</u>	<u>Native Sustainable Yield</u>	<u>Total Sustainable Yield</u>	<u>Time Period of Analysis</u>	<u>Assumed Lag Time of Return Flows</u>	<u>Annual Precipitation</u> <sup>†</sup>	<u>Runoff</u>	<u>Bedrock Infiltration</u>	<u>Native Vegetation Evapo-transpiration</u>
Problem Statement Report (Ref. 1)	60,000	85,000	110,000	1951-2005	15 - 20 years	676,000	48,200	19,800	608,000
Sheahan (Ref. 8)	106,000	150,000*	184,000*	1971-1998	7 years	279,000	46,000	61,000	172,000
Nebeker (Ref. 6)		160,000	170,000						

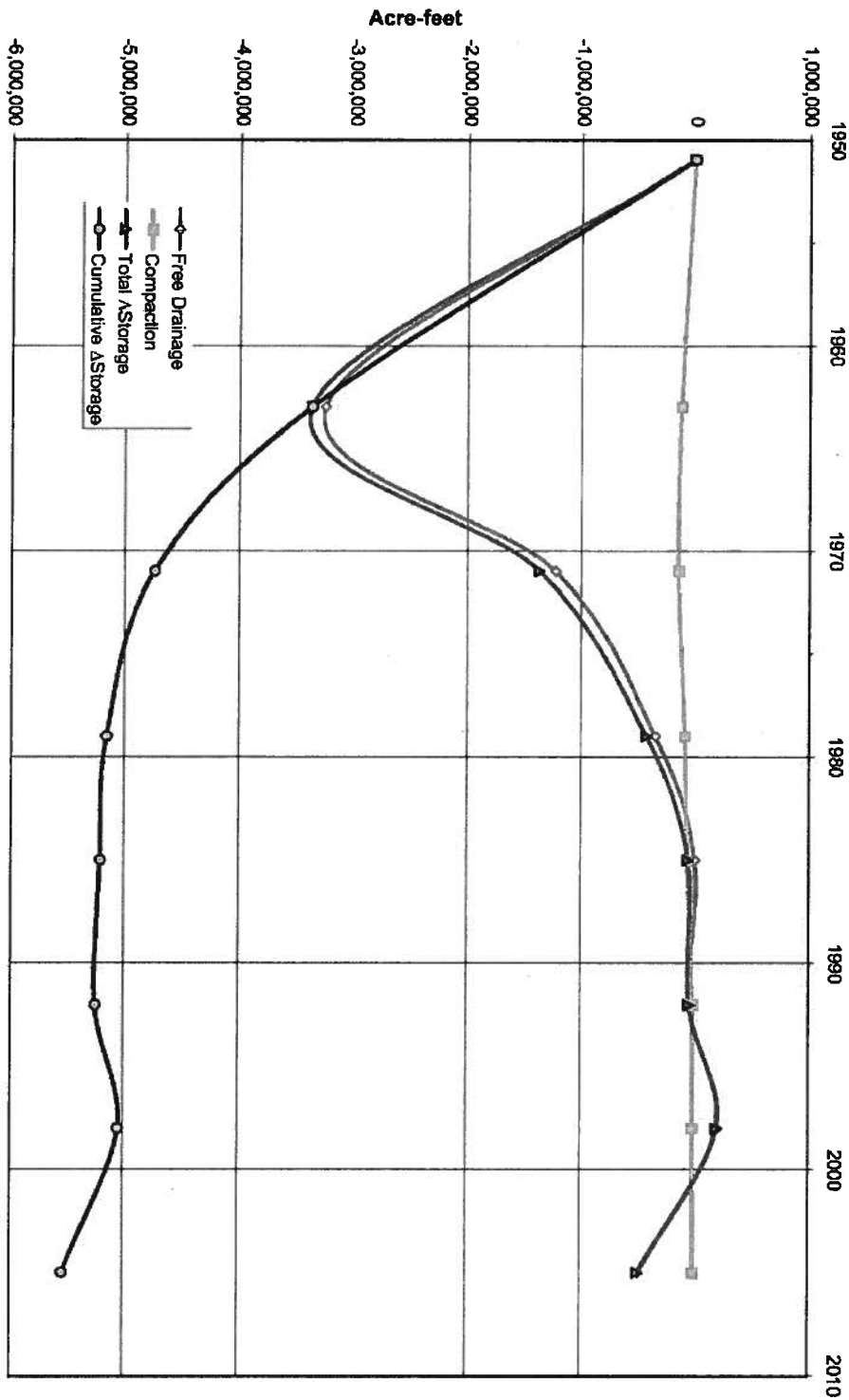
\* These values were not estimated by Sheahan. They were obtained by starting with Sheahan's lowest estimate of Native Recharge, 106,000 AF/yr, then calculating Native Sustainable Yield and Total Sustainable Yield by the method found in PSR Appendix F.

<sup>†</sup> It is not clear that Sheahan and the authors of the PSR considered the same geographic areas in assessing precipitation.

All of these assessments represent attempts to characterize and assess the same physical reality and phenomena, yet reach different conclusions. These varying conclusions can be attributed to differences in analytical approaches, key assumptions, and the values of various parameters and coefficients employed in each assessment. That they reach different conclusions is understandable in view of the sensitivity of the various assessments to the values of the factors and assumptions they rely on, and the difficulty of ground-truthing many of these factors and assumptions.

This report has attempted to identify some of these sensitivities and to assess the strength of some of the assumptions in order to provide a framework for comparing and reconciling the different assessments into a coherent (or at least not fundamentally conflicting) picture of the underlying physical reality: the present status of the groundwater resources in the Antelope Valley.

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**Figure 4.3-10: Storage Change and Storage Change Components 1951 - 2005**

Figure 1. Groundwater storage change and storage change components in the Antelope Valley, 1951-2005. (Problem Statement Report Figure 4.3-10)

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**REPORT # 4: SUMMARY AND SYNTHESIS OF AVAILABLE INFORMATION ON CHANGE IN  
GROUNDWATER STORAGE AND SUSTAINABLE YIELD IN THE ANTELOPE VALLEY**

Technical Working Group, Antelope Valley Groundwater Mediation Principals

April 24, 2010

The *Problem Statement Report, Antelope Valley Area of Adjudication* (“PSR”) (Antelope Valley Technical Committee, 6/26/08) Sections 4.3.2 and 4.3.3 provide discussions of the Change in Groundwater Storage and Natural Recharge, respectively, in the Antelope Valley.

Change in Groundwater Storage is measured by the change water levels in the aquifer as well as irreversible compaction of aquifer materials and resulting subsidence from lowering water levels. PSR Section 4.3.3 also defines Change in Storage as:

$$\text{Change in Storage } (\Delta \text{ Storage}) = \text{Inflows} - \text{Outflows}$$

If Change in Storage equals zero during a period of interest then Inflows are equal to Outflows, implying that the basin was in balance during that period. In the Problem Statement Report, Table 4.3-1 illustrates the basin wide Storage Change in acre-feet (AF) over seven discrete periods from 1951 to 2005. The smallest overall Change in Storage occurred during the period from 1979 to 1997: a cumulative increase of 109,000 AF of stored water, or an average of about 5,800 AF per year. From this relatively small amount one could conclude that the basin was essentially in balance during this time interval. Therefore, the average annual pumping during that time period, adjusted for the small Change in Storage during the same period, should provide a reasonable estimate of the annual Sustainable Yield.

The following equation was used to estimate Sustainable Yield as described above, over a given time period (“Period”):

$$\text{Sustainable Yield}_{(\text{Period})} = (\text{Total Pumping}_{(\text{Period})} - \Delta \text{ Storage}_{(\text{Period})}) / \# \text{Years in Period}$$

Where:

Total Pumping<sub>(Period)</sub> = total volume pumped during the time period of interest (“Period”);

Δ Storage<sub>(Period)</sub> = total change in storage during the time period; and,

#Years in Period = number of years from the beginning of the time period to the end.

Historical Pumping Data and the Storage Change were taken from the PSR. Additionally, revised Agricultural pumping estimates were taken from *An Estimate of Crop Water Requirements in the Antelope Valley* (“Revised Crop Requirements”) (April 2007). Please also see the second report in this series, *REPORT # 2: Summary and Synthesis of Available Information on Historical Groundwater Pumping in the Antelope Valley*, for a further discussion of the revised Agricultural pumping estimates.

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Using the aforementioned equation and PSR data for the period from 1979 to 1997, the Sustainable Yield can be calculated as:

$$\text{Sustainable Yield}_{(1979-1997)} = (2,640,415 \text{ AF} + 109,163) / 19 = 144,715 \text{ AF}$$

Using Revised Crop Requirements data for the same period yields the following value for Sustainable Yield:

$$\text{Sustainable Yield}_{(1979-1997)} = (3,012,101 \text{ AF} + 109,163) / 19 = 164,277 \text{ AF}$$

The table below illustrates the resulting Sustainable Yield estimates for both the PSR data and the Revised pumping data over the various time periods shown in Table 4.3-1 as well as other periods of interest, which were chosen for the following reasons:

- 1951-2005: The entire period of available data in the PSR
- 1951-1970: Roughly the period prior to the importation of surface water from the State Water Project (importation began in the mid 1970s) and prior to detailed crop acreage data
- 1979-1997: Period of minimal change in storage
- 1971-2005: Period during which detailed crop acreage is available to calculate Revised Crop Requirements and time during which surface water was imported from the State Water Project.

Total Surface Water refers to both local surface water supplies and imported State Water Project supplies.

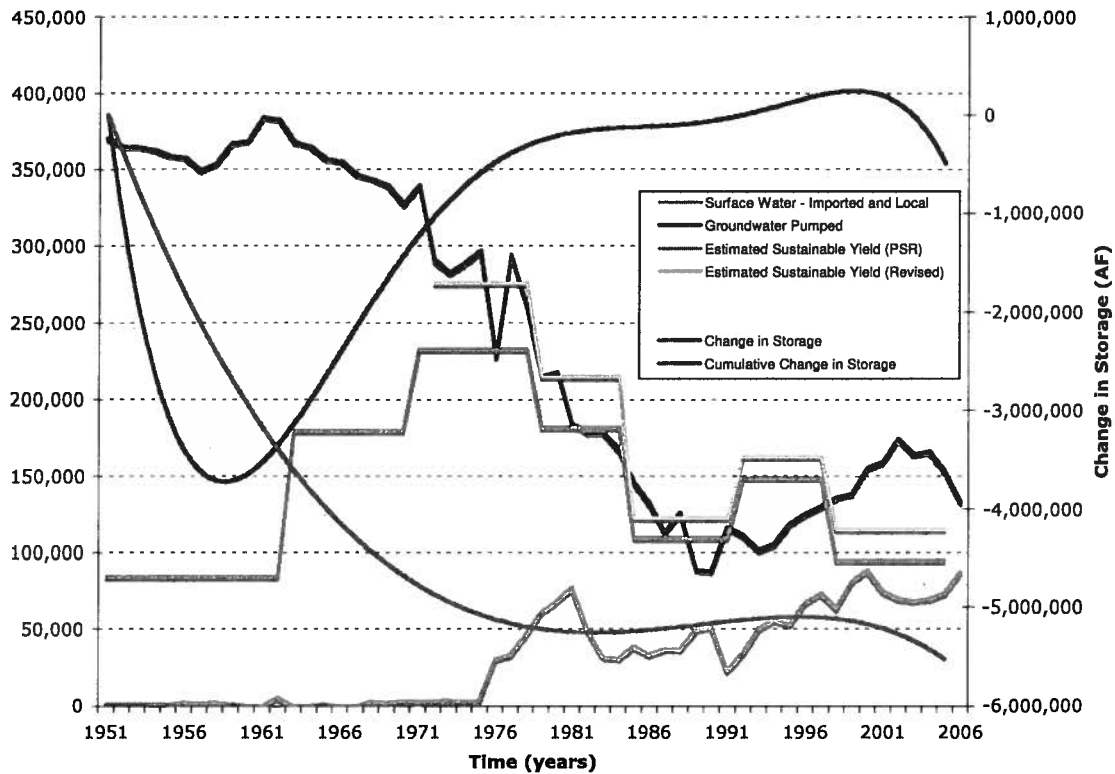
Period	Storage Change (AF)	Problem Statement		Revised Crop Requirements		Total Surface Water (AF)
		Total Pumping (AF)	Annual Sustainable Yield (AF)	Total Pumping (AF)	Annual Sustainable Yield (AF)	
1951-1962	-3,372,697	4,383,743	84,254	N/A	N/A	18,974
1963-1970	-1,363,742	2,801,983	179,780	N/A	N/A	13,132
1971-1978	-417,958	2,281,558	232,950	2,623,851	275,737	184,823
1979-1984	-50,247	1,140,626	181,730	1,339,864	214,936	296,446
1985-1991	-41,222	808,444	109,603	898,751	122,504	266,081
1992-1997	200,632	691,345	148,663	773,487	162,353	363,454
1998-2005	-490,788	1,248,040	94,657	1,411,418	115,079	612,451
<b>AVG 1951-2005</b>			<b>142,177</b>			
<b>AVG 1951-1970</b>			<b>122,464</b>			
<b>AVG 1979-1997</b>			<b>144,715</b>		<b>164,277</b>	
<b>AVG 1971-2005</b>			<b>153,441</b>		<b>178,508</b>	

The Table illustrates a wide range in the Estimated Sustainable Yield over the various periods of interest ranging from 94,000 to 233,000 AF for the PSR data and 115,000 to 276,000 AF for the Revised Crop Estimate Data. During the period of 1979-1997, which was the period demonstrating the least Change in Storage, the Estimated Sustainable Yield was approximately 145,000 AF/yr for the PSR data and 164,000 AF/yr using the higher estimates of Agricultural pumping based on the crop coefficients from Revised Crop Requirements. A comparison of the

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results based on the PSR to those based on the Revised Crop Requirements illustrates that each additional acre-foot of estimated pumping adds approximately one acre-foot to the Estimated Sustainable Yield.

The graph below illustrates the Change in Storage for each period, the Cumulative Change in Storage, the Estimated Sustainable Yield, and overlays Groundwater pumping and Surface Water usage.



The smoothed lines for Change in Storage and Cumulative Change in Storage are based on data taken from the PSR.

From the graph, one can deduce the following:

- Water was removed from storage during a period from 1951 to 1980 and again from 1999-2005.
- The Change in Storage decreasing from 1951 to 1980 coincides with a period of high groundwater pumping.
- The Change in Storage seemed to stabilize around 1980 when annual pumping was approximately 200,000 AF/yr and at the time when imported State Water Project water began to enter the Antelope Valley.
- The Change in Storage decreasing after 1999 coincides with increased groundwater pumping.

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**Additional Work**

Section 4.3.4 of the Problem Statement Report (entitled "Sustainable Groundwater Yield") attempts to answer the question of Sustainable Yield in the Antelope Valley. The results in the PSR differ from the conclusions reached above, although Section 4.3.4 does not provide any back up calculations for how its results were obtained. One possible theory for the difference may be related to the Lag in the Return Flows. Historical periods of high pumping contribute Return Flows to the basin. If those Return Flows did not contribute to the Sustainable Yield until 15-20 years after pumping, as the PSR suggests, then high pumping prior to the period that the basin was "in balance" (1979 to 1997) may have contributed to the total inflows during the period "in balance" thereby inflating the estimates for Sustainable Yield derived by the method presented here.

These results, and the differences in results obtained by different techniques or through the application of different factors such as crop water requirements, point up the need for additional investigation in order to obtain a reliable picture of groundwater processes in the Antelope Valley. Quantification of agricultural pumping, return flow rates, and lag times would be high priority research targets in an effort to resolve these issues.

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*Problem Statement Report, Antelope Valley Area of Adjudication*, Antelope Valley Technical Committee, 6/26/08

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**UPDATED ESTIMATE OF AGRICULTURAL PUMPING IN THE ANTELOPE VALLEY**

by the Mediators for the

Antelope Valley Groundwater Mediation Principals

**Introduction**

In order to devise a framework for allocating groundwater pumping rights under the settlement agreement that the Mediation Principals are negotiating it is important to understand how much groundwater is currently being pumped in the Antelope Valley Area of Adjudication ("AVAA"). The Mediators recently prepared an estimate of total pumping in the AVAA based on: self-reports by Mediation Principals; pumping records published by municipalities, water districts, and other public providers; individual communications; and estimates, where necessary.

Records and estimates for pumping by public entities and mutual water companies are generally based on meter records and accordingly can be considered relatively accurate for these purposes. The story is different, however, for groundwater pumping by agricultural operations. Use of meters is not widespread, record-keeping may be spotty where meters are used, and for business and privacy reasons operators may be reluctant to disclose information about their pumping. Questions of completeness also exist: were all pumpers of significant quantities of groundwater covered, either by individual reports or subsumed within some group such as AGWA, and could there have been double-counting, for example, where an AGWA member's pumping is also reported in pumping estimates provided by other entities that may have leased that person's land? Finally, for tactical reasons a person may have reported inflated pumping volumes in anticipation of an adjudicated allocation of groundwater based on pumping histories.

An estimation procedure that relies exclusively on self-reporting is vulnerable to all these potential sources of error. Some will drive the total down, such as failure to include a significant pumper, while some will drive the total up, e.g., double counting or inflated claims. Such errors may be self-cancelling to some extent, but it is not wise to rely on solely on self-reporting where there is no convenient way to calibrate or verify the existence or magnitude of such errors. Accordingly there is value in developing an independent estimate of agricultural pumping, one that relies on objective criteria. Such an estimate can be used to cross-check the estimate derived from self-reports, or to augment it if the independent estimate seems less vulnerable to error.

**Method**

We prepared an independent estimate of agricultural pumping using the method employed in the Problem Statement Report and in various reports prepared by the Technical Working Group. We obtained records from the Agricultural Commissioners for Los Angeles and Kern Counties of the acreages planted in various crops (or crop categories) for 2007, 2008, and 2009, for parcels located within the AVAA.<sup>1</sup> We multiplied the reported acreages for each crop by the applied water

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<sup>1</sup> These records are compiled from reports made by individual farming operations to the Agricultural Commissioners. The Commissioners treat these individual reports as proprietary business information owned by the reporting farmers. Accordingly, farm-by-farm or owner-by-owner listings are not generally available to the public.



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requirement specific to that crop to obtain the total amount of water applied for irrigation. We then scaled these results upwards by 5% to account for unreported farms, as was done in the Problem Statement Report. Finally, we subtracted the recorded volumes of surface water and reclaimed water used for irrigation from the total volume of water applied for agricultural irrigation, with the remainder thus representing the total groundwater pumped for irrigation.

We ran these estimates with two sets of crop water requirements: the crop-specific coefficients used in the calculations in the Problem Statement Report, and the revised crop water requirements developed in collaboration with University of California extension agents and now cited by the California Water Resources Control Board, Division of Water Rights, for crops grown in the Antelope Valley. Note that the coefficients used in the Problem Statement Report generally produce a lower estimate of applied water than when the revised crop water requirements are employed.

For the sake of comparison, we summed up the annual groundwater pumping volumes obtained through self-reporting by agricultural users, averaged (where possible) over the last five years. This total does not include the volumes reported or estimated for the small pumpers (Wood Class) or the mutual water companies, even though some of those users may use a portion of the water they pump for agriculture, because the amounts used for such purposes cannot be determined from the self-reported values.

**Results**

These calculations are presented in the attached spreadsheet. In summary, using the crop water requirements from the Problem Statement Report, the groundwater volume applied for agriculture in both counties, averaged over the years 2007, 2008, and 2009, is 95,825 AF/yr.<sup>2</sup> The comparable value using the revised crop water estimates is 114,988 AF/yr. The arithmetic mean of these two estimates is 105,407 AF/yr. Our estimate of annual agricultural groundwater use based on the self-reported values is 103,042 AF/yr.<sup>3</sup>

Estimated average agricultural pumping 2007-2009, using crop water requirements from Problem Statement Report	95,825 AF/yr
Estimated average agricultural pumping 2007-2009, using revised crop water requirements	114,988 AF/yr
Arithmetic mean of average estimated agricultural pumping 2007-2009	105,407 AF/yr
Average estimated agricultural pumping from self-reports	103,042 AF/yr

Instead, for publication the Commissioners have aggregated the reported acreages per crop, e.g., all acres planted in alfalfa in the Los Angeles County portion of the AVAA, the same for the Kern County, and likewise for potatoes, carrots, onions, etc. In actuality, this simplifies the computations for this analysis.

<sup>2</sup> The estimated agricultural pumping in the Problem Statement Report was approximately 107,000 AF/yr (PSR App. D-7 Table 3).

<sup>3</sup> This estimate does not reflect the unknown quantity of groundwater in this category that is used for agricultural irrigation, which could be several thousand acre-feet.

June 9, 2010

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**Discussion**

The independent estimates of groundwater used for agriculture, based on public records of acreage under cultivation for the different crops and of surface water and reclaimed water used for irrigation, avoid the shortcomings of an estimate based on self-reports. Nonetheless, it is interesting that the values produced by both approaches fall within the same general range.

The mean value, which combines the results obtained by using the revised crop requirements with results from using the coefficients from the Problem Statement report, may be a better approximation of actual present crop needs than either of the "pure" forms. The revised crop water requirements have the advantage of being specifically developed for the Antelope Valley, with participation by irrigation specialists. The downside is that they may not capture the impact of irrigation efficiency improvements realized through the adoption of additional innovative techniques that were not in general use at the time the revised crop requirements were calculated. The values used in the Problem Statement Report, on the other hand, are somewhat problematic in that they do not appear to incorporate state-of-the-art knowledge on how to calculate such coefficients and they do not seem to consider local conditions in the Antelope Valley. All that said, an intuitive argument can be made that the true value lies somewhere in between.

The acreage-based estimates of agricultural groundwater use are just that, estimates, and are only as reliable as the data fed into them, the values of the crop water requirements used to estimate water use from acreage reports, and the validity of the underlying assumptions. They do offer the advantage of being based on publicly-reported data.

In conclusion, both estimation approaches suggest that groundwater pumping for agriculture in the AVAA lies somewhere above 100,000 AF/yr. When estimates of pumping by water purveyors, mutual water companies, small pumpers, Edwards Air Force Base, and other non-agricultural users have been added to this value, the total estimated present groundwater pumping volume in the AVAA comes to approximately 173,000 AF/yr.

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**Total Agricultural Water Application in AVAA**

Year	Alfalfa/ pasture		Grain	Carrots	Onions	Orchard	Potatoes
	acres	AF/yr					
Los Angeles City.	5993	3645	2187	1885	2400	1895	1100
2008	5877	3945	3848	2000	2000	1895	1000
2009	6760	4520	2682	2000	2000	1750	500
Kern City.	935	1295	2413	742	428	428	395
2008	967	1278	3832	731	428	428	318
2009	1008	985	1562	1024	428	428	0
Total	6928	4940	4600	3142	2313	2323	1495
2008	6844	5223	7680	2731	2323	2323	1318
2009	7768	5505	4244	3024	2178	2178	500

6.5 AF/acre	2.6 AF/acre	3.9 AF/acre	4.5 AF/acre	4.9 AF/acre	2.8 AF/acre
-------------	-------------	-------------	-------------	-------------	-------------

Year	Alfalfa/ pasture		Grain	Carrots	Onions	Orchard	Potatoes	Total	Plus unreported farms (5%)	Minus surface water	Minus reclaimed water	Total applied groundwater
	acres	AF/yr										
Both counties	45,032	12,845	17,940	14,139	11,335	11,335	4,186	105,477	110,750	-13,417	-12,330	85,003
2008	44,486	13,581	29,952	12,290	11,384	11,384	3,690	115,383	121,152	-3,883	-11,771	105,488
2009	50,492	14,312	16,552	13,608	10,673	10,673	1,400	107,037	112,389	-1,974	-13,440	96,975
3-yr average:												96,826

7.7 AF/acre	3.1 AF/acre	4.6 AF/acre	5.2 AF/acre	5.4 AF/acre	3.4 AF/acre
-------------	-------------	-------------	-------------	-------------	-------------

Year	Alfalfa/ pasture		Grain	Carrots	Onions	Orchard	Potatoes	Total	Plus unreported farms (5%)	Minus surface water	Minus reclaimed water	Total applied groundwater
	acres	AF/yr										
Both counties	52,999	15,068	21,160	16,401	12,389	12,389	5,008	123,035	129,187	-13,417	-12,330	103,440
2008	52,357	15,932	35,328	14,256	12,462	12,462	4,415	134,740	141,477	-3,883	-11,771	125,823
2009	59,425	16,789	19,522	15,785	11,675	11,675	1,675	124,872	131,116	-1,974	-13,440	115,702
3-yr average:												114,988

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**CHANGE IN GROUNDWATER LEVELS 1997-2009**

**Technical Working Group, Antelope Valley Groundwater Mediation Principals**

**INTRODUCTION**

The 2006 Problem Statement Report was prepared using groundwater data through 2005 from 19 U.S. Geological Survey (“USGS”) monitoring wells. Several years have passed since the Problem Statement Report was prepared, raising the prospect that conditions have changed and making it worthwhile to review more recent groundwater level data.

This analysis offers a more current, and more comprehensive, view of the present status and recent trends in groundwater levels across the Antelope Valley Area of Adjudication.

**METHODS**

A preliminary analysis was performed to calibrate the groundwater models employed here against reference analyses prepared in the past: a USGS map entitled “Regional Water Table (1996) and Water Table Changes in the Antelope Valley Ground Water Basin, California” by Carl S. Carlson, David A Leighton, Steven P. Phillips, and Loren F. Metzger, 1998, and a map entitled “Groundwater Elevation Contours 2005” prepared by Wildermuth Environmental, Inc. and presented as Figure 4.3-8 in the Problem Statement Report. Accordingly, the modelers used data from the time periods covered by those maps as inputs for the current models to verify that the current models produce comparable results based on visual inspection of the new maps versus the reference maps.

The authors of the current analysis accessed groundwater level data from the USGS website at [http://ca.water.usgs.gov/gmaps/gw\\_map.html](http://ca.water.usgs.gov/gmaps/gw_map.html), obtaining data current through 2009. The authors examined year-by-year data sets from 183 USGS wells, spanning the entire period under study.

Once the current models had been successfully calibrated against the two reference figures, the modelers input data through 2009 into the models to produce a representation of present groundwater elevation contours and a map showing the change in groundwater levels during the period from 1997 to 2009.

**RESULTS**

Exhibits A-F demonstrate the compatibility of the methodologies used in the reference maps and the current models, show the change in groundwater levels from 1997 to 2009, and depict present-day groundwater elevation contours.

**DISCUSSION OF RESULTS**

A comparison of Exhibits A and C demonstrates that when looking at the same time period (1983-1996) the contemporary modeling procedure and the method used in the reference report produce very similar plots of the changes in the water table during that time period. Comparing Exhibits B and D shows that the contemporary and reference methods produce relatively similar

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groundwater elevation contours. Accordingly, applying the current modeling procedures to the more recent data should produce results comparable to what would be expected from application of the reference procedures.

**EXHIBIT E. Changes in Groundwater Levels from 1997-2009**

Exhibit E demonstrates that there has been significant change in basin groundwater levels from 1996 to 2009. Most notable is the change in the location and number of areas where the water table showed substantial declines, or rises. A comparison of Exhibit E with Exhibit A shows that in areas where water tables were rising in the 1998 USGS map (Exhibit A) over the period 1983-1996, the water tables were falling from 1997 to 2009, and vice versa. Overall, however, in areas of the Basin where the water tables were stable in the earlier period they were stable in the later period as well. It should be noted that the 1996 USGS map does not cover as much area as the current map, especially in the northwestern portions of the Basin.

The change in location of the areas where groundwater levels are declining is noteworthy. The most prominent shift in declining groundwater levels is from the area between the Cities of Lancaster and Palmdale northwards and eastwards into areas being used for agriculture. This area was previously found to feature rising groundwater levels. By contrast, current data show that the area south of Palmdale is experiencing rising groundwater levels—groundwater levels were falling in this area in the 1996 analysis.

There is an apparent area of sharply dropping groundwater levels in the northwestern portion of the Antelope Valley Area of Adjudication (“AVAA”). No such phenomenon was presented in Exhibit A, but as noted above the boundaries of the 1998 USGS study area did not extend that far north. It must be noted that there are very few monitoring wells in that area, and this could have influenced these results. It may be valuable for additional data to be recorded for this area and its status reassessed with a more comprehensive data set. Similar efforts might be valuable in the area of apparent sharp decline in the southwestern portion of the AVAA.

**EXHIBIT F. Water Table Level 2009**

Exhibit F can be compared with Exhibit B to demonstrate that current groundwater elevations in many areas have changed since 2005. However, without a longer time series a single “snapshot” like this cannot reveal much about trends.

July 12, 2010

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List of Exhibits

Exhibit A. “Regional Water Table (1996) and Water Table Changes in the Antelope Valley Ground Water Basin, California” by Carl S. Carlson, David A. Leighton, Steven P. Phillips, and Loren F. Metzger, 1998.

Exhibit B. “Groundwater Elevation Contours 2005” prepared by Wildermuth Environmental, Inc. and presented as Figure 4.3-8 in the Problem Statement Report.

Exhibit C. “Changes from 1983 to 1996” (for comparison with Exhibit A’s USGS map of groundwater elevation changes during the same period)

Exhibit D. “Water Table Level 2005” (shows groundwater elevation contours in 2005, for comparison with Exhibit B)

Exhibit E. “Changes from 1997 to 2009” (shows groundwater elevation changes during the subject period)

Exhibit F. “Water Table Level 2009” (shows groundwater elevation contours in 2009)



# Exhibit "A"

Prepared in cooperation with the ANTELOPE VALLEY WATER GROUP

WATER-RESOURCES INVESTIGATIONS REPORT 96-4022  
Regional Water Table (1996) and Water-Table Changes in the Antelope Valley Ground-Water Basin, California  
Sheet 2 of 2

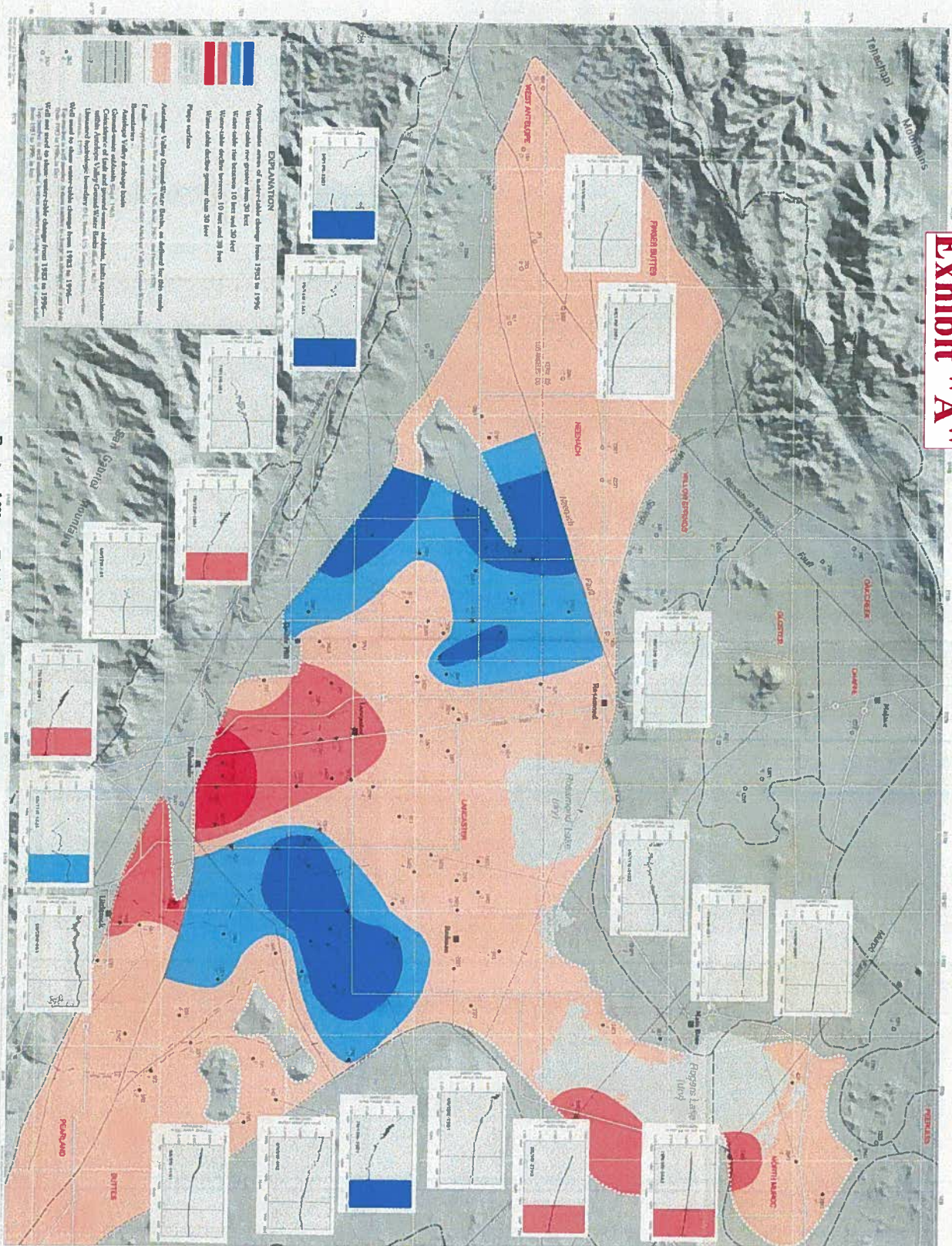
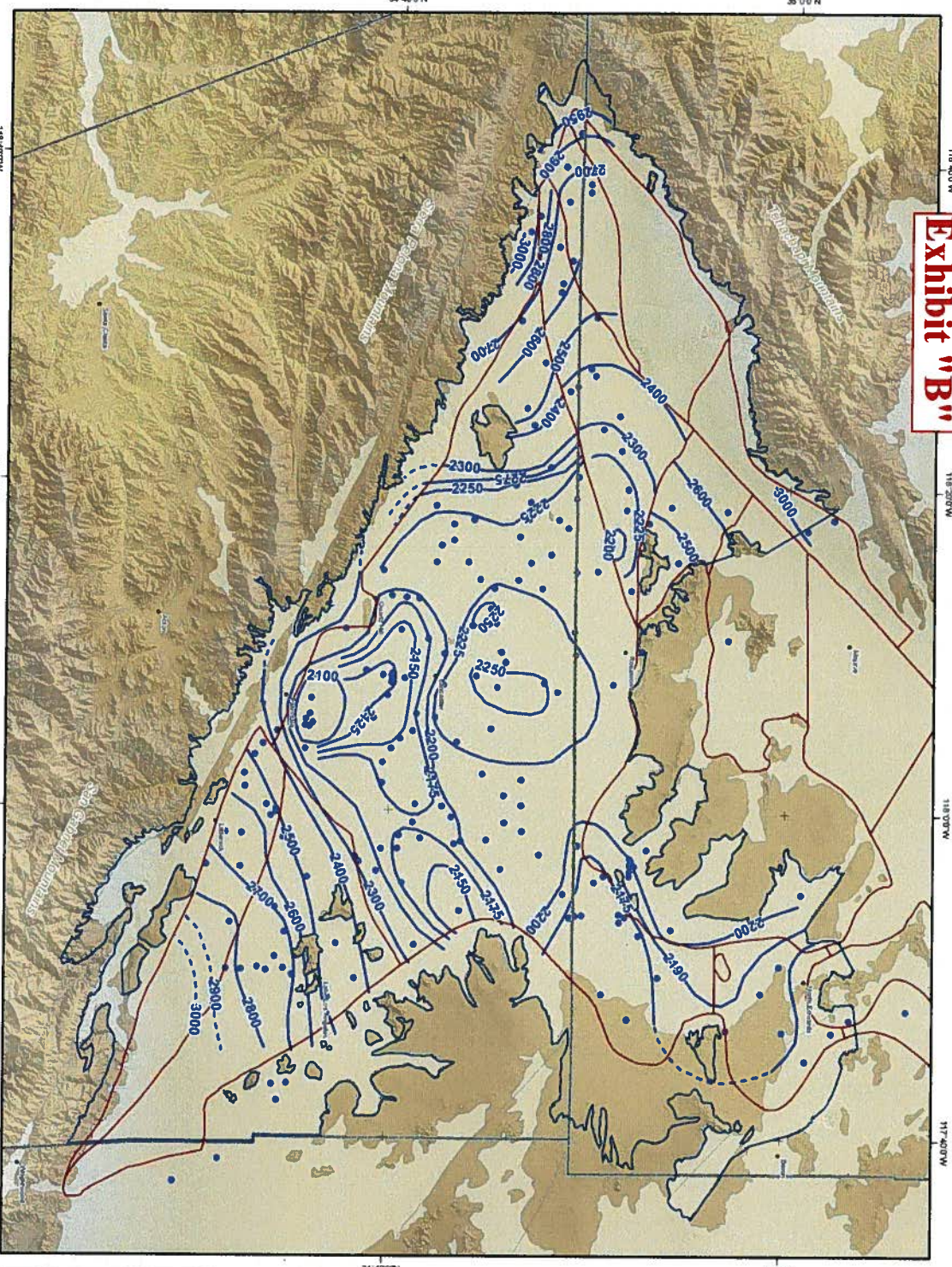


Figure 4. Water-table changes from 1983 to 1996 and selected historical hydrographs in Antelope Valley.

Regional Water Table (1996) and Water-Table Changes in the Antelope Valley Ground-Water Basin, California

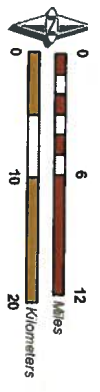


# Exhibit "B"



Produced by:  
**WILDERMUTH**  
 CONSULTANTS, INC.  
 20875 Zanker Road  
 Lancaster, CA 93530  
 Tel: 438-2879  
 Fax: 438-2879  
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Author: WBL  
 Date: 2008/03/10  
 File: 2005\_MFW4



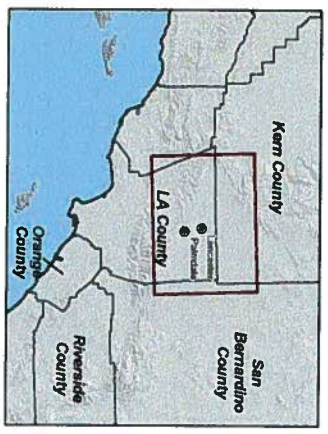
Legend  
 Groundwater Contours & Features  
 082-001  
 007

## Main Features

- Groundwater Elevation Contour (feet above msl)
- Well (water level for period)
- Well (water level interpolated)
- Antelope Valley Groundwater Basin - Adjusted
- Antelope Valley Groundwater Sub-basins

## Geologic Features

- Water-Bearing Sediments
- Pliocene to Holocene Alluvium
- Consolidated Bedrock
- Undifferentiated Pre-Tertiary to Early Pleistocene Igneous, Metamorphic, and Sedimentary Rocks



**Groundwater Elevation Contours - 2005**  
 Antelope Valley Groundwater Basin

**Figure 4.3-8**



# Exhibit "C"

## Groundwater Wells in Antelope Valley Changes from 1983 to 1996

**Groundwater Well Depth Changes from 1983 to 1996**

- Water table rise greater than 30 feet
- Water table rise between 10 and 30 feet
- Water table rise between 0 and 10 feet
- Water table decline between 0 and 10 feet
- Water table decline between 10 and 30 feet
- Water table decline greater than 30 feet

**Groundwater Well Study Area**

- Groundwater Subbasins
- Wells (USGS 1983, 1996, and other sources)
- Wells (USGS 1983, 1996, and other sources)
- Wells (USGS 1983, 1996, and other sources)

**Map Symbols**

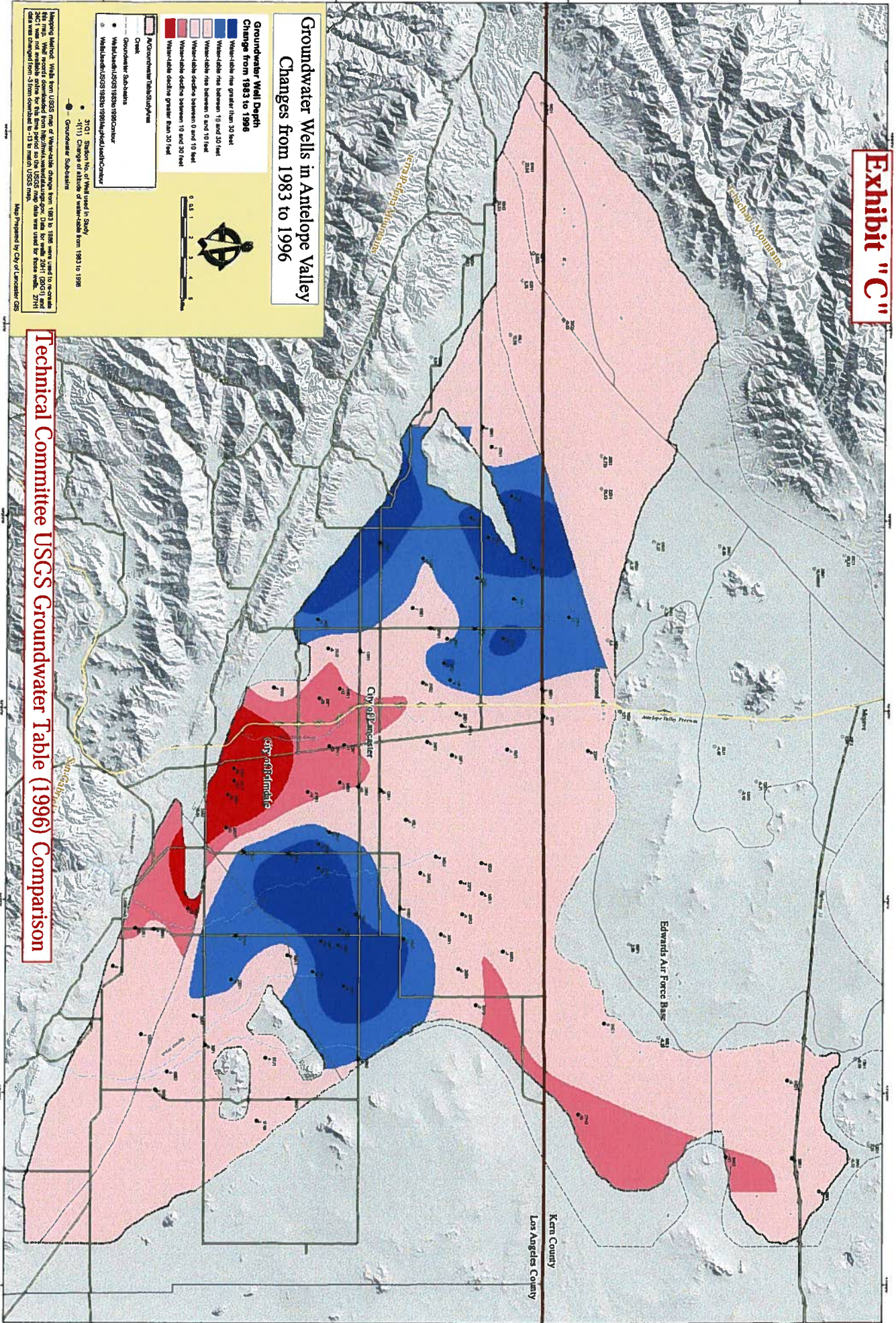
- 100' Elevation Contour
- Change in elevation of wellhead from 1983 to 1996
- Groundwater Subbasins

**Map Scale**

0 1 2 3 4 5 Miles

**Map Prepared by City of Lancaster, GIS**


## Technical Committee USGS Groundwater Table (1996) Comparison





# Exhibit "D"

## Groundwater Wells in Antelope Valley Water Table Level 2005

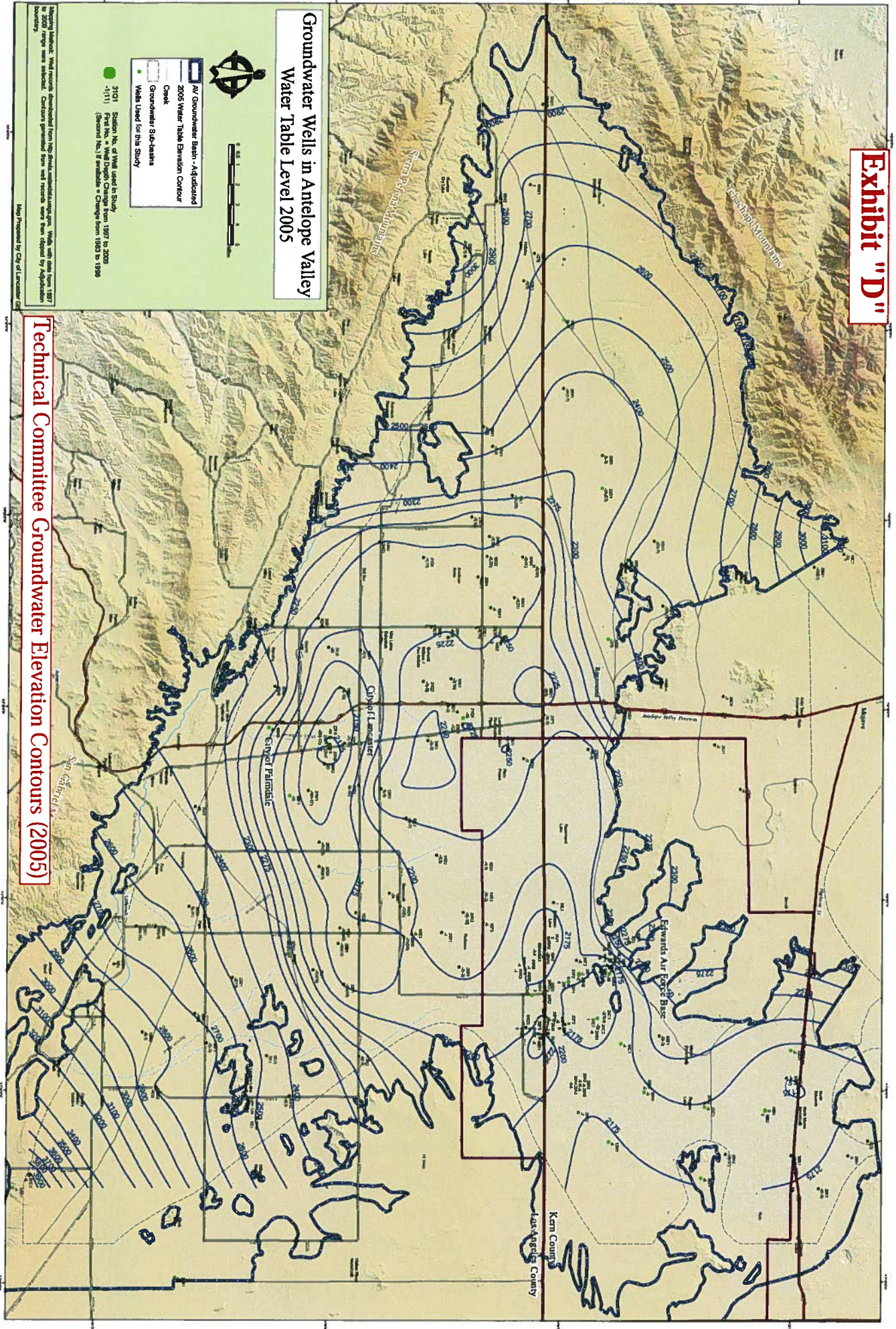


AV Groundwater Basin - Adjusted  
2005 Water Table Elevation Contour  
Creek  
Groundwater Sub-basins  
Wells Used for this Study

3101 Station No. of Well used in Study  
-1111 First No. - Well Depth Change from 1997 to 2005  
(Second No. if available - Change from 1983 to 1996)

Map Prepared by City of Lancaster

## Technical Committee Groundwater Elevation Contours (2005)





**Groundwater Wells in Antelope Valley  
Changes from 1997 to 2009**

**AV Groundwater Basin - Adjusted**

- Change in Groundwater Depth Center - 5 ft./Inch/ft
- Creek
- Groundwater Sub-basins
- Wells Used for this Study

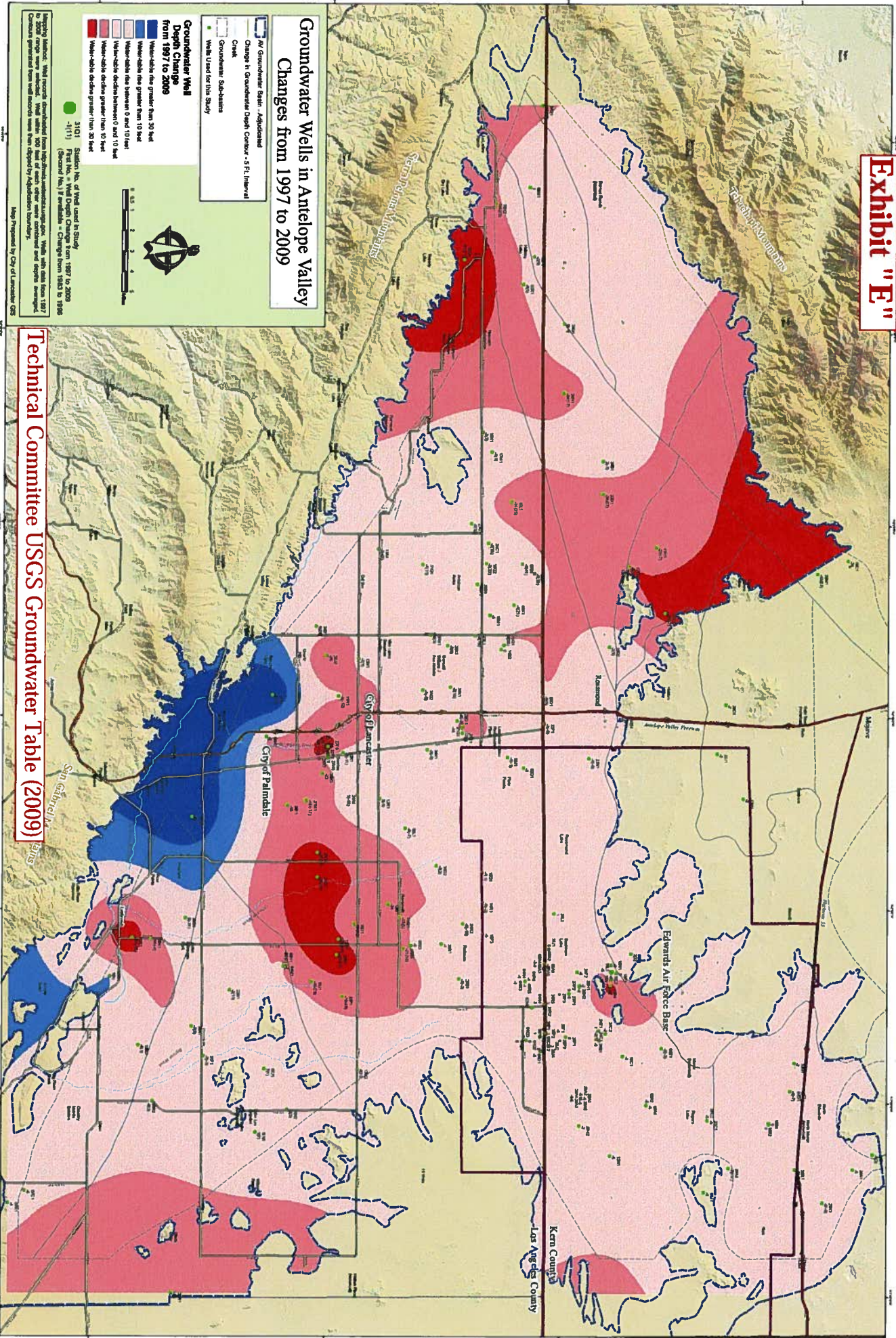
**Groundwater Well Depth Change from 1997 to 2009**

- Water table rise greater than 30 feet
- Water table rise greater than 10 feet
- Water table rise between 0 and 10 feet
- Water table decline greater than 10 feet
- Water table decline greater than 30 feet

**31Q1 Station No. of Well used in Study**

First No. = Well Depth Change from 1997 to 2009  
 Second No. if available = Change from 1982 to 1996

**Map Prepared by City of Lancaster 055**



**Technical Committee USGS Groundwater Table (2009)**



# Exhibit "F"

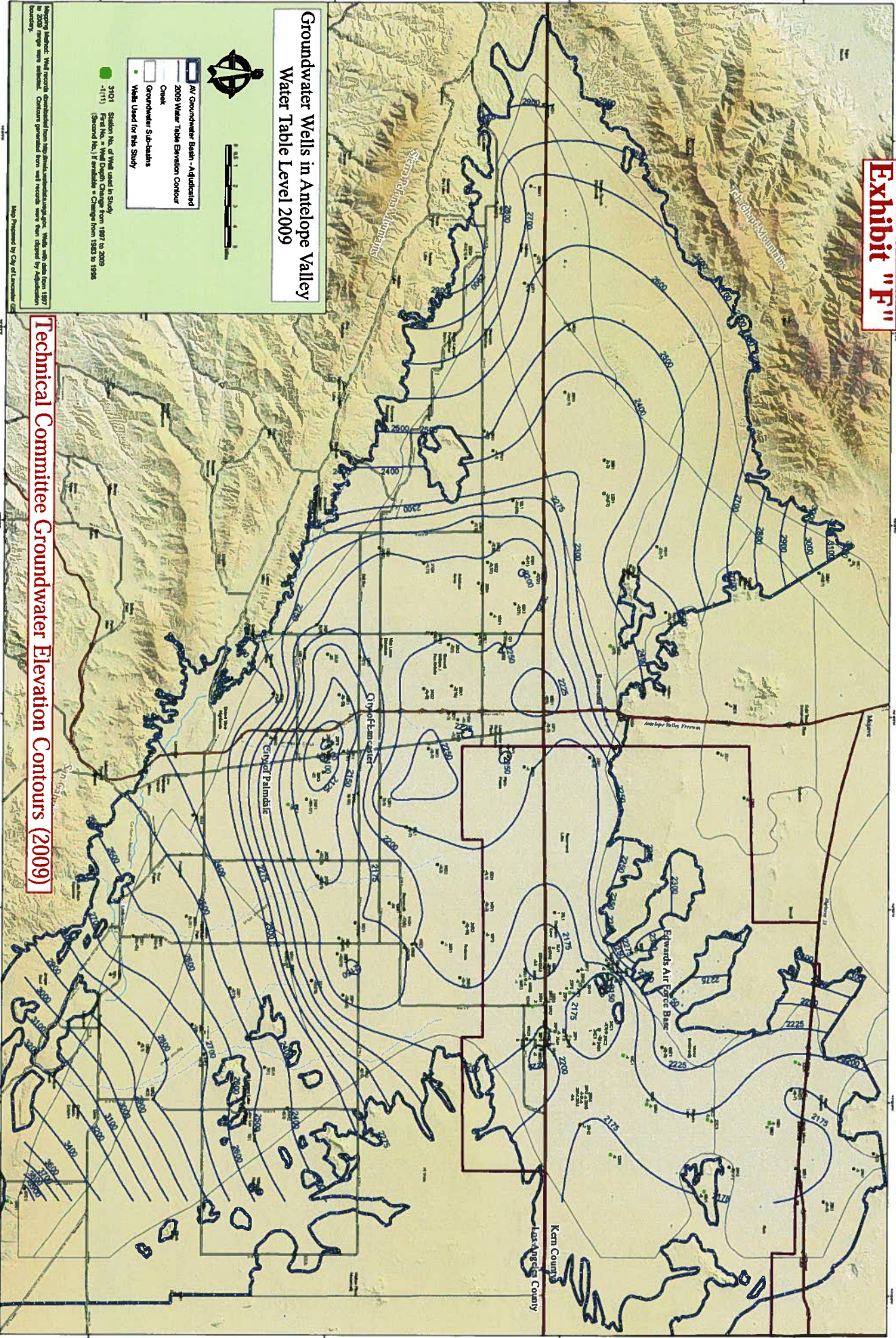
## Groundwater Wells in Antelope Valley Water Table Level 2009

**Legend:**

- AV Groundwater Basin - Adjudicated
- 2009 Water Table Elevation Contour
- Creek
- Groundwater Sub-basins
- Wells Used for this Study

**Station No. of Well used in Study**  
-1111 (Second No. if available = Change from 1983 to 1998)

**Map Projection:** NAD 83 UTM Zone 11N  
**Scale:** 1:50,000  
**Source:** Data provided by City of Lancaster, CA



## Technical Committee Groundwater Elevation Contours (2009)



KENNETH D. SCHMIDT AND ASSOCIATES  
GROUNDWATER QUALITY CONSULTANTS  
600 WEST SHAW SUITE 250  
FRESNO, CALIFORNIA 93704  
TELEPHONE (559) 224-4412

July 1, 2010

Mr. C. William West  
Attorney at Law  
1201 Pacific Avenue, Suite 2100  
Tacoma, Washington 98402

Re: Antelope Valley

Dear Bill:

Following are my responses to the questions provided in your correspondence to me of June 2, 2010.

Range of Estimated Total Sustainable Yield

Reports No. 3 and 4 discuss the sustainable yield in Antelope Valley. Although a wide range of estimated sustainable yields (94,000 to 233,000 acre-feet per year) were presented for various short time periods, a much smaller range (about 140,000 to 180,000 acre-feet per year) is indicated for longer time periods. When the revised crop requirements are used to estimate irrigation well pumpage, the range is even smaller (probably about 160,000 to 180,000 acre-feet per year). My opinion is that it is reasonable to conclude that this smaller range bounds the actual sustainable yield in light of the available data.

Another approach to estimate the sustainable yield is to add the amounts of natural recharge and surface water (local and imported). This apparently equals about 132,000 acre-feet per year. This amount should balance the consumptive use of applied water to have stabilized groundwater levels. Dividing the 132,000 acre-feet per year by the efficiency (consumptive use divided by applied water) yields about 165,000 acre-feet per year, which I believe is a reasonable value for the sustainable yield.

Identification and Assessment of Critical Factors

Report No. 1 Trends in Standing Groundwater Levels

Summary. Data from 19 U.S. Geological Survey monitor wells were updated, where possible, and used in the evaluation. The results revealed various long-term trends in groundwater levels in the valley. The water levels were dropping in the central valley and around Edwards Air Force Base; however, water levels in other

parts of the valley were relatively stable over the period examined. While the information from this review was valuable, it raised a concern that the number and location of these 19 wells did not provide adequate information for a rigorous water management program in the valley.

Response. The water-level evaluation is considered adequate, but contains several assumptions. This first is apparently that the water-level hydrographs represent an unconfined aquifer. I could not find information in the reports on the perforated intervals of the 19 wells used for the hydrograph analysis. Also, I could not find information on vertical trends in hydraulic head in Antelope Valley. For most developed alluvial basins, hydraulic heads are deeper with increasing depth (i.e. there is downward groundwater flow). The part of the PSR on subsurface geologic conditions (Chapter III) discusses three significant clay layers, which actually may be one layer. It was not clearly explained in the reports that the water-level records are apparently for composite wells (i.e. tapping many layers of deposits). It was assumed, in doing the groundwater storage calculations, that these levels represent an unconfined aquifer, but this was not demonstrated.

An important question is: "Could a better evaluation of storage changes have been done for a more recent time period (i.e. after 1970 or 1980), utilizing many more water-level hydrographs"? The 19 wells is a relatively small number, compared to all of the wells where water levels are measured in the two counties. My opinion is that it would be valuable to evaluate a time period for which at least 50 to 70 water-level hydrographs are available.

Lastly, water levels in deep wells in many alluvial groundwater basins with layered deposits are more indicative of pumpage than recharge (other than by well injection), and are likely to be indicative of confined or partly confined conditions. In contrast, water levels in shallow wells in such basins are more indicative of recharge than water levels in deep wells, and are usually indicative of unconfined conditions. Records for composite wells may not be the best ones to use for such an evaluation. I evaluated how many of the 19 wells with water-level hydrographs were in irrigated areas. This review indicated that only about one-third of the 19 wells were in or near irrigated areas. The hydrographs for the other wells may not be fully indicative of the influence of deep percolation from irrigation return flow.

Report No. 2 Historical Pumping for Irrigation Purposes

Summary. The report started with the premise that estimates of historical pumping are an important component in many groundwater

balance evaluations. The total groundwater pumpage and the part that becomes return flow were examined. One way to estimate irrigation pumping is to multiply irrigated crop acreages by crop-specific water requirements (crop coefficients). However, the crop coefficients that have been used earlier in some cases may not have reflected conditions found in Antelope Valley. Consultations with agriculture experts from the University of California and Antelope Valley growers produced revised estimates of crop coefficients specific to the valley. These are now used by the California Water Resources Control Board for estimating groundwater pumping for irrigation in the Antelope Valley. These revised crop coefficients were used in the report along with improved estimates of irrigation efficiency to show that irrigation well pumpage was greater than previous estimates.

Response. This report is excellent and correctly addresses the critical factors.

#### Report No. 3 Critical Factor Analysis

Summary. The key factors used in the various assessments of groundwater status in the valley were evaluated. The estimated amounts of pumping and native recharge were important factors used in developing the water budgets. Valley-wide groundwater storage amounts were relatively stable during the late 1970's to late 1990's, suggesting pumping for that period may be sustainable. Water levels across the valley have not been falling in recent years at the rates expected if severe overdraft was occurring.

Response. On page 5 it was stated that "much of the hypothetical 25% would be lost and would therefore not be available for return flow." My experience in many similar irrigated alluvial basins in California and Arizona is that most of this percentage should recharge the groundwater, at least after several decades of irrigation. This is usually evidenced by the chemical quality of shallow groundwater beneath irrigated areas. On Page 9, the total sustainable yield range of 175,000 to 180,000 acre-feet per year is considered higher than the actual, because of the relatively large amounts of deep percolation from irrigation return flow that originated prior to 1975. This issue was addressed on Page 4 of Report No.4.

#### Report No. 4 Estimate of Total Sustainable Yield

Summary. Water-level records from the 19 wells were used to estimate the changes in groundwater storage that have historically occurred. The water budget approach was also used to estimate the changes in groundwater storage. The estimated sustainable yield

depends highly on the base period used, the amount of irrigation pumping, and the amount and lag time of return flows. The groundwater in storage was relatively stable for the period from the late 1970's to late 1990's. The pumpage during this period ranged from about 145,000 to 164,000 acre-feet per year. The sustainable yield would be expected to generally be within this range.

Response. Page 1. Last sentence on first half of page, starting "Therefore, the average annual pumping.....". This statement is not exactly true because of the varying amounts of deep percolation from irrigation during different time periods before and after 1979. However, this was addressed on Page 4 of the report. Otherwise, I think the report correctly identifies and addresses the critical factors.

#### Other Key Factors Not Considered

Alluvial deposits in some desert areas have been indicated to be moisture deficient (i.e. moisture contents below the field capacity) prior to irrigation. Before water percolating beneath irrigated areas could move downward to the water table, this moisture deficit would first have to be met. This is another reason why it would be valuable to do the water budgets for later as opposed to earlier time periods.

Groundwater quality was not discussed in the reports. The chemical quality of shallow groundwater beneath irrigated areas and the vertical distribution of selected constituents such as electrical conductivity, nitrate, and the stable isotopes of water in the groundwater could readily prove or disprove factors such as leaching fraction, travel time, etc. These tools have been extensively used in the San Joaquin Valley and in a number of alluvial basins in Arizona to evaluate irrigation return flow.

Other aspects of groundwater quality could become important, for example, if a significant part of the groundwater is not of suitable quality for public supply at some time in the future, because of the lowering of MCLs or establishment of new MCLs.

#### Principals Conclusion on Designated Pumping

My opinion is that the 150,000 acre-feet per year of pumping over a 10-year period is a reasonable pumping volume to be used. This is based on the assumption that an average of about at least 70,000 acre-feet per year of water should be imported into the valley during the 10-year period.

Please call me if you have any questions.



---

KENNETH D. SCHMIDT AND ASSOCIATES  
GROUNDWATER QUALITY CONSULTANTS

5

Sincerely yours,



Kenneth D. Schmidt

KDS/cl

# TODD ENGINEERS

GROUNDWATER • WATER RESOURCES • HYDROGEOLOGY • ENVIRONMENTAL ENGINEERING

July 6, 2010

## MEMORANDUM

**To:** Mr. C. William West  
Attorney at Law  
Gordon Thomas Honeywell  
1201 Pacific Avenue, Suite 2100  
Tacoma, Washington 98402

**From:** David W. Abbott, P.E., C.Hg.

**Re:** Antelope Valley Area Adjudication and responses to Terms of Reference.

## INTRODUCTION

On June 14, 2010, I was authorized to proceed to: (1) review specific documents for the Antelope Valley Area of Adjudication (AVAA), (2) focus on questions prepared by the Principals and referred to as the "Terms of Reference", and (3) prepare a summary memorandum of my findings and opinions.

The following project documents were received on or after June 15, 2010:

- Problem Statement Report (PSR) for AVAA and associated Appendices (A through G) completed by the Antelope Valley Technical Committee in June 2008;
- Statement of opinion prepared by Mr. N. Thomas Sheahan (January 2008);
- Four summary reports prepared by the Technical Working Group (TWG) (Reports #1 through #4) (Spring 2010); and
- One report prepared by the Mediators (June 2010) to update the estimates of agricultural pumping.

These and other non-project but relevant references used in my review are listed in the references section to this memorandum. The project documents, specifically the PSR and appendices, were reviewed by me and provided the fundamental understanding of the Antelope Valley watershed and associated groundwater basin, significant and relevant hydrologic components and elements of the watershed and basin, changes in land-use patterns, and water balance methodology. Review of these documents allowed me to

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form an opinion to answer the four questions posed by the "Terms of Reference", which were provided prior to June 14, 2010. In this memorandum the questions are first stated (in italics), followed by the answers.

In addition to answering the questions from the "Terms of Reference", I have summarized some of my comments and suggestions concerning the summary reports prepared by TWG to improve understanding of the water balance elements for the AVAA. The purpose of these summaries reports are to: (1) establish a common understanding of the technical issues by the Principals surrounding the assessment of AVAA and the groundwater resources; (2) evaluate, re-evaluate, and discuss important recent groundwater resource trends with data collected since the PSR was published in 2008; (3) identify areas where additional information and/or analysis is needed to clarify data gaps, required in evaluating assumptions and uncertainties and to move forward in the adjudication process.

**TERMS OF REFERENCE**

**Question 1:** *Is it reasonable to conclude that the range identified in the summary reports bounds the actual total sustainable yield in light of the data available?*

Yes, it is reasonable to conclude that the range identified in the summary reports bounds the actual total sustainable yield (TSY) in light of the available data. For example, the summary table on Page 10 of Report #3 summarizes estimated ranges of TSY, key values, and assumptions. TSY ranges between 110,000 acre feet per year (AF/yr) (PSR, June 2008), 170,000 AF/yr (Nebeker, April 2007), and 184,000 AF/yr (Sheahan, May 2008). In my opinion, the actual TSY is closer to 110,000 AF/yr rather than 170,000 AF/yr; the TSY is likely to range between 110,000 and 130,000 AF/yr for the following reasons (not listed in any particular order):

- The uncertainty and significance of large standard, sampling, and bias errors of the basic hydrologic data (i.e., precipitation and stream flow) and other elements (return flows, agricultural estimates, pumping estimates, evapotranspiration, etc.) of the water balance;
- The lag times for return flows are probably longer (i.e., in the range of 15 to 20 years) rather than shorter (7 years), while the quantity of total return flows given in the PSR are probably over-estimated (see Report #3);
- Native recharge (60,000 AF/yr) is about 9 percent of annual precipitation in the PSR, which is more reasonable than a native recharge of 106,000 AF/yr or about 40 percent of precipitation. Similarly, native sustainable yield is about 13 percent of annual precipitation in the PSR, while the Sheahan report suggests about 55 percent of precipitation.
- Bedrock infiltration is three times greater in the Sheahan report than the PSR. In my opinion, the ratio between bedrock infiltration and precipitation is too high in

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the Sheahan report (22 percent) compared to the PSR (3 percent). Wilson and Guan (2004; their Table 2) summarize mountain block recharge (MBR) which suggests ranges between 0.2 to 2.7 percent of the annual precipitation in similar hydrologic and climatologic environments as Antelope Valley. The greater recharge rates (14 to 38 percent, shown on page 8 of Report #3) are dominated by significant snowmelt recharge processes that do not occur in the watershed areas of Antelope Valley; snowmelt recharge is prevalent in the Rocky Mountains (Magruder et al., 2009).

**Question 2:** *Did the summary reports correctly identify and assess the operation and significance of the critical factors (methodologies, key assumptions, and values of critical parameters) that drive the range of outcomes of the assessments considered?*

Yes, the PSR and summary reports identified and assessed the major groundwater basin operational components, elements, and parameters including: precipitation; evapotranspiration (ET); stream flow; imported water; municipal, rural, and agricultural pumping; return flows; hydrogeology; and groundwater storage. In addition, the PSR and summary reports evaluated the significance of critical factors resulting in different values of the components that ultimately drive the ranges of the TSY. These critical factors include parameter estimation, water balance methodologies, and key assumptions. The TWGs prepared four summary reports focusing on the following issues:

1. Standing groundwater levels and trends (Report #1);
2. Historical groundwater pumping (Report #2);
3. Factors affecting assessments of groundwater yield and resources (Report #3);
4. Changes in groundwater storage and sustainable yields (Report #4); and
5. In addition, the Mediators prepared an update to agricultural pumping.

The summary reports, especially Report #3, recognize that a common language with associated technical definitions is important for proper communication between stakeholders. The summary reports recognized also, and identified correctly, that additional work (including ongoing and additional monitoring) is essential in improving AVAA hydrologic understanding and to refine water balance and TSY.

An important feature of any water balance is the precision, accuracy, and sensitivity of basic- and derived-data that will impact the conclusions drawn from the water balance exercise. Precision and sensitivity were discussed in Section 4.9 of the PSR while several of the summary reports implemented a sensitivity analysis. Important potential standard, sampling, and bias errors of the water balance elements are discussed in other non-project references (Hanson and Dawdy, 1976; Rantz, 1982; Jensen et al., 1990; and Carter et al., 1963). These errors, in addition to differences in basin-related definitions and confusions in terminology, are factors that result in mixed estimates of the water balance elements and conclusion presented in the PSR and summary reports.

However, the TSY is dynamic and can vary from year to year (and decade to decade) depending on the variations of the values of the water balance components. The summary

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table presented on page 2 of Report #4 illustrates this variation in annual sustainable yield. The PSR annual sustainable yield varied by almost three-fold from 84,300 AF to 233,000 AF depending on the period of time used between 1951 and 2005, while the application of revised crop requirements to the water balance indicate a two and one-half fold variation from 115,000 AF to 276,000 AF.

The applied and hands-on review by the TWGs of certain components, elements, and parameters of the water balance plays a fundamental and important role in flushing-out new ideas and sensitizing the stakeholders to the relative uncertainties of the water balance elements. The working group exercises demonstrated the strengths and weaknesses of the water balance and associated assumptions and accuracies of the data. Not only is the value of the TSY dynamic but accurate measurements of the critical elements of the water balance are difficult (and, in some cases, impossible) to achieve, and can be imprecise.

**Question 3:** *Are there other key factors that either were not considered in the underlying assessments, or were not identified or examined in the summary reports, and if so what is their significance in terms of influencing assessment outcomes?*

No, in my opinion the PSR and the TWG reports addressed the main factors that constrain the water balance assessments which result in various estimates of the TSY. However, evaluation and re-evaluation of all the water balance elements (including additional and ongoing monitoring), hydrogeologic framework, and conceptual models can refine, re-affirm, and modify the conclusions drawn from the TWG reports and the PSR.

Other factors that may clarify (or complicate) interpretations of the water balance and TSY include focused discussions on specific yield (Johnson, 1967) related to change in storage issues, subsurface stratigraphy and basin geometry, soil properties and soil moisture changes (Dunne and Leopold, 1978), mountain block recharge (MBR) and hydrology, mountain front recharge (MFR), precipitation patterns and distributions, stream flow, return flow estimates, and ET (Jensen et al., 1990; DWR, undated). For example, a re-evaluation of soil properties, soil distributions, and change in soil moisture may help to reduce the uncertainty of return flows from native and non-native sources. Typically, ET is the most difficult element of the water balance to accurately measure or estimate.

The water balance (a conservation of mass or continuity equation) is a complex set of interactive variables that account for inflows, outflows, and storage changes to a groundwater basin:  $\text{Inflow} = \text{Outflow} \pm \text{Change in Storage}$  (Heath and Trainer, 1968). The complexity of the balance is further obscured by feedback loops illustrated in the PSR (Figure 4.1-1). For example, return flow (a feedback loop) is the amount of water that reaches a groundwater source after release from the point of use and thus becomes available for further use (AGI, 2005). Report #3 on page 5 discusses the existence and magnitude of return flows and notes that return flow studies have not been conducted or

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quantified in the AVAA. Report #3 concludes that the amounts of return flows are likely to be low relative to the total applied water; I agree.

**Question 4:** *Based on the data and analyses presently available, did the Principals reasonably conclude that the AVAA groundwater resource could sustain a designated pumping volume (150,000 AF/yr) over a specified period (10 years) without risking substantial harm to the resource?*

A qualified yes, the Principals reasonably concluded that the AVAA groundwater basin could sustain a pumping volume of 150,000 AF/yr over a 10 year period (total of 1,500,000 AF) without risking substantial harm to the groundwater resources under average or above-average operating conditions including climatologic conditions and water imports. Alternatively, a pumping volume of 110,000 AF/yr for 10 years would have a significantly lower risk of harming the groundwater resources under current conditions.

In addition to the standard, sampling, and bias errors in the data which affect the calculations, review of the AVAA hydrographs attached to Report #1 indicates a downward trend of water levels throughout the basin (see last page of Report #1 showing regional trends) under current pumping conditions. This downward trend implies a negative impact to the groundwater basin at current pumping volumes. However, the final position of the stabilized water level (if reached) under current conditions is unknown at this time. The stabilization elevation will determine the relative significance of the impact to the groundwater basin at current agricultural and municipal pumping volumes.

The overall uncertainties and unpredictability of future climatological conditions and the uncertainties inherent in the estimation of individual elements for the water balance (see Section 4.9 in the PSR) supports a conservative approach to estimate the TSY. For example, the basic hydrologic data (precipitation and stream flow) have standard errors of measurement and bias attached to them; measurement records of stream flow data (which seems, in concept, simple to measure) could range (based on a U.S. Geological Survey ranking system) from poor, fair (15 percent error), good (10 percent error), and excellent (5 percent error) (see Rantz, 1982) while precipitation has a temporal and spatial standard error, particularly in mountainous regions (Wilson and Guan, 2004). These errors and others could be cumulative rather than cancel each other out.

A related concept that is not addressed in the PSR or the TWG reports affecting the TSY of the basin is "What is the acceptable and permissible drawdown allowed in the groundwater basin?" The estimated TSY is related to the estimated pumpage and the associated drawdowns (from hydrographs). We know that the temporal and spatial drawdowns or "threshold" water levels (PSR, page IV-23) should not exceed the historical maximum drawdowns that have occurred in the groundwater basin to avoid re-activation of further subsidence. Will the maximum historical drawdowns be achieved over the ten years of operation under the assumed operating and climatological conditions? Will deeper water levels (meaning greater pumping lifts and additional power

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to retrieve the water) impact the economic usefulness of groundwater resources of the AVAA?

**SUMMARY OF REPORTS**

**Report #1:** *Summary and synthesis of available information on standing groundwater levels and significant trends.* (TWG, April 14, 2010)

The PSR was completed in June 2008. The hydrographs presented in the PSR use data that was collected prior to (and including) 2005. In April 2010, Report #1 was prepared to extend the hydrographs that are presented in the PSR to 2010. The hydrographs are presented in Figures 4.3-9 (19 graphs) and Figure 5.5 (20 graphs) of the PSR, and as a series of individual hydrographs (19 graphs) attached to Report #1. Do the selected hydrographs in the PSR and Report #1 represent basin-wide changes in water levels? Are the selected hydrographs sufficient for long-term and effective groundwater management?

Report #1 includes two maps from the U.S. Geological Survey's website showing the location of over 200 monitoring wells located in the AVAA in Los Angeles and Kern counties. The twenty (or so) hydrographs presented in the PSR and Report #1 represents less than ten percent of the available wells. Hydrographs for all monitoring wells should be presented in the PSR, even if the records are short or incomplete. Hydrographs should have consistent horizontal and vertical scales (for example Figure 5.5) which will facilitate comparisons between the hydrographs and provide an internal working consistency between groups of hydrographs and the data. Figure 5.5 uses a 150 foot vertical sliding scale between hydrographs. In contrast, Figure 4.3-9 shows hydrographs with different vertical scales.

In addition, the graphs should include a notation for the general (upper, middle, or lower aquifer) or specific screened intervals of the monitoring well and the date of well construction. These suggestions will provide a clearer and consistent picture of the basin-wide water level fluctuations and trends. Selection of the longest hydrographs with the most continuous data usually provides a basic framework for the interpretation of incomplete or partial water level records. Grouping and plotting similar hydrographs on the same paper may also help to sort-out, identify, and support the significance of spatial, temporal, and short- and long-term groundwater fluctuations and trends in water level patterns.

The last page of the report contains a map titled: "Antelope Valley Groundwater Areas and Trends" summarizing trends from the preceding updated hydrographs. The hydrographs presented in Report #1 show "red arrows" suggesting general water level trends since 2000 for many of the monitoring wells. The significance of these projected trends could be misleading. For example, using the first hydrograph presented in Report #1 (008N013W09K001S), the 2000 data would have projected a recovering trend in water levels based on the trends observed between 1990 and 2000; we know now that the trends after 2000 appear have moved downward. It is important to realize that the last few

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years of data trends may not predict future trends. In summary, I support the conclusions of Report #1 suggesting additional monitoring and review of other hydrographs throughout the AVAA.

**Report #2:** *Summary and synthesis of available information on historical groundwater pumping in the Antelope Valley.* (TWG, April 14, 2010)

Estimates of historical agricultural pumping are an important component in the water balance. Historical agricultural pumping can be estimated from: (1) actual tabulated and recorded flow measurements on well head or diversion ditches, (2) electrical power consumption of pumps, (3) crop-specific water requirements applied to acreages planted, and (4) various residuals and ratios of the water balance elements. A small portion of water pumped or diverted for agriculture-use (and municipal-use) returns to the aquifer (return flows) and increases amounts of TSY of the groundwater basin, while the remaining larger portion is consumed by the crop uptake (or municipal-use) and evaporated or transpired to the atmosphere. The irrigation efficiency is the ratio of the amount of water required by the crop versus the amount of water applied to the crop. The distribution uniformity (DU) or "catch-can" coefficient is often included in the irrigation efficiency.

Referring to Report #2, page 1 (near the bottom of the page): I do not know where the PSR "estimated the rural pumping at 8,200 AF/yr and at 3,200 AF/yr of pumping by mutual and small private water companies". The foot note refers the reader to PSR Appendix D-7, Table 4; however, my copy of Table 4 is missing the last right-hand column(s) after "ASR project LACWW40". Therefore, I am unable to determine where 8,200 and 3,200 AF/yr was estimated or obtained. The numbers appear to have been obtained from the average of the time-frame (1995 to 2006) in their respective columns of Table 4.

Does the total water applied include changes in soil moisture? Is the change in soil moisture included with the applied water for field preparation? Shouldn't total applied water also include a change in soil moisture term or is that included in the applied water for field preparation? The DU or "catch-can" of the irrigation system used in the PSR is 0.80 or 80 percent. The quotation explaining DU provided on the bottom portion of page 3 (from Hanson and Orloff letter) suggests that an "equivalent" DU (now termed Irrigation Efficiency) of 0.75 is more appropriate based on recognition of wind impacts on irrigation (Orloff and Carlson, 1997). Clearly, the various methods to estimate the water balance and corresponding definitions of technical terms (i.e., DU and irrigation efficiency) can influence the conceptual hydrologic framework and result in differences of agricultural pumping and TSY.

A sensitivity analysis for total applied water ( $AW_T$ ) is provided in Report #2 on page 5. There is a minor error in this calculation. Re-calculation of the following equation [ $AW_T = (5.03/80\%) + 0 + 0.17$ ] shown at the bottom of page 5 yields an answer of 6.46 AF (rounded to 6.50 AF). In contrast, the following equation at the bottom of the page [ $AW_T = 5.03 + 0 + 0.17 / 80\%$ ] results in an answer of exactly 6.50 AF. Note that:



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$$AW_T = (ET/DU) + AW_{er} + AW_{pr} \quad (\text{from the PSR})$$

$$AW_T = (ET + NM_{er} + NW_{pr}) / (\text{Irrigation Efficiency}) \quad (\text{Revised Crop Requirements})$$

The variables are defined in Report #2. If, as shown by the calculations presented that:

$$AW_{er} = NW_{er} = 0$$

$$AW_{pr} = NW_{pr} = 0.17$$

Irrigation Efficiency = DU = 80 percent (0.80), then

$$(ET/DU) + AW_{er} + AW_{pr} = \{(ET + AW_{er} + AW_{pr}) / DU\}_A$$

Note that  $AW_{er}$  (0) and  $AW_{pr}$  (0.17) are relatively small with respect to ET (5.03); therefore, we can ignore those terms and the equations reduce to:  $ET/DU \sim \{ET/DU\}_A$ . The equations are approximately equal only if  $AW_{er}$ ,  $AW_{pr}$ ,  $NW_{er}$ , and  $NW_{pr}$  are small relative to ET.

There also seems to be a minor discrepancy in the definition and calculation of percent change between two numbers (x and y) relative to the base (or old) number (x). Percent change was estimated in several portions of Report #2. The mathematical expression for percent change is  $[(y - x) / x] * 100$ ; expanding this expression yields  $[(y/x) - 1] * 100$ . The base number (x) for all of the calculations at the top of page 6 Report #2 is 6.5 AF. Calculations show that the percent change for the first equation equals 6.15 percent instead of 5.7 percent and for the second equation is 9.23 percent instead of 9.8 percent, while the third equation is correct 17.69 percent. The incorrect percent change for the first two equations on page 6 appears to have been estimated by using the following expression:  $[1 - (x/y)] * 100$ ; which are not equal to the percent change definition given above. Applying the incorrect expression used in the first two equations to the third yields 15.03 percent, which is incorrect; the reported correct number is 17.69 percent. I have not verified the Applied Water Calculations – PSR versus Revised Crop estimates tabulated on page 6.

**Report #3: Critical factors affecting assessments of groundwater yield and resource status in the Antelope Valley.** (April 28 - 29, 2010)

The critical factors analysis reviewed and evaluated key factors, elements, and assumptions that may influence the TSY calculations. Different assumptions and conceptual models of the hydrologic and hydrogeologic framework of the AVAA can produce different results and conclusions. The report concluded that native recharge and estimated pumping affected significantly the TSY of the AVAA.

I agree strongly that a set of project specific definitions should be provided for the terms used in the PSR, supplemental, and summary reports. The definitions will provide the "common technical language" and promote the "common understanding" of the "analytical tools and assumptions ... used in assessing the conditions of the AVAA

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groundwater resources". In short, everyone will be on the same page. These AVAA site-specific definitions should be carefully reviewed when non-project related reports and other water balance methodologies (Lerner et al., 1990; Jensen et al., 1990; Agnew and Anderson, 1992; and Wagner et. al., 2004) are evaluated to support calculations or concepts considered for the AVAA.

The table on page 4 of Report #3 compares the crop water requirements in the PSR with the revised crop requirements from Nebeker et al. (April 2007). The change in crop water requirements from the PSR to the revised requirements ranges from 7.8 to 18.0 percent averaging about 14.2 percent. This will yield approximately a 14 percent increase in the estimated amount of agricultural pumping.

The amount of groundwater in storage is permanently reduced when basin-wide land subsidence which consolidates the underlying fine-grained aquifer sediments. The quantity of return flows reaching the underlying aquifer would also be smaller because the permeability of the sediments from the ground surface to the underlying aquifers has been reduced from the subsidence event. In addition, lag-times for return flows to reach the aquifer should increase because of the compaction during subsidence.

**Report #4:** *Summary and synthesis of available information on changes in groundwater storage and sustainable yield in the Antelope Valley.* (April 24, 2010)

The TSY was evaluated in terms of changes in storage, pumping volumes, and water levels. Choosing a time interval where groundwater elevations are neither increasing nor decreasing suggests that groundwater pumping is in equilibrium with groundwater recharge to the aquifer; i.e., the groundwater pumping equals the TSY for that specific time interval. The groundwater elevations for the 20-year period starting in the late 1970s were an interval of relatively stable groundwater elevations with associated stabilized drawdowns and assumes native non-pumping conditions (i.e., prior to groundwater basin development). Calculations suggest that this interval has annual sustainable yields ranging from 145,000 AF/yr (in the PSR) to 164,000 AF/yr (in revised crop estimates; see table on page 2 of Report #4).

This type of argument and analysis may over- (or under) estimate the TSY if precipitation during the selected interval of time is different than the long-term average annual precipitation. The period 1951 to 2005 has an average annual precipitation of 10.71 inches at the Acton Escondido FC262, 040014 (see Table C.2a in Appendix C of the PSR). In contrast, the average annual precipitation for the period of water stabilization (1979 to 1997) at the Escondido Acton station is estimated to be 12.26 inches or about 14.5 percent greater than the average record annual rainfall. This implies that TSY corrected for the increased annual precipitation is 14 percent less and may range between 125,000 AF/yr (PSR) to 141,000 AF/yr (revised crop estimates).

The change in storage calculation can be misleading and over- or under-estimate the TSY. For example, suppose total pumping in the AVAA is 10,000 AF for 5 years, the change in storage is zero and the hydrographs show stabilization, then the TSY for the

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aquifer is 2,000 AF/yr at relatively shallow pumping water levels! The TSY also depends on the operable, sustainable, recommended, and acceptable basin-wide drawdowns. Large pumping volumes will create deeper stabilized, if achieved, water level elevations and drawdowns. I agree with the recommendations of Report #4 that additional work must be conducted on the storage and TSY calculations.

**Report:** *Updated estimate of agricultural pumping in the Antelope Valley.* (June 8, 2010)

I have no comments on the updated estimates of agricultural pumping in Antelope Valley prepared by the Mediators. In summary, the PSR estimated about 95,800 AF/yr was pumped from the groundwater basin for agricultural use between 2007 and 2009. This report re-evaluated the pumping based on the revised crop water estimates in Report #2 resulting in a value of 115,000 AF/yr pumped between 2007 and 2009. The average of the two estimates is 105,400 AF/yr.

The Mediators requested records for 2007 to 2009 crop acreages from the Agricultural Commissioners of Los Angeles and Kern counties (an independent source of data). The estimated agricultural pumping using these self-reporting documents was about 103,000 AF/yr or within 2.3 percent of the average of the two PSR calculations.

#### **CONCLUSIONS AND SUMMARY**

In summary, the conceptual framework for the hydrogeologic and hydrologic water balance of the AVAA was defined in the PSR. Water balances were constructed for various time intervals for the AVAA to estimate the TSY of the AVAA. The PSR is the basic document that outlines the framework and provides the initial water balance calculations and methodologies. The four TWG documents supplemented the PSR with detailed discussions about key components, elements, parameters, and applied assumptions to the water balance. These assumptions can affect the conclusions from the water balance producing various TSY estimates. The TSY is dynamic and can vary from year to year (decade to decade) depending on the changes to the water balance components and operational groundwater elevations.

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