Bighorn-Desert View Water Agency

Board of Directors
Michael McBride, President
Judy Corl-Lorono, Vice President
David Larson, Director
Terry Burkhart, Director
J. Dennis Staley, Director

Marina D West, PG, General Manager
Lyni Tompkins, Board/Exec. Secretary

A Public Agency

Agency Office
622 S. Jemez Trail
Yucca Valley, CA 92284-1440

760/364-2315 Phone
760/364-3412 Fax

www.bdvwa.org

BOARD OF DIRECTORS' REGULAR MEETING AGENDA

BOARD MEETING OFFICE
1720 N. Cherokee Trail, Landers, CA 92285
Tuesday, February 28, 2012 - 6:00 p.m.

1. **CALL TO ORDER**

2. **PLEDGE OF ALLEGIANCE**

3. **ROLL CALL**

4. **APPROVAL OF AGENDA**

DISCUSSION AND ACTION ITEMS - The Board of Directors and Staff will discuss the following items, and the Board will consider taking action, if so inclined.

The Public is invited to comment on any item on the agenda during discussion of that item.

When giving your public comment, please have your information prepared, if you wish to be identified for the record then please state your name. Due to time constraints, each member of the public will be allotted three-minutes to provide their public comment.

5. **DISSOLVE MORONGO BASIN PIPELINE (MBP) CAPACITY ALLOCATIONS AD HOC COMMITTEE**
   Board to consider dissolving the Morongo Basin Pipeline (MBP) Capacity Allocations Ad Hoc Committee

6. **FORM LAFCO SPHERE OF INFLUENCE AD HOC COMMITTEE**
   Board to consider forming an Ad Hoc Committee for the purpose of attending the LAFCO community meeting and to participate in outreach to the community regarding the benefits of being included in the BDVWA Sphere of Influence

7. **STANDING COMMITTEES, AD HOC COMMITTEE & OTHER MEETING ASSIGNMENTS 2012**
   President, with Board consensus, to consider approving the Standing Committees, Ad Hoc Committee & Other Meeting Assignments 2012, dated 2/28/2011.

8. **BOARD TO DISCUSS A COST OF LIVING ADJUSTMENT (COLA) FOR DIRECTOR'S COMPENSATION**
Board to consider directing staff to initiate the process for increasing the Board of Directors per diem compensation by 5% for fiscal year 2012/2013.

9. **WATER EDUCATION FOUNDATION 29TH ANNUAL EXECUTIVE BRIEFING DECISION POINTS 2012**
Board to consider authorizing attendance for the Water Education Foundation 29th Annual Executive Briefing Decision Points 2012 scheduled for March 27-28, 2012 at an approximate cost of $2020 per Board Member.

10. **RECEIVE AND FILE GROUNDWATER MANAGEMENT PLAN - PIPES AND RECHE GROUNDWATER SUBBASINS - AMES VALLEY GROUNDWATER BASIN SAN BERNARDINO COUNTY CA - FEBRUARY 2012**
Board to consider receiving and filing the Groundwater Management Plan for the Pipes and Reche Groundwater Subbasins of the Ames Valley Groundwater Basin, San Bernardino, CA completed February 2012.

11. **RESOLUTION NO. 12R-XX, A RESOLUTION OF THE BOARD OF DIRECTORS OF THE BIGHORN-DESERT VIEW WATER AGENCY NOMINATING TERRY BURKHART FOR REGULAR SPECIAL DISTRICT MEMBER OF THE LOCAL AGENCY FORMATION COMMISSION**
Board to consider nominating Terry Burkhart for the position of Regular Special District Member on the Local Agency Formation Commission (LAFCO).

12. **AGENCY'S APPROPRIATION LIMIT FOR FISCAL YEAR 2011/2012**
Board to consider directing staff to post the calculations made to determine the Agency's appropriation limit at least 15 days prior to the date the Board considers adoption of the Resolution establishing the Agency's appropriation limit for fiscal year 2011/2012.

13. **DISBURSEMENTS JANUARY 2012**
Recommended Action:
Ratify Check Register (payment of bills) for January 2012.

14. **CONSENT ITEMS** - The following items are expected to be routine and non-controversial and will be acted on by the Board at one time without discussion, unless a member of the Public or member of the Board requests that an item be held for discussion or further action.

    a. Financial Statements January 2012
        1. Balance Sheet
        2. Statement of Revenue and Expense
        3. General Account (Union Bank)
        4. Disbursements
        5. Local Agency Investment Fund Balance Timeline
    b. Consumption & Billing Comparison Report, January 2012
    c. Service Order Report, January 2012
    d. Production Report, January 2012
    e. Special Board Meeting Minutes, January 10, 2012
    f. Regular Board Meeting Minutes, January 24, 2012
    g. Progress Report on the Ames/Reche Recharge Facility Project, Todd Engineers, December 2011 - January 2012
    h. Resolution No. 12R-XX, A Resolution Rescinding Resolution No. 91R-08 Naming a "Designated Person" to Determine the Timeliness and/or Sufficiency of Property/Liability Claims Files Against the Agency

Recommended Action:
Approve as presented (Items a - h):

15. MATTERS REMOVED FROM CONSENT ITEMS

16. PUBLIC COMMENT PERIOD

Any person may address the Board on any matter within the Agency's jurisdiction on items not appearing on this agenda.

When giving your public comment, please have your information prepared, if you wish to be identified for the record then please state your name. Due to time constraints, each member of the public will be allotted three-minutes to provide their public comment. State Law prohibits the Board of Directors from discussing or taking action on items not included on the agenda.

17. VERBAL REPORTS - Including Reports on Courses/Conferences/Meetings.

a. GENERAL MANAGER'S REPORT
b. DIRECTORS' REPORT
c. PRESIDENT'S REPORT

18. FUTURE AGENDA ITEMS REQUESTED BY THE BOARD

19. ADJOURNMENT

In accordance with the requirements of California Government Code Section 54954.2, this agenda has been posted in the main lobby of the Bighorn-Desert View Water Agency, 622 S. Jemez Trail, Yucca Valley, CA not less than 72 hours if prior to a Regular meeting, date and time above; or in accordance with California Government Code Section 54956 this agenda has been posted not less than 24 hours if prior to a Special meeting, date and time above.

As a general rule, agenda reports or other written documentation has been prepared or organized with respect to each item of business listed on the agenda.

Copies of these materials and other discloseable public records in connection with an open session agenda item, are also on file with and available for inspection at the Office of the Agency Secretary, 622 S. Jemez Trail, Yucca Valley, California, during regular business hours, 8:00 A.M. to 4:30 P.M., Monday through Friday. If such writings are distributed to members of the Board of Directors on the day of a Board meeting, the writings will be available at the entrance to the Board of Directors meeting room at the Bighorn-Desert View Water Agency.

Internet: Once uploaded, agenda materials can also be viewed at www.bdvwa.org.

Public Comments: You may wish to submit your comments in writing to assure that you are able to express yourself adequately.

Per Government Code Section 54954.2, any person with a disability who requires a modification or accommodation, including auxiliary aids or services, in order to participate in the meeting, should contact the Board's Secretary at 760-364-2315 during Agency business hours.

BIGHORN DESERT VIEW WATER AGENCY
AGENDA ITEM SUBMITTAL

Meeting Date: February 28, 2012

To: Board of Directors

Budgeted: N/A
Budgeted Amount: N/A

From: Marina D. West

General Counsel Approval: N/A
CEQA Compliance: N/A

Subject: Form Ad Hoc Committee to Participate in a Local Area Formation Commission Sphere of Influence (LAFCO SOI) Community Meeting and Community Outreach

SUMMARY

On February 15, 2012 the Local Area Formation Commission (LAFCO) met with the intent of adopting Resolution No. 3155 reflecting its determinations for the Service Review and Sphere of Influence Update for the Bighorn-Desert View Water Agency (LAFCO 3148).

The Commission did not adopt the Resolution on February 15th but continued the matter to a future date. The Motion for continuance was passed along with a directive that LAFCO staff organize a community meeting to obtain direct input from residents within the County Service Area 70/Zone W-1 (Landers) and the un-served "cross area" near the Landers Landfill regarding their support for, or opposition to, inclusion in the Sphere of Influence.

Staff is requesting the Board consider forming an Ad Hoc Committee to attend the LAFCO community meeting and to participate in outreach to the community regarding the benefits of being included in the BDVWA Sphere of Influence.

RECOMMENDATION

The Board considers taking the following actions:

1. Form an Ad Hoc Committee for the purpose of attending the LAFCO community meeting and to participate in outreach to the community regarding the benefits of being included in the BDVWA Sphere of Influence.

BACKGROUND/ANALYSIS

No further analysis provided

PRIOR RELEVANT BOARD ACTION(S)

none

Standing Committees, Ad Hoc Committees & Other Meeting Assignments 2012

Planning/Legislative/Engineering/Grant & Security Committee
(Meeting Schedule: 3rd Thursday of every other even month 8:45 a.m.)

Chairperson: Vice President Corl-Lorono
Member: Director Burkhart

Financial/Public Relations/Education & Personnel Committee
(Meeting Schedule: 2nd Wednesday of every other odd month 4:00 p.m.)

Chairperson: Director Larson
Member: President McBride

Morongo Basin Pipeline Commission Representatives

Member: Vice President Corl-Lorono
Alternate: Director Burkhart

Mojave Water Agency Technical Advisory Committee Representatives

Member: Director Staley
Alternate: Director Burkhart

Alliance for Water Awareness and Conservation (AWAC) Representatives

Member: Vice President Corl-Lorono
Alternate: President McBride

Homestead Valley Community Council
(Normally meets 3rd Monday of each month at 3:00 p.m.)

Member: Director Larson
Alternate: Director Staley

Ames/Means Ad Hoc Committee

Chairperson: President McBride
Member: Vice President Corl-Lorono

LAFCO Sphere of Influence Ad Hoc Committee (If approved on February 28, 2012 Board of Directors Meeting)

Chairperson: Vice President Corl-Lorono
Member: Director Staley

BIGHORN DESERT VIEW WATER AGENCY
AGENDA ITEM SUBMITTAL

Meeting Date: February 28, 2012

To: Board of Directors

Budgeted: N/A
Budgeted Amount: N/A

From: Marina D. West

General Counsel Approval: N/A
CEQA Compliance: N/A

Subject: Preparation for a Cost of Living Adjustment to Board of Directors Compensation by Ordinance

SUMMARY

The Finance/Public Relations/Education/Personnel Standing Committee met on January 11, 2012 and agreed that the Board should pursue the allowable 5% cost of living adjustment for the Board of Directors per diem. The Committee then recommended that staff to bring the issue to the full Board for further consideration.

RECOMMENDATION

The Board considers taking the following actions:

1. Direct staff to initiate the process for increasing the Board of Directors per diem compensation by 5% for fiscal year 2012/13.

BACKGROUND/ANALYSIS

The Finance/Public Relations/Education/Personnel Standing Committee met on January 11, 2012 and agreed that the Board should pursue a 5% cost of living adjustment for the Board of Directors per diem. The Committee then recommended that staff to bring the issue to the full Board for further consideration to proceed.

The process of increasing the Board of Directors per diem is done by Ordinance in accordance with Section 20200 - 20207 of the California Water Code and Section 6066 of the California Government Code. The respective codes are attached for reference.

In summary, the Board of Directors can increase their per diem only by Ordinance and if increasing the per diem above one hundred dollars ($100) per day, the increase may not exceed an amount equal to 5 percent. If the Board requests the full 5 percent adjustment then per diems would effectively increase to one hundred and five dollars ($105) per day.

The Committee also recognized that the Directors no longer receive the full amount of their $100 per diem since they are now compensated through payroll (W-2's are issued annually) rather than through accounts payable (Form 1099's were issued annually). This change has effectively reduced compensation below $100 per day due to automatic deductions for Social Security and Medicare for which some directors may not otherwise be obligated to pay for under the previous compensation method.

Staff recommends that if the Board desires to increase the per diem then the process should be initiated now so that the effective date would be in concert with the adoption of the fiscal year 2012/13 budget (our calendar year).

PRIOR RELEVANT BOARD ACTION(S)

10/28/2010 Ordinance No. 10O-02 Providing for compensation of the Board of Directors and establishing procedures related thereto (increased per diem for committee meetings from $50 to $100 and increased allowable compensation days from 6 to 10 per month)

6/15/2010 Resolution No. 10R-02 A resolution establishing a policy for compensation for performance of official duties and reimbursement of actual and necessary expenses ("Official Duties Policy").

6/15/2010 **Ordinance No. 10O-01** Providing for (only) compensation of the Board of Directors and establishing procedures related thereto (excluding reimbursement of expenses guidelines for Directors).

7/5/2005 Policy No. 05P-01 Policy statement defining the criteria for reimbursement of expenses.

5/24/2005 Ordinance No. 05O-01 Fixing compensation and setting reimbursement of expenses guidelines for the Directors of the Bighorn-Desert View Water Agency.

WATER CODE
SECTION 20200-20207

20200. As used in this chapter, "water district" means any district or other political subdivision, other than a city or county, a primary function of which is the irrigation, reclamation, or drainage of land or the diversion, storage, management, or distribution of water primarily for domestic, municipal, agricultural, industrial, recreation, fish and wildlife enhancement, flood control, or power production purposes. "Water districts" include, but are not limited to, irrigation districts, county water districts, California water districts, water storage districts, reclamation districts, county waterworks districts, drainage districts, water replenishment districts, levee districts, municipal water districts, water conservation districts, community services districts, water management districts, flood control districts, flood control and floodwater conservation districts, flood control and water conservation districts, water management agencies, water agencies, and public utility districts formed pursuant to Division 7 (commencing with Section 15501) of the Public Utilities Code.

20201. Notwithstanding any other provision of law, the governing board of any water district may, by ordinance adopted pursuant to this chapter, provide compensation to members of the governing board, unless any compensation is prohibited by its principal act, in an amount not to exceed one hundred dollars ($100) per day for each day's attendance at meetings of the board, or for each day's service rendered as a member of the board by request of the board, and may, by ordinance adopted pursuant to this chapter, in accordance with Section 20202, increase the compensation received by members of the governing board above the amount of one hundred dollars ($100) per day.

It is the intent of the Legislature that any future increase in compensation received by members of the governing board of a water district be authorized by an ordinance adopted pursuant to this chapter and not by an act of the Legislature.

For purposes of this section, the determination of whether a director's activities on any specific day are compensable shall be made pursuant to Article 2.3 (commencing with Section 53232) of Chapter 2 of Part 1 of Division 2 of Title 5 of the Government Code.

20201.5. Reimbursement for expenses of members of a governing board of a water district is subject to Sections 53232.2 and 53232.3 of the Government Code.

20202. In any ordinance adopted pursuant to this chapter to increase the amount of compensation which may be received by members of the governing board of a water district above the amount of one hundred dollars ($100) per day, the increase may not exceed an amount equal to 5 percent, for each calendar year following the operative date of the last adjustment, of the compensation which is received when the ordinance is adopted.

No ordinance adopted pursuant to this chapter shall authorize

compensation for more than a total of 10 days in any calendar month.

20203. Any water district described in Section 20201 is authorized to adopt ordinances pursuant to this chapter. No ordinance shall be adopted pursuant to this chapter except following a public hearing. Notice of the hearing shall be published in a newspaper of general circulation pursuant to Section 6066 of the Government Code.

20204. An ordinance adopted pursuant to this chapter shall become effective 60 days from the date of its final passage. The voters of any water district shall have the right, as provided in this chapter, to petition for referendum on any ordinance adopted pursuant to this chapter.

20205. If a petition protesting against the adoption of the ordinance is presented to the governing board of the water district prior to the effective date of the ordinance, the ordinance shall be suspended and the governing board shall reconsider the ordinance.

If the number of votes cast for all candidates for Governor at the last gubernatorial election within the boundaries of the water district exceeds 500,000, the ordinance is subject to referendum upon presentation of a petition bearing signatures of at least 5 percent of the entire vote cast within the boundaries of the water district for all candidates for Governor at the last gubernatorial election. If the number of votes cast for all candidates for Governor at the last gubernatorial election within the boundaries of the water district is less than 500,000, the ordinance is subject to referendum upon presentation of a petition bearing signatures of at least 10 percent of the entire vote cast within the boundaries of the water district for all candidates for Governor at the last gubernatorial election.

20206. If the governing board does not entirely repeal the ordinance against which a petition is filed, the governing board shall submit the ordinance to the voters either at a regular election or a special election called for the purpose. The ordinance shall not become effective unless and until a majority of the votes cast at the election are cast in favor of it. If the ordinance is not approved by the voters, no new ordinance may be adopted by the governing board pursuant to this chapter for at least one year following the date of the election.

20207. Except as otherwise provided in this chapter, the provisions of the Elections Code applicable to the right of referendum on legislative acts of districts shall govern the procedure on ordinances against which a petition is filed.

GOVERNMENT CODE SECTION 6060-6066

6060. Whenever any law provides that publication of notice shall be made pursuant to a designated section of this article, such notice shall be published in a newspaper of general circulation for the period prescribed, the number of times, and in the manner provided in that section. As used in this article, "notice" includes official advertising, resolutions, orders, or other matter of any nature whatsoever that are required by law to be published in a newspaper of general circulation.

6061. Publication of notice pursuant to this section shall be for one time.

6061.3. Publication of notice pursuant to this section shall be for three successive times.

6062. Publication of notice pursuant to this section shall be for 10 days. The period of notice commences upon the first day of publication and terminates at the end of the tenth day, including therein the first day. Publication shall be made on each day on which the newspaper is published during the period.

6062a. Publication of notice pursuant to this section shall be for 10 days in a newspaper regularly published once a week or oftener. Two publications, with at least five days intervening between the dates of first and last publication not counting such publication dates, are sufficient. The period of notice commences upon the first day of publication and terminates at the end of the tenth day, including therein the first day.

6063. Publication of notice pursuant to this section shall be once a week for three successive weeks. Three publications in a newspaper regularly published once a week or oftener, with at least five days intervening between the respective publication dates not counting such publication dates, are sufficient. The period of notice commences upon the first day of publication and terminates at the end of the twenty-first day, including therein the first day.

6063a. Publication of notice pursuant to this section shall be for at least 10 days. Three publications in a newspaper published once a week or oftener, with at least five days intervening between the first and last publication dates not counting such publication dates, are sufficient. The period of notice commences upon the first day of publication and terminates either at the end of the day of the third publication or at the end of the tenth day, including therein the

first day, whichever period is longer.

6064. Publication of notice pursuant to this section shall be once a week for four successive weeks. Four publications in a newspaper regularly published once a week or oftener, with at least five days intervening between the respective publication dates not counting such publication dates, are sufficient. The period of notice commences with the first day of publication and terminates at the end of the twenty-eighth day, including therein the first day.

6065. Publication of notice pursuant to this section shall be once a week for eight successive weeks. Eight publications in a newspaper regularly published once a week or oftener, with at least five days intervening between the respective publication dates not counting such publication dates, are sufficient. The period of notice commences upon the first day of publication and terminates at the end of the fifty-sixth day, including therein the first day.

6066. Publication of notice pursuant to this section shall be once a week for two successive weeks. Two publications in a newspaper published once a week or oftener, with at least five days intervening between the respective publication dates not counting such publication dates, are sufficient. The period of notice commences upon the first day of publication and terminates at the end of the fourteenth day, including therein the first day.

WATER EDUCATION FOUNDATION

29th Annual

EXECUTIVE BRIEFING

Decision Points 2012

March 27-28, 2012

Doubletree Hotel • 2001 Point West Way • Sacramento, CA

WATER EDUCATION FOUNDATION
717 K Street, Suite 317
Sacramento, CA 95814
www.waterducation.org
www.aquafornia.com

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Register Online at
www.watereducation.org/conferences

A briefing for water district managers and board members, state and federal agency officials, city and county government officials, farmers, environmentalists, attorneys, consultants, engineers, business executives and public interest groups.

At this day-and-a-half event, top policy makers and leading agricultural, environmental and urban water stakeholders will provide the latest information on:

Delta Plans and Programs: Making Decisions
The Water Bond and the Ballot
The Colorado River Agreement and the Courts: What Will It Mean for California?
Water Rates on the Rise
Water and Energy: Managing the Connection
San Joaquin River Restoration: Staying the Course?

Time and Place
Tuesday, March 27, 8:45 a.m. – 4:30 p.m. (Registration begins at 8 a.m.) Wednesday, March 28, 8:30 a.m. – 12:30 p.m. at the Doubletree Hotel, 2001 Point West Way, Sacramento.

Registration
General registration for both days is $250 for Foundation major contributors ($100 or more annual contribution); $350 for non-contributors. Thursday-only: $175 for major contributors; $225 for non-contributors. Fee includes coffee breaks both days, lunch and a hosted reception on March 27.

Hotel Reservations
We have secured a limited number of rooms at the Doubletree Hotel at the special rate of $84, plus tax, per night. Room reservations can be made by contacting the Doubletree at 916-929-8855. Be sure to say you are attending the Water Education Foundation briefing.

Cancellation policy
Full refunds (less a $25 administration fee) will be given if written notice is received by 5 p.m. March 19. Substitutions may be made at any time.

Call the Foundation, 916-444-6240, for complete information on this exciting event or visit our web site, www.watereducation.org/conferences

2012 Executive Briefing

Registration

Online registration is available at www.watereducation.org/conferences
Faxed reservations will be accepted with purchase orders or credit cards.

Name(s) _____
Job Title(s) _____
Organization _____
Address _____
Email _____
City _____ State _____ Zip _____
Phone _____

Enclosed is my registration fee:
- ❑ $250 (WEF major contributor of $100 or more)
- ❑ $350 (Non-contributor)
- ❑ $175 (Thursday-only, WEF major contributor)
- ❑ $225 (Thursday-only, WEF non-contributor)

Lunch choice: ❑ Beef ❑ Chicken ❑ Vegetarian

Purchase order # _____

❑ Mastercard ❑ Visa ❑ American Express

Credit card number _____ Exp. date _____/_____

Signature _____
(must be signed to process credit card order)

Return form with payment to: Water Education Foundation, 717 K Street, Suite. 317, Sacramento, CA 95814
FAX: 916/448-7699 or register online at www.watereducation.org/conferences

BIGHORN DESERT VIEW WATER AGENCY
AGENDA ITEM SUBMITTAL

Meeting Date: February 28, 2012

To: Board of Directors

Budgeted: N/A
Budgeted Amount: N/A

From: Marina D. West

General Counsel Approval: N/A
CEQA Compliance: N/A

Subject: Groundwater Management Plan for the Pipes and Reche Groundwater Subbasins of the Ames Valley Groundwater Basin, San Bernardino, CA completed February 2012

SUMMARY

Todd Engineers has completed the Groundwater Management Plan for the Pipes and Reche Groundwater Subbasins of the Ames Valley Groundwater Basin, San Bernardino, CA completed February 2012.

This report satisfies the Agency's commitment to the EPA State and Tribal Assistance Grant (EPA STAG) Task 8 and is the technical basis for the Ames/Reche Groundwater Storage and Recovery Program and Management Agreement approved by the Board in January 2012.

RECOMMENDATION

The Board considers taking the following actions:

1. Receive and file the Groundwater Management Plan for the Pipes and Reche Groundwater Subbasins of the Ames Valley Groundwater Basin, San Bernardino, CA completed February 2012.

BACKGROUND/ANALYSIS

Todd Engineers has completed the Groundwater Management Plan for the Pipes and Reche Groundwater Subbasins of the Ames Valley Groundwater Basin, San Bernardino, CA completed February 2012 (GWMP).

This report satisfies the Agency's commitment to the EPA State and Tribal Assistance Grant (EPA STAG) Task 8 and is the technical basis for the Ames/Reche Groundwater Storage and Recovery Program and Management Agreement approved by the Board in January 2012.

Based on the previous and ongoing work by BDVWA and others, BDVWA developed a scope of work for the preparation of the GWMP including the following series of tasks listed below:

- Define the Study Area and a Study Period
- Compile/Update Hydrologic and Hydrogeologic Data
- Assess the State of the Management Area Subbasins
- Develop Groundwater Subbasin Management Objectives

- Prioritize and Evaluate Management Strategies
- Prepare an Implementation Plan

The Pipes and Reche subbasins form a significant portion of the Department of Water Resources (DWR) Ames Valley Basin. To assess the state of the Pipes and Reche subbasins, hydrologic and hydrogeologic data used in the 2007 Conceptual Model Study relevant to the Pipes and Reche subbasins and contributing watershed areas were updated through 2009 and re-evaluated. A Study Area and Study Period were selected to aid in data collection and database updates. To support the development of groundwater management objectives and evaluation of specific strategies, the United States Geological Survey MODFLOW model was developed. In addition to evaluating hydraulic impacts associated with proposed operation of the Reche Groundwater Recharge Project, the objectives of the model were to refine preliminary estimates of sustainable (perennial) yield based on a detailed analysis over an appropriate Study Period. The water budget and sustainable yield was estimated for the combined Pipes and Reche subbasins. These evaluations provided the basis for appropriate management objectives and strategies to effectively manage the subbasins.

The GWMP generally follows the components listed above and includes the following major elements:

- Data Compilation and Management
- State of the Groundwater Subbasins
- Basin Management Objectives (BMOs)
- Basin Management Strategies
- Implementation Plan

The GWMP summarizes the state of the groundwater subbasins and describes the potential for implementing a managed aquifer recharge (MAR) project using State Water Project (SWP) water. Together, GWMP and New Agreement lays out the framework for the management of the Pipes and Reche subbasins, providing management decision points and actions (e.g., pumping limits, recharge operation guidelines, banking agreements, monitoring requirements and responsibilities, and specific thresholds for action).

Staff recommends that the Board receive and file the Groundwater Management Plan for the Pipes and Reche Groundwater Subbasins of the Ames Valley Groundwater Basin, San Bernardino, CA completed February 2012.

PRIOR RELEVANT BOARD ACTION(S)

1/10/2012 Motion No. 12-004 Motion to approve the Ames/Reche Groundwater Storage and Recovery Program and Management Agreement.

11/30/2011 Motion No. 11-065 Authorize General Manager to execute Change Order No. 4 with Todd Engineers for Water Infrastructure Restoration Program Project Management, Permitting, Hydrogeologic Feasibility Study and Groundwater Management Plan Project Services in the Amount of $12,300; and extend contract completion date to March 30, 2012.

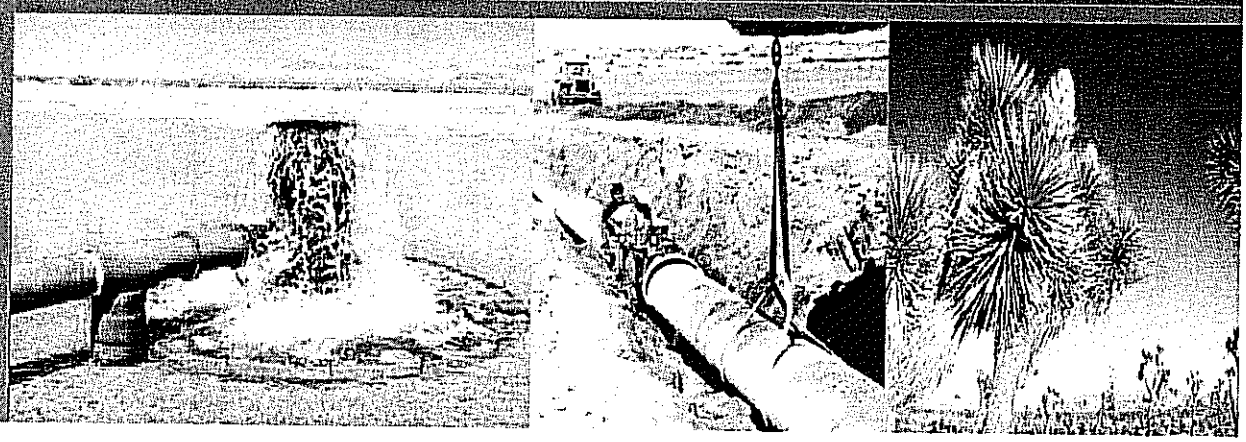
2/8/2011 Motion No. 11-006 Approve Change Order No. 3 to Todd Engineers for project management, permitting, hydrologic feasibility study and groundwater management plan project extending the contract completion date to November 30, 2011 only.
12/28/2010 Motion No. 10-080 Approved the Water Infrastructure Restoration Program/EPA STAG Grant: Corrections to Todd Engineers Change Order Nos. 1 and 2.
10/25/2010 Motion No. 10-071 Board authorization of Change Order No. 2 to Todd Engineers in the amount of $63,900 and Change Order No. 1 to Bucknam & Assoc. in the amount of $20,500 for the EPA STAG grant Ames/Reche Recharge Project
6/29/2010 Resolution No. 10R-04 Approving the Water Infrastructure Restoration Program: Ames/Reche Groundwater Storage and Recovery Program and Pipeline Installation/Replacement Program pursuant to California Environmental Quality Act (CEQA) and state of California CEQA guidelines.
6/15/2010 BOD Public Hearing: Notice of Intent to Adopt a Mitigated Negative Declaration (MND) Pertaining to the Water Infrastructure Restoration Program: Ames/Reche Groundwater Storage and Recovery Program; and Pipeline Installation/Replacement Project
1/26/2010 Board Authorization of Change Order No. 1 to Todd Engineers for an amount not to exceed $53,340 for the Project Management, Permitting, Hydrologic Feasibility Study and Groundwater Management Plan for the Ames/Reche Project.
11/17/2009 Motion to authorize staff to award Professional Services Contract to Todd Engineers/Kennedy/Jenks Consultants for Project Management, Permitting, Hydrologic Feasibility Study and Groundwater Management Plan for the Ames/Means Reche Basin Groundwater Recharge Facility in the amount of $408,463.45.
8/25/2009 Motion to authorize staff to execute Memorandum of Understanding by and between Mojave Water Agency and Bighorn Desert View Water Agency regarding Project Management of Phases for Phase I and II Planning and Design of the Ames-Means Recharge Project (aka Reche Recharge Facility) and accepting financial participation from Mojave Water Agency in the amount of $279,495.
6/16/2008 Motion to authorize staff to seek formal partnerships with interested parties to participate financially in the Agency's EPA Grant Program – Water Infrastructure Restoration Program CEQA/NEPA documentation.
3/28/2006 06R-04 Resolution authorizing General Manager to enter Grant Agreement of $477,000.

Todd Engineers
Alameda, California

Bighorn-Desert View Water Agency

Groundwater Management Plan
Pipes and Reche Groundwater Subbasins
Ames Valley Groundwater Basin
San Bernardino County, California

February 2012



Groundwater Management Plan
Pipes and Reche Groundwater Subbasins of the Ames Valley Groundwater Basin
San Bernardino County, California

February 2012

Prepared for:

Bighorn-Desert View Water Agency

622 South Jemez Trail

Yucca Valley, California 92284

Prepared by:

Todd Engineers

2490 Mariner Square Loop, Suite 215

Alameda, California 94501

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1. INTRODUCTION

The Bighorn-Desert View Water Agency (BDVWA) operates within the boundaries of the Mojave Water Agency (MWA) in the western Mojave Desert of San Bernardino County (also referred to as the High Desert). Groundwater is the primary source of water supply in the region, but increasing water demand is expected to stress limited groundwater resources in the future. BDVWA recognizes the need to manage groundwater within its jurisdiction to secure a safe, reliable, and sustainable water supply for current and future users.

The Pipes and Reche subbasins represent two of seventeen subbasins that compose the greater U.S. Geological Survey (USGS) Morongo Groundwater Basin and form a large portion of the California Department of Water Resources (DWR) Ames Valley Groundwater Basin (**Figure 1**). Recent studies by BDVWA and others have shown that beginning in the early 1990s increased production and export of water from the Pipes and Reche subbasins resulted in local overdraft conditions and significant groundwater level declines. Although groundwater levels have recently stabilized due to decreased production, water demand projections indicate that enhanced recharge of imported State Water Project (SWP) water may be needed to increase the reliability of the local groundwater supply.

Nowhere is sustainable groundwater management more important than the Pipes and Reche subbasins, which are relied upon by three municipal water purveyors, including BDVWA, Hi-Desert Water District (HDWD), and San Bernardino County Service Area 70 Zone W-1 (W-1/Landers), as well as private producers (**Figure 2**). San Bernardino County Service Area 70 Zone W-4 (W-4/Pioneertown), is located in the recharge catchment area east of the main Pipes subbasin (**Figure 1**), and within the groundwater management area; it is included in this GWMP.

In order to balance the protection of groundwater resources with the interests and rights of local stakeholders, BDVWA has prepared this Groundwater Management Plan (GWMP). The GWMP evaluates current groundwater conditions in the Pipes and Reche subbasins, develops appropriate groundwater management objectives, and prioritizes and implements strategies to address concerns related to groundwater recharge, storage, production, and quality. The GWMP considers and supports existing and ongoing groundwater management activities. These include negotiations among BDVWA, HDWD, W-1/Landers and W-4/Pioneertown, and MWA to update the Ames Valley Water Basin Agreement, an agreement effective January 10, 1991 between BDVWA and HDWD that became a Judgment on June 3, 1991 (Riverside County Superior Court Case No. 211504). This 1991 agreement represents the first attempt to establish production limits and other groundwater management criteria in the Pipes and Reche subbasins. An updated agreement, the Ames/Reche Groundwater Storage and Recovery Program and Management Agreement, will be finalized and approved by all of the above parties in February 2012.

The GWMP follows guidelines set forth in Assembly Bill (AB) 3030, which was promulgated in 1992 and allows local agencies to prepare and adopt GWMPs (California Water Code Sections 10750 through 10756). The bill was amended in 2002 by Senate Bill (SB) 1938, which provided additional GWMP requirements.

1.1. GWMP Goals

The goals of the GWMP are to:

- Operate the Pipes and Reche subbasins in a sustainable manner for beneficial uses
- Increase the reliability of the local water supply for all subbasin users
- Support the updated Ames Valley Water Basin Agreement

To achieve this goal, BDVWA recognizes the importance of characterizing water supply and water demand conditions in the subbasins and identifying specific issues to be addressed through coordinated planning and cooperative management.

1.2. Supporting Groundwater Management Activities

In support of the preparation of this GWMP, BDVWA has recently completed and is currently coordinating several groundwater-related activities. These activities are referenced throughout the GWMP and described in more detail below.

1.2.1. Ames Valley Basin Water Agreement and Stipulated Judgment

In 1991, BDVWA and HDWD entered into a Stipulated Judgment concerning the proposed construction and operation of a HDWD production well (HDWD 24) on land owned by the Bureau of Land Management (BLM) in the Reche Subbasin (Township 2N/Range 5E, Section 24). The Judgment embodies the terms and conditions outlined in the Ames Valley Water Basin Agreement (hereafter referred to as the Original Agreement), which established annual production limits for HDWD 24, rules concerning the export of water produced from HDWD 24, groundwater monitoring and reporting requirements, and criteria warranting environmental review. The Original Agreement represents the first step towards interagency groundwater management in the region.

The Original Agreement is focused primarily on the operation of HDWD 24; it does not recognize parties outside of BDVWA and HDWD. Accordingly, BDVWA has conducted and finalized negotiations with HDWD, CSA 70 (W-1 and W-4), and MWA to restructure the Original Agreement so that it more effectively addresses the current and future groundwater management issues in the Pipes and Reche subbasins. The updated Agreement will be finalized and approved in February 2012 and embodied in a Stipulation for Amended and Restated Judgment and will address the current and future water rights of all major water

purveyors in the Pipes and Reche Subbasin, define administrative rules for the future recharge and storage of imported SWP water, and delineate administrative, financial, and legal obligations of each water agency subject to the new Agreement. Together with the GWMP, the new Agreement will form the necessary institutional framework to guide future management of the Pipes and Reche subbasins.

1.2.2. 2007 Basin Conceptual Model and Assessment of Water Supply and Demand for Ames Valley Basin

In 2007, BDVWA and MWA completed a comprehensive evaluation of hydrogeologic conditions and an assessment of projected water supply and demand for the Ames Valley Basin and two other local basins. This study is documented in the report *Basin Conceptual Model and Assessment of Water Supply and Demand for the Ames Valley, Johnson Valley, and Means Valley Groundwater Basins* (Kennedy/Jenks/Todd LLC, 2007) herein referred to as the BCM Study. A key finding from the BCM Study was the identification of the need for imported SWP water to address historical groundwater level declines in the Pipes and Reche subbasins. The BCM Study also identified a favorable location for a managed aquifer recharge (MAR) project within a dry alluvial wash in the Reche Subbasin close to existing SWP water infrastructure (**Figures 1 and 2**). These findings provided the technical foundation for identifying appropriate groundwater management objectives and strategies for the area.

1.2.3. BDVWA Water System Master Plan, Water Infrastructure Restoration Program, and Recharge Feasibility Study

Concurrent with the completion of the BCM Study, BDVWA finalized its Water System Master Plan (WSMP) (Don Howard Engineering, 2007), which identified deficiencies in BDVWA's then-current water infrastructure. Infrastructure deficiencies were subsequently addressed in BDVWA's Water Infrastructure Restoration Program (WIRP), which identified 11 system improvement projects to be implemented over the next 20 years. One WIRP project, the Reche Groundwater Recharge Project, involves the development and operation of recharge spreading grounds in the Reche Subbasin at the location recommended in the BCM Study. The spreading grounds would be used to recharge imported SWP water to increase the reliability of water supply for all subbasin users.

In 2009, BDVWA procured federal assistance through the State and Tribal Assistance Grant Funding Program of the United States Environmental Protection Agency (USEPA) and matching funds from MWA to implement several of the projects identified in the WIRP, including the following work in support of the Reche Groundwater Recharge Project:

- Complete formal environmental review of the MAR project
- Perform a technical study to evaluate the feasibility of the MAR project

- Develop a numerical groundwater flow model to support a feasibility study and GWMP
- Prepare a GWMP
- Restructure the 1991 Ames Valley Water Agreement to address current and future management issues

In 2010, BDVWA completed the Initial Study (Mitigated Negative Declaration) of the WIRP in compliance with California Environmental Quality Act (CEQA) guidelines (BDVWA, May 2010). The Initial Study analyzed potential environmental impacts associated with implementation of proposed system improvements over the first five years of a 20-year period. With respect to the Reche Groundwater Recharge Project, potential groundwater quality impacts from the recharge of SWP water were evaluated. The Initial Study found that water quality impacts from recharge would be insignificant but recommended the installation of monitoring wells as well as a survey of septic tanks within a 1-mile radius of the spreading grounds to assess potential nitrate loading during recharge.

In concert with the Initial Study, BDVWA recently completed a technical feasibility evaluation of the Reche Groundwater Recharge Project (Todd Engineers, 2011). The *Reche Spreading Grounds Recharge Feasibility Study* involved a field investigation, which included the drilling and installation of two dedicated monitoring wells (BDVWA MW1 and MW2) in the vicinity of the proposed spreading grounds, laboratory permeability analysis of vadose zone samples collected during drilling, aquifer testing of HDWD 24, and groundwater quality sampling. A MODFLOW model was also developed to evaluate the impacts of enhanced recharge at the proposed spreading grounds (monitoring well locations and the MODFLOW model boundary are shown on **Figure 3**). Model results indicated that estimated water table mounding from recharge of SWP water can be easily accommodated by the available storage beneath the spreading grounds. Additionally, estimated travel times and flowpaths of recharged water would allow for efficient recovery of recharged water by existing wells in the Reche Subbasin (primarily by HDWD 24) with potential for further optimization by installing additional production wells downgradient of the spreading grounds. The MODFLOW model was also developed to evaluate and refine perennial yield estimates reported in the BCM Study in support of the New Agreement and GWMP.

1.3. Scope of Work

Based on the previous and ongoing work by BDVWA and others, BDVWA developed a scope of work for the preparation of the GWMP including the following series of tasks:

- Define the Study Area and a Study Period
- Compile/Update Hydrologic and Hydrogeologic Data
- Assess the State of the Management Area Subbasins

- Develop Groundwater Subbasin Management Objectives
- Prioritize and Evaluate Management Strategies
- Prepare an Implementation Plan

The Pipes and Reche subbasins form a significant portion of the DWR Ames Valley Basin. To assess the state of the Pipes and Reche subbasins, hydrologic and hydrogeologic data used in the 2007 Study relevant to the Pipes and Reche subbasins and contributing watershed areas were updated through 2009 and re-evaluated. A Study Area and Study Period were selected to aid in data collection and database updates. To support the development of groundwater management objectives and evaluation of specific strategies, the MODFLOW model was developed. In addition to evaluating hydraulic impacts associated with proposed operation of the Reche Groundwater Recharge Project, an objective of the model was to refine preliminary estimates of sustainable (perennial) yield based on a detailed analysis over an appropriate Study Period. The water budget and sustainable yield were estimated for the combined Pipes and Reche subbasins. These evaluations provided the basis for appropriate management objectives and strategies to effectively manage the subbasins.

1.4. GWMP Organization and Preparation

The GWMP generally follows the components listed above and includes the following major elements:

- Data Compilation and Management
- State of the Groundwater Subbasins
- Basin Management Objectives (BMOs)
- Basin Management Strategies
- Implementation Plan

The GWMP summarizes the state of the groundwater subbasins and describes the potential for implementing a MAR project using SWP water. Together, the GWMP and New Agreement provide the framework for management of the Pipes and Reche subbasins, including management decision points and actions (e.g., pumping limits, recharge operation guidelines, banking agreements, monitoring requirements and responsibilities, and specific thresholds for action).

1.5. Public Outreach

The GWMP represents one of eleven projects included in the WIRP. In order to encourage public participation and keep local agencies informed of the GWMP, a Notice of Intent to Adopt the Initial Study (Mitigated Negative Declaration) prepared for the WIRP was published on May

1, 2010. The public was given the opportunity to review and provide written comments on the Initial Study from May 10, 2010 to June 8, 2010. In addition, a public hearing was held on June 15, 2010 at the BDVWA Board of Directors meeting (see Appendix A). In addition to fulfillment of the CEQA requirements, BDVWA and its consultants have coordinated and participated in numerous meetings with HDWD, CSA 70, and MWA to discuss and refine the management strategies evaluated in this GWMP and incorporated in the New Agreement.

2. DATA SOURCES AND MANAGEMENT

To support the development of the GWMP, relevant hydrologic and hydrogeologic data were compiled for the groundwater subbasins and contributing watersheds. To guide the data collection effort and focus management activities where they are most needed, a Study Area and Study Period were defined early in the process. Because the Study Area represents a portion of the Ames Valley Basin evaluated in the 2007 BCM Study, most of the data collection process occurred in 2006. Relevant data, including groundwater production, levels, quality, and usage data for the Study Area, were updated to 2010 to support preparation of the GWMP.

2.1. Study Area

The Study Area for the GWMP is defined by the USGS-delineated Pipes and Reche subbasins (Stamos et al., 2004) and their contributing watershed areas (**Table 1** and **Figure 4**). The Pipes and Reche subbasins, along with portions of the Giant Rock and Emerson subbasins and the area historically defined as Pioneertown (Lewis, 1972), compose the Ames Valley Basin as adopted by DWR in Bulletin 118, California's Groundwater (DWR, 2003). Because DWR does not further divide the Ames Valley Basin, the USGS subbasin names and boundaries have been used to identify specific areas in the overall basin to be managed. The Study Area is larger than the subbasins of interest so that inflows from contributing watershed areas can be incorporated and the subbasins can be evaluated in a more regional context. The Study Area covers 86,738 acres (136 square miles [mi^2]) and includes portions of townships/ranges 1N/5E, 1N/6E, 2N/5E, 2N/6E, and 3N/5E. The Study Area includes the two groundwater subbasins of interest, which together cover 29,300 acres (46 mi^2), and a contributing watershed area of 57,438 acres (90 mi^2).

2.1.1. Subbasin Boundaries

The Study Area is located in the Mojave structural block of the Eastern California Shear Zone, a region of concentrated seismic activity that stretches north-northeast from the San Andreas Fault across the Mojave Desert and into the Owens Valley. The Mojave structural block is dominated by extensive northwest-trending faults that appear to terminate regionally near the Garlock Fault outside of the Study area. **Figure 5** shows the location of major faults in the Study Area, illustrating the northwest trends. As shown in the figure, many of the faults coincide with groundwater basin and subbasin boundaries, because displacements along the faults have create low permeability zones that often impede groundwater flow. Some of the boundaries of the Pipes and Reche subbasins are represented by such faults.

As shown on **Figure 5**, the Pipes and Reche subbasins are separated from neighboring subbasins by geologic faults, including the Kickapoo Fault to the north and Homestead Valley

Fault to the east. A groundwater divide forms the southern boundary of each subbasin, while bedrock outcrops of the San Bernardino Mountains represent the western boundary of the Pipes Subbasin. The Pipes and Reche subbasins are themselves separated by two faults. From Pipes Wash to the south, the two subbasins are separated by the Pipes Barrier, a geologic fault inferred by groundwater level differences across the fault. North of Pipes Wash, the two subbasins are separated by the main trace of the Johnson Valley Fault. The Homestead Valley Fault forms the boundary between the Reche Subbasin and Giant Rock Subbasin to the east. These faults represent partial barriers to groundwater flow. A groundwater divide forms the boundary between the Study Area subbasins and Copper Mountain Subbasin to the south.

2.1.2. Contributing Watersheds

The relatively high precipitation in the upper reaches of the San Bernardino Mountain watersheds generates runoff that is funneled into drainageways and flows downstream to the Study Area subbasins generally in the form of subsurface inflow. This represents the primary source of recharge to the Study Area subbasins. Due to the relatively low amount of rainfall on the valley floor (4 inches per year on average), recharge from areal precipitation on the valley floor is considered negligible. However, flash flood events may result in some additional recharge to the Pipes and Reche groundwater subbasins. As shown on **Figure 4** and **Table 2**, the total contributing watershed area can be divided into three major catchments, totaling 57,438 acres. The largest catchment is for Pipes Wash (35,423 acres), followed by Whalen's Wash (13,434 acres) and then Ruby Mountain Wash (8,581 acres).

2.2. Study Period

The Study Area is characterized by low precipitation and high evaporation, both of which limit natural recharge to groundwater. Average annual rainfall is indicated by contours of equal rainfall, or isohyets, shown on **Figure 4**. The isohyetal map was provided by MWA (James, 1992) and represents annual rainfall data from 1960 to 1991. More rainfall data from 1992 through 2010 measured at the same precipitation station are very close to the 1960 to 1991 precipitation average, and indicate that the that the historical isohyets are representative of recent conditions. An additional isohyetal map created by the USDA and NOAA using PRISM (Parameter-elevation Regressions on Independent Slope Model) was also evaluated. However, comparison of isohyets to local rain gage data indicated that the PRISM map overestimates rainfall in the Study Area contributing watersheds As shown by the isohyets, rainfall ranges from almost 16 inches per year in the upper elevations of the watersheds to between 4 and 6 inches per year across most of the Study Area.

To further evaluate rainfall in the upper reaches of the contributing watershed, rainfall data in the San Bernardino Mountains were reviewed. The closest station with a long and reliable

record (1960 to present) is at Big Bear Lake (National Weather Service [NWS] Station 040741). Data from this station provided information on applicable wet and dry periods for the Study Area.

Review of available reports and data was used to define a Study Period. To examine hydrologic periods and identify trends, rainfall data were plotted using the accumulated departure method. **Figure 6** shows the cumulative departure curve for the Big Bear Lake station. The figure depicts alternating wet, average, and dry periods of various durations, which are indicated by the direction and degree of slope on the plot. An upward slope indicates a wet period, while a downward slope indicates a dry period. A review of the rainfall data for the Big Bear Lake station indicates that over the past 20 years, the Study Area has experienced both wet and dry cycles with rainfall slightly below the long-term average. For the GWMP, the 15-year Study Period from Water Year (WY) 1994-95 through WY 2008-09 was selected to provide preliminary estimates of runoff and recharge for the Study Area. Estimates were further evaluated and adjusted using the groundwater flow model, recognizing that rainfall during the Study Period represents 85 percent of long-term average rainfall for the Study Area.

2.3. Data Sources

Most of the information used for this evaluation was compiled for the BCM Study by BDVWA, MWA, HDWD, and CSA 70 and made available digitally with a website repository through the MWA file transfer protocol (ftp) site. Data included published articles and reports, hydrogeologic data collected from cooperating water and other governmental agencies, geographic information system (GIS) shapefiles, maps, air photos, and various databases.

Additional time-dependent information, including water deliveries, monthly rainfall, and groundwater level, quality, and production data, were obtained and used to update existing databases through 2009. Unless otherwise noted, this study presents data in terms of a water year (WY), which extends from October 1 through September 30. Water years are indicated in hyphenated form (2008-09) or in condensed form by the ending year (2009).

3. STATE OF THE GROUNDWATER SUBBASINS

This section summarizes the historical and current conditions of the Pipes and Reche subbasins and contributing watersheds with respect to land use, physiography, hydrology, and hydrogeology. Subbasin inflows and outflows are evaluated using a water balance that provides both a foundation to develop appropriate basin management objectives and a baseline against which the performance of groundwater management activities can be evaluated in the future.

3.1. Land Use

The Study Area is characterized by mostly open undeveloped land. More than a third of the land is owned by various governmental agencies including the U.S. Bureau of Land Management (BLM). Private (non-governmental) land is represented primarily by residential and commercial development as well as undeveloped parcels. The community of Landers is the largest population center within the Pipes and Reche subbasins. Total private acreage within the Study Area is approximately 18,500 acres (63 percent of the 29,300-acre Study Area). Groundwater development in the Study Area was reported as early as the 1960s. Since that time, groundwater in the Study Area has primarily supported increasing urban demand. There is minimal agricultural and/or industrial water demand in the Study Area. The contributing watershed lies in the San Bernardino Mountains to the west of the Pipes Subbasin. Vegetation is sparse and consists of native vegetation. Land use in the contributing watershed has not changed significantly over the last 20 years.

3.2. Physical Setting

The Study Area is represented by eastward-sloping alluvial plains located east of the San Bernardino Mountains in the Mojave Desert. The area is characterized by arid conditions, desert vegetation, relatively sparse population, and a reliance on groundwater resources. Surface water drainages are fed by rainfall in the adjacent mountains and transport water onto alluvial fans at the mountain front and through major washes entering the Study Area. Most of the available water evaporates or percolates through basin fill sediments a short distance from the mountain source. Groundwater discharges via wells and subsurface outflow to the Giant Rock Subbasin to the east of the Study Area.

3.2.1. Topography

Surface elevations within the Study Area range from 3,800 feet above mean sea level (feet msl) in the southwestern portion of the Pipes Subbasin to less than 2,700 feet msl in the northeastern portion of the Reche Subbasin. The higher elevations are associated with alluvial fan deposits along the mountain front. The desert alluvial sediments have infilled down-dropped areas within the mountainous topography and, as such, bedrock hills and ridges interrupt the

alluvial valley floor. These inter-valley hills and ridges range in elevation up to about 4,000 feet msl.

Much higher surface elevations are associated with the adjacent San Bernardino Mountains. **Figure 4** shows the contributing watersheds of the Study Area. The elevation of the Study Area contributing watershed ranges from 3,800 feet msl along the groundwater subbasin boundaries to more than 9,000 feet msl in the west. The Digital Elevation Model (DEM) background illustrates the mountainous terrain and buried bedrock ridges within and southwest of the Study Area.

3.2.2. Precipitation and Evapotranspiration (ET)

The Study Area is characterized by low precipitation and high evaporation, both of which limit natural recharge to groundwater. Average annual rainfall is indicated by contours of equal rainfall, or isohyets, shown on **Figure 4**. The isohyetal map was provided by MWA (James, 1992) and represents annual rainfall data from 1960 to 1991. As shown by the isohyets, rainfall ranges from almost 16 inches per year in the upper elevations of the watersheds to between 4 and 6 inches per year across most of the Study Area. To further evaluate rainfall in the upper reaches of the contributing watershed, rainfall data in the San Bernardino Mountains were reviewed. The closest station with a long and reliable record (1960 to present) is at Big Bear Lake (NWS Station 040741). Data from this station provided information on applicable wet and dry periods for the Study Area (see **Figure 6**).

Average evapotranspiration (ET) is reported as 66.5 inches per year for the High Desert region (Jones, 1999). The maximum monthly ET is 9.92 inches (July). Even during winter months, ET ranges from 1.86 to 2.80 inches per month (or 0.06 to 0.09 inches per day). For an average annual rainfall of about 8 inches per year, daily precipitation in the region is not likely to exceed 0.1 inches more than 10 times or so per year. These climatic data suggest that rainfall on the valley floor does not contribute significantly to groundwater recharge. This indicates that runoff generated in the upper reaches of the contributing watershed is the primary source of water for natural recharge to the Study Area.

3.2.3. Runoff and Recharge

The relatively high precipitation in the upper reaches of the San Bernardino Mountain watersheds generates runoff that is funneled into drainageways and flows downstream to the Study Area. Runoff is variable and does not occur at the same rate with each precipitation event. Rainfall in the mountains is expected to result in very little deep percolation in the upland bedrock areas; however, some rainfall may be lost by infiltration where upland topography is relatively flat. In addition some rainfall is lost to evapotranspiration (ET). There are no stream gages or other flow estimates available in the Study Area. In the absence of streamflow data, it

is difficult to provide quantitative estimates of water budget components such as runoff and ET in each portion of the contributing watershed.

Because of the ephemeral nature of arid-zone streams, runoff is highly variable and may not occur every year, or with every storm. The best locations for runoff to recharge groundwater likely occur where flow in the main drainageways (shown in **Figure 4**) crosses the "mountain front" onto the upper portions of the groundwater basins. Runoff percolates in this area where alluvial sediments are coarse and deep and where more frequent high volume flows occur. Here, the unsaturated zone can exhibit relatively high percolation rates, and recharge can occur with less evaporation. As flow progresses downstream, the slopes become flatter and the alluvial sediments become finer, forcing the recharge pattern to widen. Because the finer sediments reduce downward velocities, recharge is more subject to evaporation.

On the lower valley floor, fine grained sediments absorb rainfall and any available soil moisture is used by the desert vegetation or evaporates. The average annual rainfall over the basin floor is four to six inches, and while individual storms may have more rainfall, water tends to collect and evaporate in low lying areas with finer grained sediments, limiting recharge. For these reasons, deep percolation of precipitation is considered negligible on the valley floor.

Although recharge from direct percolation on the valley floor is not considered significant for rainfall amounts less than eight inches per year, runoff is generated from the upland portion of the watersheds at these rainfall amounts. This runoff serves as recharge to the Study Area. To estimate the runoff source areas and associated average annual rainfall, the catchment areas for the main drainages were determined using the project GIS. Then a raster surface of the isohyetal map was constructed in GIS and the average annual rainfall for each catchment area was determined. Data are summarized in **Table 2**.

Average annual rainfall for Pipes Wash (8.54 inches) is the highest among the watersheds because of the higher elevations in the contributing watershed for that drainageway. In contrast, the catchment area for Ruby Mountain Wash is much smaller and is associated with much lower average annual rainfall (5.39 inches).

The absence of streamflow data and site-specific information makes it difficult to quantify runoff for the contributing watersheds. To overcome this data gap, a series of methodologies was created to calibrate inflows and outflows to observations of groundwater storage changes using data from the Pipes Subbasin. This methodology was then used to develop preliminary estimates of subsurface inflow to the Study Area in the groundwater flow model. The approach is described in more detail in the water balance section and in the model documentation, which is contained in the *Reche Spreading Grounds Recharge Feasibility Study* report (Todd Engineers, 2011).

3.2.4. Geology

The Mojave Desert was formed in the Tertiary Period from movement along the San Andreas Fault to the south and the Garlock Fault to the north, creating the Mojave structural block (Norris and Webb, 1990). Tectonic activity associated with the Mojave structural block was superimposed onto the previously-formed Basin and Range terrain, which was characterized by substantial faulting. The San Andreas and related faults created a horst-like block, uplifting the San Bernardino Mountains on the southwestern edge of the Study Area. Since then, deposition from the San Bernardino Mountains has created coalescing alluvial fans along the mountain front, alluvial deposits along ephemeral washes, and basin-fill deposits in the down-dropped valleys of the groundwater basins. These sediments have been deposited onto hilly topography, essentially burying hills and ridges formed from previous tectonic events. This depositional environment has resulted in groundwater basins with local shallow bedrock highs, intervening outcrops of bedrock, and a complex geometry along the base of the alluvial fill. The geometry of the basins has been altered further by movement along more recent faults that have displaced alluvial sediments and bedrock at depth.

The San Bernardino Mountains and bedrock underlying the Study Area consist mainly of Jurassic and Cretaceous granitic rocks. Because of relatively low permeability, the consolidated bedrock is considered to be non-water bearing for the purposes of groundwater basin storage. Domestic wells drilled into these rocks, however, can yield water supplies sufficient for domestic use (Lewis, 1972). Numerous wells have encountered bedrock at various depths, providing data for the interpretation of the alluvial basin bottom.

The eastern slopes of the San Bernardino Mountains dip steeply to the north and east, providing a large thickness of alluvial sediments a short distance from the mountain front. In the Pipes Subbasin, bedrock dips steeply towards the east, extending to depths of roughly 1,000 feet in the eastern portion of the Flamingo Heights alluvial fan in Pipes Subbasin.

The Tertiary and Quaternary age alluvial sediments are the main aquifers in the groundwater basin. The aquifers are the coarse-grained layers of sands and gravels with interbedded layers of silts and clays. The geometry of the Study Area and neighboring subbasins suggests that basin-fill units were deposited in alluvial fan and fluvial wash environments and sourced from erosion of rocks in the higher elevations of the San Bernardino Mountains. These deposits interfinger in the subsurface, making differentiation of discrete aquifer packages difficult on a regional basis. This phenomenon also results in variable aquifer properties across each groundwater basin.

The Mojave structural block is dominated by extensive northwest-trending faults that appear to terminate regionally near the Garlock Fault outside of the Study Area.

The Ames Valley Groundwater Basin lies within the Eastern California Shear Zone, a region of concentrated seismic activity that stretches north-northeast from the San Andreas Fault across the Mojave Desert and into the Owens Valley. Major geologic structures in the Ames Valley Groundwater Basin are shown on **Figure 5** and include Pipes Barrier and the Johnson Valley, Kickapoo, Homestead Valley, and Emerson faults. Previous researchers have identified these structures as partial barriers to groundwater flow using primarily groundwater level data (Lewis, 1972; Trayler and Koczot, 1995; GSI, 2000). The following sections describe the historic and current understanding of each structure with respect to its location and influence on groundwater flow. Interpretations are based on a literature review, groundwater level data, and results of recent geophysical (electrical resistivity and TEM) surveys conducted by Ruekert & Mielke (2007) in conjunction with the BCM Study. **Figure 4** of the BCM Report (Kennedy/Jenks/Todd LLC, 2007) shows the locations of the geophysical surveys.

3.2.5. Faults and Hydraulic Barriers

Figure 5 shows the location of major faults in the Study Area, illustrating the northwest trends. As shown on the figure, many of these faults coincide with groundwater basin and subbasin boundaries because displacement along the faults has created low permeability zones that often impede groundwater flow. Faults that form hydraulic boundaries associated with the Study Area are shown on **Figure 6** and include: 1) the Johnson Valley Fault, which separates portions of Pipes and Reche subbasins; 2) the Pipes Barrier, which separates portions of Pipes and Reche subbasins; 3) the Homestead Valley Fault, which separates Reche and Giant Rock subbasins; and 4) the Kickapoo Fault, which divides the northern portion of the Reche Subbasin.

3.2.5.1. Pipes Barrier

The Pipes Barrier is an inferred fault roughly coincident with a portion of the Pipes/Reche subbasin boundary. A steep groundwater gradient across Pipes Barrier was first identified by Lewis (1972) from 1969 groundwater level data. Because figures depicting Pipes Barrier covered a very large area, and groundwater levels for individual wells were not presented, the Lewis report cannot be used to locate precisely the trace of Pipes Barrier. Using 1994 groundwater level data, Trayler and Koczot (1995) documented a steep groundwater gradient southeast of Pipes Wash confirming the location of Pipes Barrier in this area. Although the steep groundwater gradient could not be identified northwest of Pipes Wash with groundwater level data, Trayler and Koczot inferred a single northwest-trending trace for Pipes Barrier towards its intersection with the Johnson Valley Fault. GSI (2000) later re-interpreted the trace of Pipes Barrier using gravity survey data and included two traces, one on each side of the Trayler and Koczot trace of Pipes Barrier.

Due to the significance of Pipes Barrier with respect to potential conjunctive use projects and the uncertainty surrounding its location and impact on groundwater flow, geophysical surveys

(electrical resistivity and TEM) were conducted to help refine the trace of Pipes Barrier and to determine the degree to which groundwater flow is impeded along this geologic structure (in both horizontal and vertical directions). Modeled resistivity profiles reveal a high resistivity anomaly (likely clay gouge) along Pipes Barrier (Ruekert & Mielke, 2007). Displacement is observed along two planes through Pipes Wash. The occurrence of multiple displacement planes is not surprising, considering the high degree of *en echelon* faulting (staggered or overlapping arrangement of fault traces within a fault zone) associated with the nearby Johnson Valley Fault.

The resistivity profiles also reveal a dipping high resistivity anomaly within a deeper, low-resistivity unit beneath Pipes Wash and Whalen's Wash. The anomaly does not extend into the shallow, high-resistivity unit, indicating that clay gouge may not exist in shallow sediments beneath the washes. There are currently insufficient data to confirm if 1) the lithology of the high resistivity unit is too coarse-grained to develop clay gouge, 2) the lithology of the high resistivity unit is too coarse-grained for clay gouge to be measured, or 3) the most recent displacement along Pipes Barrier occurred prior to the deposition of the shallow, high resistivity unit beneath the washes.

Regardless of which explanation(s) is correct, the horizontal resistivity boundary appears to be vertically offset and uplifted on the west side of Pipes Barrier between 40 and 60 feet. This vertical offset suggests groundwater is being restricted by and builds up along Pipes Barrier. Results of resistivity surveys and DWR well completion reports indicate that basin fill sediments located outside of the washes along Pipes Barrier generally have higher clay content than inside the washes. Therefore, it is reasonable to expect that clay gouge along Pipes Barrier also impedes groundwater flow outside of Pipe Wash and Whalen's Wash. Further evidence of the groundwater flow barrier is provided by the inverse calibration results of the MODFLOW model and measurements of groundwater elevations west and east of the fault, described below.

3.2.5.2. Johnson Valley Fault

Due to its recent rupture history and possible influence on groundwater flow, the Johnson Valley Fault has been well studied and mapped (Riley and Worts, Jr. 1953; Lewis, 1972; Rockwell, et al., 2000; GSI, 2000). **Figure 5** shows that the Johnson Valley Fault extends the length of the Pipes Subbasin in the Ames Valley Groundwater Basin. North of the junction between Pipes Barrier and Johnson Valley Fault, the Johnson Valley Fault is oriented to the northwest and represents the eastern boundary of Pipes Subbasin. South of this junction, the alignment of the main trace of Johnson Valley Fault is north-south and generally coincides with Highway 247. Riley and Worts, Jr. (1953) observed that uplift occurs on the west side of Johnson Valley Fault north of Whalen's Wash, while south of Whalen's Wash, topography along Johnson Valley Fault is characterized by a low west-facing scarp, indicating uplift occurs on the east side of the fault. Surface rupturing along the fault has been mapped with multiple planes of displacement,

particularly west of Highway 247 in the Flamingo Heights area, where *en echelon* faulting is prevalent. Surface rupture along the Johnson Valley Fault during the 1992 Landers Earthquake has led previous investigators to conclude that the fault probably impedes groundwater flow (GSI, 2000 and Rasmussen, 2000). However, historic groundwater level, pumping test, and geophysical data have been insufficient to confirm this theory.

Geophysical surveys (electrical resistivity and time-domain electromagnetic [TEM]) were conducted to confirm whether the Johnson Valley Fault impedes groundwater flow through the Pipes Subbasin specifically in the Flamingo Heights area (Lines 10 and 11). Resistivity profiles along Resistivity Lines 10 and 11 indicate that the Johnson Valley Fault dips about 45 degrees to the west in this vicinity. Displacement is evident along two planes in each profile (Ruekert & Mielke, 2007). Resistivity anomalies interpreted as clay gouge are evident and extend from the base of the profile to the ground surface. Similar to surveys across Pipes Barrier, a boundary between the shallow, high-resistivity unit and deeper, low-resistivity unit is observed. Vertical offset of the low resistivity unit across the two fault planes in Line 11 can also be seen. However, the resistivity contrast and degree of vertical offset are not as clear compared to profiles across Pipes Barrier beneath the washes, making it difficult to confirm to what degree the Johnson Valley Fault impedes groundwater flow at these locations. The dampened resistivity contrast across Johnson Valley Fault may be attributable to the presence of more heterogeneous sediments located near the fault compared to the washes. Overall, the results of electrical resistivity surveys are consistent with the presence of clay gouge along the Johnson Valley Fault and provide evidence that groundwater flow in the Pipes Subbasin is impeded by the fault. Additional groundwater monitoring wells east of Johnson Valley Fault would help verify the degree to which the fault impedes groundwater flow.

3.2.5.3. Homestead Valley Fault

The Homestead Valley Fault generally correlates to the boundary between the Reche and Giant Rock Subbasins within the Ames Valley Groundwater Basin. A groundwater level drop of 200 to 250 feet from the Reche Subbasin to the Giant Rock Subbasin was first identified by Riley and Worts Jr. (1953), indicating that the Homestead Valley Fault significantly impedes groundwater flow. However, the location of the Homestead Valley Fault through the central portion of the Reche Subbasin is unclear; accordingly, geophysical surveys (Lines 12 and 13) were conducted across the fault in this area..

Resistivity Lines 12 and 13 indicate that clay gouge occurs along two planes across the inferred location of the Homestead Valley Fault in this area. A clearly defined boundary between a shallow, high resistivity unit and deeper, low resistivity unit is seen in both profiles and coincides with the estimated groundwater level in this location. The vertical offset of the boundary between the high and low resistivity units across the displacement plane in the profile generated along Resistivity Line 12 coincides closely with the large groundwater level drop from Reche

Subbasin to Giant Rock Subbasin. Even though groundwater flow is impeded in this area, some cross flow likely occurs. Outcrops of bedrock to the north and south likely funnel groundwater flow to this area.

3.2.5.4. Kickapoo Fault

The Kickapoo Fault is located in the northern portion of the Reche Subbasin and represents a restraining bend between the Johnson Valley and Homestead Valley faults (Sowers, et al., 1994). Investigation of the surface rupture along the Kickapoo Fault after the 1992 Landers Earthquake indicates that it is structurally linked to both the Johnson Valley and Homestead Valley Faults but has a different rupture history (Rockwell, et al., 2000). Alluvial sediments have been uplifted and pressure ridges exist along the Kickapoo Fault, indicating a compressional feature (Sowers, et al., 1994). The thickness of saturated basin fill deposits is small in this area and groundwater water level data indicate that the Kickapoo Fault impedes groundwater flow from west to east.

3.3. Basin Geometry

Consolidated pre-Tertiary rocks, including quartz monzonite/diorite and schist, compose the bedrock underlying the basin fill deposits of the Ames Valley Groundwater Basin. Although small quantities of groundwater for domestic use can be extracted from fractures, bedrock is generally considered to be non water-bearing and constitutes the basin bottom. As a result of historical faulting in the area, the elevation of bedrock across the basin is highly variable.

Depths to bedrock (in feet below ground surface or bgs) were mapped for this study using lithologic logs in well completion reports, borehole geophysical logs, and geophysical (gravity and TEM) data. Depth to bedrock data were incorporated into a GIS database and calibrated to the DEM for the Study Area. A raster surface representing depth to bedrock was generated, as shown in **Figure 7**. The shading in the figure illustrates that the deepest portions of the Study Area are in the central portion of the Pipes Subbasin along the Johnson Valley Fault, where depth to bedrock exceeds 1,000 feet. Shallow bedrock is indicated by the red shading, which occurs along the southern boundaries of Pipes and Reche Subbasins and in the Pioneertown area.

Four hydrogeologic cross-sections were prepared to evaluate and illustrate bedrock elevations and basin geometry. Cross section locations, shown on **Figure 8**, were located to incorporate the maximum amount of hydrogeologic data. Cross sections A-A' through D-D' are presented on **Figures 9** through **12**, respectively and described by subbasin in more detail below.

3.3.1. Pipes Subbasin

Depth to bedrock in the Pipes Subbasin is illustrated on west to east Cross Sections A-A', B-B', and D-D' (**Figures 9, 10, and 12**). Cross Section A-A' shows that bedrock in the Pipes Subbasin

slopes from the surface along the western margin of the basin to approximately 1,300 feet deep in the vicinity of Flamingo Heights near Johnson Valley Fault (**Figure 9**). Cross Section B-B', crosses the Flamingo Heights Fan to the south and turns east, showing the bedrock geometry south of A-A' (**Figure 8**). As shown on B-B', bedrock rises in the subsurface to the east towards Pipes Barrier (**Figure 10**). Uplift due to historical fault activity has apparently created a northeast-trending bedrock ridge at the Pipes/Reche subbasin boundary as illustrated on B-B' (GSI, 2000). The ridge is encountered in the subsurface at 354 and 406 feet bgs in HDWD 6 and HDWD 20, respectively, which are located on the northwest side of this bedrock ridge. The ridge rises to the surface and crops out south of the section (**Figure 8**). Shallow bedrock is also encountered on the eastern edge of B-B' as the section leaves the Reche Subbasin (**Figure 10**). On Cross Section D-D', north of the other sections and Whalen's Wash, bedrock in the Pipes Subbasin is generally shallower and is encountered at 140 feet bgs in Well 2N/5E-10Q2 (**Figure 12**).

3.3.2. Reche Subbasin

Portions of Reche Subbasin are shown on Cross Sections A-A' through D-D' (**Figures 9 through 12**) with Cross Section C-C' extending north-south through most of the subbasin (**Figure 11**). On these sections, bedrock depths generally range from 300 to 600 feet. As shown on cross sections A-A' and B-B' (**Figures 9 and 10**) and discussed above, uplifted bedrock on the east side of Pipes Barrier has resulted in shallower bedrock elevations in Reche Subbasin relative to Pipes Subbasin. Near the intersection of Pipes Wash and Whalen's Wash, bedrock was encountered in HDWD 24 (2N/5E-24H1) at 595 feet (**Figure 9**). The variability of bedrock and basin fill in the Reche Subbasin is best illustrated on north-south Cross Section C-C' (**Figure 11**). As shown on the section, bedrock was encountered at 462 feet in Well 2N/5E-12N1 and at 485 feet in BDVWA 9 (2N/5E-12C2) just north of Whalen's Wash (**Figure 11**). Shallow bedrock north of BDVWA 9 limits the saturated thickness of sediments and generally ranges from 100 to 250 feet deep. Numerous wells in this area encountered shallow bedrock and mostly clay and decomposed granite above the bedrock surface. At the eastern edge of Reche Subbasin, bedrock was encountered in well 2N/6E-07Q3 at 346 feet (**Figure 12**).

3.4. Basin Fill Deposits and Aquifer Hydraulic Parameters

In order to resolve the complex distribution of basin fill deposits in the Study Area, an understanding of the evolution of the major geomorphic features (representing geologic units) is essential, including key alluvial washes, fans, and dry lakes. Basin fill deposits are derived principally from eroded rocks of the San Bernardino Mountains, (quartz monzonite/diorite, schists, and basalts), and consist of intercalated lenses of Tertiary and Quaternary clay, silt, sand, and gravel. Sediments were transported from the mountains by alluvial washes through the narrow canyons in the mountains and created alluvial fans when they were deposited on the

basin floor. The locations of major washes and fans including Pipes Wash, Whalen's Wash, Ruby Mountain Wash, Yucca Mesa Fan, Flamingo Heights Fan, and Ruby Mountain Fan are shown on **Figure 4 and 5** and described in more detail below.

3.4.1. Pipes Wash

Pipes Wash is a fluvial channel representing the confluence of Antelope Creek and its tributaries in the Pioneertown area (**Figure 4**). Pipes Wash enters the southern portion of Pipes Subbasin through a narrow gorge eroded in granite east of Highway 247 and traverses the Pipes, Reche, and Giant Rock Subbasins generally as a 2,000-foot wide, flat-floored wash (Rasmussen, 2000). Previous investigators concluded that the Yucca Mesa Fan to the south of the Study Area was created by sediments transported through Pipes Wash. Historical fault activity, resulting in bedrock uplift, re-oriented Pipes Wash to its existing location to the north (GSI, 2000). This interpretation is based on a gravimetric investigation in which an anomaly (interpreted as a bedrock ridge) appears to extend from a bedrock outcrop southwest of Pipes Wash to the northeast through the Pipes and Reche Subbasins.

All of the major washes in the basin are composed primarily of arkosic sediments, derived from eroded granitic rocks of the San Bernardino Mountains. Resistivity surveys (Lines 7, 8, 14, and 15) performed for the BCM Study indicate that Pipes Wash is underlain by a shallow, high resistivity (coarse-grained) unit down to a depth of 200 to 250 feet, with a low resistivity (fine-grained) unit occurring at greater depth within the Pipes and Reche Subbasins (Kennedy/Jenks/Todd LLC, 2007). Pipes Wash is deeply incised though the landscape, indicating that the wash has not migrated significantly from its current position in a relatively long time. The southeastern banks of Pipes Wash are composed of older alluvium and recent sand dunes deposited by prevailing westerly winds and rise up to 150 feet above the wash floor.

3.4.2. Whalen's Wash and Flamingo Heights Fan

Whalen's Wash originates in the Pipes Subbasin and traverses the Pipes and Reche subbasins as a 1,000-foot wide flat-floored wash (**Figure 4**). The wash merges with Pipes Wash in the Reche Subbasin. Whalen's Wash is currently bounded along the northern edge of the Flamingo Heights Fan by its incised banks, which are composed of older alluvium and rise up to 80 feet above the wash floor. Nonetheless, it is apparent that sediments transported by Whalen's Wash formed the Flamingo Heights Fan south of the current alignment of the wash (**Figure 4**).

Resistivity surveys (Lines 3 and 4) conducted for the BCM Study indicate that Whalen's Wash is underlain by coarse-grained sediments to a depth greater than 450 feet west of Highway 247 and 200 to 250 feet east of Highway 247, with progressively finer-grained sediments occurring at increasing depths (Kennedy/Jenks/Todd LLC, 2007).

The largest and steepest alluvial fan in the western portion of the basin is the Flamingo Heights Fan, which is located along and south of Whalen's Wash (see Figure 5). The width of the fan is about two miles as it crosses Highway 247 and the Johnson Valley Fault. As mentioned above, sediments of the Flamingo Heights Fan were probably deposited by Whalen's Wash in a predominantly eastern direction. Evaluation of lithologic logs, supported by resistivity surveys conducted for the BCM Study (Lines 1 and 2), indicate that shallow sediments (upper 450 feet) are coarse-grained in the upper fan area but grade quickly to silty sands down the fan axis, a depositional pattern expected for alluvial fans (Kennedy/Jenks/Todd LLC, 2007).

Some data indicate that the coarse-grained portion of the Flamingo Heights Fan extends further away from the mountain front with depth. Coarse-grained sediments were encountered during drilling of the USGS Monitoring Well and BDVWA 8 at depths of around 800 feet. Gravity surveys indicate that the thickness of basin fill sediments may be as much as 1,300 feet in this area. However, the driller's log for BDVWA 8 indicates that "hard rock" was encountered from 838 to 871 feet, indicating that matrix porosity at these depths is probably somewhat lower due to increased cementation.

3.4.3. Ruby Mountain Wash and Ruby Mountain Fan

Ruby Mountain Wash originates in the Pipes Subbasin and is located north of Whalen's Wash (**Figure 4**). Unlike the other major washes in the basin, Ruby Mountain Wash does not create a deep incision in the landscape as it crosses Pipes and Reche subbasins. Thus, the fan that Ruby Mountain Wash creates (Ruby Mountain Fan) is actively growing or prograding.

Ruby Mountain Fan is prograding in a northeasterly direction. Cross-section D-D', which crosses the southern portion of the fan, indicates that thickness of basin fill sediments increases eastward to approximately 500 feet (**Figure 12**). The driller's log for Well 2N/5E-12N1 indicates that coarse-grained sediments down to 271 feet are underlain by progressively finer-grained sediments at increasing depth before reaching granitic bedrock at 462 feet.

3.4.4. Aquifer Hydraulic Parameters

For this study, well data were reviewed and compiled to generate aquifer parameters for the Ames Valley Groundwater Basin. Specific capacity data derived from aquifer pumping tests were evaluated to estimate and identify the distribution of aquifer transmissivity and hydraulic conductivity values within the Study Area. Available hydraulic data sources for this evaluation included step-drawdown pumping test results for BDVWA and HDWD production wells and DWR driller's logs. **Table 3** shows the calculated specific capacity and estimated aquifer parameters for wells in the Study Area. Wells are grouped by groundwater basin/subbasin. For major production wells with multiple pumping test results, average hydraulic data and aquifer parameters are presented.

Specific Capacity. The specific capacity is a normalized property of a well that is defined as the discharge of the well in gallons per minute (gpm) divided by the water level drawdown in feet. This normalized parameter represents the productivity of the well. The drawdown is the vertical distance between the static water level (SWL) and the pumping water level. The specific capacity is time and discharge dependent: the greater the elapsed time of pumping the smaller the specific capacity, and the greater the discharge for a given time the smaller the specific capacity. The specific capacity for each period of continuous undisturbed pumping was computed by dividing the discharge rate by the maximum water level drawdown in the pumping well.

Specific capacity data for Study Area wells range from less than 0.1 up to 52.2 gallons per minute per foot of drawdown (gpm/ft). Specific capacities of active municipal production wells range from 16.7 to 52.2 gpm/ft in the Pipes Subbasin and from 25.9 to 48.4 gpm/ft in the Reche Subbasin. Wells screened in low permeability sediments have low specific capacities. For instance, specific capacities of wells screened in bedrock within the Pioneertown area are significantly lower and range from less than 0.1 to 0.5 gpm/ft of dd. Wells located in 3N/5E of the Reche Subbasin are screened in cemented sediments and bedrock (see Cross Section C-C', **Figure 11**) and have low specific capacities, ranging from less than 0.1 to 3.0 gpm/ft.

***Aquifer Transmissivity*.** The transmissivity of an aquifer represents the ease with which groundwater flows through an aquifer and can be measured from a constant-discharge pumping test. Large transmissivities (greater than 10,000 gpd/ft) indicate prolific aquifers that can be pumped for several hundreds or thousands of gpm; small transmissivities (less than 1,000 gpd/ft) represent low-yield aquifers that are used primarily for relatively small water supplies, such as livestock watering or domestic use. Empirically, the transmissivity in gallons per day per foot (gpd/ft) is directly proportional to the specific capacity in gpm/ft and is estimated by multiplying the specific capacity by a coefficient of 1,500 for an unconfined aquifer (Driscoll, 1986). Because the empirical method depends on the specific capacity of the pumping well (and hence the well efficiency, which is commonly less than 100 percent), the empirically derived transmissivity is considered a conservative estimate of the actual transmissivity of the aquifer. Because specific capacities sometimes are affected by well losses during pumping, aquifer transmissivities estimated from specific capacities are sometimes underestimated. A more reliable estimate of the transmissivity can be derived from time-drawdown analysis and can be compared to the empirical transmissivity to determine the well efficiency. With the exception of recent aquifer testing performed on HDWD 24 (Todd Engineers, 2011), hydraulic data collected from historical pumping tests of Study Area wells did not allow for reliable time-drawdown analysis.

To estimate the transmissivities for each well, the specific capacity was multiplied by the constant relating to unconfined conditions (1,500) (**Table 3**). **Figure 13** shows the spatial distribution of high and low transmissivities for the Study Area wells.

Figure 13 and **Table 3** show that estimated transmissivities in the Reche and Pipes Subbasins are relatively high. High transmissivities were calculated for BDVWA Wells 2, 3, 4, and 8 near the Johnson Valley Fault indicating that permeable sediments exist in the Flamingo Heights Fan possibly to depths of 700 and 800 feet. The highest transmissivity in the Pipes Subbasin was calculated for BDVWA 8 (78,375 gpd/ft). In the Reche Subbasin, high-yielding units are located near the confluence of Whalen's Wash and Pipes Wash, where coarser-grained sediments are expected. The highest transmissivity in the Reche Subbasin (based on formal aquifer testing data utilizing BDVWA MW2 as an observation well) was calculated for HDWD 24 (**Table 3**). The result of the formal pumping test conducted in October 2010 indicated the aquifer transmissivity is approximately 325,000 gpd/ft (Todd Engineers, 2011).

Wells located north of BDVWA 6, 7, and 9 in the Reche Subbasin have relatively low transmissivities ranging from 58 to 4,500 gpd/ft. Cross Section C-C' (**Figure 11**) indicates that aquifer units in this area are comprised of weathered granite and cemented sands and gravel. The average saturated screen length of wells in this area is only about 60 feet.

Hydraulic Conductivity. Hydraulic conductivity of an aquifer is a normalized quantity of the aquifer permeability and is a more fundamental property of the permeability than the transmissivity. The hydraulic conductivity in gallons per day per square foot (gpd/ft^2) is computed as the transmissivity (in gpd/ft) divided by the aquifer thickness (in feet). For this study, two methods were used to estimate the aquifer thickness, which provided the full range of possible hydraulic conductivities for each well. For the first method, the aquifer thickness was represented by the total saturated screen length. For the second method, the aquifer thickness was represented by the vertical distance between the static water level and the bottom of the lowest well screen. Using the saturated screen length as the aquifer thickness provides the upper hydraulic conductivity value, while using the vertical distance between the static water level and bottom of the lowest well screen as the aquifer thickness provides the lower hydraulic conductivity value. **Figure 14** shows the spatial distribution of the estimated K values for wells in the Ames Valley Groundwater Basin. Hydraulic conductivity calculations for each well grouped by USGS Morongo Subbasin are presented in **Table 3**.

Figure 14 shows that, similar to the distribution of transmissivities, the highest estimated hydraulic conductivities are located in the Reche and Pipes Subbasins. The highest hydraulic conductivities in the Pipes Subbasin were calculated for BDVWA 2 and 3 (479 to 515 gpd/ft^{2}and 515 to 654 gpd/ft^2, respectively). In the Reche Subbasin, the highest hydraulic conductivity was calculated for HDWD 24 (1,122 gpd/ft^2).

Storativity Values. Storativity is a unitless number that represents the relative confinement of the aquifer and, in the case of an unconfined aquifer, is the specific yield (effective porosity) of the aquifer. A constant-discharge pumping test with a nearby observation well is necessary to estimate the storativity value. Although a formal pumping test was conducted for HDWD 24 in 2010, discharge boundaries were encountered during the first few minutes of pumping, preventing the reliable estimation of storativity. A literature review indicates that the average S value of aquifer units for each of the USGS Morongo Subbasins within the Ames Valley Groundwater Basin ranges from 12 percent to 14 percent (Lewis, 1972).

During MODFLOW model calibration, an optimum uniform specific storage of 0.0021 foot^{-1} was estimated. Specific storage is equivalent to the aquifer storage coefficient divided by the aquifer saturated thickness. Although the saturated thickness in the Pipes and Reche subbasins varies, on average it is around 150 feet, which yields a storage coefficient of around 0.30. For unconfined aquifers, effective porosities are analogous to storage coefficient (specific yield). Effective porosities in soil core samples from monitoring well BDVWA MW1 drilled in 2010 ranged from 0.22 to 0.23.

3.5. Water Supply

Because groundwater is currently the sole source of supply to the area, information on water agencies, groundwater pumping, and distribution systems provides a backdrop to the groundwater basin setting. Summary information on groundwater use is provided in the sections below.

3.5.1. Local Water Agencies

As previously mentioned, service areas for four water agencies overlie portions of the Study Area and groundwater basins.. Agencies include Bighorn-Desert View Water Agency (BDVWA), San Bernardino County Special District Area No. 70 Zones W-1 (Landers) and Zone W-4 (Pioneertown), and Hi-Desert Water District (HDWD).A portion of Joshua Basin Water District (JBWD) overlies the Twentynine Palms subbasin (see Figure 1 for subbasin location). Because production in JBWD is outside of the Study Area, the district is not examined further in the GWMP. HDWD has historically pumped from the Reche Subbasin and currently maintains one active production well in the Study Area. Information on domestic groundwater production is not available, but pumping is believed to be minor compared to municipal use.

Bighorn-Desert View Water Agency (BDVWA). The BDVWA encompasses 45 square miles of desert area serving the communities of Flamingo Heights, Landers, and Johnson Valley. It has approximately 1,880 metered services. The BDVWA operates seven deep wells in the Study Area and nine above-ground reservoir tanks, and maintains about 600 fire hydrants and 130 miles of water main pipelines. The Bighorn-Desert View Intertie pipeline historically allowed

export of water pumped from the Study Area to HDWD service areas in the adjacent Copper Mountain and Warren subbasins (see Figure 1 for subbasin locations).

Hi-Desert Water District (HDWD). HDWD provides water to the town of Yucca Valley and portions of unincorporated areas of San Bernardino County. HDWD serves approximately 25,000 people (with close to 10,000 connections) in their 50 square mile service area. HDWD maintains approximately 274 miles of pipeline ranging from a diameter of 2 inches to 12 inches. There are 16 storage tanks with a total storage of 12.66 million gallons. With 17 wells in operation, HDWD is able to produce a maximum of 7,000 gallons per minute (gpm) from the Warren Subbasin. There are four HDWD wells in the Reche Subbasin, but only one is operational (HDWD 24) and is used to serve HDWD customers in the Study Area. HDWD also operates three recharge ponds in the Warren Subbasin, each of which percolates SWP water delivered by the Morongo Basin Pipeline. HDWD is currently considering construction of a wastewater treatment plant. Treated effluent from the plant is expected to be used to recharge the Warren Subbasin.

San Bernardino County Service Area 70 Zone W-1 (W-1/Landers). W-1/Landers is a water district within the Special Districts Department of the Water and Sanitation Division. It provides water services to a community of approximately 2,030 customers with 615 meters. The water system consists of three wells in the Reche Subbasin and three storage tanks with a combined capacity of 620,000 gallons.

San Bernardino County Service Area 70 Zone W-4 (W-4/Pioneertown). W-4/Pioneertown is another water district within the Special Districts Department of the Water and Sanitation Division. It encompasses less than one square mile of property in the Chaparrosa Wash between Landers and Yucca Valley, northwest of Highway 62 (**Figure 2**). W-4/Pioneertown build out is approximately 300 parcels, supplying water for a total build out of 300 gallons per minute (gpm) maximum day demand. Pioneertown has 8 wells ranging in capacity from 3 to 26 gallons per minute, with 126 metered connections (114 active and 12 inactive). Some of the wells have constituents that exceed or are on the borderline of the Maximum Contaminant Levels (MCL) set by the State Department of Public Health (DPH). Water quality concerns include high concentrations of gross alpha radioactivity, arsenic, fluoride, and iron.

Water Haulers. In addition to groundwater service through their distribution system, BDVWA provides groundwater to bulk haulers for offsite use. BDVWA currently has 80 active bulk water hauling metered accounts from three water drop locations within the Study Area. A water drop location is a tank filled with water from the BDVWA distribution system for haulers to drive up to, fill up their truck tank, and haul to an end user. The source of the water is BDVWA groundwater wells. Water hauling is used in areas where a pipeline distribution system has not been developed. Water is delivered to construction, commercial, and residential users in Johnson Valley, Landers, Pipes Canyon, Pioneertown, and possibly other locations.

Of the 80 accounts, 73 1-inch meters are held by private residents and 7 2-inch meters are held by commercial water haulers. The amounts delivered by the commercial haulers in the Study Area represent the largest accounts and total less than 10 AFY.

3.5.2. Pumping

Groundwater is pumped from 11 active wells operated by BDVWA, HDWD, and W-1/Landers in the Study Area subbasins. Almost all of the pumping provides water for residential and commercial use; there is no agricultural or industrial pumping in the Study Area. Annual groundwater production from 1970 to 2009 is summarized in the three production charts shown on **Figure 15**. The upper chart shows total production from the Pipes and Reche subbasins and illustrates how pumping increased gradually from about 80 AFY in 1970 to greater than 300 AFY from 1980 through 1987. Pumping averaged more than 600 AFY for the next five years and increased significantly from 1993 through 1999 primarily as a result of export from the Ames Valley basin by HDWD to the adjacent Copper Mountain and Warren subbasins via the BDVWA-HDWD Intertie. During that time period, annual pumping averaged about 1,700 AFY. Pumping decreased starting in 2000 and has averaged less than 1,200 AFY over the last ten years. This chart does not include production from private wells in the Study Area, which is believed to be relatively minor compared to pumping by the three agencies.

Pumping in Pipes Subbasin. The middle chart on **Figure 15** depicts the production totals from municipal wells in the Pipes Subbasin separately to examine pumping in the subbasin more closely. As shown in the figure, pumping from four BDVWA wells (2, 3, 4, and 8) represents all of the production in the Pipes Subbasin. From 1970 through 1987, production in the Pipes Subbasin represented all of the production in the Study Area. Pumping in the Pipes Subbasin increased significantly during the period from 1992 through 1999, during which average pumping was greater than 700 AFY. Since 1998, production in the Pipes Subbasin has declined, averaging just over 200 AFY over the past 12 years.

Pumping in Reche Subbasin. The lower chart on **Figure 15** depicts the production totals in the Reche Subbasin. Production in the Reche Subbasin began in 1988 with BDVWA followed by W-1/Landers and HDWD production in 1991 and 1993, respectively. From 1988 through 1993, production in the Reche Subbasin was relatively stable averaging over 250 AFY. Production increased dramatically in 1994 and has since averaged about 1,070 AFY. Due to incomplete records for W-1/Landers wells, total annual production for the Reche Subbasin is under-estimated in 2001 and from 2006 through 2009. Total annual production in 1999 is also underestimated due to incomplete records for BDVWA wells.

Almost all of the production in the Reche Subbasin is represented by HDWD, BDVWA, and W-1/Landers, the only municipal pumpers in the subbasin. From 1993 (when HDWD Well 24 began producing) through 2009, HDWD, BDVWA, and CSA W-70 production has averaged 57

percent (578 AFY) and 26 percent (262 AFY), and 17 percent (175 AFY) of the total subbasin production, respectively. From 1991 through 1994, much of the production from HDWD Well 24 was exported for out-of-subbasin use. Private well production is believed to be minor compared to total municipal production.

Pumping in W-4/Pioneertown. A relatively small amount of groundwater is pumped from the low-capacity wells in W-4/Pioneertown. Current pumping rates are around 30 AFY total. This local pumping may be reduced in the future if CSA pumps additional water from W-1/Landers wells in the Reche subbasin and conveys the pumping to W-4/Pioneertown.

3.6 Groundwater

Groundwater generally occurs under unconfined to semi-confined conditions in the Pipes and Reche subbasins. Water levels and groundwater flow in the subbasins are described in the following sections.

3.6.1 Groundwater Occurrence and Flow

A comprehensive groundwater level database was developed to evaluate groundwater flow within the Ames Valley, Johnson Valley, and Means Valley groundwater basins. For the Ames Valley Groundwater Basin, groundwater level data were sourced from the USGS National Water Information System (USGS, 2010) and the monthly data collected for the Ames Valley Water Basin Monitoring Program provided by BDVWA. Groundwater level measurements for 1969, 1975, 1994, 2004, and 2009 were calibrated to a DEM provided by MWA to produce groundwater level contour maps. **Figures 16 and 17** depict the depth to water and groundwater elevations in 2009. These maps are used to analyze groundwater flow directions from subbasin to subbasin and estimate the volume of groundwater in storage and available storage capacity in the unsaturated zone. The 2009 groundwater levels are also depicted on Hydrogeologic Cross Sections A-A' through D-D' (**Figures 9 through 12**).

Current groundwater elevations in the Study Area subbasins range from about 3,400 ft msl in the western portion of Pipes Subbasin to less than 2,900 ft msl in the eastern portion of the Reche Subbasin. Groundwater flows in an east-northeast direction across the Pipes and Reche subbasins. Results of recent geophysical surveys and water level data indicate that groundwater flow within the Pipes and Reche Subbasins is impeded by Pipes Barrier, the Johnson Valley Fault, and the Kickapoo Fault. Groundwater exits the Reche Subbasin and flows into the Giant Rock Subbasin at two locations corresponding to bedrock lows along the Homestead Valley Fault. A groundwater level drop of between 150 to 200 feet from Reche Subbasin to Giant Rock Subbasin in those two areas indicates that groundwater is significantly impeded by the Homestead Valley Fault. However, outflow apparently occurs in these areas as evidenced by water level data and bedrock outcrops. Groundwater flow to alternative outlets in the north or south is not indicated by the data.

Groundwater flow was further evaluated using the MODFLOW groundwater flow model. Note that complete documentation of the MODFLOW model is included in Appendix E of the Reche Spreading Grounds Recharge Feasibility Study Report (Todd, 2011). The numerical model simulates steady-state and transient groundwater flow in the Pipes and Reche subbasins. Groundwater recharge rates via subsurface inflow from Antelope Creek/Pipes Wash, Whalen's Wash, Ruby Mountain Wash, and distributed mountain-front recharge were estimated, along with rates of return flow from septic systems. Groundwater outflow via wells was defined based on metered pumping rates, and subsurface outflow from the Reche subbasin to the Giant Rock subbasin was simulated. After calibration, the model was used to predict water table mounding beneath the recharge basin, drawdown around nearby water supply wells, and flowpaths through the subbasins, across major geologic faults, from the recharge basin, and to the production wells.

The model was calibrated to observed historical water levels between 1994 and 2009. Both transient and steady-state flow conditions were simulated; the transient model simulates monthly stress periods between 1994 and 2009, and the steady-state model simulates average 2009 conditions. **Figure 18** shows MODFLOW-simulated groundwater elevations during 2009, and **Figure 19** shows MODPATH-simulated groundwater flowpaths. Comparison of the 2009 observed and simulated groundwater elevation maps (**Figures 17** and **18**) reveals that the model simulates southwest-northeast groundwater flow through the Pipes and Reche subbasins and the hydraulic barrier effects of the faults. **Figure 19** shows the forward flowpaths for particles generated along the western model boundaries. Forward particles track through the flow field and ultimately discharge to the production wells or into the Giant Rock Subbasin. Most of the flowpaths originating along the mountain front between Pipes and Ruby Mountain washes are captured by BDVWA production wells 2, 3, 4, and 8. The sources of water pumped from BDVWA wells 6, 7, and 9 include both inflow from Ruby Mountain Wash and adjacent mountain-front areas and septic return flows. The sources of water to production wells HDWD 24 and W-1/Landers 1, 2, and 3 are inflow via Pipes Wash and septic return flows.

Note that additional MODFLOW simulations were performed to evaluate performance of the proposed Reche Spreading Grounds recharge facility, as documented in the Recharge Feasibility Study Report (Todd, 2011).

3.6.2 Groundwater Level Trends

Figure 20 shows water level hydrographs for key production and monitoring wells within the Study Area subbasins. A discussion of water level trends by subbasin is presented below.

Pipes Subbasin. Water level hydrographs for selected key wells in the Pipes Subbasin are clustered near the bottom of **Figure 20**. Hydrographs indicate that BDVWA groundwater production in the Pipes Subbasin since the 1970s has resulted in groundwater level declines in

several wells located in the Flamingo Heights area (western Pipes Subbasin). **Table 4** summarizes changes in water levels in key Pipes Subbasin wells from 1990 to 2009; the table shows that since 1990 groundwater level declines in the Flamingo Heights production wells (BDVWA 2, 3, 4, and 8) and the nearby USGS Monitoring Well have ranged from 45 to 47 feet, with most of the decline occurring from 1992 to 1997. This six-year period coincided with the peak of groundwater pumping in Pipes Subbasin, when average annual pumping was equal to 718 AFY. Since 1997, groundwater pumping has significantly decreased, with average annual production from 1998 through 2009 of 204 AFY. Correspondingly, the rate of groundwater level declines in the Flamingo Heights wells has decreased to generally less than one foot per year for monitored wells.

Exceptions to the overall declining groundwater level trend in Pipes Subbasin include HDWD 20 and Well 1N/5E- 02N1 (eastern and southern Pipes Subbasin). Groundwater levels in HDWD 20 have historically been flat and even rose slightly from 1996 to 1999. No municipal production wells are located near HDWD 20 and the area appears to be unaffected by groundwater pumping in the Pipes Subbasin. In addition, the area likely benefits from most of the recharge along Pipes Wash. Well 1N/5E- 02N1 is located along the southern banks of Pipes Wash and is more directly influenced by seasonal recharge than groundwater production. Groundwater levels in Well 1N/5E- 02N1appear to reflect annual rainfall patterns with an approximate lag time of about one year. For example, groundwater levels in Well 1N/5E- 02N1 rose 31 feet from 1992 to 1996 when rainfall (from 1991 to 1995) was 124 percent of average annual rainfall. From 1996 to 2002, groundwater levels fell 25 feet when rainfall from 1995 to 2001 was 80 percent of average annual rainfall.

San Bernardino County Service Area 70 W-4/Pioneertown is in the upland area east of the main Pipes Subbasin, and under non-pumping conditions groundwater in this area flows west beneath Pipes Wash and recharges the Subbasin. According to the CSA website, W-4 has reached the limit of the aquifer capacity located in the Chaparrosa Wash. Monitoring data indicate that water levels in the small Subbasin are dropping and are expected to continue to drop based on anticipated future pumping.

Reche Subbasin. **Figure 20** also shows groundwater level hydrographs for selected key wells in the Reche Subbasin. Similar to the Pipes Subbasin, hydrographs indicate groundwater level declines in most of the production wells and monitoring wells, although declines are generally smaller for wells in the Reche Subbasin. Groundwater level declines are attributed to groundwater pumping in the Reche Subbasin by BDVWA (Wells 6, 7, 9), HDWD (Well 24), and San Bernardino County Service Area 70 W-1 (Wells CSA 1, 2, and 3) since 1988. As summarized in the **Table 5**, declines in wells in the Reche Basin since 1990 range from 2 to 40 feet for key wells. The table also shows that although total declines are likely related to the increases in subbasin pumping, the timing of groundwater level declines varied from well to well.

Average annual groundwater pumping in the subbasin from 1990 to 1992 was only 238 AFY. In the following years, subbasin production increased significantly from less than 400 AFY in 1993 to more than 1,500 AFY in 1997. From 1993 through 1999, average annual subbasin pumping was 1,122 AFY with significant increases in 1996 and 1997. The impacts from this increased production are reflected in water level declines in most wells during this period, particularly for HDWD 24. Since 1999, groundwater pumping has decreased slightly, with average production from 2000 through 2009 equal to 949 AFY. Pumping records reveals that combined production from BDVWA 6 and 7 was on average only 72 AFY from 1999 through 2006. Since 2007, total annual production from BDVWA 6 and 7 has increased dramatically, averaging 193 AFY. The increased local production is the primary reason for more recent groundwater level declines observed in BDVWA 6 and 7.

One exception to the trends exhibited by most Reche Subbasin wells is HDWD 6, in which groundwater levels exhibited a dramatic drop of 29 feet from 1990 to 1992, occurring mostly in 1992. The cause of this decline is unresolved, as there is no groundwater production nearby and no problem with well construction indicated. Given the timing and relative suddenness of the decline, it is suspected that seismic movement along the Pipes Barrier during the 1992 Landers earthquake may be involved.

3.6.3 Groundwater Storage and Available Storage

The amount of groundwater in storage (groundwater storage) in the Pipes and Reche subbasins was previously estimated by Lewis (1972) to be 120,000 and 240,000 acre-feet (AF), respectively. Lewis' methodology involved a single value for the average thickness of saturated sediments in each subbasin, a value determined from 1969 groundwater levels and bedrock elevations from available driller's logs. Saturated thickness values ranged from 100 feet for the Reche Subbasin to 150 feet in Pipes Subbasin. A single value representing the average specific yield of basin fill deposits for each subbasin was estimated from sediment descriptions on driller's logs. The representative specific yields for the Pipes, Reche, and Giant Rock Subbasins were 0.14, 0.12, and 0.12, respectively.

Groundwater storage in each subbasin of the Ames Valley Groundwater Basin was re-calculated for this study, because 1) subbasins defined by Lewis differ from the subbasins in this study, 2) additional subsurface data has become available since the Lewis report, and 3) historic groundwater pumping in the basin over the past 35 years has significantly impacted groundwater levels. For this study, 2009 groundwater levels (**Figure 17**) and bedrock elevations (**Figure 7**) were imported into the project GIS database. The thickness of saturated basin fill sediments was determined electronically by computing the differences in elevation between raster surfaces generated from each dataset. In areas where bedrock data were limited, bedrock elevations were estimated based on nearby known bedrock elevations and observed trends of bedrock slopes beneath the basin. A specific yield of 0.12 was applied to each

subbasin, consistent with the lower estimate of specific yield used by Lewis (1972). Groundwater storage estimates for the Pipes and Reche subbasins are summarized in **Table 6**.

The table shows that total groundwater storage in the Pipes and Reche subbasins is about 600,000 AF. Of the total storage volume, about 40 percent is stored in the Pipes Subbasin and about 60 percent is stored in the Reche Subbasin. These totals are likely on the high end of storage estimates and are higher than the amount that could be economically pumped with wells. In addition, some areas likely have lower specific yields, especially with depth. Nonetheless, these totals provide a more rigorous estimate of the total amount of groundwater in storage than past evaluations.

For groundwater basin management and conjunctive use studies, the amount of storage space available in the unsaturated zone is also an important component of the groundwater basin. Available storage capacity in the Pipes and Reche subbasins was calculated by computing the difference in elevation between the DEM and the raster surface representing 2009 groundwater elevations. Similar to the groundwater storage estimates, a specific yield of 0.12 was used for unsaturated basin fill sediments. Available groundwater storage capacity for the Pipes and Reche subbasins is summarized in **Table 7**.

The table shows that total available storage capacity in the Pipes and Reche subbasins is about 773,000 AF. Of the total available storage volume, about 46 percent is in the Pipes Subbasin and about 54 percent is in the Reche Subbasin. Although the total estimated available storage in the basin could not be utilized due to variability in topography across the basin, for perspective, the volume of available storage is larger than the amount of groundwater currently in storage in the two subbasins.

3.6.4 Groundwater Quality

Groundwater quality data sources for this study included the USGS National Water Information System (USGS, 2010), and laboratory groundwater quality reports for production wells in the Study Area provided by MWA and BDVWA. Groundwater quality data were combined into a comprehensive database and used to identify the chemical signature of groundwater and concentrations of dissolved constituents of concern within the Study Area.

Table 8 summarizes the inorganic water quality with concentrations of major cations and anions, trace metals, and radionuclides for the 11 municipal production wells and 2 newly installed BDVWA monitoring wells in the Pipes and Reche subbasins.

These data were evaluated using a geochemical plotting technique known as a Trilinear Diagram. This technique plots the major anions and cations in percent milliequivalents per liter (% meq/L) to characterize groundwater and differentiate samples of varying water quality. **Figure 21** shows a Trilinear Diagram for the 13 wells. Cations in % meq/L are plotted on the lower left

triangle and anions in % meq/L are plotted in the lower right triangle. Data are projected onto the central diamond to evaluate overall water type. Water samples of similar quality plot together in a cluster. As shown on **Figure 21**, groundwater in most of the wells cluster in the central portion of the diamond, indicating primarily a sodium/calcium-bicarbonate water type. However, wells in Pipes Subbasin generally have a higher ratio of calcium to sodium than wells in the Reche Subbasin. This is likely indicative of different recharge sources and/or cation exchange between calcium and sodium along groundwater flow paths. One exception to this trend is BDVWA 8, which has a much higher ratio of sodium to calcium than other wells in Pipes Subbasin, indicating that the flowpath of groundwater recharge to BDVWA 8 is different compared to groundwater recharge pumped by BDVWA 2, 3, and 4. This is consistent with the groundwater flow model developed for the subbasins, which indicate that the source of water for BDVWA 8 is predominantly from the Whalen's Wash watershed instead of Pipes Wash (**Figure 19**). Water quality differences are also expected given the relatively deep screen in BDVWA 8 compared to the other wells.

Table 8 indicates that groundwater in the Pipes and Reche subbasins meets drinking water standards for TDS, reported as a secondary maximum contaminant level (MCL) of 500 mg/L.

Figure 22 shows the concentrations of radionuclide parameters in production wells within the Study Area relative to MCLs. The figure shows that gross alpha and uranium concentrations in wells BDVWA 2, 3, and 4, are higher than in the other water supply wells. California MCLs for gross alpha and uranium are 15 and 20 picocuries per liter, respectively. According to the California Department of Public Health (CDPH), compliance with gross alpha and uranium MCLs is based on running annual averages (RAAs) and historical and recent RAAs for these two parameters in all wells are in compliance with the radionuclide MCLs (CDPH, 2011). FOOTNOTE GRAPH While both gross alpha and uranium concentrations have gradually increased in BDVWA 2 since 1990, elevated concentrations in BDVWA 3 and 4 have been relatively stable over the same period. In the Reche Subbasin, gross alpha and uranium concentrations are below respective MCLs, with no evidence of increasing concentration trends.

3.6.5 State Water Project Water Quality

The predominant beneficial use of groundwater in the Study Area is municipal water supply. Therefore, the significance of potential impacts is defined by drinking water standards, including maximum contaminant levels (MCLs) and health advisory levels. Primary MCLs are enforceable standards based on potential impacts to human health; secondary MCLs are associated with aesthetic impacts such as taste, color, or odor, but are not considered to be a risk to human health.

For an assessment of the potential groundwater quality impacts associated with mixing SWP water and native groundwater, SWP water quality data were obtained, evaluated, and compared

to current groundwater quality in the Reche Subbasin. The quality of SWP water was evaluated using analytical results from discrete monthly grab samples and continuous automated station water quality data downloaded from the California Department of Water Resources Division of Operations and Maintenance State Water Project website. Based on communications with MWA, it was determined that the Check 41 water quality monitoring station located on the California Aqueduct is representative of current SWP water quality for the Morongo Basin Pipeline.

Table 9 summarizes the inorganic water quality data for monthly grab water quality samples collected at SWP Check 41 from January 2008 through September 2009. Data were downloaded from the California Department of Water Resources Division of Operations and Maintenance State Water Project website. As shown in the table, detected concentrations of constituents in SWP water analyzed at Check 41 are generally below their respective primary or secondary MCL. Manganese was detected in one month above its secondary MCL, but for the other 18 months was not detected above its reporting limit. In addition, turbidity in SWP water is consistently detected above the secondary MCL; however, turbidity is not expected to impact groundwater quality, as any suspended solids in SWP water will be filtered out by the aquifer formation prior to reaching the groundwater table. The average TDS concentration and specific conductance (or electrical conductivity (EC)) of SWP from January 2008 to September 2009 was 286 milligrams per liter (mg/L) and 495 microSiemens per centimeter (μS/cm), respectively.

To characterize the inorganic water chemistry for SWP, major cation and anion data are plotted on the Trilinear Diagram, **Figure 21**. Data from separate samples are grouped together in the yellow highlighted fields on the three portions of the plot. These data provide information on the general water chemistry of SWP and indicate that SWP water is generally neutral and can be categorized as sodium/chloride-type water. The figure shows that although inorganic composition of native groundwater and SWP water are slightly different, mixing of the two waters will result in a neutral water type, and, as such, is not expected to degrade groundwater quality in the Reche Subbasin.

In addition to monthly grab samples, DWR also continuously monitors for several physical properties in SWP water, including EC and pH. Using a conversion factor, EC values can also be used to estimate TDS, providing data to supplement the measured TDS concentrations in the monthly grab samples. EC data and estimated TDS values for SWP water at Check 41 from January 2000 to December 2009 varied during this period between 300 and 700 μS/cm, with an average of 452 μS/cm, similar to average EC in 2008 and 2009. The average EC value equates to a TDS concentration of 262 mg/L (based on the average conversion factor of 0.58 EC (μS/cm) = TDS (mg/L) derived from monthly grab sample data), well below the secondary MCL for TDS. The average pH value of SWP water at Check 41 from January 2000 to December 2009 was 8.05.

DWR routinely monitors SWP water for over 150 organic compounds, including pesticides, herbicides, and volatile organic compounds (VOCs). Grab samples are collected and analyzed in March, June, and September of each year. Based on water quality results obtained from eight quarterly sampling events from March 2007 through September 2009, only two organic contaminants (the herbicide simazine and the pesticide diuron) were detected in four of the eight quarterly sampling events of SWP water at Check 41. However, in each case, detected concentrations are below the respective MCL and health advisory levels and are not expected to significantly impact groundwater quality.

3.7 Water Balance

In support of this GWMP, a water balance along with the MODFLOW model was developed to estimate and verify average annual recharge from rainfall to the Pipes and Reche subbasins. Using the estimated recharge rates, the groundwater model was calibrated to observed groundwater storages changes (as indicated by groundwater levels). The sections below describe the basin inflows, including recharge of runoff from the San Bernardino Mountains and septic return flows, and outflows, including total groundwater pumping and subsurface outflows.

3.7.1 Recharge from Rainfall

The principal source of natural groundwater recharge to the basin is the runoff of rainfall in the San Bernardino Mountains. Direct recharge from rainfall on the basin is considered negligible given the low amounts of precipitation and high evapotranspiration rates on the valley floor. **Figure 5** shows the contributing watershed area and annual rainfall isohyets for the Study Area. The contributing watershed area is divided into three major drainages. The surface areas and average annual rainfall in the three catchment areas are summarized in **Table 2**. The table shows that Antelope Creek (tributary to Pipes Wash) has the largest contributing catchment area to the basin, representing 62 percent of the overall contributing watershed area. Following Antelope Creek in order of decreasing catchment area and average annual rainfall are Whalen's Wash and Ruby Mountain Wash.

Based on a focused study of the watershed area and groundwater flow rates through Whalen's Wash and Antelope Creek/Pipes Wash, average natural subsurface inflow to the Pipes Subbasin is estimated at 2 percent of rainfall in the contributing watershed area. This average rainfall-recharge ratio is the basis for the boundary condition flux rates developed for the model.

In order to vary the amount of natural subsurface inflow to the model boundary over time, precipitation over time across the contributing watersheds was calculated based on data from the rainfall gage at Big Bear and the average annual precipitation isohyetal map (Figure 3 in the Recharge Feasibility Study report). The Big Bear rainfall gage has been active since July 1960. Average annual precipitation for 1960-61 through 2008-2009 for the Big Bear gage is 21.60

inches. To estimate monthly rainfall in which precipitation at the Big Bear gage was not reported, the average relative monthly precipitation between the Big Bear gage and Lake Arrowhead gage was applied to Lake Arrowhead gage data for that month. Note that average annual rainfall in the contributing watershed areas of the three major drainages to the Pipes Subbasin is much lower than rainfall reported at the Big Bear gage, ranging from 8.54 inches for Antelope Valley (Pipes Wash), 6.35 inches for Whalen's Wash, and 5.39 inches for Ruby Mountain Wash.

To estimate annual recharge from rainfall over varying climatic conditions, the ratio of annual rainfall at the Big Bear gage to the long-term average annual rainfall at the Big Bear gage was applied to the average annual rainfall for the contributing watershed (based on spatial analysis of the isohyetal map) multiplied by 2 percent.

Additionally, for any given period, the percentage of rainfall that represents runoff is expected to be positively related to the rainfall amount (i.e. less than 2 percent runoff is expected when rainfall is below normal, while greater than 2 percent runoff is expected when rainfall is above average). To account for this, a variable runoff factor ranging from 0.5 percent (applied to years when annual rainfall at the Big Bear gage is less than 10 inches) up to 3.0 percent (for years when annual rainfall is 30 inches or greater) was applied to rainfall in the contributing catchment areas. The weighted-average runoff factor of 2 percent was maintained over study period.

Finally, to account for the vadose and saturated zone travel time and time lag for recharge entering the Pipes Subbasin as subsurface inflow, monthly rainfall reported at the Big Bear rainfall gage was compared with groundwater elevations in Well 1N/5E-2N1, located along Pipes Wash near the intersection of Pipes Wash and Highway 247. The hydrograph for Well 1N/5E-2N1 (**Figure 18**) responds gradually to significant rainfall events in the San Bernardino Mountains and continues to do so for up to two years before receding. This process reflects the capacity of the alluvial materials to detain runoff generated in the contributing watersheds of the major drainages upgradient of the modeled area. For the model, a retention time was developed to "lag" and re-distribute the subsurface inflow over time. During calibration, the amount re-allocated to mountain-front recharge was varied, and ultimately 10 percent was used in the final calibrated model.

The average total natural recharge from rainfall through Pipes Wash, Whalen's Wash, Ruby Mountain Wash, and mountain front arcs for the simulated period from 1994-95 to 2008-09 was 765 AFY, of which 703 AFY represents the influx through the main washes and 61 AFY represents the influx through mountain flux arcs. It is noted that the estimated natural inflow for the transient model period is slightly higher than the average annual recharge estimated for the 20-year study period (1989-90 to 2008-09) in the 2007 BCM report (Kenndy Jenks/Todd/LLC, 2007). This is due primarily to the modeled detention/lag of rainfall runoff generated during the winter storms during 1992-93.

3.7.2 Septic Return Flows

Septic tanks represent the sole method of wastewater treatment and disposal in the Study Area. As such, the other major source of recharge to the Pipes and Reche subbasins is represented by septic return flows. Monthly water use rates for each assessor parcel number from 1995 through 2009 was obtained from BDVWA. Monthly water use rates were converted to recharge rates using a consumptive use factor of 20 percent, or a return flow rate of 80 percent of water use. The relatively high consumptive use factor was selected, since water use in the area is predominantly indoor, and because water use as metered at each customer site is considered under-reported by up to 20 percent by BDVWA. Historic water use of HDWD customers in the Mesa area was not available but is relatively small compared to natural recharge estimates and water use of BDVWA customers in the Study Area.

Average estimated recharge from septic return flows from BDVWA parcels in the Pipes and Reche subbasins and contributing watershed areas is 261 AFY. The septic return flow estimates are lower than those reported in the 2007 BCM Study, because the Study Area for the BCM Study included a large portion of Landers located outside and downgradient of the Study Area. The septic return values compare favorably with estimates for the Warren Subbasin, where a per-capita septic system return factor of 70 gallons per day was applied to population (Umari, et al., 1993 and Nishikawa et al., 2003).

3.7.3 Groundwater Pumping

Since 1970, groundwater pumping by BDVWA, HDWD, and the County has represented most of the pumping in the basin. Although there are numerous private wells in the Study Area, pumping from these wells is primarily for domestic purposes, with substantial returns, and is considered sufficiently small to be excluded from this preliminary water balance. Annual groundwater production for the Pipes and Reche subbasins is shown in **Figure 15**. Groundwater pumping by BDVWA in the Pipes and Reche subbasins steadily increased from approximately 100 AFY in 1969-70 to 600 AFY in 1988-89. In 1991, San Bernardino County began pumping in the Reche Subbasin, and was joined by HDWD in 1993. Total groundwater production in the subbasins peaked at 2,297 AFY in 1995-96 but has since decreased by about 50 percent. Average annual groundwater pumping in the basin from 1999-00 to 2008-09 was about 1,200 AFY.

Pipes Subbasin. The middle chart on **Figure 15** shows groundwater pumping in the Pipes Subbasin. As shown in the figure, pumping in Pipes Subbasin began in 1969-70 when 80 AF was pumped from BDVWA 2. Groundwater pumping in Pipes Subbasin peaked in 1992-93 at 1,049 AF with some water export from the subbasin occurring through the BDVWA Intertie. However, since 1998, groundwater pumping has decreased almost 80 percent in response to the 1991 Ames Valley Water Basin Agreement, completion of the Morongo Basin Pipeline and

initiation of recharge by HDWD in the adjacent Copper Mountain Subbasin, and has been relatively steady in recent years. Average annual groundwater pumping from 1999-00 to 2008-09 was 208 AFY.

Reche Subbasin. The bottom chart on **Figure 15** shows groundwater pumping in the Reche Subbasin. As shown in the figure, pumping in the Reche Subbasin began in 1987-88 when 196 AF was pumped from BDVWA 6 and 7. Subsequently, total groundwater pumping in the Reche Subbasin increased dramatically, peaking in 1997 at 1,517 AF. Since 2000, groundwater pumping has decreased by about 30 percent and has been relatively steady in recent years. Average annual production from 1999-00 to 2008-09 was 993 AFY.

3.7.4 Subsurface Outflow

A portion of groundwater flows from the Reche Subbasin across the Homestead Valley Fault and into the Giant Rock Subbasin. Although the Homestead Valley Fault significantly impedes groundwater flow, calibration of the MODFLOW model indicates that about 580 AFY of groundwater flows out of the Reche Subbasin into Giant Rock Subbasin.

3.7.5 Change in Storage and Perennial Yield

Volumetric inflow and pumping data used as input to the groundwater flow model and subsurface outflow and change in storage rates generated by MODFLOW were plotted and evaluated to determine the magnitudes of water balance components within the Study Area subbasins. **Tables 10 and 11** summarize the annual and cumulative water budget results for the 1994-2009 transient simulation; water balance components over time are charted on **Figure 23**.

The results of the water balance and observed groundwater level declines in the Study Area subbasins indicate a negative change in storage over the modeled period. This indicates that more water is being withdrawn from the subbasins than will be naturally replenished over time, a condition referred to as overdraft. Although the water balance indicates that conditions have improved marginally in recent years, storage changes are nonetheless generally negative.

Table 12 summarizes the major components of the water budget over the 15-year Study Period and under long-term average conditions. Values in the left-hand column represent annual averages over the 15-year Study Period from 1994-95 through 2008-09. As mentioned previously, rainfall at the Big Bear gage over the Study Period represented 85 percent of the long-term average rainfall at that gage. Therefore, values for natural recharge from rainfall during the Study Period were divided by 0.85 to estimate the long-term average subbasin water budget, which is shown on the right-hand column of the table.

The table shows that natural recharge from rainfall (703 AFY) and subsurface inflows (61 AFY) represent about 75 percent of subbasin inflows. The remaining 25 percent of subbasin inflows

(261 AFY) is recharge from septic return flows. Groundwater pumping represents the largest subbasin outflow, averaging 1,383 AFY (or 70 percent of subbasin outflows) over the Study Period. The remaining 30 percent of the subbasin outflows (579 AFY) is subsurface outflow from the Reche Subbasin to the Giant Rock Subbasin. Overall, the Pipes and Reche subbasins have experienced overdraft conditions with an average annual change in storage of -937 AFY over the 15-year Study period (or -813 AFY, after adjusting recharge from rainfall runoff to reflect long-term average conditions).

Overall, historical pumping is unsustainable without additional management strategies to increase basin yield or re-distribute production to capture natural (or enhanced) recharge more effectively. Over the past five years, groundwater pumping in the Pipes and Reche subbasins has decreased somewhat (to 1,145 AFY on average). As a result, the rate of groundwater storage declined has slowed to -615 AFY on average over the past five years). Assuming similar distribution of water use, production could be re-distributed to capture natural subsurface outflows to support current production levels while maintaining near balance in the Pipes and Reche subbasins.

4 BASIN MANAGEMENT OBJECTIVES

BDVWA recognizes the need for effective management to protect available groundwater resources while ensuring a reliable local water supply. Establishing basin management objectives (BMOs) can provide a clear direction for the prioritization and implementation of proposed management actions. BMOs specify the water level and quality conditions that are acceptable in the basin, address conditions that need to be remedied, and identify changes in the groundwater basin that should be avoided. In consideration of the state of the groundwater subbasins and the water supply goals of BDVWA and other subbasin users, the following BMOs are proposed.

4.6 Bring Groundwater Subbasin Supply and Demand into Operational Balance

As described in the State of the Groundwater Subbasins, the Pipes and Reche subbasins are in a state of overdraft due to overproduction and export of groundwater from the subbasins over the last 15-20 years. This condition was documented on the basis of the observed water level trends in subbasin monitoring wells and the theoretical combined subbasin water budget for the period 1994 through 2009 (**Figures 20** and **23**). Although groundwater levels in some subbasin wells have stabilized recently due to decreased pumping and export, subbasin water demands are projected to increase in the future. Additional mechanisms are needed to balance future subbasin water supply and demand and to avoid negative impacts including and associated with further depletion of groundwater storage. BDVWA supports those management strategies that increase groundwater recharge (natural or enhanced) and optimize the capture of recharge water so that water extracted from the subbasins is fully replenished over the long-term.

4.7 Bring Imported Water for Enhanced Groundwater Recharge

To supplement the limited local groundwater supply to meet current and projected water demands, BDVWA wishes to purchase and recharge SWP water in the Study Area. Other water agencies operating in the Pipes and Reche subbasins also desire to recharge SWP water. Prior to implementing such a project, the technical feasibility of a recharge project must be evaluated. Additionally, administrative rules and protocols for purchasing, recharging, and tracking imported water, as well as the roles and responsibilities of participating water agencies, must be clearly defined. This helps to ensure that the benefits of a recharge project are optimized with respect to subbasin longevity and are shared equitably by subbasin users.

4.8 Protect Groundwater Quality

Groundwater quality in the Pipes and Reche Subbasin is of high quality and currently satisfies drinking water standards. However, elevated radionuclides (gross alpha and total uranium) sourced from the granites of the San Bernardino Mountains in the contributing watershed of

Pipes and Reche subbasins present a threat to some existing water supply wells. Close monitoring of radionuclide levels will be necessary to determine the need for re-distributing production and/or installing water treatment systems to mitigate contamination at affected wells. In addition, potential groundwater quality impacts associated with recharge of imported SWP water must be evaluated prior to project implementation and considered in the design of a groundwater monitoring program.

4.9 Establish Groundwater Monitoring Plan and Protocols

In order to continue to analyze current groundwater conditions and identify trends in the subbasins from active management activities, BDVWA would like to expand and improve the current Ames Valley Water Basin Monitoring Program. Important actions include adding additional wells to the monitoring well network and developing new monitoring and reporting protocols. The monitoring program would improve the current understanding of the complex relationships between groundwater levels, storage, flow, pumping, and quality and allow for proper re-evaluation of groundwater conditions and management strategies in the future.

5 BASIN MANAGEMENT STRATEGIES

5.1 Identification of Management Strategies

Various strategies that provide for effective and efficient groundwater management of the Pipes and Reche subbasins have been evaluated and are incorporated in the attached Agreement. These and other associated strategies are listed below.

- Import SWP water for enhanced recharge
- Establish guidelines for management of pumping
- Establish water storage accounts for major water purveyors
- Develop groundwater monitoring program and protocols
- Re-distribute pumping to effectively capture natural and enhanced recharge
- Monitor and evaluate wellhead treatment to address elevated radionuclide levels
- Coordinate with federal, state, and local regulatory agencies

Each management strategy is discussed in more detail in the following sections.

5.1.1 Import SWP water for enhanced recharge

Based on water balance results and perennial yield estimates, it is evident that enhanced recharge of imported SWP water would increase the reliability of the local water supply. SWP water would be supplied to the Study Area by MWA, delivered through the existing Morongo Basin Pipeline and additional facilities. MWA has a current contractual Table A supply of SWP water amounting to 82,800 AFY (89,800 AFY in 2020). This includes 25,000 AFY of Table A watr purchased (transferred) from the Berrenda Mesa Water District in 1998 and a 14,000 AFY of Table A water purchased (transferred) from Dudley Ridge in 2009 (partial transfers of the 14,000 AFY to MWA to be phased in through 2020). The Table A amount is a reference to the amount of water listed in "Table A" of the contract between DWR and the contractor and represents the maximum amount of water that each contractor may request each year. Actual deliveries from DWR may differ from the requests due to variances in supply availability resulting from hydrology, storage availability, regulatory or operating constraints, and other factors.

Internal project allotment of SWP water within the MWA service area is for a maximum of 7,257 AFY to Improvement District M (IDM) located in the Morongo/Johnson Valley Area, which includes the Study Area. To date, historical MWA deliveries through the Morongo Basin Pipeline have been used to supply HDWD recharge facilities in the Warren Basin in and south of Yucca Valley. Based on the individual contracts between MWA and the IDM participants known as the *Agreement for Construction, Operation, and Financing of the Morongo Basin Pipeline Project* (Agreement, Mojave Water Agency and HDWD, 1991) and subsequent amendments to these

agreements, the project allotment of SWP water is divided among the following IDM water agencies as shown in **Table 13**. The entitlements in **Table 13** may be limited to the same percentage of total Table A amounts that MWA is approved to receive from the SWP. The only limitations that have occurred to date are during a few years when MWA has not delivered the full amount requested by HDWD (due mainly to constraints at the Warren recharge basins) and a year or two when MWA reduced deliveries to HDWD because of low SWP allocation.

Recognizing the fluctuations in the availability of SWP water, an evaluation was made of the available project allotments and design capacities of existing and proposed SWP water conveyance facilities to the Study Area. This evaluation is intended to ensure that requested annual volumes of SWP water can be accommodated at the Reche spreading grounds. Over the past 15 years, SWP deliveries to two HDWD recharge facilities in the Warren Subbasin have averaged 3,266 AFY, which equates to 76 percent of HDWD's 4,282 AFY project allotment under the existing Agreement. Additionally, because JBWD currently has no production wells in the Study Area, it is unlikely that JBWD would exercise its SWP water project allotment through the Reche spreading grounds in the immediate future. Based on these allocation factors, recharge of SWP water through the Reche spreading grounds by IDM agencies is not expected to exceed 2,100 AFY (7,257 AFY minus JBWD's project allotment [1,959 AFY] and HDWD project allotment used to supply Warren recharge facilities [3,236 AFY]). Although design of the Morongo Basin Pipeline turnout and pipelines to the proposed Reche spreading grounds has yet to be finalized, planned flow capacity is expected to allow for about 3,000 AFY of enhanced recharge. Based on conservative long-term percolation rates of 2 to 3 feet per day, the proposed five-acre spreading grounds would be able to recharge 3,650 AFY to 5,475 AFY. Based on these estimates, it appears that proposed recharge facilities will be able to accommodate the maximum annual recharge of SWP water at the spreading grounds.

To evaluate the hydraulic impacts of enhanced recharge, groundwater mound development and groundwater flowpaths and velocities away from the spreading grounds were simulated using the Pipes/Reche MODFLOW model, assuming a recharge volume of 1,500 AFY of SWP water over a five-month period for three alternating years (Todd, 2011). The 1,500 AFY amount was considered reasonable for planning purposes given recent annual SWP water availability and the projected SWP water needs and existing entitlements of each IDM water agency. Simulation results indicate that maximum groundwater mound height beneath the spreading grounds is less than 25 feet. Given the high permeability of vadose zone soils and a depth to water of 236 feet beneath the spreading grounds, annual recharge amounts greater than 1,500 AFY are possible. Results of groundwater flowpath analyses also indicate that travel times would allow for efficient recovery of recharged water by existing wells in the Reche Subbasin (primarily HDWD 24) with potential for further optimization by installing additional production wells downgradient of the spreading grounds.

To ensure that groundwater quality is not adversely impacted from the recharge of imported SWP water, the CEQA Initial Study (Mitigated Negative Declaration) was conducted (BDVWA, 2010). The assessment evaluated the potential for groundwater quality impacts from 1) mixing of imported SWP water with native groundwater, 2) mobilization and transport of soluble salts and/or contaminants in the underlying unsaturated zone to the water table, and 3) entrainment of naturally occurring or anthropogenic contaminants in the unsaturated zone (e.g., nitrate) or migration of low quality groundwater away from the spreading grounds. Results of the evaluation indicated that the recharge of SWP water is not expected to adversely impact groundwater quality.

For the recently completed Recharge Feasibility Study, BDVWA contacted federal, state, and local regulatory agencies with oversight responsibilities to inventory and itemize the permits required to construct and operate the Reche spreading grounds. Ongoing coordination with regulatory agencies will be critical to the successful construction, permitting, and operation of the spreading grounds.

5.1.2 Establish guidelines for management of pumping

Study Area water demand projections through 2030 have been evaluated for MWA's 2010 Urban Water Management Plan (UWMP). UWMP projections indicate a continued and increased reliance on the Pipes and Reche groundwater subbasins for water supply. Based on future demands, BDVWA and other major water purveyors agree that current production rates may increase over the next five years. Recognizing the importance and urgency of importing and recharging SWP water to protect the subbasins, the attached New Agreement establishes maximum annual production rights in the Pipes and Reche subbasins for each of the three major water purveyors (termed Annual Baseline Amount). Specifically, the New Agreement states that the Annual Baseline Amount of each water purveyor may not exceed by more than 35 percent its respective current annual production rate, which is calculated as the average annual production rate over the five-year period from calendar year 2004 through 2008. Based on this calculation, total Annual Baseline Amounts in the Pipes and Reche subbasins are limited to 1,611 AFY. **Table 14** shows the annual baseline amounts for each agency.

MWA will re-evaluate groundwater conditions every five years and provide recommendations to either decrease, increase or maintain the Annual Baseline Amounts by an across-the-board percentage deemed necessary to allow for groundwater level recovery or to access additional groundwater supplies. By limiting production rate increases to 35 percent of current production levels over the next five years, the Agreement allows for a near-future growth cushion and provides each water purveyor adequate time to plan for anticipated routine deliveries of imported SWP supplies (and possible downward adjustments to Annual Baseline Amounts in the future).

5.1.3 Establish water storage accounts for major water purveyors

As stated in the Agreement, a water storage account will be established for BDVWA, HDWD, W-1/Landers, W-4/Pioneertown, and MWA to track the balance of water production rights in the form of unused Annual Baseline Amounts and/or imported SWP water by and between each agency.

The Agreement considers the use, purchase, and sale/transfer of unused Baseline Amounts and SWP water. Currently, each agency is allowed to carryover any unused Annual Baseline Amounts for up to two fiscal years, after which the agency relinquishes such production rights for the benefit of the subbasins. Carryover rules do not apply to the purchase or transfer of SWP water. Under this accounting strategy, the water produced by each agency will be identified in the following order for each fiscal year:

1st – any unused Annual Baseline Amount in 2nd year of carryover

2nd - any unused Annual Baseline Amount in 1st year of carryover

3rd – any unused Annual Baseline Amount in current year

4th – any SWP water in storage account

Any unused Annual Baseline Amount is considered a benefit to the Pipes and Reche subbasins. In addition, with respect to enhanced recharge of SWP water, five percent of any SWP water recharged through the spreading grounds will be allocated to BDVWA's storage account. Considering that BDVWA's service area primarily overlies the subbasins of interest and water use results in a higher percentage of return flow than that of HDWD and W-1/Landers and W-4/Pioneertown, the automatic five percent transfer of imported SWP water to BDVWA's account increases the benefits of importing SWP water to the Pipe and Reche subbasins.

5.1.4 Develop groundwater monitoring program and protocols

The goal of the monitoring program is to support the long-term sustainability and protection of the groundwater resource. The objectives of the monitoring program are to better understand groundwater conditions, monitor the impacts of groundwater use, identify changes to groundwater quality, and evaluate the performance of management actions.

BDVWA desires to improve the current groundwater monitoring program to track water levels, groundwater quality, and groundwater storage throughout the subbasins and over time. Improvements involve the addition of dedicated monitoring wells that are not used for groundwater extraction. These wells provide a better representation of basin water levels and are not as influenced by near-well pumping depressions. Additional improvements include the development of specific monitoring protocols that address monitoring and reporting frequency, quality assurance/control with respect to water level measurements and water quality sampling,

and reporting and database management. The proposed monitoring program and protocols are summarized in Appendix B - Ames/Reche Groundwater Storage and Recovery Program and Management Agreement - Groundwater Monitoring Program and Protocols Plan (Draft. Agreement will be finalized in February 2012).

5.1.5 Implement groundwater monitoring and reporting program

As specified in the New Agreement, MWA will assume the responsibility of implementing the groundwater monitoring program. MWA responsibilities will likely include the measurement and/or collection of data regarding rainfall, water use, and groundwater level, quality, and production and the maintenance of associated databases in accordance with protocols reasonably satisfactory to and approved by BDVWA, HDWD, W-1/Landers and W-4/Pioneertown. Based on these data, MWA will re-evaluate the condition of the subbasins every five years to determine whether the subbasins are being managed in operational balance and to determine if management actions (such as adjustment to Annual Baseline Amounts) are warranted.

5.1.6 Re-distribute pumping to effectively capture natural and enhanced recharge

Inflows to the Pipes and Reche subbasins are composed of recharge from runoff from the San Bernardino Mountains and septic return flows. Assuming successful implementation, enhanced recharge of SWP water through the proposed Reche spreading grounds will represent an additional major subbasin inflow in the future. Although estimated inflows are not equivalent to the amount of water that can be efficiently captured by existing production wells, even if the subbasin is in balance, the re-distribution of pumping in the Pipes and Reche subbasins could be further optimized to capture a higher percentage of natural and enhanced recharge that would otherwise flow out of the subbasins as subsurface outflow.

5.1.7 Monitor and evaluate need for wellhead treatment to address elevated radionuclide levels

Water quality in BDVWA Wells 2, 3, and 4 appears to be threatened by elevated radionuclides (gross alpha and total uranium) sourced from the granites of the San Bernardino Mountains within the contributing watershed of the Pipes and Reche subbasins. BDVWA will continue to monitor radionuclide levels and evaluate the need to install appropriate groundwater treatment systems or employ other mechanisms (i.e., blending) to mitigate contamination at these production wells.

5.2 Evaluation of Management Strategies using AB3030 Checklist

Water Code Section 10753 provides a list of 12 example groundwater basin issues that may be considered in an AB3030 GWMP. These examples serve as a checklist to ensure that all potential major groundwater basin issues are addressed. For completeness, these issues are listed below followed by an explanation of the relationship between each issue and the management strategies proposed in this GWMP.

5.2.1 Control of Saline Water Intrusion

The subbasins of interest are located in upland basins away from the coast and are not subject to the typical threat of coastal seawater intrusion. However, this issue also includes the potential horizontal or vertical influx of highly mineralized water from either natural or anthropogenic (human-influenced) sources. To date, no mineralized influx or potential for such influx has been identified in the Pipes and Reche subbasins. Natural subsurface inflow to the Pipes Subbasin from the neighboring San Bernardino Mountains may be contributing to gradually increasing groundwater radionuclide levels in the Pipes and Reche Subbasins. This issue is addressed by the groundwater monitoring program.

5.2.2 Identification and Management of Wellhead Protection and Recharge Areas

Wellhead protection and recharge areas have been evaluated in the past and have been further assessed in this GWMP. In the 2007 BCM Study, recharge areas for the Pipes and Reche subbasins were delineated and characterized. Furthermore, in the recently developed MODFLOW groundwater flow model, ultimate discharge points of groundwater entering the groundwater system as recharge and the capture zones of production wells in the Pipes and Reche subbasins were simulated using the USGS particle track code MODPATH. Strategies to manage and protect groundwater recharge and well capture zones from potential anthropogenic sources of contamination involve coordination with regulatory agencies, including the County of San Bernardino Department of Public Health Division of Environmental Health Services (San Bernardino EHS), SWRCB (State Water Resources Control Board), Regional Water Quality Control Board (RWQCB), and California Department of Toxic Substances Control (DTSC) and County Planning Department, who maintain databases on potentially contaminating activities in the Study Area.

5.2.3 Regulation of the Migration of Contaminated Groundwater

The SWRCB, DTSC, and County of San Bernardino EHS provide data and information on the impacts to groundwater and potential offsite migration of existing contamination plumes. In order to identify and manage these potential threats to water supply, environmental databases, including the SWRCB *Geotracker* and DTSC *Envirostor* databases, will be periodically reviewed

by MWA according to the guidelines established in the groundwater monitoring and reporting program.

5.2.4 Administration of Well Abandonment and Destruction Program

San Bernardino EHS requires issuance of a permit for the abandonment or destruction of any well in the County (San Bernardino County, 2010). Guidance for well abandonment procedures is consistent with standards developed by DWR for drilling and destroying wells in California (DWR, 1991). In addition, the County provides a registry of approved drilling contractors who are familiar with County regulations and policies. The publication of such a list increases the likelihood that permits and proper well abandonment procedures will be followed.

5.2.5 Mitigation of Overdraft Conditions

As indicated by the water balance for the Pipes and Reche subbasins, both areas have experienced overdraft conditions over the Study Period. From 1994 through 2009, the Pipes and Reche subbasins experienced overdraft conditions with an estimated loss of approximately 13,000 AF of groundwater storage over the 15-year period. However, the water balance indicates that conditions were improving at the end of the Study Period because of decreased pumping rates in the subbasin and groundwater exports from the Study Area. The Agency is working collaboratively with other subbasin pumpers (e.g., HDWD, CSA) to control overdraft conditions through pumping limitations.

The water balance for the Pipe and Reche subbasins indicates that overdraft conditions occurred in the first ten years of the Study Period as average pumping averaged about 1,500 AFY. Groundwater levels have gradually stabilized since 2004-05 due to reductions in average pumping down to about 1,150 AF over the past five years. Given the uncertainty associated with imported water amounts in the future, BDVWA will need to rely on the groundwater subbasin for most of its water supply. This indicates that control of overdraft conditions through pumping limitations alone may be unrealistic. As such, BDVWA is developing the strategies described in Section 5.1 above to manage the limited groundwater resources while maintaining existing groundwater production.

The strategies provide for enhanced recharge in the Reche Subbasin through construction and operation of the recharge spreading grounds. Imported SWP water delivered via the Morongo Basin Pipeline will be recharged in the wash at this location to maintain water levels while allowing flexibility in pumping distribution. Strategy 2 provides the infrastructure necessary for the conveyance of water to the spreading grounds. Strategy 3 will allow for increased monitoring of groundwater levels and storage for the tracking of overdraft mitigation.

5.2.6 Replenishment of Groundwater Extracted by Water Producers

As previously discussed, replenishment of the Pipes and Reche subbasins depends on enhanced recharge, given the current and planned reliance on the subbasins for water supply. Implementation of the Reche spreading grounds project is the most important strategy for replenishment.

5.2.7 Monitoring of Groundwater Levels and Storage

The strategies provide for the adoption of a monitoring program and protocols and a commitment for improved monitoring components in the future. The current monitoring program and protocols are described in Appendix B. Also included are recommendations for future improvements to the program.

5.2.8 Facilitating Conjunctive Use Operations

To provide for the efficient use of all water sources including groundwater and imported water, the Agency is planning to operate the Reche recharge spreading grounds.

5.2.9 Identification of Well Construction Policies

Since 1949, DWR has been given the responsibility for developing well standards for the purpose of water quality protection. Standards for the construction and destruction of water wells were first published in 1968 and updated in 1974 (DWR, 1981). Subsequent amendments to the Water Code required the development of minimum standards for monitoring and cathodic wells in addition to water wells. Bulletin 74-91 (DWR, 1991) sets those standards as minimum requirements by local agencies. A permit filed in the form of a Well Completion Report/Driller's Log is required by DWR for the drilling or destruction of wells in the State. A permit is also required by San Bernardino DEH to track wells in the County and ensure adherence to minimum construction standards. The Agency has not developed their own standards, but requires DWR standards and San Bernardino DEH standards.

5.2.10 Construction and Operation of Groundwater Contamination Cleanup, Recharge, Storage, Conservation, Water Recycling, and Extraction Projects

As described above, no anthropogenic groundwater contamination plumes have been identified in the Pipes and Reche subbasins. The Agency and MWA encourage water conservation and provide information to consumers on water wise landscaping and other water saving tips. Septic systems throughout the Pipes and Reche subbasins provide for water recycling as approximately 80 percent of the water used in the subbasins is estimated to return to the groundwater basin. The Reche recharge spreading grounds project provides for recharge and storage of imported water offsetting additional local groundwater use.

5.2.11 Development of Relationships with State and Federal Regulatory Agencies

Recharge of imported water requires coordination with several agencies to ensure that land, air, and biological resources are adequately protected during initial investigations, construction, and individual recharge events. To convey SWP water from the Morongo Basin Pipeline to the proposed Reche Spreading Grounds in Pipes Wash, a pipeline would need to be constructed from the turnout on the Morongo Basin Pipeline to Pipes Wash and some earthwork would need to occur in the wash to control released flows. BDVWA maintains positive working relationships and has been coordinating with the following local, state, and federal regulatory agencies that may have oversight responsibilities regarding the construction and operation of the Reche Spreading Grounds:

- County of San Bernardino Public Works Department, Transportation Operations Division, Transportation Permit Section
- The County of San Bernardino, Public Works Department, Transportation Operations Division, Flood Control District
- The County of San Bernardino, Planning Department, Land Development
- Mojave Desert Air Quality Management District
- California Department of Public Health
- California Department of Fish and Game
- California Regional Water Quality Control Board (Region 7, Colorado River)
- U.S. Army Corps of Engineers (ACOE)
- U.S. Fish and Wildlife Service
- U.S. Bureau of Land Management

5.2.12 Review of Land Use Plans and Coordination with Land Use Planning Agencies to Assess Activities which Create a Reasonable Risk of Groundwater Contamination

The Agency can communicate closely with City and County planners on the vulnerability of the groundwater resource and appropriate protection measures to ensure that future development activities do not increase the risk of groundwater contamination.

6 IMPLEMENTATION PLAN

Achieving the goals and management objectives described in the GWMP will depend largely on how successful identified strategies are implemented. Several factors must be considered for implementation, including the prioritization of strategies/actions, implementation schedule, costs and sources of funding, and periodic evaluation of plan performance. The purpose of this section is to discuss the factors critical to the successful implementation of the GWMP.

6.1 Implementation Plan and Schedule

Effective implementation of the GWMP is enhanced by the prioritization and scheduling of recommended actions. Given the results of the water balance and the increased reliance on groundwater to satisfy future water demands, the highest priority for groundwater management are those strategies that expedite the import and recharge of SWP water. **Figure 24** shows the proposed implementation schedule for management actions related to import and recharge of SWP water. The table identifies the lead agency or agencies and milestone reporting and implementation dates for each listed action.

The implementation schedule is further described below:

- July 1, 2012: MWA will activate Annual Baseline Amounts and water storage accounts for BDVWA, HDWD, W-1/Landers and W-4 Pioneertown at this time. Additionally, MWA will begin routine collection of monitoring data in accordance with guidelines outlined in the monitoring and reporting program.
- March 1, 2012 to September 1, 2012: MWA will construct the Reche Groundwater Recharge Project spreading grounds and associated conveyance facilities for planned operation in the 2012-13 fiscal year.
- July 10, 2013: By this date BDVWA, HDWD, W-1/Landers and W-4 Pioneertown will report to MWA the annual (fiscal year 2012-13) production volumes for all production wells. Reporting will occur on the same day of each year thereafter.
- July 10, 2013 to September 1, 2013: MWA will compile all groundwater production, water level, and water quality data for fiscal year 2012-13 and prepare the first annual data report for the Pipes and Reche monitoring and reporting program. Reporting will occur on the same day of each year thereafter.
- December 2017 (estimated): MWA will provide its first five-year report evaluating subbasin conditions and recommendations for groundwater management actions, including but not limited to possible adjustment to Annual Baseline Amounts and changes to the monitoring and reporting program.
- March 2018: Final adjustments and recommendations will be formalized within 90 days after circulation of the five-year report.

The coordination efforts to implement abovementioned strategies related to enhanced recharge will rely on the successful working relationship between the participating water agencies have already begun. Coordination with regulatory agencies has been successful to date and will be ongoing during the construction, final permitting, and operation of the Reche spreading grounds and implementation of the monitoring and reporting program. Further evaluation is needed to determine the need for 1) new production well(s) by BDVWA to more effectively capture natural and enhanced recharge and 2) a water treatment system to address elevated radionuclide levels. Therefore, no milestones have been assigned to these strategies at this time.

6.2 Re-Evaluation of Management Performance

The end of the 2015-16 fiscal year marks the end of the initial five-year period for implementation of management strategies identified in this GWMP. The attached New Agreement specifies that MWA will prepare a five-year report, which will re-evaluate the state of the Pipe and Reche subbasins and evaluate the performance of groundwater management strategies. The report will present recommendations for needed groundwater management actions, including potential adjustment to Annual Baseline Amounts, changes to the monitoring and reporting program, and identification of additional management strategies. Although no publication date is provided at this time, it is anticipated that the five-year report will be published and distributed to BDVWA, HDWD, and CSA 70 by December 2016. The first determination on potential adjustment to Annual Baseline Amounts will be made 90 days after circulation of the five-year report (March 2017).

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TABLES

Table 1
Groundwater Subbasins and Watersheds

DWR Groundwater Basin (Basin No.)	USGS Morongo Subbasin	Subbasin Area (acres)	Contributing Watershed Area (acres)
Ames Valley (7-16)	Pipes	13,700	57,438
	Reche	15,600	
Total		29,300	57,438

Table 2
Surface Water Contributions to the Study Area

Surface Water Source	Average Annual Rainfall[1] (inches)	Catchment Area[2]	
		(mi^2)	(acres)
Pipes Wash (Antelope Creek)	8.5	55.3	35,423
Whalen's Wash	6.4	21.0	13,434
Ruby Mountain Wash	5.4	13.4	8,581
Total	7.6	89.7	57,438

[1]Based on a computer-generated average from a raster surface of isohyetal map by James (1992)

Table 3
Aquifer Hydraulic Parameters for Study Area Wells

USGS Morongo Subbasin	State Well Number	Common Name	Depth to SWL	Depth to Top of Well Screen	Depth to Bottom of Well Screen	Total Saturated Screen Length	Well Yield	Water Level Drawdown	Pumping Duration	Specific Capacity	Transmissivity[a]	Hydraulic Conductivity[b] b = sat. screen length	Hydraulic Conductivity[b] b = SWL - screen bottom	Data Source[e]
			feet bgs	feet	feet	feet	gpm	feet	hours	gpm/ft dd	gpd/ft	gpd/ft²	gpd/ft²	
Pioneertown	1N4E 01K5		N/A	100	422	322	2.5	200.0	2.0	0.0	19	0.1	N/A	Driller's log
Pioneertown	1N4E 01N3		23	60	100	40	7.0	137.0	1.0	0.1	77	1.9	1.0	Driller's log
Pioneertown	1N4E 01R4		69	225	325	100	5.0	200.0	4.0	0.0	38	0.4	0.1	Driller's log
Pioneertown	1N4E 02B5		70	120	280	160	10.0	40.0	2.0	0.3	375	2.3	1.8	Driller's log
Pioneertown	1N4E 02H2		38	66	305	239	4.0	150.0	2.0	0.0	40	0.2	0.1	Driller's log
Pioneertown	1N4E 02J3		50	100	205	105	5.0	40.0	2.0	0.1	188	1.8	1.2	Driller's log
Pioneertown	1N4E 11A1		45	350	370	20	0.5	195.0	0.8	0.0	4	0.2	<0.1	Driller's log
Pioneertown	1N4E 11B1		30	311	358	47	1.0	327.0	5.0	0.0	5	0.1	<0.1	Driller's log
Pioneertown	1N4E 11H1		22	60	360	300	3.0	300.0	4.0	0.0	15	0.1	<0.1	Driller's log
Pioneertown	1N4E 12D2		50	143	188	45	7.0	13.0	1.0	0.5	808	17.9	5.9	Driller's log
Pioneertown	1N5E 06B2		20	68	460	392	1.0	460.0	2.0	0.0	3	<0.1	<0.1	Driller's log
Pioneertown	1N5E 06C1		32	80	385	305	5.0	240.0	4.0	0.0	40	0.1	0.1	Driller's log
Pioneertown	1N5E 06D3		40	224	264	40	1.0	224.0	4.0	0.0	7	0.2	<0.1	Driller's log
Pioneertown	1N5E 06Q1		41	240	300	20[c]	0.5	259.0	3.0	0.0	3	0.1	<0.1	Driller's log
Pioneertown	1N5E 06R1		405	0	665	260	0.8	250.0	12.0	0.0	5	<0.1	<0.1	Driller's log
Pioneertown	1N5E 07G1		57	150	422	272	7.0	250.0	3.0	0.0	42	0.2	0.1	Driller's log
Pipes	2N5E 36C1	HDWD #20	274	260	460	166	220.0	10.4	24.0	21.2	31,731	170.6	171.0	Pumping Test
Pipes	1N5E 09P1		88	192	272	80	7.0	60.0	2.0	0.1	175	2.2	1.0	Driller's log
Pipes	1N5E 10F2		115	110	240	125	1.0	240.0	6.0	0.0	6	0.1	0.1	Driller's log
Pipes	1N5E 10F3		125	220	320	100	4.0	5.0	3.0	0.8	1,200	12.0	6.2	Driller's log
Pipes	2N5E 10Q1		253	195	385	132	3.0	104.0	30.0	0.0	43	0.3	0.3	Driller's log
Pipes	2N5E 22J1	BDVWA #8	269	250	775	506	632.0	12.1	N/A	52.2	78,375	154.9	154.9	Pumping Tests
Pipes	2N5E 23K1		229	88	450	221	50.0	180.0	4.0	0.3	417	1.9	1.9	Driller's log
Pipes	2N5E 23K3		227	225	300	73	22.0	5.0	7.0	4.4	6,600	90.4	90.4	Driller's log
Pipes	2N5E 27K2	BDVWA #2	195	184	319	109	406.5	11.3	N/A	36.3	54,500	514.6	479.1	Pumping Tests
Pipes	2N5E 27K3	BDVWA #3	181	208	316	103	453.9	10.6	N/A	45.1	67,640	653.9	515.4	Pumping Tests
Pipes	2N5E 27R1	BDVWA #4	212	260	470	72[c]	409.7	25.1	N/A	16.7	25,083	348.4	97.1	Pumping Tests
Pipes	2N5E 34H2		247	238	418	171	13.0	7.0	2.0	1.9	2,786	16.3	16.3	Driller's log
Pipes	1N5E 02A1	HDWD #21	400[d]	300	600	120[c]	15.0	200.0	N/A	0.1	113	0.9	0.6	HDWD
Reche	2N5E 12B1	BDVWA #6	145	144	384	239	344.8	11.3	N/A	30.4	45,598	190.8	190.7	Pumping Tests
Reche	2N5E 12B2	BDVWA #7	143	180	400	220	400.9	9.6	N/A	41.8	62,695	285.0	244.6	Pumping Tests
Reche	2N5E 12C2	BDVWA #9	170	200	490	290	799.4	21.6	N/A	37.2	55,813	192.5	174.6	Pumping Tests
Reche	2N5E 12E1		206	200	260	54	32.0	5.0	1.0	6.4	9,600	177.8	177.8	Driller's log
Reche	2N5E 23J1		227	225	300	73	22.0	5.0	7.0	4.4	6,600	90.4	90.4	Driller's log
Reche	2N5E 24H1	HDWD #24	290	220	580	290	759.0	11.0	24.0	69.0	325,380[f]	1122.0	1122.0	Pumping Test
Reche	2N6E 07Q3	CSA Well #3	209	253	353	100	400.0	11.0	39.0	36.4	54,545	545.5	378.8	Driller's log
Reche	2N6E 18B1	CSA Well #1	186	187	305	118	517.0	20.0	26.0	25.9	38,775	328.6	325.8	Driller's log
Reche	2N6E 30L1		285	365	375	10	2.0	20.0	6.0	0.1	150	15.0	1.7	Driller's log
Reche	2N6E 30N1	HDWD #6	256	300	920	620	160.0	254.0	71.0	0.6	945	1.5	1.4	Driller's log
Reche	3N5E 21A1		249	285	323	38	10.0	51.0	2.0	0.2	294	7.7	4.0	Driller's log
Reche	3N5E 23C2			277	345	68	26.0	30.0	1.0	0.9	1,300	19.1	3.8	Driller's log
Reche	3N5E 23M1		230	190	270	40	10.0	260.0	8.0	0.0	58	1.4	1.4	Driller's log
Reche	3N5E 23M2			200	300	100	7.0	20.0	2.0	0.4	525	5.3	1.8	Driller's log
Reche	3N5E 23N1		208	220	280	60	6.0	62.0	12.0	0.1	145	2.4	2.0	Driller's log
Reche	3N5E 26E1		86	95	126	31	10.0	20.0	2.0	0.5	750	24.2	18.8	Driller's log
Reche	3N5E 35J2		175	175	261	86	5.0	78.0	12.0	0.1	96	1.1	1.1	Driller's log
Reche	3N5E 35R1		150	149	192	42	15.0	5.0	8.0	3.0	4,500	107.1	107.1	Driller's log
Reche	3N5E 35M1		178	170	238	60	10.0	50.0	2.0	0.2	300	5.0	5.0	Driller's log

[a]Equals 1500 * Specific Capacity (Driscoll (1986) Appendix 16D for unconfined aquifers)
[b]Equals Transmissivity / effective aquifer thickness (b)
[c]Screen length is less than depth to top of screen minus depth to bottom of screen, b/c of blank screen intervals
[d]Based on historic SWL at ~400 ft bgs and assumed PWL at bottom of screen
[e]For "pumping tests" sources, well yield, SWL, and drawdown represent average values from historic pumping tests; Specific Capacity may not equal Well Yield divided by Water Level Drawdown, and Hydraulic Conductivity may not equal Transmissivity divided by thickness, b
HDWD = Memorandum RE: HDWD 21 Pumping Test Results. From Marsh Goldblatt (General Manager HDWD) to Steve Winke
[f]Estimated from 10-5-2010 pumping test with BDVWA MW2 as observation well

Table 4
Groundwater Level Trends in Pipes Subbasin Wells

State Well Number	Well Name	Well Type	Ave. Production 1990-2009 (AFY)	Change in Groundwater Level (feet)			
				1990-09	1990-91	1992-97	1998-09
2N/5E-27K2	BDVWA 2	Prod	62	-46	-2	-33	-11
2N/5E-27K3	BDVWA 3	Prod	80	-45	-2	-33	-10
2N/5E-27R1	BDVWA 4	Prod	92	-45	-3	-32	-10
2N/5E-22J1	BDVWA 8	Prod	130	-46	**	-29	-17
2N/5E-23M1	BDVWA 1	Monitor		> -29	-1	> -28	-
2N/5E-27A1	USGS Mon.	Monitor		-47	-2	-33	-12
2N/5E-36C1	HDWD 20	Monitor		±0	-1	1	±0
1N/5E-02N1		Monitor		7	-5	22	-10

** = water level data not available for BDVWA #8 for 1990 and 1991

Table 5

Groundwater Level Trends in Reche Subbasin Wells

State Well Number	Well Name	Well Type	Ave. Production 1990-2009 (AFY)	Change in Groundwater Level (feet)			
				1990-09	1990-92	1993-99	2000-09
2N/5E-12B1	BDVWA 6	Prod	78	-13	11	-6	-18
2N/5E-12B2	BDVWA 7	Prod	73	-13	10	-5	-18
2N/5E-12C2	BDVWA 9	Prod	98	-14	-1	-9	-4
2N/5E-24H1	HDWD 24	Prod	491	-36	1	-26	-11
2N/6E-18B1	CSA 70 1	Prod	54	-20	2	-10	-12
2N/6E-18B2	CSA 70 2	Prod	50	-18	2	-7	-13
2N/6E-30N1	HDWD 6	Monitor		-40	-29	-3	-8
2N/5E-01G1	Gubler Farm	Monitor		-6	3	-1	-8
2N/5E-01K1	Gubler Farm	Monitor		-2	5	-4	-3
2N/5E-13A1	Moran	Monitor		> -17	2	-10	> -9

Table 6
Groundwater in Storage

USGS Subbasin	Surface Area		Average Specific Yield	Average Thickness of Saturated Basin Fill Sediments	Groundwater in Storage
	mi^2	acres		feet	AF
Pipes	21.4	13,700	0.12	217	356,100
Reche	24.4	15,600	0.12	129	242,300
Total	45.8	29,300	0.12	181	598,400

Table 7
Available Vadose Zone Storage

USGS Subbasin	Surface Area		Average Specific Yield	Average Thickness of Unsaturated Basin Fill Sediments	Groundwater in Storage
	mi2	acres		feet	AF
Pipes	21.4	13,700.0	0	216	355,100
Reche	24.4	15,600	0.12	223	417,500
Total	45.8	29,300	0.12	220	772,600

Table 8
Groundwater Quality in Municipal Production Wells

	Drinking Water Standards (MCLs)	PIPES SUBBASIN				RECHE SUBBASIN								
		BDVWA 2	BDVWA 3	BDVWA 4	BDVWA 8	BDVWA 6	BDVWA 7	BDVWA 9	HDWD 24	CSA 70 W-11	CSA 70 W-12	CSA 70 W-13	BDVWA MW1	BDVWA MW2
		07/27/09	12/08/08	01/16/08	07/27/09	12/08/08	12/08/08	07/27/09	11/12/09	11/06/08	11/06/08	11/06/08	09/23/10	09/24/10
	(values in mg/L unless designated otherwise)													
MAJOR IONS														
Calcium		53	58	56	22	42	40	39	45	26	33	35	49	43
Magnesium		11	12	10	2	7	7	66	8	4	5	5	9	9
Potassium		4	4	2	3	3	3	3	2	2	2	3	5	5
Sodium		46	47	36	79	49	49	53	37	43	46	42	63	45
Bicarbonate		240	220	270	160	190	200	170	210	140	160	170	230	210
Chloride	250[b]	24	35	17	31	18	18	24	12	18	20	17	17	34
Sulfate	250[b]	35	46	34	46	34	33	48	22	28	30	28	21	35
MINOR IONS														
Boron		0.1	0	–	ND	0.15	0.13	0.12	–	ND	ND	0.15	0.18	0.16
Bromide		–	–	–	–	–	–	–	–	–	–	–	–	–
Iron	0.3b	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.3	0.5
Manganese	0.050[b]	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2	0.1
Nitrite and Nitrate, as N	10[a]	ND	1.5	–	1.9	1.5	1.6	2.3	1[e]	1.4	1.6	1.4	0.6	0.5
PHYSICAL PARAMETERS AND OTHER PROPERTIES														
Specific Conductance (mS/cm)	900[b]	530	560	490	470	440	450	460	440	350	390	390	530	440
Total Dissolved Solids (TDS)	500[b]	320	340	320	280	280	290	290	250	180	200	200	270	320
pH (units)	6.5-8.5[b]	7.8	7.9	7.8	8.2	7.9	7.9	8.1	7.8	8	8	7.9	7.7	7.9
Alkalinity, as $CaCO_3$		200	180	220	130	160	160	140	170	110	130	140	190	170
Hardness, as $CaCO_3$		170	190	180	64	130	130	120	150	80	110	110	140	130
Turbidity (NTU)	5[b]	ND	ND	–	ND	0.1	0.3	ND	ND	ND	ND	ND		
TRACE METALS														
Aluminum	0.1[a]	ND	ND	–	ND	ND	ND	ND	ND	ND	ND	ND	0.4	0.61
Antimony	0.006[a]	ND	ND	–	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Arsenic	0.010[a]	0.003	ND	–	0.0057	ND	ND	ND	0.0034	0.0041	0.0041	0.039	ND	ND
Barium	1[a]	ND	ND	–	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Beryllium	0.004[a]	ND	ND	–	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cadmium	0.005[a]	ND	ND	–	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chromium (total)	0.050[a]	ND	ND	–	ND	ND	ND	ND	0.0068	ND	ND	ND	ND	ND
Copper	1[a]	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Lead	0.015[a]	ND	ND	–	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Mercury	0.002[a]	ND	ND	–	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Nickel	0.1[a]	ND	ND	–	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Selenium	0.050[a]	ND	ND	–	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Silver	0.1[b]	ND	ND	–	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Thallium	0.002[a]	ND	ND	–	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Zinc	5.0[b]	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Radionuclides														
Gross Alpha (pCi/L)	15[a]	15[d]	8.1[d]	13[e]	ND	7.9[e]	8[i]	6.8	11.1	ND[m]	ND[m]	5.6[n]	11	7.3
Uranium (pCi/L)	20[a]	16[d]	14[d]	20[f]	1[g]	6[h]	7.6[j]	5.6[k]	10[l]	3.1[o]	3.2[o]	4.6[p]	14	ND

Notes:

Data are from most recent water quality sample available for each well

mg/L = milligrams per liter

mS/cm = microSiemens per centimeter

NTU = nephelometric turbidity units

pCi/L = picoCuries per liter

– = Not Analyzed

ND = Not detected above reporting limit

[a] Primary Maximum Contaminant Level (MCL)

[b] Secondary MCL

[c] Calculated from nitrate (as NO_3) result

[d] 12/14/09; [e] 6/11/07; [f] 1/28/08; [g] 2/16/99; [h] 2/22/99; [i] 1/23/08; [j] 1/14/08; [k] 8/13/07; [l] 2/20/08; [m] 10/23/02; [n] 8/16/06; [o] 10/4/06

Table 9
SWP Water Quality Summary

	Drinking Water Standards	SWP Water Quality Data		
		Mininum	Maximum	Average
	(all values in mg/L unless designated otherwise)			
MAJOR IONS				
Calcium		15	34	27
Magnesium		5	15	10
Potassium		--	--	--
Sodium		24	71	59
Bicarbonate[1]		64	111	96
Chloride	250[b]	28	100	74
Sulfate	250[b]	19	81	48
MINOR IONS				
Boron		0.1	0.3	0.2
Bromide		0.10	0.37	0.26
Iron	0.3[b]	ND	0.010	0.007
Manganese	0.050[b]	ND	0.067	ND
Nitrite and Nitrate, as N	10[a]	0.10	1.80	0.93
PHYSICAL PARAMETERS AND OTHER PROPERTIES				
Specific Conductance (uS/cm)	900[b]	233	600	495
Total Dissolved Solids (TDS)	500[b]	152	350	286
pH (units)		--	--	--
Alkalinity, as $CaCO_3$		52	91	78
Hardness, as $CaCO_3$		70	138	108
Turbidity (NTU)	5[b]	1	18	5
Organic Carbon, Dissolved		1.0	3.7	2.3
Organic Carbon, Total		1.0	3.9	2.5
Phosphate, Ortho, as P		0.01	0.10	0.04
Phosphorus, Total		0.02	0.15	0.06
TRACE METALS				
Aluminum	0.1[a]	--	--	--
Antimony	0.006[a]	--	--	--
Arsenic	0.010[a]	0.002	0.006	0.004
Barium	1[a]	--	--	--
Beryllium	0.004[a]	ND	ND	ND
Cadmium	0.005[a]	--	--	--
Chromium	0.050[a]	0.001	0.005	0.002
Copper	1[b]	0.001	0.003	0.002
Lead	0.015[a]	ND	ND	ND
Mercury	0.002[a]	--	--	--
Nickel	0.1[a]	--	--	--
Selenium	0.050[a]	0.001	0.002	0.001
Silver	0.1[b]	--	--	--
Thallium	0.002[a]	--	--	--
Zinc	5.0[b]	ND	ND	ND

Notes:
Water quality from monthly grab samples (Jan 2008 through Sep 2009) at SWP Check 41
mg/L = milligrams per liter
uS/cm = microSiemens per centimeter
NTU = nephelometric turbidity units
-- = Not Analyzed
ND = Not detected above reporting limit
[1] Calculated bicarbonate concentration: Alkalinity x 1.2192
[a] Primary Maximum Contaminant Level (MCL)
[b] Secondary MCL

Table 10
Annual Water Budget

	Subsurface Inflow	Return Flow	Pumping	Subsurface Outflow[1]	Annual Storage Change
Water Year					
1994-95	1,051	204	-1,568	-579	-893
1995-96	1,344	204	-2,297	-579	-1,329
1996-97	864	238	-1,537	-579	-1,014
1997-98	486	240	-1,901	-579	-1,754
1998-99	1,144	243	-1,424	-579	-617
1999-00	705	268	-1,135	-579	-742
2000-01	456	297	-1,296	-579	-1,122
2001-02	382	293	-1,390	-579	-1,294
2002-03	207	304	-1,148	-579	-1,216
2003-04	645	270	-1,322	-579	-986
2004-05	570	265	-1,064	-579	-808
2005-06	1,534	252	-899	-579	308
2006-07	1,033	273	-1,156	-579	-429
2007-08	442	295	-1,321	-579	-1,163
2008-09	608	273	-1,285	-579	-984
Average	765	261	-1,383	-579	-936

Values in acre-feet
[1]Value represents average based on steady-state simulation

Table 11
Cumulative Water Budget

	Cumulative Subsurface Inflow	Cumulative Return Flow	Cumulative Pumping	Cumulative Subsurface Outflow	Cumulative Annual Storage Change
Water Year					
1994-95	1,051	204	-1,568	-579	-893
1995-96	2,394	407	-3,865	-1,159	-2,222
1996-97	3,258	646	-5,402	-1,738	-3,236
1997-98	3,744	886	-7,303	-2,317	-4,991
1998-99	4,888	1,129	-8,727	-2,896	-5,607
1999-00	5,593	1,397	-9,863	-3,476	-6,349
2000-01	6,049	1,694	-11,159	-4,055	-7,471
2001-02	6,431	1,987	-12,548	-4,634	-8,764
2002-03	6,638	2,291	-13,696	-5,213	-9,980
2003-04	7,282	2,562	-15,018	-5,793	-10,966
2004-05	7,853	2,827	-16,082	-6,372	-11,774
2005-06	9,387	3,079	-16,981	-6,951	-11,466
2006-07	10,419	3,352	-18,137	-7,530	-11,896
2007-08	10,861	3,647	-19,458	-8,110	-13,059
2008-09	11,469	3,920	-20,743	-8,689	-14,043

Values in acre-feet

Table 12
Water Budget Summary

	15-Year Study Period (AFY)	Long-Term Average[a] (AFY)
TOTAL INFLOWS	**1,026**	**1,149**
Natural Recharge from Rainfall Runoff	703	827
- Pipes Wash	*490*	*577*
- Whalen's Wash	*138*	*162*
- Ruby Mountain Wash	*75*	*88*
Subsurface Inflow (Non-Wash)	61	61
Septic Return Flows Subtotal	261	261
TOTAL OUTFLOWS	**1,962**	**1,962**
Groundwater Pumping	1,383	1,383
Subsurface Outflow to Giant Rock	579.0	579.0
CHANGE IN STORAGE	**(936.2)**	**(813.0)**

[a] Natural Recharge from rainfall for Long-Term Average = 1,026 AFY / 0.85

Table 13
SWP Water Entitlement

Water Agency	SWP Water Entitlement	
	% of IDM	AFY
HDWD	59	4,282
JBWD	27	1,959
BDVWA	9	653
CSA 70 W-1	1	73
CSA 70 W-4	0	0
MWA*	4	290
TOTAL	**100**	**7,257**

*Since the MBP agreement, CSA 70 has sold/transferred back to MWA 3% of the original 4% entitlement for Zone W-1 and 1% entitlement for Zone W-4.

Table 14
Annual Baseline Amounts

Water Agency	AFY
HDWD	703
BDVWA	641
CSA 70 W-1	267

FIGURES

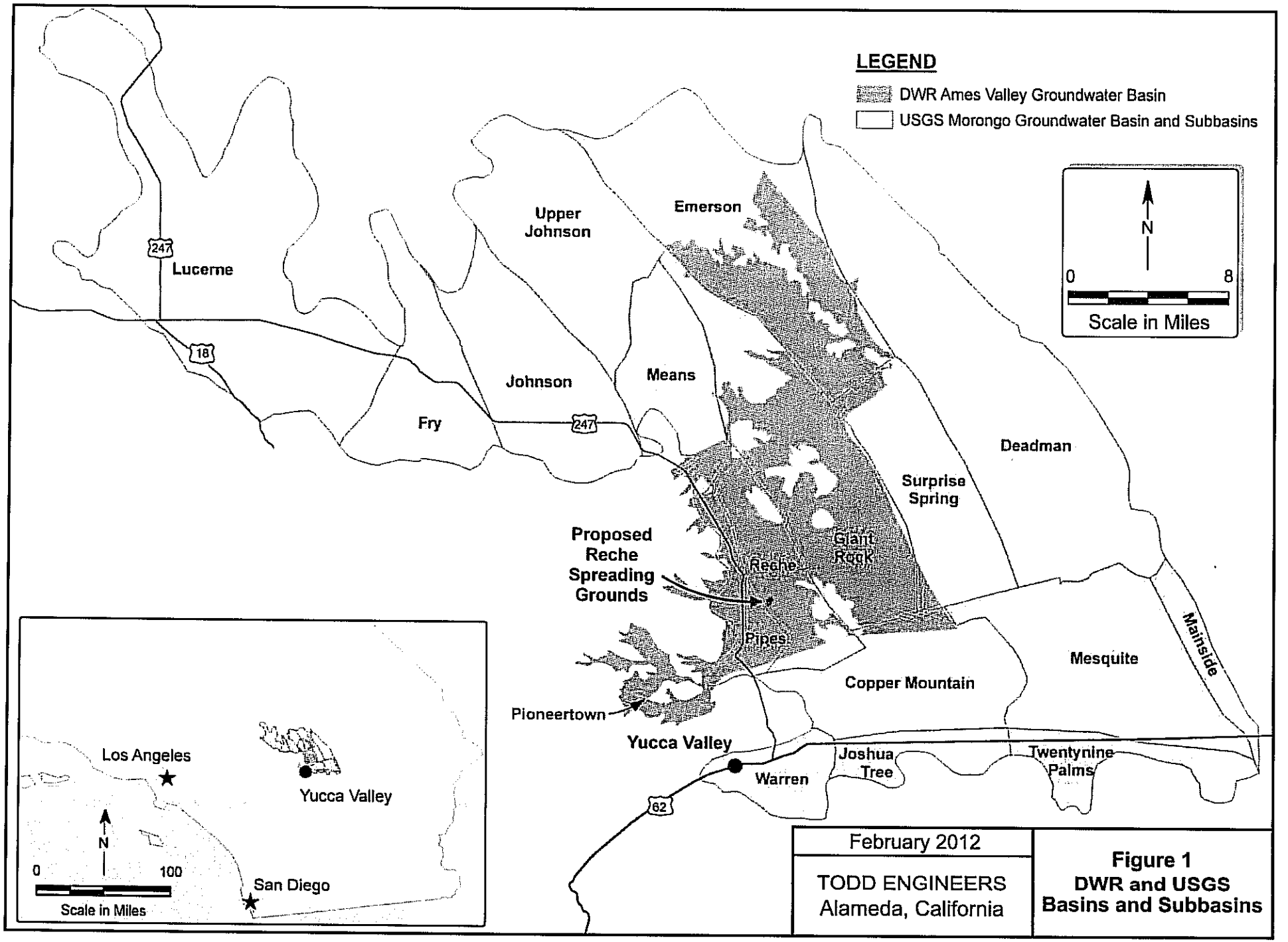

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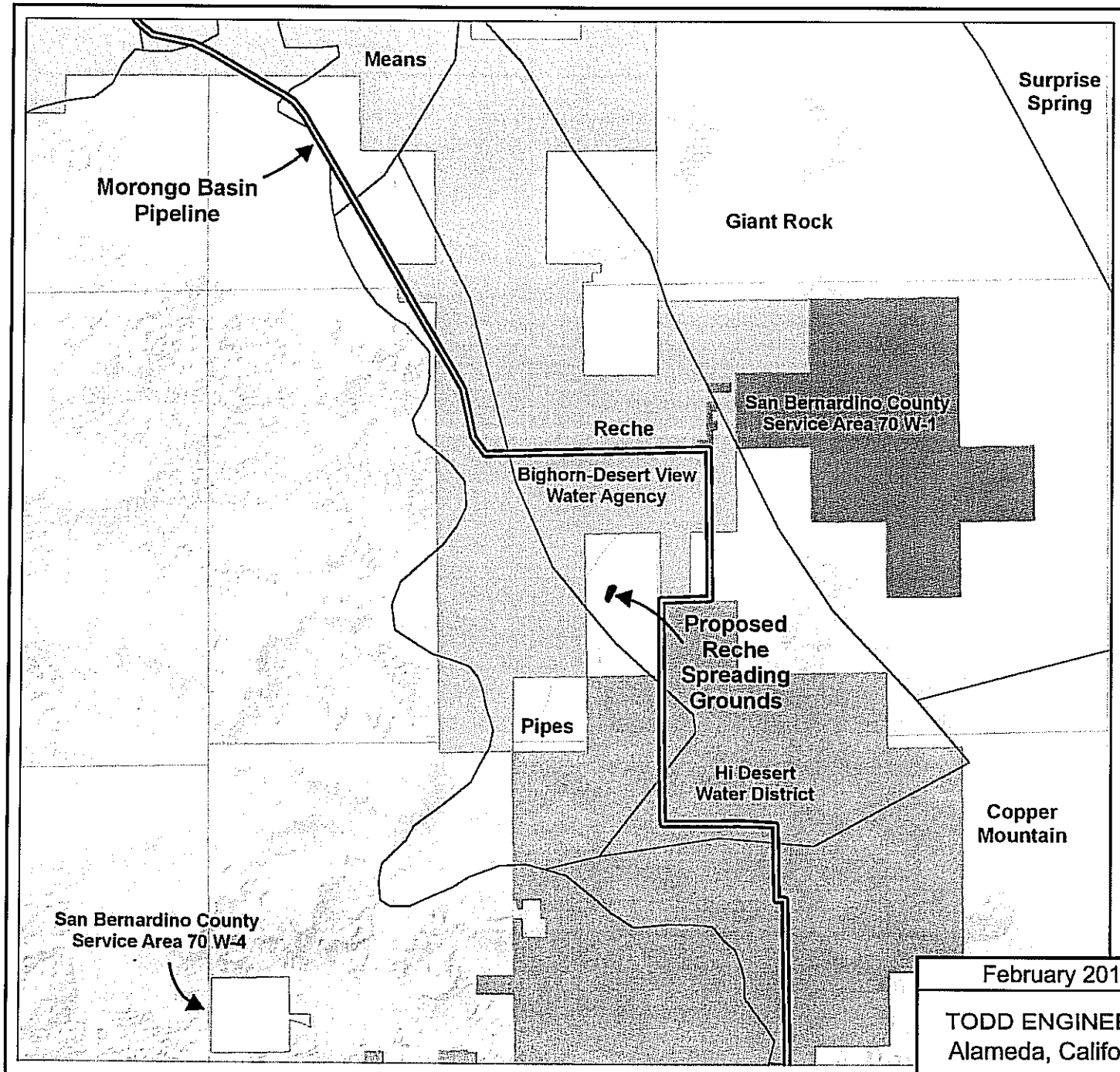
Figure 1
DWR and USGS Basins and Subbasins



LEGEND

- Morongo Basin Pipeline
- Proposed Reche Spreading Grounds
- USGS Morongo Subbasin
- Bighorn-Desert View Water Agency
- Hi Desert Water District
- County Service Area 70 W1
- County Service Area 70 W4

N

0 2

Scale in Miles

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Figure 2
Water Providers and Morongo Basin Pipeline

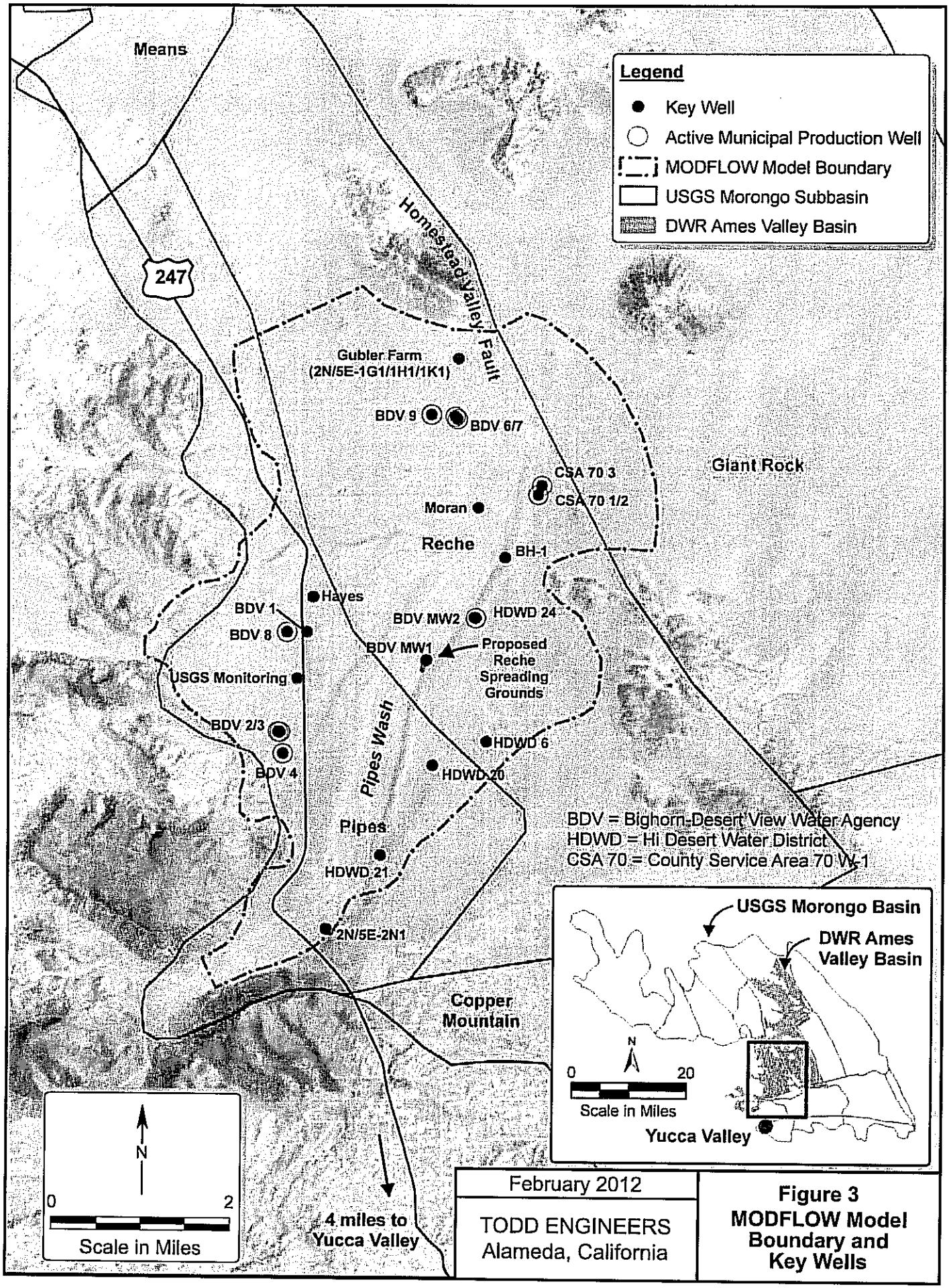

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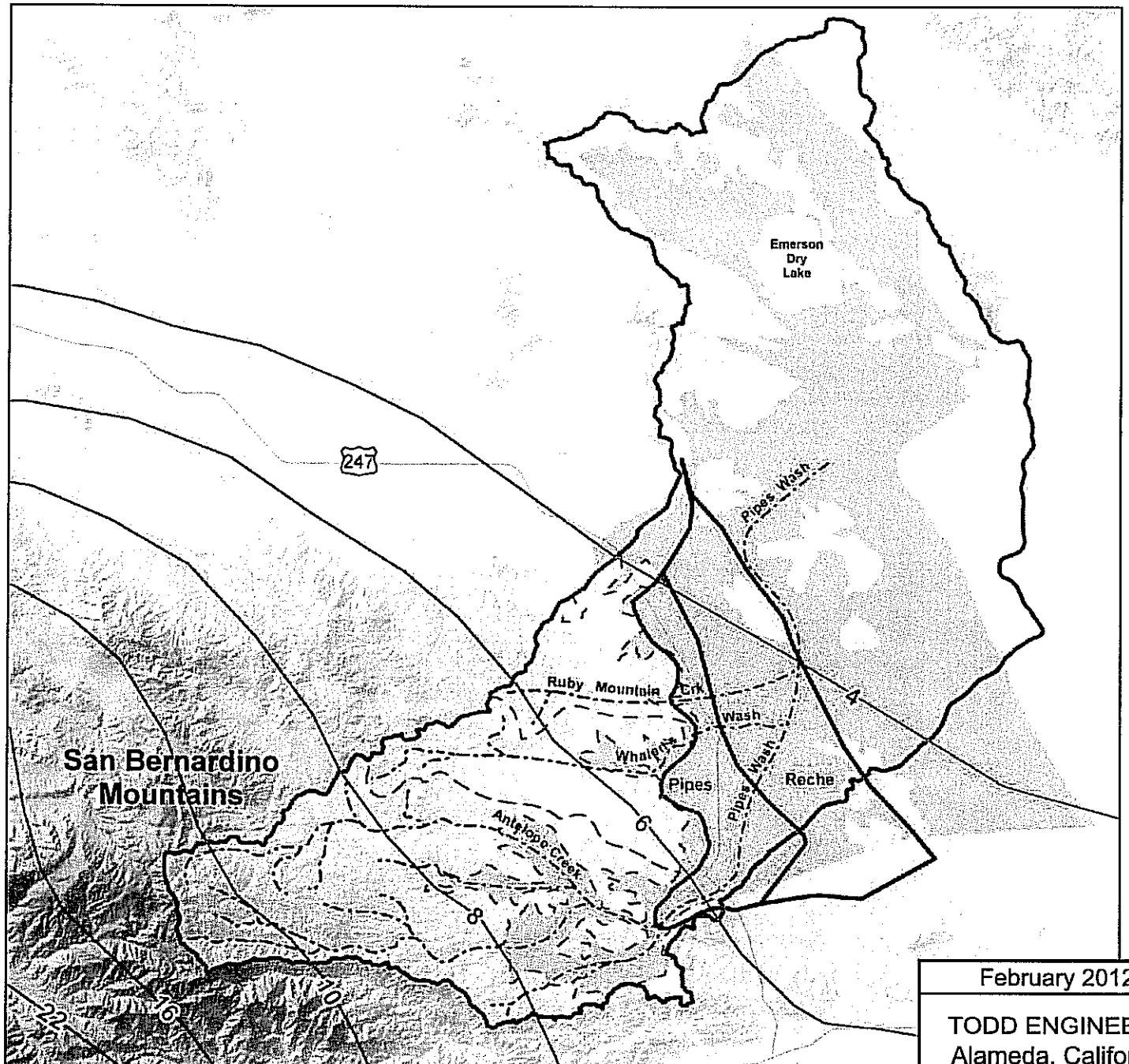
Figure 3
MODFLOW Model Boundary and Key Wells



LEGEND

- Watershed Boundary
- Contributing Catchment
- Major Drainage Channel
- Average Annual Rainfall Isohyet (in)
- Dry Lake
- USGS Morongo Subbasin
- DWR Ames Valley Basin

N

0 4

Scale in Miles

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Figure 4
Watershed and Drainages

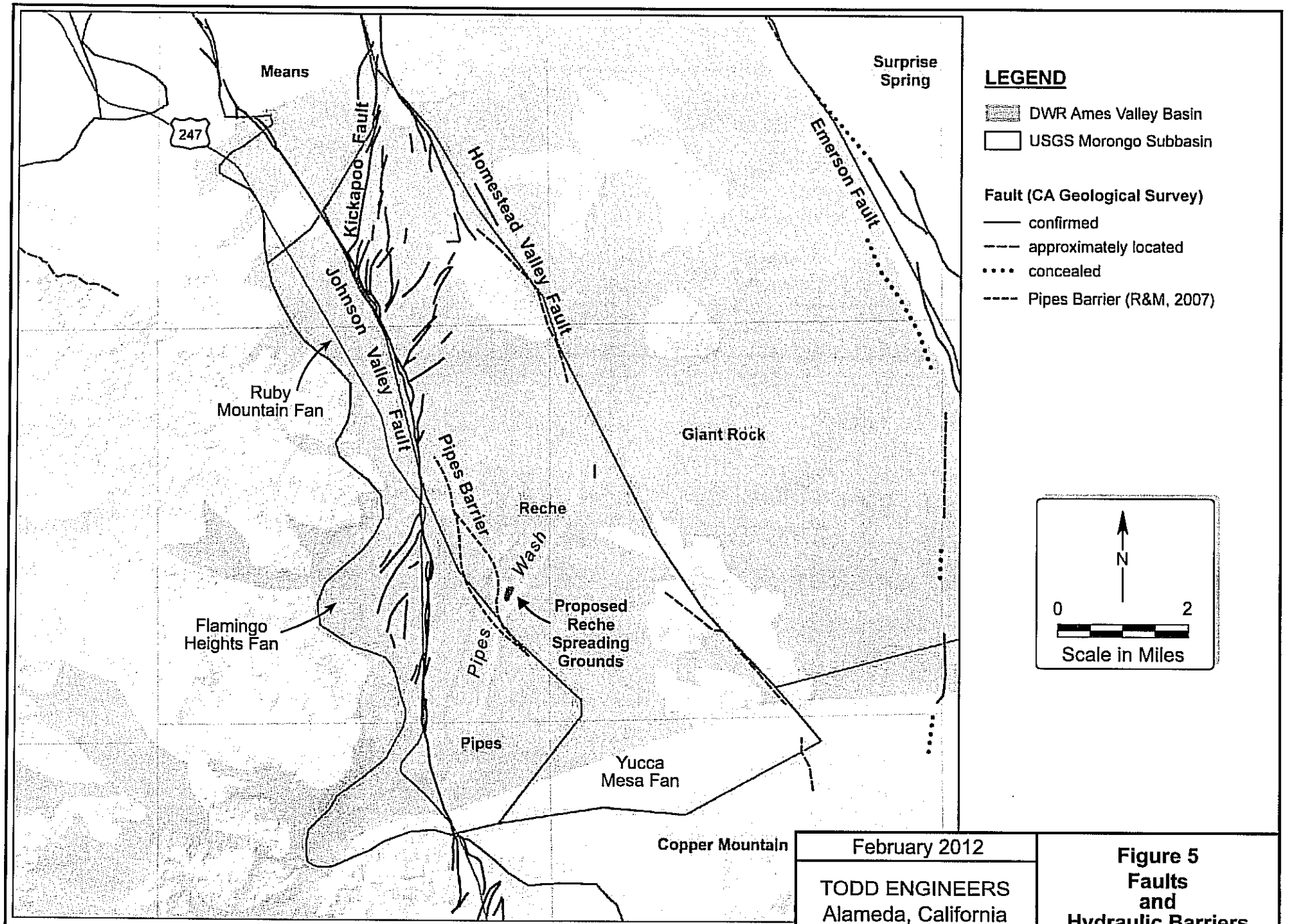

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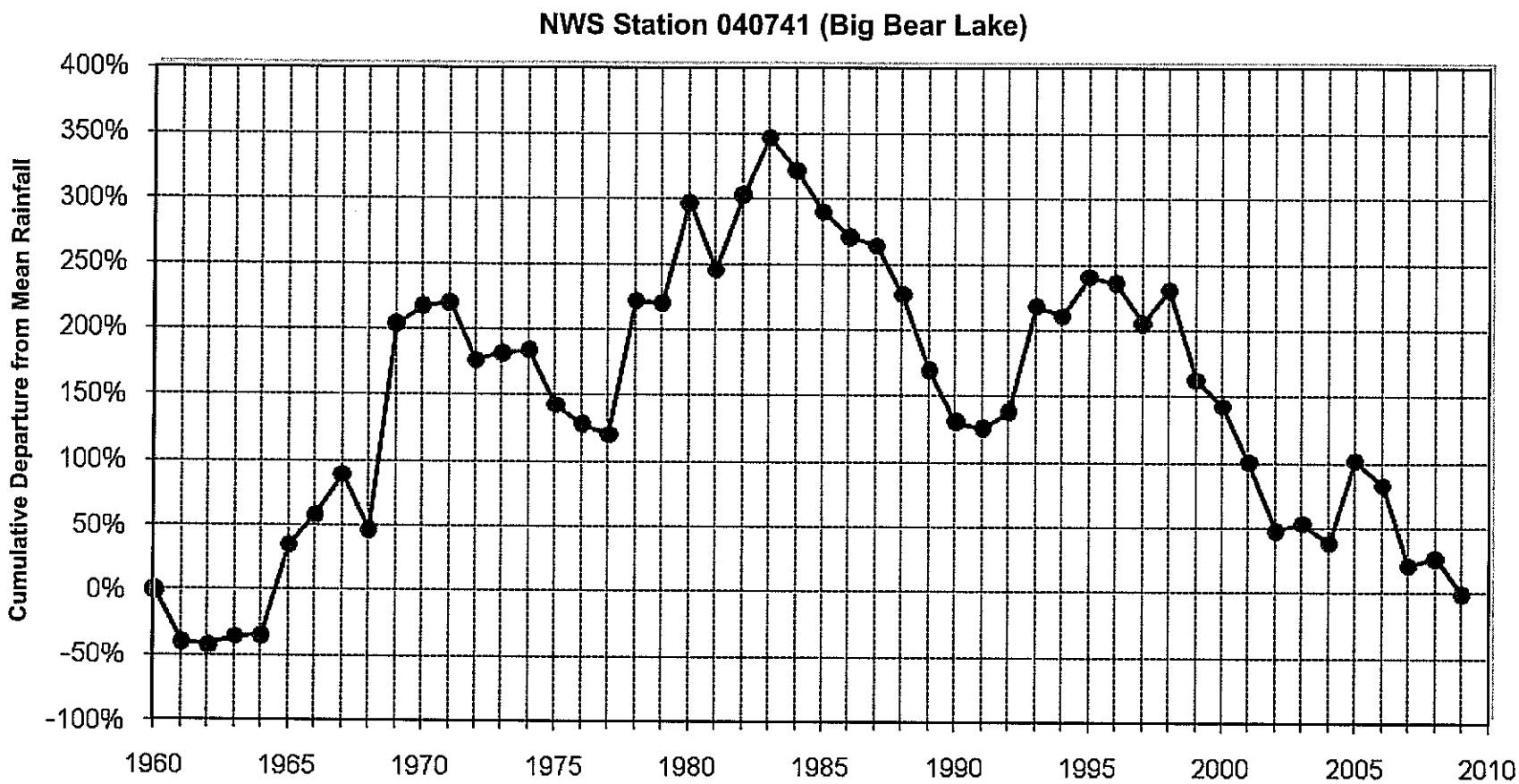
Figure 5
Faults and Hydraulic Barriers



February 2012	**Figure 6**
TODD ENGINEERS Alameda, California	**Cumulative Departure rom Mean Rainfall**

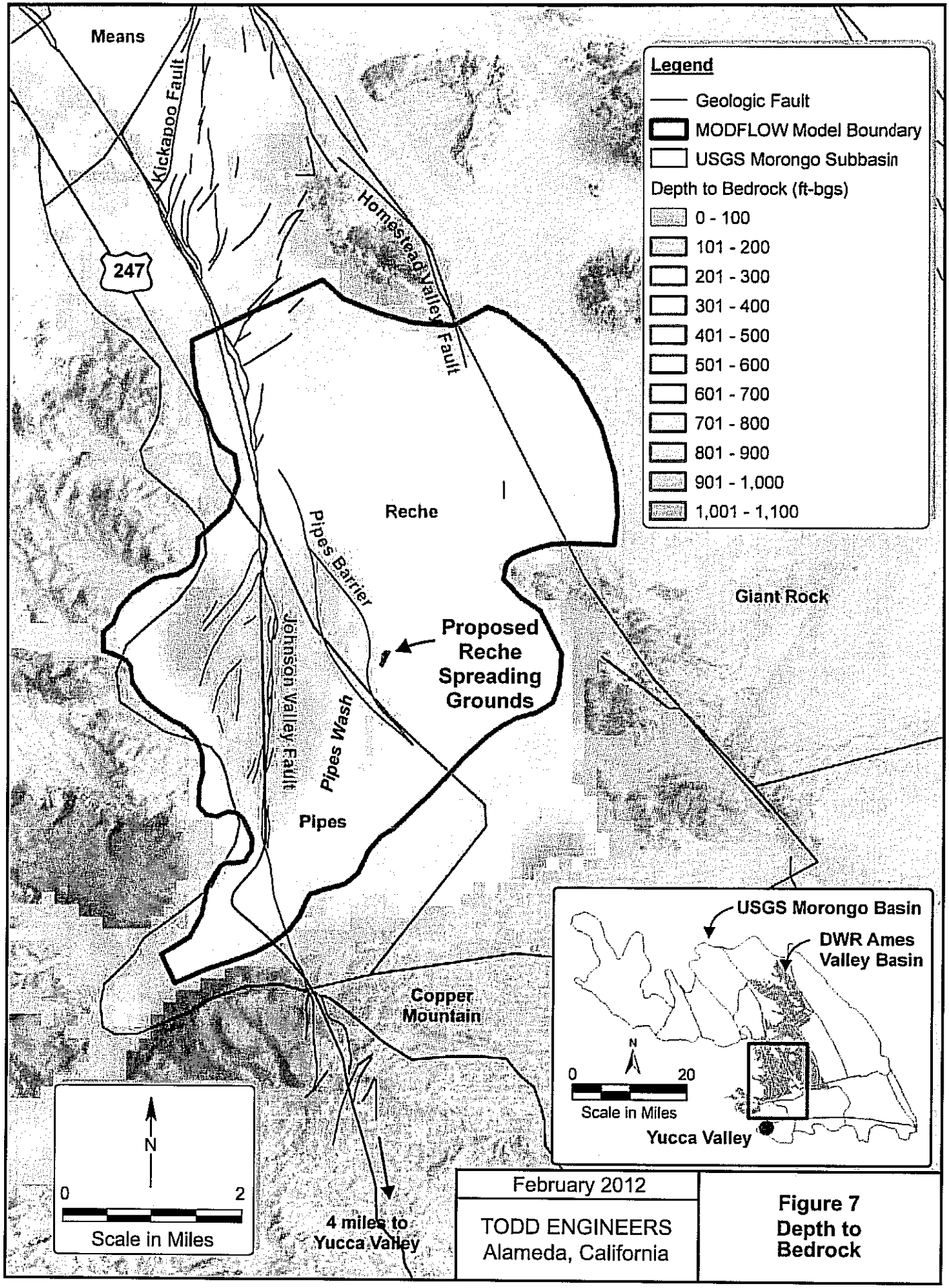


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Figure 7
Depth to Bedrock

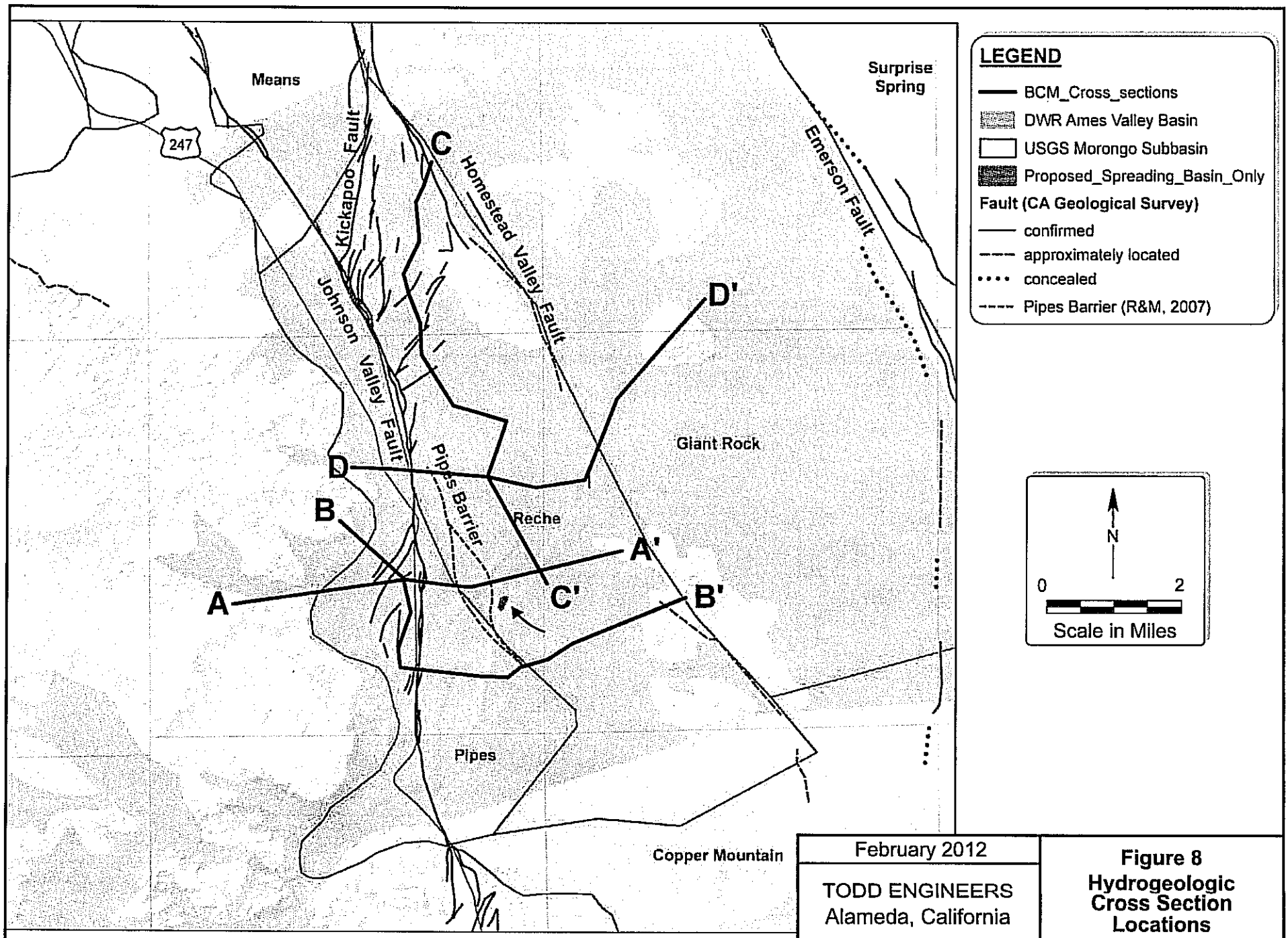

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Figure 8
Hydrogeologic Cross Section Locations

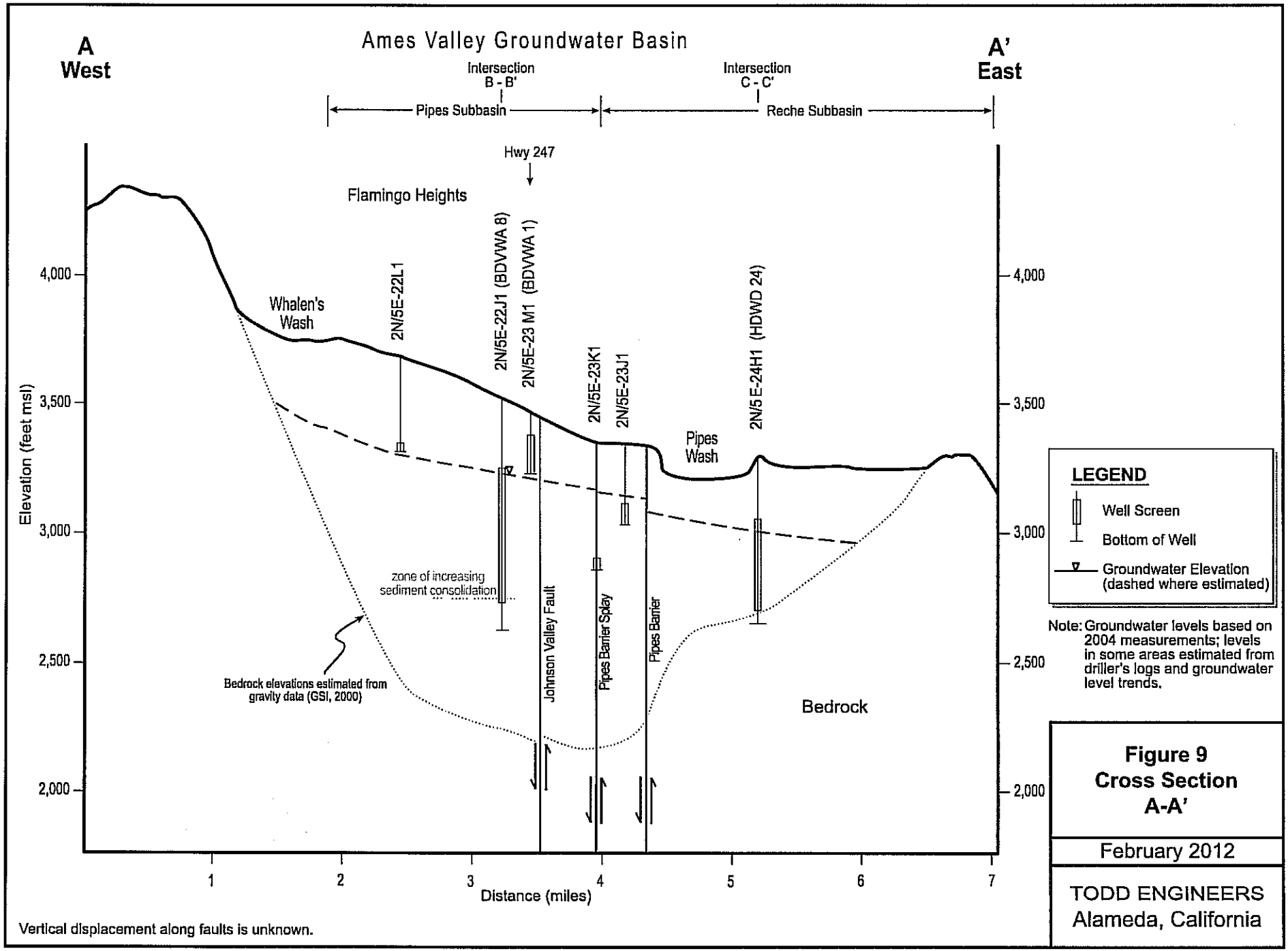

Figure 9
Cross Section
A-A'

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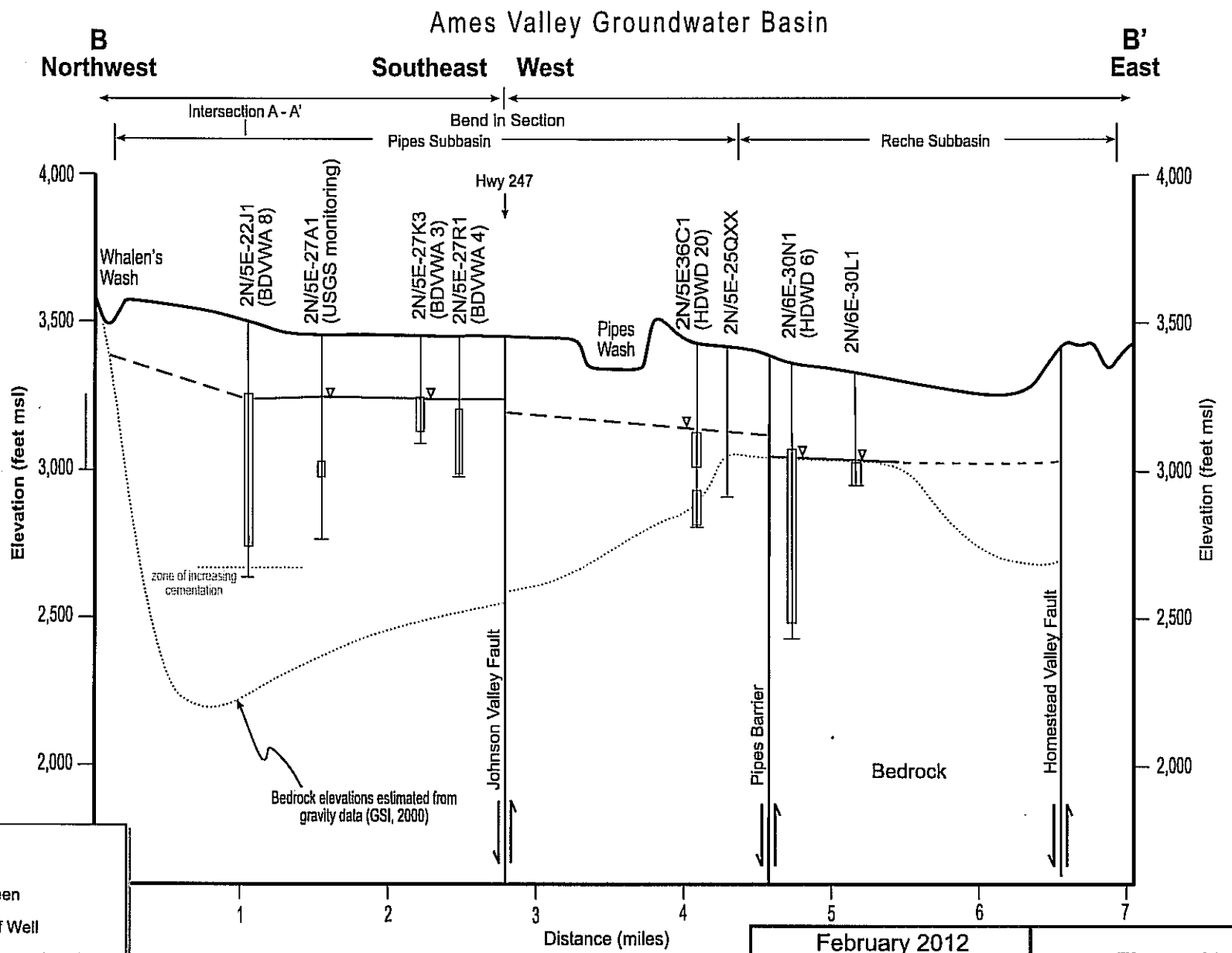

Note: Groundwater levels based on 2004 measurements; levels in some areas estimated from driller's logs and groundwater level trends.

Vertical displacement along faults is unknown.

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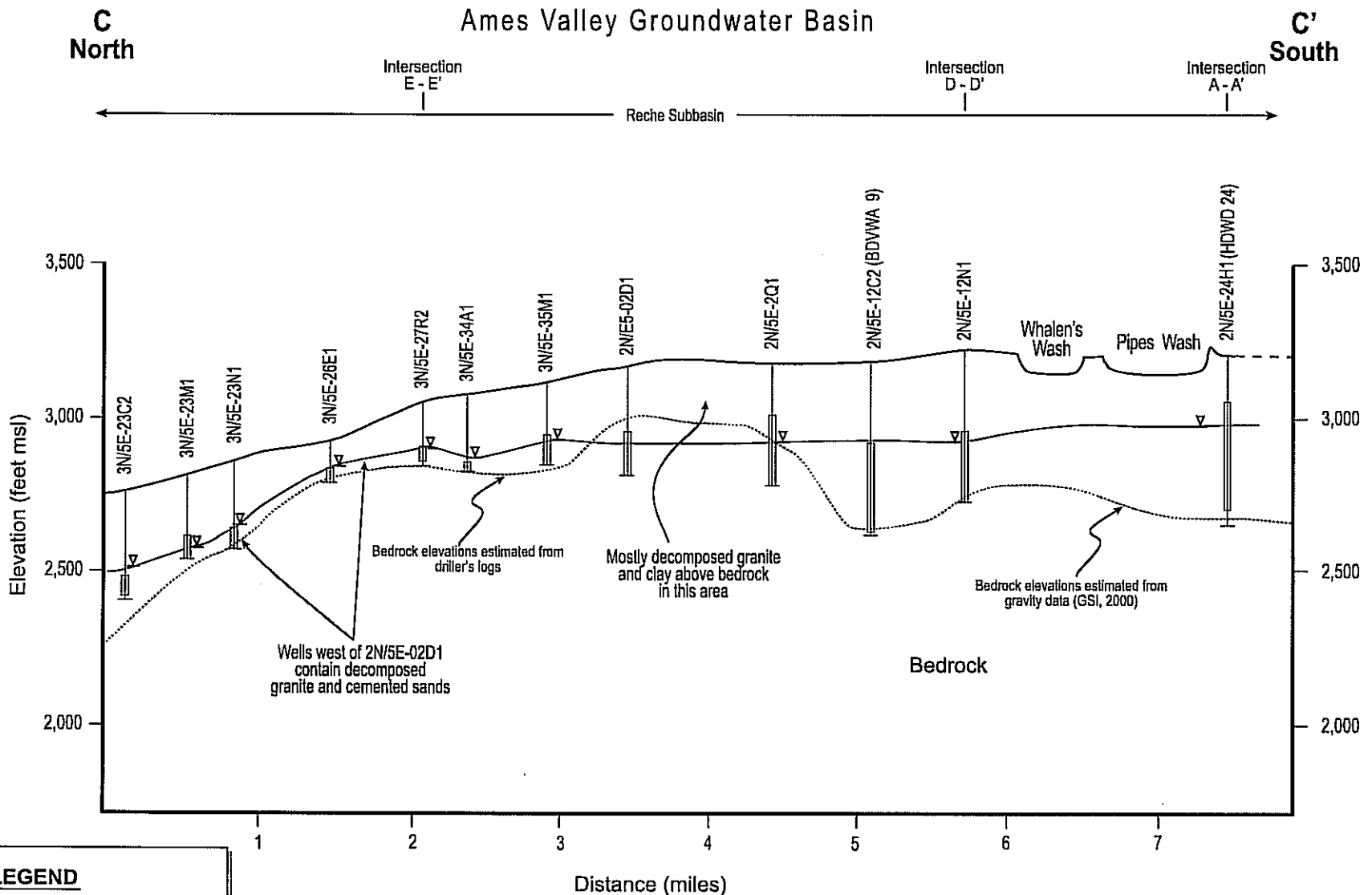
Figure 10
Cross Section
B - B'



LEGEND

- Well Screen
- Bottom of Well
- Groundwater Elevation (dashed where estimated)

Note: Groundwater levels based on 2004 measurements; levels in some areas estimated from driller's logs and groundwater level trends.

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Figure 11
Cross Section
C - C'

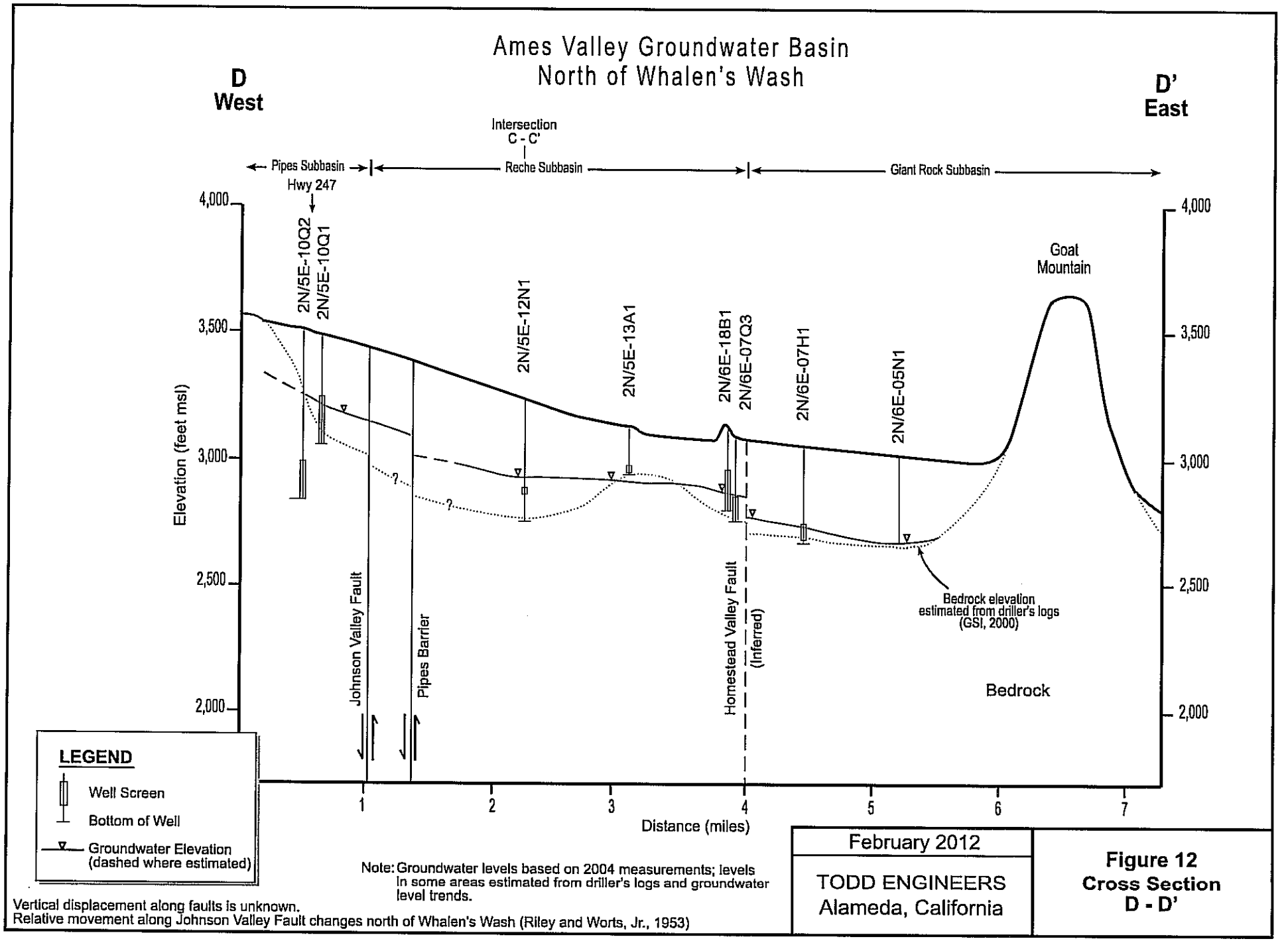
Ames Valley Groundwater Basin
North of Whalen's Wash
D
West
D'
East
Intersection
C - C'
Pipes Subbasin
Reche Subbasin
Giant Rock Subbasin
Hwy 247
2N/5E-10Q2
2N/5E-10Q1
2N/5E-12N1
2N/5E-13A1
2N/6E-18B1
2N/6E-07Q3
2N/6E-07H1
2N/6E-05N1
Goat Mountain
Elevation (feet msl)
4,000
3,500
3,000
2,500
2,000
Johnson Valley Fault
Pipes Barrier
Homestead Valley Fault
(Inferred)
Bedrock elevation estimated from driller's logs (GSI, 2000)
Bedrock
1
2
3
4
5
6
7
Distance (miles)
LEGEND
Well Screen
Bottom of Well
Groundwater Elevation (dashed where estimated)
Note: Groundwater levels based on 2004 measurements; levels in some areas estimated from driller's logs and groundwater level trends.
Vertical displacement along faults is unknown.
Relative movement along Johnson Valley Fault changes north of Whalen's Wash (Riley and Worts, Jr., 1953)
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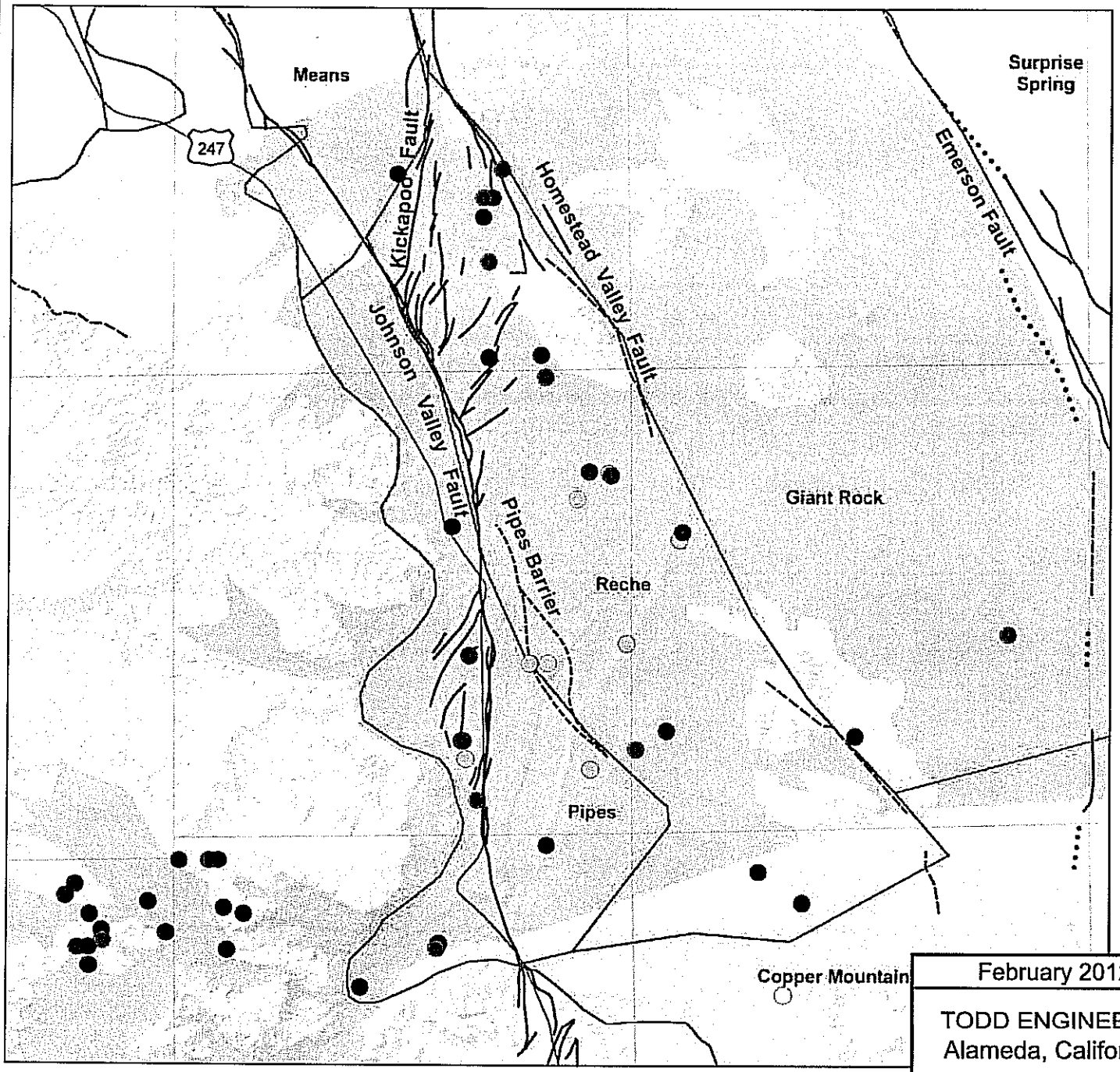
Figure 12
Cross Section
D - D'



LEGEND

- DWR Ames Valley Basin
- USGS Morongo Subbasin

Fault (CA Geological Survey)

- confirmed
- approximately located
- concealed
- Pipes Barrier (R&M, 2007)

Transmissivity (gpd/ft)

- 50001 - 80,000
- 25001 - 50000
- 10001 - 25000
- 5001 - 10000
- 501 - 5000
- < 500

N

0 2

Scale in Miles

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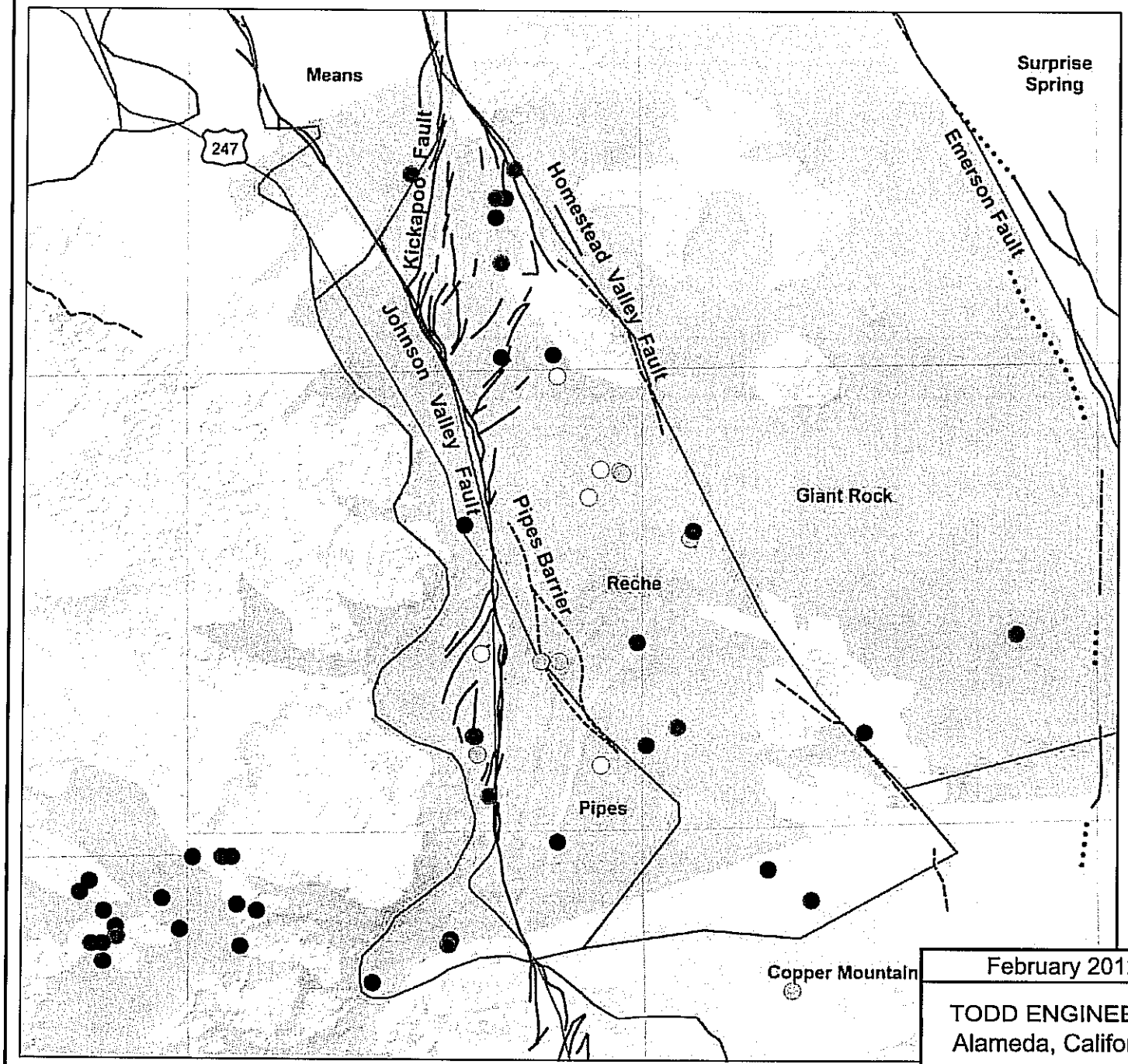
Figure 13
Aquifer Transmissivity



LEGEND

- DWR Ames Valley Basin
- USGS Morongo Subbasin

Fault (CA Geological Survey)

- confirmed
- approximately located
- concealed
- Pipes Barrier (R&M, 2007)

Hydraulic Conductivity (gpd/ft2)

- 400 - 1122
- 200 - 400
- 100 - 200
- 25 - 100
- 5 - 25
- 5.0 or less

N

0 2

Scale in Miles

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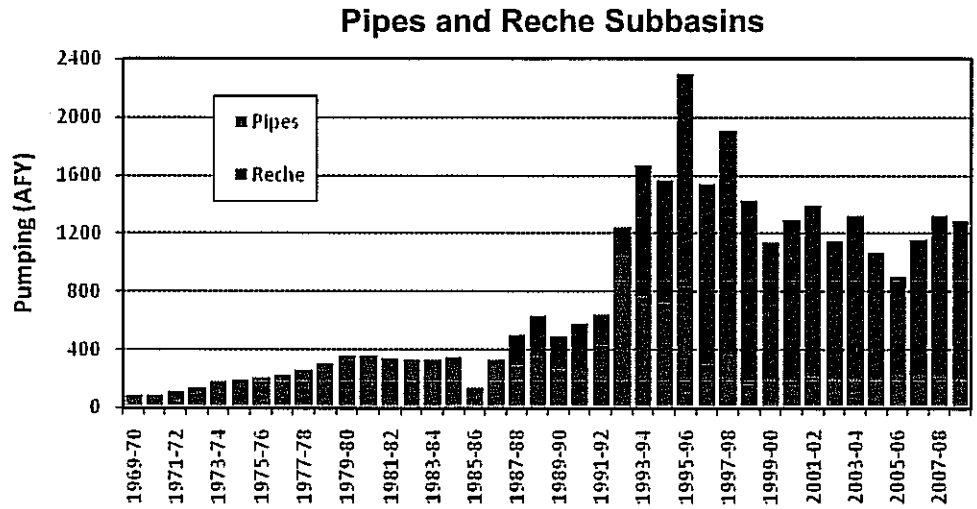
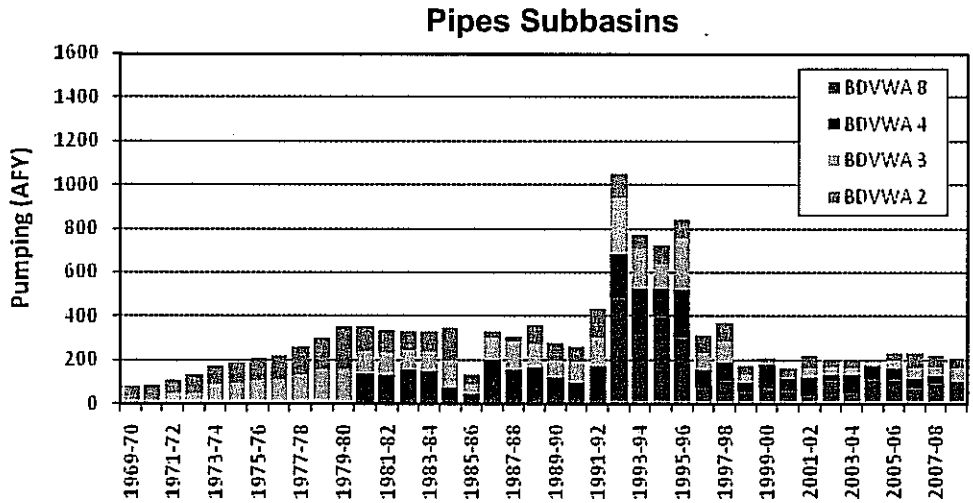
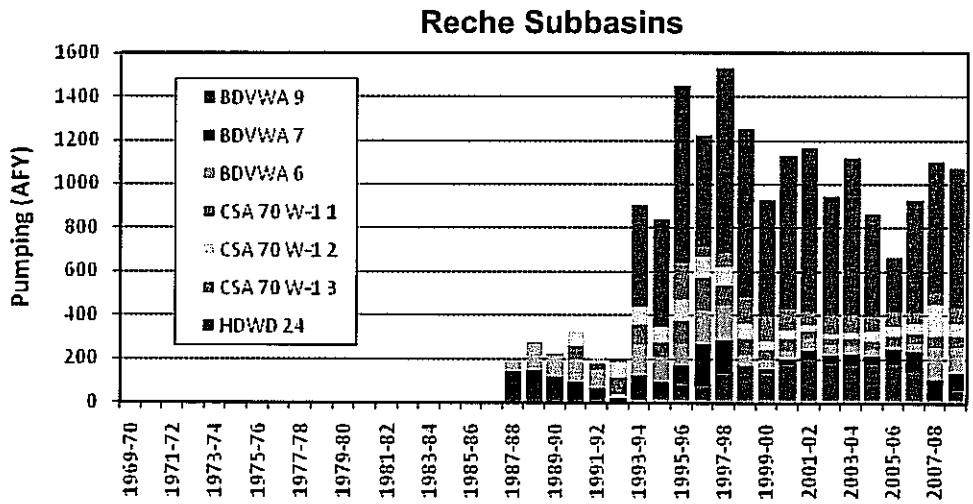
Figure 14
Aquifer
Hydraulic Conductivity







February 2012	
TODD ENGINEERS Alameda, California	**Figure 15** **Groundwater Production**

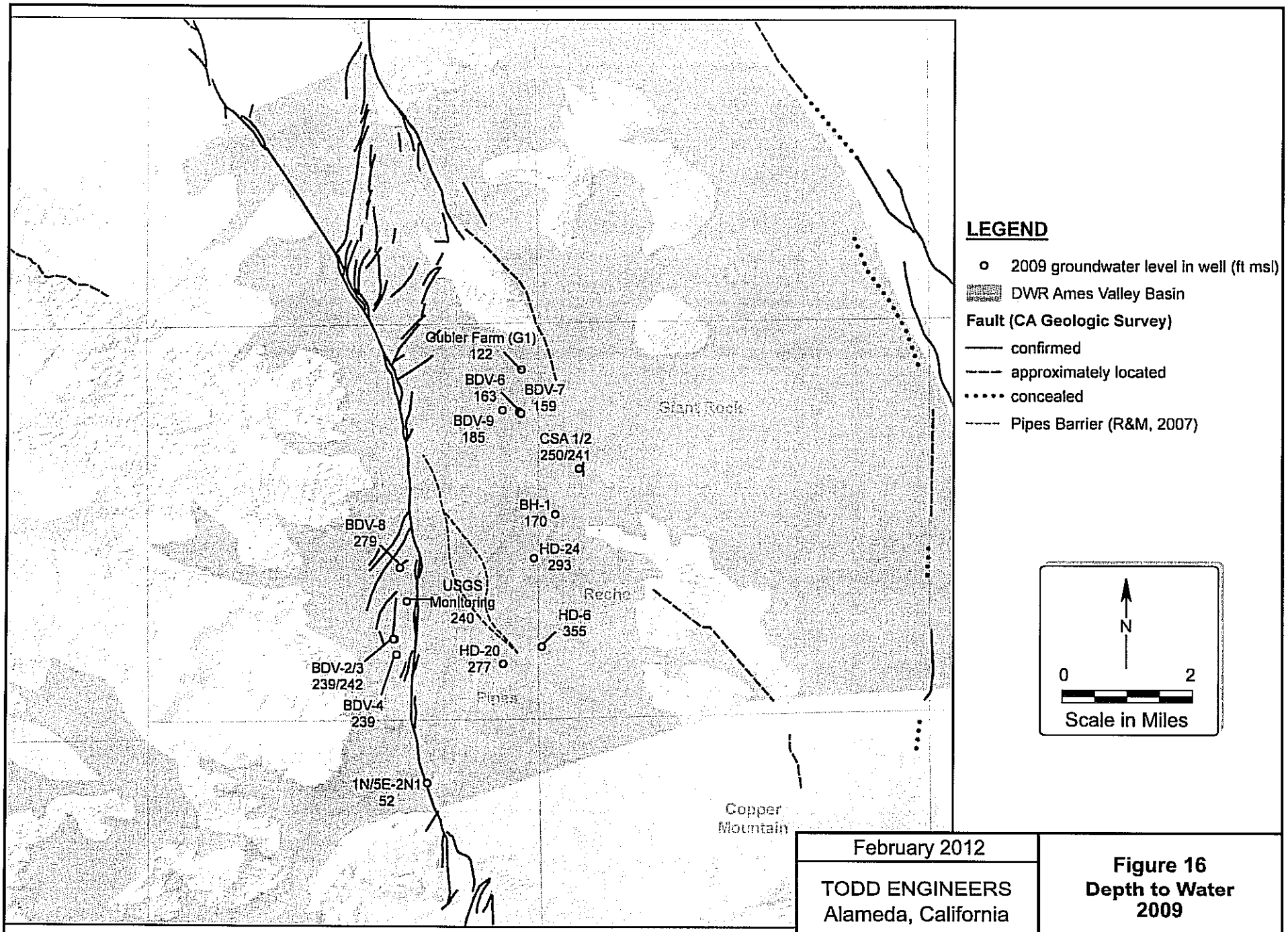


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Figure 16
Depth to Water
2009

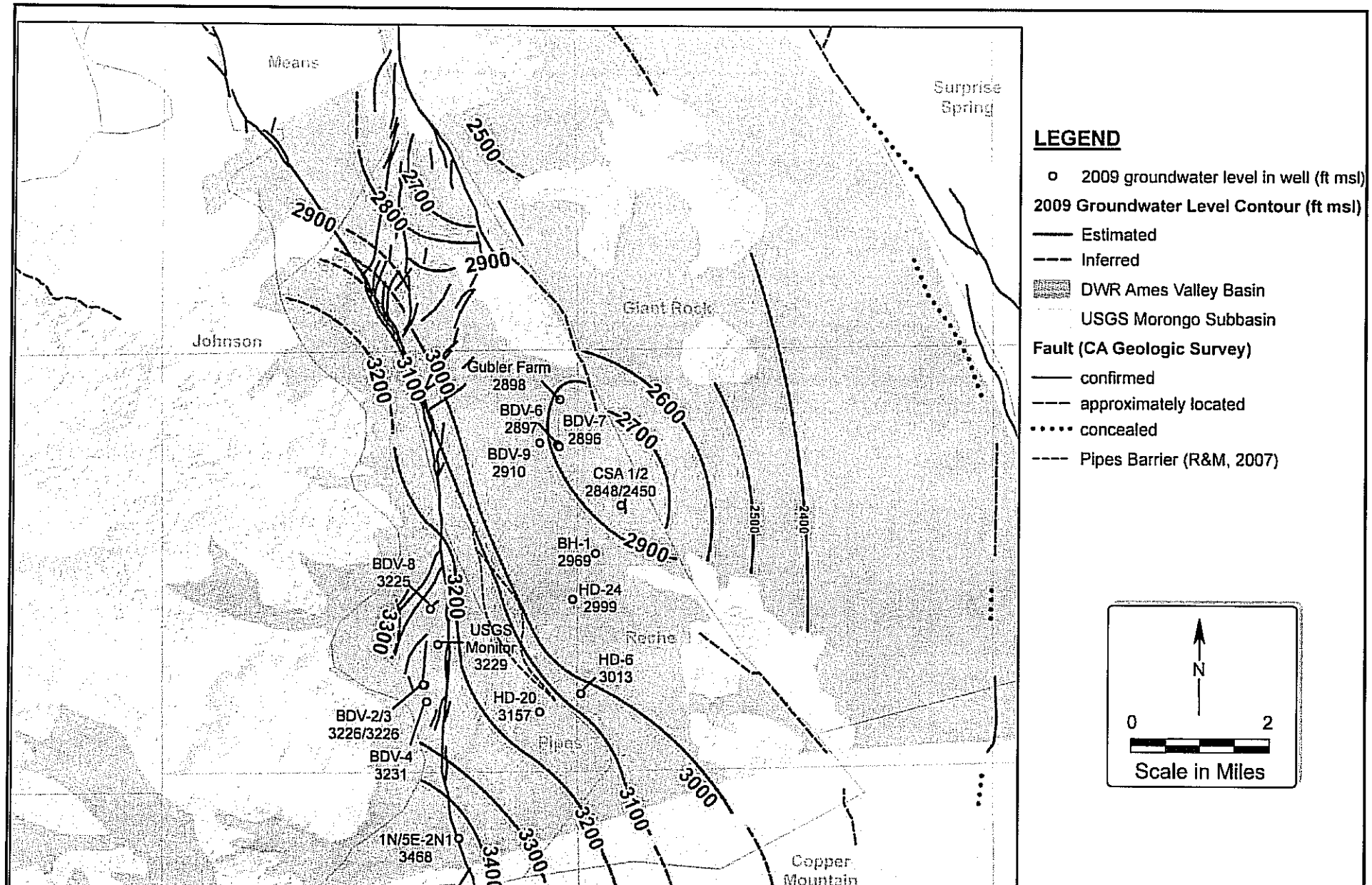

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Figure 17
Groundwater Elevations 2009

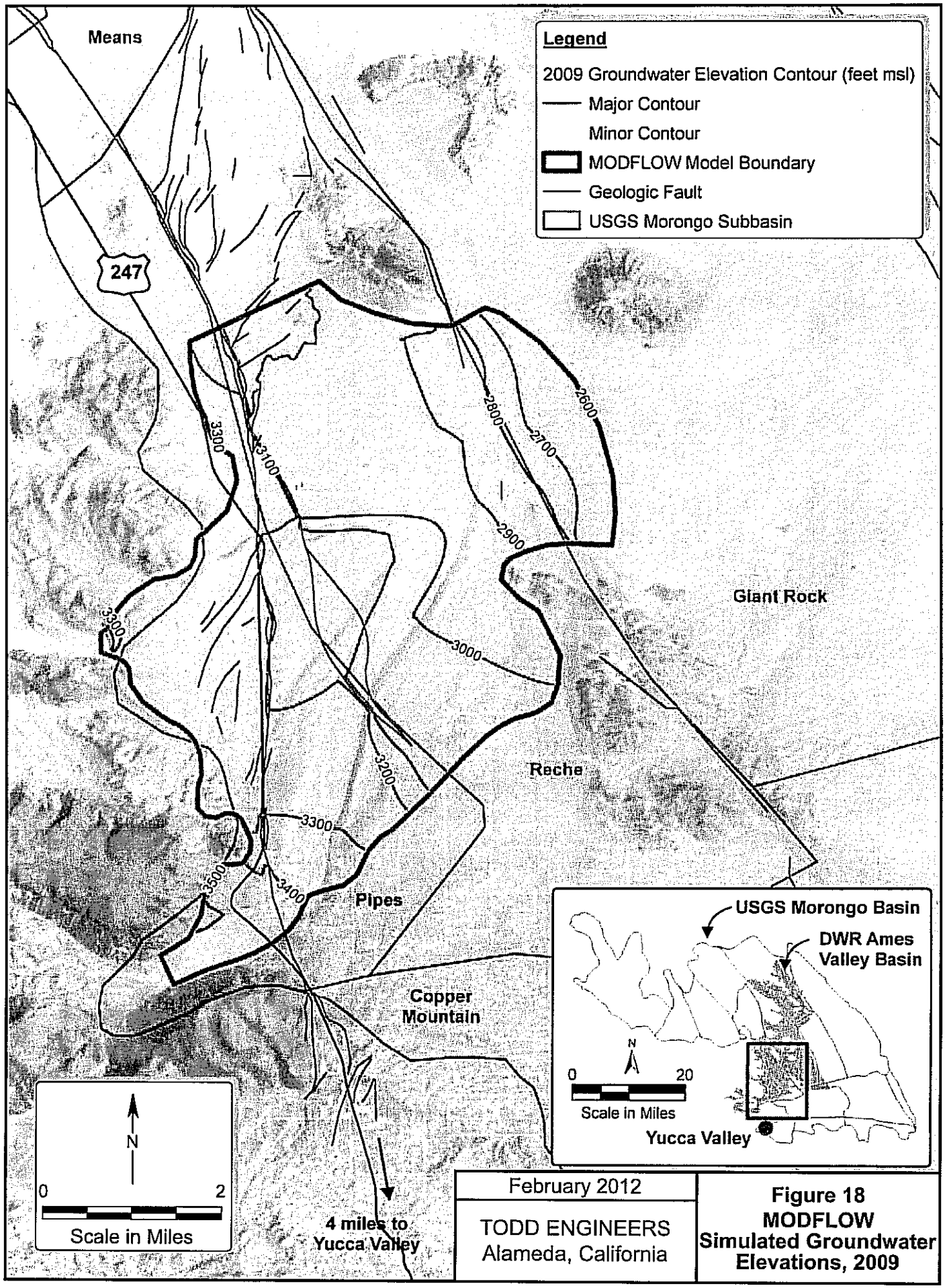

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Figure 18
MODFLOW Simulated Groundwater Elevations, 2009

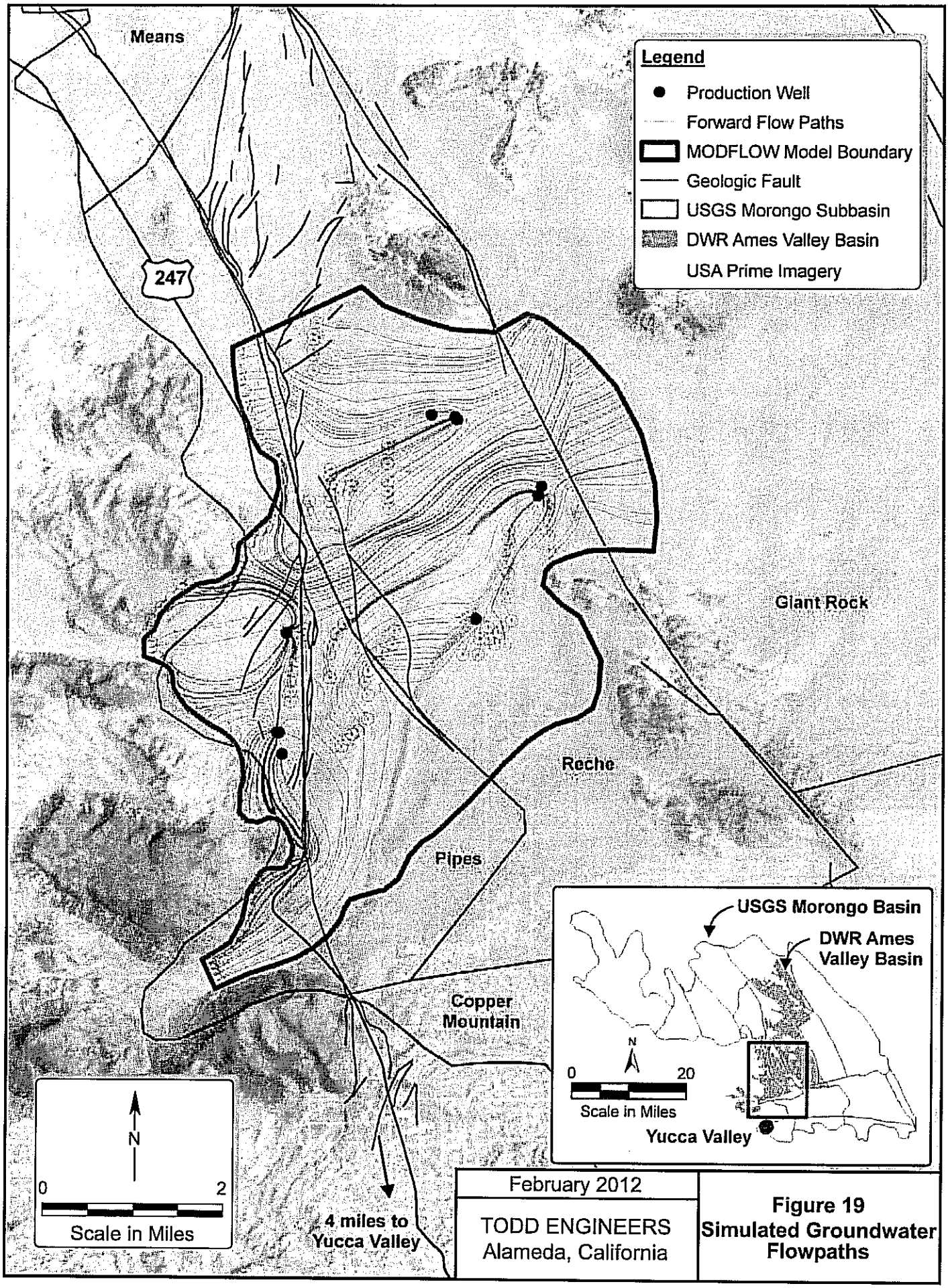

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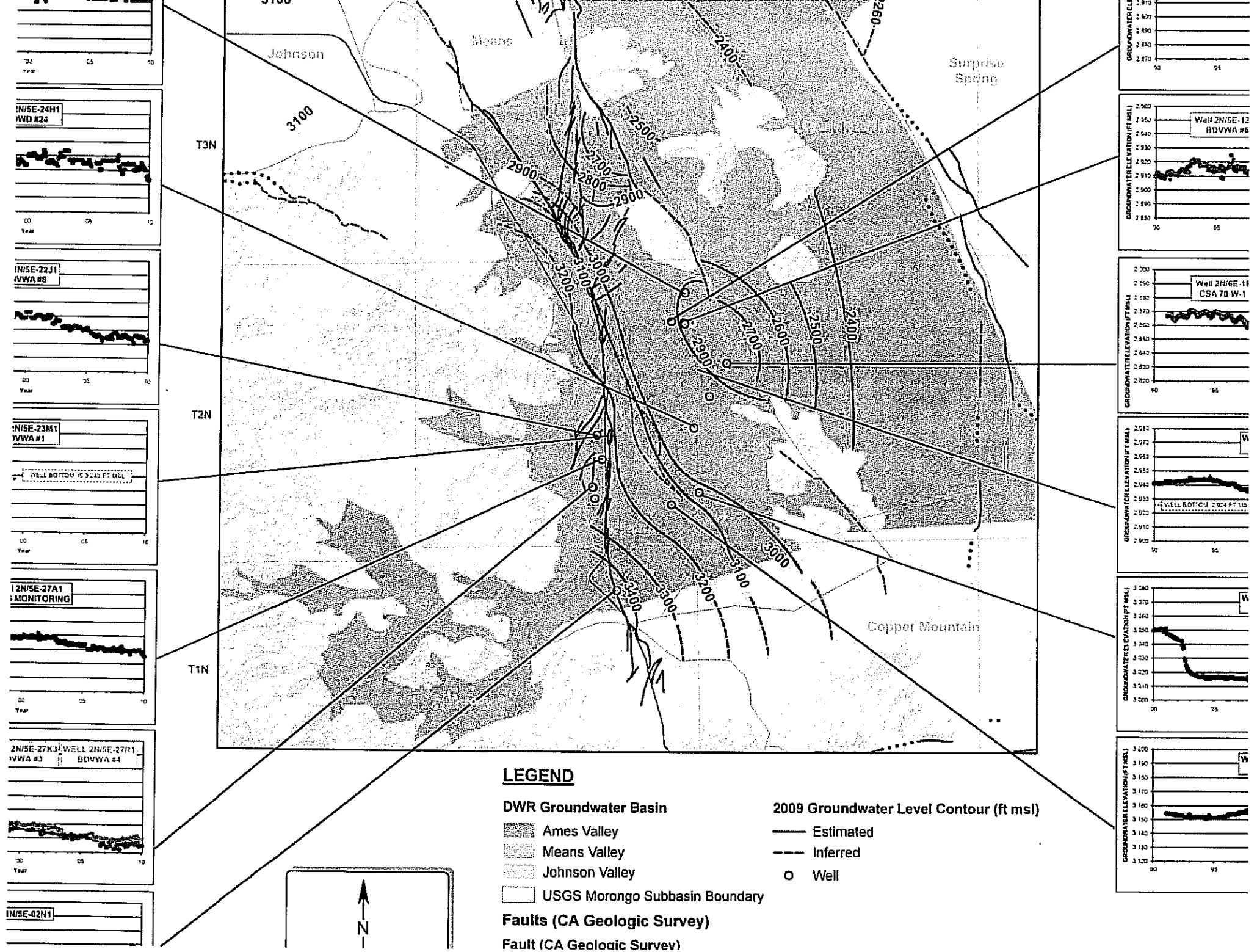
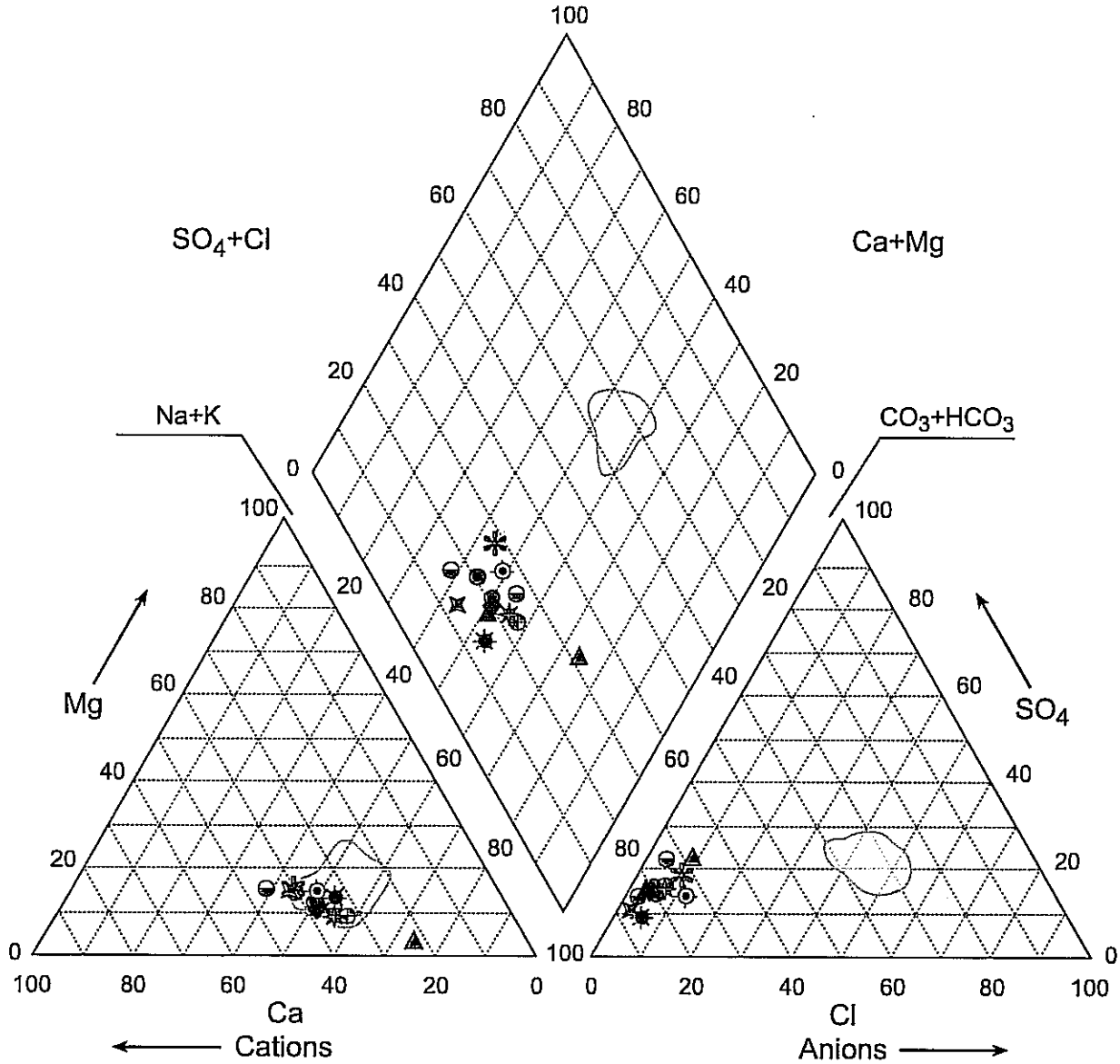
Figure 19
Simulated Groundwater Flowpaths


Johnson
Means
Surprise Spring
Copper Mountain
T3N
T2N
T1N
3100
2900
2800
2700
2600
2500
2400
2300
2260
3000
3200
3300
3400
LEGEND
DWR Groundwater Basin
Ames Valley
Means Valley
Johnson Valley
USGS Morongo Subbasin Boundary
Faults (CA Geologic Survey)
Fault (CA Geologic Survey)
2009 Groundwater Level Contour (ft msl)
Estimated
Inferred
Well
N
Year
GROUNDWATER ELEVATION (FT MSL)
Well 2N/5E-12
BDVWA #6
Well 2N/5E-1
CSA 70 W-1
WELL BOTTOM
2N/5E-24H1
WD #24
2N/5E-22J1
VWA #8
2N/5E-23M1
VWA #1
2N/5E-27A1
MONITORING
2N/5E-27K3
VWA #3
WELL 2N/5E-27R1
BDVWA #4
N/5E-02N1



LEGEND

Pipes Subbasin

- BDVWA #2
- BDVWA #3
- BDVWA #4
- BDVWA #8

Reche Subbasin

- BDVWA #6
- BDVWA #7
- BDVWA #9
- HDWD #24
- CSA 70 W-1 1
- CSA 70 W-1 2
- CSA 70 W-1 3
- BDVWA MW1
- BDVWA MW2
- SWP Water

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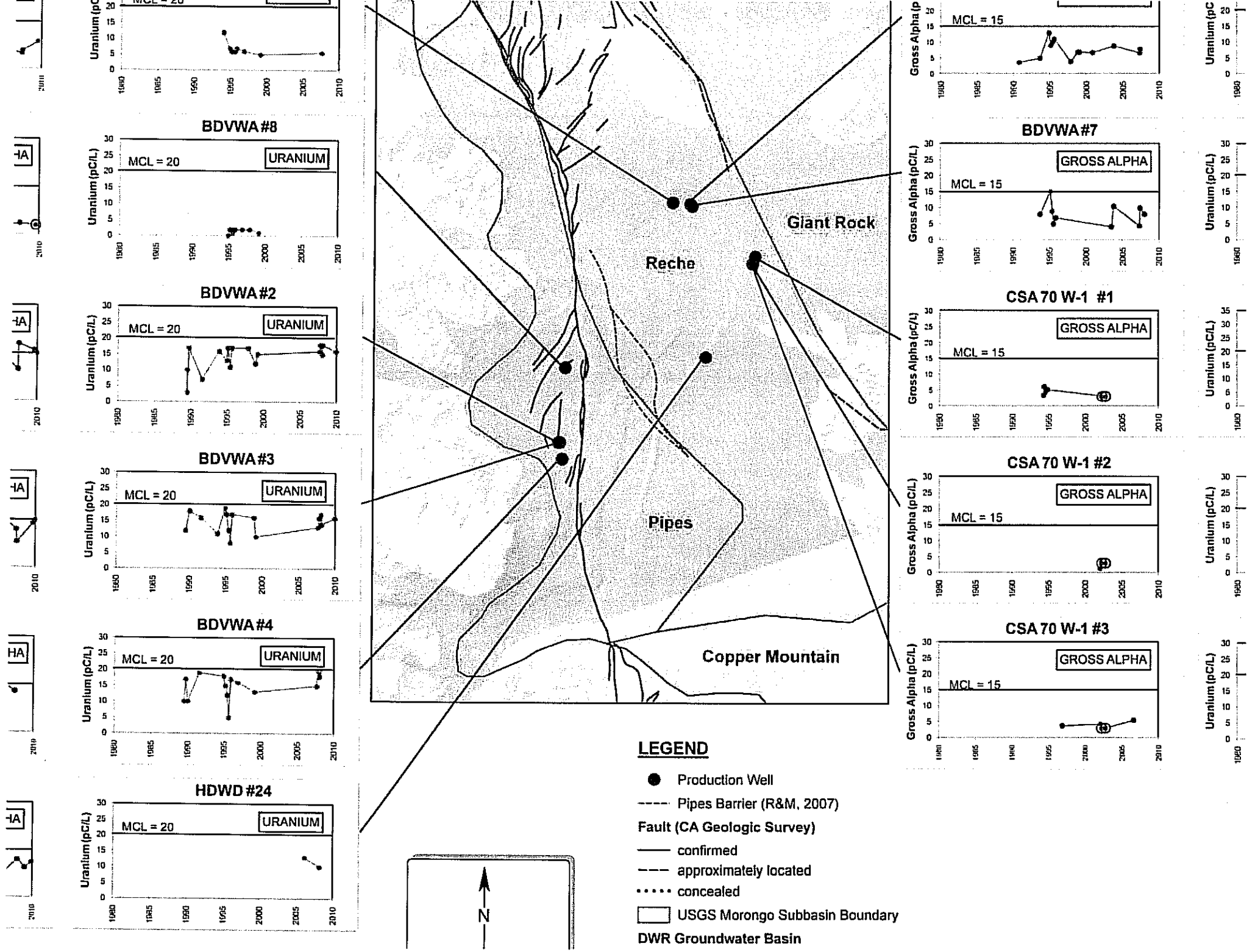
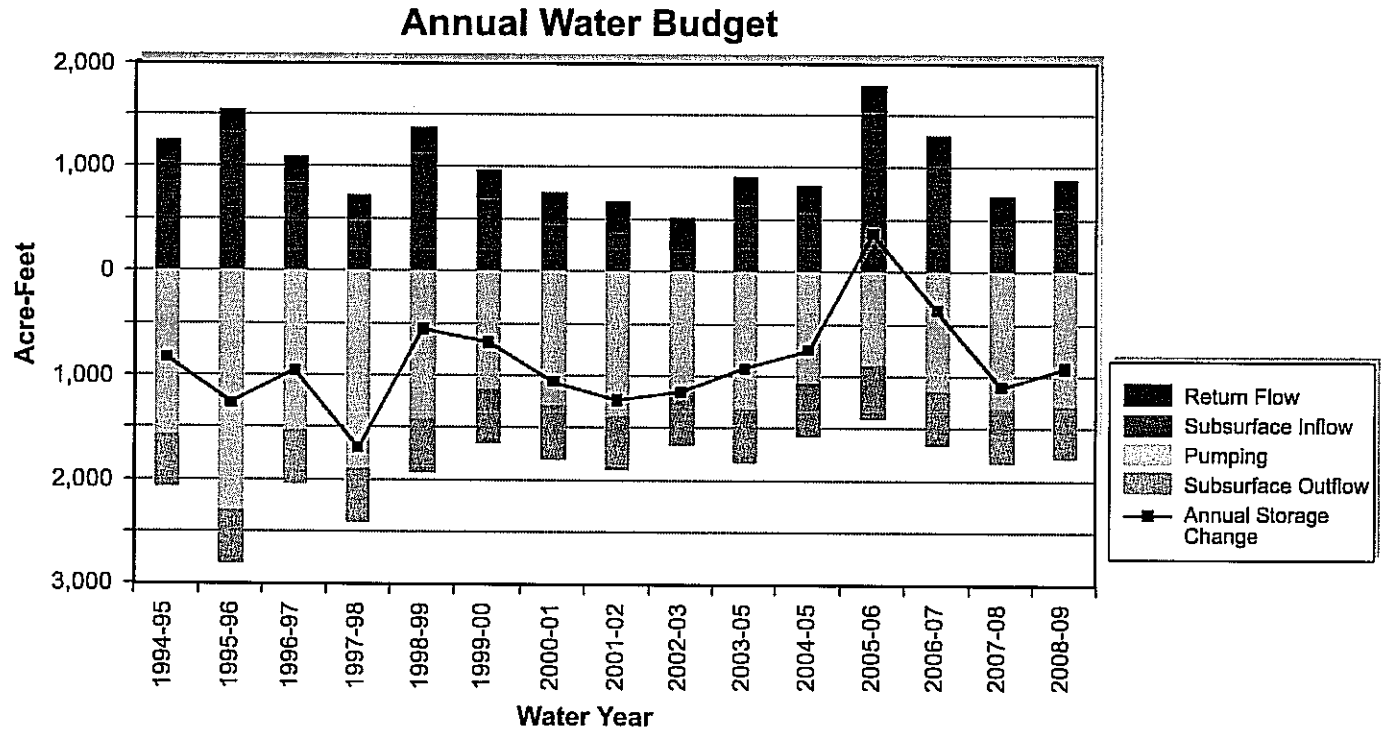
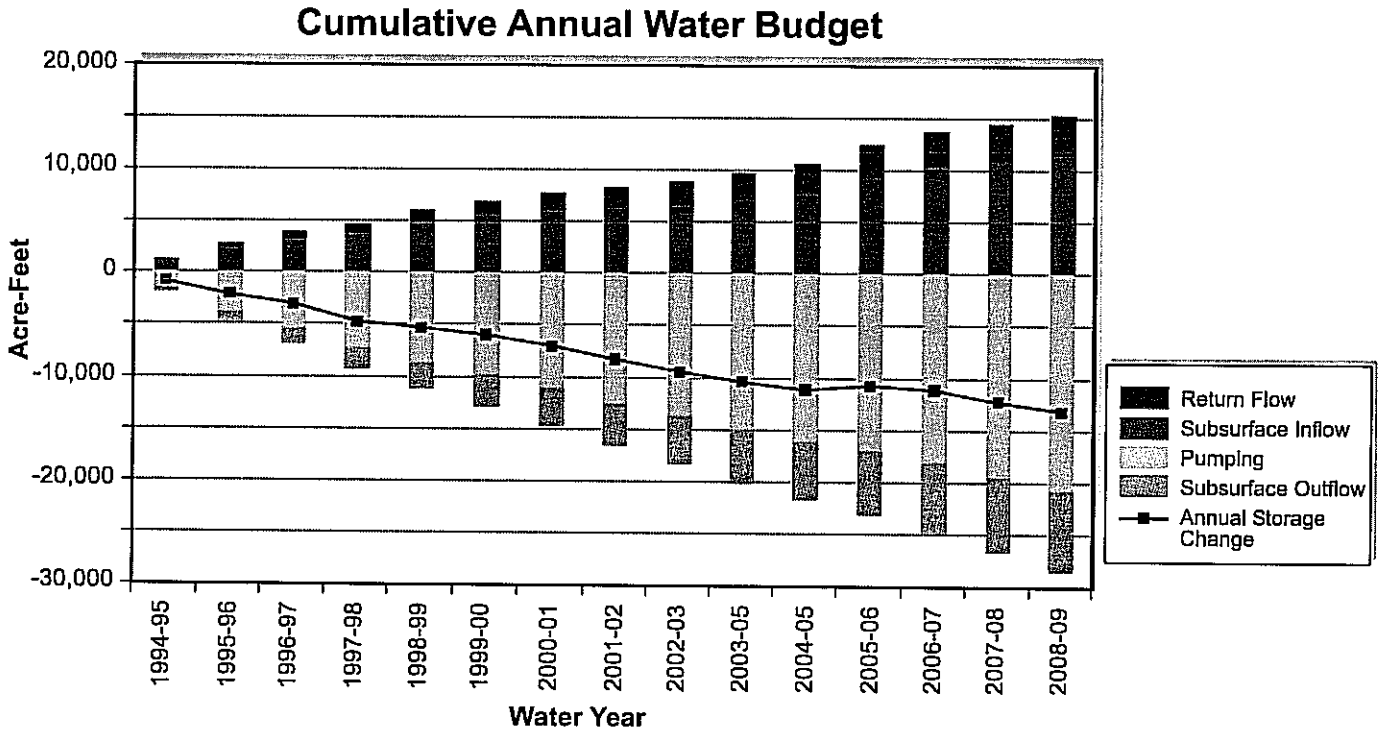
Figure 21
Cation/Anion Composition of Groundwater and SWP Water


BDVWA #8
MCL = 20
URANIUM
Uranium (pC/L)
BDVWA #2
MCL = 20
URANIUM
Uranium (pC/L)
BDVWA #3
MCL = 20
URANIUM
Uranium (pC/L)
BDVWA #4
MCL = 20
URANIUM
Uranium (pC/L)
HDWD #24
MCL = 20
URANIUM
Uranium (pC/L)
MCL = 15
Gross Alpha (pC/L)
BDVWA #7
GROSS ALPHA
MCL = 15
Gross Alpha (pC/L)
CSA 70 W-1 #1
GROSS ALPHA
MCL = 15
Gross Alpha (pC/L)
CSA 70 W-1 #2
GROSS ALPHA
MCL = 15
Gross Alpha (pC/L)
CSA 70 W-1 #3
GROSS ALPHA
MCL = 15
Gross Alpha (pC/L)
Giant Rock
Reche
Pipes
Copper Mountain
N
LEGEND
Production Well
Pipes Barrier (R&M, 2007)
Fault (CA Geologic Survey)
confirmed
approximately located
concealed
USGS Morongo Subbasin Boundary
DWR Groundwater Basin





February 2012	**Figure 23**
TODD ENGINEERS Alameda, California	**Water Budget Summary 1994 - 2009**

Management Action	Lead Agency	2012	2013	2014	2015	2016	2017	2018
		M J J A S O N D	J F M A M J J A S O N D	J F M A M J J A S O N D	J F M A M J J A S O N D	J F M A M J J A S O N D	J F M A M J J A S O N D	J F M
Finalize GWMP and New Agreement	M/B/H/C	◇						
Activate ABA and water storage accounts	M	●						
Track ABA use, sale, and transfer	M							
Construct recharge facilities	M							
Track SWP water recharge, sale, transfer	M							
Implement monitoring and reporting program	M							
Report 12-month production data to MWA	B/H/C	→	→ ● →	→ ● →	→ ● →	→ ● →	→ ●	
Publish annual monitoring report	M		♦	♦	♦	♦		
Publish 5-year State of Subbasins report	M						♦	
Implement recommended actions	M							■
Install new production well(s)	B	(as needed)						
Install wellhead treatment for radionuclides	B	(as needed)						

ABA = Annual Baseline Amounts

M = Mojave Water Agency

B = Bighorn-Desert View Water Agency

H = Hi-Desert Water District

C = San Bernardino County Service Area 70

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Figure 24
GWMP Implementation Plan and Schedule