Appendix H. Development of Groundwater-Level Thresholds

This appendix documents the ongoing development of thresholds associated with water levels measured in wells. This process has included input from stakeholders, and will continue to do so as part of the annual update and revision process.

1 Conceptual Development of Thresholds

Thresholds indicate surface or groundwater elevations that may risk adverse impacts due to groundwater seepage. The SJRRP will operate to maintain groundwater levels below thresholds. Estimates of flow increases that would exceed a threshold will trigger a site visit and a response action. Crop type and associated rooting depths, soil type, and other factors vary spatially; therefore, the thresholds are customized to represent site conditions at each monitoring well location.

Events unrelated to river flows may cause groundwater levels to exceed thresholds. For example, an irrigation event or local precipitation may cause a rapid rise in the water table. Such events would likely cause short-term saturation of the root zone resulting in no effect on crop health. Field notes during groundwater measurements and site visits address this complication. Temporal aspects to thresholds, for example during the dormant season or fallow periods, may allow increased flows, in coordination with landowners, above threshold levels.

1.1 Purpose

- To describe the development of thresholds for SJRRP wells.

1.2 Objectives

The objectives of monitoring well thresholds development include:

- Determine the components to include in threshold development.
- Determine the values to use for each of the components.
- Solicit stakeholder input and comments on each threshold component.

1.3 Approach

Reclamation has developed three different methods to determine monitoring well thresholds. These include approaches based on idealized agricultural practices, historical groundwater levels, and drainage.

1.3.1 Agricultural Practices Method

A conceptual model has been developed for determining thresholds based on idealized agricultural practices. This model is based on input from landowners and water district managers. The model considers several different components including site characteristics, farming practices, and physical processes.

The components of the threshold model, as illustrated in Figure H-1, include:

- a root zone, to provide an unsaturated zone to avoid waterlogging;
- an irrigation buffer, to allow space for furrow irrigation or leaching treatments to drain;
- a capillary fringe component, to allow for the saturated portion of the capillary rise (CR) and maintain an aerated root zone;
- a ground surface adjustment, to adjust for differences in elevation between the ground surface of the field and the ground surface at the monitoring well. Wells located in locations most convenient for landowners may not be in the most critical seepage location.

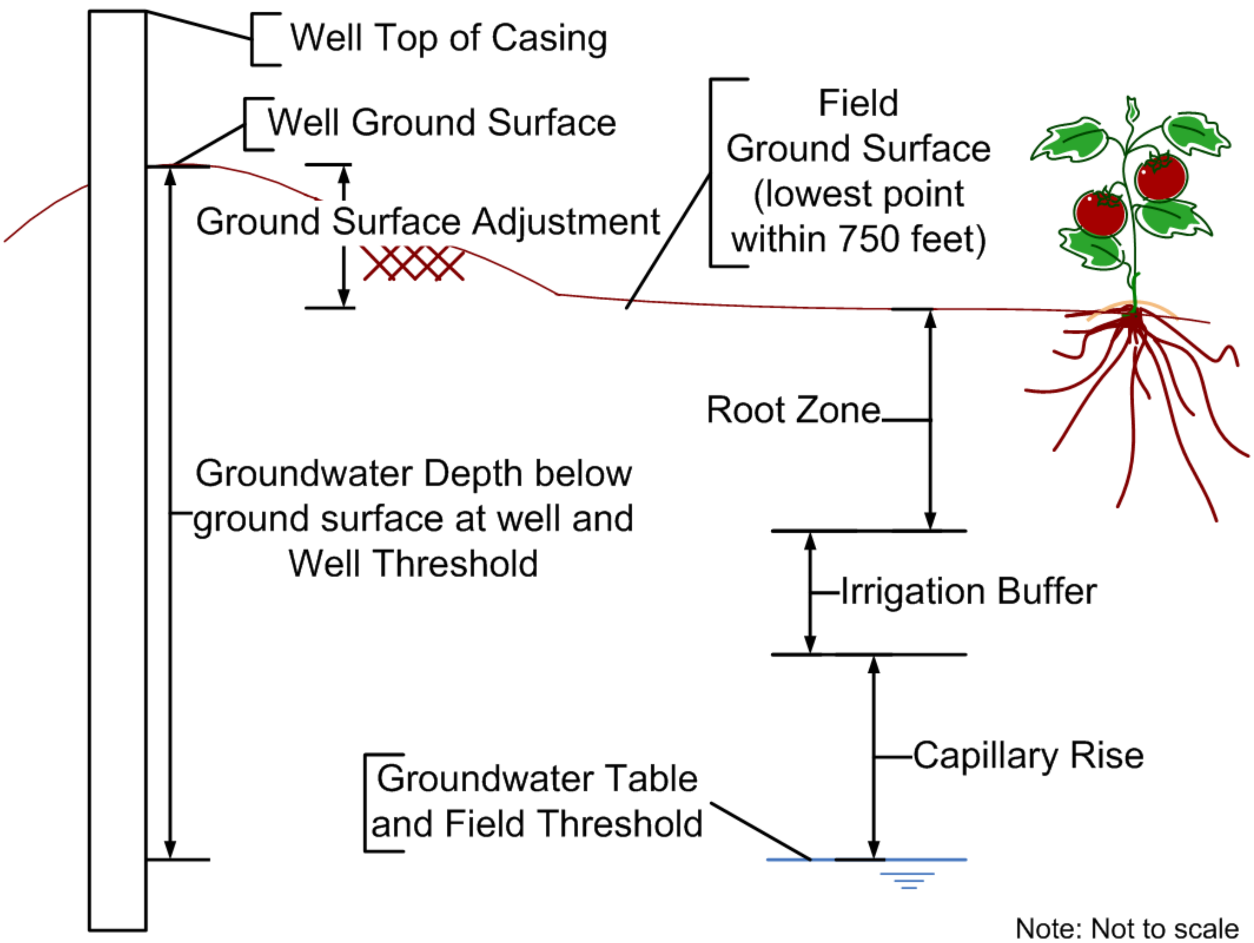

Figure H-1
Schematic Diagram of Idealized Agricultural Practices Threshold Model

The following sections detail the approaches for each of these components. The Field Threshold is defined according to the following:

$\text{Threshold}_{\text{field}} = h_{\text{Root-Zone}} + h_{\text{Capillary Fringe}} + h_{\text{IrrigationBuffer}}$

Where, $h_{Root\text{-}Zone}$ = depth of the root zone;

$h_{Capillary\ Fringe}$ = height of capillary fringe; and

$h_{IrrigationBuffer}$ = height of the buffer for leaching irrigation.

To monitor for groundwater levels at the field threshold in a monitoring well, which may not be located at the same elevation as the most critical location, a ground surface adjustment is made. The Well Threshold is defined as:

$$Threshold_{well} = h_{Root\text{-}Zone} + h_{Capillary\ Fringe} + h_{IrrigationBuffer} + (Elevation_{WellGS} - Elevation_{FieldGS}),$$

Where, $Elevation_{WellGS}$ = elevation of the ground surface at a monitoring well; and

$Elevation_{FieldGS}$ = elevation of the ground surface with 750 feet of the well in the adjacent field.

Thresholds also include a time component, resulting in different thresholds in spring than during other times throughout the year.

1.3.2 Historical Groundwater Method

In some locations along the San Joaquin River, historical groundwater measurements show elevations above the computed threshold. In locations where thresholds estimated using the outlined approach above are deeper than historical groundwater levels, historical groundwater level will be used. This second method results in more localized thresholds rather than generalizations.

The historical groundwater level depends on the season. As such, both Spring and Fall historical groundwater levels are being developed in wells with long periods of record. The United States Geological Survey (USGS) calculated historical groundwater levels in three ways for different wells.

- For wells with long-term groundwater level records, historical groundwater levels were chosen at the 75th percentile of both Spring and Fall measurements.
- For wells without long-term records, nearby wells with long-term records were used to set the Spring and Fall historical groundwater level.
- For wells without long-term records and with no nearby wells, depth to water (DTW) maps were created, interpolating groundwater levels between wells in a number of years and seasons. This analysis allows for a more site-specific historical groundwater level even without data, using all the surrounding wells to inform the choice at each location.

1.3.3 Drainage Method

In some locations along the San Joaquin River, the river channel gains water from the surrounding groundwater. For these gaining reaches, the river stage may be increased to near the level of the surrounding water table without influencing groundwater levels in adjacent fields.

The drainage method uses cross-sections at monitoring well transects to plot the river stage and groundwater table at a variety of dates.

1.4 Next Steps

Thresholds, as a component of the Seepage Monitoring and Management Plan, may undergo revisions as additional information and historical groundwater analysis becomes available. The continued development of thresholds would benefit from landowner input and knowledge.

2 Method #1: Agricultural Practices

The following section describes the components of threshold development including the crop root zone, ground surface buffer, irrigation buffer, and capillary rise.

2.1 Crop Root Zone Objectives

The objectives for crop root zones include the following:

- Identify different root zones based on crop type to expand upon the existing crop root zones in the 2009 Seepage Monitoring and Management Plan to.
- Include multiple root zones for each crop based on young and mature plants if information is available.

2.1.1 Approach

The type of crop, soil texture, irrigation practices, and depth to the groundwater table affect crop rooting depth. Poorly drained soils restrict crop root growth (Sands, 2001). Fine-grained soils can restrict crop root growth, as shown in Table H-1 below (Westlands, 2009). Irrigation practices can result in more roots near the top of the soil column and fewer roots at depth (Speigel-Roy, 1996).

A literature review was conducted to identify sources of crop root depths. References found include:

- University of California Division of Agriculture and Natural Resources Almond Production Manual Publication 3364
- University of California Division of Agriculture and Natural Resources Cotton Production Manual Publication 3352
- University of California Division of Agriculture and Natural Resources Small Grains Production Manual Publication 8167
- Westlands Irrigation District
- Allen et al., Crop Evapotranspiration, Guidelines for Computing Crop Water Requirements, FAO Irrigation and Drainage Paper No. 56.
- Food and Agriculture Organization of the United Nations, 2009 Crop Water Information.
- U.S. Department of the Interior, Bureau of Reclamation (Reclamation) Drainage Manual

The Reclamation Drainage Manual (page 48) does not make recommendations by crop type but generalizes 2 feet for the shallow-rooted crops such as potatoes and vegetables and 6 feet for peach, walnut, and avocado trees. For most irrigated crops, a 3 to 4 foot root zone can be used. The Reclamation Drainage Manual assumes adequate drainage and leaching for salinity control are provided. Crop roots may adapt to historical groundwater levels, but the current methods do not address long-term fluctuations in water tables.

Local information is available on tomato root zones from the Irrigation Training and Research Center (ITRC) report (Burt, 2010). This local information was used over other sources. Other crops were split into two groups, permanent and annual. Thresholds used root depths on the higher end of typical values for permanent crops as their roots are deep early in the season. Annual crops generally have shallower root zones.

2.1.2 Results

Table H-1 below shows crop root depths by crop type, soil type, and time in the season.

Table H-1.
Crop Root Depths

Crop	Crop Root Depth, Early Season (feet)	Crop Root Depth, Late Season (feet)	Crop Root Depth, Late (feet) – Coarse Textured Soil	Crop Root Depth, Late (feet) – Fine Textured Soil
Alfalfa (Hay)		3-6 [3], 6 [1, 2]	4-6 [1, 2], 6-12 [7]	
Almonds		3-6 [3]	2-12 [8], 9 [9]	
Barley		3-5 [3], 4 [1]	4 [1]	
Lima Beans		2-4 [3]		
Cotton	1 [4], 4/5 [10]	3-5 [3], 5 [1], 6 [10]	5-6 [1]	4-5 [1]
Grape	5 [4]	3-6 [3]		
Corn	1 [4]	3 [4]		
Melon		2-5 [3], 6 [1]	5-6 [1]	
Pistachio		3-5 [3]		
Safflower		3-6 [3],15 [1]	15 [1]	10 [1]
Spring Wheat Winter	1 [4]	4 [4]		
Sugar Beet	1 [4]	6 [4]	6 [1]	
Sugarcane		5 [4]		
Tomato	1 [4]	3 [6], 2-5 [3] , 6 [1]	5-6 [1]	
Wheat	1 [4]	3-5 [5, 3] , 5 [4]	4-5 [1]	4 [1]

Notes:
[1] Westlands Water District 2009
[2] Crop root depth could exceed 6 feet if unrestricted
[3] Allen et al. 1998, larger values are for soils having no significant layering or other characteristics that can restrict rooting depth
[4] Food and Agriculture Organization of the United Nations, www.fao.org
[5] University of California Division of Agriculture and Natural Resources Small Grains Production Manual
[6] Irrigation and Research Training Center, November 2010
[7] University of California Division of Agriculture and Natural Resources Irrigated Alfalfa Management. Under the best conditions roots will grow to 6-12 feet. A minimum of 3 feet of unrestricted rooting depth should be provided.
[8] University of California Division of Agriculture and Natural Resources Almond Production Manual. Roots of almond trees may extend to depths of 4 meters in coarse-textured, well-drained soil, but they are frequently much shallower. Often 75 percent or more of the roots are in the upper 0.7 to 1.0 meter of soil.
[9] University of California Division of Agriculture and Natural Resources Integrated Pest Management for Almonds.
[10] University of California Division of Agriculture and Natural Resources Integrated Pest Management for Cotton

For the purposes of the current Seepage Monitoring and Management Plan buffer zones and action level thresholds, the values that were used include:

- Cotton, alfalfa, other annual crops and unknown – 4 feet
- Grapes, Pistachio, and Pomegranates – 6 feet
- Almonds – 9 feet
- Tomatoes, beans, melons and corn – 3 feet

2.1.3 Limitations

Limitations of this analysis include:

- This approach does not address soil type or irrigation methods which could affect root zones and may restrict root growth to shallower depths.
- These values do not take into consideration the effects of a historically shallow water table on crop root depths or seasonal or long term trends in the water table. Comparison to historical groundwater levels in a later section accounts for this in a broad sense.
- The root depth buffer does not include changes in the root depth buffer based on age of crops and uses mature plants to choose deeper root depths.
- Field crops are generally rotated each year, which may require changing thresholds on an annual basis as crop types change. Landowners should review the SMMP and notify the SJRRP when crop changes require adjustments to the root zone assumptions.

2.2 Ground Surface Objectives

Adjustments due to changes in ground surface elevation intend to:

- Thresholds should represent groundwater levels below agricultural fields near to the well.
- To set the well threshold, adjust based on the difference between the elevation of the ground surface in the adjacent field and the ground surface elevation at the monitoring well.

2.2.1 Approach

The difference between ground surface elevation at the well and in the adjacent field was determined by the minimum field elevations within 750 feet for the field adjacent to each well. Field elevations were chosen from the 2008 LiDAR survey.

All wells drilled in Fall 2009 and Spring 2010 by Reclamation have ground surface elevations surveyed in North America Vertical Datum (NAVD) 88. In addition, Reclamation monitors several hand-augered piezometers, private wells, and Central California Irrigation District (CCID) wells that have not been surveyed. For wells that are not surveyed, a ground surface elevation was interpolated from a 2008 Light Detection And Ranging [1](LiDAR) survey.

The LiDAR survey was flown within approximately ¼ to 1 mile on either side of the San Joaquin River and flood control bypasses. Figure H-2 provides an example of one monitoring

[1] An optical remote sensing technology that measures properties of scattered light to find topographic information.

well that uses a 750 ft buffer zone that is partially missing due to the lack of available LIDAR data. Wells located outside the LiDAR data area have no ground surface buffer. Some wells used data from fields further away if there was no available LiDAR data in an adjacent field.

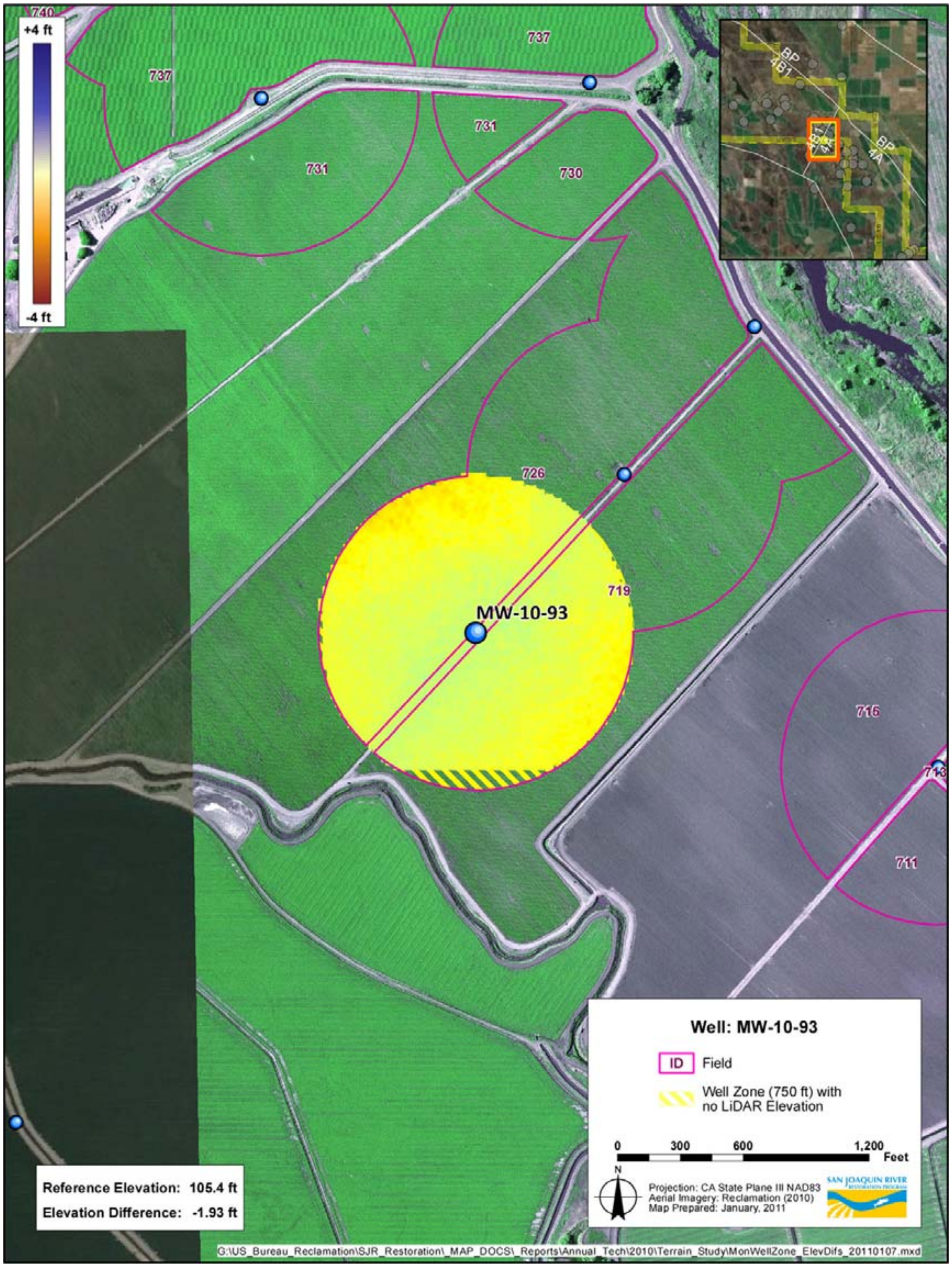

Figure H-2
Monitoring Well MW-10-93

Thresholds assume a flat groundwater surface in the area they represent. Groundwater level measurements taken in a well only accurately represent nearby groundwater conditions. Further away fields may have canals, sloughs, ditches, changes in soil type, or other factors influencing groundwater levels that are not represented in the well or threshold.

The difference between the ground surface elevation at the well and the minimum field elevation within 750 feet of the well was used as the ground surface buffer. A negative ground surface buffer indicates that the well is located lower than the adjacent field, such as in the river channel. An example of this is shown in Figure H-3 below.

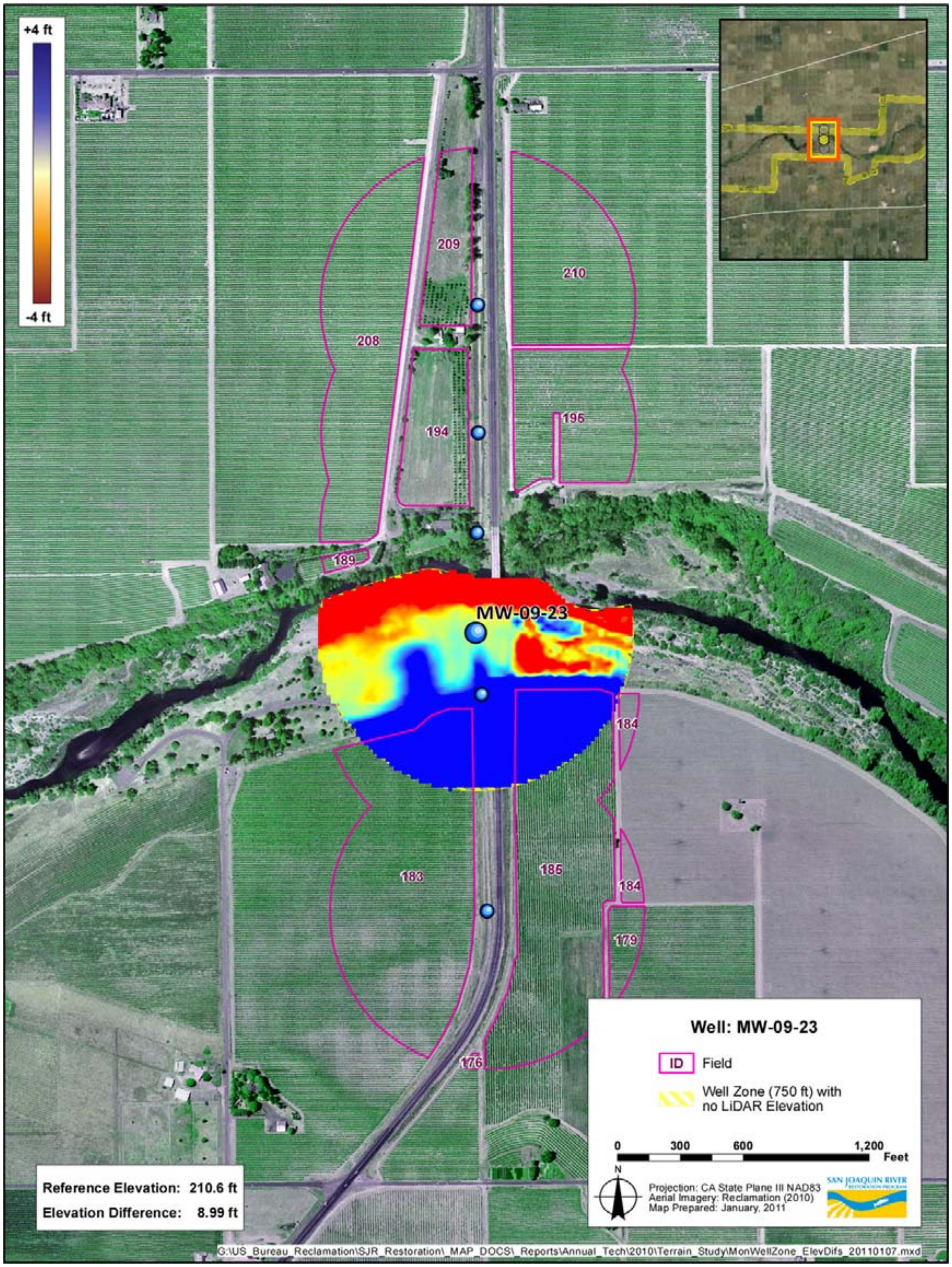

Figure H-3
Monitoring Well MW-09-23

2.2.2 Results

Corrections made for changes in elevation range from 8 to -9.5 feet. Results are shown per well in Table H-2 below.

Table H-2: Ground Surface Adjustment ($Threshold_{field}$ to $Threshold_{well}$)

Well	Ground Surface Elevation at Well (feet NAVD '88)	Minimum Adjacent Field Elevation (feet NAVD '88)	Ground Surface Buffer (feet)
191	110.9	108.0	2.8
186A	108.1	106.1	2.0
FA-1	206.87	205.1	1.8
FA-2	207.17	204.9	2.2
FA-3	206.43	204.9	1.5
FA-4	179.84	184.4	-4.6
FA-5	179.45	184.2	-4.7
FA-6	180.86	176.1	4.8
FA-7	181.57	175.9	5.6
FA-8	172.7	170.9	1.7
FA-9	174.48	170.8	3.7
MA-1	206.65	204.9	1.7
MA-2	182.69	179.8	2.9
MA-3	179	178.1	0.9
MA-4	174.45	168.4	6.1
MW-09-23	210.6	219.4	-8.8
MW-09-23B	210.6	219.4	-8.8
MW-09-36	191	186.5	4.5
MW-09-37	191.8	189.1	2.7
MW-09-37B	192.1	189.1	3.15
MW-09-39	184.9	184.4	0.5
MW-09-39B	184.9	184.4	0.5
MW-09-41	180.7	184.2	-3.5
MW-09-44	179.2	176.1	3.1
MW-09-46	173.5	170.9	2.5
MW-09-47	174.7	171.2	3.5
MW-09-49	171	169.2	1.8
MW-09-49B	170.9	169.2	1.7
MW-09-52	162.1	161.2	0.9
MW-09-54	168	160.3	7.7
MW-09-54B	168.2	160.3	7.9
MW-09-55	166.1	162.0	4.1
MW-09-55B	165.7	162.0	3.7
MW-09-56	161.2	159.5	1.7
MW-09-57	163.1	161.5	1.6
MW-09-85B	120.6	113.7	6.9
MW-09-86B	120.9	113.0	7.9
MW-09-87B	115	113.1	1.9
MW-10-100	102.7	98.2	4.5
MW-10-102	95.7	93.3	2.4
MW-10-103	99.1	94.5	4.6
MW-10-105	96.7	95.3	1.4
MW-10-106	95.08	93.1	1.9

Table H-2: Ground Surface Adjustment ($Threshold_{field}$ to $Threshold_{well}$)

Well	Ground Surface Elevation at Well (feet NAVD ’88)	Minimum Adjacent Field Elevation (feet NAVD ’88)	Ground Surface Buffer (feet)
MW-10-107	96	93.3	2.7
MW-10-108	96.5	94.7	1.7
MW-10-109	98.09	96.5	1.5
MW-10-110	88.84	87.0	1.8
MW-10-111	90.64	88.9	1.8
MW-10-113	99.53	95.1	4.4
MW-10-114	98.9	97.0	1.9
MW-10-118	138	135.6	2.4
MW-10-119	139.31	136.9	2.4
MW-10-124	154.07	153.4	0.6
MW-10-188	116.9	114.8	2.0
MW-10-74	136	131.8	4.2
MW-10-78	125.3	122.3	3.0
MW-10-80	124.9	119.8	5.1
MW-10-89	118.8	115.4	3.4
MW-10-91	107.2	103.5	3.7
MW-10-92	106	103.4	2.6
MW-10-93	105.4	103.2	2.2
MW-10-96	100.4	98.4	2.0
MW-10-97	101.2	97.8	3.4
MW-10-98	102.2	98.2	4.0
MW-10-99	104.3	99.6	4.7
PZ-09-R2B-1	155.16	153.9	1.2
PZ-09-R2B-2	153.17	149.3	3.9
PZ-09-R3-1	137.12	133.1	4.1
PZ-09-R3-2	138.39	136.8	1.5
PZ-09-R3-3	141.06	136.7	4.3
PZ-09-R3-4	140.24	136.7	3.5
PZ-09-R3-5	140.33	139.2	1.2
PZ-09-R3-6	141.56	140.1	1.5
PZ-09-R3-7	144.08	143.3	0.7
R1-1	216.85	215.3	1.5
R1-2	218.38	215.3	3.1
SJR W-1	100.17	98.4	1.8
SJR W-10	106.74	104.9	1.8
SJR W-11	108.23	106.4	1.8
SJR W-12	106.19	104.1	2.1
SJR W-2	103.19	98.9	4.2
SJR W-3	102.54	98.8	3.8
SJR W-4	106.35	105.2	1.1
SJR W-5	103.42	101.5	1.9
SJR W-6	105.65	101.3	4.4
SJR W-7	106.99	102.9	4.0
SJR W-8	108.88	105.5	3.3
SJR W-9	105.07	104.0	1.1

Key: NAVD = North America Vertical Datum

2.2.3 Limitations

Limitations of this analysis include:

- This approach assumes the groundwater level measured at a monitoring well represents the groundwater level under the lowest point within 750 feet of the well in the adjacent field. It does not address ground slope away from the river and assumes there is no groundwater table gradient within 750 feet of each well.
- The lowest adjacent field elevation within 750 feet may not represent a large acreage of the actively growing adjacent crop. The adjacent field could have a small depression that would result in a large ground surface adjustment and a conservative threshold in the well.

2.3 Irrigation Buffer Objectives

Objectives of the irrigation buffer include:

- Address salinity buildup in the soil column
- Allow space for furrow irrigation
- Allow space for leaching irrigation

2.3.1 Approach

Irrigation depends on crop type, evapotranspiration, and a variety of other factors. For the purposes of this study irrigation is generally either by drip lines or furrow.

In crops irrigated by furrow, a portion of irrigation in excess of evapotranspiration (ET), a combination of evaporation and plant transpiration of water from the soil to the atmosphere , passes through and beyond the crop root zone. The lower portion of the root zone may have higher salinity than the upper portion due to the smaller volume of water that passes through it (Ayers, 1985). Buildup of salts from irrigation or poor drainage may require periodic leaching applications. The purpose of this excess irrigation is to remove some of the applied salts from the lower portion of the root zone. This leaching fraction, with salts in a reduced volume and proportionately increased concentration, could dissolve additional salts from the underlying soil. If this situation occurs and there is inadequate drainage, a perched water table could occur, bringing water and concentrated salts back into the root zone (Rhoades, 1999).

Drip irrigation is generally matched to evapotranspiration rates, and thus has no deep percolation (Burt, 2010). These draft thresholds assume that there is no excess irrigation that could raise the water table, and thus, there is no buffer needed for drip irrigation.

The efficiency of drip lines results in a buildup of salts. These salts may require leaching. Deep percolation from drip irrigation in orchards in California leaves substantial amounts of salt in the soil (Burt, 2003). A buffer is assumed during the month prior to planting to ensure the lowering of the groundwater level prior to leaching and space for the leachate.

The irrigation buffer allows extra space for drainage following leaching of both furrow and drip irrigation to prevent a stagnant water table. This may be done pre-planting to address salt buildup in the root zone from salts that rose after the previous harvest. The lower water table avoids the waterlogging of roots and potential ‘subbing up’ of salts back into the root zone (Rhoades, 1999).

Reclamation gathered data and information from various sources for use in establishing a more locally based understanding of the irrigated agricultural practices. Table H-3 presents information on irrigation practices per crop type.

Table H-3
Irrigation By Crop Type

Crop Type	Pre-Irrigation Time	Pre-Irrigation Amount	Planting Time	Irrigation Timing	Irrigation Applied at surface (total)
Cotton and Corn (furrow)[1]	February / March	6" to 1' of water applied at surface	By May 1	June on, every 10 days	6" more than total ET, generally 3 to 3.5'
Tomatoes (drip)	Generally None[1]	Generally None[1]		Mid-May to September, every few days[3]	2.2'[2]
Wheat and small grains (furrow)				Every 7-18 days	4-8" each time[4]

Notes:
[1] C. White personal communication, 12/23/2010
[2] ITRC Report, November 2010
[3] San Juan Ranch irrigation records
[4] University of California Division of Agriculture and Natural Resources Publication 8168

Immediately following 6-inch furrow irrigation, the water can rise up to a couple of feet, however it should recede fairly rapidly with natural drainage or functioning artificial drains. On properties that do not have good natural drainage or artificial drains, extra space is allowed for excess furrow irrigation water to percolate. Reclamation has assumed an initial draft buffer during typical months of furrow irrigation, to allow groundwater levels to lower and excess irrigation to drain. This buffer may be applied as more information is obtained on properties with poor natural and no artificial drainage.

2.3.2 Results

The leaching buffer, presented in Table H-4 represents a buffer added only in certain times of the year to thresholds in areas with poor natural and no artificial drainage. Identification of additional areas with poor drainage may be aided by observation of inverted soil salinity profiles (Rhoades, 1999).The purpose of the leaching buffer is to allow for leaching irrigation, if needed, to remove accumulated salts in the soil from irrigation or groundwater. The irrigation buffer is not intended to prevent the temporary rise of the water table several feet, but rather to allow the water table to recede by allowing for drainage. A leaching application of 1 foot of water may cause a 3 foot or more rise in the water table temporarily, but would not be expected to move salts and the water table would recede.

Table H-4
Irrigation Buffer

Type	Time of Year	Leaching Buffer
Poorly drained areas	Feb & March – planting	1'

2.3.3 Limitations

SJRRP groundwater thresholds would benefit from landowner input to determine timing and amounts of leaching. Limitations of the analysis include:

- For annual crops the timing of the water table fluctuations will be different than for semi-permanent crops such as orchards and vineyards. This approach does not take a crop-specific planting time into account.
- Crop rotations may influence the irrigation buffer zones each year. Planting of winter rotation crops may result in more irrigation in the spring. This approach uses values based on general irrigation per crop as recorded in Table 2-4.
- Existing management of salinity by leaching will likely continue.
- Monitoring wells located underneath irrigation header lines will show increases in groundwater levels above the adjacent field. This approach does not take this into account.

2.4 Capillary Fringe Objectives

Inclusion of a capillary fringe buffer intends to:

- Account for the more saturated portion of the capillary zone

2.4.1 Approach

The height of the capillary fringe depends on soil texture, depth to the water table, evaporative demand of the atmosphere, and land use (Belitz, 1993). Fine-grained soil texture with broad distribution of grain sizes contains small pores, which increases the capillary rise (Hackett, 1927; Carman, 1941). A deeper water table will often have a larger capillary fringe. In addition, crop roots transpire water, affecting capillary rise and concentrating salts.

Two related items that are a part of the monitoring of a shallow water table are the potential saturation of the crop root zone and the movement of dissolved salts and potential to increase the salinity of the soil root zone.

A water table and associated CR under actively growing crops can increase soil moisture and supply some of the crop water demand, reducing irrigation (Ramirez, 1996). If the water table is too deep, then groundwater is not able to move up far enough, or at a rate fast enough, to supply much of the crop demand. If the water table is too shallow and encroaches on the root zone then crop production will suffer due to lack of air in the root zone. Also, if the water table is too saline, the crop cannot use much of the ground water.

The following illustrations presented in Figures H-4 and H-5 (Sands, 2001) show the relationship of soil CR potential vs. the amount of saturation and air in the soil pore space. Capillary forces can conduct water several feet above a water table in medium and fine textured soils. A large portion of the CR above the water table contains air and water and is not detrimental to plant root growth from the water logging standpoint. Only the part of the CR that is immediately above the water table is the area of concern for water-logging and could be included in the monitoring threshold. For the purposes of this Plan, this will be called the capillary fringe. The capillary fringe is a zone above a water table that is nearly saturated near the base and just above field capacity at the top.

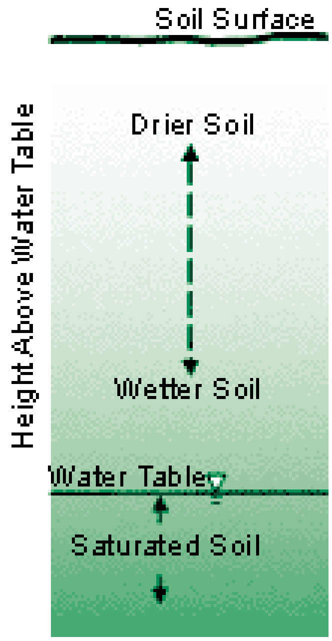

Figure H-4
Soil Moisture Variation Between the Water Table

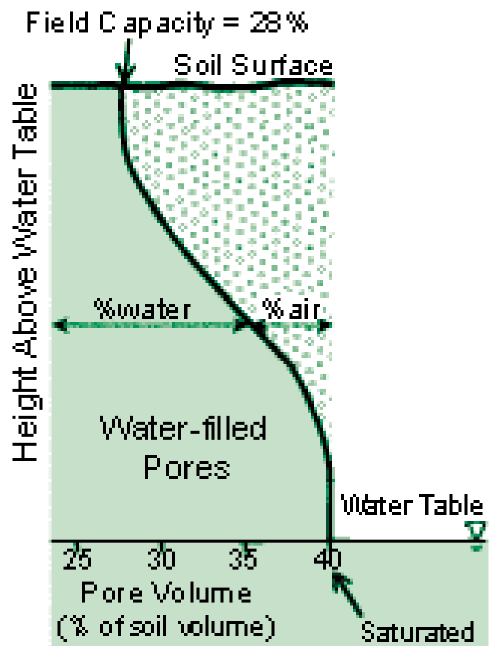

Figure H-5
Proportion of Air- and Water-Filled Pores Between the Water Table and the Soil Surface After the Downward Flow of Water Ceases

Field Capacity is less than saturation, but is moist in terms of total soil moisture. Generally field capacity moisture content is representative of the condition when a fully saturated soil profile is allowed to drain for 12-24 hours. Field capacity is water held under slight tension, often defined as 1/3 bar or 1/3 atmospheric pressure for laboratory experiments or in-field monitoring instruments (Brady, 1974).

The lower portion of the capillary fringe is considered too wet for crop health and few roots penetrate this zone. Crops do however use water from the top portion of this capillary fringe zone where there is more entrapped air. Capillary fringes may be thicker in the non crop season, under roads and other barren areas, and when water tables are deeper in the substrata.

Usually entrapped air, soil stratification and the discontinuity of soil pores and structural channels limit the thickness of a capillary fringe. The field setting can present a different capillary fringe than a theoretical or laboratory experiment under uniform controlled conditions. Thus, measurements made in the field are the basis for this analysis.

The capillary fringe is dependent on matric suction (or negative pressure head) to rise. During the furrow irrigation season, when infiltration from the ground surface adds a zone of near saturation at the top of the soil column, matric suction is reduced. If the matric suction within the pore spaces between the bottom of the irrigation zone and the capillary fringe is not great enough, capillary rise will be limited. In addition to the reduced capillary rise under irrigation, the capillary fringe and associated salinity may be pushed down depending on the leaching fraction of the applied irrigation (Rhoades, 1999). Between furrow irrigations, plants could pull up salts by transpiring water and capillary forces would then cause water and salt to rise above the water table and potentially into the root zone. These same crops could also limit the CR however, by transpiring water before it can rise further into the root zone.

Soil boring logs from 85 soil sampling sites collected in March and April of 2010 were reviewed to determine the potential thickness of capillary fringe zones in soils of various textures on lands near the San Joaquin River. These are presented in Table H-5 below.

Drill logs or, when available, the logs from soil borings offset from the wells were examined to determine soil textures in the monitoring wells from 4-6 feet deep. Many soil sampling sites were offset from stakes that were planned for future monitoring well sites when wells had not yet been drilled. In some cases the drill logs had fill. Under these circumstances the texture evaluation was 4-6 feet below the fill / native soil boundary as noted on the logs for the subsurface profile. Each well was assigned a capillary fringe thickness based on this analysis. Capillary fringe thicknesses for each well are presented in Table H-6.

2.4.2 Results

A summary of the findings from the review of soil logs is presented below in Table H-5.

Table H-5
Capillary Fringe Thickness (inches)

Category	Soil Texture	Number of Observations	Average Rise, Inches	95% Confidence Range, inches
1	Sand, loamy sand	15	6.9	4.1 – 9.1
2	Sandy loam, loamy fine sand	4	13.75	9.5 – 18.1
3	Fine sandy loam, loam, silt loam, very	21	18.3	14.3 – 22.3

	fine sandy loam			
4	Clay loam, silty clay loam, clay	6	10.3	5.1 – 15.5
2 and 3	Loamy fine sand, silt loam	25	17.6	14.1 – 20.9

Based on the data presented above from soil sampling sites (mostly in Reaches 4a and 4b) a capillary fringe (CF) thickness of 1 foot for all soils except the loamy sand and sand soils was incorporated. A 0.5 foot CF thickness would be used for these soils. The reasons for this decision are listed below.

- The sites were evaluated based on spring conditions before the crop season. When an actively growing crop is present and is consuming water from the upper portion of the capillary fringe the thickness of the capillary fringe should be less.
- The upper portion of CF contains enough air to permit root establishment.
- Categories 2-4 were combined since the 95 percent confidence intervals overlapped. The clay loam and clay soils were added to the 1 foot CF category since the low macro pore space present in these soils makes field observations of capillary fringe difficult.
- Only hand augured holes were evaluated. Large drill rigs tend to advance flight augurs too rapidly to evaluate and estimate capillary fringe conditions.
- The thick capillary fringe observed in October by ITRC researchers (Burt, 2010) was partially due to the lack of crop in the field and the depth to the water table. No crop roots were using water from the capillary fringe at the time, resulting in large observed capillary moisture content at some distance above the actual water table. The water table was about 7 to 8 feet deep rather than in the 4-5 foot threshold range. Capillary fringe thickness should increase with a deeper water table that is farther away from the influences of evaporative and crop consumptive use forces near the soil surface.

2.4.3 Limitations

- Timing of the capillary fringe vs. growing season or root development is not addressed in this approach.
- Water quality of the groundwater is not included as part of this evaluation. The irrigation buffer discussed below allows for leaching of potentially saline groundwater from the root zone.
- This approach does not address the degree of soil salinity existing at each site. Soil salinity is addressed through the irrigation buffer.

2.5 Agricultural Practices Threshold Results

Table H-6 below shows the results of the agricultural practices method.

Table H-6: Agricultural Practices Method Thresholds

Well ID	Reach	Bank	Crop Type	Root Zone (feet)	Capillary Rise (feet)	Threshold in field (feet bgs)	Ground Surface Adjustment	Threshold in well (feet bgs)
JR-1	1A	Left	Public Land	4	1	5.0	0	5.0
JR-2	1A	Left	Public Land	4	1	5.0	0	5.0
MW-09-1	1A	Right	Public Land	4	.5	4.5	0	4.5
MW-09-2	1A	Right	Public Land	4	.5	4.5	0	4.5
FA-1	1B	Left	Vineyard	6	1	7.0	1.8	8.8
FA-2	1B	Left	Vineyard	6	1	7.0	2.2	9.2
FA-3	1B	Left	Vineyard	6	1	7.0	1.5	8.5
MA-1	1B	Left	Fallow	4	1	5.0	1.7	6.7
MW-09-23	1B	Left	Public Land	4	.5	4.5	-8.8	-4.3
MW-09-23B	1B	Left	Public Land	4	.5	4.5	-8.8	-4.3
MW-09-25	1B	Right	Public Land	4	1	5.0	-9.6	-4.6
R1-1	1B	Right	Pomegranate	6	.5	6.5	1.5	8.0
R1-2	1B	Right	Pomegranate	6	.5	6.5	3.1	9.6
FA-4	2A	Left	River Channel	4	1	5.0	-4.6	0.4
FA-5	2A	Left	River Channel	4	1	5.0	-4.7	0.3
FA-6	2A	Left	River Channel	4	1	5.0	4.8	9.8
FA-7	2A	Left	Almonds	9	1	10.0	5.6	15.6
FA-8	2A	Left	River Channel	4	1	5.0	1.7	6.7
FA-9	2A	Left	Alfalfa	4	1	5.0	3.7	8.7
MA-2	2A	Right	Annual Crops	4	1	5.0	2.9	7.9
MA-3	2A	Right	Annual Crops	4	1	5.0	0.9	5.9
MA-4	2A	Right	Vineyard w Drains	6	1	7.0	6.1	13.1
MW-09-36	2A	Right	Annual Crops	4	1	5.0	4.5	9.5
MW-09-37B	2A	Left	Vineyard	6	1	7.0	3.0	10.1
MW-09-39B	2A	Left	Almonds	9	.5	9.5	0.5	10.0
MW-09-47	2A	Right	Vineyard w Drains	6	1	7.0	3.5	10.5
MW-09-49B	2A	Left	Annual Crops w Drains	4	.5	4.5	1.7	6.2
MW-09-52	2B	Right	Almonds	9	1	10.0	0.9	10.9
MW-09-54B	2B	Right	Almonds	9	1	10.0	7.9	17.9

Table H-6: Agricultural Practices Method Thresholds								
Well ID	**Reach**	**Bank**	**Crop Type**	**Root Zone (feet)**	**Capillary Rise (feet)**	**Threshold in field (feet bgs)**	**Ground Surface Adjustment**	**Threshold in well (feet bgs)**
MW-09-55B	2B	Left	Palms	6	1	7.0	3.7	10.7
MW-09-56	2B	Left	Pistachios	6	1	7.0	1.7	8.7
PZ-09-R2B-1	2B	Right	Annual Crops	4	1	5.0	1.3	6.3
PZ-09-R2B-2	2B	Right	Annual Crops	4	.5	4.5	3.9	8.4
155	3	Left	Almonds	9	1	10.0	3.3	13.3
MW-10-117	3	Right		4	1	5.0	0	5.0
MW-10-118	3	Right		4	1	5.0	2.4	7.4
MW-10-119	3	Right		4	1	5.0	2.4	7.4
MW-10-120	3	Left		4	1	5.0	0	5.0
MW-10-121	3	Left		4	1	5.0	0	5.0
MW-10-122	3	Right		4	1	5.0	0	5.0
MW-10-123	3	Left		4	1	5.0	0	5.0
MW-10-124	3	Right		4	1	5.0	0.6	5.6
MW-10-74	3	Left	Almonds	9	.5	9.5	4.2	13.7
MW-10-75	3	Left	Almonds	9	1	10.0	0.5	10.5
MW-10-76	3	Left	Annual Crops	4	1	5.0	2.7	7.7
MW-10-78	3	Right	Annual Crops	4	1	5.0	3.0	8.0
PZ-09-R3-1	3	Right		4	.5	4.5	4.1	8.6
PZ-09-R3-2	3	Right	Annual Crops	4	1	5.0	1.5	6.5
PZ-09-R3-3	3	Right	Annual Crops	4	1	5.0	4.3	9.3
PZ-09-R3-4	3	Right	Annual Crops	4	1	5.0	3.5	8.5
PZ-09-R3-5	3	Right	Annual Crops	4	1	5.0	1.2	6.2
PZ-09-R3-6	3	Right	Annual Crops	4	1	5.0	1.5	6.5
PZ-09-R3-7	3	Right	Annual Crops	4	.5	4.5	0.7	5.2
191	4A	Left		4	1	5.0	2.9	7.9
186A	4A	Left		4	1	5.0	2.0	7.0
MW-09-83B	4A	Right	Public Land	4	1	5.0	0	5.0
MW-09-85B	4A	Right	Public Land	4	1	5.0	6.9	11.9
MW-09-86B	4A	Left	Public Land	4	1	5.0	7.9	12.9
MW-09-87B	4A	Left	Public Land	4	.5	4.5	1.9	6.4

Table H-6: Agricultural Practices Method Thresholds

Well ID	Reach	Bank	Crop Type	Root Zone (feet)	Capillary Rise (feet)	Threshold in field (feet bgs)	Ground Surface Adjustment	Threshold in well (feet bgs)
MW-09-88	4A	Left	Public Land	4	1	5.0	2.2	7.2
MW-10-115	4A	Left		4	1	5.0	0	5.0
MW-10-116	4A	Right		4	1	5.0	0	5.0
MW-10-188	4A	Left	Annual Crops	4	1	5.0	2.1	7.1
MW-10-80	4A	Right	Annual Crops	4	1	5.0	5.1	10.1
MW-10-89	4A	Right	Almonds	9	.5	9.5	3.4	12.9
MW-10-91	4A	Left	Tomatoes	3	1	4.0	3.7	7.7
MW-10-92	4A	Left	Tomatoes	3	1	4.0	2.6	6.6
MW-10-93	4A	Left	Tomatoes	3	1	4.0	2.2	6.2
SJR W-10	4A	Left	Tomatoes	3	1	4.0	1.8	5.8
SJR W-11	4A	Left	Tomatoes	3	1	4.0	1.8	5.8
SJR W-12	4A	Left	Tomatoes	3	1	4.0	2.1	6.1
SJR W-4	4A	Left	Corn	3	1	4.0	1.1	5.1
SJR W-5	4A	Left	Tomatoes	3	1	4.0	1.9	5.9
SJR W-6	4A	Left	Tomatoes	3	1	4.0	4.4	8.4
SJR W-7	4A	Left	Tomatoes	3	1	4.0	4.0	8.0
SJR W-8	4A	Left	Alfalfa	4	1	5.0	3.3	8.3
SJR W-9	4A	Left	Tomatoes	3	1	4.0	1.1	5.1
MW-10-100	4B1	Left	Annual Crops	4	1	5.0	4.5	9.5
MW-10-102	4B1	Right	Annual Crops	4	1	5.0	2.4	7.4
MW-10-103	4B1	Right	Annual Crops	4	1	5.0	4.6	9.6
MW-10-105	4B1	Left		4	1	5.0	1.4	6.4
MW-10-106	4B1	Left		4	1	5.0	2.0	7.0
MW-10-107	4B1	Left		4	1	5.0	2.7	7.7
MW-10-108	4B1	Left		4	1	5.0	1.7	6.7
MW-10-109	4B1	Left		4	1	5.0	1.5	6.5
MW-10-110	4B1	Left		4	1	5.0	1.8	6.8
MW-10-111	4B1	Left		4	1	5.0	1.8	6.8
MW-10-112	4B1	Right		4	1	5.0	0	5.0
MW-10-113	4B1	Left		4	1	5.0	4.4	9.4
MW-10-114	4B1	Left		4	1	5.0	1.9	6.9
MW-10-90	4B1	Right	Pistachios	6	1	7.0	4.7	11.7

Table H-6: Agricultural Practices Method Thresholds								
Well ID	**Reach**	**Bank**	**Crop Type**	**Root Zone (feet)**	**Capillary Rise (feet)**	**Threshold in field (feet bgs)**	**Ground Surface Adjustment**	**Threshold in well (feet bgs)**
MW-10-94	4B1	Right	Pistachios	6	1	7.0	0	7.0
MW-10-95	4B1	Right	Alfalfa	4	1	5.0	2.2	7.2
MW-10-96	4B1	Right	Alfalfa	4	1	5.0	2.0	7.0
MW-10-97	4B1	Right	Annual Crops	4	.5	4.5	3.4	7.9
MW-10-98	4B1	Left	Annual Crops	4	1	5.0	4.0	9.0
MW-10-99	4B1	Left	Annual Crops	4	1	5.0	4.7	9.7
SJR W-1	4B1	Left		4	1	5.0	1.8	6.8
SJR W-2	4B1	Left		4	1	5.0	4.2	9.2
SJR W-3	4B1	Left		4	1	5.0	3.8	8.8
MW-09-125	5	Right	Alfalfa	4	1	5.0	0	5.0

3 Historical Groundwater Levels

The second method of analysis, historical groundwater levels, makes use of long-term groundwater-level measurements to derive thresholds in the context of historical field conditions and agricultural practices. Groundwater level data along the San Joaquin River does not exist in all areas and times of interest. Sources of historical groundwater data include CCID, which maintains a network of shallow monitoring wells; the United States Geological Survey (USGS); and the California Department of Water Resources (DWR). Ninety percent of the available records represent the period from 1960 to the present, with some wells covering a longer time period. Although some wells have monthly or weekly measurements for short periods of time, the majority of wells have biannual spring and fall measurements.

3.1 Objectives

The objective of the historical groundwater level method is to use long-term groundwater-level data to indicate hydrologic conditions under which agriculture has historically operated, and to derive thresholds on the basis of this information.

3.2 Approach

Threshold development using historical groundwater levels is approached in three ways, depending on availability of long-term data:

1. If the threshold well has been monitored long term, the groundwater levels are used directly to derive a threshold;

2. If the threshold well has not been monitored long term, but one or more nearby wells has, the groundwater levels from the nearby well(s) are used indirectly to derive a threshold; or

3. If the threshold well has not been monitored long term, and no nearby wells have been monitored long term, mapped estimates of the depth to water at the well location are used to derive a threshold.

3.2.1 Method A: Thresholds for long-term wells

Long-term groundwater level data for a shallow well provide a good indication of historical variability and position of the water table. These data reflect a combination of climatic influences and agricultural practices. Climatic influences include local precipitation and flows in canals and the river. Agricultural practices include irrigation, groundwater pumping, and various forms of drainage. Groundwater levels represent the combined effect of these processes, making these data very useful for developing monitoring thresholds.

Hydrographs were made for threshold wells having available data during the period from 1983 through September 2009, just prior to the first Interim Restoration flows in October 2009. This time period is relatively data rich, and represents the post-recovery period following importation of surface water to the region and associated decline in groundwater pumping (Belitz and others, 1993).

From these hydrographs, spring (March through May) and fall (September through November) measurements were identified and grouped. Spring and fall thresholds were defined as the 75th percentile of each group of spring and fall measurements. A percentile is the value of a variable below which a certain percent of observations fall. The 75th percentile of spring measurements represents the measurement below which 75 percent of the measurements fall; the other 25 percent of the measurements are greater than the 75th percentile. This methodology shaves off the highest 25 percent of groundwater level measurements, thereby excluding high levels associated with extreme climatic events and irrigation events that coincided with the measurements.

Figure H-7 shows an example of spring and fall thresholds developed for threshold well CCID-191 using this method. Groundwater levels (points) shown in red were measured during the spring, and those in green were measured during the fall; blue points represent other seasons and measurements after September 2009. The red dashed line is the 75th percentile during the spring, or the spring threshold; the green dashed line is that for the fall. Note that the high groundwater levels associated with 1983 and other relatively wet years are above the thresholds, as they should be.

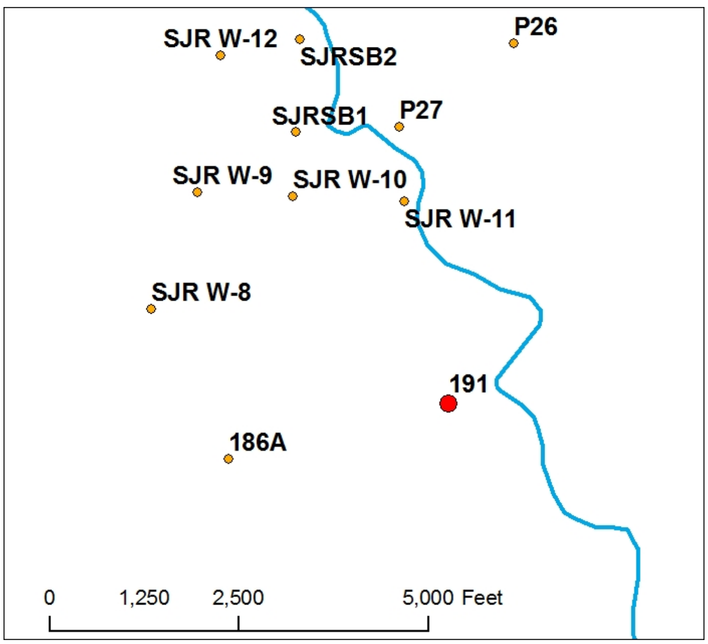

Figure H-6
General location of CCID shallow monitoring well 191

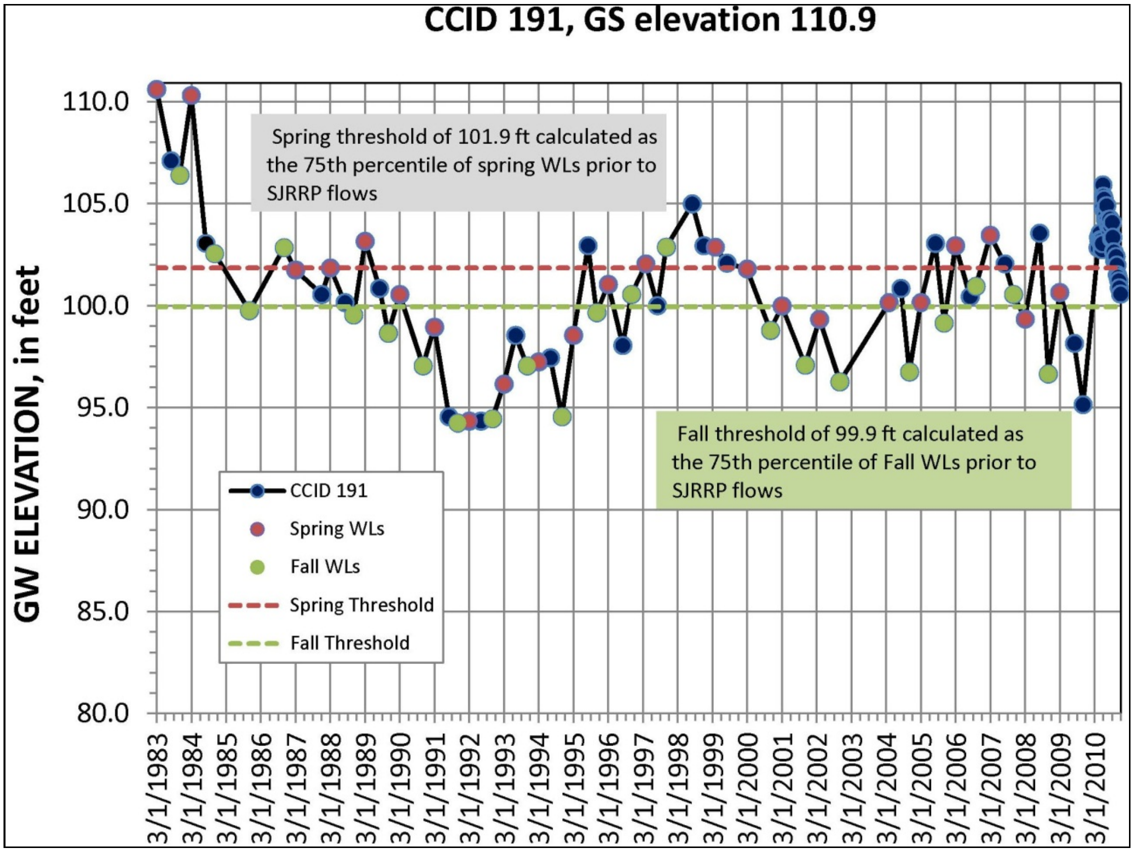

Figure H-7
Thresholds developed using historical groundwater-level measurements in CCID Well 191

3.2.2 Method B: Thresholds for wells near long-term wells

To assign thresholds for wells having only short-term groundwater level date (i.e., beginning in 2009 or later), use was made of long-term groundwater level data associated with a nearby well. Thresholds were calculated as described above using long-term groundwater levels from the nearby well, with one exception: groundwater-level elevations for the nearby well were adjusted by the difference in ground-surface elevation between the nearby and threshold wells.

A key assumption in this approach is that hydrologic conditions local to the well(s) having long-term data, such as depth to water, are similar to those at the threshold well. This assumption was tested graphically by comparing historical data from the nearby well to short-term data from the threshold well. The potential effect of Interim Restoration flows on the short-term groundwater levels from the threshold well makes this an imperfect comparison, but it is a reasonable test of the assumption.

Figure H-8 shows an example of spring and fall thresholds developed for threshold well MW-10-93 using this method. The nearby well having long-term groundwater level data that was used to develop the threshold is CCID-184. The ground surface at the CCID well is 0.4 ft lower than at the threshold well; this amount was therefore added to the groundwater level elevations of the CCID well to match the assumed equivalent hydrologic conditions at MW-10-93. Note that the cluster of blue data points on the right side of the plot, which were measured in MW-10-93, reasonably match historical conditions measured in CCID-184.

Groundwater levels (points) shown in red in Figure H-9 were measured during the spring, and those in green were measured during the fall; blue points represent other seasons and measurements after September 2009. The red dashed line is the 75th percentile during the spring, or the spring threshold; the green dashed line is that for the fall. Note that the high groundwater levels associated with 1983 and other relatively wet years are above the thresholds, as they should be.

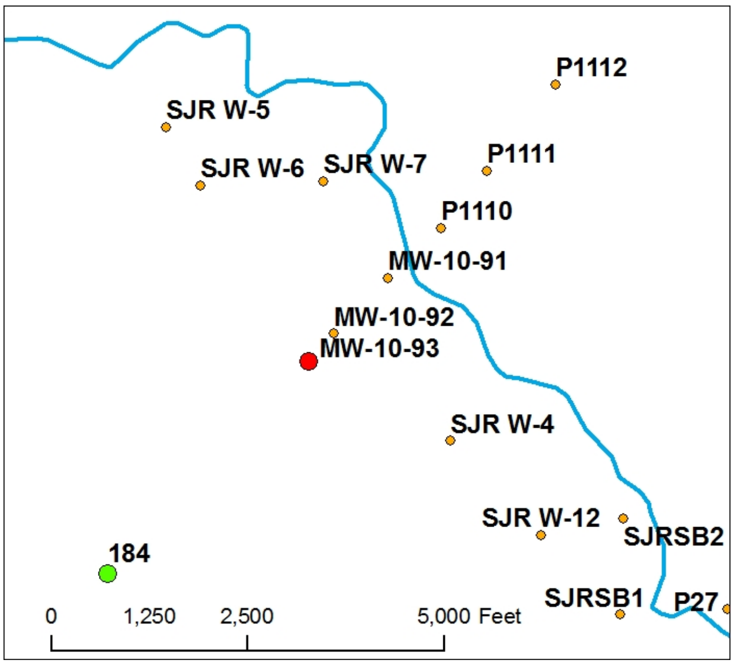

Figure H-8

General location of well MW-10-93 and nearby CCID shallow monitoring well 184

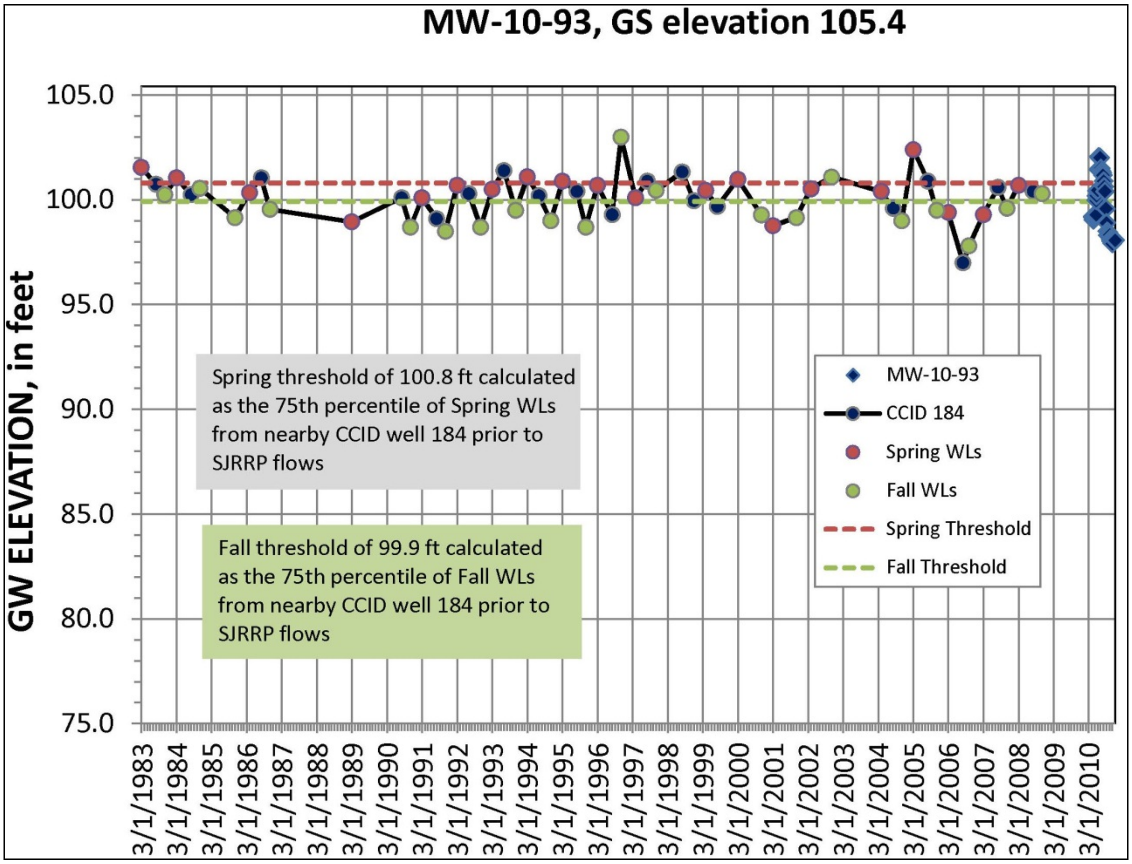

Figure H-9
Thresholds developed for MW-10-93 using historical groundwater-level measurements from the nearby CCID well

3.2.3 Method C: Thresholds for wells with no long-term data

There is a set of threshold wells for which little or no short-term groundwater level data are available, and no nearby wells provide long-term data. Thresholds for these wells based on historic groundwater levels, regardless of methodology, will have a relatively high degree of uncertainty. A means was developed, however, for providing ballpark threshold estimates using existing maps of depth to water, and a new map based on average long-term data from CCID.

3.2.3.1 Thresholds Based on Maps of Depth to Water

The USGS developed maps of depth to water (DTW) for various years from the 1960s to present having the greatest number of measurements. These maps were developed before some of the well construction information was available, and therefore include both shallow and deep wells in some areas. There are few shallow wells available outside of Reaches 3 and 4A. The DTW maps cover a variety of year types; the three maps chosen for use in this analysis represent average, or normal, conditions. Spring 2008 represents springtime conditions in normal-dry year, fall 2008 represents fall conditions in a normal-dry year, and fall 1999 represents fall conditions in a normal-wet year. The water-level database contains few spring groundwater level measurements, thus few spring DTW maps were made, and no map is available to represent normal-wet springtime conditions. This, and the inclusion of deep wells, may result in lower groundwater levels than a truly representative sample.

The DTW maps developed by the USGS, and presented in Figures H-10 through H-15, were developed using data from CCID, DWR, and USGS; these data were interpolated using the inverse distance weighting (IDW) method. The IDW method averages the depth to water in adjacent wells while weighting measurements from closer wells more heavily than those from more distant wells. A greater concentration of points results in a better interpolation. Interpolations in areas having few or no wells can only be considered an approximation of actual conditions. Interpolated depths to water at SJRRP monitoring well locations were assigned as threshold values. In areas completely without data (for example, in Fall 2008 Reaches 1A through 2A - Figure H-10 below), no thresholds were assigned.

The SJRRP converted depths to water from the maps below, which represent depth to water below the field, to depth to water in the well assuming the same ground surface adjustment used in the Agricultural Practices Method.

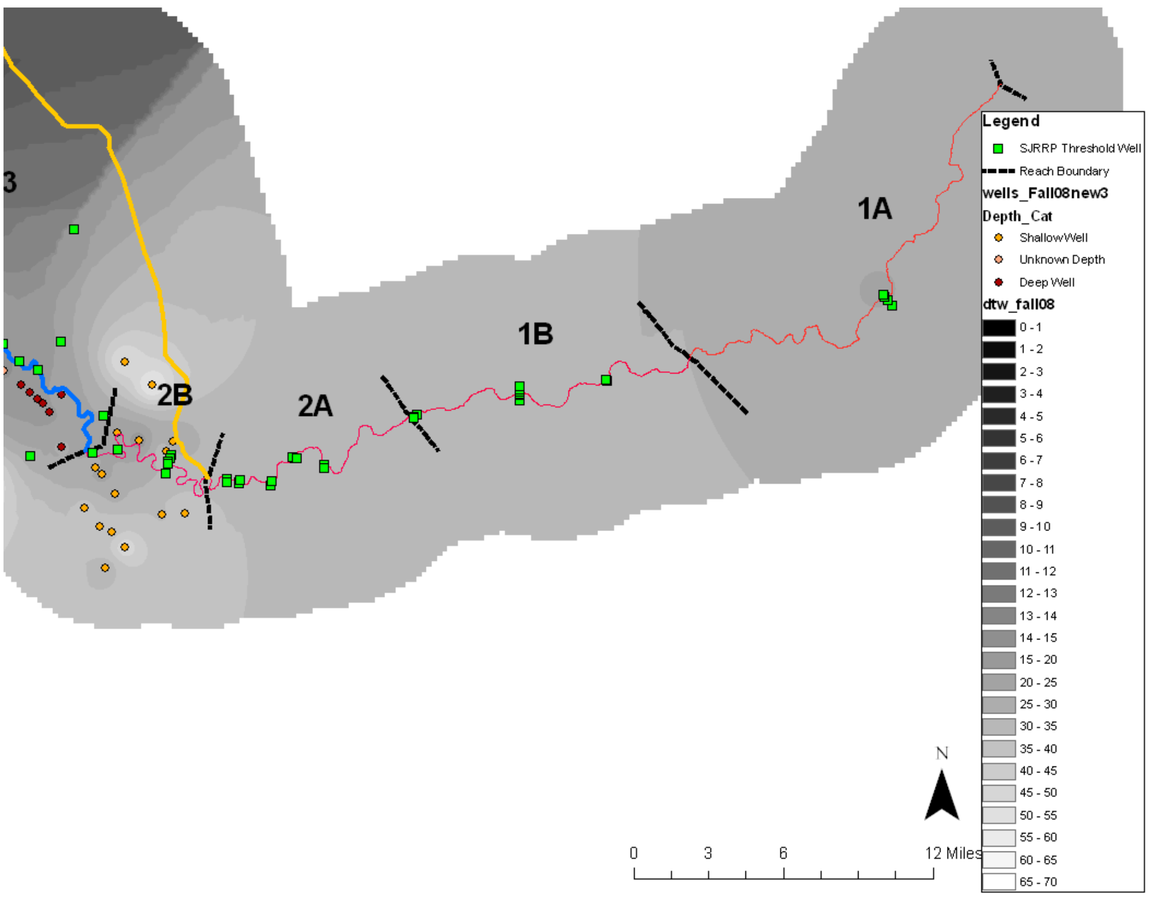

Figure H-10
Fall 2008 Depth to Water in Reaches 1A through 2B

The DTW maps contain deep wells, which likely represent hydraulic conditions within the confined aquifer, where the majority of groundwater pumping occurs, rather than the unconfined surface aquifer that contains the water table. These wells include Mendota Pool Group production wells and other groundwater extraction wells. Because of this, low spots can be seen on the maps surrounding production wells; this is particularly noticeable in Figure H-13. When interpolated on DTW maps with sparse data, these pumping centers affect groundwater levels far away from the pumps. This limitation, combined with the fact that they may represent the production zone of the confined aquifer, calls into question their appropriateness for representing water-table conditions. However, some deep wells may have water levels representative of the water table, especially those northeast of the San Joaquin River. To reduce the influence of deep pumping wells on results, the minimum value from the three DTW maps was assigned as the DTW-based threshold.

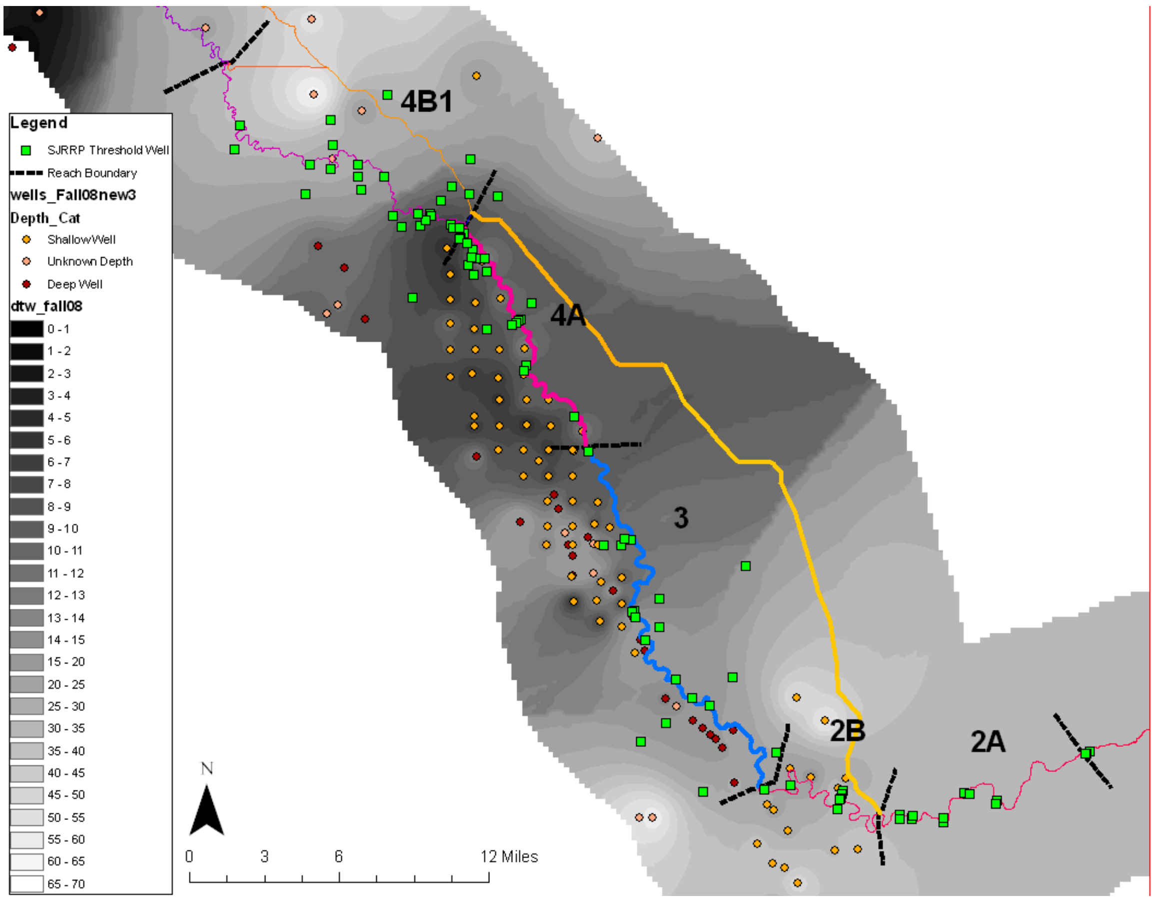

Figure H-11
Fall 2008 Depth to Water in Reaches 2B through 4B1

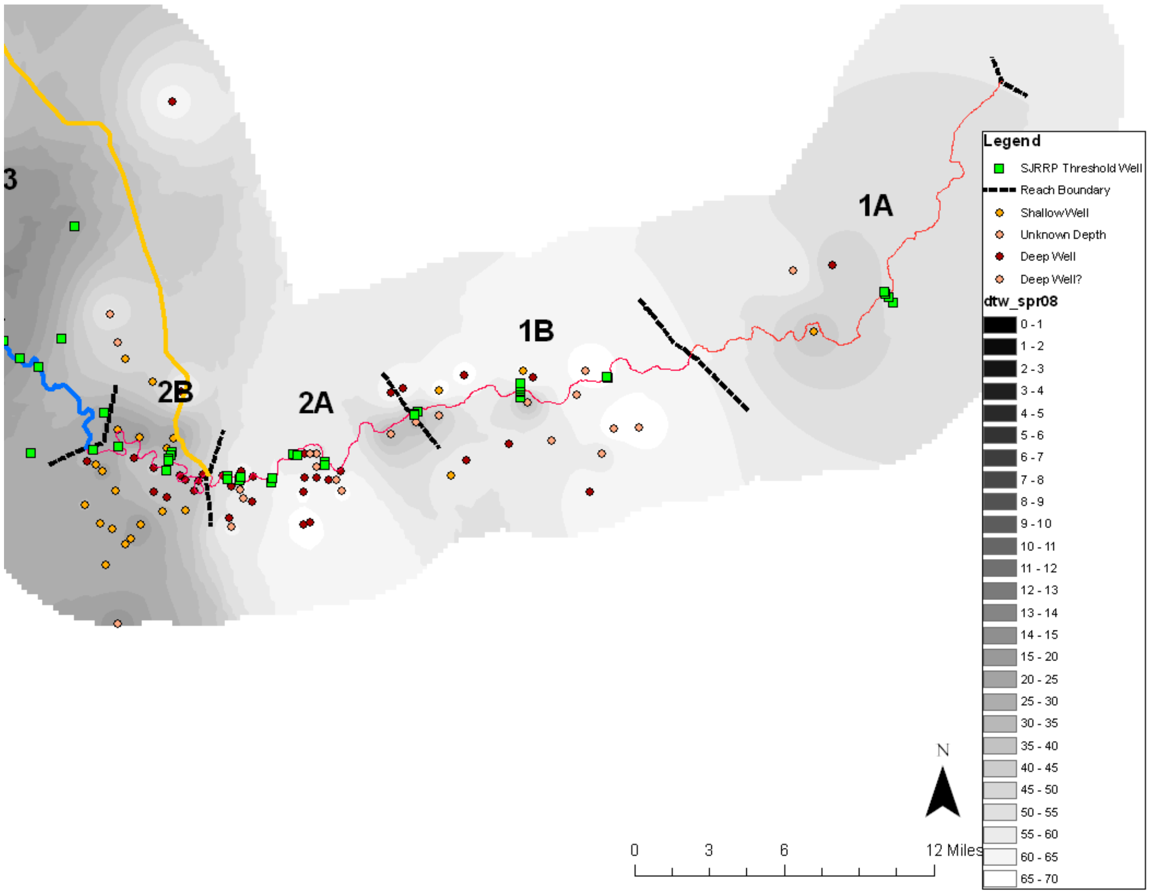

Figure H-12
Spring 2008 Depth to Water in Reaches 1A through 2B

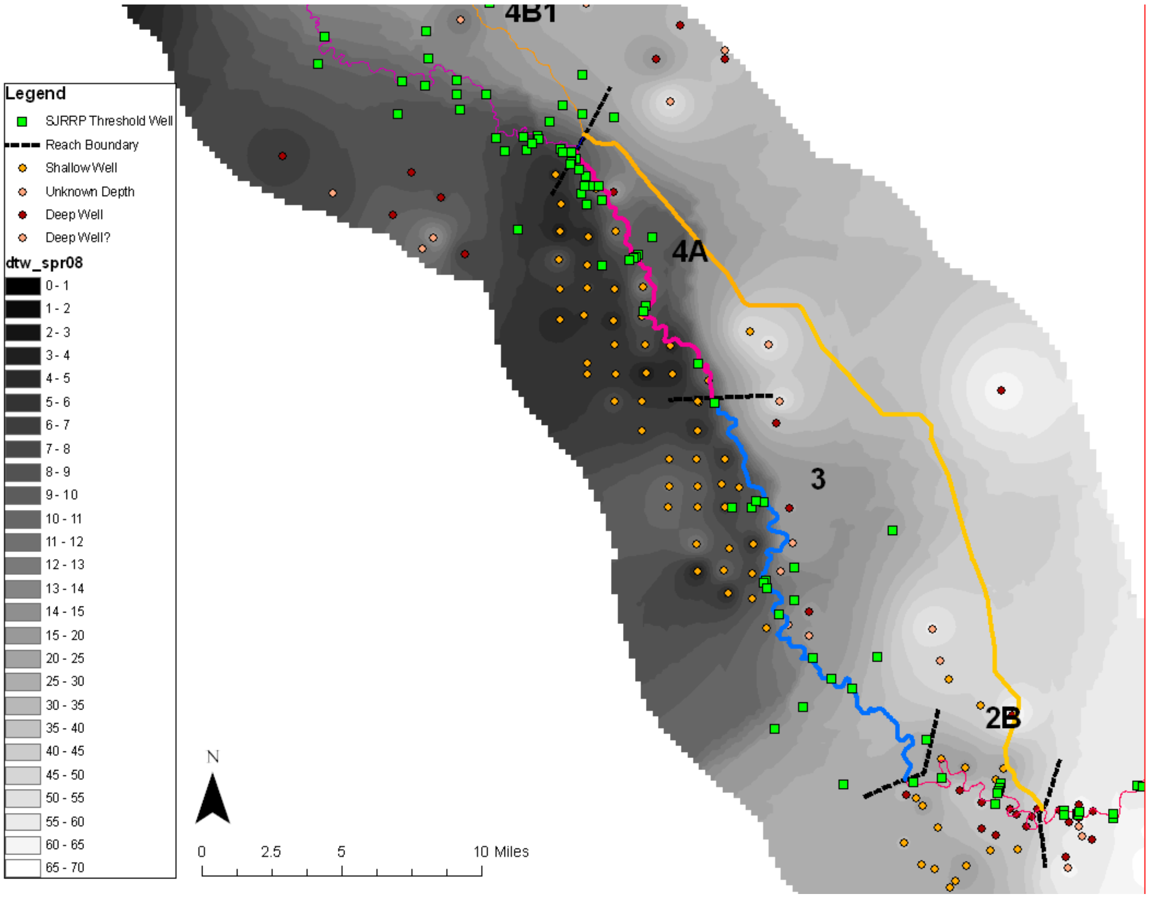

Figure H-13
Spring 2008 Depth to Water in Reaches 2B through 4B1

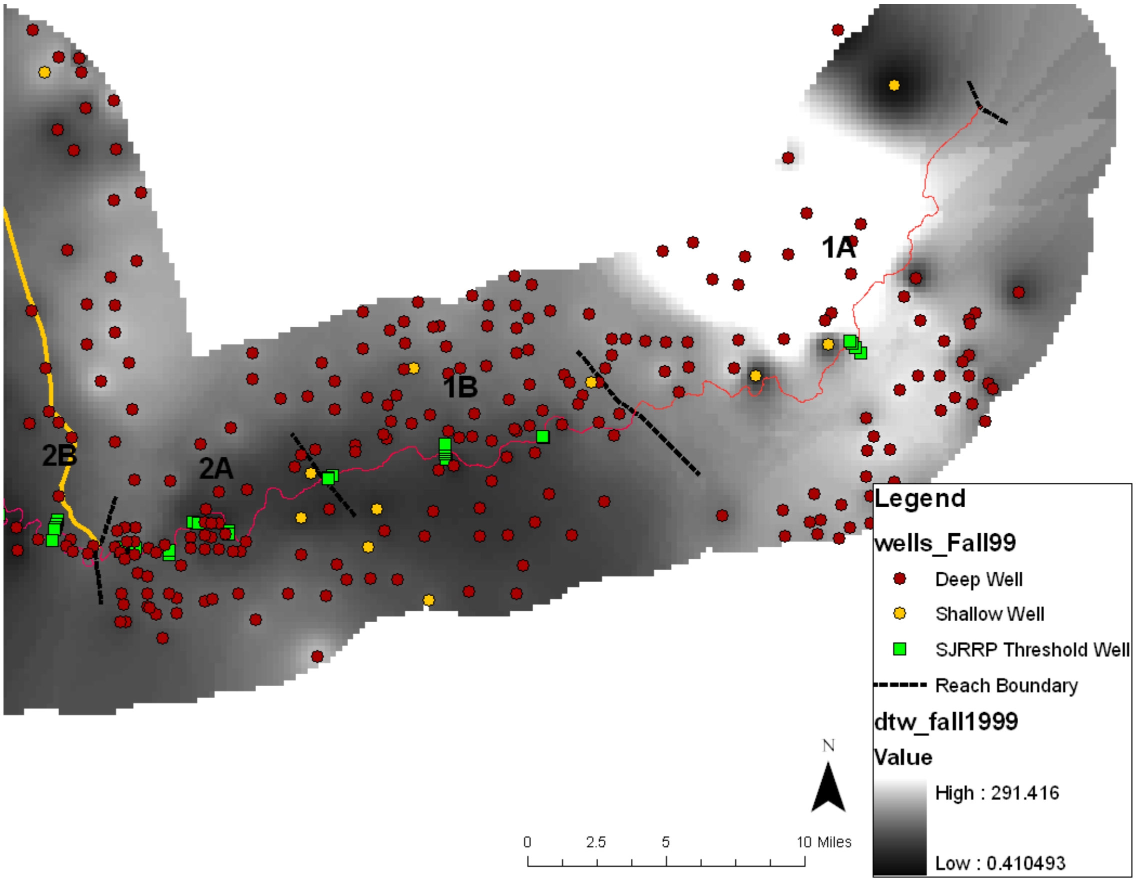

Figure H-14
Fall 1999 Depth to Water in Reaches 1A through 2B

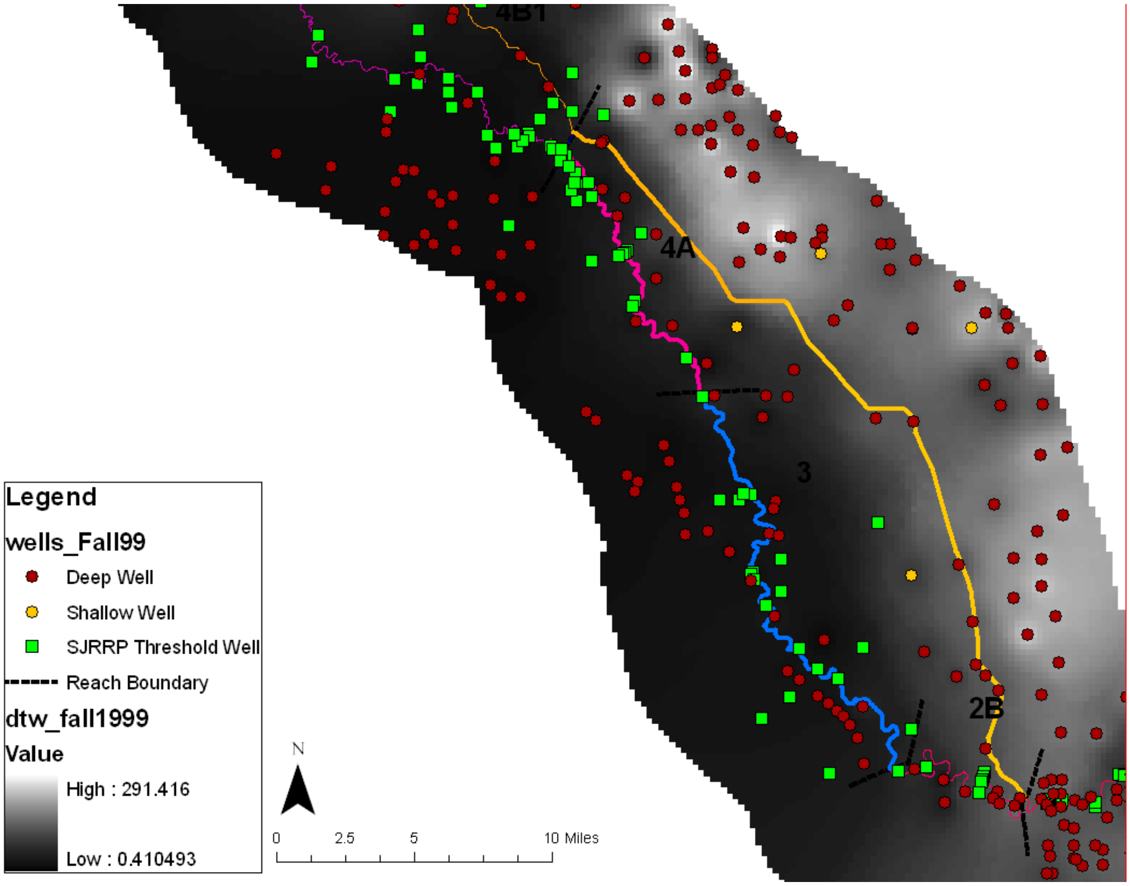

Figure H-15.
Fall 1999 Depth to Water in Reaches 2B through 4B1

3.2.4 CCID Threshold Wells

3.2.4.1 Thresholds Based on Map of Long-Term Average CCID Data

The above approach uses a database of mainly bi-annual measurements. However, CCID maintains an extensive monitoring well network along the west side of Reaches 3 and 4A of the San Joaquin River, representing a long historical record. Ground surface elevation is available for all CCID wells, thus ensuring vertical control and a large set of groundwater levels that represent the water table. Groundwater levels were averaged for each well; these measurements were made over an extensive period of time and at a set interval, which raises confidence that an average of these measurements best represents average groundwater conditions in this area.

Figure H-16 shows a typical hydrograph for wells in CCID. The dotted line represents the average groundwater level during the period shown. Average groundwater levels for wells similar to this were used in the analysis; wells indicating strong influence from groundwater pumping were not used.

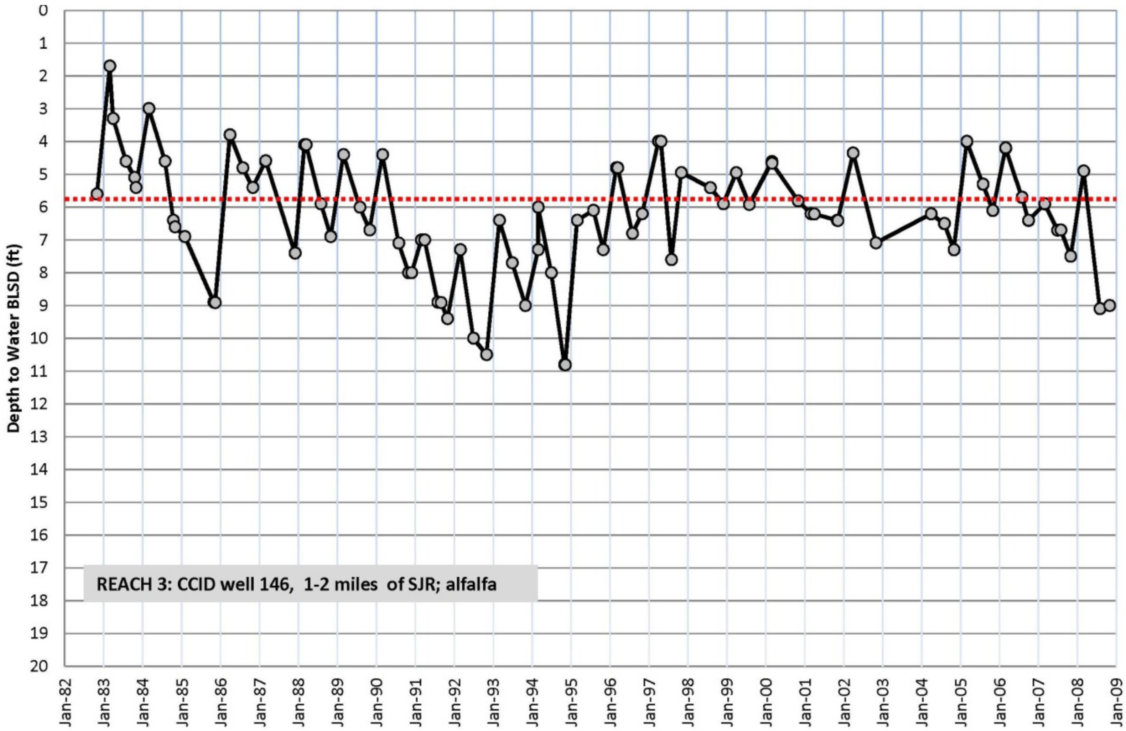

Figure H-16
Hydrograph of CCID Well 146 showing long-term average

As a first step, average DTW below ground surface was converted to water-table elevation using the known ground surface elevation of CCID wells and interpolated using IDW across Reaches 3 and 4A.

Figure H-17 below shows the resultant water table elevation map. Green stars represent the subset of CCID wells with consistent data that the USGS created hydrographs for. These represent data points used for interpolation. Thresholds at this point were assigned for wells marked with a black square on the basis of the colored interpolation surface in Figure H-17. This water-table elevation was converted back to DTW for each well. Converting to elevation and then back to DTW below ground surface corrects for wells located on levee banks or otherwise at a different elevation.

Once the first two methods of historical groundwater analysis (using long-term hydrographs) are complete, a smaller number of wells will use the depth to water map values in this section.

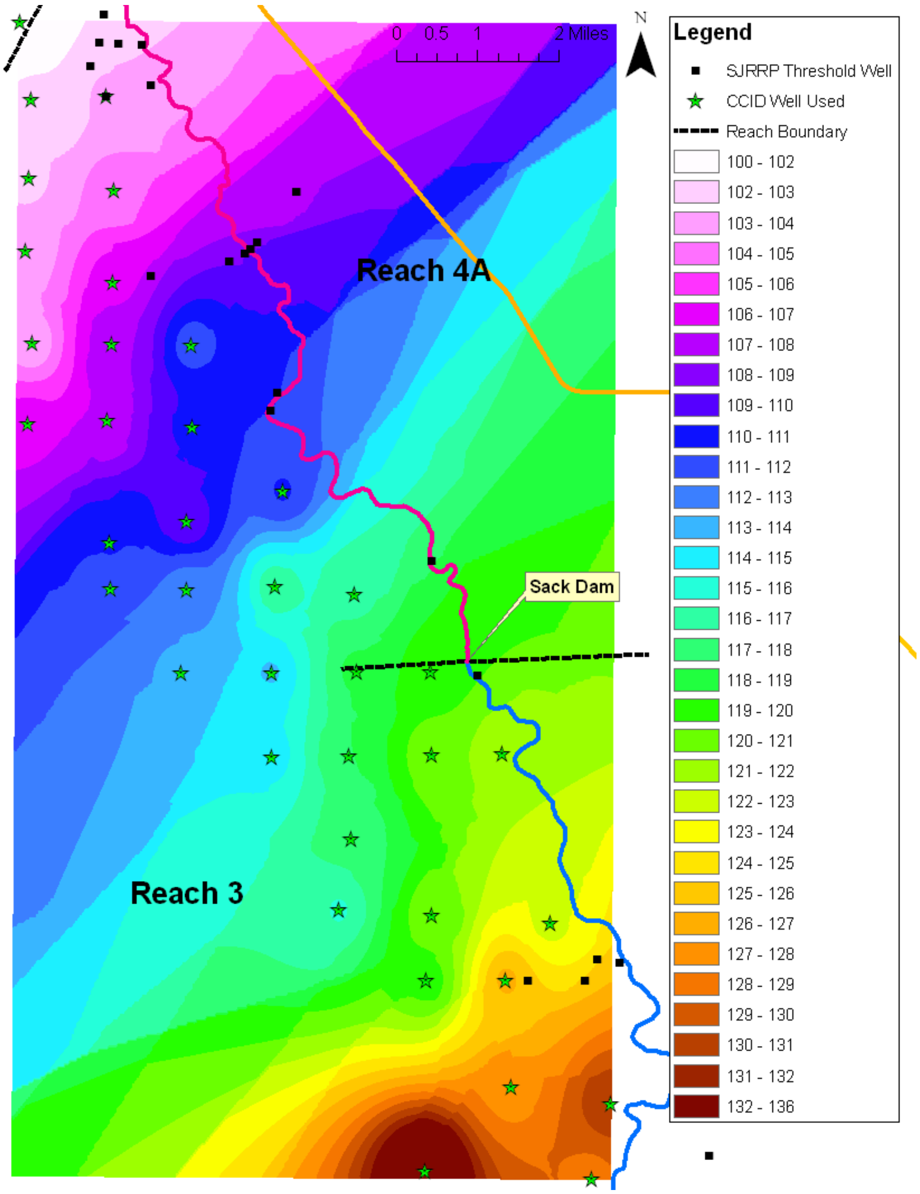

Figure H-17
Map of Average Historical Water-Table Elevation in CCID wells

3.3 Results

Table H-7 below shows thresholds derived from historical groundwater levels, based on these analyses. Note: these analyses are preliminary and ongoing; results for the first two methods are currently populated only for Reach 4A.

Table H-7: Historical Groundwater Method Thresholds										
Well ID	**Method A - 75th Percentile Groundwater Depth (feet bgs in field)**	**Method B - 75th Percentile Nearby Groundwater Depth (feet bgs in field)**	**Method C - CCID Well Average Groundwater Elevation (feet)**	**Method C - CCID Well Average Groundwater Depth (feet bgs in field)**	**Method C - Groundwater Depth Fall 1999 (feet bgs in field)**	**Method C - Groundwater Depth Spring 2008 (feet bgs in field)**	**Method C - Groundwater Depth Fall 2008 (feet bgs in field)**	**Historical Groundwater Method Used**	**Historical Groundwater (feet bgs in field)**	**Historical Groundwater (feet bgs at well)**
JR-1						50		3	50	50
JR-2						50		3	50	50
MW-09-1					112	51		3	51	51
MW-09-2					101	51		3	51	51
FA-1					48	44		3	44	45
FA-2					46	36		3	36	38
FA-3					46	36		3	36	38
MA-1					46	36		3	36	38
MW-09-23					50	54		3	50	41
MW-09-23B					50	54		3	50	41
MW-09-25					50	54		3	50	40
R1-1					58	65		3	58	60
R1-2					61	66		3	61	64
FA-4					42	59		3	42	37
FA-5					42	59		3	42	37
FA-6					63	60		3	60	65
FA-7					63	60		3	60	66
FA-8					73	58		3	58	60
FA-9					72	60		3	60	64
MA-2					40	59		3	40	43
MA-3					60	60		3	60	61
MA-4					72	54		3	54	60
MW-09-36					49	56		3	49	54
MW-09-37B					49	56		3	49	53
MW-09-39B					34	59		3	34	34
MW-09-47					72	60		3	60	63
MW-09-49B					68	56		3	56	58

Table H-7: Historical Groundwater Method Thresholds										
Well ID	**Method A - 75th Percentile Groundwater Depth (feet bgs in field)**	**Method B - 75th Percentile Nearby Groundwater Depth (feet bgs in field)**	**Method C - CCID Well Average Groundwater Elevation (feet)**	**Method C - CCID Well Average Groundwater Depth (feet bgs in field)**	**Method C - Groundwater Depth Fall 1999 (feet bgs in field)**	**Method C - Groundwater Depth Spring 2008 (feet bgs in field)**	**Method C - Groundwater Depth Fall 2008 (feet bgs in field)**	**Historical Groundwater Method Used**	**Historical Groundwater (feet bgs in field)**	**Historical Groundwater (feet bgs at well)**
MW-09-52					58	31	31	3	31	31
MW-09-54B					59	33	33	3	33	40
MW-09-55B					60	33	32	3	32	35
MW-09-56					57	38	31	3	31	33
PZ-09-R2B-1					34	27	24	3	24	26
PZ-09-R2B-2					30	27	24	3	24	28
155			125.3	6.0		8	12	3	6.0	9.3
MW-10-117						24	16	3	16	16
MW-10-118					15	14	13	3	13	16
MW-10-119					15	13	15	3	13	16
MW-10-120						14	21	3	14	15
MW-10-121					15	16	16	3	15	15
MW-10-122						33	21	3	21	21
MW-10-123						29	27	3	27	27
MW-10-124						28	25	3	25	26
MW-10-74			125.6	6.2	13	11	12	3	6.2	10.4
MW-10-75			125.0	6.3		9	12	3	6.3	6.8
MW-10-76			125.3	2.7		7	13	3	2.7	5.4
MW-10-78			119.9	2.4	29	8	9	3	2.4	5.4
PZ-09-R3-1					12	9.7	14	3	9.7	13.8
PZ-09-R3-2					12	9.7	14	3	9.7	11.2
PZ-09-R3-3					12	9.9	16	3	9.9	14.2
PZ-09-R3-4					17	12	17	3	12	16
PZ-09-R3-5					14	19	16	3	14	15
PZ-09-R3-6					13	15	15	3	13	14
PZ-09-R3-7					16	28	18	3	16	17
191	9.0		103.1	5	16	10	10	1	9.0	11.9
186A	3.5		103.1	3		6	8	1	3.5	5.5
MW-09-83B			107.6	7.4		9	10	3	7.4	7.4

Table H-7: Historical Groundwater Method Thresholds										
Well ID	Method A - 75th Percentile Groundwater Depth (feet bgs in field)	Method B - 75th Percentile Nearby Groundwater Depth (feet bgs in field)	Method C - CCID Well Average Groundwater Elevation (feet)	Method C - CCID Well Average Groundwater Depth (feet bgs in field)	Method C - Groundwater Depth Fall 1999 (feet bgs in field)	Method C - Groundwater Depth Spring 2008 (feet bgs in field)	Method C - Groundwater Depth Fall 2008 (feet bgs in field)	Historical Groundwater Method Used	Historical Groundwater (feet bgs in field)	Historical Groundwater (feet bgs at well)
MW-09-85B			108.4	5.3		9	10	3	5.3	12.2
MW-09-86B		3.9	108.4	5.0		9	10	2	3.9	11.8
MW-09-87B			108.9	4.2		9	10	3	4.2	6.1
MW-09-88		4.1	107.6	2		6	8	2	4.1	6.3
MW-10-115						5.6	8	3	5.6	5.6
MW-10-116					55	22	11	3	11	11
MW-10-188		6.7	111.0	4	23	9	9	2	6.7	8.8
MW-10-80		3.3	117.6	2	18	9	9	2	3.3	8.4
MW-10-89		3.8	111.2	4	21	9	9	2	3.8	7.2
MW-10-91		4.6				8	8	2	4.6	8.3
MW-10-92		4.6				8	7	2	4.6	7.2
MW-10-93		4.6				7	7	2	4.6	6.8
SJR W-10		3.2	102.8	2	18	11	13	2	3.2	5.0
SJR W-11		3.3	102.9	4	17	11	14	2	3.3	5.1
SJR W-12		3.3				9	10	2	3.3	5.4
SJR W-4		3.5				8	9	2	3.5	4.6
SJR W-5						8	7.0	3	7.0	8.9
SJR W-6						7	6.8	3	6.8	11.2
SJR W-7						9	7.2	3	7.2	11.2
SJR W-8		3.4	102.8	3		7	8	2	3.4	6.7
SJR W-9		3.2	102.5	1		9	9	2	3.2	4.3
MW-10-100					7	6.5	8	3	6.5	11.0
MW-10-102						14	36	3	14	16
MW-10-103					11	13	28	3	11	16
MW-10-105					7.4	10	28	3	7.4	8.8
MW-10-106					9.6	10	27	3	9.6	11.6
MW-10-107					6.9	9	21	3	6.9	9.6
MW-10-108					9.1	12	25	3	9.1	10.8
MW-10-109					7.8	11	22	3	7.8	9.3

Table H-7: Historical Groundwater Method Thresholds

Well ID	Method A - 75th Percentile Groundwater Depth (feet bgs in field)	Method B - 75th Percentile Nearby Groundwater Depth (feet bgs in field)	Method C - CCID Well Average Groundwater Elevation (feet)	Method C - CCID Well Average Groundwater Depth (feet bgs in field)	Method C - Groundwater Depth Fall 1999 (feet bgs in field)	Method C - Groundwater Depth Spring 2008 (feet bgs in field)	Method C - Groundwater Depth Fall 2008 (feet bgs in field)	Historical Groundwater Method Used	Historical Groundwater (feet bgs in field)	Historical Groundwater (feet bgs at well)
MW-10-110						12	34	3	12	14
MW-10-111						10	30	3	10	12
MW-10-112					20	17	30	3	17	17
MW-10-113					7.7	11	20	3	7.7	12.1
MW-10-114					7.3	9	20	3	7.3	9.2
MW-10-90						15	11	3	11	15
MW-10-94					36	23	14	3	14	14
MW-10-95					13	15	11	3	11	13
MW-10-96						11	9.0	3	9.0	11.0
MW-10-97						8.2	9	3	8.2	11.6
MW-10-98						8.2	8.0	3	8.0	12.0
MW-10-99						6.6	8	3	6.6	11.3
SJR W-1						6.8	10	3	6.8	8.6
SJR W-2					6.2	8	11	3	6.2	10.4
SJR W-3					5.5	7	9	3	5.5	9.3
MW-09-125						9.3	10	3	9.3	9.3

Key: bgs = below ground surface; CCID = Central California Irrigation District
Note: Thresholds are rounded to the nearest ½ foot.

3.4 Limitations

All thresholds based on measured groundwater levels are subject to inaccuracies associated with the DTW measurements themselves, and with the local datum used to calculate groundwater level elevations. Given the low-precision nature of threshold estimation and good measurement protocols in place, the potential error in measurement of DTW can be neglected. However, some measurements may have been taken during, or soon after, irrigation and would not represent static conditions. If field notes are obtained, these measurements will be filtered from the data set.

There may be substantial error associated with elevations associated with the CCID and other well networks. Although internally consistent – differences between the measuring point, ground surface at the well, and ground surface at field level are accurate – elevations associated with each well may be offset from the true value and inconsistent with other wells in the network. To eliminate this source of error, the CCID network is being surveyed; the results will be used to update the analyses presented above.

Thresholds calculated on the basis of long-term spring and fall water levels measured in the threshold well are strongly tied to known field conditions, and therefore are relatively well posed. The use of the 75^{th} percentile is somewhat subjective, and is subject to change as analysis of additional wells continues.

Thresholds calculated using long-term data from a nearby well are subject to error from the assumption that hydrologic conditions at the two wells are similar. This error is minimized by graphically comparing groundwater level elevations for each well (having offset values for the nearby well by the difference in ground surface elevations); however, historic conditions differ from those that include Interim Restoration flows, so a graphical comparison is an imprecise indication of error.

Those thresholds estimated using interpolated values from various maps, because the threshold well and nearby wells had no long-term measurements, have the greatest potential for error. The DTW maps used to estimate thresholds have several limitations, including:

- Only three seasonal maps were available that represent average (normal) conditions; only one of these represents spring conditions, and that was for a normal-dry year. Threshold elevations based on these maps are therefore biased low.
- DTW maps do not take into account elevation differences between wells and fields.
- The available DTW maps include deep production wells; this also leads to lower estimates of threshold elevations.

The map generated using only CCID well data has clear advantages, including a data set of only shallow wells relatively unaffected by groundwater pumping and compensation for varying ground surface elevations, but also has disadvantages, including:

- The average of all measured groundwater elevations was used for each CCID well. With regard to a threshold, this translates to having historically been at or above the threshold about 50 percent of the time. Consideration will be given to using an alternative to the average, e.g., the 75th percentile.

- There are no CCID wells east of the San Joaquin River, and most of the SJRRP threshold wells are east of the CCID wells; therefore, extrapolated, not interpolated values are assigned as thresholds.

4 Method #3: Drainage

The third method of calculating thresholds considers drainage and the slope of the groundwater table.

4.1 Objectives

The drainage method considers data from groundwater transects to determine the slope of the groundwater table, and to derive thresholds on the basis of this information. For river stages that allow water to drain from fields into the channel, restrictions on the release of Interim Flows below groundwater will not reduce or avoid seepage into adjacent fields.

4.2 Approach

The SJRRP plotted cross-sections of the water table and terrain at groundwater transects. The slope of the water table gives an indication of the elevation of the threshold by tracking baseline groundwater levels and the rise in groundwater as river stage increases.

Cross-sections showing a gaining reach will set thresholds at baseline groundwater levels in the fields as Method #3.

For losing reaches, the groundwater gradient provides a check on the historical groundwater analysis. A threshold below baseline groundwater levels would indicate conservatism.

4.3 Results

Monitoring data at groundwater transects during the 2010 Interim Flows shows the horizontal groundwater gradient away from the river. As shown by this data, the groundwater surface is not flat. Influences include irrigation and groundwater pumping as well as river stage. Generally the cross-sections show increasing groundwater levels near to the river as river stage increases, and the influence of the river decreases as distance from it increases.

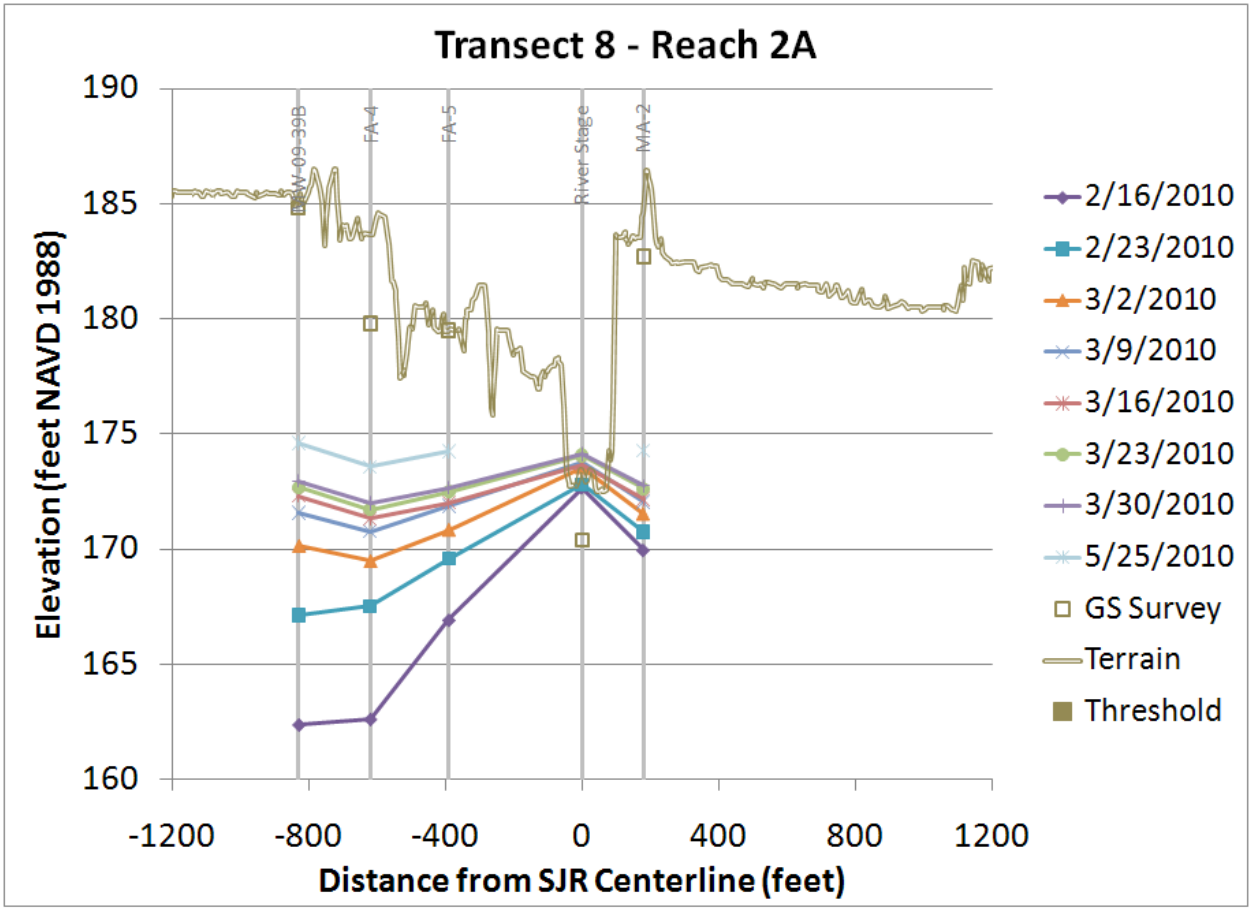

Figure H18.
Cross-section plot at Transect 8 in Reach 2A.

This transect includes wells from the Pilot Project drilled to measure groundwater for riparian vegetation. It does not have wells located in agricultural fields. This indicates an increase in near-river groundwater levels as river stage increases. It also shows a slope to the groundwater table away from the river, and the influence of additional factors – perhaps irrigation. The lack of groundwater level data in fields makes interpretation of groundwater gradients difficult at this transect.

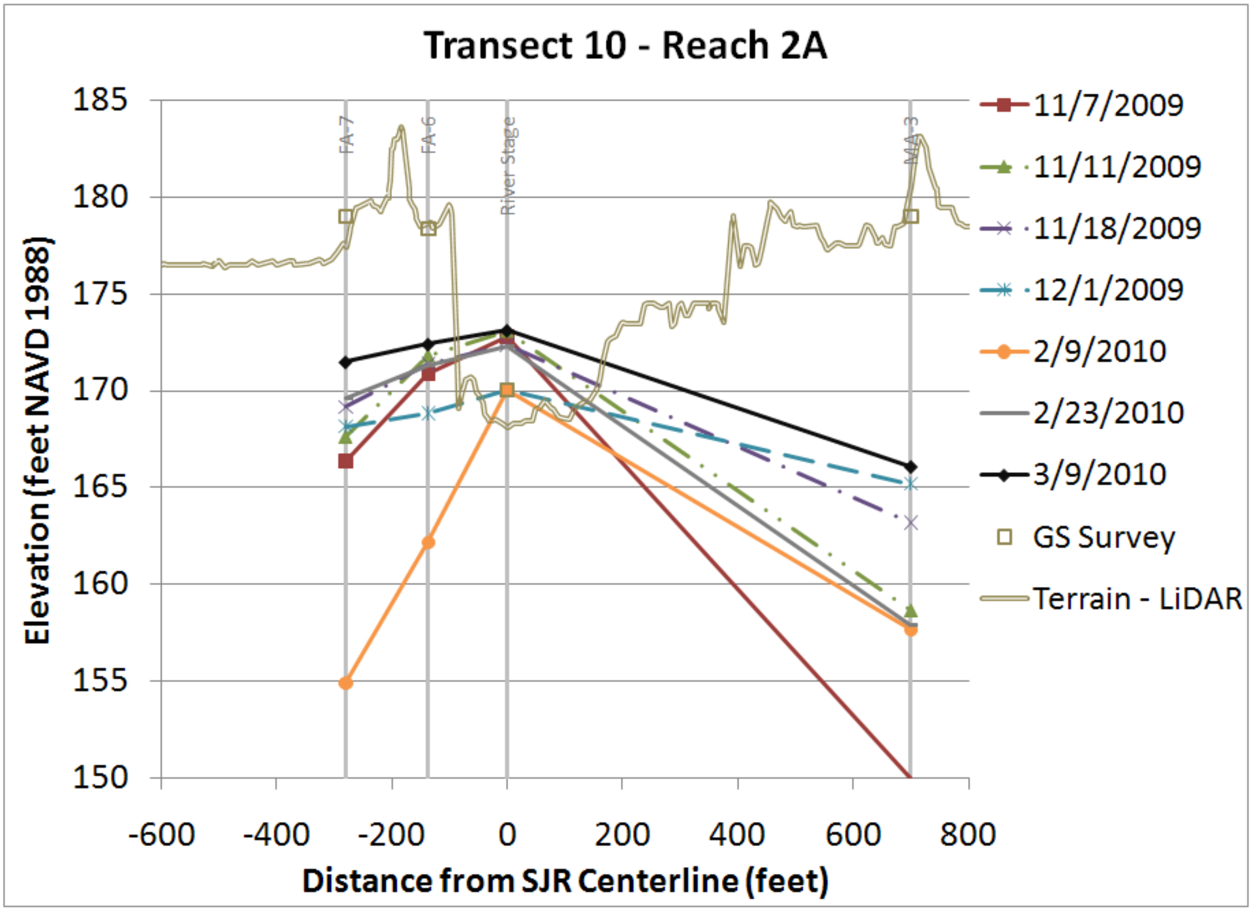

Figure H19.
Cross-section plot at Transect 10 in Reach 2A.

This transect also includes wells from the Pilot Project drilled to measure groundwater for riparian vegetation. It does not have wells located in agricultural fields. This indicates an increase in near-river groundwater levels as river stage increases. It also shows a slope to the groundwater table away from the river, which decreases with increasing river stage as the influence of the river increases in lateral extent.

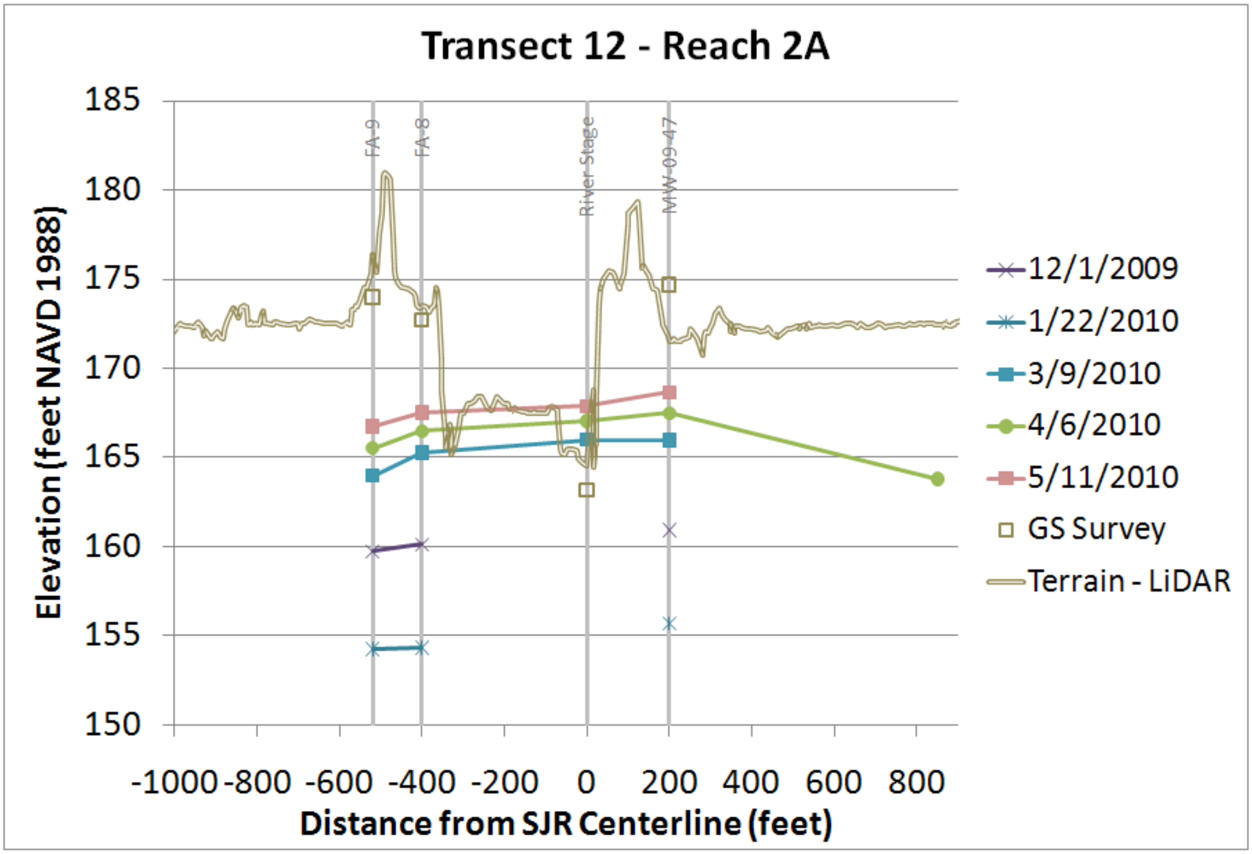

Figure H20.
Cross-section plot at Transect 12 in Reach 2A.

This transect also includes wells from the Pilot Project drilled to monitor water levels for riparian vegetation. It does not have wells located in agricultural fields, with the exception of hand-auger hole drilled and groundwater level measured on April 6, 2010. This indicates an increase in near-river groundwater levels as river stage increases. The monitoring wells would indicate a nearly flat groundwater table, but the addition of the hand-auger data indicates there is a slope to the groundwater table away from the river channel.

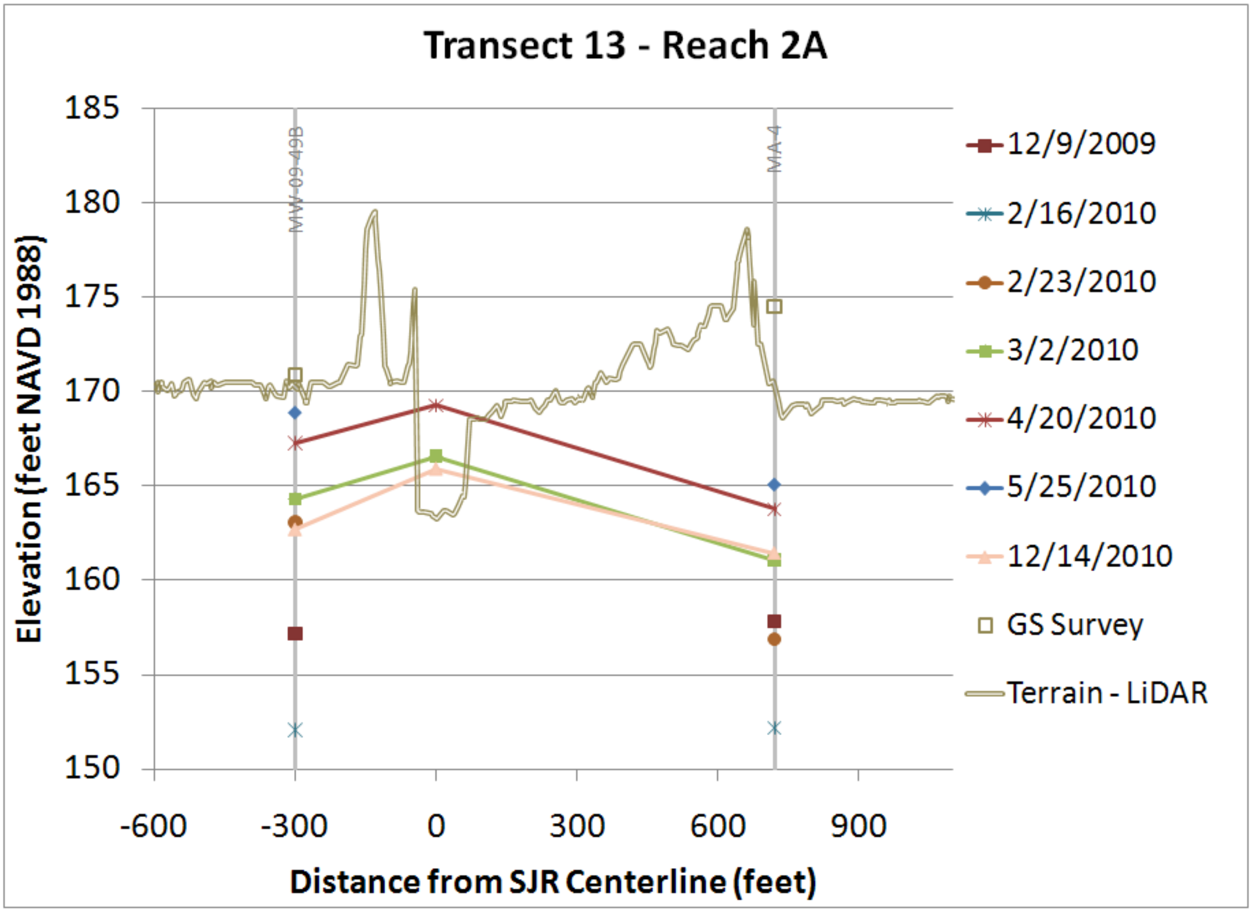

Figure H21.
Cross-section plot at Transect 13 in Reach 2A.

This transect also includes wells from the Pilot Project drilled to monitor water levels for riparian vegetation. It does not have wells located in agricultural fields. This indicates an increase in near-river groundwater levels as river stage increases.

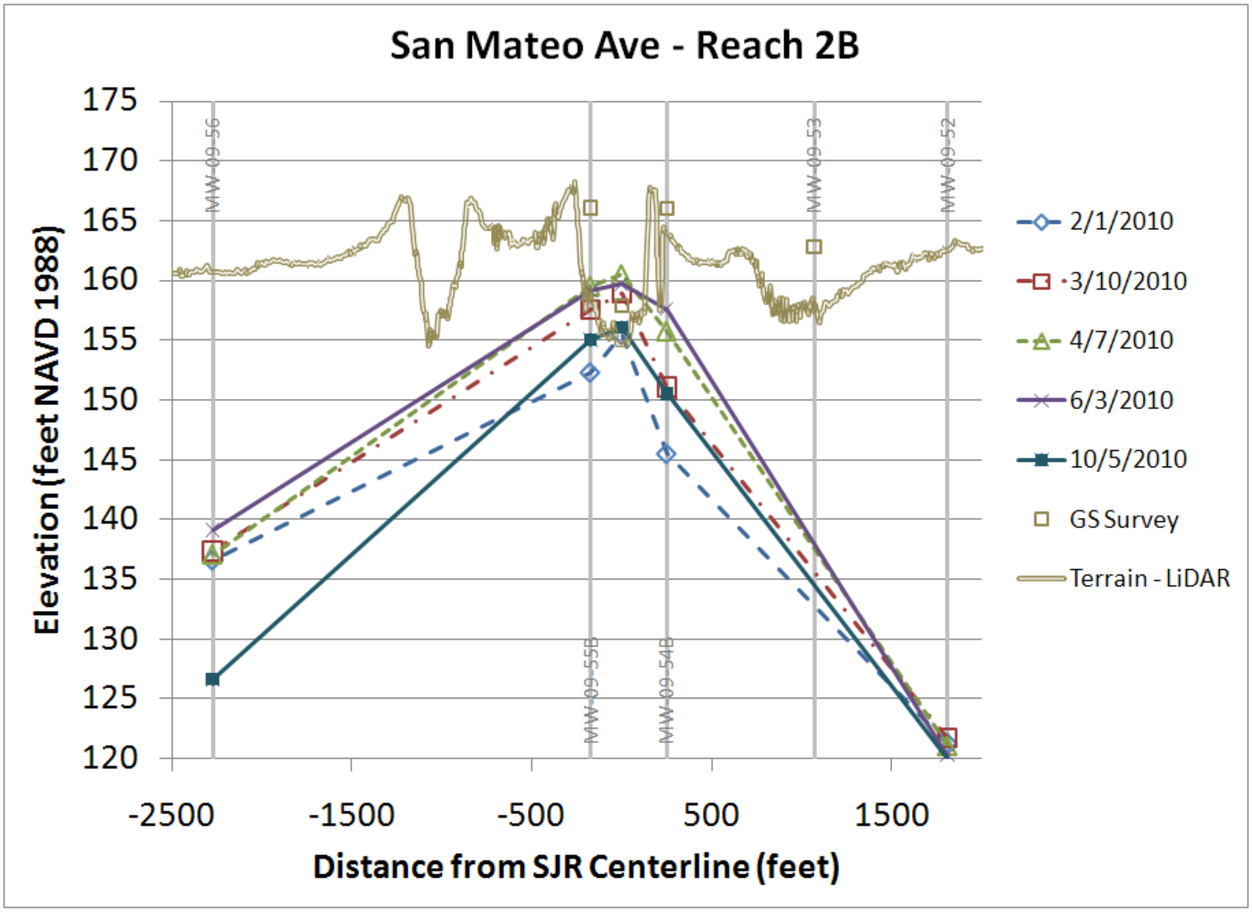

Figure H22.
Cross-section plot at San Mateo Avenue in Reach 2B.

This cross-section, at San Mateo Avenue, has groundwater wells located further away from the river channel. It appears that groundwater levels 2000 feet away from the river on the North-East side of the river channel (positive values on this plot) are not influenced by river stage. This may be due to the influence of groundwater pumping. Baseline groundwater levels in Reach 2B appear to be around an elevation of 125 feet (approximately 40 feet below ground surface). A threshold below this would be too conservative. The chosen threshold is above these levels.

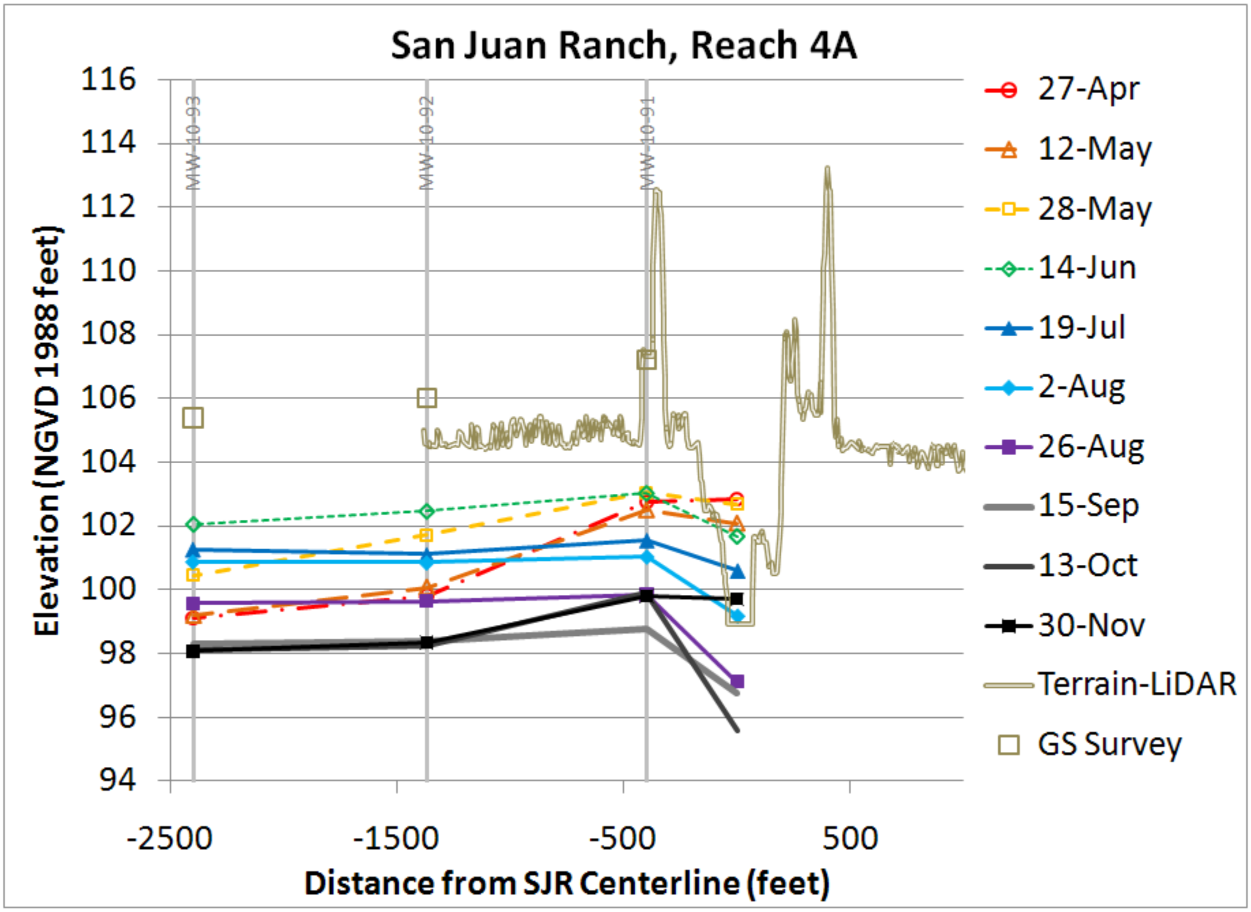

Figure H23.
Cross-section plot at San Juan Ranch in Reach 4A.

Baseline groundwater levels at the end of Reach 4A appear to be around an elevation of 98 feet (approximately 7 to 9 feet below ground surface). A threshold below this would be too conservative.

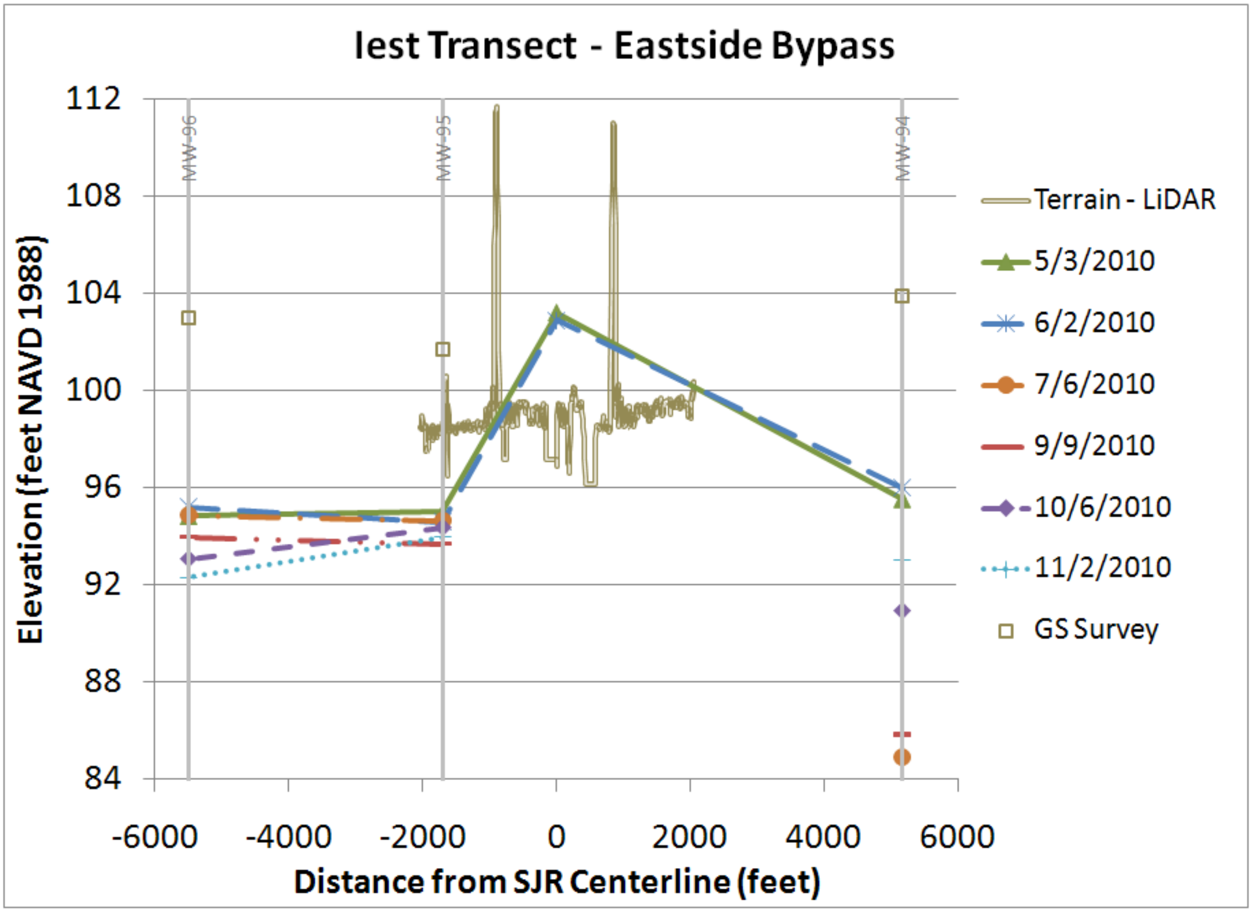

Figure H24.
Cross-section plot at the Eastside Bypass near El Nido Road.

This transect includes monitoring wells distant from the Eastside Bypass. Groundwater levels do not appear to have much of a gradient during the irrigation season. Groundwater levels on the South-West side of the bypass (negative values on this plot) are flat and constant from May to July. This may indicate irrigation is a controlling factor. Groundwater levels begin to recede as Interim Flows and then irrigation begin to slow in the fall. Baseline groundwater levels on the South-West side of the river appear to be around an elevation of 93 feet. A threshold below this would be too conservative.

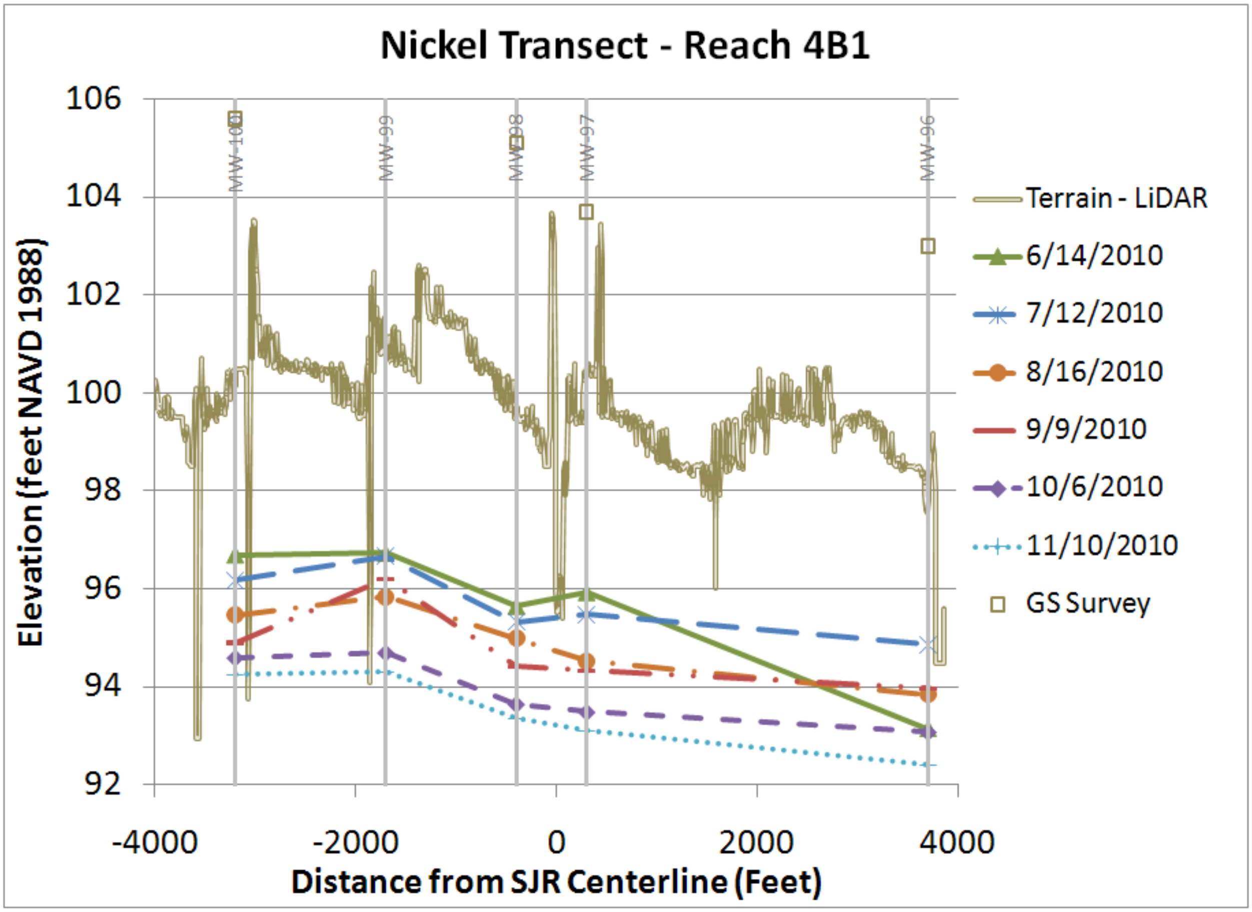

Figure H25.
Cross-section plot at Reach 4B1.

This transect includes monitoring wells near the Reach 4B1 channel, which does not convey Interim Flows. Groundwater levels appear to decrease on the left (South-West) side of the river after June and on the right (North-East) side of the river decrease after July. Additional monitoring data may allow a better determination of baseline groundwater levels, but an elevation of 94 feet seems likely based on this data.

None of the cross-sections show a gaining reach at all river stage levels, so Method #3 will not be used to set thresholds based on data available to date.

4.4 Validation of thresholds

The Reclamation Drainage Manual was first printed in 1978 and revised in 1993. The drainage manual states: “All the methods and techniques covered in the manual have proven to be very satisfactory through observed field conditions on irrigated lands throughout the world. Some methods have a more elegant development and basis in science than others, but all have been designed to solve practical problems in the field. The manual contains techniques developed over the last 50 years by personnel in the Bureau of Reclamation.”

According to the Drainage manual, a depth-to-water table of 3 to 5 feet is generally satisfactory, depending on local conditions including type of crops grown (Reclamation, 1993;

pg 132). Many thresholds established above are deeper than 3 to 5 feet, indicating that those thresholds may be conservative, depending on crop type and other factors.

5 Threshold Results

The results of the threshold analyses are presented in Table H-8; some considerations follow:

- Three CCID wells are measured frequently by Reclamation; thresholds were developed for these wells. No other CCID wells are measured by Reclamation; thus, no thresholds have been developed for the rest of the CCID wells.
- Several SJRRP monitoring wells are deeper wells, intended to monitor groundwater flow across a transect rather than water-table effects. Thresholds were developed for these wells, but will not be used for operations as they do not monitor the shallow groundwater table.
- A negative threshold indicates the well is in the river channel, and screened at an interval deeper below ground surface than the threshold in the adjacent field. These wells cannot be used to monitor groundwater levels in the adjacent field and will not be used for operations.
- Wells without a threshold elevation have not yet been surveyed and were outside of the LiDAR survey range. Thus, the ground surface elevation for these wells is unknown.
- Thresholds will continue to be revised as additional monitoring and data collection results in modification to assumptions. The results of surveying for CCID wells will result in adjusted thresholds.

Table H-8: Threshold Summary Table									
Well ID	**Reach**	**Bank**	**Crop Type**	**Method 1 - Agricultural Practices (feet bgs) in field**	**Method 2 - Historical Groundwater (feet bgs) in field**	**Method Used**	**Threshold in field (feet bgs)**	**Threshold in well (feet bgs)**	**Threshold Elevation (feet)**
JR-1	1A	Left	Public Land	5.0	50	1	5.0	5.0	
JR-2	1A	Left	Public Land	5.0	50	1	5.0	5.0	
MW-09-1	1A	Right	Public Land	4.5	51	1	4.5	4.5	266.2
MW-09-2	1A	Right	Public Land	4.5	51	1	4.5	4.5	265.7
FA-1	1B	Left	Vineyard	7.0	44	1	7.0	8.8	193.7
FA-2	1B	Left	Vineyard	7.0	36	1	7.0	9.2	196.1
FA-3	1B	Left	Vineyard	7.0	36	1	7.0	8.5	196.0
MA-1	1B	Left	Fallow	5.0	36	1	5.0	6.7	199.9
MW-09-23	1B	Left	Public Land	4.5	50	1	4.5	-4.3	214.9
MW-09-23B	1B	Left	Public Land	4.5	50	1	4.5	-4.3	214.9
MW-09-25	1B	Right	Public Land	5.0	50	1	5.0	-4.6	229.5
R1-1	1B	Right	Pomegranate	6.5	58	1	6.5	8.0	208.8
R1-2	1B	Right	Pomegranate	6.5	61	1	6.5	9.6	208.8
FA-4	2A	Left	River Channel	5.0	42	1	5.0	0.4	179.4
FA-5	2A	Left	River Channel	5.0	42	1	5.0	0.3	179.2
FA-6	2A	Left	River Channel	5.0	60	1	5.0	9.8	168.6
FA-7	2A	Left	Almonds	10.0	60	1	10.0	15.6	163.4
FA-8	2A	Left	River Channel	5.0	58	1	5.0	6.7	166.0
FA-9	2A	Left	Alfalfa	5.0	60	1	5.0	8.7	165.3
MA-2	2A	Right	Annual Crops	5.0	40	1	5.0	7.9	174.8
MA-3	2A	Right	Annual Crops	5.0	60	1	5.0	5.9	173.1
MA-4	2A	Right	Vineyard w Drains	7.0	54	1	7.0	13.1	161.4
MW-09-36	2A	Right	Annual Crops	5.0	49	1	5.0	9.5	181.5
MW-09-37B	2A	Left	Vineyard	7.0	49	1	7.0	10.1	182.1
MW-09-39B	2A	Left	Almonds	9.5	34	1	9.5	10.0	174.9
MW-09-47	2A	Right	Vineyard w Drains	7.0	60	1	7.0	10.5	164.2
MW-09-49B	2A	Left	Annual Crops w Drains	4.5	56	1	4.5	6.2	164.7

Table H-8: Threshold Summary Table									
Well ID	**Reach**	**Bank**	**Crop Type**	**Method 1 - Agricultural Practices (feet bgs) in field**	**Method 2 - Historical Groundwater (feet bgs) in field**	**Method Used**	**Threshold in field (feet bgs)**	**Threshold in well (feet bgs)**	**Threshold Elevation (feet)**
MW-09-52	2B	Right	Almonds	10.0	31	1	10.0	10.9	151.2
MW-09-54B	2B	Right	Almonds	10.0	33	1	10.0	17.9	150.3
MW-09-55B	2B	Left	Palms	7.0	32	1	7.0	10.7	155.0
MW-09-56	2B	Left	Pistachios	7.0	31	1	7.0	8.7	152.5
PZ-09-R2B-1	2B	Right	Annual Crops	5.0	24	1	5.0	6.3	148.9
PZ-09-R2B-2	2B	Right	Annual Crops	4.5	24	1	4.5	8.4	144.8
155	3	Left	Almonds	10.0	6.0	2	6.0	9.3	125.3
MW-10-117	3	Right		5.0	16	1	5.0	5.0	
MW-10-118	3	Right		5.0	13	1	5.0	7.4	130.6
MW-10-119	3	Right		5.0	13	1	5.0	7.4	131.9
MW-10-120	3	Left		5.0	14	1	5.0	5.0	
MW-10-121	3	Left		5.0	15	1	5.0	5.0	
MW-10-122	3	Right		5.0	21	1	5.0	5.0	
MW-10-123	3	Left		5.0	27	1	5.0	5.0	
MW-10-124	3	Right		5.0	25	1	5.0	5.6	148.4
MW-10-74	3	Left	Almonds	9.5	6.2	2	6.2	10.4	125.6
MW-10-75	3	Left	Almonds	10.0	6.3	2	6.3	6.8	125.0
MW-10-76	3	Left	Annual Crops	5.0	2.7	2	2.7	5.4	125.3
MW-10-78	3	Right	Annual Crops	5.0	2.4	2	2.4	5.4	119.9
PZ-09-R3-1	3	Right		4.5	9.7	1	4.5	8.6	128.6
PZ-09-R3-2	3	Right	Annual Crops	5.0	9.7	1	5.0	6.5	131.8
PZ-09-R3-3	3	Right	Annual Crops	5.0	9.9	1	5.0	9.3	131.7
PZ-09-R3-4	3	Right	Annual Crops	5.0	12	1	5.0	8.5	131.7
PZ-09-R3-5	3	Right	Annual Crops	5.0	14	1	5.0	6.2	134.2
PZ-09-R3-6	3	Right	Annual Crops	5.0	13	1	5.0	6.5	135.1
PZ-09-R3-7	3	Right	Annual Crops	4.5	16	1	4.5	5.2	138.8
191	4A	Left		5.0	9.0	1	5.0	7.9	103.0
186A	4A	Left		5.0	3.5	2	3.5	5.5	102.6
MW-09-83B	4A	Right	Public Land	5.0	7.4	1	5.0	5.0	110.0
MW-09-85B	4A	Right	Public Land	5.0	5.3	1	5.0	11.9	108.7
MW-09-86B	4A	Left	Public Land	5.0	3.9	2	3.9	11.8	109.1

Table H-8: Threshold Summary Table

Well ID	Reach	Bank	Crop Type	Method 1 - Agricultural Practices (feet bgs) in field	Method 2 - Historical Groundwater (feet bgs) in field	Method Used	Threshold in field (feet bgs)	Threshold in well (feet bgs)	Threshold Elevation (feet)
MW-09-87B	4A	Left	Public Land	4.5	4.2	2	4.2	6.1	108.9
MW-09-88	4A	Left	Public Land	5.0	4.1	2	4.1	6.3	105.7
MW-10-115	4A	Left		5.0	5.6	1	5.0	5.0	
MW-10-116	4A	Right		5.0	11	1	5.0	5.0	
MW-10-188	4A	Left	Annual Crops	5.0	6.7	1	5.0	7.1	109.8
MW-10-80	4A	Right	Annual Crops	5.0	3.3	2	3.3	8.4	116.5
MW-10-89	4A	Right	Almonds	9.5	3.8	2	3.8	7.2	111.6
MW-10-91	4A	Left	Tomatoes	4.0	4.6	1	4.0	7.7	99.5
MW-10-92	4A	Left	Tomatoes	4.0	4.6	1	4.0	6.6	99.4
MW-10-93	4A	Left	Tomatoes	4.0	4.6	1	4.0	6.2	99.2
SJR W-10	4A	Left	Tomatoes	4.0	3.2	2	3.2	5.0	101.7
SJR W-11	4A	Left	Tomatoes	4.0	3.3	2	3.3	5.1	103.1
SJR W-12	4A	Left	Tomatoes	4.0	3.3	2	3.3	5.4	100.8
SJR W-4	4A	Left	Corn	4.0	3.5	2	3.5	4.6	101.7
SJR W-5	4A	Left	Tomatoes	4.0	7.0	1	4.0	5.9	97.5
SJR W-6	4A	Left	Tomatoes	4.0	6.8	1	4.0	8.4	97.3
SJR W-7	4A	Left	Tomatoes	4.0	7.2	1	4.0	8.0	99.0
SJR W-8	4A	Left	Alfalfa	5.0	3.4	2	3.4	6.7	102.1
SJR W-9	4A	Left	Tomatoes	4.0	3.2	2	3.2	4.3	100.8
MW-10-100	4B1	Left	Annual Crops	5.0	6.5	1	5.0	9.5	93.2
MW-10-102	4B1	Right	Annual Crops	5.0	14	1	5.0	7.4	88.3
MW-10-103	4B1	Right	Annual Crops	5.0	11	1	5.0	9.6	89.5
MW-10-105	4B1	Left		5.0	7.4	1	5.0	6.4	90.3
MW-10-106	4B1	Left		5.0	9.6	1	5.0	7.0	88.1
MW-10-107	4B1	Left		5.0	6.9	1	5.0	7.7	88.3
MW-10-108	4B1	Left		5.0	9.1	1	5.0	6.7	89.8
MW-10-109	4B1	Left		5.0	7.8	1	5.0	6.5	91.5
MW-10-110	4B1	Left		5.0	12	1	5.0	6.8	82.0
MW-10-111	4B1	Left		5.0	10	1	5.0	6.8	83.9
MW-10-112	4B1	Right		5.0	17	1	5.0	5.0	
MW-10-113	4B1	Left		5.0	7.7	1	5.0	9.4	90.1

Table H-8: Threshold Summary Table									
Well ID	**Reach**	**Bank**	**Crop Type**	**Method 1 - Agricultural Practices (feet bgs) in field**	**Method 2 - Historical Groundwater (feet bgs) in field**	**Method Used**	**Threshold in field (feet bgs)**	**Threshold in well (feet bgs)**	**Threshold Elevation (feet)**
MW-10-114	4B1	Left		5.0	7.3	1	5.0	6.9	92.0
MW-10-90	4B1	Right	Pistachios	7.0	11	1	7.0	11.7	89.6
MW-10-94	4B1	Right	Pistachios	7.0	14	1	7.0	7.0	94.6
MW-10-95	4B1	Right	Alfalfa	5.0	11	1	5.0	7.2	91.8
MW-10-96	4B1	Right	Alfalfa	5.0	9.0	1	5.0	7.0	93.4
MW-10-97	4B1	Right	Annual Crops	4.5	8.2	1	4.5	7.9	93.3
MW-10-98	4B1	Left	Annual Crops	5.0	8.0	1	5.0	9.0	93.2
MW-10-99	4B1	Left	Annual Crops	5.0	6.6	1	5.0	9.7	94.6
SJR W-1	4B1	Left		5.0	6.8	1	5.0	6.8	93.4
SJR W-2	4B1	Left		5.0	6.2	1	5.0	9.2	94.0
SJR W-3	4B1	Left		5.0	5.5	1	5.0	8.8	93.8
MW-09-125	5	Right	Alfalfa	5.0	9.3	1	5.0	5.0	69.4

Key: Bgs – below ground surface
Note: Thresholds have been rounded to the nearest ½ foot.