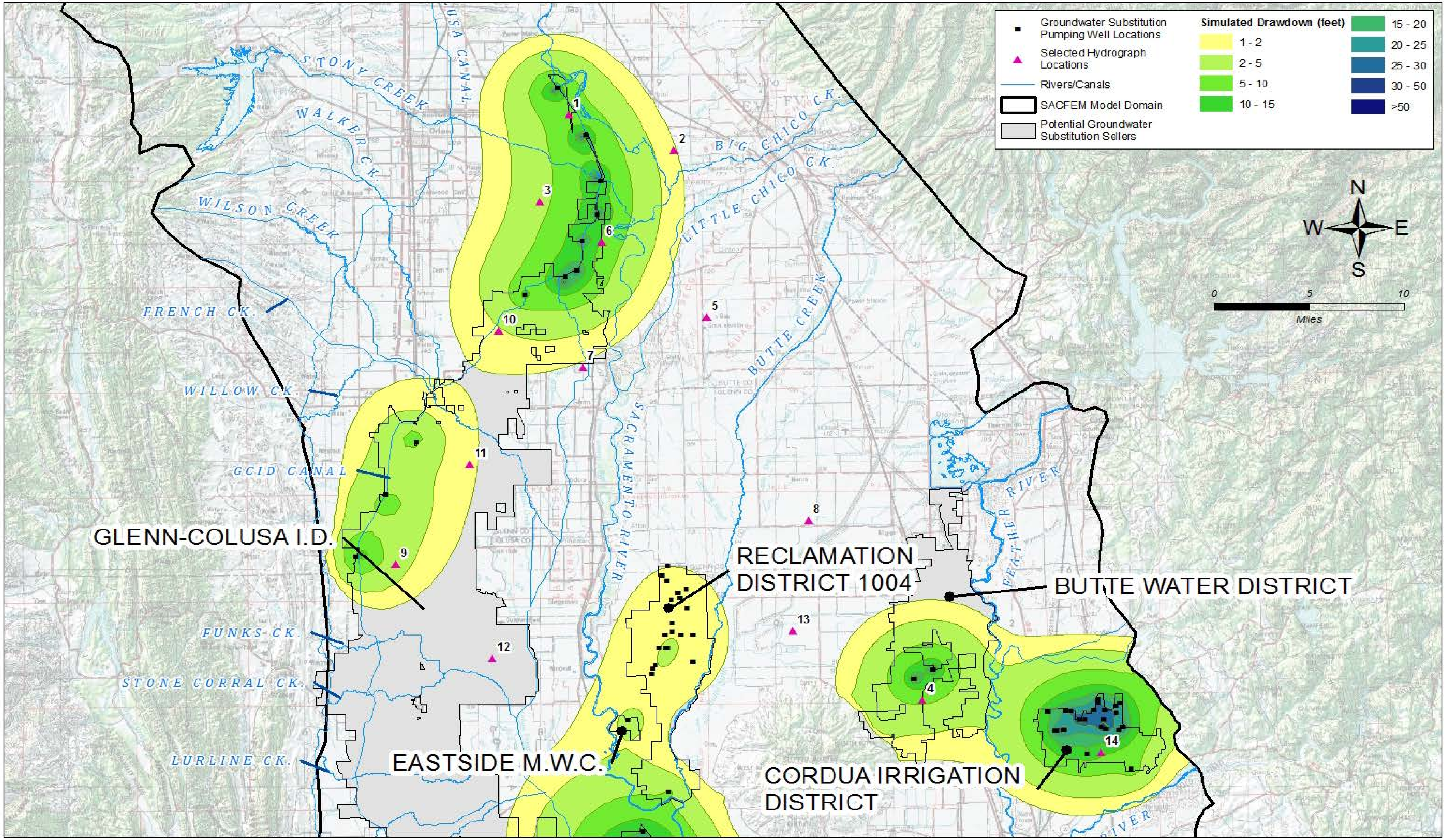

Figure 3.3-30a. Simulated Change in Groundwater Head (Aquifer Depth of Approximately 700 to 900 feet), Based on September 1976 Hydrologic Conditions

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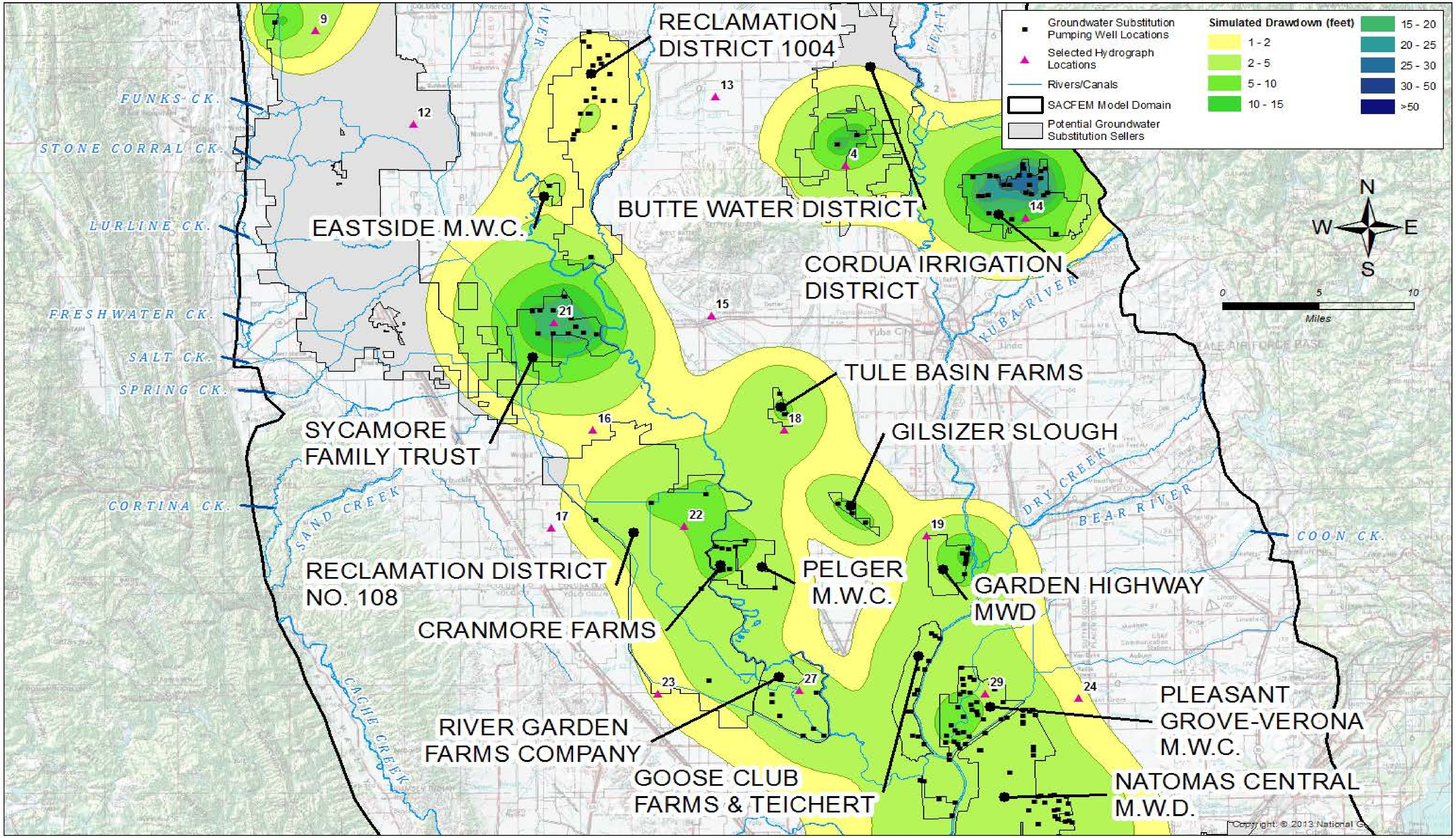

Figure 3.3-~~29.~~-30b. Simulated Change in Groundwater Head (Aquifer Depth of Approximately 700 to 900 feet), Based on September 1976 Hydrologic Conditions

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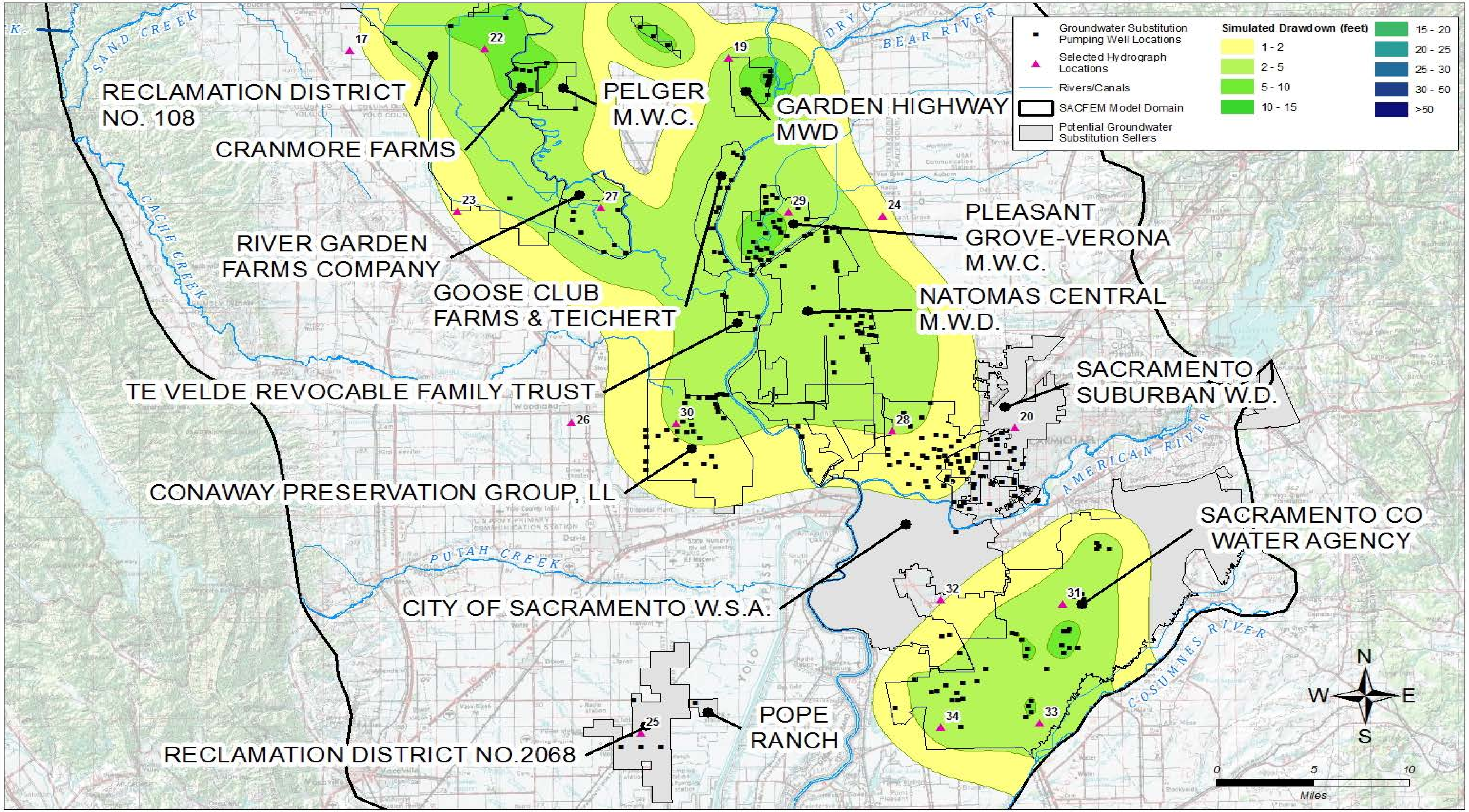

Figure 3.3-30c. Simulated Change in Groundwater Head (Aquifer Depth of Approximately 700 to 900 feet), Based on September 1976 Hydrologic Conditions

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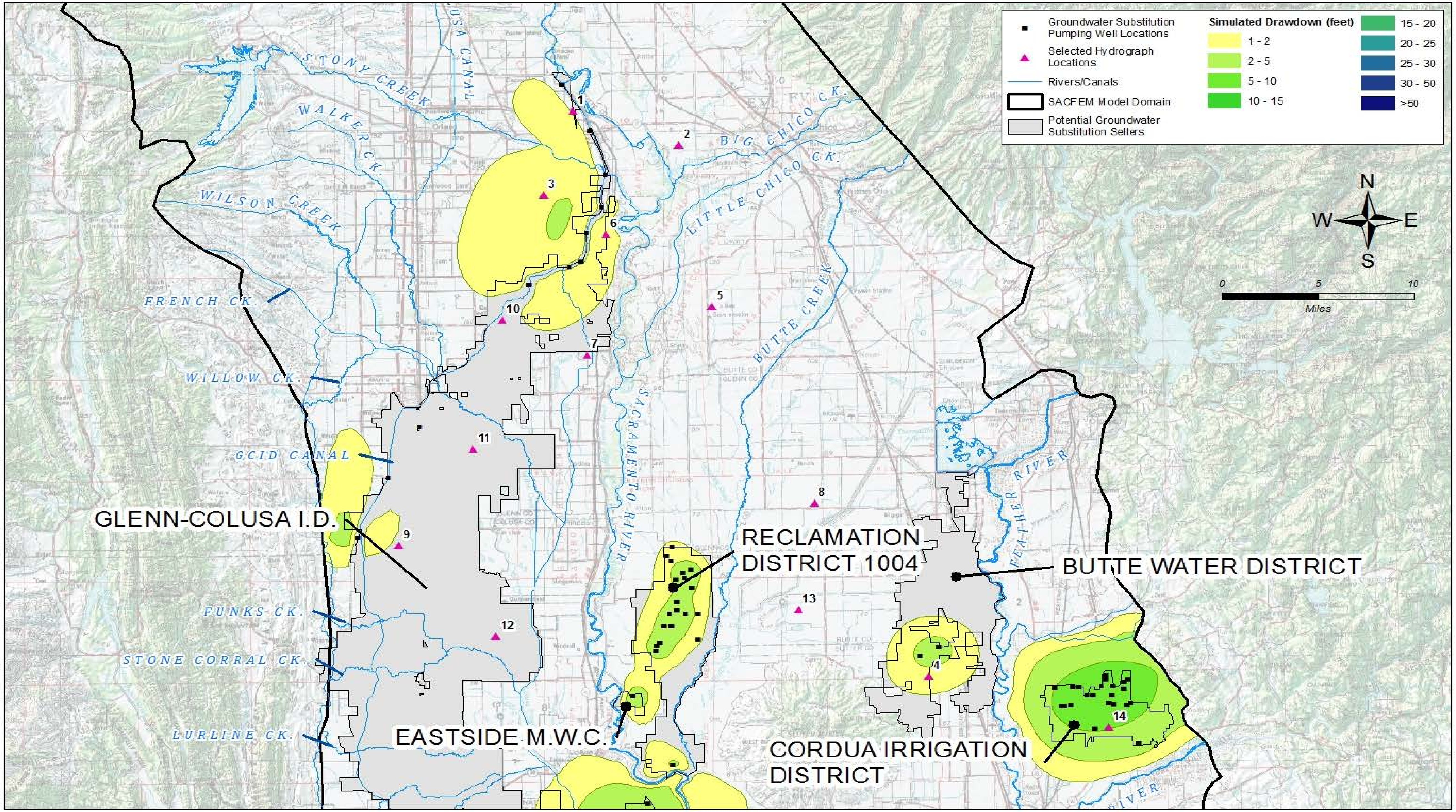

Figure 3.3-31a. Simulated Change in Water Table Elevation (Aquifer Depth up to Approximately 35 feet), Based on September 1990 Hydrologic Conditions

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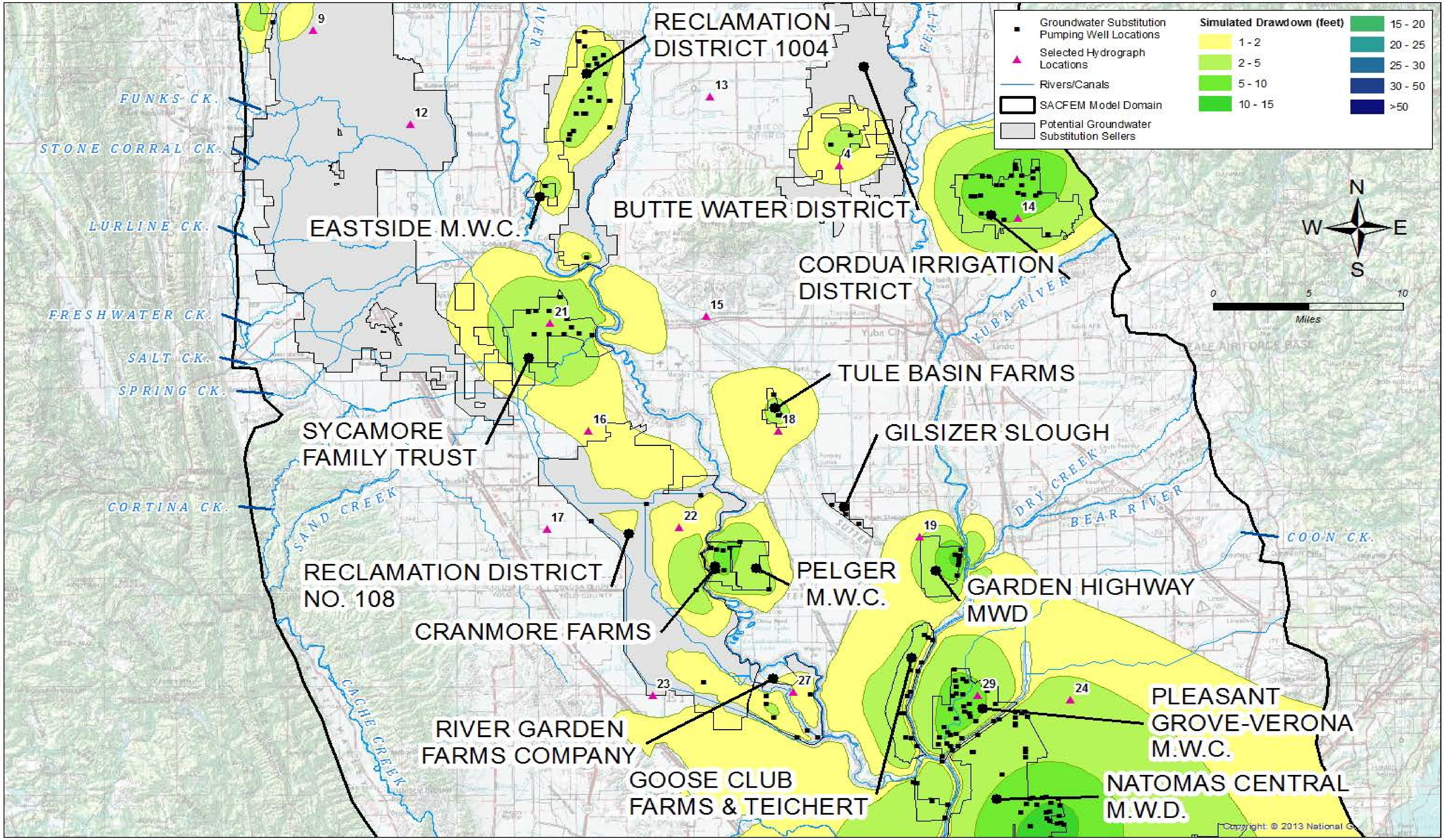

Figure 3.3-~~30.~~-31b. Simulated Change in Water Table Elevation (Aquifer Depth up to Approximately 35 feet), Based on September 1990 Hydrologic Conditions

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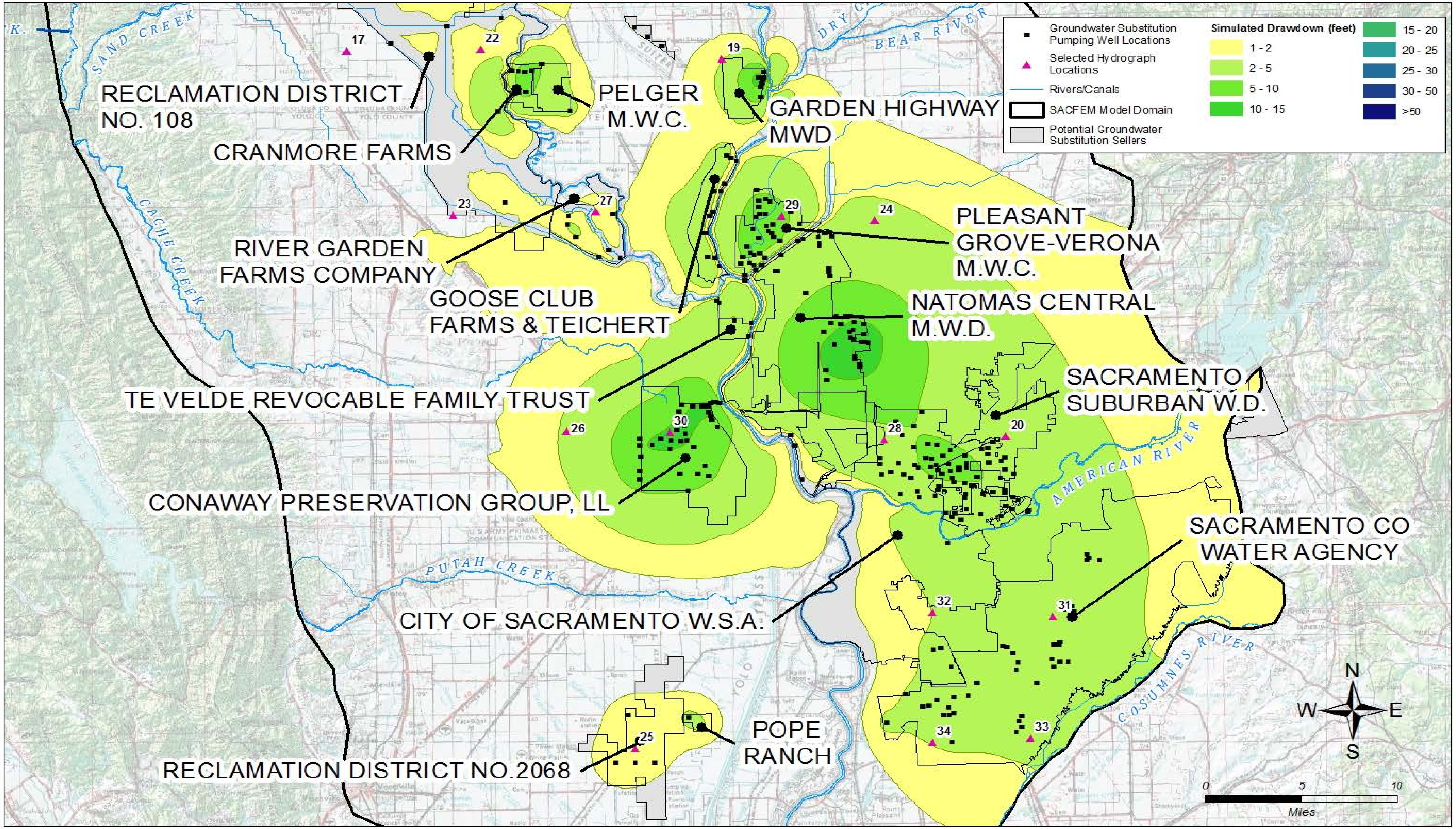

Figure 3.3-31c. Simulated Change in Water Table Elevation (Aquifer Depth up to Approximately 35 feet), Based on September 1990 Hydrologic Conditions

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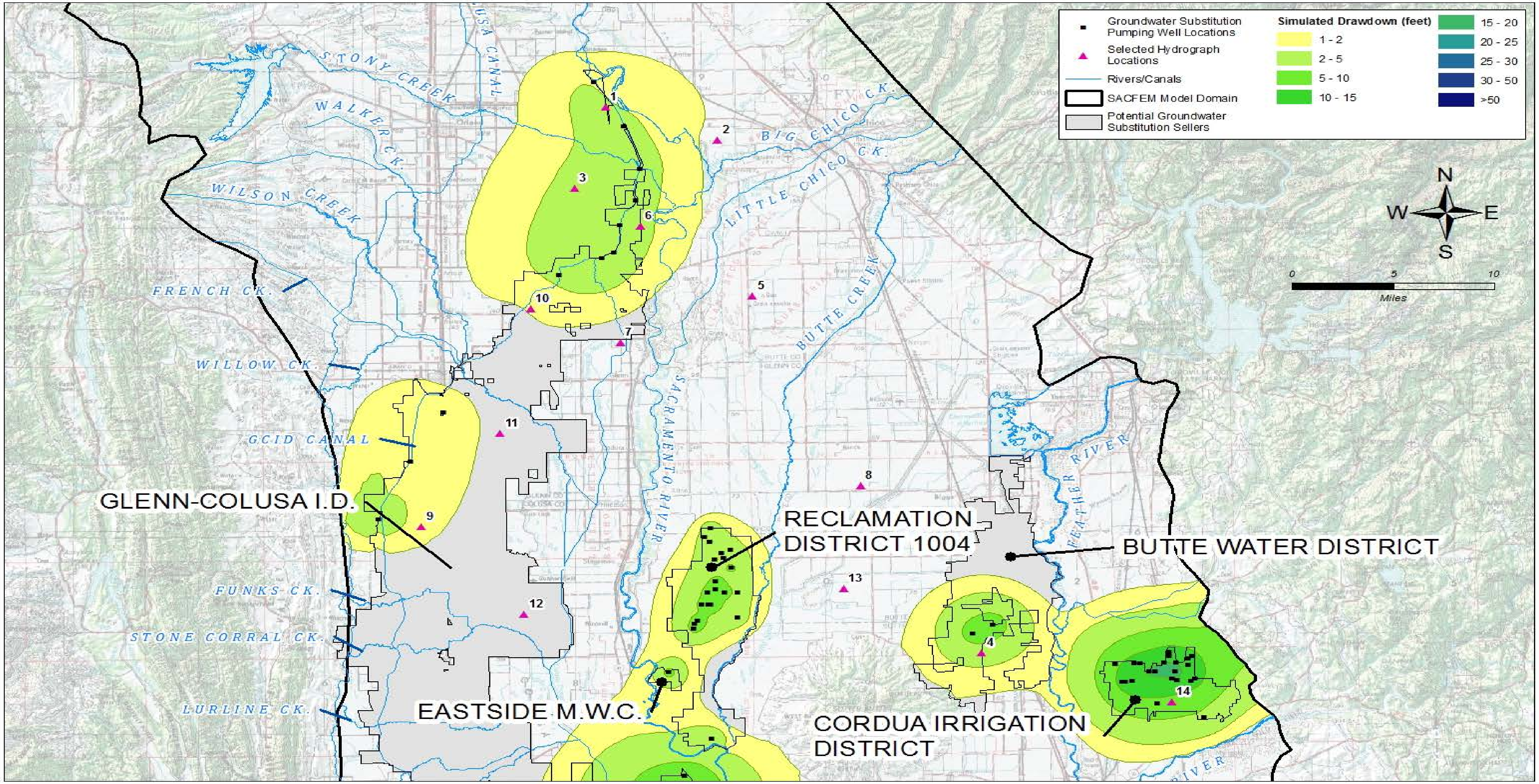

Figure 3.3-32a. Simulated Change in Groundwater Head (Aquifer Depth of Approximately 200 to 300 feet), Based on September 1990 Hydrologic Conditions

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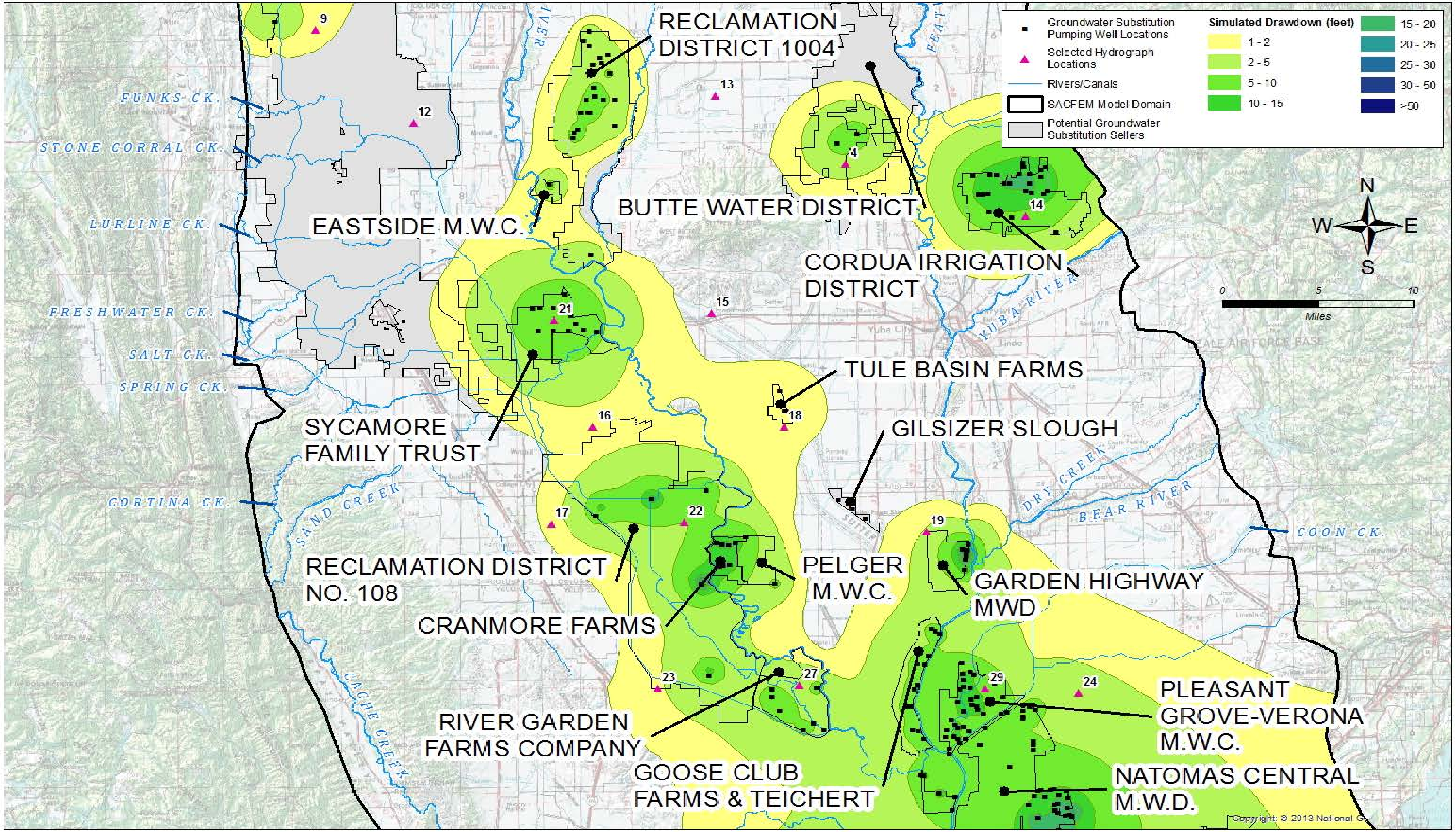

Figure 3.3-~~31.~~-32b. Simulated Change in Groundwater Head (Aquifer ~~depth~~Depth of Approximately 200 to 300 feet), Based on September 1990 Hydrologic Conditions

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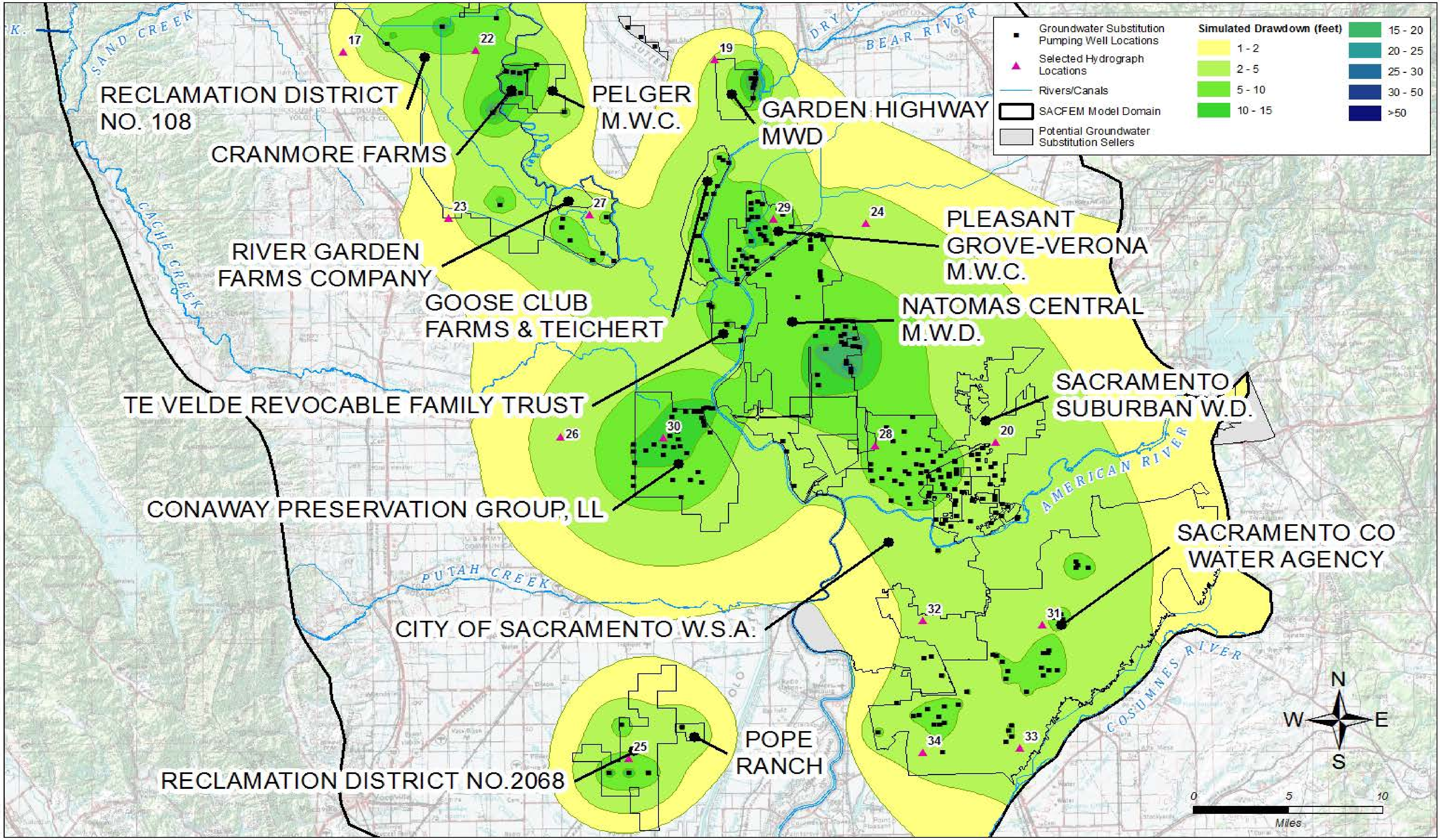

Figure 3.3-32c. Simulated Change in Groundwater Head (Aquifer Depth of Approximately 200 to 300 feet), Based on September 1990 Hydrologic Conditions

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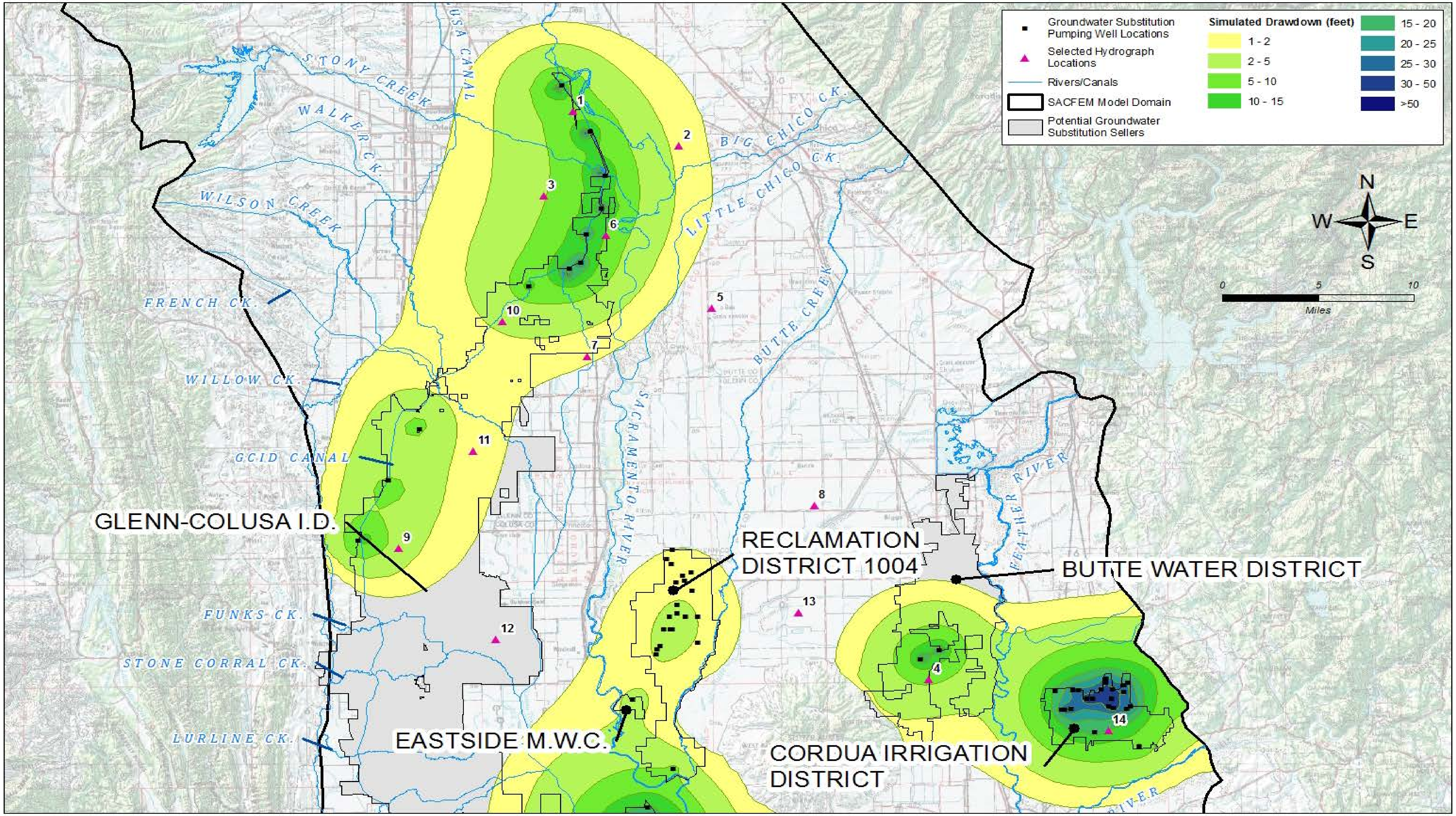

Figure 3.3-33a. Simulated Change in Groundwater Head (Aquifer Depth of Approximately 700- to 900 feet), Based on September 1990 Hydrologic Conditions

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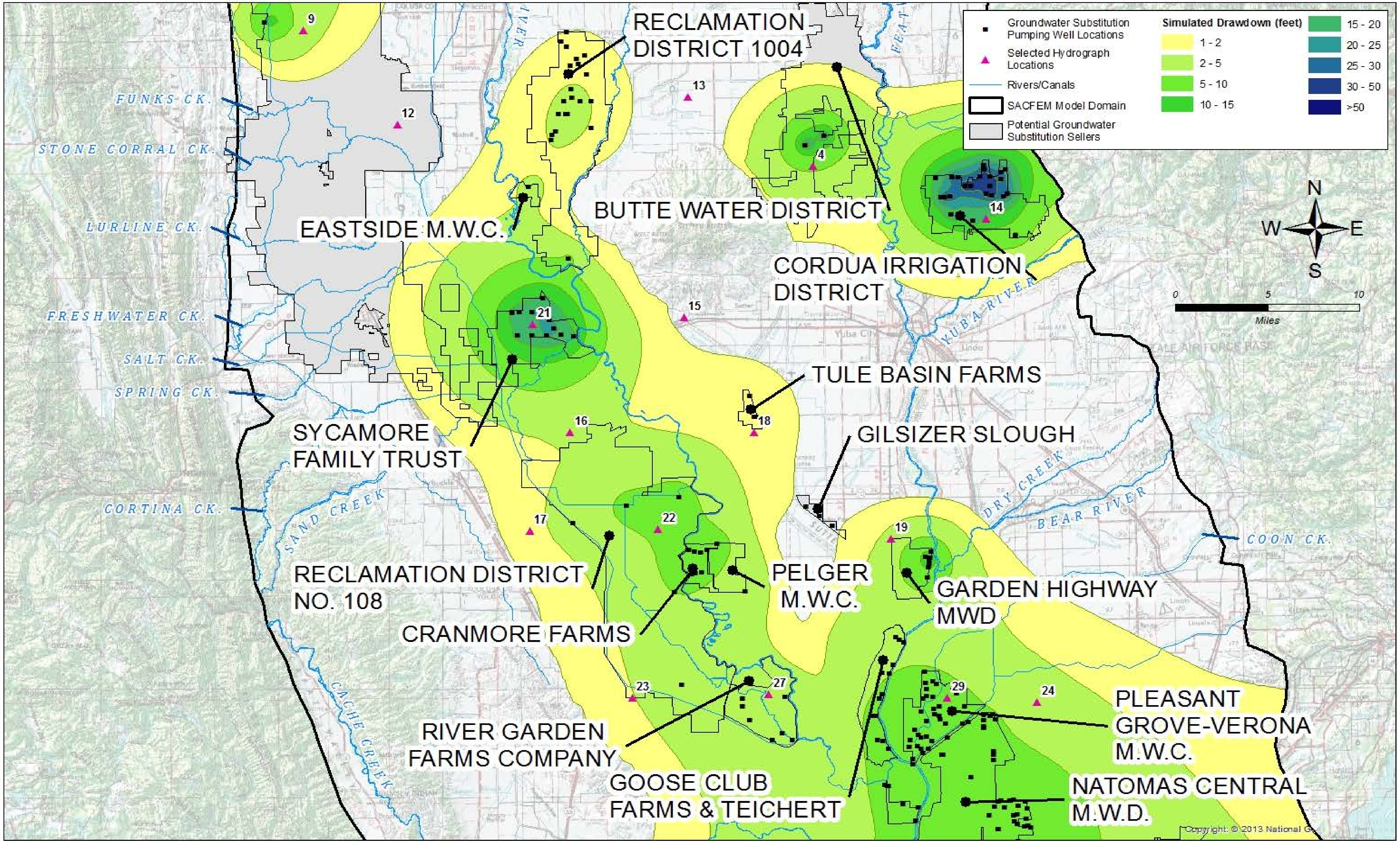

Figure 3.3-~~32.~~-33b. Simulated Change in Groundwater ~~Table Elevation (~~Head (Aquifer Depth of Approximately 700 to 900 feet), Based on September 1990 Hydrologic Conditions

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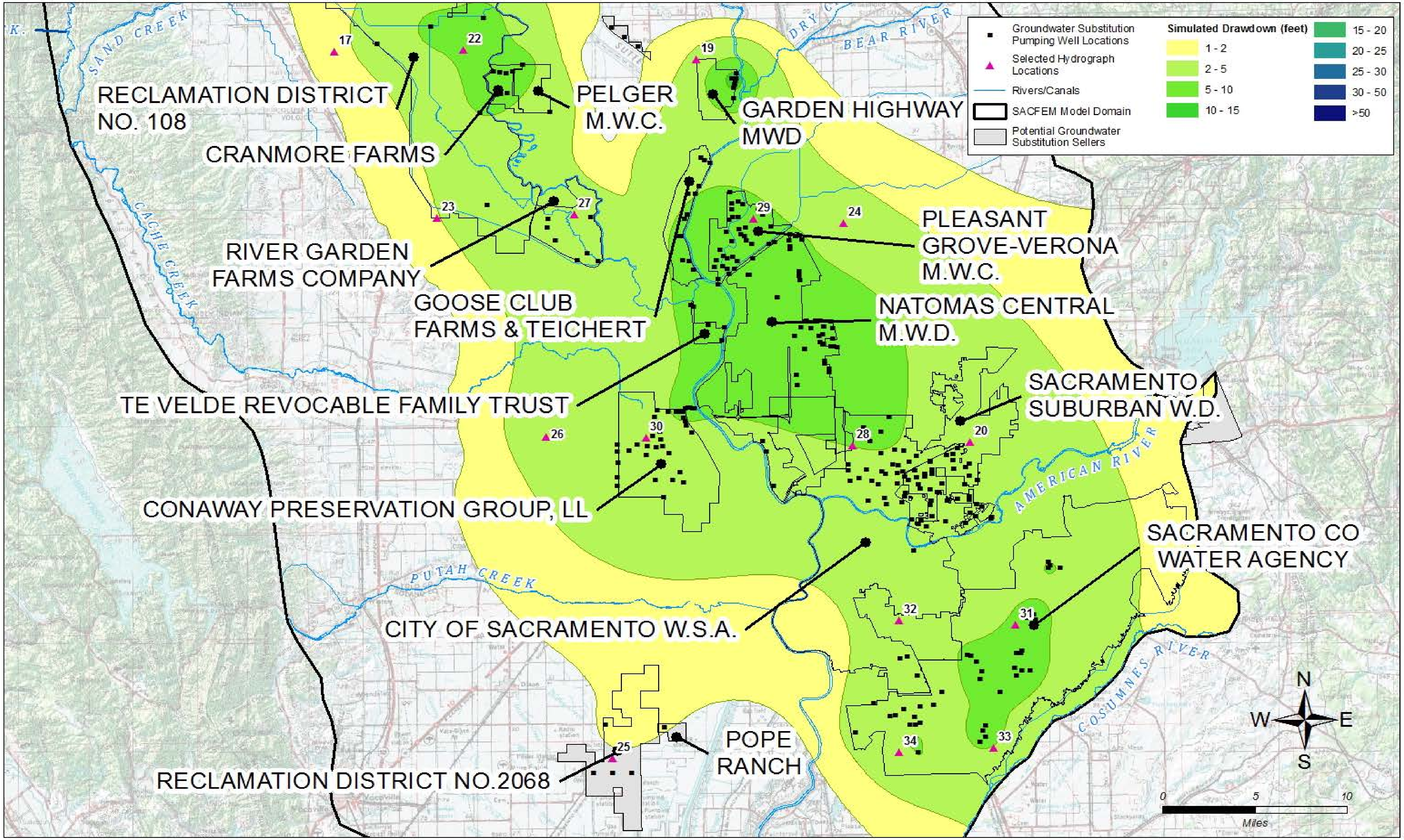

Figure 3.3-33c. Simulated Change in Groundwater Head (Aquifer Depth of Approximately 700 to 900 feet), Based on September 1990 Hydrologic Conditions

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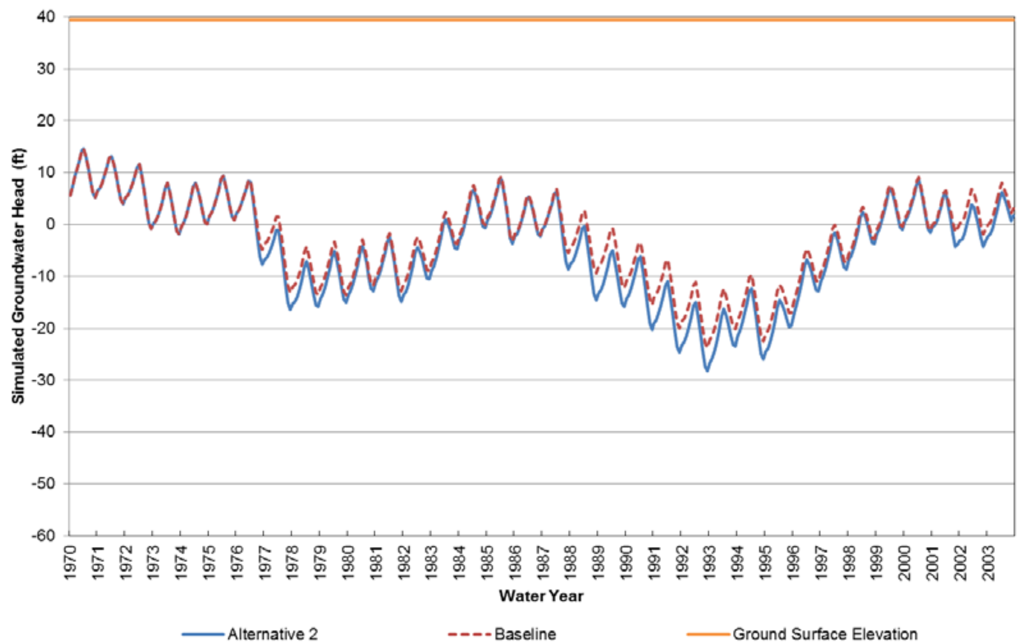


Figure 3.3-34a. Simulated Groundwater Head (Approximately 0-70 feet bgs) at Location 21

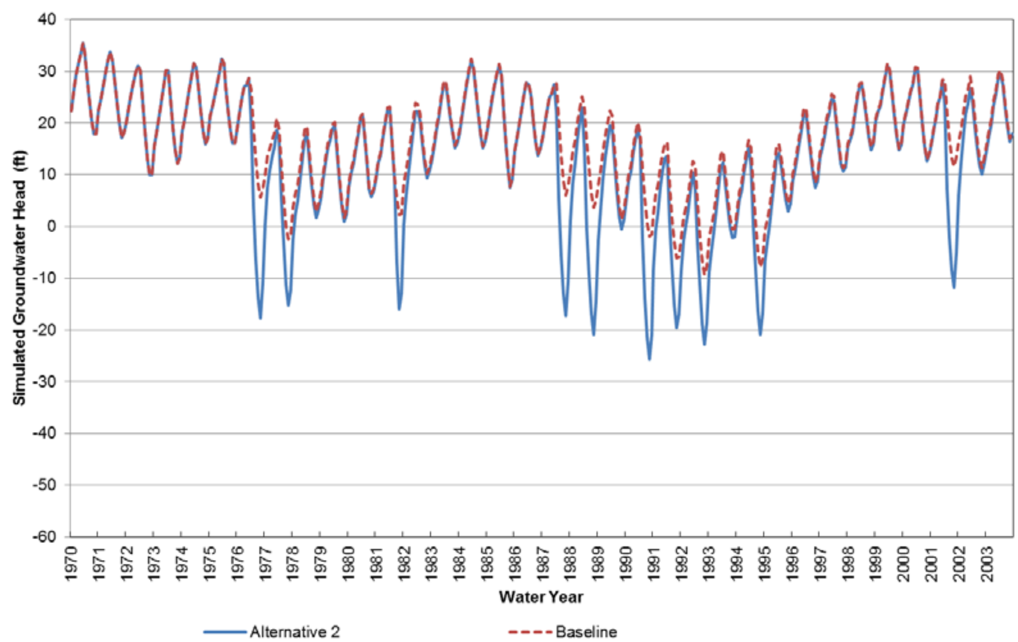


Figure 3.3-~~33.~~-34b. Simulated Groundwater Head (Approximately 690-910 feet bgs) at Location 21

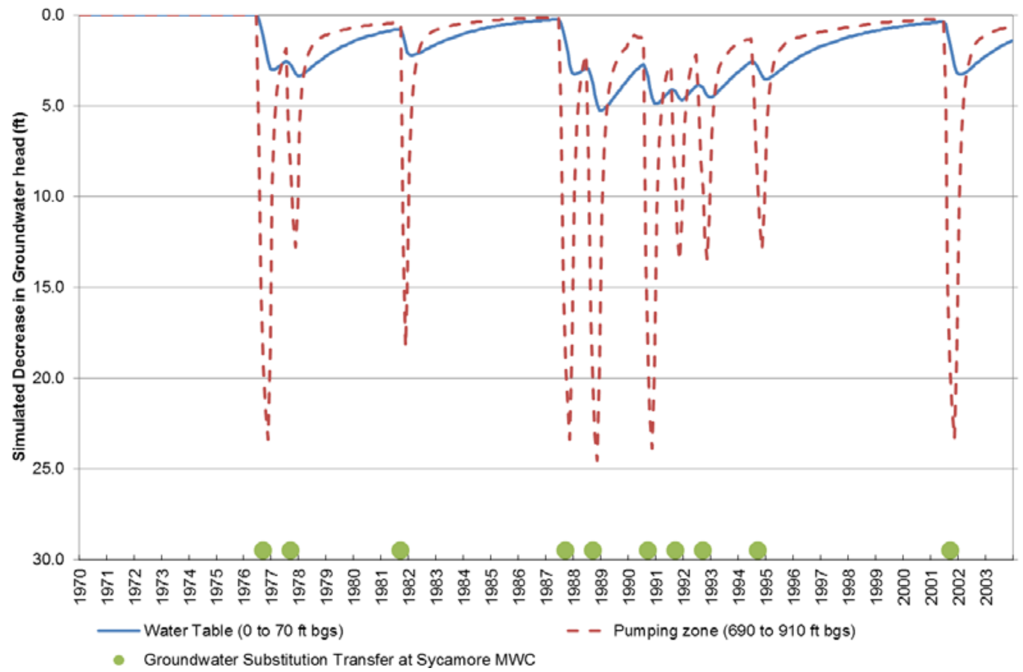


Figure 3.3~~-34.~~-34c. Simulated Change in Groundwater Head at Location 21

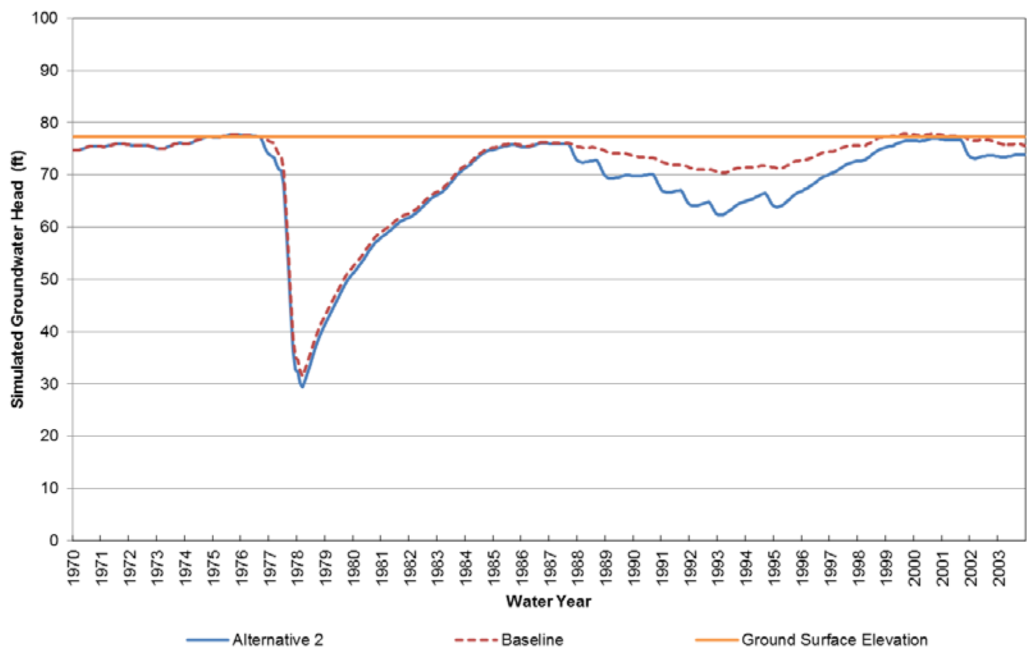


Figure 3.3~~-35.~~-35a. Simulated Groundwater ~~Table Elevation~~Head (Approximately 0 to 40 feet bgs) at Location 14

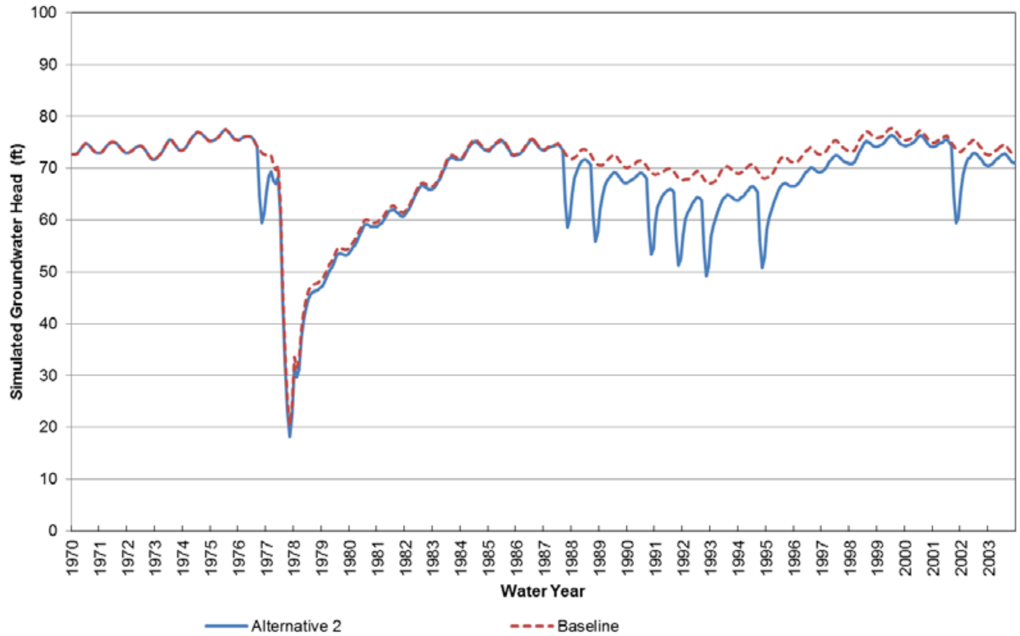


Figure 3.3~~-36.~~-35b. Simulated Groundwater Head (Approximately 310 to 420 feet bgs) at Location 14

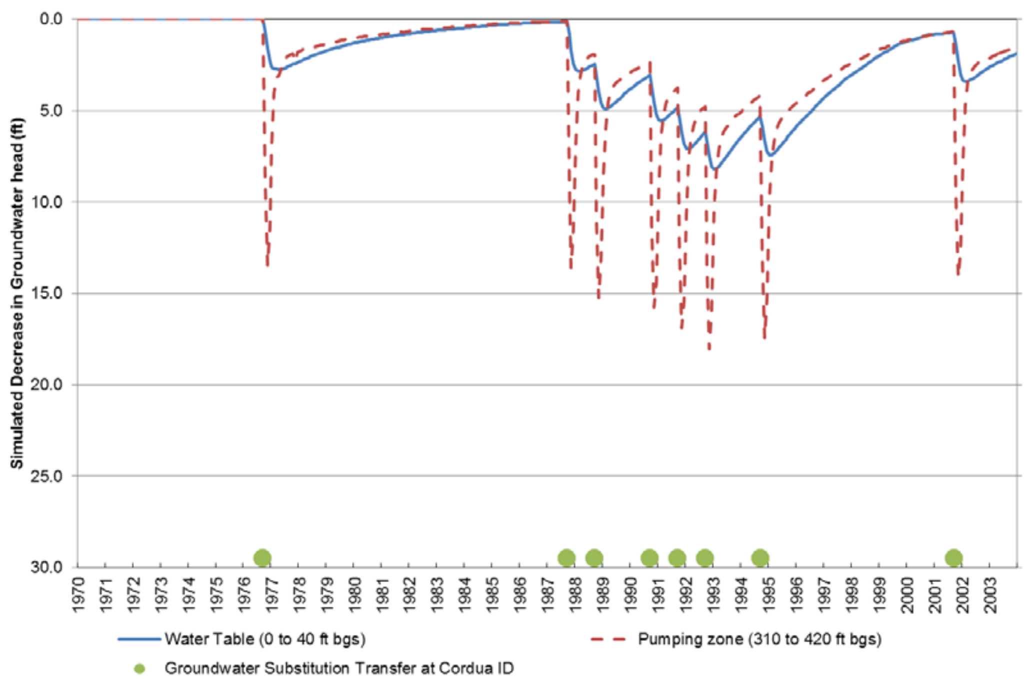


Figure 3.3~~-37.~~-35c. Simulated ~~change~~Change in Groundwater Head at Location 14

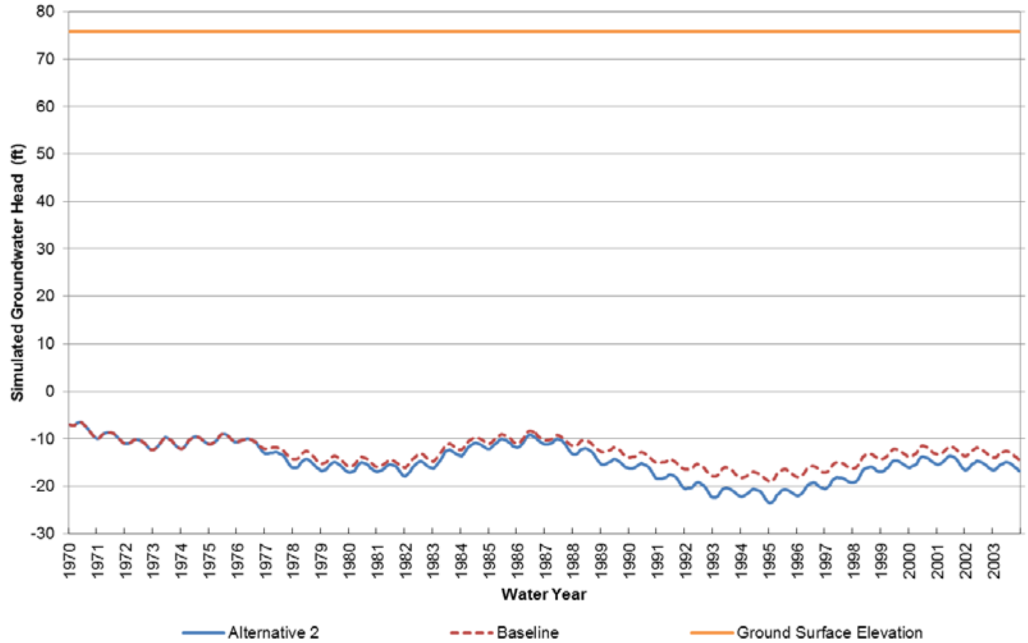


Figure 3.3-~~38.~~-36a. Simulated Groundwater ~~Table Elevation~~Head (Approximately 0 to 70 feet bgs) at Location 31

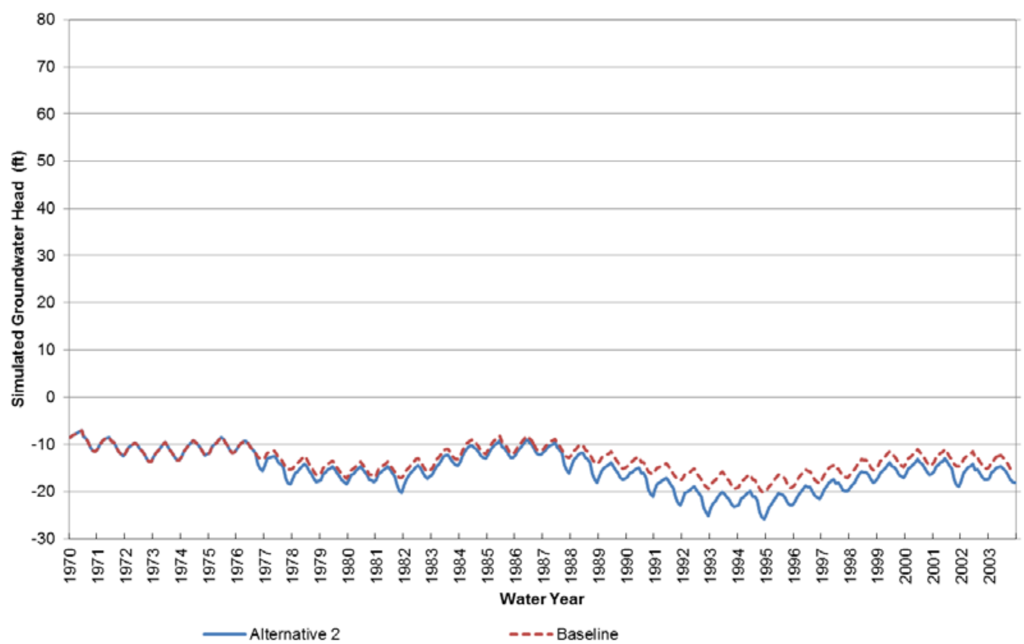


Figure 3.3-~~39.~~-36b. Simulated Groundwater Head (Approximately 200 to 330 feet bgs) at Location 31

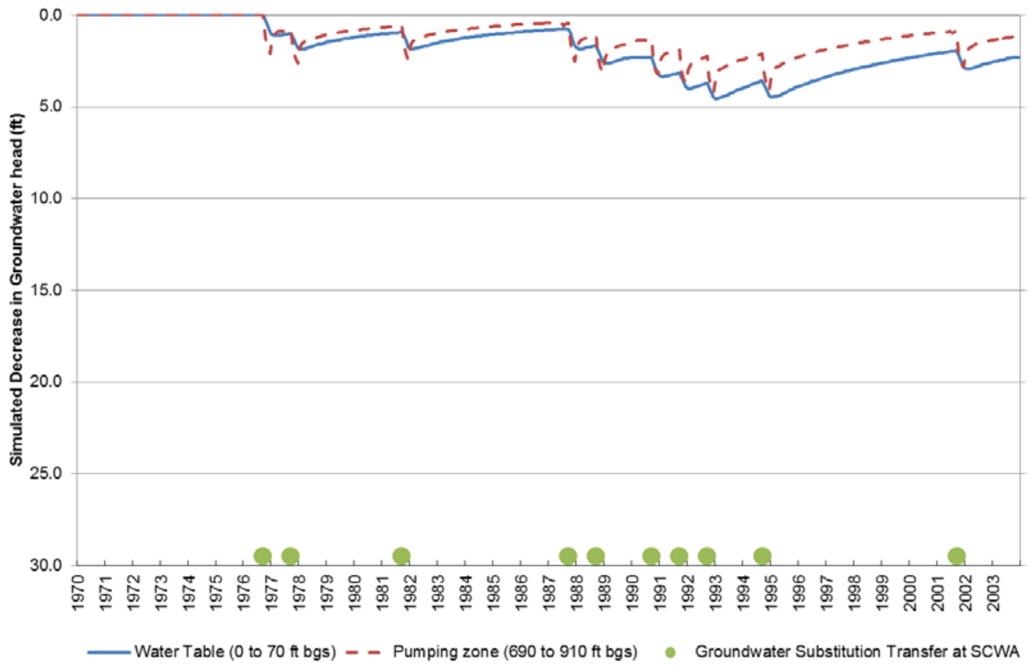


Figure 3.3-~~40.~~-36c. Simulated ~~change~~Change in Groundwater Head at Location 31

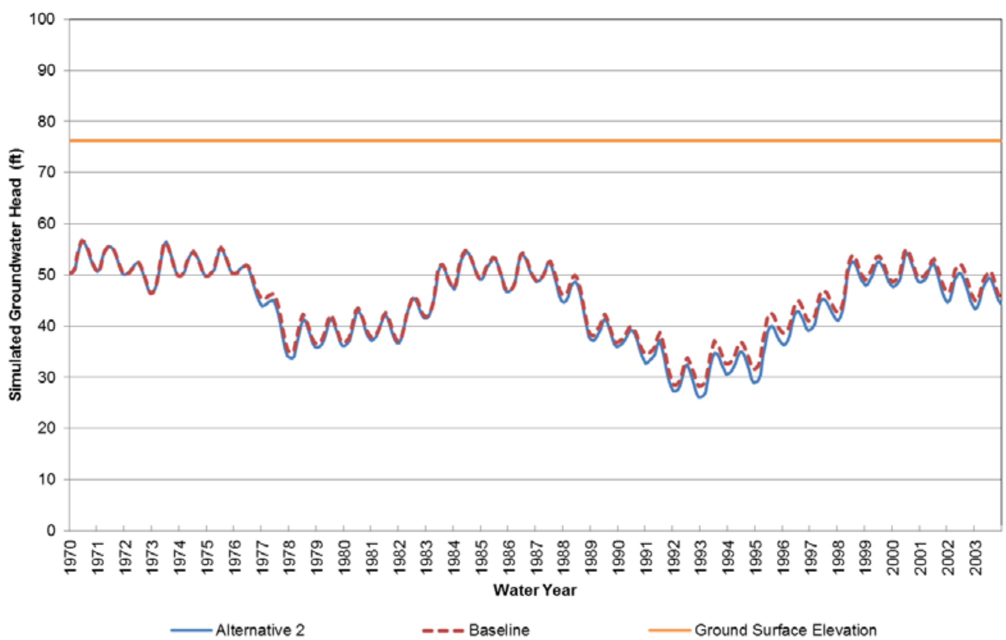


Figure 3.3-37a. Simulated Groundwater Head (Approximately 0 to 70 feet bgs) at Location 4

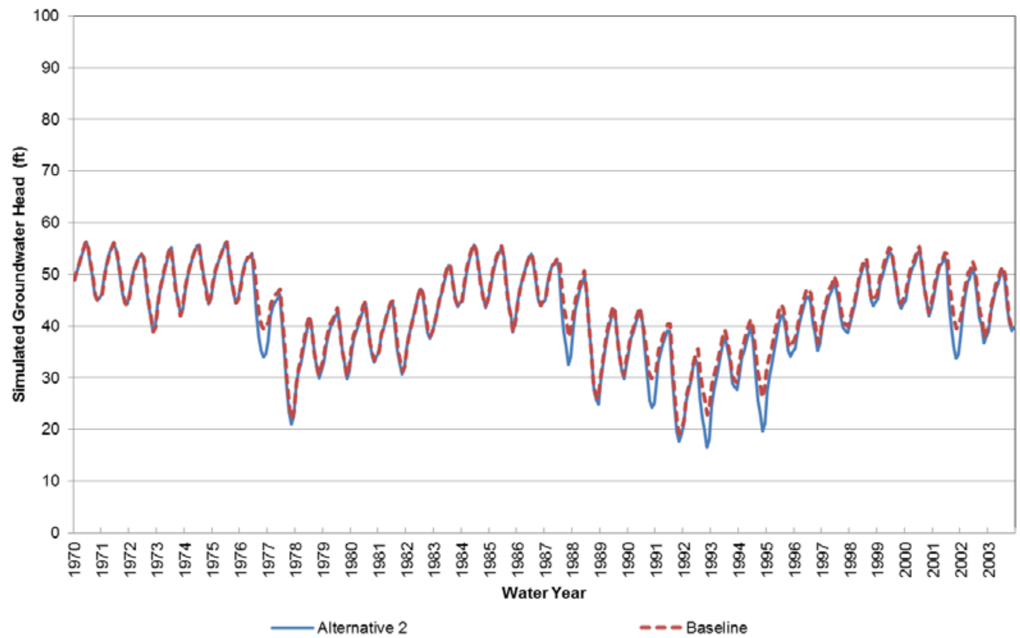


Figure 3.3-37b. Simulated Groundwater Head (Approximately 420 to 580 feet bgs) at Location 4

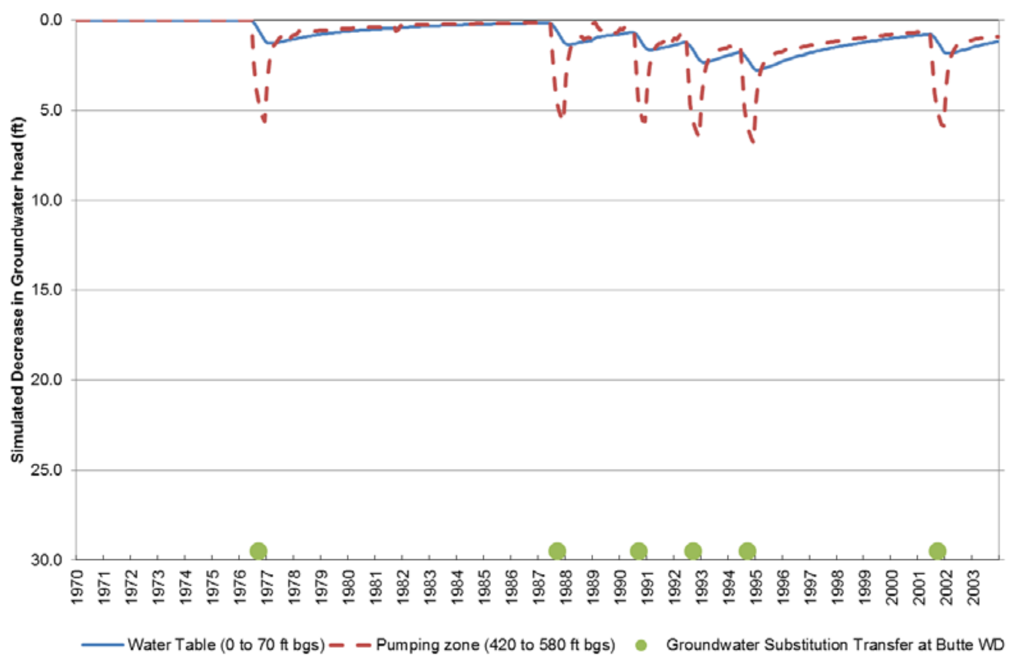
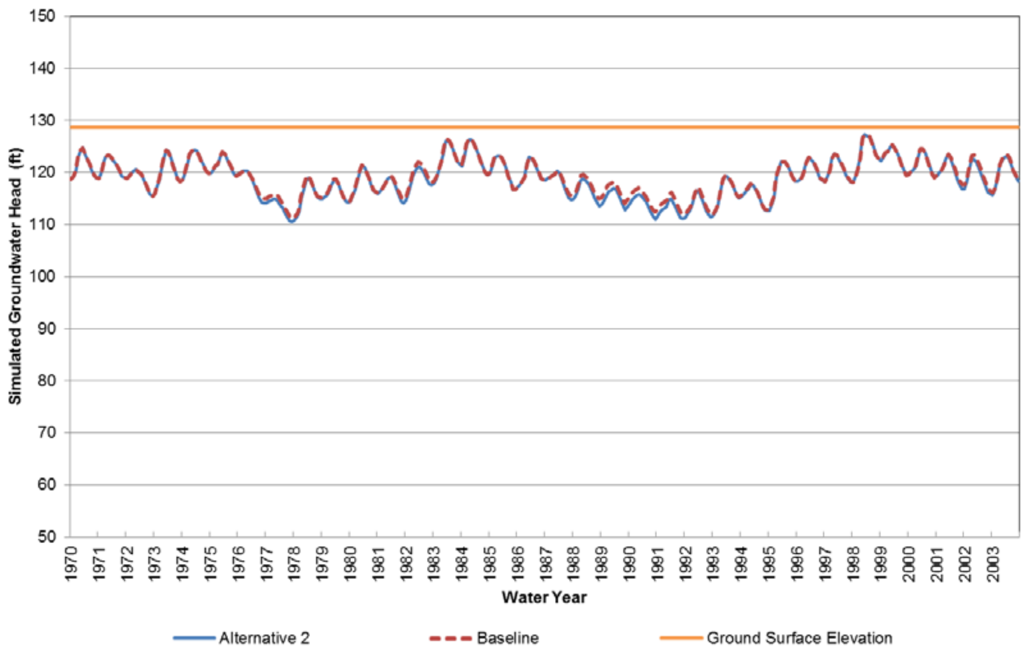
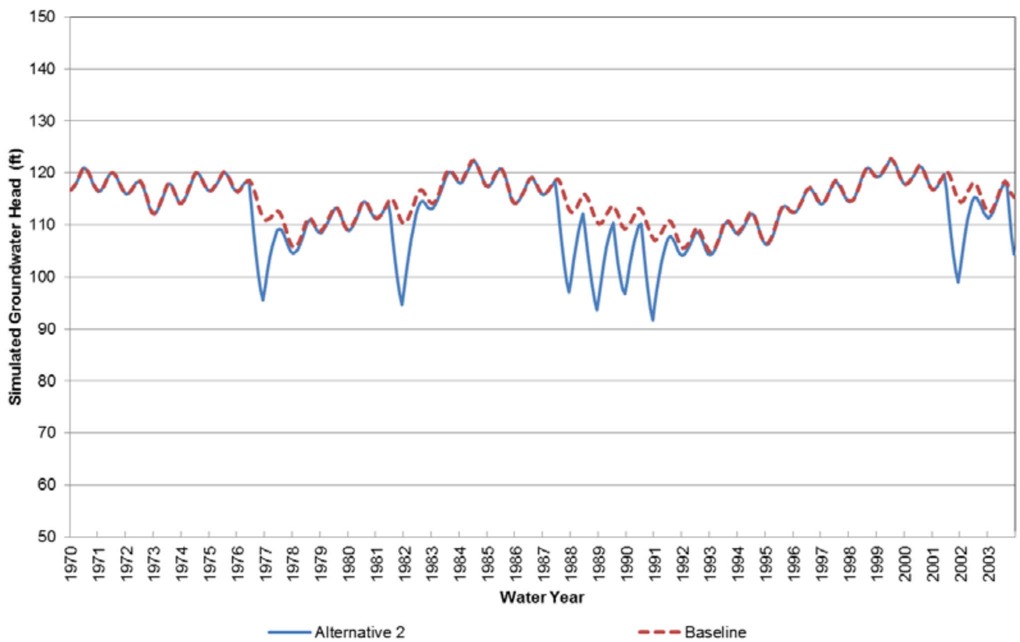


Figure 3.3-37c. Simulated Change in Groundwater Head at Location 4



<u>Figure 3.3-38a. Simulated Groundwater Head (Approximately 0 to 70 feet bgs) at Location 6</u>



<u>Figure 3.3-38b. Simulated Groundwater Head (Approximately 860 to 1290 feet bgs) at Location 6</u>

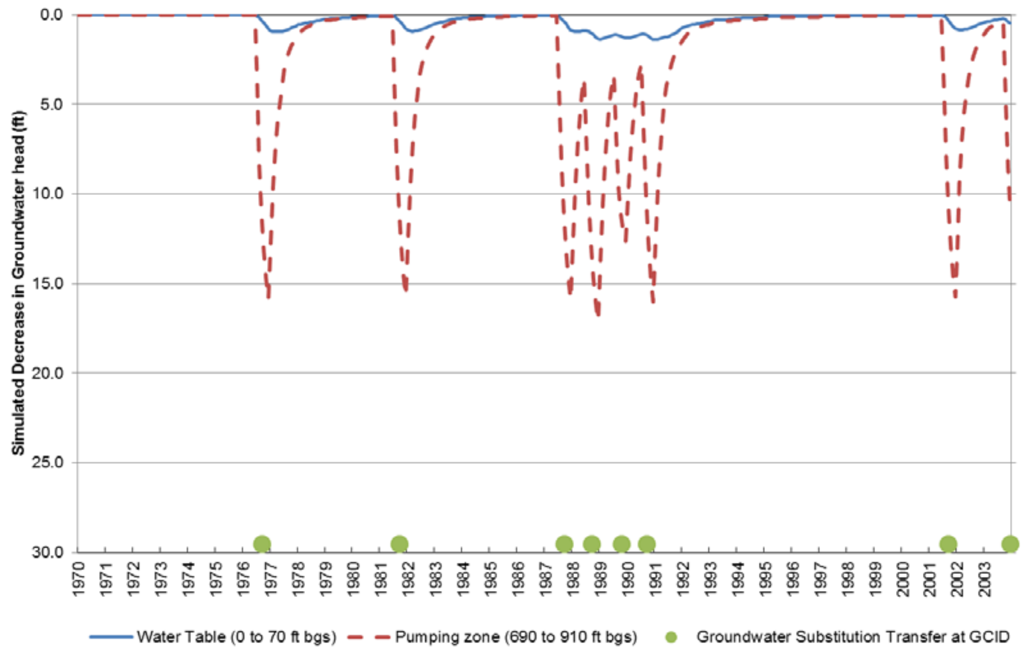


Figure 3.3-38c. Simulated Change in Groundwater Head at Location 6

As shown in Figure 3.3-26 through Figure 3.3-31, the maximum groundwater level declines resulting from substitution transfers within the Sacramento Valley Groundwater Basin range widely depending on the distance from the transfer groundwater pumping. The maximum groundwater level declines tend to be focused in the areas immediately surrounding the proposed groundwater substitution production wells. Seasonal groundwater level declines would be greater than the typical fluctuation when substitution pumping is included, indicating the potential for adverse effects. The potential for adverse drawdown effects would increase as the amount of extracted water increased. The potential for adverse effects would be higher during dry years, when baseline fluctuations would already be large and groundwater levels would likely be lower than normal.

Table 3.3-~~4~~6 shows the ~~number~~ depth range and average depth of domestic and irrigation wells within the areas of potential transferring agencies in the Sacramento Valley Groundwater Basin. On average, most wells in these areas are deeper than the levels that would result after potential drawdowns caused by groundwater substitution pumping; therefore, groundwater pumping would not cause them to go dry. However, groundwater level declines at the shallow wells could reduce the yield of these wells.

Groundwater substitution transfers could result in groundwater declines in excess of seasonal variation and these effects on non-transferring wells could be significant. To reduce these effects, the Mitigation Measure GW-1 (Section 3.3.4.1) specifies that transferring agencies establish monitoring and mitigation programs for groundwater substitution transfers. The programs would monitor groundwater level fluctuations within the local pumping area and if effects were reported or occurred, the participating seller agencies in the Sacramento basin would compensate for effects or reduce pumping until the groundwater basin recharges. Mitigation Measure GW-1 would reduce the impacts to less than significant.

Table 3.3-6. Well Depths in the Sacramento Valley Groundwater Basin

Groundwater Subbasin	Domestic Wells Depth Range (ft bgs)	Domestic Wells Average Depth (ft bgs)	Municipal/ Irrigation Wells Depth Range (ft bgs)	Municipal/ Irrigation Wells Average Depth (ft bgs)
Colusa	11 – 870	155	20 – 1,340	368
East Butte	25 – 639	101	35 - 983	285
North American	50 – 1,750	190	77 – 1,025	396
Solano	38 – 1,070	239	62 – 2,275	510
South American	87 – 575	247	41 – 1,000	372
Sutter	35 – 320	121	60 - 672	205
West Butte	15 – 680	136	40 - 920	321
Yolo	40 – 600	230	50 – 1,500	400

Source- DWR 2003
Key:
bgs = below ground surface
ft = feet

Groundwater extraction for groundwater substitution transfers would decrease groundwater levels, increasing the potential for subsidence. Most areas of the Sacramento Valley Groundwater Basin have not experienced land subsidence that has caused impacts to the overlying land. As shown in Figure 3.3-11, portions of Colusa and Yolo counties have experienced subsidence and subsidence has also been measured at Conaway Ranch (Yolo County). Table 3.3-~~5~~7 provides the simulated change in groundwater level due to transfer pumping at eight monitoring well locations shown in Figure 3.3-8 and Figure 3.3-9. The historic low groundwater level elevations were determined based on the monitored groundwater level data shown in Figure 3.3-8 and Figure 3.3-9. Based on the calculated historic low, groundwater levels since 2008 and the simulated change in groundwater level due to transfer pumping, there is potential for land subsidence at two of the eight monitoring wells (22N01E28J003M and 19N02W13J001M) presented in Table 3.3-7~~5~~. Additionally, the change in groundwater elevation at Conaway Ranch would be between the Proposed Action and the No Action Alternative ranges between 2.5-12 feet (Appendix E, Location 30 hydrograph). Therefore, the effect of potential land subsidence in the Seller Service Area could be significant. To reduce these effects, the Mitigation Measure GW-1 (Section 3.3.4.1) specifies that transferring agencies establish monitoring and mitigation programs for groundwater substitution transfers. This program will include periodic determination of land surface elevation in strategic locations throughout the transfer area. Mitigation Measure GW-1 would reduce the impacts to less than significant.

Table 3.3-7. Simulated Change in Groundwater Level at Monitoring Well Locations

Monitoring Well	Historic Low (preconsolidated heads)[1]	GWL in the last 7 years (2008 to Present)[1]	Maximum change in GWL under Proposed Action[2]	Average change in GWL under Proposed Action[2]
20N02E28N001M	110.5	116.8 - 112.1	-0.08	-0.03
22N01E28J003M*	119.8	145.2 - 119.8	-0.20	-0.07
19N04W12E001M	61.0	161.1 - 129.3	-0.90	-0.22
19N02W13J001M*	71.2	81.4 - 71.2	-0.34	-0.09
16N02W25B002M	25.7	45 - 32.4	-1.08	-0.39
11N02E20K004M	-22.6	33.2 - 20	-2.49	-0.69
12N05E12Q001M	20.5	NA	-1.56	-0.66
11N05E32R001M	-70.8	NA	-5.65	-2.03

Source: *DWR 2010b*
Note: NA= Data not available for period of record
* Wells with potential for land subsidence based on data presented in table
[1] Based on data ~~presented in **Figure 3.3-8** and~~
~~Figure 3.3-9~~
~~Figure 3.3-8 and Figure 3.3-9~~from DWR Water Data Library (DWR 2010b)
[2] Based on SACFEM2013 modeling results

Groundwater extraction for groundwater substitution transfers could cause migration of reduced quality water, agricultural use of reduced quality water, or the distribution of reduced quality water.

Migration of Reduced Quality Groundwater

Inducing the movement or migration of reduced quality water into previously unaffected areas ~~through~~due to groundwater ~~pumping~~substitution transfers is not likely to be a concern unless groundwater levels and/or flow patterns are substantially altered for a long period of time. Groundwater ~~extraction~~substitution pumping under the Proposed Action would be limited to short-term withdrawals during the irrigation season. Consequently, effects from the migration of reduced groundwater quality would be less than significant.

On-Farm Use of Reduced Quality Groundwater

Potential sellers that may participate in groundwater substitution transfers could experience changes in water quality as they switch from surface water to groundwater. Groundwater quality is good for most agricultural and municipal uses throughout the Sacramento Valley Groundwater Basin; therefore, potential regional impacts would be minimal and this impact would be less than significant.

Distribution of Reduced Quality Groundwater

Groundwater extracted could be of reduced quality relative to the surface water supply deliveries the seller districts normally receive; however, groundwater quality in the area is normally adequate for agricultural purposes. Distribution of groundwater for municipal supply is subject to groundwater quality monitoring and quality limits prior to distribution to customers. Therefore, potential impacts to the distribution of groundwater would be minimal and this impact would be less than significant.

Water transfers via cropland idling could decrease applied water recharge to the local groundwater system underlying the barren (idled) fields that could result in decline in groundwater levels. Table 3.3-~~6~~8 shows potential maximum water transferred via cropland idling.

Table 3.3-8. Maximum Annual Water Transfer from Cropland Idling under the Proposed Action

County	Rice (AF)	Alfalfa (AF)	Corn (AF)	Tomatoes (AF)	Total (AF)
Colusa, Glenn, Yolo	40,700	1,400	400	400	42,900
Butte, Sutter	10,770	600	800	400	12,570
Solano	-	3,000	1,500	-	4,500
Total	51,470	5,000	2,700	800	59,970

Cropland idling would eliminate the applied water on participating fields within the Seller Service Area. A portion of that applied water percolates into the groundwater aquifer; therefore, reducing applied water would result in a loss of recharge to the Sacramento Valley Groundwater Basin. Because only a small portion of the applied (i.e., transferred) water would have percolated to the groundwater table, the reduction in recharge is expected to be well below the 59,970 AF listed in Table 3.3-~~6~~8. This reduction in recharge would also be relatively small when compared to the total of amount of water that recharges the Sacramento Valley Groundwater Basin. A large portion of the total recharge to the basin occurs through precipitation and runoff over the spring and winter months.

Of the participating crops listed in Table 3.3-~~6~~8, rice represents the greatest amount of land idled for transfers. Rice farming practices include a constant supply of irrigation water that remains on rice fields during the growing season. The land used for rice production, however, is typically underlain by soils with low permeability (such as clay). A substantial portion of the water applied to rice fields does not percolate to the underlying aquifer because of the underlying soils, but rather discharges to the farmer's surface drainage system.

A reduction in applied water recharge because of cropland idling could have effects on groundwater recharge and levels; however, this action would not be likely to substantially reduce the amount of recharge for the basin. Consequently, the potential lowering of groundwater levels due to a reduction in groundwater recharge as a result of cropland idling would be less than significant.

Water Transfers via cropland idling may cause groundwater level declines that lead to permanent land subsidence or changes in groundwater quality. As discussed earlier in the section, cropland idling would not be likely to substantially lower groundwater levels in the basin causing land subsidence or changing groundwater quality. Consequently, subsidence and groundwater quality changes because of a reduction in groundwater recharge as a result of cropland idling would be less than significant.

3.3.2.4.3 Buyer Service Area

Decreased groundwater pumping in the Buyer Service Area may result in a temporary rise in groundwater levels in the Buyer Service Area. The Proposed Action ~~would~~may result in a reduced use of groundwater resources during periods of shortage by supplementing water supply with transferred water. Therefore, the impact of the Proposed Action on groundwater levels in the Buyer Service Area would be beneficial.

Decreased groundwater pumping in the Buyer Service Area would cause a decrease in water level declines thus, decreasing permanent land subsidence. The Proposed Action ~~would~~may result in a reduced use of groundwater resources during periods of shortage by supplementing water supply with transferred water. This potential decrease in the use of groundwater resources may result in a slowing of groundwater level decline or potentially cause an increase in groundwater levels. A slowed rate of decline or an increase in groundwater levels would help to slow the rate of subsidence. Therefore, the impact of the Proposed Action on potential land subsidence in the Buyer Service Area would be beneficial.

Changes in groundwater levels, or in the prevailing groundwater flow regime, could cause a change in groundwater quality. The Proposed Action would result in a reduced use of groundwater resources during periods of shortage by supplementing water supply with transferred water. Therefore, the impact of the Proposed Action on potential land subsidence in the Buyer Service Area would be beneficial.

3.3.2.5 Alternative 3: No Cropland Modifications

Alternative 3 involves transfers through groundwater substitution and no cropland idling. The impacts associated with the groundwater substitution transfers would be the same as the Proposed Action.

3.3.2.6 Alternative 4: No Groundwater Substitution

Alternative 4 involves transfers through cropland idling and no groundwater substitution. The impacts associated with the cropland idling transfers would be the same as the Proposed Action.

3.3.3 Comparative Analysis of Alternatives

Table 3.3-~~7~~9 summarizes the effects of each of the action alternatives. The following text supplements the table by describing the magnitude of the effects under the action alternatives and No Action/No Project Alternative.

Table 3.3-~~7~~9. Comparison of Alternatives

Potential Impact	Alternative(s)	Significance	Proposed Mitigation	Significance after Mitigation
Groundwater pumping within the Buyer Service Area in response to shortages could cause reduction in groundwater levels.	1	NCFEC	None	NCFEC
Groundwater pumping within the Buyer Service Area in response to shortages could cause subsidence.	1	NCFEC	None	NCFEC
Groundwater pumping within the Buyer Service Area in response to shortages could cause changes to groundwater quality.	1	NCFEC	None	NCFEC
Land idling that temporarily converts cropland to bare fields in response to shortages in the Buyer Service Area could cause reduction in groundwater levels due to decreased applied water recharge.	1	NCFEC	None	NCFEC
Groundwater substitution transfers could cause a reduction in groundwater levels in the Seller Service Area.	2, 3	S	GW-1	LTS
Groundwater substitution transfers could cause subsidence in the Seller Service Area.	2, 3	S	GW-1	LTS
Groundwater substitution transfers could cause changes to groundwater quality in the Seller Service Area.	2, 3	LTS	None	LTS
Cropland idling transfers could cause reduction in groundwater levels in the Seller Service Area due to decreased applied water recharge.	2, 4	LTS	None	LTS
Water transfers could reduce groundwater pumping during shortages in the Buyer Service Area, which could increase groundwater levels, decrease current rate of subsidence, and improve groundwater quality.	2, 3, 4	Beneficial	None	Beneficial

Key:
NCFEC: No change from existing conditions

S: Significant
LTS: Less than Significant

3.3.3.1 No Action/No Project Alternative

There would be no changes to groundwater levels, quality, or land subsidence in the Seller Service Area relative to existing conditions. In the Buyer Service Area, increased land idling and groundwater substitution transfers could occur in response to CVP shortages, which could cause a reduction in groundwater levels, a change in groundwater quality or subsidence. However, these actions to address shortages are already underway, and the No Action/No Project Alternative would not represent a change from existing conditions.

3.3.3.2 Alternative 2: Full Range of Transfers (Proposed Action)

Groundwater substitution transfers under the Proposed Action could decrease groundwater levels, potentially affecting non-transferring wells near participating substitution wells. Declining groundwater levels could also affect land subsidence and groundwater quality; however, these effects would be less than significant. Cropland idling transfers under the Proposed Action could reduce percolation to groundwater, but the reduction would be small because rice (the main crop proposed for idling) is typically grown on soils with low permeability. Potential effects on groundwater resources in the Seller Service Area under Proposed Action would be greater than the No Action/No Project Alternative. These effects could be reduced by Mitigation Measure GW-1 (Section 3.3.4.1).

In the Buyer Service Area, transfers would reduce the need to pump groundwater during shortages and could result in beneficial effects to groundwater levels, land subsidence, and groundwater quality.

3.3.3.3 Alternative 3: No Cropland Modification

The No Cropland Modification Alternative does not include cropland idling but would include groundwater substitution transfers. The effects in the Seller Service Area from Alternative 3 would be the same as those associated with groundwater substitution in the Proposed Action. These effects could be reduced by Mitigation Measure GW-1. Similar to the Proposed Action, transfers could improve groundwater levels, land subsidence, and groundwater quality in the Buyer Service Area by reducing groundwater pumping during shortages.

3.3.3.4 Alternative 4: No Groundwater Substitution

The No Groundwater Substitution does not include groundwater substitution transfers, but cropland idling transfers have the potential to reduce recharge to the groundwater basin. However, the reduction in percolation would be less than significant because rice is the primary crop and grown on soils with low permeability. Similar to the Proposed Action, transfers could increase groundwater levels, eliminate or minimize land subsidence, and improve groundwater quality in the Buyer Service Area by reducing groundwater pumping during shortages.

3.3.4 Environmental Commitments/Mitigation Measures

3.3.4.1 Mitigation Measure GW-1: Monitoring Program and Mitigation Plans

The *DRAFT Technical Information for Preparing Water Transfer Proposals* ~~(Reclamation and DWR 2013) and Addendum~~ (Reclamation and DWR 2014) provides guidance for ~~the~~ development of ~~proposals for~~ groundwater substitution water transfer proposals. The technical information ~~and addendum~~ informs the development of the monitoring and mitigation program for ~~this project~~the range of potential transfer activities evaluated in this EIS/EIR, ~~which~~ and will be updated as appropriate based on the most current version of the technical paper each year of ~~this long-term project~~the ten-year term of potential activities.

The objectives of ~~the monitoring and mitigation plan are~~Mitigation Measure GW-1 is~~:~~ to ~~mitigate~~ avoid significant adverse environmental effects ~~that~~ and ensure prompt corrective action in the event unanticipated effects occur. The measure accomplishes this by monitoring groundwater and/or surface water levels during transfers to avoid potential effects. The objectives of this process are to:~~;~~ (1) ~~to~~ minimize potential effects to other legal users of water; ~~to~~ (2) provide a process for review and response to reported effects to non-transferring parties; ~~and~~ (3)~~to~~ assure that a local mitigation strategy is in place prior to the groundwater transfer; and (4) mitigate significant adverse environmental effects. Reclamation will verify that sellers adopt and implement these mitigation measures to avoid potentially significant adverse effects of transfer-related groundwater extraction. In addition, each entity participating in a groundwater substitution transfer ~~will be required to~~must confirm that the proposed groundwater pumping will be compatible with state and local regulations and GMPs. As GSPs are developed by Groundwater Sustainability Agencies, potential sellers must confirm that the proposed pumping is compatible with applicable GSPs. ~~Reclamation's transfer approval process and groundwater mitigation measures set forth a framework that is designed to avoid and minimize adverse groundwater effects. Reclamation will verify that sellers adopt and implement these mitigation measures to minimize the potential for adverse effects related to groundwater extraction.~~

3.3.4.1.1 Well Review Process

Potential sellers ~~will be required to~~must submit well data for Reclamation and, where appropriate, DWR review, as part of the transfer approval process. Required information will be detailed in the most current version of the *DRAFT Technical Information for Preparing Water Transfer Proposals.*

3.3.4.1.2 Monitoring Program

Potential sellers will be required tomust complete and implement a monitoring program subject to Reclamation's approval that mustshall, at a minimum, include the following components:

Monitoring Well Network.

The monitoring program will shall incorporate a sufficient number of monitoring wells, as determined by Reclamation and the sellers in relation to local conditions, to accurately characterize groundwater levels and response in the area before, during, and after transfer pumping takes place. Depending on local conditions, additional groundwater level monitoring may be required near ecological resource areas.

Groundwater Pumping Measurements

All wells pumping to replace surface water designated for transfer shall be configured with a permanent instantaneous and totalizing flow meter capable of accurately measuring well discharge rates and volumes. Flow meter readings will be recorded just prior to initiation of pumping and at designated times, but no less than monthly and as close as practical to the last day of the month, throughout the duration of the transfer.

Groundwater Levels

Sellers will collect measurements of groundwater levels in both participating transfer wells and monitoring wells. Groundwater level monitoring will include measurements before, during and after transfer-related pumping. The water transfer proponentseller will measure groundwater levels as follows:

- Prior to transfer: Groundwater levels will be measured monthly from March in the year of the proposed transfer-related pumping until the start of the transfer (where possible).
- Start of transfer: Groundwater levels will be measured on the same day that the transfer-related pumping begins, prior to the pump being turned on.
- During transfer-related pumping: Groundwater levels will be measured weekly throughout the transfer-related pumping period, unless site specific information indicates a different interval should be used.
- Post-transfer pumping: Groundwater levels will be measured weekly for one month after the end of transfer-related pumping, after which groundwater levels will be measured monthly through March of the year following the transfer.

Sellers thus monitor effects to groundwater levels that may result from the proposed transfer and avoid significant impacts. The primary criteria used to identify potentially significant impacts to groundwater levels are the BMOs set by GMPs. In the Sacramento Valley, several counties have established GMPs to provide guidance in managing the resource. The existing GMPs and BMOs are discussed in Section 3.3.1.2, Regulatory Setting.

In areas where quantitative BMOs do not exist, Reclamation, SLDMWA, and the potential seller(s) will coordinate closely with potentially impacted third parties to collect and monitor groundwater data. If a third party expects that it may be impacted by a proposed transfer, that party should contact Reclamation and the seller with its concern. The burden of collecting groundwater data will not be the responsibility of the third party. If warranted, groundwater level monitoring to address the third-party's concern may be incorporated in the monitoring and mitigation plans required by Mitigation Measure GW-1.

Additionally, to avoid significant effects to vegetation and allow sellers to modify actions before significant effects occur, sellers will monitor groundwater depth data to verify that significant adverse effects to deep-rooted vegetation are avoided. If monitoring data indicate that water levels have dropped below root zones (i.e., more than 10 feet where groundwater was 10 to 25 feet below ground surface prior to starting the transfer of surface water made available from groundwater substitution actions), the seller must implement actions set forth in the mitigation plan. If historic data show that groundwater elevations in the area of transfer have typically varied by more than this amount annually during the proposed transfer period, then the transfer may be allowed to proceed. If there is no deep-rooted vegetation (i.e., oak trees and riparian trees that would have tap roots greater than 10 feet deep) within one-half mile of the transfer wells or the vegetation is located along waterways that will continue to have water during the transfer, the transfer may be allowed to proceed. If no existing monitoring points exist in the shallow aquifer, monitoring would be based on visual observations of the health of these areas of deep-rooted vegetation. If significant adverse impacts to deep-rooted vegetation (that is, loss of a substantial percentage of the deep-rooted vegetation as determined by Reclamation based on site-specific circumstances in consultation with a qualified biologist) occur as a result of the transfer despite the monitoring efforts and implementation of the mitigation plan, the seller will prepare a report documenting the result of the restoration activity to plant, maintain, and monitor restoration of vegetation for 5 years to replace the losses.

Groundwater Quality

For municipal sellers, the comprehensive water quality testing requirements of Title 22 ~~should be~~are considered sufficient for the water transfer monitoring program. Agricultural sellers shall measure specific conductance in samples from each participating production well. Samples shall be collected when the seller first initiates pumping, monthly during the transfer period, and at the termination of transfer pumping.

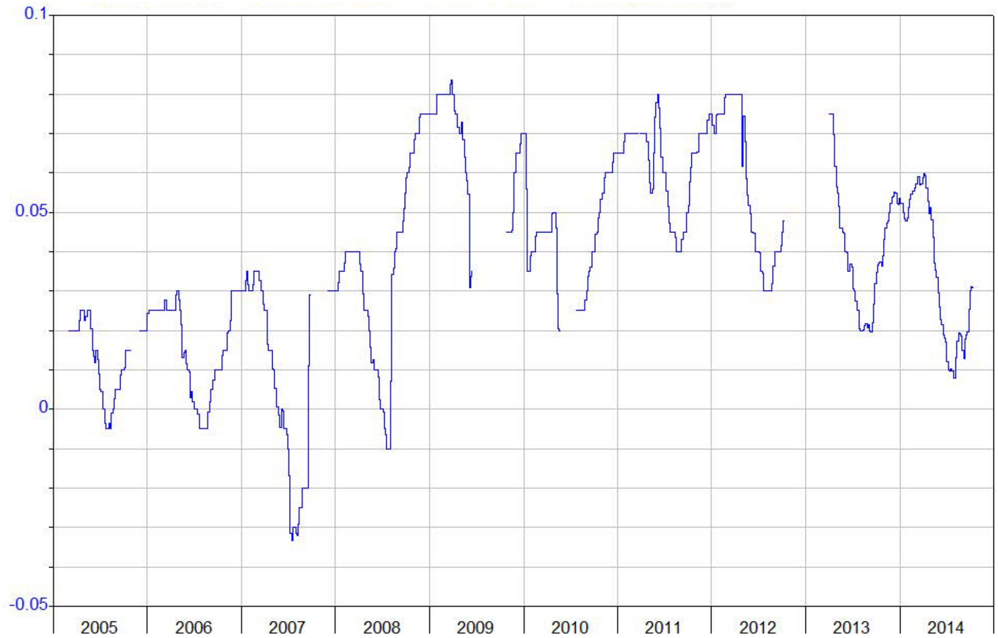
Land Subsidence

Subsidence monitoring will be required if groundwater levels decline below historic low levels during the proposed water transfer. Before a transfer, each seller will examine local groundwater conditions and groundwater level changes based on past pumping events or groundwater substitution transfers. This existing information will be the basis to estimate if groundwater levels are likely to decline below historic low levels, which would trigger land surface elevation measurements (as described below).

If the measured groundwater level falls below the historic low level, the seller must confirm the measurement within seven days. If the water level has risen above the historic low level, the seller may continue transfer pumping. If the measured groundwater level remains below the historic low level, the seller will stop transfer-related pumping immediately or begin determination of land surface elevation measurements in strategic locations within and/or near throughout the transfer-related pumping area. Measurements may include (1) extensometer monitoring, (2) continuous GPS monitoring, or (3) extensive land-elevation benchmark surveys conducted by a licensed surveyor. at the beginning and end of each transfer year. This data could be collected by the seller or from other sources (such as public extensometer data). Measurements must be completed on a monthly basis during the transfer.

If the land surface elevation survey indicates an elevation decrease between 0.1 foot and 0.2 foot from the initial measurement, the seller could have significant impacts and would need to start the process identified below in the Mitigation Plan (Section 3.3.4.1.3). The seller will also work with Reclamation to assess the accuracy of the survey measurements based on current limitations of technology, professional engineering/surveying judgment, and any other data available in or near the transferring area.

The threshold of 0.1 foot was chosen as this value is typical of the elastic (i.e., recoverable) portion of subsidence; the threshold of 0.2 foot was selected considering limitations of current land survey technology. This threshold is supported by a review of data from extensometers within the Sacramento Valley. Figure 3.3-39 shows the subsidence data from extensometer 22N02W15C002M, in Glenn County. This extensometer has not been identified as having long-term declining trends, but exhibits a small amount of movement (up to about 0.1 foot).



Source: DWR Water Data Library 2014

Figure 3.3-39. Measured Ground Surface Displacement (in feet) at Extensometer 22N02W15C002M in Glenn County

Coordination Plan

The monitoring program will include a plan to coordinate the collection and organization of monitoring data~~, and communication with the well operators~~. This plan will describe how input from third parties will be incorporated into the monitoring program, and will include a plan for communication with Reclamation as well as ~~and~~ other decision makers and third parties.

Evaluation and Reporting

The ~~proposed~~ monitoring program will describe the method of reporting monitoring data. At a minimum, sellers will provide data summary tables to Reclamation, both during and after transfer-related groundwater pumping. Post-program reporting will continue through March of the year following the transfer. ~~Water transfer proponents~~Sellers will provide a final summary report to Reclamation evaluating the effects of the water transfer. The final report will identify transfer-related ~~impacts~~ effects on groundwater and surface water (both during and after pumping), and the extent and significance, if any, of ~~impacts~~ effects on local groundwater users. It ~~should~~ shall include groundwater elevation contour maps for the area in which transfer operations are located, showing pre-transfer groundwater elevations, groundwater elevations at the end of the transfer, and recovered groundwater elevations in March of the year following the transfer. The summary report shall also identify the extent and significance, if any, of transfer-related effects to ecological resources such as fish, wildlife, and vegetation resources.

3.3.4.1.3 Mitigation Plan

Potential sellers ~~will also be required to~~must complete and implement a mitigation plan to avoid potentially significant groundwater impacts and ensure prompt corrective action in the event unanticipated effects occur. ~~If the seller's monitoring efforts indicate that the operation of wells for groundwater substitution pumping are causing substantial adverse impacts, the seller will be responsible for mitigating any significant environmental impacts that occur.~~ Mitigation actions ~~must be implemented to reduce impacts to a less than significant level and~~ could include:

- Curtailment of pumping until natural recharge corrects the issue.
- Lowering of pumping bowls in non-transferring wells affected by transfer pumping.
- Reimbursement for significant increases in pumping costs due to the additional groundwater pumping to support the transfer.
- Curtailment of pumping until water levels r~~a~~ise above historic lows if non-reversible subsidence is detected (based on local data to identify elastic versus inelastic subsidence).
- Reimbursement for modifications to infrastructure that may be affected by non-reversible subsidence.
- Other appropriate actions based on local conditions, as ~~appropriate~~determined by Reclamation.

As summarized above, the purpose of Mitigation Measure GW-1 is to monitor groundwater levels during transfers to avoid potentially significant adverse effects. The mitigation plan will describe how to avoid significant effects and address any significant effects that occur despite the monitoring efforts. The objectives of this process are to: (1) minimize potential effects to other legal users of water; (2) provide a process for review and response to reported effects; and (3) assure that a local mitigation strategy is in place prior to the groundwater transfer. Accordingly, t~~T~~o ensure that mitigation plans will be feasible, effective, and tailored to local conditions, the plan must include the following elements:

- A procedure for the seller to receive reports of purported environmental effects or effects to non-transferring parties;
- A procedure for investigating any reported effect;
- Development of mitigation options, in cooperation with the affected parties, for legitimate significant effects; and

- Assurances that adequate financial resources are available to cover reasonably anticipated mitigation needs.

~~The purpose of Mitigation Measure GW-1 is to monitor groundwater levels during transfers to avoid potential effects. If any effects occur despite the monitoring efforts, the mitigation plan will describe how to address those effects. The objectives of this process are to: (1) mitigate adverse environmental effects that occur; (2) minimize potential effects to other legal users of water; (3) provide a process for review and response to reported effects; and (4) assure that a local mitigation strategy is in place prior to the groundwater transfer.~~

~~Each potential seller will be required to confirm that the proposed groundwater pumping will be compatible with state and local regulations and GMPs. Reclamation's transfer approval process and groundwater mitigation measures set forth a framework that is designed to avoid and minimize adverse groundwater effects. Reclamation will verify that sellers adopt and implement these measures to minimize the potential for adverse effects related to groundwater extraction.~~

Mitigation to avoid potentially significant subsidence impacts and ensure prompt corrective action in the event that unanticipated effects occur is described by the following stages.

Stage 1: Groundwater Levels
Irreversible subsidence would not occur if groundwater levels stay above historic low levels for the entire transfer season. As groundwater is pumped from an aquifer, the pore water pressure in the aquifer is reduced. This reduction in pore water pressure increases the effective stress on the structure of the aquifer itself. This increase in effective stress can cause the aquifer structure to deform, or compress, resulting in the subsidence of the ground surface elevation. Subsidence can be irreversible if the reduced effective stress is lower than the historically low effective stress. Typically this would be the result of groundwater levels reaching levels lower than the historical low level.

Before a transfer, each seller will examine local groundwater conditions and groundwater level changes based on past pumping events or groundwater substitution transfers. This existing information will be the basis to estimate if groundwater levels are likely to decline below historic low levels as a result of the proposed transfer. If the pre-transfer assessment indicates that groundwater levels will stay above historic low levels, and this finding is confirmed by monitoring during the transfer-related pumping period, then no additional actions for subsidence monitoring or mitigation are necessary. Sellers would need to proceed to stage 2 for land surface elevation monitoring if the pre-transfer estimates indicate that groundwater levels are anticipated to decline below historic low levels. If monitoring during the transfer-related pumping period (confirmed by two measurements within seven days) indicates that groundwater levels have fallen below historic low levels, sellers must immediately stop pumping from transfer wells in the area that is affected or proceed to stage 2.

Stage 2: Ground Surface Elevations
Stage 2 includes monthly ground surface monitoring during transfer-related pumping if pumping could cause groundwater levels to fall below historic low levels, as described above in the Monitoring Plan. If ground surface elevations decrease between 0.1 and 0.2 foot, the seller will evaluate the accuracy of the information based on the current limitations of technology, professional engineering/surveying judgment, and other local data. If the elevations decline more than 0.2 foot, this change could indicate inelastic subsidence, which would trigger a shift to Stage 3.

Stage 3: Local Investigation
If the threshold of 0.2 foot of ground surface elevation change is exceeded, the seller shall cease groundwater substitution pumping for the transfer until one of the following occurs: (1) groundwater levels recover above historic low groundwater levels; (2) seller completes a more detailed local investigation identifying hydrogeologic conditions that could potentially allow continued transfer-related pumping from a subset of wells (if the seller can provide evidence that this pumping is not expected to cause additional subsidence); or (3) seller completes an investigation of local infrastructure that could be affected by subsidence (such as water delivery infrastructure, water supply facilities, flood protection facilities, highways, etc.) indicating the local threshold of subsidence that could be experienced before these facilities would be adversely affected. Any option should also consider the effect of non-transfer pumping that may be causing subsidence.

Stage 4: Mitigation
If subsidence effects to local infrastructure occur despite monitoring efforts, then the sellers must work with the lead agencies to determine ~~if~~whether the measured subsidence may be caused by transfer-related pumping. Any significant adverse subsidence effects caused by transfer pumping activities must be addressed. A contingency plan must be developed in the event that a need for further corrective action is necessary. This contingency plan must be approved by Reclamation before transfer-related pumping could continue after Stage 3.

Stage 5: Continued Monitoring
The sellers will continue to monitor for subsidence while groundwater levels remain below historic low levels. If the seller has ceased transfer-related pumping but groundwater levels remain below historic lows, subsidence monitoring will need to continue until the spring following the transfer. The results of subsidence monitoring will be factored into monitoring and mitigation plans for future transfers.

3.3.5 Potentially Significant Unavoidable Impacts

None of the alternatives would result in potentially significant unavoidable impacts after mitigation.

3.3.6 Cumulative Effects

The timeframe for the groundwater resources cumulative effects analysis extends from 2015 through 2024, a ten year period. The cumulative effects area of analysis for groundwater resources is the same as shown in Figure 3.3-1 above.

The projects considered for the groundwater resources cumulative condition are the SWP water transfers, Northern Sacramento Valley Integrated Regional Water Management Plan (NSV IRWMP), Tuscan Aquifer Investigation, Glenn-Colusa ID's Supplemental Supply Program, Davis-Woodland Water Supply Project and CVP M&I Water Shortage Policy (WSP), described in more detail in Section 4.3 in Chapter 4. SWP transfers could involve groundwater substitution transfers in the Seller Service Area and, therefore, could affect groundwater resources. The NSV IRWMP may also involve groundwater substitution transfers in the Seller Service Area. The WSP could reduce agricultural water deliveries and increase land idling in the Buyer Service Area. Effects of the WSP in the Seller Service Area would be minor as agricultural water supplies would not substantially change relative to existing conditions.

The following sections describe potential groundwater resources cumulative effects for each of the proposed alternatives.

3.3.6.1 Alternative 2: Full Range of Transfers (Proposed Action)

3.3.6.1.1 Seller Service Area

Groundwater substitution pumping and cropland idling transfers in the Seller Service Area under the Proposed Action in combination with other cumulative projects would contribute to groundwater level declines in the region. SWP transfers would include groundwater substitution, but the quantities of groundwater substitution transfers are very small (approximately 6,800 AF) in relation to overall transfers from the Seller Service Area. Some SWP groundwater substitution transfers could occur in Sutter County, which is included in the area of analysis for the Proposed Action. It is possible that the SWP transfers would compound the declines in groundwater levels in Sutter County.

The NSV IRWMP is a project that aims to provide a regional perspective to planning for water use in the northern Sacramento Valley, including Butte, Colusa, Glenn, Shasta, Sutter, and Tehama Counties. The plan is still under development; however, it is expected that the plan will help to provide management objectives that would be protective of the groundwater resources in the northern Sacramento Valley.

The Tuscan Aquifer Investigation project, conducted by the Butte County Department of Water and Resource Conservation, included numerous field data collection activities to allow for a more complete understanding of the Tuscan Aquifer. This project included the drilling of groundwater monitoring wells and the gaging of several streams in the Sierra Nevada foothills. Aquifer performance testing (i.e., pumping tests) was also performed at three existing production wells. The pumping associated with this project has been completed and would not contribute to cumulative effects. Information collection was primarily within Butte County, but the information about the Tuscan Aquifer could provide useful information about aquifer properties that would be useful in the other counties that are over the same aquifer (Glenn, Colusa, and Tehama Counties).

Glenn-Colusa ID’s Supplemental Supply program proposes to operate ten groundwater wells (five existing wells and five proposed wells) to augment surface water diversions for use within Glenn-Colusa ID. These wells will be operated on an as needed basis during dry and critically dry water years and with an annual pumping volume not exceeding 28,500 AF. Glenn-Colusa ID’s supplemental supply program and Glenn-Colusa ID’s groundwater substitution pumping transfers are not expected to occur simultaneously (Thad Bettner, Personal Correspondence January 2014).

The Davis-Woodland Water Supply Project would reduce the City of Davis, City of Woodland and University of California Davis’s reliance on regional groundwater supplies as a municipal water supply source. Dewatering operations may occur during the construction phase of this project that would result in localized and temporary declines of groundwater resources. This project will provide 12 million gallons per day (MGD) of surface water from the Sacramento River to Davis water customers and 18 MGD to Woodland customers. The project will divert up to 45,000 AF of water per year from the Sacramento River per water rights were granted in March 2011, and will be subject to conditions imposed by the state, including being limited during summer and other dry periods. The project also purchased a more senior water right for 10,000 AF from the Conaway Preservation Group to provide summer water supply.

The Proposed Action and these other projects in the basin could have significant cumulative effects on groundwater resources. The groundwater substitution pumping in the Proposed Action could result in significant effects to groundwater resources; however, implementation of Mitigation Measure GW-1 will reduce impacts from long-term transfers to less than significant. Therefore, with implementation of Mitigation Measure GW-1, the Proposed Action’s incremental contribution to groundwater resources impacts would not be cumulatively considerable.

The increased pumping under the Proposed Action in combination with other cumulative projects could cause land subsidence. The groundwater substitution pumping associated with the SWP transfers would occur in an area that is historically not subject to significant land subsidence. In the overall area of analysis, land subsidence is occurring in several areas, as described in Section 3.3.1.3.2. This subsidence may be part of normal cropping cycles, when the soils below agricultural lands undergo shrinking and swelling. This subsidence would not likely result in substantial risk to life or property; however, the existing subsidence along with future increases in groundwater pumping in the cumulative condition could cause potentially significant cumulative effects. The impacts of the Proposed Action would be reduced through Mitigation Measure GW-1 (Section 3.3.4.1) to less than significant. Therefore, with implementation of Mitigation Measure GW-1, the Proposed Action's incremental contribution to subsidence impacts would not be cumulatively considerable.

Groundwater levels in the Seller Service Area may change under the Proposed Action in combination with other cumulative projects and cause the movement or mobilization of poorer quality groundwater into existing wells. SWP transfers and the Tuscan Aquifer Investigation Project would increase pumping within (or near) the Seller Service Area. However, as discussed in the Proposed Action, most of the Seller Service Area has high quality groundwater and changes in groundwater flow patterns should not cause migration of poor quality groundwater. Therefore, the Proposed Action in combination with other cumulative actions would not result in a cumulative significant impact related to groundwater quality.

3.3.6.1.2 Buyer Service Area

The Proposed Action in combination with other cumulative past, present, and future projects could affect groundwater levels, land subsidence, and groundwater quality in the Buyer Service Area. As described in Section 3.3.1.3.2, groundwater pumping in the San Joaquin Valley has created some groundwater depressions over time. Additionally, some areas of the region have poor quality groundwater and have experienced land subsidence. The long-term historic pumping in the basin has contributed to locally significant cumulative impacts. The Proposed Action, however, would partially offset this cumulative impact by offsetting groundwater pumping during shortages. Therefore, the Proposed Action's incremental contribution to potentially significant cumulative groundwater impacts would not be cumulatively considerable.

3.3.6.2 Alternative 3: No Cropland Modification

The cumulative impacts of Alternative 3 would be the same as described for groundwater substitution in the Proposed Action in the Seller Service Area. Additionally, the cumulative effects of Alternative 3 in the Buyer Service Area would be the same as the Proposed Action.

3.3.6.3 Alternative 4: No Groundwater Substitution

Alternative 4 would not include groundwater substitution transfers; therefore, the contribution of this alternative to the groundwater cumulative condition would not be cumulatively considerable. The cumulative effects of Alternative 4 in the Buyer Service Area would be the same as the Proposed Action.

3.3.7 References

Anderson-Cottonwood Irrigation District. 2013. Initial Study and Proposed Negative Declaration for Anderson-Cottonwood Irrigation District's 2013 Water Transfer Program. Available at: http://www.andersoncottonwoodirrigationdistrict.org/library.html or at: http://www.usbr.gov/mp/nepa/nepa_projdetails.cfm?Project_ID=13310

Belitz, K., and Landon, M.K. 2010. Groundwater Quality in the Central Eastside San Joaquin Valley, California: U.S. Geological Survey Fact Sheet 2010-3001, 4 p. Available at: http://pubs.usgs.gov/fs/2010/3001/

Bennett, G.L., V, Fram, M.S., and Belitz, Kenneth. 2011a. Groundwater quality in the Middle Sacramento Valley, California: U.S. Geological Survey Fact Sheet 2011-3005, 4 p. Available at: http://pubs.usgs.gov/fs/2011/3005/

______. 2011b. Groundwater quality in the Southern Sacramento Valley, California: U.S. Geological Survey Fact Sheet 2011-3006, 4 p. Available at: http://pubs.usgs.gov/fs/2011/3006/pdf/fs20113006.pdf

Bennett V, G.L., and Belitz, K. 2010. Groundwater quality in the Northern San Joaquin Valley, California: U.S. Geological Survey Fact Sheet 2010-3079, 4 p. Available at: http://pubs.usgs.gov/fs/2010/3079/

Bertoldi, G. L. 1991. Groundwater in the Central Valley, California – A Summary Report, Regional Aquifer-System Analysis-Central Valley, California: U.S. Geological Survey, Professional Paper 1401-A. Available at: http://pubs.usgs.gov/pp/1401a/report.pdf

Burton, C.A., and Belitz, Kenneth. 2012. Groundwater Quality in the Southeast San Joaquin Valley, California: U.S. Geological Survey Fact Sheet 2011-3151, 4 p. Available at: http://pubs.usgs.gov/fs/2011/3151/

Brush, C.F., Dogrul, E.C., and Kadir, N.T. 2013. Development and Calibration of the California Central Valley Groundwater-Surface Water Simulation Model (C2VSim), Version 3.02-CG. Available at: http://baydeltaoffice.water.ca.gov/modeling/hydrology/C2VSim/download/C2VSim_Model_Report_Final.pdf

CALFED. 2000. Final Programmatic Environmental Impact Statement/Environmental Impact Report. pp. 5.4-1 to 5.4-14. Available at: http://calwater.ca.gov/calfed/library/Archive_EIS.html

CH2M Hill. 1997. Final Report Shasta County Water Resources Management Plan Phase 1 Report Current and Future Water Needs. Prepared for Redding Area Water Council and Other Shasta County Water Users. October. ***as cited in*** CH2M Hill. 2003. Final Report Redding Basin Water Resources Management Plan Phase 2C Report. Prepared for Redding Area Water Council. August. Available at: http://www.co.shasta.ca.us/docs/Public_Works/docs/wag-Enc2.pdf?sfvrsn=0

______. 2003. Final Report Redding Basin Water Resources Management Plan Phase 2C Report. Prepared for Redding Area Water Council. August. Available at: http://www.co.shasta.ca.us/docs/Public_Works/docs/wag-Enc2.pdf?sfvrsn=0

City of Chico. 2006. City of Chico Municipal Service Review, August. Available at: http://www.chico.ca.us/document_library/departments/planning_department/Municipal_Service_Review_(Final)_October_2006/Sec_41_Water.pdf

Colusa County. 1999. Chapter 43 Groundwater Management . Colusa County. Sec 43-1 –43-17. Available at: http://www.codepublishing.com/ca/colusacounty/html/ColusaCounty43.html

Contra Costa WD. 2011. Urban Water Management Plan. June. Available at: http://www.water.ca.gov/urbanwatermanagement/2010uwmps/Contra%20Costa%20Water%20District/CCWD_FINAL%202010%20UWMP.pdf

Dickinson. 2014. *Assembly Bill No. 1739 Chapter 347, Legislative Counsel's Digest*. Available: http://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201320140AB1739.

DWR. 1967. Evaluation of groundwater Resources South Bay Appendix A: Geology Bulletin 118-1, August. Available at: http://www.water.ca.gov/publications/browse.cfm?display=topic&pub=120,125,226,9829

______. 1975. Evaluation of groundwater Resources South San Francisco Bay Volume III Northern Santa Clara County Area: Bulletin 118-1, December. Available at:

http://www.water.ca.gov/publications/browse.cfm?display=topic&pub=120,125,226,9829

______. 1978. Evaluation of groundwater Resources: Sacramento Valley: Bulletin 118-6, August. http://www.water.ca.gov/groundwater/bulletin118/series.cfm

______. 1981. Evaluation of groundwater Resources South San Francisco Bay Volume IV South Santa Clara County Area: Bulletin 118-1, May. Available at: http://www.water.ca.gov/publications/browse.cfm?display=topic&pub=120,125,226,9829

______. 2003. California's Groundwater: Bulletin 118, Update 2003. October. Available at: http://www.water.ca.gov/pubs/groundwater/bulletin_118/california's_groundwater__bulletin_118_-_update_2003_/bulletin118_entire.pdf

______. 2008. http://www.water.ca.gov/groundwater/docs/WhatIsLandSubsidence.pdf. Accessed July 7, 2014.

______. 2010a. Integrated Water Resources Information System (IWRIS). Available at: http://www.water.ca.gov/iwris/ Accessed July, 2014.

______. 2010b. Water Data Library. Available at: http://www.water.ca.gov/waterdatalibrary/index.cfm Accessed July, 2014.

______. 2011. http://www.water.ca.gov/groundwater/data_and_monitoring/south_central_region/images/groundwater/sjv2010spr_unc_elev.pdf

______. 2013. http://www.water.ca.gov/groundwater/data_and_monitoring/northern_region/GroundwaterLevel/SacValGWContours/100t400_Wells_Spring-2013.pdf

______. Water Data Library 2014, Available at:

http://www.water.ca.gov/waterdatalibrary/docs/Hydstra/index.cfm?site=22N02W15C002M. Accessed March, 2015.

______. 2014a. Public Update for Drought Response Groundwater Basins with Potential Water Shortages and Gaps in Groundwater Monitoring, April. Available at: http://www.water.ca.gov/waterconditions/docs/Drought_Response-Groundwater_Basins_April30_Final_BC.pdf

_______. 2014b. http://www.water.ca.gov/waterdatalibrary/docs/Hydstra/docs/09N03E08C004M/POR/GROUND_SURFACE_DISPLACEMENT_POINT_PLOT.PNG. Accessed on February 11, 2015.

_______. 2015. Groundwater Information Center. http://www.water.ca.gov/groundwater/maps_and_reports/northern_region/GroundwaterLevel/gw_level_monitoring.cfm Accessed January 9,2015.

_______. 2015b. Water Data Library. http://www.water.ca.gov/waterdatalibrary/groundwater/hydrographs/index_trs.cfm

DWR Northern District. 2002. Sacramento River Basinwide Water Management Plan. Available at: http://www.water.ca.gov/pubs/groundwater/sacramento_river_basinwide_water_management_plan/sacbasmgmtplan.pdf

DWR Northern District.2014. Geology of the Northern Sacramento Valley, California. Available at: http://www.water.ca.gov/pubs/geology/geology_of_the_northern_sacramento_valley__california__june_2014-web/geology_of_the_northern_sacramento_valley__california__june_2014__updated_09_22_2014__website_copy_.pdf

EBMUD. 2012. Water Supply Management Program 2040 Plan. April. Available at: https://ebmud.com/sites/default/files/pdfs/wsmp-2040-revised-final-plan.pdf

Faunt, C.C., ed. 2009. Groundwater Availability of the Central Valley Aquifer, California: U.S. Geological Survey Professional Paper 1766, 225 p. Available at: http://pubs.usgs.gov/pp/1766/PP_1766.pdf

Famiglietti J.S., et al. 2011. Satellites measure recent rates of groundwater depletion in California's Central Valley. Available at: http://onlinelibrary.wiley.com/doi/10.1029/2010GL046442/abstract

Page, R. W (U.S. Geological Survey). 1986. Geology of the Fresh Ground-Water Basin of the Central Valley, California, with Texture Maps and Sections. Regional Aquifer-System Analysis. U.S. Geological Survey, Professional Paper 1401-C. Available at: http://pubs.er.usgs.gov/publication/pp1401C

Pavley. 2014a. *SB 1168 Chapter 346, Legislative Counsel's Digest*. Available: http://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201320140SB1168.

_______. 2014b. *SB 1319 Chapter 348, Legislative Counsel's Digest*. Available: http://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201320140SB1319.

Planert, Michael, and Williams, J.S. 1995. Ground water atlas of the United States: Segment 1, California, Nevada: U.S. Geological Survey Hydrologic Atlas. Available at: http://pubs.er.usgs.gov/publication/ha730B

RWA. 2012. http://www.rwah2o.org/rwa/programs/arbcup/. Accessed June 29.

Reclamation. 1990. A Management Plan for Agricultural Subsurface Drainage and Related Problems on the Westside San Joaquin Valley. Available at: http://esrp.csustan.edu/projects/lrdp/documents/rainbowreport.pdf

_______. 1997. Central Valley Project Improvement Act Draft Programmatic Environmental Impact Statement.

Reclamation and DWR. 2014~~3~~. DRAFT Technical Information for Preparing Water Transfer Proposals~~-~~. ~~October~~November. Accessed on March 2, 2015. Available at: http://www.water.ca.gov/watertransfers/docs/2015_Water_Transfer_White_Paper.pdf ~~http://water.ca.gov/watertransfers/docs/DTIWT_2014_Final_Draft.pdf~~

~~_______. 2014. Addendum to DRAFT Technical Information for Preparing Water Transfer Proposal, January. Available at: http://water.ca.gov/watertransfers/docs/2014/2014_Water_Transfer_Guidlines_Addendum.pdf~~

Santa Clara Valley WD. 2000. Relationship between groundwater elevations and land subsidence in Santa Clara County, May. Available at: http://www.valleywater.org/WorkArea/DownloadAsset.aspx?id=430

_______. 2001. Santa Clara Valley Water District Groundwater Management Plan, July. Available at: http://www.water.ca.gov/urbanwatermanagement/2010uwmps/Morgan%20Hill,%20City%20of/ELECTRONIC.Groundwater%20Management%20Plan.pdf

_______. 2010. Santa Clara Valley Water District Urban Water Management Plan . Available at: http://www.valleywater.org/services/uwmp2010.aspx

_______. 2012. Santa Clara Valley Water District Groundwater Management Plan. Available at: http://www.valleywater.org/Services/Groundwater.aspx

Shasta County Water Agency. 2007. Coordinated AB 3030 GMP for the Redding Groundwater Basin (Prepared November 1998), Updated May 2007.

Sneed, Michelle, Brandt, Justin, and Solt, Mike. 2013. Land subsidence along the Delta-Mendota Canal in the northern part of the San Joaquin Valley, California, 2003–10: U.S. Geological Survey Scientific Investigations Report 2013–5142, 87 p . Available at: http://pubs.usgs.gov/sir/2013/5142/ Accessed February 3, 2014.

State Water Resources Control Board, Division of Water Rights, California Environmental Protection Agency. 1999. A Guide to Water Transfers. Available at: http://www.waterrights.ca.gov/watertransferguide.pdf

_______.2014. State Water Resources Control Board GeoTracker database. Available at: http://geotracker.waterboards.ca.gov/

Water Forum. 1999. Water Forum Agreement. Available at: http://www.waterforum.org/agreement.cfm Accessed May 21, 2002.

West Yost Associates. 2012. Stony Creek Fan Final Investigative Report, December. Available at: http://www.gcid.net/StonyCreek.html

Westlands WD. 1996. Westlands Water District GMP. Available at: http://www.westlandswater.org/long/200207/gwmp2.pdf?title=Groundwater%20Management%20Plan%20(AB3030)&cwide=1440

_______.2000. Land Retirement Demonstration Project 1999 Annual Report. pp. 60-68. Available at: http://esrp.csustan.edu/publications/pdf/lrdp/1999ar/LRDPanrep1999.pdf

Williamson, A. K. 1989 Ground-Water Flow in the Central Valley, California, Regional Aquifer-System Analysis U.S. Geological Survey, Professional Paper 1401-D. Available at: http://pubs.usgs.gov/pp/1401d/report.pdf

Woodland Davis Clean Water Agency. Davis-Woodland Water Supply Project description. Available at http://www.wdcwa.com/the_project

WRIME. 2011. Peer review of Sacramento valley Finite Element Groundwater Model (SACFEM2013), October.

Yolo County. 1996. Yolo County Ordinance No. 1195, an Ordinance Adding Chapter 7 to Title 10 of the Yolo County Code Regarding the Extraction and Exportation of Groundwater from Yolo County. Available at: http://www.yolocounty.org/home/showdocument?id=1899

______. 2009: Yolo County, 2009. 2030 Countywide General Plan Yolo County. Available at: http://www.yolocounty.org/general-government/general-government-departments/county-administrator/general-plan-update/draft-2030-countywide-general-plan

Section 3.4 Geology and Soils

This section presents the existing conditions of geology and soils within the area of analysis and discusses potential effects on geology and soils from the proposed alternatives.

Because long-term water transfers would not involve the construction or modification of infrastructure that could be adversely affected by seismic events, seismicity is not discussed in this section. Further, the alternatives do not require construction activities; therefore, people and/or structures would not be exposed to geologic hazards such as ground failure or liquefaction. The focus of this section is on the chemical processes, properties, and potential erodibility of soils due to cropland idling transfers. This analysis considers how factors such as surface soil texture, wind velocity and duration, and shrink-swell potential may affect soils. Crop shifting, groundwater substitution, conservation, and stored reservoir release transfers are not expected to affect geology and soils, and thus are not further discussed in this section. Section 3.3, Groundwater Resources, evaluates groundwater substitution transfers in detail and discusses geomorphology and land subsidence. Section 3.2, Water Quality, discusses the potential for salts and other toxic substances to be transported by water or wind to adjacent fields.

3.4.1 Affected Environment/ Environmental Setting

3.4.1.1 Area of Analysis

Figure 3.4-1 shows the area of analysis for geology and soils. The area of analysis for geology and soils is composed of counties in the Seller Service Area in which cropland idling transfers could originate and counties in the Buyer Service Area where transferred water would be used for agricultural purposes. Counties in the Seller Service Area include Glenn, Colusa, Butte, Sutter, Yolo, and Solano counties and counties in the Buyer Service Area include San Joaquin, Stanislaus, Merced, San Benito, Fresno, and Kings counties.

Figure 3.4-1. Geology and Soils Area of Analysis

3.4.1.2 Existing Conditions

Potential geologic and soil effects associated with cropland idling water transfers are related to soil erosion and soil expansiveness.

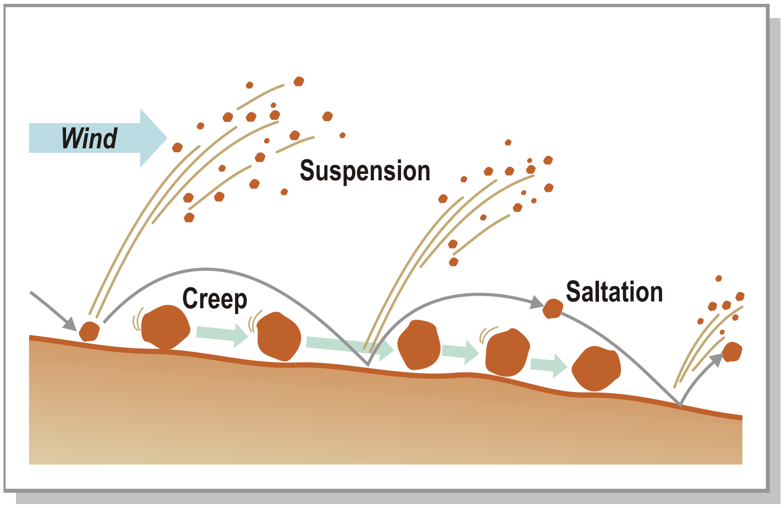
3.4.1.2.1 Soil Erosion by Wind

Soil erosion by wind is a complex process involving detachment, transport, sorting, abrasion, avalanching, and deposition of soil particles. Winds above a threshold velocity (13 miles per hour at one foot above ground) blowing over erodible soils can cause erosion in three ways (James et al. 2009, U.S. Department of Agriculture [USDA] Natural Resources Conservation Service [NRCS] 2009a):

- **Saltation:** Individual particles are lifted off the soil surface by wind; then they return and the impact dislodges other particles. Fifty to 80 percent of total transport is by saltation.

- **Suspension:** Dislodged particles, small enough to remain airborne for an extended period of time (less than 0.1 mm in diameter), are moved upward by diffusion. Suspension accounts for 20 to 60 percent of the total soil transport, depending on soil texture and wind velocity.

- **Surface creep**: Sand-sized particles are set in motion by the effect of saltating particles. During high winds, these sand sized particles creep slowly along the surface. Up to 25 percent of total transport may be from surface creep.



Source: James et al. 2009

Figure 3.4-2. Wind Erosion Processes

Figure 3.4-2 shows the wind erosion processes described above. Wind erosion and the release of windblown dust are influenced by soil erodibility, climatic factors, soil surface roughness, width of field, and the quantity of vegetative coverage. Soils most vulnerable to windblown erosion are coarser textured soils like sandy loams, loamy sands, and sands (USDA NRCS 2009a). Specifically, soils are vulnerable to wind erosion when (USDA NRCS 2009a):

- The soil is dry, loose, and finely granulated;
- The soil surface is smooth with little or no vegetation present;
- Fields are sufficiently large, and therefore, susceptible to erosion; and,
- There is sufficient wind velocity to move soil.

Wind erosion can also be a concern because it reduces soil depth and can remove organic matter and needed plant nutrients by dispersing the nutrients contained in the surface soils. Fields continually subjected to erosion can result in land that is incapable of returning to cropping (USDA NRCS 2009a). Increases in erosion from wind blowing across exposed nonpasture agricultural land results in particulate matter emissions. Section 3.5, Air Quality, discusses effects of fugitive dust emissions as a result of cropland idling.

3.4.1.2.2 Soil Erosion from Farming Practices

In addition to natural properties predisposing soils to erosion, land preparation activities, such as discing, and harvesting can cause soil particles to be broken down and can increase the potential for erosion. Much of the farm equipment used during the cropping season disturbs the soil and produces dust that contributes to soil loss. The following paragraphs describe common cropping practices for rice, processing tomatoes, field corn, and alfalfa, which are representative of crops that could be idled in water transfers.

Rice

During a typical calendar year of operation for rice production, farm equipment is required for preparing seedbeds, plowing and discing in March through May. Water seeding is the primary seeding method in California and most planting is done from April 20 to May 20, but can continue into June (University of California Cooperative Extension [UCCE] 2007).

Rice farmers apply herbicides and pesticides during May and June to control weeds and in May to control insects, algae, and shrimp. One pesticide application in the spring controls diseases from July through August that can attack the crop. The rice crop is harvested using a combine with a cutter-bar header (UCCE 2007).

Equipment used to grow rice includes tractors, bankout wagons, discs, mowers, pickup trucks, a triplane, and a V-ditcher (UCCE 2007).

Processing Tomatoes

Primary tillage of processing tomatoes, including laser leveling, discing, subsoiling, land planning, and listing beds is done from August through early November in the year preceding planting (UCCE 2008a).

Farmers spread planting over a three-month period from late March through early June. Beginning in January, weed spray is applied on the fallow beds to control emerged weeds. This process is repeated later to help control weeds. Before planting, the beds are cultivated twice to control weeds and to prepare the seedbed. A combination of hand weeding and mechanical cultivation is also used for weed control. During the cropping season, growers apply pesticides to combat various pests. Tomato harvest begins in early July and continues through mid-to-late October.

Equipment used to grow processing tomatoes includes tractors, crawlers, all-terrain vehicles (ATVs), bait applicators, bed shapers, cultivators, cultivators (sled), ditchers, incorporators, listers, mulchers, plows, rear blades, saddle tanks, spray booms, subsoilers, triplanes, vine diverters, and vine trainers.

Field Corn

Primary tillage for field corn includes laser leveling, discing, rolling, subsoiling, land leveling, and listing beds. Land preparation occurs in October of the year preceding planting. Farmers generally plant corn from late March through April (UCCE 2008b).

Fertilizers are applied throughout the growing season and irrigation is applied biweekly in April through July for a total of six post-plant irrigations. Herbicides are applied by airplane and tractor in February and May to control weeds. Insects are controlled by pesticide application using a tractor-mounted application in May. Mites, another common corn pest, can be a problem late in the season, and may be controlled by air application of pesticides in June.

The corn is harvested in August. Equipment used to grow field corn includes tractors, crawlers, ATVs, bait applicators, bankout wagons, combines with no header, corn headers, cultivators, ditchers, listers, planters, saddle tanks, scrapers, sprayer systems, subsoilers, and triplanes (UCCE 2008b).

Alfalfa

Stand establishment begins with laser leveling (when necessary) and then discing the fields to reduce the residue from the previous crop (UCCE 2008c). Alfalfa seed is planted in September and the stand life is four years. The field is harrowed and ring rolled after planting.

Fertilizer application occurs in September and can be sufficient for three years (UCCE 2008c). Water for seed germination is sprinkled immediately after planting and then again two weeks later. Herbicides are applied in December or January for weed control.

Alfalfa can be harvested seven times for hay: April, May, June, July (twice), August, and September. Equipment used to grow alfalfa includes ATVs, a tractor, a crawler, a seeder, a chisel, a cultipacker, discs, a pickup truck, and a triplane (UCCE 2008c).

3.4.1.2.3 Soil Erosion from Changes in River Flows

Increases in streamflow in the Seller Service Area could occur as a result of water transfers. The Sacramento and San Joaquin rivers and their tributaries, the Yuba, Feather, American, and Merced rivers, transport water as part of the Central Valley Project (CVP) and State Water Project (SWP). Each of these river channels has a maximum conveyance capacity as described in Section 3.17.1.3.1.

3.4.1.2.4 Expansive Soils

In addition to soil erosion, expansive properties, or linear extensibility, represent another soil attribute that could be affected by water transfers.

Expansive soils are soils with the potential to experience considerable changes in volume, either shrinking or swelling, with changes in moisture content.

Therefore, the expansive nature of soils is characterized by their shrink-swell capacity. Changes in soil volume are often expressed as a percent, and in soil surveys the percent represents the overall change for the whole soil.

Soils composed primarily of sand and gravel are not considered expansive (i.e., the soil volume does not change with a change in moisture content). Soils containing silts and clays may possess expansive characteristics. The magnitude of shrink-swell capacity in expansive soils is influenced by:

- Amount of expansive silt or clay in the soil;
- Thickness of the expansive soil zone;
- Thickness of the active zone (depth at which the soils are not affected by dry or wet conditions); and
- Climate (variations in soil moisture content as attributed to climatic or man-induced changes).

Soils are classified as having low, moderate, high, and very high potential for volume changes. The linear extensibility is expressed by percentages; the range of valid values is from 0 to 30 percent (USDA NRCS no date). Table 3.4-1 summarizes shrink-swell classes and the associated linear extensibility percentage. If the shrink-swell potential is rated moderate to very high, shrinking and swelling can cause damage to buildings, roads, and other structures (USDA NRCS no date).

Table 3.4-1. Shrink-Swell Class and Linear Extensibility

Shrink-Swell Class	Linear Extensibility (%)
Low	< 3
Moderate	3-6
High	6-9
Very High	≥ 9

Source: USDA NRCS no date.

3.4.1.2.54 Seller Service Area

This section describes the general soils, including soil erosion and shrink-swell properties, within the Seller Service Area that could be affected by cropland idling transfers. Data on expansive soils was obtained at the county level from the USDA NRCS's web soil survey soil reports.

Generalized soil textures for the counties in the Sellers Service Area are shown in Figure 3.4-3. Figure 3.4-4 shows the shrink-swell potentials of soils in these counties.

Glenn County

Soils in the western part of the Glenn County are largely gravelly loam, gravelly sandy clay loam, and gravelly sandy loam (USDA NRCS 2011a). These soil textures are also dominant in the northeastern part of the county. These soils generally have low erodibility and low shrink-swell potentials (USDA NRCS 2011b and 2011c).

The eastern part of the county is mainly composed of unweathered bedrock, clays, and silty clay loam (USDA NRCS 2011a). These soils have mid-range erodibility and low to high shrink-swell potentials (USDA NRCS 2011b and 2011c). Smaller portions of very gravelly sandy loam and loam border these dominant eastern soils. These soils have mid-range erodibility and low shrink-swell potential. The center of the county is defined by areas of loam, gravelly clay, gravelly clay loam, clay loam, and unweathered bedrock. These soils have mid-range erodibility and high shrink-swell potentials.

Colusa County

The western part of Colusa County is a mixture of areas of moderately decomposed plant material, silt loam, gravelly sandy loam, very gravelly loam, sandy loam, and gravelly loam (USDA NRCS 2009b). These soils have low to mid-range erodibility and low to moderate shrink-swell potentials (USDA NRCS 2009c and 2009d). The central part of the county is composed of clay loam and loam with some areas in the south central part of the county which are sandy clay loam. These soils have low erodibility and low shrink-swell potentials. In the eastern part of the county, there are two areas of land that have a combination of clay loam and sandy loam, one in the south of the county and one in the north. These soils have low to mid-range erodibility and low to moderate shrink-swell potentials. The remainder of the eastern part of the county is silty clay, silt loam, clay, and clay loam (USDA NRCS 2009b). The silty clay and clay soils have mid-range erodibility and high shrink-swell potentials. The clay loam soils have low erodibility and low shrink-swell potentials.

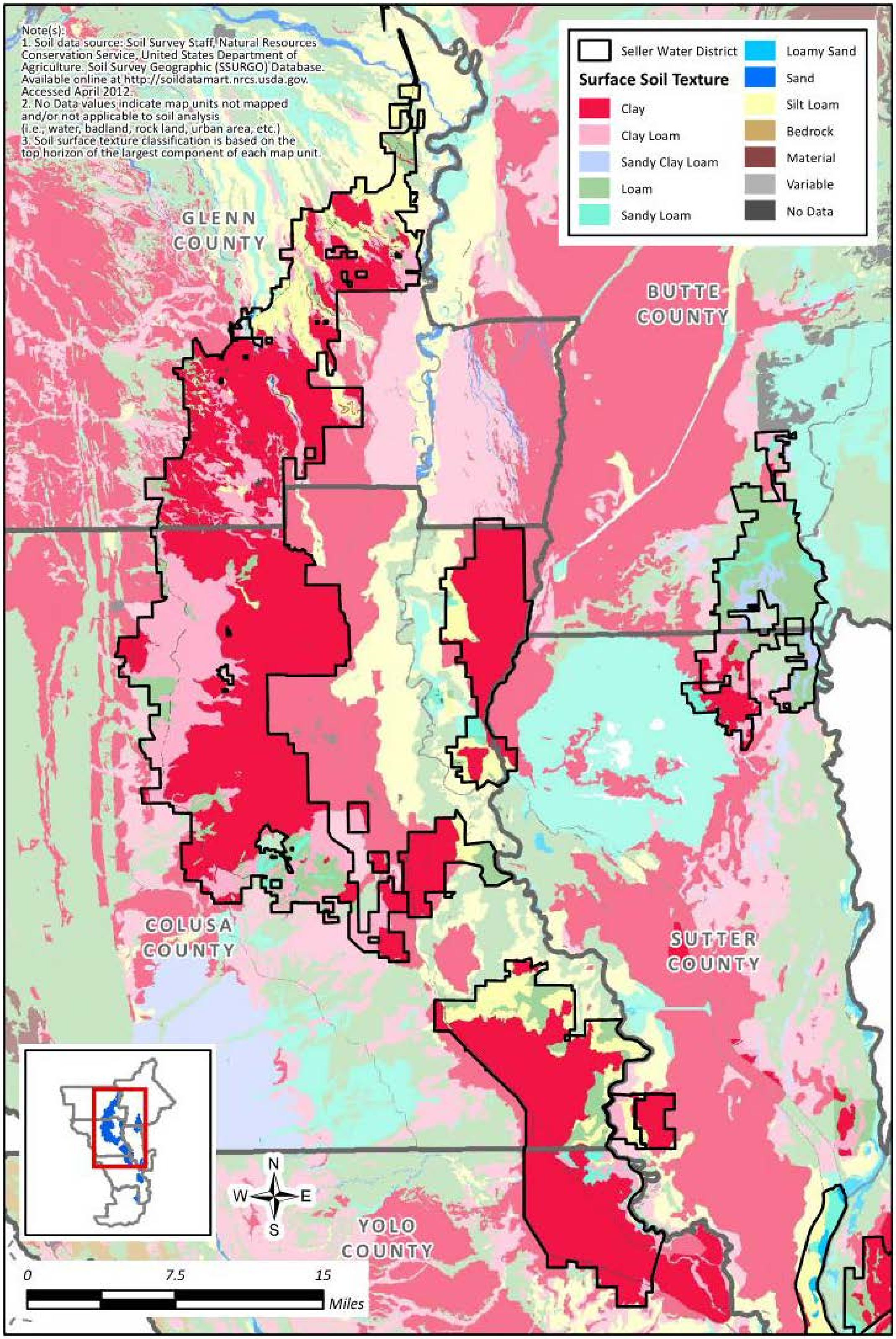


Figure 3.4-3a. Surface Soil Texture – Seller Service Area

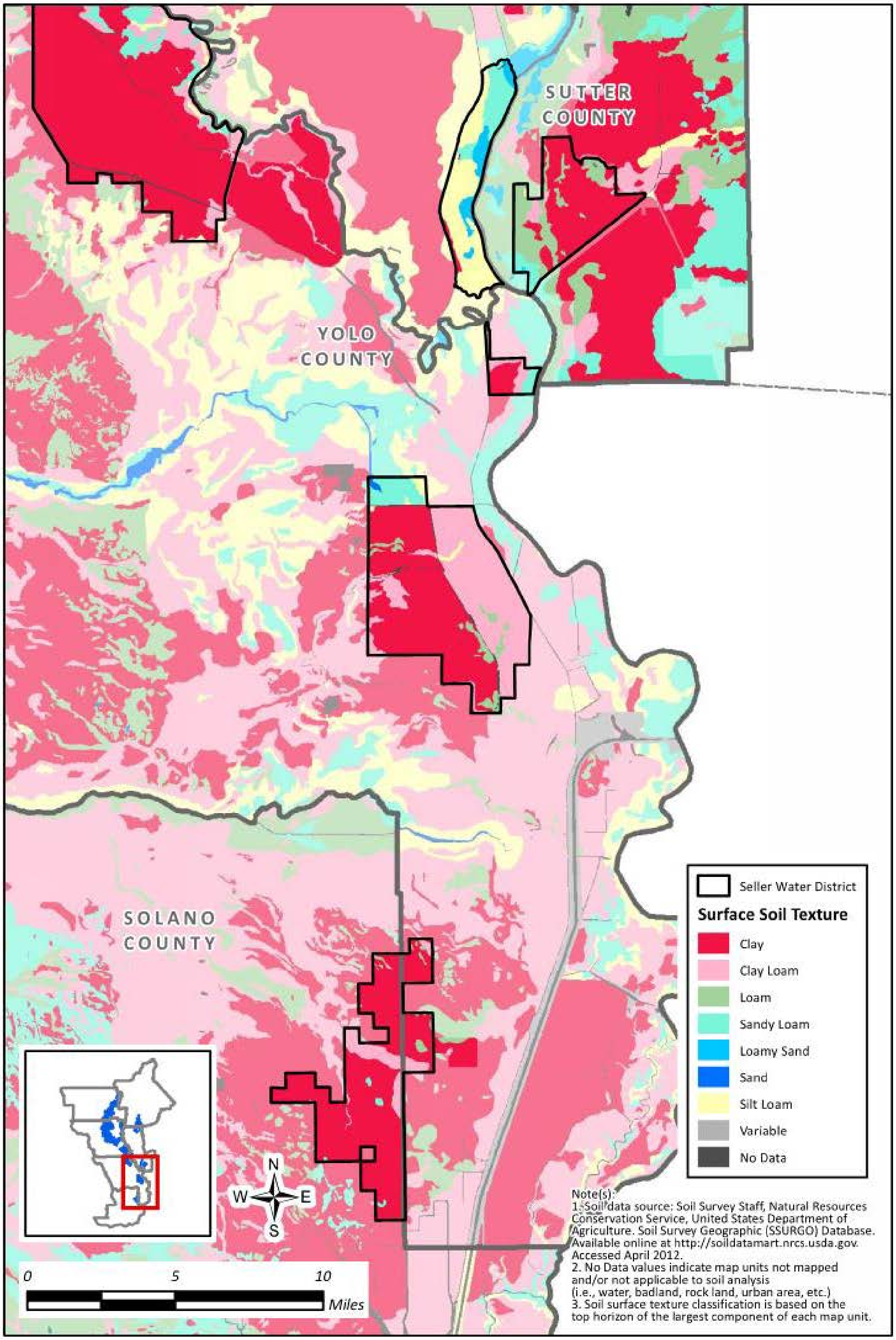


Figure 3.4-3b. Surface Soil Texture – Seller Service Area

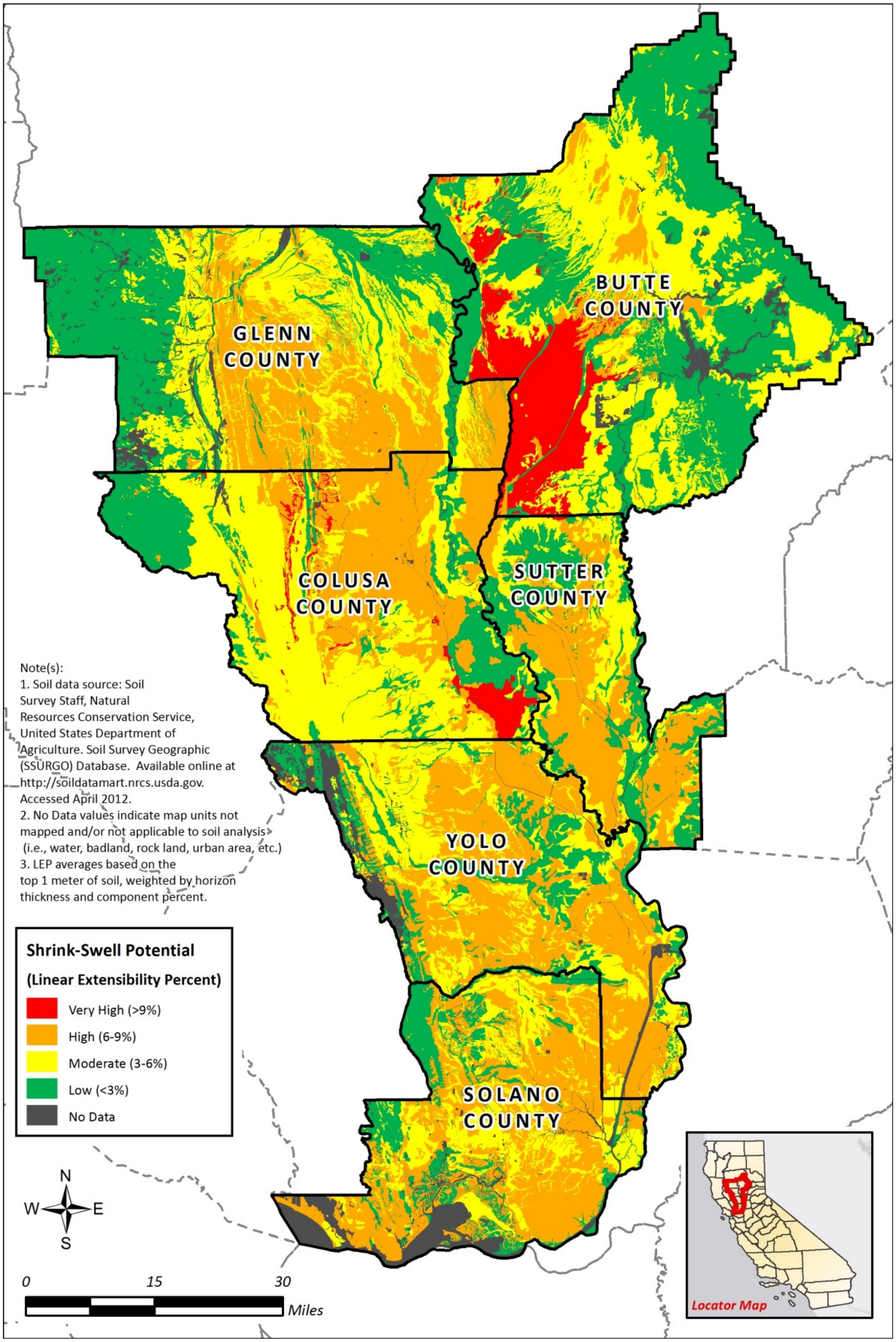


Figure 3.4-4. Shrink-Swell Potential – Seller Service Area

Butte County

The southwestern part of the county (where transfers could occur) is a mixture of loams, clay loam, sandy loam, and clay. These soils have low to mid-range erodibility and low to high shrink-swell potentials (USDA NRCS 2013a, 2013b, 2013c).

Sutter County

The eastern part of the county is a mixture of loams, clay loam, sandy loam, and an area of silty clay in the southeastern corner of the county. These soils have low to mid-range erodibility and low to high shrink-swell potentials. The western part of the county is largely comprised of clay, with a band of clay soils running down the mid-western area of the county. The western boundary of the county is defined by loam, silty clay, and silty clay loam. Clays in this area have mid-range erodibility and high shrink-swell potentials. Soils along the western boundary of the county have high to low erodibility and low shrink-swell potentials, with one area of high shrink-swell potential in the northwestern corner of the county (USDA NRCS 2009e, 2009f, 2009g).

Yolo County

The soils along the western boundary of Yolo County are a mixture of cobbly clay, clay, and silt loam (USDA NRCS 2012a). These soils have low erodibility and low shrink-swell potentials. The central part of the county is a diverse mixture of sandy loams, gravelly loams, gravelly sandy loam, silt loam, silty clay loam, and silty clay. Soils throughout the western part of the county have low erodibility and low to high shrink-swell potentials (USDA NRCS 2012b and 2012c). The eastern part of the county is mainly composed of silt loam, loam, and silty clay loam. These soils are also defined by low erodibility and low to high shrink-swell potentials. There are two areas of very fine sandy loam in the northeast and southeast parts of the county (USDA NRCS 2012a). These soil types have mid-range erodibility and high erosion potentials.

Solano County

Soils throughout the county are mainly clays and clay loams with some areas of sandy loam in the middle of the county. Clays have low erodibility and high shrink-swell potentials. Clay loams also have low erodibility, but have moderate shrink-swell potentials. Sandy loams in the central-north part of the county have high erodibility and low shrink-swell potentials (USDA NRCS 2007a, 2007b, 2007c). The eastern part of the county is largely made up of clays, clay loam, and silty clay loam (USDA NRCS 2007a). In addition to sandy loam, the middle portion of the county also contains gravelly loam and loam soils (USDA NRCS 2007a). These soils have low erodibility and low shrink-swell potentials. The western part of the county is a mixture of silty clay loam, clay loam, loam, and clay.

3.4.1.2.65 Buyer Service Area

This section describes the general topography, geology, and soils in the counties within the Buyer Service Area. Generalized soil textures for counties in the Buyer Service Area are shown in Figure 3.4-5. Figure 3.4-6 illustrates the shrink-swell potentials of soils in these counties.

San Joaquin County

Soil textures in the southwestern corner of the county consist mainly of loam and sandy loam (USDA NRCS 2013d). These soils have low to mid-range erodibilities and low shrink-swell potentials (USDA NRCS 2013e). To the east of this area, the soil texture transitions to clay and clay loam. These soils have low erodibility and moderate-to-high shrink-swell potentials (USDA NRCS 2013e). Soil textures in the other portions of the county also include bedrock, sandy clay loam, and loamy sand, but these areas do not include transfer buyers and do not have the potential to be affected.

Stanislaus County

Soil textures on the western side of the county consist mainly of loam, sandy loam, and sandy clay loam (USDA NRCS 2013f). These soils have low to mid-range erodibilities and low shrink-swell potentials (USDA NRCS 2013g). These soils transition to clay and clay loam to the east of this area, but transfer buyers are only on the west side of the San Joaquin River and would not affect these soil types.

Merced County

Soil textures in the western portion of the county consist mainly of fine sandy loam, fine sand, and loamy sand (USDA NRCS 2008a). These soils have high erosion potentials and low shrink-swell potentials (USDA NRCS 2008b and 2008c). Soils in the south of the county are dominated by loam, silt loam, and silt clay loam. These soils have low to mid-range erodibility and low shrink-swell potentials. The north-central area of the county is mainly fine sand and the south-central portion of the county contains clay loam. These soils generally have low erodibility and low to high shrink-swell potentials (USDA NRCS 2008a; 2008b; 2008c). Soils in the eastern part of the county are generally comprised of silt loam and gravelly loam. These soils have low erosion potentials and low shrink-swell ratings.

Fresno County

Soil textures in the eastern part of the county are dominated by gravelly loam, gravelly sandy loam, and sandy loam (USDA NRCS 2008d). These soils have low to mid-range erodibilities and low shrink-swell potentials (USDA NRCS 2008e and 2008f). In areas along the San Joaquin River and the Fresno Slough, the soil texture is sandy loam (USDA NRCS 2008a). Sandy loam has mid-range erodibility and high to very high shrink-swell potential. The western edge