APPENDIX D

City of Fresno Metro Plan Update Phase 2 Modeling

CITY OF FRESNO METRO PLAN UPDATE
PHASE 2 MODELING

Prepared for the City of Fresno

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CITY OF FRESNO METRO PLAN UPDATE PHASE 2 MODELING

INTRODUCTION

This memorandum discusses the approach and assumptions used in the technical analysis to evaluate the impacts and benefits to the groundwater for the City of Fresno (City) Metropolitan Water Resources Management Plan update (Metro Plan) under "Baseline" and the "With Project" scenarios.

The Kings Basin Integrated Groundwater Surface Water Model (Kings IGSM) was used to evaluate the groundwater impacts of the land use changes that would occur under projected urban growth from 2005 to 2060. The Kings IGSM model analysis will help the City to:

1. Determine the effects of future growth;
2. Determine the effects of new water supply facilities; and
3. Provide a basis for comparing the impacts and benefits of the "With Project" alternative.

In this memorandum, information on the Kings IGSM model is provided, the assumptions for areas outside the City are documented, and the results of the modeling are described.

APPROACH AND METHOD OF ANALYSIS- KINGS IGSM

The City overlies only a portion of the Kings Groundwater Basin (Kings Basin). The geographic extent of the Kings IGSM is the entire Kings Basin. The groundwater basin is interconnected and activities within the Kings Basin can affect the City. The land use and growth within the City may also affect the surrounding area. It is thus important to define the assumptions for land use, water demand and water supplies for both the City and the areas surrounding the City.

The Kings IGSM model was developed to support both the City and the Upper Kings Basin Water Forum (Water Forum) with an integrated analytical tool to evaluate the hydrologic and hydrogeologic conditions within the Kings Groundwater Basin (Kings Basin). The Water Forum includes representatives from the overlying water districts, counties, incorporated cities, and environmental and other community interest groups. The Water Forum's Technical Analysis and Data Work Group provided oversight and direction during the development and calibration of the Kings IGSM. The Kings IGSM Model Development and Calibration report (WRIME, 2007) is available online at http://project.wrime.com/krcd/krcd_igsm.htm.

The model was used to evaluate the effects on groundwater of future land uses for the City and surrounding area. This is important because under current water supply conditions in the City, when land is converted from agricultural uses to urban uses, the water supply generally shifts from agricultural irrigation with Kings River or Central Valley Project surface water, to groundwater. This shift to exclusive use of groundwater occurs in all areas except developing urban areas that are to be provided treated surface water from the existing drinking water treatment plants located in the City and Clovis.

The Kings IGSM model represents the existing land use and water supply, the existing surface water treatment plants, the existing or approved groundwater recharge facilities (Leaky Acres, Waldron Pond, Fresno/Fresno Metropolitan Flood Control District ponds); and the increased volumes of wastewater that are treated and percolated at the City's Regional Wastewater Reclamation Facility (RWRF).

MODELING ASSUMPTIONS AND INPUT SUMMARY

The Kings IGSM model was used to evaluate two conditions based on future growth without project condition (Baseline) and a projected growth with new water supply projects and water conservation efforts (With Project). The model input files for the two conditions were developed using projected data from the cities or water purveyors, and based on assumptions listed in Table 1. The model assumptions cover the City, the districts within City's Sphere of Influence (SOI), the immediate area outside the City which includes the 2060 Growth Fringe, and the City of Clovis. Figure 1 shows the City's sphere-of-influence, the Southeast Growth Area, and the 2060-Growth Fringe areas. Some of the pertinent data inputs to the model that may have an influence on the groundwater budget are: hydrology, surface water deliveries, land use, water use, groundwater pumping, and groundwater recharge.

In addition, assumptions on the initial conditions include values for groundwater levels, soil moisture, unsaturated soil moisture and small watershed soil moisture conditions and are set at the average groundwater levels in 2005 (Figure 2).

LAND USE

Growth in the City results in land use conversion from open space or agriculture to urban. The City land use information within the SOI and 2060 Growth Fringe was provided by West Yost Associates (West Yost) for the years 2005, 2010, 2025, and 2060 are shown in Figures 3a, 3b, 3c, and 3d, respectively. The land use conditions were interpolated linearly for the other years to develop the model input files. For the Baseline conditions, it was assumed that there are no new water resources projects or supplies.

Three other water producing agencies exist within the SOI: Pinedale Water District (Pinedale), Bakman Water Company (Bakman) and California State University Fresno (CSUF). Little or no growth is expected within these areas. The City is assumed to develop outside of its current SOI into the Southeast Growth Area and the 2060 Growth Fringe. The 2060 Growth Fringe overlies portions of other subregions in the Kings IGSM model within the Fresno Irrigation District and Consolidated Irrigation District. Urban development is not solely due to

Table 1. Kings IGSM Dynamic Model Assumptions

	City of Fresno		City of Clovis / Non Fresno
	Baseline	With Project	
Land Use	Land use for 2005, 2010, 2025...2060 provided by West Yost;	Same	Land use linearly interpolated from 2005 to 2030 then held constant at 2030 conditions.
Agricultural Water Demand	Based on: - 2005-2060 Land Use and Crop Acreage - 1964-2004 Repeated Hydrology	Same	Based on: - 2005 & 2030 Land Use and Crop Acreage - 1964-2004 Hydrology
Crop Acreage	2005, 2010, ...2060 Crop Acreage; Inbetween years linearly interpolated	Same	2030 Crop Acreage (2004 crop acreage minus agricultural areas converted to urban)
Urban Water Demand	2005, 2010, …,2060 Urban Demand Estimate by West Yost	2005, 2010, …,2060 Urban Demand with conservation efforts provided by West Yost	2005 to 2030 Urban Demand based on UWMP or other public documents
Recharge @ Leaky Acres	- For 1973-2004 use historical recharge rates - For 1964-2004 use 1973-2004 recharge rates based on San Joaquin Hydrology Index	Same	N/A
Recharge @ Existing FMFCD Ponds	- For 1994-2004 use historical recharge rates - For 1964-1993 use 1994-2004 recharge rates based on San Joaquin Hydrology Index - Use ponds that are active in 2004 - Use 2000-2004 average recharge ratios for distribution of total recharge to individual ponds	Same	Same as Fresno (N/A for Non Fresno)
Recharge @ Future FMFCD Ponds	For 2025 to 2060 recharge estimates based on land use/area within 11 Divisions in the Growth Fringe	Same	N/A
Recharge @ other ponds	Use 2004 conditions	Same	Use Clovis Estimates (Non Fresno) 2004 Conditions plus Waldron Ponds (FID)& Harter Ponds (CID)
Recharge @ creeks and streams	Use 2004 conditions		
Surface Water Treatment Plant	Use Full Capacity Rates by 2010 (30 TAF)	Increase capacity for existing SWTP to (60 TAF) New SE SWTP (60 TAF)	Use 2005 Monthly Flow Ratios up to Use 2030 Rates (30 MGD) (N/A for Non Fresno)
Wastewater Treatment Plant Total Flows	RWRF effluent flows to: Percolation Ponds; FID Canals; On-site irrigation (See Table 3-13 of Metro Plan Update Phase 1) Linear Interpolation for values in between Use 2004 conditions x (95,400)/(78,400) for 2010 Use 2004 conditions x (127,700)/(78,400) for 2025	Decrease inflow and percolation due to water conservation	(Clovis Satelite Treatment Plant (tertiary treatment) - 2,900 AF/yr increased to '- 7,600 AF/yr for 2010 and 2030, respectively - Plant outflow to be used for landscape irrigation in Clovis and CSUF (Non Fresno) Use 2004 conditions for: Selma-Kingsburg-Fowler (SKF) WWTP & Other non-Fresno WWTP
Municipal Wells Pumping	Well location and schedule provided by West Yost for Fresno SOI, SEGA and Growth Fringe	New Well location and schedule based on water conservation and decreased water pumping; provided by West Yost for Fresno SOI, SEGA and Growth Fringe	Use 2004 Pumping Rates minus Surface Water Plant's 2030 Flows - Proportionally reduce pumping rate of each well Flows remain constant from 2030 to 2060 (Non Fresno) Municipal pumping by element
Hydrology	Repeated 41-year hydrologic cycle\		
San Joaquin River Boundary Conditions	Seepage from the river: 50% into the basin Subsurface boundary flow along the SJ river: -No flow condition east of highway 99 -General head boundary conditions west of highway 99		
Surface Water Deliveries - Kings River	Historical deliveries and diversions revised for capture of flood flows at Waldron/Harter ponds - Adjust for SWTP flows	Historical deliveries and diversions revised for capture of flood flows at Waldron/Harter ponds - Adjust for increase capacity SWTP flows	(Non Fresno) Historical deliveries and diversions revised for capture of flood flows at Waldron/Harter ponds
Surface Water Deliveries - Friant-Kern & CVP to Non-Fresno/Clovis Areas	West Yost estimates of deliveries to FID & Fresno (60 TAF/yr, 17.9 TAF/yr for critically dry years) - Adjust for SWTP flows	West Yost estimates of deliveries to FID & Fresno (60 TAF/yr, 17.9 TAF/yr for critically dry years) - Adjust for SWTP flows	(Non Fresno) Historical deliveries and diversions
Land Use, Demand, Supply for Backman, Pinedale, and CSUF	2004 conditions	2004 conditions	N/A
Pine Flat Reservoir Operations	Historical releases and flows		
Initial Conditions	- Use End of Sep 2004 values for GW levels, soil moisture, unsaturated soil moisture, and small watershed soil moisture		

conversion of agricultural land, but may also be due to urbanization of native, or other vacant land.

The land use for the area beyond the SOI and 2060-Growth Fringe are assumed to expand or grow based on projected growth found within general plans or other public documents. The land use projections were for the years 2005 to 2030. The land use projection beyond 2030 for all non-Fresno areas are assumed to remain constant, with no change from 2030 to 2060.

HYDROLOGY

Since future rainfall and streamflow conditions are not known, a representative hydrologic period was selected using the historical conditions to represent likely future water supply conditions. The Kings IGSM model uses the hydrology and surface water deliveries that occurred during the calibration period, from 1964 to 2004, to represent future conditions for 2005 to 2060. It is assumed that the hydrologic conditions observed over the past 41-years for Kings River and San Joaquin streamflows and diversions would occur over the next 41 years. Since the 41-year calibration period does not cover the entire projection period, it was assumed that the 41-year hydrology would be repeated from the first year. In other words, years 2005 to 2045 would coincide with the 41-year hydrology period of 1964 to 2004, and then the same cycle would be repeated for the following 15 years, 2046 to 2060. The 1964 to 2004 calibration period contained both wet and dry periods and appropriate hydrologic variability to represent a range of conditions, shown in Figure 3e.

Streamflow and Boundary Condition

The northern boundary of the Kings IGSM model is the San Joaquin River which separates Fresno and Madera Counties. Groundwater subsurface flow across the northern boundary and seepage from the San Joaquin River is impacted by the conditions of groundwater hydraulic head and the level of future development. Development north of the City across the San Joaquin River within Madera County is unknown; it is assumed that efforts made by the City will also be made by others to maintain groundwater level north of the San Joaquin River as development progresses. This implies that groundwater extraction and recharge will be concurrent north and south of the San Joaquin River. This assumption applies to both the Baseline and With Project scenarios. This would result in similar groundwater level conditions north and south of the San Joaquin River. It is thus assumed that half of the seepage from the San Joaquin River will recharge the groundwater within Fresno County and the other half will recharge in Madera County. This assumption will be along the entire length of the northern boundary of the Kings IGSM model.

The boundary condition along the northern boundary of the model operates under a no-flow condition across the San Joaquin River. This means that groundwater will not migrate across the border between the City of Fresno and Madera County. This assumption helps reduce the impacts for the unknown development in Madera County. The no-flow condition is applied along the San Joaquin River east of Highway 99 where development is predominantly occurring or is likely to occur near the northern boundary of the model within Fresno and Madera Counties. West of Highway 99, the boundary condition is set to a general hydraulic head boundary condition. The Kings IGSM model calibration applied the general head boundary condition to simulate historical groundwater levels. Under the general head boundary condition, groundwater flows along the hydraulic gradient from north to south providing groundwater recharge to the western Kings Basin. It is assumed that the western region of basin will not undergo a significant change in the land use and water use conditions.

WATER USE

The sources of water for the City are groundwater and surface water diverted from the Kings River and the San Joaquin River via Friant-Kern Canal. The groundwater is used to meet the agricultural and urban water demands that are not met by surface water. The assumptions for surface water use under Baseline conditions are that the existing 30 million gallon per day (MGD) Surface Water Treatment Facility (SWTF) produced 15.8 TAF per year in 2005 and will increase to its maximum rate of 32.5 TAF per year (30 MGD) by 2010. The increase in surface water uses reduces groundwater extraction within City of Fresno. The quantity of treated surface water produced is approximately 30.8 TAF instead of 32.5 TAF to allow for 1 month of downtime for maintenance each year. Under Baseline conditions, the additional water demand from 2010 to 2060 is met exclusively by groundwater. Groundwater pumping in 2005 is 141 TAF increasing to 349 TAF per year by 2060 under Baseline conditions.

The With Project conditions implement a change in groundwater demands with a 10% reduction in water consumption due to water conservation, increased treated surface water production, and utilizing recycled water in-lieu of groundwater pumping. The water conservation includes a 5% reduction by all customers by 2010 and an additional 5% reduction in 2020. Water conservation efforts will equate to a savings in water use by 38 TAF per year by 2060. The second strategy included in the model is to reduce groundwater extraction by increased use of treated surface water. The With Project condition includes development of a new 60 MGD SWTF in the southeast portion of Fresno and the expansion of 30 MGD to the northeast plant. A new 60 MGD SWTF will be set to begin production in 2015. The expansion of the existing 30 MGD SWTF in the northeast will increase capacity to 60 MGD by 2020. The increased capacity of treated surface water is a total of 123 TAF per year. The With Project conditions reduced groundwater pumping from 141 TAF per year in 2005 to 82 TAF per year in 2020 when the maximum water conservation efforts and the expansion of the SWTFs come online. Groundwater extraction is reduced in 2025 with the use of 25 TAF per year of recycled water in-lieu of pumping.

A summary of the projected water use is found in Figure 2-3 in the Metro Plan Update Phase 2 Report (West Yost, 2008). A map of the groundwater well locations and the pumping distribution pattern and capacity for the Baseline and With Project conditions are found in Figures 4a and 4b, respectively.

RECHARGE

FMFCD Existing and Future Ponds

The data available for recharge was limited to recent years when most of the ponds were in operation. Observed data was available from the Fresno Metropolitan Flood Control District (FMFCD) only for the period from 1980 to 2004. To evaluate potential future conditions a synthetic recharge schedule was developed using the average monthly recharge distribution and the San Joaquin River hydrologic index. The synthetic schedule was used to approximate the total recharge within the cities of Fresno and Clovis that will occur in future scenarios. The average annual water recharged in the existing FMFCD ponds is 18 TAF per year.

An estimate for future ponding acreage in the areas to be developed was also needed to evaluate future conditions. Annual water recharged and monthly distribution assumptions for the 2060 Growth Fringe were provided by the FMFCD. The 2060 Growth Fringe was divided into 11 subgroups, Division 1 to 11 shown in Figure 4c. Each division assumed a percolation rate ranging from 0.2 to 0.5 feet per day and the ponding acreage required to support mixed urban development as provided by West Yost. Impacts on total recharge for low water years, maintenance, excavation and other unknowns were taken into account in the estimated and calculated average annual recharge. The future recharge schedule was used as part of the input files for 2025 and 2060 Baseline Conditions. The average annual water recharged in the existing FMFCD ponds is 10 TAF per year.

Project Recharge Ponds

Figure 4c shows the location of the three project pond locations (i.e., regional recharge basins). Deliveries of surface water to groundwater recharge ponds begin in 2025 with 26.1 TAF per year into Pond 1. An additional 48.8 TAF per year into Pond 2 by 2030 and 37.4 TAF per year by 2037 of groundwater recharge into Pond 2. A total of 112.3 TAF per year was added to the groundwater storage. The water supply will in part come from additional Kings River water deliveries and a new source of surface water of 35 TAF per year beginning in 2035 increasing to 55 TAF per year by 2050.

MODEL RESULTS

This section provides the summary of the Kings IGSM modeling results for the City of Fresno Baseline and With Project scenarios. The groundwater response is depicted by the groundwater level contour maps, well hydrographs and changes in groundwater storage calculations for the Fresno area for the 2005 to 2060 period.

GROUNDWATER ELEVATION

The change in groundwater elevation associated with Baseline and With Project conditions is shown in a series of contour maps showing the groundwater elevation above mean sea level (MSL). The Baseline groundwater levels in Figures 5a through 5g, show the average annual groundwater elevation for the years 2010 through 2060, respectively. Figures 6a through 6g show the average annual groundwater levels for the With Project conditions for the years 2010 through 2060, respectively. The 2005 groundwater elevation map, Figure 2, is used as the same common starting point.

The initial groundwater elevations are set at the year 2005 levels. The groundwater surface elevation range from 270 to 300 feet MSL in the northern and eastern portions of the SOI to 180 to 190 feet MSL in the southwest. The existing groundwater gradient is from the northeast, with higher groundwater surface elevation, to the southwest. The gradient is relatively flat within the central portion of the SOI but begins to decline in the southwestern area outside of the SOI in the 2060 Growth Fringe section near the Regional Wastewater Reclamation Facility (RWRF) where the groundwater levels continue to drop below 150 feet MSL. The groundwater level contours show some mounding effects of the percolation of wastewater near the RWRF. A 10-foot groundwater depression is estimated near the center of the SOI, north of downtown, with an elevation of 170 to 180 feet MSL. A second groundwater depression is estimated in the eastern section of the SOI in the Bakman Water District (Bakman), also at 170 to 180 feet MSL.

Groundwater Levels Under Baseline Conditions

The groundwater levels, under Baseline conditions, drop 10 feet from 2005 to 2010, increasing the depression throughout most of the western SOI. By 2025, the groundwater levels at the central portion of the City continue to decline to 140 to 150 feet MSL. The second depression at Bakman continues to spread to a larger region toward the west. By 2060, the groundwater levels dropped below 110 feet in most of the City and Bakman. The mound is evident at the RWRF.

Figure 7a shows the change in groundwater level that occurred from 2005 to 2060. A negative value represents a drop, or decrease, in groundwater level as compared to the level in 2005. By the end of the modeling simulation, the groundwater levels are simulated to drop 70 to 85 feet along Highway 99. The depression is projected to be relatively evenly spread along the highway with two valleys in the groundwater depression located in the northwest and southeast Fresno area. These valleys are most likely the result of pumping distribution patterns shown previously in Figure 4a. The groundwater levels throughout the area are projected to drop; there are some areas where mounding, relative to the surrounding groundwater levels, are noticed. The mound in the southwest located beneath the RWRF is a result of the wastewater percolation. The groundwater levels drop by 70 to 75 feet in the surrounding area but only 65 feet at the RWRF. The groundwater mounding northeast of Highway 180, with a drop of only 40 feet, and in the northeast portion along Big Dry Creek, with a gain of 10 feet, is due to hydrology and soil conditions. The difference in hydrology between 2005 and 2060 is that more surface water is available to flow in the canals in 2060 as compared to 2005. The two areas of mounding are areas of high conductivity or infiltration rates, meaning the water within the canals recharge the groundwater faster in these areas.

Groundwater Levels Under With Project Conditions

Under With Project conditions the groundwater follows a similar trend from 2005 to 2010 with a drop in groundwater levels by 10 feet in the western SOI. From 2010 to 2020 the depression in the center of the City has been reduced and groundwater levels increased to 180 to 200 feet MSL. The increase in groundwater levels was the result of water conservation and increased treated surface water production. The groundwater levels in the eastern portion of the SOI increased with a depression present at Bakman 10 feet below the surrounding area. Since Bakman is supported exclusively by groundwater extraction, a depression is likely to continue in this area.

At the end of simulation, 2060, the groundwater in the center of the City is at 200 to 210 feet MSL, an increase of 25 to 30 feet from 2005, shown in Figure 7b. Along Highway 99, the groundwater levels range from 0 feet to 15 feet, indicating no change to an increase by 15 feet compared to 2005. There are areas of mounding in the northeast SOI and the City of Clovis. The mounding in the City of Clovis results from the benefits of groundwater recharge in the Marion basin near Dry Creek canal. This mounding effect is amplified by the gains in groundwater level within the SOI due to the increased capacity in the Northeast SWTF and reduction in groundwater pumpage. Other areas where beneficial groundwater mounding is evident is at the project ponds sites. The groundwater recharged in these areas shows an improvement to the surrounding groundwater by 5 to 10 feet compared to 2005.

Areas outside of the Fresno area that are affected by the project conditions are the groundwater depression southwest of the City and the eastern portion of the Fresno Irrigation District. The area southwest of Highway 99 continues to lose groundwater down gradient from the northeast to the southwest. The gradient is caused by a groundwater depression in the western portion of the Kings Basin located near Raisin City. The groundwater depression formed east of the City is a result of the increased groundwater pumping to meet agricultural demands. The surface water from the Kings River was diverted and reallocated to meet the City's water use requirements, either for the surface water treatment or recharge. The remaining water was used to support the crop water demand in the surrounding areas.

Baseline and With Project Groundwater Level Comparison

A comparison of the changes in groundwater levels, under Baseline and With Project conditions, are shown using a contour map and well hydrographs. The contour map, Figure 8, shows difference in groundwater levels at 2060 (With Project minus Baseline). Near the center of the SOI, the simulated groundwater difference is 105 feet. This is an increase in groundwater level relative to 2060 Baseline condition. Alternatively, the increase in groundwater level in this figure represents the benefit of the projects implemented under the With Project condition when compared to the Baseline condition at the end of the model simulation.

The changes in groundwater levels from 2005 to 2060 are shown using eight representative well hydrographs and three simulated hydrographs at the project pond sites. The well hydrographs show historical observed groundwater levels, for comparative purposes, represented by red diamonds along with a red line for the simulated groundwater levels for the Baseline conditions and a black line for the With Project conditions. The peaks and valleys in the lines show the changes in groundwater level at different time periods of the year (e.g., spring and fall). The hydrographs that have an exaggerated variance indicate an area with higher areas of water permeability like agricultural areas. The hydrographs at the pond location do not include historical observed level since these are only simulated and wells do not existing at these locations. The well and pond locations are shown in Figure 9a and the simulated well 9hydrographs in Figure 9b and 8c.

Figure 9a shows Well 35, located in the southwest portion within the 2060 Growth Fringe, near the regional wastewater treatment plant. The historical data shows a decline in groundwater elevation of approximately 25 feet. The Baseline condition shows an additional 70 feet decline from 2005 to 2060. The With Project condition shows a decline of groundwater elevation of 25 feet by 2060. There are three notable inflections that occur in the With Project groundwater level line: 1. New/Expanded SWTF in 2015 to 2020 cause an upward trend; 2. Use of recycled water for irrigation reducing wastewater percolation produces a downward trend; and 3. Additional surface water supply (New) for recharge shown by an upward trend in 2030 and 2050.

A similar effect can be seen in the pond location hydrographs. In the Pond 2 hydrograph, the With Project groundwater levels begin to deviate from the Baseline beginning at 2010 which coincides with the 5% water conservation efforts. Most noticeably is the dramatic increase of 25 feet in groundwater in 2030 when the pond begins to receive water to recharge the groundwater. The groundwater simulation ends in 2060 with the With Project groundwater level at 195 feet and the Baseline at 110 feet. The difference of 85 feet in groundwater levels shows the benefits realized of the projects implemented versus doing nothing (Baseline condition).

Table 2. Well Hydrograph Summary

Location		2005 GWL (feet)	2060 GWL (feet)	2060 - 2005 Change in GWL (feet)	Project minus Baseline (feet)
Well 35	Project		160	-25	
	Baseline	185	110	-75	50
Well 45	Project		195	0	
	Baseline	195	105	-90	90
Well 47	Project		230	35	
	Baseline	195	140	-55	90
Well 58	Project		210	15	
	Baseline	195	110	-85	100
Well 60	Project		186	0	
	Baseline	186	105	-81	81
Well 70	Project		300	-15	
	Baseline	315	270	-45	30
Well 239	Project		217	27	
	Baseline	190	123	-67	94
Well 240	Project		240	35	
	Baseline	205	170	-35	70
Pond 1	Project		178	-10	
	Baseline	188	110	-78	68
Pond 2	Project		195	0	
	Baseline	195	110	-85	85
Pond 3	Project		257	12	
	Baseline	245	165	-80	92

Table 2 is a comparative summary of groundwater level at the well and pond locations between the Baseline and With Project conditions. The column for "With Project minus Baseline" shows the amount of groundwater stored from the projects implemented, under With Project conditions, versus no actions taken. The benefits range from 30 to 100 feet of potential gains in groundwater.

CHANGE IN GROUNDWATER STORAGE SUMMARY

The Baseline condition results in a decline in groundwater storage from 2005 to 2060 at a rate of 20 TAF per year within the SOI. The overdraft causes a drop of 80 feet in groundwater levels from 180 MSL to 100 MSL by 2060 in the approximate center of the City north of downtown. The decline under Baseline conditions in water level and depletion of groundwater storage are associated with the increased urban development and the increased urban reliance on groundwater.

Under With Project conditions there is an average annual surplus of groundwater of 4 TAF per year and an increase in groundwater level from 180 MSL to 200 MSL from 2005 to 2060. The projects implemented in this scenario allowed for increased use of surface and recycled water in-lieu of groundwater pumping and allow for greater opportunity to capture surface for storage in the project ponds. The difference in groundwater storage under various hydrologic conditions, Table 3, shows the benefit of the ability to recharge more groundwater, improve conservation efforts and reduce groundwater pumping. Detailed groundwater budgets for the Baseline and With Project conditions are included in Tables 4 and 5, respectively.

Table 3. Change in Groundwater Storage within SOI by Hydrologic Period

MODEL RUNS	2005-2060 Annual Average	2018 Dry Year	2024 Wet Year	2028-2033 Multiple Dry Years	2036-2039 Multiple Wet Years
Baseline Conditions (TAF)	-20	-76	50	-43	17
With Project Conditions (TAF)	4	-39	73	-3	38

In the dry hydrologic periods, the With Project scenario counters the dependence on groundwater by a reduction of pumping. During the dry year period in 2018, the groundwater storage will decline 76 TAF under Baseline conditions. In the With Project scenario, the groundwater storage will decline 39 TAF. The savings in groundwater, in this time period, is due to the new 60 MGD SWTF and 5% water conservation, and results in a savings of 37 TAF of groundwater. In the multiple dry years, 2028 to 2033, the 40 TAF reduction in groundwater loss is attributed to the 25 TAF of recycled water being used in-lieu of groundwater extraction.

The benefits of increased groundwater storage capacity with the project recharge ponds (i.e., regional recharge basins) and a reduction in groundwater pumping are seen during the wet hydrologic periods. In 2024, an additional 23 TAF of groundwater storage results from

Table 4. Average Annual Groundwater Budget, Baseline

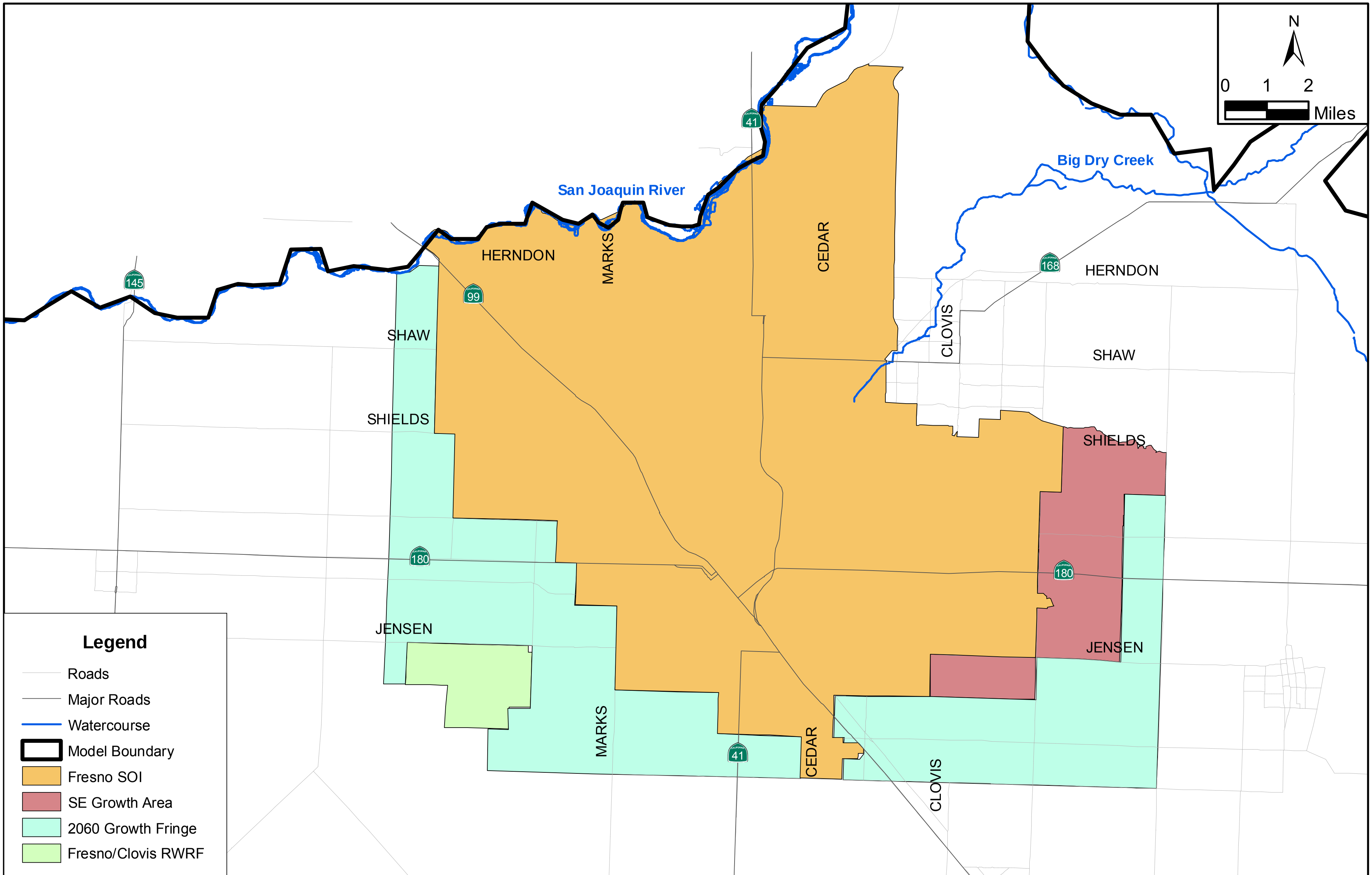
Groundwater Budget for the City of Fresno Sphere of Influence - Baseline Simulation (General Head west of Hwy 99, 50% SJ River Flux east of Hwy 99) All Units in Acre-Feet														
	Inflow										Outflow			
	Percolation	Boundary Inflow					Seepage and Recharge			Total	Pumping		Total	
Water Year	Deep Percolation from Rain and Applied Water	San Joaquin River Seepage	Northwest	Southwest	Northeast	Southeast	Seepage From Major Canals	Recharge from Other Canals and Ponds	Project Recharge	Total Inflow	City of Fresno Municipal Well Pumping	Other Pumping	Total Outflow	Change in Storage
2005	31,152	25,497	-12,530	-2,594	16,855	54,916	13,809	37,382	0	**164,488**	141,513	85,673	**227,186**	**-58,503**
2006	31,864	23,555	-11,548	-2,515	19,029	59,293	25,792	42,597	0	**188,066**	138,447	79,685	**218,132**	**-29,827**
2007	31,074	23,066	-11,319	-2,977	18,884	58,433	16,195	43,150	0	**176,506**	134,836	87,260	**222,096**	**-45,813**
2008	35,099	45,820	-21,681	-4,519	17,259	60,871	43,441	47,399	0	**223,689**	131,151	80,671	**211,822**	**12,207**
2009	30,986	21,341	-10,369	-2,726	18,360	65,264	16,762	42,969	0	**182,588**	127,480	82,769	**210,249**	**-27,963**
2010	49,910	58,170	-26,949	-6,299	15,608	60,914	54,221	44,725	0	**250,300**	123,838	82,280	**206,118**	**44,465**
2011	37,185	19,740	-9,438	-1,270	17,474	65,235	36,250	49,151	0	**214,328**	125,750	81,252	**207,002**	**7,211**
2012	30,975	16,848	-8,072	-5,261	17,981	64,122	27,870	43,855	0	**188,318**	128,949	78,554	**207,503**	**-19,181**
2013	27,765	22,862	-11,112	-9,023	17,895	58,167	15,698	42,069	0	**164,321**	132,056	77,244	**209,300**	**-45,204**
2014	36,619	34,245	-16,453	-10,153	18,009	59,091	30,314	49,880	0	**201,552**	135,256	74,601	**209,857**	**-8,036**
2015	33,397	29,037	-13,973	-6,183	19,570	63,936	26,483	48,766	0	**201,034**	138,459	72,030	**210,489**	**-9,431**
2016	27,957	19,430	-9,332	-3,949	20,881	64,249	25,104	45,488	0	**189,829**	141,655	72,446	**214,101**	**-24,229**
2017	27,168	28,302	-13,807	-7,188	19,810	58,362	17,196	38,449	0	**168,292**	144,850	75,727	**220,577**	**-52,540**
2018	24,645	30,932	-15,116	-11,082	19,642	50,355	12,193	37,619	0	**149,188**	148,186	77,020	**225,206**	**-76,094**
2019	35,130	52,783	-24,851	-9,603	19,865	55,791	34,688	47,138	0	**210,942**	151,409	63,697	**215,106**	**-3,880**
2020	33,293	30,131	-14,580	-1,904	22,416	63,650	27,429	47,606	0	**208,042**	154,649	65,560	**220,209**	**-12,092**
2021	34,347	52,058	-24,755	-1,063	22,740	65,390	25,321	49,502	0	**223,540**	158,992	62,039	**221,031**	**2,513**
2022	29,086	24,900	-12,010	591	23,849	66,979	23,342	44,427	0	**201,164**	163,732	58,515	**222,247**	**-21,076**
2023	28,133	42,692	-20,418	423	23,461	66,074	29,804	44,612	0	**214,781**	168,391	53,252	**221,643**	**-6,764**
2024	41,512	81,510	-38,257	5,267	23,985	71,101	39,870	46,276	0	**271,264**	173,115	48,169	**221,284**	**50,037**
2025	31,004	44,110	-21,019	6,596	24,198	69,810	33,356	52,581	0	**240,636**	177,784	43,609	**221,393**	**19,132**
2026	26,393	23,831	-11,408	6,172	25,335	67,655	21,876	49,149	0	**209,003**	178,914	42,348	**221,262**	**-12,293**
2027	30,902	45,818	-21,778	1,894	24,689	67,821	21,423	47,471	0	**218,240**	178,986	42,536	**221,522**	**-3,250**
2028	27,790	24,267	-11,682	-528	23,807	62,599	18,141	44,330	0	**188,725**	179,107	44,632	**223,739**	**-35,268**
2029	23,906	28,701	-13,984	181	23,784	59,971	18,040	41,079	0	**181,678**	179,461	45,968	**225,429**	**-43,739**
2030	24,536	29,967	-14,659	1,304	22,806	57,284	18,089	43,120	0	**182,447**	179,597	46,614	**226,211**	**-43,731**
2031	24,971	33,278	-16,408	-1,018	23,477	52,613	13,481	37,280	0	**167,674**	179,858	48,158	**228,016**	**-60,431**
2032	26,535	36,319	-17,988	-1,921	21,560	52,422	44,744	40,342	0	**202,013**	180,117	49,718	**229,835**	**-27,721**
2033	28,614	36,851	-18,196	2,284	22,958	52,615	19,168	41,980	0	**186,275**	180,266	50,913	**231,179**	**-44,949**
2034	34,602	44,005	-21,584	6,739	24,837	57,282	28,271	49,122	0	**223,275**	180,430	52,097	**232,527**	**-8,930**
2035	28,875	37,087	-18,326	11,416	26,205	60,237	18,093	41,460	0	**205,048**	180,780	53,676	**234,456**	**-29,517**
2036	34,538	62,633	-29,928	13,151	26,798	62,320	32,484	43,186	0	**245,182**	181,023	53,893	**234,916**	**10,491**
2037	31,761	44,098	-21,544	20,784	28,577	66,935	27,485	46,649	0	**244,746**	181,176	54,551	**235,727**	**9,096**
2038	35,581	54,150	-25,982	21,046	28,104	69,287	31,523	45,158	0	**258,867**	181,360	55,252	**236,612**	**22,231**
2039	38,062	66,157	-31,326	20,685	27,997	68,130	32,091	41,927	0	**263,724**	181,637	54,659	**236,296**	**27,451**
2040	30,707	41,818	-20,506	22,959	29,125	67,020	23,638	45,139	0	**239,900**	181,832	55,401	**237,233**	**2,596**
2041	31,530	38,333	-18,763	18,104	26,019	68,288	42,865	43,894	0	**250,269**	182,007	55,766	**237,773**	**12,540**
2042	30,104	38,523	-19,008	15,333	25,299	64,966	23,432	38,687	0	**217,335**	182,255	56,093	**238,348**	**-21,203**
2043	27,057	37,233	-18,441	14,455	26,239	61,385	22,896	41,949	0	**212,774**	182,433	56,401	**238,834**	**-26,060**
2044	26,161	37,695	-18,713	13,526	26,232	58,580	20,675	41,632	0	**205,788**	182,739	56,702	**239,441**	**-33,585**
2045	27,014	37,279	-18,516	16,140	26,979	59,222	19,388	41,259	0	**208,766**	182,953	57,074	**240,027**	**-31,396**
2046	24,515	25,138	-12,285	12,383	26,921	52,596	8,621	35,636	0	**173,525**	183,175	57,439	**240,614**	**-67,276**
2047	26,099	23,447	-11,394	14,710	28,513	52,706	15,767	40,068	0	**189,917**	183,495	57,476	**240,971**	**-50,913**
2048	26,011	22,693	-11,029	16,747	29,081	53,475	11,160	39,697	0	**187,836**	183,849	57,932	**241,781**	**-54,005**
2049	28,436	47,106	-23,037	17,531	28,161	58,495	36,918	43,948	0	**237,559**	184,066	57,743	**241,809**	**-4,051**
2050	26,951	21,135	-10,196	21,496	29,638	59,461	11,047	37,000	0	**196,532**	184,347	58,443	**242,790**	**-46,365**
2051	38,897	62,950	-30,301	17,623	25,812	59,179	62,708	45,200	0	**282,068**	184,444	58,416	**242,860**	**39,352**
2052	33,195	20,227	-9,643	25,395	29,757	63,304	23,447	41,051	0	**226,733**	184,547	58,484	**243,031**	**-16,299**
2053	28,225	16,575	-7,874	22,556	30,426	60,272	12,625	37,848	0	**200,653**	184,675	58,471	**243,146**	**-42,510**
2054	25,133	21,496	-10,443	20,242	30,613	56,678	9,137	36,103	0	**188,959**	184,780	58,671	**243,451**	**-54,613**
2055	30,763	34,571	-16,855	18,199	29,553	62,259	28,443	42,593	0	**229,527**	184,930	58,625	**243,555**	**-13,884**
2056	30,525	29,242	-14,269	21,848	30,472	65,407	23,641	41,453	0	**228,320**	185,102	58,405	**243,507**	**-15,151**
2057	26,570	18,848	-9,037	23,266	31,267	61,019	14,985	40,339	0	**207,258**	185,273	58,469	**243,742**	**-36,493**
2058	25,543	26,492	-12,967	19,585	30,381	56,207	11,392	35,116	0	**191,749**	185,350	58,557	**243,907**	**-52,321**
2059	23,830	28,519	-14,022	15,450	30,146	50,582	7,838	34,837	0	**177,180**	185,553	58,553	**244,106**	**-67,045**
2060	30,813	55,520	-27,315	16,159	29,665	57,732	38,211	43,242	0	**244,027**	185,753	58,662	**244,415**	**-210**
Average	**30,419**	**35,340**	**-17,089**	**7,330**	**24,447**	**60,857**	**24,801**	**42,939**	**0**	**209,043**	**168,335**	**60,872**	**229,207**	**-20,081**

Table 5. Average Annual Groundwater Budget, With Project

Groundwater Budget for the City of Fresno Sphere of Influence - With Project Simulation (General Head west of Hwy 99, 50% SJ River Flux east of Hwy 99)
All Units in Acre-Feet

	Inflow										Outflow			
	Percolation	Boundary Inflow					Seepage and Recharge			Total	Pumping		Total	
Water Year	Deep Percolation from Rain and Applied Water	San Joaquin River Seepage	Northwest	Southwest	Northeast	Southeast	Seepage From Major Canals	Recharge from Other Canals and Ponds	Project Recharge	Total Inflow	City of Fresno Municipal Well Pumping	Other Pumping	Total Outflow	Change in Storage
2005	31,161	25,495	-12,530	-1,635	18,303	56,656	13,804	37,382	0	**168,636**	141,706	82,633	**224,339**	**-55,703**
2006	31,975	23,567	-11,548	-2,247	18,935	59,174	25,727	42,597	0	**188,180**	139,431	77,949	**217,380**	**-29,200**
2007	31,233	23,090	-11,319	-2,984	18,627	57,641	16,179	43,159	0	**175,626**	136,479	77,141	**213,620**	**-37,994**
2008	34,695	45,702	-21,681	-4,862	16,815	59,994	43,354	47,483	0	**221,500**	133,490	72,210	**205,700**	**15,800**
2009	30,664	21,374	-10,369	-3,400	17,924	63,736	16,686	43,016	0	**179,632**	130,607	71,331	**201,938**	**-22,306**
2010	49,280	57,818	-26,949	-7,040	15,031	59,161	54,440	44,757	0	**246,498**	127,725	67,827	**195,552**	**50,944**
2011	36,475	19,730	-9,438	-2,952	16,394	62,733	36,873	49,168	0	**208,983**	120,547	68,236	**188,783**	**20,201**
2012	30,372	16,933	-8,072	-7,874	16,101	60,973	28,839	43,824	0	**181,096**	112,571	67,627	**180,198**	**898**
2013	27,240	22,967	-11,112	-13,022	15,203	54,232	16,177	42,245	0	**153,930**	104,513	68,495	**173,008**	**-19,079**
2014	36,330	34,047	-16,453	-15,985	13,948	53,998	32,956	49,999	0	**188,841**	96,544	68,128	**164,672**	**24,168**
2015	32,689	28,830	-13,973	-10,980	15,260	57,966	27,153	46,703	0	**183,648**	88,481	81,616	**170,097**	**13,549**
2016	27,202	19,502	-9,332	-14,044	14,706	56,650	25,096	44,757	0	**164,536**	85,163	69,976	**155,139**	**9,398**
2017	26,472	28,114	-13,807	-20,867	12,427	49,136	16,245	37,877	0	**135,596**	82,641	71,561	**154,202**	**-18,606**
2018	23,675	30,499	-15,116	-26,790	11,376	40,841	11,485	37,214	0	**113,185**	80,082	72,566	**152,648**	**-39,463**
2019	34,673	50,381	-24,851	-24,812	10,893	45,691	37,877	44,695	0	**174,546**	77,547	72,125	**149,672**	**24,874**
2020	31,646	29,402	-14,580	-22,106	11,853	51,766	27,981	46,058	0	**162,021**	75,068	62,898	**137,966**	**24,055**
2021	32,562	48,821	-24,755	-19,780	12,390	53,708	27,014	46,485	0	**176,444**	75,105	79,448	**154,553**	**21,891**
2022	26,897	24,379	-12,010	-23,744	11,925	53,901	23,372	42,805	0	**147,525**	76,557	58,471	**135,028**	**12,496**
2023	26,004	40,208	-20,418	-27,423	10,443	51,292	32,405	43,051	0	**155,562**	77,962	54,722	**132,684**	**22,877**
2024	40,274	75,283	-38,257	-22,694	10,792	53,839	46,651	43,678	0	**209,566**	79,387	57,366	**136,753**	**72,814**
2025	27,480	40,655	-21,019	-13,746	13,421	54,229	37,553	47,440	0	**186,014**	80,883	73,351	**154,234**	**31,779**
2026	23,587	22,977	-11,408	-14,801	13,519	53,415	23,944	46,272	0	**157,506**	81,792	68,195	**149,987**	**7,518**
2027	28,949	42,243	-21,778	-19,806	13,198	53,778	21,539	43,074	0	**161,197**	81,880	67,033	**148,913**	**12,283**
2028	25,009	23,217	-11,682	-23,653	12,205	50,393	15,705	40,252	0	**131,446**	81,970	64,291	**146,261**	**-14,814**
2029	21,323	27,386	-13,984	-29,947	9,841	45,569	20,132	39,423	0	**119,742**	82,058	48,784	**130,842**	**-11,100**
2030	22,586	28,523	-14,659	-43,264	5,004	37,923	16,778	38,508	41,829	**133,228**	82,147	46,201	**128,348**	**4,880**
2031	22,919	31,296	-16,408	-48,453	5,136	31,812	10,262	36,185	41,829	**114,579**	82,237	47,440	**129,677**	**-15,098**
2032	25,108	33,863	-17,988	-50,122	3,151	27,293	51,636	40,134	41,829	**154,903**	82,326	48,581	**130,907**	**23,996**
2033	26,792	34,226	-18,196	-48,863	3,096	28,738	19,854	37,627	41,829	**125,102**	82,417	49,386	**131,803**	**-6,700**
2034	33,494	40,056	-21,584	-47,218	3,825	33,505	32,093	41,930	41,829	**157,930**	82,508	50,142	**132,650**	**25,280**
2035	25,722	33,894	-18,326	-44,185	5,009	34,983	18,797	38,741	41,829	**136,463**	82,596	51,471	**134,067**	**2,395**
2036	33,320	55,777	-29,928	-44,992	4,519	35,588	34,879	40,859	41,829	**171,850**	82,614	51,706	**134,320**	**37,530**
2037	28,812	39,082	-21,544	-40,286	5,654	39,727	30,483	43,632	41,829	**167,389**	82,614	52,383	**134,997**	**32,392**
2038	33,695	47,414	-25,982	-42,136	4,510	38,847	36,979	41,902	41,829	**177,058**	82,615	53,269	**135,884**	**41,175**
2039	36,410	57,046	-31,326	-43,077	4,494	37,783	34,936	39,895	41,829	**177,989**	82,615	52,902	**135,517**	**42,473**
2040	26,348	36,033	-20,506	-41,055	6,274	39,052	21,135	41,961	41,829	**151,072**	82,615	53,674	**136,289**	**14,783**
2041	29,843	33,654	-18,763	-46,879	2,355	32,720	54,763	41,455	41,829	**170,977**	82,617	54,151	**136,768**	**34,208**
2042	26,723	33,572	-19,008	-49,597	1,618	30,312	28,853	37,603	41,829	**131,905**	82,618	54,700	**137,318**	**-5,412**
2043	23,601	32,593	-18,441	-50,819	2,021	28,839	27,490	39,518	41,829	**126,630**	82,618	55,125	**137,743**	**-11,112**
2044	23,372	33,197	-18,713	-51,477	2,266	27,970	21,875	39,722	41,829	**120,040**	82,618	55,487	**138,105**	**-18,065**
2045	24,686	32,765	-18,516	-48,665	3,376	30,087	17,898	39,166	41,829	**122,625**	82,618	56,031	**138,649**	**-16,024**
2046	21,255	23,074	-12,285	-50,523	3,880	24,690	7,654	35,564	41,829	**95,137**	82,620	56,441	**139,061**	**-43,923**
2047	24,137	21,827	-11,394	-46,533	6,062	29,088	11,489	38,061	41,829	**114,566**	82,620	56,717	**139,337**	**-24,771**
2048	23,623	21,219	-11,029	-44,330	6,769	32,877	8,558	37,673	41,829	**117,188**	82,620	57,408	**140,028**	**-22,840**
2049	27,009	42,206	-23,037	-44,095	5,032	33,803	40,439	39,339	41,829	**162,524**	82,620	57,411	**140,031**	**22,493**
2050	23,841	19,602	-10,196	-40,059	7,206	36,631	7,703	35,924	41,829	**122,480**	82,620	58,092	**140,712**	**-18,230**
2051	40,279	54,789	-30,301	-45,114	3,358	28,412	71,922	41,964	41,829	**207,139**	82,620	58,091	**140,711**	**66,427**
2052	29,013	18,813	-9,643	-40,197	5,851	37,704	25,092	37,959	41,829	**146,422**	82,620	58,272	**140,892**	**5,529**
2053	24,579	15,682	-7,874	-41,826	7,002	37,949	10,171	37,151	41,829	**124,662**	82,618	58,372	**140,990**	**-16,326**
2054	22,080	20,179	-10,443	-43,803	6,964	35,944	7,723	35,396	41,829	**115,869**	82,617	58,692	**141,309**	**-25,439**
2055	30,586	31,690	-16,855	-47,232	4,071	34,896	39,857	39,277	41,829	**158,119**	82,617	58,762	**141,379**	**16,740**
2056	27,627	26,932	-14,269	-43,533	5,657	39,562	21,030	39,092	41,829	**143,927**	82,614	58,737	**141,351**	**2,576**
2057	22,899	18,236	-9,037	-41,950	7,348	38,850	11,480	38,192	41,829	**127,847**	82,614	58,958	**141,572**	**-13,726**
2058	23,115	24,762	-12,967	-46,065	5,981	35,501	10,281	34,987	41,829	**117,423**	82,608	59,043	**141,651**	**-24,228**
2059	20,805	26,577	-14,022	-49,811	5,591	31,210	6,960	34,716	41,829	**103,855**	82,607	59,223	**141,830**	**-37,974**
2060	31,935	49,792	-27,315	-50,042	4,203	32,430	43,545	38,832	41,829	**165,209**	82,606	58,946	**141,552**	**23,657**
Average	**28,644**	**32,875**	**-17,089**	**-32,025**	**8,907**	**42,950**	**26,104**	**41,007**	**23,155**	**154,528**	**89,461**	**61,246**	**150,707**	**3,820**

increased capacity of 30 MGD in the northeast SWTF and 10% water conservation implementation. In the multiple wet years period increased groundwater recharge of new water supply of 35 TAF results in a 21 TAF of additional storage over baseline conditions. The projects implemented produced a sustainable balanced groundwater table under increasing urban water demands from 2005 to 2060.



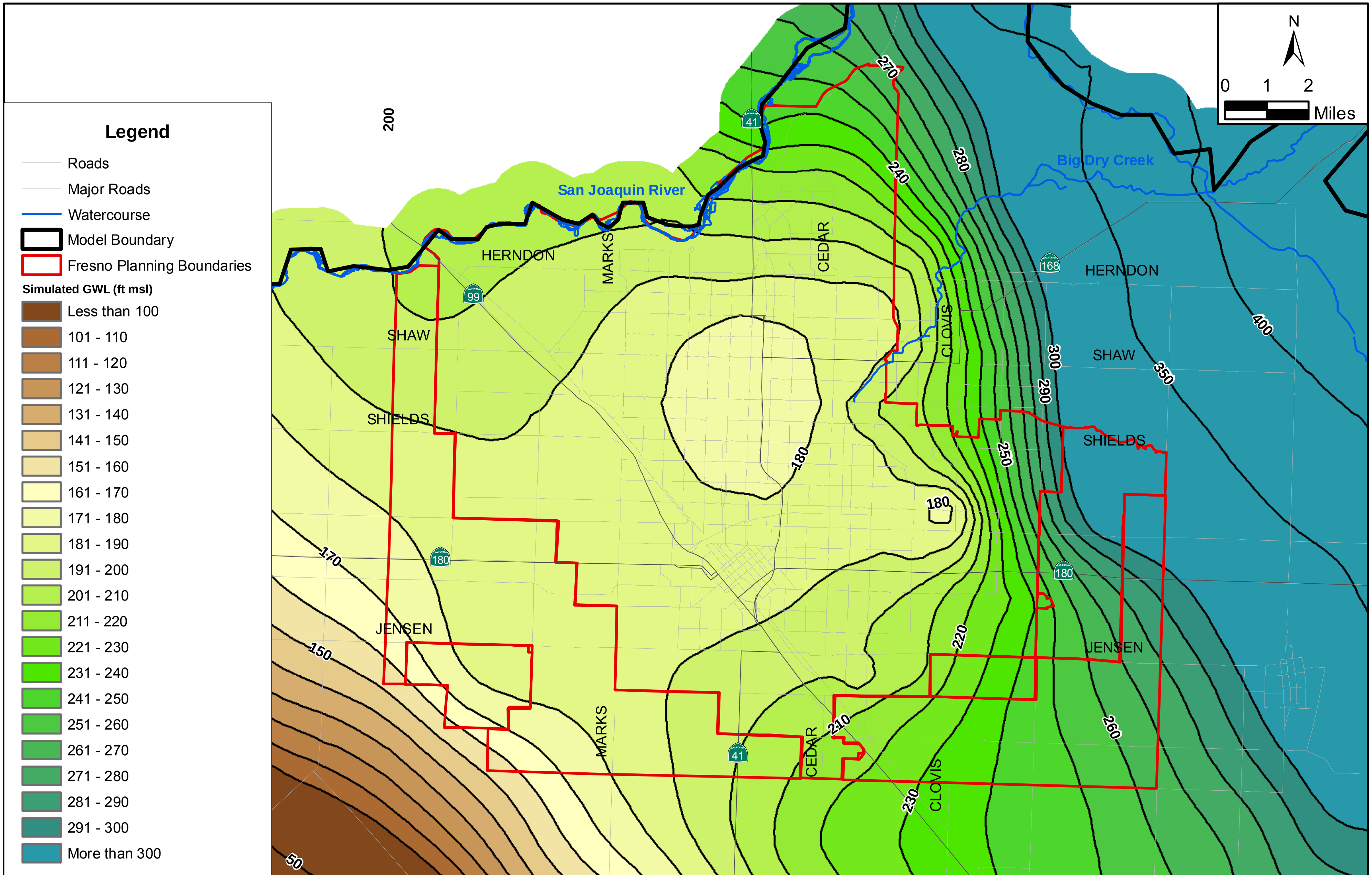
RIME

Reference Map

Fresno Metro Plan - Phase 2

November 2008

Figure 1



ωRIME

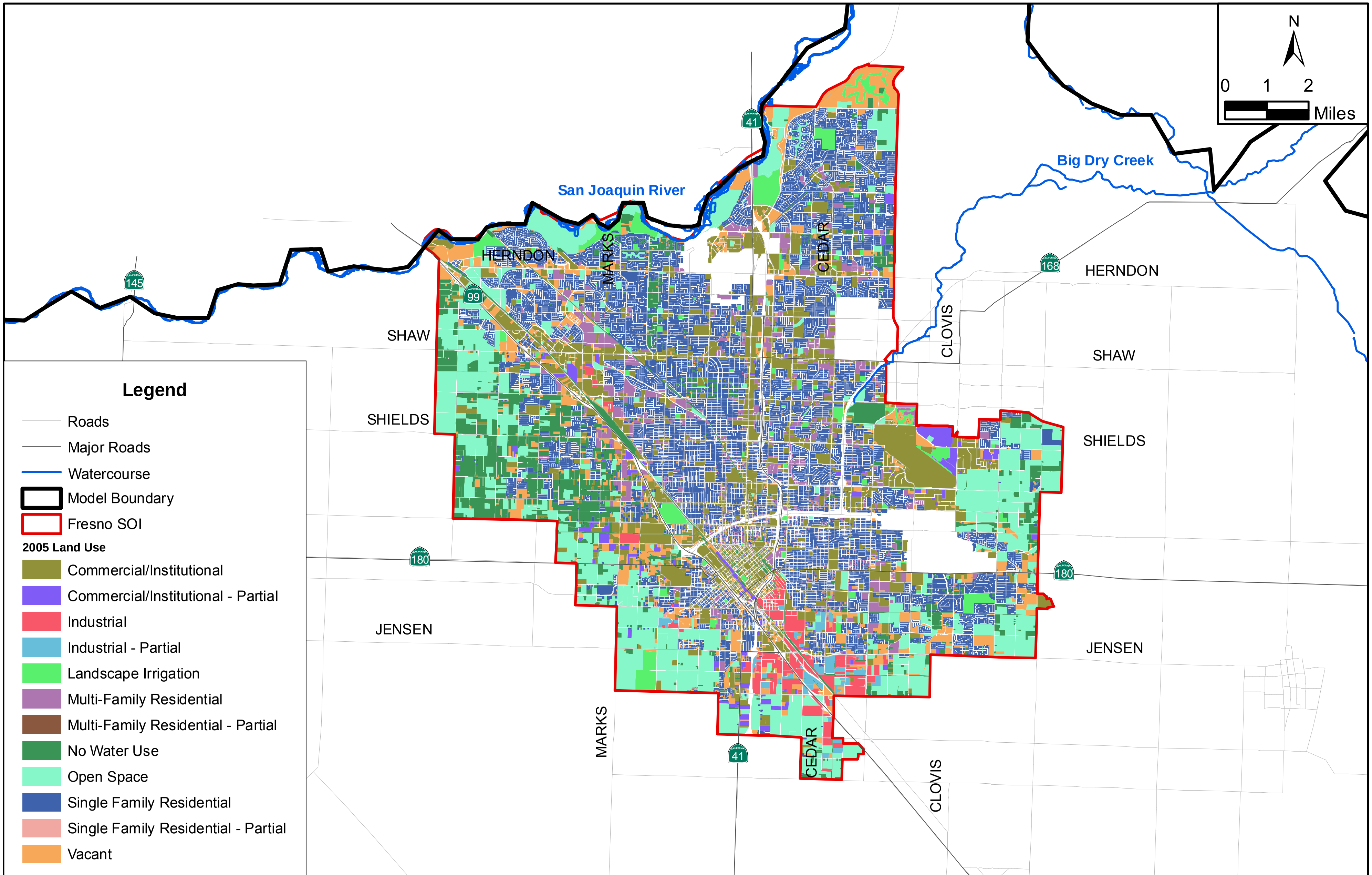
Simulated Groundwater Levels (Initial Conditions - 2005)

Fresno Metro Plan - Phase 2

Simulated groundwater levels are an average of model layers 1 and 2 and an average of each of the 12 months for the water year

November 2008

Figure 2



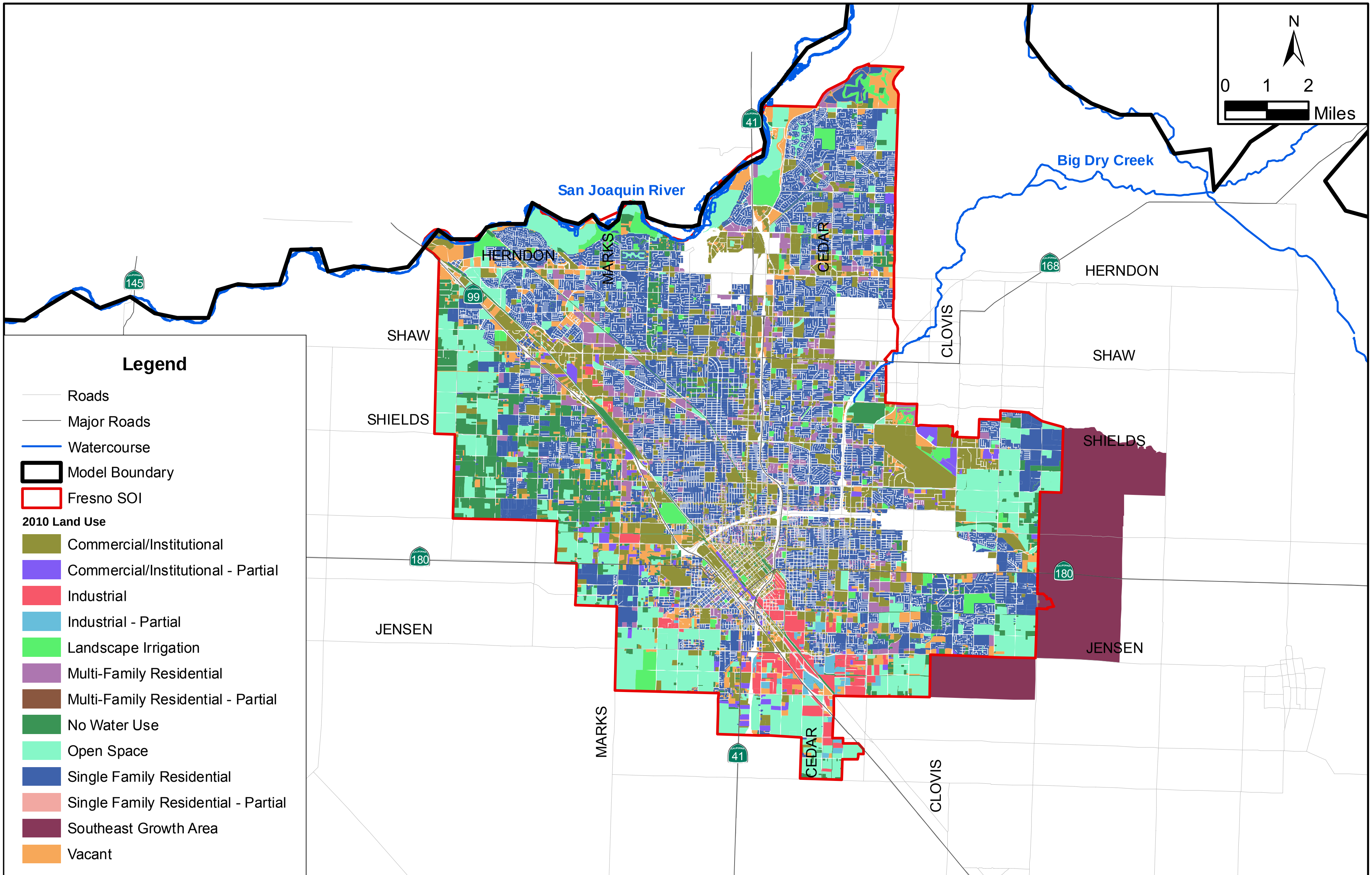
RIME

2005 Land Use

Fresno Metro Plan - Phase 2

November 2008

Figure 3a



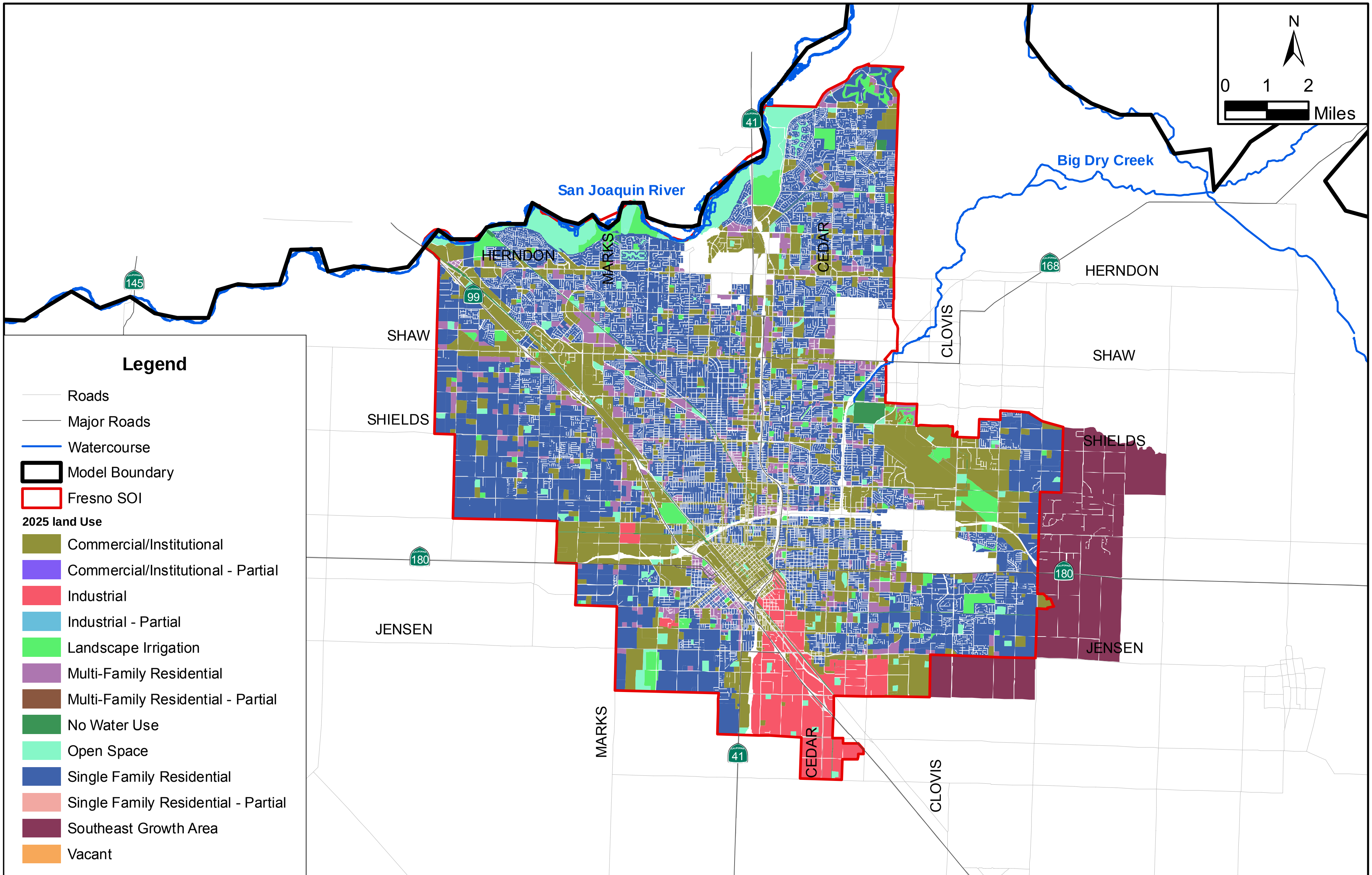
RIME

2010 Land Use

Fresno Metro Plan - Phase 2

November 2008

Figure 3b



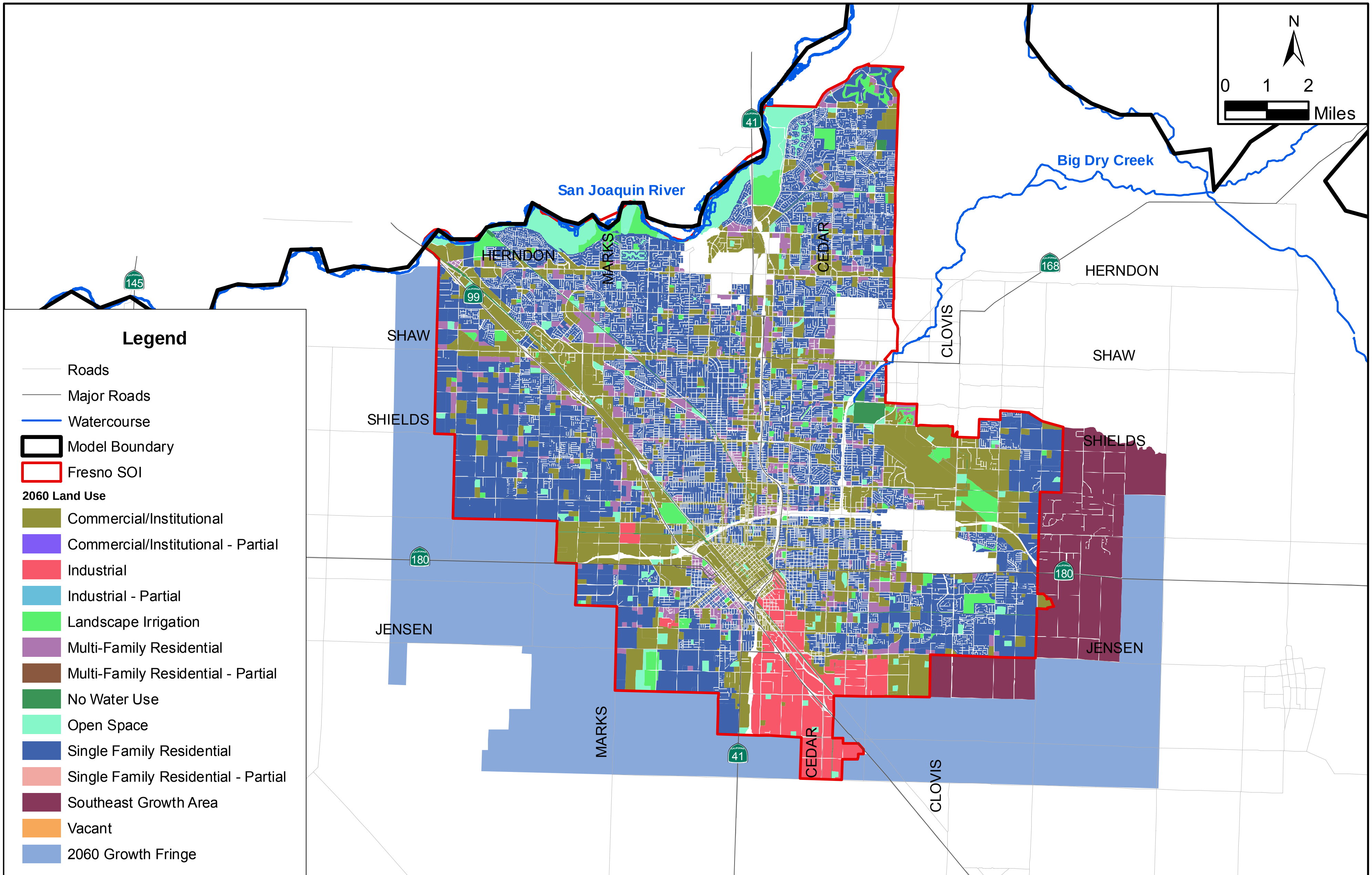
RIME

2025 Land Use

Fresno Metro Plan - Phase 2

November 2008

Figure 3c



RIME

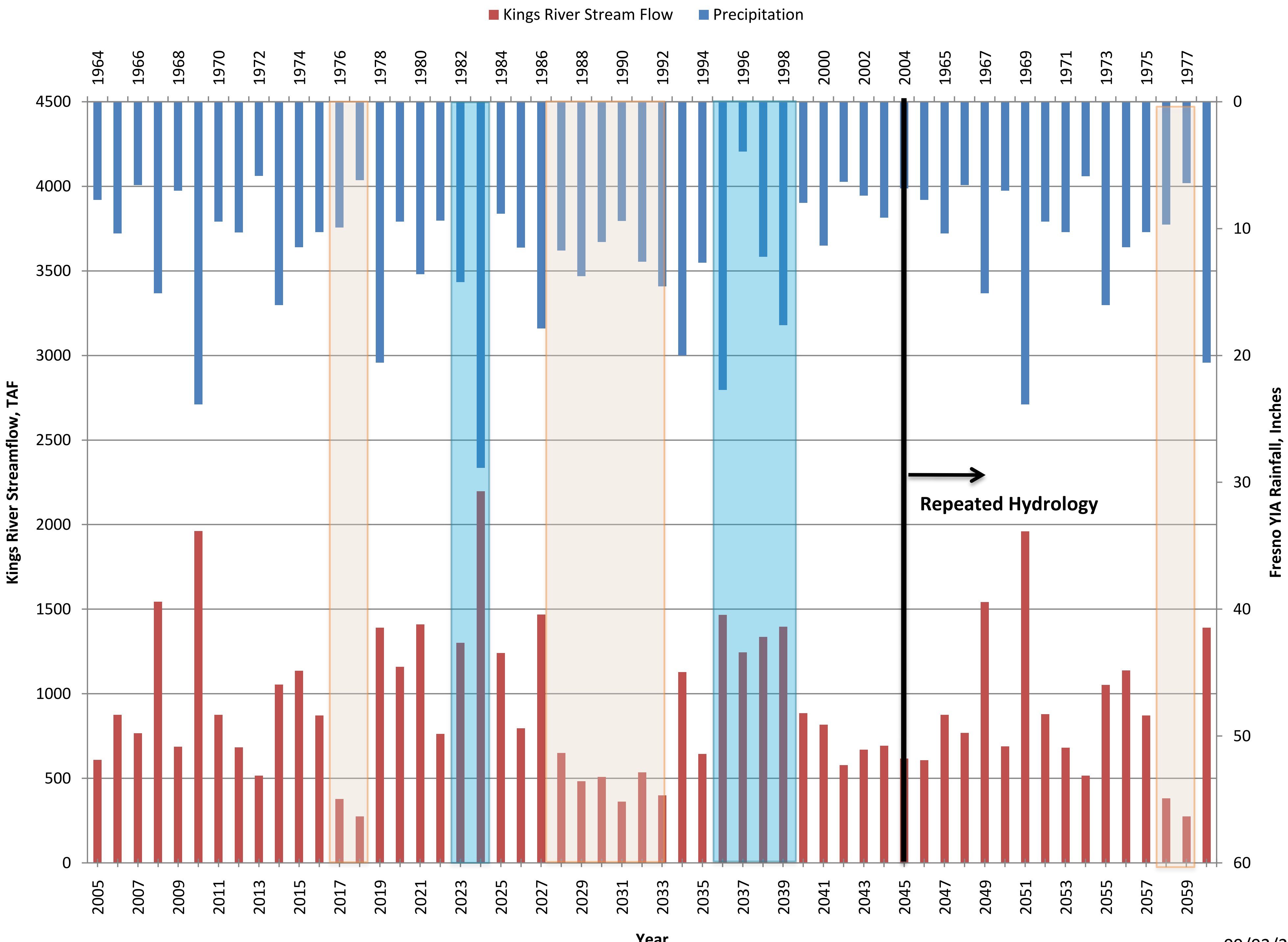
2060 Land Use

Fresno Metro Plan - Phase 2

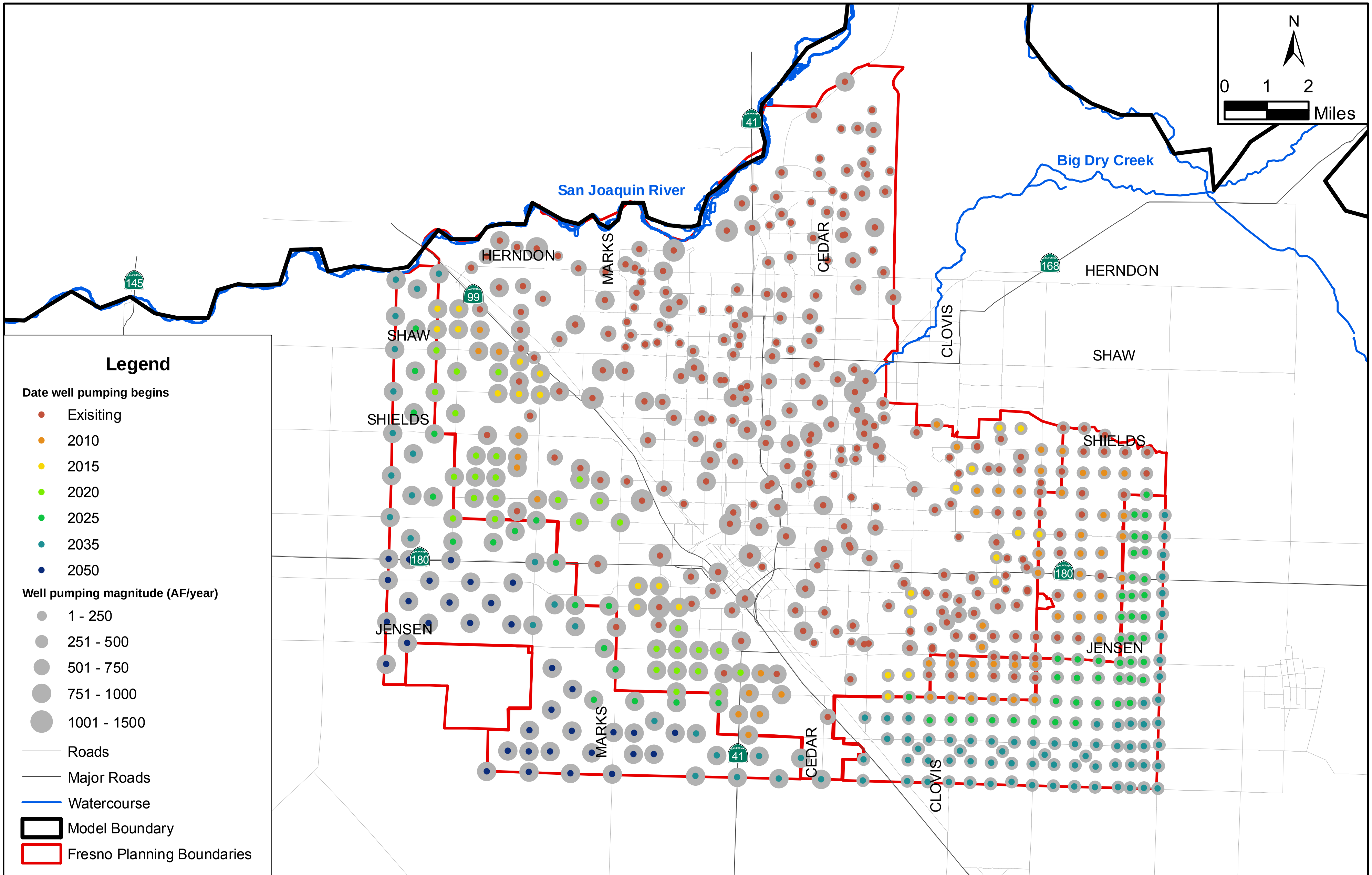
November 2008

Figure 3d

Figure 3e. Average Annual Streamflow vs. Precipitation



09/02/2008

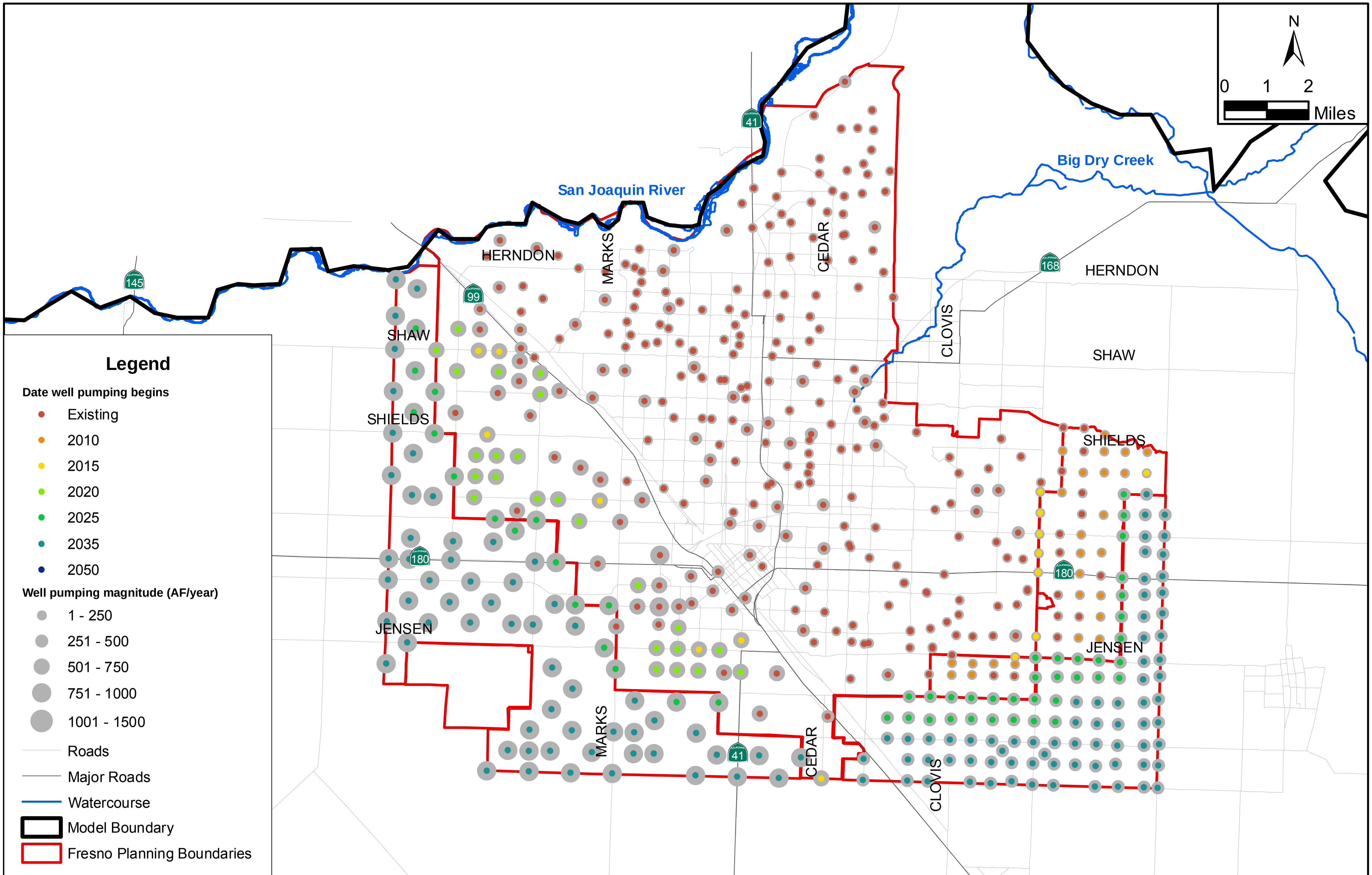


RIME

Fresno Municipal Groundwater Pumping Distribution
Baseline - 2060
Fresno Metro Plan - Phase 2

November 2008

Figure 4a



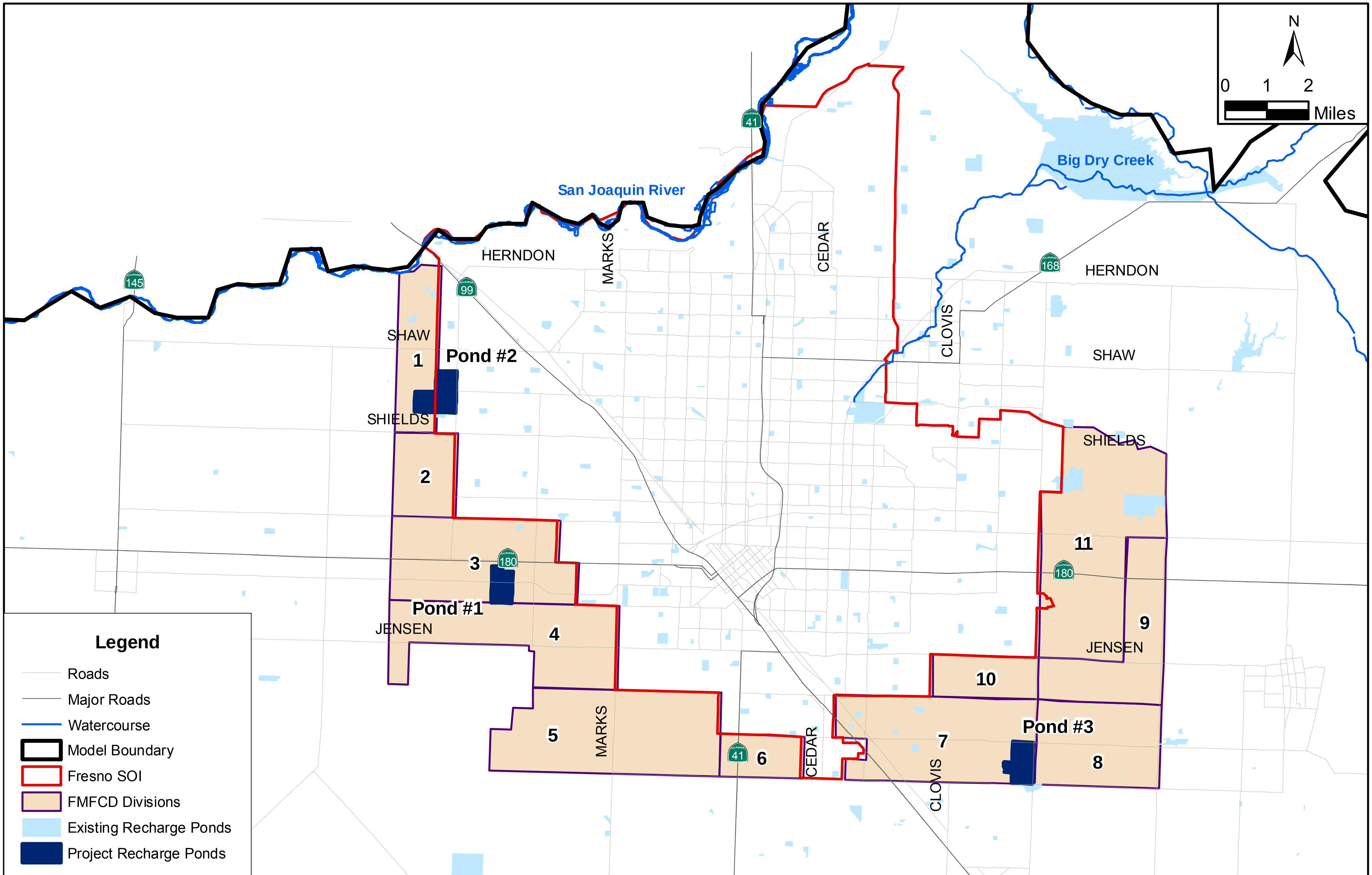
RIME

Fresno Municipal Groundwater Pumping Distribution With Project - 2060

Fresno Metro Plan - Phase 2

November 2008

Figure 4b



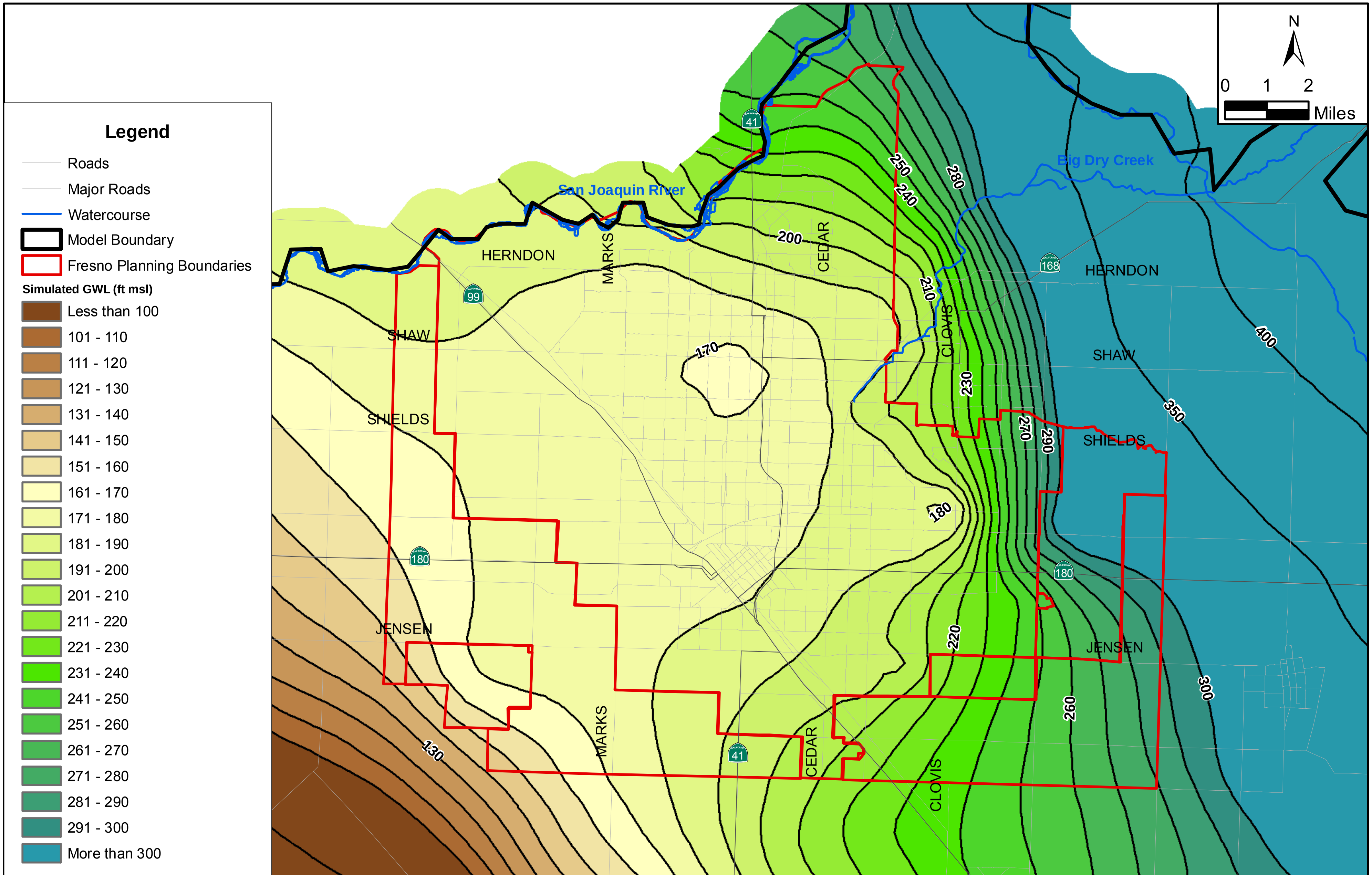
RIME

Regional Recharge Pond Locations and FMFCD Divisions

Fresno Metro Plan - Phase 2

November 2008

Figure 4c



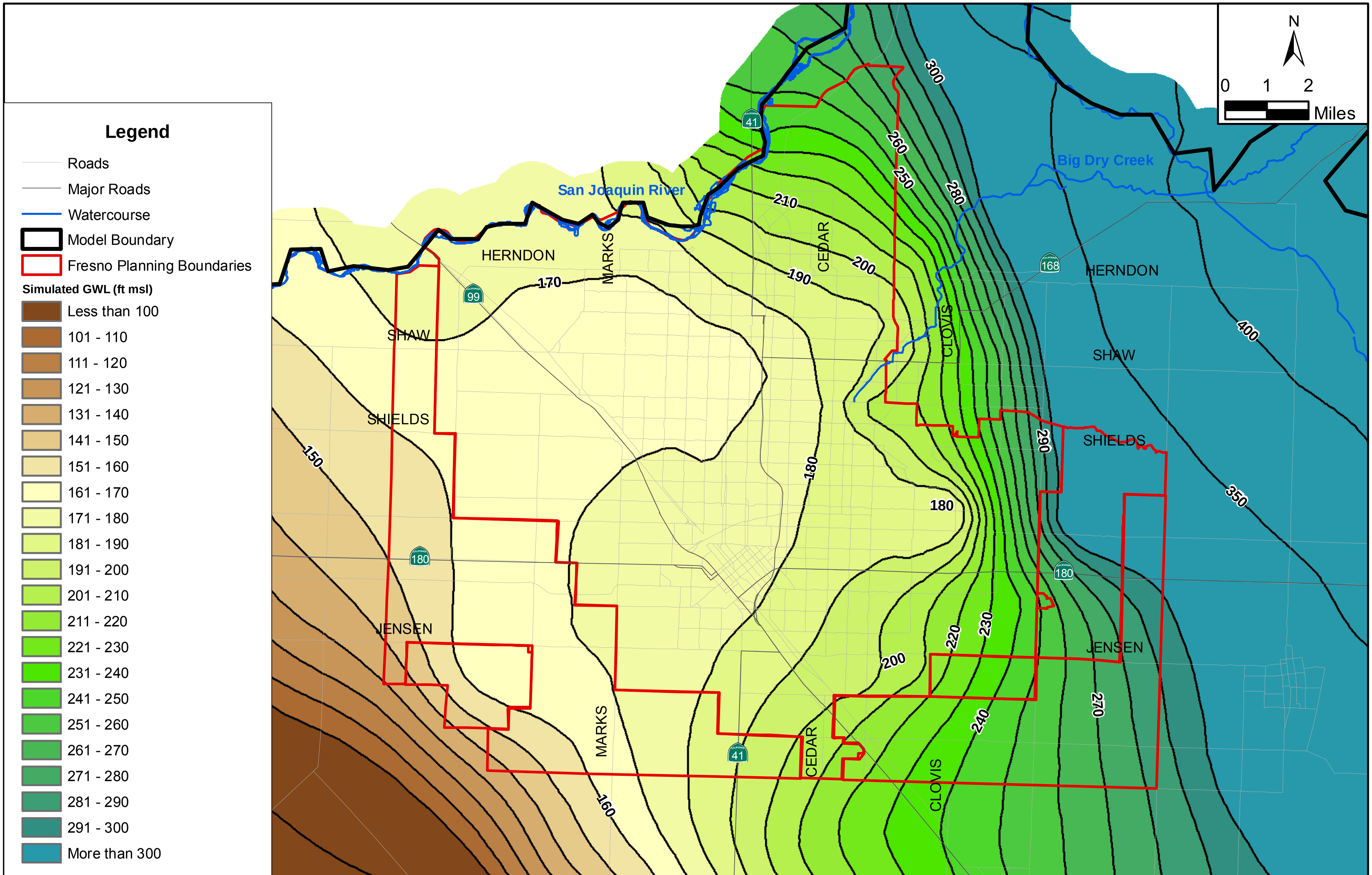
Simulated Groundwater Levels
(Baseline - 2010)

Fresno Metro Plan - Phase 2

Simulated groundwater levels are an average of model layers 1 and 2 and an average of each of the 12 months for the water year

November 2008

Figure 5a



ωRIME

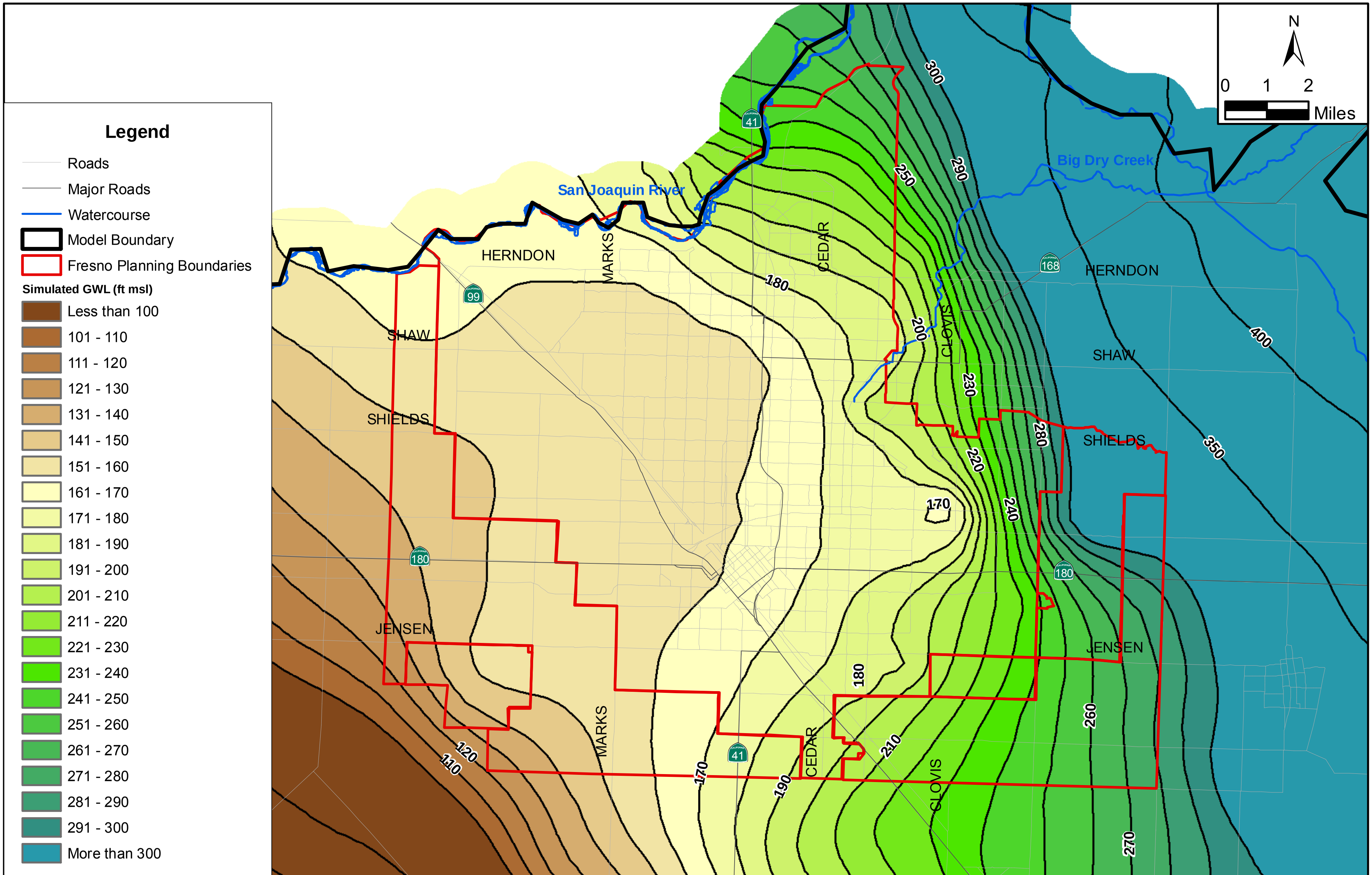
Simulated Groundwater Levels
(Baseline - 2015)

Fresno Metro Plan - Phase 2

Simulated groundwater levels are an average of model layers 1 and 2 and an average of each of the 12 months for the water year

November 2008

Figure 5b



Simulated Groundwater Levels (Baseline - 2020)

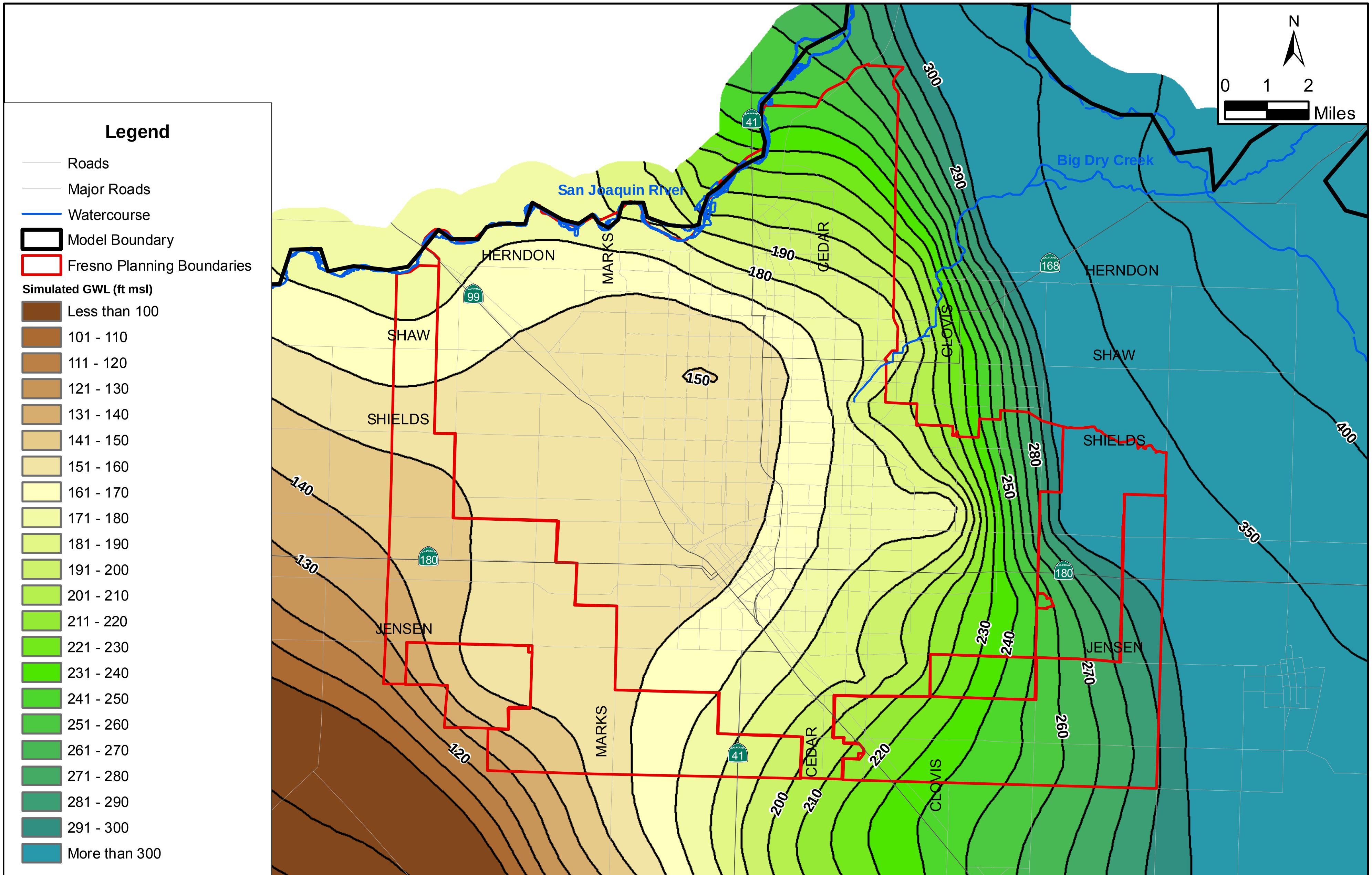
Fresno Metro Plan - Phase 2

Simulated groundwater levels are an average of model layers 1 and 2 and an average of each of the 12 months for the water year

November 2008

Figure 5c

RIME



ωRIME

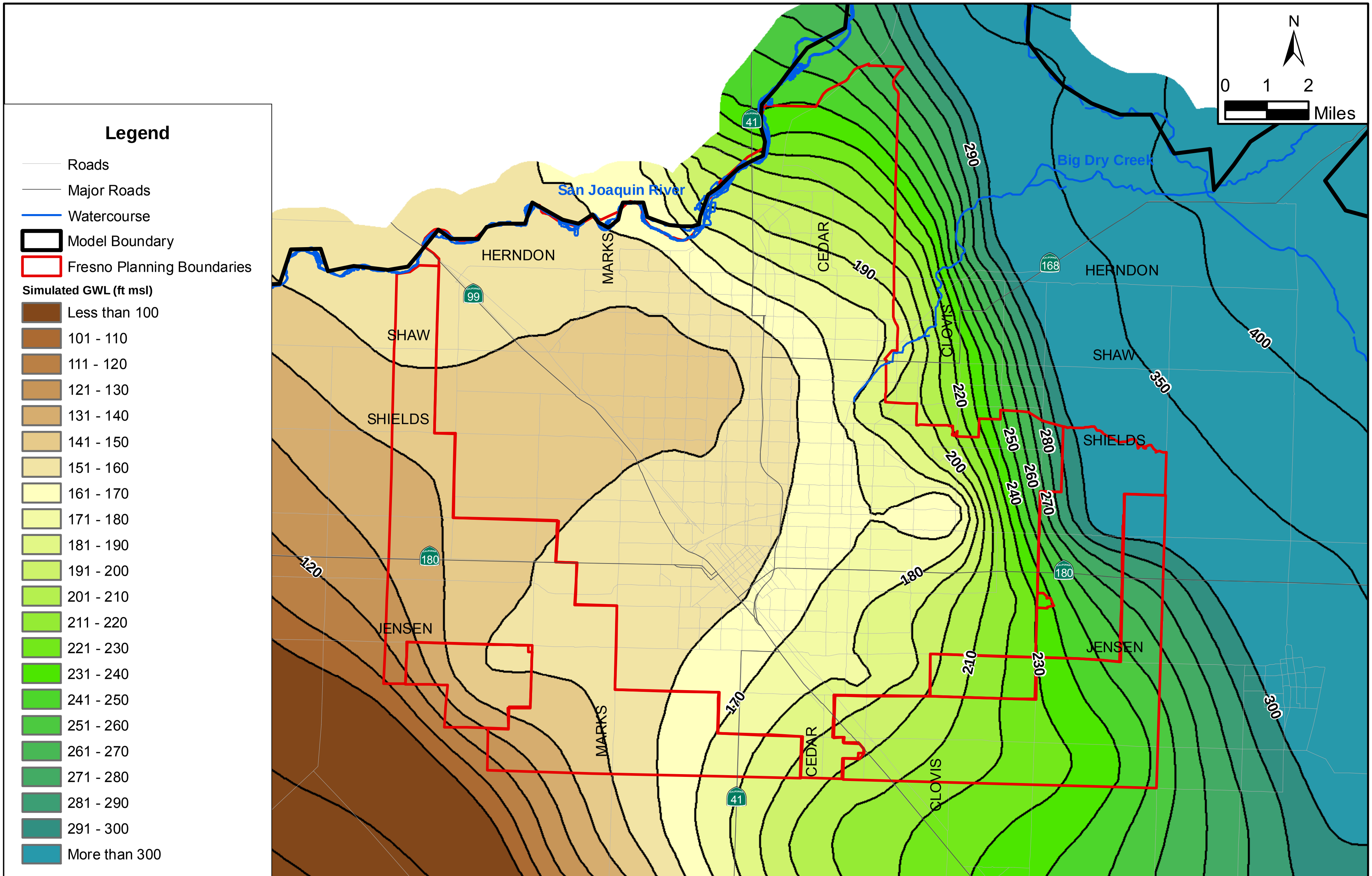
Simulated Groundwater Levels (Baseline - 2025)

Fresno Metro Plan - Phase 2

Simulated groundwater levels are an average of model layers 1 and 2 and an average of each of the 12 months for the water year

November 2008

Figure 5d



RIME

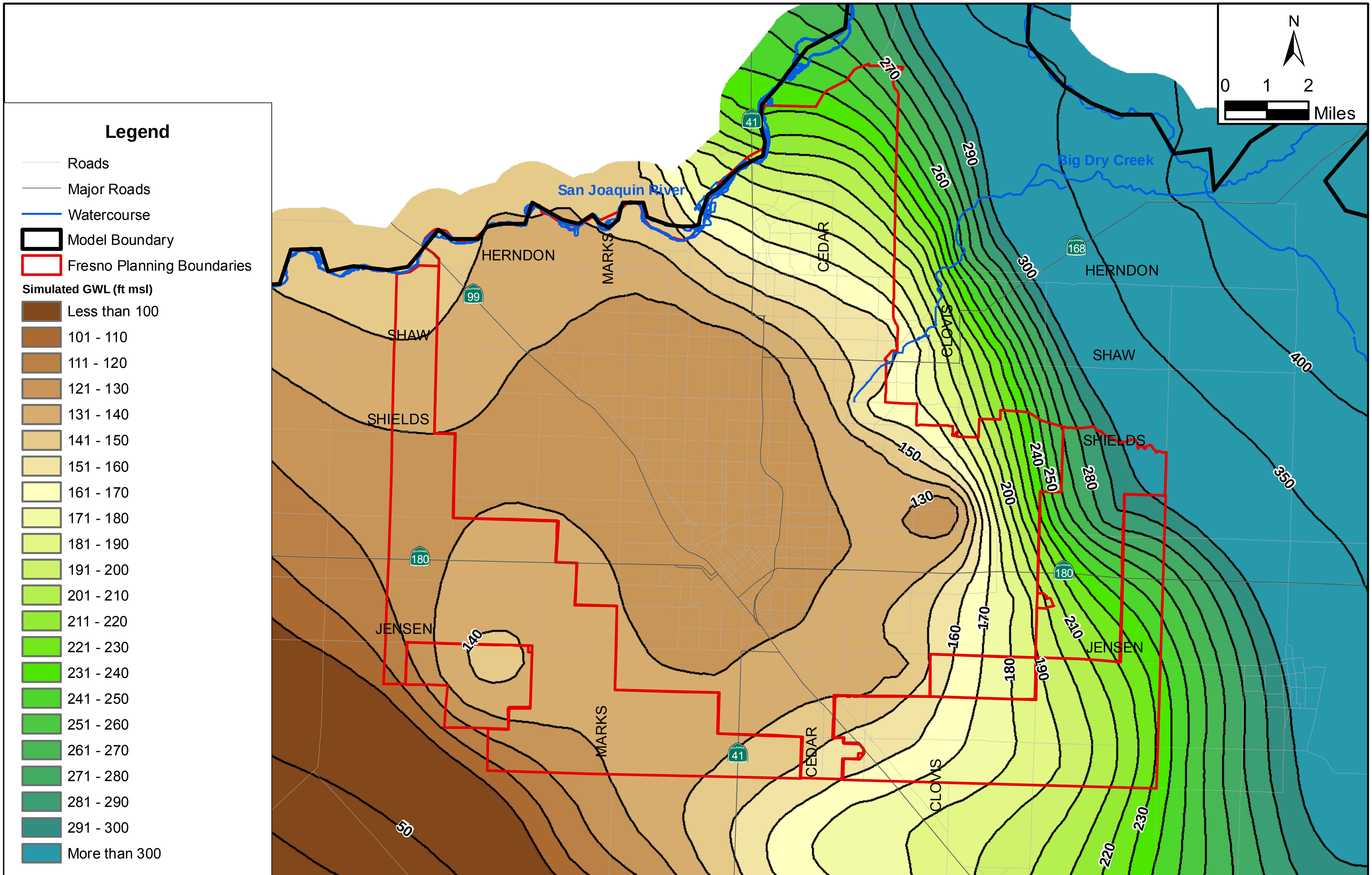
Simulated Groundwater Levels (Baseline - 2030)

Fresno Metro Plan - Phase 2

Simulated groundwater levels are an average of model layers 1 and 2 and an average of each of the 12 months for the water year

November 2008

Figure 5e



ωRIME

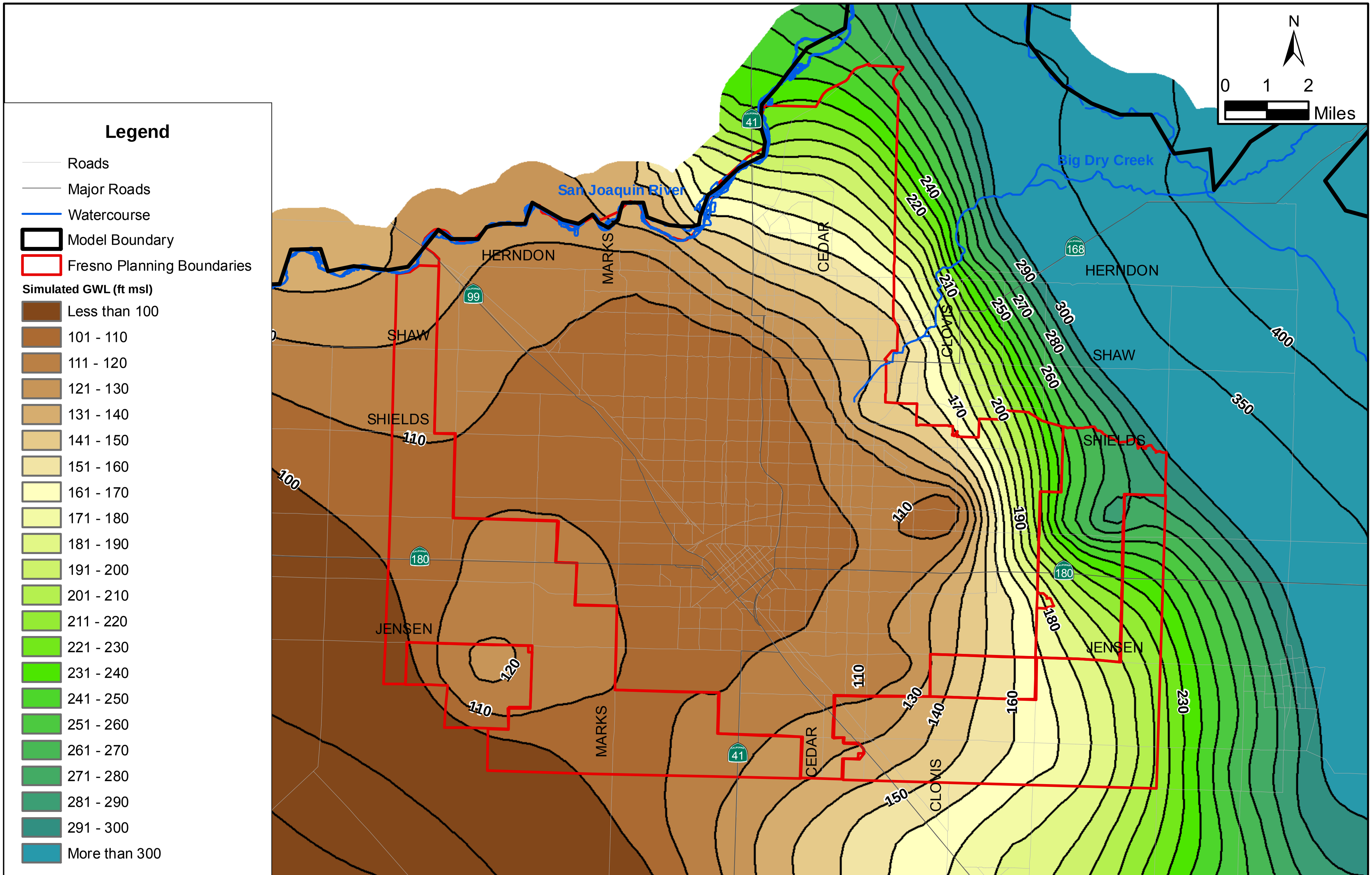
Simulated Groundwater Levels
(Baseline - 2050)

Fresno Metro Plan - Phase 2

Simulated groundwater levels are an average of model layers 1 and 2 and an average of each of the 12 months for the water year

November 2008

Figure 5f



ωRIME

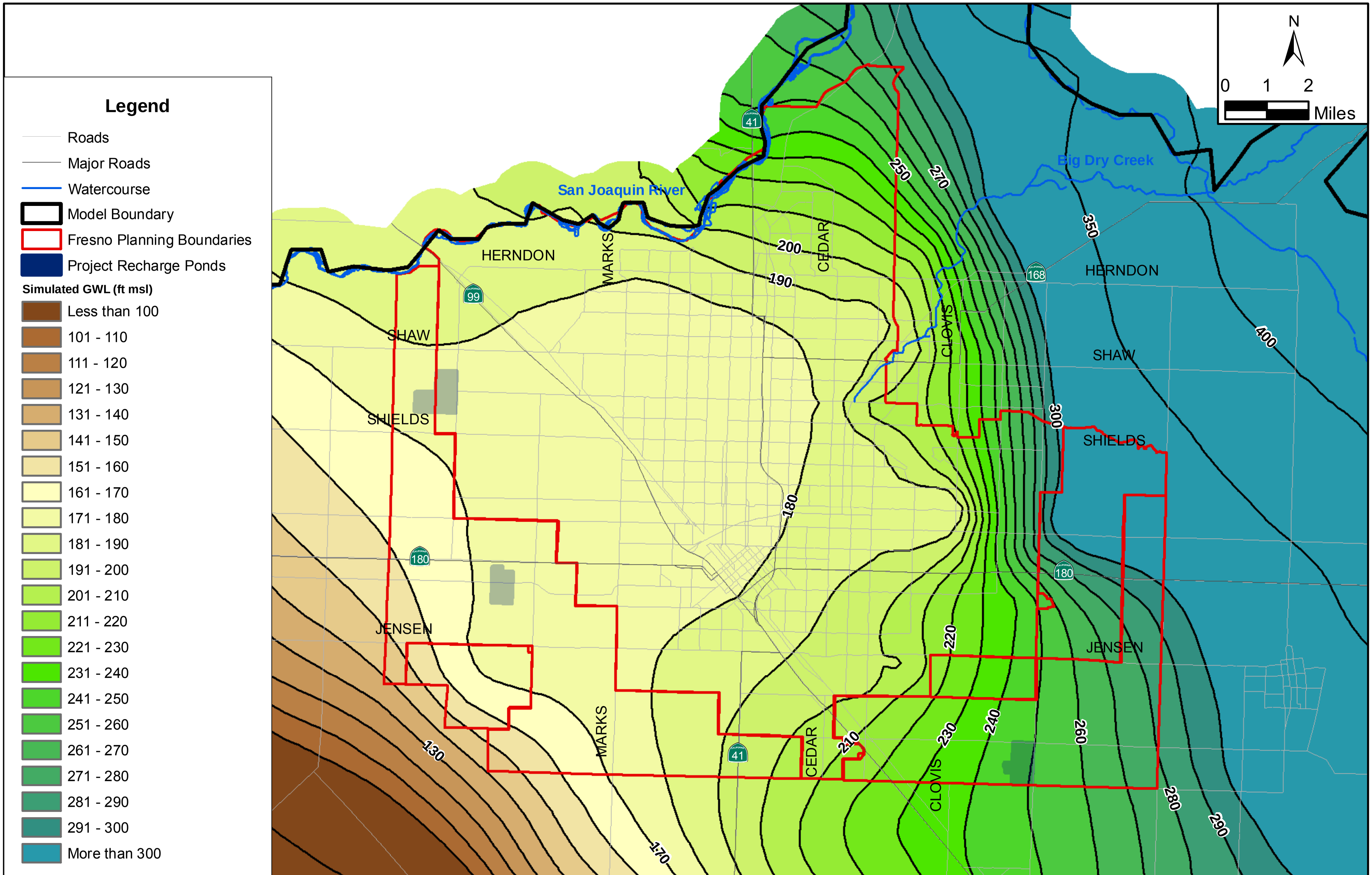
Simulated Groundwater Levels (Baseline - 2060)

Fresno Metro Plan - Phase 2

Simulated groundwater levels are an average of model layers 1 and 2 and an average of each of the 12 months for the water year

November 2008

Figure 5g



RIME

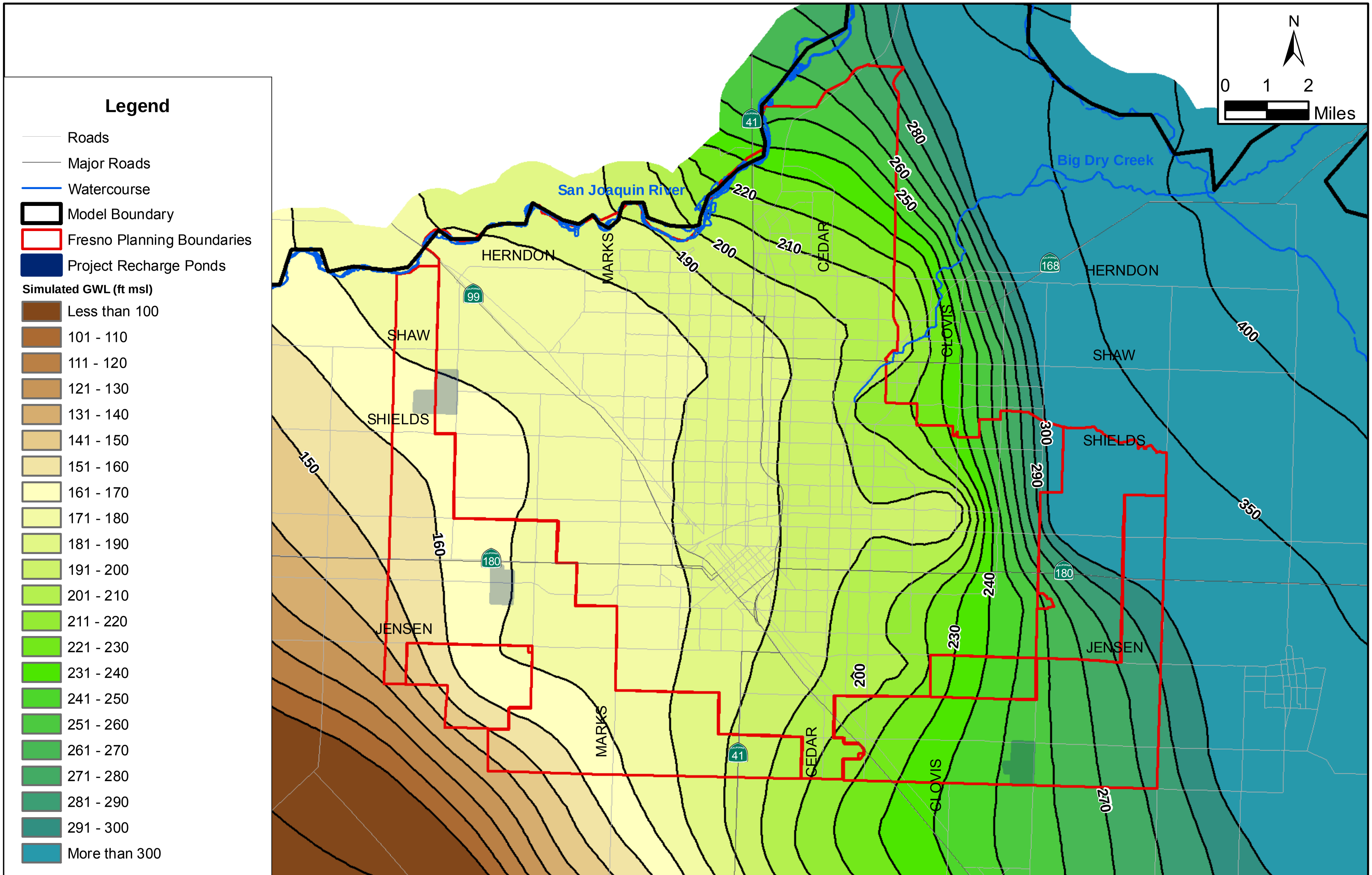
Simulated Groundwater Levels (With Project - 2010)

Fresno Metro Plan - Phase 2

Simulated groundwater levels are an average of model layers 1 and 2 and an average of each of the 12 months for the water year

November 2008

Figure 6a



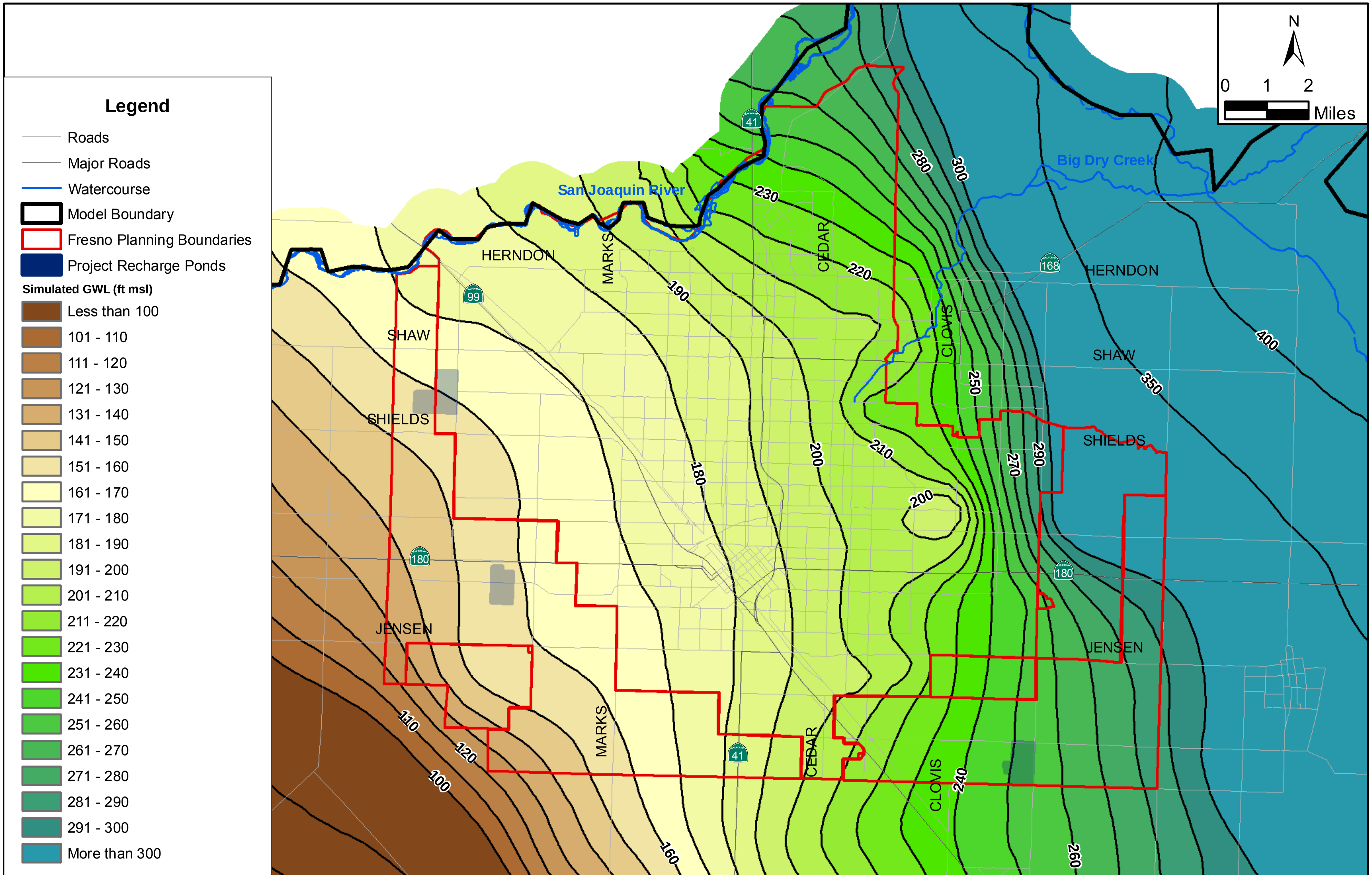
Simulated Groundwater Levels (With Project - 2015)

Fresno Metro Plan - Phase 2

Simulated groundwater levels are an average of model layers 1 and 2 and an average of each of the 12 months for the water year

November 2008

Figure 6b



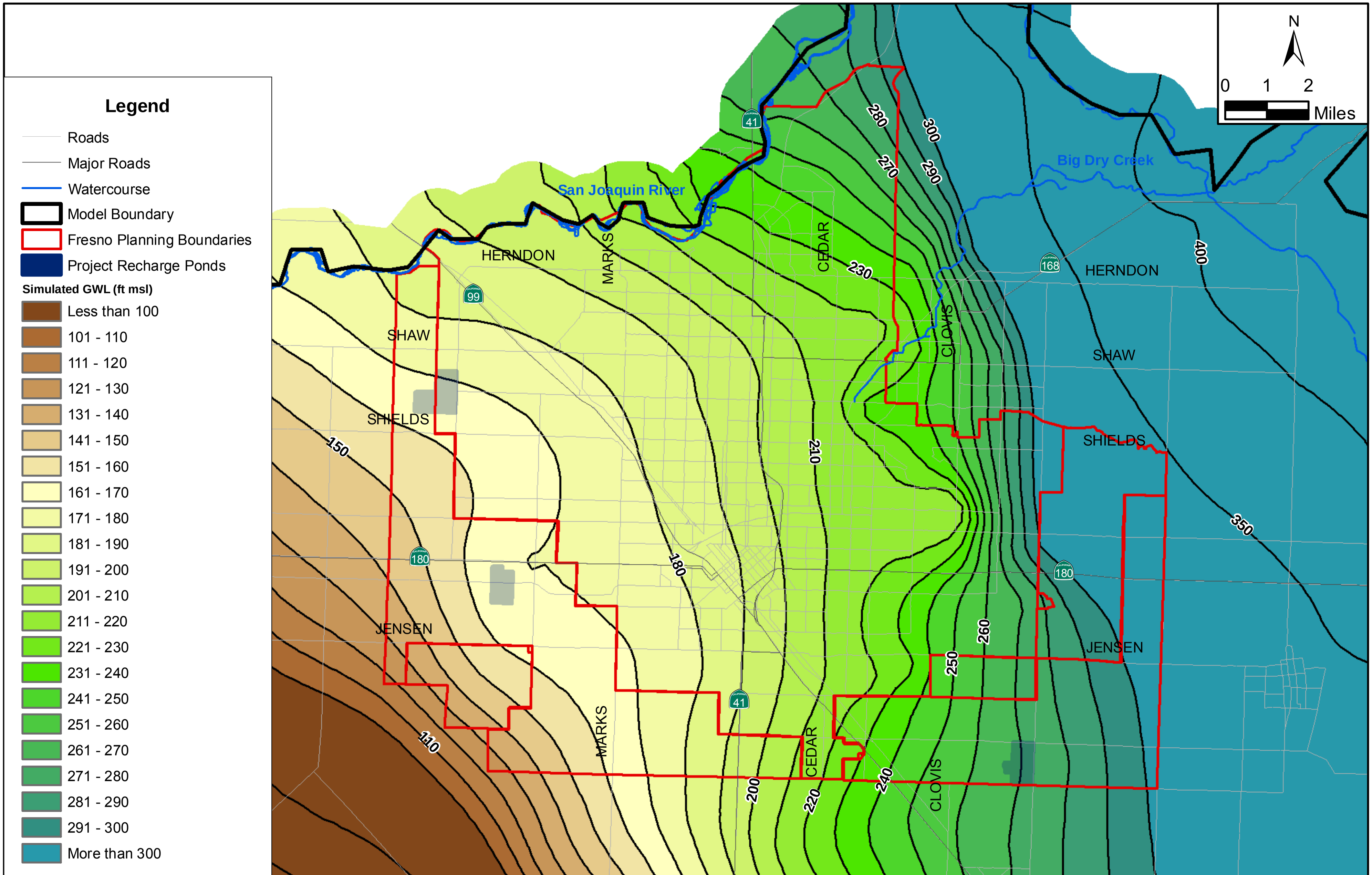
Simulated Groundwater Levels (With Project - 2020)

Fresno Metro Plan - Phase 2

Simulated groundwater levels are an average of model layers 1 and 2 and an average of each of the 12 months for the water year

November 2008

Figure 6c



ωRIME

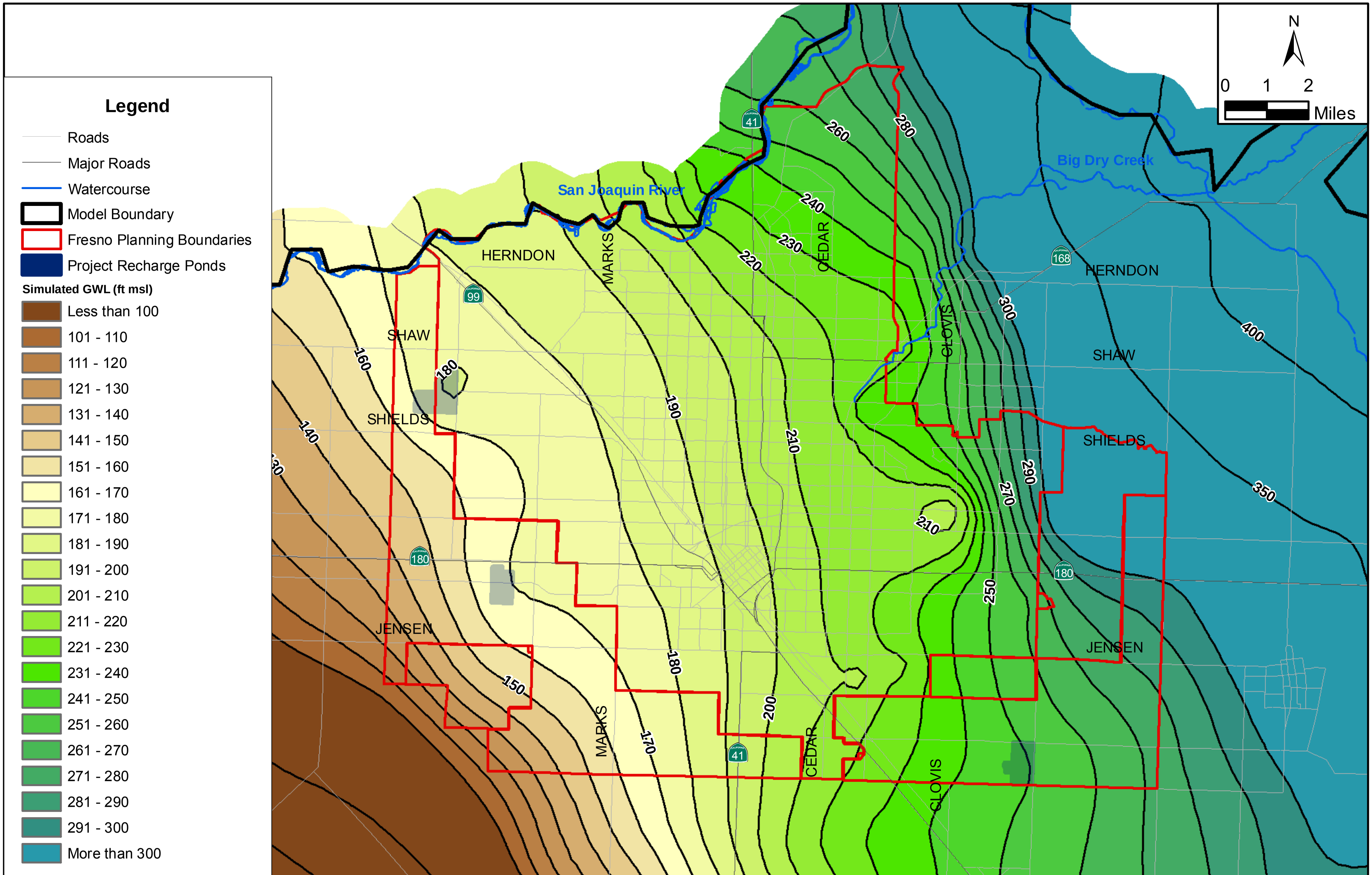
Simulated Groundwater Levels (With Project - 2025)

Fresno Metro Plan - Phase 2

Simulated groundwater levels are an average of model layers 1 and 2 and an average of each of the 12 months for the water year

November 2008

Figure 6d



RIME

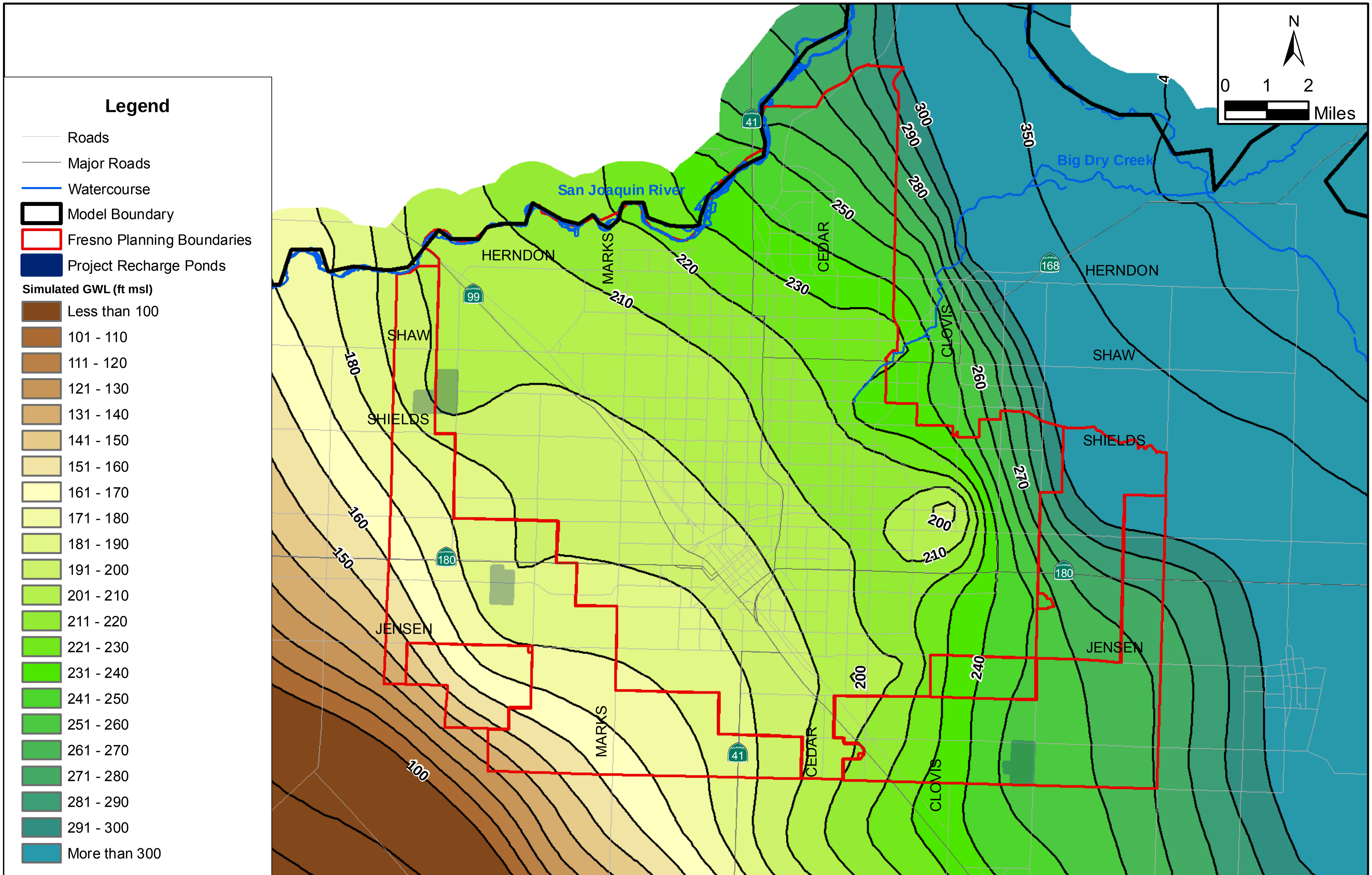
Simulated Groundwater Levels
(With Project - 2030)

Fresno Metro Plan - Phase 2

Simulated groundwater levels are an average of model layers 1 and 2 and an average of each of the 12 months for the water year

November 2008

Figure 6e



RIME

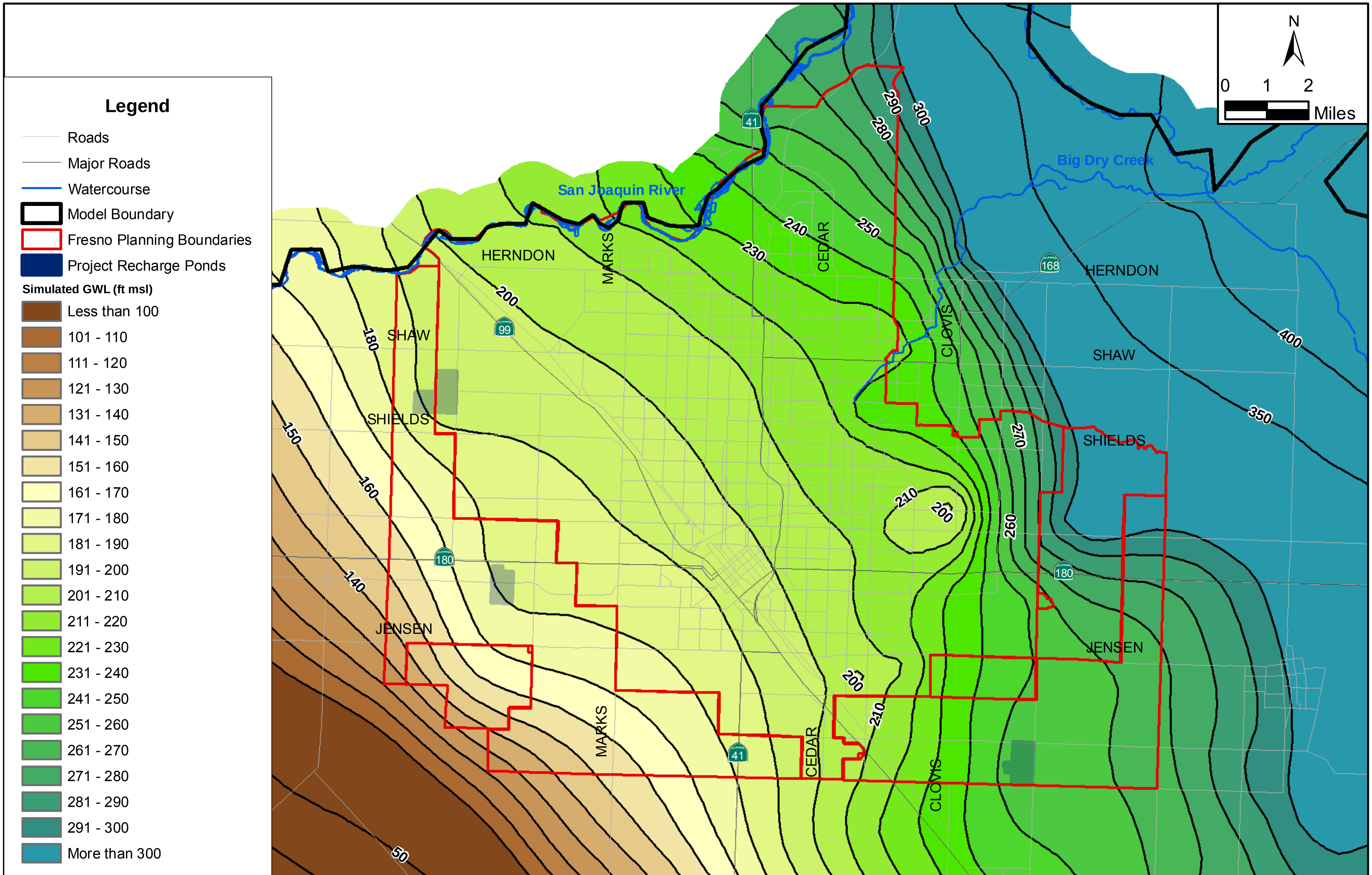
Simulated Groundwater Levels (With Project - 2050)

Fresno Metro Plan - Phase 2

Simulated groundwater levels are an average of model layers 1 and 2 and an average of each of the 12 months for the water year

November 2008

Figure 6f



ωRIME

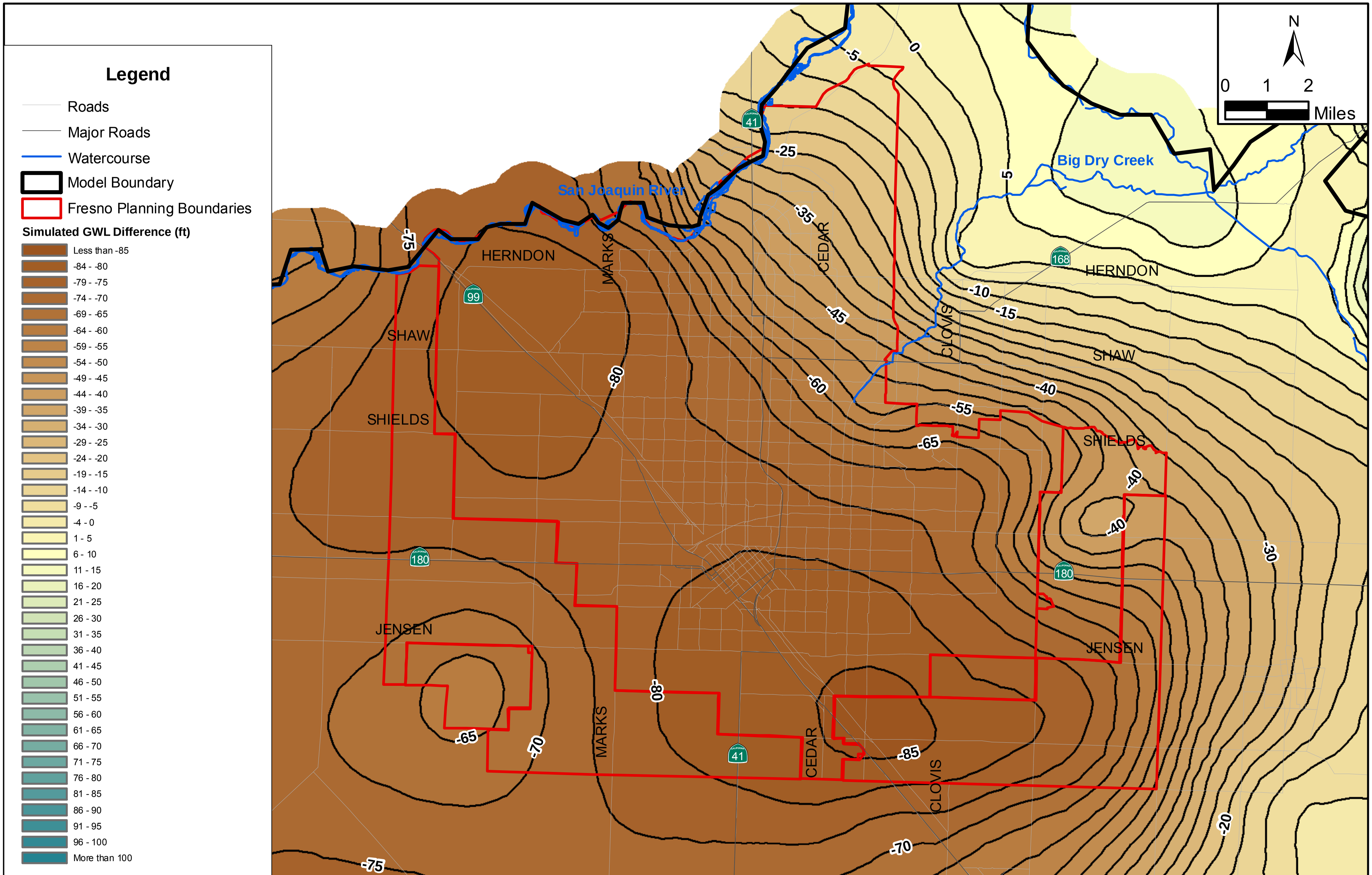
Simulated Groundwater Levels (With Project - 2060)

Fresno Metro Plan - Phase 2

Simulated groundwater levels are an average of model layers 1 and 2 and an average of each of the 12 months for the water year

November 2008

Figure 6g



Change in Simulated Groundwater Levels
(Baseline - 2060 minus 2005)

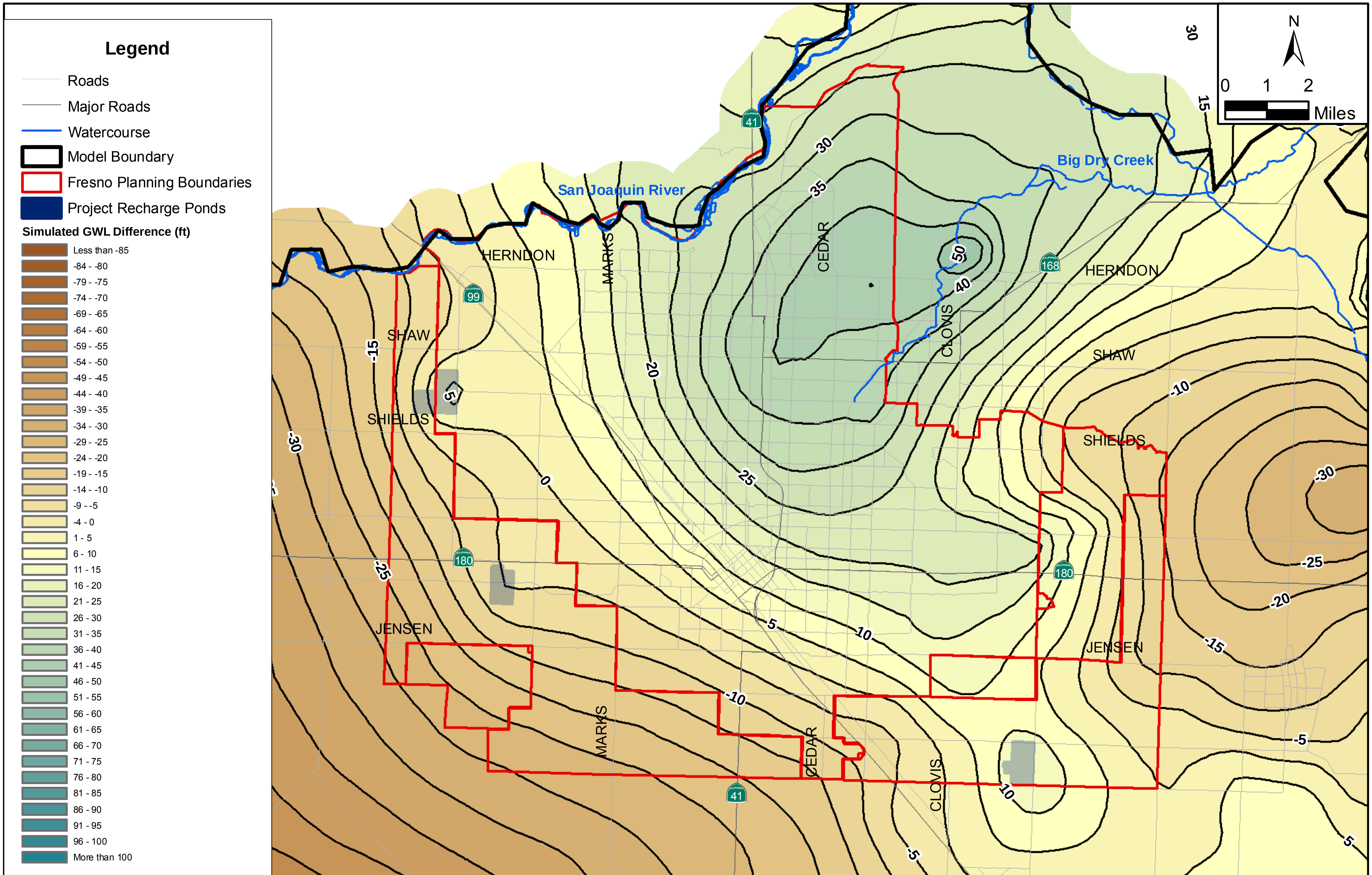
Fresno Metro Plan - Phase 2

Simulated groundwater levels are an average of model layers 1 and 2 and an average of each of the 12 months for the water year

RIME

November 2008

Figure 7a



WRIME

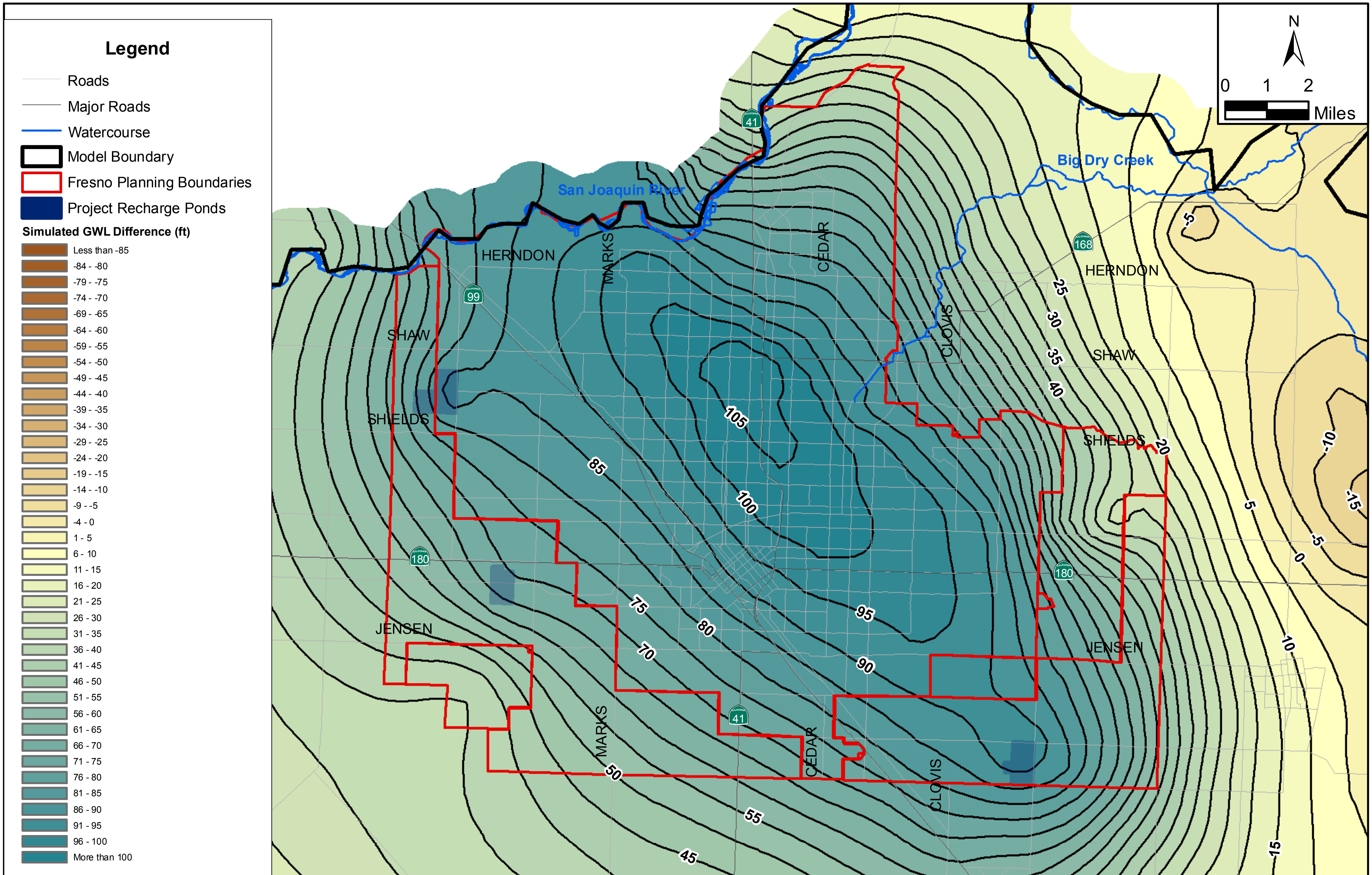
Change in Simulated Groundwater Levels (With Project - 2060 minus 2005)

Fresno Metro Plan - Phase 2

Simulated groundwater levels are an average of model layers 1 and 2 and an average of each of the 12 months for the water year

November 2008

Figure 7b



RIME

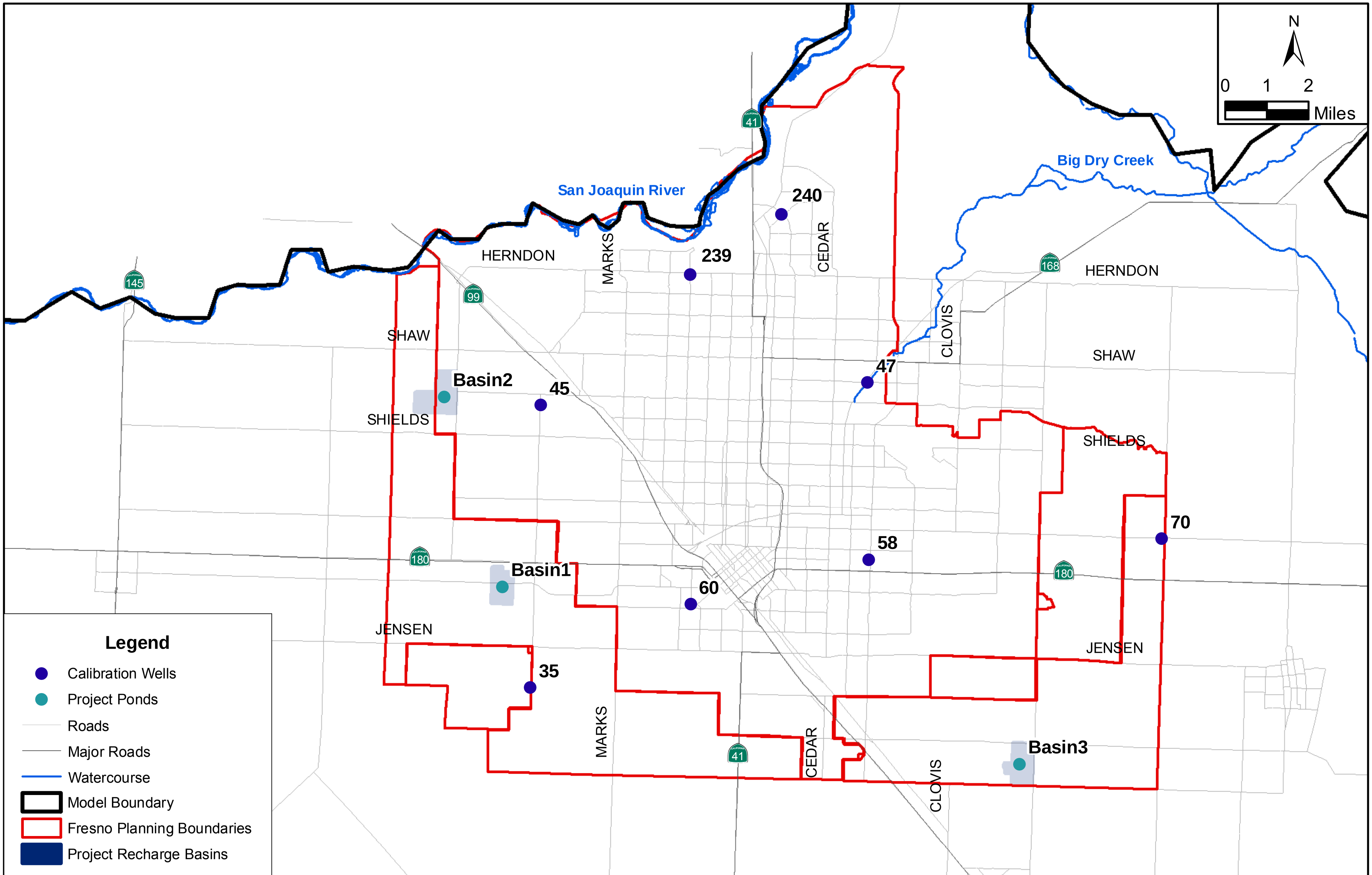
Change in Simulated Groundwater Levels (With Project minus Baseline - 2060)

Fresno Metro Plan - Phase 2

Simulated groundwater levels are an average of model layers 1 and 2 and an average of each of the 12 months for the water year

November 2008

Figure 8



Hydrograph Locations

Fresno Metro Plan - Phase 2

November 2008

Figure 9a

Figure 9b. Simulated Well Hydrographs

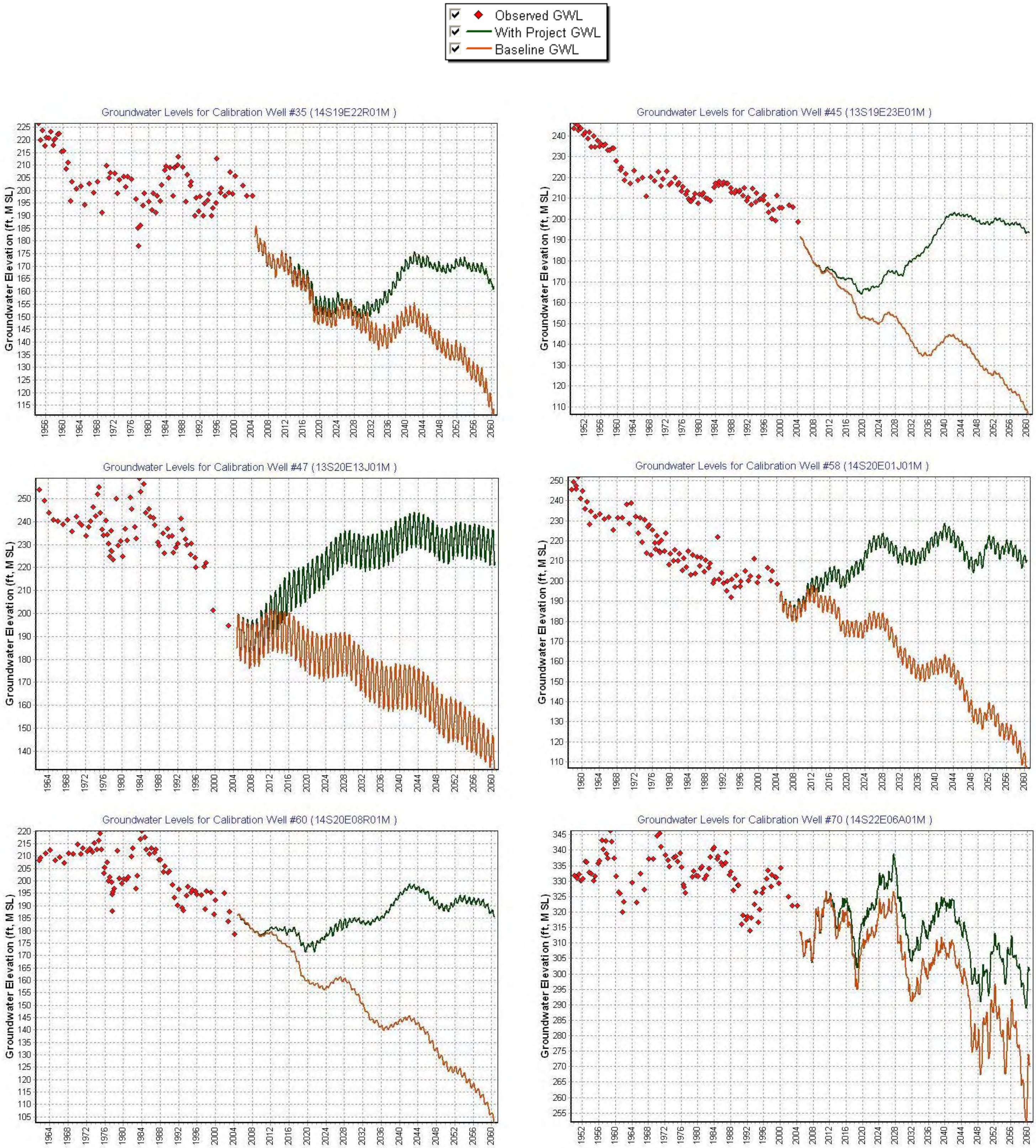


Figure 9c. Simulated Well Hydrographs