Appendix 7-2

DWR Kern Water Bank Model Results Technical Report

Prepared for:

State of California
California Natural Resources Agency
Department of Water Resources

Prepared by:

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With Technical Assistance from:

RMC Water and Environment
Fugro Consultants
The Sandberg Group

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ACRONYMS AND OTHER ABBREVIATIONS

AF	acre-feet
AFO	Analysis of Future Operations
AFY	acre-feet per year
Amec	Amec Foster Wheeler
APO	Analysis of Past Operations
BC	Buildout Conditions
bgs	below ground surface
C2VSim	California Central Valley Groundwater–Surface Water Simulation
Cal Water	California Water Service Company
CASGEM	California Statewide Groundwater Elevation Monitoring
CHD	MODFLOW time-variant specified-head
COB	City of Bakersfield
Court	Sacramento County Superior Court
CVHM	Central Valley Hydrologic Model
Department	California Department of Water Resources
EC	Existing Conditions
EIR	environmental impact report
GHB	general head boundary
GIS	geographic information system
ID4	Improvement District No. 4
KCWA	Kern County Water Agency
KFMC	Kern Fan Monitoring Committee
KWB	Kern Water Bank
KWBA	Kern Water Bank Authority
Kx/Kz ratio	horizontal to vertical conductivity ratio
LOD	level of development
LsCuS	Large-Scale Coarsening-Upward Sequences
MAF	million acre-feet
Monterey Plus	Monterey Amendment to the State Water Project Contracts (Including Kern Water Bank Transfer) and Associated Actions as Part of a Settlement Agreement
Monterey Plus EIR	*Environmental Impact Report for the Monterey Amendment to the State Water Project Contracts (Including Kern Water Bank Transfer) and Associated Actions as Part of a Settlement Agreement*
Monterey Plus Revised EIR or REIR	*Revised Environmental Impact Report for the Monterey Amendment to the State Water Project Contracts (Including Kern Water Bank Transfer) and Associated Actions as Part of a Settlement Agreement*
NRMS	normalized root mean squared
REIR	*Revised Environmental Impact Report for the Monterey Amendment to the State Water Project Contracts (Including Kern Water Bank Transfer) and Associated Actions as Part of a Settlement Agreement*
Rosedale or RRBWSD	Rosedale–Rio Bravo Water Storage District
SWP	State Water Project
TAF	thousand acre-feet

USGS	U.S. Geological Survey
UWMP	urban water management plan
WD	Water District
WEL	MODFLOW Well
WSD	Water Storage District

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1. INTRODUCTION

1.1 PURPOSE AND SCOPE OF THIS TECHNICAL REPORT

To evaluate the potential groundwater impacts of the Kern Water Bank (KWB) operations, the California Department of Water Resources (Department or DWR) developed a groundwater model, called the DWR Kern Water Bank Model (DWR KWB Model), in 2015.

Quantitative assessment of the impacts of KWB activities on groundwater resources in the Kern County subbasin No. 5-22.14 (as identified in DWR Bulletin 118) was conducted using the DWR KWB Model. The purpose of this technical report is to:

- describe the three modeling scenarios used to evaluate the impacts of KWB activities, and
- document the results of the modeling analysis for each scenario.

This technical report is organized into the following four major chapters:

- Chapter 1 presents the purpose and scope of this technical report,
- Chapter 2 describes the modeling scenarios and assumptions for the Revised Environmental Impact Report (REIR) analysis,
- Chapter 3 describes the results of the modeling analysis, and
- Chapter 4 lists the references cited in this technical report.

2. MODELING SCENARIOS AND ASSUMPTIONS

Three primary modeling scenarios were constructed to evaluate the effects of KWB activities under different levels of development (historical, existing conditions, and buildout conditions) within the model domain. The primary differences among the three scenarios are changes in agricultural and urban pumping attributable to different land uses and additional groundwater-related projects within the model domain. Each scenario is introduced below and described in detail in the following subsections:

1. The Analysis of Past Operations (APO) scenario examines historical groundwater conditions during the period of KWB operations (i.e., from 1995 through 2014).

2. The Analysis of Future Operations (AFO) under Existing Conditions (EC) scenario, referred to here as “AFO-EC,” examines a similar duration as the APO scenario, but fixes land use at 2015 conditions and uses groundwater banking facilities constructed as of 2014.

3. The AFO under Buildout Conditions (BC) scenario, referred to here as “AFO-BC,” examines groundwater conditions under 2030 land use conditions, groundwater banking facilities constructed as of 2014, and selected groundwater banking facilities likely to be operational by 2030.

Each scenario was run “With KWB Operations” and “Without KWB Operations,” for a total of six model runs. The model simulation period for the APO scenario is a 20-year past period (1995-2014) using the historical hydrology from 1995 through 2015. The model simulation period for both AFO scenarios is a 21-year future period (2015-2035) using historical 2015 hydrology in simulation year 1 (2015) and repeating the historical 1995-2014 hydrology for simulation years 2 to 21 (2016-2035).

Additional descriptions of these scenarios are provided below.

2.1 ANALYSIS OF PAST OPERATIONS

The APO “With KWB Operations” scenario is equivalent to the DWR KWB Model historical calibration described in Technical Report entitled “Development of DWR Kern Water Bank Model: Model Review, Selection, and Enhancements” (DWR, 2016). The DWR KWB Model simulates the period from 1988 through 2014, but the focus of the APO scenario is the 20-year period of KWB activities, from 1995 through 2014. This scenario includes historical urban and agricultural land uses, operation of recharge and recovery facilities, and hydrologic conditions (Table 2.1-1).

2.2 SCENARIOS WITHOUT KERN WATER BANK OPERATIONS

KWB recharge and recovery operations were removed from the model as if the land was fallowed for all “Without KWB Operations” scenarios (Table 2.1-1). Historical recharge of floodwater on KWB Lands was also removed from the model for “Without KWB Operations” scenarios. Lack of recharge and recovery at KWB facilities under “Without KWB Operations” scenarios was not offset by increased recharge and recovery at other groundwater banking facilities. These “Without KWB Operations” assumptions are not discussed separately in the subsections below because they are shared for the APO, AFO-EC, and AFO-BC scenarios.

TABLE 2.1-1

SUMMARY OF KERN WATER BANK REVISED ENVIRONMENTAL IMPACT REPORT SCENARIOS

Model Component	APO		AFO-EC		AFO-BC	
	With KWB Operations	Without KWB Operations	With KWB Operations	Without KWB Operations	With KWB Operations	Without KWB Operations
Hydrologic Simulation Period	20 year simulation period (1995–2014 historic hydrology)	20-year simulation period (1995–2014 historic hydrology)	21-year simulation period from 2015 through 2035 (The hydrology of year 1 is similar to 2015 and years 2 to 21 are similar to 1995–2014 historical hydrology)	21 year simulation period from 2015 through 2035 (The hydrology of year 1 is similar to 2015 and years 2 to 21 used 1995–2014 historical hydrology)	21-year simulation period from 2015 through 2035 (The hydrology of year 1 is similar to 2015 and years 2 to 21 used 1995–2014 historical hydrology)	21-year simulation period from 2015 through 2035 (The hydrology of year 1 is similar to 2015 and years 2 to 21 used 1995–2014 historical hydrology)
Land Use (areas outside of KWB Lands)	1995–2014 Historic Land Use in the DWR KWB Model	1995–2014 historic land use in the DWR KWB Model	2015 level of land use in the model domain held constant for the 21-year future simulation period (2015–2035) Agricultural area ~ 132,000 acres Urban area ~ 56,000 acres	2015 level of land use in the model domain held constant for the 21-year future simulation period (2015–2035) Agricultural area ~ 132,000 acres Urban area ~ 56,000 acres	2015 level of land use in the model domain held constant for the 21-year future simulation period (2015–2035) Agricultural area ~ 110,000 acres Urban area ~ 83,000 acres	2015 level of land use in the model domain held constant for the 21-year future simulation period (2015–2035) Agricultural area ~ 110,000 acres Urban area ~ 83,000 acres
Land Use (on KWB Lands	No agriculture on KWB lands	No agriculture on KWB lands	No agriculture on KWB lands	No agriculture on KWB lands	No agriculture on KWB lands	No agriculture on KWB lands
Agricultural Pumping (areas outside of KWB Lands)	7,935,432 AF (historical total for 1995–2014, a 20 -year period)	7,935,432 AF (historical total for 1995–2014, a 20-year period)	8,436,580 AF (total for 2016–2035, a 20-year period with constant 2015 level of agricultural land use	8,436,580 AF (total for 2016–2035, a 20-year period with constant 2015 level of agricultural land use	7,001,724 AF (total for 2016–2035, a 20-year period with constant 2030 level of agricultural land use	7,001,724 AF (total for 2016–2035, a 20-year period with constant 2030 level of agricultural land use)
Agricultural Pumping (on KWB Lands)	No agricultural pumping	No agricultural pumping	No agricultural pumping	No agricultural pumping	No agricultural pumping	No agricultural pumping
Urban Pumping	Total volume: 700,272 AF	Total volume: 700,272 AF	Total volume: 1,592,424 AF	Total volume: 1,592,424 AF	Total volume: 1,652,826 AF	Total volume: 1,652,826 AF
KWB Recharge	Total volume after 6 percent loss: 2,006,372 AF	0 AF	Total volume after 6 percent loss: 2,112,325 AF (Note: All operational ponds in 2015 would be used for future recharge during 2015–2035)	0 AF	Total volume after 6 percent loss: 2,112,325 AF (Note: All operational ponds in 2015 plus an additional 1,090 acres of recharge ponds would be used for future recharge during 2015–2035)	0 AF
KWB Recharge Distribution	1995–2014 historical recharge distribution in the DWR KWB Model	None	Recharge distribution rearranged to match KWB recharge priority order. More water is recharged in eastern ponds	None	Recharge distribution rearranged to match KWB recharge priority order. More water is recharged in eastern ponds	None
KWB Recovery	Total volume: 1,389,113 AF	0 AF	Total volume: 1,546,368 AF (Note: All operational wells in 2015 would be used for future recovery during 2015–2035)	0 AF	Total volume: 1,614,236 AF (Note: All operational wells in 2015 plus three planned recovery wells would be used for future recovery during 2015–2035)	0 AF
KWB Recovery Distribution	1995–2014 historical recovery distribution in the DWR KWB Model	None	All operational wells in 2015 are used for future recovery during 2015–2035	None	All operational wells in 2015 plus 3 planned recovery wells are used for future recovery during 2015–2035	N/A
Other Water Banks Recharge & Recovery	Historic recharge/recovery in the DWR KWB Model	Historic recharge/recovery in the DWR KWB Model	Historic recharge/recovery in the DWR KWB Model	Historic recharge/recovery in the DWR KWB Model	Historic recharge/recovery in the DWR KWB Model	Historic recharge/recovery in the DWR KWB Model

TABLE 2.1-1

SUMMARY OF KERN WATER BANK REVISED ENVIRONMENTAL IMPACT REPORT SCENARIOS

Model Component	APO		AFO-EC		AFO-BC	
	With KWB Operations	Without KWB Operations	With KWB Operations	Without KWB Operations	With KWB Operations	Without KWB Operations
Kern River Flooding on KWB Lands	Historical 1988–2014 flood water recharge in the KWB	0 AF	Historical 1995-2014 flood water recharge in the KWB plus additional recharge because of increased capacity for operational ponds in 2015	0 AF	Historical 1995–2014 flood water recharge in the KWB plus additional recharge because of increased capacity for operational ponds in 2015	0 AF
Boundary Conditions	1995–2014 historical boundary conditions in the DWR KWB Model	1995–2014 historical boundary conditions in the DWR KWB Model	1995–2014 historical boundary conditions in the DWR KWB Model are adjusted for 2015 conditions to follow similar pattern of fluctuations under historical hydrology, while starting from the December 2014 simulated groundwater elevations at boundary control points of the historical calibrated groundwater model.	1995-2014 historical boundary conditions in the DWR KWB Model are adjusted for 2015 conditions to follow similar pattern of fluctuations under historical hydrology, while starting from the December 2014 simulated groundwater elevations at boundary control points of the historical calibrated groundwater model.	1995–2014 historical boundary conditions in the DWR KWB Model are adjusted for 2015 conditions to follow similar pattern of fluctuations under historical hydrology, while starting from the December 2014 simulated groundwater elevations at boundary control points of the historical calibrated groundwater model.	1995-2014 historical boundary conditions in the DWR KWB Model are adjusted for 2015 conditions to follow similar pattern of fluctuations under historical hydrology, while starting from the December 2014 simulated groundwater elevations at boundary control points of the historical calibrated groundwater model.
Initial Conditions	Simulated December 1994 conditions from the historical calibrated model	Simulated December 1994 conditions from the historical calibrated model	Simulated December 2014 conditions generated by the APO-run "With KWB Operations"	Simulated December 2014 conditions generated by the APO-run "Without KWB Operations"	Simulated December 2014 conditions generated by the APO-run "With KWB Operations"	Simulated December 2014 conditions generated by the APO-run "Without KWB Operations"
Aquifer Parameters	Aquifer parameters from the historical calibrated model	Aquifer parameters from the historical calibrated model	Aquifer parameters from the historical calibrated model	Aquifer parameters from the historical calibrated model	Aquifer parameters from the historical calibrated groundwater model	Aquifer parameters from the historical calibrated groundwater model
Future Projects on KWB Lands	Historic operation; therefore, no future projects	None	All currently active projects on KWB Lands	None	Groundwater operations related projects.	None
Future Projects Outside KWB Lands	Historic operation; therefore, no future projects	None	All currently active projects outside KWB Lands	All currently active projects outside KWB Lands	Groundwater operations related projects.	Groundwater operations related projects.

Notes: AF = acre-feet; APO = Analysis of Past Operations; DWR = Department of Water Resources; KWB = Kern Water Bank; KWBA = Kern Water Bank Authority; N/A = not applicable

2.3 ANALYSIS OF FUTURE OPERATIONS

The AFO scenarios evaluate potential future operations of recharge and recovery facilities within the model domain. APO scenarios include the historical timing of recharge and recovery facilities as they are brought into operation; AFO scenarios assume that all infrastructure for recharge and recovery is in place at the start of the simulation period. The following subsections discuss elements of the AFO that are common to both the EC and BC scenarios and those model elements that are unique to EC or BC scenarios.

2.3.1 COMMON ELEMENTS BETWEEN SCENARIOS: ANALYSES OF FUTURE OPERATIONS UNDER EXISTING AND BUILDOUT CONDITIONS

This subsection describes model components that changed for both the AFO-EC and AFO-BC scenarios relative to the APO scenario.

2.3.1.1 Simulation Period

Both the AFO-EC and AFO-BC scenarios consist of a 21-year simulation period. Year 1 hydrology for AFO scenarios is similar to 2015, while Years 2–21 of the AFO scenarios use similar hydrology as 1995.

The decision to approximate 2015 conditions for Year 1 of AFO scenarios was made because of evidence (e.g., from discussions with representatives from groundwater banking projects) that significant groundwater banking recovery was occurring in 2015 because of drought conditions. Simply repeating the 1995–2014 historical hydrology for AFO runs would ignore that evidence and potential impacts that could result from starting the future analysis in a recovery cycle (as was the case for 2015). Additional details regarding the approximation of 2015 conditions in the model (e.g., locations and quantity of groundwater banking recovery) are provided below.

2.3.1.2 Initial Conditions

Initial heads for the AFO “With KWB Operations” and AFO “Without KWB Operations” scenarios were taken from the final time step of the APO “With KWB Operations” and APO “Without KWB Operations” simulations, respectively. This assumption, therefore, allows comparisons of the differences between continued operations of the KWB into the future versus a scenario in which the KWB never operated. Any impacts (positive or negative) that accrued over the 1995–2014 operation of the KWB are carried over to the start of the AFO scenarios.

2.3.1.3 Boundary Conditions

AFO general head boundary (GHB) conditions are assumed to follow similar patterns of fluctuations as those that occurred under historical hydrology. Transient heads for AFO GHBs were developed as follows (see Figure 2.3-1):

- The starting elevation for Year 1 of the simulation is the same as the ending elevation for the APO simulation (i.e., from the end of 2014).
- Transient head fluctuations (i.e., the monthly change relative to starting elevation) in Year 1 are copied from the GHB heads for the period corresponding to calendar year 2014 in the Kern Water Bank Authority (KWBA) historical model.
- Transient head fluctuations for Years 2–21 are copied from the GHB heads in the KWBA historical model and pasted to the levels at the end of Year 1.

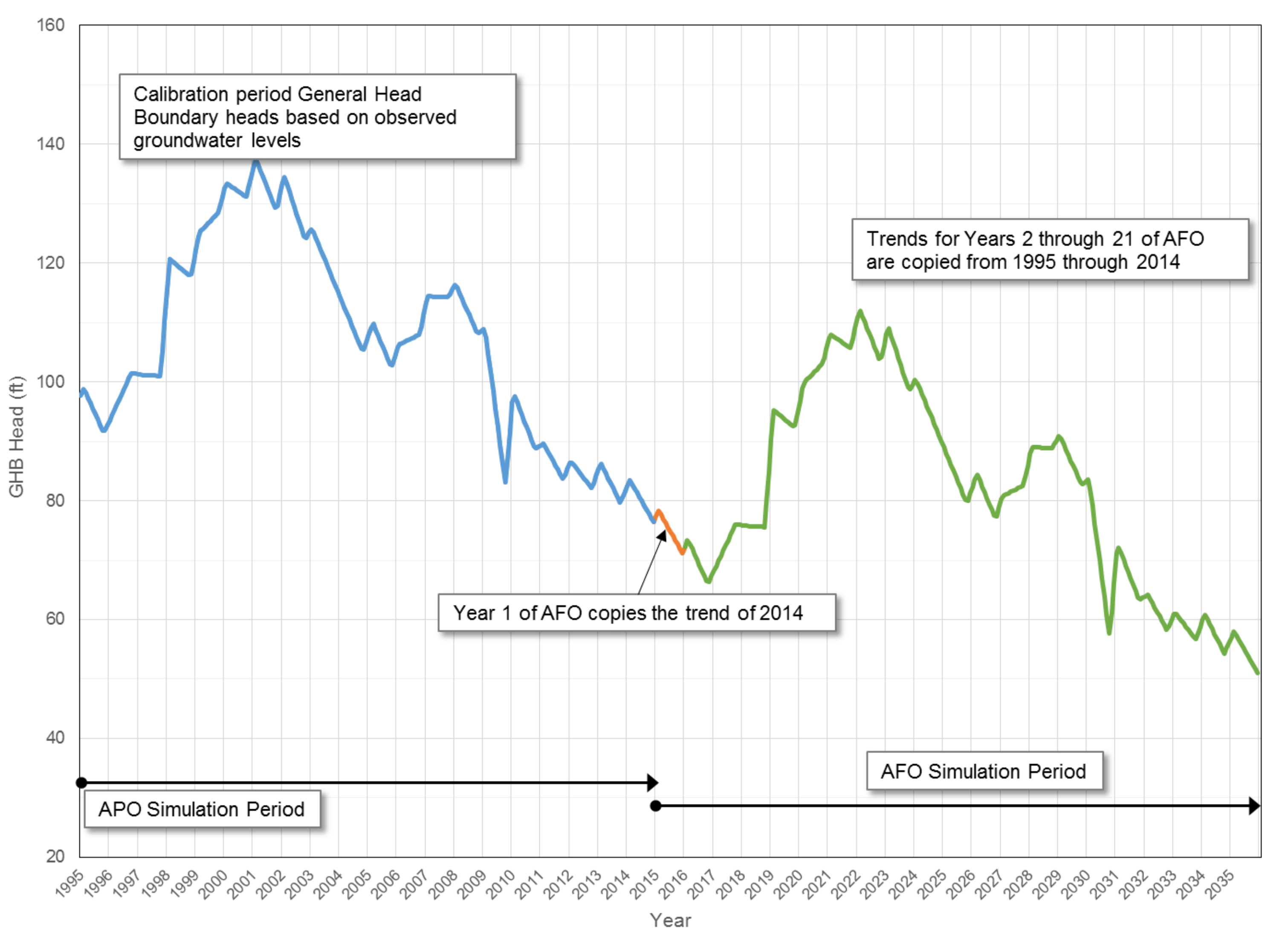


FIGURE 2.3-1. **Example of Heads for General Head Boundary Condition Cells in the Analysis of Past Operations and Analysis of Future Operations Scenarios, 1995-2035**

These transient GHB heads were used for both the AFO-EC and AFO-BC scenarios. GHB conductance was not modified relative to the DWR KWB Model.

2.3.2 ANALYSIS OF FUTURE OPERATIONS UNDER EXISTING CONDITIONS

For this study, “existing conditions” refers to a 2015 level of development (LOD). The AFO-EC scenarios assume that the footprint of groundwater banking facilities, agricultural lands, and urban lands is held constant at the 2015 LOD for the entire simulation. Recharge and recovery facilities that were constructed as of the end of 2014 are available to operate throughout the AFO-EC simulation period. Historical hydrology from 1995 through 2014 is incorporated into the AFO-EC scenario via the timing of groundwater banking recharge and recovery operations. Specific components of the AFO-EC are noted in Table 2.1-1 and described below.

2.3.2.1 Existing Conditions Groundwater Banking Operations

Since the start of the APO model simulation in 1988, groundwater banking projects within the model domain have expanded facilities and increased capacity for both recharge and recovery. The AFO-EC “With KWB Operations” scenario includes all existing groundwater banking recharge ponds and recovery wells active by the end of 2014 and assumes that no changes to infrastructure occur during the 21-year simulation period. Existing recharge and recovery capacity at the end of 2014 is held constant for the entire AFO-EC simulation period. The AFO-EC “Without KWB Operations” scenario is the same, except that recharge and recovery for the KWB is set to zero for the entire simulation period.

Kern Water Bank Recharge Operations

Within the KWB, recharge practices and facilities have changed throughout KWB’s lifetime. Since KWB operations began in 1995, the KWB has adjusted recharge practices to recharge more water in the eastern portion of KWB Lands. Additionally, new ponds have come into existence. AFO-EC KWB recharge (Figure 2.3-2) is based on historical recharge rates from 1995 through 2014, with modifications to account for the capacity for additional recharge volume and the distribution of recharged water, as described below.

<u>Additional Recharge Volume</u>

Historically, the KWB has maximized its recharge capacity during flood years. Construction of additional recharge ponds has increased KWB’s recharge capacity beyond what was available historically. Additional capacity for each month of the AFO-EC was estimated by assigning historically averaged, pond-specific recharge rates to ponds that were inactive or did not exist during past recharge cycles. The volumes that could have filled the additional ponds are considered the additional capacity for recharge.

Flood years were identified as those where April–July Kern River flows exceeded 170 percent of the historical average flow. These years were identified as 1995, 1998, 2005, 2006, and 2011. During years of high flow, Kern River water that is not recharged to the KWB or other projects is routed to the Kern River–California Aqueduct Intertie and taken out of the region through the California Aqueduct. With the addition of new ponds, the KWB has increased capacity to recharge a portion of this excess floodwater that otherwise would leave the region. Additional Kern River water recharged to the KWB is limited based on the availability of excess Kern River water and the capacity for recharge within the bank. Historical data showed that excess Kern River water was available for recharge in 1995, 1998, and 2006. In 1995, 42,000 acre-feet (AF) of Kern River water flooded farmland, while in 1998 and 2006, 132,266 and 70,624 AF of Kern River water reached the intertie, respectively. Based on capacity and availability, an additional 39,480 AF, 55,785 AF, and 17,459 AF of water could be recharged in the KWB in the 1995, 1998, and 2006 hydrologic years, respectively.

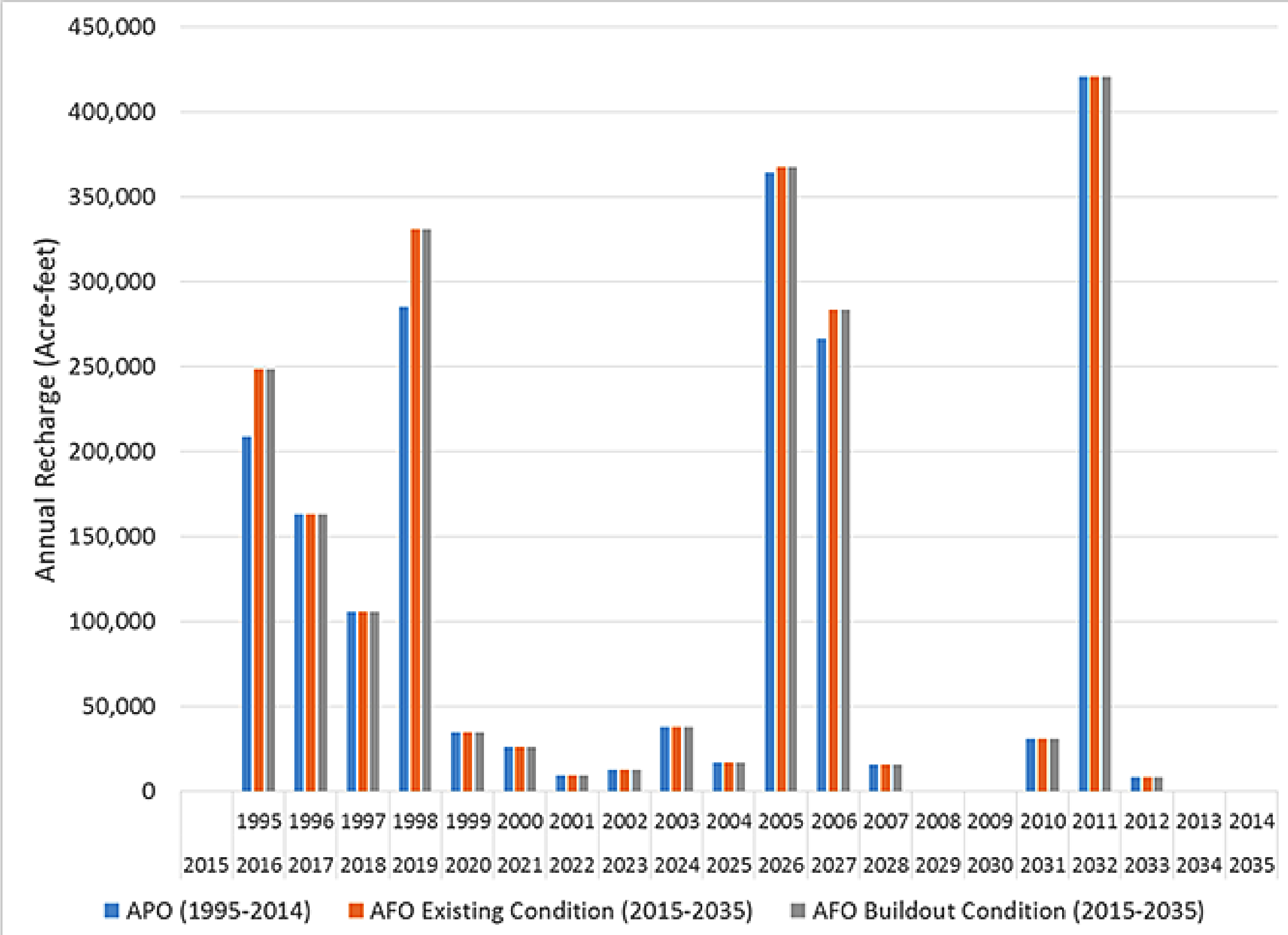


FIGURE 2.3-2. Kern Water Bank Recharge Volumes for the Analysis of Past Operations and Analysis of Future Operations Scenarios, 1995-2035

To avoid surface ponding from four consecutive years of high recharge, the additional water allocated for KWB in 2019 (1998 hydrology) was reduced by 10,000 AF from 55,785 AF to 45,785 AF.

In addition to Kern River water, Article 21 State Water Project (SWP) water is available in some months. For the AFO, the KWB first recharges available Kern River water and then takes Article 21 water if additional recharge capacity is available. Under these assumptions, an additional 3,230 AF of Article 21 water is recharged to the KWB in the AFO year corresponding to 2005 hydrology.

Recharge Distribution

Once the increased recharge volumes from floodwater and Article 21 water are determined (as described above), AFO-EC recharge is distributed to ponds according to 2011 patterns, the only historical recharge year when current recharge practices were employed. Current KWB recharge practices specify that when there is insufficient water to fill all ponds, water is recharged preferentially to the C, M1–M8, N, S, E, and R ponds (referred to hereafter as the preferential ponds; see Figure 2.3-3). In 2011, 301,032 AF of water was recharged to the preferential ponds while 132,403 AF went to remaining ponds. In AFO-EC years when total recharge is less than 301,032 AF, water is distributed only to the preferential ponds, and each pond receives the same relative percentage as in 2011. In years when total recharge exceeds 301,032 AF, preferential ponds receive the same volume as in 2011 and the remaining water is distributed across remaining ponds with the same percentages as those ponds received in 2011. During years of very high recharge (1998, 2005, 2006 hydrology), the recharge distribution is iteratively adjusted to avoid surface ponding.

After annual recharge volumes are calculated for each pond in the AFO-EC, volumes are distributed monthly based on the historical availability of water. The fraction of total annual water delivered to the KWB each month is calculated based on historical deliveries plus additional floodwater and Article 21 water. The new annual recharge volumes are then scaled accordingly, preserving the historical timing of deliveries to the KWB.

Kern Water Bank Recovery Operations

The AFO-EC KWB recovery operations repeated historical pumping volumes (Figure 2.3-4). KWB participants do not anticipate increasing requests for water from the KWB in the future. The operational philosophy is to save water in the KWB for the worst drought years.

Non–Kern Water Bank Groundwater Banking Operations

For non-KWB groundwater banking projects, historical recharge and recovery volumes are repeated for the corresponding hydrologic year of the AFO-EC model simulation. The historical recharge volumes for each project are distributed over the ponds existing in 2014. Between 1995 and 2014, non-KWB groundwater banking projects expanded existing ponds but did not add new ponds, meaning that no changes had to be made regarding the location of recharged water.

2.3.2.2 Existing Conditions Land Use and Derived Data

Land use drives the calculation of pumping in agricultural areas and return flows in agricultural and urban areas. Following are discussions of AFO-EC urban and agricultural land use distributions and their derived datasets.

Urban Area and Calculated Return Flows

Two types of urban areas were defined for the DWR KWB Model: urban areas on sewer systems (referred to hereafter simply as "urban" areas) and urban areas on septic systems (referred to hereafter as "urban on septic" areas). Urban areas define a single recharge zone in the model that accounts for time-varying return flows (i.e., recharge to groundwater) in areas with sewer systems. Twelve separate urban on septic recharge zones were defined in the DWR KWB Model to account for return flows in areas without sewer systems. The 12 different zones are used to account for variations in return flows for areas with different population density.

An urban area coverage corresponding to the 2015 LOD was developed (Figure 2.3-5), using the DWR KWB Model urban area at the end of the historical calibration period (i.e., 2014) as a starting point. Additional urban area was added based on an evaluation of aerial imagery to account for areas where urbanization (e.g., construction of new homes) had occurred but that were not included in the DWR KWB Model. Relative to the 2014 urban area in the DWR KWB Model, an additional 9,658 acres of urban area was added to the AFO-EC urban footprint. Nearly all of the updated urban footprint replaced areas of native vegetation in the DWR KWB Model. Therefore, the expanded urban area did not result in a significant decrease in calculated agricultural pumping.

The volume of urban return flow in the KWBA historical model was taken directly from the Rosedale-Rio Bravo Water Storage District (Rosedale or RRBWSD) Model. The Rosedale Model's urban return flow is based on the assumption that 12.5 percent of urban water deliveries end up as groundwater recharge, primarily from inefficient irrigation of outdoor landscaping. To maintain a consistent methodology, urban water management plan (UWMP) projections of 2015 total water demand in the City of Bakersfield (COB) water service area and the California Water Service Company (Cal Water) service area were compiled (Table 2.3-1), and 12.5 percent of those projections was used as the total annual urban return flow for each year of the AFO-EC simulation. Note that only 60 percent of the Cal Water UWMP projection was used for the return flow calculation, to account for the fact that roughly 40 percent of the Cal Water service area is outside the model domain. Annual urban return flow was apportioned among each monthly stress period based on the same monthly pattern as the 2014 urban return flow in the KWBA historical model. Monthly return flow volume was apportioned among each model cell in the urban recharge zone based on the cell area.

Urban on septic areas corresponding to the 2015 LOD were similarly developed using 2014 urban on septic areas from the DWR KWB Model as a starting point. Additional urban on septic areas were added based on an analysis of aerial imagery (i.e., by finding developed areas outside the urban footprint and not included in the KWBA urban on septic zones). The distinction between areas on sewer versus septic systems was made based on published information on city limit boundaries and sewer pipelines available from the COB GIS Web portal. Figure 2.3-5 shows urban on septic areas used for AFO-EC simulations.

Urban on septic recharge rates in the DWR KWB Model were taken directly from the Rodale Model. The Rosedale Model used different recharge volumes for each zone that appear to be based on housing density within the zone. Recharge volumes for the expanded AFO-EC urban on septic areas were determined based on proximity to the historical urban on septic zones and visual inspection of the new areas in aerial imagery (e.g., Google Earth) to determine the approximate housing density.

Agricultural Area and Calculated Agricultural Pumping and Return Flow

Agricultural areas (i.e., generally those areas outside of the urban and urban on septic areas, and outside of the groundwater banking areas) were held constant at their 2014 conditions from the DWR KWB Model for the entire AFO-EC simulation period (i.e., the extent and types of crops did not change).

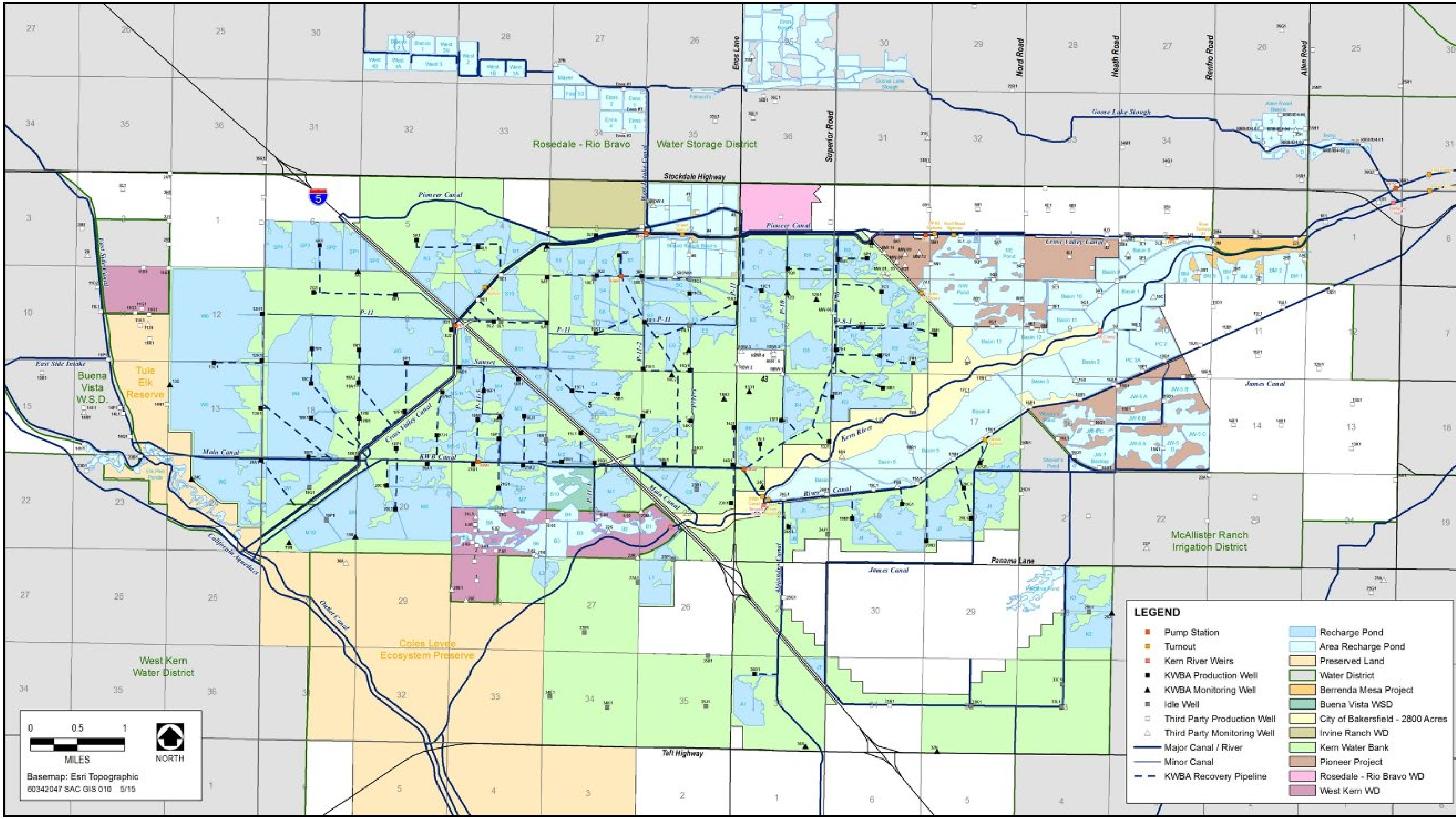


FIGURE 2.3-3. Groundwater Bank Infrastructure in the Kern Water Bank Area

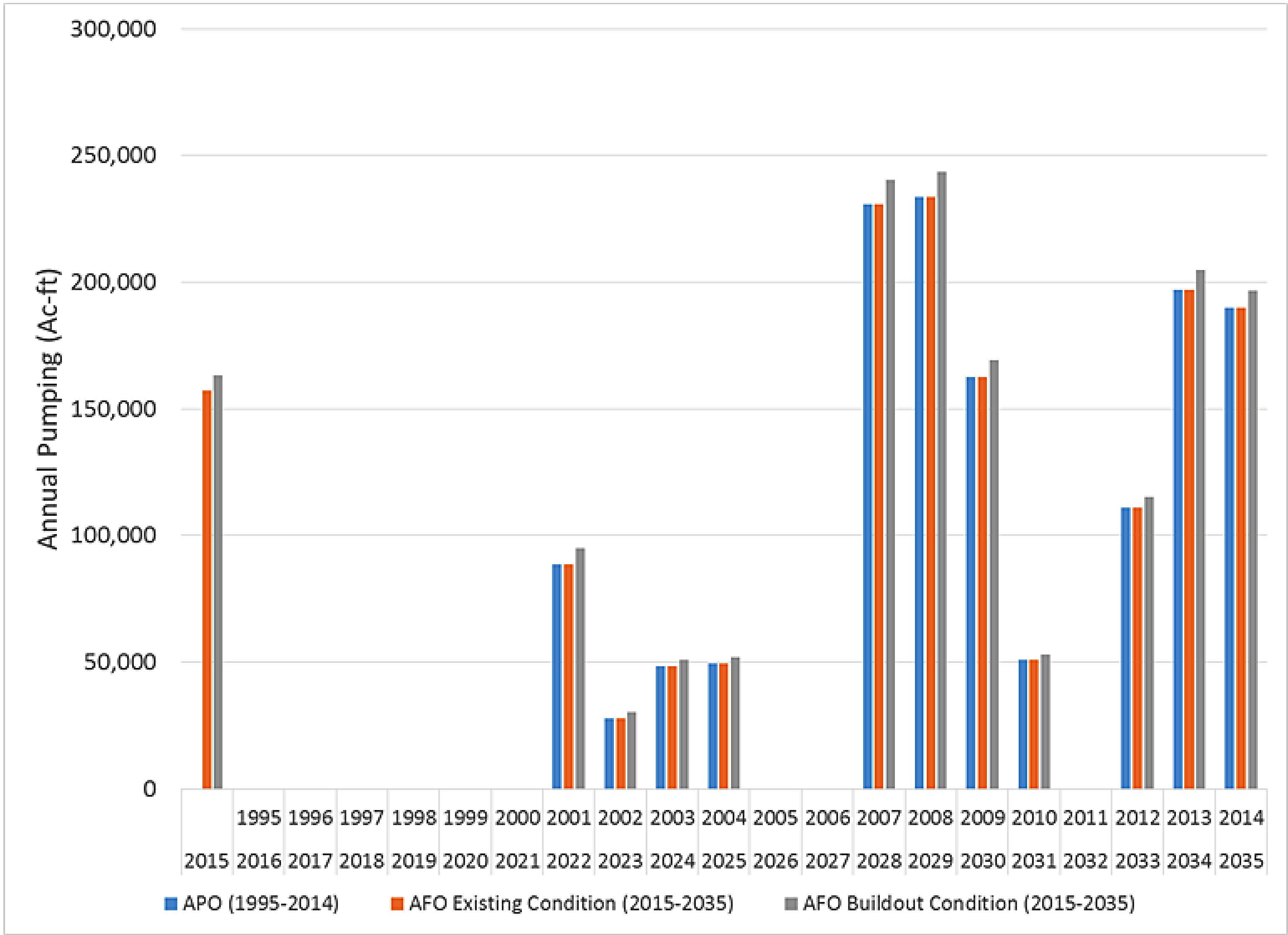


FIGURE 2.3-4. Kern Water Bank Recovery Volumes for the Analysis of Past Operations and Analysis of Future Operations Scenarios, 1995-2035

TABLE 2.3-1 URBAN DEMANDS USED FOR ANALYSIS OF FUTURE OPERATIONS RETURN FLOW CALCULATIONS			
Agency	**Existing Conditions (2015) Urban Water Demand (acre-feet per year)**	**Future Conditions (2030) Total Water Demand (acre-feet per year)**	**Comment**
City of Bakersfield	45,906	52,735	Source: City of Bakersfield 2010 UWMP; Table 10
California Water Service Company	84,029	93,400	Source: 2010 Urban Water Management Plan—Bakersfield District; Table 4.1-1 AFO scenarios use 60 percent of these values because of partial overlap of the Cal Water service area and the DWR KWB Model domain
Notes: AFO = Analysis of Future Operations; Cal Water = California Water Service Company; KWBA = Kern Water Bank Authority; UWMP = Urban Water Management Plan Sources: City of Bakersfield 2010 UWMP, 2010 Urban Water Management Plan—Bakersfield District			

Agricultural pumping in the KWBA historical model was calculated using a preprocessor that considered water demands by crop type and area, as well as the long-term average precipitation. Agricultural return flows (i.e., recharge to groundwater from deep percolation of applied water) were also calculated by the preprocessor, and were based entirely on the volume of groundwater pumping (i.e., they did not consider return flows from surface water deliveries).

For the AFO simulations, agricultural pumping and return flows were calculated using a modified version of the existing preprocessor. The preprocessor was modified to include consideration of historical variations in precipitation when calculating agricultural pumping. Each year of the period from 1995 through 2014 was classified as either critical, dry, below normal, above normal, or wet using the San Joaquin Water Year Type (Table 2.3-2). Historical precipitation, as measured at the Bakersfield Meadows Field Airport for each year within each year type classification, was averaged to develop an annual average precipitation by year type. The appropriate annual average precipitation values were then used to calculate agricultural pumping for the AFO scenarios.

The preprocessor was modified for AFO simulations to consider the total water use (i.e., pumping of groundwater plus surface water delivery) when calculating return flow.

Annual agricultural pumping for the AFO-EC scenario is compared to pumping for the APO scenario in Figure 2.3-6.

Use of Recycled Water from Wastewater Treatment Plant No. 3

There are several wastewater treatment plants in Kern County; however, only COB's Wastewater Treatment Plant No. 3 is located within the DWR KWB Model domain. Recycled water from this plant is used to irrigate nearby soccer fields and the Green Acres Farm, which occupies approximately 4,700 acres 16 miles southwest of Bakersfield and 1 mile northeast of Lake Buena Vista. The Green Acres Farm has been purchased by the City of Los Angeles to ensure a reliable place to manage the city's biosolids produced at wastewater treatment plants. The biosolids are used as a soil conditioner and fertilizer to help promote crop growth. Farm activities produce non-food-chain crops that are sold as feedstock to local dairies. Model files were modified for the AFO scenarios to include irrigation of the soccer fields and the Green Acres Farm by recycled water.

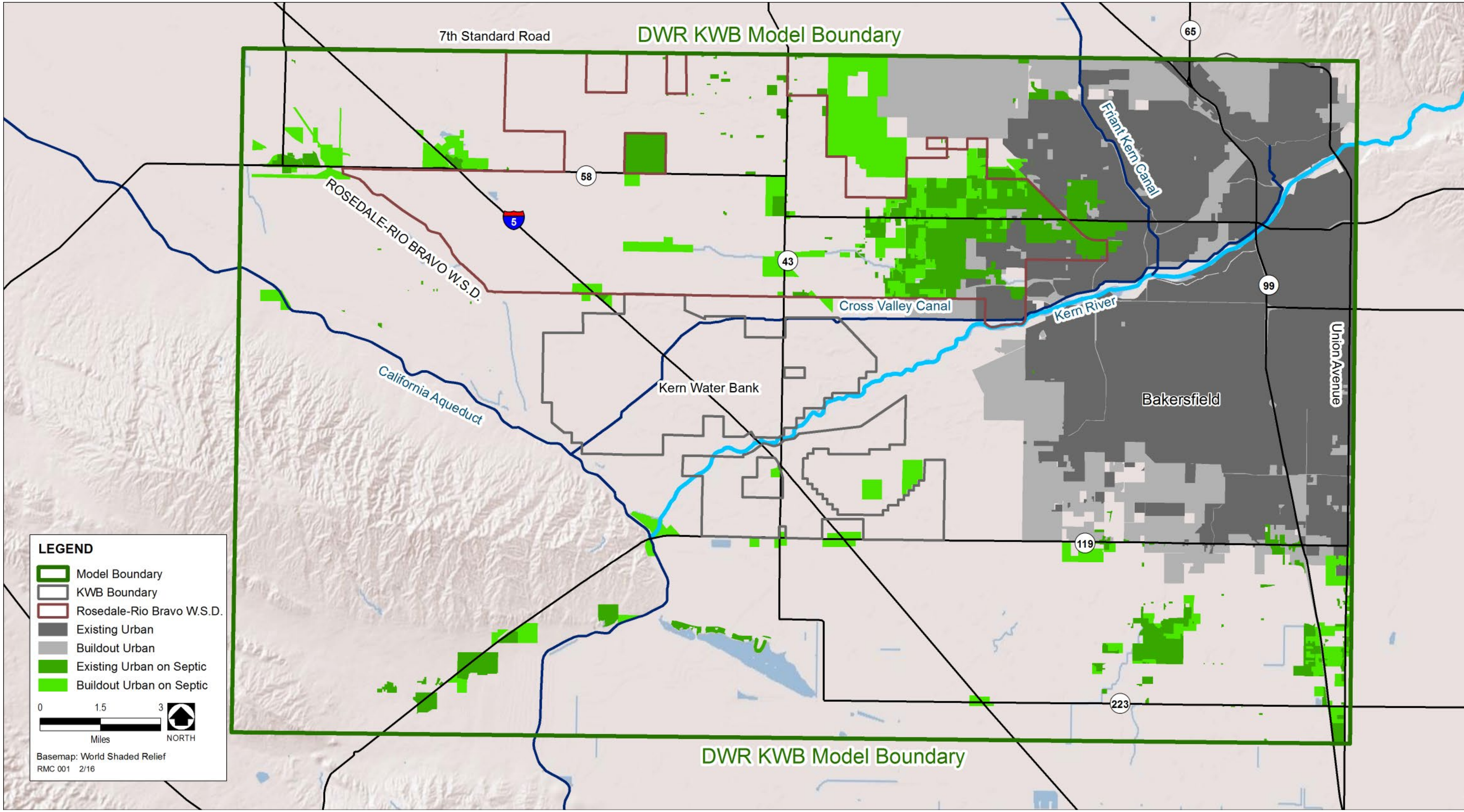


FIGURE 2.3-5. Urban Areas Used for Analysis of Future Operations Scenarios

TABLE 2.3-2 HYDROLOGIC YEAR TYPE AND MEASURED PRECIPITATION, 1995–2014		
Year	**San Joaquin Valley Water Year Type**	**Bakersfield Meadows Field Airport Measured Precipitation (inches)**
1995	Wet	9.84
1996	Wet	8.07
1997	Wet	5.87
1998	Wet	13.33
1999	Above Normal	6.00
2000	Above Normal	4.96
2001	Dry	7.39
2002	Dry	4.29
2003	Below Normal	5.15
2004	Dry	5.57
2005	Wet	8.03
2006	Wet	6.17
2007	Critical	2.98
2008	Critical	3.24
2009	Below Normal	5.12
2010	Above Normal	12.52
2011	Wet	4.39
2012	Dry	4.42
2013	Critical	3.44
2014	Critical	4.03
Sources: CDEC 2015, NOAA 2015		

2.3.2.3 Existing Conditions Urban Pumping

Unlike agricultural pumping, urban pumping in the KWBA historical model is based on reported values from municipal water providers. The initial plan for AFO-EC scenario development was to base urban pumping on 2014 rates in the DWR KWB Model because they would closely represent the 2015 LOD demands. However, during preparation of the AFO scenarios, it was found that the DWR KWB Model omits municipal pumping from large areas within its domain, including the Cal Water service area and portions of the COB water service area. The DWR KWB Model developers used urban pumping locations and rates from the Rosedale Model but did not account for urban pumping outside of the smaller Rosedale Model domain. Use of 2014 urban pumping as represented in the DWR KWB Model for AFO-EC would thus underestimate actual pumping. Therefore, annual AFO-EC urban pumping was developed based on UWMP 2015 projections, as shown in Table 2.3-3.

The AFO-EC scenarios used projected groundwater pumping volumes from COB, Cal Water, Vaughn Mutual Water Company, and Improvement District No. 4 (ID4). Only 60 percent of the Cal Water UWMP projection was used because approximately 40 percent of Cal Water's service area is outside the model domain. Municipal providers' annual groundwater pumping volumes were apportioned among months based on the demand pattern from 2014 in the KWBA historical model. Monthly pumping was then distributed to each municipal well based on the well's pumping pattern in 2014.

Cal Water wells were not included in the KWBA historical model and information on the wells was not provided by Cal Water for this study. Based on well capacity information in Cal Water's UWMP, 18 assumed wells are evenly distributed throughout the service area. Annual pumping (based on the 2015 UWMP projections) was apportioned to months based on the demand pattern from COB wells. Monthly pumping was evenly distributed to each of the assumed wells.

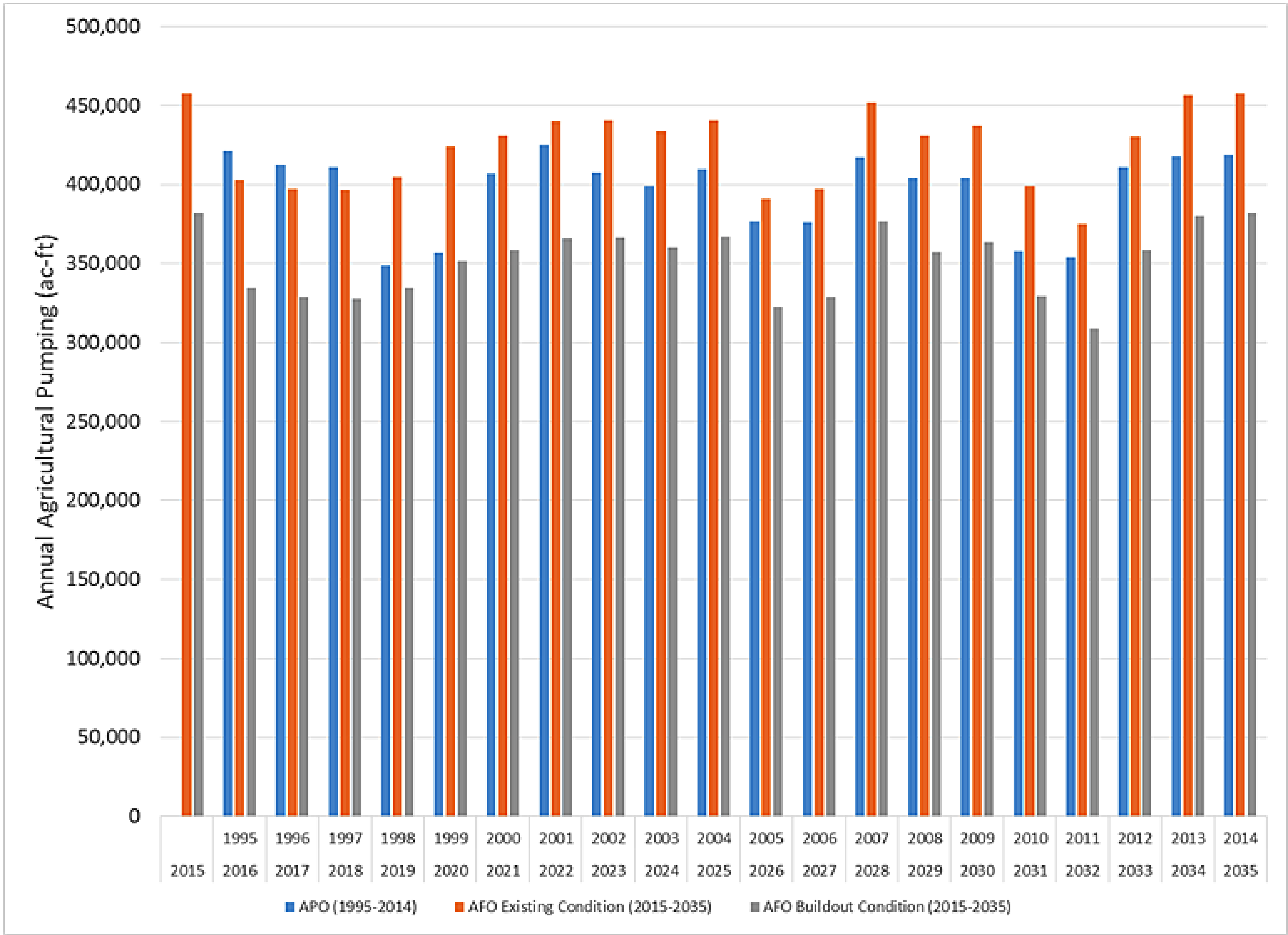


FIGURE 2.3-6. Calculated Agricultural Pumping for the Analysis of Past Operations and Analysis of Future Operations Scenarios, 1995-2035

TABLE 2.3-3 URBAN DEMANDS USED FOR ANALYSIS OF FUTURE OPERATIONS RETURN FLOW CALCULATIONS			
Agency	**Existing Conditions (2015) Urban Pumping (acre-feet per year)**	**Future Conditions (2030) Urban Pumping (acre-feet per year)**	**Comment**
City of Bakersfield	36,406	41,735	Source: City of Bakersfield 2010 UWMP; Table 10
California Water Service Company	35,345	18,013	Source: 2010 Urban Water Management Plan—Bakersfield District; Table 4.1-1 AFO scenarios use 60 percent of these values because of partial overlap of the Cal Water service area and the DWR KWB Model domain
Vaughn Water Company	14,962	19,576	Source: Vaughn Water Company 2010 Water Management Plan; Table 9
ID4	9,620	10,600	Source: ID4 2010 Urban Water Management Plan; Table 3-10

Notes:

AFO = Analysis of Future Operations; Cal Water = California Water Service Company; ID4 = Improvement District No. 4;. KWBA = Kern Water Bank Authority; UWMP = Urban Water Management Plan

Sources: City of Bakersfield 2010 UWMP, 2010 Urban Water Management Plan—Bakersfield District, Vaughn Water Company 2010 Water Management Plan, ID4 2010 Urban Water Management Plan

2.3.3 ANALYSIS OF FUTURE OPERATIONS UNDER BUILDOUT CONDITIONS

The AFO-BC scenario is similar to the AFO-EC scenario, except that (1) the urban footprint is expanded to represent a future urban buildout condition, and (2) selected planned recharge and recovery projects are added to the model.

2.3.3.1 Buildout Conditions Groundwater Banking Operations

The AFO-BC simulation includes several proposed new or expanded groundwater banking projects (Table 2.3-4). Within KWB Lands, 1,090 acres of ponds (nine expansions to existing ponds and seven entirely new ponds) were added along with three new recovery wells. In addition to the new KWB facilities, the AFO-BC simulation considers the operations of the James Groundwater Storage and Recovery Project, the Stockdale Projects, and Strand Ranch (Figure 2.3-7).

Kern Water Bank Recharge Operations

KWB recharge for the AFO-BC simulation (Figure 2.3-2) is calculated using the same methodology as used for the AFO-EC simulation. Historically, the KWB has maximized its recharge capacity during flood years. The projected construction of an additional 1,090 acres of recharge ponds by 2030 increases the project's recharge capacity beyond what was available historically. Additional capacity for each month is estimated by assigning pond-specific recharge rates to ponds that were inactive or did not exist during past recharge cycles. For expansions to existing ponds, the recharge rate is assumed to remain the same as the rate during historical operations and volumes are scaled up by area. New ponds are assumed to follow the average recharge rate of existing ponds in the same group (e.g., a new pond in Group C is assumed to follow the average recharge rate of the existing Group C ponds for the purposes of estimating capacity). The volumes that could have potentially filled the new and expanded ponds are considered the additional capacity for recharge under the AFO-BC scenario.

TABLE 2.3-4

FUTURE PROJECTS INCLUDED IN ANALYSIS OF FUTURE OPERATIONS BUILDOUT CONDITIONS SCENARIOS

Project Type	Agency	Project	Description
Groundwater Banking	Kern Water Bank Authority	Kern Water Bank Recharge and Recovery Project	Additional basins and three new wells within the Kern Water Bank
	Buena Vista Water Storage District	James Groundwater Storage and Recovery Project	NOP shows project footprint and anticipated maximum recharge capacity
	Rosedale–Rio Bravo Water Storage District	Drought Relief Project	11 new wells (three on West Basins, six in the vicinity of Superior Basins, two on Stockdale East), pumping plant, turnout, development of Stockdale East basins
Urban Development	Regional and Local Development Plans and Programs	City of Bakersfield General Plan	Implemented via revised urban footprint
		Kern County General Plan	Implemented via revised urban footprint
	City of Bakersfield	West Ming Specific Plan	Specific Plan outlines development areas
		Rosedale Ranch (approved residential development)	Implemented via revised urban footprint
		Saco Ranch (approved commercial development)	Implemented via revised urban footprint
		Strand Ranch (approved residential and commercial development)	Implemented via revised urban footprint
		Stockdale Ranch (approved residential development)	Implemented via revised urban footprint
		Old River Ranch (approved residential and commercial development)	Implemented via revised urban footprint
		Bakersfield Commons (approved commercial development)	Implemented via revised urban footprint
		Ashe No. 4 (approved residential development)	Implemented via revised urban footprint
		Hosking Commercial Center (proposed commercial development)	Implemented via revised urban footprint
	Kern County	Reina Ranch (proposed residential development and drill island for petroleum extraction)	Implemented via revised urban footprint
		Rosedale & Renfro Precise Development Plan	Implemented via revised urban footprint

Notes:
NOP = Notice of Preparation
Sources: KWBA 2015, RRBWSD 2015, City of Bakersfield General Plan 2010

Historical flood years were identified as those where April–July Kern River flows exceeded 170 percent of the historical average flow; these years were identified as 1995, 1998, 2005, 2006, and 2011. During years of high flow, Kern River water that is not recharged to the KWB or other projects is routed to the Kern River–California Aqueduct Intertie and taken out of the region through the California Aqueduct. With the addition of new ponds, the KWB has increased capacity to recharge a portion of this excess floodwater that otherwise would leave the region. Additional Kern River water recharged to the KWB is limited based on the availability of excess Kern River water and the capacity for recharge within the bank. Historical data showed that excess Kern River water was available for recharge in 1995, 1998, and 2006. In 1995, 42,000 AF of Kern River water flooded farmland, while in 1998 and 2006, 132,266 and 70,624 AF of Kern River water reached the intertie, respectively. Based on capacity and availability, an additional 39,480 AF, 122,412 AF, and 66,387 AF of water could be recharged in the KWB in the 1995, 1998, and 2006 hydrologic years, respectively. However, to avoid surface ponding due to additional recharge from KWB operations as well as recharge from other banking projects, volumes were kept consistent with existing condition levels.

In addition to Kern River water, Article 21 SWP water is available in some months. For the AFO-BC, the KWB first recharges available Kern River water and takes Article 21 water if additional recharge capacity is available. Under these assumptions, an additional 3,230 AF of Article 21 water is recharged to the KWB in 2005, the same as in the AFO-EC simulation.

Kern Water Bank Recovery Operations

For the AFO-BC simulation, the KWB includes three new wells in addition to the existing wells from the historical simulation. Pumping from existing wells repeats historical pumping patterns and volumes according to the corresponding hydrologic year. The three new wells are assumed to be active during all historical KWB recovery cycles. Each of the three wells is assigned a pumping rate equal to the average historical rate for wells active during the corresponding hydrologic month. During the 21-year simulation, the three new wells recover a total of 67,868 AF of water, with a maximum annual per-well recovery rate of 3,275 AF in Year 15 of the AFO-BC simulation (hydrologically equivalent to 2008).

Non–Kern Water Bank Groundwater Banking Operations

<u>James Groundwater Banking Project</u>

The James Groundwater Banking Project, referred to here as the "James Project," consists of 1,400 acres of recharge ponds with a recharge capacity of up to 150,000 acre-feet per year (AFY) and 14 groundwater wells that can recover up to 50,000 AFY during times of need. The James Project is located directly south of the South Pioneer ponds and recovery wells. Recharge rates and patterns for the South Pioneer project were scaled proportionately and used to estimate operations for the James Project. The maximum historical recharge year for the Pioneer Project was scaled up to the maximum estimated recharge capacity of the James Project (150,000 AFY), and the ratio is used to scale the remaining recharge years accordingly. Recovery patterns for James Project wells were assumed to follow the same timing as South Pioneer wells. Each of the 14 James Project recovery wells is assigned a pumping rate equal to the average historical rate for South Pioneer wells active during the corresponding hydrologic month.

<u>Stockdale Integrated Banking Project and Strand Ranch</u>

The Stockdale Integrated Banking Project consists of the Stockdale East and Stockdale West recharge ponds and 11 new recovery wells. Stockdale East and Stockdale West have estimated recharge capacities of 19,000 AFY and 27,100 AFY, respectively. Strand Ranch has an estimated annual recharge capacity of 37,000 AFY. Future recharge to Stockdale East, Stockdale West, and Strand Ranch are assumed to follow the same recharge patterns as the rest of the Rosedale ponds. The maximum historical recharge year for Rosedale is scaled up to the estimated recharge capacity of each respective project. The corresponding ratios are then used to estimate the volumes recharged in the remaining years. Strand Ranch and Stockdale West began operations in 2010 and 2011, respectively. Historical recharge values were applied to the two projects in the corresponding hydrologic years for the AFO-BC simulation.

For the three new banking projects, recharge during exceptionally high recharge years (1998, 2005, 2006), was reduced by 50% to avoid surface ponding within the basin.

2.3.3.2 Buildout Conditions Land Use and Derived Data

As noted in Section 2.3.2.2, land use drives the calculation of pumping in agricultural areas and return flows in agricultural and urban areas. Following are discussions of AFO-BC urban and agricultural land use distributions and their derived datasets.

Urban Area and Calculated Return Flows

Background information on urban areas and the ways they are used to generate model inputs is provided in Section 2.3.2.2 for the AFO-EC scenarios. The AFO-BC urban area was developed using the AFO-EC urban area as a starting point. Additional area was added to the AFO-BC urban footprint based on general plan land use GIS data from COB and Kern County. General plan areas designated with urban uses (e.g., various types of residential, commercial, recreation, and industrial classifications) were added to the urban footprint. The general plan areas were inclusive of many smaller planned urban developments, a list of which is provided in Table 2.3-4. Relative to the AFO-EC urban area, the AFO-BC urban area expanded by roughly 18,850 acres. Similar to the AFO-EC, AFO-BC urban return flows were calculated using 12.5 percent of 2030 UWMP water demand projections (Table 2.3-1).

AFO-BC urban on septic zones were developed by expanding the AFO-EC urban on septic areas to include locations where general plan data indicated that urban development is likely to occur. AFO-BC urban on septic recharge rates were assumed based on the closest nearby recharge rates from the APO simulation.

Agricultural Area

Agricultural areas outside of the AFO-BC banking project, urban, and urban on septic footprints were held constant at their 2014 conditions (i.e., extent and crop type) from the DWR KWB Model for the entire AFO-BC simulation period. Pumping and return flows for these agricultural areas were calculated using the same preprocessor used for the AFO-EC.

2.3.3.3 Buildout Conditions Urban Pumping

Similar to the development of AFO-EC urban pumping, AFO-BC urban pumping was developed using 2030 UWMP pumping projections (Table 2.3-3). Annual flows were apportioned into monthly values for each well using a similar methodology as described for the AFO-EC in Section 0. No additional municipal supply wells were simulated except for Vaughn Mutual Water Company, where seven additional wells were estimated to be required to meet 2030 demand projections based on existing well capacities.

2.4 MODEL INPUTS

The information collected and processed during scenario development was used to build new model input files. As described in Section 2, the DWR KWB Model is built on the MODFLOW-NWT code. MODFLOW models allow the user to specify various packages and processes that each represent different components of the groundwater flow system (e.g., for simulation of wells, streams, or recharge). In general, data for each package or process are contained in one or more ASCII text files. The collection of these text files is referred to collectively as the “input files.” The user specifies the name of each package or process input file in a Name (or NAM) file. The NAM file directs MODFLOW where to find the required inputs for each package and process used in the model.

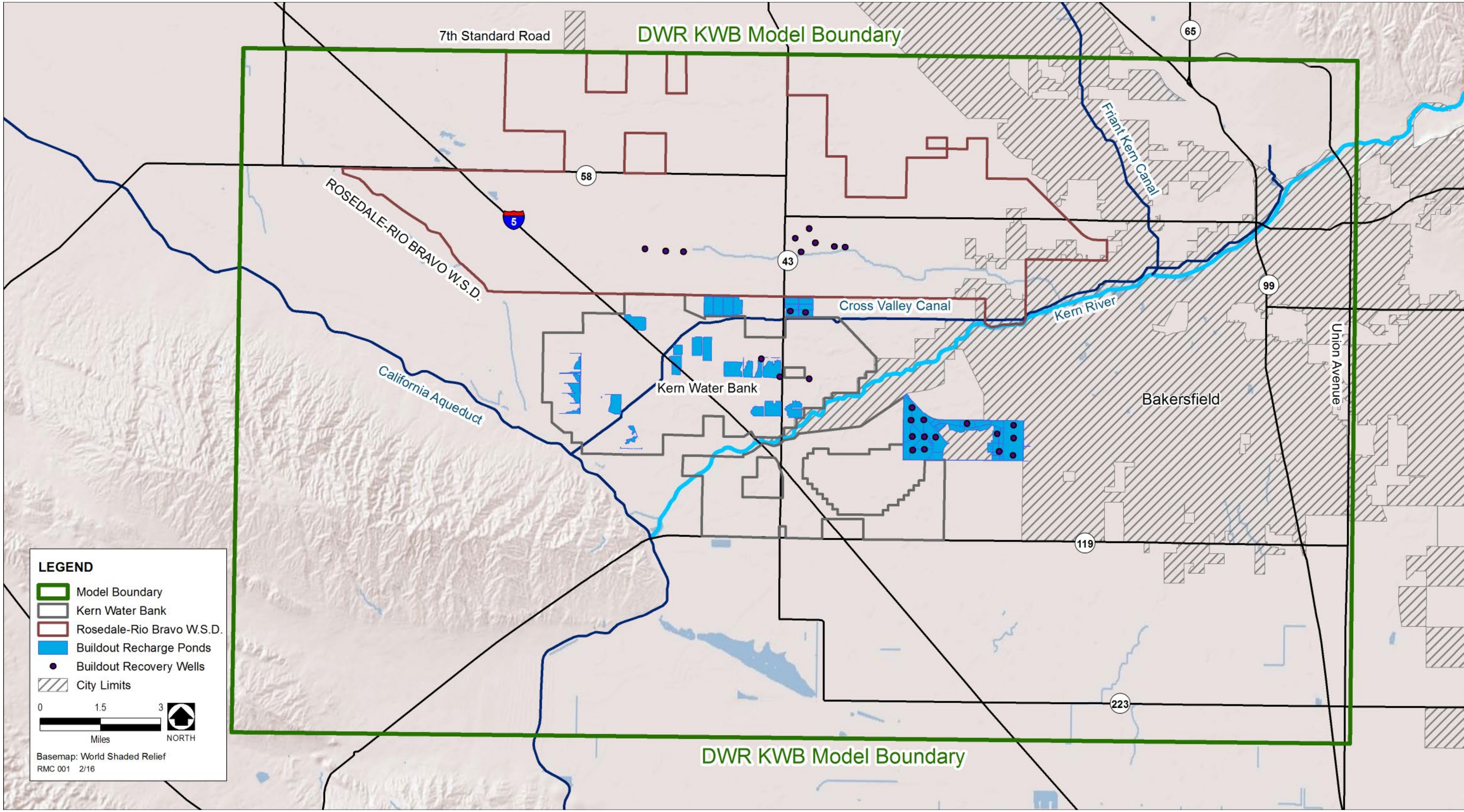


FIGURE 2.3-7 **Future Groundwater Banking Projects Used in the Analysis of Future Operations under Buildout Conditions Scenario**

Table 2.4-1 specifies all of the input files required to run the DWR KWB Model. Some of the input files were taken directly from the DWR KWB Model calibration run described in the technical report, “Development of DWR Kern Water Bank Model: Model Review, Selection, and Enhancements” and used for each model scenario without modification (DWR, 2016). An example is the Upstream Weighting (or UPW) file, which is used to specify the properties controlling flow between cells in the model (e.g., horizontal and vertical hydraulic conductivity, specific yield, storage). Other files, including those representing pumping and recharge, changed significantly for the different scenarios. Table 2.4-1 specifies where changes to the model input files were required during scenario development.

TABLE 2.4-1

KERN WATER BANK AUTHORITY MODEL INPUT FILES

File (Abbreviation)	Description	Modified from KBWA Calibration Model[1]?	
		For APO Without Project	For AFO
Name (NAM)	The Name file contains the names of all model inputs, and directs MODFLOW where to find each file	No	No
Basic (BAS6)	The Basic package specifies (1) locations of active, inactive, and specified head cells; (2) head stored in inactive cells; and (3) the initial heads in all cells.	No	Yes
Discretization (DIS)	The Discretization file is used to specify (1) the number of rows, columns, and layers; (2) cell sizes; (3) the presence of Quasi-3D confining beds; and (4) time discretization.	No	Yes (time discretization only)
Upstream Weighting (UPW)	The Upstream Weighting package is used to specify properties controlling flow between cells in MODFLOW-NWT.	No	No
Multi-Node Well, version 2 (MNW2)	The Multi-Node Well package is used to simulate wells that are connected to more than one node of the finite-difference grid. Nearly all irrigation, recovery, and urban wells in the model are simulated as multi-node wells.	Yes	Yes
Multi-Node Well Information (MNWI)	The Multi-Node Well Information package controls how multi-node well output is printed.	No	No
Well (WEL)	Relative to MNW2, the Well package offers a simplified, specified flux representation of wells. The Well package is used to simulate leakage from canals (positive pumpage) and pumping from a few selected wells.	No	Yes
General-Head Boundary (GHB)	General-head boundaries are a type of head-dependent boundary condition where a head and conductance are specified at each GHB cell. Water can flow into or out of these cells based on the GHB properties and heads in surrounding cells.	No	Yes
Recharge (RCH)	The Recharge package is specified flux boundary condition package whereby recharge entering the water table (uppermost saturated cell) is assigned on a cell by cell basis. The Recharge package is used to represent urban and agricultural return flows and to represent recharge operations.	Yes	Yes
Output Control (OC)	Controls the frequency and types of output data printed as the model runs.	No	No
Newton Solver (NWT)	The Newton solver is used to solve the finite difference equations in each step of a MODFLOW-NWT stress period.	No	No

TABLE 2.4-1

KERN WATER BANK AUTHORITY MODEL INPUT FILES

File (Abbreviation)	Description	Modified from KBWA Calibration Model[1]?	
		For APO Without Project	For AFO
Stream (STR)	The Stream package is used to simulate streams in a model. The DWR KWB Model uses the Stream package to route discharges to the Kern River from groundwater to downstream reaches.	No	No

Notes:

AFO = Analysis of Future Operations; APO = Analysis of Past Operations; KWBA = Kern Water Bank Authority

[1] Includes enhancements to DWR KWB Model described in Appendix 7-2 Section 3.

Source: USGS 2015

3. MODEL RESULTS

This section describes the model results for simulations conducted to evaluate the impact of historical (1995–2014), existing, and future KWB facilities and operations on the groundwater table within the DWR KWB Model domain.

3.1 MODEL COMPARISON METHODS

Numerous possible methods and metrics can be used to compare model scenarios. The discussion below focuses on those comparison methods that are most relevant to supporting the analysis of the impacts of KWB operation. The methods described in this section include comparing changes in groundwater levels and storage between the “With KWB Operations” and “Without KWB Operations” variations of the three primary model scenarios (APO, AFO-EC, and AFO-BC). The comparison methods include:

1. **Groundwater budgets**—Tables are generated to show annual rates of inflow and outflow components of the groundwater flow system.

2. **Groundwater elevation difference contour maps**—The modeling results from one layer and at one point in time for the “Without KWB Operations” scenario are subtracted from the results in the same layer and time as the “With KWB Operations” scenario. Areas where the elevation difference is positive (greater than zero) indicate locations where groundwater levels are higher under the “With KWB Operations” scenario. Negative values mean that water levels are lower under the “With KWB Operations” scenario.

3. **Groundwater level hydrographs**—Simulated groundwater elevations for the “With KWB Operations” and “Without KWB Operations” scenarios are plotted for selected monitoring wells for the 1995–2014 simulation period.

4. **Time series of affected area**—Areas outside KWB Lands with head differences between the “With KWB Operations” and “Without KWB Operations” scenarios exceeding specified levels are identified and calculated for each month of the simulation period.

5. **Maps showing the spatial extent of negative and positive head differences—**Maps show the extent of areas with various levels of head difference (-60 feet, -45 feet, -30 feet, -20 feet, -10 feet, -5 feet, +5 feet, +10 feet, +20 feet, +30 feet, +45 feet, +60 feet) for “With KWB Operations” and “Without KWB Operations” scenarios at any time during the simulation period. These boundary lines show the outermost edge of all model cells that have ever exceeded the corresponding specified level of elevation difference at any time during the model simulation period. No model cells outside the boundary line have ever exceeded the corresponding specified level of elevation difference. These maps were constructed by identifying all model cells where the groundwater elevation difference exceed the specified level at any time step and drawing a boundary line by connecting the outermost edges of the identified cells.

6. **Maps showing the frequency distribution of groundwater elevation difference—**Maps showing the percent of months in the simulation period when groundwater elevation differences exceed specified levels are examined to show how often these specified levels of impacts may occur over an affected area.

7. **Zonal average groundwater elevation and elevation difference hydrographs—**Charts of average groundwater elevation and elevation differences over specified zones (0–1 mile, 1–2 miles, 2–3 miles, 3–4 miles, and 4–5 miles) outside the KWB boundary are examined to show the rise and attenuation of the groundwater mound as it moves away from the KWB boundary.

8. **Total area of negative and positive elevation differences—**Total areas of "positive elevation difference" and "negative elevation difference" outside KWB Lands are examined to show the overall groundwater response to KWB recharge and recovery operations.

3.2 RESULTS OF ANALYSIS OF PAST OPERATIONS SCENARIOS

The results of the APO "With KWB Operations" and "Without KWB Operations" scenarios are presented in the following subsections.

3.2.1 WATER BUDGET AND RECHARGE AND RECOVERY AT KERN WATER BANK

The historical DWR KWB Model was used to develop an annual water budget for the entire model domain for the 1995–2014 KWB operation period. Table 3.2-1 shows key components of the water budget, including the change in groundwater storage within the model domain.

Boundary inflow and outflow are the largest components of the DWR KWB Model water budget. Boundary inflow, with an annual average of approximately 546,000 AFY, is approximately 10,925,000 AF for the 1995–2014 period. Boundary outflow, with an annual average of approximately 527,000 AFY, is approximately 10,534,000 AF for the same period.

Agricultural and urban water demand during the 1995–2014 period is partially met by a total of 7,935,000 AF of agricultural pumping and 700,000 AF of urban pumping. Approximately 1,536,000 AF of applied water returns to the aquifer as deep percolation.

During the 1995–2014 period, the KWB recharged surface water into the underlying aquifer in high-flow years and recovered some of the stored groundwater in relatively dry years. The KWB has recharged 2,006,000 AF (after a 6 percent evaporation loss) of water from 1995 through 2014 while recharge at other banking projects within the DWR KWB Model domain during the same period was 3,383,000 AF. The KWB has recovered 1,389,000 AF of the recharged water from 1995 through 2014 while other projects within the model domain have recovered 1,247,000 AF. This results in a balance of 617,000 AF of stored water for the KWB and 2,136,000 AF of stored water for other banking projects. The KWB annual recharge, recovery, and cumulative balance of stored water are shown in Figure 3-2.1.

3.2.2 GROUNDWATER ELEVATION DIFFERENCE FOR WITH AND WITHOUT KERN WATER BANK OPERATIONS

KWB operations result in the rise (during recharge periods) and fall (during recovery periods) of the local groundwater table. The largest changes in groundwater elevation occur within the KWB and in the area immediately adjacent to it. Groundwater elevation differences for the APO "With KWB Operations" and "Without KWB Operations" scenarios were evaluated by (1) comparing simulated groundwater elevation hydrographs at several monitoring wells (Method No. 3 in Section 3.1), and (2) developing groundwater elevation difference contour maps at the end of several representative recharge and recovery cycles (Method No. 2 in Section 3.1).

TABLE 3.2-1

WATER BUDGET FOR ANALYSIS OF PAST OPERATIONS WITH KERN WATER BANK OPERATIONS, 1995–2014

Year	INFLOW Into Model						OUTFLOW from Model						Calculated Change in Storage
	Deep Percolation of Applied Water	KWB Recharge	Other Banking Projects Recharge	River and Canal Seepage	Boundary Inflow through DWR KWB Model Domain	Total Inflow	Agricultural Pumping	Urban Pumping	KWB Pumping	Other Banking Projects Pumping	Boundary Outflow through DWR KWB Model Domain	Total Outflow (Positive)	
	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY
1995	84,545	208,924	441,854	178,936	545,738	1,459,997	(421,043)	(15,659)	–	(17,928)	(507,390)	962,020	497,977
1996	82,417	163,443	245,865	166,869	599,272	1,257,867	(412,395)	(16,936)	–	(19,083)	(502,367)	950,781	307,086
1997	82,819	105,526	218,780	164,725	617,828	1,189,678	(410,830)	(19,175)	–	(18,136)	(487,990)	936,130	253,548
1998	68,681	284,901	373,720	152,887	594,141	1,474,331	(348,574)	(15,217)	–	(18,411)	(508,336)	890,538	583,793
1999	67,197	34,548	66,269	146,220	585,953	900,187	(356,515)	(21,780)	–	(21,134)	(540,184)	939,613	(39,426)
2000	75,704	25,924	90,944	117,264	593,947	903,783	(406,632)	(21,853)	–	(24,687)	(526,859)	980,032	(76,249)
2001	79,320	9,428	13,784	83,336	488,151	674,020	(425,390)	(43,099)	(88,699)	(99,660)	(586,962)	1,243,810	(569,790)
2002	76,515	12,633	10,815	106,200	530,104	736,267	(407,749)	(28,009)	(27,596)	(54,607)	(548,585)	1,066,545	(330,278)
2003	75,983	37,952	54,469	140,967	553,785	863,156	(399,019)	(30,289)	(48,367)	(35,501)	(533,262)	1,046,438	(183,281)
2004	77,259	16,981	35,728	92,596	535,366	757,930	(409,965)	(29,545)	(49,289)	(53,768)	(531,476)	1,074,043	(316,113)
2005	76,378	364,304	576,669	187,847	590,181	1,795,378	(376,566)	(26,677)	–	(34,346)	(504,703)	942,292	853,087
2006	76,845	266,239	357,693	171,055	591,154	1,462,987	(376,300)	(27,628)	–	(29,280)	(509,484)	942,692	520,295
2007	78,297	15,724	22,711	56,251	498,929	671,912	(417,412)	(59,464)	(230,686)	(124,924)	(567,567)	1,400,053	(728,141)
2008	79,491	–	10,626	63,460	444,553	598,130	(403,843)	(77,102)	(233,703)	(144,984)	(577,926)	1,437,559	(839,429)
2009	77,068	–	14,413	63,825	479,246	634,552	(404,194)	(60,206)	(162,461)	(116,792)	(529,256)	1,272,910	(638,357)
2010	73,493	31,143	195,061	198,235	537,514	1,035,446	(357,623)	(32,882)	(50,969)	(50,256)	(499,837)	991,566	43,880
2011	74,115	420,319	583,911	262,648	606,634	1,947,627	(354,040)	(23,151)	–	(26,735)	(477,414)	881,339	1,066,288
2012	77,726	8,383	69,909	77,153	538,882	772,053	(411,068)	(29,562)	(110,830)	(47,061)	(530,423)	1,128,945	(356,891)
2013	75,806	–	–	54,142	499,711	629,659	(417,457)	(29,642)	(196,819)	(136,997)	(566,377)	1,347,292	(717,633)
2014	76,215	–	–	51,390	493,828	621,434	(418,816)	(92,396)	(189,695)	(173,046)	(497,433)	1,371,385	(749,952)
Total 1995–2014	**1,535,875**	**2,006,372**	**3,383,223**	**2,536,007**	**10,924,917**	**20,386,393**	**(7,935,432)**	**(700,272)**	**(1,389,113)**	**(1,247,334)**	**(10,533,831)**	**21,805,983**	

Notes: AFY = acre-feet per year; KWB = Kern Water Bank; KWBA = Kern Water Bank Authority

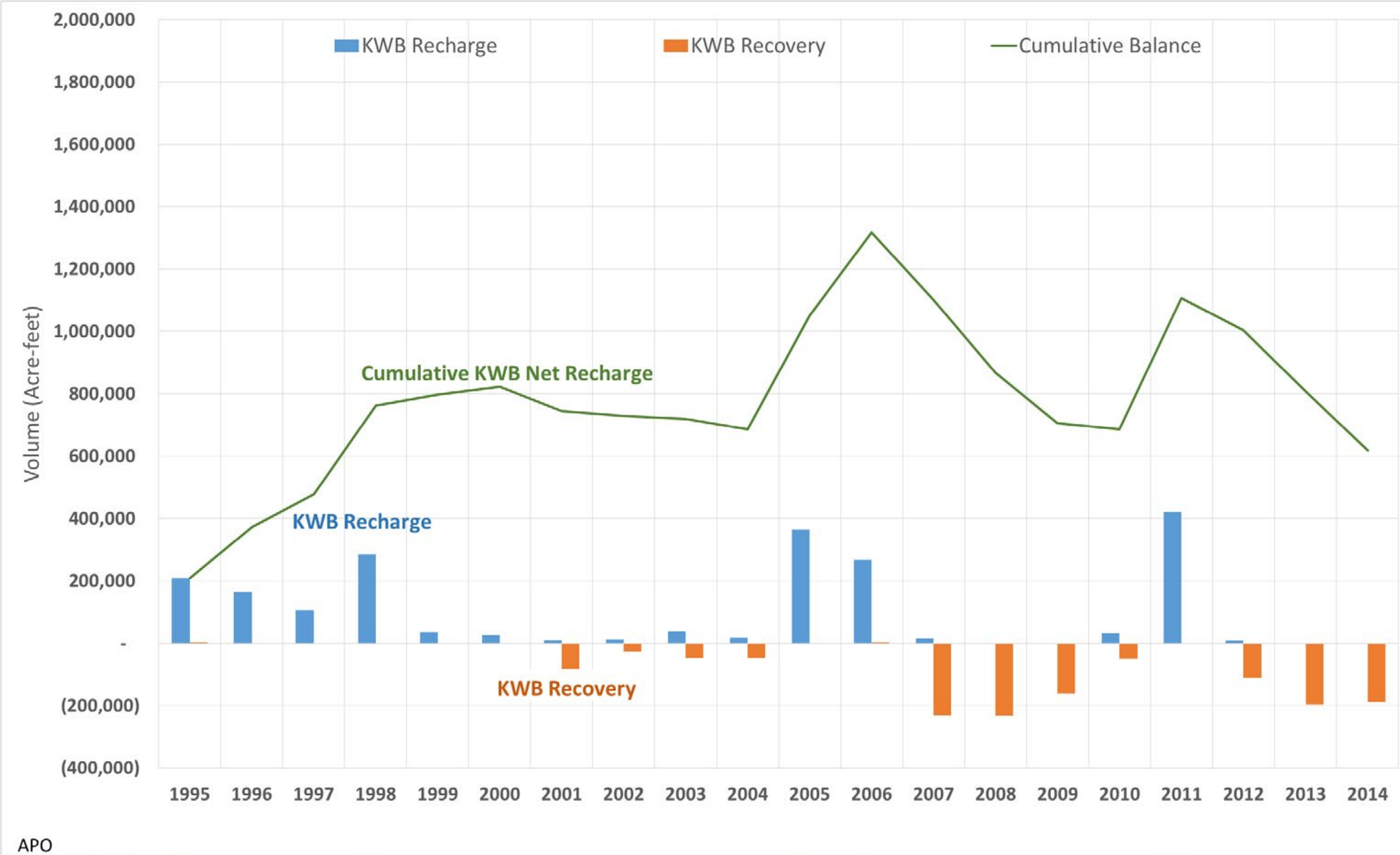


FIGURE 3.2-1 **Analysis of Past Operations—Historical (1995–2014) Kern Water Bank Annual and Cumulative Recharge and Recovery, and Cumulative Stored Water, 1995-2014**

3.2.2.1 Hydrographs

Hydrographs of simulated groundwater levels for "With KWB Operations" and "Without KWB Operations" scenarios were developed at 31 wells (14 wells inside KWB Lands and 17 wells outside KWB Lands; Appendix 7-2D). The locations and hydrographs for three of these wells are shown in Figures 3.2-2 and 3.2-3a to 3.2-3c.

3.2.2.2 Contour Maps

The distribution of groundwater elevation differences between the "With KWB Operations" and "Without KWB Operations" scenarios after major KWB recharge and recovery cycles is shown in Figures 3.2-5 and 3.2-6. Figures 3.2-5a through 3.2-5c show groundwater elevation differences after the 1995–2000, 2005–2006, and 2011 recharge cycles, respectively. Figures 3.2-6a through 5.2-6c show groundwater elevation differences after the 2001–2004, 2007–2009, and 2012–2014 recovery cycles, respectively.

3.2.3 AFFECTED AREAS OUTSIDE THE KERN WATER BANK

The impact of KWB activities on groundwater elevations outside KWB Lands for the APO "With KWB Operations" and "Without KWB Operations" scenarios are evaluated using time series charts showing areas affected by head differences of ±5 feet (Method No. 4 in Section 3.1), maps of the spatial extent of negatively and positively impacted areas (Method No. 5 in Section 3.1), and tables summarizing the acreage of impacted areas.

3.2.3.1 Time Series of Affected Area

At every time step of the simulation, the total area of the model with groundwater elevation difference greater than 5 feet and groundwater elevation difference less than -5 feet was calculated. Time series of these areas are shown in Figure 3.2-7. A detailed chart showing areas impacted by less than -5, -10, -20, -30, -45, and -60 feet is shown in Figure 3.2-8. Figure 3.2-9 shows areas impacted by groundwater levels greater than 5, 10, 20, 30, and 45 feet.

Negative differences exceeding -5 feet occur after about 2 years of recovery, as in the 2007–2009 and 2011–2014 periods (Figure 3.2-7). In the first 13 years of KWB operations (1995–2007), there are no elevation differences more negative than -5 feet outside KWB Lands. Negative groundwater elevation differences occur over a maximum area of about 22,000 acres at the end of 2014, after 497,000 AF was recovered during 2012–2014.

Figure 3.2-8 indicates that negative differences exceeding -30 feet in areas outside KWB Lands are limited to years of groundwater pumping, occurring in 3 of the 7 recovery years, and that the impacted area is less than 5,000 acres outside and near KWB Lands.

3.2.3.2 Spatial Extent of Affected Area

Figure 3.2-10 shows the maximum spatial extent of negative elevation differences exceeding -60 feet, -45 feet, -30 feet, -20 feet, -10 feet, and -5 feet. This figure shows that negative elevation differences do not spread beyond approximately 2 to 3 miles outside the KWB boundary. Negative elevation differences exceeding -30 feet do not occur inside the Rosedale boundary; but negative elevation differences between -5 feet and -20 feet do occur inside the Rosedale boundary. The total area affected by negative elevation differences between -5 feet and -20 feet inside the Rosedale boundary is approximately 4,600 acres of agricultural land.

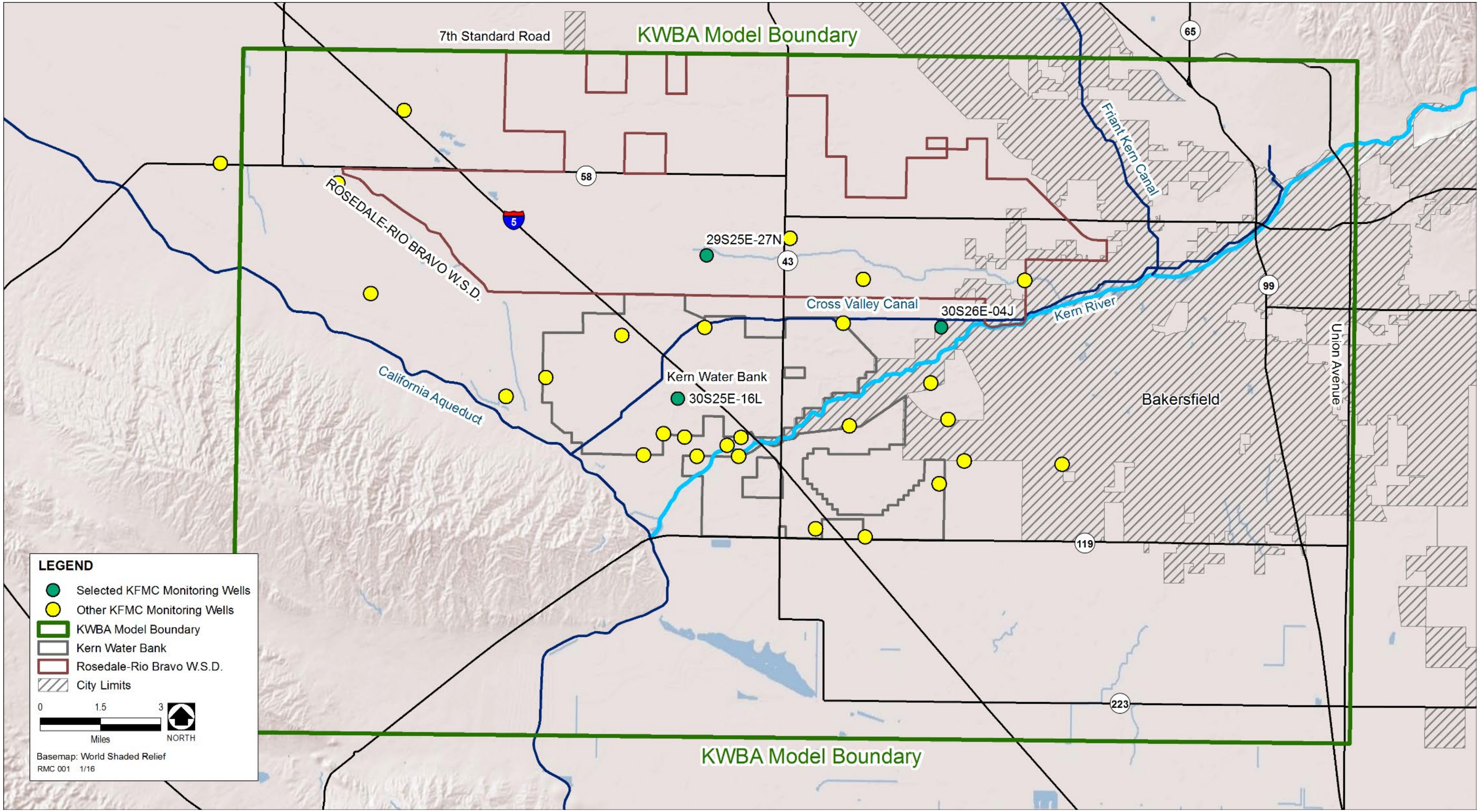


FIGURE 3.2-2. **Location of Three Selected Monitoring Wells within and outside Kern Water Bank Lands**

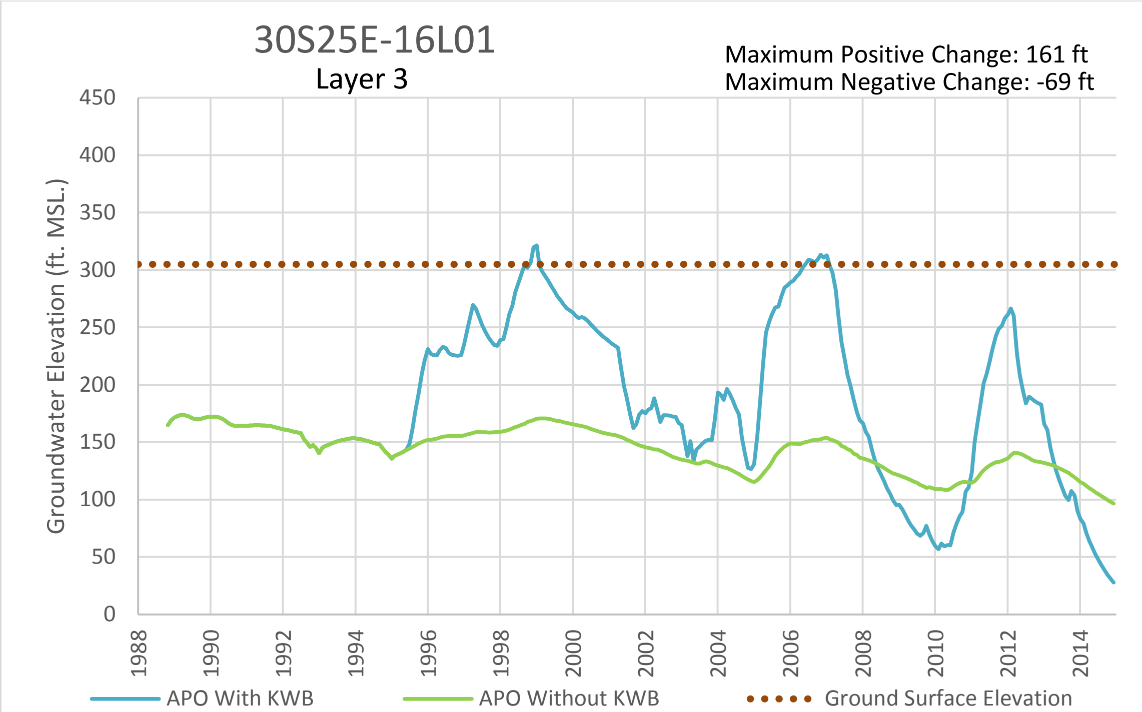


FIGURE 3.2-3. **Hydrographs of Analysis of Past Operations Simulated Water Levels at Monitoring Well 30S25E-16L, 1988-2014**

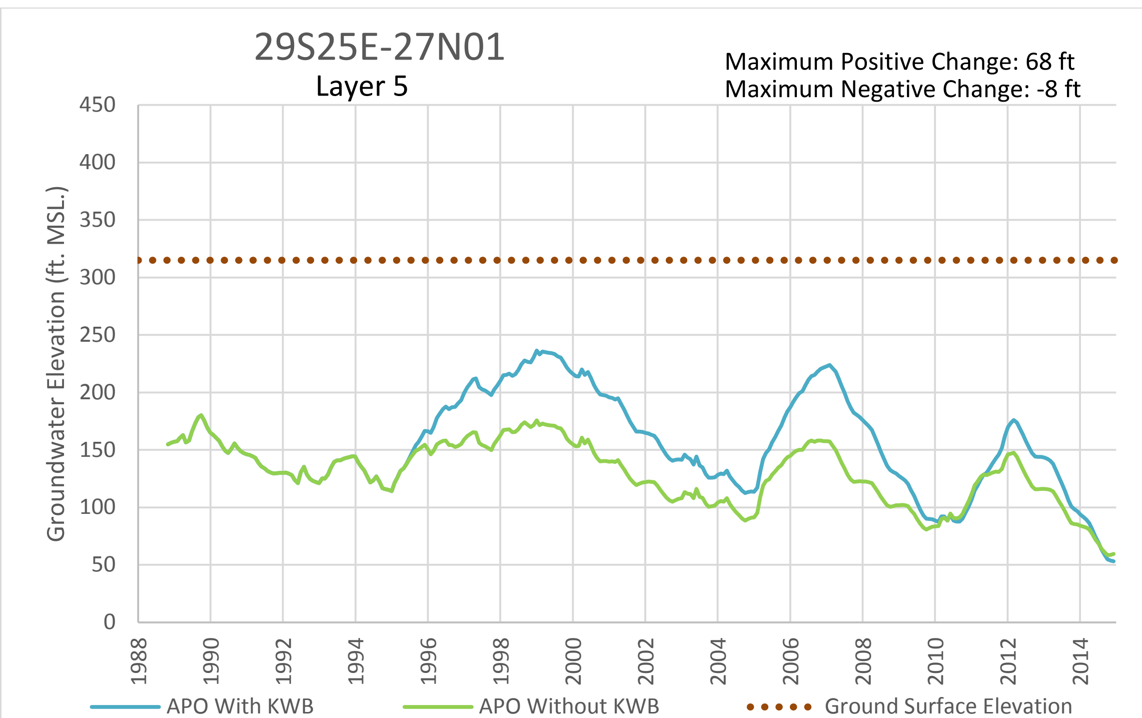


FIGURE 3.2-3b. **Hydrographs of Analysis of Past Operations Simulated Water Levels at Monitoring Well 29S25E-27N, 1988-2014**

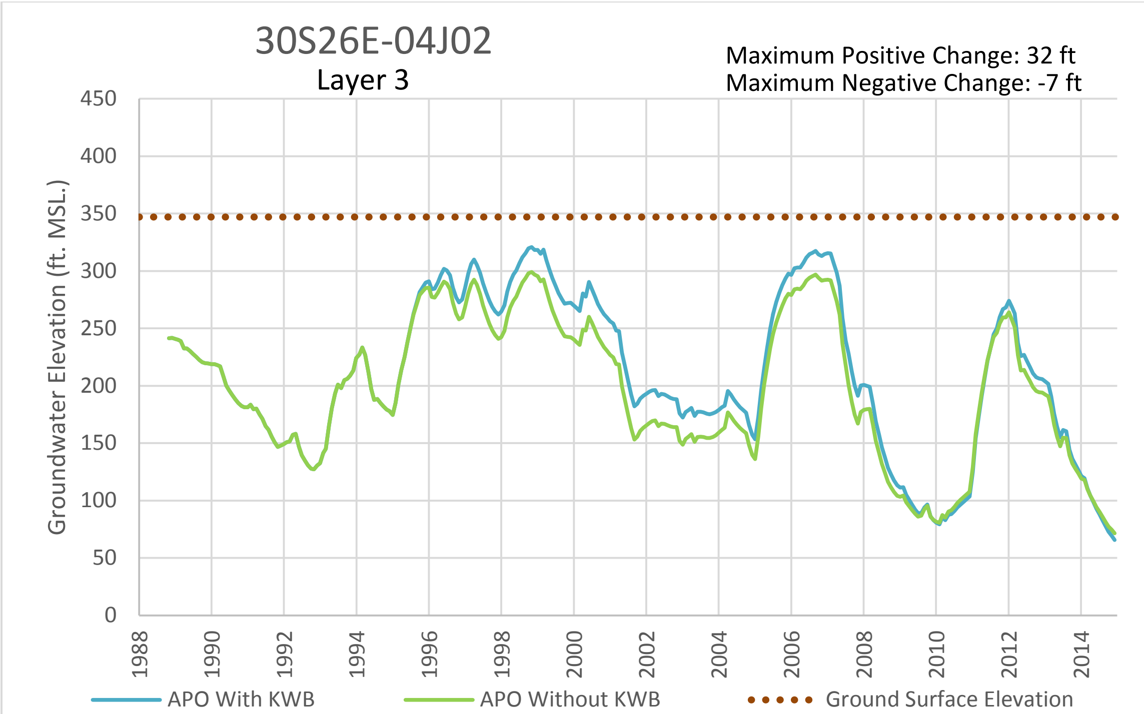


FIGURE 3.2-3c. **Hydrographs of Analysis of Past Operations Simulated Water Levels at Monitoring Well 30S26E-04J, 1988-2014**

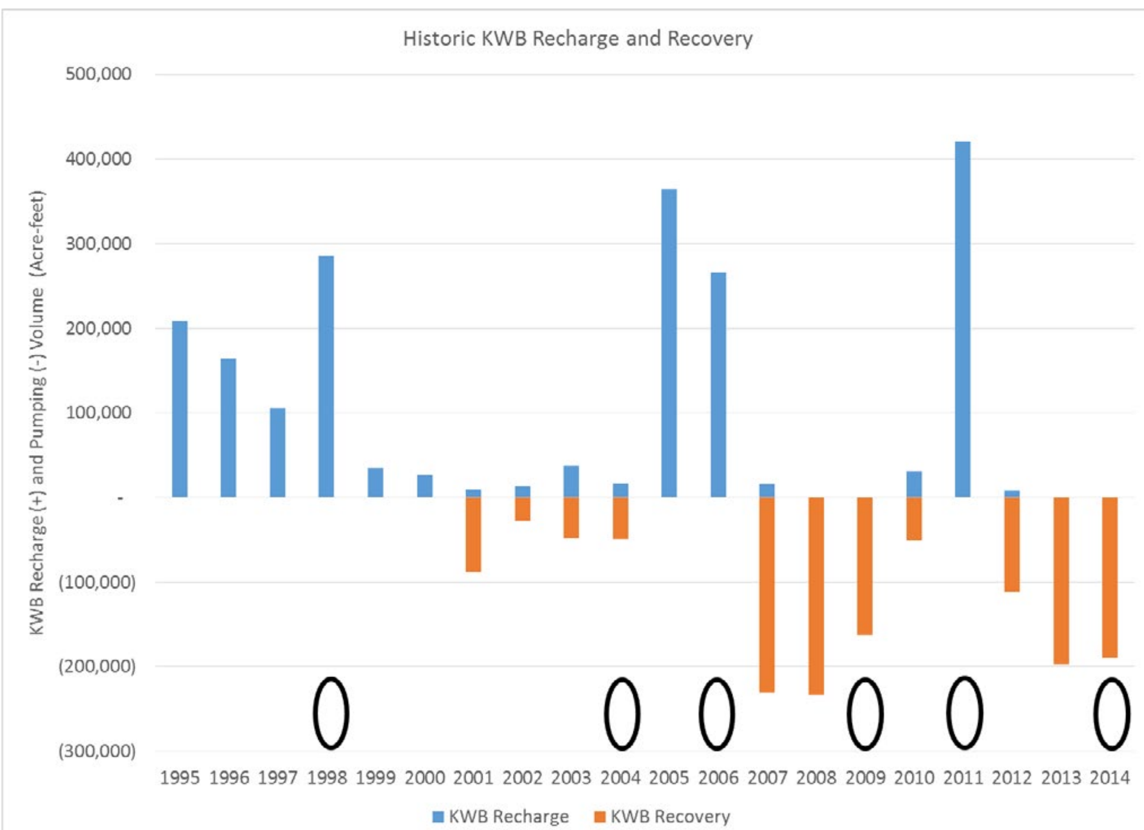


FIGURE 3.2-4. **Selected Recharge and Recovery Cycles for Developing the Head Difference Contour Maps, 1995-2014**

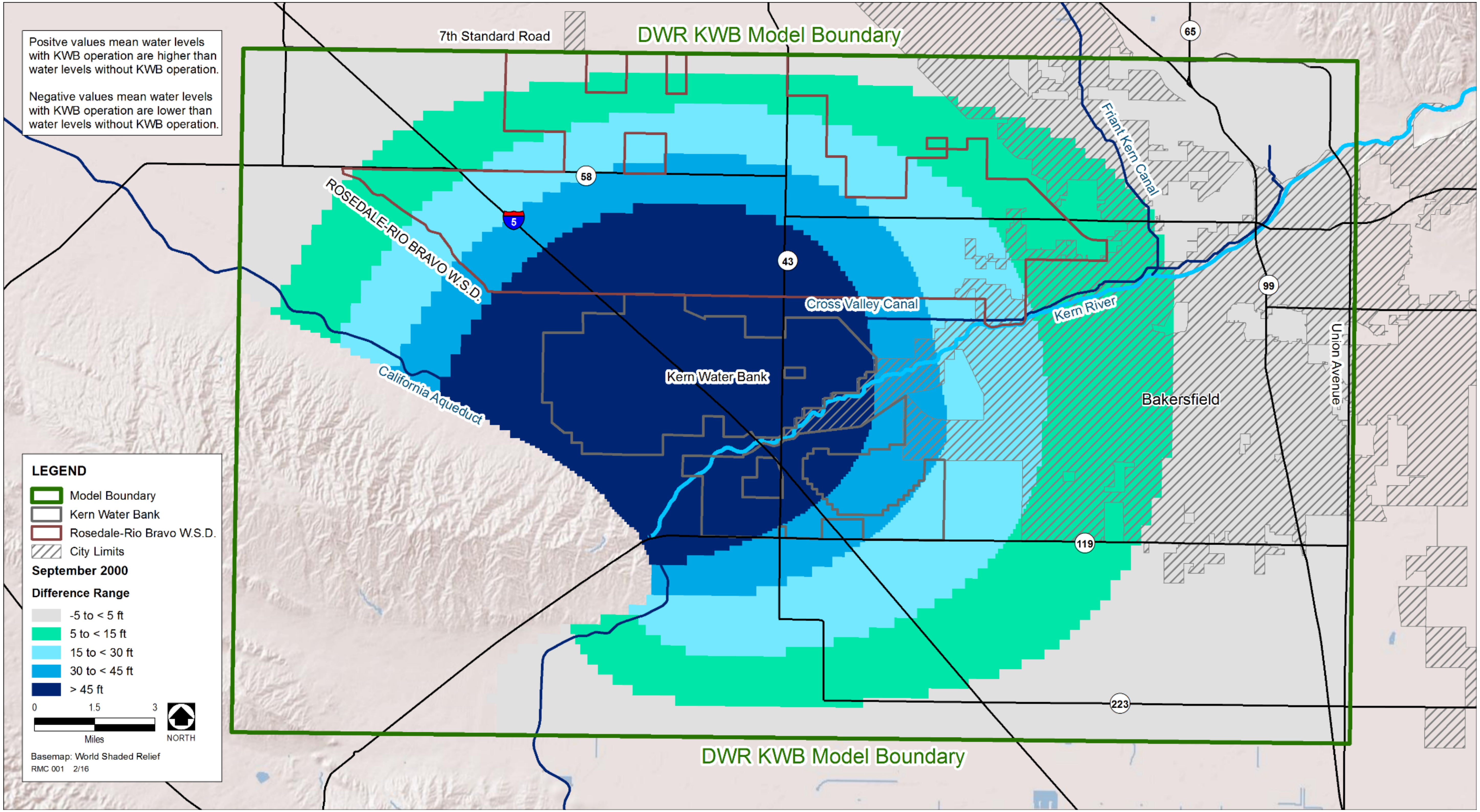


FIGURE 3.2-5a. **Analysis of Past Operations: Groundwater Elevation Difference Contour Map at the End of the 1995–2000 Recharge Cycle**

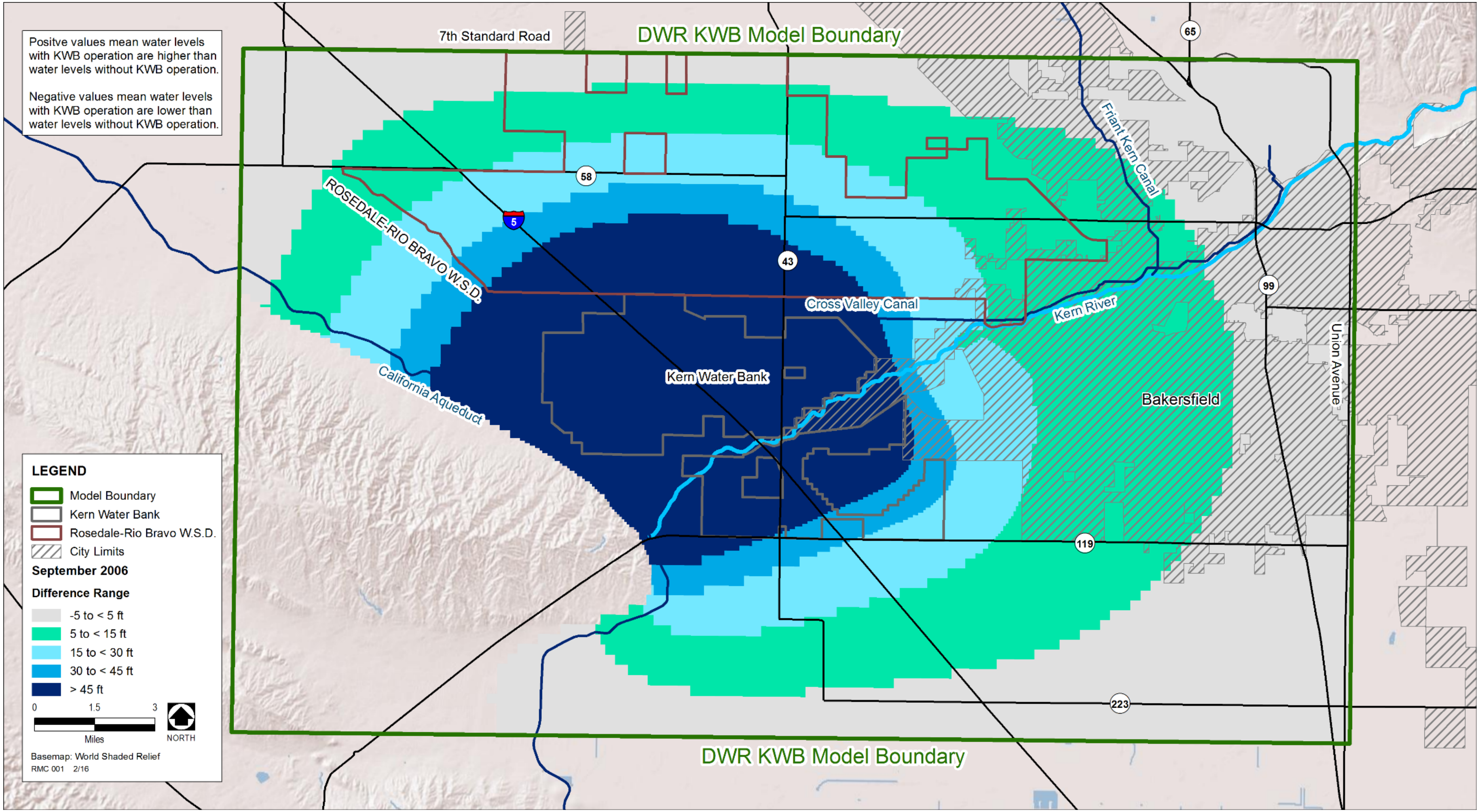


FIGURE 3.2-5b. **Analysis of Past Operations: Groundwater Elevation Difference Contour Map at the End of the 2006 Recharge Cycle**

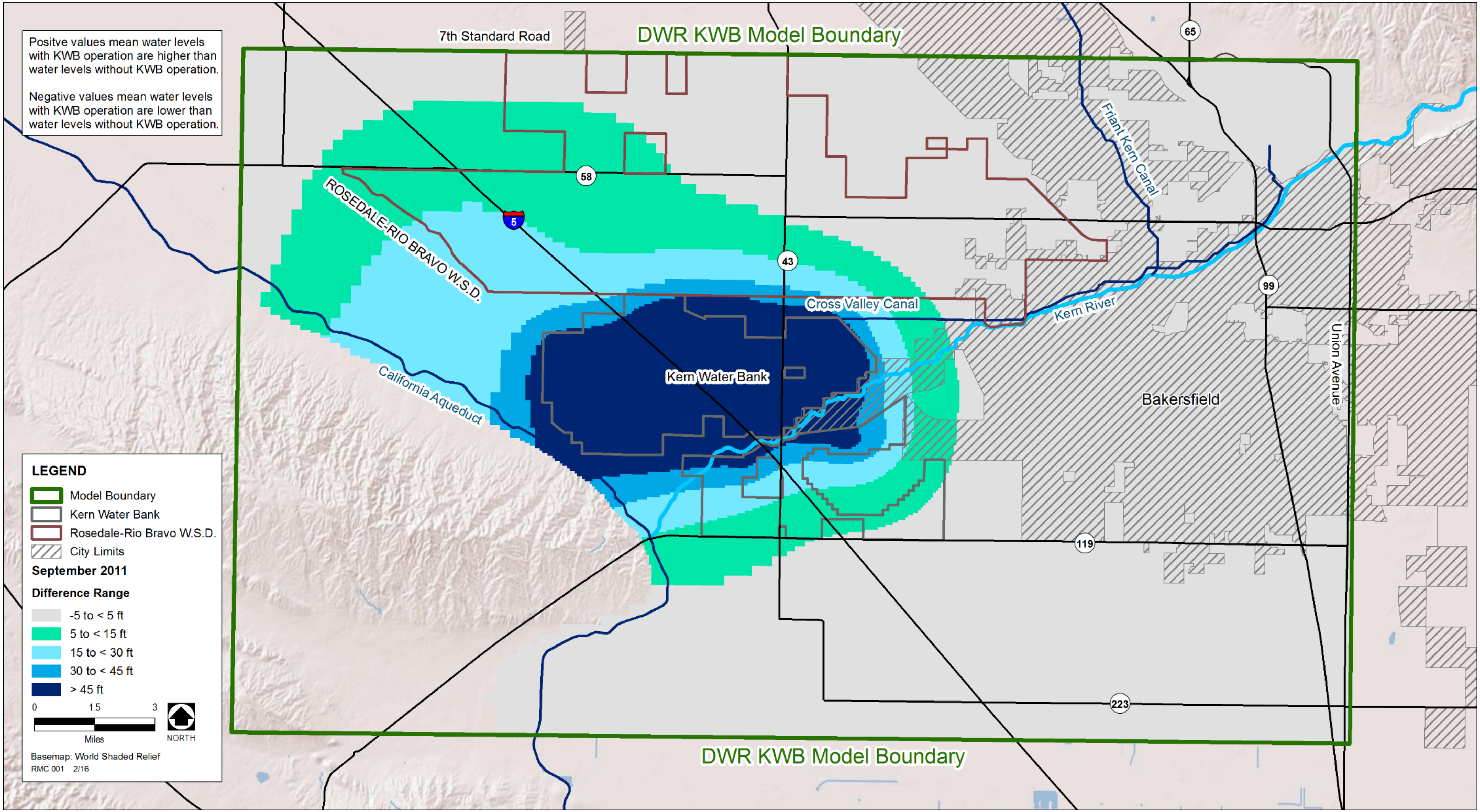


FIGURE 3.2-5c. Analysis of Past Operations: Groundwater Elevation Difference Contour Map at the End of the 2011 Recharge Cycle

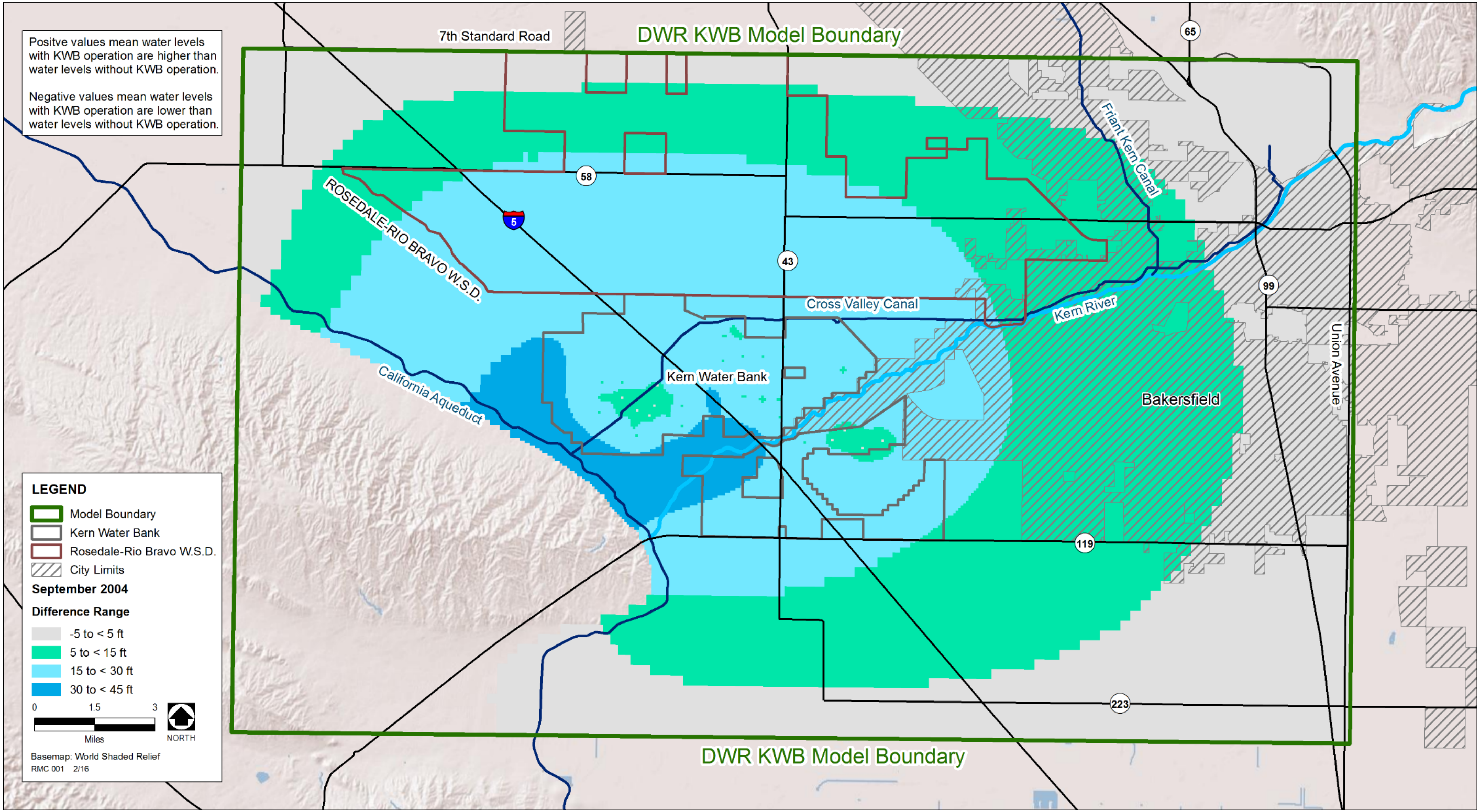


FIGURE 3.2-6a. **Analysis of Past Operations: Groundwater Elevation Difference Contour Map at the End of the 2001–2004 Recovery Cycle**

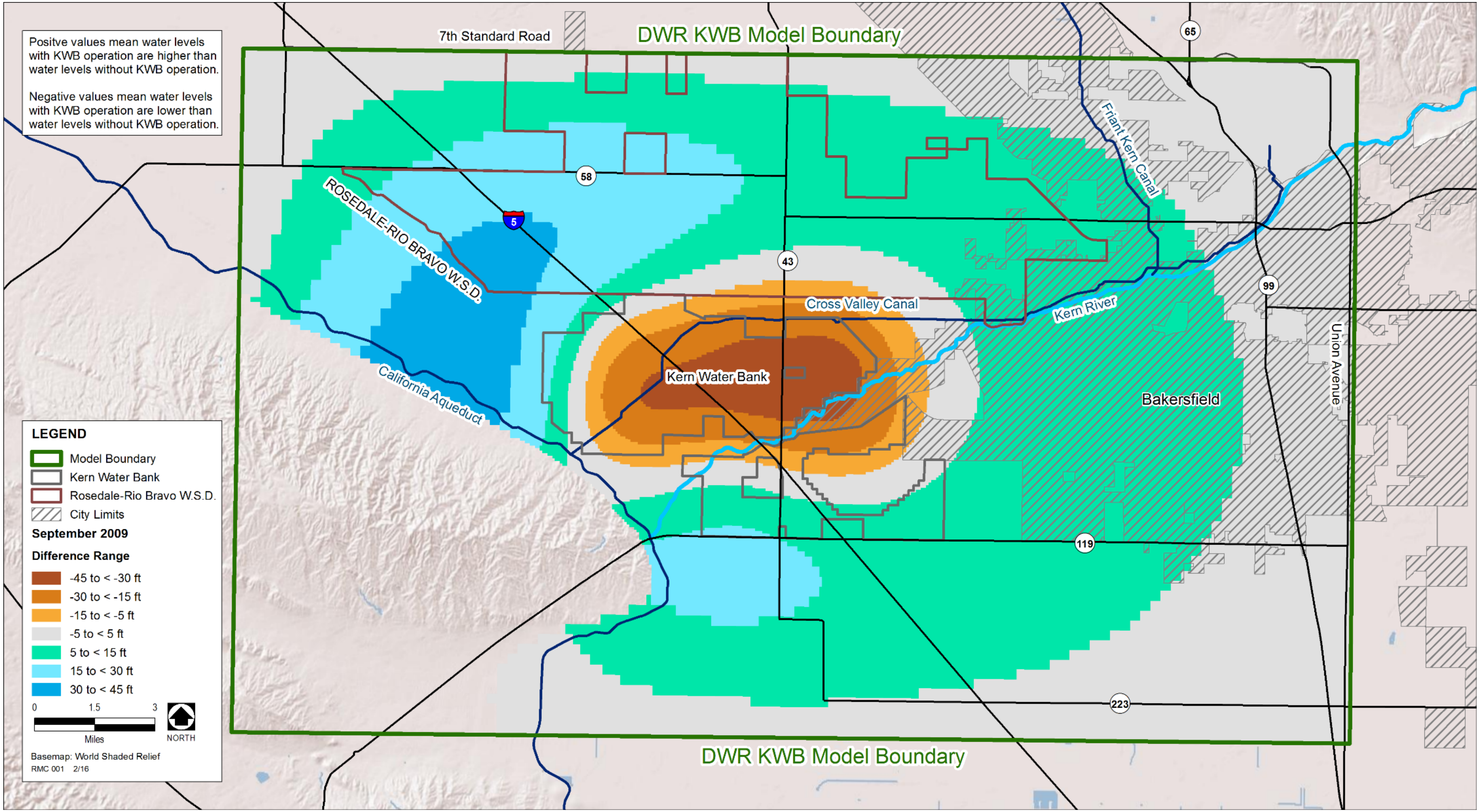


FIGURE 3.2-6b. Analysis of Past Operations: Groundwater Elevation Difference Contour Map at the End of the 2009 Recovery Cycle

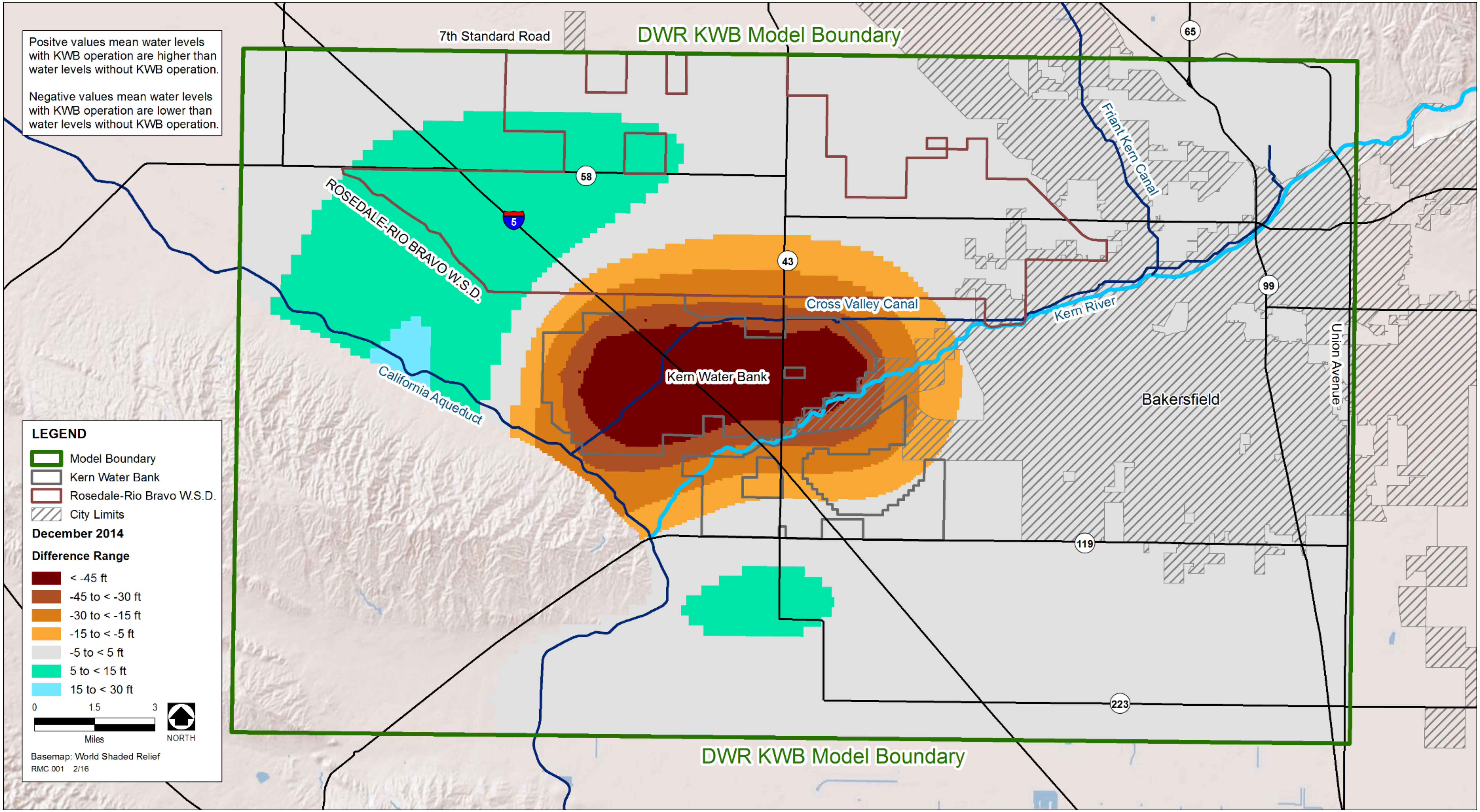


FIGURE 3.2-6c. Analysis of Past Operations: Groundwater Elevation Difference Contour Map at the End of the 2014 Recharge Cycle

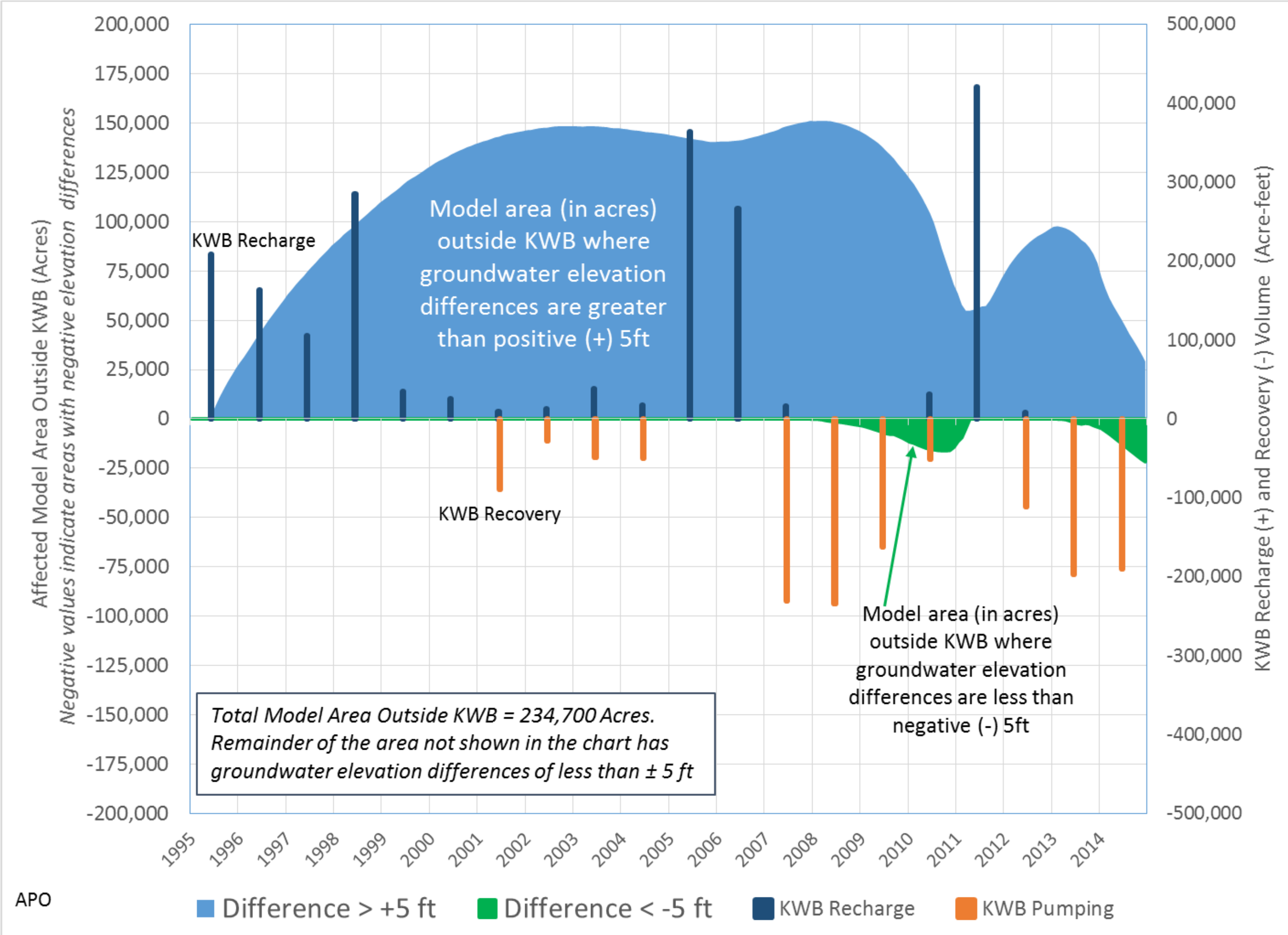


FIGURE 3.2-7. **Analysis of Past Operations: Time vs. Affected Area Outside the Kern Water Bank Exceeding ± 5 Feet Differences in Groundwater Elevations ("With Kern Water Bank Operations" Minus "Without Kern Water Bank Operations"), 1995-2014**

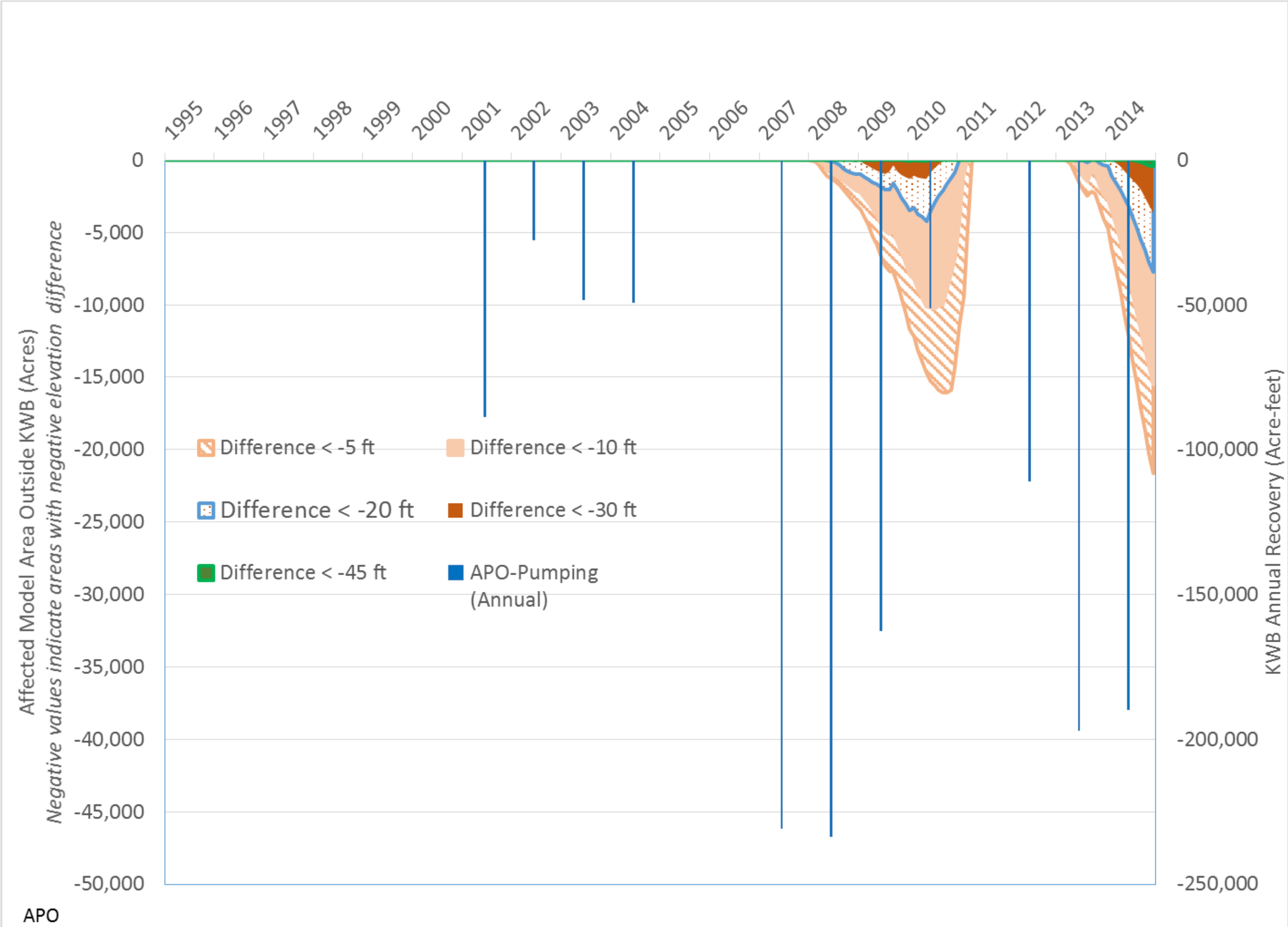


FIGURE 3.2-8. **Analysis of Past Operations: Time vs. Affected Area Outside Kern Water Bank at Various Levels of Negative Elevation Differences ("With Kern Water Bank Operations" Minus "Without Kern Water Bank Operations"), 1995-2014**

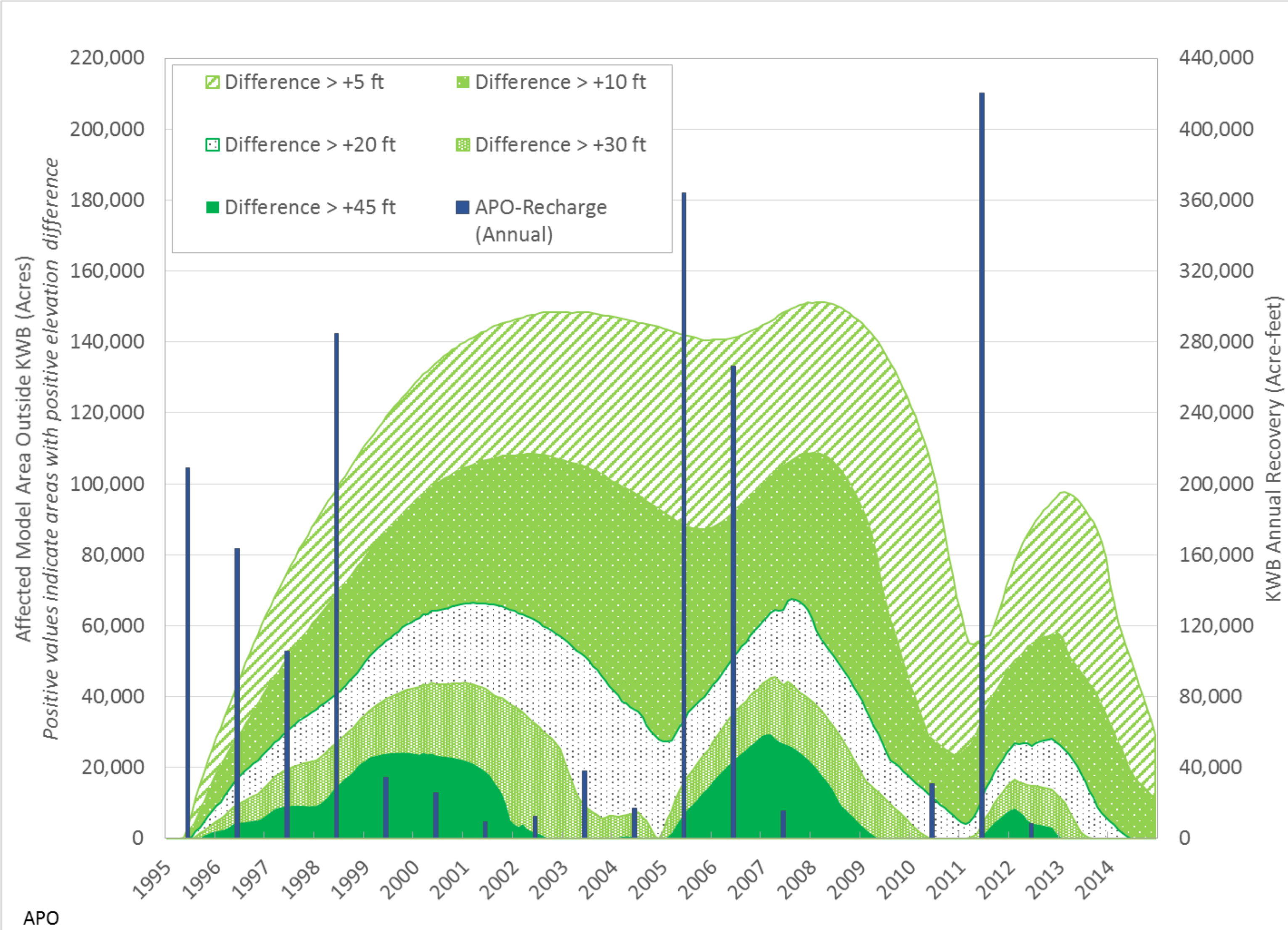


FIGURE 3.2-9. **Analysis of Past Operations: Time vs. Affected Area Outside Kern Water Bank at Various Levels of Positive Elevation Differences ("With Kern Water Bank Operations" Minus "Without Kern Water Bank Operations"), 1995-2014**

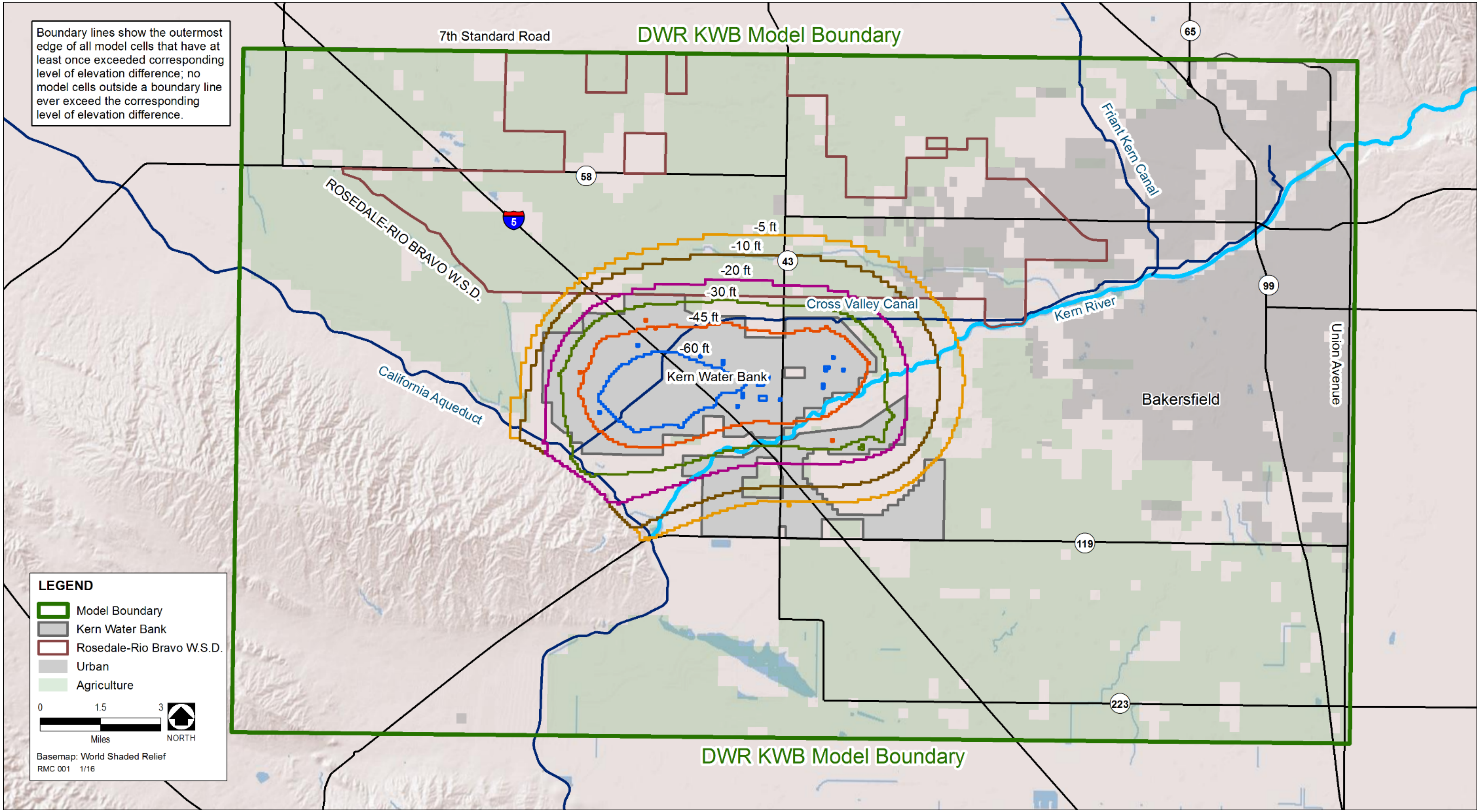


FIGURE 3.2-10. Analysis of Past Operations: Contours of Maximum Negative Differences ("With" minus "Without"), 1995-2014

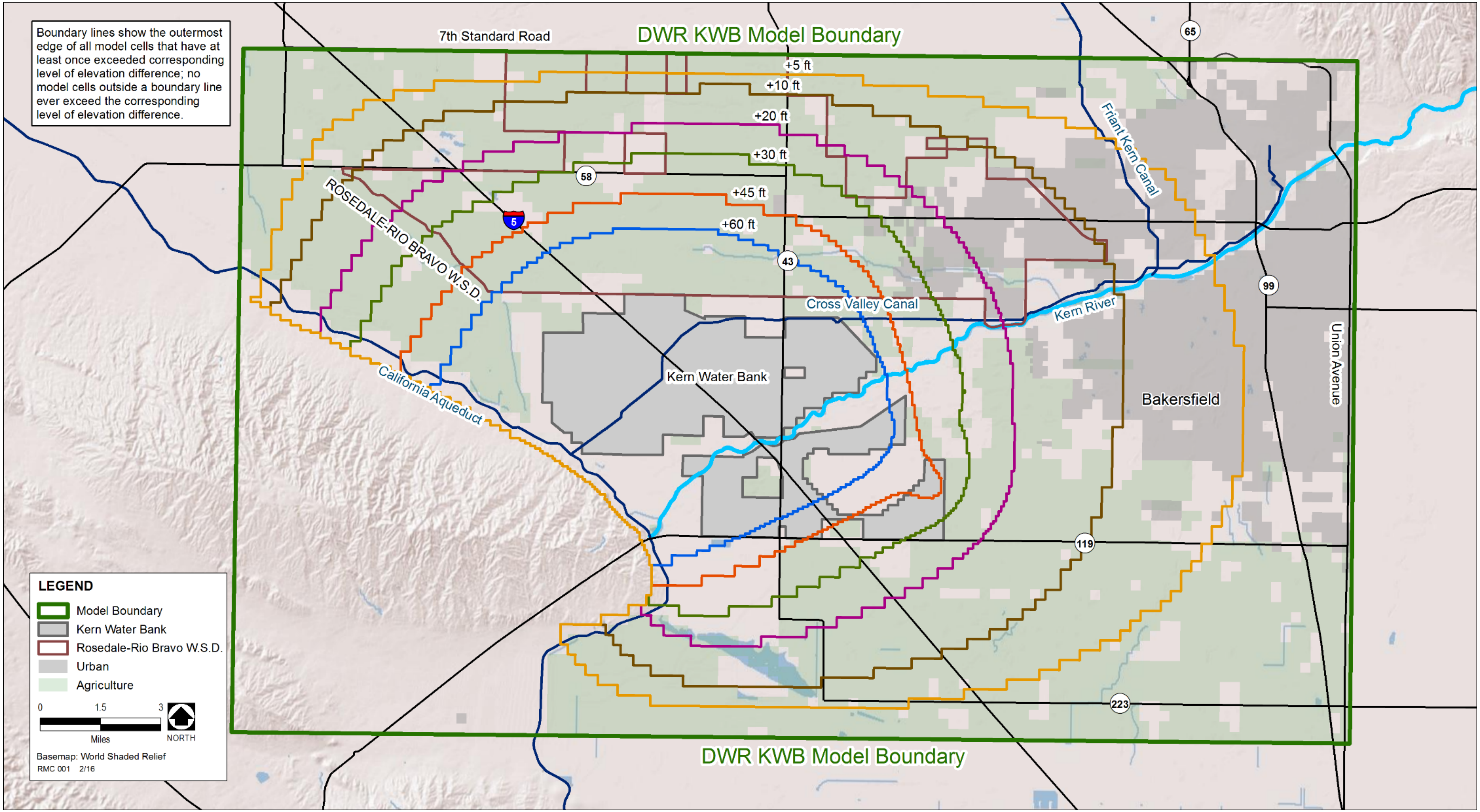


FIGURE 3.2-11. Analysis of Past Operations: Contours of Maximum Positive Elevation Differences (“With” minus “Without”), 1995–2014

Figure 3.2-11 shows the maximum spatial extent of positive elevation differences exceeding +5 feet, +10 feet, +20 feet, +30 feet, +45 feet, and +60 feet. Positive differences in groundwater elevation attributable to KWB operations spread as far as 6 miles from the northern and eastern edges of KWB Lands and as far as 4 miles from the southern edge of KWB Lands.

3.2.3.3 Acreages of Affected Areas

The -30 feet negative elevation difference boundary line (see Figure 3.2-10) extends into the agricultural area north and east of the KWB boundary. The negative differences in groundwater elevations between "With" and "Without" KWB operations spread into more agricultural areas as the specified levels change from -30 feet to -5 feet. Acreages where water level differences exceed specified levels are shown in Tables 3.2-2 and 3.2-3. Areas of affected agricultural and urban lands are shown in Tables 3.2-4 and 3.2-5.

3.2.4 FREQUENCY DISTRIBUTION OF GROUNDWATER ELEVATION DIFFERENCE

Maps were prepared to evaluate the location and frequency with which groundwater elevation differences between the APO "With KWB Operations" and "Without KWB Operations" scenarios exceeded selected values (Metric 6 of Section 3.1). Frequency distributions of negative groundwater elevation differences exceeding -45 feet, -30 feet, -20 feet, and -10 feet are shown in Figures 3.2-12a to 3.2-12d, respectively. Frequency distributions of groundwater elevation differences exceeding +10 feet, +30 feet, and +60 feet are shown in Figures 3.2-13a to 3.2-13c, respectively.

Figure 3.2-12a shows that negative elevation differences exceeding -45 feet are contained entirely within the KWB boundary at all times. Figure 3.2-12b shows that negative elevation differences exceeding -30 feet are contained entirely within the KWB boundary approximately 90 percent of the time.

Positive elevation differences exceeding +60 feet (Figure 3.2-13c) are mostly contained within the KWB boundary. Approximately 25 percent of the time such differences occur outside the KWB boundary, but in the immediate vicinity.

3.2.5 ZONAL AVERAGE GROUNDWATER ELEVATION HYDROGRAPHS

Average groundwater elevations outside KWB Lands (Metric 7 of Section 3.1) were evaluated at five 1-mile zones (Figure 3.2-14). Simulated head was averaged for each cell in a particular zone for each monthly time step of the simulation period. Average groundwater elevations for Zones 1–5 are shown in Figures 3.2-15a to 3.2-15e. Figure 3.2-16 shows the average elevation difference in each zone, which was calculated by subtracting the "Without KWB Operations" run from the "With KWB Operations" run data shown in Figures 3.2-15a to 3.2-15e. These figures indicate that the rise and fall of the groundwater mound follows KWB recharge and recovery cycles, and is correlated with the cumulative KWB storage balance. At a distance beyond approximately 2 miles outside the KWB boundary, the average groundwater elevation difference between the "With KWB Operations" and "Without KWB Operations" run is always positive.

3.2.6 HIGH GROUNDWATER LEVELS AND IMPACT ON INFRASTRUCTURE

Historic recharge operations at KWB during the recharge periods of 1996–1998, 2005–2006, and 2011, concomitant with similar recharge operations at other neighboring groundwater banks, resulted in high groundwater elevations within KWB Lands and the surrounding areas. High groundwater elevations resulted in some damages to Cross Valley Canal (CVC) lining in the mid-1990s.

High groundwater elevations could impact the existing infrastructure within and in the vicinity of the KWB. Large urban areas to the east and northeast of KWB Lands use septic system. Additionally, there are small residential areas in the vicinity of KWB Lands that are on septic systems or dry wells. The CVC and residential area septic systems are the main infrastructure in the DWR KWB Model domain that might potentially be impacted by high water levels.

Results of APO model scenario were evaluated to determine the potential impact of KWB recharge operation during high groundwater elevations on the CVC and nearby areas on septic systems.

Figures 3.2-17 to 3.2-19 show the spatial characteristics of the groundwater mounds that form during recharge operations of 1999-1998, 2005-2006, and 2011 under APO conditions “With KWB Operations.”

Impacts of KWB recharge operations during high groundwater elevations for APO on the CVC and nearby areas on septic systems were evaluated by analyzing water levels at locations along the CVC and at nearby areas with septic systems.

Figure 3.2-20 shows the locations of the two selected water level hydrographs along the CVC. The hydrograph locations were selected based on locations of the piezometers and pumping stations of the CVC; these hydrographs are used to demonstrate the impacts on CVC. Figure 3.2-21 shows the areas near KWB Lands that are on septic systems or dry wells as obtained from the Kern County General Plan and Google Earth; it also shows the locations of two selected water level hydrographs used to demonstrate the impacts on septic areas.

Figure 3.2-22 shows the groundwater level hydrographs at two selected locations along the CVC. The hydrographs show the water levels at the selected locations for the APO “With KWB Operations” and “Without KWB Operations” scenarios, ground surface elevation, and the CVC invert elevation. It is assumed that the CVC invert is 10 feet below ground surface. The impact of the KWB recharge operations on the CVC is discussed below.

Figure 3.2-23 shows water level hydrographs at two locations near KWB Lands with groundwater levels that have the potential to impact septic systems. The hydrographs show the water levels for the APO “With KWB Operations” and “Without KWB Operations” scenarios and the ground surface elevation.

3.2.6.1 1995-1998 Recharge Operations

As shown in Figures 3.2-17 and 3.2-22, 1995-1999 recharge operations resulted in water levels rising to within 5 feet from ground surface along the section of the CVC in the western parts of KWB Lands, while the water levels were lower along the section of the CVC in the northern parts of KWB Lands and only rose to 20 feet from ground surface.

The recharge operations in 1995-1999 did not result in high enough water levels to impact the septic systems as the depth to water in residential areas with septic systems located north of KWB Lands exceeds 50 feet. As shown in Figure 3.2-23, depth to groundwater in areas in the vicinity of KWB Lands with septic systems or dry wells was more than 35 feet west of KWB Lands and more than 40 feet north of KWB Lands. Groundwater elevations are not high enough to impact the septic systems of these areas

3.2.6.2 2005-2006 Recharge Operations

As shown in Figures 3.2-18 and 3.2-22, 2005-2006 recharge operations resulted in water levels rising to within 5 feet from ground surface along most of the CVC in western parts of KWB Lands, while the water levels were about 40 feet from ground surface along the section of the CVC in the northern parts of KWB Lands.

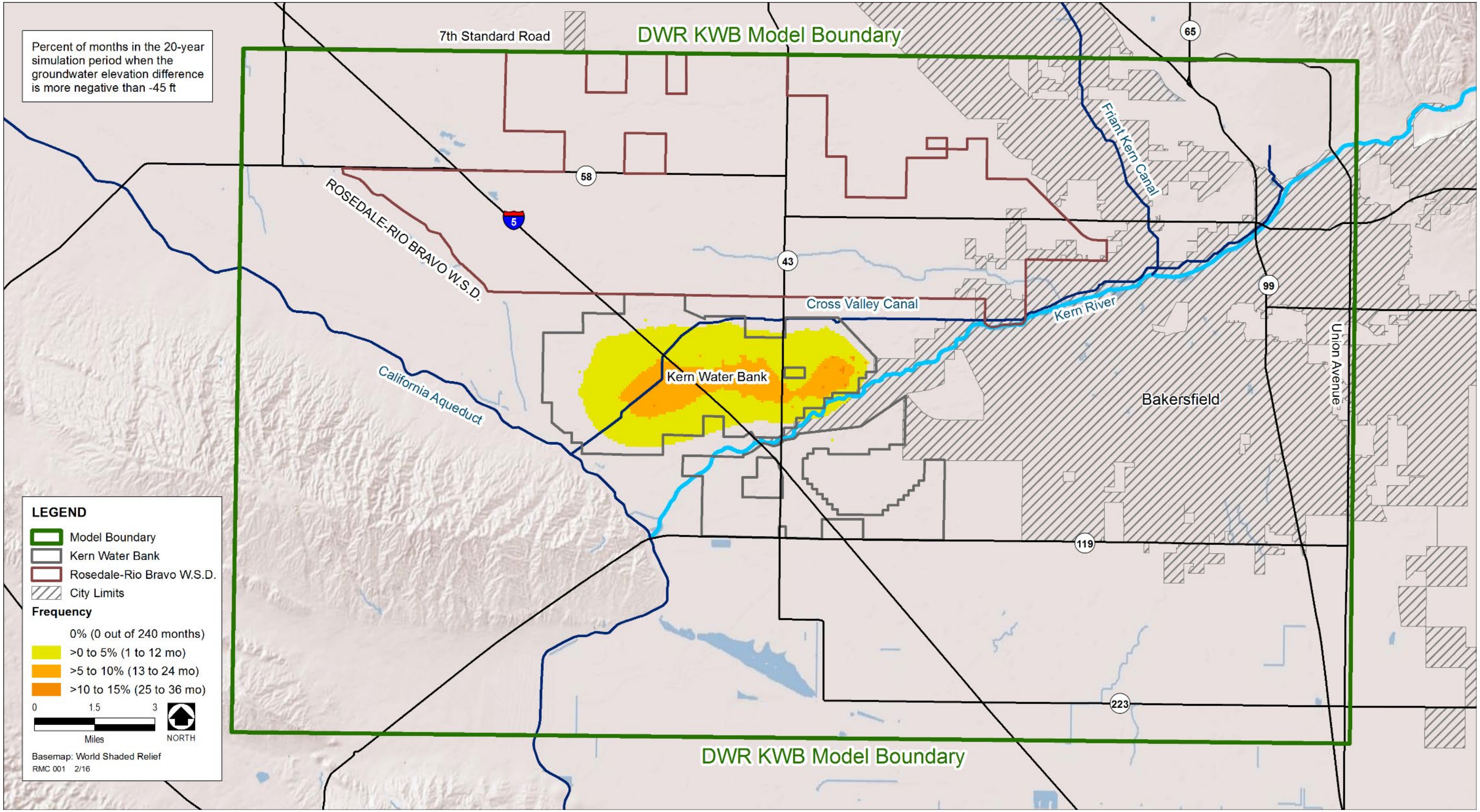


FIGURE 3.2-12a. **Analysis of Past Operations: Frequency Distribution (% of Months) of Areas with > -45 Feet Difference in Groundwater Elevations ("With Kern Water Bank Operations" Minus "Without Kern Water Bank Operations"), 1995-2014**

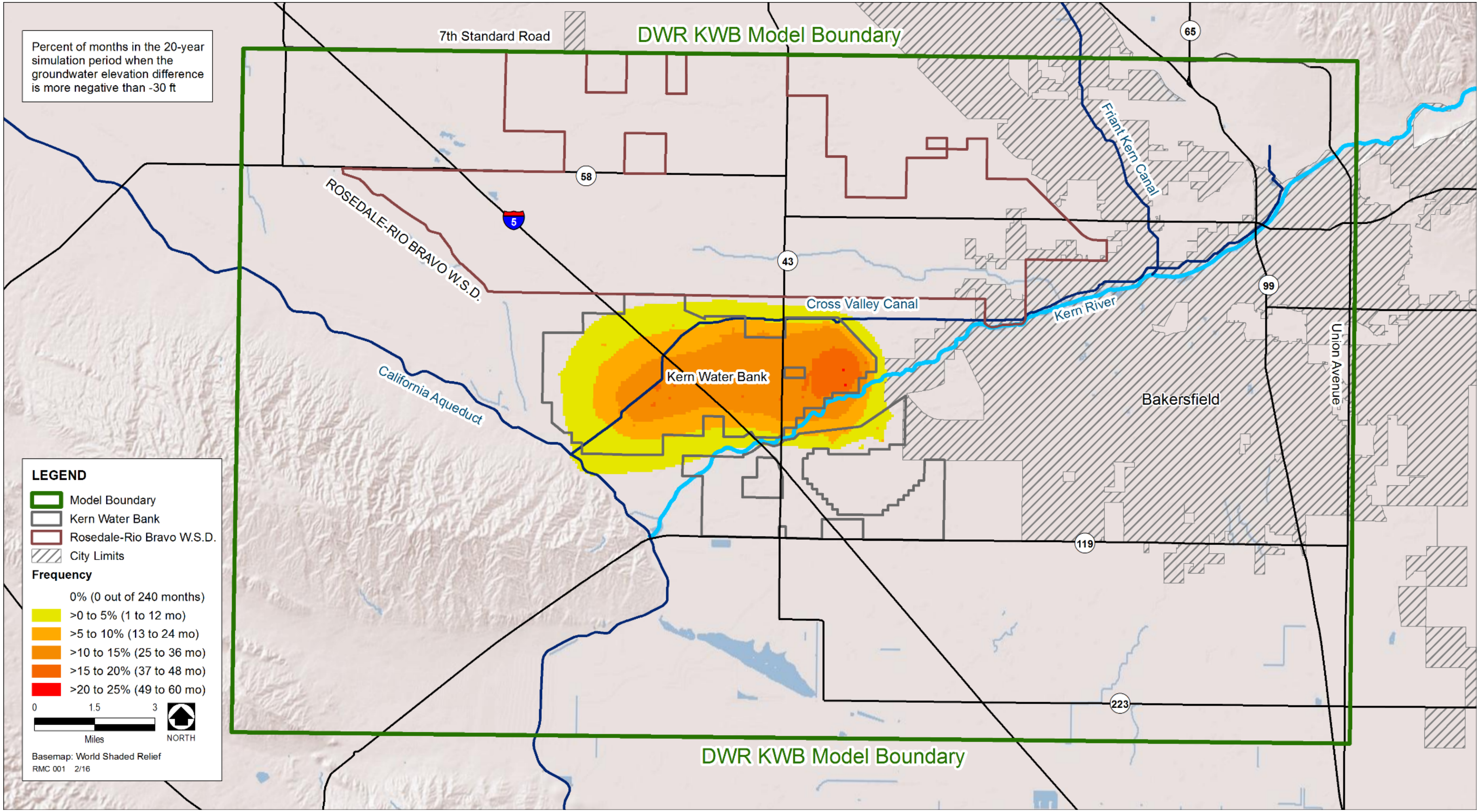


FIGURE 3.2-12b. **Analysis of Past Operations: Frequency Distribution (% of Months) of Areas with > -30 Feet Difference in Groundwater Elevations ("With Kern Water Bank Operations" Minus "Without Kern Water Bank Operations"), 1995-2014**

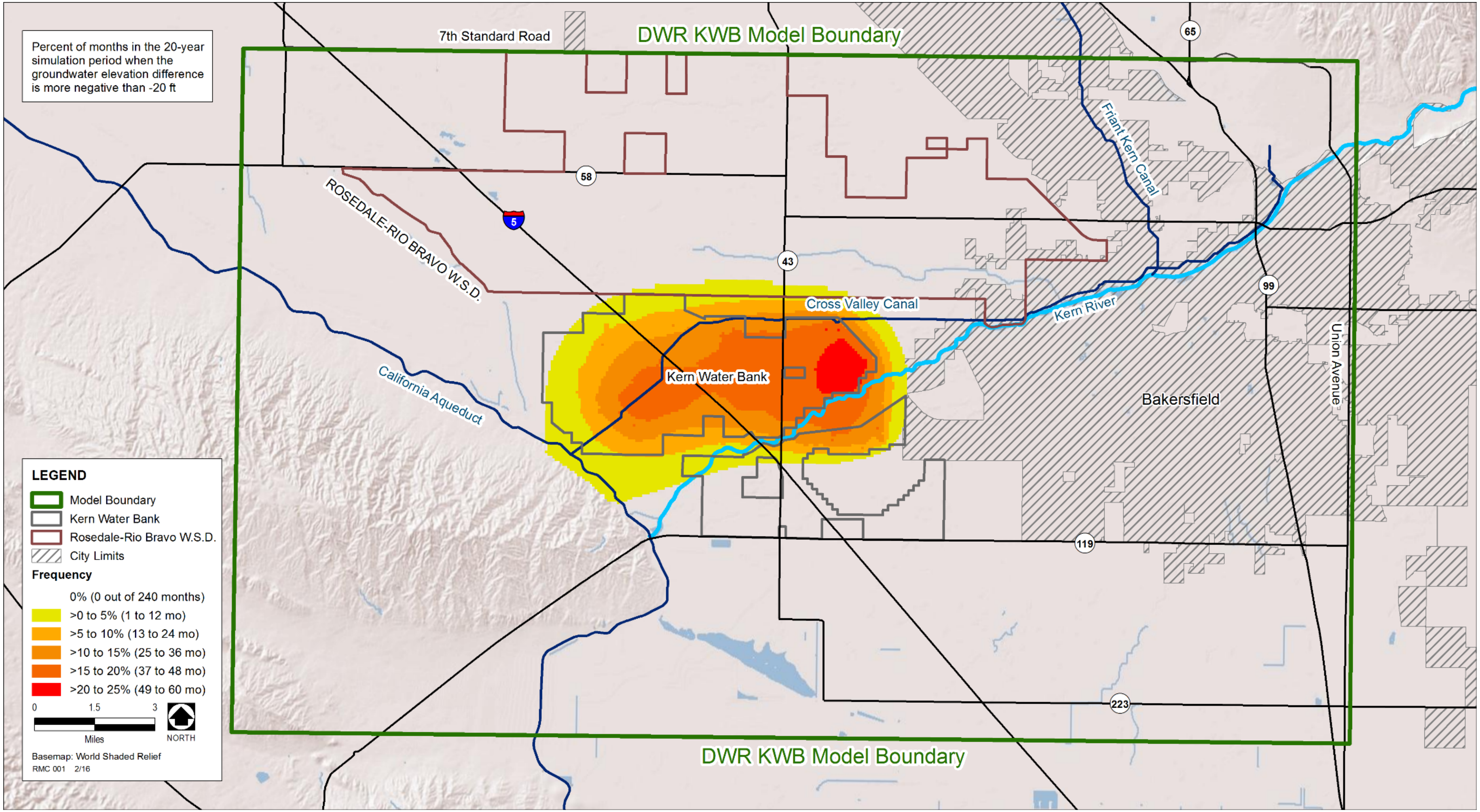


FIGURE 3.2-12c. **Analysis of Past Operations: Frequency Distribution (% of Months) of Areas with > -20 Feet Difference in Groundwater Elevations ("With Kern Water Bank Operations" Minus "Without Kern Water Bank Operations"), 1995-2014**

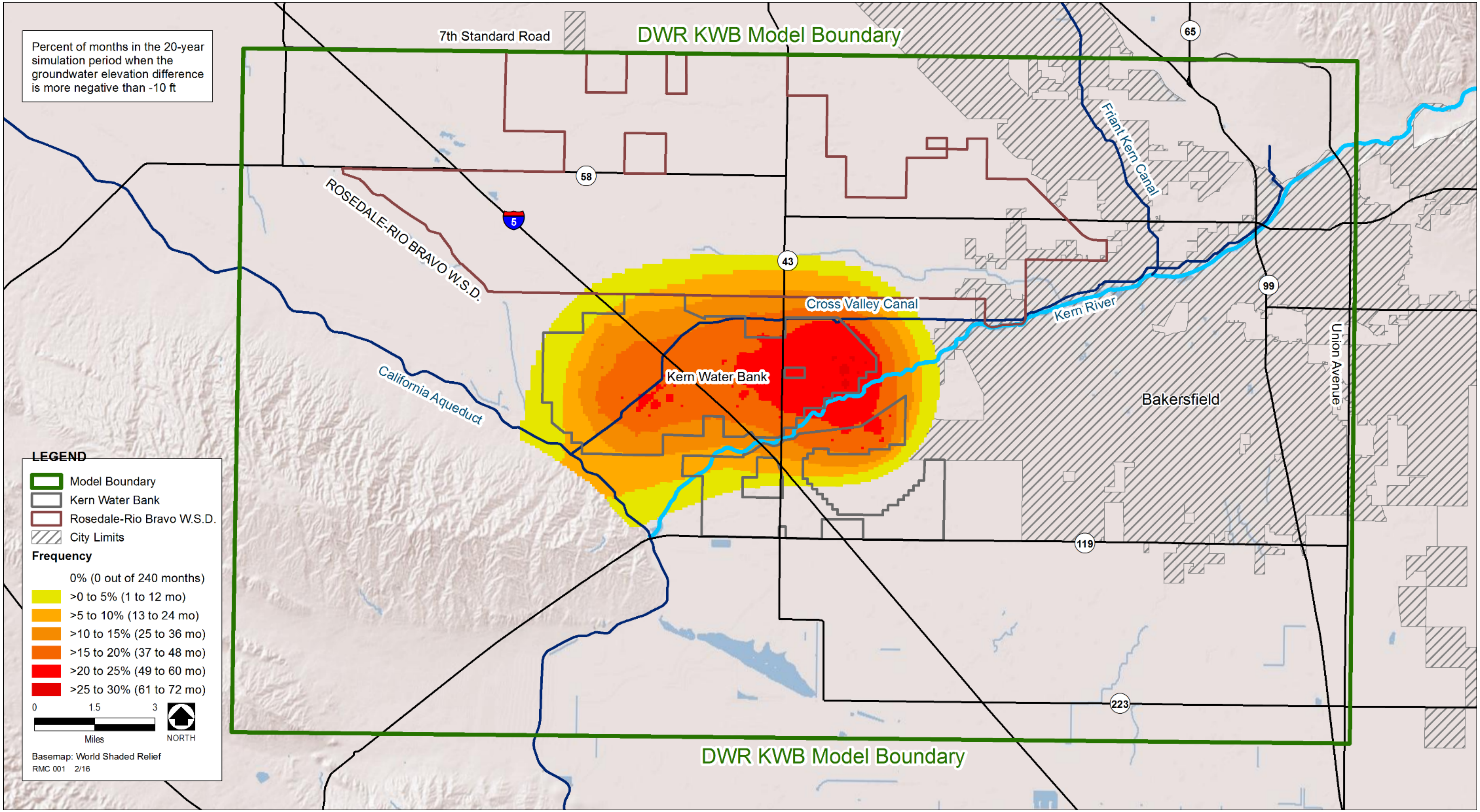


FIGURE 3.2-12d. **Analysis of Past Operations: Frequency Distribution (% of Months) of Areas with > -10 Feet Difference in Groundwater Elevations (“With Kern Water Bank Operations” Minus “Without Kern Water Bank Operations”), 1995-2014**

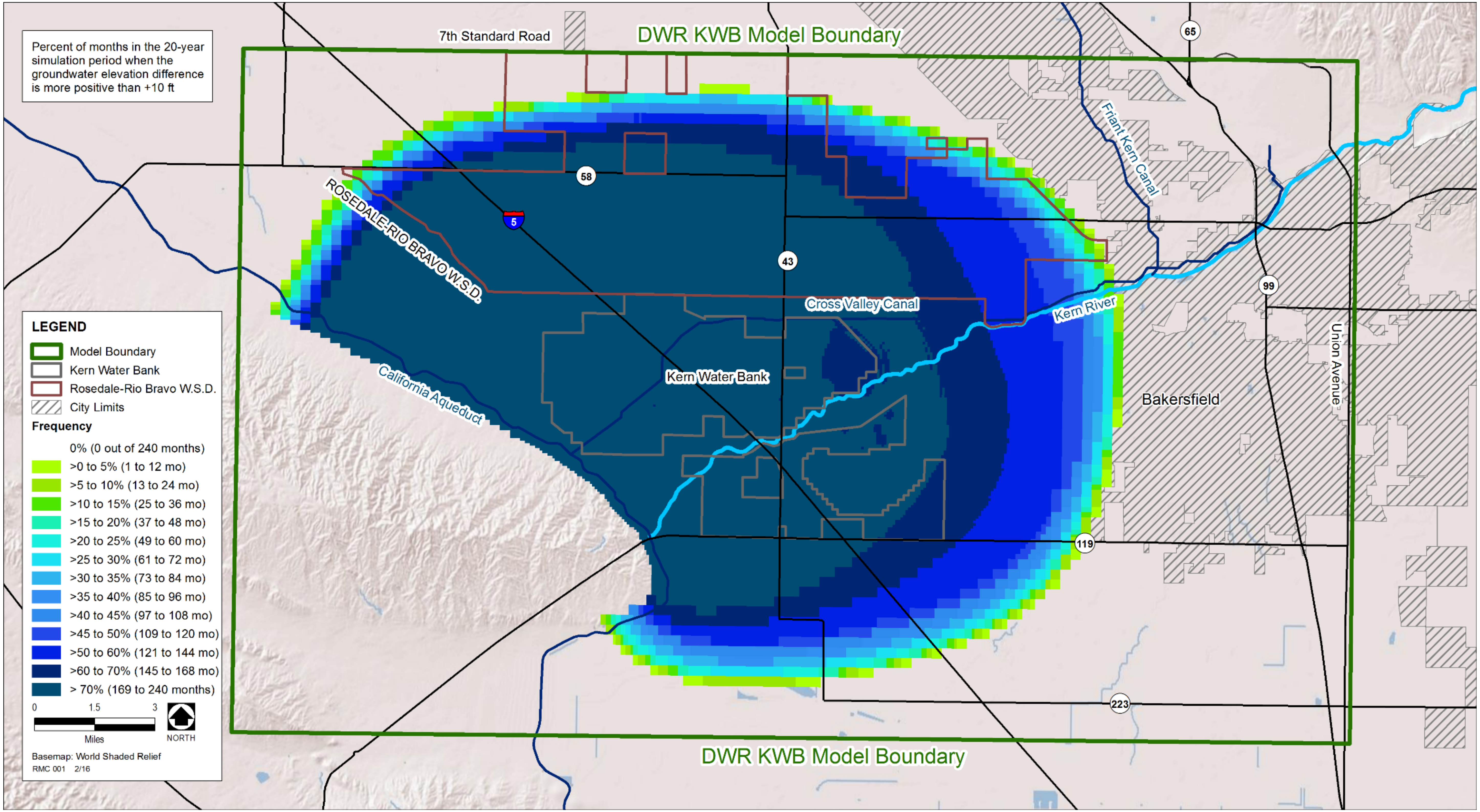


FIGURE 3.2-13a. **Analysis of Past Operations: Frequency Distribution (% of Months) of Areas with > +10 Feet Difference in Groundwater Elevations (“With Kern Water Bank Operations” Minus “Without Kern Water Bank Operations”), 1995-2014**

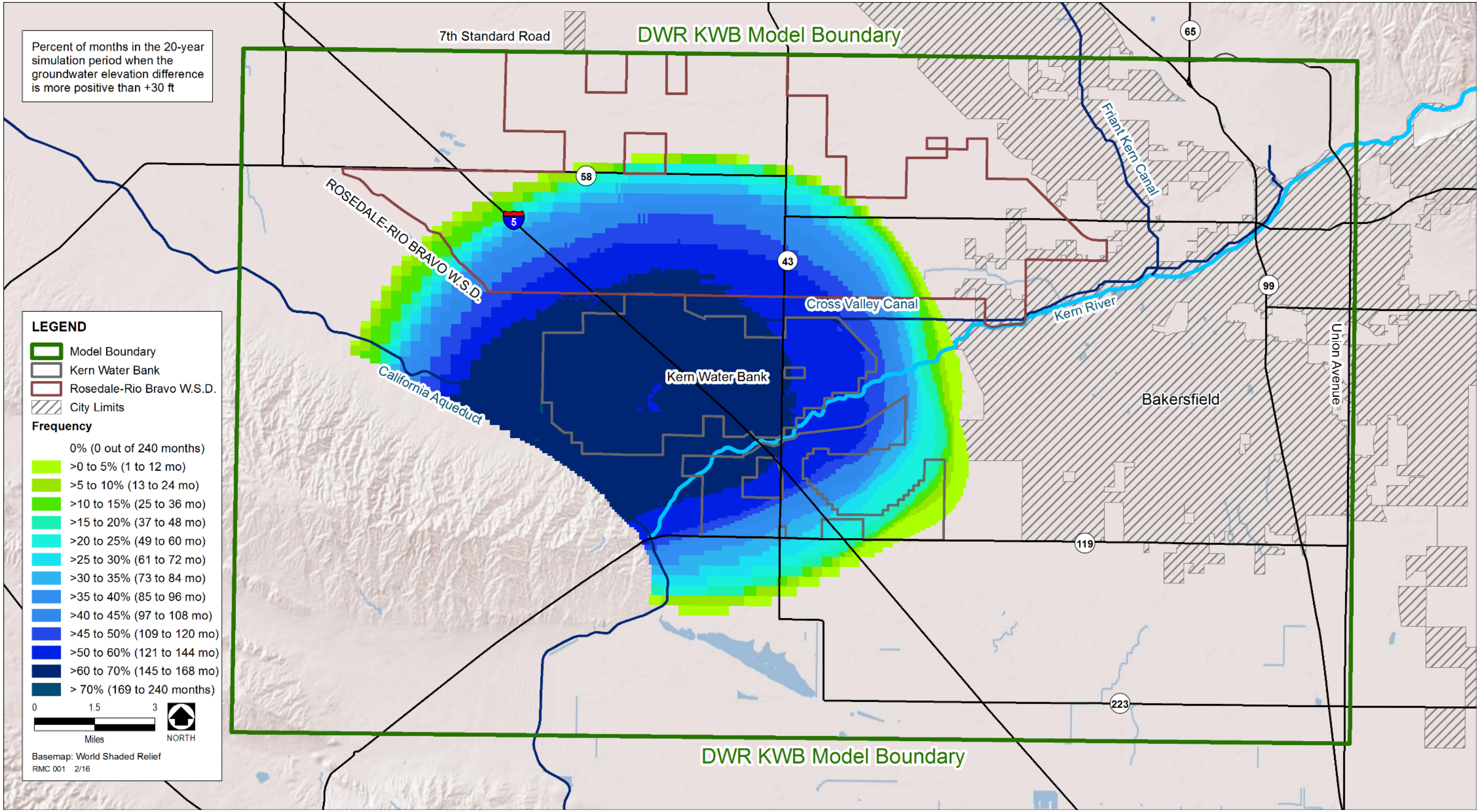


FIGURE 3.2-13b. Analysis of Past Operations: Frequency Distribution (% of Months) of Areas with > +30 Feet Difference in Groundwater Elevations (“With Kern Water Bank Operations” Minus “Without Kern Water Bank Operations”), 1995-2014

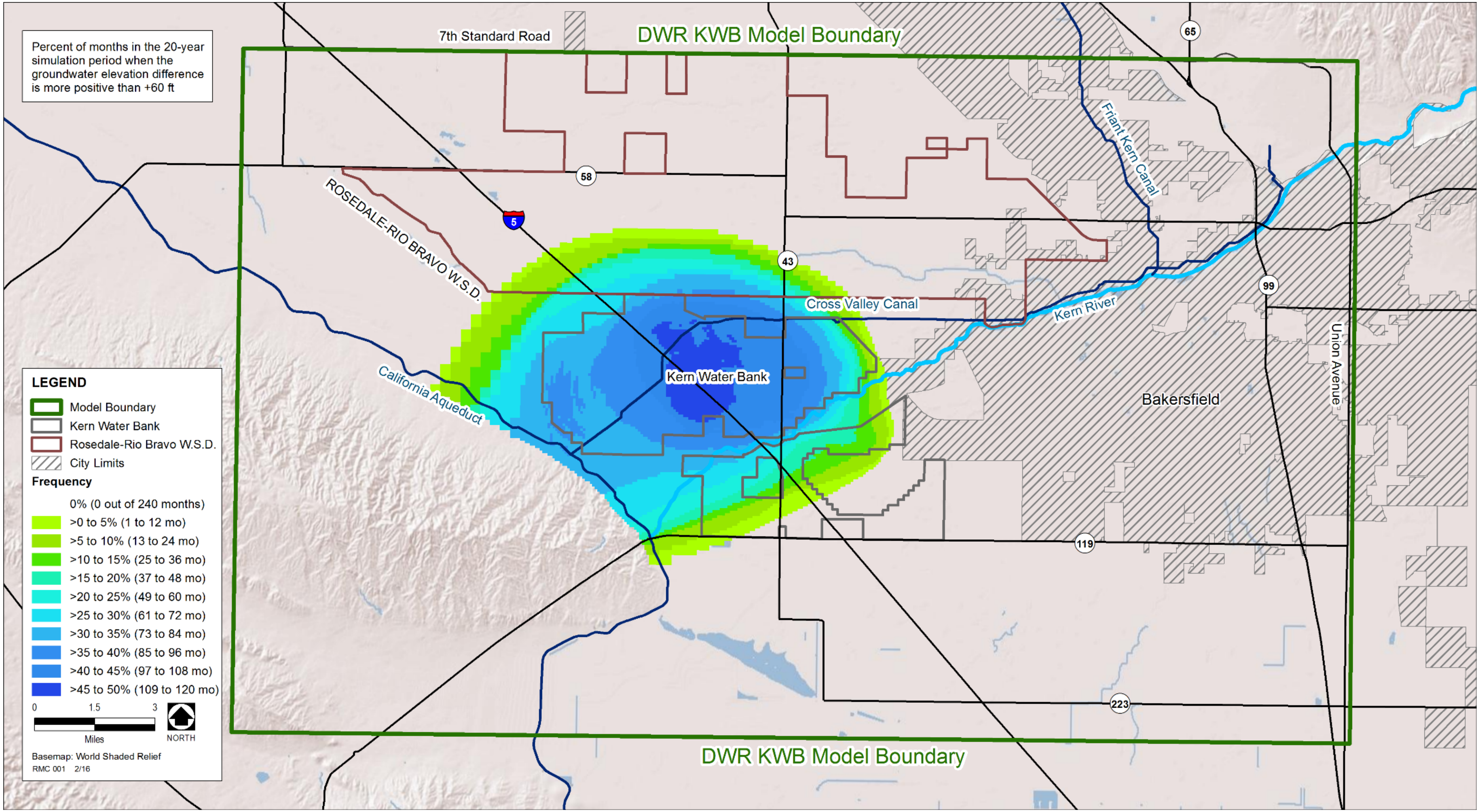


FIGURE 3.2-13c. Analysis of Past Operations: Frequency Distribution (% of Months) of Areas with > +60 Feet Difference in Groundwater Elevations (“With Kern Water Bank Operations” Minus “Without Kern Water Bank Operations”), 1995-2014

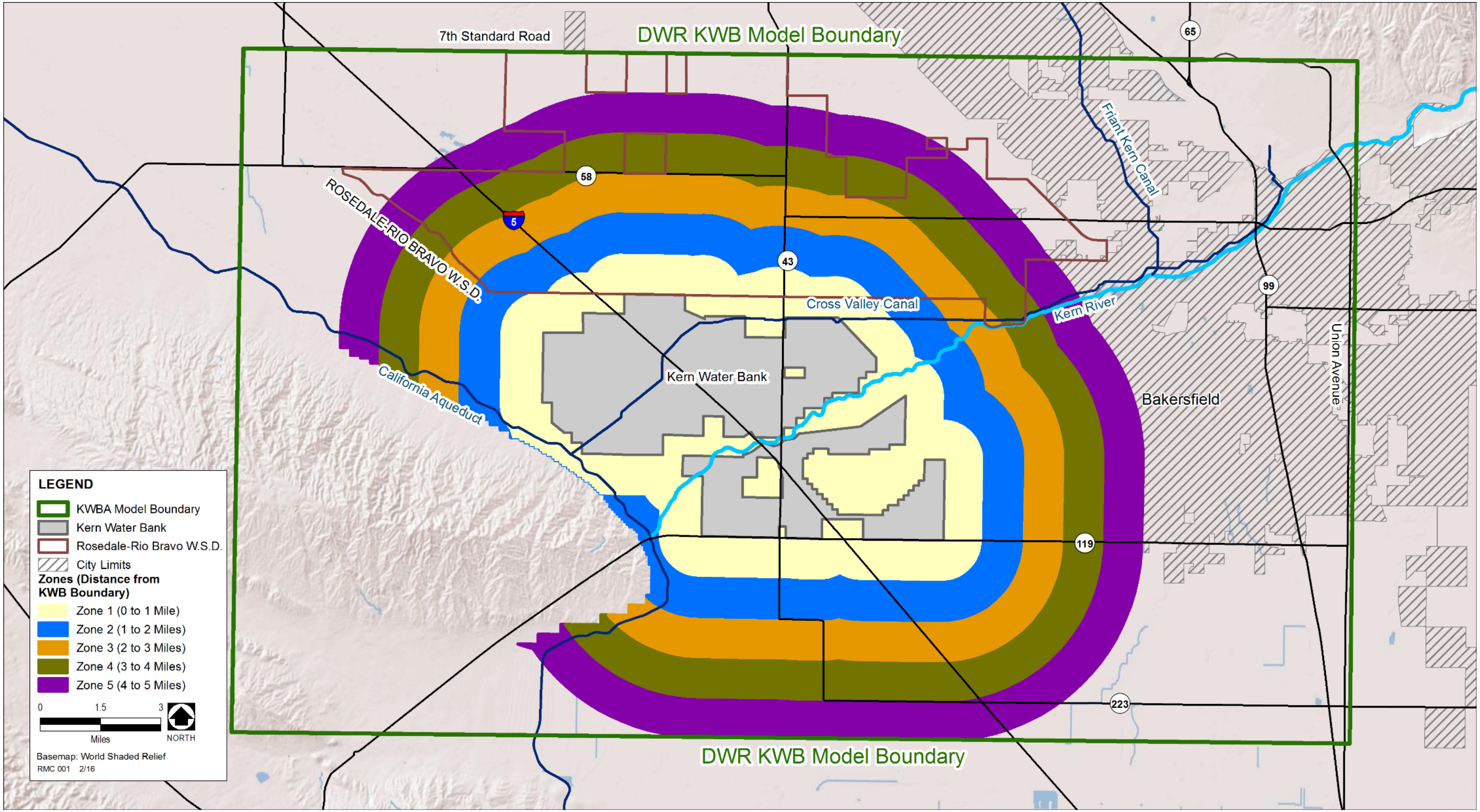


FIGURE 3.2-14. Area Zones Outside the Kern Water Bank Boundary

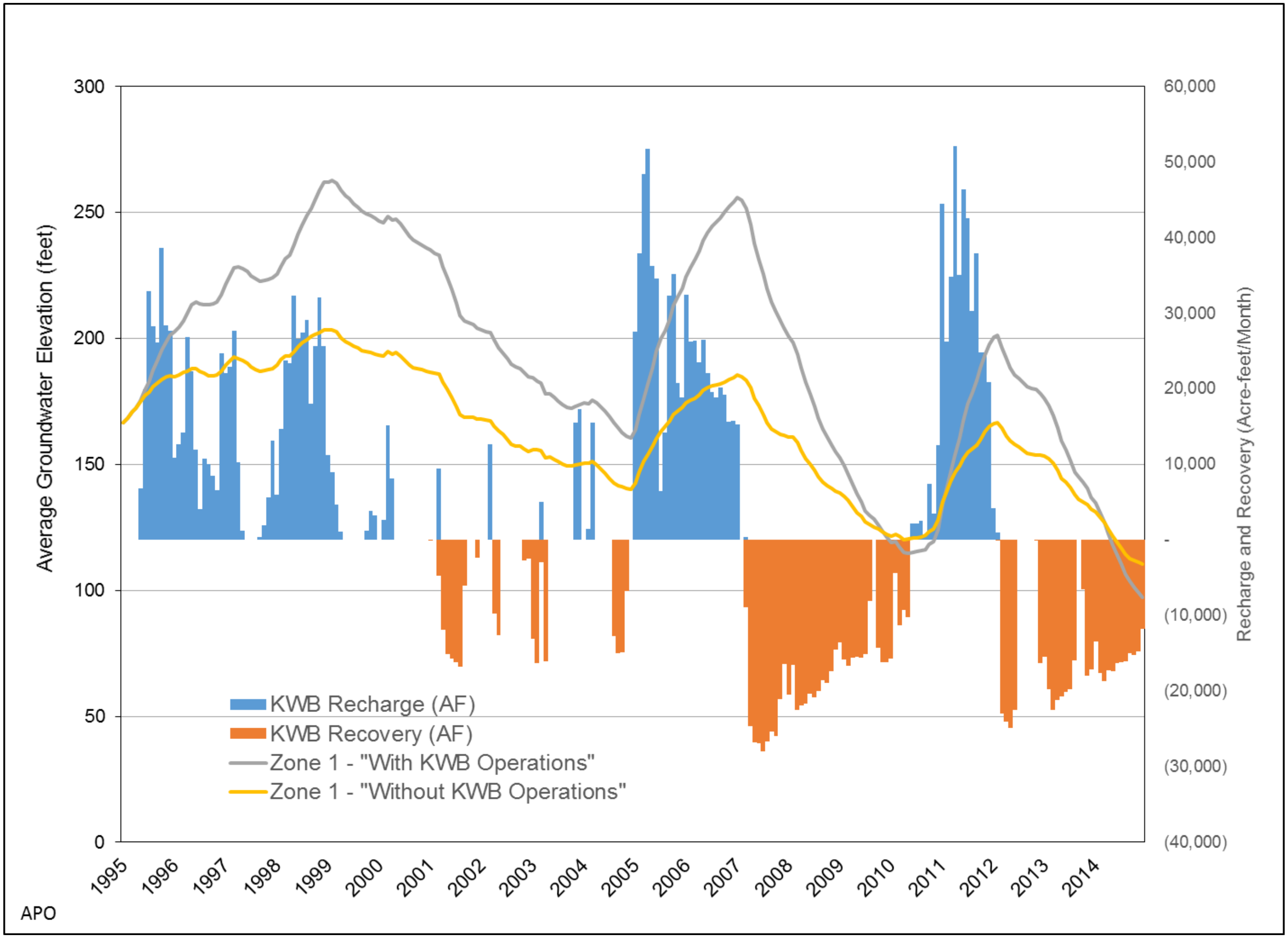


FIGURE 3.2-15a. **Analysis of Past Operations: Average Groundwater Elevation Over Zone 1 (0 to 1 Mile Outside the Kern Water Bank Boundary), 1995-2014**

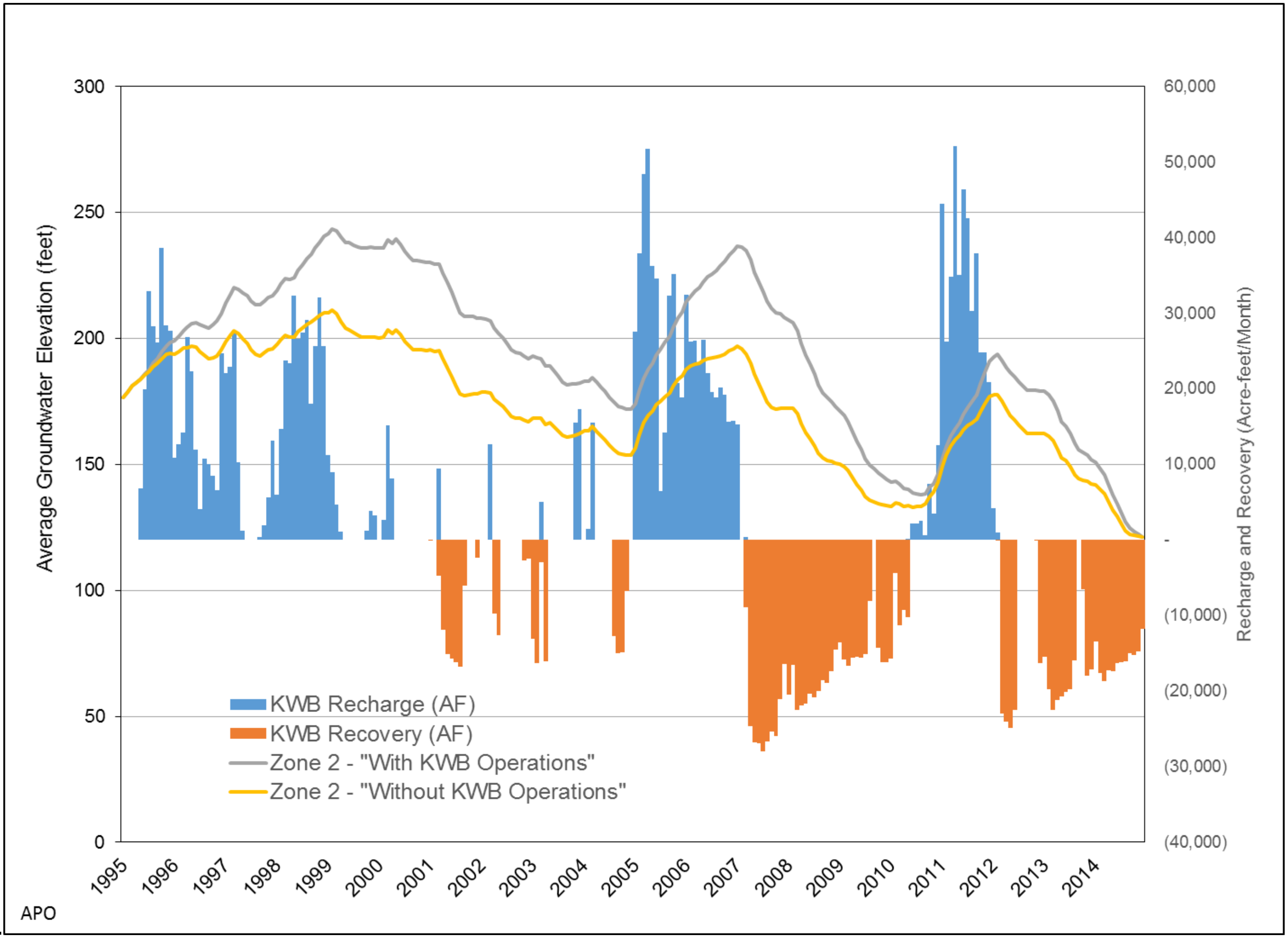


FIGURE 3.2-15b. Analysis of Past Operations: Average Groundwater Elevation Over Zone 2 (1 to 2 Miles Outside the Kern Water Bank Boundary), 1995-2014

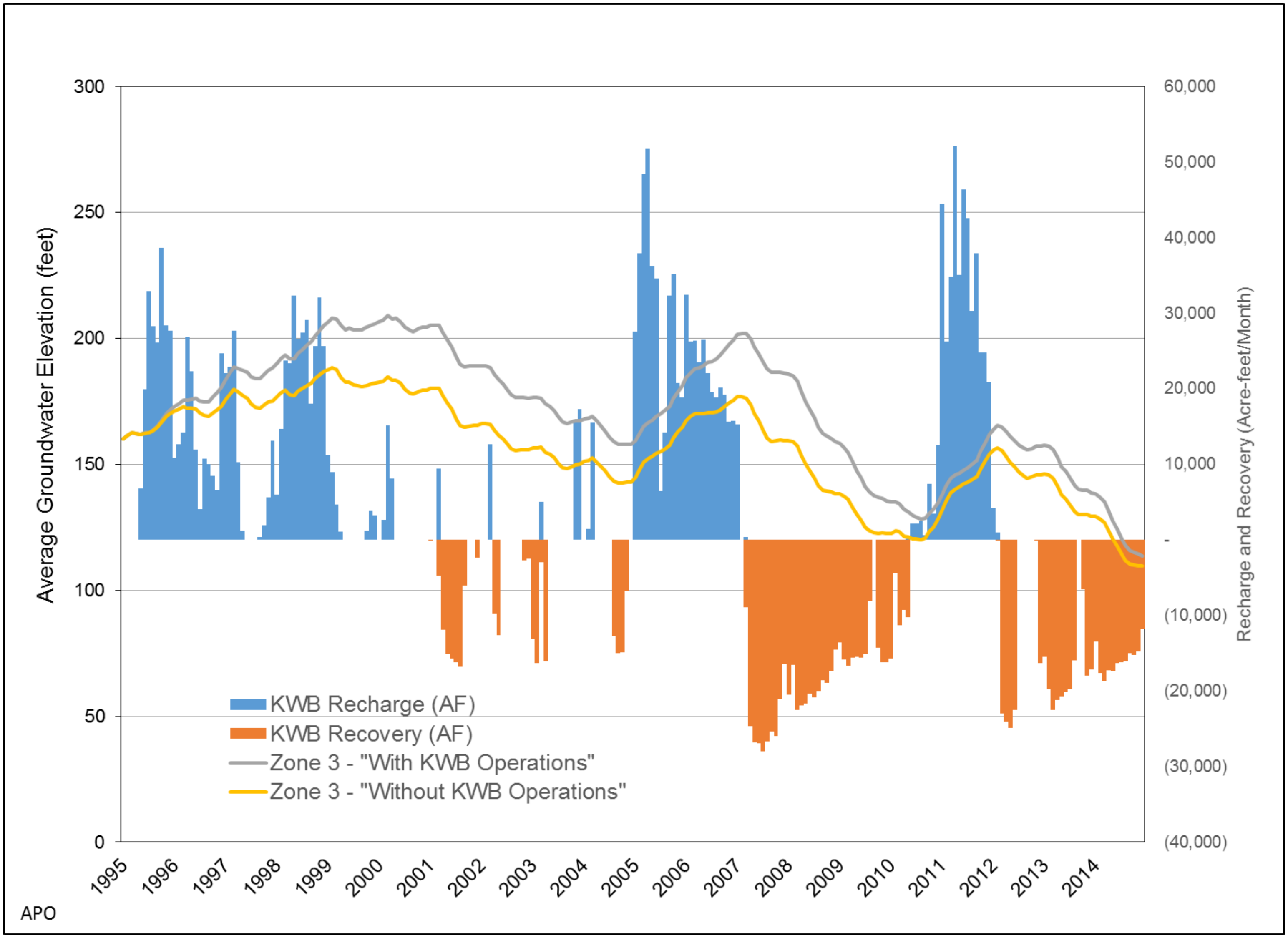


FIGURE 3.2-15c. Analysis of Past Operations: Average Groundwater Elevation Over Zone 3 (2 to 3 Miles Outside the Kern Water Bank Boundary), 1995-2014

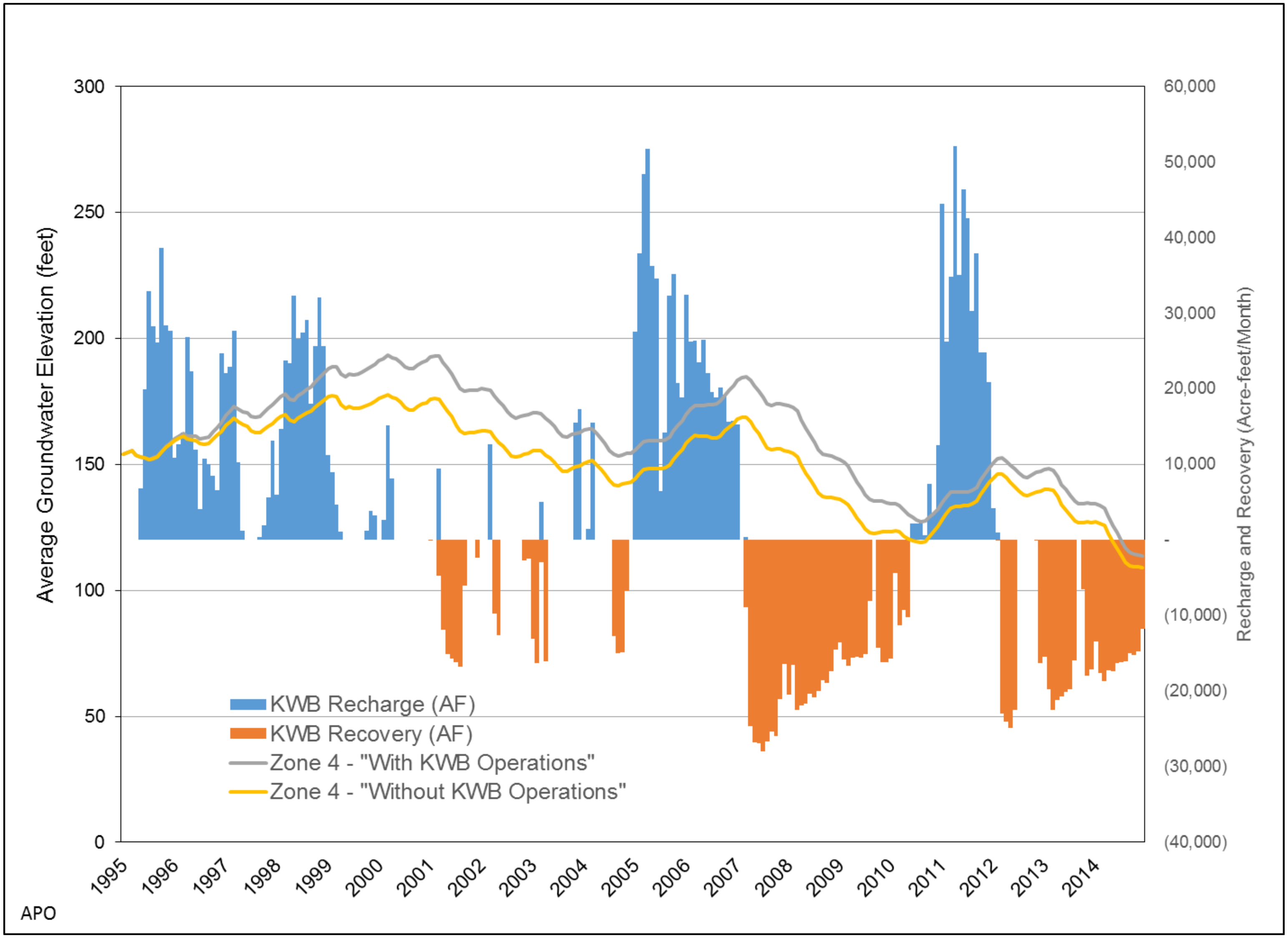


FIGURE 3.2-15d. Analysis of Past Operations: Average Groundwater Elevation Over Zone 4 (3 to 4 Miles Outside the Kern Water Bank Boundary), 1995-2014

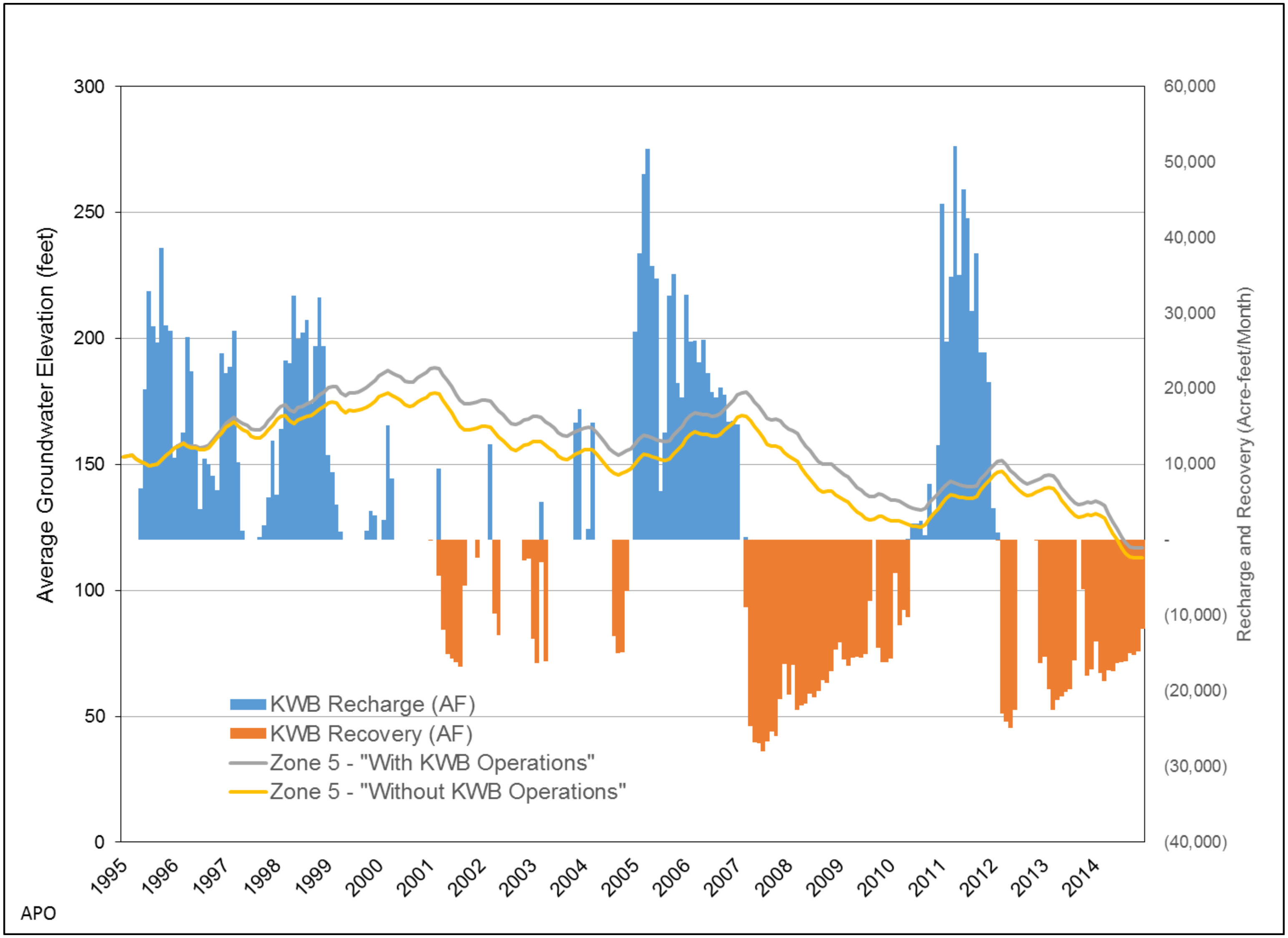


FIGURE 3.2-15e. Analysis of Past Operations: Average Groundwater Elevation Over Zone 5 (4 to 5 Miles Outside the Kern Water Bank Boundary), 1995-2014

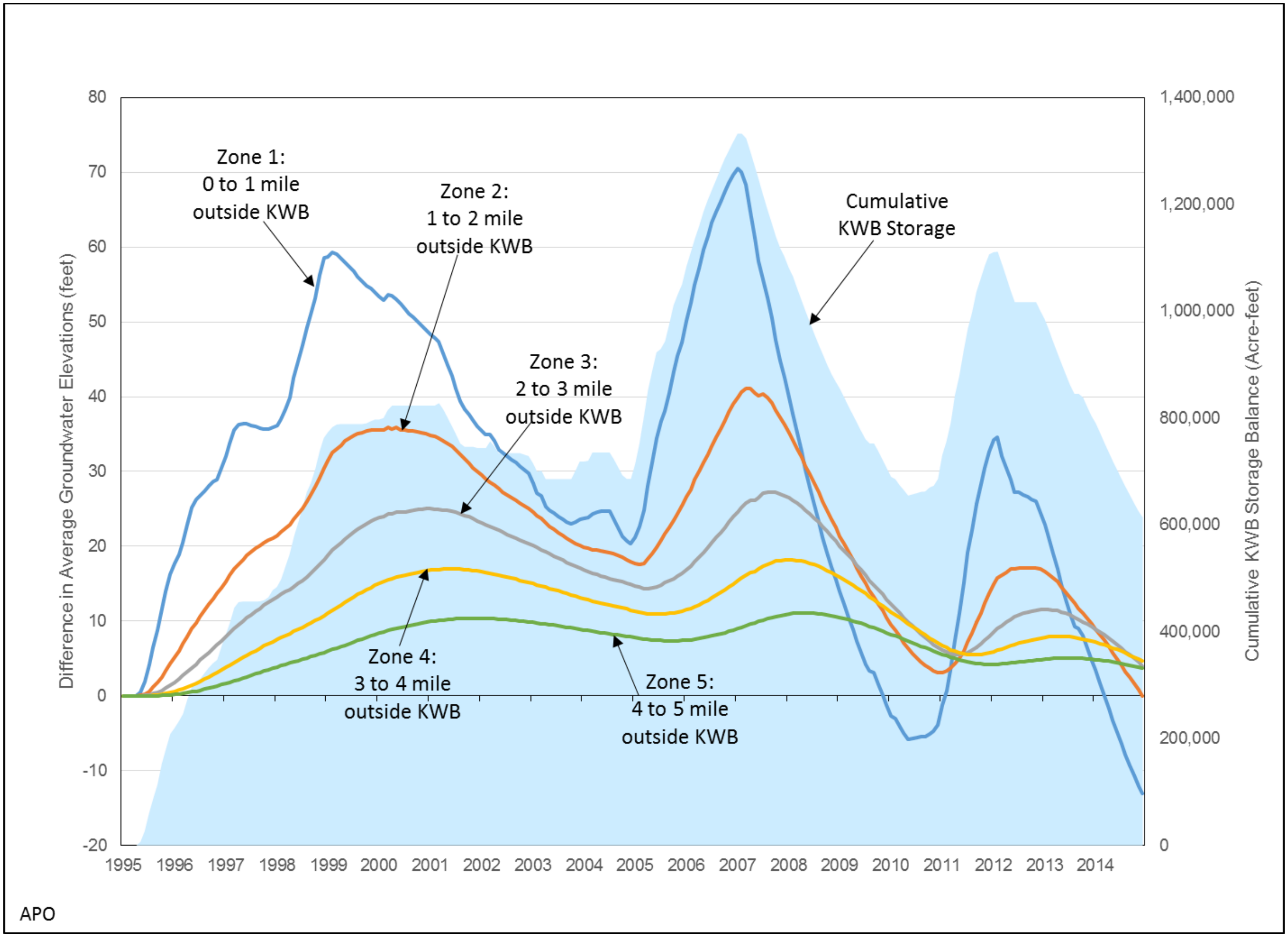


FIGURE 3.2-16. **Analysis of Past Operations: Average Groundwater Elevation Differences in Zones Outside the Kern Water Bank Boundary, 1995-2014**

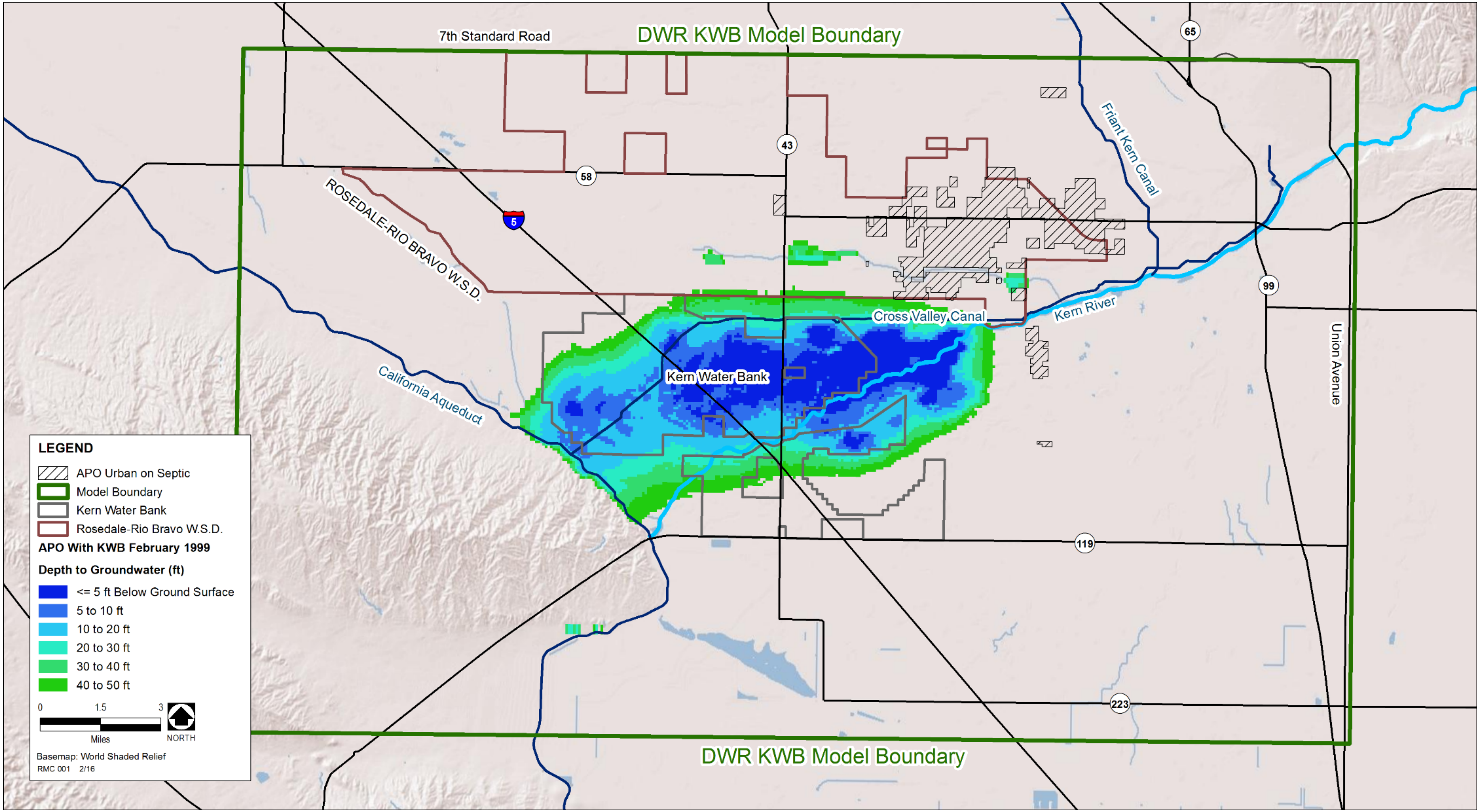


FIGURE 3.2-17. Analysis of Past Operations: Depth to Groundwater Contour Map, February 1999

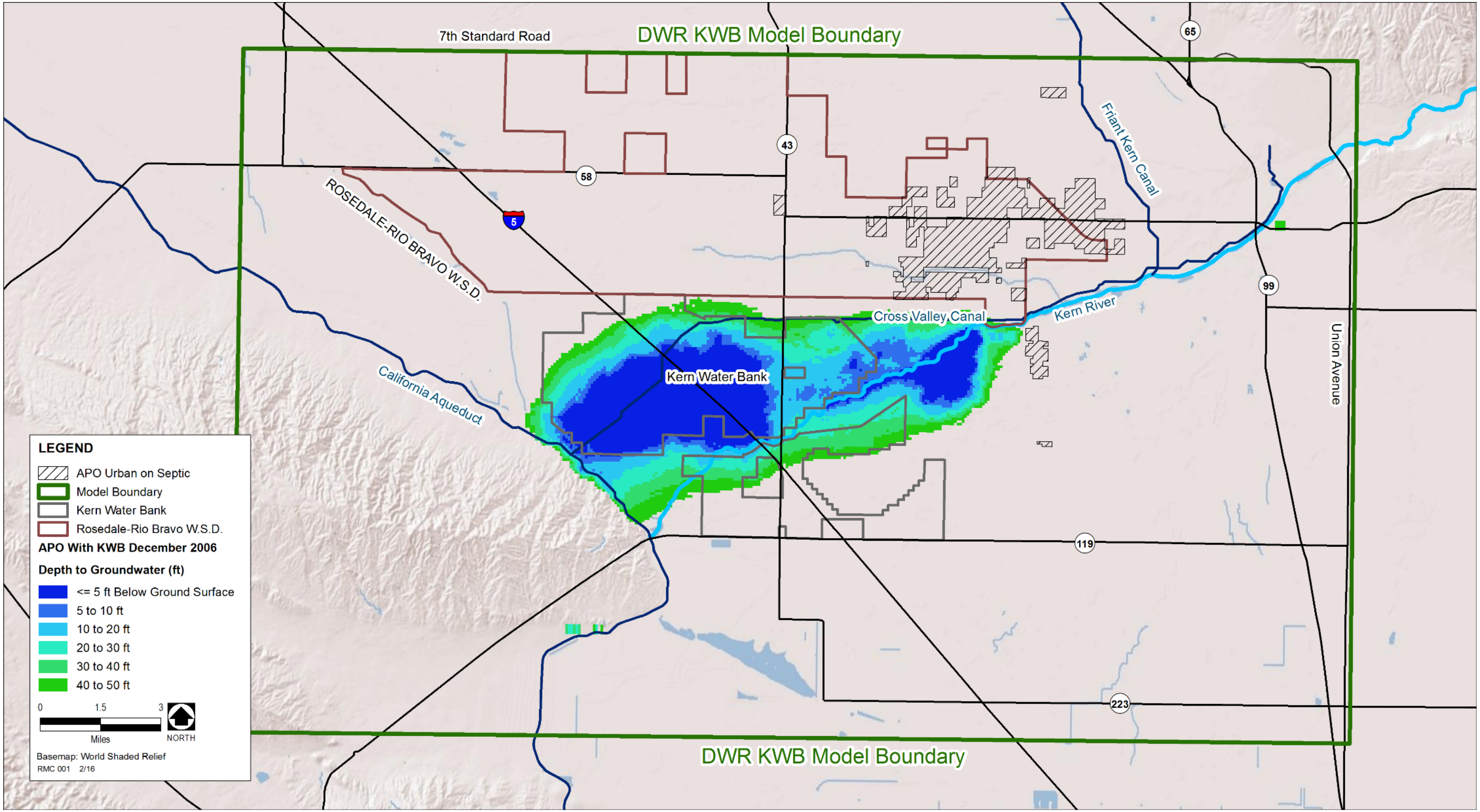


FIGURE 3.2-18. Analysis of Past Operations: Depth to Groundwater Contour Map, December 2006

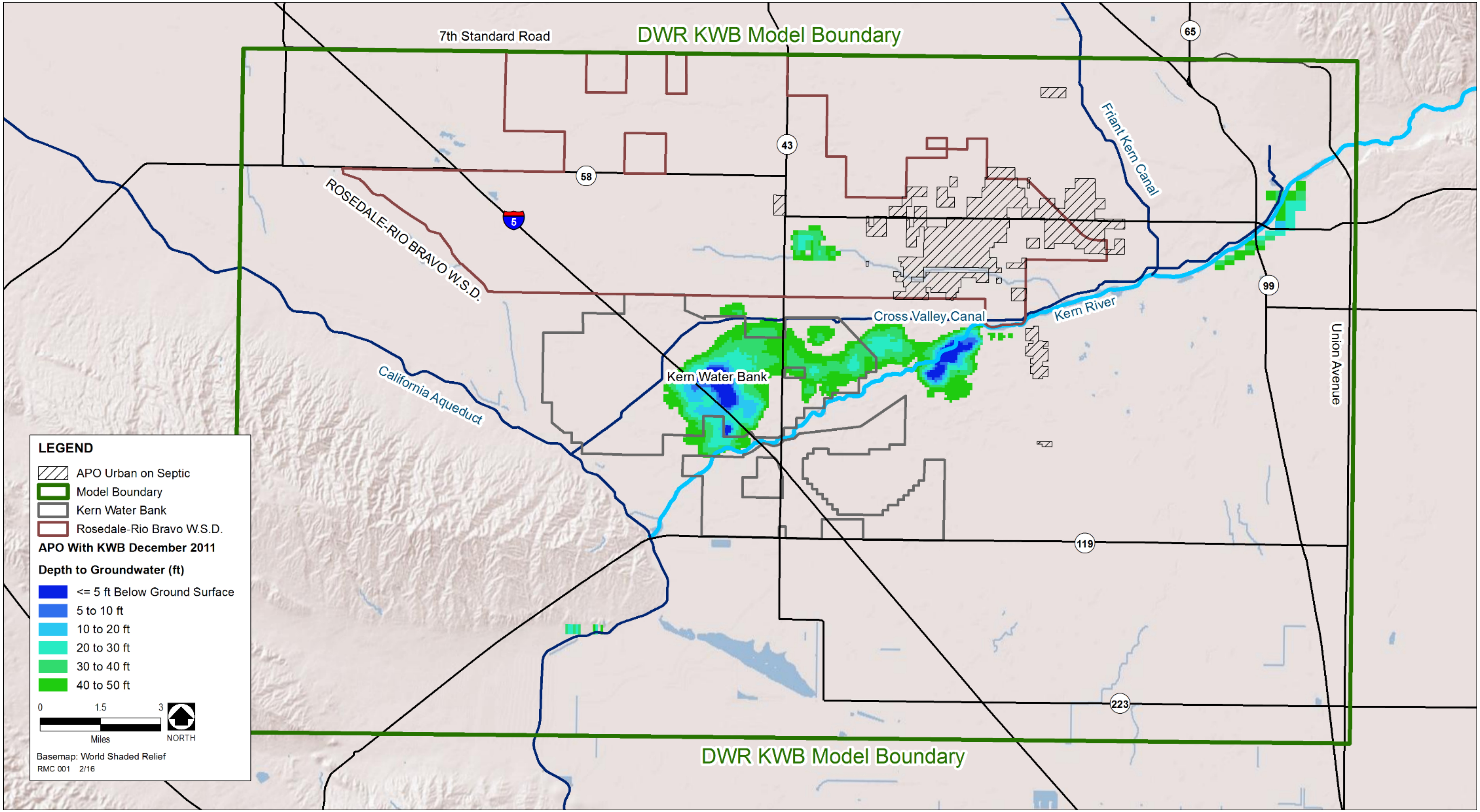


FIGURE 3.2-19. Analysis of Past Operations: Depth to Groundwater Contour Map, December 2011

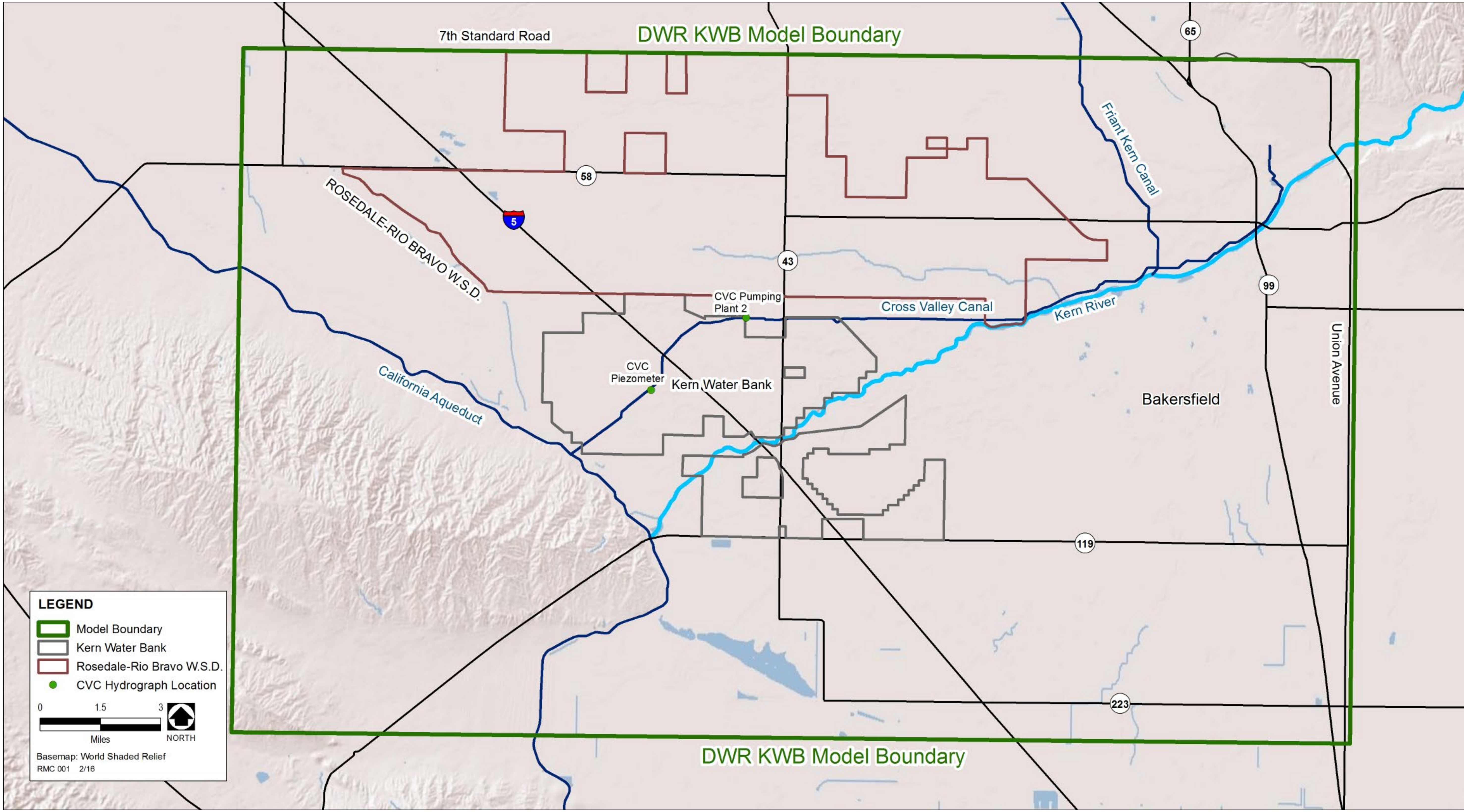


FIGURE 3.2-20. **Selected Hydrograph Locations along the CVC**

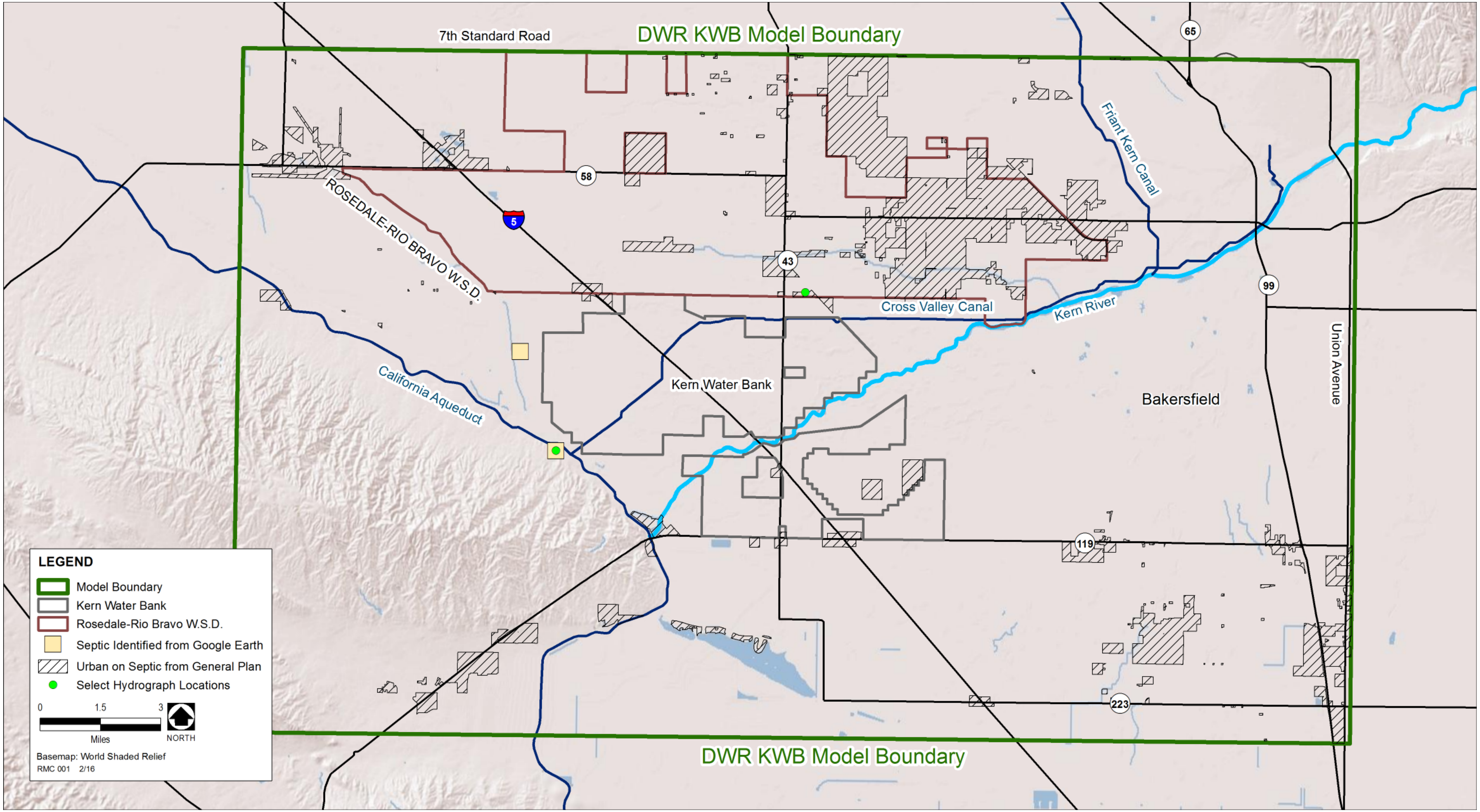
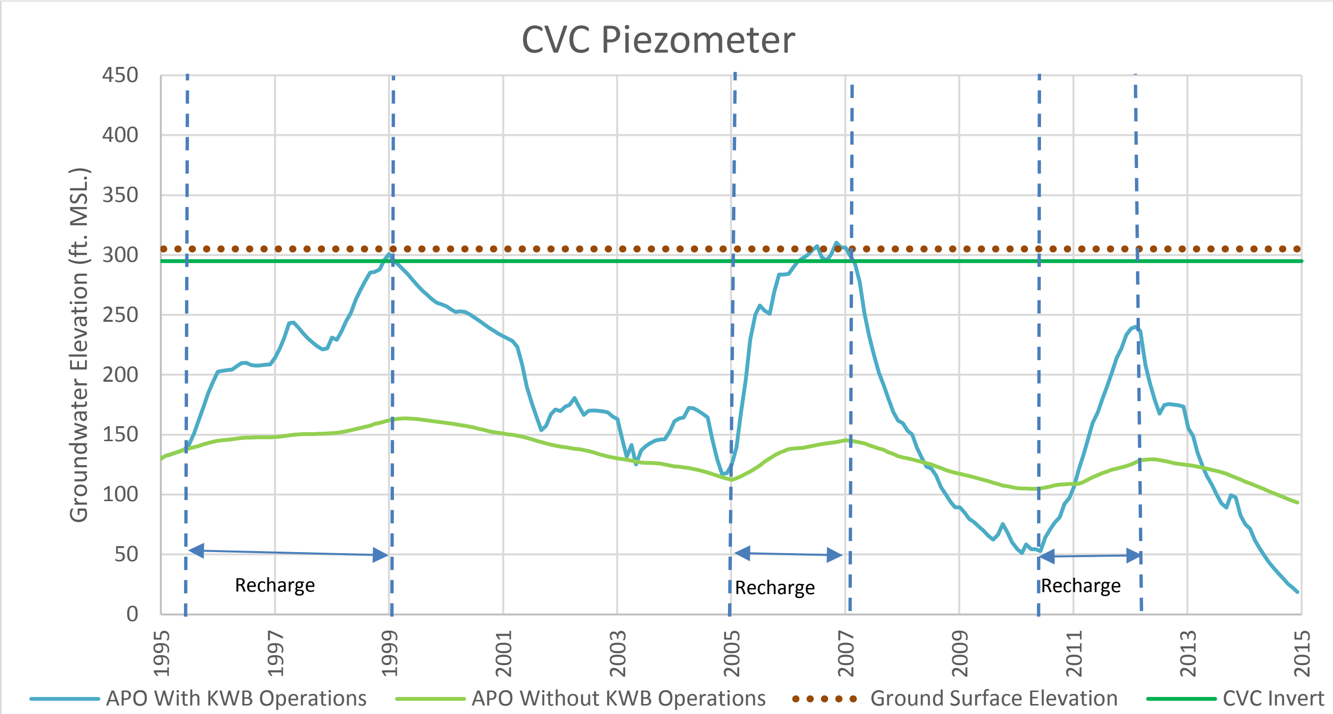


FIGURE 3.2-21. Areas on Septic Systems



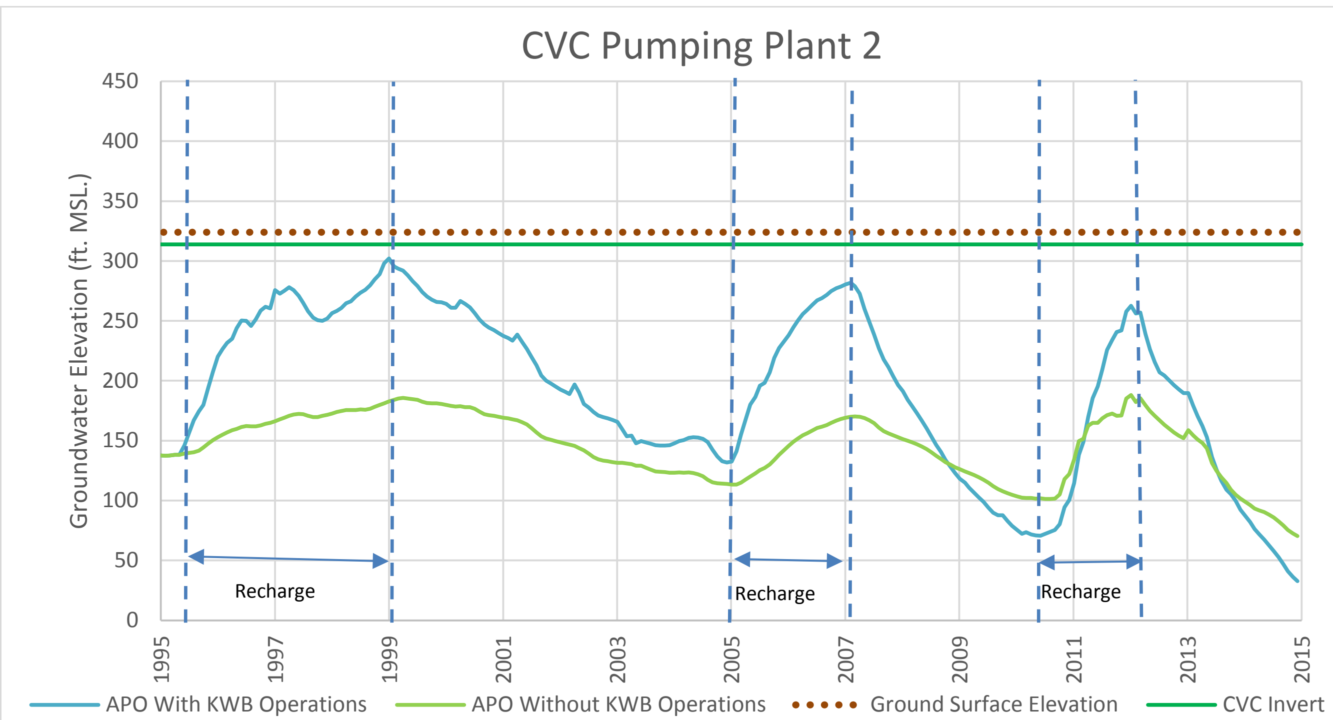


FIGURE 3.2-22. Groundwater Elevation Hydrographs at Selected Locations along the Cross Valley Canal for APO Scenario, 1995-2015

As shown in Figure 3.2-23 and similar to 1995-1998 conditions, depth to groundwater in areas in the vicinity of KWB Lands with septic systems or dry wells were more than 50 feet west of KWB Lands and more than 65 feet north of KWB Lands.

3.2.6.3 2011 Recharge Operations

As shown in Figure 3.2-19 and 3.2-22, water levels were lower than 50 feet from surface along the entire length of the CVC in the KWB area. Water levels were generally lower than 1995-1999 and 2005-2006 levels. This is partly due to 2011 being a single-year recharge period while the other two recharge periods are 4- and 2-year recharge periods, respectively. KWBA also shifted a larger percentage of recharge water in 2011 to mitigate the low water levels on the east side of KWB Lands.

As shown in Figure 3.2-23, depth to groundwater as a result of 2011 recharge operations were more than the previous two recharge periods. Depth to groundwater was more than 125 feet west of KWB Lands and more than 90 feet north of KWB Lands.

Piezometers have been installed along the CVC for detecting and monitoring shallow groundwater conditions near the CVC. Kern County Water Agency (KCWA) and KWBA have developed operating guidelines during shallow groundwater conditions. The Operating Guidelines include three major components: piezometer installation, groundwater monitoring, and evaluation of groundwater condition.

3.2.7 HIGH GROUNDWATER LEVELS AND IMPACT ON NEIGHBORING RECHARGE FACILITIES

Historic recharge operations at the KWB during the recharge periods of 1995-1998, 2005-2006, and 2011, concomitant with similar recharge operations at other neighboring groundwater banks, resulted in high groundwater elevations on KWB Lands and surrounding areas. High groundwater elevations could potentially effect recharge operations at neighboring recharge facilities, such as Rosedale recharge basins north of KWB Lands, Pioneer and 2800 Acre recharge facilities east of KWB Lands, and West Kern Water District recharge facilities south of KWB Lands.

Impacts of KWB recharge operations on the recharge operations of neighboring recharge facilities during high groundwater elevations with all the groundwater banks operating simultaneously under APO conditions were evaluated by using water level hydrographs at these recharge facilities.

Figure 3.2-24 shows the locations of the selected water level hydrographs at the neighboring recharge facilities. Figure 3.2-25 shows the water level hydrographs at these locations. Table 3.2-6 shows the modeled minimum depth to water under APO conditions at the four selected recharge facilities. The impact of the KWB recharge operations on the neighboring recharge facilities during high groundwater elevations with all the groundwater banks operating simultaneously are discussed below.

3.2.7.1 1995-1998 Recharge Operations

The water level analysis shows that at the adjacent recharge facilities, groundwater levels almost reached the ground surface in 2800 Acre recharge facility with all other groundwater banks in the area operating simultaneously; the groundwater mounding associated with the KWB operations and all the groundwater banks operating simultaneously would potentially interfere with recharge operations of neighboring groundwater banks at individual ponds. Any impact of KWB operations in West Kern Water District (West Kern WD) is resolved by an existing agreement between West Kern WD and KWBA.

3.2.7.2 2005-2006 Recharge Operations

The water levels at the adjacent recharge facilities were generally lower than 1995-1998 conditions and groundwater levels did not reach the ground surface; thus, the groundwater mounding associated with the KWB operations and all the groundwater banks operating simultaneously would not preclude recharge operations of neighboring groundwater banks.

3.2.7.3 2011 Recharge Operations

Water levels for 2011 recharge operations were significantly lower than the previous two recharge operations in 1995-1998 and 2005-2006 and groundwater levels did not reach the ground surface; thus, simultaneous operations of KWB and all other groundwater banks in the area are not expected to impact neighboring groundwater banks.

3.2.8 ANALYSIS OF PAST OPERATIONS RESULTS SUMMARY

A summary of the evaluation of effects of KWB historical operations during 1995–2014 on the groundwater table is provided in Table 3.2-7 for the APO scenario. Consecutive years of recovery attributable to historical KWB operations under the historical level of development may cause groundwater levels to fall such that existing wells in the area immediately outside the KWB boundary are impacted. In contrast, consecutive years of recharge may cause groundwater levels to rise and impact sections of the CVC within KWB Lands.

3.3 RESULTS OF ANALYSIS OF FUTURE OPERATIONS UNDER EXISTING CONDITIONS SCENARIOS

The results of the AFO-EC “With KWB Operations” and “Without KWB Operations” runs are presented in the following subsections.

3.3.1 WATER BUDGET AND RECHARGE AND RECOVERY AT THE KERN WATER BANK

The AFO-EC “With KWB Operations” run was used to develop an annual water budget for the entire model domain for the 2015–2035 future operation period. Table 3.3-1 shows key components of the water budget, including the change in groundwater storage.

As with the APO scenario (Section 3.2.1), boundary inflow and outflow components are the largest components of the water budget for the DWR KWB Model area. Boundary inflow, with an annual average of approximately 300,000 AFY, is approximately 8,413,000 AF for the 2015–2035 AFO-EC future operation period. Boundary outflow, with an annual average of approximately 272,000 AFY, is approximately 5,720,000 AF over the same period.

Agricultural and urban water demands during the 2015–2035 period are partially met by a total of 8,845,000 AF of agricultural pumping and 1,727,000 AF of urban pumping. Approximately 1,947,000 AF of applied water is projected to return to the aquifer as deep percolation.

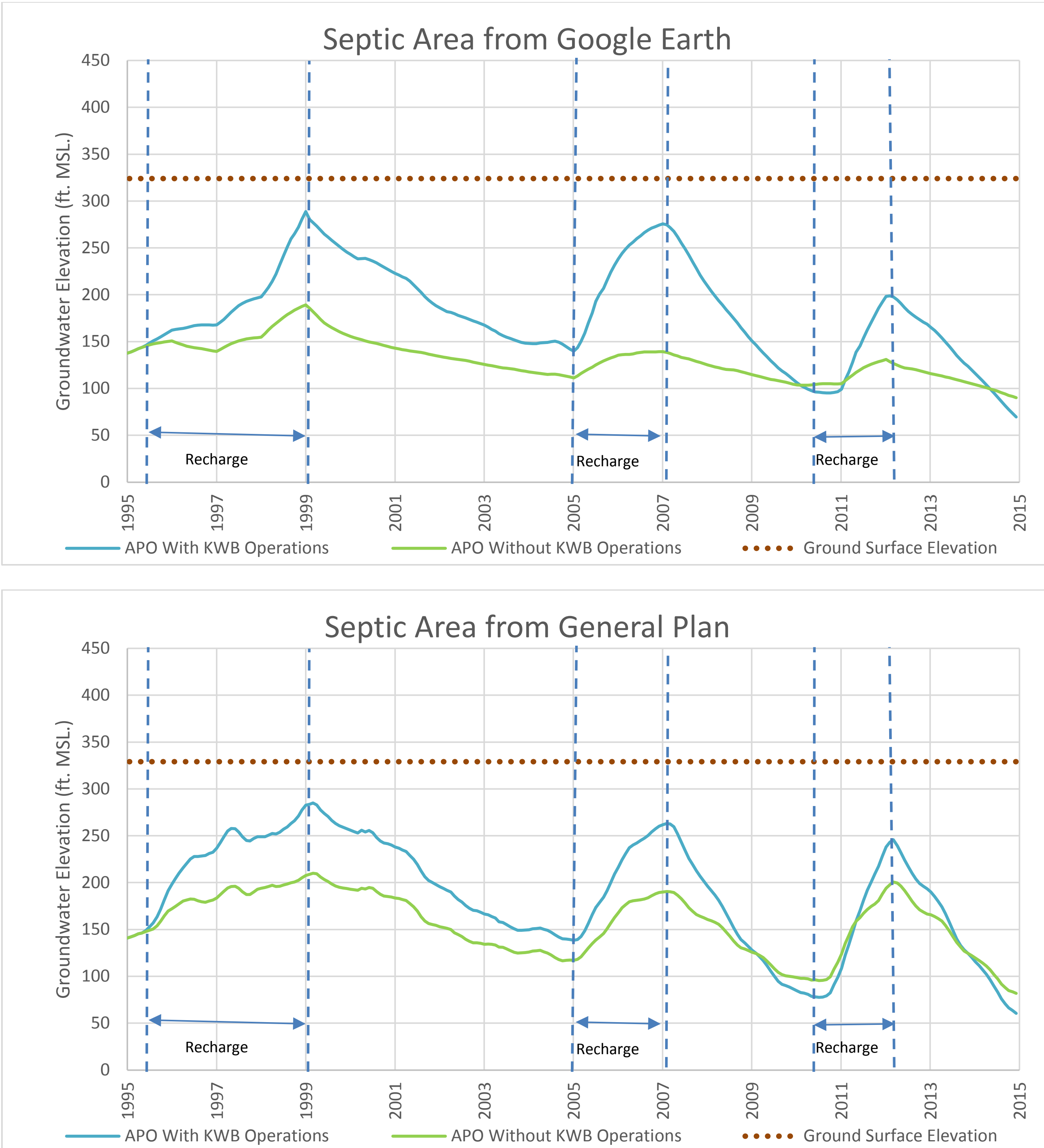


FIGURE 3.2-23. Groundwater Elevation Hydrographs at Selected Areas on Septic Systems for APO Scenario, 1995-2015

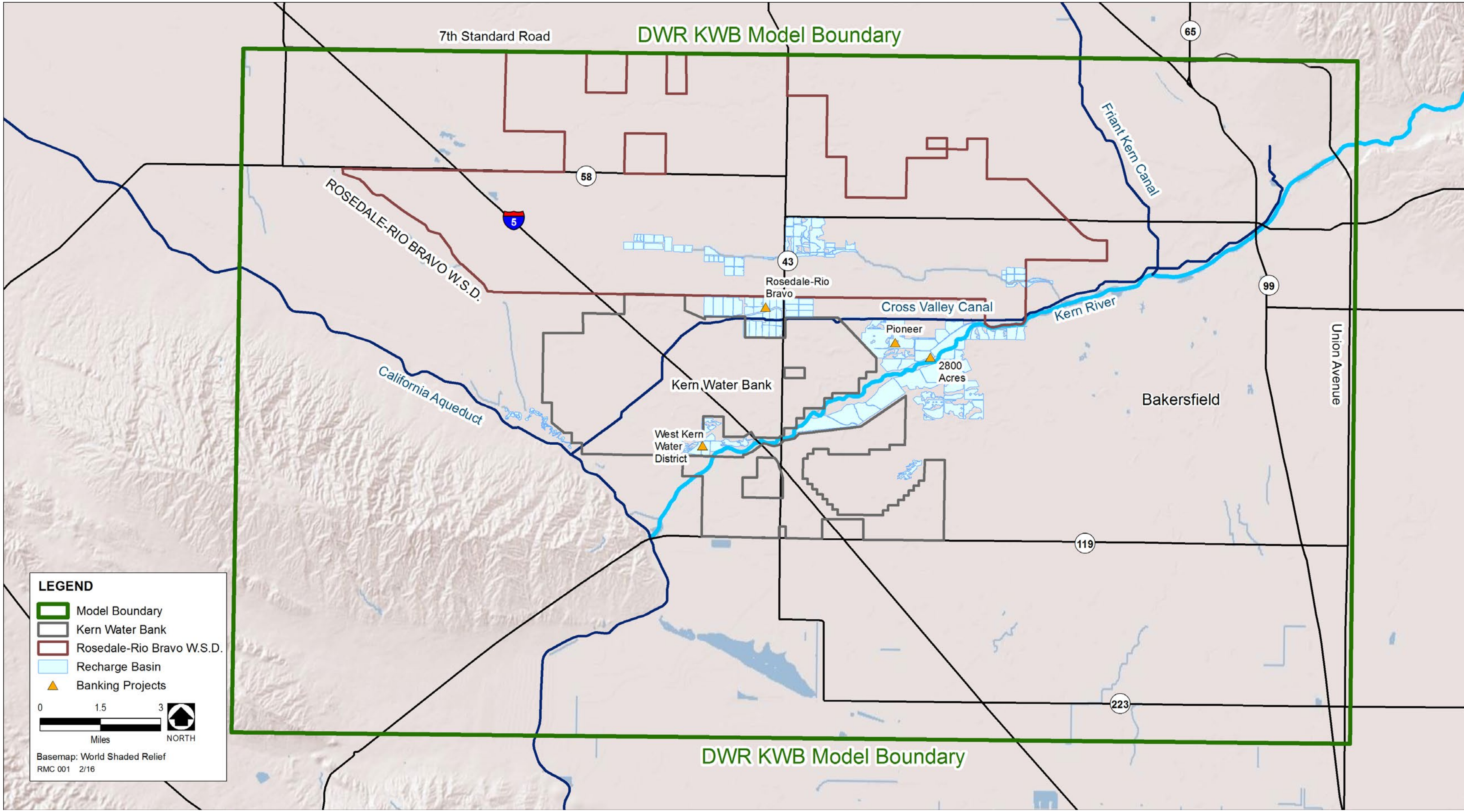


FIGURE 3.2-24. Groundwater Recharge Projects Neighboring Kern Water Bank and Locations of Selected Water Levels Hydrographs

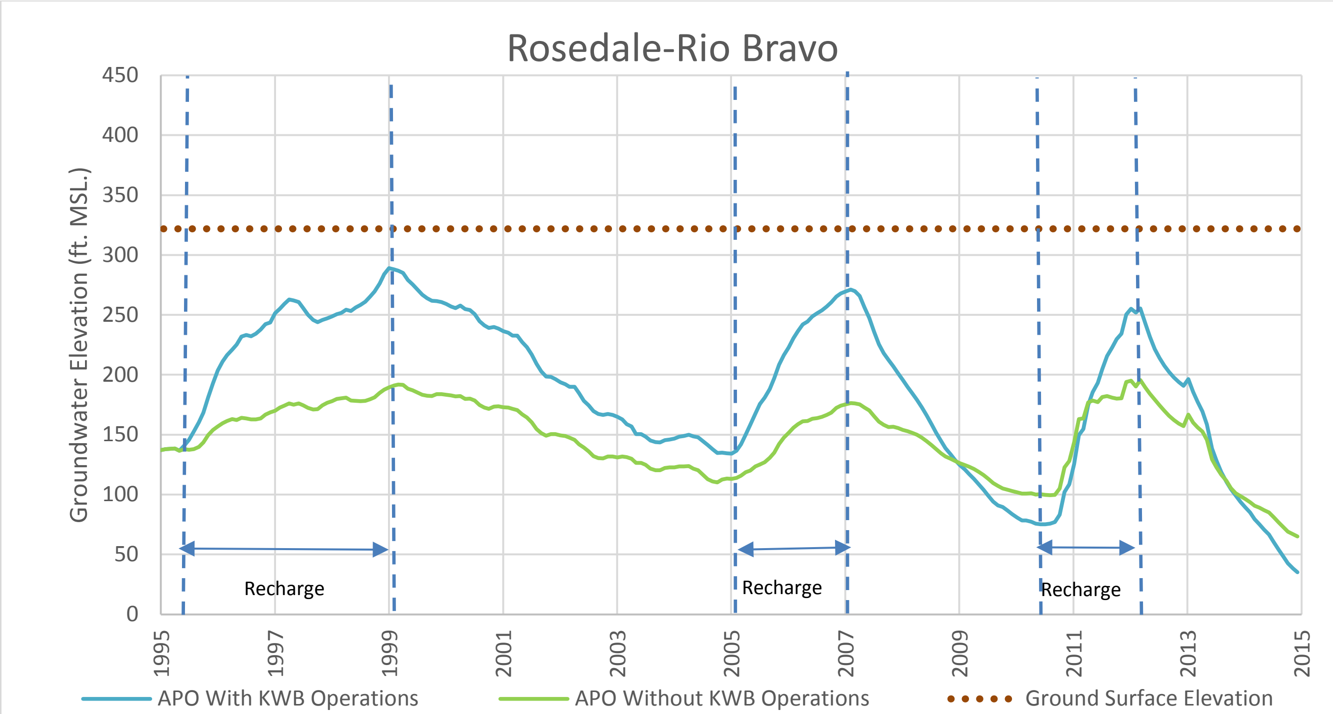


FIGURE 3.2-25a. Groundwater Elevation Hydrographs at Rosedale-Rio Bravo Water Storage District Recharge Pond for APO, 1995-2015

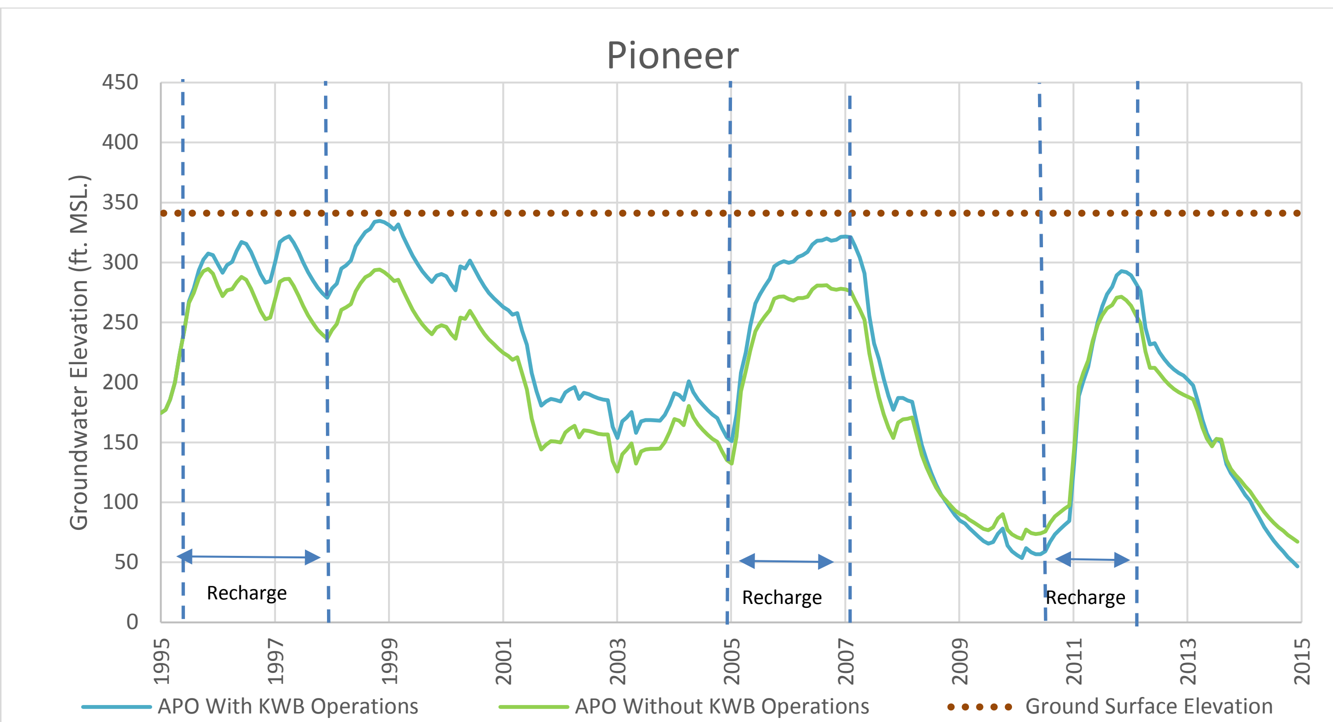


FIGURE 3.2-25b. Groundwater Elevation Hydrographs at Pioneer Recharge Pond for APO, 1995-2015

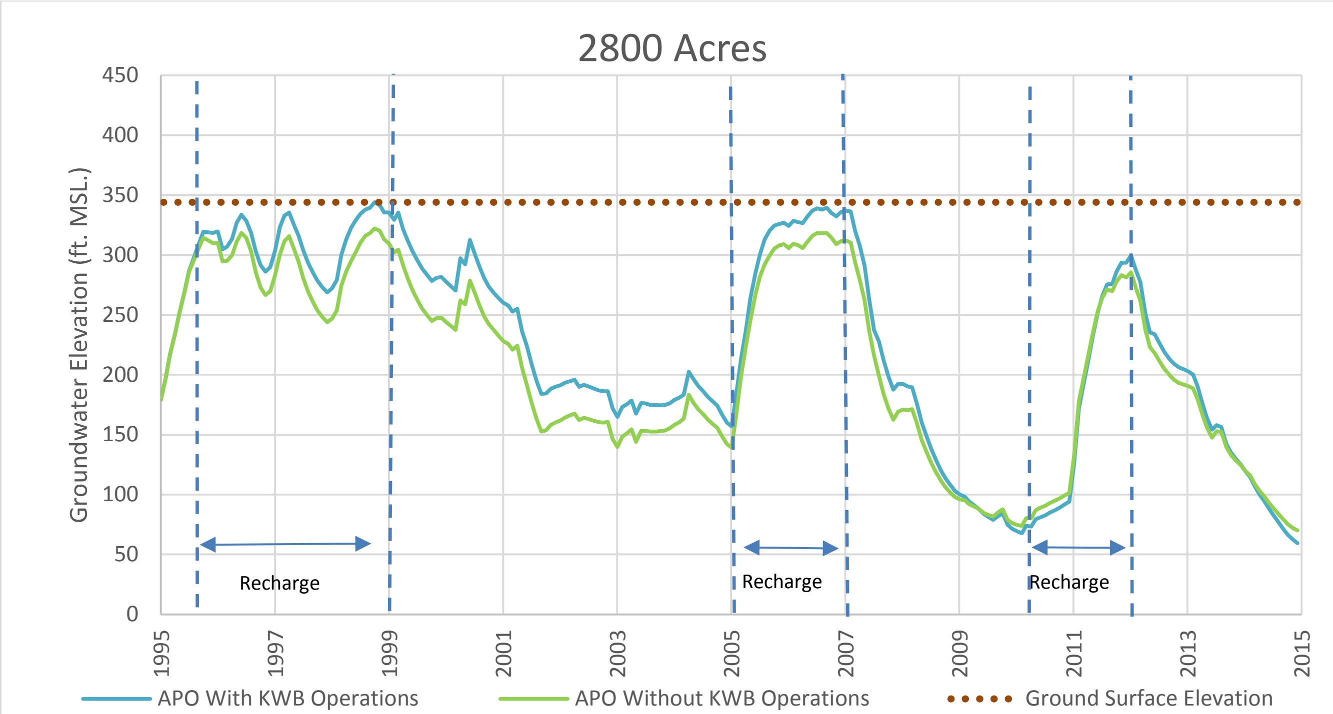


FIGURE 3.2-25c. Groundwater Elevation Hydrographs at 2800 Acres Recharge Pond for APO, 1995-2015

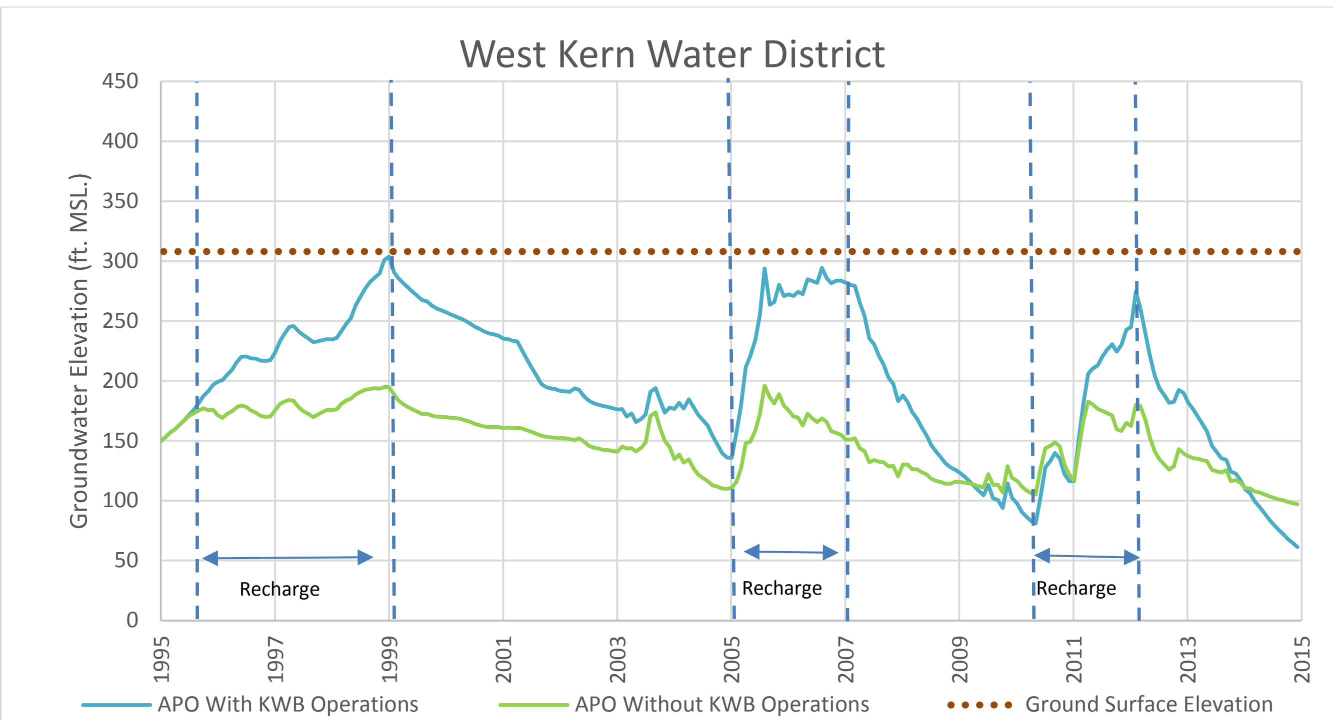


FIGURE 3.2-25d. Groundwater Elevation Hydrographs at West Kern Water District Recharge Pond for APO, 1995-2015

TABLE 3.2-2

MODEL AREA OUTSIDE THE KERN WATER BANK AREA AFFECTED AT DIFFERENT WATER LEVELS (ANALYSIS OF PAST OPERATIONS), 1995–2014

	Impacted Area Outside Kern Water Bank Lands (acres)									
Frequency for 20- Year Simulation	**-60 Feet**	**-45 Feet**	**-30 Feet**	**-20 Feet**	**-10 Feet**	**+10 Feet**	**+20 Feet**	**+30 Feet**	**+45 Feet**	**+60 Feet**
Never Occurs	232,404	231,919	228,599	224,354	216,414	116,731	159,016	180,609	199,641	211,277
1–12 months	0	485	2,675	4,725	6,403	1,490	2,015	2,628	2,775	2,433
13–24 months	0	0	715	1,540	4,350	2,220	2,308	2,635	3,385	3,653
25–36 months	0	0	415	985	2,880	2,160	2,870	2,665	2,813	2,210
37–58 months	0	0	0	795	1,408	2,000	2,810	2,428	2,180	1,773
59–60 months	0	0	0	5	950	1,950	2,915	3,798	2,855	2,383
61–72 months	0	0	0	0	0	3,030	3,770	3,578	3,140	3,463
73–84 months	0	0	0	0	0	2,820	3,935	3,605	4,138	3,500
85–96 months	0	0	0	0	0	3,215	3,785	4,040	4,313	1,080
97–108 months	0	0	0	0	0	4,090	4,258	4,455	3,243	623
109–120 months	0	0	0	0	0	5,158	4,848	5,313	3,633	13
121–144 months	0	0	0	0	0	16,498	9,008	7,880	290	0
145–168 months	0	0	0	0	0	15,775	9,165	8,758	0	0
168 or more months	0	0	0	0	0	55,268	21,703	15	0	0

TABLE 3.2-3

MODEL AREA AFFECTED AT DIFFERENT WATER LEVELS FOR THE ENTIRE MODEL AREA (ANALYSIS OF PAST OPERATIONS), 1995–2014

	Impacted Area in Model Domain (acres)									
Frequency for 20-Year Simulation	**-60 Feet**	**-45 Feet**	**-30 Feet**	**-20 Feet**	**-10 Feet**	**+10 Feet**	**+20 Feet**	**+30 Feet**	**+45 Feet**	**+60 Feet**
Never Occurs	251,354	243,772	236,054	229,527	220,462	116,731	159,016	180,794	201,076	214,037
1–12 months	3,090	7,730	7,308	8,115	8,085	1,490	2,015	3,095	3,293	3,200
13–24 months	5	2,920	4,160	4,518	6,753	2,220	2,308	2,835	3,605	4,475
25–36 months	0	28	6,090	5,323	6,373	2,160	2,870	2,945	3,165	3,038
37–58 months	0	0	833	6,133	7,938	2,000	2,810	2,830	2,623	2,633
59–60 months	0	0	5	835	4,760	1,950	2,933	3,940	3,918	3,163
61–72 months	0	0	0	0	80	3,030	3,893	3,725	4,045	4,635
73–84 months	0	0	0	0	0	2,820	4,330	4,028	4,723	7,098
85–96 months	0	0	0	0	0	3,215	4,478	4,770	5,403	5,008
97–108 months	0	0	0	0	0	4,090	4,628	5,133	7,003	4,913
109–120 months	0	0	0	0	0	5,158	4,943	6,100	10,510	2,253
121–144 months	0	0	0	0	0	16,498	9,653	12,040	5,088	0
145–168 months	0	0	0	0	0	17,935	18,718	22,188	0	0
168 or more months	0	0	0	0	0	75,153	31,858	28	0	0

TABLE 3.2-4

AREA AFFECTED AT DIFFERENT LEVELS OF NEGATIVE DIFFERENCES (ANALYSIS OF PAST OPERATIONS) ("WITH KERN WATER BANK OPERATIONS" MINUS "WITHOUT KERN WATER BANK OPERATIONS"), 1995–2014

Level of Negative Difference	Agricultural Area (Acres)	Urban Area (Acres)
-45 feet	95	–
-30 feet	843	–
-20 feet	2,677	–
-10 feet	6,700	28
-5 feet	9,660	250

TABLE 3.2-5

AREA AFFECTED AT DIFFERENT LEVELS OF POSITIVE DIFFERENCES (ANALYSIS OF PAST OPERATIONS) ("WITH KERN WATER BANK OPERATIONS" MINUS "WITHOUT KERN WATER BANK OPERATIONS"), 1995–2014

Level of Positive Difference	Agricultural Area (Acres)	Urban Area (Acres)
5 feet	95,160	22,355
10 feet	72,600	9,665
20 feet	45,010	2,390
30 feet	30,065	640
45 feet	18,308	-

TABLE 3.2-6

MODEL-GENERATED MINIMUM DEPTH TO WATER FOR APO CONDITIONS

Simulation Period	Recharge Facility			
	Rosedale	Pioneer	2800 Acre	West Kern Water District
1995-1998	33	6.3	0.1	4.2
2005-2006	50.9	19.4	4.5	13.6
2011	66.6	48.3	44.3	33.4

TABLE 3.2-7

SUMMARY OF ANALYSIS OF PAST OPERATIONS MODEL SCENARIO RESULTS AFFECTING THE LOCAL GROUNDWATER TABLE, 1995–2014

Evaluation Metric	Conclusion
Water Budgets (Section 3.2.1)	The KWB had a balance off +617,000 AF of stored water at the end of 2014.
Groundwater Elevation Differences (Hydrographs and Contour Maps) (Section 3.2.2)	The positive groundwater elevation differences extend to almost all of the model domain. The negative groundwater elevation differences are limited to KWB Lands and the surrounding area.
Temporal Variation in Area of Negative and Positive Elevation	Outside the KWB boundary, negative elevation differences

TABLE 3.2-7

SUMMARY OF ANALYSIS OF PAST OPERATIONS MODEL SCENARIO RESULTS AFFECTING THE LOCAL GROUNDWATER TABLE, 1995–2014

Evaluation Metric	Conclusion
Differences (Section 3.2.3)	occur after about 2 years of recovery.
Spatial Extent of Negative and Positive Elevation Differences (Section 3.2.3)	Outside the KWB boundary, negative elevation differences exceeding -30 feet are contained within 1 mile of the KWB boundary and do not spread inside the Rosedale boundary. Outside the KWB boundary, negative elevation differences exceeding -30 feet affect less than 900 acres of agricultural land in the immediate vicinity of KWB Lands, which represents less than one percent of the total agricultural area within the model domain. Outside the KWB boundary, positive elevation differences exceeding +60 feet (indicative of a high water table) are contained within 2 miles of the KWB boundary.
Frequency Distribution of Negative and Positive Elevation Difference (Section 3.2.4)	Negative elevation differences exceeding -30 feet remain within the KWB boundary 90% of the time. Positive elevation differences exceeding +60 feet remain within the KWB boundary 75% of the time.
Average Elevation and Elevation Difference in Selected Zones (Section 3.2.5)	On an average basis, there is always a groundwater mound beyond 2 miles of the KWB boundary that exceeds at least 5 feet in groundwater elevation when compared to the elevation of "Without KWB Operations."
High Groundwater Levels and Existing Infrastructure (Section 3.2.6)	Groundwater levels may rise to within 5 feet from ground surface and impact sections of the CVC in the western parts of KWB Lands.
High Groundwater Levels and Neighboring Recharge Facilities (Section 3.2.7)	KWB operations, concomitant with the operations of other neighboring groundwater banks, may potentially interfere with the recharge operations at neighboring groundwater banks.
Notes: AF = acre-feet; CVC = Cross Valley Canal; KWB = Kern Water Bank	

During the 21-year (2015–2035) simulation period of the AFO-EC scenario, the KWB is projected to recharge 2,112,000 AF of water while recharge by other banking projects in the model domain is projected to be 3,383,000 AF. AFO-EC KWB recharge is slightly higher than KWB recharge during the historical (1995–2014) period because increased recharge pond areas under existing conditions allow the KWB to recharge additional water (e.g., floodwater) that was available under a hydrologic conditionsimilar to the 1995–2014 period. The KWB is projected to recover 1,546,000 AF during the AFO-EC simulation period, while recovery at other projects is projected to be 1,401,000 AF. The total volume of water recovered from the KWB and other banking projects in the AFO-EC scenario is higher than the historical amount because of an additional year of pumping in 2015. This generates a balance of 566,000 AF of stored water for the KWB and 1,982,168 AF of stored water for other banking projects. The KWB annual recharge, recovery, and cumulative balance of stored water amounts are shown in Figure 3-3.1.

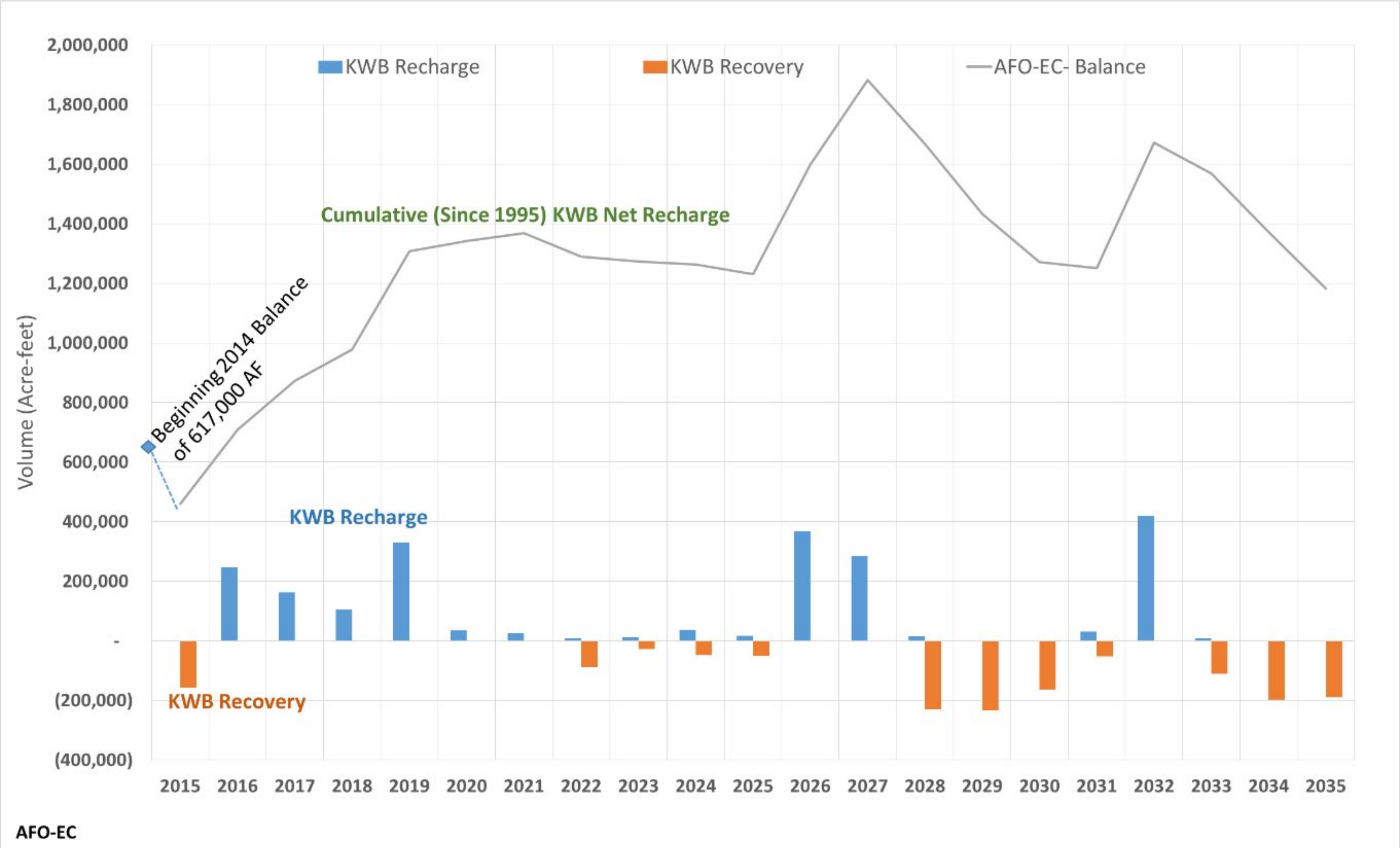


FIGURE 3.3-1. **Analysis of Future Operations under Existing Conditions: Kern Water Bank Annual and Cumulative Recharge and Recovery, and Cumulative Stored Water, 2015-2035**

Note that there was an accumulated balance of 617,000 AF of stored water at the end of the 1995–2014 historical KWB operations period. When this prior balance is added to the additional 2015–2035 stored water, there is a total balance of 1,183,216 AF of stored water in the aquifer at the end of 2035 under the AFO-EC scenario.

3.3.2 GROUNDWATER ELEVATION DIFFERENCE FOR WITH AND WITHOUT KERN WATER BANK OPERATIONS

As with the APO (see Section 3.2.2), groundwater elevation differences for the AFO-EC "With KWB Operations" and "Without KWB Operations" scenarios were evaluated by comparing simulated groundwater elevation hydrographs at several monitoring wells (Method No. 3 in Section 3.1) and developing groundwater elevation difference contour maps at the end of several representative recharge and recovery cycles (Method No. 2 in Section 3.1).

3.3.2.1 Hydrographs

Hydrographs of simulated groundwater levels for the "With KWB Operations" and "Without KWB Operations" scenarios were developed at 31 wells (14 wells inside the KWB boundary and 17 wells outside the KWB boundary (Appendix 7-2E).

3.3.2.2 Contour Maps

The distribution of groundwater elevation differences between "With KWB Operations" and "Without KWB Operations" scenarios after major KWB recharge and recovery cycles is shown in Figures 3.3-3 and 3.3-4. Figures 3.3-3a to 3.3-3c show groundwater elevation differences after the 1995–2000, 2005–2006, and 2011 recharge cycles, respectively. Figures 3.3-4a to 3.3-4c show groundwater elevation differences after the 2001–2004, 2007–2009, and 2012–2014 recovery cycles, respectively.

3.3.3 AFFECTED AREAS OUTSIDE THE KERN WATER BANK LANDS

The impact of KWB operations on groundwater elevations outside KWB Lands for the AFO-EC "With KWB Operations" and "Without KWB Operations" scenarios are evaluated using time series charts showing areas affected by head differences of ±5 feet (Method No. 4 in Section 3.1), maps of the spatial extent of negatively and positively impacted areas (Method No. 5 in Section 3.1), and tables summarizing acreage of impacted areas.

3.3.3.1 Time Series of Affected Area

At every time step of the simulation, the total area of the model was calculated with (1) groundwater elevation difference greater than 5 feet, and (2) groundwater elevation difference less than -5 feet. Time series of these areas are shown in Figure 3.3-5. A detailed chart showing areas impacted by less than -5, -10, -20, -30, -45, and -60 feet is shown in Figure 3.3-6. Figure 3.3-7 shows areas impacted by groundwater levels greater than 5, 10, 20, 30, and 45 feet.

Negative elevation differences exceeding -5 feet continue to spread over a large area (52,000 acres in 2015) because of continued recovery in 2015 (the first year of the AFO-EC scenario), which was preceded by 3 consecutive years of recovery from 2012 to 2014 (the last 3 years of the APO scenario). Three consecutive years of recharge from 2016 through 2018 reduce the area with negative elevation differences exceeding -5 feet to zero. Areas with negative elevation differences reappear after periods of about 2 years of recovery (e.g., 2028–2029 and 2033–2034).

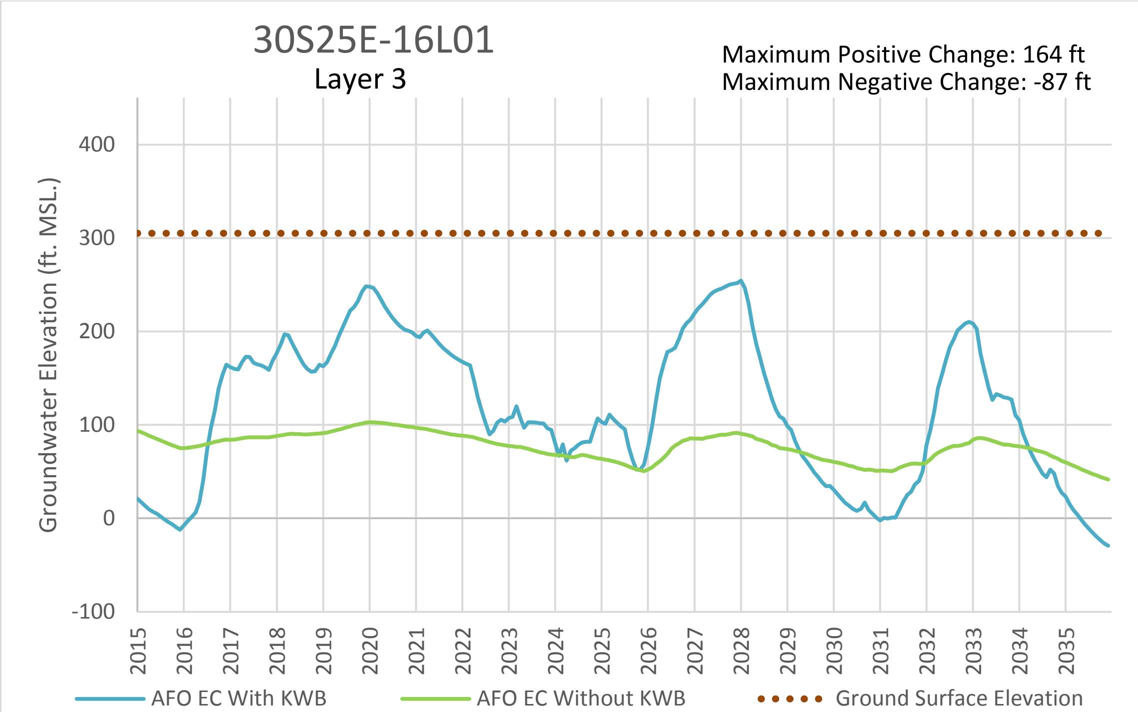


FIGURE 3.3-2a. **Hydrographs of Analysis of Future Operations under Existing Conditions: Simulated Water Levels at Monitoring Well 30S25E-16L, 2015-2035**

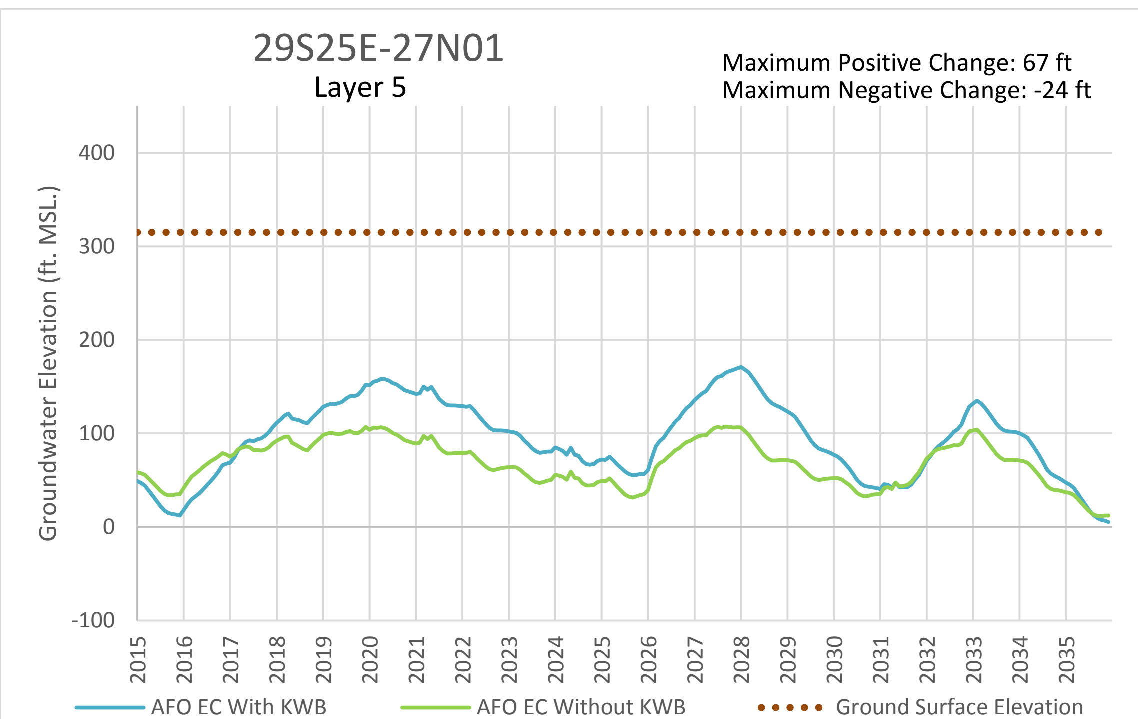


FIGURE 3.3-2b. **Hydrographs of Analysis of Future Operations under Existing Conditions: Simulated Water Levels at Monitoring Well 29S36E-27N, 2015-2035**

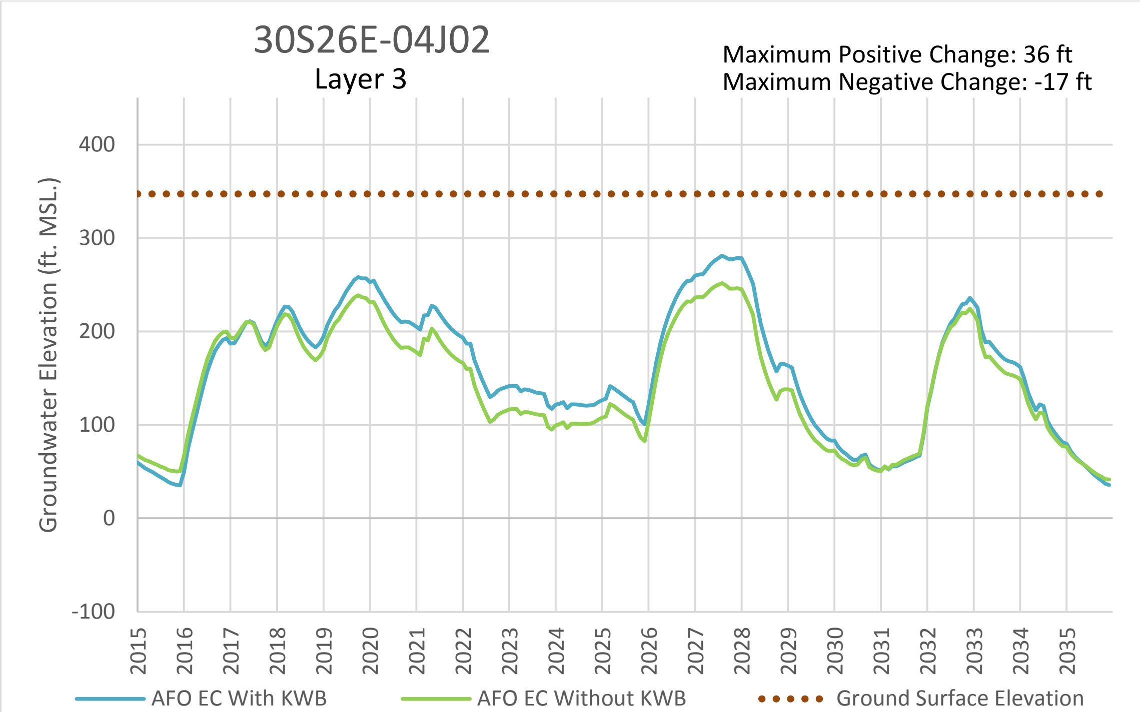


FIGURE 3.3-2c. Hydrographs of Analysis of Future Operations under Existing Conditions: Simulated Water Levels at Monitoring Well 30S26E-04J, 2015-2035

Figure 3.3-6 indicates that any negative differences exceeding -30 feet in areas outside KWB Lands are limited to years of groundwater recovery, affecting a maximum area of about 10,000 acres near KWB Lands in 2015 after 4 consecutive years of recovery (2012–2015).

3.3.3.2 Spatial Extent of Affected Area

Figure 3.3-8 shows the maximum spatial extent of negative elevation differences exceeding -60 feet, -45 feet, -30 feet, -20 feet, -10 feet, and -5 feet. This figure shows that negative elevation differences under the AFO-EC scenario spread about 5 miles outside the KWB boundary. Inside the Rosedale boundary, negative elevation differences exceeding -45 feet do not occur, but negative elevation differences between -5 feet and -45 feet do occur. The total area affected by negative elevation differences between -5 feet and -45 feet inside the Rosedale boundary is 18,781 acres of agricultural land.

Figure 3.3-9 shows the maximum spatial extent of positive elevation differences exceeding +5 feet, +10 feet, +20 feet, +30 feet, +45 feet, and +60 feet. Positive differences in groundwater elevation attributable to KWB operations spread as far as 5.5 miles from the northern and eastern edges of KWB Lands and as far as 4 miles from the southern edge of KWB Lands.

3.3.3.3 Acreages of Affected Areas

The -30 feet negative elevation difference boundary line (see Figure 3.3-8) extends into agricultural area north and east of the KWB boundary. The negative differences in groundwater elevations between "With" and "Without" KWB operations spread into more agricultural areas as the specified levels change from -30 feet to -5 feet. Tables 3.3-2 and 3.3-3 show the area affected at different water level differences for the area outside KWB Lands and the entire model area. Tables 3.3-4 and 3.3-5 show the agricultural areas affected by different levels of negative and positive differences, respectively.

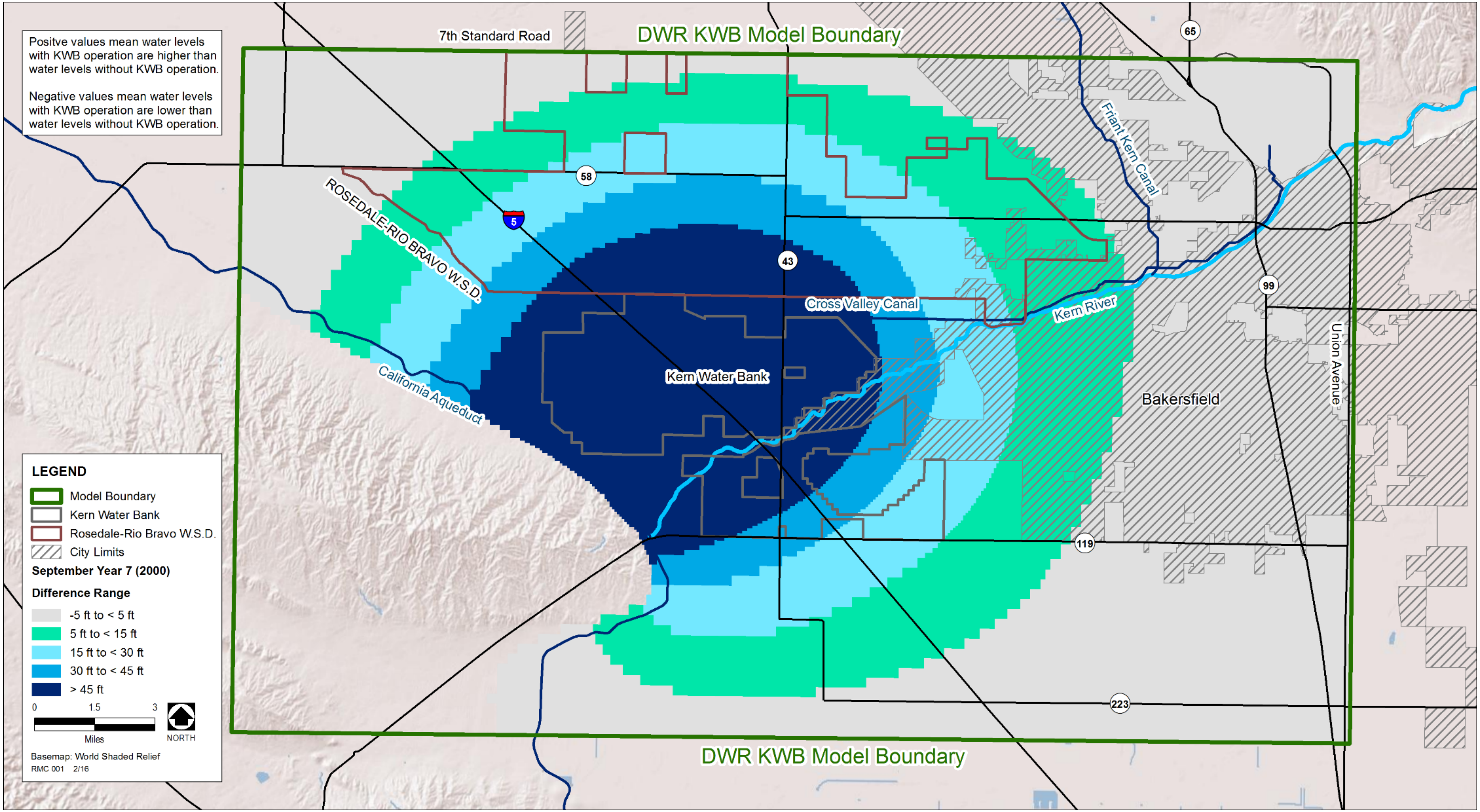


FIGURE 3.3-3a. Analysis of Future Operations under Existing Conditions: Groundwater Elevation Difference Contour Map at the End of the 1995–2000 Equivalent Recharge Cycle

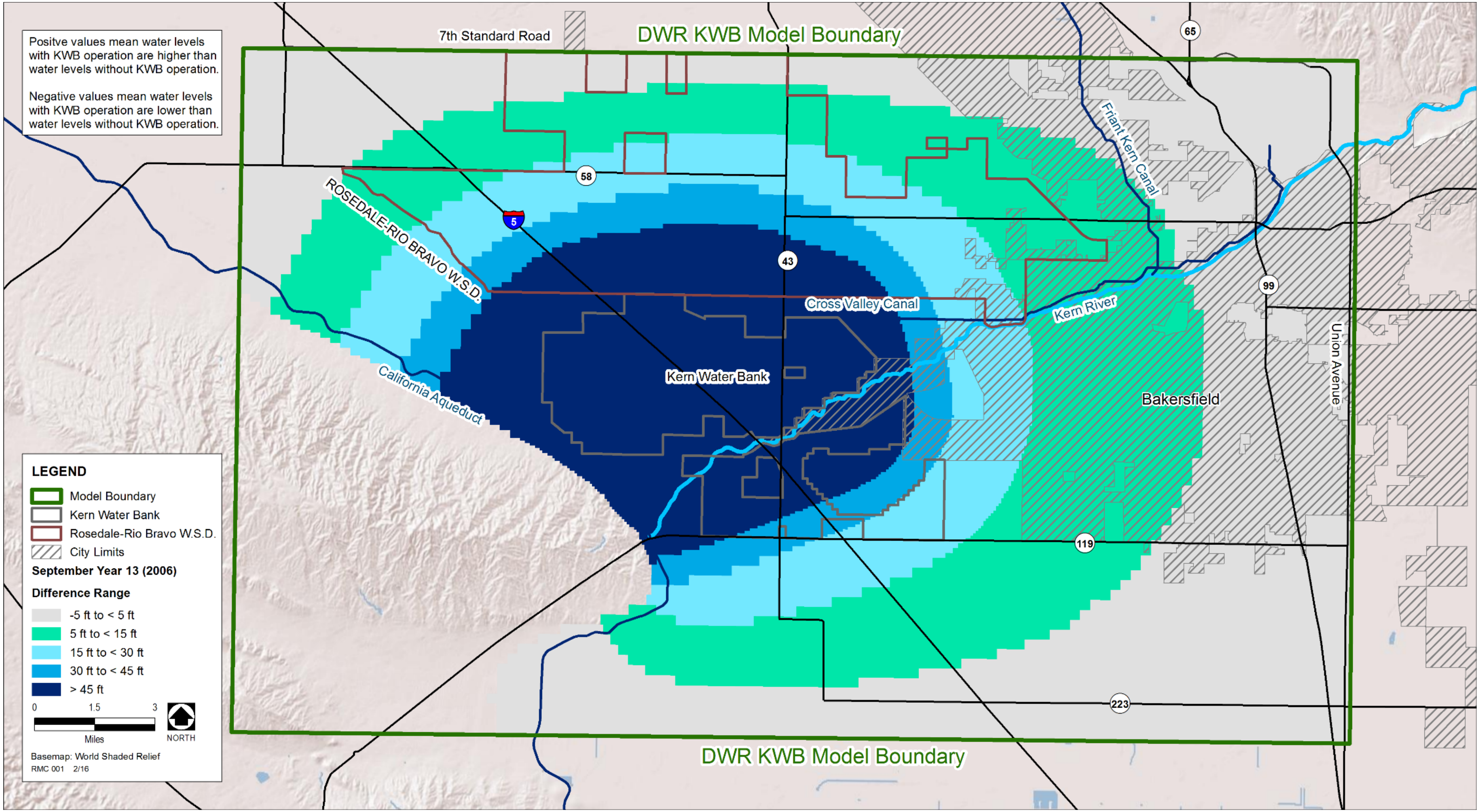


FIGURE 3.3-3b. **Analysis of Future Operations under Existing Conditions: Groundwater Elevation Difference Contour Map at the End of the 2006 Equivalent Recharge Cycle**

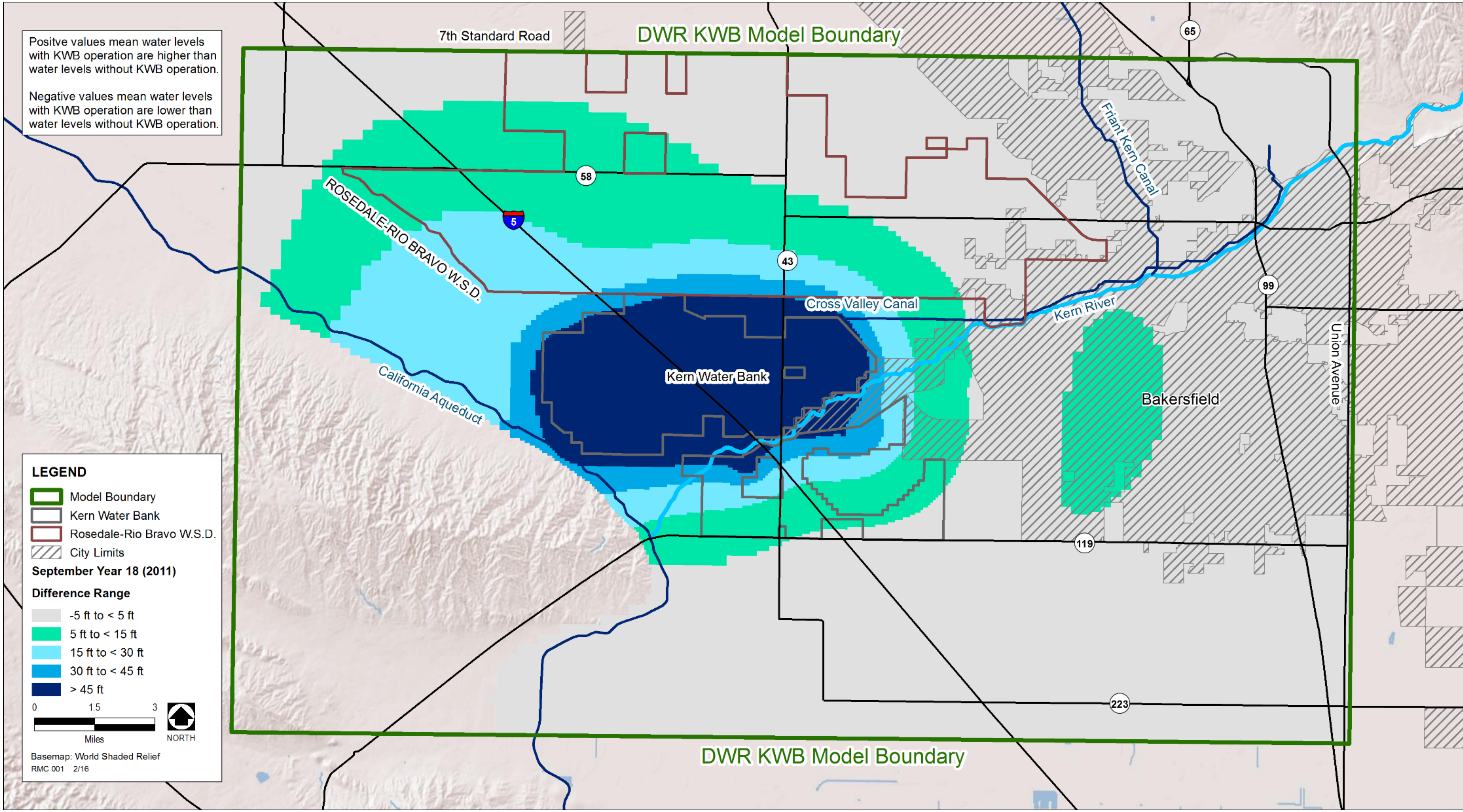


FIGURE 3.3-3c. **Analysis of Future Operations under Existing Conditions: Groundwater Elevation Difference Contour Map at the End of the 2011 Equivalent Recharge Cycle**

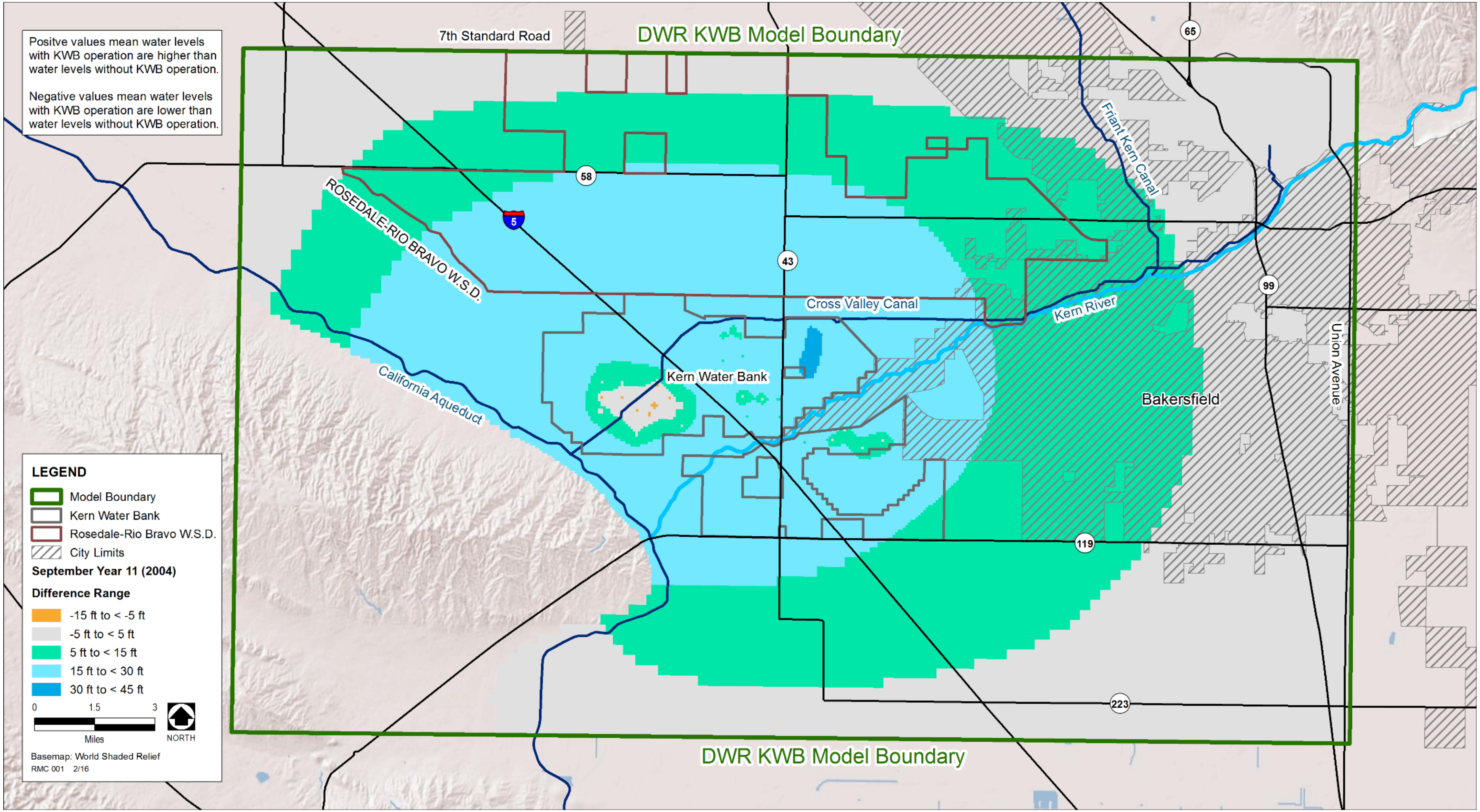


FIGURE 3.3-4a. Analysis of Future Operations under Existing Conditions: Groundwater Elevation Difference Contour Map at the End of the 2001–2004 Equivalent Recovery Cycle

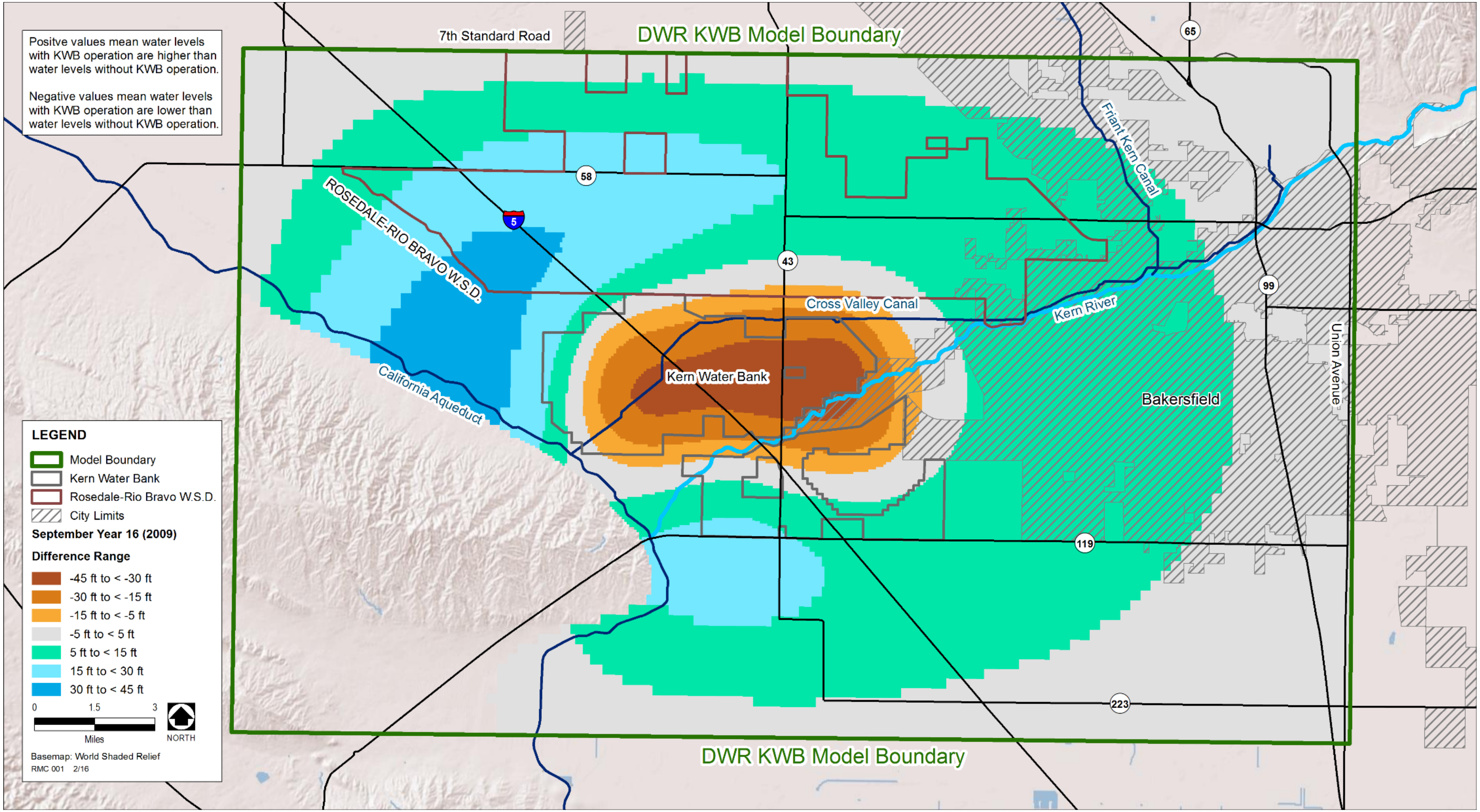


FIGURE 3.3-4b. Analysis of Future Operations under Existing Conditions: Groundwater Elevation Difference Contour Map at the End of the 2009 Equivalent Recovery Cycle

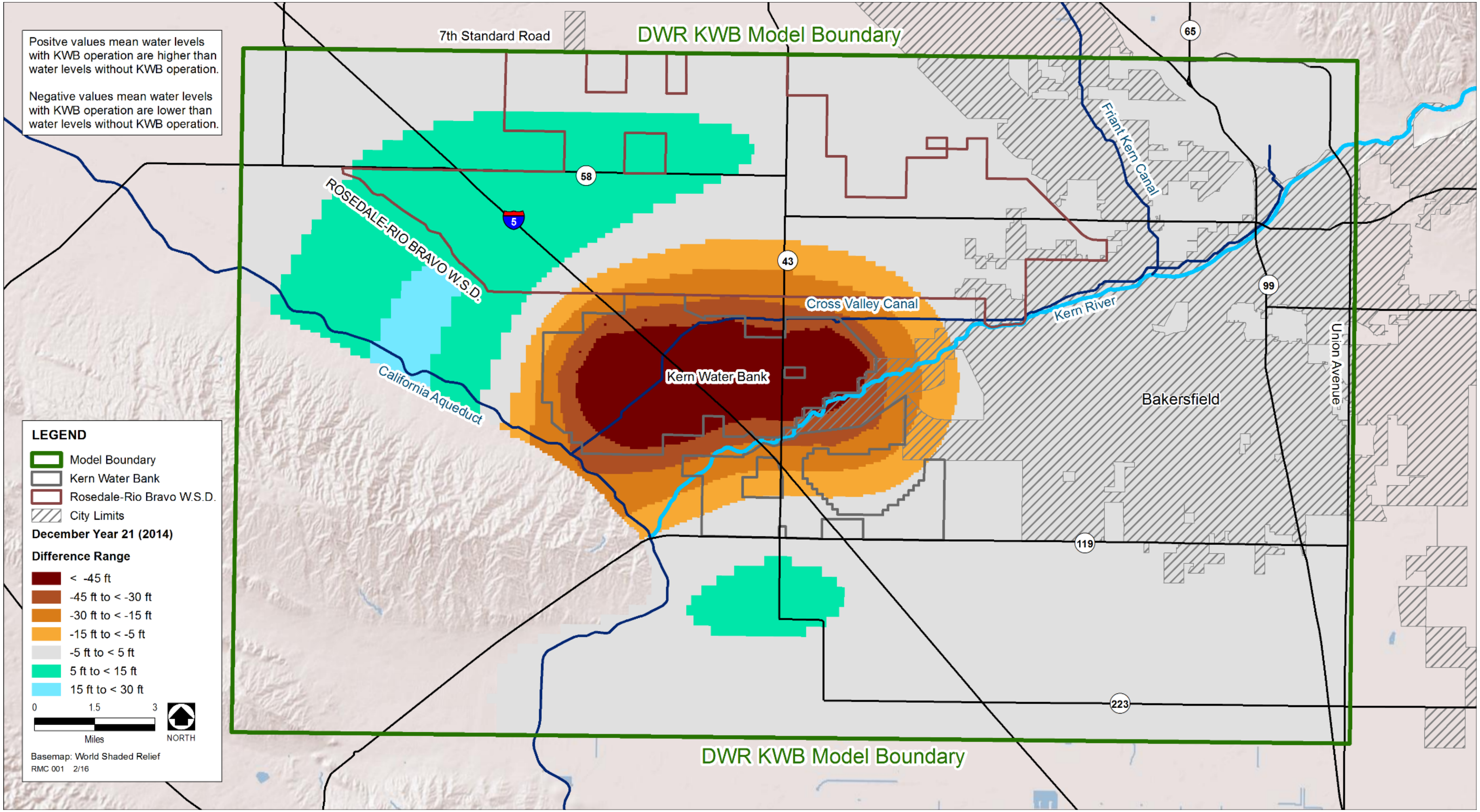


FIGURE 3.3-4c. **Analysis of Future Operations under Existing Conditions: Groundwater Elevation Difference Contour Map at the End of the 2014 Equivalent Recovery Cycle**

TABLE 3.3-1

WATER BUDGET FOR THE ANALYSIS OF FUTURE OPERATIONS UNDER EXISTING CONDITIONS SCENARIO WITH KERN WATER BANK OPERATIONS, 2015–2035

Year	INFLOW Into Model						OUTFLOW from Model						Calculated Change in Storage
	Deep Percolation of Applied Water	KWB Recharge	Other Banking Projects Recharge	River and Canal Seepage	Boundary Inflow through DWR KWB Model Domain	Total Inflow	Agricultural Pumping	Urban Pumping	KWB Pumping	Other Banking Projects Pumping	Boundary Outflow through DWR KWB Model Domain	Total Outflow (Positive)	
	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY
2015	95,214	-	-	-	401,426	496,641	(455,364)	(82,240)	(157,255)	(148,911)	(258,014)	1,101,784	(605,143)
2016	86,793	248,404	441,854	178,936	397,151	1,353,137	(400,515)	(82,240)	-	(17,463)	(243,186)	743,404	609,733
2017	88,425	163,443	245,865	166,869	430,529	1,095,131	(395,174)	(82,240)	-	(18,618)	(223,050)	719,081	376,049
2018	88,521	105,526	218,780	164,725	473,458	1,051,010	(394,117)	(82,240)	-	(17,671)	(218,268)	712,296	338,714
2019	89,222	330,686	373,720	152,887	441,202	1,387,718	(402,296)	(82,240)	-	(18,168)	(227,933)	730,637	657,081
2020	93,165	34,548	66,269	146,220	447,890	788,092	(421,696)	(82,240)	-	(20,942)	(254,533)	779,411	8,681
2021	92,756	25,924	90,944	117,264	445,227	772,114	(428,578)	(82,240)	-	(23,473)	(243,469)	777,760	(5,646)
2022	94,160	9,428	13,784	83,336	330,790	531,498	(437,431)	(82,240)	(88,699)	(98,833)	(300,603)	1,007,806	(476,308)
2023	94,200	12,633	10,815	106,200	373,807	597,656	(438,160)	(82,240)	(27,596)	(55,517)	(276,158)	879,671	(282,015)
2024	94,166	37,952	54,469	140,967	411,196	738,750	(431,147)	(82,240)	(48,367)	(36,789)	(278,090)	876,633	(137,882)
2025	94,209	16,981	35,728	92,596	400,021	639,534	(438,096)	(82,240)	(49,289)	(53,401)	(287,919)	910,945	(271,411)
2026	91,087	367,533	576,669	187,847	425,256	1,648,392	(388,665)	(82,240)	-	(34,127)	(263,945)	768,976	879,416
2027	91,531	283,698	357,693	171,055	420,029	1,324,006	(395,042)	(82,240)	-	(31,057)	(256,502)	764,842	559,164
2028	95,214	15,724	22,711	56,251	349,425	539,325	(449,579)	(82,240)	(230,686)	(126,812)	(309,102)	1,198,419	(659,094)
2029	95,280	-	10,626	63,460	331,459	500,825	(428,202)	(82,240)	(233,703)	(145,551)	(348,833)	1,238,529	(737,704)
2030	94,443	-	14,413	63,825	356,841	529,522	(434,533)	(82,240)	(162,461)	(117,154)	(308,669)	1,105,057	(575,535)
2031	92,990	31,143	195,061	198,235	392,052	909,481	(396,670)	(82,240)	(50,969)	(51,656)	(279,118)	860,653	48,828
2032	91,547	420,319	583,911	262,648	454,809	1,813,234	(372,534)	(82,240)	-	(27,811)	(247,511)	730,097	1,083,138
2033	94,110	8,383	69,909	77,153	389,893	639,448	(428,063)	(82,240)	(110,830)	(47,016)	(286,371)	954,520	(315,072)
2034	95,214	-	-	54,142	350,415		(453,805)	(82,240)	(196,819)	(137,019)	(322,573)	1,192,455	(692,684)
2035	95,214	-	-	51,390	390,424	537,029	(455,364)	(82,240)	(189,695)	(173,067)	(285,742)	1,186,108	(649,080)
Total 2015–2035	1,947,460	2,112,325	3,383,223	2,536,007	8,413,299	17,892,543	(8,845,032)	(1,727,040)	(1,546,368)	(1,401,055)	(5,719,589)	19,239,083	

Notes: AFY = acre-feet per year; KWB = Kern Water Bank; KWBA = Kern Water Bank Authority

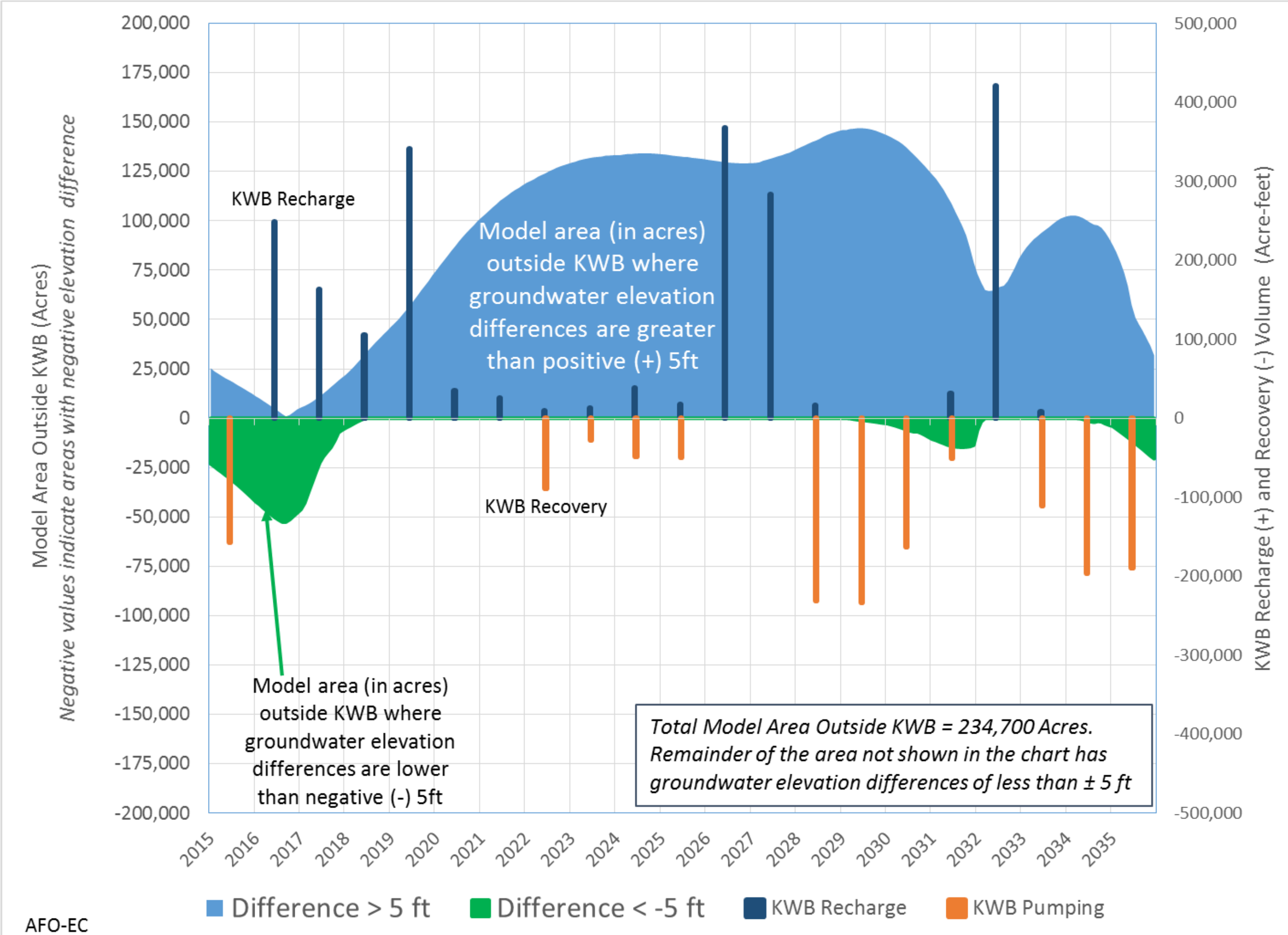


FIGURE 3.3-5. Analysis of Future Operations under Existing Conditions: Time vs. Affected Area Outside Kern Water Bank Exceeding ± 5 Feet Differences in Groundwater Elevations ("With Kern Water Bank Operations" Minus "Without Kern Water Bank Operations"), 2015-2035

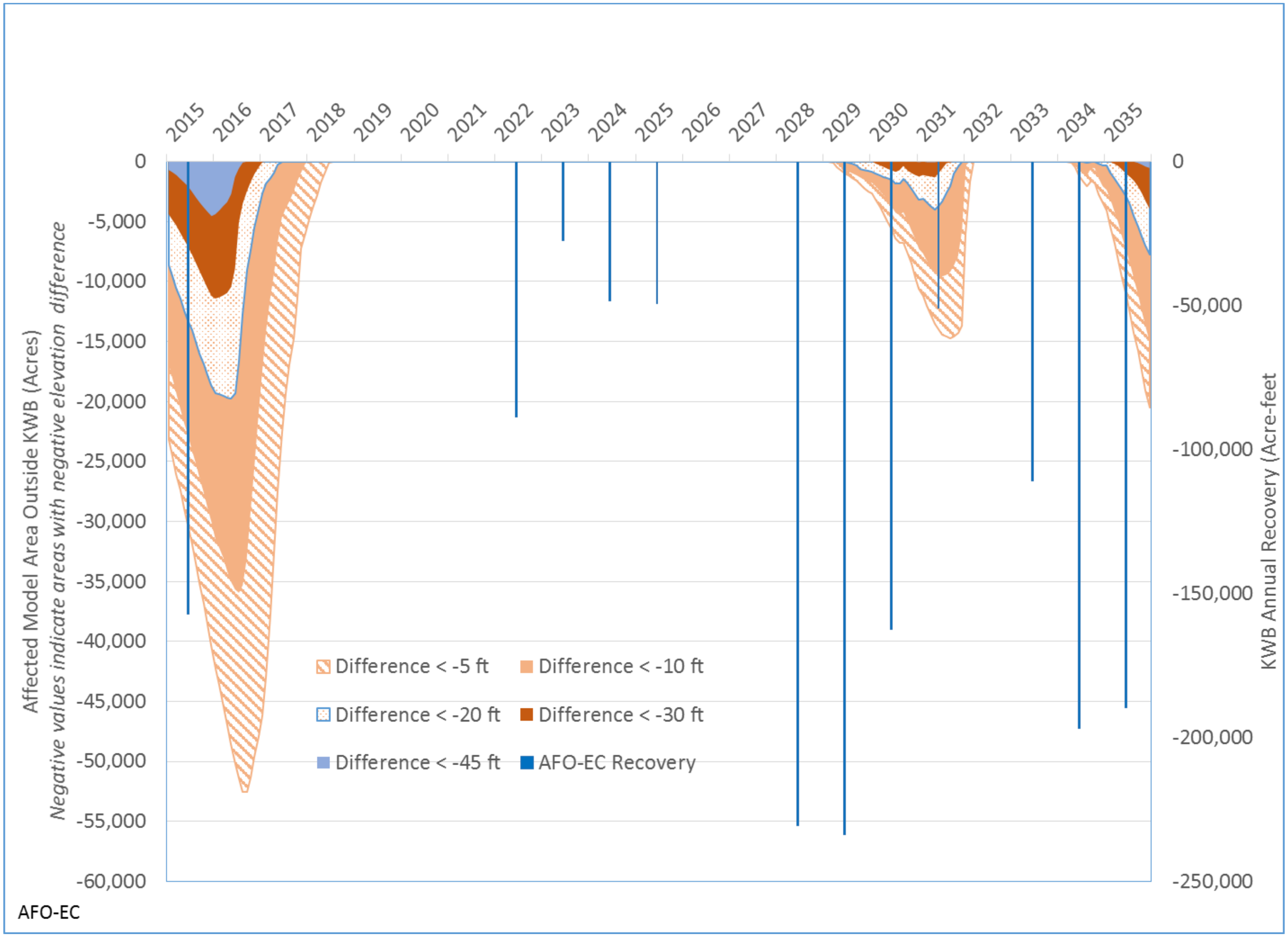


FIGURE 3.3-6. **Analysis of Future Operations under Existing Conditions: Time vs. Affected Area Outside Kern Water Bank at Various Levels of Negative Elevation Differences ("With Kern Water Bank Operations" Minus "Without Kern Water Bank Operations"), 2015-2035**

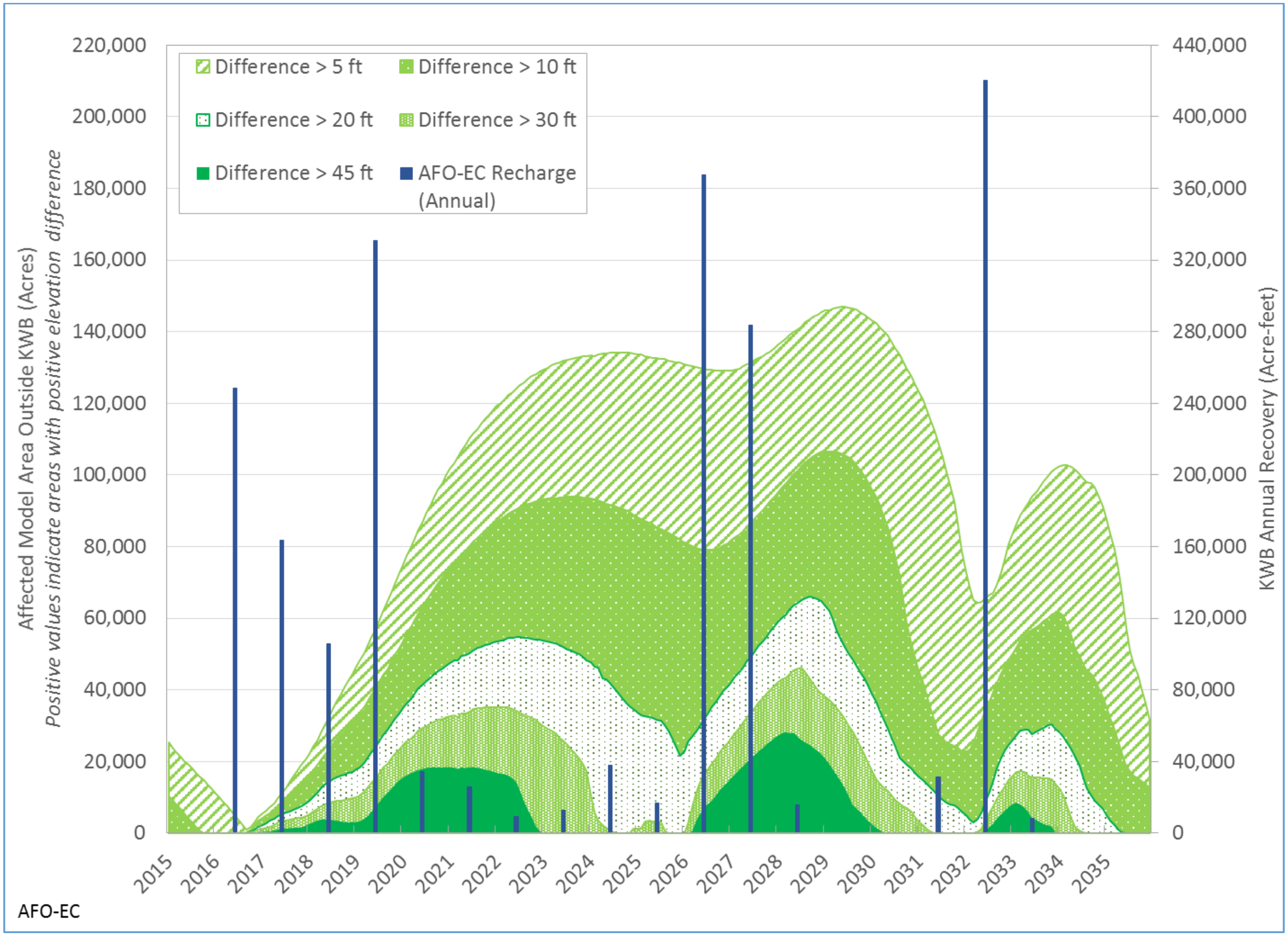


FIGURE 3.3-7. **Analysis of Future Operations under Existing Conditions: Time vs. Affected Area Outside Kern Water Bank at Various Levels of Positive Elevation Differences ("With Kern Water Bank Operations" Minus "Without Kern Water Bank Operations"), 2015-2035**

3.3.4 FREQUENCY DISTRIBUTION OF GROUNDWATER ELEVATION DIFFERENCES

Maps were prepared to evaluate the location and frequency with which groundwater elevation differences between the AFO-EC "With KWB Operations" and "Without KWB Operations" scenarios exceeded selected values (Metric 6 of Section 3.1). Frequency distributions of negative groundwater elevation differences exceeding -45 feet, -30 feet, -20 feet, and -10 feet are shown in Figures 3.3-10a to 3.3-10d, respectively. Frequency distributions of groundwater elevation differences exceeding +10 feet, +30 feet, and + 60 feet are shown in Figures 3.3-11a to 3.3-11c, respectively.

Figure 3.3-10a shows that negative elevation differences exceeding -45 feet are contained entirely within the KWB boundary at all times. Figure 3.3-10b shows that negative elevation differences exceeding -30 feet are contained entirely within the KWB boundary approximately 90 percent of the time during future (2015–2035) operations under the AFO-EC scenario.

Positive elevation differences exceeding +60 feet (Figure 3.3-11c) are mostly contained within the KWB boundary. Approximately 25 percent of the time such differences occur outside the KWB boundary, but in the immediate vicinity.

3.3.5 ZONAL AVERAGE GROUNDWATER ELEVATION HYDROGRAPHS

Average groundwater elevations outside KWB Lands (Metric 7 of Section 3.1) were evaluated at five 1-mile zones (Figure 3.2-14). Simulated head was averaged for each cell in a particular zone for each monthly time step of the simulation period. Average groundwater elevations for Zones 1–5 are shown in Figures 3.3-12a to 3.3-12e. Figure 3.3-13 shows the average elevation difference in each zone, which was calculated by subtracting the "Without KWB Operations" run from the "With KWB Operations" run data shown in Figures 3.3-12a to 3.3-12e. These figures indicate that the rise and fall of the groundwater mound follows KWB recharge and recovery cycles, and is correlated with the cumulative KWB storage balance. The impacts of consecutive years of pumping, such as the 4-year period of 2012–2015, are seen in the lowering of the average groundwater elevation in Zones 1–3 in the first few years of the AFO-EC scenario, until successive years of recharge in 2016–2017 (hydrologically similar to 1995–1996) result in an increase in the average groundwater level.

3.3.6 HIGH GROUNDWATER LEVELS AND IMPACT ON INFRASTRUCTURE

Future recharge operations at KWB during the recharge periods of 2016–2019, 2026–2027, and 2032 under AFO-EC conditions (similar to 1995–1998, 2005–2006, and 2011 hydrologic conditions, respectively) could result in high groundwater elevations (<50 feet bgs) within KWB Lands and surrounding areas.

High groundwater elevations could impact the existing infrastructure within and in the vicinity of the KWB. Large urban areas to the east and northeast of KWB Lands use septic systems. Additionally, there are small residential areas in the vicinity of KWB Lands that are on septic systems or dry wells. High groundwater elevations in these areas could potentially impact the septic systems and dry wells. The CVC and residential areas on septic systems are the main infrastructure in the DWR KWB Model domain that might potentially be impacted by high water levels.

Results of the AFO-EC model scenario were evaluated to determine the impact of high groundwater elevations on the CVC and nearby residential areas on septic systems.

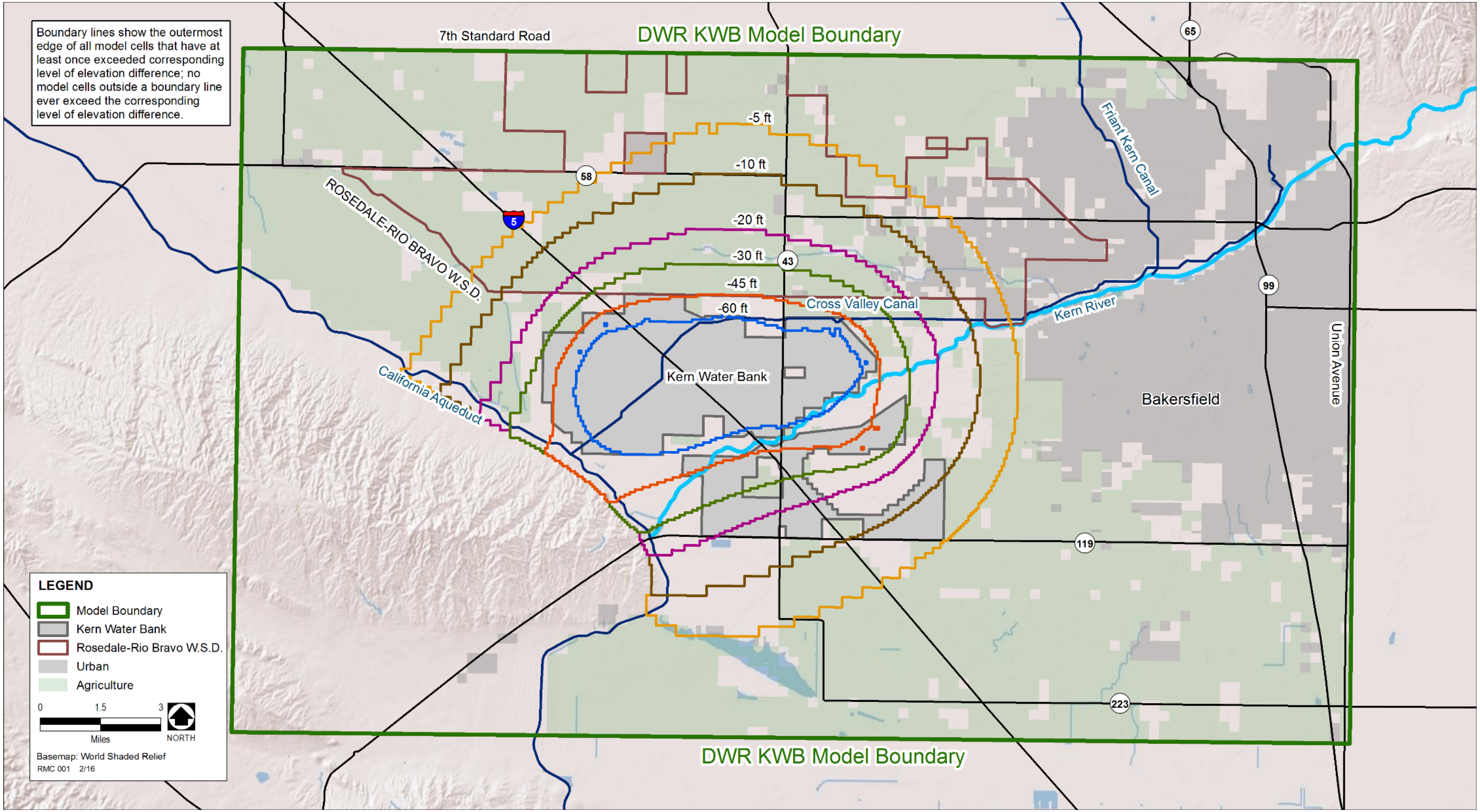


FIGURE 3.3-8. **Analysis of Future Operations under Existing Conditions: Contours of Negative Differences ("With" minus "Without"), 2015–2035**

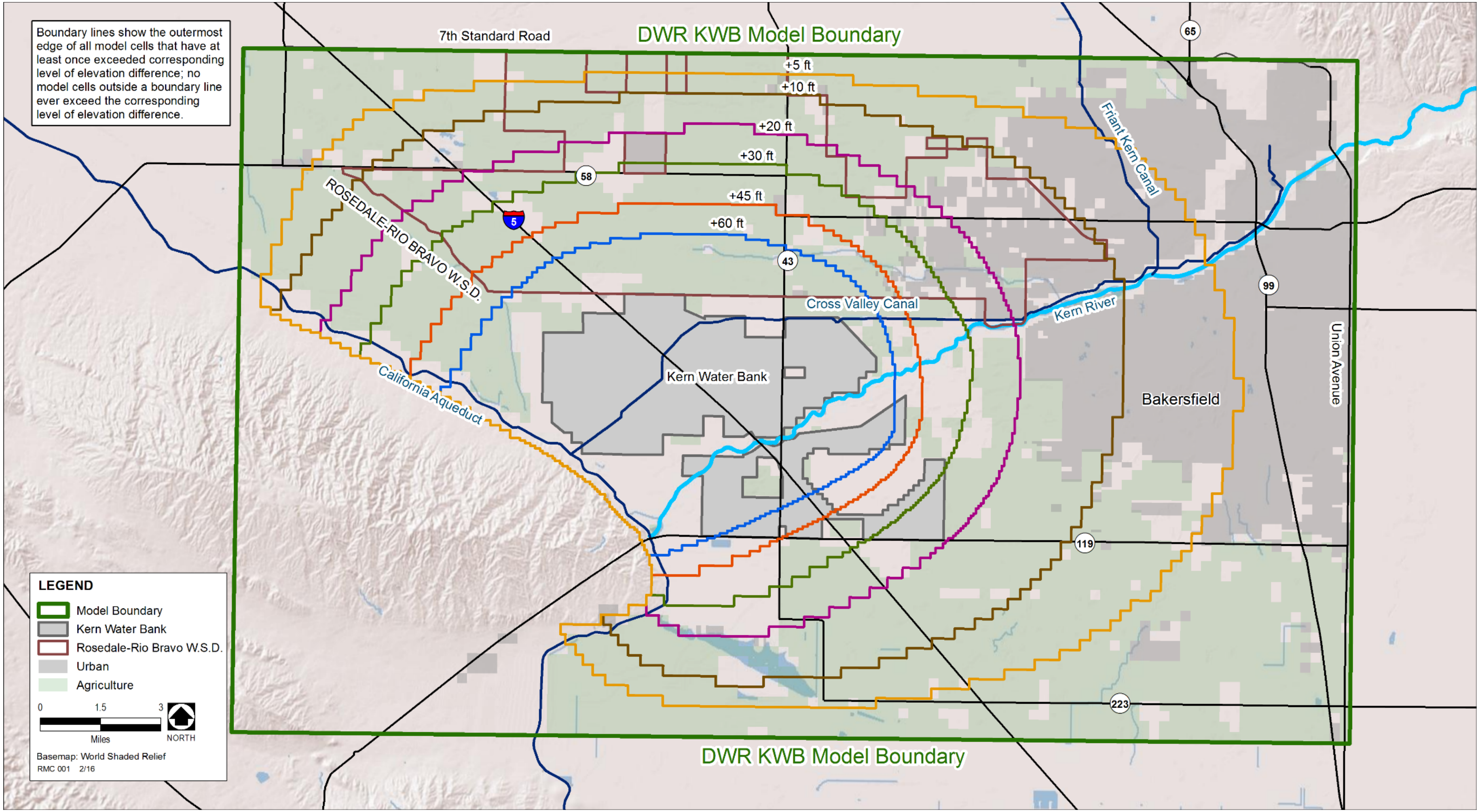


FIGURE 3.3-9. Analysis of Future Operations under Existing Conditions: Contours of Positive Elevation Differences ("With" minus "Without"), 2015–2035

TABLE 3.3-2

AREA AFFECTED AT DIFFERENT WATER LEVELS FOR THE AREA OUTSIDE THE KERN WATER BANK LANDS (ANALYSIS OF FUTURE OPERATIONS UNDER EXISTING CONDITIONS), 2015–2035

	Impacted Area Outside the Kern Water Bank Lands (acres)									
Frequency for 20-Year Simulation	**-60 Feet**	**-45 Feet**	**-30 Feet**	**-20 Feet**	**-10 Feet**	**+10 Feet**	**+20 Feet**	**+30 Feet**	**+45 Feet**	**+60 Feet**
Never Occurs	231,742	227,554	220,112	211,139	193,714	121,061	162,459	183,114	201,534	212,059
1–12 months	580	2,905	4,200	4,860	6,123	1,770	3,150	3,333	3,735	3,825
13–24 months	83	1,928	6,703	10,415	15,998	6,035	6,308	5,448	4,623	4,533
25–36 months	0	18	703	3,778	7,993	5,198	2,750	3,118	3,618	2,840
37–58 months	0	0	683	1,268	5,245	2,348	3,255	3,793	2,478	2,128
59–60 months	0	0	5	928	2,205	2,400	3,195	3,528	3,085	2,625
61–72 months	0	0	0	18	1,128	2,928	3,330	4,265	4,548	2,603
73–84 months	0	0	0	0	0	3,163	4,830	4,663	3,188	1,248
85–96 months	0	0	0	0	0	3,000	5,173	2,918	3,238	250
97–108 months	0	0	0	0	0	5,100	3,905	3,060	1,663	295
109–120 months	0	0	0	0	0	8,480	2,828	4,950	698	0
121–144 months	0	0	0	0	0	13,298	5,963	9,465	0	0
145–168 months	0	0	0	0	0	20,948	24,908	753	0	0
168 or more months	0	0	0	0	0	36,678	353	0	0	0

TABLE 3.3-3

AREA AFFECTED AT DIFFERENT WATER LEVELS FOR THE ENTIRE MODEL AREA (ANALYSIS OF FUTURE OPERATIONS UNDER EXISTING CONDITIONS), 2015–2035

	Impacted Area in Model Domain (acres)									
Frequency for 20-Year Simulation	**-60 Feet**	**-45 Feet**	**-30 Feet**	**-20 Feet**	**-10 Feet**	**+10 Feet**	**+20 Feet**	**+30 Feet**	**+45 Feet**	**+60 Feet**
Never Occurs	242,669	234,504	224,287	213,892	194,754	121,061	162,459	184,084	203,452	215,207
1–12 months	5,180	5,293	5,088	5,668	6,518	1,770	3,173	3,913	4,143	4,783
13–24 months	6,555	9,440	11,030	12,980	18,375	6,035	6,648	5,570	5,348	5,483
25–36 months	45	4,643	4,958	6,443	9,413	5,198	2,883	3,130	3,910	3,358
37–58 months	0	570	7,068	5,853	7,953	2,348	3,438	3,860	3,033	2,778
59–60 months	0	0	2,013	8,285	8,233	2,400	3,398	3,775	3,948	3,920
61–72 months	0	0	8	1,330	8,950	2,928	3,720	4,953	5,645	6,465
73–84 months	0	0	0	0	255	3,163	5,205	5,643	5,918	5,545
85–96 months	0	0	0	0	0	3,000	5,245	3,570	7,253	1,608
97–108 months	0	0	0	0	0	5,100	4,215	3,748	4,600	5,288
109–120 months	0	0	0	0	0	8,505	3,178	7,350	6,105	18
121–144 months	0	0	0	0	0	14,830	9,330	20,285	1,098	0
145–168 months	0	0	0	0	0	31,795	40,958	4,570	0	0
168 or more months	0	0	0	0	0	46,318	603	0	0	0

TABLE 3.3-4 ANALYSIS OF FUTURE OPERATIONS UNDER EXISTING CONDITIONS: AREA AFFECTED AT DIFFERENT LEVELS OF NEGATIVE DIFFERENCES (“WITH KERN WATER BANK OPERATIONS” MINUS “WITHOUT KERN WATER BANK OPERATIONS”), 2015–2035		
Level of Negative Difference	**Agricultural Area (Acres)**	**Urban Area (Acres)**
-45 feet	770	0
-30 feet	4,702	68
-20 feet	9,830	110
-10 feet	19,815	748
-5 feet	33,023	2,790

Table 3.3-5 Analysis of Future Operations Under Existing Conditions: Area Affected at Different Levels of Positive Differences (“With Kern Water Bank Operations” Minus “Without Kern Water Bank Operations”), 2015–2035		
Level of Positive Difference	**Agricultural Area (Acres)**	**Urban Area (Acres)**
5 feet	90,180	27,698
10 feet	67,250	13,270
20 feet	41,145	3,138
30 feet	28,093	860
45 feet	17,378	125

Figures 3.3-14 to 3.3-16 show the spatial characteristics of the groundwater mound that form during recharge operations of 2016-2019, 2026-2027, and 2032 under AFO-EC “With KWB Operations” conditions.

Figure 3.2-20 shows the locations of the two selected water level hydrographs along the CVC. The hydrograph locations were selected based on locations of the piezometers and pumping stations of the CVC; these hydrographs are used to demonstrate the impacts on CVC. Figure 3.2-21 shows the areas near KWB Lands that are on septic systems or dry wells as obtained from the Kern County General Plan and Google Earth; it also shows the locations of two selected water level hydrographs used to demonstrate the impacts on septic areas.

Figure 3.3-17 shows the groundwater level hydrographs at two selected locations along the CVC. The hydrographs show the water levels at the selected locations for the AFO-EC “With KWB Operations” and “Without KWB operations” scenarios, ground surface elevation, and the CVC invert elevation. It is assumed that the CVC invert is 10 feet below ground surface. The impact of the KWB recharge operations on the CVC is discussed below.

Figure 3.3-18 shows the water level hydrographs at two locations near KWB Lands, as shown in Figure 3.2-21. The hydrographs show the water levels for the AFO-EC “With KWB Operations” and “Without KWB Operations” scenarios and the ground surface elevation. The impact on the KWB recharge operations on the septic systems is discussed below.

3.3.6.1 2016-2019 Recharge Operations

As shown in Figures 3.3-14 and 3.3-17, 2016-2019 recharge operations resulted in water levels lower than 50 feet from surface along the entire length of the CVC in the KWB area. As shown in Figure 3.3-18, depth to groundwater in residential areas on septic systems located northeast of KWB Lands exceeds 50 feet. Groundwater elevations are not high enough to impact the CVC and the septic systems.

3.3.6.2 2026-2027 Recharge Operations

As shown in Figures 3.3-15 and 3.3-17, similar to 2016-2019 conditions, 2026-2027 recharge operations resulted in water levels lower than 50 feet from surface along the entire length of the CVC in the KWB area. High groundwater levels would be limited to the area within KWB Lands and east of the CVC. As shown in Figure 3.3-18, depth to groundwater in residential areas using septic systems located northeast of KWB Lands would exceed 50 feet. Groundwater elevations are not high enough to impact the CVC and the septic systems.

3.3.6.3 2032 Recharge Operations

As shown in Figure 3.3-16 and 3.3-18, water levels would be lower than 50 feet from surface along the entire length of the CVC and within almost all of the KWB area. Water levels in 2032 would be generally lower than 2019 and 2027 levels due to 2032 being a single-year recharge period while the other two recharge periods are 4- and 2-year recharge periods, respectively. Also, a higher percentage of KWB recharge is shifted to eastern ponds to be consistent with current recharge management practices of the KWB.

3.3.7 HIGH GROUNDWATER LEVELS AND IMPACT ON NEIGHBORING RECHARGE FACILITIES

Impacts of KWB recharge operations on the recharge operations of neighboring recharge facilities during high groundwater elevations with all the groundwater banks operating simultaneously under AFO-EC conditions were evaluated by using water level hydrographs at the neighboring recharge facilities.

Figure 3.2-24 shows the locations of the selected water level hydrographs at the neighboring recharge facilities. Figure 3.3-19 shows the representative water level hydrographs at these locations. Table 3.3-6 shows the minimum depth to water under AFO-EC conditions at the four selected recharge facilities. The impact of KWB recharge operations on the neighboring recharge facilities during high groundwater elevations with all the groundwater banks operating simultaneously are discussed below.

TABLE 3.3-6

MODEL-GENERATED MINIMUM DEPTH TO WATER FOR AFO-EC CONDITIONS

Simulation Period	Recharge Facility			
	Rosedale	Pioneer	2800 Acre	West Kern Water District
2016-2019	104.4	75.2	63.7	78.3
2026-2027	94.9	62.4	41.5	87
2032	105.6	88.7	85	99.1

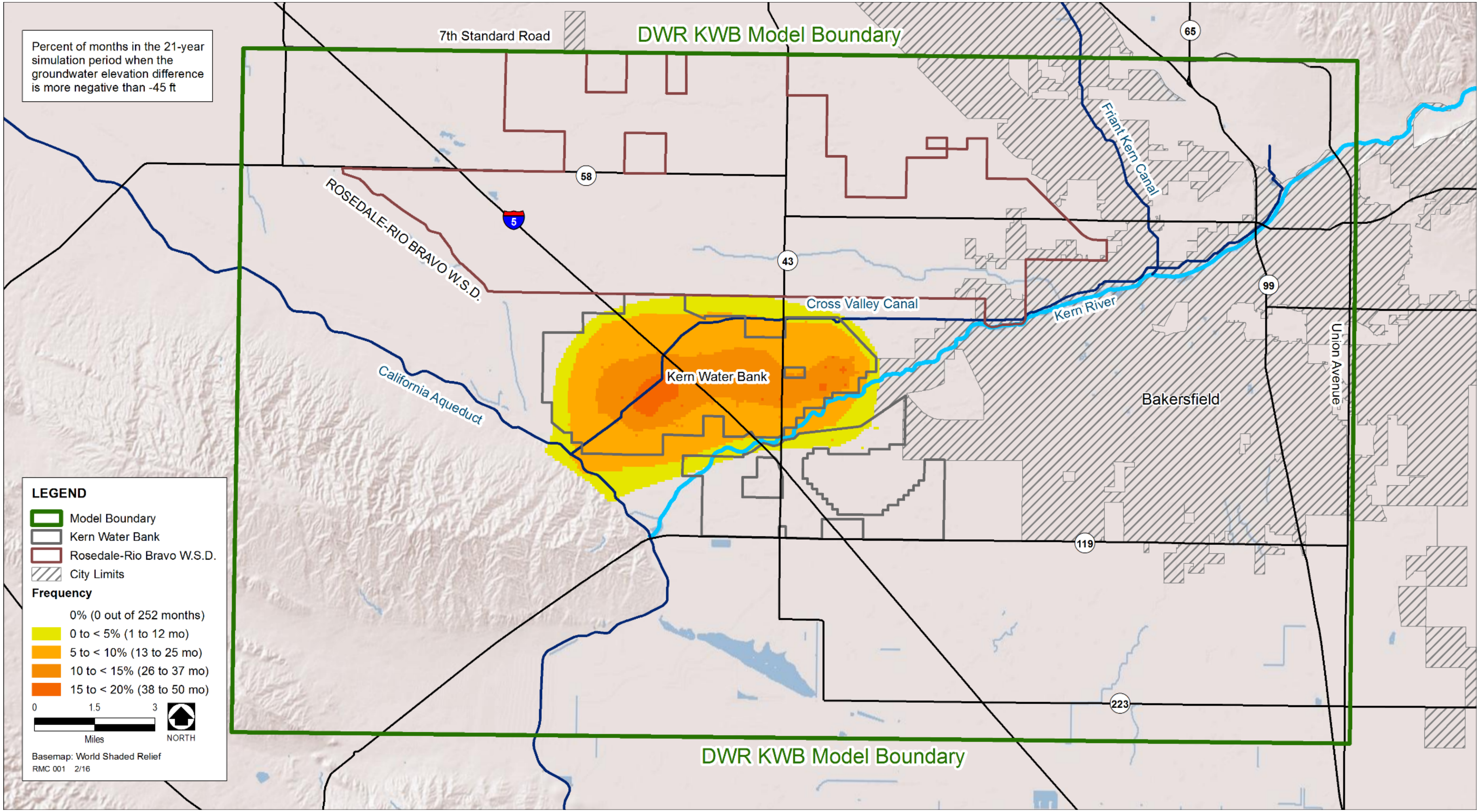


Figure 3.3-10a. **Analysis of Future Operations under Existing Conditions: Frequency Distribution (% of Months) of Areas with > -45 Feet Difference in Groundwater Elevations ("With Kern Water Bank Operations" Minus "Without Kern Water Bank Operations"), 2015-2035**

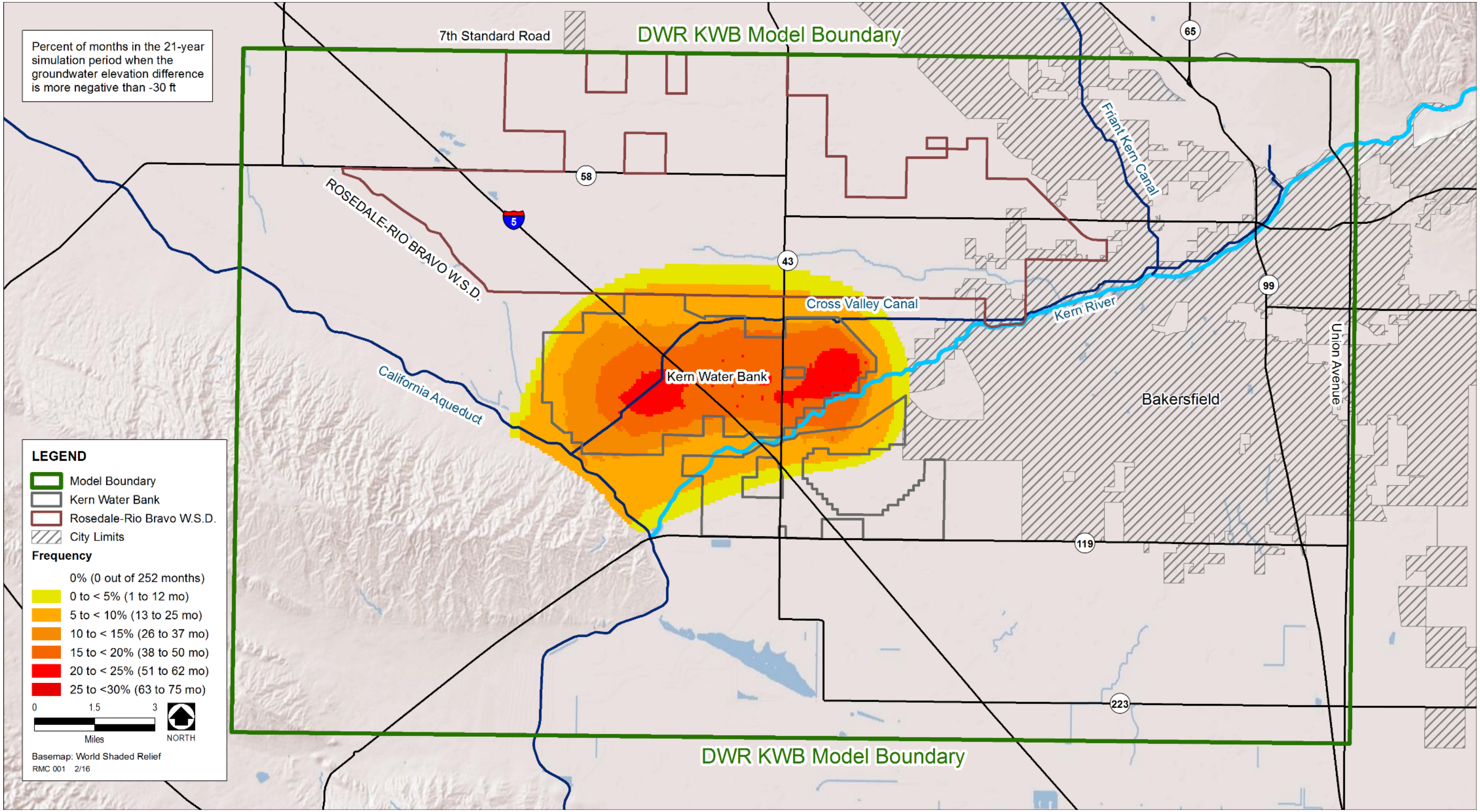


FIGURE 3.3-10b. **Analysis of Future Operations under Existing Conditions: Frequency Distribution (% of Months) of Areas with > -30 Feet Difference in Groundwater Elevations ("With Kern Water Bank Operations" Minus "Without Kern Water Bank Operations"), 2015-2035**

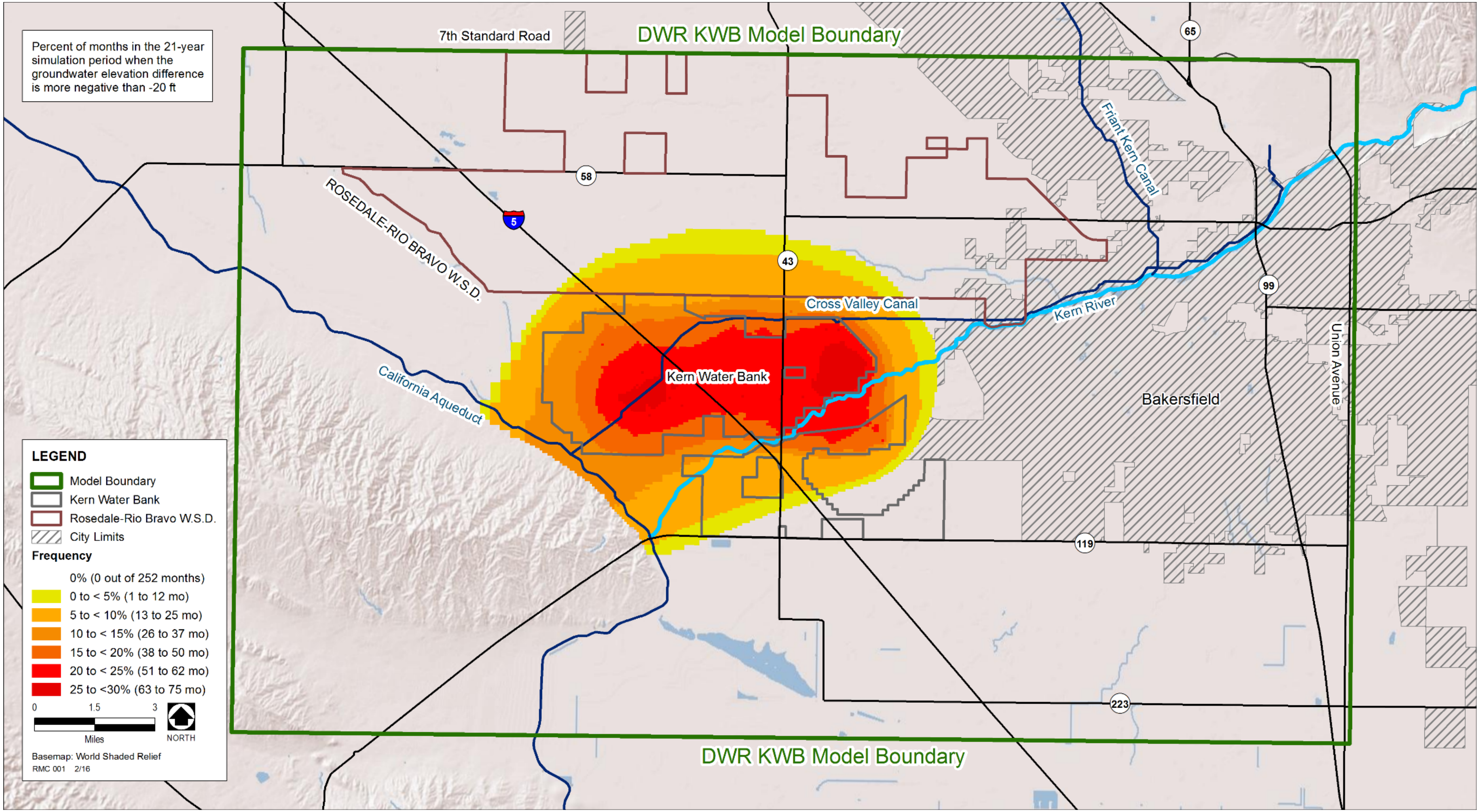


FIGURE 3.3-10c. **Analysis of Future Operations under Existing Conditions: Frequency Distribution (% of Months) of Areas with > -20 Feet Difference in Groundwater Elevations ("With Kern Water Bank Operations" Minus "Without Kern Water Bank Operations"), 2015-2035**

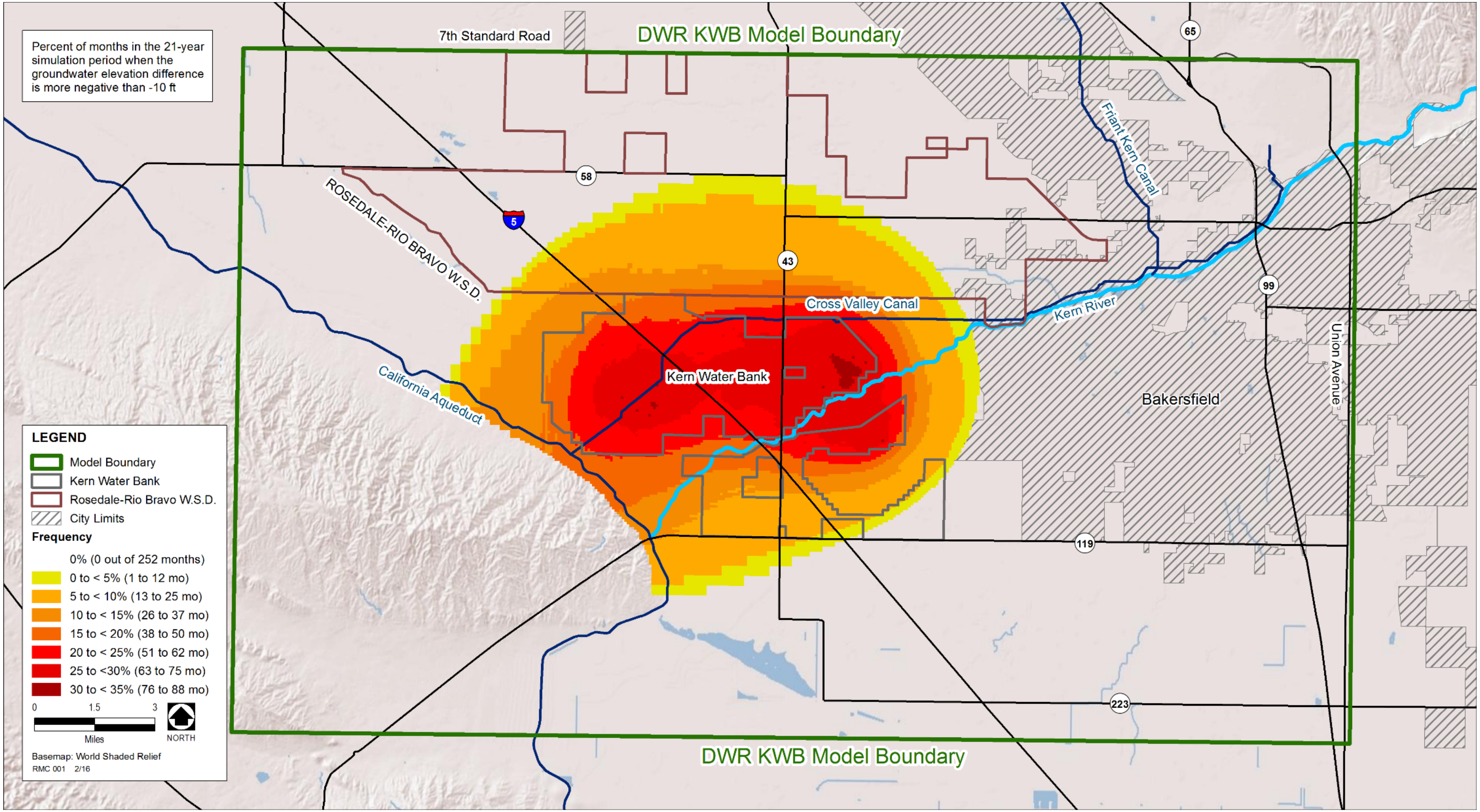


FIGURE 3.3-10d. **Analysis of Future Operations under Existing Conditions: Frequency Distribution (% of Months) of Areas with > -10 Feet Difference in Groundwater Elevations ("With Kern Water Bank Operations" Minus "Without Kern Water Bank Operations"), 2015-2035**

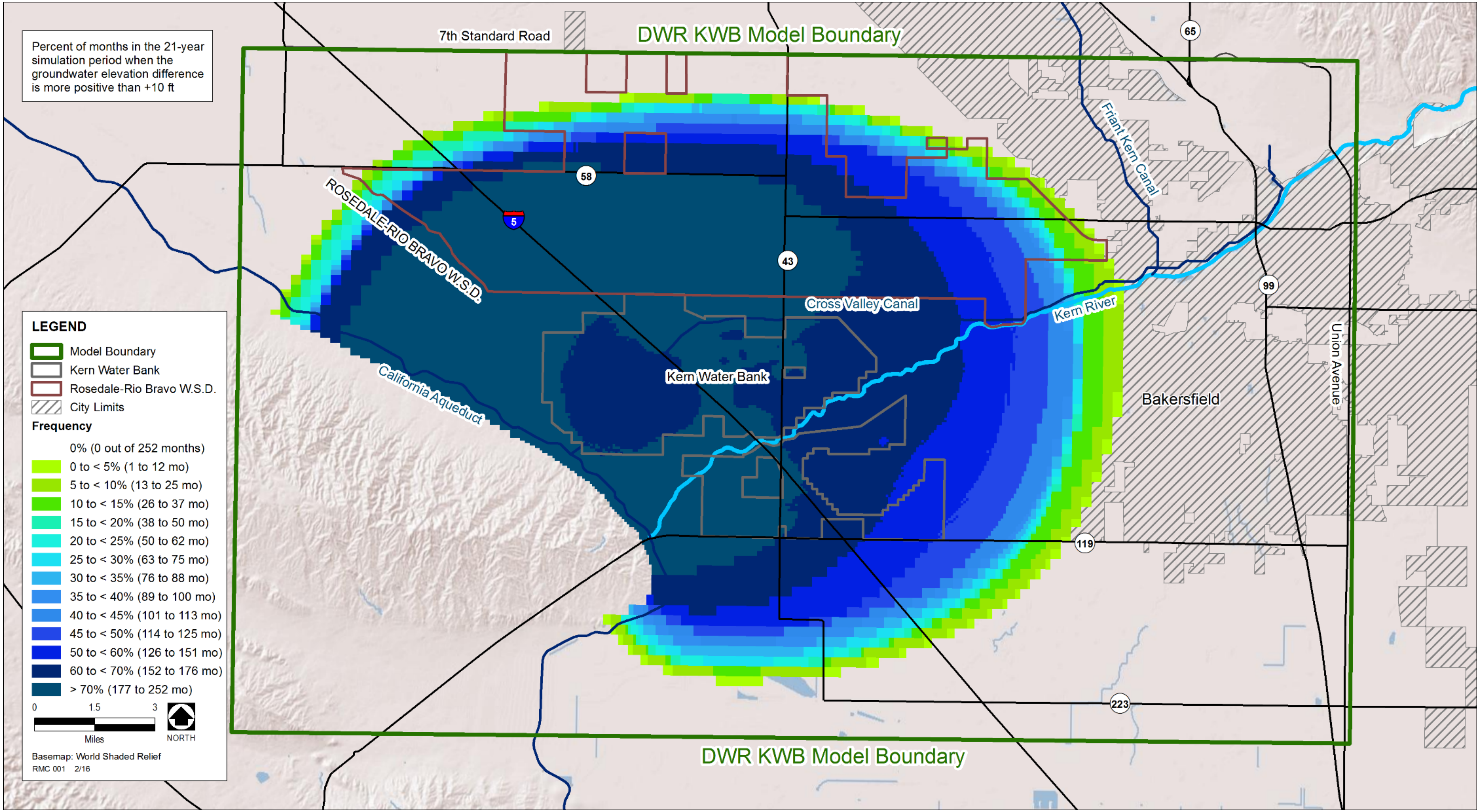


FIGURE 3.3-11a. Analysis of Future Operations under Existing Conditions: Frequency Distribution (% of Months) of Areas with > +10 Feet Difference in Groundwater Elevations ("With Kern Water Bank Operations" Minus "Without Kern Water Bank Operations"), 2015-2035

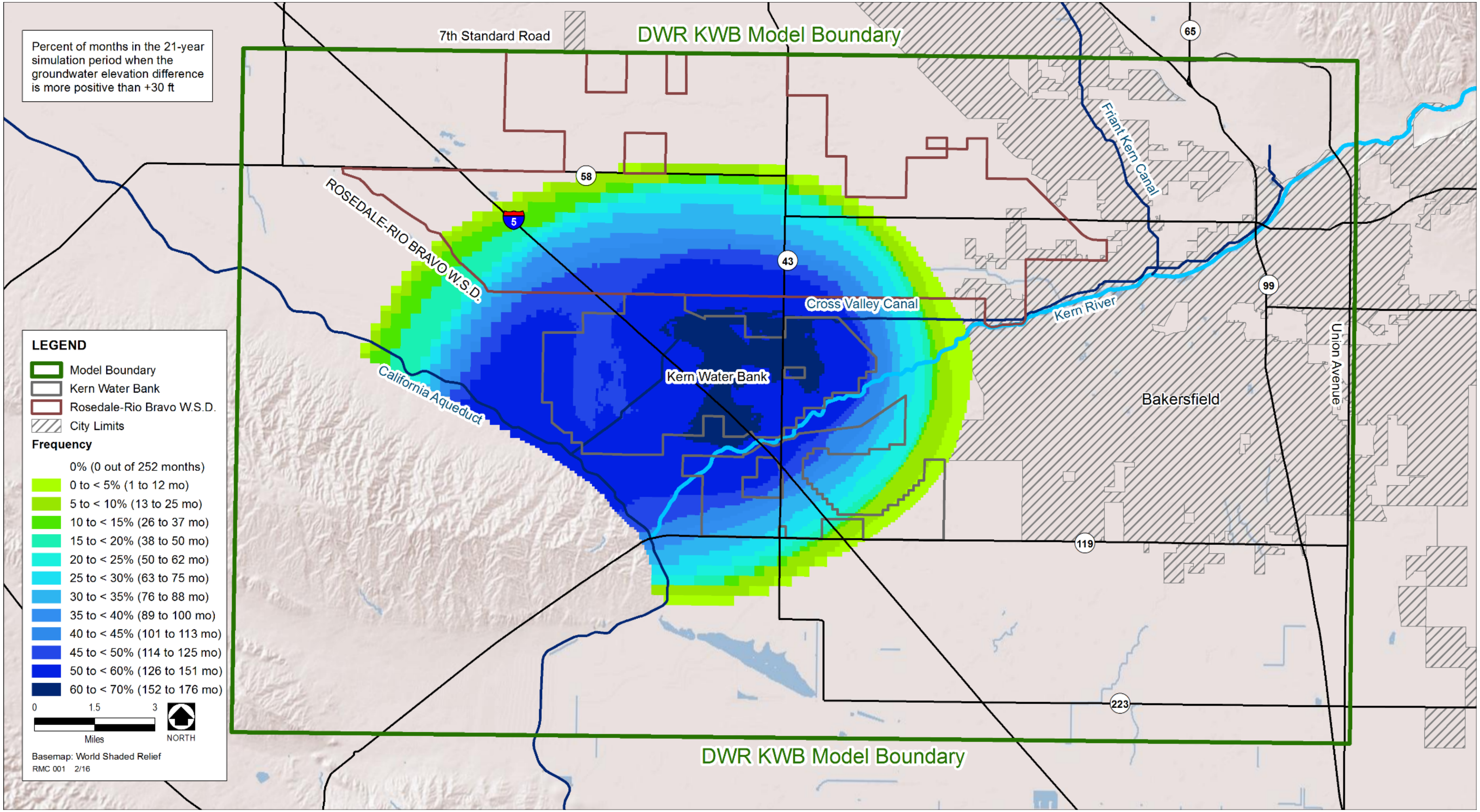


FIGURE 3.3-11b. Analysis of Future Operations under Existing Conditions: Frequency Distribution (% of Months) of Areas with > +30 Feet Difference in Groundwater Elevations ("With Kern Water Bank Operations" Minus "Without Kern Water Bank Operations"), 2015-2035

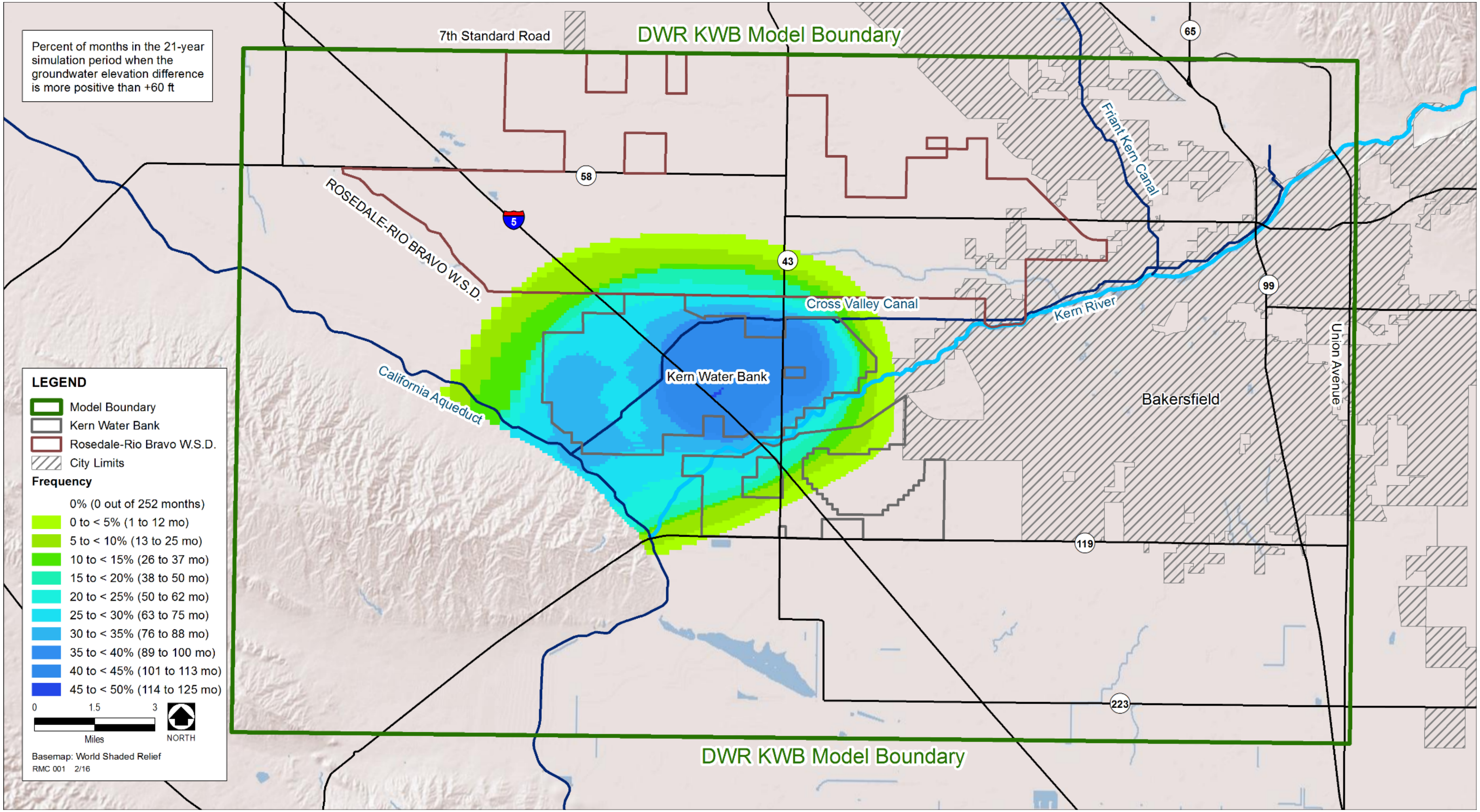


FIGURE 3.3-11c. Analysis of Future Operations under Existing Conditions: Frequency Distribution (% of Months) of Areas with > +60 Feet Difference in Groundwater Elevations ("With Kern Water Bank Operations" Minus "Without Kern Water Bank Operations"), 2015-2035

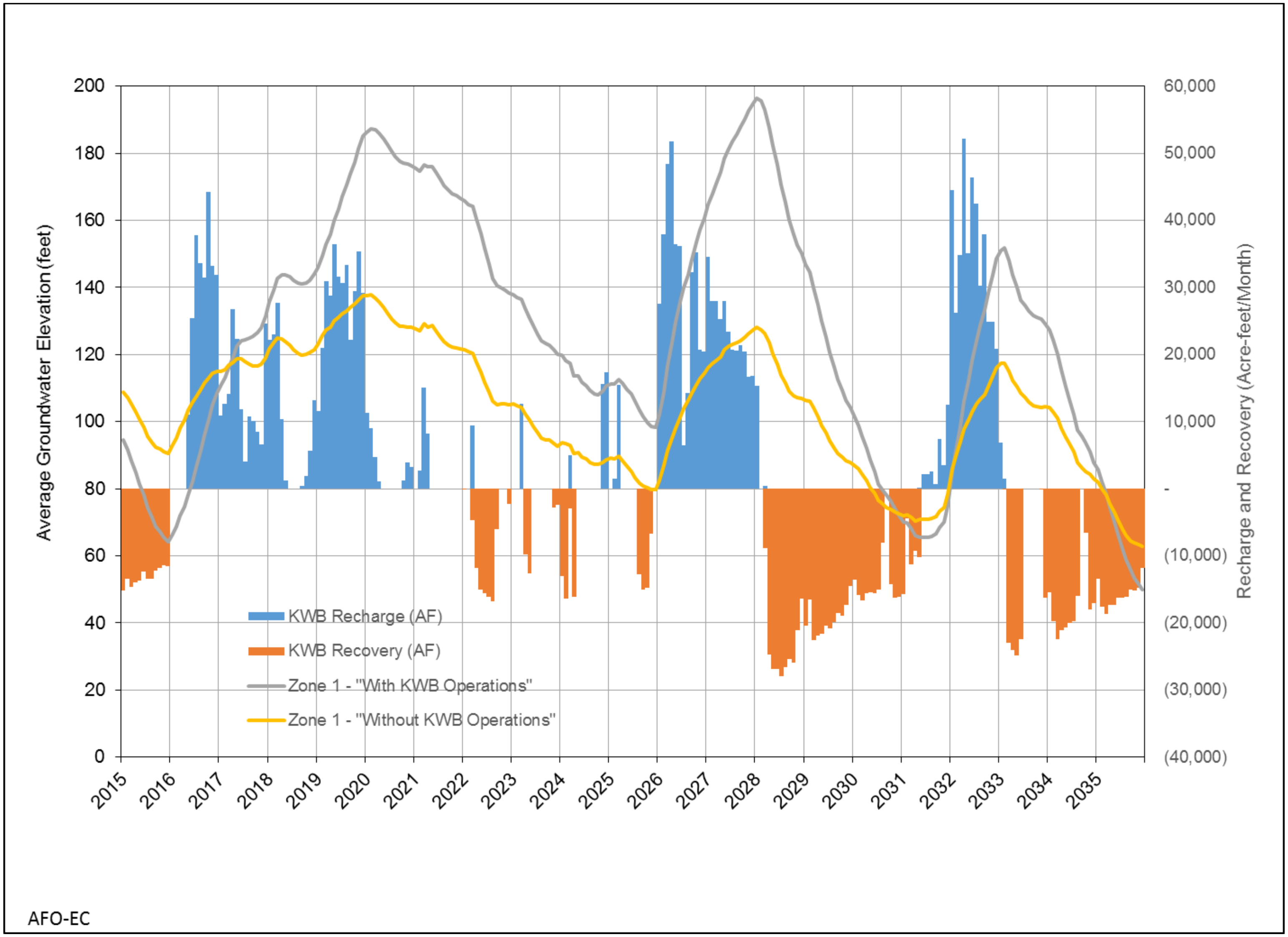


FIGURE 3.3-12a. Analysis of Future Operations under Existing Conditions: Average Groundwater Elevation Over Zone 1 (0 to 1 Mile Outside the Kern Water Bank Boundary), 2015-2035

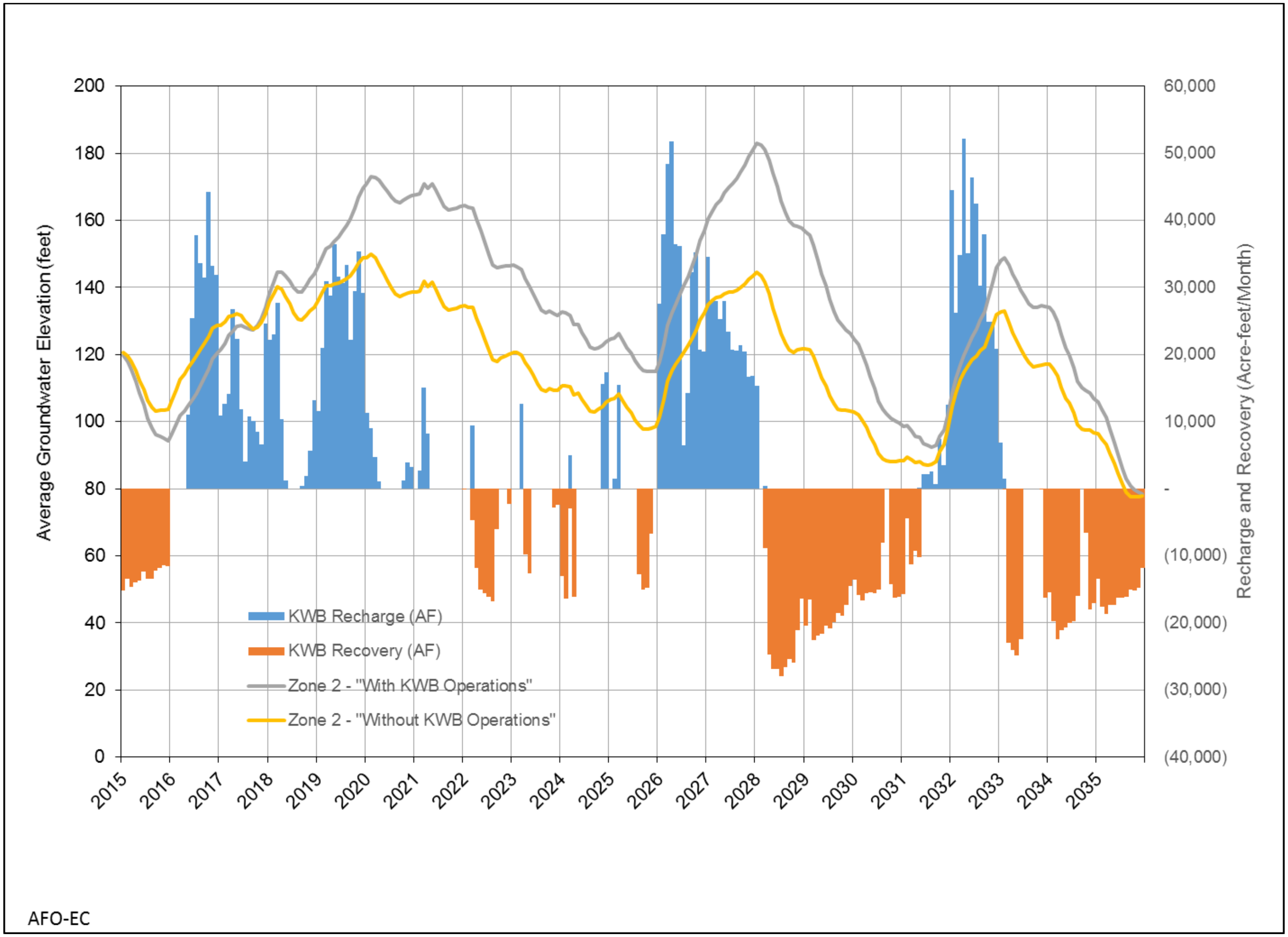


FIGURE 3.3-12b. **Analysis of Future Operations under Existing Conditions: Average Groundwater Elevation Over Zone 2 (1 to 2 Miles Outside the Kern Water Bank Boundary), 2015-2035**

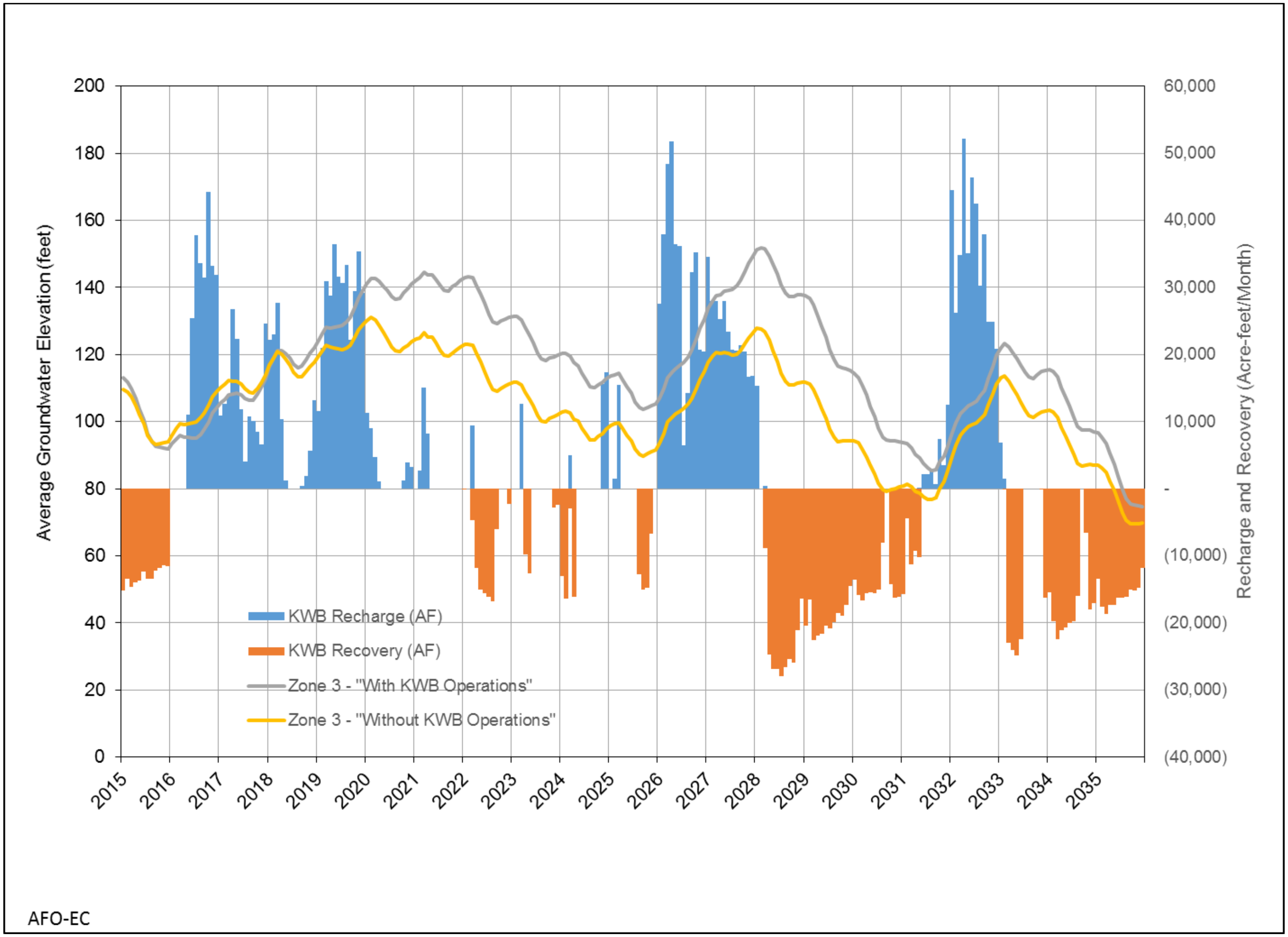


FIGURE 3.3-12c. Analysis of Future Operations under Existing Conditions: Average Groundwater Elevation Over Zone 3 (2 to 3 Miles Outside the Kern Water Bank Boundary), 2015-2035

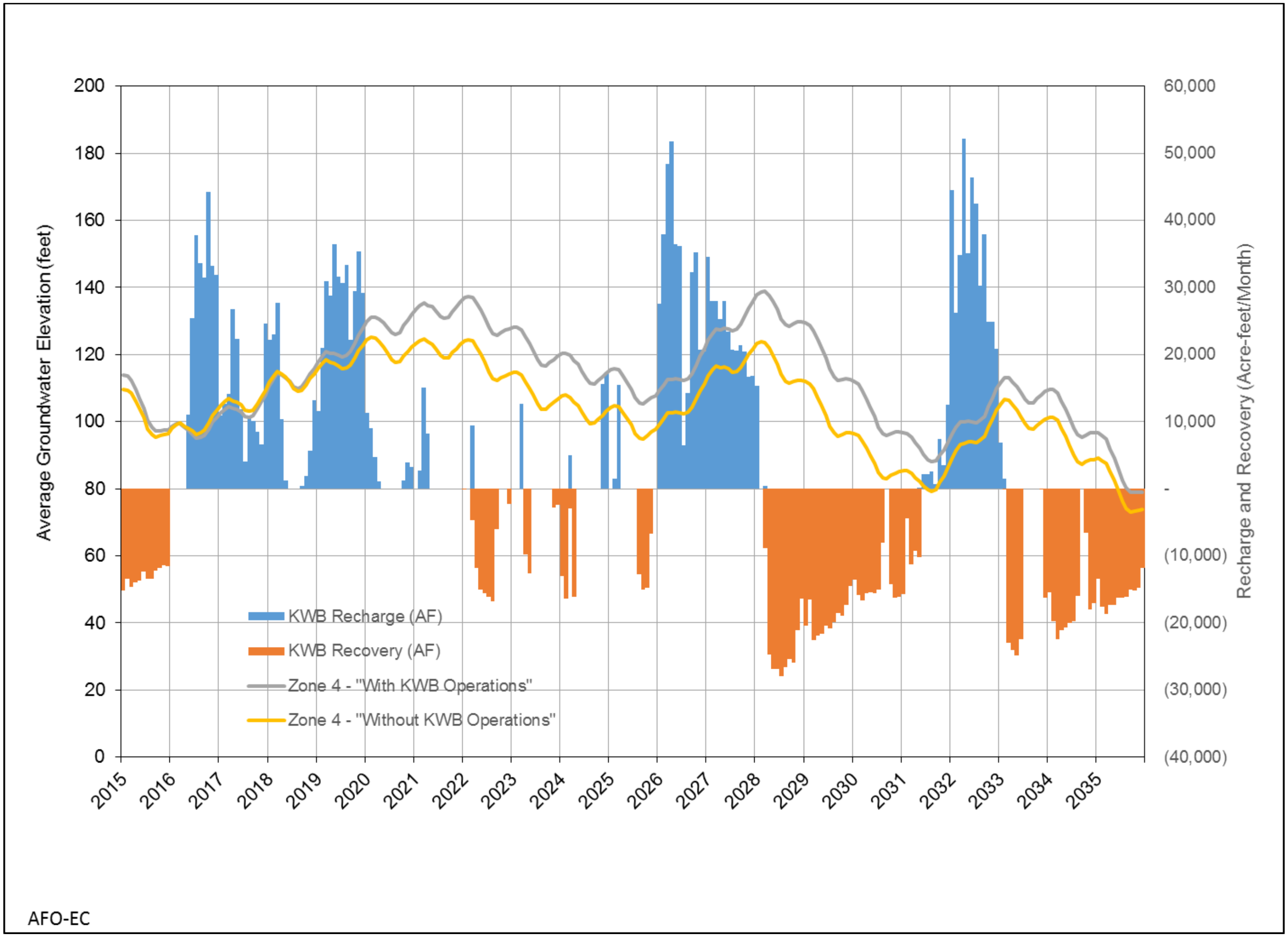


FIGURE 3.3-12d. Analysis of Future Operations under Existing Conditions: Average Groundwater Elevation Over Zone 4 (3 to 4 Miles Outside the Kern Water Bank Boundary), 2015-2035

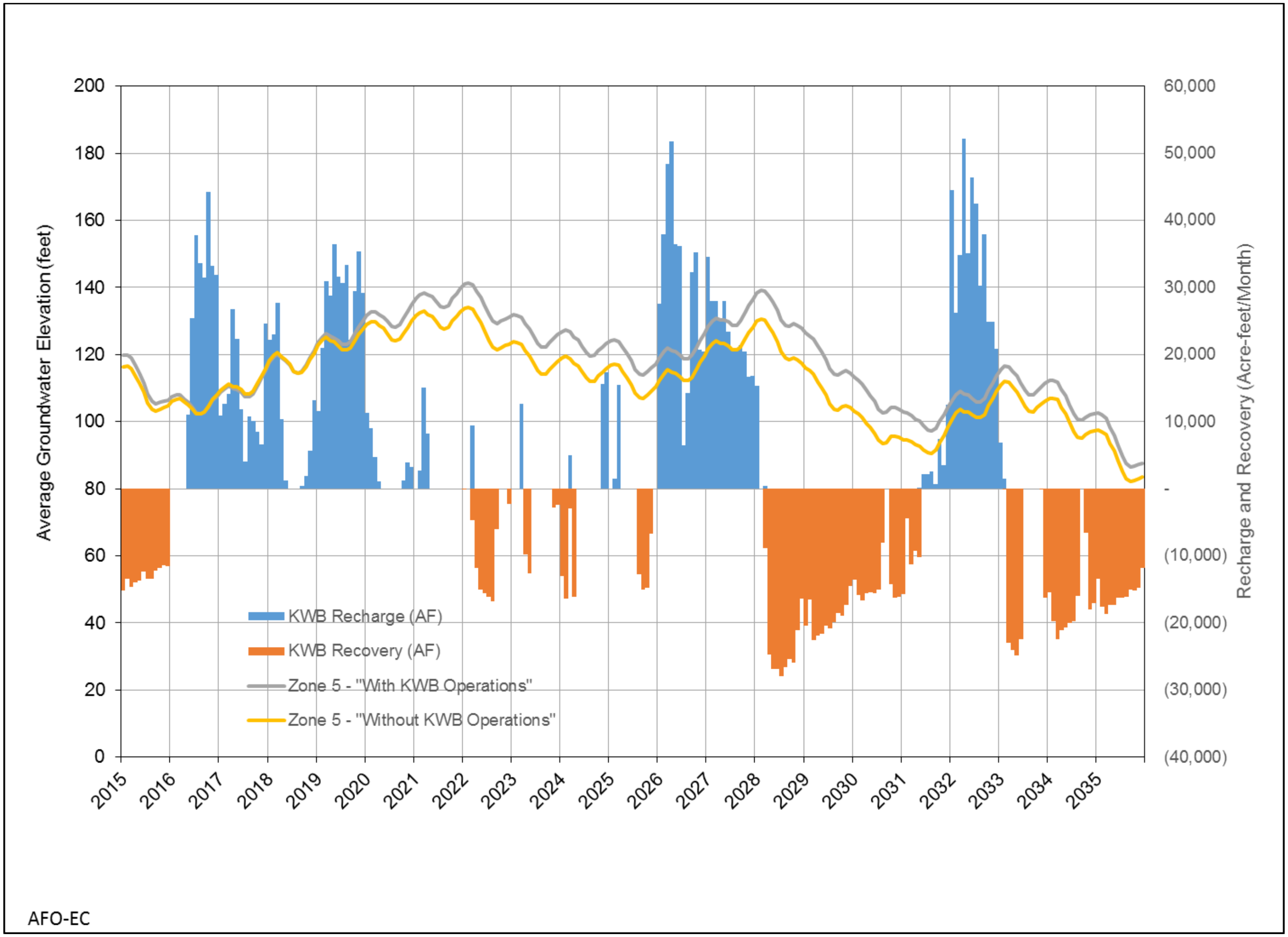


FIGURE 3.3-12e. **Analysis of Future Operations under Existing Conditions: Average Groundwater Elevation Over Zone 5 (4 to 5 Mile Outside the Kern Water Bank Boundary), 2015-2035**

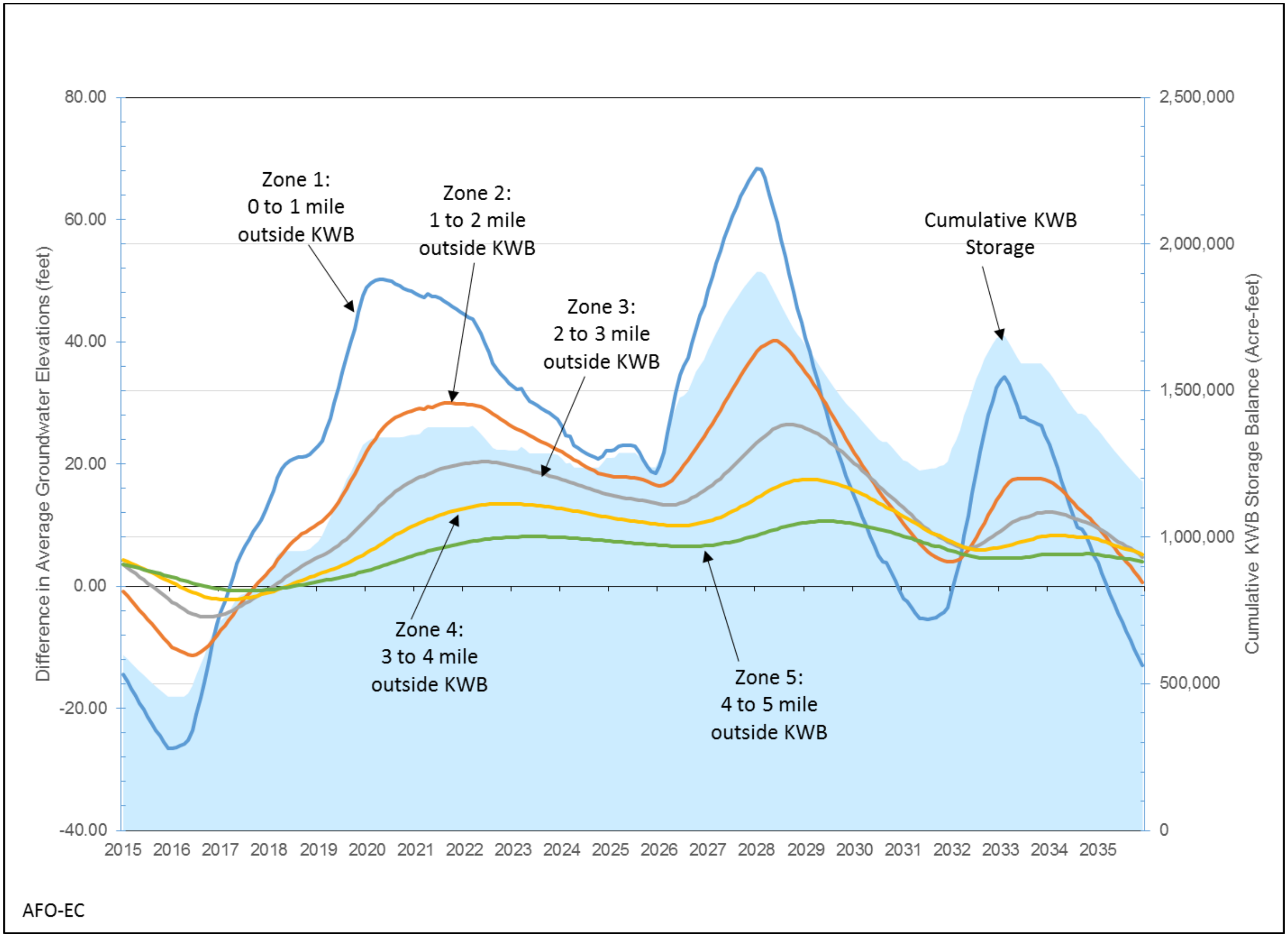


FIGURE 3.3-13. **Analysis of Future Operations under Existing Conditions: Groundwater Elevation Differences in Zones 1 to 5, 2015-2035**

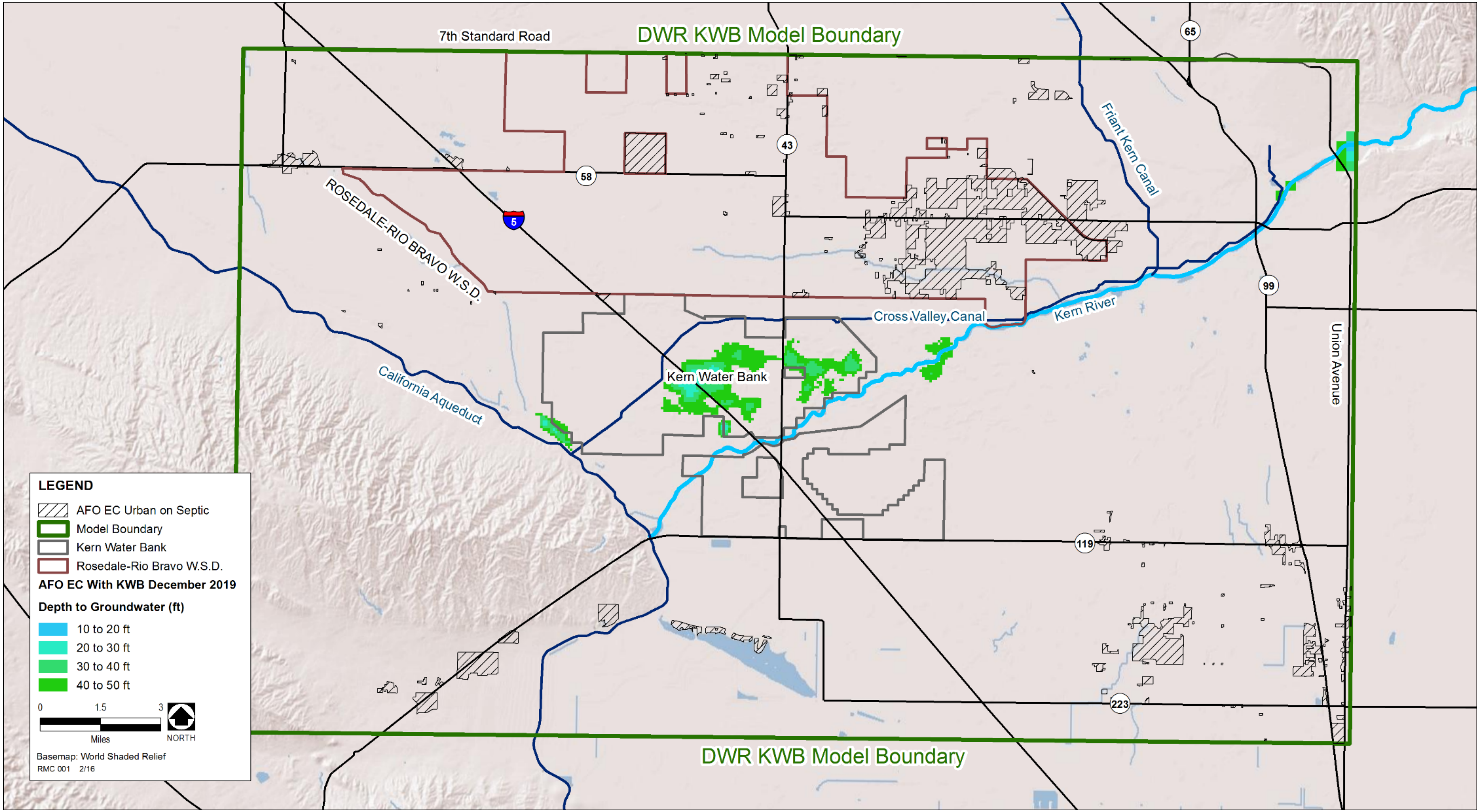


FIGURE 3.3-14. Analysis of Future Operations under Existing Conditions: Depth-to-Groundwater Contour Map, December 2019

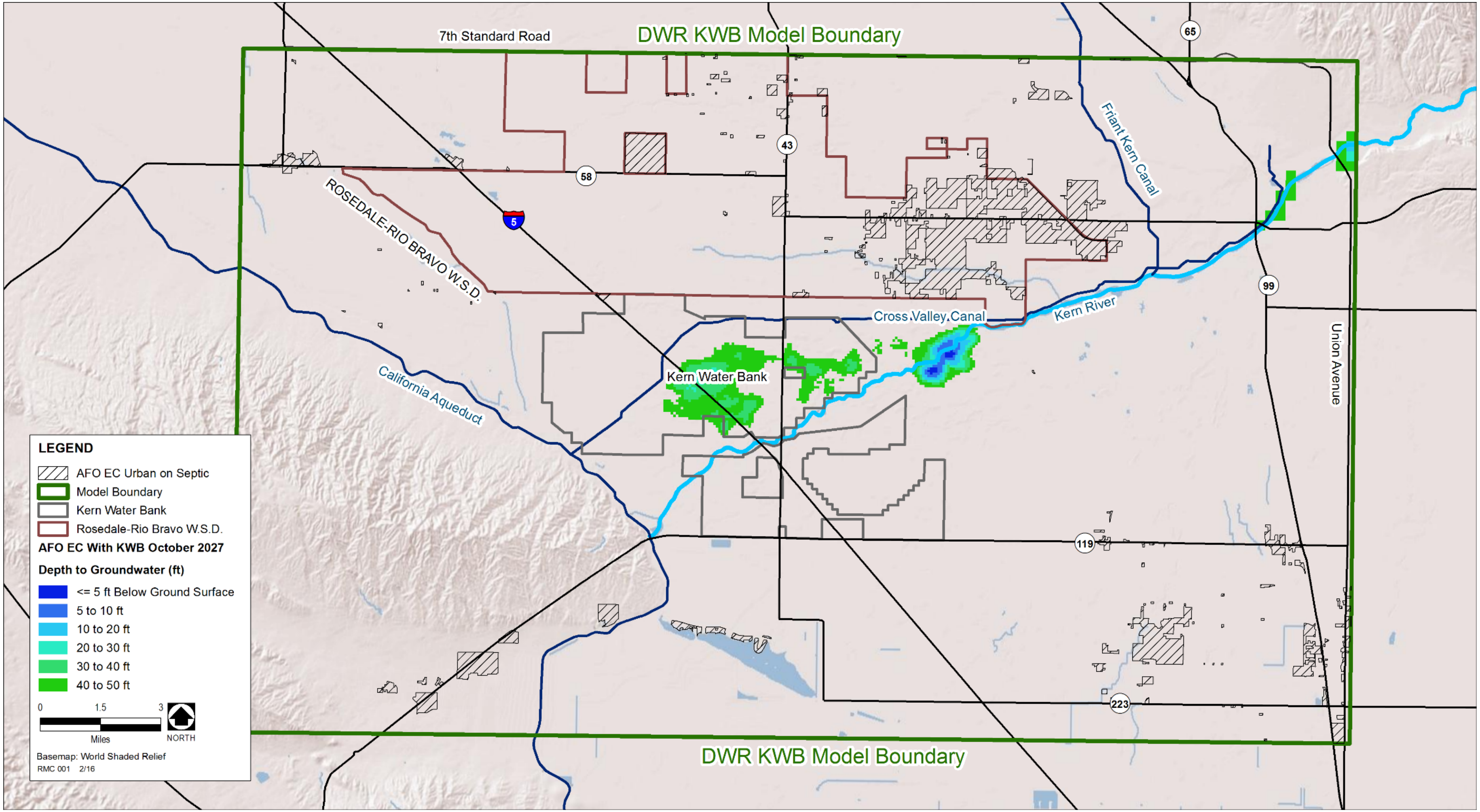


FIGURE 3.3-15. Analysis of Future Operations under Existing Conditions: Depth-to-Groundwater Contour Map, October 2027

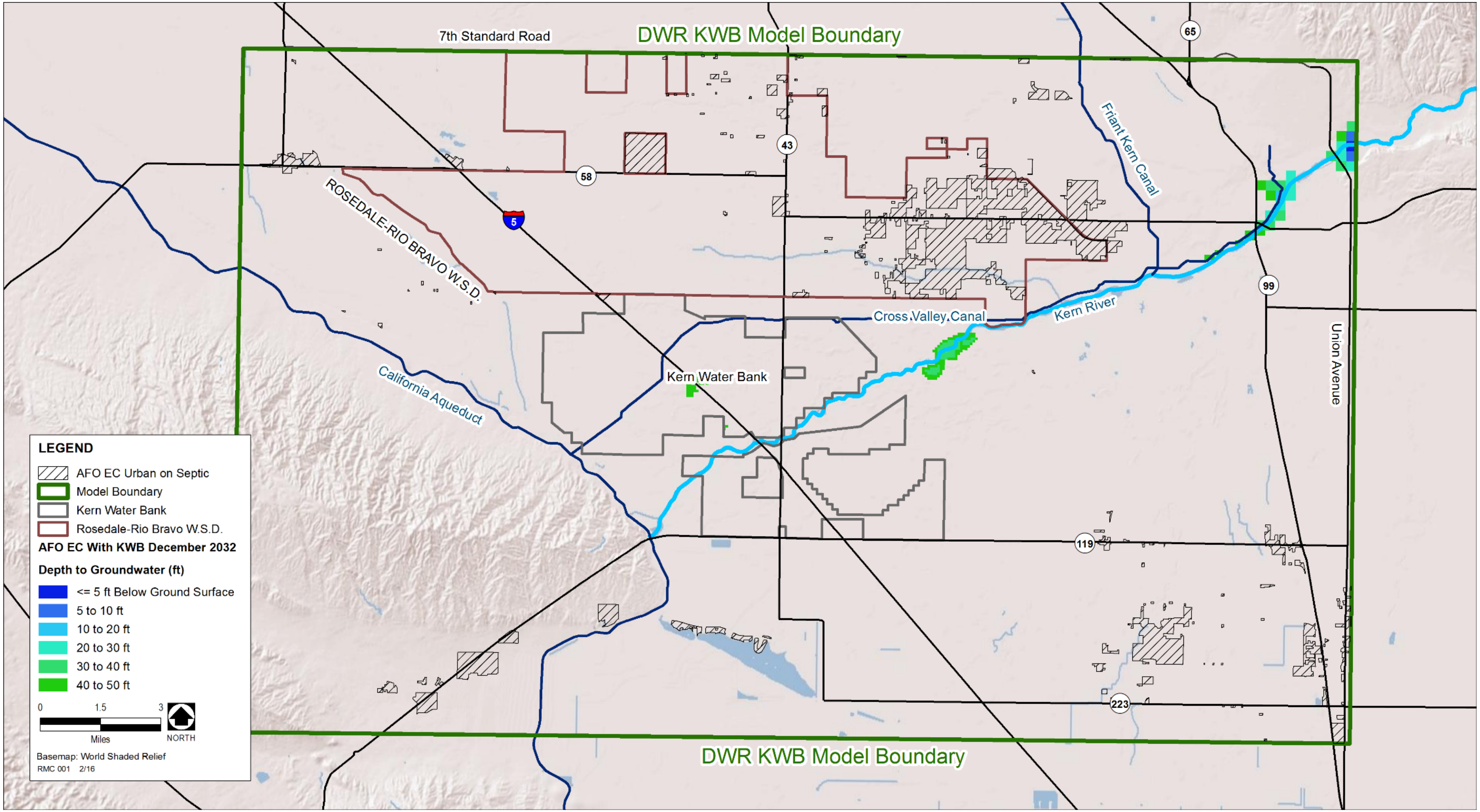
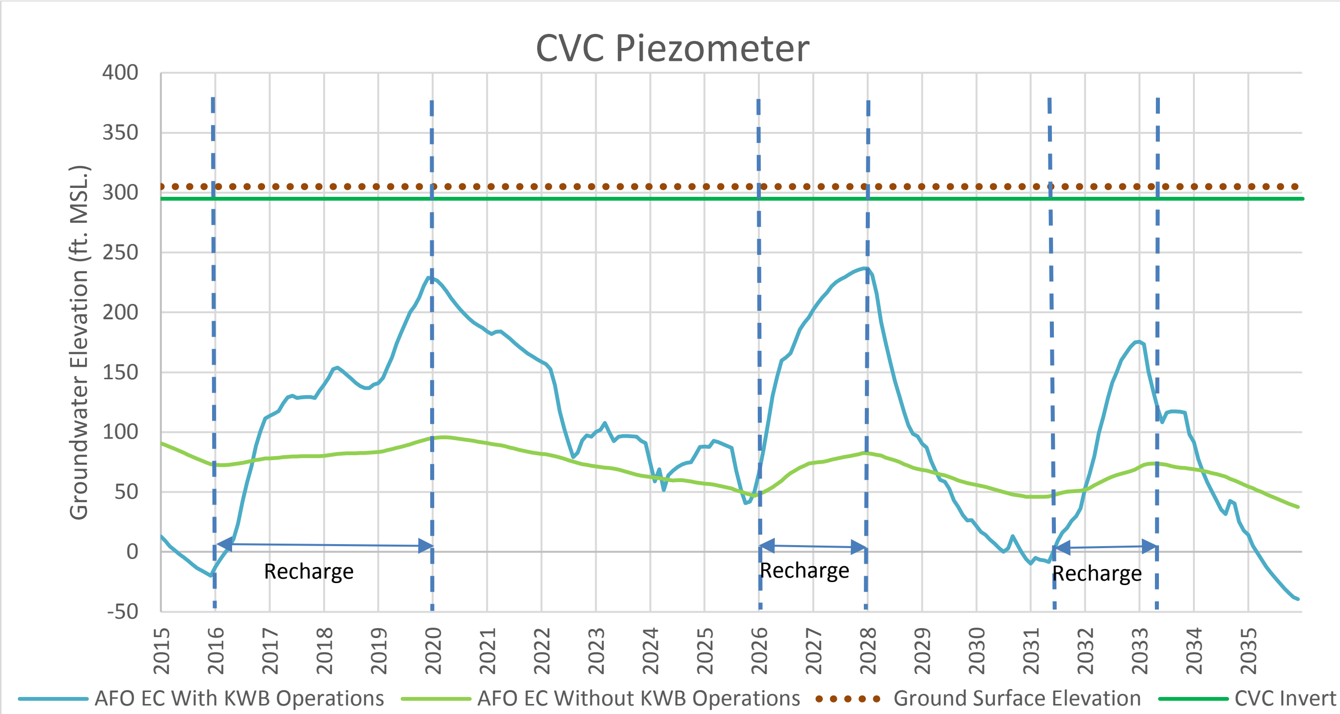


FIGURE 3.3-16. Analysis of Future Operations under Existing Conditions: Depth-to-Groundwater Contour Map, December 2032



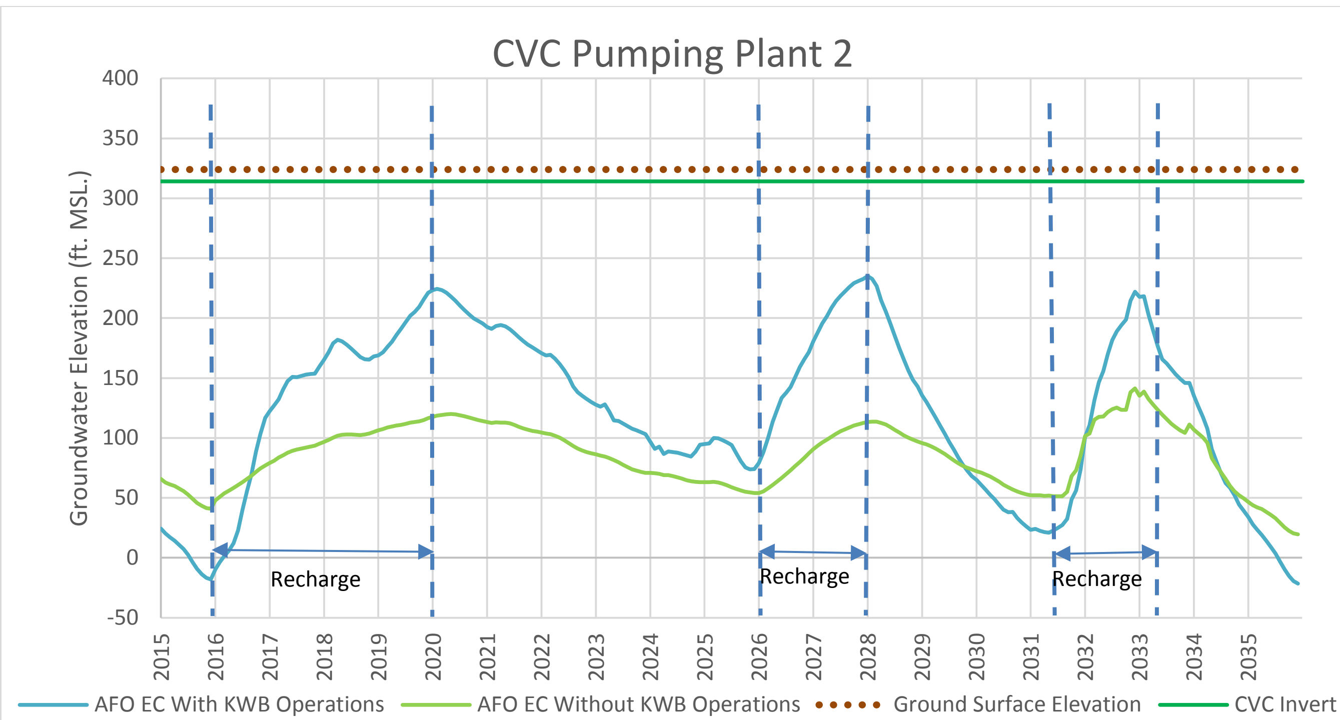
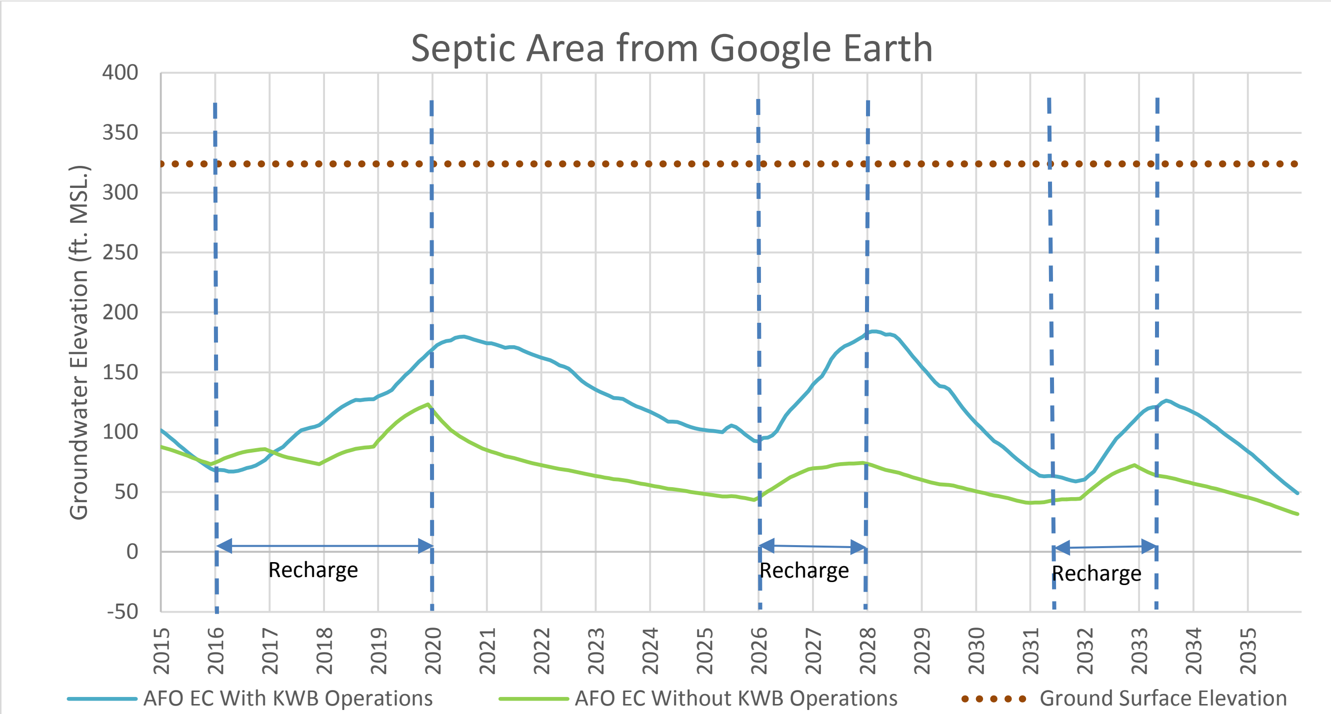


FIGURE 3.3-17. Groundwater Elevation Hydrographs at Selected Locations along the CVC for AFO-EC Scenario, 2015-2035



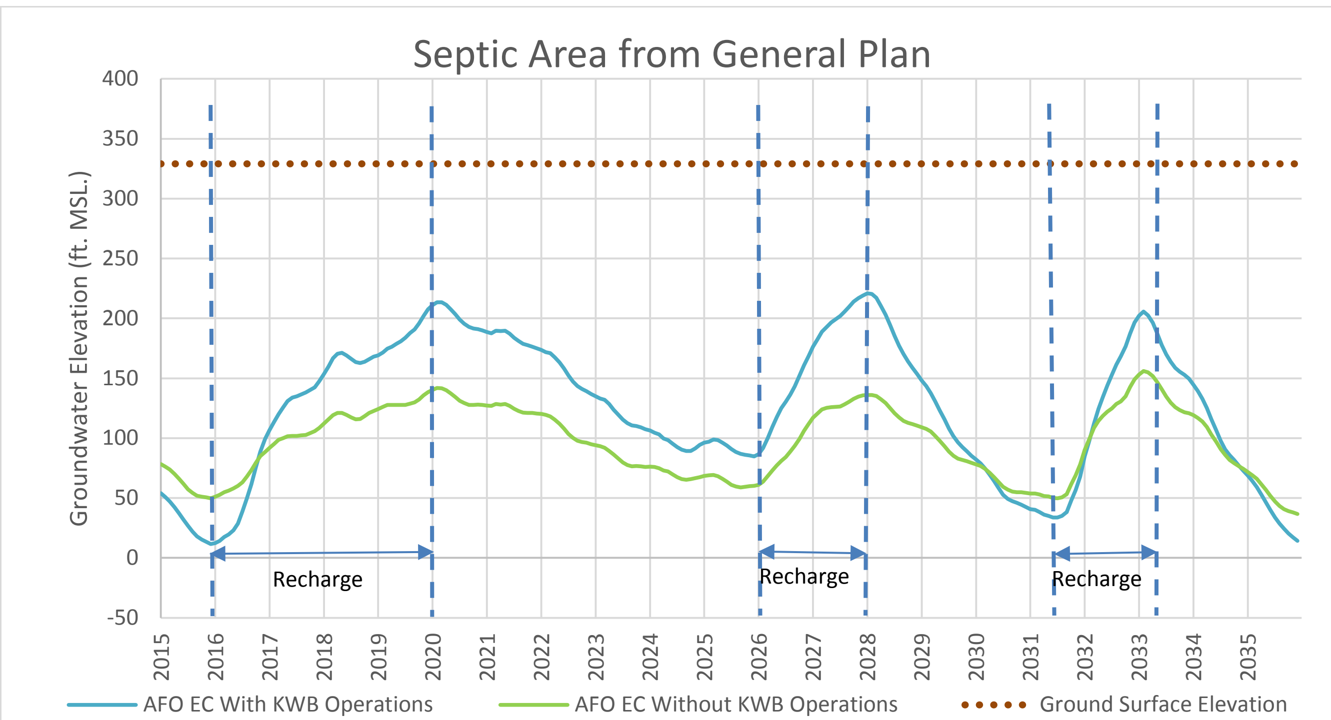


FIGURE 3.3-18. Groundwater Elevation Hydrographs at Selected Areas on Septic Systems for AFO-EC Scenario, 2015-2035

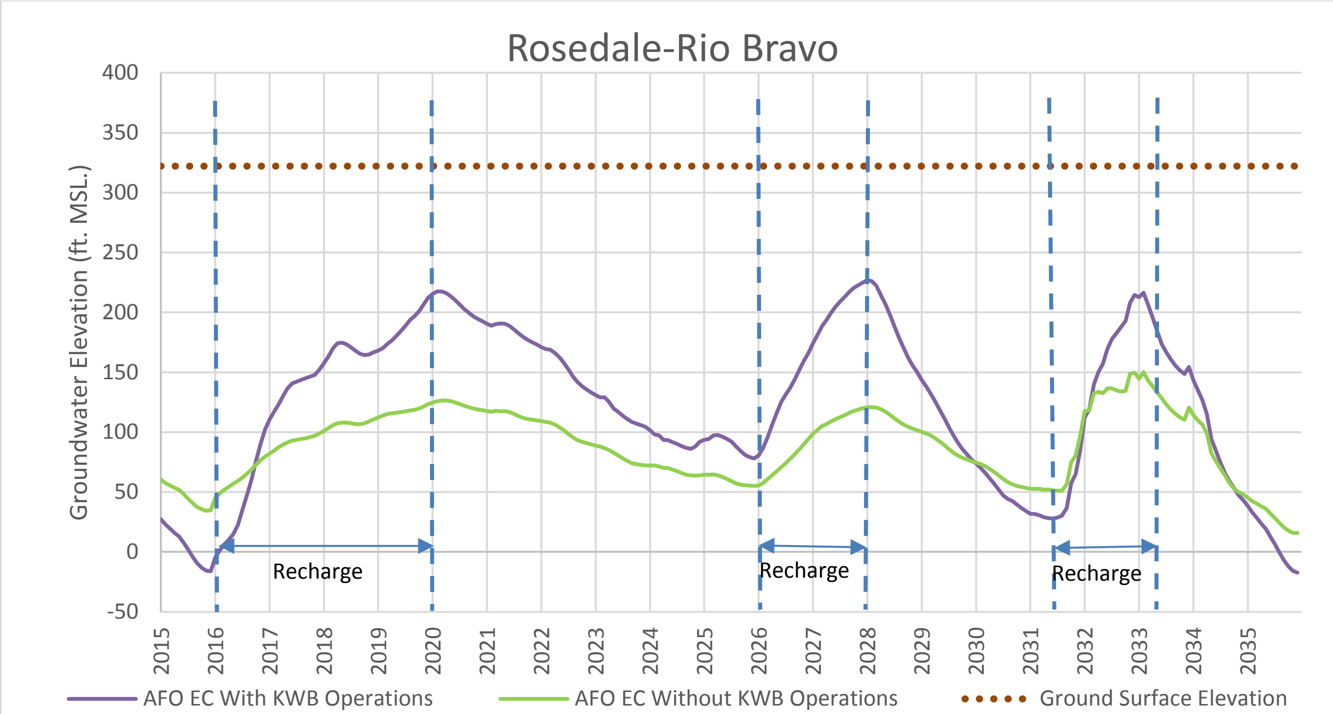


FIGURE 3.3-19a. Groundwater Elevation Hydrographs at Rosedale-Rio Bravo Recharge Pond for AFO-EC, 2015-2035

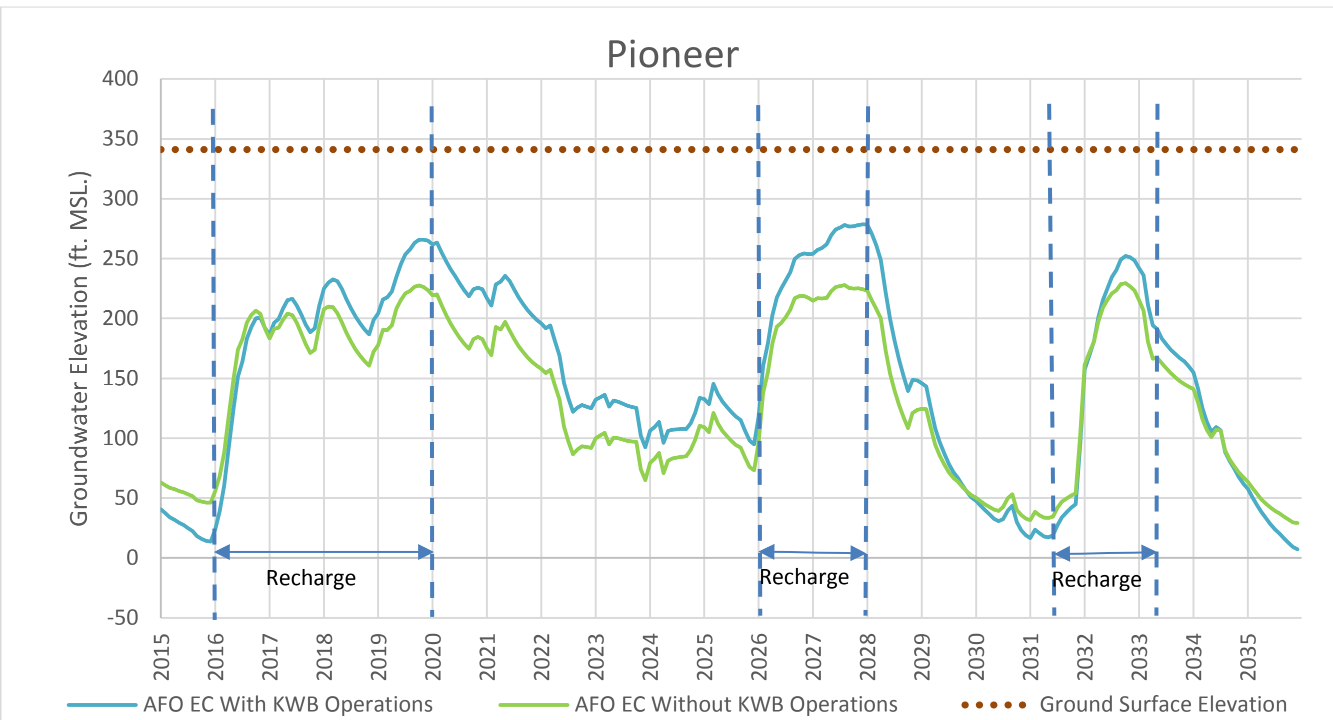


FIGURE 3.3-19b. Groundwater Elevation Hydrographs at Pioneer Recharge Pond for AFO-EC, 2015-2035

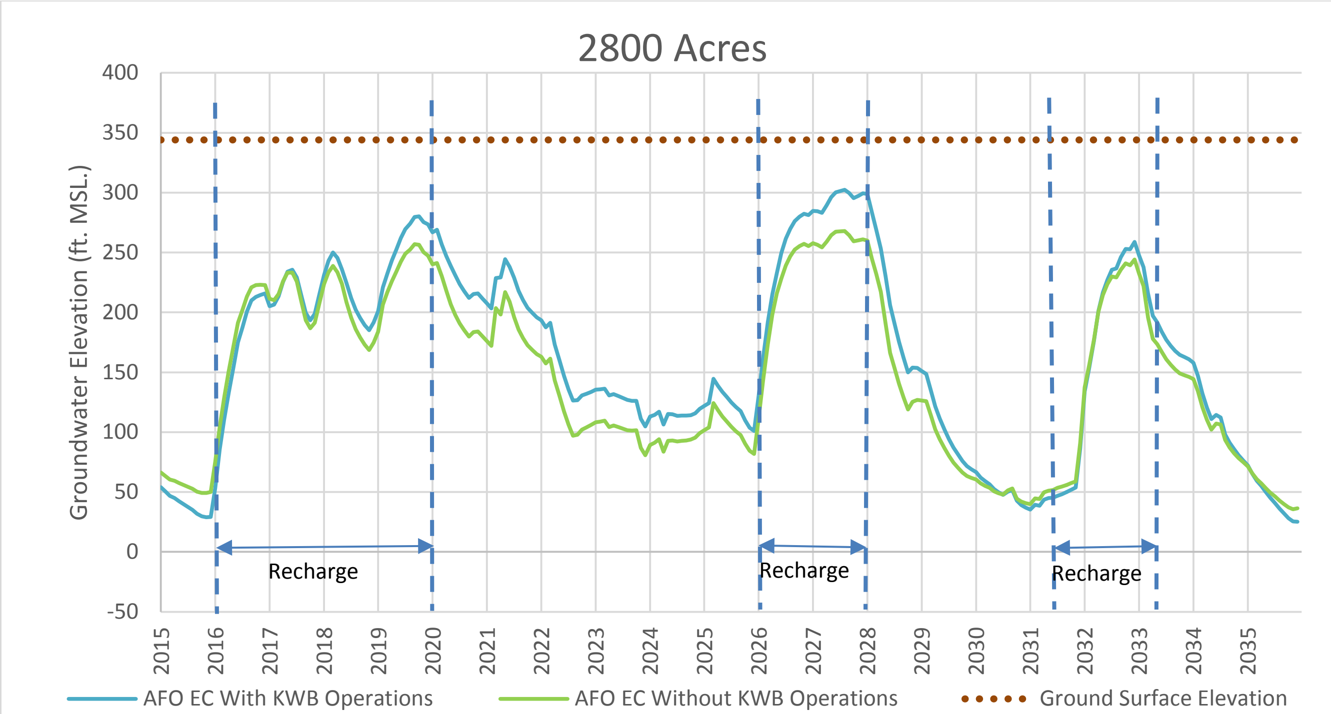


FIGURE 3.3-19c. Groundwater Elevation Hydrographs at 2800 Acres Recharge Pond for AFO-EC, 2015-2035

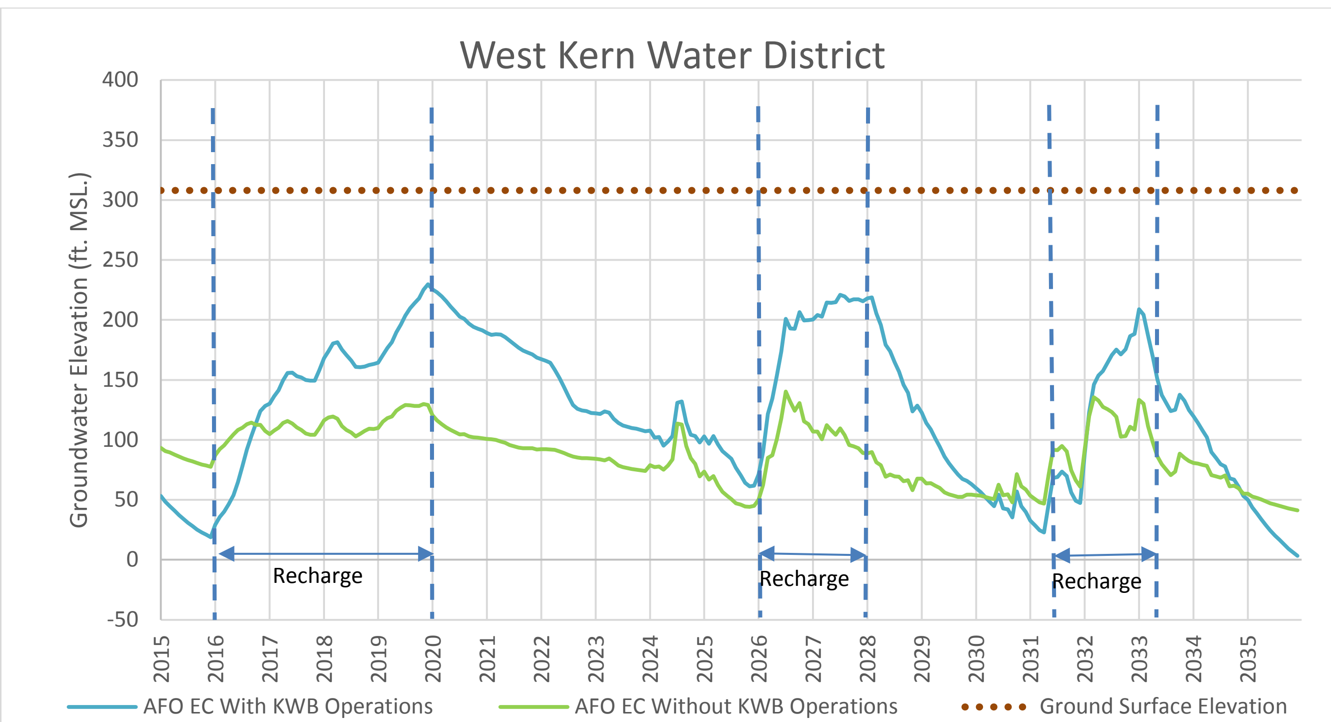


FIGURE 3.3-19d. Groundwater Elevation Hydrographs at West Kern Water District Recharge Pond for AFO-EC, 2015-2035

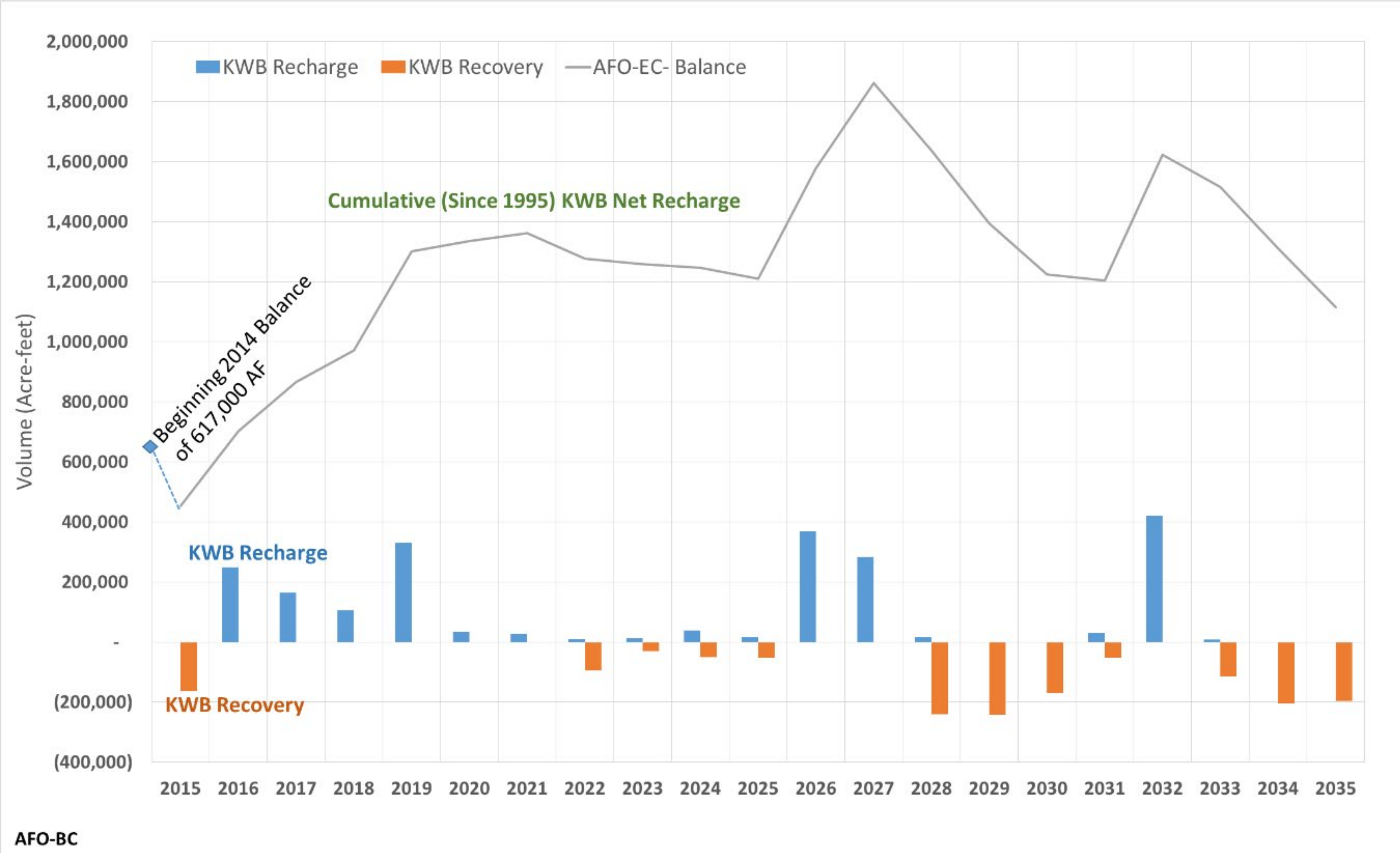


FIGURE 3.4-1. **Analysis of Future Operations under Buildout Conditions: Kern Water Bank Annual and Cumulative Recharge and Recovery, and Cumulative Stored Water, 2015-2035**

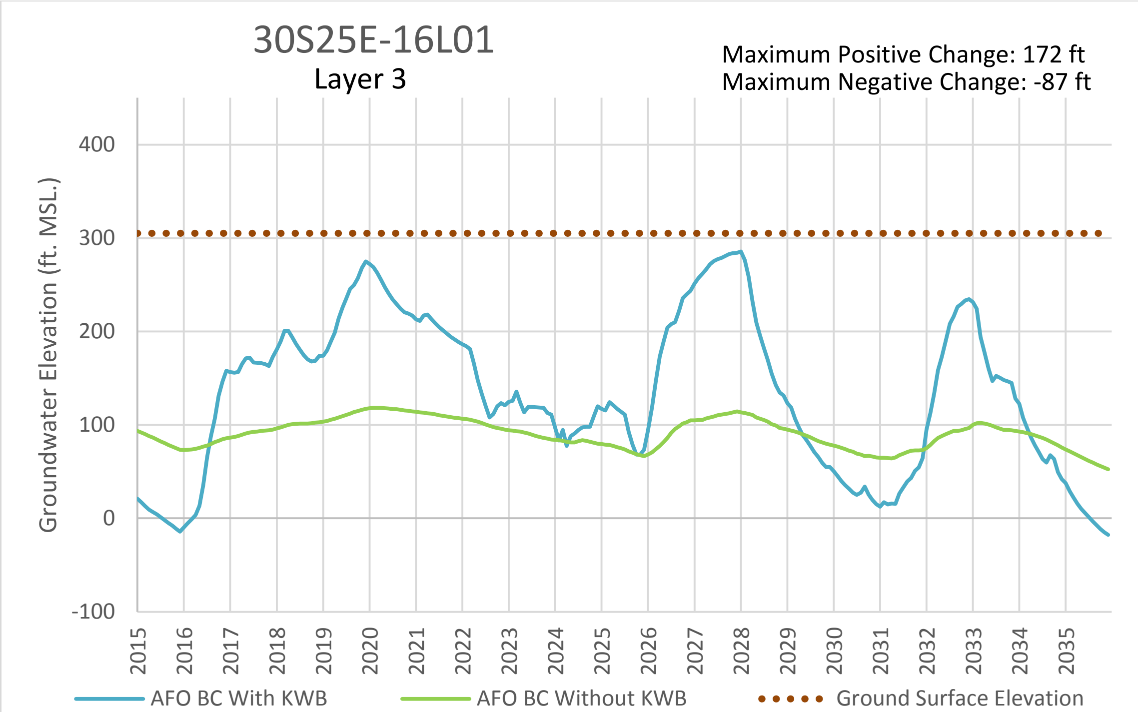


FIGURE 3.4-2a. Hydrographs of Analysis of Future Operations under Buildout Conditions: Simulated Water Levels at Monitoring Well 30S25E-16L, 2015-2035

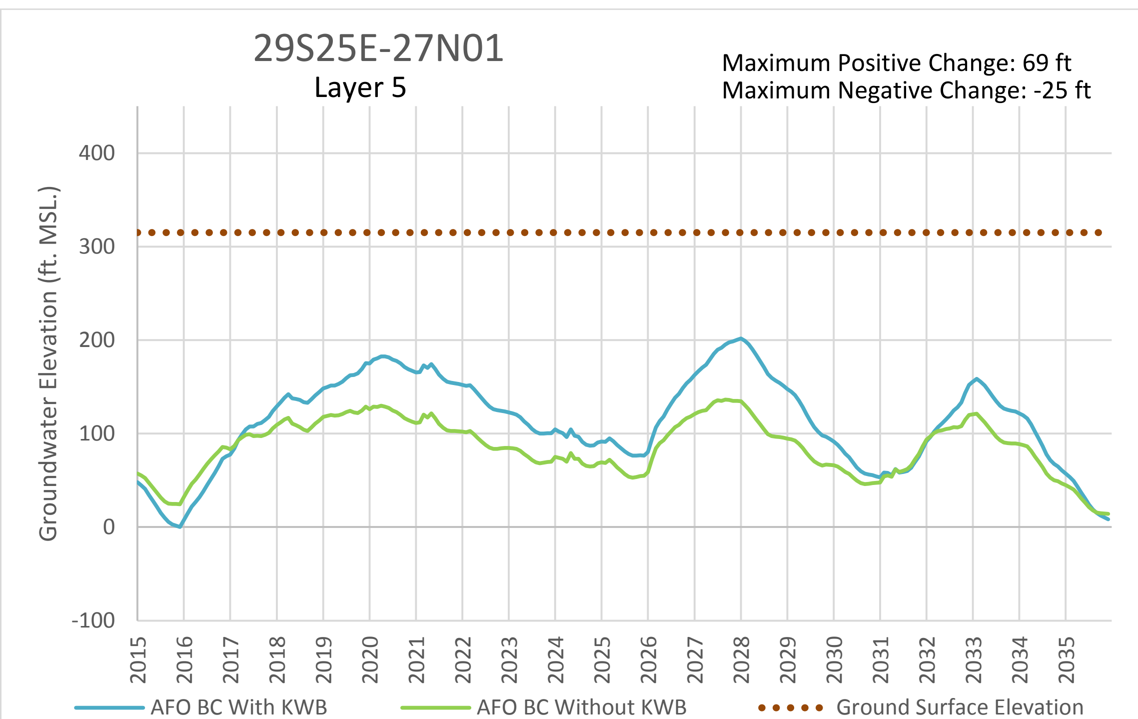


FIGURE 3.4-2b. Hydrographs of Analysis of Future Operations under Buildout Conditions: Simulated Water Levels at Monitoring Well 29S25E-27N, 2015-2035

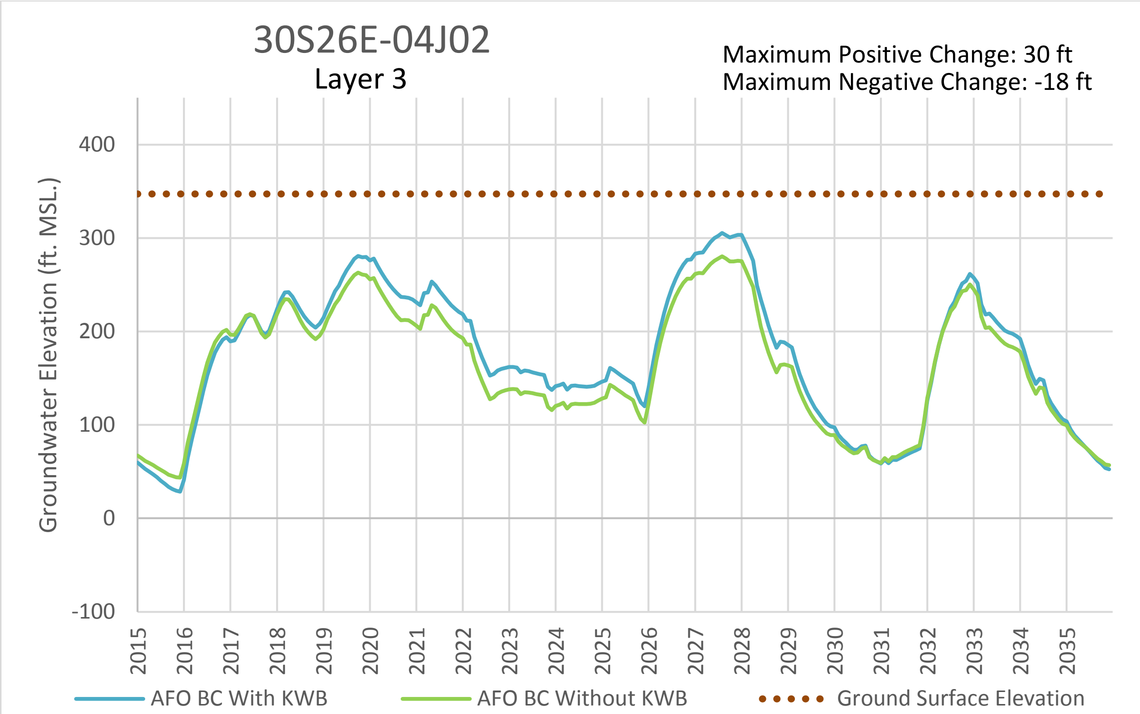


FIGURE 3.4-2c. Hydrographs of Analysis of Future Operations under Buildout Conditions: Simulated Water Levels at Monitoring Well 30S26E-04J, 2015-2035

3.3.7.1 2016-2019 Recharge Operations

The water level analysis shows that at the adjacent recharge facilities, groundwater levels were lower than 63 feet below the ground surface; thus, the groundwater mounding associated with the simultaneous operations of KWB and all other neighboring groundwater banks would not interfere with recharge operations of neighboring basins.

3.3.7.2 2026-2027 Recharge Operations

The water levels at the adjacent recharge facilities were generally lower than 2016-2019 conditions and lower than 41 feet below the ground surface; thus, the groundwater mounding associated with simultaneous operations of KWB and all other neighboring groundwater banks would not interfere with recharge operations of neighboring basins.

3.3.7.3 2032 Recharge Operations

The water levels for 2032 recharge operations were significantly lower than the previous two recharge operations in 2016-2019 and 2026-2027 and groundwater levels were lower than 85 feet below the ground surface; thus, the groundwater mounding associated with simultaneous operations of KWB and all other neighboring groundwater banks are not expected to interfere with recharge operations of neighboring basins.

3.3.8 ANALYSIS OF FUTURE OPERATIONS UNDER EXISTING CONDITIONS RESULTS SUMMARY

A summary of the evaluation of impacts on the groundwater table from KWB future operations under the AFO-EC scenario is provided in Table 3.3-7. Consecutive years of recovery attributable to future KWB operations under the existing level of development may cause groundwater levels to fall such that existing wells in the area immediately outside the KWB boundary are impacted. Unlike, APO conditions, recharge operations under AFO-EC conditions did not cause groundwater levels to rise enough to impact the CVC and residential area septic systems.

TABLE 3.3-7

SUMMARY OF ANALYSIS OF FUTURE OPERATIONS UNDER EXISTING CONDITIONS: MODEL SCENARIO RESULTS AFFECTING THE LOCAL GROUNDWATER TABLE, 2015-2035

Evaluation Metric	Conclusion
Water Budgets (Section 3.3.1)	The KWB has a balance of +566,000 AF of stored water at the end of 2035. With the addition of APO balance of +617,000 AF, KWB has a cumulative balance of +1,183,000 AF in aquifer volume of stored water at the end of 2035 under the AFO-EC scenario.
Groundwater Elevation Differences (Hydrographs & Contour Maps) (Section 3.3.2)	The positive groundwater elevation differences extend to almost all of the model domain. The negative groundwater elevation differences are limited to KWB Lands and the surrounding area.
Temporal Variation Area of Negative and Positive Elevation Differences (Section 3.3.3)	Outside the KWB boundary, negative elevation differences occur in the first year of simulation because of the prior 3 years of recovery; thereafter, negative elevation differences occur after about 2 years of recovery following a recharge cycle.
Spatial Extent of Negative and Positive Elevation Differences (Section 3.3.3)	Outside the KWB boundary, negative elevation differences exceeding -30 feet are contained within 1.5 mile of the KWB boundary. Outside the KWB boundary, negative elevation differences exceeding -30 feet affect less than 5,000 acres of agricultural land in the immediate vicinity of KWB Lands, which represents less than four percent of the total agricultural area within the model domain. Outside the KWB boundary, positive elevation differences exceeding +60 feet (indicative of a high water table) are contained within 2.5 miles of the KWB boundary.
Frequency Distribution of Negative and Positive Elevation Difference (Section 3.3.4)	Negative elevation differences exceeding -30 feet remain within the KWB boundary 90% of the time. Positive elevation differences exceeding +60 feet remain within the KWB boundary 75% of the time.
Average Elevation and Elevation Difference in Selected Zones (Section 3.3.5)	The average groundwater elevation of "With KWB Operations" in Zones 1–3 is lower than that of "Without KWB Operations" in 2015 and 2016, because of 4 consecutive years of recovery from 2012 through 2015.
High Groundwater Levels and Existing Infrastructure (Section 3.3.6)	Groundwater levels will not rise enough to impact the CVC and residential septic systems.
High Groundwater Level and Neighboring Recharge Facilities (Section 3.3.7)	KWB operations, concomitant with the operations of other neighboring groundwater banks, may not potentially interfere with the recharge operations at neighboring groundwater banks.

Notes: AF = acre-feet; AFO-EC = Analysis of Future Operations under Existing Conditions; APO = Analysis of Past Operations; KWB = Kern Water Bank

3.4 RESULTS OF ANALYSIS OF FUTURE OPERATIONS UNDER BUILDOUT CONDITIONS SCENARIOS

The results of the AFO-BC "With KWB Operations" and "Without KWB Operations" scenarios are presented in the following subsections.

3.4.1 WATER BUDGET AND RECHARGE AND RECOVERY AT THE KERN WATER BANK

The AFO-BC "With KWB Operations" model was used to develop an annual water budget for the entire model domain for the 2015–2035 KWB future operations period. Table 3.4-1 shows key components of the water budget, including the change in groundwater storage.

Boundary inflow and outflow components are the largest components of the water budget. Boundary inflow, with an annual average of approximately 377,000 AFY, is approximately 7,910,000 AF for the 2015–2035 AFO-BC future operation period. Boundary outflow, with an annual average of approximately 300,000 AFY, is approximately 6,297,000 AF for the same period.

Agricultural and urban water demand during the 2015–2035 period is partially met by a total of 7,383,000 AF of agricultural pumping and 1,736,000 AF of urban pumping. Approximately 1,680,000 AF of applied water is projected to return to the aquifer as deep percolation.

During the 21-year (2015–2035) simulation period for the AFO-BC scenario, the KWB is projected to recharge 2,112,000 AF of water while recharge by other banking projects in the model domain is projected to be 4,158,000 AF. AFO-BC recharge at the KWB and other banking facilities are higher than historical (1995–2014) recharge because increased pond areas under buildout conditions allow the water banks to recharge additional water (e.g., floodwater) that was available under hydrologic conditions similar to the 1995–2014 period. The KWB is projected to recover 1,614,000 AF during the AFO-BC simulation period while recovery at other projects is projected to be 2,029,000 AF. The total volume of water recovered from the KWB and other water banking projects is higher than the historical amount because of an additional year of pumping in 2015 and increased recovery wells under buildout conditions. This generates a balance of 498,000 AF of stored water for the KWB and 2,129,000 AF of stored water for other banking projects. The KWB annual recharge, recovery, and cumulative balance of stored water amounts are shown in Figure 3.4-1.

Note that there was an accumulated balance of 617,000 AF of stored water at the end of the 1995–2014 historical KWB operations period. When this prior balance is added to the additional 2015–2035 stored water, there is a cumulative balance of 1,115,000 AF of stored water in the aquifer at the end of 2035 under the AFO-BC scenario.

3.4.2 GROUNDWATER ELEVATION DIFFERENCE FOR WITH AND WITHOUT KERN WATER BANK OPERATIONS

As with the APO (see Section 3.2.2), groundwater elevation differences for the AFO-BC "With KWB Operations" and "Without KWB Operations" scenarios were evaluated by comparing simulated groundwater elevation hydrographs at several monitoring wells (Method No. 3 in Section 3.1) and developing groundwater elevation difference contour maps at the end of several representative recharge and recovery cycles (Method No. 2 in Section 3.1).

3.4.2.1 Hydrographs

Hydrographs of simulated groundwater levels for the "With KWB Operations" and "Without KWB Operations" scenarios were developed at 31 wells (14 wells inside the KWB boundary and 17 wells outside the KWB boundary; Appendix 7-2F). The locations and hydrographs for three of these wells are shown in Figures 3.2-2 and 3.4-2a to 3.4-2c.

3.4.2.2 Contour Maps

The distribution of groundwater elevation differences between the "With KWB Operations" and "Without KWB Operations" scenarios after major KWB recharge and recovery cycles is shown in Figures 3.4-3 and 3.4-4. Figures 3.4-3a to 3.4-3c show groundwater elevation differences after the 1995–2000, 2005–2006, and 2011 recharge cycles, respectively. Figures 3.4-4a to 3.4-4c show groundwater elevation differences after the 2001–2004, 2007–2009, and 2012–2014 recovery cycles, respectively.

3.4.3 AFFECTED AREAS OUTSIDE THE KERN WATER BANK LANDS

The impacts of KWB operations on groundwater elevations outside KWB Lands for the AFO-BC "With KWB Operations" and "Without KWB Operations" scenarios are evaluated using time series charts showing areas affected by head differences of ±5 feet (Method No. 4 in Section 3.1), maps of the spatial extent of negatively and positively impacted areas (Method No. 5 in Section 3.1), and tables summarizing the acreage of impacted areas.

3.4.3.1 Time Series of Affected Area

At every time step of the simulation, the total area of the model with groundwater elevation difference greater than 5 feet and groundwater elevation difference less than -5 feet was calculated. Time series of these areas are shown in Figure 3.4-5. A detailed chart showing areas impacted by less than -5, -10, -20, -30, -45, and -60 feet is shown in Figure 3.4-6. Figure 3.4-7 shows areas impacted by groundwater levels greater than 5, 10, 20, 30, and 45 feet.

Negative elevation differences exceeding -5 feet continue to spread over a large area (52,000 acres in 2015) because of continued recovery in 2015 (the first year of the AFO-BC scenario), which was preceded by 3 consecutive years of recovery from 2012 to 2014 (the last 3 years of the APO scenario). Three consecutive years of recharge from 2016 through 2018 reduce the area with negative elevation differences exceeding -5 feet to zero. Areas with negative elevation differences reappear after periods of about 2 years of recovery (e.g., 2028–2029 and 2033–2034).

Figure 3.4-6 indicates that any negative differences exceeding -30 feet in areas outside KWB Lands are limited to years of groundwater recovery, affecting a maximum area of about 10,000 acres near KWB Lands in 2015 after 4 consecutive years of recovery (2012–2015).

3.4.3.2 Spatial Extent of Affected Area

Figure 3.4-8 shows the maximum spatial extent of negative elevation differences exceeding -60 feet, -45 feet, -30 feet, -20 feet, -10 feet, and -5 feet. This figure shows that negative elevation differences under the AFO-EC scenario spread about 4.5 miles outside the KWB boundary. Inside the Rosedale boundary, negative elevation differences exceeding -45 feet do not occur, but negative elevation differences between -5 feet and -45 feet do occur. The total area affected by negative elevation differences between -5 feet and -45 feet inside the Rosedale boundary is 16,562 acres of agricultural land.

TABLE 3.4-1

WATER BUDGET FOR ANALYSIS OF FUTURE OPERATIONS UNDER BUILDOUT CONDITIONS WITH KERN WATER BANK OPERATIONS, 2015-2035

Year	INFLOW Into Model						OUTFLOW from Model						Calculated Change in Storage
	Deep Percolation of Applied Water	KWB Recharge	Other Banking Projects Recharge	River and Canal Seepage	Boundary Inflow through DWR KWB Model Domain	Total Inflow	Agricultural Pumping	Urban Pumping	KWB Pumping	Other Banking Projects Pumping	Boundary Outflow through DWR KWB Model Domain	Total Outflow (Positive)	
	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY
2015	86,120	-	-	-	402,593	488,713	(381,757)	(82,673)	(163,306)	(280,776)	(258,335)	1,166,847	(678,134)
2016	70,062	248,404	561,186	179,029	390,276	1,448,957	(334,399)	(82,673)	-	(26,080)	(248,419)	691,571	757,386
2017	73,850	163,443	337,595	166,869	418,692	1,160,449	(328,524)	(82,673)	-	(25,761)	(231,863)	668,822	491,627
2018	72,679	105,526	282,490	164,725	455,582	1,081,002	(327,678)	(82,673)	-	(24,802)	(230,428)	665,581	415,421
2019	72,527	330,686	454,237	153,668	418,217	1,429,336	(334,699)	(82,673)	-	(24,027)	(245,012)	686,410	742,926
2020	82,645	34,548	90,420	146,220	422,018	775,850	(351,336)	(82,673)	-	(26,952)	(277,657)	738,618	37,232
2021	81,368	25,924	101,942	117,264	416,150	742,648	(358,232)	(82,673)	-	(31,548)	(270,994)	743,448	(800)
2022	84,840	9,428	15,239	83,336	305,560	498,403	(366,037)	(82,673)	(94,890)	(128,111)	(336,400)	1,008,112	(509,708)
2023	85,056	12,633	12,130	106,200	346,184	562,203	(366,596)	(82,673)	(30,381)	(64,024)	(311,367)	855,041	(292,837)
2024	83,799	37,952	62,887	140,967	383,405	709,011	(360,238)	(82,673)	(50,927)	(44,465)	(313,120)	851,423	(142,412)
2025	84,702	16,981	38,481	92,596	371,511	604,272	(366,720)	(82,673)	(52,071)	(71,338)	(321,803)	894,605	(290,333)
2026	70,938	367,533	678,089	187,847	396,810	1,701,217	(322,587)	(82,673)	-	(41,093)	(296,993)	743,346	957,871
2027	75,282	283,698	423,325	172,651	389,992	1,344,948	(328,761)	(82,673)	-	(38,687)	(289,054)	739,175	605,773
2028	85,653	15,724	33,840	57,508	321,008	513,734	(376,441)	(82,673)	(240,435)	(187,231)	(347,562)	1,234,343	(720,610)
2029	85,877	-	10,626	63,540	303,852	463,895	(357,337)	(82,673)	(243,528)	(223,716)	(390,279)	1,297,533	(833,637)
2030	85,306	-	14,575	63,858	328,436	492,176	(363,303)	(82,673)	(169,108)	(178,173)	(345,999)	1,139,256	(647,080)
2031	75,959	31,143	224,623	198,235	365,668	895,627	(329,505)	(82,673)	(53,022)	(68,150)	(313,341)	846,691	48,936
2032	69,119	420,319	742,715	262,648	427,089	1,921,890	(308,662)	(82,673)	-	(34,803)	(276,725)	702,863	1,219,026
2033	82,850	8,383	73,773	77,153	362,353	604,513	(358,544)	(82,673)	(115,228)	(62,853)	(316,757)	936,056	(331,543)
2034	86,120	-	-	54,142	323,419		(380,368)	(82,673)	(204,723)	(195,330)	(357,296)	1,220,389	(756,709)
2035	86,120	-	-	51,390	360,766	498,276	(381,757)	(82,673)	(196,616)	(251,427)	(317,946)	1,230,420	(732,144)
Total 2015–2035	1,680,874	2,112,325	4,158,176	2,539,847	7,909,579	17,937,120	(7,383,481)	(1,736,139)	(1,614,236)	(2,029,347)	(6,297,349)	19,060,552	

Notes: AFY = acre-feet per year; KWB = Kern Water Bank.

Figure 3.4-9 shows the maximum spatial extent of positive elevation differences exceeding +5 feet, +10 feet, +20 feet, +30 feet, +45 feet, and +60 feet. Positive differences in groundwater elevation attributable to KWB operations spread as far as 5.5 miles from the northern and eastern edges of KWB Lands and as far as 4 miles from the southern edge of KWB Lands.

3.4.3.3 Acreages of Affected Areas

The -30 feet elevation difference boundary line (see Figure 3.4-8) extends into agricultural area north and east of the KWB boundary. The negative differences in groundwater elevations between "With" and "Without" KWB operations spread into more agricultural areas as the specified levels change from -30 feet to -5 feet. Tables 3.4-2 and 3.4-3 show the area affected at different water level differences for the area outside KWB Lands and the entire model area. Tables 3.4-4 and 3.4-5 show the agricultural area affected by different levels of negative and positive differences, respectively.

3.4.4 FREQUENCY DISTRIBUTION OF GROUNDWATER ELEVATION DIFFERENCES

Maps were prepared to evaluate the location and frequency with which groundwater elevation differences between the AFO-BC "With KWB Operations" and "Without KWB Operations" scenarios exceeded selected values (Metric 6 of Section 3.1). Frequency distributions of negative groundwater elevation differences exceeding -45 feet, -30 feet, -20 feet, and -10 feet are shown in Figures 3.4-10a to 3.4-10d, respectively. Frequency distributions of groundwater elevation differences exceeding +10 feet, +30 feet, and +60 feet are shown in Figures 3.4-11a to 3.4-11c, respectively.

Figure 3.4-10a shows that negative elevation differences exceeding -45 feet are contained entirely within the KWB boundary at all times. Figure 3.4-10b shows that negative elevation differences exceeding -30 feet are contained entirely within the KWB boundary approximately 90 percent of the time during future (2015–2035) operations under the AFO-BC scenario.

Positive elevation differences exceeding +60 feet (Figure 3.3-11c) are mostly contained within the KWB boundary. Approximately 25 percent of the time such differences occur outside the KWB boundary, but in the immediate vicinity.

3.4.5 ZONAL AVERAGE GROUNDWATER ELEVATION HYDROGRAPHS

Average groundwater elevations outside KWB Lands (Metric 7 of Section 3.1) were evaluated at five 1-mile zones (Figure 3.2-14). Simulated head was averaged for each cell in a particular zone for each monthly time step of the simulation period. Average groundwater elevations for Zones 1–5 are shown in Figures 3.4-12a to 3.4-12e. Figure 3.4-13 shows the average elevation difference in each zone, which was calculated by subtracting the "Without KWB Operations" run from the "With KWB Operations" run data shown in Figures 3.4-12a to 3.4-12e. These figures indicate that the rise and fall of the groundwater mound follows KWB recharge and recovery cycles, and is correlated with the cumulative KWB storage balance. Impacts of consecutive years of pumping, such as the 4-year period of 2012–2015, are seen in the lowering of the average groundwater elevation in Zones 1–3 in the first few years of the AFO-EC scenario, until successive years of recharge in 2016–2017 (hydrologically similar to 1995–1996) result in an increase in the average groundwater level.

3.4.6 HIGH GROUNDWATER LEVELS AND IMPACT ON INFRASTRUCTURE

Future recharge operations at the KWB during the recharge periods of 2016–2019, 2026–2027, and 2032 under AFO-BC conditions (similar to 1995–1998, 2005–2006, and 2011 hydrologic conditions, respectively) could result in high groundwater elevations (<50 feet bgs) within KWB Lands and the surrounding areas.

AFO-BC has 1,090 acres of additional recharge ponds and could recharge more water during the years when Kern River flood water is available for recharge at KWB recharge facilities. This may cause the available water to exceed the total recharge capacity of the KWB and development of high groundwater elevations within the KWB area. Increased monitoring of groundwater elevations and recharge rates of KWB recharge ponds under AFO-BC conditions may be necessary to maintain the proposed recharge volumes.

High groundwater elevations could impact the existing infrastructure within and in the vicinity of KWB Lands. The CVC and residential areas on septic systems are the main infrastructure in the DWR KWB Model domain that might potentially be impacted by high water levels.

Results of AFO-BC model scenario were evaluated to determine the impact of high groundwater elevations on CVC and residential areas on septic systems.

Figures 3.4-14 to 3.4-16 show the spatial characteristics of the groundwater mound that form during recharge operations of 2019, 2027, and 2032 under AFO-BC “With KWB Operations” conditions. AFO-BC recharge operation includes recent recharge management improvements by KWBA to move more recharge to eastern ponds.

Figure 3.2-20 shows the locations of the two selected water level hydrographs along the CVC. The hydrograph locations were selected based on locations of the piezometers and pumping stations of the CVC; these hydrographs are used to demonstrate the impacts on CVC. Figure 3.2-21 shows the areas near KWB Lands that are on septic systems or dry wells as obtained from the Kern County General Plan and Google Earth; it also shows the locations of two selected water level hydrographs used to demonstrate the impacts on septic areas.

Figure 3.4-17 shows the groundwater level hydrographs at two selected locations along the CVC. The hydrographs show the water levels at the selected locations for the AFO-BC “With KWB Operations” and “Without KWB Operations” scenarios, ground surface elevation, and the CVC invert elevation. It is assumed that the CVC invert is 10 feet below ground surface. The impact of the KWB recharge operations on the CVC is discussed below.

Figure 3.4-18 shows the water level hydrographs at two locations near KWB Lands, as shown in Figure 3.2-21. The hydrographs show the water levels for the AFO-BC “With KWB Operations” and “Without KWB Operations” scenarios and the ground surface elevation. The impact on the KWB recharge operations on the septic systems is discussed below.

3.4.6.1 2016-2019 Recharge Operations

As shown in Figures 3.4-14 and 3.4-17, 2016-2019 recharge operations resulted in water levels lower than 50 feet from surface along the entire length of the CVC in the KWB area. As shown in Figure 3.4-18, depth to groundwater in residential areas on septic systems located northeast of KWB Lands exceeds 50 feet. Groundwater elevations are not high enough to impact the CVC and the septic systems.

3.4.6.2 2026-2027 Recharge Operations

As shown in Figures 3.4-15 and 3.4-17, similar to 2016-2019 conditions, 2026-2027 recharge operations resulted in water levels lower than 50 feet from surface along the entire length of the CVC in the KWB area. High groundwater levels would be limited to the area within KWB Lands and east of the CVC. As shown in Figure 3.4-18, depth to groundwater in residential areas using septic systems located northeast of KWB Lands would exceed 50 feet. Groundwater elevations are not high enough to impact the CVC and the septic systems.

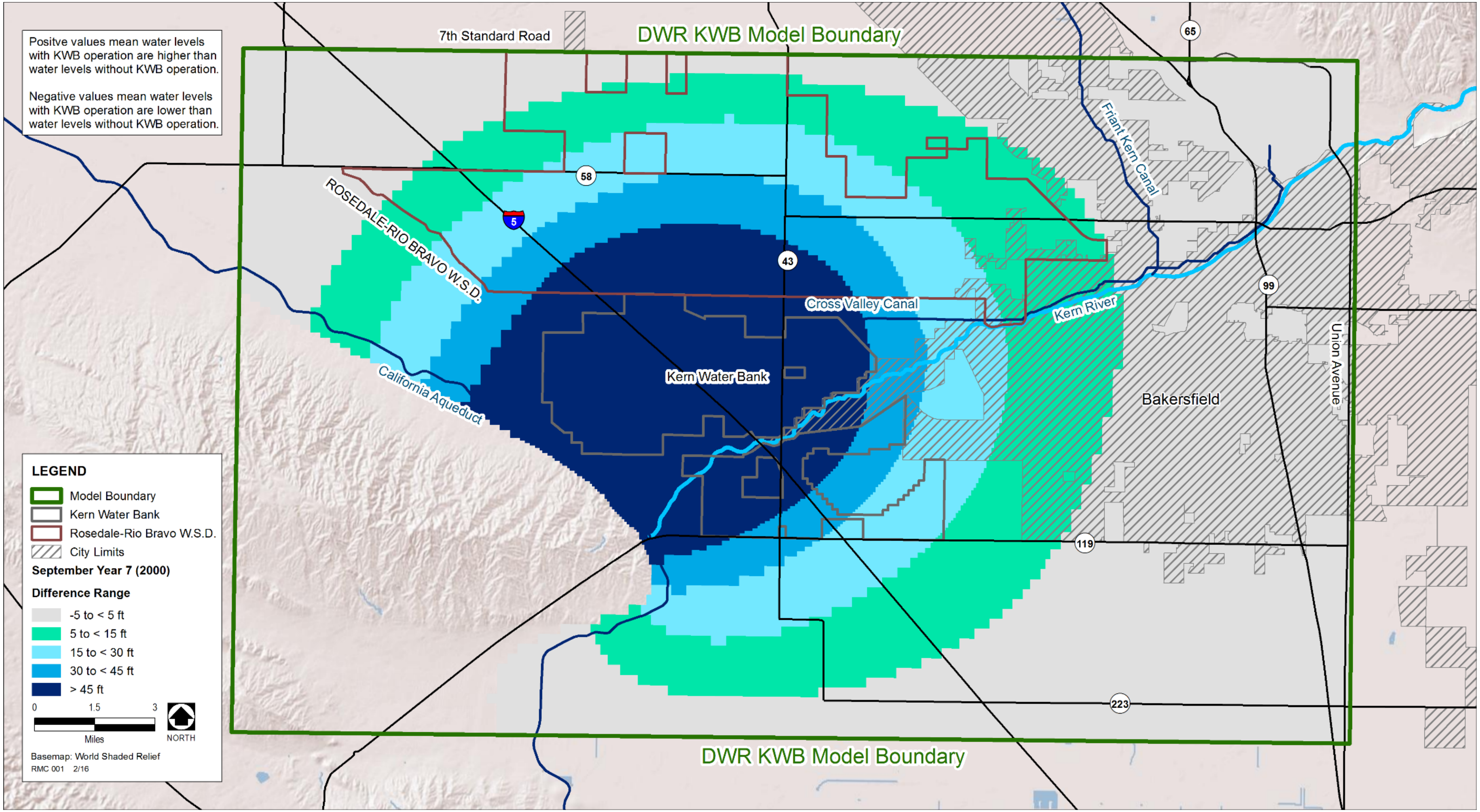


FIGURE 3.4-3a. **Analysis of Future Operations under Buildout Conditions: Groundwater Elevation Difference Contour Map at the End of the 1995–2000 Equivalent Recharge Cycle**

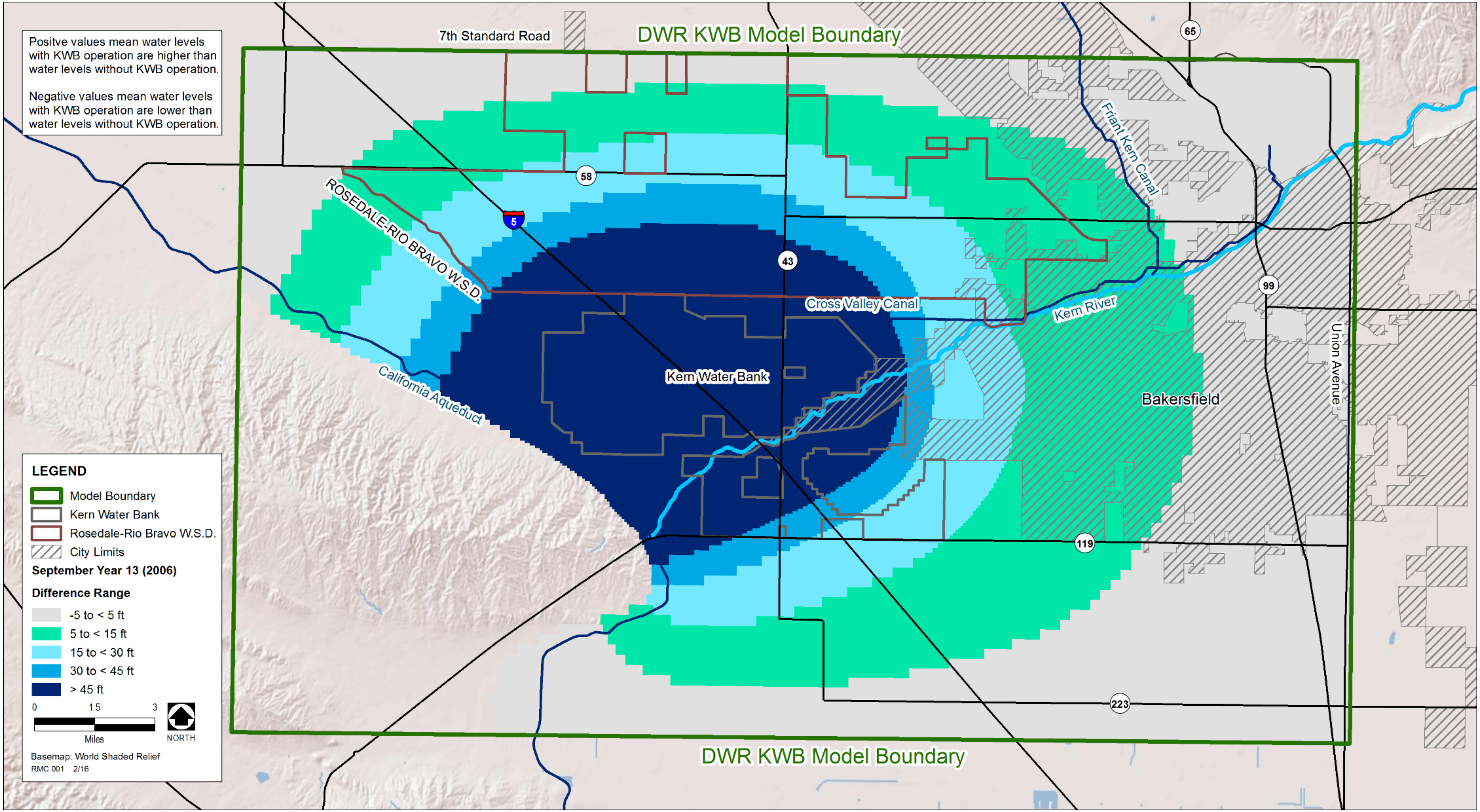


FIGURE 3.4-3b. Analysis of Future Operations under Buildout Conditions: Groundwater Elevation Difference Contour Map at the End of the 2006 Equivalent Recharge Cycle

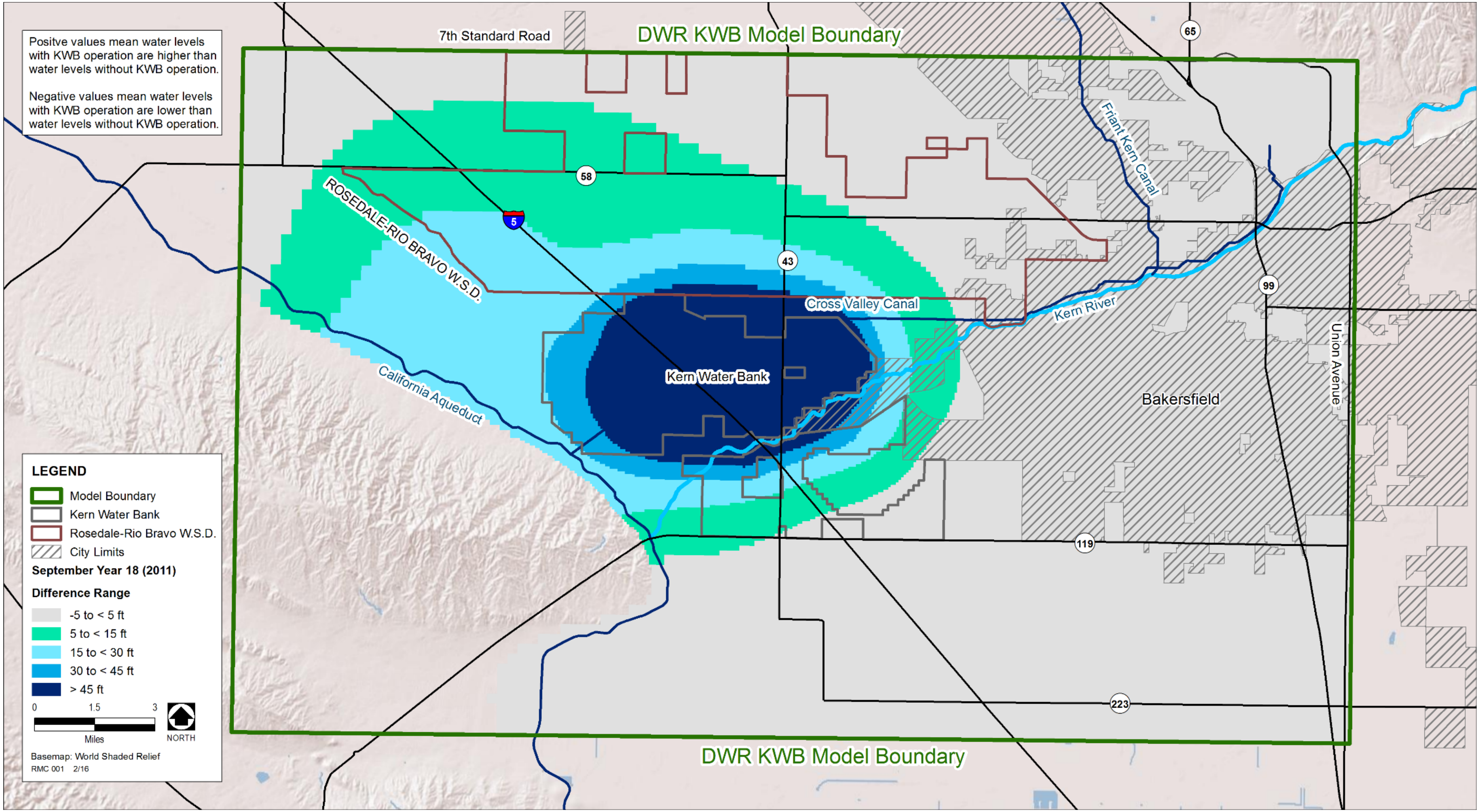


FIGURE 3.4-3c. Analysis of Future Operations under Buildout Conditions: Groundwater Elevation Difference Contour Map at the End of the 2011 Equivalent Recharge Cycle

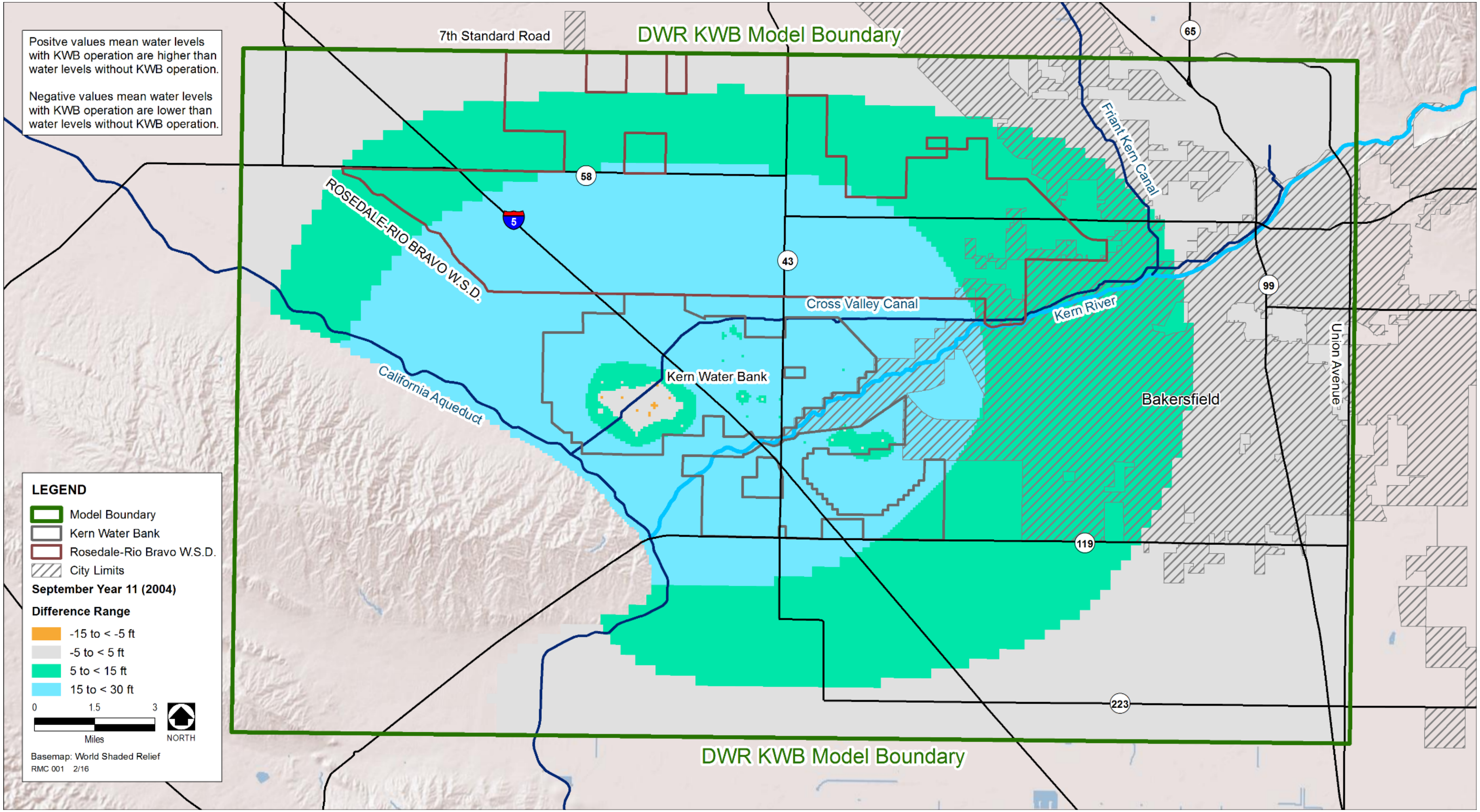


FIGURE 3.4-4a. **Analysis of Future Operations under Buildout Conditions: Groundwater Elevation Difference Contour Map at the End of the 2001–2004 Equivalent Recovery Cycle**

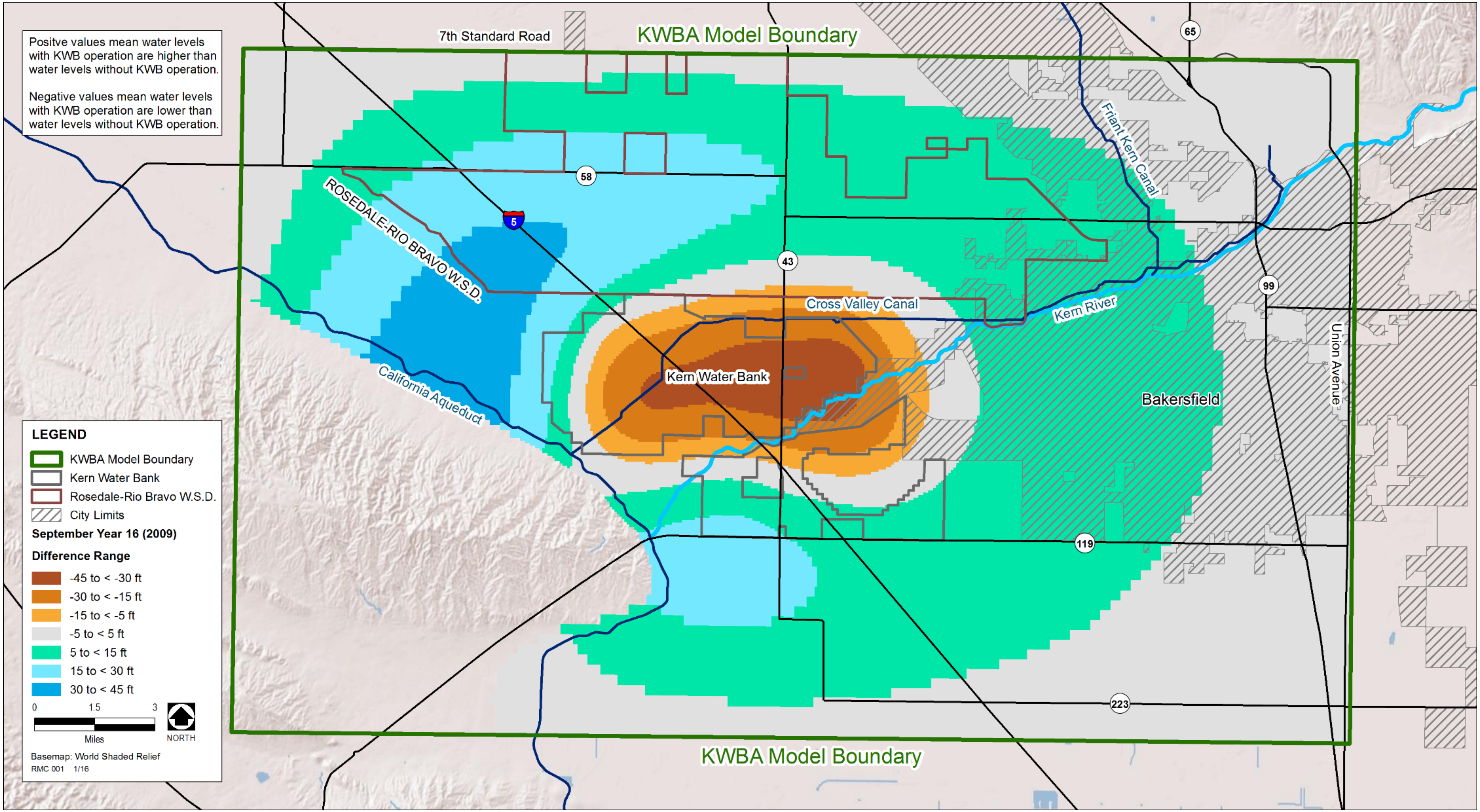


FIGURE 3.4-4b. Analysis of Future Operations under Buildout Conditions: Groundwater Elevation Difference Contour Map at the End of the 2009 Equivalent Recovery Cycle

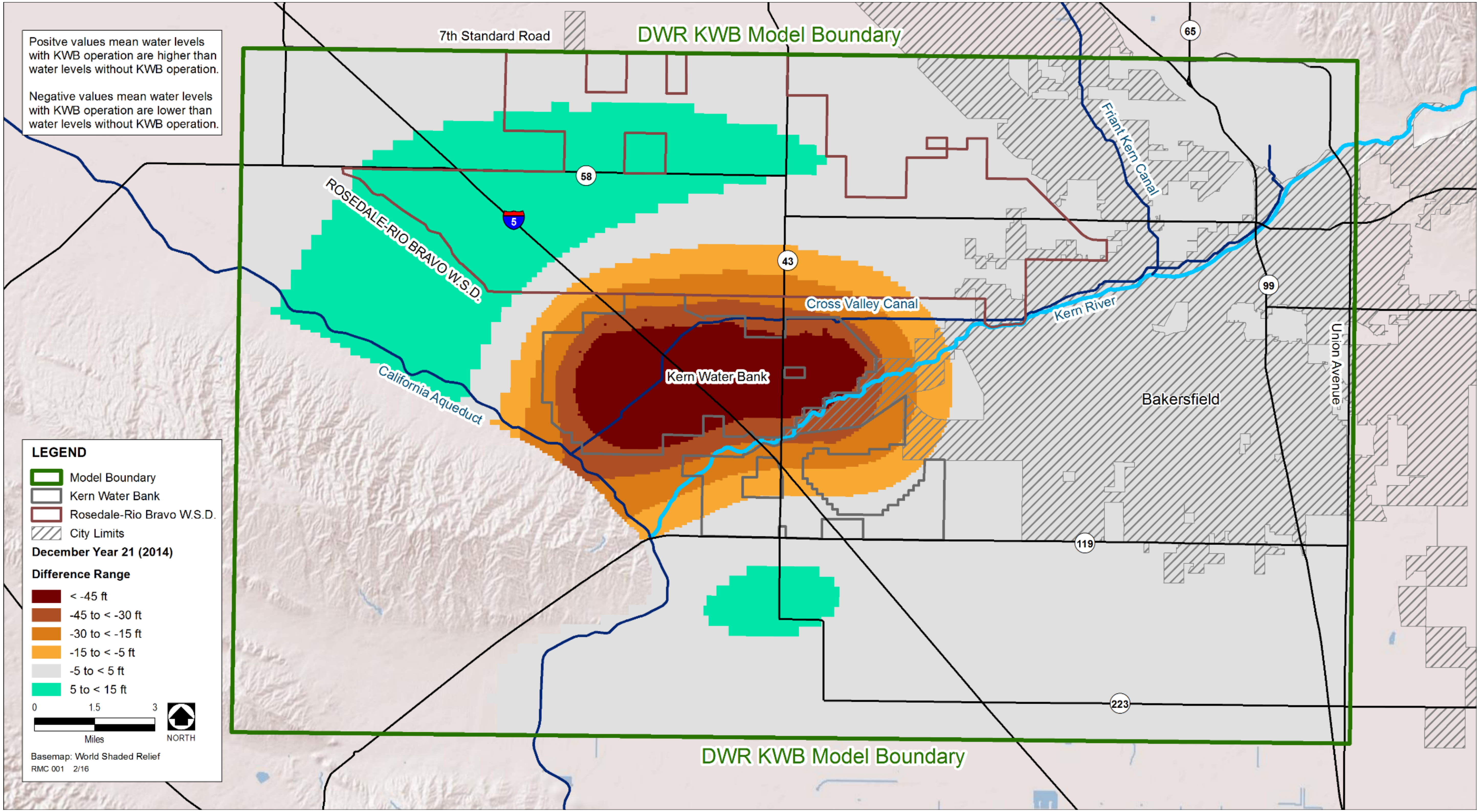


FIGURE 3.4-4c. **Analysis of Future Operations under Buildout Conditions: Groundwater Elevation Difference Contour Map at the End of the 2014 Equivalent Recovery Cycle**

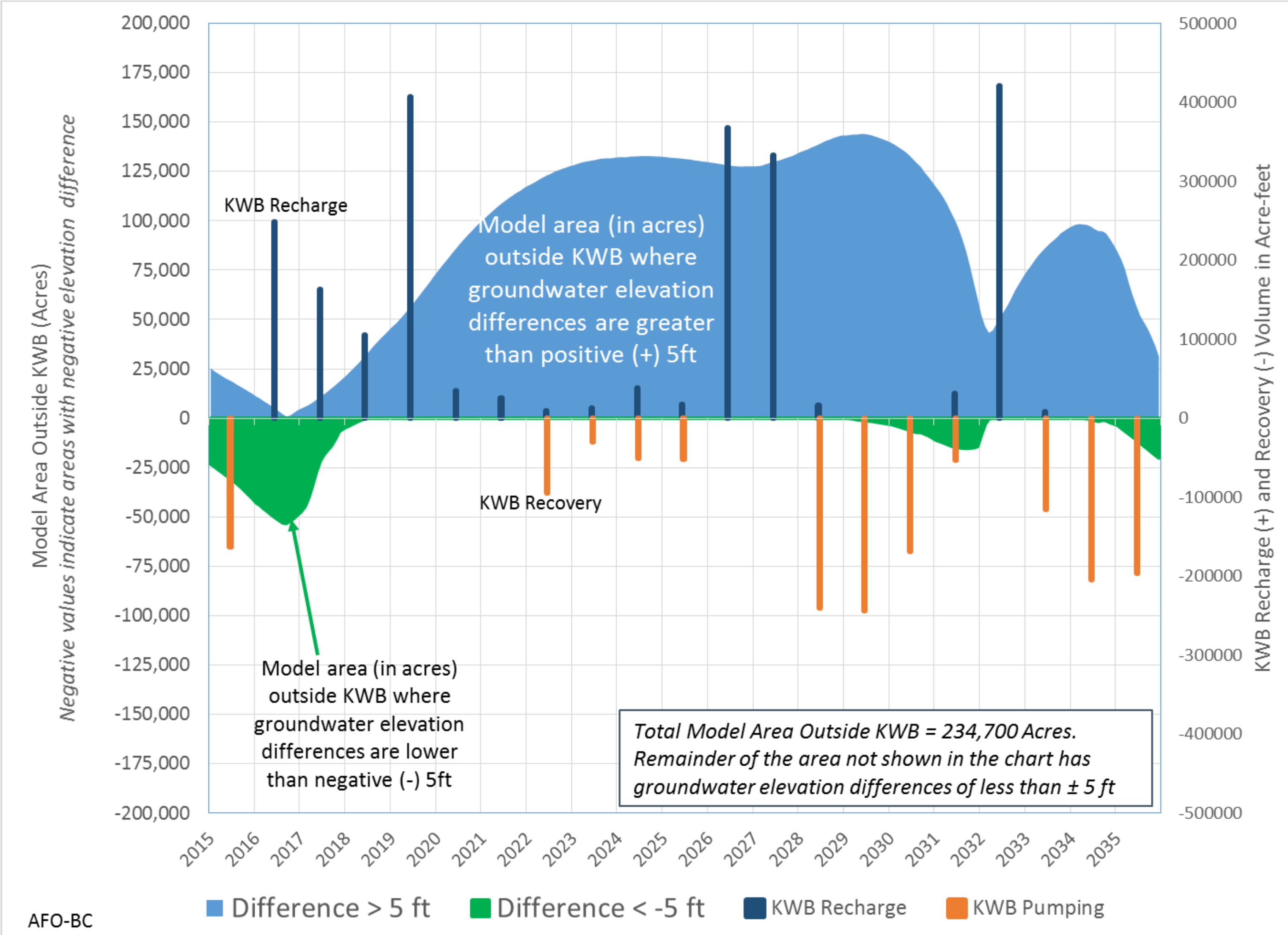


FIGURE 3.4-5. **Analysis of Future Operations under Buildout Conditions: Time vs. Affected Area Outside Kern Water Bank Exceeding ± 5 Feet Differences in Groundwater Elevations ("With Kern Water Bank Operations" Minus "Without Kern Water Bank Operations"), 2015-2035**

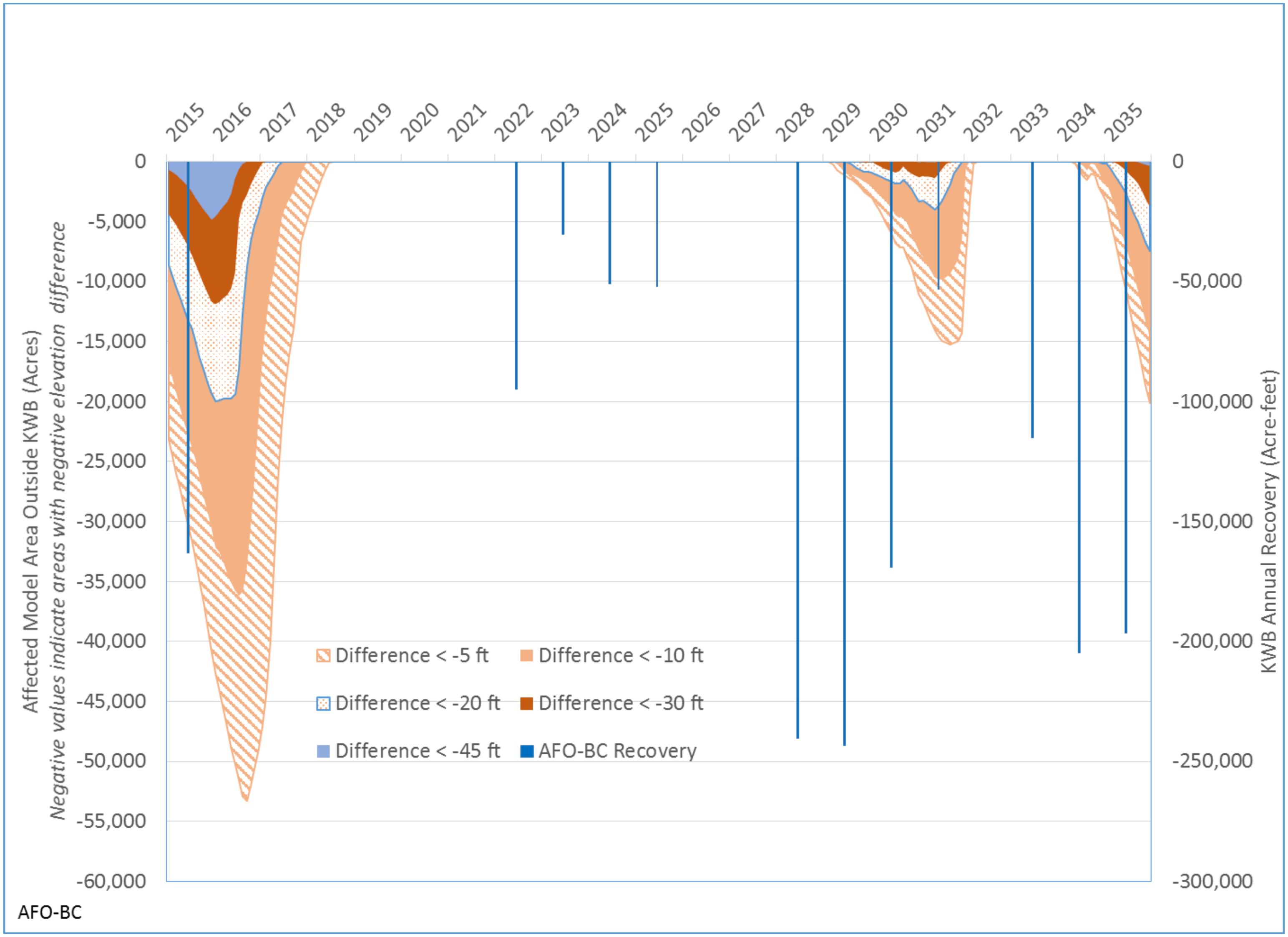


FIGURE 3.4-6. **Analysis of Future Operations under Buildout Conditions: Time vs. Affected Area Outside Kern Water Bank at Various Levels of Negative Elevation Differences ("With Kern Water Bank Operations" Minus "Without Kern Water Bank Operations"), 2015-2035**

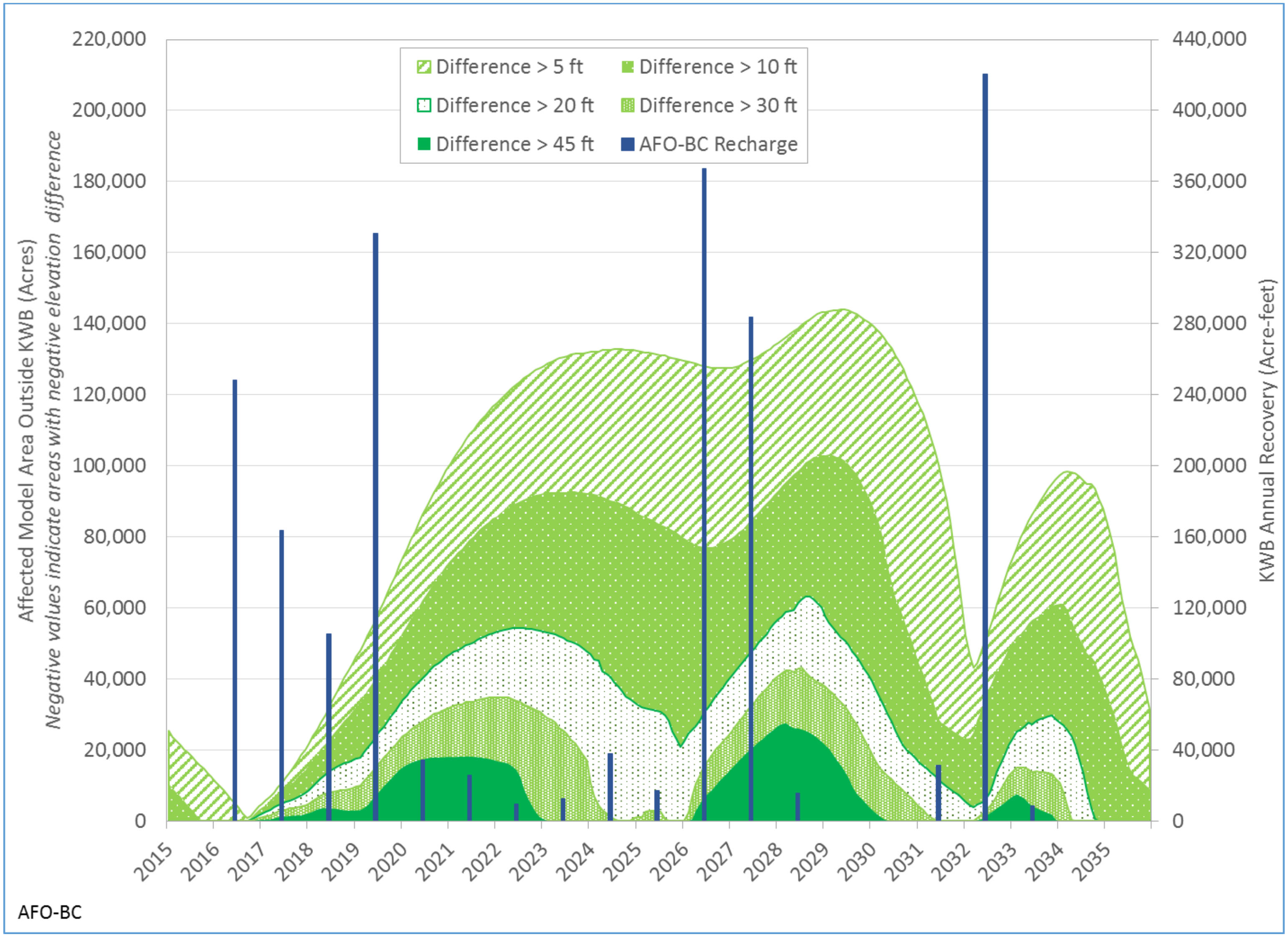


FIGURE 3.4-7. **Analysis of Future Operations under Buildout Conditions: Time vs. Affected Area Outside Kern Water Bank at Various Levels of Positive Elevation Differences ("With Kern Water Bank Operations" Minus "Without Kern Water Bank Operations"), 2015-2035**

3.4.6.3 2032 Recharge Operations

As shown in Figure 3.4-16 and 3.4-18, water levels would be lower than 50 feet from surface along the entire length of the CVC and within almost all of the KWB area. Water levels in 2032 would be generally lower than 2019 and 2027 levels due to 2032 being a single-year recharge period while the other two recharge periods are 4- and 2-year recharge periods, respectively. Also, a higher percentage of KWB recharge is shifted to eastern ponds to be consistent with current recharge management practices of the KWBA.

3.4.7 HIGH GROUNDWATER LEVELS AND IMPACT ON NEIGHBORING RECHARGE FACILITIES

Impacts of KWB recharge operations on the recharge operations of neighboring recharge facilities during high groundwater elevations with all the groundwater banks operating simultaneously under AFO-BC conditions were evaluated by using water level hydrographs at the neighboring recharge facilities.

Figure 3.2-24 shows the locations of the selected water level hydrographs at the neighboring recharge facilities. Figure 3.4-19 shows the representative water level hydrographs at these locations. Table 3.4-6 shows the minimum depth to water under AFO-BC conditions at the four selected recharge facilities. The impact of the KWB recharge operations on the neighboring recharge facilities during high groundwater elevations with all the groundwater banks operating simultaneously are discussed below.

3.4.7.1 2016-2019 Recharge Operations

The water level analysis shows that at the adjacent recharge facilities, groundwater levels were lower than 40 feet below the ground surface; thus, the groundwater mounding associated with the simultaneous operations of KWB and all other neighboring groundwater banks would not interfere with recharge operations of neighboring basins.

3.4.7.2 2026-2027 Recharge Operations

The water levels at the adjacent recharge facilities were generally higher than 2016-2019 conditions and lower than 15 feet below the ground surface; thus, the groundwater mounding associated with simultaneous operations of KWB and all other neighboring groundwater banks would not interfere with recharge operations of neighboring basins.

3.4.7.3 2032 Recharge Operations

The water levels for 2032 recharge operations were significantly lower than the previous two recharge operations in 2016-2019 and 2026-2027, and groundwater levels were lower than 48 feet below the ground surface; thus, the groundwater mounding associated with simultaneous operations of KWB and all other neighboring groundwater banks are not expected to interfere with recharge operations of neighboring basins.

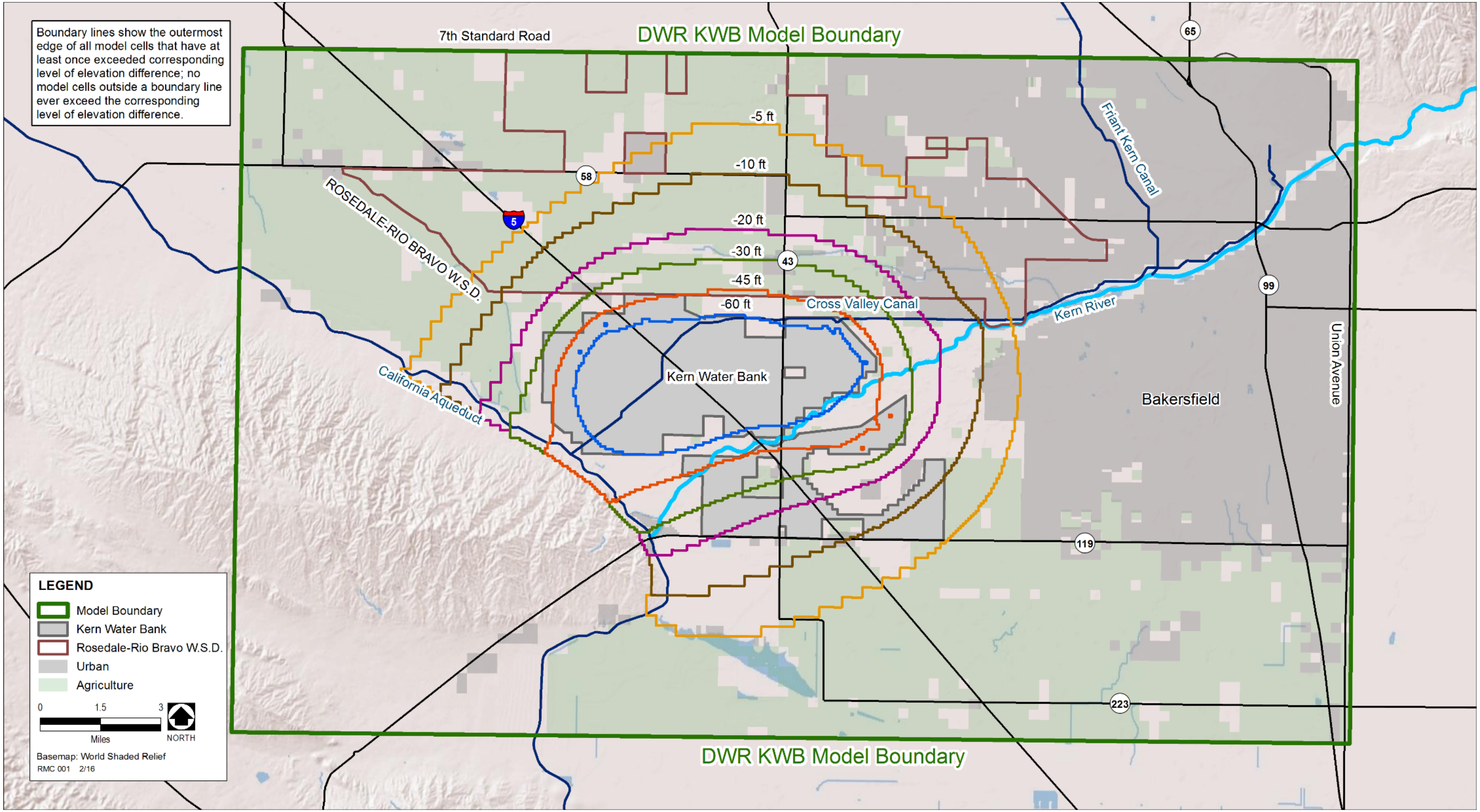


FIGURE 3.4-8. **Analysis of Future Operations under Buildout Conditions: Contours of Negative Differences (“With” minus “Without”), 2015–2035**

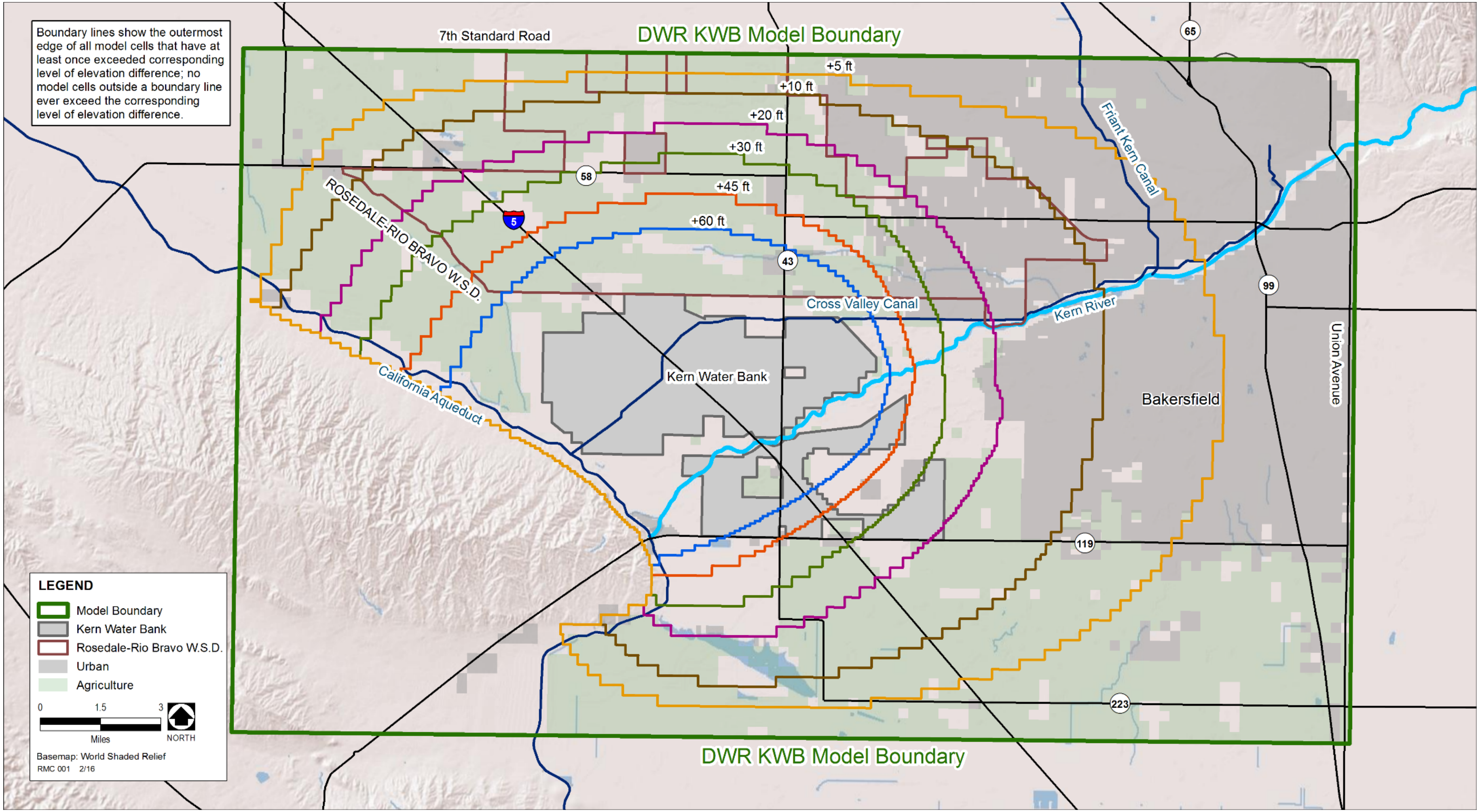


FIGURE 3.4-9. Analysis of Future Operations under Buildout Conditions: Contours of Positive Elevation Differences (“With” minus “Without”), 2015–2035

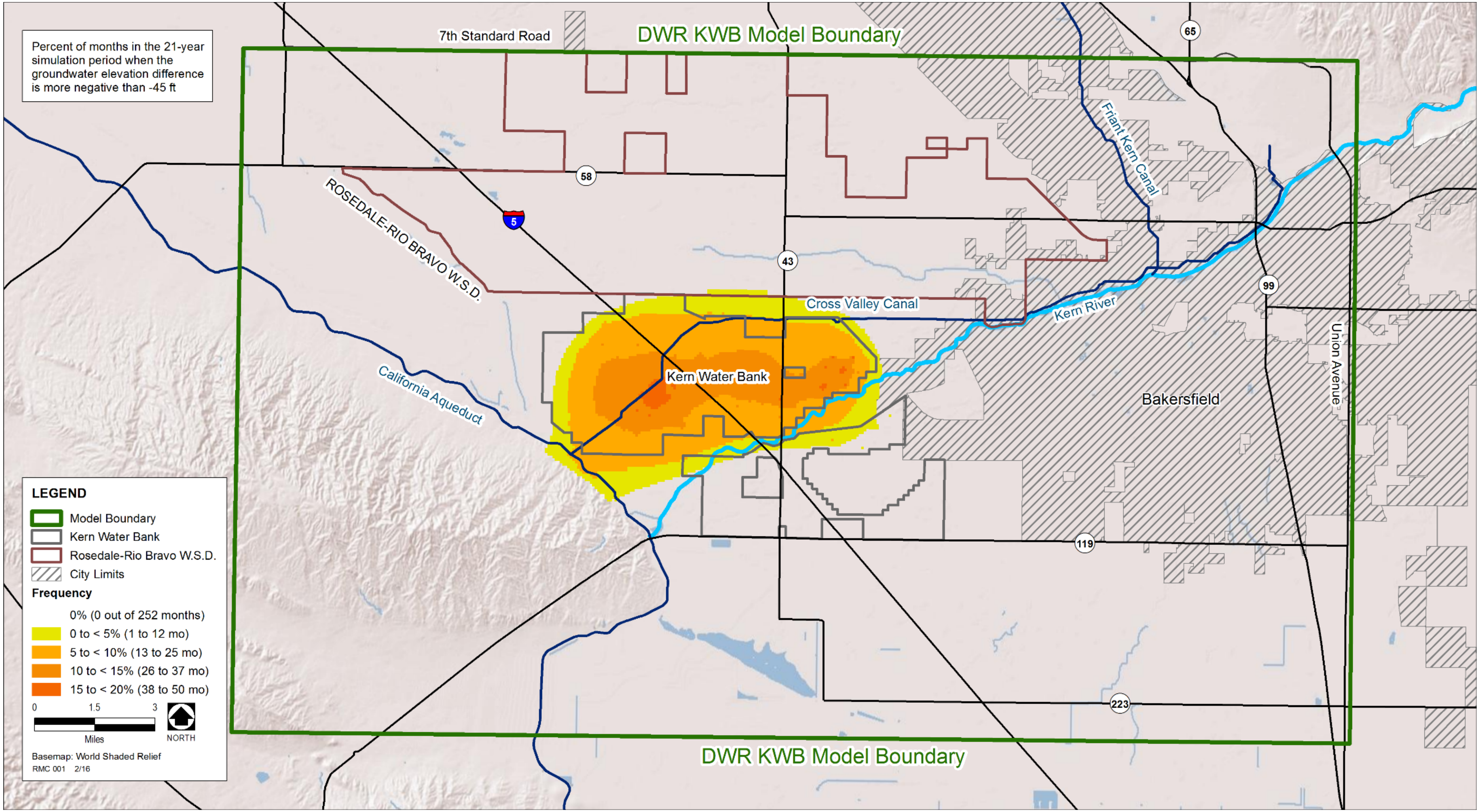


FIGURE 3.4-10a. Analysis of Future Operations under Buildout Conditions: Frequency Distribution (% of Months) of Areas with > -45 Feet Difference in Groundwater Elevations ("With Kern Water Bank Operations" Minus "Without Kern Water Bank Operations"), 2015-2035

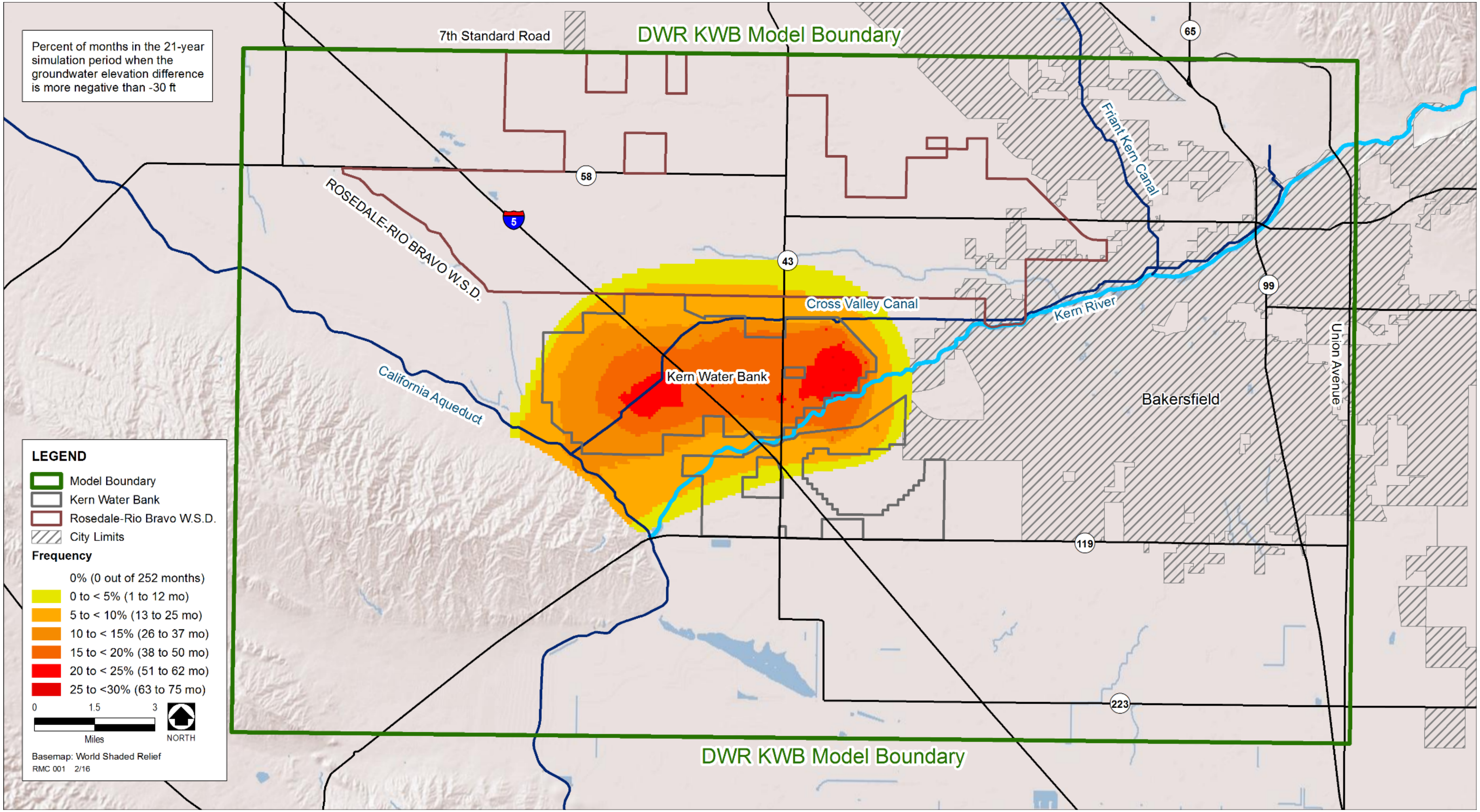


FIGURE 3.4-10b. **Analysis of Future Operations under Buildout Conditions: Frequency Distribution (% of Months) of Areas with > -30 Feet Difference in Groundwater Elevations ("With Kern Water Bank Operations" Minus "Without Kern Water Bank Operations"), 2015-2035**

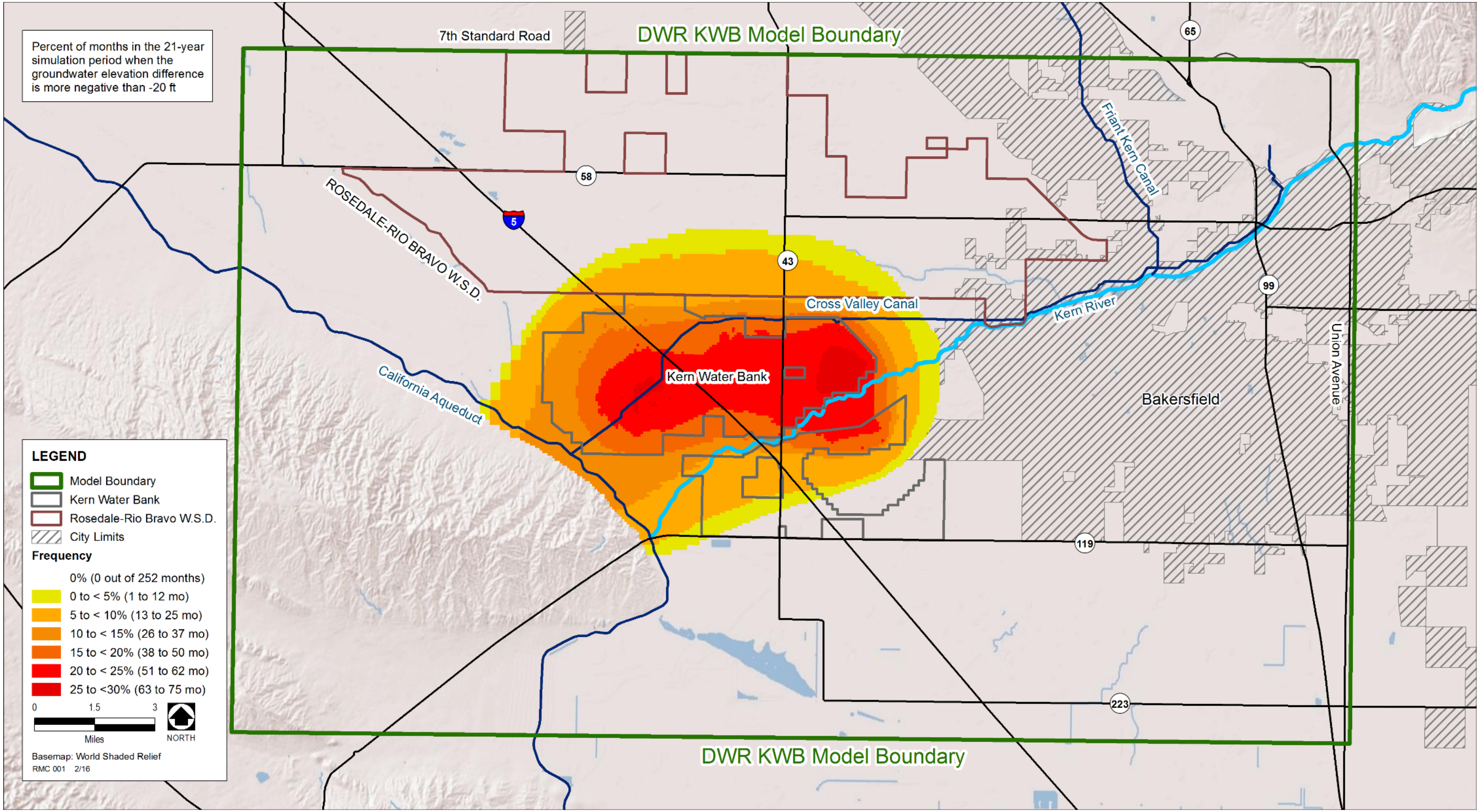


FIGURE 3.4-10c. **Analysis of Future Operations under Buildout Conditions: Frequency Distribution (% of Months) of Areas with > -20 Feet Difference in Groundwater Elevations ("With Kern Water Bank Operations" Minus "Without Kern Water Bank Operations"), 2015-2035**

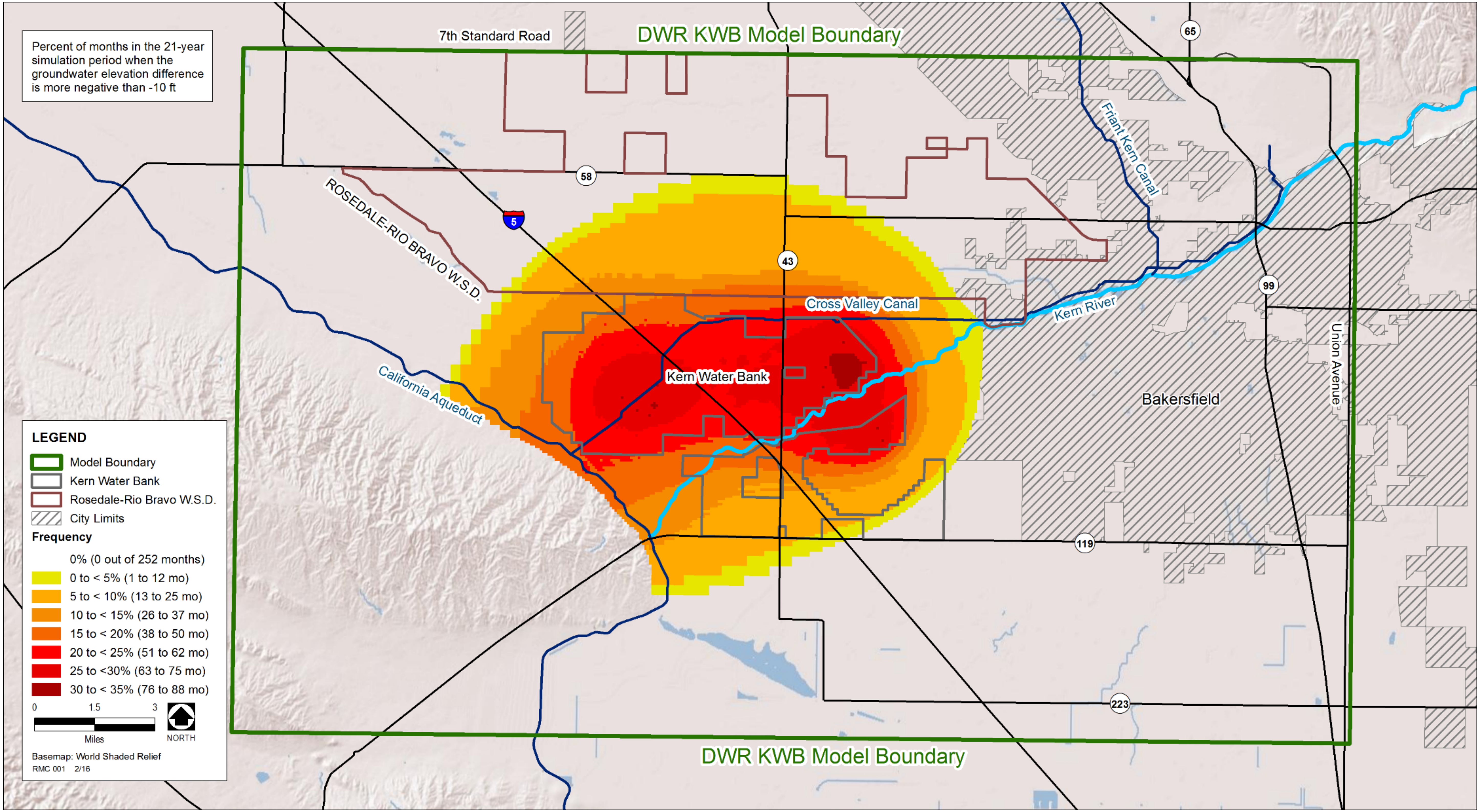


FIGURE 3.4-10d. **Analysis of Future Operations under Buildout Conditions: Frequency Distribution (% of Months) of Areas with > -10 Feet Difference in Groundwater Elevations ("With Kern Water Bank Operations" Minus "Without Kern Water Bank Operations"), 2015-2035**

TABLE 3.4-2

AREA AFFECTED AT DIFFERENT LEVELS OF WATER LEVEL FOR AREA OUTSIDE THE KERN WATER BANK LANDS (ANALYSIS OF FUTURE OPERATIONS UNDER BUILDOUT CONDITIONS), 2015-2035

	Impacted Area Outside the Kern Water Bank Lands (acres)									
Frequency for 20-Year Simulation	**-60 Feet**	**-45 Feet**	**-30 Feet**	**-20 Feet**	**-10 Feet**	**+10 Feet**	**+20 Feet**	**+30 Feet**	**+45 Feet**	**+60 Feet**
Never Occurs	231,692	227,239	219,594	210,664	193,359	124,341	164,861	184,421	201,869	212,062
1–12 months	650	3,183	4,715	5,328	6,178	2,065	3,468	3,603	3,735	3,858
13–24 months	63	1,968	6,268	10,240	16,768	5,623	4,180	4,503	4,750	4,548
25–36 months	0	15	1,123	4,070	6,985	3,143	2,848	3,253	3,405	2,713
37–58 months	0	0	688	1,145	5,558	2,743	3,463	3,835	2,173	1,813
59–60 months	0	0	18	958	2,443	2,538	3,138	3,235	3,038	2,510
61–72 months	0	0	0	0	1,115	3,008	3,350	3,875	4,318	3,368
73–84 months	0	0	0	0	0	3,200	5,270	4,285	5,770	985
85–96 months	0	0	0	0	0	3,463	5,053	3,180	878	233
97–108 months	0	0	0	0	0	5,828	3,295	5,090	1,383	318
109–120 months	0	0	0	0	0	9,103	2,750	6,153	1,053	0
121–144 months	0	0	0	0	0	11,260	6,903	6,095	35	0
145–168 months	0	0	0	0	0	19,288	22,643	878	0	0
168 or more months	0	0	0	0	0	36,805	1,185	0	0	0

Table 3.4-3

Area Affected at Different Water Levels for the Entire Model Area (Analysis of Future Operations Under Buildout Conditions), 2015-2035

Frequency for 20-Year Simulation	Impacted Area in Model Domain (acres)									
	-60 Feet	-45 Feet	-30 Feet	-20 Feet	-10 Feet	+10 Feet	+20 Feet	+30 Feet	+45 Feet	+60 Feet
Never Occurs	242,487	234,139	223,752	213,429	194,371	124,341	164,916	185,944	203,917	215,494
1–12 months	5,363	5,610	5,618	6,150	6,590	2,065	3,645	3,738	4,475	4,885
13–24 months	6,440	9,428	10,435	12,715	19,170	5,623	4,558	4,530	5,313	5,343
25–36 months	160	4,970	5,830	7,078	8,310	3,143	3,048	3,295	3,600	3,193
37–58 months	0	303	7,023	5,970	8,608	2,743	3,690	4,053	2,728	2,493
59–60 months	0	0	1,783	8,160	9,513	2,538	3,425	3,765	3,923	3,568
61–72 months	0	0	10	948	7,498	3,008	3,628	4,425	5,233	9,490
73–84 months	0	0	0	0	390	3,200	5,358	5,083	10,998	2,915
85–96 months	0	0	0	0	0	3,463	5,195	3,668	2,723	1,388
97–108 months	0	0	0	0	0	5,828	3,700	5,778	3,698	3,373
109–120 months	0	0	0	0	0	9,653	3,135	10,288	5,465	2,310
121–144 months	0	0	0	0	0	12,665	10,085	13,908	2,380	0
145–168 months	0	0	0	0	0	28,845	38,460	5,978	0	0
168 or more months	0	0	0	0	0	47,338	1,608	0	0	0

TABLE 3.4-4 Analysis of Future Operations Under Buildout Conditions: Area Affected at Different Levels of Negative Differences ("With Kern Water Bank Operations" Minus "Without Kern Water Bank Operations"), 2015-2035		
Level of Negative Difference	**Agricultural Area (Acres)**	**Urban Area (Acres)**
-45 feet	760	8
-30 feet	4,078	578
-20 feet	7,942	1,265
-10 feet	16,228	3,717
-5 feet	27,628	7,810

TABLE 3.4-5 Analysis of Future Operations Under Buildout Conditions: Area Affected at Different Levels of Positive Differences ("With Kern Water Bank Operations" Minus "Without Kern Water Bank Operations"), 2015-2035		
Level of Positive Difference	**Agricultural Area (Acres)**	**Urban Area (Acres)**
5 feet	74,380	42,650
10 feet	55,780	21,850
20 feet	35,138	6,535
30 feet	24,840	3,170
45 feet	15,658	1,115

TABLE 3.4-6 MODEL-GENERATED MINIMUM DEPTH TO WATER FOR AFO-BC CONDITIONS				
Simulation Period	**Recharge Facility**			
	Rosedale	**Pioneer**	**2800 Acre**	**West Kern Water District**
2016-2019	65	50.2	40.3	64.4
2026-2027	53.2	39.9	15.7	63.4
2032	65.7	67	48.9	86.9

3.4.8 ANALYSIS OF FUTURE OPERATIONS UNDER BUILDOUT CONDITIONS RESULTS SUMMARY

A summary of the evaluation of impacts on the groundwater table attributable to KWB future operations under the AFO-BC scenario is provided in Table 3.4-7. Consecutive years of recovery from future KWB operations under the buildout level of development may cause groundwater levels to fall such that existing wells in an area immediately outside the KWB boundary are impacted. In contrast, consecutive years of recharge may cause groundwater levels to rise and impact sections of the CVC within KWB Lands and residential areas on septic systems located north of KWB Lands.

TABLE 3.4-7

SUMMARY OF ANALYSIS OF FUTURE OPERATIONS UNDER BUILDOUT CONDITIONS MODEL SCENARIO RESULTS AFFECTING THE LOCAL GROUNDWATER TABLE, 2015-2035

Evaluation Metric	Conclusion
Water Budget (Section 3.4.1)	The KWB has a balance of +498,000 AF stored water at the end of 2035. With the addition of APO balance of +617,000 AF, the KWB has a accumulated balance of +1,115,000 AF in aquifer volume of stored water at the end of 2035 under the AFO-BC scenario.
Groundwater Elevation Differences (Hydrographs and Contour Maps) (Section 3.4.2)	The positive groundwater elevation differences extend to almost all of the model domain. The negative groundwater elevation differences are limited to KWB Lands and the surrounding area.
Total Area of Negative and Positive Elevation Differences (Section 3.4.3)	Outside the KWB boundary, negative elevation differences occur in the first year of simulation because of the prior 3 years of recovery; thereafter, negative elevation differences occur after about 2 years of recovery following a recharge cycle.
Spatial Extent of Negative and Positive Elevation Differences (Section 3.4.3)	Outside the KWB boundary, negative elevation differences exceeding -30 feet are contained within 1 mile of the KWB boundary. Outside the KWB boundary, negative elevation differences exceeding -30 feet affect less than 5,000 acres of agricultural land in the immediate vicinity of KWB Lands, which represents less than five percent of the total agricultural area within the model domain. Outside the KWB boundary, positive elevation differences exceeding +60 feet (indicative of high water table) are contained within 1 mile of the KWB boundary.
Frequency Distribution of Negative and Positive Elevation Difference (Section 3.4.4)	Negative elevation differences exceeding -30 feet remain within the KWB boundary 90% of the time. Positive elevation differences exceeding +60 feet remain within the KWB boundary 75% of the time.
Average Elevation and Elevation Difference in Selected Zones (Section 3.4.5)	The average groundwater elevation of "With KWB Operations" in Zones 1–3 is lower than that of "Without KWB Operations" in 2015 and 2016, because of 4 consecutive years of recovery from 2012 through 2015.
High Groundwater Levels and Existing Infrastructure (Section 3.4.6)	Groundwater levels may impact sections of the CVC within KWB Lands. However, residential areas with septic systems located north of the KWB will not be impacted.
High Groundwater Levels and Neighboring Recharge Facilities (Section 3.4.7)	KWB operations, concomitant with the operations of other neighboring groundwater banks would not interfer with the recharge operations at neighboring groundwater banks.

Notes: AF = acre-feet; AFO-BC = Analysis of Future Operations under Buildout Conditions; APO = Analysis of Past Operations; KWB = Kern Water Bank; RRBWSD = Rosedale–Rio Bravo Water Service District

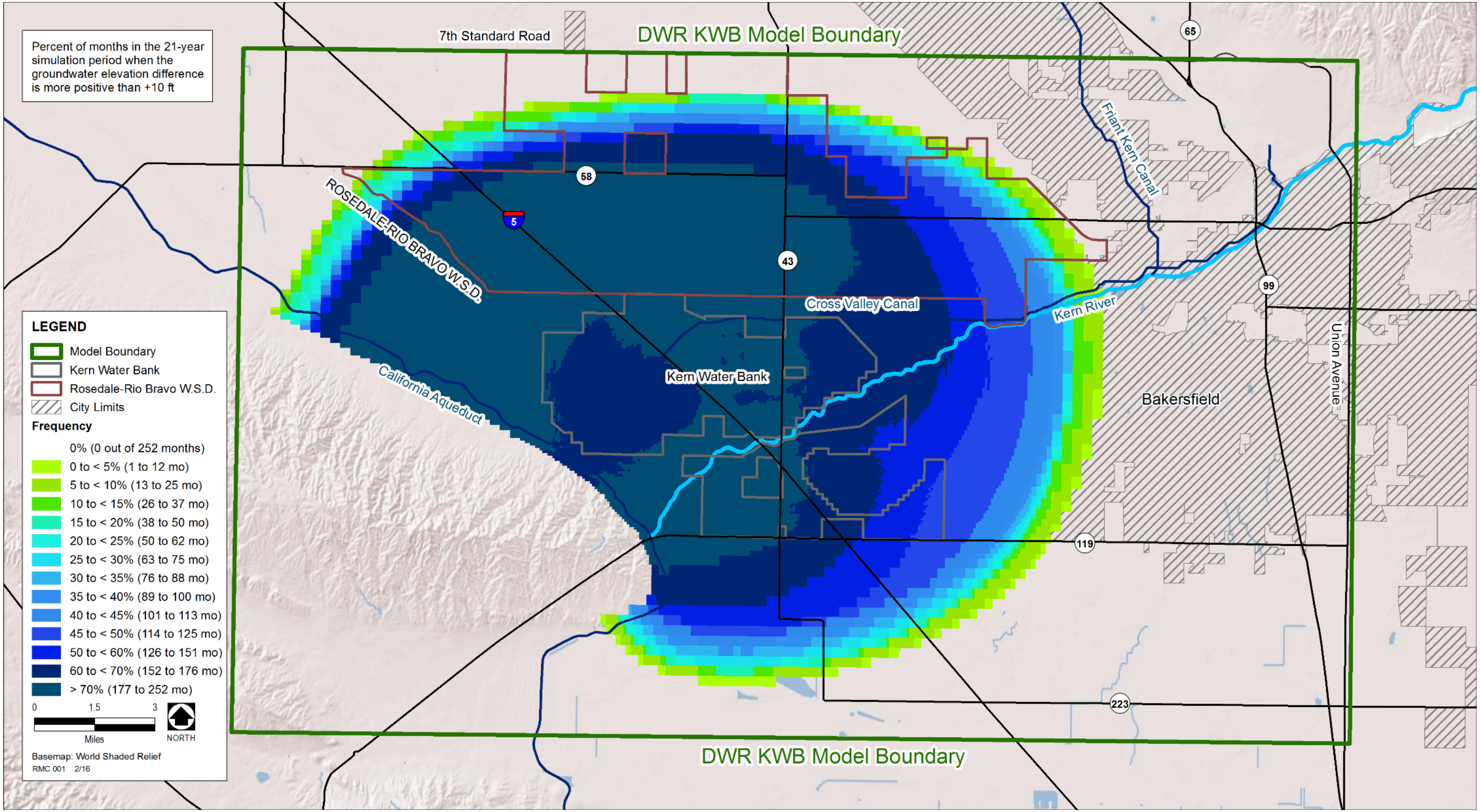


Figure 3.4-11a. **Analysis of Future Operations under Buildout Conditions: Frequency Distribution (% of Months) of Areas with > +10 Feet Difference in Groundwater Elevations ("With Kern Water Bank Operations" Minus "Without Kern Water Bank Operations"), 2015-2035**

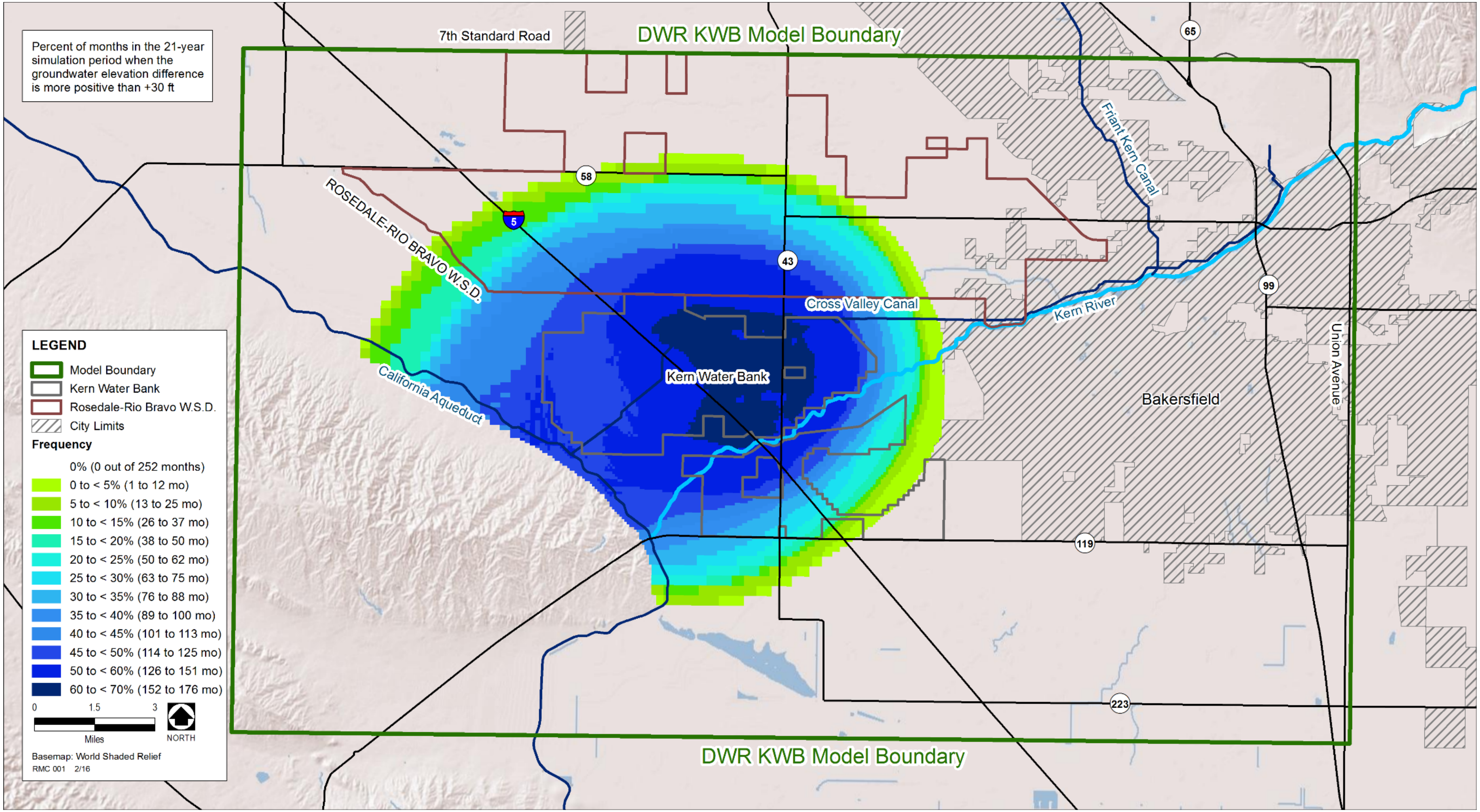


FIGURE 3.4-11b. Analysis of Future Operations under Buildout Conditions: Frequency Distribution (% of Months) of Areas with > +30 Feet Difference in Groundwater Elevations ("With Kern Water Bank Operations" Minus "Without Kern Water Bank Operations"), 2015-2035

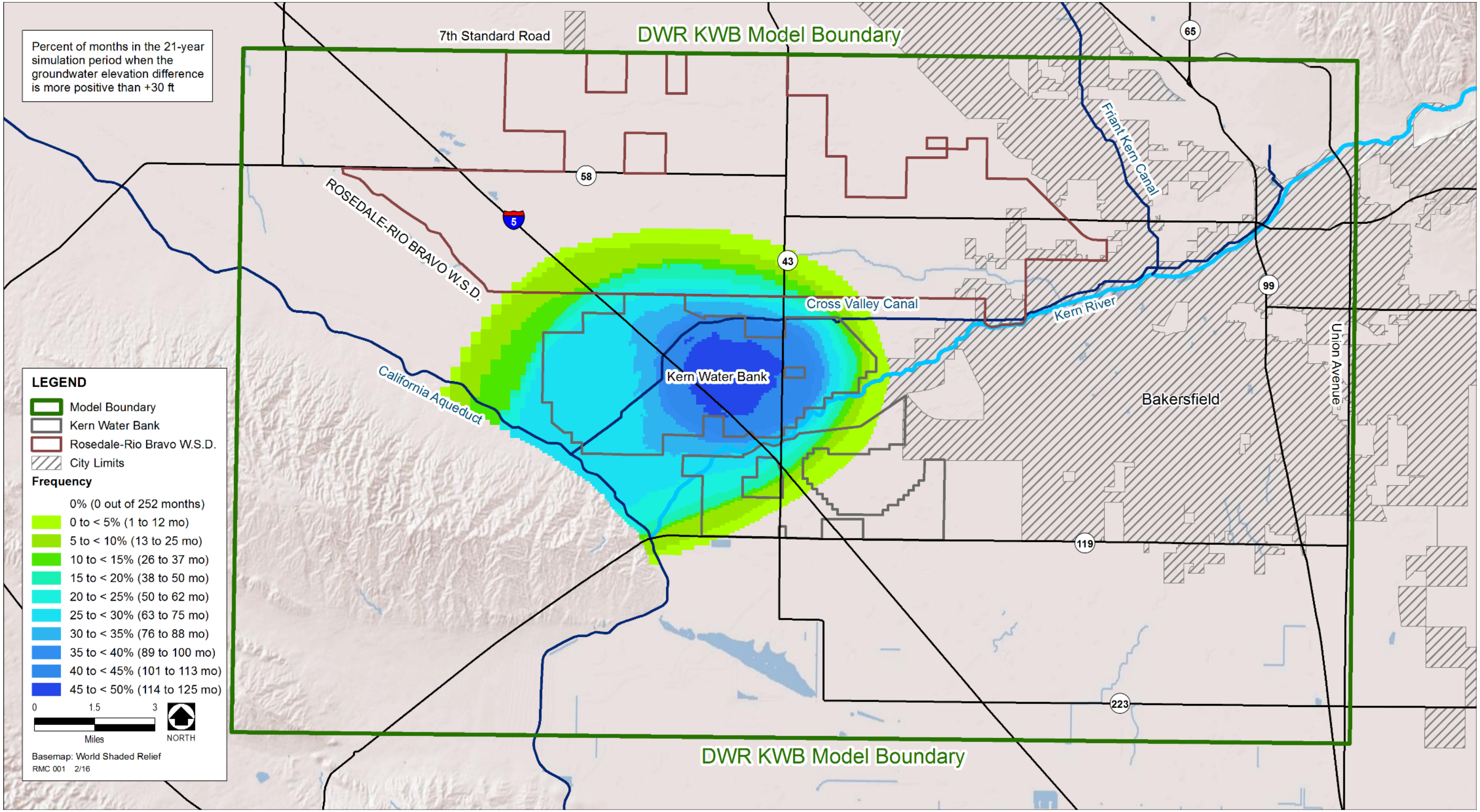


FIGURE 3.4-11c. **Analysis of Future Operations under Buildout Conditions: Frequency Distribution (% of Months) of Areas with > +60 Feet Difference in Groundwater Elevations ("With Kern Water Bank Operations" Minus "Without Kern Water Bank Operations"), 2015-2035**

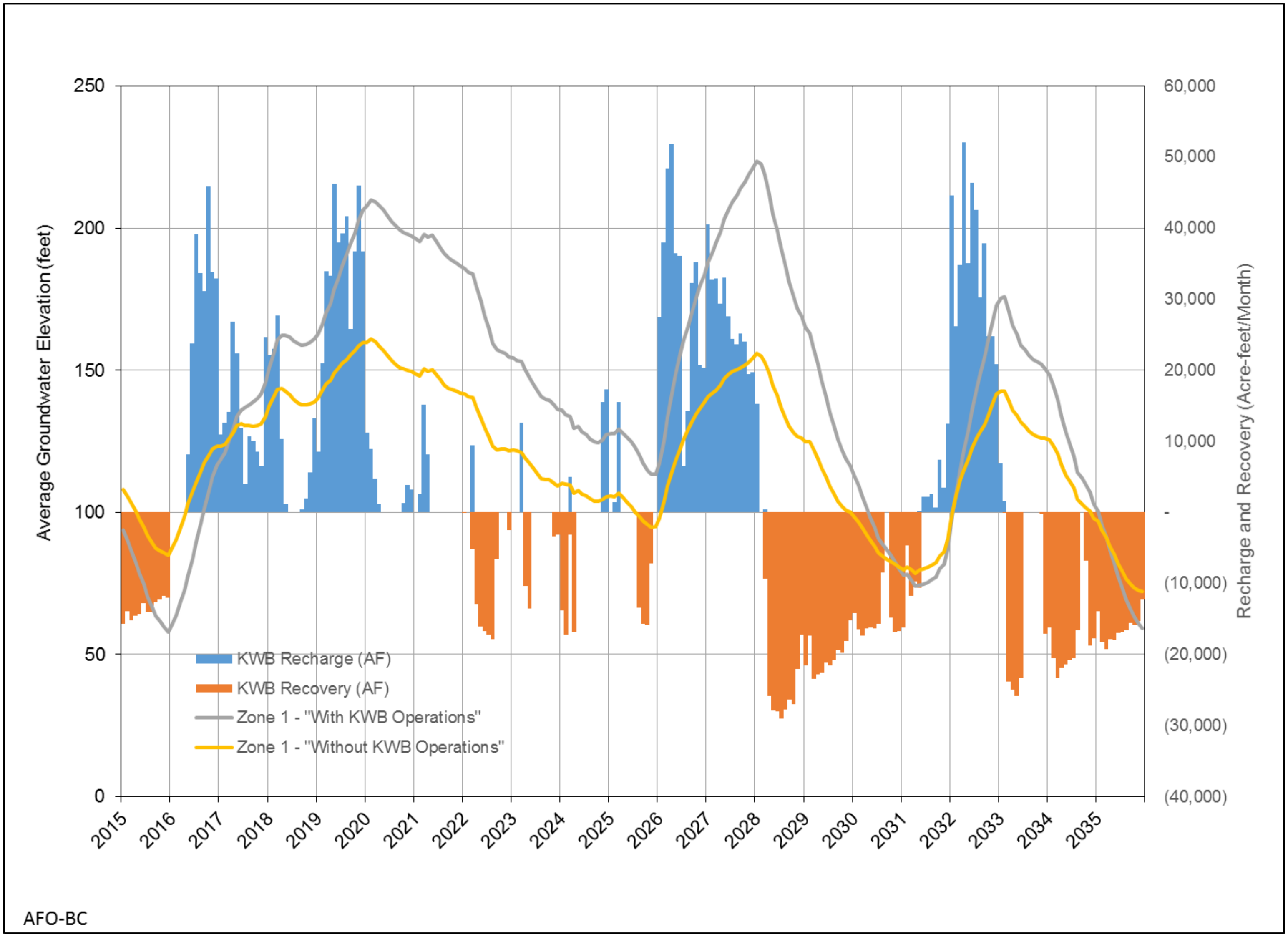


FIGURE 3.4-12a. Analysis of Future Operations under Buildout Conditions: Average Groundwater Elevation Over Zone 1 (0 to 1 Mile Outside the Kern Water Bank Boundary), 2015-2035

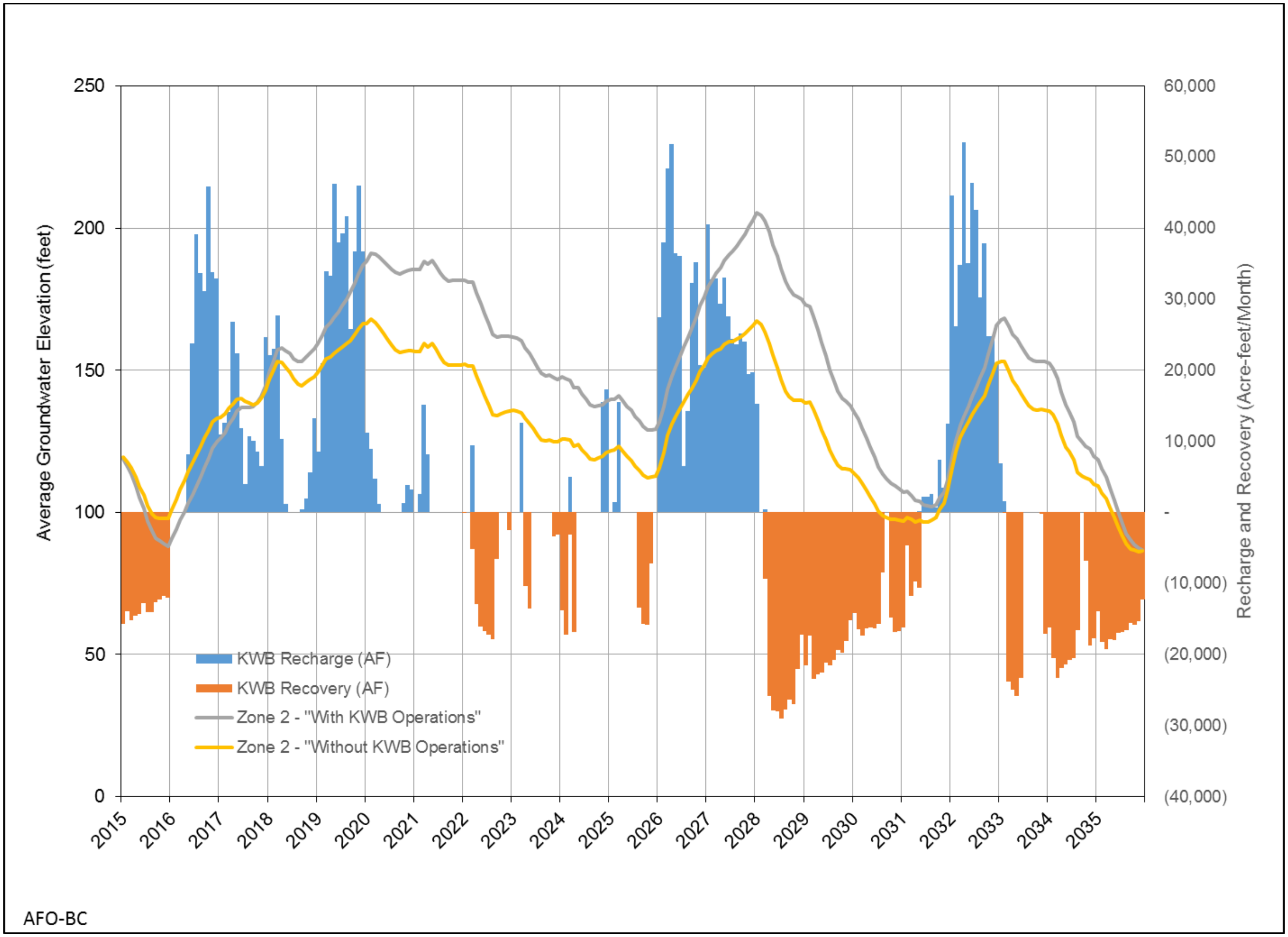


FIGURE 3.4-12b. Analysis of Future Operations under Buildout Conditions: Average Groundwater Elevation Over Zone 2 (1 to 2 Miles Outside the Kern Water Bank Boundary), 2015-2035

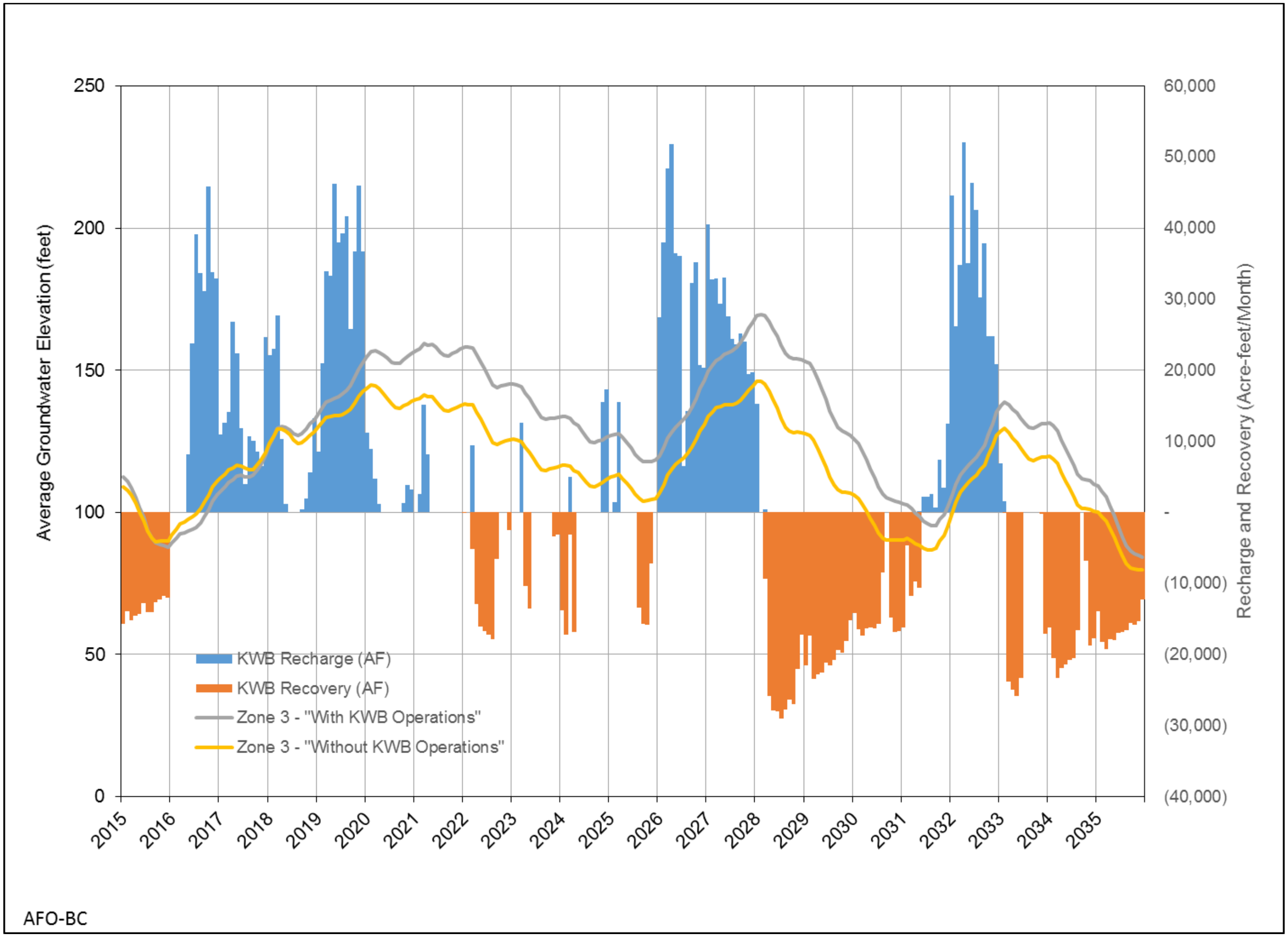


FIGURE 3.4-12c. Analysis of Future Operations under Buildout Conditions: Average Groundwater Elevation Over Zone 3 (2 to 3 Miles Outside the Kern Water Bank Boundary), 2015-2035

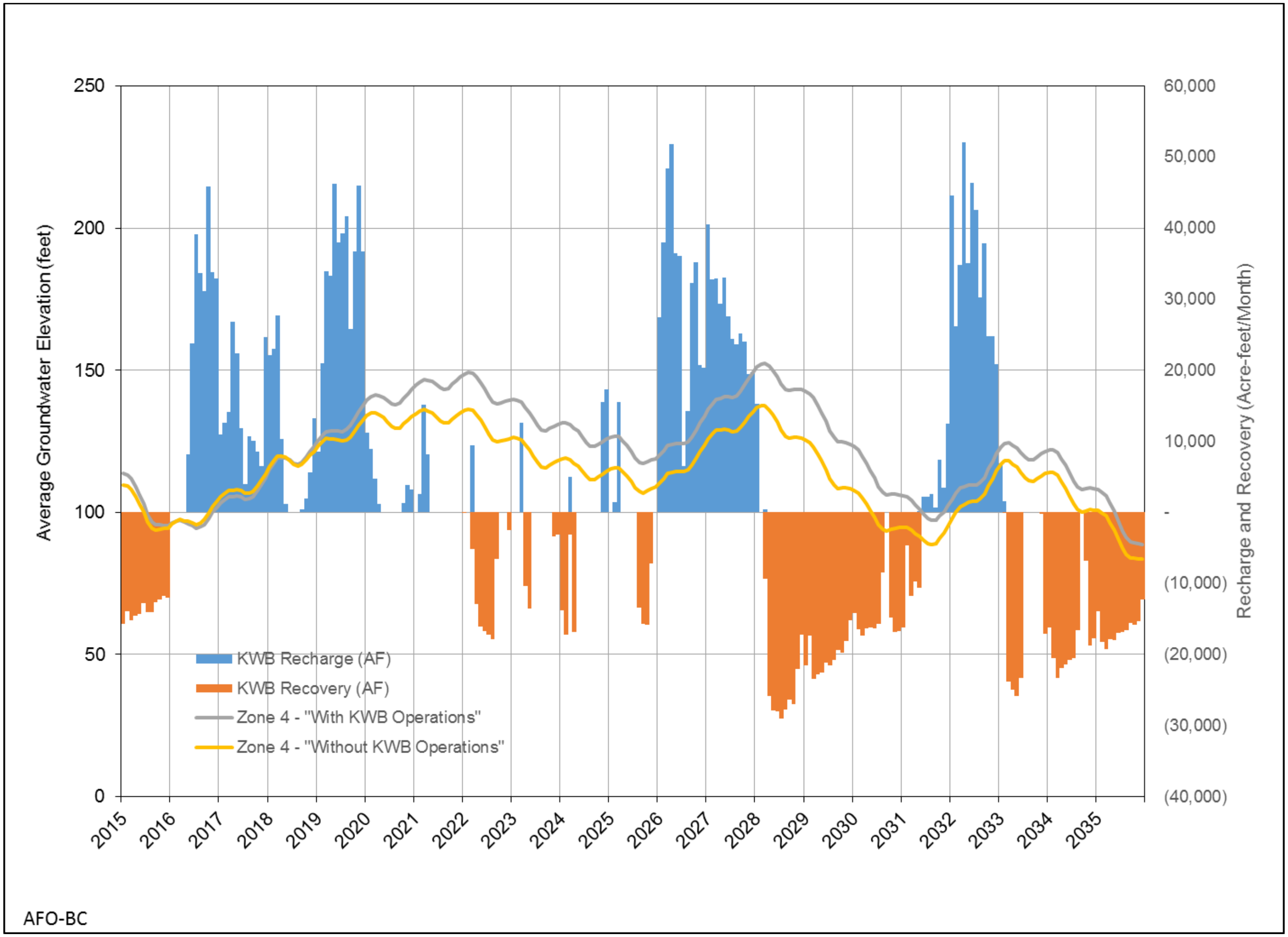


FIGURE 3.4-12d. Analysis of Future Operations under Buildout Conditions: Average Groundwater Elevation Over Zone 4 (3 to 4 Miles Outside the Kern Water Bank Boundary), 2015-2035

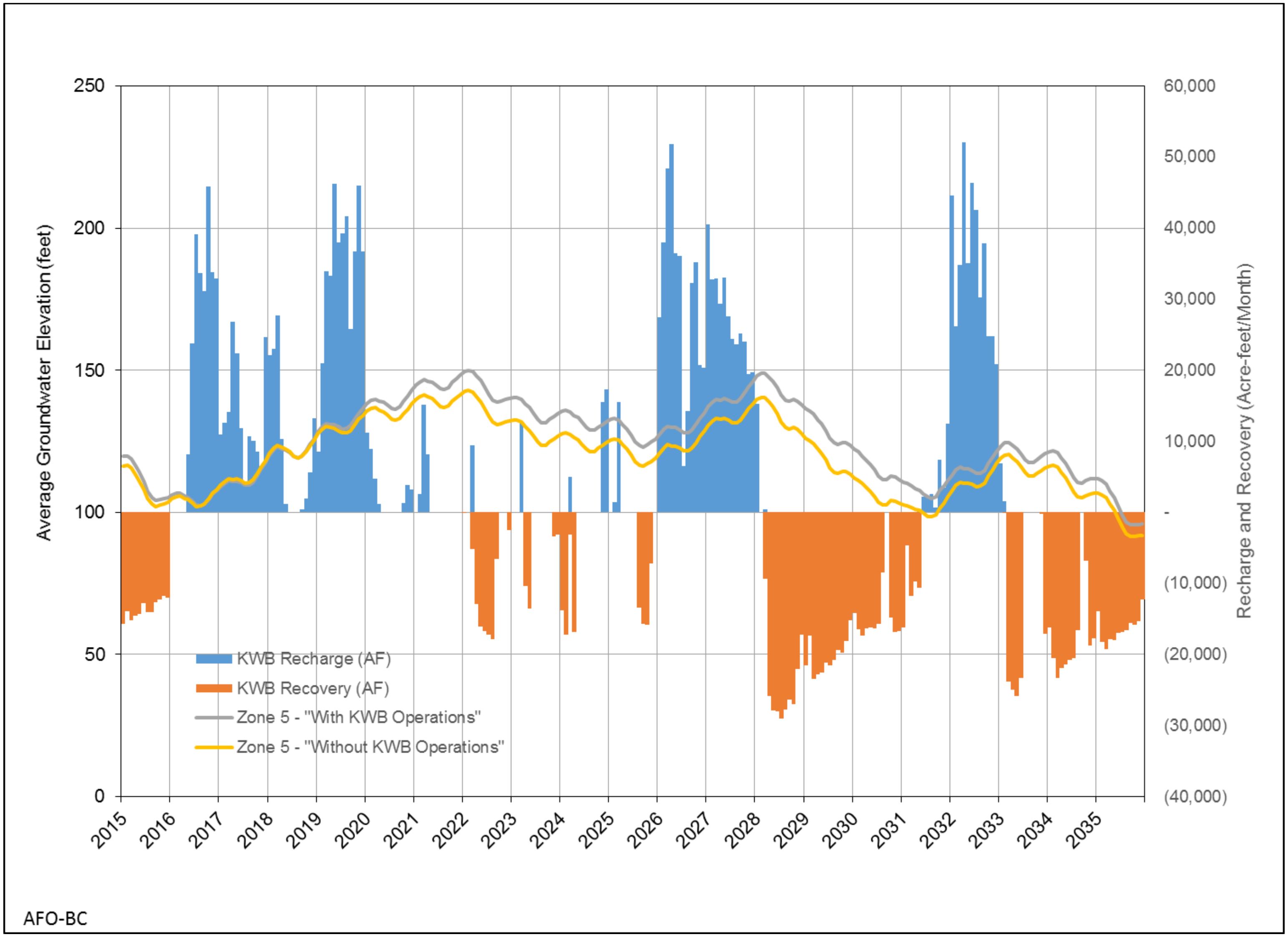


FIGURE 3.4-12e. **Analysis of Future Operations under Buildout Conditions: Average Groundwater Elevation Over Zone 5 (4 to 5 Miles Outside the Kern Water Bank Boundary), 2015-2035**

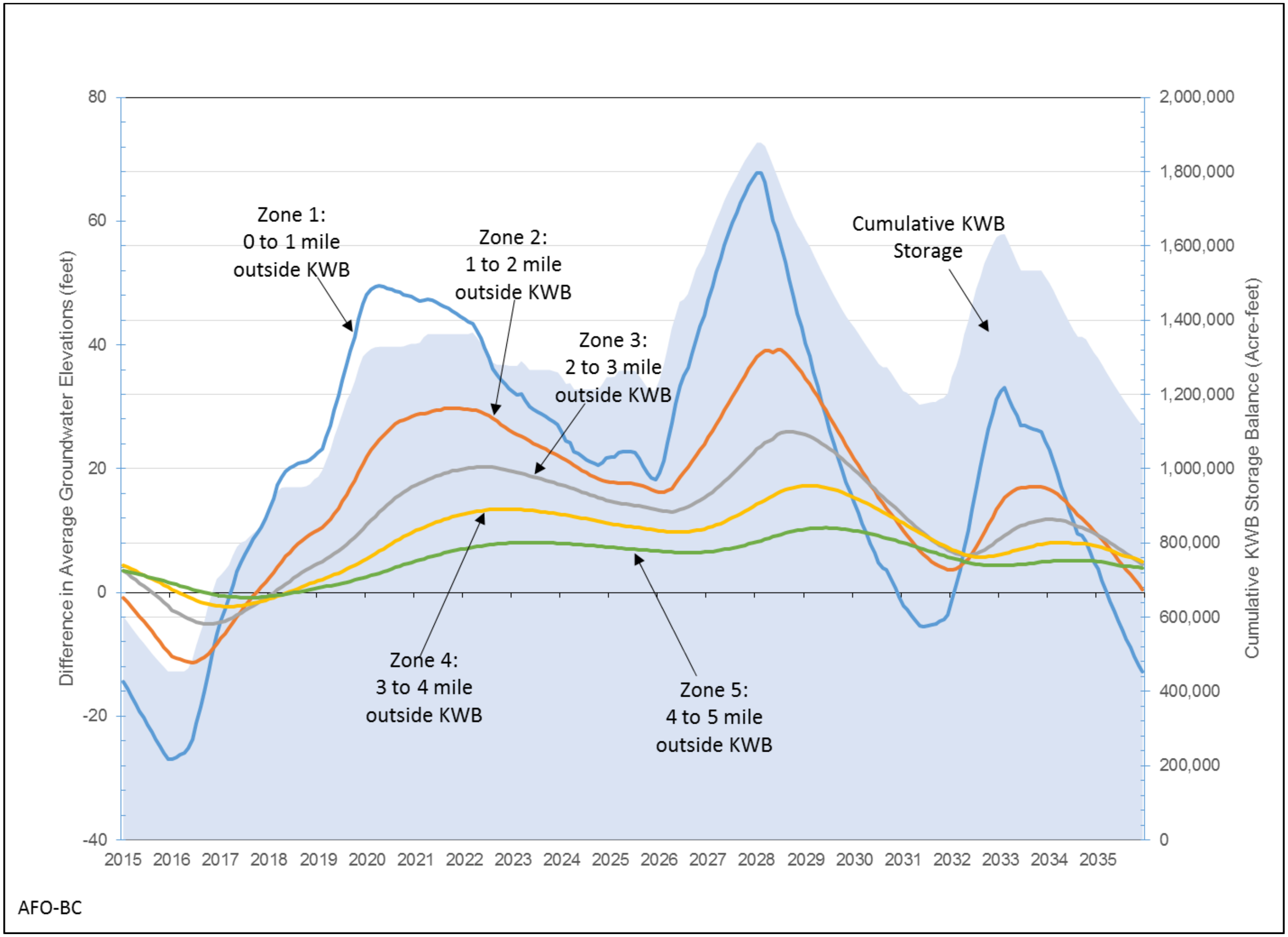


FIGURE 3.4-13. Analysis of Future Operations under Buildout Conditions: Groundwater Elevation Differences in Zones 1 to 5, 2015-2035

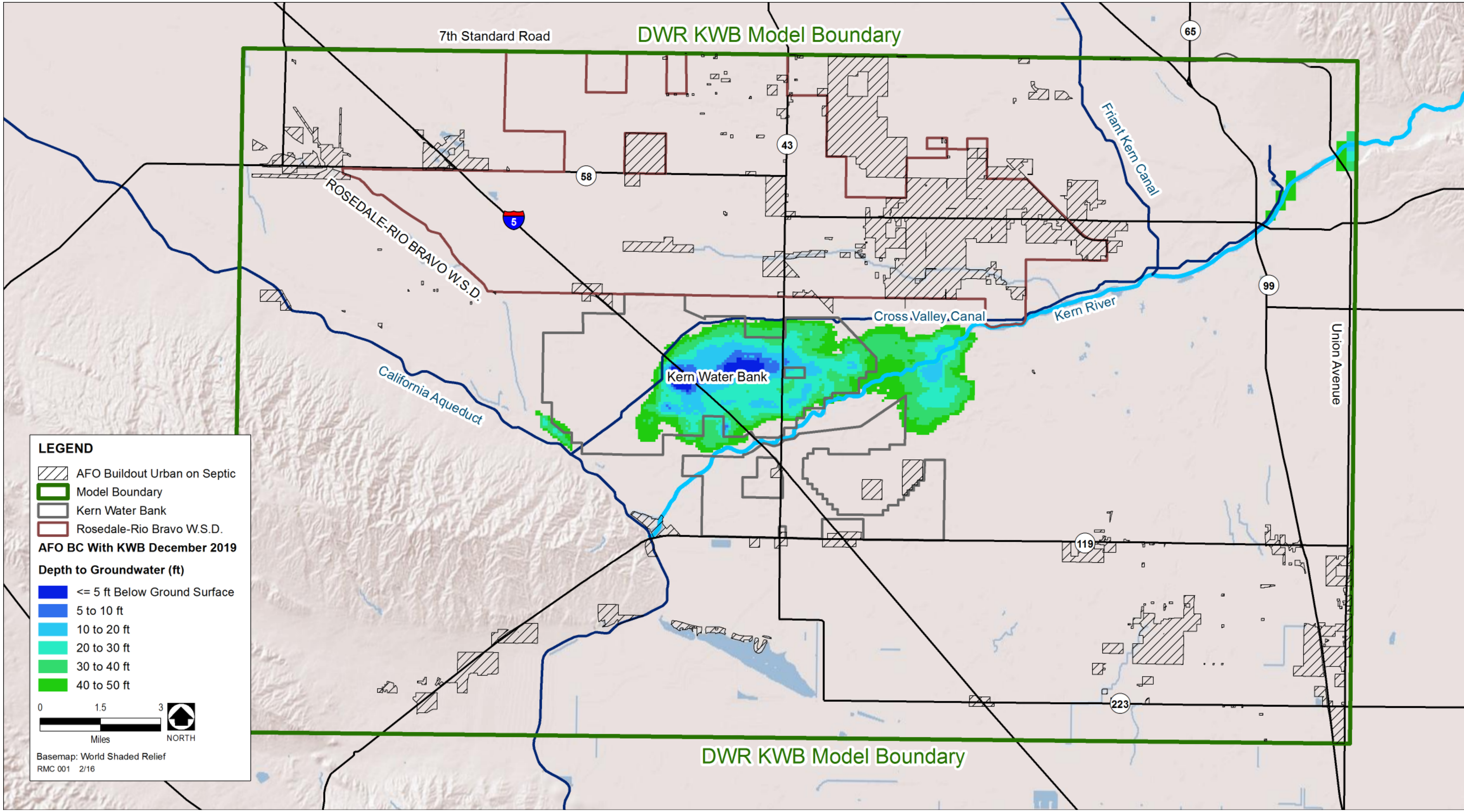


FIGURE 3.4-14. Analysis of Future Operations under Buildout Conditions: Depth-to-Groundwater Contour Map, December 2019

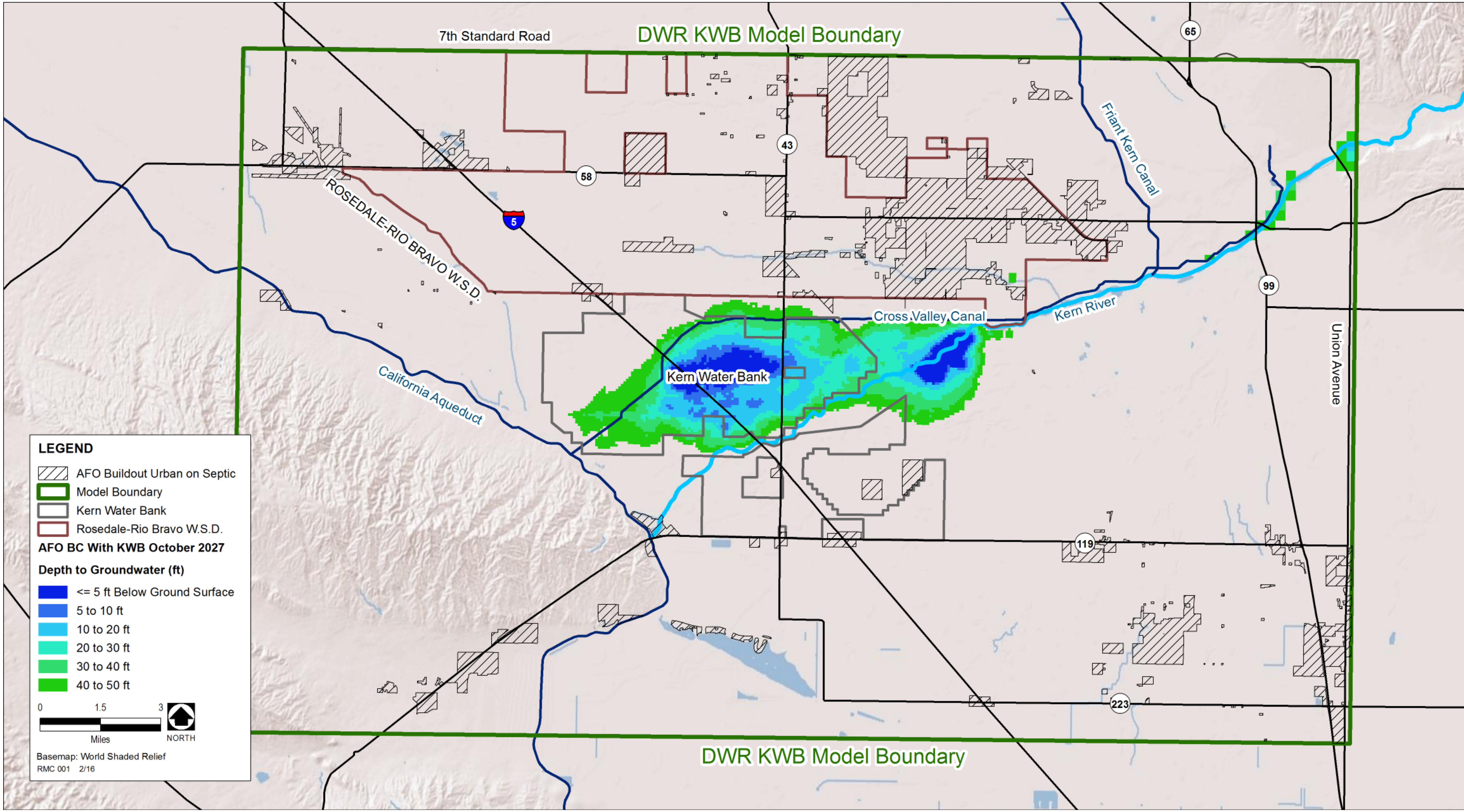


FIGURE 3.4-15. Analysis of Future Operations under Buildout Conditions: Depth-to-Groundwater Contour Map, October 2027

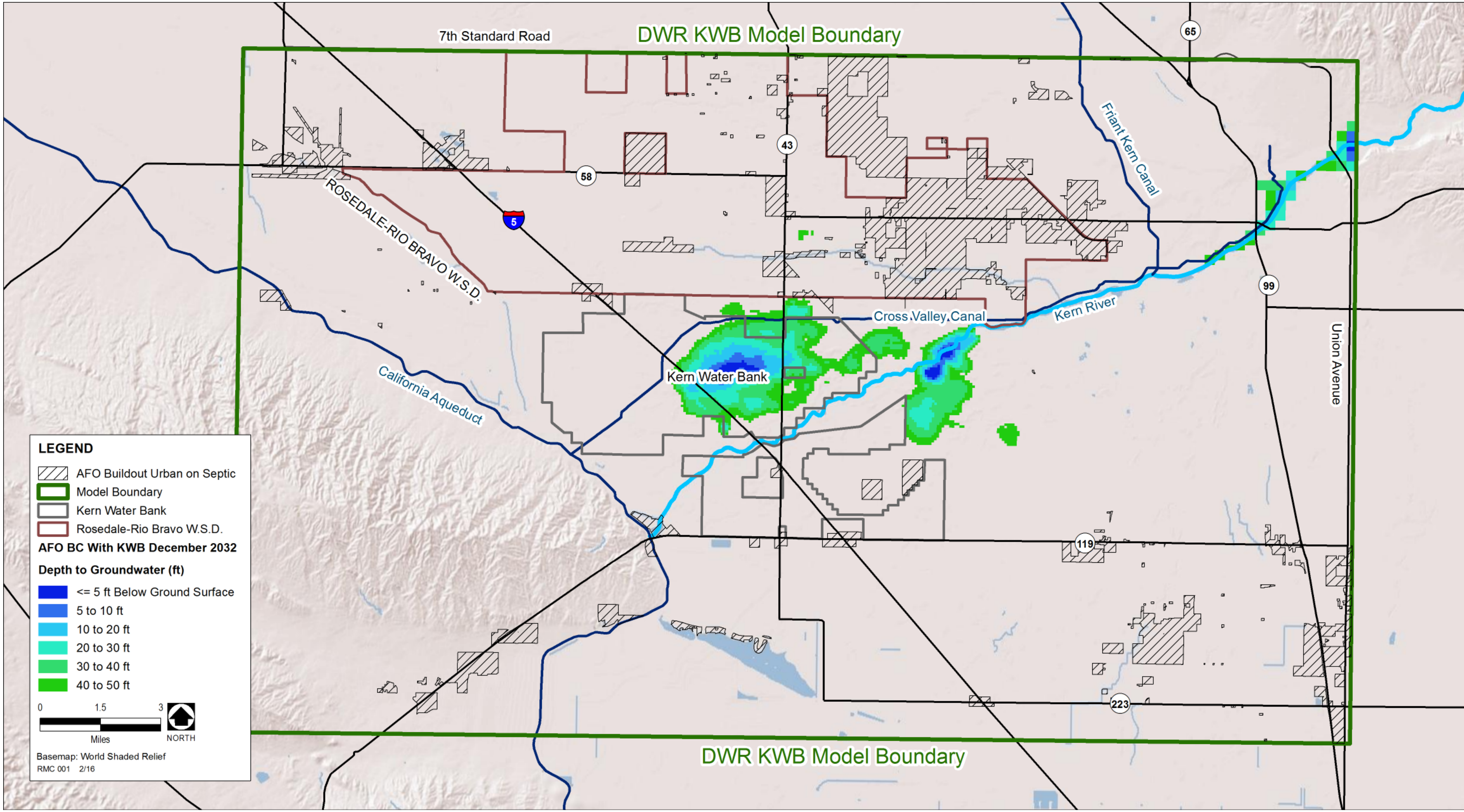
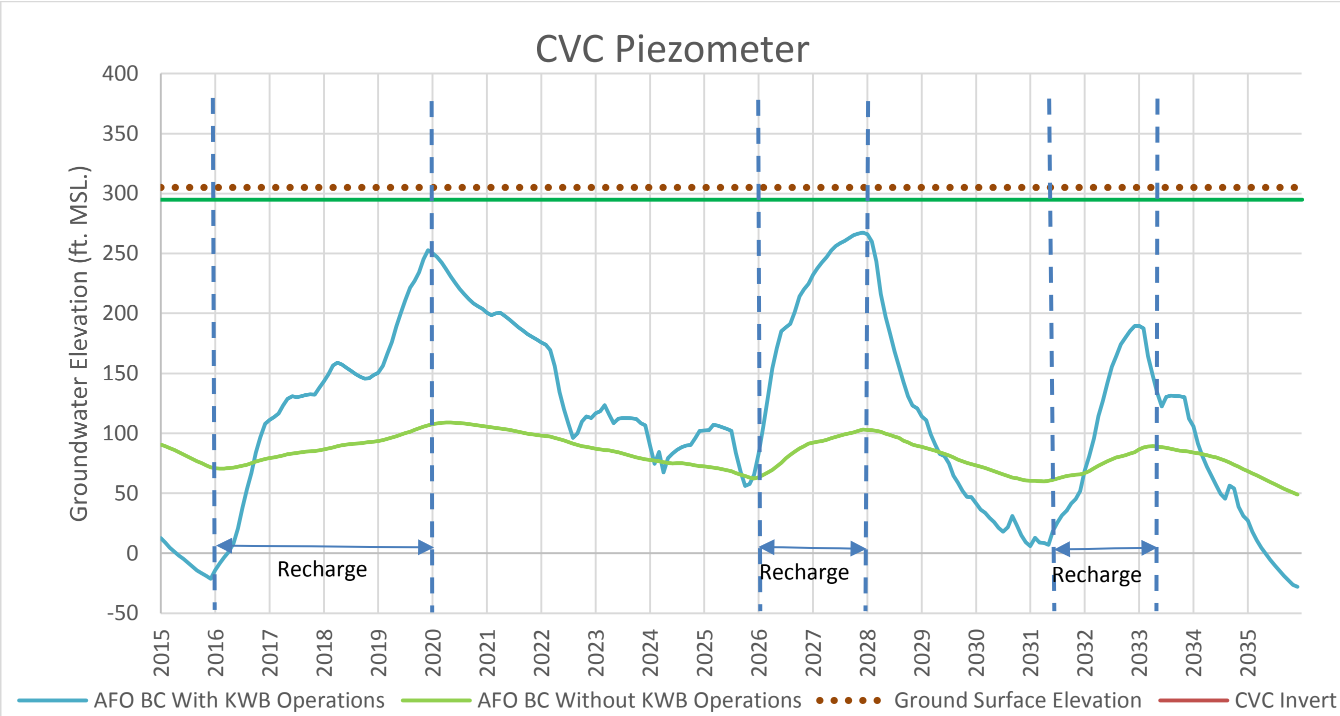


FIGURE 3.4-16. Analysis of Future Operations under Buildout Conditions: Depth- to-Groundwater Contour Map, December 2032



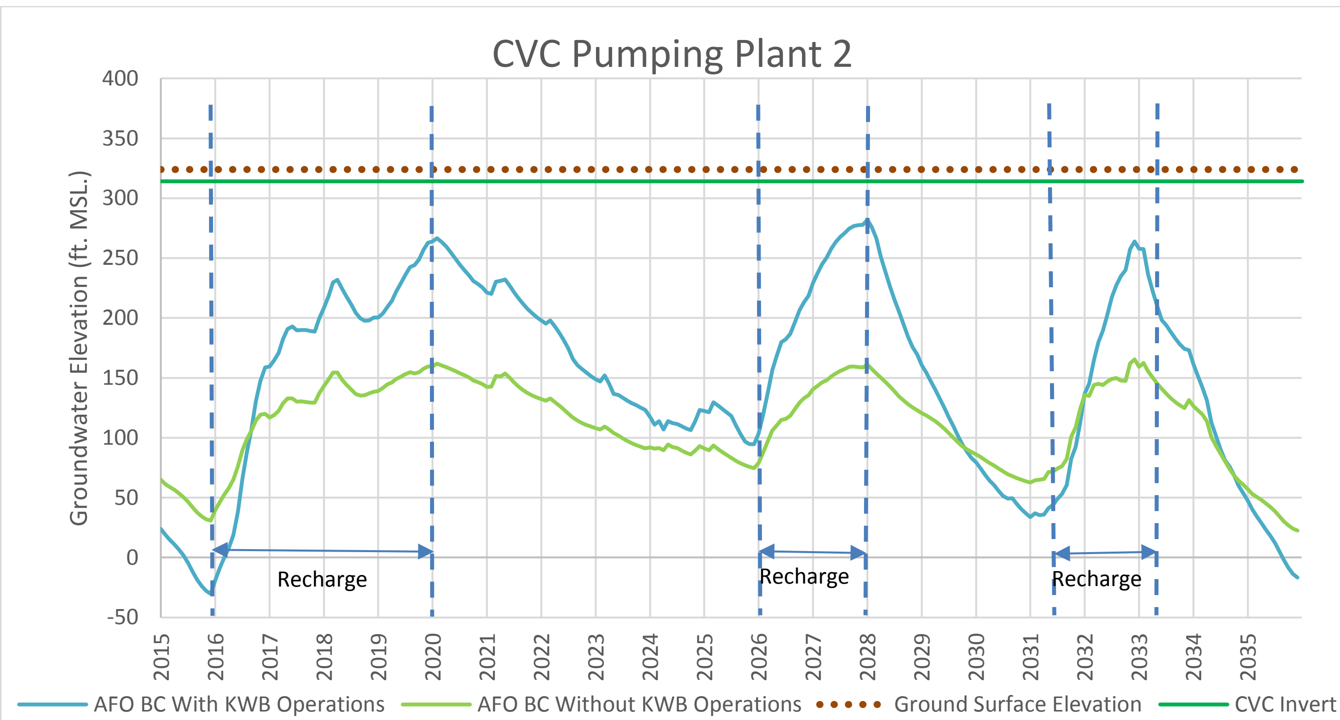
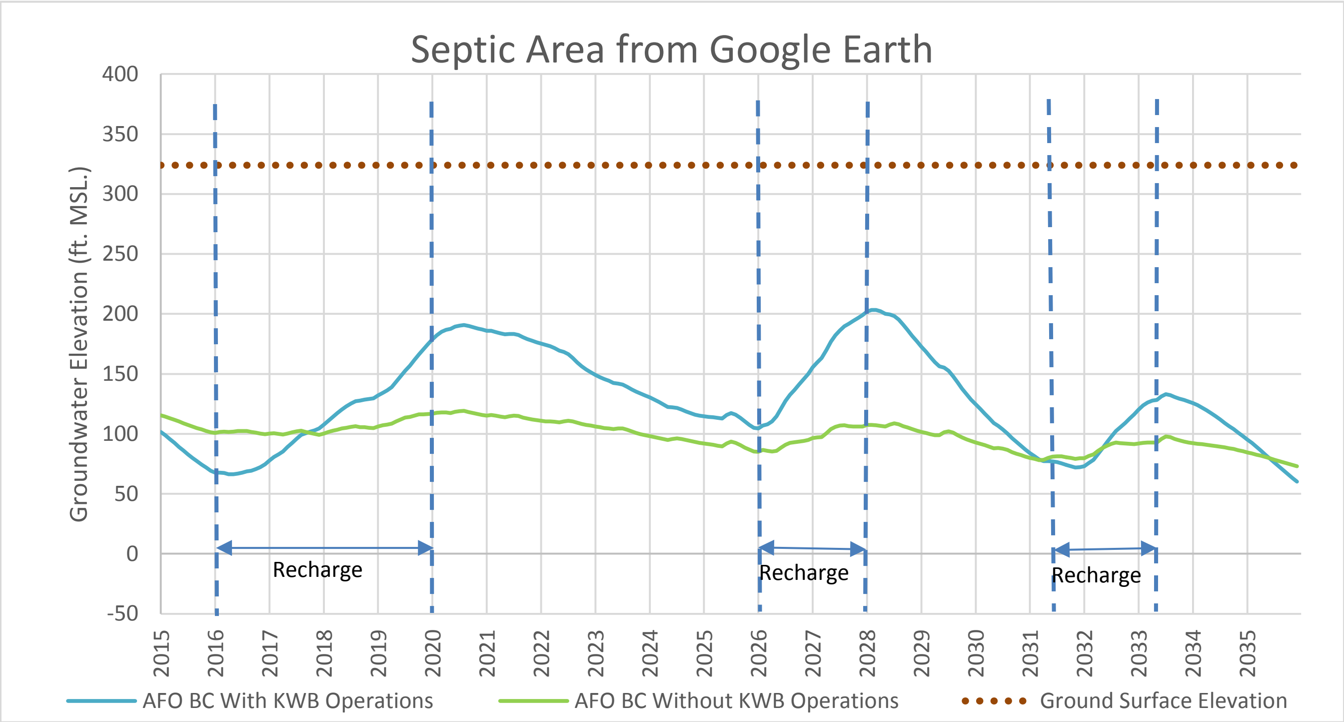


FIGURE 3.4-17. Groundwater Elevation Hydrographs at Selected Locations along the CVC for AFO-BC Scenario, 2015-2035



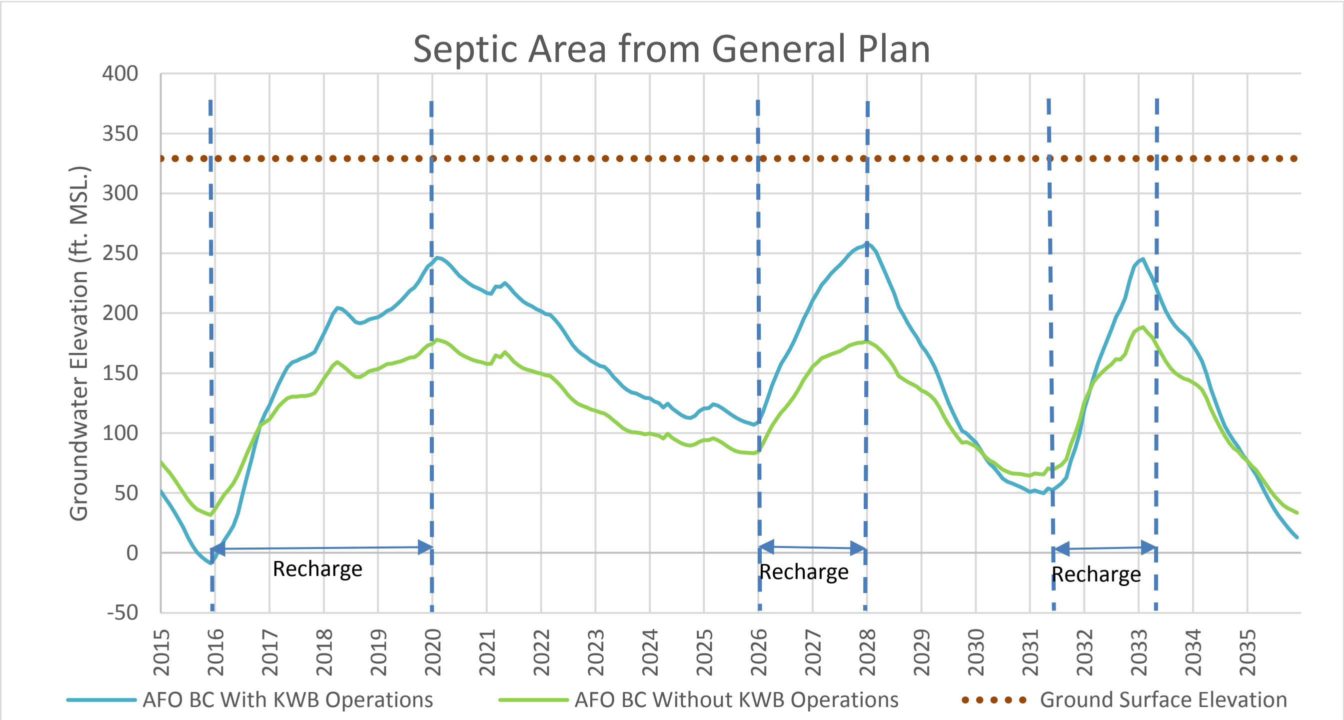


FIGURE 3.4-18. Groundwater Elevation Hydrographs at Selected Areas on Septic Systems for AFO-BC Scenario, 2015-2035

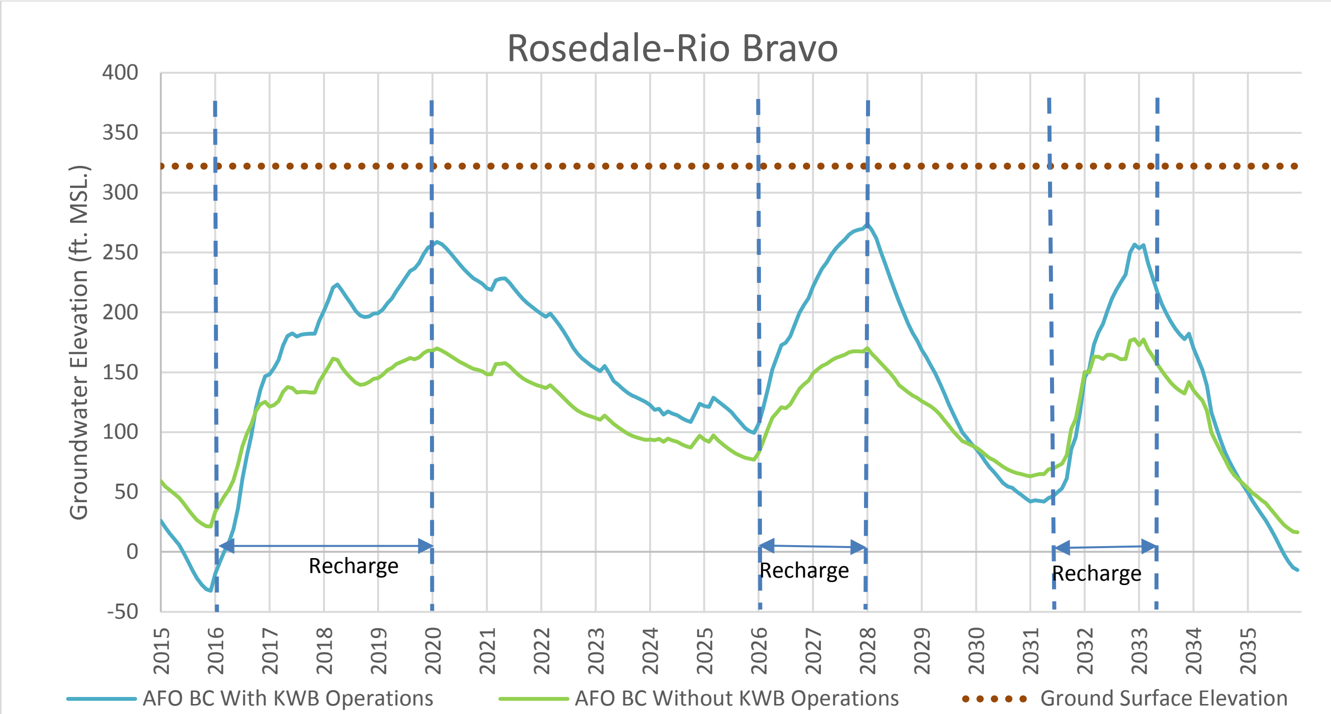


FIGURE 3.4-19a. Groundwater Elevation Hydrographs at Rosedale-Rio Bravo Recharge Pond for AFO-BC, 2015-2035

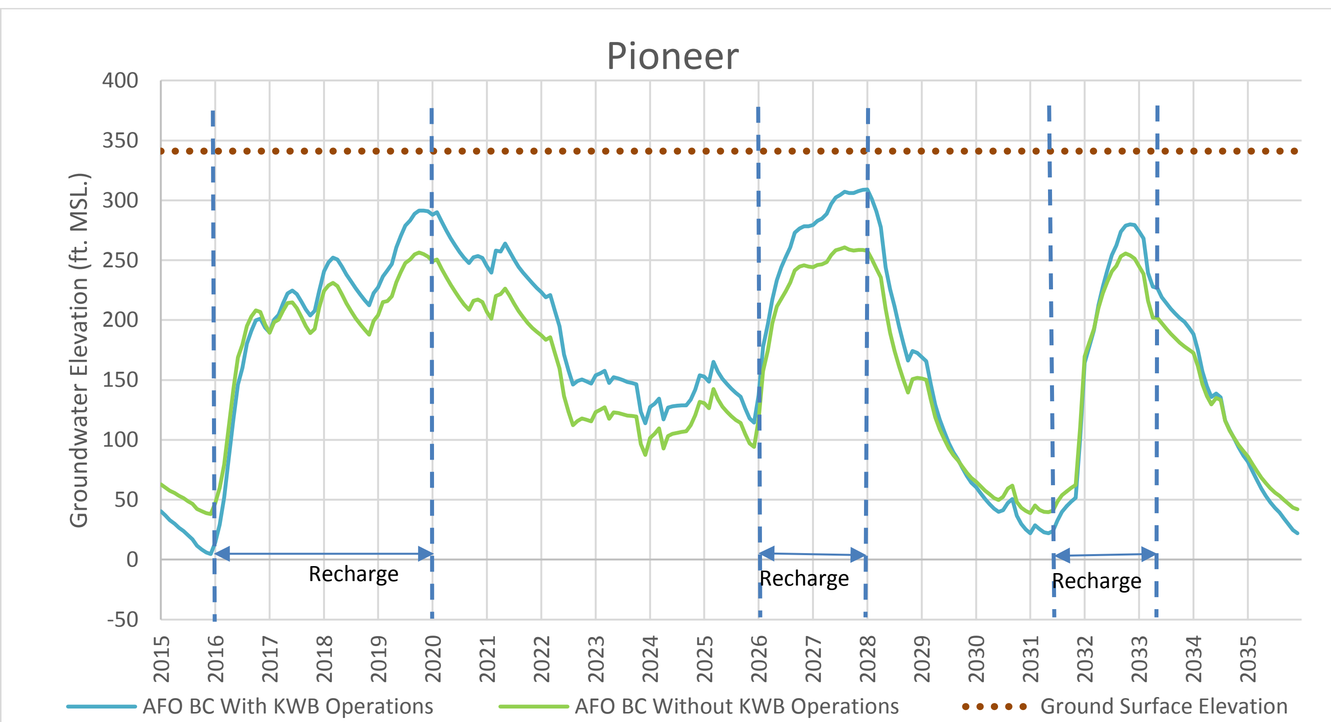


FIGURE 3.4-19b. Groundwater Elevation Hydrographs at Pioneer Recharge Pond for AFO-BC, 2015-2035

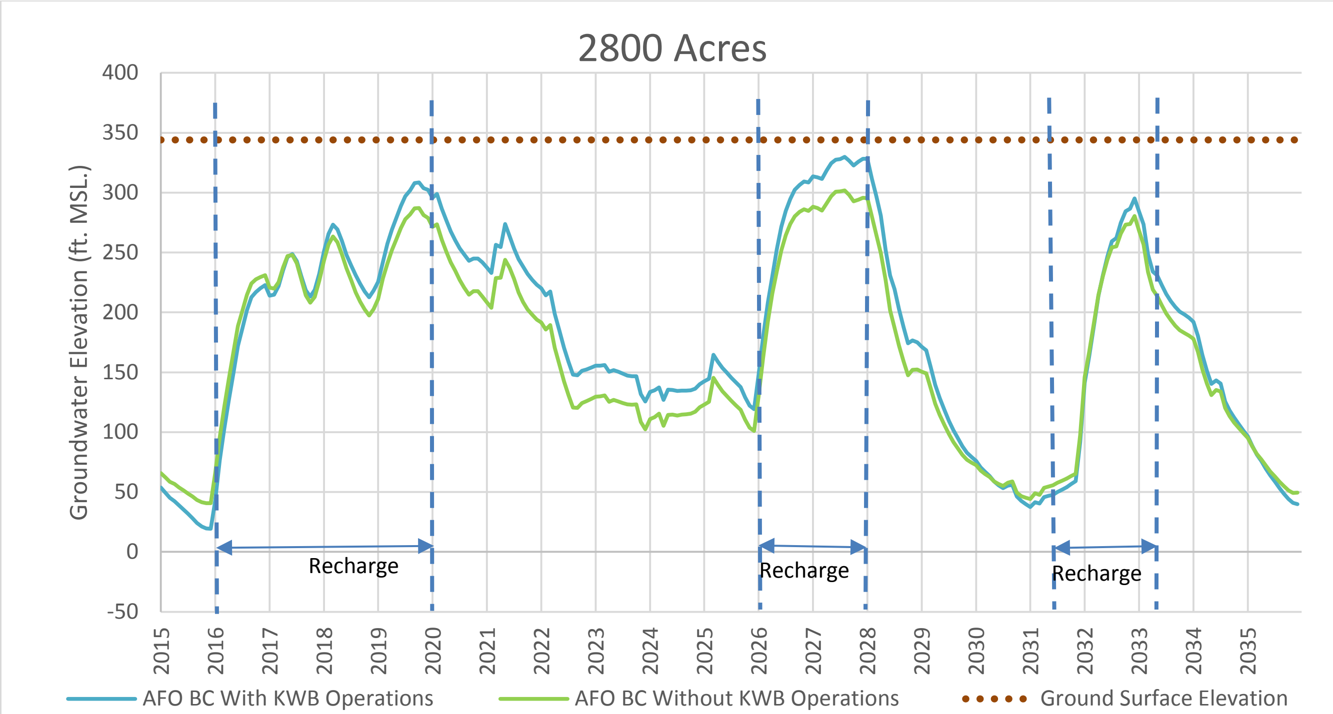


FIGURE 3.4-19c. **Groundwater Elevation Hydrographs at 2800 Acres Recharge Pond for AFO-BC, 2015-2035**

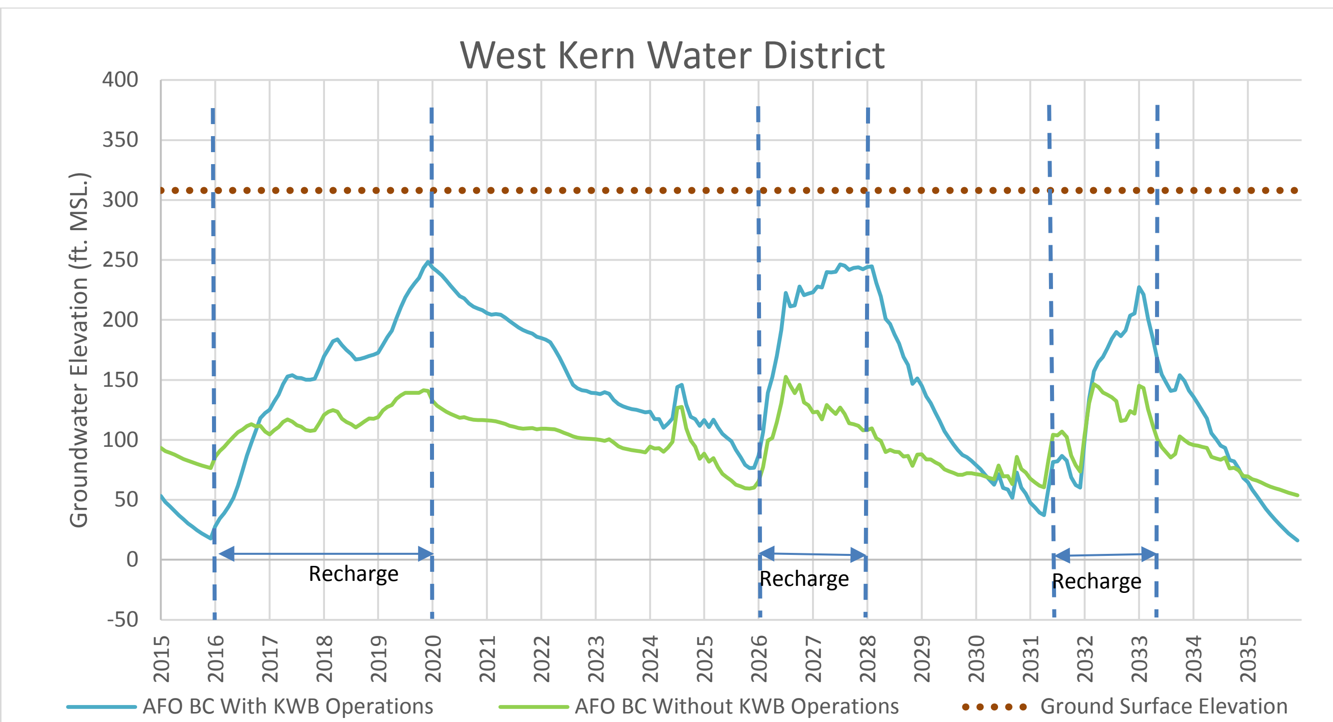


FIGURE 3.4-19d. **Groundwater Elevation Hydrographs at West Kern Water District Recharge Pond for AFO-BC, 2015-2035**

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APPENDIX 7-2
A. APO HYDROGRAPHS

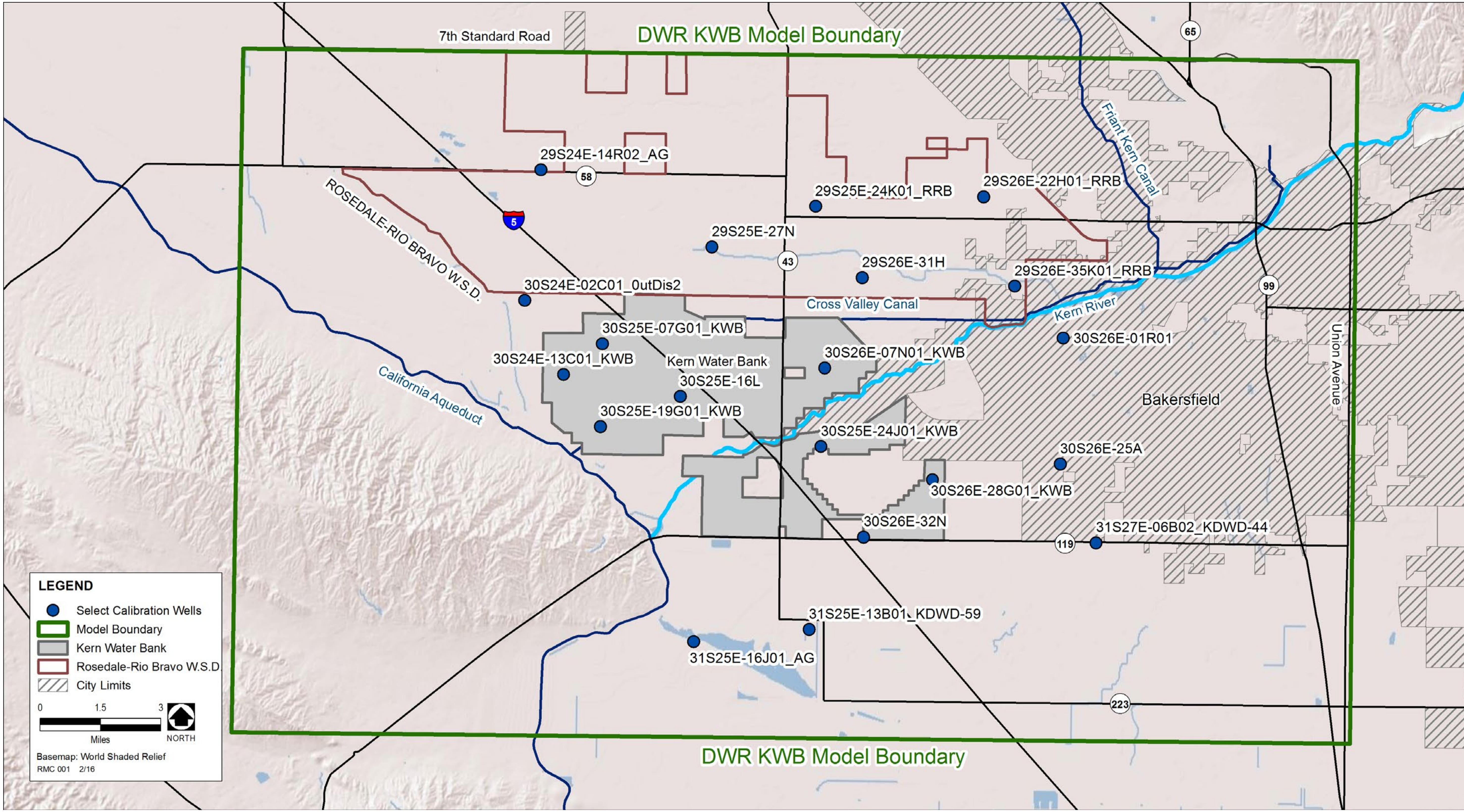

FIGURE 7-2 A.1. Location of Select Monitoring Wells Inside (14 Wells) and Outside (17 Wells) of Kern Water Bank

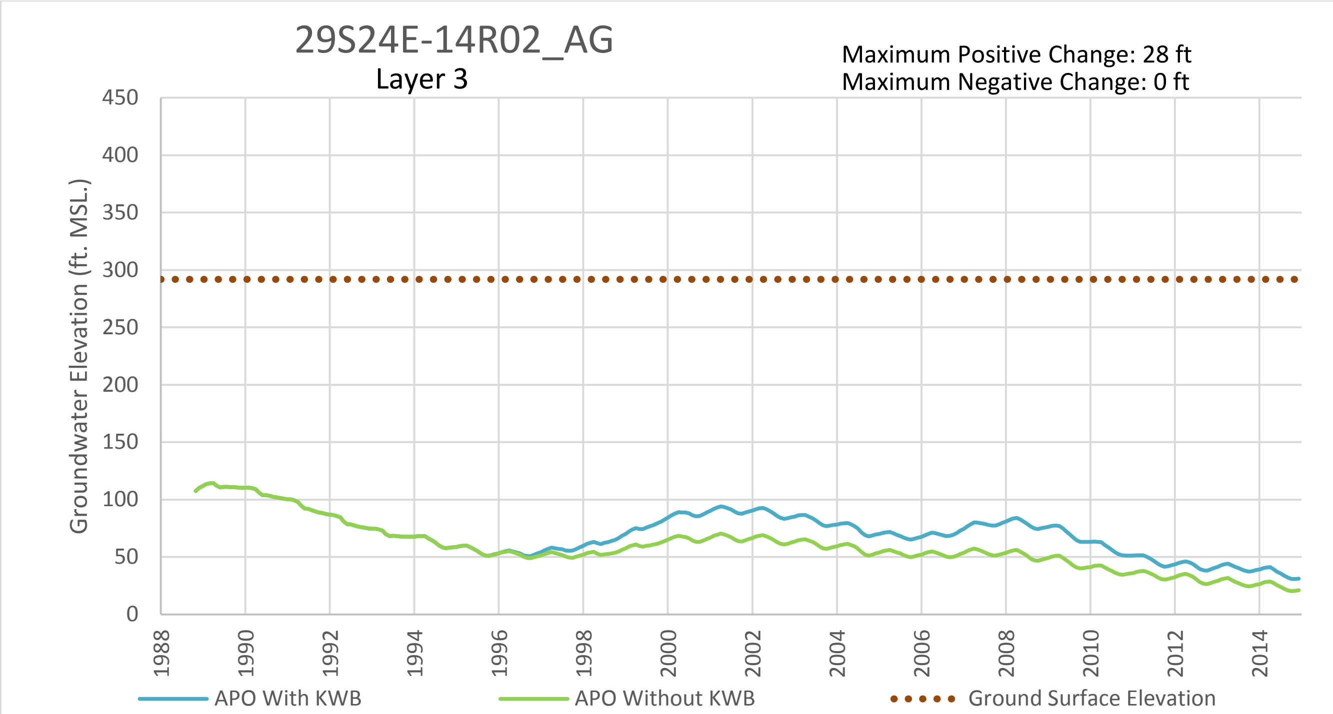

FIGURE 7-2 A.2 Hydrograph of Simulated Water Levels at Monitoring Well 29S24E14R02_Ag, 1988-2014

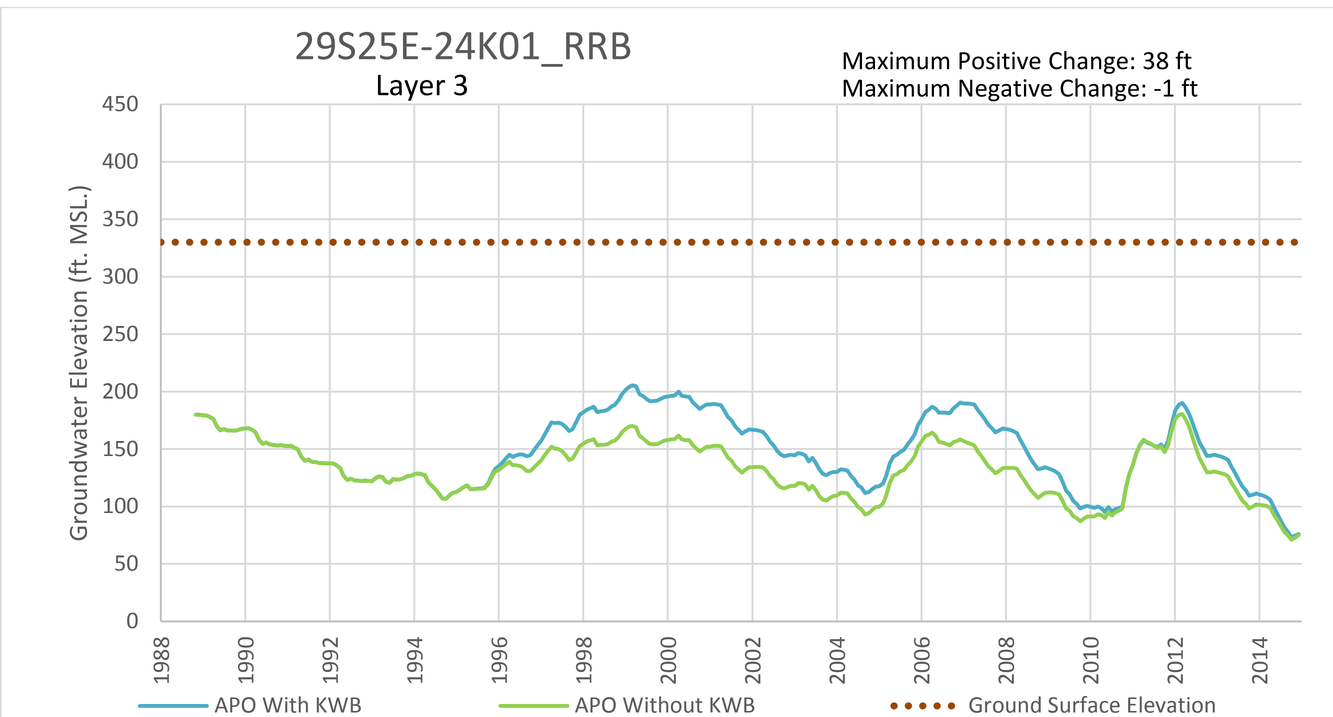

FIGURE 7-2 A.3. Hydrograph of Simulated Water Levels at Monitoring Well 29S257-24K01_RRB, 1988-2014

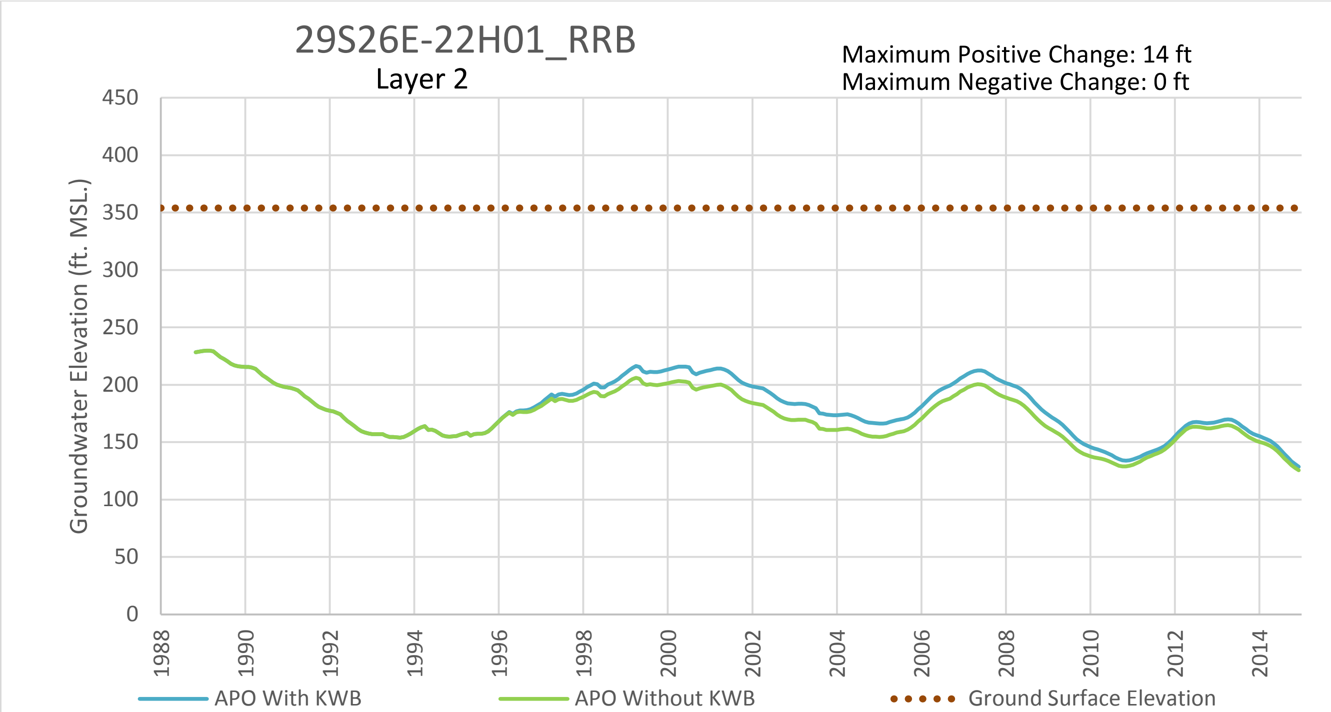

FIGURE 7-2 A.4. Hydrograph of Simulated Water Levels at Monitoring Well 29S267-22H01_RRB, 1988-2014

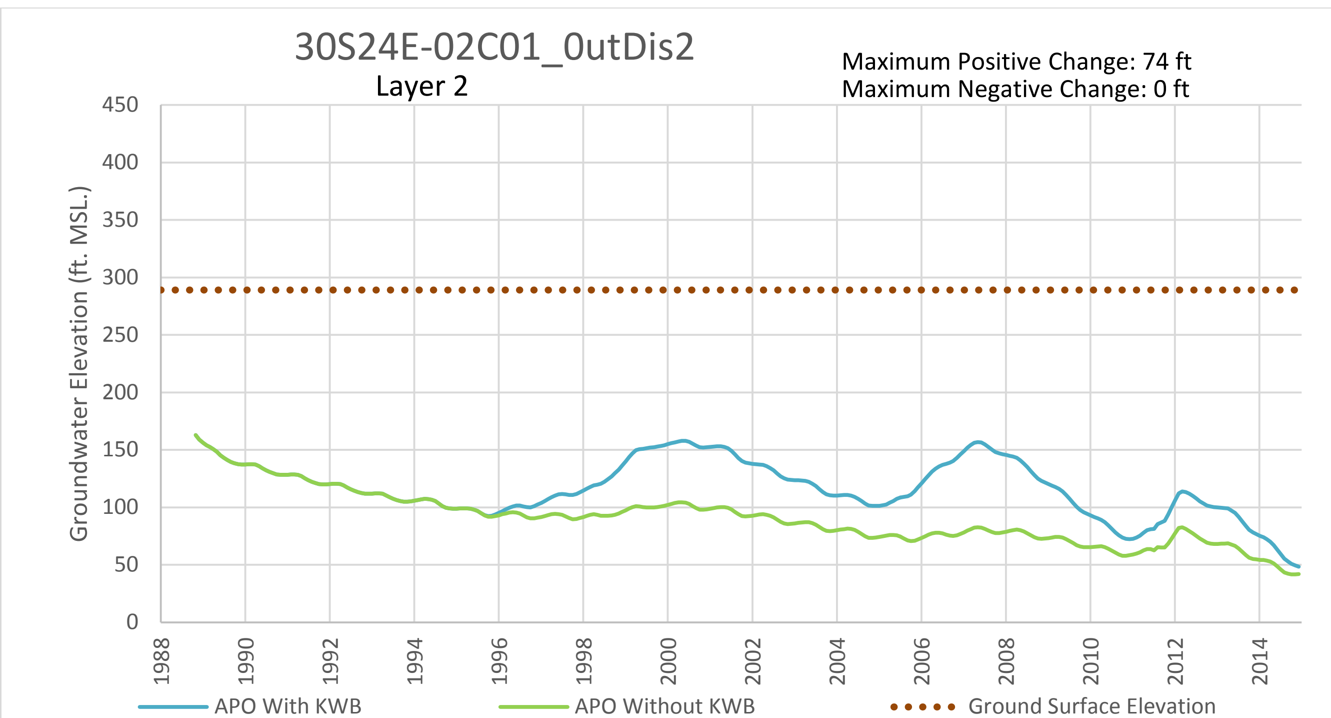

FIGURE 7-2 A.5. Hydrograph of Simulated Water Levels at Monitoring Well 30S24E-02C01_0utDis2, 1988-2014

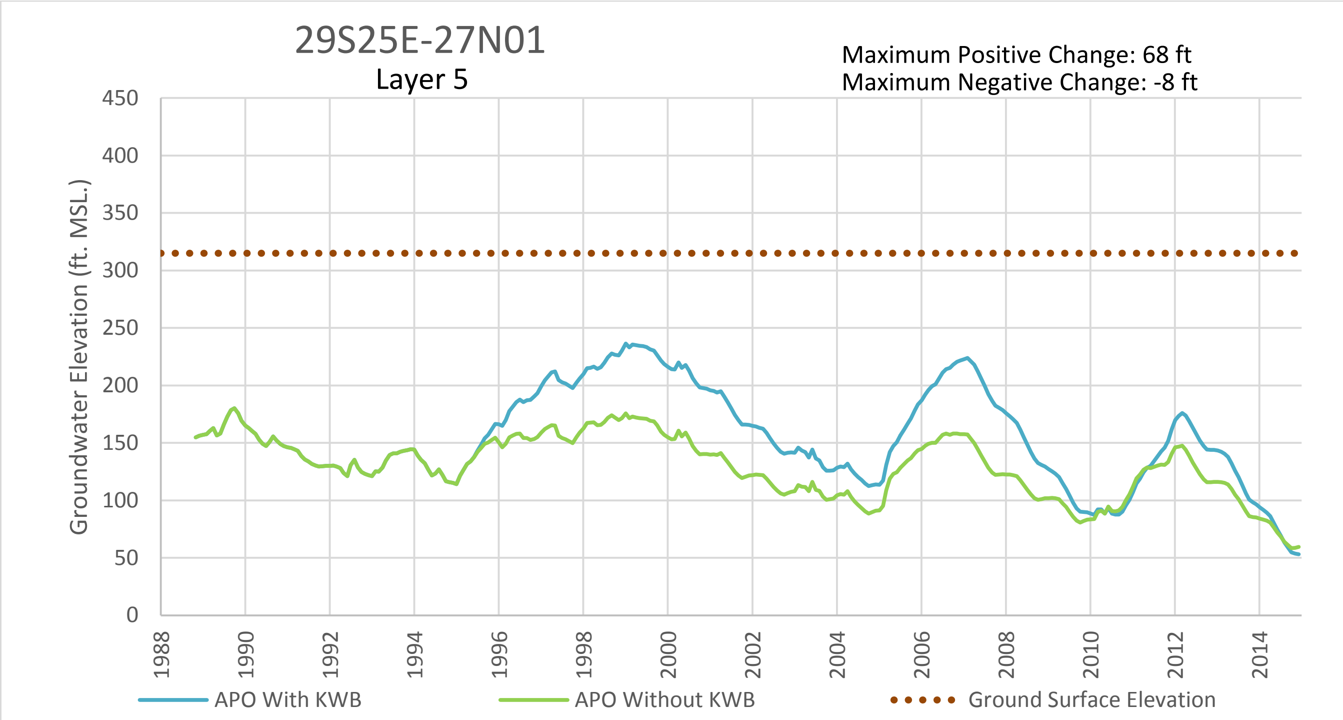

FIGURE 7-2 A.6. **Hydrograph of Simulated Water Levels at Monitoring Well 29S257-27N01, 1988-2014**

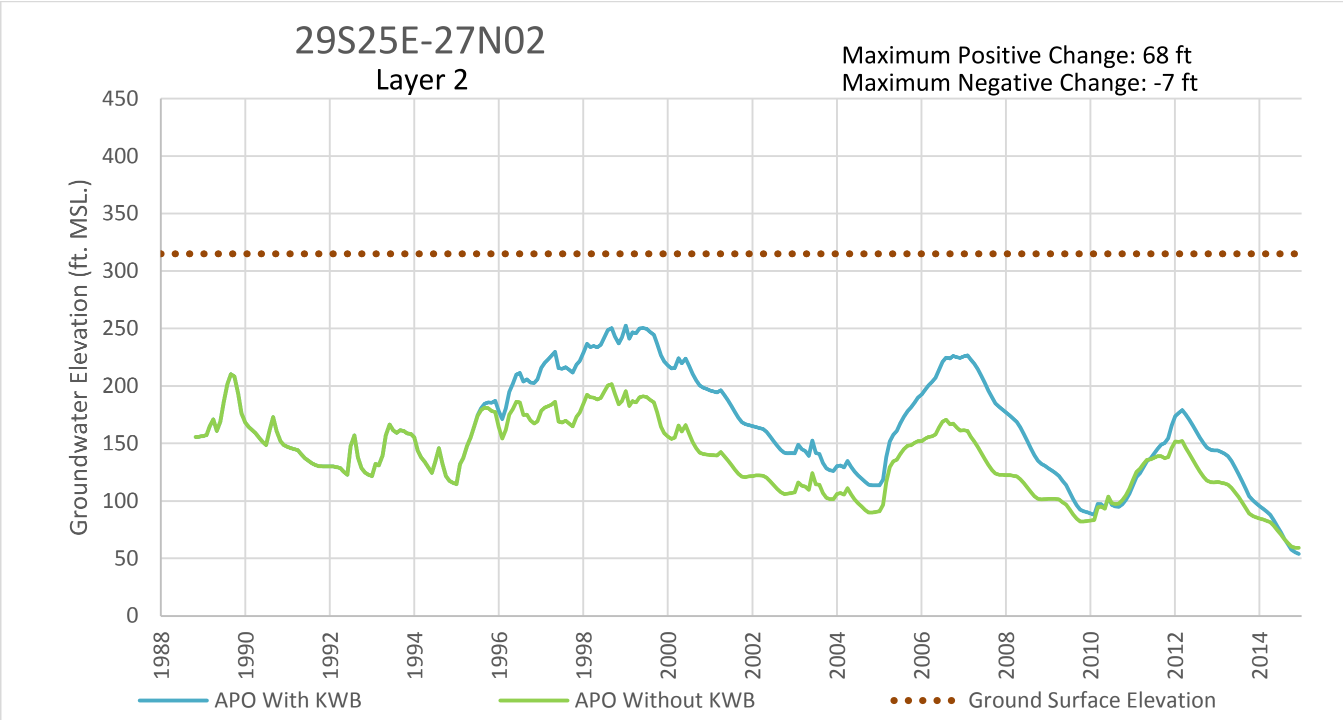

FIGURE 7-2 A.7. **Hydrograph of Simulated Water Levels at Monitoring Well 29S257-27N02, 1988-2014**

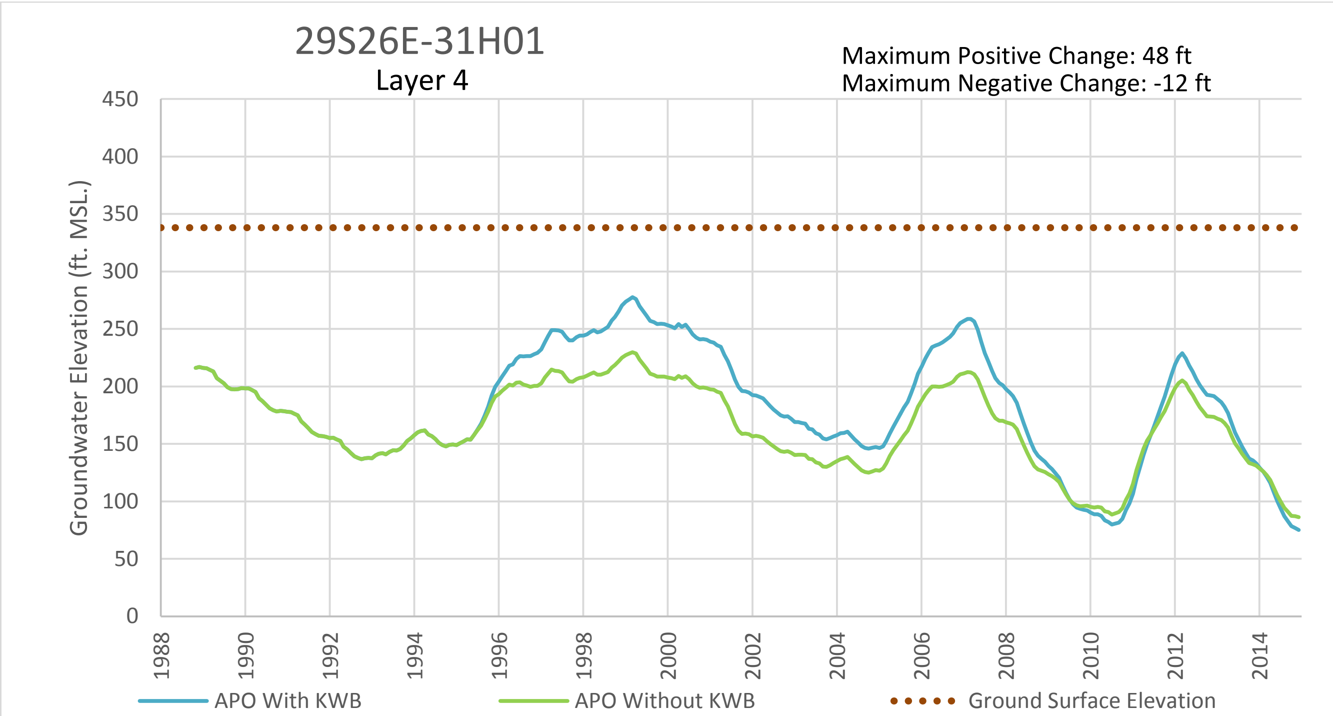

FIGURE 7-2 A.8. Hydrograph of Simulated Water Levels at Monitoring Well 29S26E-31H01, 1988-2014

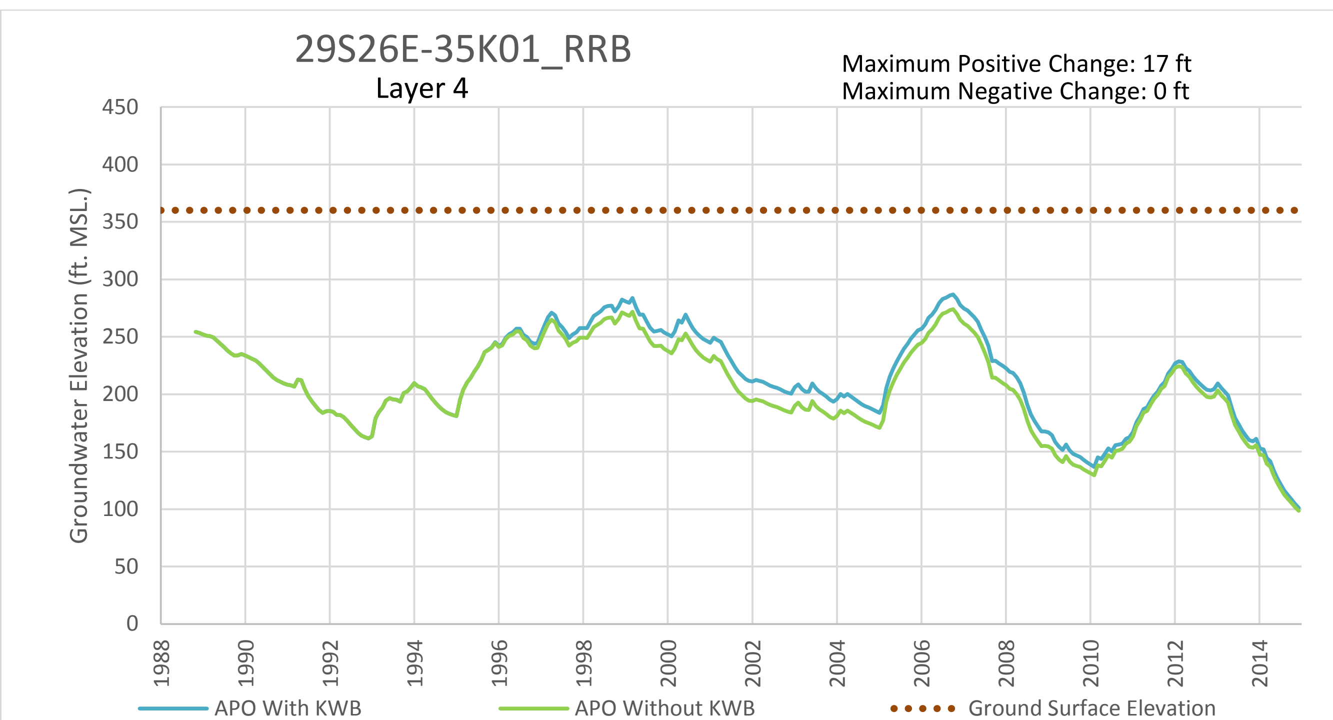

FIGURE 7-2 A.9. Hydrograph of Simulated Water Levels at Monitoring Well 29S26E-35K01_RRB, 1988-2014

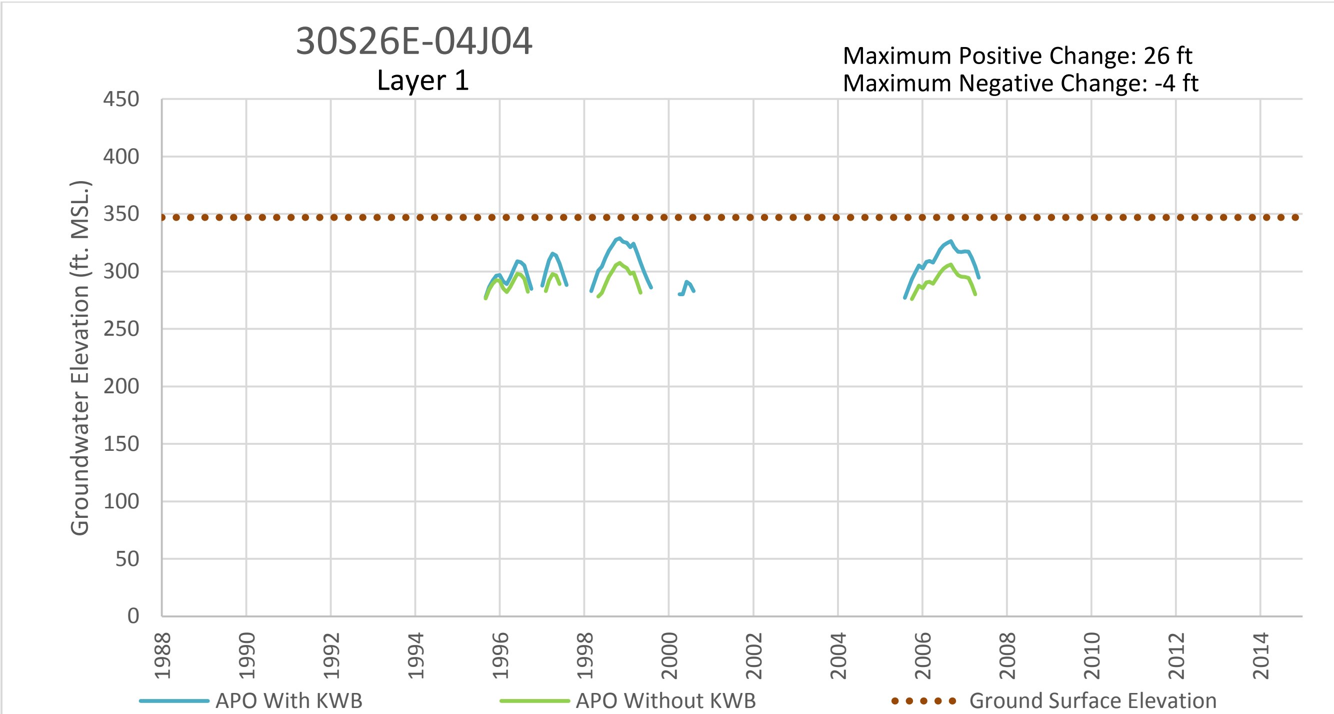

FIGURE 7-2 A.10. Hydrograph of Simulated Water Levels at Monitoring Well 30S26E-04J04, 1988-2014

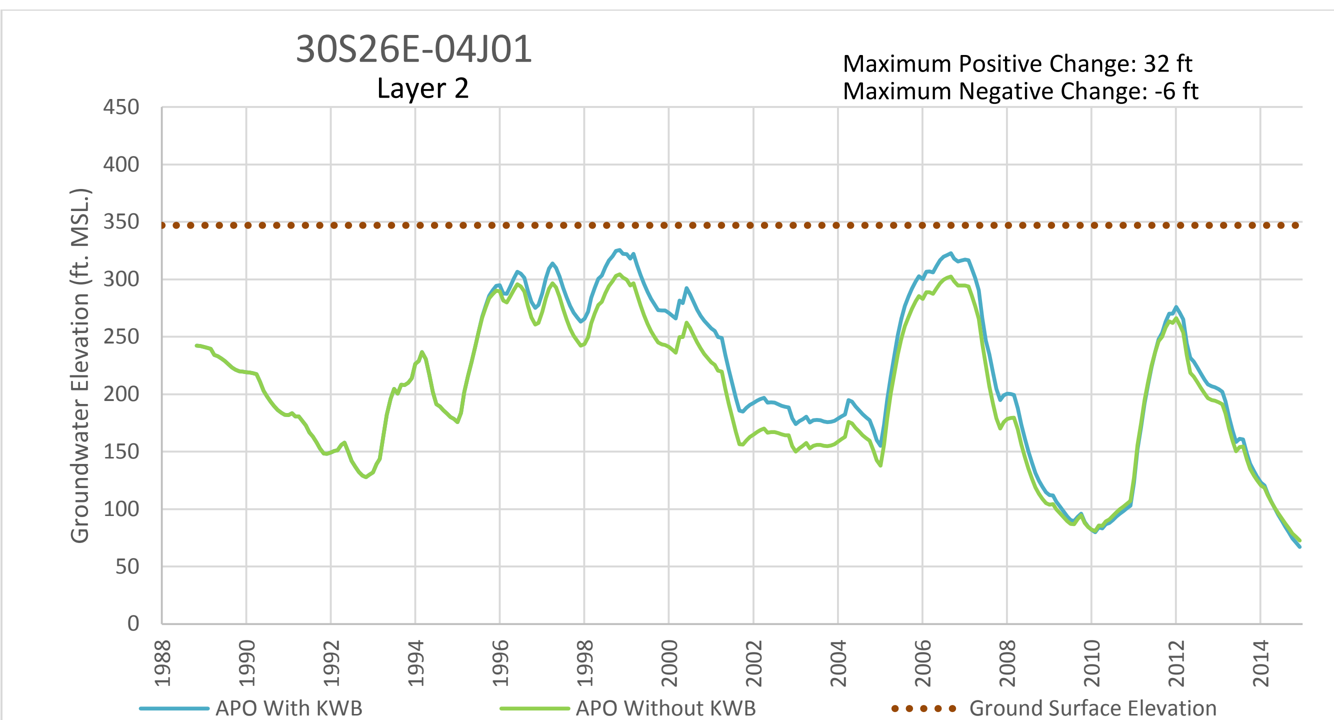

FIGURE 7-2 A.11. Hydrograph of Simulated Water Levels at Monitoring Well 30S26E-04J01, 1988-2014

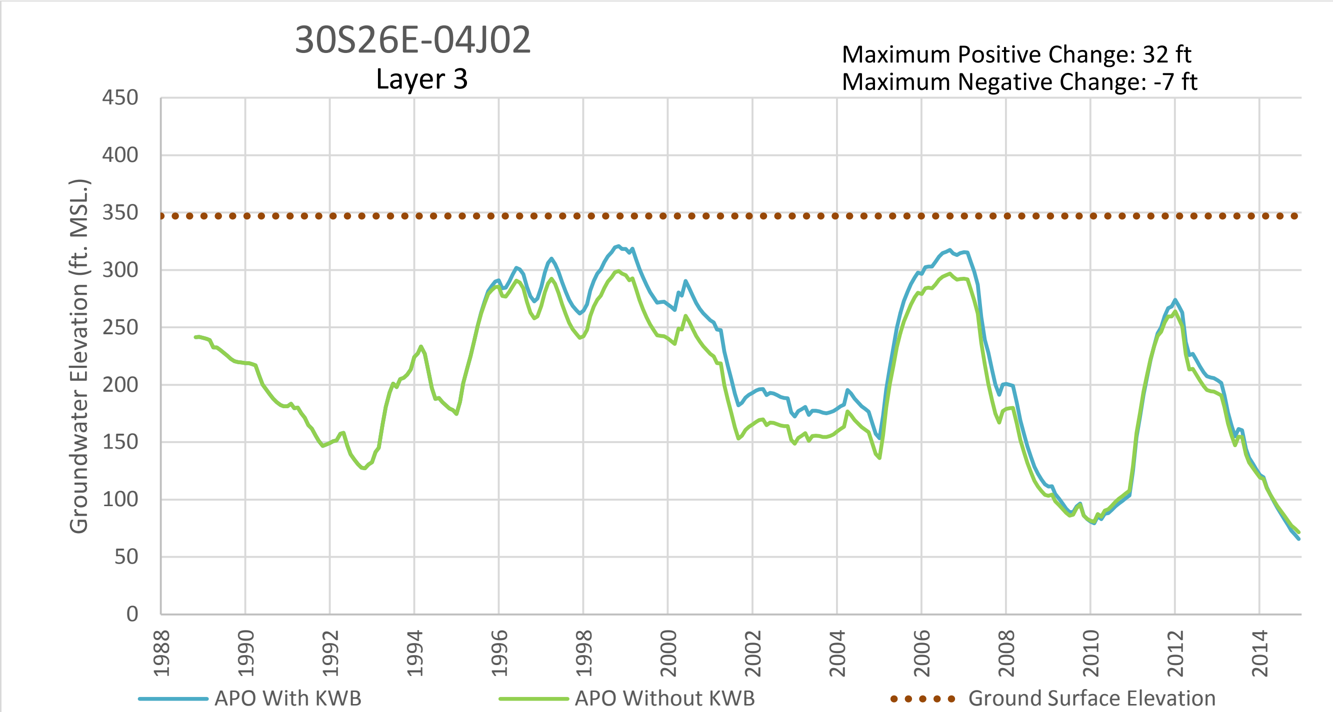

FIGURE 7-2 A.12. Hydrograph of Simulated Water Levels at Monitoring Well 30S26E-04J02, 1988-2014

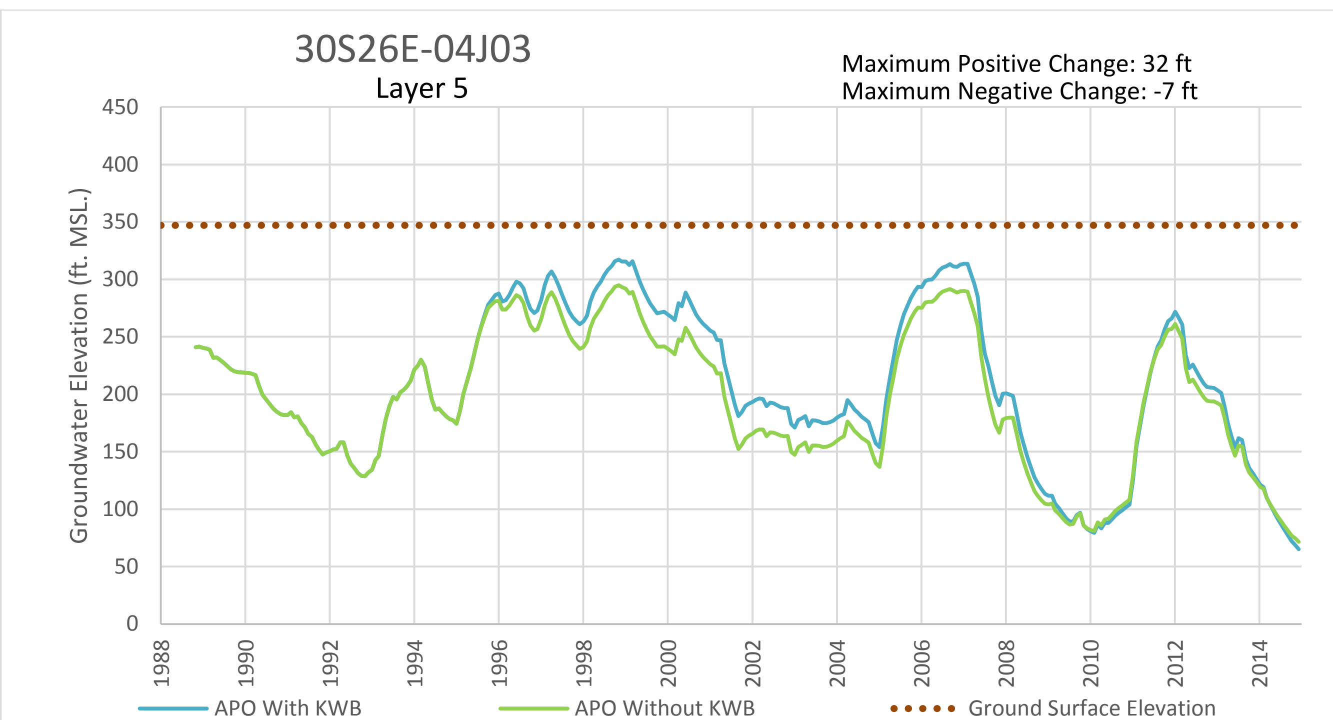

FIGURE 7-2 A.13. Hydrograph of Simulated Water Levels at Monitoring Well 30S26E-04J03, 1988-2014

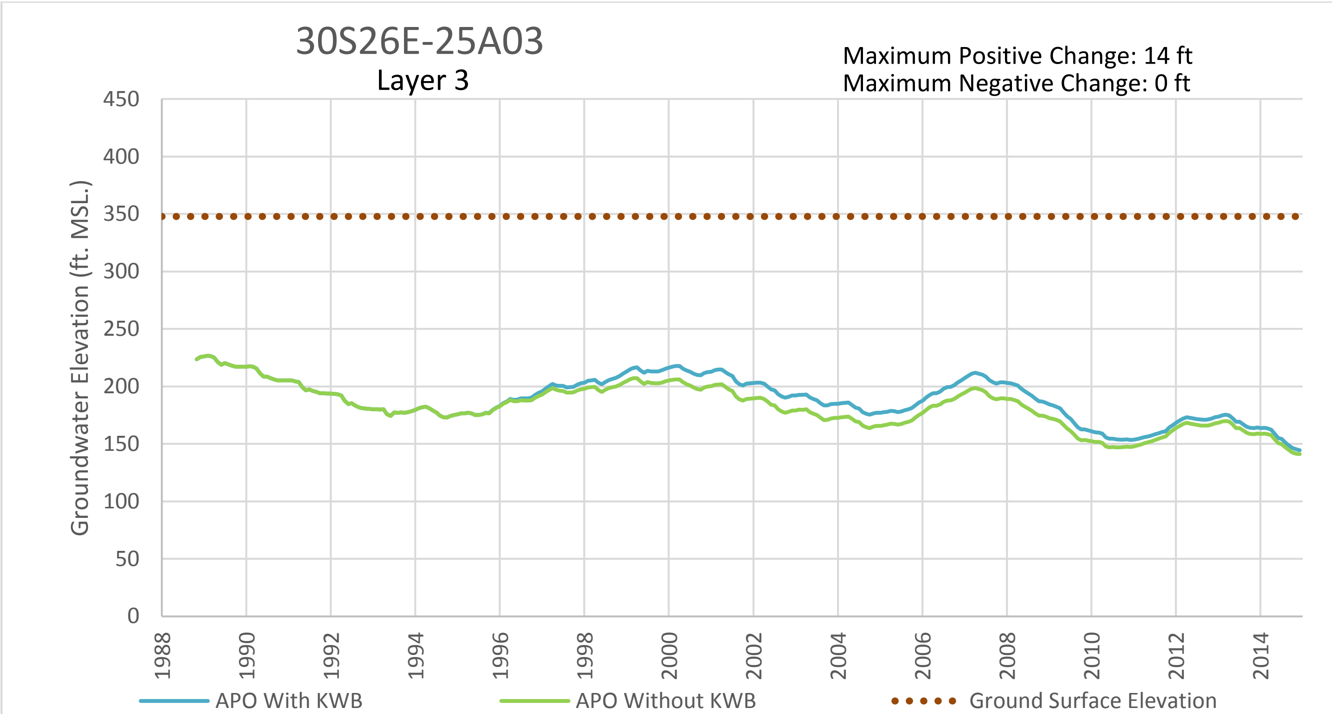

FIGURE 7-2 A.14. Hydrograph of Simulated Water Levels at Monitoring Well 30S267-25A03, 1988-2014

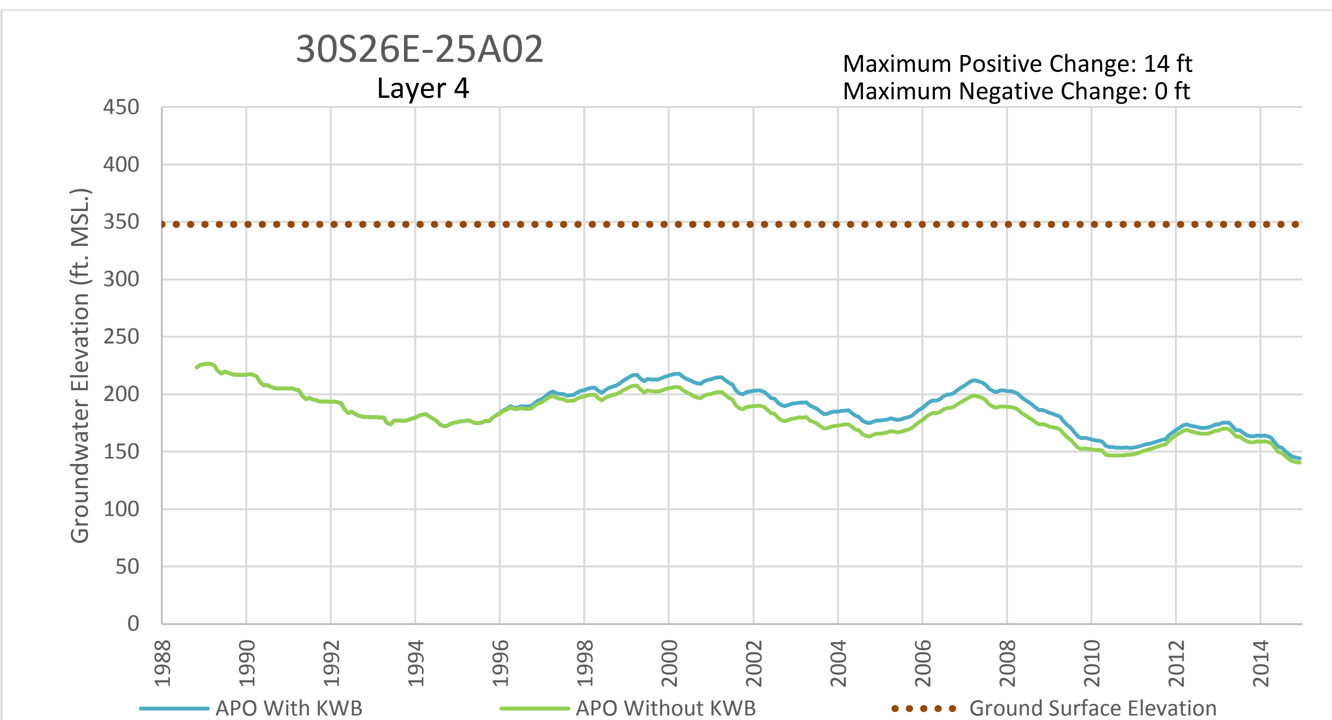

FIGURE 7-2 A.15. Hydrograph of Simulated Water Levels at Monitoring Well 30S267-25A02, 1988-2014

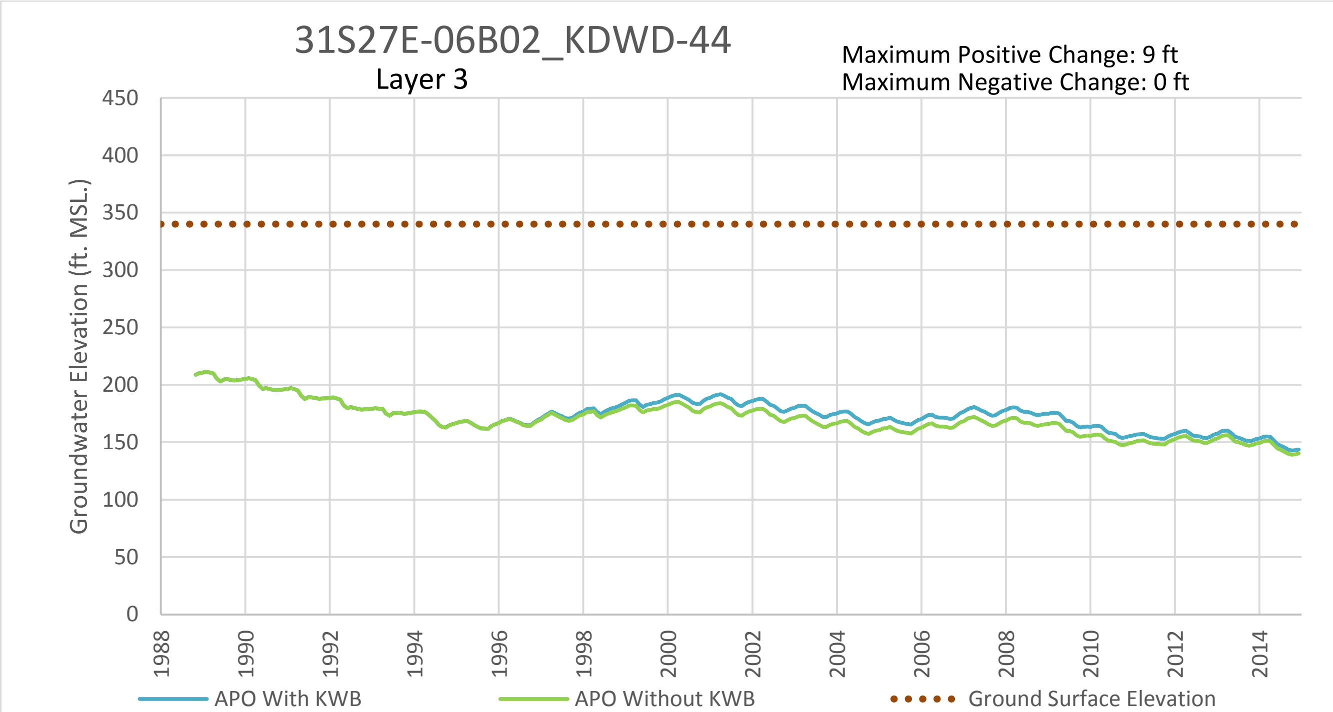

FIGURE 7-2 A.16. Hydrograph of Simulated Water Levels at Monitoring Well 31S27E-06B02_KDWD-44, 1988-2014

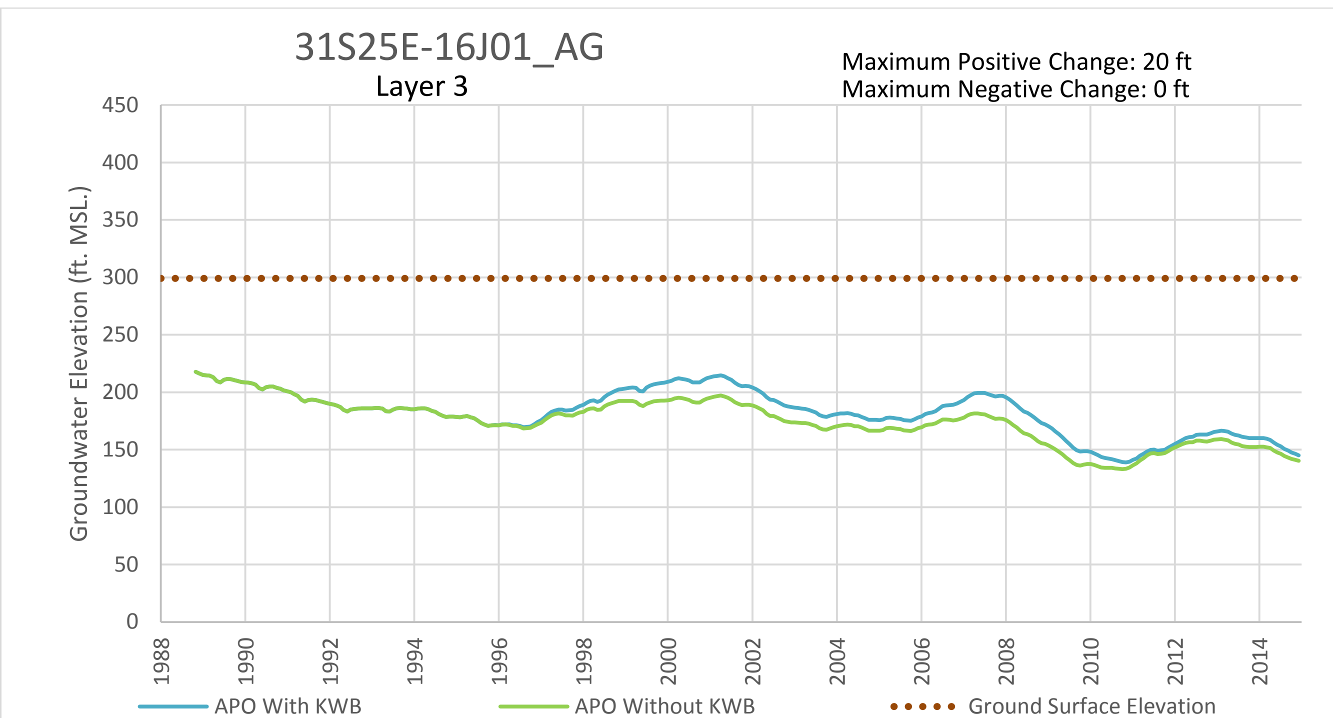

FIGURE 7-2 A.17. Hydrograph of Simulated Water Levels at Monitoring Well 31S25E-16J01_AG, 1988-2014

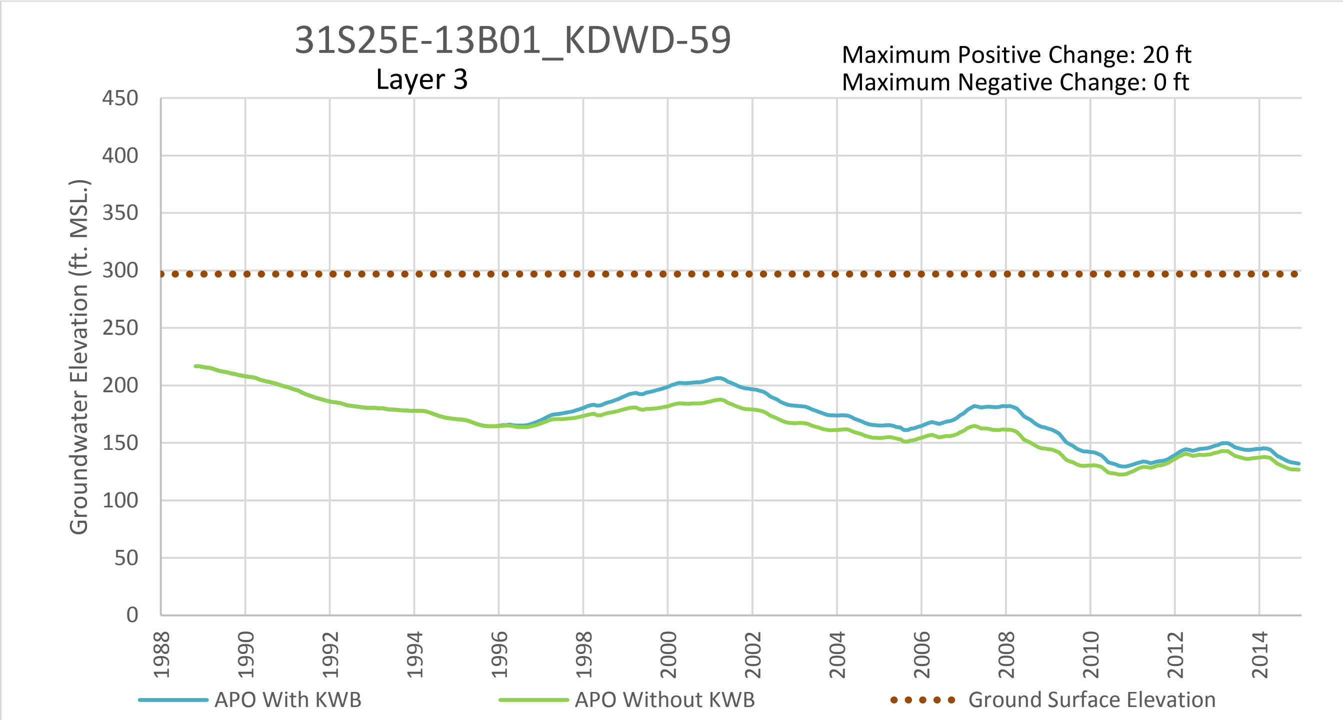

FIGURE 7-2 A.18. Hydrograph of Simulated Water Levels at Monitoring Well 31S25E-13B01_KDWD-59, 1998-2014

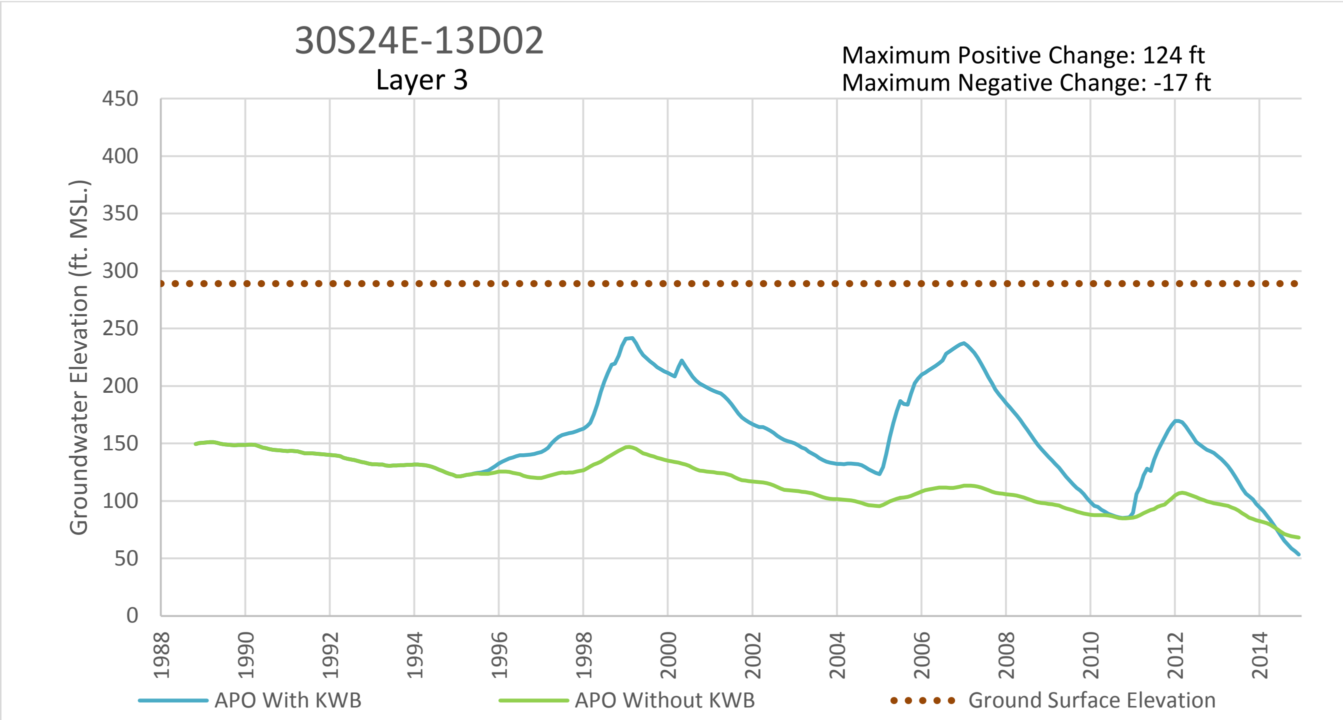

FIGURE 7-2 A.19. Hydrograph of Simulated Water Levels at Monitoring Well 30S24-13D02, 1988-2014.

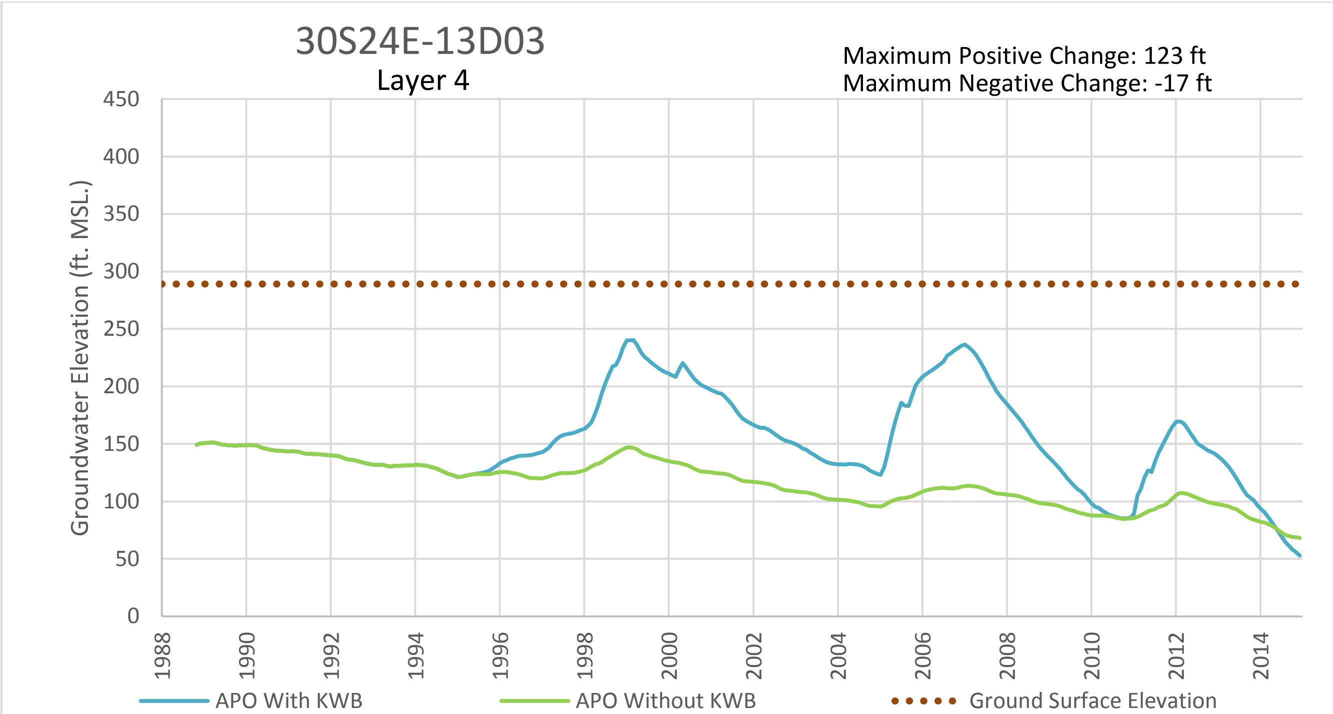

FIGURE 7-2 A.20. Hydrograph of Simulated Water Levels at Monitoring Well 30S24-13D03, 1988-2014

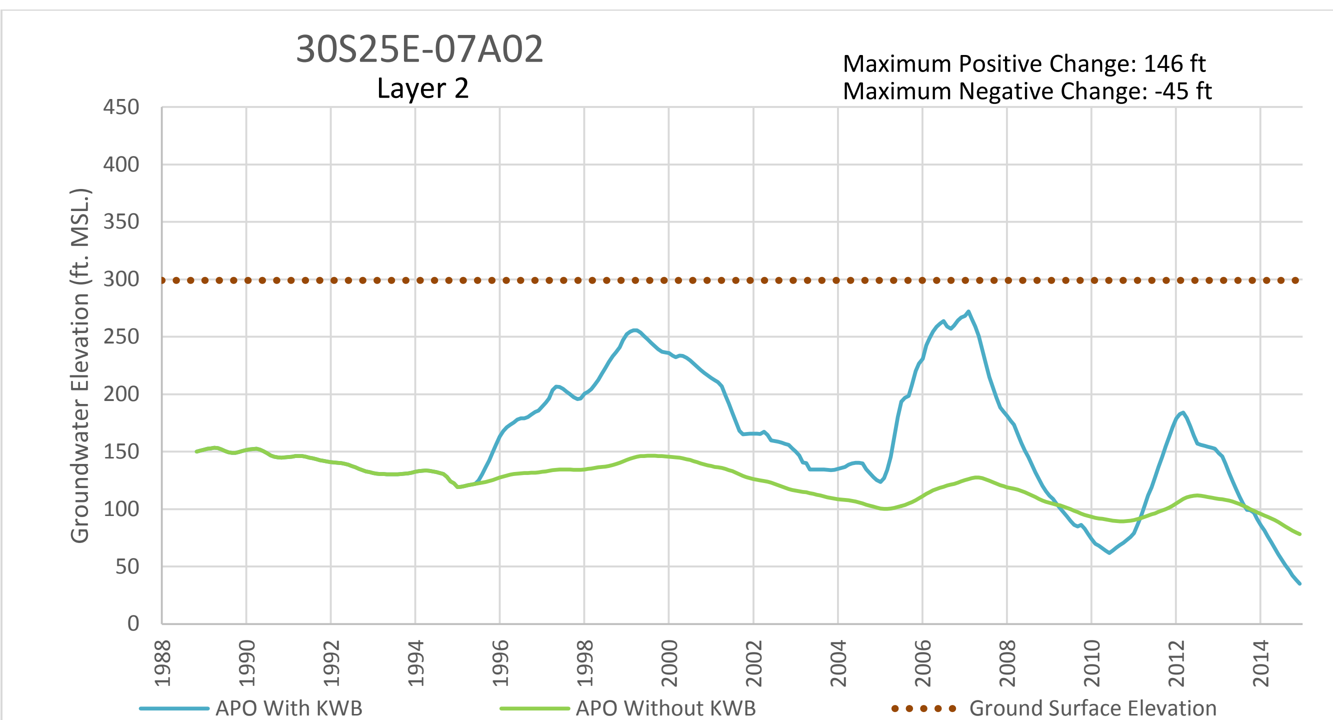

FIGURE 7-2 A.21. Hydrograph of Simulated Water Levels at Monitoring Well 30S25E-07A02, 1988-2014

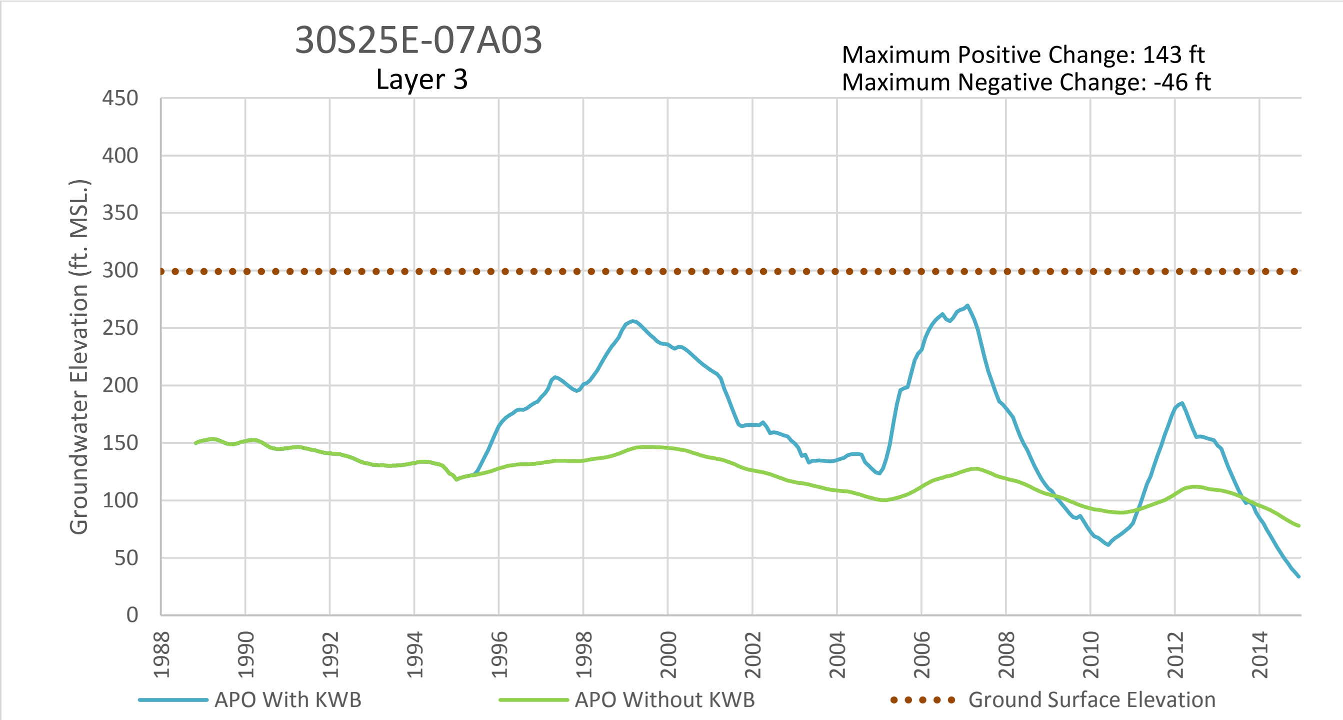

FIGURE 7-2 A.22. Hydrograph of Simulated Water Levels at Monitoring Well 30S25E-07A03, 1988-2014

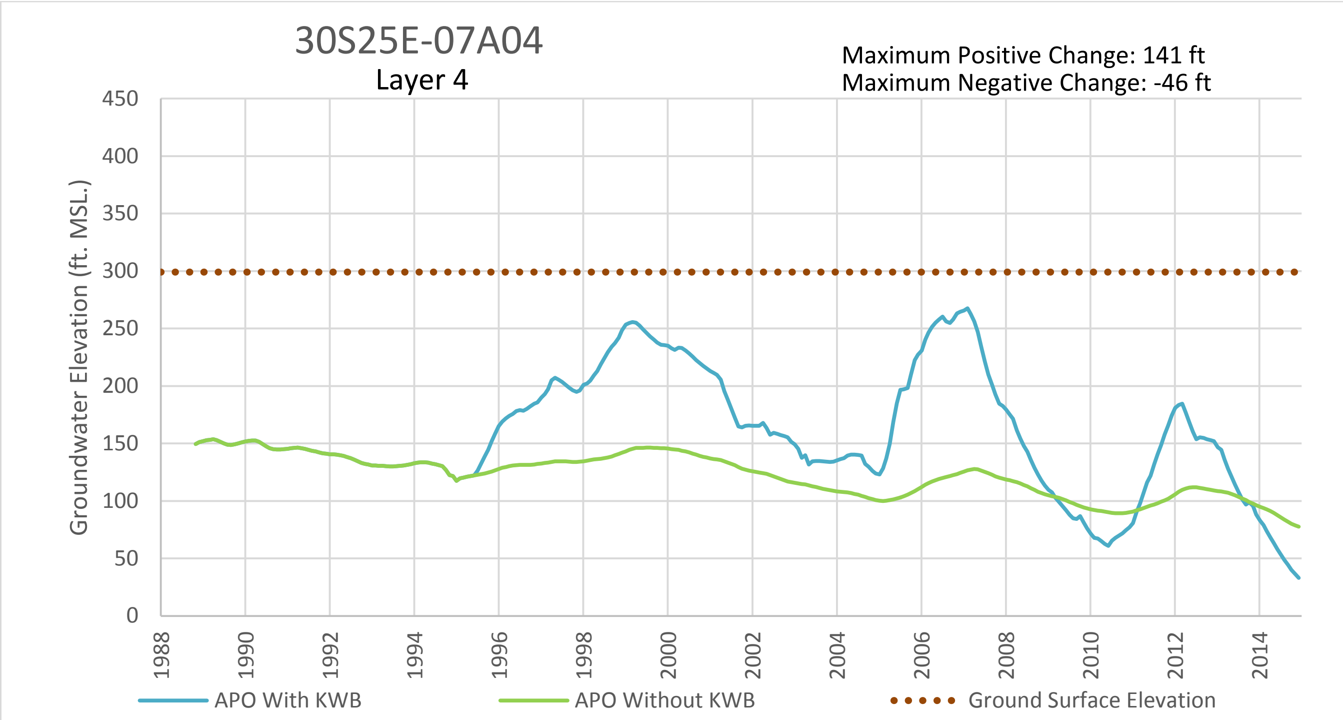

FIGURE 7-2 A.23. Hydrograph of Simulated Water Levels at Monitoring Well 30S25E-07A04, 1988-2014

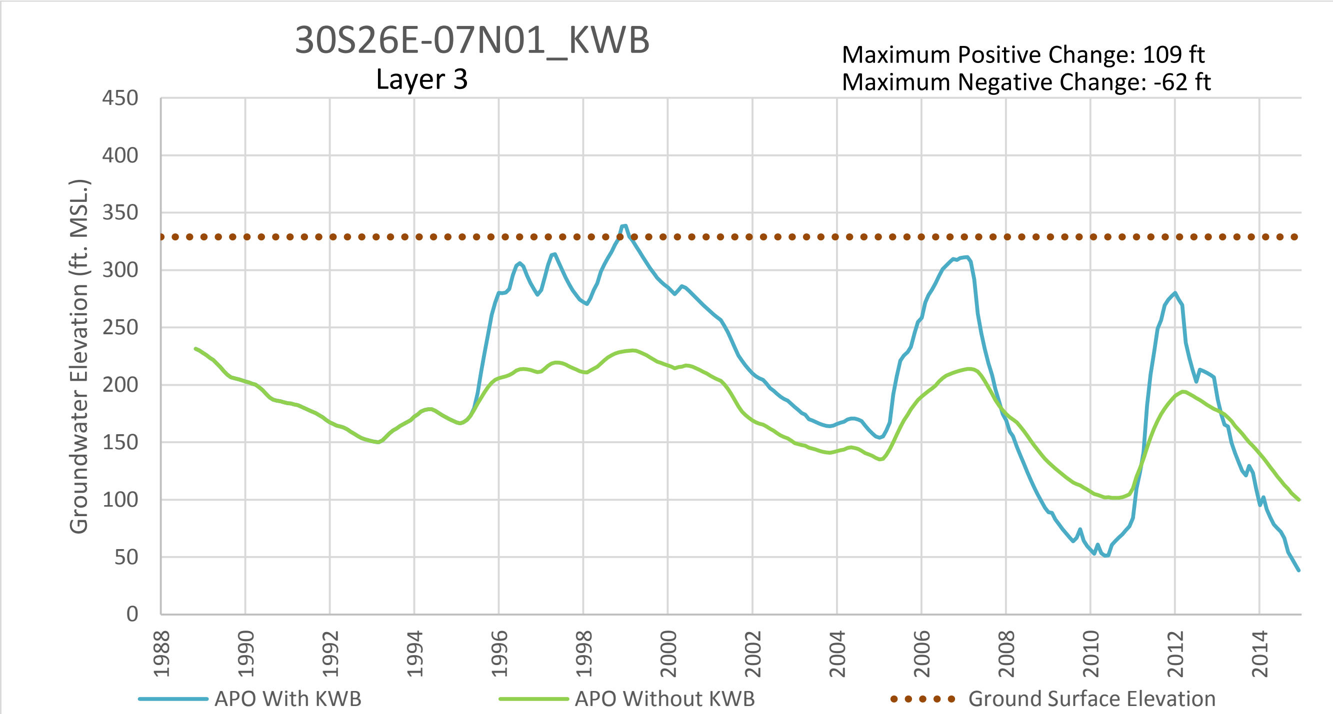

FIGURE 7-2 A.24. Hydrograph of Simulated Water Levels at Monitoring Well 30S26E-07N01_KWB, 1988-2014

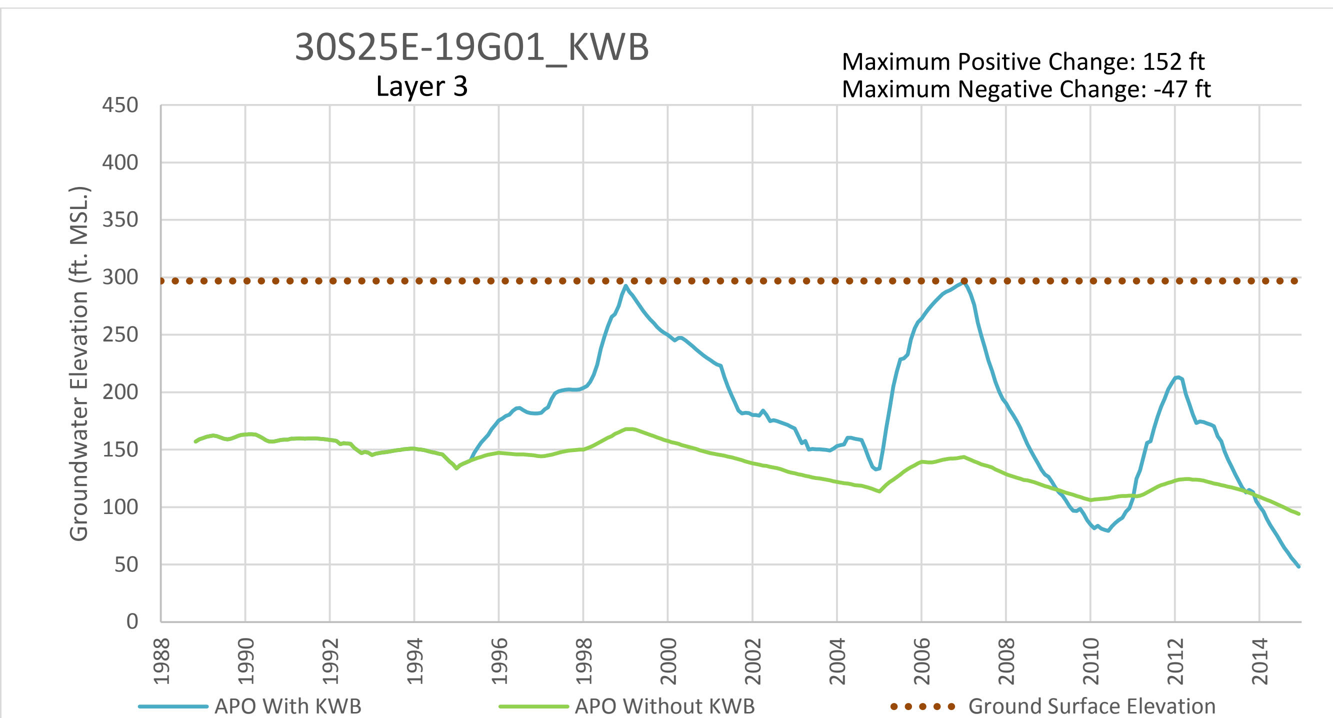

FIGURE 7-2 A.25. Hydrograph of Simulated Water Levels at Monitoring Well 30S25E-19G01_KWB, 1988-2014

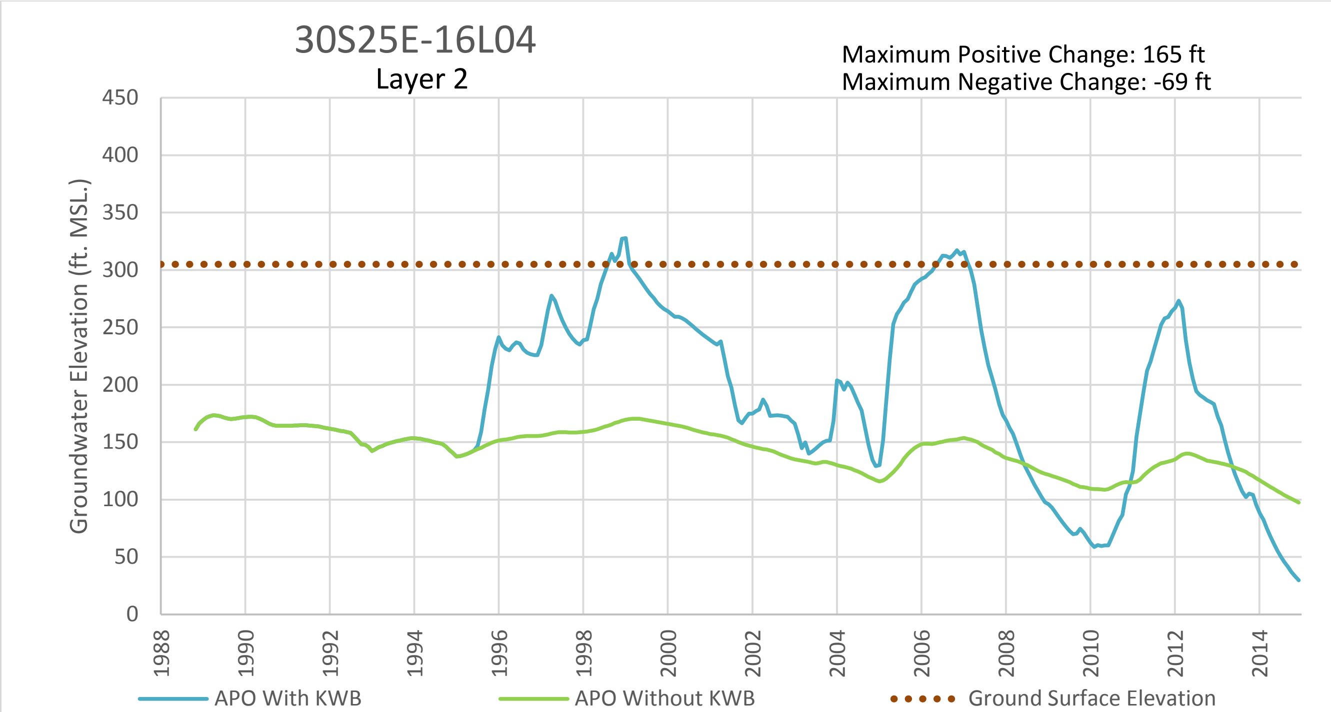

FIGURE 7-2 A.26. Hydrograph of Simulated Water Levels at Monitoring Well 30S25E-16L04, 1988-2014

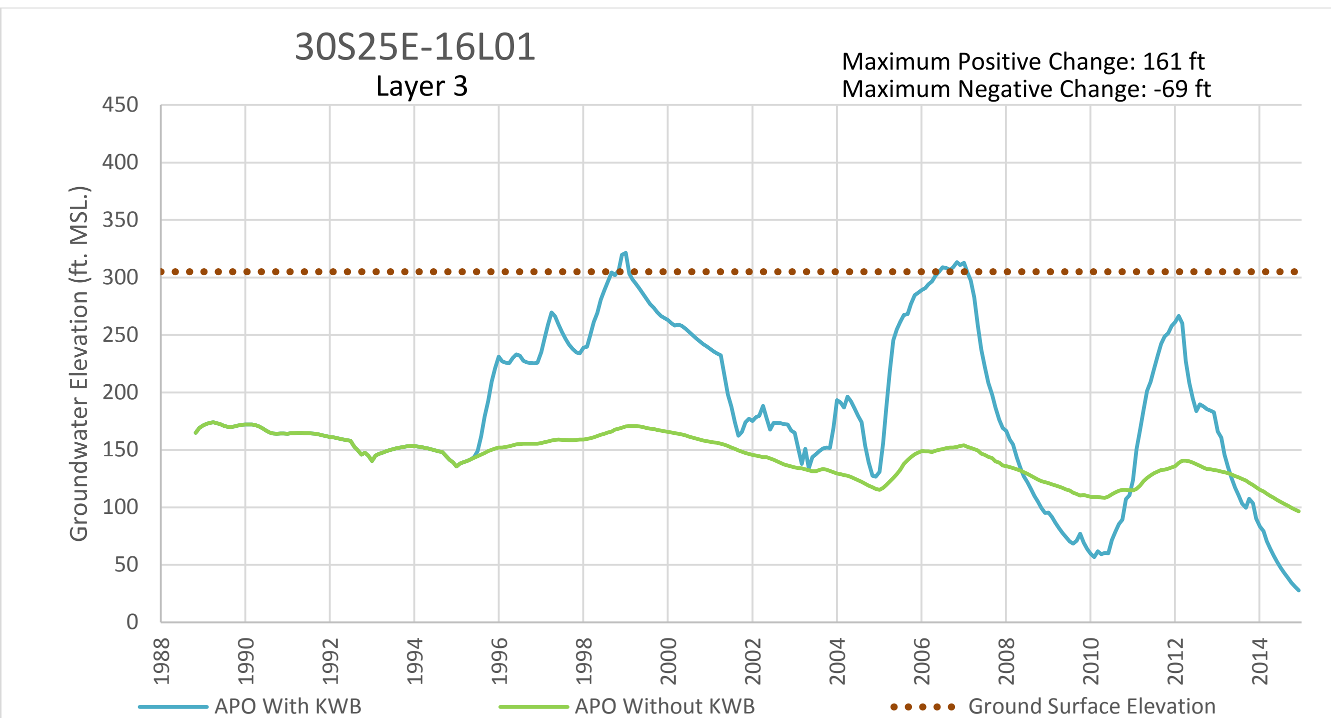

FIGURE 7-2 A.27. Hydrograph of Simulated Water Levels at Monitoring Well 30S25E-16L01, 1988-2014

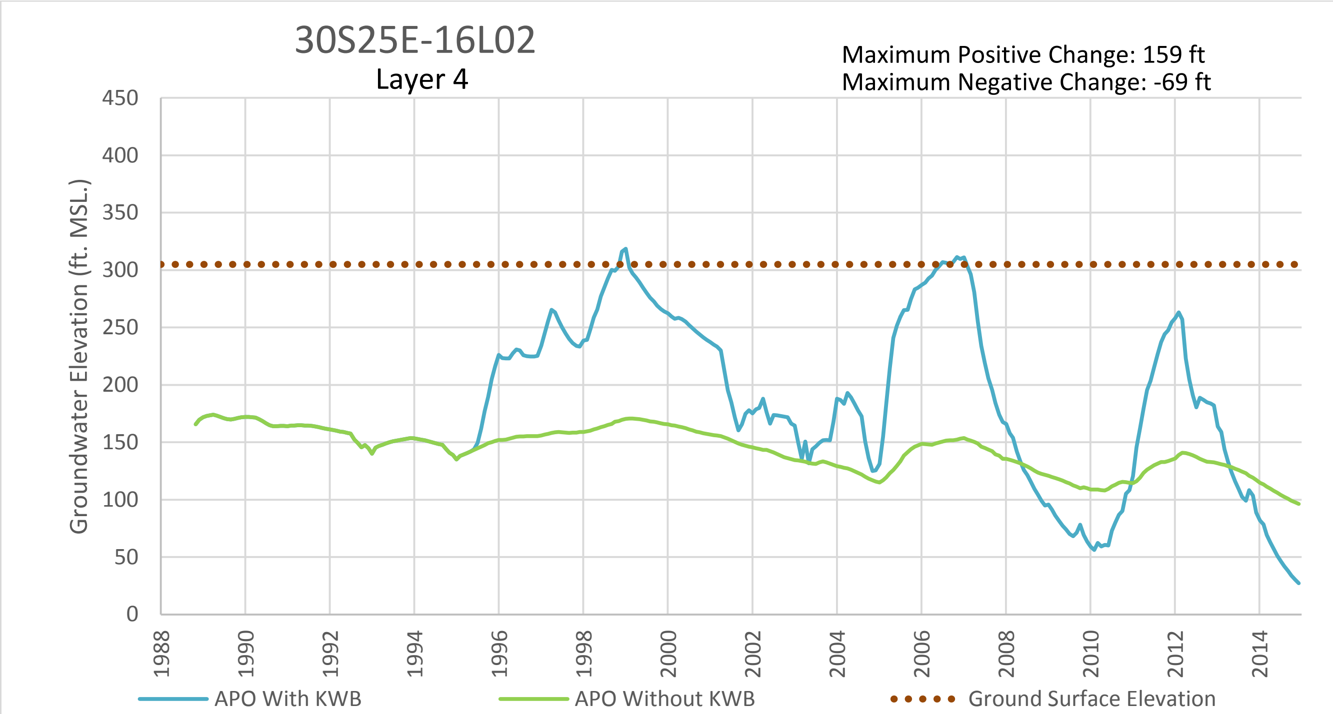

FIGURE 7-2 A.28. Hydrograph of Simulated Water Levels at Monitoring Well 30S25E-16L02, 1988-2014

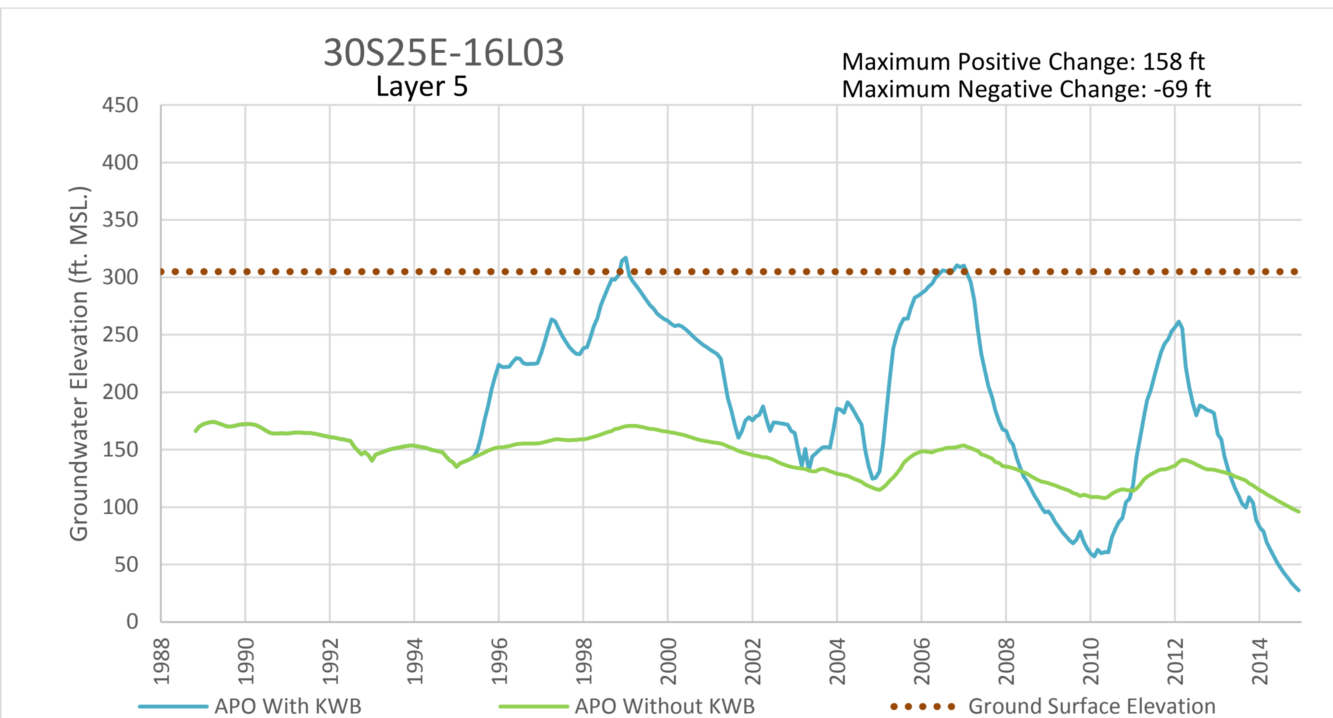

FIGURE 7-2 A.29. Hydrograph of Simulated Water Levels at Monitoring Well 30S25E-16L03, 1988-2014

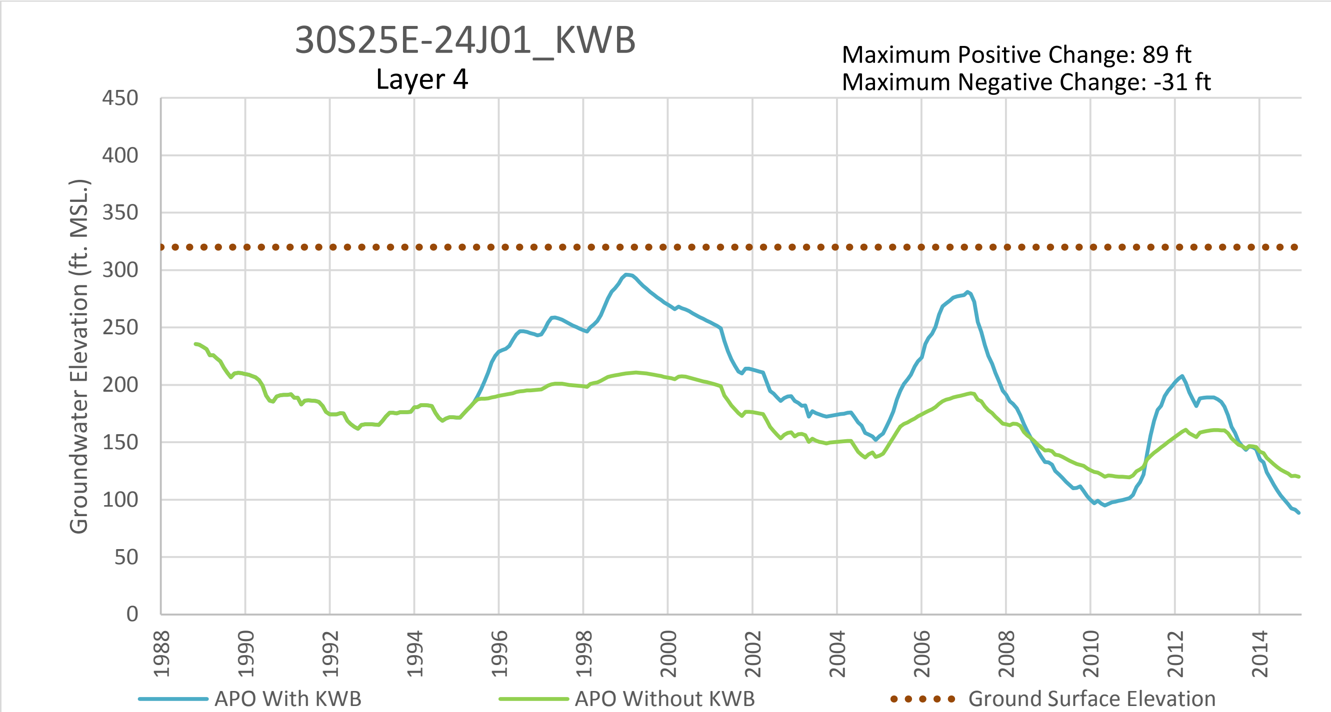

FIGURE 7-2 A.30. Hydrograph of Simulated Water Levels at Monitoring Well 30S257-24J01_KWB, 1988-2014

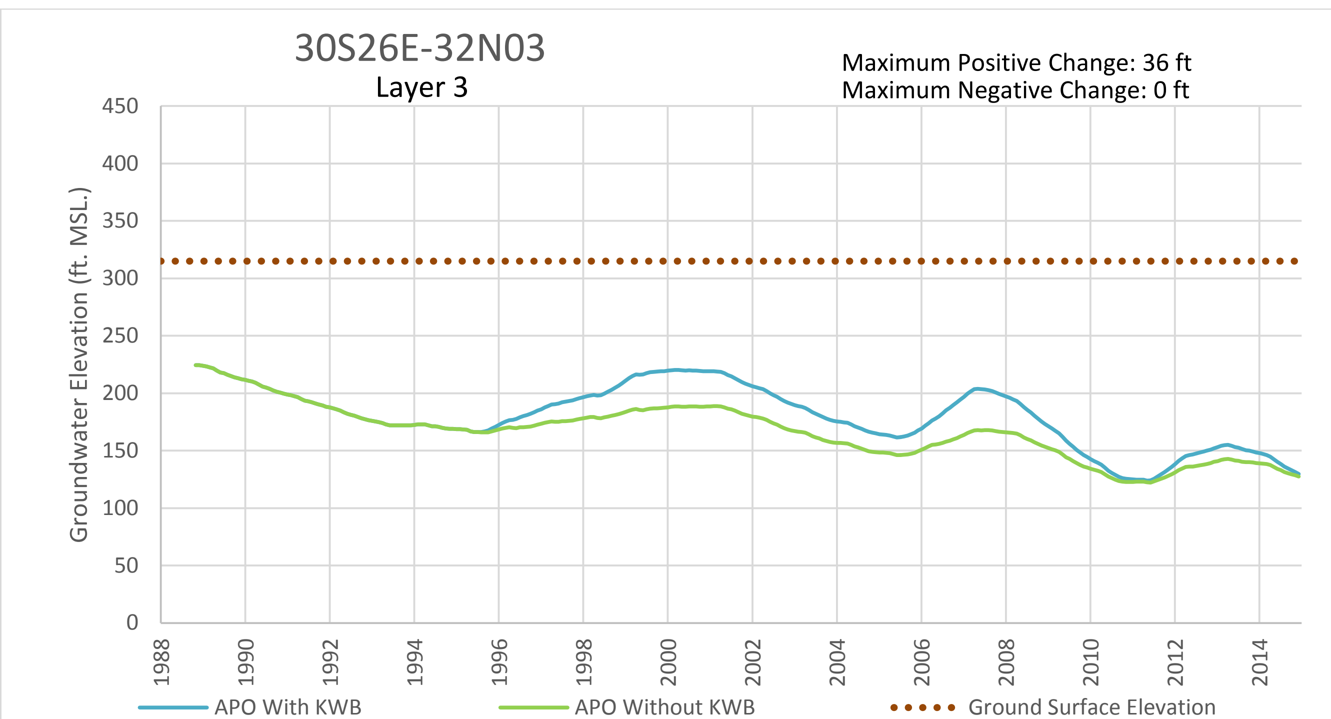

FIGURE 7-2 A.31. Hydrograph of Simulated Water Levels at Monitoring Well 30S26E-32N03, 1988-2014

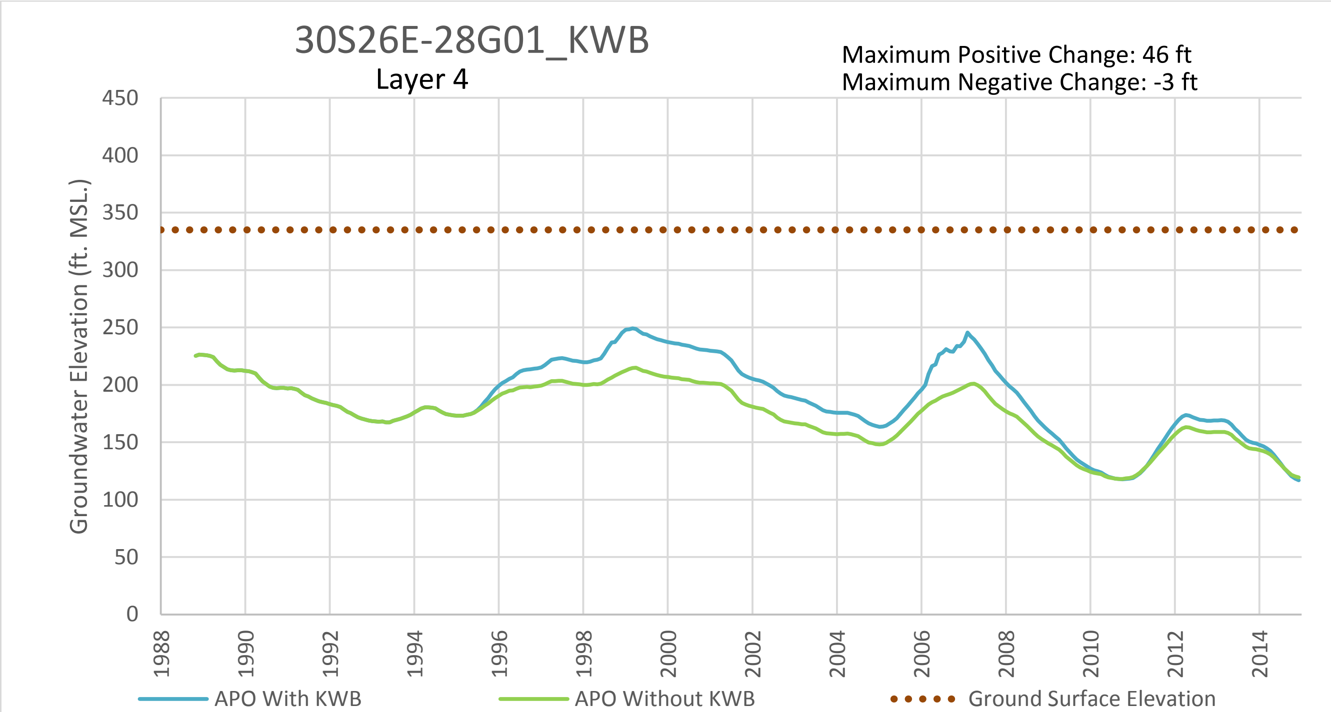

FIGURE 7-2 A.32. Hydrograph of Simulated Water Levels at Monitoring Well 30S267-28G01_KWB, 1988-2014

APPENDIX 7-2
B. AFO-EC HYDROGRAPHS

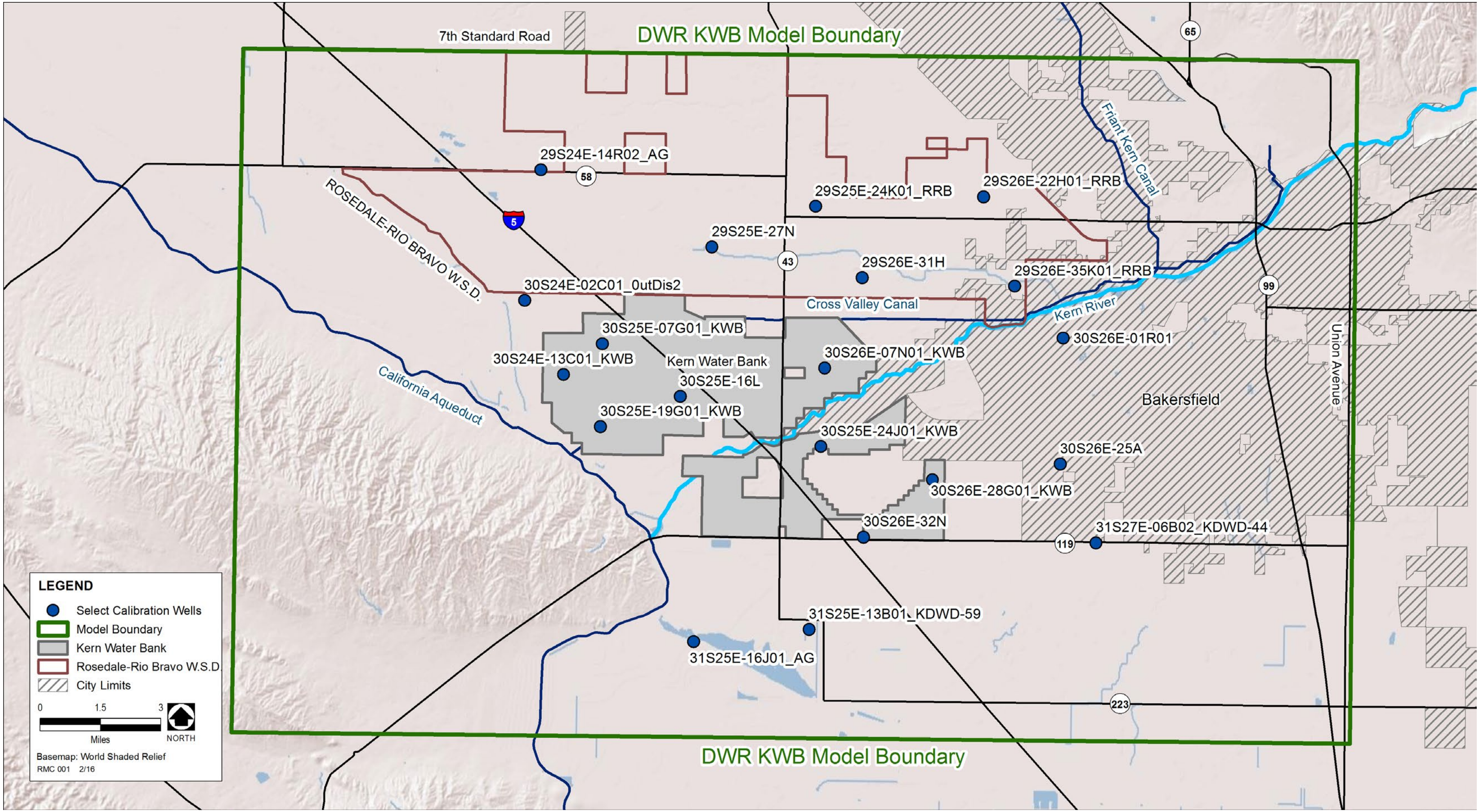

FIGURE 7-2 B.1. Location of Select Monitoring Wells Inside (14 Wells) and Outside (17 Wells) of Kern Water Bank

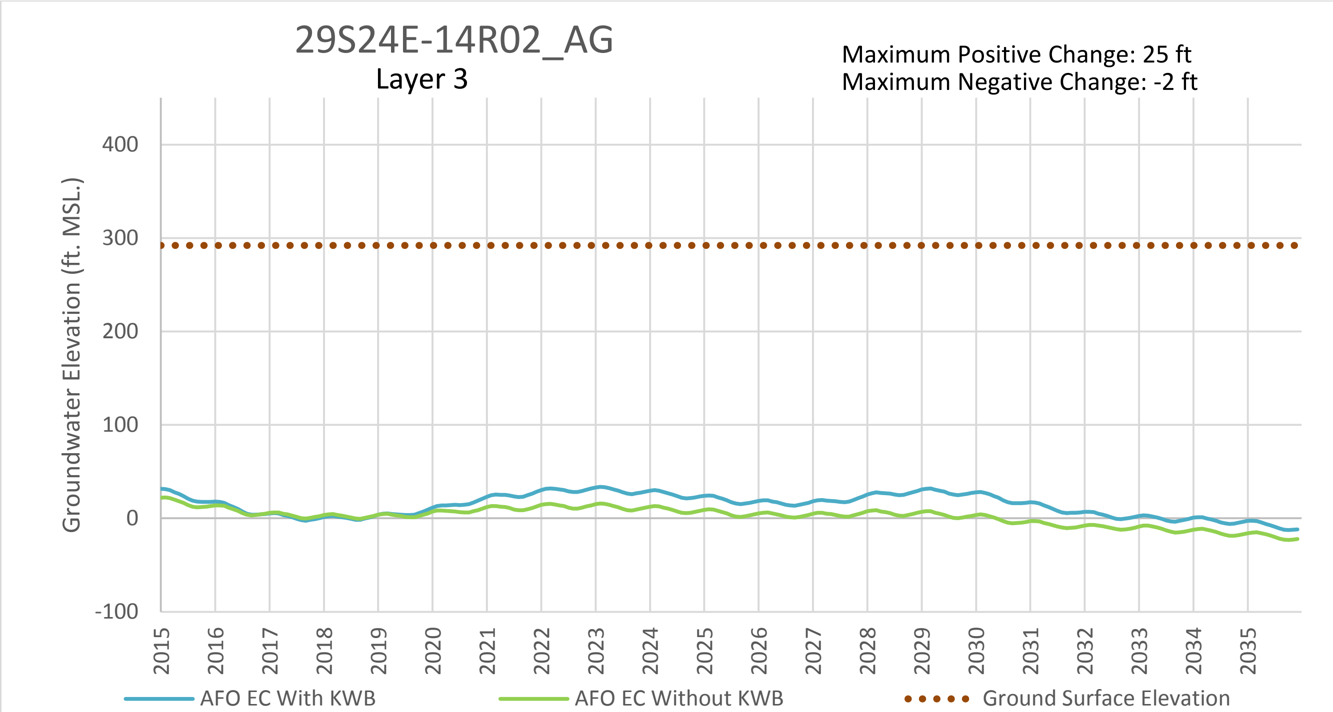

FIGURE 7-2 B.2. **Hydrograph of Simulated Water Levels at Monitoring Well 29S24E14R02_Ag, 2015-2035**

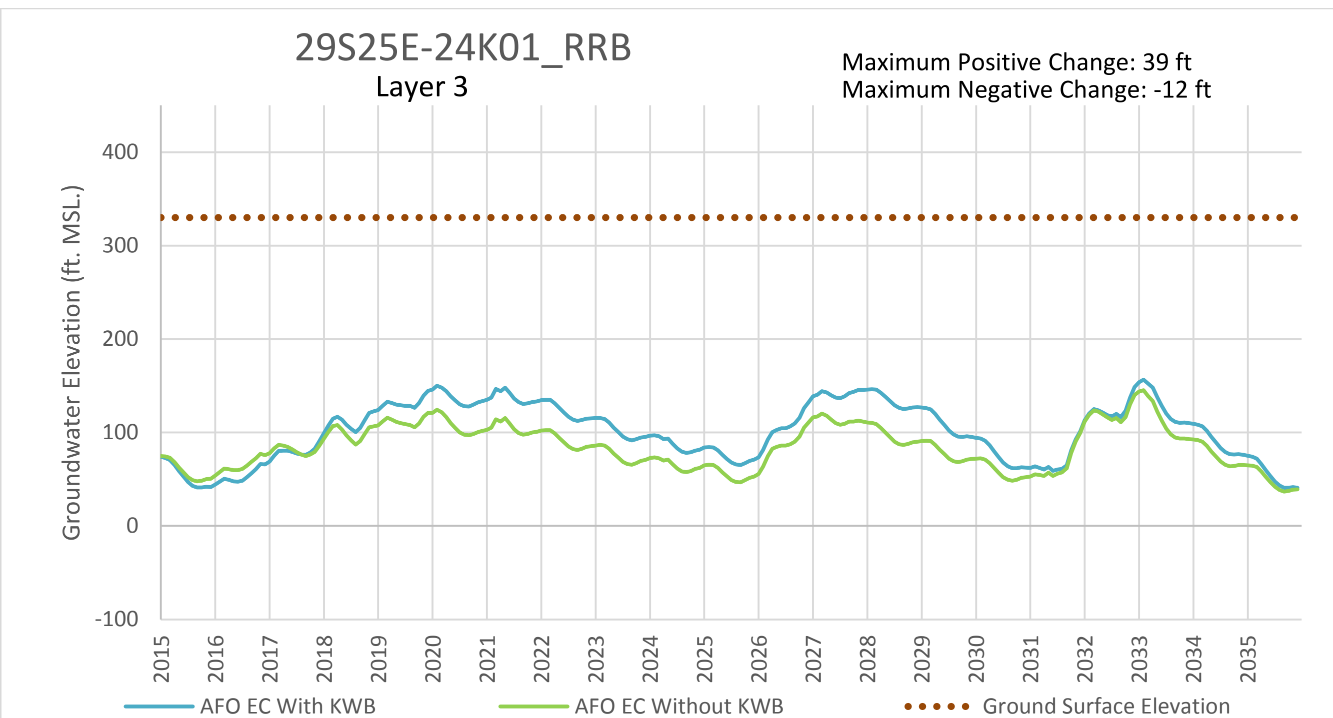

FIGURE 7-2 B.3. **Hydrograph of Simulated Water Levels at Monitoring Well 29S257-24K01_RRB, 2015-2035**

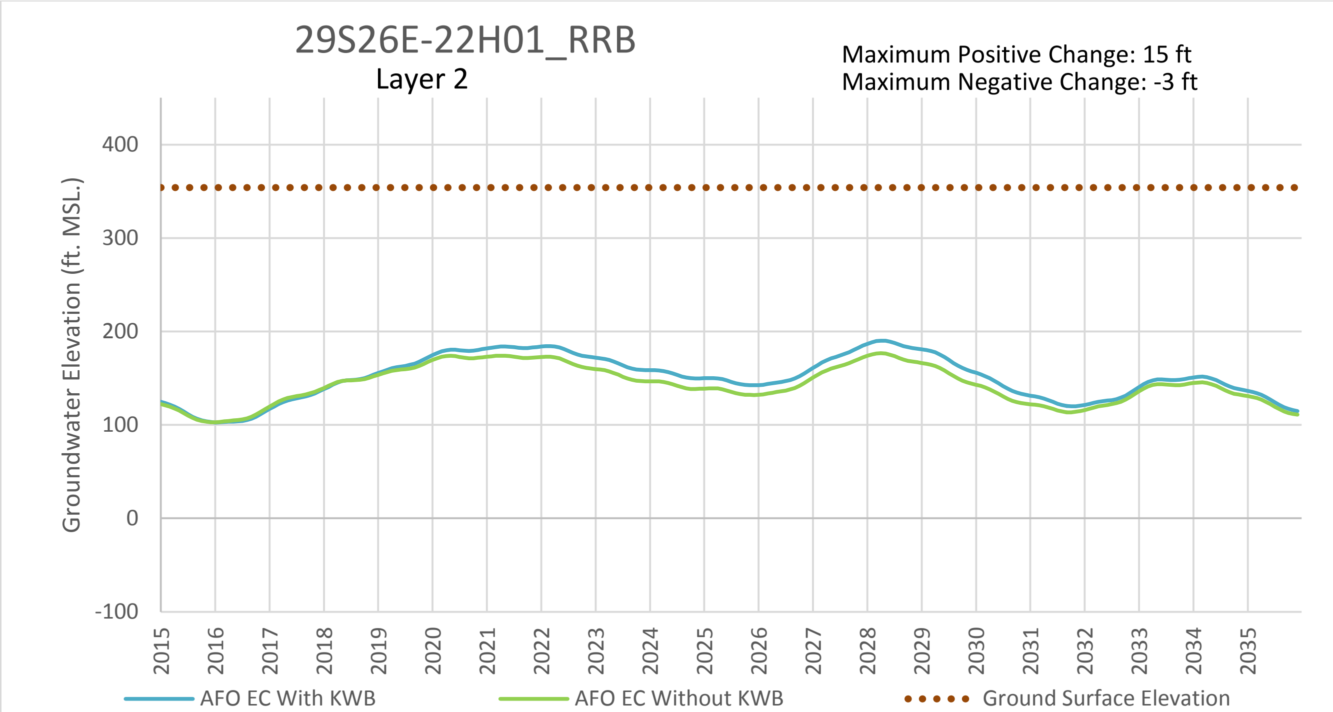

FIGURE 7-2 B.4. **Hydrograph of Simulated Water Levels at Monitoring Well 29S267-22H01_RRB, 2015-2035**

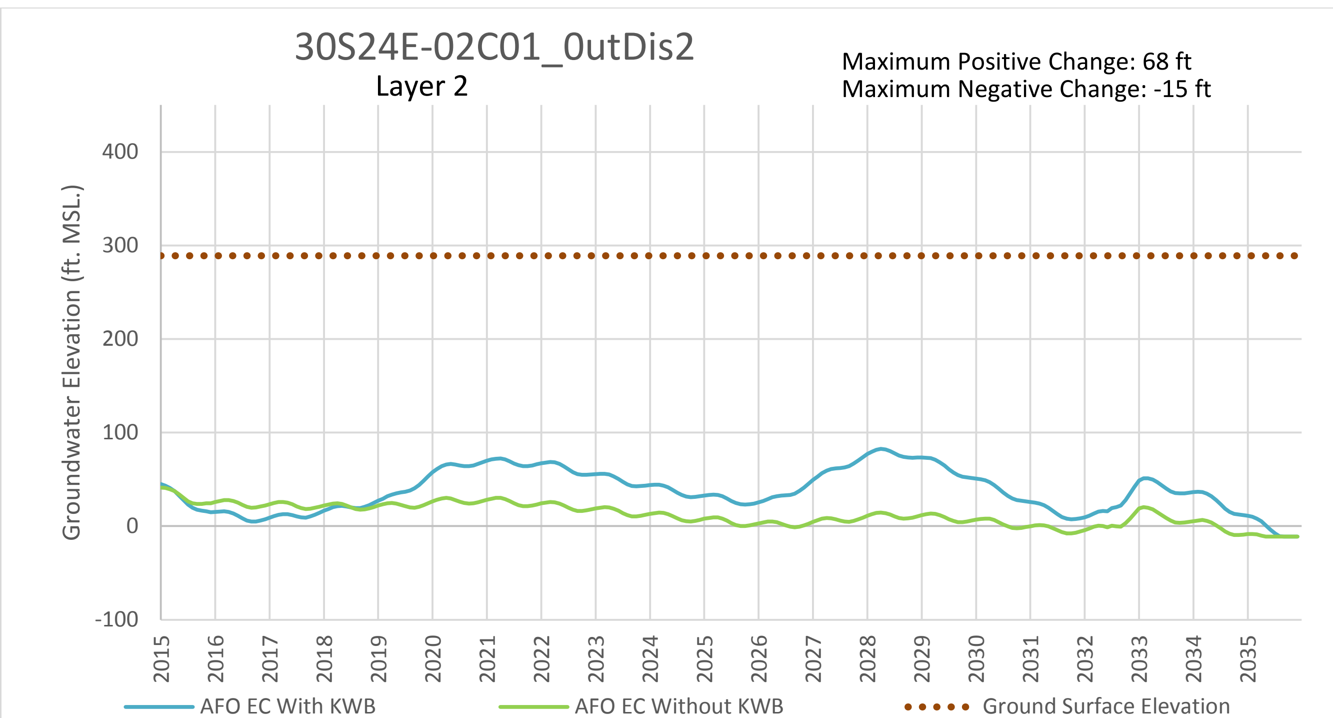

FIGURE 7-2 B.5. **Hydrograph of Simulated Water Levels at Monitoring Well 30S24E-02C01_0utDis2, 2015-2035**

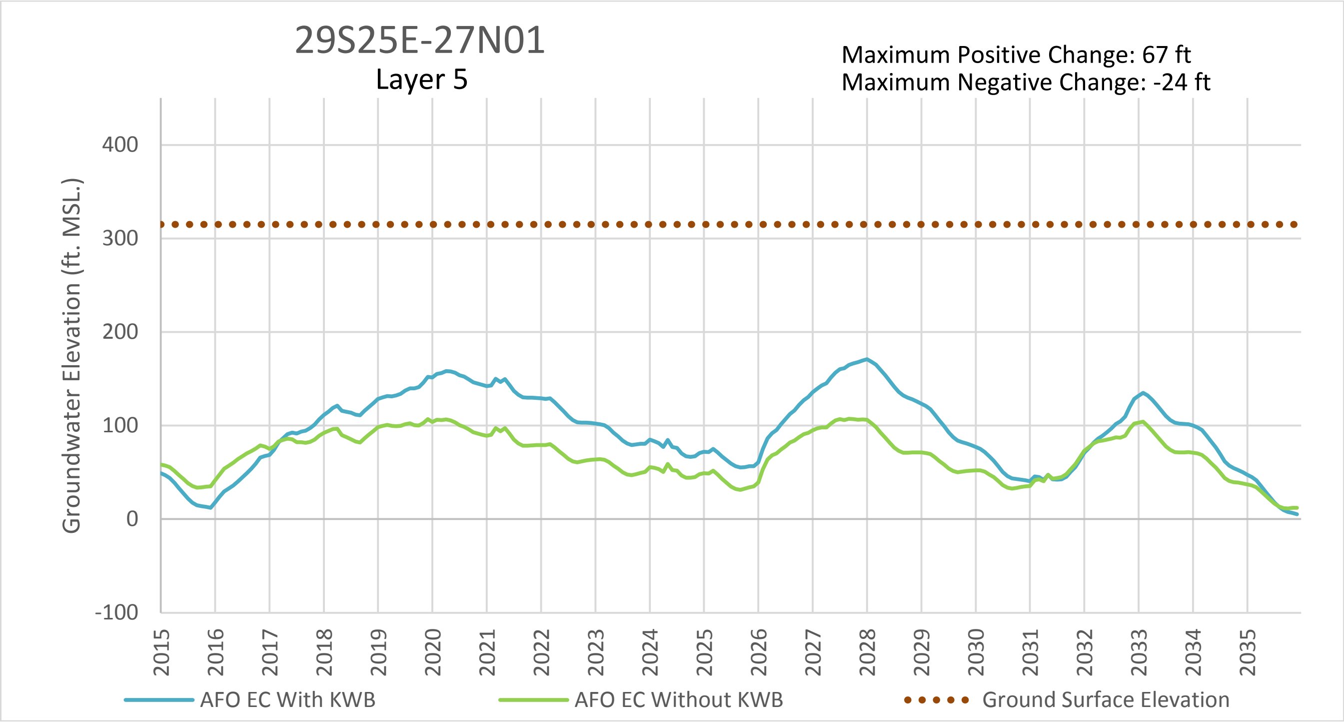

FIGURE 7-2 B.6. Hydrograph of Simulated Water Levels at Monitoring Well 29S257-27N01, 2015-2035

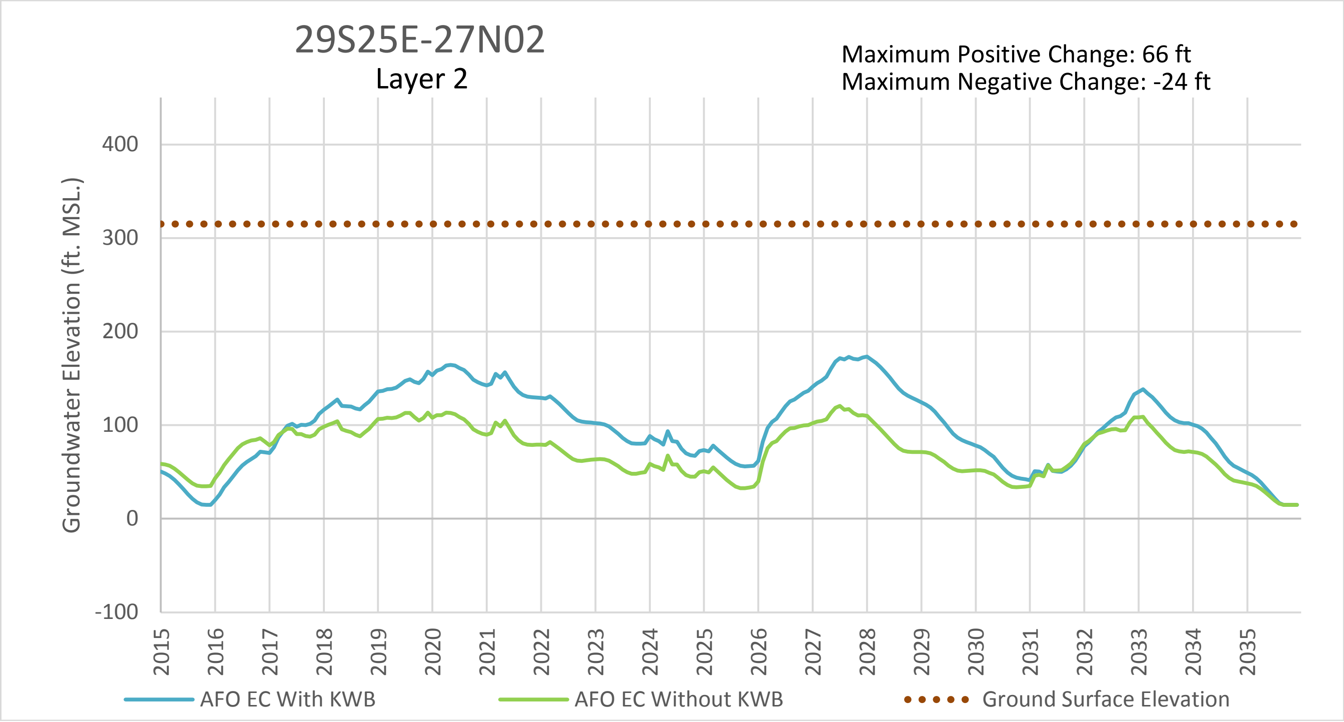

FIGURE 7-2 B.7. Hydrograph of Simulated Water Levels at Monitoring Well 29S257-27N02, 2015-2035

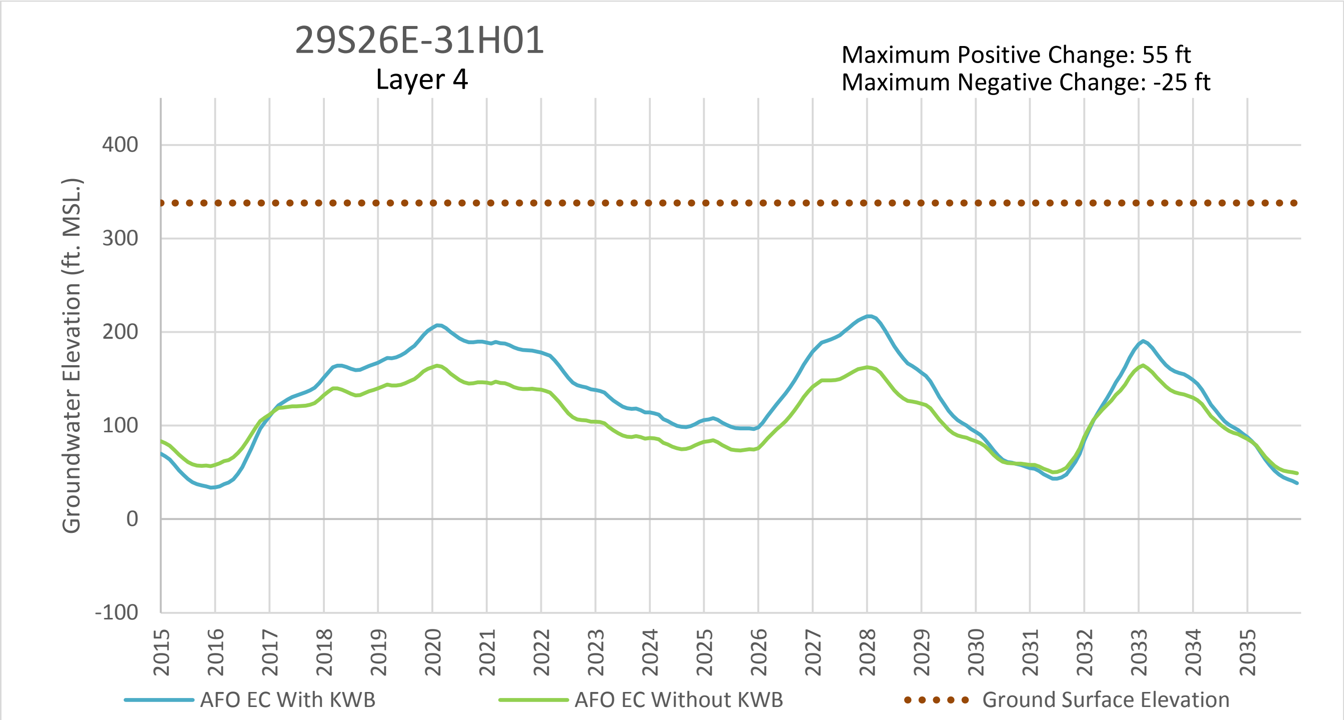

FIGURE 7-2 B.8. Hydrograph of Simulated Water Levels at Monitoring Well 29S26E-31H01, 2015-2035

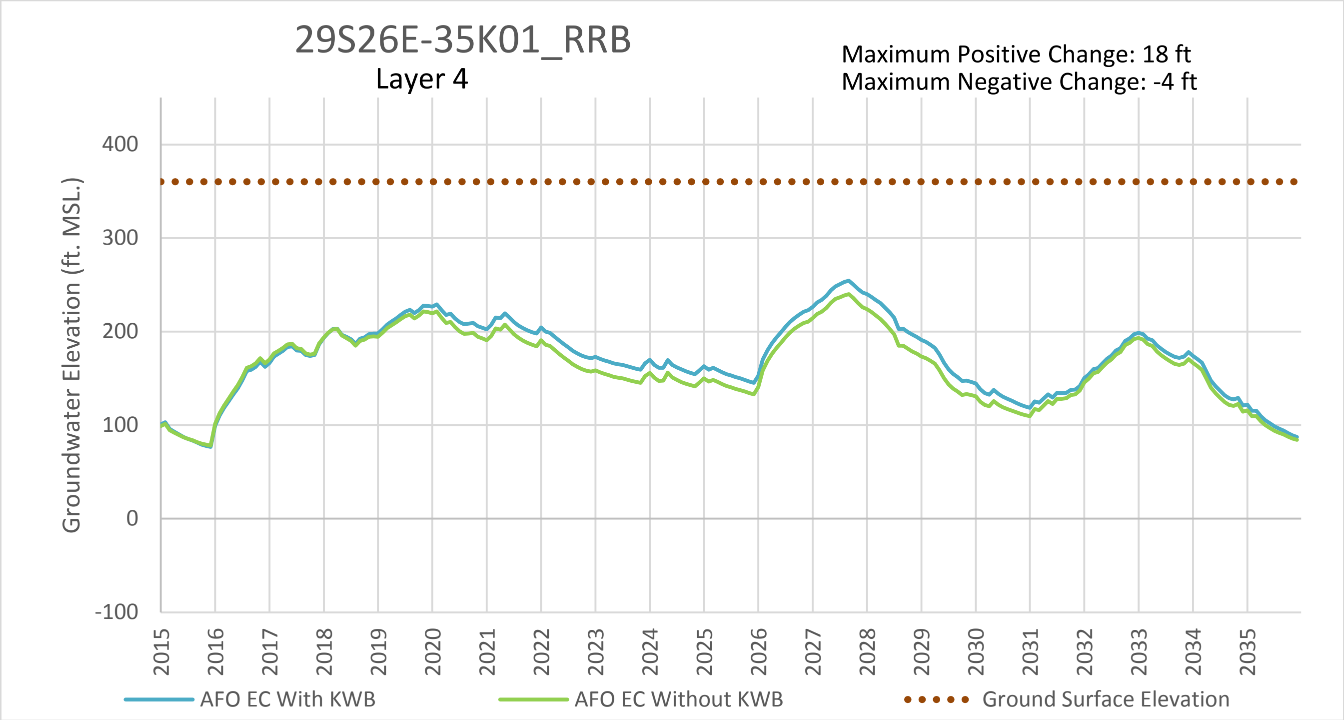

FIGURE 7-2 B.9. Hydrograph of Simulated Water Levels at Monitoring Well 29S26E-35K01_RRB, 2015-2035

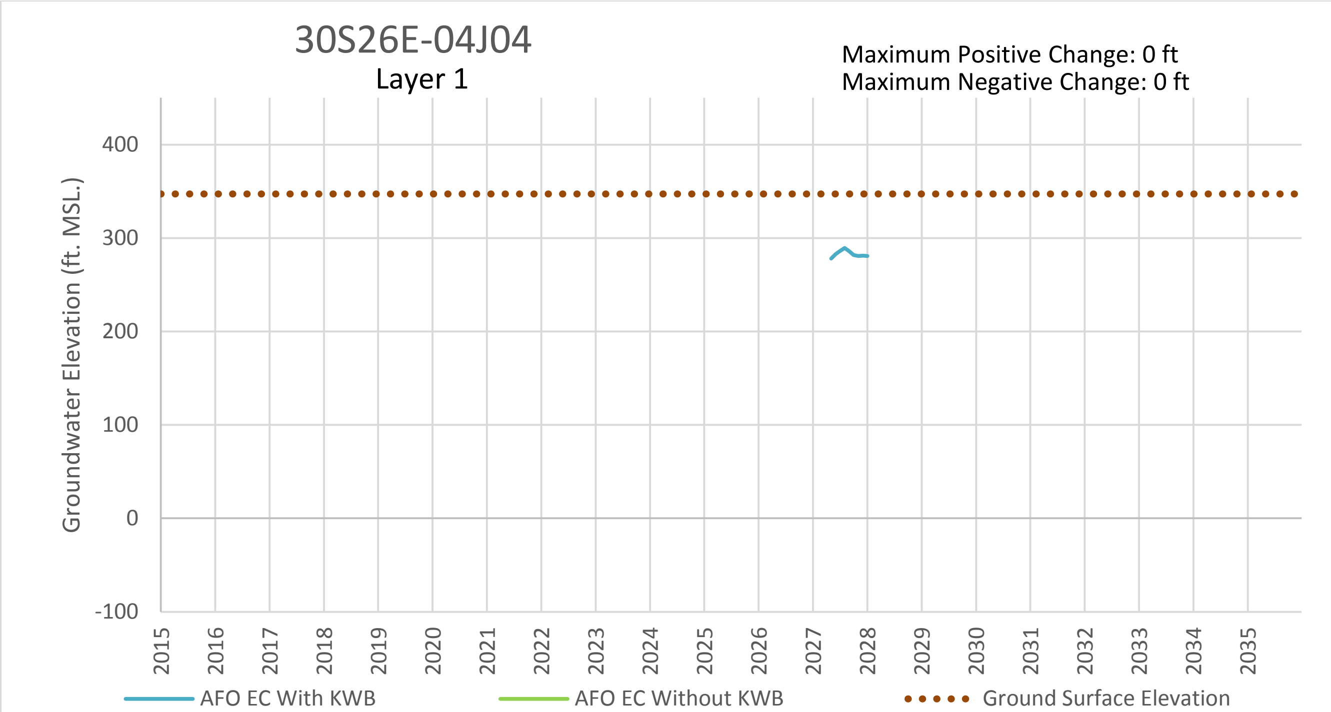

FIGURE 7-2 B.10. Hydrograph of Simulated Water Levels at Monitoring Well 30S26E-04J04, 2015-2035

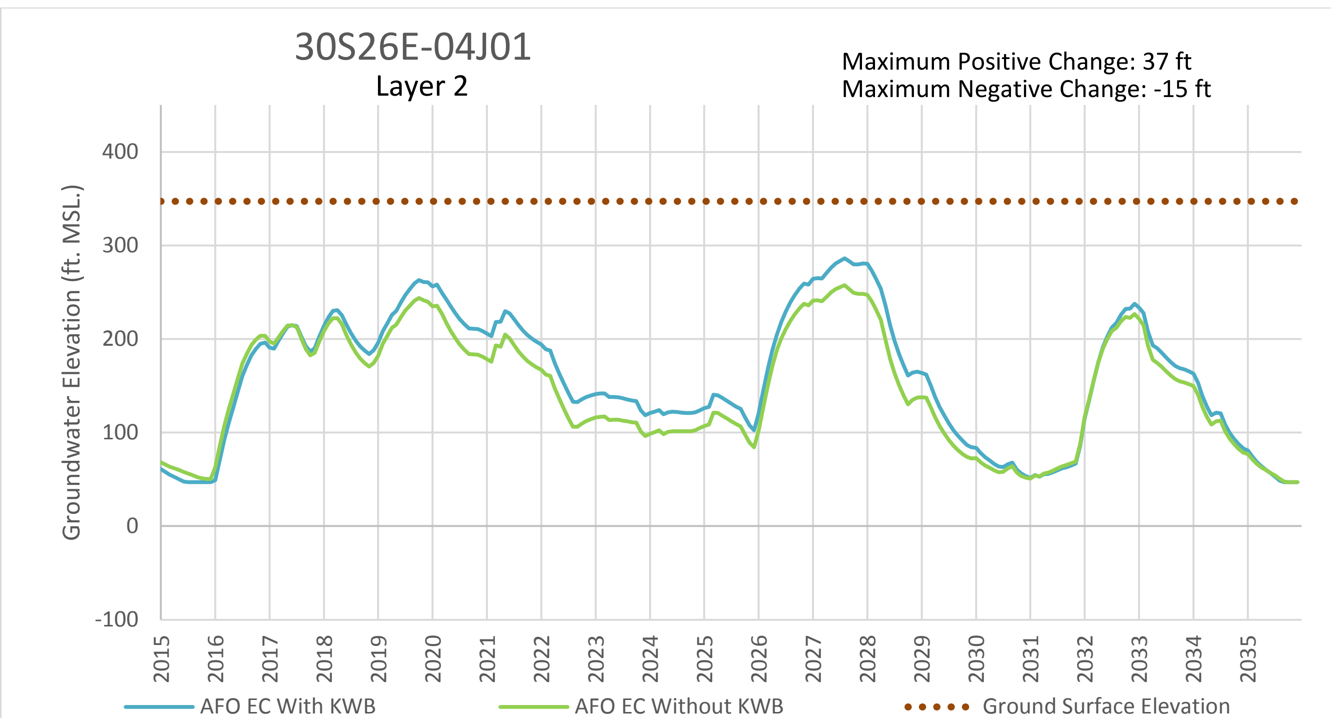

FIGURE 7-2 B.11. Hydrograph of Simulated Water Levels at Monitoring Well 30S26E-04J01, 2015-2035

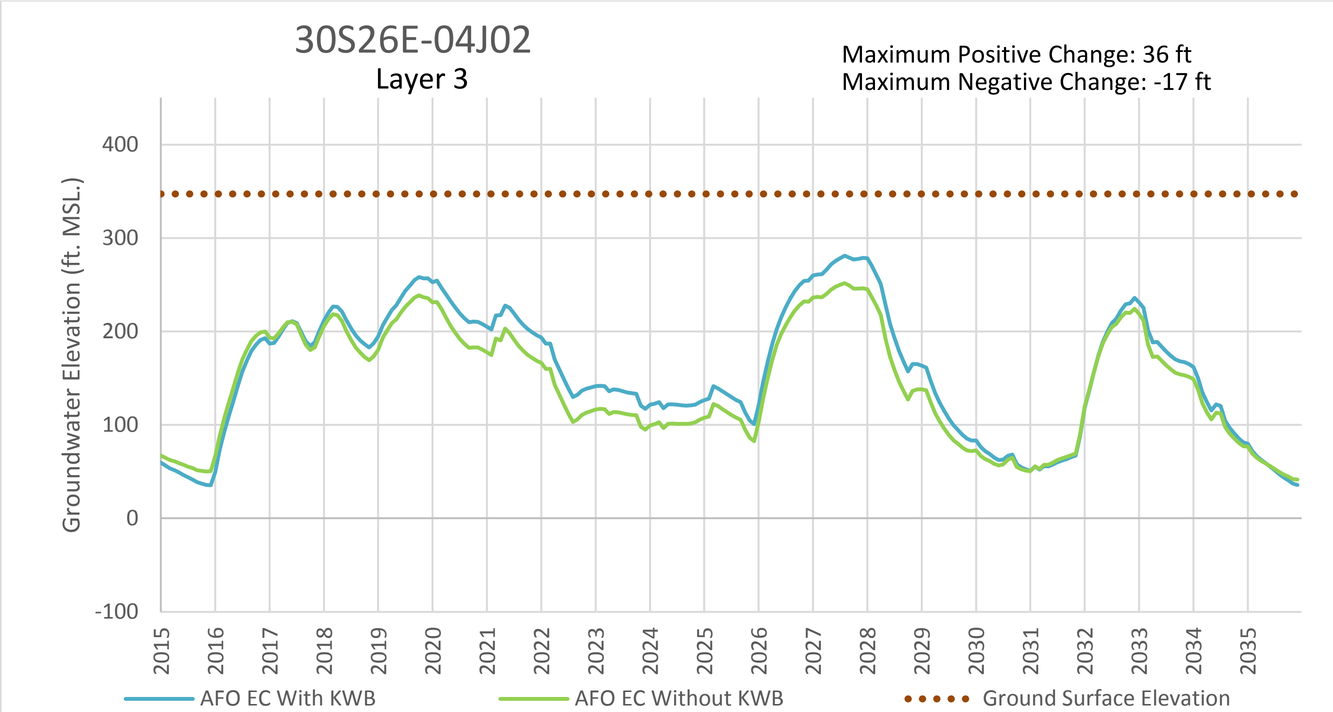

FIGURE 7-2 B.12. Hydrograph of Simulated Water Levels at Monitoring Well 30S26E-04J02, 2015-2035

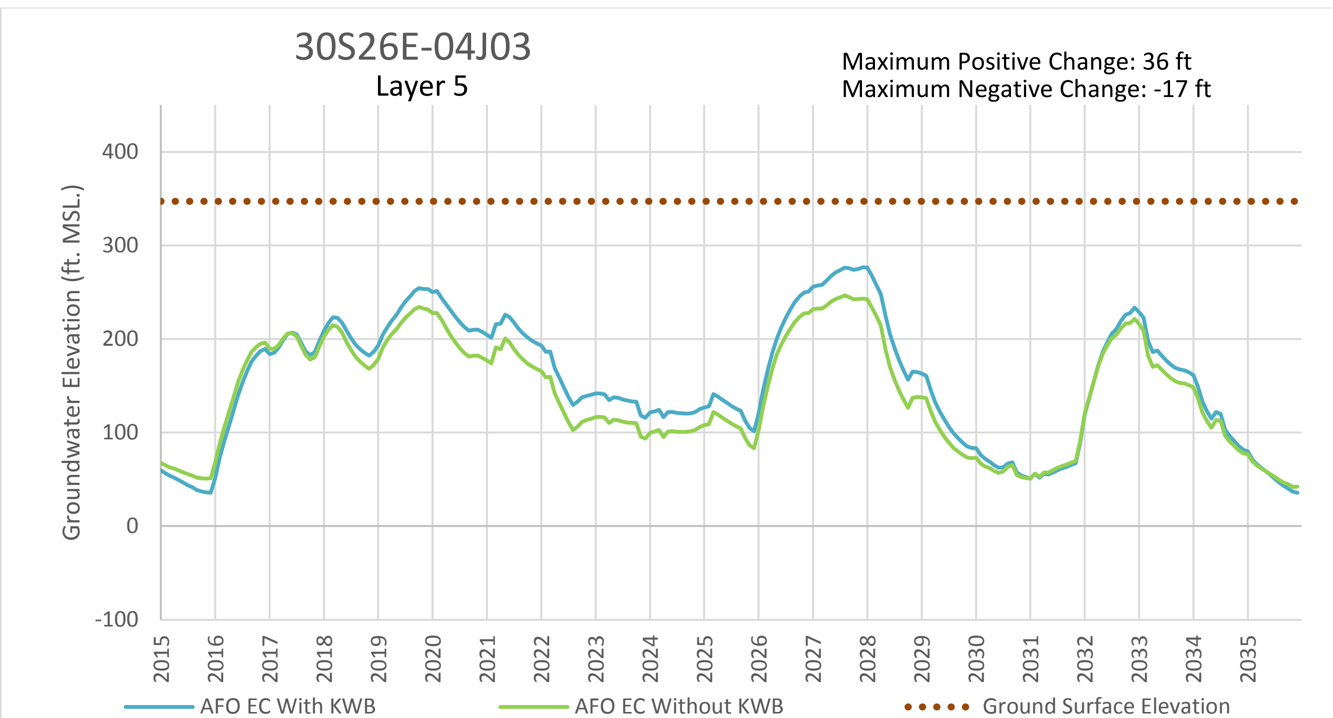

FIGURE 7-2 B.13. Hydrograph of Simulated Water Levels at Monitoring Well 30S26E-04J03, 2015-2035

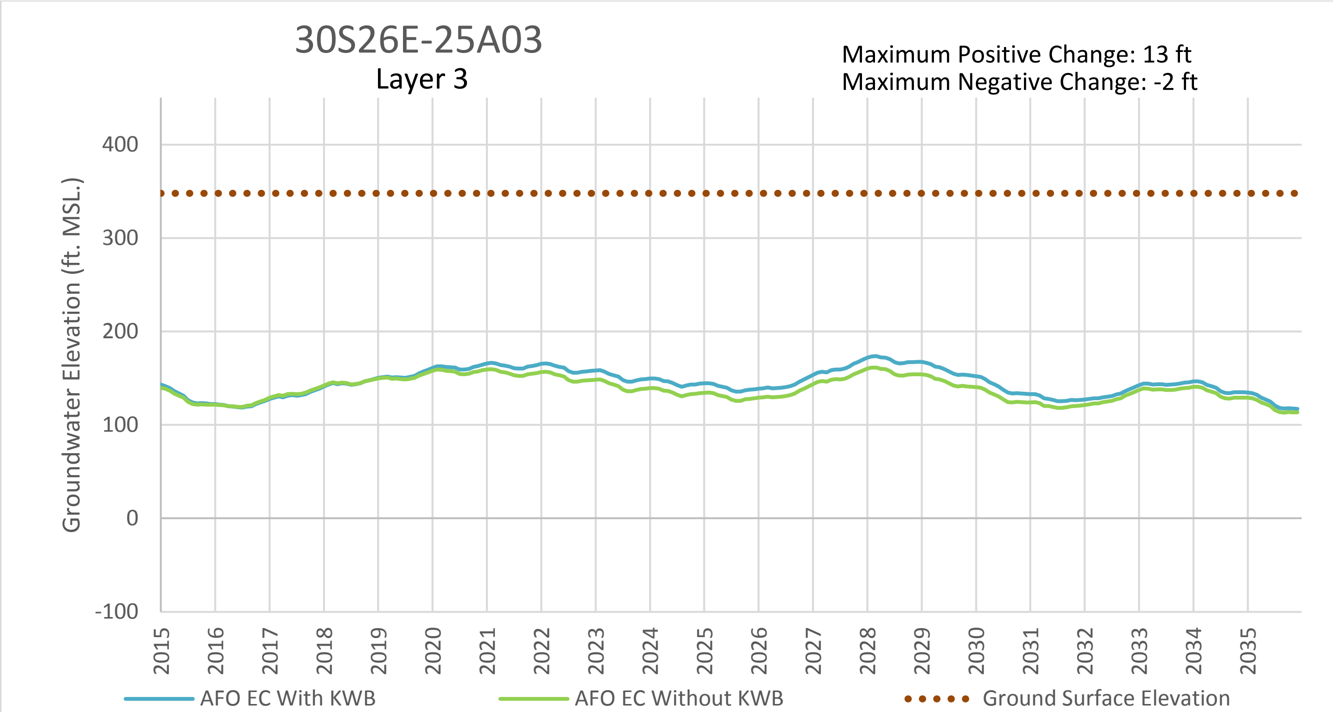

FIGURE 7-2 B.14. Hydrograph of Simulated Water Levels at Monitoring Well 30S267-25A03, 2015-2035

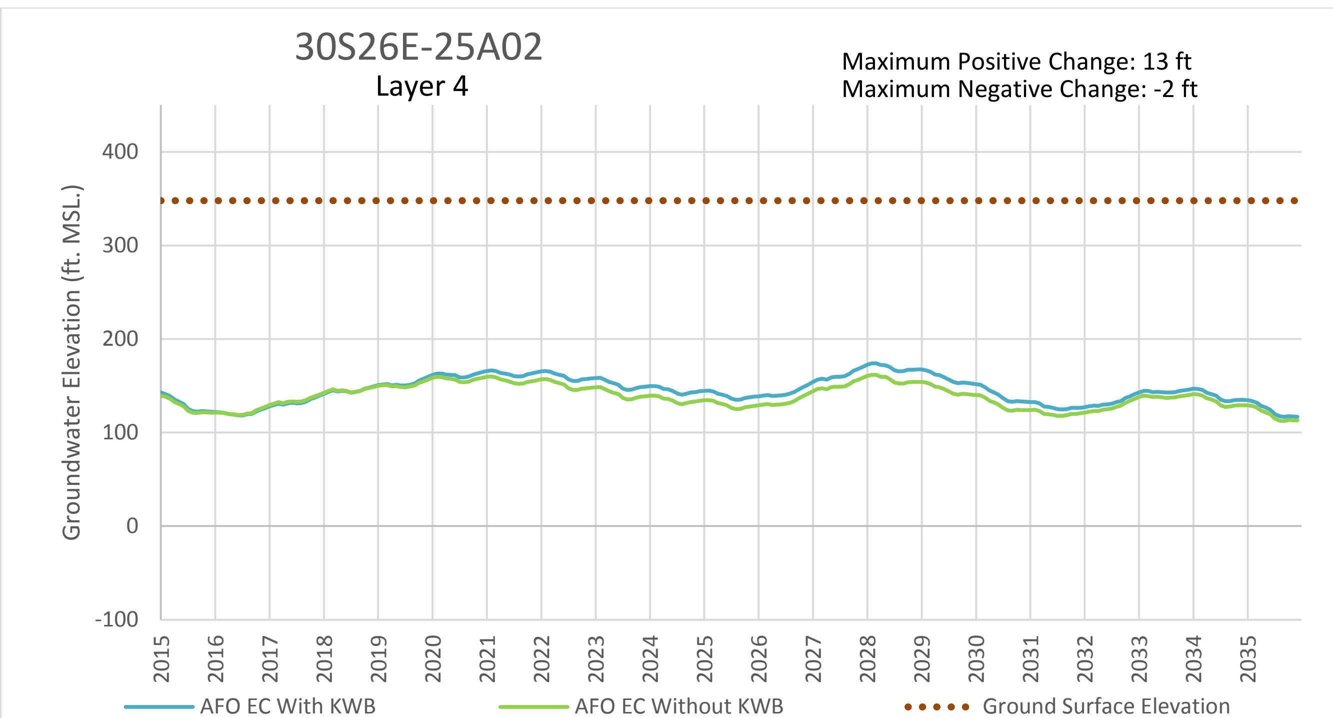

FIGURE 7-2 B.15. Hydrograph of Simulated Water Levels at Monitoring Well 30S267-25A02, 2015-2035

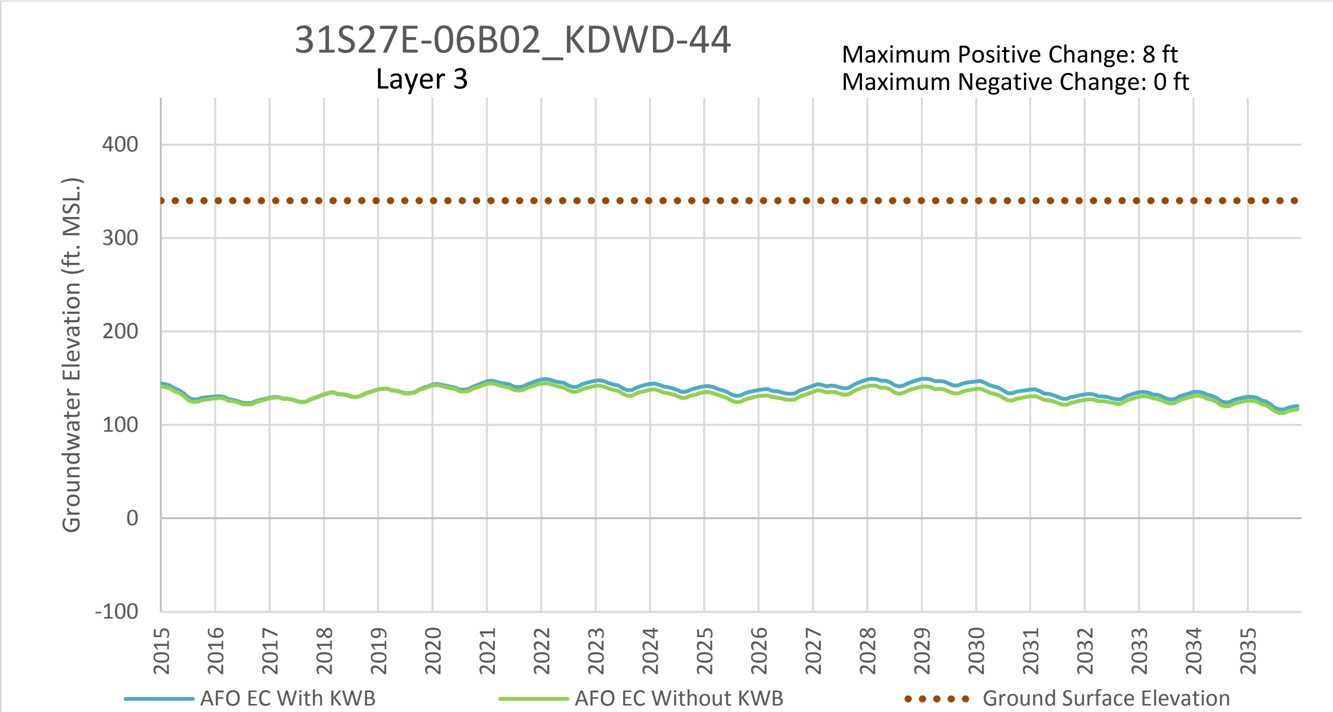

FIGURE 7-2 B.16. Hydrograph of Simulated Water Levels at Monitoring Well 31S27E-06B02_KDWD-44, 2015-2035

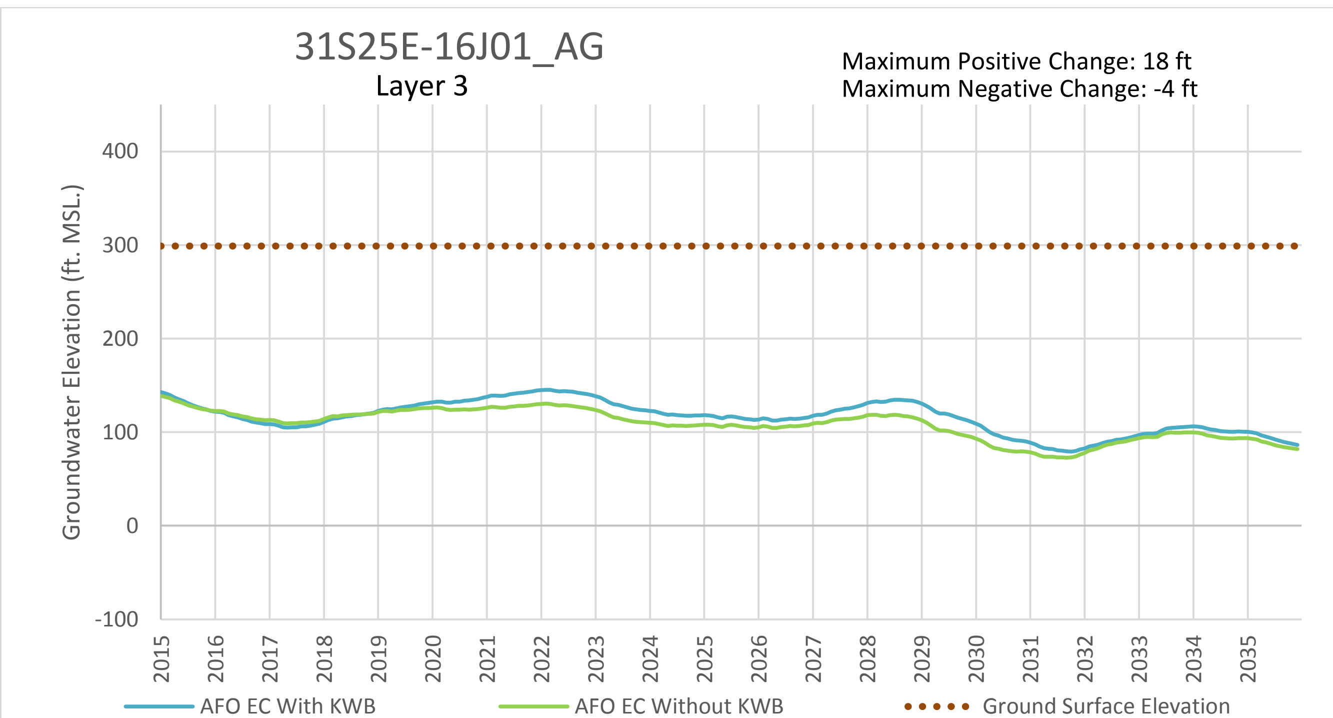

FIGURE 7-2 B.17. Hydrograph of Simulated Water Levels at Monitoring Well 31S25E-16J01_AG, 2015-2035

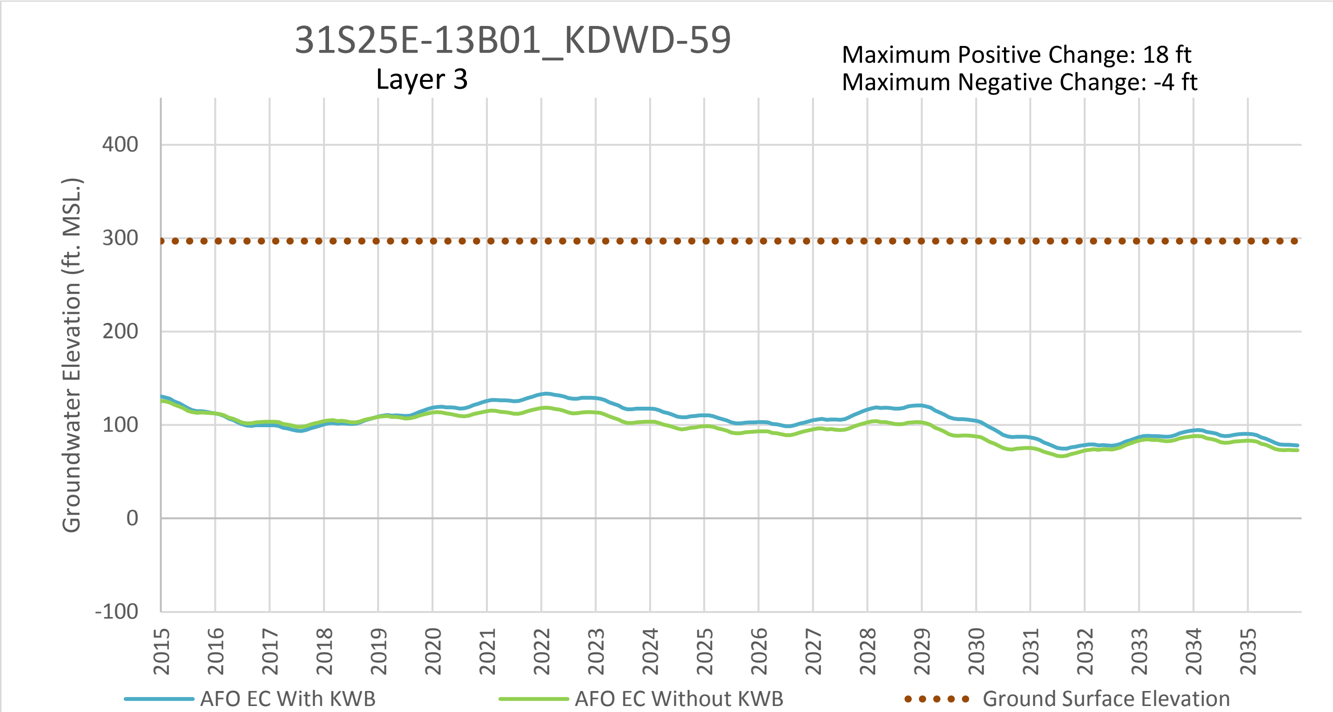

FIGURE 7-2 B.18. Hydrograph of Simulated Water Levels at Monitoring Well 31S25E-13B01_KDWD-59, 2015-2035

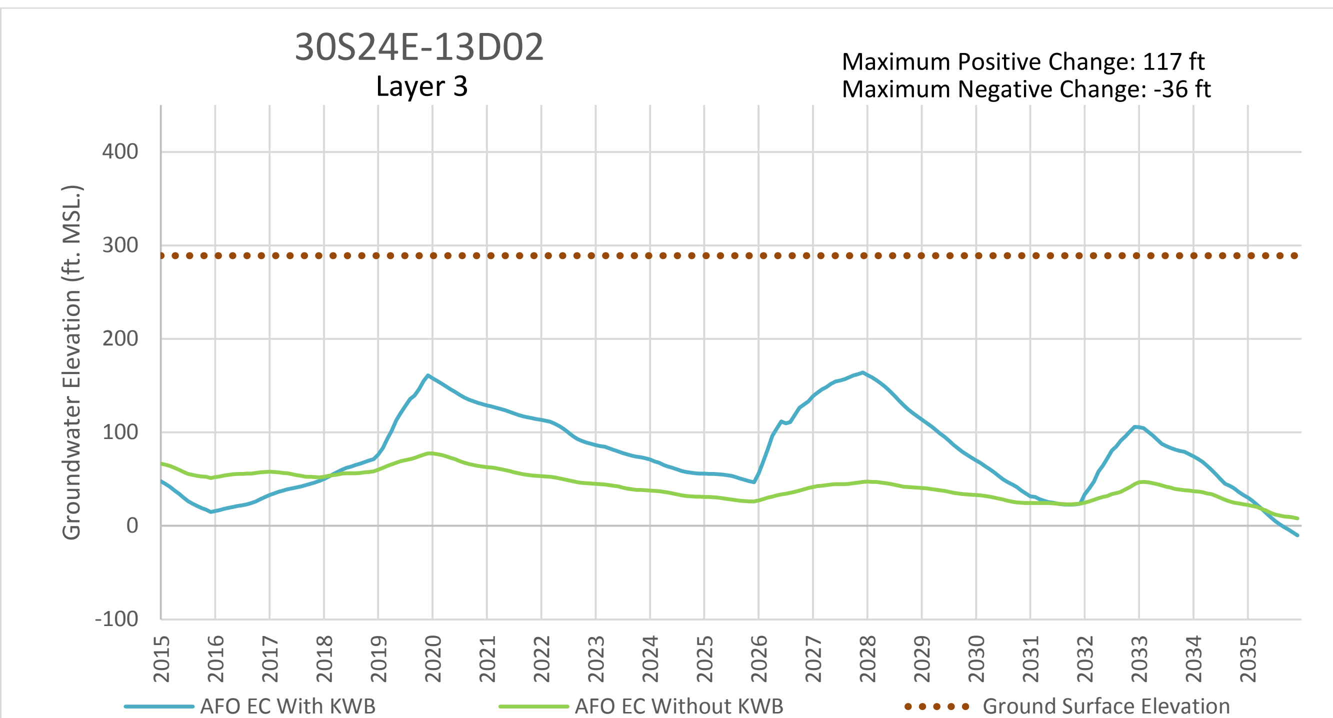

FIGURE 7-2 B.19. Hydrograph of Simulated Water Levels at Monitoring Well 30S24-13D02, 2015-2035

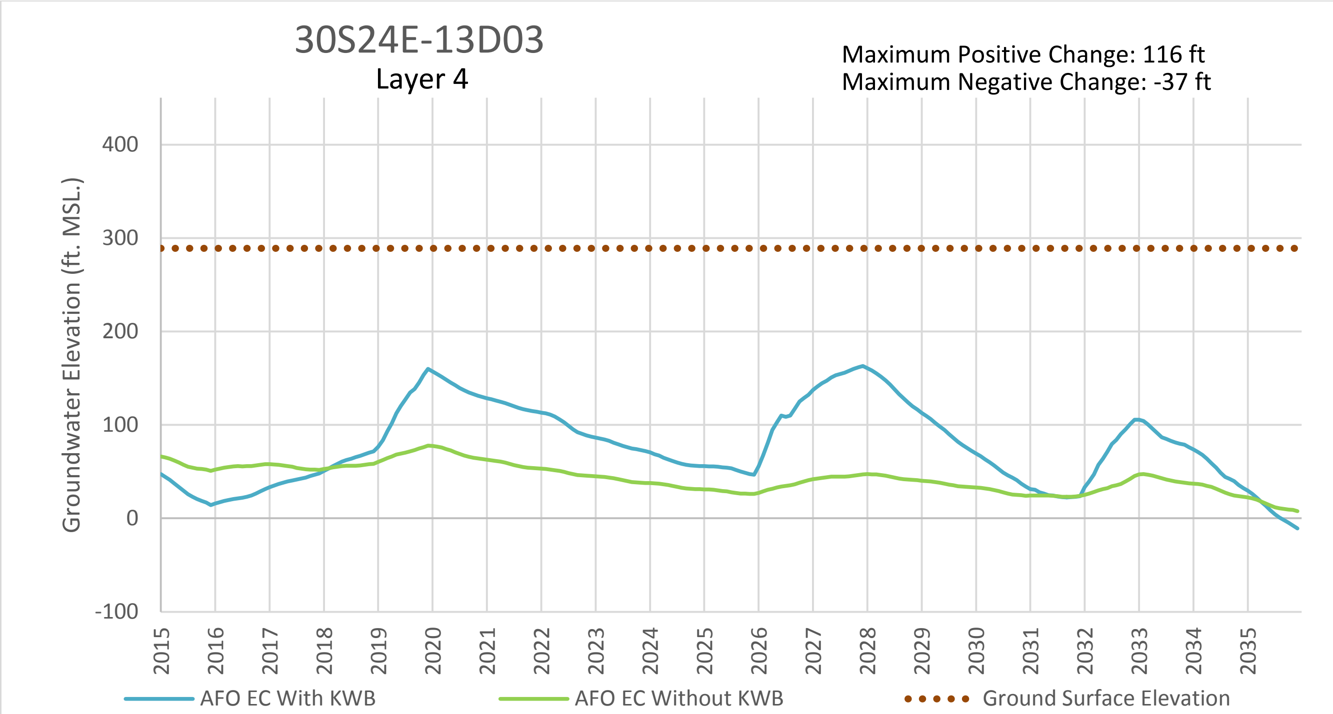

FIGURE 7-2 B.20. Hydrograph of Simulated Water Levels at Monitoring Well 30S24-13D03, 2015-2035

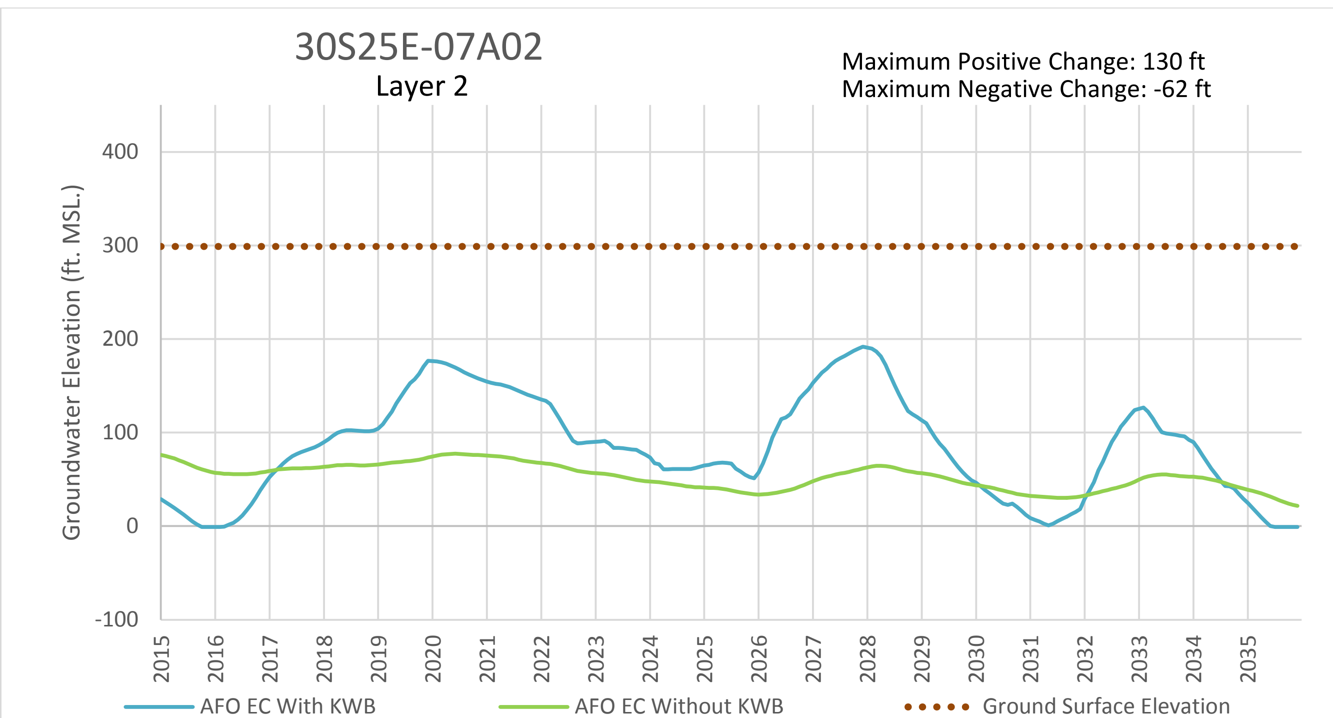

FIGURE 7-2 B.21. Hydrograph of Simulated Water Levels at Monitoring Well 30S25E-07A02, 2015-2035

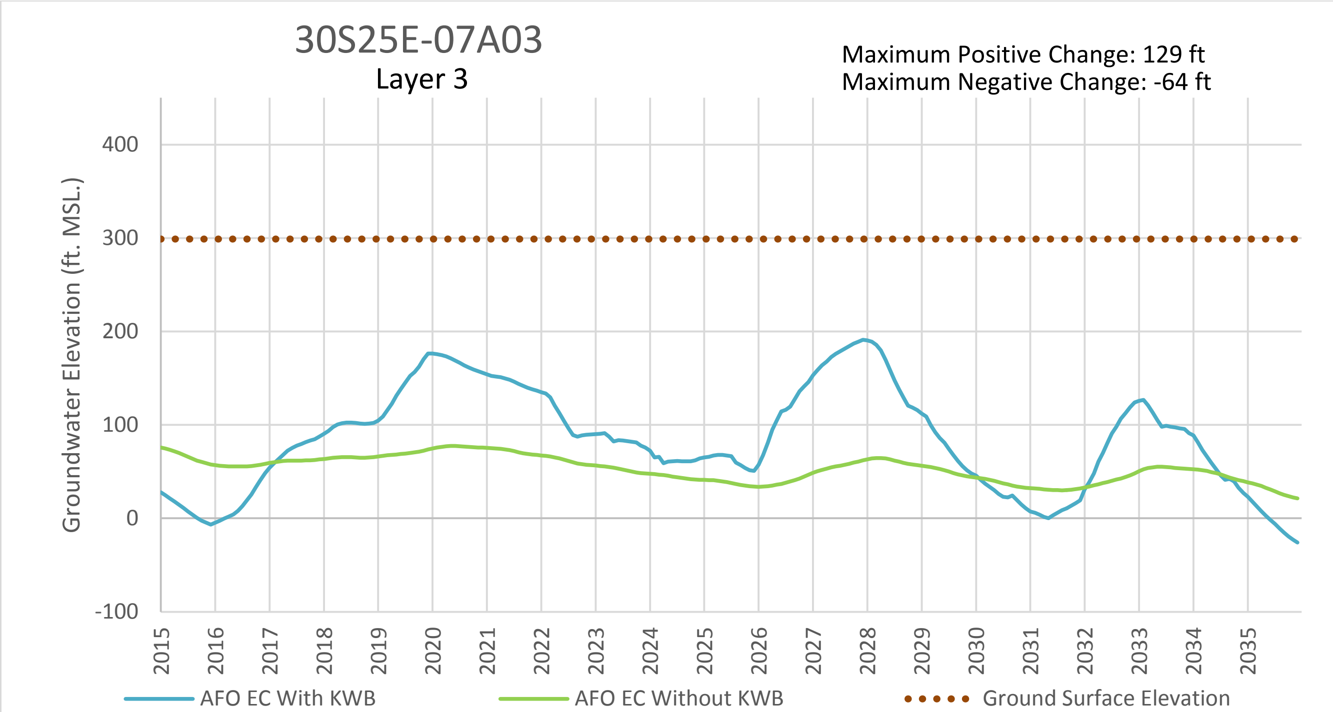

FIGURE 7-2 B.22. Hydrograph of Simulated Water Levels at Monitoring Well 30S25E-07A03, 2015-2035

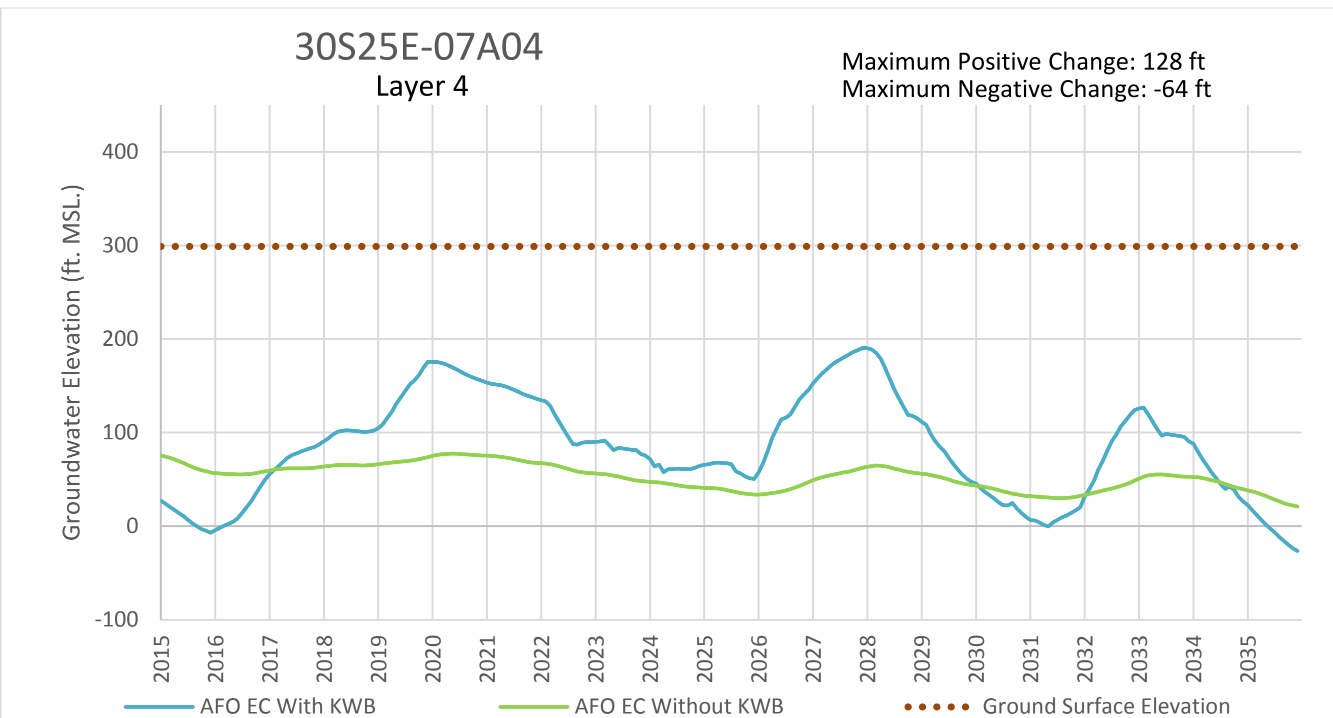

FIGURE 7-2 B.23. Hydrograph of Simulated Water Levels at Monitoring Well 30S25E-07A04, 2015-2035

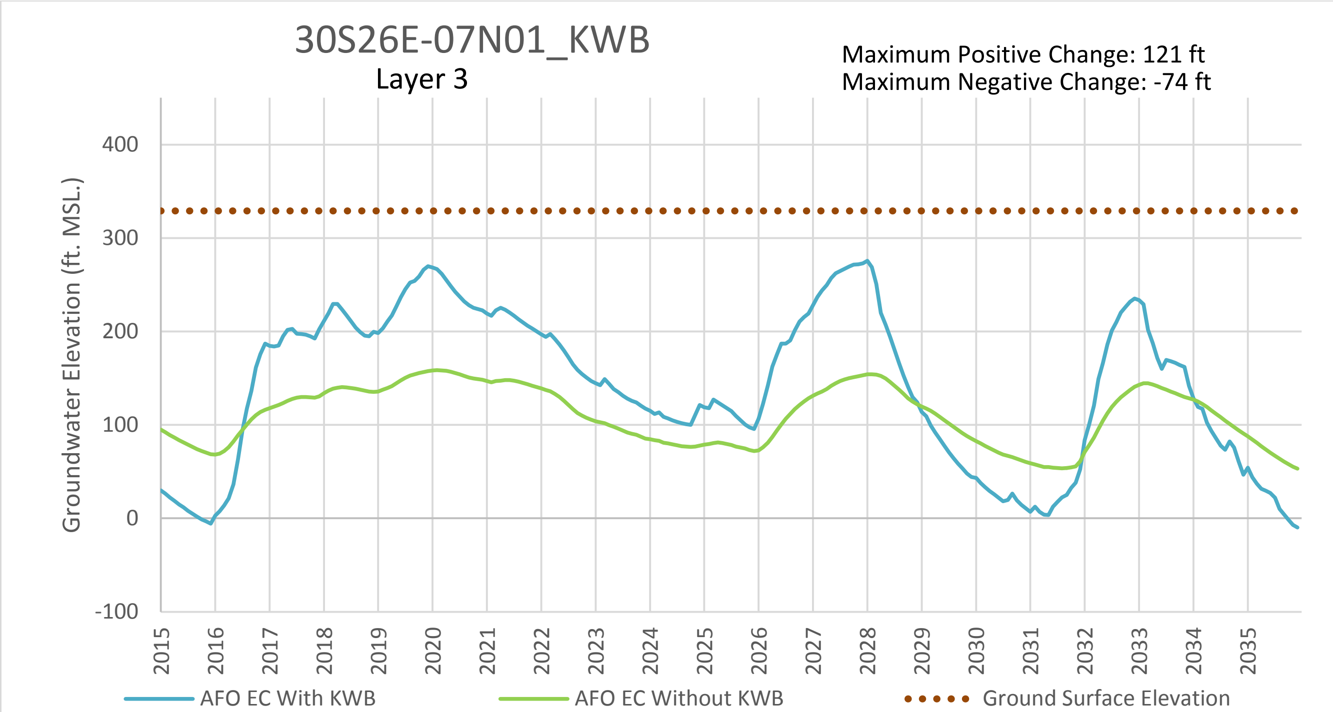

FIGURE 7-2 B.24. Hydrograph of Simulated Water Levels at Monitoring Well 30S26E-07N01_KWB, 2015-2035

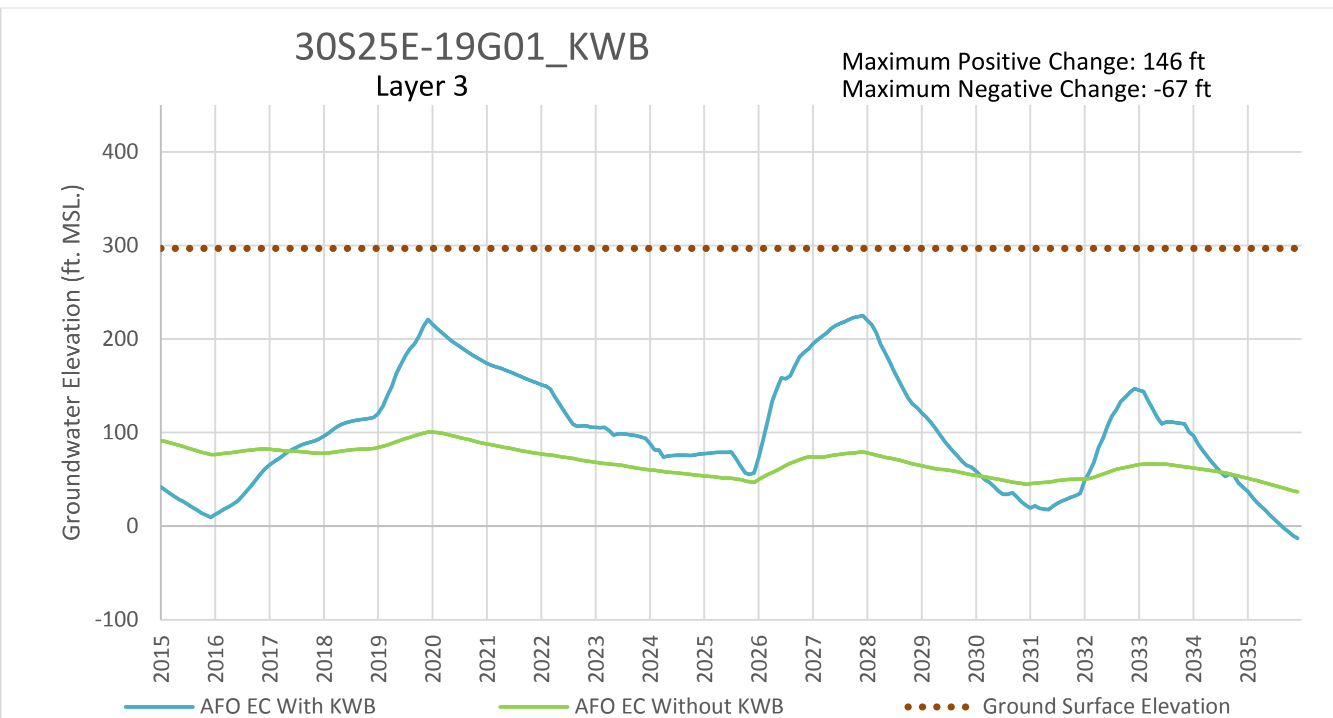

FIGURE 7-2 B.25. Hydrograph of Simulated Water Levels at Monitoring Well 30S25E-19G01_KWB, 2015-2035

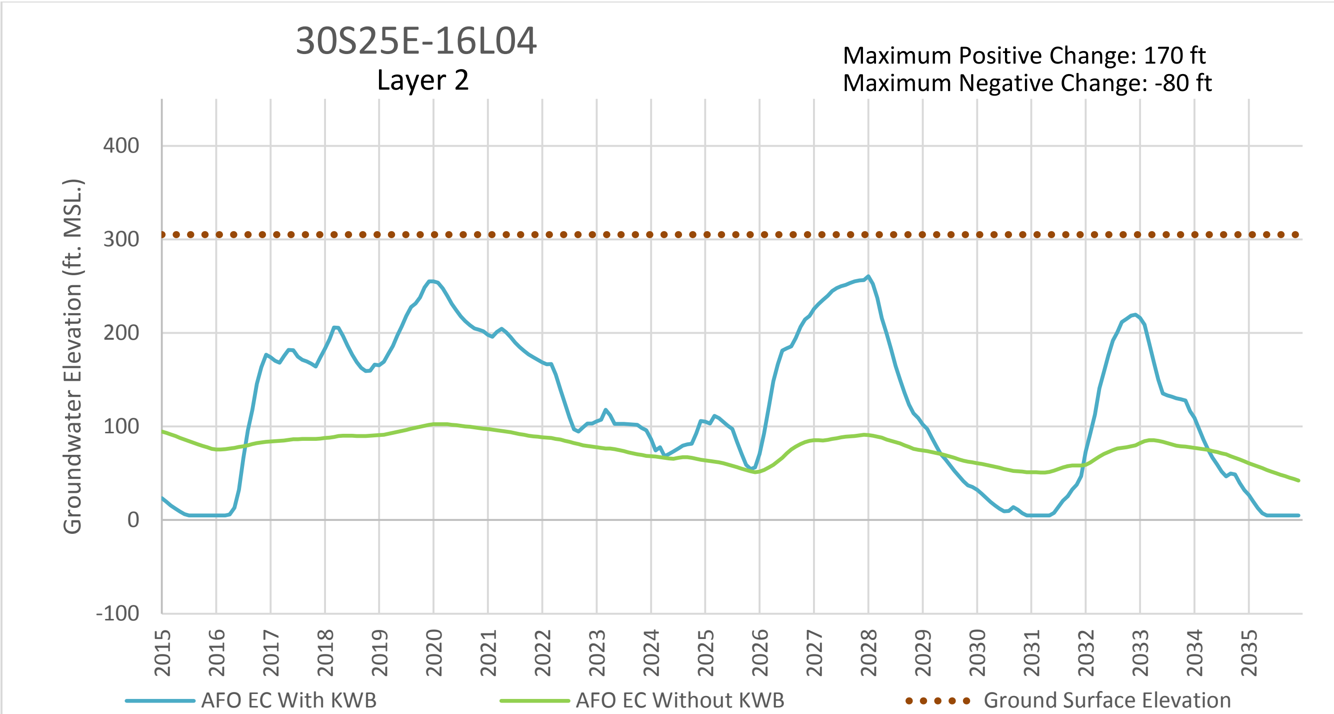

FIGURE 7-2 B.26. Hydrograph of Simulated Water Levels at Monitoring Well 30S25E-16L04, 2015-2035

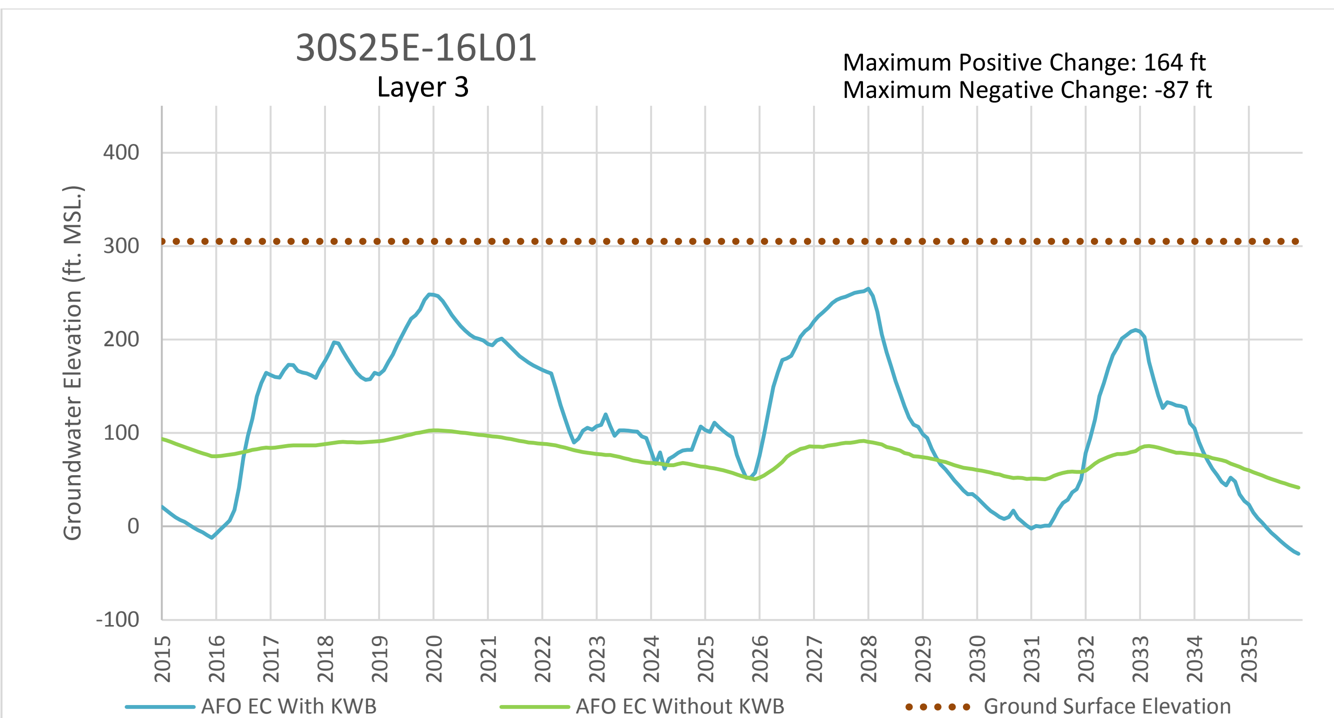

FIGURE 7-2 B.27. Hydrograph of Simulated Water Levels at Monitoring Well 30S25E-16L01, 2015-2035

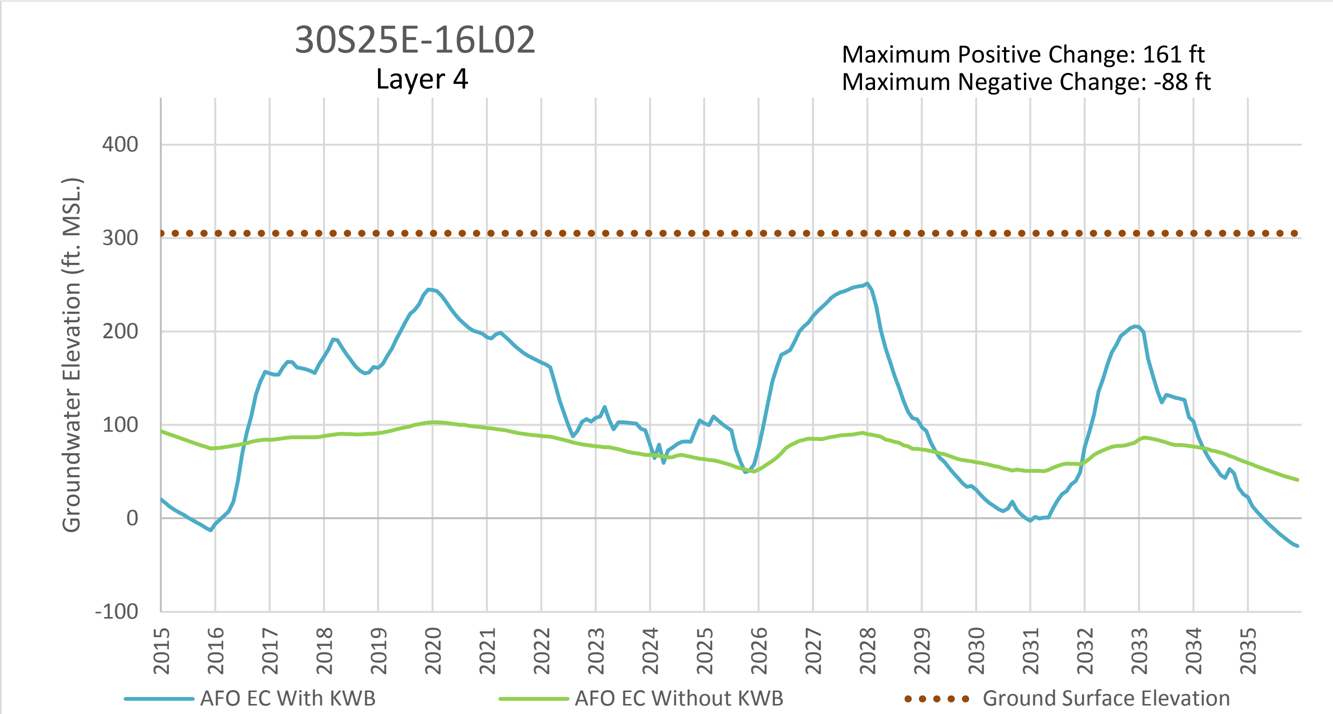

FIGURE 7-2 B.28. Hydrograph of Simulated Water Levels at Monitoring Well 30S25E-16L02, 2015-2035

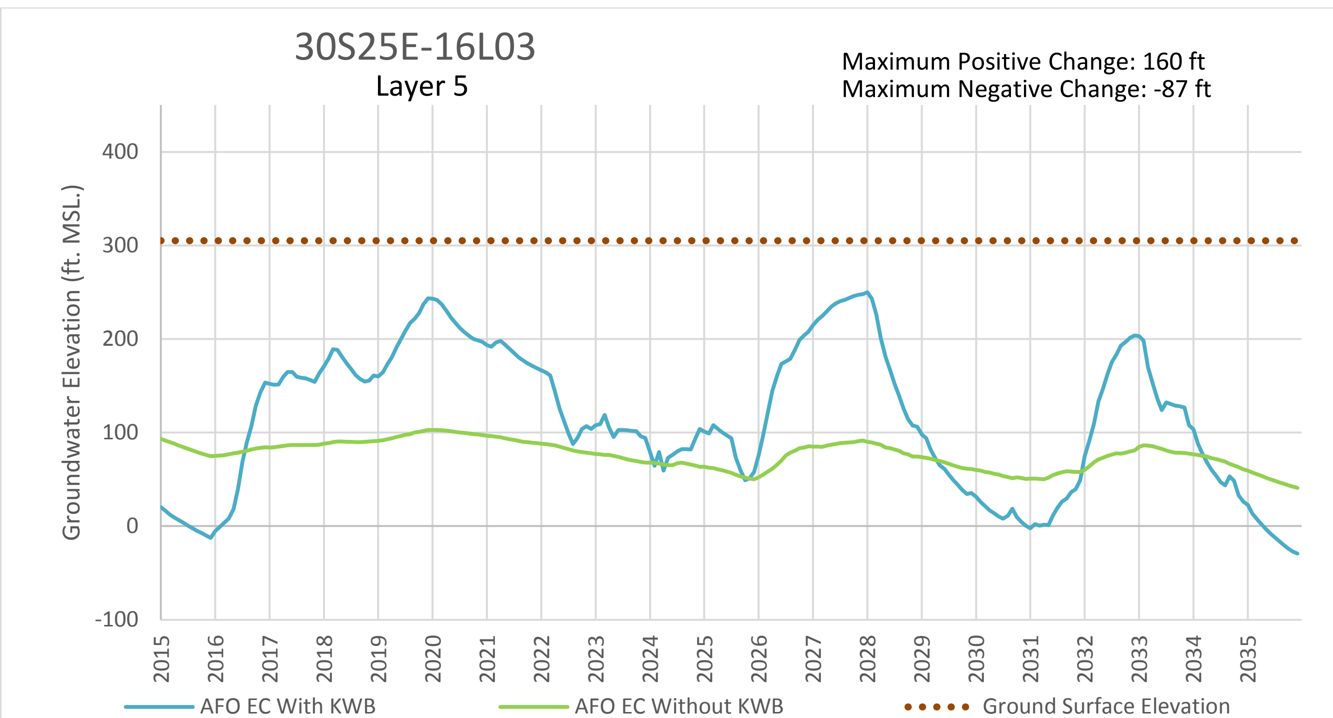

FIGURE 7-2 B.29. Hydrograph of Simulated Water Levels at Monitoring Well 30S25E-16L03, 2015-2035

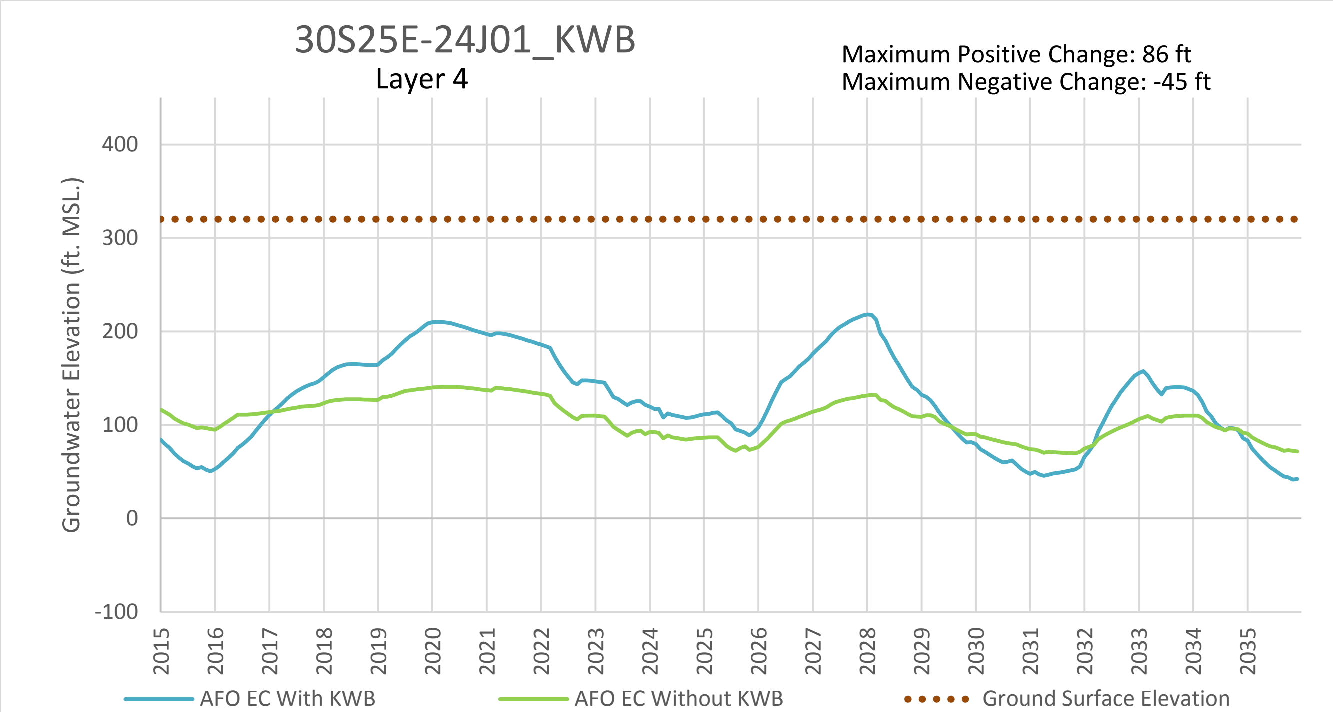

FIGURE 7-2 B.30. Hydrograph of Simulated Water Levels at Monitoring Well 30S257-24J01_KWB, 2015-2035

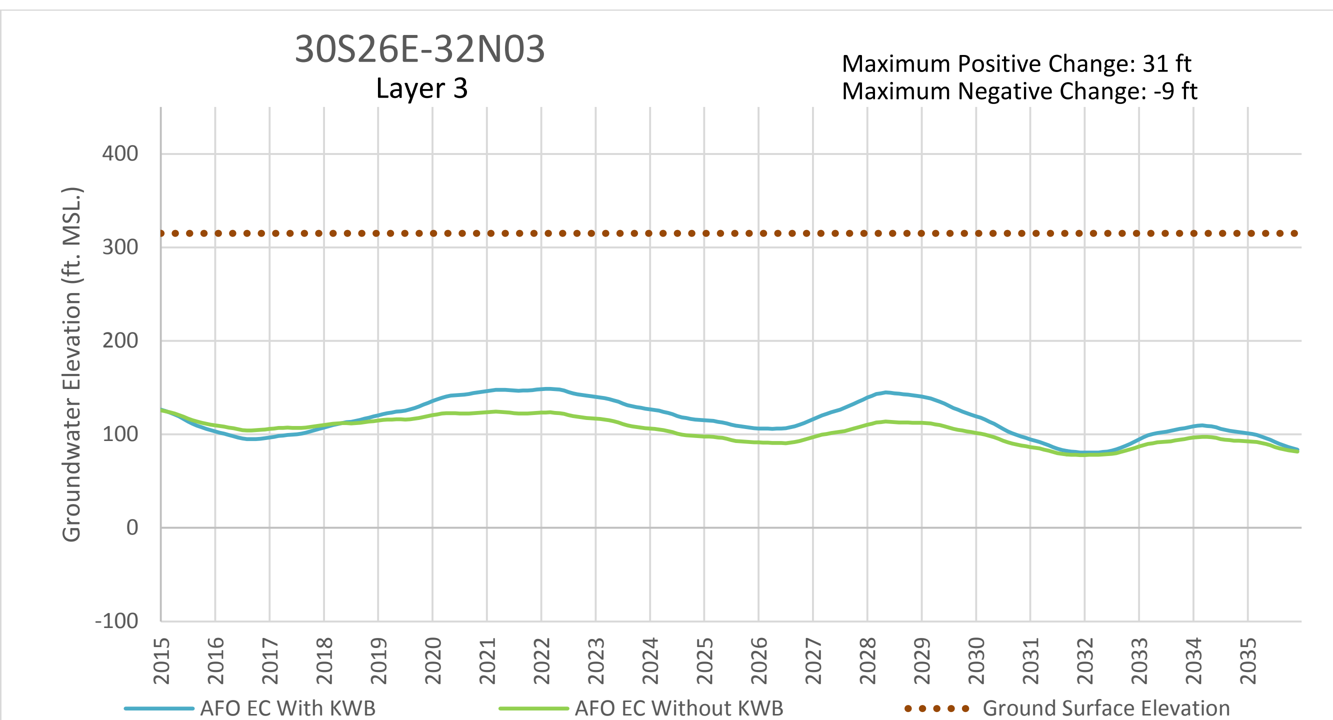

FIGURE 7-2 B.31. Hydrograph of Simulated Water Levels at Monitoring Well 30S26E-32N03, 2015-2035

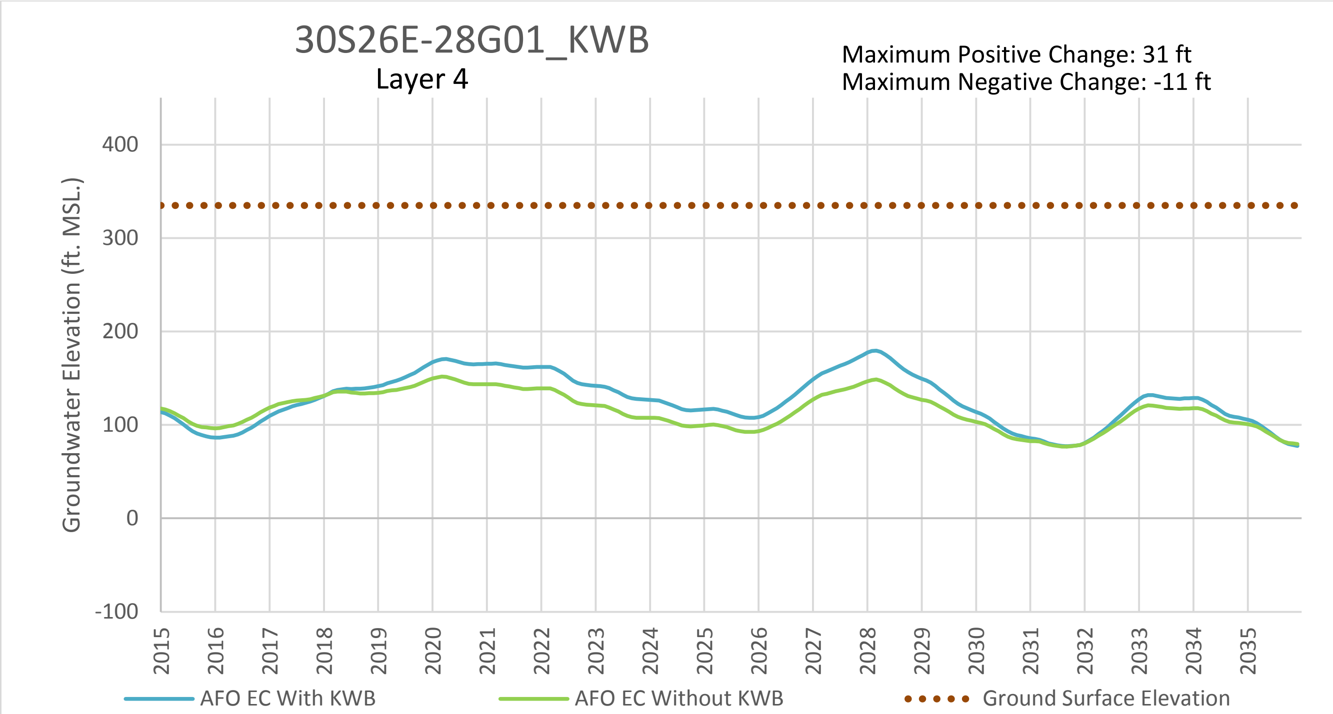

FIGURE 7-2 B.32. Hydrograph of Simulated Water Levels at Monitoring Well 30S267-28G01_KWB, 2015-2035

APPENDIX 7-2
C. AFO-BC HYDROGRAPHS

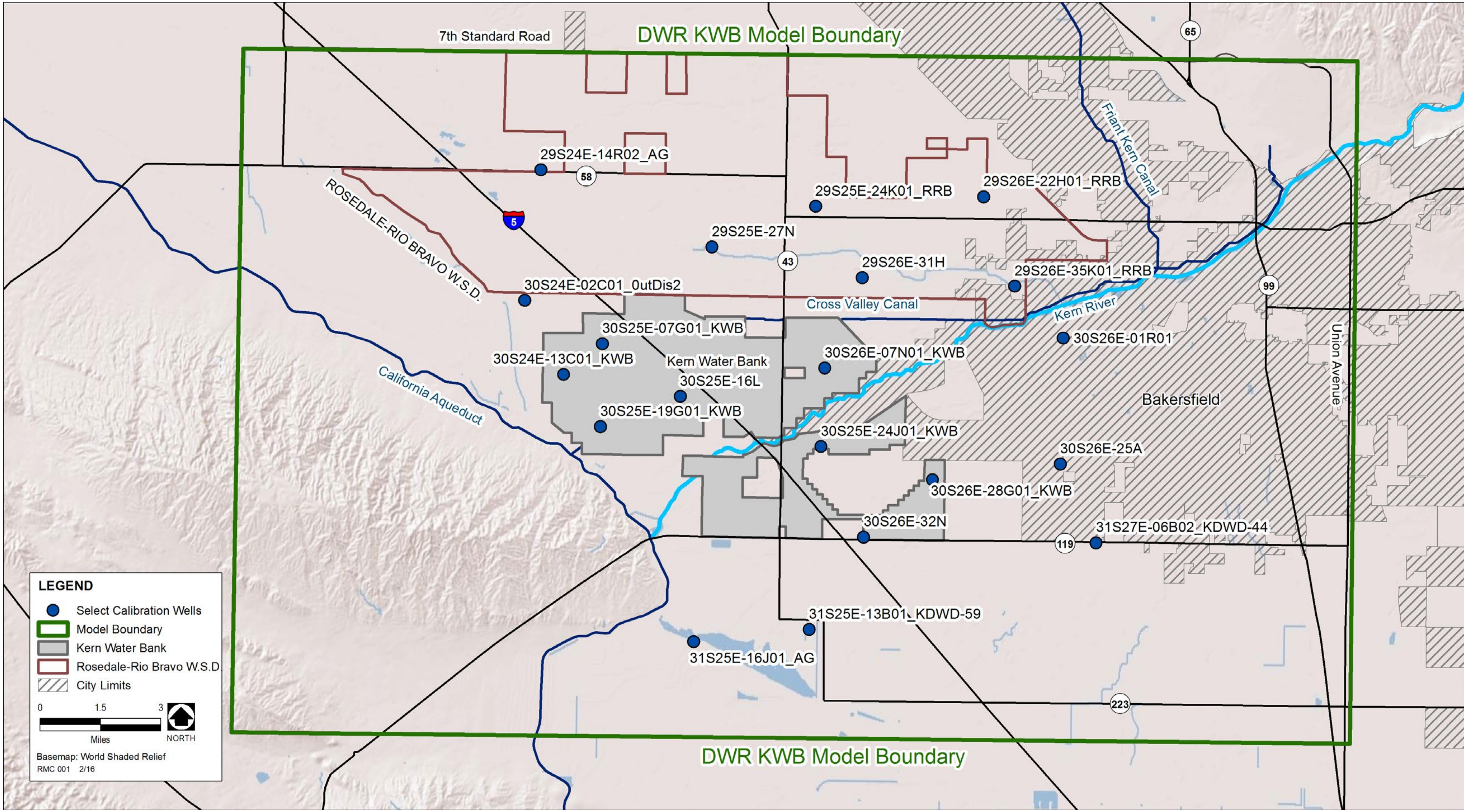

FIGURE 7-2 C.1. **Location of Select Monitoring Wells Inside (14 Wells) and Outside (17 Wells) of Kern Water Bank**

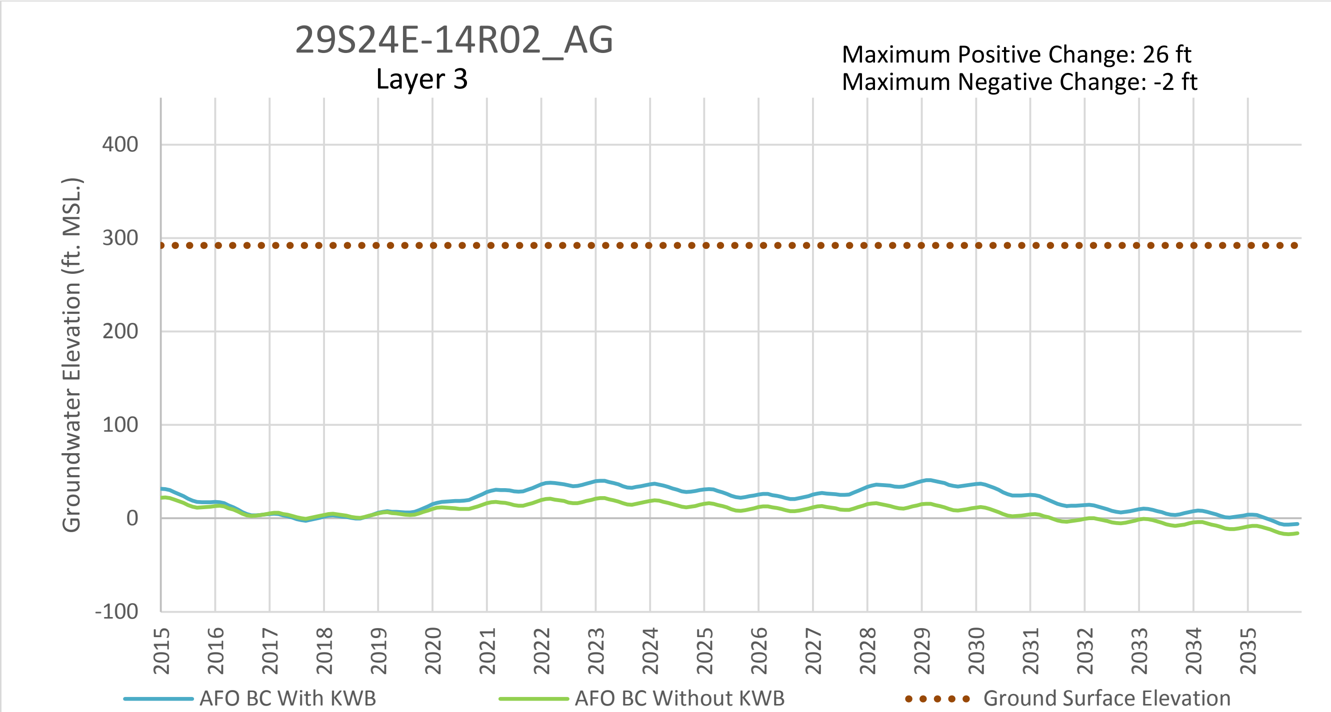

FIGURE 7-2 C.2. **Hydrograph of Simulated Water Levels at Monitoring Well 29S24E14R02_Ag, 2015-2035**

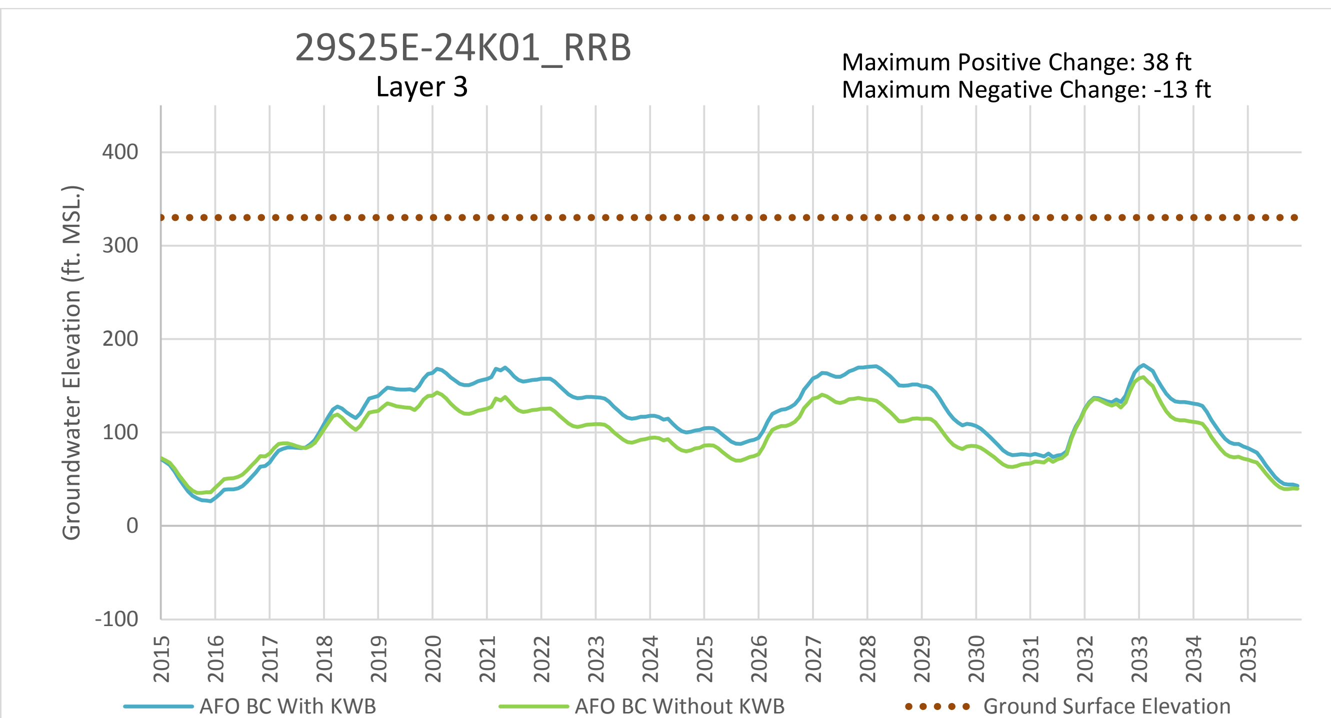

FIGURE 7-2 C.3. **Hydrograph of Simulated Water Levels at Monitoring Well 29S257-24K01_RRB, 2015-2035**

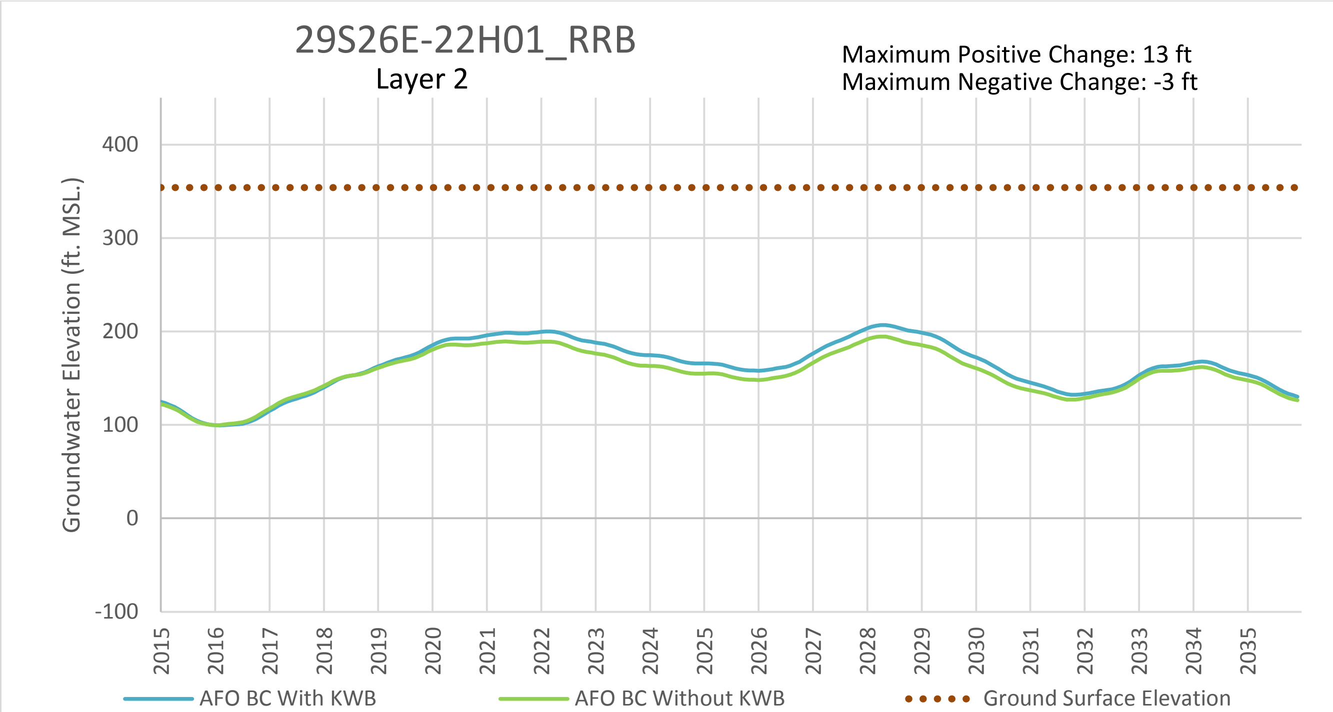

FIGURE 7-2 C.4. Hydrograph of Simulated Water Levels at Monitoring Well 29S267-22H01_RRB, 2015-2035

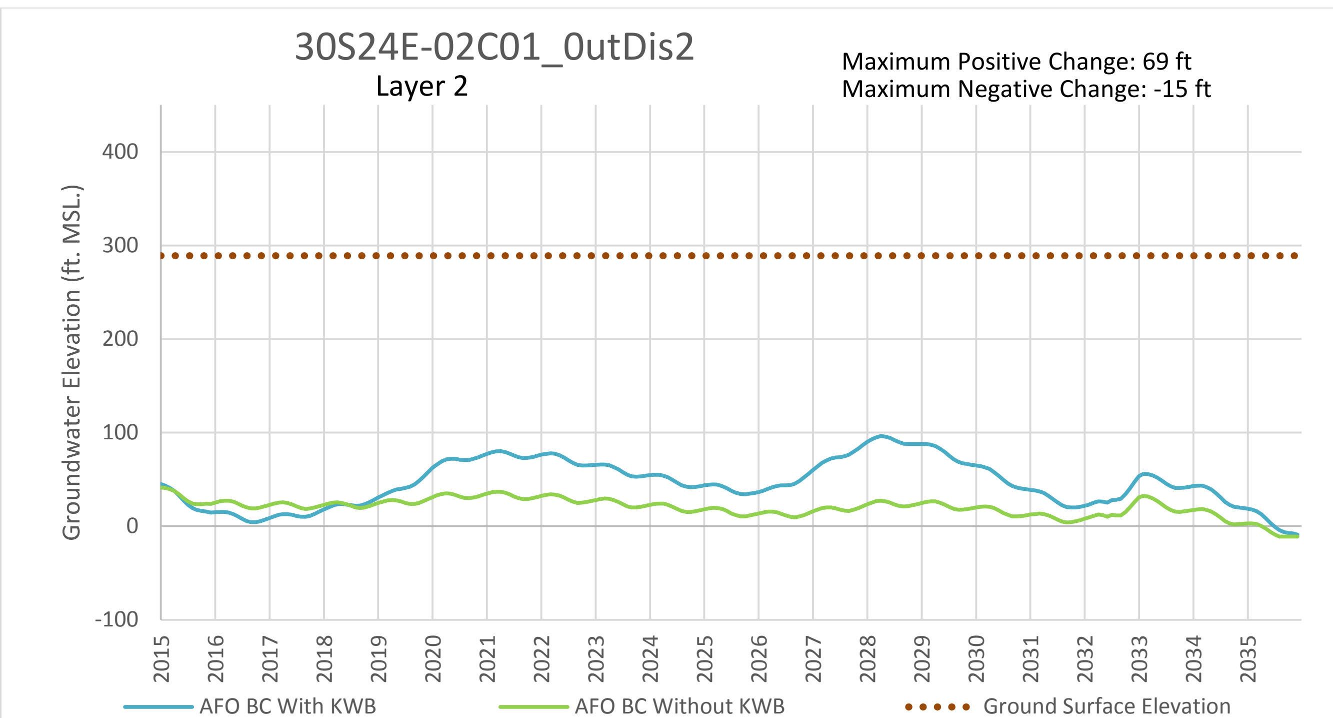

FIGURE 7-2 C.5. Hydrograph of Simulated Water levels at Monitoring Well 30S24E-02C01_0utDis2, 2015-2035

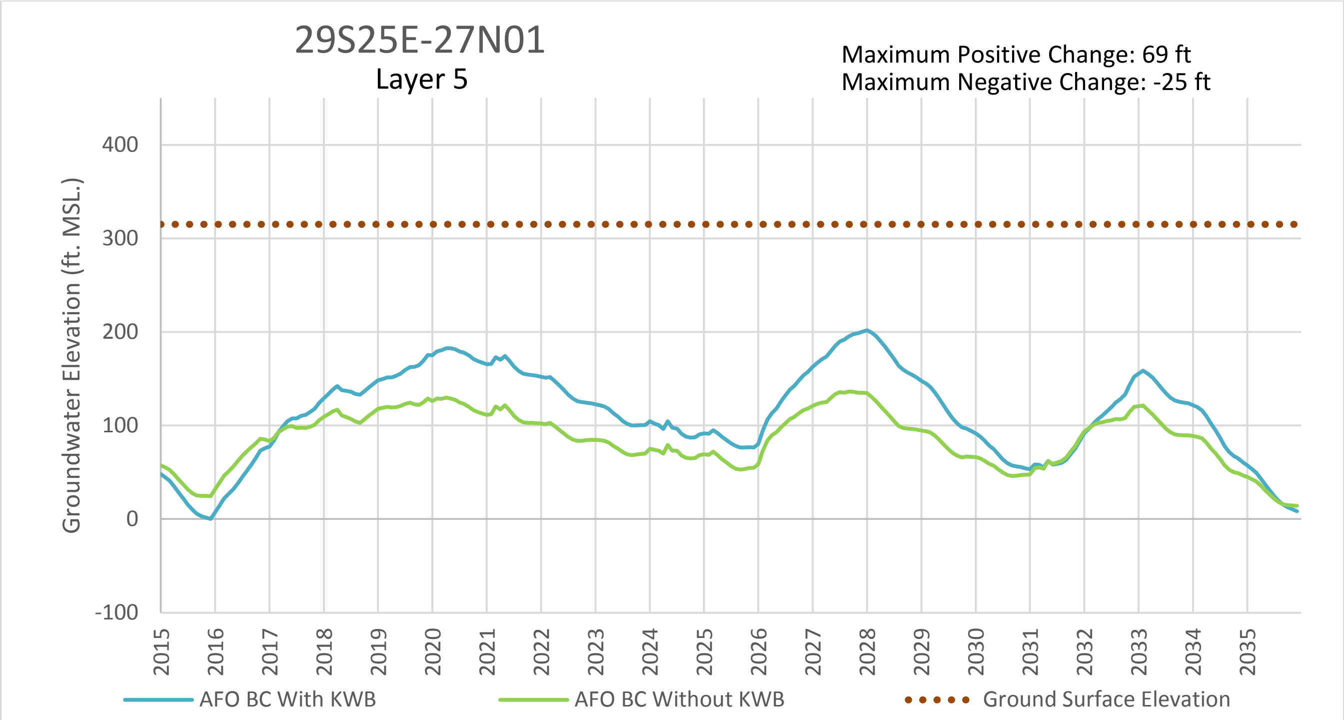

FIGURE 7-2 C.6. **Hydrograph of Simulated Water Levels at Monitoring Well 29S257-27N01, 2015-2035**

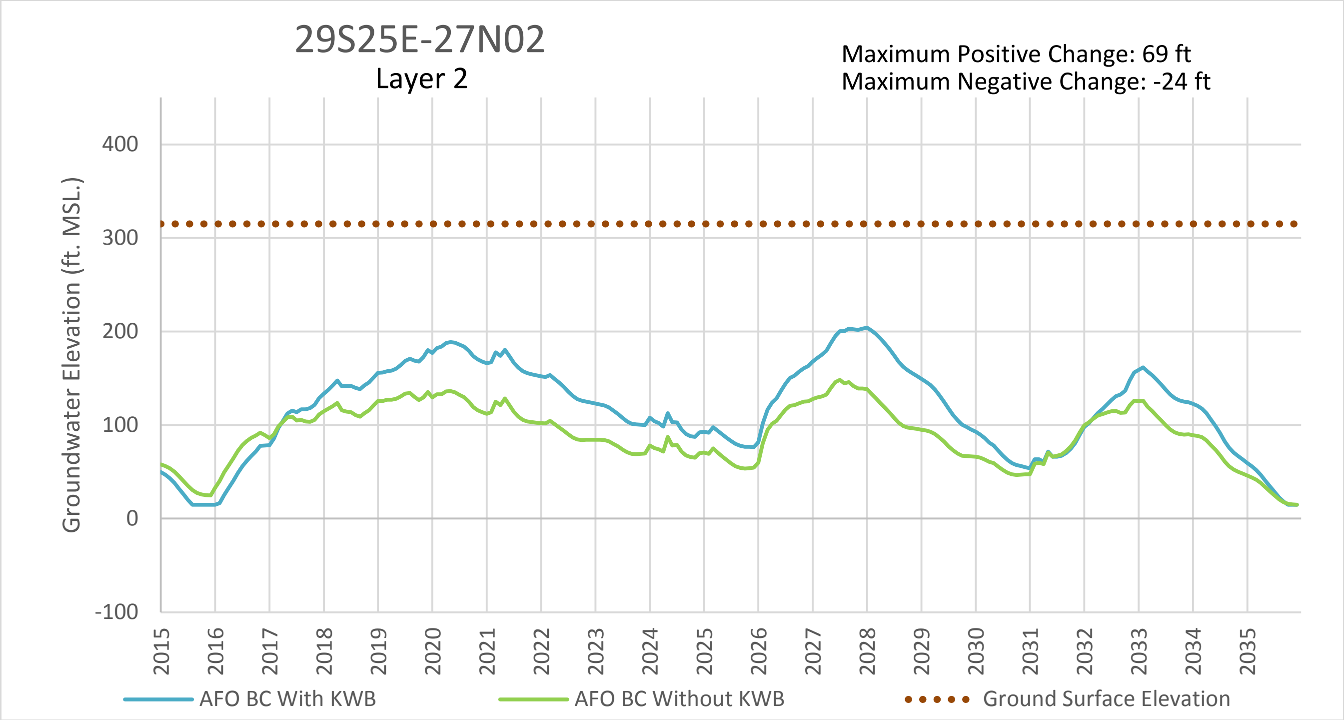

FIGURE 7-2 C.7. **Hydrograph of Simulated Water Levels at Monitoring Well 29S257-27N02, 2015-2035**

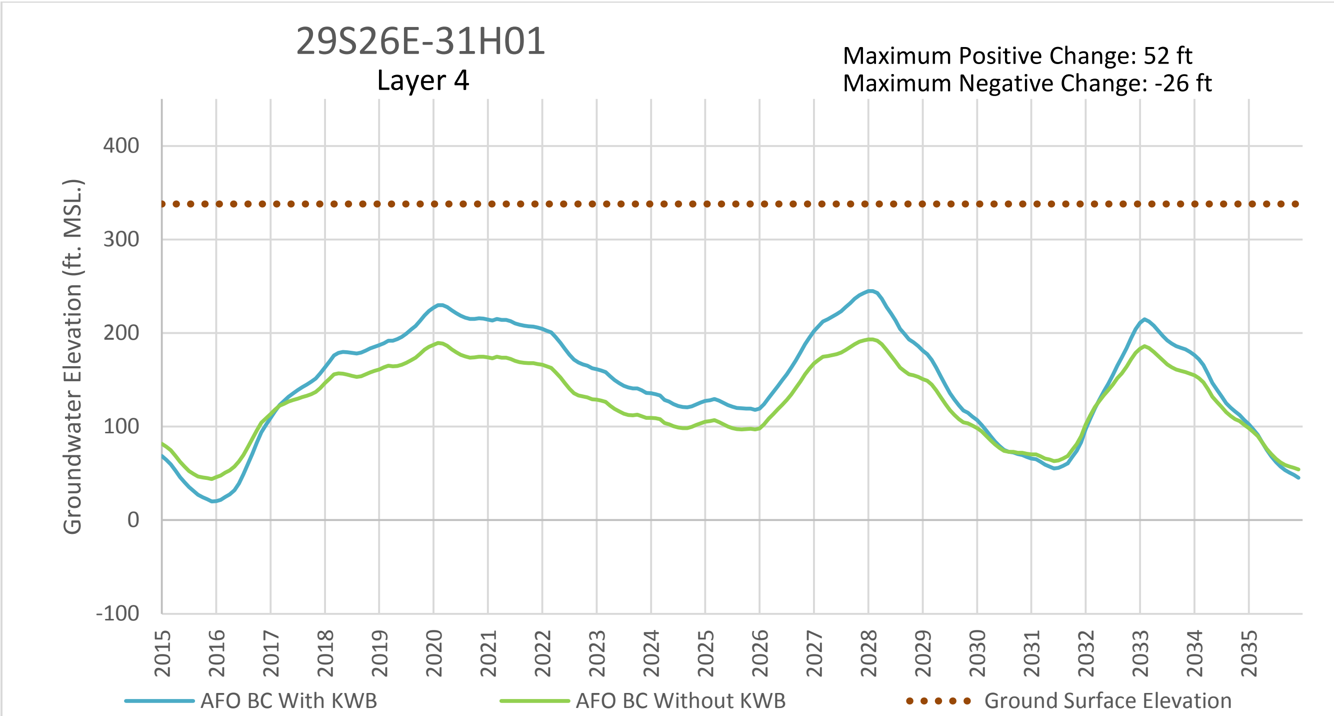

FIGURE 7-2 C.8. Hydrograph of Simulated Water Levels at Monitoring Well 29S26E-31H01, 2015-2035

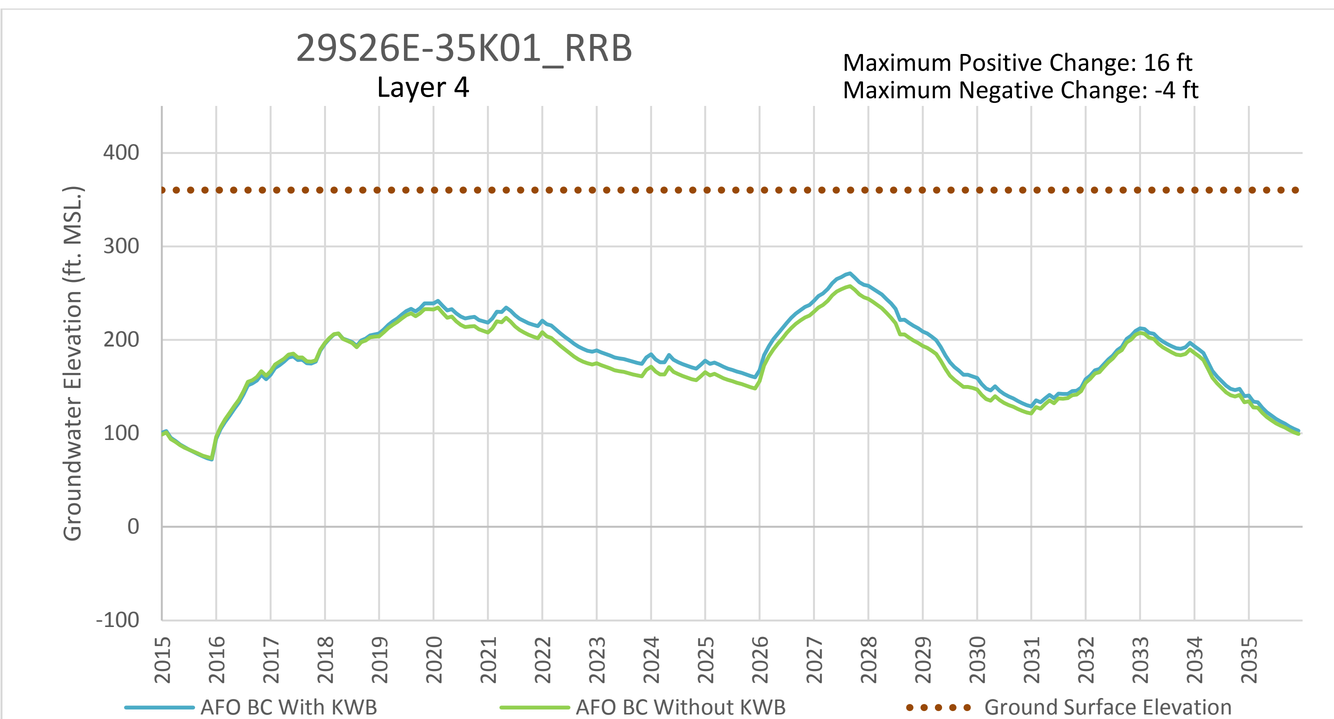

FIGURE 7-2 C.9. Hydrograph of Simulated Water Levels at Monitoring Well 29S26E-35K01_RRB, 2015-2035

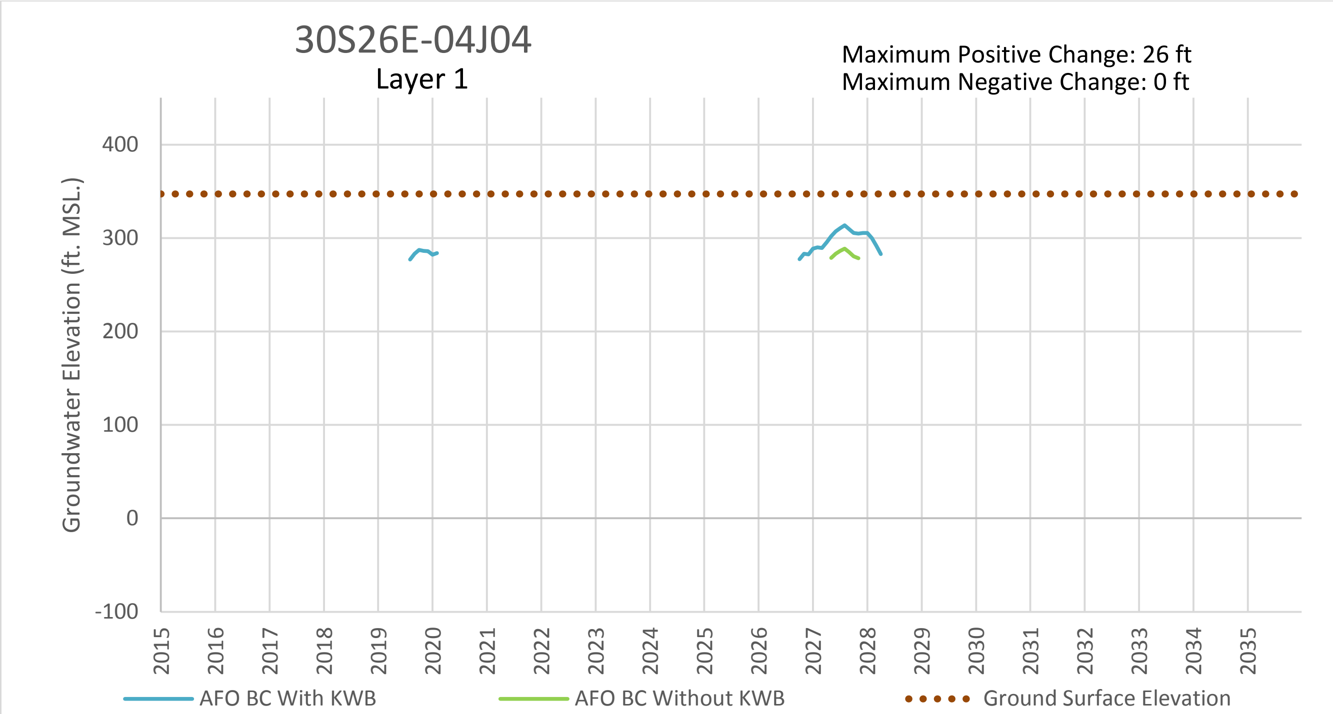

FIGURE 7-2 C.10. Hydrograph of Simulated Water Levels at Monitoring Well 30S26E-04J04, 2015-2035

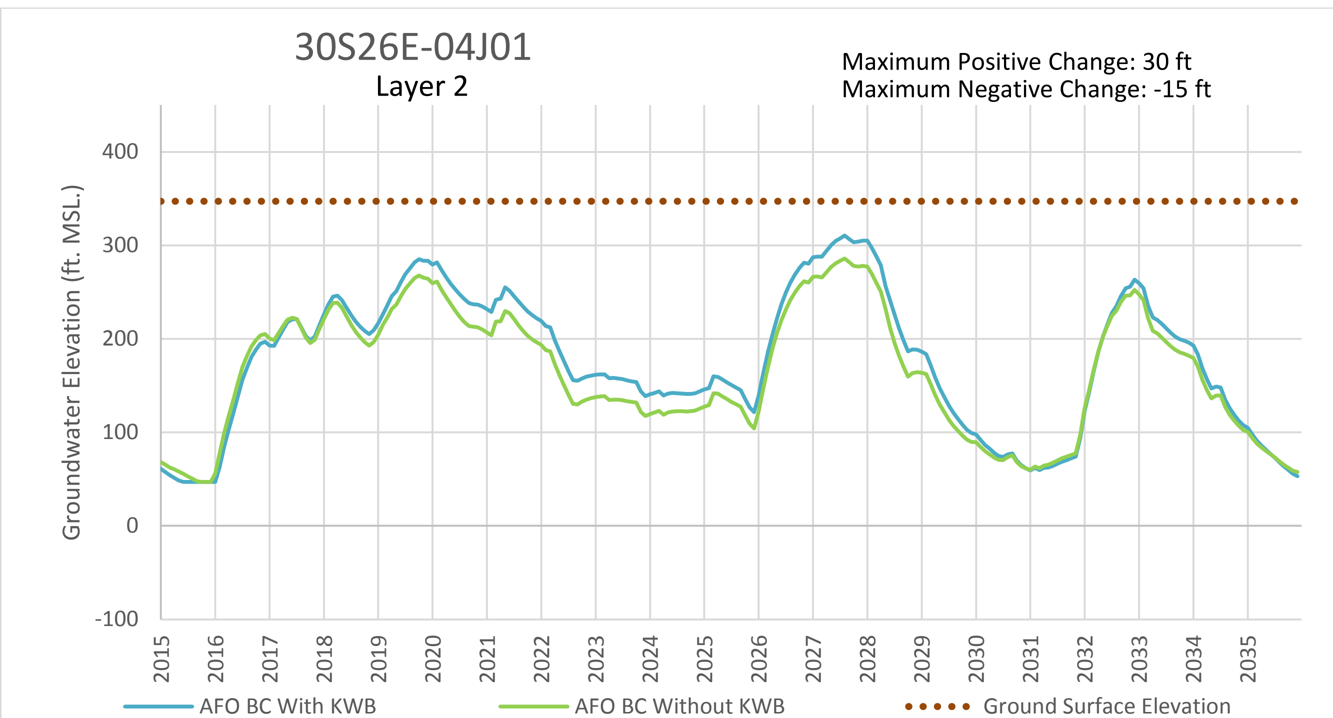

FIGURE 7-2 C.11. Hydrograph of Simulated Water Levels at Monitoring Well 30S26E-04J01, 2015-2035

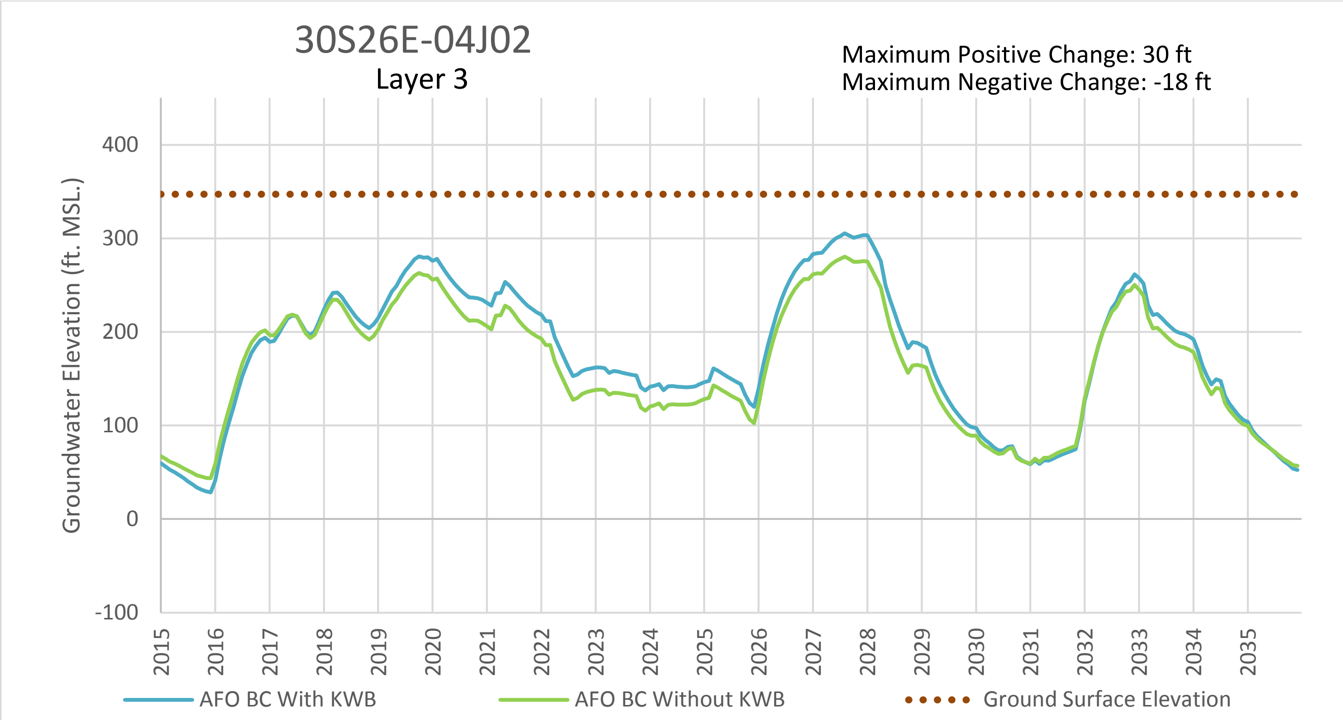

FIGURE 7-2 C.12. Hydrograph of Simulated Water Levels at Monitoring Well 30S26E-04J02, 2015-2035

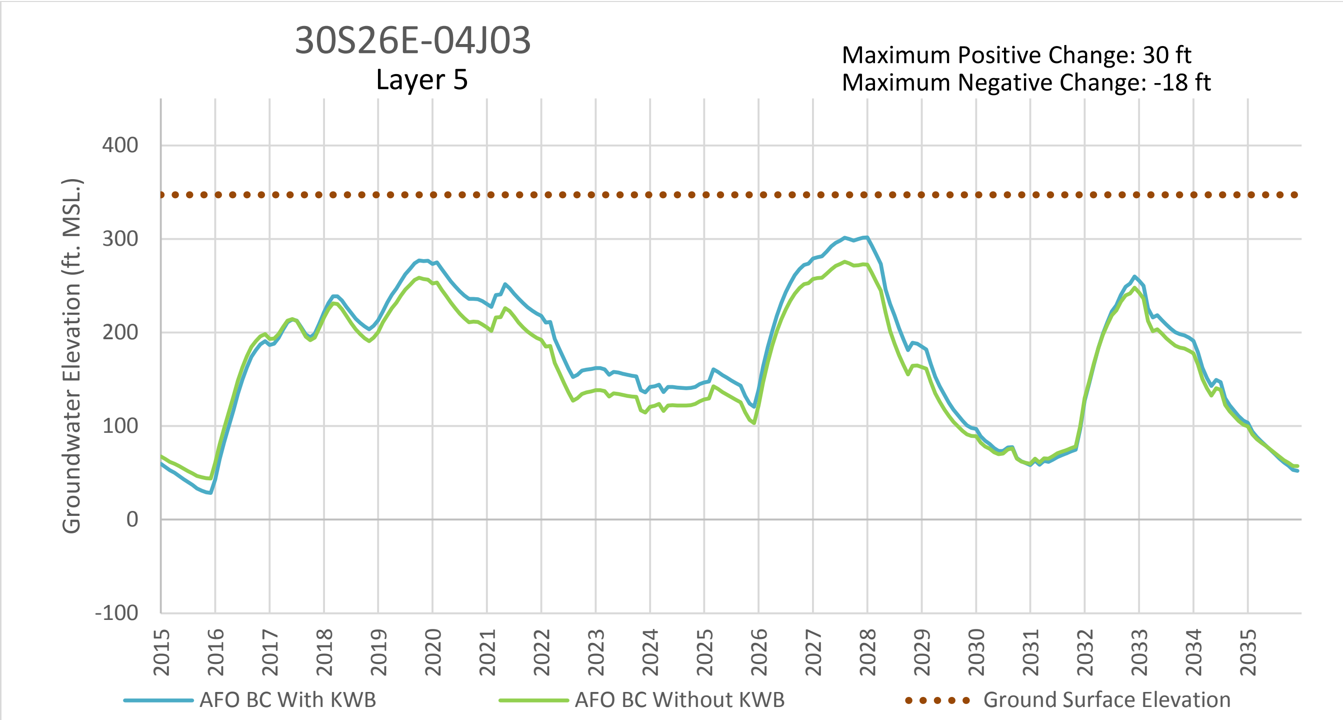

FIGURE 7-2 C.13. Hydrograph of Simulated Water Levels at Monitoring Well 30S26E-04J03, 2015-2035

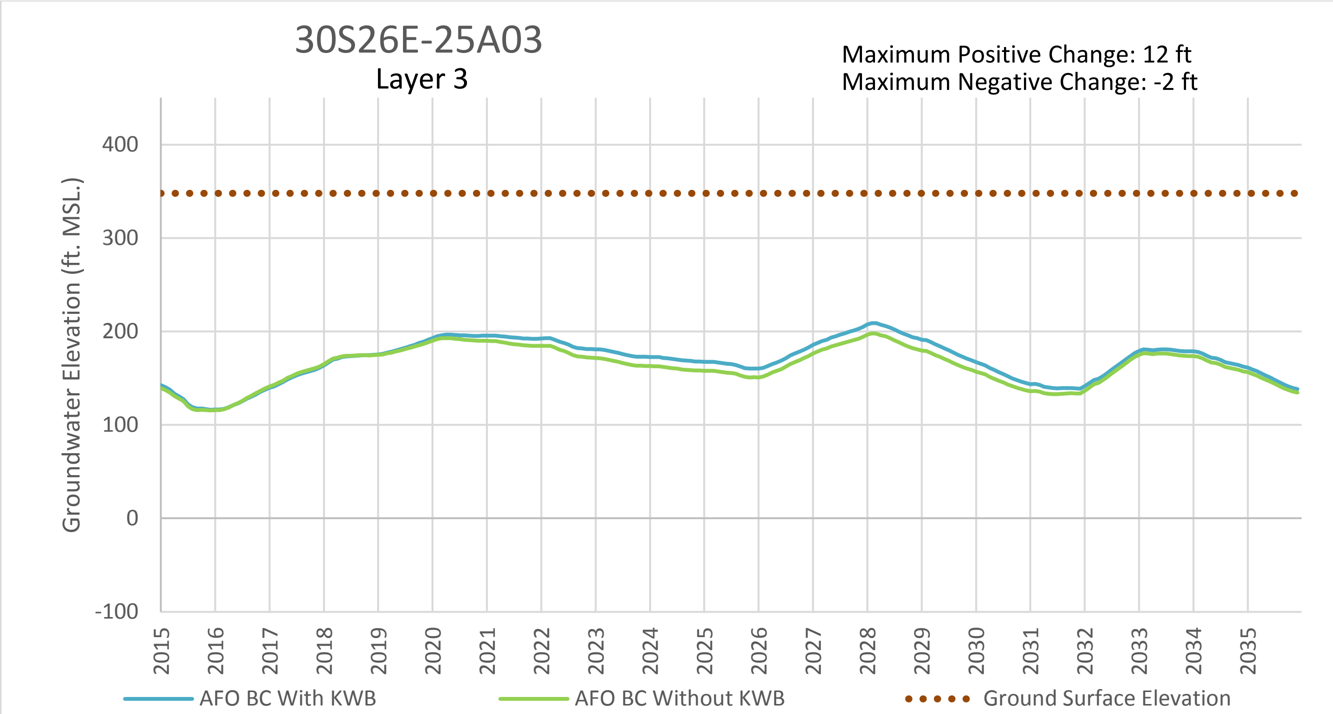

FIGURE 7-2 C.14. Hydrograph of Simulated Water Levels at Monitoring Well 30S267-25A03, 2015-2035

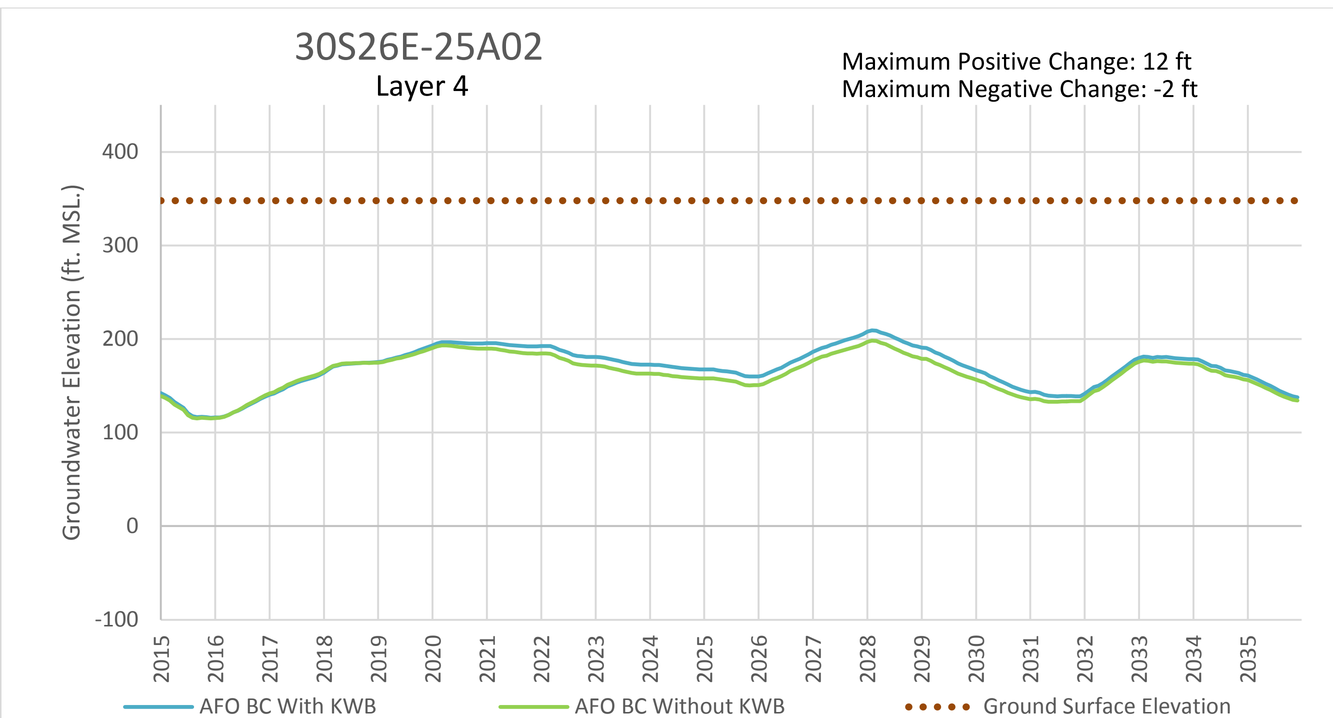

FIGURE 7-2 C.15. Hydrograph of Simulated Water Levels at Monitoring Well 30S267-25A02, 2015-2035

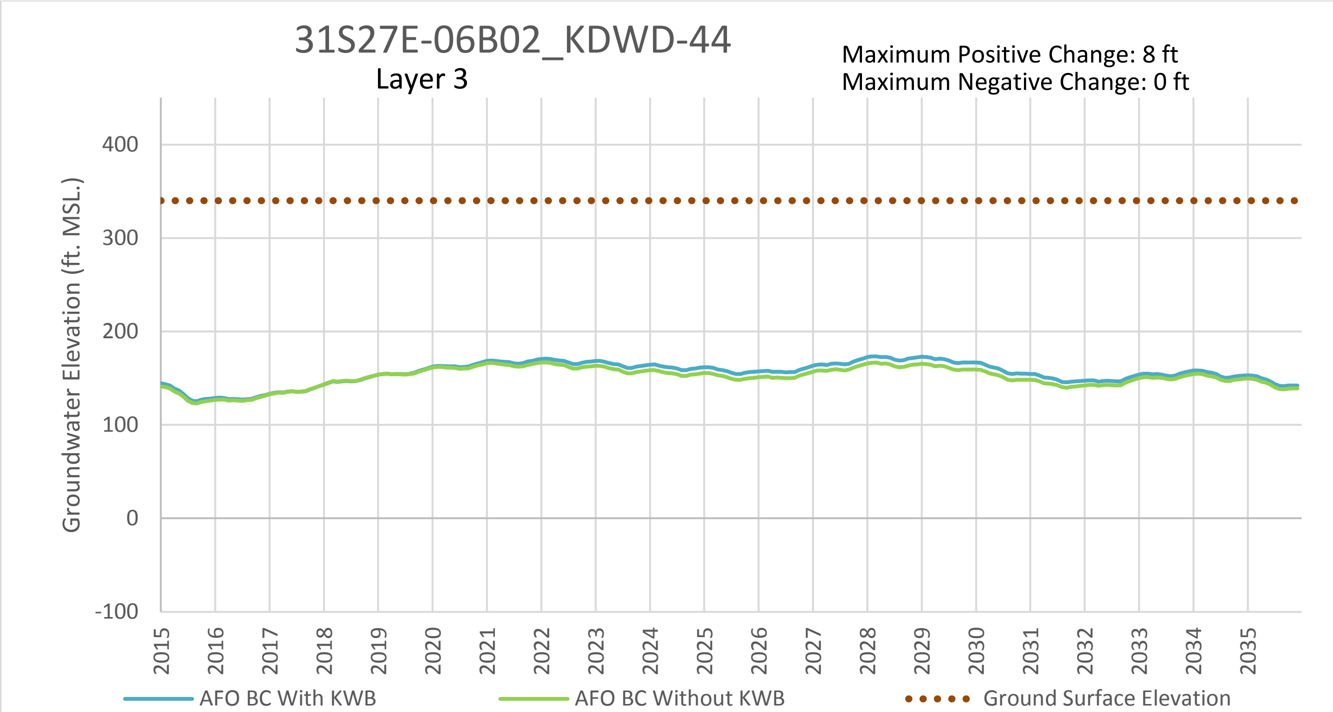

FIGURE 7-2 C.16. Hydrograph of Simulated Water Levels at Monitoring Well 31S27E-06B02_KDWD-44, 2015-2035

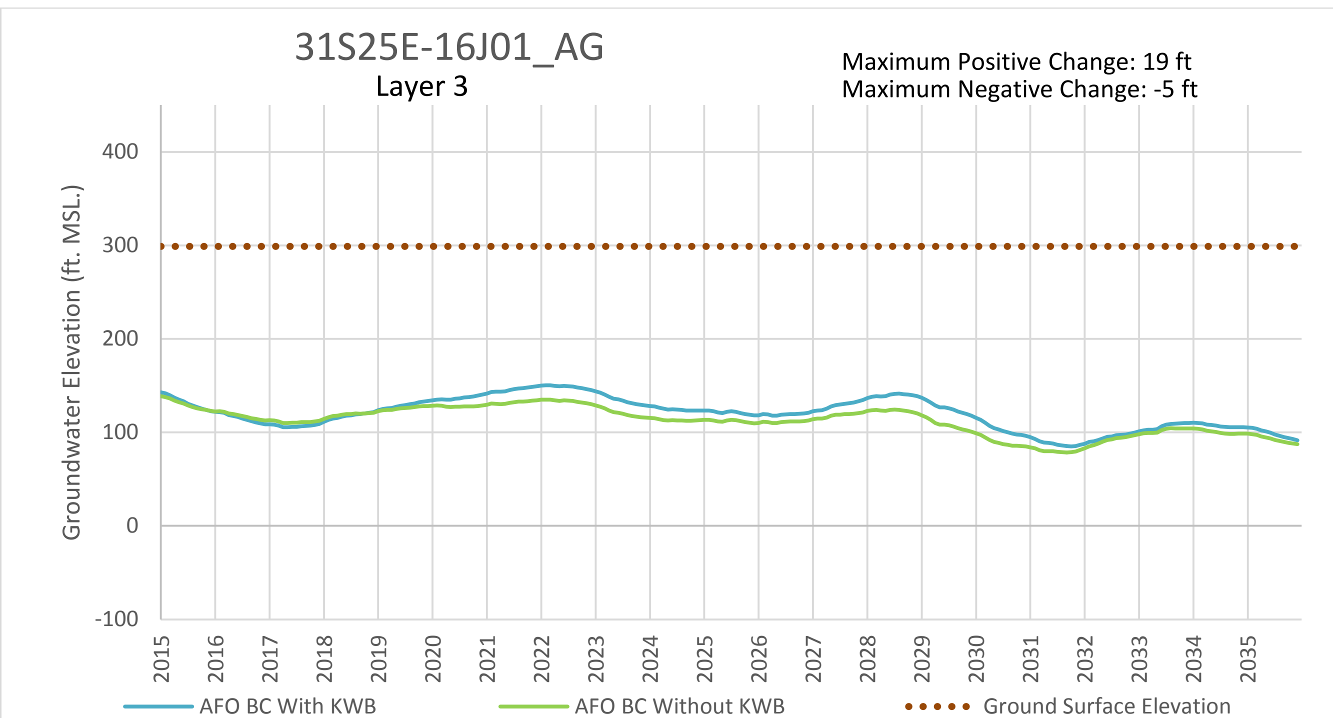

FIGURE 7-2 C.17. Hydrograph of Simulated Water Levels at Monitoring Well 31S25E-16J01_AG, 2015-2035

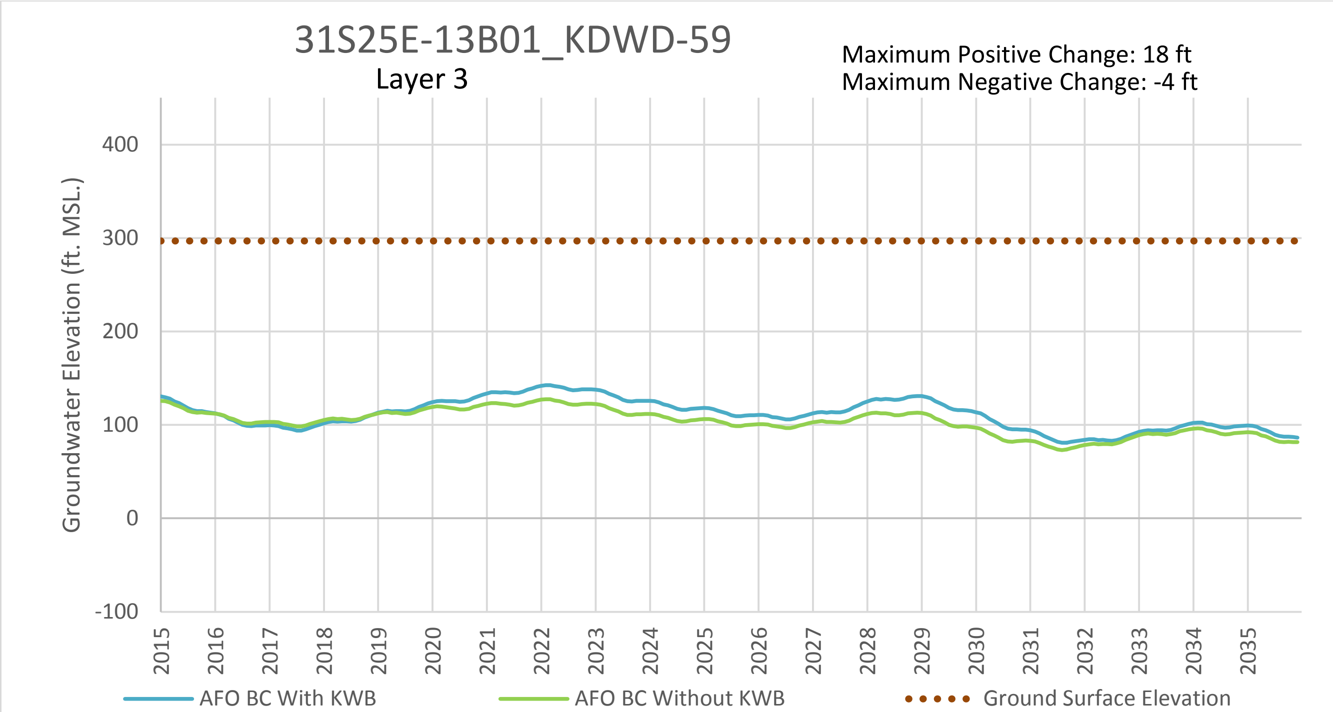

FIGURE 7-2 C.18. Hydrograph of Simulated Water Levels at Monitoring Well 31S25E-13B01_KDWD-59, 2015-2035

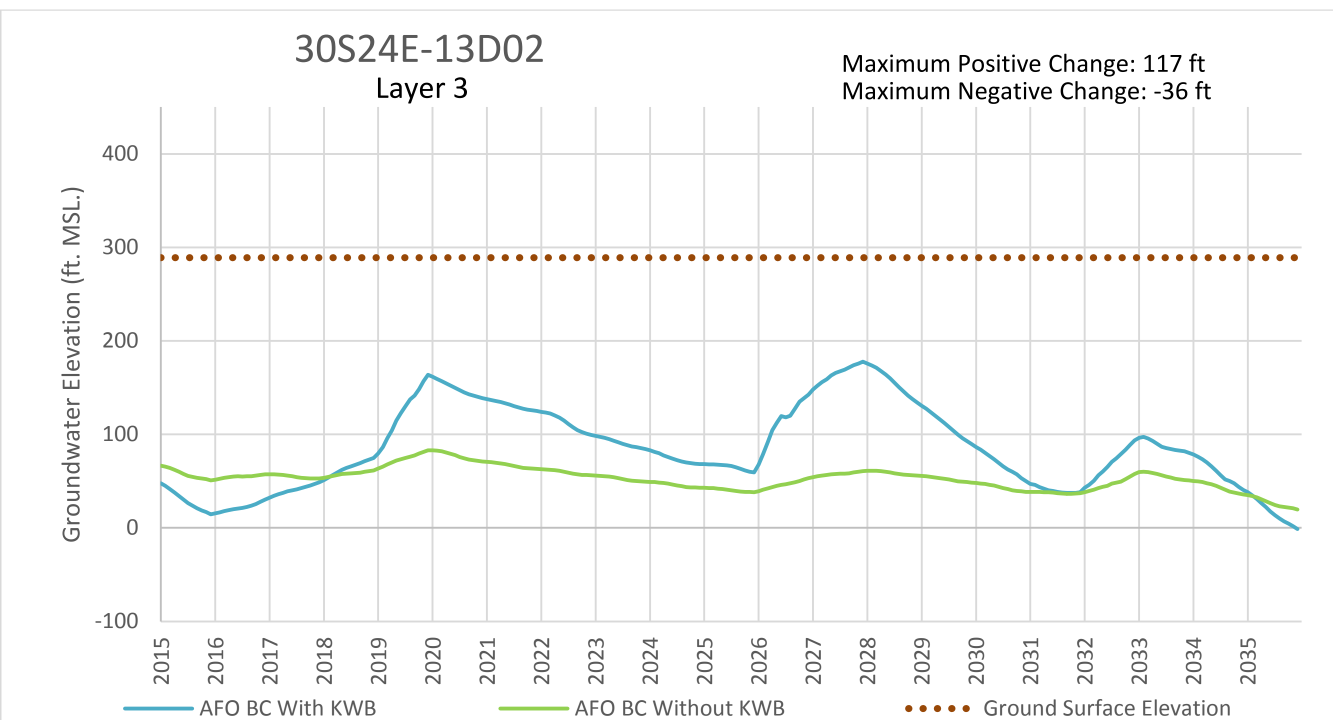

FIGURE 7-2 C.19. Hydrograph of Simulated Water Levels at Monitoring Well 30S24-13D02, 2015-2035

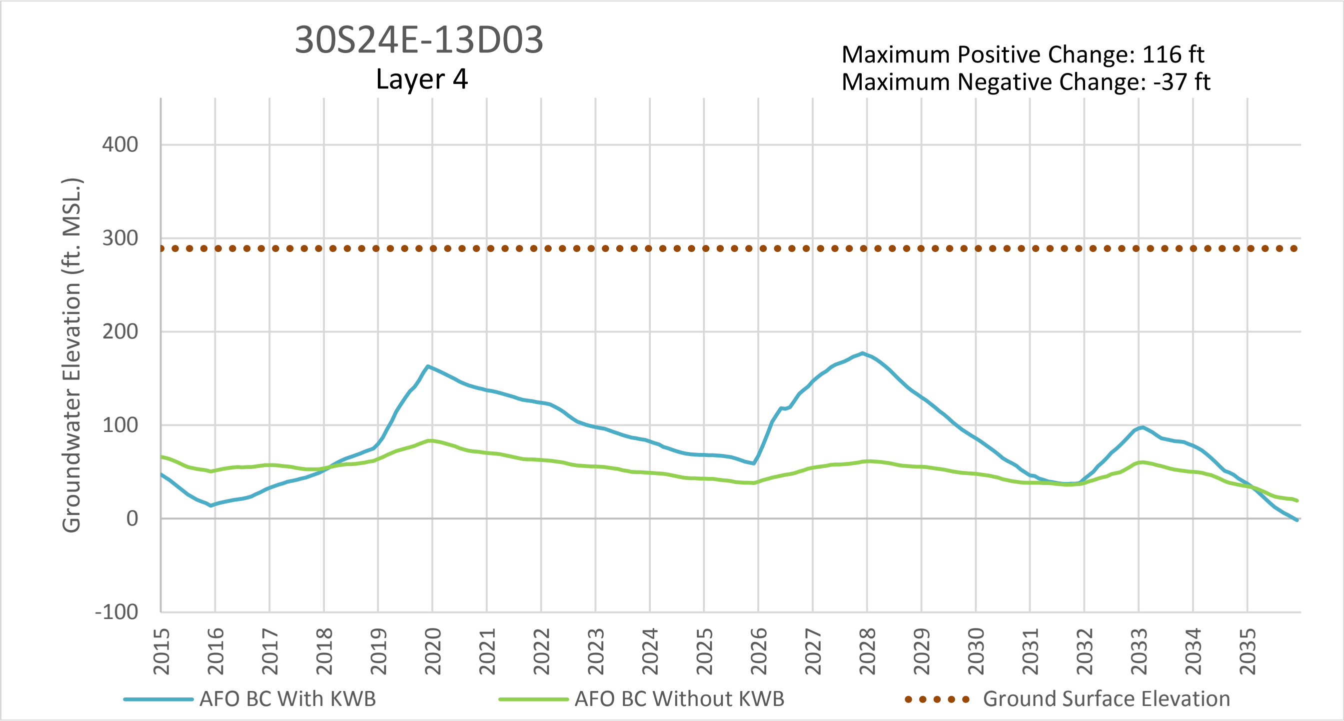

FIGURE 7-2 C.20. Hydrograph of Simulated Water Levels at Monitoring Well 30S24-13D03, 2015-2035

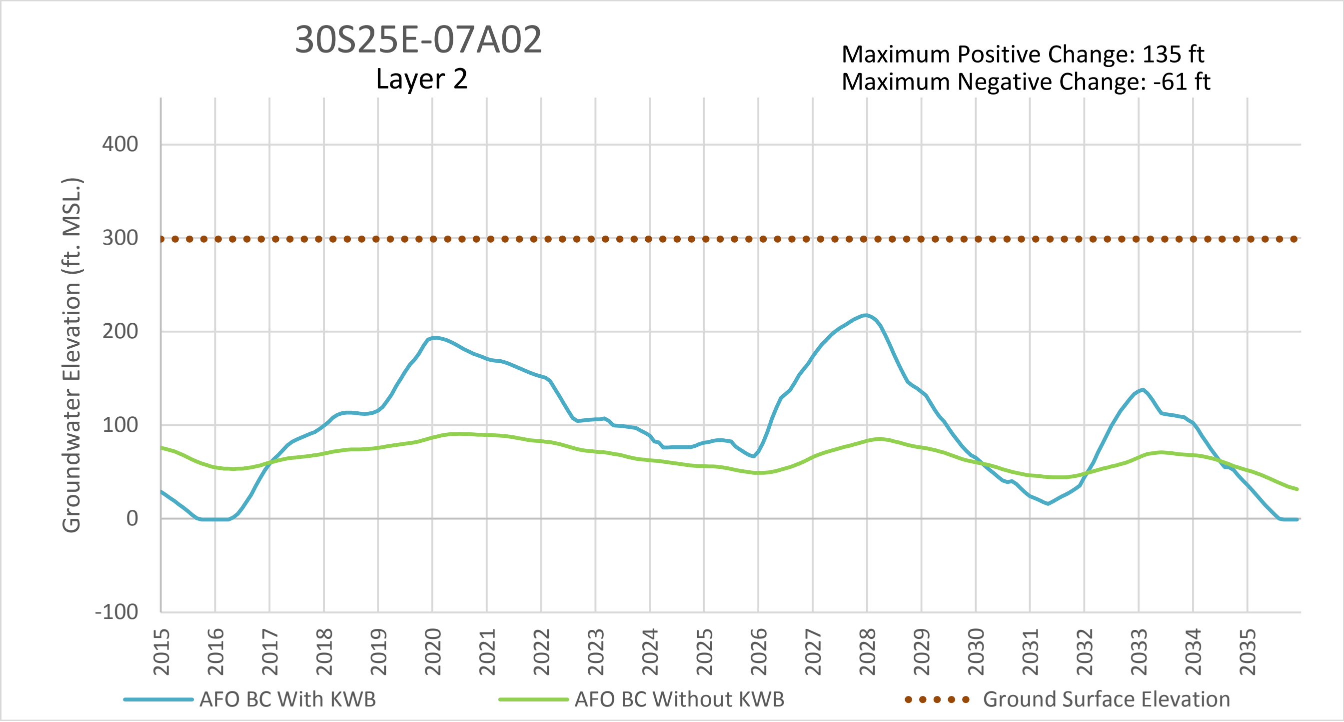

FIGURE 7-2 C.21. Hydrograph of Simulated Water Levels at Monitoring Well 30S25E-07A02, 2015-2035

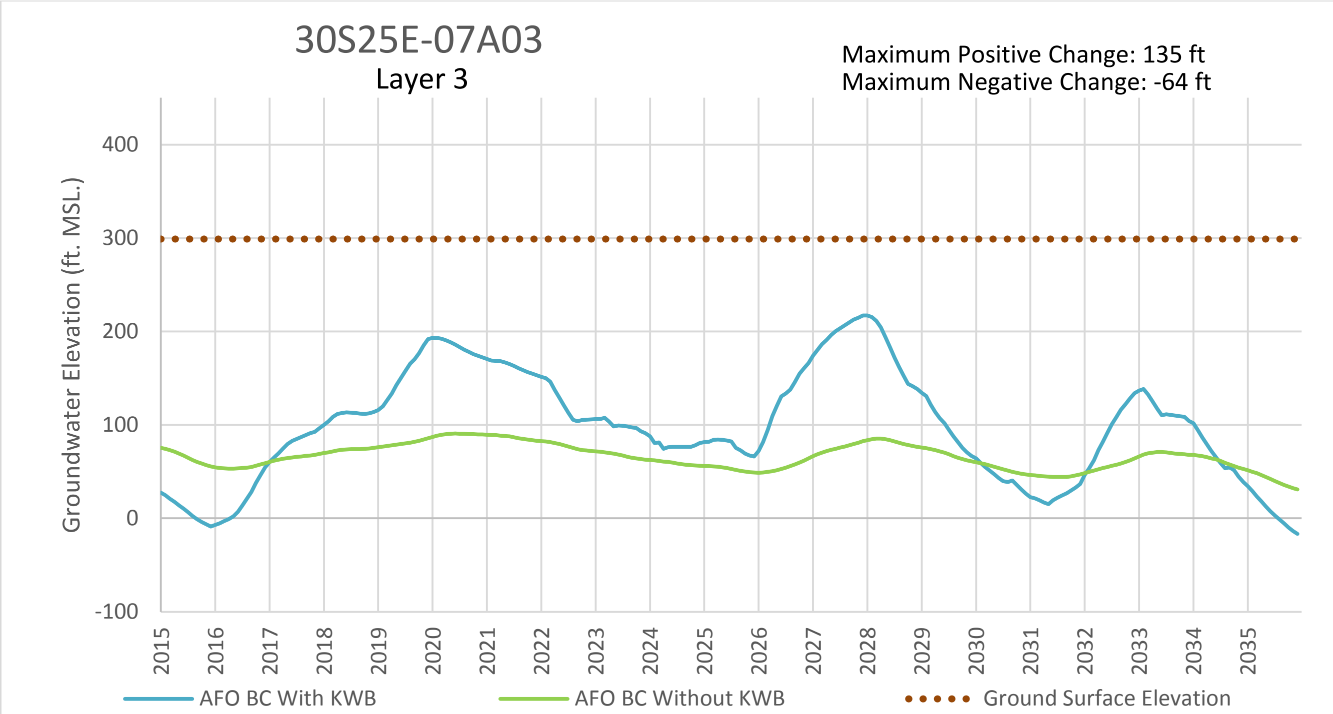

FIGURE 7-2 C.22. Hydrograph of Simulated Water Levels at Monitoring Well 30S25E-07A03, 2015-2035

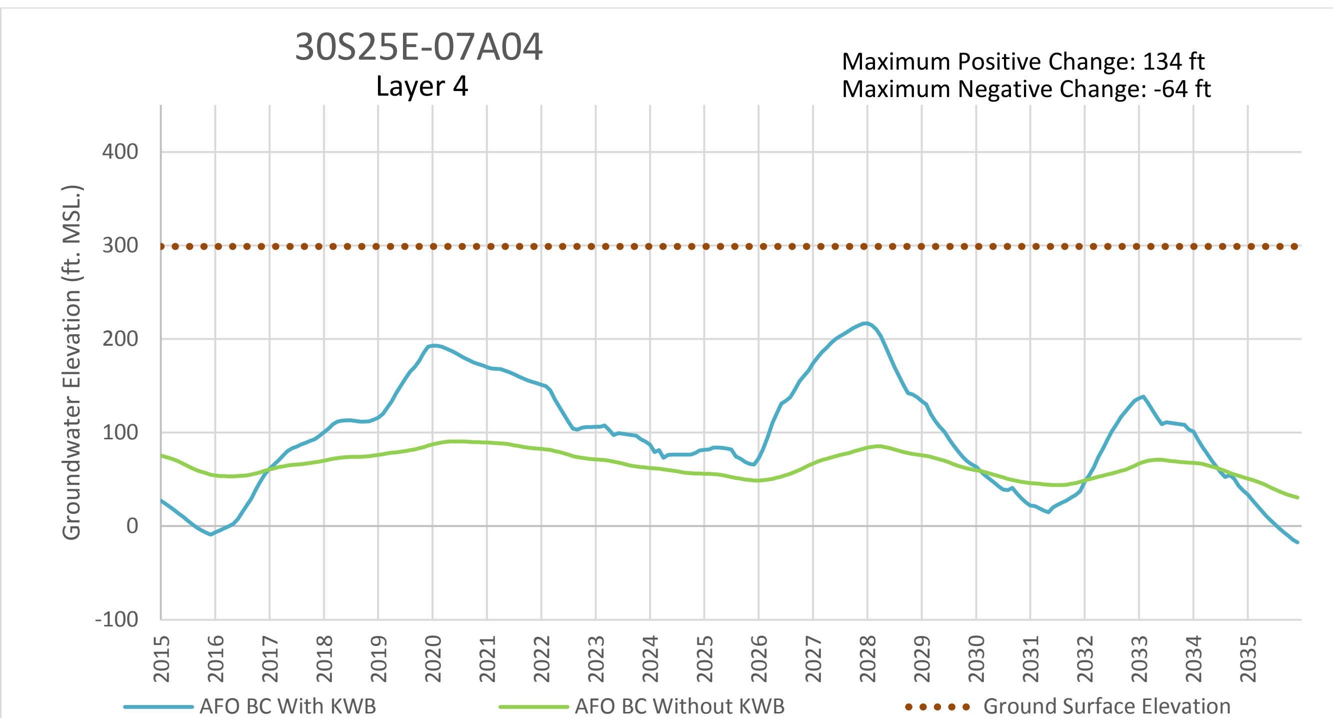

FIGURE 7-2 C.23. Hydrograph of Simulated Water Levels at Monitoring Well 30S25E-07A04, 2015-2035

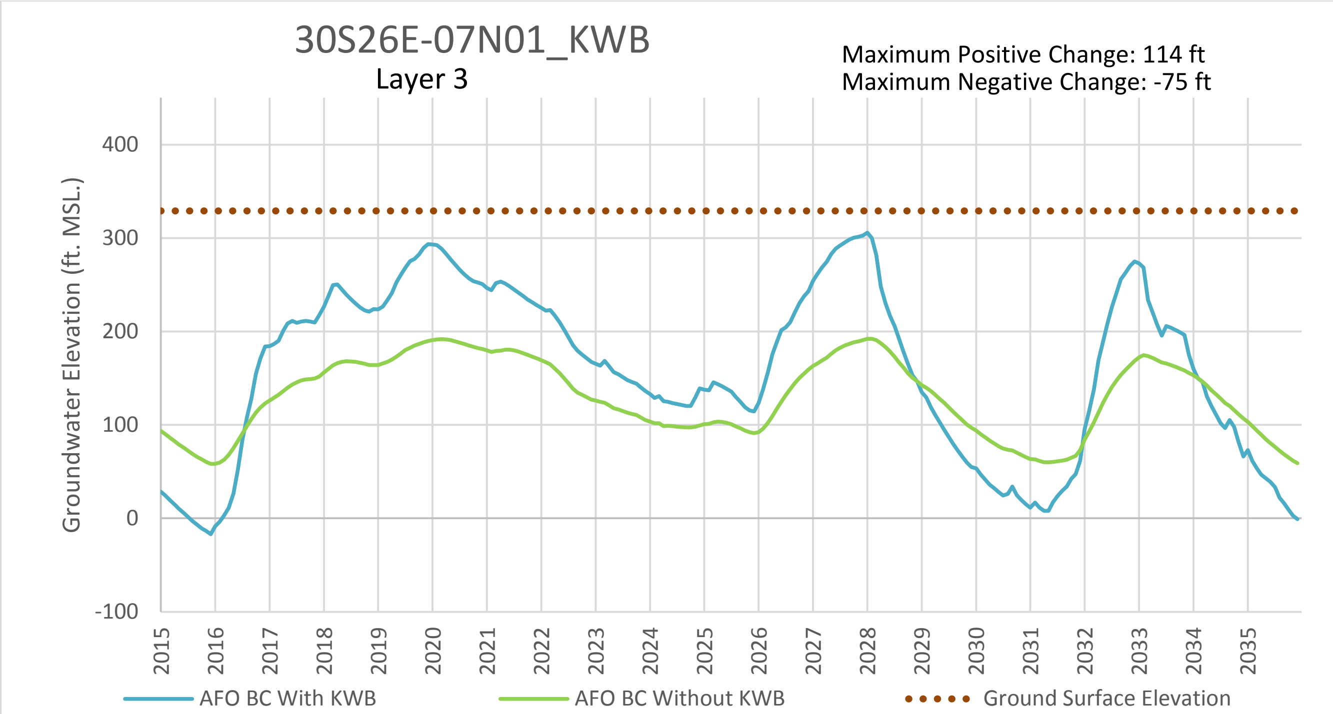

FIGURE 7-2 C.24. Hydrograph of Simulated Water Levels at Monitoring Well 30S26E-07N01_KWB, 2015-2035

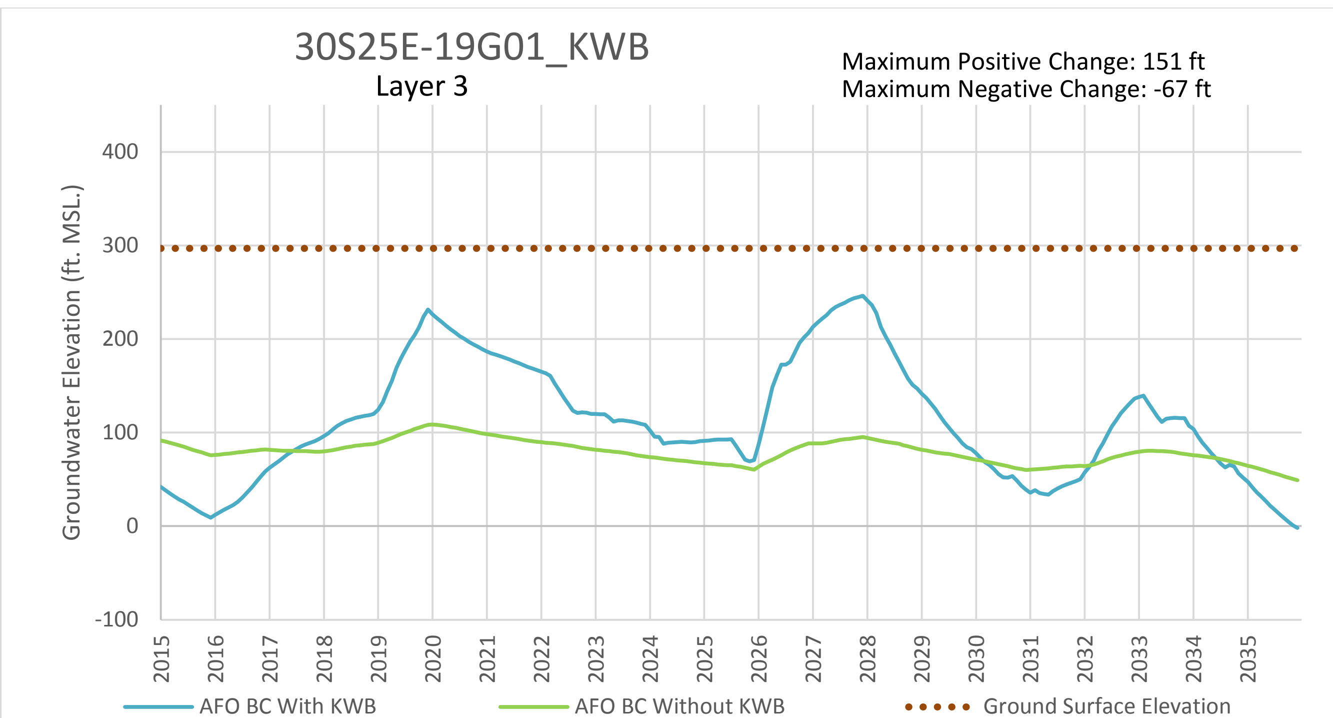

FIGURE 7-2 C.25. Hydrograph of Simulated Water Levels at Monitoring Well 30S25E-19G01_KWB, 2015-2035

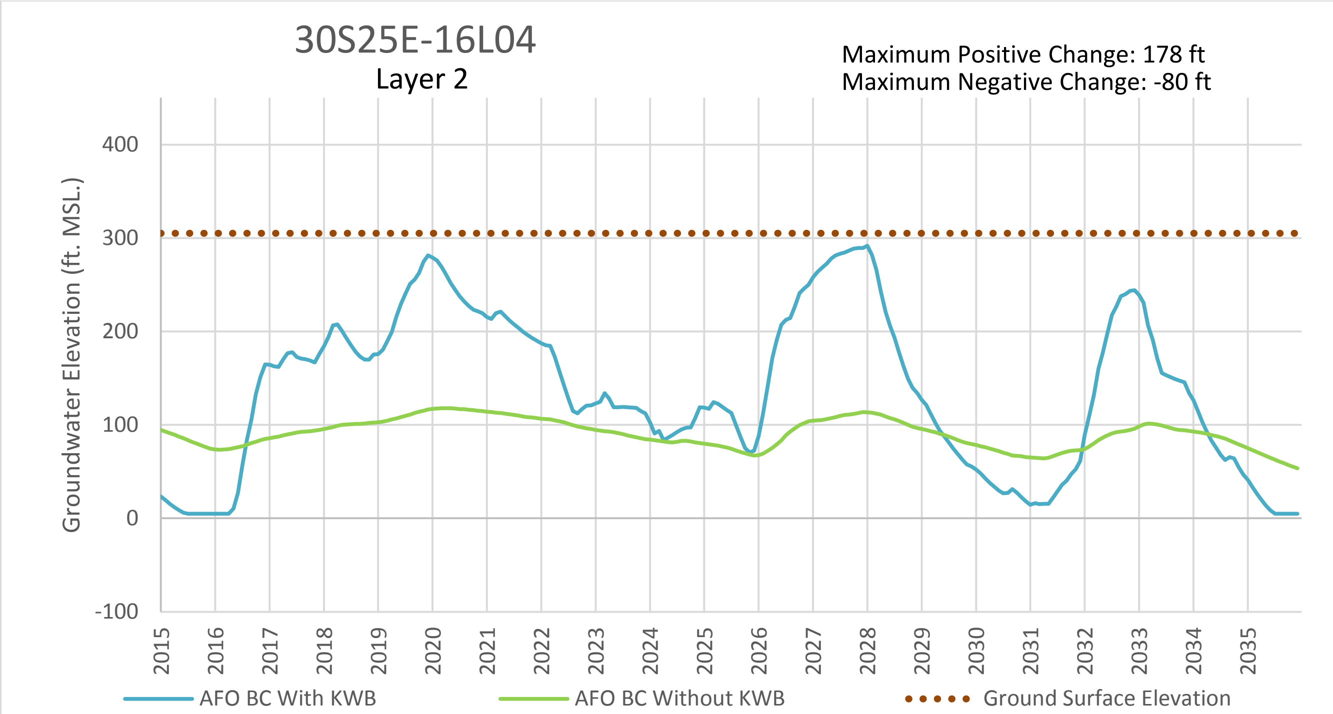

FIGURE 7-2 C.26. Hydrograph of Simulated Water Levels at Monitoring Well 30S25E-16L04, 2015-2035

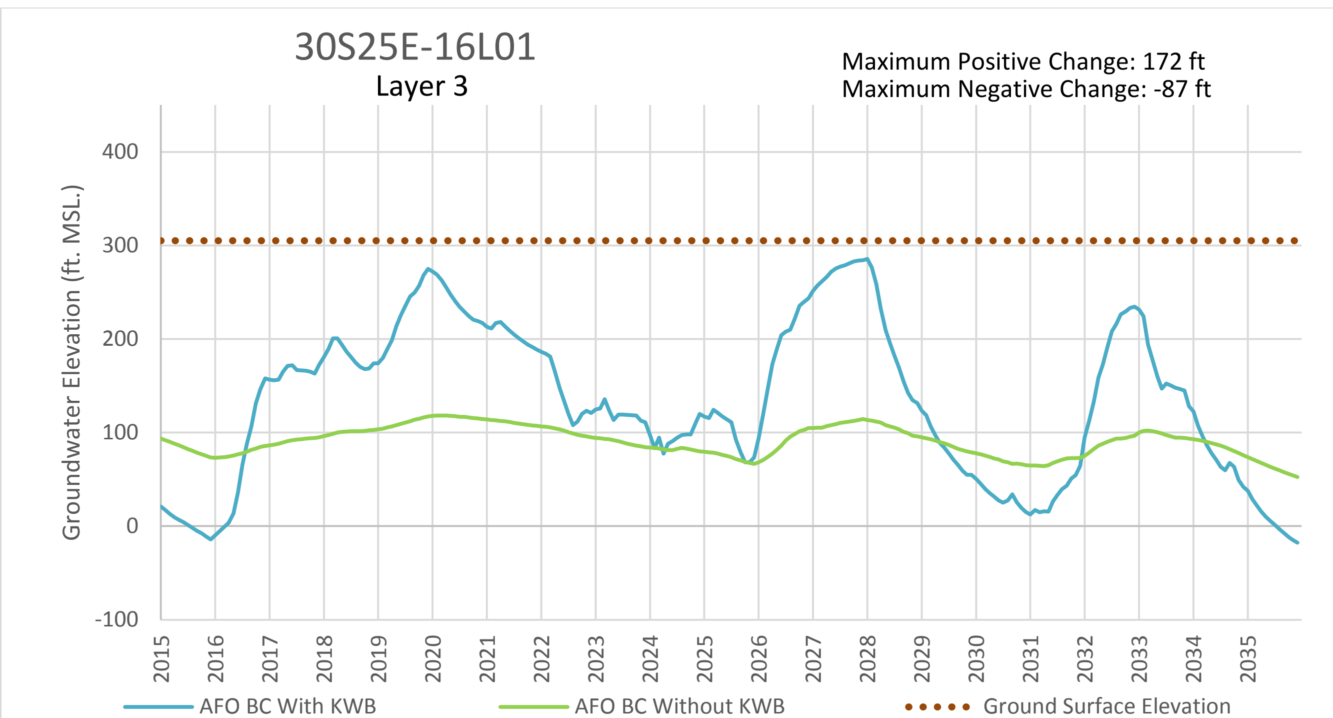

FIGURE 7-2 C.27. Hydrograph of Simulated Water Levels at Monitoring Well 30S25E-16L01, 2015-2035

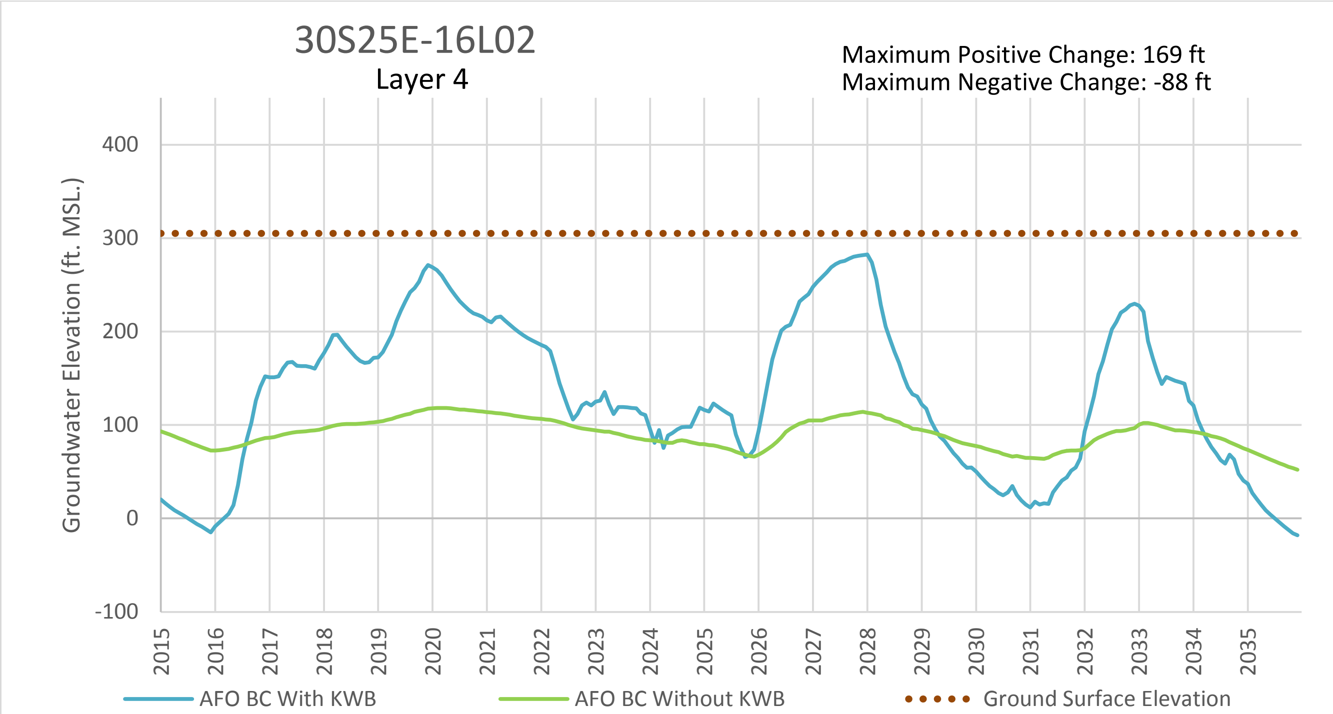

FIGURE 7-2 C.28. Hydrograph of Simulated Water Levels at Monitoring Well 30S25E-16L02, 2015-2035

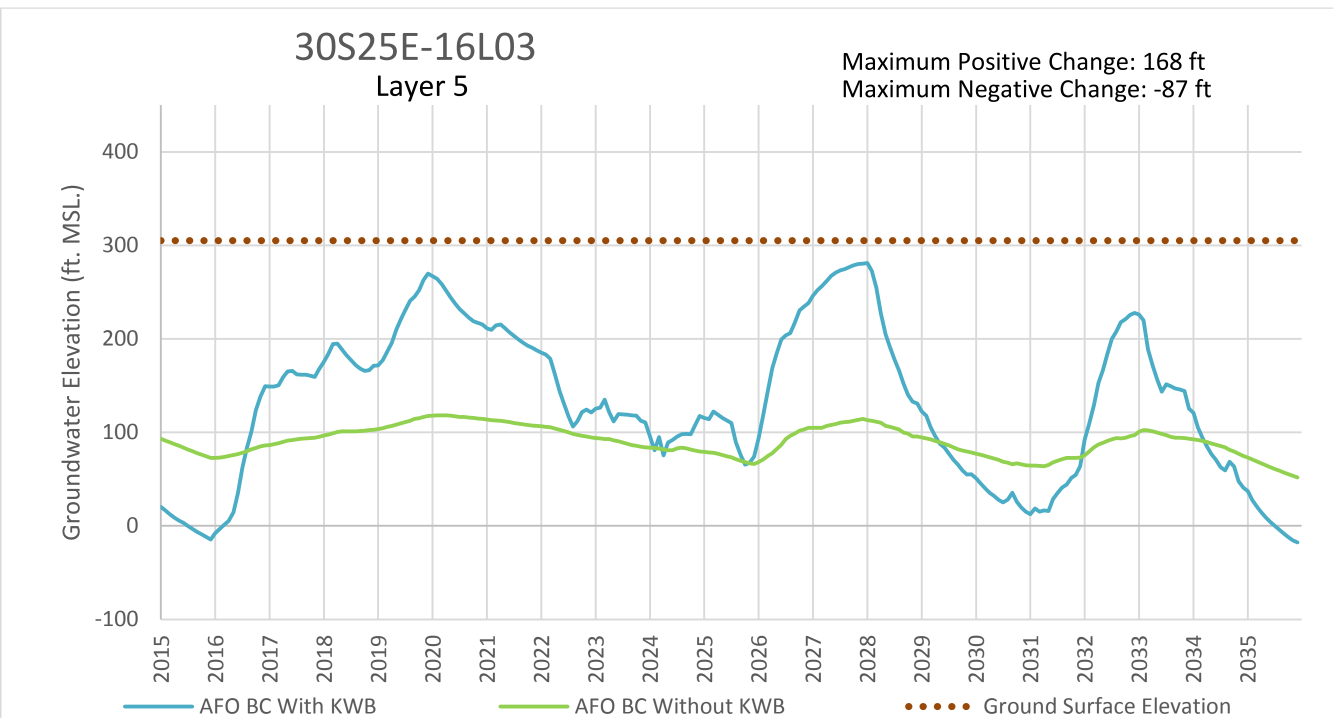

FIGURE 7-2 C.29. Hydrograph of Simulated Water Levels at Monitoring Well 30S25E-16L03, 2015-2035

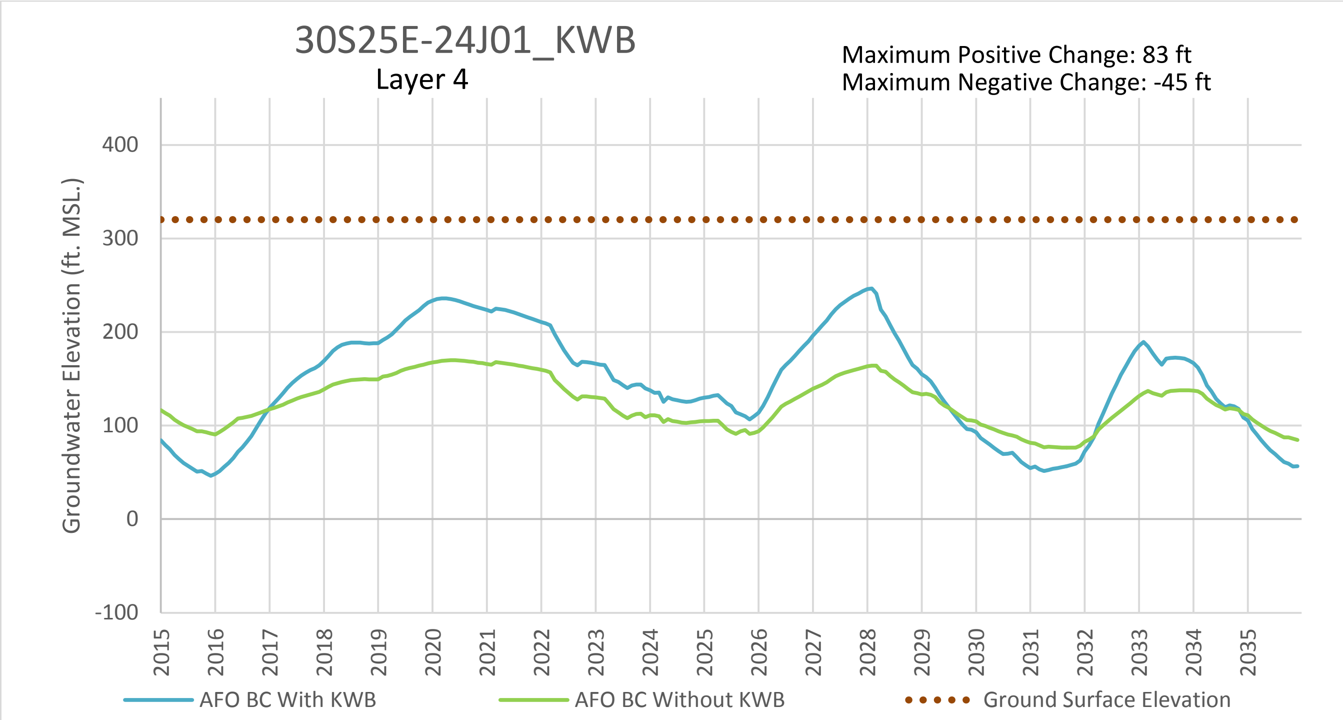

FIGURE 7-2 C.30. Hydrograph of Simulated Water Levels at Monitoring Well 30S257-24J01_KWB, 2015-2035

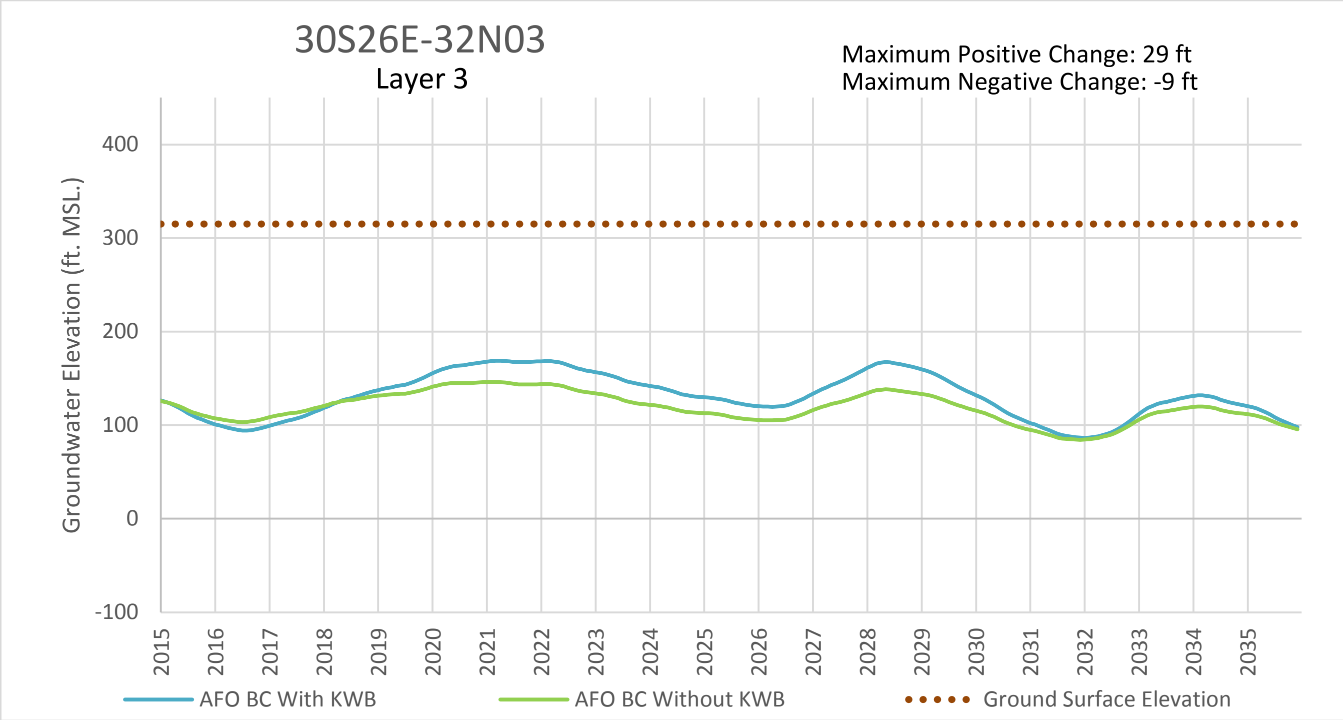

FIGURE 7-2 C.31. Hydrograph of Simulated Water Levels at Monitoring Well 30S26E-32N03, 2015-2035

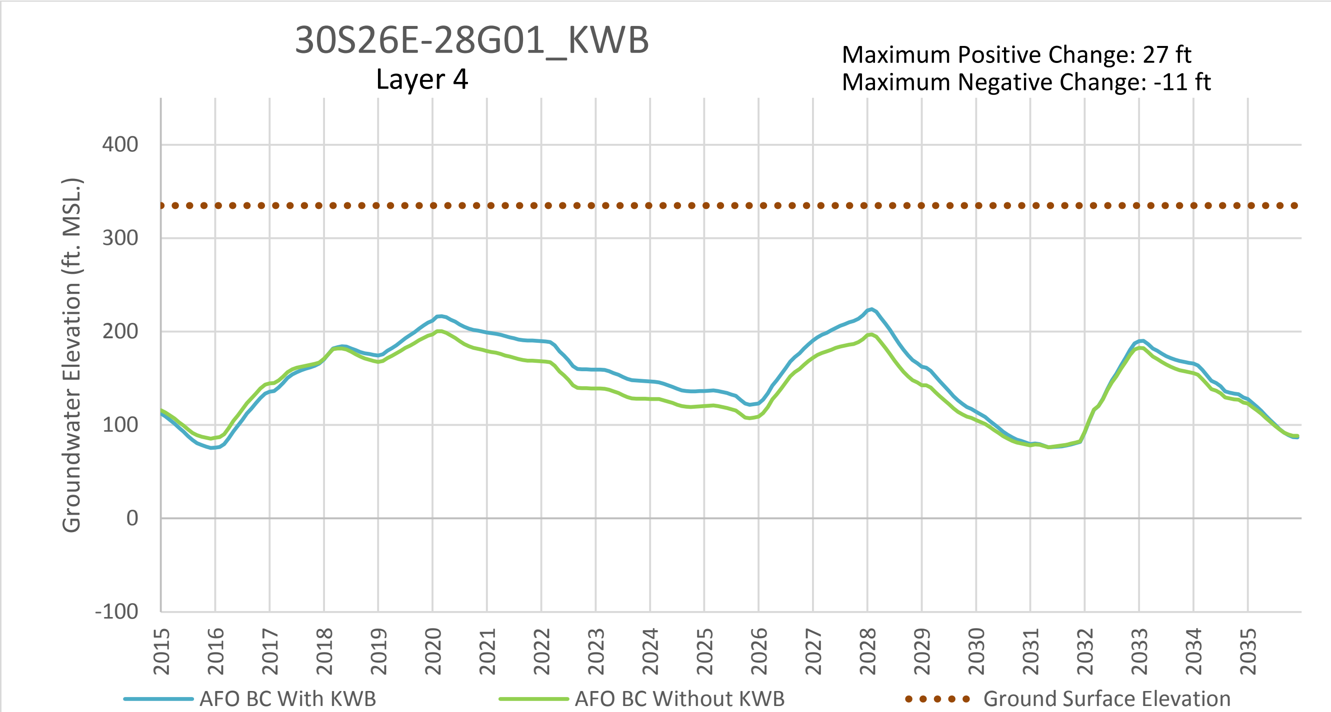

FIGURE 7-2 C.32. Hydrograph of Simulated Water Levels at Monitoring Well 30S267-28G01_KWB, 2015-2035