ADDENDUM TO PRELIMINARY EVALUATION OF IMPACTS OF POTENTIAL GROUNDWATER SUSTAINABILITY INDICATORS ON FUTURE GROUNDWATER EXTRACTION RATES – OXNARD PLAIN AND PLEASANT VALLEY GROUNDWATER BASINS

United Water Conservation District
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PREPARED BY

GROUNDWATER RESOURCES DEPARTMENT

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THIS REPORT IS PRELIMINARY AND IS SUBJECT TO MODIFICATION BASED UPON FUTURE ANALYSIS AND EVALUATION

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TABLE OF CONTENTS

LIST OF FIGURES

(Figures are located at the end of this report)

LIST OF TABLES

(Tables are located at the page numbers indicated)

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1 PURPOSE AND SCOPE OF THIS ADDENDUM

This addendum to United Water Conservation District's (United) Open-File Report (OFR) 2017-02 titled "Preliminary Evaluation of Impacts of Potential Groundwater Sustainability Indicators on Future Groundwater Extraction Rates – Oxnard Plain and Pleasant Valley Groundwater Basins" (United, 2017) describes the methods and results for simulation of a pumping scenario (Scenario F) conducted in addition to the five pumping scenarios (Scenarios A through E) that were described in OFR 2017-02. Scenario F was simulated in response to a request from the Fox Canyon Groundwater Management Agency (FCGMA) to support their Groundwater Sustainability Plan (GSP), specifically to develop estimates of the combined sustainable yield for the Oxnard Plain (including Forebay) and Pleasant Valley groundwater basins (the study area) under the following assumed conditions:

- A uniform reduction in pumping rates at all groundwater extraction wells throughout the study area would be applied to achieve sustainable yield.
- United's surface-water diversions from the Santa Clara River at Freeman Diversion would continue at 1985-2015 rates.

Scenario A of OFR 2017-02 relied on a similar assumption regarding reduction of pumping rates in the study area, except in the Forebay, where pumping rates were assumed to continue at 1985-2015 rates. It should be noted that Scenario A was simulated using the September 2016 version of United's model, while Scenario F was simulated using the October 2017 version, which has improved historical-calibration results compared to the September 2016 version. Despite the evolution of the model during the past year, the updated version produces similar forecasts of groundwater elevation along the coast (a primary indicator of sustainable yield under the assumptions applied to OFR 2017-02) to those forecasted by the previous version of the model. Therefore, results of Scenario A can be compared to results of Scenario F without significant caveat.

In addition to the pumping- and diversion-rate assumptions described above, a key assumption used in OFR 2017-02 regarding Target Groundwater Levels was modified for this addendum. Information reviewed by United subsequent to publishing OFR 2017-02 suggests that lateral seawater intrusion is probably not occurring directly through the Lower Aquifer System (LAS) in the vicinity of Mugu Lagoon. The additional information includes:

- United's most recent Saline Intrusion Update report (United, 2016b), which interpreted the source of elevated chloride concentrations in the LAS near Mugu Lagoon to be saline water yielded from marine clays and/or from adjacent Tertiary-age sedimentary rocks, as a result of large declines in potentiometric head in the LAS over the past several decades. The primary source of chloride in the LAS in this area is not interpreted to be lateral seawater intrusion through the aquifer.
- A U.S. Geological Survey (USGS) model of the basin used as a starting point for United's model includes faults in the Mugu Lagoon area that limit the hydraulic connection of the LAS in the Oxnard basin to the Pacific Ocean (Hanson and others, 2003). Although this

configuration of the USGS model was developed based on limited data and was considered by United to be hypothetical at the time modeling for OFR 2017-02 was being conducted, subsequent updates and calibration of United's more detailed groundwater flow model supports the USGS conceptual model regarding fault-related horizontal flow barriers in the Mugu Lagoon area, resulting in limited connection of the LAS to the ocean.

Based on the above information, the evaluation of Scenario F assumed that future increases in salinity in the LAS in the Mugu Lagoon area could be prevented by:

- Maintaining groundwater elevations in the LAS in this area at higher levels than they have been in recent decades (target groundwater level of approximately -20 feet mean sea level [ft msl] or higher, on average, instead of typical historical levels of -60 to -80 ft msl).
- Maintaining groundwater elevations in the Upper Aquifer System (UAS) at levels that prevent seawater intrusion (+6 ft msl or higher, on average), thereby eliminating the possibility of seawater migrating inland via the UAS, then migrating vertically into the LAS. This target groundwater level is unchanged from the equivalent target groundwater level assumed in OFR 2007-02.
- Maintain a hydraulic divide in the LAS north of Mugu Lagoon, to prevent further inland migration of high-chloride groundwater (currently a divide exists in this area in the form of an elongate cone of depression).

2 METHODS

Information about the overall modeling approach used to estimate safe-yield of the study area under each hypothetical pumping scenario are described in OFR 2017-02 (United, 2017). Saline intrusion has historically been (and continues to be) the most pressing groundwater sustainability challenge along the coast within the study area. The sole approach considered in this evaluation to achieve assumed management objectives for saline intrusion was to simulate reduction of groundwater withdrawals (pumping). The simulated reduction in pumping resulted in forecasted groundwater levels in the UAS and LAS rising to levels that equaled or exceeded the density-corrected head of seawater, stopping (or reversing, in some areas) lateral intrusion of seawater from the Pacific Ocean. The forecasted groundwater-level increases extended throughout the model area, not only meeting assumed management objectives for seawater intrusion, but also meeting assumed management objectives for other sustainability indicators in the Oxnard Plain and Pleasant Valley basins. It should be noted that simulated reductions in pumping are just one alternative for potentially achieving sustainable yield, and likely are less effective and efficient than some of the other alternatives described in OFR 2017-02. United is not advocating for this reduced-pumping alternative, and is actively working with the FCGMA and other stakeholders to develop basin-wide approaches to water supply that would optimize the quantity and cost of water available for municipal, agricultural, and environmental uses in the study area. However, simulation of reduced pumping is a simple, straightforward approach for estimating the sustainable-yield of the study area under historic conditions, providing a useful comparison to more realistic water-supply scenarios for the future.

Under Scenario F, the "seawater intrusion management (SWIM) area" that was assumed in OFR 2017-02 has been eliminated, because a uniform reduction in pumping is simulated throughout the study area to achieve sustainable yield. However, maintaining groundwater elevations along the coast at levels sufficiently high to prevent lateral seawater intrusion and other forms of saline intrusion is still a key criterion for defining sustainable yield of the Oxnard Plain and Pleasant Valley basins under current conditions. Near Port Hueneme, where the UAS and LAS are both believed to have a direct hydraulic connection to the Pacific Ocean, assumed minimum thresholds and Target Groundwater Levels remain unchanged from those assumed in OFR 2017-02, as shown in Table 2-1, below. Consistent with the assumptions described in Section 1 of this addendum, the assumed minimum threshold (and target groundwater level) for the LAS near Mugu Lagoon under Scenario F is -20 feet relative to the National Geodetic Vertical Datum of 1929 (ft NGVD), instead of +18.5 ft NGVD as assumed in OFR 2017-02 (Table 2-1).

As noted in OFR 2017-02, the modeled base period for all of the hypothetical pumping scenarios (Scenarios A through F) was January 1985 through December 2015 (31 years). Each pumping scenario consisted of 1985 through 2015 boundary conditions and aquifer stresses (e.g., groundwater recharge and extractions), with extractions under each pumping scenario reduced proportionately relative to reported extractions from 1985 through 2015. Forecasting of future climatic conditions, land use, and changes in water sources in the study area was beyond the scope of this effort. Therefore, this approach is, in effect, an evaluation of the reduction in pumping that would have been required to achieve sustainable yield in the study area during the period from 1985 through 2015. Other assumptions and limitations described in OFR 2017-02 remain applicable to Scenario F, unless specifically noted to the contrary in this report.

Table 2-1. Assumed Minimum Thresholds and Target Groundwater Levels

Area	Aquifer System	Assumed Minimum Threshold for Each Sustainability Indicator (feet NGVD29)						Target Groundwater Level[a] (feet NGVD29)
		Lowering Groundwater Levels	Reduction of Groundwater Storage	Seawater Intrusion	Degraded Water Quality	Land Subsidence	Surface Water Depletion	
Forebay	UAS	---	-100	---	+20	-100	---	**+20**
	LAS	---	-150	---	---	-150	---	**-150**
Oxnard Plain basin (excluding Forebay)	UAS	---	-100	---	---	-100	---	**-100**
	LAS	---	-150	---	---	-150	---	**-150**
Pleasant Valley basin	UAS	---	-100	---	---	-100	---	**-100**
	LAS	---	-200	---	---	-200	---	**-200**
Port Hueneme	UAS	---	-100	+6	---	-100	---	**+6**
	LAS	---	-150	+18.5	---	-150	---	**+18.5**
Mugu Lagoon	UAS	---	-100	+6	---	-100	---	**+6**
	LAS	---	-150	-20	---	-150	---	**-20**

Notes: --- = Not applicable

[a] Target Groundwater Levels represent the highest of the minimum thresholds, and the lowest that groundwater elevations could be maintained during average hydrogeologic conditions without causing undesirable results. Groundwater elevations can be higher than the Target Groundwater Levels without causing undesirable results.

Under Scenario F, simulated pumping rates throughout the study area were reduced by 50 percent in both the UAS and the LAS compared to 1985 through 2015 reported pumping rates, to achieve Target Groundwater Levels. Table 2-2, below, summarizes the annual average groundwater extraction rates assumed under Scenario F. Also shown, for reference purposes, is the sum of annual average groundwater and surface water use for the modeled basins combined. The percent reductions in groundwater use and total water use (groundwater plus surface water imports and diversions) assumed in each scenario—compared to the base case—are shown in the right-hand column of Table 2-2.

Table 2-2. Summary of Pumping Rates Assumed for Scenario F

Scenario	Average Groundwater Extractions (AF/yr)				Average Combined Groundwater and Surface Water Use (AF/yr)	Percent Reduction Compared to Base Case (Groundwater / Total Water)
	Oxnard Plain	Forebay	Pleasant Valley	Sum		
Base Case from OFR 2017-02 (no changes in pumping from 1985-2015 rates)	54,000	24,000	21,000	**99,000**	**143,000**	**0% / 0%**
Scenario F (50% reduction in pumping from UAS and LAS in the Oxnard Plain [including the Forebay] and Pleasant Valley basins)	27,000	12,000	10,000	**49,000**	**93,000**	**50% / 35%**
Note: All pumping rates have been rounded to the nearest 1,000 AF/yr.						

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3 RESULTS

Model results were evaluated by comparing forecasted groundwater elevations for simulated pumping Scenario F to the Target Groundwater Levels described in Section 2 of this addendum. Results are illustrated using the time-series hydrographs shown on Figures 3-1 through 3-4. These hydrographs compare Target Groundwater Levels to simulated groundwater elevations under Scenario F in the Oxnard aquifer (representative of the UAS) and the Fox Canyon aquifer (representative of the LAS) at wells near Port Hueneme and Mugu Lagoon—where seawater intrusion problems are most pronounced—and in the eastern Oxnard Plain basin near the boundary with the Pleasant Valley basin. In addition, time series hydrographs are shown for the Semi-perched aquifer and the Oxnard aquifer at a well in the northwest Oxnard Plain basin adjacent to the perennial reach of the Santa Clara River (between U.S. Highway 101 and the coast). The locations for these wells are shown on Figures 3-5 and 3-6. Detailed inspection of model results reported in OFR 2017-02 indicated that forecasted groundwater elevations in the Mugu aquifer were typically within a few inches to a few feet of those in the Oxnard aquifer, and that forecasted groundwater elevations in the Hueneme and Grimes Canyon aquifers were within a few feet of those in the Fox Canyon aquifer. Therefore, to conduct the evaluations efficiently, results for only the Oxnard and Fox Canyon aquifers are described in this report, but are applicable to the other aquifers in the UAS and LAS, respectively.

Maps showing groundwater elevations forecasted under Scenario F during December 2012 are provided on Figures 3-5 and 3-6; forecasted groundwater elevations as of December 2012 approximate common fall-season lows for the period from 1995 through 2012, which is representative of average climatic and hydrogeologic conditions in the Oxnard Plain and Pleasant Valley basins. This period is referred to as “typical” subsequently in this report. Forecasted groundwater elevations during the first 10 years of the simulation period (1985 through 1994) are anomalously low due to the higher pumping rates occurring in the region from 1985 through 1990 and the exceptional drought that persisted through 1990. Similarly, forecasted groundwater elevations during the last three years of the simulation period (2013 through 2015) are anomalously low due to a recent period of exceptional drought. Forecasted groundwater elevations throughout the study area as of December 2012 are influenced by low precipitation that year; therefore, they are slightly lower than average long-term seasonal-low groundwater elevations for the period from 1995 through 2012, and represent a conservatively low estimate of “typical” groundwater levels.

Pumping Scenario F is forecasted to result in groundwater elevations that are typically above Target Groundwater Levels. Groundwater elevations in the UAS throughout the study area are forecasted to remain above Target Groundwater Levels most of the time, even through most drought periods (Figures 3-1 through 3-4). Groundwater elevations in the LAS are also forecasted to remain above Target Groundwater Levels most of the time, except near Mugu Lagoon, where they are forecasted to decline below Target Groundwater Levels during periods of exceptional drought (Figure 3-2). Figure 3-5 indicates seaward hydraulic gradients, which would halt or reverse seawater intrusion, occur in the UAS at Port Hueneme and Mugu Lagoon under typical conditions. Figure 3-6 indicates that shallow (-10 to -20 ft msl) cones of depression form in the LAS at Mugu Lagoon under typical conditions; however, as discussed in Section 1, this condition would be an improvement over current conditions, and is not expected to result in significant and unreasonable expansion of the area or magnitude of saline intrusion problems in the LAS near Mugu Lagoon. However, it is possible that shifting hydraulic gradients associated with the reduction in pumping rates assumed under Scenario F could cause movement of existing high-chloride groundwater in the LAS near Mugu Lagoon at a local scale, potentially impacting water-supply wells in the immediate vicinity. If reductions in surface-water diversions (and corresponding decreases in rates of artificial recharge and deliveries of surface water in lieu of groundwater in the study area) were implemented to meet the goals of a 2008 Biological Opinion by the National Marine Fisheries Service regarding steelhead trout passage in the Santa Clara River at Freeman Diversion, then past modeling by United indicates that groundwater elevations throughout the study area would decline, requiring additional pumping reductions to maintain groundwater levels sufficiently high to achieve sustainable yield (United, 2016a).

It should be noted that the pumping-rate reductions assumed in Scenario F are only hypothetical, and do not appear to United to represent reasonable or realistic approaches to achieving sustainable yield in the Oxnard Plain and Pleasant Valley basins. Other scenarios presented in OFR 2017-02, involving reductions in pumping where overdraft is causing the greatest problems, combined with increases in pumping in areas where groundwater elevations are mostly higher than Target Groundwater Levels, result in greater sustainable yield estimates for the basin, while avoiding undesirable results.

4 CONCLUSIONS

Scenario F is forecasted to achieve the revised assumed minimum thresholds for the applicable sustainability indicators most of the time (except during exceptional droughts). The combined annual average pumping rate in the study area is 49,000 AF/yr under this scenario, which would comprise a 50 percent reduction compared to the average annual pumping reported for the period from 1985 through 2015 (or a 35 percent reduction from average total water use, including surface water diversions and imports, reported for 1985 through 2015). The total pumping rate applied to Scenario F defines the potential sustainable yield for the two basins (combined), under the assumptions regarding sustainability criteria, minimum thresholds, and future water-supply (including climatic) conditions as described in OFR 2017-02 and this addendum. The potential sustainable yield could change if other assumptions are made regarding minimum thresholds, distribution of pumping, forecasted climatic/hydrologic conditions, changes in surface water availability, and future water-supply or mitigation projects.

Comparison of forecasted groundwater elevations under Scenario F to those of Scenarios A through E reinforces an important conclusion from OFR 2017-02—that sustainable yield of the study area is not only dependent on how much is pumped, but ***where*** that pumping occurs. Pumping near the coast, especially around the Mugu Lagoon area, requires larger reductions in pumping at all wells throughout the basin in order to prevent seawater intrusion, compared to scenarios where pumping reductions are focused near the coast and relaxed in an inland direction. This conclusion is consistent with findings of the FCGMA (2007) Groundwater Management Plan update.

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FIGURES

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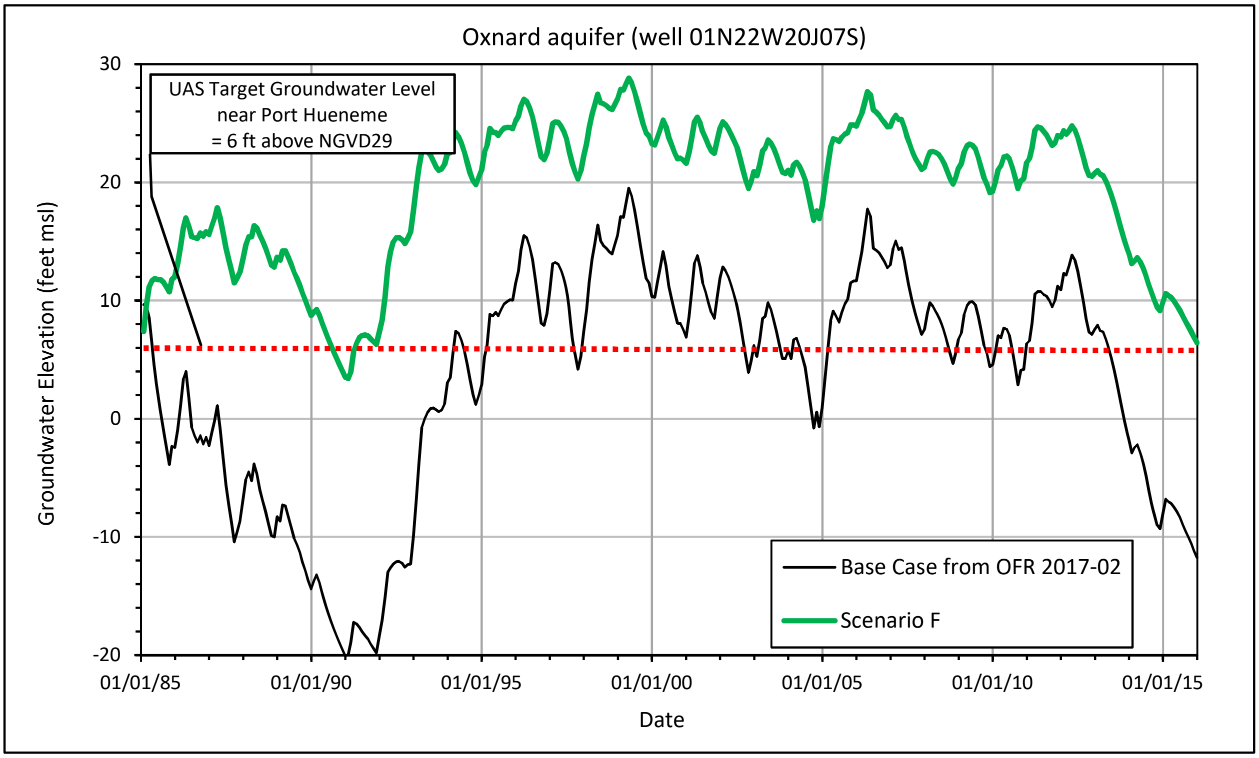


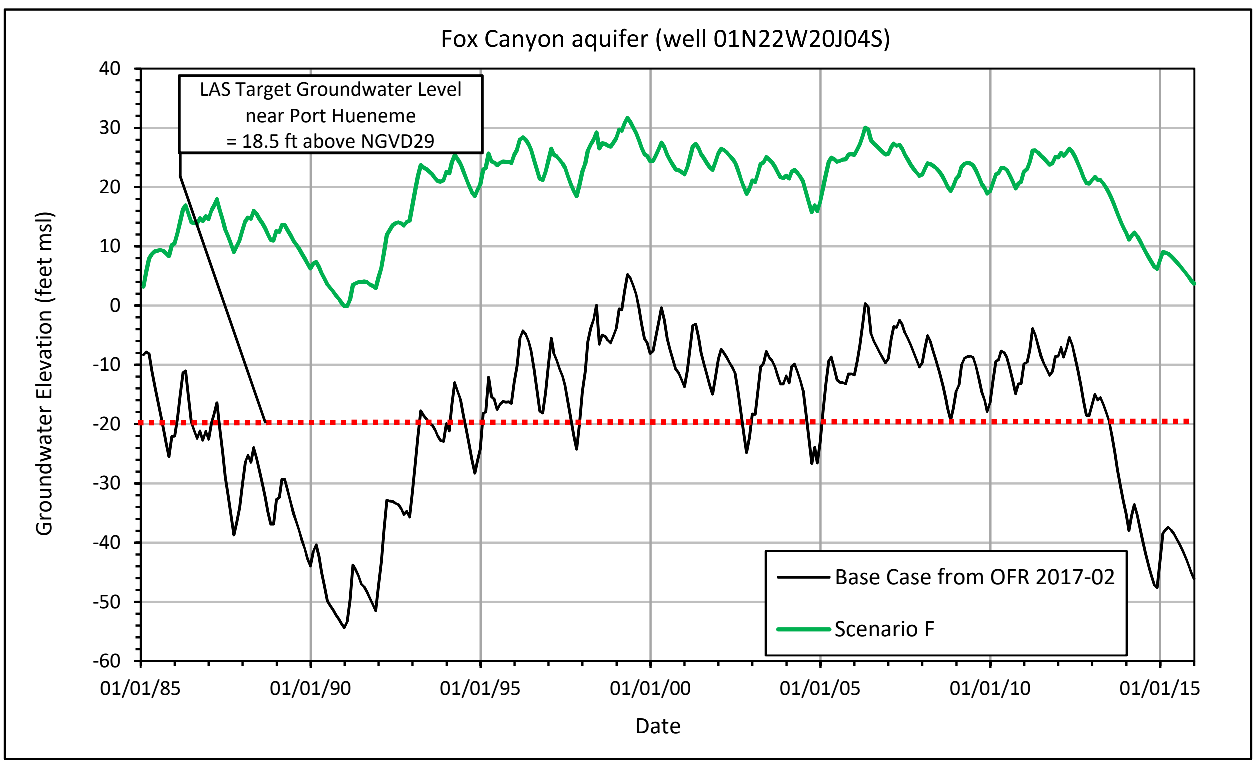
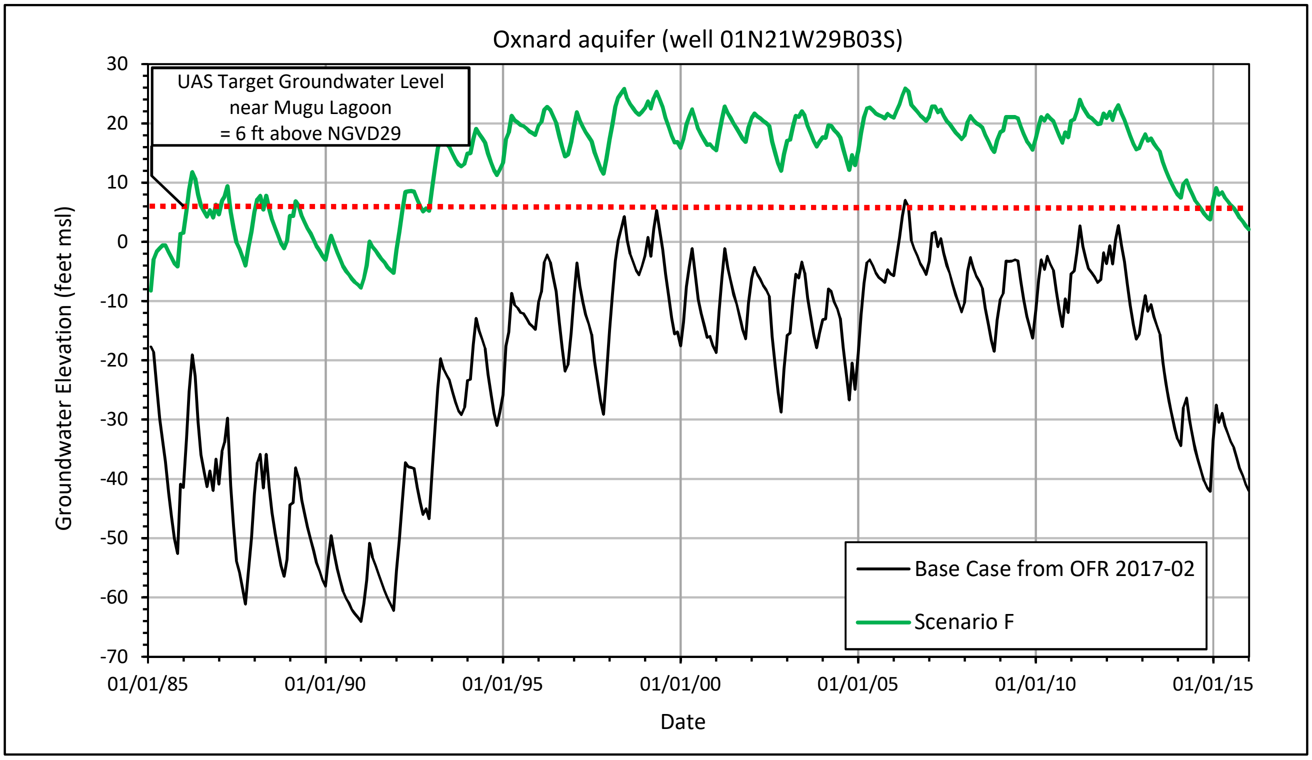


Figure 3-1. Time-Series Hydrographs of Simulated Groundwater Levels in Port Hueneme Area.



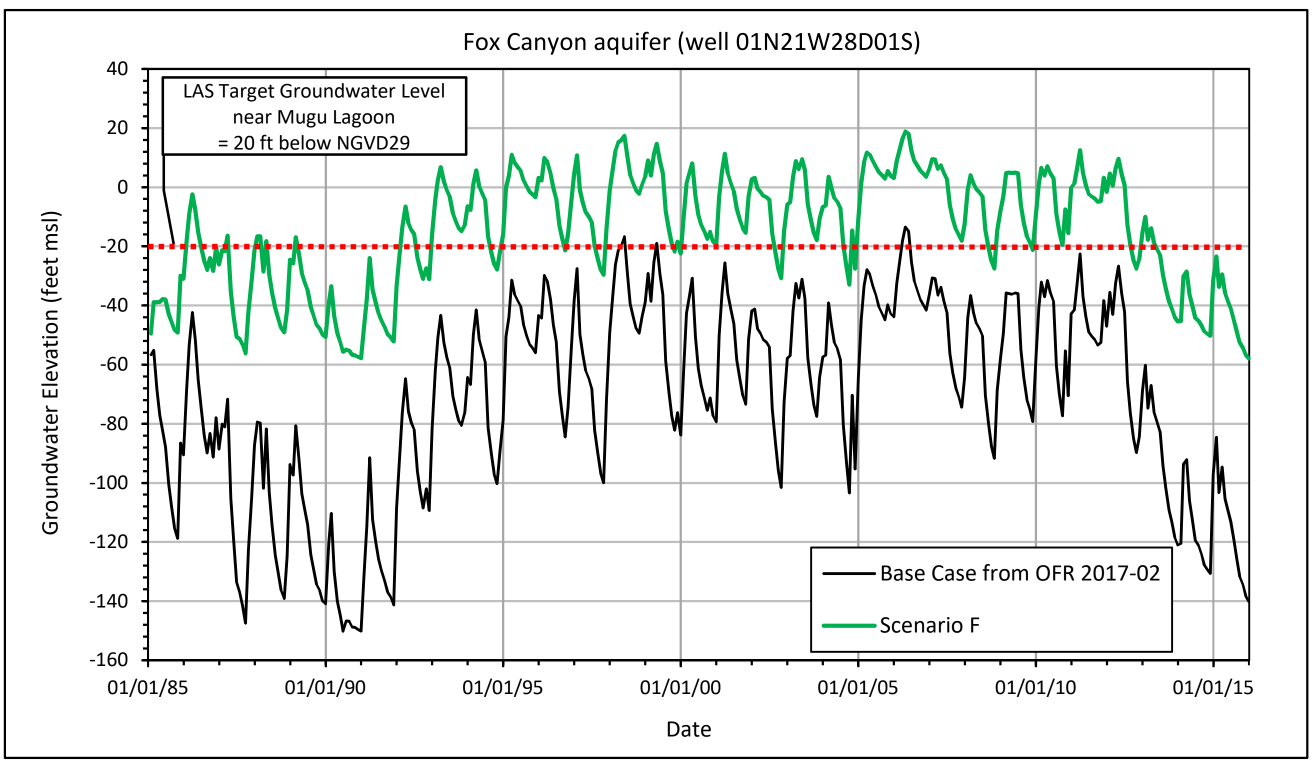
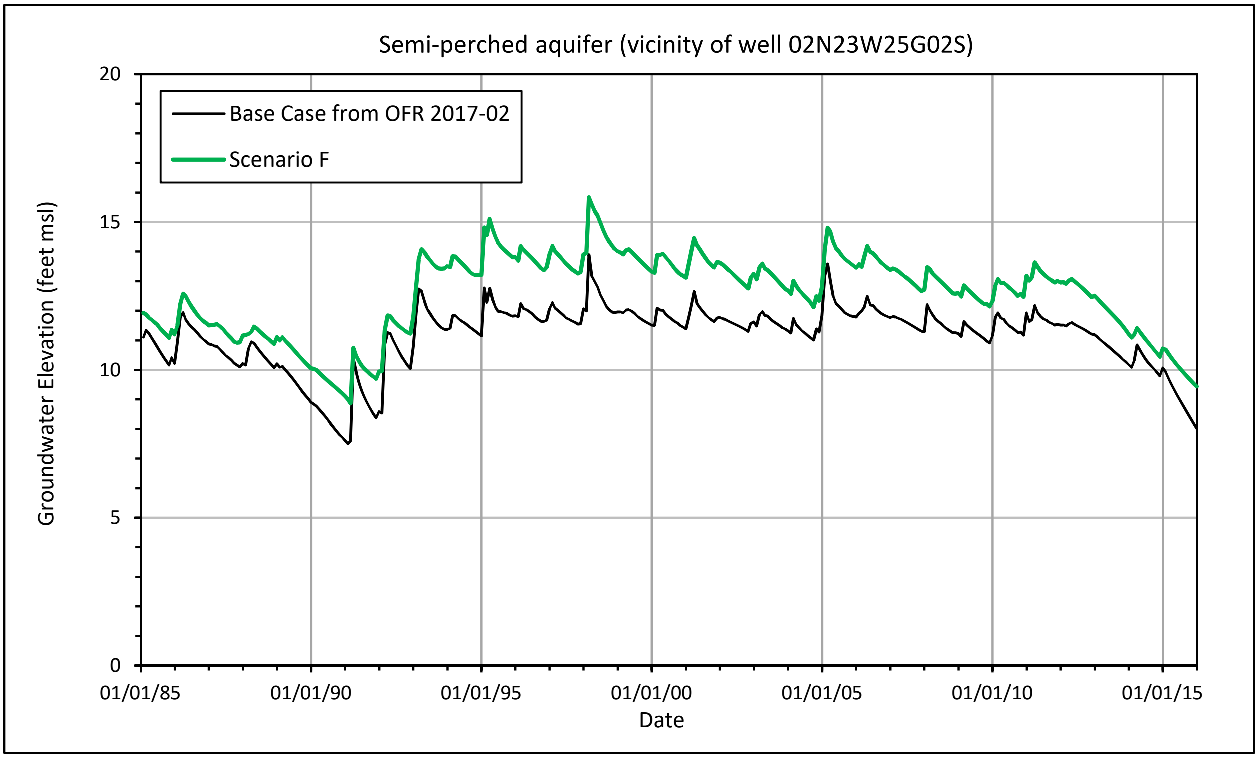


Figure 3-2. Time-Series Hydrographs of Simulated Groundwater Levels in Mugu Lagoon Area.



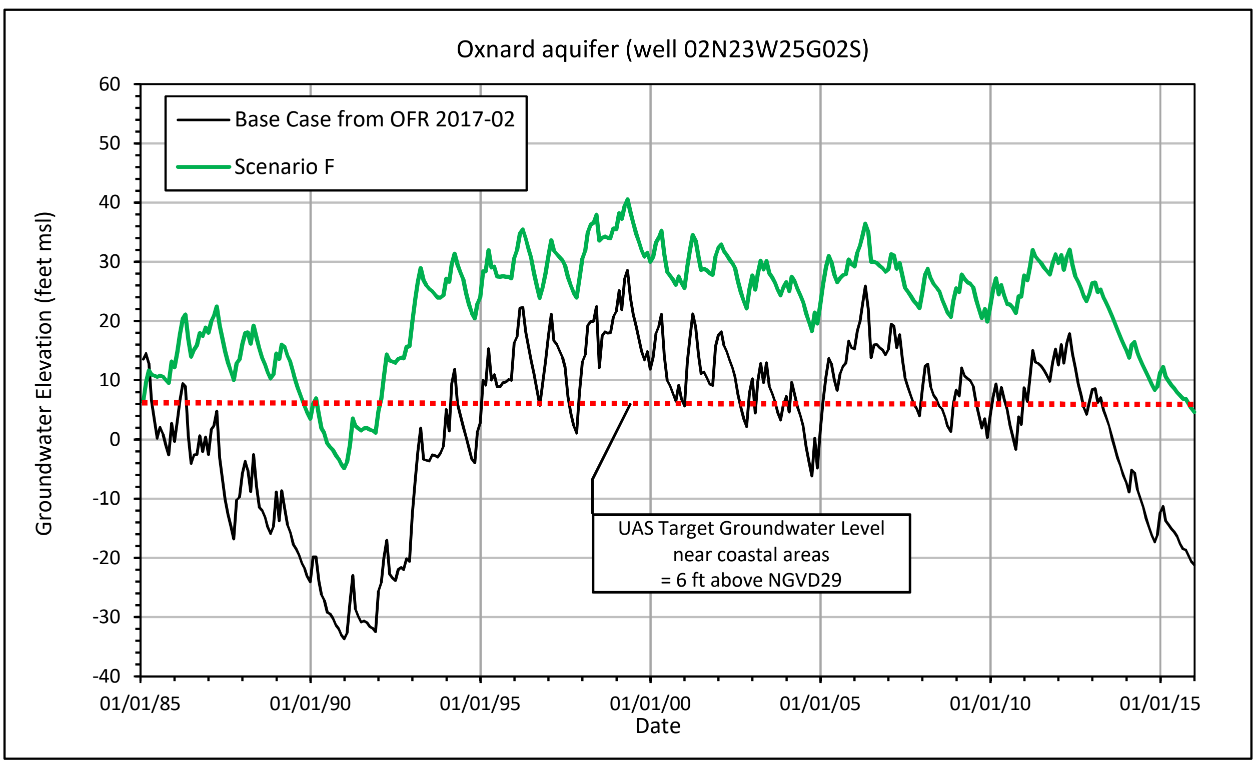
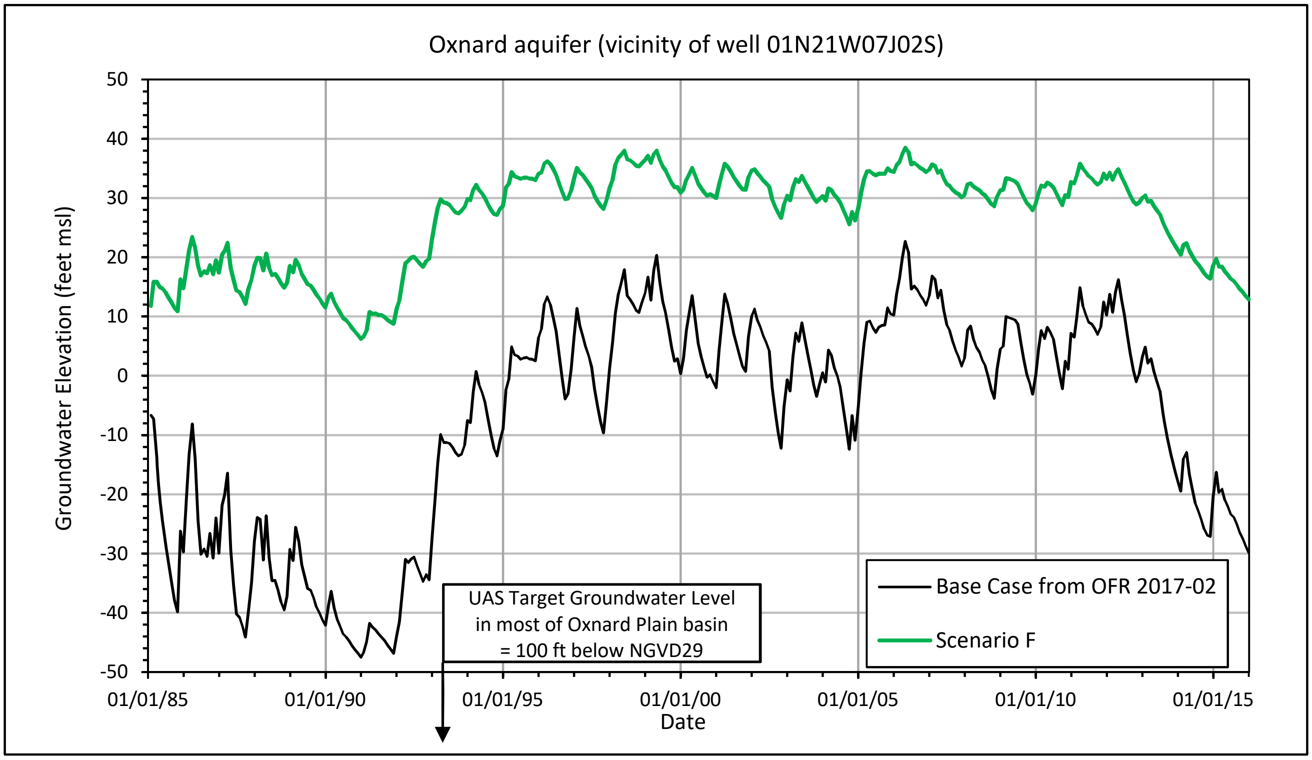


Figure 3-3. Time-Series Hydrographs of Simulated Groundwater Levels in Northwestern Oxnard Plain near Santa Clara River.



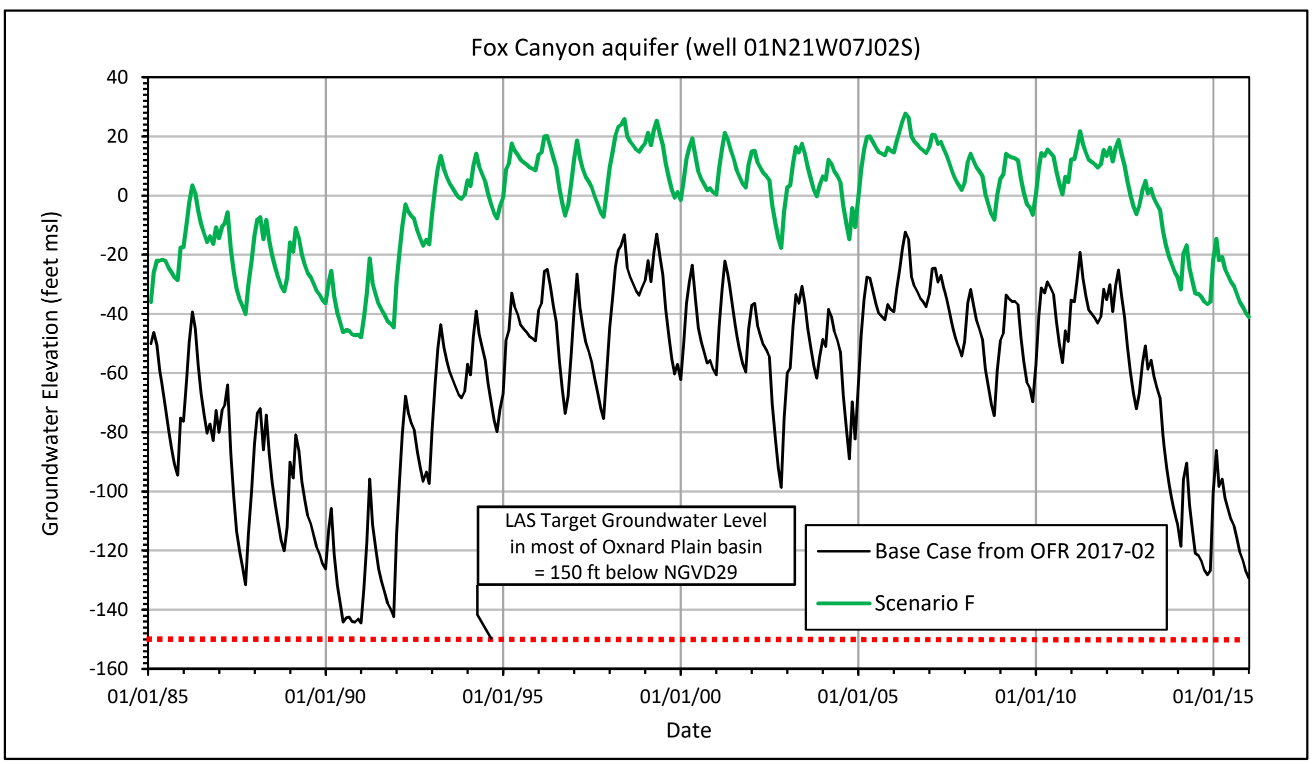


Figure 3-4. Time-Series Hydrographs of Simulated Groundwater Levels in Eastern Oxnard Plain Basin near Boundary with Pleasant Valley Basin.

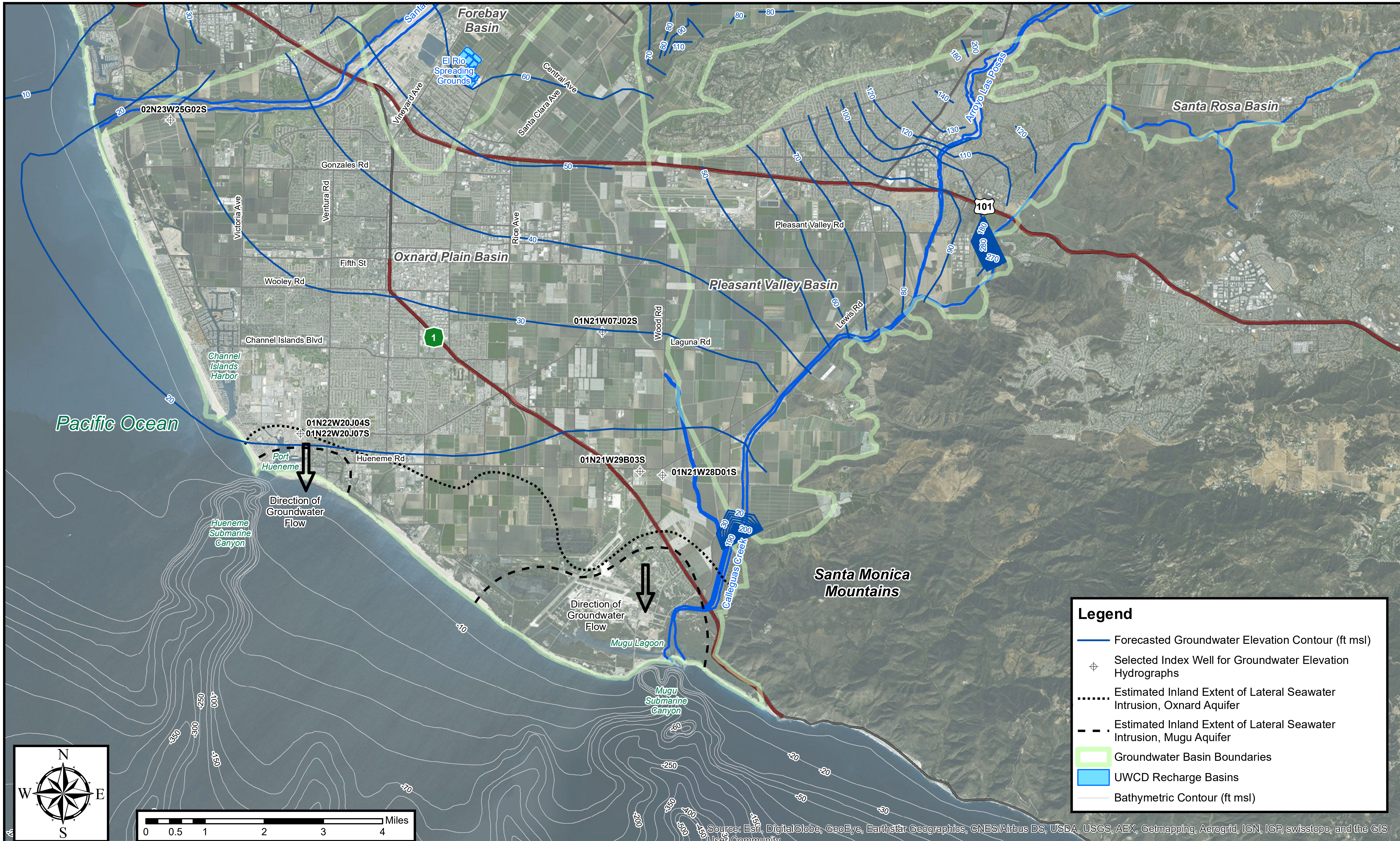


Figure 3-5. Simulated Groundwater Elevations in Oxnard Aquifer Under Scenario F, Typical Water-Year Conditions.

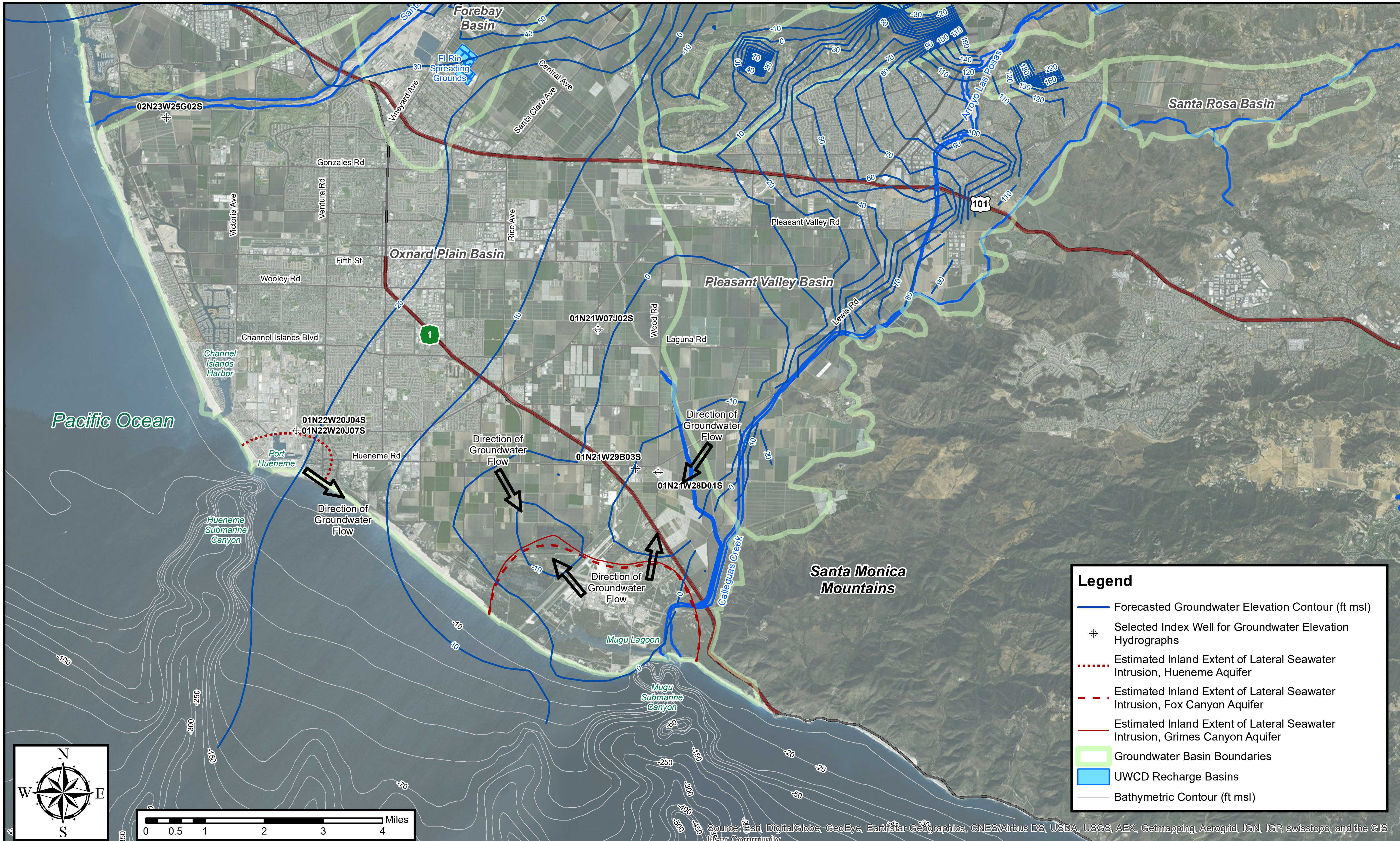


Figure 3-6. Simulated Groundwater Elevations in Fox Canyon (main) Aquifer Under Scenario F, Typical Water-Year Conditions.