

**FORECASTED EFFECTS OF “HYBRID SEAWATER  
INTRUSION BARRIER/OPTIMIZATION”  
PROJECT SCENARIO ON SUSTAINABLE YIELD  
AND WATER SUPPLY  
IN OXNARD AND PLEASANT VALLEY BASINS**

United Water Conservation District  
Open-File Report 2022-02  
November 2022



WATER RESOURCES DEPARTMENT  
UNITED WATER CONSERVATION DISTRICT

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

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Preferred Citation: United Water Conservation District, 2022, *Forecasted Effects of “Hybrid Seawater intrusion Barrier/Optimization” Project Scenario on Sustainable Yield and Water supply in Oxnard and Pleasant Valley Basins*, United Water Conservation District Open-File Report 2022-02.

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## EXECUTIVE SUMMARY

This report documents the methods and results of an evaluation of model-forecasted hydrogeologic conditions in the Oxnard subbasin of the Santa Clara River basin (abbreviated herein as “Oxnard basin”) and the Pleasant Valley basin (together referred to as the “OPV basins”) assuming implementation of the “Hybrid Seawater Intrusion Barrier/Optimization” project scenario (Hybrid Scenario) selected by the Fox Canyon Groundwater Management Agency’s (FCGMA) *ad hoc* OPV Projects Committee (Projects Committee) in December 2020. The three Hybrid Scenario alternatives include expansion of some of the existing water supply and conjunctive-use projects in the OPV basins, together with construction of a proposed new seawater-intrusion extraction barrier and brackish-water treatment facility, to increase sustainable yield of the OPV basins and provide additional sources of fresh water.

Water users in the OPV basins have attempted to mitigate, with varying degrees of success, local groundwater supply and quality challenges related to basin discharge frequently exceeding recharge. Past and current approaches have included artificial recharge of groundwater, conjunctive-use projects, and demand-reduction measures, including conservation. All of these approaches have been proven to be partially effective, but seawater intrusion has continued to be a persistent challenge. The Groundwater Sustainability Plans (GSPs) adopted in December 2019 for the OPV basins included six new water supply projects, but those projects alone were not sufficient to mitigate seawater intrusion. Results of the “Reduction with Projects” scenarios presented in the Oxnard and Pleasant Valley basin GSPs indicated that pumping reductions of 35 percent (relative to 2015-17 average production rates) in Oxnard basin, 20 percent in Pleasant Valley basin, and 20 percent in the west part of the Las Posas Valley basin, combined with the new projects, would come close to achieving sustainable yield (eliminate most, but not all, seawater intrusion in the Oxnard basin). However, the FCGMA reiterated in February 2021 that “The GSP estimate should be considered the base estimate of sustainable yield. The GSPs clearly articulate that additional projects should be developed and implemented to increase the water supplies and sustainable yield of the basins.” In response, an *ad hoc* Projects Committee was formed by the FCGMA from “core stakeholders” in the OPV basins in September 2020 to identify “a cost-effective portfolio of projects and optimization measures that align with the GSP objectives and respond to regional water needs,” and “recommend a cohesive strategy to bring these projects into fruition.”

The Projects Committee recommended that several projects “move forward for further analysis.” United was asked to use its groundwater flow and surface-water distribution models to simulate a combination of projects referred to as the “Hybrid Scenario,” because it would include a seawater-intrusion barrier, new fresh water sources, and optimization of pumping throughout the OPV basins to achieve sustainable yield. The projects included in the Hybrid Scenario are:

- Recycled Water to Farms

- Incentivized Fallowing
- State Water Project (SWP) Interconnect Flushing
- Freeman Diversion Expansion (Phases 1 & 2)
- SWP Article 21 Purchases, Exchanges, and Transfers
- Optimization of Pumping (Phases 1 & 2)
- Extraction Barrier and Brackish Water Treatment (EBB Water)

Combined, these projects were intended to achieve sustainable yield and provide sufficient water to meet current (2015-17) demand in the OPV basins. As modeling progressed throughout 2021 and more than 20 scenarios were evaluated, some of the project proponents and FCGMA staff met occasionally with United staff and made suggestions for options regarding scale of their projects or approaches to mitigate seawater intrusion (e.g., construction of an injection barrier at Port Hueneme). Two alternatives to the “base-case” Hybrid Scenario were developed that were sufficiently distinct from each other to have potentially different forecasted outcomes. Therefore, three variations of the original Hybrid Scenario were modeled, and are designated here as follows:

- Hybrid Scenario with Injection Wells at Port Hueneme (abbreviated as “Hybrid Scenario with Injection” alternative)—Scenario 22 (S22)
- Hybrid Scenario without Injection Wells at Port Hueneme (“Hybrid Scenario without Injection” alternative)—Scenario 23 (S23)
- Hybrid Scenario with Expanded Recycled Water Use alternative—Scenario 24 (S24)

The optimization of groundwater pumping assumed in all three the Hybrid Scenario alternatives (S22 through S24), combined with the addition of new or expanded sources, required United to assume expansion and improvement of the existing conveyance infrastructure and operations within the OPV basins. Groundwater flow modeling and particle tracking were used to forecast effects of the Hybrid Scenario alternatives on groundwater conditions from 2020 through 2069, focusing primarily on changes in groundwater elevations (drawdown) and movement of the seawater intrusion front within the aquifers of the OPV basins. The water supply distribution and groundwater modeling of the Hybrid Scenario alternatives progressed in an iterative fashion, with output from each simulation providing information that was used to further modify input parameters such as locations of new wells, pumping rates, and optimal distribution systems. It was found that changes to individual projects, or to configurations of multiple projects, yielded differences in recharge rates, groundwater elevations, and seawater intrusion extents to some degree. Results from this iterative process were used to refine estimates of additional yield to the OPV basins for the projects included in the Hybrid Scenario.

Improvements to United's Coastal Plain model and an update of the 2019 seawater intrusion fronts were also applied to the Reduction with Projects scenario that was included in the Oxnard basin GSP. The goal of updating the GSP's Reduction with Projects simulation, using the improved Coastal Plain model and updated seawater intrusion fronts, was to allow direct comparison to particle-tracking results from the Hybrid Scenario alternatives.

Following is a summary of key conclusions from modeling the Hybrid Scenario alternatives and the updated Reduction with Projects scenario from the GSPs for the OPV basins:

- The Hybrid Scenario alternatives are projected to result in approximately 27,000 AFY more water available to agricultural, M&I, and domestic users in the OPV basins (meeting current demand) than would be available under the Reduction with Projects scenario presented in the GSPs for the OPV basins.
- In all of the Hybrid Scenario alternatives, the modeled extraction barrier is projected to be largely successful at mitigating seawater intrusion, particularly near Naval Base Ventura County (NBVC) Point Mugu, where seawater has historically intruded the fastest and farthest.
- In the Oxnard Aquifer, particle tracks are forecasted to retreat back toward the coast up to 1.5 miles over the 50-year simulation period, representing 2,800 acres of aquifer that could potentially be restored to fresh groundwater. In the Mugu Aquifer, some particle tracks are forecasted to retreat back toward the coast up to a mile, representing 300 to 800 acres of aquifer that could potentially be restored to fresh groundwater.
- In the Fox Canyon and Grimes Canyon Aquifers, some particle tracks are forecasted to continue migrating inland approximately  $\frac{1}{4}$  to  $\frac{1}{2}$  mile before the EBB Water project extraction wells are assumed to become fully operational. At that time, many of these particle tracks are projected to turn back toward the coast (the extraction wells). These particle tracks were not projected to turn back toward the coast in the revised Reduction with Projects scenario. The Hybrid Scenario alternatives provide improved mitigation of seawater intrusion in these aquifers compared to the Reduction with Projects scenario.
- In all of the Hybrid Scenario alternatives, projected groundwater elevations rise substantially above historical low levels during the 50-year simulation period, with some brief (1 to 3 month) deviations below historical lows at a few wells during droughts. These deviations may be a result of the spatial and temporal discretization limitations of United's Coastal Plain Model, rather than "real-world" phenomena.
- Injection wells simulated around Port Hueneme are forecasted to provide limited mitigation of the small areas of seawater intrusion in the Mugu and Hueneme

Aquifers in that area. Seawater intrusion in this area has historically been relatively slow-moving within the Mugu and Hueneme Aquifers. It should be noted that the Hueneme Aquifer is absent to the southeast of Port Hueneme. No existing active water supply wells screened in the Mugu and Hueneme Aquifers are forecasted to be affected by seawater intrusion in the Port Hueneme area within the 50-year simulation period, whether or not injection wells are assumed to be installed.

- The Hybrid Scenario alternative with Expanded Recycled Water Use is projected to increase southward (toward the coast) migration of the seawater intrusion front and increase groundwater elevations near the coast compared to the other Hybrid Scenario alternatives. However, the positions of the seawater intrusion fronts in each aquifer after 50 years under this alternative are not substantially different than the positions of the seawater intrusion fronts under the alternatives that did not include expanded recycled water use.
- Modeling results indicate that the EBB Water project would be effective at reversing most historical seawater intrusion and mitigating potential future seawater intrusion. This effectiveness could potentially make one or more of the modeled pumping-optimization projects unnecessary.

Following is a summary of recommendations for further evaluation:

- Share details of the modeled scenarios with OPV basin stakeholders and the FCGMA to clarify and seek feedback on the assumptions regarding production, distribution, and end-use of the new and expanded water supply sources assumed in the Hybrid Scenario. Ideally, a single preferred alternative would be selected following this input, for further evaluation and advancement. Also seek input from stakeholders regarding acceptability of forecasted groundwater elevations and particle tracks. If the small areas where the seawater intrusion fronts in some aquifers are projected to advance  $\frac{1}{4}$  to  $\frac{3}{4}$  mile are deemed “significant and unreasonable” by the FCGMA and basin stakeholders, then the preferred alternative could be revised and re-evaluated during subsequent phases of design to attempt to eliminate these areas.
- Conduct detailed seawater-intrusion modeling for the preferred alternative using United’s new MODFLOW-USG Transport model. Although the particle-tracking described in this report (using the Coastal Plain Model) provides a helpful depiction of projected movement of the seawater intrusion front in each aquifer, a more detailed forecast can be provided with the new model, albeit with significantly more time and effort required to complete the modeling.
- Using United’s new MODFLOW-USG Transport model, quantify potential for land subsidence in the OPV basins under the preferred alternative. None of the Hybrid

Scenario alternatives are expected to induce significant land subsidence, but verification with the new model would be prudent.

- Conduct additional modeling (using the Coastal Plain Model with particle tracking) to evaluate the effects of removing each pumping-optimization project on mitigation of seawater intrusion. The benefits of some of the optimization projects may be negligible or limited in comparison to the EBB Water project.

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**Appendix A. Hydrographs Showing Projected Groundwater Elevations at Selected Wells  
in OPV Basins under Hybrid Scenario Alternatives**

# 1 OBJECTIVE

United Water Conservation District (United or UWCD) is a California Special District with a service area of approximately 335 square miles (214,000 acres) in southern Ventura County. United's service area includes the Ventura County portion of the Santa Clara River Valley and much of the Oxnard Coastal Plain, including the lower part of the Calleguas Creek watershed, as shown on Figure 1. United serves as a steward for surface water and groundwater resources within all or part of seven groundwater basins (Figure 1). United is governed by a seven-person board of directors elected by region, and receives revenue from property taxes, pump charges, recreation fees, and water delivery charges. United is authorized under the California Water Code to conduct water resource investigations, acquire water rights, build facilities to store and recharge water, construct wells and pipelines for water deliveries, commence actions involving water rights and water use, prevent interference with or diminution of stream/river flows and their associated natural subterranean supply of water, and to acquire and operate recreational facilities (California Water Code, section 74500 et al).

The objective of this report is to document the methods and results of an evaluation of model-forecasted hydrogeologic conditions in the Oxnard subbasin of the Santa Clara River basin (abbreviated herein as "Oxnard basin") and the Pleasant Valley basin (together referred to as the "OPV basins") assuming implementation of the "Hybrid Seawater Intrusion Barrier/Optimization" project scenario (Hybrid Scenario) selected by the Fox Canyon Groundwater Management Agency's (FCGMA) *ad hoc* OPV Projects Committee (Projects Committee) in December 2020 (Consensus Building Institute, 2020a). More information about the Projects Committee's conclusions and recommendations is provided in Section 2.4 of this report. The three Hybrid Scenario alternatives include expansion of some of the existing water supply and conjunctive-use projects in the OPV basins, together with construction of a proposed new seawater-intrusion barrier and brackish-water treatment facility, to increase sustainable yield of the OPV basins and provide additional sources of fresh water.

The study area for this evaluation includes the OPV basins (Figure 1), and the assumed timeframe for expansion of existing projects and construction of new projects is 2022 through 2036. At the time the Hybrid Scenario was selected for further evaluation by the Projects Committee, the yields and effects on groundwater conditions that were anticipated to result from the proposed projects were, in some cases, conceptual or based on preliminary analysis. As evaluation of the Hybrid Scenario progressed throughout 2021, simulation of the conveyance and distribution of the multiple sources of existing and new water supply across the OPV basins (using United's distribution model, described in Section 3.1) was continually improved. At the same time, United's Coastal Plain groundwater flow model (United, 2018) was updated with additional data and refined assumptions regarding coastal hydrogeology, and seawater-intrusion-barrier well-

configuration alternatives were applied (United, 2021a and 2021b). Therefore, although conceptually the elements of the Hybrid Scenario are essentially unchanged from late-2020 as envisioned by the Projects Committee, the potential yields of individual projects and the distribution assumptions regarding the water they would produce have been adjusted to incorporate the new information (as described in Section 3).



## 2 BACKGROUND

This section provides a summary of the FCGMA's stakeholder-driven process that led to development of the Hybrid Scenario. This section also includes a description of United's process for developing updated, model-based estimate of the location of the seawater intrusion "fronts" in each aquifer of the OPV basins as of 2019. Seawater intrusion is the main driver for the sustainable yield estimates provided in the GSPs for the OPV basins and west part of the Las Posas Valley basins (Dudek, 2019a, 2019b, and 2019c).

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### 2.1 SUSTAINABLE YIELD ESTIMATES PROVIDED IN THE GROUNDWATER SUSTAINABILITY PLANS FOR THE OPV BASINS

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In September 2014, California's Sustainable Groundwater Management Act (SGMA) was signed into law, requiring formation of local Groundwater Sustainability Agencies (GSAs) and preparation of Groundwater Sustainability Plans (GSPs) for groundwater basins designated as "medium" or "high" priority by the California Department of Water Resources (DWR). In addition, some basins were considered to be "critically overdrafted" by DWR. Both the Oxnard and Pleasant Valley basins were designated as high priority and critically overdrafted. SGMA required that GSPs for critically overdrafted basins be completed and submitted to DWR by January 30, 2020. In January 2015, the FCGMA Board adopted Resolution No. 2015-01, which elected the FCGMA to be the GSA for the OPV basins (as well as the Las Posas Valley basin). Other agencies elected to be the GSAs for four small "outlying areas" along the margins of the OPV basins outside of the FCGMA's boundaries. In 2016 and 2018, some minor changes were proposed to the boundaries of the OPV and adjacent basins by the FCGMA and Mound basin GSA based on administrative and scientific grounds (<https://sgma.water.ca.gov/basinmod/modrequest/submitted>). These changes resulted in the current DWR-defined basin boundaries, as shown on Figures 1 and 2. The FCGMA's consultant, Dudek, completed GSPs for the OPV basins that were adopted by the FCGMA's Board of Directors in December 2019 and submitted to DWR in January 2020. DWR approved the GSPs for the OPV basins—with some recommended corrective actions—in November 2021 (DWR, 2021a and 2021b).

The GSP for the Oxnard basin (Dudek, 2019b) estimated that the combined sustainable yield of the UAS and LAS in that basin is 39,000 AFY, with an uncertainty of +/-8,300 AFY, for the 50-year planning and implementation period (2020 through 2069). The GSP for the Pleasant Valley basin (Dudek, 2019a) estimated that the combined sustainable yield of the Shallow Alluvial Aquifer and the LAS in that basin is 11,600 AFY, with an uncertainty of +/-1,200 AFY, for the same 50-year planning and implementation period. These sustainable yield estimates were based primarily on modeled estimates of seawater intrusion in the Oxnard basin, and assumed that pumping reductions in the Oxnard, Pleasant Valley, and Western Management Area of the

Las Posas Valley basin would be the primary method of mitigating seawater intrusion. In addition, several projects were incorporated in the GSPs to provide alternative sources of supply to replace a small portion of the water supply lost to the pumping reductions that were contemplated in the GSPs (Dudek, 2019a, 2019b, and 2019c). The simulated pumping reductions were forecasted to result in groundwater elevations rising above mean sea level across much of the Oxnard, Pleasant Valley, and Las Posas Valley basins, mitigating most concerns about chronic lowering of groundwater levels, reduction of groundwater storage, degraded groundwater quality, land subsidence, and depletions of interconnected surface water. The projected rise in groundwater levels would also result in a net seaward flow of groundwater, reversing the flow of intruded seawater back toward the ocean, together with some brackish and fresh groundwater.

Solely considering the water balances in the OPV basins, the groundwater budget summaries provided in the GSPs for the Oxnard and Pleasant Valley basins suggest that the “overdraft” (groundwater outflow exceeding inflow, or decline in groundwater in storage) in the UAS and LAS of the Oxnard basin during the modeled historical period (1986 through 2015) was 4,400 AFY, and in Pleasant Valley basin there was a net *increase* in groundwater in storage of 1,500 AFY over the same period. If seawater intrusion was not counted as an “inflow,” then the overdraft in the Oxnard basin would have been 13,800 AFY. DWR (2021a), in their review of the Oxnard basin GSP, noted that the average decrease in “freshwater storage” from 1986 through 2015 in the Oxnard basin was 12,700 AFY, which is slightly less than the 13,800 AFY value reported in the groundwater budget tables in the GSP (Dudek, 2019b).

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## 2.2 PROJECTS INCLUDED IN THE OPV GROUNDWATER SUSTAINABILITY PLANS

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The GSPs for the OPV basins identified several new or expanded water supply projects that “were suggested by stakeholders and were reviewed by the Operations Committee of the FCGMA Board” (Dudek, 2019a and 2019b). The projects were intended “to address potential impacts to beneficial uses and users of groundwater in the (Oxnard) Subbasin resulting from groundwater production in excess of the current sustainable yield” (Dudek, 2019b).

In the Oxnard basin, the following projects were included:

- “GREAT Program Advanced Water Purification Facility (AWPF)”—This project assumed that some or all of the 2019 capacity of the City of Oxnard’s recycled water discharged from their AWPF (4,600 AFY) could be put to beneficial use and would reduce groundwater extractions an equivalent amount. This recycled water was assumed to be delivered to agricultural users in both the Oxnard and Pleasant Valley basins.

- “GREAT Program AWP Expansion”—This project assumed a 4,500 AFY expansion of the AWP that would result in an equivalent reduction in groundwater extractions.
- “Riverpark-Saticoy Groundwater Replenishment and Reuse Project (GRRP) Recycled Water Project”—This project assumed that the 4,500 AFY of recycled water from Oxnard’s AWP expansion (above) would be recharged at United’s recharge basins in the Saticoy area of the Forebay. The City of Oxnard submitted a comment letter (after release of the Oxnard basin GSP) that objected to including this project in the GSP; therefore, it is highly unlikely that this project would advance as described in the GSP.
- “Freeman Expansion Project”—This project assumed that United would expand its Freeman Diversion on the Santa Clara River to allow United to take approximately 7,400 AFY additional “peak flows” of high-silt, high-turbidity surface water than was historically possible. This additional surface water would be recharged in the Forebay area of the Oxnard basin.
- “Temporary Agricultural Land Fallowing”—This project assumed that the FCGMA would lease agricultural land for temporary fallowing, to reduce groundwater demand in the Oxnard basin by 500 AFY. Land in areas susceptible to seawater intrusion would be targeted.

In the Pleasant Valley basin, one new project was included:

- “Temporary Agricultural Land Fallowing”—This project assumed that the FCGMA would lease agricultural land in the Pleasant Valley basin for temporary fallowing, to reduce groundwater demand by 2,400 AFY. Land “in areas susceptible to contributing to seawater intrusion in the adjacent Oxnard basin” would be targeted.

The GSPs for the OPV basins also included a “Management Action” that could be implemented if new or expanded water supply projects were not capable of achieving sustainable yield. Specifically, “Management Action No. 1” in both the Oxnard and Pleasant Valley basin GSPs consisted of mandated reductions in groundwater pumping. Results of the “Reduction with Projects” scenarios presented in the Oxnard and Pleasant Valley basin GSPs (Dudek, 2019b and 2019a) indicated that if the projects described above were implemented, pumping reductions of 35 percent (relative to 2015-17 average production rates) in Oxnard basin, 20 percent in Pleasant Valley basin, and 20 percent in the west part of the Las Posas Valley basin, combined with the new projects, would come close to achieving sustainable yield (eliminate most, but not all, seawater intrusion in the Oxnard basin). However, the FCGMA reiterated in February 2021 that “The GSP estimate should be considered the base estimate of sustainable yield. The GSPs clearly articulate that additional projects should be developed and implemented to increase the water supplies and sustainable yield of the basins” (FCGMA, 2021).

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## 2.3 POST-GSP DEVELOPMENT OF WATER SUPPLY PROJECTS IN OPV BASINS

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Several new or expanded water supply projects were proposed by various water agencies in 2018 and 2019 as the GSPs for the OPV basins were being prepared, but were deemed to be insufficiently developed for inclusion in the GSPs (FCGMA, 2021). By early 2022 some of these projects were considered sufficiently developed to be incorporated by the FCGMA into the 2021 annual GSP update reports for the Oxnard and Pleasant Valley basins (Dudek, 2022a and 2022b). The public process by which these new projects were developed, and a summary of the yields and benefits of each project, are summarized in this section.

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## 2.4 PROJECTS COMMITTEE OF OPV STAKEHOLDERS

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Water users in the OPV basins expressed concern about the likely economic, environmental, and social consequences from reducing groundwater extractions by 35 percent in the Oxnard basin and 20 percent in the Pleasant Valley and Western Management Area of the Las Posas Valley basins, unless more projects were considered for the GSP implementation period. In response, a Projects Committee was formed by the FCGMA from “core stakeholders” in the OPV basins in September 2020 to identify “a cost-effective portfolio of projects and optimization measures that align with the GSP objectives and respond to regional water needs,” and “recommend a cohesive strategy to bring these projects into fruition” (Consensus Building Institute, 2020b).

The Projects Committee met eight times between August and December 2020, and ultimately recommended that several projects, listed in Table 1 of this report, “move forward for further analysis.” Combined, these projects were expected to achieve sustainable yield and provide sufficient water supplies to meet current (2015-17) demand in the OPV basins. United was asked to use its groundwater flow and surface-water distribution models to simulate a scenario named the “Hybrid Scenario,” because it would include a seawater-intrusion barrier, optimization of pumping throughout the OPV basins, and new or expended water supplies to achieve sustainable yield (Consensus Building Institute, 2020a).

United began modeling the combined effects of the projects in the Hybrid Scenario in February 2021, and presented initial results to FCGMA staff, the FCGMA Operations Committee, and the FCGMA Board of Directors during a series of meetings in May 2021. United staff also presented the results to United’s Water Resources Committee and Board of Directors during meetings in June 2021, and at United’s “Water Sustainability Summit” with stakeholders and state agencies in October 2021. Key conclusions from the initial modeling completed to that point were that:

- The Hybrid Scenario would stop and ultimately reverse seawater intrusion in most areas along the coast, potentially reducing the area of existing seawater intrusion by one or more square miles.
- However, there were small areas of continued seawater intrusion forecasted in the LAS near Port Hueneme and Point Mugu that would require modification of the simulated locations for extraction wells (or possibly use of injection wells) to improve control over seawater intrusion.
- During periods of abundant rainfall, it could be difficult to make full use of recycled water under the pipeline and pumping scenarios considered, due to lack of demand.

Also during 2021, the design and implementation of United's Extraction Barrier and Brackish Water Treatment Project (EBB Water) and Freeman Expansion projects were advancing. Therefore, United has continued to revise the modeling assumptions regarding timeline and yield of these and other projects through early 2022.

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## 2.5 PROJECTS ADDED TO OPV GROUNDWATER SUSTAINABILITY PLANS IN 2021 ANNUAL UPDATE REPORTS

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In December 2021, DWR solicited proposals for Round 1 of its "Sustainable Groundwater Management" (SGM) grant opportunities, which offered up to \$7.6 million per basin using California Proposition 68 and 2021 Budget Act funding to design and implement water supply projects in critically overdrafted basins, including the OPV basins. One of the requirements of the SGM grants is that the proposed water supply projects must be included in the GSPs, or in annual GSP update reports. In response, the FCGMA asked stakeholders in the OPV basins to provide grant proposals for new projects that had been developed subsequent to preparation of the Oxnard and Pleasant Valley basin GSPs. The *ad hoc* Projects Committee was reconvened by the FCGMA in January 2022 to evaluate the grant proposals submitted by proponents and rank them by order of preference for SGM grant funding. Also in January 2022, the FCGMA's Board of Directors approved adding several water supply projects that were not included in the original Oxnard and Pleasant Valley basin GSPs to the 2021 Annual GSP Update reports (Dudek, 2022a and 2022b), and updating information on yields, timing or benefits of previously proposed projects. The projects included in the 2021 Annual GSP Update reports that increased yield of the basins are summarized in Table 2. In addition to the water supply projects listed in Table 2, five feasibility studies proposed by the City of Camarillo were included in the Pleasant Valley basin Annual GSP Update report for potential new stormwater recharge projects and the North Pleasant Valley Desalter Expansion project. Anticipated timelines or additional yields of these potential projects were not provided by the City of Camarillo, thus are not included in the Hybrid Scenario at this time.

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## 2.6 SEAWATER INTRUSION IN THE OPV BASINS

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Seawater intrusion has long been the primary groundwater sustainability concern in the OPV basins, and the GSP for the Oxnard basin identifies seawater intrusion as “the primary sustainability indicator in the Oxnard Subbasin.” Past efforts to increase yield of, and limit groundwater extractions from, the OPV basins have slowed the advance of seawater intrusion, as discussed further below. However, additional projects to improve sustainable yield and provide sources of water other than groundwater will be needed if major reductions in the total available water supply to the OPV basins are to be avoided (Dudek, 2019a and 2019b). Without new projects, the GSPs for the OPV basins indicate that groundwater withdrawals would have to be reduced by approximately 30,000 AFY, to hold the seawater intrusion fronts in each aquifer at their current positions, assuming that the reductions in pumping would be applied uniformly in wells across the Oxnard, Pleasant Valley, and western Las Posas Valley basins (Dudek, 2019a, 2019b, and 2019c).

The 30,000 AFY reduction in pumping envisioned in the GSPs to achieve sustainable yield is significantly larger than the 13,000 to 14,000 AFY net imbalance between groundwater inflows and outflows in the Oxnard basin described in Section 2.1 of this report. The reason for that difference is because simply achieving an overall balance between inflow to and outflow from the OPV basins will not prevent localized inland hydraulic gradients from persisting along the coastline. Local hydraulic gradients can still draw seawater into the aquifers toward wells inland from the Mugu and Hueneme submarine canyons, unless there is a barrier to seawater intrusion. If seawater intrusion is mitigated with a barrier, then the primary driver for sustainable yield will become eliminating the 13,000 to 14,000 AFY long-term-average deficit between groundwater inflows and outflows in the Oxnard basin, as noted above.

United has periodically prepared maps of saline intrusion within each aquifer system (UAS and LAS) or aquifer (Oxnard, Mugu, Hueneme, Fox Canyon, and Grimes Canyon Aquifers) since 1994. United (2022a) includes saline intrusion maps for 2003, 2015, and 2020 as representative examples of the changing extents and interpretations of chloride-impacted groundwater underlying the OPV basins during the past 20 years. The 2003, 2015, and 2020 saline intrusion maps are based on available data at the time, and show limited northward advancement of the seawater intrusion front in some aquifers. Changes in saline intrusion are most notable at the southeastern margin of the Oxnard basin near NBVC Point Mugu, but the fronts in this area do not appear to have advanced north of Hueneme Road except near Port Hueneme, where saline intrusion in the UAS has been consistently mapped slightly north of Hueneme Road since the late 1950s.

In 2022, United used its new MODFLOW-USG Transport (Panday and others, 2017) groundwater flow and transport model of the Oxnard coastal plain (MODFLOW-USG transport model; United, 2021d) to estimate the location of the seawater-intrusion front in each aquifer of the Oxnard basin

from 1985 through 2019 (the model calibration period). Figures 3 through 7 show the 2019 modeled chloride concentrations in the Oxnard, Mugu, Hueneme, Fox Canyon, and Grimes Canyon Aquifers. The 100 milligram per liter (mg/L) chloride contour is used to represent the seawater intrusion front in each aquifer. The 2019 chloride concentration maps developed using the calibrated MODFLOW-USG Transport model have a significant advantage compared to chloride concentration maps prepared solely from available data in each aquifer: that is, where data are limited by a paucity of monitoring points, the modeled seawater intrusion fronts are estimated based on physical processes occurring in each aquifer, rather than simple interpolation between, or extrapolation beyond, known data points.

Comparison of the modeled 2019 seawater intrusion fronts (Figures 3 through 7) to United's 2020 estimates for seawater intrusion fronts that were based solely on available chloride data (United, 2022a) shows that the two methods provide generally similar results, except for the area immediately south from the intersection of Hueneme Road and Rice Avenue. In this area, the modeled seawater intrusion fronts include previously unrecognized lobes of elevated chloride concentrations (100 to 500 mg/L) in the Mugu, Hueneme, and Fox Canyon Aquifers (Figures 4 through 6). Review of MODFLOW-USG Transport model results indicates that if these lobes do indeed exist, they are a result of downward hydraulic gradients and thinning of confining units between aquifers that allow downward migration of saline water from the Oxnard Aquifer. United is currently developing plans to construct monitoring wells in this area to confirm the model results. It should be noted that these lobes do not necessarily represent "expansion" in recent years of the seawater intrusion front; rather, the lobes may represent previously unrecognized (due to a lack of monitoring in the immediate vicinity) areas of elevated chloride concentrations.

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### 3 EVALUATION METHODS

As was described in Section 2 United began simulating the Hybrid Scenario in early 2021, including the projects selected by the FCGMA's *ad hoc* OPV Projects Committee (Table 1). As modeling progressed throughout 2021, some of the project proponents, FCGMA staff, and FCGMA consultants met occasionally with United staff and made suggestions for options regarding scale of the projects or approaches to mitigate seawater intrusion (e.g., construction of an injection barrier at Port Hueneme). Two alternatives to the “base-case” Hybrid Scenario were developed that were sufficiently distinct from each other to potentially have significantly different forecasted outcomes. Therefore, three variations of the original Hybrid Scenario were modeled, and are designated as follows:

- Hybrid Scenario with Injection Wells at Port Hueneme (abbreviated as “Hybrid Scenario with Injection” alternative)—Scenario 22 (S22)
- Hybrid Scenario without Injection Wells at Port Hueneme (“Hybrid Scenario without Injection” alternative)—Scenario 23 (S23)
- Hybrid Scenario with Expanded Recycled Water Use alternative—Scenario 24 (S24)

More details regarding these modeled scenarios are provided in Section 3.1 and in Table 3. Scenarios 1 through 21, which are not listed above, were preliminary modeling efforts that were modified or abandoned as new information came to light during 2021 through early 2022 as project designs advanced, new hydrogeologic information in the southern portion of the Oxnard basin was added to the models, or a scenario failed to meet minimum expectations for mitigation of seawater intrusion (typically due to ineffective locations or insufficient pumping rates for simulated extraction or injection wells).

The optimization of groundwater pumping assumed in all three Hybrid Scenario alternatives (S22 through S24), combined with additional new water supplies, required United to assume expansion and improvement to some of the existing conveyance infrastructure and operations within the OPV basins. A description of United's process and tools for water supply distribution modeling is provided in Section 3.1. Groundwater flow modeling and particle tracking were used to forecast effects of the Hybrid Scenario alternatives on groundwater conditions, focusing primarily on changes in groundwater elevations and projected movement of the seawater intrusion front within the aquifers of the OPV basins. A description of how United's Coastal Plain Model was used for this evaluation is provided in Section 3.2.

The water supply distribution and groundwater modeling of the Hybrid Scenario alternatives progressed in an iterative fashion, with output from each simulation providing information that was used to further modify input parameters such as locations of new wells, pumping rates, and

extents of distribution systems. It was found that changes to individual projects, or to different configurations of multiple projects, yielded changes to recharge rates, groundwater elevations, and seawater intrusion extents to some degree. Results from this iterative process were used to refine estimates of additional yield to the OPV basins for some of the projects described in Table 2, as discussed below and summarized in Table 4.

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### 3.1 WATER DISTRIBUTION MODELING

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The distribution of project water to groundwater recharge and pipeline deliveries for agricultural irrigation in the OPV basins was simulated by United's Oxnard Plain Surface Water Distribution Model (SWDM). The SWDM matches supply from various sources with capacity for artificial recharge and irrigation demand for surface water, considering limitations in pipeline conveyance capacity and operational constraints (United, 2021c). The SWDM runs in daily timesteps to account for the highly variable diversions (due to variable river flows and bypass flow operations) and to reflect the daily variability in artificial recharge operations and irrigation demands. The SWDM does not include hydraulic modeling (e.g., heads or flow rates in pipelines or canals). Some processes and calculations that are included in the SWDM are dependent on groundwater elevations in the Forebay area of the Oxnard basin, and therefore iterative runs are often performed where groundwater elevation outputs from United's Coastal Plain (groundwater flow) Model, described in Section 3.2, were input to the SWDM until groundwater elevations converged toward stable, consistent values between model runs. The model input structure is flexible so that different project alternatives can be analyzed, new projects can be added, or scale of the projects can be modified in the future. Modeling was performed for the historical hydrology period from 1930 to 1979, corresponding to future modeling period 2020 to 2069, identical to the period modeled in the GSPs for the OPV basins (Dudek, 2019a and 2019b).

Three distribution areas are defined in the SWDM for modeling groundwater and surface water deliveries on the Oxnard coastal plain: the PTP area, PVP area, and Coastal area. Each of these areas is depicted on Figure 8. For modeling purposes, it is assumed that 90% of the daily demand within each area can be met by pipeline deliveries, which will require extending existing pipelines to reach more farmland. The SWDM assumes pipeline deliveries are made to each area when water supply is available, until demands in these areas are met. Irrigation demand in excess of available pipeline deliveries in the PTP, PVP, and Coastal areas is assumed to be met by groundwater. Total water demands in these areas are assumed equal to the average annual pumping reported to United and FCGMA during calendar years 2015 through 2017 for groundwater wells in each area, as prescribed for the GSP model runs (Dudek, 2019a and 2019b). For the PVP area, total demand included an additional 2,600 AFY to account for Camrosa Water District historical surface-water deliveries from Conejo Creek. Surface-water deliveries from natural flows diverted from the Santa Clara River did not occur during 2015, 2016, or 2017. Total demands in the portion of the Oxnard basin outside of the PTP area, and the portion of the Pleasant Valley basin outside of the PVP area, were calculated by subtracting demand within

these areas from total basin pumping. Total groundwater pumping from the Oxnard, Pleasant Valley and West Las Posas Valley basins was obtained from the GSPs (Dudek, 2019a, 2019b, and 2019c). Water demand for each area is summarized in Table 5.

Assumptions specific to the Hybrid Scenario SWDM runs are described below for each of the water supply projects described in Table 4. Unless noted otherwise in Table 4, projects were assumed to come online at the beginning of the simulation period. A few years delay or early implementation of some of these projects is possible, but such shifts in timing would not be expected to have substantial effects on forecasted groundwater conditions over the course of the 50-year simulation period.

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### 3.1.1 FREEMAN DIVERSION EXPANSION PROJECT AND SUPPLEMENTAL STATE WATER IMPORTS

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The Freeman Diversion Expansion project (Phases 1 and 2) and SWP Article 21 Purchases, Exchanges, and Transfers project both increase surface water diversions from the Santa Clara River for recharge and conjunctive use in the OPV basins. This section briefly describes the diversion simulations and how both projects are incorporated in the diversion calculations.

A combination of five hydrological models was used to simulate available diversions at the Freeman Diversion for the 2020-2069 future modeling period, representing upstream reservoir operations, streamflow routing in the Santa Clara River, and Freeman Diversion operations, as follows:

- **Castaic Reservoir Model.** Simulates releases from Castaic Lake (reservoir) into Castaic Creek.
- **Santa Clara River Hydrological Simulation Model – Fortran (HSPF).** Historical streamflows are adjusted to account for current land use, which strongly influences runoff rates and volumes, yielding more realistic projections of streamflow during the 2020-2069 future modeling period.
- **Lake Piru Reservoir Model.** Simulates releases from Santa Felicia Dam to lower Piru Creek.
- **Upper Basins Routing Model.** Calculates streamflow in the Santa Clara River at the Freeman Diversion based on streamflow inputs from Los Angeles County, lower Piru Creek, Hopper Creek, Sespe Creek and Santa Paula Creek.
- **Hydrological Operations Simulation System (HOSS).** Simulates diversions and bypass flows based on streamflow in the Santa Clara River at the Freeman Diversion and bypass flow requirements.

All models are run in daily timesteps in Excel spreadsheets (except for the HSPF model). The modeling workflow is depicted graphically on Figure 9. The two reservoir models, HSPF, Upper Basins Routing Model, and HOSS were described in United's technical memorandum on modeling for the Mound, Fillmore, and Piru basins (United, 2021b). The modeling described in this report used the same model inputs and assumptions as described previously by United (2021a and 2021b), with the following modifications to simulate the Hybrid Scenario alternatives:

- **Supplemental State Water Project (SWP) imports** were included in the Lake Piru Reservoir Model and routed downstream via the Upper Basins Routing Model and HOSS. It is simulated that approximately 6,000 AFY additional SWP imports (including SWP transfers and Article 21 purchases) would reach the Freeman Diversion, in addition to United's current Table A allocation. A technical memorandum details how much supplemental State Water needs to be acquired to meet this goal at the Freeman Diversion, accounting for potential losses during transport from Lake Piru to the Freeman Diversion (United, 2022b). Supplemental SWP imports are input to the Lake Piru Reservoir Model combined with United's regular Table A imports, increasing the volume available for conservation releases from Lake Piru. Most of the released State Water is ultimately diverted at the Freeman Diversion. Implementation of the project is assumed to occur in 2020.

The **Freeman Diversion Expansion Project** includes infrastructure improvements to allow higher diversion rates during storm events, when flow and suspended sediment concentrations in the Santa Clara River are high. The project is simulated in the HOSS by increasing the suspended sediment limit for diversions and maximum diversion rate, while implementing the necessary bypass flows. Implementation of Freeman Expansion Phase 1 is assumed to occur in 2028, and Phase 2 in 2036.

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### 3.1.2 STATE WATER PROJECT INTERCONNECTION PIPELINE FLUSHING

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The City of Ventura is currently planning construction of an approximately 7-mile pipeline between its municipal water supply infrastructure in eastern Ventura (in Santa Paula basin) to the existing terminus of Calleguas MWD's pipeline near the western end of the Camarillo Hills. The project will enable delivery of SWP water to the City. The project includes two turnouts to United's Saticoy recharge facility, allowing delivery of pipeline flushing water and (potentially) supplemental SWP water to the Rose and El Rio recharge basins. A total 500 AFY of new imported surface water is assumed with this project starting in 2027, equally divided between the El Rio and Rose recharge basins during November and June of each year.

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### 3.1.3 INCENTIVIZED FALLOWING

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Temporary Agricultural Land Fallowing was included in the GSPs for the OPV basins (Dudek, 2019a and 2019b). This project proposes the use of replenishment fees to pay for temporary

fallowing of small areas of agricultural land in order to reduce groundwater extraction from the basins. Incentivized fallowing is implemented in the SWDM by reducing the total water demand in the PVP area by 2,000 AFY, and in the PTP area by 700 AFY. Project implementation is assumed to occur in 2020.

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### **3.1.4 EXTRACTION BARRIER AND BRACKISH WATER TREATMENT PROJECT (EBB WATER)**

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The EBB Water project will create an extraction barrier to intercept seawater entering the aquifers in the southern Oxnard basin, remove much of the brackish groundwater currently present in those aquifers as a result of past seawater intrusion, and treat the extracted brackish groundwater to suitable quality for artificial recharge, agricultural, or M&I use. The following assumptions are made for modeling purposes:

- Annual brackish-groundwater extraction rates of 10,000 AF, starting in year 2027. The SWDM calculates daily extraction rates assuming constant pumping (24 hours per day, 7 days per week).
- Efficiency of brackish groundwater treatment to produce treated water is 60%, delivery of 1,500 AFY of treated product water to NBVC Point Mugu, and delivery of the remainder of the treated product water (4,500 AFY) to agricultural users in the PVP area, the PTP area, and United's El Rio artificial recharge facility, in that order of priority. All treated brackish groundwater could be delivered to the El Rio recharge facility for artificial recharge, as another alternative for consideration. However, for simplicity at this point in the modeling effort, direct delivery of the treated brackish groundwater to agricultural users is assumed to be the first priority for distribution.

Each Hybrid Scenario alternative presented in this report assumes twelve brackish-groundwater extraction wells in the Oxnard Aquifer, ten in the Mugu Aquifer, and two in the Fox Canyon Aquifer, all located in the vicinity of NVBC Point Mugu and generally consistent with well locations and pumping distribution as implemented in United's Proposition 1 modeling effort (United, 2021d). However, the Hybrid Scenario assumes addition of two extraction wells in the upper Fox Canyon Aquifer, as well. The Oxnard and Mugu Aquifer extraction wells are assumed to pump a total of 8,000 AFY, and the Fox Canyon Aquifer extraction wells are assumed to pump a total of 2,000 AFY.

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### **3.1.5 AWPf RECYCLED WATER TO FARMS**

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The production capacity of the City of Oxnard's AWPf is currently 6.25 million gallons per day (MGD; approximately 7,000 AFY; Water Systems Consulting, 2021). For this report, the following assumptions were made for the delivery of AWPf recycled water to agriculture:

- Annual deliveries of 4,600 AFY for scenarios S22 and S23, consistent with assumed agricultural deliveries of AWPf recycled water as described in the GSPs for the OPV basins (Dudek, 2019a and 2019b). AWPf recycled water deliveries are implemented in 2020. Scenario S24 assumes increased deliveries of 7,000 AFY in 2028.
- AWPf recycled water was modeled to first be used to meet demand in the Coastal area. Scenarios S22 and S23 assume limited or no expansion of the existing pipeline infrastructure in the Coastal area, and maximum deliveries of 15% of daily demand. Remaining available AWPf recycled water is delivered to the PVP area first, and then to the PTP area if there is insufficient demand in the PVP area. When daily agricultural demands are low, any remaining AWPf water is delivered to United's El Rio artificial recharge facility in the Forebay area. Scenario S24 assumes significant expansion of pipeline infrastructure in the Coastal area, and maximum deliveries of 90% of daily demand. Any additional AWPf supply not used in the Coastal area is delivered to the PVP and PTP areas, as for the other scenarios.

A 15% reduction in irrigation water use is assumed for land receiving recycled water due to the decreased demand for salt leaching from the root zone associated with the use of low total-dissolved-solids (TDS) content in AWPf water. The increased irrigation efficiency is only simulated in the Coastal area, where AWPf recycled water would not be blended with relatively high-TDS surface water from Conejo Creek or with groundwater (in the PVP and PTP delivery areas)

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### 3.1.6 SATICOY WELL FIELD EXPANSION

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The Saticoy Well Field Expansion project is part of the "Optimization of Pumping" project (Table 5). This project assumes construction of ten new water supply wells in the Forebay area with connections to United's Main Supply Pipeline along Rose Avenue and Pleasant Valley Pipeline along Central Avenue (Figure 2), allowing delivery of additional pumped groundwater to the PTP and PVP systems (Figure 8). The proposed new Saticoy wells will be deeper than the existing Saticoy wells, thus their use would be less limited by changes in groundwater elevations in the Forebay than the existing wells. The following assumptions are made in the SWDM:

- Well field capacity of 50 cfs (approximately 32 MGD).
- Project implementation in 2027.
- Pumping of the Saticoy Well Field occurs when there is a demand on the PTP or the PVP systems that is not met by EBB Water deliveries, AWPf recycled water deliveries, or surface water deliveries from the Freeman Diversion.



- No pumping occurs when available storage in the Forebay exceeds 80,000 AF, in order to avoid groundwater elevations in the Forebay declining below sea level.

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### 3.1.7 PTP AND PVP EXPANSION

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Expansion of the PTP and PVP systems is a component of the “Optimization of Pumping” project described in Table 4 (and shown on Figure 8). Each Hybrid Scenario alternative assumes expansion/extension of the PTP and PVP pipeline infrastructure so that up to 90% of the demand in each area can be met with sources other than local groundwater (when alternative sources of water are available), with the goal of minimizing groundwater withdrawals in the PTP and PVP areas.

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### 3.1.8 SHIFT PTP PUMPING FROM THE LAS TO THE UAS

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United’s five PTP wells currently pump from the LAS to reduce pumping stress in the UAS, where the threat of seawater intrusion was historically a great concern. However, the Oxnard basin GSP (Dudek, 2019b) notes that under anticipated future conditions, the estimated sustainable yield for the LAS (7,000 AFY) will be much smaller than the estimated sustainable yield for the UAS (32,000 AFY). Furthermore, the Oxnard basin GSP states that “None of the model scenarios described in Section 2.4.5 (of the GSP) successfully eliminated seawater intrusion in the LAS during the 50-year model period or the 30-year sustaining period, while the majority of the model scenarios resulted in net freshwater loss from the UAS to the Pacific Ocean” (Dudek, 2019b). In response to these concerns, it was assumed for the Hybrid Scenario alternatives that the production from United’s PTP wells would be replaced with wells that are screened in the UAS, to reduce pumping stress in the LAS and capture some of the fresh groundwater that was anticipated to discharge to the ocean in the Oxnard basin GSP.

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## 3.2 GROUNDWATER MODELINGS

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The groundwater flow model used to evaluate the Hybrid Scenario alternatives presented in this report is a refinement of the Coastal Plain Model developed by United (2018) and applied by United on behalf of the FCGMA to estimate sustainable yield of the Oxnard, Pleasant Valley, and western Las Posas Valley basins (Dudek, 2019a, 2019b, and 2019c). Specifically, model input files for the Hybrid Scenario alternatives incorporated many of the assumptions described in Section 2.4.5.1 of the Oxnard and Pleasant Valley basin GSPs (Dudek, 2019a and 2019b), modified as needed to reflect the different pumping rates, artificial recharge volumes, and irrigation return flows resulting from the new and expanded projects included in the Hybrid Scenario alternatives (described in Section 3.1). Following is a summary of some key assumptions from the GSP modeling effort that were “carried forward” to the Hybrid Scenario simulations presented in this report:

- The same production wells that were included in the GSP modeling (Dudek, 2019a and 2019b) are included in the Hybrid Scenario simulations. Two minor revisions were made to the pumping input file subsequent to the GSP simulations of 2019, in response to updated information. In one case, a well identifier had changed when a new liner was installed in the well. In the second case, a well (pumping an average of 95 AFY for the 2015-17 period) was inadvertently omitted from the GSP simulations due to confusion resulting from an issue with well destruction records on file. The total change in pumping volume represents approximately 0.1 percent of total pumping from all wells in the OPV basins during the 2015-17 period, therefore the effects of including these changes in the GSP modeling are considered to be negligible.
- Starting groundwater levels for simulations of 2020-2069 conditions were set to the December 2015 groundwater levels from the historical (1985-2015) simulations, identical to the modeling supporting the GSPs (Dudek, 2019a and 2019b). Groundwater levels in the OPV basins in December 2019 were similar to groundwater levels observed in December 2015. Therefore, continuing to use December 2015 groundwater levels as the starting elevations did not significantly affect model results, and maintains consistency between the Hybrid Scenarios and the GSP modeling.
- Precipitation and streamflow from the 1930-1979 period, and perturbation of these inputs based on 2070 climate-change factors, were the same as those used for the GSP scenarios.
- Recharge and other boundary flow parameters inputs to the Hybrid Scenario simulations were the same as those input to the GSP scenarios.
- The City of Camarillo's North Pleasant Valley Desalter project and Camrosa Water District's Conejo Creek Diversion deliveries to PVCWD were included in the Hybrid Scenario simulations, consistent with the GSP simulations.
- The Hybrid Scenarios implemented MODFLOW-NWT (Niswonger et al., 2011), the same modeling software utilized for the GSPs.

Improvements made to United's Coastal Plain Model (United, 2021e) subsequent to the GSP modeling effort (which was completed three years ago), together with changes made to model input files to reflect addition of projects included in the Hybrid Scenario alternatives (described in Section 3.1), are summarized as follows:

- The hydrostratigraphic conceptual model for the southern Oxnard basin between Port Hueneme and Point Mugu was updated with new data and updated interpretation of the geometry and hydraulic properties of aquifers and aquitards in the area (United, 2021e and 2021f). These updates improved model calibration to measured groundwater elevations in the LAS.



- The assumed extents of the PTP, PVP, and Coastal areas (for calculating irrigation return flows), and the volumes pumped by water supply wells within those areas in response to future availability of water from new and expanded projects, were modified in accordance with the assumptions for the SWDM as described in Section 3.1.
- Twenty-four brackish groundwater extraction wells (thirteen unique site locations) assumed for the EBB Water Project were simulated in the vicinity of NBVC Point Mugu, as described in Section 3.1.4 (specific locations for the extraction wells are discussed in Section 4).
- Ten new water supply wells assumed for the Saticoy Well Field Expansion (Optimization of Pumping) Project were simulated in the Forebay area, as described in Section 3.1.6 (specific locations for the new Saticoy wells are discussed in Section 4). The new wells are assumed to be screened across both the Hueneme Aquifer and the upper part of the Fox Canyon Aquifer.
- Monthly extraction rates from existing water supply wells in selected areas were adjusted to reflect new and expanded alternative sources of water supply from proposed projects, which will offset pumping as determined from the SWDM (Section 3.1). Groundwater pumping of the GSP scenario “Future Baseline simulation with Projects” was modified based on SWDM inputs primarily in the PTP, PVP, and Coastal areas, but other areas of the basin also were assumed to be affected to some degree by pumping offsets resulting from new and expanded projects. Although pumping rates for individual wells in the PTP, PVP, and Coastal areas were changed from the pumping rates assumed in the GSP simulations, the total pumping that was modeled in each area by the SWDM (Section 3.1) was distributed in accordance with the assumptions applied to the GSP simulations. Effectively, the fraction of pumping for a given well in relation to the total within the area (PTP, PVP, or Coastal) remained consistent with the GSP simulations. In one case, a well screened in the LAS was included as part of the Coastal Zone for optimization purposes, but the water pumped from that well was applied to the PVP Zone as part of the recharge package due to that well being part of the PVP system.
- The five existing PTP wells (Figure 2), which are screened across the aquifers of the LAS, were assumed to be replaced with new wells screened in the Oxnard and Mugu Aquifers (Section 3.1.7).
- Scenarios S22 and S24 assumed construction of six new injection wells in the vicinity of Port Hueneme to mitigate seawater intrusion entering the Oxnard basin via the Hueneme Submarine Canyon. It was further assumed that 2,000 AFY of groundwater would be pumped from United’s El Rio well field (Figure 2) and conveyed via the OH Pipeline to the six new injection wells, three of which would

be screened in the Mugu Aquifer, and three of which would be screened in the Hueneme Aquifer.

In addition to the model refinements and updates to input files described above, the starting points for tracking projected (future) movement of the seawater intrusion fronts from their current inland extents in each aquifer were updated. For the Hybrid Scenarios, the USGS particle tracking software, MODPATH Version 6 (Pollock, 2012) was used to simulate the movement of particles released at the vertical midpoint of each aquifer for the duration of the simulation. Specifically, the seawater intrusion fronts (defined by the 100 mg/L concentration contour) as of December 2019 (Figures 3 through 7) were estimated using United's recently refined unstructured grid (USG) version of its Coastal Plain Model, which includes both groundwater flow and solute transport (United, 2021f). The advantages of using the December 2019 modeled seawater intrusion fronts rather than the 2015 or 2020 estimated seawater intrusion fronts are described in Section 2.4.

## 4 RESULTS

Mitigating seawater intrusion in the Oxnard basin and preventing excessive groundwater-level decline are key to achieving the sustainability goals of the GSPs for the Oxnard and Pleasant Valley basins (Dudek, 2019a and 2019b), as well as the Western Management Area of the Las Posas Valley basin (Dudek, 2019c). Both seawater intrusion and groundwater-level decline are strongly affected by the locations and rates of groundwater withdrawals, surface water deliveries (from conjunctive-use or recycled-water projects), and artificial recharge volumes. As described in Section 3, United's SWDM (for simulation of distribution of water from different sources) and Coastal Plain Model (for simulation of groundwater flow and particle tracking) were used to forecast effects of the three Hybrid Scenario alternatives (S22 through S24; Table 3) on future water supply and demand, seawater intrusion extents, and groundwater elevations in the OPV basins. This section describes and compares the forecasted results of the Hybrid Scenario alternatives.

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### 4.1 SOURCES AND QUANTITIES OF SURFACE AND GROUNDWATER TO MEET DEMAND UNDER SCENARIOS EVALUATED

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Simulated artificial recharge volumes and deliveries of groundwater, surface water, and recycled water to the PTP, PVP and Coastal areas under each of the Hybrid Scenario alternatives are summarized in Table 6. Simulated deliveries of water to end users under the Hybrid Scenario with Injection (S22) and the Hybrid Scenario without Injection (S23) are identical because the only difference between these scenarios is a simulated seawater injection barrier near Port Hueneme.

Figure 10 illustrates the simulated water deliveries and pumping for the PTP, PVP and Coastal areas (which are used as input to the groundwater model) for scenarios S22 and S23. The total bar height on Figure 10 indicates total water demand in each area. For the PTP and PVP areas, 61 to 70 percent of the demand is met by the expanded and new water supply projects, resulting in groundwater pumping of 5,746 AFY in the PTP area and 6,002 AFY in the PVP area. Only 15 percent of water demand in the Coastal area is met by the new and expanded projects under scenarios S22 and S23, resulting in groundwater pumping of 8,803 AFY. Simulated water sources to pipelines under scenarios S22 and S23 are:

- 3,309 AFY from the Saticoy Well Field Expansion project
- 3,862 AFY from the EBB Water project
- 4,590 AFY from Oxnard's AWPf recycled water (Table 7).

These average rates reflect the projects' implementation schedules over the next 50 years (2020 through 2069). For example, given the assumed implementation of the EBB Water project in 2027, the 50-year average of EBB Water deliveries is less than the plant's assumed annual delivery of 4,500 AF of treated water for recharge, the PVP, or the PVP area during each of the 43 years it is assumed to be active (2027 through 2069).

Scenario S24 simulates expanded AWPf recycled water deliveries to the Coastal area compared to scenarios S22 and S23. Simulated AWPf recycled water deliveries increased from 4,590 AFY in scenario S22 to 6,650 AFY in scenario S24, as shown on Figure 11. Most of the increased supply was delivered to the Coastal area, as shown on Figure 12. The expansion of AWPf recycled water deliveries to the Coastal area resulted in changes in deliveries to the other pipelines, including:

- Reduced AWPf recycled water deliveries to the PTP and PVP areas.
- Increased deliveries from the Freeman Diversion and, to a lesser extent, the Saticoy Well Field Expansion Project, to the PVP area (Table 7).

Total deliveries to the PVP area were slightly lower for scenario S24 compared to scenarios S22 and S23 (Figure 12). In scenario S24, pumping in the Coastal area is significantly reduced (from 8,803 AFY in scenarios S22 and S23 to 3,914 AFY in scenario S24), while pumping in the PVP area is slightly increased, and pumping in the PTP area is largely unchanged, as shown on Figure 13.

Modeled long-term average volumes of fresh water supplied to agricultural, M&I, and domestic users during the period from 2040 through 2069 (referred to as the "sustaining period" in the GSPs for the OPV basins) under the modeled alternatives are summarized in Table 7. In each of the Hybrid Scenario alternatives, it is assumed that total water demand will continue into the future at 2015-17 average rates, but groundwater pumping for water supply will be reduced and shifted to optimal locations to mitigate seawater intrusion issues. Water supplied by the new or expanded projects is assumed to make up for the reduction in groundwater extractions, allowing the OPV basins to continue operating at 2015-17 water-demand rates throughout the entire planning horizon (2020 through 2069) without ramp-downs in agricultural, M&I, or domestic water use. Modeled long-term average volumes under the "Reduction with Projects" scenario of the Oxnard and Pleasant Valley basin GSPs (Dudek, 2019a and 2019b) from 2040 through 2069 are also shown on Table 7, for comparison. Of the scenarios considered in the GSPs, the Reduction with Projects scenario was closest to achieving sustainable yield in the OPV basins. However, even with the substantial reductions in water supply contemplated in the Reduction with Projects scenario, net long-term inflow of seawater was still forecasted to occur in the LAS in the Oxnard basin, and the area of seawater intrusion was forecasted to expand slightly in some areas and aquifers (Dudek, 2019b). The modeled total water supply from major sources available to all users in the OPV basins under all three Hybrid Scenario alternatives (S22, S23, and S24) is

116,000 to 117,000 AFY, compared to just under 90,000 AFY available under the Reduction with Projects scenario included in the GSPs for the OPV basins (Table 8).

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## 4.2 FORECASTED GROUNDWATER CONDITIONS AND EFFECTS ON SUSTAINABLE YIELD

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All three Hybrid Scenario alternatives (S22, S23, and S24) include reductions in groundwater pumping from most water supply wells in the OPV basins, and supplementing pumped groundwater with expanded conjunctive use projects or new sources, as summarized in Table 7. Despite the overall modeled reduction in pumping, the Hybrid Scenario alternatives assume construction of new brackish-water extraction wells at NBVC Point Mugu (for the EBB Water project, described in Section 2.3) and additional conjunctive-use water supply wells in the Forebay area (expansion of United's Saticoy well field); locations for these new wells, together with existing water supply wells, are shown on Figure 14. Additionally, Hybrid Scenario alternatives S22 and S24 include 2,500 AFY of increased (compared to the historical average) pumping at United's El Rio well field, accompanied by injection of an equivalent volume of groundwater at wells located east and north of Port Hueneme to mitigate seawater intrusion in that area (Figure 14). As a result, simulated future pumping in these specific areas is greater under the Hybrid Scenario alternatives compared to historical pumping and the assumed future pumping under the Reduction with Projects scenario included in the GSPs for the OPV basins.

All three Hybrid Scenario alternatives forecast mitigation (halt or reversal) of seawater intrusion in most areas of most aquifers in the OPV basins, and are particularly effective in the UAS, where the seawater intrusion front historically has migrated inland the fastest and farthest. Details regarding the forecasted effects of each scenario on migration of the seawater intrusion front and groundwater elevations are described below, illustrated with maps showing forecasted particle tracks and forecasted groundwater-elevation contours near the end of simulated future droughts and multi-year wet periods. Groundwater-level hydrographs for selected wells in the OPV basins are provided in Appendix A, showing projected changes in groundwater elevations over time. It should be noted that particle tracking considers only advective flow of groundwater, and ignores processes such as diffusion, dispersion, and density-driven flow. For a conservative solute, such as chloride, particle-track modeling can provide a reasonable approximation of likely migration directions and distances under future groundwater flow conditions (Anderson and Woessner, 2002). However, when one or more of these scenarios is carried forward to more advanced stages of design, use of United's MODFLOW-USG Transport model, which incorporates additional processes, should be used to provide more detailed projections of chloride concentrations at specific locations and times during and after project implementation.

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## 4.3 UPDATED OXNARD GSP “REDUCTION WITH PROJECTS” SCENARIO

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The recent improvements to United’s Coastal Plain Model and the update of the seawater intrusion fronts (to represent conditions as of December 2019) were applied to both the Hybrid Scenario alternatives that are the subject of this report, and to the Reduction with Projects scenario described in the Oxnard basin GSP (Dudek, 2019b). The Reduction with Projects scenario as depicted in the GSP for the Oxnard basin (Dudek, 2019b) used United’s 2015 estimated seawater intrusion fronts in each aquifer as starting points for particle tracking. The goal of updating the GSP’s Reduction with Projects scenario, using the improved Coastal Plain Model and the 2019 modeled seawater intrusion fronts, was to allow direct comparison of the particle-tracking results from the Hybrid Scenario alternatives, which were modeled using the updated information and the improved model. Figures 15 through 20 show projected particle tracks from the leading edge of the 2019 modeled seawater intrusion front in each aquifer for the 2020-2069 simulation period under the Reduction with Projects scenario. Green dots on each figure represent particle-track start points along the simulated 2019 seawater intrusion front, and red dots represent the end points after 50 years of travel (for particles that are still “active” and have not been intercepted by a water supply well). Notable differences between results of the updated Coastal Plain Model with 2019 seawater-intrusion fronts compared to particle-tracking results presented in the Oxnard basin GSP (Dudek, 2019b) include the following:

- Some particle tracks in the Mugu Aquifer near Port Hueneme migrate farther east in the updated model compared to the original GSP model results, and some particles in the Mugu Aquifer near NBVC Point Mugu migrate farther north in the updated model compared to the original GSP model results.
- Particle tracks in the Hueneme Aquifer near Port Hueneme are not projected to move as far eastward in the updated model compared to the original GSP model results. A low-permeability sedimentary fill feature, likely deposited within a paleo-channel (buried canyon), was identified from lithologic and geophysical logs for wells east of Port Hueneme at depths equivalent to the Hueneme Aquifer during an update of the hydrogeologic conceptual model for this area (United, 2021e). Based on this information, model grid cells representing the Hueneme Aquifer in this area were assigned a correspondingly lower hydraulic conductivity in United’s Coastal Plain Model. This lower hydraulic conductivity would tend to significantly limit simulated eastward particle migration within the model layer representing the Hueneme Aquifer in this area.
- Some particle tracks in the upper and basal Fox Canyon Aquifer near NBVC Point Mugu are projected to migrate farther north in the updated model compared to the original GSP model results.

These differences are partly due to the refinements made to the Coastal Plain Model in the past three years, and partly due to the updated locations of the seawater intrusion fronts in each aquifer as of 2019. In other locations and aquifers (excluding the Grimes Canyon Aquifer), the differences between the original particle tracking results presented for the Oxnard basin GSP's Reduction with Projects scenario (Dudek, 2019b) and the updated results (Figures 15 through 20) are minor. The Oxnard basin GSP did not include a figure depicting particle tracks in the Grimes Canyon Aquifer.

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## 4.4 HYBRID SCENARIO WITH INJECTION WELLS AT PORT HUENEME (S22)

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Figures 21 through 26 show projected particle tracks from the leading edge of the 2019 modeled seawater intrusion front in each aquifer for the 2020-2069 simulation period under the Hybrid Scenario with Injection. Groundwater elevations in the OPV basins were near historical lows at the beginning of the simulation period (2020) as a result of the exceptional drought of 2012-16, and reversal of the landward hydraulic gradients that drive seawater intrusion does not occur immediately under any of the modeled scenarios, including the Reduction with Projects scenario from the Oxnard basin GSP (Dudek, 2019b). As a result, basin groundwater conditions are forecasted to allow the seawater intrusion fronts to continue slowly moving inland at some locations and aquifers during the first few years of the simulation period, similar to observed seawater intrusion during previous droughts. Despite the initial landward advancement of particle tracks during the first few simulated years of the Hybrid Scenario with Injection, when projects come on line in the mid- to late-2020s most of the particle tracks shift direction and are either pushed back toward the coastline (by rising groundwater elevations in the interior of the OPV basins) or pulled toward the EBB Water project extraction wells, where much of the intruded seawater is ultimately removed from the aquifers. Details regarding forecasted effects of the S22 Hybrid Scenario with Injection within each aquifer are provided below.

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### 4.4.1 OXNARD AQUIFER

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In the Oxnard Aquifer, particle tracks shown on Figure 21 initially migrate northward approximately 1,000 to 2,000 feet from the 2019 seawater intrusion front in response to the existing landward hydraulic gradient, but then turn southeastward and southward toward the EBB Water project at NBVC Point Mugu as that project and others come online. The net effect is retreat of the seawater intrusion front by 1 to 1.5 miles toward the coast by 2069. The area of the Oxnard Aquifer represented by this retreat of the seawater intrusion front is approximately 2,800 acres, or 4.4 square miles.

Figures 27 and 28 show groundwater elevation contours in the Oxnard Aquifer during an assumed future drought (October 2055) when groundwater elevations would be at or near their lowest projected levels, and during an assumed future wet period (April 2035) when groundwater

elevations would be at or near their highest projected levels, respectively. Inspection of Figures 27 and 28 indicates that the cone of depression in the Oxnard Aquifer in the vicinity of the EBB Water project persists through both wet and dry periods, providing hydraulic containment and control to prevent further seawater intrusion after the project comes online, and hydraulic gradients to pull the present-day seawater intrusion front south and southeast toward the coast.

Hydrographs showing measured groundwater elevations from 1985 through 2019 and simulated groundwater elevations from 1985 through 2069 under this scenario at representative wells are provided in Appendix A. Locations for the wells are shown on Figure A-1; Figures A-2 through A-16 show hydrographs for wells screened in the Oxnard Aquifer (or stratigraphically equivalent “Older Alluvium” in Pleasant Valley basin (Dudek, 2019a)). Figures A-2 through A-16 show that projected future groundwater elevations under the Hybrid Scenario with Injection remain above historical measured or simulated lows (which typically occurred during the drought years of 1990 or 2018), at most monitoring wells screened in the Oxnard Aquifer. At most of these wells, future groundwater elevations are projected to rise substantially above 2019 groundwater levels and remain elevated, largely in response to reduced reliance on groundwater throughout the OPV basins under this scenario. However, groundwater elevations in the Oxnard Aquifer are forecasted to dip 0.5 to 10 feet below historical lows for brief periods (one to three months), typically during fall of extreme drought years, at four monitoring wells located within or adjacent to the EBB Water project extraction well field under this scenario (Figures A-3, A-11, A-14, and A-15).

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#### 4.4.2 MUGU AQUIFER

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In the Mugu Aquifer, particle tracks shown on Figure 22 mostly migrate south and southeast toward the coast and the EBB Water project at NBVC Point Mugu. There is also some continued movement of particles between the Port Hueneme and NBVC Point Mugu areas, but the injection wells are projected to force nearly all of those particles toward the coastline or offshore, without being drawn into water supply wells between these areas. The area of the Mugu Aquifer represented by this retreat of the seawater intrusion front is approximately 300 acres, or 0.5 square miles.

Figures 29 and 30 show groundwater elevation contours in the Mugu Aquifer during the assumed 2055 drought and 2035 wet period, respectively. Similar to the Oxnard Aquifer, the cone of depression in the Mugu Aquifer in the vicinity of the EBB Water project persists through both wet and dry periods, providing hydraulic containment and control of seawater intrusion. Figures 29 and 30 also show persistent elevated groundwater levels at the simulated injection wells screened in the Mugu Aquifer east of Port Hueneme. The elevated groundwater levels in this area provide a hydraulic barrier to inland movement of seawater and create a seaward hydraulic gradient that “pushes” chloride-contaminated groundwater in the Mugu Aquifer back toward the ocean, as shown on Figure 22.



Figures A-17 through A-25 (Appendix A) show that projected future groundwater elevations in the Mugu Aquifer under the Hybrid Scenario with Injection are higher than historical measured or simulated lows at representative wells. At most of these wells, future groundwater elevations are forecasted to rise substantially above 2019 groundwater levels and remain elevated.

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#### 4.4.3 HUENEME AQUIFER

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In the Hueneme Aquifer (which is absent along most of the coastline southeast of Port Hueneme, as shown on Figure 23), particle tracks around Port Hueneme show little movement of the seawater intrusion front during the simulation period, with a few particles being driven downward into the Fox Canyon Aquifer by the increased vertical gradient that results from the injection of water into the Mugu and Hueneme Aquifers. After migrating downward, these particles are then projected to migrate northward approximately 2,000 feet over 50 years in response to the horizontal hydraulic gradient in the Fox Canyon Aquifer. It should be noted that the updated Reduction with Projects scenario from the Oxnard basin GSP also allows some northward migration of the seawater intrusion front in the Hueneme Aquifer (Figure 5). Several combinations of injection well locations, depths, and injection rates were simulated by United during this evaluation to improve hydraulic control of the seawater intrusion front in the Hueneme Aquifer near Port Hueneme, but no practical and implementable solution proved superior to the configuration of injection wells shown on Figure 23. A hypothetical injection well field that included 45 injection wells located along a 14,000-foot long array across NBVC Port Hueneme, and including up to 10,000 AFY of injection throughout the Oxnard, Mugu, Hueneme, and Fox Canyon Aquifers, showed promise for preventing northward advancement of the seawater intrusion front at Port Hueneme. However, constructing such an extensive injection well field (especially within an active Navy base) and providing such a large volume of source water for injection, was not considered a feasible alternative. Therefore, modeling of that configuration did not advance to completion.

Figures 31 and 32 show persistent elevated groundwater levels projected to occur at the easternmost of the assumed injection wells screened in the Hueneme Aquifer northeast of Port Hueneme, but the other two Hueneme-Aquifer injection wells in this area do not produce the same magnitude of “mounding” of groundwater. The slightly to significantly elevated groundwater levels in this area provide some hydraulic control that mitigates inland movement of seawater in the Hueneme Aquifer, but not enough of a seaward hydraulic gradient is produced to push all of the seawater intrusion front back toward the ocean.

Figures A-26 through A-37 (Appendix A) show that projected future groundwater elevations in the Hueneme Aquifer under the Hybrid Scenario with Injection are much higher than historical measured or simulated lows, which typically occur in the early 1990s or late 2010s, at most representative monitoring wells screened in the Hueneme Aquifer in the OPV basins. This

significant rise in groundwater elevations is largely a result of significantly less pumping occurring in the LAS under this scenario.

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#### 4.4.4 FOX CANYON AQUIFER

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In the upper and basal layers of the Fox Canyon Aquifer, particle tracks near NBVC Point Mugu show little movement of the seawater intrusion front during the forecasted period (Figures 24 and 25), with some particles migrating inland approximately  $\frac{1}{4}$  to  $\frac{1}{2}$  mile toward existing water supply wells before turning south or east (back toward the ocean or the EBB Water extraction wells), to terminate near the 2019 seawater intrusion front. The initial landward migration and subsequent reversal is a result of the depressed groundwater levels in the OPV basins resulting from the past decade of exceptional drought, before some of the larger water supply projects are expected to come online in the late 2020s. However, only one agricultural water supply well that is located near the 2019 seawater intrusion front appears to be threatened by this limited movement of the seawater intrusion front under this scenario.

Figures 33 through 36 show a persistent cone of depression projected to occur at the southeastern EBB Water project extraction well screened in the upper and basal Fox Canyon Aquifer at NBVC Point Mugu, but the other Fox Canyon extraction well to the northwest does not produce a cone of depression of similar magnitude. The combined effects of these two extraction wells provide sufficient hydraulic control to mitigate landward movement of seawater in the Fox Canyon Aquifer, and reverse the direction of the seawater intrusion front (back toward the coast) during wet periods, but the simulated extraction rates are insufficient to extract seawater from such large areas as was forecasted to occur in the Oxnard and Mugu Aquifers.

Figures A-34 through A-54 (Appendix A) also show that projected future groundwater elevations under the Hybrid Scenario with Injection are projected to be higher than historical measured or simulated lows, which typically occur in the early 1990s, at most wells screened in the upper or basal Fox Canyon Aquifers. Again, this trend of rising groundwater elevations is largely in response to reduced reliance on groundwater from the LAS under this scenario. However, groundwater elevations are forecasted to decline significantly below historical lows for brief periods (1 to 3 months), at one monitoring well located adjacent to the simulated expansion of the Saticoy well field (in the Forebay) under this scenario (Figure A-44). These brief, but sharp, declines below historical low groundwater elevations are not projected for other wells, and may be an artifact of the Coastal Plain Model's grid design rather than a realistic representation of future groundwater-elevation trends. Regardless, such brief declines would not be expected to contribute significantly to land subsidence. If this scenario advances to the design stage, additional modeling could be conducted to further investigate both potential subsidence and effects on nearby water supply wells.

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#### 4.4.5 GRIMES CANYON AQUIFER

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In the Grimes Canyon Aquifer, particle tracks near NBVC Point Mugu show little movement of the seawater intrusion front during the forecasted period (Figure 26), similar to the Fox Canyon Aquifer. Most particle tracks in this aquifer are projected to migrate less than 2,000 feet either landward or seaward from the 2019 seawater intrusion front.

Figure 37 shows a northeastward (landward) hydraulic gradient occurring in the Grimes Canyon Aquifer throughout the area of seawater intrusion in the NBVC Point Mugu area during drought, while Figure 38 shows a cone of depression near the EBB Water extraction wells screened in the overlying Fox Canyon Aquifer during wet periods. Similar to the Fox Canyon Aquifer under this scenario, the fluctuating hydraulic gradients provide sufficient hydraulic control to mitigate landward movement of seawater in the Grimes Canyon Aquifer, and reverse the direction of the seawater intrusion front (back toward the coast) at some locations during wet periods, but the simulated extraction rates are insufficient to extract seawater from large areas in the Grimes Canyon Aquifer.

Figures A-55 and A-56 (Appendix A) show that projected future groundwater elevations under the Hybrid Scenario with Injection are projected to be substantially higher than historical measured or simulated lows at the two representative monitoring wells that are screened in the Grimes Canyon Aquifers (both are located near NBVC Point Mugu).

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### 4.5 HYBRID SCENARIO WITHOUT INJECTION AT PORT HUENEME (S23)

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The Hybrid Scenario without Injection does not include a hydraulic injection barrier designed to stop or reverse historical seawater intrusion at Port Hueneme. Figures 39 through 44 show projected particle tracks from the leading edge of the 2019 modeled seawater intrusion front in each aquifer for the 2020-2069 simulation period under this S23 alternative. Figures 45 through 56 show groundwater elevation contours in each aquifer during an assumed future drought (October 2055) and during an assumed future wet period (April 2035), identical to the contoured periods described above for the Hybrid Scenario with Injection.

Total groundwater pumping in the OPV basins in this alternative is nearly identical to groundwater pumping under the Hybrid Scenario with Injection, with the primary difference being no groundwater extraction at the El Rio well field to supply water for an injection barrier at Port Hueneme. Accordingly, particle tracks, groundwater-level contours, and hydrographs (shown in Appendix A) for wells in the area are similar between these alternatives, except in the vicinity of Port Hueneme. Details regarding forecasted effects within each aquifer are provided below.

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#### 4.5.1 OXNARD AQUIFER

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In the Oxnard Aquifer, particle tracks shown on Figure 39 are nearly identical to those shown for the Hybrid Scenario with Injection, migrating southeastward and southward toward the EBB Water project at NBVC Point Mugu over the simulation period. This is to be expected, considering that the Hybrid Scenario with Injection did not include injection wells in the Oxnard Aquifer. Groundwater elevation contours in the Oxnard Aquifer under the Hybrid Scenario without Injection, shown on Figures 45 and 46, are very similar to those under the Hybrid Scenario with Injection.

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#### 4.5.2 MUGU AQUIFER

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In the Mugu Aquifer, particle tracks around NBVC Point Mugu mostly migrate toward the EBB Water project extraction wells (Figure 40), nearly identical to the Hybrid Scenario with Injection. However, the Hybrid Scenario without Injection allows particle migration of approximately  $\frac{3}{4}$ -mile east from the Port Hueneme area (Figure 40), rather than “pushing” particles south toward the ocean as was seen in the Hybrid Scenario with Injection. This limited eastward migration of seawater in the Mugu Aquifer is the most notable difference between this alternative and the Hybrid Scenario with Injection. Groundwater elevation contours in the Mugu Aquifer under the Hybrid Scenario without Injection, shown on Figures 47 and 48, are very similar to those under the Hybrid Scenario with Injection in most areas. However, east of Port Hueneme the hydraulic gradient is consistently eastward, without any hydraulic barrier to seawater intrusion created by injection wells.

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#### 4.5.3 HUENEME AQUIFER

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In the Hueneme Aquifer, more of the particle tracks around Port Hueneme are projected to migrate northeastward from the 2019 seawater intrusion front (Figure 41) compared to the Hybrid Scenario with Injection. However, the difference in area represented by the advance of the seawater intrusion front under the Hybrid Scenario without Injection is small compared to the Hybrid Scenario with Injection (approximately 100 acres, or 0.2 square miles). Groundwater elevation contours in the Hueneme Aquifer under the Hybrid Scenario without Injection, shown on Figures 49 and 50, are very similar to those under the Hybrid Scenario with Injection in most areas. However, east of Port Hueneme the hydraulic gradient is consistently eastward, without any hydraulic barrier to seawater intrusion.

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#### 4.5.4 FOX CANYON AQUIFER

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In the upper and basal layers of the Fox Canyon Aquifer, projected particle tracks (Figures 42 and 43) and groundwater level contours (Figures 51 through 54) are nearly identical to those shown

for the Hybrid Scenario with Injection, indicating little movement of the seawater intrusion front over the 50-year simulation period (2020-2069).

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#### 4.5.5 GRIMES CANYON AQUIFER

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In the Grimes Canyon Aquifer, projected particle tracks (Figure 44) and groundwater level contours (Figures 55 and 56) are, again, nearly identical to those shown for the Hybrid Scenario with Injection, with little net movement of the seawater intrusion front.

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### 4.6 HYBRID SCENARIO WITH EXPANDED RECYCLED WATER USE (S24)

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The Hybrid Scenario with Expanded Recycled Water Use includes the same projects and assumptions as the Hybrid Scenario with Injection, but the volume of AWPf recycled water from the City of Oxnard's project delivered to farms is increased by 2,400 AFY (from 4,600 AFY to 7,000 AFY). The additional AWPf recycled water is assumed to be distributed mostly in the Coastal area, as described in Section 3.1.5, but some is also assumed to be distributed to the PTP and PVP areas. Figures 57 through 62 show projected particle tracks from the leading edge of the 2019 modeled seawater intrusion front in each aquifer for the 2020-2069 simulation period under this alternative. Figures 63 through 74 show groundwater elevation contours in each aquifer during an assumed future drought (October 2055) and during an assumed future wet period (April 2035), as was displayed for the other Hybrid Scenario alternatives.

Slightly less groundwater pumping is assumed in the OPV basins for agricultural use in this alternative compared with the other alternatives, because some agricultural irrigation demand is met with the additional AWPf recycled water. Accordingly, groundwater elevation contours and hydrographs (shown in Appendix A) for wells in the area under the Hybrid Scenario with Expanded Recycled Water Use indicate higher groundwater elevations across the OPV basins and throughout the simulation period compared to the other alternatives.

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#### 4.6.1 OXNARD AQUIFER

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In the Oxnard Aquifer, particle tracks shown on Figure 57 retreat 1,000 to 2,000 feet farther south (toward the coastline) under this alternative compared to the Hybrid Scenario alternatives that don't include expanded use of AWPf recycled water. This reduction in the area of seawater intrusion in the Oxnard Aquifer under the Hybrid Scenario with Expanded Recycled Water Use is a result of higher groundwater elevations throughout the OPV basins caused by reduced groundwater pumping, which in turn is a result of the increased supply of AWPf recycled water to farms. Groundwater elevation contours in the Oxnard Aquifer under this alternative are shown on Figures 63 and 64. As expected, groundwater elevations are projected to be higher in the PTP

and PVP areas under this alternative than under the alternatives that assume smaller deliveries of AWPf recycled water (Figures 27, 28, 45, and 46).

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#### 4.6.2 MUGU AQUIFER

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In the Mugu Aquifer, particle tracks for the Hybrid Scenario with Expanded Recycled Water Use extend 1,000 to 2,000 feet farther south (toward the coast) or east toward the EBB Water extraction wells (Figure 58) compared to the other alternatives. Groundwater elevation contours in the Mugu Aquifer under this alternative are shown on Figures 64 and 65. Similar to the Oxnard Aquifer, groundwater elevations in the Mugu Aquifer are projected to be higher in the PTP and PVP areas under this alternative than under the alternatives that assume delivery of smaller volumes of AWPf recycled water to those areas (Figures 29, 30, 47, and 48).

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#### 4.6.3 HUENEME AQUIFER

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In the Hueneme Aquifer, particle tracks for the Hybrid Scenario with Expanded Recycled Water Use (Figure 59) are nearly identical to those projected for the Hybrid Scenario with Injection. Groundwater elevation contours in the Hueneme Aquifer under this alternative are shown on Figures 67 and 68, and again are projected to be higher in the PTP and PVP areas under the Hybrid Scenario with Expanded Recycled Water Use than under the other alternatives.

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#### 4.6.4 FOX CANYON AQUIFER

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In the upper and basal Fox Canyon Aquifer, most particle tracks for the Hybrid Scenario with Expanded Recycled Water Use in the area north of NVBC Point Mugu (Figures 60 and 61) remain close to the 2019 seawater-intrusion front, instead of extending 1,000 to 2,000 feet northward before turning around as they do under the alternatives that do not include expansion of AWPf recycled water deliveries to agriculture. Groundwater elevation contours in the upper and basal Fox Canyon Aquifer under this alternative are shown on Figures 69 through 72, and again are projected to be higher areas under the Hybrid Scenario with Expanded Recycled Water Use than under the other alternatives.

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#### 4.6.5 GRIMES CANYON AQUIFER

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In the Grimes Canyon Aquifer, particle tracks for the Hybrid Scenario with Expanded Recycled Water Use (Figure 62) are nearly identical to those projected for the other alternatives. Groundwater elevation contours in the Grimes Canyon Aquifer under this alternative are shown on Figures 73 and 74, and again are projected to be higher in the PTP and PVP areas under the Hybrid Scenario with Expanded Recycled Water Use than under the other alternatives.

## 5 CONCLUSIONS AND RECOMMENDATIONS

The following key conclusions can be inferred from the modeling results presented in this report for the Hybrid Scenario alternatives and the updated Oxnard GSP “Reduction with Projects” scenario:

- The Hybrid Scenario alternatives are projected to result in approximately 27,000 AFY more water available to agricultural, M&I, and domestic users in the OPV basins (meeting current demand) than would be available under the Reduction with Projects scenario presented in the GSPs for the OPV basins (Dudek, 2019a and 2019b).
- In each of the Hybrid Scenario alternatives, the modeled extraction barriers are projected to be largely successful at mitigating seawater intrusion, particularly near NBVC Point Mugu, where seawater has historically intruded the fastest and farthest.
- In the Oxnard Aquifer, particle tracks are forecasted to retreat back toward the coast up to 1.5 miles over the 50-year simulation period, representing 2,800 acres of aquifer that could potentially be restored to fresh groundwater. In the Mugu Aquifer, some particle tracks are forecasted to retreat back toward the coast up to a mile, representing 300 to 800 acres of aquifer that could potentially be restored to fresh groundwater.
- In the Fox Canyon and Grimes Canyon Aquifers, some particle tracks are forecasted to continue migrating inland approximately  $\frac{1}{4}$  to  $\frac{1}{2}$  mile before the EBB Water project extraction wells are assumed to become fully operational. At that time, many of these particle tracks are forecasted to turn back toward the coast or the extraction wells. These particle tracks were not forecasted to turn back toward the coast in the revised Reduction with Projects scenario, which includes the original assumptions from the OPV basins GSPs, but applies the updated seawater intrusion front as of 2019 and improved conceptual model for hydrostratigraphy between Port Hueneme and NBVC Point Mugu. The Hybrid Scenario alternatives provide improved mitigation of seawater intrusion in these aquifers compared to the Reduction with Projects Scenario.
- Similar to the Reduction with Projects scenario presented in the Oxnard basin GSP, the Hybrid Scenario alternatives forecast the development of a few small areas where the seawater-intrusion front in some aquifers is projected to migrate  $\frac{1}{4}$  to  $\frac{3}{4}$  mile inland or parallel to the coastline beyond its estimated present-day extent without subsequently reversing direction. One agricultural water supply well (in the Fox Canyon Aquifer north of NBVC Point Mugu) is projected to intercept some of the particle tracks that extend beyond the 2019 modeled seawater intrusion front, and a few other agricultural water supply wells near the



seawater intrusion front are close enough to projected particle tracks that they could potentially be subject to rising chloride concentrations in the future, under all scenarios and alternatives, including the Reduction with Projects scenario. Solute-transport modeling would be required to conduct a detailed evaluation of the potential for increased chloride concentrations at specific wells near the margins of the seawater intrusion front.

- In all of the Hybrid Scenario alternatives, projected groundwater elevations rise substantially above historical low levels during the 50-year simulation period, with some brief (1 to 3 month) deviations below historical lows at a few wells during droughts. These deviations may be a result of the spatial and temporal discretization limitations of United's Coastal Plain Model, rather than "real-world" phenomena. Such excursions would not be expected to result in significant land subsidence, but subsidence can be quantified during subsequent modeling if a scenario advances for further evaluation.
- The injection wells simulated around Port Hueneme are forecasted to provide limited mitigation of the small areas of seawater intrusion in the Mugu and Hueneme Aquifers in that area. Seawater intrusion in this area has historically been relatively slow moving within the Mugu and Hueneme Aquifers. It should be noted that the Hueneme Aquifer is absent to the southeast of Port Hueneme. No existing, active water supply wells screened in the Mugu and Hueneme Aquifers are forecasted to be affected by seawater intrusion in the Port Hueneme area within the 50-year simulation period, whether or not injection wells are assumed to be installed. However, if migration of seawater intrusion of  $\frac{3}{4}$  mile in this area is deemed by the FCGMA and stakeholders to be unreasonable and significant, despite not affecting any water supply wells, then additional modeling could be conducted to develop a more effective injection or extraction barrier for this area.
- The Hybrid Scenario alternative with Expanded Recycled Water Use shows an increase in the southward (toward the coast) migration of the seawater intrusion front to a modest degree and increase groundwater elevations near the coast compared to the other Hybrid Scenario alternatives. This scenario was expected to significantly improve hydraulic control of the EBB Water extraction wells (due to reduced pumping demand in the Coastal area water supply wells). However, the improvements were smaller than expected.
- Modeling results indicate that the EBB Water project would be significantly more effective at reversing historical seawater intrusion and mitigating potential future seawater intrusion than expected when the Hybrid Scenario was being developed by the Projects Committee. This effectiveness could potentially reduce the contribution of the pumping-optimization projects included in the Hybrid Scenario (i.e., Saticoy well field expansion, PTP/PVP pipeline expansion, and shifting pumping from United's PTP well field from the LAS to the UAS) toward mitigation of seawater intrusion and sustainable yield of the OPV basins. Additional



modeling could be conducted to evaluate the effects of removing each pumping-optimization project on mitigation of seawater intrusion.

As some of the projects included in the Hybrid Scenario alternatives advance to the next level of planning and design, recommendations for further evaluation include:

- Share details of the modeled scenarios with OPV basin stakeholders and the FCGMA to clarify and seek feedback on the assumptions regarding production, distribution, and end-use of the new and expanded water supply sources assumed in the Hybrid Scenario. Ideally, a single preferred alternative would be selected following this input, for further evaluation and advancement. Also seek input from stakeholders regarding acceptability of forecasted groundwater elevations and particle tracks. If the small areas where the seawater intrusion fronts in some aquifers are projected to advance  $\frac{1}{4}$  to  $\frac{3}{4}$  mile are deemed “significant and unreasonable” by the FCGMA and basin stakeholders, then the preferred alternative could be revised and re-evaluated during subsequent phases of design to attempt to eliminate these areas.
- Conduct detailed seawater-intrusion modeling for the preferred alternative (or a new alternative) using United’s new MODFLOW-USG Transport model. Although the particle track methods described in this report (using the Coastal Plain Model) provides a helpful depiction of projected movement of the seawater intrusion fronts in each aquifer, a more detailed forecast can be provided with the new model, albeit with significantly more time and effort required to complete the advanced modeling. Accordingly, solute transport modeling is recommended for only one or two preferred scenarios.
- Using United’s Coastal Plain Model, quantify potential for land subsidence in the OPV basins under the preferred alternative. None of the Hybrid Scenario alternatives are expected to induce significant land subsidence, but verification with the MODFLOW subsidence package would be prudent.
- Conduct additional modeling (using the Coastal Plain Model with particle tracking) to evaluate the effects of removing each pumping-optimization project on mitigation of seawater intrusion. The benefits of some of the optimization projects may be negligible or limited in comparison to the EBB Water project.

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## TABLES

**Table 1. Water Supply Projects Recommended by Projects Committee of OPV Stakeholders for Further Evaluation Using United's Groundwater Flow Model**

<b>Project Name (and Proponent)</b>	<b>Estimated Yield when Proposed in December 2020 (AFY)</b>	<b>Notes</b>
Recycled Water to Farms (City of Oxnard)	4,600	Consistent with "GREAT Program Advanced Water Purification Facility (AWPF)" project identified in Oxnard basin GSP (more detail is provided in Section 2.2 of this report).
Incentivized Fallowing (FCGMA)	2,700	Consistent with "Temporary Agricultural Land Fallowing" project identified in GSPs for OPV basins (more detail is provided in Section 2.2 of this report).
SWP Interconnect Flushing (United and Ventura Water)	Up to 500	A new project that was not included in the GSPs for the OPV basins. The project consists of artificial recharge by United of imported water flushed or occasionally purchased from the City of Ventura's planned SWP Interconnect pipeline.
Freeman Diversion Expansion Phase 1 (United)	4,000	The first phase of an updated version of the "Freeman Expansion Project" identified in the Oxnard basin GSP (more detail is provided in Section 2.2 of this report).
Freeman Diversion Expansion Phase 2 (United)	4,000	The second phase of an updated version of the "Freeman Expansion Project" identified in the Oxnard basin GSP (more detail is provided in Section 2.2 of this report).
SWP Article 21 Purchases, Exchanges, and Transfers (United)	6,000	A new project that was not included in the GSPs for the OPV basins. The project consists of United purchasing Article 21 water from the SWP (when available), or making transfer and exchange agreements with other SWP contractors, with the goal of increasing the volume of imported water conveyed down the Santa Clara River and diverted at Freeman Diversion for artificial recharge or delivery as surface water via pipeline to users.
Optimization of Pumping, Phase 1 (United)	4,000	The first phase of a new project that was not included in the GSPs for the OPV basins. The project consists of reducing pumping near the coast by providing alternative sources (recycled water or expanded surface-water deliveries via pipeline) to reduce the rate of seawater intrusion, thereby increasing sustainable yield.
Optimization of Pumping, Phase 2 (United)	1,000	The second phase of a new project that had not been proposed in the GSPs for the OPV basins. The project consists of expanding groundwater withdrawals in the Forebay when groundwater levels there are relatively high, and delivering that groundwater to the PTP and PVP areas to reduce pumping from the LAS in those areas. This project also includes shifting PTP pumping from the LAS to the UAS. By shifting pumping to the Forebay and the UAS, this project has the potential to increase sustainable yield of the OPV basins by 1,000 AFY or more without reducing total groundwater use an equivalent amount.

Project Name (and Proponent)	Estimated Yield when Proposed in December 2020 (AFY)	Notes
Extraction Barrier and Brackish (EBB) Water Treatment, Phase 1 (United)	12,000 to 16,000 (5,000 AFY of treated brackish water, and 7,000 to 11,000 AFY in increased sustainable yield)	A new project that was proposed by United in 2018 for inclusion in the GSPs for the OPV basins, but was not sufficiently developed at that time for acceptance by the FCGMA. This project would increase sustainable yield of the basins by use of extraction wells to intercept and remove seawater from aquifers near NBVC Point Mugu (seawater intrusion is the primary sustainability criteria driving the sustainable yields estimated for the OPV and Las Posas Valley basins in their GSPs). This project would also provide a new source of fresh water for the basins via treatment of the extracted brackish water.
Reduce Pumping (FCGMA)	Not applicable	Would be implemented if the above projects were insufficient to achieve sustainable yield (prevent “undesirable results” in the OPV basins).

**Table 2. Selected Water Supply Projects Added by FCGMA to the 2021 Annual GSP Update Reports for the Oxnard and Pleasant Valley Basins**

<b>Project Name (and Proponent)</b>	<b>Additional Yield (AFY)</b>	<b>Description</b>
<i>Oxnard basin:</i>		
AWPF Phase II (City of Oxnard)	2,400	Expand recycled-water production capacity to 7,000 AFY (from 4,600 AFY existing capacity), to be used to “support the regional water management actions to increase the sustainable yield of the Subbasin” (Oxnard basin).
EBB Water (United)	12,000	Construct extraction wells to intercept and remove brackish groundwater along the coast resulting from seawater intrusion, and construct a brackish-water treatment plant to produce fresh water from the extracted brackish groundwater. The sustainable yield increase resulting from produced fresh water and interception of seawater intrusion is anticipated to be approximately 15,000 AFY combined for the Oxnard and Pleasant Valley basins.
Freeman Diversion Expansion (United)	8,000	Construct facilities capable of diverting surface water at higher flow rates and with higher sediment loads than currently possible. Total anticipated yield increase is approximately 10,000 AFY combined for the Oxnard and Pleasant Valley basins in two phases.
Ferro Rose Artificial Recharge (United)	2,000 to 3,000	A component of the Freeman Diversion Expansion project, formerly referred to as “Freeman Expansion Phase 1.” The 2,000 to 3,000 AFY yield improvement of this project constitutes a portion of the total yield of the Freeman Diversion Expansion project described above.
Laguna Road Recycled Water Pipeline Interconnection (United)	1,500	A new pipeline interconnection between United’s PTP system and PVCWD’s distribution system, to enable use of recycled water from a variety of sources within the PTP system.
Nauman Road Recycled Water Pipeline Interconnection (United)	1,500 (alternative to Laguna Rd. project described above, not an additional 1,500)	A new pipeline interconnection between United’s PTP system and Oxnard’s Hueneme Road recycled-water pipeline, to enable use of recycled water from Oxnard’s AWPf within the PTP system. This project is currently envisioned as an alternative to the Laguna Road pipeline, and would not necessarily result in additional yield to the basin if the Laguna Road pipeline were also built.
Purchase of Supplemental SWP Water (United)	6,000 (long-term average; highly variable from year to year)	United, with financial support of stakeholders, would purchase supplemental SWP water (in addition to United’s existing Table A allocation) for artificial recharge in the Oxnard basin or delivered to users on the PTP and PVCWD systems.
Seawater Intrusion Injection Barrier (FCGMA)	To be determined	Potentially design and construct an injection barrier near Port Hueneme to prevent further inland intrusion of seawater in that area, potentially as a companion project to United’s EBB Water project. No estimate of potential yield or sources of water to be injected was provided by FCGMA.
<i>Pleasant Valley basin:</i>		
Private Reservoir Program (PVCWD)	500 to 1,000	Incentivize the use of existing--and construction of new--privately owned and operated reservoirs for capture of surface water during rain events.

<b>Project Name (and Proponent)</b>	<b>Additional Yield (AFY)</b>	<b>Description</b>
Recycled Water Connection Pipeline (PVCWD)	1,000 to 2,000	Connect the east and west zones of PVCWD's distribution system to allow more effective distribution of recycled water from the City of Oxnard's AWPf and surface water from the Conejo Creek. This project would also connect the PVCWD distribution system to United's PTP system.
EBB Water (United)	3,000	Same as described above for Oxnard basin; included in Pleasant Valley basin GSP to reflect that this project will benefit both basins.
Freeman Diversion Expansion (United)	2,000	Same as described above for Oxnard basin; included in Pleasant Valley basin GSP to reflect that this project will benefit both basins.
Laguna Road Recycled Water Pipeline Interconnection (United)	To be determined	Same as described above for Oxnard basin; included in Pleasant Valley basin GSP to reflect that this project will benefit both basins.
Purchase of Supplemental SWP Water (United)	To be determined	Same as described above for Oxnard basin; included in Pleasant Valley basin GSP to reflect that this project will benefit both basins.
Indoor Grow Facility RO Brine Recovery (Houweling Nursery)	320	Use new technology to recover 99 percent of reverse-osmosis (RO) effluent used in a hydroponic plant nursery. This project is anticipated to reduce groundwater extractions in the Pleasant Valley basin by approximately 320 AFY



**Table 3. Summary of Key Differences between Hybrid Scenario Alternatives**

<b>Modeled Hybrid Scenario Alternative</b>	<b>Oxnard's AWPf Recycled Water to Farm Land (AFY)</b>	<b>EBB Water Extraction Rate (AFY)</b>	<b>Port Hueneme Injection Barrier Included?</b>
Hybrid Scenario with Injection Wells at Port Hueneme (S22)	4,600	10,000	Yes
Hybrid Scenario without Injection Wells at Port Hueneme (S23)	4,600	10,000	No
Hybrid Scenario with Expanded Recycled Water Use (S24)	4,600 (starting in 2020) 7,000 (starting in 2027)	10,000	Yes

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**Table 4. Annual Volume of Additional Water Produced by Projects Included in Hybrid Scenario Alternatives**

<b>Project (and Year Modeled to Begin Operating)</b>	<b>Water Produced (AFY)</b>	<b>Notes</b>
Oxnard's AWPf Recycled Water to Farm Land (2020-2027)	4,600 (S22 & S23) 7,000 (S24)	Assumed to increase to 7,000 AFY in 2027 under S24.
Incentivized Following (2020)	2,600	This project would reduce demand for groundwater, rather than produce water—this value is slightly different than the 2,730 AFY described in the Oxnard basin GSP, but the difference is negligible.
SWP Interconnect Flushing (2027)	500	Includes both flushing water and occasional purchases of SWP water, as described in text and in Table 2.
Freeman Diversion Expansion (2027-2035)	11,400	Includes both Phase 1, starting in 2027, and Phase 2, starting in 2035.
SWP Article 21 Purchases, Exchanges, and Transfers by United (2020)	6,000	This estimate is for SWP water reaching (and diverted at) Freeman Diversion; it does not include SWP water that infiltrates in basins upstream from Freeman Diversion.
Optimization of Pumping (2020-2027)	Variable increase in sustainable yield between Hybrid Scenario alternatives	Optimization of pumping includes Saticoy well field expansion, PTP/PVP pipeline expansion, and shifting pumping from United's PTP well field from the LAS to the UAS; these projects do not produce "new" water, but instead increase sustainable yield of the OPV basins by shifting pumping away from the coast.
EBB Water (2027)	4,500	This 4,500 AFY does not include approximately 1,500 AFY of treated brackish groundwater assumed to be delivered directly to NBVC Point Mugu, nor does it include the increase to sustainable yield of the OPV basins resulting from the project's mitigation of seawater intrusion.
<p>Note: To simplify the modeling effort, projects were simulated to become operational in one of three years: 2020 (the beginning of the simulation), 2027, or 2035. In some cases, these years are somewhat different than the assumed project timelines provided in other tables in this document, or in other United reports and presentations. The project start times in this table are just simplifying assumptions, and do not represent a change in United's plans or projects schedules. Minor deviations in start dates are anticipated to have negligible effects on groundwater model results presented in this report.</p>		

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**Table 5. Average Water Demand during January through June (Period 1) and July through December (Period 2) in Specific Areas of the OPV and Las Posas Valley Basins**

Area	Period 1 (AF)	Period 2 (AF)	Total (AFY)
PTP area	7,071	8,475	15,546
PVP area (includes 1,300 AF per period of demand from Camrosa WD surface water deliveries)	8,665	13,259	21,924
Coastal area	4,162	6,195	10,357
Oxnard basin outside of PTP area	19,867	23,044	42,912
Pleasant Valley basin outside of PVP area	2,506	2,907	5,413
Western Management Area of Las Posas basin (as defined in Oxnard basin GSP)	6,826	7,918	14,711

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**Table 6. Long-Term Average Simulated Deliveries of Water to the PTP, PVP, and Coastal Areas from Selected Sources during the Modeled Period (2020-2069)**

From	To	Scenarios S22 & S23 (AFY)	Scenario S24 (AFY)
Freeman Diversion (including increased yield following expansion, and supplemental SWP imports)	Recharge (Saticoy and El Rio)	51,795	50,896
	PTP area	4,774	4,816
	PVP area	4,173	5,070
	<i>Subtotal</i>	<i>60,742</i>	<i>60,783</i>
Saticoy Well Field Expansion	PTP area	2,147	2,159
	PVP area	1,163	1,494
	<i>Subtotal</i>	<i>3,309</i>	<i>3,653</i>
EBB Water	Recharge (El Rio)	303	303
	PTP area	1,933	1,933
	PVP area	1,626	1,626
	<i>Subtotal</i>	<i>3,862</i>	<i>3,862</i>
Oxnard's AWPf recycled water to Farm Land	Recharge (El Rio)	564	728
	PTP area	246	157
	PVP area	2,460	288
	Coastal area	1,321	5,477
	<i>Subtotal</i>	<i>4,590</i>	<i>6,650</i>
Camrosa WD	PVP area	4,500	4,500
SWP interconnect pipeline	Recharge	430	430
<p><i>Note: The delivered quantities shown consist of the total delivered water over the 2020-2069 simulation period divided by 50 years (the length of the simulation), and may be different than the annual deliveries anticipated or modeled in a given year after a project comes online or expands. Projects that are modeled to come online in the late 2020s or 2030s will have reduced average deliveries over the 50-year simulation period compared to their expected yields in a given year due to the fact that the averaging period (50 years) includes several years when the projects will not yet be producing water.</i></p>			

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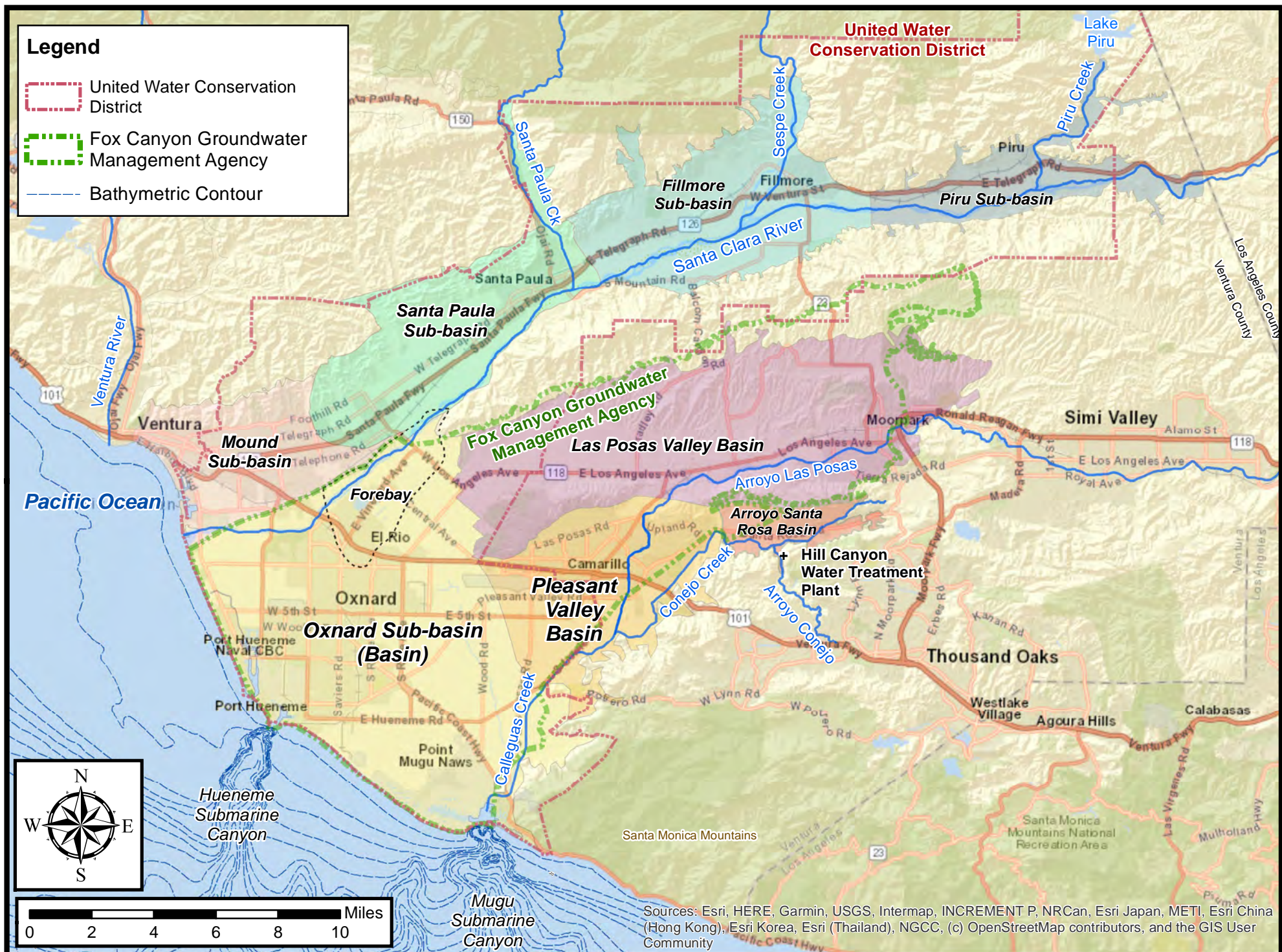
**Table 7. Modeled Long-Term Average Volumes Provided by Major Fresh Water Sources during “Sustaining Period” (2040-2069) of Oxnard and Pleasant Valley Basin GSPs**

<b>Water supply Source (and year assumed to become operational)</b>	<b>S22: Hybrid Scenario with Injection Wells at Port Hueneme (AFY)</b>	<b>S23: Hybrid Scenario without Injection at Port Hueneme (AFY)</b>	<b>S24: Hybrid Scenario with Expanded Recycled Water Use (AFY)</b>	<b>Oxnard Basin GSP “Reduction with Projects” Scenario (AFY)</b>
<b>Total Water Supply for Ag, M&amp;I, and Domestic Users</b>	<b>116,900</b>	<b>116,900</b>	<b>116,100</b>	<b>89,800</b>
Groundwater Pumped from Wells (includes wells operated by water users and well fields operated as part of United’s existing and planned conjunctive-use projects [i.e., Saticoy, El Rio, PTP])	72,900	72,900	69,100	46,900
Surface Water from Santa Clara River Delivered to PTP and PVP Areas (includes natural flows diverted by an expanded Freeman Diversion and supplemental SWP water released from upstream reservoirs)	7,700	7,700	8,500	12,300
Surface Water from Conejo Creek Delivered to PTP and PVP Areas	4,500	4,500	4,500	4,500
EBB Water (includes only water delivered directly to end users, not water that is artificially recharged by United)	5,700	5,700	5,700	0
Recycled Water (includes recycled water delivered directly to end users by City of Oxnard [AWPF], City of Camarillo, and Camrosa Water District)	6,000	6,000	8,200	6,000
Imported SWP Water Delivered Directly to M&I Users by Calleguas MWD	20,100	20,100	20,100	20,100

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## FIGURES

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**Figure 1. Regional Map of Hydrologic Features and Groundwater Basins**



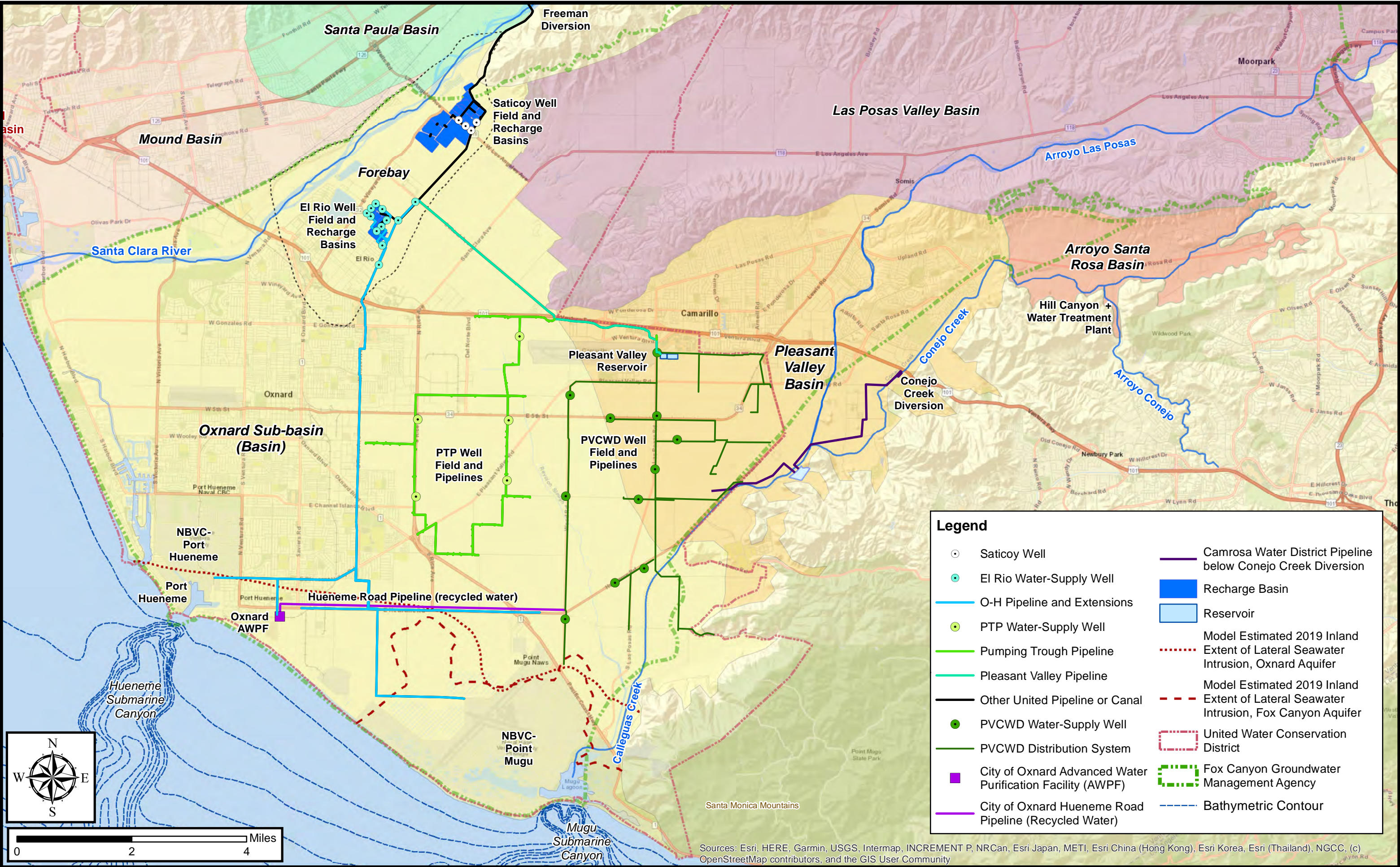
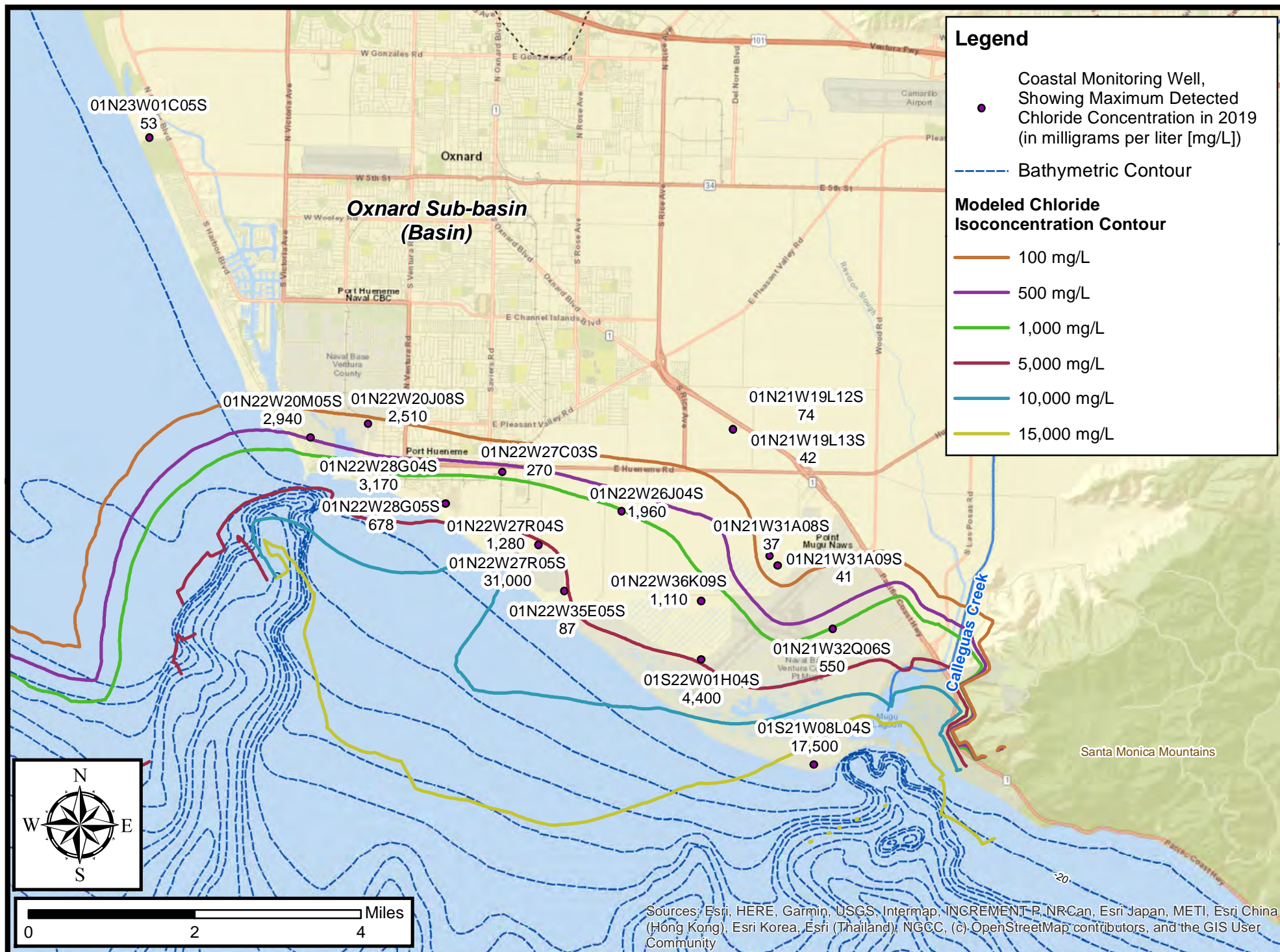


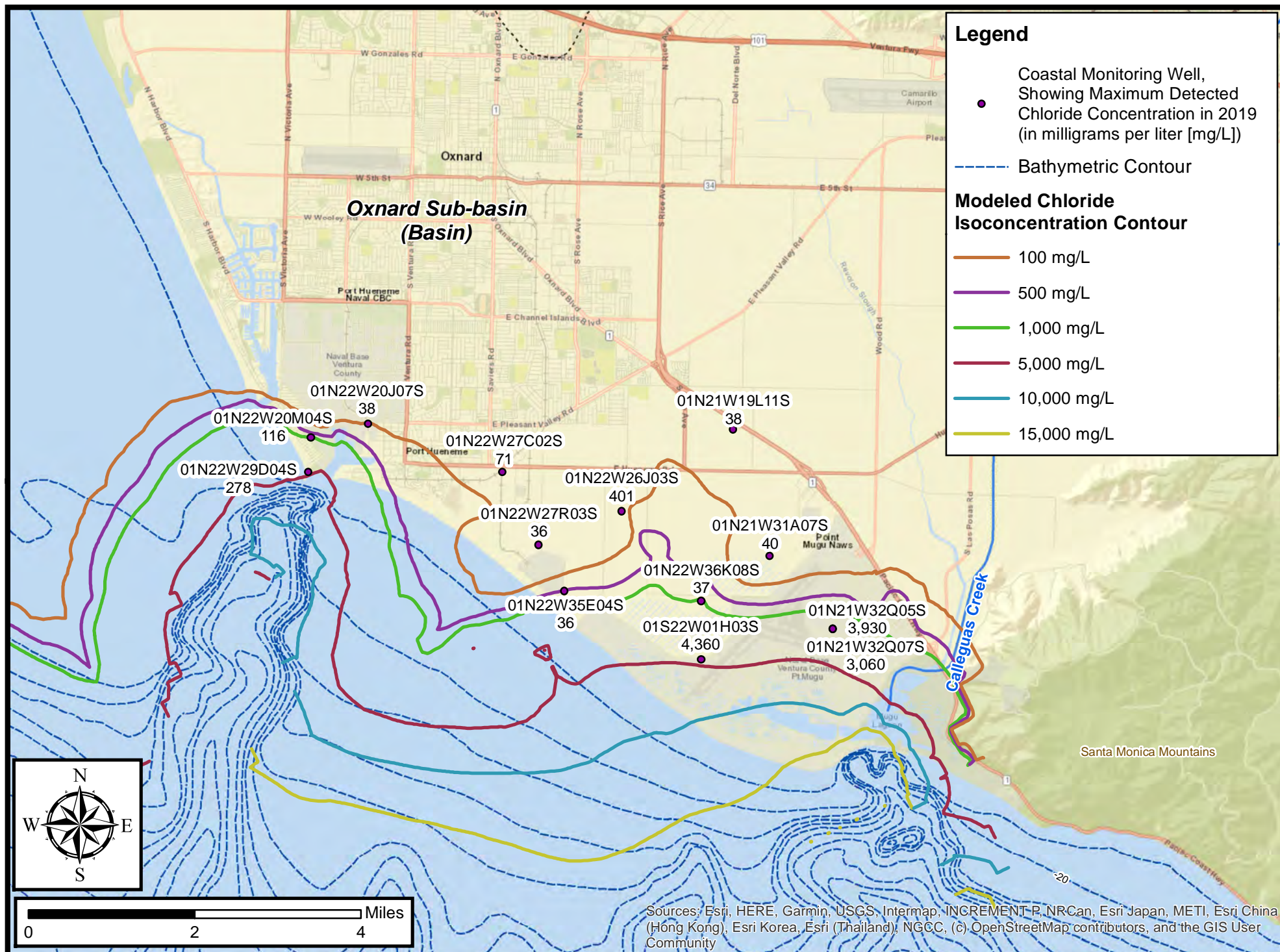
Figure 2. Map of Key Artificial Recharge, Conjunctive Use, and Recycled Water Infrastructure in OPV Basins





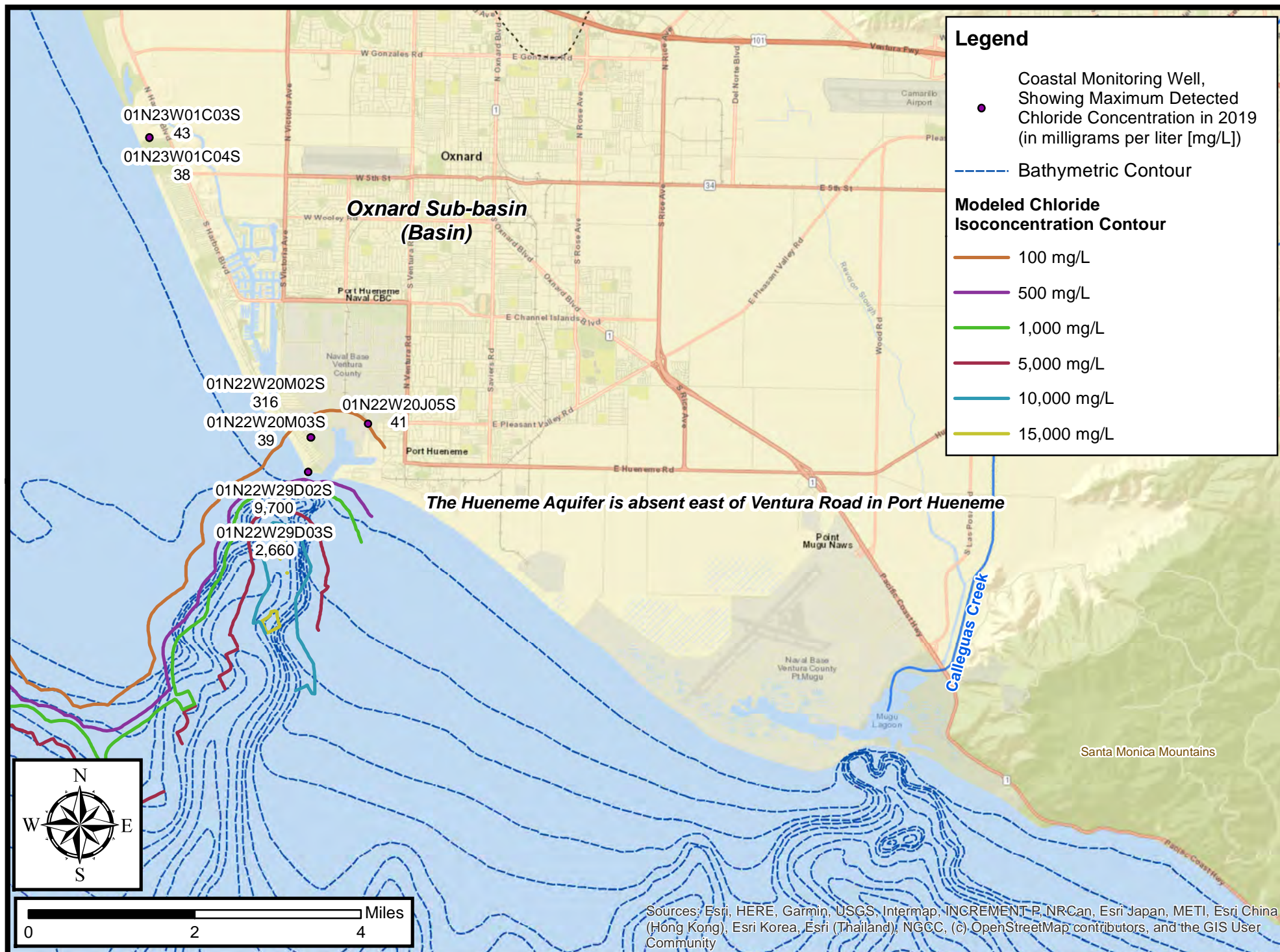
**Figure 3. Modeled Chloride Concentrations in Oxnard Aquifer, December 2019**





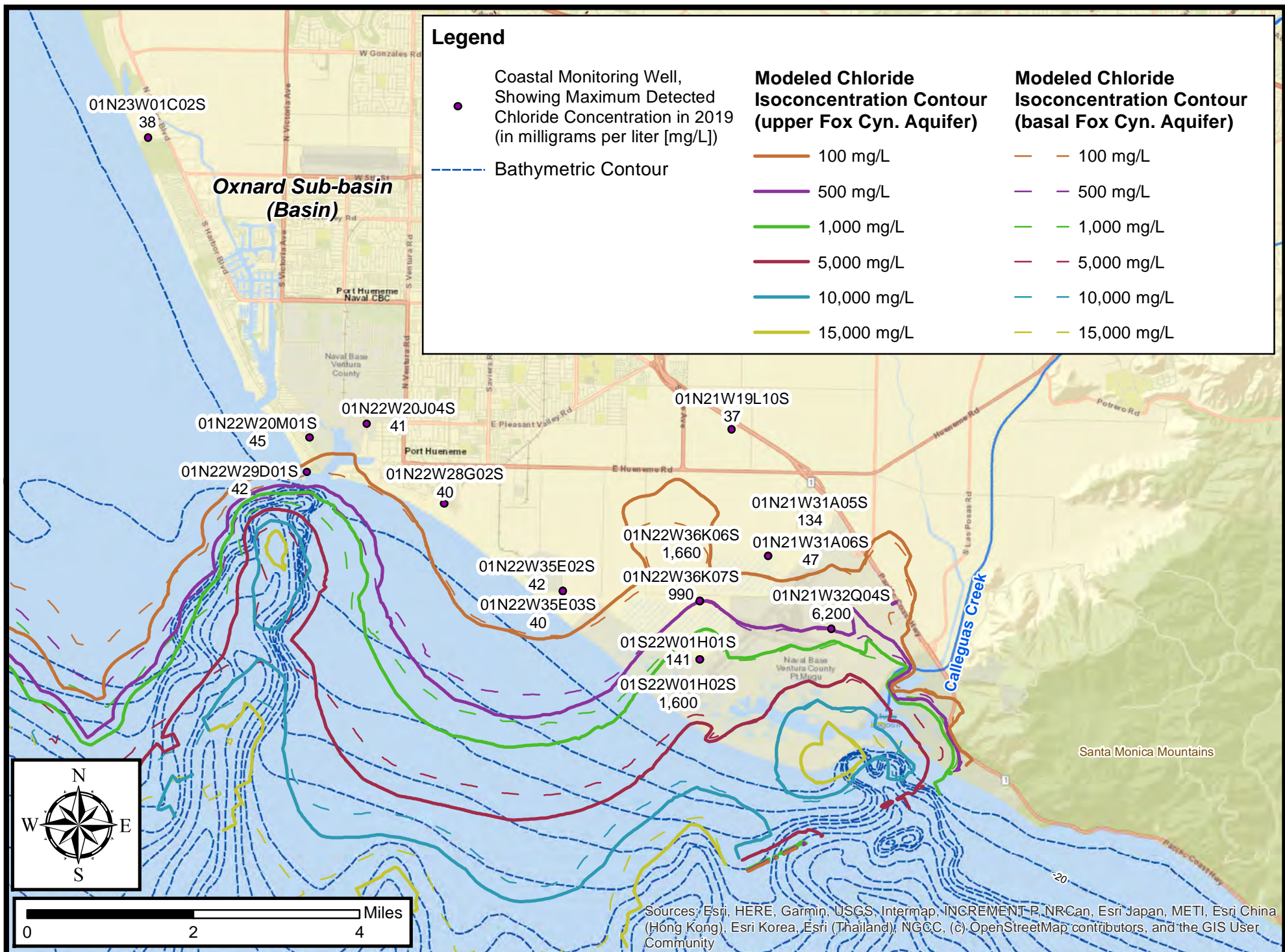
**Figure 4. Modeled Chloride Concentrations in Mugu Aquifer, December 2019**





**Figure 5. Modeled Chloride Concentrations in Hueneme Aquifer, December 2019**





**Figure 6. Modeled Chloride Concentrations in Upper and Basal Layers of Fox Canyon Aquifer, December 2019**



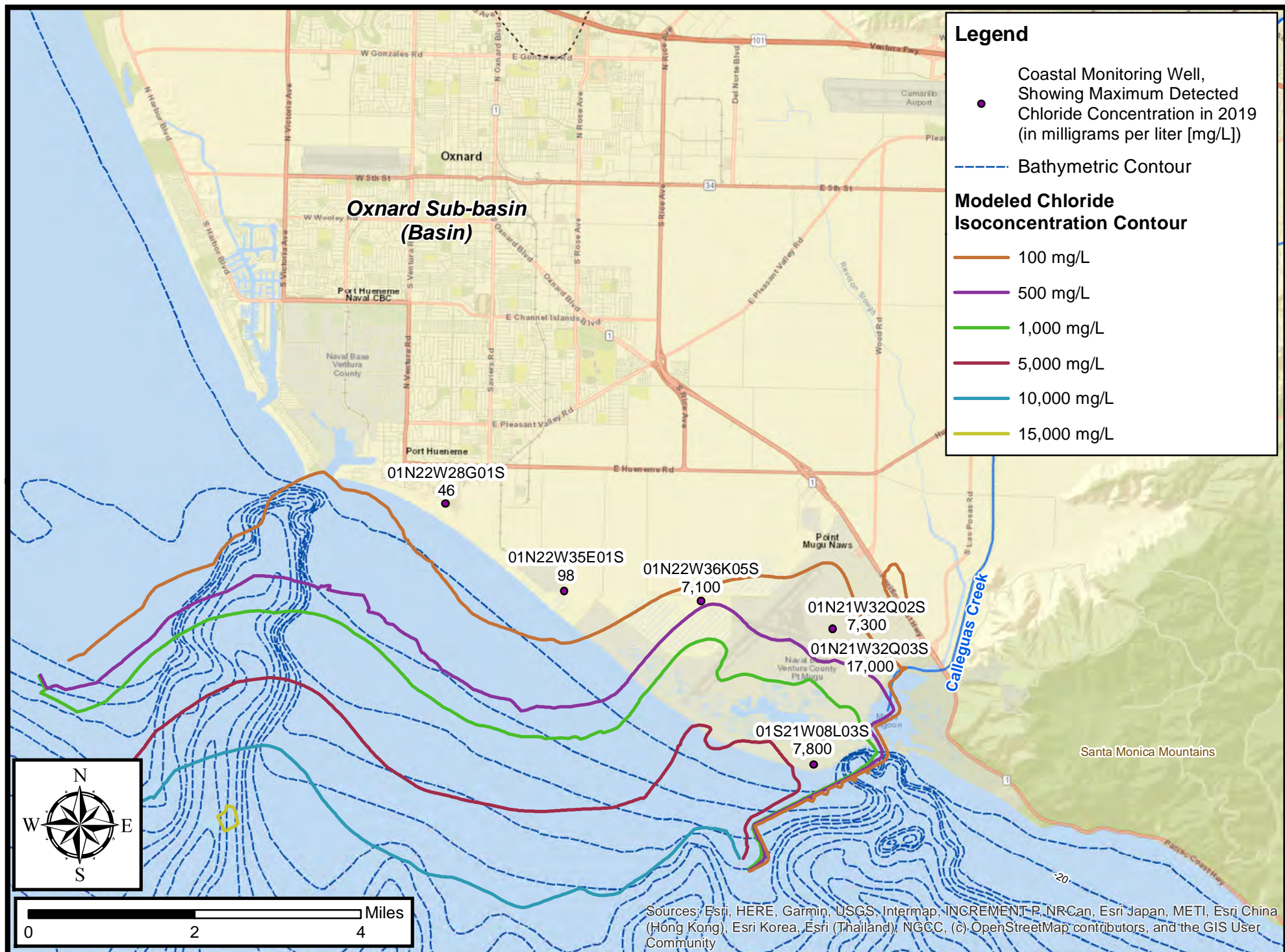


Figure 7. Modeled Chloride Concentrations in Grimes Canyon Aquifer, December 2019



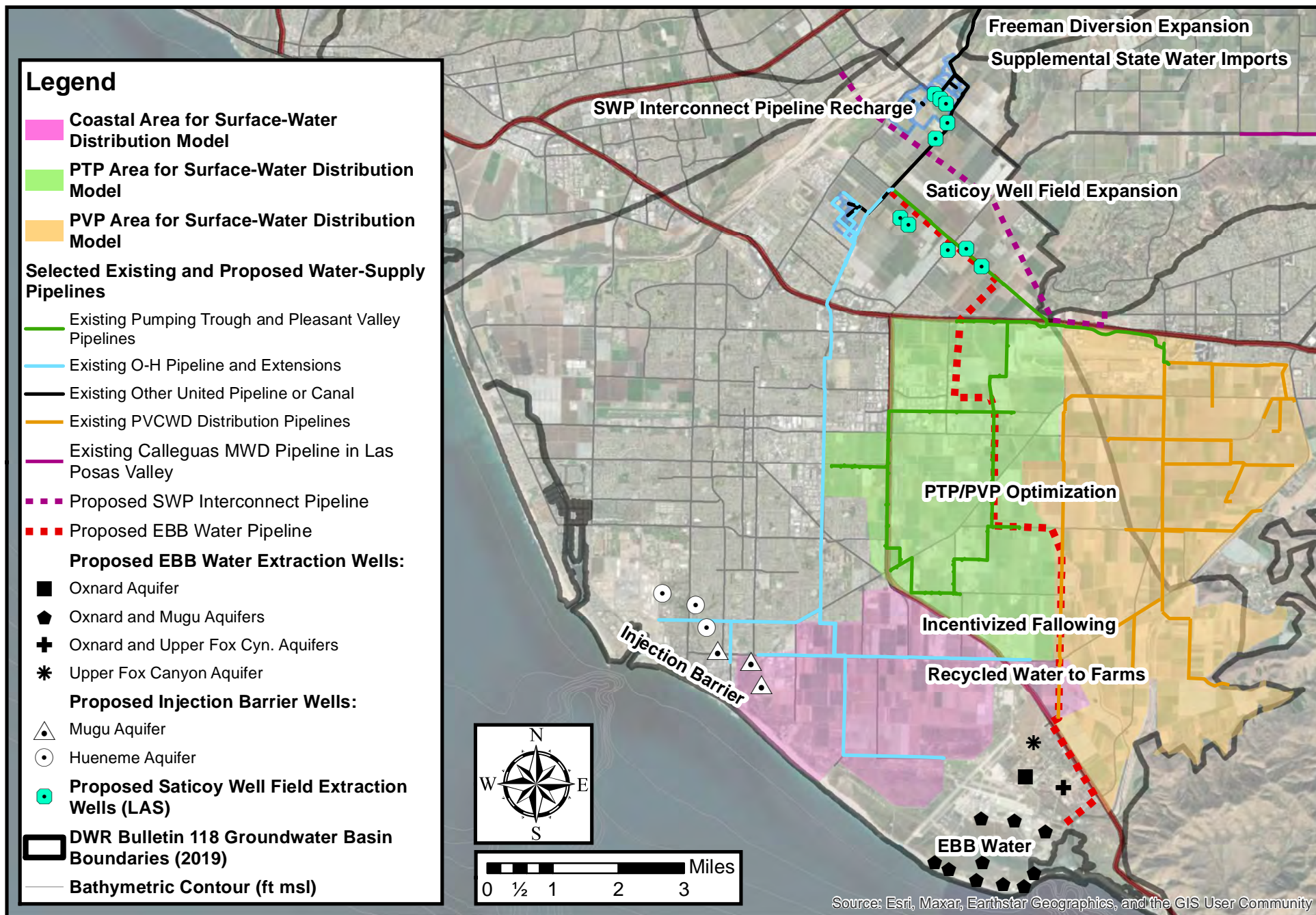
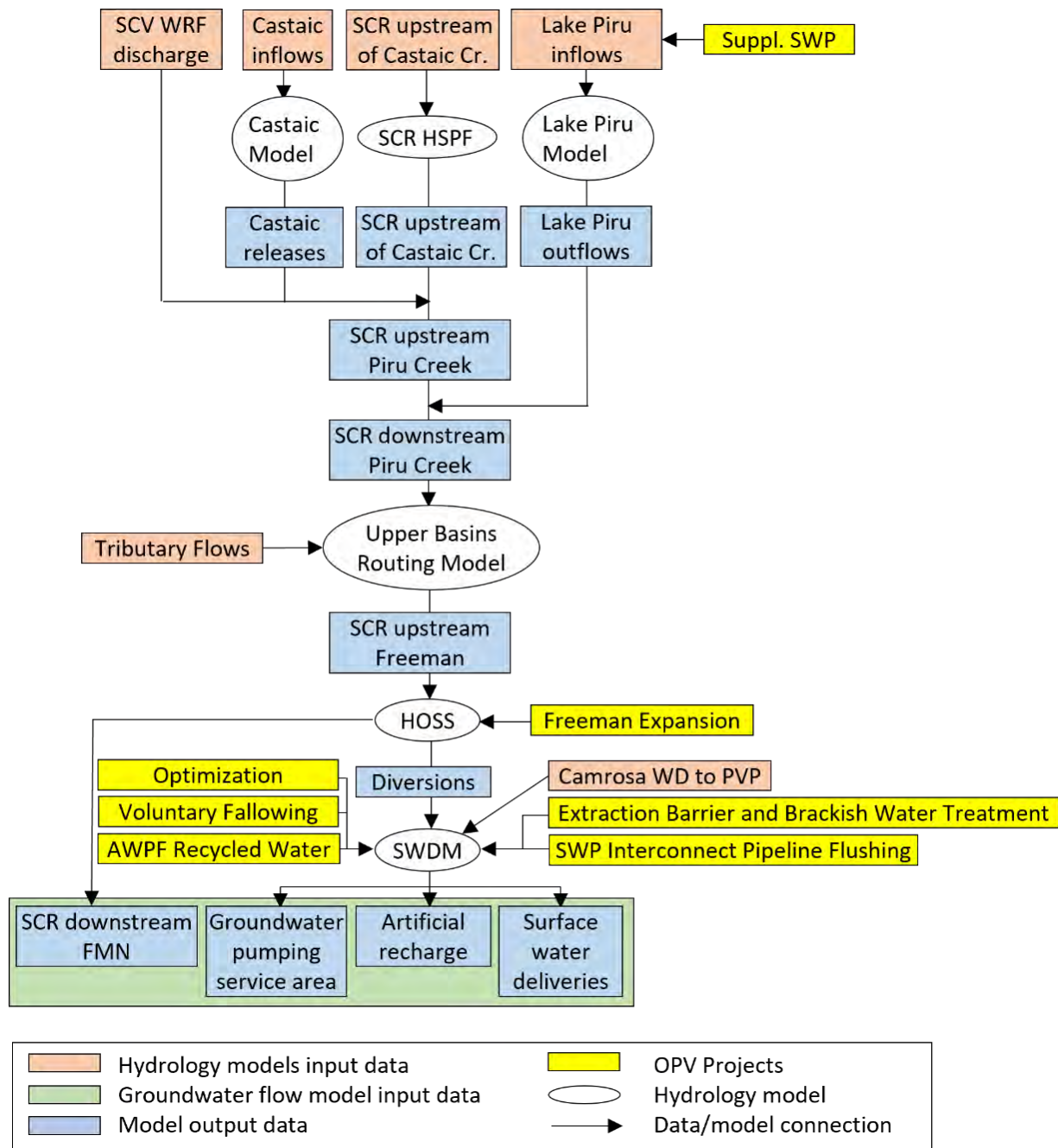
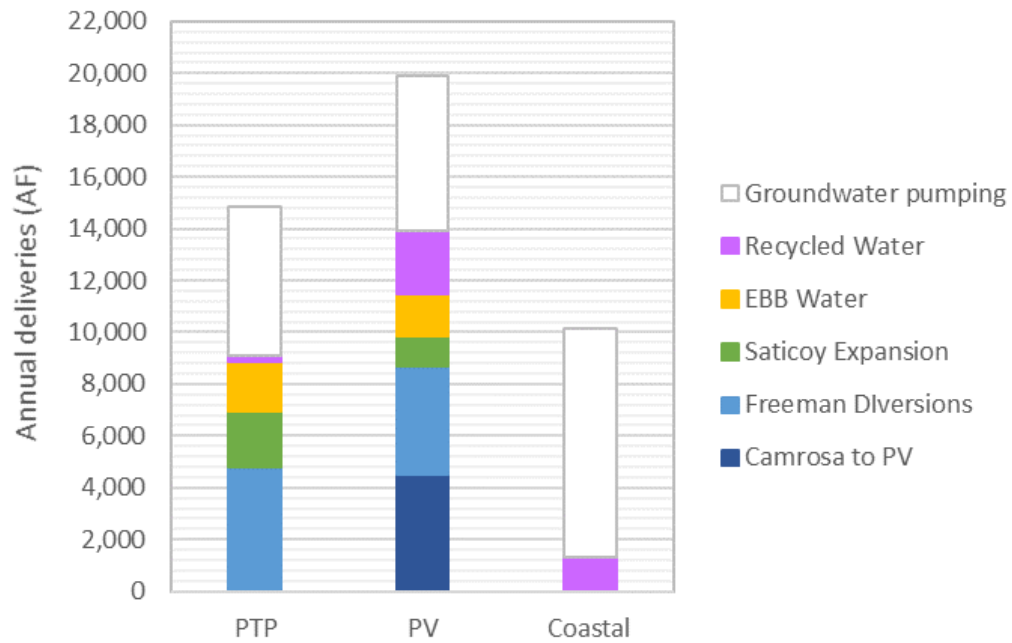


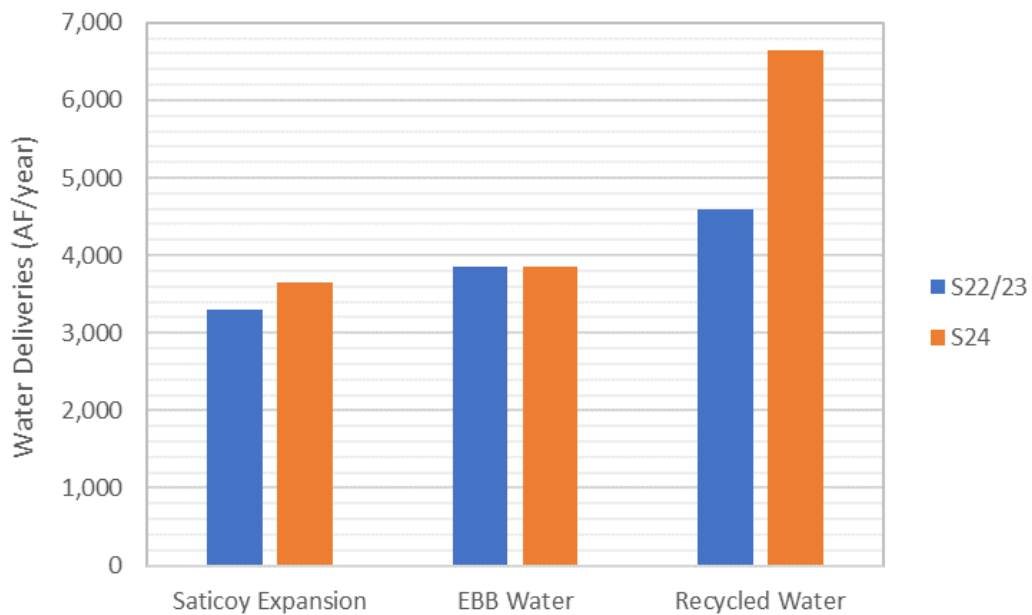
Figure 8. Map of Modeled Hybrid Scenario Projects and Surface Water Distribution Areas



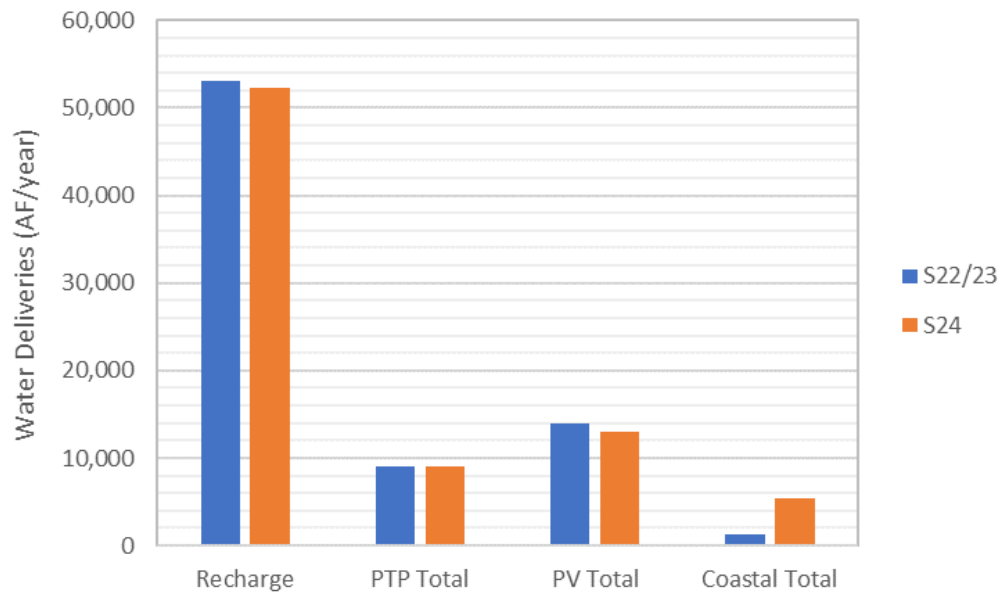
**Figure 9. Modeling Workflow to Calculate Diversions and Water Distribution on Oxnard Plain for Simulating the Hybrid Scenario**



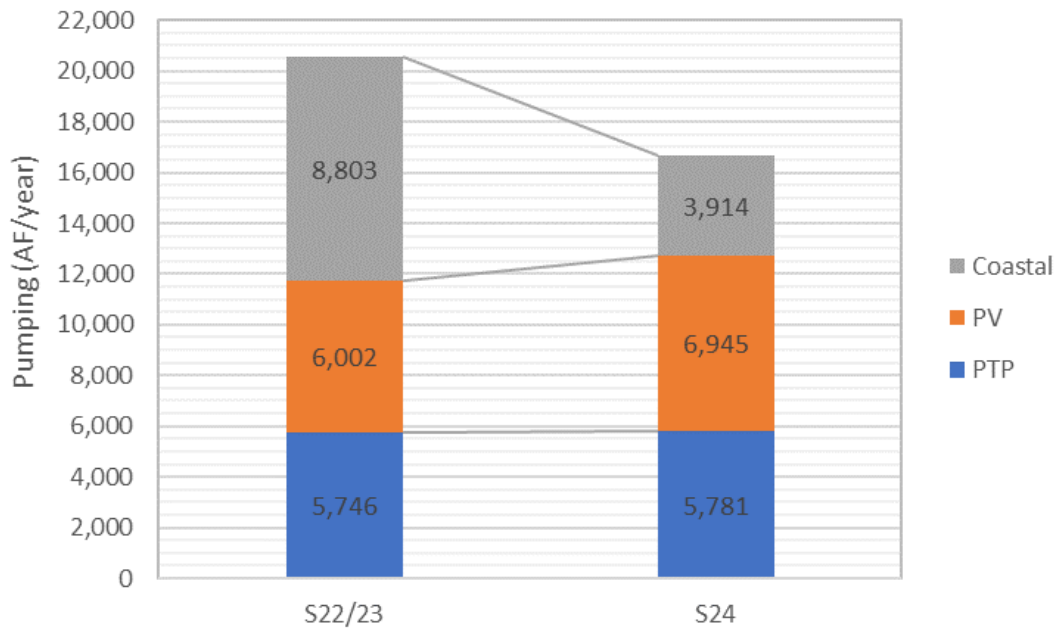
**Figure 10. Simulated Water Deliveries and Pumping for the PTP, PVP, and Coastal Management Areas for Hybrid Scenario Alternatives S22 and S23**



**Figure 11. Simulated Water Deliveries for the Saticoy Well Field Expansion, EBB Water, and Recycled Water Projects for Hybrid Scenario Alternatives S22 through S24**



**Figure 12. Simulated Total Recharge at Saticoy and El Rio Facilities, and Pipeline Deliveries to the PTP, PVP and Coastal Areas for Hybrid Scenario Alternatives S22 through S24**



**Figure 13. Simulated Pumping in the PTP, PVP, and Coastal Management Areas for Hybrid Scenario Alternatives S22 through S24**



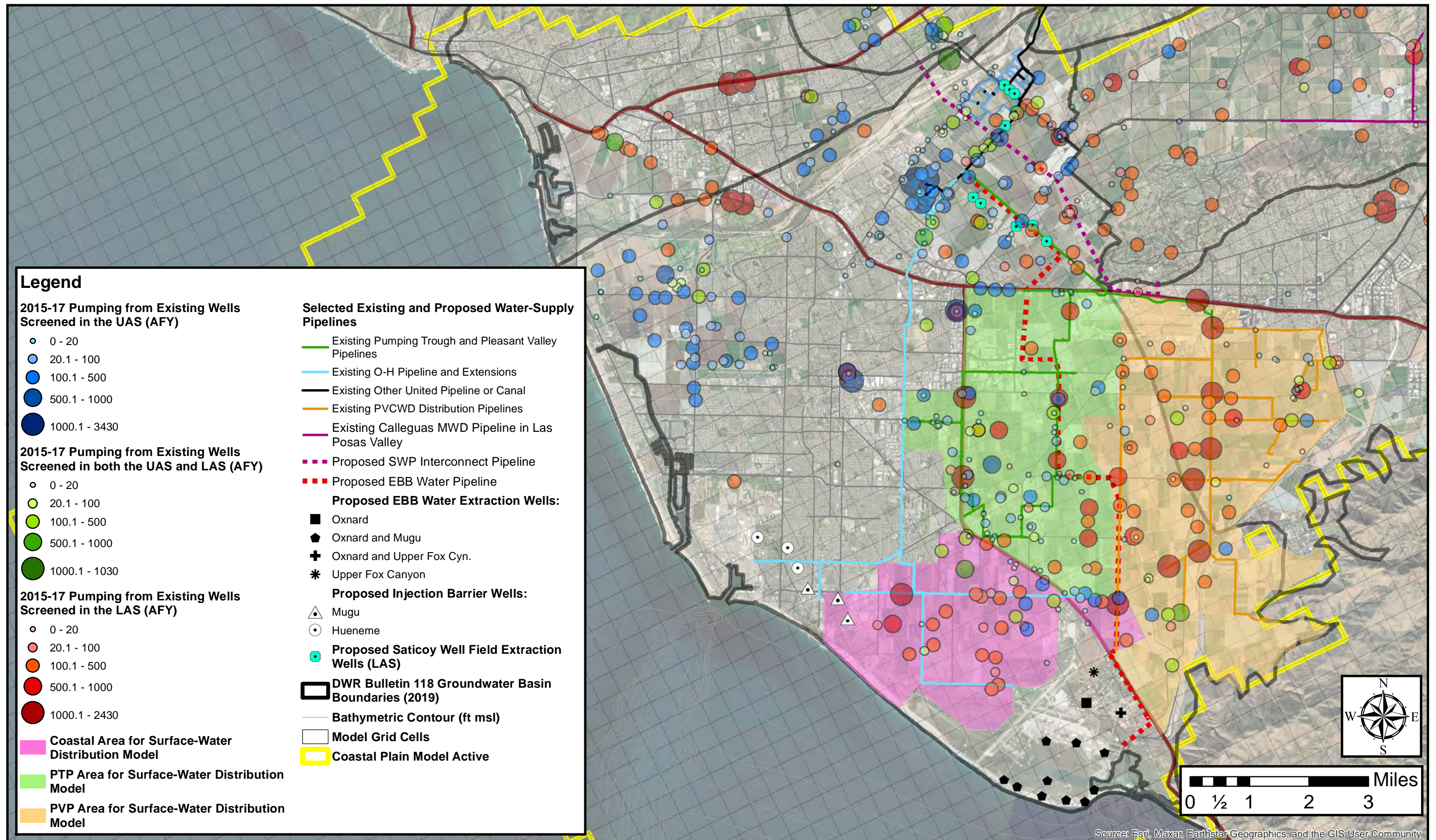


Figure 14. Locations of Existing Water-Supply Wells and Simulated Extraction and Injection Wells Included in Hybrid Scenario Alternatives



Note:  
All existing water supply wells are set to be partially transparent for all aquifers.

**Legend**

**Simulated Intrusion in Oxnard Aquifer (Model Layer 3 Release)**

**Particle Movement (As Applicable)**

- Orange Lines = Moved Upward from Release Layer
- Light Blue Lines = Remained in Release Layer
- Dark Blue Lines = Moved Downward from Release Layer

Simulated Starting Locations Representing Inland Extent of Seawater Intrusion in Oxnard Aquifer as of December 2019 (100 mg/L chloride)

- Green Dots = Simulated Starting Locations
- Red Dots = Simulated Ending Locations (Active Only)

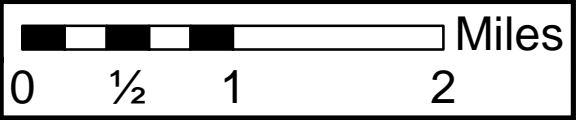
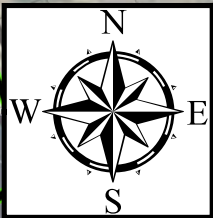
Limit of Active Grid Cells in Model Layer 3

Model Grid Cell

DWR Bulletin 118 Groundwater Basin Boundaries (2019)

Coastal Plain Model Active Grid

Bathymetric Contour (msl, 10 meter intervals)

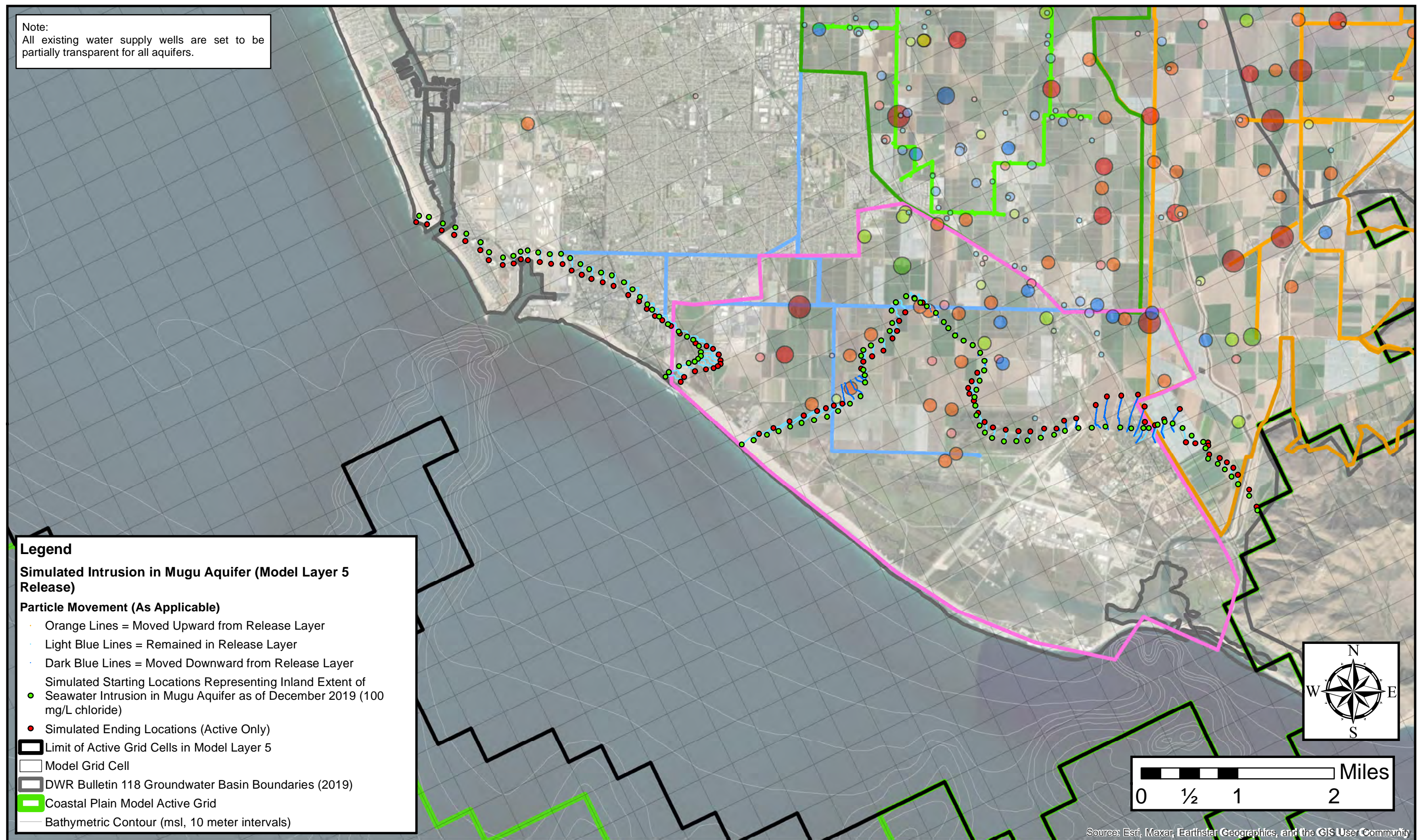


Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

Figure 15. Updated Particle Tracks for Oxnard Basin GSP "Reduction with Projects" Scenario--Oxnard Aquifer



Note:  
All existing water supply wells are set to be partially transparent for all aquifers.



**Figure 16. Updated Particle Tracks for Oxnard Basin GSP "Reduction with Projects" Scenario--Mugu Aquifer**



Note:  
All existing water supply wells are set to be partially transparent for all aquifers.

**Legend**

**Simulated Intrusion in Hueneme Aquifer (Model Layer 7 Release)**

**Particle Movement (As Applicable)**

Orange Lines = Moved Upward from Release Layer

Light Blue Lines = Remained in Release Layer

Dark Blue Lines = Moved Downward from Release Layer

Simulated Starting Locations Representing Inland Extent of Seawater Intrusion in Hueneme Aquifer as of December 2019 (100 mg/L chloride)

Simulated Ending Locations (Active Only)

Area of Absent Hueneme Aquifer

Limit of Active Grid Cells in Model Layer 7

Model Grid Cell

DWR Bulletin 118 Groundwater Basin Boundaries (2019)

Coastal Plain Model Active Grid

Bathymetric Contour (msl, 10 meter intervals)

Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

Figure 17. Updated Particle Tracks for Oxnard Basin GSP "Reduction with Projects" Scenario--Hueneme Aquifer



Note:  
All existing water supply wells are set to be partially transparent for all aquifers.

**Legend**

**Simulated Intrusion in Upper Fox Canyon Aquifer (Model Layer 9 Release)**

**Particle Movement (As Applicable)**

- Orange Lines = Moved Upward from Release Layer
- Light Blue Lines = Remained in Release Layer
- Dark Blue Lines = Moved Downward from Release Layer

Simulated Starting Locations Representing Inland Extent of Seawater Intrusion in Upper Fox Canyon Aquifer as of December 2019 (100 mg/L chloride)

- Green Dots = Simulated Starting Locations
- Red Dots = Simulated Ending Locations (Active Only)

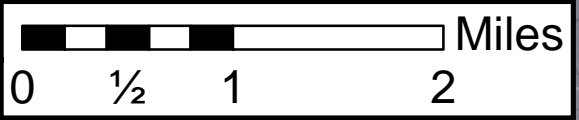
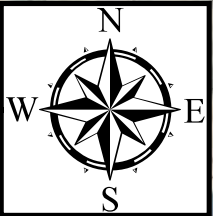
Limit of Active Grid Cells in Model Layer 9

Model Grid Cell

DWR Bulletin 118 Groundwater Basin Boundaries (2019)

Coastal Plain Model Active Grid

Bathymetric Contour (msl, 10 meter intervals)



Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

**Figure 18. Updated Particle Tracks for Oxnard Basin GSP "Reduction with Projects" Scenario--Upper Fox Canyon Aquifer**



Note:  
All existing water supply wells are set to be partially transparent for all aquifers.

**Legend**

**Simulated Intrusion in Basal Fox Canyon Aquifer (Model Layer 11 Release)**

**Particle Movement (As Applicable)**

- Orange Lines = Moved Upward from Release Layer
- Light Blue Lines = Remained in Release Layer
- Dark Blue Lines = Moved Downward from Release Layer

Simulated Starting Locations Representing Inland Extent of Seawater Intrusion in Basal Fox Canyon Aquifer as of December 2019 (100 mg/L chloride)

- Green Dots = Simulated Starting Locations
- Red Dots = Simulated Ending Locations (Active Only)

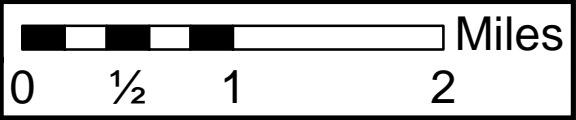
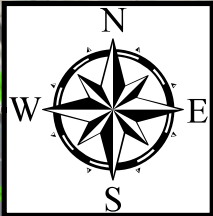
Limit of Active Grid Cells in Model Layer 11

Model Grid Cell

DWR Bulletin 118 Groundwater Basin Boundaries (2019)

Coastal Plain Model Active Grid

Bathymetric Contour (msl, 10 meter intervals)



Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

**Figure 19. Updated Particle Tracks for Oxnard Basin GSP "Reduction with Projects" Scenario--Basal Fox Canyon Aquifer**



Note:  
All existing water supply wells are set to be partially transparent for all aquifers.

**Legend**

**Simulated Intrusion in Grimes Canyon Aquifer (Model Layer 13 Release)**

**Particle Movement (As Applicable)**

- Orange Lines = Moved Upward from Release Layer
- Light Blue Lines = Remained in Release Layer
- Dark Blue Lines = Moved Downward from Release Layer

Simulated Starting Locations Representing Inland Extent of Seawater Intrusion in Grimes Canyon Aquifer as of December 2019 (100 mg/L chloride)

- Green Dots = Simulated Starting Locations
- Red Dots = Simulated Ending Locations (Active Only)

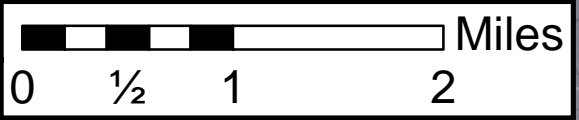
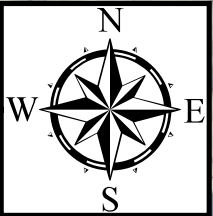
Limit of Active Grid Cells in Model Layer 13

Model Grid Cell

DWR Bulletin 118 Groundwater Basin Boundaries (2019)

Coastal Plain Model Active Grid

Bathymetric Contour (msl, 10 meter intervals)



Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

**Figure 20. Updated Particle Tracks for Oxnard Basin GSP "Reduction with Projects" Scenario--Grimes Canyon Aquifer**



Note:  
Extraction barrier and injection barrier wells are set to be partially transparent when not located in the current aquifer.

All existing water supply wells are set to be partially transparent for all aquifers.

**Legend**

**EBB Water Extraction Wells**

Oxnard Aquifer

Oxnard and Mugu Aquifers

Oxnard and Upper Fox Aquifers

Upper Fox Canyon Aquifer

**Port Hueneme Injection Wells**

Mugu Aquifer

Hueneme Aquifer

**Simulated Intrusion in Oxnard Aquifer (Model Layer 3 Release)**

**Particle Movement (As Applicable)**

Orange Lines = Moved Upward from Release Layer

Light Blue Lines = Remained in Release Layer

Dark Blue Lines = Moved Downward from Release Layer

Simulated Starting Locations Representing Inland Extent of Seawater Intrusion in Oxnard Aquifer as of December 2019 (100 mg/L chloride)

Simulated Ending Locations (Active Only)

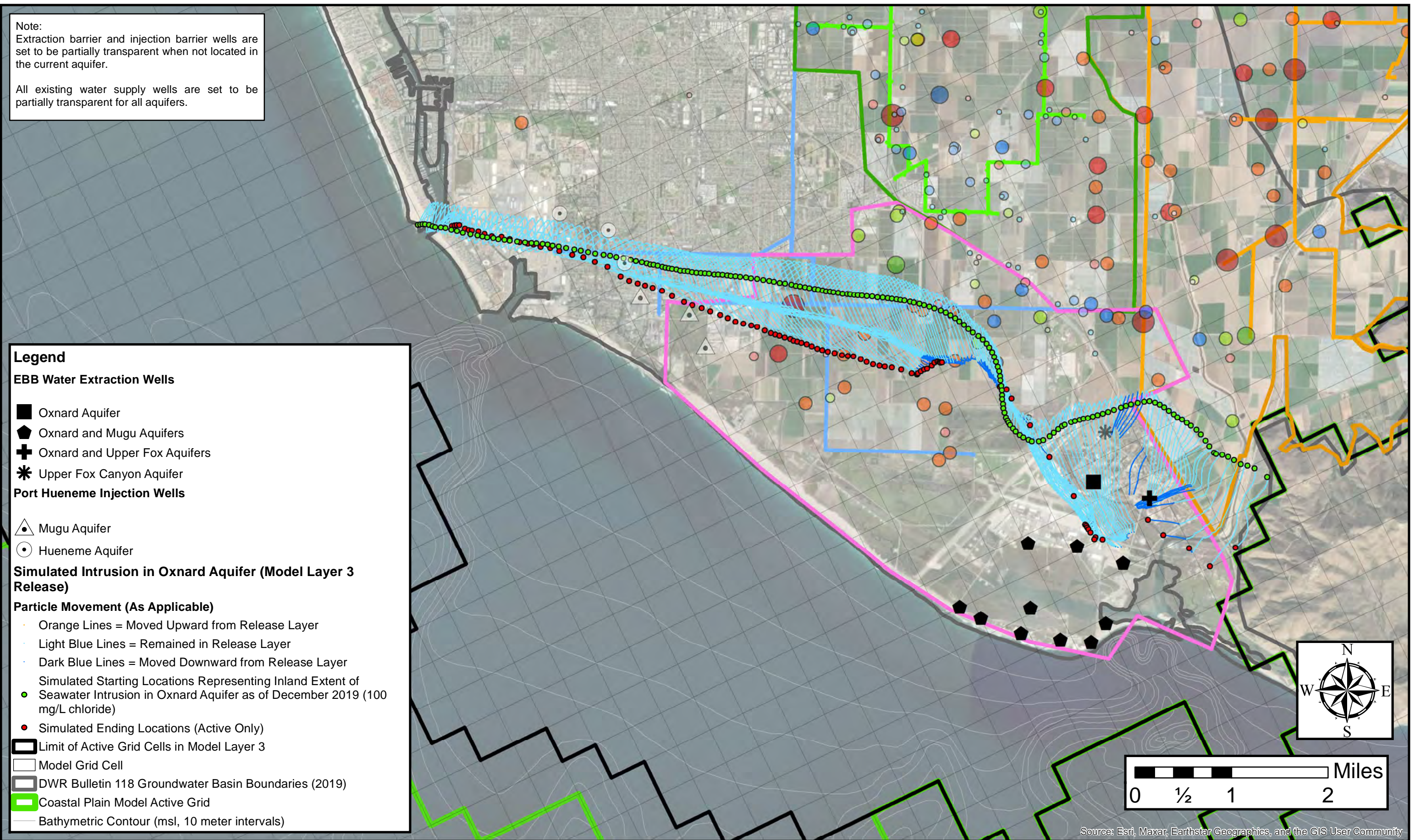
Limit of Active Grid Cells in Model Layer 3

Model Grid Cell

DWR Bulletin 118 Groundwater Basin Boundaries (2019)

Coastal Plain Model Active Grid

Bathymetric Contour (msl, 10 meter intervals)



Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

**Figure 21. Forecasted Particle Tracks for Hybrid Scenario with Injection Wells at Port Hueneme (S22)--Oxnard Aquifer (Model Layer 3)**



Note:  
Extraction barrier and injection barrier wells are set to be partially transparent when not located in the current aquifer.

All existing water supply wells are set to be partially transparent for all aquifers.

**Legend**

**EBB Water Extraction Wells**

- Oxnard Aquifer
- Oxnard and Mugu Aquifers
- Oxnard and Upper Fox Aquifers
- Upper Fox Canyon Aquifer

**Port Hueneme Injection Wells**

- Mugu Aquifer
- Hueneme Aquifer

**Simulated Intrusion in Mugu Aquifer (Model Layer 5 Release)**

**Particle Movement (As Applicable)**

- Orange Lines = Moved Upward from Release Layer
- Light Blue Lines = Remained in Release Layer
- Dark Blue Lines = Moved Downward from Release Layer

Simulated Starting Locations Representing Inland Extent of Seawater Intrusion in Mugu Aquifer as of December 2019 (100 mg/L chloride)

Simulated Ending Locations (Active Only)

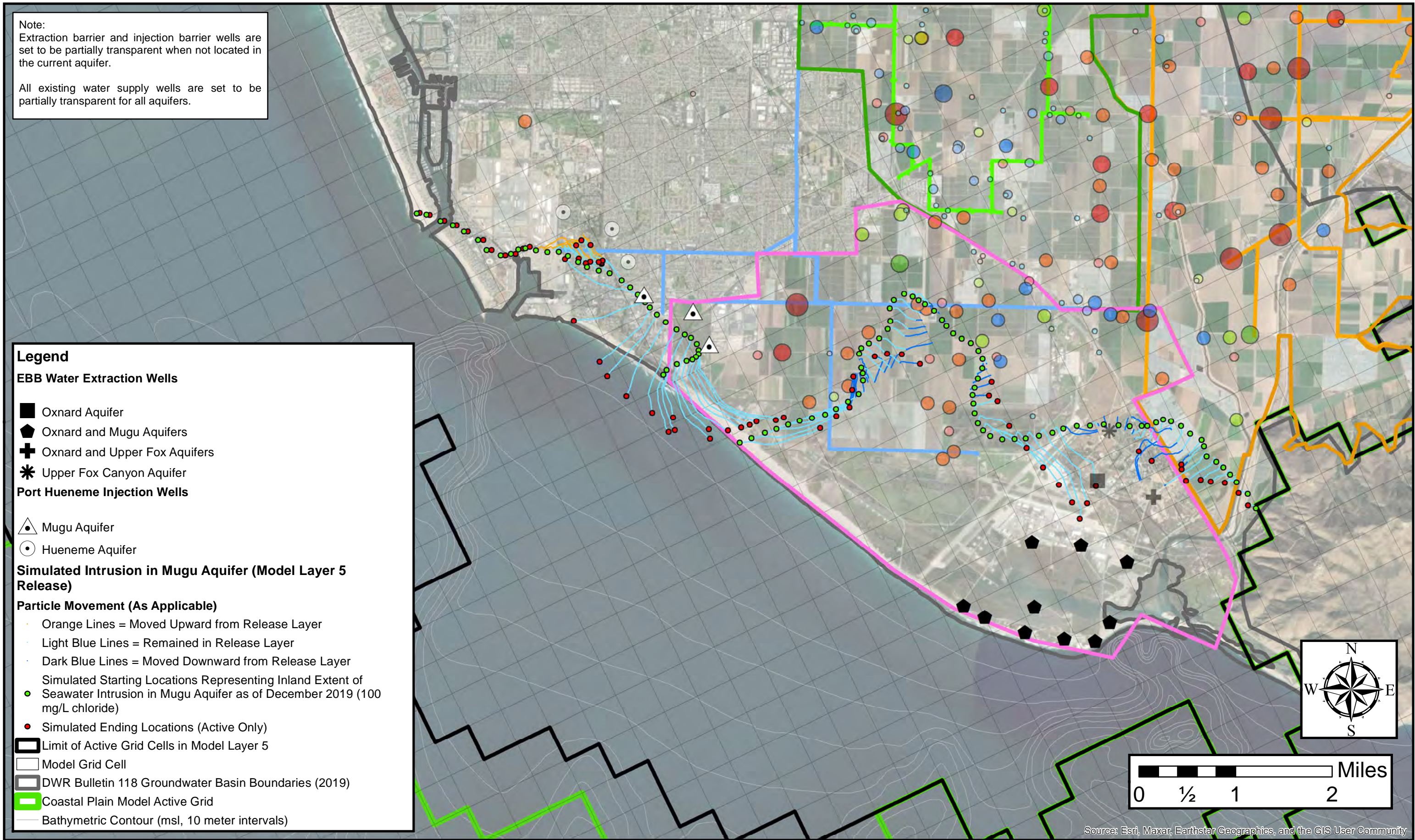
Limit of Active Grid Cells in Model Layer 5

Model Grid Cell

DWR Bulletin 118 Groundwater Basin Boundaries (2019)

Coastal Plain Model Active Grid

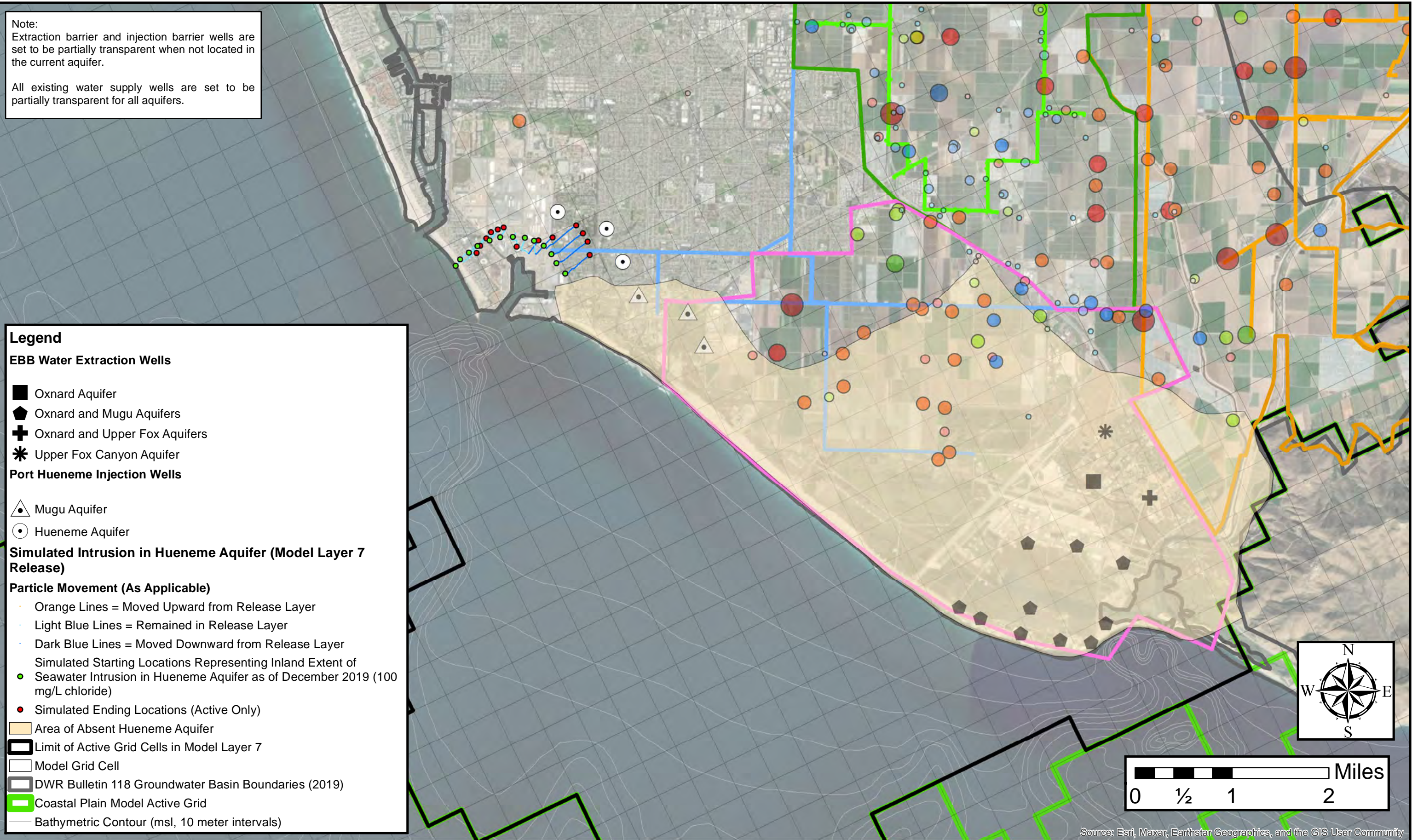
Bathymetric Contour (msl, 10 meter intervals)



Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

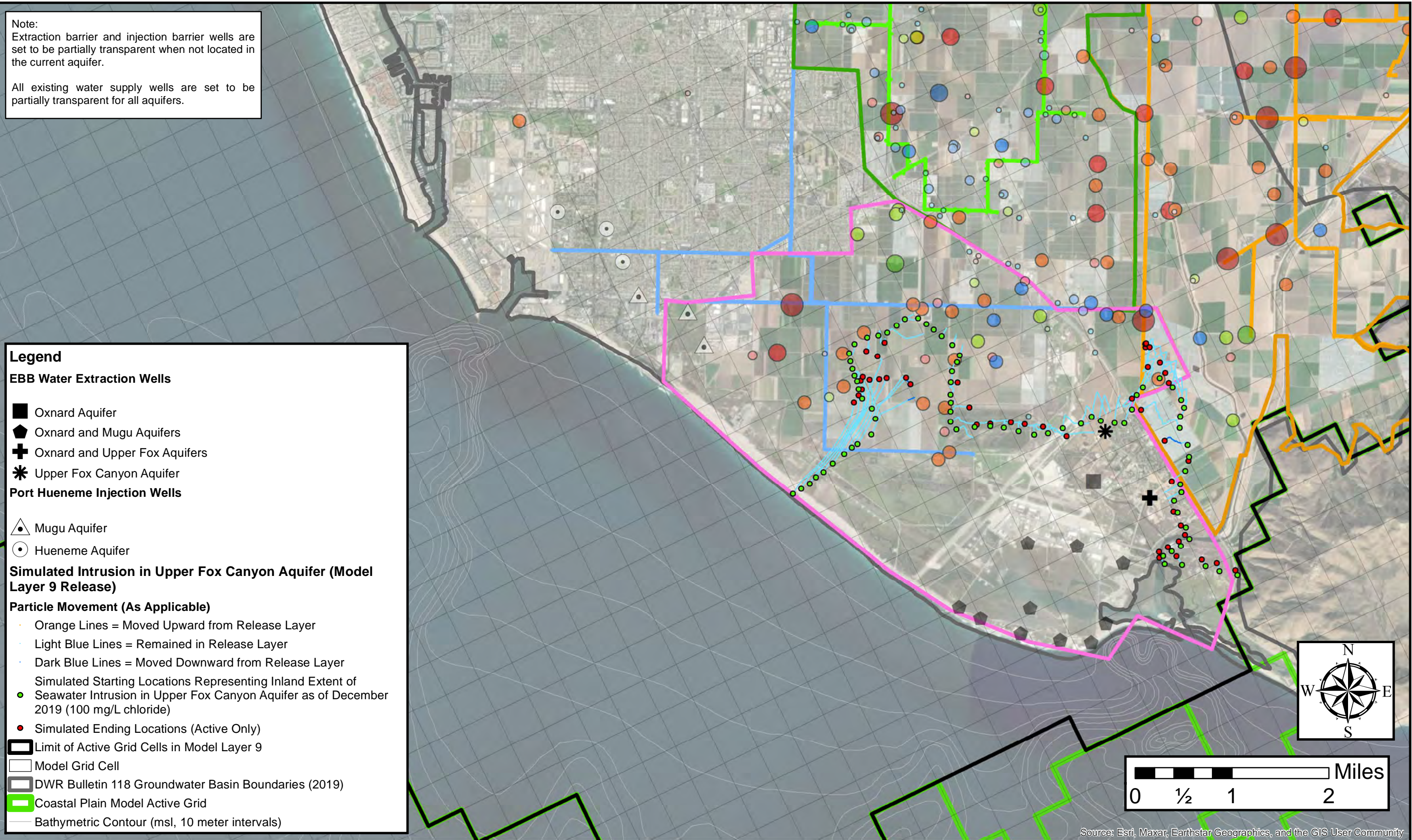
**Figure 22. Forecasted Particle Tracks for Hybrid Scenario with Injection Wells at Port Hueneme (S22)--Mugu Aquifer (Model Layer 5)**





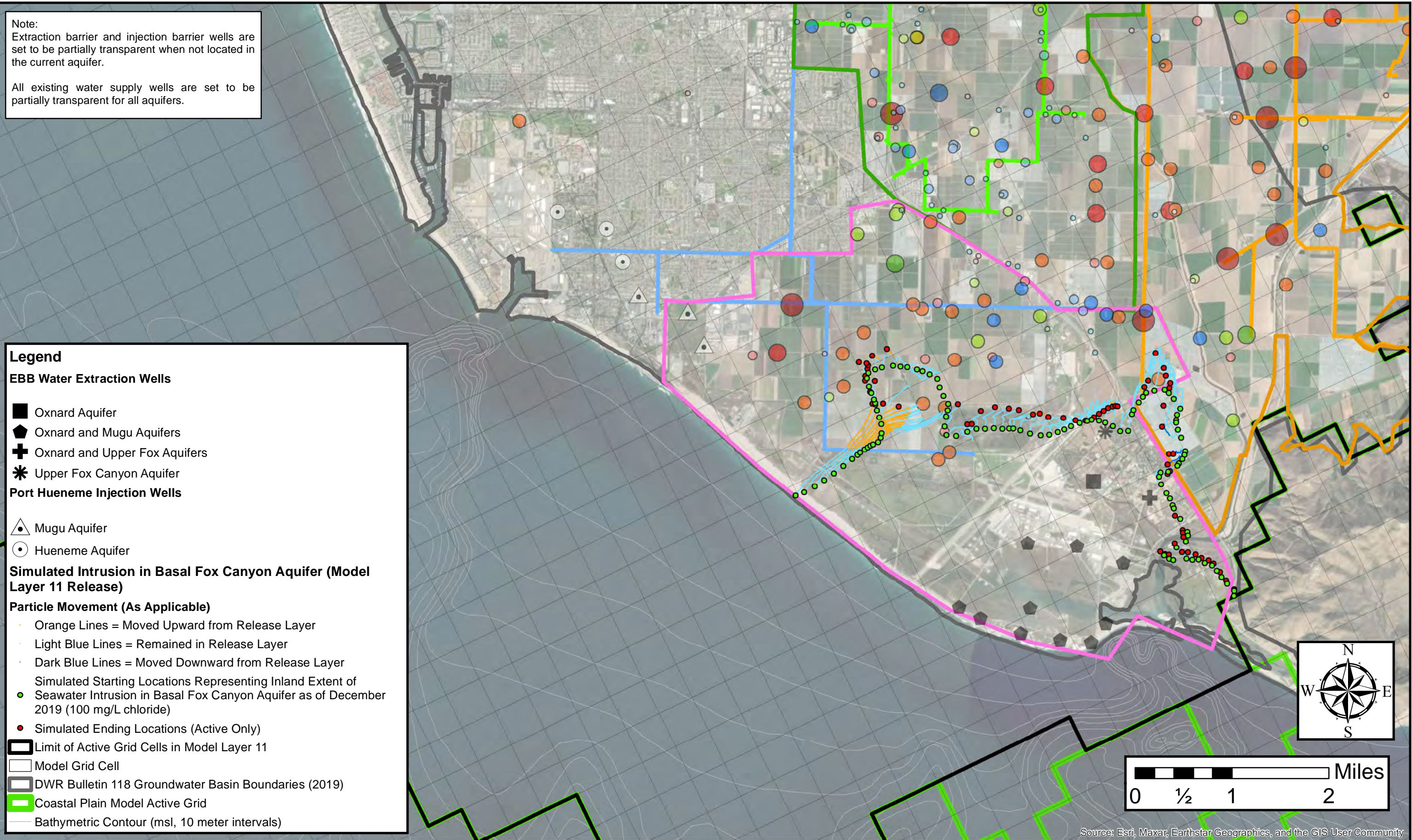
**Figure 23. Forecasted Particle Tracks for Hybrid Scenario with Injection Wells at Port Hueneme (S22)--Hueneme Aquifer (Model Layer 7)**





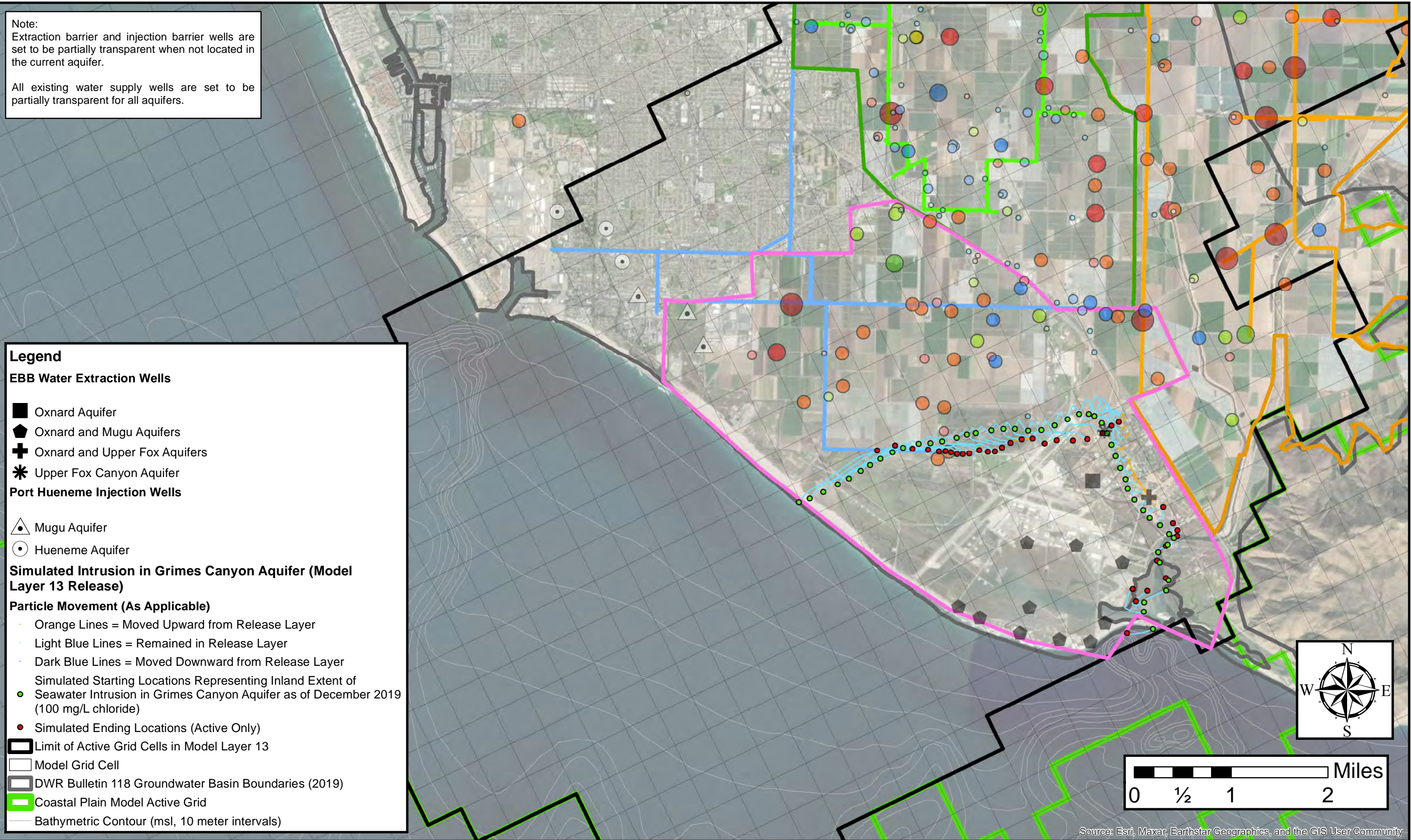
**Figure 24. Forecasted Particle Tracks for Hybrid Scenario with Injection Wells at Port Hueneme (S22)--Upper Fox Canyon Aquifer (Model Layer 9)**





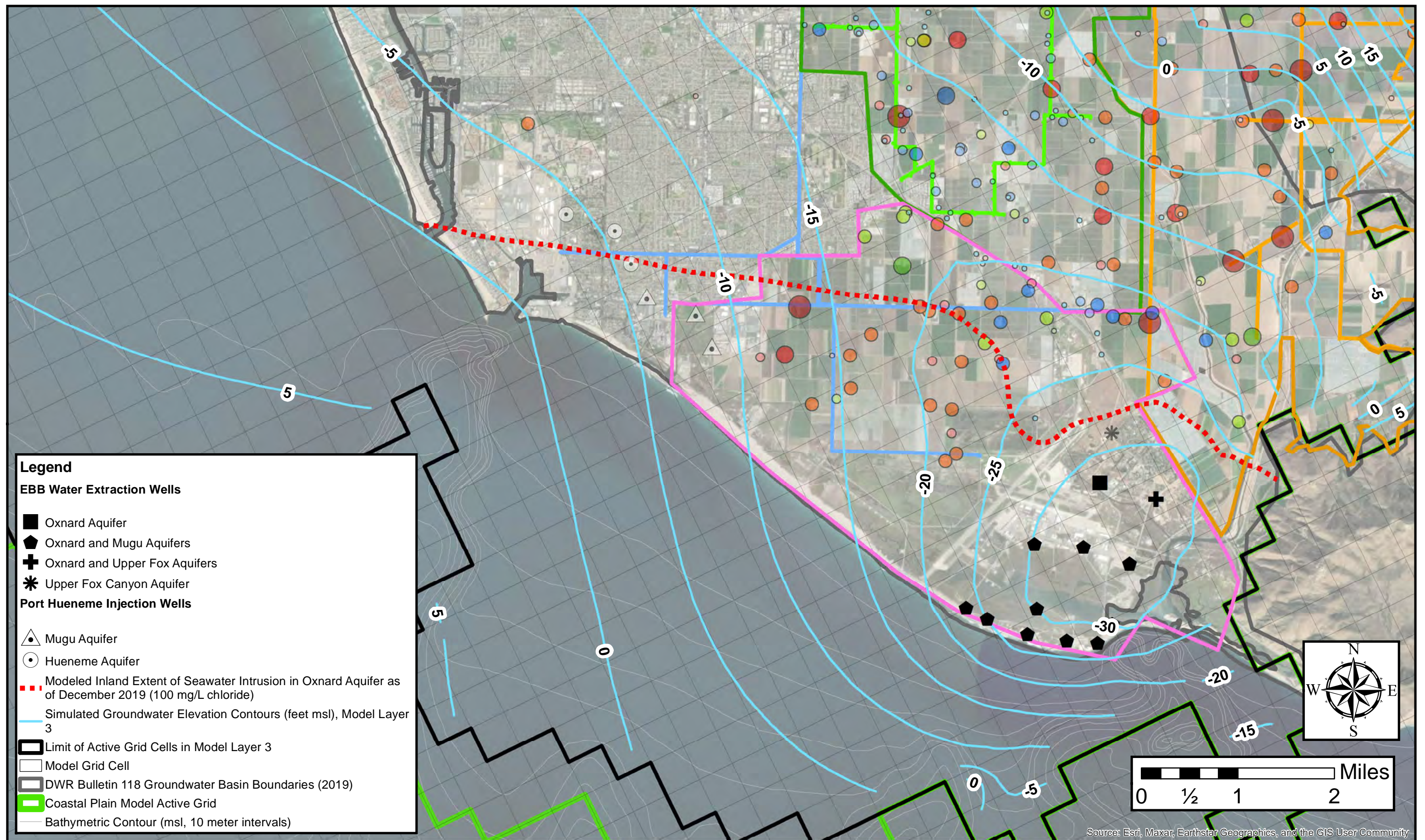
**Figure 25. Forecasted Particle Tracks for Hybrid Scenario with Injection Wells at Port Hueneme (S22)--Basal Fox Canyon Aquifer (Model Layer 11)**





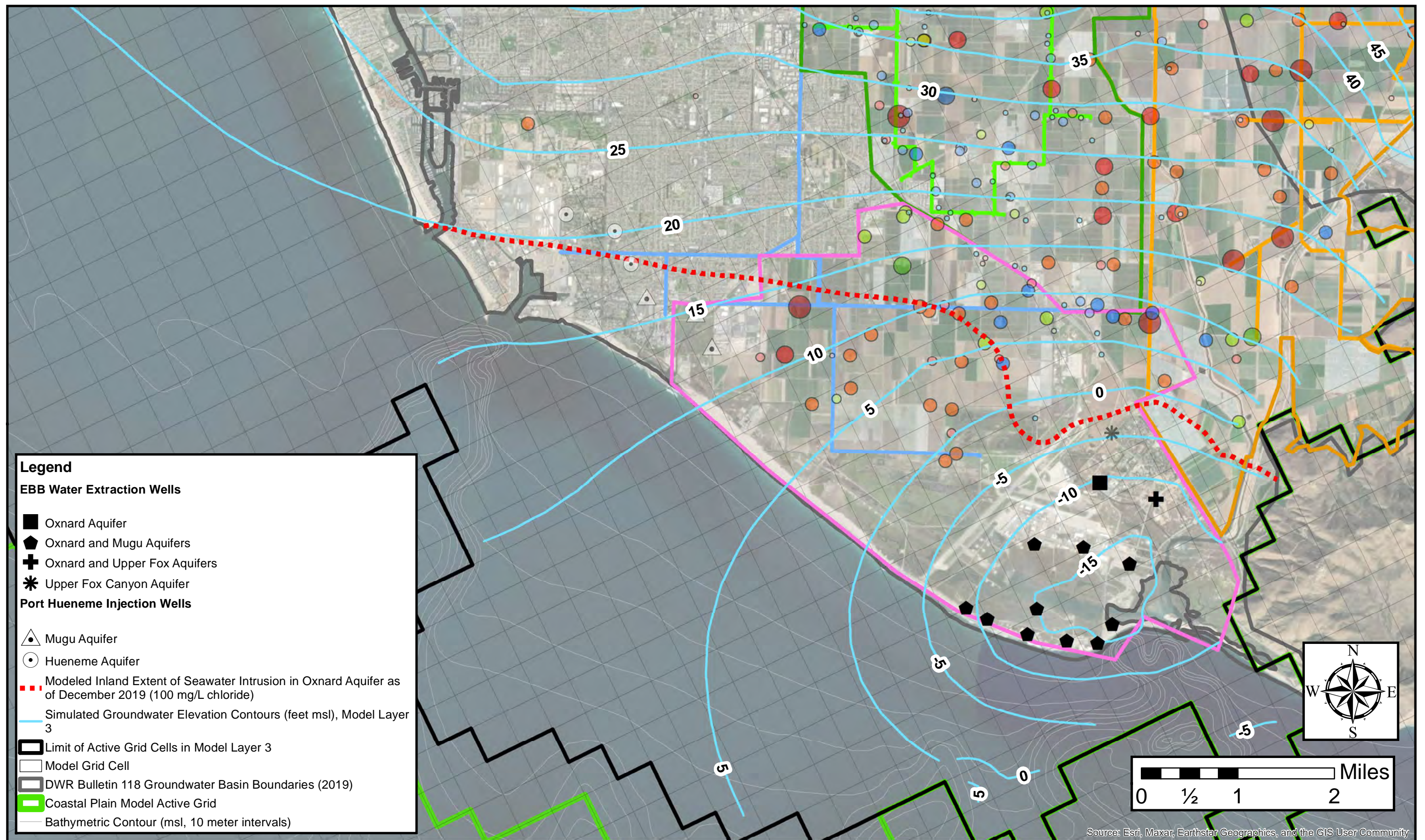
**Figure 26. Forecasted Particle Tracks for Hybrid Scenario with Injection Wells at Port Hueneme (S22)--Grimes Canyon Aquifer (Model Layer 13)**





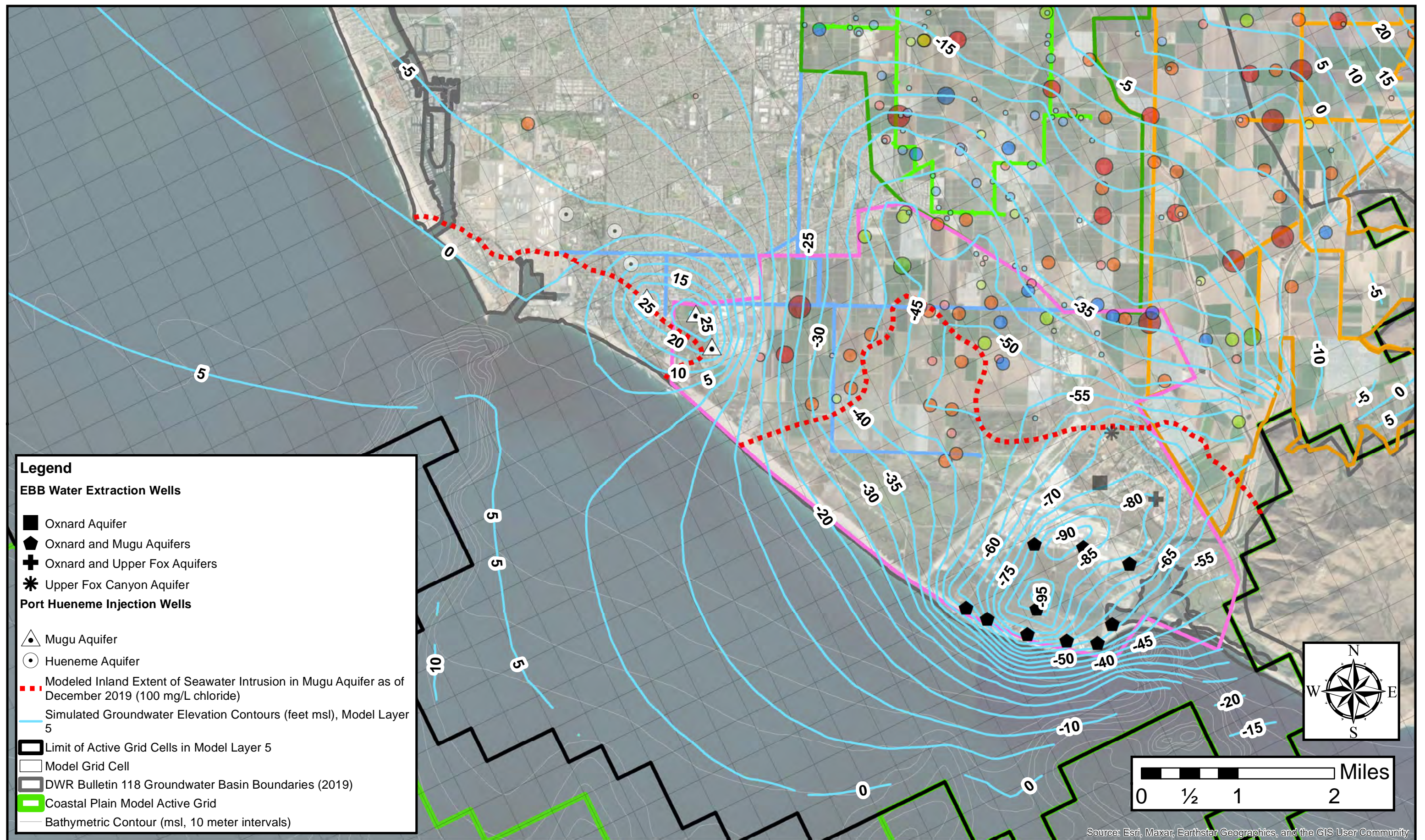
**Figure 27. Forecasted Groundwater Level Contours during Drought Periods for Hybrid Scenario with Injection Wells at Port Hueneme (S22)--Oxnard Aquifer (Model Layer 3)**





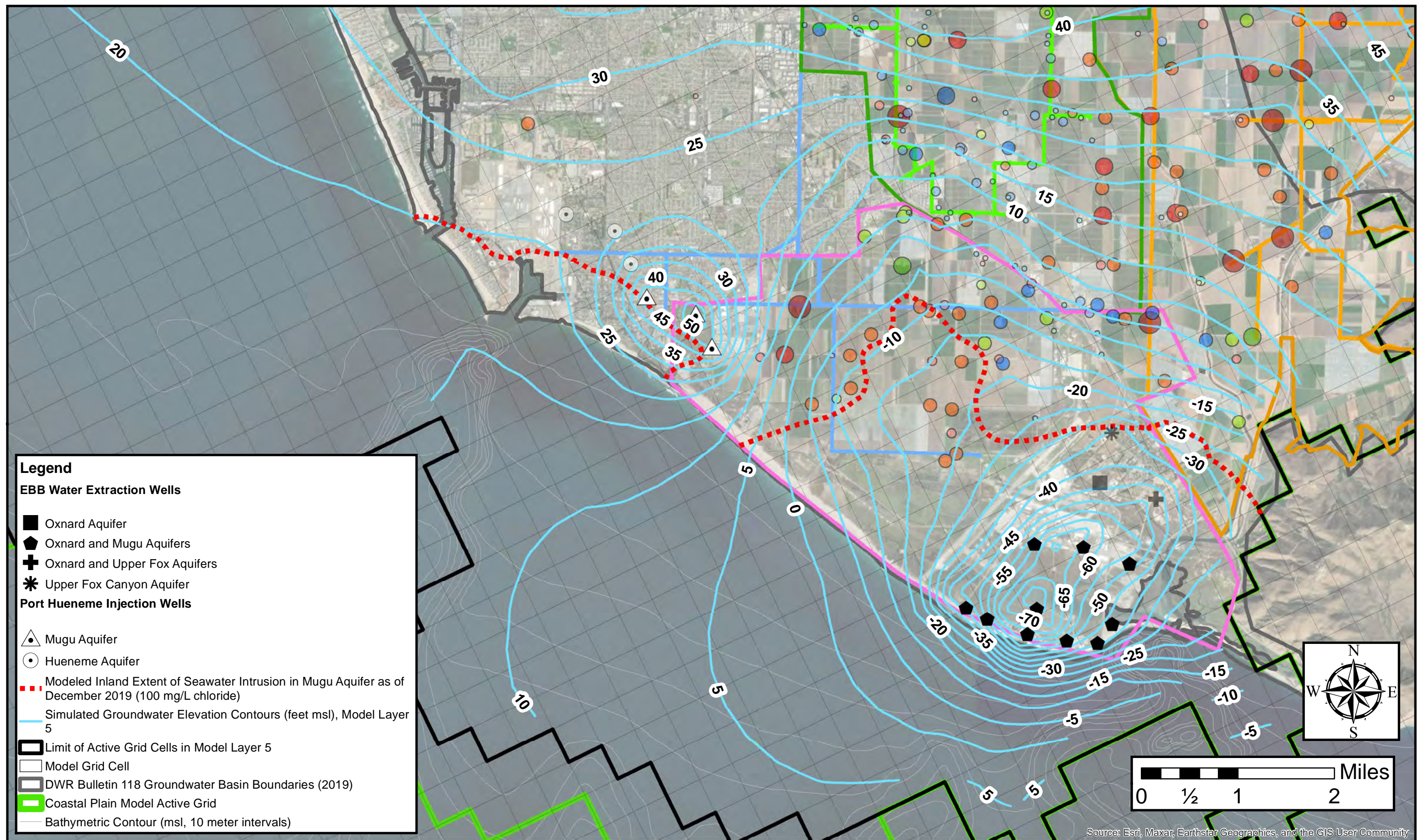
**Figure 28. Forecasted Groundwater Level Contours during Multi-Year Wet Periods for Hybrid Scenario with Injection Wells at Port Hueneme (S22)--Oxnard Aquifer (Model Layer 3)**





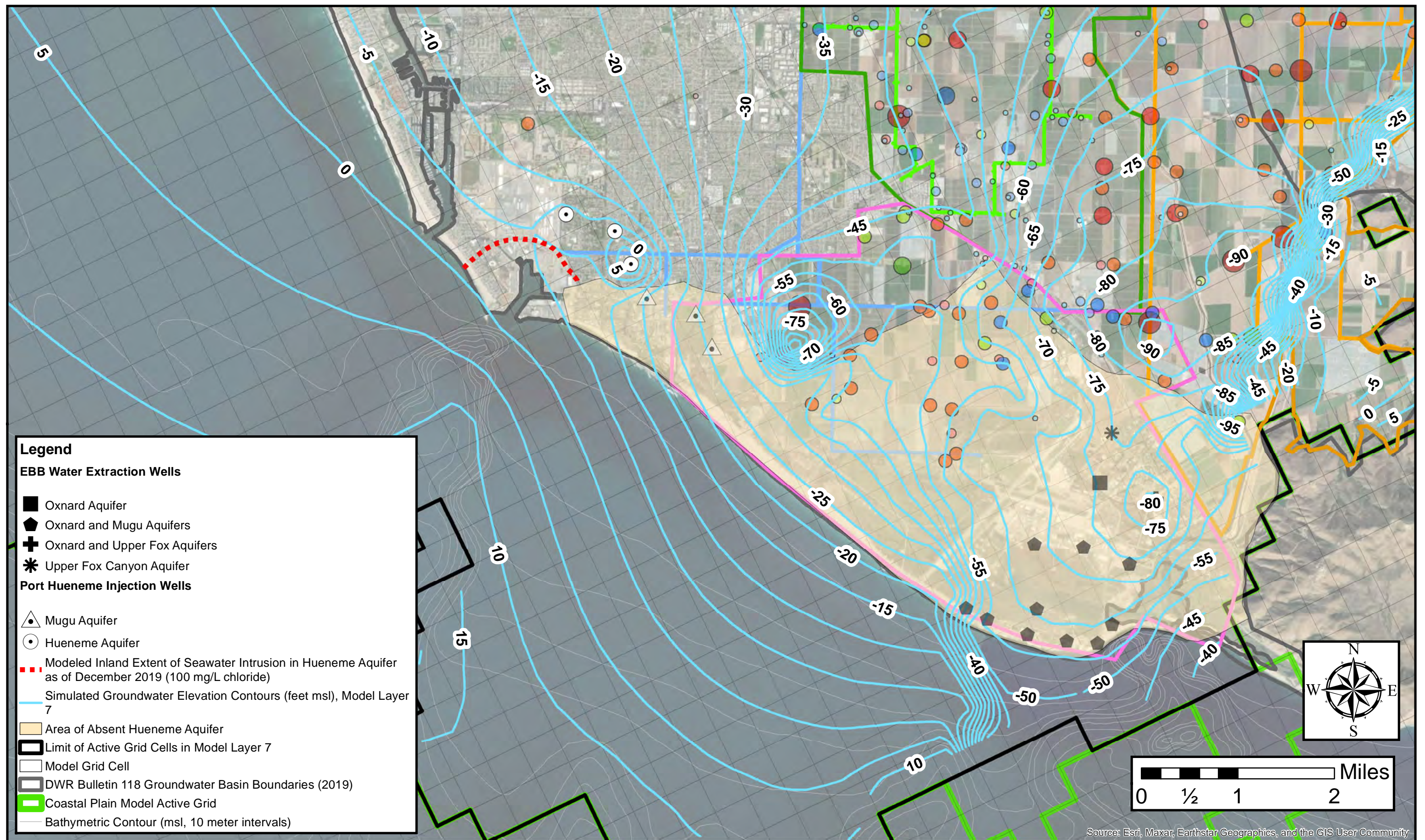
**Figure 29. Forecasted Groundwater Level Contours during Drought Periods for Hybrid Scenario with Injection Wells at Port Hueneme (S22)--Mugu Aquifer (Model Layer 5)**





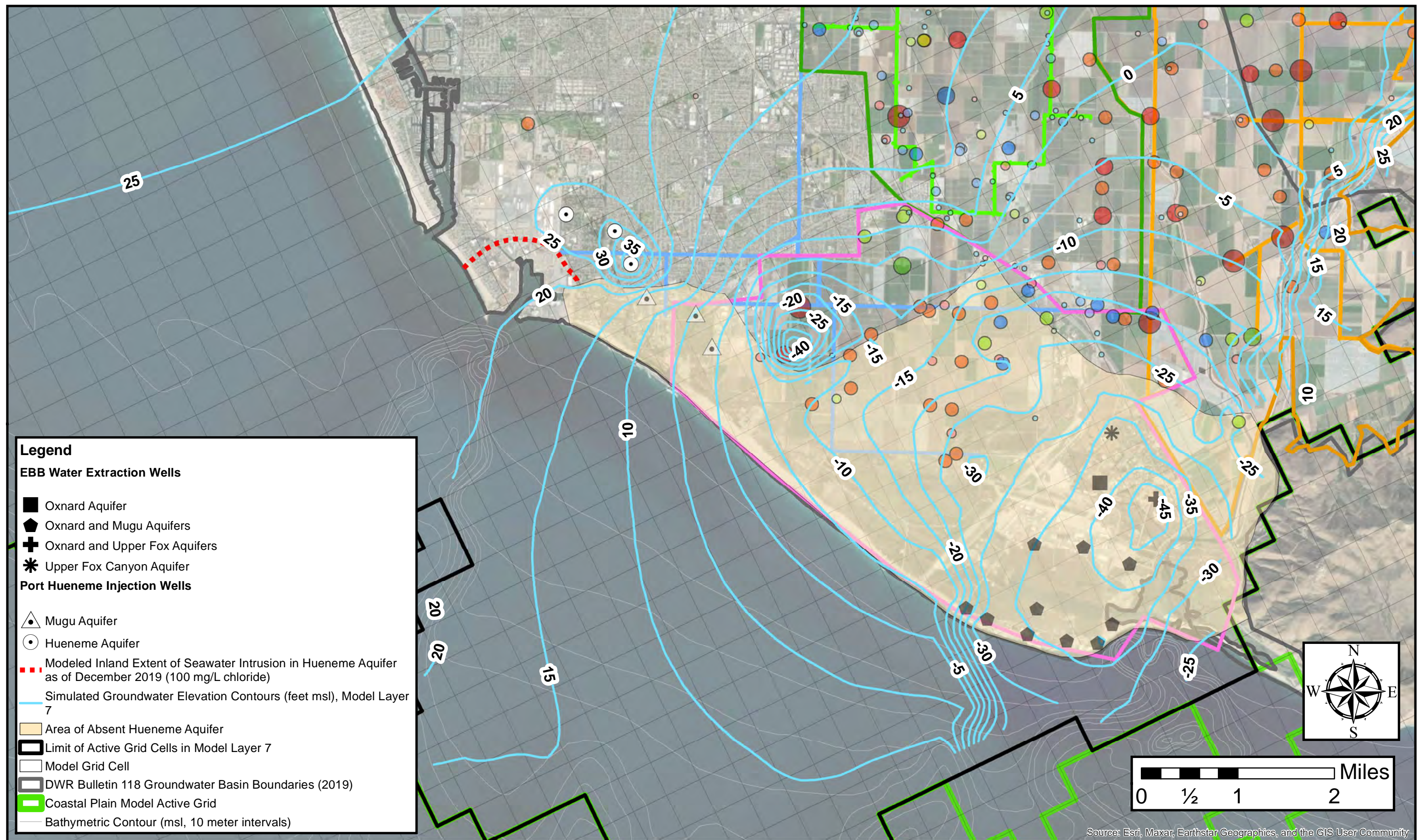
**Figure 30. Forecasted Groundwater Level Contours during Multi-Year Wet Periods for Hybrid Scenario with Injection Wells at Port Hueneme (S22)--Mugu Aquifer (Model Layer 5)**





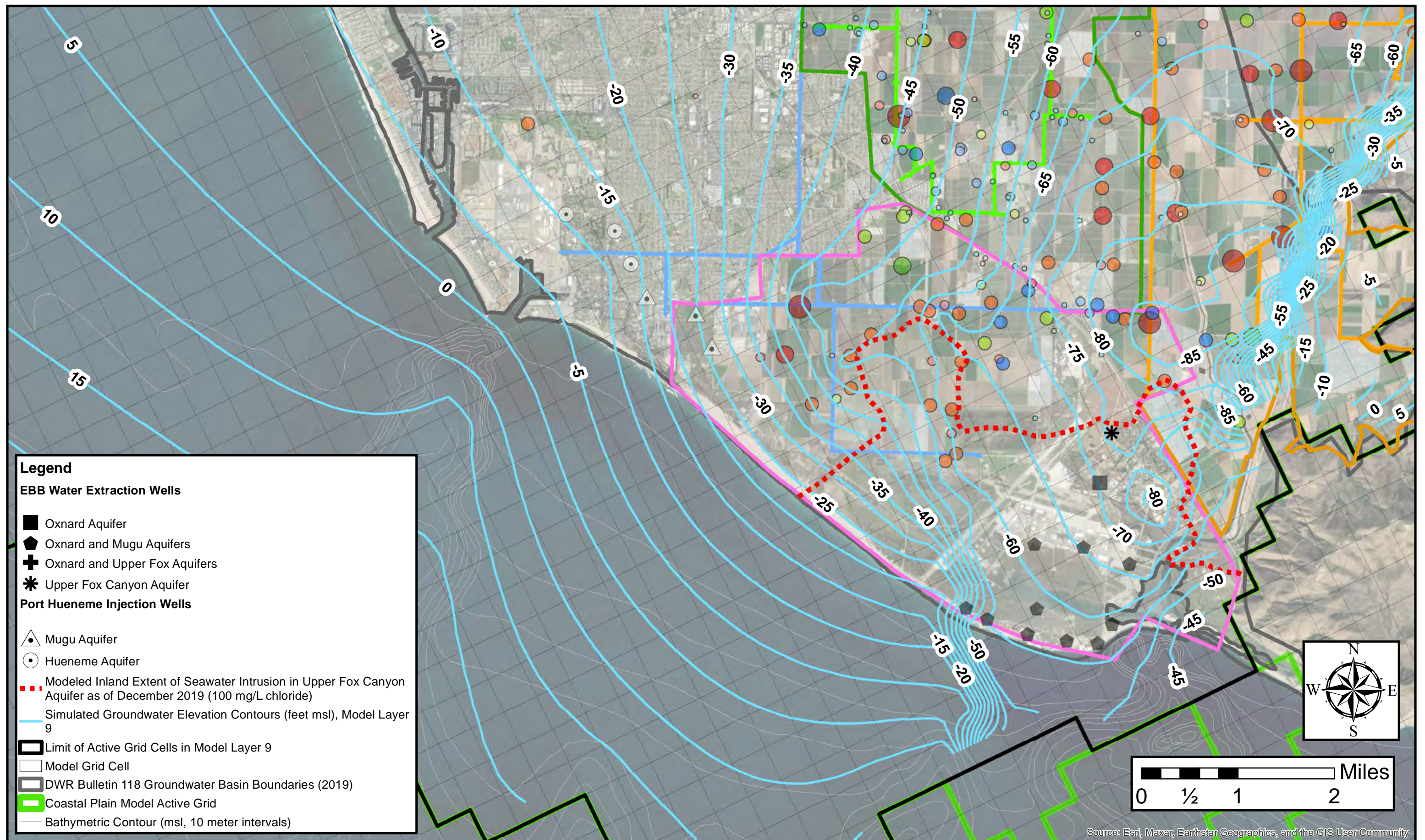
**Figure 31. Forecasted Groundwater Level Contours during Drought Periods for Hybrid Scenario with Injection Wells at Port Hueneme (S22)--Hueneme Aquifer (Model Layer 7)**





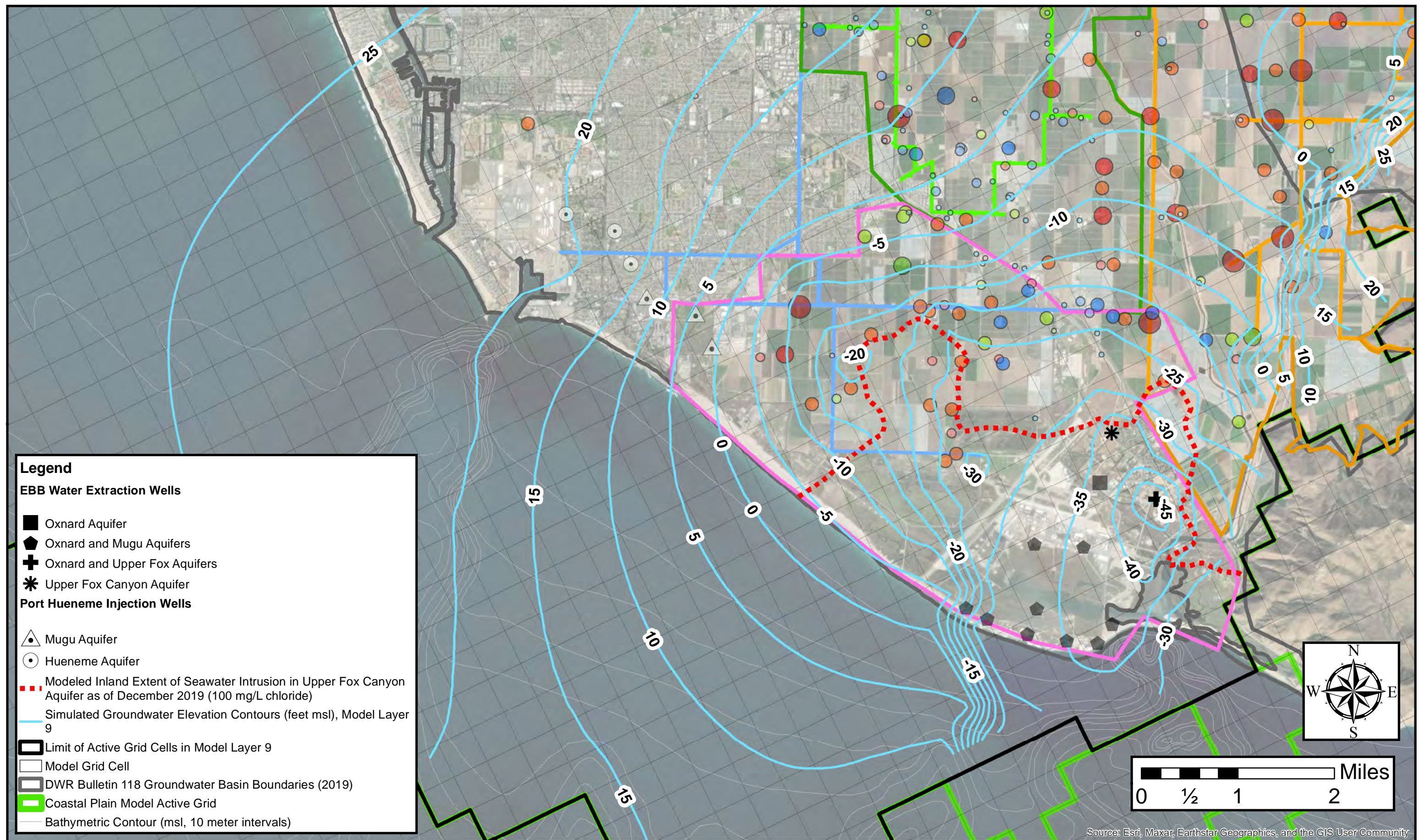
**Figure 32. Forecasted Groundwater Level Contours during Multi-Year Wet Periods for Hybrid Scenario with Injection Wells at Port Hueneme (S22)--Hueneme Aquifer (Model Layer 7)**





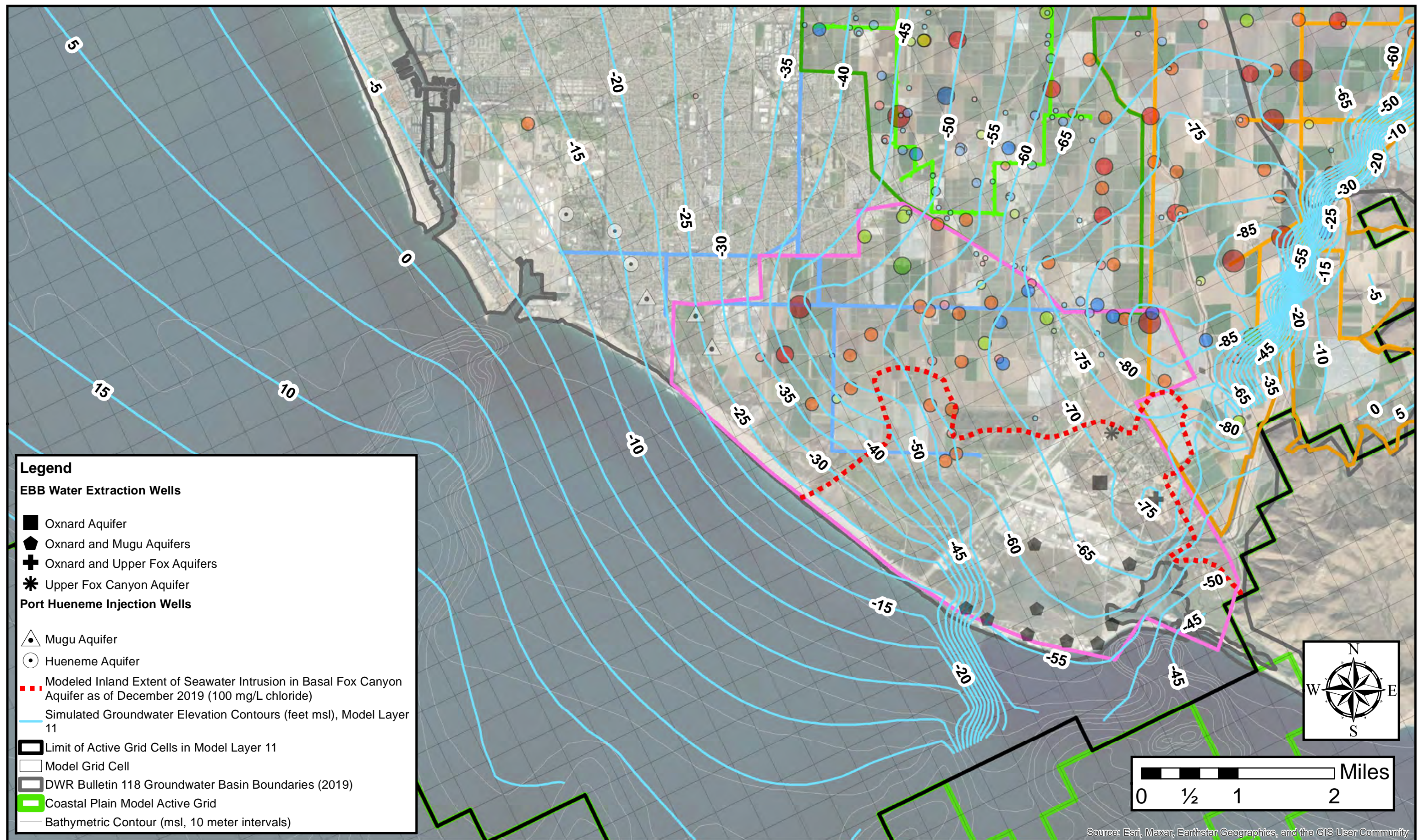
**Figure 33. Forecasted Groundwater Level Contours during Drought Periods for Hybrid Scenario with Injection Wells at Port Hueneme(S22)-- Upper Fox Canyon Aquifer (Model Layer 9)**





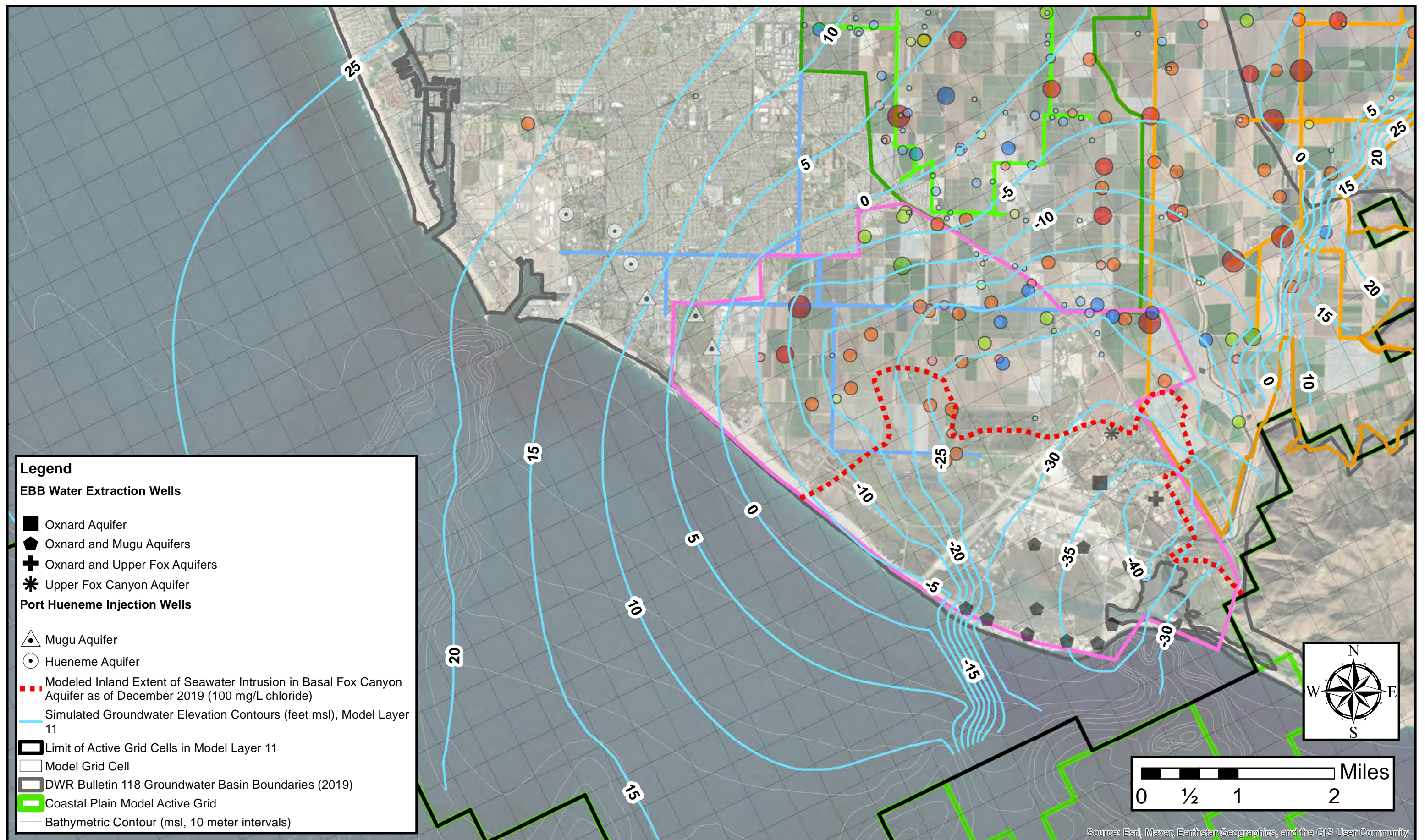
**Figure 34. Forecasted Groundwater Level Contours during Multi-Year Wet Periods for Hybrid Scenario with Injection Wells at Port Hueneme (S22)--Upper Fox Canyon Aquifer (Model Layer 9)**





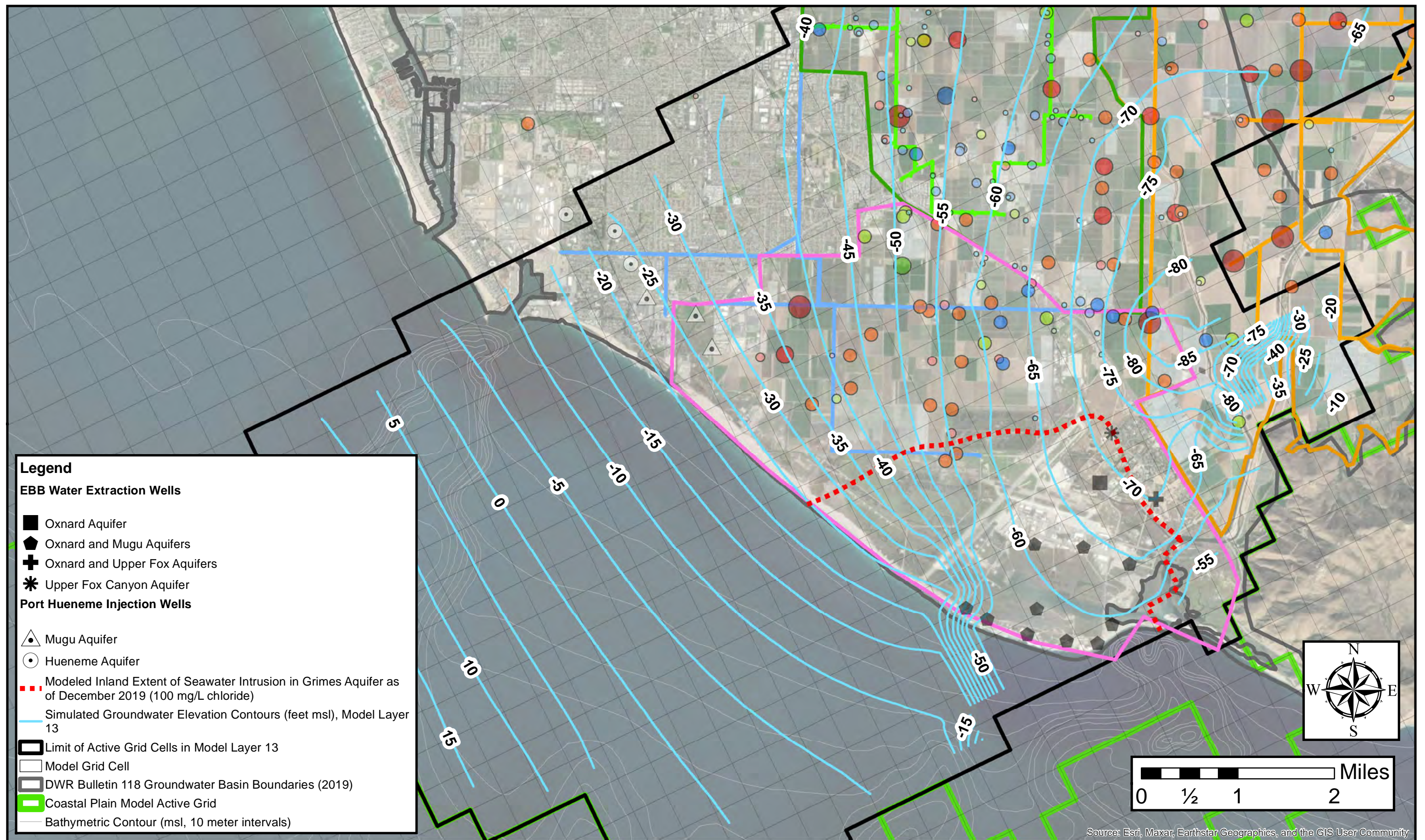
**Figure 35. Forecasted Groundwater Level Contours during Drought Periods for Hybrid Scenario with Injection Wells at Port Hueneme (S22)-- Basal Fox Canyon Aquifer (Model Layer 11)**





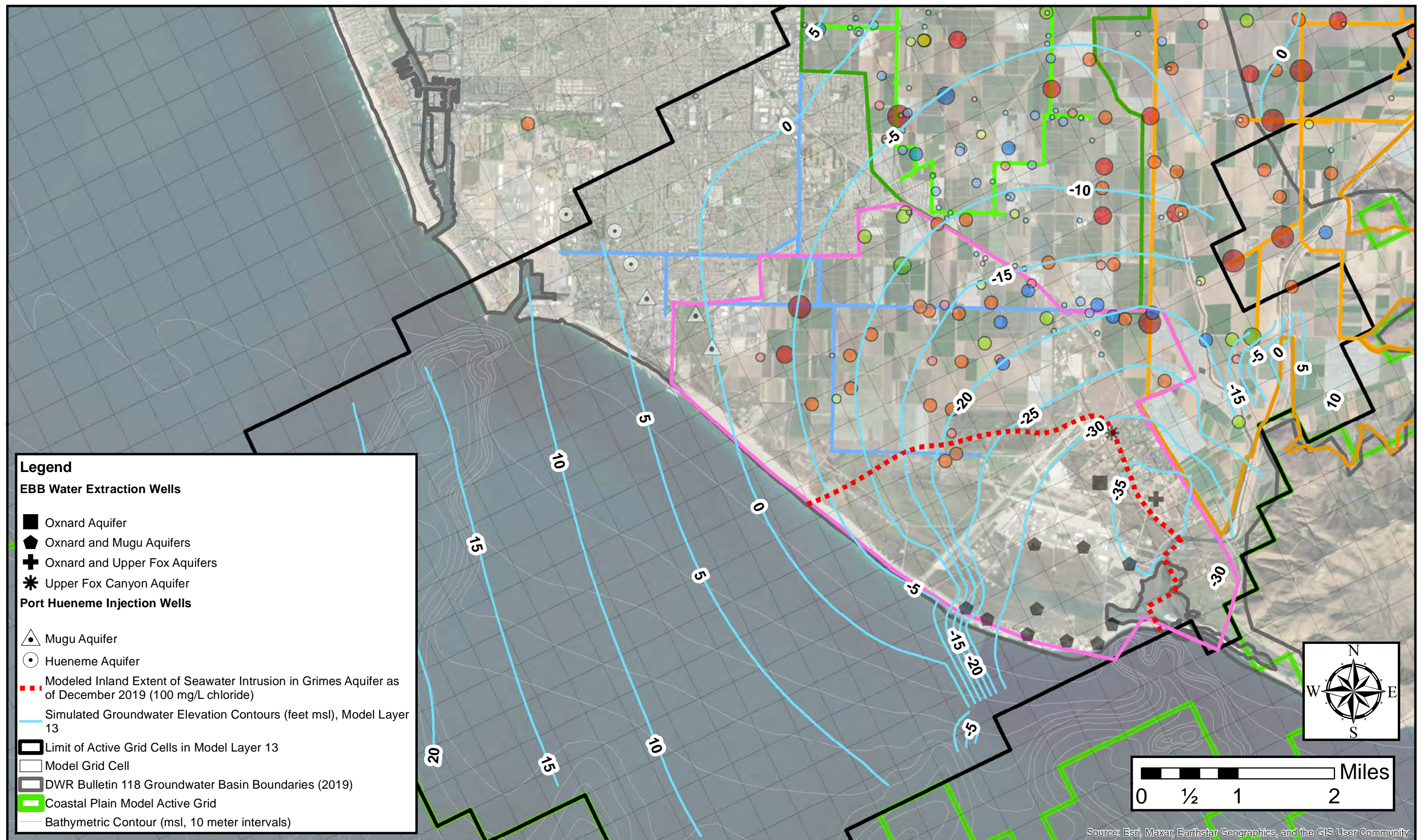
**Figure 36. Forecasted Groundwater Level Contours during Multi-Year Wet Periods for Hybrid Scenario with Injection Wells at Port Hueneme (S22)--Basal Fox Canyon Aquifer (Model Layer 11)**





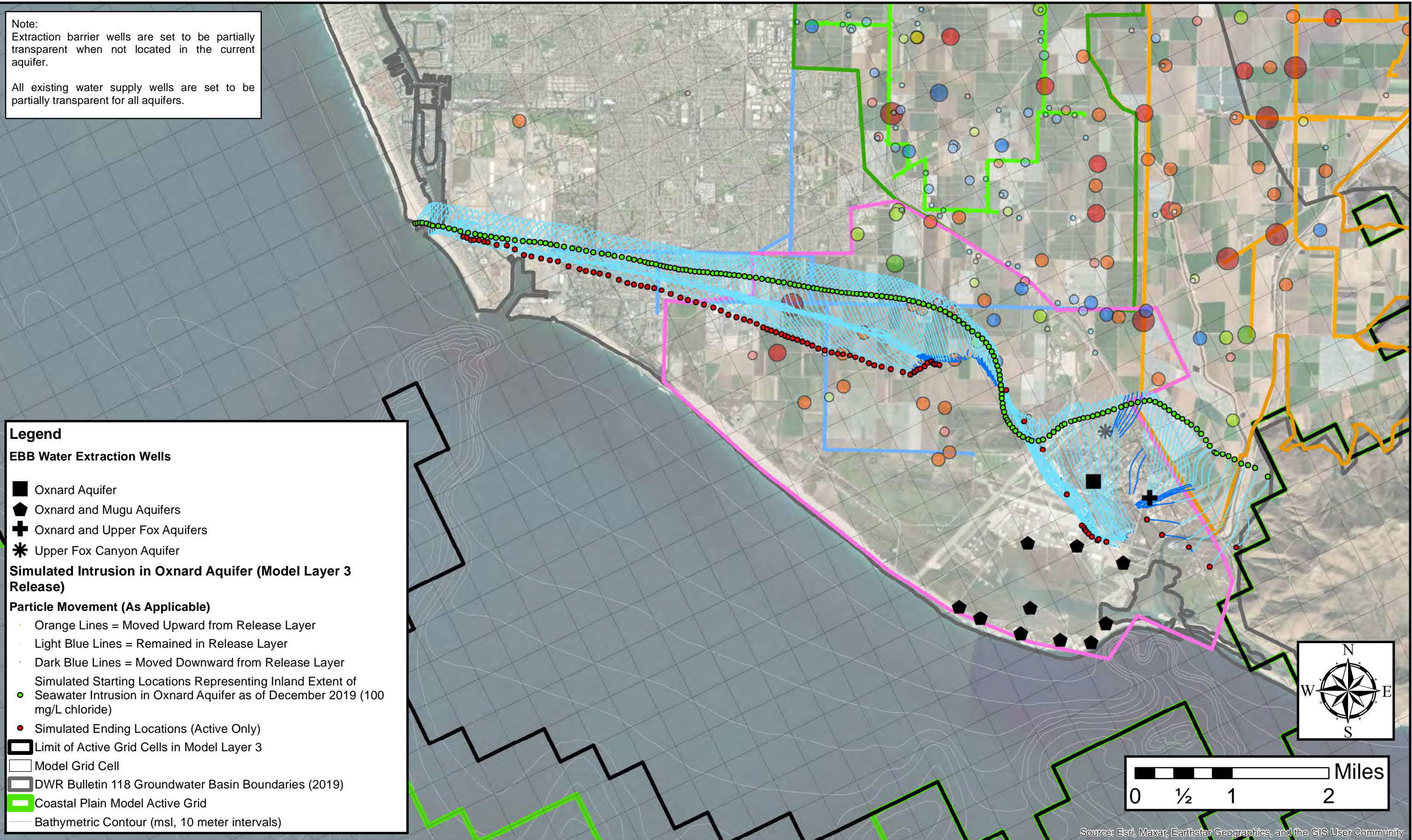
**Figure 37. Forecasted Groundwater Level Contours during Drought Periods for Hybrid Scenario with Injection Wells at Port Hueneme (S22)--Grimes Canyon Aquifer (Model Layer 13)**





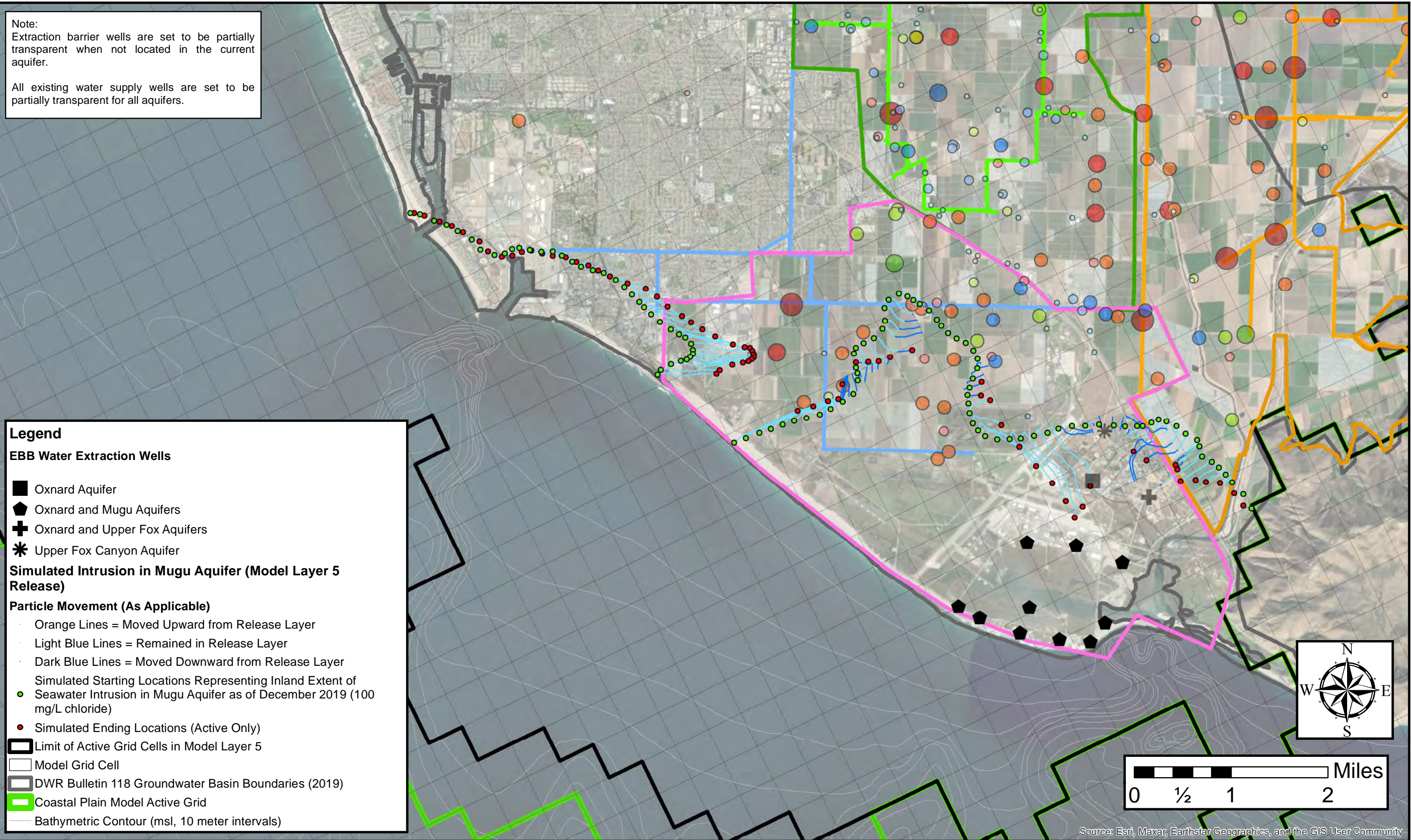
**Figure 38. Forecasted Groundwater Level Contours during Multi-Year Wet Periods for Hybrid Scenario with Injection Wells at Port Hueneme (S22)--Grimes Canyon Aquifer (Model Layer 13)**





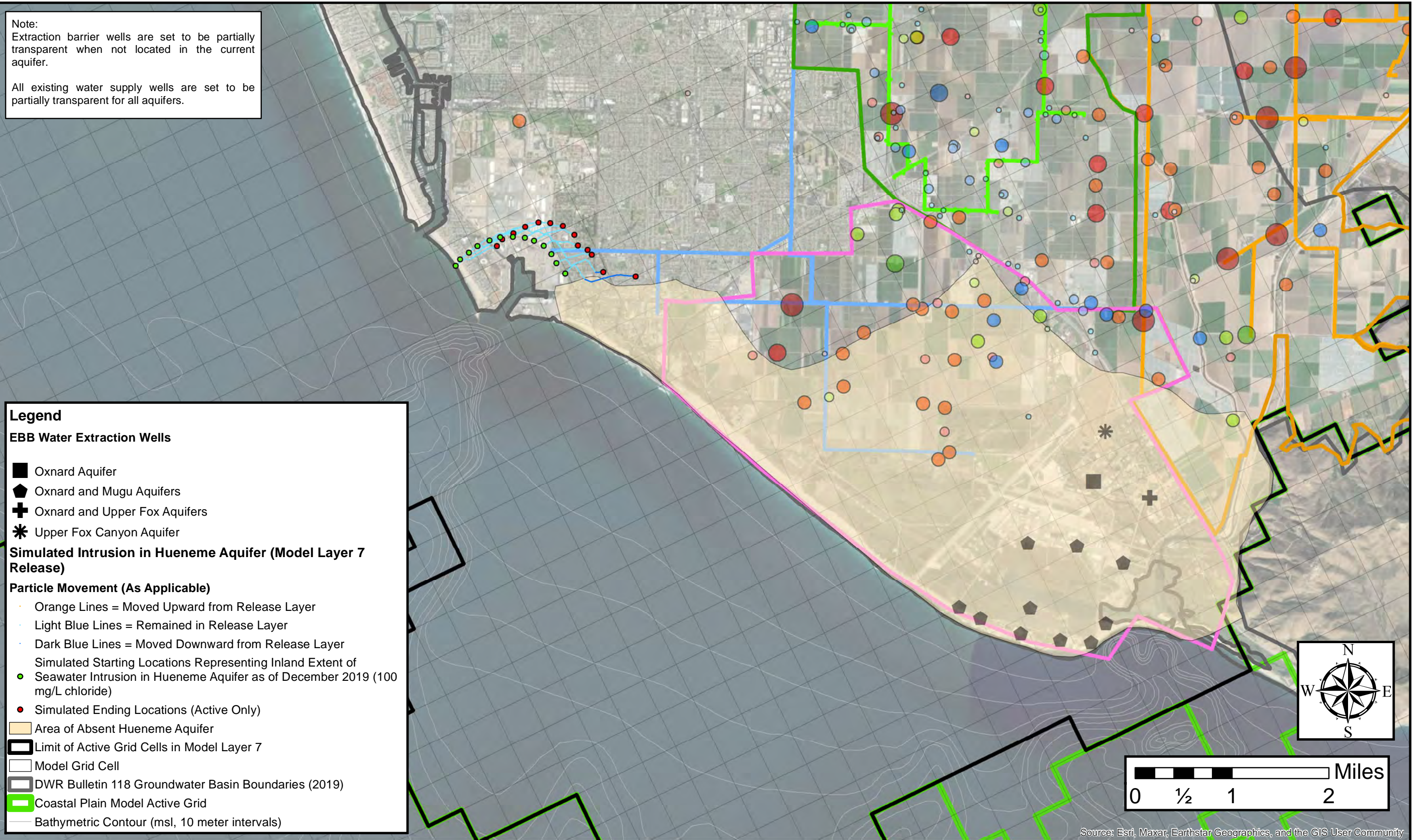
**Figure 39. Forecasted Particle Tracks for Hybrid Scenario without Injection Wells at Port Hueneme (S23)--Oxnard Aquifer (Model Layer 3)**





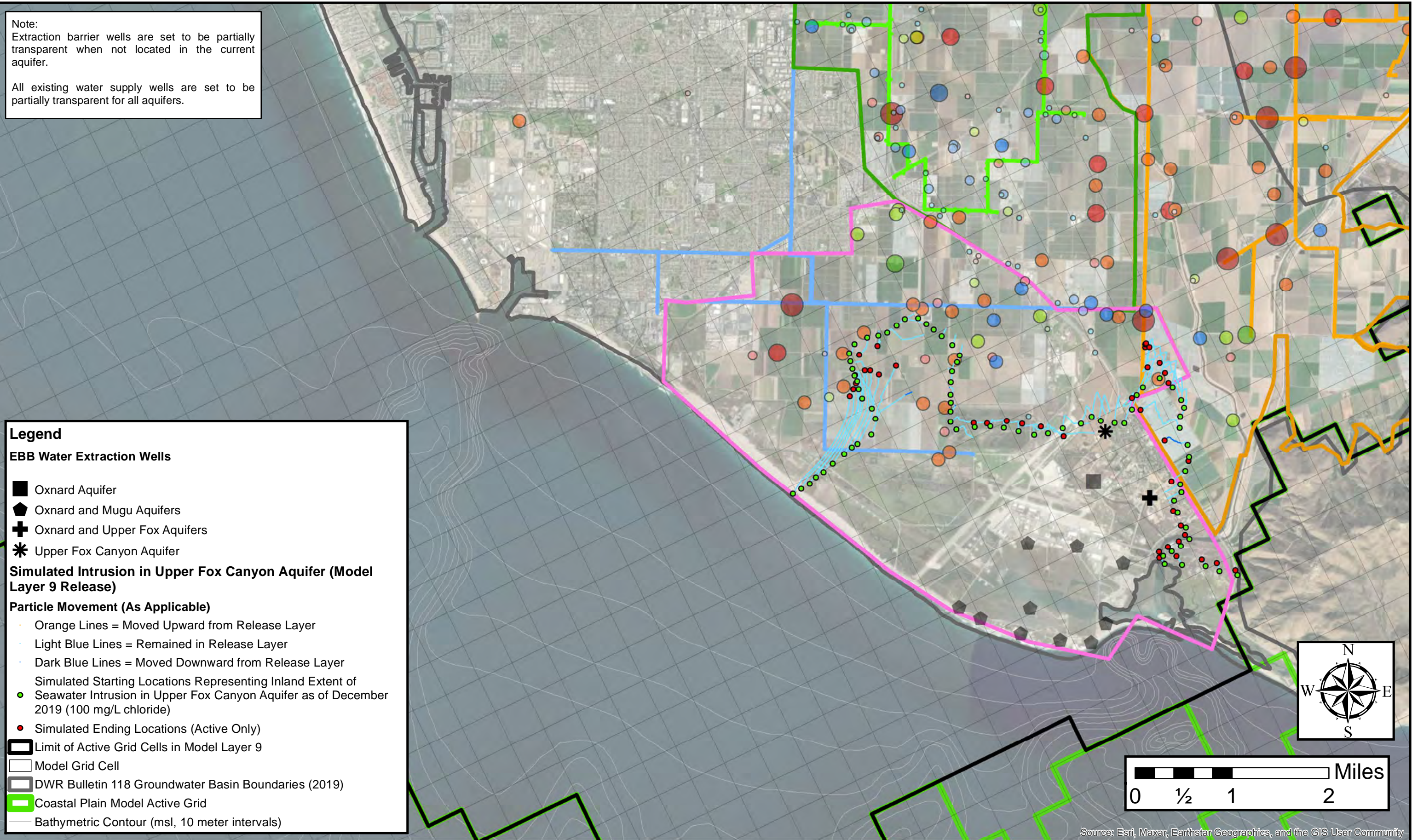
**Figure 40. Forecasted Particle Tracks for Hybrid Scenario without Injection Wells at Port Hueneme (S23)--Mugu Aquifer (Model Layer 5)**





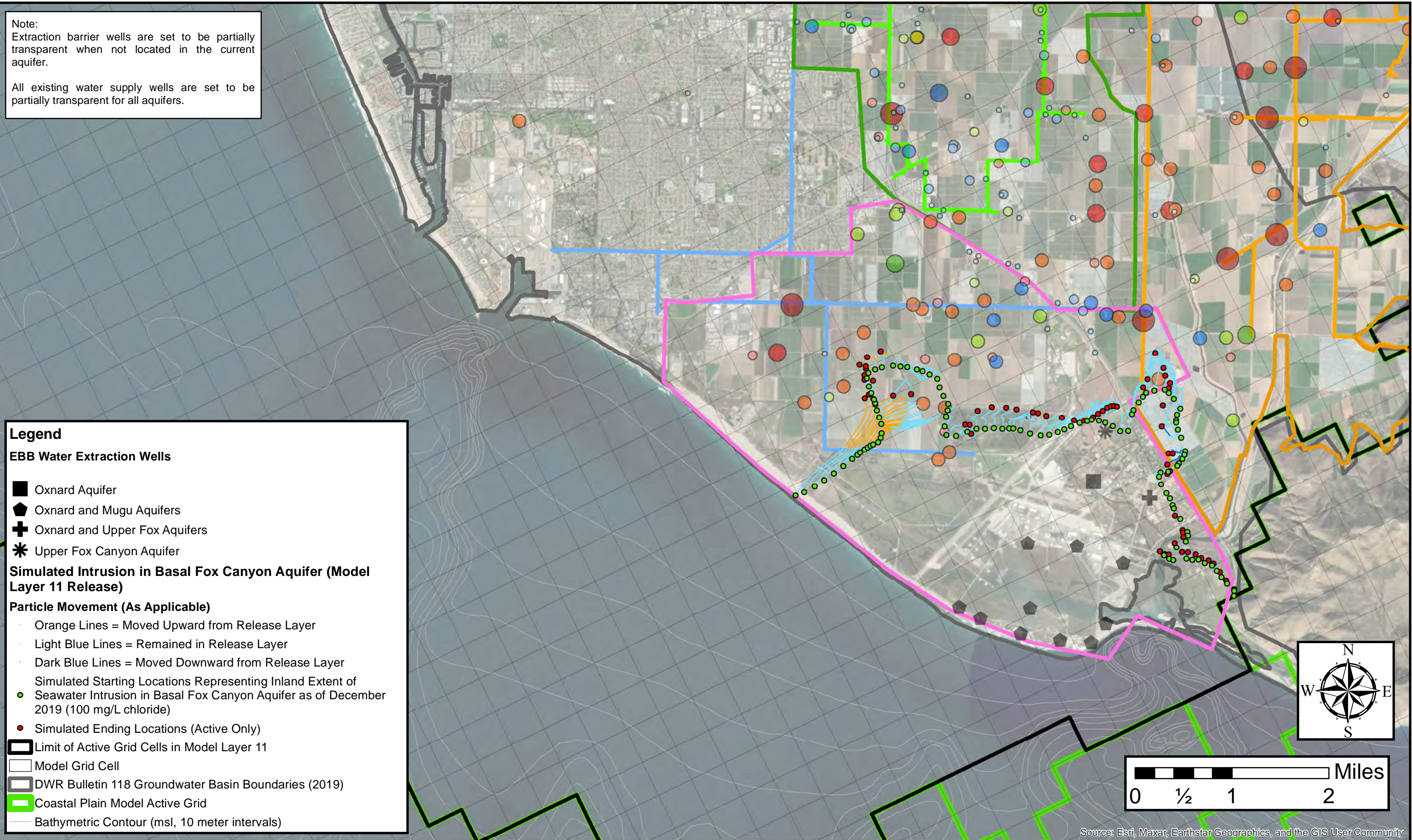
**Figure 41. Forecasted Particle Tracks for Hybrid Scenario without Injection Wells at Port Hueneme (S23)--Hueneme Aquifer (Model Layer 7)**





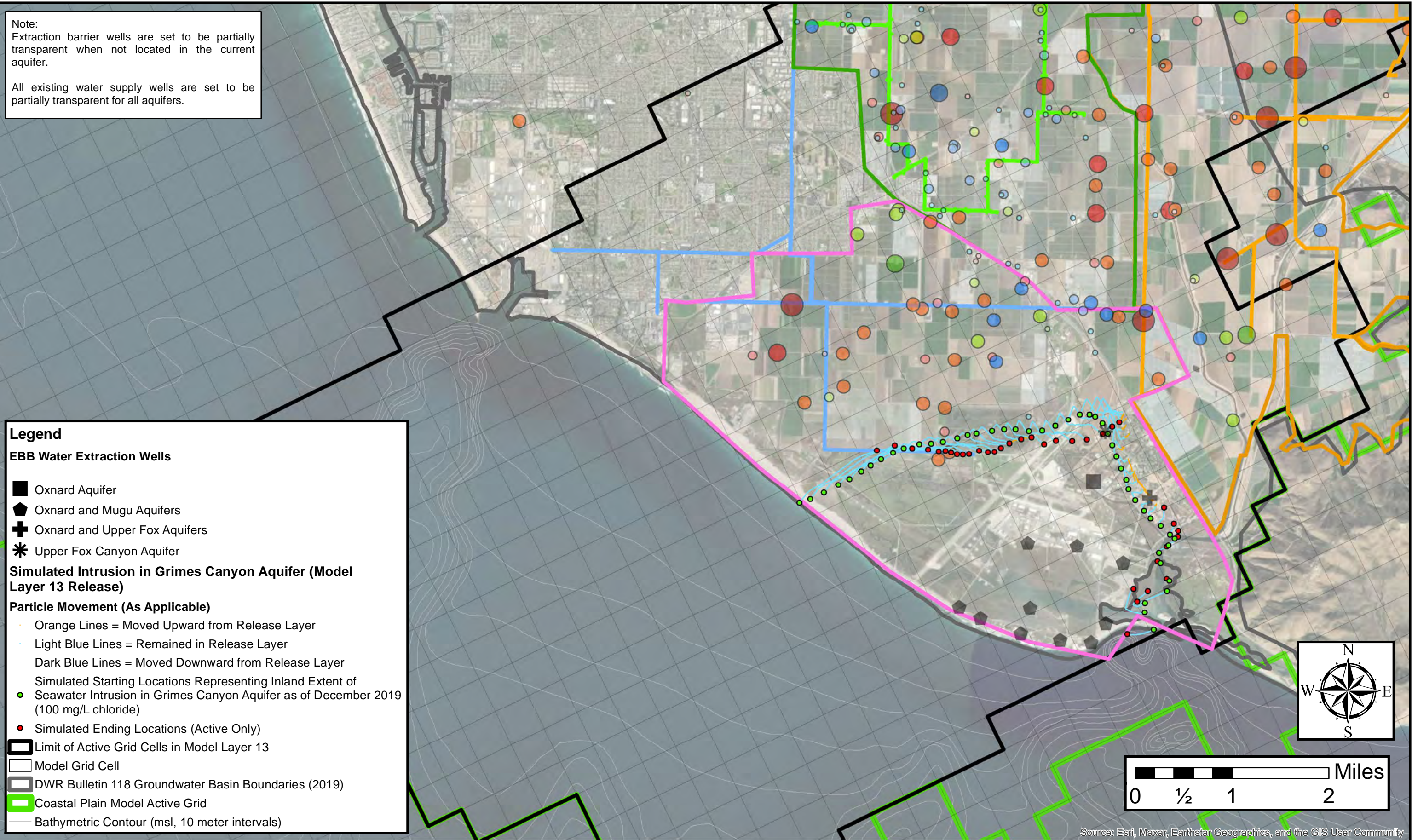
**Figure 42. Forecasted Particle Tracks for Hybrid Scenario without Injection Wells at Port Hueneme (S23)--Upper Fox Canyon Aquifer (Model Layer 9)**





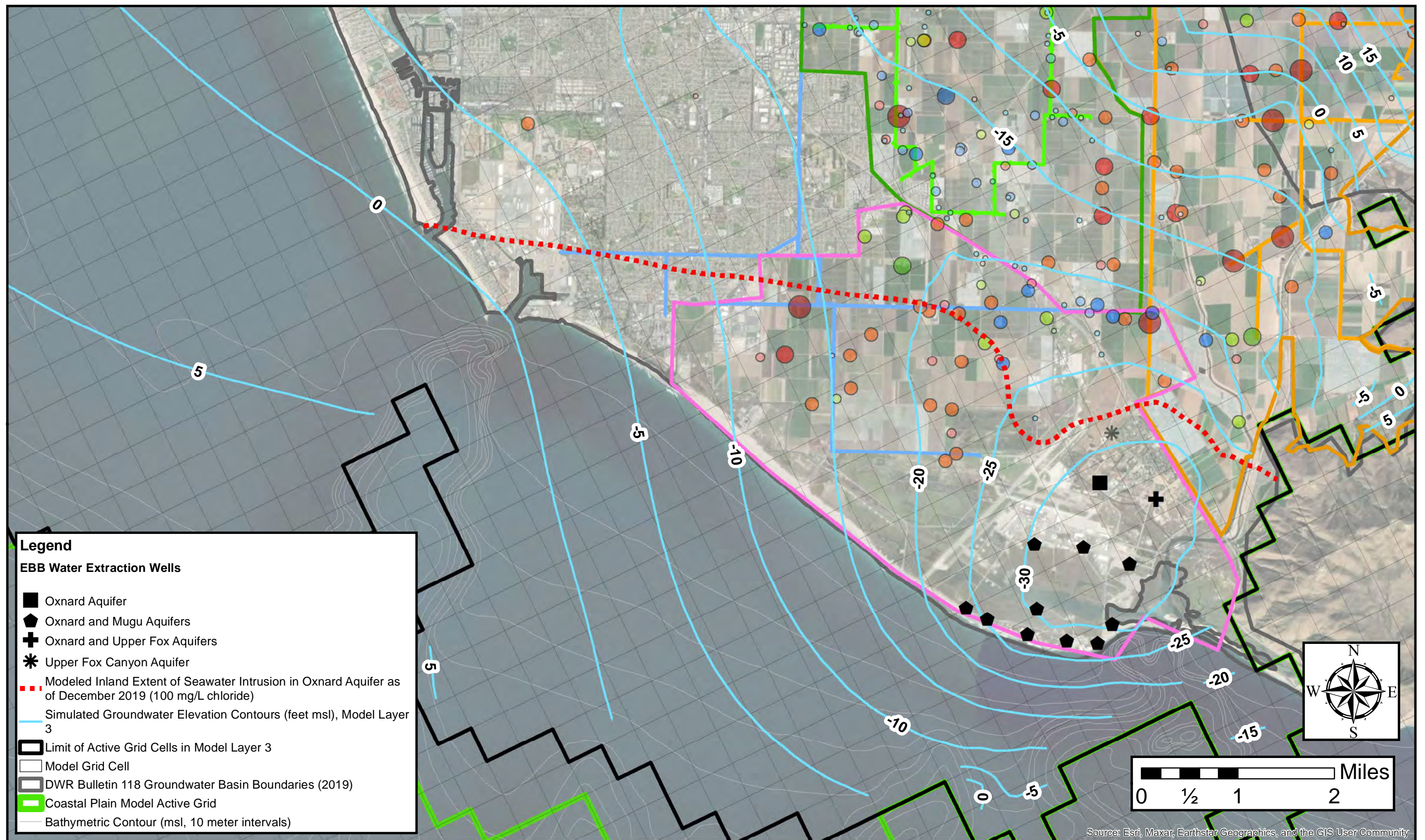
**Figure 43. Forecasted Particle Tracks for Hybrid Scenario without Injection Wells at Port Hueneme (S23)--Basal Fox Canyon Aquifer (Model Layer 11)**



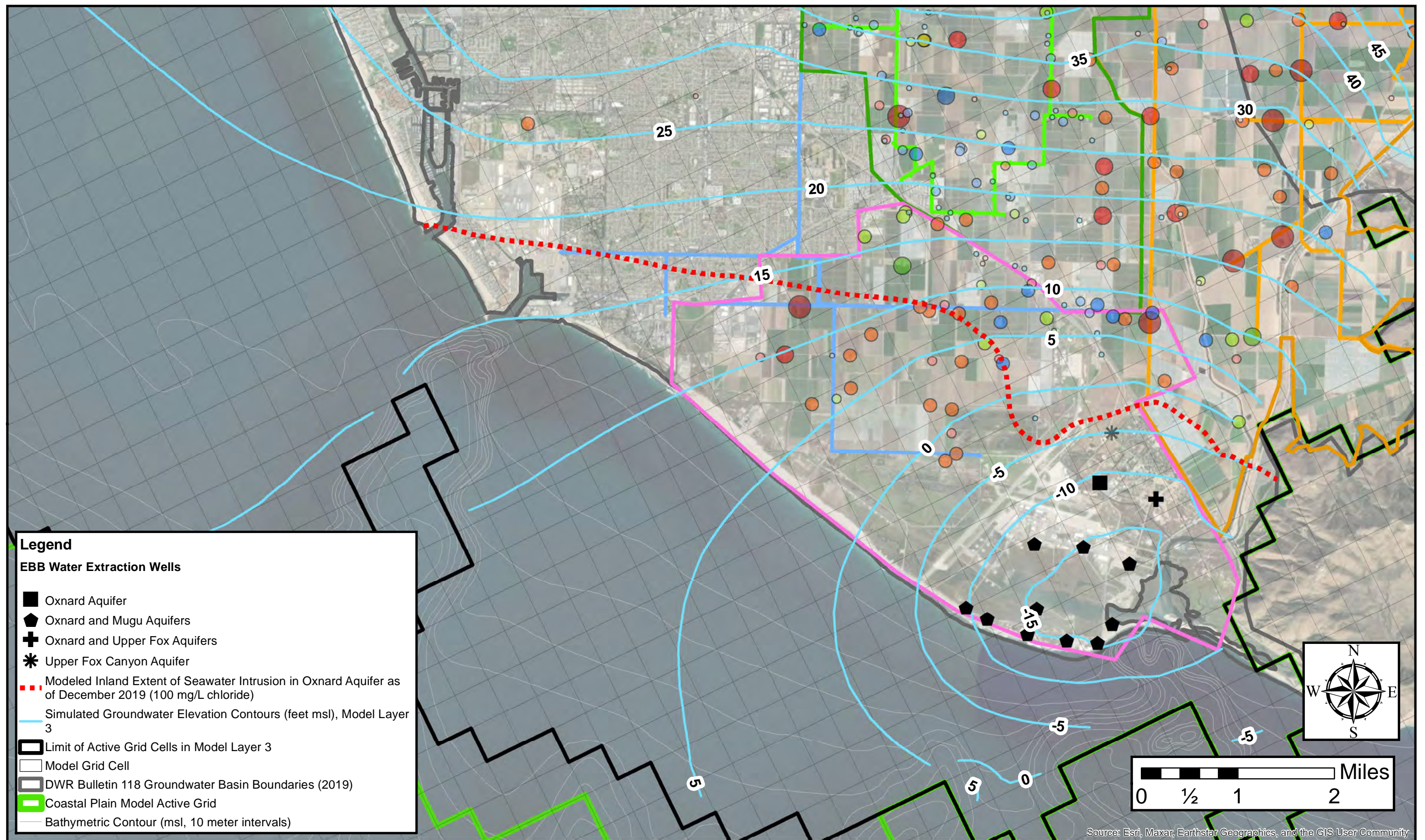


**Figure 44. Forecasted Particle Tracks for Hybrid Scenario without Injection Wells at Port Hueneme (S23)--Grimes Canyon Aquifer (Model Layer 13)**



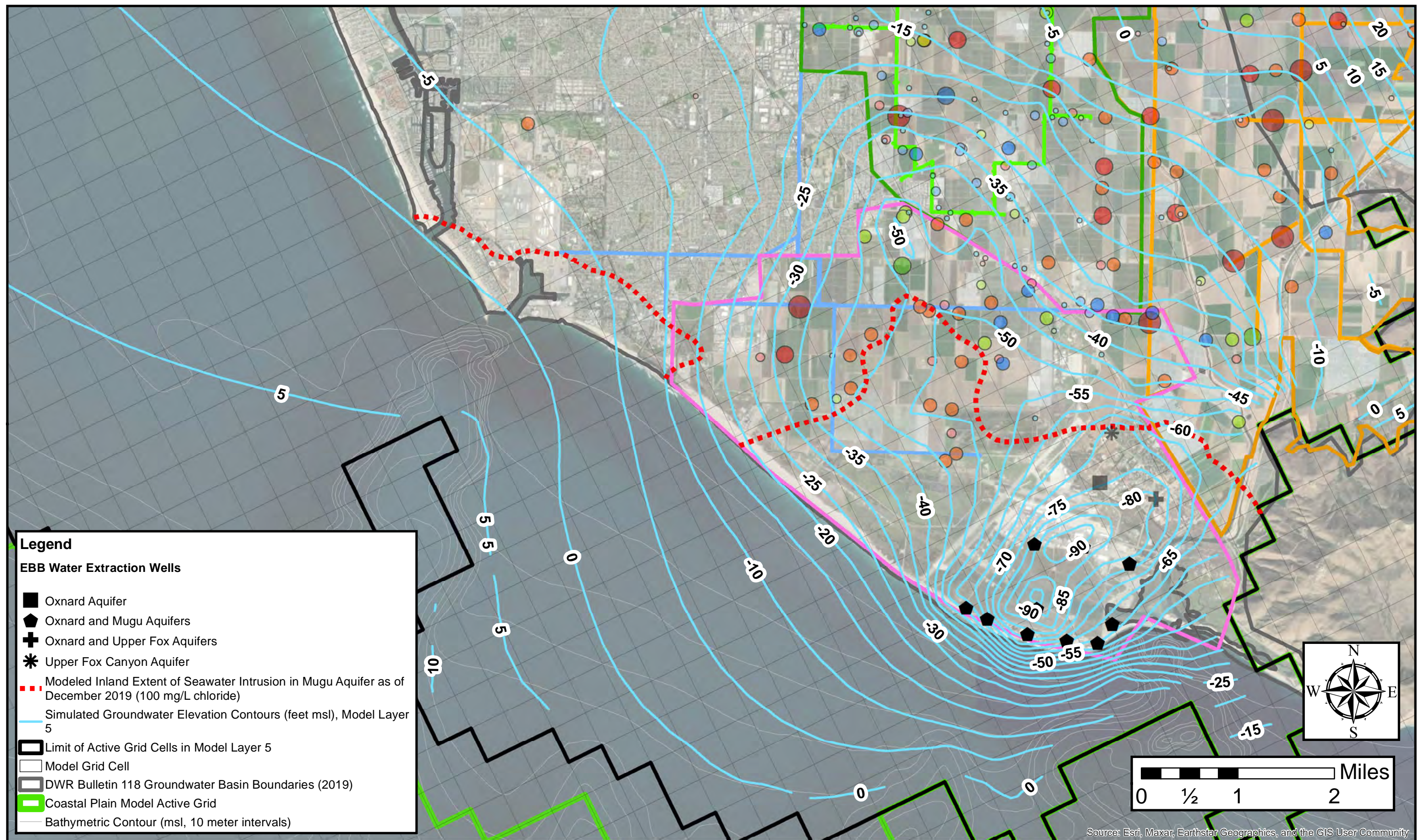






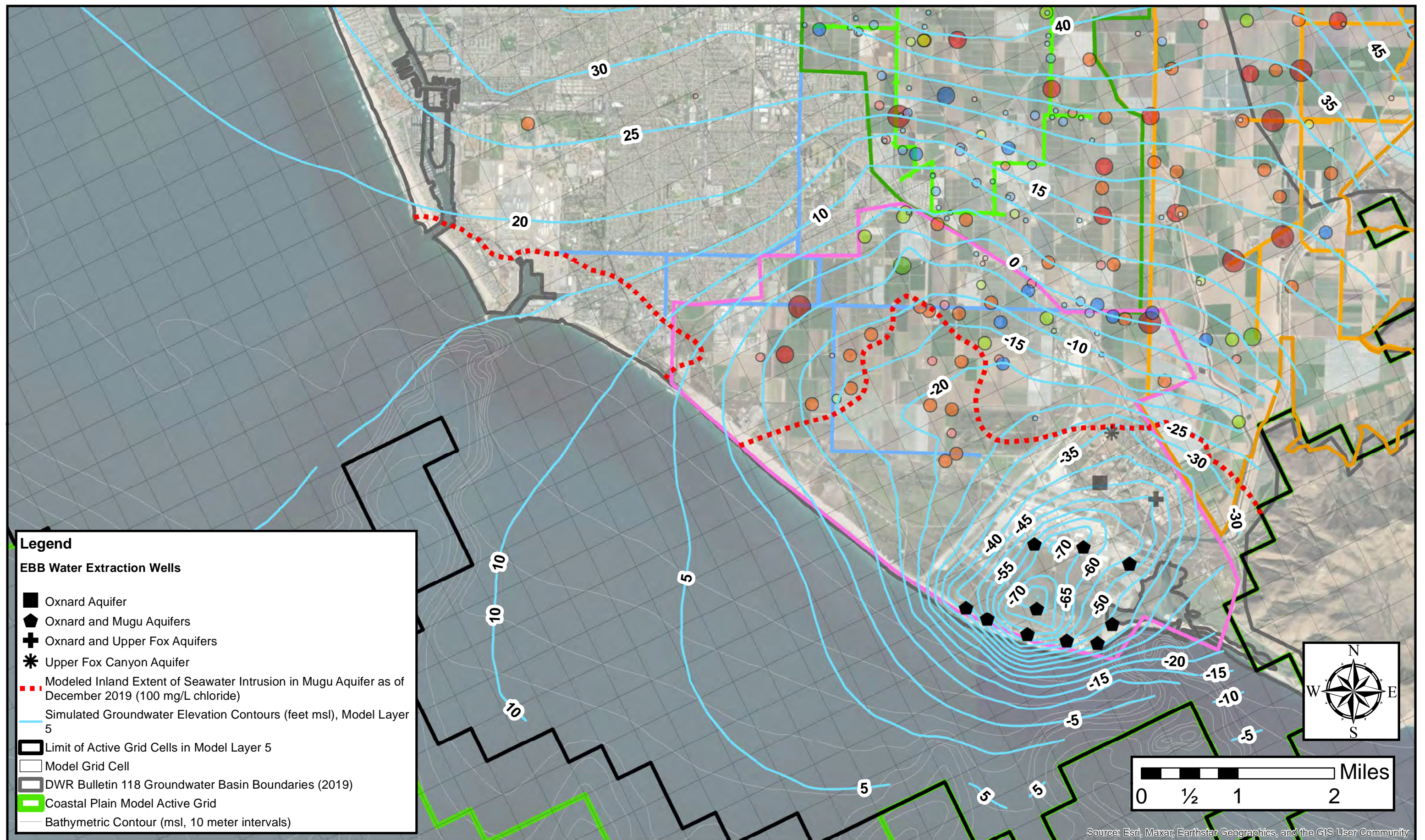
**Figure 46. Forecasted Groundwater Level Contours during Multi-Year Wet Periods for Hybrid Scenario without Injection Wells at Port Hueneme (S23)--Oxnard Aquifer (Model Layer 3)**





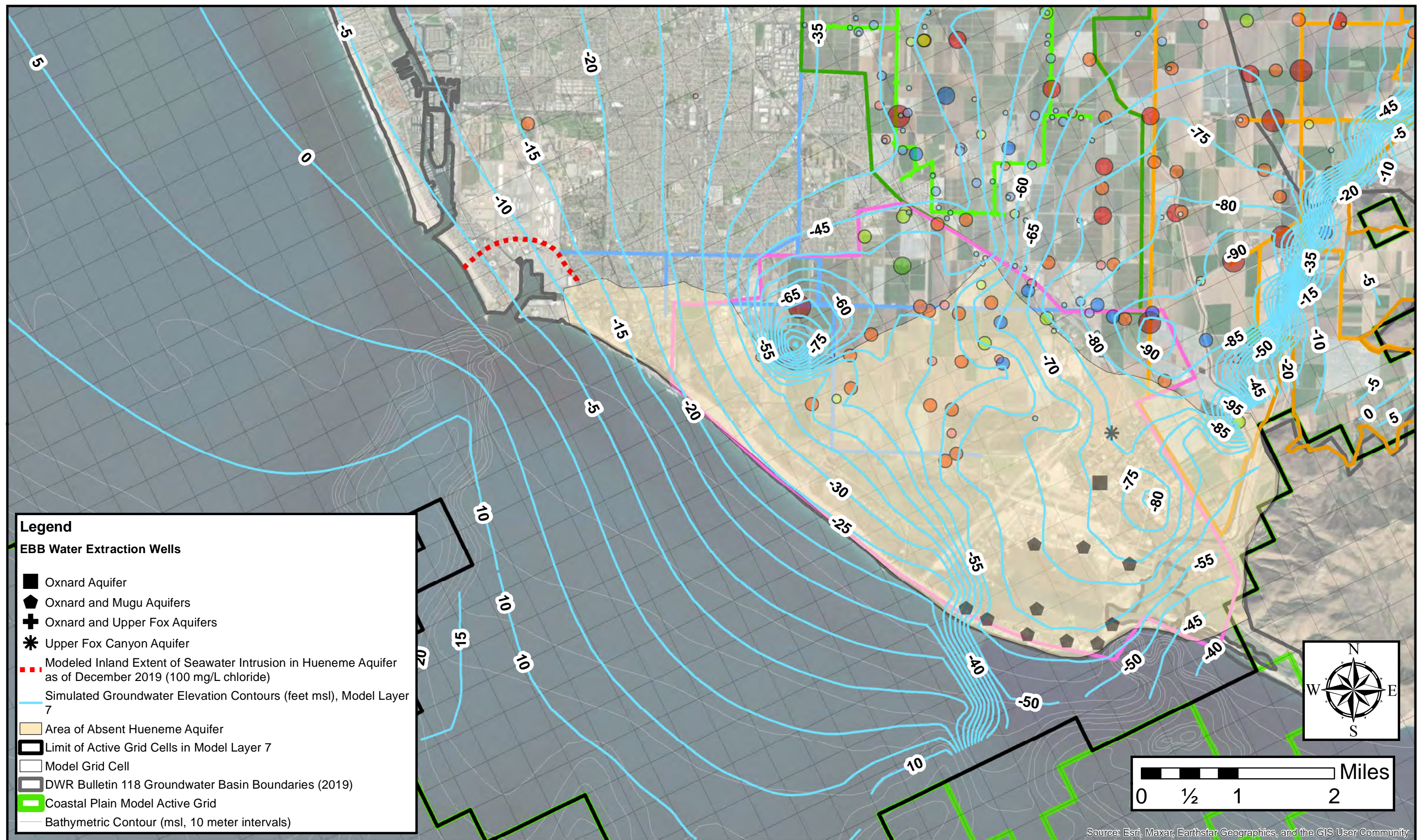
**Figure 47. Forecasted Groundwater Level Contours during Drought Periods for Hybrid Scenario without Injection Wells at Port Hueneme (S23)--Mugu Aquifer (Model Layer 5)**





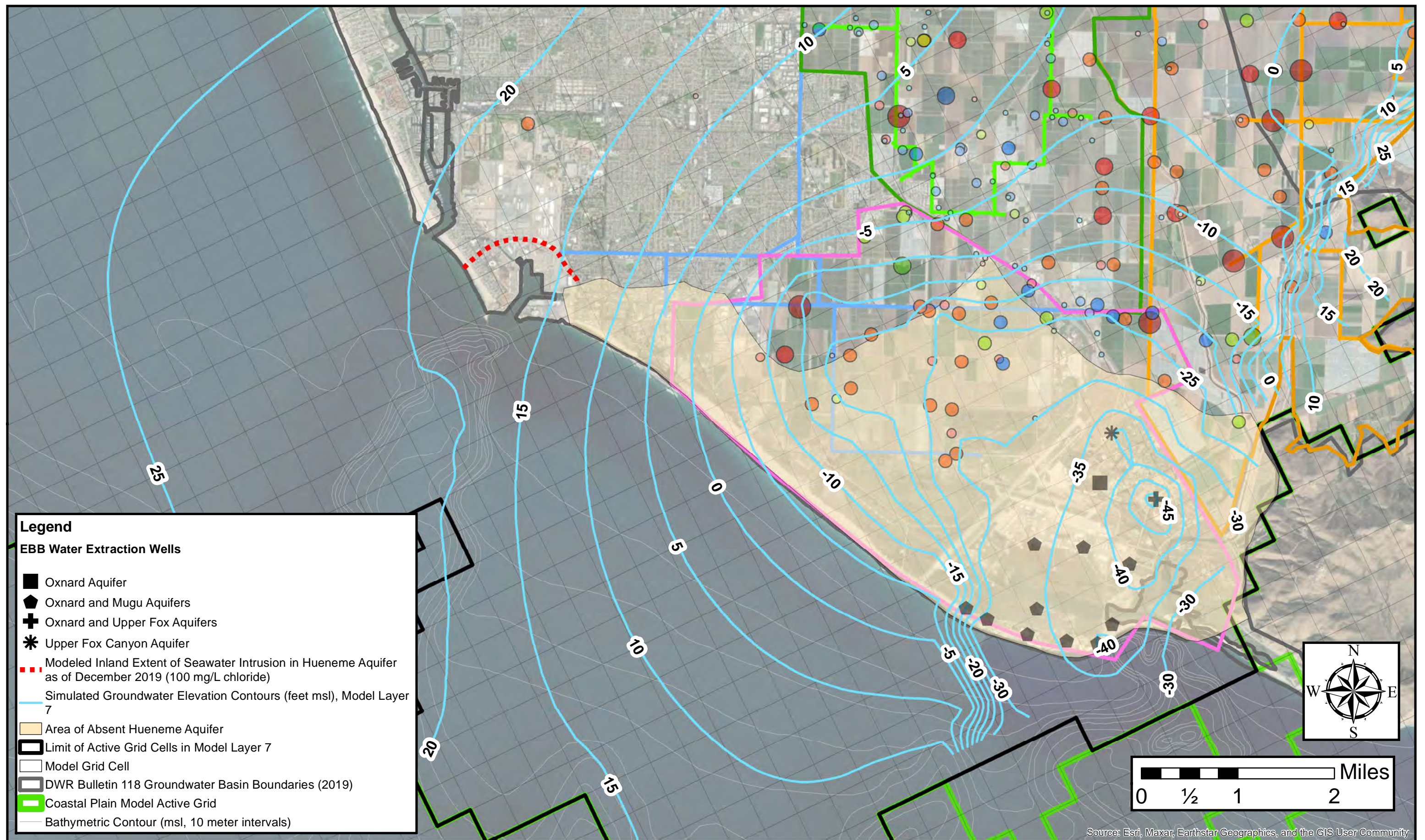
**Figure 48. Forecasted Groundwater Level Contours during Multi-Year Wet Periods for Hybrid Scenario without Injection Wells at Port Hueneme (S23)--Mugu Aquifer (Model Layer 5)**





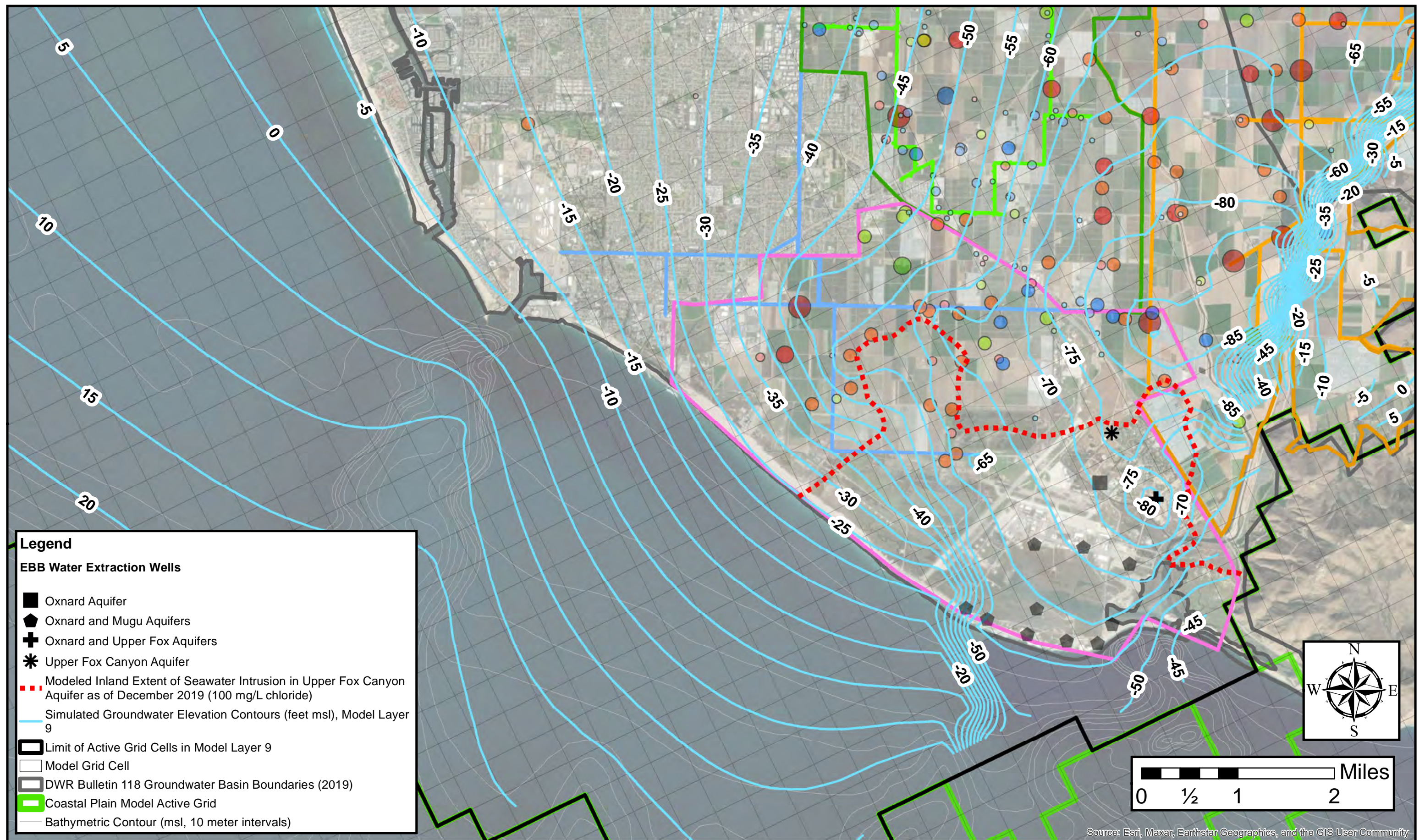
**Figure 49. Forecasted Groundwater Level Contours during Drought Periods for Hybrid Scenario without Injection Wells at Port Hueneme (S23)--Hueneme Aquifer (Model Layer 7)**





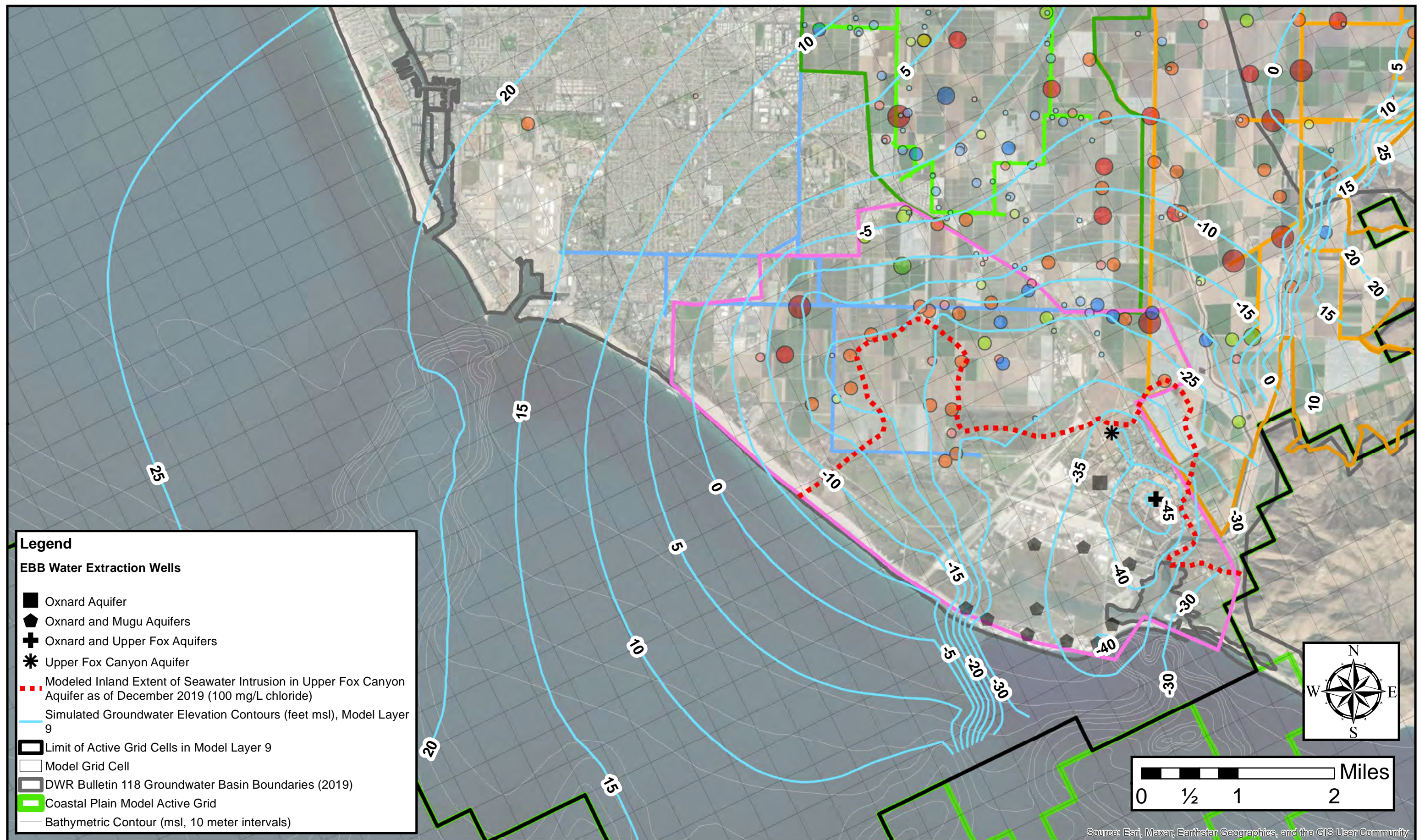
**Figure 50. Forecasted Groundwater Level Contours during Multi-Year Wet Periods for Hybrid Scenario without Injection Wells at Port Hueneme (S23)--Hueneme Aquifer (Model Layer 7)**





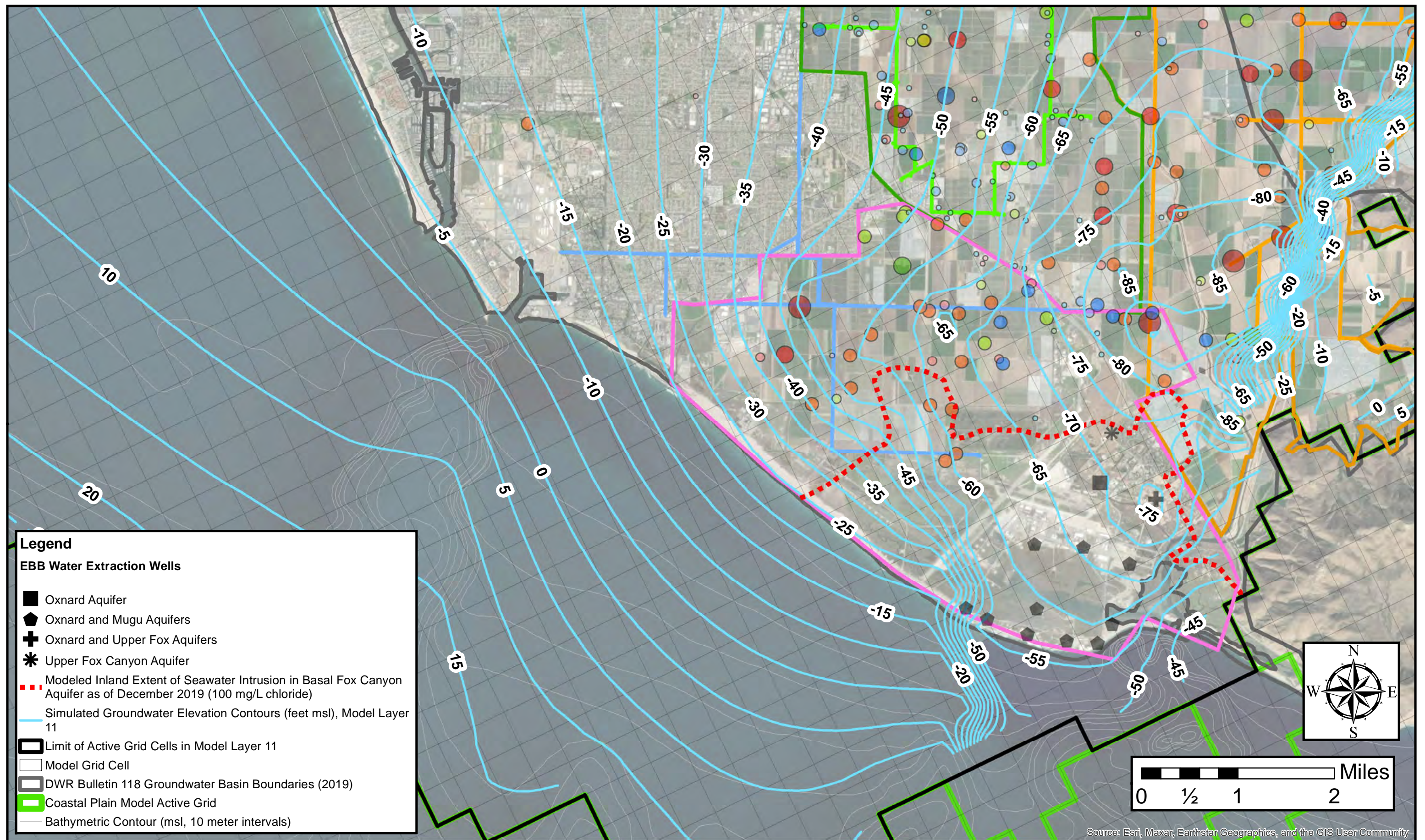
**Figure 51. Forecasted Groundwater Level Contours during Drought Periods for Hybrid Scenario without Injection Wells at Port Hueneme (S23)-- Upper Fox Canyon Aquifer (Model Layer 9)**





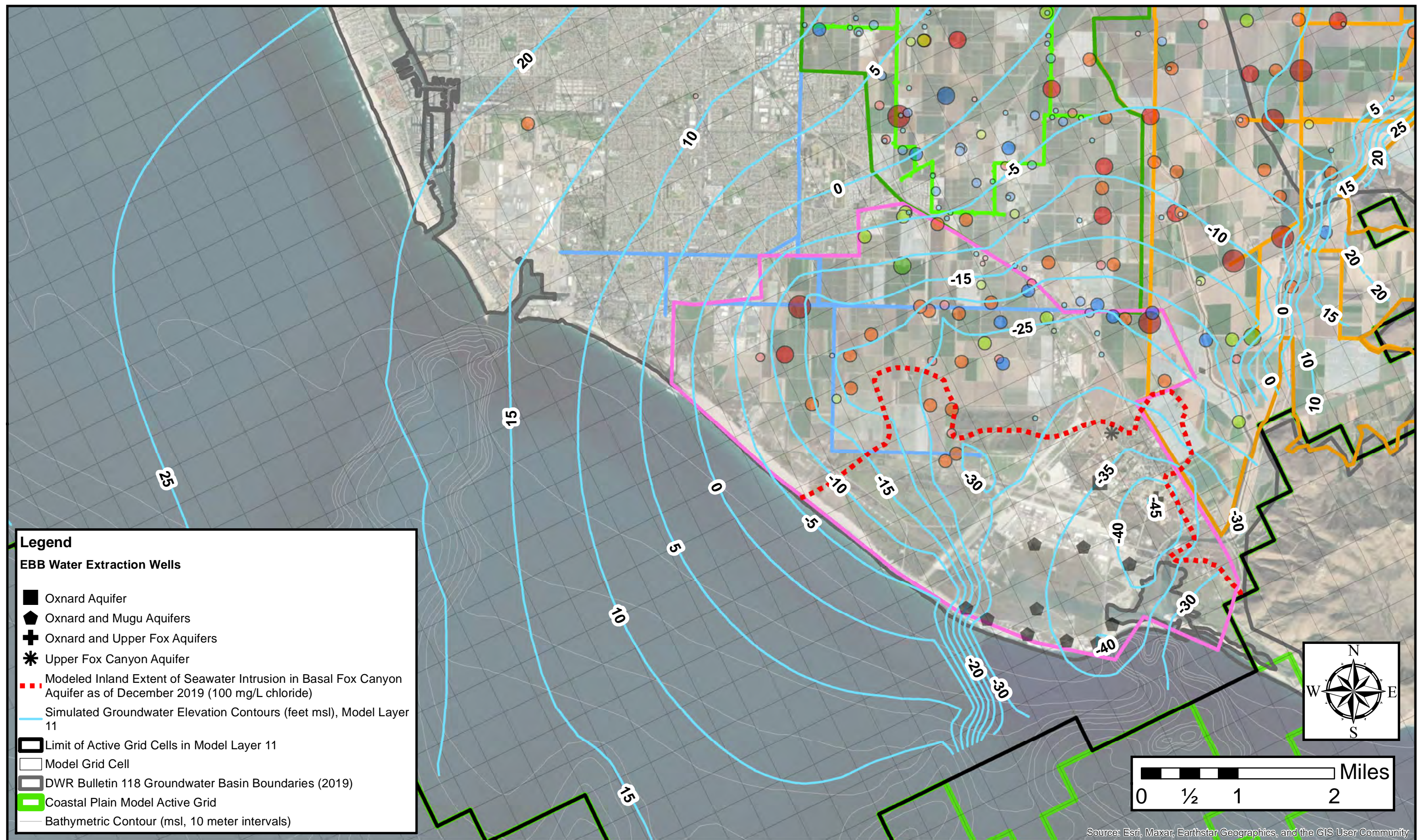
**Figure 52. Forecasted Groundwater Level Contours during Multi-Year Wet Periods for Hybrid Scenario without Injection Wells at Port Hueneme (S23)--Upper Fox Canyon Aquifer (Model Layer 9)**





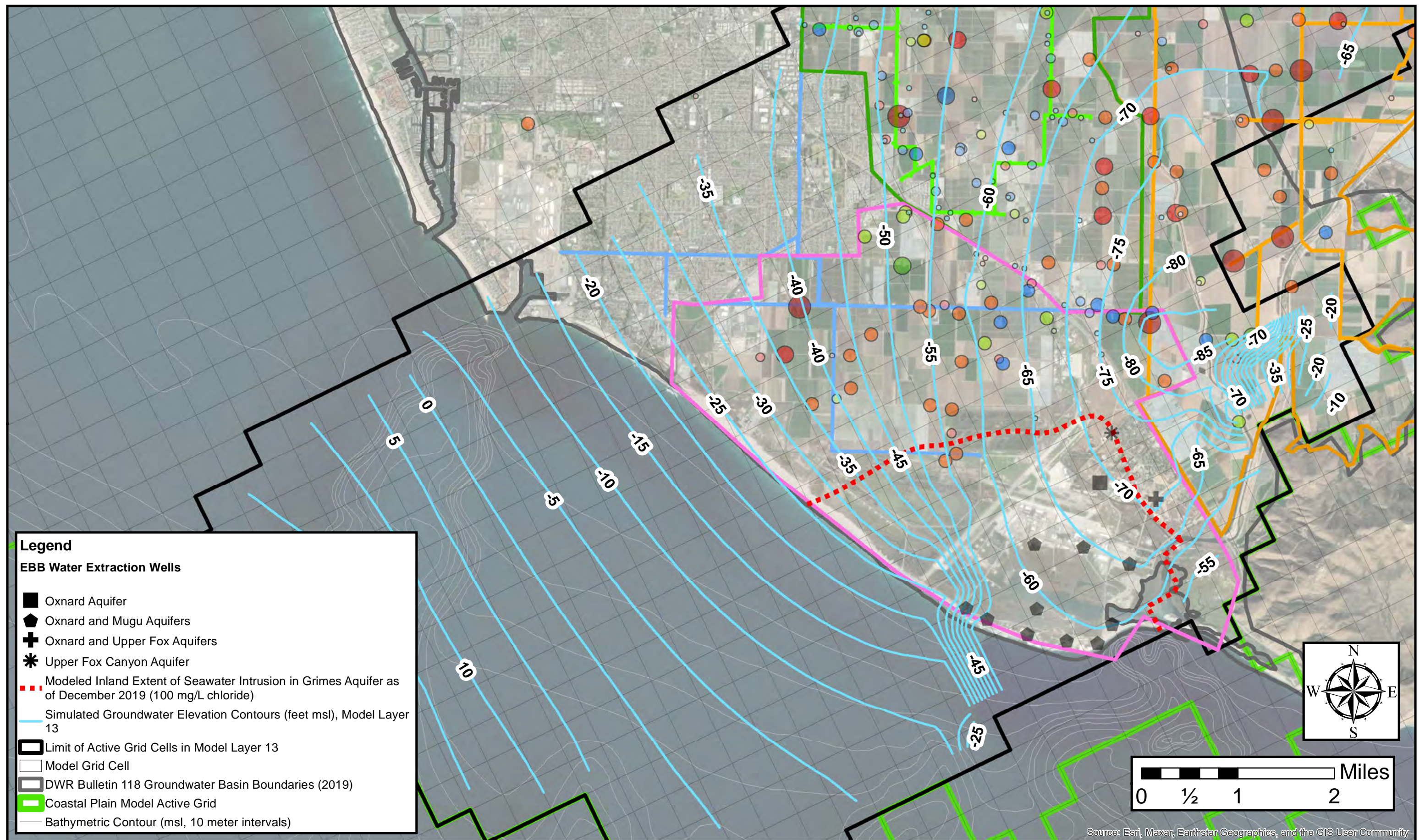
**Figure 53. Forecasted Groundwater Level Contours during Drought Periods for Hybrid Scenario without Injection Wells at Port Hueneme (S23)-- Basal Fox Canyon Aquifer (Model Layer 11)**





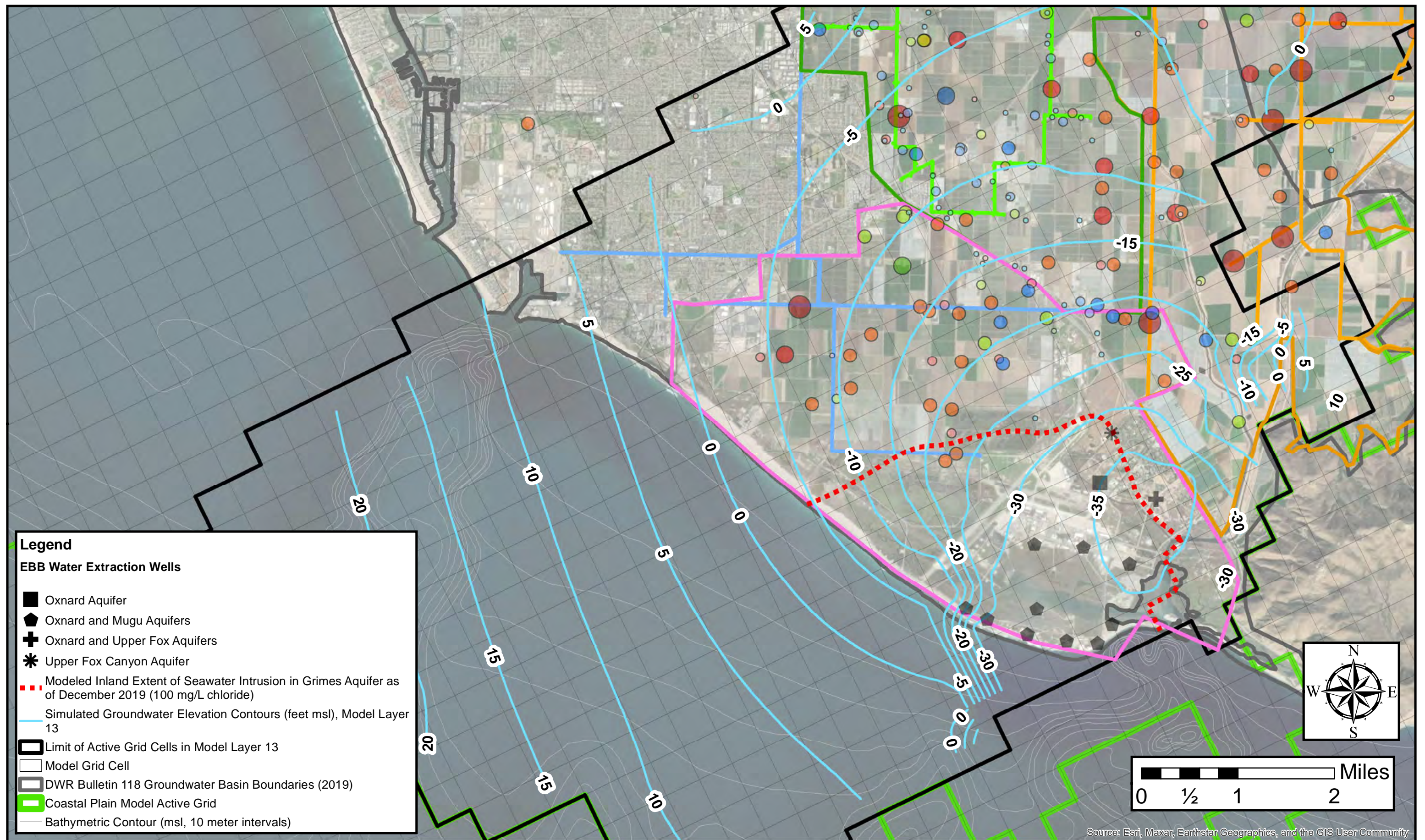
**Figure 54. Forecasted Groundwater Level Contours during Multi-Year Wet Periods for Hybrid Scenario without Injection Wells at Port Hueneme (S23)--Basal Fox Canyon Aquifer (Model Layer 11)**





**Figure 55. Forecasted Groundwater Level Contours during Drought Periods for Hybrid Scenario without Injection Wells at Port Hueneme (S23)--Grimes Canyon Aquifer (Model Layer 13)**





**Figure 56. Forecasted Groundwater Level Contours during Multi-Year Wet Periods for Hybrid Scenario without Injection Wells at Port Hueneme (S23)--Grimes Canyon Aquifer (Model Layer 13)**



Note:  
Extraction barrier and injection barrier wells are set to be partially transparent when not located in the current aquifer.

All existing water supply wells are set to be partially transparent for all aquifers.

**Legend**

**EBB Water Extraction Wells**

Oxnard Aquifer

Oxnard and Mugu Aquifers

Oxnard and Upper Fox Aquifers

Upper Fox Canyon Aquifer

**Port Hueneme Injection Wells**

Mugu Aquifer

Hueneme Aquifer

**Simulated Intrusion in Oxnard Aquifer (Model Layer 3 Release)**

**Particle Movement (As Applicable)**

Orange Lines = Moved Upward from Release Layer

Light Blue Lines = Remained in Release Layer

Dark Blue Lines = Moved Downward from Release Layer

Simulated Starting Locations Representing Inland Extent of Seawater Intrusion in Oxnard Aquifer as of December 2019 (100 mg/L chloride)

Simulated Ending Locations (Active Only)

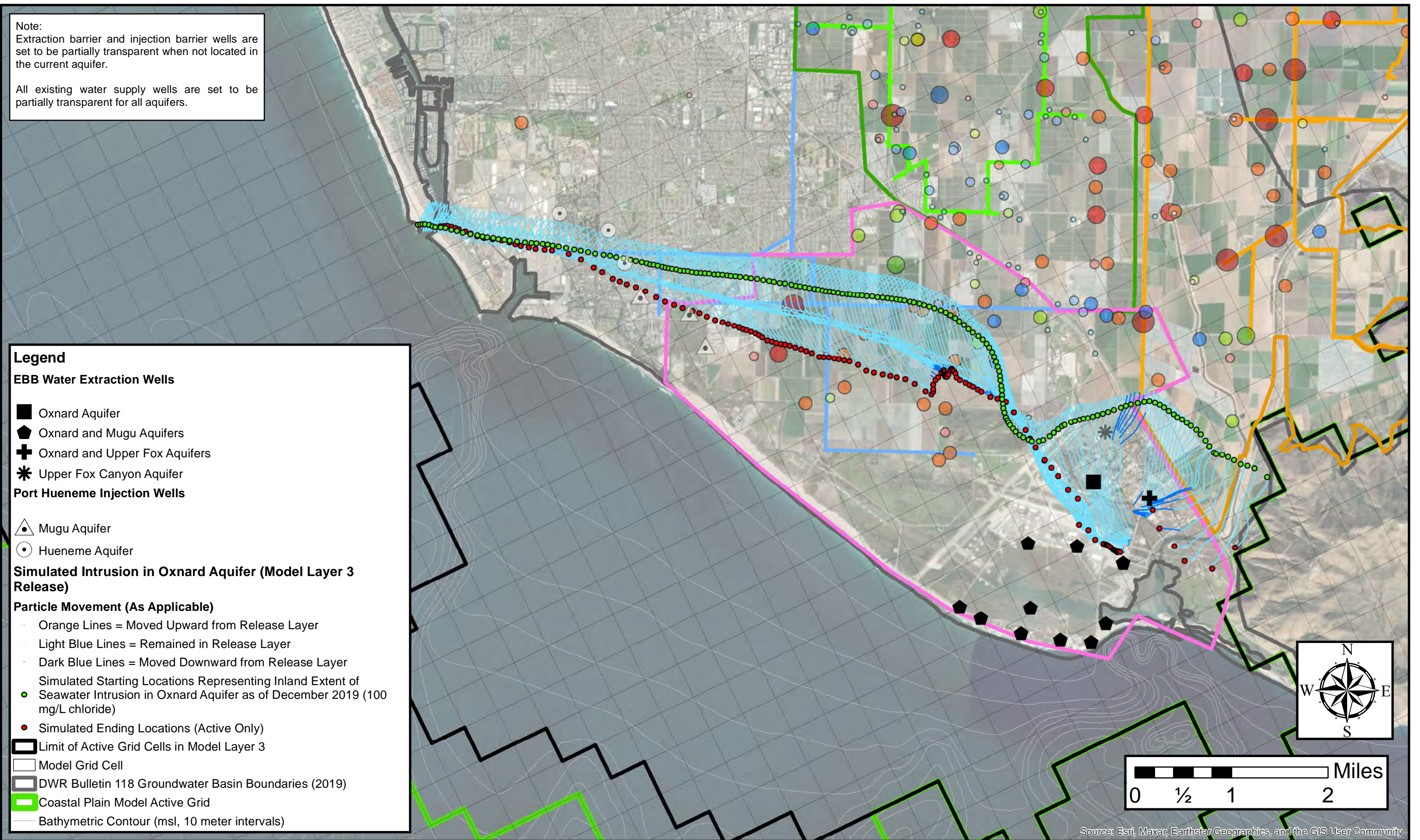
Limit of Active Grid Cells in Model Layer 3

Model Grid Cell

DWR Bulletin 118 Groundwater Basin Boundaries (2019)

Coastal Plain Model Active Grid

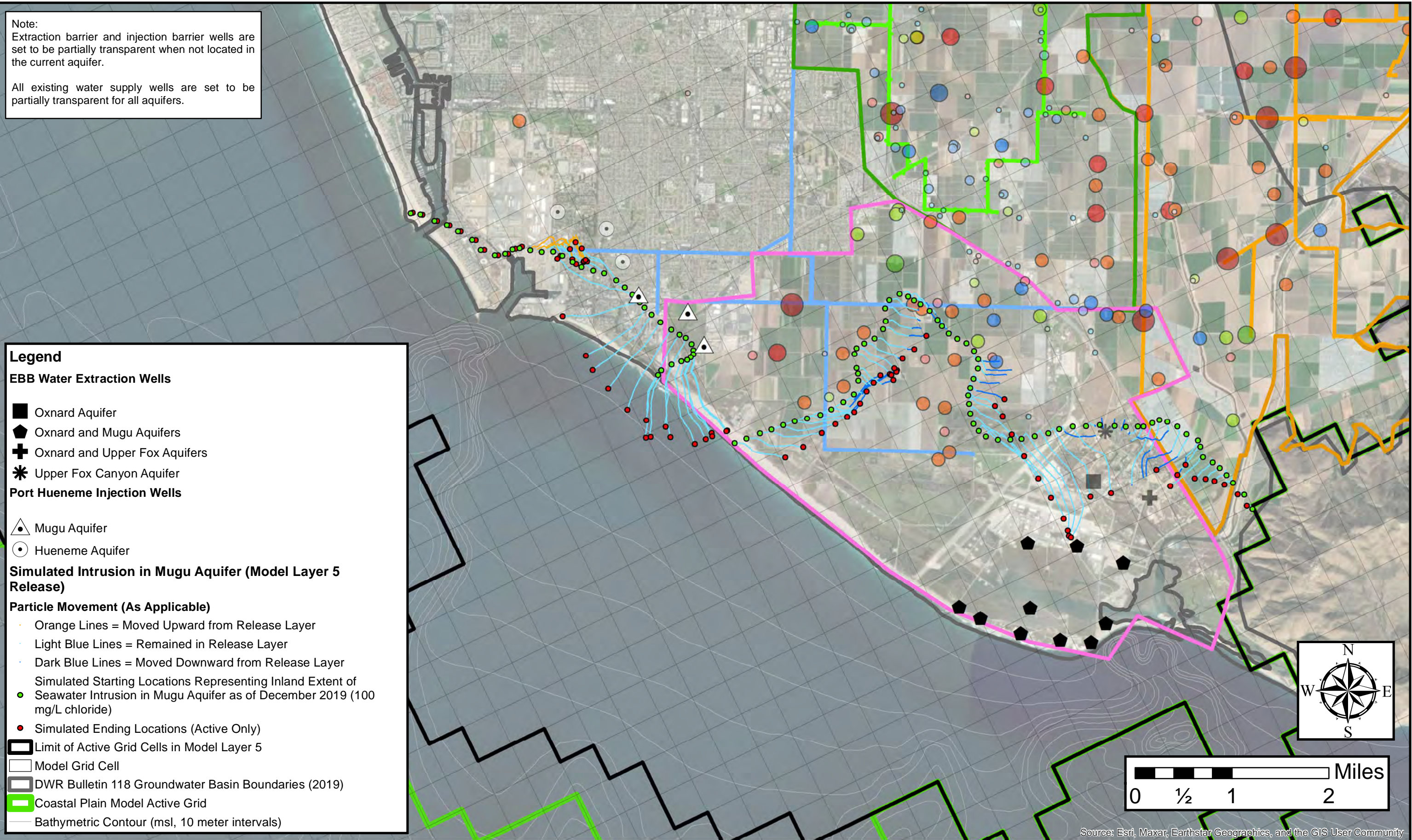
Bathymetric Contour (msl, 10 meter intervals)



Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

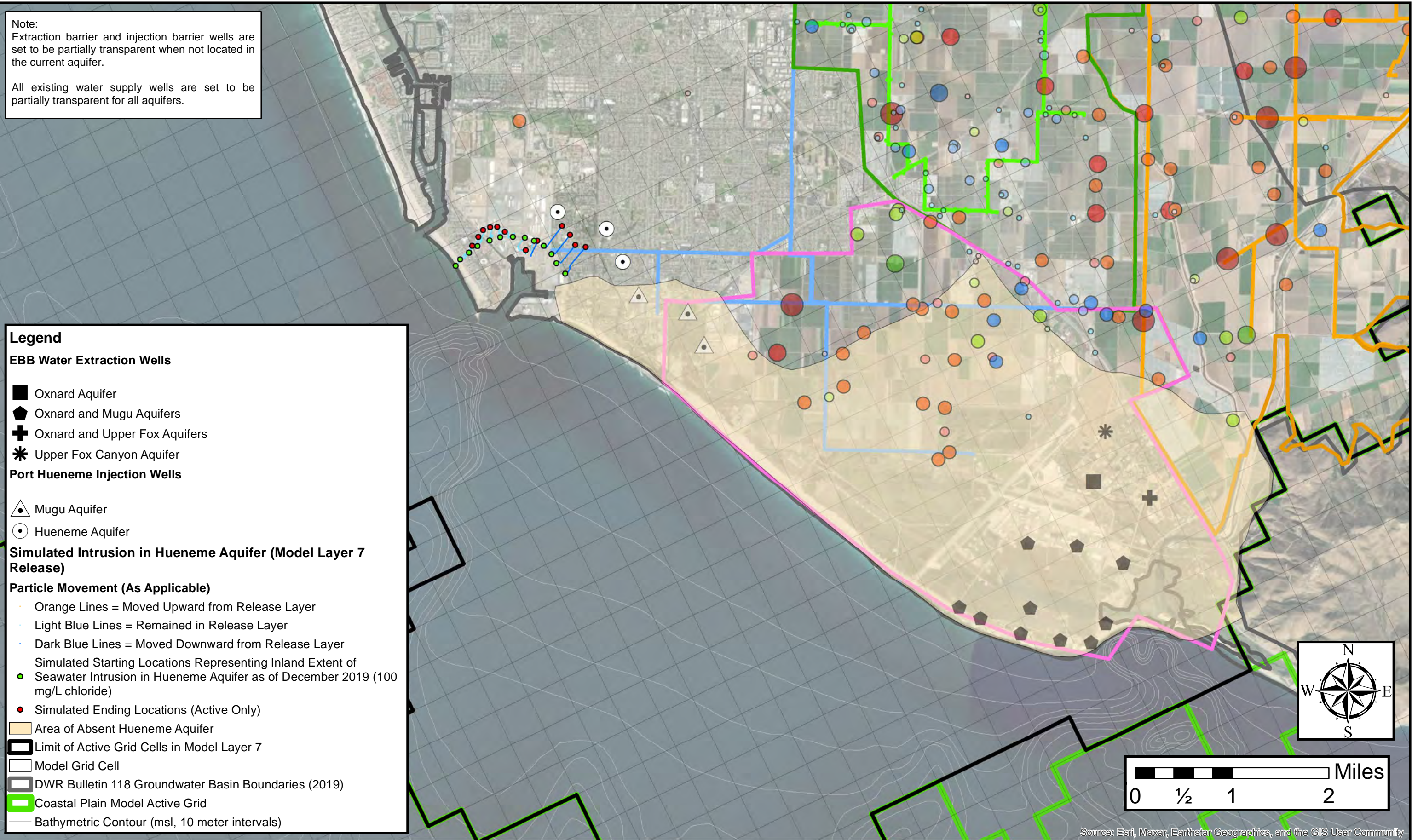
**Figure 57. Forecasted Particle Tracks for Hybrid Scenario with Expanded Recycled Water Use (S24)--Oxnard Aquifer (Model Layer 3)**





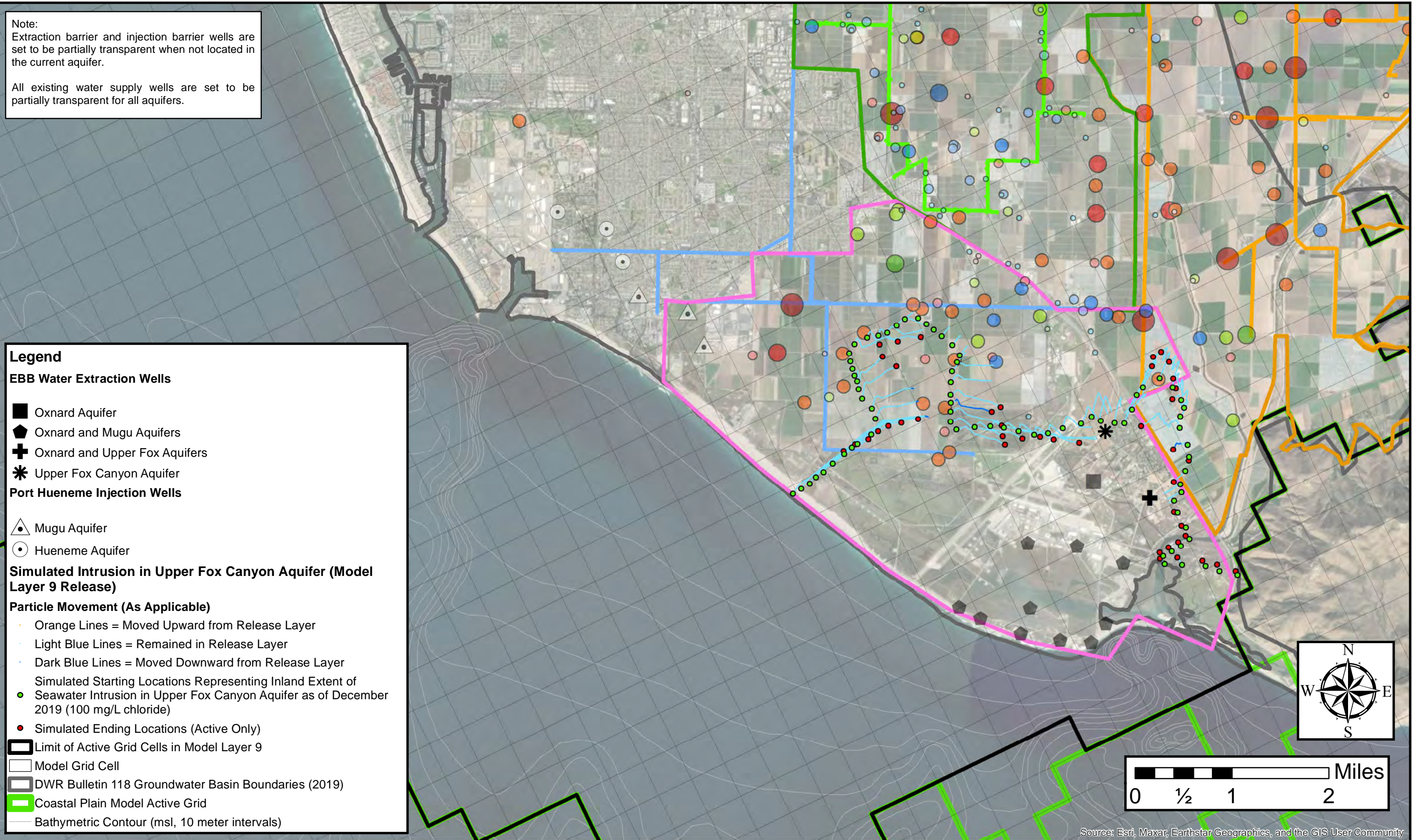
**Figure 58. Forecasted Particle Tracks for Hybrid Scenario with Expanded Recycled Water Use (S24)--Mugu Aquifer (Model Layer 5)**





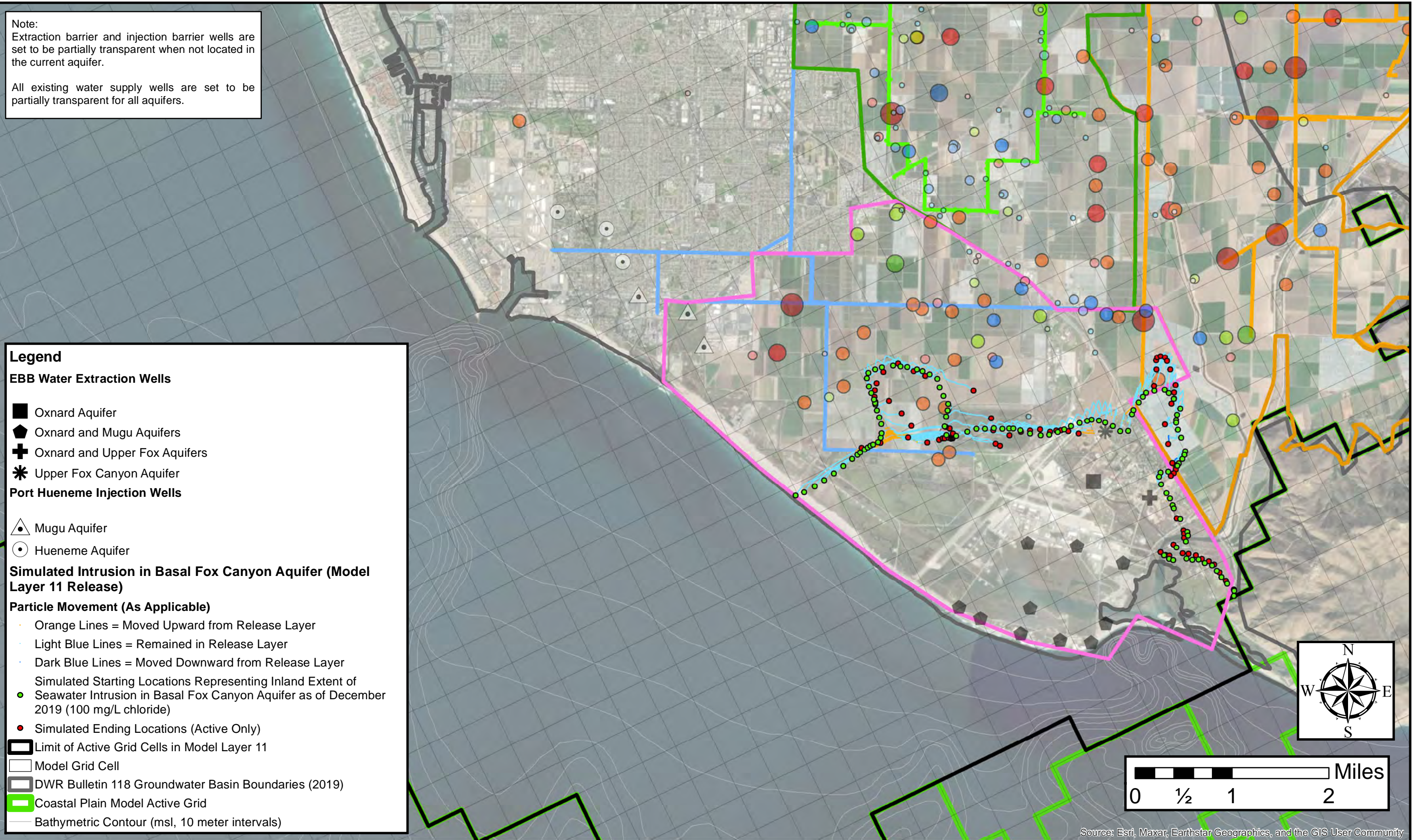
**Figure 59. Forecasted Particle Tracks for Hybrid Scenario with Expanded Recycled Water Use (S24)--Hueneme Aquifer (Model Layer 7)**





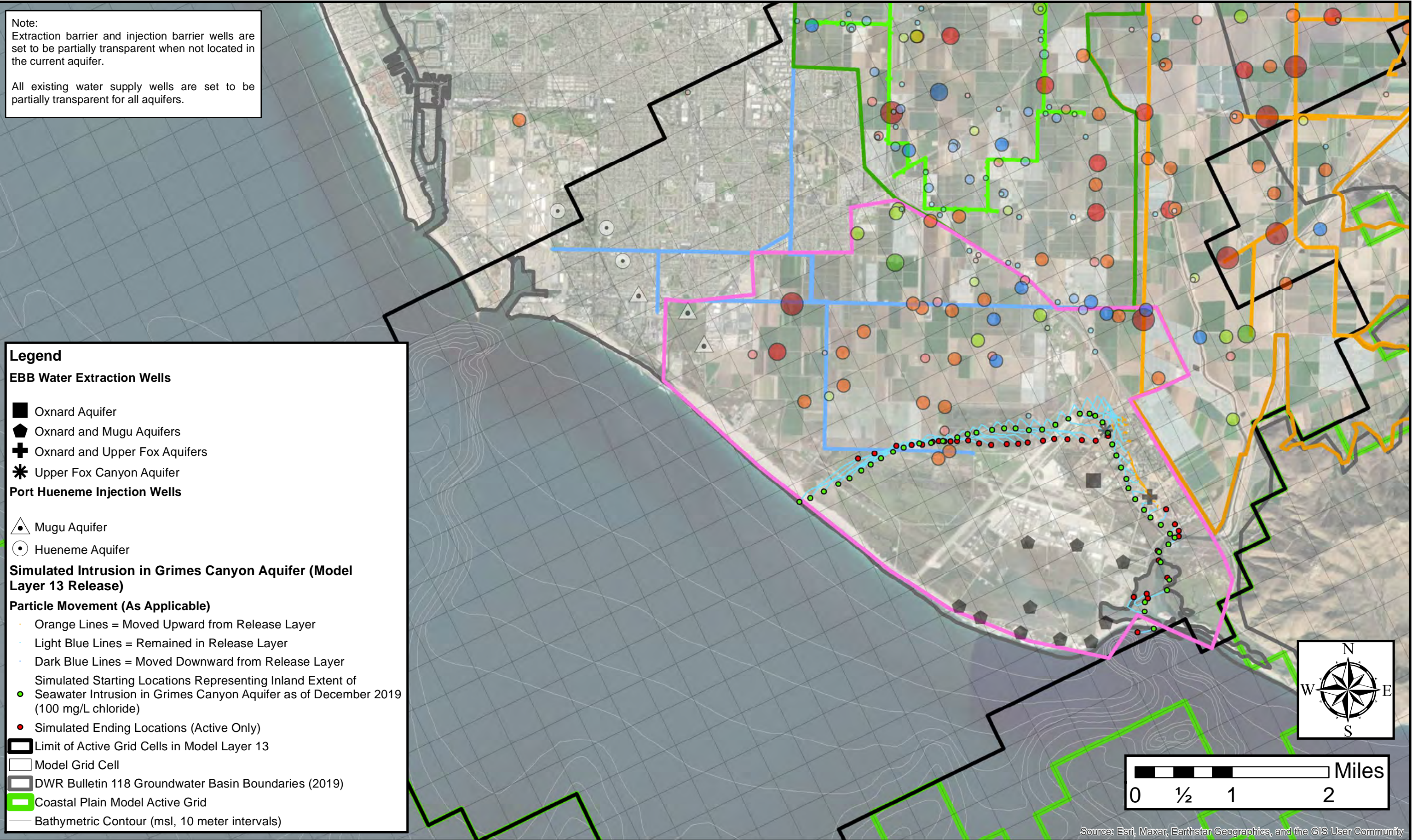
**Figure 60. Forecasted Particle Tracks for Hybrid Scenario with Expanded Recycled Water Use (S24)--Upper Fox Canyon Aquifer (Model Layer 9)**





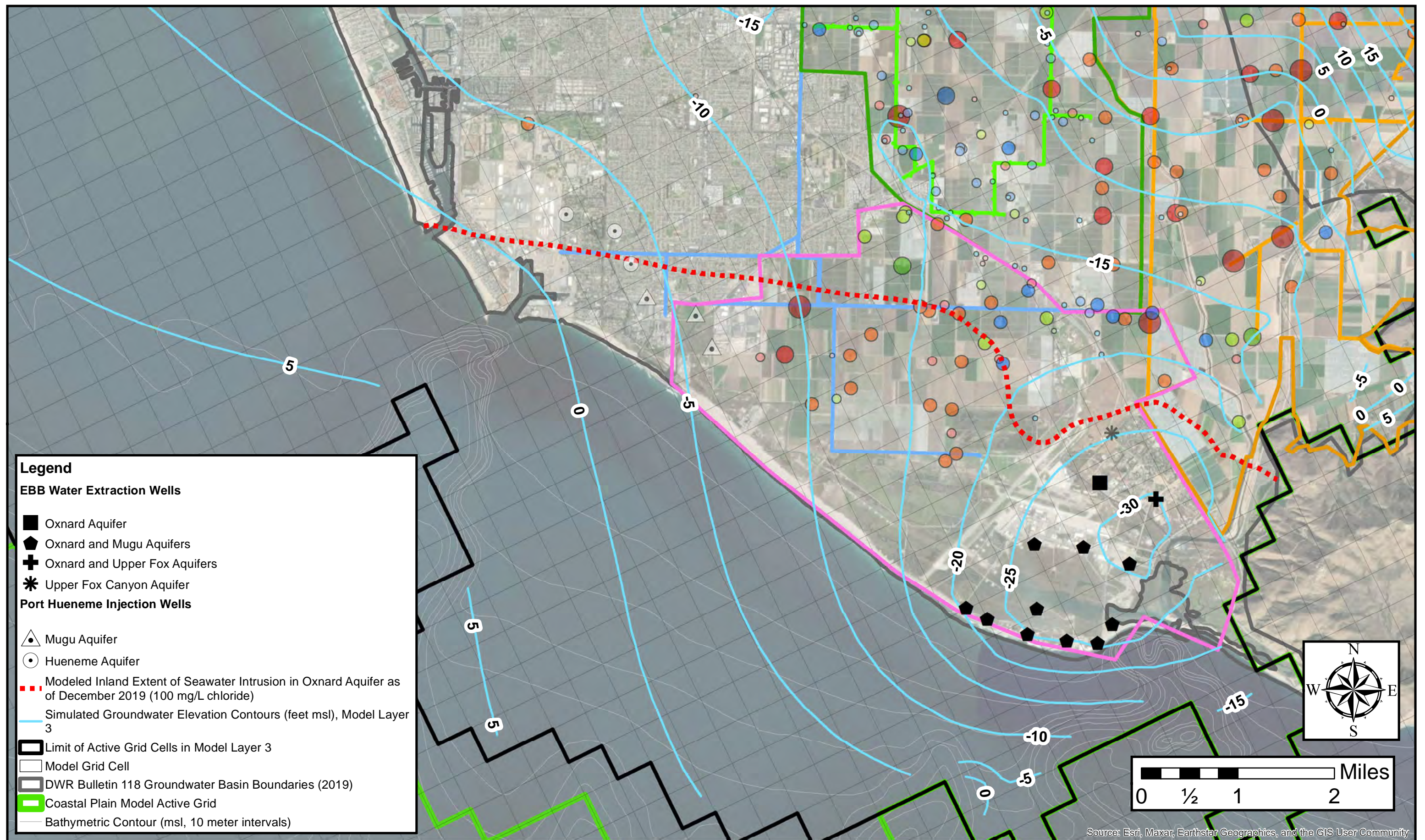
**Figure 61. Forecasted Particle Tracks for Hybrid Scenario with Expanded Recycled Water Use (S24)--Basal Fox Canyon Aquifer (Model Layer 11)**





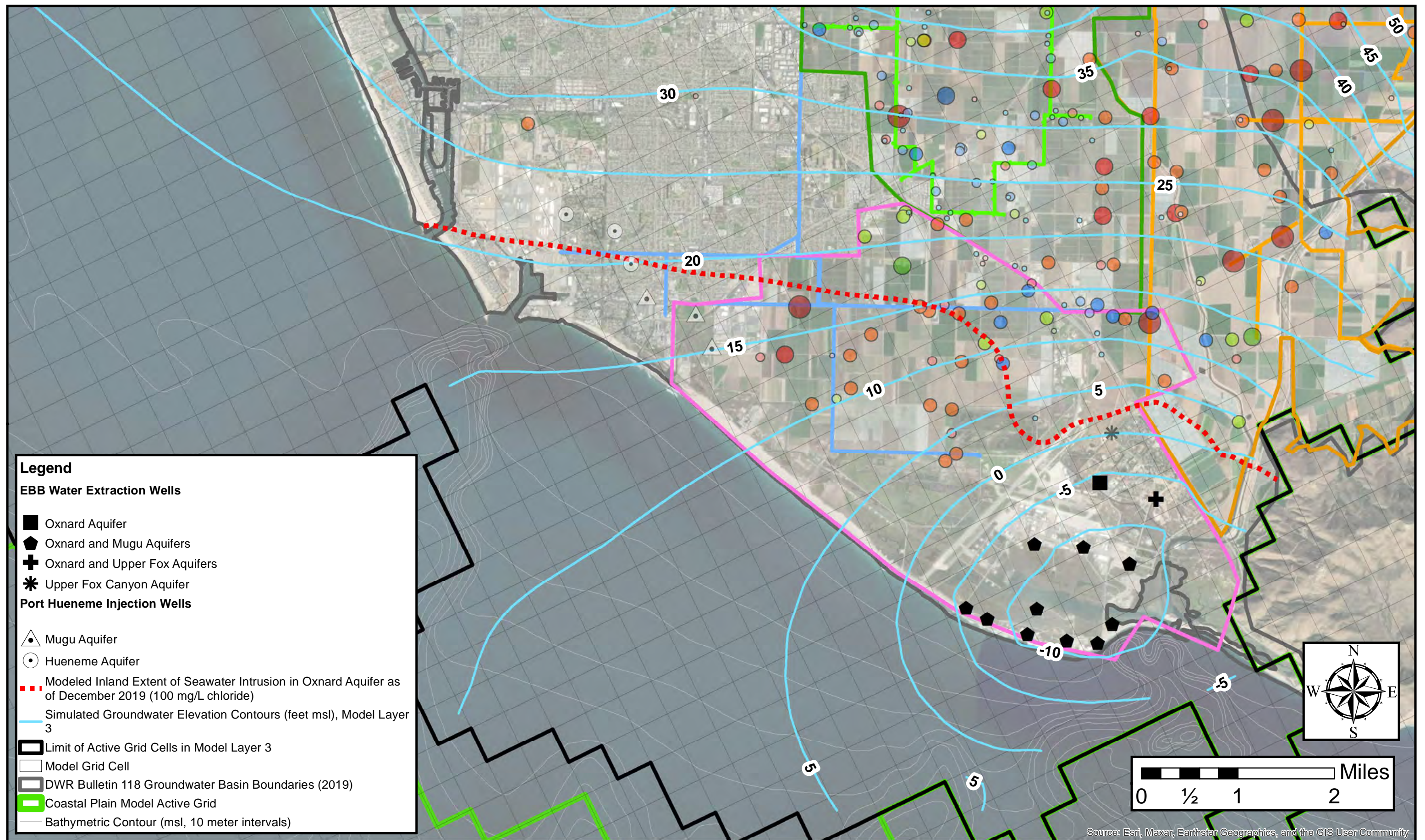
**Figure 62. Forecasted Particle Tracks for Hybrid Scenario with Expanded Recycled Water Use (S24)--Grimes Canyon Aquifer (Model Layer 13)**





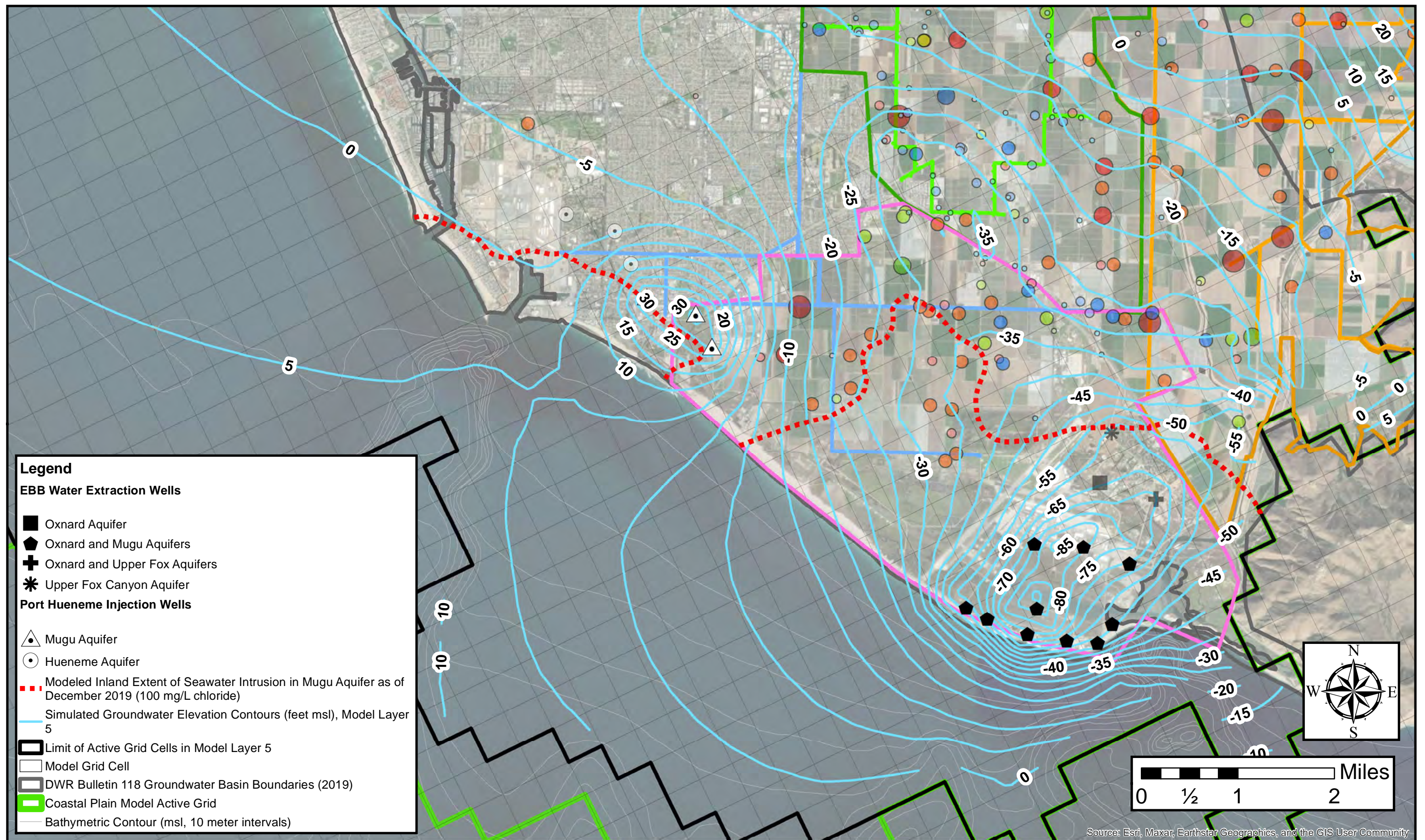
**Figure 63. Forecasted Groundwater Level Contours during Drought Periods for Hybrid Scenario with Expanded Recycled Water Use (S24)--Oxnard Aquifer (Model Layer 3)**





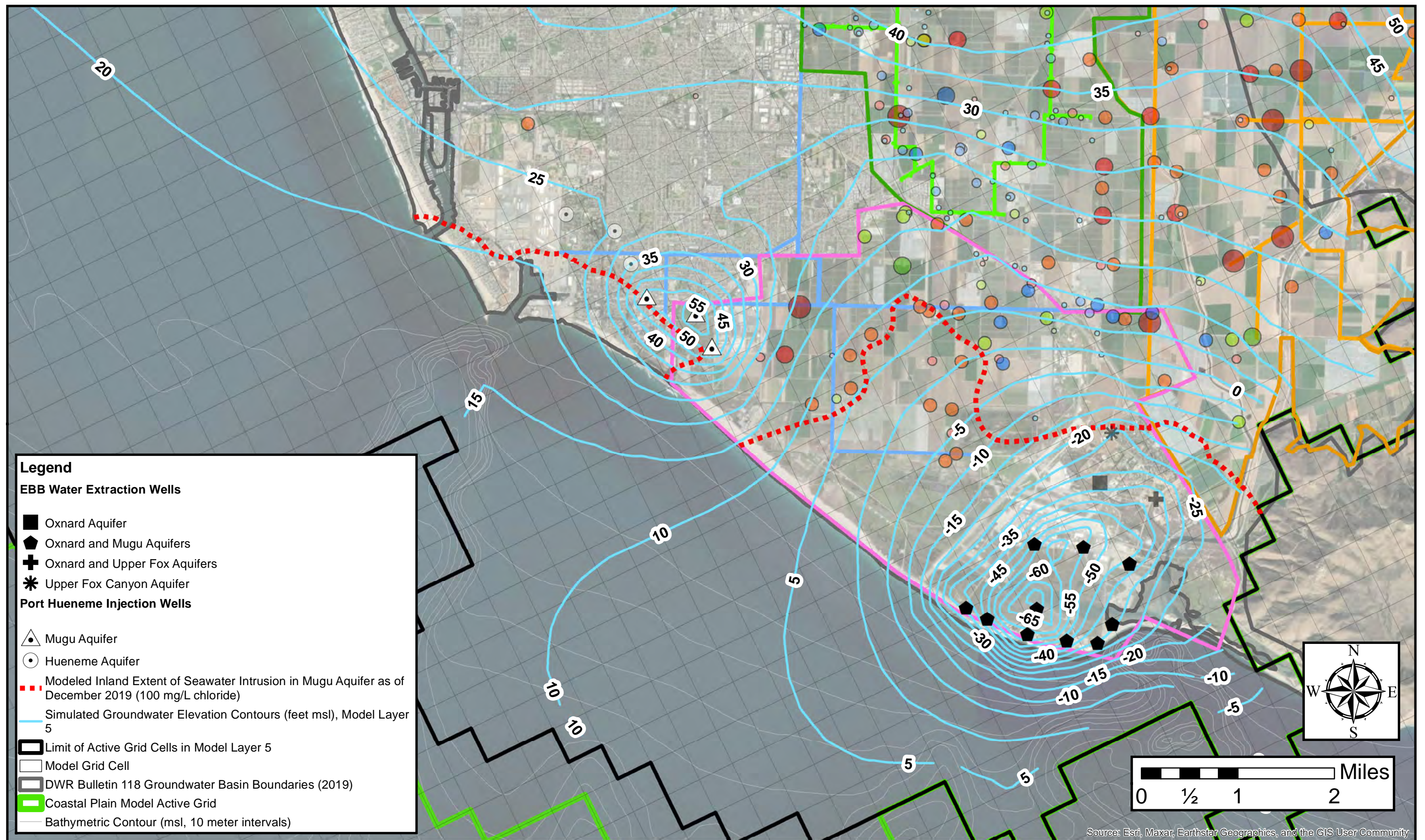
**Figure 64. Forecasted Groundwater Level Contours during Multi-Year Wet Periods for Hybrid Scenario with Expanded Recycled Water Use (S24)--Oxnard Aquifer (Model Layer 3)**





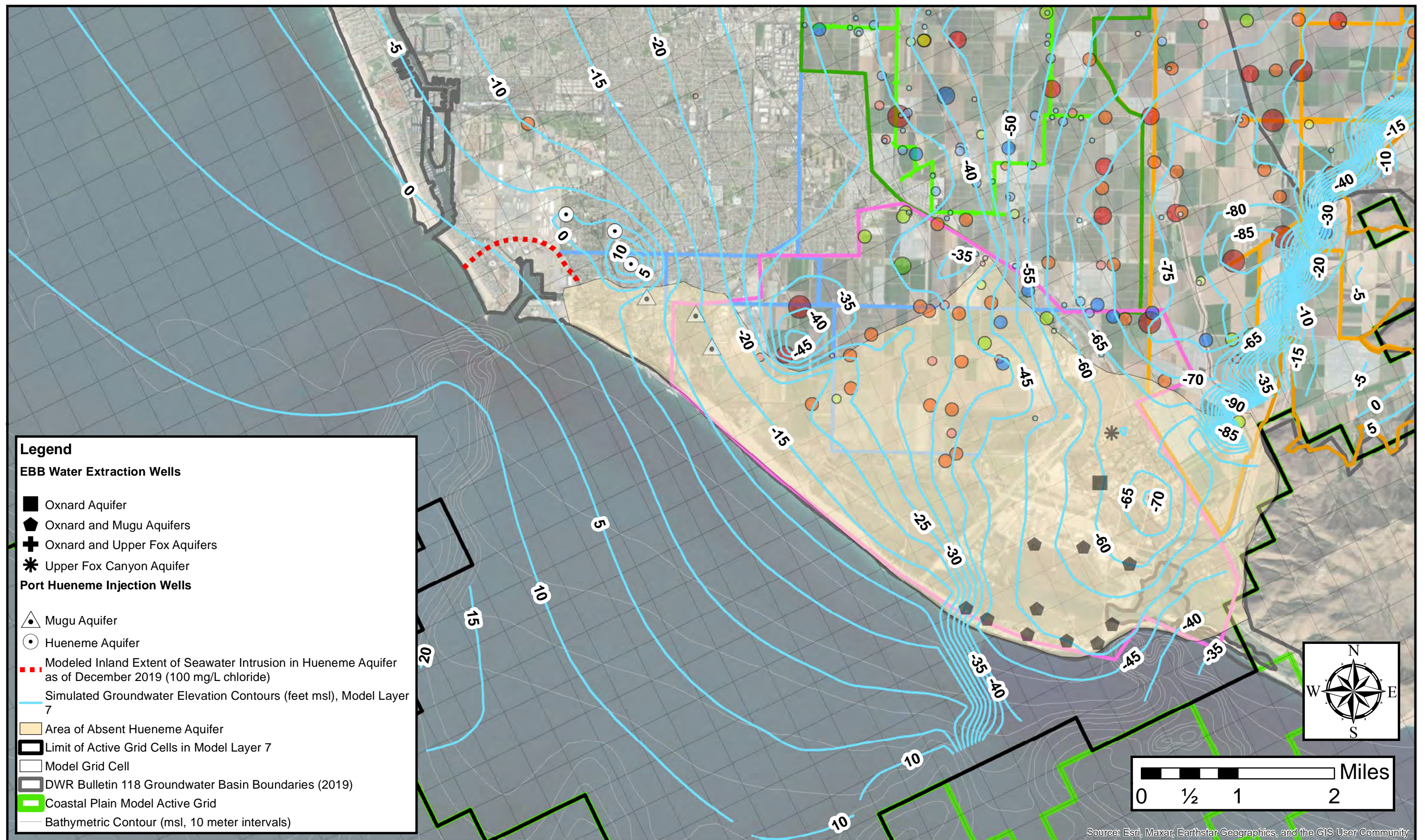
**Figure 65. Forecasted Groundwater Level Contours during Drought Periods for Hybrid Scenario with Expanded Recycled Water Use (S24)-- Mugu Aquifer (Model Layer 5)**





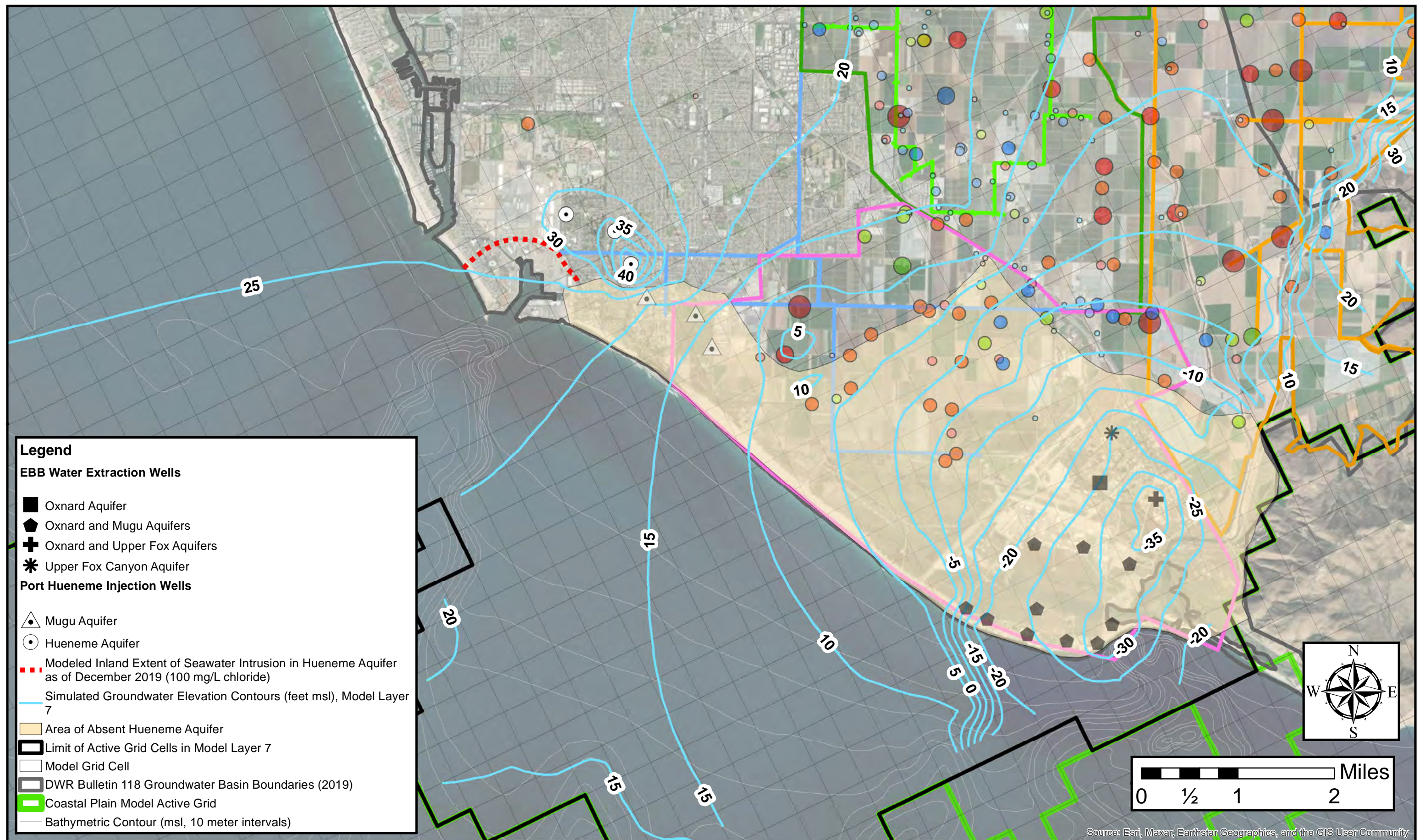
**Figure 66. Forecasted Groundwater Level Contours during Multi-Year Wet Periods for Hybrid Scenario with Expanded Recycled Water Use (S24)--Mugu Aquifer (Model Layer 5)**





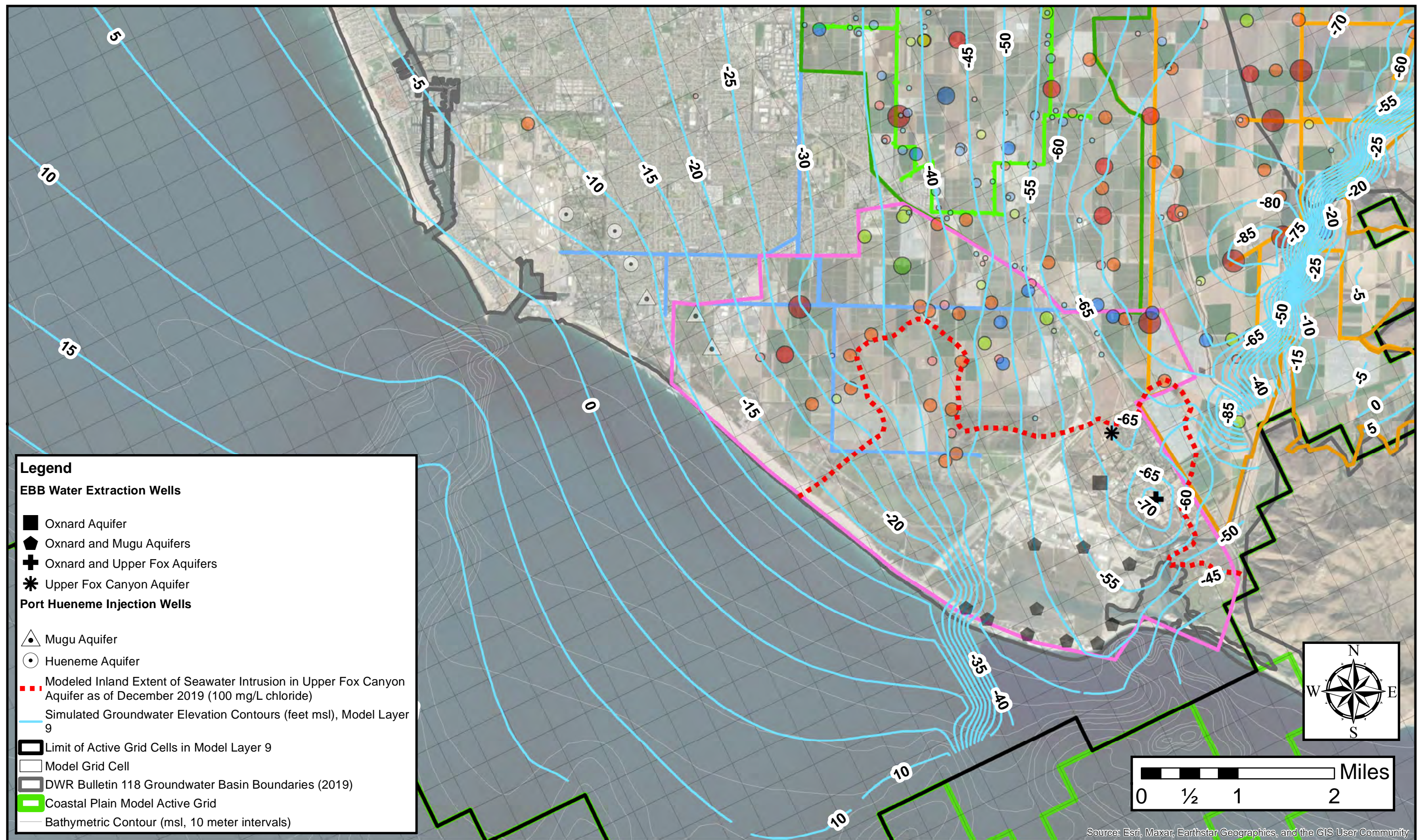
**Figure 67. Forecasted Groundwater Level Contours during Drought Periods for Hybrid Scenario with Expanded Recycled Water Use (S24)--Hueneme Aquifer (Model Layer 7)**





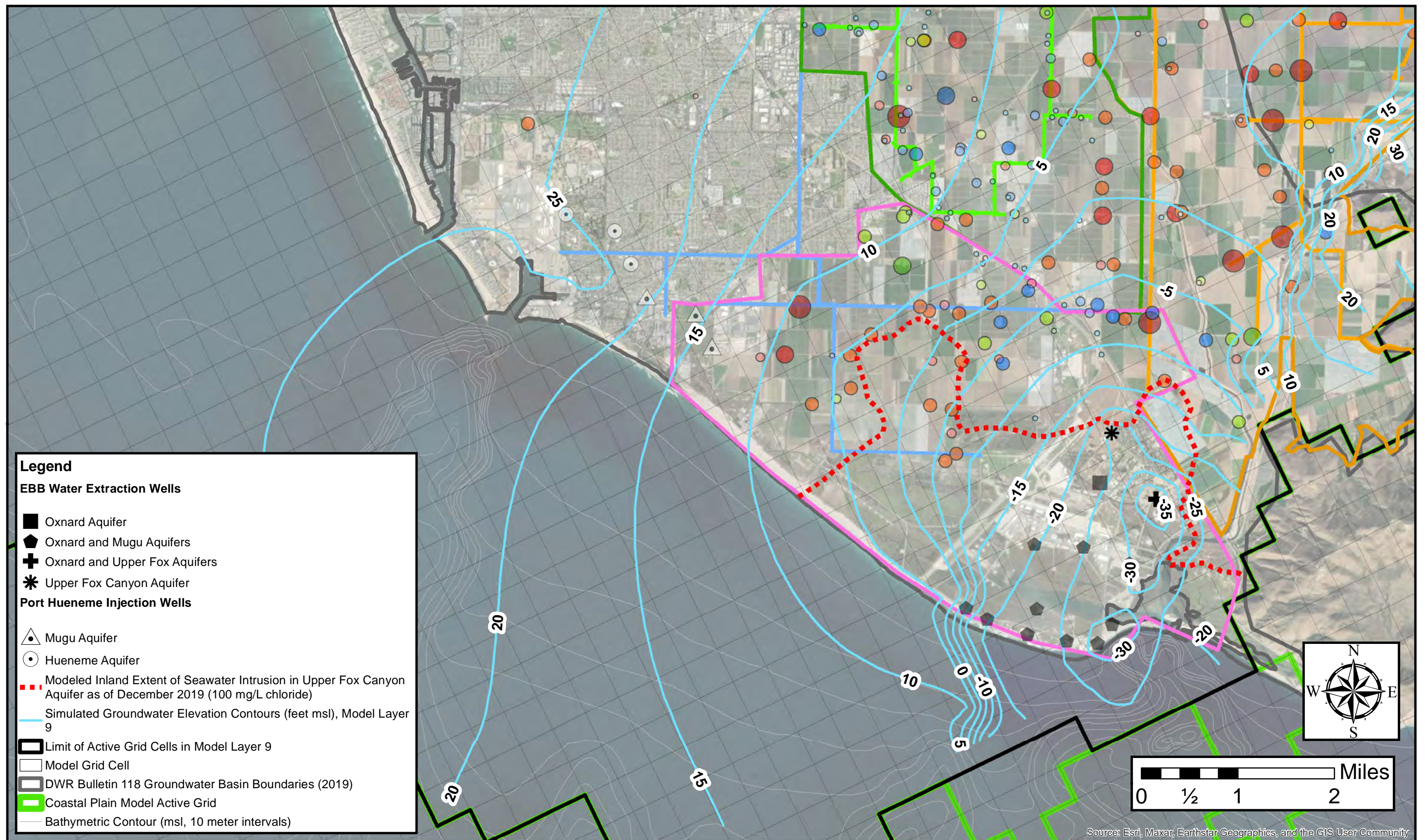
**Figure 68. Forecasted Groundwater Level Contours during Multi-Year Wet Periods for Hybrid Scenario with Expanded Recycled Water Use (S24)--Hueneme Aquifer (Model Layer 7)**





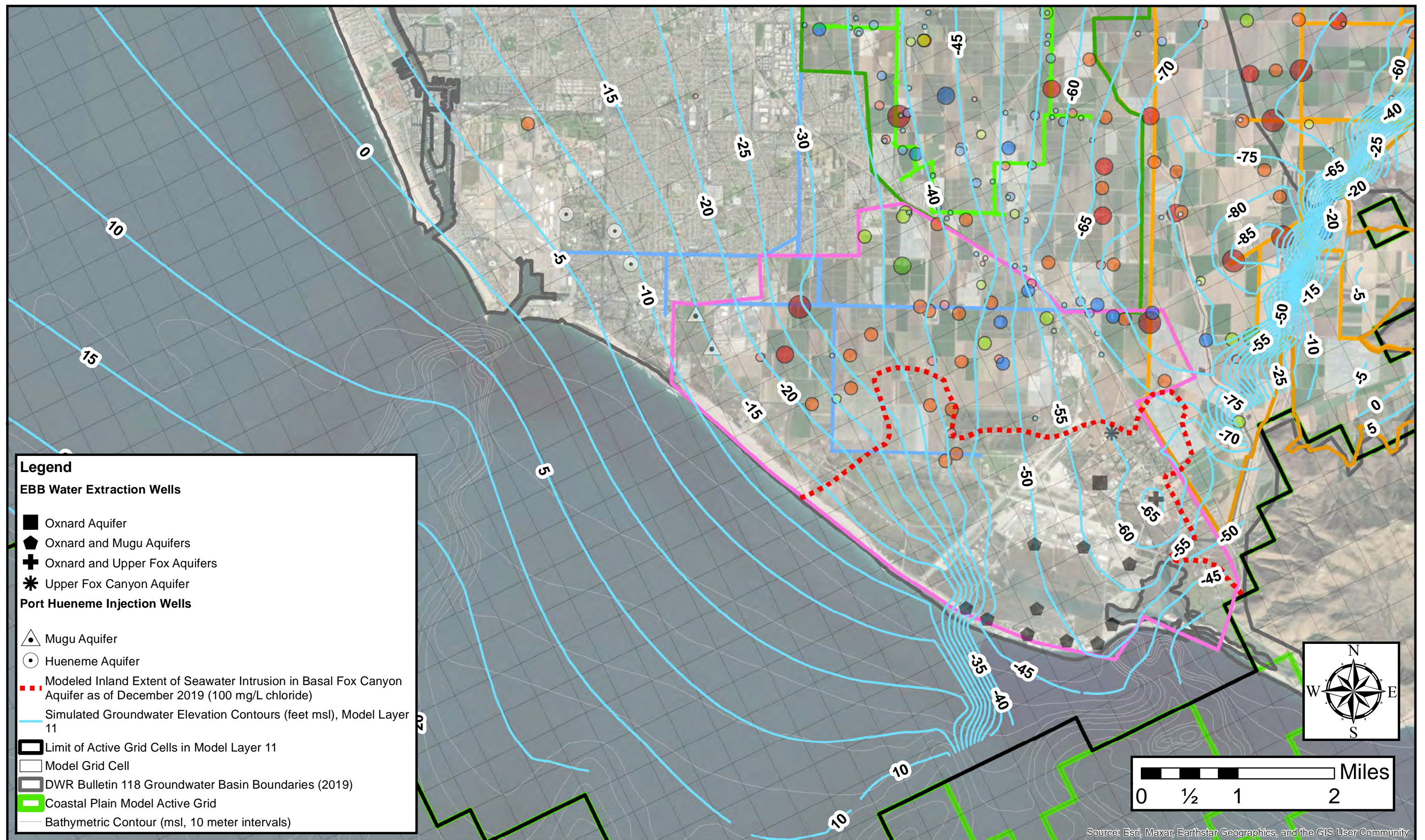
**Figure 69. Forecasted Groundwater Level Contours during Drought Periods for Hybrid Scenario with Expanded Recycled Water Use (S24)-- Upper Fox Canyon Aquifer (Model Layer 9)**





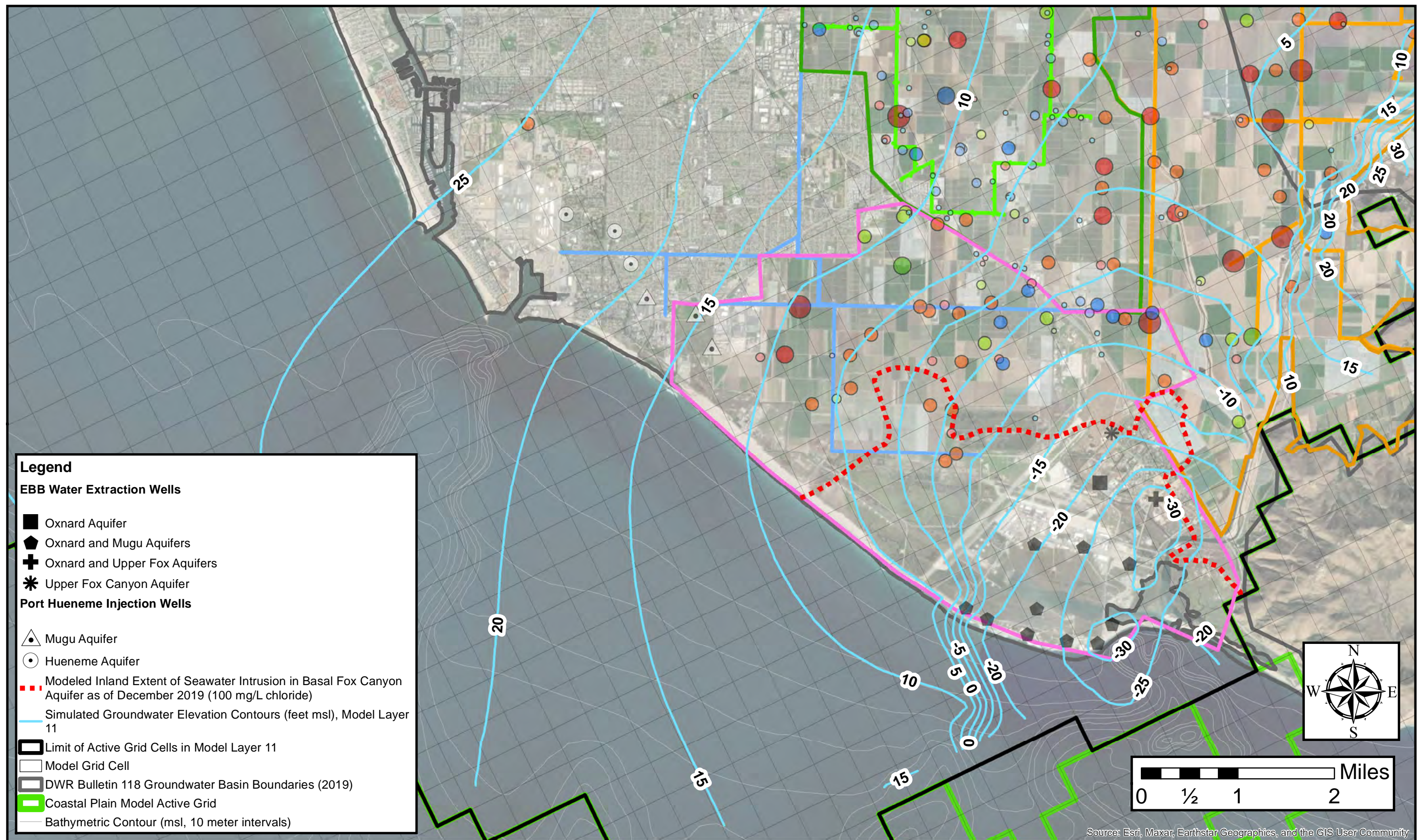
**Figure 70. Forecasted Groundwater Level Contours during Multi-Year Wet Periods for Hybrid Scenario with Expanded Recycled Water Use (S24)-- Upper Fox Canyon Aquifer (Model Layer 9)**





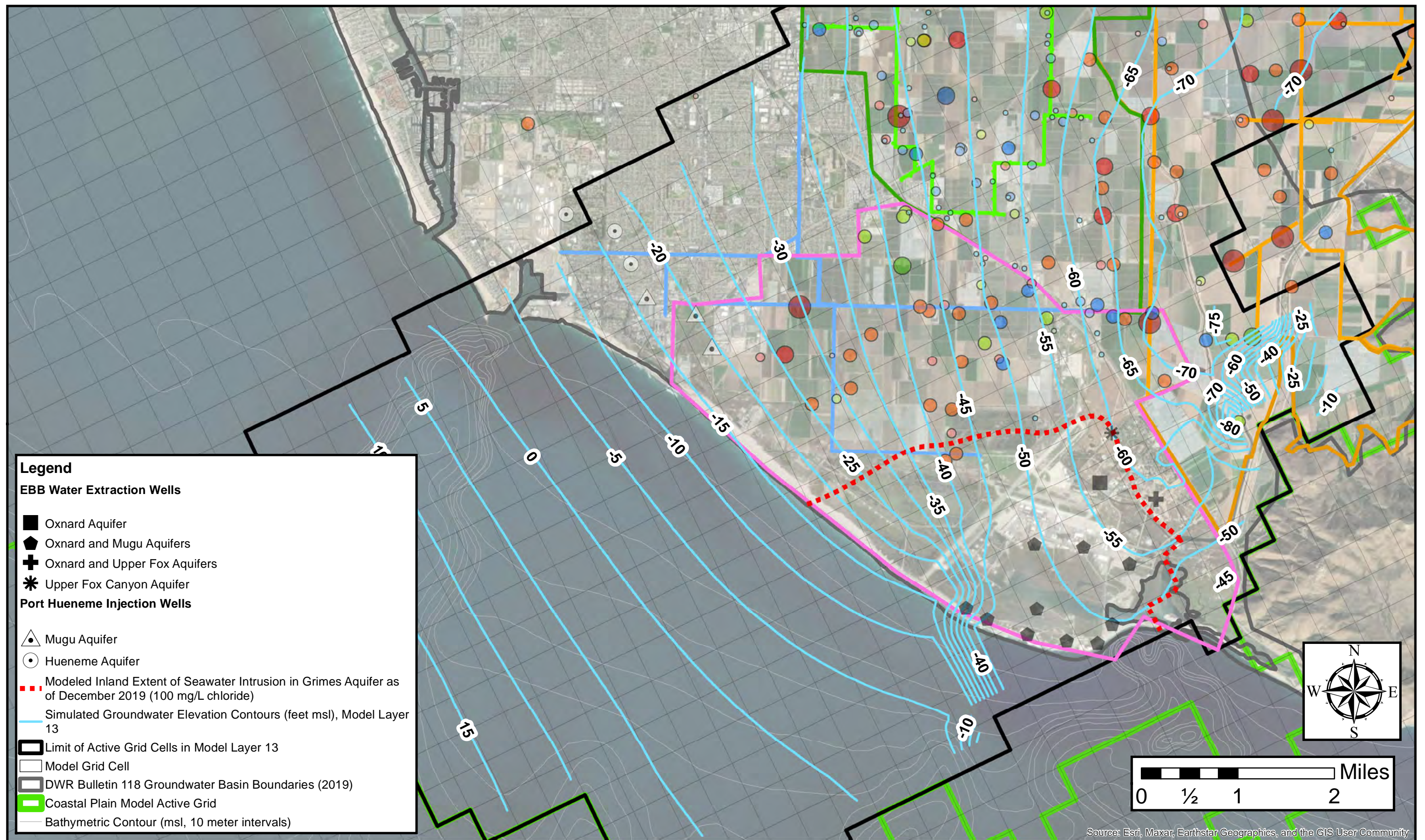
**Figure 71. Forecasted Groundwater Level Contours during Drought Periods for Hybrid Scenario with Expanded Recycled Water Use (S24)-- Basal Fox Canyon Aquifer (Model Layer 11)**



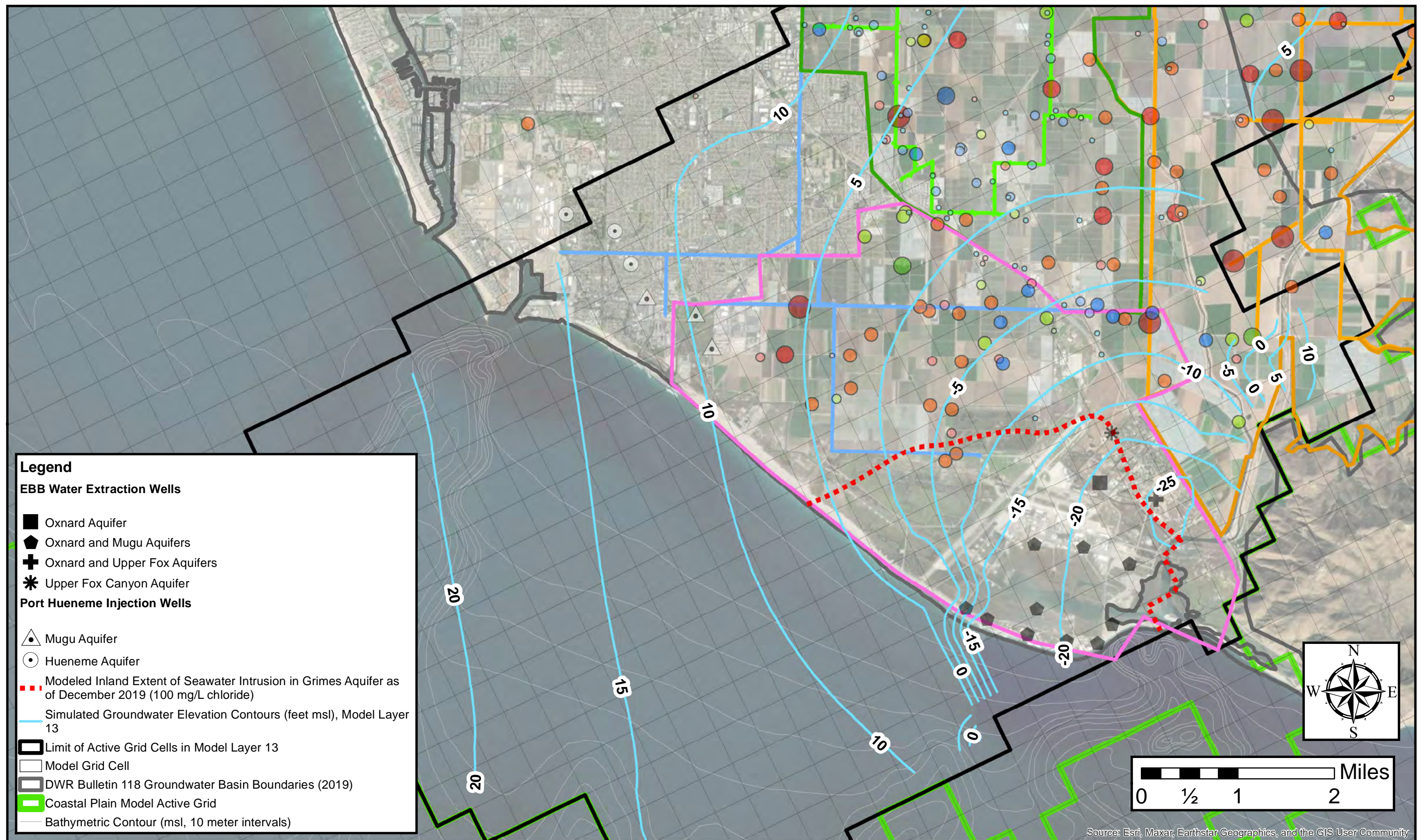


**Figure 72. Forecasted Groundwater Level Contours during Multi-Year Wet Periods for Hybrid Scenario with Expanded Recycled Water Use (S24)-- Basal Fox Canyon Aquifer (Model Layer 11)**



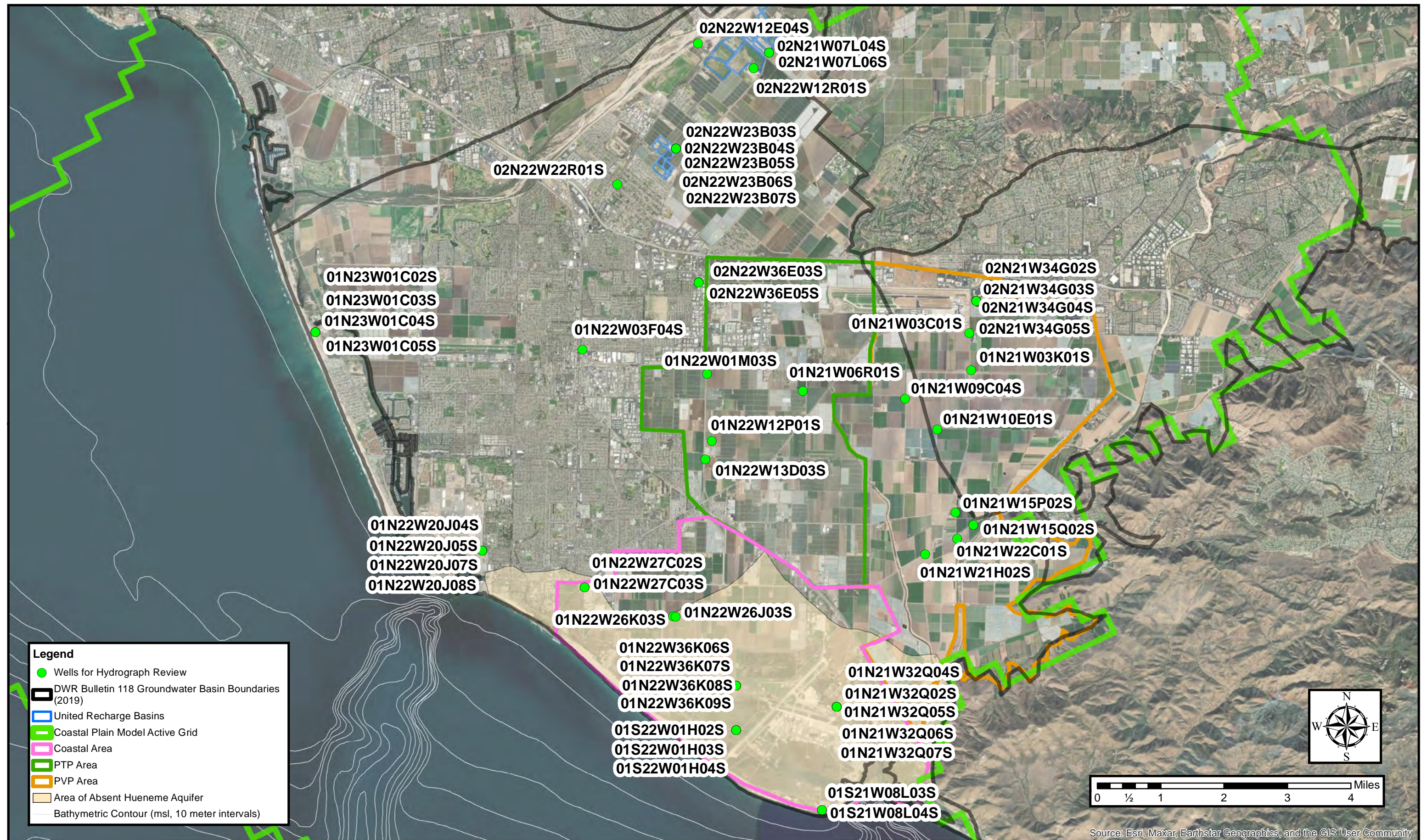






**Figure 74. Forecasted Groundwater Level Contours during Multi-Year Wet Periods for Hybrid Scenario with Expanded Recycled Water Use (S24)--Grimes Canyon Aquifer (Model Layer 13)**





**Figure A-1. Location Map for Groundwater Elevation Hydrographs**



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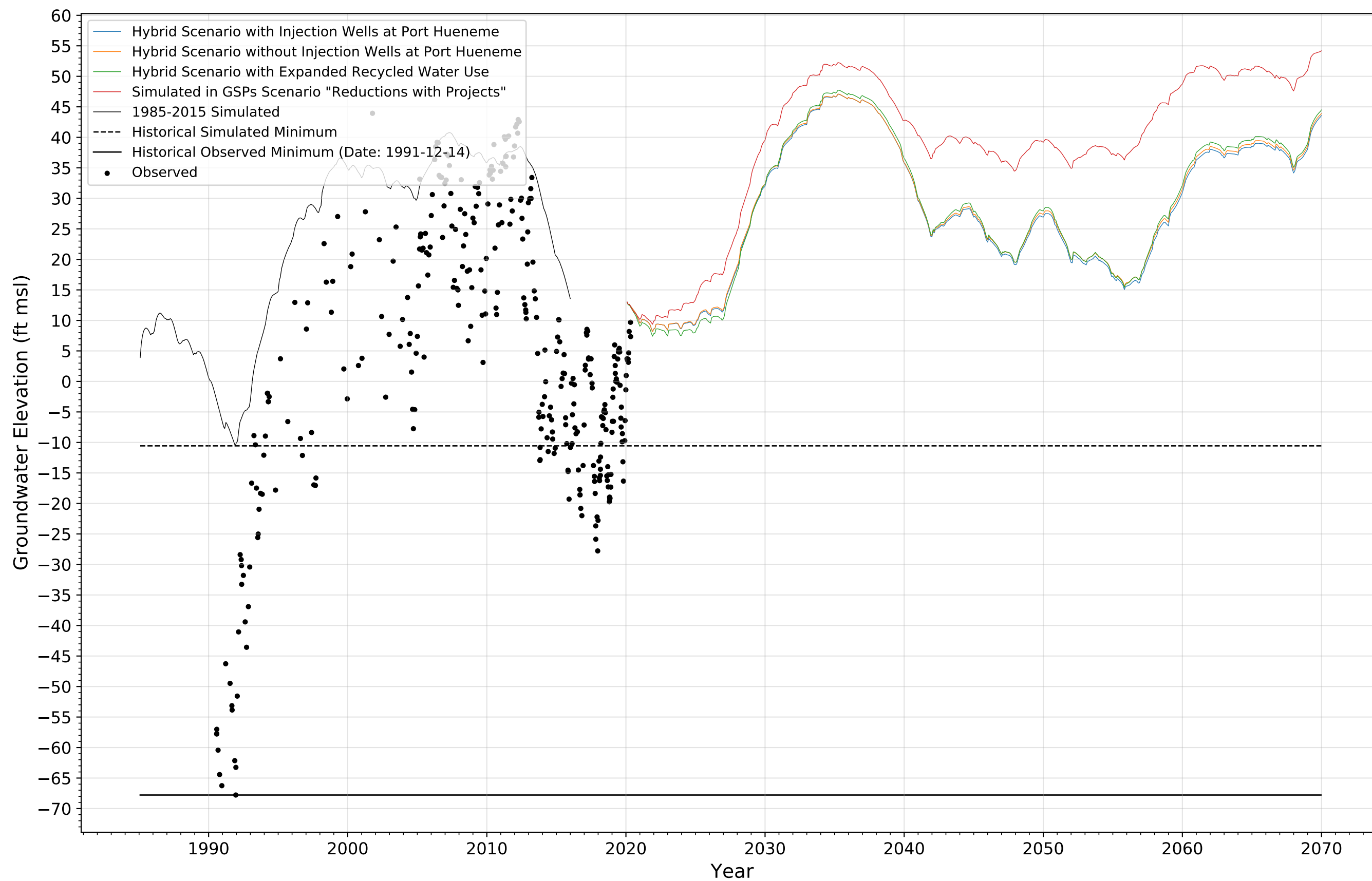


**APPENDIX A. HYDROGRAPHS SHOWING PROJECTED GROUNDWATER ELEVATIONS  
AT SELECTED WELLS IN OPV BASINS UNDER HYBRID SCENARIO ALTERNATIVES**



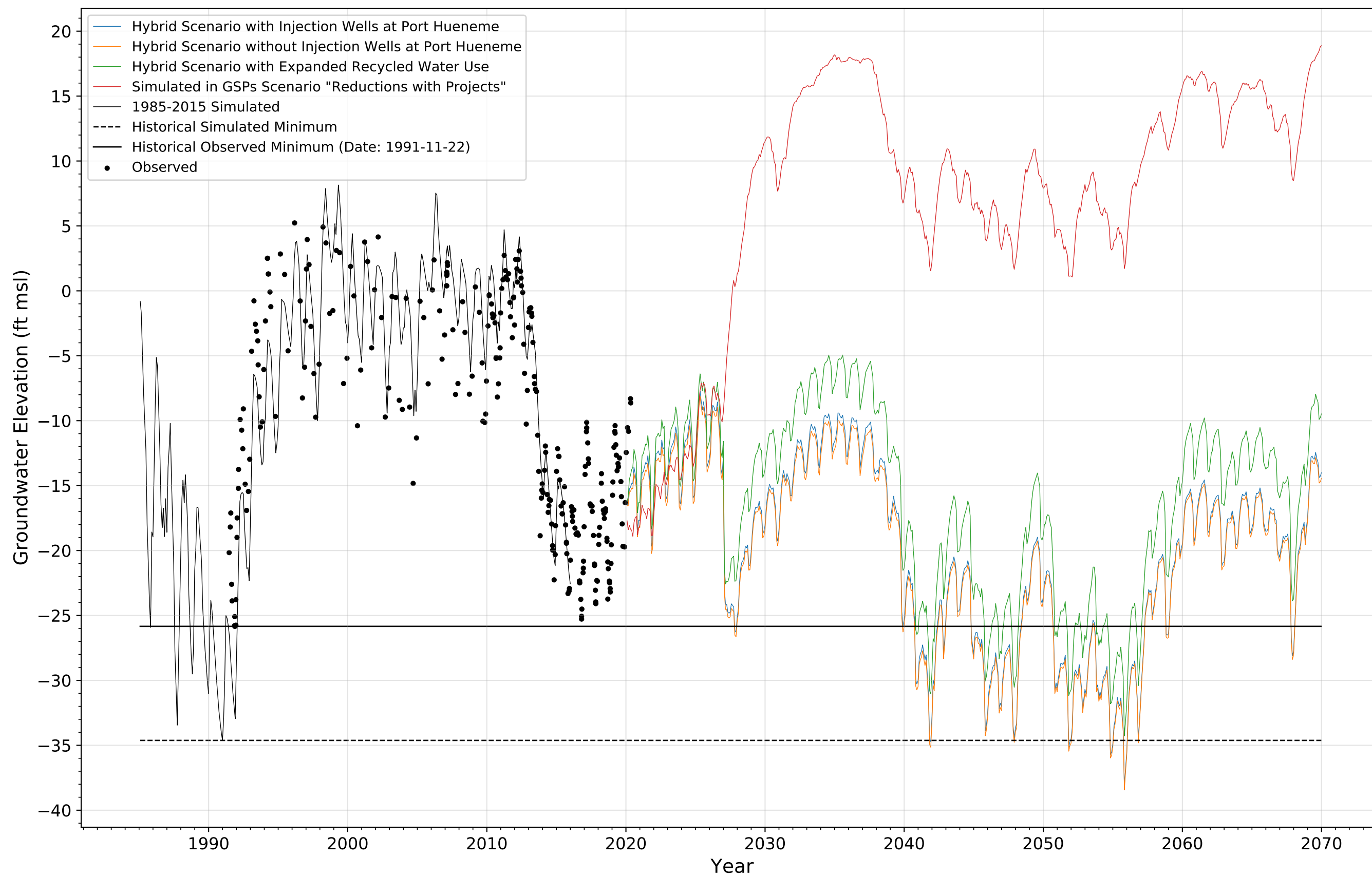
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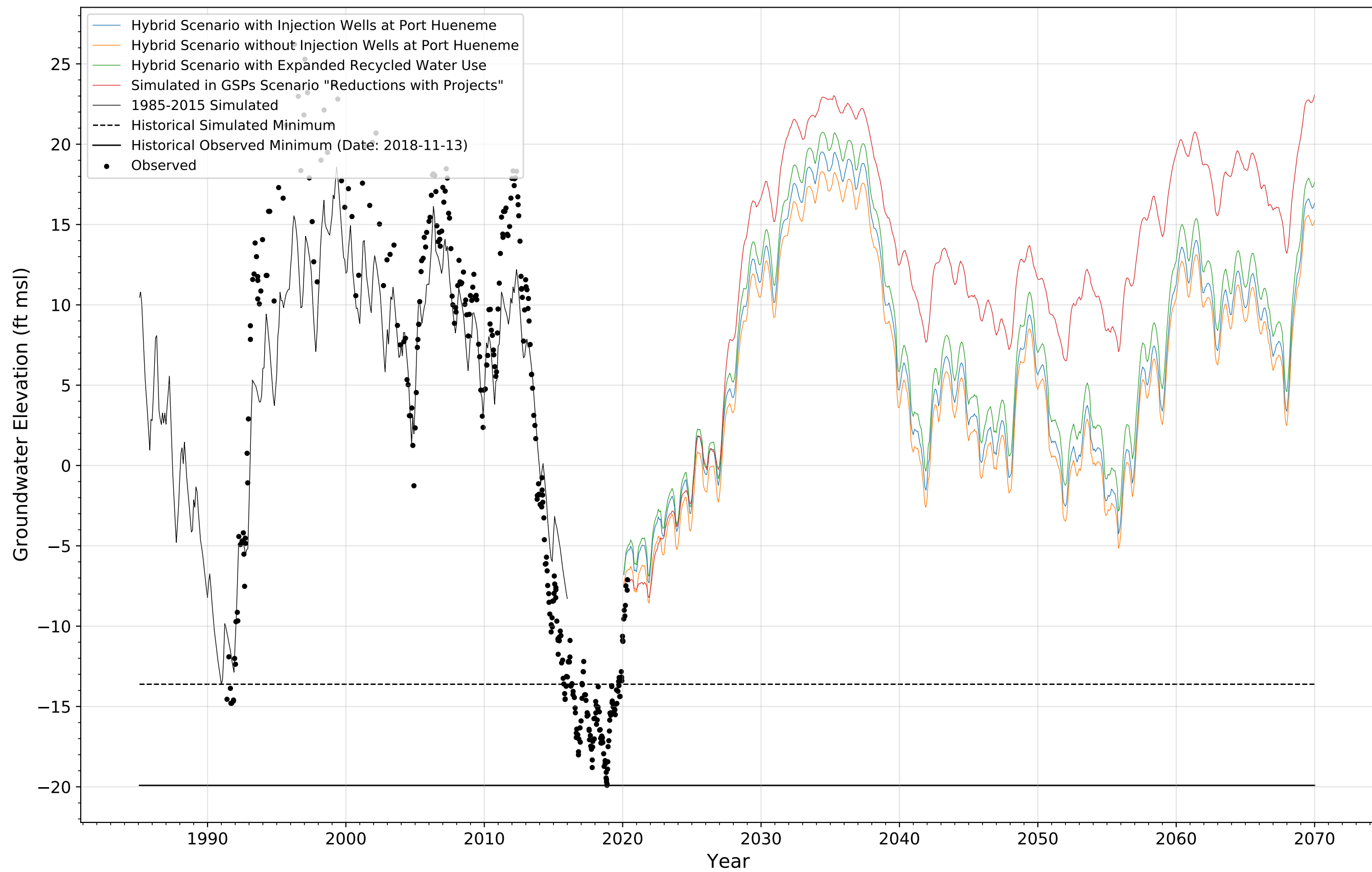
**Figure A-2. Modeled and Measured Groundwater Elevations at Well 02N21W34G05S, Screened in Older Alluvium**





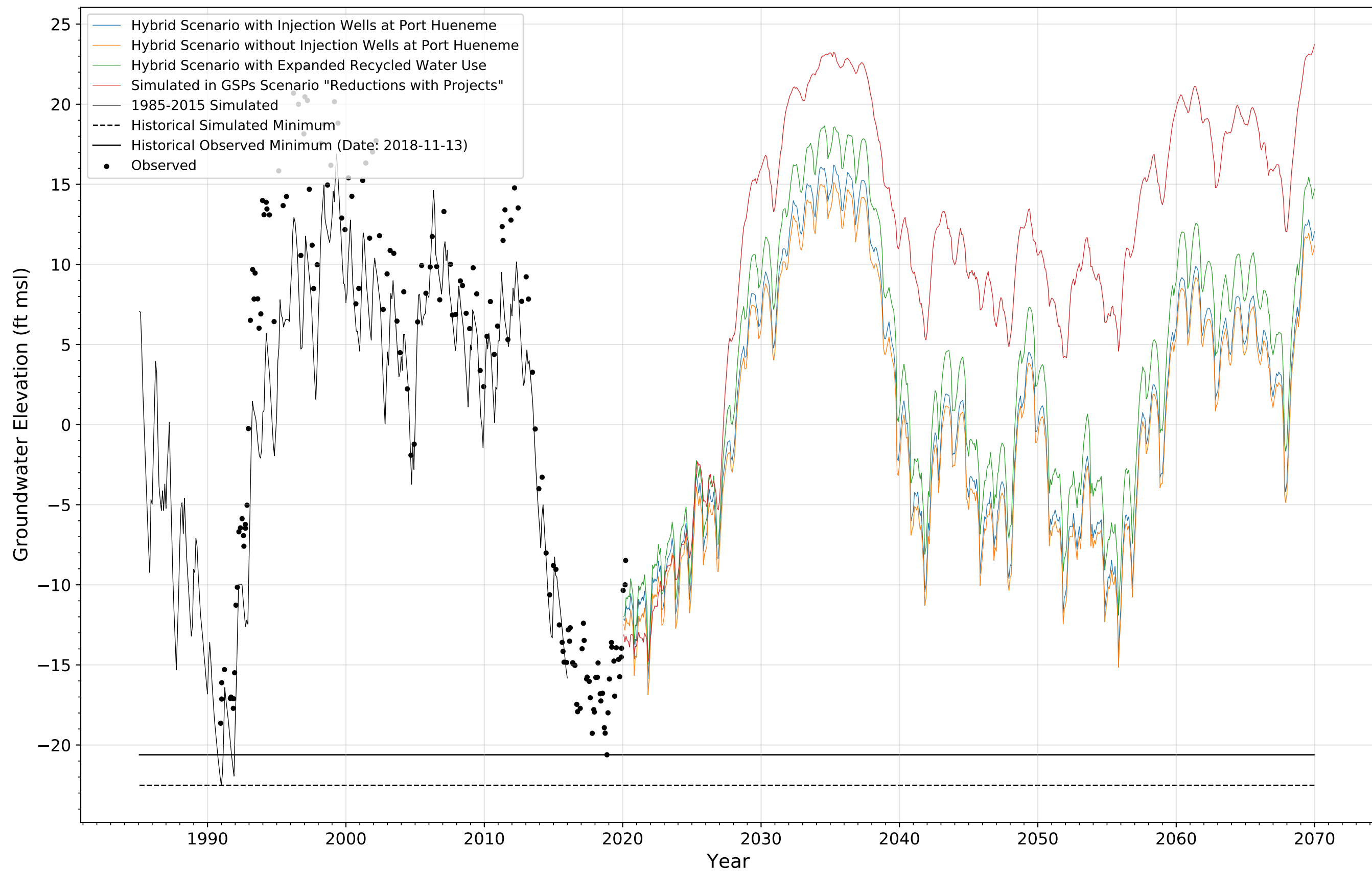
**Figure A-3. Modeled and Measured Groundwater Elevations at Well 01N21W32Q06S, Screened in Oxnard Aquifer**





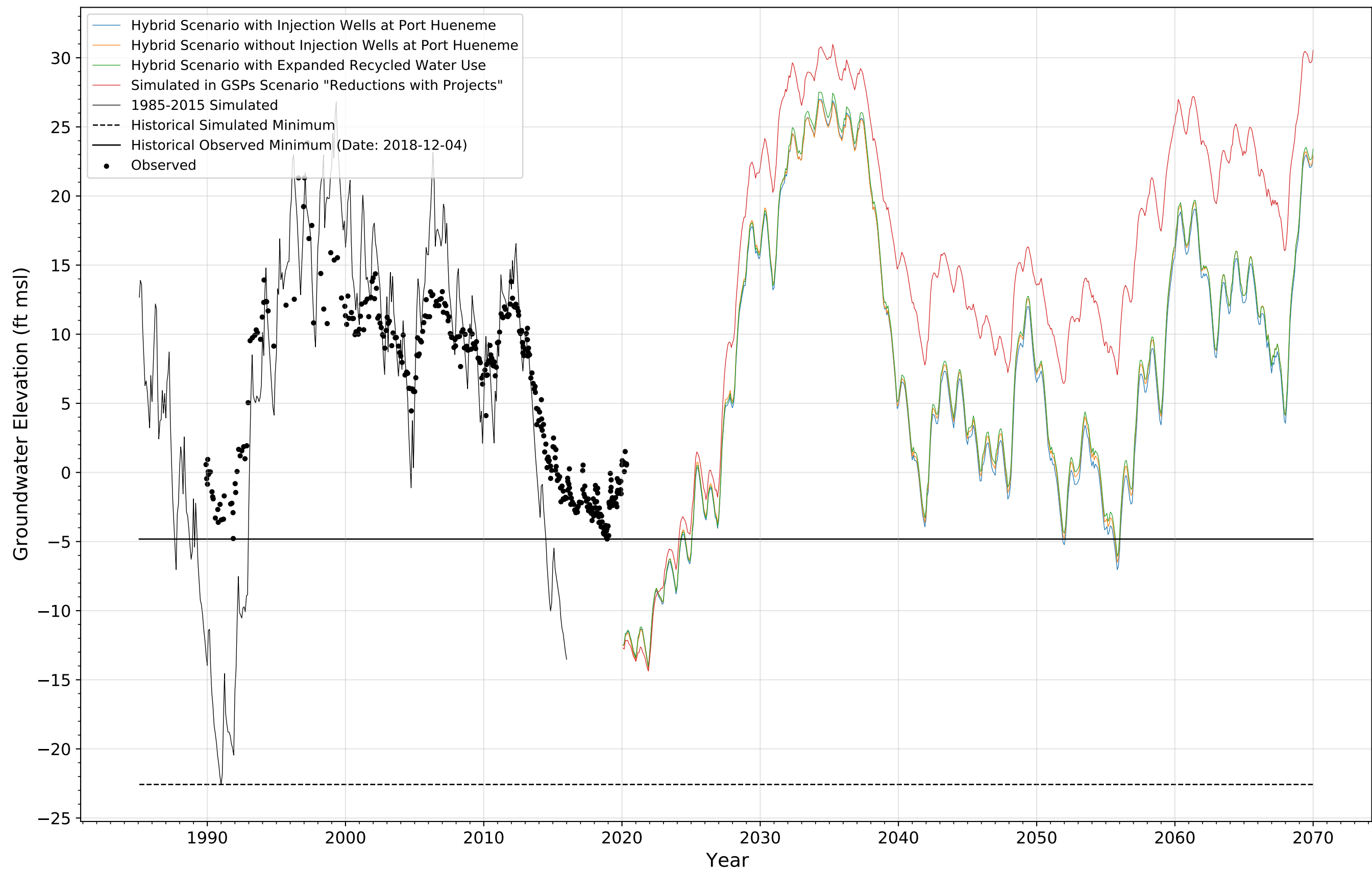
**Figure A-4. Modeled and Measured Groundwater Elevations at Well 01N22W20J08S, Screened in Oxnard Aquifer**





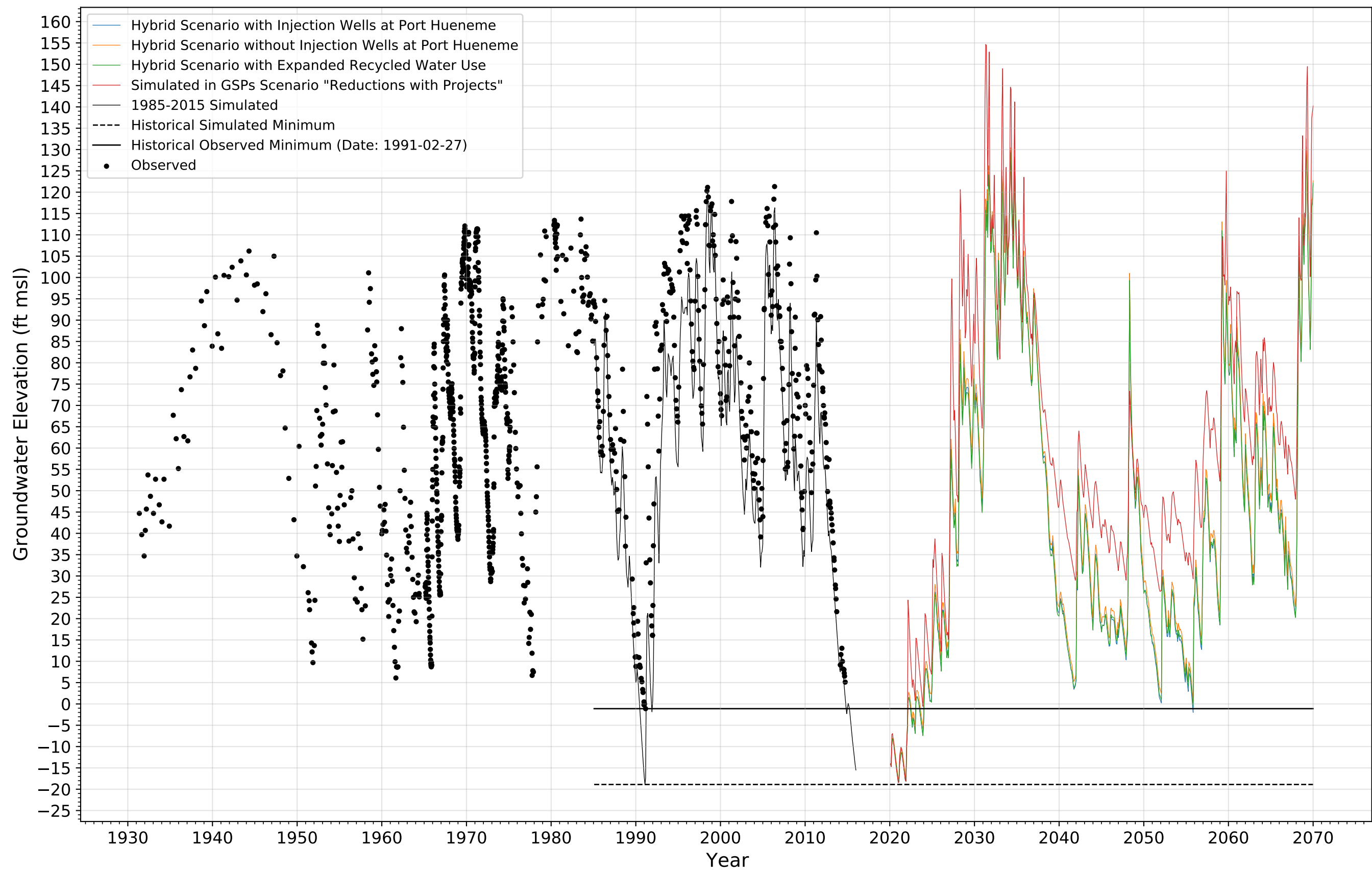
**Figure A-5. Modeled and Measured Groundwater Elevations at Well 01N22W27C03S, Screened in Oxnard Aquifer**





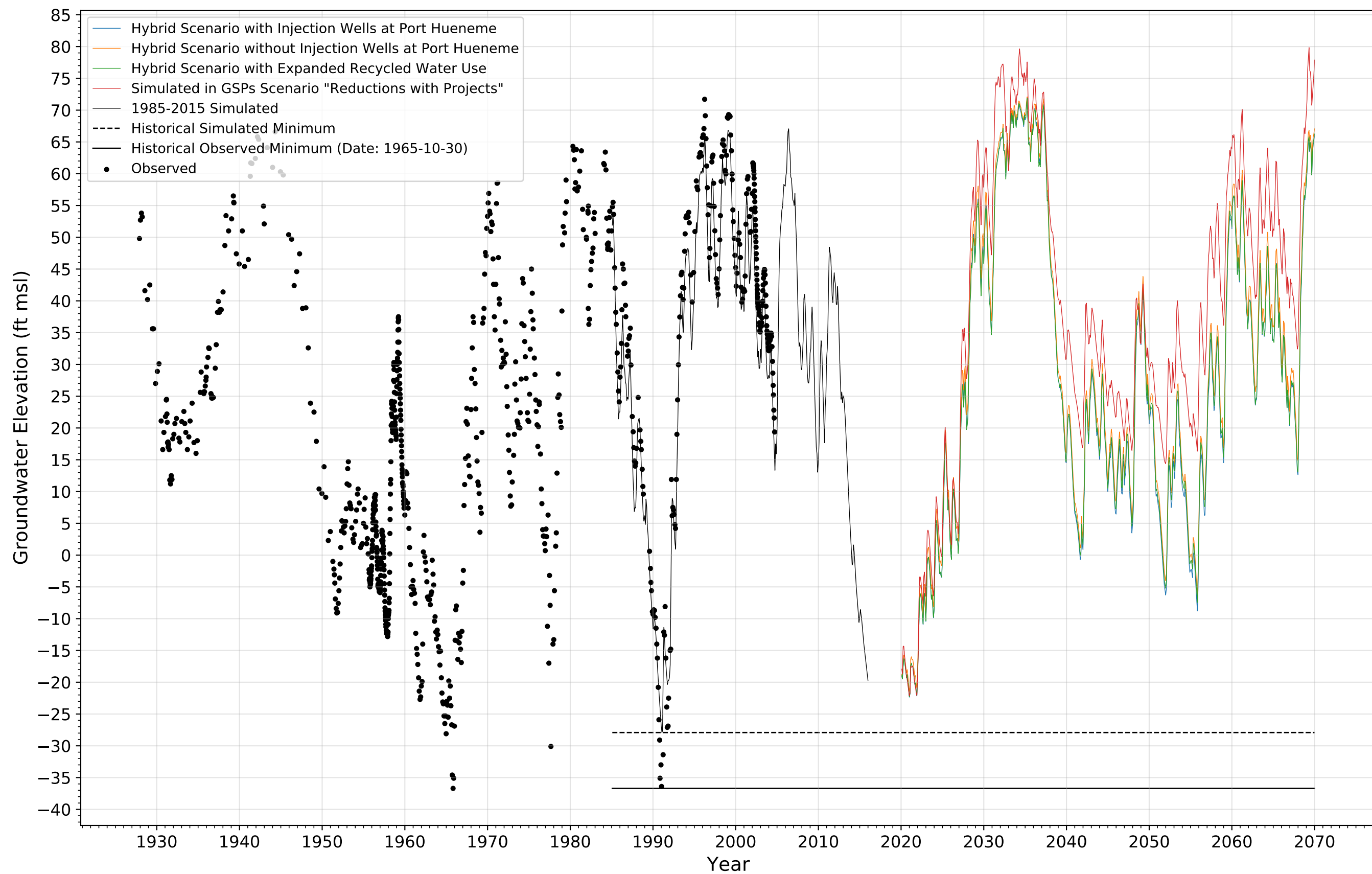
**Figure A-6. Modeled and Measured Groundwater Elevations at Well 01N23W01C05S, Screened in Oxnard Aquifer**





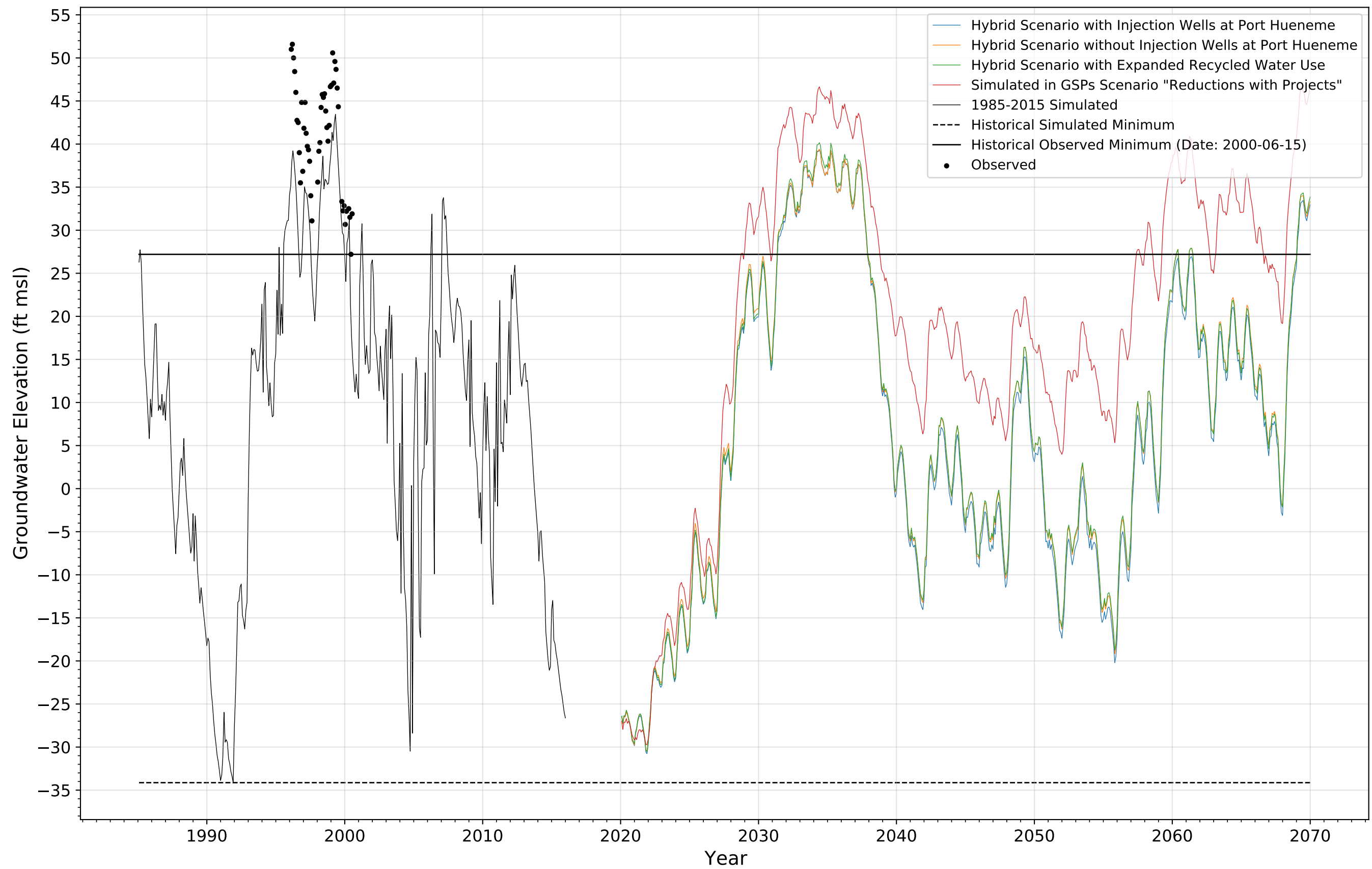
**Figure A-7. Modeled and Measured Groundwater Elevations at Well 02N22W12R01S, Screened in Oxnard Aquifer**





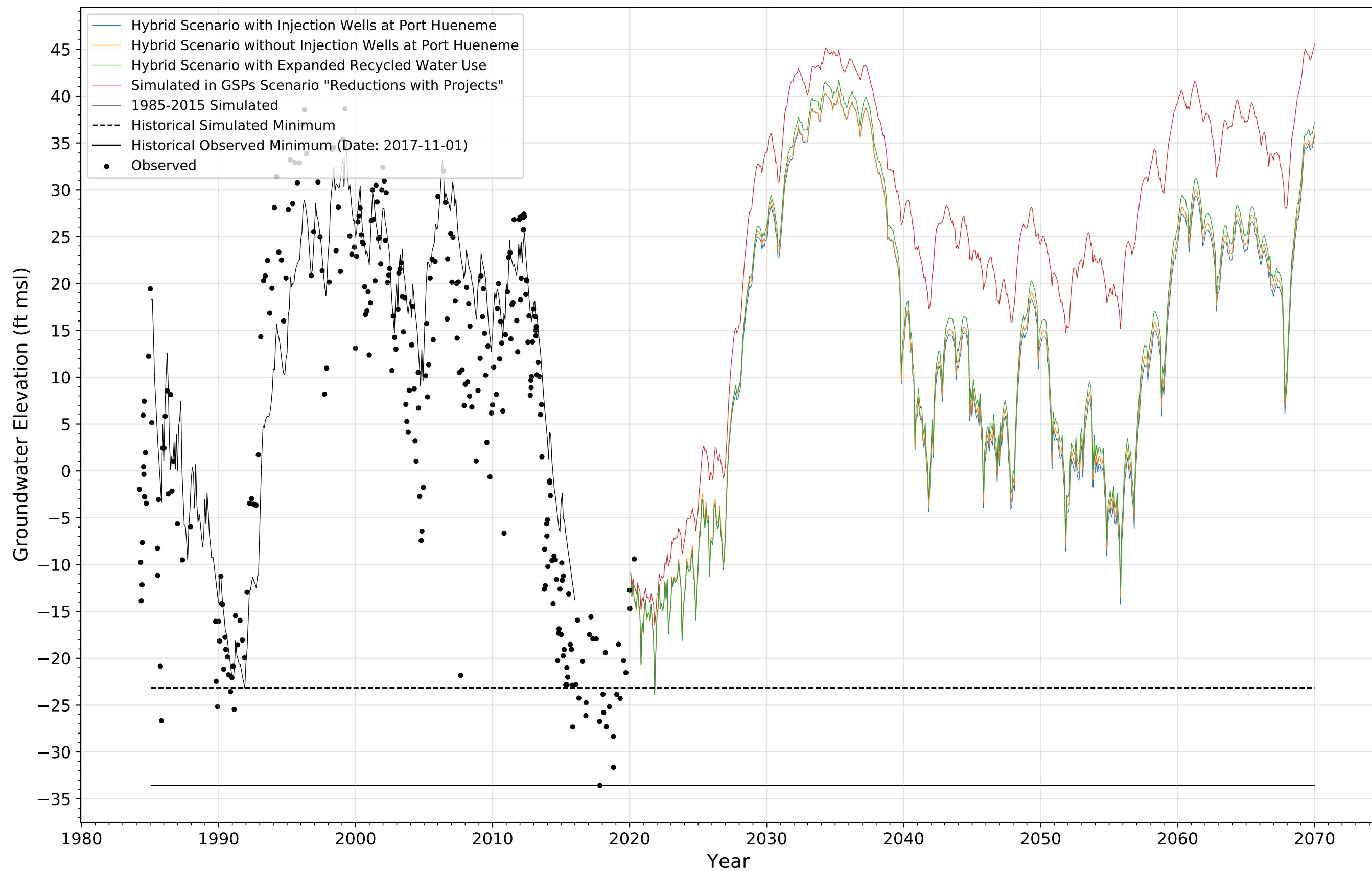
**Figure A-8. Modeled and Measured Groundwater Elevations at Well 02N22W22R01S, Screened in Oxnard Aquifer**





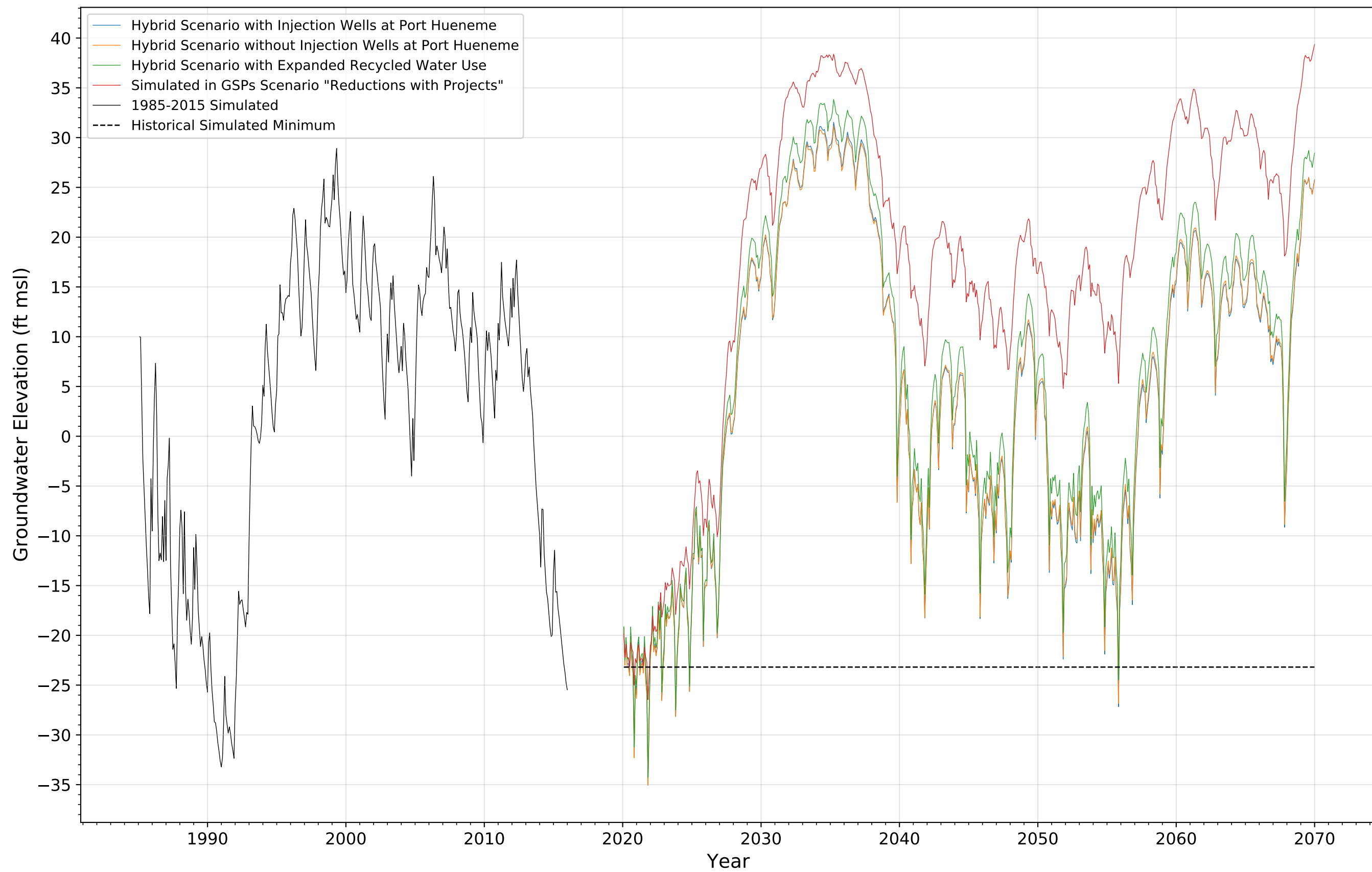
**Figure A-9. Modeled and Measured Groundwater Elevations at Well 01N22W03F04S, Screened in Oxnard Aquifer**





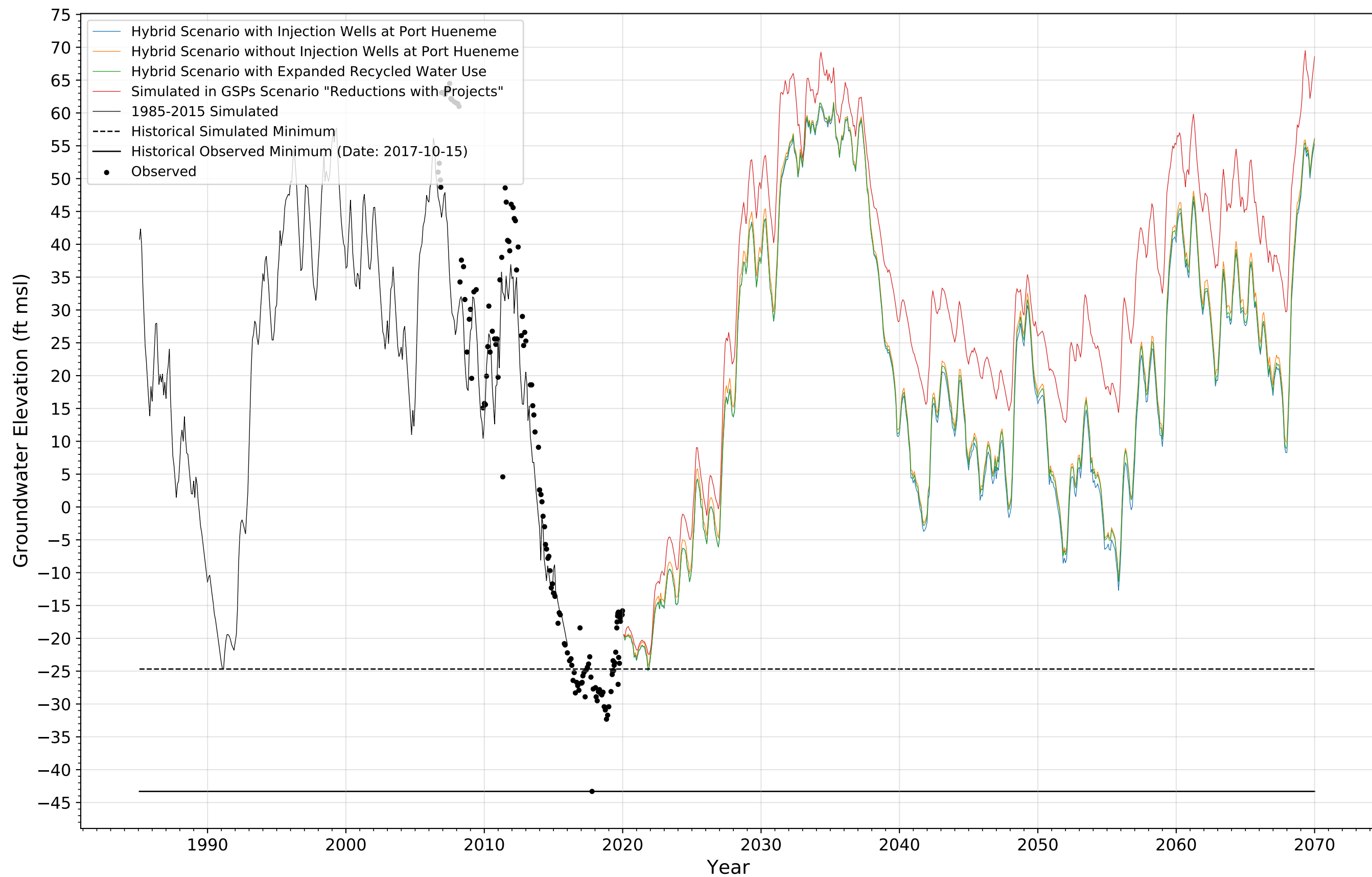
**Figure A-10. Modeled and Measured Groundwater Elevations at Well 01N21W06R01S, Screened in Oxnard Aquifer**





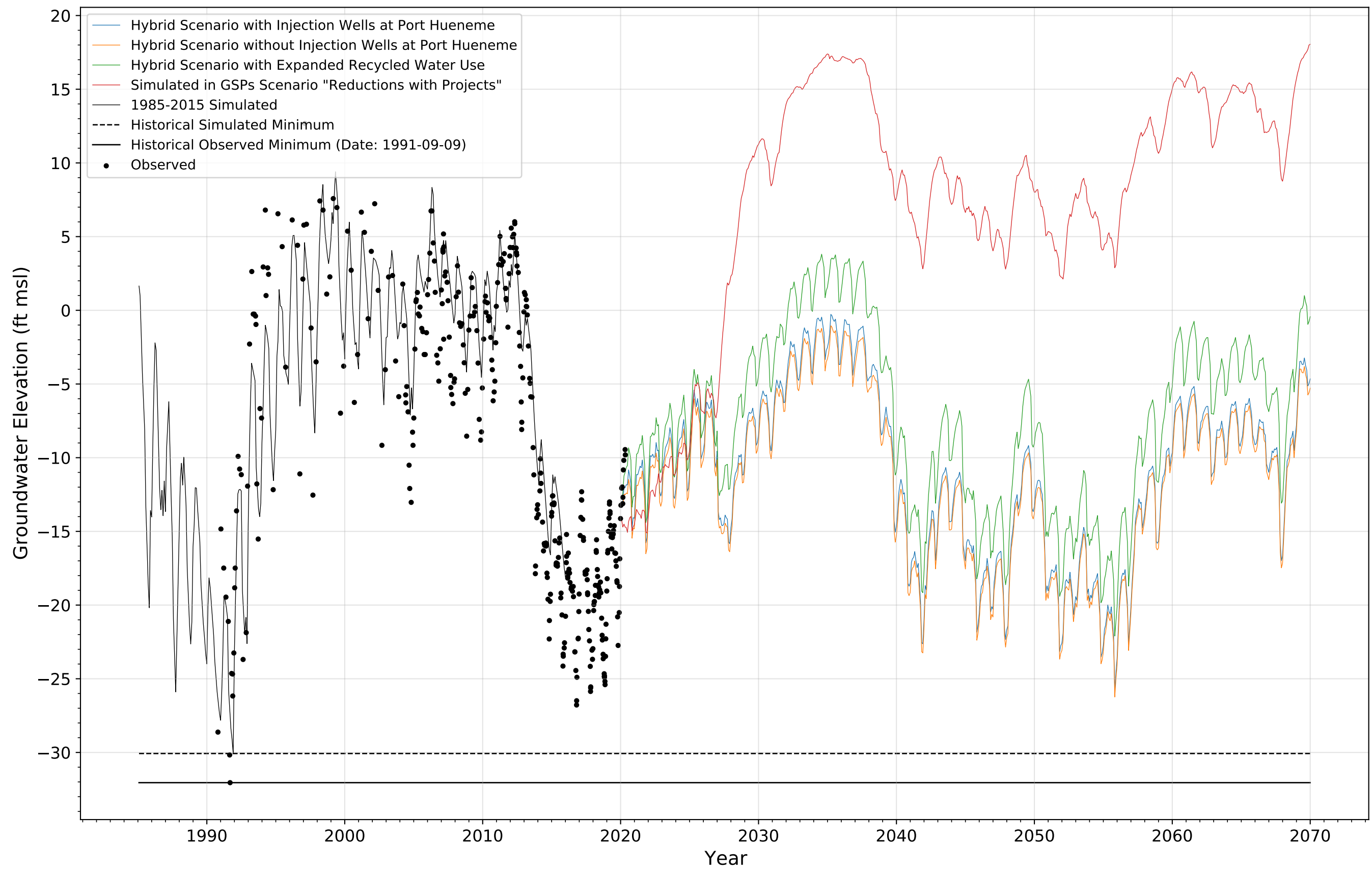
**Figure A-11. Modeled and Measured Groundwater Elevations at Well 01N22W12P01S, Screened in Oxnard Aquifer**





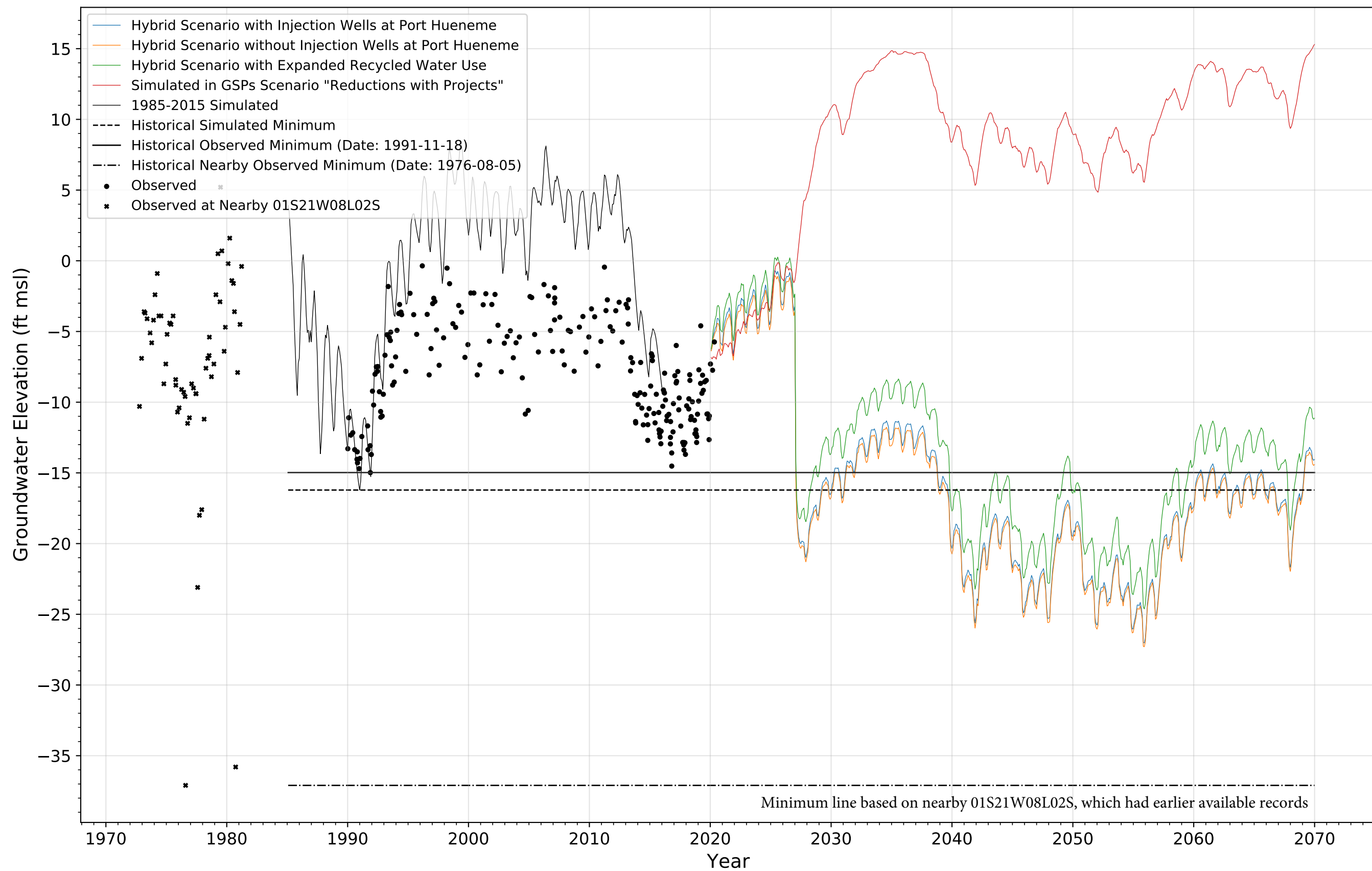
**Figure A-12. Modeled and Measured Groundwater Elevations at Well 02N22W36E05S, Screened in Oxnard Aquifer**





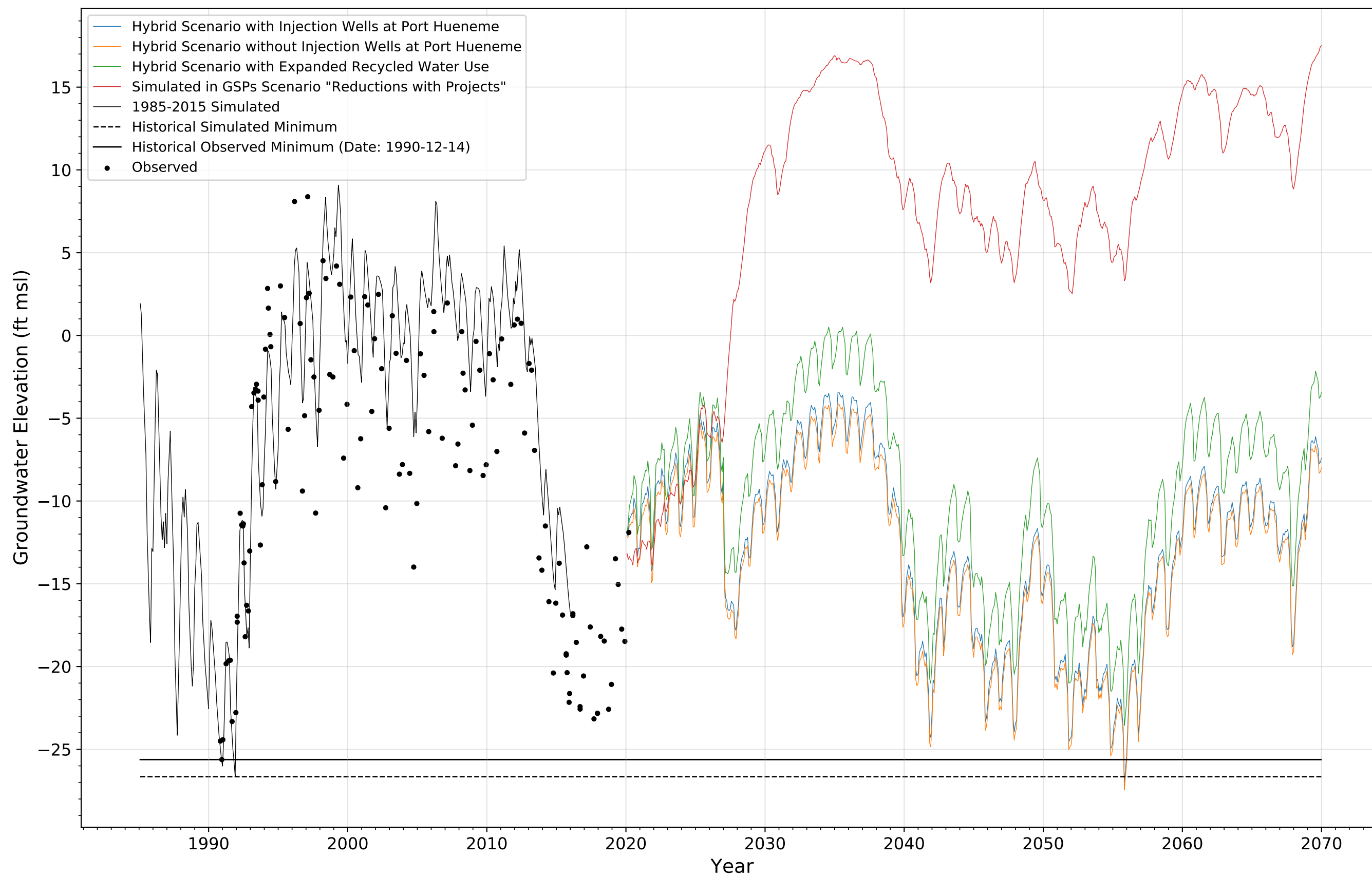
**Figure A-13. Modeled and Measured Groundwater Elevations at Well 01N22W36K09S, Screened in Oxnard Aquifer**





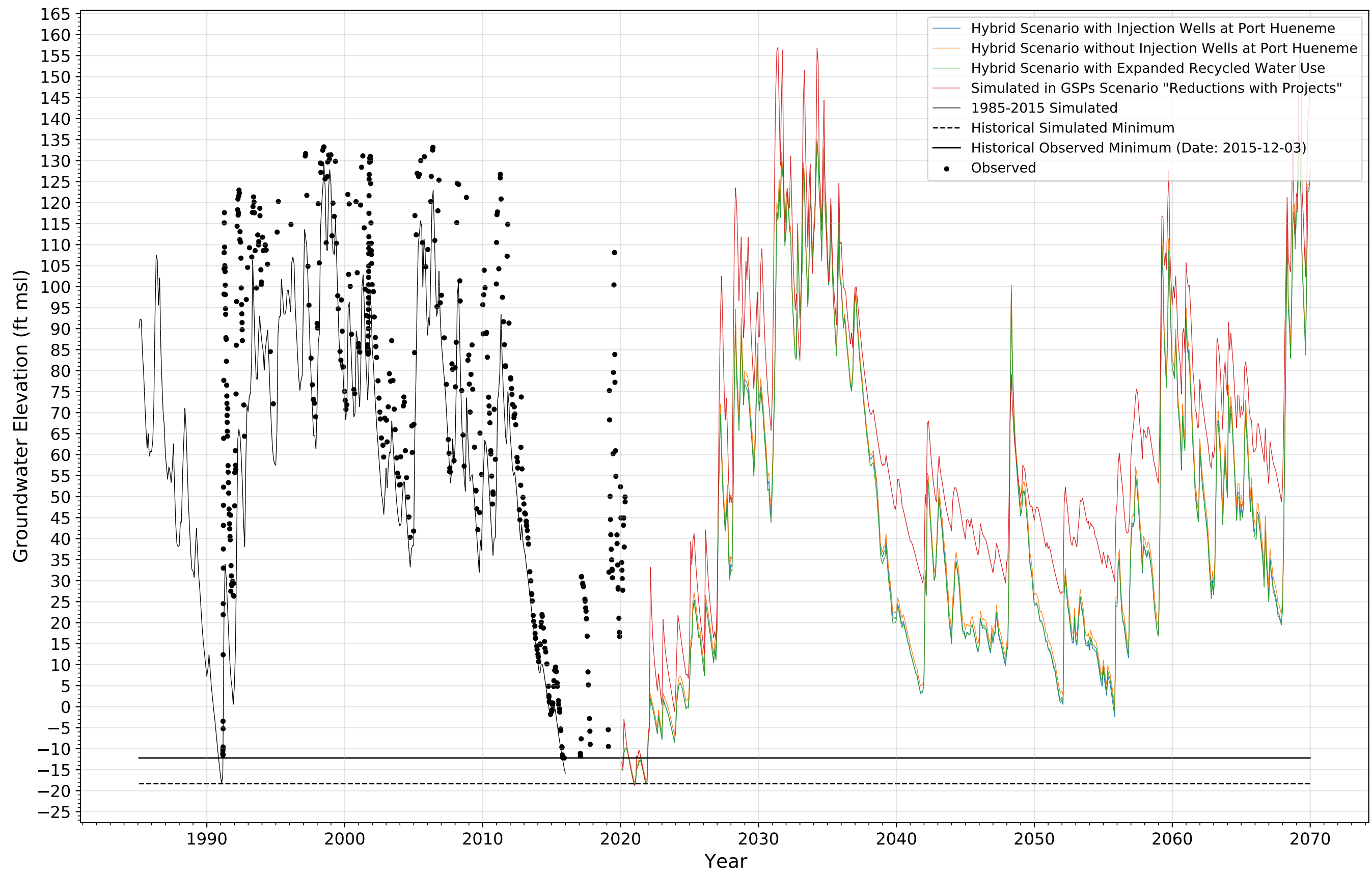
**Figure A-14. Modeled and Measured Groundwater Elevations at Well 01S21W08L04S, Screened in Oxnard Aquifer**





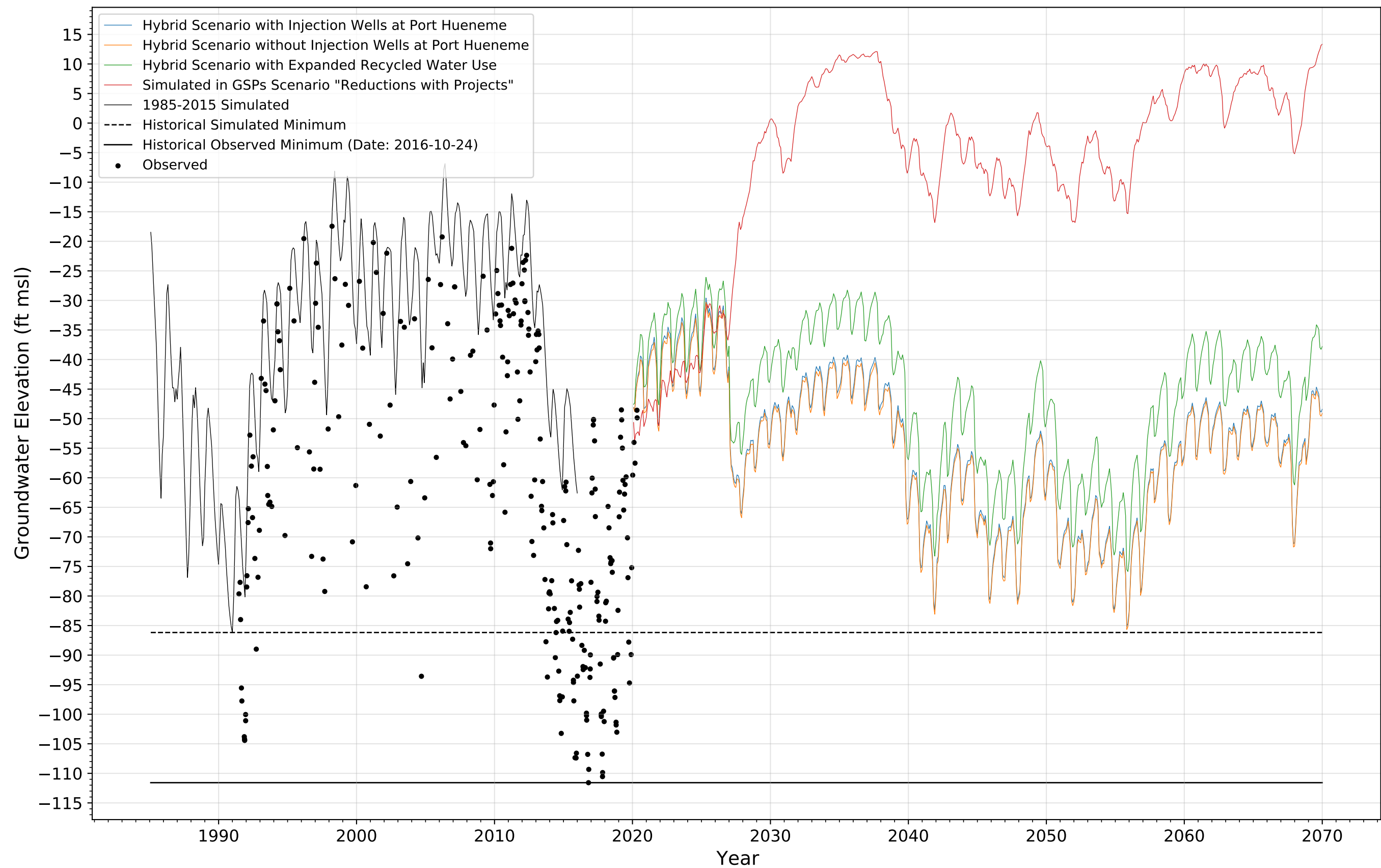
**Figure A-15. Modeled and Measured Groundwater Elevations at Well 01S22W01H04S, Screened in Oxnard Aquifer**





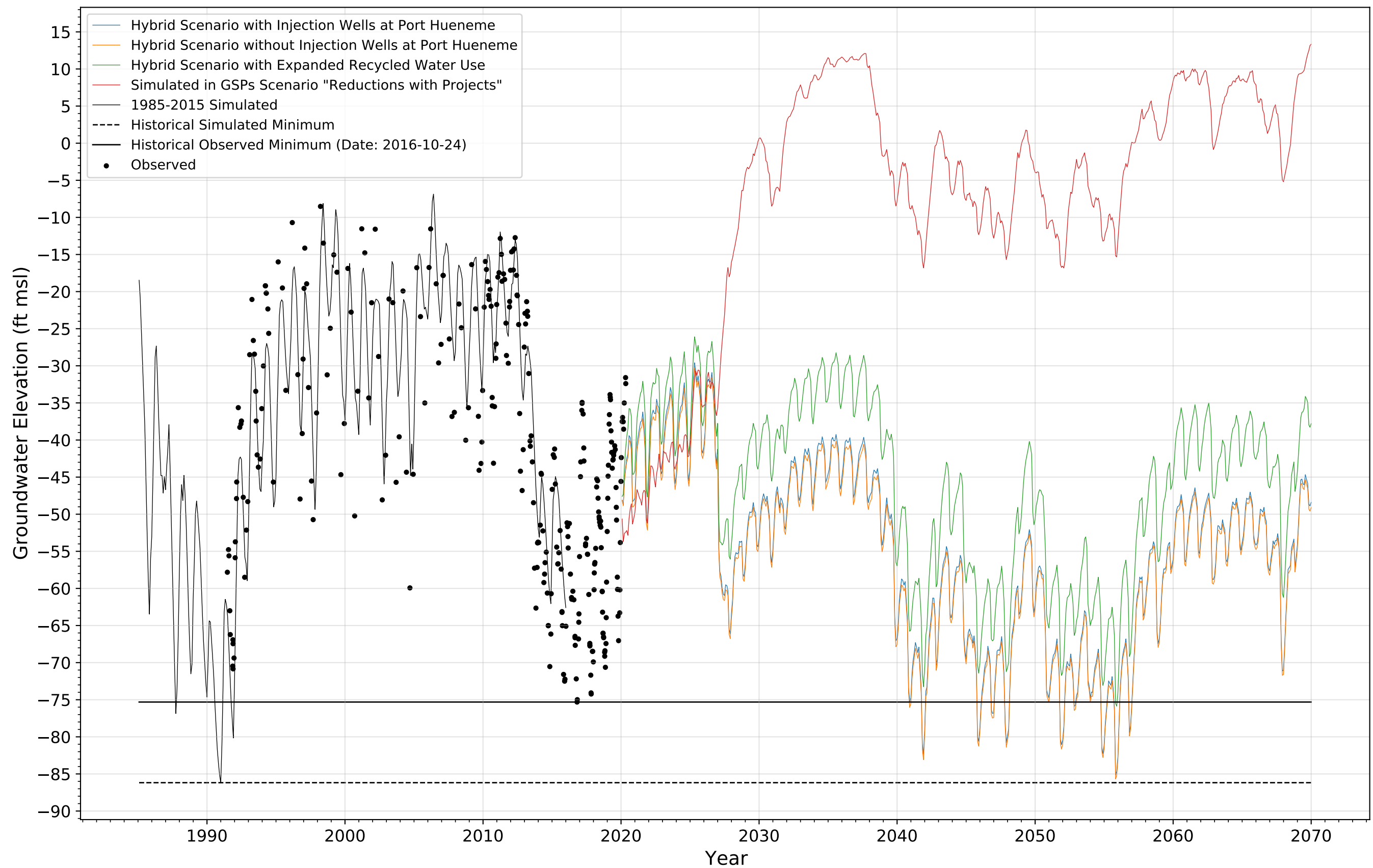
**Figure A-16. Modeled and Measured Groundwater Elevations at Well 02N21W07L06S, Screened in Oxnard Aquifer**





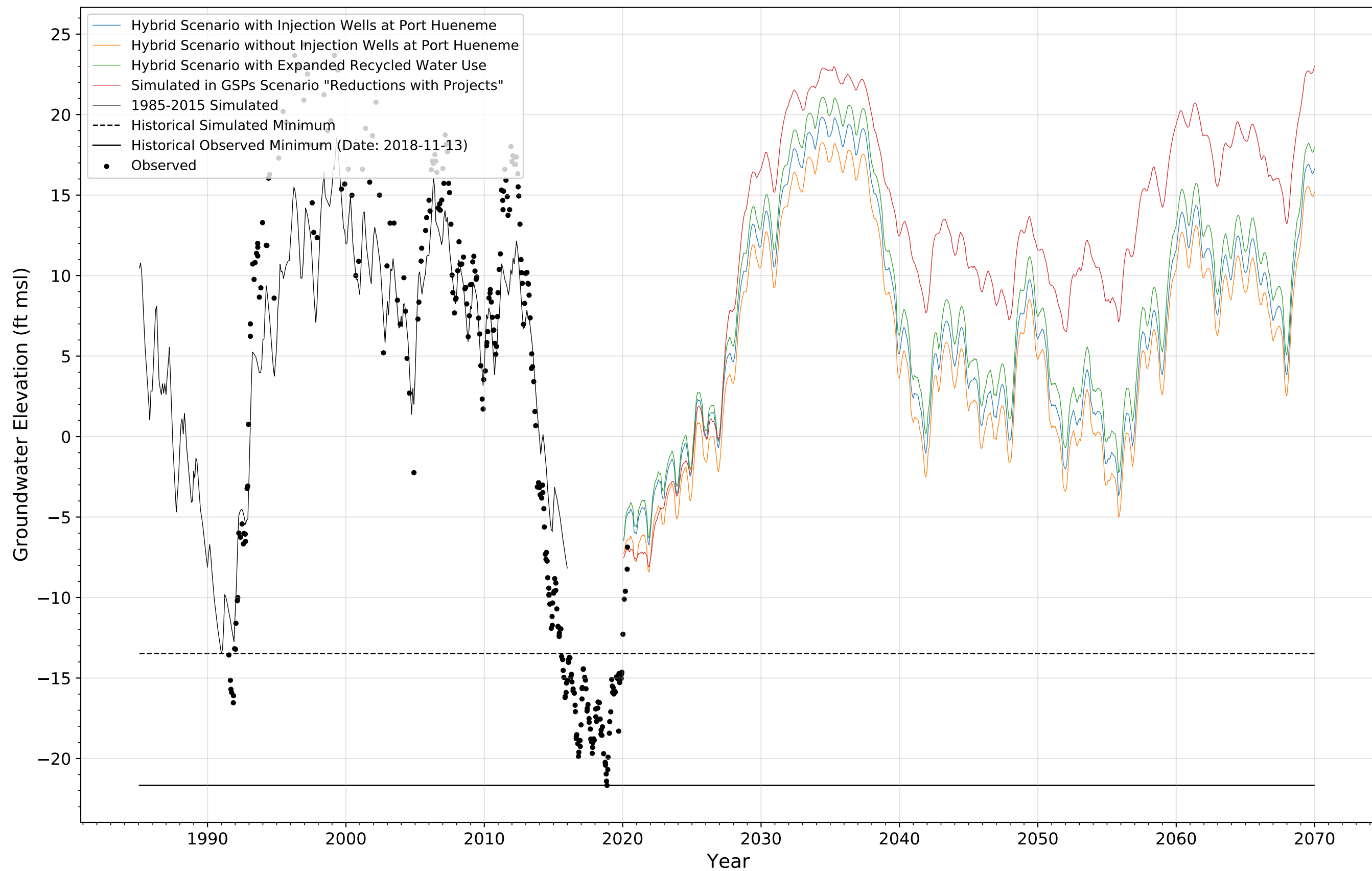
**Figure A-17. Modeled and Measured Groundwater Elevations at Well 01N21W32Q05S, Screened in Mugu Aquifer**





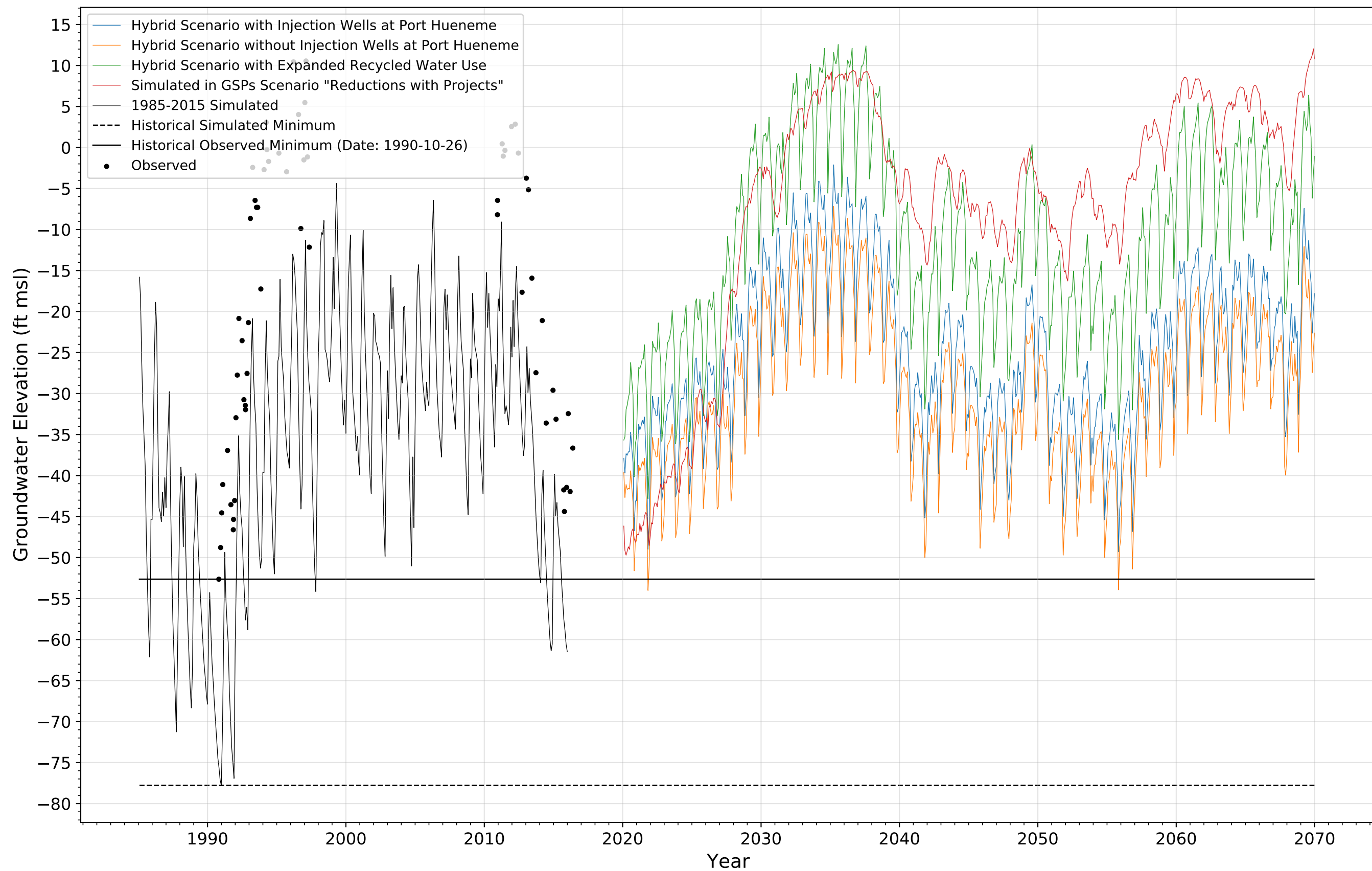
**Figure A-18. Modeled and Measured Groundwater Elevations at Well 01N21W32Q07S, Screened in Mugu Aquifer**





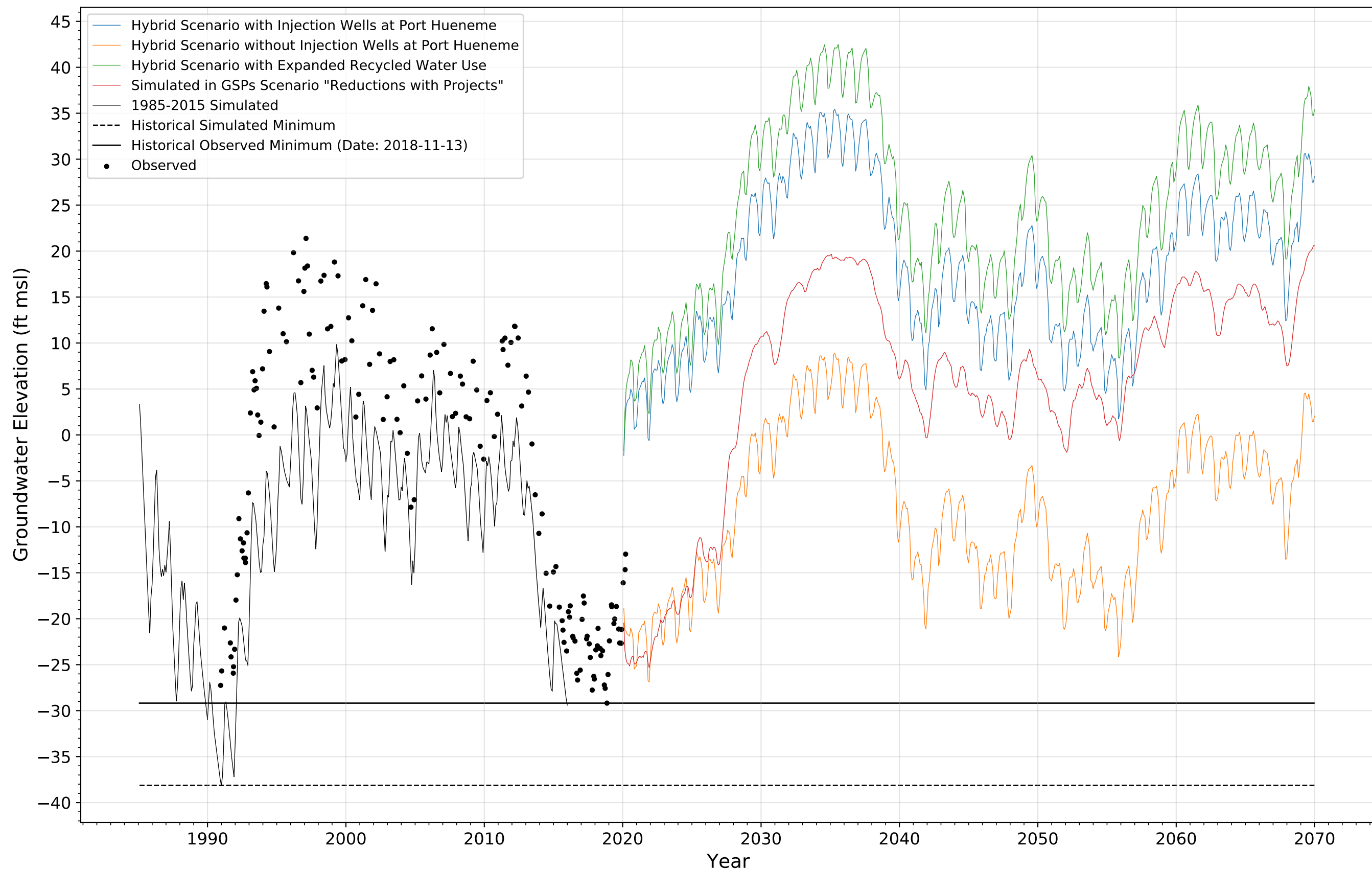
**Figure A-19. Modeled and Measured Groundwater Elevations at Well 01N22W20J07S, Screened in Mugu Aquifer**





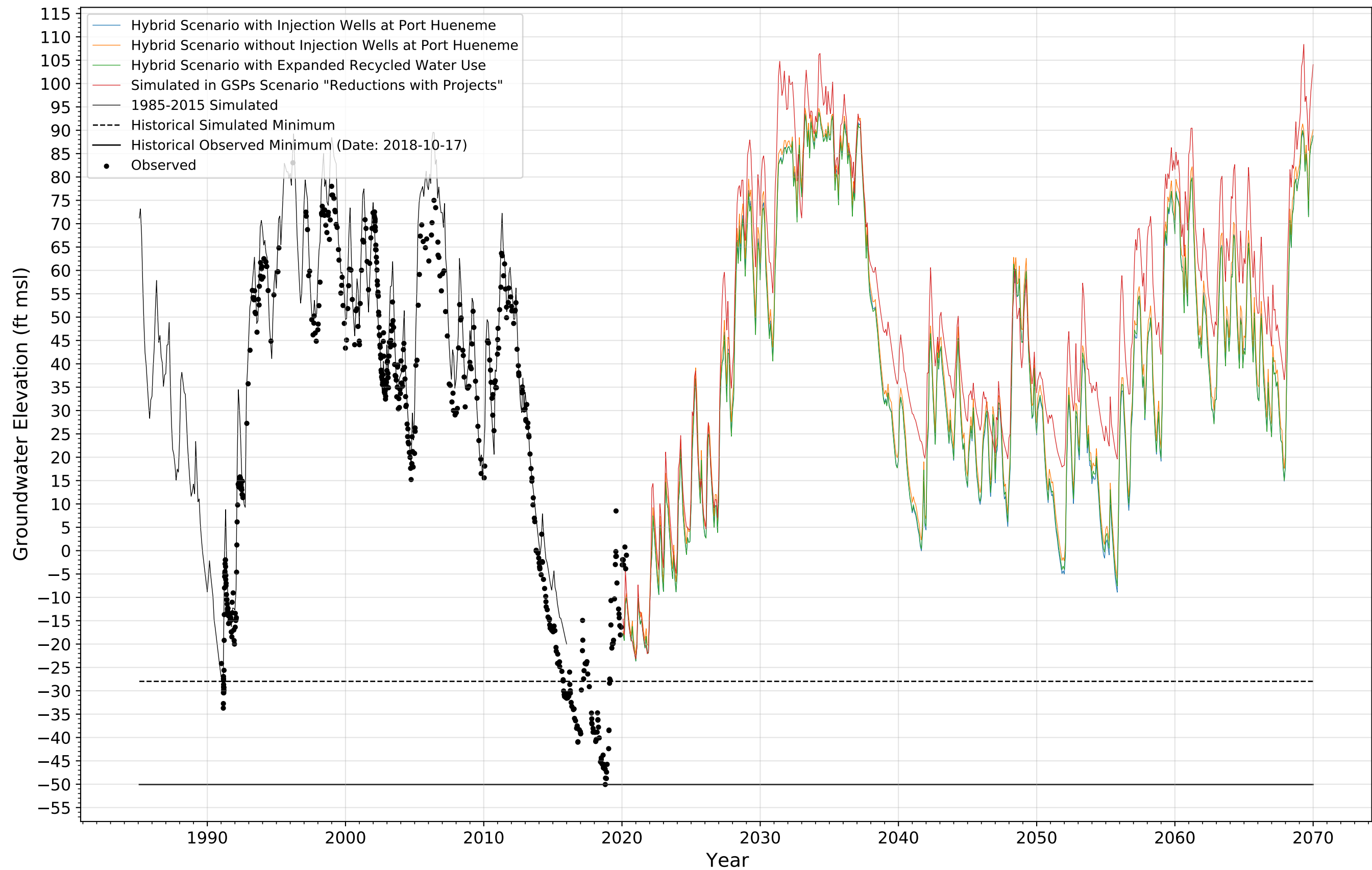
**Figure A-20. Modeled and Measured Groundwater Elevations at Well 01N22W26J03S, Screened in Mugu Aquifer**





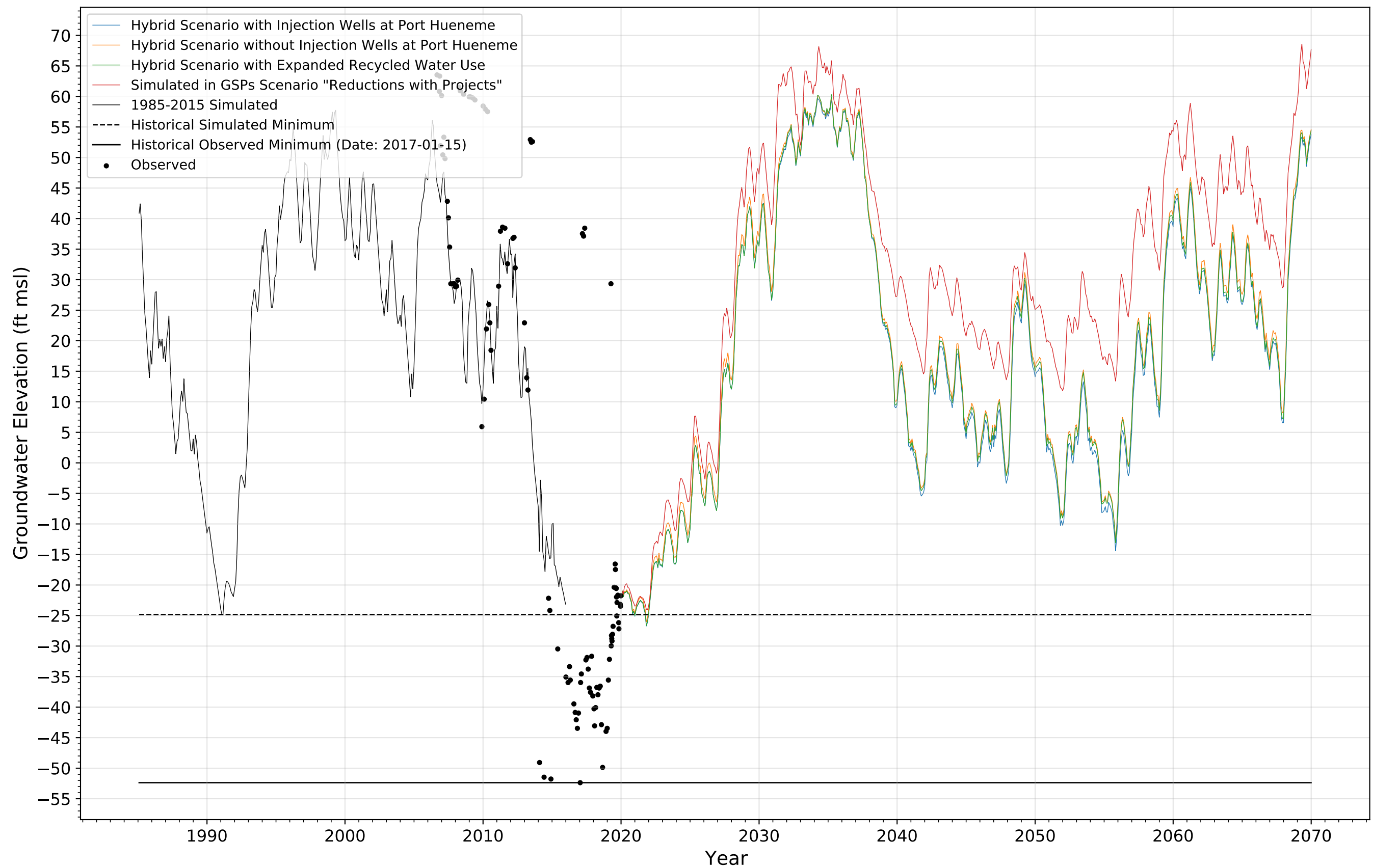
**Figure A-21. Modeled and Measured Groundwater Elevations at Well 01N22W27C02S, Screened in Mugu Aquifer**





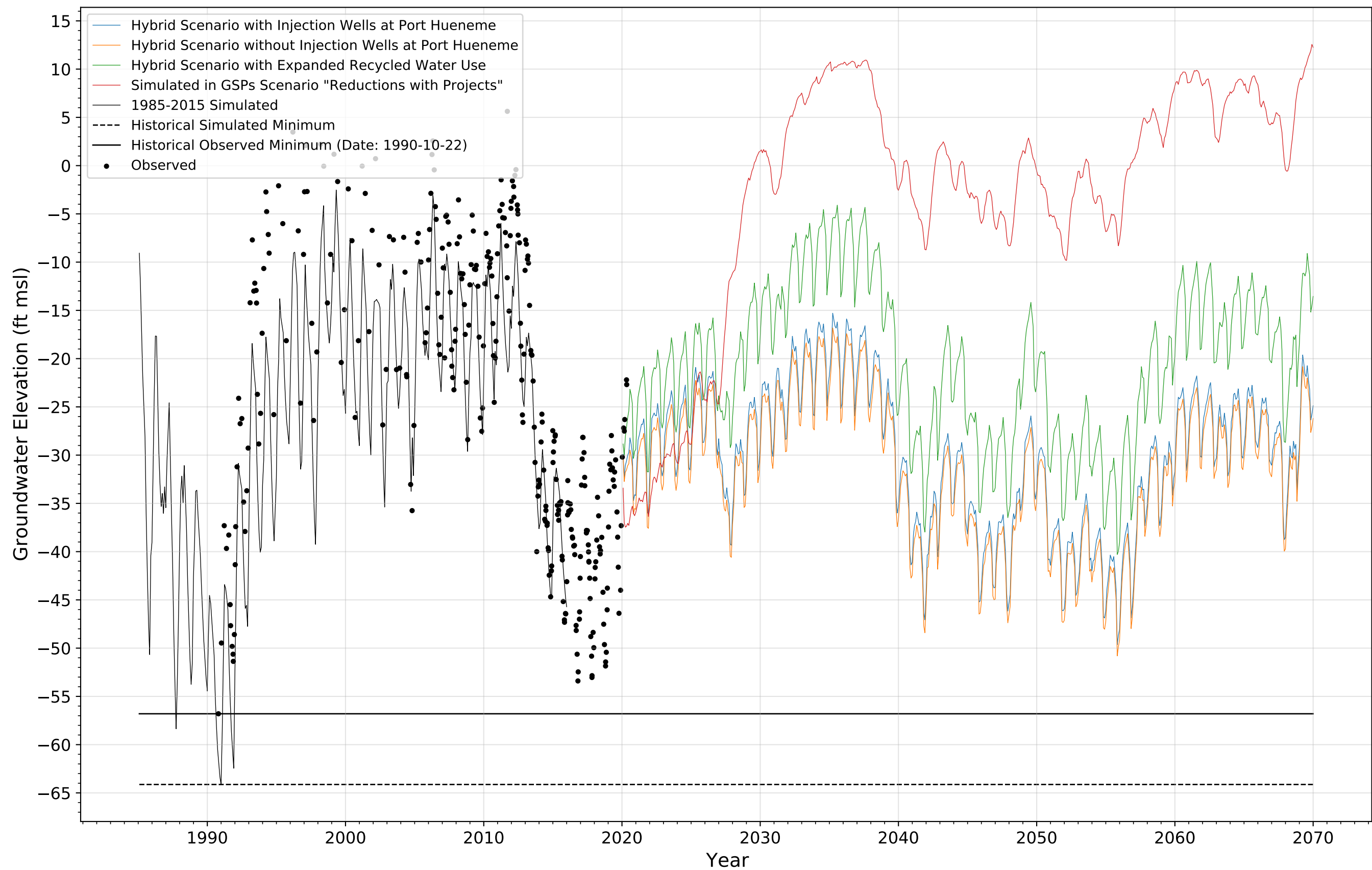
**Figure A-22. Modeled and Measured Groundwater Elevations at Well 02N22W23B07S, Screened in Mugu Aquifer**





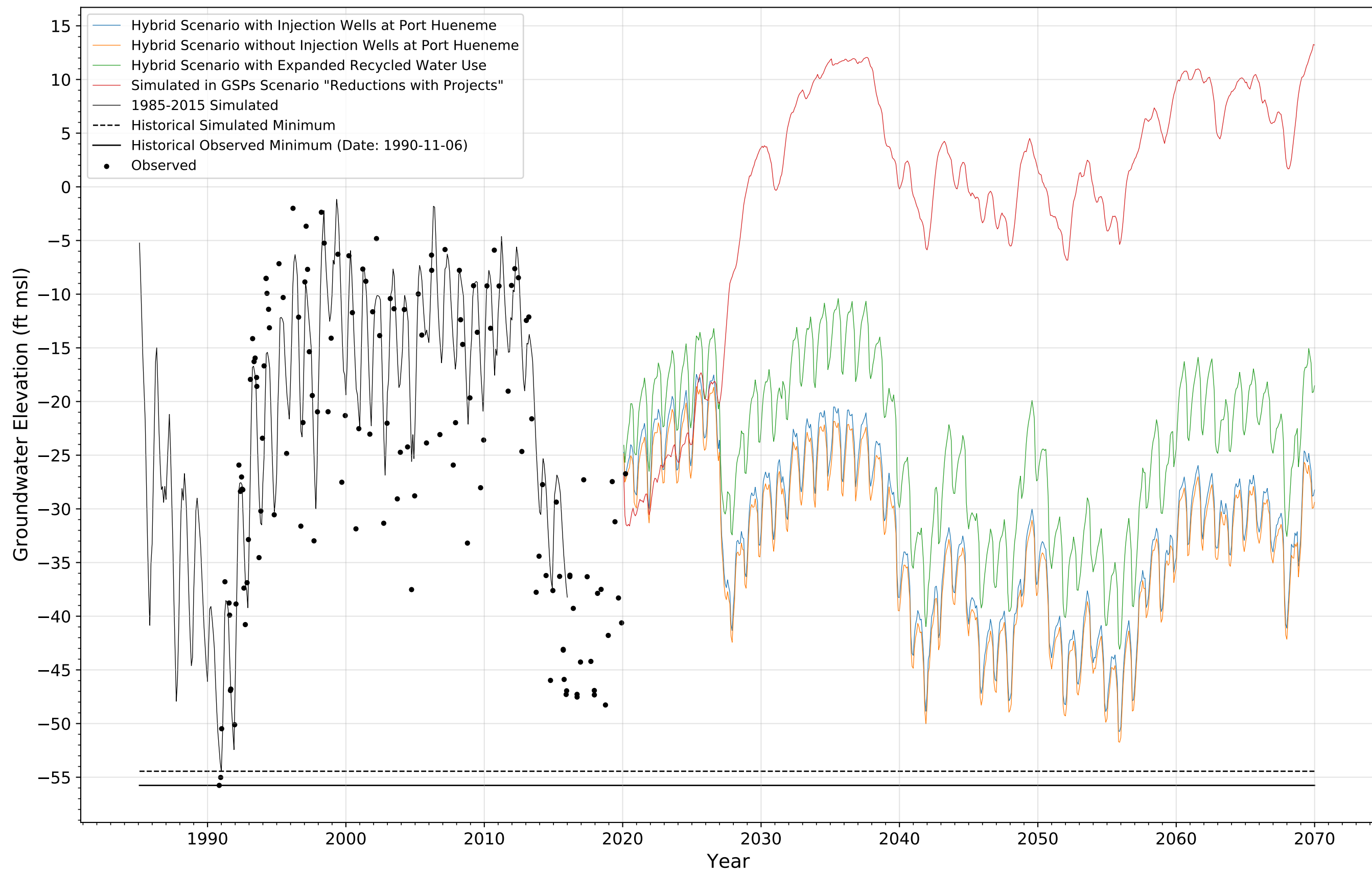
**Figure A-23. Modeled and Measured Groundwater Elevations at Well 02N22W36E03S, Screened in Mugu Aquifer**





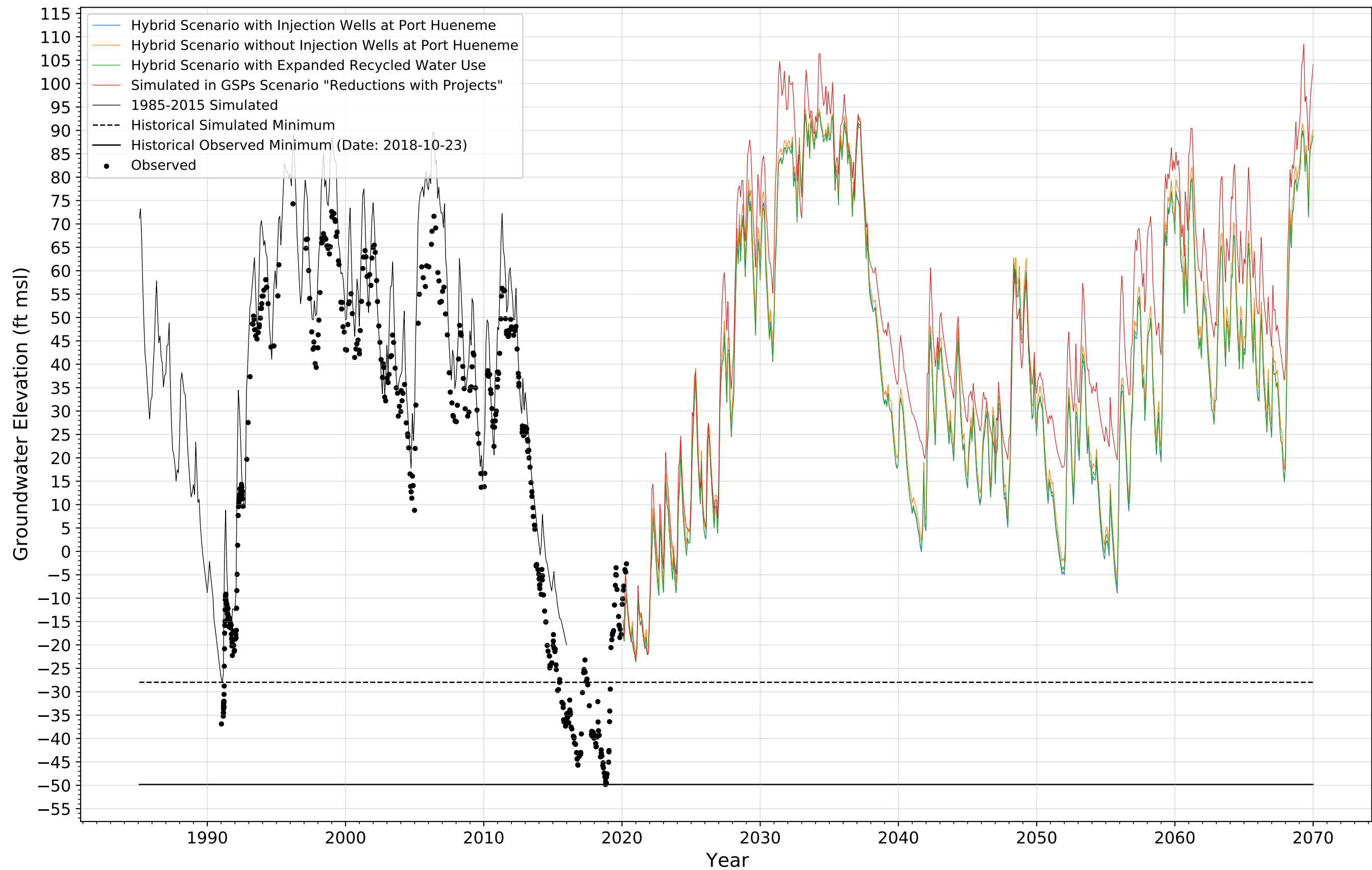
**Figure A-24. Modeled and Measured Groundwater Elevations at Well 01N22W36K08S, Screened in Mugu Aquifer**





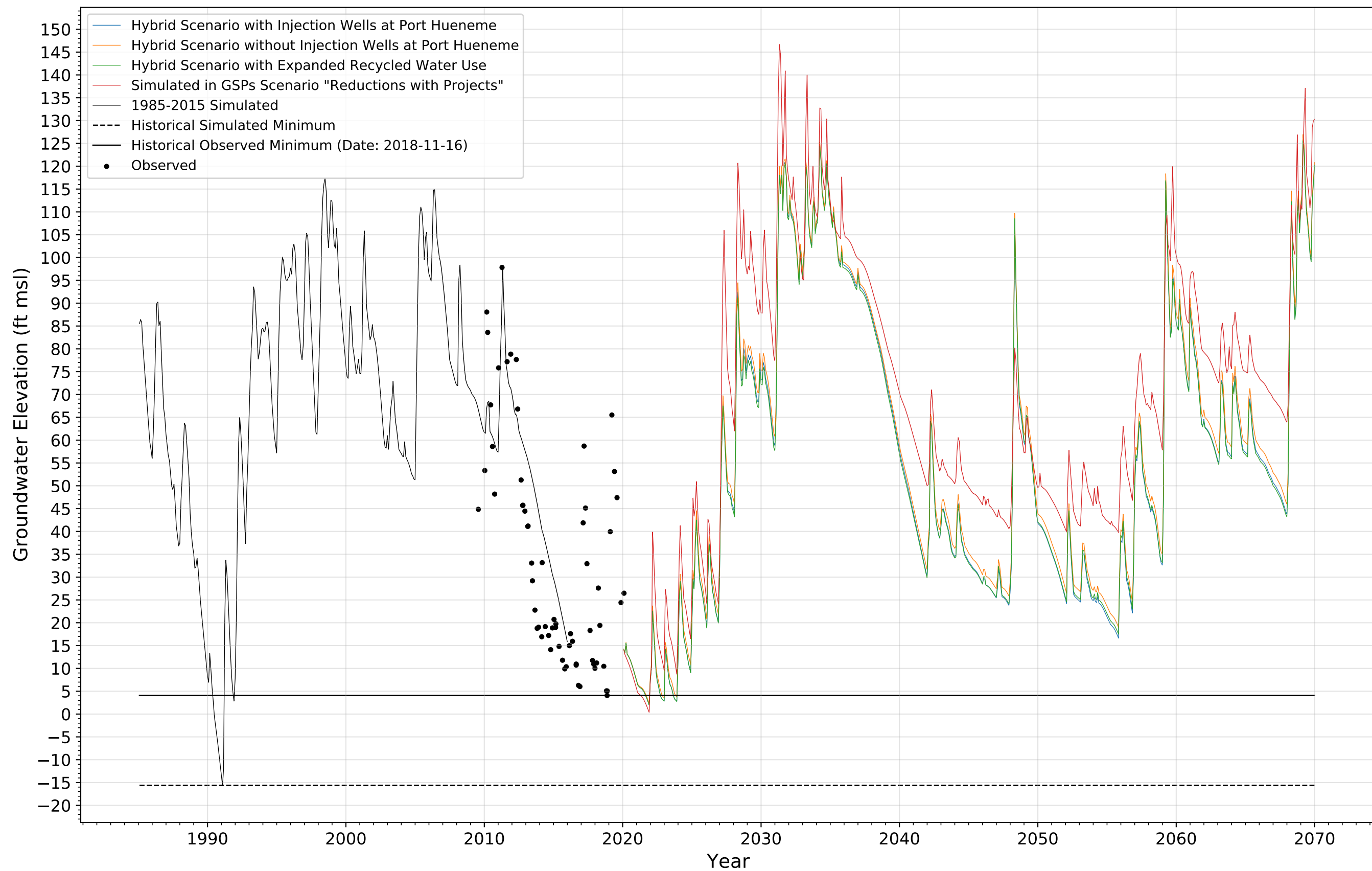
**Figure A-25. Modeled and Measured Groundwater Elevations at Well 01S22W01H03S, Screened in Mugu Aquifer**





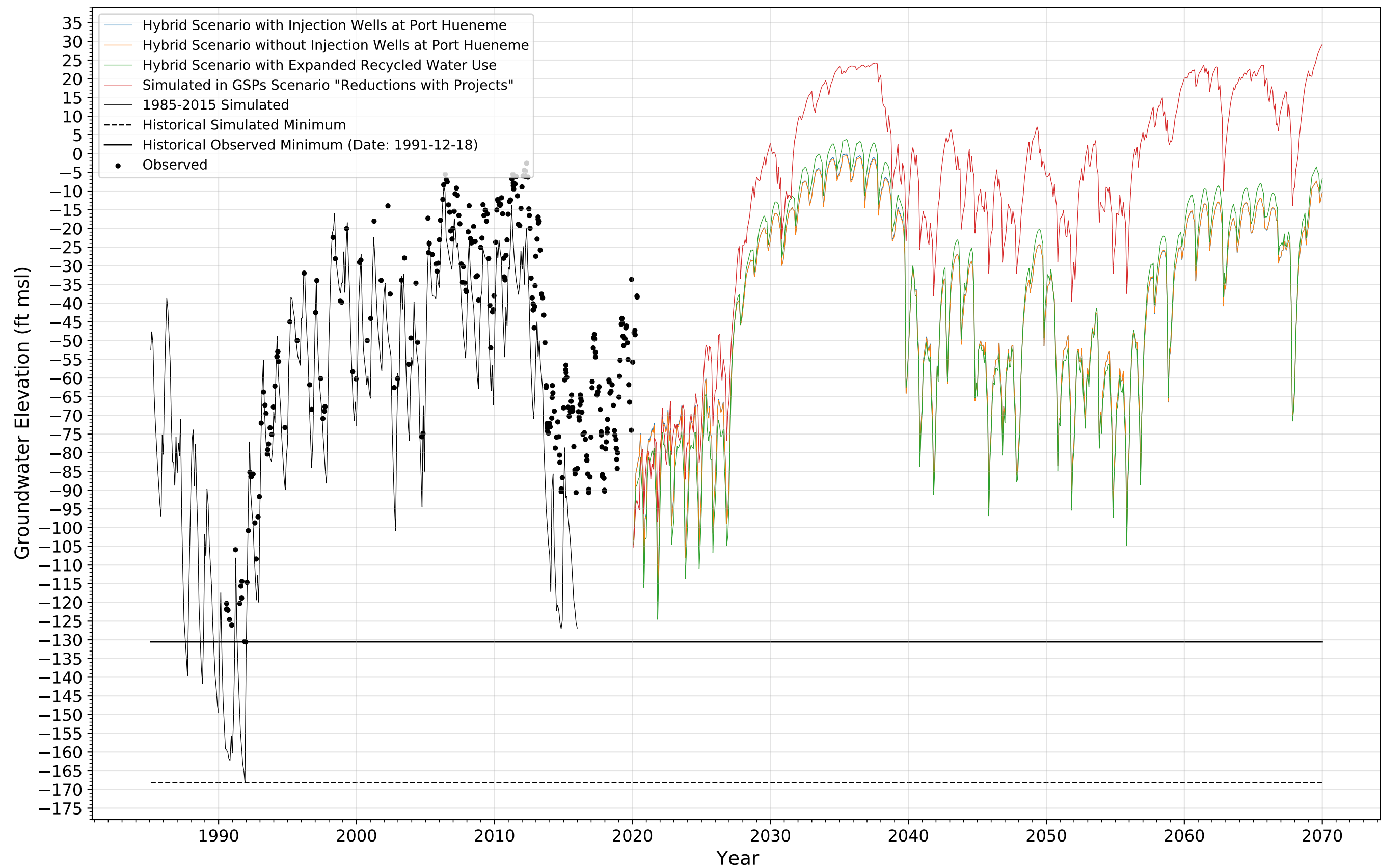
**Figure A-26. Modeled and Measured Groundwater Elevations at Well 02N22W23B06S, Screened in Mugu and Hueneme Aquifers**





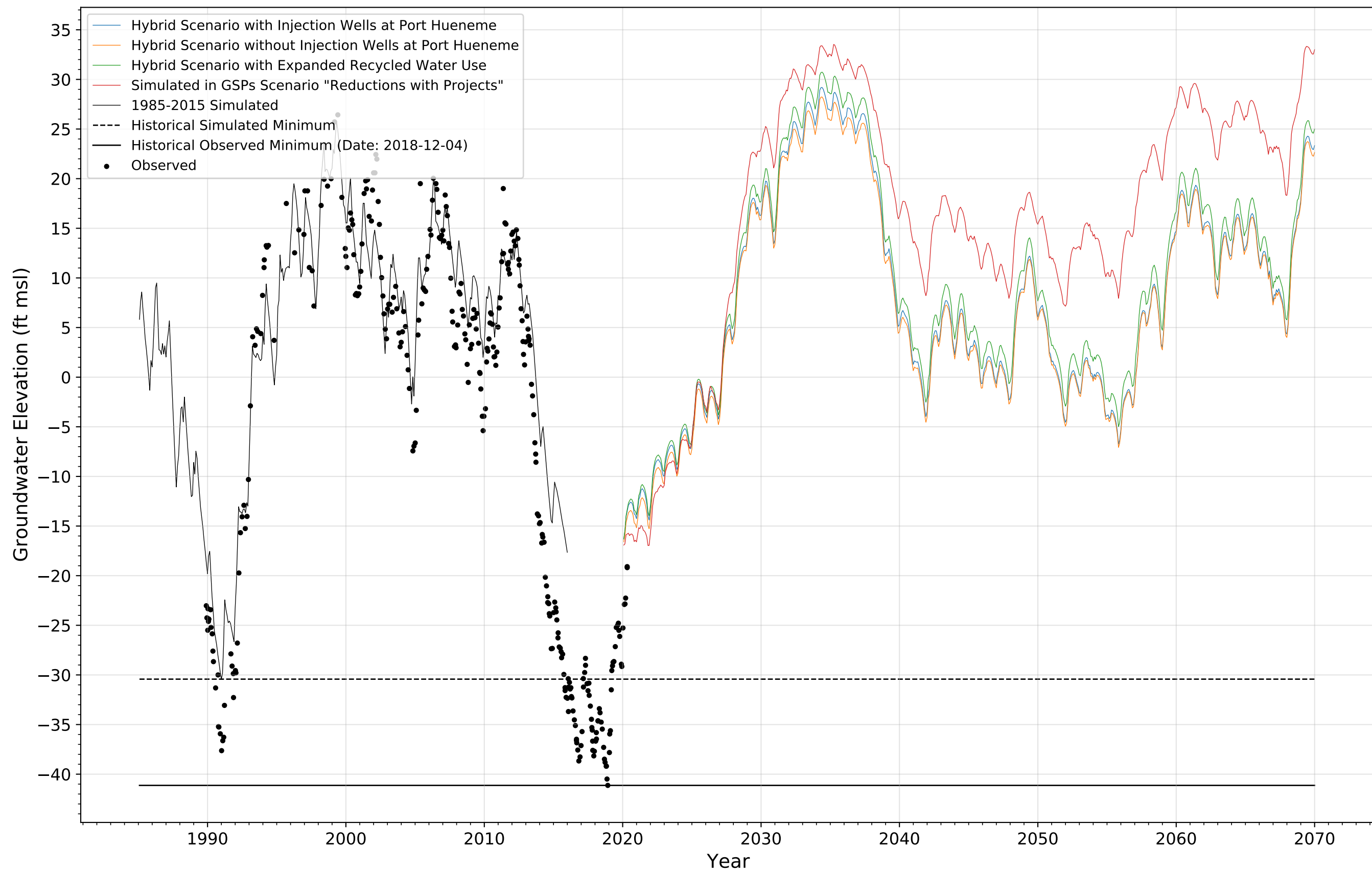
**Figure A-27. Modeled and Measured Groundwater Elevations at Well 02N22W12E04S, Screened in Mugu, Hueneme, and Upper Fox Canyon Aquifers**





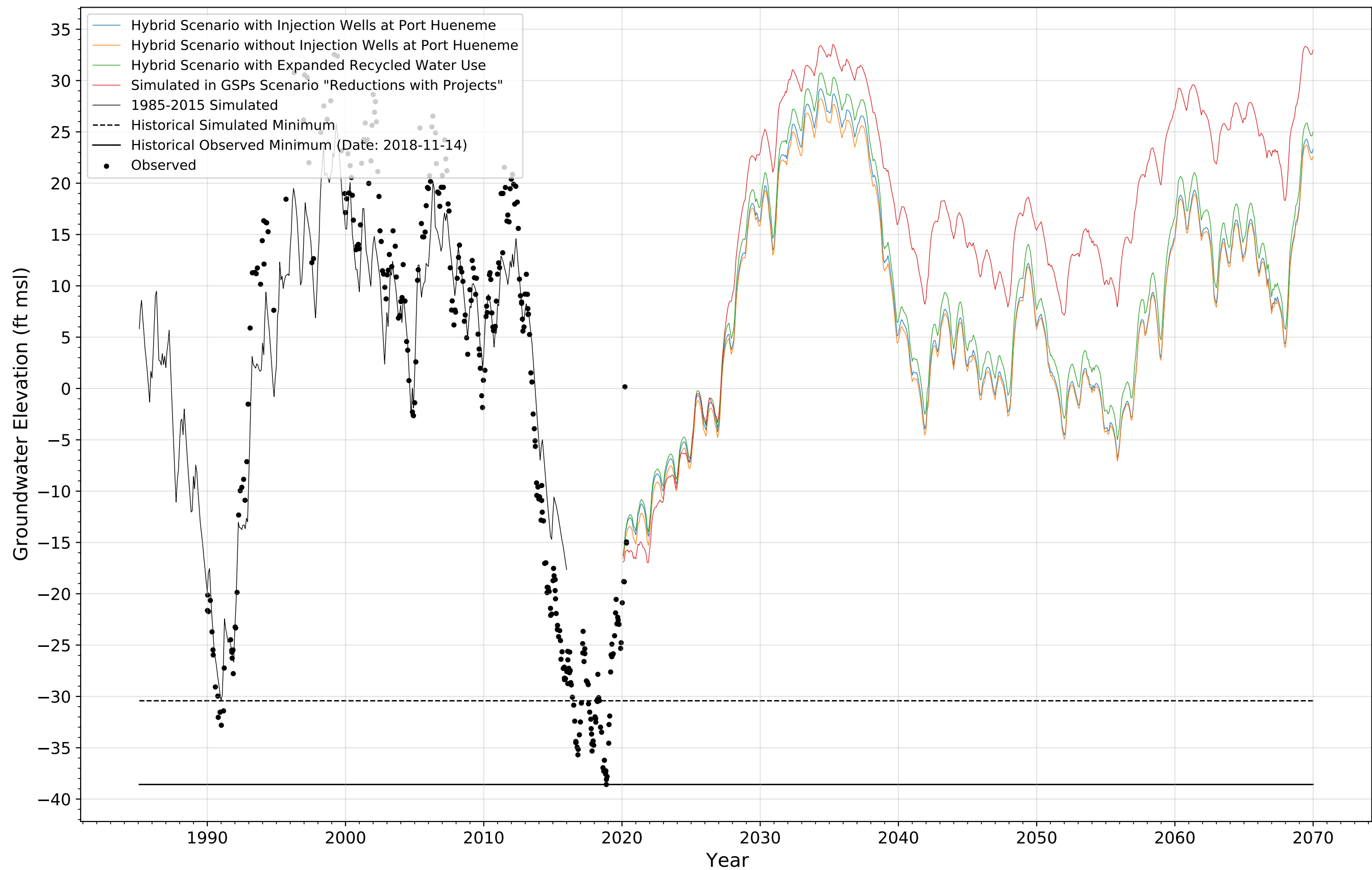
**Figure A-28. Modeled and Measured Groundwater Elevations at Well 02N21W34G04S, Screened in Hueneme Aquifer**





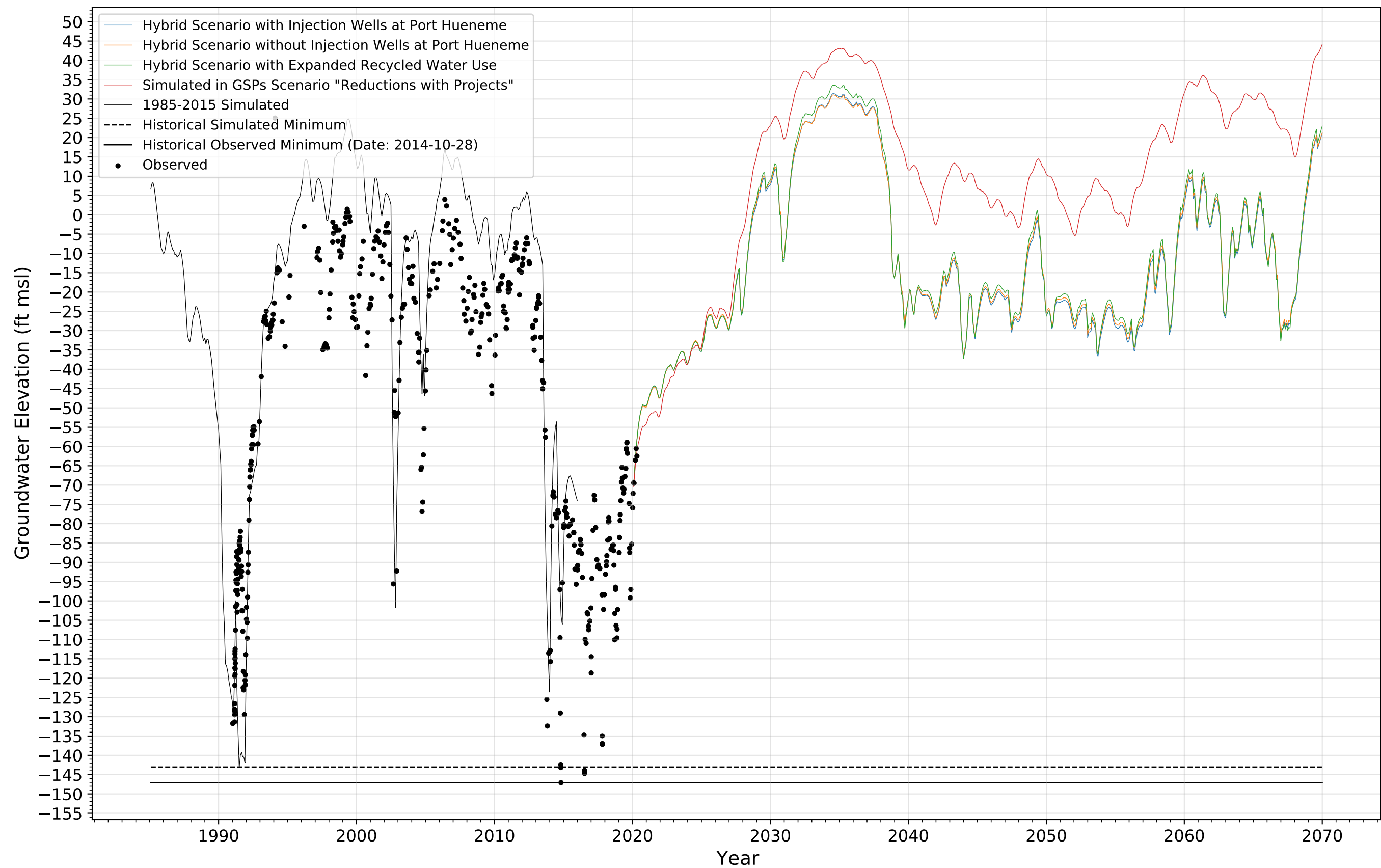
**Figure A-29. Modeled and Measured Groundwater Elevations at Well 01N23W01C03S, Screened in Hueneme Aquifer**





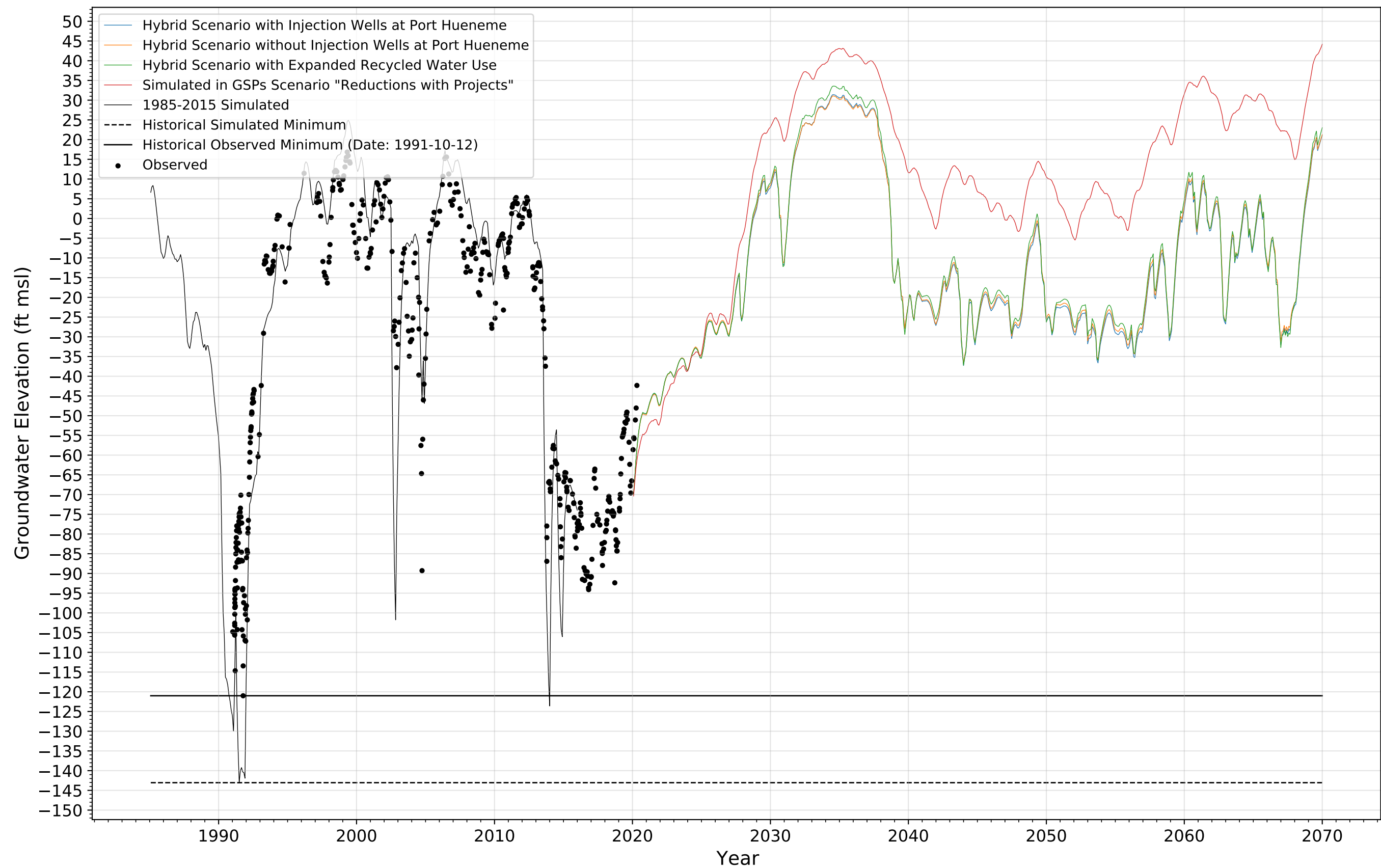
**Figure A-30. Modeled and Measured Groundwater Elevations at Well 01N23W01C04S, Screened in Hueneme Aquifer**





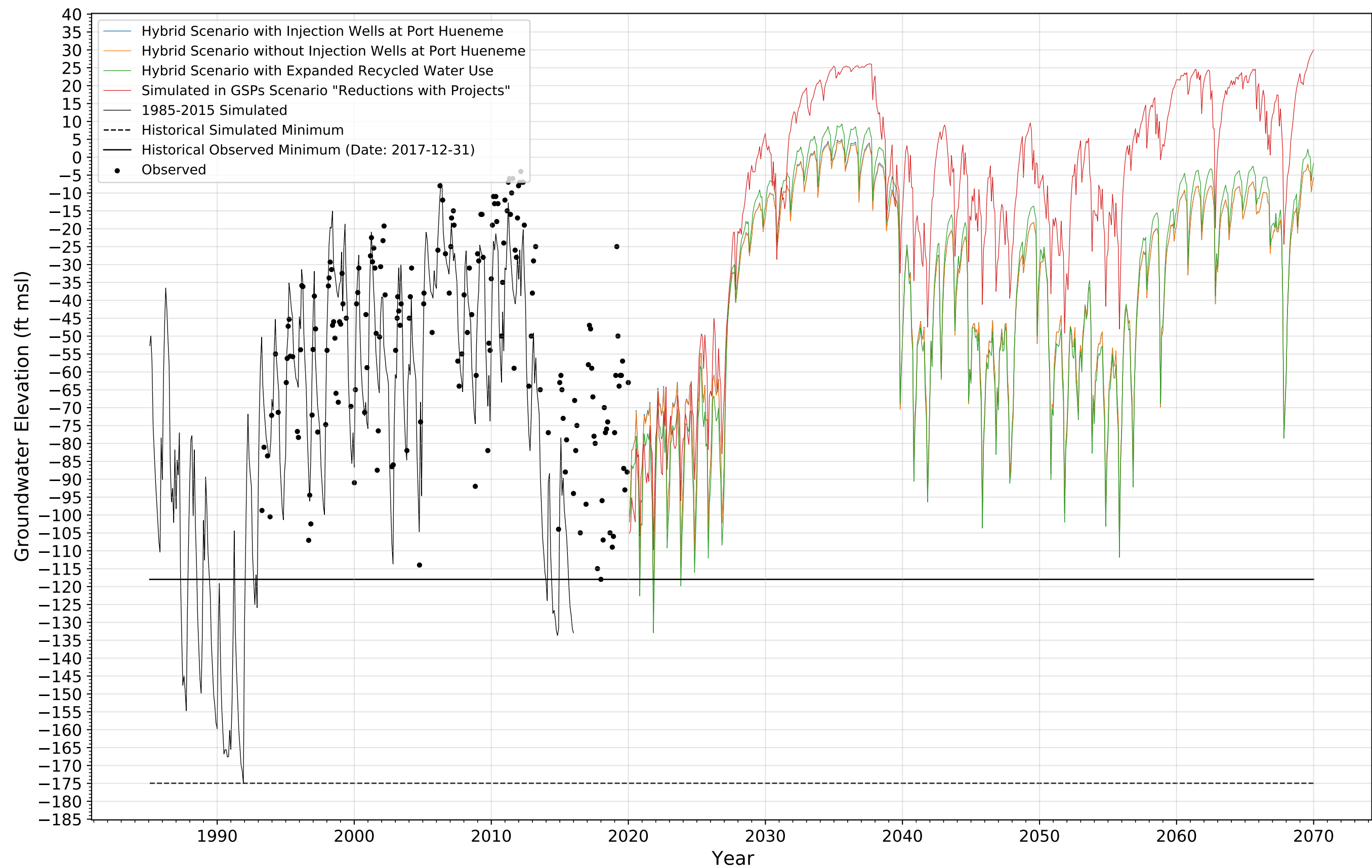
**Figure A-31. Modeled and Measured Groundwater Elevations at Well 02N22W23B04S, Screened in Hueneme Aquifer**





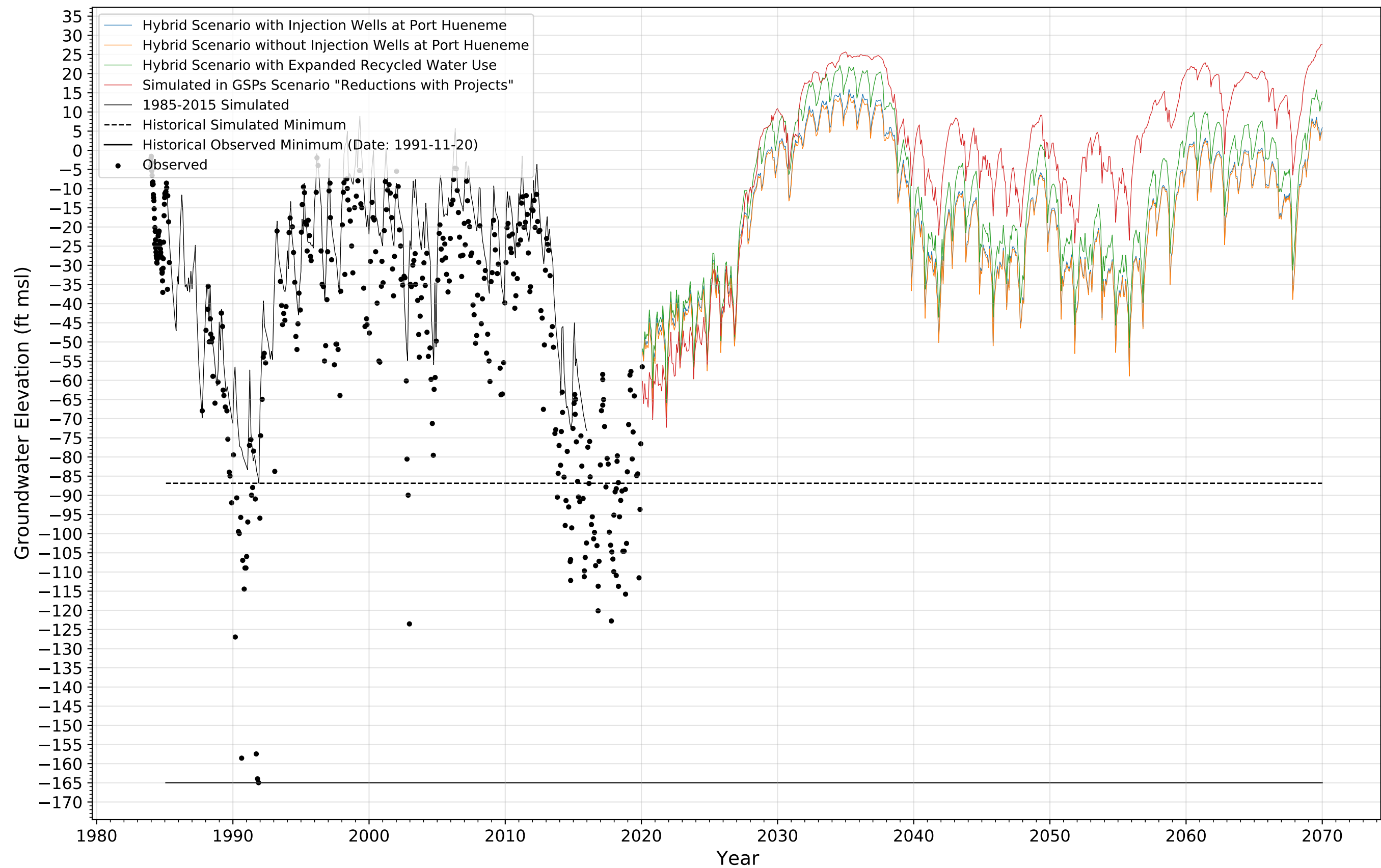
**Figure A-32. Modeled and Measured Groundwater Elevations at Well 02N22W23B05S, Screened in Hueneme Aquifer**





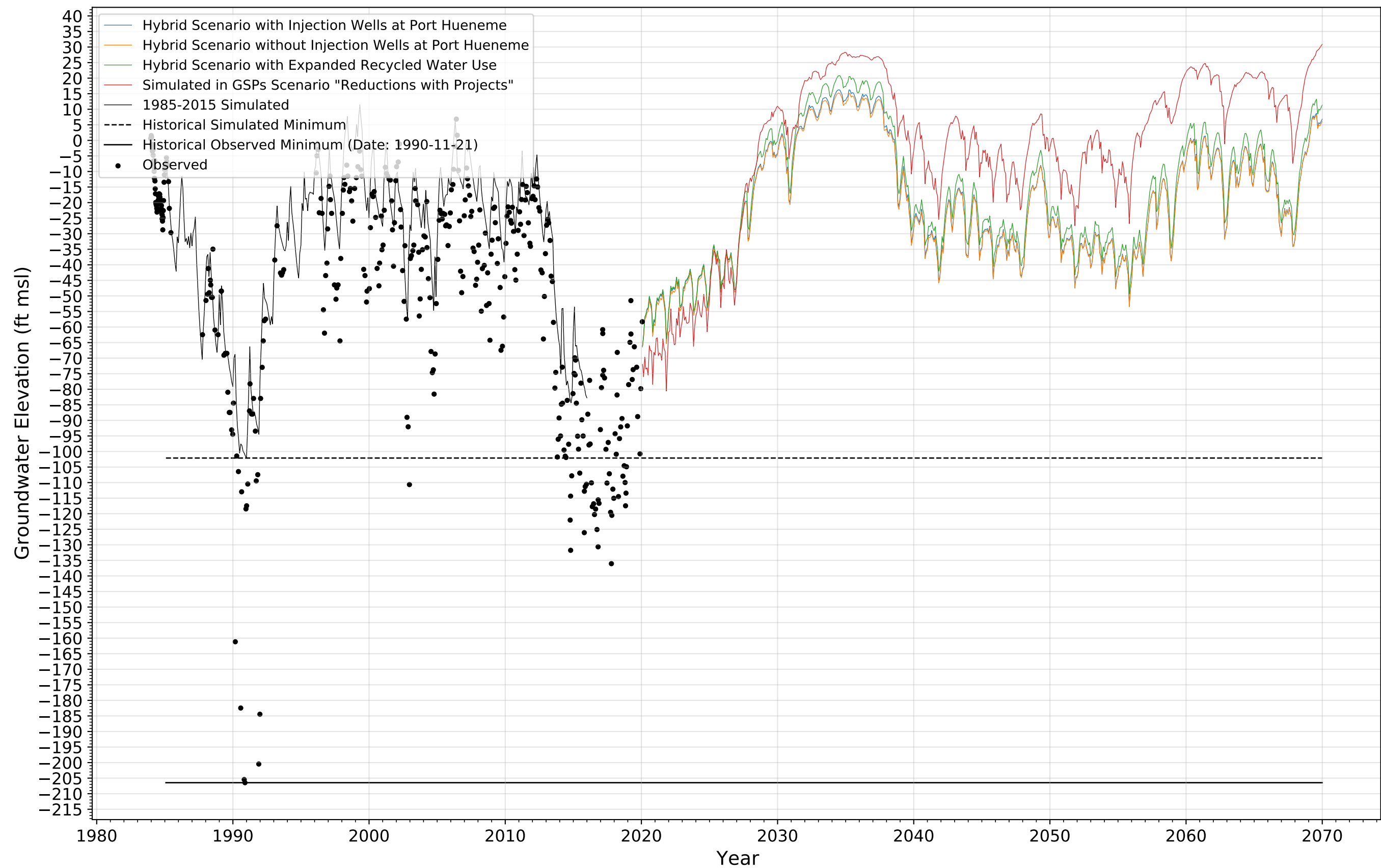
**Figure A-33. Modeled and Measured Groundwater Elevations at Well 01N21W03K01S, Screened in Hueneme Aquifer**





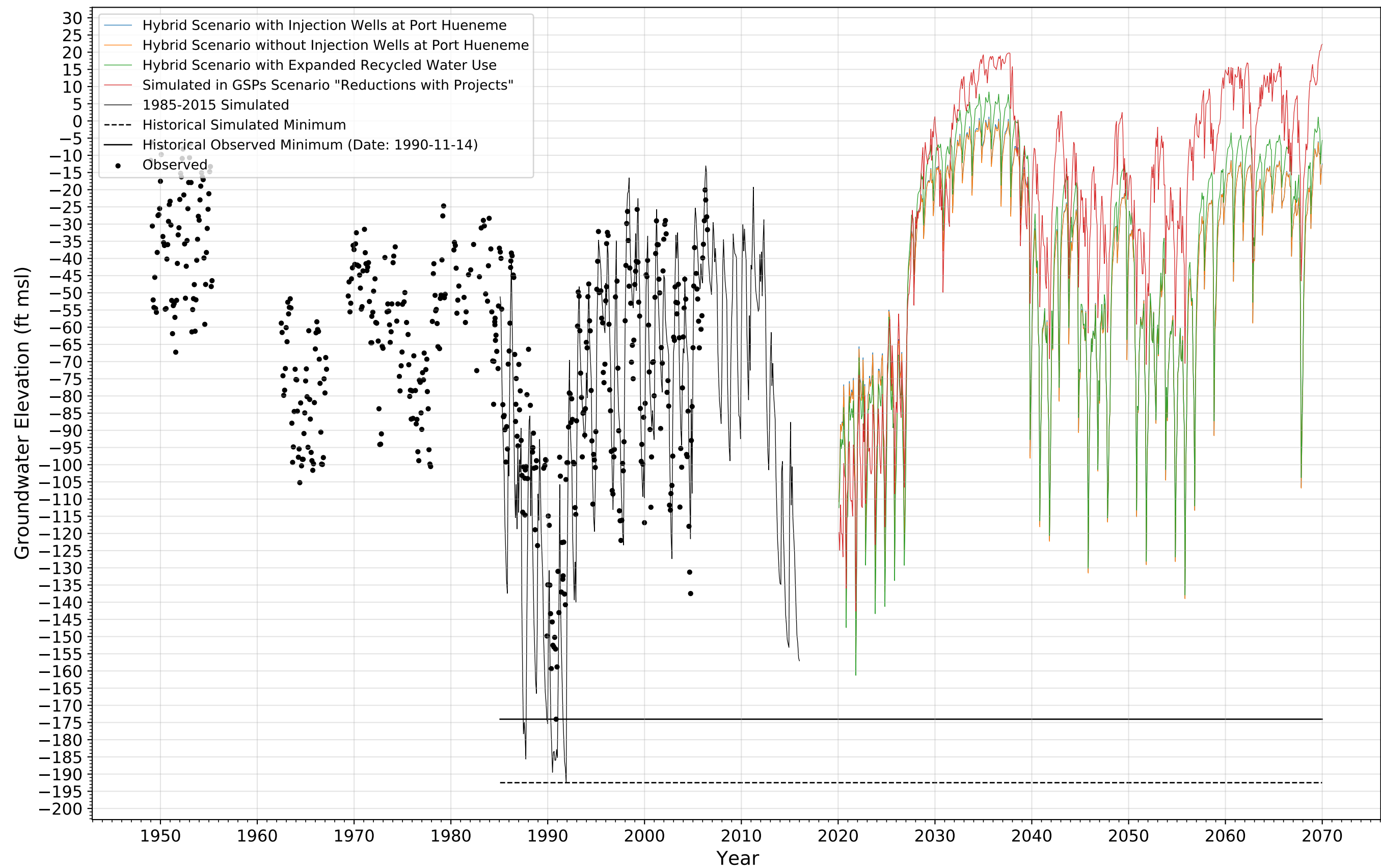
**Figure A-34. Modeled and Measured Groundwater Elevations at Well 01N22W13D03S, Screened in Hueneme and Upper Fox Canyon Aquifers**





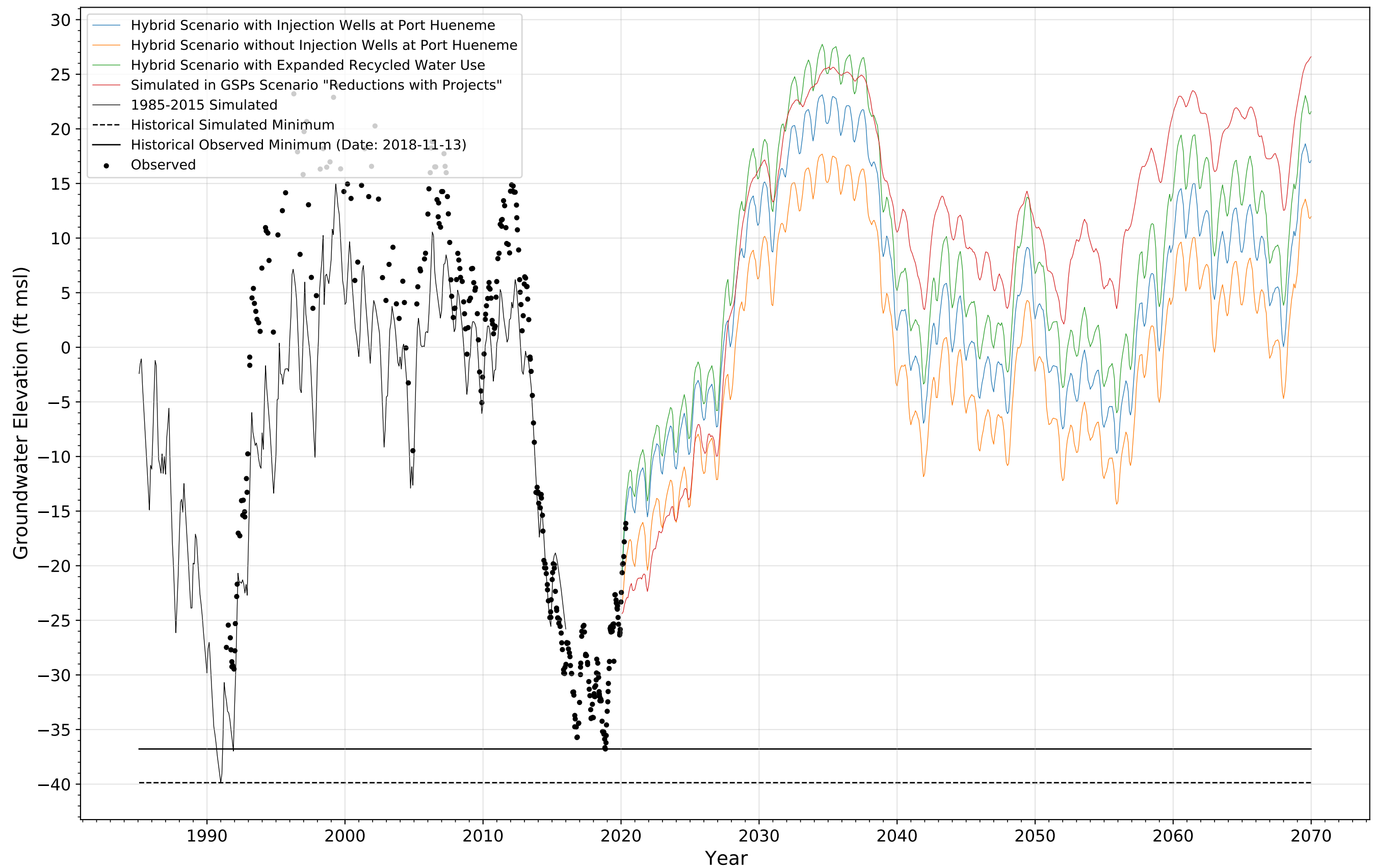
**Figure A-35. Modeled and Measured Groundwater Elevations at Well 01N22W01M03S, Screened in Hueneme and Upper Fox Canyon Aquifers**





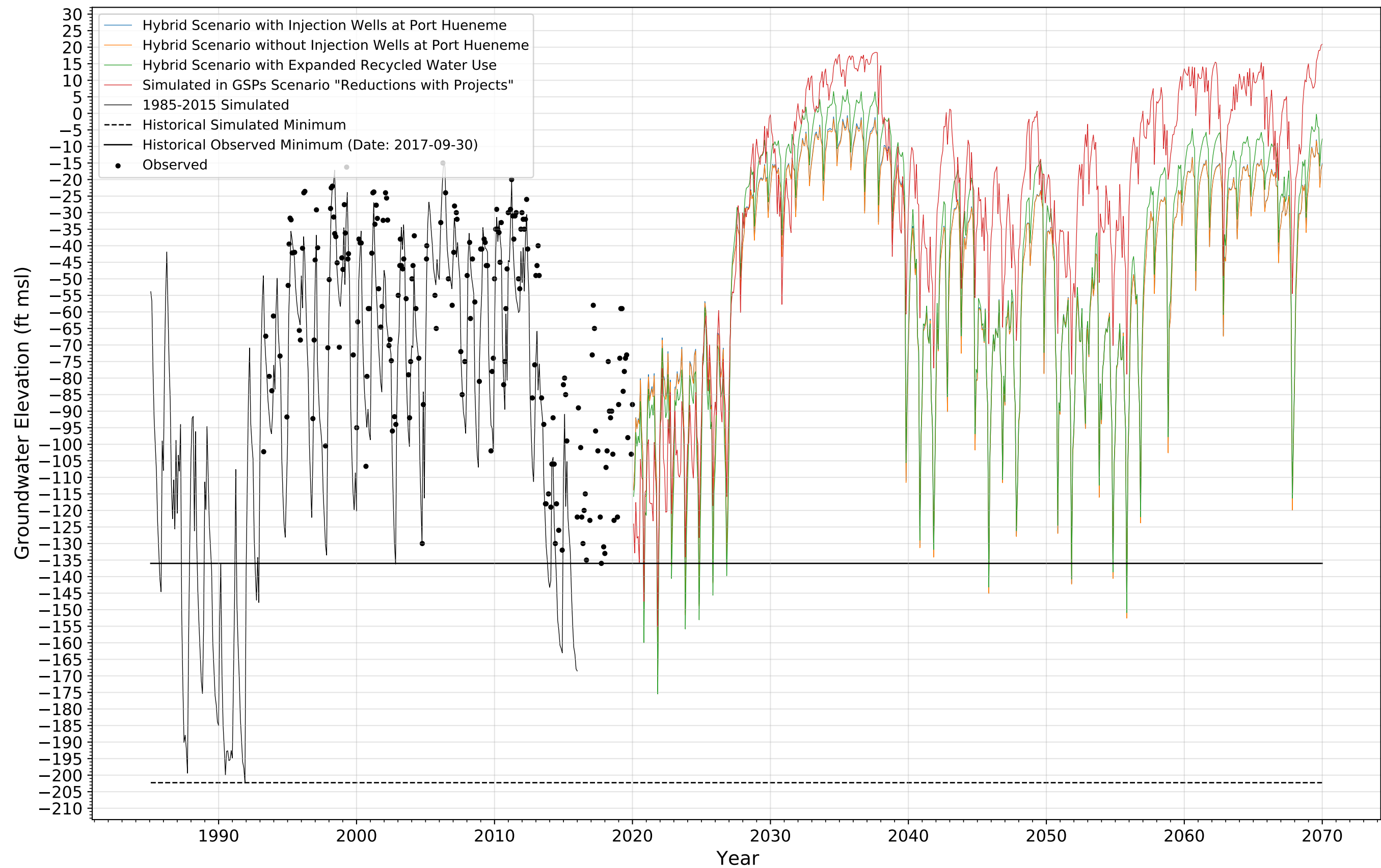
**Figure A-36. Modeled and Measured Groundwater Elevations at Well 01N21W15Q02S, Screened in Hueneme and Upper Fox Canyon Aquifers**





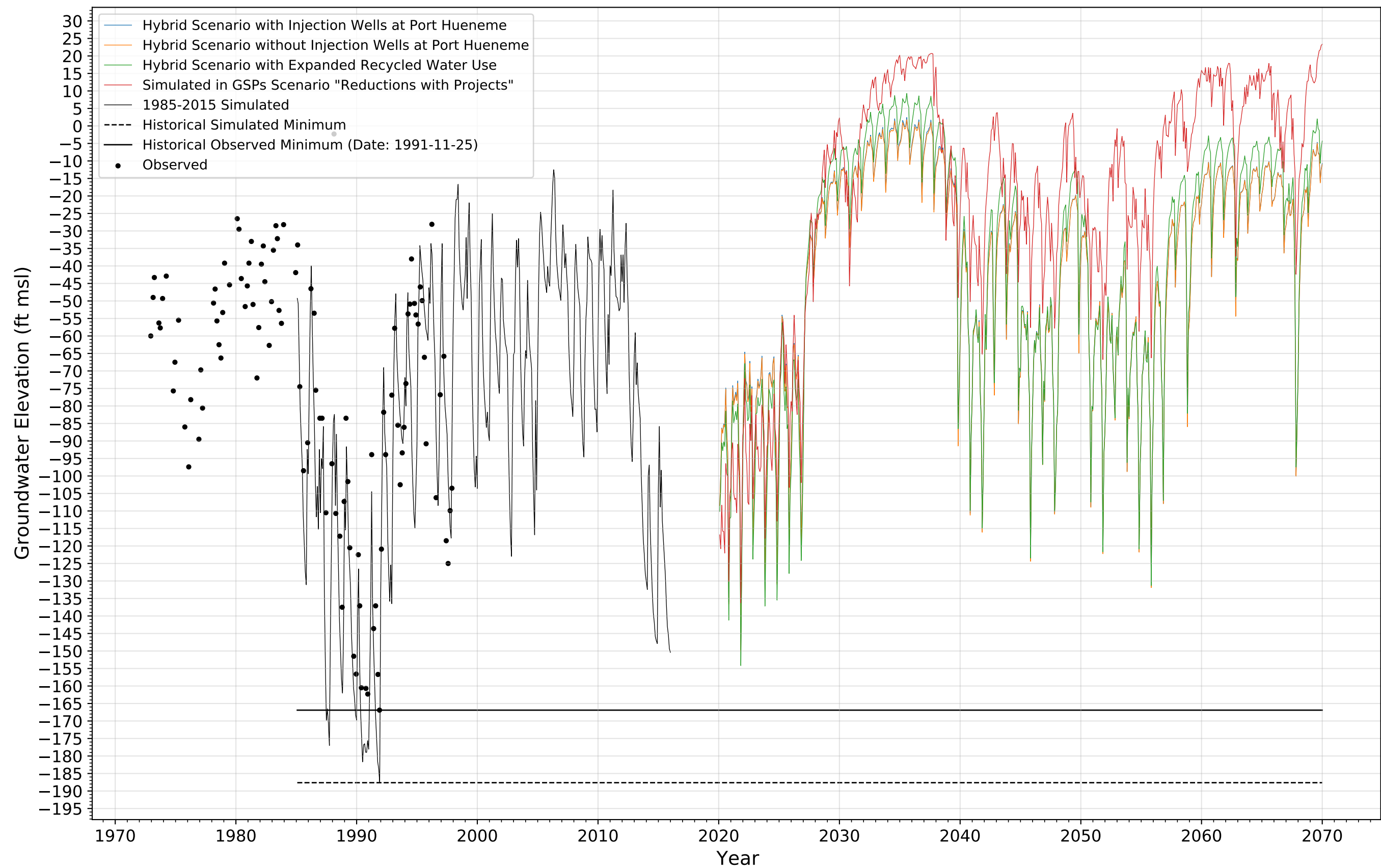
**Figure A-37. Modeled and Measured Groundwater Elevations at Well 01N22W20J05S, Screened in Hueneme and Upper Fox Canyon Aquifers**





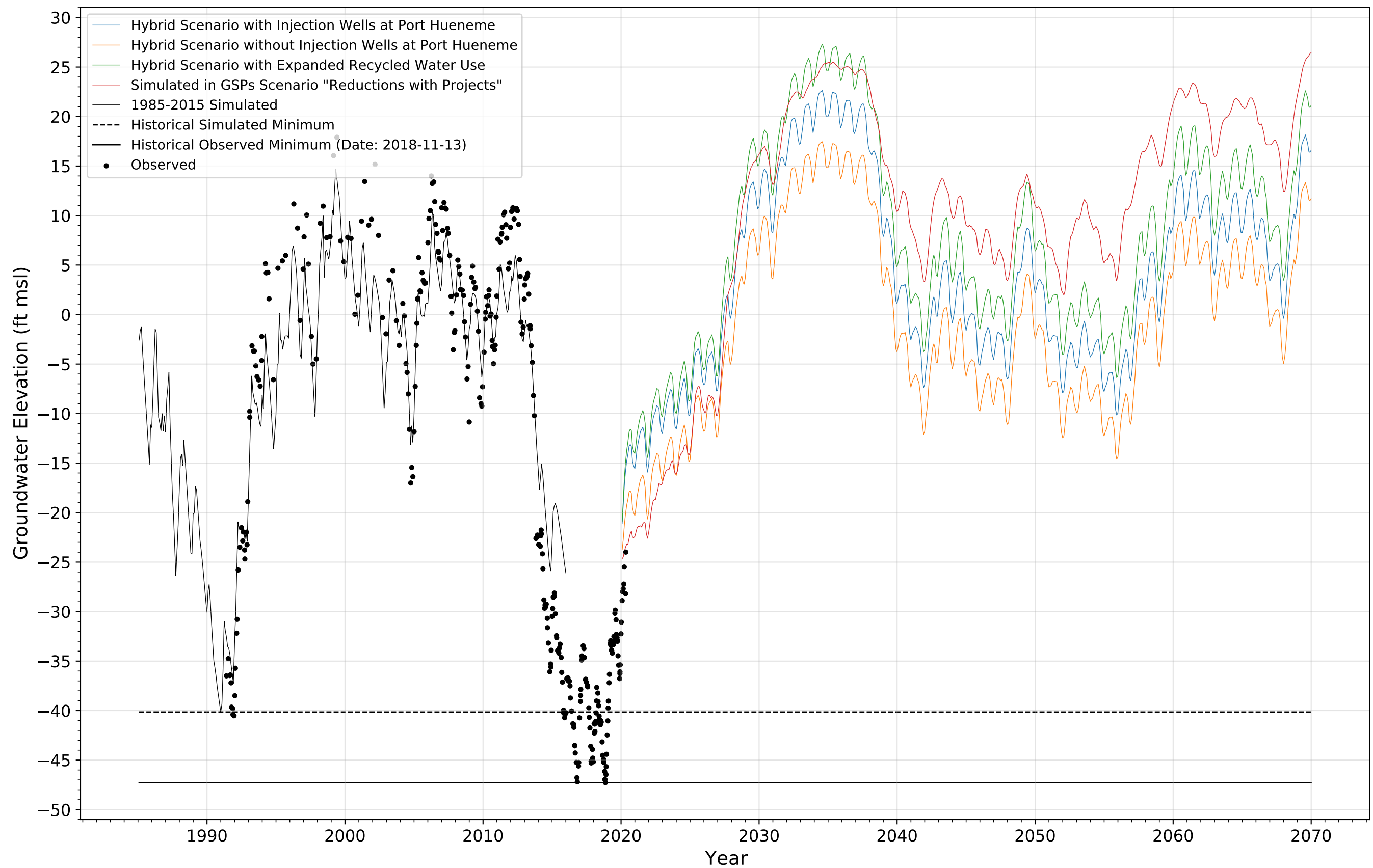
**Figure A-38. Modeled and Measured Groundwater Elevations at Well 01N21W22C01S, Screened in Hueneme, Upper, and Basal Fox Canyon Aquifers**





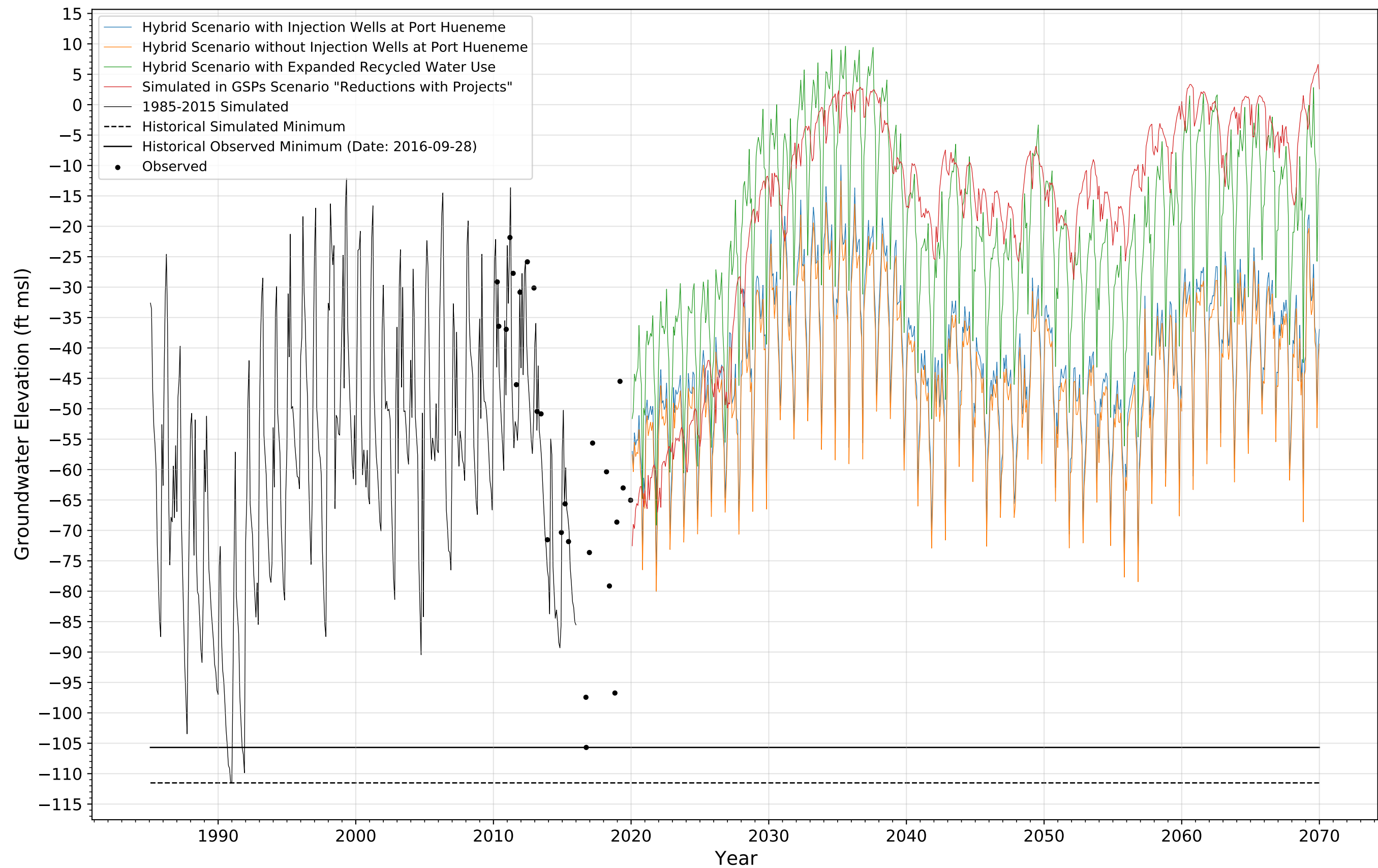
**Figure A-39. Modeled and Measured Groundwater Elevations at Well 01N21W15P02S, Screened in Hueneme, Upper, and Basal Fox Canyon Aquifers**





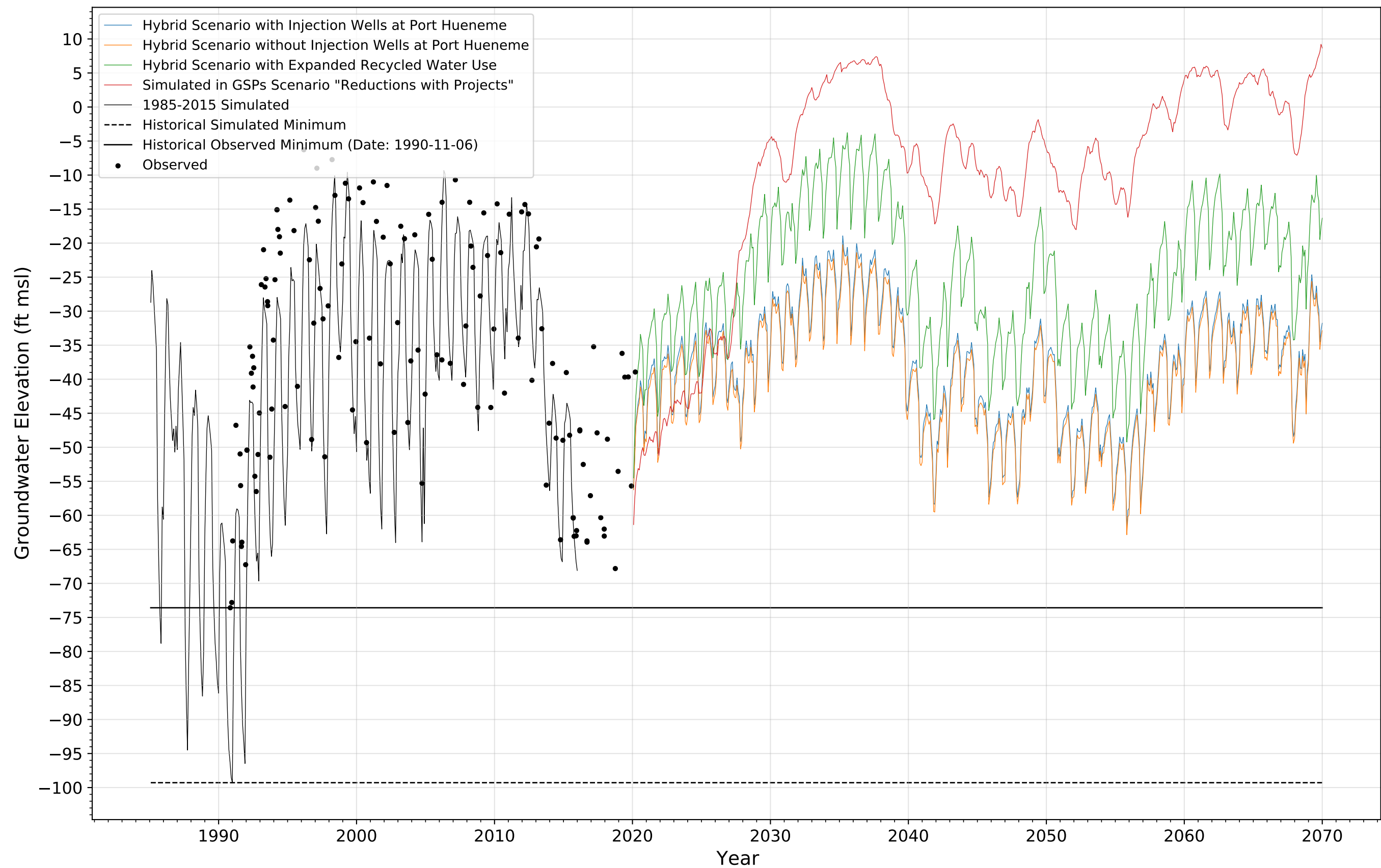
**Figure A-40. Modeled and Measured Groundwater Elevations at Well 01N22W20J04S, Screened in Upper Fox Canyon Aquifer**





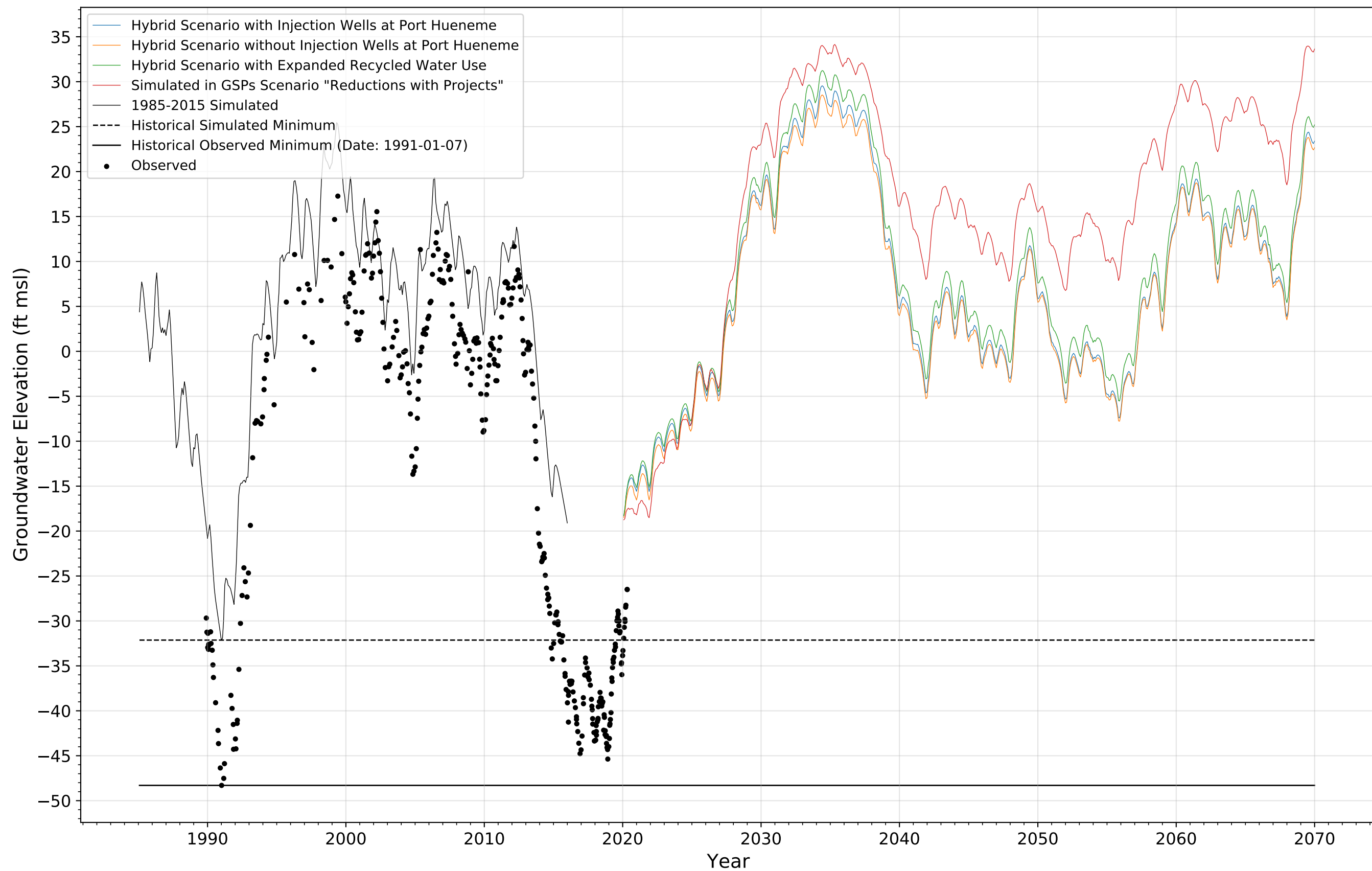
**Figure A-41. Modeled and Measured Groundwater Elevations at Well 01N22W26K03S, Screened in Upper Fox Canyon Aquifer**





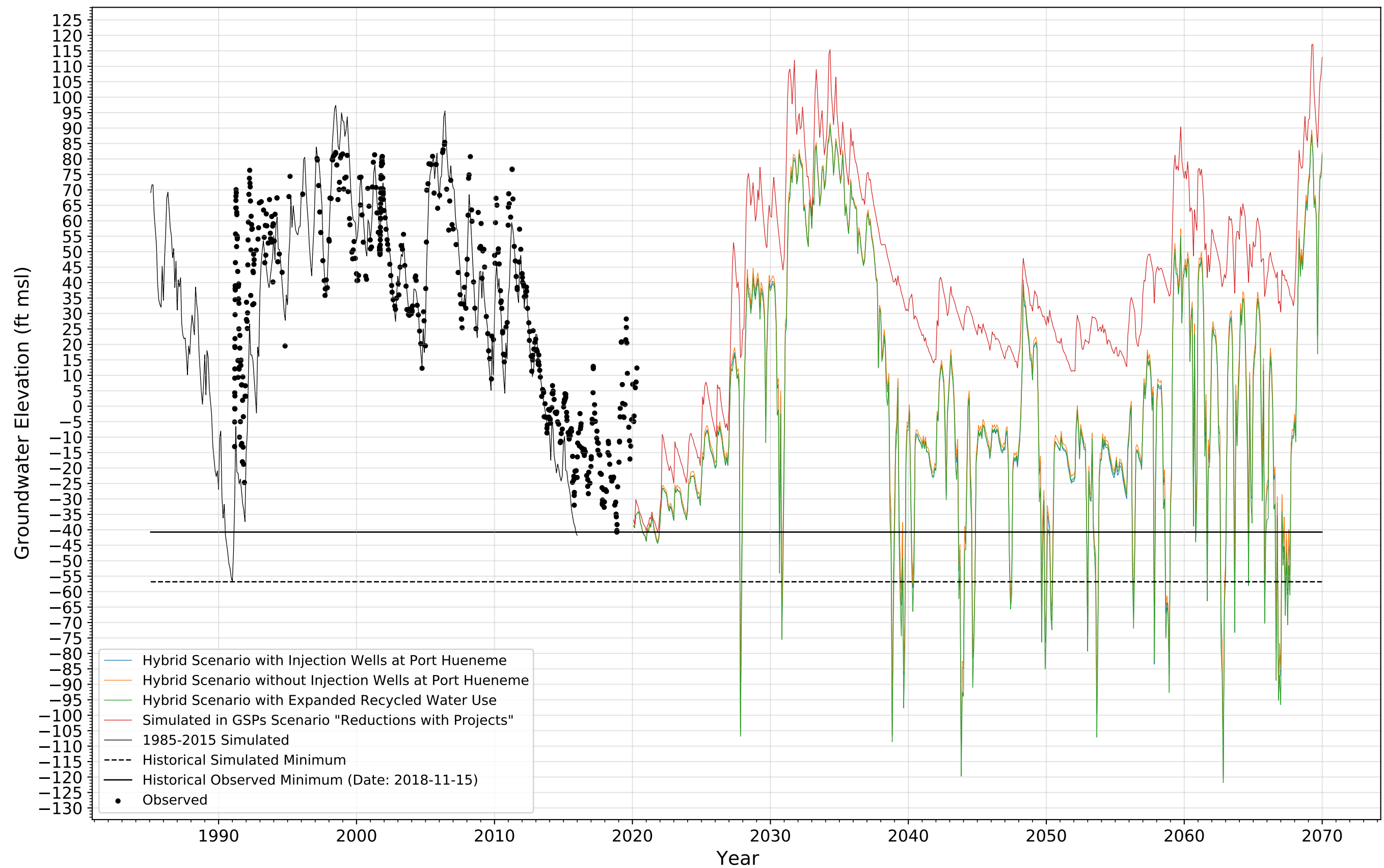
**Figure A-42. Modeled and Measured Groundwater Elevations at Well 01S22W01H02S, Screened in Upper Fox Canyon Aquifer**





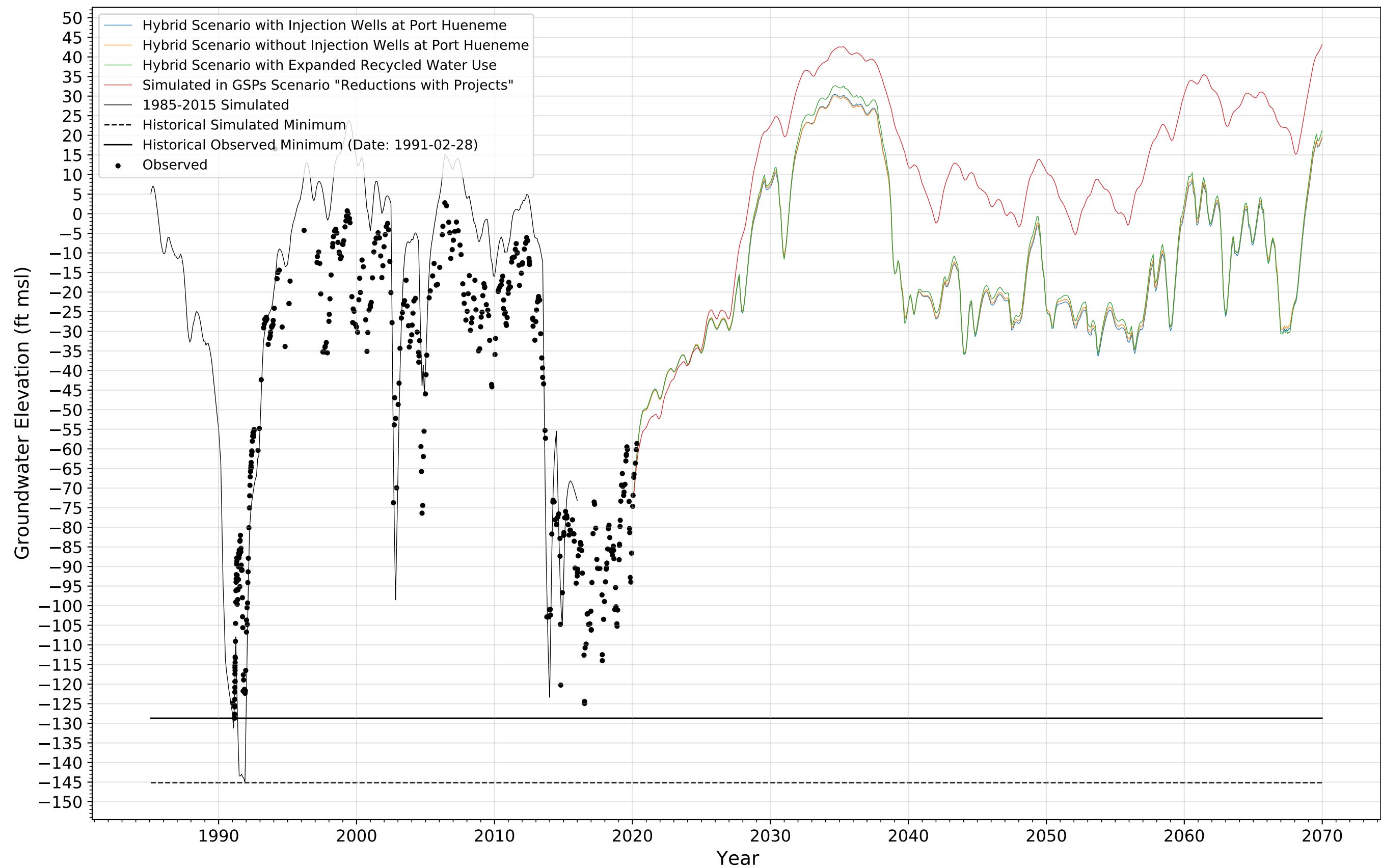
**Figure A-43. Modeled and Measured Groundwater Elevations at Well 01N23W01C02S, Screened in Upper Fox Canyon Aquifer**





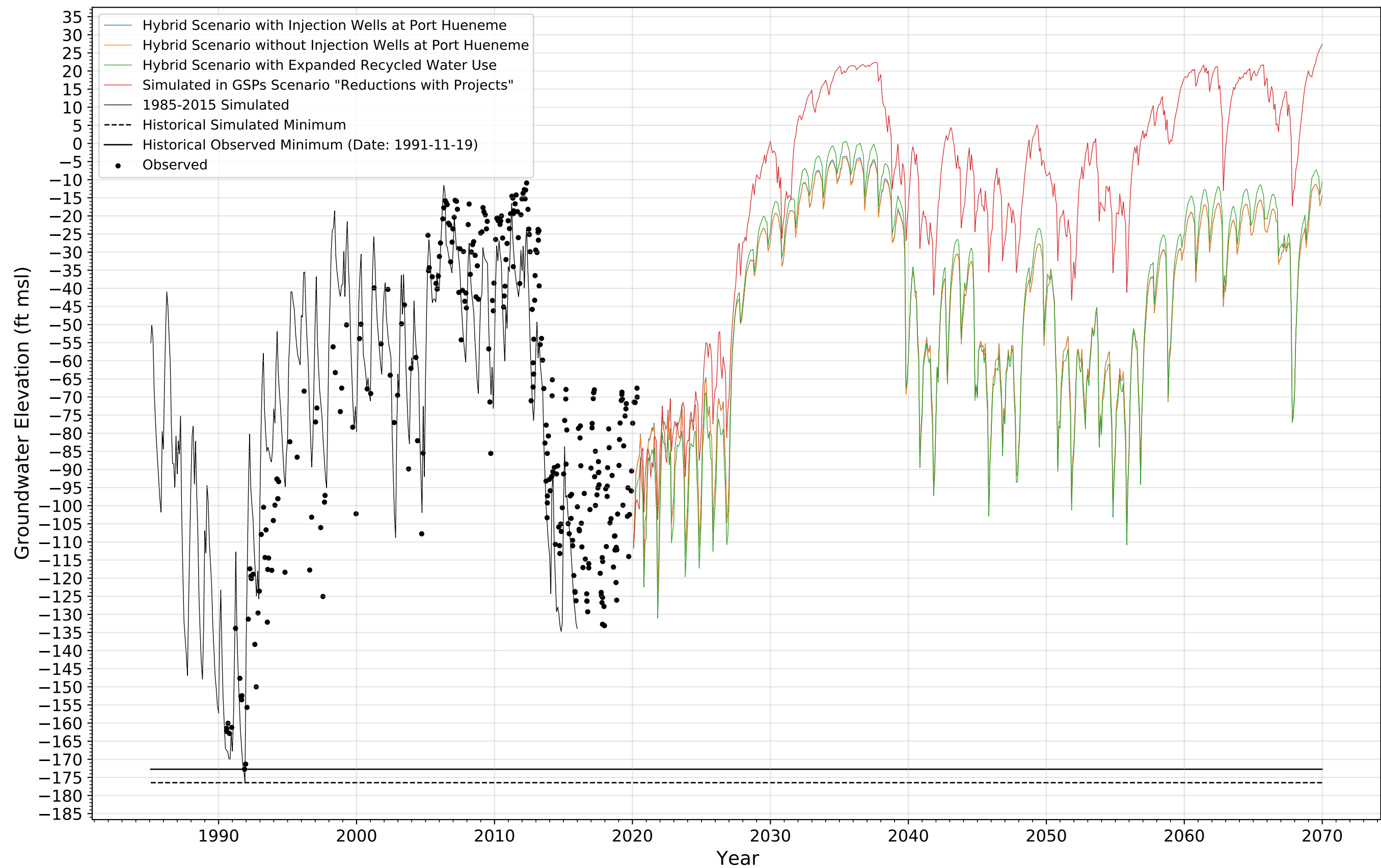
**Figure A-44. Modeled and Measured Groundwater Elevations at Well 02N21W07L04S, Screened in Upper Fox Canyon Aquifer**





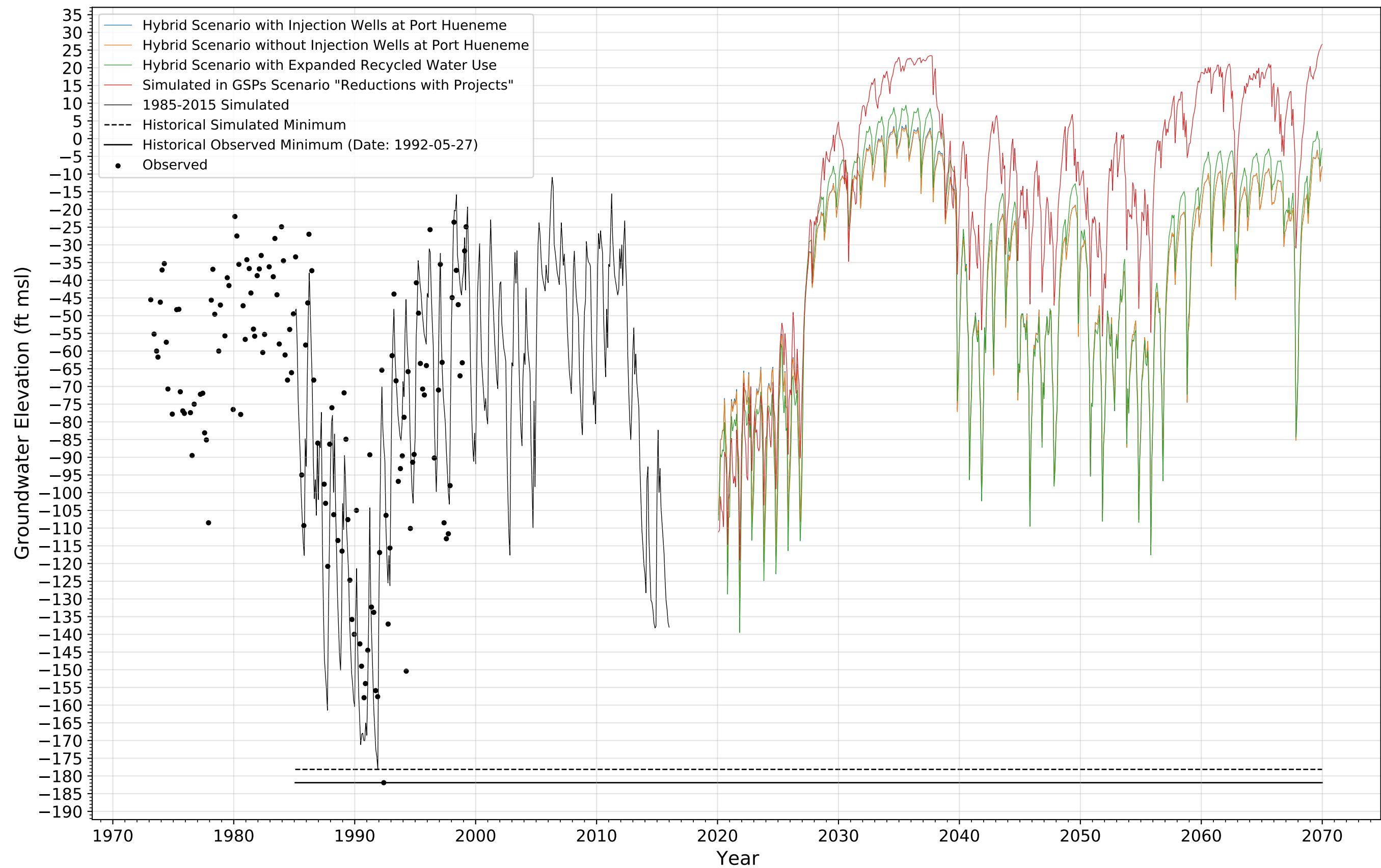
**Figure A-45. Modeled and Measured Groundwater Elevations at Well 02N22W23B03S, Screened in Upper Fox Canyon Aquifer**





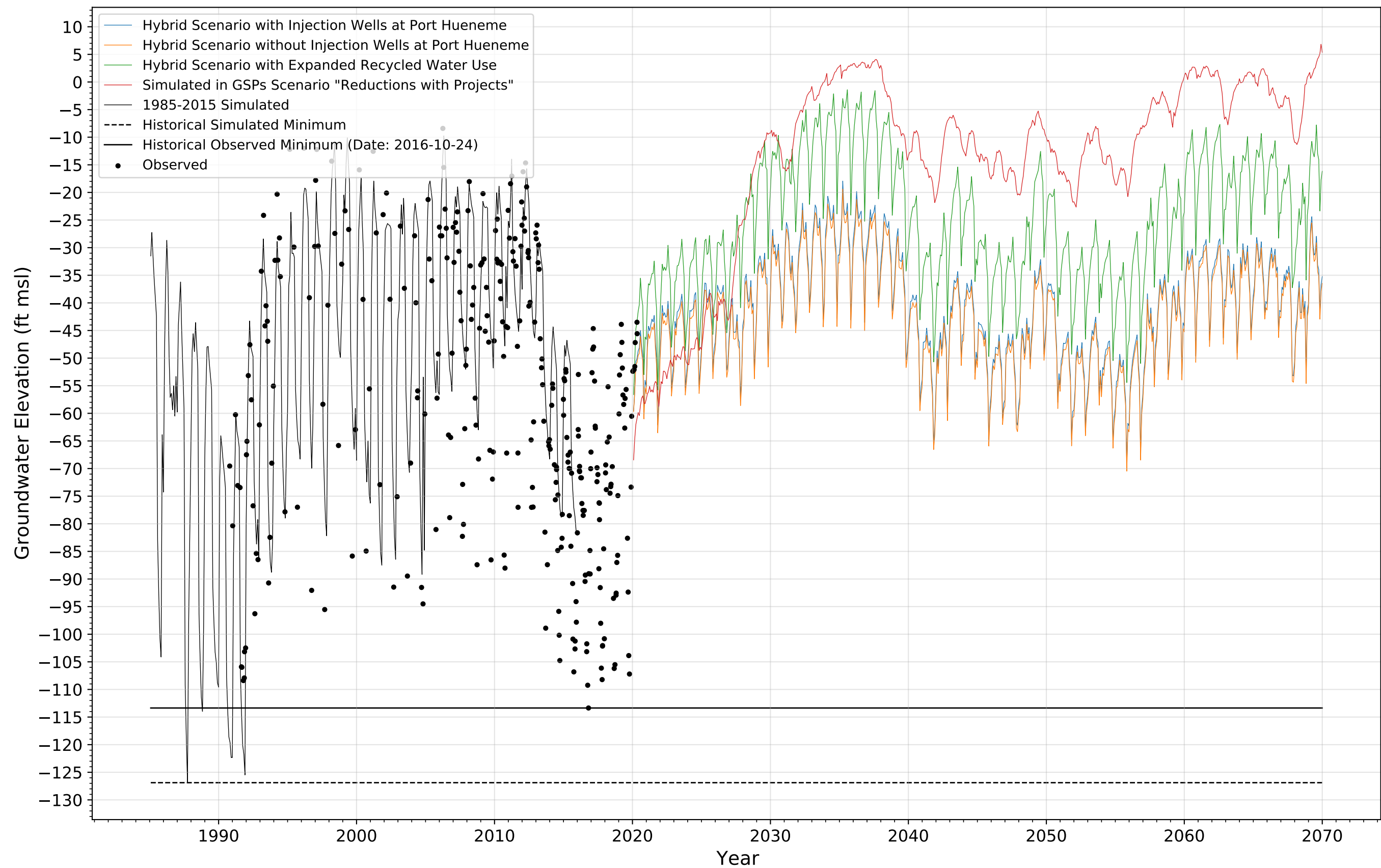
**Figure A-46. Modeled and Measured Groundwater Elevations at Well 02N21W34G03S, Screened in Upper Fox Canyon Aquifer**





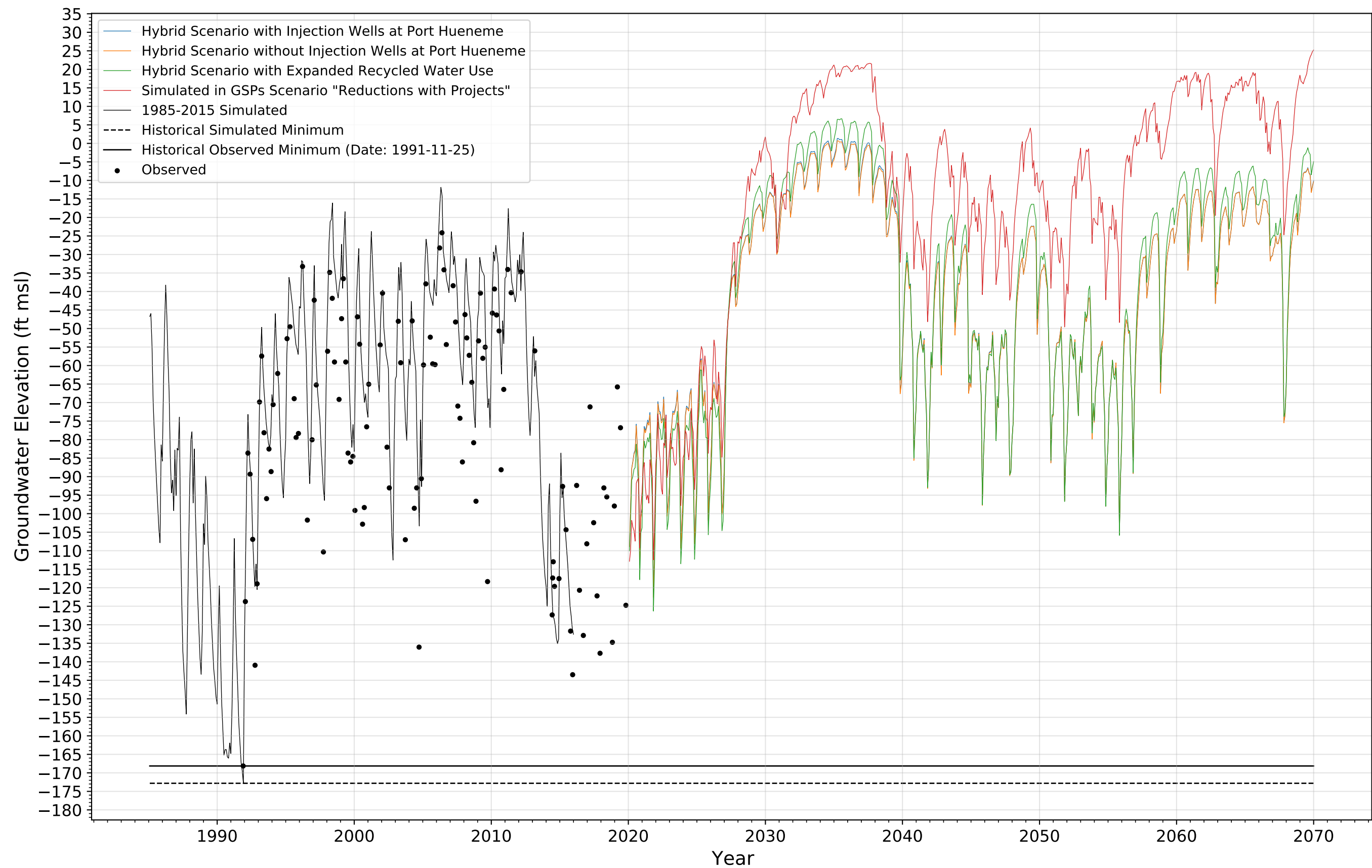
**Figure A-47. Modeled and Measured Groundwater Elevations at Well 01N21W10E01S, Screened in Upper Fox Canyon Aquifer**





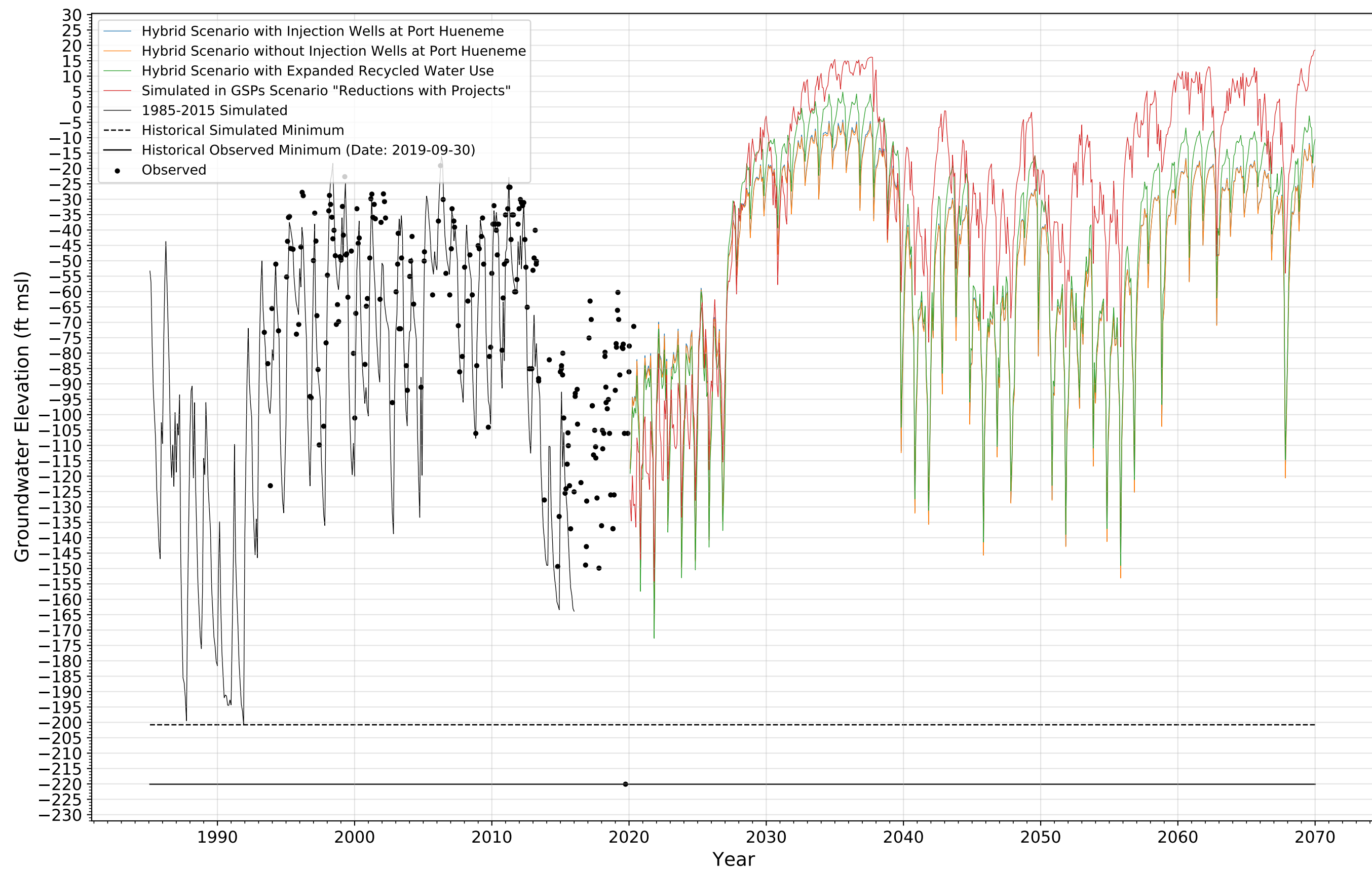
**Figure A-48. Modeled and Measured Groundwater Elevations at Well 01N22W36K07S, Screened in Upper Fox Canyon Aquifer**





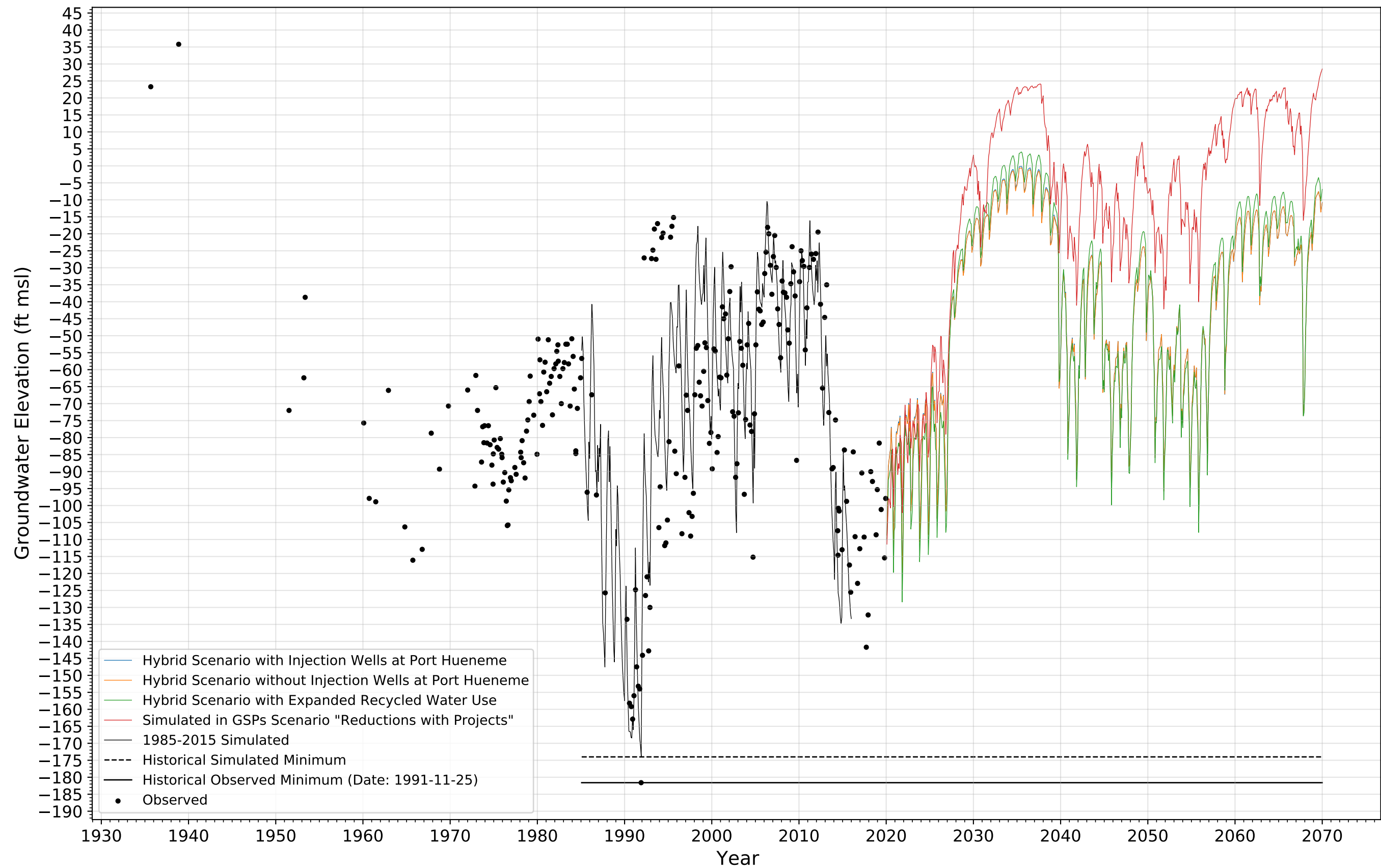
**Figure A-49. Modeled and Measured Groundwater Elevations at Well 01N21W09C04S, Screened in Upper and Basal Fox Canyon Aquifers**





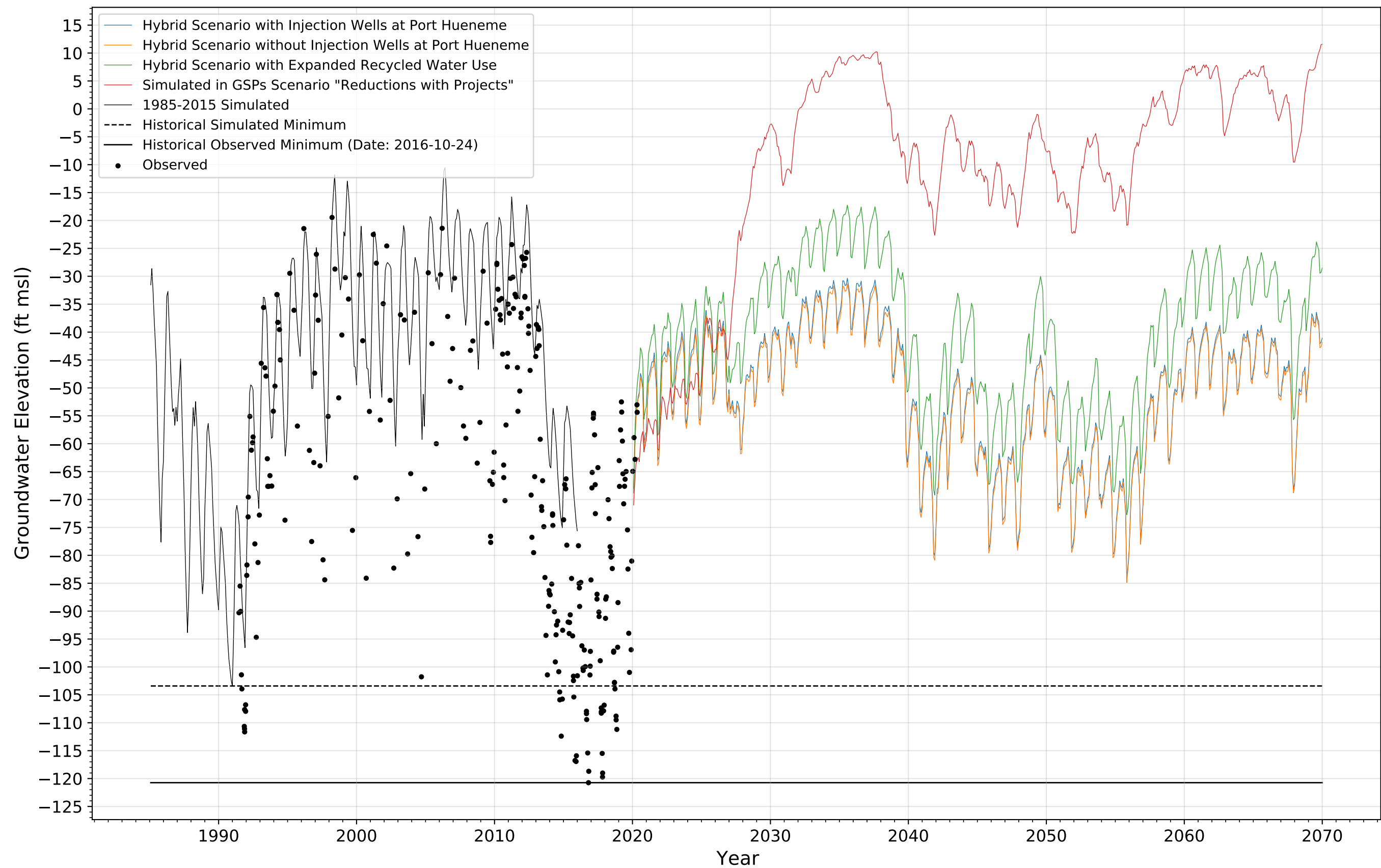
**Figure A-50. Modeled and Measured Groundwater Elevations at Well 01N21W21H02S, Screened in Upper and Basal Fox Canyon Aquifers**





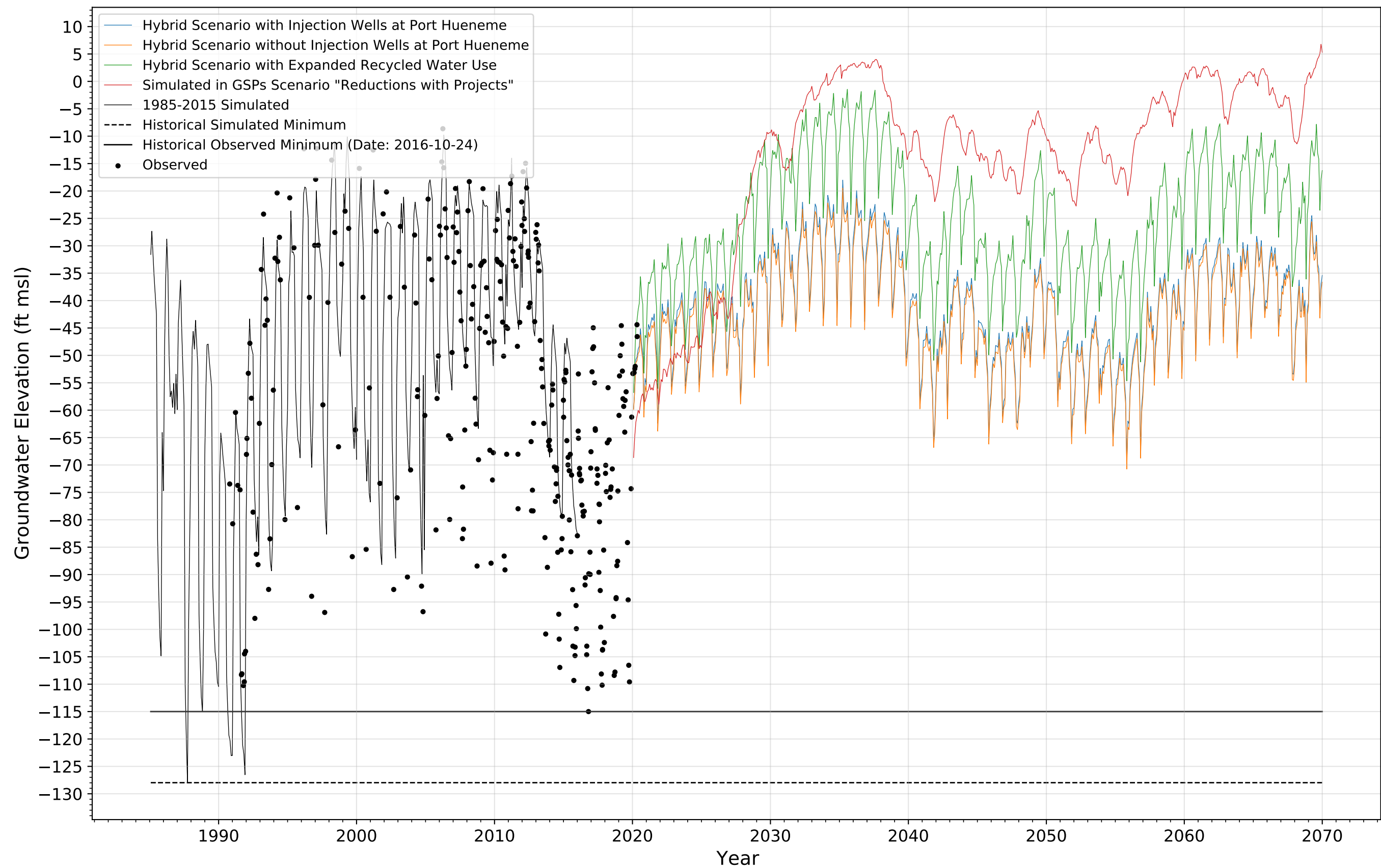
**Figure A-51. Modeled and Measured Groundwater Elevations at Well 01N21W03C01S, Screened in Upper and Basal Fox Canyon Aquifers**





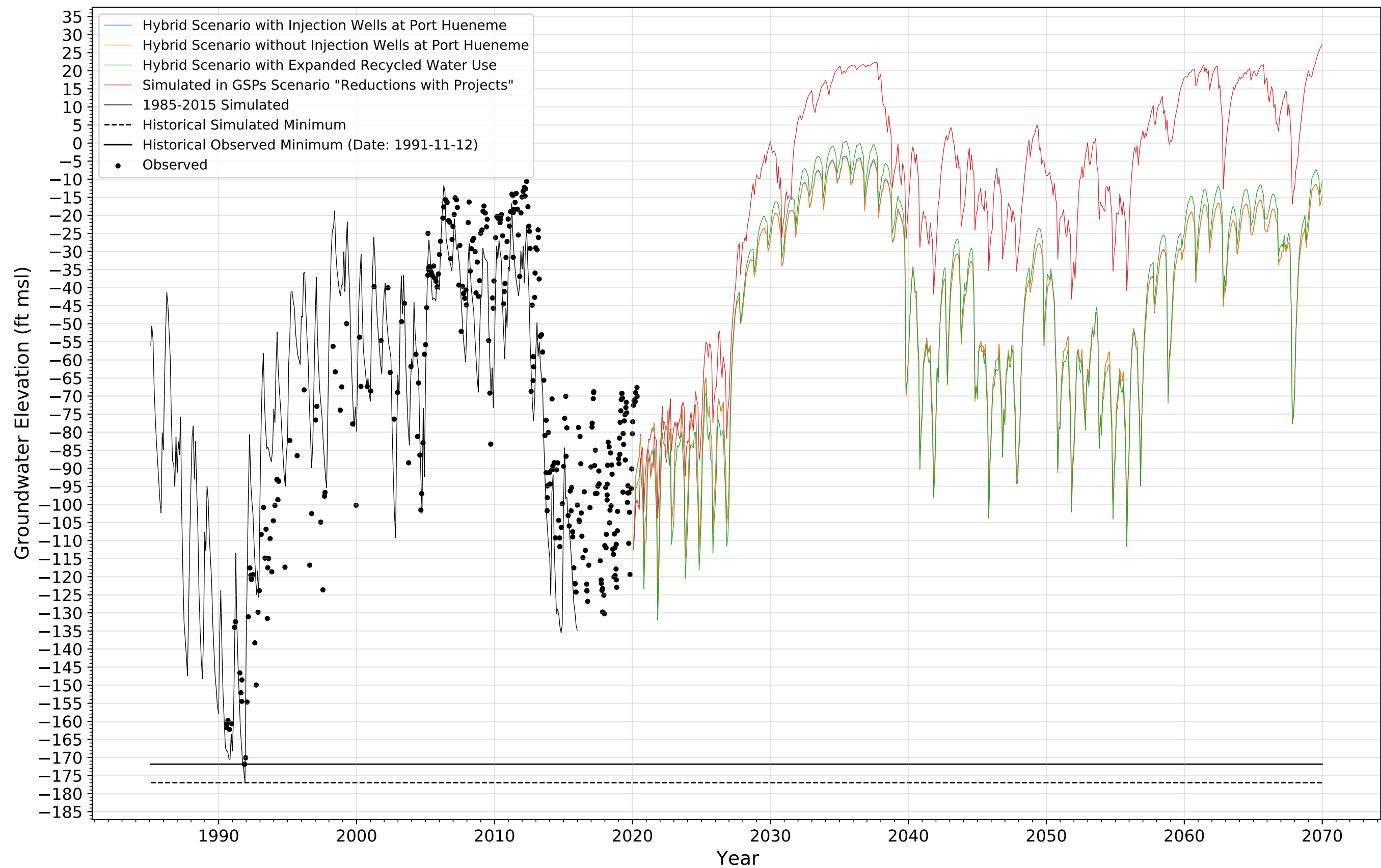
**Figure A-52. Modeled and Measured Groundwater Elevations at Well 01N21W32Q04S, Screened in Basal Fox Canyon Aquifer**





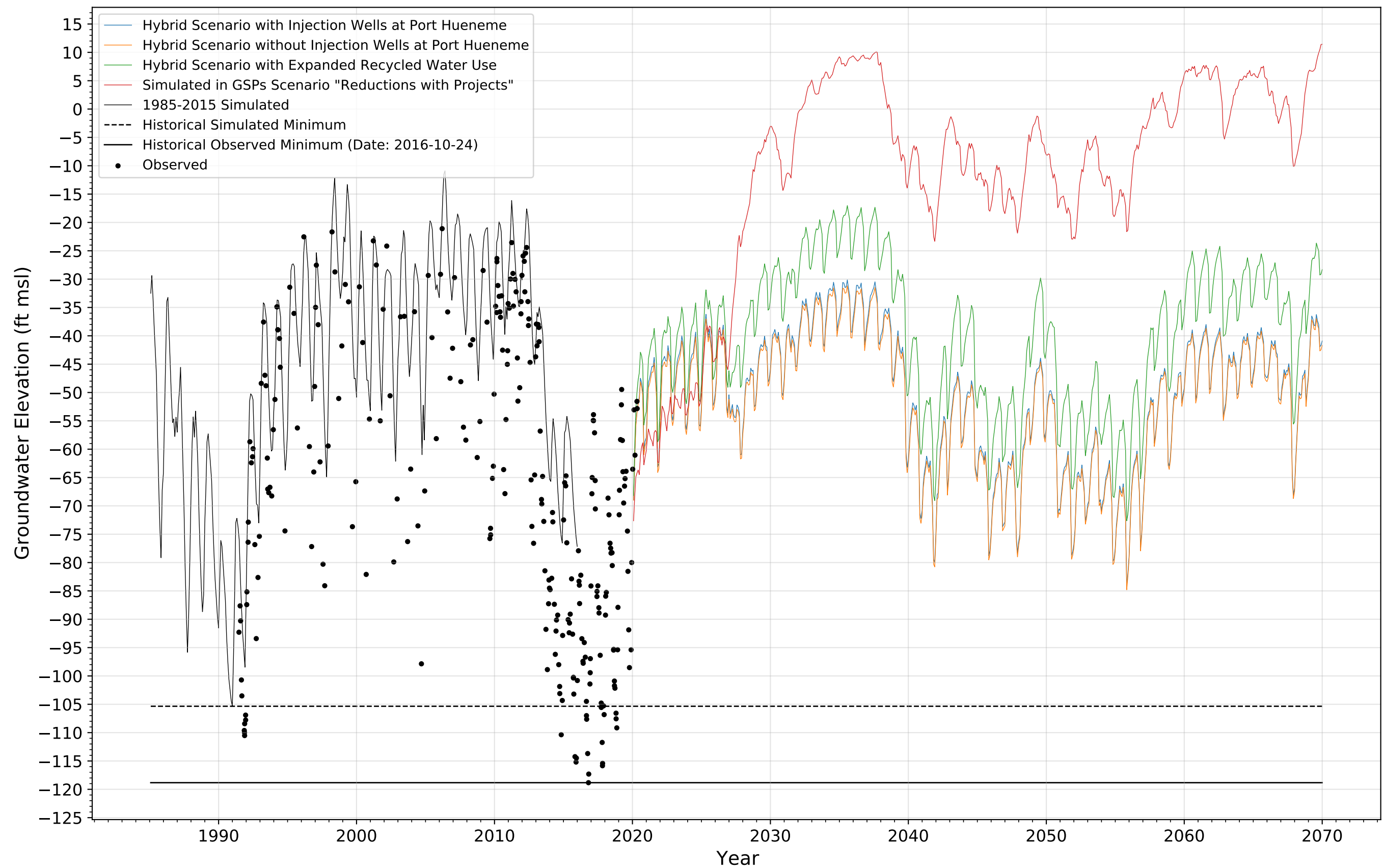
**Figure A-53. Modeled and Measured Groundwater Elevations at Well 01N22W36K06S, Screened in Basal Fox Canyon Aquifer**





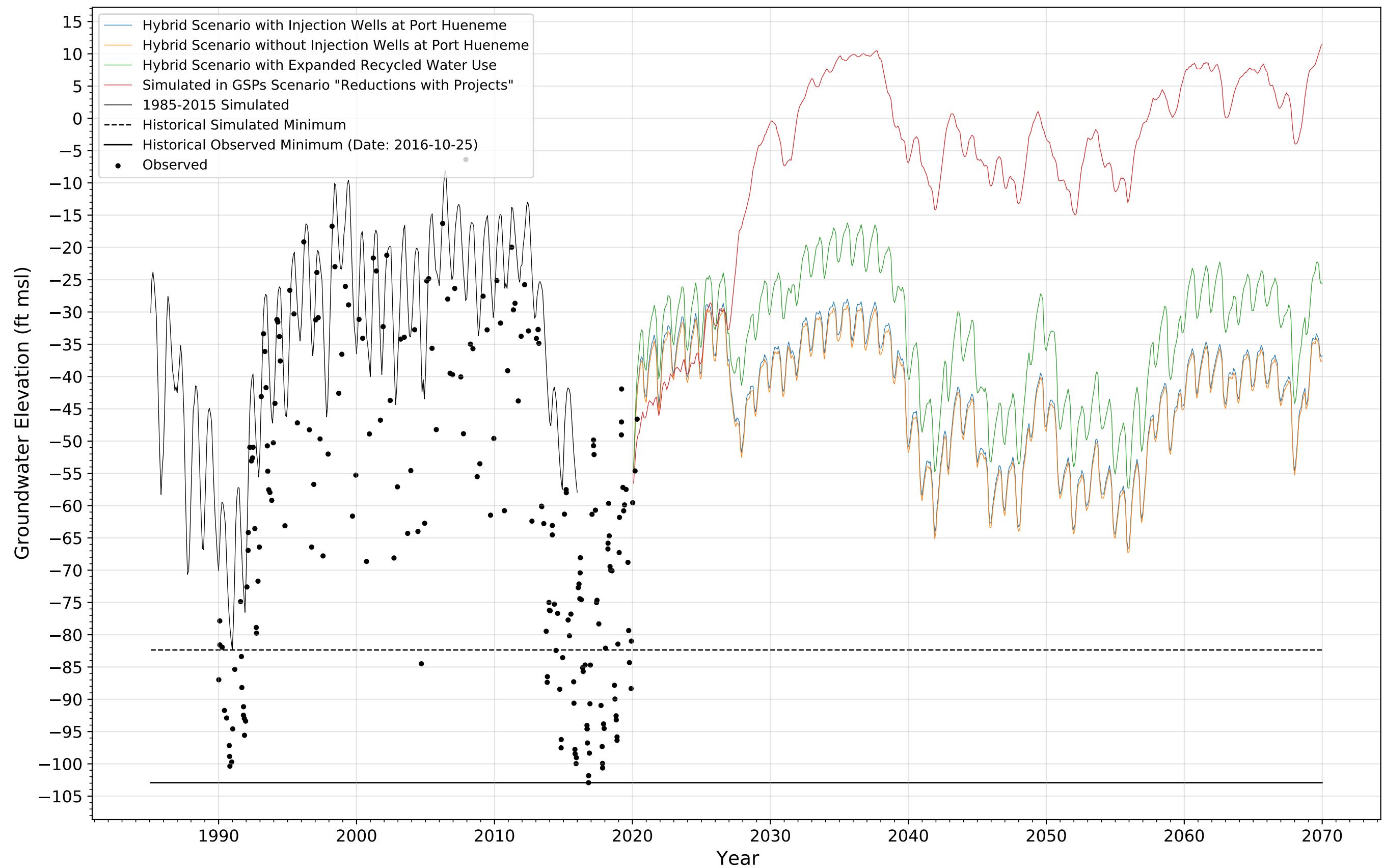
**Figure A-54. Modeled and Measured Groundwater Elevations at Well 02N21W34G02S, Screened in Basal Fox Canyon Aquifer**





**Figure A-55. Modeled and Measured Groundwater Elevations at Well 01N21W32Q02S, Screened in Grimes Canyon Aquifer**





**Figure A-56. Modeled and Measured Groundwater Elevations at Well 01S21W08L03S, Screened in Grimes Canyon Aquifer**



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