PHASE 1 EXTRACTION BARRIER AND BRACKISH WATER TREATMENT PROJECT FEASIBILITY STUDY: GROUNDWATER MODELING

United Water Conservation District

Technical Memorandum

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WATER RESOURCES DEPARTMENT
UNITED WATER CONSERVATION DISTRICT

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1 PURPOSE AND SCOPE

This Technical Memorandum serves as an addendum to the United Water Conservation District's (United) December 2021 Technical Memorandum titled *Extraction Barrier and Brackish Water Treatment Project Feasibility Study: Groundwater Modeling* that modeled extraction barriers near Mugu Canyon at various scales, and showed that annual extraction rates of as little as 5,000 acre-feet per year (AFY) are effective in preventing new episodes of seawater intrusion inland of the proposed barrier wells and in removing brackish water from inland areas surrounding the project area. Before investing significant resources to construct a full-scale extraction barrier system and water treatment facility, it is prudent to test the concept of the extraction barrier by constructing a Phase 1 extraction barrier. United proposes a Phase 1 extraction barrier consisting of seven extraction wells located near Mugu Lagoon, and extracting 3,500 AFY.

This addendum to United's *Extraction Barrier and Brackish Water Treatment Project Feasibility Study: Groundwater Modeling* (UWCD, 2021) presents the model results for the proposed Phase 1 extraction barrier, using the same methods and similar outputs to those presented in the previous Technical Memorandum (Tech Memo). The scenario detailed in this addendum report includes simulation results that included the following changes:

- A decrease in the proposed annual extraction totals (from 5,000 AFY extraction to 3,500 AFY)
- Changes to the proposed well locations
- Estimates of salt removal from the Oxnard basin.

The proposed Phase 1 project alternative is similar in scope and design to the previously-modeled scenarios; the extraction barrier well field will intercept the intrusion of seawater near the Mugu submarine canyon, and the extracted water will be pumped-to-waste during the initial project phase (Phase 1). A secondary objective of the Phase 1 project is to induce vertical gradients from the unconfined Semi-perched aquifer to the underlying confined Oxnard aquifer, and then assess the degree to which these increased gradients affect flow between the aquifers.

2 EXTRACTION PROJECT ALTERNATIVE: 3,500 AFY

To model the proposed 3,500 AFY extraction barrier scenario (Phase 1 scenario), United utilized the MODFLOW-USG-Transport model that was developed in fall 2021 and was used for the previously simulated extraction barrier scenarios; see UWCD (2021) for details regarding the model development, calibration, and potential project scenarios. The MODFLOW-USG-Transport model was used to evaluate a total of seven projects, including the proposed Phase 1 project detailed in this addendum. The previously modeled project alternatives included a "no action" base case, and five extraction barrier designs with various extraction rates. The Phase 1 project scenario detailed here (Scenario 3.5K W) is based on an annual extraction rate of 3,500 AFY;

2,500 AFY extracted from five Oxnard aquifer wells, and 1,000 AFY from two Mugu aquifer wells. Compared to the previously modeled 5K W scenario (5,000 AFY total), the Phase 1 scenario considers a decrease in annual extractions of 500 AFY from the Oxnard aquifer, and 1,000 AFY from the Mugu aquifer (Table 2-1). Similar to the Scenario 5K W, Scenario 3.5K W is also simulated as pump-to-waste, and therefore does not include the treated water distribution that is included in other proposed scenarios for the full-scale Extraction Barrier and Brackish (EBB) Water Treatment Project (UWCD, 2021).

United staff, in collaboration with the U.S. Navy, visited the Naval Base Ventura County installation at Point Mugu to identify potential well sites for the extraction barrier wells. The preliminary list of potential well locations for the Phase 1 project (3.5K W scenario) are vetted sites for well installations and are shown in Figure 2-1.

The Phase 1 scenario, and the six other project alternatives simulated previously, are listed below in Table 2-1.

Table 2-1. Brackish Barrier Project Alternatives.

Scenario	Extraction rate (AFY)	Treated water for usage (AFY)	Treated water usage (AFY)			Oxnard well count	Mugu well count	Oxnard Extraction (AFY)	Mugu Extraction (AFY)
			Navy	PTP	PV				
No Action	0	0	0	0	0	0	0	0	0
3.5K W	**3500**	**0**	**0**	**0**	**0**	**5**	**2**	**2500**	**1000**
5K W	5000	0	0	0	0	6	4	3000	2000
5K T	5000	2500	1500	500	500	6	4	3000	2000
10K	10000	5000	1500	1750	1750	12	10	6000	4000
15K	15000	7500	1500	3000	3000	16	12	10000	5000
20K	20000	10000	1500	4250	4250	20	20	14000	6000

To maintain consistency with the scenarios previously evaluated by United (2021), the same future hydrology (1930-1979 hydrologic conditions with 2070 climate change factor), the same basin conditions (future groundwater recharge and extractions), and the same initial conditions (the December 2015 simulated groundwater level and chloride concentration) were used to simulate the Phase 1 scenario. The simulated hydrologic conditions and the basin conditions are detailed in the United Tech Memo (UWCD, 2021). The initial water level and chloride concentration conditions for the simulations were based on the model calibration period January 1985 to December 2015 (UWCD 2021). The initial groundwater levels were calibrated to 1985-2015 groundwater level measurements, and the simulated initial chloride concentration was calibrated to an interpreted brackish water inland extent (100 mg/L); this extent was interpreted by United staff from water quality data and recent geophysical studies (UWCD, 2016). The initial chloride concentrations, and the inland extent as interpreted by United staff in Oxnard and Mugu aquifers for future simulations are shown in Figure 2-2 and Figure 2-3.

3 PROJECT FEASIBILITY DISCUSSION

Feasibility of the Phase 1 project scenario was evaluated similarly to the modeled scenarios detailed in the United Tech Memo (2021). The evaluations include the following considerations:

- Well extraction rates and the potential limitations of the local geology on extraction rates.
- Containment of the inland extent of brackish water and the prevention of seawater intrusion in the future.
- The flow of water from shallower or deeper aquifers not targeted for groundwater production, resulting from changes in vertical groundwater head gradients.
- Changes in groundwater elevation in the production aquifers in the areas surrounding NBVC Point Mugu, which could impact existing wells and water users.

United staff collaborated with the U.S. Navy to review land use in the project area to identify potential well locations for constructing extraction wells. Five well locations were selected, as shown on Figure 2-1. An initial model run was performed to ensure that the annual extraction rate of 500 acre-ft for five wells in the Oxnard aquifer and two wells in the Mugu aquifer was not limited by local geologic constraints. The total annual extraction from the Phase 1 wells is 3,500 acre-ft 2,500 acre-ft from the Oxnard Aquifer (five extraction wells) and 1,000 acre-ft from the Mugu aquifer (two extraction wells).

The prevention of additional seawater intrusion and the containment or draw-back of existing brackish water from inland areas was evaluated by analyzing the simulated chloride concentrations in the aquifers over time. To evaluate the effect of the Phase 1 scenario (3,500 AFY extraction barrier), the simulated chloride concentrations are compared to the No Action scenario. The simulated chloride concentrations for the Phase 1 and No action scenarios are shown for the Oxnard aquifer in Figures 3-1, 3-2, and 3-3. Those figures show chloride concentration over a 50-year period and include a wet period, a dry period, and final results. From Figures 3-1 to 3-3, it is observed that the chloride concentration is reduced near the extraction barrier wells in the Phase 1 scenario relative to the No Action scenario. The inland extent (the contour of 100 mg/L chloride concentration) is pulled back and retreats toward the coast. These observations (from both wet and dry periods) suggest that the Phase 1 scenario with the 3,500 AFY extraction barrier is effective in both preventing and remediating seawater intrusion in the Oxnard aquifer.

Figures 3-4, 3-5, and 3-6 show the chloride concentrations in the Mugu aquifer over the same time periods and between the two scenarios. From Figures 3-4 to 3-6, it is observed that the chloride concentration is reduced in the Phase 1 scenario relative to the No Action scenario, while the inland extent (the contour of 100 mg/L chloride concentration) is relatively stable and does not move significantly. Results shown in Figures 3-4 to 3-6 suggest that the inland extent is little affected by Phase 1 extractions over a wet and dry period, and the extent is modestly improved in the final results; this suggests that the Phase 1 scenario with the 1,000 AFY extraction barrier system is effective in stabilizing the inland extent of seawater intrusion in the Mugu aquifer. In both the Phase 1 and No Action scenarios, these results suggest that the Phase 1 scenario with the 3,500 AFY extraction barrier system is effective in preventing the expansion of seawater intrusion in the Mugu aquifer in the project area.

When the extraction barrier wells are operating, a groundwater pumping depression is formed around the extraction well field which intercepts the landward flow of seawater from the ocean in both the Oxnard and Mugu aquifers. Figures. 3-7 to 3-8 show the Phase 1 project extraction barrier radius of influence (ROI), where gradients are influenced by Phase 1 project pumping to control and intercept seawater intrusion. Figures 3-7 to 3-8 compare groundwater elevation contours and chloride concentrations after 5 years of Phase 1 project operation and the no action scenario; the observed ROI is approximately 5,000 ft in both aquifers, as shown on the figures.

Phase 1 project results show lateral groundwater flow toward the extraction wells is dominant, but the induced vertical gradients also increase the more limited vertical flow between hydrostratigraphic units; therefore it is important to characterize the changes in vertical flow from the aquifers above and below the Oxnard and Mugu aquifers that result from the project. The simulated vertical flows between Semi-perched, Oxnard, Mugu, and Fox Canyon aquifers for all scenarios are listed in Table 3-1. From Table 3-1, it is noted that vertical flow from Semi-perched aquifer to Oxnard aquifer increases as the total extraction rate increases. The vertical flow from the Semi-perched to Oxnard is increased to 838 AFY for the Phase 1 scenario, relative to 388 AFY for the No Action scenario. In the Mugu aquifer, the existing downward vertical flow to the Fox Canyon aquifer reverses to an upward vertical gradient as the modeled extraction rates increase. The vertical flow from the Mugu aquifer to the Fox Canyon aquifer decreases from 905 AFY for the No Action scenario to 244 AFY for the Phase 1 scenario. To further evaluate vertical flow from the Semi-perched aquifer to Oxnard aquifer, the average seepage velocity (the groundwater flow seeping from the Semi-perched to the Oxnard aquifer) was calculated. The average seepage velocity is small, in the range of 7.0E-04 ft/day for the Phase 1 scenario (see Table 3-1). The areal (spatially varied) seepage velocity was modeled and is shown in Figure 3-9; this areal seepage velocity represents the end of multi-year drought (November 1965) period when groundwater elevations for the simulation period are lowest in the production aquifers.

Table 3-1. Modeled Vertical Flow Between Aquifers.

Average Annual Vertical Flow (AFY)								
From Aquifer	To Aquifer	No Action	3.5K W	5K W	5K T	10K	15K	20K
Semi-Perched	Oxnard	388	838	961	920	1391	1942	2406
Oxnard	Mugu	575	676	820	803	1169	1236	1217
Mugu	Fox Canyon	905	244	15	-8	-552	-938	-1698
Average Vertical Leakage (FT/DAY)								
From Aquifer	To Aquifer	No Action	3.5K W	5K W	5K T	10K	15K	20K
Semi-Perched	Oxnard	3E-04	7E-04	7E-04	7E-04	1E-03	1E-03	2E-03
Oxnard	Mugu	4E-04	5E-04	6E-04	6E-04	9E-04	1E-03	9E-04
Mugu	Fox Canyon	7E-04	2E-04	1E-05	-6E-06	-4E-04	-7E-04	-1E-03

1. The average vertical (AFY) is calculated based on an area (3,526 acres) covering most NBVC installation at Point Mugu and includes the lagoon area

2. The average vertical leakage (ft/day) is an average over the same area (3,526 acres)

3. Negative values indicate the flows are reveres in direction

Given the low seepage velocity from the Semi-perched aquifer to the Oxnard aquifer listed in Table 3-1, United’s Tech Memo (UWCD, 2021) further evaluated the interaction of the horizontal flow in the Semi-perched aquifer with the vertical flow from the Semi-Perched to the Oxnard aquifer using a particle track simulation. It was estimated that all the particles remain within the Semi-perched aquifer under all six scenarios (No Action and the total extraction rates from 5,000 to 20,000 AFY). The particle movement between the No Action scenario and the five scenarios included in UWCD (2021) are very similar, indicating that horizontal flow is dominant in the Semi-perched aquifer, and this flow is little affected by vertical gradients induced by extraction barrier pumping (UWCD, 2021). Particle tracking was not simulated for the Phase 1 extraction barrier as the total extraction rate is lower and would therefore have less of an effect on vertical gradients. United is constructing a new multi-layered groundwater flow model for the Semi-perched aquifer in order to better assess both shallow and deep flow within that unconfined aquifer, including vertical flow down to the Oxnard aquifer and the extent of the saltwater density wedge at the base of the Semi-perched aquifer.

Lastly, the potential impact of operation of the Phase 1 extraction barrier on nearby wells was evaluated by calculating the groundwater elevation drawdown in the greater Project area. Figure 3-10 shows the simulated groundwater elevation contours in November 1965 (at the end of multi-year drought) in the Oxnard aquifer for the scenarios No Action, and 3.5K W (Phase 1). Figure 3-11 shows the simulated groundwater elevation contours in the Mugu aquifer for the same period and scenarios. To compare the groundwater drawdown side-by-side between Scenario No Action and Phase 1, simulated water levels in two “hypothetical” monitoring wells were generated (Wells A and B in Figures 3-12 and 3-13). Well A is located north of the Project extraction wells at the NBVC Point Mugu installation boundary. Well B is located approximately 2 miles from the NBVC Point Mugu, and represents the location of an existing production well. As shown on Figures 3-12 and 3-13, the water level drawdown caused by the Phase 1 extraction barrier system at Well A is less than 10 ft in the Oxnard aquifer and less than 5 ft in the Mugu aquifer, suggesting the water level drawdown around the Navy base is modest. As mentioned above, Well B may serve as a local user's production well. The groundwater level drawdown at Well B may represent the drawdown on local user's production wells caused by the Phase 1 extraction barrier scenario, which is also relatively small, less than 10 ft in both the Oxnard and Mugu aquifers.

4 MASS BALANCE DISCUSSION

The extraction barrier well field is designed to prevent new episodes of seawater intrusion and extract brackish water out of the aquifers to remediate water quality degradation associated with historic seawater intrusion into the aquifers. United simulated chloride concentrations (mg/L) in the aquifers using the calibrated MODFLOW-USG density dependent transport model to evaluate the improvement in groundwater quality and the total dissolved solids (TDS) removal through operation of the extraction barrier wells. In order to estimate the mass of salts removed from the aquifers by the proposed project, simulated chloride concentrations were converted to TDS based on the ratio of the chloride concentration in seawater, (19,400 mg/L) to the TDS of seawater (35,000 mg/L or 2.185 lb/ft^3). For example, 9,700 mg/L in simulated chloride concentration is converted to 1.0925 lb/ft^3 in TDS. Because seawater intrusion impacts extend across the southern coastal areas of the Oxnard basin between Port Hueneme and Point Mugu, an area near the project site (i.e., the approximate area of project influence) was selected to evaluate the effect of the Phase 1 project for mass balance calculations (see Figure 4-1). The selected area, shown in blue, is approximately 11,622 acres. The areas outside the selected zone are not considered to be significantly influenced by the 3,500 AFY extraction barrier.

For this discussion, the beneficial results of the Phase 1 extraction barrier are evaluated by these considerations: the reduction in acreage of poor water quality (chloride concentration equal to or greater than 100 mg/L and 1,000 mg/L), the TDS removed from the aquifers (in tons), and the total volume of water showing improved quality as a result of project operation after 5 and 25 years (in acre-feet). Within the evaluation area shown in Figure 4-1, the areas with simulated chloride concentrations equal to or greater than 100 mg/L and 1,000 mg/L were calculated. Table 4-1 lists the difference in area between the Phase 1 project and the No Action scenarios after 5 years of extraction barrier operation. It is noted that the area of chloride concentration equal to or greater than 100 mg/L is reduced by 57 acres in Oxnard aquifer, and 52 acres in Mugu aquifer. For chloride concentrations equal to or greater than 1,000 mg/L, the area is reduced by 178 acres in Oxnard aquifer, and 103 acres in Mugu aquifer.

Table 4-1. Modeled reduction of area impacted by chloride in the Oxnard and Mugu aquifers, within the evaluation area.

Aquifer	Area with Chloride Conc >=100 mg/L, (ACRES)			Area with Chloride Conc >=1000 mg/L, (ACRES)		
	Phase 1	No Action	Reduction	Phase 1	No Action	Reduction
Oxnard	5533	5590	57	3972	4149	178
Mugu	5016	5068	52	3214	3317	103

Table 4-2 lists TDS in the Oxnard and Mugu aquifers calculated within the evaluation area shown in Figure 4-1. It is shown that after 5 years of Phase 1 project operation TDS is reduced (from areas inland of the extraction barrier wells) by 186,010 tons in the Oxnard aquifer (or 74,404,000 pounds per year). Over the same period of project operation in the Mugu aquifer, TDS is reduced by 31,115 tons (or 12,446,000 pounds per year). The total TDS removed after 5 years (including seawater from areas seaward of the extraction barrier wells) is 462,863 tons by the Oxnard aquifer wells and 158,301 tons by the Mugu aquifer wells. The total TDS removal by the extraction barrier wells is higher than the TDS reduction in the inland area of the aquifers because a majority of TDS is from seawater entering the evaluation area, but does not move past the extraction barrier wells.

Table 4-2: The Total Dissolved Solids (TDS) Budget within the area of evaluation after 5 years of operation.

Aquifer	Initial Total Dissolved Solids in Tons	Total Dissolved Solids removed from inland areas after 5 years, in Tons			Total TDS Removal by Extraction Barrier Wells, in Tons
		Phase 1	No Action	Reduction	
Oxnard	1,070,568	1,119,490	1,305,500	186,010	462,863
Mugu	518,506	560,500	591,615	31,115	158,301

Groundwater quality within the evaluation area (Figure 4-1)_in the Oxnard and Mugu aquifers is notably improved by Phase 1 extraction barrier operation, as detailed above. The following content characterizes the volume of fresh water protected from chloride contamination, as opposed to reduction in chloride concentrations addressed above. To calculate the volume of fresh groundwater protected by the Phase 1 project, the total volume of fresh groundwater within the evaluation area is calculated at the end of 5 years and 25 years, both with and without project operation. As shown in Table 4-3 the volume of fresh groundwater preserved by the Phase 1 extraction barrier operation in the Oxnard aquifer is 510 acre-feet (AF) after 5 years, and 6,799 AF after 25 years. The volume of fresh groundwater preserved by the extraction barrier wells in the Mugu aquifer is 939 AF after 5 years and 3,230 AF after 25 years.

Table 4-3: Total volume of fresh groundwater preserved within the evaluation area for the Oxnard and Mugu aquifers with Phase 1 project operation.

Aquifer	The Initial Total Fresh Water (AF)	Total Fresh Water Preserved (AF) after 5 years			Total Fresh Water Preserved (AF) after 25 years		
		Phase 1	No Action	Water Preserved	Phase 1	No Action	Water Preserved
Oxnard	95,505	89,299	88,789	510	94,959	88,161	6,799
Mugu	118,712	115,429	114,490	939	110,023	106,793	3,230

5 CONCLUSIONS

The MODFLOW-USG-Transport model results detailed in this Addendum simulate the groundwater flow and saline water transport associated with the Phase 1 extraction barrier. Model results from the Phase 1 project (extraction rate of 3,500 AFY) were compared to the results of the No Action scenario, and various other scenarios evaluated in the previous United Tech Memo (2021) detailing larger-scale extraction barrier scenarios.

The results presented in this addendum to the United Tech Memo (2021) show that at a reduced extraction rate (relative to previous scenarios) of 3,500 AFY, the extraction barrier still prevents further seawater intrusion in both Oxnard and Mugu aquifers and remediates some of the impacts associated with past intrusion events in the vicinity of NBVC Point Mugu. In the Oxnard aquifer, the 2,500 AFY extraction rate is shown to be sufficient to draw back the inland extent of brackish water and reduce concentrations of chloride in areas previously impacted near the coast. In the Mugu aquifer, the 1,000 AFY extraction rate improves chloride concentration in the project area and arrests the expansion of seawater intrusion.

Project impacts on the under- and overlying aquifers were evaluated for changes in vertical flow between aquifers resulting from extraction barrier pumping. The model results show that the impacts to vertical flow are minor, and previously modeled particle track simulations suggest that induced vertical gradients, resulting from extraction barrier pumping, have little effect on vertical flow between the Semi-perched and Oxnard aquifer. However, United is developing a multi-layer groundwater flow model for the Semi-perched aquifer to better characterize flow within the unconfined Semi-perched aquifer and vertical flow down to the Oxnard aquifer.

Project benefits were evaluated by comparing the reduction in area of poor-quality water, the volume of TDS removed from aquifers, and the volume of fresh water protected by the Phase 1 project, as compared to the No Action scenario. The reduction in total acreage impacted by chloride concentrations of 100 mg/L or greater was 57 acre after five years of Phase 1 operation in the Oxnard aquifer; and the reduction was 52 acres in the Mugu aquifer over the same period. From the area inland of the extraction barrier wells, the Phase 1 project results in a simulated TDS reduction of 74,404,000 pound per year in the Oxnard aquifer, and a reduction of 12,446,000 pounds per year in the Mugu aquifer. This represents a reduction of 86,850,000 pounds per year of TDS from the Oxnard and Mugu aquifer from the area inland of the extraction barrier wells; over five years of operation some 217,125 tons of TDS are removed from the drinking water aquifers. After five years of Phase 1 project operation, an estimated 510 AF of freshwater is preserved in the Oxnard aquifer, and 939 AF is preserved in the Mugu aquifer.

The Phase 1 extraction barrier simulations demonstrate the feasibility and effectiveness of the extraction barrier wells to remediate brackish water and mitigate seawater intrusion without incurring unacceptable adverse effects in the Oxnard and Mugu aquifers. Following construction of the Phase 1 extraction barrier and additional monitoring and modeling, United intends to design and construct the larger Extraction Barrier and Brackish Water Treatment Project. The full EBB Water project will have a larger and more effective extraction barrier well field, and treat the produced water for beneficial use within the Oxnard basin.

REFERENCES

UWCD (United Water Conservation District), 2016, Saline intrusion update, Oxnard Plain and Pleasant Valley basins, United Water Conservation District Open-File Report 2016-04.

UWCD (United Water Conservation District), Technical Memorandum. 2021. Extraction Barrier and Brackish Water Treatment Project Feasibility Study: Groundwater Modeling. December.

FIGURES

LIST OF FIGURES

Figure 4-1. Greater project area selected for mass balance evaluations.

Figure 2-1. Proposed extraction well locations. Oxnard aquifer extraction wells are proposed at all shown locations; Mugu aquifer extraction wells are proposed at the two northern sites B-6 and B-7. The green and purple lines show the 2015 interpreted inland extent of seawater intrusion for the Oxnard aquifer and Mugu aquifer, respectively.

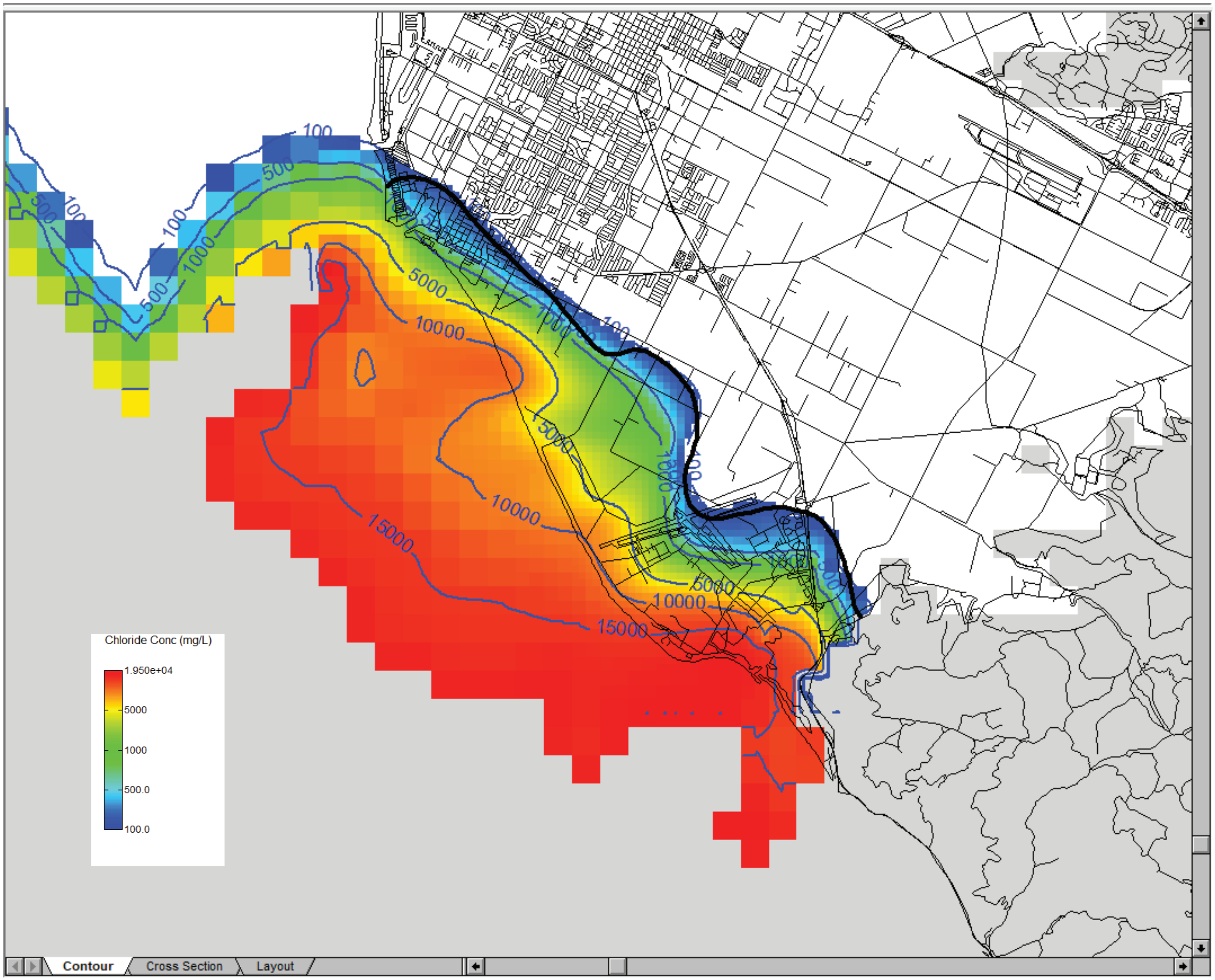


Figure 2-2. Simulated chloride concentrations in the Oxnard aquifer at the end of 2015, and the 2015 interpreted inland extent of brackish water (black line). This simulated chloride concentration was used as the initial conditions for Phase 1 Project scenarios.

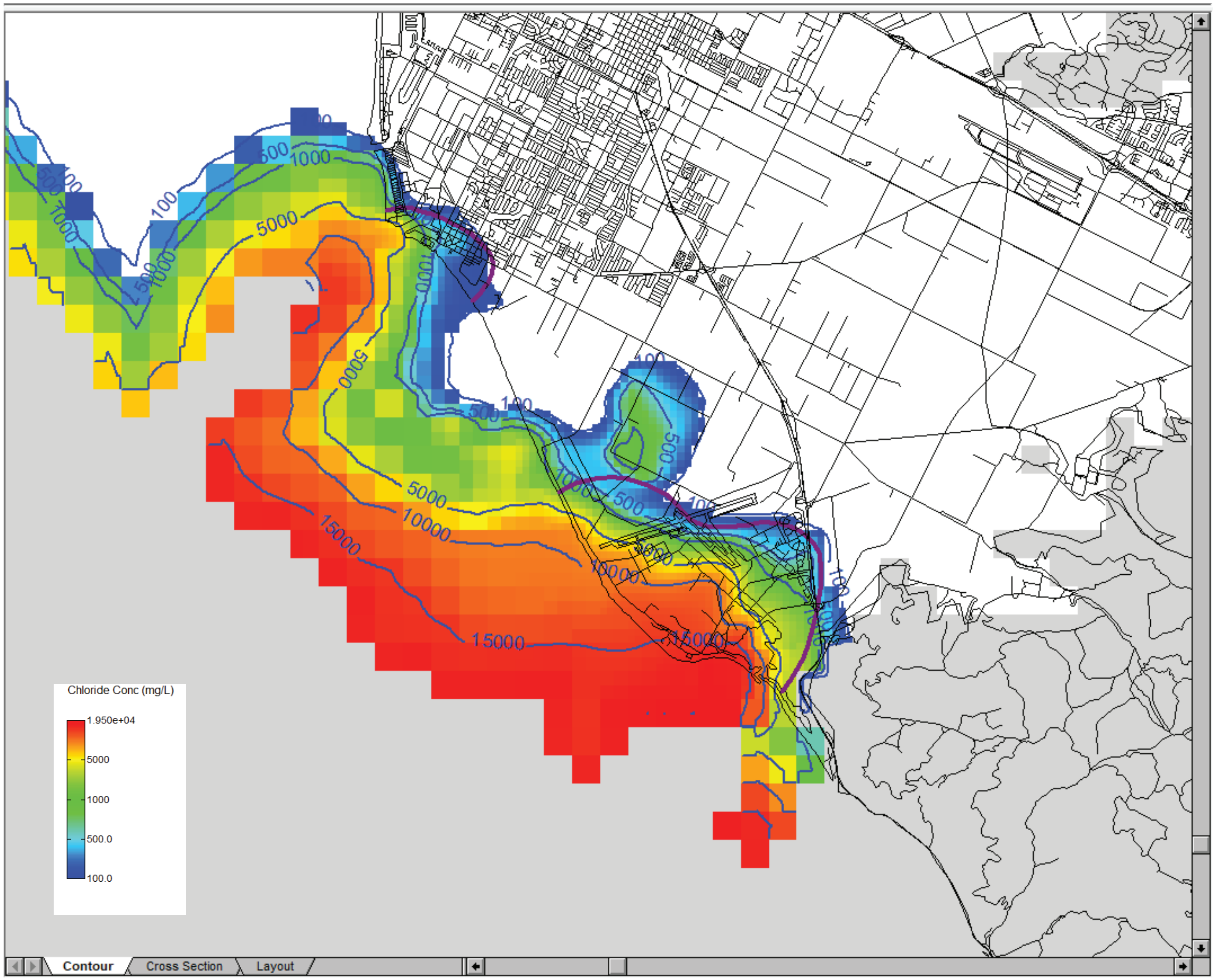
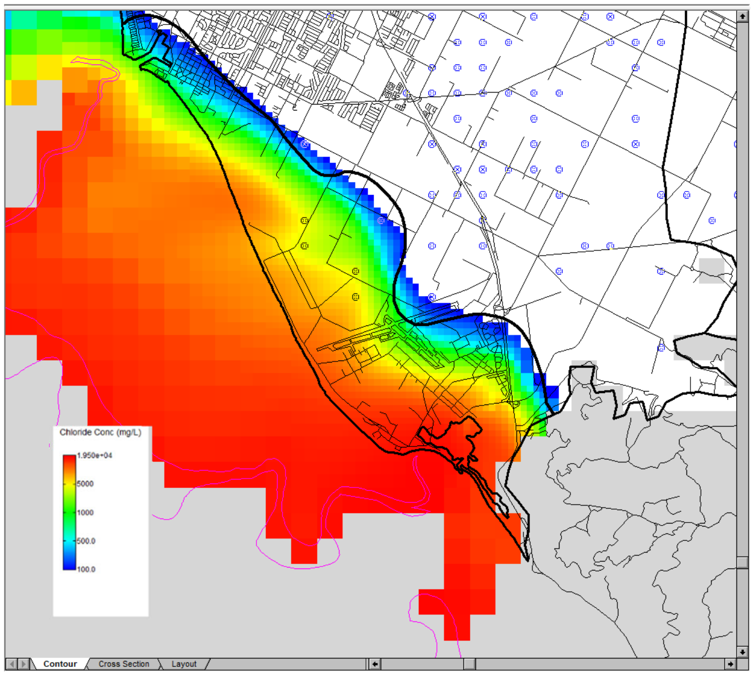


Figure 2-3. Simulated chloride concentrations in the Mugu aquifer at the end of 2015, and the 2015 interpreted inland extent of brackish water (pink line). This simulated chloride concentration was used as the initial conditions for Phase 1 Project scenarios.

Simulated chloride concentrations No Action (September 1947, end of wet cycle)



Simulated chloride concentrations with Phase 1 extraction barrier(September 1947, end of wet cycle)

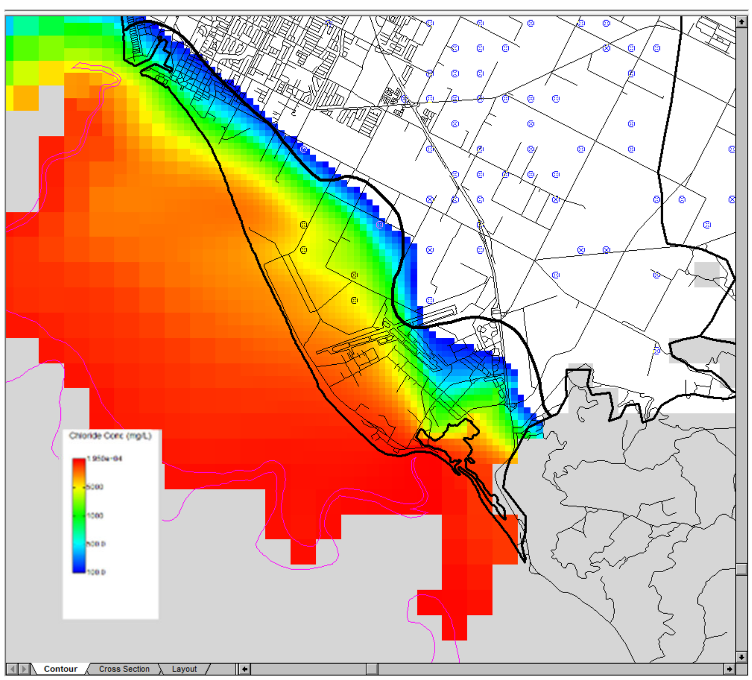
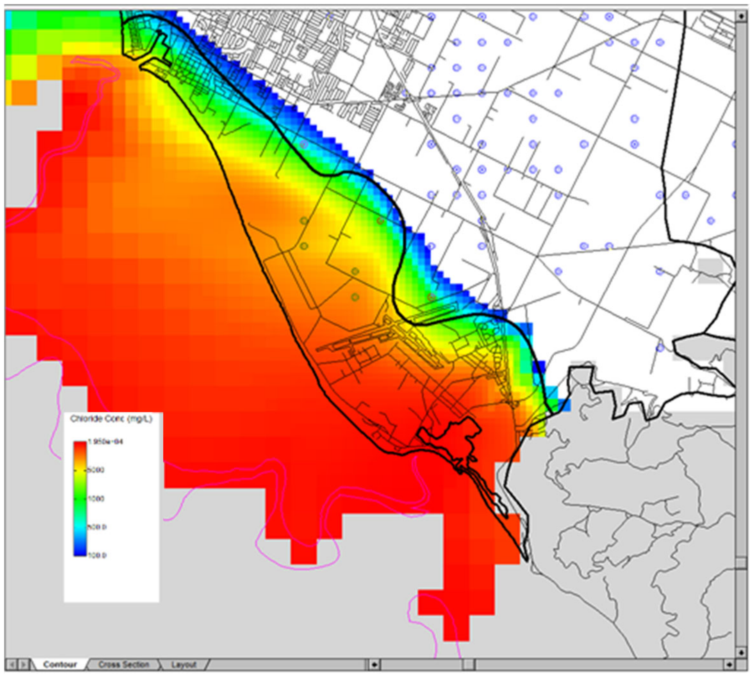


Figure 3-1. Simulated chloride concentrations in the Oxnard aquifer after 17.8 years of Phase 1 project operation. Results show chloride concentrations results at the end of a wet period.

Simulated chloride concentrations No Action (November 1965, end of dry cycle)



Simulated chloride concentrations with Phase 1 extraction barrier (November 1965, end of dry cycle)

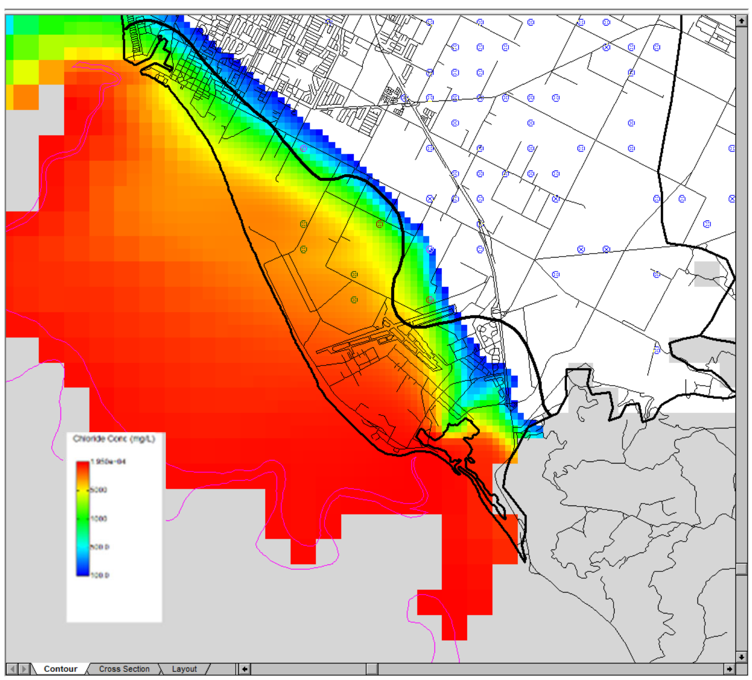
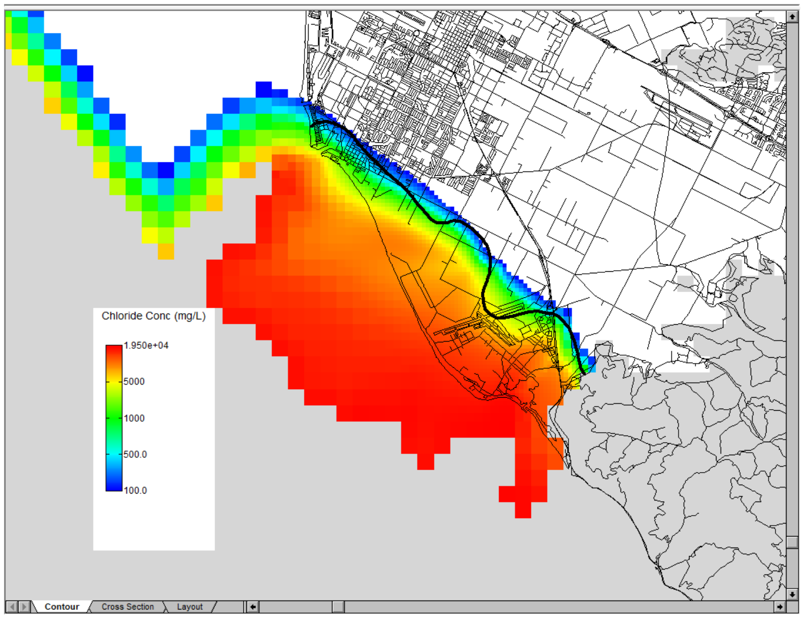


Figure 3-2. Simulated chloride concentrations in the Oxnard aquifer after 35.9 years of Phase 1 project operation. Results show chloride concentrations at end of a dry period.

Simulated chloride concentrations No Action (December, 1979)



Simulated chloride concentrations with Phase 1 extraction barrier (December, 1979)

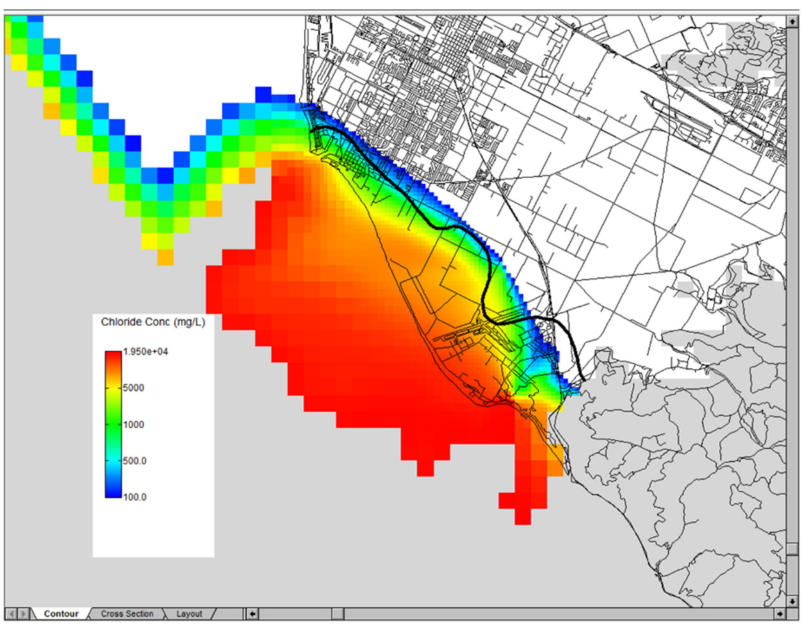
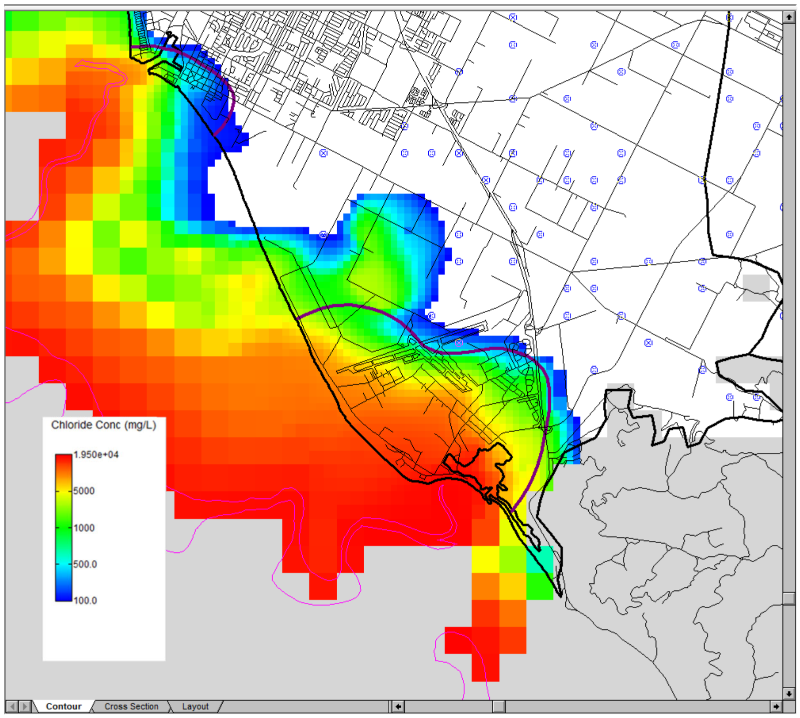


Figure 3-3. Simulated chloride concentrations in the Oxnard aquifer after 50 years of Phase 1 project operation.

Simulated chloride concentrations No Action (September 1947, end of wet cycle)



Simulated chloride concentrations with Phase 1 extraction barrier (September 1947, end of wet cycle)

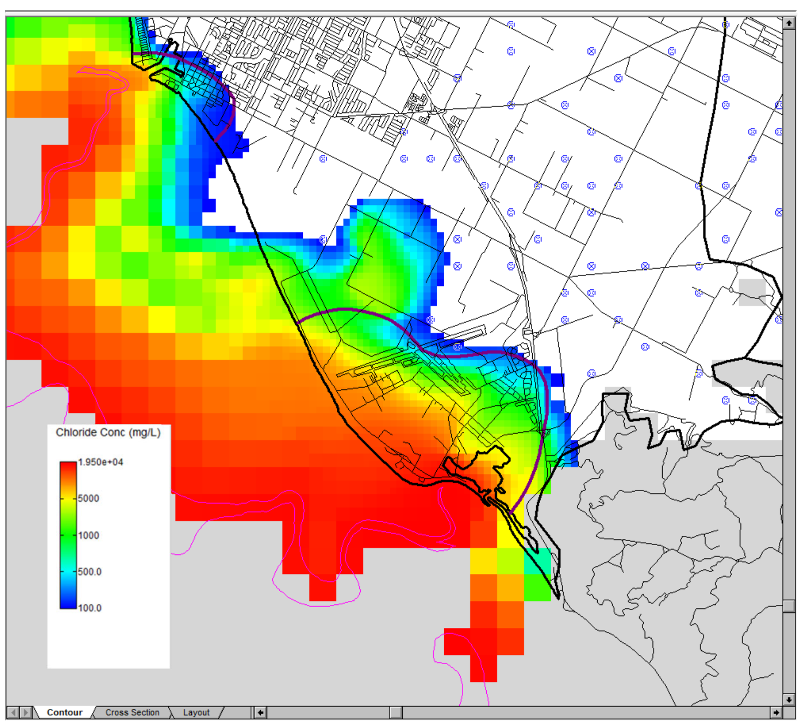
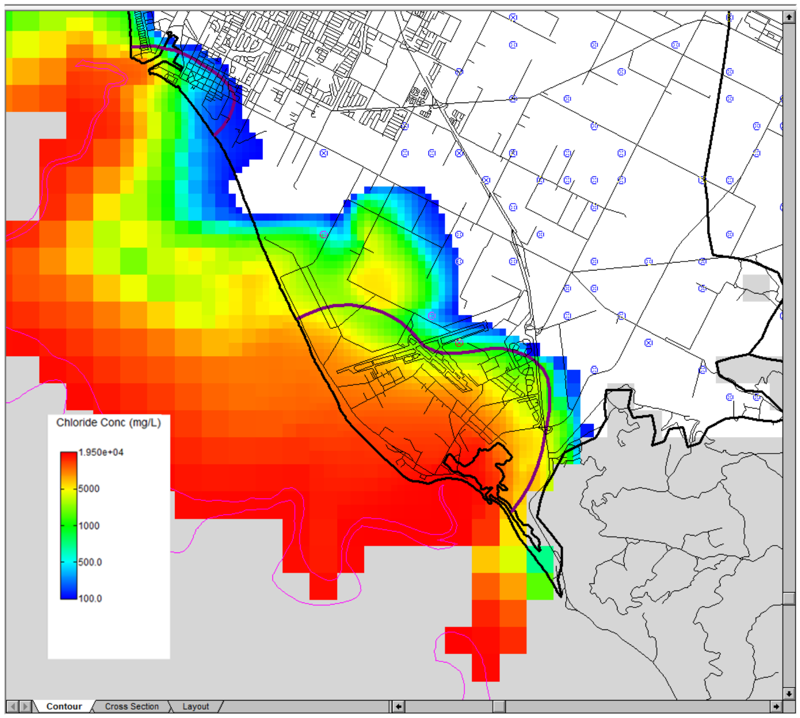


Figure 3-4. Simulated chloride concentrations in the Mugu aquifer after 17.8 years of Phase 1 project operation. Results show chloride concentrations at end of a wet period.

Simulated chloride concentrations No Action (November 1965, end of dry cycle)



Simulated chloride concentrations with Phase 1 extraction barrier (November 1965, end of dry cycle)

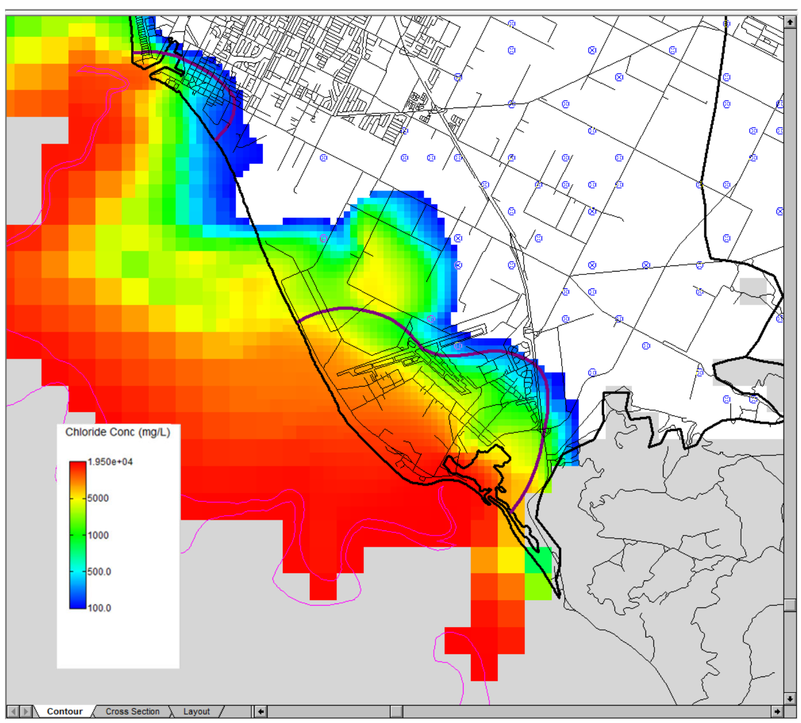
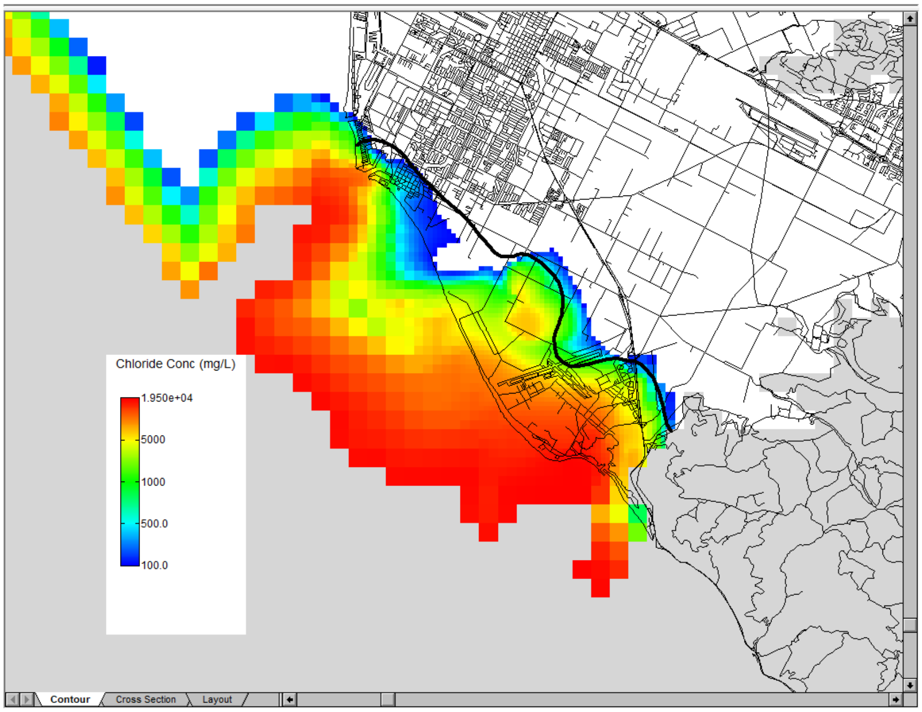


Figure 3-5. Simulated chloride concentrations in the Mugu aquifer after 35.9 years of Phase 1 project operation. Results show chloride concentrations at end of a dry period.

Simulated chloride concentrations No Action (December, 1979)



Simulated chloride concentrations with Phase 1 extraction barrier (December, 1979)

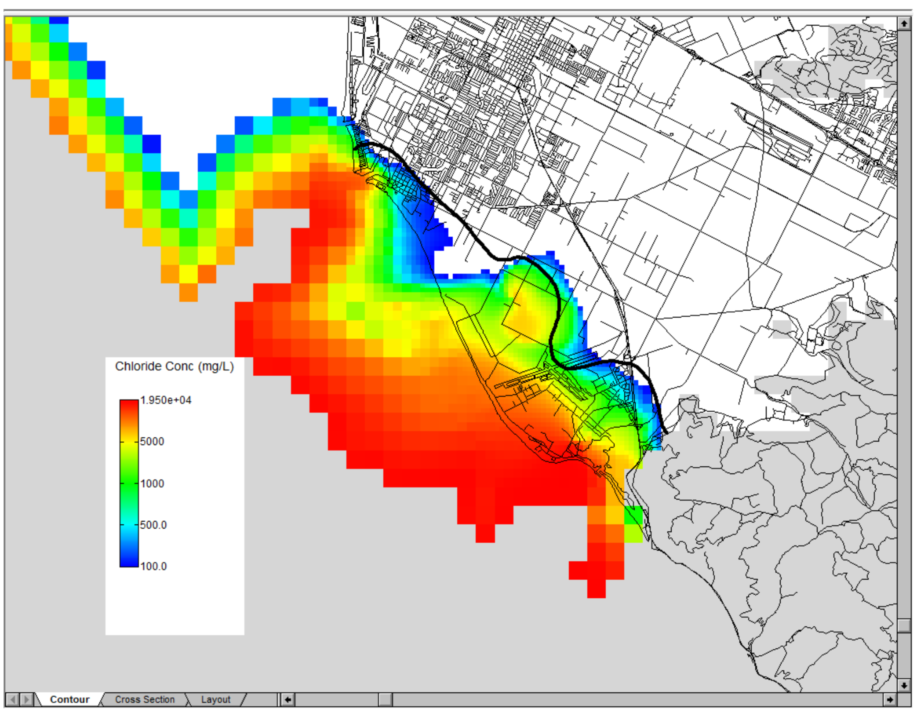
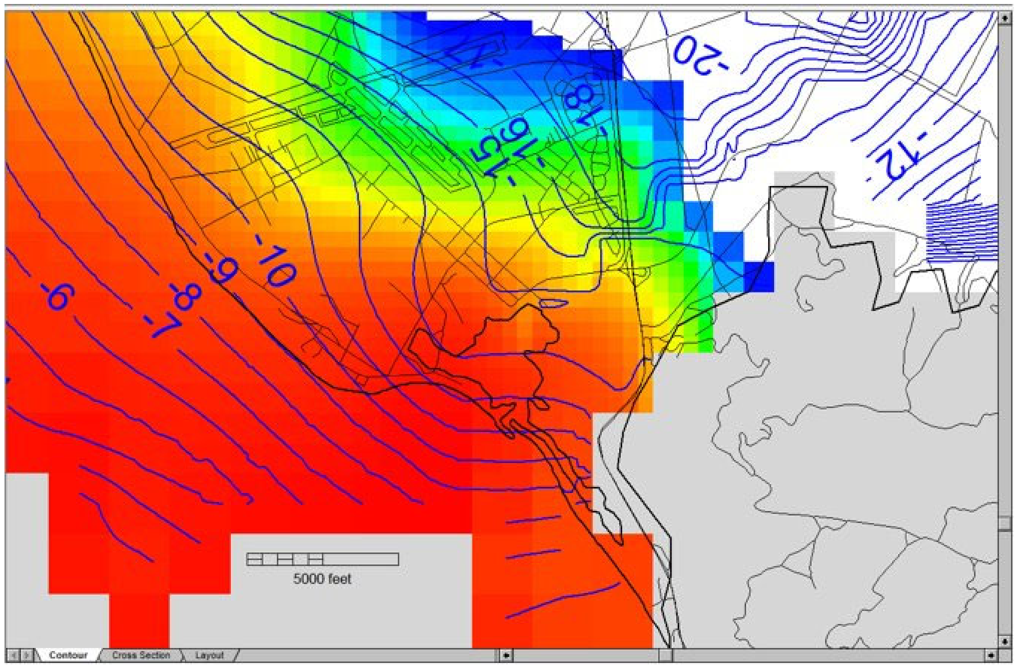


Figure 3-6. Simulated chloride concentrations in the Mugu aquifer after 50 years of Phase 1 project operation**.**

No Action



Phase 1 project

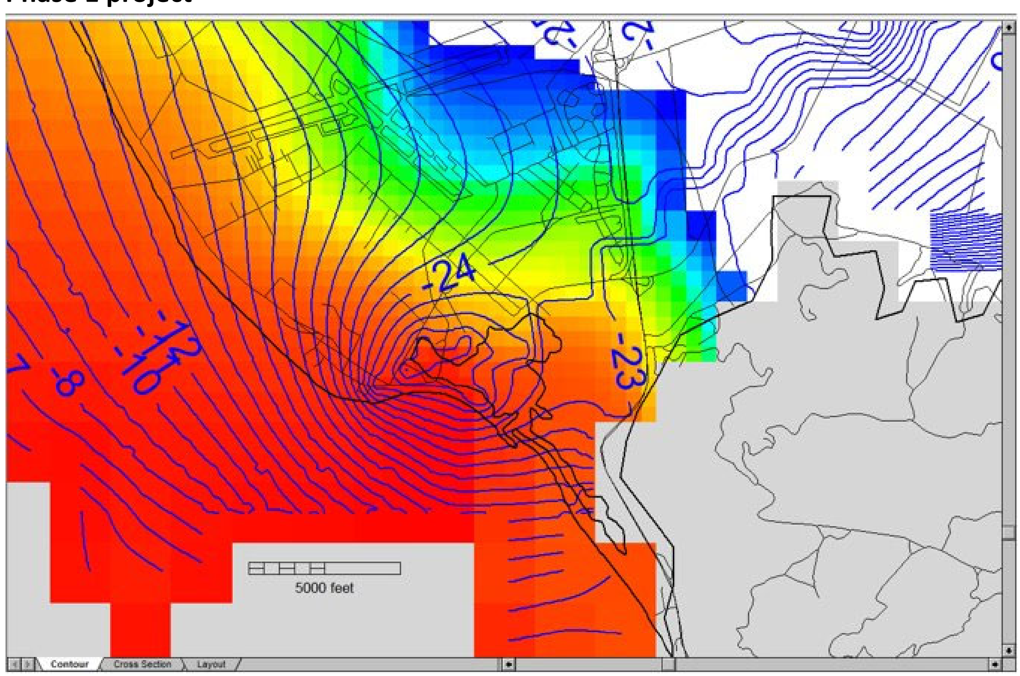
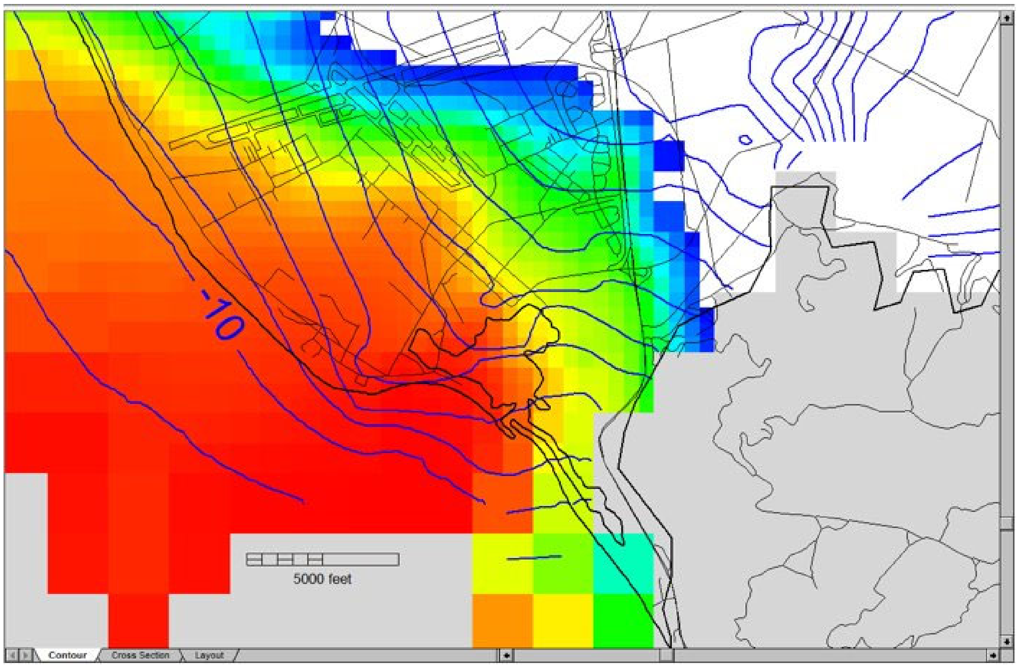


Figure 3-7. Phase 1 extraction wells radius of influence on groundwater elevations and chloride concentrations in the Oxnard aquifer after 5 years of project operation.

No Action



Phase 1 project

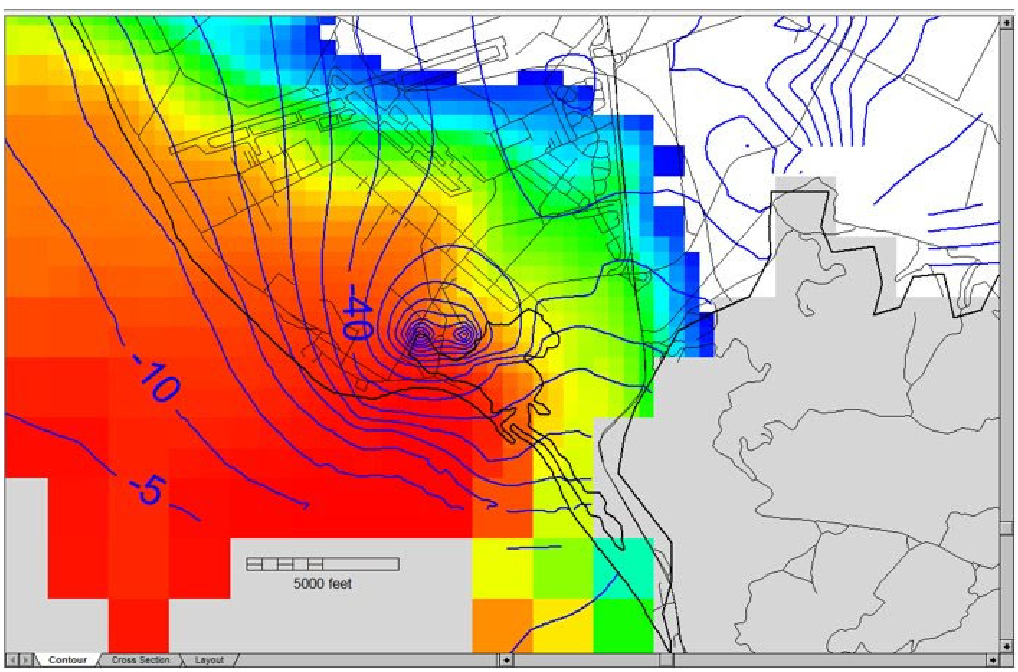
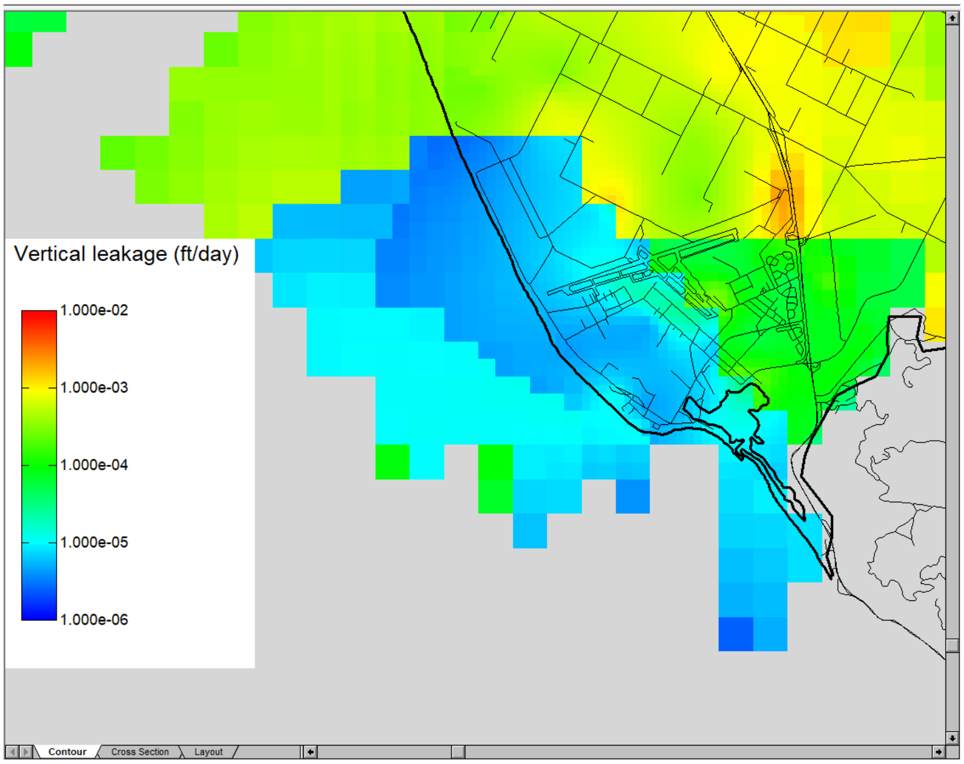


Figure 3-8. Phase 1 extraction wells radius of influence on groundwater elevations and chloride concentrations in the Mugu aquifer after 5 years of project operation.

No Action



Phase 1 project

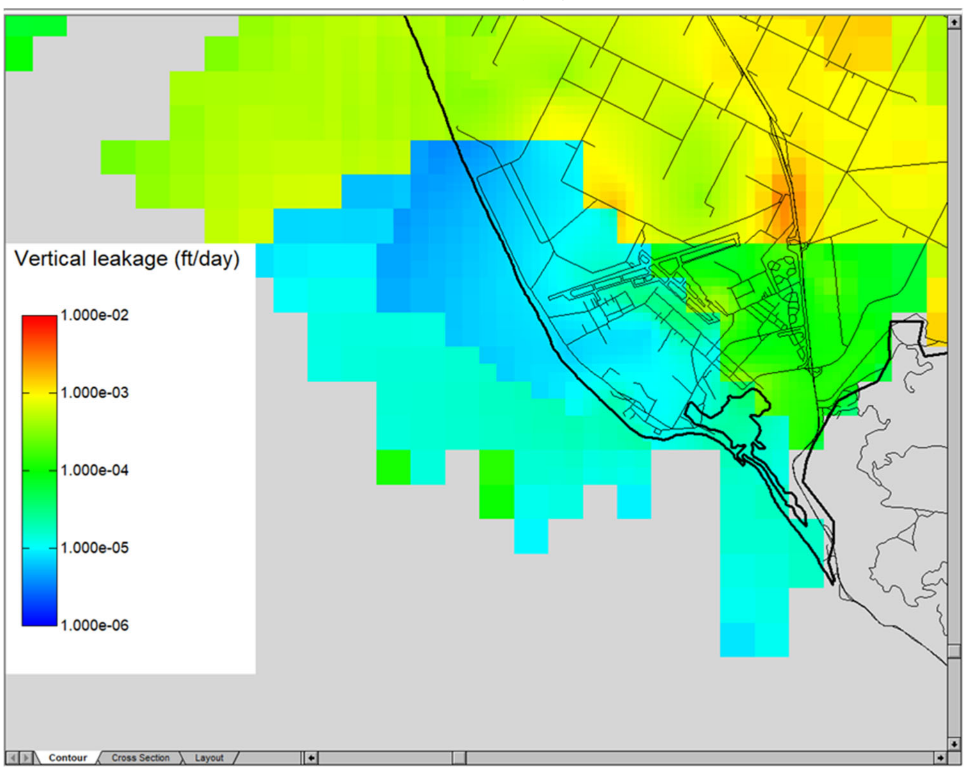
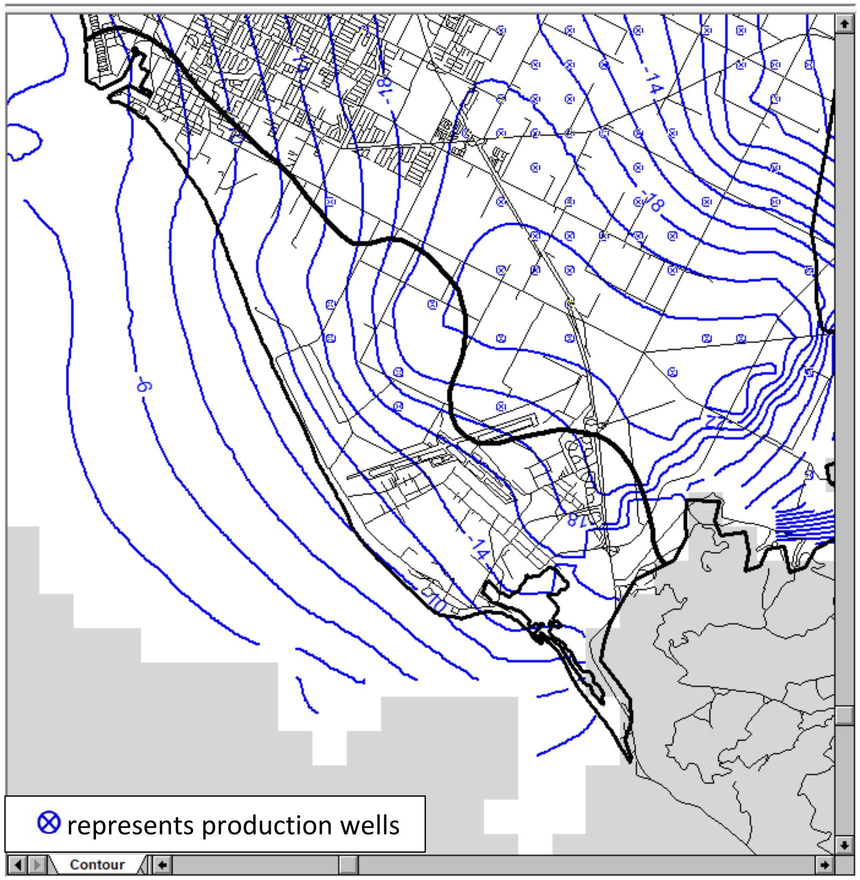


Figure 3-9. Simulated vertical groundwater flow velocity from the Semi-perched aquifer to the Oxnard aquifer in November 1965 (end of multi-year drought).

No Action (No extraction well barriers)



Phase 1 project

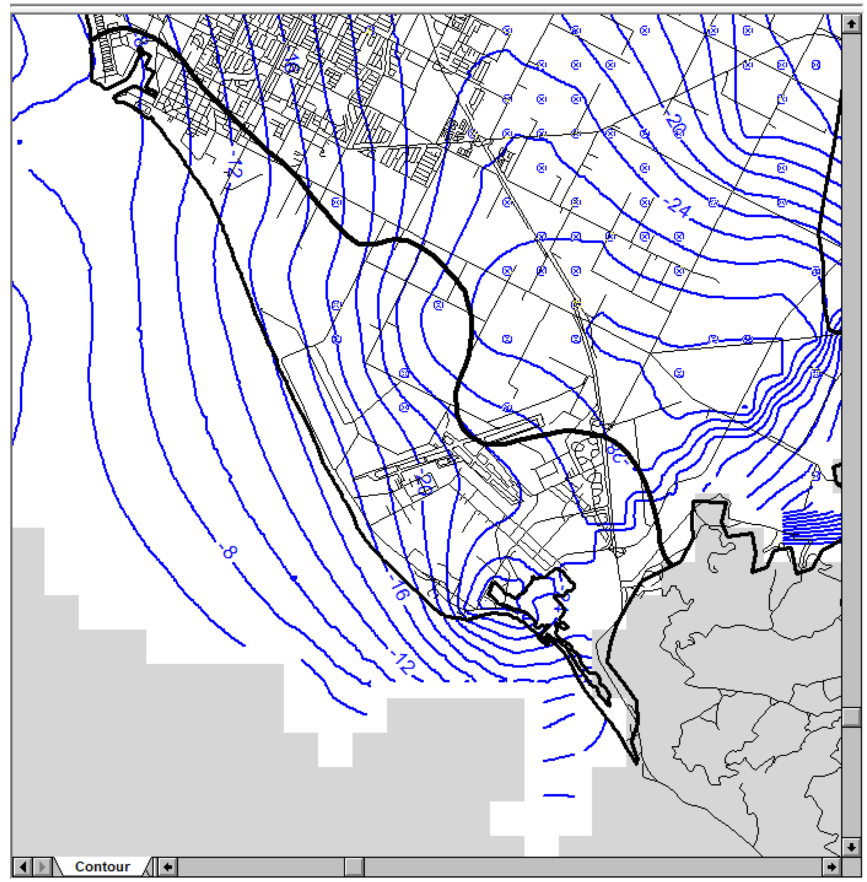


Figure 3-10. Simulated groundwater elevation contours in the Oxnard aquifer in November 1965 (end of multiple year drought) for scenarios No Action and Phase 1 (3.5K W scenario, 2,500 AFY extraction from the Oxnard aquifer).

No Action (No extraction well barriers) **Phase 1 project**

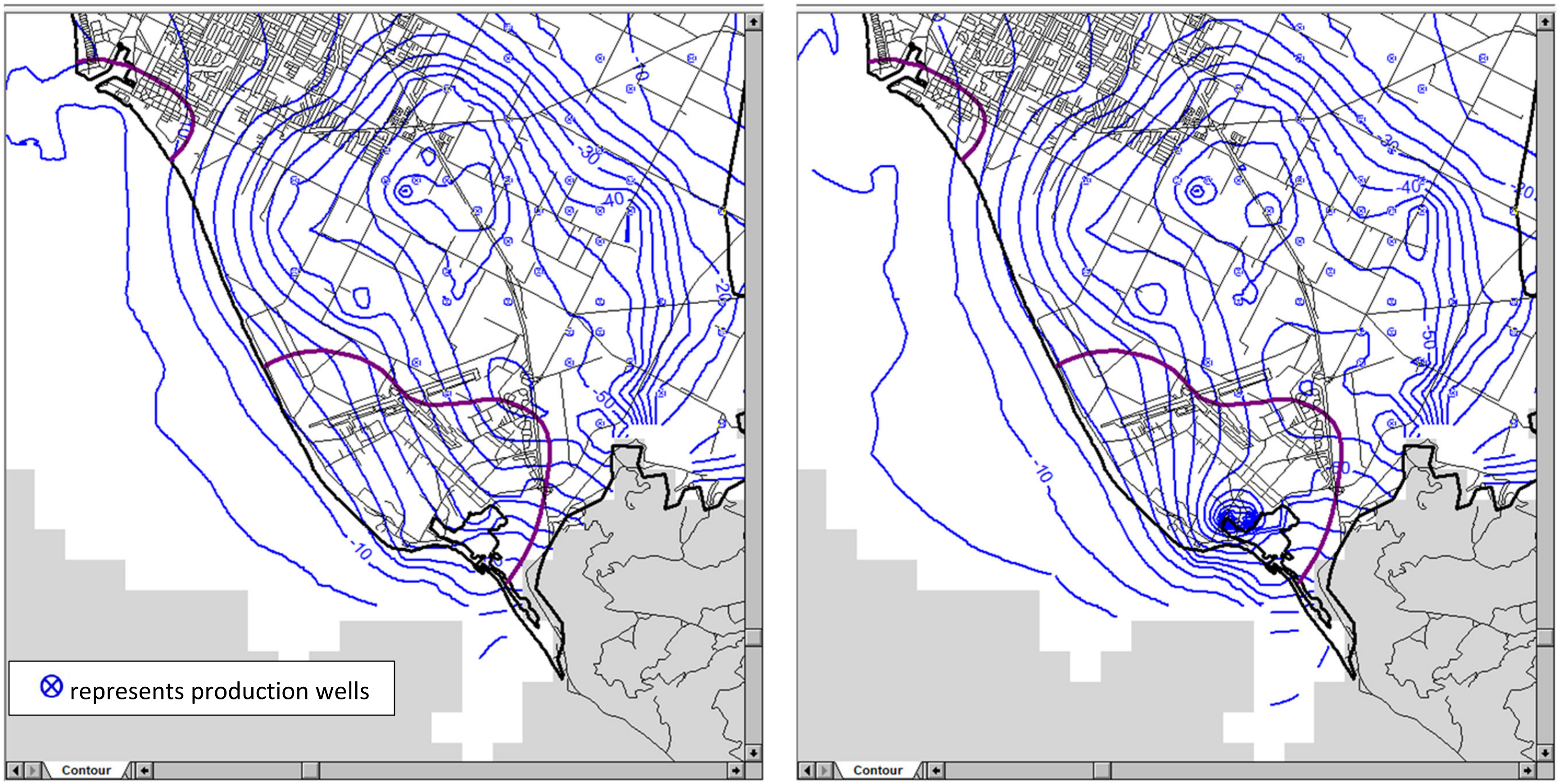


Figure 3-11. Simulated groundwater elevation contours in the Mugu aquifer in November 1965 (end of multiple year drought) for scenarios No Action and Phase 1 (3.5K W scenario, 1,000 AFY extraction from the Mugu aquifer wells).

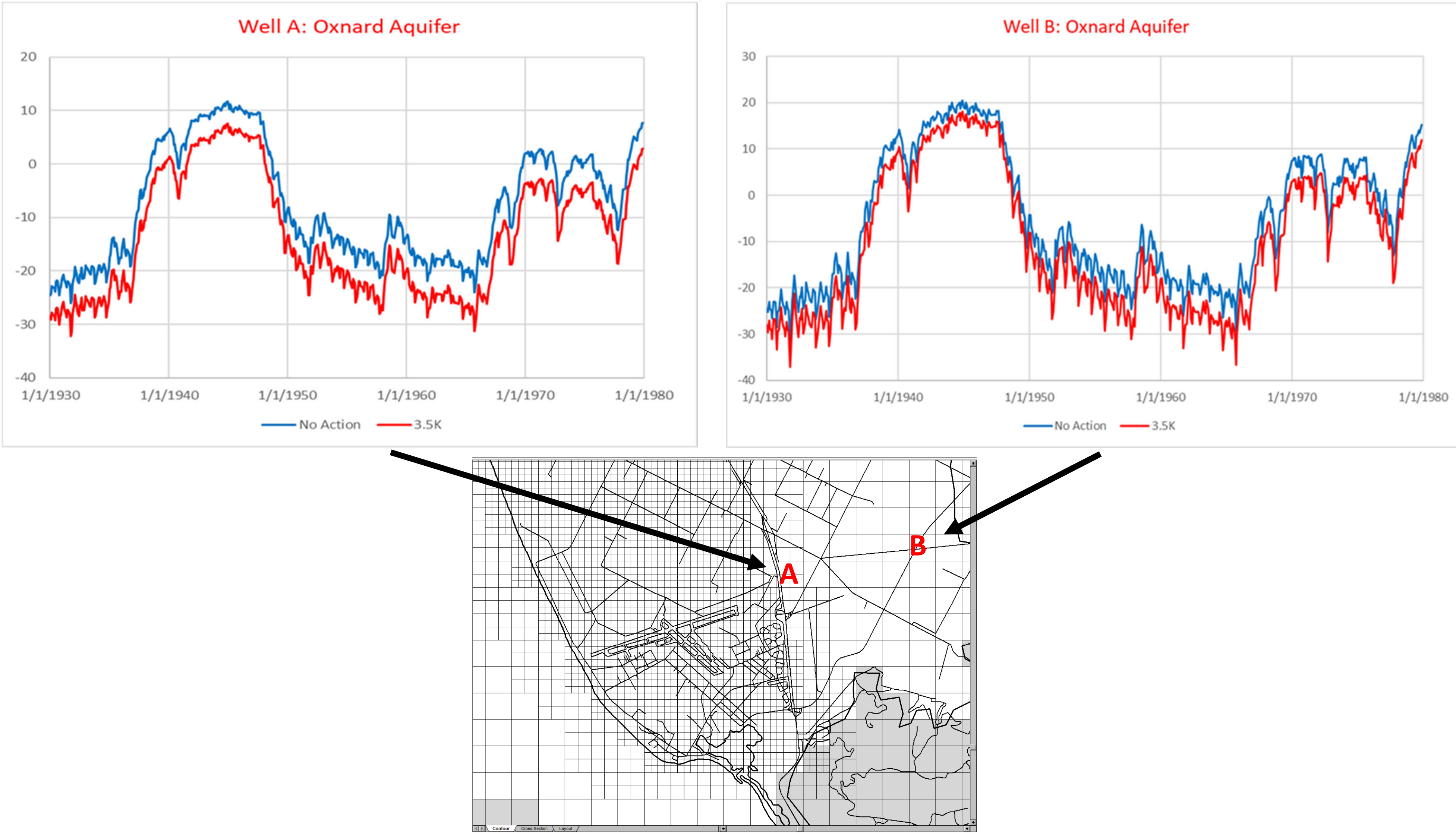


Figure 3-12. Simulated water levels in the Oxnard aquifer at the A & B well locations, located near NBVC Point Mugu. The plots show simulated drawdown in the wells caused by Phase 1 extraction barrier pumping, compared to the No Action scenario.

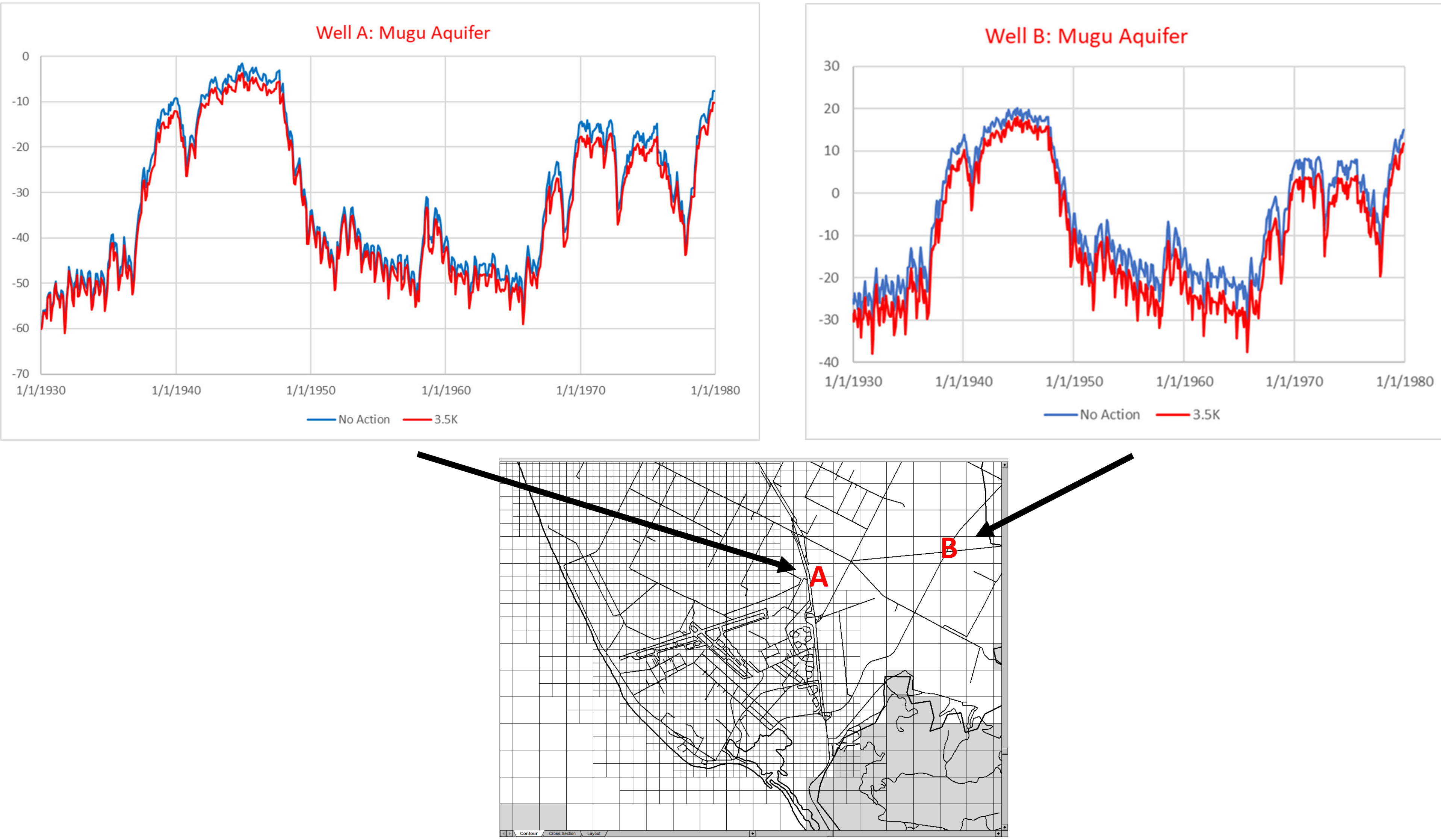


Figure 3-13. Simulated water levels in the Mugu aquifer at the A & B well locations, located near NBVC Point Mugu. The plots show simulated drawdown in the wells caused by Phase 1 extraction barrier pumping, compared to the No Action scenario.

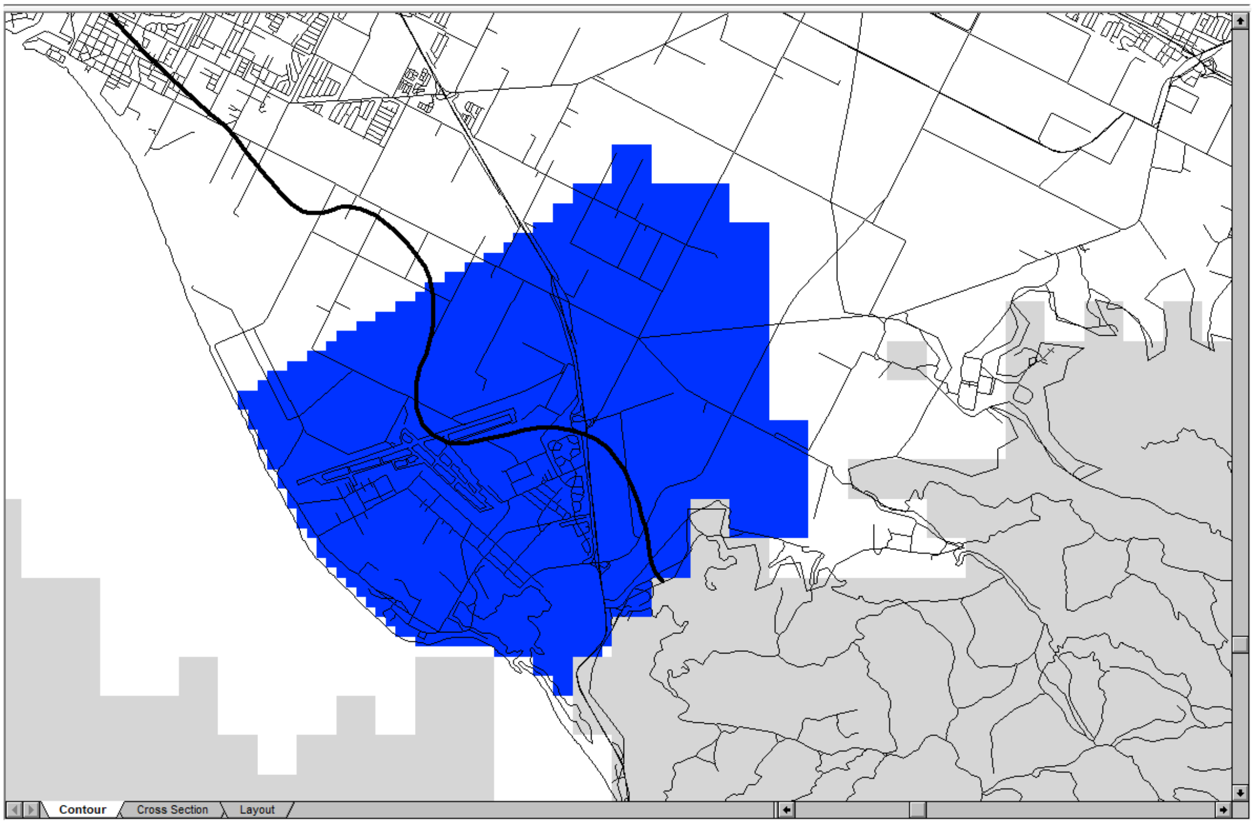


Figure 4-1. Area selected for mass balance calculations (in blue).