HYDROFOCUS INC.
Solutions for Land and Water Resources

March 10, 2020

Mr. Ray Heimstra
Orange County Coastkeeper
Costa Mesa, CA

Mr. Joe Geever
Residents for Responsible Desalination
Long Beach, CA

Subject: Huntington Beach Seawater Desalination Facility - Assessment of Effects of Varying Water-Level Elevations in the Seawater Intrusion Barrier Wells on Sources of Groundwater to Slant Wells

Dear Mr. Heimstra and Mr. Geever,

Please find enclosed the subject report prepared by HydroFocus. We used the groundwater-flow model developed by Geosyntec Consultants to assess the effects of varying groundwater elevations in the seawater intrusion barrier wells. Results from the simulations with the Geosyntec model with varying inputs for slant-well pumping rates and groundwater-level elevations in the seawater intrusion barrier wells indicated that for all pumping rates, the simulated percentage of ocean water increased with lower water-level elevations in the seawater intrusion barrier wells.

Moreover, the particle tracking results indicate that a greater percentage of ocean water flows to the slant wells for lower water-level elevations in the seawater intrusion barrier wells. The simulated ocean-water percentage approaches or equals 90% for all slant-well pumping rates when the water-level elevations in the seawater intrusion barrier wells are close to sea level.

The model simulations demonstrate that slant well pumping will result in inland groundwater to flow towards the slant wells and the groundwater-level elevation in the seawater intrusion barrier wells influences groundwater flow towards the slant wells such that the greater the elevation in the barrier wells, the greater the percentage of inland groundwater that is captured by slant wells. Because the slant wells would lower the groundwater elevation near the ocean and cause inland groundwater flow towards the ocean, the model results point to a lessened need for maintenance of elevated groundwater levels in the seawater intrusion barrier wells with the implementation of slant-well pumping.

2827 Spafford Street, Davis, CA 95617-2401 ● Tel: (530) 759-2484 ● Fax: (530) 756-2687
www.hydrofocus.com

As noted in our previous report, however, the model should be calibrated with groundwater data and a test slant well, similar to what was done for the proposed seawater slant-well desalination facility in Monterey.

Thank you for the opportunity to work on this project and be of service. Please contact us if you have any further questions.

Sincerely,

Steven Deverel, Ph.D., P.G., C.HG.
Principal Hydrologist

PROFESSIONAL GEOLOGIST
STEVEN DEVEREL
No. GEO 8690
expires 3/2022
STATE OF CALIFORNIA

CERTIFIED HYDROGEOLOGIST
STEVEN JOHN DEVEREL
1073
expires 3/2022
STATE OF CALIFORNIA

2827 Spafford Street, Davis, CA 95617-2401 ● Tel: (530) 759-2484 ● Fax: (530) 756-2687
www.hydrofocus.com

Assessment of Effects of Varying Water-Level Elevations in the Seawater Intrusion Barrier Wells on Sources of Groundwater to Slant Wells

HydroFocus, Inc., Davis, CA
March 10, 2020

Contents

Introduction and Background

Geosyntec Consultants (Geosyntec) on behalf of Poseidon Resources (Poseidon) evaluated the feasibility of subsurface intake for the proposed Huntington Beach Seawater Desalination Facility (Desal Facility). Poseidon proposes to locate the Desal Facility site in a coastal lowland area known as the Talbert Gap. HydroFocus previously evaluated the model and performed an analysis of the factors influencing the simulated percentage of ocean water captured by the slant wells. Herein, we present the results of additional work to assess the effect of varying water levels in the Talbert Seawater Intrusion Barrier at the northern edge of the Talbert Gap operated by Orange County Water District.

Brief description of hydrogeology

The Talbert Gap is part of the Coastal Plain of Orange County Groundwater Basin identified by the California Department of Water Resources (CDWR).[1] The Talbert Gap is an erosional channel filled with permeable alluvium between Huntington Beach mesa to the northwest and the Newport mesa to the southeast. The primary water-bearing zone in the Talbert Gap is the Talbert Aquifer. The Talbert Aquifer extends offshore and, therefore, allows exchange of groundwater with the ocean. The Talbert Aquifer is overlain by fine-grained sediments and underlain by a zone of fine-grained sediments and deeper aquifers.

The connection of the Talbert Aquifer with the ocean has allowed seawater to intrude into the aquifer as a result of inland pumping. The Orange County Water District operates the Talbert Seawater Intrusion Barrier at the northern edge of the Talbert Gap.[2] The barrier is comprised of 36 wells that inject water into the aquifers to control seawater intrusion and replenish the basin.

Groundwater modeling

Geosyntec[3] developed a groundwater-flow model to simulate the effects of pumping groundwater from multiple slant wells along the coast. The model simulated a pumping rate of 127 million gallons per day (MGD) from 40 slant wells screened in the Talbert Aquifer. The model was designed to evaluate the effects of pumping the proposed slant wells.

HydroFocus obtained Geosyntec model versions 6, 7 and 8 in July 2016. The model was developed using the U.S. Geological Survey MODFLOW 2000 code[4]. Model version 6 incorporates several recommended changes from previous versions of the model. This version includes the addition of constant head cells[5]

---

[1] California Department of Water Resources, California's Groundwater, Bulletin 118 – Update 2003. www.water.ca.gov/groundwater/bulletin118/update_2003.cfm

[2] Orange County Water District Groundwater Management Plan, 2015 Update.

[3] Geosyntec Consultants, 2013, Feasibility Assessment of Shoreline Subsurface Collectors Huntington Beach Seawater Desalination Project Huntington Beach, California.
Thrup, Gordon, 2015, Revision and Sensitivity Analyses of Slant Well SSI Model, Geosyntec Consultants Technical Memorandum to Scott McCreary.

[4] Harbaugh, Arlen W., et al., 2000, MODFLOW-2000, The U.S. Geological Survey Modular Ground-Water Model-Users Guide to Modularization Concepts and The Ground-Water Flow Process.

[5] In constant head model cells, the hydraulic head is specified in advance by the user and remains constant throughout all time steps of the simulation.

to represent a portion of coastal marsh and wetland areas, and the model grid was refined to provide a larger portion of the coast with finer grid spacing. Model version 6 was used to conduct several sensitivity runs to test the effects of varying aquifer properties and slant well pumping rates. Model versions 7 and 8 are similar to version 6 with the exception of the location of the slant wells.

The model consists of 10 layers; Layer 1 represents the ocean only, Layers 2-4 represent fine-grained sediments[6] above the Talbert Aquifer, Layers 5-8 represent the Talbert Aquifer, Layer 9 represents the fine-grained sediments below the Talbert Aquifer, and Layer 10 represents the deep aquifers. The Talbert Aquifer is represented by four layers to allow the pumping wells to be simulated with a slanted configuration increasing in depth as the wells extend away from the coast toward the ocean. Pumping from the slant wells occurs in Layers 5-8.

Previous Evaluation of the Model

Previously, HydroFocus reviewed the model used in the Well Investigation Team Report, performed model runs using varying model input values, assessed the sensitivity of model outputs to variations in model inputs. Water level declines will be greatest in the vicinity of the slant wells. The model results indicate that the majority of the water extracted from the slant wells will come from the ocean, but some groundwater will originate inland and some will originate in the coastal wetlands. The HydroFocus report concluded that pumping of slant wells would likely have a positive impact on the operation of the seawater intrusion barrier by increasing hydraulic gradients towards the ocean and reducing the impact of seawater intrusion into the inland portion of the Talbert Aquifer. However, we found that the model should be calibrated with groundwater data, similar to what was done for the proposed slant-well seawater desalination facility in Monterey.

Further, in both the Geosyntec and our model runs, the water levels in the seawater intrusion barrier were simulated by specifying the water-level elevation at about 7 feet above mean sea level (MSL). Modifying this specified assumption is the focus of this study.

Objective

By conducting additional model runs, HydroFocus assessed the interaction of slant well pumping and water levels in the Orange County Water District Talbert Seawater Intrusion Barrier at the northern edge of the Talbert Gap.[7] Our objective was to determine the effects of varying pumping rates and groundwater elevations in the barrier wells on the simulated sources of groundwater to the slant wells.

Methods

HydroFocus used the Geosyntec model version 6 using MODFLOW-2005 to assess the effects of varying slant well pumping rates and groundwater levels in the Talbert Seawater Intrusion Barrier wells. The scenarios are summarized in Table 1. In the original model, the Talbert Seawater Intrusion Barrier is represented by a distribution of constant-head boundary cells with groundwater elevations ranging

[6] Fine-grained sediments typically consist of clays and silts. Coarse-grained sediments typically consist of sands and gravels.
[7] Orange County Water District Groundwater Management Plan, 2015 Update.

from 6 to 10 ft. For the HydroFocus model simulations, the specified heads in these cells were multiplied by a constant factor to result in lower values for groundwater elevations during the model simulations. Therefore, the values reported for water level in Table 1 correspond to the approximate new average of the groundwater level distribution for each scenario.

Table 1. Scenarios considered in sensitivity analysis with their respective slant wells pumping rates Talbert Barrier constant heads.

Model Run identification	Pumping rate in million gallons per day (MGD)	Specified water level in Talbert Seawater Intrusion Barrier wells (feet above MSL)
Run 25_D	25	0
Run 25_2ft	25	Approximately 2
Run 25_5ft	25	Approximately 5
Run 25_Ori	25	Approximately 7
Run 50_D	50	0
Run 50_2ft	50	Approximately 2
Run 50_5ft	50	Approximately 5
Run 50_Ori	50	Approximately 7
Run 100_D	100	0
Run 100_2ft	100	Approximately 2
Run 100_5ft	100	Approximately 5
Run 100_Ori	100	Approximately 7

To assess the sources of water to the simulated slant wells, the ZONEBUDGET post-processing[8] program was used by HydroFocus personnel to estimate the contributions (ocean, wetlands, surface recharge and inland) to the volume pumped by the slant wells.

HydroFocus personnel performed particle tracking using the program MODPATH 6[9] following the procedure described in the HydroFocus 2016 report. From these analyses, simulated path lines of water particles pumped by the slant wells were mapped. The path lines were classified into two categories, those which originated inland, and those which originated in the ocean. The same particle starting locations used in the HydroFocus 2016 report[10] were employed.

[8] Harbaugh, A.W., 1990, A computer program for calculating subregional water budgets using results from the U.S. Geological Survey modular three-dimensional ground-water flow model: U.S. Geological Survey Open-File Report 90-392, 46 p.
[9] Pollock, D.W., 2012, User Guide for MODPATH Version 6—A Particle-Tracking Model for MODFLOW: U.S. Geological Survey Techniques and Methods 6–A41, 58 p.
[10] *Ibid.* [3]

Results

Contributions to slant wells

Table 2 and Figure 1 illustrate how the different zones of the model contribute to the volume of water pumped by the slant wells for the different scenarios. These data provide insight on how the slant-well pumping rate and the groundwater level elevation at the seawater intrusion barrier would likely interact to influence the composition of the pumped groundwater. Table 2 and Figure 1 illustrate that for each pumping rate ranging from 25 to 100 MGD, the simulated volume of ocean water captured by the slant well increased with decreasing groundwater elevations in the seawater intrusion barrier wells. For all simulations using the Geosyntec model results, the ocean water percentage approaches or equals 90% when elevations in the seawater intrusion barrier wells are near sea level. The simulated groundwater flow paths show the simulated movement to the slant wells.

Table 2. Results of model simulations with varying pumping rates and seawater intrusion barrier elevations.

Model Run	Project Pumping with Slant Wells, MGD	Project Pumping with Slant Wells, AFY	Length of Slant Well, ft	Seawater Intrusion Protective Elevation at the Talbert Gap, ft msl	Flow Contributed to Slant Well, %			
					Ocean	Wetlands	Areal Recharge	Inland
Geosyntec Run V6*	126.7	141900	425	Approximately 7	87%	2%	1%	**10%**
Run 100_Ori	100.0	112000	425	Approximately 7	87%	2%	1%	**10%**
Run 100_5ft	100.0	112000	425	Approximately 5	87%	2%	1%	**10%**
Run 100_2ft	100.0	112000	425	Approximately 2	88%	2%	1%	**9%**
Run 100_D	100.0	112000	425	0	90%	2%	1%	**7%**
Run 50_Ori	50.0	56000	425	Approximately 7	84%	2%	2%	**12%**
Run 50_5ft	50.0	56000	425	Approximately 5	85%	2%	2%	**11%**
Run 50_2ft	50.0	56000	425	Approximately 2	87%	2%	2%	**9%**
Run 50_D	50.0	56000	425	0	90%	2%	2%	**6%**
Run 25_Ori	25.0	28000	425	Approximately 7	77%	2%	4%	**17%**
Run 25_5ft	25.0	28000	425	Approximately 5	80%	2%	4%	**14%**
Run 25_2ft	25.0	28000	425	Approximately 2	84%	2%	4%	**10%**
Run 25_D	25.0	28000	425	0	89%	2%	4%	**4%**

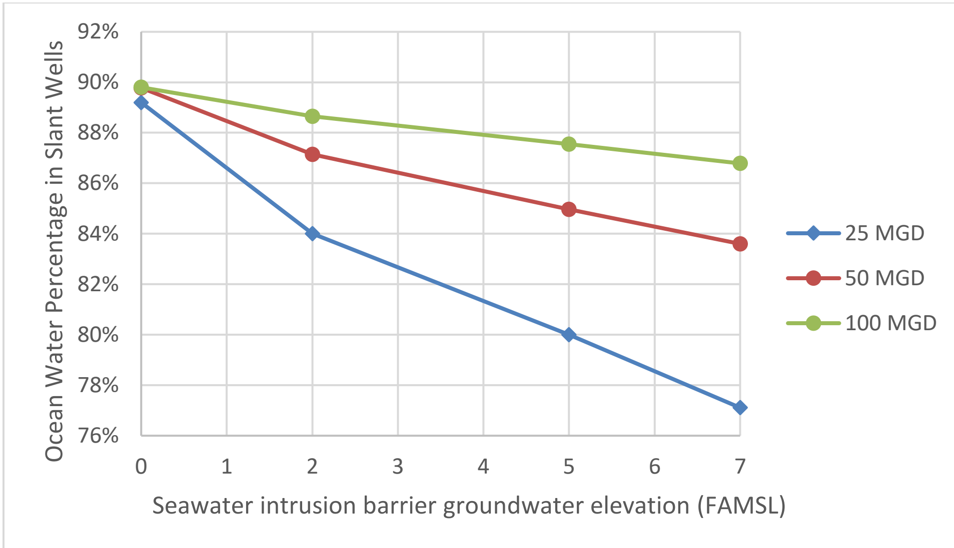
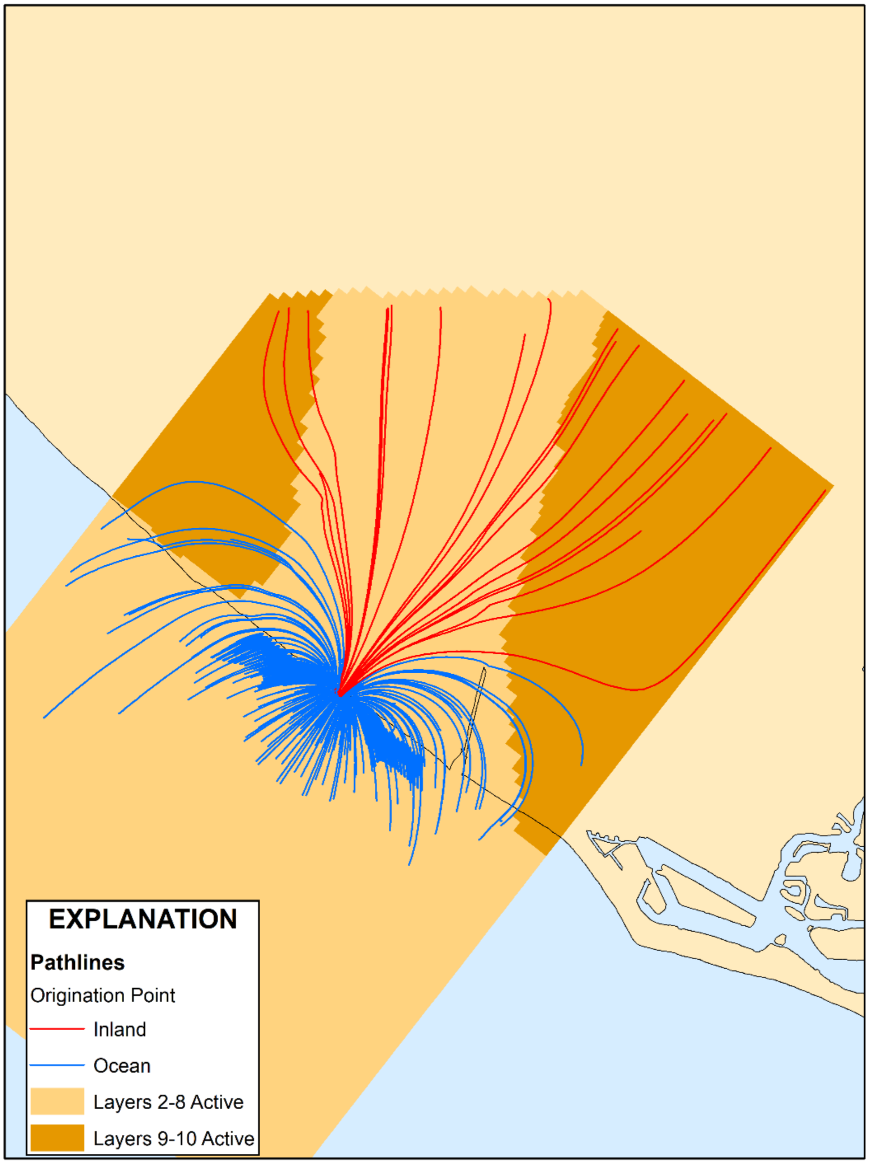


Figure 1. Inland and Ocean contributions to slant wells pumping for different values of seawater intrusion protection at the Talbert Gap.

Groundwater flow paths

Using the backward tracking feature in MODPATH, particle tracking results were calculated for the scenarios to visualize simulated groundwater flow paths. Path lines were classified according to their origin either inland or the ocean. Figure 2 displays example path lines for 25 MGD of slant well pumping. Maps for the rest of the scenarios are presented in Appendix B. Particle-tracking counts and percentual distributions of path lines according to the origin of the particles are summarized in Table 3. Similar to the water budget calculation described above, the simulated proportion of flow from inland areas decreased with decreased water-level elevations in the seawater intrusion barrier wells. Moreover, flow paths indicate inland groundwater flow towards the ocean for all scenarios.



\\HF-SVR\Shared Folders\Company\Projects\5612 Orange County Coast Keeper\GIS\Maps\2020\Particle Tracking 25_0.mxd

Figure 2. Example backwards particle tracking analyses for scenario 25 MGD of pumping from slant wells and 0 ft of head at saline control barrier. Blue lines represent path lines for water parcels that originated in the ocean, while red lines represent path lines for water parcels originated inland.

Table 3. Classification of path lines according to their origin for modeled scenarios

Slant Wells Pumping (MGD)	Barrier Head (ft)	Path lines Originated in the Ocean Zone (count)	Path lines Originated Inland (count)	Path lines Originated in the Ocean Zone (%)	Path lines Originated Inland (%)
100	7	1168	128	90.1	9.9
100	5	1175	121	90.7	9.3
100	2	1189	107	91.7	8.3
100	0	1206	90	93.1	6.9
50	7	1217	79	93.9	6.1
50	5	1227	69	94.7	5.3
50	2	1238	58	95.5	4.5
50	0	1252	44	96.6	3.4
25	7	1233	63	95.1	4.9
25	5	1237	59	95.4	4.6
25	2	1254	42	96.8	3.2
25	0	1270	26	98.0	2.0

Summary

Results from the Geosyntec model with varying inputs for slant-well pumping rates and groundwater-level elevations in the seawater intrusion barrier wells indicated that for all pumping rates, the simulated percentage of ocean water increased with lower water-level elevations in the seawater intrusion barrier wells. Moreover, the particle tracking results indicate that more ocean water flows to the slant wells for lower water-level elevations in the seawater intrusion barrier wells. The simulated ocean-water percentage approaches or equals 90% for all slant-well pumping rates when the water-level elevations in the seawater intrusion barrier wells are close to sea level.

The model simulations demonstrate that slant well pumping will cause inland groundwater to flow towards the slant wells. The groundwater-level elevation in the seawater intrusion barrier wells influences groundwater flow towards the slant wells such that the greater the elevation in the barrier wells, the greater the percentage of inland groundwater that is captured by slant wells. Because the pumping from the slant wells would lower the groundwater elevation near the ocean and cause inland groundwater flow towards the ocean, the model results point to a lessened need for maintenance of elevated groundwater levels in the seawater intrusion barrier wells with the implementation of slant-well pumping.

Appendix A

For this end, zone budgets obtained from HF runs were classified into contributions to slant wells from the ocean, wetland, inland, and recharge, according to the following criteria:

$$Q_{ocean} = CH_{in}^{ocean} - CH_{out}^{ocean} \quad (1)$$

$$Q_{wetland} = CH_{in}^{wetland} - CH_{out}^{wetland} \quad (2)$$

$$Q_{inland} = CH_{in}^{rest} - CH_{out}^{rest} + CH_{in}^{barrier} - CH_{out}^{barrier} \quad (3)$$

$$Q_{rech} = R^{rest} + R^{ocean} + R^{wetland} + R^{barrier} \quad (4)$$

Where:

Q_{ocean}: Contribution to slant wells from ocean constant head boundaries

$Q_{wetland}$: Contribution to slant wells from wetland and lagoon constant head boundaries

Q_{inland}: Contribution to slant wells from inland constant head boundaries

Q_{rech}: Contribution to slant wells from surface recharge

CH_{in}^{ocean}: Constant head boundary flow into the model in the ocean (zone 2)

CH_{out}^{ocean}: Constant head boundary flow out of the model in the ocean (zone 2)

$CH_{in}^{wetland}$: Constant head boundary flow into the model in the wetland (zone 3)

$CH_{out}^{wetland}$: Constant head boundary flow out of the model in the wetland (zone 3)

CH_{in}^{rest}: Constant head boundary flow into the model in the rest of the domain (zone 1)

CH_{out}^{rest}: Constant head boundary flow out of the model in the rest of the domain (zone 1)

$CH_{in}^{barrier}$: Constant head boundary flow into the model in the barrier (zone 4)

$CH_{out}^{barrier}$: Constant head boundary flow out of the model in the barrier (zone 4)

R^{rest}: Surface recharge flow into the model in the rest of the domain (zone 1)

R^{ocean}: Surface recharge flow into the model in the ocean (zone 2)

$R^{wetland}$: Surface recharge flow into the model in the wetland (zone 3)

$R^{barrier}$: Surface recharge flow into the model in the barrier (zone 4)

With the aforementioned contributions, HF personnel reproduced the table given by Geoscience in the tab “tableupdated” from the workbook. Flows were converted from CFD to MGD and AFY using the following factors:

$$1\,CFD = 7.48 * 10^{-6} MGD$$

$$1\,CFD = \ 1120.14406\,MGD$$

Afterwards, HF personnel reproduced the table delivered by Geoscience in the tab “PctOceanVsBarrierElev_Chart” using Q_{inland} as “Freshwater Flow Contributed to Slant Well from Inland”.

Appendix B

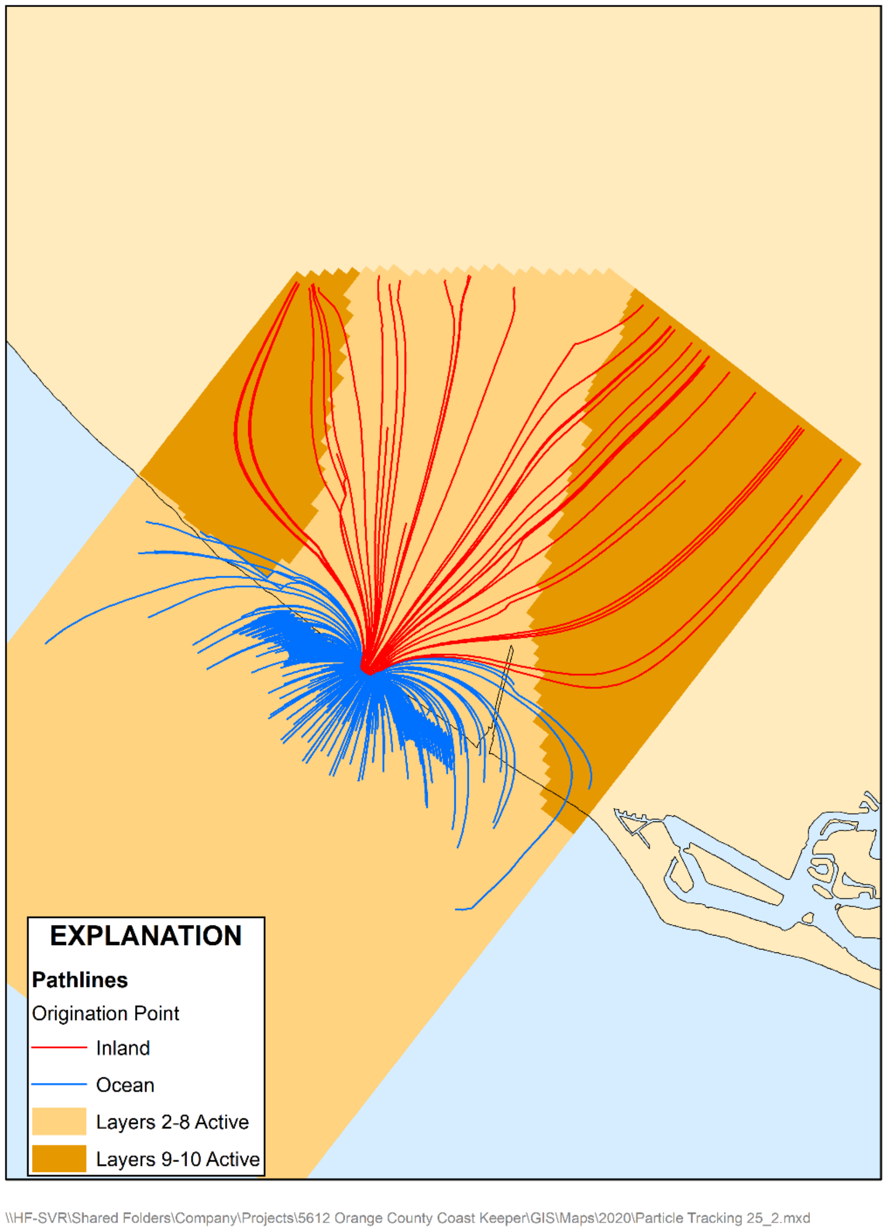
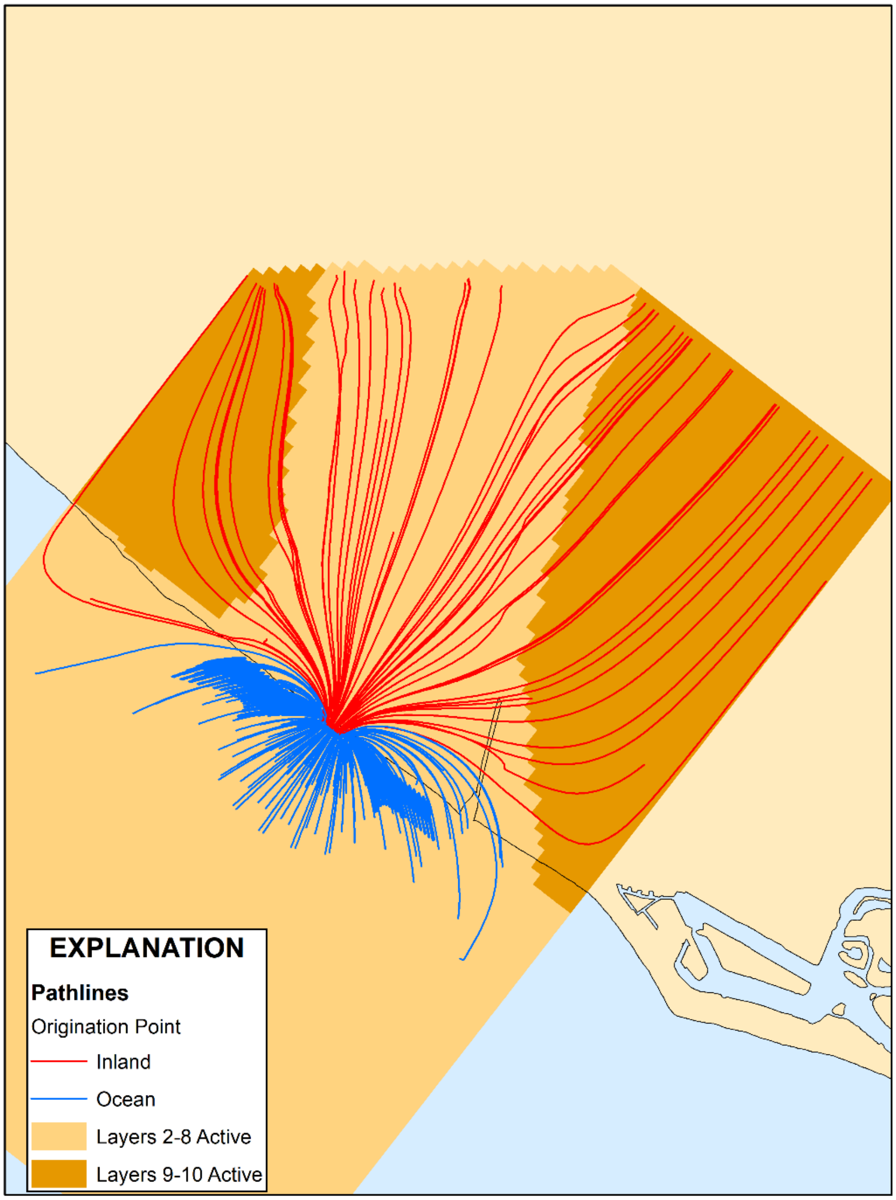


Figure B 1. Backwards particle tracking analyses for scenario 25 MGD of pumping from slant wells and 2 ft of head at saline control barrier. Blue lines represent pathlines for water parcels originated in the ocean zone, while red lines represent pathlines for water parcels originated inland.



\\HF-SVR\Shared Folders\Company\Projects\5612 Orange County Coast Keeper\GIS\Maps\2020\Particle Tracking 25_5.mxd

Figure B 2. Backwards particle tracking analyses for scenario 25 MGD of pumping from slant wells and 5 ft of head at saline control barrier. Blue lines represent pathlines for water parcels originated in the ocean zone, while red lines represent pathlines for water parcels originated inland.

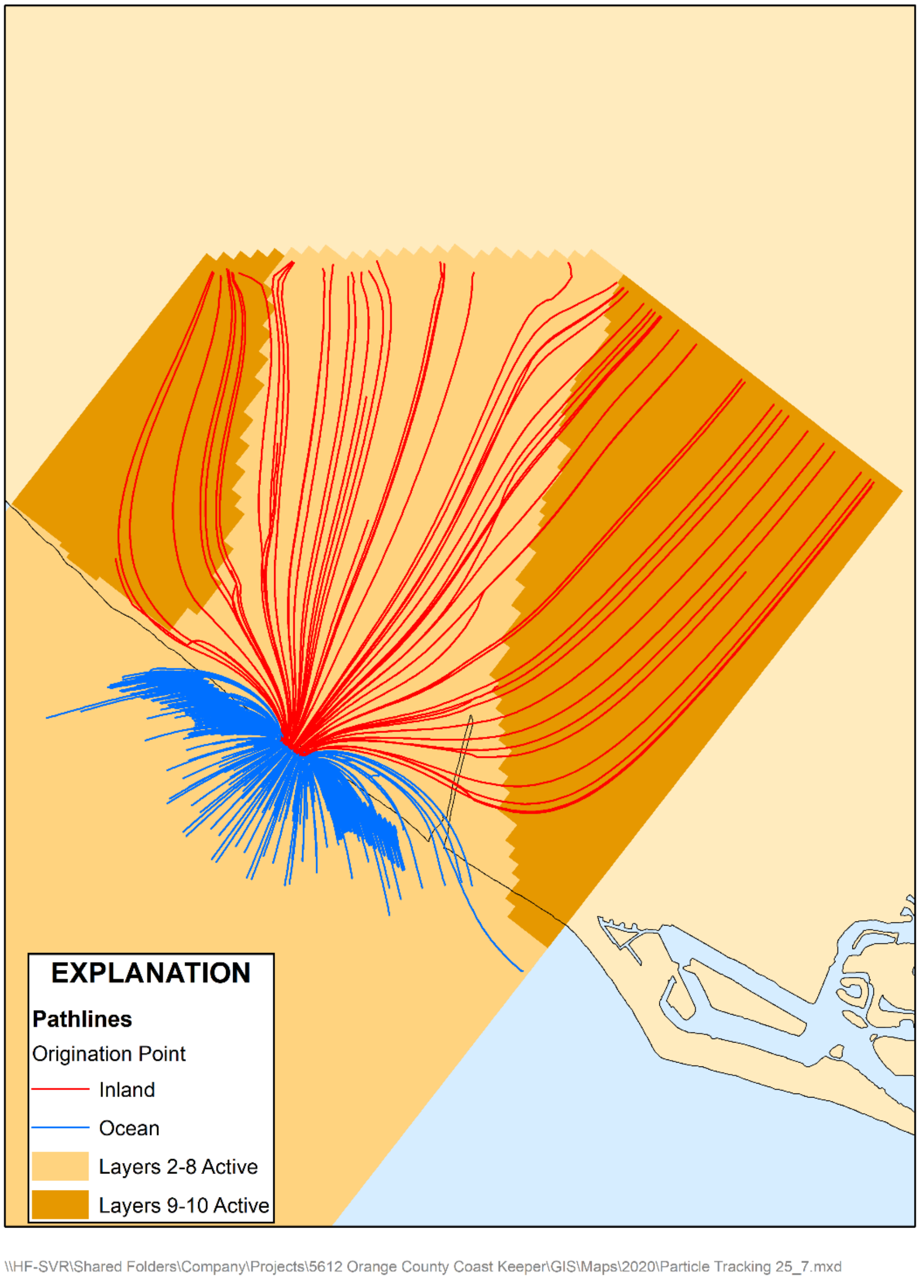
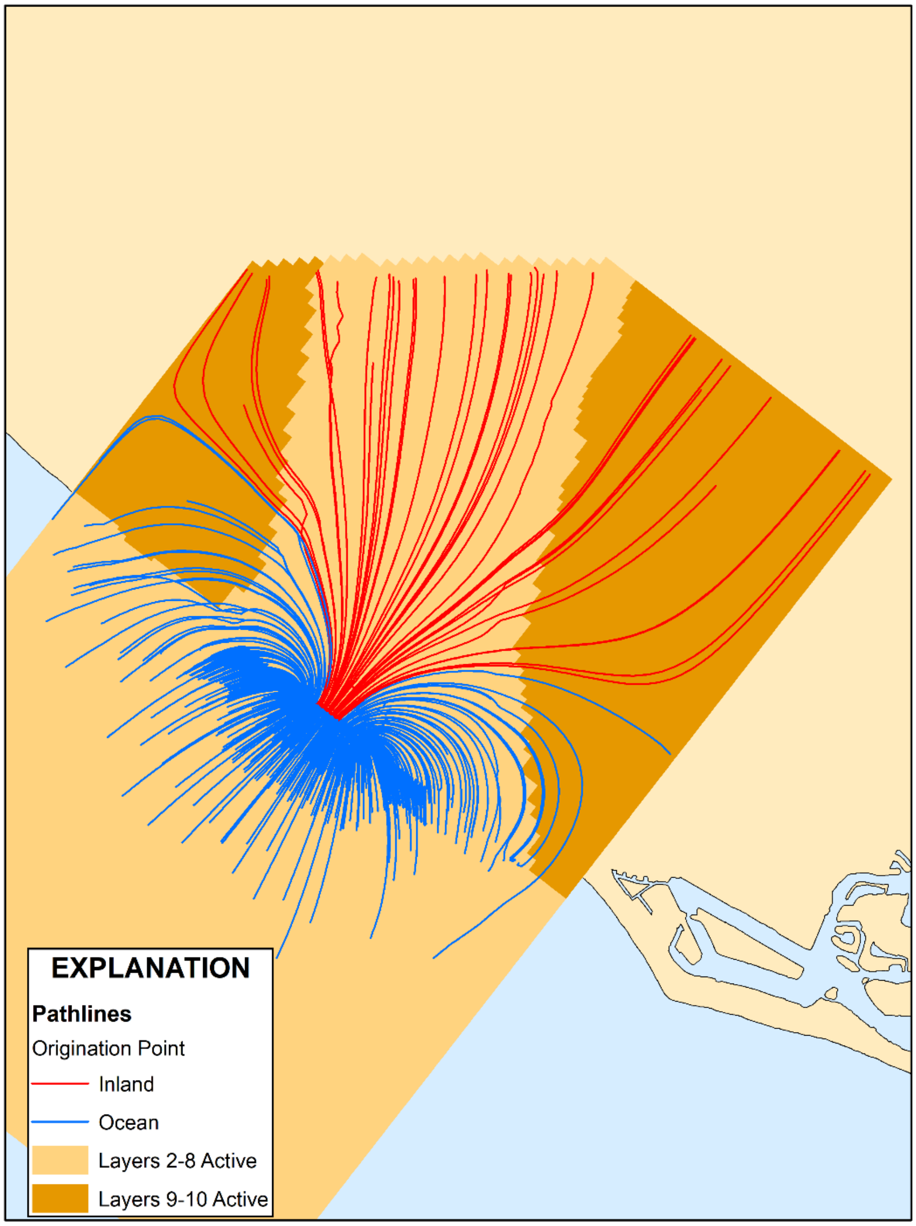
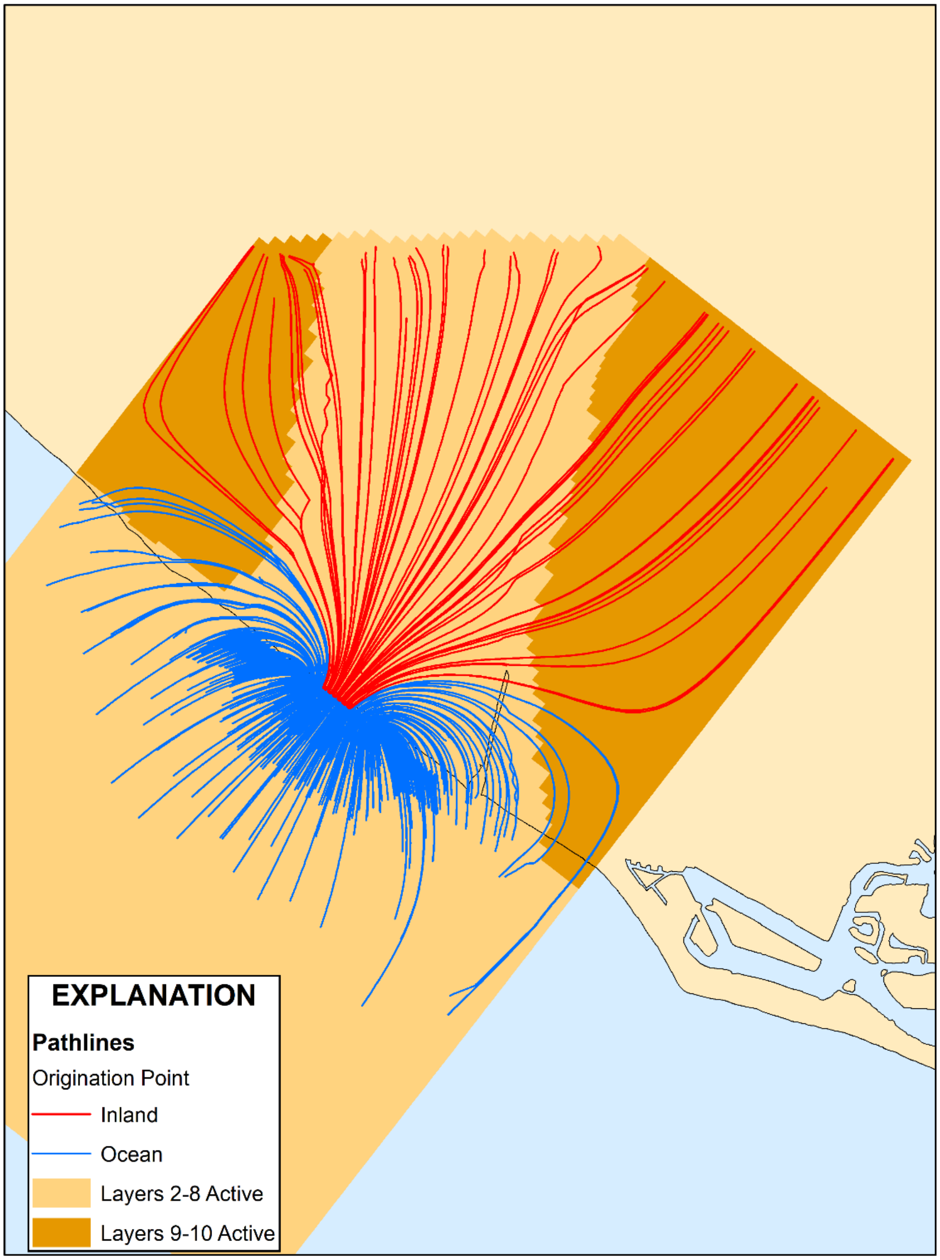


Figure B 3. Backwards particle tracking analyses for scenario 25 MGD of pumping from slant wells and 7 ft of head at saline control barrier. Blue lines represent pathlines for water parcels originated in the ocean zone, while red lines represent pathlines for water parcels originated inland.



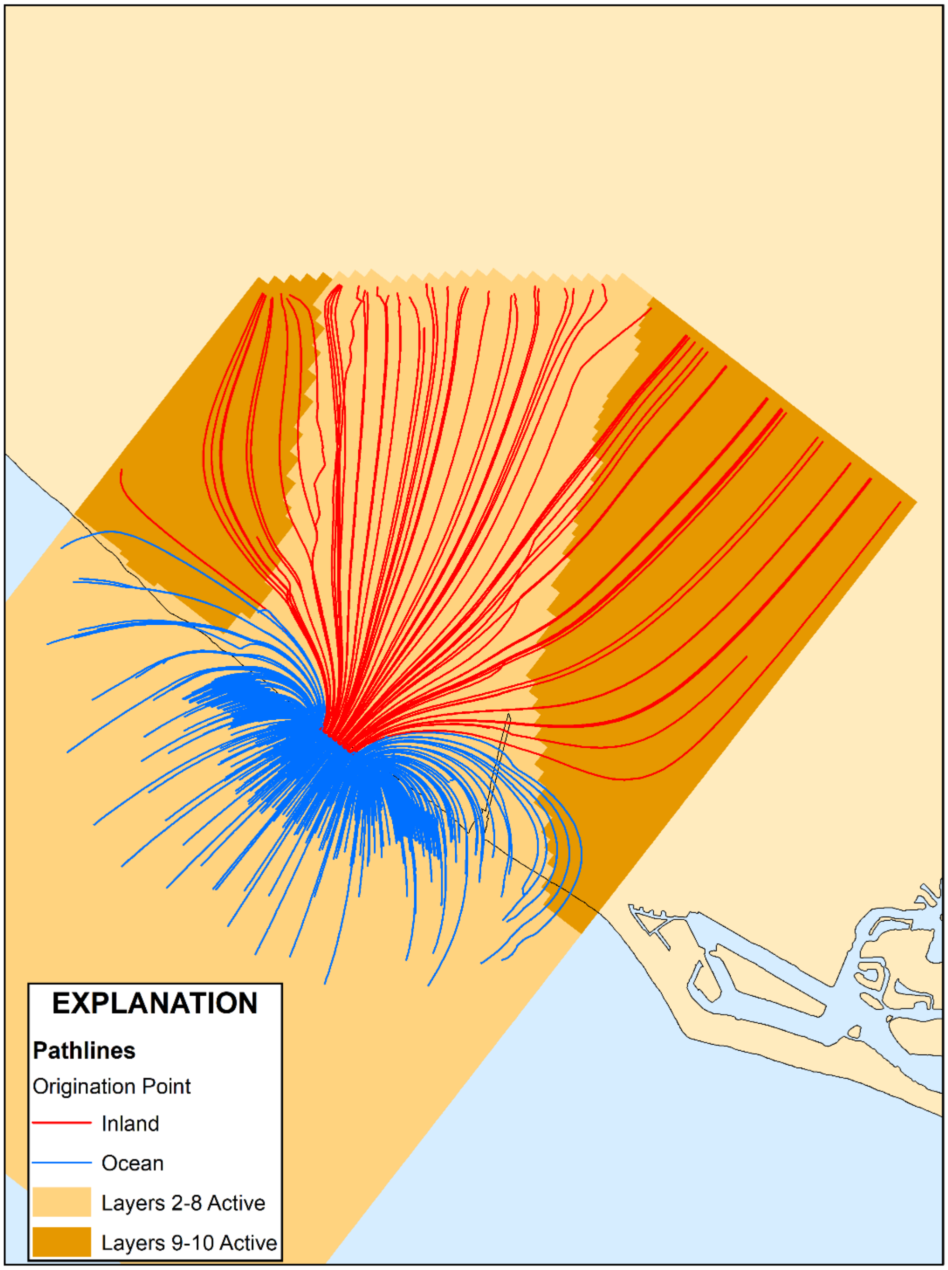
\\HF-SVR\Shared Folders\Company\Projects\5612 Orange County Coast Keeper\GIS\Maps\2020\Particle Tracking 50_0.mxd

Figure B 4. Backwards particle tracking analyses for scenario 50 MGD of pumping from slant wells and 0 ft of head at saline control barrier. Blue lines represent pathlines for water parcels originated in the ocean zone, while red lines represent pathlines for water parcels originated inland.



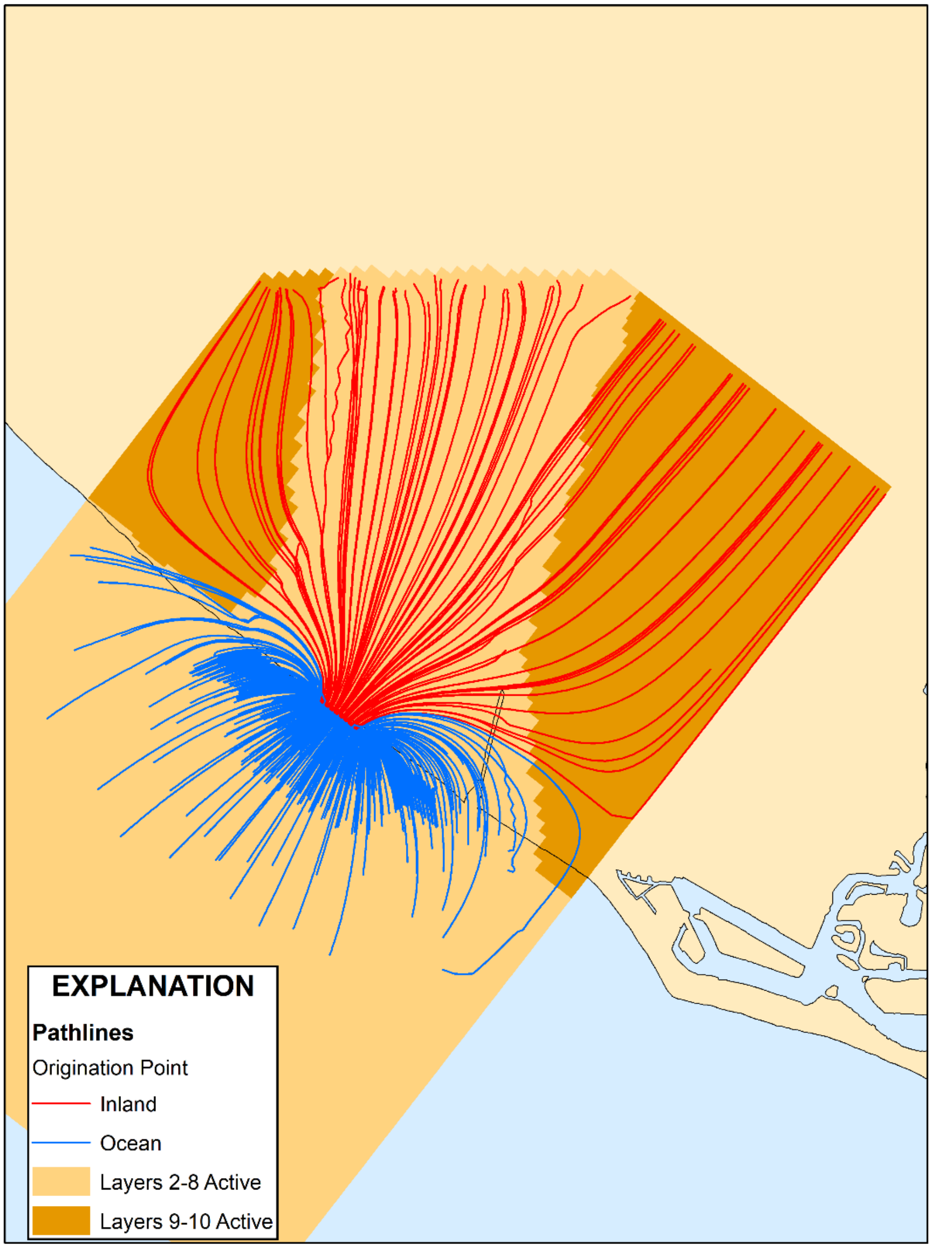
\\HF-SVR\Shared Folders\Company\Projects\5612 Orange County Coast Keeper\GIS\Maps\2020\Particle Tracking 50_2.mxd

Figure B 5. Backwards particle tracking analyses for scenario 50 MGD of pumping from slant wells and 2 ft of head at saline control barrier. Blue lines represent pathlines for water parcels originated in the ocean zone, while red lines represent pathlines for water parcels originated inland.



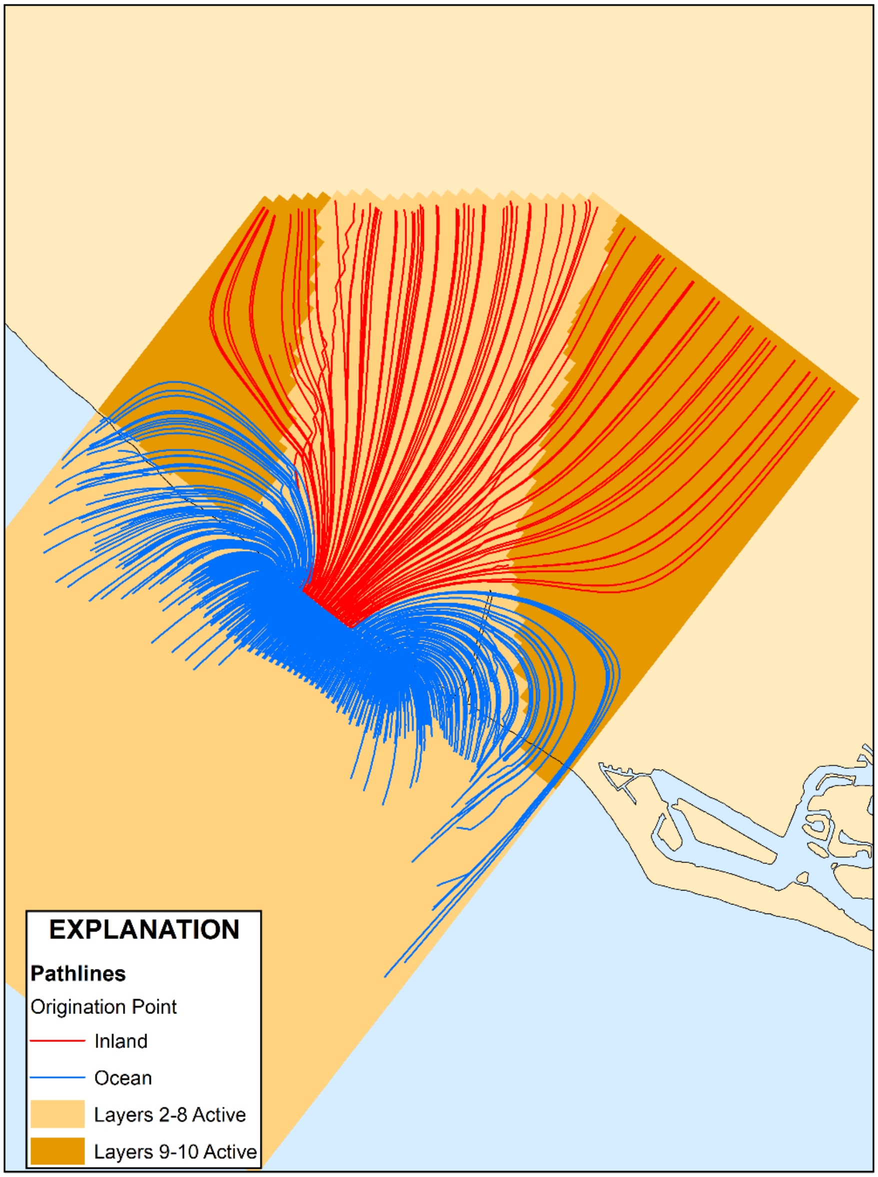
\\HF-SVR\Shared Folders\Company\Projects\5612 Orange County Coast Keeper\GIS\Maps\2020\Particle Tracking 50_5.mxd

Figure B 6. Backwards particle tracking analyses for scenario 50 MGD of pumping from slant wells and 5 ft of head at saline control barrier. Blue lines represent pathlines for water parcels originated in the ocean zone, while red lines represent pathlines for water parcels originated inland.



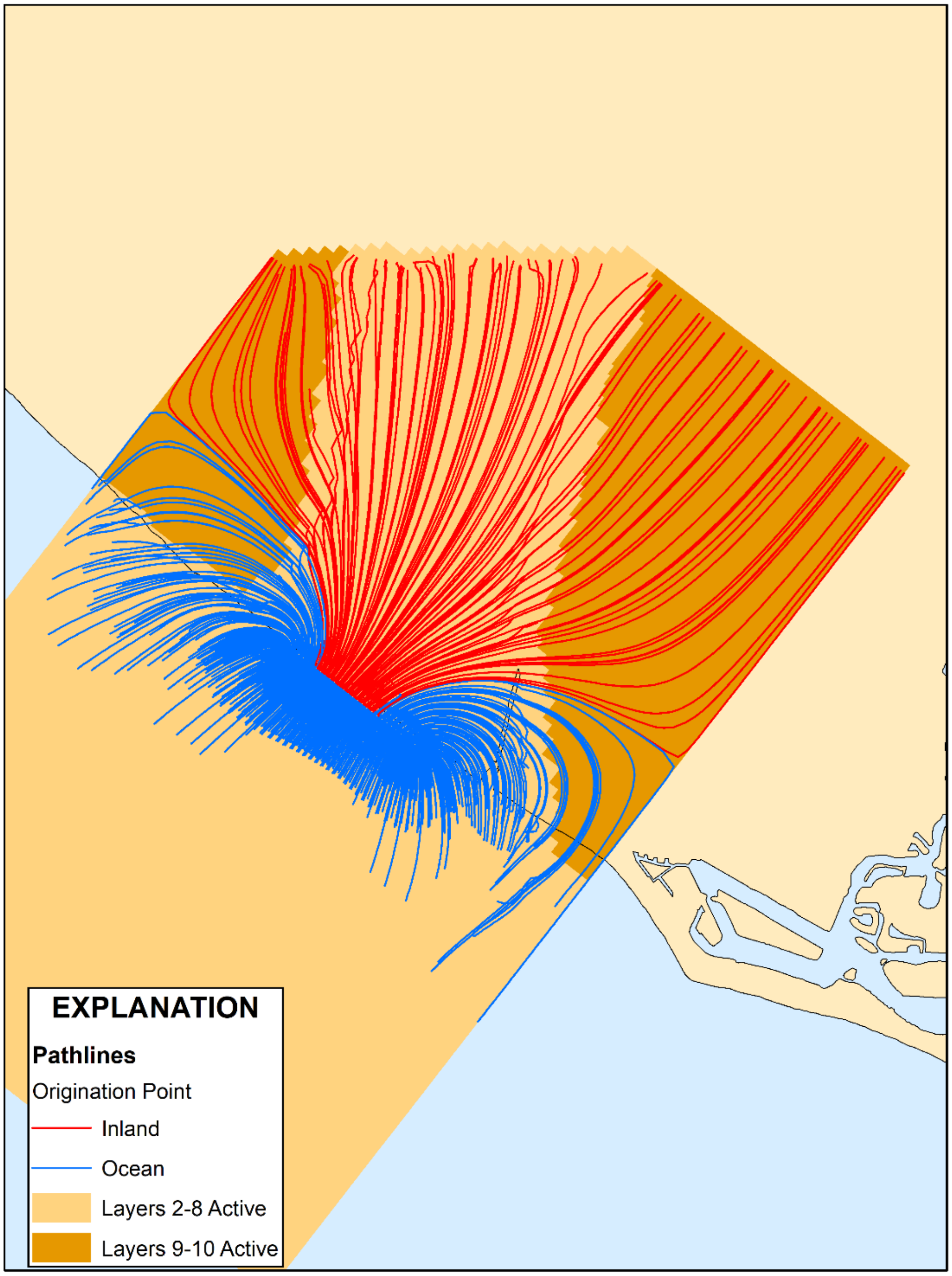
\\HF-SVR\Shared Folders\Company\Projects\5612 Orange County Coast Keeper\GIS\Maps\2020\Particle Tracking 50_7.mxd

Figure B 7. Backwards particle tracking analyses for scenario 50 MGD of pumping from slant wells and 7 ft of head at saline control barrier. Blue lines represent pathlines for water parcels originated in the ocean zone, while red lines represent pathlines for water parcels originated inland.



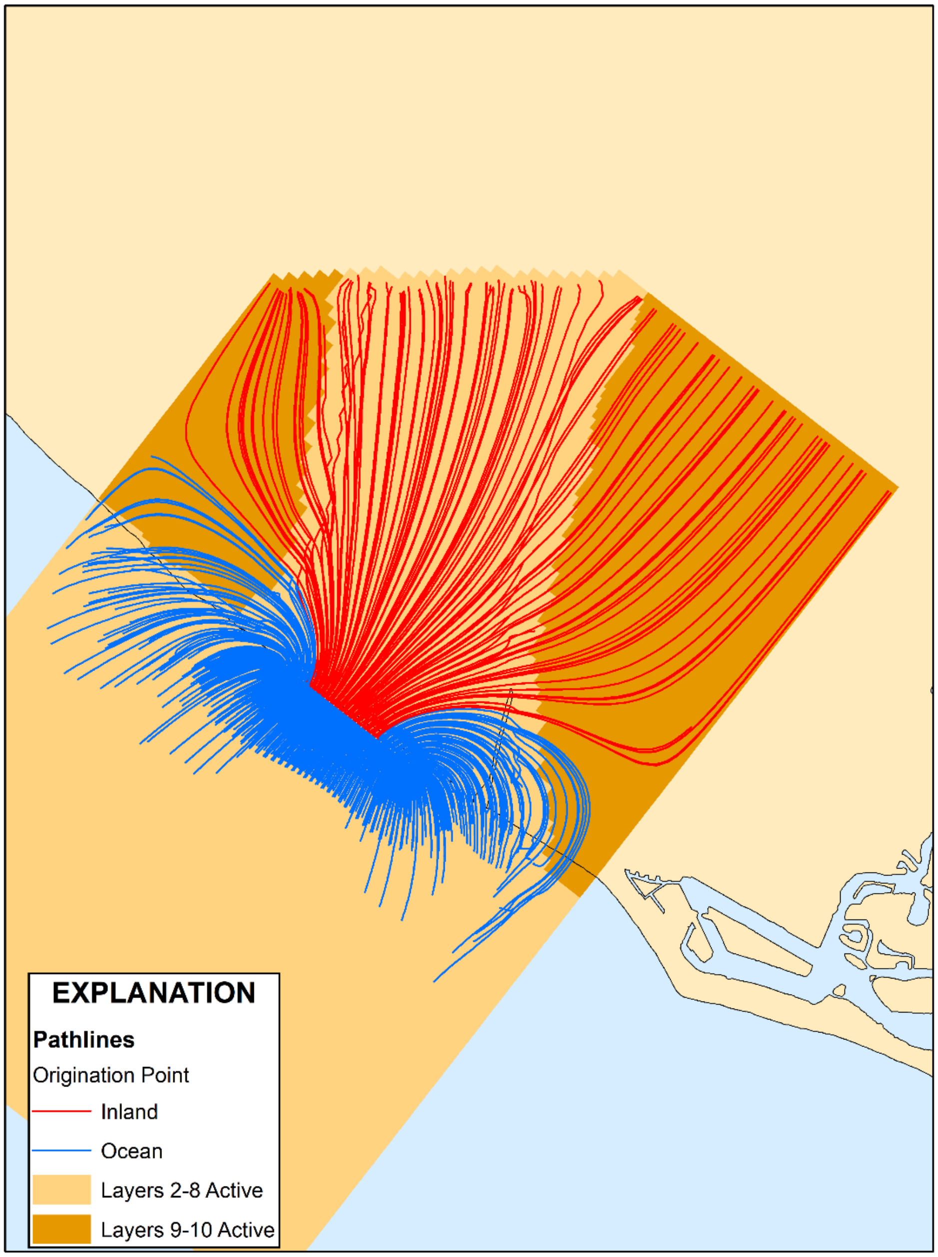
\\HF-SVR\Shared Folders\Company\Projects\5612 Orange County Coast Keeper\GIS\Maps\2020\Particle Tracking 100_0.mxd

Figure B 8. Backwards particle tracking analyses for scenario 100 MGD of pumping from slant wells and 0 ft of head at saline control barrier. Blue lines represent pathlines for water parcels originated in the ocean zone, while red lines represent pathlines for water parcels originated inland.



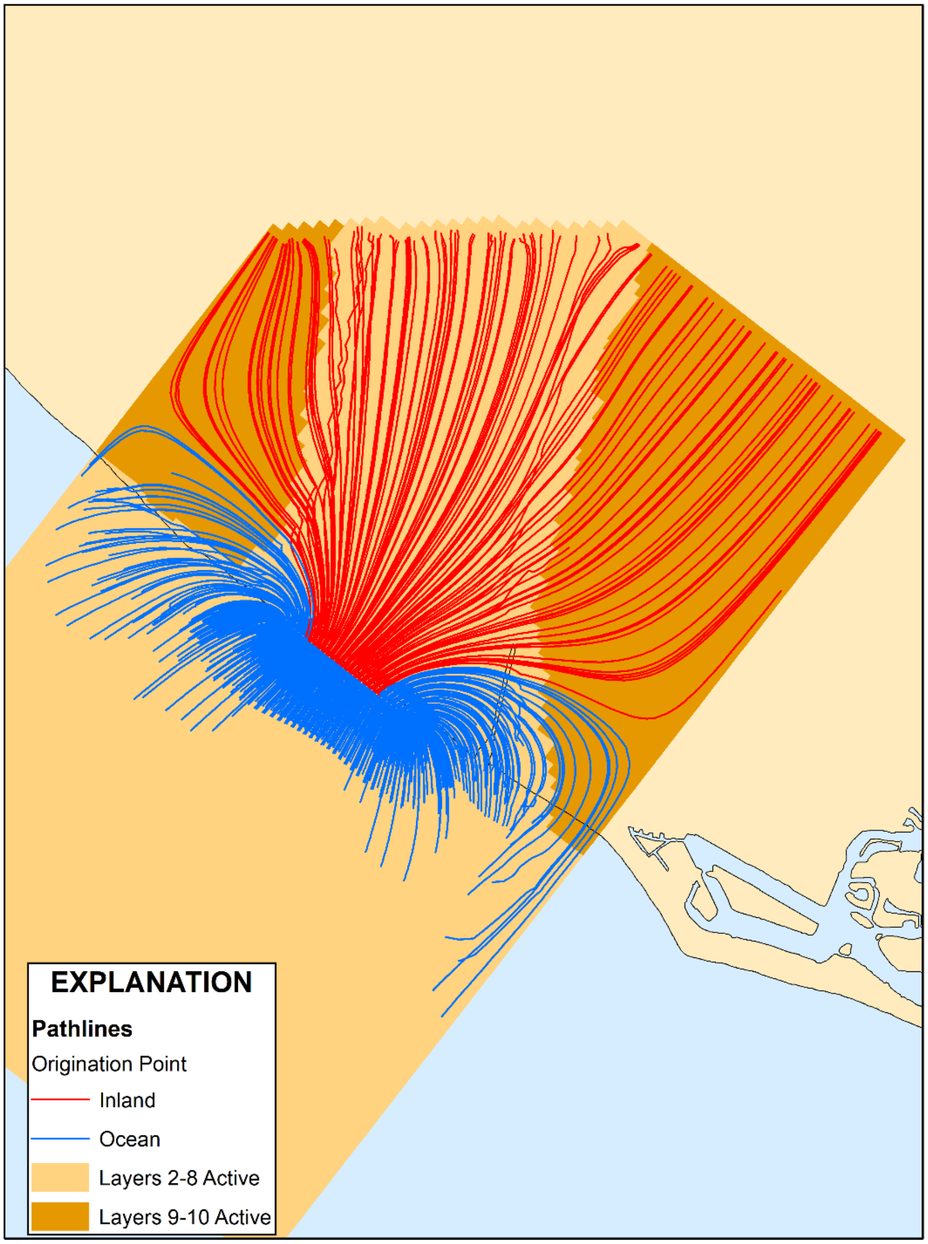
\\HF-SVR\Shared Folders\Company\Projects\5612 Orange County Coast Keeper\GIS\Maps\2020\Particle Tracking 100_2.mxd

Figure B 9. Backwards particle tracking analyses for scenario 100 MGD of pumping from slant wells and 2 ft of head at saline control barrier. Blue lines represent pathlines for water parcels originated in the ocean zone, while red lines represent pathlines for water parcels originated inland.



\\HF-SVR\Shared Folders\Company\Projects\5612 Orange County Coast Keeper\GIS\Maps\2020\Particle Tracking 100_5.mxd

Figure B 10. Backwards particle tracking analyses for scenario 100 MGD of pumping from slant wells and 5 ft of head at saline control barrier. Blue lines represent pathlines for water parcels originated in the ocean zone, while red lines represent pathlines for water parcels originated inland.



\\HF-SVR\Shared Folders\Company\Projects\5612 Orange County Coast Keeper\GIS\Maps\2020\Particle Tracking 100_7.mxd

Figure B 11. Backwards particle tracking analyses for scenario 100 MGD of pumping from slant wells and 7 ft of head at saline control barrier. Blue lines represent pathlines for water parcels originated in the ocean zone, while red lines represent pathlines for water parcels originated inland.