Appendix L

Streambed Percolation Analysis

Technical Memorandum

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Date:	January 19, 2021	
Subject:	**Pismo Beach Phase 1B EIR Support – Streambed Percolation Analysis**	

1.0 INTRODUCTION

Central Coast Blue (CCB) is a regional recycled water project that will reduce the risk of seawater intrusion and improve water supply sustainability in northwestern Santa Maria River Valley Groundwater Basin (Basin). The project will use advanced-treated recycled water from the City of Pismo Beach and the South San Luis Obispo County Sanitation District (SSLOCSD) Wastewater Treatment Plants (WWTPs) as an injection water source. This water will be injected in the Arroyo Grande-Tri-Cities Mesa portion of the Basin to establish a seawater intrusion barrier and improve the reliability of groundwater supplies in the region.

As part of the Phase 1B Hydrogeologic Evaluation, GEOSCIENCE Support Services, Inc. (GEOSCIENCE) was tasked with expanding the previous Regional Groundwater Sustainability Project (RGSP) Phase 1A Model to include an evaluation of injection and extraction scenarios with flows from the SSLOCSD and City of Pismo Beach WWTPs. This evaluation was included in the draft Environmental Impact Report (EIR), summarizing the proposed project's potential environmental impacts. Comments received on the draft EIR included questions from the California State Parks about potential impacts of CCB on streambed percolation. This technical memorandum (TM) was developed in response to these questions.

2.0 PHASE 1B MODEL

The CCB Phase 1B Model was developed for the unconsolidated to semi-consolidated water-bearing sediments within the Northern Cities Management Area (NCMA), Nipomo Mesa Management Area (NMMA), and portion of the Santa Maria Valley Management Area (SMVMA) (Figure 1). SEAWAT, a block-centered, finite-difference groundwater flow code developed by the United States Geologic Survey (USGS; Guo and Langevin, 2002), represents the model code used for model development (refer to GEOSCIENCE, 2019a and 2019c for detailed model description and discussion). The main water-bearing formations are the Paso Robles Formation and the Careaga Sand, which constitute the deeper aquifer, and the dune sand, terrace deposits, and quaternary alluvium, which constitute the shallow aquifer (LSCE, 2017). The low-yield formations which underlie and generally flank the main groundwater basin are considered impermeable and are not part of the modeled groundwater flow system.

2.1 Model Calibration in the Shallow Aquifer

The method of calibration used for the Phase 1B Model was the industry standard "history matching" technique, which involves adjusting model parameters to produce the best-fit between simulated and observed groundwater system responses. During the process of calibration, model parameters are adjusted using reasonable anticipated values until model-generated water levels and concentrations match historical observations. In addition, the model was calibrated in a multi-step process involving external review of initial calibration results by the Technical Advisory Committee (TAC)[1] and implementation of revisions to the model as part of subsequent calibration efforts.

The transient calibration period used for model calibration was from 1977 through 2016 using monthly stress periods. Calibration results for wells completed in the Shallow Aquifer along Arroyo Grande Creek are shown on Figure 2. Calibration in these wells shows a good correlation and model-calculated water levels reflect the general pattern and long- and short-term temporal trends in groundwater observations.

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[1] The Phase 1B Model development represented a collaborative process by which the model development and calibration was modified based on feedback from the Technical Advisory Committee (TAC). Members of the TAC included representatives of the Nipomo Mesa Management Area Technical Group (NMMA TG), GSI (representing the NCMA), and Water Systems Consulting, Inc. (WSC). Comments during the process were provided during routine progress meetings as well as in response to a series of technical memorandums (TMs) that were issued throughout the process of developing the model and running project scenarios to document the work.

2.2 Model-Calculated Streambed Percolation

2.2.1 Streamflow Routing Package

Streams are simulated in the Phase 1B Model by the Streamflow Routing Package. Surface water runoff and interflow estimated by the surface water model are routed downstream by the sequential numbering of reaches and segments. A stream reach is a section of the stream that is associated with a particular finite-difference cell. The reaches are numbered in a downstream order to represent the direction of flow. Reaches can be grouped into segments that represent lengths of the stream between connections with another stream or tributary, lake, or watershed boundary. The streambed locations modeled in the Phase 1B Model are indicated on Figure 3.

Inflows to a stream reach include user-specified inflow to the first reach of a stream segment, inflows from upstream reaches, precipitation directly onto the stream channel, surface runoff and interflow from adjacent watershed areas, and groundwater discharge to the streambed. Outflows include diversions, evaporation, downward leakage across the streambed, and stream outflow. The downward leakage or streambed percolation is calculated as a function of the hydraulic conductivity of the streambed, the wetted perimeter of the streambed, the length of the stream reach, the underlying groundwater head, the stream stage, and the streambed thickness.

In the Phase 1B Model, streambed elevation was determined from Digital Elevation Models (DEMs) for the 7.5" topographic quadrangles in the model area. DEMs consist of a sampled array of elevations for a number of ground positions at regularly spaced intervals. These digital cartographic/geographic data files are produced by the USGS as part of the National Mapping Program.

2.2.2 Mechanisms of Percolation

A stream gains or loses water depending on the relative head in the stream and in the underlying aquifer. This interchange of water between the stream and the aquifer (e.g., Dune Sand or alluvium) varies spatially and temporally, and is influenced most by changes in the height of the nearby groundwater table and by changes in the hydraulic conductivity of the streambed deposits. To explore this further, we can consider three different theoretical scenarios with different groundwater level positions. In the first case, the water table, or groundwater head, is below the bottom of the streambed and the stream loses water to the aquifer – as shown in the figure below.

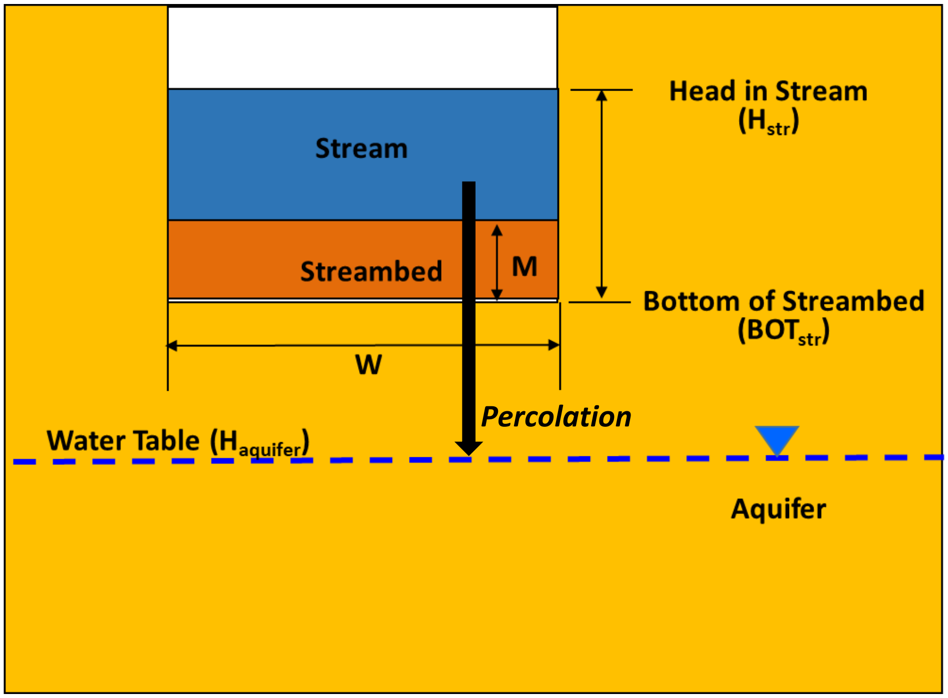


Figure A. Surface Water and Groundwater Interaction – Water Table below Bottom of Streambed

Under these conditions, streambed percolation can be described through the following equation:

When $BOT_{str} > H_{aquifer}$,

Streambed Percolation = $C_{str} (H_{str} - BOT_{str})$ Eqn. (1)

$C_{str} = K_{str} \times W \times L \times M$ Eqn. (2)

Where

BOT_{str} = Bottom of streambed,

$H_{aquifer}$ = Water table or groundwater surface,

C_{str} = Streambed conductance,

H_{str} = Head in stream,

K_{str} = Hydraulic conductivity of streambed sediments,

W = Width of streambed,

L = Length of streambed segment, and

M = Streambed sediment thickness.

As indicated by Eqn (1), the streambed percolation under these conditions (i.e., water table below the bottom of the streambed) is only a function of the streambed conductance and the stream head. Percolating water is therefore in freefall condition below the stream and the groundwater level relative to the streambed has no impact on percolation until the water table rises high enough to come in contact with the streambed. Under this second case, let us consider a water table that is positioned above the bottom of the streambed but below the head in the stream – as shown below.

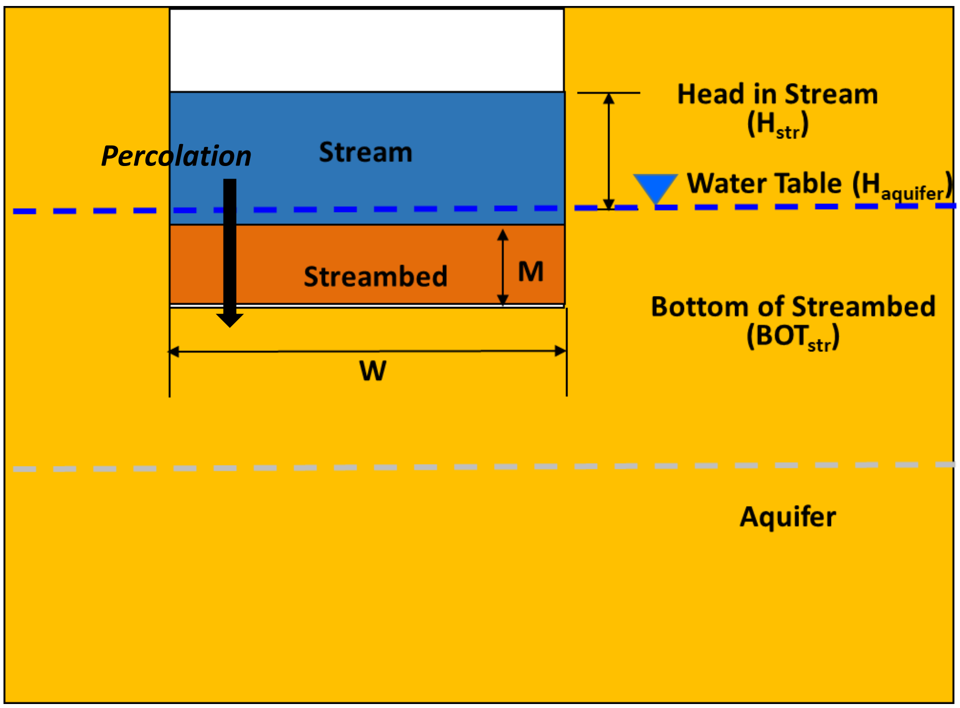


Figure B. Surface Water and Groundwater Interaction – Water Table above Bottom of Streambed but below Head in Stream

Under these conditions, the stream is still losing water to the aquifer. Streambed percolation can be described using the following equation:

When $H_{str} > H_{aquifer} > BOT_{str}$,

$$\text{Streambed Percolation} = C_{str}\,(H_{str} - H_{aquifer}) \qquad \text{Eqn. (3)}$$

Eqn. (3) indicates that under these conditions (i.e., water table that is positioned above the bottom of the streambed but below the head in the stream), streambed percolation is a function of the streambed conductance, stream head, and groundwater level elevation. Therefore, fluctuation of the groundwater surface within this range will affect how much streambed percolation occurs (the greater the difference in head, the more percolation will occur). However, if the head in the aquifer rises above the head in the stream, the stream will become a gaining stream and gain water from the aquifer. This third case is illustrated below.

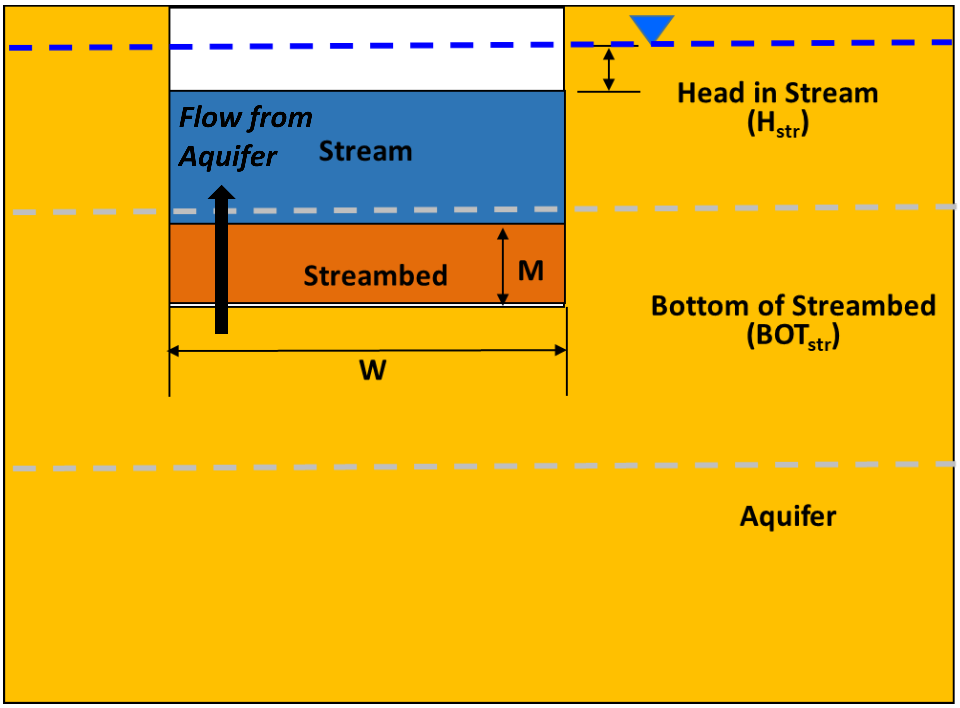


Figure C. Surface Water and Groundwater Interaction – Water Table above Head in Stream

Under these conditions, streambed percolation can be described using the following equation:

When $H_{aquifer} > H_{str}$,

$$\text{Groundwater Flow to Stream} = C_{str}\,(H_{aquifer} - H_{str}) \qquad \text{Eqn. (4)}$$

Eqn. (4) indicates that when the water table is positioned above the head in the stream, the groundwater flow from the aquifer system to the stream is a function of the streambed conductance, groundwater level elevation, and stream head. As with the previous case, fluctuation of the groundwater surface above the stream head stage will affect how much flow from the aquifer occurs (the greater the difference in head, the more gaining streamflow will occur).

2.2.3 Scenario Results

Streamflow into the model area in the Arroyo Grande and Los Berros Creek was based on USGS gaged streamflow from the Arroyo Grande at Arroyo Grande Gage (Site No. 11141500) and Los Berros Creek near Nipomo CA Gage (Site No. 11141600), respectively. Surface runoff within the model area also contributed to streamflow and was calculated based on land use type (with industrialized land use having less permeability and more potential for runoff).

The development of streambed conductivity values was conceptual and aided by previous studies. During model calibration, conductivity values were adjusted to match observed water level conditions and are within published ranges of typical conductivity values. With limited reliable streamflow data available to assess model simulation of flow and streambed percolation, the accuracy of the magnitude of model-calculated streambed percolation may be limited. However, it is reasonable and industry standard to use the model to estimate the relative changes between a baseline and scenario runs – thereby isolating potential project effects.

A baseline and six project scenarios were made with the Phase 1B model using MODFLOW groundwater flow model code. The results are presented in GEOSCIENCE (2019b). For the purpose of this discussion, only results from Scenario 2 are provided, as Scenario 2 represents the first phase of the project and was identified by State Parks as being of particular concern. Major assumptions for the Baseline scenario and Scenario 2 are summarized in the following table.

Table 2-1. Model Scenario Assumptions

Model Scenario	Hydrology	Groundwater Pumping			CCB Implementation
		Agricultural	NMMA	NCMA	
Baseline	Historical (1977-2016)	Based on 2016 Crop Distribution and Historical Rainfall	Average of Last 5 Years (2012-2016) (5,663 AFY)	Average of Last 5 Years for Municipal (1,080 AFY) and Small Purveyors	None
2	Historical (1977-2016)	Based on 2016 Crop Distribution and Historical Rainfall	Average of Last 5 Years (5,663 AFY)	Municipal Extraction of 2,500 AFY	Phase 1 (900 AFY)

For the purpose of this evaluation, streambed percolation was analyzed in two areas of the Arroyo Grande Creek: Part 1 and Part 2 (see Figure 3). The relative difference in streambed percolation between the Baseline scenario and Scenario 2 (Scenario 2 minus Baseline) is presented in attached Table 1. As shown, the proposed project is not anticipated to affect streambed percolation in Part 2 of the Arroyo Grande

Creek. Streambed conductance in this area is lower than in Part 1 (conceptually, lower stream reaches typically have greater concentrations of fine-grained sediments which reduce the ease with which water can percolate through the streambed) and water levels tend to fluctuate less closer to the coast due to the influence of the ocean (constant head). Since streambed percolation is a function of streambed conductance and head (both in the surrounding aquifer system and stream), low conductance and less change in head lead to overall lower percolation rates.

In Part 1, streambed percolation shows predicted increases in five of the 40 years included in the model simulation period. These five years reflect hydrological conditions from 1983, 1995, 1996, 1997, and 1998 – all with above average rainfall. During these wet years, water levels in the surrounding aquifer system rise, creating conditions similar to those shown in Figures 2-2 and 2-3 above. Under these conditions, groundwater elevation affects the amount of streambed percolation, and that is why slight differences are seen between baseline (no project) conditions and CCB Scenario 2 project conditions. In other years, groundwater conditions are likely similar to those shown in Figure 2-1, and the fluctuation of groundwater elevation does not affect streambed percolation. However, the predicted increased streambed percolation (leading to a corresponding reduction in streamflow) under Scenario 2 conditions is minimal – ranging from 0.2 acre-ft/yr in 1996 to 29.0 acre-ft/yr in 1998, occurring in wet years during which streamflow is higher than average conditions. Therefore, under Scenario 2 conditions, the proposed CCB project is not anticipated to significantly impact streambed percolation or surface flow in Arroyo Grande Creek.

3.0 REFERENCES

GEOSCIENCE, 2019a. City of Pismo Beach and South San Luis Obispo County Sanitation District Central Coast Blue Phase 1B Hydrogeologic Evaluation – Technical Memorandum No. 3: Model Calibration. Prepared for Water Systems Consulting, Inc. Dated May 14.

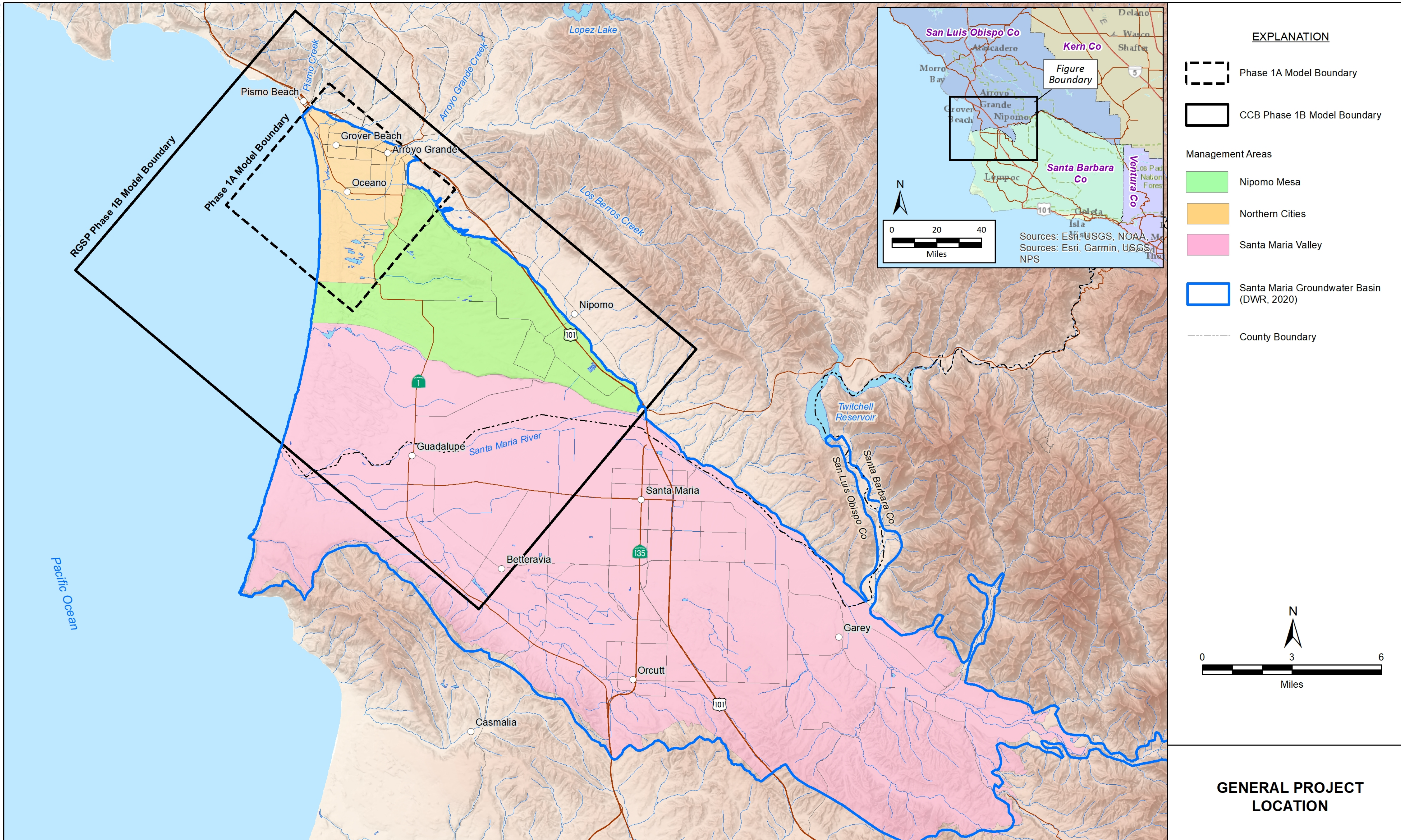
GEOSCIENCE, 2019b. City of Pismo Beach and South San Luis Obispo County Sanitation District Central Coast Blue Phase 1B Hydrogeologic Evaluation – Technical Memorandum No. 4: Model Scenario Evaluation. Prepared for Water Systems Consulting, Inc. Dated May 14.

GEOSCIENCE, 2019c. City of Pismo Beach and South San Luis Obispo County Sanitation District Central Coast Blue Phase 1B Hydrogeologic Evaluation – Executive Summary. Prepared for Water Systems Consulting, Inc. Dated November 25.

Guo, W., and C.D. Langevin, 2002. User's Guide to SEAWAT: A Computer Program for Simulation of Three-Dimensional Variable-Density Ground-Water Flow. U.S. Geological Survey Techniques of Water-Resources Investigations 6-A7.

LSCE (Luhdorff & Scalmanini Consulting Engineers), 2017. 2016 Annual Report of Hydrogeologic Conditions, Water Requirements, Supplies and Disposition – Santa Maria Valley Management Area. Dated April.

FIGURES



GENERAL PROJECT LOCATION

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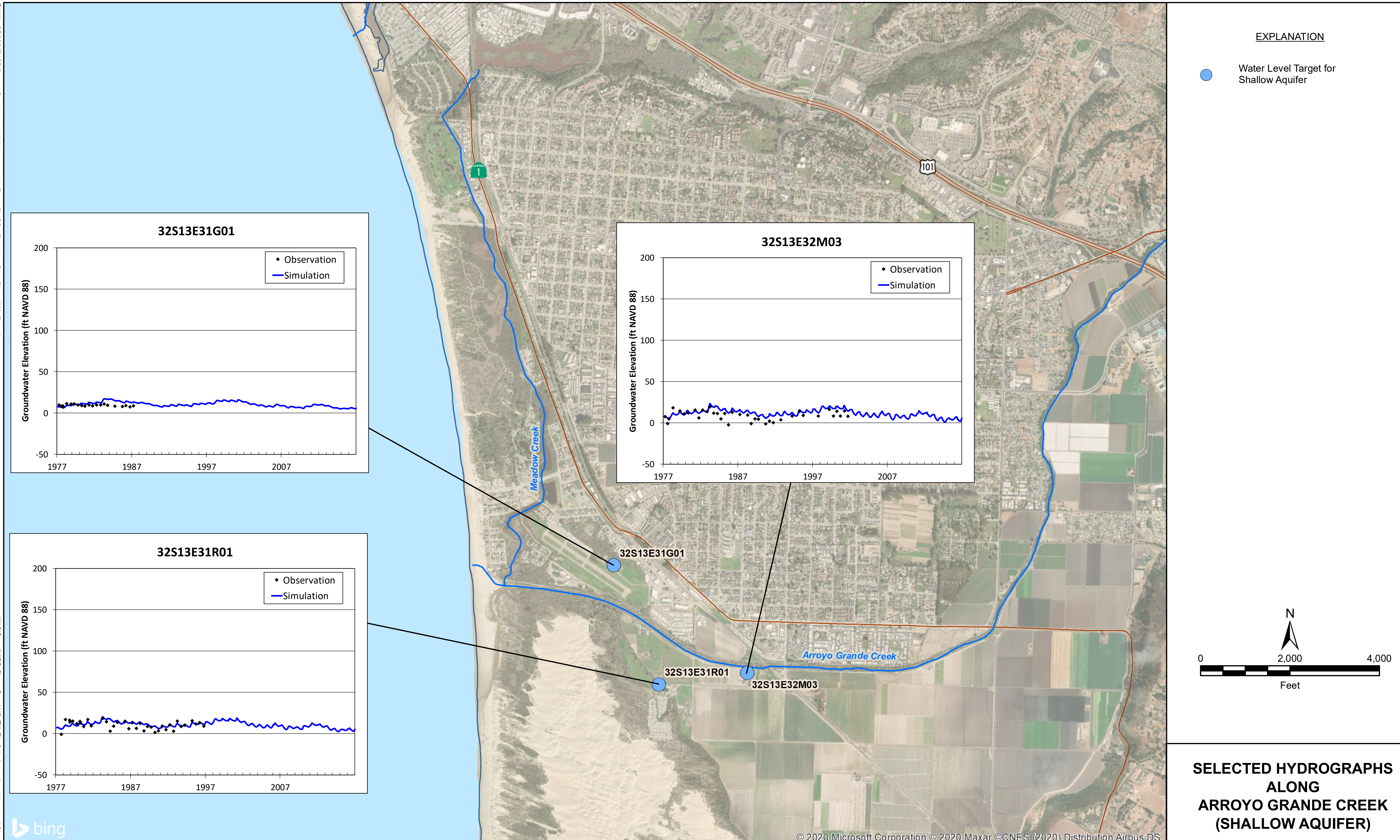
Jan-21

WATER SYSTEMS CONSULTING, INC.

PISMO BEACH PHASE 1B EIR SUPPORT – STREAMBED PERCOLATION ANALYSIS

FIGURE 1

GEOSCIENCE



SELECTED HYDROGRAPHS ALONG ARROYO GRANDE CREEK (SHALLOW AQUIFER)

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FIGURE 2

PISMO BEACH PHASE 1B EIR SUPPORT – STREAMBED PERCOLATION ANALYSIS

GEOSCIENCE

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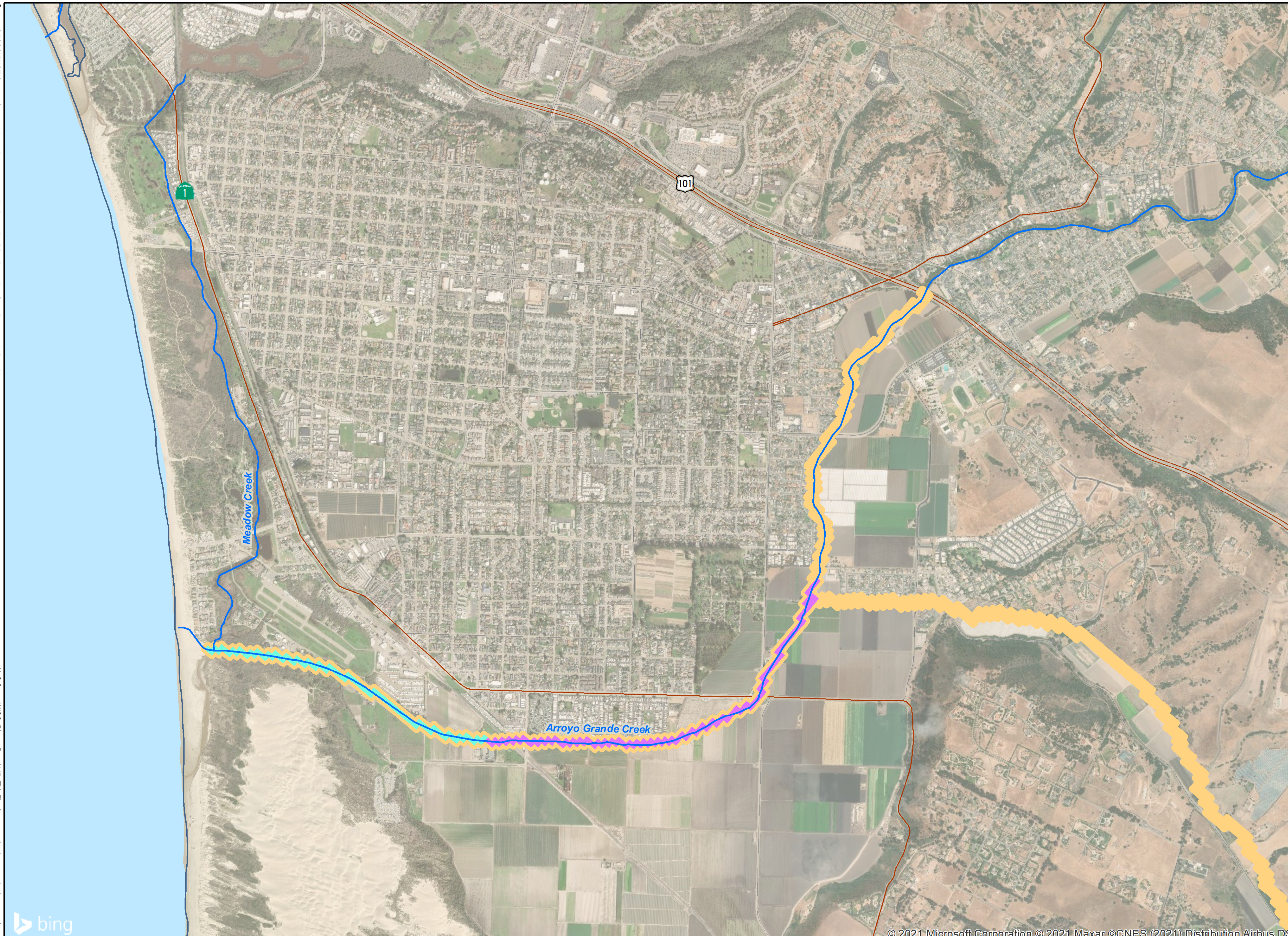

EXPLANATION

Model Cells Used to Simulate Streambed Percolation

Selected Model Cells Used for Streambed Percolation Analysis

Part 1

Part 2

N

0 2,000 4,000

Feet

LOCATION OF STREAMBED PERCOLATION

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FIGURE 3

PISMO BEACH PHASE 1B EIR SUPPORT – STREAMBED PERCOLATION ANALYSIS

GEOSCIENCE

TABLE

Streambed Percolation along Arroyo Grande Creek (1977 - 2016)

Year	Scenario 2 minus Baseline	
	Part 1	Part 2
	acre-ft/yr	acre-ft/yr
1977	0.0	0.0
1978	0.0	0.0
1979	0.0	0.0
1980	0.0	0.0
1981	0.0	0.0
1982	0.0	0.0
1983	**25.3**	0.0
1984	0.0	0.0
1985	0.0	0.0
1986	0.0	0.0
1987	0.0	0.0
1988	0.0	0.0
1989	0.0	0.0
1990	0.0	0.0
1991	0.0	0.0
1992	0.0	0.0
1993	0.0	0.0
1994	0.0	0.0
1995	**5.7**	0.0
1996	**0.2**	0.0
1997	**13.6**	0.0
1998	**29.0**	0.0
1999	0.0	0.0
2000	0.0	0.0
2001	0.0	0.0
2002	0.0	0.0
2003	0.0	0.0
2004	0.0	0.0
2005	0.0	0.0
2006	0.0	0.0
2007	0.0	0.0
2008	0.0	0.0
2009	0.0	0.0
2010	0.0	0.0
2011	0.0	0.0
2012	0.0	0.0
2013	0.0	0.0
2014	0.0	0.0
2015	0.0	0.0
2016	0.0	0.0
Average	**1.8**	**0.0**