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Paso Robles Basin Recharge Siting Feasibility Study for the Huer Huero Creek

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Prepared for:

San Luis Obispo County
Flood Control and Water Conservation District

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TODD GROUNDWATER

RMC water and environment

WOODARD & CURRAN

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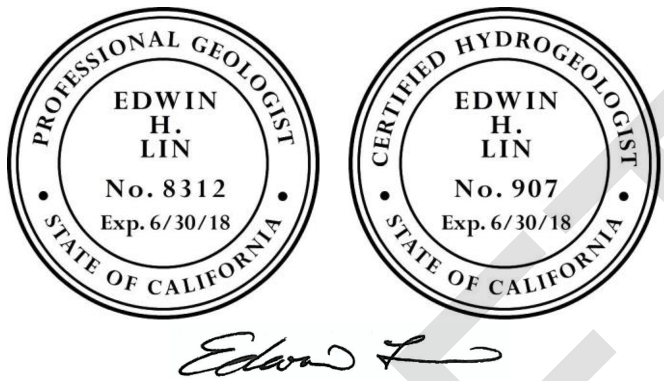

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1 INTRODUCTION

1.1 Project Background

In March 2016, the County of San Luis Obispo (County) was awarded a California Department of Water Resources (DWR) grant administered through the Proposition 1 Sustainable Groundwater Planning "Counties with Stressed Basins" Program. Grant funding has been applied by the County to complete a series of planning activities to facilitate sustainable groundwater management initiatives, including technical studies to support the development of a Groundwater Sustainability Plan (GSP) for the Paso Robles Area Subbasin (Paso Robles Basin).

As part of the SGWP Grant application, the County proposed to conduct a recharge siting feasibility study of the Huer Huero Creek watershed (Recharge Feasibility Study). The Recharge Feasibility Study is a desktop-based, screening-level evaluation designed to identify areas in the Huer Huero Creek watershed with relatively high groundwater recharge potential and to assess the feasibility of implementing recharge projects at favorable locations. Potential concepts include in-channel and off-channel modifications to increase the capture and recharge of ephemeral creek discharges and overland flows as well as more capital-intensive projects involving conveyance and recharge of supplemental water supplies.

In June 2017, the County selected Todd Groundwater (Todd), in partnership with Woodard & Curran, to complete the Recharge Feasibility Study. This report documents the results of the study, and presents key findings, knowledge gaps, and recommendations for future data collection and evaluations.

1.2 Study Area and Hydrogeologic Conditions

The Paso Robles Area Subbasin (Paso Robles Basin), DWR Basin Number 3-4.06, is located within the greater Salinas Valley Groundwater Basin. The Study Area for this evaluation includes Paso Robles Basin areas located within the Huer Huero Creek watershed (**see Figures 1 and 2**). The Huer Huero Creek watershed covers approximately 103,000 acres and includes approximately one-fifth of the Paso Robles Basin.

Huer Huero Creek is an ephemeral stream comprised of three major drainages (West, Middle, and East Forks). The creek receives additional flows from two ephemeral tributaries, Cripple Creek and Dry Creek (Figure 2). The creek's headwaters are located in the Coast Ranges, south of Creston and reach elevations of approximately 3,300 feet. Huer Huero Creek joins the Salinas River north of the City of Paso Robles. Average annual rainfall in the watershed ranges from 30 inches in the south to 12 inches in the north.

Local groundwater is used primarily for agricultural irrigation as well as municipal and rural water supply, and golf course and landscape irrigation. Historical overpumping of the Paso Robles Basin has resulted in significant groundwater levels declines across the Study Area. As shown on **Figure 2**, groundwater level declines for the 16-year period from 1997 to 2013 ranged from approximately 20 feet along the southern basin margins to greater than 70 feet in the northern portion of the Huer Huero Creek watershed.

Two major surface water pipelines – the Coastal Branch of the State Water Project (SWP) and the Nacimiento Water Project (NWP) pipeline – represent potential supplemental water supplies for the Study Area. The SWP pipeline crosses along the southern margins of the Paso Robles Basin within the Study Area, while the NWP pipeline is located west of the Huer Huero Creek watershed. Santa Margarita

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Lake (also known as the Salinas Reservoir) and recycled water from the City of Paso Robles represent potential supplemental water supplies for the Study Area. New infrastructure (e.g., pipelines and spreading basins) would be needed to convey supplemental water supply sources to favorable recharge locations in the Huer Huero Creek watershed.

1.3 Scope of Work

The primary objectives of the Recharge Feasibility Study are to identify favorable areas for groundwater recharge and evaluate the feasibility of implementing recharge projects to mitigate historical local and basin-wide groundwater level declines.

The Recharge Feasibility Study includes three major components: (1) compilation of pertinent hydrogeologic and land use spatial datasets in a project geodatabase, (2) development of a GIS-based approach to map relative groundwater recharge potential across the study area, and (3) prioritization of high-value managed aquifer recharge opportunities based on the evaluation of conceptual project benefits and implementation potential.

The scope of work for the Recharge Feasibility Study was divided into the following four tasks:

- Acquire hydrogeologic and land use spatial datasets pertinent to groundwater recharge and create a GIS database for Paso Robles Basin areas within the Huer Huero Creek watershed
- Perform a screening-level analysis of key hydrogeologic factors and map groundwater recharge potential across the Study Area.
- Develop conceptual recharge projects and assess project implementation costs and schedule considering potential groundwater storage benefits. Integrate local stakeholders and incorporate public feedback in project concepts.
- Document study findings, knowledge gaps, and recommendations for additional data collection and technical evaluations in draft and final project reports.

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2 RECHARGE POTENTIAL MAPPING

The feasibility of implementing a groundwater recharge project is dependent on a combination of hydrogeologic and operational factors. These include (1) the lithology and permeability properties of vadose zone and saturated zone sediments, (2) groundwater occurrence and flow, (3) distance between recharge facilities and existing wells, (4) groundwater and recharge water quality, and (5) timing, location, and rates of recharge.

Surface recharge methods are applicable where the vadose zone does not have extensive fine-grained clay layers that would restrict vertical migration of recharge water to the water table. Receiving aquifers should generally be unconfined and sufficiently permeable to accommodate lateral and vertical flow of the infiltrating water away from the recharge area without forming an excessive groundwater mound that could negatively impact surface infiltration rates. Depth to water is also a consideration for the implementation of surface recharge facilities, as a shallow water table can adversely impact infiltration rates, while an exceptionally deep water table can increase vadose zone travel time of recharge water to the water table, in turn, delaying and/or muting groundwater storage benefits. In the Paso Robles Basin, the presence of fine-grained clay deposits in the saturated zone also must be considered to determine the degree to which surface recharge may benefit deeper production zone aquifers.

2.1 Mapping Approach

To support the mapping of groundwater recharge potential and pertinent land use factors across the Study Area, a project Geographical Information System (GIS) database was developed. The following key spatial datasets pertinent to delineation of recharge areas were obtained from SLO County and other public agencies and incorporated into the GIS database:

- Topography (slope)
- Soil hydraulic properties (saturated hydraulic conductivity)
- Surficial geology
- Aquifer hydraulic properties (horizontal hydraulic conductivity)
- Ground cover (paved/unpaved areas and 2016 crop coverages)
- Assessor's parcel boundaries and land use designations / agricultural crop lands
- Flood zone areas
- Surface water drainage features
- Water supply and wastewater infrastructure

Additional spatial datasets, including annual rainfall distribution and aquifer occurrence, were also evaluated and determined to be insignificant for the purpose of recharge potential mapping.

Spatial datasets were evaluated and preliminary ranking structures were developed to identify the most critical hydrogeologic factors and the optimal combination of factors to produce a well-differentiated map of recharge potential for the Study Area. Based on the evaluation of available spatial datasets, three factors were identified to be the most critical to recharge potential mapping: (1) topographic slope, (2) soil saturated hydraulic conductivity, and (3) aquifer horizontal hydraulic conductivity of the uppermost model layer from the updated Paso Robles Basin groundwater model (Geoscience, 2016). For each factor, a representative scale (from 0 to 10) was developed. Additionally, relative (percentage)

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weighting factors were selected to normalize final recharge potential values to a scale ranging from 1 (low recharge potential) to 10 (high recharge potential).

A description of each hydrogeologic factor and other land use considerations is provided below along with the final recharge potential maps.

2.2 Topographic Slope

For this study, spatial analysis tools in ArcGIS were applied to a digital elevation model of the Study Area to calculate topographic slopes. Slopes were divided into seven classes and ranked as shown below in **Table 1**. Flatter, low-percentage sloped terrain is considered to have higher recharge potential, as natural storm runoff has a better opportunity to percolate in such areas. The ability to contour land to minimize the effect of topographic slopes is considered in the overall weighting factor applied.

Table 1
Topographic Slope Recharge Ranking

% Slope	Recharge Ranking
0 – 5	10 – very high
5 – 10	8 – high
10 – 15	6 – medium high
15 – 20	4 – medium
20 – 25	3 – medium low
25 – 30	2 – low
30 - 70	1 – very low

Figure 3 shows the distribution of topographic slope and associated slope recharge ranking for the Study Area. As shown on of the figure, flatter slopes (green color) are observed along and adjacent to the main drainage pathways of Huer Huero Creek and increase both to the east and west.

It is noted that four areas with high recharge potential were identified at the completion of recharge potential mapping. These areas are identified on Figures 3 through 8 (Area 1 through Area 4 boxes) to help the reader compare the values of individual hydrogeologic factors with final recharge potential ranking values.

2.3 Soil Hydraulic Conductivity

Saturated hydraulic conductivity of surficial soils (from 0 to 5 feet below ground surface [ft-bgs]) is a good indicator of the surface infiltration potential of a recharge site. For this study, the digital soil survey for San Luis Obispo County from the U.S. Department of Agriculture (USDA) was downloaded, and soil hydraulic conductivities were divided into 6 classes and ranked as shown below in **Table 2**.

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Table 2
Soil Hydraulic Conductivity Ranking

Hydraulic Conductivity (inches/hour)	Recharge Ranking
>4	10 – very high
3 – 4	8 – high
Unknown	7 – medium high
2 – 3	6 – medium
1 – 2	4 – low
<1	2 – very low

Figure 4 shows the distribution of mean saturated hydraulic conductivity of soils across the Study Area. The coverage was developed from the USDA soil survey using the GIS-enabled Soil Data Viewer Add-In. As shown on the map, soil hydraulic conductivities greater than 4 feet per day (ft/day) (green and dark green colors) are aligned tightly along the main drainages of Huer Huero Creek. The distribution of hydraulic conductivity generally correlates with the extent of surficial geologic units (see next section for description of geology) with lower soil hydraulic conductivity zones (red color) correlating to areas underlain by older alluvium and Paso Robles Formation. It is noted that a soil ranking value of 7 was manually assigned for soils lacking hydraulic conductivity values are based on their close proximity to adjacent zones with similar soil hydraulic conductivity rankings.

2.4 Geology

2.4.1 Surficial Geology

Figure 5 shows the surficial geologic map of the Study Area. The Study Area is underlain primarily by three major geologic deposits. Quaternary (Holocene age) alluvium (green color) underlies the main drainages of Huer Huero Creek and tributaries and consists of highly permeable, unconsolidated, fine- to coarse-grained sand with gravel and pebbles. The width of Quaternary alluvial deposits generally ranges from about 500 feet to 1,000 feet with a maximum width of about 3,000 feet occurring in localized areas. The thickness of the Holocene alluvium is generally less than 30 feet in minor stream valleys in the basin (DWR, 2004). Holocene age alluvium is underlain by Quaternary older alluvium and/or Pleistocene-Tertiary age Paso Robles Formation across the Study Area.

Based on examination of available driller's logs along Huer Huero Creek within the City of Paso Robles (Todd, 2016), Quaternary older alluvium (light green color on map) is generally composed of dense, weakly consolidated sand and gravel deposits interbedded with sandy silt, clayey sand, and silty clay deposits. Older alluvial deposits are less permeable than Quaternary (Holocene-age) alluvium. The thickness of older alluvium generally ranges from less than 10 feet to greater than 100 feet.

The Paso Robles Formation (light tan color) is a non-marine deposit consisting of unconsolidated to weakly consolidated deposits of gravel, sand, silt, and clay (Hart, 1976). In addition to the recent Holocene Alluvium, the Paso Robles Formation is the major water producing unit. Based on available driller's logs in the Study Area, the thickness of the Paso Robles Formation exceeds 1,000 feet.

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The figure shows that generally more permeable Quaternary alluvial, older alluvial, and terrace deposits coincide with the major drainages and tributaries of Huer Huero Creek. Less permeable, typically semi-consolidated Quaternary/Pliocene (representing the Paso Robles Formation) underlie the surficial alluvial deposits beneath the creek and outcrop outside of the main creek drainages.

The surficial geologic map is a good basis for understanding the depositional environment and provides context for observed distribution of soil hydraulic properties across the Study Area. However, because the surficial geologic map does not capture (1) the subsurface relationship between alluvial deposits and Paso Robles Formation and (2) likely variability in aquifer hydraulic properties of the Paso Robles Formation, the surficial geology map provides limited value and was not used for final recharge potential mapping.

2.4.2 Simulated Aquifer Hydraulic Conductivity

As mentioned previously, surface recharge projects are viable where the vadose zone does not have extensive fine-grained clay layers, and target receiving aquifers are unconfined and sufficiently permeable. Recent field investigations (Todd, 2016; Fugro 2005, 2006a, and 2006b) within the City of Paso Robles indicate that sand deposits (Holocene age alluvium) underlying the main drainages of Huer Huero Creek can be relatively thin (10 feet or less) and can be underlain by fine-grained (clay) deposits that extend to depths of at least 100 ft-bgs. The degree to which percolating streamflows or imported recharge water migrates to deeper production zone aquifers depends on the hydraulic properties of underlying deposits.

For this study, simulated hydraulic conductivity values from the updated Paso Robles Basin regional groundwater flow model (Geoscience, 2016) were used to characterize the recharge potential of vadose zone (below the soil zone) and upper saturated zone sediments.

Figure 6 shows the resulting distribution of simulated aquifer hydraulic conductivity across the Study Area. Because the lateral extent of the four model layers vary across the Study Area, hydraulic conductivity values shown on the map represent those of the uppermost layer in the model. Soil hydraulic conductivities were divided into 6 classes and ranked as shown below in **Table 3**.

Table 3
Aquifer Hydraulic Conductivity Ranking

Hydraulic Conductivity (feet per day)	Recharge Ranking
>20	10 – very high
15 - 20	9 – high
10 - 15	7 – medium
5 - 10	5 – moderately low
2 - 5	3 – low
0 – 2	1 – very low

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As shown on the map, higher aquifer hydraulic conductivity values in flow model were simulated in the southern portion of the Study Area. Notwithstanding the high conductivities associated with Model Layer 1 at the very northern tip of Huer Huero Creek, generally lower hydraulic conductivities are shown in the northern half of the Study Area. The lower conductivity values in the north are in agreement with findings from subsurface investigations completed along Huer Huero Creek within the City of Paso Robles limits, which revealed relatively thick clay-rich sediments underlying the alluvial sand and gravel channel deposits.

2.5 Huer Huero Creek Recharge Potential Map

A final recharge potential map was developed based on the combination of slope, soil hydraulic conductivity, and aquifer hydraulic conductivity rankings. Following general approaches used in similar studies (Aller et al., 1987; Muir and Johnson, 1979; Sesser et al., 2011), a weighting factor of 50 percent for soil conductivity, 30 percent for aquifer conductivity, and 20 percent for topographic slope was used. Topographic slope was considered to be the least important of the three factors, as it is assumed land can be modified and re-contoured to create suitable detention/recharge areas in steeper terrain.

Final recharge potential ranking was divided into nine classes and normalized to a scale of 1 (low recharge potential) to 10 (high recharge potential). **Figure 7** illustrates the distribution of recharge potential across the Study Area. As shown on the map, areas with relatively high recharge potential (green color) coincide with major drainages along Huer Huero Creek. This is expected, given the flat topography and relatively high soil hydraulic conductivity values along the creek. Areas along Huer Huero Creek with the highest recharge potential are located in the southern portion of the Study Area. This correlates with the higher aquifer hydraulic conductivity values assigned to these areas.

2.5.1 Physical Features and Flow Points

The locations of key physical features and observations of surface flows during the 2016-2017 winter along Huer Huero Creek are shown on **Figure 8**. The map shows two sites located along the southern margins of the Paso Robles Basin – Levasay's Reservoir and Iron Springs. These sites were identified by local stakeholders as potential sites for future recharge projects during a public workshop held in Paso Robles on October 11, 2017. While potentially favorable areas for enhanced recharge are not limited to these areas, they appear to be favorably located in the upgradient (southern) portion of the Study Area, where recharge water can migrate vertically and reach underlying production zone aquifers.

Also shown on **Figure 8** are key locations in Huer Huero Creek where surface water flows were observed during and following large winter storm events in 2016-17. As shown on the figure, surface flows were observed from the upgradient (southern) reaches of the creek to the northern extent of Area 2 in the central portion of the Study Area. Relatively short reaches of intermittent flow downstream of the confluences with Cripple Creek and Dry Creek were also observed. Surface flows in Huer Huero Creek did not reach the Salinas River during the 2016-2017 winter, despite the relatively wet conditions observed that year.

Observations of surface flows generally indicate that stream flows naturally infiltrate even during relatively large storm events. While infiltrating streamflows are more likely to reach lower principal (water supply) aquifers in the south (because of the higher aquifer hydraulic conductivity), significant groundwater storage benefits afforded by future projects that enhance natural recharge are likely to be realized when Huer Huero Creek flows are large enough to reach the Salinas River and exit the Study Area and the Paso Robles Basin. This is expected to occur relatively infrequently given these conditions did not occur during the relatively wet 2016-2017 winter.

2.5.2 Groundwater Occurrence and Flow

Groundwater flows in a southeast-to-northwest direction across the Study Area in both the shallow alluvial aquifer and deeper Paso Robles Formation aquifer. Groundwater generally occurs under unconfined conditions in the shallow alluvial aquifer and confined conditions in deeper Paso Robles Formation aquifers.

Depth to water is a consideration for recharge potential, as a shallow water table can adversely impact infiltration rates, while an exceptionally deep water table can increase vadose zone travel time of recharge water to the water table, in turn, delaying and/or muting groundwater storage benefits.

For this evaluation, simulated Fall 2011 depth to water from the uppermost model layer of the regional Paso Robles Basin model was imported into the GIS database. While it is recognized that groundwater levels fluctuate over time, use of 2011 simulated depth to water was considered reasonable for the screening-level evaluation.

Figure 9 shows areas where the depth to water is greater than 250 feet. These areas are considered to be poor for recharge due to the long travel times needed for recharge water to migrate to the water table and the increased likelihood for recharge water to be impeded by low-permeability layers in the vadose zone. These areas also generally coincide with areas of low soil and aquifer hydraulic conductivity and steeper terrain.

2.5.3 Additional Land Use Factors

Additional land use factors were imported into the GIS database for consideration of recharge implementation potential. A description of each land use factor is provided below along with maps showing the spatial relationship of each factor to the recharge potential.

2.5.3.1 Agricultural Crop Lands

Recharge on certain agricultural crop lands is a potentially viable option, but requires cooperation with willing landowners. **Figure 10** shows the distribution of agricultural crops (vineyard vs. non-vineyard) in 2016, as delineated by the SLO County Agricultural Commissioner's Office, in relation to recharge potential rankings.

2.5.3.2 Flood Zone Areas

Areas susceptible to flooding are not likely to be developed in the future and represent areas likely to receive significant runoff during large storm events. Accordingly, flood zones represent favorable locations for future recharge projects. **Figure 11** shows the 100-year flood zone in the Study Area. As expected, the 100-year flood zone coincides with the major drainages of Huer Huero Creek and its tributaries, including areas with high recharge potential.

2.5.3.3 Septic Tanks

Potential subsurface entrainment of septic tank discharge is undesirable and should be avoided when planning future recharge projects. **Figure 11** shows the location of existing permitted septic tanks field. The selection of preferred recharge project sites should consider the project's proximity to existing septic tanks.

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2.6 Target Recharge Areas

Four areas with high recharge potential (Areas 1 through 4) were identified to focus the development of potential recharge projects. Zoomed-in maps (**Figures 13 through 16**) were developed to facilitate discussion of project concepts at the public workshop held on October 11, 2017 with local stakeholders. The maps depict the distribution of recharge potential and pertinent land use factors (e.g., crop coverages, septic tanks, and pipelines). Discussion of conceptual recharge project concepts is presented in the following section.

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3 CONCEPTUAL RECHARGE PROJECT DEVELOPMENT

This section presents the assessment of conceptual recharge projects in the Huer Huero Creek watershed, including a preliminary evaluation of project cost and implementation feasibility.

3.1 Recharge Concepts

Two general categories of recharge water supplies were considered: (1) stream and overland flow and (2) supplemental supplies. Additionally, two general recharge locations were considered: (1) in-channel and (2) off-channel. Each water supply and recharge location presents different opportunities and constraints, as summarized in **Table 4** and discussed in further detail below.

Table 4
Recharge Concept Matrix

	Enhanced Natural Recharge (Surface and Overland Flow)	Supplemental Water Recharge
In-Channel Recharge	Centralized detention and recharge of large creek flows	Centralized recharge of supplemental water
Off-Channel Recharge	De-centralized recharge of overland flow via swales and land re-contouring	Centralized recharge in off-channel recharge basins
Limitations/ Constraints	Significant storage benefits realized only during large storm events when surface flows would exit the Basin	High costs to convey supplemental water; variable water availability/reliability
Regulatory/ Institutional Constraints	Permitting requirements for in-channel facilities	Water rights difficult to secure and potentially cost-prohibitive

3.1.1 Enhanced Natural Recharge

Based on long-term observations from local residents in the watershed, surface water flow in Huer Huero Creek is intermittent, and continuous flow from the creek's headwaters in the south to the Salinas River occurs infrequently. As shown on **Figure 8**, surface flows disappeared at multiple locations along the creek during the 2016-17 winter. It is likely that a portion of the streamflow continues within the alluvial aquifer (just below the channel) to the Salinas River while a portion migrates downward and recharges deeper production zones aquifers. If all of the stream flows recharge deeper production zone aquifers, then enhanced natural recharge projects would not provide any additional regional benefits for the Paso Basin; although, there may be localized benefits. If all of the stream flows discharge to the Salinas River and exit the Study Area, then enhanced natural recharge can significantly increase recharge to the Study Area. Successful operation of a recharge project will depend on local hydrogeologic conditions, which was considered in the recharge mapping (aquifer hydraulic properties), but requires confirmation through site-specific field investigations.

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As part of the County's Supplemental Supply Options Feasibility Study (Carollo, 2017), groundwater modeling of recharge through surface spreading basins adjacent to Huer Huero Creek estimated that between 80 and 97 percent of recharged water remained in the Paso Robles Basin. Based on the modeling results and actual observations of flow conditions by local residents during the wet 2016-2017 winter, it can be inferred that most of the natural flows in Huer Huero Creek typically percolates through the creek bottom and remains in the Basin. Accordingly, enhanced natural recharge has the potential to provide only slight increases in water recharging the deep basin, with storage benefits realized only during extremely wet conditions when flows reach the Salinas River and exit the Basin. While localized groundwater level benefits are likely for enhanced natural recharge projects, additional basin yield is difficult to estimate due to lack of stream gauges on the creek and variable hydrogeologic conditions beneath the creek.

Enhanced natural recharge projects could be sited directly within or adjacent to the creek channel. In-channel recharge facilities have the potential to detain and recharge significant volumes of water associated with large storms. Decentralized off-channel facilities, such as engineered swales and land re-contouring, have the potential to collectively capture a similar volume of water in the form of overland flow. Off-channel recharge facilities require cooperation from willing private landowners, but are more likely to have lower environmental permitting requirements compared to in-channel projects. While downstream water rights and environmental flows on the Salinas River must be considered if large volumes of water are captured for recharge, it is not expected to be a significant issue.

3.1.2 Supplemental Water Recharge

There are four primary supplemental supplies in the vicinity of the Huer Huero Creek watershed:

- State Water Project (SWP)
- Nacimiento Water Project (NWP)
- Recycled water (RW) from the Paso Robles WWTP
- Santa Margarita Reservoir

The County's Paso Robles Groundwater Basin Supplemental Supply Options Feasibility Study (Carollo, 2017) evaluated each of these options. Preliminary cost estimates for acquisition of the water were developed for various groundwater model simulations that assumed direct use or recharge or supplemental water in the Huer Huero Creek watershed. A brief summary of each water supply source is presented below.

3.1.2.1 State Water Project

The Central Coast Water Authority's (CCWA) Coastal Branch conveys treated SWP water across the East Fork and Middle Fork of Huer Huero Creek, as shown on **Figure 2**. The Supplemental Supply Options Study estimated a long-term average available supply of 8,860 AFY and dry-year yield of 3,970 AFY. SWP water can be acquired by purchasing from an existing SWP subcontractor or by becoming a new subcontractor. The latter approach results in purchase costs of roughly $2,500/AF. The former option should have lower costs by avoiding "buy-in" costs, which make up about $2,000/AF of the purchase cost; however, there is limited precedence for this approach. Accordingly, the costs for SWP water are assumed to be $2,500/AF for this study.

3.1.2.2 Nacimiento Water Project

The NWP pipeline conveys untreated water from Lake Nacimiento and generally follows the Salinas River (Figure 2). The pipeline is roughly 6 miles from the West Fork of the Huer Huero Creek and roughly

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9 miles from the main creek. The Supplemental Supply Options Study estimated a long-term average available supply of 7,100 AFY and dry-year yield of 4,100 AFY. NWP water can be acquired by purchasing from an existing project participant or by becoming a new project participant. The NWP is fully allocated so a new participant would have to purchase allocation from an existing participant at a purchase cost of roughly $2,000/AF. Most of this cost is associated with "buy-in" cost for debt service while roughly annual operating, maintenance, and energy costs are roughly $250/AF. NWP water can be purchased from a willing participant at an acceptable price for both parties.

3.1.2.3 Recycled water from the Paso Robles WWTP

The City of Paso Robles is currently designing a recycled water distribution system for the northeast portion of the City. The distribution system is near Huer Huero Creek within the City and its southern terminus is approximately 5 miles from the closest high potential recharge area - Area 1. The Supplemental Supply Options Study estimated a long-term average available supply and dry-year yield of 4,000 AFY. However, since the study was completed, the City has advanced plans to maximize direct use of recycled water for agricultural irrigation in the vicinity of the City and discharge to Huer Huero Creek. The City is still determining the price of recycled water; a cost of $2000/AF is assumed.

Recycled water was not considered further for this study, due to the potentially low availability and the City's plan to discharge recycled water in Huer Huero Creek near the recycled water distribution system.

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3.1.2.4 Santa Margarita Reservoir

The Supplemental Supply Options Study TM2 evaluated the potential for increased yield from Santa Margarita Reservoir. Increased yield would require increased reservoir storage from a raised dam that would require structural improvements, which are assumed to be cost prohibitive due to seismic retrofit requirements. Also, the rights for expansion would need to be granted to the project beneficiaries by the State Water Resources Control Board. The Supplemental Supply Options Study did not further evaluate this option due to the cost required to modify the dam and potential water rights issues.

3.1.2.1 Supplemental Water Summary

Table 5 summarizes the potential yield and purchase price of evaluated supplemental water supplies.

Table 5
Supplemental Water Supplies

Supplemental Water Supply	Long-Term Average Yield	Average Dry-Year Yield	Estimated Purchase Price
State Water Project	8,860 AFY	3,970 AFY	$2,500/AF
Nacimiento Project	7,100 AFY	4,100 AFY	$2,000/AF
Recycled Water	4,000 AFY(1)	4,000 AFY(1)	$2,000/AF
Salinas Dam(2)	N/A	N/A	N/A

Notes:
1. Substantially less recycled water may be available since the completion of the Supplemental Supply Options Study; the City plans to maximize use of recycled water for agricultural irrigation and Huer Huero Creek discharge.
2. The Supplemental Supply Options Study screened out Santa Margarita Reservoir expansion due to the cost required to modify the dam and potential water rights issues.

Recharge of supplemental supplies either in-channel or off-channel have similar considerations as enhanced natural recharge. In-channel facilities, such as temporary dirt berms, and off-channel facilities, such as percolation basins can be constructed to recharge similar volumes of water. Off-channel facilities require willing landowners but are able to avoid environmental permitting associated with in-channel that can be restrictive.

In addition, treated SWP water provides the opportunity for direct delivery of water to the deep basin via injection wells. However, injection wells have a higher cost with a typical well exceeding $1 million and require higher levels of maintenance.

3.2 Project Concepts

The recharge potential mapping described in Section 2 identified several areas with high recharge potential. Project concepts were developed based on these locations for enhanced natural recharge opportunities and considered the location of supplemental water infrastructure for supplemental water opportunities with the ultimate goal of enhancing groundwater recharge through management activities.

3.2.1 Concept Definition

Project concepts are defined on a conceptual level based on limited information similar to AACE International Class 5 Estimate[1]. Project concept definitions include water sources, facilities, yield, and assumptions. Project concepts are characterized by size and capacity of the recharge area; preliminary cost estimate; preliminary timeframe to complete; and relative environmental impacts and permitting requirements. Advantages and disadvantages for each recharge option are presented at the end of this section.

3.2.2 Enhanced Natural Recharge

Enhanced natural recharge provides an opportunity to capture overland or surface flows that would otherwise travel to the Salinas River and potential out of basin. The source water for enhanced natural recharge project concepts is natural overland or surface water flows. As noted above, potential yield from enhanced natural recharge is difficult to estimate due to lack of stream gauges on the creek, complex hydrogeology below the creek, and indication that most natural Huer Huero Creek flows remain in the Paso Robles Basin. Therefore, enhanced natural recharge has the potential to provide slight increases in water recharging the deep basin, primarily during extremely wet conditions when flows are more likely to reach the Salinas River.

Three project concepts were identified for enhanced natural recharge:

- In-Channel Recharge Area
- In-Channel Diversion to Off-Channel Recharge Basin
- Decentralized Off-Channel Recharge Practices

A summary of the advantages and disadvantages of each concept is provided in **Table 6** with additional discussion below.

[1] https://web.aacei.org/docs/default-source/rps/10s-90.pdf?sfvrsn=18

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Table 6
Advantages and Disadvantages of
Enhanced Natural Recharge Project Concepts

Concept	Pros	Cons
In-Channel Recharge Area	Simple and inexpensive	Low net yield (new recharge water) Environmental approval and permitting risks and costs
In-Channel Diversion to Off-Channel Basin	Simple and slightly more expensive than in-channel recharge Larger recharge area available	Low net yield (new recharge water) Environmental approval and permitting risks and costs Need to acquire land
Decentralized Off-Channel Recharge	Simple and inexpensive No in-channel impacts	Low net yield (new recharge water) Extensive participation needed for notable yield

In-Channel Recharge Area consists of temporary dirt berms constructed in the creek channel to back up surface water flows and promote recharge. The recharge area is dependent on the creek cross-section and slope. Construction and operations should be low since only common machinery is needed. Facilities could be constructed fairly quickly (less than one month) once environmental approvals and permits are acquired. The environmental approvals and permits are the largest risk and potential cost for the project concepts. Multiple regulatory agencies have potential jurisdiction and the authority to halt project implementation or require extensive mitigation measures. Costs associated with environmental approvals and permits are associated with requested studies and monitoring and reporting requirements.

In-Channel Diversion to Off-Channel Recharge Basins consists of temporary dirt berms constructed in the creek channel to divert surface water flows to proximate recharge basins. The berms could be replaced with a dam structure (inflatable or flashboard dam) but high capital costs likely could not be justified with potential yields. The recharge area can be scaled based on expected surface water diversions. Land must be acquired on a seasonal or permanent basis. Construction and operations should be low since only common machinery is needed. Facilities could be constructed fairly efficiently (less than one month) once environmental approvals and permits are acquired. Similar to the in-channel recharge area concept, environmental approvals and permits are the largest risk and potential cost for the project concepts.

Decentralized Off-Channel Recharge Practices consists of minor modifications to land, such as engineered swales and land re-contouring, to individually capture smaller volumes of water than the other concepts while collectively capturing significant volumes. The recharge area is dependent on the land contours and total area is dependent on cooperation from willing landowners. Construction and operations should be low since only common machinery is needed. Facilities could be constructed fairly quickly (less than one month) once environmental approvals and permits are acquired. The environmental approvals and permits are lower risk than the in-channel recharge and diversion concepts but can still result in project restrictions and/or extensive mitigation measures. Also, approvals and permitting of each individual site could collectively result in substantial costs. Development of a

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general permit with approved activities defined could be used to streamline permitting and reduce costs.

3.2.3 Supplemental Water Recharge

Supplemental recharge water involves new water sources to the Study Area, in contrast to enhanced natural recharge where the surface water recharge source originates within the watershed. Project cost is the biggest hurdle to supplemental water recharge. Of the four primary supplemental supplies in the vicinity of the Huer Huero Creek watershed, SWP water has the lowest conveyance costs, since the South Coastal Branch pipeline crosses the East Fork and Middle Fork of Huer Huero Creek. In comparison, NWP pipeline water, Santa Margarita Reservoir water, and recycled water are between 5 and 9 miles to the nearest areas with favorable recharge potential. All of the supplemental supplies have substantial acquisition costs of up to $2,500/AF, which is cost prohibitive; although, the purchase price may be negotiable.

Once the supplemental water is near the creek, the recharge method is either in-channel recharge (natural or berms) or off-channel recharge basins. Natural in-channel recharge is preferred over in-channel berms considering the high permeability of the creek channel, demonstrated by extensive sections of dry creek even following large winter storms. In-channel recharge with no land modifications will still require environmental and general use permits. However, the hurdles will be lower than constructing berms/basin in the creek. Off-channel recharge avoids most of the environmental and permitting issues, but would require land acquisition (seasonal or permanent) for recharge basins. Overall, natural in-channel recharge (with no land modifications) is preferred, because recharge rates are high in the channel and less infrastructure is needed.

Four project concepts were identified for supplemental water recharge:

- SWP, In-Channel Recharge
- SWP, Off-Channel Recharge
- NWP, In-Channel Recharge
- NWP, Off-Channel Recharge

SWP water use requires a new turnout on the SWP pipeline and distribution pipeline to the discharge/recharge area. In-channel recharge would require a discharge structure that could be located close to the SWP pipeline such that distribution costs are minimal. In-channel recharge could occur at the East Fork or Middle Fork of the creek. Off-channel recharge requires land acquisition, recharge basins, and pipelines to the basins. An area approximately 1 mile north of the SWP pipeline along the Middle Fork was identified as a potentially favorable recharge site (Iron Springs on **Figure 15**).

NWP water use requires a new turnout off the NWP pipeline in Atascadero (near Highway 41) and 6 to 9 miles of pipeline, depending on the discharge/recharge area. Similar to SWP, in-channel recharge would require a discharge structure while off-channel Recharge requires land acquisition and recharge basins. In-channel recharge assumes a 6-mile pipeline to the upper reaches of the West Fork of the creek while a 9-mile pipeline is assumed for off-channel recharge at an area near Highway 41 and the creek.

3.2.3.1 Facilities and Preliminary Cost Estimates

Preliminary cost estimates are based on unit costs from the Supplemental Supply Options Study as follows: (1) pipelines at $3.0 million per mile; (2) turnouts at $0.5 million each; (3) recharge basins at $50,000 per acre. These costs include construction contingencies and “soft” costs, such as design, permitting, and environmental documentation. Capital costs are annualized assuming borrowing at 5

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percent interest rate for a 30-year term (annual payment = 0.0651 * capital cost). To simplify the comparison between supplemental supplies, each project is assumed to yield 4,000 AFY. This requires about 10 acres of land for recharge basins assuming a rough percolation rate of 1.0 ft/day.

A summary of estimated costs and implementation timeline are provided below in **Table 7**.

Table 7
Costs for Supplemental Water Recharge Project Concepts

Concept	Facilities	Preliminary Facilities Cost Estimate	Preliminary Purchase Price
SWP, In-Channel Recharge	Turnout Miscellaneous	Capital Cost: $1.0M Unit Cost: $20/AF	Up to $2,500/AF
SWP, Off-Channel Recharge	Turnout Pipeline (1 mile) Recharge Basins	Capital Cost: $4.0M Unit Cost: $70/AF	Up to $2,500/AF
NWP, In-Channel Recharge	Turnout Pipeline (6 miles)	Capital Cost: $18.5M Unit Cost: $310/AF	Up to $2,000/AF
NWP, Off-Channel Recharge	Turnout Pipeline (9 miles) Recharge Basins	Capital Cost: $28.0M Unit Cost: $460/AF	Up to $2,000/AF

3.2.3.2 Comparison of Supplemental Water Project Concepts

Overall, in-channel recharge is preferred over off-channel due to the lower costs as long as environmental and permitting requirements are not overly burdensome or costly. SWP has the lowest facilities cost but this is offset by the higher potential purchase price. An in-channel SWP project could be implemented, if SWP can be acquired for an acceptable price on a temporary or permanent basis. The timeline for implementation would be driven by the time needed to acquire SWP water and gain approval for a new SWP turnout.

NWP concepts have high facilities costs due to the distance to the creek but may be attractive if an acceptable purchase price can be negotiated with existing project participants. The project timeline is several years due to need to design and construct several miles of pipeline and the need to secure a long-term purchase agreement.

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4 CONCLUSIONS

Based on the mapping of groundwater recharge potential and evaluation of benefits, costs, and overall implementation feasibility of viable recharge concepts, the following conclusions can be made:

- Evaluation of spatial hydrogeologic datasets pertinent to recharge potential (including topographic slope, soil hydraulic conductivity, and aquifer hydraulic conductivity) indicates that portions of the Paso Robles Basin within the Huer Huero Creek watershed have high recharge potential.
- Areas with relatively high recharge potential generally coincide with the flat topography and high soil hydraulic conductivity values along major drainages of Huer Huero Creek. Areas with the highest recharge potential are located in the southern portion of the Study Area, where aquifer hydraulic conductivity values are highest.
- While enhanced recharge of natural storm runoff in favorable areas can provide local benefits, significant groundwater storage benefits will be realized only when Huer Huero Creek flows are large enough to reach the Salinas River and exit the Study Area and the Paso Robles Basin. This is expected to occur relatively infrequently.
- Existing land uses, including agricultural crop lands and flood zones, represent favorable sites for recharge projects and should be considered in future recharge project planning. Recharge projects should be located away from undesirable land uses, such as septic tanks, to protect groundwater quality.
- Potential natural recharge enhancement projects include direct in-channel recharge, in-channel diversion to off-channel recharge basins, and decentralized off-channel recharge practices. Environmental approvals and permits are the largest risk and potential cost for in-channel project concepts. Costs for approvals and permitting of individual decentralized off-channel projects could be reduced is a general permit of approved activities can be developed.
- With respect to supplemental water projects, an in-channel SWP project could be implemented, if SWP can be acquired for an acceptable price on a temporary or permanent basis. The timeline for implementation would be driven by the time needed to acquire SWP water and gain approval for a new SWP turnout.
- NWP concepts have high facilities costs due to the distance to the creek but may be attractive if an acceptable purchase price can be negotiated with existing project participants. The project timeline is several years due to need to design and construct several miles of pipeline and the need to secure a long-term purchase agreement.
- While a GIS-based evaluation provides an indication of site recharge potential, field verification of lithologic and hydraulic properties is essential to a reliable evaluation.

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5 RECOMMENDATIONS

This memorandum provides a screening level evaluation of recharge potential and project concepts for the Huer Huero Creek watershed. Results of recharge mapping and project concept development are based on the evaluation of existing spatial datasets for the Study Area. To more reliably quantify potential groundwater storage benefits and refine infrastructure requirements for preferred recharge projects, additional focused evaluations and field investigations are needed to confirm hydrologic and hydrogeologic conditions along Huer Huero Creek.

To support future planning, including implementation of future groundwater recharge projects, the following site-specific field investigations are recommended for preferred recharge sites:

- Perform cone penetration test soundings (CPT) and soil borings; the depth of investigation should penetrate the vadose zone and reach the water table
- Install groundwater monitoring wells to monitor groundwater levels and characterize local groundwater quality
- Conduct field-scale percolation tests to estimate the infiltration capacity of surficial soils and shallow aquifer sediments
- Simulate preferred recharge projects using the regional Paso Robles Basin groundwater flow model to evaluate the fate of recharged water and benefits to groundwater storage.

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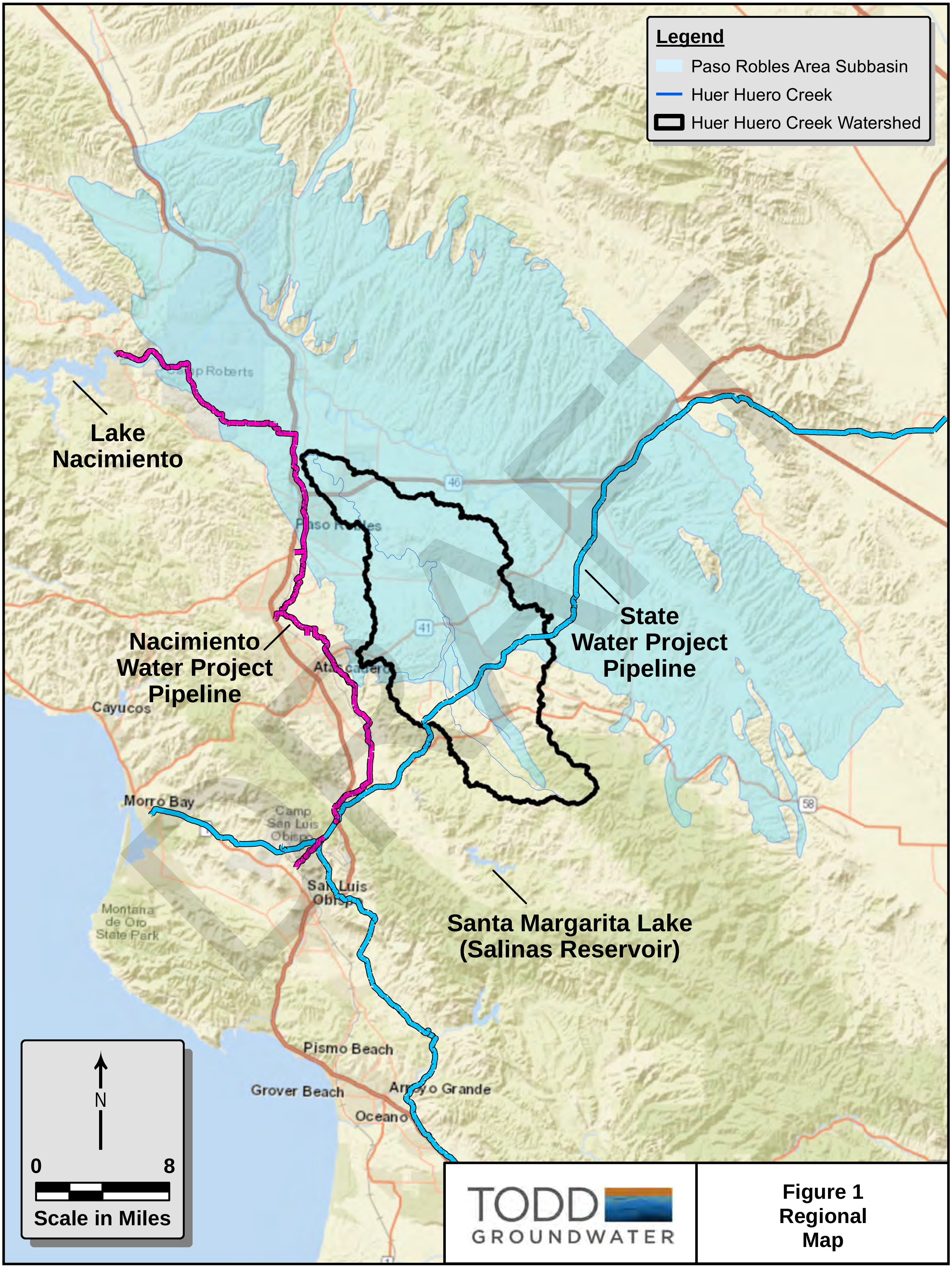


Figure 1
Regional Map

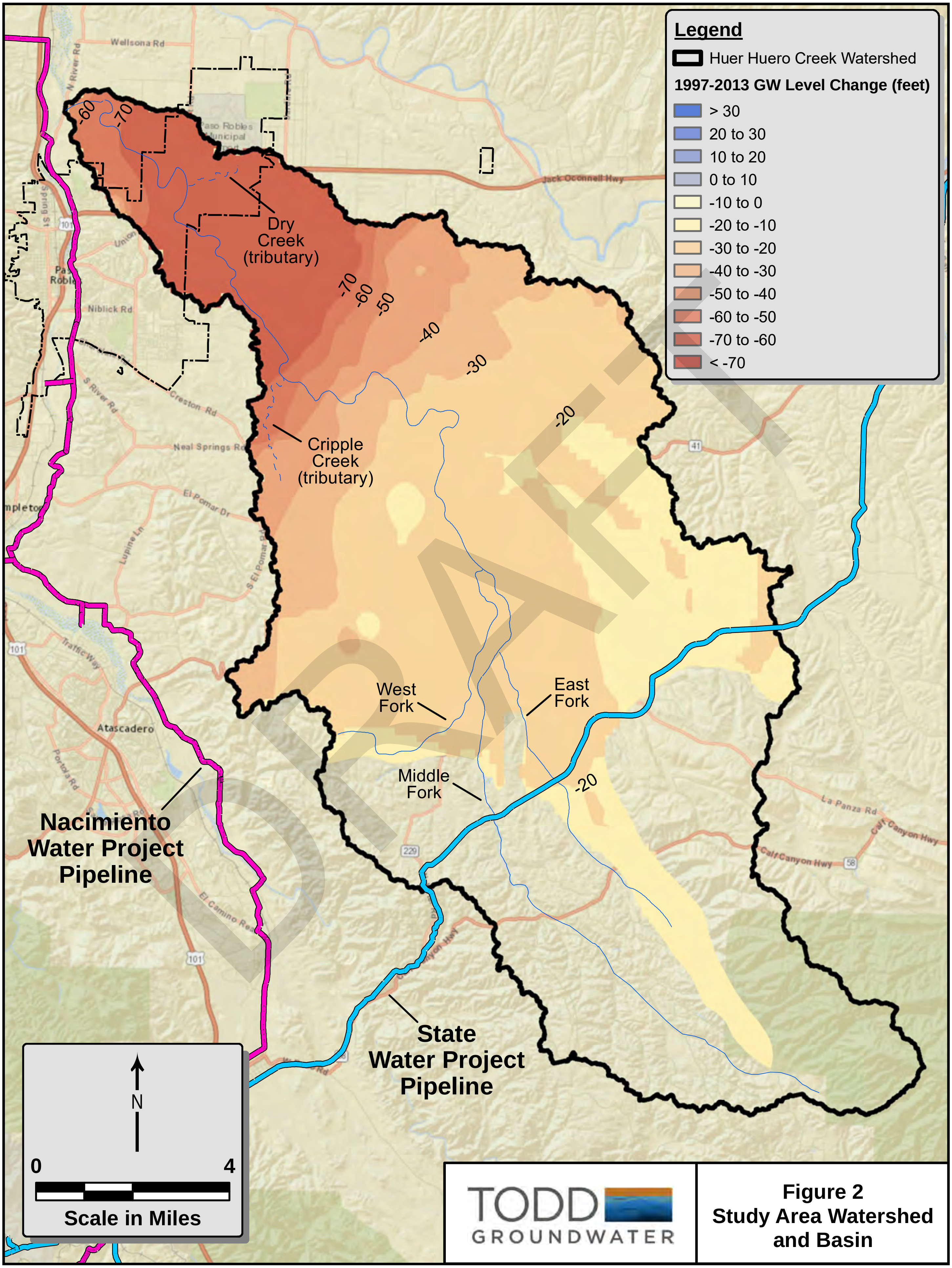


Figure 2
Study Area Watershed and Basin

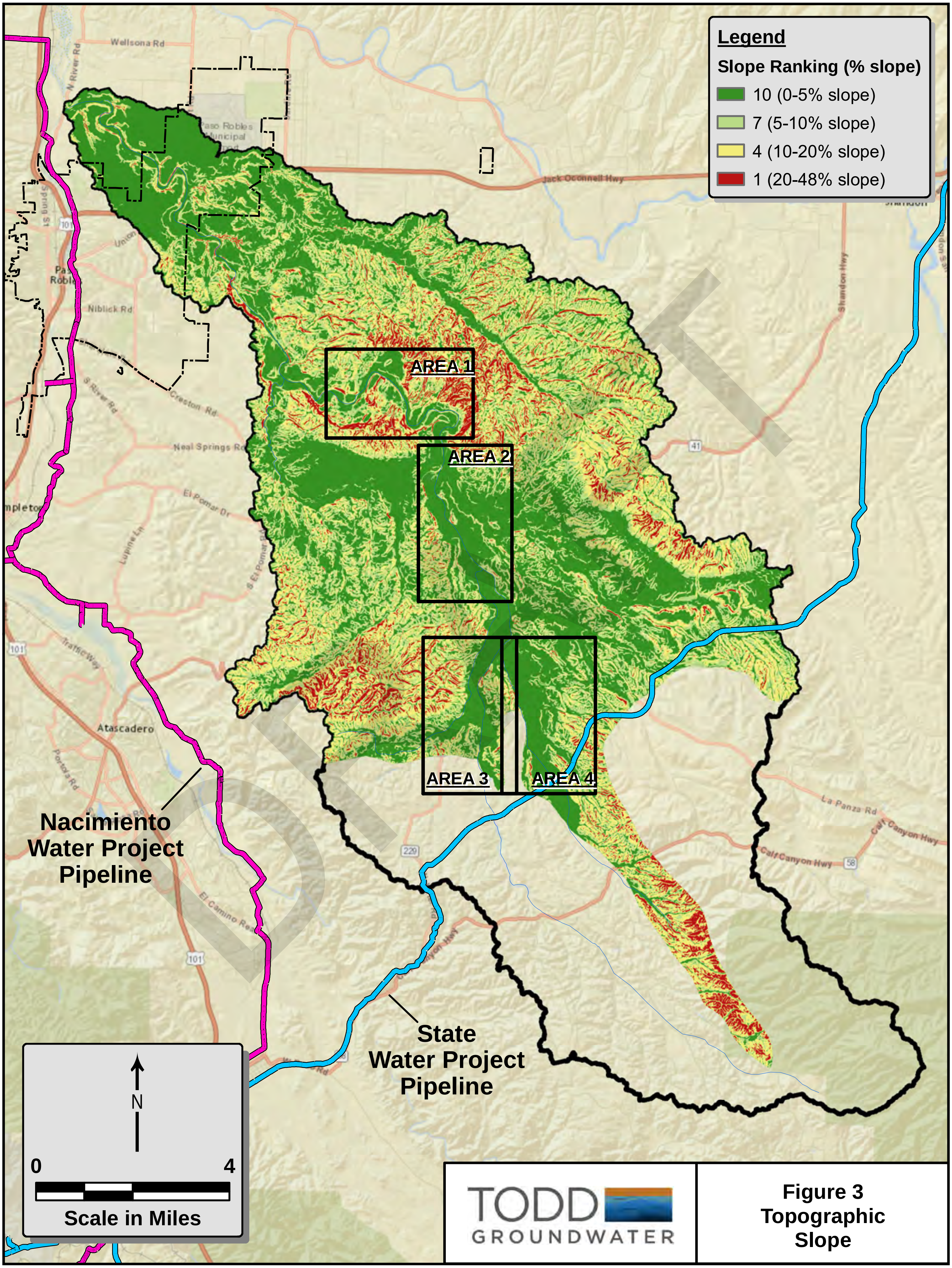


Figure 3
Topographic Slope

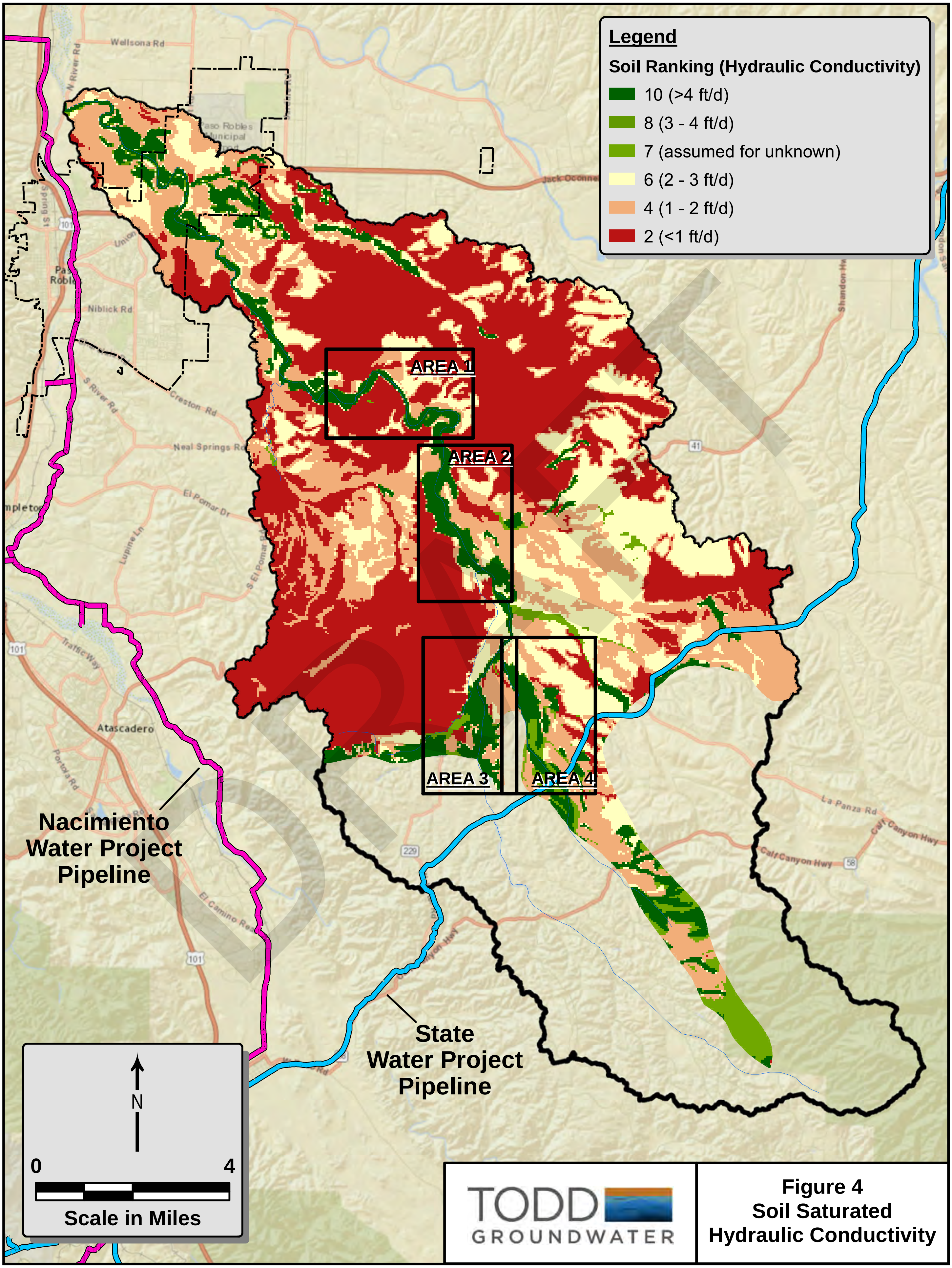
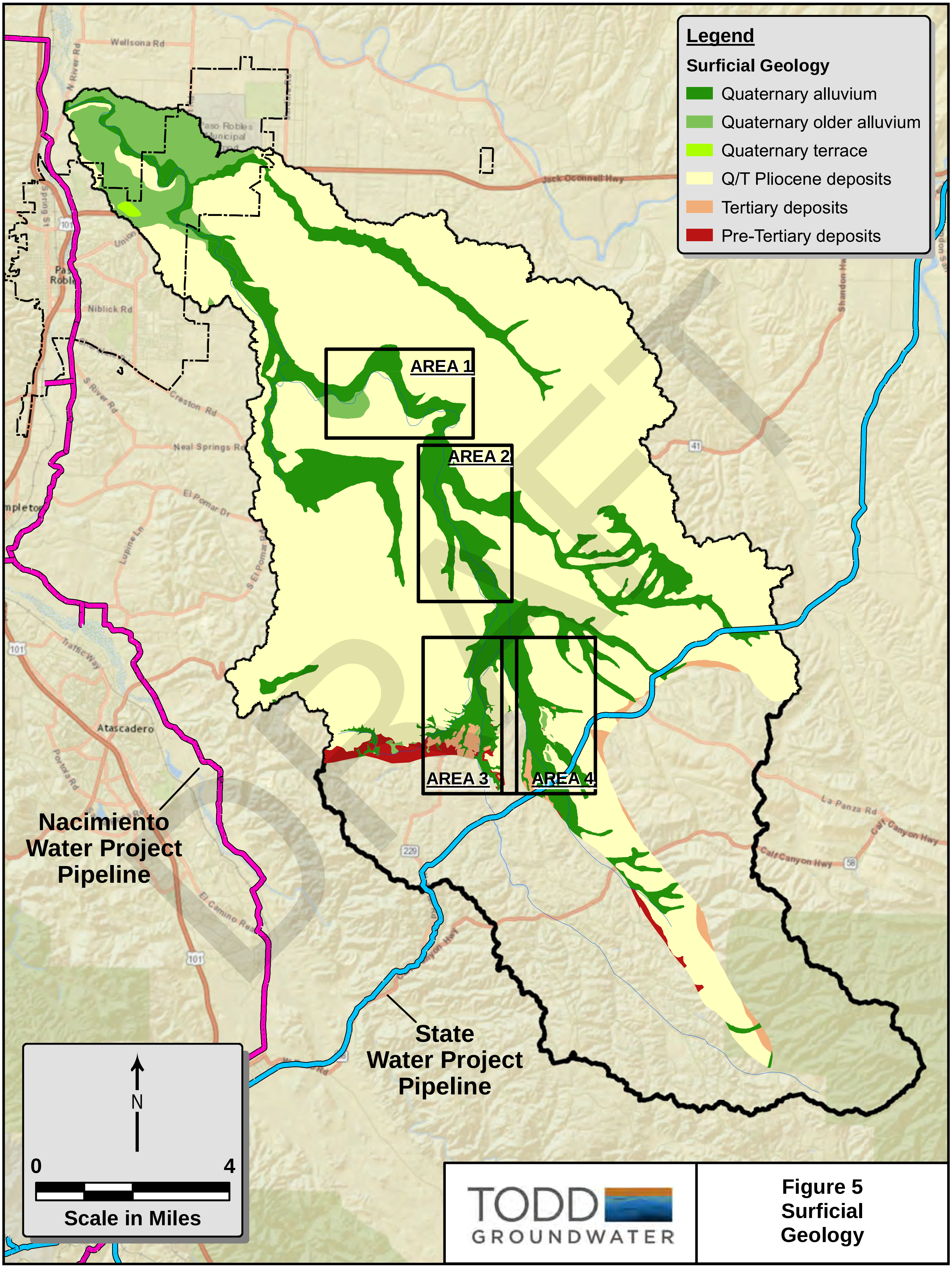
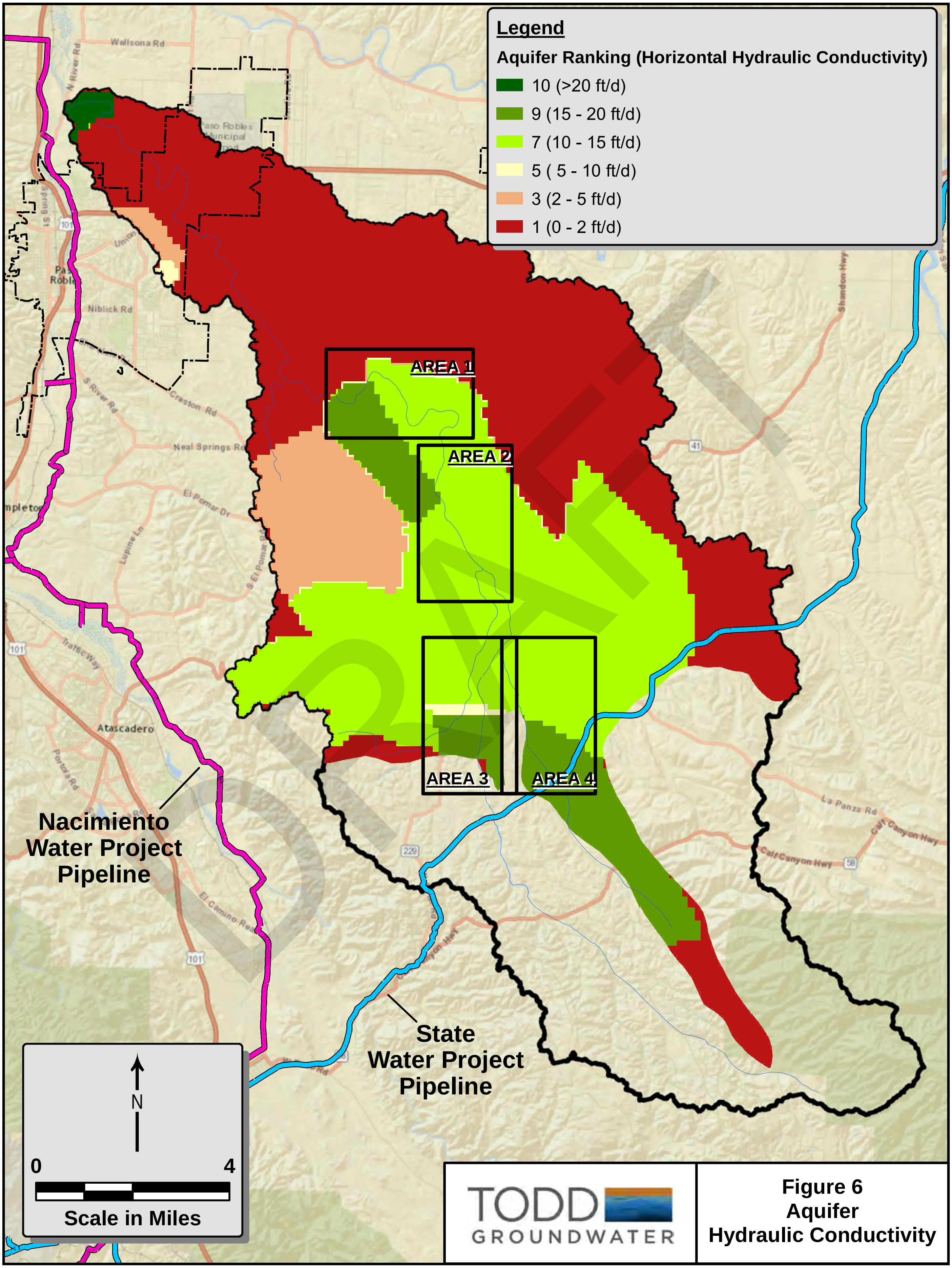


Figure 4
Soil Saturated Hydraulic Conductivity


Legend
Surficial Geology
Quaternary alluvium
Quaternary older alluvium
Quaternary terrace
Q/T Pliocene deposits
Tertiary deposits
Pre-Tertiary deposits
AREA 1
AREA 2
AREA 3
AREA 4
Nacimiento Water Project Pipeline
State Water Project Pipeline
N
0
4
Scale in Miles
TODD GROUNDWATER
Figure 5
Surficial Geology



TODD GROUNDWATER

Figure 6
Aquifer Hydraulic Conductivity

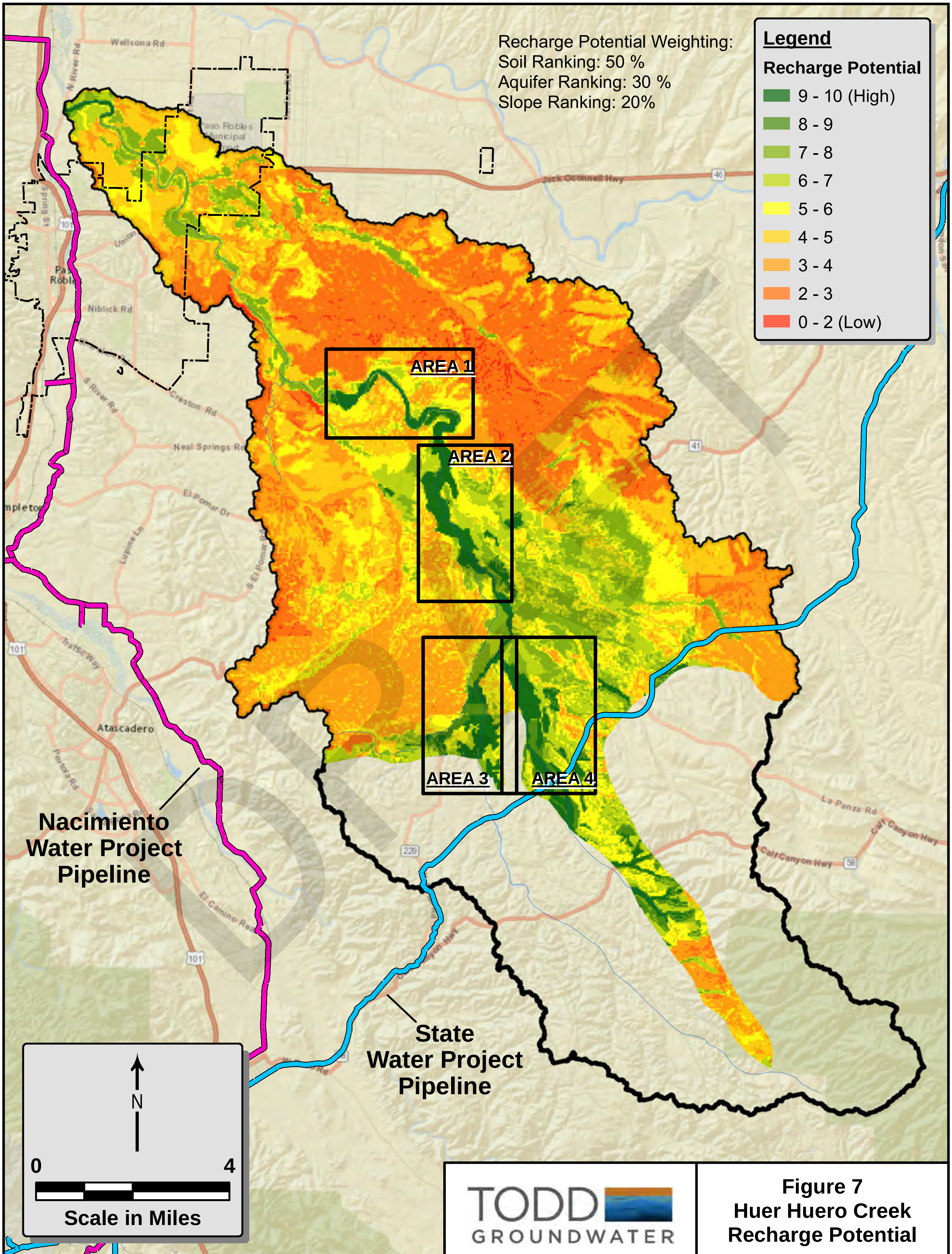
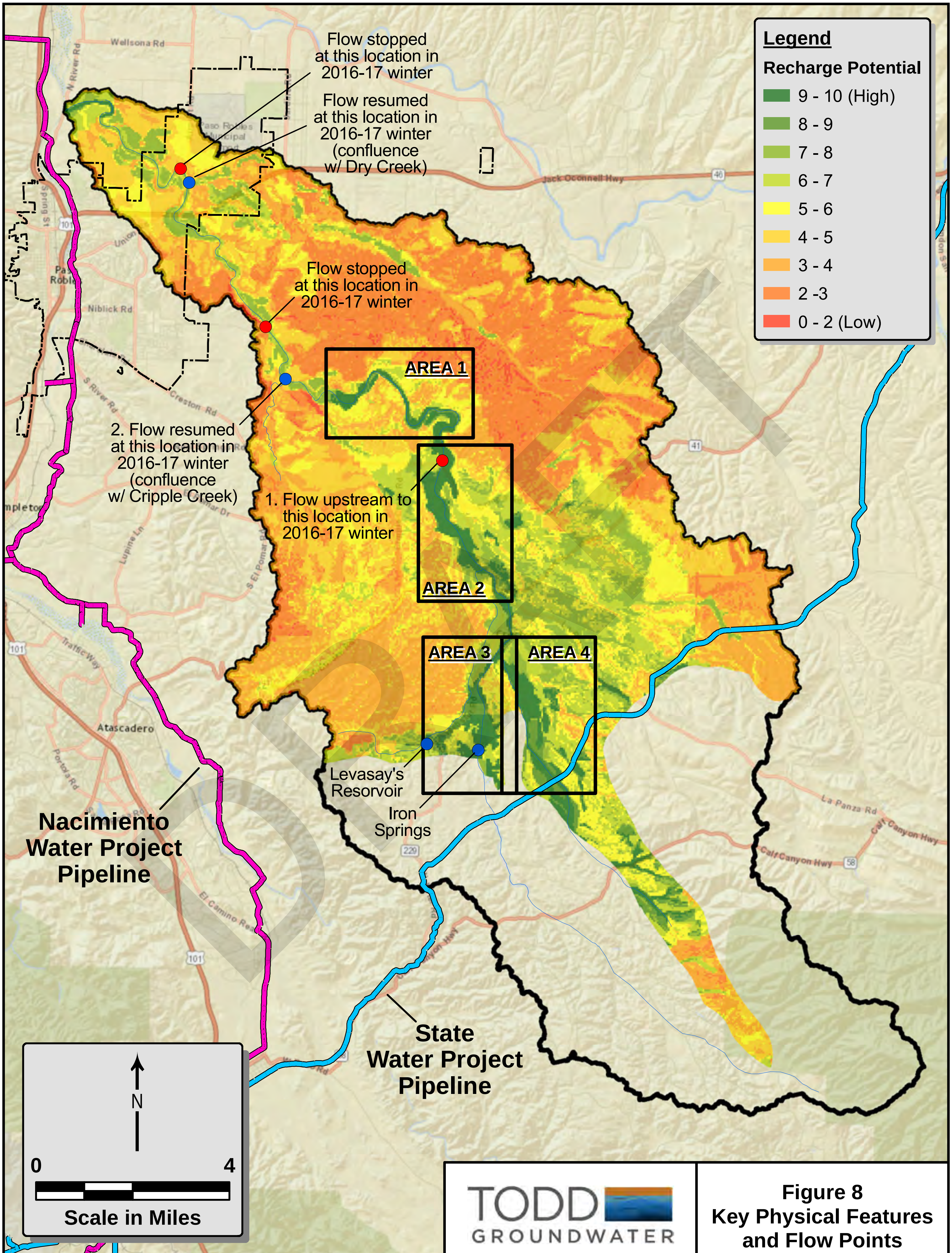


Figure 7
Huer Huero Creek
Recharge Potential



TODD GROUNDWATER

Figure 8
Key Physical Features and Flow Points

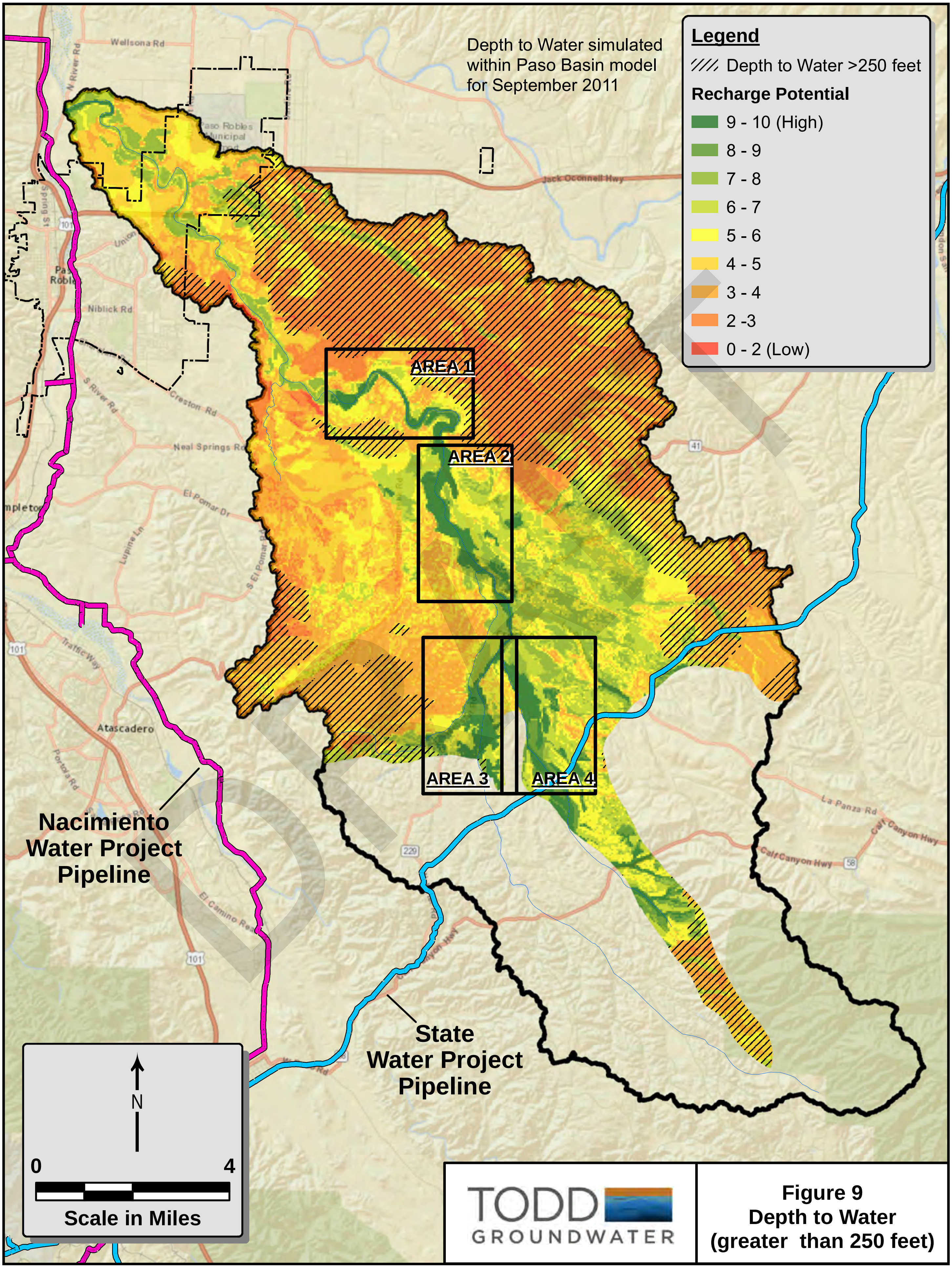


Figure 9
Depth to Water
(greater than 250 feet)

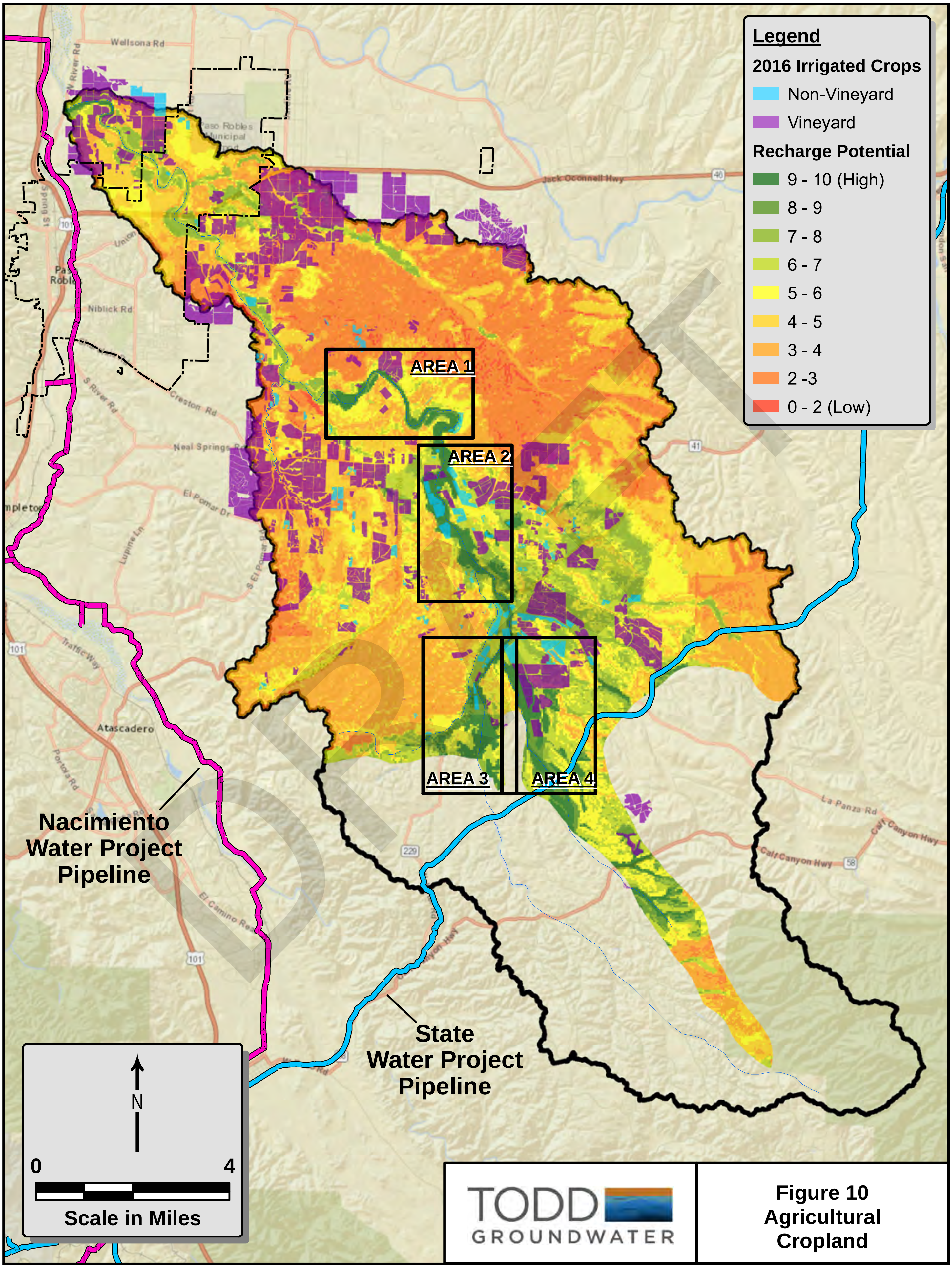


Figure 10
Agricultural Cropland

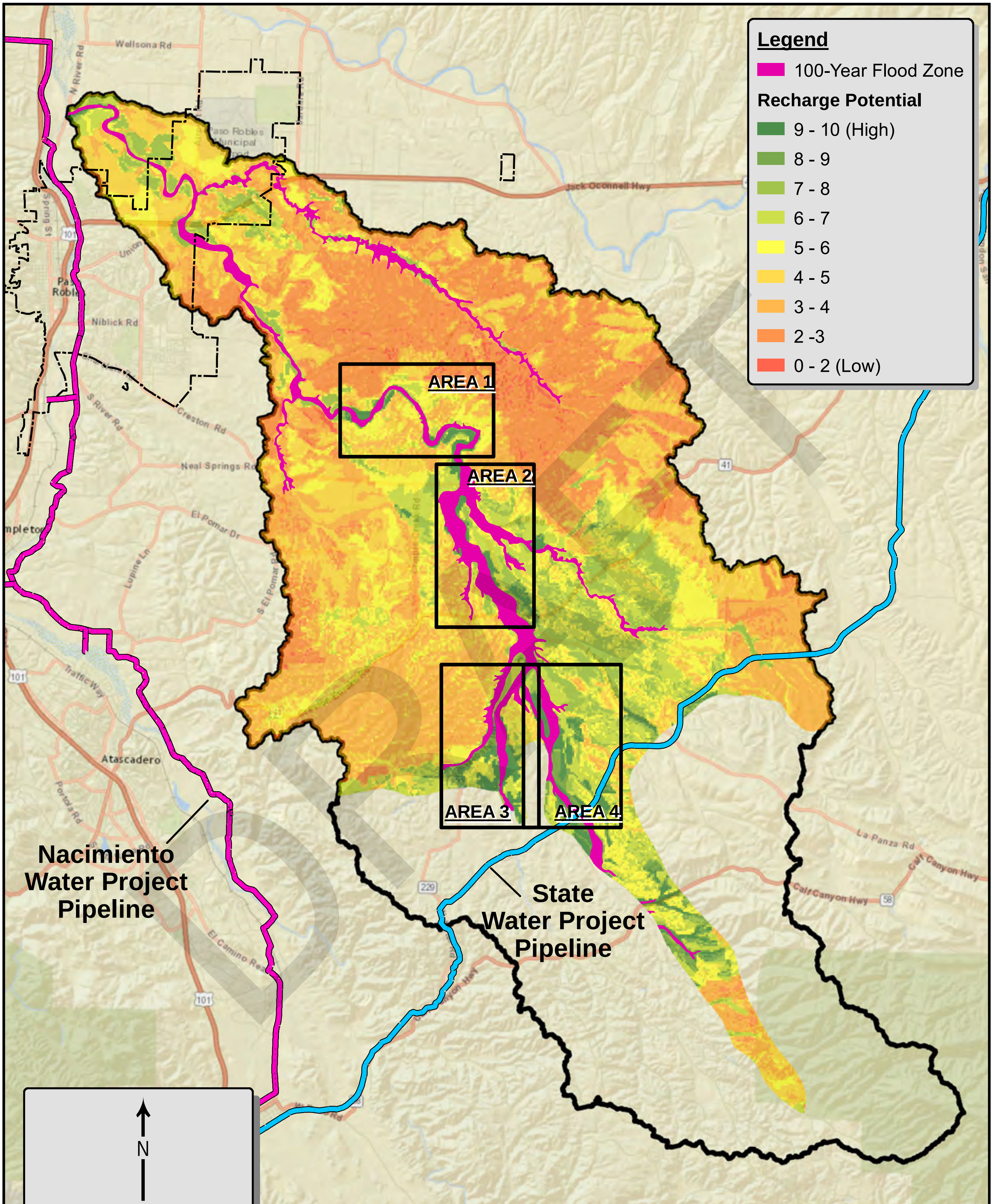
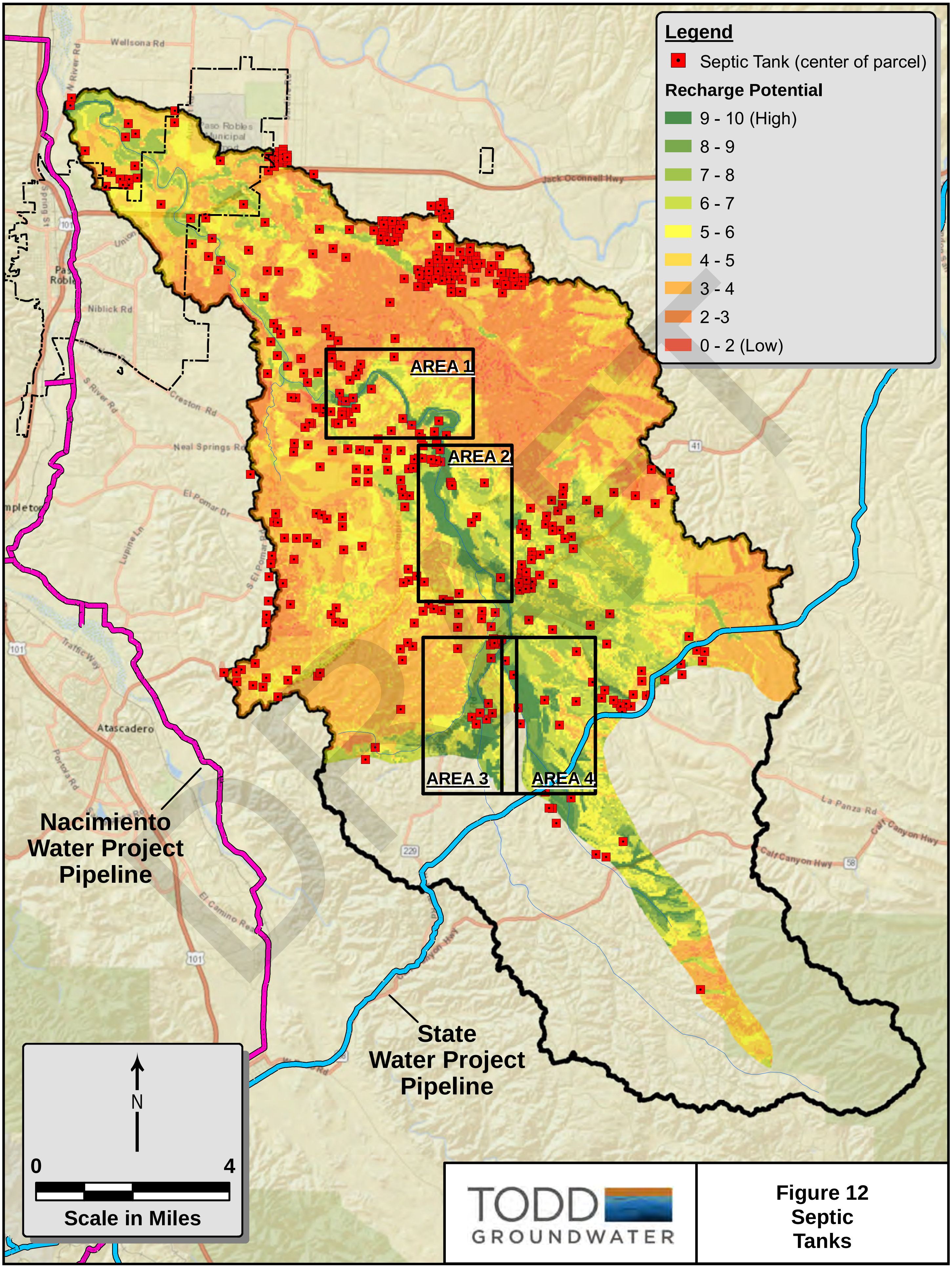


Figure 11
100-Year Flood Zone



TODD GROUNDWATER

Figure 12
Septic
Tanks

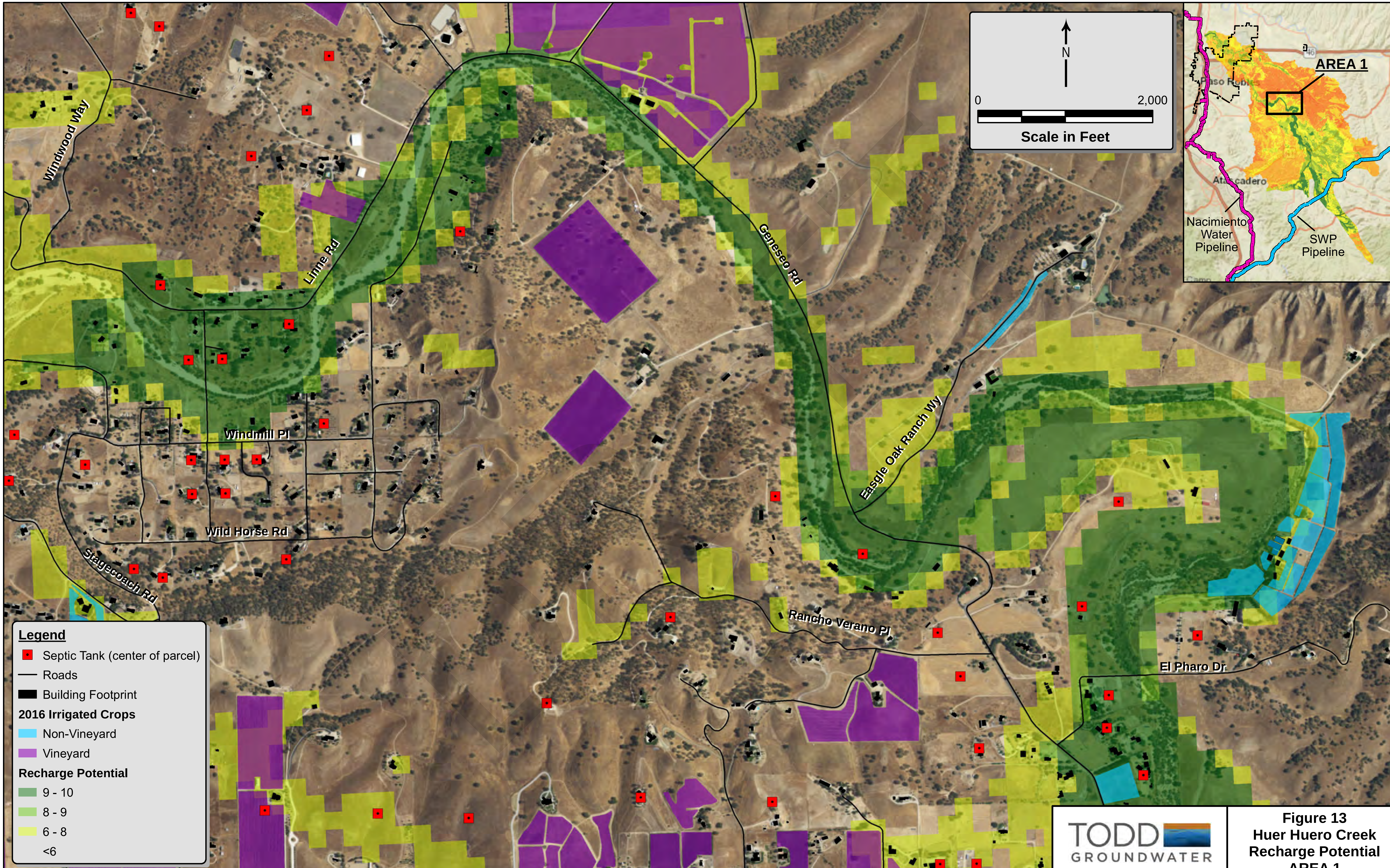
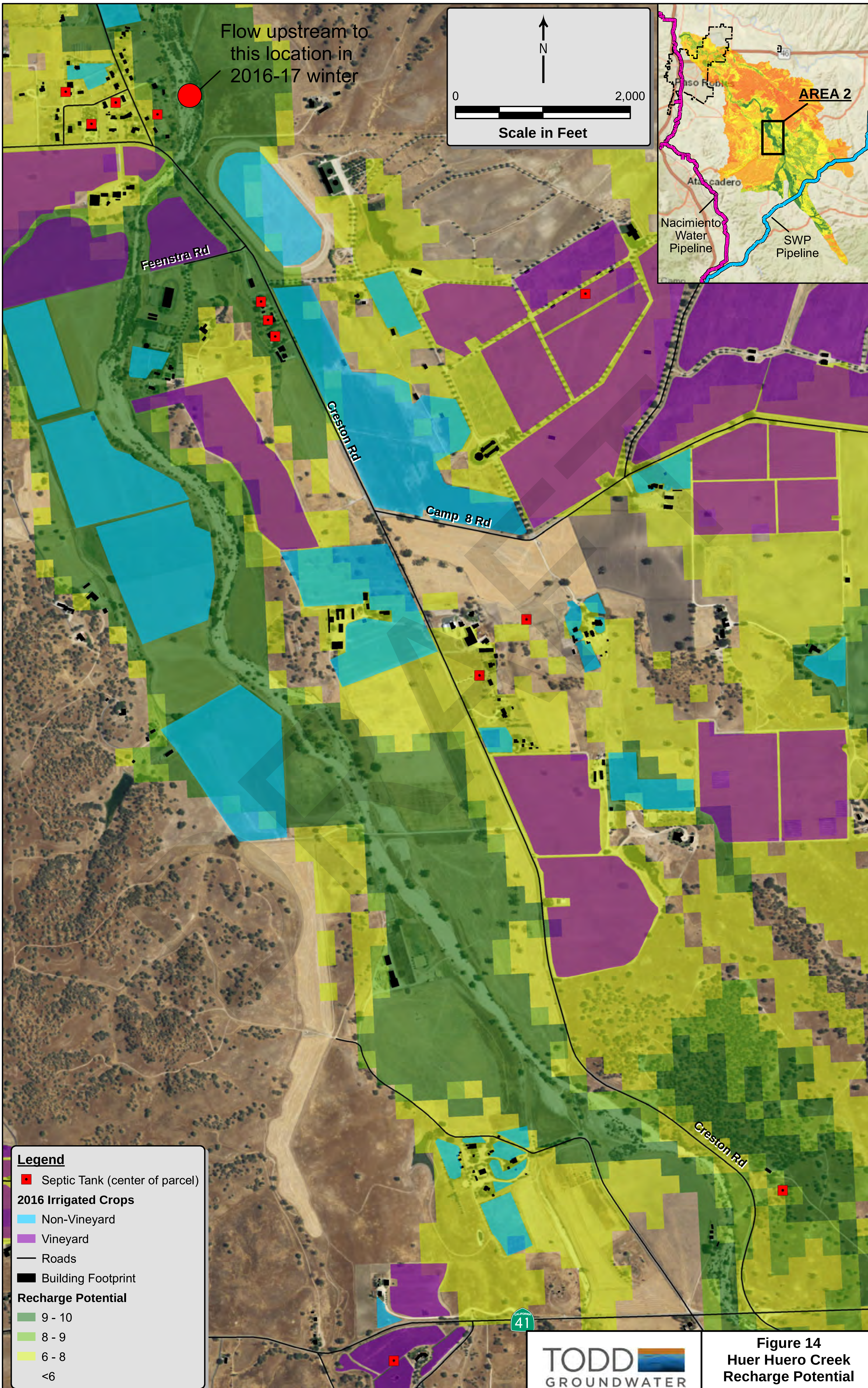


Figure 13
Huer Huero Creek
Recharge Potential
AREA 1



TODD GROUNDWATER

Figure 14
Huer Huero Creek Recharge Potential
AREA 2

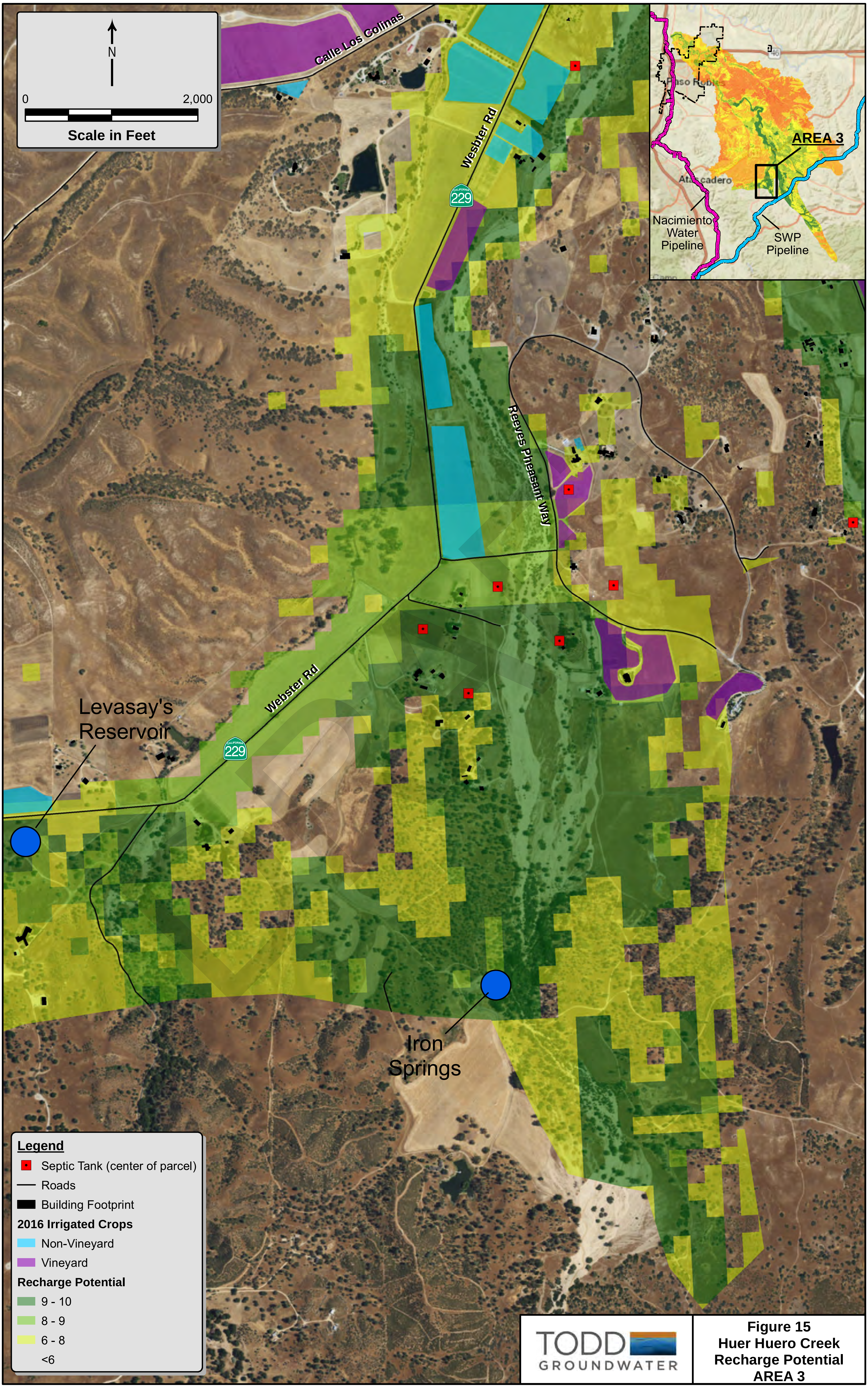


Figure 15
Huer Huero Creek Recharge Potential AREA 3

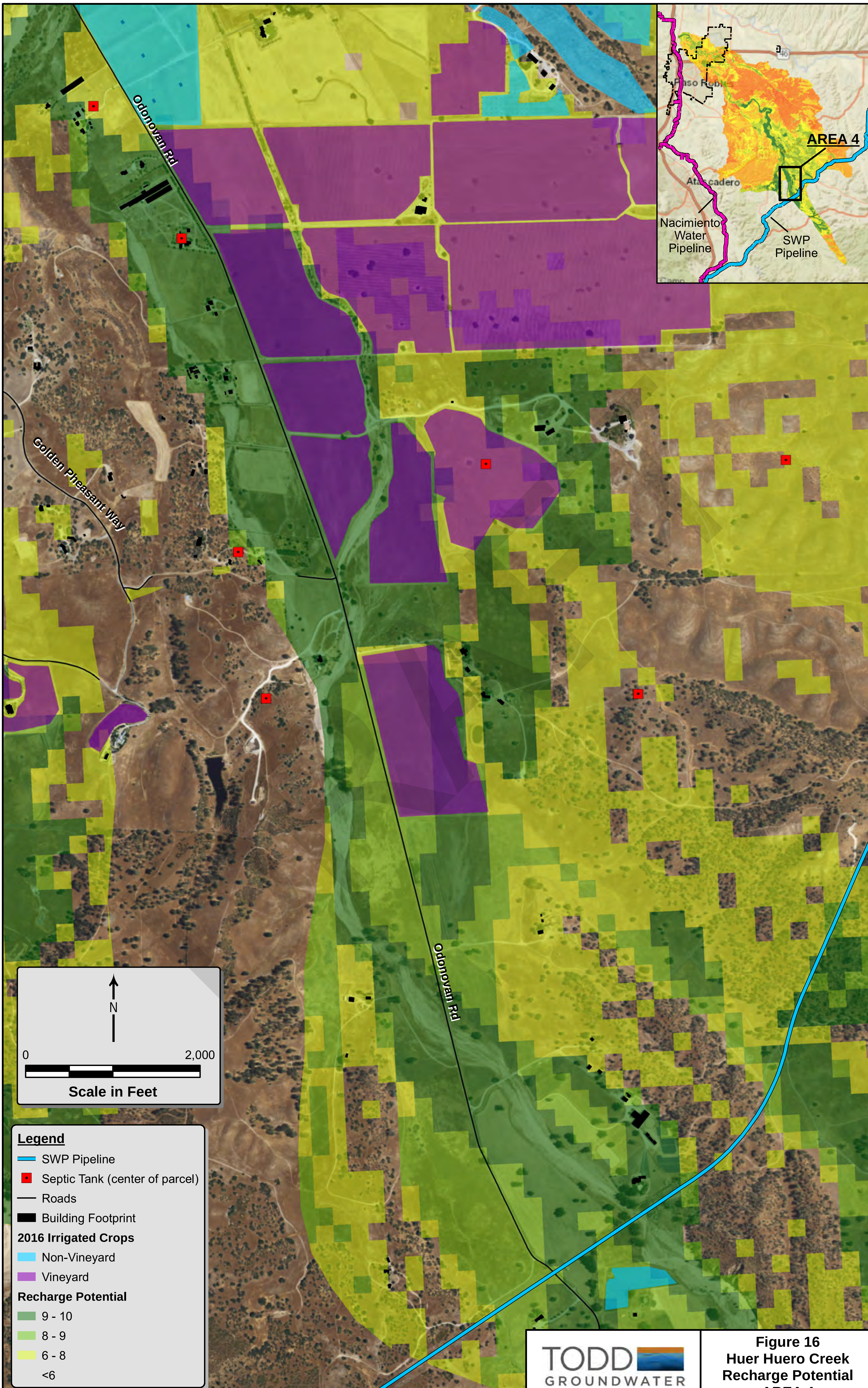


Figure 16
Huer Huero Creek
Recharge Potential
AREA 4