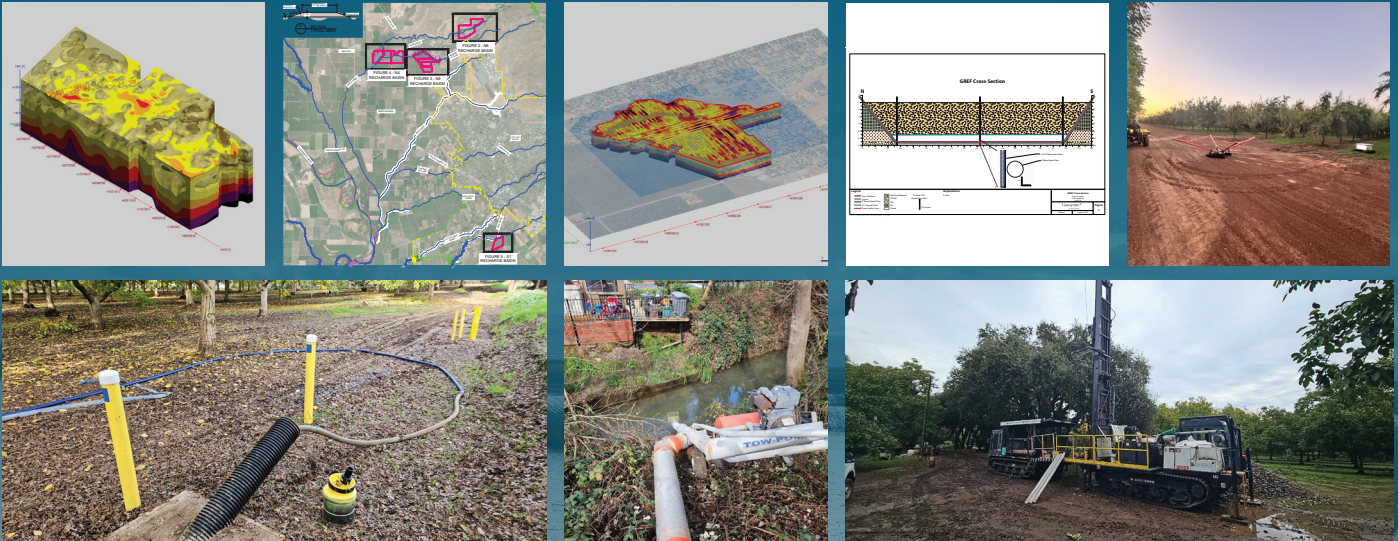


COMBINED

GROUNDWATER RECHARGE INVESTIGATION AND PRELIMINARY DESIGN REPORT PILOT PROJECT IMPLEMENTATION REPORT

Vina Groundwater Sustainability Agency SGM Grant
Component 5: Surface Water Supply and Recharge Feasibility Study



SUSTAINABLE GROUNDWATER MANAGEMENT (SGM) GRANT PROGRAM



ACKNOWLEDGEMENTS

This report was prepared through the collaborative efforts of numerous agencies, organizations, and individuals dedicated to advancing sustainable groundwater management in the Vina Subbasin.

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The Project Team—Geosyntec Consultants, Inc., BCWRC, Agricultural Groundwater Users of Butte County (AGUBC), and Water and Land Solutions (WLS)—worked collaboratively to deliver this effort. In particular, AGUBC provided critical support for stakeholder engagement, landowner outreach, and facilitation of site identification and field investigations.

We also acknowledge the valuable collaboration and support provided by the following local agencies and partners:

- **Durham Mutual Water Company**
- **Tuscan Water District**
- **Western Canal Water District**
- **Paradise Irrigation District**

Finally, we extend sincere appreciation to the participating landowners and agricultural partners who provided access to their properties and supported field investigations and pilot testing. Their cooperation was essential to advancing practical, on-the-ground groundwater recharge solutions in the Vina Subbasin.



Combined Groundwater Recharge Investigation and Preliminary Design Report Pilot Project Implementation Report

Vina Groundwater Sustainability Agency Grant

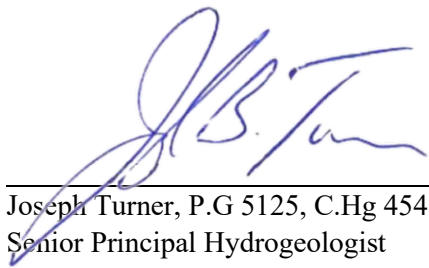
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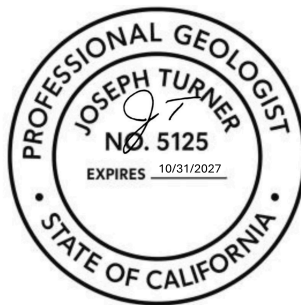
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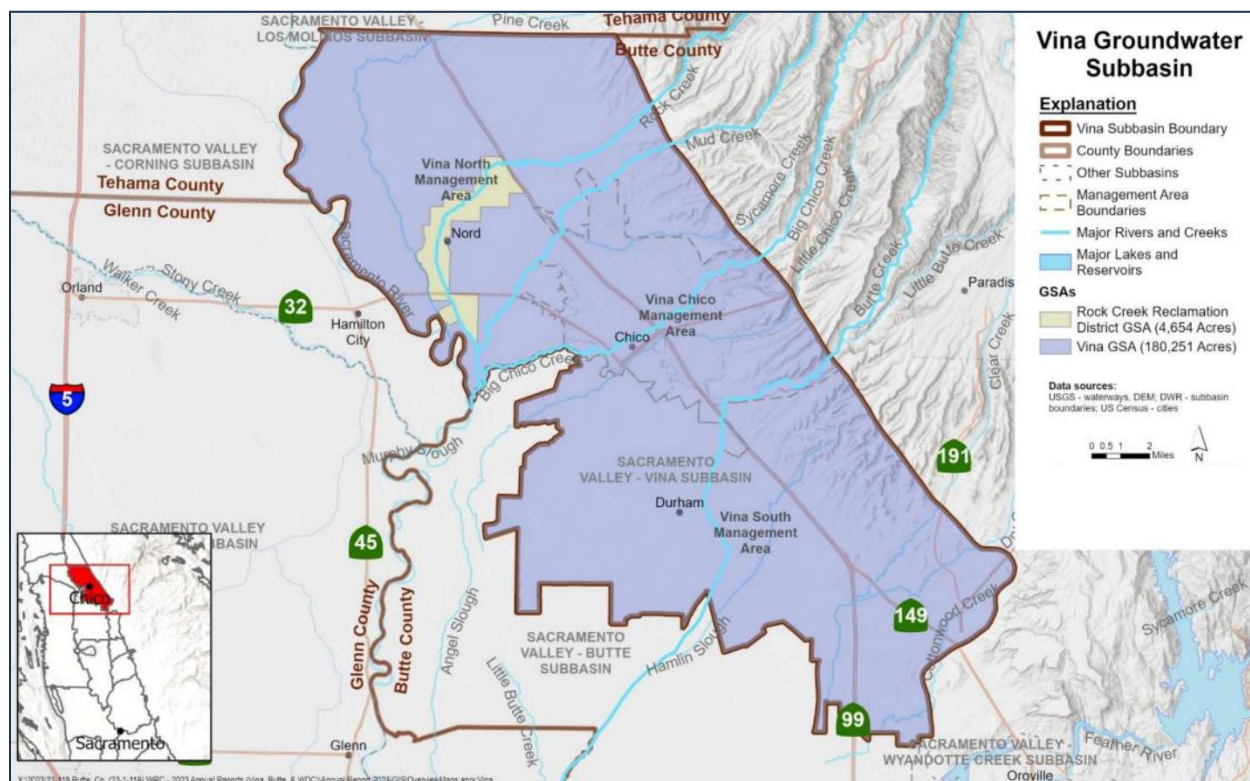
June 2026

Preface

The Vina Subbasin

The Vina Subbasin (DWR Basin No. 5-021.57) covers approximately 289 square miles—roughly 185,000 acres—on the western side of Butte County in the Northern Sacramento Valley. The subbasin includes the City of Chico, the communities of Nord and Durham, and the surrounding rural residential and agricultural lands. Approximately 110,000 people reside in the subbasin, with the majority of residents in Chico.

Figure P1 - Vina Groundwater Subbasin.



The Vina Subbasin is predominantly groundwater dependent. Approximately 91 percent of its water supply comes from groundwater, with the remaining 9 percent from surface water. Agricultural irrigation accounts for 93 percent of total water use, supporting orchards, rice, row crops, vineyards, and grazing. Municipal and domestic uses account for the remaining 7 percent.

Groundwater Conditions and the GSP

There are two Groundwater Sustainability Agencies (GSAs) within the Vina Subbasin, the Vina GSA and the Rock Creek Reclamation District (RCRD) GSA that have entered into a cooperative agreement to prepare a single Groundwater Sustainability Plan (GSP). The GSP was submitted in January 2022 (Geosyntec, 2021; GSP), and the California Department of Water Resources (DWR) approved it in July 2023. The GSP estimates the subbasin’s sustainable yield at 233,500 acre-feet per year (AFY), based on historical pumping of approximately 243,500 AFY and an annual storage

decrease of approximately 10,000 AFY, and may be as high as 20,000 AFY. Although recent wetter years have stabilized groundwater levels, action is still needed to address these longer-term declines and prepare for the next drought. Under SGMA, the subbasin must achieve sustainability by 2042.

Approach to Sustainability

Closing the gap between current groundwater use and sustainable yield requires a portfolio of actions. No single project will likely be sufficient. Grant funds from the California Department of Water Resources (DWR) Sustainable Groundwater Management grant program (SGM grant) funded a suite of feasibility studies and pilot projects conducted in 2024-2026. The Vina and Rock Creek GSAs and their partners—including Butte County, the City of Chico, Durham Irrigation District, Tuscan Water District, and the Agricultural Groundwater Users of Butte County—are advancing a coordinated strategy across four categories:

Demand Reduction and Conservation

Pilot programs for extended orchard replacement and precision irrigation were investigated with SGM grant funds to explore approaches for reducing agricultural water demand. Results of the pilot studies provide information on potential water savings and costs of the programs.

Groundwater Recharge

The Butte County Recharge Action Plan, adopted by the Board of Supervisors in February 2024, establishes a recharge target of at least 20,000 AFY and prioritizes the Vina Subbasin. The enclosed SGM grant funded Recharge Feasibility Analysis identifies potential recharge sites and assesses site feasibility and multi-benefit opportunities throughout the subbasin. Additionally, the Feasibility of Enhanced Recharge in the Lindo Channel study provides a recharge feasibility and alternatives report for exploring recharge within the City of Chico.

Increasing Surface Water Supplies

This strategy reduces the reliance on groundwater in the subbasin by identifying and refining surface water supply projects. The Surface Water Supply Feasibility Analysis evaluates opportunities to deliver surface water to farms that currently rely entirely on groundwater, directly offsetting pumping through conjunctive use.

Planning and Partnerships

Inter-basin coordination, partnerships with water districts (e.g., Western Canal Water District, Paradise Irrigation District), engagement with state and federal agencies, and collaboration with local entities such as Tuscan Water District enable the other strategies to succeed.

Purpose of This Combined Groundwater Recharge Investigation and Pilot Project Implementation Report

This project is Component 5 of the SGM Grant, Surface Water Supply and Recharge Feasibility Study. This component is a planning effort to identify the best opportunities to use more surface water for irrigation to reduce groundwater pumping and to add more water back into the ground (i.e. enhance recharge) to strengthen and sustain groundwater supplies. The surface water component of this project has been completed as detailed in the Vina Subbasin Surface Water Supply Feasibility Analysis Report prepared by Water and Land Solutions (WLS, 2026). This

report presents the results of groundwater investigations and pilot tests focused on assessing potential sites and methods for conducting groundwater recharge projects within the Vina Subbasin.

To select sites for investigations and pilot tests, Butte County led a public process to obtain information from stakeholders regarding potential recharge projects that could be implemented within a short time frame. Based on this information and extensive landowner outreach through the Agricultural Groundwater Users of Butte County, more than 15 sites were identified and assessed for potential groundwater recharge projects. Assessments included review of previous efforts such as Butte County Recharge Action Plan and the California Department of Water Resources airborne electromagnetic (AEM) geophysical survey and site visits with project proponents and landowners to gather additional details and discuss feasibility of conducting groundwater recharge projects. From these efforts, seven sites were selected for groundwater investigations focused on assessing their ability to allow water applied to the site to infiltrate to the groundwater system (recharge). Investigations included the land-based form of the AEM survey, towed-transient electromagnetic (tTEM) surveys, cone penetrometer testing that provides lithologic descriptions (e.g. sands, gravels, clays) and permeability data (how fast can water migrate down), measurement of potential infiltration rates, soil borings to visually look at soil material, installation of monitoring wells to assess the first groundwater aquifer, water quality testing, and continuous water level measurements of groundwater and surface waters to assess seasonal trends and interactions between these systems.

From these field investigations, four sites were selected to conduct pilot tests of potential groundwater recharge methods that included infiltration basins, reverse tile drains (perforated horizontal pipes below ground surface) and FloodMAR projects following California's Water Code 1242.1 that allows use of flood water without obtaining a water rights permit. Key findings of the field investigations and pilot testing indicate that groundwater recharge is feasible at select locations within the Vina Subbasin, with performance highly dependent on site-specific soil and subsurface conditions. The most favorable results were observed at a site along Comanche Creek and one near the confluence of Keefer Slough and Rock Creek, where permeable materials supported effective infiltration. Pilot projects successfully demonstrated multiple recharge approaches, including Flood-MAR implementation under Water Code Section 1242.1. Other sites were screened out due to limiting factors such as low-permeability soils or perched groundwater conditions. Based on these results, three projects have been advanced for preliminary design and further development.

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ACRONYMS AND ABBREVIATIONS

AFY – Acre-Feet per Year
AEM – Airborne Electromagnetic
AGF – Aqua Geo Frameworks
AGUBC – Agricultural Groundwater Users of Butte County
ASTM – American Society for Testing and Materials
BCWRC – Butte County Department of Water and Resource Conservation
BCEHD – Butte County Environmental Health Division
BMP – Best Management Practice
bgs – Below Ground Surface
CASGEM – California Statewide Groundwater Elevation Monitoring
CEQA – California Environmental Quality Act
CalEPA – California Environmental Protection Agency
Cl – Chloride
CPT – Cone Penetrometer Testing
DWR – California Department of Water Resources
EC – Electrical Conductivity
EPA – U.S. Environmental Protection Agency
FloodMAR – Flood-Managed Aquifer Recharge
ft/day – Feet per Day
GIS – Geographic Information System
GSA – Groundwater Sustainability Agency
GSAs – Groundwater Sustainability Agencies
GSP – Groundwater Sustainability Plan
HPT – Hydraulic Profiling Tool
IRWMP – Integrated Regional Water Management Plan
K – Potassium
MAR – Managed Aquifer Recharge
Mg – Magnesium
mL/min – Milliliters per Minute
Na – Sodium
NO₃ – Nitrate
ORP – Oxidation-Reduction Potential
pH – Measure of Acidity/Alkalinity
RCRD – Rock Creek Reclamation District
RWQCB – Regional Water Quality Control Board
Rx – Receiver (coil)
SAGBI – Soil Agricultural Groundwater Banking Index
SGM – Sustainable Groundwater Management Grant
SGMA – Sustainable Groundwater Management Act
SO₄ – Sulfate
SWRCB – State Water Resources Control Board

TDEM – Time-Domain Electromagnetic
TEM – Transient Electromagnetic
TDS – Total Dissolved Solids
TM – Technical Memorandum
tTEM – Towed Transient Electromagnetic
Tx – Transmitter (coil)
USA – Underground Service Alert
USACE – United States Army Corps of Engineers
USBR – United States Bureau of Reclamation
USEPA – United States Environmental Protection Agency
USGS – United States Geological Survey
VOC(s) – Volatile Organic Compound(s)
WLS – Water and Land Solutions
 $\Omega \cdot m$ – Ohm-meter

1. INTRODUCTION

The Vina Subbasin (California Department of Water Resources [DWR] Basin No. 5-021.57) encompasses approximately 289 square miles (approximately 185,000 acres) on the western side of Butte County in the northern Sacramento Valley. Figure 1 shows the geographic extent of the Vina Groundwater Subbasin. The subbasin includes the City of Chico; the communities of Nord and Durham; and surrounding rural residential and agricultural lands. The Vina Subbasin is predominantly groundwater-dependent, with approximately 91 percent of its water supply derived from groundwater and the remaining 9 percent from surface water. Two Groundwater Sustainability Agencies (GSAs) operate within the subbasin: the Vina GSA and the Rock Creek Reclamation District (RCRD).

The Vina GSA is implementing several projects funded through the Sustainable Groundwater Management Act (SGMA) grant program. These projects are intended to improve understanding of groundwater conditions, address data gaps, support long-term planning, and evaluate solutions to help manage shared groundwater resources. Component 5 of the SGMA grant, the Surface Water Supply and Recharge Feasibility Study, is a planning effort to identify opportunities to increase the use of surface water for irrigation to reduce groundwater pumping and to enhance groundwater recharge. This component is divided into two parts:

- Surface Water Supplies Feasibility Analysis
- Recharge Feasibility Analysis

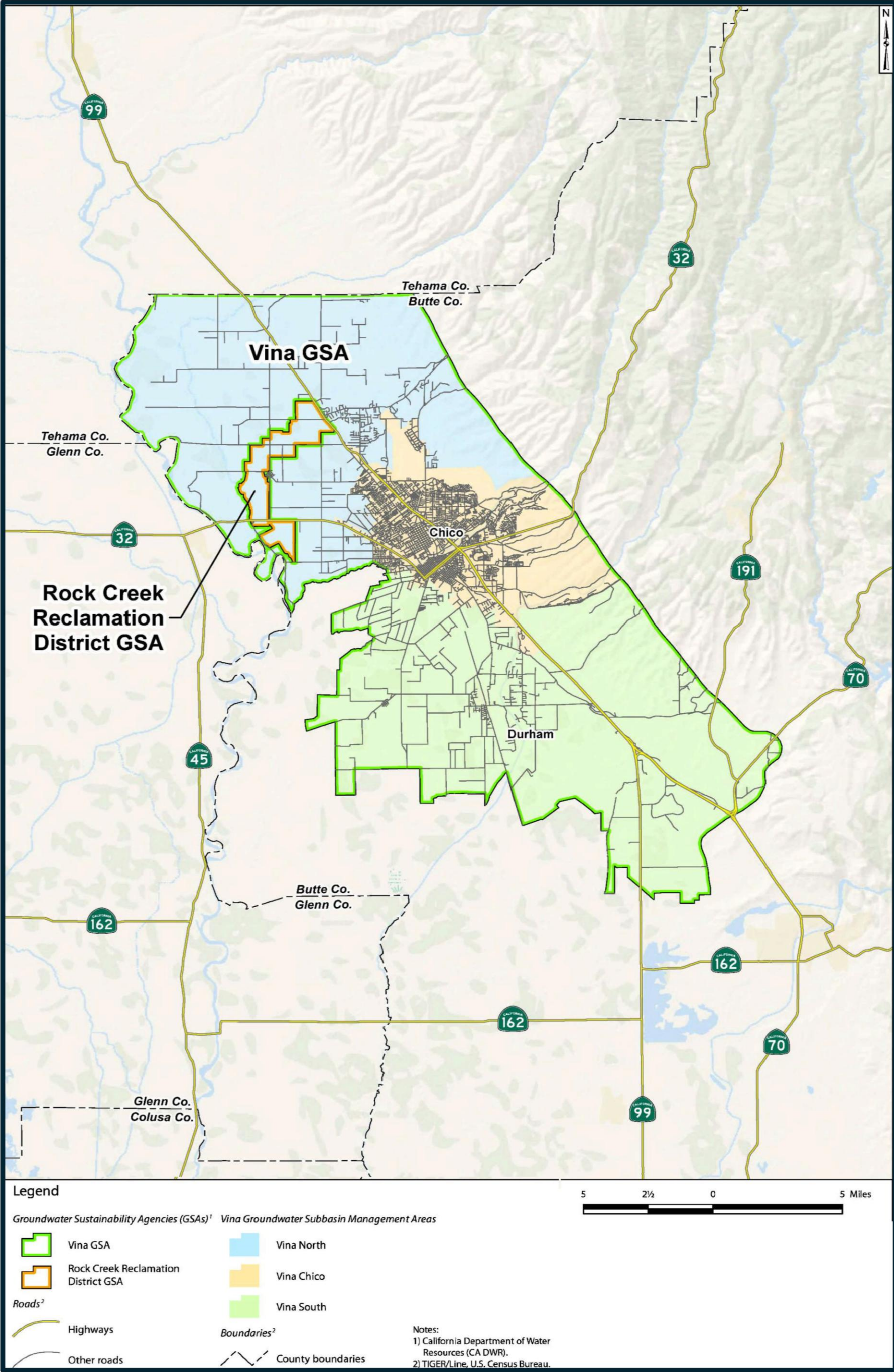
Butte County is administering Component 5 of the SGMA grant awarded to the Vina GSA and retained Geosyntec Consultants, Inc. (Geosyntec) to complete the work in accordance with Contract Number X25488 (Contract), dated April 8, 2024, and amended on July 29, 2025. The Contract specifies four deliverables: the Surface Water Supplies Feasibility Analysis; a Technical Memorandum (TM) summarizing potential recharge projects; the Groundwater Recharge Investigation and Preliminary Design Report; and the Pilot Project Implementation Report.

The Surface Water Supplies Feasibility Analysis was submitted on March 4, 2026 (Water and Land Solutions, 2026), and the TM summarizing potential recharge projects was submitted on May 1, 2026 (Geosyntec, 2026a) and is attached as Appendix A. This report presents the remaining two deliverables: the Groundwater Recharge Investigation Report (Sections 1 through 5) and the Pilot Project Implementation Report (Section 6).

Additionally, the Vina GSA contracted with the Agricultural Groundwater Users of Butte County to provide project management support, outreach support, and facilitation of site identification and investigations with landowners for both the water supply and recharge feasibility studies.

1.1 Purpose and Objectives

The purpose of the groundwater recharge investigations is to evaluate the recharge potential of sites identified in the Technical Memorandum (TM) (Geosyntec, 2026a). The groundwater recharge pilot test projects are intended to provide proof of concept for specific recharge methods and to assess their feasibility for implementation in long-term recharge projects throughout the Vina Subbasin.



Map showing the Vina Groundwater Subbasin boundary within Butte County, including major communities and rivers.

Figure 1

Collectively, these field programs are designed to generate data to support the following objectives:

- Evaluate the suitability of identified sites for recharging applied water and estimate the annual volume that can be recharged to the underlying groundwater system.
- Develop monitoring recommendations to quantify recharge and ensure that recovery does not adversely affect the groundwater subbasin or nearby public or private wells.
- Identify the most suitable locations within the evaluated sites for implementation of recharge projects.
- Demonstrate the effectiveness of different groundwater recharge methods through proof-of-concept testing.
- Assess operation and maintenance requirements for selected recharge approaches.
- Prepare a preliminary design for at least one project to support future grant applications.

The results of these efforts will inform the planning, design, and implementation of sustainable groundwater recharge projects within the Vina Subbasin.

1.2 Scope of Work

The scope of field investigations included towed transient electromagnetic (tTEM) surveys, cone penetrometer testing (CPT), drilling and lithologic logging of soil borings, infiltration testing, downhole permeability testing, installation of groundwater monitoring wells, installation of stilling wells for surface water level monitoring, and water quality sampling and analysis. Groundwater recharge methods evaluated through pilot testing included infiltration basins, reverse tile drains, and Flood-MAR (Managed Aquifer Recharge) in accordance with California Water Code Section 1242.1.

The preliminary design for selected projects comprised the following elements:

- Evaluation of available water supplies and estimation of recharge volumes
- Development of conceptual site layouts incorporating flood flow access or diversion structures, conveyance infrastructure, and site-specific water distribution and management strategies
- Identification of applicable environmental compliance and clearance requirements
- Assessment of permitting requirements
- Development of monitoring plans, including cost estimates
- Preparation of operations and maintenance (O&M) recommendations
- Estimation of probable design and construction costs
- Evaluation of funding mechanisms for capital implementation and long-term O&M, based on geographic benefit areas.
- Estimation of unit costs expressed as cost per acre-foot of recharged water.

Three projects were advanced to the preliminary design phase to support future funding opportunities. One project, the Durham Mutual Water Company Pipeline Restoration Project, is documented separately (Geosyntec, 2026b) and is included as Appendix B.

1.3 Report Format

The organization of this report follows the sequence of tasks completed for the project. Section 1 presents an introduction, including the project purpose, objectives, and defined scope of work. Section 2 summarizes prior groundwater recharge efforts and describes how these efforts informed the development of the investigations and projects presented herein. Section 3 provides an overview of the hydrogeologic setting of the Vina Subbasin, with a focus on the anticipated migration and behavior of recharge water. Section 4 describes the methods and procedures employed during field investigations, and Section 5 presents the results of those investigations. Section 6 details the design, implementation, performance, and results of the groundwater recharge pilot tests. Section 7 presents the preliminary design of two selected projects. As noted previously, a third project selected for preliminary design has already been completed and is included in Appendix B. References cited in this report are compiled in Section 8.

2. PREVIOUS STUDIES

In addition to the Groundwater Sustainability Plan (GSP, Geosyntec, 2022) prepared for the Vina Subbasin, several studies have been completed within the subbasin to assess potentials for groundwater recharge including the following:

1. Lower Tuscan Aquifer (LTA) Monitoring, Recharge, and Data Management Project (LTA Project, Brown and Caldwell, 2013)
2. Stable Isotope Recharge Study (Brown and Caldwell, 2017)
3. Evaluation of Restoration and Recharge within the Butte County Groundwater Basins (GEI Consultants, 2018).
4. Hydrogeologic Framework of Selected Area in Butte and Glenn Counties, California (Aqua Geo Frameworks (AGF), 2019).
5. Butte County Recharge Action Plan (Butte County Department of Water and Resource Conservation (BCWRC), 2024).
6. Feasibility of Enhanced Recharge in the Lindo Channel (Geosyntec, 2026c).

The AGF (2019) report listed above is the results of the airborne electromagnetic (AEM) geophysical survey overseen by DWR.

A summary of each of these studies as it relates to potential recharge projects within the Vina Groundwater Subbasin are presented in the following sections.

2.1 LTA Project

The LTA project (Brown and Caldwell, 2013) was a multi-year hydrogeologic investigation conducted to better understand groundwater movement, recharge mechanisms, and connectivity within the Tuscan Formation underlying much of the northeastern Sacramento Valley, including the Vina Subbasin. The study was undertaken to resolve long-standing uncertainty about where and how recharge occurs—particularly given increasing groundwater management pressures and to provide a scientific basis for sustainable groundwater management and recharge planning. By integrating geologic mapping, groundwater level data, aquifer testing, and water quality testing including isotopic analyses, the project aimed to identify the sources of recharge and the pathways by which water moves from the surface and shallow zones into deeper aquifer units.

The study found that recharge from streams, especially where they cross Tuscan outcrops in confined canyon reaches, is limited, contradicting earlier assumptions that streams are the dominant recharge mechanism. Instead, recharge was determined to be largely broad and areal, occurring across the landscape via precipitation, irrigation return flow, and shallow infiltration that moves downward into deeper aquifer units. This indicates that the most effective recharge opportunities in Vina are not limited to stream corridors but rather are widely distributed and should be evaluated across the valley floor.

A second key finding is the importance of vertical connectivity within the aquifer system. The LTA study showed that there is significant potential for water to recharge the deeper Lower Tuscan

aquifer through the overlying shallow alluvial aquifer, and that aquitards separating these zones allow measurable leakage. This means that recharge projects do not need to directly target deep Tuscan units; instead, they can be sited in areas where shallow infiltration can effectively percolate downward. However, the study also emphasized that aquifer properties are highly heterogeneous, so recharge success depends strongly on local soil and geologic conditions, reinforcing the need for site-specific screening and testing.

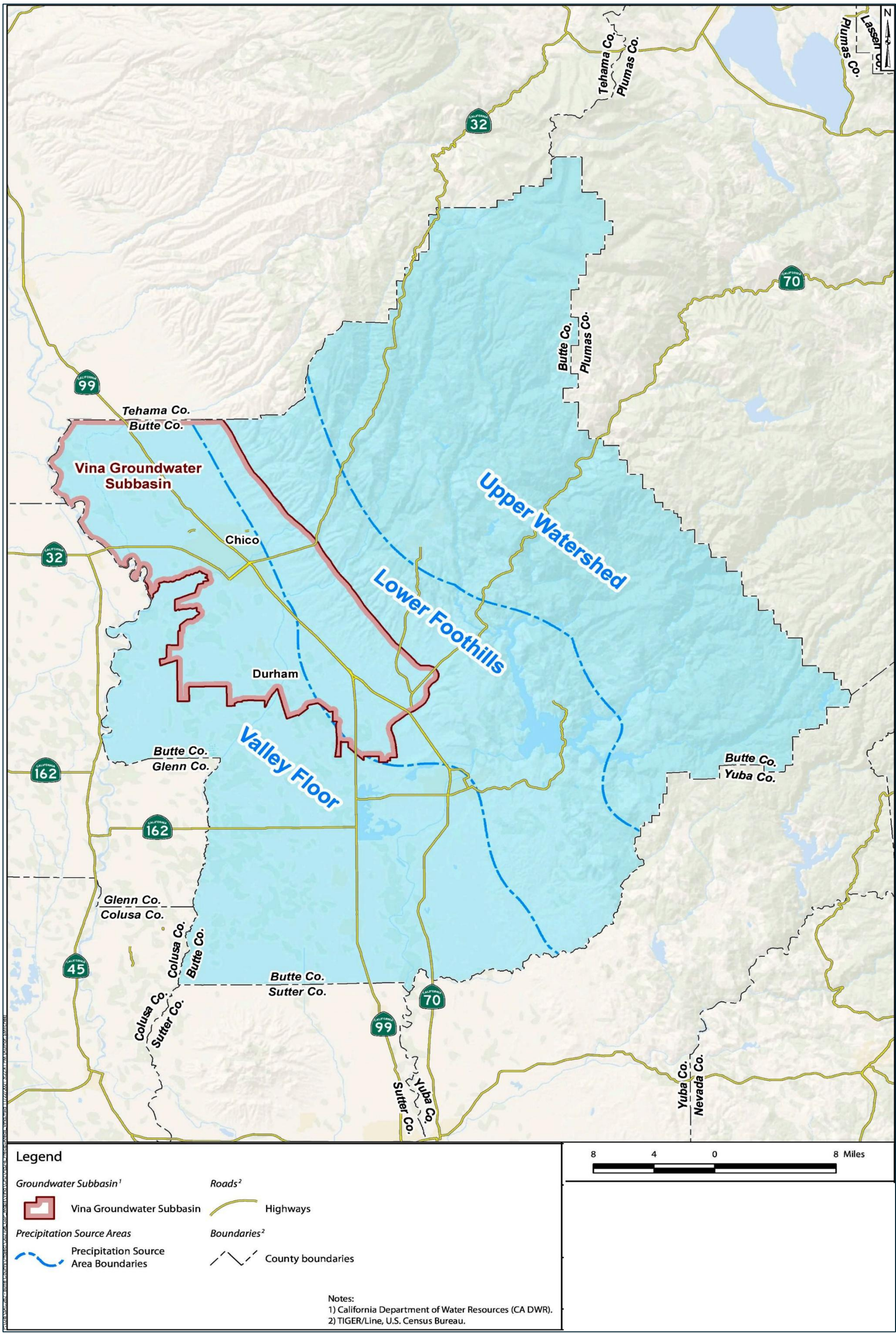
Importantly, the LTA investigation had a geographic limitation that should be considered when applying its conclusions to recharge planning in the Vina Subbasin. The field investigations and stream recharge analyses were focused primarily on major east-side creeks and did not evaluate west-flowing drainages and channels. As a result, the conclusion that stream-based recharge is limited may not fully apply to western portions of the subbasin, where geomorphic conditions and sediment characteristics could provide greater opportunities for infiltration and flood-flow spreading. This highlights a key data gap and suggests that additional evaluation of west-side systems may identify higher-value recharge areas not captured in the original LTA study.

As discussed in the Vina GSP, Davids et al (2020) did a streamflow study along the west side of Big Chico Creek and Butte Creek that clearly showed progressive decrease in streamflow from June to July, followed by a more gradual decrease in July indicating surface water is moving downward. The study consisted solely of streamflow data and no groundwater information or analysis was conducted. However, as discussed below for the Lindo Channel enhanced recharge project, groundwater recharge from in the western portion of this stream system was clearly documented (Geosyntec, 2026).

2.2 Stable Isotope Recharge Study

The Stable Isotope Recharge Study (Brown and Caldwell, 2017) delineated three areas based on land surface elevation that are general sources of precipitation and serve as water sources to the surface water and groundwater systems in Butte County. Figure 2 illustrates precipitation source areas influencing recharge. Identifying these source areas and then observing the destination of that source water within the aquifer system using stable isotope analysis for samples from multi-completion wells led to insights about recharge sources and mechanisms in the Vina Subbasin.

The Vina Subbasin is located primarily within the Valley Floor area, as shown in Figure 2. The Upper Watershed receives rain and snow, primarily during the winter and spring months. Rainfall runoff and snowmelt from the Upper Watershed enters the Valley Floor via streamflow of major streams and rivers that originate at higher elevations, including Butte Creek and the Sacramento River. Geologically, the Upper Watershed consists primarily of volcanic, granitic, and metamorphic rocks that do not have any appreciable primary porosity. Fracturing within these rock units may occur locally, but the fractures are not pervasive on a regional scale, which limits the amount of water that can percolate into the bedrock geologic units and the volume of groundwater available to migrate to other regions such as the valley alluvial groundwater basin on the Valley Floor (Brown and Caldwell, 2017).



Map showing precipitation source regions labeled Upper Watershed, Lower Foothills, and Valley Floor.
Figure 2

The Lower Foothills region occurs within a relatively narrow topographic band along the eastern edge of the Sacramento Valley and contains the outcrop of the Tuscan Formation in addition to small alluvial fans and other Recent sedimentary deposits that directly overlie the Lower Tuscan Formation. Rainfall that occurs in the Lower Foothills may percolate into the Tuscan Formation and the recent alluvial sediments or it may run off through local, ephemeral streams to the Valley Floor. In both cases, this precipitation source is potentially a direct source of recharge to the aquifer system.

Recharge mechanisms vary both by depth and area across the Vina Subbasin. Results from stable isotope data indicated that the only route by which the Upper Watershed provides recharge to the groundwater system in the vicinity of Butte Creek is through percolation. This includes percolation from Butte Creek and possibly the Sacramento River as they traverse the Vina Subbasin, or via percolation of applied surface water for irrigation diverted from Butte Creek or the Sacramento River. Evidence of the Upper Watershed water source was observed in isotope data in relatively shallow portions of the aquifer system (400 feet below ground surface (bgs) or shallower).

Isotope data from well samples indicated that intermediate and deeper depth intervals are recharged from rainfall and percolation in the Lower Foothills region. Rainfall in this region percolates directly into the Tuscan Formation at the outcrop or may percolate into the small alluvial fans and other sedimentary deposits in the Lower Foothills area.

2.3 Evaluation of Restoration and Recharge

The Evaluation of Restoration and Recharge within the Butte County Groundwater Basins (GEI Consultants, 2018) was a technical study prepared to support Butte County's compliance with California's Sustainable Groundwater Management Act (SGMA). Funded through a state grant, the report aimed to help the County and local agencies develop effective Groundwater Sustainability Plans by identifying feasible strategies to restore and enhance groundwater supplies. Its primary purpose was to evaluate where and how groundwater recharge could occur across the county's four subbasins and to provide tools for long-term water resource planning.

A major component of the report was the identification and evaluation of groundwater recharge opportunities. The study examined both direct recharge methods, such as recharge basins, flooding, and injection wells, and indirect (in-lieu) recharge, which involves substituting surface water for groundwater use. Using geographic information system (GIS) analysis, the report mapped suitable areas for recharge based on key criteria including soil type, aquifer properties, groundwater depth, land use, and environmental constraints. This "recharge constraints analysis" helped prioritize locations where recharge would be most effective and practical.

The report also evaluated water supply and implementation considerations for recharge projects. It emphasized that successful recharge depends not only on favorable hydrogeologic conditions but also on the availability of surface water, infrastructure for conveyance, and compatibility with existing agricultural or environmental uses. The study highlighted the importance of integrating recharge efforts into broader land and water management systems, including coordination with irrigation practices and protection of sensitive habitats.

The study further provided conceptual project designs and planning guidance to support future implementation. It outlined a range of potential recharge strategies and emphasized the need to tailor approaches to local conditions, recognizing that no single method would be effective across all areas. By offering practical design options and prioritization tools, the report created a foundation for incorporating recharge projects into SGMA-required groundwater sustainability planning.

In conclusion, the report found that increasing groundwater recharge will be a critical component of achieving long-term sustainability in Butte County, but it must be combined with careful management of groundwater demand. It concluded that suitable recharge opportunities do exist across the county, particularly where favorable soils, aquifer conditions, and water supplies align, but successful implementation will require coordinated planning, investment in infrastructure, and integration with land use practices. Overall, the study emphasized that a balanced strategy, combining recharge expansion, surface water use, and demand reduction, is necessary to prevent overdraft and ensure reliable groundwater resources into the future.

2.4 Hydrogeologic Framework of Selected Areas

The Hydrogeologic Framework of Selected Areas in Butte and Glenn Counties, California (Aqua Geo Frameworks, 2019) was developed to improve understanding of subsurface aquifer conditions in the northern Sacramento Valley, including the Vina Subbasin. The project used airborne electromagnetic (AEM) geophysical surveys to map the three-dimensional distribution of aquifer materials such as sands, gravels, and clays. This effort was undertaken to support groundwater sustainability planning under California's Sustainable Groundwater Management Act (SGMA), particularly to identify areas where managed aquifer recharge could be most effective.

A key finding of the AGF report is that recharge suitability in the Vina Subbasin is strongly controlled by the distribution of coarse-grained materials (sand and gravel) versus fine-grained deposits (silts and clays). The AEM data allowed delineation of zones with higher resistivity, which correspond to more permeable sediments capable of transmitting water downward into the aquifer system. These permeable zones are critical because successful recharge projects depend on both high infiltration capacity at the surface and sufficient permeability at depth to avoid perched conditions. In contrast, areas dominated by clay-rich basin deposits exhibit low permeability and are generally unsuitable for large-scale recharge projects because they limit infiltration and storage potential.

Within the Vina Subbasin, the report and related analyses highlight several geographic trends relevant for siting recharge projects. The report stated that higher recharge potential is associated with the eastern margin of the valley near the volcanic uplands (Tuscan Formation), where coarse alluvial fan and volcanoclastic deposits are more prevalent and hydraulically connected. However, as discussed in Section 3, the eastern part of the Vina Basin is underlain by a cemented unit that to the AEM study registers the same as permeable gravel units and as stated in Section 3, most of the eastern portion of the basin is not underlain by permeable material. As indicated above, this is also the conclusion of the LTA project.

Additional potentially favorable zones include areas adjacent to major stream channels and certain regions west and north of Chico where permeable soils and subsurface sediments coincide. Conversely, low-lying western areas, particularly those influenced by fine-grained floodplain deposits, tend to be less suitable due to thick clay layers that impede vertical flow.

Overall, the AGF framework provides a screening-level tool for prioritizing recharge project locations by integrating geophysical data with geology and soil information. The results suggest that optimal recharge sites in the Vina Subbasin are those where permeable surface soils align with thick, laterally connected sand-and-gravel aquifer units at depth, especially along the eastern side of the basin and near stream corridors, although as stated above, the eastern side is underlain by cemented units that are not conducive to groundwater recharge. These insights have been used to guide subsequent feasibility studies and pilot recharge efforts, helping local agencies focus investments on areas most likely to yield significant groundwater storage benefits while avoiding locations with poor infiltration or limited aquifer connectivity.

2.5 Vina Subbasin GSP

The Vina Subbasin GSP (Geosyntec, 2022) identifies groundwater recharge as a central strategy for achieving long-term sustainability, with a mix of conceptual, pilot, and infrastructure-based projects to be implemented over time. Rather than relying on a single large facility, the GSP promotes a distributed approach to recharge that combines on-farm practices, improvements to existing waterways, and targeted infrastructure investments. These projects are designed to capture excess surface water, especially during wet years—and increase infiltration into the aquifer while also supporting flood management and reducing groundwater pumping.

A major category of recharge projects focuses on managed aquifer recharge (MAR) on working lands, particularly agricultural fields. These include spreading floodwater or stormwater runoff across farmland to allow it to percolate into the ground, as well as pilot techniques such as reverse tile drain systems that deliver water below the root zone directly into permeable soils. The GSP envisions testing these approaches through pilot projects, collecting site-specific data, and scaling successful methods into broader programs. In addition, retaining stormwater on fields and modifying irrigation or drainage systems are identified as practical, near-term opportunities to expand recharge without major new infrastructure.

Another set of project's centers on enhancing recharge in natural and modified channels. This includes evaluating and implementing recharge opportunities along creeks, floodways, and engineered channels such as the Lindo Channel, where feasibility studies were also conducted using SGM grant funds. These efforts aim to “slow and spread” flows during high-water events to increase infiltration, while also coordinating with flood control operations. The GSP also evaluates opportunities to expand the use of available surface water supplies, including diverting high flows or unused water for recharge and increasing conjunctive use to reduce groundwater pumping in wetter periods.

Finally, the GSP outlines enabling actions needed to implement recharge projects, including feasibility studies, data collection, monitoring networks, and institutional coordination. Many recharge projects are still in planning or pilot phases, requiring additional technical evaluation,

funding, and partnerships—particularly with implementing entities like the Tuscan Water District, which is responsible for constructing and operating recharge infrastructure. Overall, the Vina GSP’s recharge program emphasizes adaptive management, starting with pilot projects and feasibility analyses and transitioning to larger-scale implementation as projects are proven effective and funding becomes available.

2.6 Butte County Recharge Action Plan

The Butte County Recharge Action Plan is a countywide strategy adopted in February 2024 to increase groundwater recharge and improve long-term water sustainability. It was developed by the Butte County Department of Water and Resource Conservation in collaboration with the Butte County Water Commission, Butte County Technical Advisory Committee, and local groundwater sustainability agencies. The plan was created largely in response to California’s recent drought conditions and a 2023 state executive order that made it easier to capture and divert floodwater for groundwater recharge. Its core purpose is to address declining groundwater levels—especially in the Vina Subbasin—by taking advantage of wet-period water supplies to replenish aquifers and improve resilience to future droughts.

The plan establishes a clear goal of expanding average annual groundwater recharge by about 20,000 acre-feet. It is intended as a practical, near-term action framework that identifies specific opportunities and steps to increase recharge, while also documenting existing conditions, scientific understanding, and available resources. A key focus is leveraging high-flow storm events—particularly atmospheric river storms—to capture excess water that would otherwise leave the region. The plan emphasizes collaboration among local agencies, landowners, and water managers to implement projects at both basin-wide and site-specific scales.

To achieve its goals, the Recharge Action Plan outlines five main categories of actions. These include spreading and slowing flood flows to allow more water to infiltrate into the ground, retaining stormwater on agricultural fields, managing flows in natural channels to increase infiltration, expanding use of existing surface water supplies, and identifying policy or regulatory changes needed to support recharge efforts. Many of these strategies rely on enhancing natural processes rather than building large new infrastructure, such as using farmland or rangeland to temporarily store water during wet periods.

Overall, the plan serves as a roadmap for improving groundwater conditions in Butte County by aligning local actions with broader state goals for sustainable groundwater management. It prioritizes near-term, achievable projects while also setting the stage for longer-term investments, funding opportunities, and adaptive management. By focusing on capturing excess water during wet years and recharging aquifers, the plan aims to stabilize groundwater levels, protect domestic wells, support agriculture, and increase the region’s resilience to climate variability and future water shortages.

2.7 Feasibility of Enhanced Recharge in Lindo Channel

The April 2026 Feasibility of Enhanced Recharge in the Lindo Channel (Geosyntec, 2026c) report concludes that the Lindo Channel represents a highly promising natural recharge feature that can be leveraged across the Vina Subbasin. The study shows that the unlined, gravel-rich channel has

very high infiltration capacity, with measured rates commonly exceeding 100 ft/day and reaching several hundred ft/day in many locations. These conditions confirm that significant volumes of stormwater and diverted creek flows can rapidly percolate to groundwater, with modeled recharge on the order of tens to over 100 acre-feet per day during flow events. This demonstrates that similar natural channels and coarse alluvial features throughout the subbasin are strong candidates for future recharge projects.

The report shows that groundwater levels in nearby wells respond to channel flows, confirming active recharge. Importantly, the most favorable conditions were identified in areas west of Highway 99 where cemented geologic units pinch out, allowing more permeable alluvial deposits to be exposed and connected to the aquifer consistent with the findings of the LTA project as discussed in Section 2.1. This geologic transition zone is especially well suited for recharge and provides a guide for targeting other high-potential areas across the Vina Subbasin.

3. KEY HYDROSTRATIGRAPHIC PROPERTIES RELEVANT TO RECHARGE

Critical parameters used to assess the suitability of a potential site for groundwater recharge include the following.

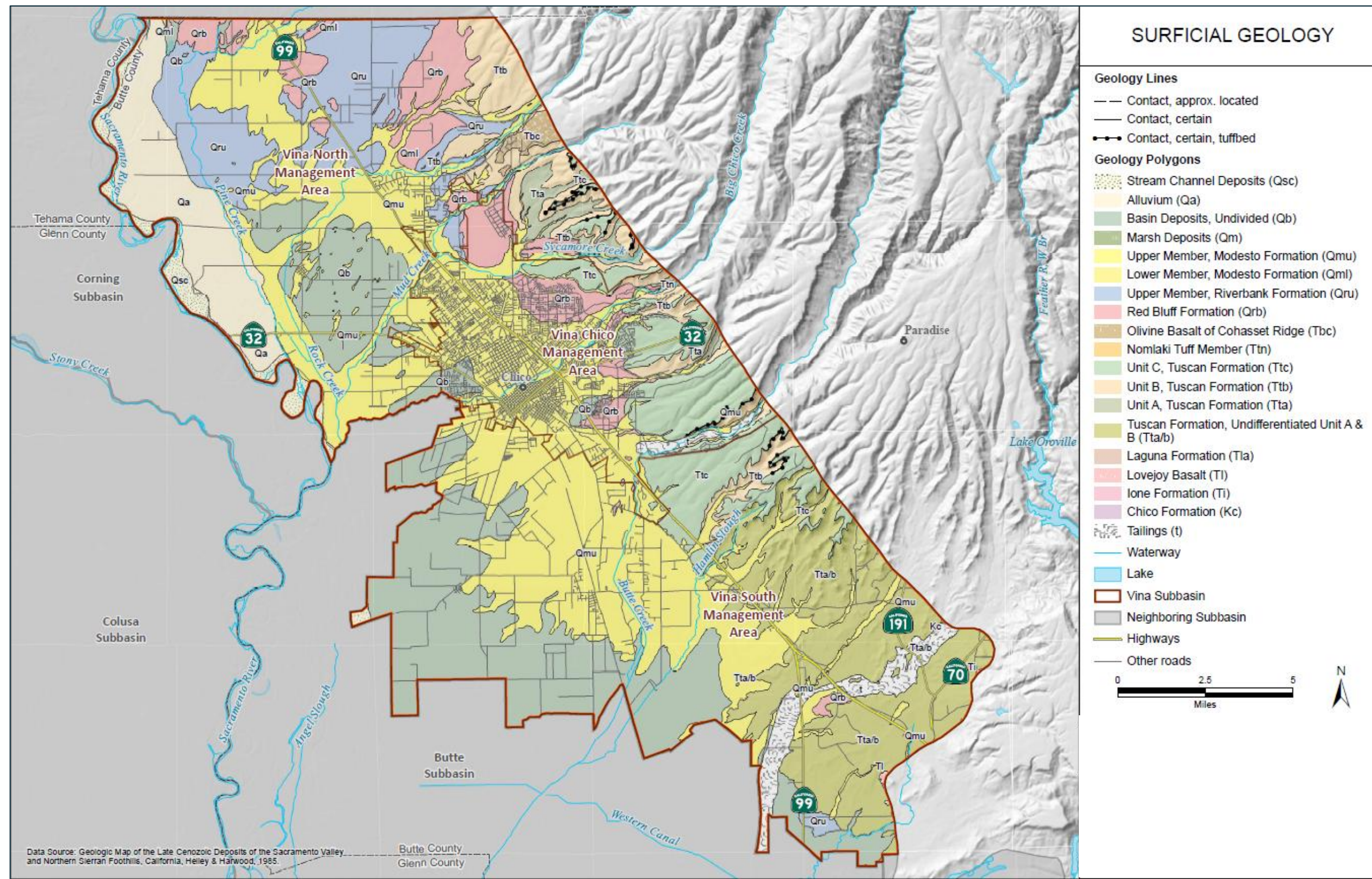
- There must be a viable pathway for recharge water applied at the surface to migrate to the underlying groundwater aquifer at a reasonable rate. Low infiltration rates will limit the volume of water that can be placed within a facility.
- There must be sufficient storage capacity within the unsaturated zone, which is reflected by the depth to groundwater. Where groundwater is shallow, recharge water may mound and potentially reach the ground surface.
- The underlying first groundwater zone must be sufficiently permeable to accept recharge water at a reasonable rate in order to minimize groundwater mounding.

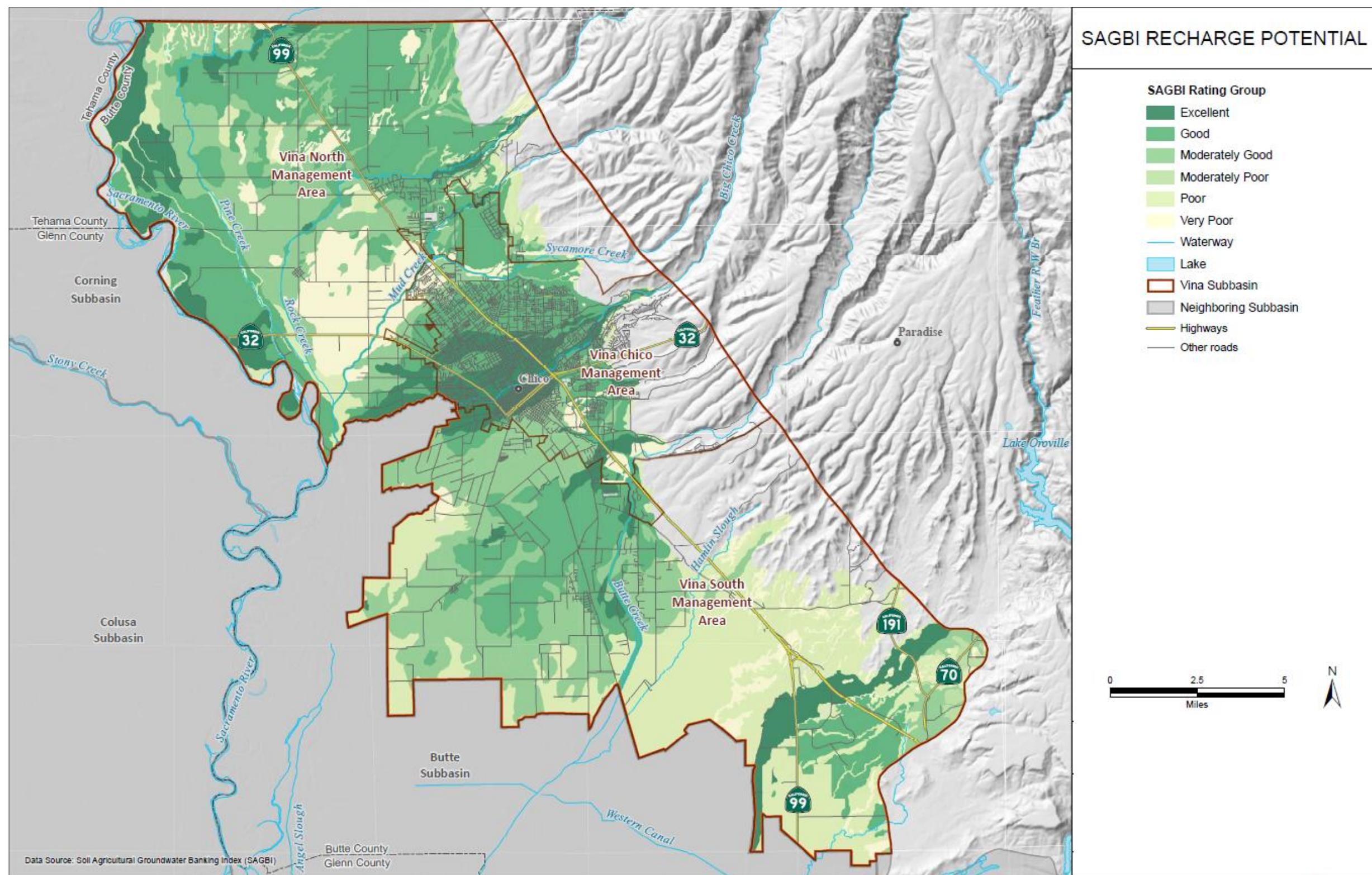
Previous studies discussed in Section 2 provided an initial regional-scale evaluation of these parameters. Detailed descriptions of the hydrogeologic framework of the Vina Subbasin, including initial assessments of recharge suitability, are presented in the Groundwater Sustainability Plan (GSP; Geosyntec, 2022) and the Lower Tuscan Aquifer (LTA) Project Final Report (Brown and Caldwell, 2013). A geologic map of the subbasin is provided in Figure 3. This project follows the nomenclature established in the LTA study, which describes the Vina Subbasin aquifer system as a heterogeneous sequence of alluvial and volcanic deposits of the Tuscan Formation overlain by Quaternary deposits. The Quaternary deposits include formations shown on Figure 3 such as the Modesto and Riverbank Formations.

To evaluate areas where recharge water can migrate to underlying groundwater at a reasonable rate, both the GSP and the GEI (2018) study reviewed regional screening tools such as the Soil Agricultural Groundwater Banking Index (SAGBI) and DWR's Airborne Electromagnetic (AEM) data. These tools provide useful initial screening but only a broad, or "blurry," representation of site-specific recharge potential.

Figure 4 depicts SAGBI recharge potential across the subbasin. SAGBI provides an integrated assessment of recharge suitability based on five controlling factors: deep percolation capacity (hydraulic conductivity), root zone residence time, topography, chemical limitations such as salinity, and soil surface condition. High SAGBI ratings indicate soils capable of sustaining deep percolation without prolonged saturation or degradation of soil structure, making them suitable for agricultural recharge methods such as field flooding or on-farm recharge. A key limitation of SAGBI is that it considers only the upper approximately 10 to 15 feet of soil and therefore does not characterize deeper subsurface conditions.

To evaluate recharge pathways at greater depths, DWR's AEM survey data for the subbasin were reviewed. For this study, the AEM data were downloaded and used to construct a three-dimensional subsurface model using Leapfrog software. AEM data characterizes subsurface





lithology based on variations in electrical resistivity. Coarse-grained materials such as sands and gravel typically exhibit higher resistivity due to lower surface conductivity, whereas clay-rich sediments exhibit lower resistivity because of their higher conductivity and bound water content. Resistivity values are expressed in ohm-meters. Based on regional experience, resistivity values were classified into relative permeability categories as follows: values less than 12 ohm-meters represent fine-grained, low-permeability materials; values between 12 and 20 ohm-meters represent marginal permeability; values between 20 and 30 ohm-meters represent permeable materials; and values greater than 30 ohm-meters represent coarse, highly permeable materials.

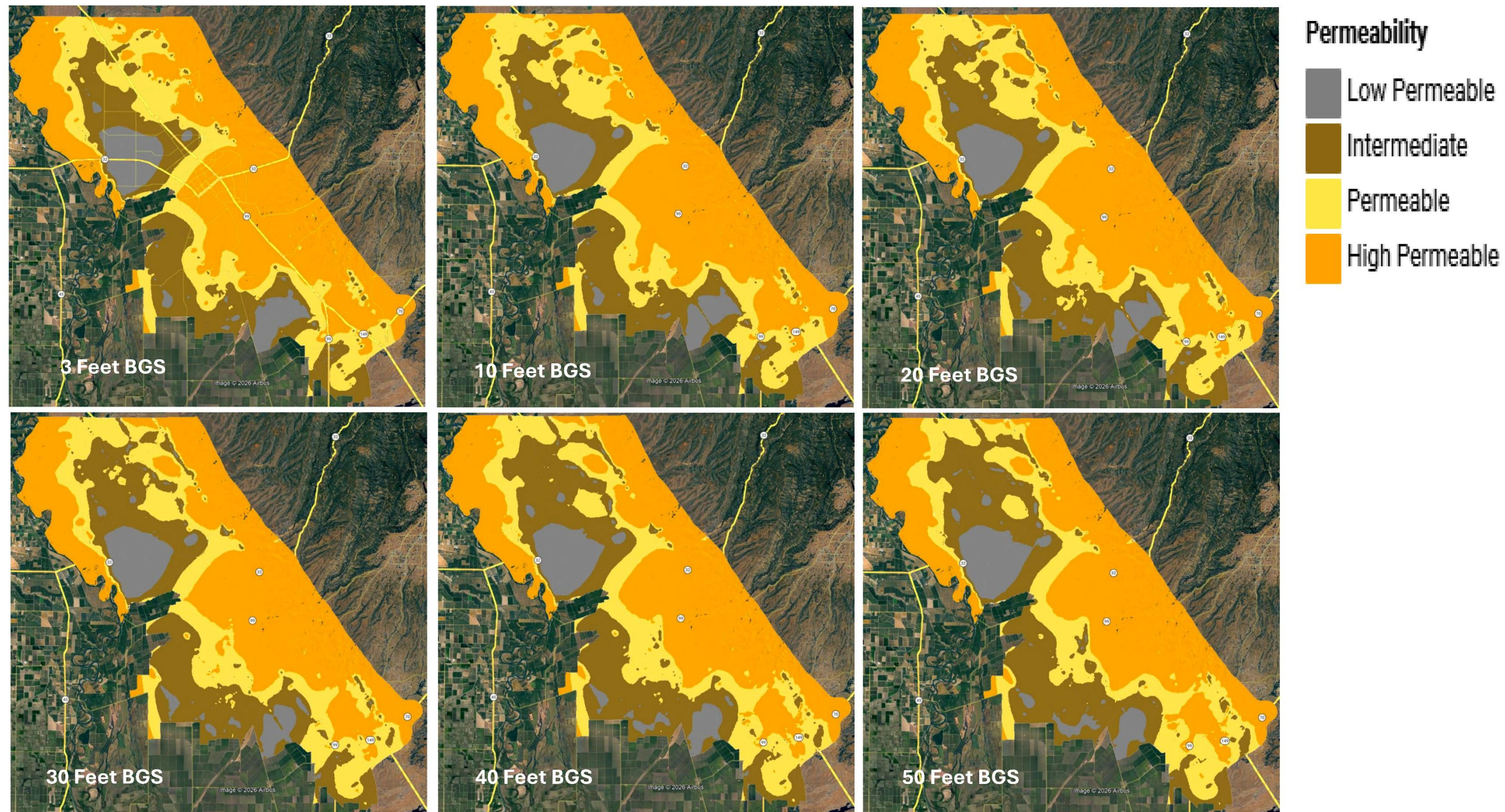
Figure 5 shows AEM depth slices from the three-dimensional subsurface model. The results indicate that multiple areas within the basin appear favorable for groundwater recharge. However, an important limitation of AEM interpretation is that high resistivity values may also correspond to rock or cemented materials, such as lahar deposits within the Tuscan Formation, which can exhibit low permeability despite their resistivity signature.

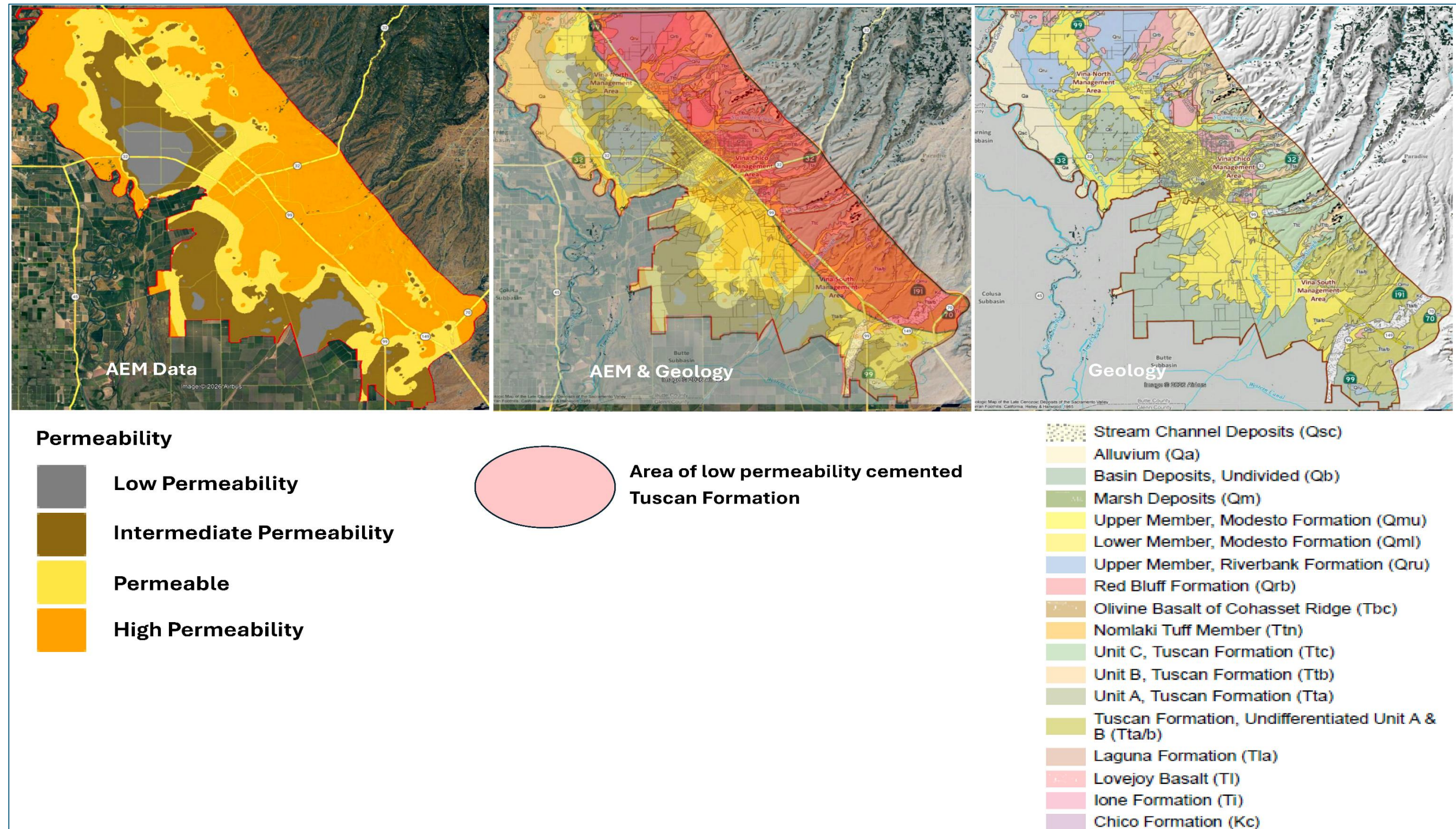
To address this limitation, Figure 6 overlays mapped extents of the Tuscan Formation outcrops along the eastern portion of the basin onto the AEM results. As discussed in the LTA Final Report, these areas generally exhibit poor recharge potential. Other regional tools, including Stanford's Fastpath application and DWR's Basin Characterization datasets, show similar results.

In valley areas of the subbasin, the depth to the first groundwater zone generally ranges from about 30 to 50 feet below ground surface, with greater depths observed farther from valley centers. In the eastern foothills, groundwater depths are typically deeper. For example, monitoring wells at the Chico Airport screened in the first water-bearing zone indicate groundwater at approximately 80 feet below ground surface (Geocon, 2025). However, as discussed in Section 5, perched groundwater conditions were observed at several sites, with water encountered at depths of approximately 5 to 10 feet. Perched aquifers form where downward percolation is impeded by a low-permeability layer, resulting in localized and often transient zones of saturation. The presence of perched conditions may limit the effectiveness of groundwater recharge.

Results from the LTA Project indicate that large portions of the underlying aquifer system have high hydraulic conductivities, greater than 100 feet per day, suggesting sufficient capacity to accept recharge water. The Lindo Channel Recharge Investigation (Geosyntec, 2026c), Component 4 of the Vina SGMA Grant, evaluated the potential to enhance recharge by increasing flows within the channel. The study showed that sediments west of Highway 99 are highly permeable and capable of supporting recharge rates of up to approximately 100 acre-feet per day when flow is present. In this area, the first groundwater zone, located at depths of 40 to 50 feet, has sufficient capacity to accept recharge water. In contrast, sediments east of Highway 99 are more cemented, and little direct recharge to deeper zones likely occurs.

Overall, although the Vina Subbasin has historically been considered favorable for managed aquifer recharge due to its thick alluvial system and moderate storage capacity, findings from the LTA investigations and the Lindo Channel Recharge Study indicate that recharge potential may be more limited and spatially variable than previously assumed, particularly along the eastern portion of the basin. Detailed hydrogeologic characterization of the Tuscan Formation shows that





extensive lahar-derived volcanic units are commonly well cemented, resulting in low primary permeability and limited vertical hydraulic connectivity. These cemented units are prevalent across much of the eastern alluvial fan and foothill transition zone and act as semi-confining to confining layers that restrict downward percolation and reduce the effectiveness of surface spreading recharge.

LTA findings further indicate that, although localized fracture flow and interbedded permeable zones are present resulting in natural recharge from precipitation and runoff events, widespread recharge from surface application in Tuscan outcrop areas is generally limited. Recharge to deeper aquifers may occur only where preferential pathways are present. Accordingly, the most favorable areas for managed recharge basins shift away from the eastern alluvial fans toward more localized zones where permeable near-surface materials overlie less restrictive subsurface conditions. These include stream corridor deposits such as Butte Creek and Big Chico Creek downstream of foothill outcrops where coarse alluvium is thicker and better connected, portions of the central subbasin near Chico where younger and less cemented alluvial deposits are present, and areas where subsurface investigations confirm the absence of cemented Tuscan units or identify transmissive interbeds.

In contrast, much of the eastern flank, which is underlain by cemented Tuscan lahar units, and portions of the western basin dominated by fine-grained floodplain deposits are less suitable for direct surface spreading recharge. However, these areas likely provide significant natural recharge inflow to the subbasin and may still be conducive to smaller-scale managed recharge efforts intended to address localized flooding conditions.

4. FIELD METHODS AND PROCEDURES

As discussed in the project identification TM (Appendix A), after site visits, discussions with landowners, and review of existing information, seven sites were selected for field investigations. These sites were selected from a list of 15 sites assessed as shown in Figure 7. Field investigations included towed transient electromagnetic surveys (tTEM), cone penetrometer tests (CPT), drilling and sampling of soil borings, infiltration testing, installation of temporary groundwater monitoring wells, installation of stilling wells within streams and creeks, and water quality testing. Table 1 summarizes the activities conducted at each of the sites.

Table 1. Investigation activities conducted at each site.

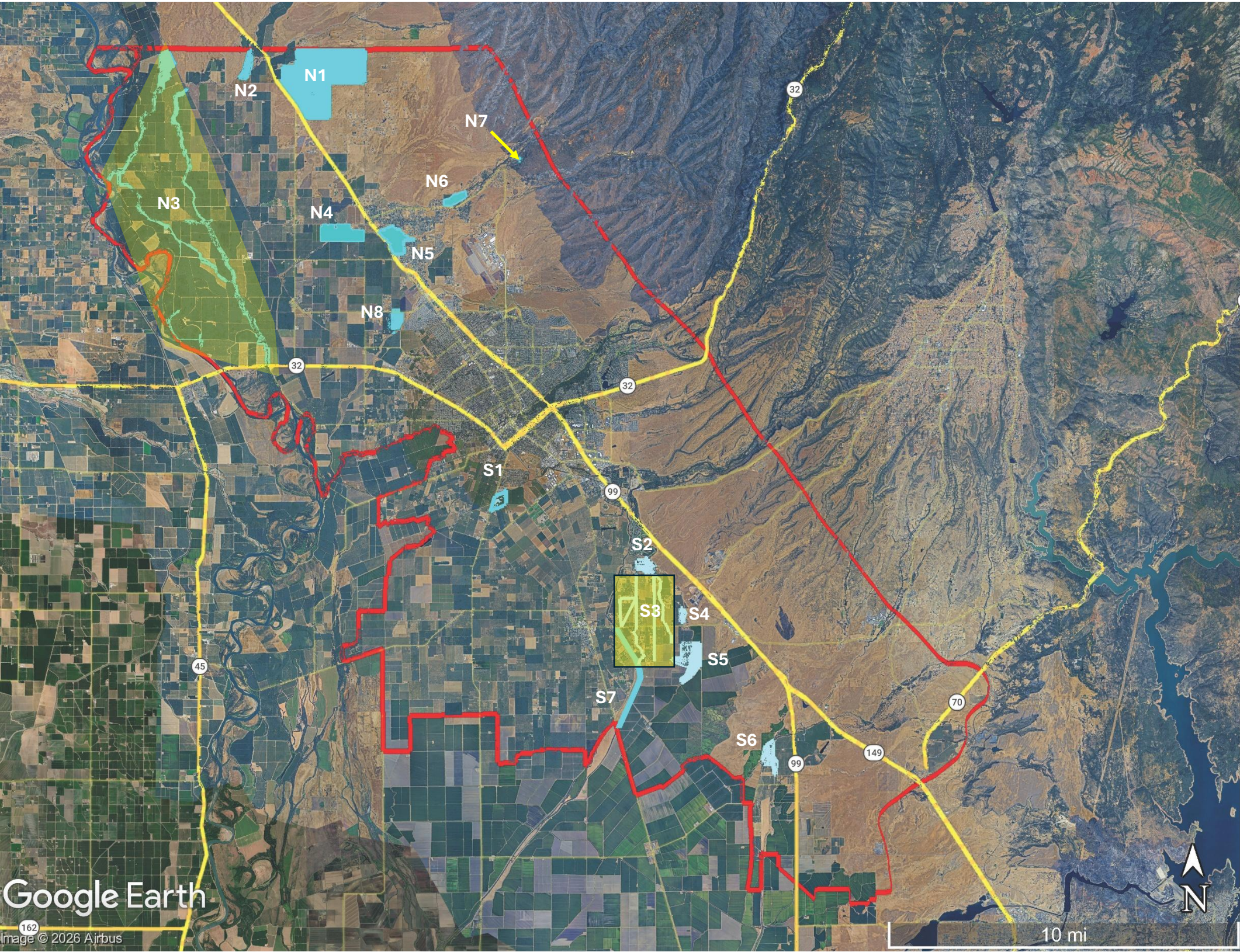
Activity	N3	N4	N5	N6	N8	S1	S6
tTEM		•	•	•	•	•	•
CPT			•			•	
Soil Borings		•	•	•		•	•
Infiltration Testing	•	•	•	•		•	•
Monitoring Well		•				•	•
Stream Stilling Wells		•	•			•	
Water Quality Testing		•				•	•

Field methods and procedures conducted for pilot testing are discussed in Section 6 for each of the selected sites. All field activities described in this section were conducted under the oversight of a Geosyntec California-licensed Professional Geologist.

4.1 Field Setup and Coordination

Prior to finalizing the locations for invasive field activities such as CPT points and soil borings, a site visit was conducted by field staff to ensure ability to access sites, location concerns, and utility marking. Only minor adjustments to locations were made in the field due to access issues. The final locations were marked with a stake and recorded using a GPS application. The location of points is provided in figures in the following sections.

After clearance, drilling permits were obtained from the Butte County Environmental Health Division (BCEHD) and the Underground Service Alert (USA) were contacted for clearance of underground utilities. Table 2 summarizes the permit number and USA ticket number for each of the points. Copies of these permits are provided in Appendix C.



Site	Size (Acres)
N1	1,900
N2	50
N3 ¹	700
N4	342
N5	242
N6	92
N7	5
N8	103
S1	88
S2	93
S3	7 miles ²
S4	29
S5	297
S6	133
S7 ³	3.2 miles

- 1. The highlighted cells are the sites selected for field investigations.
- 2. The site is along a linear pathway on easements next to canals/drainage ways.
- 3. Pipeline.

Map showing locations of potential groundwater recharge sites labeled across the study area.
Figure 7

Table 2. Permit and USA Ticket Numbers

Location	USA Ticket Number	BCEHD Permit Number
N4	2025081500622-000	EH-MWSB-25-000703
	2025081500701-000	
	2025081500731-000	
	2025081500764-000	
	2026011301432-000	
N5	2025081204051-000	EH-MWSB-25-000703
	2025081300409-000	EH-MWSB-26-0267
	2026011301432-000	EH-MWSB-26-0268
N6	2026040201165-000	EH-MWSB-26-0269
		EH-MWSB-26-0270
S1	2025081204143-000	147750171
	2025081302591-000	EH-MWSB-25-000855
	2025101701930-000	EH-MW-SB-15-000856
S6	2026010701902-000	EH-MWSB-26-0015
	2026010701837-000	EH-MWSB-26-0016
		EH-MWSB-26-0029

4.2 tTEM Surveys

Transient electromagnetic (TEM) or time-domain electromagnetic (TDEM) investigations provide characterization of electrical properties of earth materials from the land surface downward using electromagnetic induction. **Error! Reference source not found.** 1 shows the tTEM version of TEM that is conducted by pulling the TEM instrumentation behind an all-terrain vehicle (ATV).

To collect TEM data, an electrical current is sent through a large loop of wire consisting of multiple turns, which generates an electromagnetic (EM) field. This is called the transmitter (Tx) coil. After the EM field produced by the Tx coil is stable, it is switched off as abruptly as possible. The EM field dissipates and decays with time, traveling deeper and spreading wider into the subsurface. The rate of dissipation is dependent on the electrical properties of the subsurface (controlled by the material composition of the geology, including the amount of mineralogical clay, the water content, the presence of dissolved solids, the metallic mineralization, and the percentage of void space). At the moment of turnoff, a secondary EM field, which also begins to decay, is generated within the subsurface. The decaying secondary EM field generates a current in a receiver (Rx) coil. This current in the Rx coil is measured at several different moments in time (each moment being



Photograph 1. The tTEM setup and Site N5.

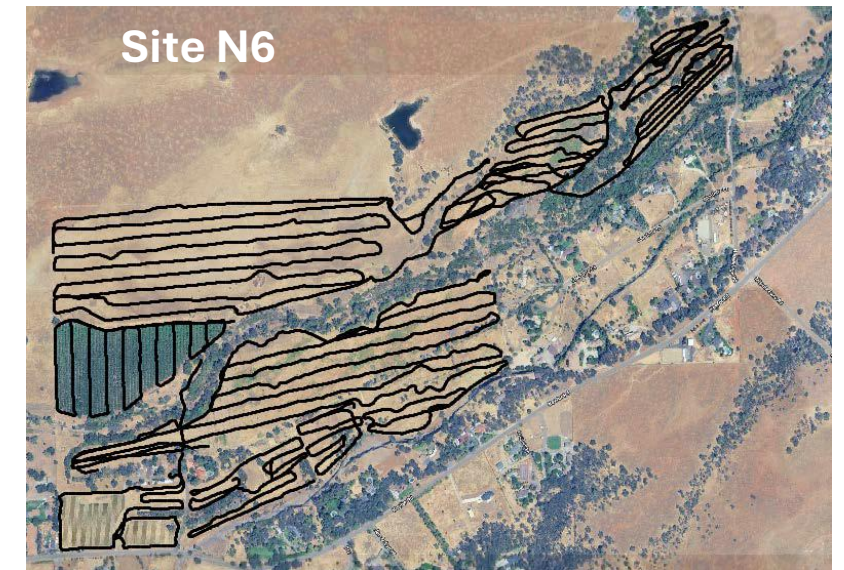
within a time band called a “gate”). From the induced current, the time rate of decay of the magnetic field, B , is determined (dB/dt). When compiled in time, these measurements constitute a “sounding” at that location. Each TEM measurement produces an EM sounding at one point on the surface. A more detailed discussion of this method is presented in the geophysical reports for each site provided in Appendix D.

As shown on Table 1, six tTEM surveys were conducted at sites N4, N5, N6, N8, S1, and S6 (Figure 7). Figure 8 illustrates the tTEM survey lines conducted at each of these sites. The tTEM data were processed using Aarhus Workbench version 6.8.0.0.

4.3 CPT Program

The CPT drilling methodology was used to further evaluate soil lithology and geotechnical soil properties at sites S1 and N5 (Figure 7). Due to drilling refusal at these two sites, this method was not attempted at the other sites. The CPT method involves hydraulically pushing a cone penetrometer into the ground and recording the resistance. Figure 9 illustrates the CPT instrument. Based on published correlations, the data obtained are used to estimate stratigraphy, soil type, groundwater depth, and in situ parameters. The CPT data can also be used to estimate hydraulic conductivity values. CPT soundings are performed in accordance with revised American Society for Testing and Materials (ASTM) International standards (D 5778-12).

In addition to the CPT tool, a hydraulic profiling tool (HPT) was run simultaneously with the CPT. The HPT system is designed to evaluate the hydraulic behavior of unconsolidated materials. As the probe is pushed, clean water is injected through a screen on the side of the HPT probe at a flow rate usually less than 300 milliliters per minute (mL/min). The injection pressure, which is



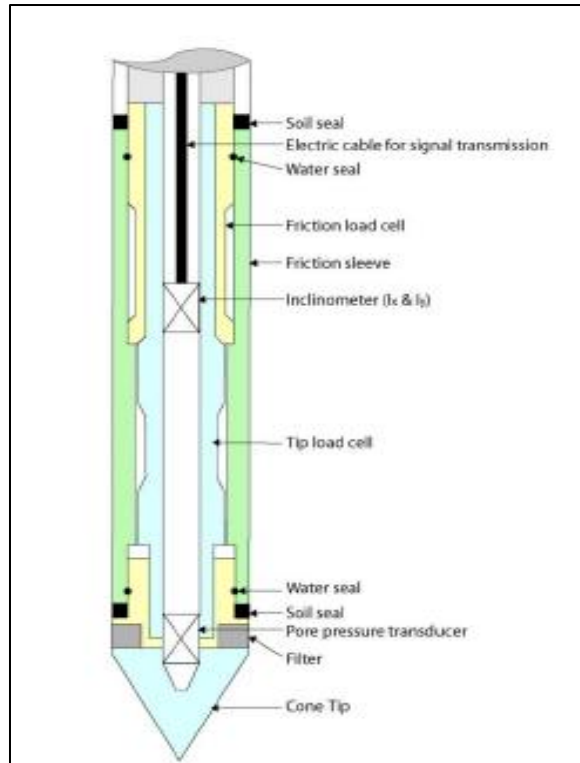


Figure 9. Diagram of a cone penetrometer testing (CPT) instrument and its components (Appendix E)

monitored and plotted with depth, is an indication of the hydraulic properties of the soil. A relatively low-pressure response indicates a relatively large grain size and the ability to easily transmit water. However, a relatively high-pressure response indicates a relatively small grain size, which correlates with the inability to transmit water.

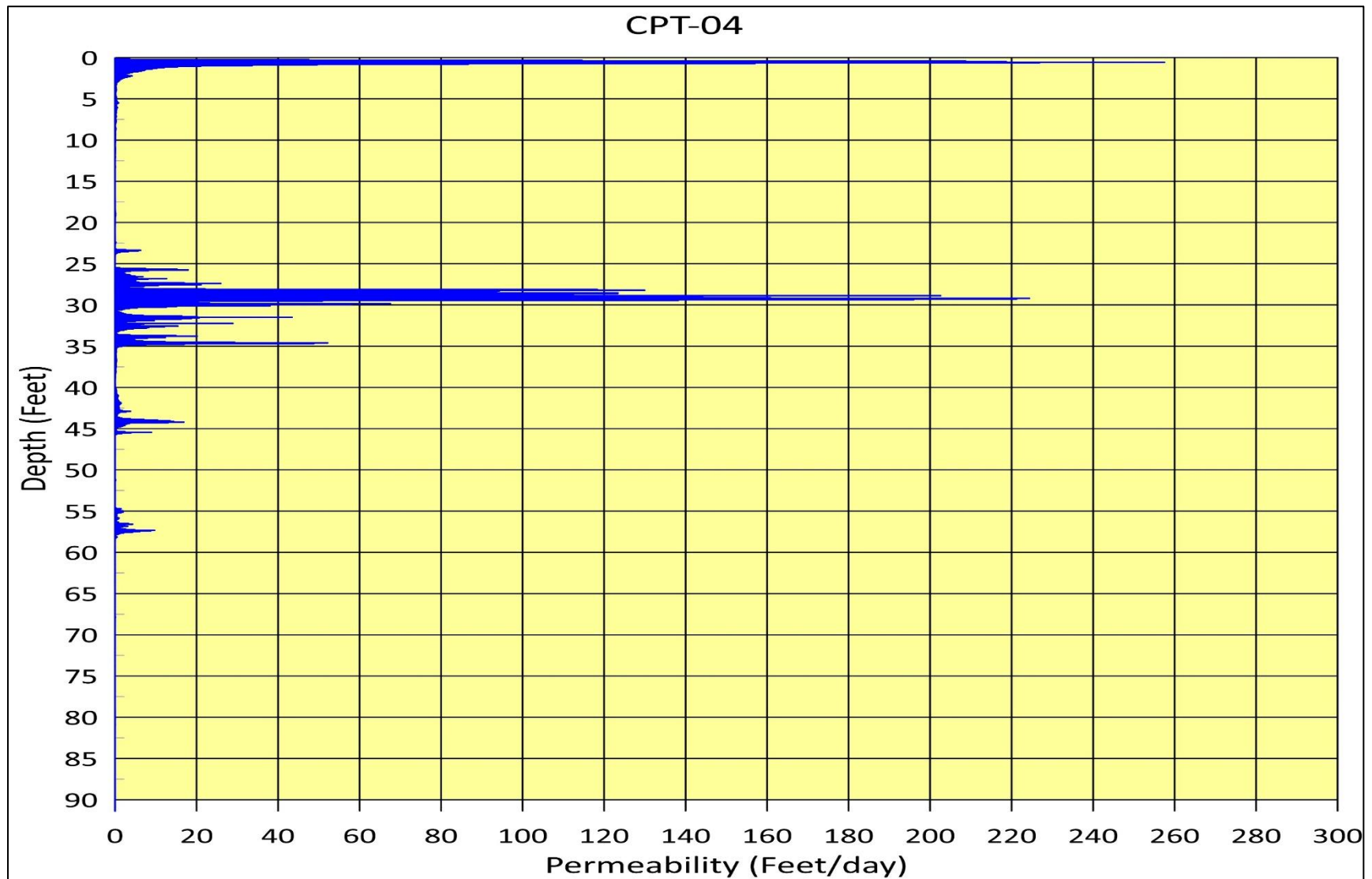
The CPT survey for both sites was conducted from September 3, 2025, to September 5, 2025, by ConTec of Richmond, California, a C-57 licensed driller. Photograph 2 shows the ConTec CPT rig used for the project. A copy of the ConTec report is provided in Appendix E. Figure 10 provides an example of the primary CPT plot provided by ConTec that includes soil type. Figure 11 provides a graph illustrating the estimated saturated infiltration rates that are also produced from the CPT survey using normalized interpretative soil behavior types (SBTn). Eight CPT/HPT points were completed at Site S1, designated CPT-1 through CPT-8, and two were completed at Site N5, designated CPT-B1 and CPT-B2. Figure 12 shows the location of the CPT points. Table 3 summarizes completion date, total depth, latitude, and longitude for each point. As discussed in the introduction to this section, many CPT points encountered refusal where the rig could not push the CPT instrument any further and the desired depth was not obtained. It is believed that the hard material encountered was either a cemented unit or large gravels. Because these hard units were encountered at the first two sites, the CPT program was discontinued for the other sites. After completion of each CPT/HPT point, the boreholes were grouted in accordance with BCEHD guidelines.

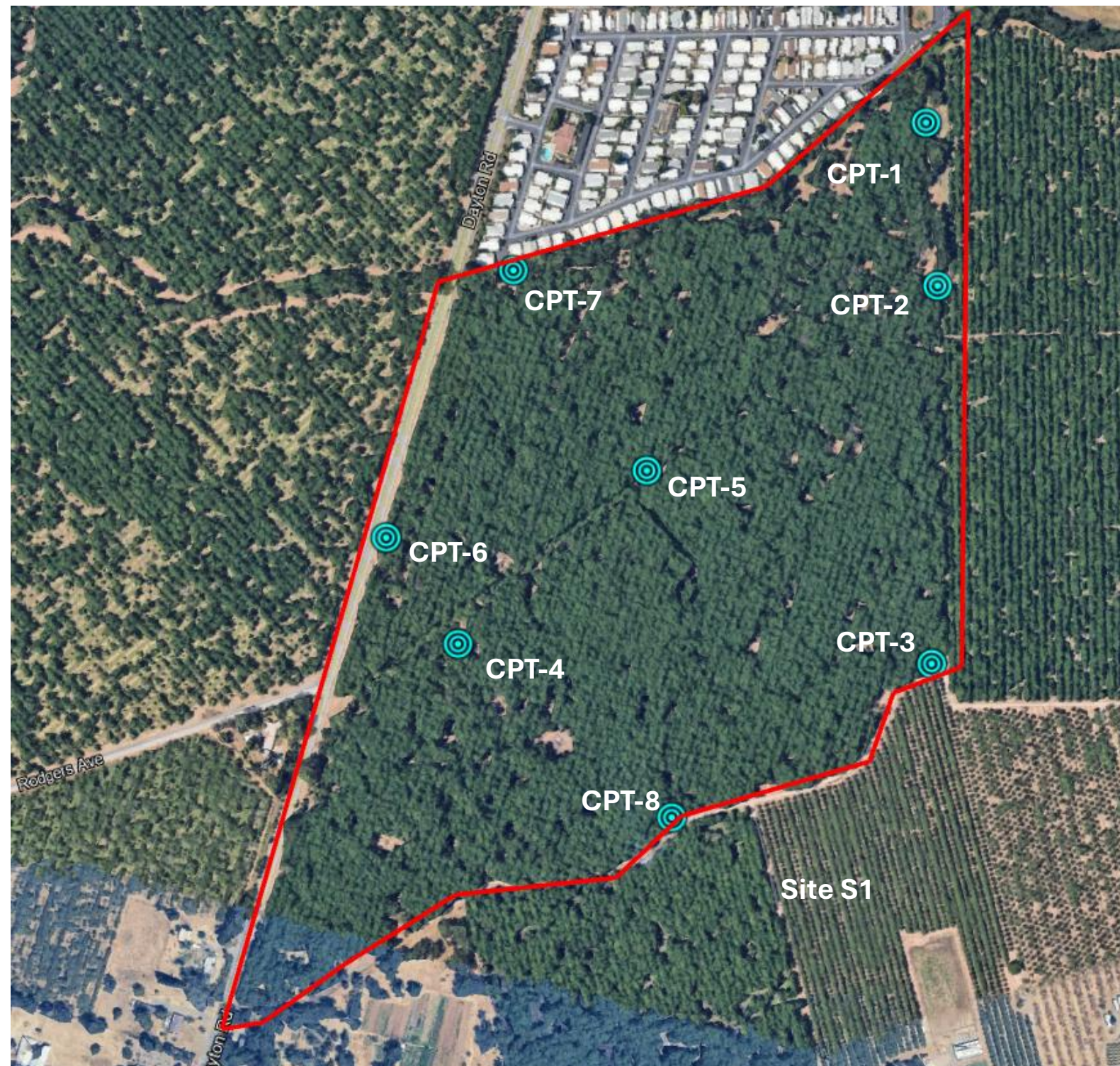


Photograph 2. ConTec CPT rig.

Table 3. Summary of CPT Points

Site	CPT Point	Date	Total Depth (feet bgs)	Latitude	Longitude
S1	CPT-1	9/3/2025	30.92	39.701596	-121.843886
	CPT-2	9/3/2025	41.99	39.700099	-121.843748
	CPT-3	9/4/2025	42.08	39.696631	-121.843817
	CPT-4	9/4/2025	91.37	39.696813	-121.849471
	CPT-5	9/4/2025	28.30	39.698404	-121.847217
	CPT-6	9/4/2025	47.74	39.695029	-121.850329
	CPT-7	9/3/2025	37.65	39.700240	-121.848808
	CPT-8	9/4/2025	33.79	39.695220	-121.846920
N5	CPT-B-1	9/5/2025	18.04	39.805884	-121.908867
	CPT-B-2	9/5/2025	17.06	39.806007	-121.909449





4.4 Soil Borings

Fifteen soil borings were completed for the project, four each at sites N5, N6 and S6, two at site S1 and one at N4. Monitoring wells were completed for one of the soil borings at sites N4, S1, and S6 as discussed in Section 4.5. The locations of the soil borings are shown on Figure 13. The borings were drilled using the sonic drilling method by Cascade Drilling LP for Sites S1 and N4, Geocentric Drilling Inc. for Site S6, and Penecore Drilling for Sites N5 and N6. Photograph 3 shows a sonic rig setup at Site S6. This method allows collection of continuous core samples that provide a detailed lithologic assessment at each boring for the presence of permeable materials. Photograph 4 shows a picture of a core sample from one of the soil borings. This method also allows performance of downhole permeability testing as discussed in Section 4.6.

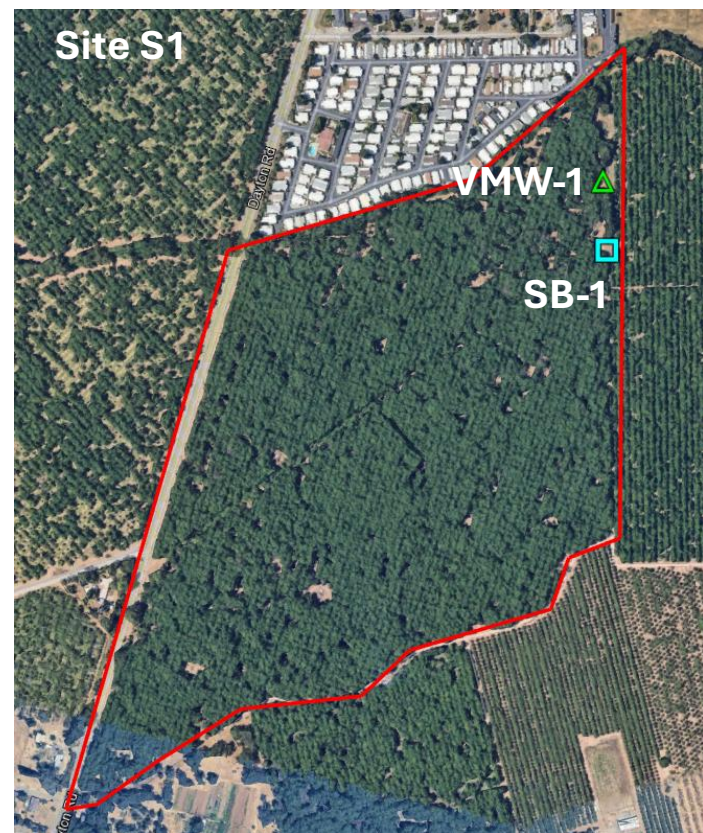
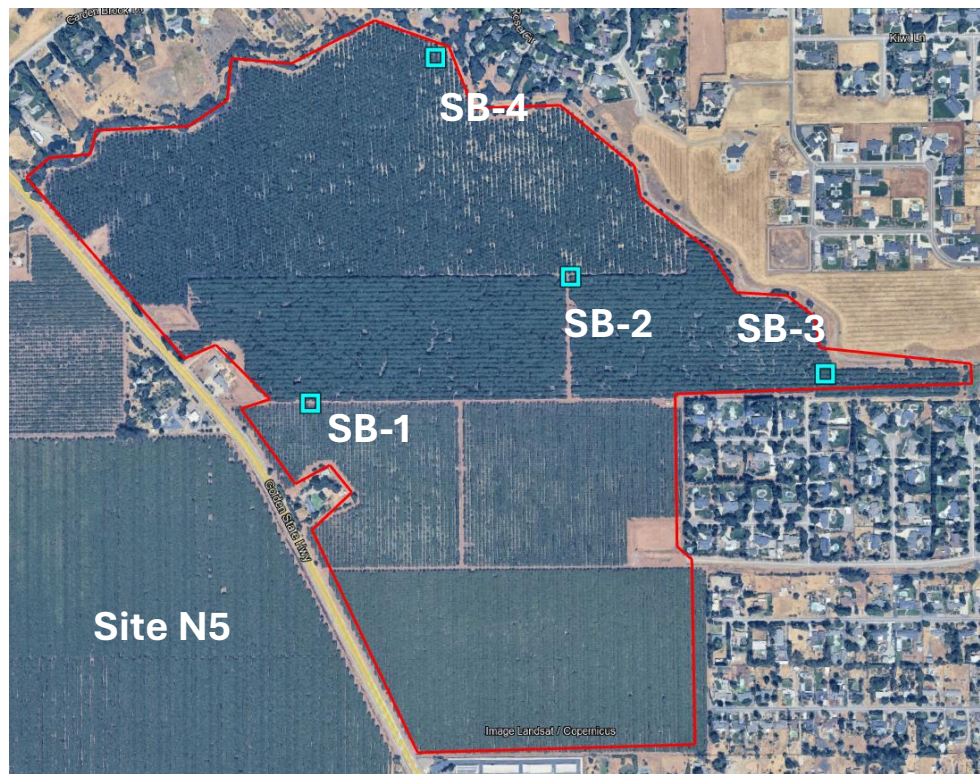
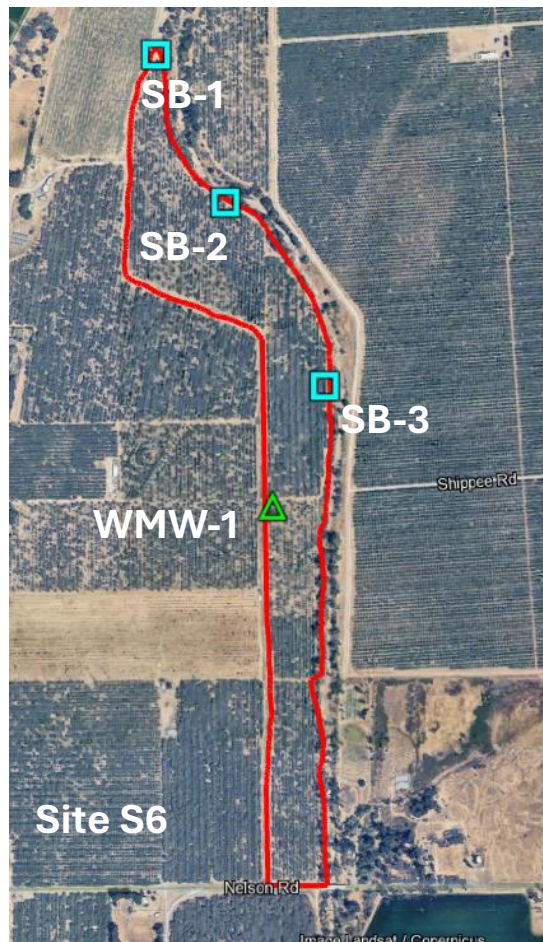
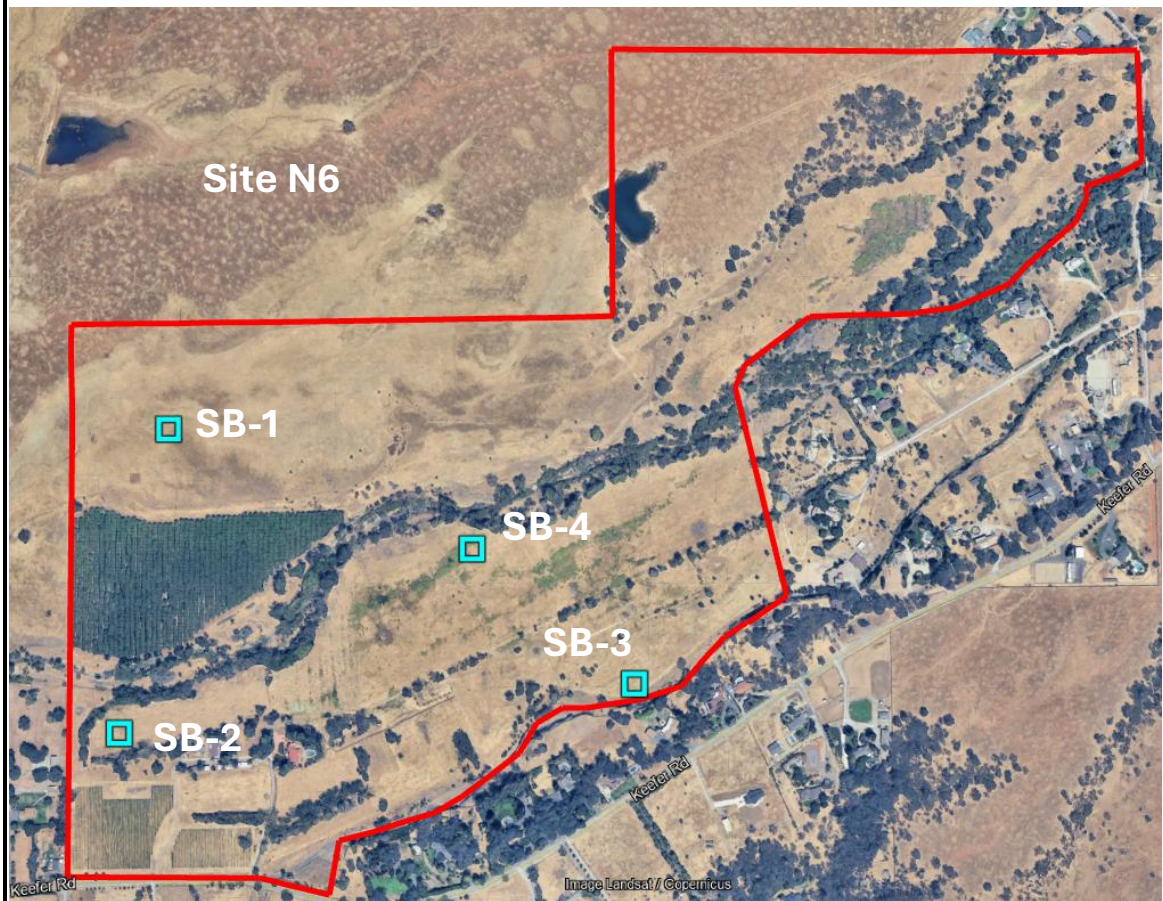
Lithology was logged by the field geologist according to methods described in ASTM International D2488-84 and recorded continuously on a geologic boring log. Copies of the geologic boring logs are provided in Appendix F. Table 4 provides a summary of the soil borings including date drilled, site location, and total depth. As stated above, Section 4.6 discusses the methods and procedures used for the downhole permeability testing. Total depths were selected to provide information on the unsaturated zone and the upper saturated zone.

4.5 Well Installation

At Sites N4, S1, and S6, one of the soil borings was converted to a temporary groundwater monitoring well designated RMW-1 (Site N4), VMW-1 (Site S1) and WMW-1 (Site S6). Figure 13 shows the locations of soil borings and monitoring wells. Using the information collected during the drilling of the soil borings, a California Certified Hydrogeologist developed the final well design including screen intervals, slot size and gravel pack size. Table 5 summarizes the well completion details. Well completion diagrams are provided in Appendix F. Each well was installed using the following procedures:

- The well casing, including a 2-inch bottom cap and screen, were suspended in the borehole to the desired depth.
- The total depth of the well was then confirmed by hard-tagging the inside of the well.
- The filter pack material was then placed to approximately 2 to 4 feet above the top of the screen interval. During placement, the top of the filter pack was confirmed by hard tag measurements. A 2 to 3-foot seal of bentonite chips was then placed above the filter pack.
- The remainder of the annular seal was then filled with a cement grout in accordance with BCEHD requirements.

After installation, a steel locking well case was cemented in place surrounded by steel cement filled bollards for protection. After a minimum of 24 hours after placement of the grout seal, each well was developed by bailing, surging, and pumping. Groundwater samples were collected from each of the new wells as discussed in Section 4.7. Photograph 5 shows the surface completion well VMW-01.



□ Soil Boring

△ Soil Boring Converted to Monitoring Well

Map showing soil boring and monitoring well locations across multiple sites.

Figure 13



Photograph 3. Sonic drill rig used for completion of soil borings.



Photograph 4. Continuous core sample collected during drilling.

Table 4. Summary of soil boring completions

Site	I.D	Date Drilled	Total Depth (feet bgs)	Latitude	Longitude
S1	VSB-2	11/4/2025	77	39.700099	-121.843739
	VMW-01	11/3/2025	57	39.700945	-121.843797
S6	WSB-1	1/15/2026	55	39.595493	-121.702973
	WSB-2	1/15/2026	60	39.592992	-121.701452
	WSB-3	1/14/2026	63	39.589882	-121.699270
	WMW-01	1/14/2026	60	39.587847	-121.700409
N4	RMW-01	1/16/2026	60	39.808848	-121.923982
N5	NSB-1	4/7/2026	15	39.804589	-121.906144
	NSB-2	4/7/2026	40	39.806627	-121.900683
	NSB-3	4/7/2026	40	39.805062	-121.895342
	NSB-4	4/6/2026	20	39.810163	-121.903520
N6	RiSB-1	4/9/2026	30	39.824732	-121.875630
	RiSB-2	4/9/2026	40	39.820685	-121.876357
	RiSB-3	4/8/2026	70	39.821339	-121.867463
	RiSB-4	4/9/2026	60	39.820685	-121.876357



Photograph 5. Surface completion of monitoring well as Site S1

Table 5. Well completion details.

Well I.D.	VMW-01	WMW-01	RMW-01
Site	S1	S6	N4
State Well Completion Number	WCR2025-011984	WCR2026-002384	WCR2026-004392
Date Completed	11/4/2025	1/15/2026	1/16/2026
Total Boring Depth	57	60	60
Boring Diameter	6	6	6
Screen Interval (feet bgs)	25-45	35-50	30-50
Casing Diameter (inches)	2	2	2
Screen Material	PVC	PVC	PVC
Screen Slot Size	0.02	0.02	0.02
Blank Casing (feet bgs)	0-25	0-35	0-30
Filter Pack (feet bgs)	23-47	33-51	25.5-60
Filter Pack Material	#3 Sand	#3 Sand	#3 Sand
Bentonite Pellet Seal (feet bgs)	20-23	30-33	20-25.5
Grout (feet bgs)	1-20	0-30	0-20
Latitude	39.700945	39.587847	39.808848
Longitude	-121.843797	-121.700409	-121.923982
Top of Casing Stickup (above ground surface)	3.25	2.83	2.96
Ground Surface Elevation (feet above mean sea level)	178	176	188

4.6 Infiltration Testing

Infiltration testing was conducted to evaluate how quickly and effectively water can penetrate the soil, helping determine whether the site can support groundwater recharge. This testing also helps to identify soil limitations, permeability, and potential clogging risks, which are critical for designing efficient and sustainable recharge systems. Two methods were used for the project. The first method was conducted by hand auguring or using a solid stem augur attached to a backhoe to a specific depth. A polyvinyl chloride (PVC) casing was then placed within the boring. Prior to placement of the PVC casing, loose soil was removed from the bottom of the boring and a thin layer of sand (less than 3 inches) was placed at the bottom. After placement of the PVC casing, the annular space (outside of PVC casing) was filled with bentonite pellets to minimize water used for the infiltration test coming up the outside of the casing. During placement, water was added to hydrate the bentonite pellets.

After allowing hydration of the bentonite chips, a pressure transducer was lowered down the PVC casing and programmed to record water levels at intervals between 1-second to 1 minute. An In-Situ Inc. Level Troll 700 or 500 vented transducer (Photograph 6) was used for the project. The use of vented transducers eliminates the need for barometer and correction of data based on barometric changes. To conduct the downhole permeability test, the PVC casing was filled with water, then allowed to infiltrate into the desired materials at the bottom of the boring. Photograph 7 shows a picture of the PVC with transducers installed for conducting the test.



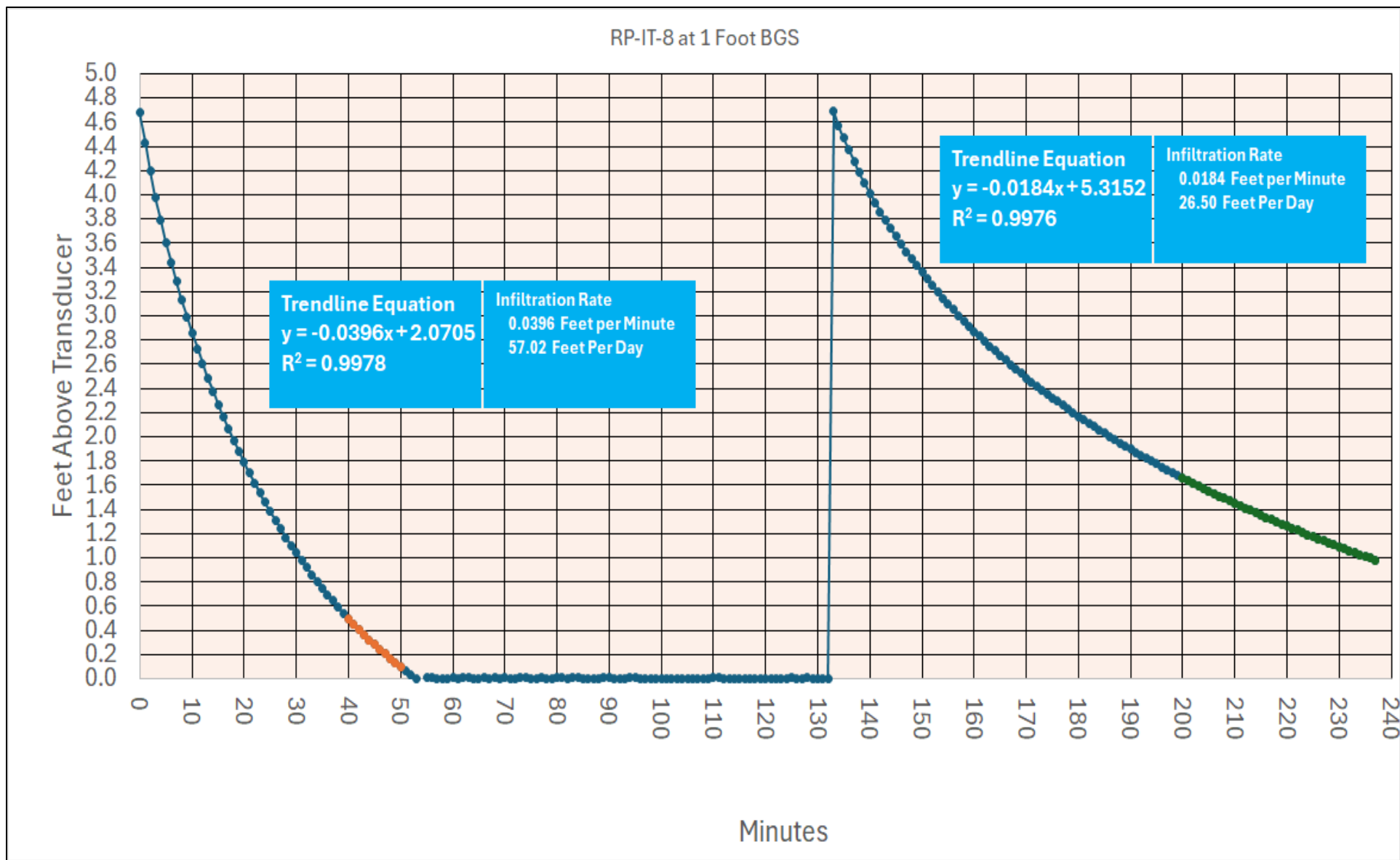
Photograph 6. In Situ Level Troll 700 transducer.



Photograph 7. Setup for permeability testing

The infiltration rates for each test are calculated from the slope of the line ($y = mx + b$, $m = \text{slope}$) developed during this process, as illustrated on Figure 14. The value for the slope “m” equals the infiltration rate in units of vertical access over units of horizontal access (e.g. feet per minute).

The second method was by conducting down-hole permeability testing during drilling of soil borings. For this method, the infiltration tests were conducted by advancing the outer casing of the



sonic drill stem to the desired depth. A pressure transducer was lowered down the drill stem and programmed to record water levels at 1 second intervals. To conduct the test, the drill stem was filled with water, then allowed to infiltrate into the desired materials. At least 30 minutes of infiltration was allowed for each test. The infiltration rates for each test are calculated the same as those for the tests discussed above and illustrated on Figure 14. The graphs produced for calculation of infiltration rates for both methods are presented in Appendix H.

4.7 Water Quality Testing

As discussed in Section 4.5, groundwater samples were collected from each of the newly installed groundwater monitoring wells located at Sites N4, S1, and S6. Prior to sampling, the static water level was recorded within each well. The well was then purged of a minimum of three casing volumes. During purging, field measurements of pH, electrical conductivity (EC), oxidation-reduction potential (ORP), and temperature (T) were recorded. Field records of water sampling are provided in Appendix I.

After purging, the water sample at Site S1 was collected by using a clean disposable bailer. At Sites N4 and S6, the samples were collected directly out of the low flow pump used for purging the wells. Samples were placed into containers supplied by the analytical laboratory. Samples intended for metals or cations analyses were filtered in the field using a 0.45-micron filter.

Grab water samples were also collected from Comanche Creek adjacent to Site S1 and Keefer Slough located next to Site N4. The Keefer Slough sample was collected only for analysis of particle size. The samples were collected by placing the laboratory provided containers directly into the surface water. Field measurements of pH, EC, ORP, and T were also recorded for these samples and recorded on the field record of water sampling Form (Appendix I).

Samples for chemical analysis were submitted to Enthalpy Analytical of Orange California. Surface water samples for particle size distribution and solids analysis were submitted to Cooper Testing Laboratory of Palo Alto California. Table 6 lists the parameters requested for analysis by the analytical laboratories. Copies of the analytical laboratory reports are provided in Appendix J.

Table 6. Summary of analytical testing for groundwater and surface water samples.

Analysis	Method	Date Collected	RMW-01 (Site N4)	VMW-01 (Site S1)	WMW-01 (Site S6)	Commanche Creek (Site S1)	Keefer Slough (Site N4)
Volatile Organic Compounds (VOCs)	EPA Method 5030B	1/7/2026 3/26/2026		X X			
Calcium (Ca), iron (Fe), magnesium (Mg), manganese (Mn), potassium (K), sodium (Na)	EPA Method 200.8	1/7/2026 3/26/2026	X	X X	X	X	
Chloride (Cl), sulfate (SO4), Nitrate (NO3) as N	EPA Method 300.0	1/7/2026 3/26/2026	X	X X	X	X	
Alkalinity	Standard Method 2320B	1/7/2026 3/26/2026	X	X X	X	X	
Total Dissolved Solids (TDS)	Standard Method 2540C	1/7/2026 3/26/2026	X	X X	X	X	
Stable Isotopes	Headspace equilibration using GasBench-IRMS	1/7/2026 3/26/2026	X	X X	X	X	
Particle size analysis	ASTM D 422M	2/21/2026				X	X
Solids analysis	Standard Method 2540 C,D	2/21/2026				X	X

5. RESULTS

This section presents the results of field activities outlined in Section 4 specifically:

- Section 5.1 provides the results of infiltration from CPT data, infiltration testing, and down-hole permeability testing.
- Section 5.2 provides the results of the water quality testing.
- Section 5.3 discusses site hydrostratigraphy based on results of the tTEM surveys, CPT data, soil borings, and monitoring wells.

5.1 Infiltration Testing

As described in Sections 4.3 and 4.6, infiltration rates were estimated using data obtained from the CPT program and field infiltration testing. Section 4.3 outlines the estimation of saturated horizontal hydraulic conductivity (K_h) based on CPT data using normalized Soil Behavior Type (SBT_n) interpretations. The vertical hydraulic conductivity (K_v) is generally 0.1 of K_h and is what is used to assess potential infiltration rates at the site. Due to shallow refusal of the CPT instrument, these data were only obtained at Sites S1 and N5. Figure 12 shows the location of these points for both sites.

Appendix G presents figures illustrating CPT-derived K_h estimates in relation to interpreted soil types within the upper 30 feet, corresponding to the unsaturated zone at both sites (see Section 5.3). Figure 15 provides a representative example for CPT-2. As shown in these figures and summarized in Table 7, K_h values within the unsaturated zone range from a maximum of 1,995 feet per day (CPT-3 at 24.11 feet bgs) to less than 0.0001 feet per day across multiple intervals within CPT-6 and CPT-7.

As described in Section 4.6, infiltration testing was conducted using backhoe excavations, hand augers, and downhole permeability testing within soil borings. The resulting values are considered estimates of infiltration rates. For all test methods, infiltration rates were calculated from the slope of the linear portion of the time versus falling-head water level plots, as shown in Figure 14. Supporting plots are included in Appendix H, and the results are summarized in Table 8. Figures 16 (Sites S1 and N3) and 17 (Site N4) show the locations of these points. The locations for Sites S6, N5, and N6 are the same as those shown for the soil borings on Figure 13.

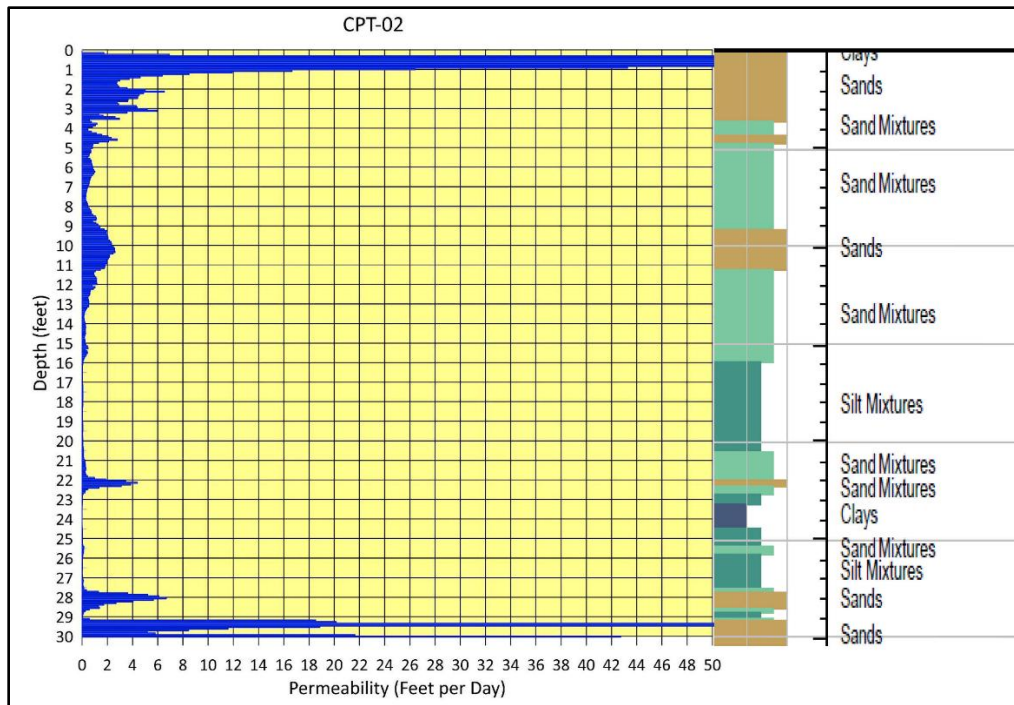


Figure 15. Plot of estimated permeabilities for Site S1 CPT-2 aligned with CPT lithologic data for upper 30 feet.

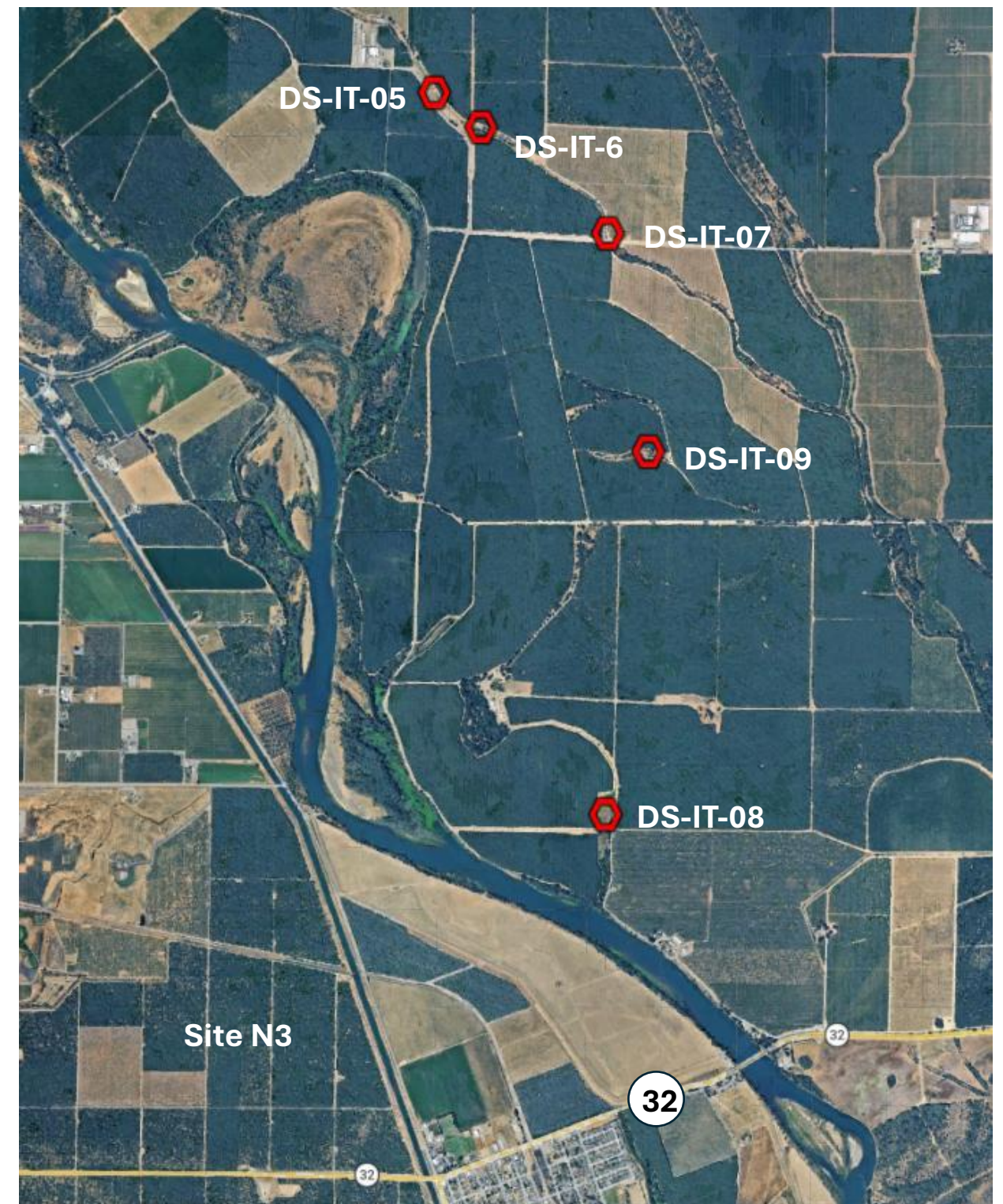
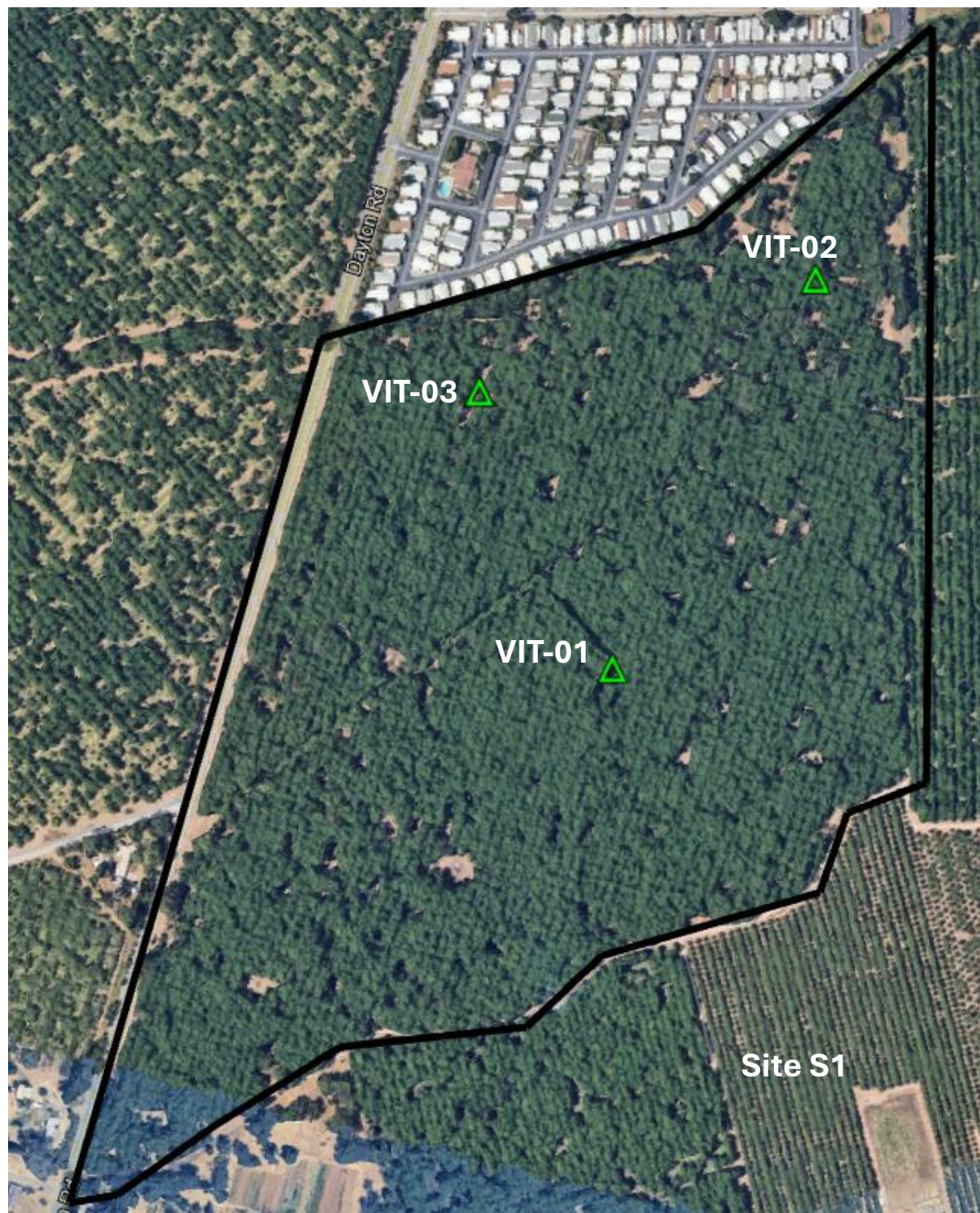
Table 7. Summary of CPT Kh values for data from 0 to 30 feet bgs. The Kv values are generally 0.1 of Kh.

CPT Number	Max Kh (feet/day)	Min Kh (feet/day)	Average Kh (feet/day)
Site S1			
CPT-1	1,087	0.005	54.95
CPT-2	261	0.002	5.21
CPT-3	1,995	0.006	134.93
CPT-4	258	0.001	12.31
CPT-5	378	0.013	16.43
CPT-6	755	0.0001	10.80
CPT-7	31	0.0001	0.31
CPT-8	1,053	0.03	44.80
Site N5			
CPT-B-1	444	0.03	15.82
CPT-B-2	700	0.01	22.01

Table 8. Summary of Infiltration Testing Results

Site Location	Test Location	Depth (Feet)	Date	Time Interval (Minutes)	Infiltration Rate (Feet/Day)
S1	VIT-01	1	9/16/2025	80 to 98 220 to 265	23.90 13.25
	VIT-02	1	9/16/2025	450 to 950	1.87
	VIT-03	1	9/17/2025	864 to 1,152	2.14
S6	WSB-1	2	2/4/2026	1 to 237	0.84
		4		259 to 302	0.50
		7		86 to 115 259 to 281	22.71 19.84
	WSB-2	3		14 to 100	0.06
		5		14 to 124	1.0
		6		29 to 86	22.60
	WSB-3	3		-	<0.001
		8		14 to 58	14.85
N3	DS-IT-5	3	2/3/2026	200 to 1,500	0.43
		5		100 to 1,500	0.58
	DS-IT-6	3		0 to 1,500	0.14
		6		700 to 1,460	0.29
	DS-IT-7	3		400 to 1,400	0.14
		4		100 to 1,370	1.30
	DS-IT-8	3		100 to 300	0.12
		5		100 to 325	0.14
		7		100 to 300	0.09
	DS-IT-9	1		0 to 1,340	0.43
		3.5		-	>100 ¹
N4	RP-IT-1	1	12/12/2025	0 to 69	21.46
	RP-IT-2	1		100 to 150	21.6
	RP-IT-3	1		120 to 240	6.48
	RP-IT-4	1		0 to 88	6.62
	RP-IT-5	1		30 to 100	5.47
	RP-IT-6	1		50 to 166	2.59
		2	12/18/2025	20 to 60	41.90
	RP-IT-8	1	12/12/2025	40 to 50 200 to 238	57.02 26.50
		3	12/18/2025	0 to 59	27.65
N5	NSB-1	5	4/7/2026	0 to 30	<0.001
	NSB-2	5	4/7/2026	0 to 25	38.02
	NSB-3	5	4/6/2026	0 to 25	27.94
		10	4/6/2026	0 to 20	89.71
	NSB-4	5	4/7/2026	0 to 30	33.12
N6	RiSB-1	5	4/9/2026	0 to 89	70.60
	RiSB-3	5	4/8/2026	0 to 25	19.01

1. Data is suspect.





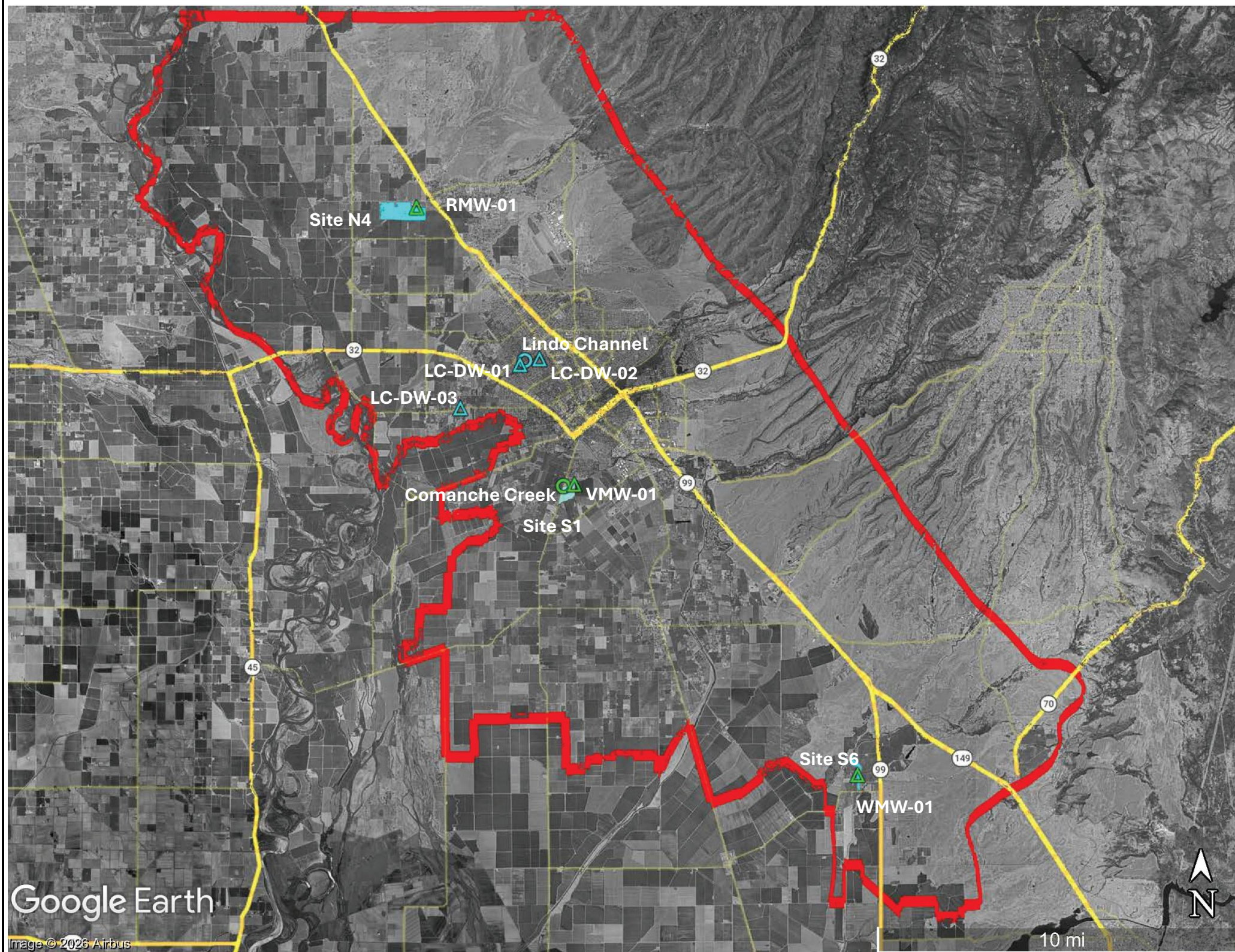
5.2 Water Quality

As discussed in Section 4.7, groundwater samples were collected from monitoring wells VMW-01, RMW-01, and WMW-01 and from surface water at Comanche Creek. Samples to assess particle size and solids analysis used to assess settling times of sediments from floodwaters were also collected from Comanche Creek and Keefer Slough the results of which are discussed in Sections 7.1 and 7.2. Additional hydrochemical data from the Lindo Channel enhanced recharge project (Geosyntec, 2026c), Component 4 of the Vina GSA grant, were incorporated to provide broader spatial context within the Vina Subbasin; this dataset includes a surface water sample from the Lindo Channel and groundwater samples from nearby domestic wells (LC-DW-01 through LC-DW-03).

All groundwater samples are from wells completed in the first water-bearing zone adjacent to stream channels; however, surface water was only sampled at Comanche Creek and the Lindo Channel. Figure 18 shows the locations of water sampling points, which span northern (RMW-01), central (Lindo Channel, LC-DW wells, and VMW-01), and southern (WMW-01) portions of the subbasin. Table 9 summarizes detected chemical constituents. As discussed in Section 5.3.1, due to nearby sites with known groundwater impacts, the samples from VMW-01 were submitted for volatile organic compounds (VOCs). No VOCs were reported for the water samples collected from this well. The remainder of this section provides an evaluation of groundwater and surface water chemistry in the Vina Subbasin using Piper and Durov diagrams (Figure 19) in conjunction with stable isotopes deuterium ($\delta^2\text{H}$) and oxygen ($\delta^{18}\text{O}$) data (Figure 20) to identify hydrochemical facies, dominant geochemical processes, and seasonal and spatial recharge influences. Although these plots are developed for assessment of groundwater, the surface waters are also included in plots for comparison with the groundwater samples.

The Piper diagram (Figure 19) indicates that all samples, surface water and groundwater, plot within the Ca–Mg– HCO_3 hydrochemical facies, indicating a consistent shallow groundwater system dominated by carbonate dissolution. Surface water samples show dilute end-members, with Lindo Channel (72 mg/L TDS) and Comanche Creek (100 mg/L TDS) reflecting results that are similar to recently recharged groundwater from precipitation. Groundwater in the Lindo Channel area plots closest to these compositions, showing low TDS (approximately 140 to 220 mg/L in winter) and low sulfate and chloride, indicating strong hydraulic connection to channel recharge. VMW-01 at Site S1 is similar but more variable (approximately 160 to 300 mg/L TDS), reflecting moderate water–rock interaction.

In contrast, both RMW-01 (north) and WMW-01 (south) exhibit more evolved groundwater, or recharged water that has been in contact with sediments for longer periods, with higher TDS (360 mg/L at RMW-01 and 510 mg/L at WMW-01) and elevated nitrate, chloride, and sulfate. As shown in Figure 18, this indicates that groundwater mineralization does not follow a simple north to south trend; instead, the most dilute conditions occur near the Lindo Channel, while both northern and southern sites reflect greater geochemical evolution due to localized factors such as recharge availability, residence time, or anthropogenic sources as discussed below.



Project Locations

-  Comanche Creek Surface Water Sample
-  Monitoring Well Groundwater Sample

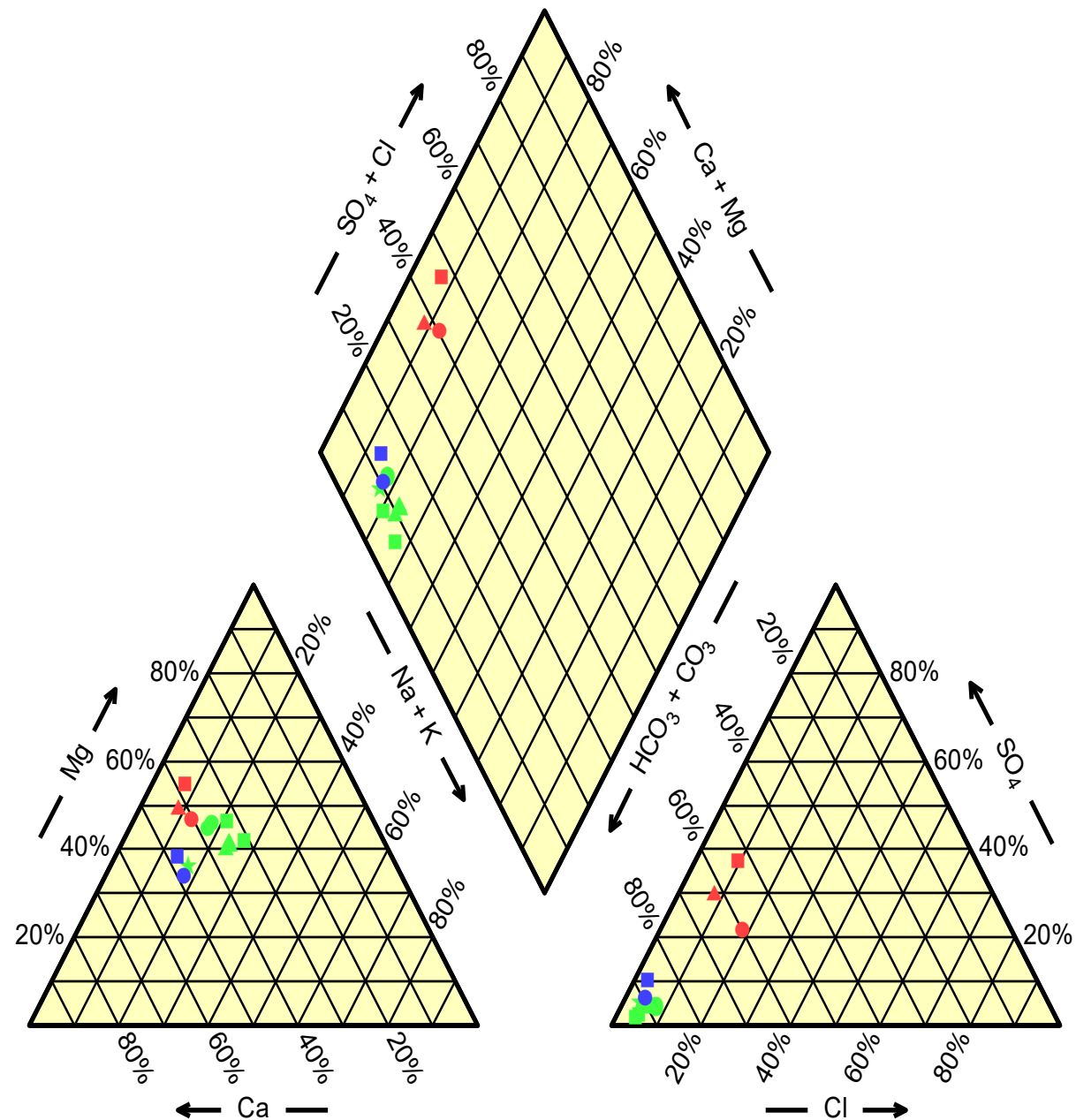
Lindo Channel

-  Lindo Channell Surface Water Sample
-  Domestic Well Groundwater Sample

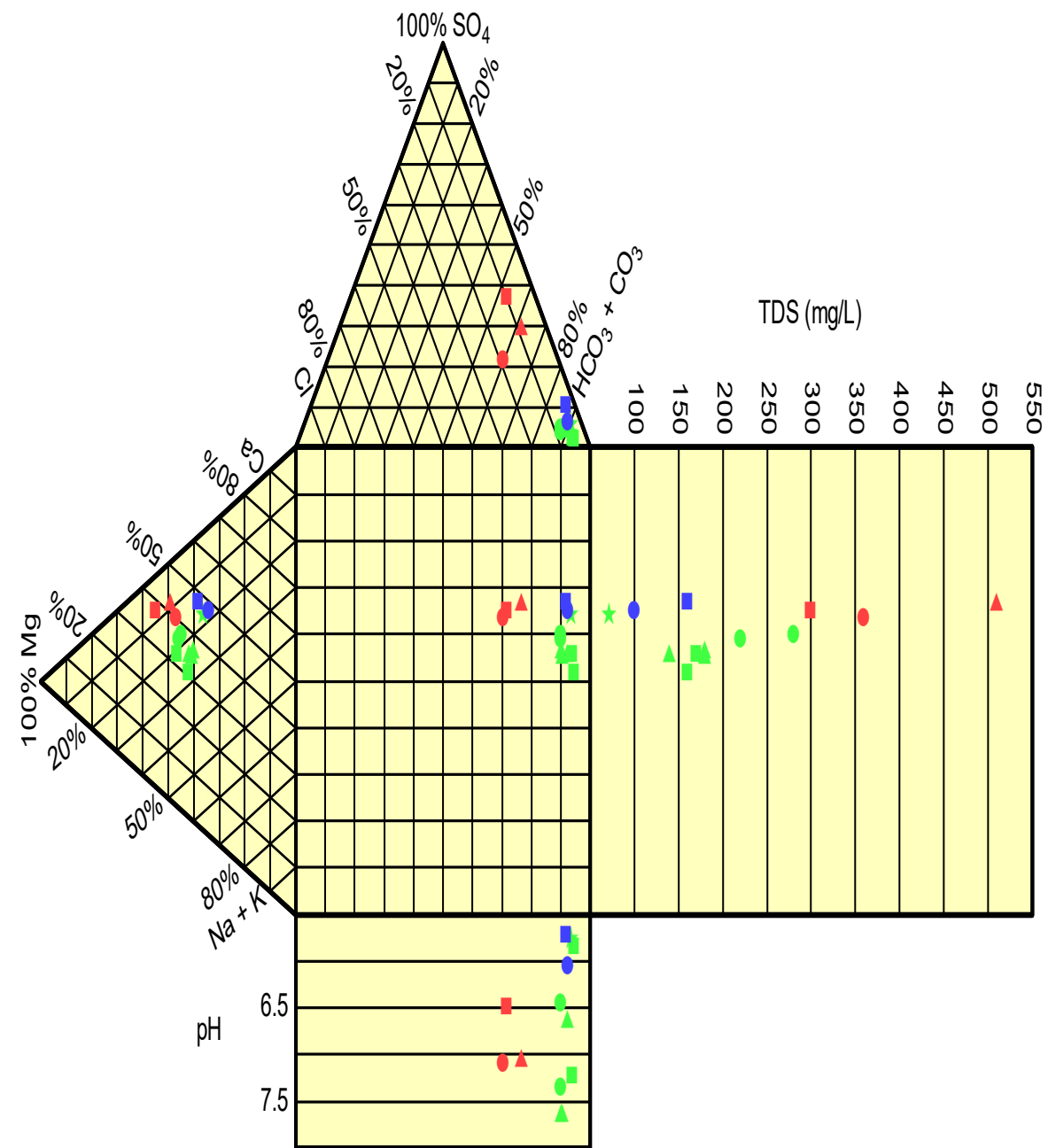
Table 9. Summary of analytical results for water samples.

Sample I.D.	Date	Ca mg/L	Fe mg/L	Mg mg/L	Mn mg/L	K mg/L	Na mg/L	Cl mg/L	NO3 as N mg/L	SO4 mg/L	TDS mg/L	T Degrees C	pH pH Units	ORP mV	EC μS/cm	Alkalinity Mg CaCO3/L	Deuterium SMOW-^2H	Oxygen-18 SMOW-^{18}O
VMW-01	1/7/2026	15	0.12	7.3	0.035	<0.5	5	2	1.6	9.8	160	15.63	5.72	143	148	84	-76.3	-11.1
	3/26/2026	34	0.36	30	0.02	<0.25	7.6	13	13	68	300	18.5	6.48	226	431	100	-66.2	-10.20
RMW-01	3/26/2026	37	0.3	26	0.013	0.86	13	22	21	35	360	19.48	7.09	215	456	100	-58.8	-8.81
WMW-01	3/26/2026	65	0.32	46	0.023	1.4	15	21	10	100	510	20.24	7.07	184	681	220	-50.6	-7.76
Comanche Creek	1/7/2026	17	0.12	7.3	<0.01	1.6	6.2	2.4	0.81	4.7	100	13.56	6.04	112	111	68	-60.5	-9.59

Piper Diagram



Durov Diagram



Lindo Channel Water Samples (Geosyntec, 2026)

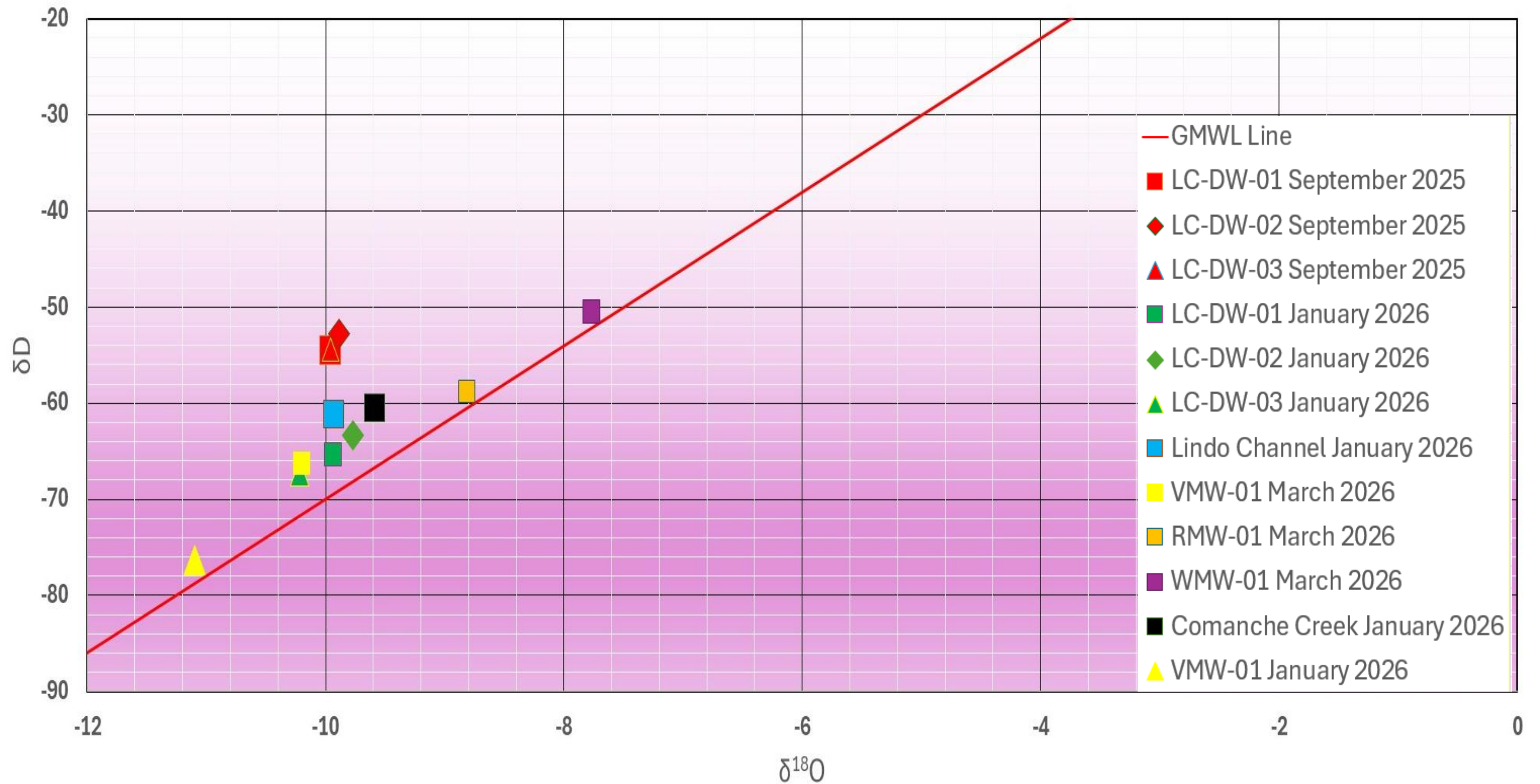
- LC-DW-01
- LC-DW-02
- ▲ LC-DW-03 (duplicate sample LC-DW-04)
- ★ Lindo Channel

Project Samples Collected January 7, 2026

- Comanche Creek
- VMW-01

Project Samples Collected March 26, 2026

- RMW-01
- VMW-01
- ▲ WMW-01



Seasonally, September 2025 samples from the Lindo Channel wells show higher TDS (up to 280 mg/L) and increased sulfate, chloride, and nitrate, reflecting late-season concentration under limited recharge and higher evapotranspiration. In contrast, January 2026 samples show lower TDS (as low as 140 mg/L) and reduced solute concentrations, reflecting dilution from winter recharge. These seasonal trends shift samples toward more mixed facies in late summer and toward bicarbonate-dominated compositions during winter.

The Durov diagram (Figure 19) supports that carbonate dissolution is the primary geochemical control, with surface water plotting where groundwater would be interpreted as recharge-dominated and groundwater following dissolution trends. Samples from the Lindo Channel area plot closest to recharge fields, while RMW-01 and WMW-01 plot in more evolved positions with increased sulfate and chloride, indicating greater geochemical development. Seasonal shifts are also evident, with winter samples plotting closer to recharge conditions and late summer samples reflecting modest solute accumulation.

For stable isotope data (Figure 20) surface water samples from the Lindo Channel and Comanche Creek plot within the range of local meteoric water and are consistent with precipitation-derived recharge. Groundwater samples show a relatively narrow isotopic range overall, indicating a common meteoric source and supporting the interpretation of a hydraulically connected shallow system (i.e. water from these surface water bodies are recharging the shallow groundwater system). These observations are consistent with the Butte County Stable Isotope Recharge Study (Brown and Caldwell, 2017), which found that both surface water and groundwater in the region generally plot along the Global Meteoric Water Line (GMWL), indicating recharge derived primarily from local precipitation with only limited evaporative effects.

Seasonally, the September 2025 samples from Lindo Channel are generally less depleted, which is consistent with recharge occurring under warmer conditions and as noted in the County study, may reflect some degree of evaporative enrichment prior to infiltration. In contrast, January 2026 samples are more depleted, indicating recharge during cooler winter conditions when evaporation is minimal. These seasonal shifts are consistent with the County's finding that surface water and recharge sources exhibit measurable seasonal isotopic variation tied to precipitation timing and temperature.

Spatially, wells in the Lindo Channel area exhibit isotopic compositions most similar to winter precipitation and surface water, indicating strong and relatively direct recharge from nearby channels. In contrast, RMW-01 and WMW-01 exhibit slightly less depleted isotopic values, suggesting a greater proportion of recharge occurring during warmer periods and/or slightly longer residence times that allow for minor evaporative modification prior to infiltration. Overall, the absence of strongly enriched isotope values supports the conclusion that evaporation is not a dominant control and that recharge occurs relatively rapidly following precipitation or streamflow events, consistent with regional findings for the Vina Subbasin.

Anthropogenic influences are present but localized. Elevated nitrate at RMW-01 (21 mg/L as N) likely reflects nearby land use such as agriculture. Minor increases in chloride and sodium at RMW-01 and LC-DW-02 suggest limited anthropogenic inputs, but these do not alter the dominant hydrochemical facies. Stable isotope results as discussed above indicate these constituents are

introduced within locally derived meteoric recharge rather than from distinct external sources. The data also suggests that using floodwater from local streams will improve the ambient water quality with the nitrate and chloride concentrations in Comanche Creek being significantly lower than the groundwater samples. Similar results were seen for a water sample collected from Lindo Channel where nitrate (as N) was 0.71 mg/L and chloride was 1 mg/L (Geosyntec, 2026c).

Overall, groundwater and surface water within the Vina Subbasin form a shallow, hydraulically connected system dominated by carbonate dissolution and recharge from precipitation. Figure 18 shows that variability is controlled primarily by proximity to active recharge features rather than a simple north–south gradient, with the Lindo Channel area representing the most dilute conditions and both northern and southern sites exhibiting more evolved groundwater. Seasonal recharge strongly influences water chemistry, producing dilution and isotopic depletion in winter and modest solute concentration in late summer. Despite localized anthropogenic effects, the hydrochemical facies remain consistent, indicating limited geochemical evolution and relatively short groundwater residence times.

5.3 Site Hydrostratigraphy

Six sites, S1, S6, N4, N5, N6, and N8 (Figure 7), were evaluated through lithologic assessments based on data obtained from the tTEM surveys, CPT program, soil borings, and installation of monitoring wells. The tTEM method characterizes subsurface electrical properties by measuring the resistance of geologic materials to the flow of electrical current. These measurements are expressed in ohm-meters ($\Omega\cdot m$) and reported as electrical resistivity (ρ).

In freshwater sedimentary environments, resistivity is primarily governed by grain size distribution and moisture content. Fine-grained materials (e.g., silts and clays) with higher moisture content generally exhibit lower resistivity values due to increased electrical conductivity. In contrast, coarse-grained materials such as sands and gravels typically yield higher resistivity values and are commonly associated with greater hydraulic conductivity and permeability.

Using data from the CPT, soil boring program and experience within the subbasin, an interpretive framework relating resistivity values to lithologic units was developed as summarized on Table 10. This framework along with data from the CPT, soil boring, and monitoring well results was used to characterize the hydrostratigraphy at each of the six sites. To illustrate the hydrostratigraphy, three-dimensional (3-D) models were developed using the software package leapfrog.

5.3.1 Site S1

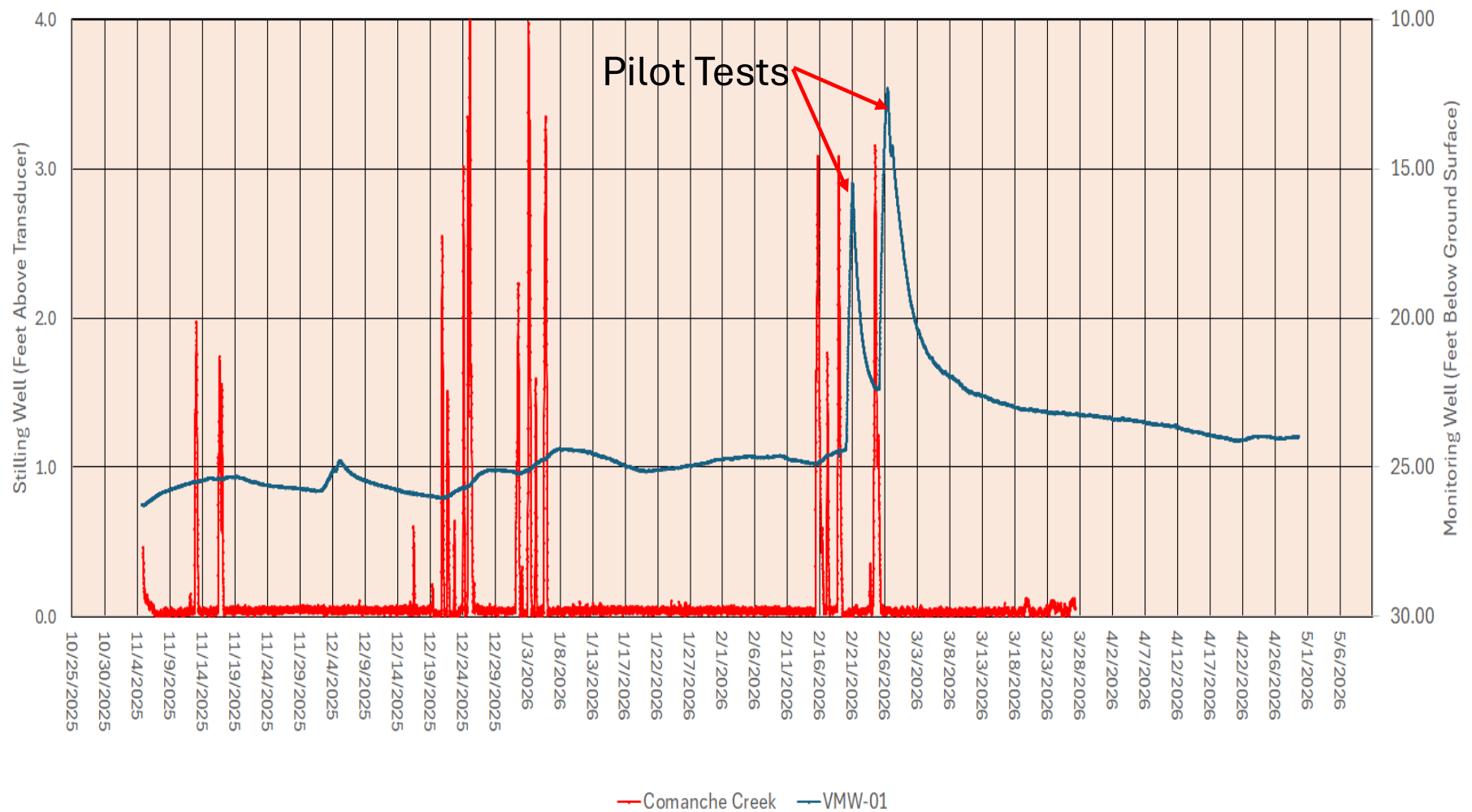
As discussed in Section 4, Site S1 included completion of a tTEM survey, 8 CPT points, and two soil borings, one of which was converted to a groundwater monitoring well designated VMW-01. Figure 21 shows the hydrograph developed for VMW-01 covering the period from November 5, 2025, through April 30, 2026. As seen on this figure, depth to water ranged between 24 to 26 feet bgs except during the period when the pilot tests for this site (see Section 6.1) were conducted when water levels rose between 12 to 16 feet bgs.

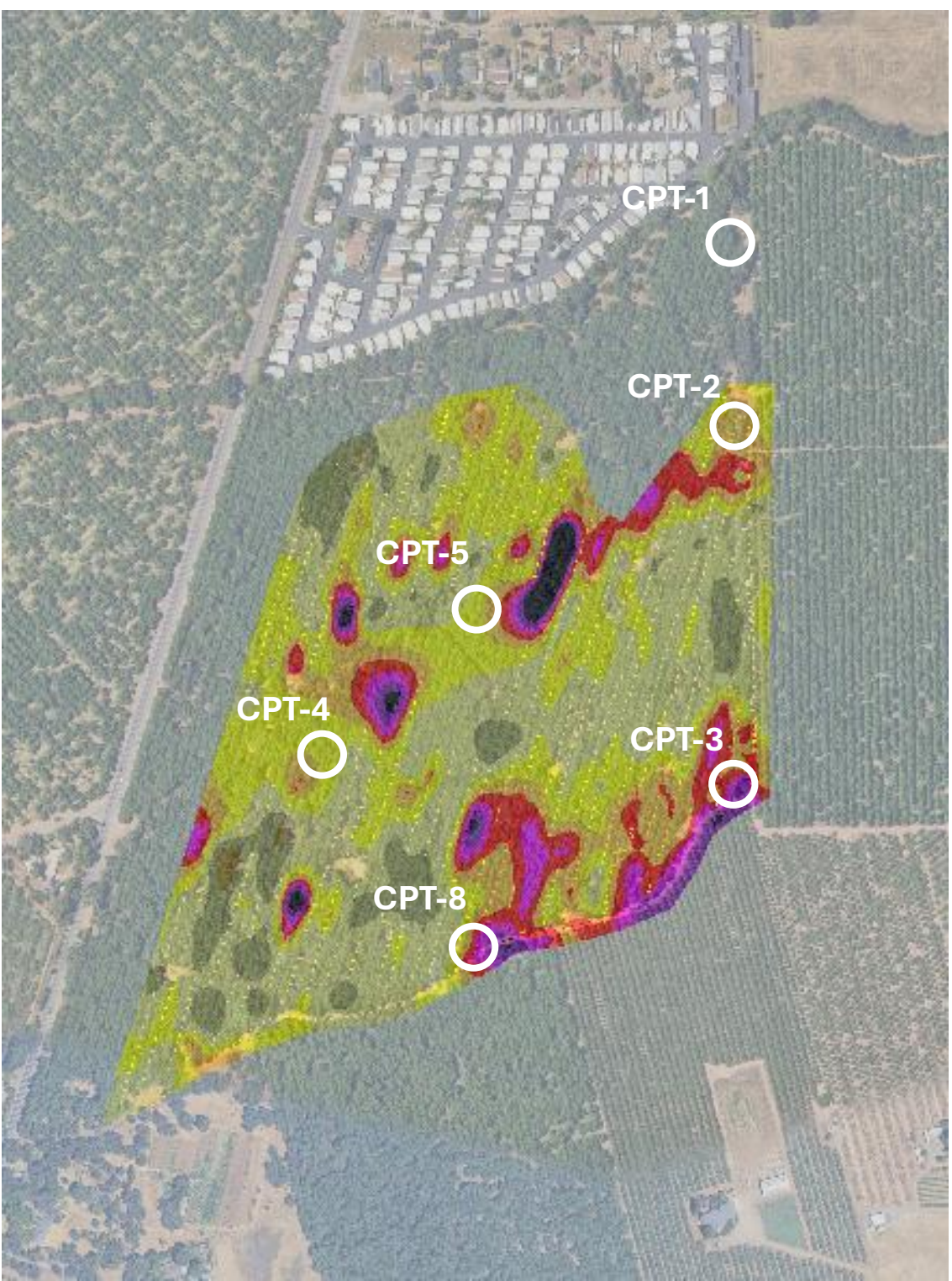
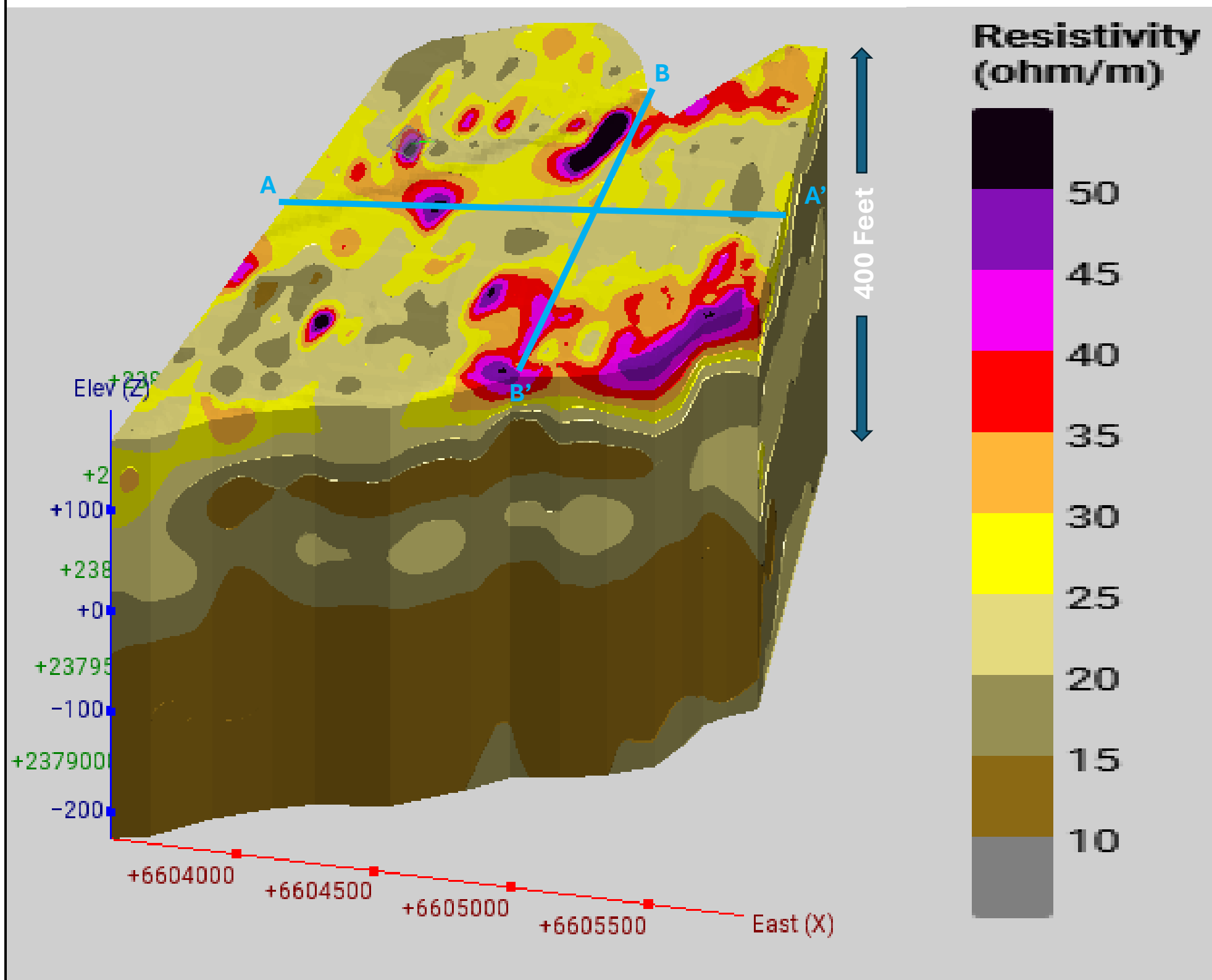
Table 10. Range of resistivity values determined for lithologic units.

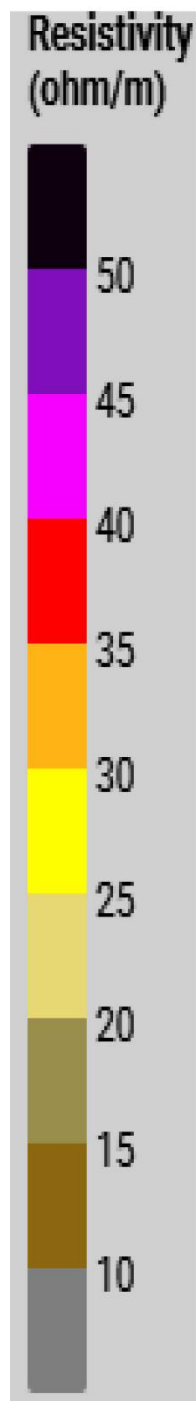
Resistivity Range (Ω -m)	Interpreted Lithology
Above the water table	
<5	Clay
5 to 12	Silty Clay to Sandy Clay
12 to 20	Clayey Sand to Silty Sand
20 to 30	Sand
30 to 40	Coarse Sand and Gravel
>40	Gravel to Coarse Gravel
Below the water table	
<5	Clay
5 to 10	Sandy Clay
10 to 15	Silt to Silty Sand
15 to 20	Silty Sand to Sand
20 to 30	Fine Sand to Sand
30 to 40	Medium Sand to Coarse Sand
40 to 50	Sand and Gravel
>50	Gravel

Figure 22 shows a still shot from the 3-D model constructed for the site. As seen on this figure, the upper portion of the site has resistivity values above 20 Ω ·m that as summarized on Table 10 should be permeable sands and gravels. To assess these designations, Figure 23 shows two CPT lithologic graphs compared to the tTEM data at these points. As seen on this figure, Table 10 provides an accurate interpretation of the tTEM results. As such, Figure 22 suggests that water placed at the surface within Site S1 should migrate to the water table aquifer encountered between 24 to 26 feet that was confirmed during the pilot testing discussed in Section 6. Figure 24 presents a north to south and west to east cross sections constructed from the 3-D model that clearly shows permeable materials from the surface to the groundwater table. As shown on Tables 7 and 8, permeabilities of these coarser materials range from about 2 feet/day up to 155 feet/day.

VMW-01 plots in the calcium–magnesium–bicarbonate (Ca–Mg–HCO₃) field on the Piper diagram (Figure 19), indicating a dilute, recharge-dominated groundwater controlled primarily by natural mineral weathering. Major ion chemistry supports this interpretation, with calcium and



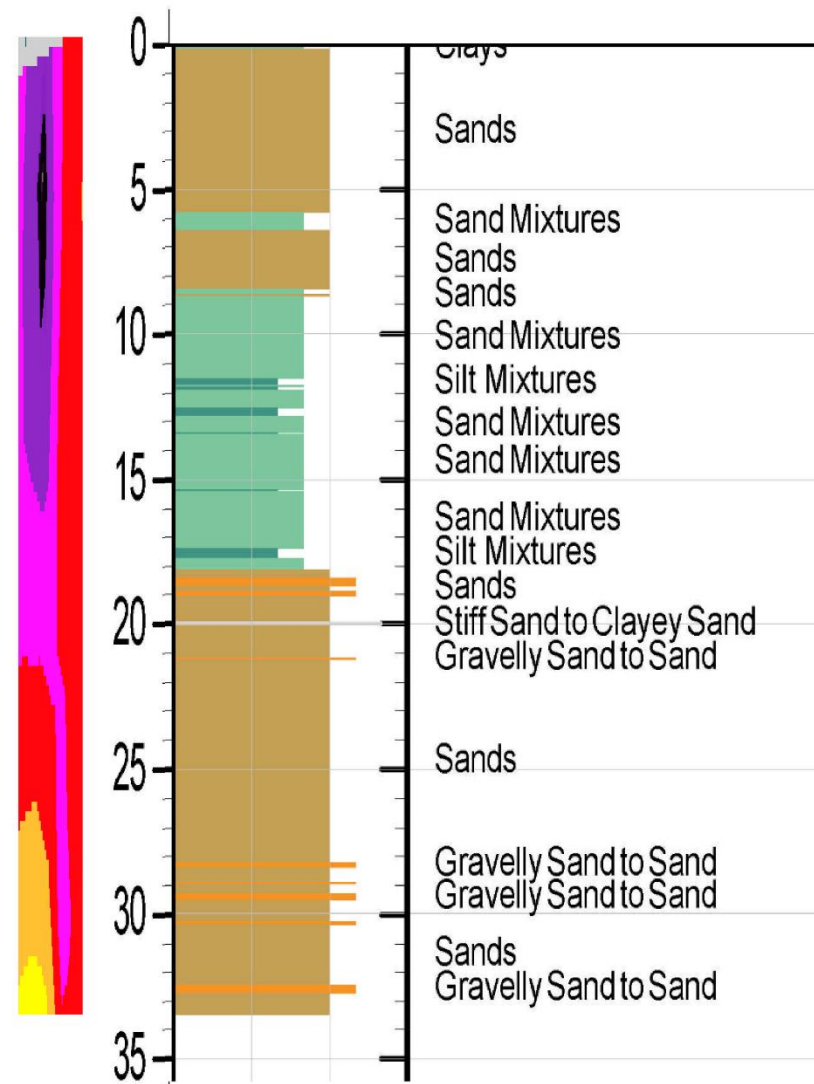




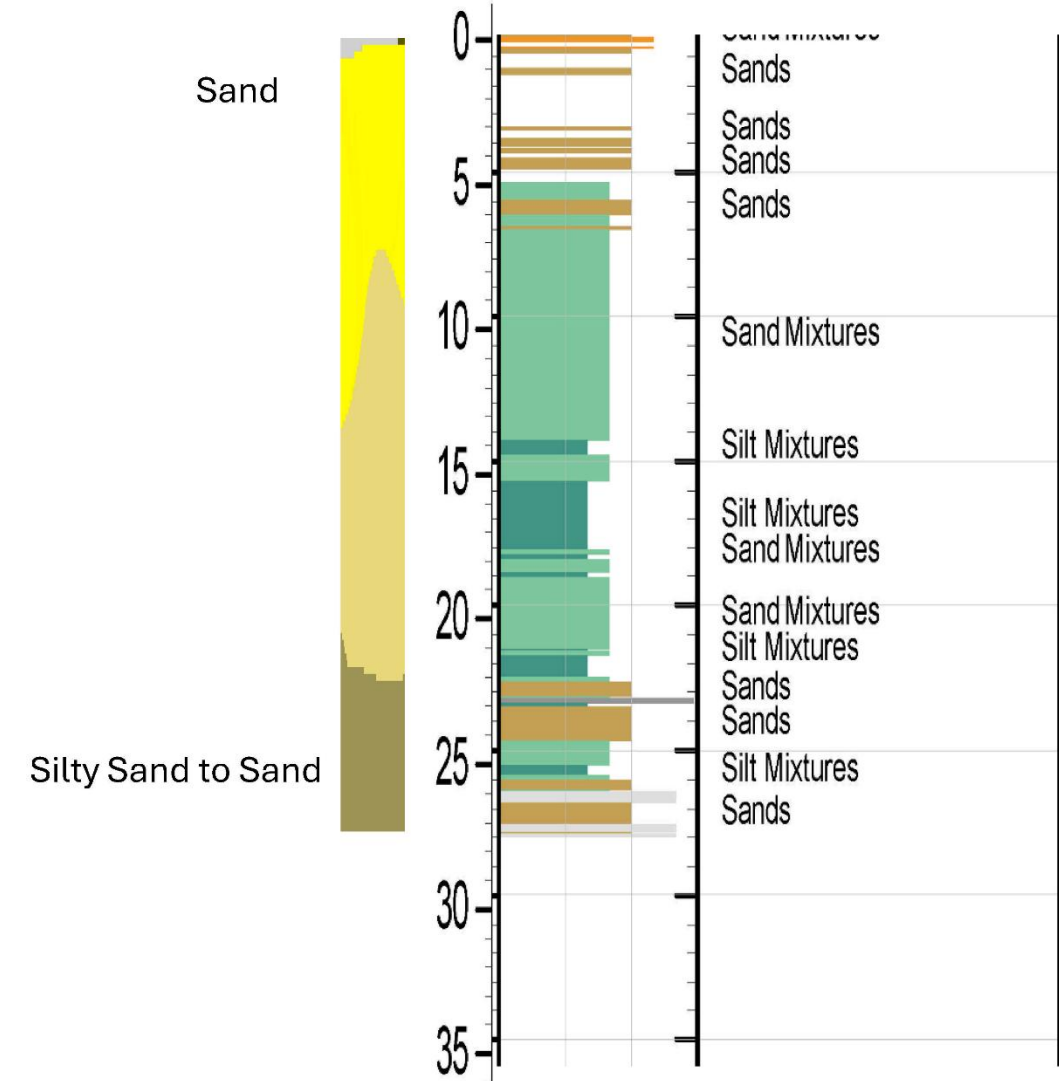
Coarse Sand to Coarse Gravel

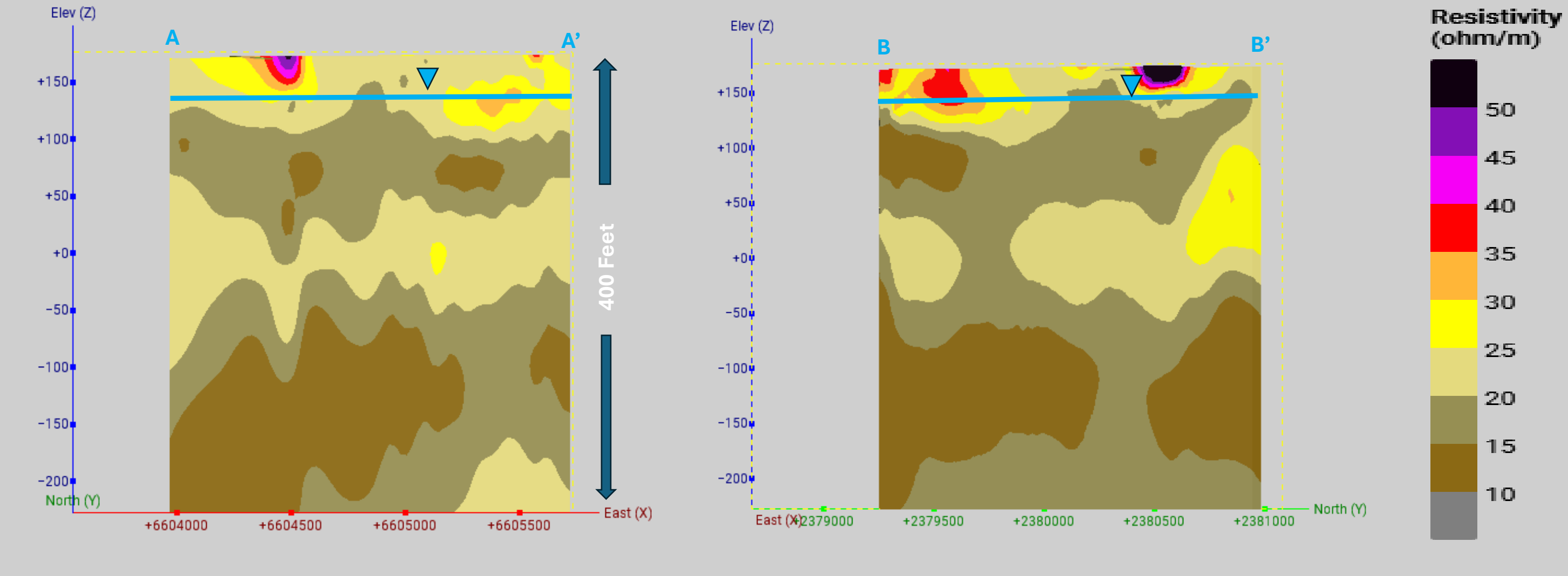
Sand to Coarse Sand and Gravel

CPT-8



CPT-5





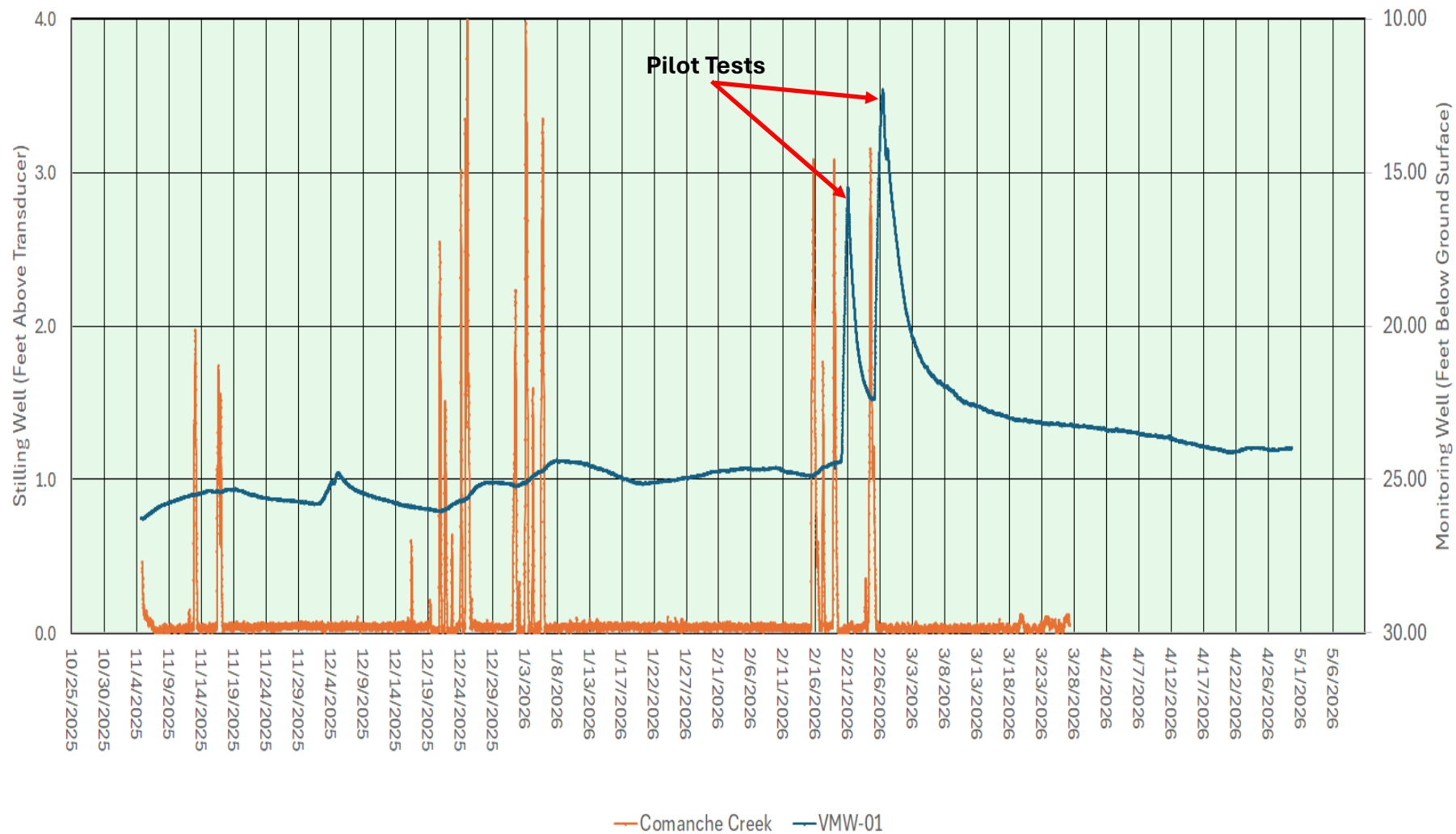
magnesium dominating over sodium and bicarbonate (alkalinity) exceeding sulfate and chloride. While nitrate concentrations (up to 13 mg/L as N) suggest a minor anthropogenic influence, overall dissolved solids and low chloride indicate no strong contamination signal. Stable isotope data (Figure 20) show that VMW-01 groundwater is more depleted than adjacent Comanche Creek surface water, indicating meteoric recharge with limited evaporation and suggesting that groundwater is not dominated by direct surface water infiltration.

As seen on Figure 25, water level data from the VMW-01 monitoring well and the Comanche Creek stilling well (see Section 6.1 for installation of stilling well) indicate closely correlated and generally parallel fluctuations, with corresponding rises and declines and a small hydraulic head difference typically less than approximately 3 feet. Periods of pronounced groundwater level increases correspond to pilot testing activities, during which Flood-Managed Aquifer Recharge (Flood-MAR) was conducted in a small basin adjacent to the creek (see Section 6.1), temporarily elevating groundwater levels near VMW-01. Despite these testing influences, the overall patterns provide strong evidence of hydraulic connectivity between the creek and the shallow groundwater system, with Comanche Creek likely functioning as a losing reach under typical conditions based on relative water levels at VMW-01. Surface water stage variations are reflected in the groundwater hydrograph with a slight lag and dampened response, consistent with stream–aquifer interaction. Although groundwater levels and creek levels often rise and fall together, isotope evidence and occasional differences between them show that creek water is not directly mixing into the groundwater in large amounts. Instead, the two are connected through flows from hydraulically connected zones, but actual exchange of water between them is limited under the observed conditions.

Regionally, Site S1 is located within an area of multiple groundwater plumes (Figures 26) and falls within a BCEHD VOC concern area (Figure 27). However, as discussed in Section 5.2, VOCs were not detected in the two groundwater samples collected from Site S1 monitoring well VMW-01, which is screened from approximately 25 to 45 feet bgs. Evaluation of the nearby Victor Industries 20th Street plume indicates that no wells with reported VOC detections are screened within a comparable shallow interval or exhibit similar groundwater elevations (approximately 24 to 26 feet bgs). The nearest well with a reported VOC detection (VMW-26B) is screened at a substantially deeper interval (117 to 127 feet bgs) with groundwater levels exceeding 50 feet bgs, confirming it represents a distinct, deeper hydrostratigraphic unit; this well reported TCE at 2.2 µg/L on March 13, 2024.

Groundwater elevation data (Figure 25), supported by continuous monitoring data from VMW-01 and Comanche Creek, indicate that the shallow aquifer is hydraulically connected to the creek. Groundwater level fluctuations at VMW-01 closely correspond with variations in creek stage, with periods of nearly synchronous response and, during higher-stage events, short lag times followed by dampened groundwater increases. These consistent correlations demonstrate active hydraulic interaction between the creek and the shallow groundwater system within the screened interval of VMW-01.

As a result, Comanche Creek functions as a hydraulic control feature and effective boundary to shallow groundwater flow. The observed relationship indicates that the creek limits northward

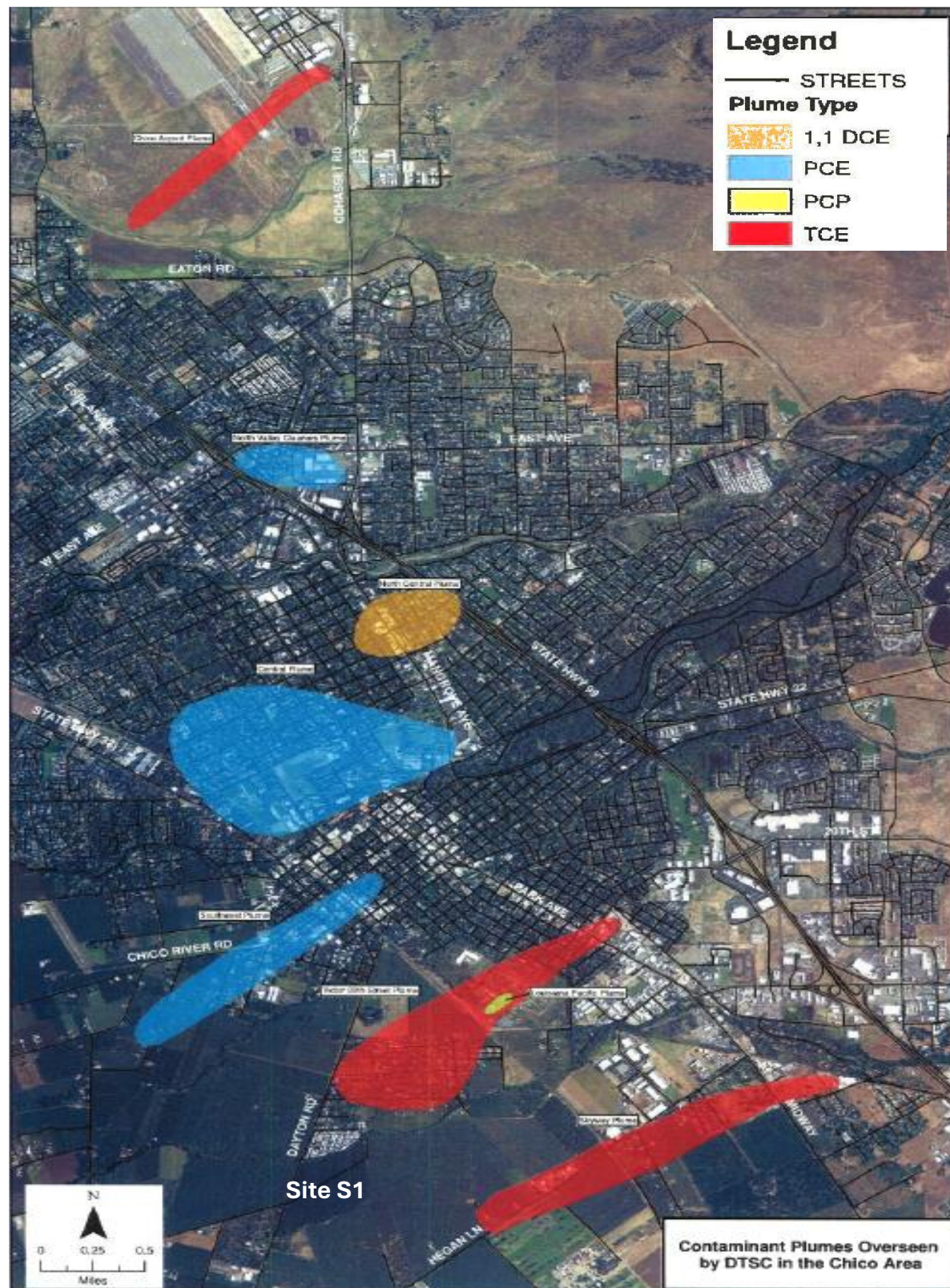


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Time-series graphs comparing groundwater levels and stream stage in Comanche Creek.

Figure 25

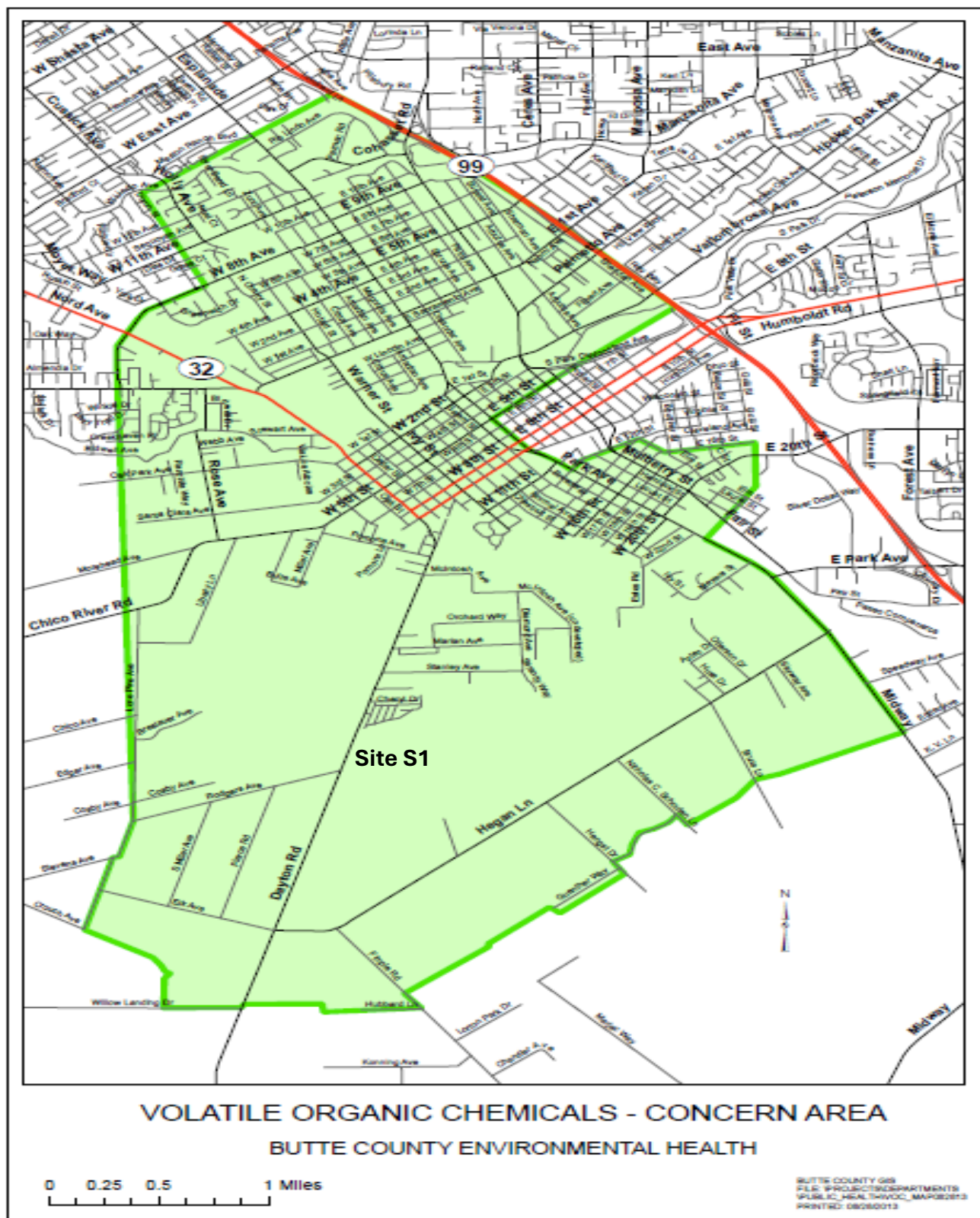


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Map showing known groundwater plumes near Site S1.

Figure 26



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Map showing designated VOC
concern areas near Site S1.

Figure 27

groundwater migration from Site S1 while also restricting potential southward movement of shallow groundwater originating north of the creek.

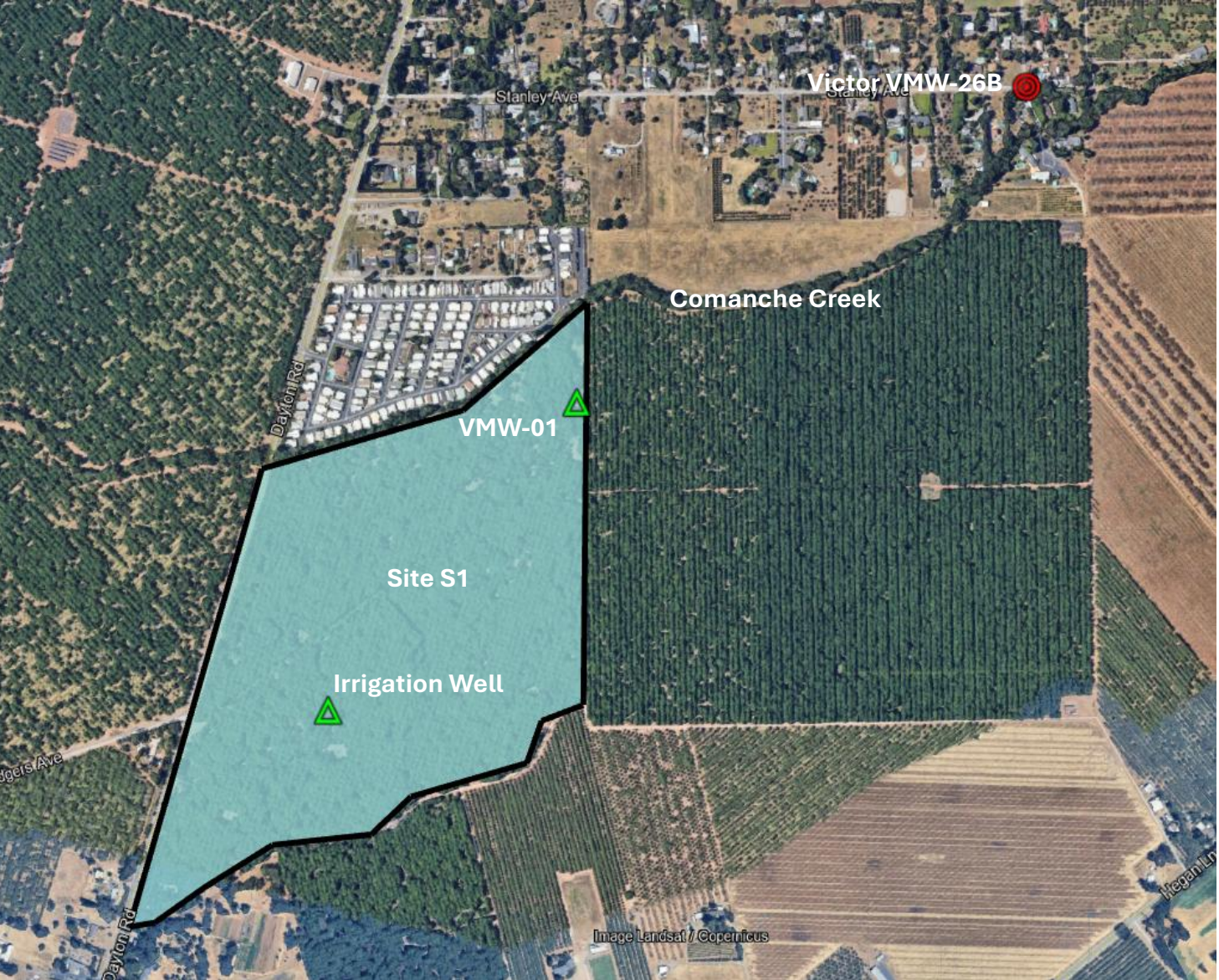
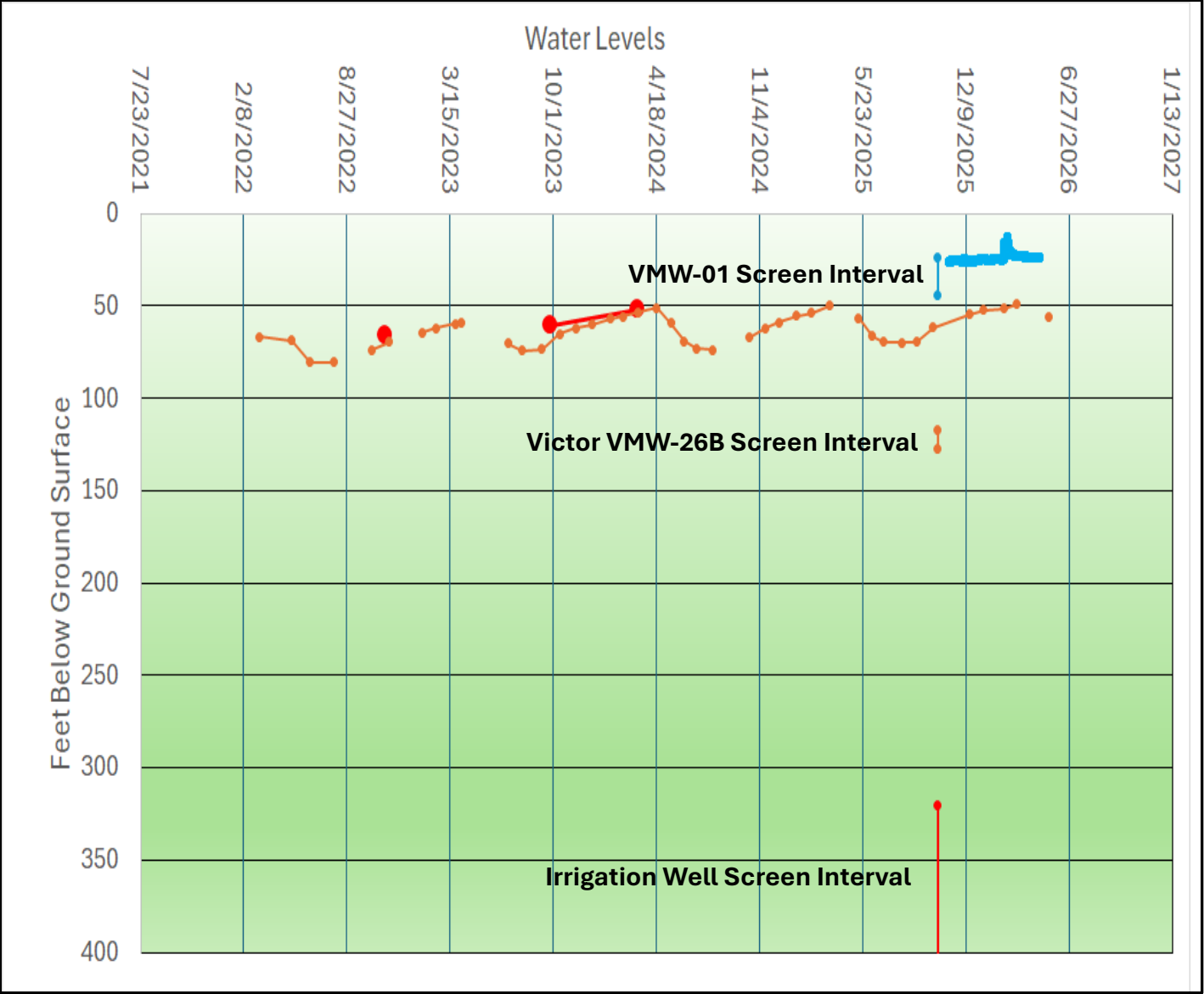
In contrast, monitoring wells associated with the Victor plume are screened at depths at least 60 feet below VMW-01, indicating that the detected volatile organic compound (VOC) impacts occur within a deeper, hydraulically distinct groundwater system that is not directly influenced by the creek-stage fluctuations observed in the shallow zone. Figure 28 provides a hydrograph showing water levels from the Site VMW-01 well, the Victor VMW-26B well, and an onsite irrigation well monitored by DWR along with their screen intervals. The irrigation well is screened starting at 320 feet bgs. This figure also provides the locations of these wells. As seen on this figure, water levels recorded in Site S1 monitoring well are clearly above the other wells supporting the separation of aquifer systems. Figure 29 reproduces Figure 3-12 from AECOM (2024) showing the extent of the TCE plume within the A-Zone or shallowest zone monitored for site. As seen on this figure, the TCE plume in the upper zone stops well north of Site S1.

Although it is believed that a recharge project conducted at Site S1 would not impact the known plumes in the area, any proposed project for this site should include a monitoring plan that further assesses this potential.

5.3.2 Site S6

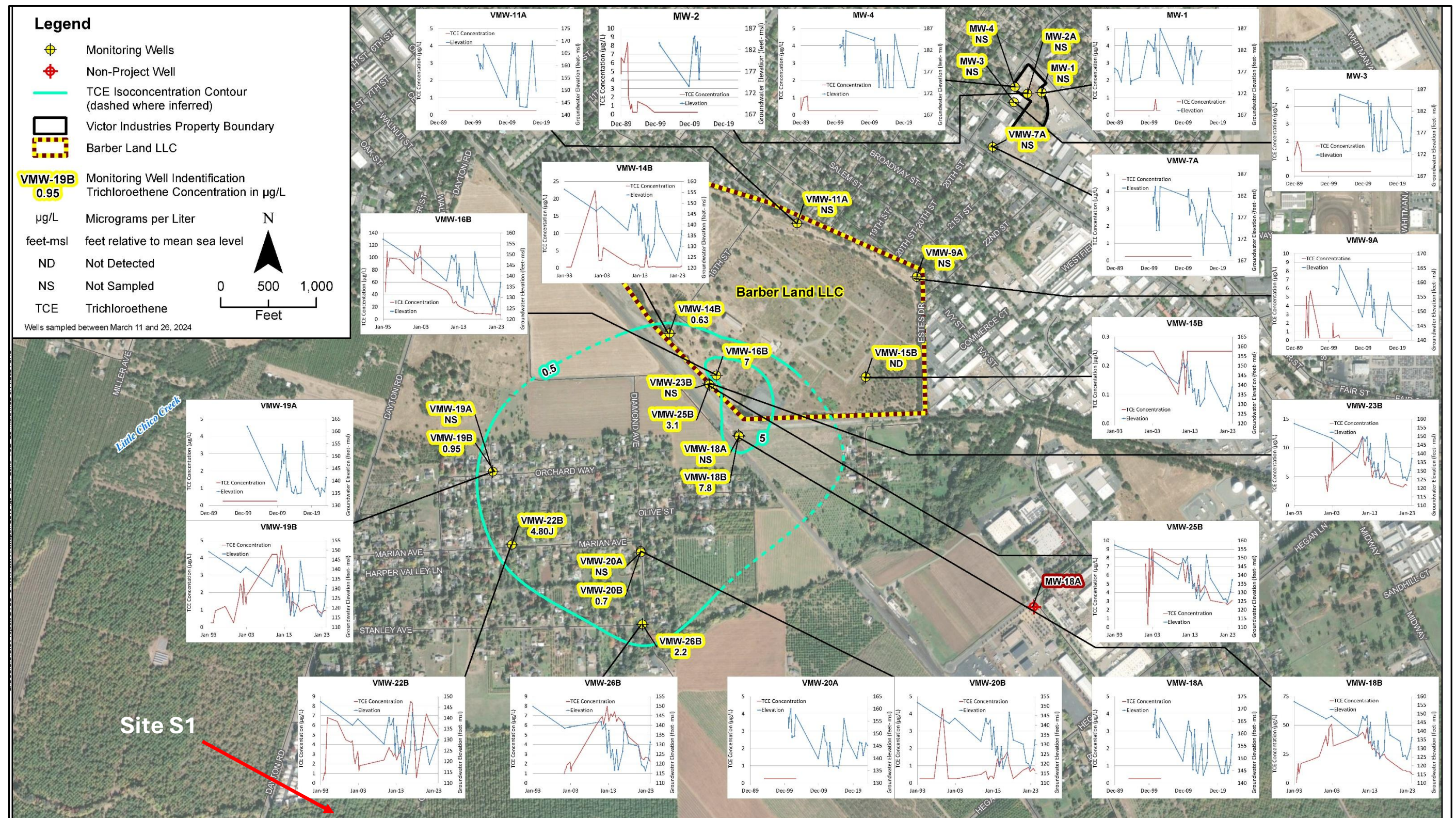
As discussed in Section 4, Site S6 included completion of a tTEM survey and four soil borings, one of which was converted to a groundwater monitoring well designated WMW-01. Figure 30 shows the hydrograph developed for WMW-01 covering the period from January 22, 2026, through April 30, 2026. As seen on this figure, depth to water ranged between 36 to 38 feet bgs.

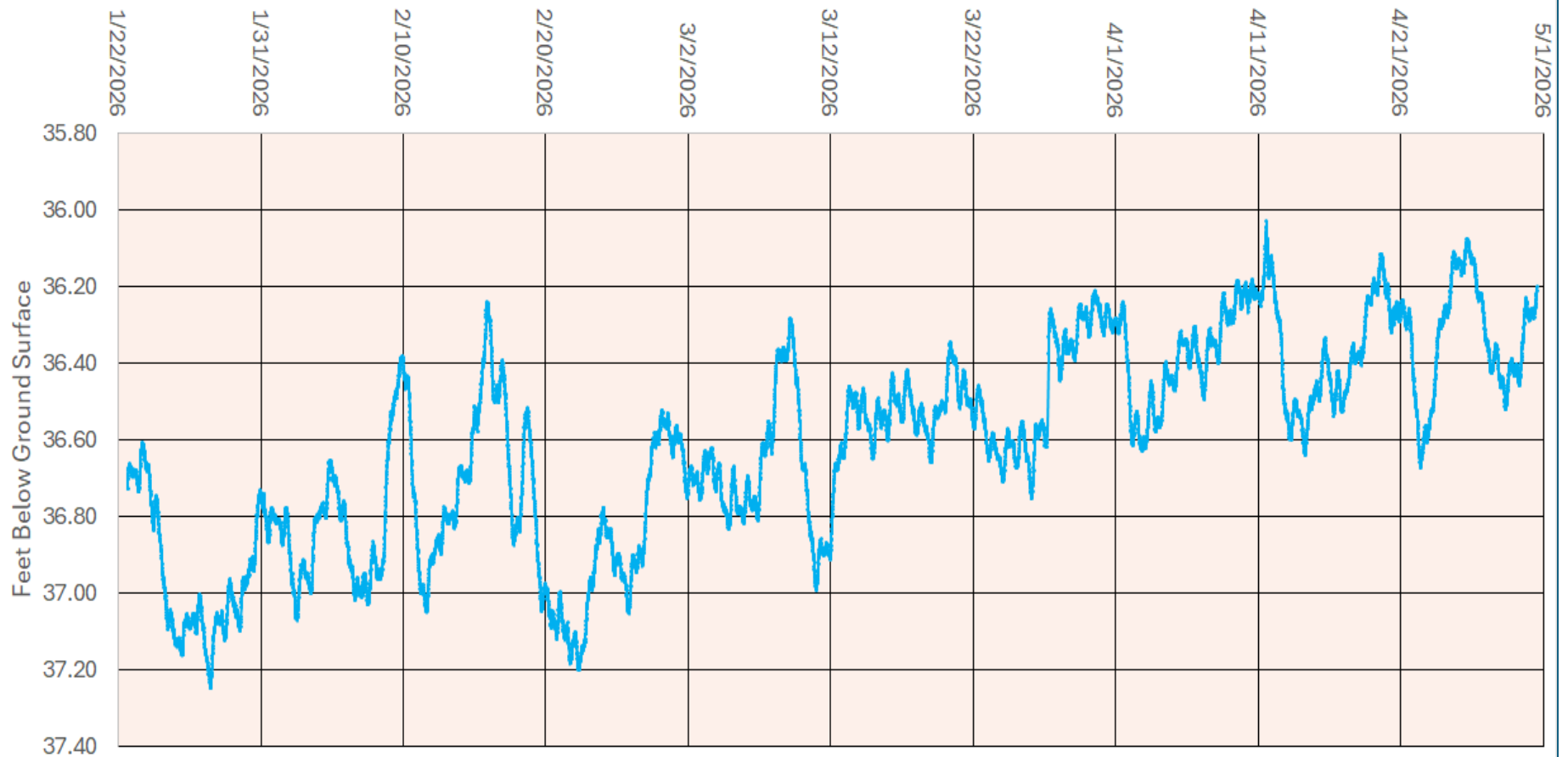
Figure 31 shows a still shot from the 3-D model constructed for the site. As seen on this figure, the majority of the upper portion of the site has resistivity values below $20\ \Omega\cdot\text{m}$ that as summarized on Table 10 should be clayey sands to clay. There is a small area in the center of S6 that shows resistivity values in the upper portions above $30\ \Omega\cdot\text{m}$ that indicate coarse sands to gravels. To assess these designations, Figure 32 shows two soil boring lithologic graphs compared to the tTEM data at these points. As seen on this figure, Table 10 provides an accurate interpretation of the tTEM results. As such, Figure 31 suggests that over large areas of the site water placed at the surface within Site S6 would migrate slowly to the water table aquifer encountered between 36 to 38 feet with an exception in the middle of the property where there appears to be an area that a recharge project might be successful due to higher infiltration rates. However, as shown on Table 8, infiltration rates from the soil boring in this area (WSB-3) had very low values at 3 feet bgs (<0.001 feet/day) and did not have permeable rates until 8 feet bgs (14.85 feet/day). As shown on Table 8, permeabilities of the upper 5 feet for most of the site reported values less than 1 foot/day.



- Victor Well VMW-26B
- VMW-01
- Irrigation Well

Graph comparing groundwater levels in Site S1 wells and nearby deeper wells.
Figure 28



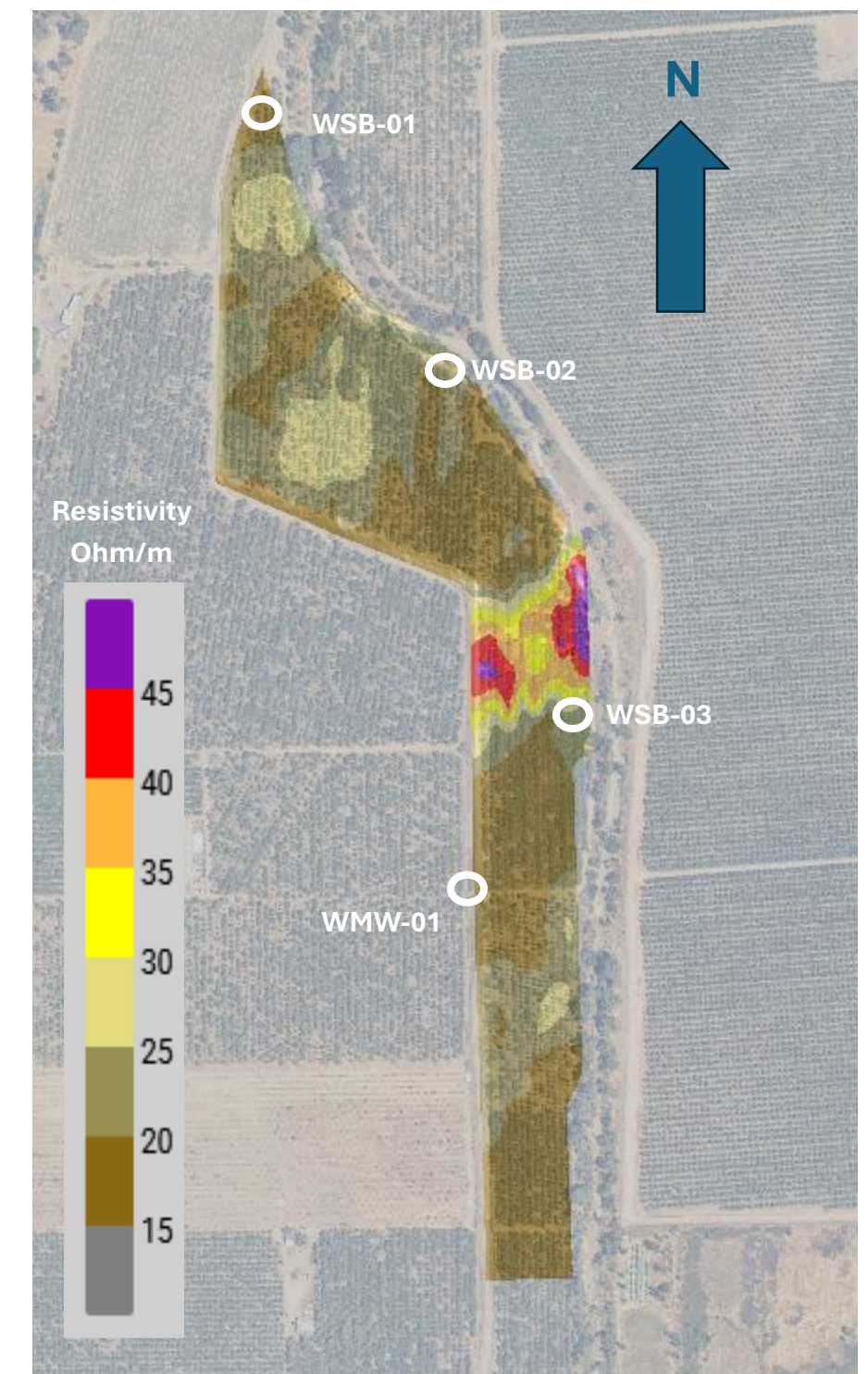
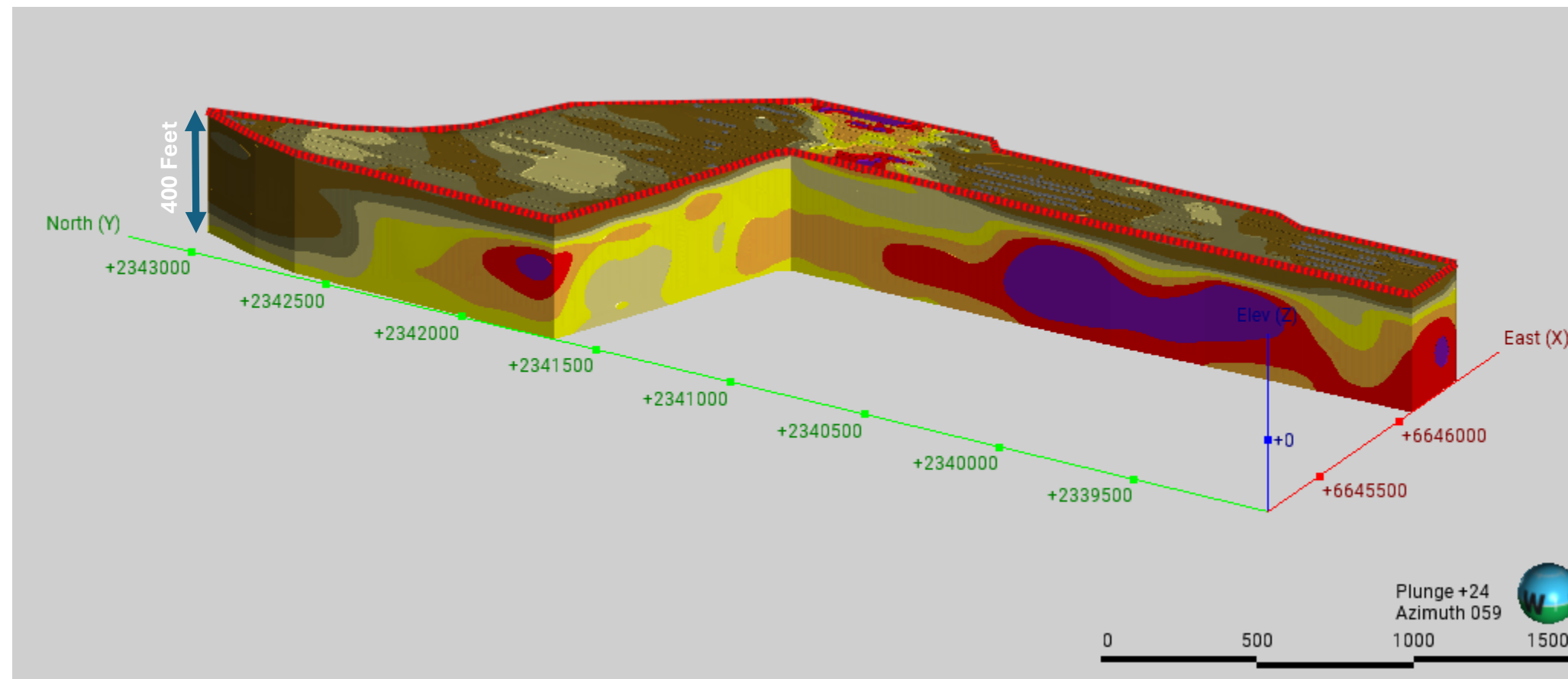


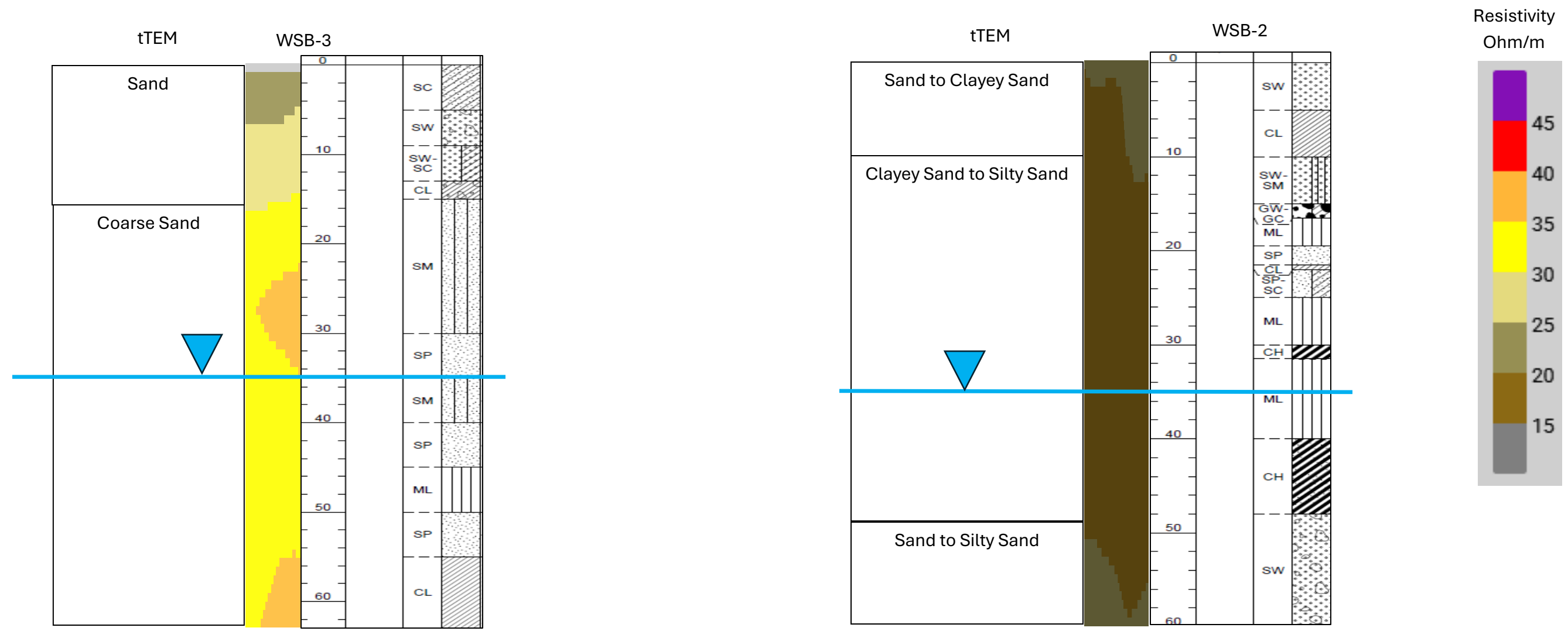
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Time-series graph showing groundwater levels at monitoring well WMW-01 at Site S6.

Figure 30





As discussed in section 5.2, WMW-01 plots within a more evolved calcium–magnesium–bicarbonate–sulfate hydrochemical field on the Piper diagram (Figure 19), indicating groundwater that has undergone greater water–rock interaction compared to VMW-01. Major ion chemistry shows elevated calcium (65 mg/L) and magnesium (46 mg/L), with sodium (15 mg/L) remaining subordinate, while alkalinity (220 mg/L as CaCO₃) is high but accompanied by substantial sulfate (100 mg/L) and moderate chloride (21 mg/L). These characteristics reflect a chemically mature groundwater influenced by extended mineral weathering, with sulfate likely derived in part from mineral sources but potentially enhanced by agricultural inputs. The elevated total dissolved solids (510 mg/L) further suggest longer residence time and/or interaction with more mineralized sediments. Nitrate concentrations (10 mg/L as N) are consistent with groundwater beneath agricultural land use and likely indicate fertilizer-derived recharge, representing a modest anthropogenic influence. Stable isotope data (Figure 20) show that WMW-01 groundwater is isotopically more enriched relative to Comanche Creek surface water, suggesting some degree of evaporative enrichment prior to or during recharge, which may be associated with irrigation return flow. Overall, WMW-01 represents a geochemically evolved groundwater system reflecting both natural mineral weathering and agricultural land-use influences, with evidence for partial evaporation effects in the recharge process.

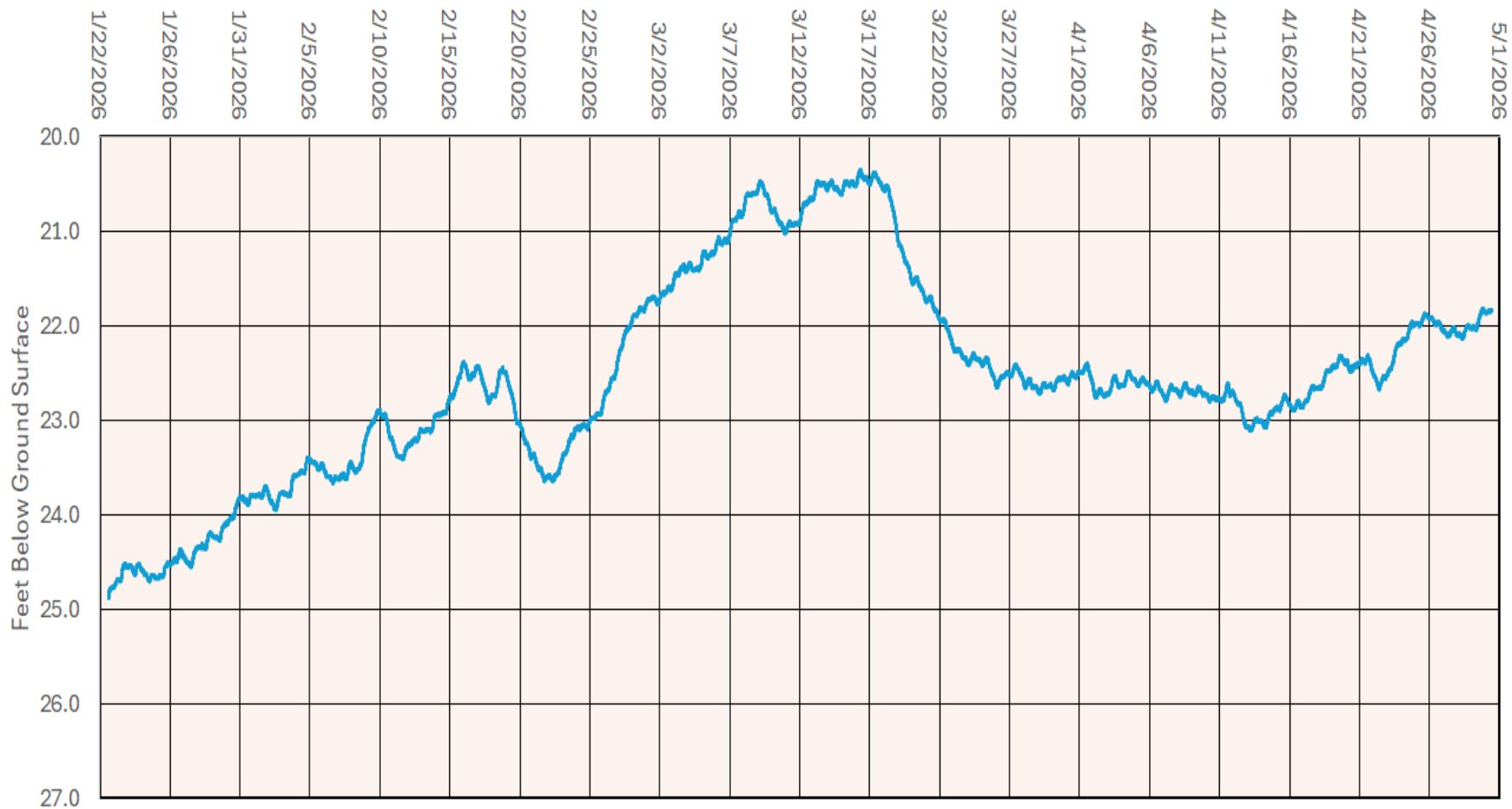
5.3.3 Site N4

As discussed in Section 4, Site N4 included completion of a tTEM survey, and one soil boring converted to a groundwater monitoring well designated RMW-01 (Figure 13). Figure 33 shows the hydrograph developed for RMW-01 covering the period from January 22, 2026, through April 30, 2026. As seen on this figure depth to water ranged between 20 to 25 feet bgs.

Figure 34 shows a still shot from the 3-D model constructed for the site. As seen on this figure, the upper portion for many areas of the site has resistivity values above 20 $\Omega \cdot m$ that as summarized on Table 10 should be permeable sands and gravels. To assess these designations, Figure 35 shows lithologic log for RMW-01 compared to the tTEM data at these points. As seen on this figure, Table 10 provides an accurate interpretation of the tTEM results for this site. As such, Figure 34 suggests that water placed at the surface within Site N4 should migrate to the water table aquifer encountered between 20 to 25 feet that was confirmed during the pilot testing discussed in Section 6.

Figure 36 presents a west to east cross section constructed from the 3-D model that clearly shows permeable materials from the surface to the groundwater table. As shown on Tables 7 and 8, permeabilities of these coarser materials range from about 2 feet/day up to 57 feet/day.

As discussed in Section 5.2, RMW-01 plots within a calcium–magnesium–bicarbonate–sulfate hydrochemical field on the Piper diagram (Figure 19), indicating moderately evolved groundwater influenced by both mineral weathering and land use. Major ion chemistry is characterized by calcium (37 mg/L) and magnesium (26 mg/L) dominance over sodium (13 mg/L), with bicarbonate alkalinity (100 mg/L as CaCO₃) balanced by appreciable sulfate (35 mg/L) and chloride (22 mg/L). Compared to the more dilute, recharge-dominated VMW-01 and the more mineralized WMW-01,

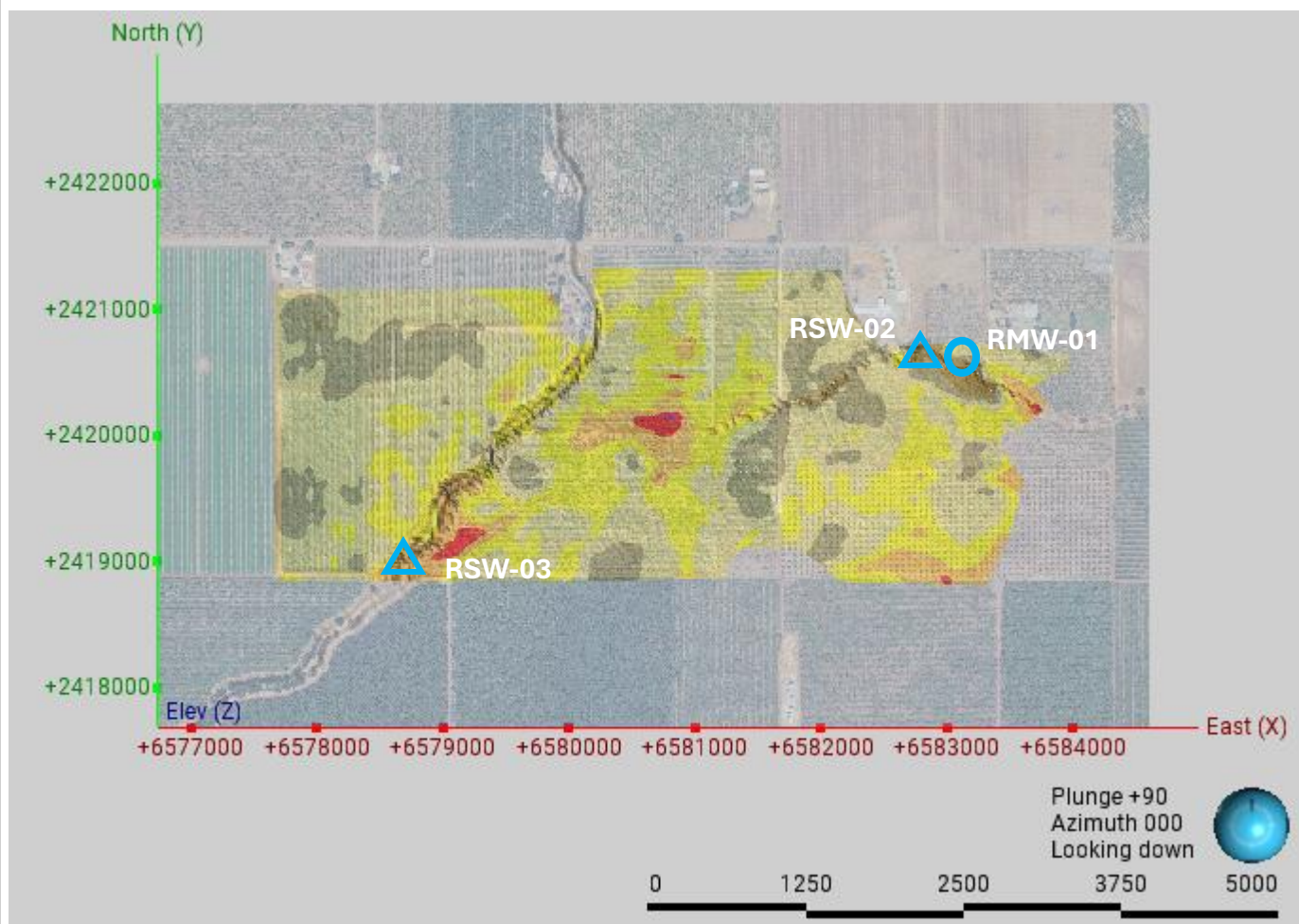
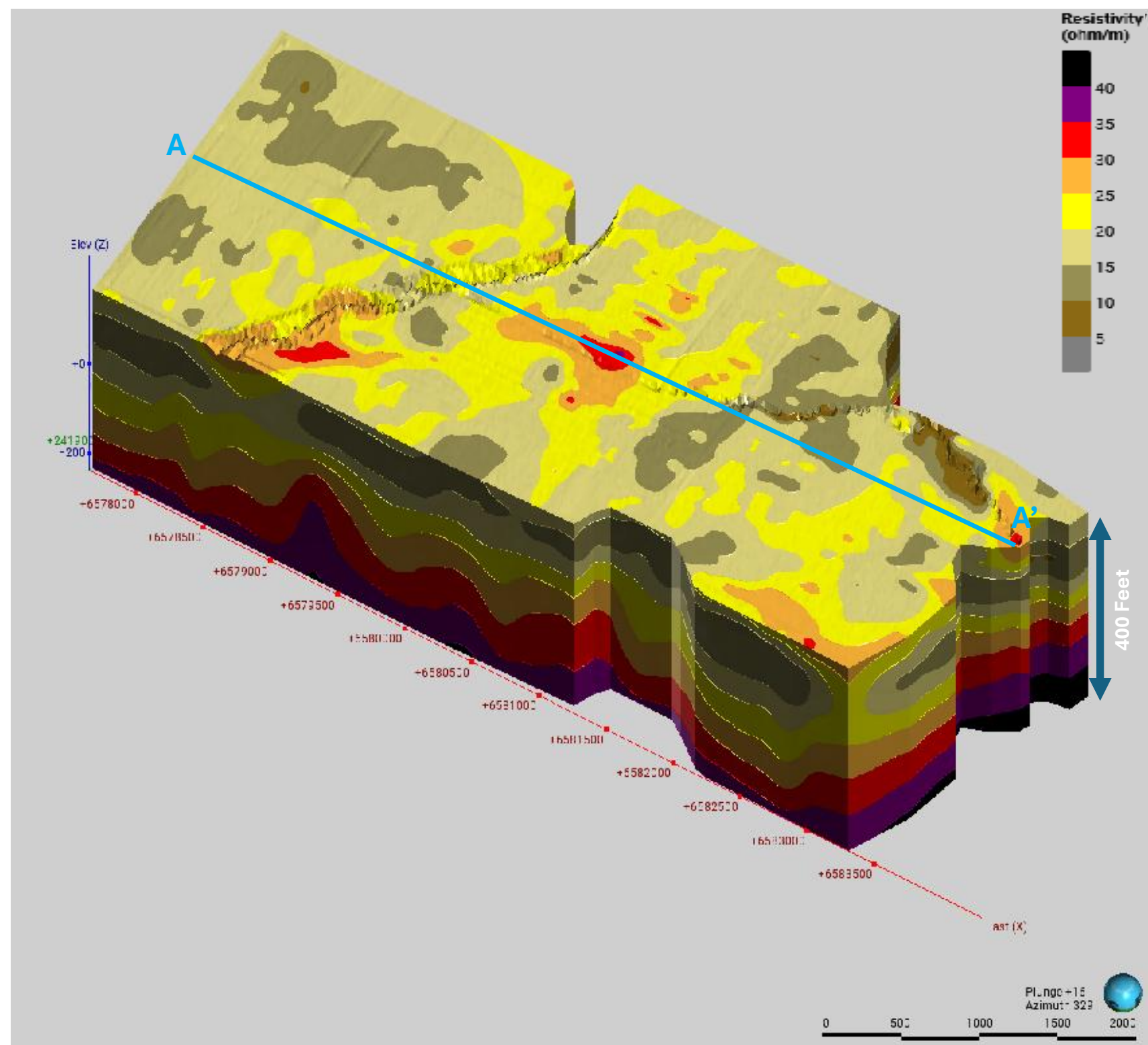


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Time-series graphs showing groundwater levels for RMW-01 at Site N4.

Figure 33



Scales shown on figures are in feet

See Table 10 for lithologic interpretation of resistivity values

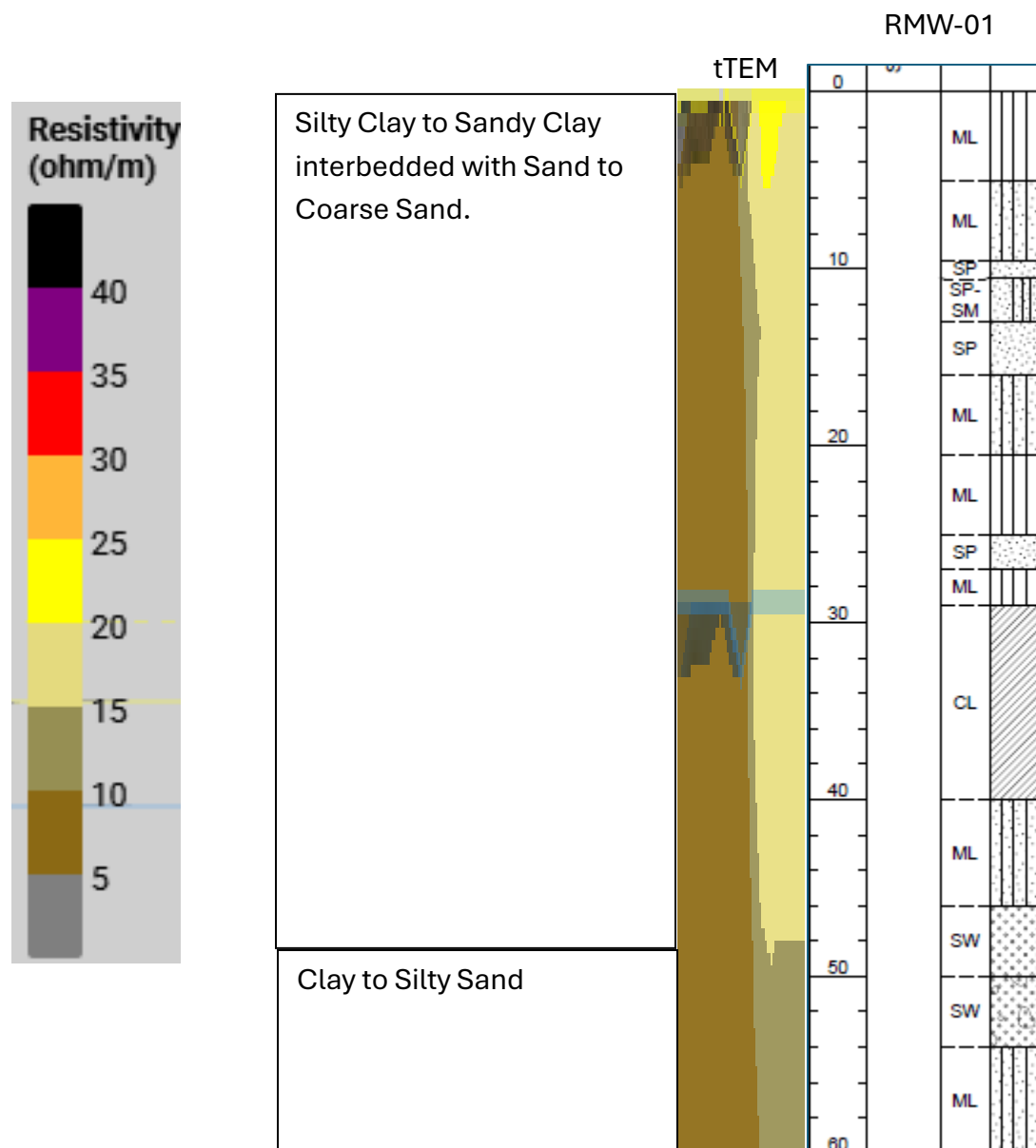
— Cross section line for cross sections shown in Figure 36

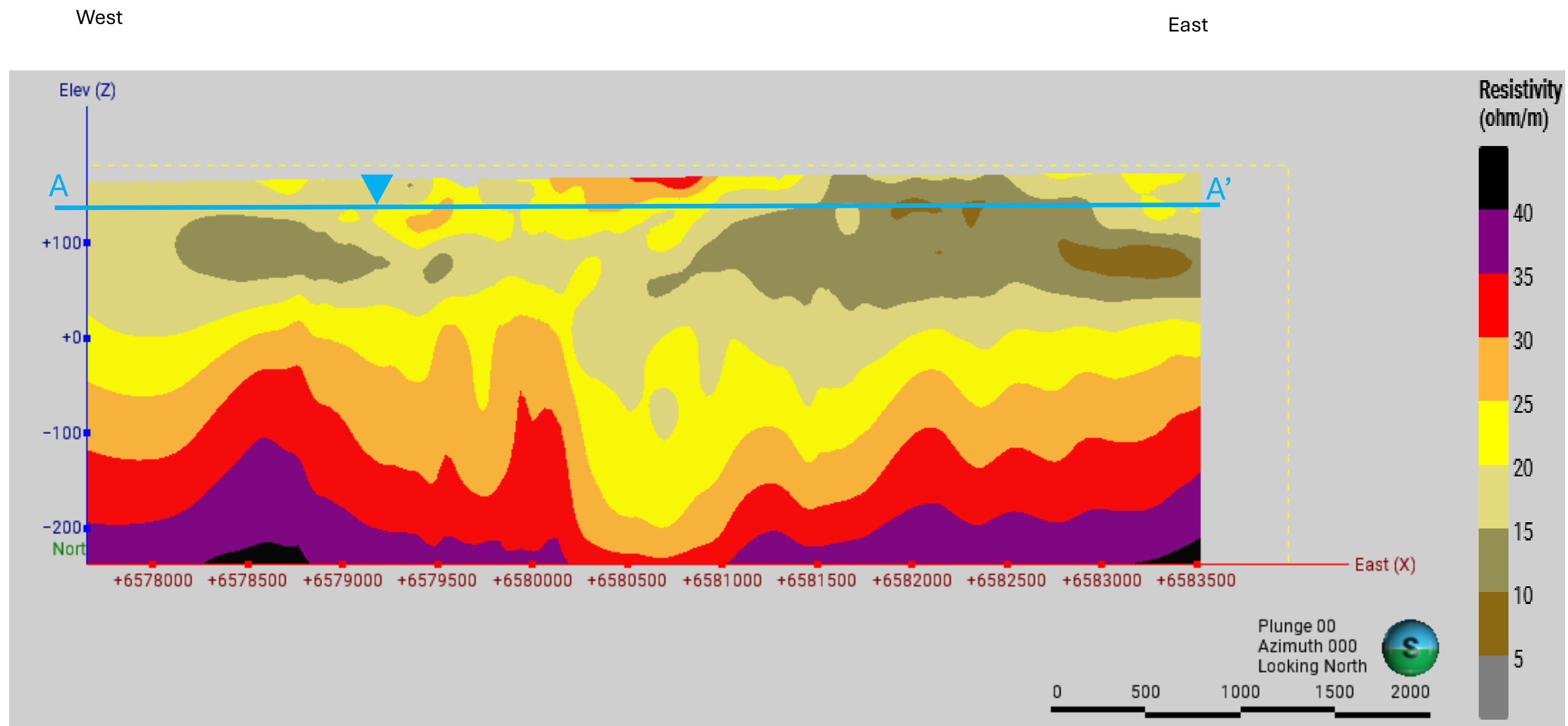
○ Monitoring Well

△ Stilling Well

Three-dimensional model showing subsurface resistivity distribution at Site N4.

Figure 34





RMW-01 represents an intermediate composition, with total dissolved solids (360 mg/L) reflecting moderate geochemical evolution.

No water quality samples were collected from Keefer Slough or Rock Creek. However, relative to Lindo Channel surface water that would be similar to these waters and exhibits substantially lower dissolved solids, sulfate, chloride, and alkalinity, RMW-01 is more chemically evolved, indicating limited direct surface water influence and a stronger role of subsurface processes. However, elevated nitrate (21 mg/L as N) relative to both VMW-01 and Lindo Channel are consistent with agricultural land use and likely reflect fertilizer application and irrigation return flow. Stable isotope values (Figure 20) are more enriched than VMW-01 and Lindo Channel but less enriched than WMW-01, suggesting meteoric recharge with some evaporative enrichment, consistent with irrigation-influenced recharge rather than direct stream infiltration. Overall, RMW-01 represents a transitional groundwater system, bridging dilute recharge conditions and more evolved groundwater, with chemistry influenced by both natural mineral weathering and agricultural practices.

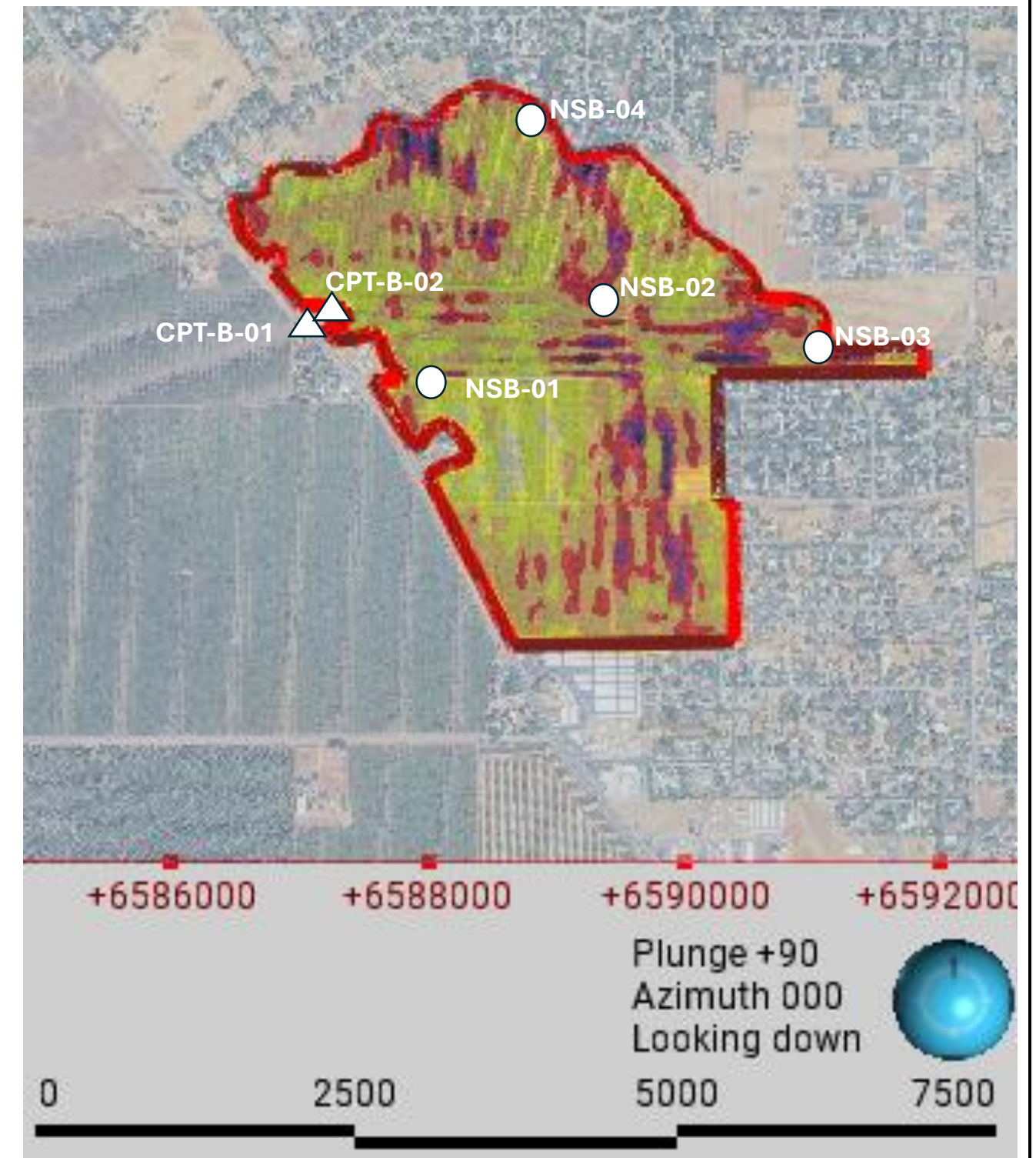
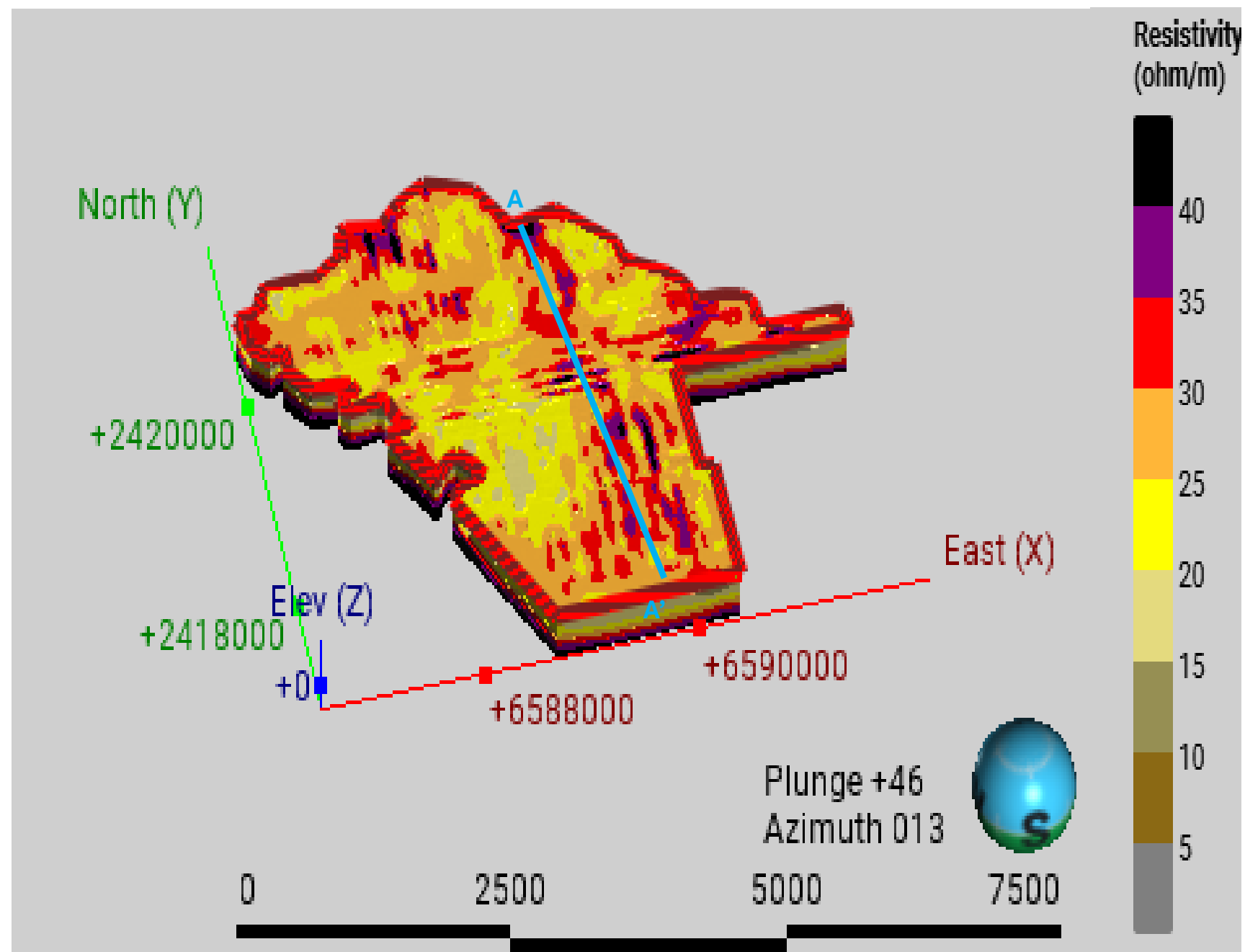
5.3.4 Site N5

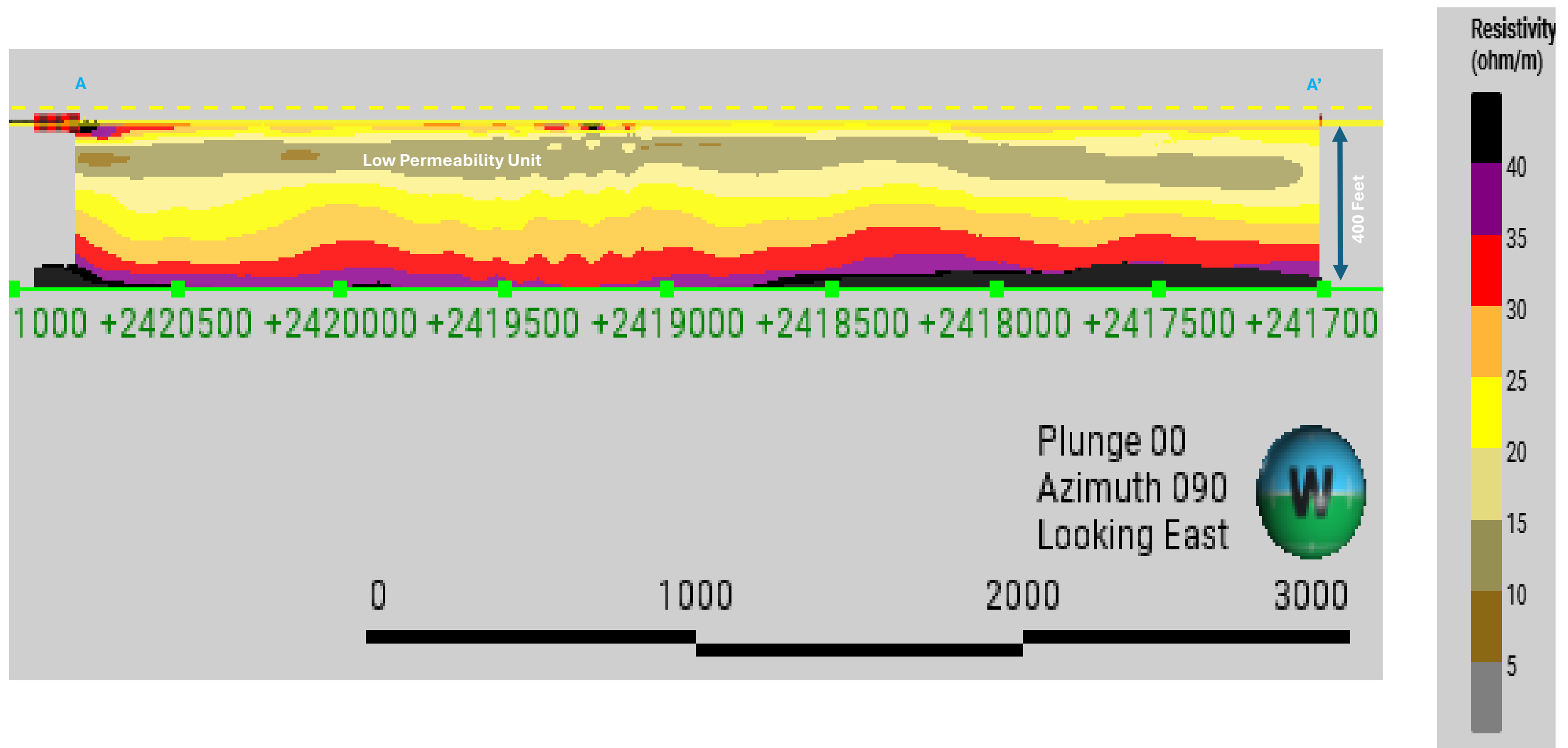
As discussed in Section 4, Site N5 included completion of a tTEM survey, 2 CPT points, and four soil borings. During drilling of the soil borings, first water was observed between 10 to 11 feet bgs. The two CPT points completed on September 5, 2025, recorded first water at about 7 feet bgs. These two points are located in a surface impoundment that is approximately 3 feet lower in elevation than the rest of the property and these water levels are consistent with the first water observed within the soil borings. These water levels indicate that there is a perched water system at this site. Based on water levels reported in DWR's Water Data Library (<https://wdl.water.ca.gov/waterdatalibrary/>) for wells within 1 mile of the site, the regional water table is around 30 to 40 feet bgs. Using the California Statewide Groundwater Elevation Monitoring (CASGEM) program, the tTEM report (Appendix D) estimated first groundwater at 75 feet bgs.

Figure 37 shows a still shot from the 3-D model constructed for the site. As seen on this figure, the upper portion for site has resistivity values above 20 $\Omega \cdot m$ that as summarized on Table 10 should be permeable sands and gravels. As such, Figure 37 suggests that water placed at the surface within Site N5 should migrate downward. However, as stated above, a perched water system exists around 10 feet bgs limited the storage capacity of this site. Figure 38 shows a north south cross section across the site. As seen on this figure, a low permeability unit (resistivity values below 20 $\Omega \cdot m$, is encountered around 15 to 20 feet that most likely forms the bottom of the perched water zone. The 3-D model also suggests that this unit may pinch out to the south that would allow the shallow water to migrate down to the regional groundwater aquifer.

5.3.5 Site N6

As discussed in Section 4, Site N6 included completion of a tTEM survey and four soil borings. During drilling of the soil borings conducted on April 8, 2026, and April 9, 2026, first water was observed between 5 to 10 feet bgs. These water levels indicate that there is a perched water system





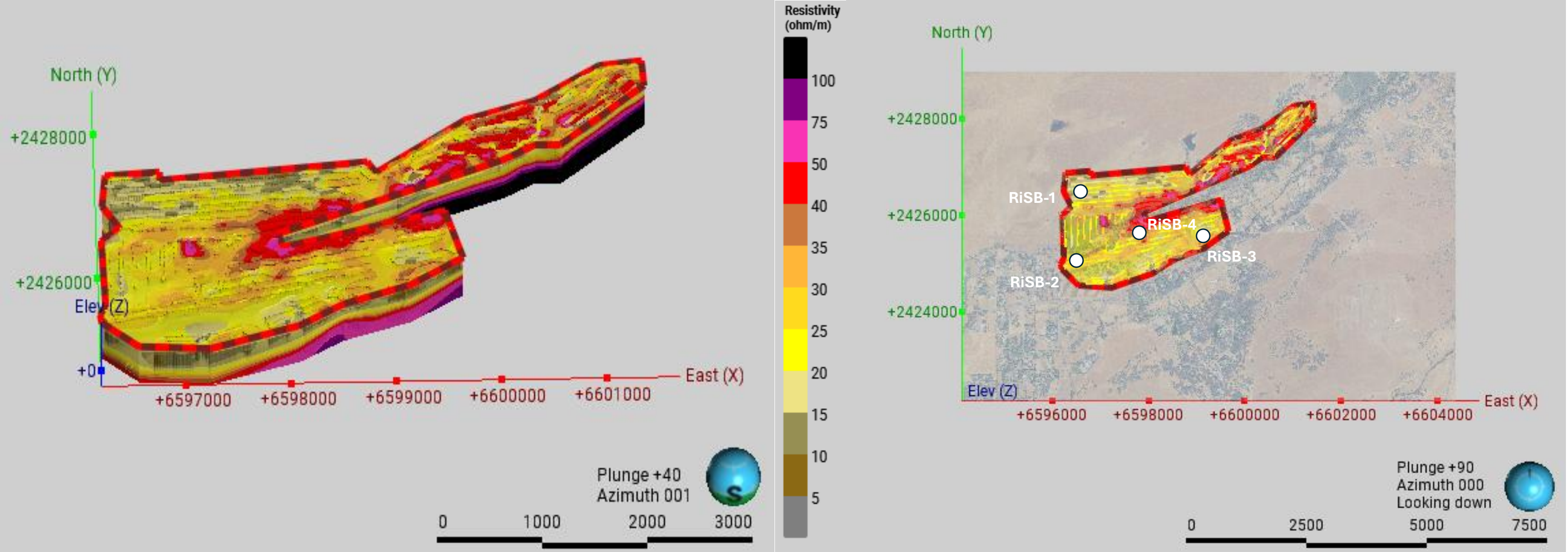
at this site. The regional water table in this area is reported to be around 80 feet bgs (Geocon, 2025).

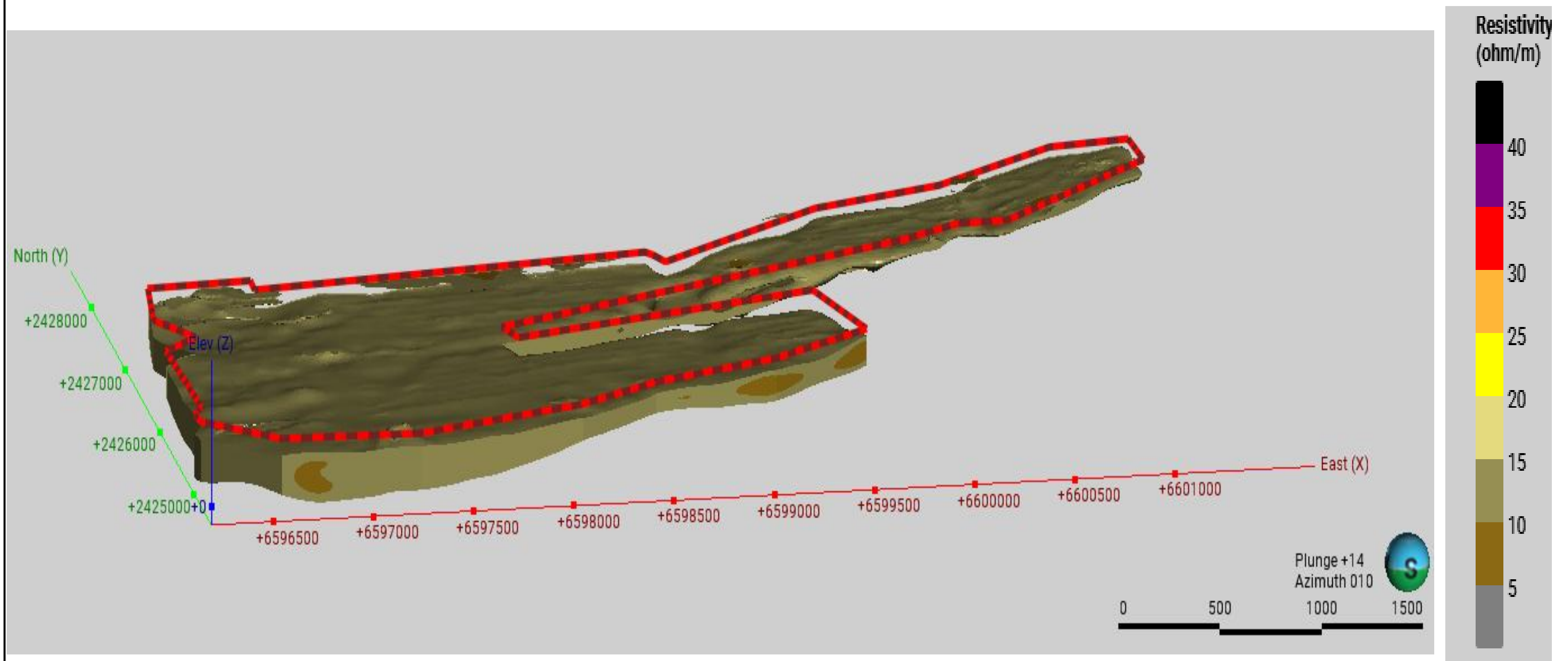
Figure 39 shows a still shot from the 3-D model constructed for the site. As seen on this figure, the upper portion for site has resistivity values above $20 \Omega \cdot m$ that as summarized on Table 10 should be permeable sands and gravels. However, there is a low permeability unit encountered across the site at depths of about 40 feet in the east and 70 feet in the west. Figure 40 illustrates this layer by removing all resistivity values greater than $15 \Omega \cdot m$ from the model. This unit accounts for the perched water system observed at the site during the drilling of soil borings.

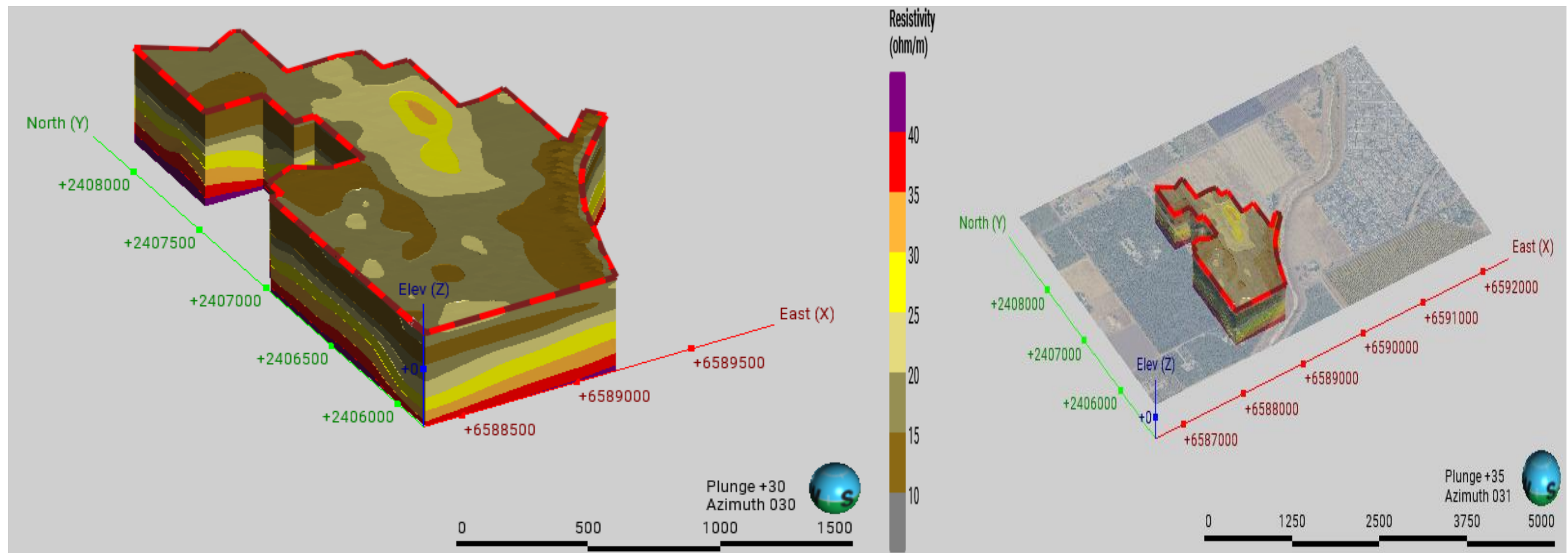
During drilling of RiSB-3, the shallow water was encountered around 10 feet bgs but when the boring was drilled through this low permeability unit, the water was not present within the soil boring supporting the presence of a perched system. The east to west slope of this unit indicates that water within the perched system will flow east to west and possibly hit areas where the low permeability unit pinches out, allowing water to migrate downwards. The high resistivity values ($>80 \Omega \cdot m$) at the base of the model could represent bedrock material that is also sloping from east to west.

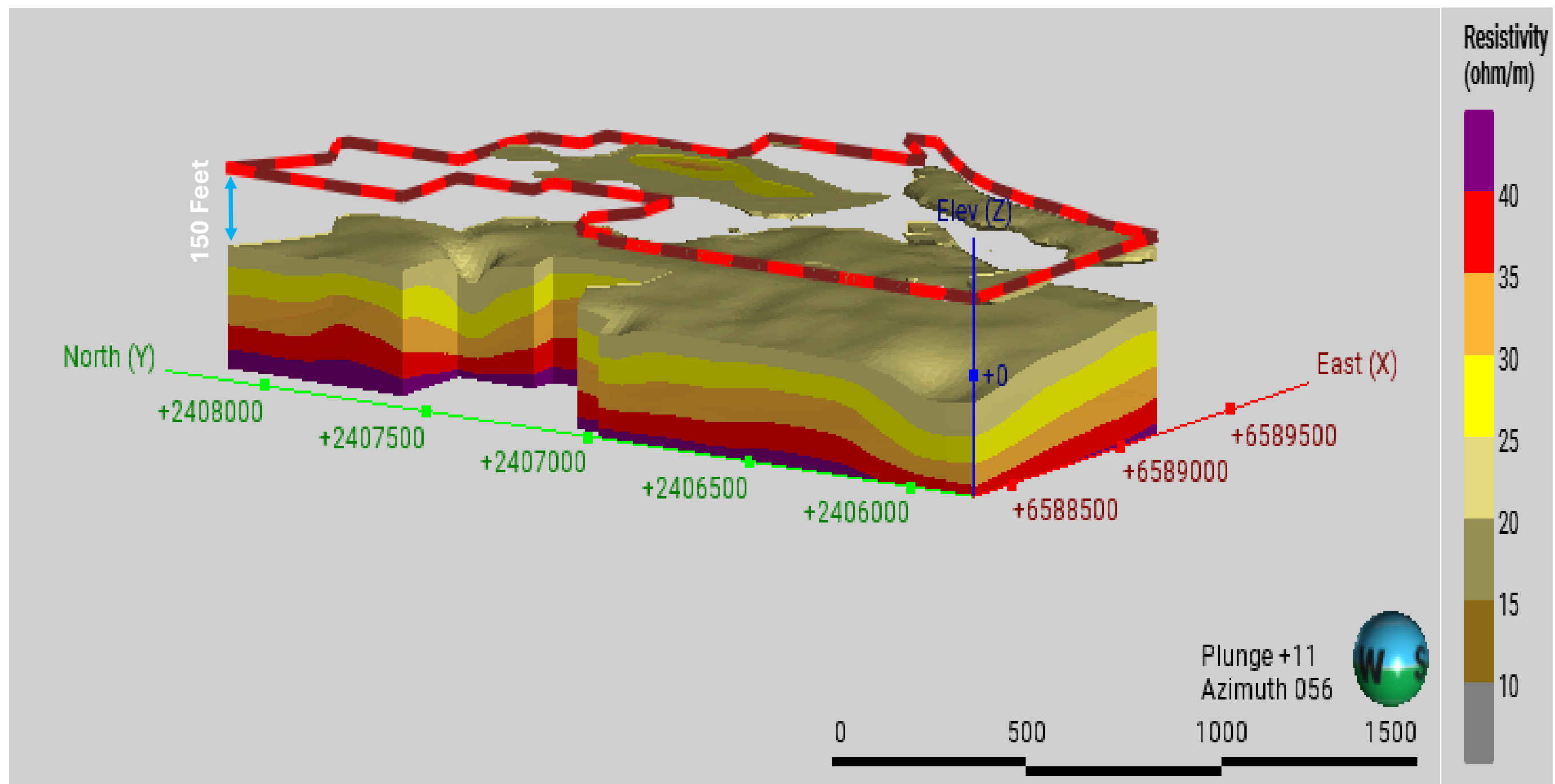
5.3.6 Site N8

As discussed in Section 4, Site N8 only included completion of a tTEM survey. It is anticipated that groundwater levels at this site will be similar to Site N4 where first water was observed between 20 to 25 feet bgs. Figure 41 shows a still shot from the 3-D model constructed for the site. As seen on this figure, from the surface down, large areas of the site show low permeability areas with resistivity values below $20 \Omega \cdot m$. Figure 42 shows the model with all resistivity values below $20 \Omega \cdot m$ removed. As seen on this figure, there appears to only be limited areas from the surface down that might allow some recharge to shallow systems.









6. PILOT TESTS

Based on the results of the groundwater investigations discussed in Sections 4 and 5 and discussions with landowners, pilot tests were conducted at the following four sites, Site S1, N3, N4, and N5 (Figure 7). The pilot tests included infiltration basins at all four sites, and a reverse tile drain system at Site S1. For the infiltration basin at Site S1, California Water Code 1242.1 was used to divert flood flows to the basin. Table 11 provides a summary of the results for each site that includes range of infiltration rates calculated from the tests and the key takeaway from the tests.

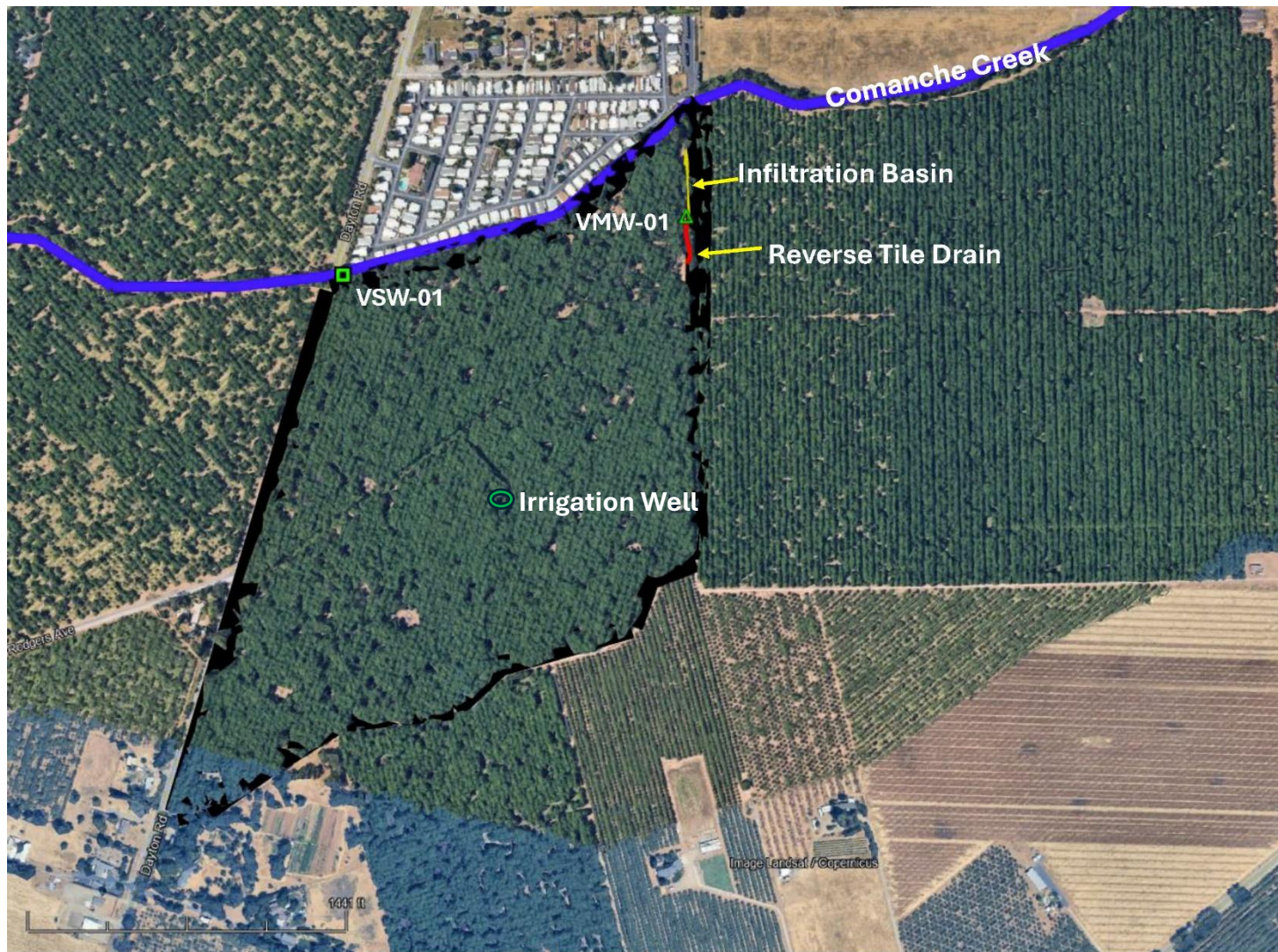
Table 11. Summary of pilot test results and key takeaways

Site	Pilot Test	Range of Infiltration Rates (feet/day)	Key Take Away
S1	Infiltration Basin	10.5 to 14	When normalized to a 1-acre basin, infiltration ranged from 2.1 to 2.9 acre-feet per day, indicating excellent infiltration capacity. Recharge water successfully percolated to groundwater, and the groundwater system demonstrated sufficient capacity to accept the inflow.
	Reverse Tile Drain	2 to 50	Test indicated potential for up to 0.86 gpm per liner foot of tile drain that for 4,000 feet of tile drain equates to 15.2 acre-feet/day. Recharge water successfully percolated to groundwater, and the groundwater system demonstrated sufficient capacity to accept the inflow.
N3	Infiltration Basins	0.02 to 0.64	Poor infiltration rates are not conducive to successful recharge projects. Shallow perched groundwater observed from 7 to 4 feet bgs.
N4	Infiltration Basins	0.35 to 2.52	Average rate measured 1.36 feet/day – excellent rate for recharge basins. As with S1, recharge water successfully percolated to groundwater, and the groundwater system demonstrated sufficient capacity to accept the inflow.
N5	Infiltration Basin	0.27 to 0.63	Low infiltration rates due to shallow perched water system.

A detailed discussion of the methods and results of each of these pilot tests is provided in the following sections.

6.1 Site S1

As stated above, pilot testing at Site S1 included a reverse tile drain and infiltration basin. Figure 43 shows the location of each of the features along with the location of a monitoring well and stilling well within Comanche Creek that were used for monitoring during the pilot tests.



△ VMW-01-Monitoring Well

□ VSW-01-Stilling Well

○ Irrigation Well

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Site map showing locations of pilot test features including basins, wells, and tile drains.

Figure 43

A reverse tile drain is a subsurface drainage system designed to enhance groundwater recharge by directing collected water into a subsurface perforated pipe. For this project, a small 140-foot-long trench (Photograph 8) was excavated to about 12 feet bgs where an 8-inch perforated pipe (Photograph 9) was installed. Three vertical observation points, designated OPS-1 through OPS-3 (Photograph 10), were also installed within the trench to measure water levels during the pilot testing. Gravel was then placed within the trench to a depth of 10 to 9 feet bgs. A 0.25-inch fabric material was placed above the gravel to minimize fines from above migrating into the gravel pack. The remainder of the trench was then backfilled with excavated material. Figure 44 presents a schematic drawing of the reverse tile drain system.



Photograph 8. Photograph showing excavation of trench with perforated pipe installed.



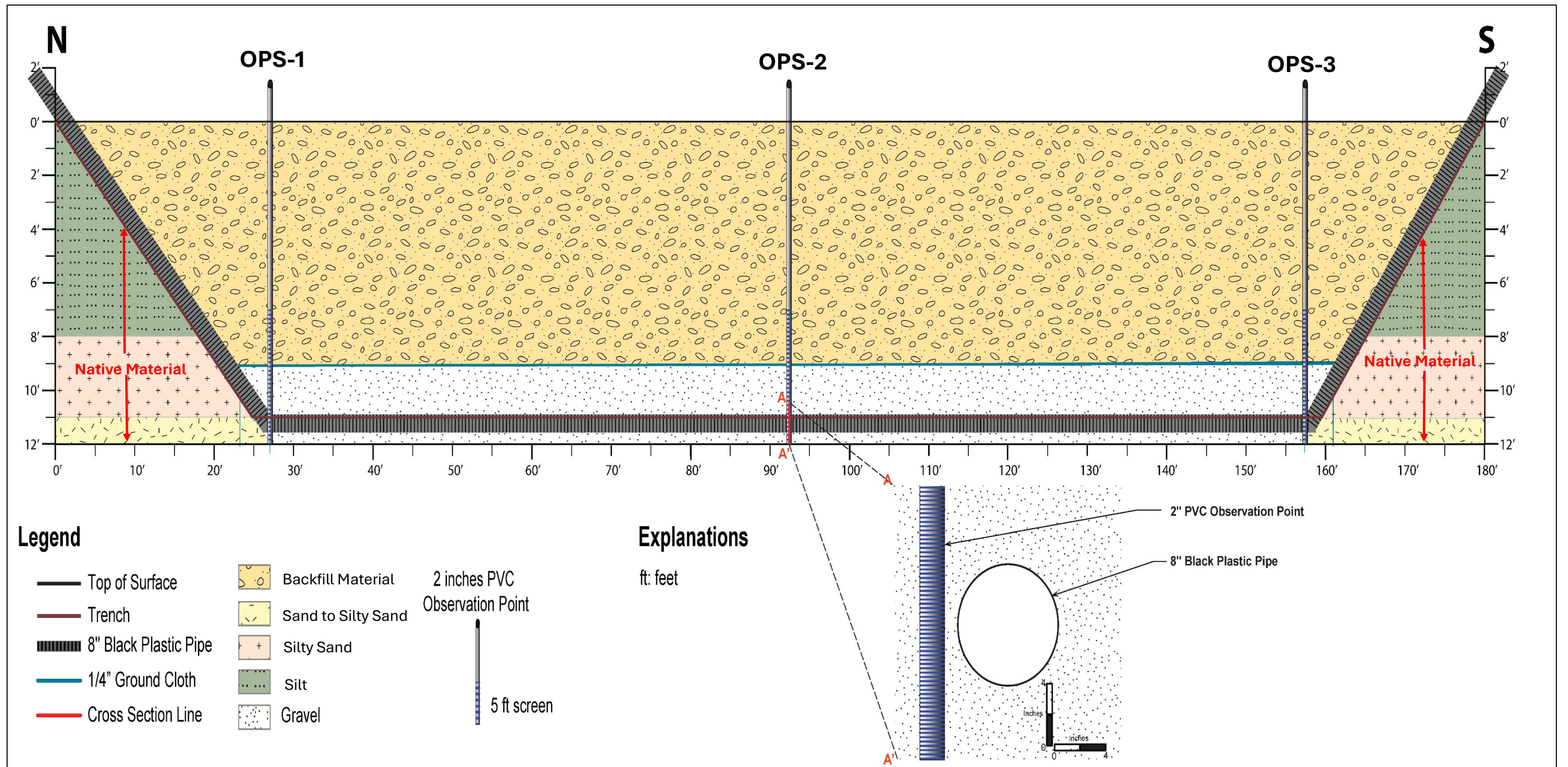
Photograph 9. Eight-inch perforated pipe installed in bottom of trench. Photograph on right shows perforation.



Photograph 10. Observation points (yellow pipes) installed within trench to record water levels during pilot testing.

Pilot testing of this system was conducted in two phases. The first phase was conducted by injecting water from an onsite irrigation well (Figure 43, Photograph 11). The test started on December 2, 2025, at 09:28 and ended on December 4, 2025, at 10:57. During the test, a totalizer (Photograph 12) recorded the total volume of water added to the system and water levels were recorded in the three tile drain observation wells and within monitoring well VMW-01. Water levels were recorded using the vented In Situ pressure transducers programed to record water levels every 5 minutes within the observation points and the monitoring well VMW-01. Table 12 summarizes the totalizer readings and indicates that a total of 225,193 gallons were added to the system with an average pumping rate of about 77 gallons per minute (gpm).

Figure 45 presents the hydrographs for the observation points within the tile drain and for VMW-01. As seen on this figure, the pilot test of the tile drain recharge system demonstrated consistent and effective infiltration along the 140-ft long trench. During injection at approximately 77 gpm, water levels in the OPS observation points responded in a uniform but subdued manner, indicating good longitudinal connectivity within the trench but limited vertical head buildup. The observation wells showed gradual increases in water levels with relatively small overall changes (generally on the order of a few tenths of a foot), while the nearby monitoring well VMW-01 showed only minor fluctuation (less than 0.5 feet), confirming that the deeper formation accepted recharge without significant mounding. The two declines visible in the data for the observation points correspond





Photograph 11. Discharge line from irrigation well going into reverse tile drain system.



Photograph 12. Totalizer used to record volume of water injected into reverse tile drain system.

Table 12. Summary of totalizer readings for injection into tile drain from irrigation well.

Date and Time	Totalizer Reading	Total Gallons Injected	Minutes From Startup	Comments
12/2/2025 9:28	467.30	0	0.00	
12/2/2025 9:35	741.80	275	7.00	
12/2/2025 9:45	911.00	169	17.00	
12/2/2025 10:06	1767.00	856	38.00	
12/2/2025 10:21	2471.00	704	53.00	
12/2/2025 10:41	3639.00	1,168	73.00	
12/2/2025 11:04	4859.00	1,220	96.00	
12/2/2025 11:17	5568.00	709	109.00	
12/2/2025 11:30	6317.00	749	122.00	
12/2/2025 11:49	7319.00	1,002	141.00	
12/2/2025 12:04	8137.00	818	156.00	
12/2/2025 12:19	8941.00	804	171.00	
12/2/2025 12:30	9688.10	747	182.00	Stop to Change Line
12/2/2025 13:00	9769.16	0	212.00	Restarted
12/2/2025 13:15	10293.00	524	227.00	
12/2/2025 14:08	14118.00	3,825	280.00	
12/2/2025 14:38	15925.00	1,807	310.00	
12/2/2025 15:27	19895.00	3,970	359.00	
12/2/2025 15:40	20945.70	1,051	372.00	Stop to fix discharge line
12/2/2025 15:56	20945.70	0	388.00	Restarted
12/2/2025 15:59	21073.00	127	391.00	
12/2/2025 17:10	26785.00	5,712	462.00	
12/2/2025 20:17	41763.00	14,978	649.00	
12/3/2025 0:14	60735.00	18,972	886.00	
12/3/2025 5:38	86466.00	25,731	1,210.00	
12/3/2025 9:09	103205.00	16,739	1,421.00	
12/3/2025 14:09	126989.00	23,784	1,721.00	
12/3/2025 17:50	144513.00	17,524	1,942.00	
12/3/2025 19:59	154829.00	10,316	2,071.00	
12/4/2025 6:22	204161.00	49,332	2,694.00	
12/4/2025 10:57	225741.05	21,580	2,969.00	
Totals		225,193	2,923	Number subtracts the times pump is off
Average Pumping Rate (GPM)			77	

to temporary pump shutdowns, with rapid stabilization when pumping resumed, and the final decline reflecting shutdown at the end of the test.

Based on the observed trends, the effective infiltration rate is on the order of 2 to 4 feet/day in the shallow system, with short periods indicating higher up to about 50 feet/day during peak acceptance. For comparison, excellent soils for recharge on the SAGBI maps are based on an infiltration rate of 1 foot/day where the sediments at this site indicate at least twice this rate. Overall, the system performed efficiently, showing steady infiltration, minimal backpressure, and no evidence of clogging or hydraulic limitation over the test duration. The muted response across OPS-1 through OPS-3 indicates that the full trench length was contributing, while the modest response in monitoring well VMW-01 suggests moderate transmissivity and good vertical distribution of recharge. Given the stable behavior at 77 gpm and lack of excessive mounding, the system could likely sustain somewhat higher rates; a reasonable estimate for sustainable operation is on the order of 80 to 120 gpm for this 140-ft section.

Scaling the pilot test results, a 140-foot section accepted approximately 77 gpm, which corresponds to about 0.55 gpm per linear foot of trench. Applying this rate to a 5,000-ft long system yields an estimated flow capacity of roughly 2,700 to 2,800 gpm under similar design and subsurface conditions. This estimate assumes that infiltration performance remains consistent along the entire length, with uniform soils and effective distribution. In practice, some reduction in efficiency would be expected due to head loss and flow distribution constraints, so a more realistic sustainable operating range would likely be on the order of approximately 2,000 to 2,700 gpm or 8.8 to acre-feet/day. 11.9

The second test used flood waters from Comanche Creek following California Water Code 1242.1. Water Code 1242.1, added by Senate Bill (SB) 122 in 2023, creates a fast-track legal mechanism to divert flood flows during extreme storm or flood conditions for managed aquifer recharge (MAR) without needing an appropriative water right, which normally takes years to obtain and is costly. The statute's core purpose is dual: Reduce flood risk and accelerate groundwater recharge to address overdraft and SGMA groundwater sustainability needs. For this pilot test, the water was directed into an infiltration basin located just north of the reverse tile drain system (Figure 42) then from the south end of the basin, water was pumped into the reverse tile drain system. Prior to conducting these tests, an implementation plan was developed for review by the appropriate agencies. A copy of this plan is provided in Appendix K along with the noticing and submitted reports to the California State Water Resources Control Board.

The infiltration basin was constructed by excavating material over an approximate 0.1-acre area and using this material to form berms. Photograph 13 shows a portion of the basin being constructed. After construction, gravel berms were placed at various points to reduce sediments in the flood waters before pumping portion of the water into the reverse tile drain system. A portable pump was then rented and placed within Comanche Creek for pumping water into the basin (Photograph 14). Photograph 15 shows the discharge line going into the north end of the infiltration basin onto gravel to reduce sediment load. Two stilling wells were placed into the infiltration basin, one on the north end (designated influent) and one on the south end (designated effluent, Photograph 16). The pressure transducers installed within these stilling wells, the monitoring well,

and the observation points within the reverse tile drain were all programed to record water levels at 15-minute intervals. The stilling well within Comanche Creek (Figure 42) was also monitored for the pilot tests and programed to record water levels at 15-minute intervals. A flow meter and totalizer were also installed on the discharge line to record volumes of water discharged.



Photograph 13. Poriton of Site S1 infiltration basin



Photograph 14. Pump intake going into Comanche Creek.



Photograph 15. Discharge line from Comanche Creek going into north end of infiltration basin.



Photograph 16. Stilling well at south end (effluent) of infiltration basin.

To conduct the pilot test, “imminent risk” needed to trigger the Water Code 1242.1 process was determined by analyzing previous flood events and the precipitation that was forecasted prior to those events. Through tracking predicted storm events and coordinating with Butte County Department of Water and Resource Conservation, Public Works, and Emergency Management, Vina GSA, and the DWR, two events were identified to conduct the pilot tests. The first test was conducted between February 20, 2026, and February 21, 2026 and the second test was conducted between February 25, 2026 and February 27, 2026. Figure 46 provides the data evaluated to conduct the tests and the notification that was provided for the February 25, 2026, event.

The first FloodMAR test started at noon on February 20, 2026, and ended at noon on February 21, 2026. Table 13 summarizes the totalizer readings and indicates that a total of 998,735 gallons (3.07 acre-feet) were added to the system. During the test, pumping rates were estimated from the totalizer readings and ranged from 650 gpm to 1,000 gpm with an average pumping rate of 694 gpm. Pumping to the reverse tile drain started at 13:52 on February 20, 2026, and ended at 12:07 on February 21, 2026. A total of 49,689 gallons were pumped into the reverse tile drain. The pumping to the reverse tile drain was not continuous, but when operating, the pumping rate was about 40 gpm.

Figure 47 shows the hydrographs for the stilling wells in the infiltration basin, monitoring well VMW-01, and the pumping rates during the test. As seen on this figure, the basin exhibited a rapid hydraulic response following the onset of pumping. Water levels at the influent rose quickly during the first several hours, reaching approximately 2 feet of ponded depth, which reflects high initial infiltration capacity under relatively dry antecedent conditions. As the test progressed, ponded water levels approached a somewhat steady-state condition in which inflow was approximately balanced by infiltration losses. This equilibrium indicates that the basin was capable of infiltrating a substantial portion of the applied flow during sustained operation.

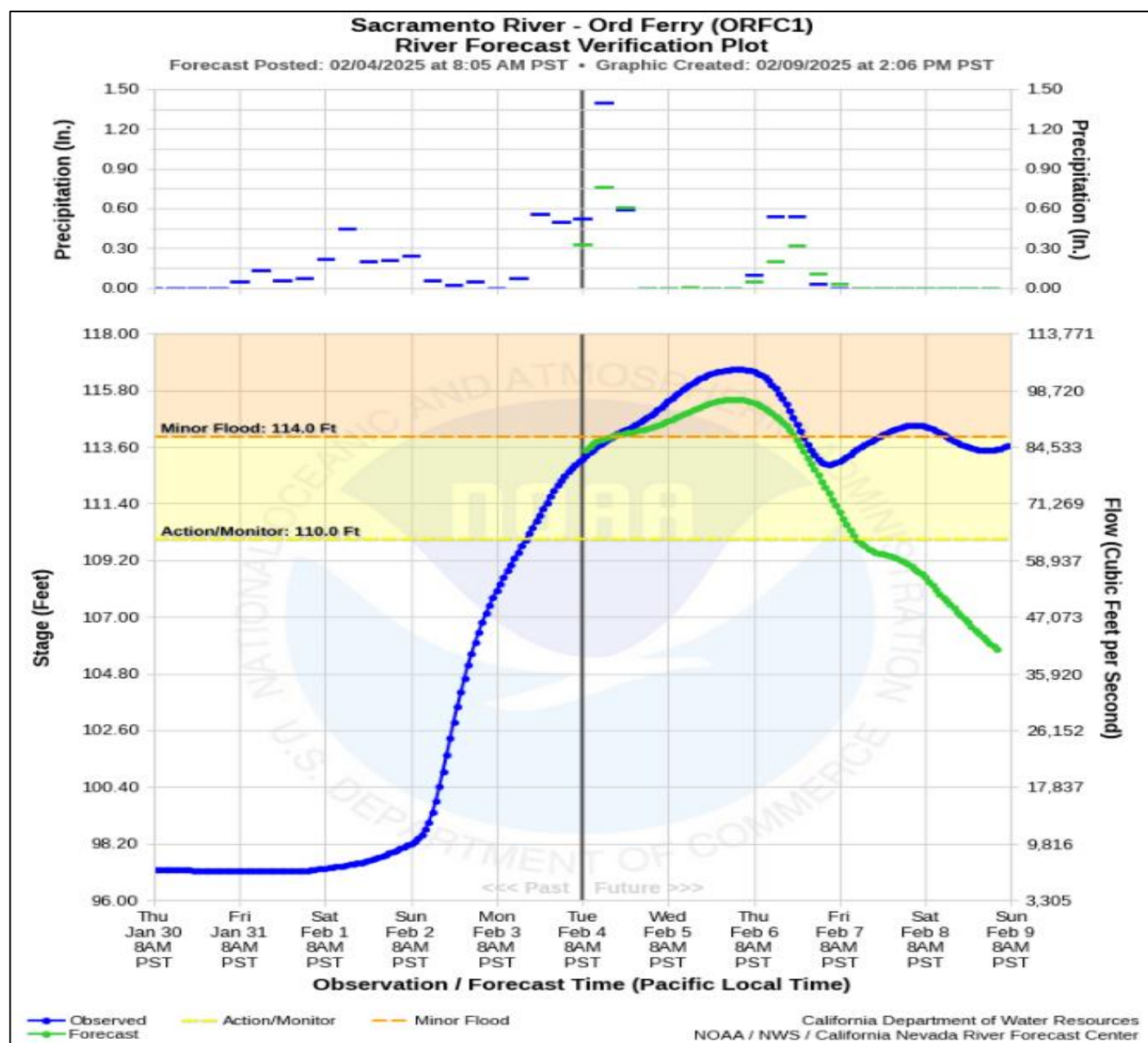
The outfall stilling well at the south end of the basin, showed comparatively low and stable water levels throughout the test relative to the influent. This pattern indicates that lateral flow across the basin was limited and that vertical percolation was the dominant mechanism of water loss. The limited hydraulic gradient between the north and south ends of the basin further supports the conclusion that infiltration was occurring primarily beneath the basin rather than through significant surface flow toward the outlet.

Based on totalizer measurements, a total of approximately 998,735 gallons was recharged over an approximately 24-hour period during Test 1, which is equivalent to about 3.06 acre-feet of water. When applied to the 0.1-acre pilot basin, this corresponds to approximately 0.29 acre-feet per day, or 2.88 acre-feet per day when scaled to a one-acre basin.

Analysis of water level trends during pump-off periods indicates that the basin exhibited an average infiltration rate of approximately 0.0099 feet per minute, equivalent to about 14.3 feet per day. When normalized to a one-acre basin, this rate corresponds to a theoretical infiltration capacity of approximately 14.3 acre-feet per day. However, as shown in Figure 47, water levels within the basin remained relatively stable during sustained pumping at an average rate of approximately 694 gpm (about 3 acre-feet per day applied over the 0.1-acre basin), indicating that the long-term infiltration capacity of the system was significantly lower than the short-term

Table 13. Summary of totalizer readings – Test 1 FloodMAR.

Date	Time	Totalizer Reading (0.001 acre-feet)	Gallons Injected	Comments
2/20/2026	12:00	953510	0	650gpm
	12:30	953580	22,810	At 12:15 pump rate 1,000 gpm
	13:00	953678	54,743	
	13:30	953746	76,901	
	14:00	953848	110,138	650 gpm
	14:30	953897	126,105	
	15:00	953952	144,026	850 gpm
	15:30	954100	192,252	
	16:00	954108	194,859	
	19:30	954610	358,437	650 gpm
2/21/2026	09:00	956174	868,068	
	09:30	956250	892,833	1000 gpm
	10:00	956321	915,968	750 gpm
	10:30	956386	937,149	
	11:00	956453	958,981	
	11:30	956554	991,892	
	12:00	956575	998,735	



Date of flood event	Reported Flooding	Prior 5-day forecast (ORFC1)
11-23-2024	Ord Ferry Rd/River Rd ⁷	7.35"
2-5-2025	Ord Ferry Rd/River Rd ⁸	3.75"
12-15-2024	Ord Ferry/River Rd ⁹	2.05"



Vina Groundwater Sustainability Agency

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February 25, 2026

NOTICE

DIVERSIONS FOR GROUNDWATER RECHARGE AND FLOOD MANAGEMENT

On February 25, 2026, the Vina Groundwater Sustainability Agency (GSA) began diversions from Comanche Creek at the location depicted in Figure 1, for a groundwater recharge pilot project in accordance with California Water Code section 1242.1 (CWC 1242.1).

CWC 1242.1 allows for the diversion of flood water for groundwater recharge while also reducing flood risks and impacts. Furthermore, California Governor's Executive Order N-16-25 encourages local agencies to provide these dual benefits of improved groundwater levels and flood management in specified counties, including Butte County. The Vina GSA is issuing this notice in its capacity as a local public agency, under authority of the State of California, in coordination and communication with Butte County Department of Water and Resource Conservation and other County departments, such as Public Works and Butte County Emergency Management. Implementation of this pilot recharge project using floodflows is consistent with Action 1.1 described in the Butte County Recharge Action Plan, adopted by the Butte County Board of Supervisors in 2024.

River Road and Seven Mile Lane are downstream of the identified diversion location. On February 25, 2026 at 9:45 AM, River Road was closed due to flooding and Butte County Public Works issued a warning for unpredictable conditions on Seven Mile Lane, following several days of precipitation and high Sacramento River flows. Additionally, the California Nevada River Forecast Center (CNRFC) [ORFC1 gage](#) on the Sacramento River, downstream of Comanche Creek, is forecasted to reach 110 feet on February 25, 2026 and 114 feet on February 26, 2026. This location on the Sacramento River has an established "Action/Monitor" stage at 110 feet and "Minor Flooding" at 114 feet. At these levels the Sacramento River is known to flood Ord Ferry Road, River Road, and neighboring properties.

This floodflow diversion began at approximately 10:00 am on February 25, 2026 and will end after 24 hours or when observed flooding of roadways subsides. The Vina GSA will communicate the cessation of diversions via a notice posted to its website. The Vina GSA will divert floodflows utilizing temporary pumps, equipped with screens as required by CWC 1242.1(d), to adjacent farmland in the identified pilot area, where it will be applied for the purpose of groundwater recharge. Diverted water will be applied only to land that complies with the restrictions of CWC 1242.1(b), including actively cultivated agricultural fields.

Consistent with CWC 1242.1(f), no water right is claimed based on this diversion and recharge. Diverted water benefits the net groundwater balance of the Vina Subbasin.

In accordance with CWC 1242.1(g), the Vina GSA will file a Notice, Preliminary Report, and Final Report with the State Water Resources Control Board at FloodDiversion@waterboards.ca.gov, documenting the diversion including GPS coordinates, dates, maps, and estimated acre-feet diverted.

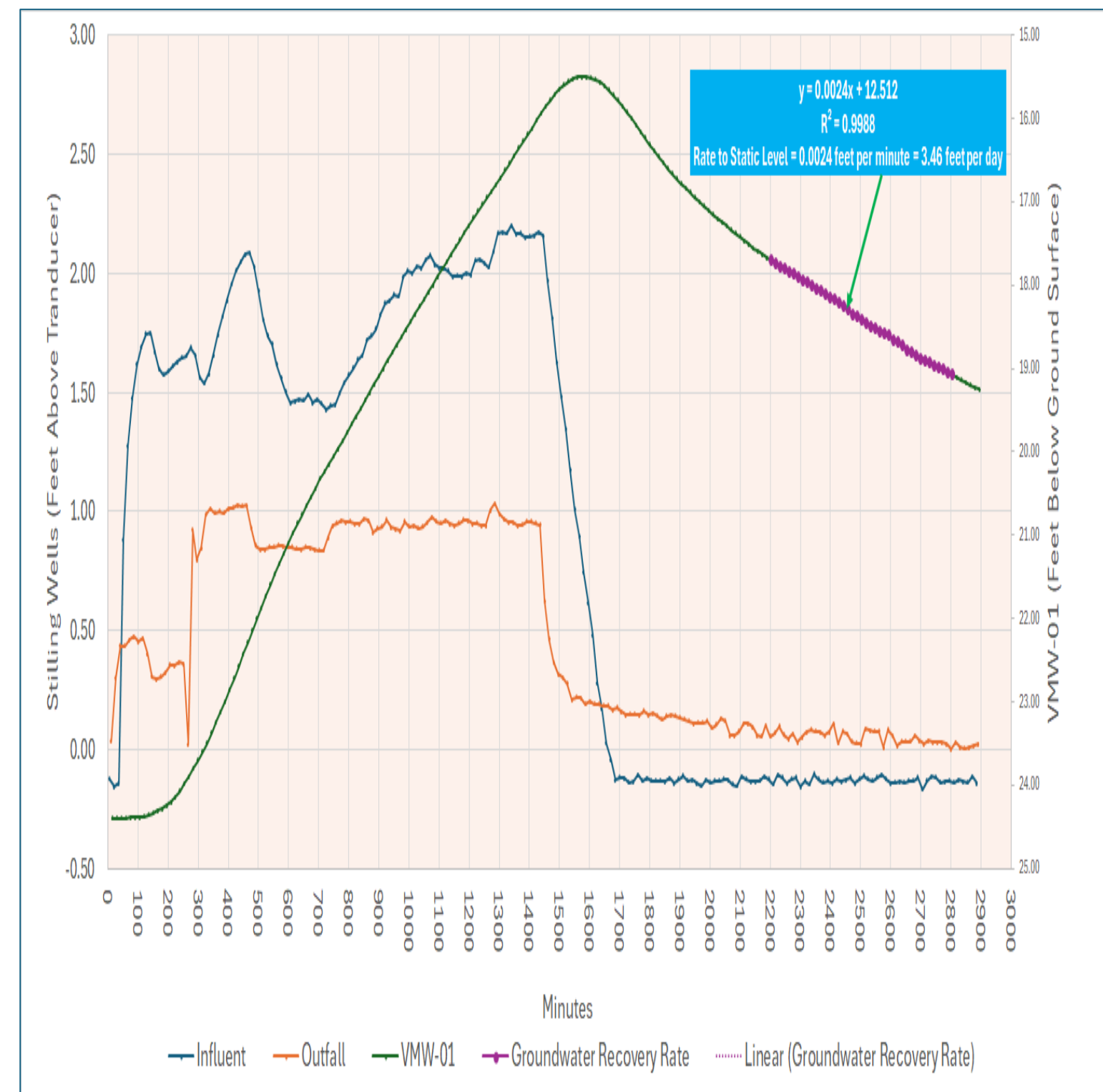
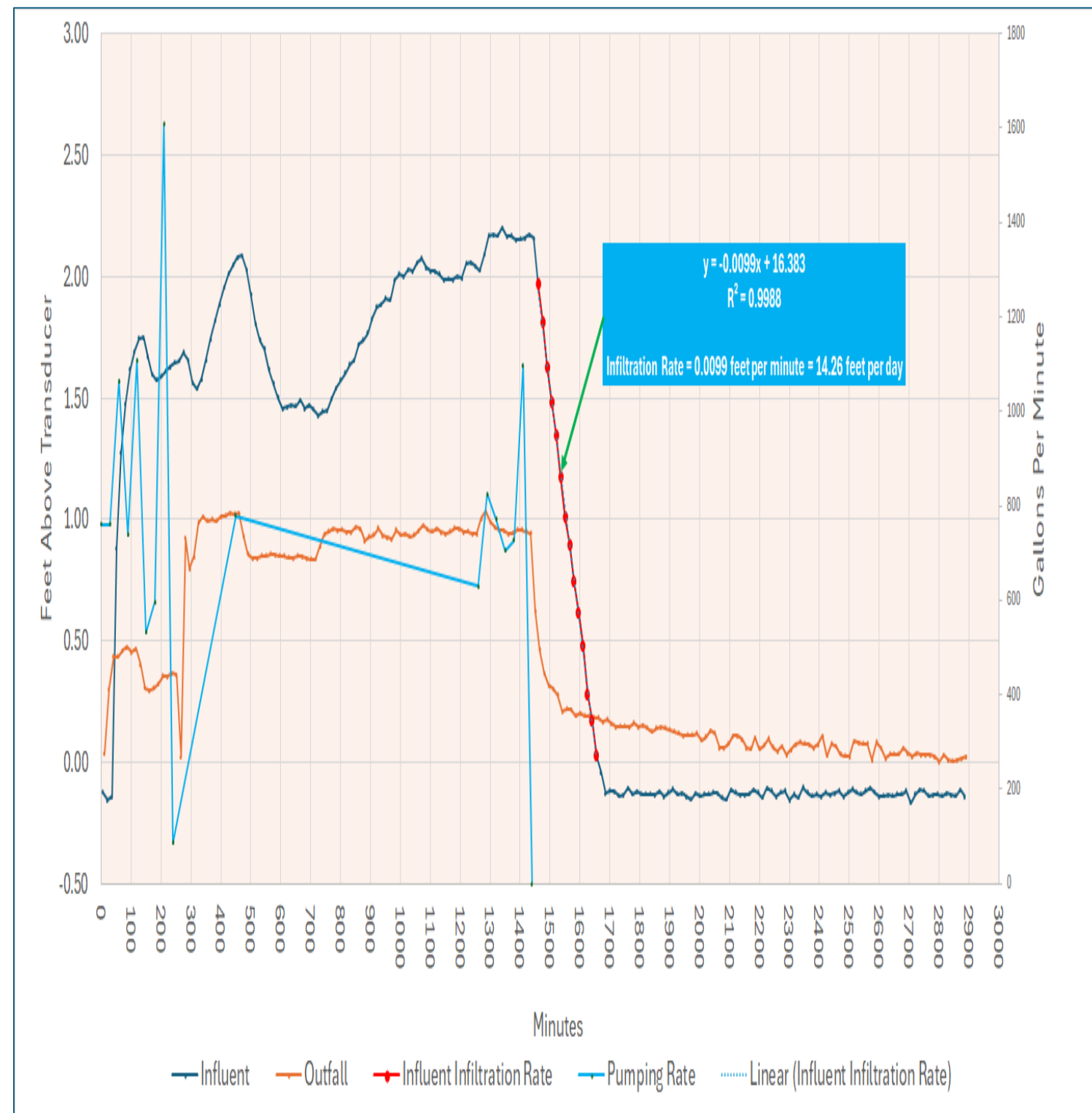
Questions regarding this notice may be directed to the Vina GSA at VinaGSA@gmail.com or (530) 552-3593.

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Graphs showing 1242.1 Trigger levels and Noticing for Site S1

Figure 46

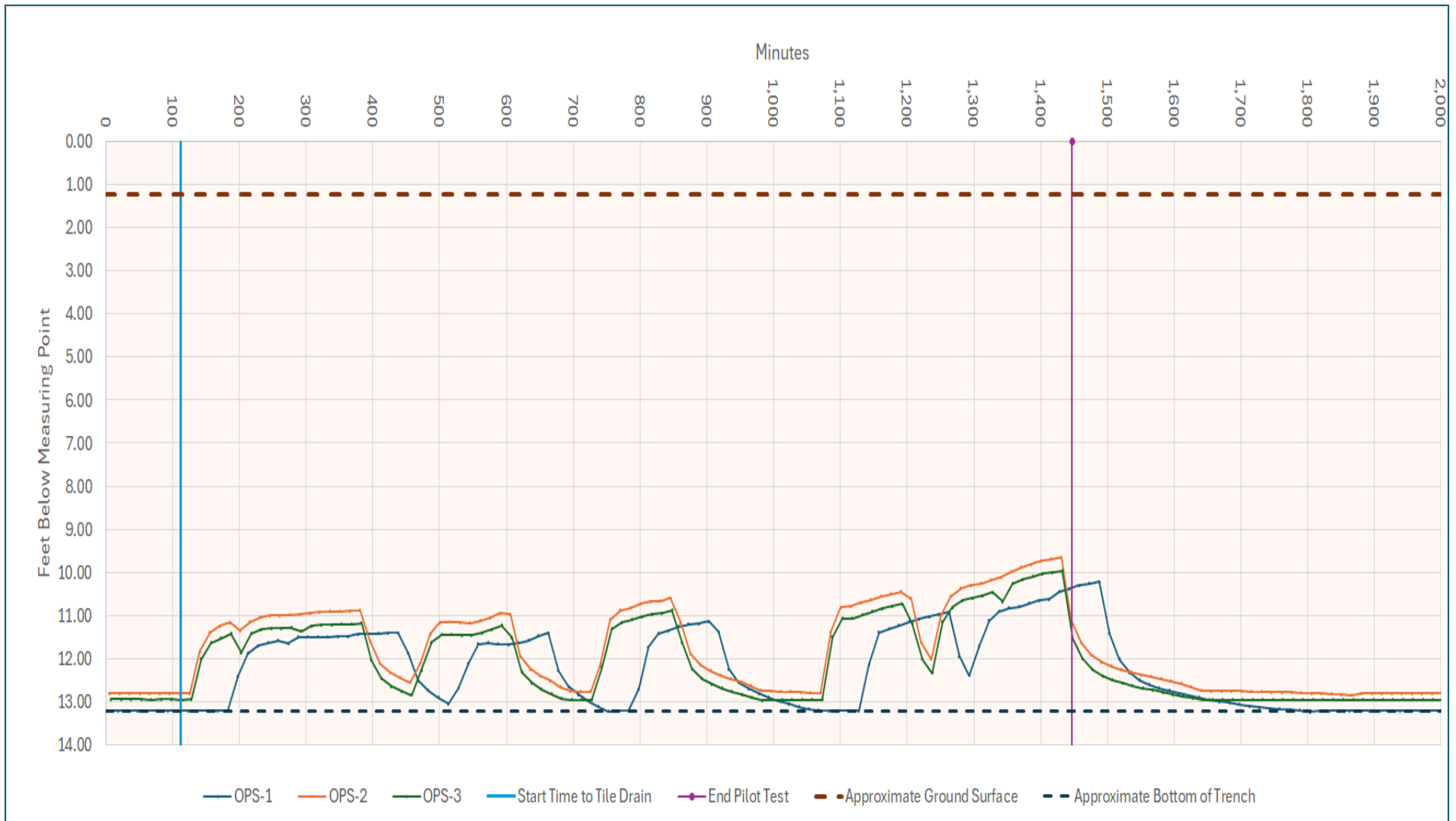


rates inferred from drawdown. Therefore, the basin-scale recharge rate of approximately 2.88 acre-feet per day per acre is considered the most representative value for sustained operation, while the higher rate of approximately 14.3 feet per day reflects short-term infiltration response under elevated hydraulic gradients.

Groundwater monitoring results from VMW-01, which is screened between 25 and 45 feet below ground surface, confirm that infiltrated water successfully reached the shallow aquifer. Groundwater levels increased steadily throughout the test, showing a delayed and attenuated response relative to changes in basin water levels. This lagged response reflects the time required for water to percolate through the vadose zone and enter the saturated zone. Groundwater levels continued to rise even as ponded water depths began to decline, indicating that infiltration and recharge processes were ongoing and that the aquifer was continuing to accept and store water. This response suggests moderate subsurface permeability with sufficient storage capacity to accommodate recharge without rapid dissipation. As shown on Figure 21 that provides the entire record of VMW-01 and the Comanche Creek stilling well, groundwater levels gradually decline back toward static conditions over a period of a few weeks with the delayed recovery reflecting continued redistribution of recharge water within the aquifer system. Figure 21 also shows that although VMW-01 responded to storm events prior to the pilot tests, the response from the pilot tests were significantly higher.

Figure 48 presents the hydrographs for the observation wells within the reverse tile drain during the first test. As stated above, operation of the tile drain during Test 1 was characterized by intermittent pumping at an approximate rate of 40 gpm, with cycling clearly evident in the monitoring data as trench water levels rose during pumping and declined once pumping stopped. When the pump was active, water levels increased predominantly near the north end and then propagated along the length of the trench, indicating effective horizontal distribution through the gravel backfill. However, the system did not exhibit sustained water level buildup, which indicates that infiltration into the surrounding soils was occurring continuously and prevented excessive storage within the trench.

The periods when the pump was turned off provide the clearest indication of system performance. The slope of the water level decline during these pump-off intervals reflects gravity-driven infiltration into the surrounding formation. Based on these drawdown trends, the tile drain exhibited passive infiltration rates on the order of approximately 20 to 35 gpm, corresponding to about 0.088 to 0.155 acre-feet per day. The relatively steep initial decline in water levels immediately after pump shutoff indicates strong hydraulic connectivity and high permeability near the trench, while the gradual flattening of the slope over time reflects decreasing gradients as the system approaches equilibrium. Analysis of the data suggests that if water levels in the trench were allowed to increase approximately 7 feet above the bottom, the resulting increase in hydraulic head could raise the maximum short-term infiltration capacity to approximately 80 to 120 gpm (0.35 to 0.53 acre-feet per day), depending on soil response and saturation effects. These results are consistent with the first test of this system using the irrigation well as the source water.



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Graphs showing water levels at tile drain observation points during testing at Site S1.

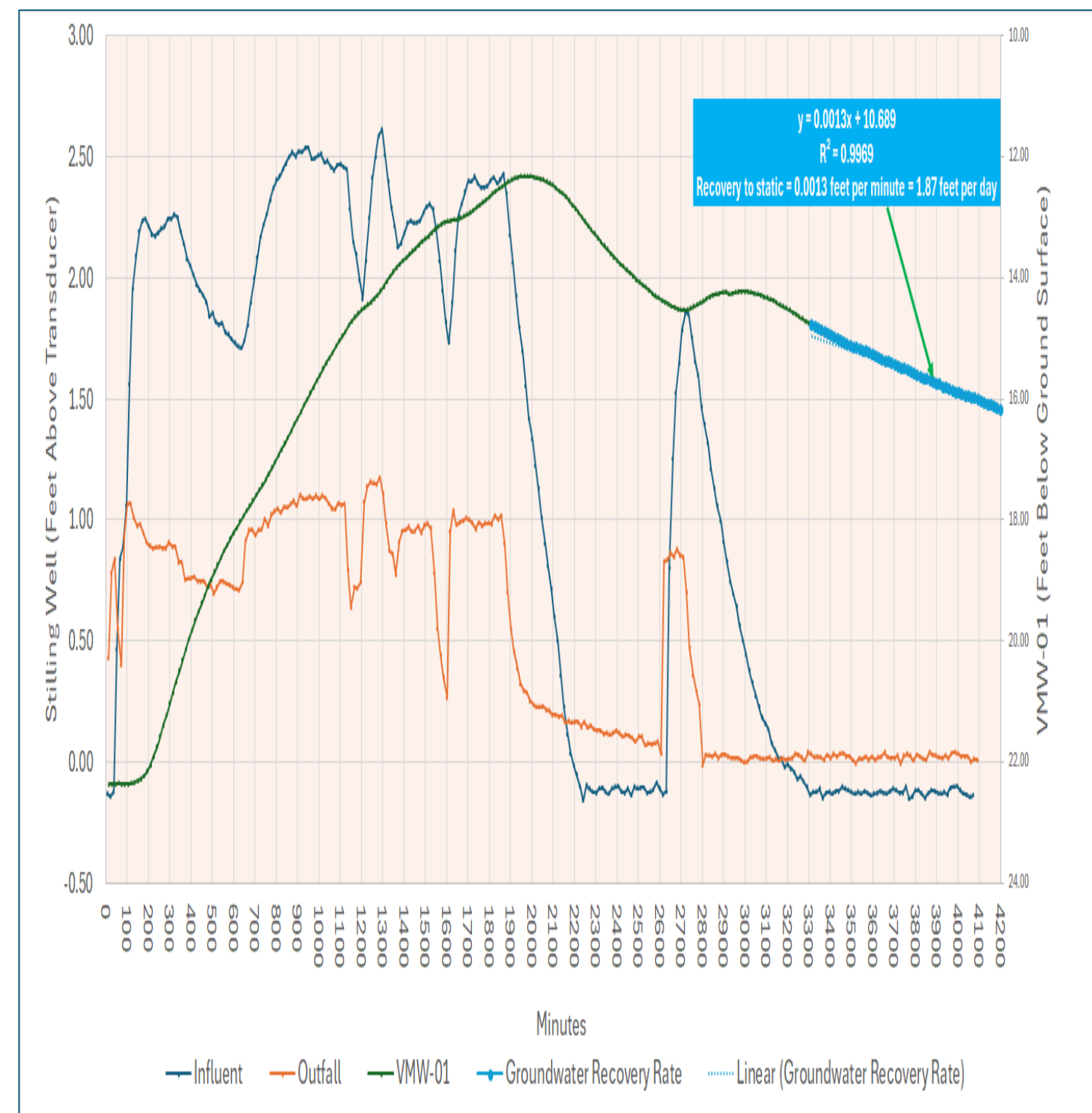
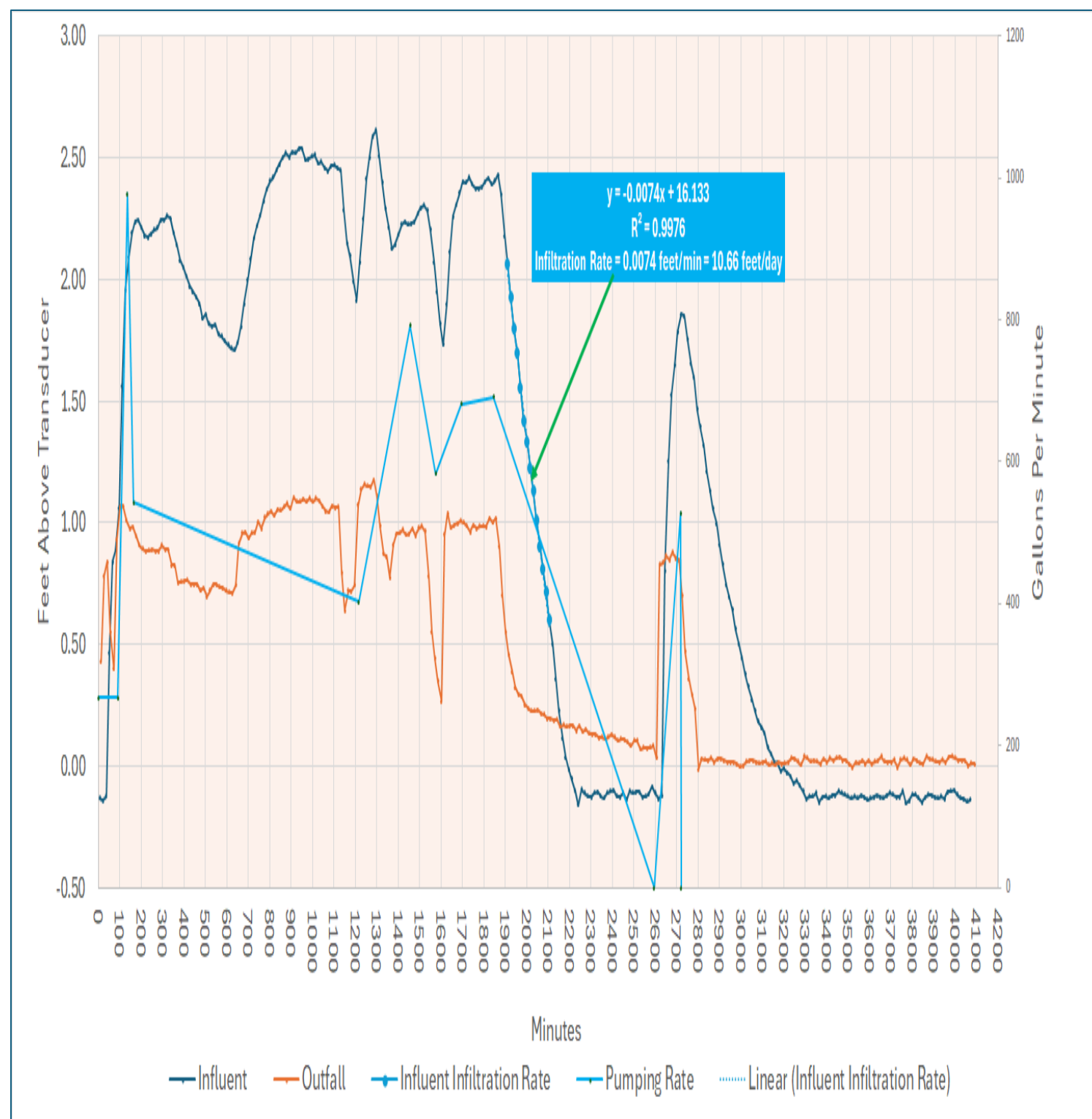
Figure 48

FloodMAR Test 2 provides a longer-duration assessment of basin performance and generally confirms the trends observed during Test 1. The test started at 13:15 on February 25, 2026, and ended at 10:35 on February 27, 2026. The pump was shut off at 20:00 on February 26, 2026 then turned back on at 08:30 on February 27, 2026, before turning off for the final time at 10:35 on February 27, 2026. Table 14 summarizes the totalizer readings and indicates that a total of 1,018,286 gallons (3.13 acre-feet) were added to the system. During the test, pumping rates were estimated from the totalizer readings and ranged from 650 gpm to 1,000 gpm. Subtracting out when the pump was shut off noted in Table 14, the average pumping rate was 535 gpm. Pumping to the reverse tile drain started at 14:40 on February 25, 2026, and ended at 20:00 on February 26, 2026. A total of 38,900 gallons were pumped into the reverse tile drain. The pumping to the reverse tile drain was not continuous but started at a pumping rate of about 40 gpm then was increased to a pumping rate around 90 gpm.

Table 14. Summary of totalizer readings – Test 2 FloodMAR

Date	Time	Totalizer Reading (0.001 acre-feet)	Gallons Injected	Comments
2/25/2026	13:15	956578	0	Start at 650gpm. Shut off from 13:55 to 14:30
	14:45	956652	24,113	1000 gpm
	15:30	956787	68,103	750 gpm
	16:00	956837	84,396	
2/26/2026	09:30	958135	507,351	650 gpm. Pump shut off from 08:00 to 08:30
	13:30	958718	697,322	
	15:30	958933	767,380	1000 gpm
	17:30	959184	849,169	
	20:00	959502	952,790	Pump shut off from 20:00 to 08:30 on 2/27/2026
2/27/2026	08:30	959502	952,790	650 gpm
	10:35	959703	1,018,286	0 gpm

Figure 49 shows the hydrographs for the stilling wells in the infiltration basin, monitoring well VMW-01, and the pumping rates during this test. As in Test 1, the basin exhibited rapid initial ponding followed by a transition toward quasi steady-state conditions, where inflow was balanced by infiltration. Groundwater response again showed a delayed but sustained increase, confirming that recharge continued to propagate through the vadose zone into the aquifer.



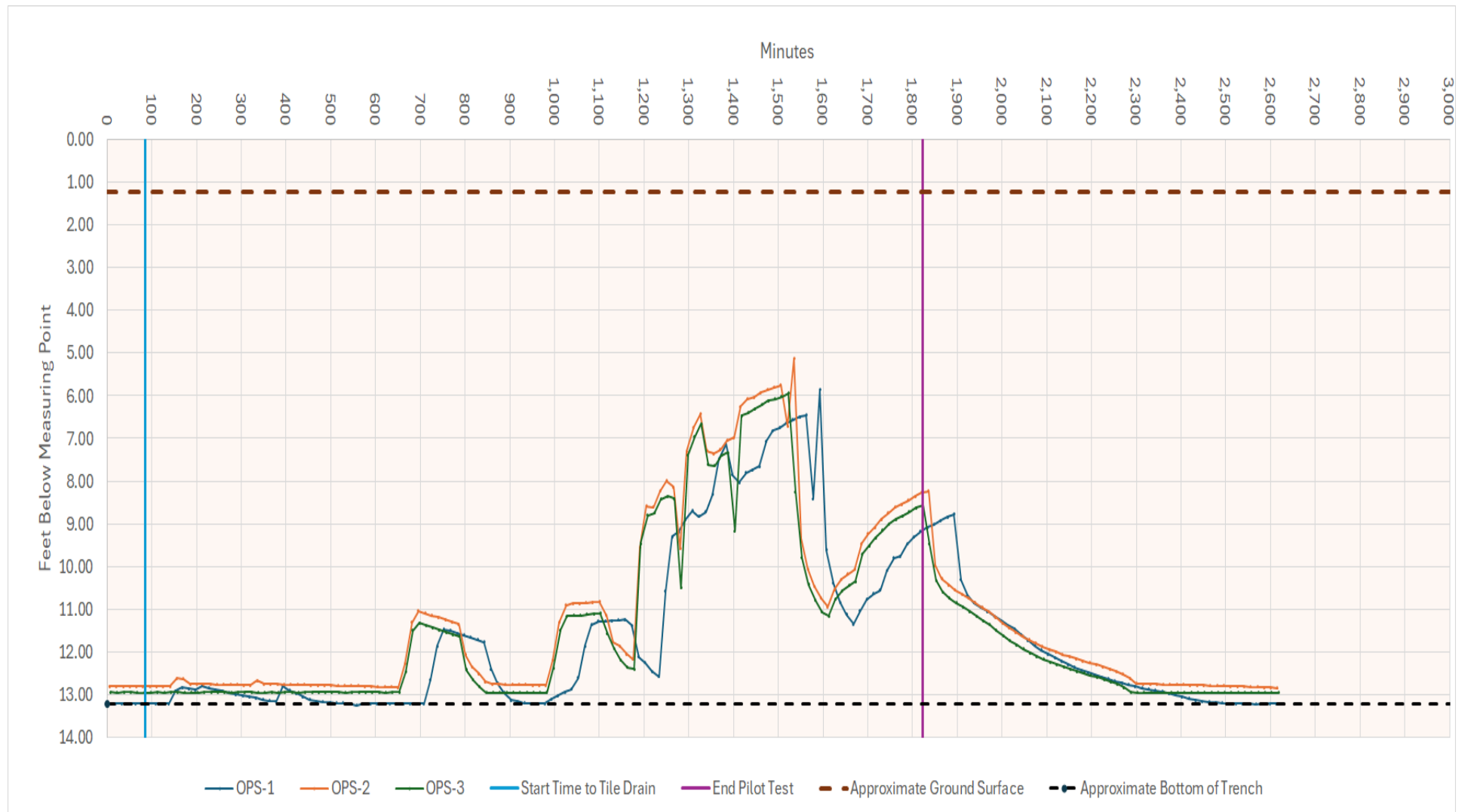
Graphs showing water levels and pumping rates for a second infiltration basin test.
 Figure 49

The most reliable comparison between the two tests comes from the rate of water level decline during pump-off periods, which directly reflects infiltration capacity. In Test 1, the basin exhibited an infiltration rate of approximately 14 feet per day, while Test 2 showed a slightly lower rate of approximately 10.5 feet per day. This represents a reduction of roughly 25 percent, indicating that infiltration capacity decreased modestly between tests but remained relatively high. Therefore, the estimate of 2.88 acre-feet per day for a one-acre basin from the first test would be 2.16 acre-feet per day for the second test. This difference is consistent with expected field behavior and likely reflects increased soil moisture, partial clogging from suspended sediments, or reduced hydraulic gradients due to antecedent wetting rather than any fundamental limitation of the basin design. Using this range of values, a 30-acre infiltration basin could recharge approximately 65 to 86 acre-feet per day of flood waters (approximately 14,700 to 19,600 gpm). As discussed in Section 7, this site was selected to develop a long-term project description, and additional potential recharge rates were developed based on varying soil properties across the site using the tTEM data and other infiltration tests.

The similarity in these rates confirms that the system remains effective under repeated operation. Test 2 indicates that the basin transitions from an initially very high infiltration state toward a slightly lower, more stabilized condition after prior use. This behavior is typical for infiltration systems and supports the conclusion that long-term operation will require management strategies such as drying cycles or sediment control to maintain peak efficiency.

Figure 50 presents the hydrographs for the observation wells within the reverse tile drain during the second test. As with the first test, the system was operated with intermittent pumping. The start of the test pumping was as with the first test around 40 gpm, and a similar response was noted. Later in the test, the pumping rate was increased to around 90 gpm, which is reflected in the increased water levels seen on Figure 50. The response to 90 gpm with water levels rises around 6 feet are consistent with the projected maximum pumping rate of 80 to 120 gpm or 0.35 to 0.53 acre-feet per day. These pumping rates equate to 0.57 gpm per linear feet to 0.86 gpm per linear feet. Using these values and assuming consistent soil properties at the site, 5,000 feet of reverse tile drain could accept between 2,800 gpm (12.4 acre-feet per day) and 4,300 gpm (19 acre-feet per day).

The pilot test also included collecting a sample of the flood waters from Comanche Creek for analysis of particle sizes of sediment in the water. The laboratory report for this analysis is presented in Appendix J. Using these results, at 12,000 to 16,000 gpm estimated for a 30-acre basin, 2-hours of retention is needed to allow a significant portion of sediment to settle out, 1.5-to-2-acre settlement basin, or forebay, would be needed.



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Graphs showing water levels at tile drain observation points for the second test. Site S1

Figure 50

6.2 Site N3

Pilot tests at Site N3 included assessing infiltration rates within areas that naturally flood within the area. Six sites were assessed designated DS-SW-1, and DS-SW-5 through DS-SW-9 as shown on Figure 51. Infiltration rates were assessed by placement of a stilling well placed within the area of flooding as shown on Photograph 17. Pressure transducers within the stilling wells were programed to record water levels every 15-minutes. As discussed in Section 5.1, shallow perched water systems were observed at several of the sites during infiltration tests. At the DS-SW-5 site, the stilling well was installed about 4 feet bgs to observe the rate of infiltration within the perched system at this site. This stilling well also recorded data where water levels went above the ground surface.

Table 15 summarizes the results of these pilot tests. Infiltration rates were estimated using the same method of infiltration tests where rates are calculated from the slope of the linear portion of the time versus falling-head water level plots when water levels are falling. Figure 52 provides an example of these plots for the pilot test basin at DS-SW-7. As seen on this figure, four events occurred over the period of measurements where infiltration rates could be calculated. The infiltration plots for this test and other tests are provided in Appendix H. As seen on Table 12, infiltration rates within the pilot test basins ranged from 0.02 feet/day to 0.64 feet/day with an average rate of 0.23 feet per day. At DS-SW-05, the rates of decline within the perched water system ranged from 0.09 feet/day to 0.64 feet/day. Based on these data and the presence of shallow perched water systems, it does not appear that site N3 would be a good area for successful groundwater recharge programs.



Photograph 17. Site N3 infiltration basin pilot test. White pipe is stilling well with pressure transducer inside to record changes in water levels over time.

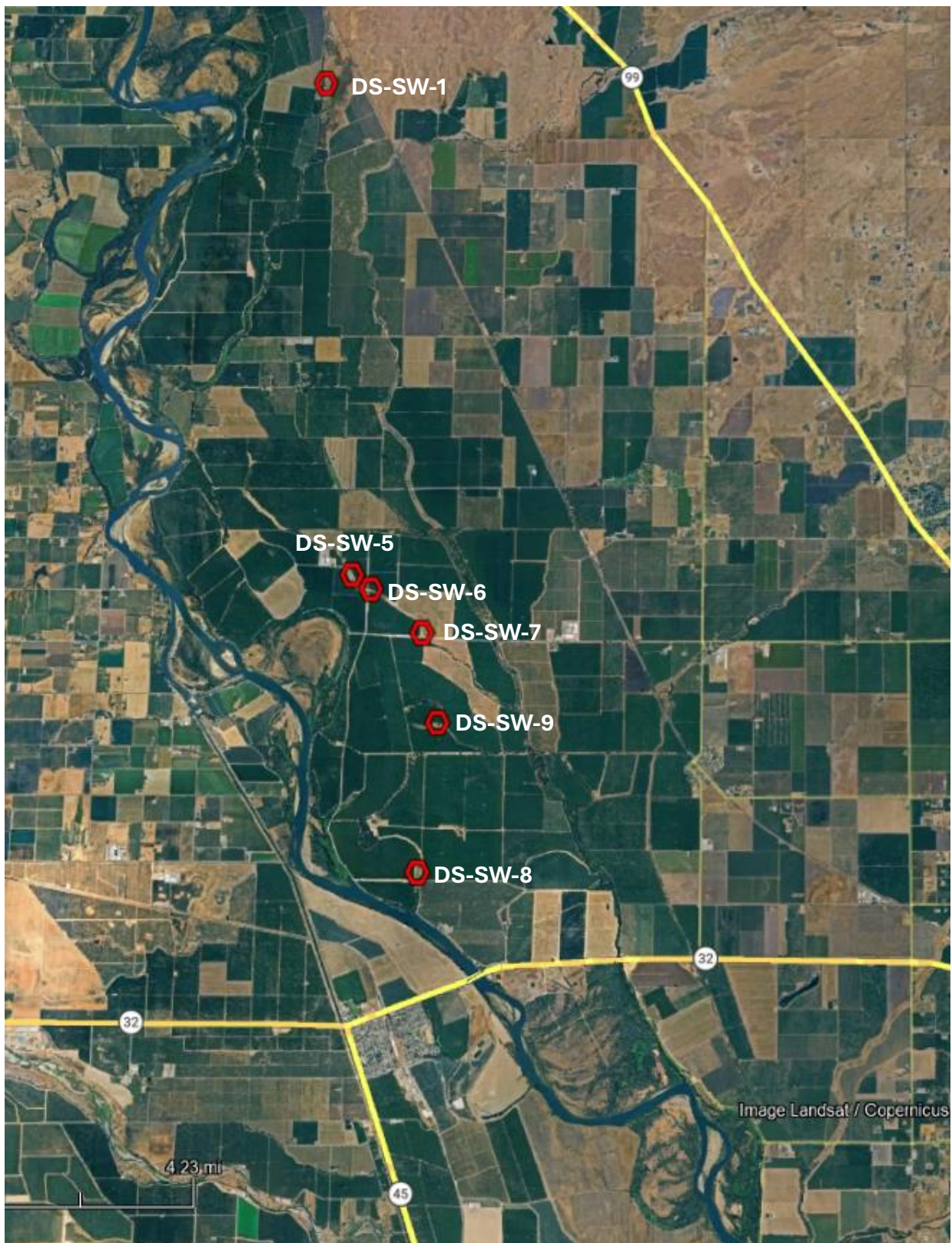


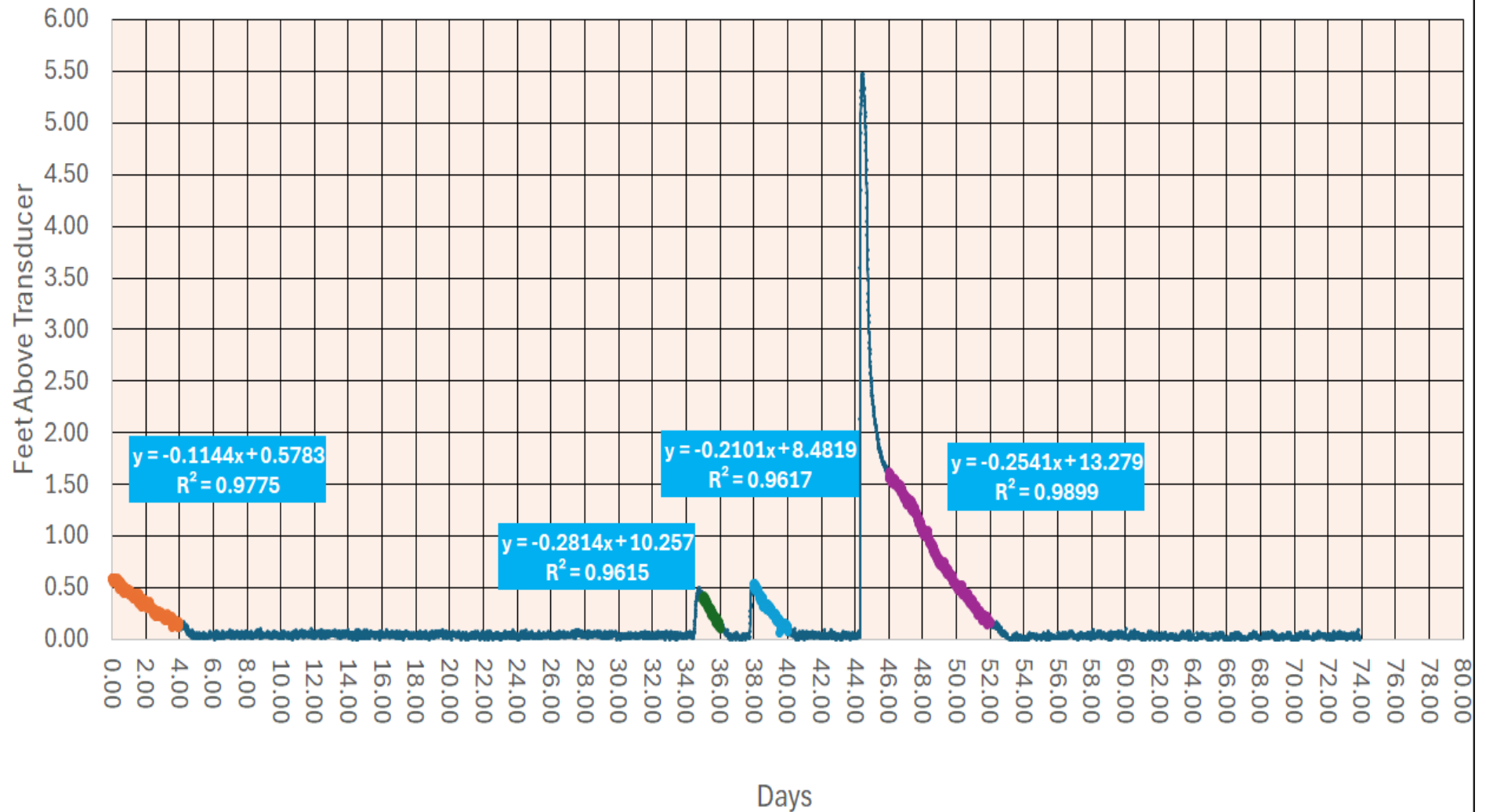
Table 15. Summary of results for infiltration basin pilot tests, Site N3

Site I.D.	Date Range of Pilot Test	Total Days Monitored	Days with Plot	Infiltration Rate (feet/day)
DS-SW-01	1/15/2026 to 3/27/2026	71	5 to 15	0.04
			45 to 60	0.02
DS-SW-05	2/3/2026 to 3/27/2026	52	0 to 5 ¹	0.34
			10 to 12 ¹	0.64
			25 to 30	0.15
			37 to 38 ¹	0.49
			45 to 52 ¹	0.09
DS-SW-06	1/12/2026 to 3/27/2026	74	47 to 51	0.21
DS-SW-07	1/12/2026 to 3/27/2026	74	0 to 4	0.11
			35 to 36	0.28
			38 to 40	0.21
			46 to 52	0.25
DS-SW-08	1/15/2026 to 3/27/2026	71	45 to 55	0.42
DS-SW-09	1/15/2026 to 3/27/2026	71	10 to 15	0.06
			55 to 60	0.08

6.3 Site N4

The pilot test at Site N4 consisted of constructing two infiltration basins at the locations shown on Figure 53. Photograph 18 shows construction of the South infiltration basin. After finishing the basins, stilling wells were installed equipped with pressure transducers. Each of the infiltration basins were placed in areas that the landowner indicated were flooded with waters from Keefer Slough (see Figure 53) during high rain events. The two stilling wells installed within Keefer Slough (RSW-02) and Rock Creek (RSW-03) and the groundwater monitoring well, RMW-01 discussed in Section 5.3.3 were also monitored during the pilot tests. As shown in Table 5, well RMW-01 is screened from 30 to 50 feet. All transducers were programed to record water levels at 15-minute intervals.

DS-SW-7



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Graph illustrating calculation of infiltration rates from
test data at Site N3.

Figure 52





Photograph 18. Construction of South infiltration basin.

Figure 54 provides the hydrographs for the stilling wells within the two infiltration basins. Water levels within the basins were recorded for the period December 18, 2025, to March 25, 2026. The x-axis on the hydrographs presented in Figure 54 is in days with day 0 corresponding to noon on December 18, 2025, for the South basin and 14:00 on December 18, 2025, for the North basin. As seen in Figure 54, three events with flooding into the infiltration basin within the first 20 days occurred in the South basin and four events with flooding occurred over a 70-day period within the North basin. Table 16 summarizes the infiltration rates in the basin for each of these events.

As seen on this table, the North infiltration basin recorded infiltration rates between 0.35 and 1.38 feet/day whereas the South infiltration basin recorded infiltration rates between 2.02 and 2.52 feet per day. These differences are consistent with the results of the tTEM data and infiltration testing that indicated varying soil properties across Site N4. As with Site S1, this site was selected to develop a long-term project description, and additional potential recharge rates were developed based on varying soil properties across the site using the tTEM data and other infiltration tests.

Figure 33 provides the entire hydrographs for monitoring well RMW-01. As seen on this figure, monitoring well RMW-01 did not start recording water levels until January 22, 2026, so evaluation of groundwater responses cannot be assessed for the storm events recorded in the infiltration basins before this date. Figure 55 presents the hydrographs for the monitoring well and stream stilling well points for the period January 22, 2026, to March 26, 2026, that includes five rain events, one of which was recorded as a flooding event in the South basin around February 24, 2026.

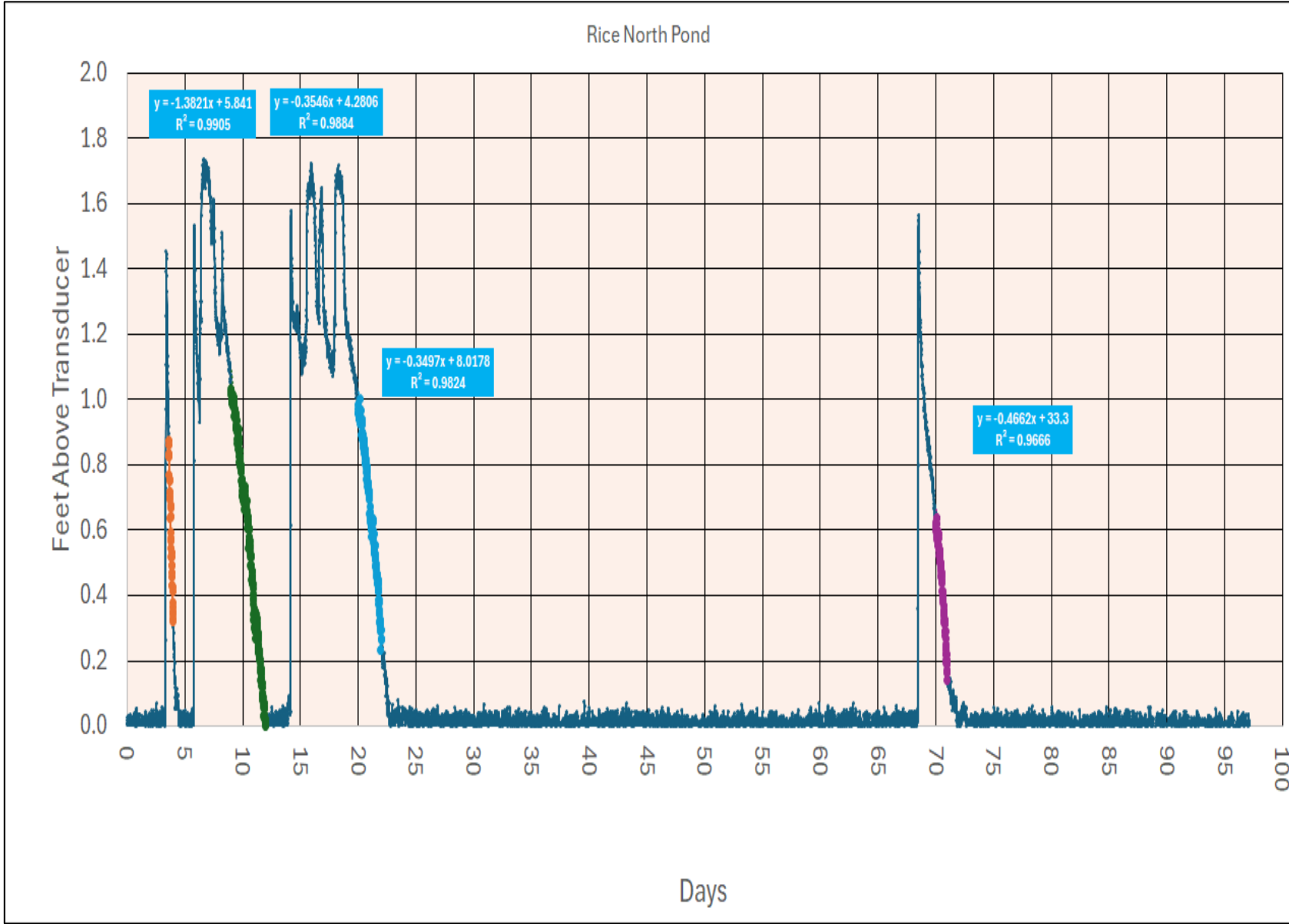
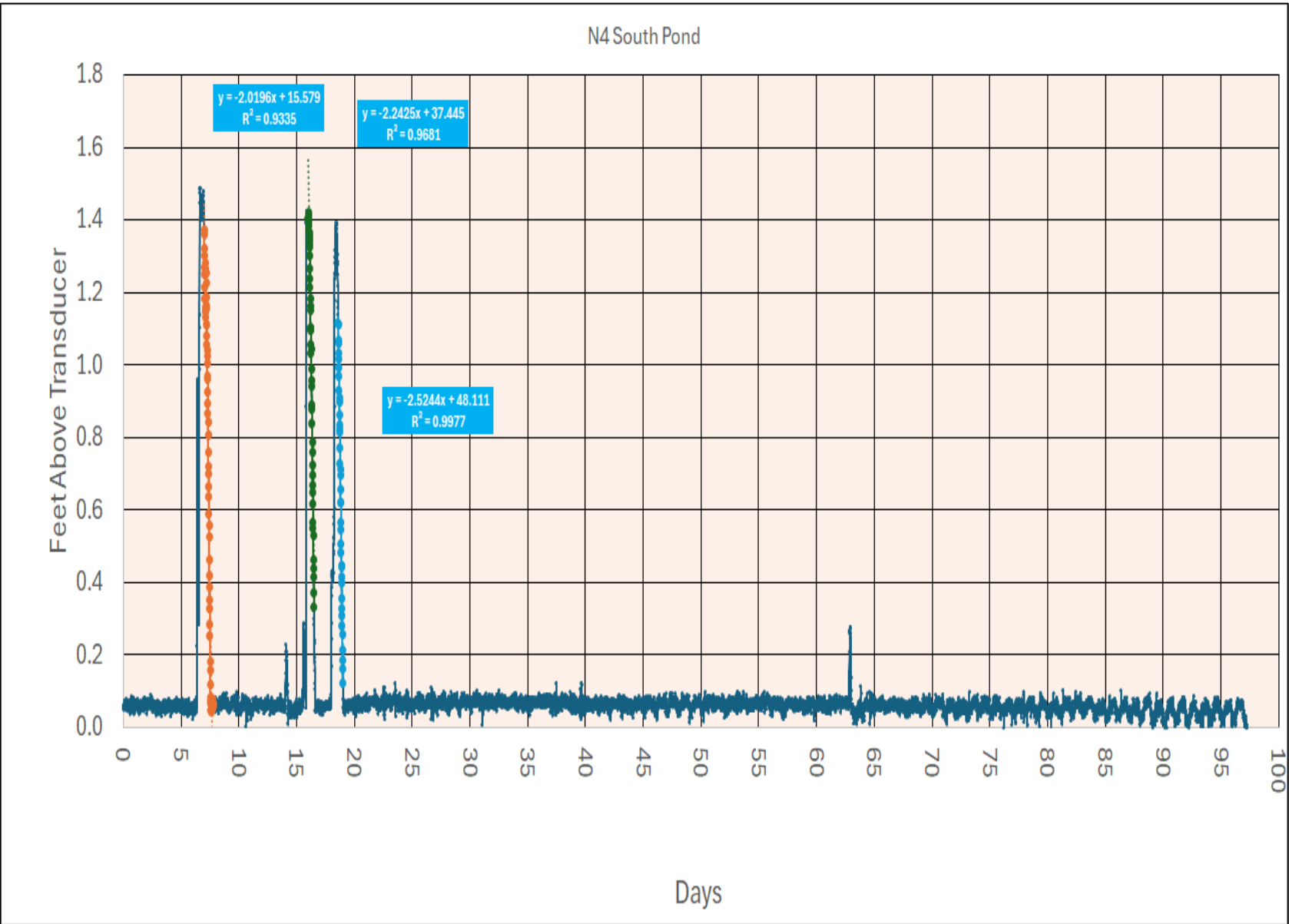


Table 16. Summary of infiltration rates calculated during pilot tests of Site N4 infiltration basins.

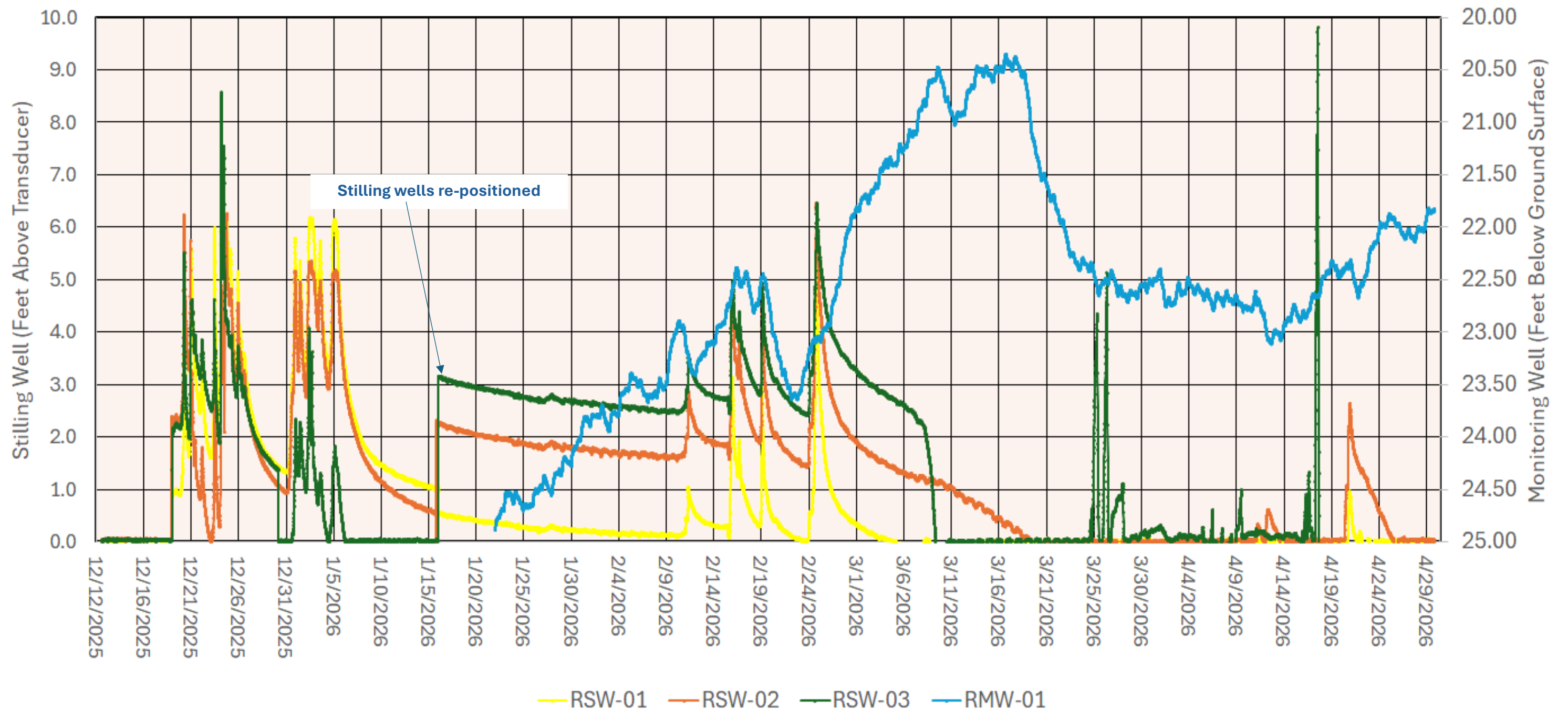
Infiltration Basin	Days Recorded (From Day "0")	Maximum height Recorded (Feet above Transducer	Infiltration Rate (feet/day)
North	3 to 4	1.44	1.38
	5 to 12	1.73	0.35
	14 to 22	1.70	0.35
	68 to 72	1.55	0.47
South	6 to 8	1.47	2.02
	15 to 17	1.41	2.42
	18 to 19	1.40	2.52

As seen on Figure 55, RMW-01 water levels were rising before storm events recorded during monitoring of the well, most likely due to the storm events observed in the stilling wells on this figure in December 2025 and early January 2026. After these events, RMW-01 shows an attenuated yet responsive hydrograph relative to fluctuations in surface water stage. The timing and magnitude of groundwater level variations indicate a hydraulically connected system, wherein increases in stream stage during storm events produce measurable responses in the adjacent aquifer. However, reduced peak amplitudes in RMW 01 relative to those observed in RSW 02 suggest the influence of subsurface storage and delayed transmission through the vadose zone and aquifer matrix. The observed responses suggest deeper alluvial aquifer conditions, rather than shallow perched water as seen at sites N3, N5, and N6. The delayed response relative to surface stage peaks suggests vertical percolation controls and moderate permeability of intervening sediments, consistent with layered alluvial deposits typical of the Chico area.

The hydrograph analysis supports several key considerations for recharge basin development. The observed connection between surface water (RSW 02) and groundwater (RMW 01) indicates a hydraulically connected system, suggesting that managed recharge basins located near Keefer Slough would likely facilitate effective transmission of water to the aquifer. This connection supports the feasibility of using nearby surface water sources to enhance groundwater recharge.

Groundwater responses observed at depths of approximately 30 to 50 feet indicate that sufficient unsaturated zone thickness exists to accommodate infiltration processes while also allowing recharge to reach deeper aquifer zones relevant for water supply. This balance suggests both adequate storage capacity and vertical connectivity within the subsurface.

Additionally, documented flooding south of the site highlights areas of natural ponding that may present opportunities for recharge basin development. These low-lying zones could be leveraged or modified through grading or berm construction to direct surface water toward engineered infiltration areas, thereby improving recharge efficiency and capturing an additional portion of



stormwater that would otherwise flow out of the subbasin. These data were used in the development of the proposed recharge basins presented in Section 7.2 for this site.

6.4 Site N5

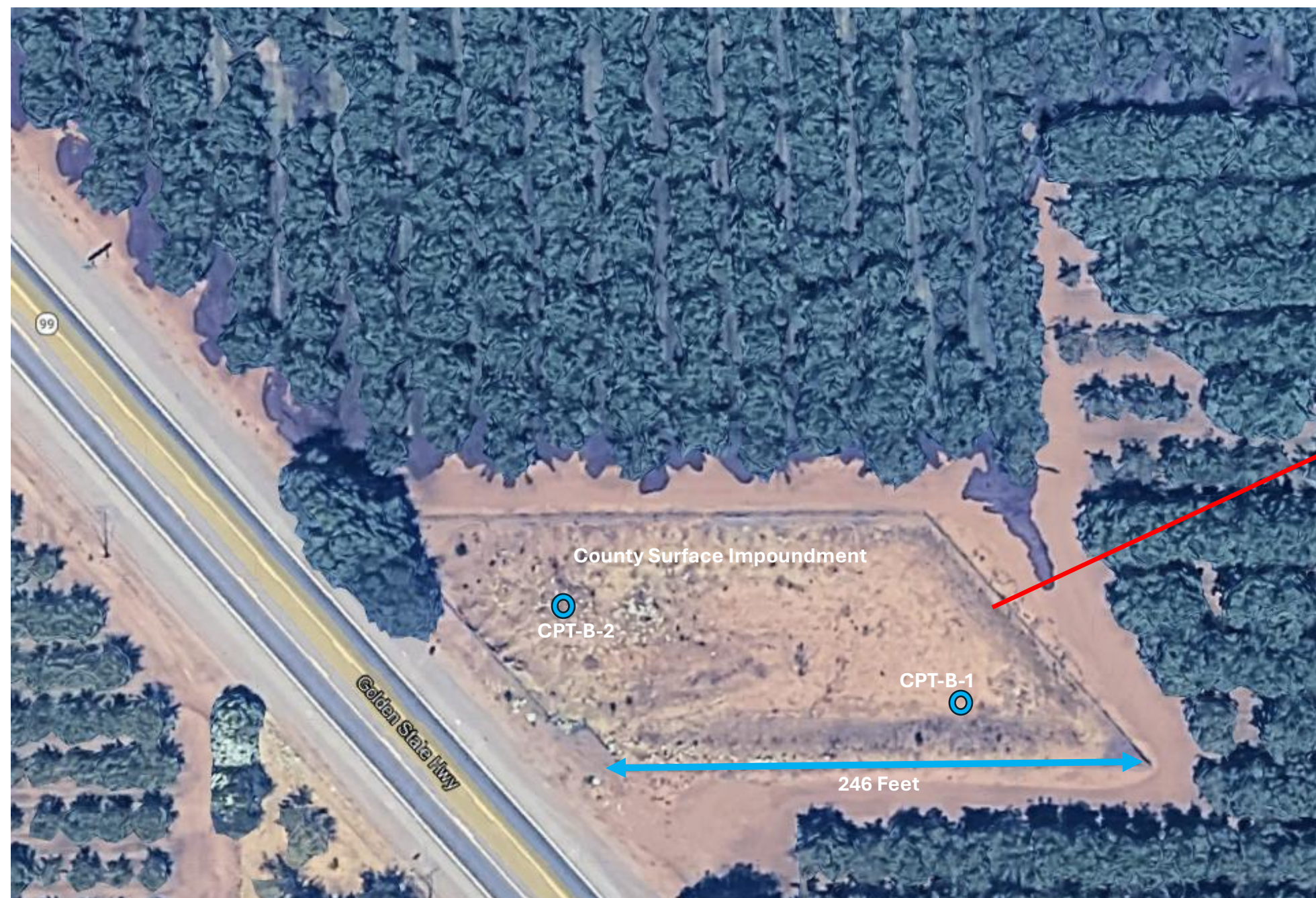
The pilot test at Site N5 consisted of monitoring infiltration rates within an existing surface impoundment owned by Butte County immediately adjacent to Site N5. Figure 56 shows the location of this surface impoundment. The pilot test for this site consisted of monitoring infiltration rates within the impoundment after a flooding event from the adjacent Keefer Slough. A stilling well was installed within the surface impoundment and programmed to record water levels every 15-minutes.

Figure 57 presents the hydrograph for the surface impoundment that provides data from October 13, 2025, through April 30, 2026. Day 0 on this hydrograph is 16:00 on October 13, 2025. As seen on this figure, water began to enter the surface impoundment from flooding on December 24, 2025 (Day 71) and remained in the pond until January 29, 2026 (Day 107). The highest recorded water level within the surface impoundment was about 7.3 feet above the transducer on January 5, 2026. Photograph 19 shows the surface impoundment on January 7, 2026. The top of the stilling well is below the surface of the water. Another smaller event occurred between February 25, 2026 (Day 134) and February 27, 2026 (Day 136). The highest recorded water level for this event was 1.67 feet above the transducer on February 25, 2026.

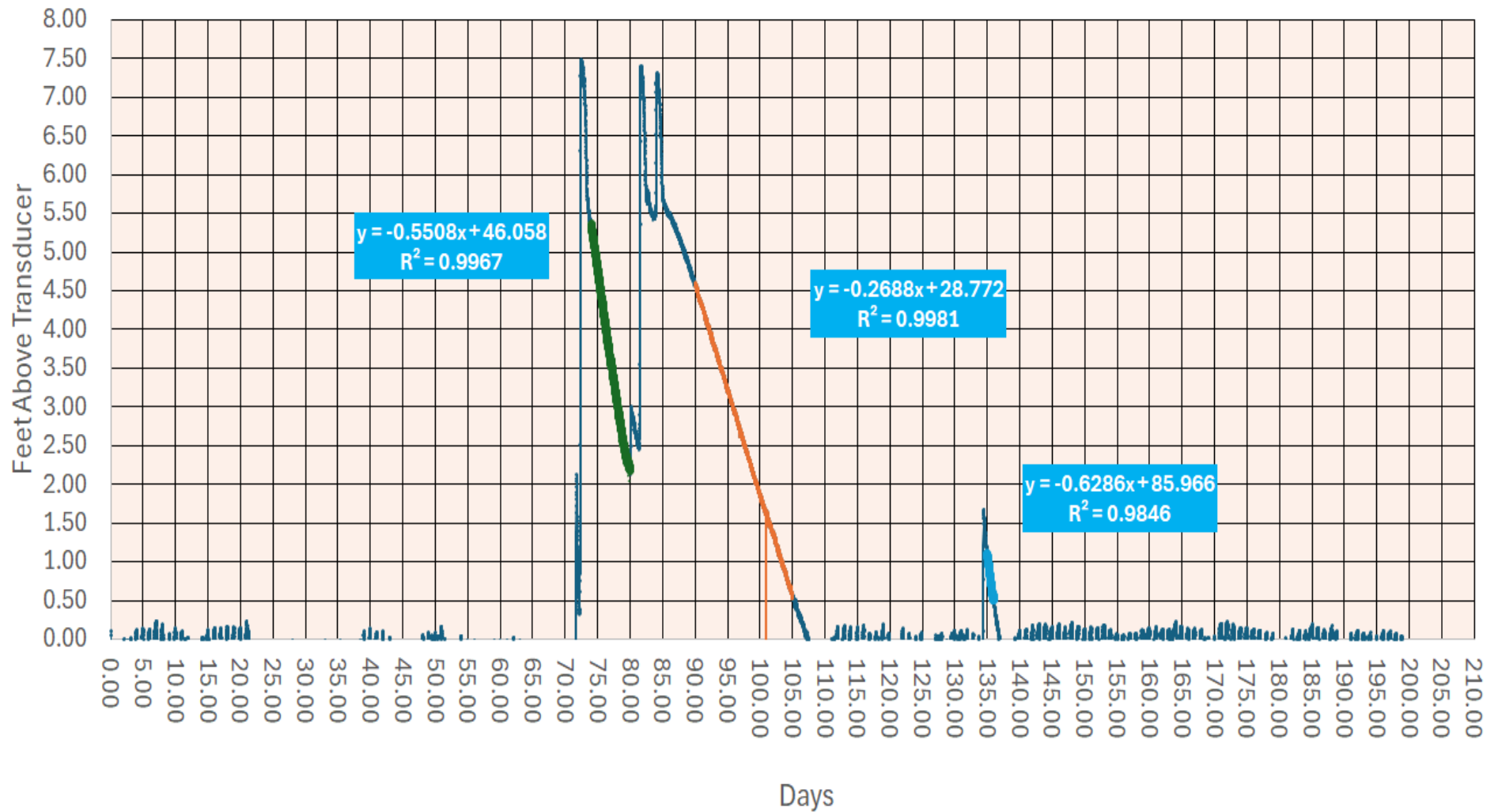


Photograph 19. Surface impoundment full of flood waters on January 7, 2026.

Table 17 summarizes the infiltration rates calculated during the pilot testing. As seen on this table, infiltration rates ranged from 0.27 to 0.63 feet per day in sharp contrast with the infiltration numbers recorded by the two CPT points completed in the basin (locations shown on Figure 56).



County Impoundment



As seen on Table 7, data from the CPT points indicated an average permeability value between 15 to 22 feet/day. However, as discussed in Section 5.3.4, a perched water level was encountered approximately 7 feet below the bottom of the surface impoundment. As such, the infiltration rates recorded for this pilot test most likely reflect the values for the underlying perching layer.

Table 17. Summary of infiltration rates calculated during pilot tests of Site N5 surface impoundment.

Days Recorded (From Day "0")	Maximum height Recorded (Feet above Transducer)	Infiltration Rate (feet/day)
74 to 80	7.3	0.55
90 to 105	7.26	0.27
135 to 136	1.67	0.63

7. PROJECT DESCRIPTIONS

This section presents the preliminary design and evaluation of groundwater recharge projects identified through the investigations and pilot testing described in Sections 4 through 6. The objective is to advance technically feasible and implementable projects through the development of conceptual designs. These designs include assessments of available water supplies, conceptual site layouts, permitting considerations, monitoring requirements, operations and maintenance (O&M) needs, and planning-level cost estimates.

Two projects were selected for preliminary design: (1) a FloodMAR infiltration project at Site S1, and (2) a FloodMAR system consisting of a series of infiltration basins along the Rock Creek–Keefer Slough corridor. Figure 58 provides a key map of proposed recharge projects.

The second project encompasses Sites N6, N5, and N4, which together represent a series of FloodMAR recharge projects along the Keefer Slough–Rock Creek corridor. Collectively, these projects are designed to capture and distribute high-flow surface water across multiple locations to enhance groundwater recharge while reducing peak flows within the watershed. By slowing and spreading flows, the projects may attenuate peak flows in Keefer Slough and Rock Creek, thereby decreasing downstream flood risk. In addition, the increased residence time and enhanced hydraulic interaction between surface water and the subsurface promote in-stream recharge and improve overall watershed function.

Depending on available funding, both projects may be implemented in phases. For example, at Site S1, an initial phase could include property acquisition and construction of a forebay and a single infiltration basin. Early-stage FloodMAR recharge could be conducted using portable pumps, similar to those used during pilot testing, until funding becomes available for rehabilitation of the existing diversion structure and installation of permanent pump stations.

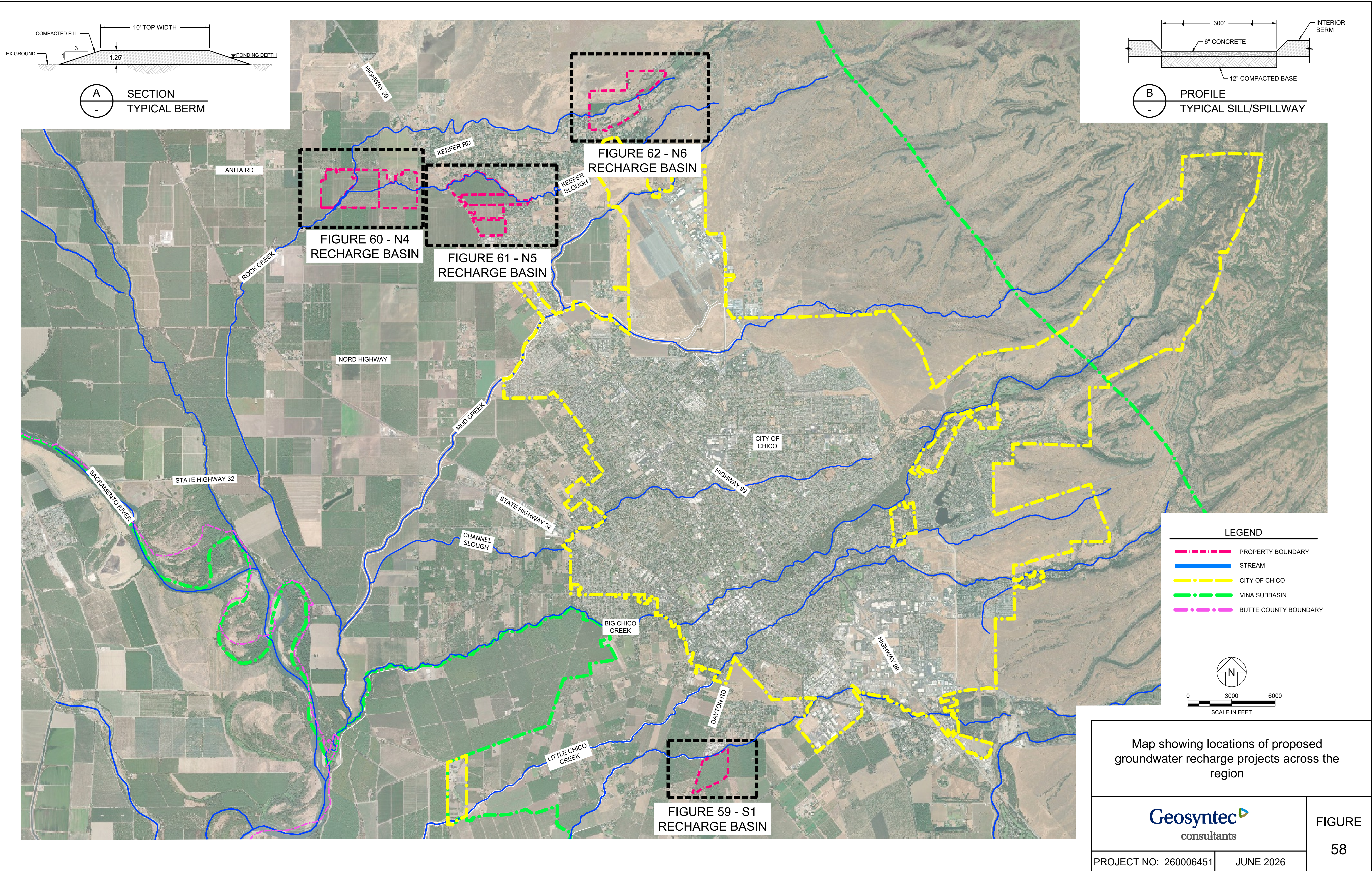
For the second project, individual infiltration sites (N4, N5, and N6) could be constructed sequentially rather than as a single, unified project. Accordingly, each site is discussed separately in the following sections. The planning-level cost estimates presented for each site reflect full project buildout.

As discussed in each of the projects, the source of water being considered in FloodMAR using Water Code 1242.1 similar to the process used for the pilot test at Site 1. Appendix K provides the implementation plan, notifications, and reporting completed for this process. As such, Section 7.1 provides an overview of this Water Code including proposed changes plus an estimated of potential number of days that could occur for the projects using this source of water. Section 7.1 also discusses other potential methods to obtain water using flood waters that may increase the number of days the water can be sent to each site.

7.1 Water Code 1242.1

Water Code §1242.1, enacted through Senate Bill 122 in 2023, establishes a temporary pathway allowing the diversion of flood flows for groundwater recharge without the need for an appropriative water right, provided specific conditions are met as discussed in Section 6.1. The statute was created with the dual objective of reducing flood risk while simultaneously

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replenishing depleted groundwater basins. Under this framework, diversion is limited to periods when a local or regional agency provides public notice that flows present an imminent risk of flooding and inundation of land, roads, or structures, and diversions must cease once those conditions subside. Flood flow is defined as water exceeding flood stage or escaping a channel such that it threatens developed areas or infrastructure, and the statute includes reporting requirements and safeguards to avoid impacts to downstream water rights and environmental resources. The authority is currently time-limited, applying to diversions initiated through January 1, 2029.

Based on analysis of precipitation thresholds, observed flood-trigger events, and stage exceedance characteristics, the Rock Creek–Keefer Slough system provides a limited but measurable number of diversion opportunities under this framework. Storms producing approximately 3 inches or more of precipitation, which occur on average one to two times per year in the Vina Subbasin under a Mediterranean winter rainfall regime, consistently generate runoff sufficient to approach or exceed flood-stage conditions. Application of a stage-based triggers as outlined in Appendix K indicates that a substantial portion of these events produces qualifying “imminent risk” conditions, resulting in approximately 0.5 to 1.5 diversion events per year. Hydrograph evaluation demonstrates that exceedance durations are short, generally on the order of 0.5 to 1.5 days per event, reflecting the rapid rise and recession of flows in this watershed. Taken together, these factors indicate that diversion opportunities occur for approximately 3 days per year on average, with wetter years characterized by multiple qualifying storm events yielding up to 4 to 6 days per year of total diversion opportunity.

Subsequent policy actions and proposed legislation seek to expand and streamline this framework to increase the feasibility and effectiveness of flood-managed aquifer recharge. Executive Order N-16-25 (January 2025) suspended certain administrative requirements, including the need for formal flood planning documentation, allowing agencies to more rapidly determine flood conditions and initiate diversions. Building on this approach, proposed legislation such as Assembly Bill 2026 would further modify §1242.1 by simplifying eligibility criteria, expanding the definition of “flood flow” (including certain controlled reservoir releases), and reducing permitting and environmental review requirements for recharge projects. These changes would allow diversion to begin earlier in rising flows and continue longer into recession conditions, increasing the duration of individual events. As a result, the number of days during which diversion could occur is expected to increase by approximately 1 to 3 days per year, yielding a total average of approximately 4 to 6 days per year, with wetter years supporting up to 6 to 10 days per year of diversion opportunity.

7.1.1 Additional Permitting Pathways to Increase Recharge Diversions

In addition to Water Code §1242.1, several permitting pathways are available that can substantially increase the frequency, duration, and volume of water diverted to recharge basins. Section 1242.1 is limited to emergency flood conditions, requiring diversion only when flows present an imminent risk of flooding and cessation once those conditions subside. As a result, reliance on §1242.1 alone constrains diversion opportunities to short-duration peak flow events.

To expand beyond these limitations, project proponents may pursue additional water rights and regulatory approvals that allow diversion during a broader range of hydrologic conditions. The most significant mechanism is obtaining an appropriative water right permit from the State Water Resources Control Board. Unlike §1242.1, an appropriative right allows diversion under defined flow conditions that are not limited to active flood risk, subject to bypass flow requirements, seasonal restrictions, and protection of downstream users. This enables capture of high flows below flood stage and extended portions of storm hydrographs, resulting in substantially greater annual diversion opportunities.

In addition, Temporary Urgency Change Petitions (TUCPs) may be used during wet years to temporarily modify existing water rights, allowing increased diversion rates or expanded timing in response to high-flow conditions. Other mechanisms include coordinated recharge efforts implemented through Groundwater Sustainability Agencies (GSAs) under the Sustainable Groundwater Management Act, which can integrate surface water diversions, conveyance infrastructure, and recharge facilities into basin-wide management strategies.

Implementation of these pathways may also require environmental and construction approvals, including compliance with the California Environmental Quality Act (CEQA) and, where applicable, lake and streambed alteration agreements. While these approvals do not independently authorize diversion, they are necessary to construct and operate recharge infrastructure. Legislative proposals aimed at streamlining these requirements may further improve feasibility and implementation timelines.

Collectively, these permitting approaches allow diversion across a wider range of hydrologic conditions, moving beyond the narrow window of flood emergencies defined under §1242.1. As summarized in Table 18, combining these pathways can significantly increase both the reliability and total volume of water available for recharge.

Table 18. Comparative effect on annual diversion availability

Permitting Pathway	Effect on Diversion (days per year)	Typical Time to Obtain	Typical Cost Range
Water Code §1242.1 (Flood-Only)	~3 days/year	Immediate to weeks (notice-based)	Low (staff time, reporting)
Appropriative Water Right Permit	Additional ~10–30+ days/year	~2 to 5+ years	~\$100,000 to >\$1M
Temporary Urgency Change Petition (TUCP)	Additional ~5–15 days (wet years)	~1 to 6 months	~\$10,000 to \$100,000

7.1.2 Permitting Time and Cost Considerations

The time and cost required to implement these permitting pathways vary significantly depending on project complexity and the level of environmental review required (see Table 15). Section §1242.1 provides the most rapid implementation pathway, as it relies on a notice-based process and does not require a new water right; implementation can occur within days to weeks, with relatively low administrative costs limited to monitoring and reporting.

In contrast, obtaining an appropriate water right permit is typically a multi-year process (approximately 2 to 5 years or more), driven by application review, CEQA documentation, protest resolution, and development of permit conditions. Total costs can range from hundreds of thousands to more than one million dollars, depending on project scale and regulatory complexity. Shorter-term mechanisms such as Temporary Urgency Change Petitions offer a more rapid pathway, often completed within several months, and generally costing on the order of tens of thousands of dollars for application preparation and agency coordination.

These permitting timelines and cost considerations are critical components of project feasibility and should be evaluated alongside the expected increase in diversion opportunity when selecting an implementation strategy.

7.2 Site S1 Recharge Project

This Section presents the preliminary design and evaluation of the proposed Flood-Managed Aquifer Recharge (FloodMAR) project at Site S1. This site was selected for advancement based on the results of field investigations and pilot testing, which demonstrated favorable hydrogeologic conditions, including permeable near-surface materials, strong vertical connectivity to the underlying aquifer, and the ability to sustain relatively high infiltration rates under operational conditions. Unlike other evaluated sites where recharge is constrained by perched groundwater or low-permeability layers, Site S1 represents a high-capacity recharge opportunity capable of directly augmenting the regional groundwater system.

The proposed project builds on pilot-scale testing of both infiltration basins and reverse tile drain systems and is designed to capture and manage high-flow surface water under FloodMAR conditions consistent with California Water Code Section 1242.1. The following section describes the conceptual layout, anticipated recharge performance, and key implementation considerations for Site S1, including infrastructure requirements, permitting pathways, operational approach, and preliminary cost estimates.

7.2.1 Preliminary Design

Site S1 is proposed as a Flood-Managed Aquifer Recharge (FloodMAR) project designed to divert and capture high-flow surface water from Comanche Creek and infiltrate it into the underlying groundwater system. The conceptual design is based on the field investigations and pilot testing results presented in Sections 5 and 6, which demonstrate that the site is underlain by permeable sands and gravels extending from the ground surface to the water table at approximately 24 to 26 feet below ground surface. These conditions, along with the high infiltration rates measured during testing and the observed hydraulic connectivity between surface water and groundwater, confirm that Site S1 has the capacity to accept significant volumes of recharge without excessive

groundwater mounding. As a result, Site S1 represents one of the most favorable locations evaluated for large-scale recharge implementation.

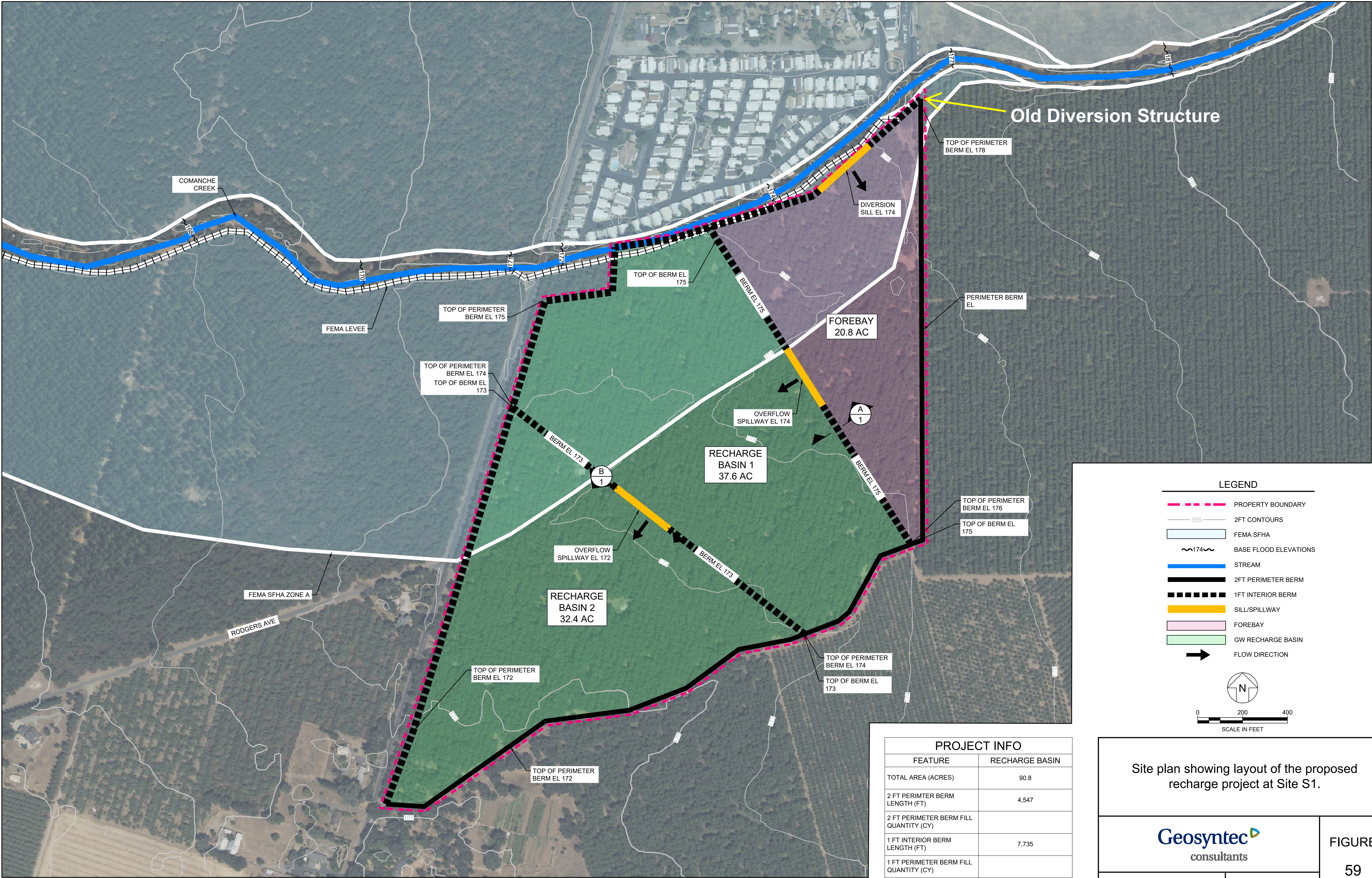
The proposed layout for the Site S1 recharge facility is shown on Figure 59 and consists of a forebay, and two recharge basins constructed within an approximately 90.8-acre footprint. The forebay encompasses approximately 20.8 acres and is designed to receive diverted flows from Comanche Creek, allowing for initial sediment settling and controlled distribution of water to the recharge basins. Recharge Basin 1 occupies approximately 37.6 acres and Recharge Basin 2 occupies approximately 32.4 acres. The system is configured such that water is conveyed to the forebay and then distributed through the basins using low-gradient flow paths, maximizing infiltration across the basin floors. Perimeter berms define the limits of the facility and provide containment, while interior berms allow for operational staging, flow control, and distribution between basin cells. Overflow spillways and diversion features are incorporated to manage high flows and maintain system stability during large recharge events.

Grading for the project has been designed to balance storage capacity, hydraulic control, and operational flexibility. As shown on Figure 59, perimeter berm crest elevations range from approximately elevation (El.) 172 to El. 178 feet, while interior berms are constructed at slightly lower elevations to facilitate controlled movement of water between cells. Spillways are set at elevations between approximately El. 172 and El. 174 feet, and the diversion sill is set at approximately El. 174 feet. These elevations were selected based on available topographic information to: provide 1-2 feet of freeboard between overflow spillways, interior berms, and perimeter berms; allow controlled overtopping at select locations using overflow spillways; and allow operation under a range of inflow conditions. All berm construction and grading are expected to use on-site materials, minimizing construction costs and simplifying implementation.

Recharge water will be supplied from flood flows in Comanche Creek in accordance with California Water Code Section 1242.1. The conceptual design assumes the use or rehabilitation of an existing diversion structure located adjacent to the site. Photographs 20 and 21 show pictures of this old feature along the creek and going into Site S1. Because the diversion point is located at a lower elevation than the forebay and basin system, pumping is required to convey water into the facility. Once water is delivered to the forebay, it is distributed through the basins by gravity flow. Based on conceptual design assumptions and basin storage requirements, total pumping capacity required to fully utilize the system is estimated to range from approximately 14,000 to 49,800 gallons per minute. Due to high costs for pumping, actual pumping rates may be lower than these values unless an alternative diversion is proposed (e.g., upstream diversion into canal)”

Consistent with the overall project strategy, implementation is expected to occur in phases, with initial construction focused on the forebay and Basin 1 to match available pumping capacity and water supply, followed by expansion to Basin 2 as additional infrastructure and funding become available.

The Site S1 property is currently developed as a walnut orchard. Construction of the forebay and the first recharge basin will require removal of orchard trees within these areas, with additional removal required during future development of the second basin. Conversion of the site from



Site plan showing layout of the proposed recharge project at Site S1.

agricultural production to recharge use is consistent with regional groundwater management objectives and allows for long-term operation of the recharge facilities.



Photograph 20. Photograph of old diversion structure looking from Comanche Creek.



Photograph 21. Picture of old diversion structure looking from Site S1.

7.2.2 Infiltration Capacity

Recharge performance for Site S1 is based on infiltration testing, CPT-derived hydraulic conductivity data summarized in Table 7 and Table 8 and pilot testing discussed in Section 6.1. These data indicate that infiltration rates at the site are highly variable but generally favorable,

with shallow infiltration testing results ranging from approximately 1.87 to 23.9 feet per day and CPT-derived hydraulic conductivity values indicating permeabilities ranging from less than 0.01 feet per day in finer-grained intervals to greater than 100 feet per day in coarser materials.

During pilot basin operation, groundwater monitoring indicated a clear and rapid response to applied water, with measurable groundwater level increases occurring during recharge events. This response confirms that water applied at the surface migrates vertically through the unsaturated zone to the shallow aquifer and that the underlying aquifer has sufficient capacity to accept recharge without excessive mounding under pilot-scale conditions.

Using the data from field investigation and pilot tests, representative design infiltration rates were developed for each basin, including the Forebay, by assigning minimum, maximum, and average infiltration rates at specific depth intervals calculated from the resistivity values developed for the 3-D model of the site presented in Section 5.3.1. Since the primary function of the forebay is to allow settlement of fines from the surface water, infiltration rates within this basin will decrease over time.

The depth intervals used for these calculations are 0, 1, 3, 5, 10, 15, 20, 25, and 30 feet bgs. The top of the still shot in Figure 22 shows the 0-foot bgs depth layer. Uniform infiltration values were assigned to each depth layer based on the maximum, minimum, and average of estimated infiltration rates within the resistivity ranges shown in Table 19.

Table 19. Range of infiltration rates for resistivity ranges.

Resistivity Ranges ($\Omega \cdot m$)	Minimum Infiltration Rate (feet per day)	Maximum Infiltration Rate (feet per day)	Average Infiltration Rate (feet per day)
>40	4	12	8
30 to 40	1	3	2
20 to 30	0.5	2	1.25
12 to 20	0.5	1	0.75
5 to 12	0.01	0.05	0.03
<5	0.001	0.09	0.05

To calculate the infiltration estimates for each depth interval, the percentage of area covered by the individual resistivity range is multiplied by the infiltration rate with the assumed total infiltration rate being the sum of the calculated numbers for each soil zone. For example, the average infiltration rate for Basin 1 at 3 feet bgs is calculated as follows:

- 40 $\Omega \cdot m$: 5.8% of the area times 8 feet per day is 0.467 feet per day.
- 30 to 40 $\Omega \cdot m$: 20.5% of the area times 2 feet per day is 0.411 feet per day.
- 20 to 30 $\Omega \cdot m$: 69.5% of the area times 1.25 feet per day is 0.869 feet per day.
- 12 to 20 $\Omega \cdot m$: 4.1% of the area times 0.75 feet per day is 0.031 feet per day.
- 5 to 12 and <5 $\Omega \cdot m$: are 0% of the area times are 0 feet per day.
- Using these numbers, the assumed average infiltration rate at 3 feet bgs in Basin 1 is:
0.467 plus 0.411 plus 0.869 plus 0.031, plus 0, plus 0 = 1.78 feet per day.

To estimate the volume of water that could infiltrate directly from the surface, the harmonic mean for the upper 20 feet and 30 feet for infiltration rates were used. The two depths were used based on the range of measured groundwater levels that were observed. Using the harmonic mean to estimate and rank infiltration rates for groundwater recharge basins is a technically defensible approach, particularly for comparative screening where vertical flow through layered soils controls performance.

In recharge settings, water must pass sequentially through multiple soil layers, and overall infiltration is governed by the least permeable intervals rather than the highest. The harmonic mean appropriately reflects this behavior because it weights low hydraulic conductivities more strongly than the arithmetic mean, thereby reducing the risk of overestimating basin performance where low-permeability lenses or layers are present. As such, the harmonic mean provides a conservative, hydraulically realistic representation of effective infiltration capacity through the depth of influence considered. The minimum, maximum, and average infiltration rates for each depth interval for the two basins and forebay shown in Figure 59 are summarized in Appendix L. Table 20 provides an example of these calculations for Basin 1.

Using these values, the estimated volume that can directly infiltrated the entire portion of each basin is summarized on Table 21. As seen on this table, the average calculated infiltration rates to 20 feet bgs ranges from 2.63 feet per day (Basin 1) to 0.59 feet per day (Forebay). Using these values, the estimated size of each area, assuming infiltration periods using as discussed in Section 7.1 for Water Code 1242.1 of 1, 4, 6, and 10 days, the calculated average volume of water that might be infiltrated ranges from 63 acre-feet for 1 day at the low estimates to 2,205 acre-feet for 10-days at the high estimate. Additional days may be realized using other methods to obtain flood flows as discussed in Section 7.1. However, as discussed in Section 7.1.1, the limiting factor for this site is that water will need to be pumped into the basins. Using the daily rates shown in Table 17, pumping rates needed to fill all three basin ranges from 14,000 gpm to 49,800 gpm.

Based on these pumping rates, it is recommended that initially only the forebay and Basin 1 be constructed. This configuration provides immediate operational capability at a meaningful scale while allowing future expansion through construction of the second recharge basin and obtaining future funding for additional pumping capacity. The pilot test results indicated that forebay sediment management will be an important component of long-term performance, as maintaining infiltration capacity in basin areas will depend on minimizing fine sediment transport into the recharge basins.

7.2.3 Monitoring Programs

As discussed in Section 5.3.1, Site S1 is located within an area of known groundwater impacts. Data collected during this project indicate that shallow groundwater conditions at the site are suitable for recharge and are hydraulically distinct from deeper impacted zones. However, a comprehensive monitoring program will be implemented to evaluate project performance and ensure protection of groundwater quality. In addition, the regulatory agency overseeing these groundwater impacts will be consulted prior to proceeding with full-scale design of the project.

Table 20. Infiltration Calculations for Basin 1, Site S1 operational thresholds.

Total Area - Forebay	1,637,856.00 square feet							
	37.6 Acres							
Layer	Infiltration Rates (Feet/Day)			0 Foot BGS		Calculation of Infiltration Rate		
	Low	High	Average	Portion of Area (%)	Square Feet	Low	High	Average
>40 ohm/m	4	12	8.00	6.8%	111,047	0.271	0.814	0.542
30 to 40 ohm/m	1	3	2.00	20.5%	335,269	0.205	0.614	0.409
20 to 30 ohm/m	0.5	2	1.25	65.7%	1,075,580	0.328	1.313	0.821
12 to 20 ohm/m	0.5	1	0.75	7.1%	115,960	0.035	0.071	0.053
5 to 12 ohm/m	0.01	0.05	0.03	0.0%	0	0.000	0.000	0.000
<5 ohm/m	0.001	0.09	0.05	0.0%	0	0.000	0.000	0.000
Assumed Infiltration						0.84	2.81	1.83
Layer	Infiltration Rates (Feet/Day)			1 Foot BGS		Calculation of Infiltration Rate		
	Low	High	Average	Portion of Area (%)	Square Feet	Low	High	Average
>40 ohm/m	4	12	8.00	6.4%	104,495	0.255	0.766	0.510
30 to 40 ohm/m	1	3	2.00	20.5%	335,760	0.205	0.615	0.410
20 to 30 ohm/m	0.5	2	1.25	67.1%	1,099,165	0.336	1.342	0.839
12 to 20 ohm/m	0.5	1	0.75	6.0%	98,271	0.030	0.060	0.045
5 to 12 ohm/m	0.01	0.05	0.03	0.0%	0	0.000	0.000	0.000
<5 ohm/m	0.001	0.09	0.05	0.0%	0	0.000	0.000	0.000
Assumed Infiltration						0.83	2.78	1.80
Layer	Infiltration Rates (Feet/Day)			3 Feet BGS		Calculation of Infiltration Rate		
	Low	High	Average	Portion of Area (%)	Square Feet	Low	High	Average
>40 ohm/m	4	12	8.00	5.8%	95,651	0.234	0.701	0.467
30 to 40 ohm/m	1	3	2.00	20.5%	70	0.205	0.616	0.411
20 to 30 ohm/m	0.5	2	1.25	69.5%	1,138,637	0.348	1.390	0.869
12 to 20 ohm/m	0.5	1	0.75	4.1%	66,988	0.020	0.041	0.031
5 to 12 ohm/m	0.01	0.05	0.03	0.0%	0	0.000	0.000	0.000
<5 ohm/m	0.001	0.09	0.05	0.0%	0	0.000	0.000	0.000
Assumed Infiltration						0.81	2.75	1.78
Layer	Infiltration Rates (Feet/Day)			5 Foot BGS		Calculation of Infiltration Rate		
	Low	High	Average	Portion of Area (%)	Square Feet	Low	High	Average
>40 ohm/m	4	12	8.00	5.0%	82,220	0.201	0.602	0.402
30 to 40 ohm/m	1	3	2.00	20.7%	339,691	0.207	0.622	0.415
20 to 30 ohm/m	0.5	2	1.25	72.4%	1,186,299	0.362	1.449	0.905
12 to 20 ohm/m	0.5	1	0.75	1.8%	29,645	0.009	0.018	0.014
5 to 12 ohm/m	0.01	0.05	0.03	0.0%	0	0.000	0.000	0.000
<5 ohm/m	0.001	0.09	0.05	0.0%	0	0.000	0.000	0.000
Assumed Infiltration						0.78	2.69	1.74
Layer	Infiltration Rates (Feet/Day)			10 Feet BGS		Calculation of Infiltration Rate		
	Low	High	Average	Portion of Area (%)	Square Feet	Low	High	Average
>40 ohm/m	4	12	8.00	4.1%	66,661	0.163	0.488	0.326
30 to 40 ohm/m	1	3	2.00	19.9%	325,278	0.199	0.596	0.397
20 to 30 ohm/m	0.5	2	1.25	75.0%	1,228,228	0.375	1.500	0.937
12 to 20 ohm/m	0.5	1	0.75	1.1%	17,689	0.005	0.011	0.008
5 to 12 ohm/m	0.01	0.05	0.03	0.0%	0	0.000	0.000	0.000
<5 ohm/m	0.001	0.09	0.05	0.0%	0	0.000	0.000	0.000
Assumed Infiltration						0.74	2.59	1.67
Layer	Infiltration Rates (Feet/Day)			15 Feet BGS		Calculation of Infiltration Rate		
	Low	High	Average	Portion of Area (%)	Square Feet	Low	High	Average
>40 ohm/m	4	12	8.00	2.7%	44,713	0.109	0.328	0.218
30 to 40 ohm/m	1	3	2.00	22.0%	360,492	0.220	0.660	0.440
20 to 30 ohm/m	0.5	2	1.25	73.6%	1,205,134	0.368	1.472	0.920
12 to 20 ohm/m	0.5	1	0.75	1.7%	27,516	0.008	0.017	0.013
5 to 12 ohm/m	0.01	0.05	0.03	0.0%	0	0.000	0.000	0.000
<5 ohm/m	0.001	0.09	0.05	0.0%	0	0.000	0.000	0.000
Assumed Infiltration						0.71	2.48	1.59
Layer	Infiltration Rates (Feet/Day)			20 Feet BGS		Calculation of Infiltration Rate		
	Low	High	Average	Portion of Area (%)	Square Feet	Low	High	Average
>40 ohm/m	4	12	8.00	1.6%	26,369	0.064	0.193	0.129
30 to 40 ohm/m	1	3	2.00	22.5%	368,681	0.225	0.675	0.450
20 to 30 ohm/m	0.5	2	1.25	72.6%	1,189,739	0.363	1.453	0.908
12 to 20 ohm/m	0.5	1	0.75	3.2%	52,903	0.016	0.032	0.024
5 to 12 ohm/m	0.01	0.05	0.03	0.0%	0	0.000	0.000	0.000
<5 ohm/m	0.001	0.09	0.05	0.0%	0	0.000	0.000	0.000
Assumed Infiltration						0.67	2.35	1.51
Layer	Infiltration Rates (Feet/Day)			25 Feet BGS		Calculation of Infiltration Rate		
	Low	High	Average	Portion of Area (%)	Square Feet	Low	High	Average
>40 ohm/m	4	12	8.00	1.9%	31,283	0.076	0.229	0.153
30 to 40 ohm/m	1	3	2.00	19.8%	324,459	0.198	0.594	0.396
20 to 30 ohm/m	0.5	2	1.25	73.6%	1,204,807	0.368	1.471	0.920
12 to 20 ohm/m	0.5	1	0.75	4.7%	77,307	0.024	0.047	0.035
5 to 12 ohm/m	0.01	0.05	0.03	0.0%	0	0.000	0.000	0.000
<5 ohm/m	0.001	0.09	0.05	0.0%	0	0.000	0.000	0.000
Assumed Infiltration						0.67	2.34	1.50
Layer	Infiltration Rates (Feet/Day)			30 Feet BGS		Calculation of Infiltration Rate		
	Low	High	Average	Portion of Area (%)	Square Feet	Low	High	Average
>40 ohm/m	4	12	8.00	2.2%	36,197	0.088	0.265	0.177
30 to 40 ohm/m	1	3	2.00	17.7%	290,556	0.177	0.532	0.355
20 to 30 ohm/m	0.5	2	1.25	74.1%	1,213,160	0.370	1.481	0.926
12 to 20 ohm/m	0.5	1	0.75	6.0%	97,780	0.030	0.060	0.045
5 to 12 ohm/m	0.01	0.05	0.03	0.0%	0	0.000	0.000	0.000
<5 ohm/m	0.001	0.09	0.05	0.0%	0	0.000	0.000	0.000
Assumed Infiltration						0.67	2.34	1.50
						Harmonic Mean to 20 Feet	0.76	2.63
						Harmonic Mean to 30 Feet	0.72	2.50

Table 21. Estimated infiltration capacity for Site S1.

Area	Size	Calculated Infiltration Rages (Feet/Day)			Estimated Recharge Volume (Acre-Feet)												
	(Acres)	low	High	Average	Number of Days	1			4			6			10		
Harmonic Mean to 20 Feet						Low	High	Average	Low	High	Average	Low	High	Average	Low	High	Average
Basin 1	37.60	0.76	2.63	1.69		29	99	64	114	396	254	171	593	381	286	989	635
Basin 2	32.40	0.68	2.36	1.52		22	76	49	88	306	197	132	459	295	220	765	492
Forebay	20.80	0.59	2.17	1.38		12	45	29	49	181	115	74	271	172	123	451	287
Harmonic Mean to 30 Feet					Totals	63	220	141	252	882	566	377	1,323	849	629	2,205	1,415
Basin N1	37.60	0.72	2.63	1.69		27	99	64	108	396	254	162	593	381	271	989	635
Basin N2	32.40	0.68	2.38	1.53		22	77	50	88	308	198	132	463	297	220	771	496
ForebayW	20.80	0.56	2.11	1.33		12	44	28	47	176	111	70	263	166	116	439	277
					Totals	61	220	141	243	880	563	365	1,319	845	608	2,199	1,408

The monitoring network will include a combination of existing and new monitoring wells distributed within, upgradient of, and downgradient of the recharge facilities. Wells will be screened in the first water zone that is being recharged and within the zone where the groundwater impacts have been reported (approximately 100 feet bgs). The existing Site S1 monitoring well (VMW-01) will be incorporated into the monitoring network. It is anticipated that approximately four to six monitoring wells will be required, including one upgradient/background well, two to three wells within or adjacent to recharge basins, and one to two downgradient wells to evaluate groundwater movement and potential mounding. In addition, one to two surface water monitoring locations will be maintained within Comanche Creek to evaluate flow conditions and support operational decisions.

Groundwater levels will be monitored using a combination of continuous data loggers and periodic manual measurements. Water quality sampling will be conducted on a quarterly basis during initial operations and will include analysis of major ions, nutrients, metals, and volatile organic compounds to confirm that recharge activities do not adversely affect groundwater conditions. Stilling wells will be placed within each of the basins to record water levels and document actual infiltration rates.

7.2.4 Operation and Maintenance

Operation and maintenance of the Site S1 recharge project will be focused on managing diversion of flood flows, maintaining conveyance infrastructure, and ensuring proper functioning of the recharge facilities. Pump operation will be required during flood events to convey water to the forebay, and flow distribution within the site will be managed using control structures.

Routine maintenance activities will include inspection and repair of berms and spillways, vegetation management within basins, and removal of accumulated sediment within the forebay. Sediment removal will be required periodically to maintain storage capacity and infiltration performance. Monitoring system maintenance and data collection will also be part of routine operations. Implementation of the project will require coordination with local, regional, and state agencies. Use of flood flows will be conducted in accordance with California Water Code Section 1242.1.

Implementation of the Site S1 recharge project will rely on an adaptive management framework informed by real-time and event-based monitoring data collected during FloodMAR operations. Monitoring of stilling wells within Basin 1, Basin 2, and the forebay), in combination with nearby groundwater monitoring wells, will provide the primary dataset for evaluating infiltration performance and subsurface response. These data will be used to track ponding depths, assess infiltration rates, identify the development of steady-state conditions during pumping, and evaluate groundwater mounding beneath and adjacent to the recharge facilities.

Monitoring results will be evaluated both during and following individual flood events to assess system performance and identify trends over time. Key indicators include changes in ponding depth relative to pumping rates, differences between influent and effluent stilling well levels, rates of drawdown following cessation of flows, and groundwater level response in adjacent wells. These data will allow comparisons of performance between FloodMAR events and provide a

quantitative basis for identifying changes in infiltration efficiency or subsurface conditions. Where feasible, automated monitoring equipment will be used to capture short-duration system dynamics associated with high-flow events.

Operational adjustments may be made in real time based on monitoring results, including modification of pumping rates, redistribution of flow within Basin 1 and Basin 2, or temporary suspension of recharge if infiltration capacity declines or groundwater levels approach

The presence of a dedicated pump and rehabilitated diversion structure will allow for rapid response to changing site conditions, ensuring that available flood flows can be effectively utilized while maintaining system performance.

Monitoring data will also be used to establish maintenance and rehabilitation triggers for Basin 1 and Basin 2. Indicators of reduced performance may include sustained increases in ponding depth at comparable inflow rates, reduced differentiation between influent and effluent stilling well levels, extended periods of standing water following events, or increased groundwater mounding without corresponding increases in recharge volume. When these conditions are observed consistently, they will indicate reduced infiltration capacity due to sediment accumulation or surface clogging.

Based on these observations, rehabilitation of Basin 1 and Basin 2 should be implemented when infiltration performance declines below levels necessary to efficiently utilize available FloodMAR flows. Rehabilitation activities may include surface scarification, removal of accumulated fine-grained sediments, and regrading of basin bottoms. Some of this material maybe used to build up berms if the material is suitable to reduce export costs. Timing of these activities will typically occur during the dry season following one or more events that demonstrate reduced performance, allowing basins to be restored prior to the next flood season.

Because communication protocols and agency coordination requirements have already been established under Water Code 1242.1, operations at Site S1 are primarily focused on efficient execution and repeatability once qualifying conditions occur. The availability of permanent infrastructure, combined with monitoring-informed decision-making, allows for consistent implementation of FloodMAR events while ensuring protection of infrastructure and groundwater resources.

Post-event evaluation will be conducted following each FloodMAR diversion to assess overall system performance, including recharge volumes, infiltration rates, groundwater response, and sediment impacts. These evaluations will be used to refine operational procedures, optimize basin performance, and guide maintenance activities, including the timing and extent of basin rehabilitation. Over time, this adaptive approach will improve the reliability and effectiveness of the Site S1 recharge project and support long-term groundwater sustainability objectives.

Water quality testing should be incorporated as an integral component of project implementation and long-term operation to verify that recharge activities do not adversely affect underlying groundwater systems. As demonstrated in the field investigations (Section 4.7) and results (Section 5.2), the shallow groundwater system is generally characterized by a Ca–Mg–HCO₃ hydrochemical facies with no detected VOCs in samples collected from the Site S1 monitoring

well; however, given the proximity of certain sites to known VOC concern areas and mapped plumes, continued monitoring is warranted. A project-specific monitoring program should include baseline and periodic sampling of groundwater and recharge source water for VOCs, nutrients, major ions, metals, and general chemistry parameters. Monitoring networks should include strategically placed wells screened across both shallow and deeper intervals to assess vertical gradients and potential migration pathways, as well as surface water sampling where recharge is sourced from nearby channels. Collectively, these data will allow for evaluation of any changes in groundwater quality attributable to recharge operations and provide an early warning framework to identify and mitigate potential mobilization or alteration of existing VOC plumes, ensuring that recharge activities remain protective of groundwater resources and consistent with regulatory and GSP objectives.

7.2.5 Permitting

Implementation of the proposed recharge project will require compliance with a range of local, state, and potentially federal permitting requirements. As identified during the preliminary design phase, permitting considerations include land disturbance, water diversion and use, environmental review, and coordination with regulatory agencies. Early engagement with permitting authorities will be critical to confirm requirements, streamline approvals, and align project design with regulatory expectations.

At the local level, grading permits will be required for construction of recharge basins, forebays, conveyance features, and associated infrastructure. These permits are typically administered by Butte County and will require submittal of engineering plans, erosion and sediment control measures, and stormwater management provisions. If construction activities disturb more than one acre, coverage under the State Water Resources Control Board (SWRCB) Construction General Permit (CGP) will also be required, including preparation of a Stormwater Pollution Prevention Plan (SWPPP) and implementation of best management practices during construction.

Environmental review under the California Environmental Quality Act (CEQA) will be required prior to project implementation. Depending on the scope and potential impacts of the project, this may involve preparation of an Initial Study/Mitigated Negative Declaration or an Environmental Impact Report (EIR). Key impact areas likely to be evaluated include biological resources, cultural resources, hydrology and water quality, and land use compatibility. The results of the field investigations and pilot testing described in this report, including infiltration performance and water quality data, will inform the CEQA analysis and help support impact determinations and mitigation measures.

For projects involving diversion of surface water, particularly under Flood-MAR conditions, coordination with the California Department of Water Resources (DWR) and the State Water Resources Control Board will be required. As demonstrated during pilot testing, Water Code Section 1242.1 may be utilized to divert flood flows during high-flow events without a traditional water right, provided that the required notifications and conditions are met. However, long-term project implementation will still require clear operational protocols and documentation to ensure compliance with applicable statutes and to demonstrate that diversions occur only under appropriate hydrologic conditions.

Implementation of the proposed recharge project includes rehabilitation and potential modification of the existing diversion infrastructure used to convey surface water to recharge facilities. Existing diversion structures, including in-stream intake points, headgates, or informal diversion features, should be evaluated for structural integrity, hydraulic capacity, sediment management, and fish passage considerations. Rehabilitation activities may include repair or replacement of control structures, installation of screened intake systems to meet current regulatory standards, stabilization of banks and approach channels, and improvements to conveyance efficiency to reduce losses and operational constraints. Any modification to an existing diversion structure will be subject to applicable permitting requirements, including coordination with the California Department of Fish and Wildlife (CDFW) under Section 1602, and may require review by the State Water Resources Control Board and other agencies to confirm compliance with water diversion regulations and protection of aquatic resources. Incorporating upgrades to existing diversion infrastructure into the overall project design can reduce costs relative to new construction while improving operational reliability and ensuring consistency with current environmental and regulatory standards.

Given the proximity of the site to known groundwater quality concerns, including mapped VOC plume areas as discussed in previous sections, permitting agencies may require additional documentation or conditions related to groundwater protection. This may include preparation of a monitoring and reporting plan, incorporation of contingency measures, and demonstration that recharge activities will not adversely affect existing groundwater conditions or mobilize constituents of concern. As such, permitting efforts should be closely coordinated with development of the project monitoring program described in Section 7.1.4 to ensure consistency and regulatory acceptance.

Overall, successful permitting will depend on proactive coordination with agencies, clear documentation of project benefits and safeguards, and incorporation of monitoring and adaptive management measures into project design. Early identification of permitting pathways and timelines will support efficient project implementation and position the project competitively for future funding opportunities.

7.2.6 Estimation of probable design and construction costs

This section provides an order-of-magnitude estimate of probable design, permitting, construction, and operation and maintenance (O&M) costs for implementation of a simplified Flood-MAR recharge project at Site S1. This estimate reflects a low-complexity approach that maximizes the use of existing infrastructure, minimizes pumping requirements, and relies primarily on gravity diversion and on-site earthwork to construct recharge basins.

Costs presented herein are planning-level estimates intended to support feasibility evaluation and comparison with other recharge alternatives. Final costs will depend on detailed design, permitting requirements, and site-specific construction conditions.

The cost estimate is based on the following assumptions:

- Acquisition of approximately 90 acres of existing walnut orchard
- Removal of orchard trees and preparation of the site for basin construction

- Construction of forebay and infiltration basins using on-site earthwork only
- Rehabilitation of an existing diversion structure for Flood-MAR operations
- Minimal conveyance infrastructure, prioritizing gravity flow where feasible
- Installation of a basic monitoring network
- Implementation of permitting and environmental compliance requirements

Unit costs reflect recent local experience using agricultural contractors and simplified construction approaches common to recharge projects in the region.

Property Acquisition (Walnut Orchard)

The Site S1 property is assumed to be in active walnut production. Agricultural land values in the Butte County area vary based on water availability, orchard age, and productivity but typically range from \$15,000 to \$30,000 per acre. For approximately 90 acres, property acquisition costs range from \$1.4 million to \$2.7 million. This represents a significant portion of overall project cost and may vary depending on negotiations, existing infrastructure, and market conditions.

Orchard Removal and Site Preparation

Conversion of the property to recharge use will require removal of walnut trees, root balls, and irrigation infrastructure, followed by rough grading. Typical unit costs for these items are:

- Tree removal and disposal: \$1,000 to \$3,000 per acre
- Ripping and site preparation: \$500 to \$1,500 per acre

Estimated total cost is \$150,000 to \$400,000.

Earthwork and Basin Construction

Earthwork will consist of shallow excavation, berm construction, and grading to create the forebay and infiltration basins using on-site soils. Based on local agricultural construction practices, basin grading and shaping ranges from \$1,500 to \$4,000 per acre. For the 90 acres, the total estimated costs range from \$150,000 to \$400,000. Earthwork costs are relatively low due to the shallow nature of excavation and minimal need for engineered compaction or imported materials.

Diversion, Pumping, and Conveyance Facilities

Although the project is configured as a simplified Flood-MAR system, delivery of surface water from Comanche Creek to the recharge basins is assumed to require pumping to achieve the desired flow rate of approximately 15,000 gpm during high-flow events. To maintain a low-cost approach consistent with agricultural practices in Butte County, pumping is assumed to be provided using portable or skid-mounted diesel-driven pumps or tractor-powered pumps, rather than construction of a permanent pump station. These systems are commonly used for seasonal irrigation and flood-flow diversion and provide substantial cost savings in both capital and permitting.

Under this approach, the pumping system would consist of:

- Multiple portable pumps (e.g., 3–5 units rated at 3,000 to 5,000 gpm each)
- Temporary screened intake structure at the diversion point

- Flexible conveyance (e.g., lay-flat hose or short-run pipe) to the forebay
- Minimal electrical infrastructure (diesel-powered systems preferred)

This configuration avoids the need for permanent foundations, electrical service upgrades, and control systems typical of fixed pump stations. Table 22 summarizes these costs.

Table 22. Summary of pump and conveyance costs

Component	Estimated Cost
Portable pumps	\$200,000 to \$500,000
Intake structure and screening	\$50,000 to \$200,000
Lay-flat hose/temporary conveyance	\$50,000 to \$200,000
Setup, fittings, and controls	\$25,000 to \$100,000
Total Pumping and Conveyance Cost	\$325,000 to \$1,000,000

This represents a significantly lower cost compared to permanent pump stations, which could exceed several million dollars for similar capacity. In addition, if there is limited funding the project could start out with lower pumping rates.

Rehabilitation of Existing Diversion Structure

The existing diversion structure will function primarily as a controlled intake location supporting portable pumping operations. Rehabilitation work will focus on:

- Stabilizing the diversion location to support pump placement and operation
- Installing or upgrading intake screening to meet regulatory requirements
- Minor grading and erosion protection at the diversion point
- Improving access for seasonal equipment deployment

Because flow is driven by portable pumps rather than a fixed intake structure, rehabilitation requirements are limited, and costs remain relatively low at \$150,000 to \$400,000.

Monitoring and Instrumentation

Monitoring infrastructure will include a limited number of groundwater monitoring wells and associated instrumentation. Estimated costs:

- Monitoring wells and installation: \$25,000 to \$50,000 per well (3–5 wells assumed)
- Instrumentation and data systems: \$50,000 to \$150,000

Estimated total - \$125,000 to \$300,000.

Permitting and Environmental Compliance Costs

Permitting and environmental compliance costs include CEQA review, technical studies, and agency coordination for diversion and recharge activities. Key components include:

- CEQA documentation (anticipated Initial Study/Mitigated Negative Declaration)

- Biological and cultural resource evaluations
- Streambed Alteration Agreement (CDFW)
- Coordination with SWRCB and Regional Water Board
- Preparation of a Stormwater Pollution Prevention Plan (SWPPP)

Estimated cost for these is \$250,000 to \$750,000.

Engineering and Design Costs

Engineering and design costs include preparation of plans and specifications, permitting support, and construction management. The estimated range is 15 to 25 percent of construction costs or \$200,000 to \$700,000

Estimated Total Capital Cost

Based on the simplified Flood-MAR approach, incorporation of portable pumping to achieve approximately 15,000 gpm, and cost assumptions representative of Butte County agricultural construction practices, the total project cost for Site S1 is estimated as shown on Table 19.

Table 23. Summary of Capital Costs

Cost Component	Estimated Range
Property Acquisition (Walnut Orchard)	\$1.4M – \$2.7M
Orchard Removal & Site Preparation	\$0.15M – \$0.40M
Earthwork & Basin Construction	\$0.15M – \$0.40M
Diversion Structure Rehabilitation	\$0.15M – \$0.40M
Pumping & Conveyance (15,000 gpm, portable system)	\$0.33M – \$1.00M
Monitoring Infrastructure	\$0.10M – \$0.30M
Subtotal Construction + Land	\$2.3M – \$5.2M
Permitting & Environmental Compliance	\$0.25M – \$0.75M
Engineering, Design & Construction Management	\$0.25M – \$0.80M
Total Project Cost	\$2.8 million – \$6.8 million

The dominant cost components are property acquisition and pumping/conveyance, rather than basin construction. Earthwork associated with development of recharge basins represents a relatively minor portion of total cost due to the ability to utilize on-site soils and implement agricultural grading methods.

The inclusion of portable, diesel-driven pumping systems to convey up to 15,000 gpm provides a cost-effective alternative to a permanent pump station, reducing capital costs while maintaining

the ability to capture high flows during Flood-MAR events. This approach also minimizes permitting complexity and allows operational flexibility. Permitting and engineering costs remain significant but manageable due to the anticipated use of a Mitigated Negative Declaration (MND)-level CEQA review, reliance on existing infrastructure, and limited in-stream construction.

The total project cost of approximately \$2.8 million to \$6.8 million reflects a practical, low-infrastructure Flood-MAR implementation strategy that is consistent with regional construction practices and pilot test findings. This cost range demonstrates that meaningful recharge capacity can be developed at Site S1 with relatively modest capital investment compared to more infrastructure-intensive recharge projects, particularly when leveraging existing diversion features and agricultural-scale construction methods.

Operations and Maintenance (O&M) Costs

O&M costs for the simple Flood-MAR configuration are expected to be relatively low due to the absence of major pumping or complex infrastructure. Costs are primarily associated with periodic maintenance and monitoring. Key components include:

- Basin maintenance (sediment removal, vegetation control, periodic regrading)
- Diversion structure inspection and cleaning
- Monitoring, sampling, and reporting
- Seasonal labor for operation during recharge events

Estimated O&M costs:

- \$50 to \$150 per acre-foot of recharge, or
- \$75,000 to \$250,000 annually, depending on hydrologic conditions and recharge frequency

Costs will vary from year to year depending on availability of flood flows and operational intensity.

Unit Cost of Recharge

The unit cost of recharge for the Site S1 project was evaluated based on both total project costs and anticipated local implementation costs. Because capital costs associated with land acquisition and construction may be funded through state or local grant programs, two cost metrics are presented to reflect both the full economic cost and the cost to the implementing agency.

The total economic cost includes both annualized capital costs and annual operations and maintenance (O&M) costs divided by the estimated annual recharge volume. Based on the estimated project cost and recharge volumes, the total economic cost of recharge is approximately \$100 to \$700 per acre-foot. This range reflects variability in annual recharge volumes, with lower costs occurring during wetter years when recharge volumes are higher.

If capital costs are fully funded through grants, the cost to the implementing agency is limited to annual O&M expenses. Under this scenario, the unit cost of recharge is estimated as \$50 to \$200 per acre-foot. This cost represents labor, maintenance, monitoring, and pumping (fuel) costs associated with seasonal operation of the project.

7.3 Site N4 Recharge Project

This section presents the preliminary design and evaluation of the proposed FloodMAR project at Site N4. This site was selected for advancement based on the results of field investigations and pilot testing, which indicate favorable conditions for groundwater recharge, including permeable near-surface materials, consistent infiltration capacity, and strong hydraulic connectivity to the underlying aquifer system. Compared to other evaluated sites, Site N4 demonstrated reliable infiltration performance without significant limitations from perched groundwater or low-permeability subsurface units, supporting its suitability for sustained recharge operations and direct augmentation of the regional groundwater system.

The proposed project is designed to passively capture and manage high-flow surface water diverted from the Rock Creek–Keefer Slough system under FloodMAR conditions. While Site N4 is the primary location for effective recharge, it functions as part of a broader, integrated system with upstream Sites N6 and N5. In this system, Site N6 serves as an initial capture and flow distribution area, and Site N5 provides intermediate storage and attenuation, particularly where perched groundwater conditions limit deep percolation. These upstream sites help regulate and extend the duration of flows delivered to Site N4, improving overall system efficiency and operational flexibility during flood events.

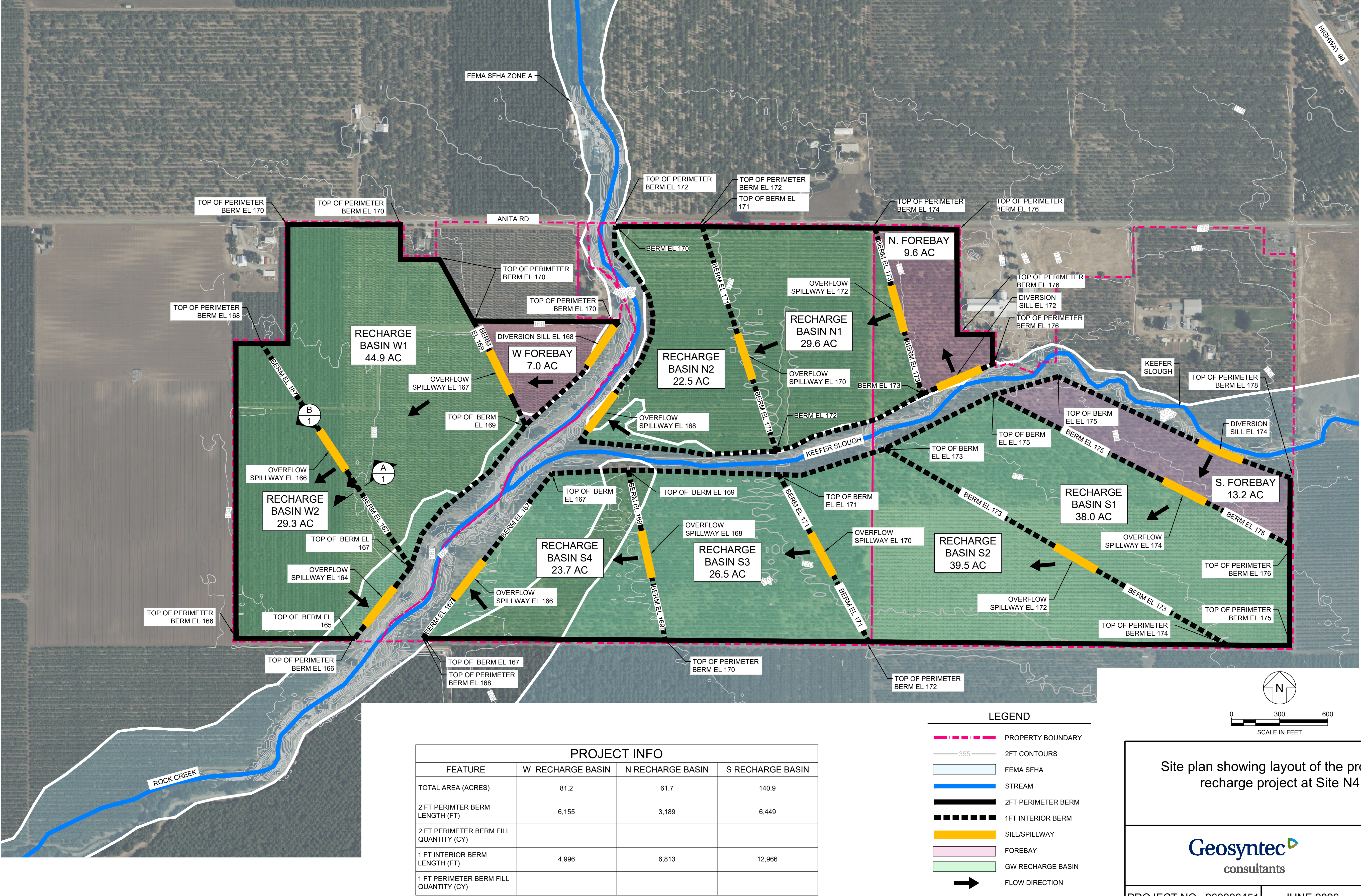
Utilizing gravity-driven conveyance and a series of infiltration basins, the Site N4 project emphasizes operational simplicity, reduced infrastructure requirements, and the ability to concentrate recharge in areas with the most favorable hydrogeologic conditions. Pilot testing confirmed the ability of the site to accept applied water with measurable groundwater response, indicating effective transmission of recharge to the shallow aquifer system.

The following subsections describe the conceptual layout, anticipated recharge performance, and key implementation considerations for Site N4, including diversion and conveyance infrastructure, basin configurations, monitoring approaches, permitting requirements, operations and maintenance, and order-of-magnitude cost estimates.

7.3.1 Preliminary Design

The Site N4 project is a FloodMAR recharge project designed to capture high-flow surface water from Keefer Slough and Rock Creek and distribute flows across the site for infiltration to the underlying groundwater aquifer. Based on field investigations discussed in Sections 4 and 5, Site N4 is underlain by permeable sediments extending from the ground surface to the water table at approximately 20 to 25 feet below ground surface (bgs), providing favorable conditions for groundwater recharge.

The project layout, shown in Figure 60, consists of three forebays (N. Forebay, S. Forebay, and W. Forebay) and eight recharge basins configured to receive, distribute, and infiltrate flows conveyed from Keefer Slough and Rock Creek. The N. Forebay is located on the eastern side of the site north of Keefer Slough, and the S. Forebay is located immediately south of Keefer Slough, while the W. Forebay is located on the western portion of the site. These forebays receive incoming flows and allow for initial sediment settling prior to distribution to the recharge basins.



The recharge basins include Basins N1 and N2 located north of Keefer Slough; Basins S1 through S4 located south of Keefer Slough; and Basins W1 and W2 located in the western portion of the site. The basins are configured to promote even distribution of flows across the site and maximize infiltration capacity.

Site grading includes perimeter berm elevations ranging from approximately EL 166 to EL 176, with interior berms and flow control features used to direct flows between forebays and recharge basins. Overflow spillways are incorporated throughout the site with elevations ranging from approximately EL 164 to EL 174, and diversion sill elevations are approximately EL 168 to EL 174, allowing for controlled movement of water between basin features and return to Keefer Slough and Rock Creek under high-flow conditions.

Flows are conveyed into the site from Keefer Slough and Rock Creek through graded inlet locations along the channel banks. Once within the site, flows are distributed to the forebays and routed to the recharge basins through low-gradient channels and overland flow paths. The system operates under gravity conditions and does not require pumping or mechanical conveyance.

Operation of the Site N4 project consists of passively capturing high-flow conditions in Keefer Slough and Rock Creek and distributing these flows across the forebays and recharge basins. Excess flows are conveyed through overflow pathways back to Keefer Slough, Rock Creek, or downstream portions of the site. Because the project relies entirely on gravity flow, no pump stations or diversion structures are required.

7.3.2 Infiltration Capacity

Recharge performance for Site S1 is based on infiltration testing, CPT-derived hydraulic conductivity data summarized in Table 7 and Table 8 and pilot testing discussed in Section 6.3. These data indicate that infiltration rates at the site are highly variable but generally favorable, with shallow infiltration testing results ranging from approximately 0.35 to 57 feet per day.

During pilot basin operation, groundwater monitoring indicated a clear response to applied water, with measurable groundwater level increases occurring during recharge events. This response confirms that water applied at the surface migrates vertically through the unsaturated zone to the shallow aquifer and that the underlying aquifer has sufficient capacity to accept recharge without excessive mounding under pilot-scale conditions.

As with Site S1, estimated infiltration capacities were calculated using the same depth layers indicated in Section 7.1.2 and the range of infiltration rates for resistivity ranges indicated in Table 15. The minimum, maximum, and average infiltration rates for each depth interval for the infiltration basins and forebays shown in Figure 60 are summarized in Appendix L.

Using these values, the estimated volume that can directly infiltrate the entire portion of each basin is summarized on Table 24. As seen on this table, the average calculated infiltration rates for the infiltration basins to 20 feet bgs ranges from 0.76 feet per day (Basin W2) to 1.04 feet per day (Basin S1). Using these values, the estimated size of each area, assuming infiltration periods using Water Code 1242.1 of 1, 4, 6, and 10 days, the calculated average volume of water that might be infiltrated ranges from 136 acre-feet for 1 day at the low estimates to 3,428 acre-feet for 10-days

Table 24. Estimated infiltration capacity for infiltration basins and forebays, Site N4.

Area	Size (Acres)	Calculated Infiltration Rates (Feet/Day)			Estimated Recharge Volume (Acre-Feet)												
	Acres	low	High	Average	Number of Days	1			4			6			10		
Harmonic Mean to 20 Feet						Low	High	Average	Low	High	Average	Low	High	Average	Low	High	Average
Basin N1	29.60	0.47	1.07	0.77		14	32	23	56	127	91	83	190	137	139	317	228
Basin N2	22.50	0.51	1.44	0.98		11	32	22	46	130	88	69	194	132	115	324	221
Basin S1	38.00	0.54	1.53	1.04		21	58	40	82	233	158	123	349	237	205	581	395
Basin S2	39.50	0.43	1.07	0.75		17	42	30	68	169	119	102	254	178	170	423	296
Basin S3	26.50	0.47	1.18	0.83		12	31	22	50	125	88	75	188	132	125	313	220
Basin S4	23.70	0.50	1.37	0.93		12	32	22	47	130	88	71	195	132	119	325	220
Basin W1	44.90	0.48	1.08	0.78		22	48	35	86	194	140	129	291	210	216	485	350
Basin W2	29.30	0.49	1.03	0.76		14	30	22	57	121	89	86	181	134	144	302	223
Forebay N	9.60	0.26	0.55	0.41		2	5	4	10	21	16	15	32	24	25	53	39
Forebay S	13.20	0.52	1.69	1.11		7	22	15	27	89	59	41	134	88	69	223	147
Forebay W	7.00	0.50	1.19	0.85	4	8	6	14	33	24	21	50	36	35	83	60	
Harmonic Mean to 30 Feet					Totals	136	343	240	544	1,371	959	816	2,057	1,439	1,360	3,428	2,399
Basin N1	29.60	0.44	0.94	0.69		13	28	20	52	111	82	78	167	123	130	278	204
Basin N2	22.50	0.50	1.33	0.91		11	30	20	45	120	82	68	180	123	113	299	205
Basin S1	38.00	0.52	1.44	0.98		20	55	37	79	219	149	119	328	223	198	547	372
Basin S2	39.50	0.37	0.87	0.62		15	34	24	58	137	98	88	206	147	146	344	245
Basin S3	26.50	0.43	1.03	0.73		11	27	19	46	109	77	68	164	116	114	273	193
Basin S4	23.70	0.49	1.26	0.87		12	30	21	46	119	82	70	179	124	116	299	206
Basin W1	44.90	0.49	1.08	0.78		22	48	35	88	194	140	132	291	210	220	485	350
Basin W2	29.30	0.50	1.01	0.75		15	30	22	59	118	88	88	178	132	147	296	220
Forebay N	9.60	0.15	0.33	0.24		1	3	2	6	13	9	9	19	14	14	32	23
Forebay S	13.20	0.54	1.72	1.13		7	23	15	29	91	60	43	136	89	71	227	149
Forebay W	7.00	0.50	1.10	0.80		4	8	6	14	31	22	21	46	34	35	77	56
					Totals	130	316	222	522	1,263	890	782	1,894	1,334	1,304	3,156	2,224

at the high estimate. As discussed in Section 7.1, additional days may be realized using other methods to obtain flood waters. As with Site S1, the forebay sediment management will be an important component of long-term performance, as maintaining infiltration capacity in basin areas will depend on minimizing fine sediment transport into the recharge basins.

7.3.3 Monitoring Programs

The monitoring network will include a combination of existing and new monitoring wells distributed within, upgradient of, and downgradient of the recharge facilities. Wells will be screened in the first water zone that is being recharged. The existing Site N4 monitoring well (RMW-01) will be incorporated into the monitoring network. It is anticipated that approximately four to six monitoring wells will be required, including one upgradient/background well, two to three wells within or adjacent to recharge basins, and one to two downgradient wells to evaluate groundwater movement and potential mounding. In addition, one to two surface water monitoring locations will be maintained within Keefer Slough and Rock Creek to evaluate flow conditions and support operational decisions.

Groundwater levels will be monitored using a combination of continuous data loggers and periodic manual measurements. Water quality sampling will be conducted on a quarterly basis during initial operations and will include analysis of major ions, nutrients, and metals to confirm that recharge activities do not adversely affect groundwater conditions. Stilling wells will be placed within each of the basins to record water levels and document actual infiltration rates.

7.3.4 Operation and Maintenance

Operations and maintenance (O&M) for the Site N4 recharge basins would be consistent with those described for Site S1, with modifications reflecting the larger basin footprint and distributed configuration of the N4 facility. Routine O&M activities would include inspection of diversion structures, forebays, conveyance features, and basin surfaces prior to and during recharge events to ensure proper operation and to identify any maintenance needs. Unlike Site S1, operation of the Site N4 system would not require active pumping, as water can be conveyed and distributed across the site by gravity flow.

Sediment accumulation within forebays and basins is expected due to the use of surface water supplies; therefore, periodic sediment removal will be required to maintain infiltration capacity. Forebays are specifically included in the design to concentrate coarse sediment deposition and reduce maintenance requirements within the primary recharge basins. Vegetation management will also be required to prevent excessive growth that could inhibit flow distribution or reduce infiltration rates.

Basin bottoms may require periodic scarification or light grading to address clogging caused by fine sediment deposition or biological growth. The frequency of these activities will depend on source water quality, duration of operation, and observed infiltration performance during recharge events.

Instrument maintenance, including calibration and periodic replacement of pressure transducers and monitoring equipment, will also be required to ensure accurate data collection. Overall, O&M

requirements for Site N4 are expected to be moderate and comparable to Site S1, with potentially increased effort due to the larger total area and number of individual basin cells, but reduced operational complexity due to the absence of pumping requirements.

7.3.5 Permitting

Permitting and environmental requirements for the Site N4 recharge project are expected to be similar to those identified for Site S1, with site-specific considerations related to proximity to Keefer Slough and the larger project footprint. Implementation would likely require compliance with the California Environmental Quality Act (CEQA), including preparation of appropriate environmental documentation to evaluate potential impacts associated with construction and operation.

Permits or notifications may be required for diversion of surface water to the site under California Water Code Section 1242.1 (FloodMAR), depending on the source and timing of water use. Coordination with the State Water Resources Control Board would be required to ensure compliance with water rights and diversion regulations. The absence of pump installations reduces permitting complexity relative to Site S1 by eliminating the need for electrical and well pumping system considerations.

Because the project is adjacent to Keefer Slough, additional coordination with regulatory agencies may be required to address potential impacts to jurisdictional waters or wetlands. This could include consultation with the U.S. Army Corps of Engineers and the Regional Water Quality Control Board if work occurs within regulated areas. Construction activities would also need to comply with stormwater regulations, including preparation of a Stormwater Pollution Prevention Plan (SWPPP) for disturbance exceeding regulatory thresholds.

No known environmental contamination concerns have been identified at Site N4 that would preclude recharge. However, continued evaluation of groundwater quality, particularly with respect to nitrate, should be incorporated into project planning and monitoring.

Overall, permitting requirements for Site N4 are anticipated to be manageable and consistent with those described for Site S1, with additional coordination related to surface water features and project scale, and reduced complexity due to the gravity-driven design that does not require pumping infrastructure.

7.3.6 Estimation of probable design and construction costs

This section provides an order-of-magnitude estimate of probable design, permitting, construction, and operation and maintenance (O&M) costs for implementation of a simplified Flood-MAR recharge project at Site N4. This estimate reflects a low-complexity approach that maximizes the use of gravity diversion from Keefer Slough, eliminates the need for pumping infrastructure, and relies primarily on on-site earthwork to construct recharge basins.

Costs presented herein are planning-level estimates intended to support feasibility evaluation and comparison with other recharge alternatives. Final costs will depend on detailed design, permitting requirements, and site-specific construction conditions.

The cost estimate is based on the following assumptions:

- Acquisition of approximately 342 acres of existing walnut and almond orchards.
- Removal of orchard trees and preparation of the site for basin construction.
- Construction of multiple forebays and infiltration basins using on-site earthwork only.
- Construction of new diversion and gravity conveyance from Keefer Slough.
- No pumping infrastructure required (gravity-driven system).
- Installation of a basic monitoring network.
- Implementation of permitting and environmental compliance requirements.

Unit costs reflect recent local experience using agricultural contractors and simplified construction approaches common to recharge projects in the region.

Property Acquisition (Walnut and Almond Orchards)

The Site N4 property is assumed to be in active walnut and almond production. Agricultural land values in the Butte County area vary based on water availability, orchard age, and productivity but typically range from \$15,000 to \$30,000 per acre.

For approximately 342 acres, this results in a total estimated land acquisition cost of: \$5.1 million to \$10.3 million. This represents a significant portion of overall project cost and may vary depending on negotiations, existing infrastructure, and market conditions. As with Site S1, this project could be constructed in phases starting with the Forebay S and the southern infiltration basins.

Orchard Removal and Site Preparation

Conversion of the entire property to recharge use will require removal of all walnut and almond trees, root balls, and irrigation infrastructure across the full 342-acre site, followed by rough grading.

Typical unit costs for these items are:

- Tree removal and disposal: \$1,000 to \$3,000 per acre
- Ripping and site preparation: \$500 to \$1,500 per acre

Estimated total cost (342 acres) is \$500,000 to \$1.5 million

Earthwork and Basin Construction

Earthwork will consist of shallow excavation, berm construction, and grading to create the forebay and infiltration basins using on-site soils. Based on local agricultural construction practices, basin grading and shaping ranges from \$1,500 to \$4,000 per acre. For approximately 283 acres of basin development, the total estimate is \$400,000 to \$1.1 million. Earthwork costs are relatively low due to the shallow nature of excavation and minimal need for engineered compaction or imported materials.

Diversion and Conveyance Facilities (Gravity System)

The project is configured as a simplified Flood-MAR system without pumping. Water will be diverted from Keefer Slough and conveyed to the recharge basins using gravity flow. The diversion system consists of:

- New diversion structure at Keefer Slough
- Gravity conveyance (channels, culverts, or short-run pipe)
- Flow distribution between basins
- Minimal electrical or mechanical infrastructure

Estimated cost is \$800,000 to \$2.0 million. This eliminates the need for portable or permanent pumping systems required at Site S1, reducing both capital and operational costs.

Diversion Structure Construction

A new diversion structure is required to facilitate Flood-MAR operations. Construction includes:

- Intake structure and screening
- Bank stabilization and erosion control
- Access improvements
- Basic flow control features

Estimated cost is \$300,000 to \$800,000.

Monitoring and Instrumentation

Monitoring infrastructure will include groundwater monitoring wells and instrumentation.

Estimated costs:

- Monitoring wells and installation: \$25,000 to \$50,000 per well (3–5 wells assumed)
- Instrumentation and data systems: \$50,000 to \$150,000

Estimated total is 100,000 to \$300,000.

Permitting and Environmental Compliance Costs

Permitting and environmental compliance costs include CEQA review, technical studies, and agency coordination. Key components include:

- CEQA documentation (anticipated Initial Study/Mitigated Negative Declaration)
- Biological and cultural resource evaluations
- Streambed Alteration Agreement (CDFW) for Keefer Slough
- Coordination with SWRCB and Regional Water Board
- Preparation of a Stormwater Pollution Prevention Plan (SWPPP)

Estimated cost is \$250,000 to \$750,000.

Engineering and Design Costs

Engineering and design costs include preparation of plans and specifications, permitting support, and construction management. The estimated range for these items is 15 to 25 percent of construction costs or \$500,000 to \$825,000. However, these costs may be reduced based on savings for similar services for the other projects and assuming a programmatic implementation, a 10 to 20 percent construction costs may be accomplished, or \$330,000 to \$660,000.

Estimated Total Capital Cost

Based on the simplified Flood-MAR approach and cost assumptions representative of Butte County agricultural construction practices, the total project cost for Site N4 is estimated as shown on Table 26. The dominant cost component for Site N4 is property acquisition, followed by diversion and conveyance infrastructure. Earthwork associated with development of recharge basins remains a relatively minor portion of total cost due to the ability to utilize on-site soils and agricultural grading methods.

Table 25. Summary of Capitol Costs

Cost Component	Estimated Range
Property Acquisition (Walnut Orchard)	\$5.1M – \$10.3M
Orchard Removal & Site Preparation	\$0.5M – \$1.5M
Earthwork & Basin Construction	\$0.4M – \$01.1M
Diversion Structure Construction	\$0.3M – \$0.8M
Diversion & Conveyance (gravity system)	\$0.8M – \$2.0M
Monitoring Infrastructure	\$0.1M – \$0.3M
Subtotal Construction + Land	\$7.2M – \$16.0M
Permitting & Environmental Compliance	\$0.25M – \$0.75M
Engineering, Design and CMA	\$0.5M-\$1.5M
Total Project Cost	\$8.0 to \$18.5M

O&M Costs

O&M costs for the simplified Flood-MAR configuration are expected to be relatively low due to the absence of pumping or complex infrastructure. Costs are primarily associated with periodic maintenance and monitoring.

Key components include:

- Basin maintenance (sediment removal, vegetation control, periodic regrading)
- Diversion structure inspection and cleaning
- Monitoring, sampling, and reporting
- Seasonal labor for operation during recharge events

Estimated O&M costs are \$30 to \$120 per acre-foot of recharge, or \$150,000 to \$400,000 annually.

Unit Cost of Recharge

The unit cost of recharge for the Site N4 project was evaluated using the same methodology as Site S1. The total economic cost, including capital and O&M, is estimated at \$80 to \$500 per acre-foot. If capital costs are funded through grants, the cost to the implementing agency is limited to O&M costs, resulting in \$30 to \$150 per acre-foot.

7.4 Site N5 Recharge Project

This section presents the preliminary design and evaluation of the proposed FloodMAR project at Site N5. This site was advanced based on field investigations and pilot testing that identified its role as a floodwater detention and management feature, rather than a high-capacity direct recharge site. Hydrogeologic conditions at Site N5 are characterized by a shallow perched groundwater system and the presence of underlying low-permeability units, which limit vertical connectivity to the regional aquifer. As a result, infiltration at this site is constrained primarily to the shallow subsurface and does not consistently translate into significant recharge of the deeper groundwater system.

Despite these limitations, Site N5 provides important functional value within the broader Rock Creek–Keefer Slough FloodMAR system. Positioned between upstream Site N6 and downstream Site N4, Site N5 serves as an intermediate storage and attenuation facility that can capture, spread, and temporarily retain high flows during flood events. This function helps regulate the timing and magnitude of flows conveyed downstream, reducing peak discharge and extending the duration of water available for recharge at Site N4, where hydrogeologic conditions are more favorable. In this way, Site N5 contributes to overall system performance by enhancing operational flexibility and supporting a more controlled and sustained recharge regime.

The proposed project utilizes passive, gravity-driven diversion and conveyance to route flood flows into surface impoundments and infiltration areas. While deep aquifer recharge is limited, the site provides multi-benefit outcomes, including flood attenuation, localized groundwater mounding within the perched system, and improved water distribution across the corridor.

The following subsections describe the conceptual design, anticipated hydraulic performance, and key implementation considerations for Site N5, including diversion infrastructure, basin configuration, monitoring approaches, permitting requirements, operations and maintenance, and order-of-magnitude cost estimates.

7.4.1 Preliminary Design

The Site N5 project is a FloodMAR recharge project designed to capture high-flow surface water and distribute flows across the site for infiltration to the underlying groundwater aquifer. Based on field investigations discussed in Sections 4 and 5, Site N5 includes permeable near-surface materials; however, a perched groundwater system is present at approximately 7 to 11 feet below ground surface (bgs), with the regional water table at depths of approximately 30 to 40 feet bgs. This condition limits the available storage capacity for recharge at the site.

The project layout, shown in Figure 61, consists of a forebay and four recharge basins (Recharge Basin 1 through Recharge Basin 4) configured to receive, distribute, and infiltrate flows across the site. The forebay is located adjacent to Keefer Slough and functions as the initial receiving area for flows entering the site. The recharge basins are distributed across the site to promote infiltration under varying site conditions.

Site grading includes perimeter berm elevations generally ranging from approximately EL 183 to EL 194, with interior berms used to direct flows between the forebay and recharge basins. Overflow spillways are incorporated throughout the site with elevations generally ranging from approximately EL 181 to EL 188, and a diversion sill is present at approximately EL 192, allowing for controlled movement of water within the system and return flows to Keefer Slough under high-flow conditions.

Flows are conveyed into the site from Keefer Slough through graded inlet locations along the channel. Once within the site, flows are routed to the forebay and distributed to the recharge basins through low-gradient channels and overland flow paths. The system operates under gravity conditions and does not require pumping or mechanical conveyance.

Infiltration rates for Site N5 are based on infiltration testing results presented in Section 5 and indicate variable performance due to the presence of the perched groundwater system. While near-surface materials are capable of transmitting water, downward migration may be limited by underlying lower-permeability units.

Operation of the Site N5 project consists of capturing high-flow conditions in Keefer Slough and distributing these flows across the forebay and recharge basins. Excess flows are conveyed through overflow pathways back to Keefer Slough or downstream portions of the site.

7.4.2 Infiltration Capacity

Tables 7 and 8 indicate that the near-surface materials at Site N5 are inherently permeable, with CPT-derived hydraulic conductivities averaging on the order of ~15 to 22 ft/day (with maxima up to several hundred ft/day) and field infiltration test values commonly ranging from ~30 to 90 ft/day in more permeable intervals. However, these high potential rates are not realized at the site scale because a perched water system is present at approximately 7 to 11 ft below ground surface, underlain by a low-permeability unit at roughly 15 to 20 ft bgs. As observed in the Section 6.4 pilot study at N5, actual infiltration rates from the surface impoundment are much lower (~0.27 to 0.63 ft/day), reflecting hydraulic limitation at the perched zone rather than the higher permeability indicated by CPT data. These results indicate that the majority of applied water will infiltrate rapidly through the shallow vadose zone but will be captured and stored within the perched system, with only a limited fraction migrating downward to the regional groundwater table at ~30 to 40 ft bgs unless localized pinch-outs in the confining layer allow deeper percolation.

Given this condition, the N5 basin will function primarily as a temporary storage and attenuation feature rather than an efficient groundwater recharge facility. Water delivered from Keefer Slough during high-flow events will be detained in the basin and shallow subsurface, where it will be released slowly through the perched system at rates on the order of less than 1 ft/day, potentially dampening peak flows. This delayed release provides a beneficial “slow-release” mechanism,

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reducing the timing and magnitude of return flows to Keefer Slough while promoting incremental recharge where hydraulic pathways exist. Overall, only a relatively small portion of the total applied water is expected to reach the deeper aquifer directly, with the dominant benefit of the basin being short-term storage and flow attenuation that moderates downstream discharge to Keefer Slough rather than large-volume direct groundwater recharge.

7.4.3 Monitoring Programs

A monitoring program for Site N5 should include both onsite instrumentation and monitoring within Keefer Slough to evaluate the interaction between diverted surface water, shallow perched storage, and downstream flow attenuation. Similar to Site N4, the program must quantify inflows, infiltration, and groundwater responses; however, at Site N5, additional emphasis is required on distinguishing shallow perched storage from deeper recharge and on assessing how the basin modifies flows to Keefer Slough.

The onsite monitoring network should consist of shallow and deeper observation points as previously described, including: (1) shallow monitoring points screened within the perched zone (approximately 7 to 15 feet bgs), (2) intermediate piezometers below the low-permeability unit (approximately 15 to 25 feet bgs), and (3) a deeper monitoring well screened within the first regional aquifer (approximately 30 to 40 feet bgs). Continuous water-level monitoring using pressure transducers should be conducted to evaluate infiltration rates, perched water development, and vertical gradients between zones. These data will confirm that most recharge is retained within the perched system and only slowly transmitted downward.

In addition to onsite monitoring, surface water monitoring within Keefer Slough is critical to evaluate basin performance. At a minimum, a stilling well or pressure transducer should be installed upstream of the diversion point and downstream of the basin discharge or influence area. These locations will allow measurement of stage changes during diversion events and evaluation of how basin operations modify flow timing and magnitude within the slough. Flow measurements (via stage–discharge relationships or portable flow meters) should be developed where feasible to quantify diversion volumes and attenuated return flows.

During high-flow events, the monitoring program should document the volume of water diverted from Keefer Slough into the basin, the duration and depth of ponding, and the rate at which water levels decline due to infiltration. These data can then be compared with downstream Keefer Slough hydrographs to quantify the degree of peak flow reduction and lag time introduced by basin storage. Given pilot test results showing effective infiltration rates of approximately 0.27 to 0.63 ft/day under ponded conditions, it is expected that the basin will significantly delay return flows relative to direct conveyance in the slough.

Water quality monitoring should also be conducted in both the basin and Keefer Slough to evaluate recharge sources and potential changes associated with infiltration and storage. Sampling of Keefer Slough upstream and downstream of the project area, along with shallow and deeper groundwater at the site, should include major ions, nutrients (e.g., nitrate), and stable isotopes. These data will help assess whether water stored in the perched system is returning to the slough, migrating to deeper groundwater, or undergoing geochemical changes during detention.

Key performance metrics for the Site N5 monitoring program should therefore include:

- Volume of water diverted from Keefer Slough
- Ponded depth and duration within the basin
- Infiltration rates under operational conditions
- Magnitude and persistence of perched groundwater mounding
- Evidence of vertical leakage to the regional aquifer
- Reduction and delay of peak flows in Keefer Slough downstream

Overall, the combined onsite and Keefer Slough monitoring program will confirm that Site N5 functions primarily as a flow attenuation and temporary storage facility. Monitoring within the slough is particularly important because the primary project benefit at this site is not large-scale groundwater recharge, but rather the capture and delayed release of flood flows, which reduces peak discharge and provides a controlled, gradual return of water to Keefer Slough.

7.4.4 Operation and Maintenance

Operation and maintenance (O&M) of the proposed recharge basin at Site N5 should be focused on managing surface water diversion from Keefer Slough, maintaining basin infiltration capacity, and addressing the unique constraint of a shallow perched groundwater system. While the general operational approach is similar to Site N4, key differences at Site N5 include limited vertical infiltration capacity, reliance on shallow storage, and the need to manage prolonged perched water conditions.

Operations at Site N5 will consist primarily of diverting high flows from Keefer Slough into the surface impoundment during storm or flood events, consistent with applicable diversion criteria and water availability. Diversion structures (e.g., weirs) should be operated to capture excess flows while maintaining downstream conveyance capacity and avoiding adverse impacts to the slough. During diversion events, basin water levels should be monitored to ensure that ponded depths remain within design limits and do not overtop perimeter berms. Because infiltration rates observed during pilot testing are relatively low (approximately 0.27 to 0.63 ft/day), ponded water may remain in the basin for extended periods following large events. Therefore, operations should account for available storage volume prior to additional diversion, and diversion should be curtailed if the basin is nearing capacity.

Operational considerations should also include coordination with Keefer Slough stage conditions. During high-flow events, the basin will function to temporarily detain water and reduce peak flows. As stored water infiltrates and drains through the shallow subsurface, return flows to Keefer Slough will occur over a longer time period, providing attenuation benefits. Operators should track inflow volumes, ponded depths, and drainage rates to evaluate performance and refine operational criteria over time.

Maintenance of the basin should focus on preserving infiltration capacity and ensuring proper function of diversion and conveyance infrastructure. Routine inspections should be conducted before and after storm events to identify sediment accumulation, erosion, or debris that may

impede flow into or within the basin. Because water diverted from Keefer Slough may carry fine sediments, periodic sediment removal from the basin floor may be required to prevent clogging and maintain infiltration rates. This is particularly important at Site N5, where effective infiltration is already limited by the underlying low-permeability unit and additional surface clogging could further reduce performance.

Vegetation management should also be conducted to maintain appropriate ground cover while preventing excessive growth that could inhibit flow distribution or contribute organic clogging. Light vegetation may be beneficial for stabilizing soils, but dense vegetation should be removed as needed.

Given the presence of a perched water system at depths of approximately 7 to 11 feet bgs, O&M procedures should include periodic evaluation of the basin floor condition and infiltration behavior. Extended saturation conditions may promote fine migration or biological growth that could reduce infiltration efficiency over time. If significant declines in infiltration rates are observed, maintenance measures such as scarification, shallow ripping, or removal of clogged surface layers should be implemented to restore infiltration capacity.

Inspection and maintenance of diversion structures and any control features connected to Keefer Slough are also critical. These structures should be checked for blockage, structural integrity, and proper operation prior to and during the wet season. After major storm events, inspections should confirm that no damage has occurred and that flow paths remain unobstructed.

Overall, the O&M program for Site N5 recognizes that the basin will function primarily as a detention and slow-release system rather than a high-efficiency recharge facility. As such, successful operation will depend on managing available storage, maintaining consistent infiltration through the basin floor, and ensuring that diversion and conveyance systems operate reliably. Regular monitoring and adaptive management will be important to optimize performance, particularly in balancing flow attenuation benefits to Keefer Slough with the limited capacity for deeper groundwater recharge.

7.4.5 Permitting

Permitting requirements for the proposed recharge basin at Site N5 are generally similar to those identified for Site N4; however, several important distinctions arise due to the hydraulic connection to Keefer Slough and the limited recharge functionality associated with the perched groundwater system. The project is best characterized as a floodwater diversion, detention, and infiltration facility, rather than a high-capacity managed aquifer recharge (MAR) project, which influences the permitting strategy and regulatory considerations.

Surface Water Diversions (Water Rights and Floodwater Use).

As with the pilot testing conducted under Section 6.4, diversion of water from Keefer Slough during high-flow conditions may be conducted under California Water Code Section 1242.1, which allows temporary diversion of flood flows for recharge and flood risk reduction without obtaining a permanent appropriative water right, provided that required notifications and conditions are met. Operation under this provision will require coordination with the State Water Resources Control Board (SWRCB) to document qualifying flow conditions, diversion timing,

and volumes. Because Site N5 primarily attenuates flows rather than rapidly recharging groundwater, the project should emphasize flood control and incidental recharge benefits in its notification and supporting documentation.

Stream Alteration (CDFW Section 1600 Agreement).

Because the project involves diversion of flows from Keefer Slough and potential modifications to the channel or banks (e.g., installation of diversion structures, culverts, or berms adjacent to the slough), a Lake and Streambed Alteration Agreement (LSAA) from the California Department of Fish and Wildlife (CDFW) will likely be required. The permitting process will need to address potential impacts to aquatic habitat, flow continuity, and sediment transport. Design considerations such as screening of diversion structures, maintaining minimum bypass flows, and limiting construction within the active channel will be important to minimize impacts and facilitate approval.

Clean Water Act (Section 404/401).

If construction activities involve placement of fill or excavation within waters of the United States, including portions of Keefer Slough or adjacent wetlands, authorization from the U.S. Army Corps of Engineers (USACE) under Section 404 of the Clean Water Act may be required. Corresponding water quality certification from the Central Valley Regional Water Quality Control Board (RWQCB) under Section 401 will also be necessary. Given that the basin is primarily located off-channel, permitting requirements will depend on the extent of direct disturbance within jurisdictional waters. Early delineation of wetlands and other waters is recommended to define permitting pathways.

Water Quality (RWQCB).

Recharge projects are subject to oversight by the RWQCB to ensure protection of groundwater quality. For Site N5, the permitting approach should recognize that most infiltrated water will be retained in a shallow perched system with limited vertical migration to the regional aquifer. As a result, permitting documentation should include evaluation of water quality within both the perched zone and underlying groundwater, as well as potential for lateral movement or return flow to Keefer Slough. The RWQCB may require preparation of a Waste Discharge Requirements (WDR) application or enrollment under an applicable general order, along with a monitoring and reporting program consistent with Section 7.3.3.

Local Permitting and Land Use Approvals.

Local approvals from Butte County will be required for grading, construction of berms, and modification of existing drainage features. This may include grading permits, encroachment permits for work near Keefer Slough, and consistency review with local floodplain management requirements. Because the site is intended to store and attenuate flood flows, coordination with local flood control agencies will be important to ensure compatibility with regional drainage infrastructure and flood conveyance capacity.

California Environmental Quality Act (CEQA).

Implementation of the proposed project at Site N5 will require compliance with CEQA. The level of review will depend on project scale and potential impacts, particularly related to biological resources, hydrology, and water quality associated with Keefer Slough. Given that the project primarily involves use of existing flood flows and off-channel storage, impacts may be mitigated through design measures such as maintaining bypass flows and minimizing disturbance to sensitive habitats.

7.4.6 Estimation of probable design and construction costs

This section provides an order-of-magnitude estimate of probable design, permitting, construction, and operation and maintenance (O&M) costs for implementation of a simplified Flood-MAR recharge project at Site N5. Similar to Site N4, this estimate reflects a low-complexity approach that maximizes the use of gravity diversion from Keefer Slough, eliminates the need for pumping infrastructure, and relies primarily on on-site earthwork to construct detention and infiltration basins.

Costs presented herein are planning-level estimates intended to support feasibility evaluation and comparison with other recharge alternatives. Final costs will depend on detailed design, permitting requirements, and site-specific construction conditions.

The cost estimate is based on the following assumptions:

- Acquisition of approximately 242 acres of existing orchard (walnut and/or almond).
- Removal of orchard trees and preparation of the site for basin construction.
- Construction of forebay and infiltration/detention basins using on-site earthwork only.
- Construction of new diversion and gravity conveyance from Keefer Slough.
- Installation of a basic monitoring network.
- Implementation of permitting and environmental compliance requirements.

Unit costs reflect recent local experience using agricultural contractors and simplified construction approaches common to recharge projects in the region.

Property Acquisition (Orchard)

The Site N5 property is assumed to be in active orchard production. Agricultural land values in the Butte County area typically range from \$15,000 to \$30,000 per acre depending on orchard condition, water availability, and productivity. For approximately 242 acres, this results in a total estimated land acquisition cost of \$3.6 million to \$7.3 million. This remains the largest single cost component and may vary depending on negotiations, orchard condition, and market conditions.

Orchard Removal and Site Preparation

Conversion of the entire property to recharge use will require removal of orchard trees, root systems, and irrigation infrastructure, followed by rough grading. Typical unit costs:

- Tree removal and disposal: \$1,000 to \$3,000 per acre

- Ripping and site preparation: \$500 to \$1,500 per acre

Estimated total cost (242 acres) is \$360,000 to \$1.1 million.

Earthwork and Basin Construction

Earthwork consists of shallow excavation, berm construction, and grading to create forebay and infiltration/detention basins using native soils. Based on local agricultural construction practices, basin grading ranges from \$1,500 to \$4,000 per acre. Assuming approximately 195 acres of basin development, the total estimate is \$300,000 to \$800,000. Earthwork costs remain relatively low due to shallow excavation depths and minimal need for engineered materials.

Diversion and Conveyance Facilities (Gravity System)

The project is configured as a simplified Flood-MAR system without pumping. Water will be diverted from Keefer Slough and conveyed using gravity. Components include:

- New diversion structure at Keefer Slough
- Gravity conveyance (channels, culverts, or pipeline)
- Flow distribution within basins
- Minimal electrical/mechanical infrastructure

Estimated cost is \$600,000 to \$1.8 million.

Diversion Structure Construction

A new diversion structure will be required to facilitate Flood-MAR operations, including:

- Intake structure and screening
- Bank stabilization and erosion control
- Access improvements
- Basic flow control features

Estimated cost is \$250,000 to \$700,000.

Monitoring and Instrumentation

Monitoring infrastructure will include groundwater wells and instrumentation. Estimated costs:

- Monitoring wells: \$25,000 to \$50,000 per well (3–5 wells assumed)
- Instrumentation and data systems: \$50,000 to \$150,000

Estimated total is \$100,000 to \$300,000.

Permitting and Environmental Compliance Costs

Permitting and environmental compliance costs include CEQA review and agency coordination:

- CEQA documentation (Initial Study/MND anticipated)
- Biological and cultural resource evaluations
- Streambed Alteration Agreement (CDFW)
- Coordination with SWRCB and RWQCB

- SWPPP preparation

Estimated cost is \$250,000 to \$750,000.

Engineering and Design Costs

Engineering and design costs include preparation of plans, permitting support, and construction management.

Estimated range:

- If done as individual project, 15 to 25% of construction costs: \$400,000 to \$1.2 million
- Reduced programmatic range with other projects (10–20%): \$300,000 to \$700,000

Estimated Total Capital Costs

Based on the simplified Flood-MAR approach and cost assumptions representative of Butte County agricultural construction practices, the total project cost for Site N5 is estimated as shown on Table 27. The dominant cost component for Site N5 is property acquisition, followed by diversion and conveyance infrastructure from Keefer Slough. Orchard removal and site preparation represent a somewhat greater relative cost component compared to some other sites due to the full conversion of agricultural land. In contrast, earthwork associated with development of the detention and infiltration basins remains a relatively minor portion of total cost due to the ability to utilize on-site soils and standard agricultural grading methods. Overall, although Site N5 employs a similar low-complexity, gravity-driven design approach as Site N4, its cost profile reflects its role as a flow attenuation and shallow storage facility, with capital investment driven primarily by land acquisition rather than engineered infrastructure.

Table 26. Summary of Capitol costs

Cost Component	Estimated Range
Property Acquisition (Walnut Orchard)	\$3.6M – \$7.3M
Orchard Removal & Site Preparation	\$0.36M – \$1.1M
Earthwork & Basin Construction	\$0.3M – \$0.8M
Diversion Structure Construction	\$0.25M – \$0.7M
Diversion & Conveyance (gravity system)	\$0.6M – \$1.8M
Monitoring Infrastructure	\$0.1M – \$0.3M
Subtotal Construction + Land	\$5.2M – \$12.0M
Permitting & Environmental Compliance	\$0.25M – \$0.75M
Engineering, Design and CMA	\$0.3M-\$1.2M
Total Project Cost	\$5.8 to \$13.9M

O&M Costs

O&M costs are expected to remain relatively low due to the absence of pumping or complex infrastructure. Key components include:

- Basin maintenance (sediment removal, vegetation control, regrading)
- Diversion structure inspection and cleaning
- Monitoring and reporting
- Seasonal labor during recharge events

Estimated O&M costs are \$30 to \$120 per acre-foot, or approximately \$100,000 to \$300,000 annually.

Unit Cost of Recharge

The unit cost of recharge at Site N5 was evaluated using the same methodology as Site N4. Due to the perched groundwater system, a smaller proportion of water reaches the regional aquifer, resulting in higher unit costs.

Estimated total economic cost: \$100 to \$700 per acre-foot

If capital costs are grant-funded: \$30 to \$150 per acre-foot

Although unit recharge cost is higher than Site N4, the project provides important multi-benefit outcomes including flood attenuation, flow management in Keefer Slough, and temporary storage. Since water is being slowed down within the watershed, additional groundwater recharge will also occur instream.

7.5 Site N6 Recharge Project

This section presents the preliminary design and evaluation of the proposed FloodMAR project at Site N6. This site was identified through field investigations as a strategically located upstream control point within the Rock Creek–Keefer Slough system, with the primary function of capturing, diverting, and distributing high-flow surface water during flood events. While Site N6 exhibits relatively high shallow infiltration rates, hydrogeologic conditions are characterized by a perched groundwater system and the presence of a laterally variable, low-permeability unit at depth that limits vertical connectivity to the regional aquifer. As a result, the site provides limited direct recharge to deeper groundwater but is well suited for flow routing, temporary storage, and system-wide water management.

Within the broader FloodMAR system, Site N6 functions as the initial point of flow interception and distribution. Floodwaters diverted from Rock Creek and Keefer Slough are conveyed across the site using gravity-driven infrastructure and distributed among a network of basins and conveyance features. Water retained at Site N6 may infiltrate into the shallow perched system or be progressively routed downstream to Sites N5 and N4. In this configuration, Site N6 plays a critical role in moderating peak flows, extending the duration of water availability, and enabling more controlled delivery of water to downstream recharge areas, particularly Site N4 where conditions are more favorable for deep percolation.

The proposed project emphasizes a passive design approach using topography and basin configuration to manage flows. Although deep aquifer recharge is limited at this location, the project provides important system-level benefits including flood attenuation, increased operational flexibility, and improved distribution of recharge water across the corridor. Additionally, lateral movement within the perched system may contribute to localized recharge where subsurface conditions allow downward migration.

The following subsections describe the conceptual layout, anticipated hydraulic performance, and key implementation considerations for Site N6, including diversion and conveyance infrastructure, basin configurations, monitoring strategies, permitting requirements, operations and maintenance considerations, and order-of-magnitude cost estimates.

7.5.1 Preliminary Design

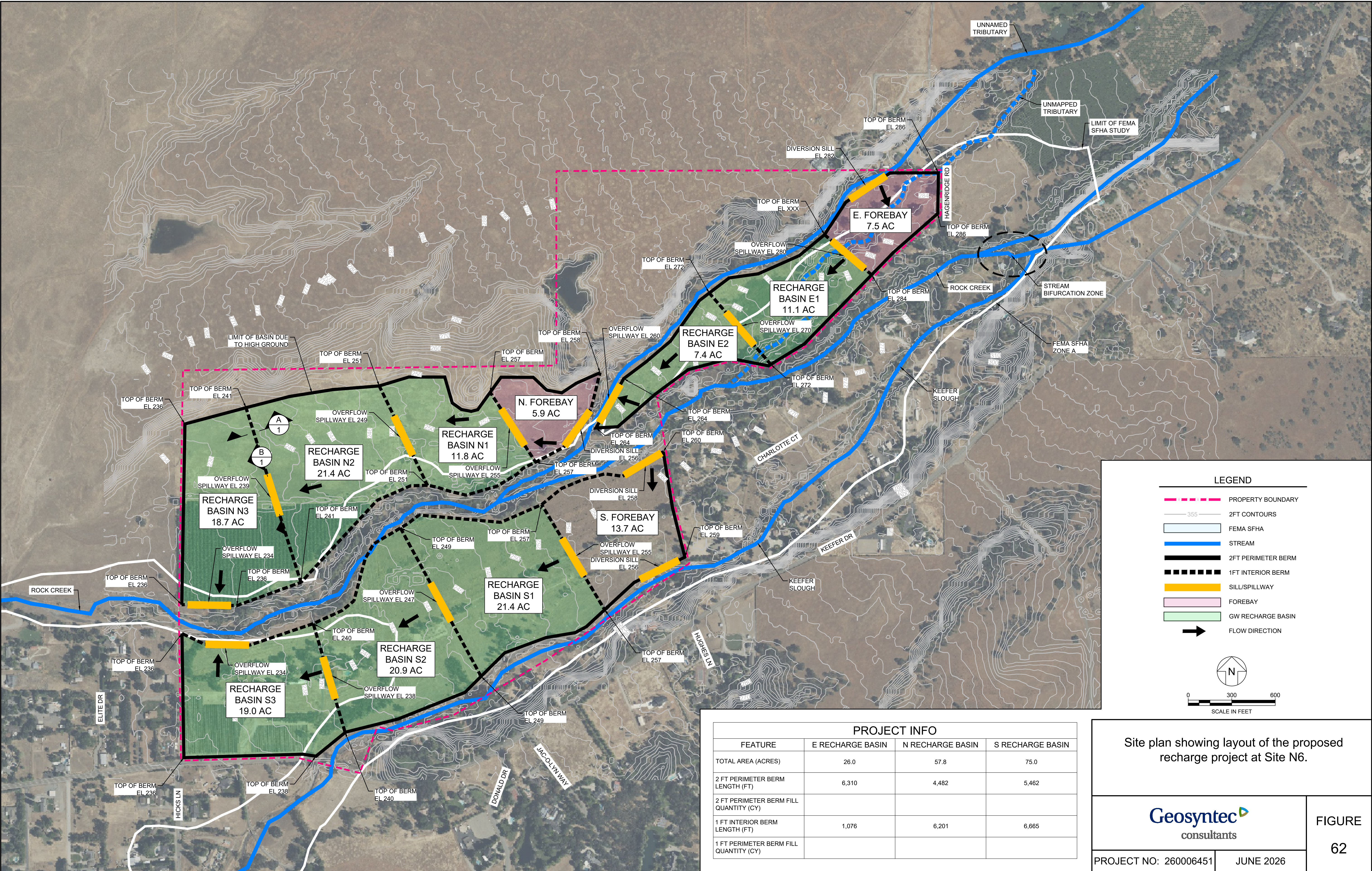
Site N6 is located immediately downstream of the bifurcation of Rock Creek and Keefer Slough and represents the upstream component of the N4, N5, and N6 FloodMAR system. The site consists of a series of recharge basins, forebays, diversion structures, perimeter berms, and overflow spillways configured to capture and distribute high flows from both channels under gravity flow conditions. Figure 62 shows the preliminary design for the Site N6 recharge project.

The facility includes multiple basin groups consisting of northern basins (N1, N2, N3) with a northern forebay, southern basins (S1, S2, S3) with a southern forebay, and eastern basins (E1, E2) with an eastern forebay. The basin system is enclosed by perimeter berms with crest elevations generally ranging from approximately EL 236 to EL 286, with interior berms used to subdivide basin cells and direct flow between basins. Site grading is configured to promote gravity-driven flow from inlet locations toward lower elevation basin areas, with controlled routing between basin cells and toward defined overflow structures.

Flows from both Rock Creek and Keefer Slough are diverted to the site during qualifying high-flow events under California Water Code 1242.1 and conveyed into the forebay system where initial flow distribution occurs. Conveyance within the site is achieved through a combination of forebay distribution areas, shallow channels, overland flow, and interior berm control features. The system operates entirely under gravity conditions and does not require pumping for normal operation.

Each basin cell includes overflow spillways and diversion sills that control maximum water surface elevations and regulate flow routing across the site. Spillway invert elevations generally range from approximately EL 234 to EL 240 for lower elevation basin features and up to approximately EL 255 to EL 280 for higher elevation control points. As water levels rise within the basins, flows cascade through these control structures to adjacent basin cells and ultimately exit the site through designated overflow pathways.

The grading and spillway configuration are designed such that all basin discharge is routed back to Rock Creek downstream of the bifurcation. Flows captured at Site N6, including those influenced by Keefer Slough, are redistributed across the basin system and conveyed through controlled overflow pathways that return flow to Rock Creek, thereby reducing the proportion of high flows that would otherwise continue down Keefer Slough.



Site N6 functions as the upstream intake and distribution facility within the N4, N5, N6 system. High flows are first captured and distributed at Site N6 and are then conveyed downstream through natural channels and engineered pathways toward Sites N5 and N4, where additional storage, routing, and recharge occur. The system operates as a continuous, gravity-driven FloodMAR corridor, with Site N6 establishing the initial hydraulic conditions that control downstream flow routing.

During high-flow events, water is diverted from Rock Creek and Keefer Slough into Site N6, distributed across the forebays and basin cells, and retained until water surface elevations reach spillway control elevations. Excess flows then pass through overflow structures and are conveyed downstream to Rock Creek and to downstream sites within the system. The overall configuration relies on constructed grades, berm elevations, and spillway controls to passively manage flow distribution without mechanical systems.

7.5.2 Infiltration Capacity

Infiltration capacity at Site N6 is primarily controlled by the hydrostratigraphic conditions described in Section 5. The upper portion of the site is underlain by permeable sands and gravels, which allow relatively rapid infiltration of applied water. Field infiltration testing conducted at the site indicates infiltration rates on the order of approximately 19 to 70 feet per day within the shallow subsurface materials, confirming that the near-surface soils are capable of transmitting water efficiently from the basin bottoms.

Despite the high permeability of the shallow materials, Site N6 is characterized by a perched groundwater system, with groundwater encountered at depths of approximately 5 to 10 feet below ground surface during drilling. This perched system is underlain by a laterally extensive low-permeability unit occurring at depths of approximately 40 feet in the eastern portion of the site and up to 70 feet in the western portion. This unit restricts vertical migration of infiltrated water and hydraulically separates the shallow perched zone from the deeper regional aquifer, which is present at approximately 80 feet below ground surface.

As a result, the effective infiltration capacity of the site must be considered in two distinct components: (1) the rate of water movement through the shallow soils, and (2) the capacity for that water to migrate beyond the perched system to the regional groundwater aquifer. While the shallow soils exhibit relatively high infiltration rates, the presence of the low-permeability unit limits the long-term vertical percolation capacity of the site. Infiltrated water will accumulate within the perched zone, resulting in temporary groundwater mounding and storage within the shallow subsurface rather than immediate recharge to the deeper aquifer.

Observations during drilling support this interpretation. At boring RiSB-3, shallow groundwater was encountered at approximately 10 feet below ground surface, but when drilling advanced through the low-permeability unit, water was no longer present in the borehole, confirming that the shallow groundwater system is perched and not directly connected to the underlying regional aquifer.

The geometry of the low-permeability unit influences the ultimate recharge potential of the site. The unit exhibits an east-to-west slope and may locally pinch out, creating areas where perched

groundwater may migrate laterally and, in some locations, percolate downward into the deeper system. Accordingly, groundwater movement at Site N6 is expected to occur primarily as lateral flow within the perched zone, with localized vertical recharge where subsurface conditions allow.

Given these conditions, infiltration at Site N6 will occur rapidly from the basin surface into the shallow subsurface; however, the overall recharge capacity to the regional aquifer is constrained by the limited vertical connectivity. Water applied to the basins will primarily be stored temporarily within the perched system and redistributed laterally, with additional recharge occurring indirectly through downgradient migration and through increased conveyance of flows to downstream reaches where more favorable hydrogeologic conditions may exist.

Overall, Site N6 should be considered a high infiltration rate but storage-limited system, where the controlling factor for recharge is not the ability of the surface soils to accept water, but the ability of the underlying subsurface to transmit that water vertically to the regional aquifer.

7.5.3 Monitoring Programs

Monitoring at Site N6 will be implemented to evaluate groundwater response, document recharge performance, and support adaptive management of the basin system. The program will be consistent with monitoring approaches described for Sites N4 and N5, while incorporating additional considerations associated with the perched groundwater system identified at the site.

Monitoring will include installation of both shallow and deep observation points to distinguish between water stored in the perched zone and water reaching the regional groundwater system. Shallow monitoring points will be screened within the upper perched interval (approximately 5 to 20 feet below ground surface) to track groundwater mounding, lateral movement, and recession following recharge events. Deep monitoring points, where feasible, will be screened below the low-permeability unit to evaluate whether any recharge is transmitted to the regional aquifer.

Groundwater levels will be measured using automated pressure transducers with continuous data logging at selected monitoring locations. These data will be supplemented with periodic manual measurements to confirm instrument accuracy. The monitoring network will be configured to assess both vertical gradients between perched and deeper zones and horizontal gradients that may control lateral migration of water within the perched system.

Surface water monitoring will also be conducted to document flow volumes and routing through the site. This will include observation of inlet flows from Rock Creek and Keefer Slough, as well as overflow discharge from the basin system to Rock Creek. Where feasible, staff gauges or continuous stage recorders will be installed at key inlet and outlet locations to document timing, duration, and magnitude of flow events.

Because infiltration at Site N6 results primarily in temporary storage within the perched system, monitoring will focus on quantifying the magnitude and duration of groundwater mounding and evaluating the rate at which stored water drains laterally or vertically following recharge events. These data will be used to assess basin recovery time and to inform operational decisions such as the timing of subsequent diversion events.

In addition, periodic visual inspections will be conducted to evaluate basin performance and maintenance needs, including sediment accumulation, vegetation growth, and evidence of preferential flow paths or localized ponding. These observations will support ongoing operation and maintenance activities intended to preserve infiltration capacity.

Monitoring results will be reviewed on a regular basis to evaluate system performance and to support adaptive management of the site. If all three sites are constructed, data collected at Site N6 will also be evaluated in conjunction with monitoring data from Sites N5 and N4 to assess the performance of the integrated N4, N5, and N6 system and to understand the extent to which captured flows contribute to recharge within downstream portions of the corridor.

7.5.4 Operation and Maintenance

Operation of Site N6 will be conducted to maximize the effectiveness of floodwater capture, distribution, and controlled routing while maintaining available storage capacity and proper function of hydraulic features. The system is designed to operate passively under gravity flow conditions; however, active oversight will be required during high-flow events to manage diversion, observe basin filling, and confirm that inlet and outlet structures are functioning as intended.

During qualifying high-flow events under California Water Code 1242.1, flows will be diverted from Rock Creek and Keefer Slough into the site through inlet structures and conveyed into the forebay and basin system. Operators will monitor inflows and basin water surface elevations to ensure that flows are distributed across available storage and that overflow structures are operating as designed. As basin water levels approach spillway elevations, excess flows will pass through the system of overflow structures and be routed back to Rock Creek. Operational focus will be on maintaining safe operating levels within the basins and preventing unintended overtopping of perimeter berms.

Site N6 may ultimately function as part of a broader system with Sites N5 and N4; however, it is expected to be capable of operating as a standalone facility. In the absence of downstream sites, flows released from Site N6 will be routed directly back to Rock Creek. If downstream facilities are constructed in the future, operational coordination may be implemented, as needed, to manage flow timing and volumes through the system.

Routine maintenance will be required to sustain long-term performance of the recharge basins and associated infrastructure. Maintenance activities will include periodic removal of accumulated sediment from forebays, inlet channels, and basin bottoms to maintain storage capacity and hydraulic function. Sediment removal will focus on areas where deposition is most likely to occur during high-flow events.

Vegetation management will be performed within basin areas, along berms, and near hydraulic structures to prevent obstruction of flow paths and maintain clear conveyance. Vegetation will be controlled to minimize the accumulation of fine sediments and reduce the potential for root-related impacts to berm stability.

Basin surface maintenance may include periodic scarification or disking of basin bottoms where surface sealing or compaction is observed. The frequency of this activity will depend on site conditions and observed basin performance over time.

Inspection and maintenance of hydraulic features will be conducted on a routine basis, including diversion structures, spillways, and berms. Inspections will verify that structures remain free of debris, are structurally stable, and continue to function at intended elevations. Any erosion, settlement, or damage will be repaired to maintain design grades and proper flow routing.

Operational considerations will also include observation of basin drawdown following recharge events. Given site conditions, operators will monitor the duration of ponding to confirm that adequate storage capacity is available prior to subsequent diversion events.

Overall, operations and maintenance requirements for Site N6 are expected to be relatively low due to the passive, gravity-driven design, with performance supported by periodic inspection, sediment management, vegetation control, and routine upkeep of hydraulic control features.

7.5.5 Permitting

Implementation of the Site N6 project will require compliance with applicable federal, state, and local permitting requirements associated with diversion, conveyance, and recharge of surface water, as well as construction within and adjacent to jurisdictional waters and floodplain areas. Permitting requirements for Site N6 are expected to be consistent with those identified for the other project sites.

Diversion of high flows from Rock Creek and Keefer Slough will be conducted under the provisions of California Water Code Section 1242.1, which allows diversion of flood flows for groundwater recharge under specified conditions. Implementation will require coordination with the State Water Resources Control Board (SWRCB) to ensure that diversions meet the criteria for high-flow events and do not impact downstream water rights or environmental flows.

Because the project involves construction of diversion structures, conveyance facilities, and grading activities within or near stream channels, a Lake and Streambed Alteration Agreement (LSAA) will be required from the California Department of Fish and Wildlife (CDFW) pursuant to Fish and Game Code Section 1600. This authorization will address potential impacts to streambed and riparian resources associated with project construction and operation.

If project features result in impacts to waters of the United States, including wetlands or stream channels, permits may be required under Section 404 of the Clean Water Act from the U.S. Army Corps of Engineers (USACE), along with Section 401 Water Quality Certification from the applicable Regional Water Quality Control Board (RWQCB). The need for these permits will depend on the extent of jurisdictional features affected by construction activities.

The project may also require authorization under Waste Discharge Requirements (WDRs) or a waiver thereof issued by the RWQCB for groundwater recharge activities, depending on the final design and potential water quality considerations associated with infiltration and recharge.

Environmental review will be conducted in accordance with the California Environmental Quality Act (CEQA). The level of review (e.g., Initial Study/Mitigated Negative Declaration or

Environmental Impact Report) will be determined based on the potential for project impacts to biological resources, hydrology, land use, and other environmental factors.

Additional coordination may be required with local agencies and flood control authorities related to construction within mapped floodplain areas, including compliance with Federal Emergency Management Agency (FEMA) floodplain management requirements, if applicable.

Overall, permitting for Site N6 is expected to follow standard pathways for FloodMAR recharge projects involving surface water diversion and channel-adjacent construction, with requirements similar to those identified for Sites N4 and N5. Early coordination with regulatory agencies will support efficient permitting and help refine project design to minimize environmental impacts.

7.5.6 Estimation of probable design and construction costs

This section provides an order-of-magnitude estimate of probable design, permitting, construction, and operation and maintenance (O&M) costs for implementation of a simplified FloodMAR recharge project at Site N6. Similar to Sites N4 and N5, this estimate reflects a low-complexity approach that maximizes the use of gravity diversion from Rock Creek and Keefer Slough, eliminates the need for pumping infrastructure, and relies primarily on on-site earthwork to construct detention and infiltration basins.

Costs presented herein are planning-level estimates intended to support feasibility evaluation and comparison with other recharge alternatives. Final costs will depend on detailed design, permitting requirements, and site-specific construction conditions.

The cost estimate is based on the following assumptions:

- Acquisition of approximately 249 acres of property, including a mix of orchard, vineyard (approximately 20 acres orchard and 15 acres vineyard), and other land uses.
- Removal of orchard trees, vineyard plantings, and associated irrigation infrastructure.
- Demolition and removal of an existing residential structure and other improvements.
- Site preparation and grading for basin construction.
- Construction of forebay and detention/infiltration basins using primarily on-site earthwork.
- Construction of diversion and gravity conveyance from Rock Creek and Keefer Slough.
- Installation of a basic monitoring network.
- Implementation of permitting and environmental compliance requirements.

Unit costs reflect recent local experience using agricultural contractors and simplified construction approaches common to recharge projects in the region.

Property Acquisition (Mixed Agricultural Land and Structures)

The Site N6 property is assumed to include approximately 249 acres of agricultural land and associated improvements. Agricultural land values in the Butte County area typically range from \$15,000 to \$30,000 per acre depending on crop type, water availability, and productivity.

For approximately 249 acres, the estimated acquisition cost is \$3.7 million to \$7.5 million, with additional value attributed to residential improvements included within this range. This remains the largest single cost component and may vary depending on negotiations, structure value, and market conditions.

Orchard/Vineyard Removal and Site Preparation

Conversion of the site to recharge use will require removal of orchard trees and vineyard plantings, root systems, irrigation infrastructure, and demolition of existing structures, followed by rough grading. Typical unit costs include:

- Tree and vine removal and disposal: \$1,000 to \$3,000 per acre
- Ripping and site preparation: \$500 to \$1,500 per acre
- Structure demolition and disposal: site-specific allowance included

While only a portion of the site is actively planted, broader site preparation and grading will be required for basin development. Estimated total cost is \$400,000 to \$1.2 million.

Earthwork and Basin Construction

Earthwork consists of shallow excavation, berm construction, and grading to create forebay and detention/infiltration basins using native soils. Based on local agricultural construction practices, basin grading ranges from \$1,500 to \$4,000 per acre.

Assuming a substantial portion of the site (on the order of ~200 acres) is developed as basin area, the total estimate is \$0.3 million to \$0.8 million. Earthwork costs remain relatively low due to shallow excavation depths and minimal need for engineered materials.

Diversion and Conveyance Facilities (Gravity System)

The project is configured as a simplified FloodMAR system without pumping. Water will be diverted from Rock Creek and Keefer Slough and conveyed using gravity. Components include:

- Diversion structures at Rock Creek and/or Keefer Slough
- Gravity conveyance (channels, culverts, or pipeline)
- Flow distribution within basins
- Minimal electrical/mechanical infrastructure

Estimated cost is \$600,000 to \$1.8 million.

Diversion Structure Construction

Diversion structures will be required to facilitate FloodMAR operations from both creeks, including:

- Intake structures and screening
- Bank stabilization and erosion control
- Access improvements
- Basic flow control features

Estimated cost is \$250,000 to \$700,000.

Monitoring and Instrumentation

Monitoring infrastructure will include groundwater wells and instrumentation. Estimated costs:

- Monitoring wells: \$25,000 to \$50,000 per well (3–5 wells assumed)
- Instrumentation and data systems: \$50,000 to \$150,000

Estimated total is \$100,000 to \$300,000.

Permitting and Environmental Compliance Costs

Permitting and environmental compliance costs include CEQA review and agency coordination:

- CEQA documentation
- Biological and cultural resource evaluations
- Streambed Alteration Agreement (CDFW)
- Coordination with SWRCB and RWQCB
- SWPPP preparation

Estimated cost is \$250,000 to \$750,000.

Engineering and Design Costs

Engineering and design costs include preparation of plans, permitting support, and construction management. Estimated range:

- Individual project (15 to 25% of construction costs): \$400,000 to \$1.2 million
- Programmatic implementation with other sites (10–20%): \$300,000 to \$700,000

Estimated Total Capital Costs

Based on the simplified FloodMAR approach and cost assumptions representative of Butte County agricultural construction practices, the total project cost for Site N6 is estimated in Table 28. The dominant cost component is property acquisition due to the overall site size. Diversion and conveyance infrastructure represents the next largest cost element, while earthwork remains a relatively small component due to the use of on-site soils and conventional grading methods.

O&M Costs

O&M costs are expected to remain relatively low due to the absence of pumping or complex infrastructure. Key components include:

- Basin maintenance (sediment removal, vegetation control, regrading)
- Diversion structure inspection and cleaning
- Monitoring and reporting
- Seasonal labor during recharge events

Estimated O&M costs are \$30 to \$120 per acre-foot, or approximately \$100,000 to \$300,000 annually.

Table 27. Summary of capital costs, Site N6

Cost Component	Estimated Range
Property Acquisition (Walnut Orchard)	\$3.7M – \$7.5M
Orchard/Vinyard Removal & Site Preparation	\$0.4M – \$1.2M
Earthwork & Basin Construction	\$0.3M – \$0.8M
Diversion Structure Construction	\$0.25M – \$0.7M
Diversion & Conveyance (gravity system)	\$0.6M – \$1.8M
Monitoring Infrastructure	\$0.1M – \$0.3M
Subtotal Construction + Land	\$5.4M – \$12.3M
Permitting & Environmental Compliance	\$0.25M – \$0.75M
Engineering, Design and CMA	\$0.3M-\$1.2M
Total Project Cost	\$6.0 to \$14.2M

Unit Cost of Recharge

The unit cost of recharge at Site N6 is expected to follow a similar methodology to Sites N4 and N5. Due to the perched groundwater system, a smaller proportion of water reaches the regional aquifer, resulting in higher unit costs.

- Estimated total economic cost: \$100 to \$700 per acre-foot
- If capital costs are grant-funded: \$30 to \$150 per acre-foot

Although unit recharge costs are higher relative to sites with more favorable hydrogeologic conditions, Site N6 provides important multi-benefit outcomes including flow redistribution from Keefer Slough to Rock Creek, flood attenuation, and temporary storage. Because flows are slowed and redistributed within the watershed, additional groundwater recharge is expected to occur through downstream conveyance and in-channel processes.

8. POTENTIAL FUNDING

This section identifies potential funding sources for implementation of the proposed FloodMAR recharge projects at Sites S1, N4, N5, and N6, including programs that support property acquisition, design, construction, monitoring, and operation and maintenance (O&M). A range of state, federal, and other funding opportunities are available, many of which prioritize projects that provide multi-benefit outcomes, including groundwater recharge, flood risk reduction, climate resilience, and ecosystem enhancement. Given current timing, several 2026 federal opportunities have recently closed, and emphasis should be placed on upcoming and recurring funding cycles.

State funding programs in California are expected to represent the primary source of funding for implementation of these projects. The California Department of Water Resources (DWR) administers several programs that support groundwater recharge and SGMA implementation, including the Sustainable Groundwater Management (SGM) Grant Program and the Integrated Regional Water Management (IRWM) Program. These programs provide grant funding for recharge basin construction, conveyance systems, and monitoring infrastructure, and have historically supported similar projects throughout the state. Funding under these programs is expected to continue through periodic competitive solicitations over the next several years.

A major near-term funding opportunity is the Proposition 4 Climate Bond (2024), which allocates approximately \$3.8 billion for water resilience, including groundwater recharge, flood management, and multi-benefit land repurposing projects. Initial implementation began in 2025–2026, with larger funding solicitations expected in subsequent years as program guidelines are finalized. These funds are expected to be distributed through DWR and other state agencies and are highly aligned with the FloodMAR project objectives at Sites S1, N4, N5, and N6.

The Multi-Benefit Land Repurposing Program (MLRP), administered by the California Department of Conservation, is one of the most directly applicable funding sources for these projects, particularly for property acquisition and conversion of agricultural land. MLRP provides funding to support voluntary repurposing of irrigated agricultural land to uses that reduce groundwater demand and provide multiple benefits, including groundwater recharge basins, floodplain expansion, and habitat restoration. This program is specifically designed to support SGMA implementation, making it highly aligned with the proposed projects.

MLRP funding is typically delivered through regional block grants to Groundwater Sustainability Agencies (GSAs), which then partner with local landowners and project proponents. This structure makes coordination with the applicable GSA essential. MLRP is especially well suited for Sites N5 and N6, where large-scale land acquisition, orchard and vineyard removal, and conversion to recharge use are major project components. Funding is expected to continue through ongoing state drought and climate resilience initiatives, with additional opportunities anticipated in the 2025–2027 timeframe.

Programs administered by the California Wildlife Conservation Board (WCB) and the Department of Conservation may also provide funding for land acquisition, conservation easements, and habitat components associated with these projects. Many of these programs are available on a rolling basis and are well suited for projects that integrate floodplain restoration and recharge.

While these programs may not fund full project implementation, they can be an important source of funding for land purchase or cost-share requirements.

The State Water Resources Control Board (SWRCB) administers additional funding programs that can support project implementation. The Stormwater Grant Program provides grants for projects that capture and beneficially use stormwater, including recharge basins and FloodMAR projects. The Clean Water State Revolving Fund (CWSRF) provides low-interest financing for water infrastructure and watershed improvement projects. These programs are generally more applicable to construction and infrastructure than land acquisition but can be used to supplement other funding sources.

At the federal level, several programs provide important funding opportunities, although many are competitive and require significant lead time for application and project development. The FEMA Building Resilient Infrastructure and Communities (BRIC) program and the Flood Mitigation Assistance (FMA) program provide funding for flood risk reduction, including infrastructure, floodplain restoration, and property acquisition. These programs can fund activities such as structure removal, floodplain reconnection, and conveyance improvements, and often provide high federal cost shares. However, the most recent application cycles for these programs closed in July and August 2026, and future funding opportunities are expected on an annual or biennial basis, subject to federal appropriations. Projects must typically be well developed and included in local hazard mitigation plans to be competitive.

The U.S. Department of Agriculture Natural Resources Conservation Service (NRCS) administers the Watershed Protection and Flood Prevention Program (PL-566), which provides technical and financial assistance for watershed-scale projects, including flood control, groundwater recharge, and water management infrastructure. This program is available on a rolling basis, but requires development of a watershed plan and a local sponsor, making it a longer-term funding pathway.

The U.S. Bureau of Reclamation WaterSMART Program provides grants for water supply reliability and recharge-related projects, typically requiring a 50 percent non-federal cost share. These funding opportunities are generally released annually, although funding levels have varied in recent years. WaterSMART is best suited to support design and construction of recharge and conveyance infrastructure once projects are more fully developed.

Additional funding opportunities may include U.S. Fish and Wildlife Service habitat programs, HUD Community Development Block Grants (CDBG), and other local or nonprofit funding sources. These programs are typically smaller in scale but may support specific project elements such as habitat enhancements or community benefits.

For Sites S1, N4, N5, and N6, the most effective funding strategy will involve layering multiple funding sources. State programs, particularly DWR grants, Proposition 4 funding, and MLRP, are expected to provide the primary funding for land acquisition, basin construction, and SGMA implementation activities. Federal programs such as FEMA, NRCS, and Reclamation can provide supplemental funding for flood risk reduction, watershed planning, and infrastructure.

Given the significant land acquisition requirements for the sites, programs that support land repurposing and acquisition, especially MLRP and state conservation programs, are critical to

project feasibility. Infrastructure-focused programs (DWR, SWRCB, and WaterSMART) are expected to supplement these efforts by funding basin construction and conveyance.

Overall, the proposed projects are well aligned with current funding priorities at both the state and federal levels. Their ability to provide multi-benefit outcomes, including groundwater recharge, flood attenuation, flow redistribution, and climate resilience, positions them competitively for future funding opportunities. A coordinated strategy that advances project design, permitting, and environmental review in advance of funding solicitations will improve competitiveness and increase the likelihood of securing funds as they become available.

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