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TECHNICAL MEMORANDUM

DATE: February 25, 2026 **PROJECT #:** 9400

TO: Marcus Trotta and Andy Rich, Sonoma Water

FROM: Georgina King, P.G., C.Hg., Jane Patel, and Mekha Pereira

REVIEWED BY: Lisa Porta, P.E.

PROJECT: Technical Support to GSAs for GSP Implementation

SUBJECT: Santa Rosa Plain Subbasin Updated ISW and GDE Characterization

INTRODUCTION

This technical memorandum (TM) summarizes analysis conducted by Montgomery & Associates (M&A) to improve spatial and temporal understanding of interconnected surface water (ISW) and groundwater-dependent ecosystems (GDEs) in the Santa Rosa Plain Subbasin. Depletion of ISW and groundwater levels that adversely impact the viability of GDEs are considered significant and unreasonable conditions.

In 2022, the Santa Rosa Plain (SRP) Subbasin Groundwater Sustainability Plan (GSP) identified data gaps in the analysis of depletion of ISW that the Groundwater Sustainability Agency (GSA) would address early during GSP implementation. GSP-identified data gaps included a lack of detailed information needed to characterize GDEs that rely on ISW. In response, M&A developed an approach to help the GSAs prioritize and address ISW and GDE data gaps, summarized in the TM titled "Recommended Approach for Improving Interconnected Surface Water and Groundwater-Dependent Ecosystem Characterization and Monitoring" (M&A, 2023).

This TM provides an overview of the analysis aimed at enhancing the characterization of ISWs and GDEs and hydrologic/hydrogeologic conditions relevant to sustainability indicators outlined in the Santa Rosa Plain GSP. Information is provided on the data sources, methodology, and results of analysis to investigate ISWs and GDEs, as well as a summary of how the updated analysis is used to inform monitoring recommendations for the GSAs to implement in the summer/fall of 2025.

A Work Group consisting of local and interested GDE and ISW practitioners provided expert advice and perspectives to the technical team of Sonoma Water and M&A at 5 meetings starting

in September 2024 and ending in February 2026. Additionally, the technical team met with Napa County Resource Conservation District in January 2025 to share ISW/GDE characterization and monitoring approaches being taken. Input from these meetings were incorporated into the work documented in this TM.

The TM is prepared for Sonoma Water under its technical service agreement.

INTERCONNECTED SURFACE WATER

ISW Background

GSP regulations define ISWs as "surface water that is hydraulically connected at any point by a continuous saturated zone to the underlying aquifer and the overlying surface water is not completely depleted."[1] In the hydrogeologic setting of the Santa Rosa Plain Subbasin, most streams likely experience some degree of connection to the shallow aquifer, and the interaction between shallow groundwater and streamflow can change in magnitude and direction (gaining or losing) seasonally and spatially. Factors such as geology, recharge events, groundwater extraction, and surface water diversions influence the relationship of ISW to shallow groundwater. Effective ISW management protects ecosystems and water users and supports meeting SGMA's sustainability goals.

In the Santa Rosa Plain GSP, locations of likely ISW are identified in the Subbasin using a combination of groundwater level observations compared to streambed elevations and groundwater modeling (using outputs related to percent of time a stream is gaining, median stream flow, and surface leakage estimates). The 2 types of data are combined into a scoring system to determine where ISWs likely occur throughout the basin[2]. shows the simulated reaches classified as interconnected to groundwater based on the scoring results.

The GSP states "Significant and unreasonable depletion of surface water from interconnected streams occurs when surface water depletion, caused by groundwater pumping within the Subbasin, exceeds historical depletion or adversely impacts the viability of groundwater-dependent ecosystems (GDEs) or other beneficial users of surface water."[3] The GSP recognizes data are insufficient to directly calculate the rate or volume of surface water depletions due to groundwater pumping, and additional data and model improvements are required to quantify surface water depletion due to pumping using a modeling tool. Isolating the impacts of pumping on ISWs is challenging due to other influences on changes in streamflow, such as precipitation, stream diversions, evapotranspiration, and gaining/losing conditions due to naturally occurring

[1] California Code of Regulations Title 23 – Waters, § 351 [o]
[2] Section 3.2.6.2 of GSP: https://santarosaplaingroundwater.org/wp-content/uploads/000_Santa_Rosa_GSP_508.pdf
[3] Section 4.10.1 of GSP: https://santarosaplaingroundwater.org/wp-content/uploads/000_Santa_Rosa_GSP_508.pdf

conditions such as geology. Therefore, initial sustainable management criteria (SMC) for ISW were established using groundwater levels as a proxy for rate/volume of surface water depletion. Using data from 7 shallow monitoring wells, the GSP set minimum thresholds (MTs) based on groundwater level data during the 3-year period for which the model simulated the highest levels of streamflow depletion (2014-2016), and measurable objectives (MOs) based on the average dry season groundwater level observed from 2004 to 2020.

In Water Year (WY) 2022, Sonoma Water began performing seepage runs in the Subbasin to assist in mapping ISWs. By comparing downstream flow to the sum of upstream flow at 49 measurement sites, Sonoma Water classified stream segments as gaining or losing, or neutral in the case that difference in upstream and downstream flow is within the measurement uncertainty. Staff performed 6 seepage runs every other month of WY 2022 starting in October, followed by events in July 2023, October 2023, and August 2024. A technical memorandum describing the methodology and results of the seepage runs is posted on the GSA website [4]. Figure 2 shows an example of seepage run results from December 2021.

[4] Technical Memorandum: Santa Rosa Plain Seepage Runs, October 2021 to August 2022: https://santarosaplaingroundwater.org/wp-content/uploads/2022-11-08-SRP-Seepage-Runs-Final.sp_ada.pdf

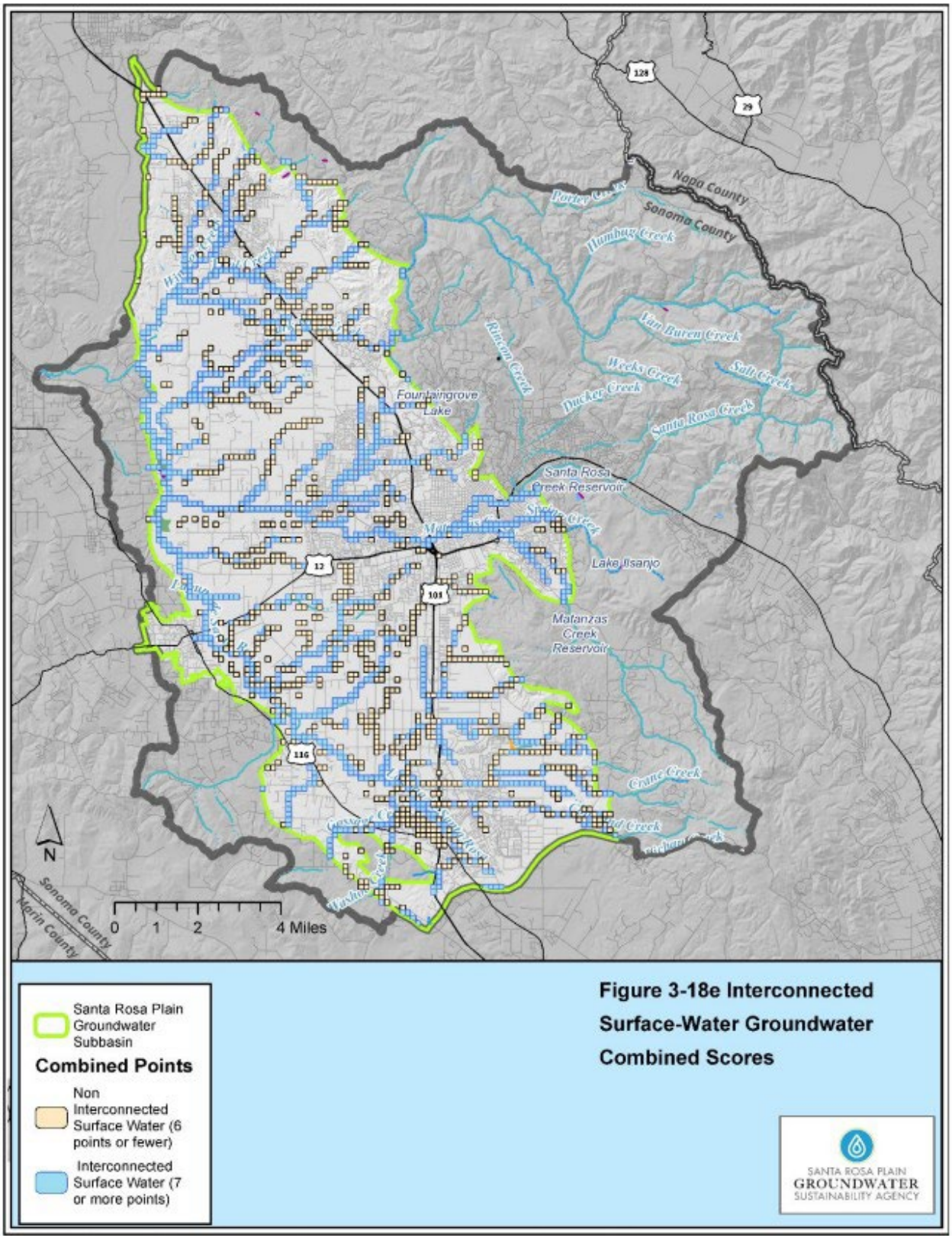


Figure 1. Interconnected Surface Water Map from GSP[5]

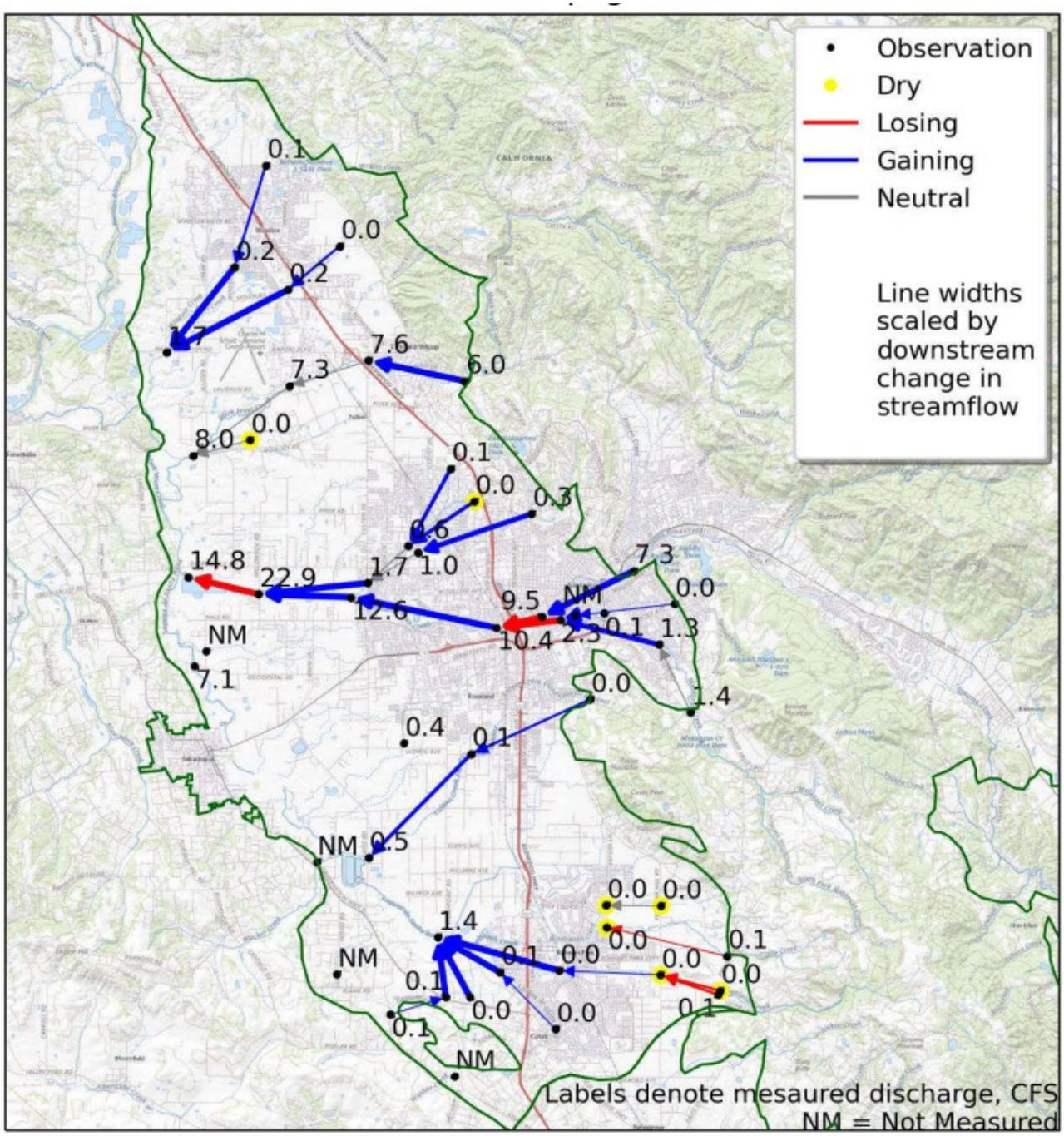


Figure 2. Example Santa Rosa Plain Subbasin Seepage Run Results Map for December 2021[6]

[6]Technical Memorandum: Santa Rosa Plain Seepage Runs, October 2021 to August 2022: http://santarosaplainground water.org/wp-content/uploads/2022-11-08-SRP-Seepage-Runs-Final.sp_ada.pdf

M&A recommended ISW refinement should consider the following (M&A, 2023):

1. Continuation of seasonal seepage runs
2. Additional evaluation of historical seepage run data and comparison to new seepage runs
3. Additional evaluation of data from paired shallow monitoring wells and surface water gauge sites from current and future monitoring sites as they become available
4. Additional analysis on gaining and losing streams to complete evaluation from GSPs
5. Updates to integrated hydrologic numerical model based on new data gathered and analysis from seepage runs
6. Review of the California Environmental Flows Framework (CEFF) and identification of steps that could be used to advance monitoring approaches and knowledge of ISW and GDEs in the basin, as appropriate. CEFF review and implementation could be conducted in partnership with other Sonoma County agencies and local environmental organizations that work on habitat management and restoration efforts
7. Evaluation of losing streams due to pumping, primarily using analytical and modeling tools, and potential additional targeted site-specific monitoring near pumping centers

The following Data Sources, Methods, and Results sections provide documentation for ISW analysis, addressing recommendations 1 through 4, which focus on hydrologic review of streamflow, stage, and groundwater levels to improve ISW characterization. These efforts led to recommendations for additional GDE and ISW field studies to fill data gaps during the summer of 2025. Recommendations 5 and 7 focus on assessing the effects of pumping on streams. These steps are in progress and are reliant on completion of the groundwater model update, which will be reported on separately. The ISW evaluation can be combined with the GDE analysis to better understand potential GDE health issues due to ISW conditions and related pumping effects. ISW and GDE monitoring established by the GSA will directly support CEFF efforts should that framework be implemented (Recommendation 6).

ISW Data Sources

Table 1 summarizes data sources used for the ISW analysis, which provided information on stream networks, streamflow, groundwater elevation, and precipitation.

Table 1. Data Sources for Interconnected Surface Water Analysis

Dataset	Source	Frequency
Stream discharge	USGS	15 minutes
Stream stage	USGS	15 minutes
Streambed elevation	Estimated from LiDAR	N/A
Stream network	NHD Flowlines	N/A
Seepage run flow measurements	Sonoma Water	Variable from October 2021 to August 2024
Groundwater elevation	Sonoma Water	Daily
Precipitation	NOAA (Climate Station USC00047965)	Daily
Water Year Classification	Santa Rosa Plain Subbasin Water Year 2023 Annual Report	Annual based on 3-year rolling weighted average

USGS = United States Geological Survey
NOAA = National Oceanic and Atmospheric Administration

Since GSP development, the GSAs have continued to collect data to fill data gaps. New data collected to address ISW data gaps during GSP implementation includes the following:

- In WY 2022, Sonoma Water began performing seepage runs in the Subbasin to assist in mapping ISWs. Staff performed 6 seepage runs every other month of WY 2022 starting in October, followed by events in July 2023, October 2023, and August 2024.

- Four multi-level nested wells were constructed in the Santa Rosa Plain Subbasin in 2022 to address data gaps in the groundwater level and ISW monitoring networks and couple them with stream monitoring. Two additional multi-level nested wells and two shallow single completion wells are expected to be installed in summer 2025 to fill remaining shallow groundwater level monitoring data gaps.

- A comprehensive well inventory database was created to support implementation of the GSPs. The updated well inventory was used to map well density by depth to evaluate the concentration of supply wells near ISW and GDEs. Supply well density is used as a surrogate for groundwater pumping in lieu of accurate pumping information from each well. This provides an initial screening of potential impacts on GDEs from well pumping; more detailed analysis will be conducted with the groundwater models when they are ready.

ISW Characterization Methods

Since the initial ISW analysis conducted for the GSP was performed, Sonoma Water has continued to collect groundwater level data at shallow monitoring wells and perform seepage runs to characterize gaining/losing stream conditions throughout the basin. M&A's updated ISW analysis incorporates groundwater elevation data from additional shallow monitoring wells beyond the existing network of 7 representative monitoring point (RMP) wells and includes further evaluation of historical seepage run data to better assess the connectivity between surface water and shallow groundwater across the Subbasin. Comparing groundwater elevation in shallow monitoring wells to streambed elevations indicates gaining or losing conditions at the point scale, whereas seepage run data provide information on gaining or losing conditions averaged over a stream segment. Overlaying both sets of information on graphs and a map allows for more holistic interpretation of the data. The following sections summarize the analysis and interpretation approach of both the point well data and seepage run data.

ISW Classification Based on Well Data

The method described in Sonoma Valley GSP Appendix 3-D: Detailed Analysis of Interconnected Surface Water Based on Shallow Well Data[7] informed the approach used to analyze shallow groundwater level data in the Santa Rosa Plain Subbasin. This updated ISW analysis includes wells that meet the following criteria:

- A transducer records high frequency (daily) water level data
- The well is within 400 feet of a stream, measured using GIS by the perpendicular distance from the well to the nearest National Hydrography Dataset (NHD) flowline
- The well depth or screen interval is within 100 feet of the ground surface

When multiple wells meet the criteria and are in close proximity, the shallowest well is generally selected for analysis. Additionally, although well SRP0712 is over 900 feet from the closest stream and does not meet the above criteria, it is retained for analysis because it is a current RMP for ISW. Figure 3 shows the location of shallow monitoring wells, stream gages, and streams in the Subbasin.

Groundwater elevation data for the resulting 16 wells are graphed with precipitation (or streamflow if near a United States Geological Survey (USGS) stream gage) to determine responsiveness to surface water trends, and with streambed elevation (or stream stage elevation if

[7] Appendix 3-D Detailed Analysis of Interconnected Surface Water Based on Shallow Well Data: https://sonomavalleygroundwater.org/wp-content/uploads/3-D-SV-Detailed-analysis-interconnect-sw-based-on-shallow-well-data-042021_pdf-_ada.pdf

near a USGS stream gage) to determine gaining/losing conditions. To estimate approximate streambed elevation, a Light Detection and Ranging (LiDAR) dataset is used to extract the ground elevation along a perpendicular transect from the well (or USGS stream gage) through the nearest NHD flowline. Streambed elevation is approximated by the minimum elevation along the transect, which is verified to represent the stream through aerial imagery.

Based on evaluation of graphs compiling groundwater levels and surface water data, wells are classified into the following ISW categories:

- Connected: groundwater elevation tracks stage/precipitation trends or is at times above the streambed elevation (Figure 4)
    - Gaining: groundwater elevation is always above streambed (or stream stage) elevation
    - Gaining and Losing: groundwater elevation fluctuates above and below the streambed seasonally
    - Mostly Losing: groundwater elevation is generally below streambed (or stream stage) elevation and rises above only for short periods in response to precipitation events
    - Losing: Groundwater elevation is always below streambed (or stream stage) elevation
- Disconnected: Groundwater elevation does not track stage/precipitation trends and is always below the streambed (or stream stage) elevation (Figure 5)

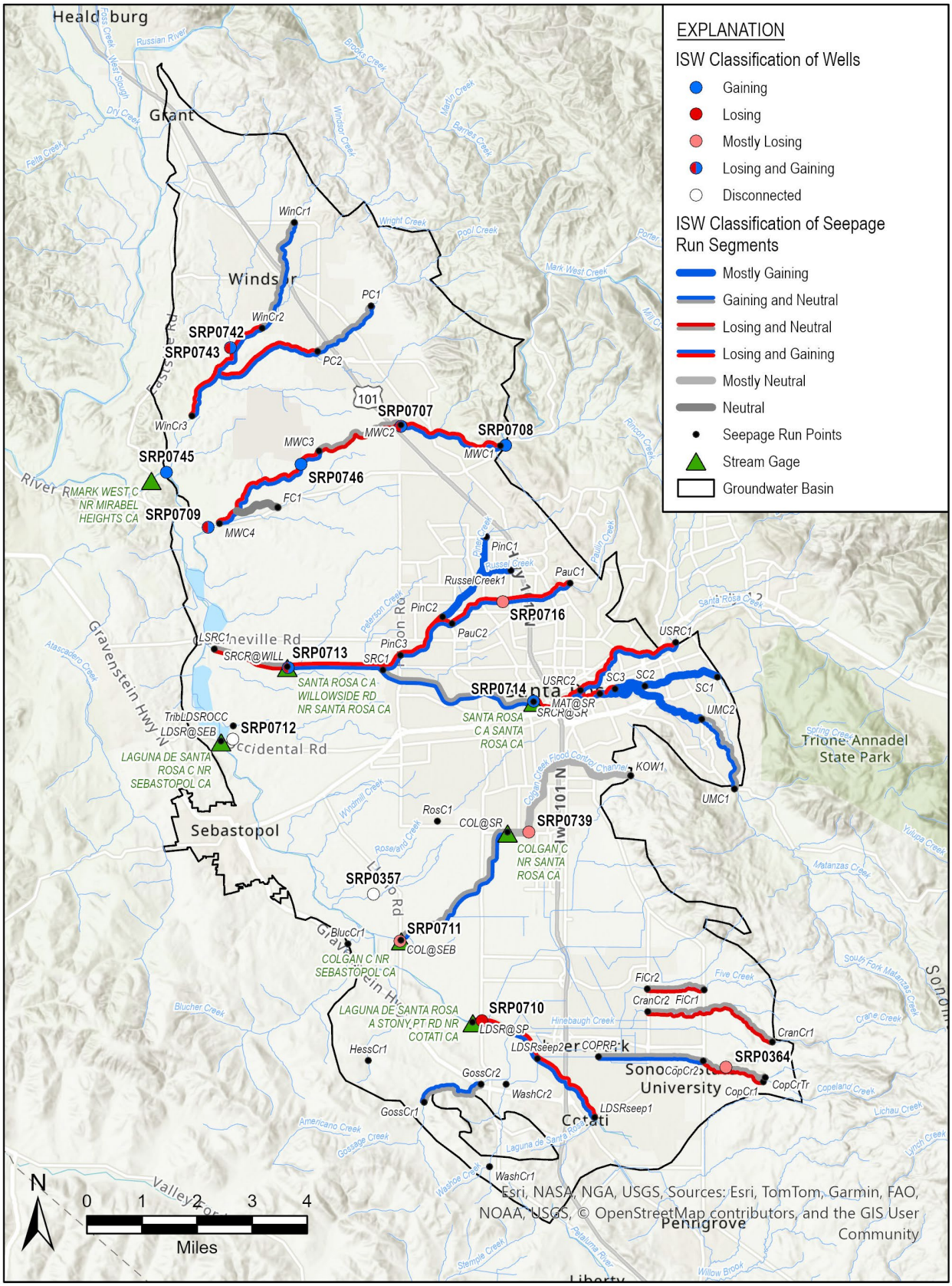


Figure 3. Santa Rosa Plain Subbasin Interconnected Surface Water Classification

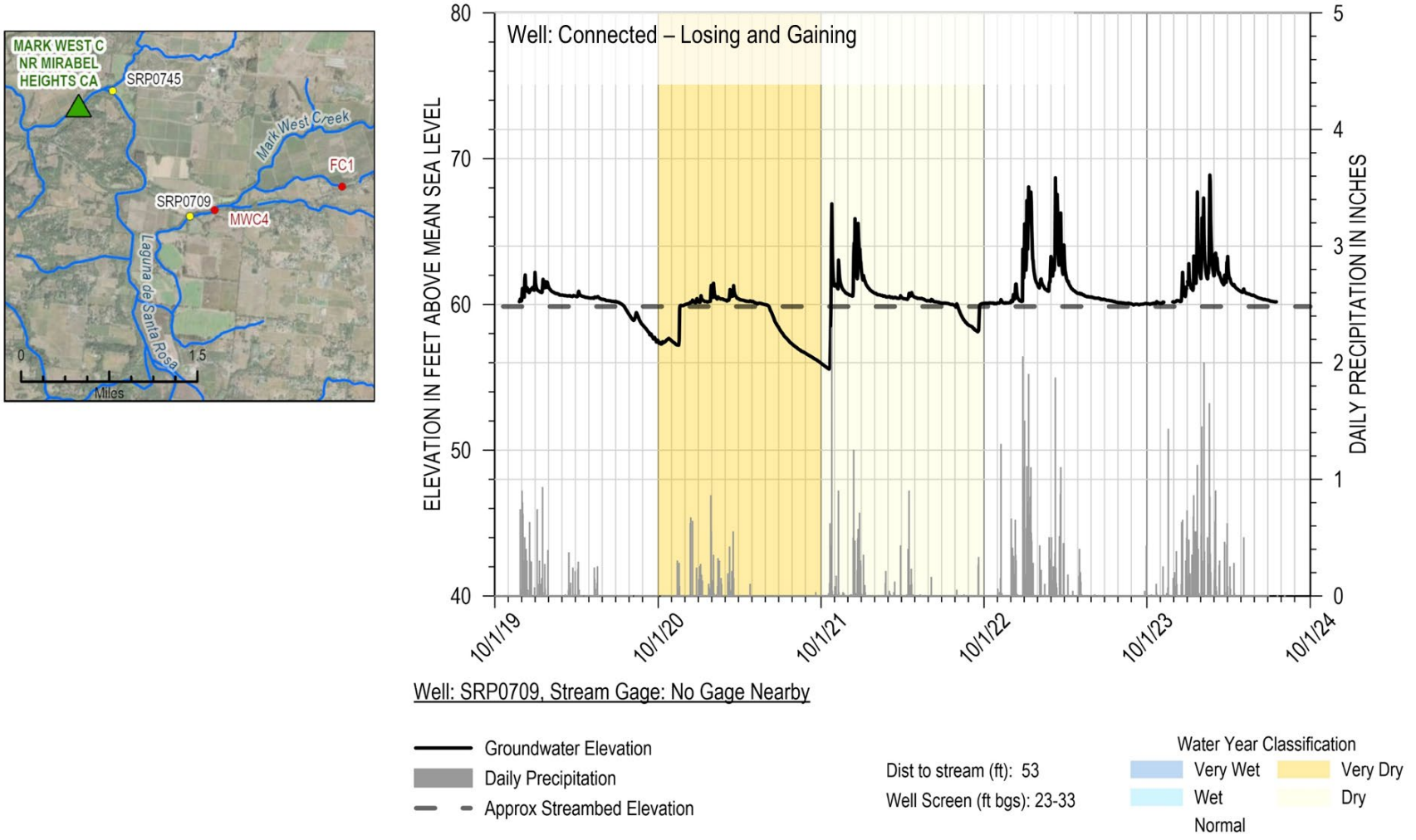


Figure 4. Example of a Welll Location with Connected Surface Water and Groundwater

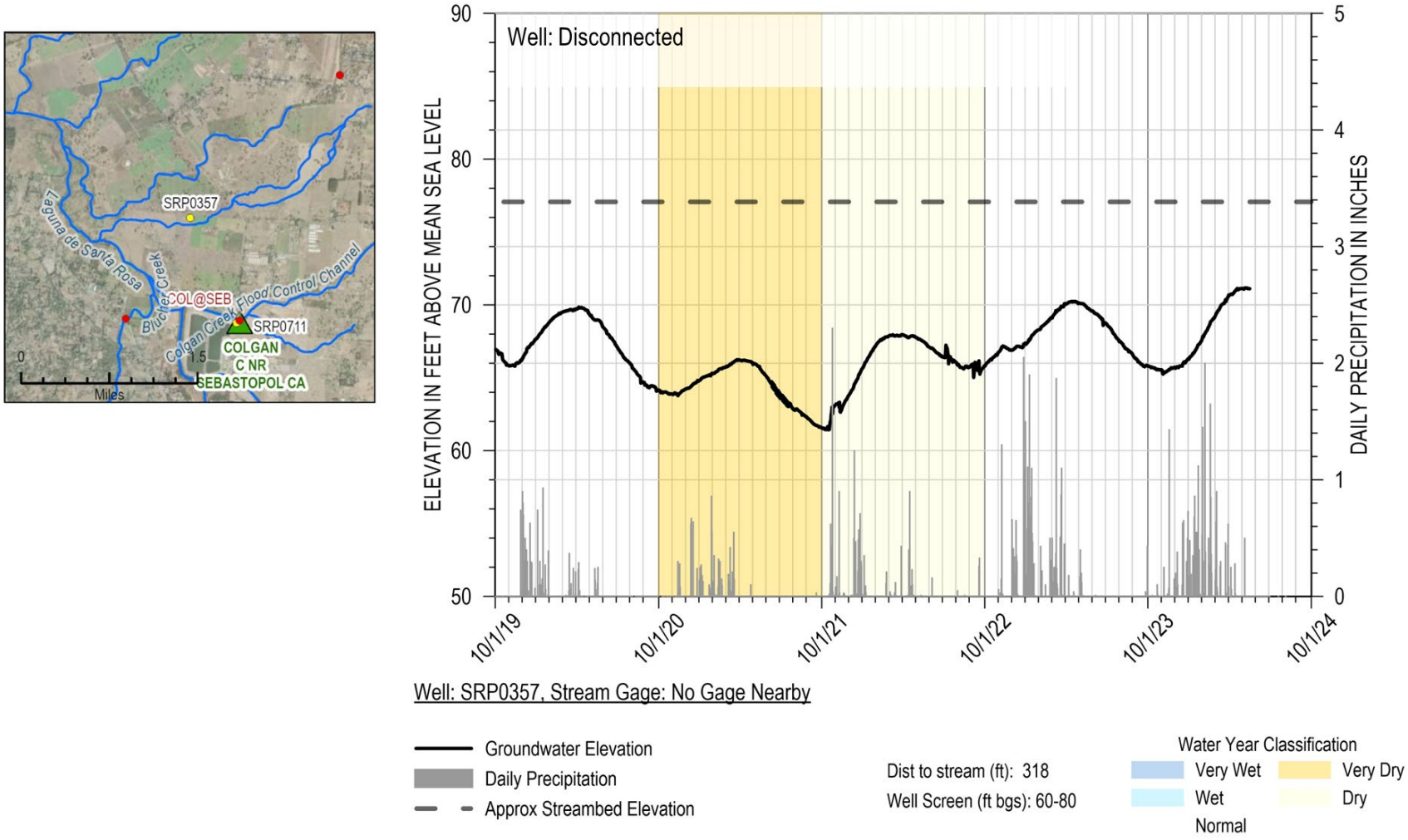


Figure 5. Example of a Well Location with Disconnected Surface Water and Groundwater

ISW Classification Based on Seepage Run Results

A 2022 Technical Memorandum summarized results of seepage run events in Water Year 2022[8]. This additional analysis evaluates seepage run results relative to shallow groundwater data as well as broadly classifies stream reaches based on the frequency of gain/loss conditions over time through 2024.

To evaluate seepage run results relative to shallow groundwater levels, the gain/loss classifications are added to hydrographs when 1 of the 16 shallow groundwater wells is near the downstream end of a seepage run segment. Additionally, scatter plots comparing groundwater elevation versus the change in streamflow on the date of the seepage run help determine if change from gaining to losing conditions could be correlated with a specific shallow groundwater elevation. Figure 6 shows an example of the combined seepage run and groundwater level data.

To compare with the ISW classification based on the well data, ISW classifications of stream segments are assigned to the following categories based on the frequency of gaining/losing/neutral conditions over the 5 to 10 seepage runs performed along various segments:

- Gaining/Losing/Neutral: All seepage runs on that segment resulted in the same classification
- Mostly Gaining/Losing/Neutral: At least 80% of the seepage runs along that segment resulted in the same classification
- Gaining/Losing and Neutral: Conditions for the stream segment varied between gaining and neutral or losing and neutral with no classification occurring more than 80% of the time
- Losing and Gaining: Conditions for the stream segment varied between losing and gaining with no classification occurring more than 80% of the time

[8] Technical Memorandum: Santa Rosa Plain Seepage Runs, October 2021 to August 2022: https://santarosaplaingroundwater.org/wp-content/uploads/2022-11-08-SRP-Seepage-Runs-Final.sp_ada.pdf

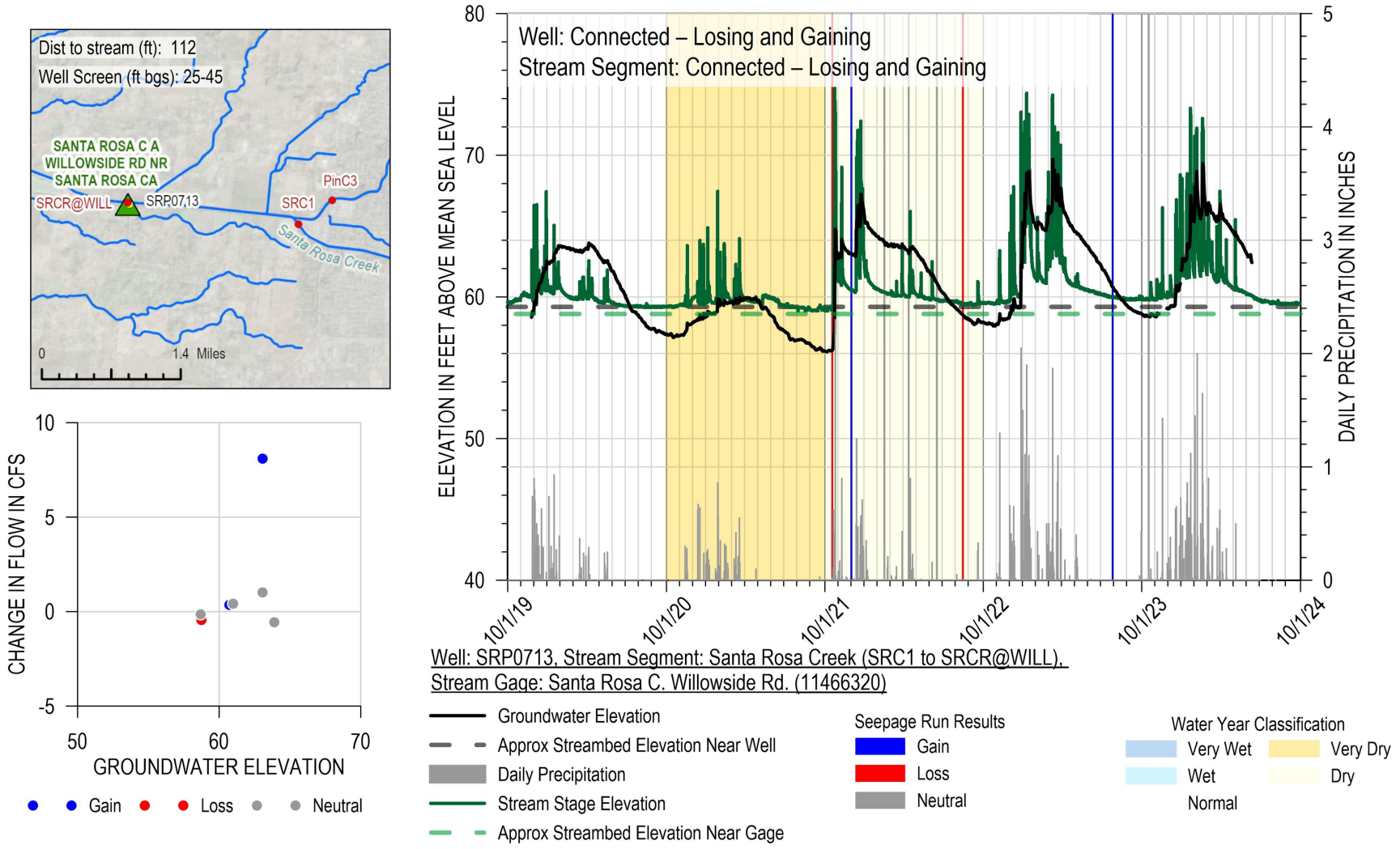


Figure 6. Example of Graph Combining Seepage Run and Groundwater Level Data

ISW Characterization Results

Attachment 1 provides a compilation of graphs for the Santa Rosa Plain Subbasin showing hydrographs for wells included in the ISW analysis as well as seepage run results over time. Graphs in Attachment 1 are generally organized from north to south and upstream to downstream. Figure 3 shows a map overlaying the well and stream segment ISW classifications. The map highlights that throughout the Subbasin, shallow groundwater and streamflow data generally indicate some degree of connection and gaining/losing conditions vary over time.

While gaining stream conditions confirm interconnectedness of surface and groundwater, losing conditions on its own does not confirm a lack of connection. At monitoring wells SRP0739 and SRP0710, losing conditions are indicated by the groundwater elevation but interconnectedness is still evident. Though shallow groundwater levels are below the streambed elevation, they respond readily to precipitation and streamflow events. It is, however, difficult to determine whether this response is due to direct vertical infiltration of water through the streambed or if due to recharge of the entire shallow aquifer system, which occurs rapidly in this hydrogeologic setting. Similarly, losing stream reaches as measured by seepage runs do not on their own indicate disconnected conditions.

Almost all mapped stream systems indicate interconnection at some segments, including Windsor Creek, Pool Creek, Mark West Creek, Piner Creek, Russel Creek, Paulin Creek, Matanzas Creek, Santa Rosa Creek, Colgan Creek, Laguna De Santa Rosa, Gosser Creek, and Copeland Creek. Along Windsor Creek system and Santa Rosa Creek system, gaining conditions are observed high in the watershed where the alluvial aquifer is thin and bedrock is shallow, resulting in limited losses to the alluvial sediments. As streams enter the valley and alluvial sediments thicken, a combination of gaining and losing conditions are observed. In the southeast portion of the Subbasin around Crane Creek, the presence of high permeability alluvial fan deposits results in high infiltration rates and generally losing stream conditions.

Data from only 2 wells indicate disconnection: SRP0712 with a well screen depth of 24-48 feet and 991 feet from the nearest stream and SRP0357 with a well screen depth of 60-80 feet and 318 feet from the nearest stream. Well SRP0712 is a current RMP well but data collected from it indicate it is likely too far from the stream to be a meaningful well in assessing ISW. Well SRP0357 is also likely too far from the stream given its deeper screen interval depth to be sufficient for assessment of ISW; the only other well with a similar distance from a stream that shows surface water connection in its groundwater level response is well SRP0364 with a much shallower screen depth of 11-26 feet.

Due to the difference in spatial scale of the seepage run and groundwater level data analyses, it is inevitable that the 2 approaches for ISW classification sometimes provide differing results. An example on Figure 3 is the “Mostly Losing” classification of well SRP0711 versus the “Gaining

and Neutral" classification of the upstream segment along Colgan Creek. The seepage run results based on a mass balance approach compare downstream flow to the sum of upstream flow, which can obscure changes in gaining/losing conditions on a small scale throughout the segment. The well observations, however, provide point data that indicate conditions can change between gaining/losing even along relatively small segments of streams.

Overall, the ISW analysis indicates varying degrees of surface water interconnection throughout the Subbasin and on its own is limited in ability to highlight critical areas of ISW for protection. Other factors such as GDE health, presence of critical habitat, or vulnerability to groundwater pumping are important to inform priorities for policy considerations and establishment of protective metrics. Consideration of these factors informed recommendations for additional high value monitoring and data collection, summarized briefly in the Monitoring Recommendations section of this TM. Location specific field data collection recommendations for summer of 2025 were developed in collaboration with Sonoma Water and are documented in a separate workplan (M&A, 2025).

GROUNDWATER-DEPENDENT ECOSYSTEMS

GDE Background

GDEs are important ecological features found throughout the Santa Rosa Plain Subbasin. Aquatic GDEs and vegetation GDEs are characterized by their connection to shallow groundwater on which they depend solely or partially to maintain their structure and function. GDEs are recognized as beneficial users of groundwater by SGMA and therefore their characterization and impacts need to be evaluated as part of the GSP.

As part of the GSP, habitat and ISW delineation were used to map aquatic species GDEs. In the Santa Rosa Plain Subbasin, 8 streams are identified as potential habitat for at least 1 of the species or groups of species chosen for long-term monitoring (Sonoma Water and University of California Cooperative Extension/California Sea Grant, 2014). Steelhead are the most widespread species occurring in each of the 8 streams. The distribution of Chinook salmon and coho salmon overlap entirely with steelhead streams. For this reason, steelhead are essentially used as a priority indicator species to cover all aquatic GDEs in the Subbasin. The GSP analysis that considered aquatic GDEs was used, in part, to inform ISW/GDE data gaps identified in the GSP and subsequent TM recommending the approach for improving ISW and GDE characterization and monitoring (M&A, 2023).

Vegetation GDEs were mapped in 2020 using high-resolution local mapping available from the Sonoma County Veg Map, depth to groundwater and rooting depths of common tree species. Riparian woodland, oak woodland, freshwater marsh and aquatic vegetation types are considered to be potentially reliant groundwater and evaluated against a depth to water threshold of 30 feet.

Those mapped vegetation with depth to water within 30 feet of land surface and riparian woodland or oak woodland habitat within 100 feet of ISW were included as vegetation GDEs in the original GSP. Figure 7 shows the aquatic species and vegetation GDEs mapped as part of the Santa Rosa Plain Subbasin GSP.

Vegetation GDEs are updated as part of the revision of GDE characterization and aquatic GDEs from the previous assessment are included in the overall mapping of GDEs within the Santa Rosa Plain Subbasin. The remainder of this document uses "GDE" to reference vegetation GDEs.

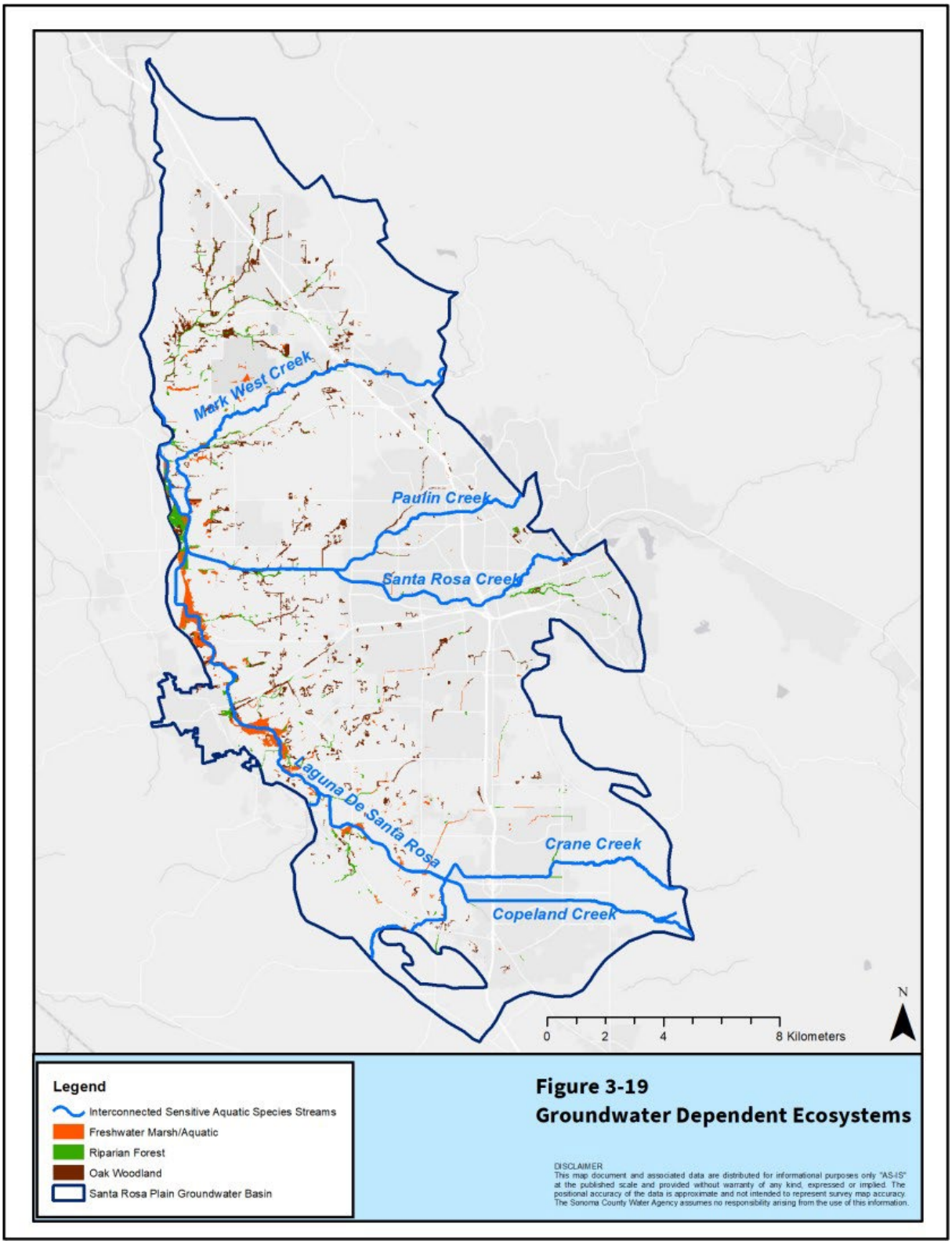


Figure 7. Santa Rosa Plain GDEs Mapped in 2022 GSP[9]

[9] Section 3.2.6.4 of GSP .https://santarosaplaingroundwater.org/wp-content/uploads/000_Santa_Rosa_GSP_508.pdf

GDE Data Sources

Data sources used to update, characterize, and evaluate GDEs include datasets recommended by Sonoma Water along with updated versions of existing datasets summarized in Table 2.

Table 2. Data Sources for Groundwater-Dependent Ecosystems

Dataset	Source	Date of Acquisition	Date of Publication
Natural Communities Commonly Associated with Groundwater (NCCAG 2.0)	The Nature Conservancy (TNC)	August 6, 2024	April 2021
Sonoma County Fine-Scale Vegetation and Habitat Map	Sonoma Veg Map	November 4, 2024	May 1, 2017
Groundwater Levels	Sonoma Water	Fall 2024	N/A
LiDAR Derived Digital Elevation Model of Bare Earth	Sonoma Veg Map	August 14, 2024	February 19, 2014
Groundwater Users Information Data Exchange (GUIDE)	Santa Rosa Plain Groundwater Sustainability Agency	April 16, 2025	N/A
Well Density Evaluation of Well Inventory	Montgomery & Associates	February 13, 2025	February 13, 2025
Normalized Difference Vegetation Index (NDVI)	TNC - LandSat	February 21, 2025	2025 – Continuously Updated
Precipitation and Temperature	NOAA – Global Historical Climate Network, PRISM	August 14, 2024	August 14, 2024
Fire Perimeter	Monitoring Trends in Burn Severity (MTBS)	February 25, 2025	2024

Natural Communities Commonly Associated with Groundwater (NCCAG 2.0, 2021)

The Natural Communities dataset is a compilation of public datasets that map vegetation, wetlands, springs, and seeps in California that are likely to be associated with groundwater. The dataset is split into wetland features commonly associated with the expression of groundwater and vegetation features associated with subsurface presence of water (phreatophytes). Wetlands include springs, perennial wetlands, and rivers whose flow is augmented by groundwater. Vegetation communities that rely on the subsurface presence of groundwater for some or all their water needs are included in the NCCAG 2.0 dataset.

An earlier version of this dataset was used in the classification of GDEs in the GSP. Within the Santa Rosa Plain Subbasin there were no updates to the NCCAG 2.0 dataset.

Sonoma County Fine-Scale Vegetation and Habitat Map (2013)

Sonoma County Agricultural Preservation and Open Space District and Sonoma County Water Agency developed the Sonoma County Vegetation Mapping and Lidar Program as a joint

program to produce high resolution vegetation, habitat and hydrologic maps within the County (Sonoma Veg Map, 2018). These datasets are critical to many aspects of Sonoma County management including hydrologic evaluations, natural resource planning, and watershed assessments. The fine-scale vegetation map contains detailed information on vegetation classification which is filtered to identify vegetation commonly associated with groundwater (riparian woodland, oak woodland, freshwater marsh, and aquatic) and filtered to exclude vernal pools (Sonoma Veg Map, 2017).

Groundwater Elevation Datasets (1985-2024)

Groundwater elevation datasets for the Subbasin were provided by Sonoma Water. These datasets include a Subbasin-wide interpolated groundwater elevation surface for each year from 1985 to 2024. Groundwater elevations are used to determine depth to water for each potential GDE by averaging groundwater elevations intersecting the potential GDE polygons derived from NCCAG and Sonoma Veg Map. Depth to water is used to identify GDEs from potential GDEs for all vegetation polygons from NCCAG and Sonoma Veg Map.

Ground Surface Elevation (2013)

A digital elevation model (DEM) was prepared as part of the Sonoma Veg Map program (Sonoma Veg Map, 2018). The DEM is used to average ground surface elevations at potential GDE polygons. Subtracting the groundwater elevation at the GDE from its surface elevation is used to determine depth to groundwater at the potential GDE.

Groundwater Users Information Data Exchange (GUIDE)

Groundwater use for each parcel is initially based on publicly available information. Thereafter, groundwater use is updated annually to incorporate landowner reported surveys on the property's water sources and water use. GUIDE was developed through the Santa Rosa Plain, Petaluma Valley, and Sonoma Valley Groundwater Sustainability Agencies as part of the 2024 Rate and Fee Study (SCI and LWA, 2022). The GUIDE dataset is made available through a shapefile of parcels and an accompanying table of associated water sources and parcel water use. Total groundwater use per parcel and groundwater use by acre are used to understand the spatial distribution of groundwater use throughout the Subbasin.

Water Supply Well Density

The Sonoma Well Inventory prepared by M&A (2025) was used to create a kernel density surface for different categories of supply wells. Two depth categories were used to calculate kernel density throughout the Subbasin:

- Shallow supply wells are those non-monitoring well types with total depth less than or equal to 200 feet
- Deeper supply wells are those non-monitoring well types with total depth greater than 200 feet

Density of shallow supply wells shows where groundwater pumping of the shallow aquifer may have a more immediate impact on GDEs while density of deeper supply wells is an indicator of deeper groundwater pumping that has a longer timeline to potentially impact GDEs.

Normalized Difference Vegetation Index Composite Image Collection (1985-2023)

The Normalized Difference Vegetation Index (NDVI) is a remote sensing technique used to measure vegetation health in potential GDEs. NDVI is used by The Nature Conservancy (TNC) in the GDE Pulse application to evaluate vegetation health trends and local groundwater conditions across California. TNC uses a single summer NDVI value (July through September) to characterize vegetation health when vegetation is more likely to be dependent on groundwater as their primary water source.

The tiles created and maintained in a composite image collection hosted by TNC are used for this evaluation. TNC source code (TNC, 2019) is used to calculate average NDVI at each GDE polygon.

Precipitation and Temperature

Long-term daily temperature and precipitation data are compiled from Parameter-elevation Regressions on Independent Slopes Model (PRISM) at the location of the NOAA National Climatic Data Center's gage for USC00047965 - Santa Rosa, CA located at (38.45579, -122.71335)[10]. These data are extracted from the PRISM data explorer[11] and summarized in the following ways:

- Monthly precipitation totaled by water year
- Maximum monthly temperatures averaged by water year
- Average maximum monthly precipitation is used to characterize climate in the basin from 1985 to 2024

[10] https://www.ncei.noaa.gov/cdo-web/datasets/GHCND/stations/GHCND:USC00047965/detail
[11] https://prism.oregonstate.edu/explorer/

Fire Perimeter

Fire perimeters are sourced from the Monitoring Trends in Burn Severity (MTBS, https://www.mtbs.gov/). The fire boundary dataset includes burned extents from 1894 to 2024. Fire perimeters from 1985 to 2024 are used to identify where GDE health had been impacted by fire over the period of record.

GDE Characterization Methods

The revised GDE characterization followed the sequential data analysis approach as described below.

Develop Updated Map of GDEs

Identification of GDEs in the GSP was informed by areas where groundwater levels in the shallow aquifer system between 2015 and 2016 were within 30 feet of land surface. Drought conditions prior to and in 2015 and 2016 likely underestimated the extent of GDEs since groundwater levels were lower at that time. This updated characterization uses spring 2023 groundwater levels—as recommended by the ISW/GDE Workgroup—to identify GDEs. Spring 2023 had relatively high groundwater levels since rainfall that water year was more than 10 inches greater than the long-term average.

Average groundwater elevation is calculated across each GDE polygon using the spring 2023 shallow groundwater elevation grid. Average ground surface elevation is calculated using the Sonoma Veg Map DEM. The difference between land surface and groundwater elevation is assigned to each GDE polygon as depth to water in feet below land surface. If the depth to water for a potential GDE polygon is greater than 30 feet below land surface then that polygon is excluded. All polygons with depth to water less than or equal to 30 feet are designated as GDEs.

NDVI GDE Health Evaluation

The subset of GDEs with depth to water within 30 feet of the land surface are used to evaluate vegetation health. To understand trends and changes in GDE health, average NDVI is calculated across each GDE polygon using the NDVI composite image collection prepared and maintained by TNC from 1985 to 2023. Summer NDVI is plotted over time and trends are assigned to those time-series. Summer NDVI trends indicate where vegetation health is declining or improving over the entire record; the long-term trend could be compared to the most recent 10 years of data to see if there are more recent shifts in GDE health. Average NDVI over the last 4 years represents current vegetation health. Vegetation health categories based on NDVI are presented in Table 3. The thresholds for categorization are commonly used by TNC (personal communication) and provide a framework for understanding the general condition of vegetation in GDE polygons.

Table 3. Vegetation Health Categories by NDVI Value

Vegetation Health Category	NDVI Range
Standing Water or Bare Ground	< 0
Unhealthy	0 – 0.3
Poor Health	0.3 to 0.45
Moderately Healthy	0.45 to 0.6
Very Healthy	0.6 to 1

Groundwater Level Impacts on GDE Health

Groundwater level data and zonal averages of NDVI are used in an approach described by Rohde *et al.* (2024) to evaluate GDE responses to changes in depth to groundwater. Vegetation responses to groundwater level change are challenging to capture due to varying spatial, temporal, seasonal, species-specific patterns. This approach uses Z scores to standardize depth to water and NDVI to indicate how many standard deviations an observation value is from the mean. This approach is used within vegetation groups in the Santa Rosa Plain Subbasin to develop an understanding of the effects of groundwater level changes on vegetation health. Vegetation groups examined in Santa Rosa Plain Subbasin are oak woodland, riparian, wetlands, and all vegetation. Detailed methodology, results and interpretations from this evaluation are presented in Attachment 2.

GDE Characterization Results

The map of GDEs in the Santa Rosa Plain Subbasin is expanded from that included in the 2022 GSP by using spring 2023's shallower depth to water. Areas with less than or equal to 30 feet depth to water are where GDEs are likely to occur. In general, the update resulted in an increase of 888 acres compared to the map in the GSP (Table 4, Figure 8).

Using 2023 depth to water results in some vegetation classes increasing in extent while others decreased (Table 4). This occurs because while much of the Subbasin experienced groundwater level increases, some areas had declines in levels.

Table 4. Santa Rosa Plain Subbasin Change in GDE Extent Based on Using Spring 2023 Depth to Water

GDE Category	GDE Area based on 2015/2016 Spring Depth to Water	GDE Area based on 2023 Spring Depth to Water
Freshwater Marsh (Sonoma Veg Map)	952	1,249
Oak Woodland (Sonoma Veg Map)	1,710	1,999
Riparian Forest (Sonoma Veg Map)	1,152	1,556
Wetlands (TNC/NCCAG)	452	413
Phreatophyte Vegetation (TNC/NCCAG)	817	752

Seasonality is important for understanding GDEs in Sonoma County's Mediterranean climate. Dry season remote sensing data are critical for confirming that GDEs exist as they may suffer at times when groundwater is too deep to access. If robust phreatophyte vegetation is observed throughout the dry season, this is a good indicator that the habitat has sufficient groundwater available, especially in areas where creeks seasonally go dry. Extended periods of low or declining NDVI during the dry period could indicate lack of available water. Evaluating NDVI time-series with climate (precipitation and temperature) and groundwater levels can show when these trends might be correlated. Long-term NDVI trends (1985-2024) are calculated and evaluated against shorter-term trends (2015-2024). In cases where the trend changed (e.g., from positive to negative) those GDEs are evaluated to verify if there is an isolated instance of lower NDVI and potential causes of that low index. Average NDVI from 2020 to 2024 is also calculated to understand the current condition of the GDEs. Vegetation health categories reflective of current vegetation condition (average NDVI from 2020 to 2024) are used to show general condition of GDEs in the most recent 5 years (Figure 9).

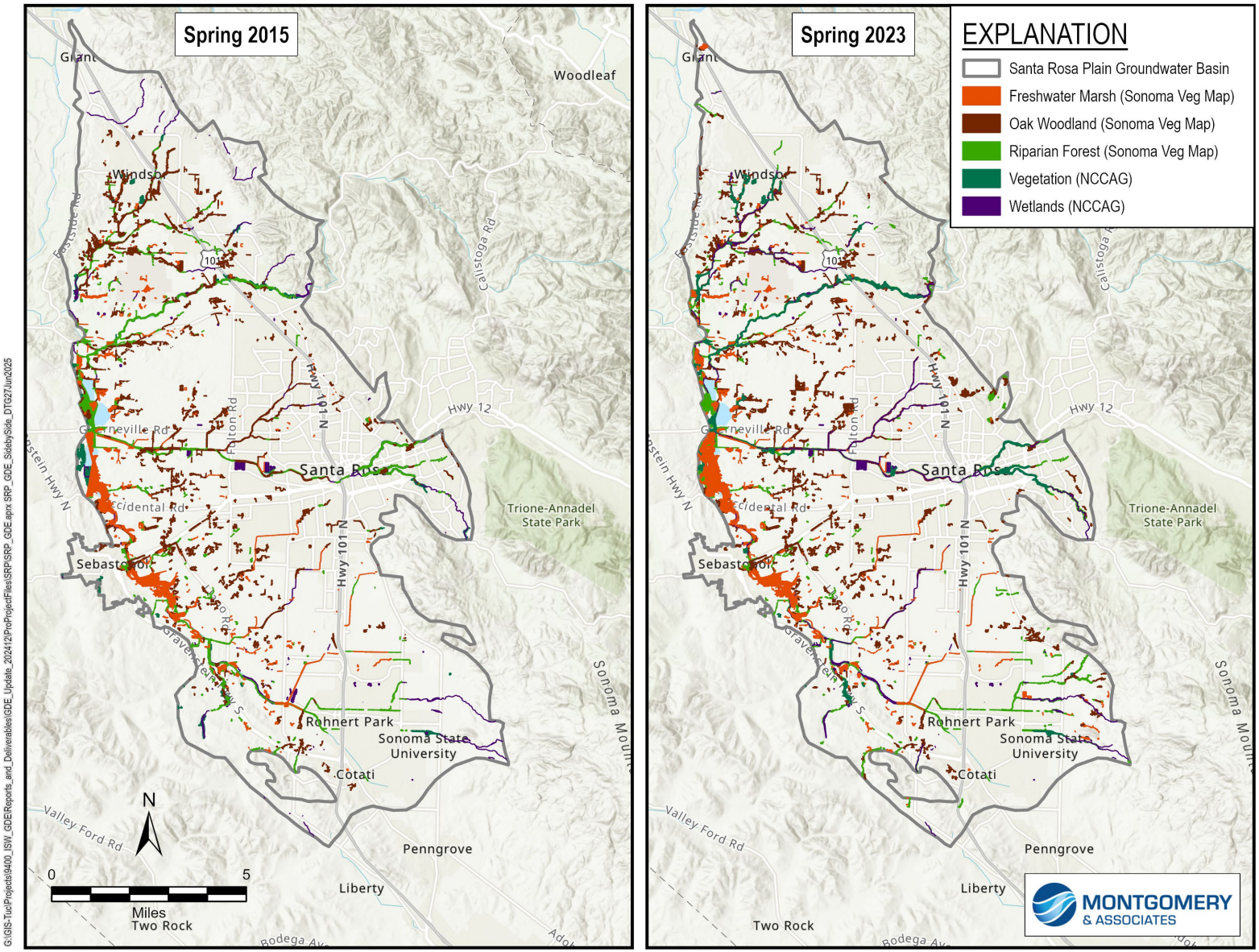


Figure 8. Santa Rosa Plain Subbasin Groundwater-Dependent Ecosystem Extent Comparision
Based on Spring 2015/2016 and Spring 2023 Depth to Groundwater

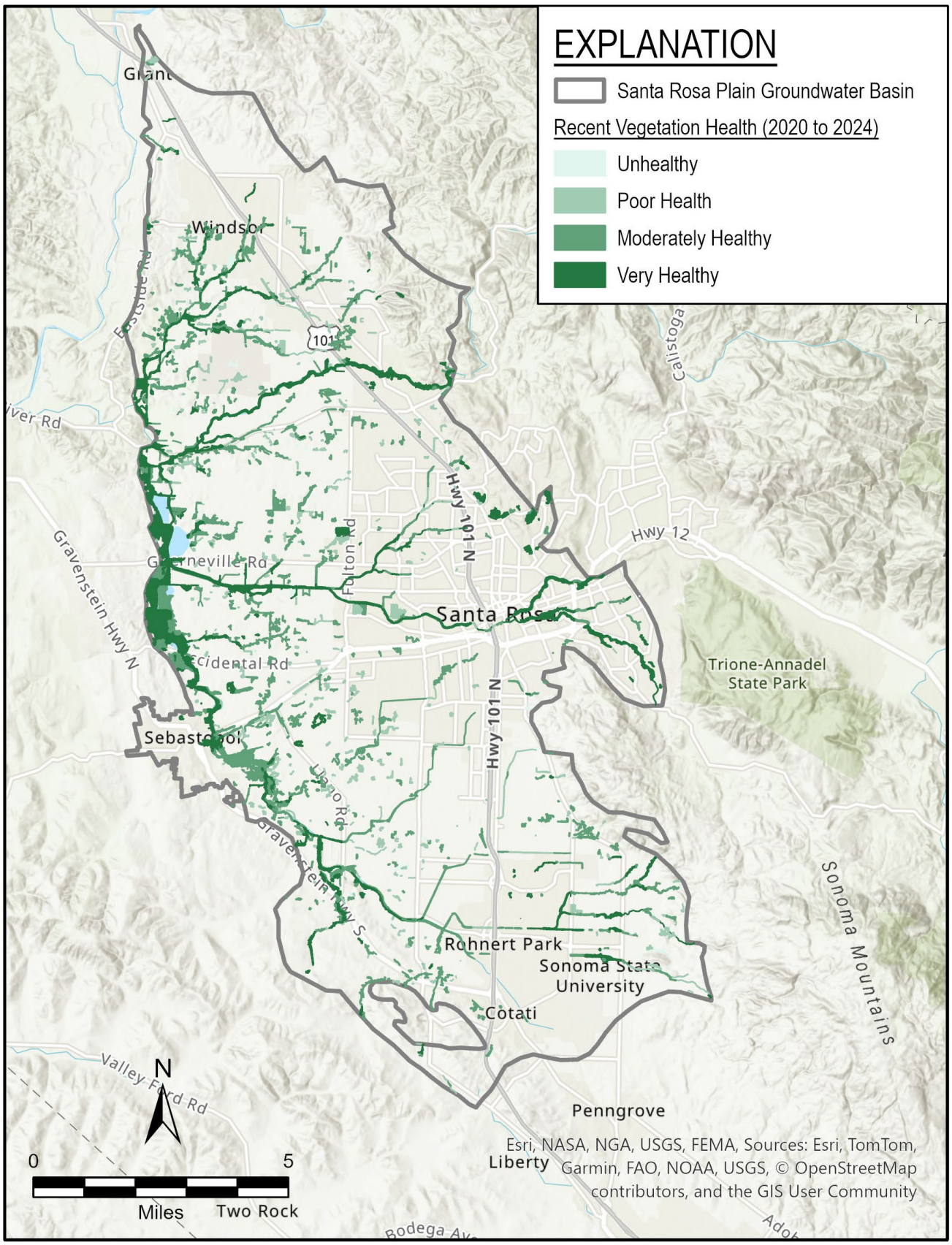


Figure 9. Recent Vegetation Heatlh Based on NDVI Averaged from 2020 to 2024

As expected, Santa Rosa Plain Subbasin vegetation GDEs in summer of 2023 were generally healthy with over 75% of the GDE polygons having an average NDVI of 0.45 or higher and an average NDVI for all GDE polygons of 0.57. Healthy vegetation in 2023 was expected since rainfall that water year was higher than the long-term average. Most of the GDE polygons exhibit stable or slightly increasing trends in vegetation health from 1985 to 2024 (examples of increasing trends are shown on Figure 10 through Figure 12). The 5-year Subbasin-wide average (2020-2024) NDVI is 0.54, which is in the moderately healthy range. Only 8.6% of GDEs show declining trends) over the long term (1985-2024) (Figure 13). However, nearly 30% of GDE polygons show declining NDVI trends over the shorter term (2015-2024).

Some changes in NDVI are related to changes to land cover such as wildfire or development. Instances where decreased NDVI is due to development of a landscape are excluded from GDE evaluation as those GDEs no longer represent the mapped vegetation (Figure 14).

In some cases, a decrease in NDVI is due to wildfires and those GDEs are flagged so that lower vegetation health is not attributed to climate or groundwater level changes. The Tubbs (2017), Nuns (2017), and Kincade (2019) fires affected the Subbasin during the period evaluated. Vegetation health changes from wildfire are reflected as abrupt NDVI declines the year following those fires followed by increases in NDVI in subsequent years (Figure 15). Vegetation regrowth following wildfires may not always be the origin species so the GDE vegetation category may need to be updated in these instances.

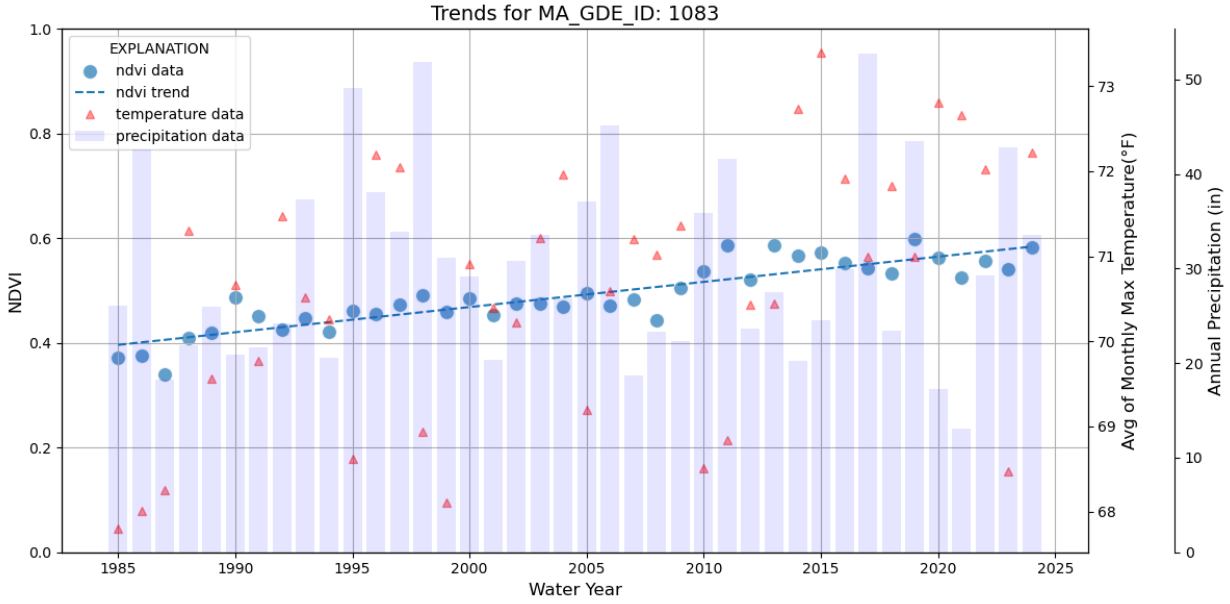


Figure 10. Example of Healthy Oak Woodland

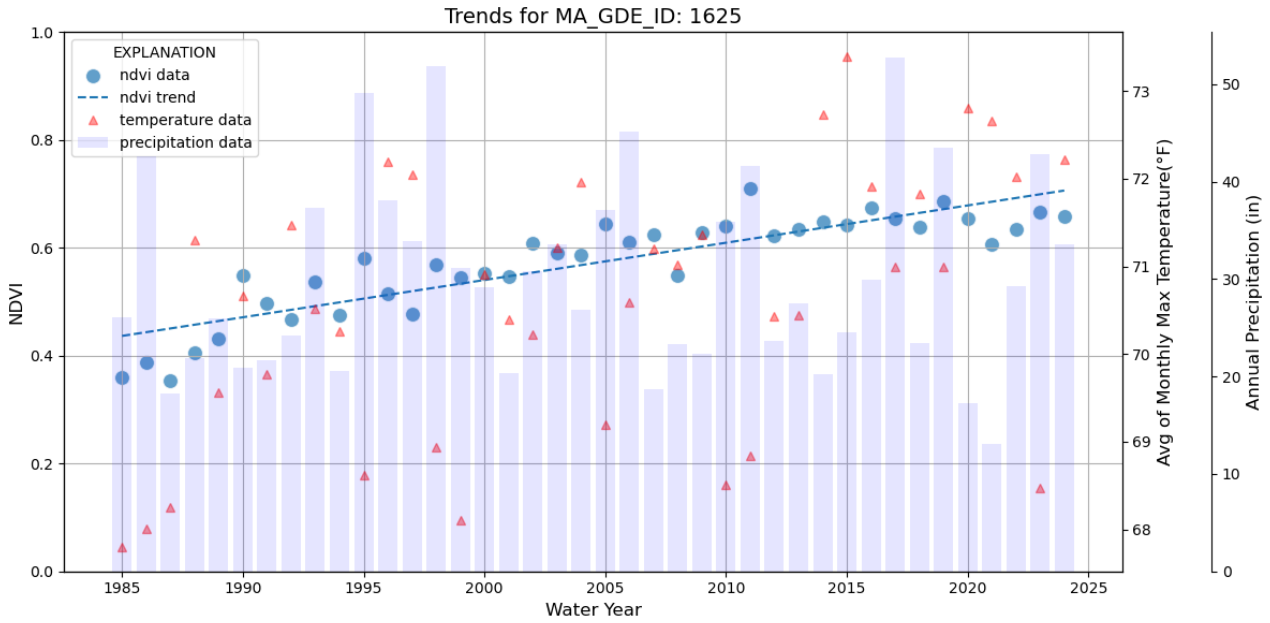


Figure 11. Example of Healthy Riparian Forest

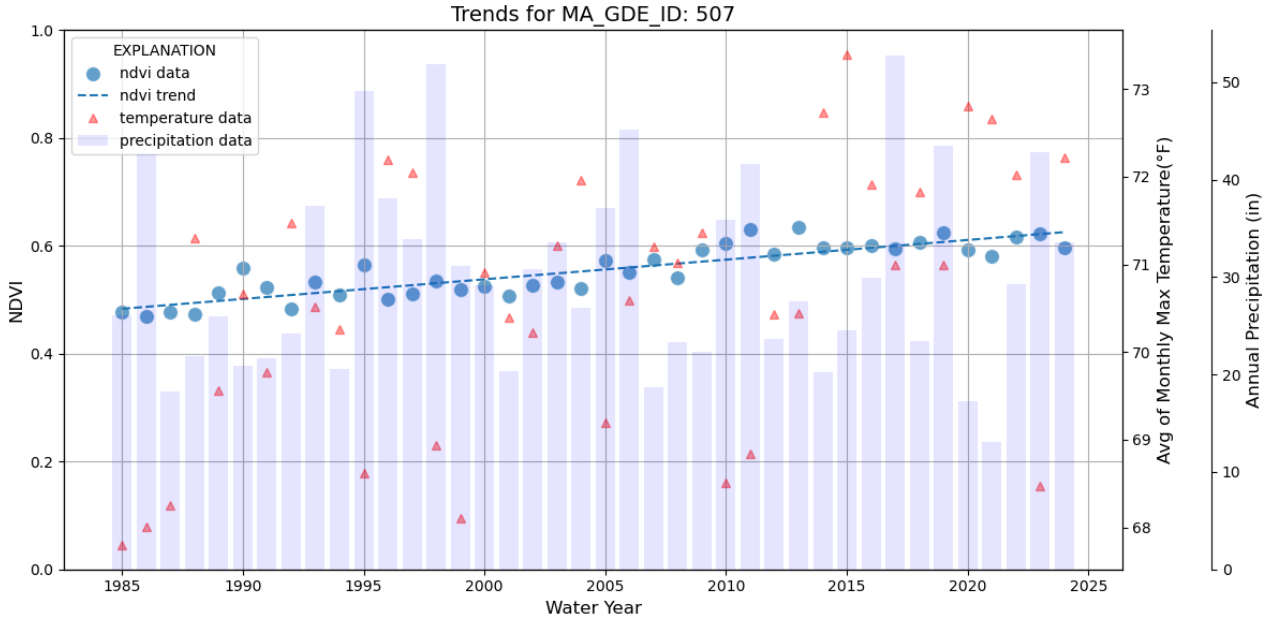


Figure 12. Example of Healthy Wetland

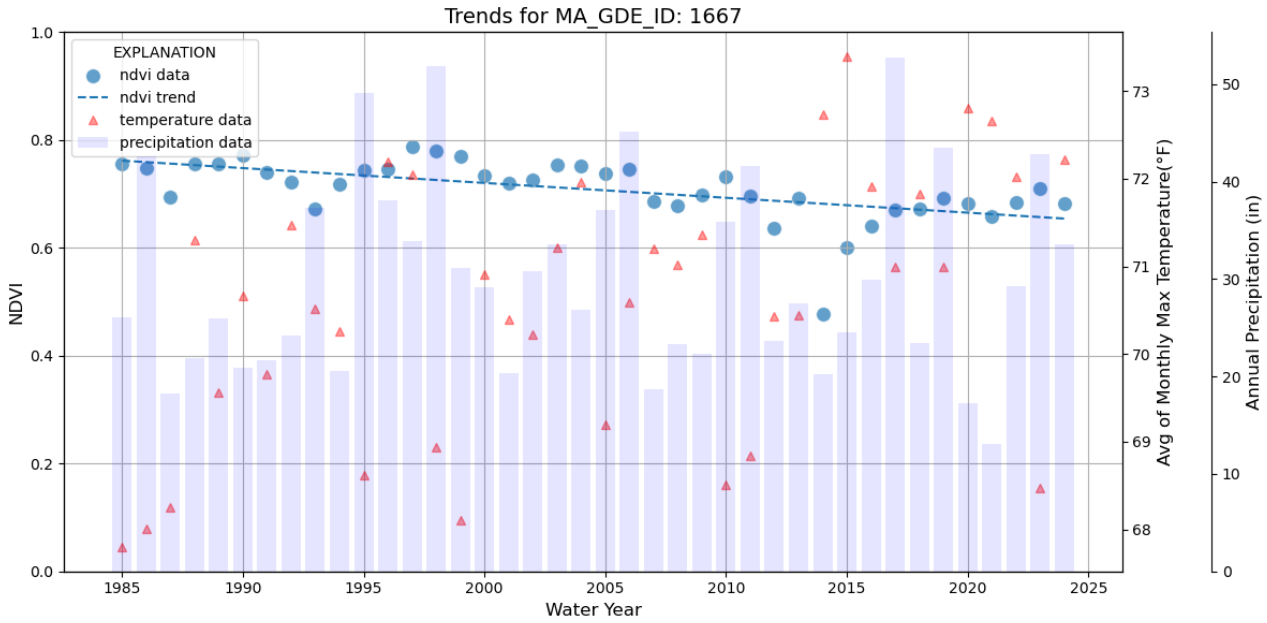


Figure 13. Example of Declining NDVI Trend

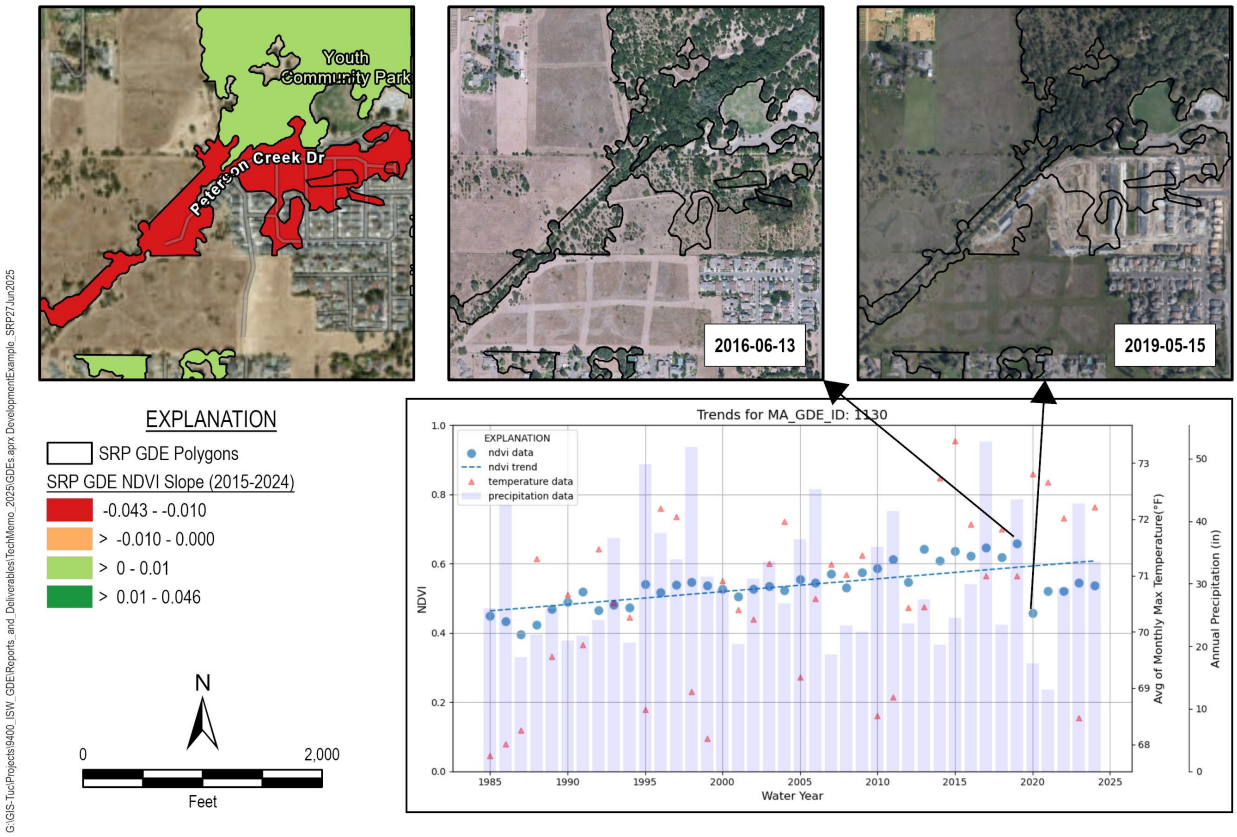


Figure 14. Declining Short-Term NDVI Trend Due to Suburban Development

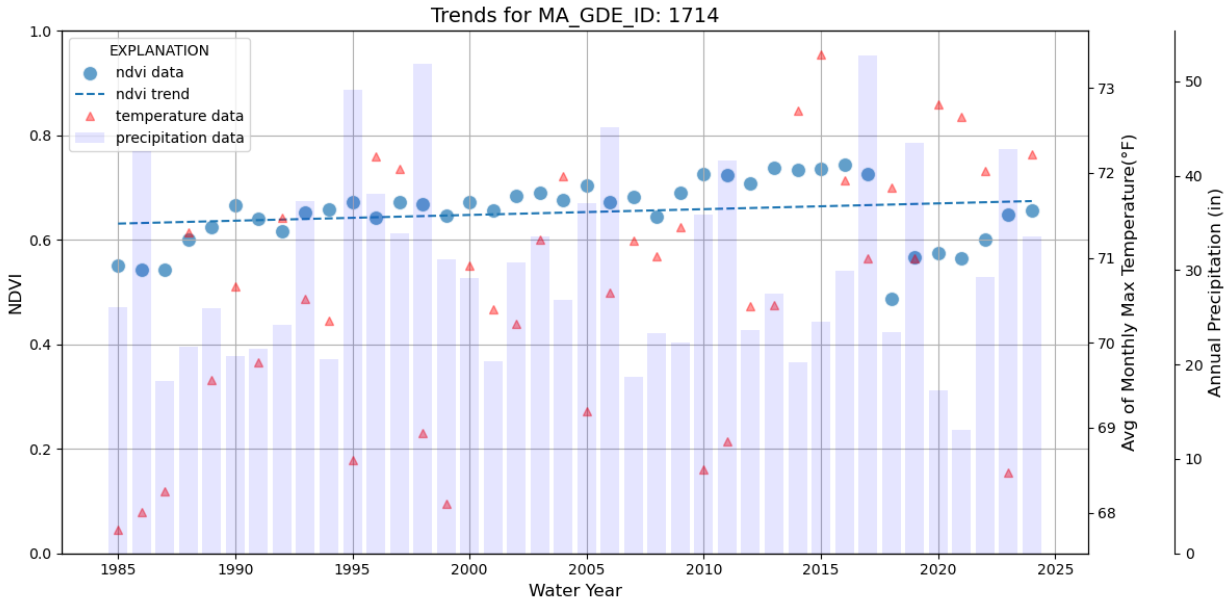


Figure 15. NDVI Changes at a GDE Impacted by the Tubbs Wildfire in 2017

For those GDEs where negative trends are observed and fire or development are not the driver, climate and groundwater levels are reviewed, and further analysis and monitoring should be conducted to understand how and why those GDEs are changing.

Limitations of this analysis are dependent on available groundwater level, imagery, and vegetation data. Groundwater raster data can provide general information about depth to water but discrete points associated with GDE polygons would be more representative of groundwater levels for individual GDE sites. LandSat imagery was used to calculate NDVI and the 30-meter pixel size can misrepresent a GDE polygon depending on the overlap of a GDE and LandSat pixels. Finally, vegetation polygons mapped by NCCAG and Sonoma Veg Map represent classification of vegetation at a particular point in time. Temporary and permanent landscape changes due to land use change or fire may change vegetation types at those locations. These considerations should be taken into account when using updated GDE characterizations for monitoring and management decisions.

MONITORING APPROACH DEVELOPMENT

The ISW/GDE analysis was used to identify remaining data gaps to address with field monitoring and data collection. To determine the monitoring approach for the Santa Rosa Plain Subbasin, the following steps were taken:

1. Collect, combine, evaluate all new relevant data together with existing data
2. Overlay mapped data for a basin-wide evaluation of potential remaining data gaps

3. Assess data gaps for monitoring needs
4. Identify monitoring methods
5. Develop monitoring workplan

The updated ISW and GDE characterization (items 1 – 3) informs recommended field monitoring to fill data gaps and verify satellite data analysis of GDE health. High priority areas for monitoring are scheduled for July/August 2025. A workplan (item 5) was developed to describe the monitoring approaches in greater detail and document monitoring sites. Monitoring locations and datasets used to inform monitoring location selections are available in an ArcGIS Online web map[12]. The following sections focus on the technical considerations that informed monitoring recommendations.

Goals of ISW and GDE Monitoring

Monitoring efforts will support the following remaining analysis needs:

1. Refine ISW and GDE characterization
   - Improve spatial and temporal understanding of interactions between surface water, groundwater and GDE habitat
2. Improve ISW and GDE monitoring
   - Assess/monitor impacts of groundwater pumping on habitats associated with ISW
3. Refine Sustainable Management Criteria for ISW
   - Protect beneficial users from groundwater pumping impacts
   - Support policy-making and planning efforts aimed at addressing or mitigating any projected impacts
4. Recommend projects and management actions that benefit and protect ISW and GDEs from groundwater pumping impacts

12 https://mahydro.maps.arcgis.com/apps/instant/atlas/index.html?appid=ef6cdf6946b5400f8e1b95e10c09d818&webmap=6119c089c82e458e995bebfa4836431c

The additional monitoring data will be used to:

- Improve hydrogeologic conceptual understanding of the shallow aquifer zone as it interacts with overlying streams and may affect GDE habitat
- Inform long-term monitoring network
- Support CEFF monitoring needs
- Support model verification and calibration
- Re-evaluate GSP SMC as necessary during the upcoming 5-year GSP Periodic Evaluation assessment

Potential Monitoring Methods

The GSAs are planning to collect field data to supplement ISW and GDE analyses performed to date and fill remaining data gaps and for longer-term monitoring needs. The *Recommended Approach for Improving ISW and GDE Characterization and Monitoring* (M&A, 2023) outlines various field methods used typically used to evaluate ISW and GDEs. The merits of potential field monitoring approaches from this report were discussed with the GSAs and Work Group at previous meetings.

Potential monitoring methods for ISW and GDEs are summarized in Table 5 and Table 6, respectively. These tables include the method, purpose, pros, cons, and a recommendation for near-term monitoring. Specific recommendations for the Santa Rosa Plain Subbasin are summarized in the following section.

Table 5. Interconnected Surface Water Potential Monitoring Methods

Method	Description	Pros	Cons	Recommendation
Seepage Runs	Field discharge measurements at selected reaches along a creek or river to determine gaining and losing reaches	-Relatively simple to implement -Direct measurement -Can be valuable in combination with other evaluations	-Intensive field work -Results provide snapshots in time and can be misleading for long segments throughout which conditions are variable on a smaller scale, or for which unmeasured tributaries intervene -Influence of precipitation can obscure results if runs occur too soon after rainfall -Measurement error	Continue conducting seepage runs in later summer/early fall only; add Petaluma Valley seepage runs
Flow Connectivity Surveys (wet/dry mapping)	Assess dry-season flow connectivity in critical areas. Map at least four times annually, starting in spring and continuing through the dry season (as long as wet conditions persist within the reach) and include the extent of connected flow, any dry reaches, and the locations of isolated pools. Could be accomplished through field staff, citizen science volunteers, drones surveys.	-Relatively simple to implement -Strong indicator of dry season groundwater contributions to ephemeral streams -Citizen science approach is relatively low cost and provides public education, outreach, and engagement opportunity	-Qualitative, does not measure flows or estimate groundwater contributions -Citizen science approach requires effort to organize and train volunteers. Quality of data recorded may be variable among volunteers.	Potentially in critical areas for aquatic GDEs. Andy Rich (Sonoma Water) has developed a citizen science app STAGE (stream tracking and groundwater evaluation_ that is being rolled out to users in SRP.
Drone Surveys	Flow connectivity monitoring to map wet/dry areas over time. Include both visual and thermal bands to identify where groundwater is entering streams.	-Less labor intensive method for wet/dry mapping -Provides temperature information where continuous temperature data is not available -Cost effective for large areas -Very high resolution data	-Accuracy for this temperature application? -How to filter out other temperature signals? -Complex data processing for thermal data? - Regulatory barriers and access issues	Not recommended since seepage run coverage is generally good

Method	Description	Pros	Cons	Recommendation
Temperature Profiling below Streambeds	Install depth specific temperature sensors in streambed to observe changes in groundwater gains and losses to the stream over time. Temperature data should be analyzed in combination with stream stage data and shallow groundwater data.	-Detailed information about temperature variations at different depths, helping to identify groundwater inflows - Continuous data collection	-Point data -Large amount of data generated can be overwhelming and requires robust data management and analysis systems	Recommended in some areas where shallow groundwater monitoring is not available
Fiber Optic Distributed Temperature Sensing	Fiber-optic cables for continuous temperature measurements along the stream length and identify gaining segments where colder groundwater enters the stream.	Capture fine scale changes in gain/loss conditions that may be averaged out over large seepage run segments	Deploying and maintaining temperature profiling equipment can be challenging	Not recommended; costly
Spring Mapping and Monitoring	Map location of springs, if not known, to identify locations of known groundwater-surface water connection	Potential evidence of groundwater-surface water connection	Costly and time consuming due to large number of springs throughout the basins. Can be difficult to discern what wetted areas are groundwater fed springs based on field observations.	Not recommended

Method	Description	Pros	Cons	Recommendation
Environmental or Artificial Tracers	Environmental tracers can be used to: i. identify if and where groundwater discharge occurs in a surface water body ii. estimate the proportion of different sources of water in a water body iii. estimate the age and velocity of groundwater iv. quantify the groundwater flux to a surface water body.	In addition to providing information on timing of groundwater contribution to streams, information also supports overall understanding of hydrologic conceptual model for basin by providing information on source, age, recharge environment, and mixing of water types.	Some tracers can be expensive and time consuming to monitor but stable isotopes are relatively inexpensive	Stilling wells with loggers to record stage, water temperature, and dissolved oxygen may be useful as a cheaper option to supplement monitoring wells determination of the timing of depletions of ISW (losing conditions)
Additional Targeted Groundwater Level Monitoring	Continuous and high frequency groundwater depth and elevation monitoring paired with streamflow monitoring. -shallow groundwater wells -multi-depth wells to evaluate relationship between shallow groundwater levels and any deeper aquifers where groundwater pumping occurs. -multiple wells located perpendicular to stream to evaluate gaining/losing conditions based on gradient towards/away from stream	Critical direct observation data for assessment of ISWs	Expensive, extensive lead time for permitting and logistics	Not feasible for near-term field work; potential for future additional monitoring needs in the basins
Additional Targeted Stream Gaging Stations	Continuous high frequency streamflow monitoring, paired with shallow groundwater level monitoring	Critical direct observation data for assessment of ISWs	Expensive, extensive lead time for permitting and logistics	Not feasible for near-term field work – note: City of Petaluma received CalSIP funding for 4 new stream gages

Method	Description	Pros	Cons	Recommendation
Geophysical Surveys	Geophysical methods, such as electrical resistivity tomography and electrical magnetism, can provide relatively inexpensive and high-resolution spatial data to identify and map regions of differing soils and water.	Inexpensive	Specialized skills needed for data interpretation	Useful to identify confining layers and groundwater salinity. Not expected to be applicable to ISW analysis in this area where extreme difference in groundwater and surface salinity is not expected in areas of groundwater pumping.
Geomorphic and Streambed Conductivity Assessments	Field surveys to identify channel geometry and conductivity	-Supports model development and calibration -Provides information on streambed habitat	-Conductivity can vary significantly over short distances, making it challenging to obtain representative data - Costly due to the need for advanced technology and skilled personnel	Not directly applicable to ISW characterization, more applicable to model parameters.

Table 6. Groundwater-Dependent Ecosystem Potential Monitoring Method

Method	Description	Pros	Cons	Recommendation
Field verification at selected GDE locations to ground truth remote sensing health indices	Field confirmation of GDE location, type, and health. Ground truth against NDVI. Activities may include: -vegetation type and condition verification -verification of what the likely water source is for GDE habitat -surface water measurements and observations -Specific conductance and temperature -Photographs and qualitative observations -Target field verification during dry season conditions -Observations on human activity, artificial recharge, land use and management practices etc.	- Ground truth remote sensing data - Ground-truthing of a GDE associated with specific geomorphic or hydrogeologic conditions in 1 area may be used to infer the presence and distribution of similar GDEs over larger spatial scales using aerial photographs, for example (DWR, 2022).	- Extensive field work and habitat specialists required - This allows for more efficient GDE identification over larger scales, that can be confirmed as necessary.	Recommend verifying remote sensing monitoring at select sites.

ISW & GDE MONITORING RECOMMENDATIONS

ISW and GDE data collection and analysis since GSP development has improved understanding of conditions. There are a few remaining data gaps that can be addressed with near-term field monitoring.

Based on the methods reviewed and summarized in Table 5 and Table 6, our recommendation is to use several methods grouped into a complementary approach to fill data gaps and improve ISW and GDE understanding. The subsections below describe the methods in more detail.

ISW Monitoring Recommendations

The seepage run network in Santa Rosa Plain Subbasin is extensive with minimal data gaps on major streams. Discharge measurements are only taken along a single point along Roseland Creek during the seepage runs and an additional downstream location is recommended for completeness to classify the gain/loss conditions of that stream as it approaches Laguna De Santa Rosa.

M&A recommended an ISW-focused monitoring system comprised of stilling wells coupled with shallow piezometers and a subsurface temperature rod to provide data for further evaluation of both ISW and aquatic GDE conditions in critical areas Figure 16 provides a schematic of an ISW monitoring cluster. An advantage of this setup is the low cost and ease of installation compared to monitoring wells and stream gage stations. This monitoring setup includes equipping the 3 monitoring features as follows:

- Stilling well with dataloggers to monitor stream stage and temperature
- Two piezometers per site (one on the bank and the other in the middle of the stream) with pressure transducers to monitor shallow groundwater elevation
- Temperature rod with temperature sensors to measure the temperature depth profile at discrete depths below the streambed; analysis of the data will be useful for estimating surface water and groundwater interactions

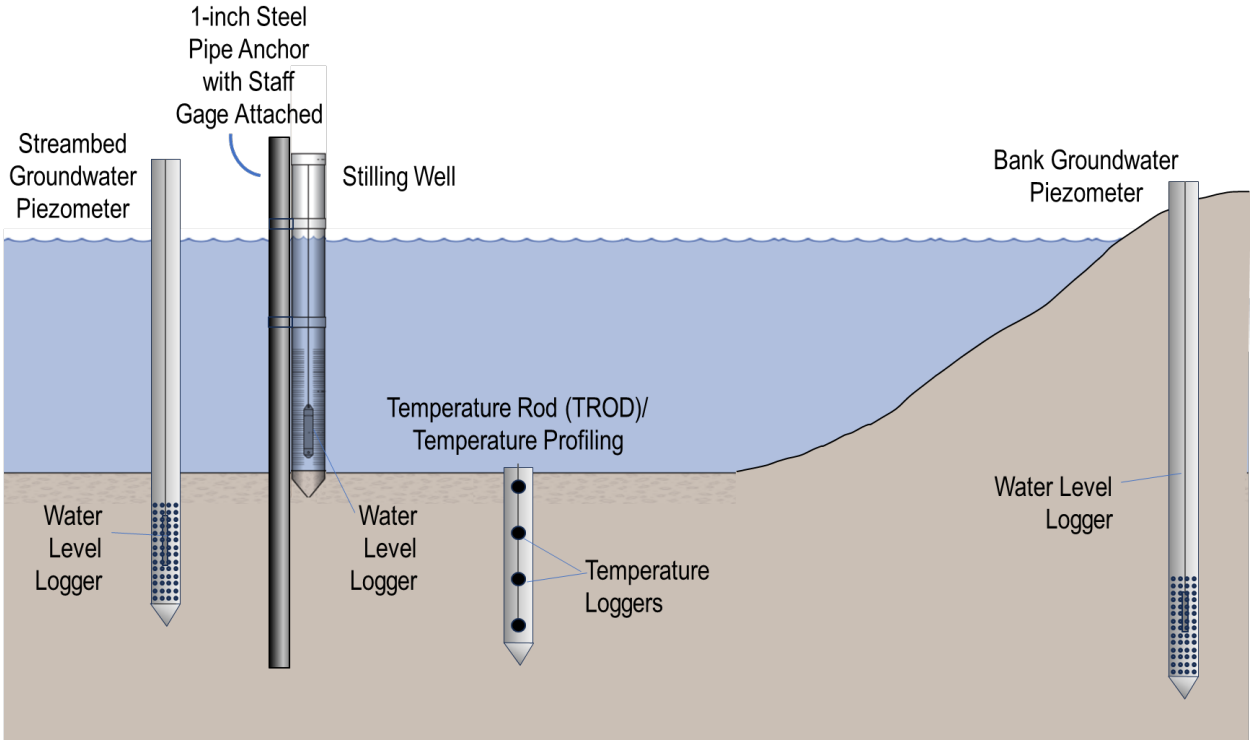


Figure 16. Schematic Diagram of Stilling Well/Piezometer/Temperature Rod Installation

Technical considerations that informed selection of potential ISW monitoring cluster installations in the Subbasin included:

- Existing ISW monitoring: prioritize locations with no existing shallow groundwater and streamflow data, although at least 1 installation should be co-located with an existing well and stream gage to verify correlation with the piezometer and stilling well data
- Critical habitat: prioritize additional monitoring on sections of streams with mapped presence of salmonid resources and no existing monitoring features
- ISW classification: prioritize refined characterization of stream segments that vary between gaining and losing conditions
- Shallow well density: prioritize additional monitoring along streams that flow through areas of relatively higher shallow well density, which may indicate a higher potential for depletion of ISW from groundwater pumping
- GDE health: clear relationships between GDE health and ISW conditions have not been observed, as even losing reaches of stream segments supported healthy GDEs with increasing NDVI trends. Regardless, areas of declining GDE health should be prioritized for additional monitoring, such as the oak GDEs along Windmill Creek near Llano Rd.

Guided by these considerations, 7 potential stilling well/piezometers/temperature rod installation sites were recommended. Prioritization and feasibility of various locations were evaluated in collaboration with Sonoma Water, resulting in 3 monitoring site locations selected. The Santa Rosa Plain Subbasin sites and the installation of the monitoring clusters are described in an ISW Monitoring Cluster Installation Technical Memorandum (Attachment 3).

GDE Monitoring Recommendations

Characterization of GDE health using NDVI is the main criteria used to select GDEs to monitor. Within each vegetation category (oak woodland, riparian forest, and wetland) different health categories are selected for monitoring. Trends in vegetation health and significant changes in vegetation health from 2015 to 2023 are also considered in selecting monitoring locations. Density of shallow groundwater wells and GUIDE data are used to understand how changes in GDE health could be attributed to groundwater pumping. Without more clear information about groundwater use, those datasets are used as a visual aid in the selection of monitoring locations. Areas influenced by fire or experiencing land use changes are excluded from monitoring considerations.

For the Santa Rosa Plain Subbasin, 11 areas representing different vegetation categories and NDVI values were initially selected as potential survey sites. Based on access limitations due to some sites being on private property, 6 GDE survey sites of approximately 0.5 acres were surveyed in September 2025. Two surveys were in riparian forest and 4 sites in oak woodlands. The form developed for field surveys is included as Attachment 4. Figure 17 shows the location of the surveys within the Basin. Table 7 provides a summary of the field surveyed GDE health conditions compared to average NDVI values between July and September 2025 and the recent NDVI trend.

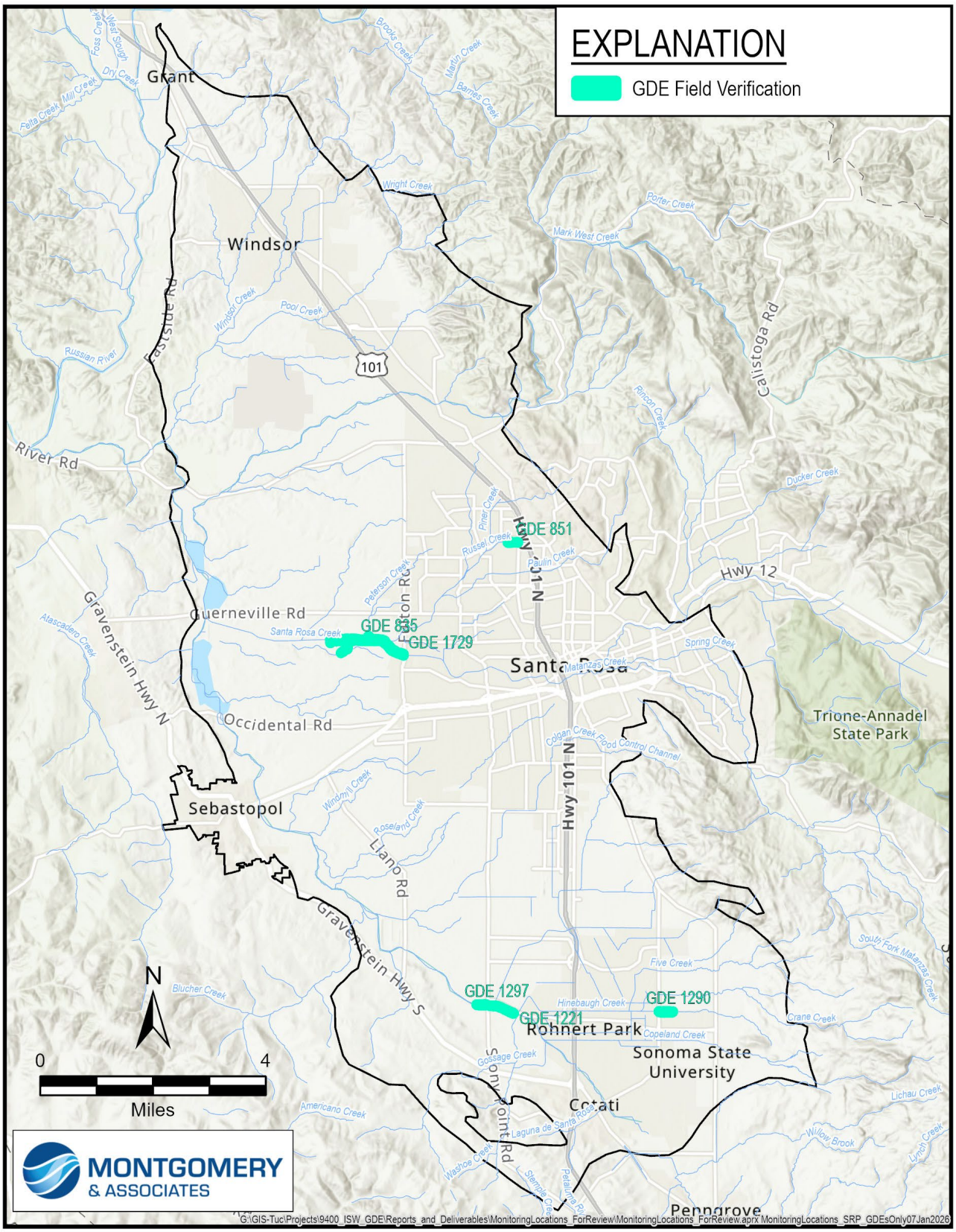


Figure 17. Santa Rosa Plain Subbasin GDE Survey Locations

Table 7. Summary of Santa Rosa Plain Subbasin GDE Surveys (September 2025)

GDE Survey Site	GDE Site Number GDE Classification	GDE Health Summary	Average NDVI (Jul-Sept 2025) and Recent Trend
Santa Rosa Creek Trail Location "Oaks"	SRP GDE 835 Oak and Laurel	The ecosystem is generally healthy, with robust vegetation and typical fauna. Minor stress indicators are present in some trees, but there is no sign of acute ecosystem degradation.	0.69 Increasing
Santa Rosa Creek Trail Location "Riparian"	SRP GDE 1729 Riparian	The ecosystem is vigorous and not stressed overall, with dense willow cover and healthy riparian vegetation. Some localized stress in understory species. Human disturbance and nearby land use changes due to vineyard removal.	0.73 Increasing
Laguna West	SRP GDE 1221 Riparian	The ecosystem is vigorous and well-covered, with most dominant species showing little to no stress. Some localized stress and mortality in sandbar willow and cocklebur, especially in trampled areas. Dense vegetation and lack of observed fauna may be due to heat of day.	0.63 Recovering – GDE health appears to decline in very wet years where GDE are impacted by high flows
Laguna East	SRP GDE 1297 Riparian	The ecosystem is generally healthy, with most dominant species showing little stress. Some Oregon ash trees are stressed due to dryness and insect damage. Non-native species present but not dominant. Dense vegetation and lack of surface water may affect some species.	0.78 Increasing - GDE health appears to decline in very wet years where GDE are impacted by high flows
Laurence E. Jones School Rohnert Park	SRP GDE 1290 Riparian	The ecosystem is healthy and well-vegetated, with dense pockets of willow and a mix of mature and young trees. Some non-native species show stress, but dominant native species are vigorous. Human maintenance is limited to edges, allowing for natural creek conditions.	0.72 Increasing - GDE health appears to decline in very wet years where GDE are impacted by high flows
Russell Creek East of Range Ave	SRP GDE 851 Oak and Laurel	The ecosystem is robust, with high canopy and plant cover and healthy aquatic and terrestrial species. Some stress in willows and coast live oaks, but overall vegetation is vigorous. Non-native species present but not dominant. Human disturbance is present but does not appear to significantly impact ecosystem health.	0.43 Increasing

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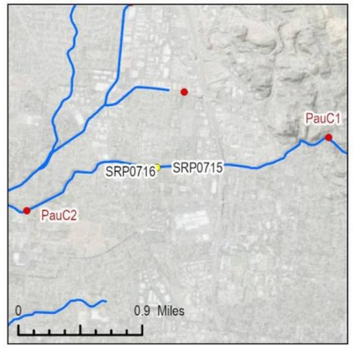
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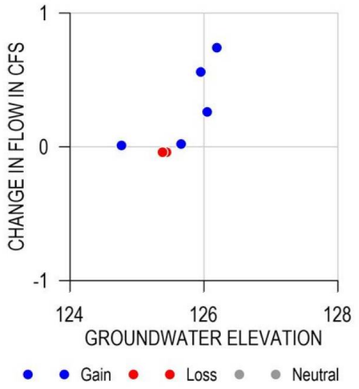
MONTGOMERY & ASSOCIATES

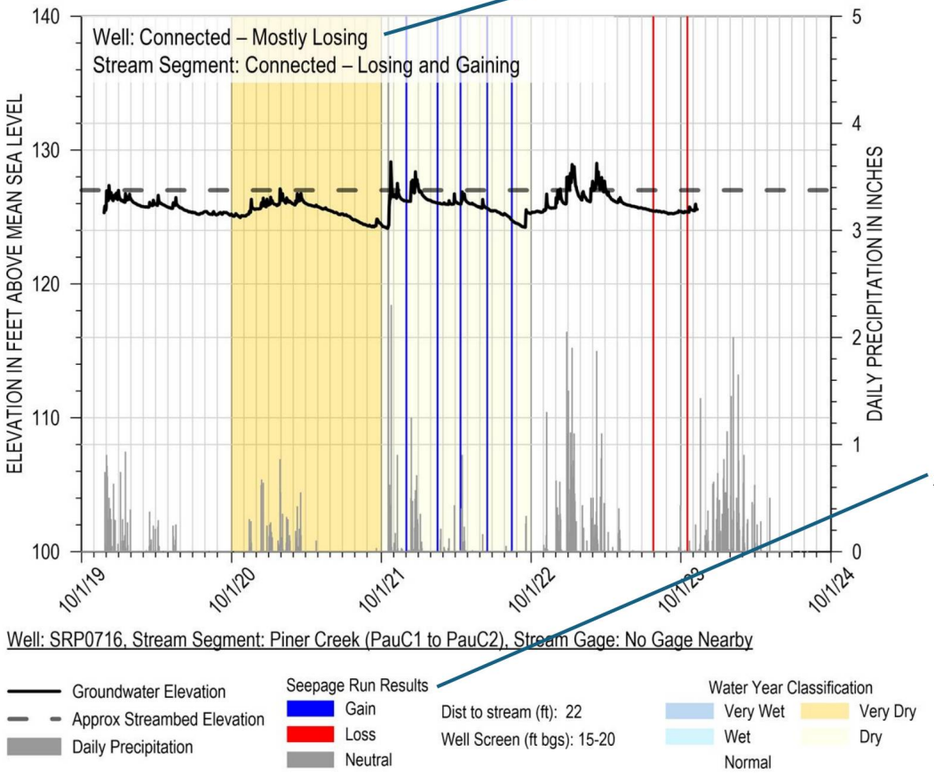
ATTACHMENT 1

SANTA ROSA PLAIN SUBBASIN INTERCONNECTED SURFACE WATER (ISW) HYDROGRAPHS

ISW Classification Rationale







Hydrographs are shown with seepage run results if the well is situated near the middle or downstream end of the stream segment.

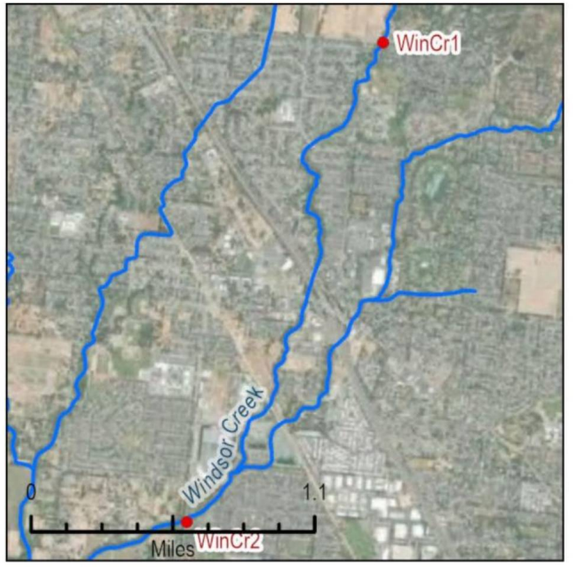
Well

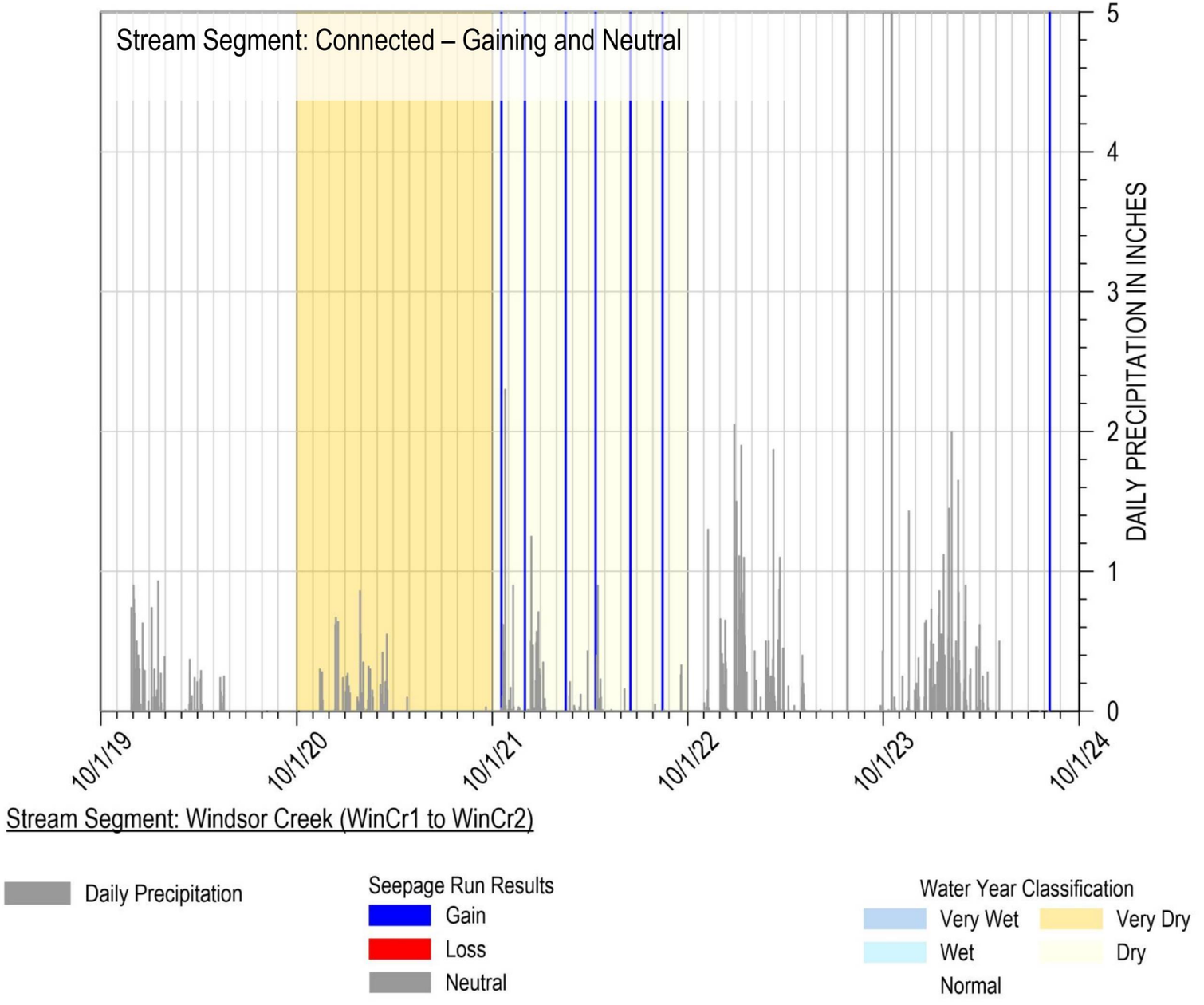
- Disconnected: Groundwater (GW) elevation is below streambed elevation and GW level trends do not track stage/precipitation trends
- Connected: GW elevation is at times above the streambed elevation or GW levels trends track stage/precipitation trends
  - Gaining: GW elevation is above streambed elevation
  - Losing: GW elevation is below streambed elevation
  - Mostly Losing: GW elevation is generally below streambed elevation, raises above only for short periods in response to precipitation events
  - Gaining and Losing: GW elevation fluctuates above and below the streambed seasonally

Stream Segment

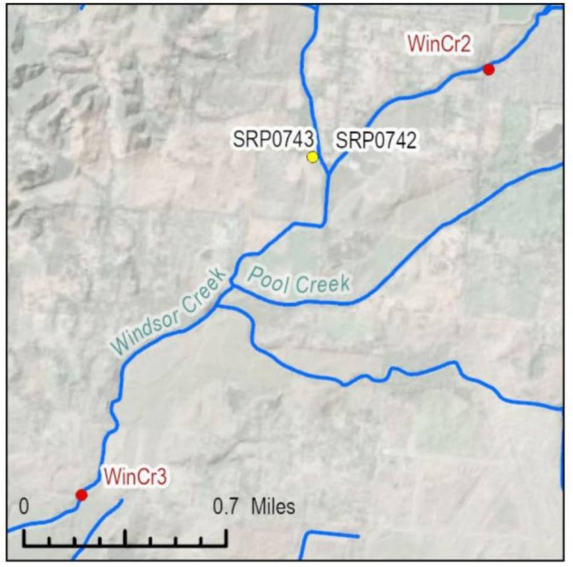
- Gaining: Downstream flow measurement is greater than sum of applicable upstream flow measurements
- Losing: Downstream flow measurement is less than sum of applicable upstream flow measurements
- Neutral: Difference between downstream flow measurement and sum of applicable upstream flow measurements is less than measurement error
- “Mostly” Gaining/Losing/Neutral indicates at least 80% of the seepage runs for that segment resulted in the same classification

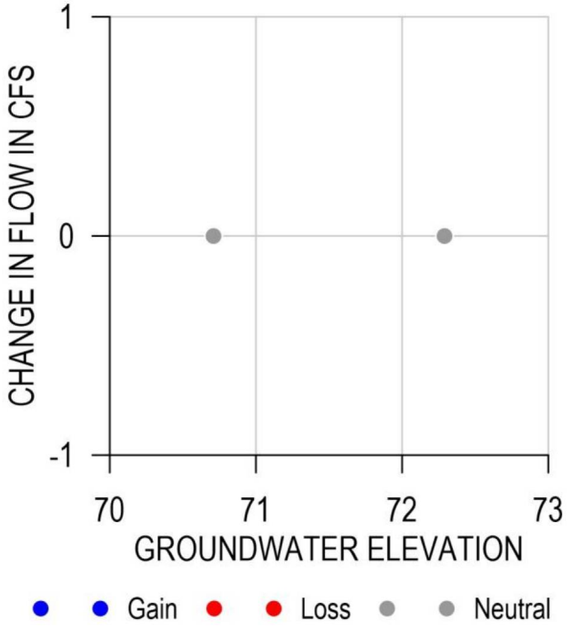
MONTGOMERY & ASSOCIATES

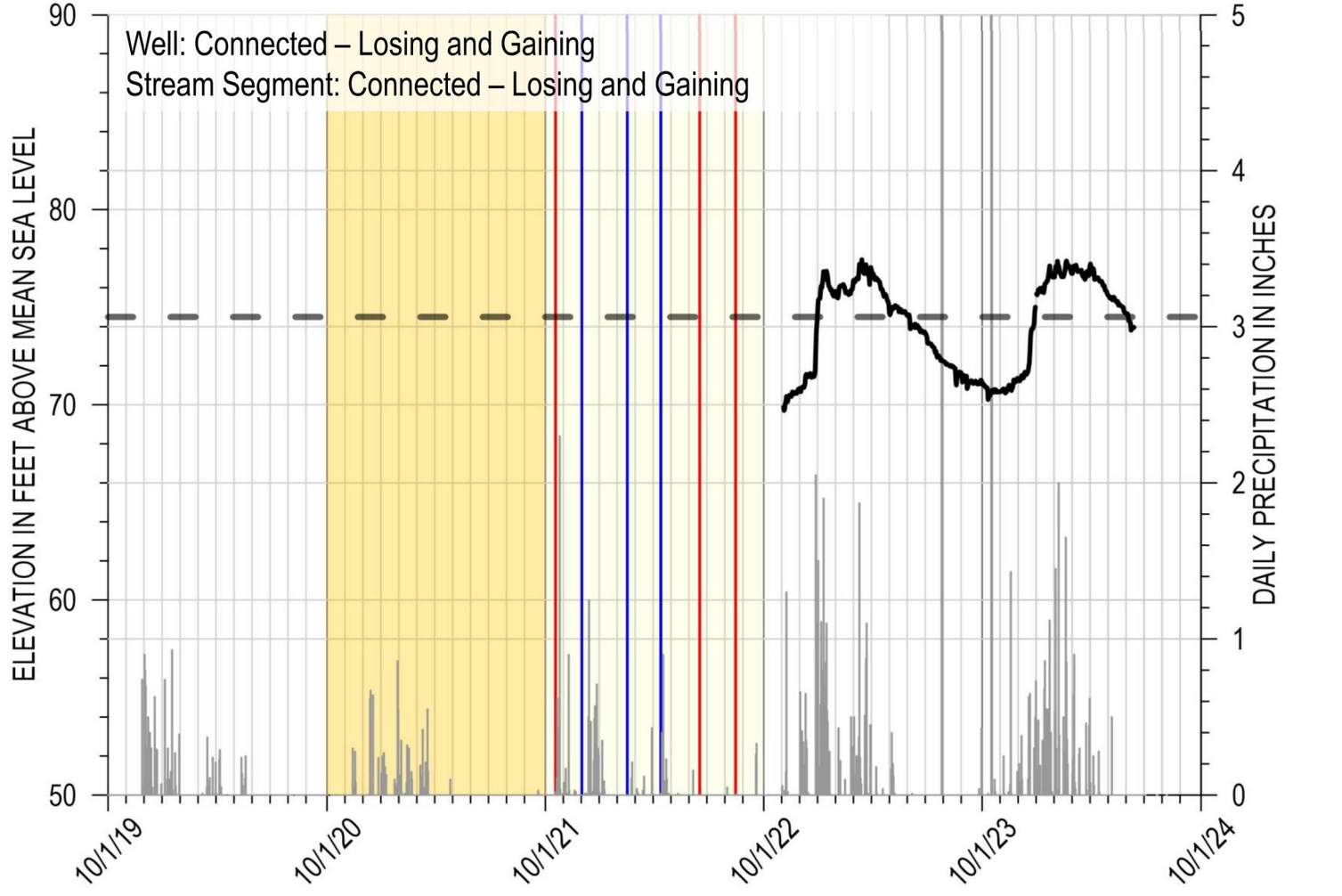




MONTGOMERY & ASSOCIATES







Well: SRP0742, Stream Segment: Windsor Creek (WinCr2 to WinCr3), Stream Gage: No Gage Nearby

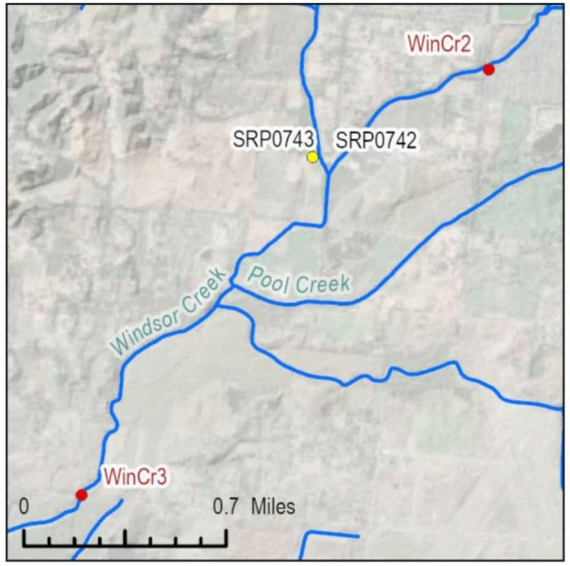
Groundwater Elevation
Approx Streambed Elevation
Daily Precipitation

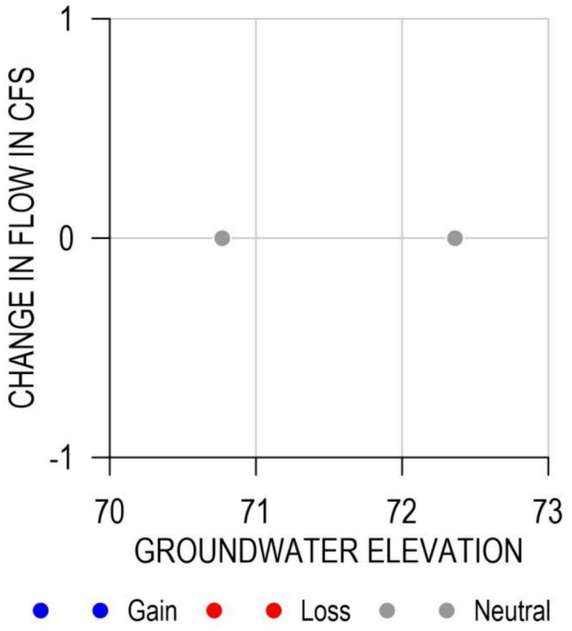
Seepage Run Results
Gain
Loss
Neutral

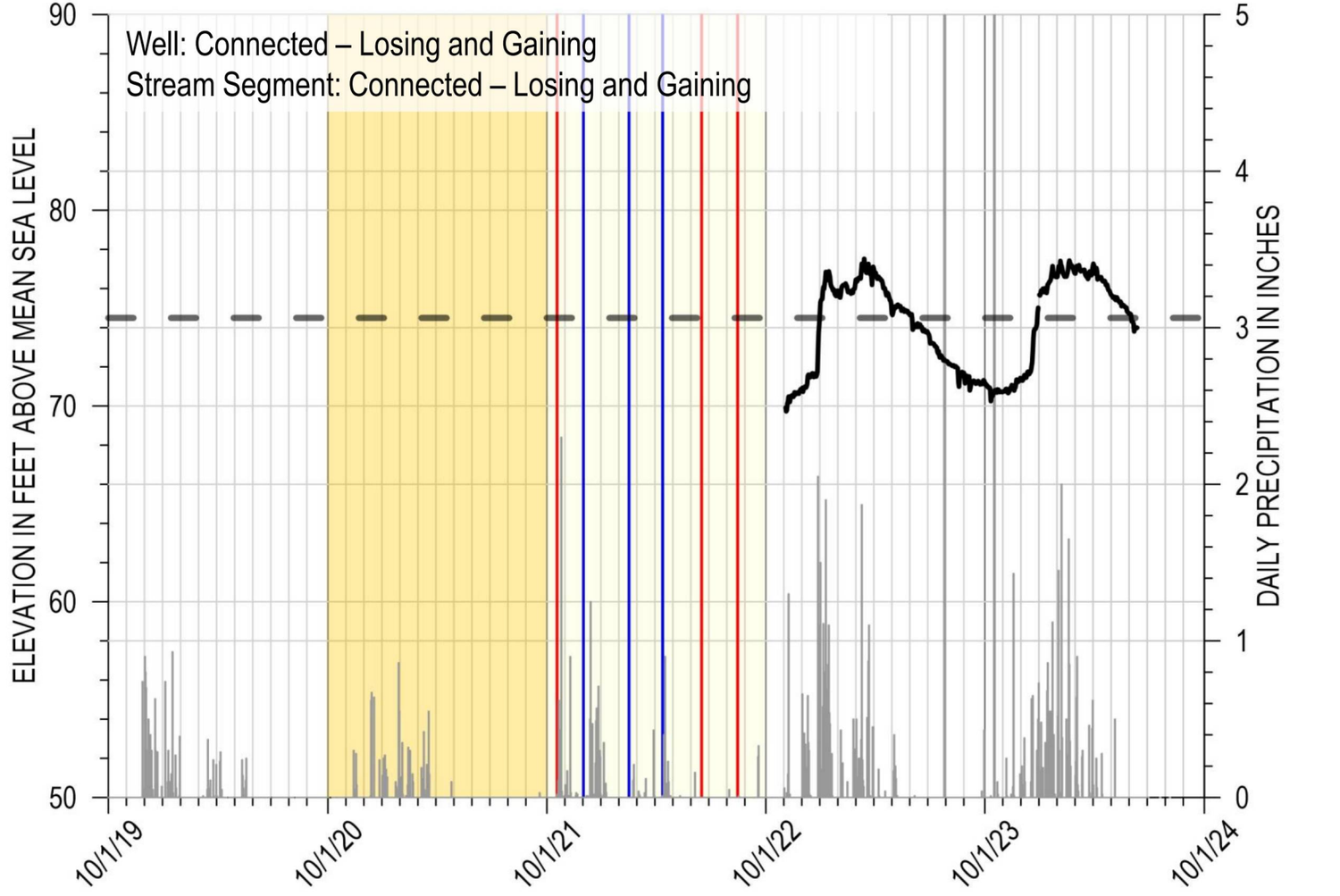
Dist to stream (ft): 126
Well Screen (ft bgs): 30-45

Water Year Classification
Very Wet
Wet
Normal
Dry
Very Dry

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Well: SRP0743, Stream Segment: Windsor Creek (WinCr2 to WinCr3), Stream Gage: No Gage Nearby

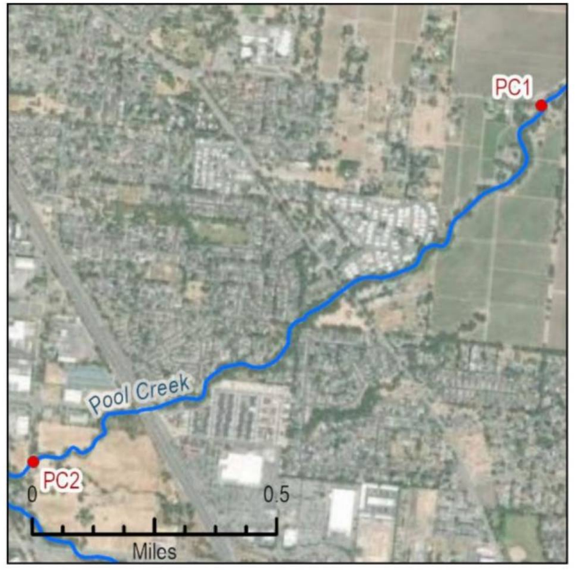
Groundwater Elevation
Approx Streambed Elevation
Daily Precipitation

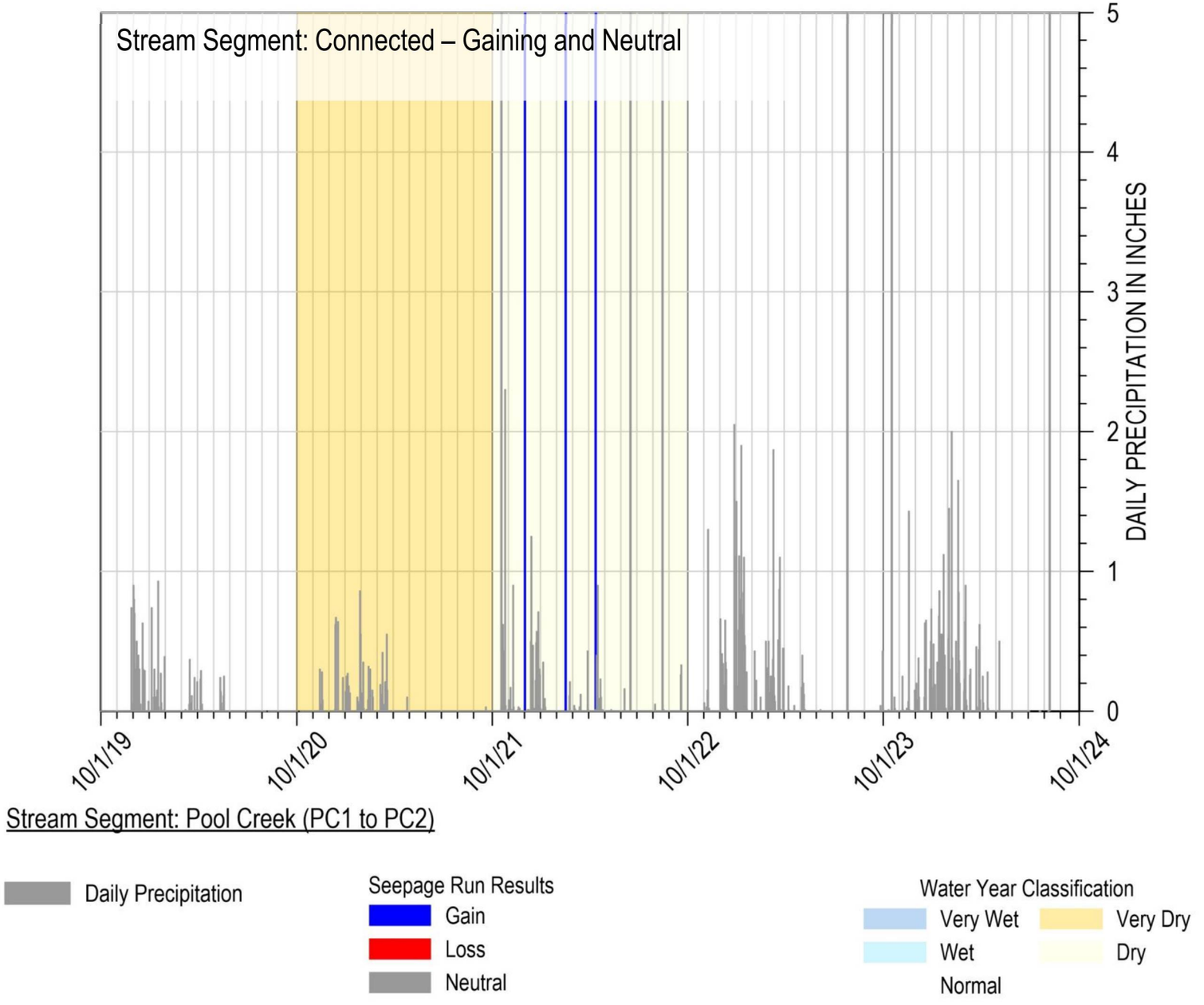
Seepage Run Results
Gain
Loss
Neutral

Dist to stream (ft): 126
Well Screen (ft bgs): 66-81

Water Year Classification
Very Wet
Wet
Normal
Dry
Very Dry

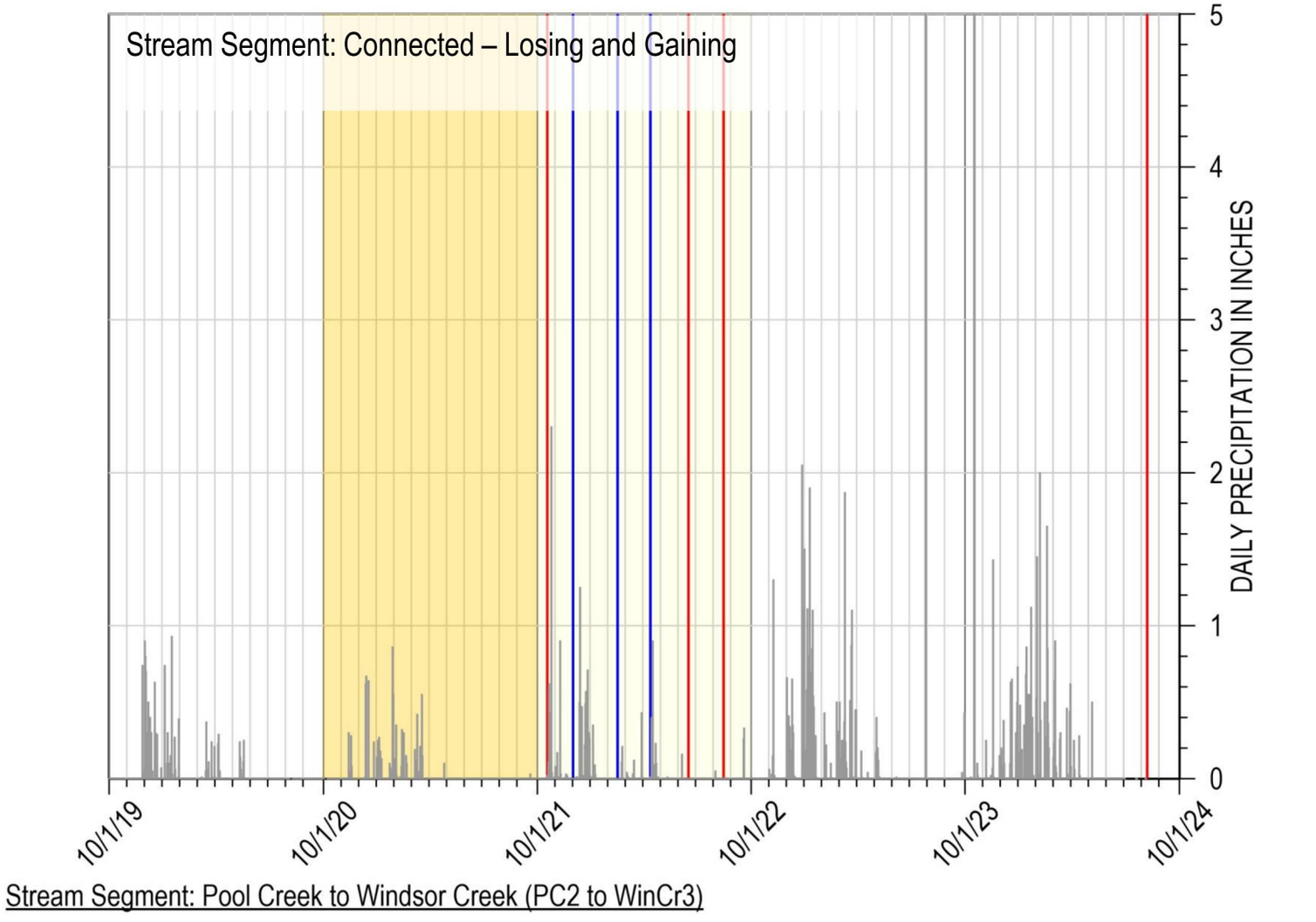
MONTGOMERY & ASSOCIATES



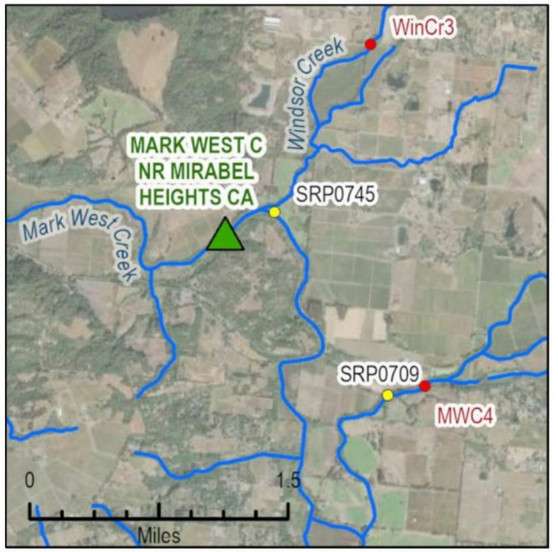


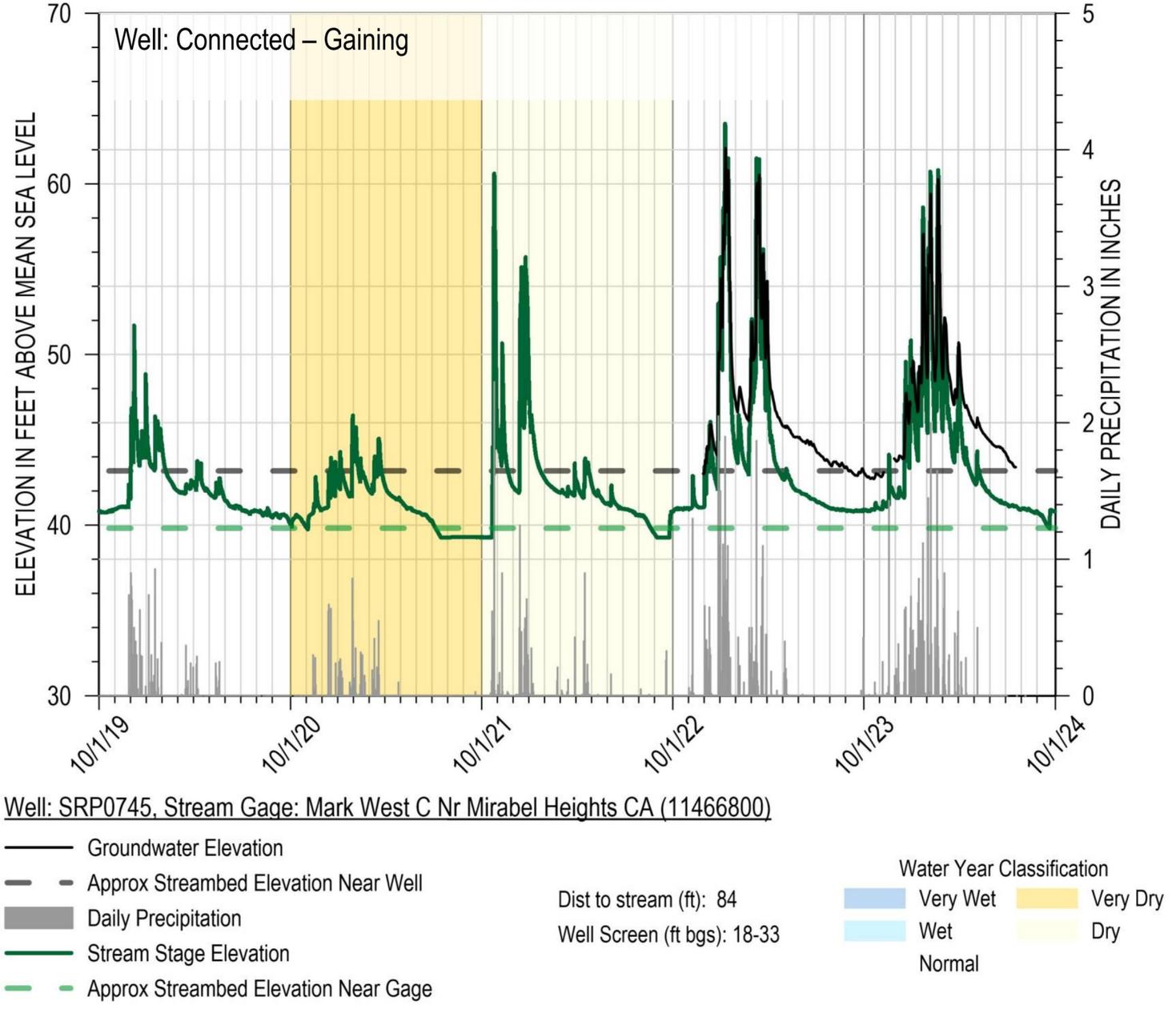
MONTGOMERY & ASSOCIATES



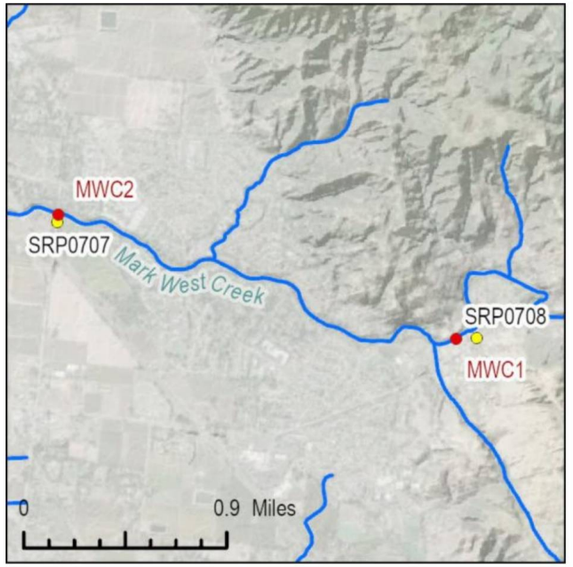


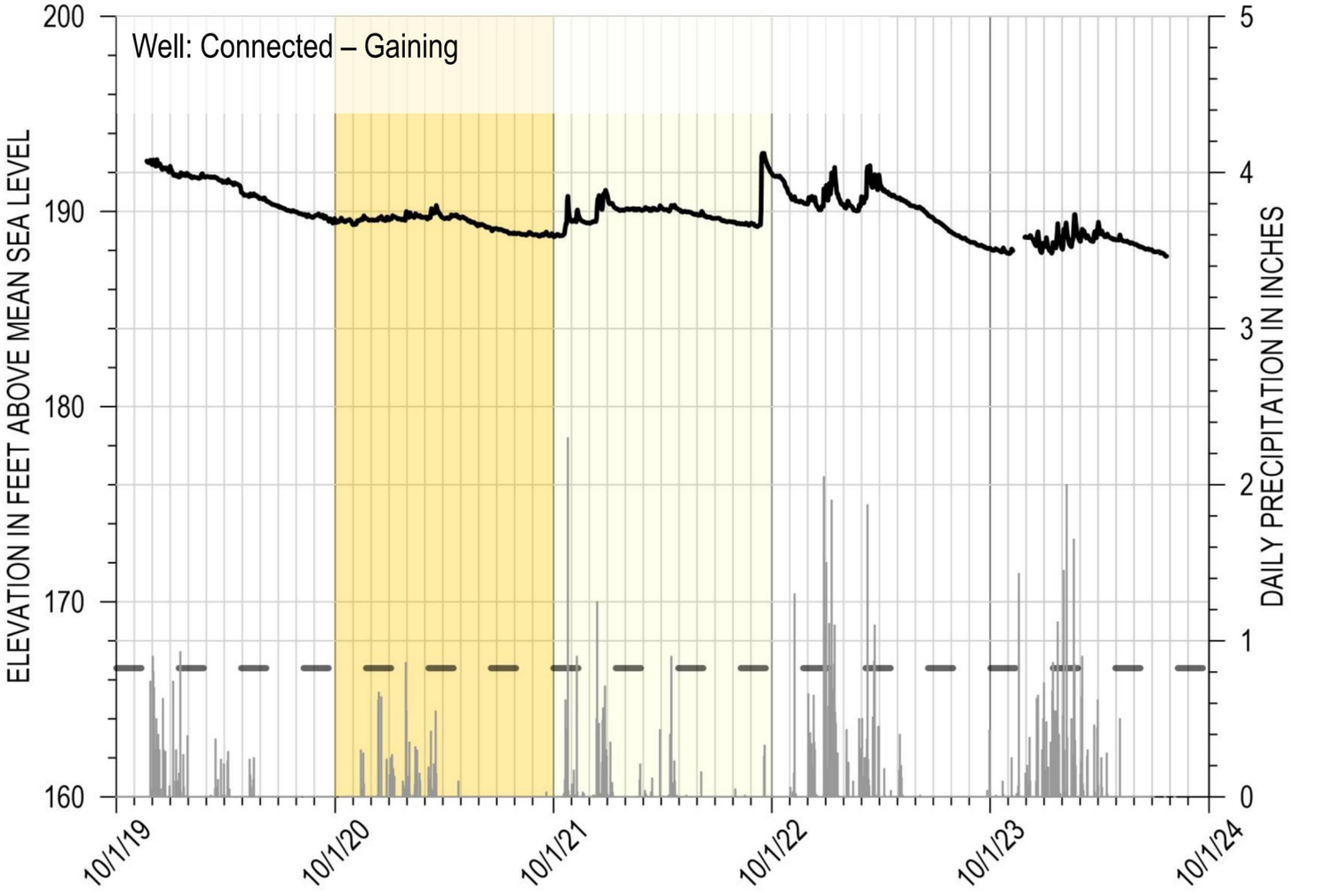
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Well: SRP0708, Stream Gage: No Gage Nearby

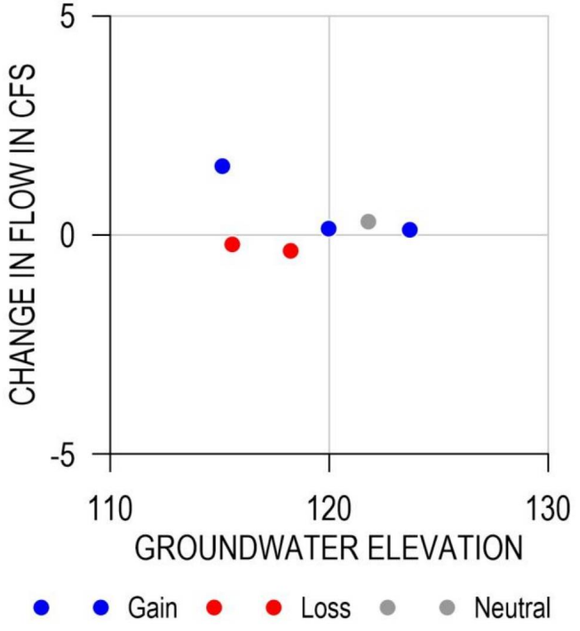
Groundwater Elevation
Approx Streambed Elevation
Daily Precipitation

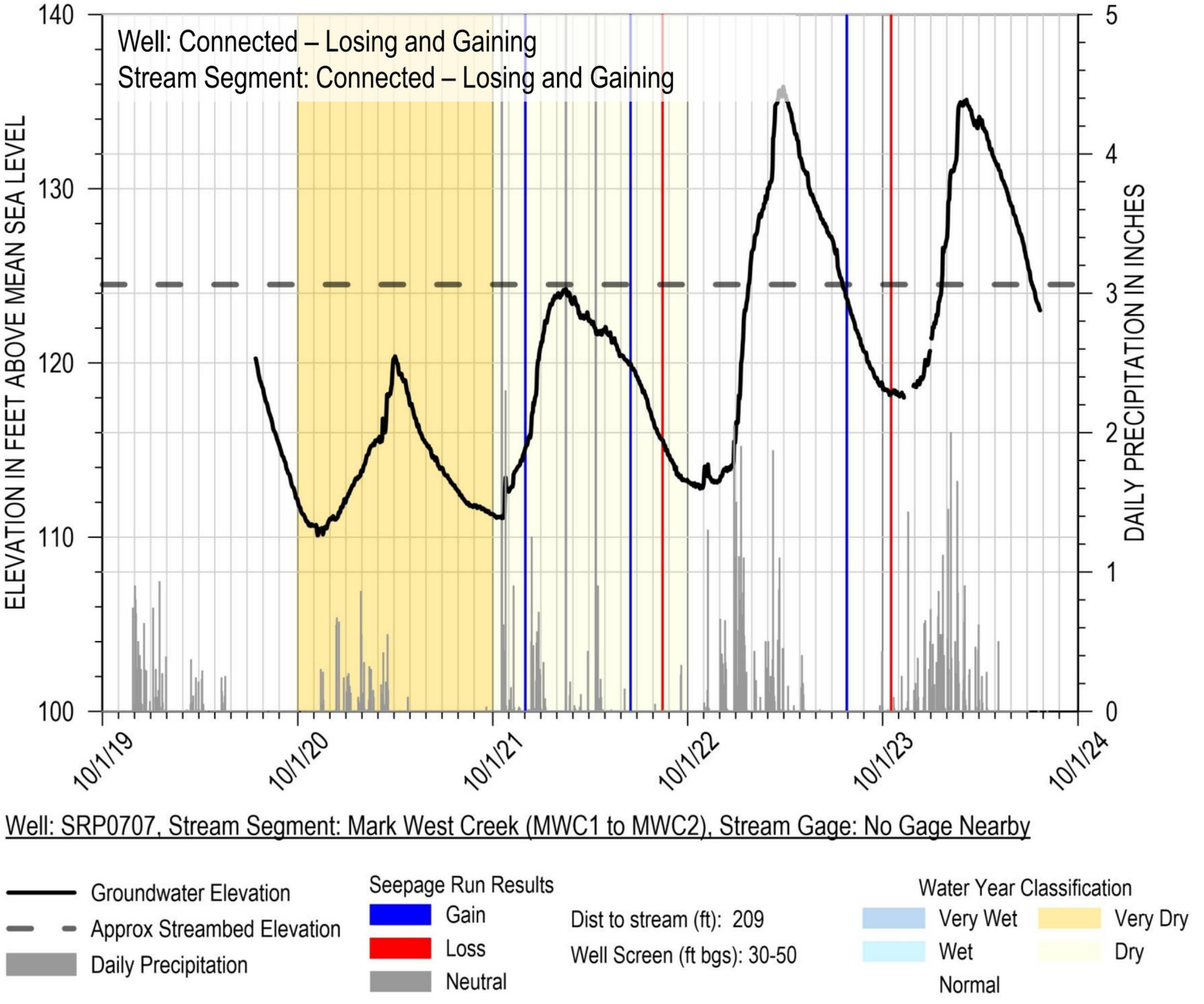
Dist to stream (ft): 217
Well Screen (ft bgs): 15-25

Water Year Classification
Very Wet
Very Dry
Wet
Dry
Normal

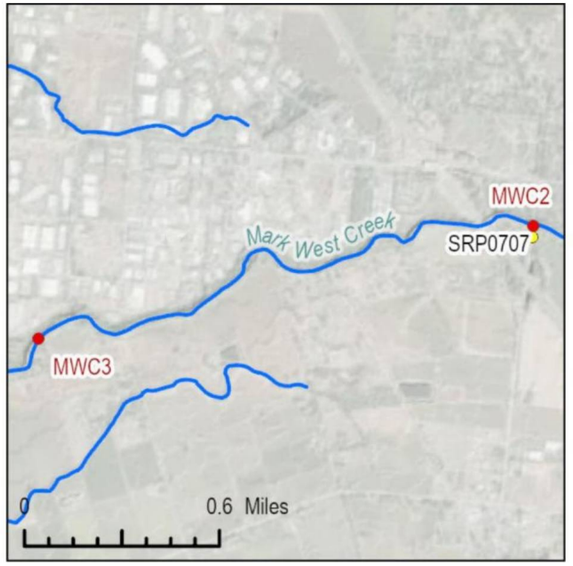
MONTGOMERY & ASSOCIATES

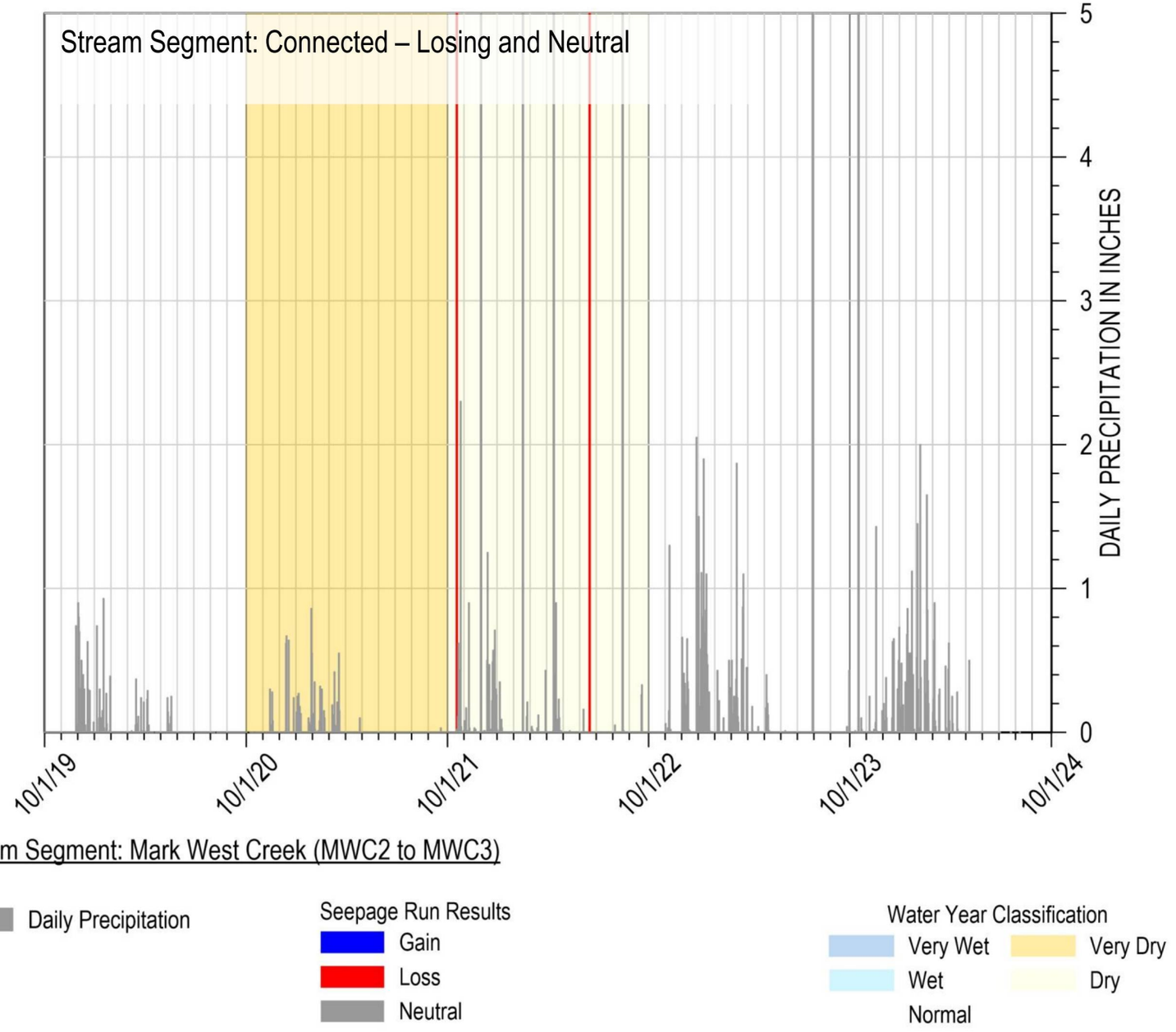




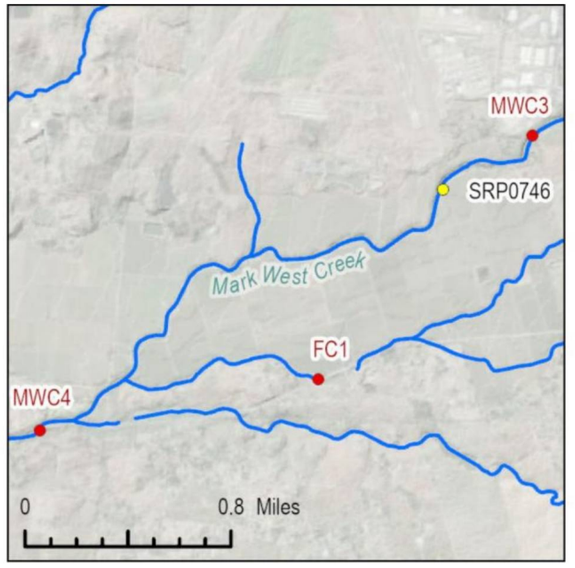


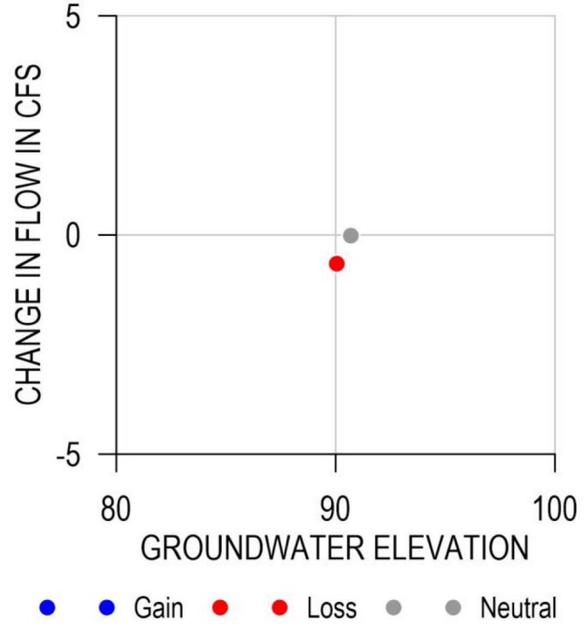
MONTGOMERY & ASSOCIATES

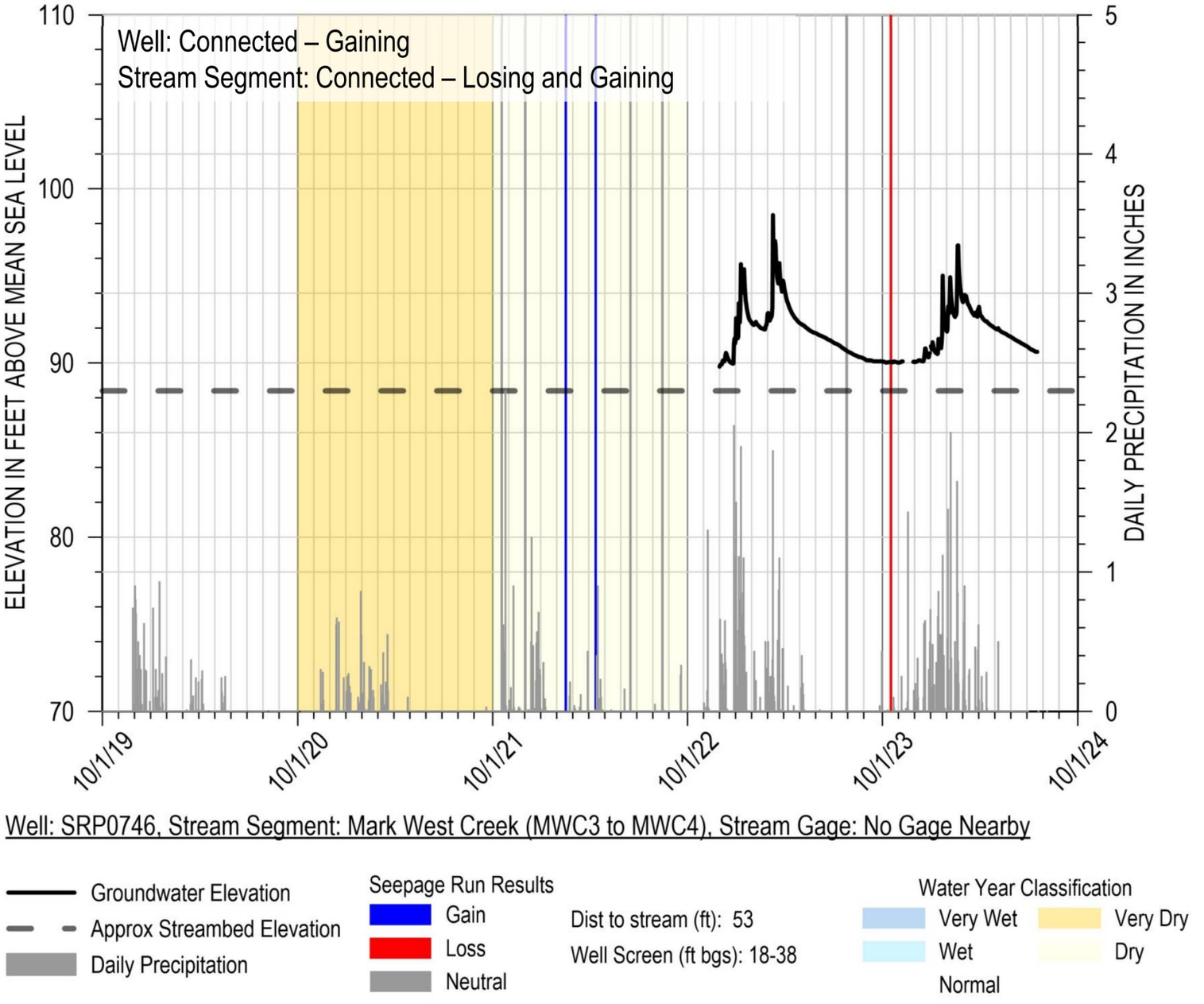




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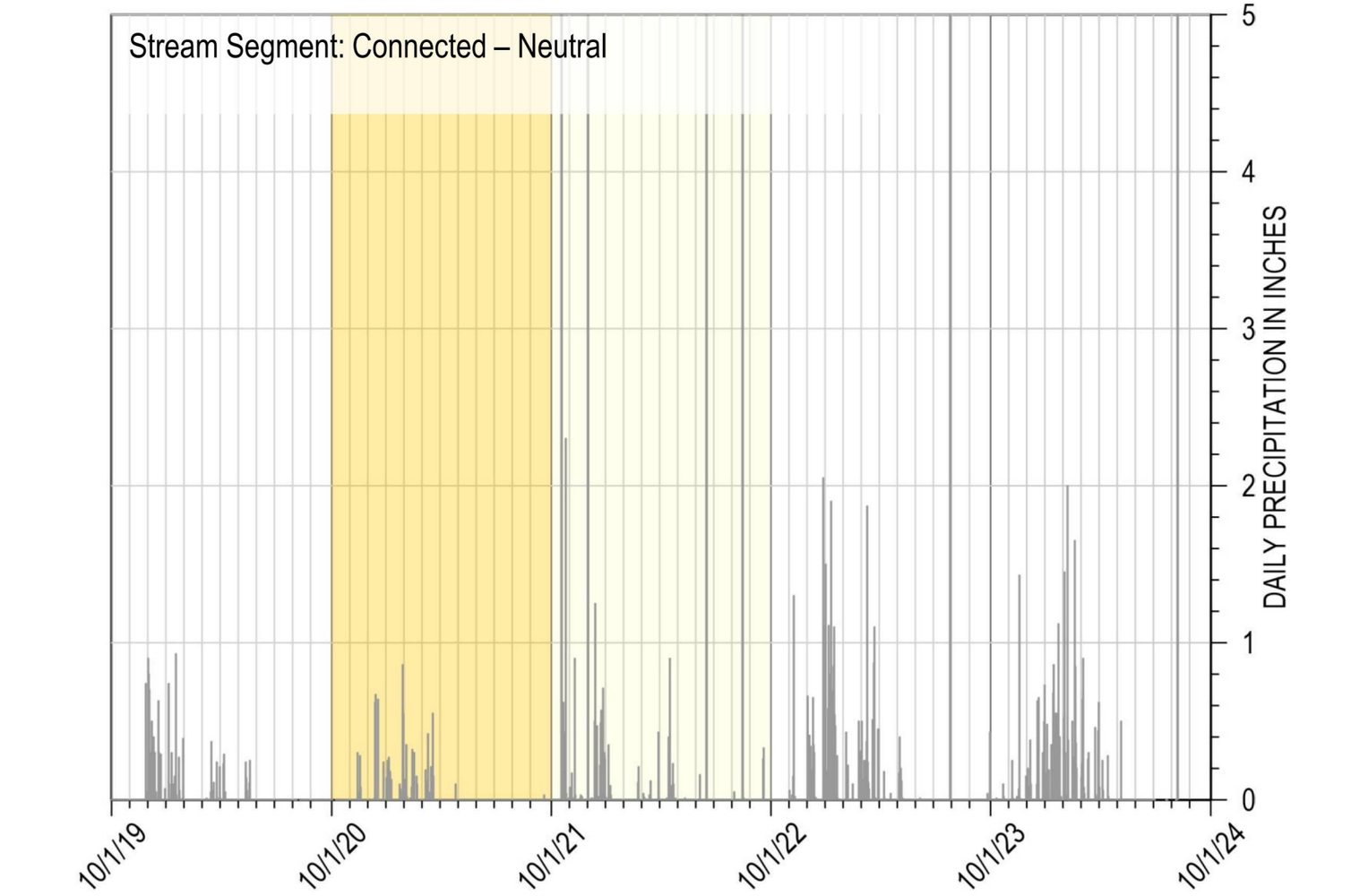






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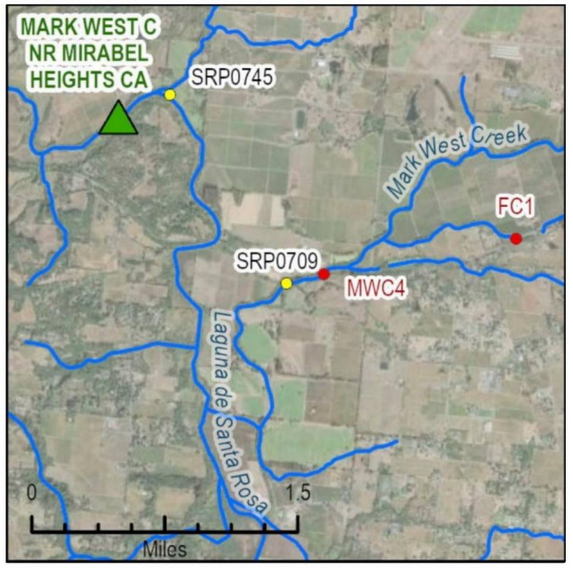
Stream Segment: Mark West Creek (FC1 to MWC4)

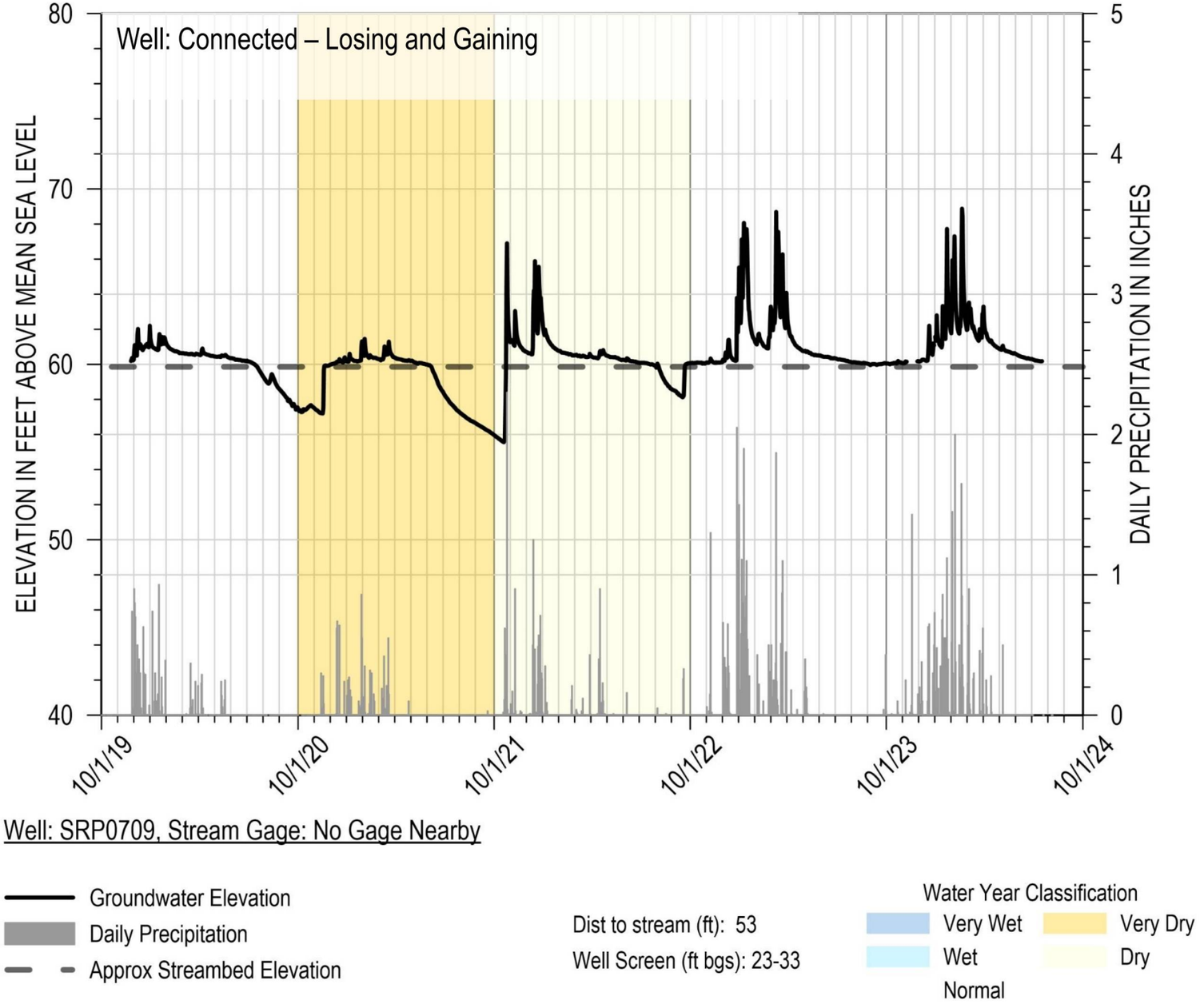
Daily Precipitation

Seepage Run Results
- Gain
- Loss
- Neutral

Water Year Classification
- Very Wet
- Wet
- Normal
- Very Dry
- Dry

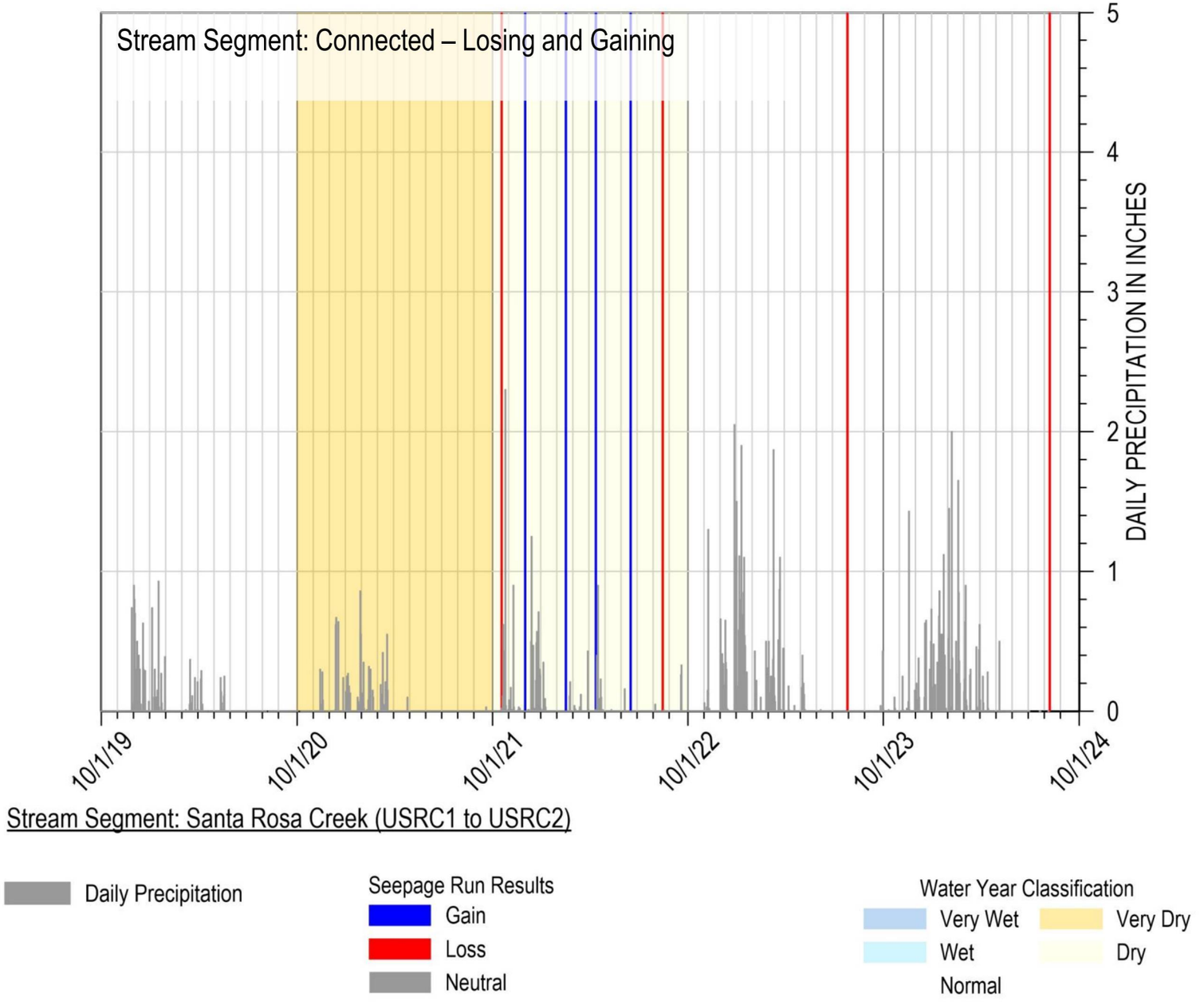
MONTGOMERY & ASSOCIATES



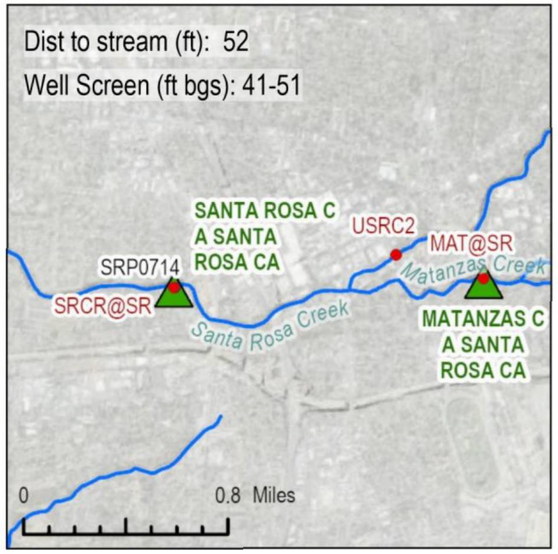


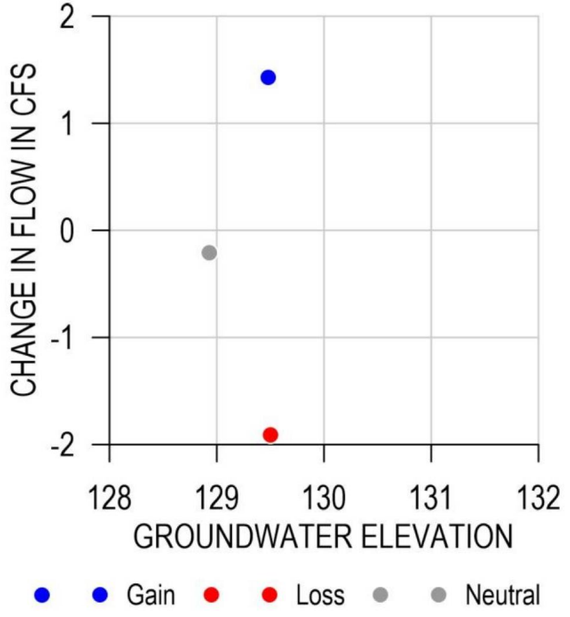
MONTGOMERY & ASSOCIATES

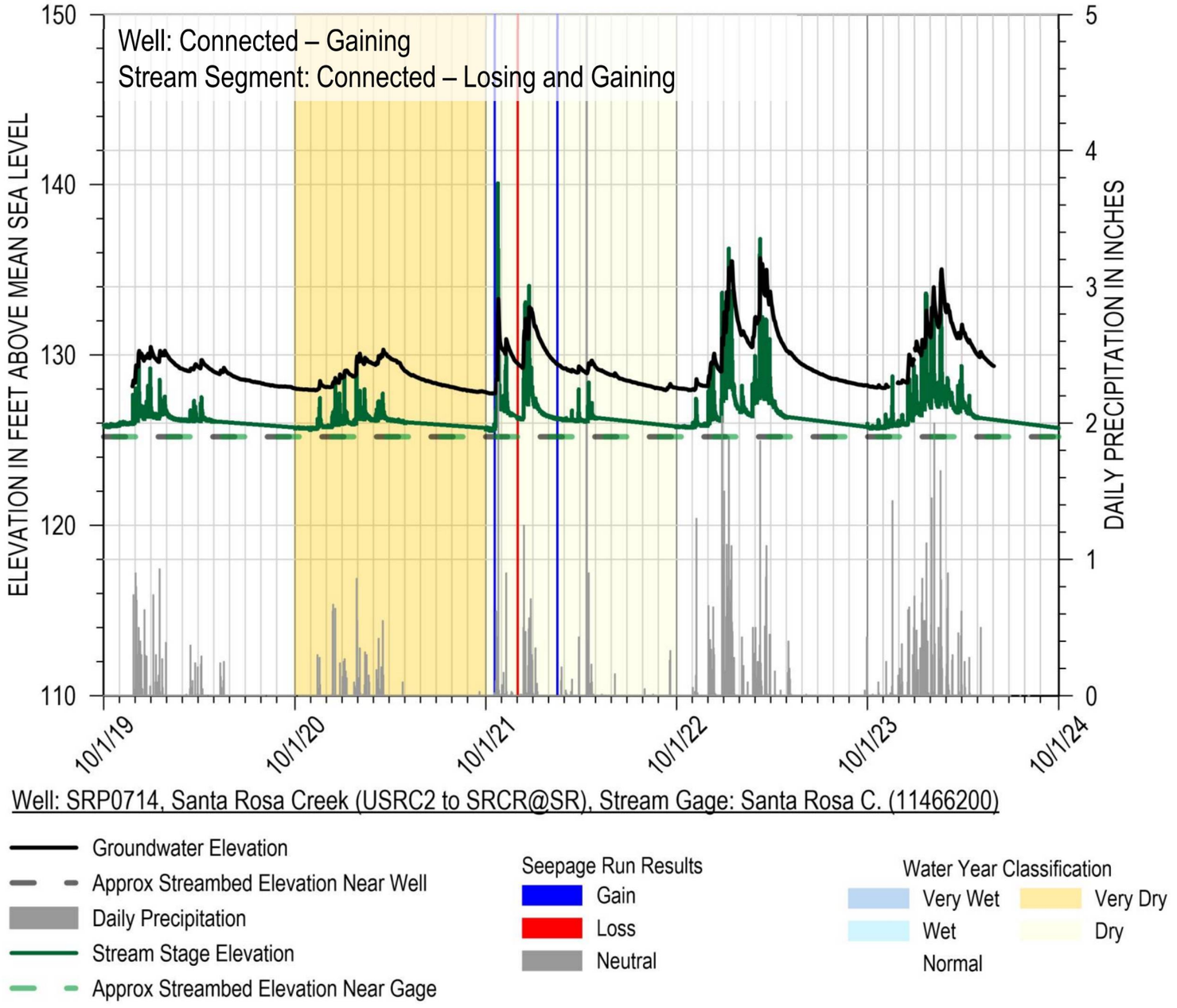




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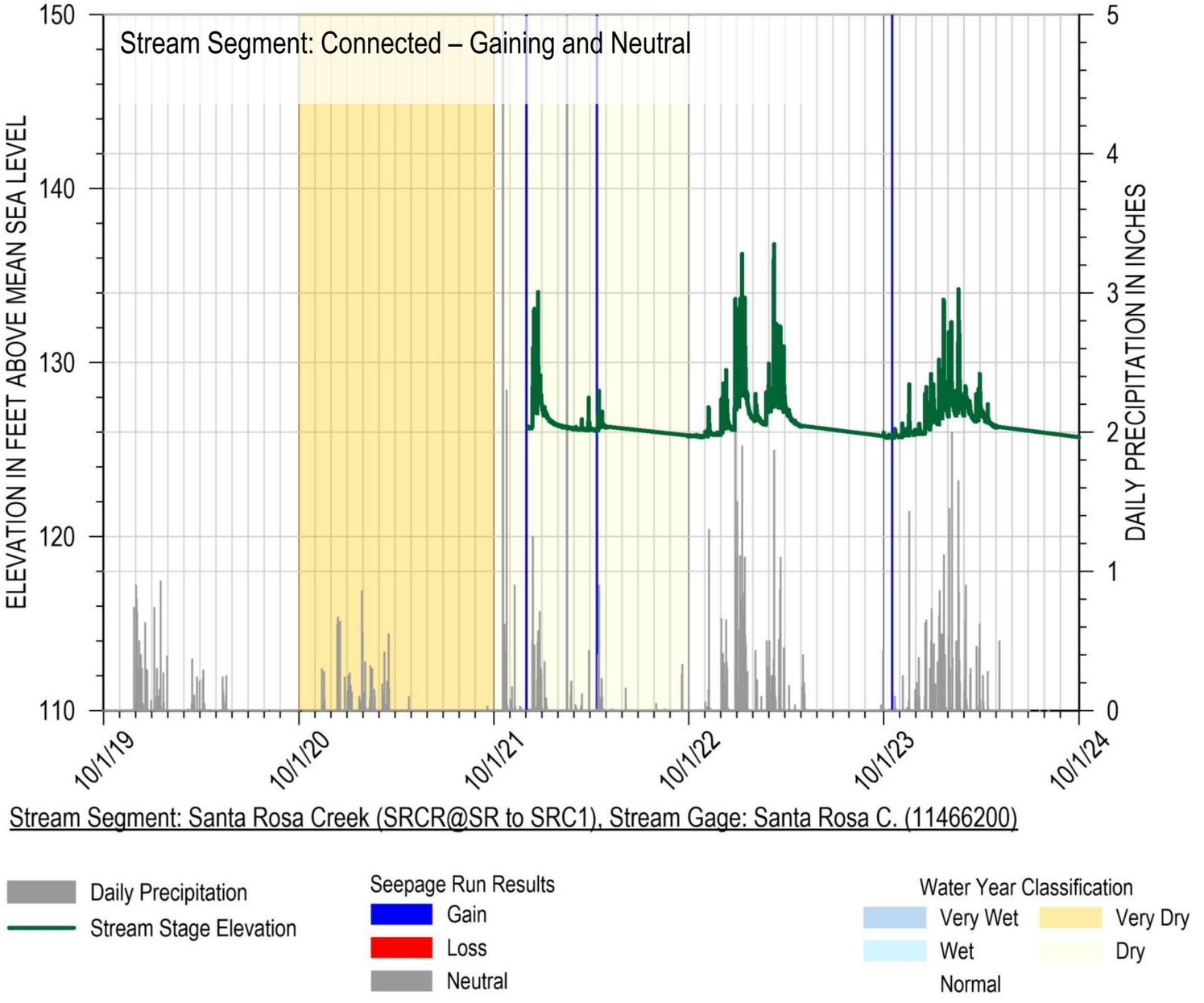




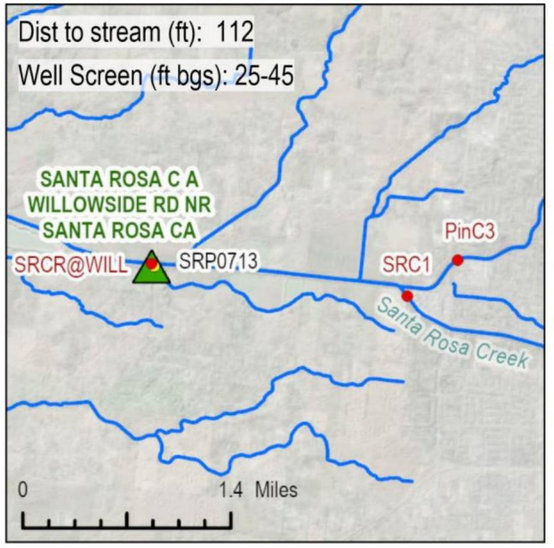


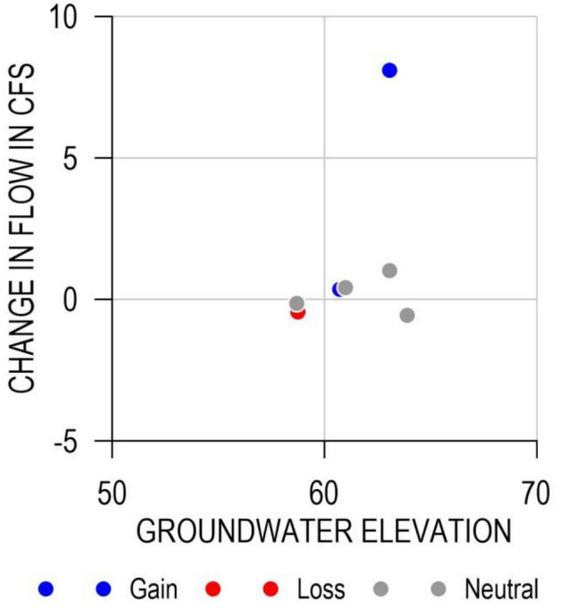
MONTGOMERY & ASSOCIATES

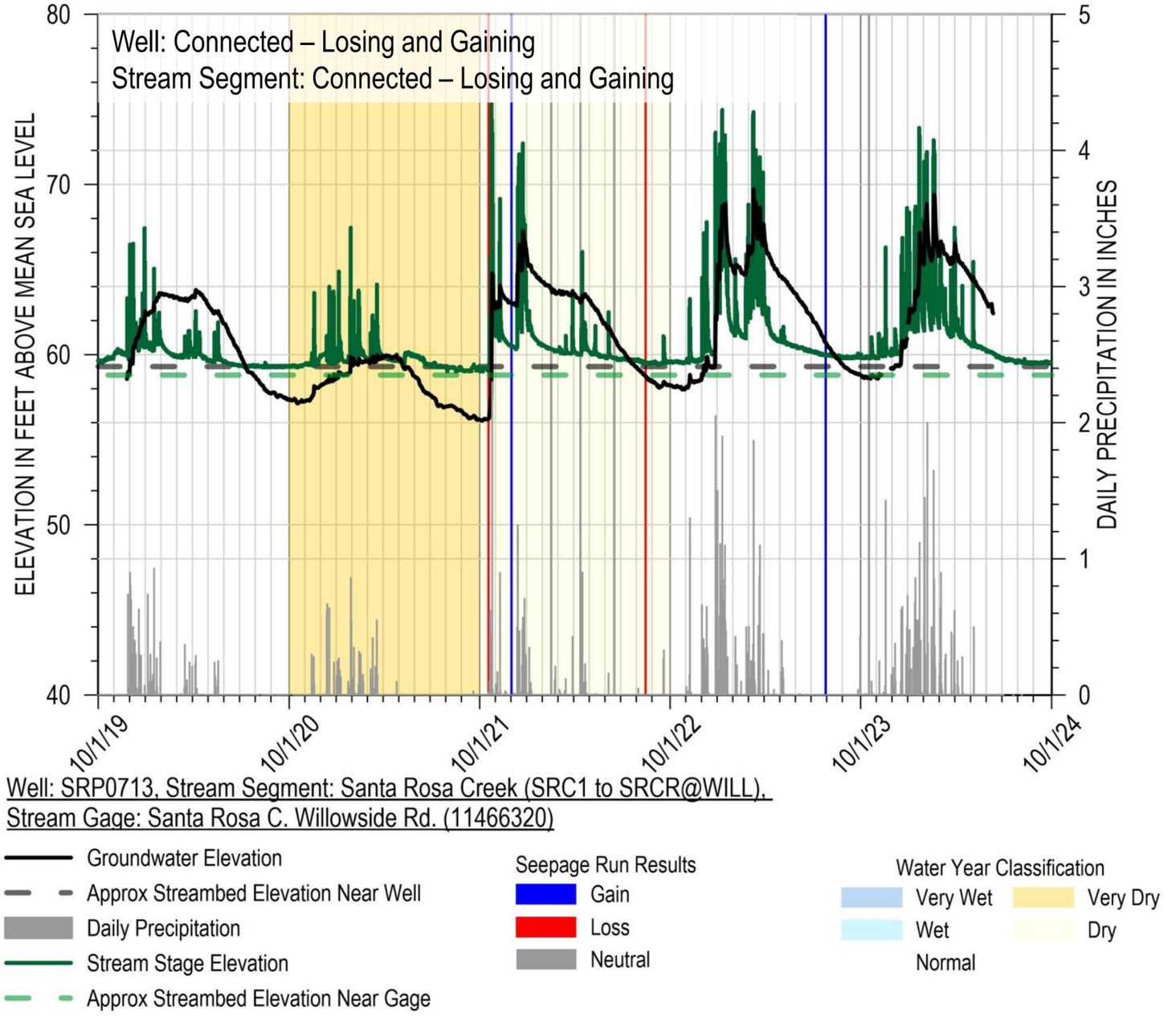




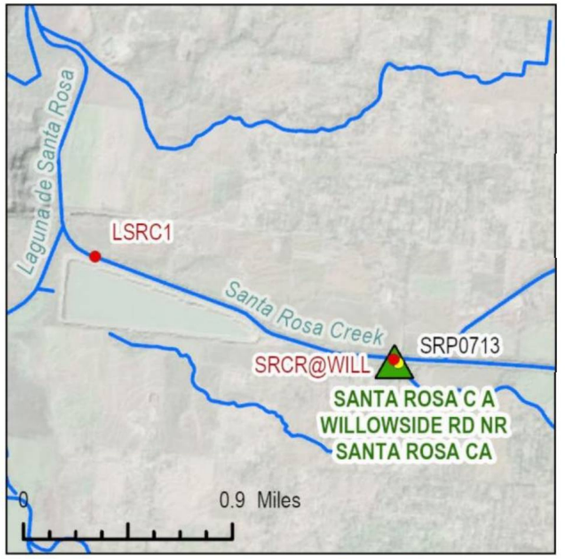
MONTGOMERY & ASSOCIATES

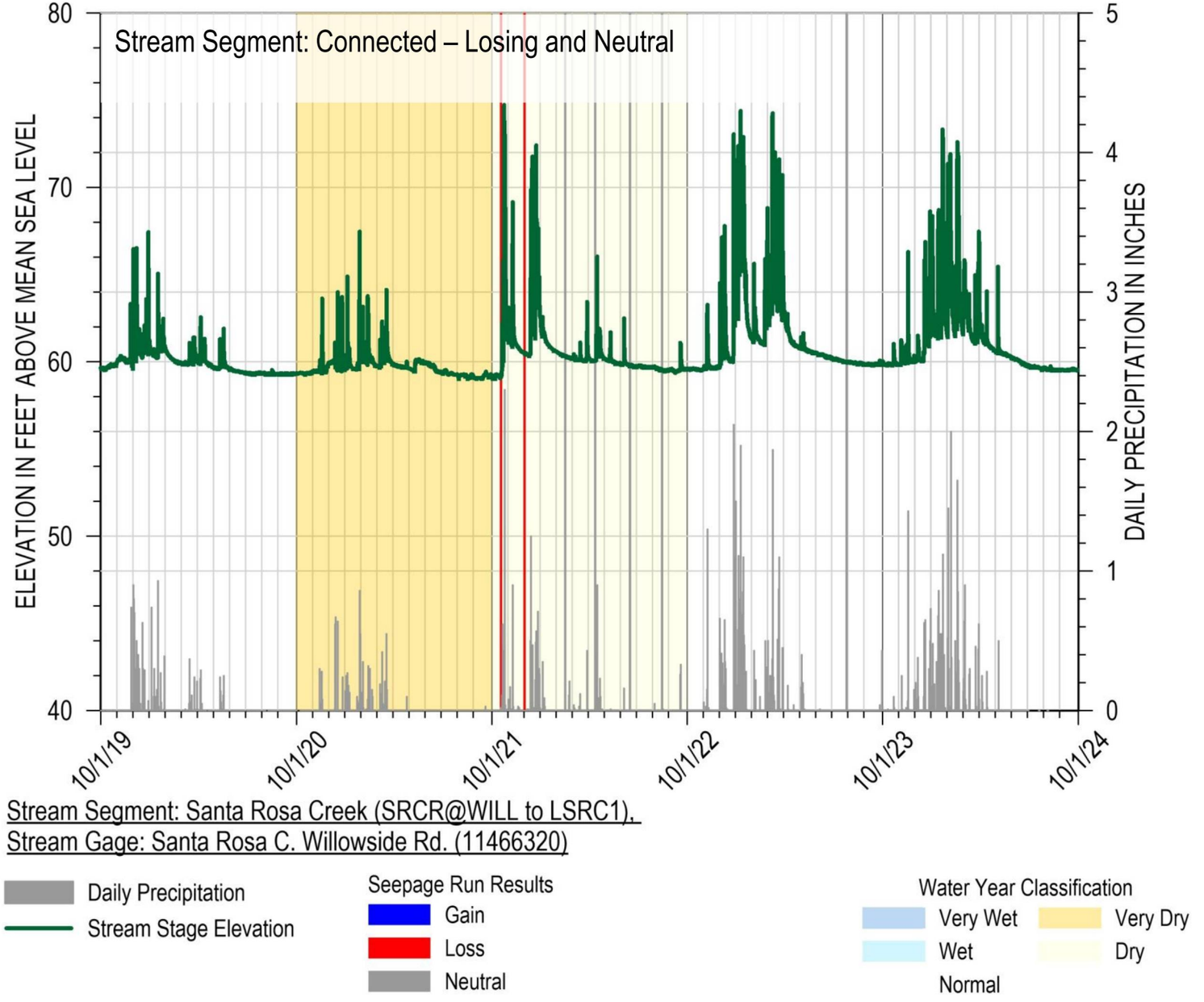




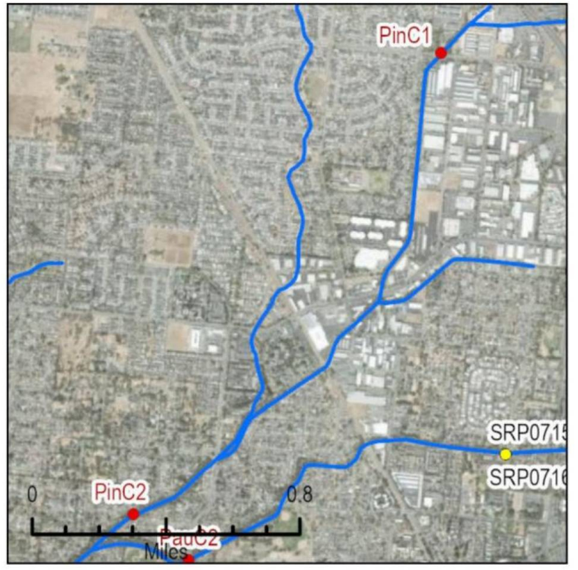


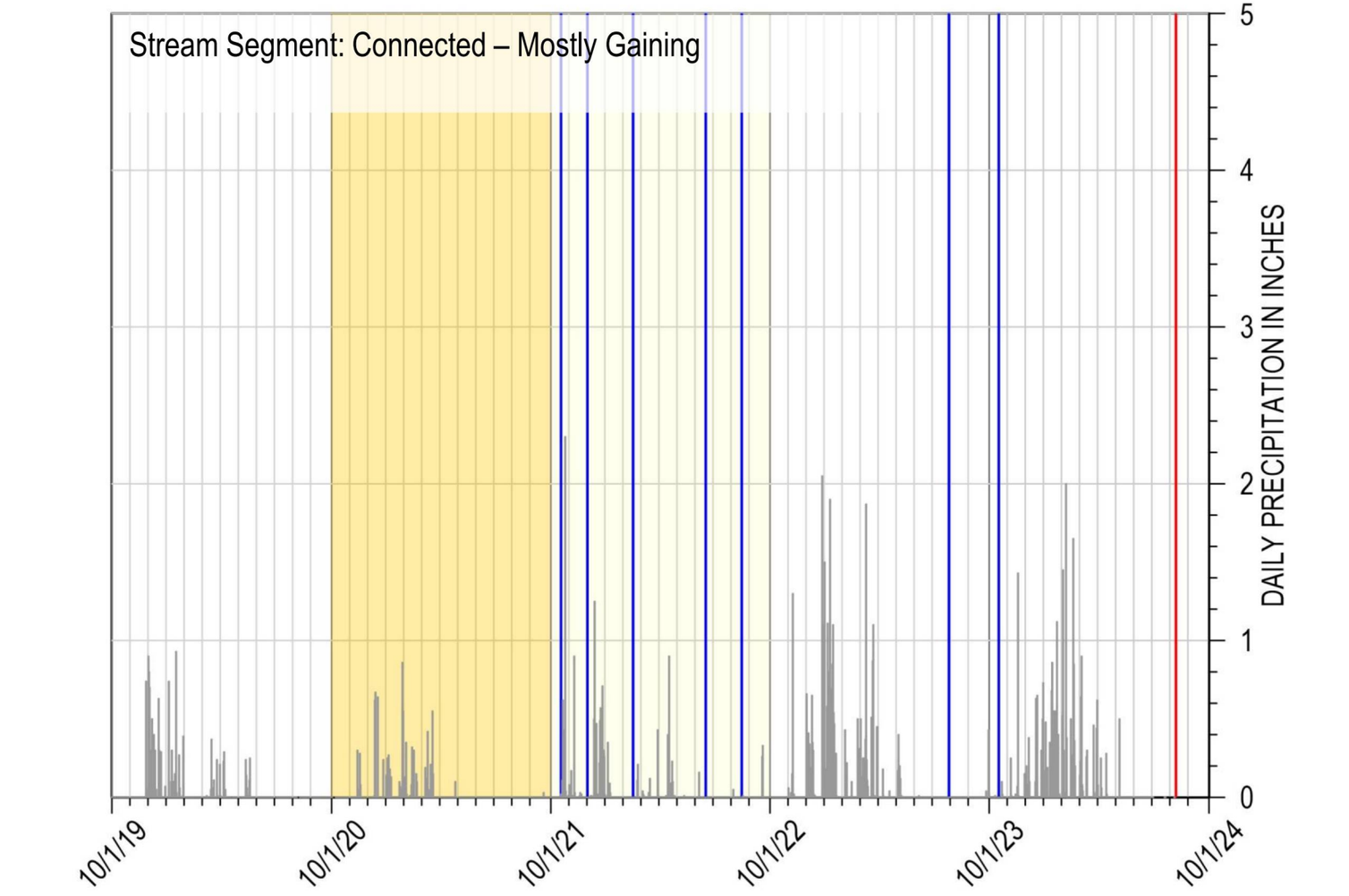
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Stream Segment: Piner Creek (PinC1 to PinC2)

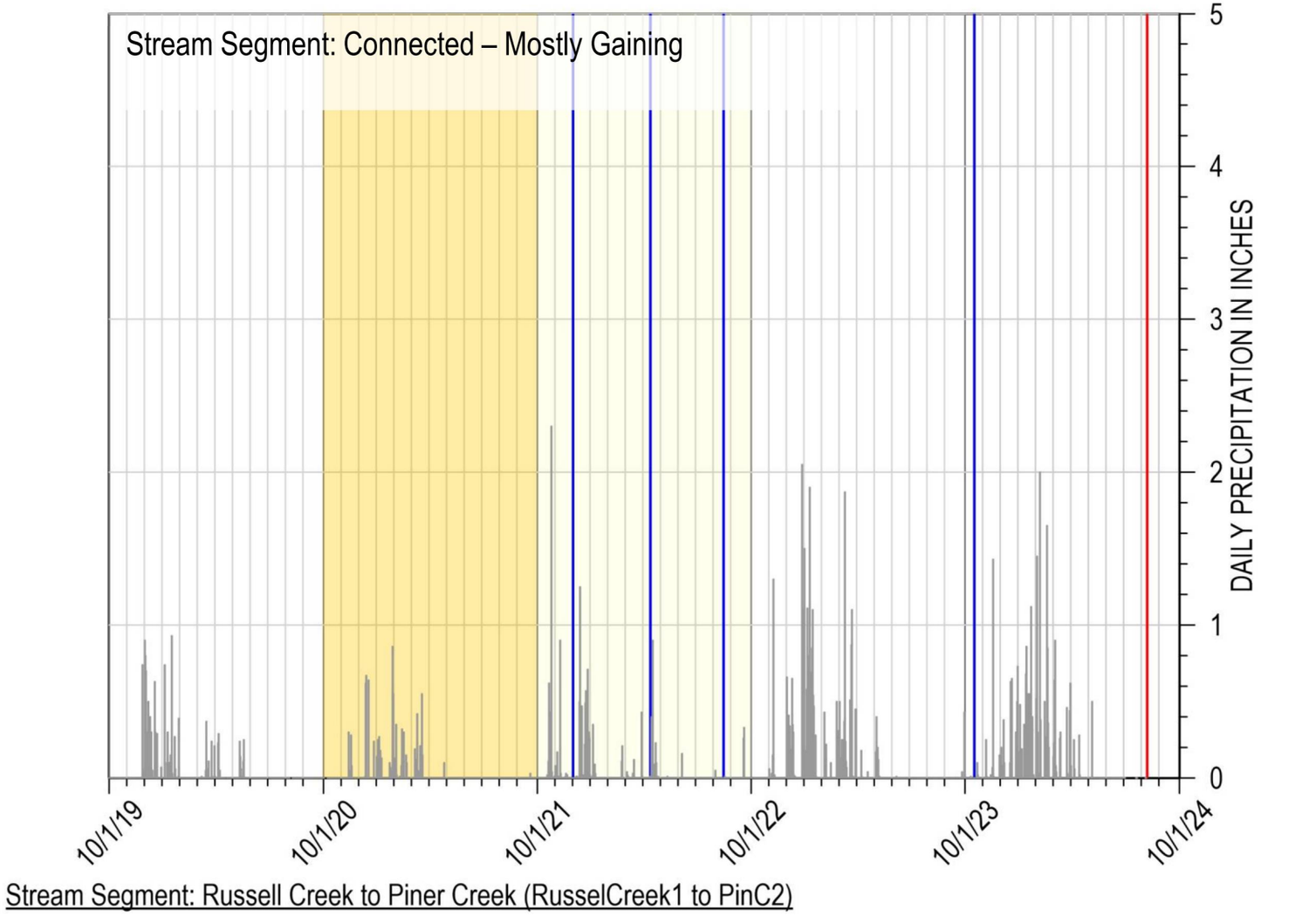
Daily Precipitation

Seepage Run Results
- Gain
- Loss
- Neutral

Water Year Classification
- Very Wet
- Wet
- Normal
- Very Dry
- Dry

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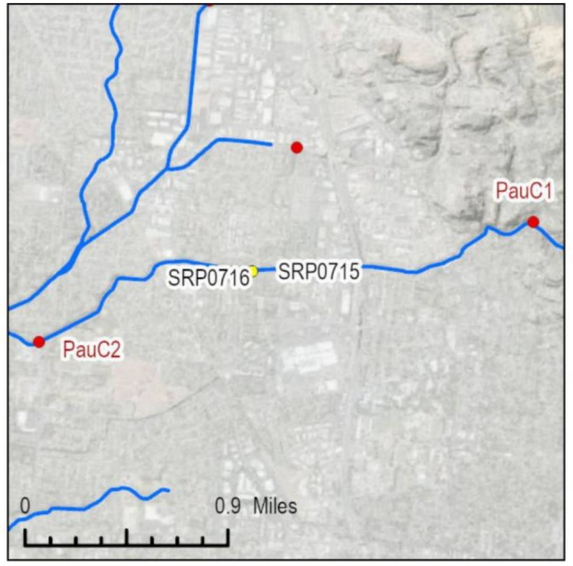
Stream Segment: Russell Creek to Piner Creek (RusselCreek1 to PinC2)

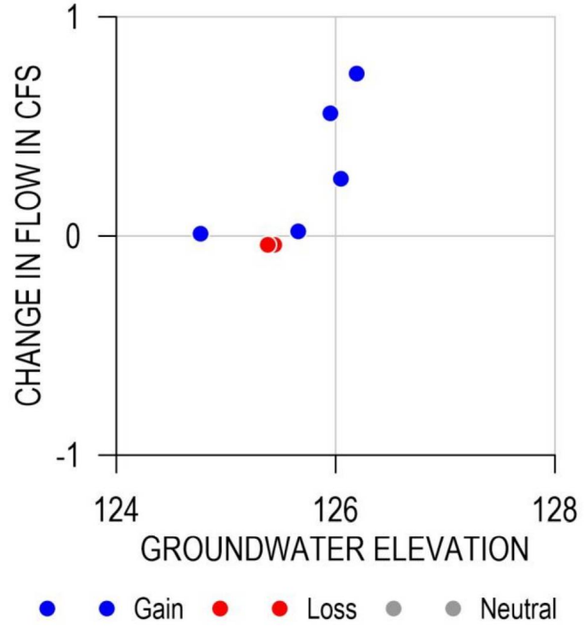
Daily Precipitation

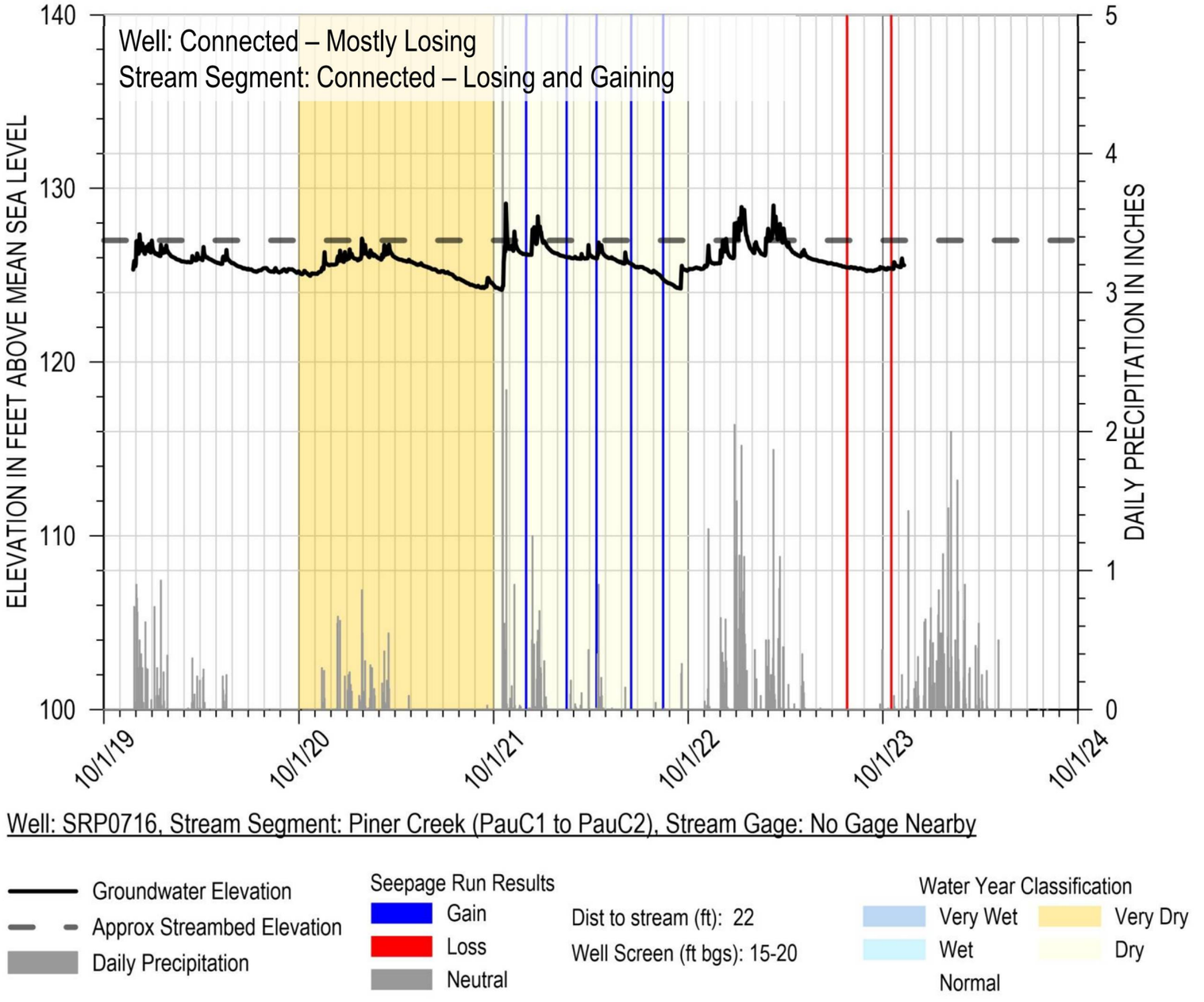
Seepage Run Results
- Gain
- Loss
- Neutral

Water Year Classification
- Very Wet
- Wet
- Normal
- Very Dry
- Dry

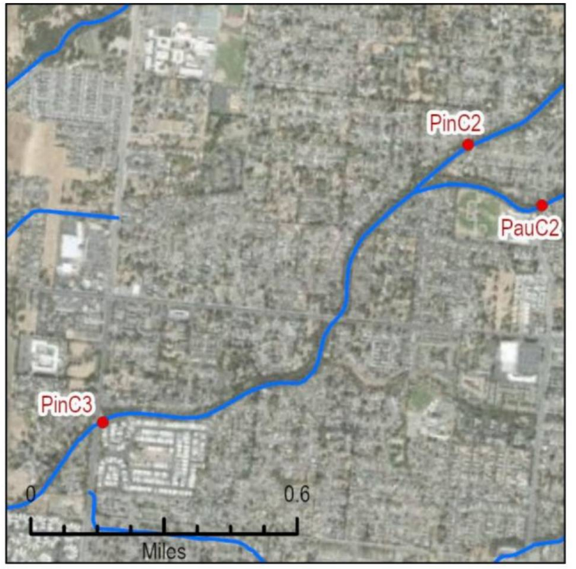
MONTGOMERY & ASSOCIATES

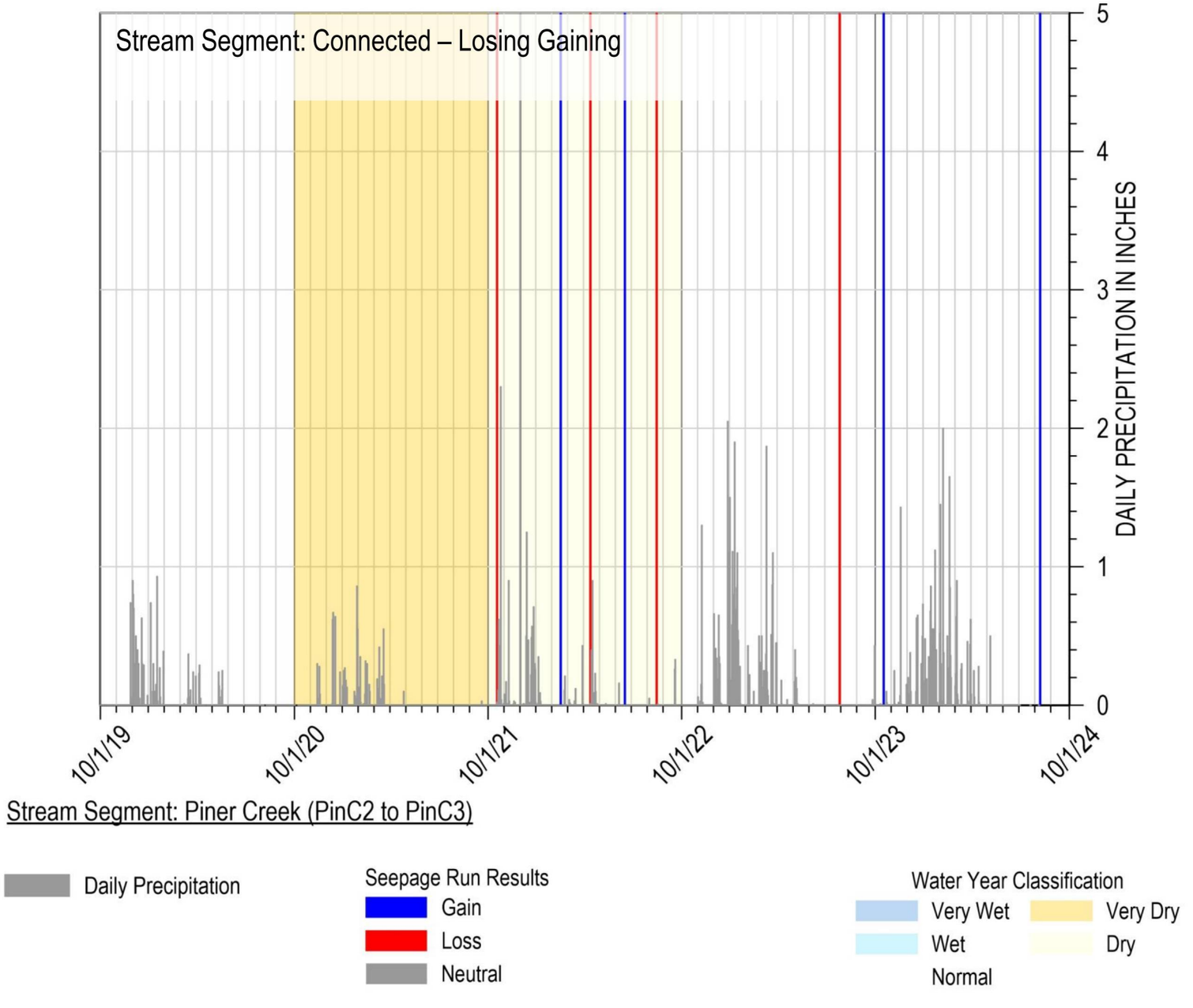




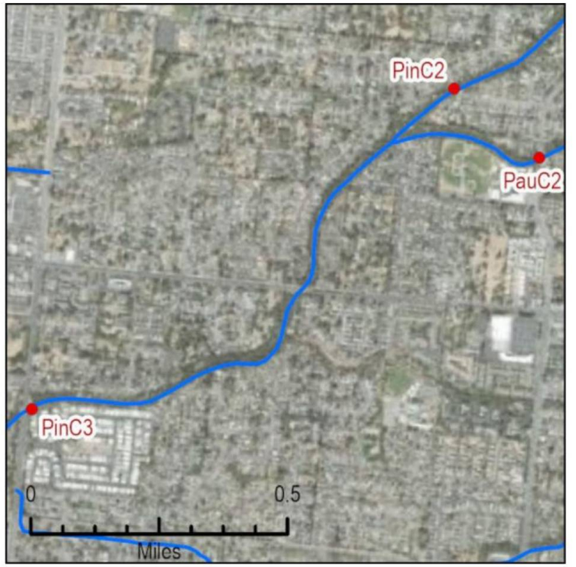


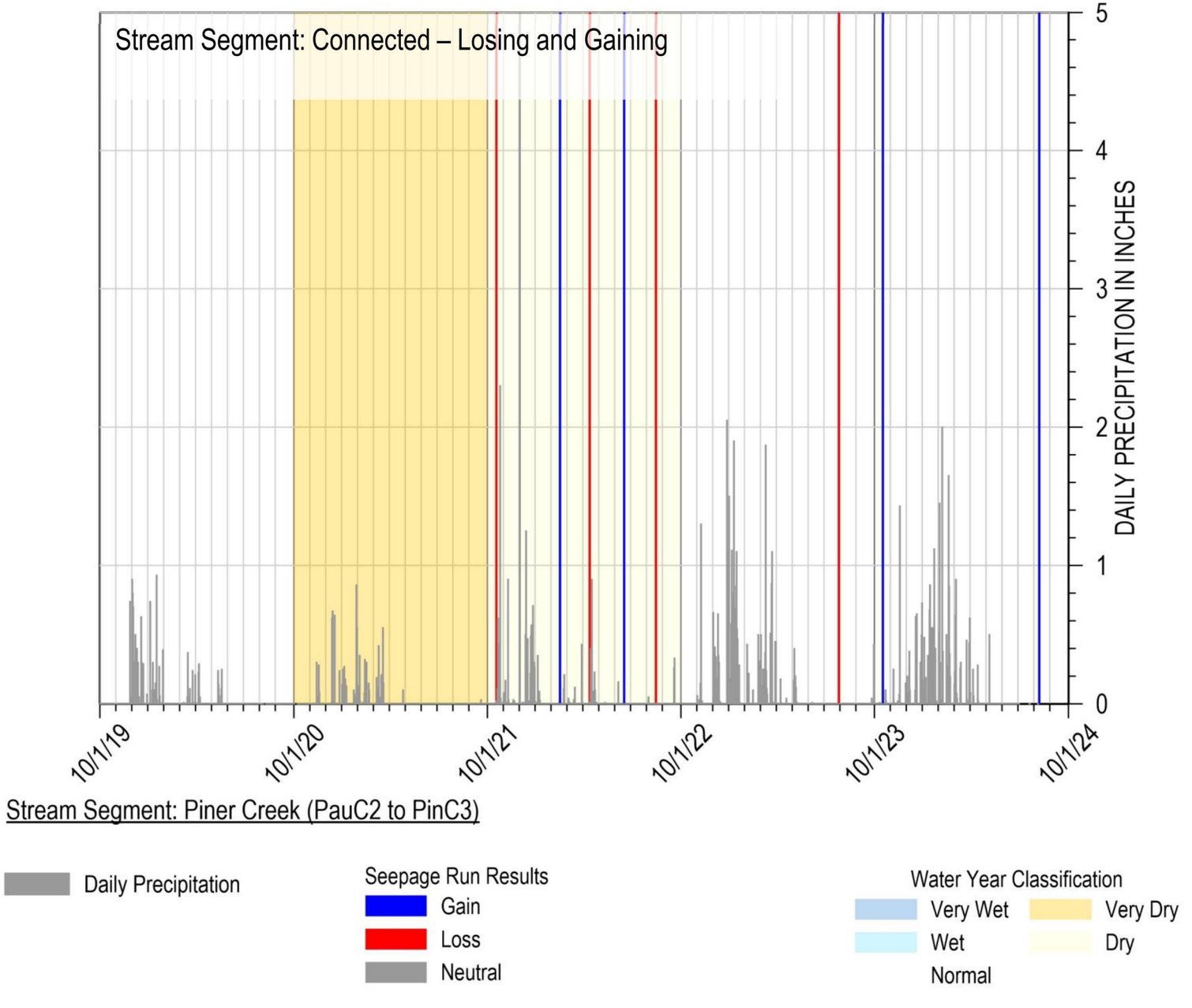
MONTGOMERY & ASSOCIATES



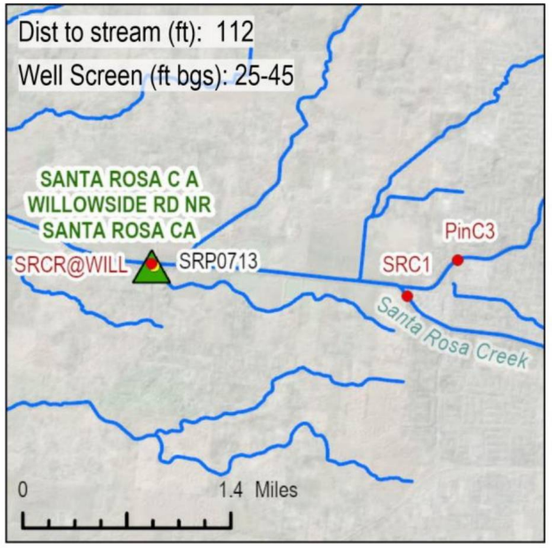


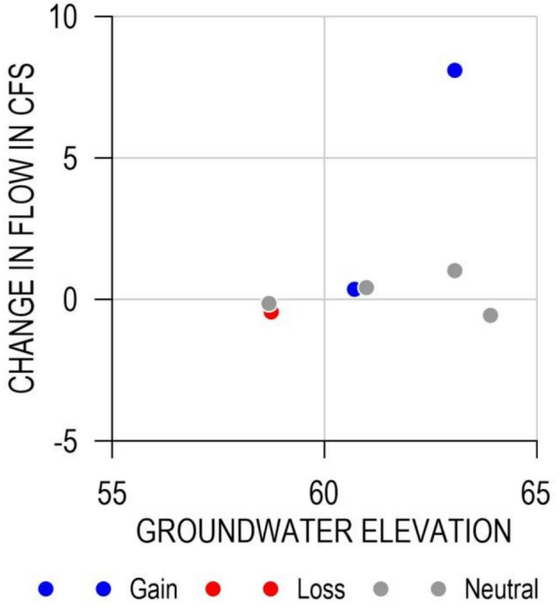
MONTGOMERY & ASSOCIATES

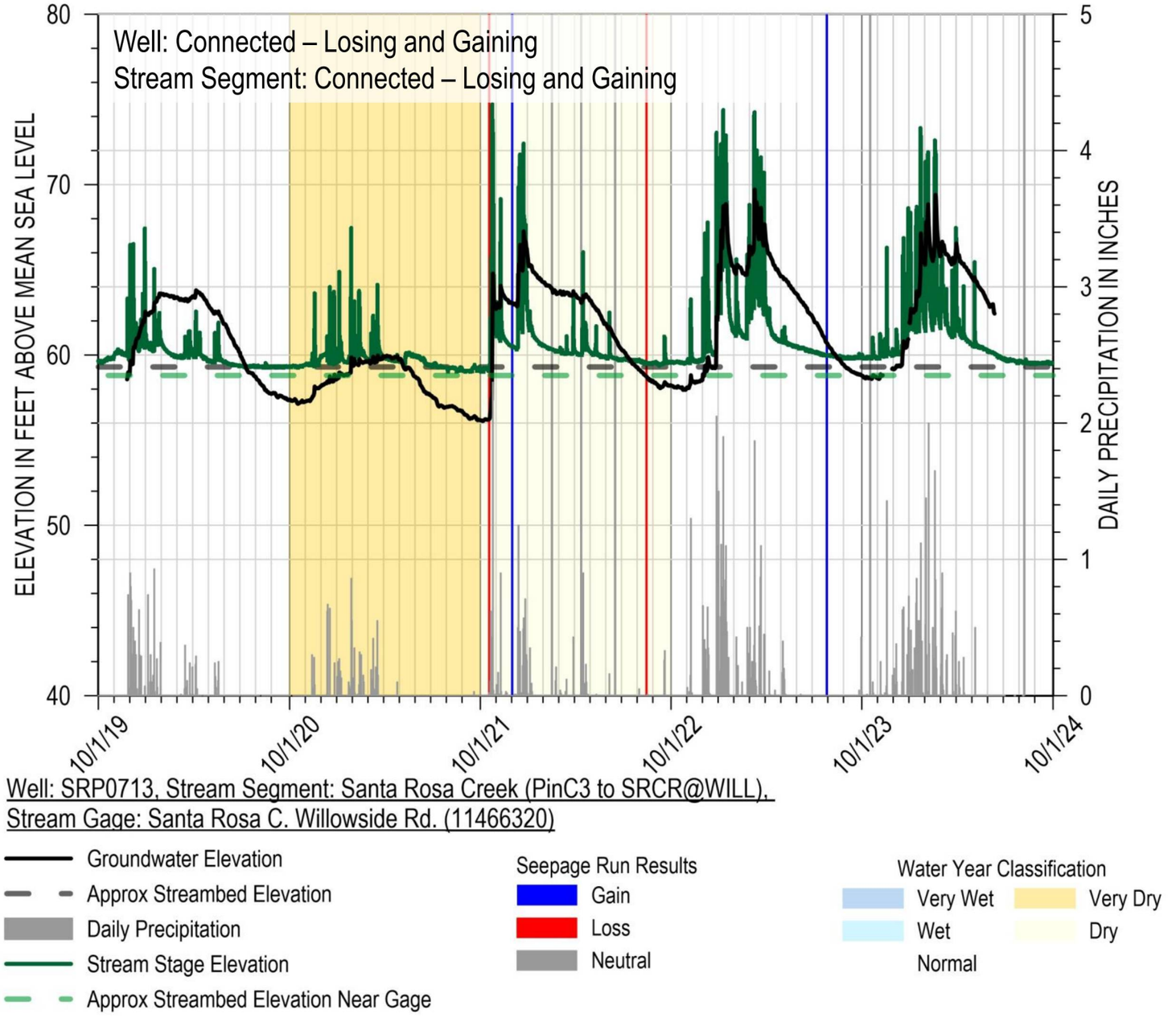




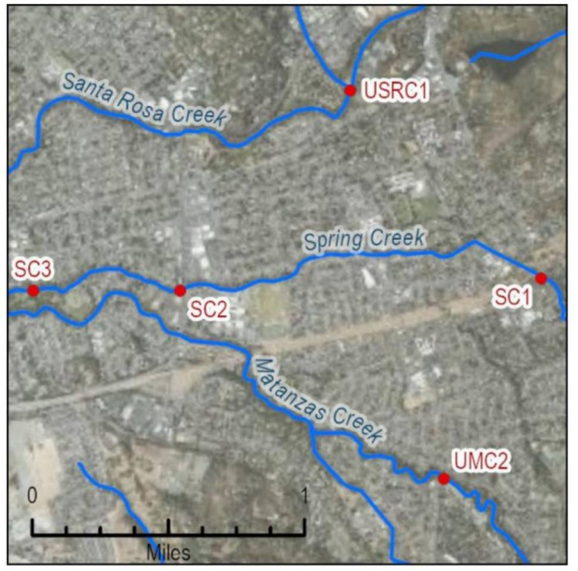
MONTGOMERY & ASSOCIATES

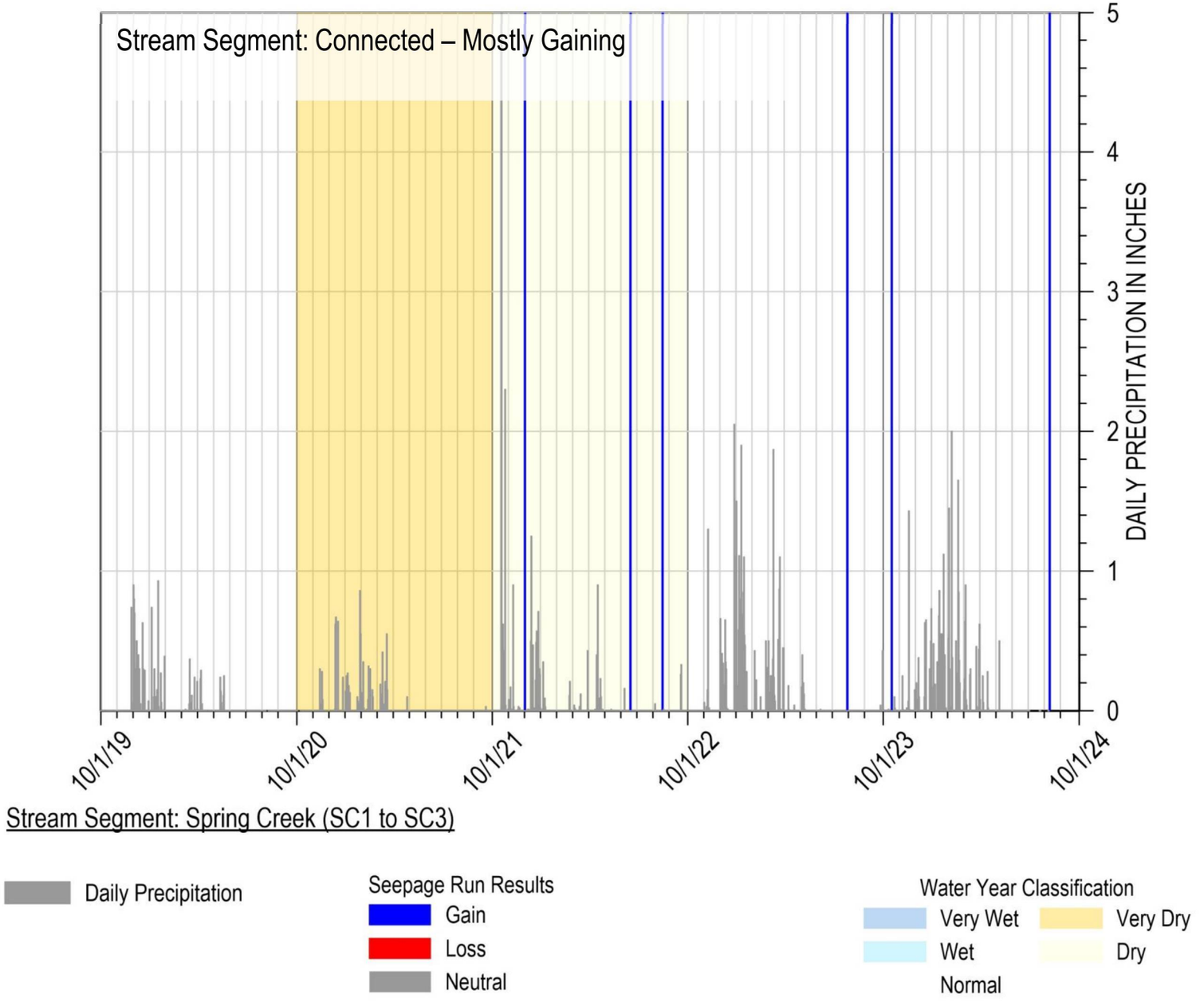






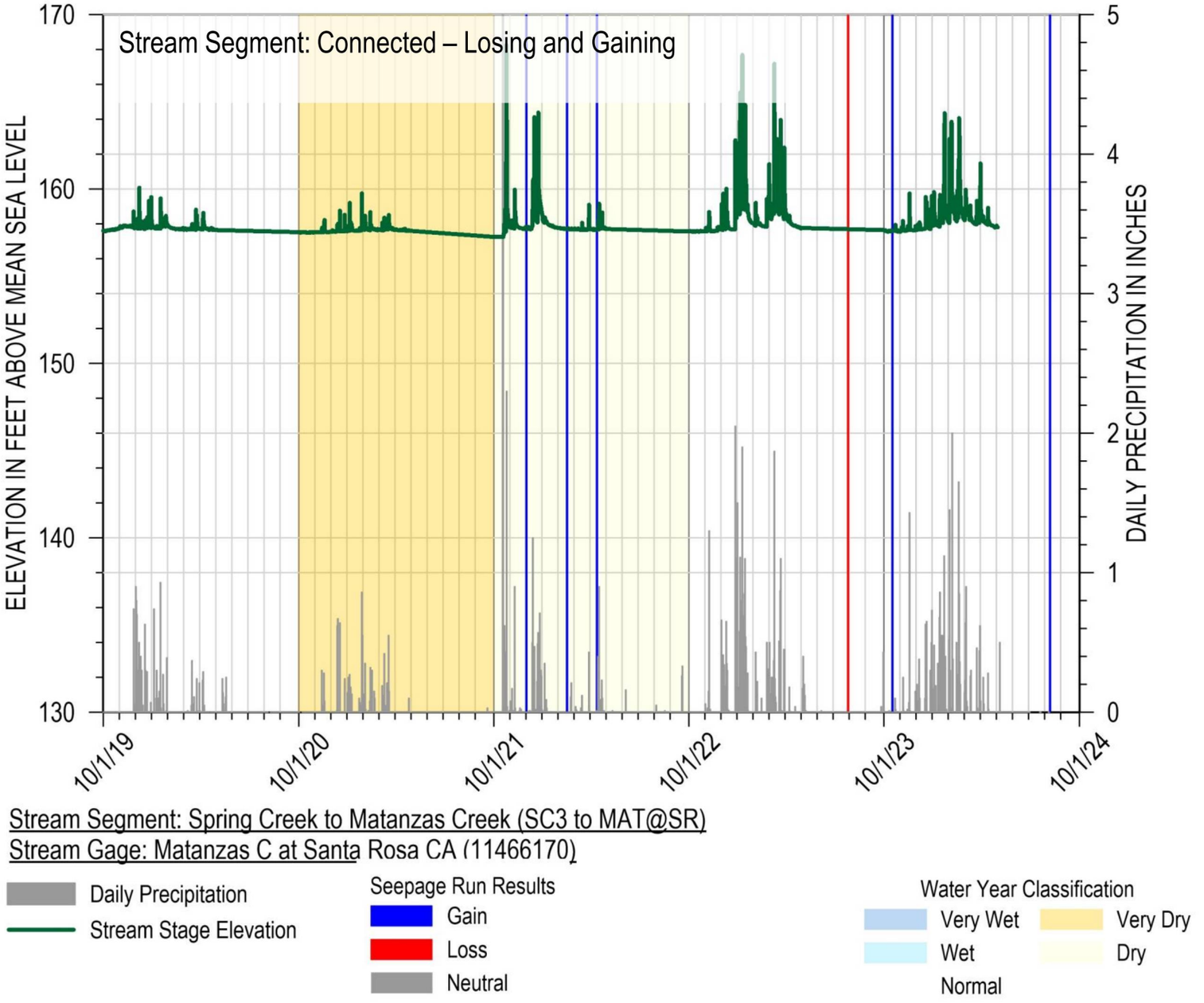
MONTGOMERY & ASSOCIATES



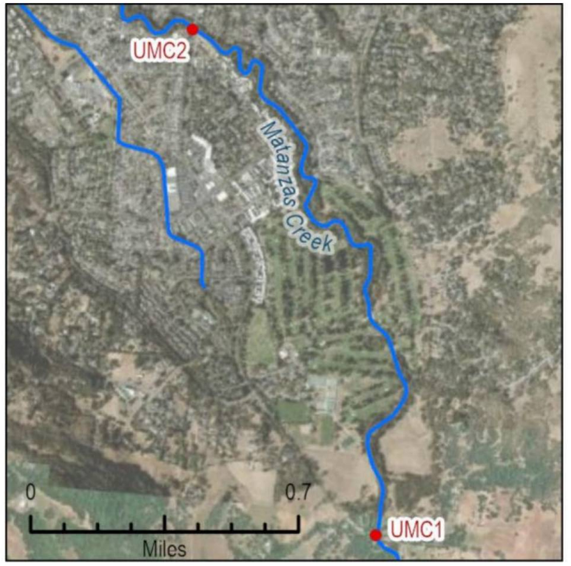


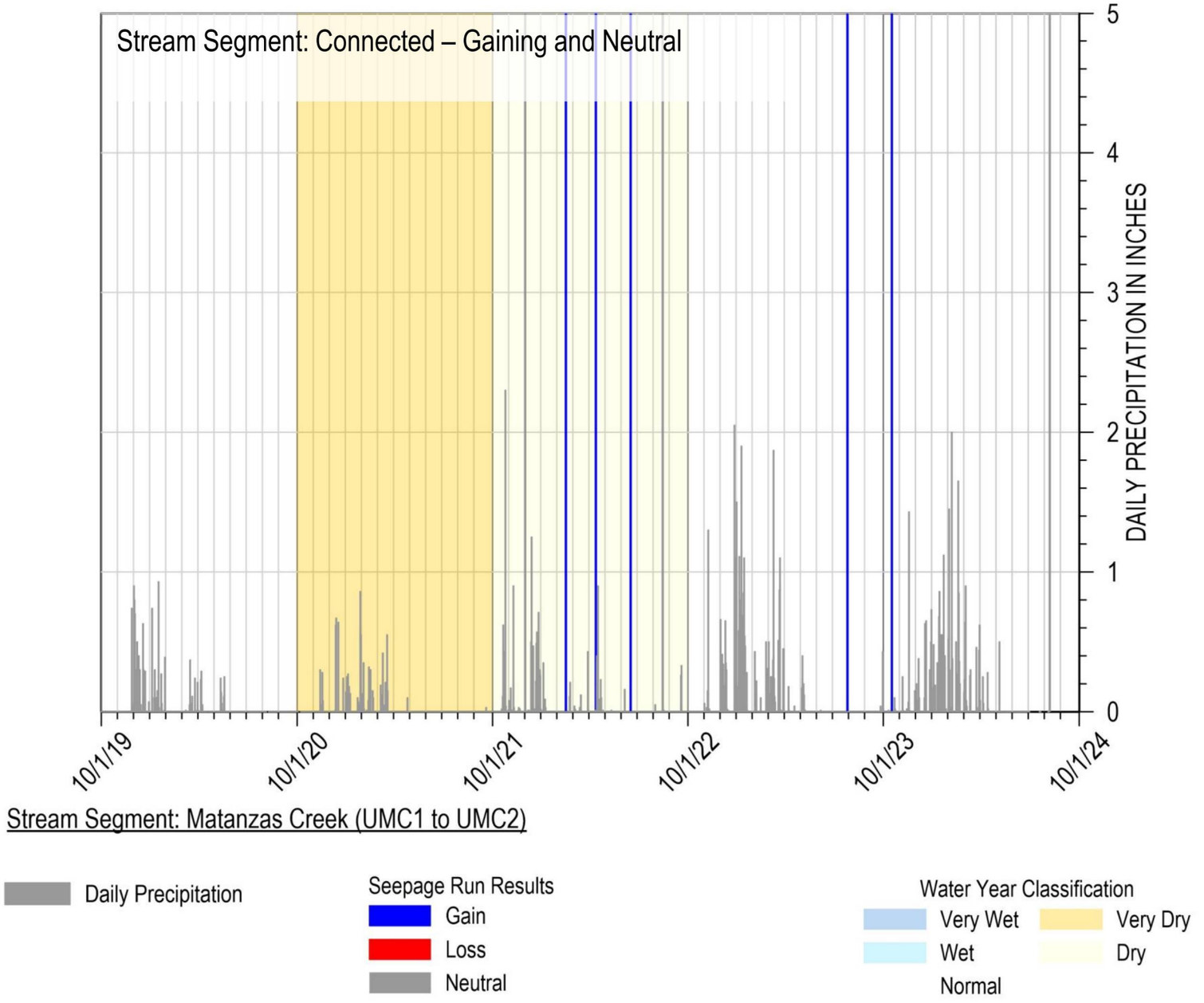
MONTGOMERY & ASSOCIATES



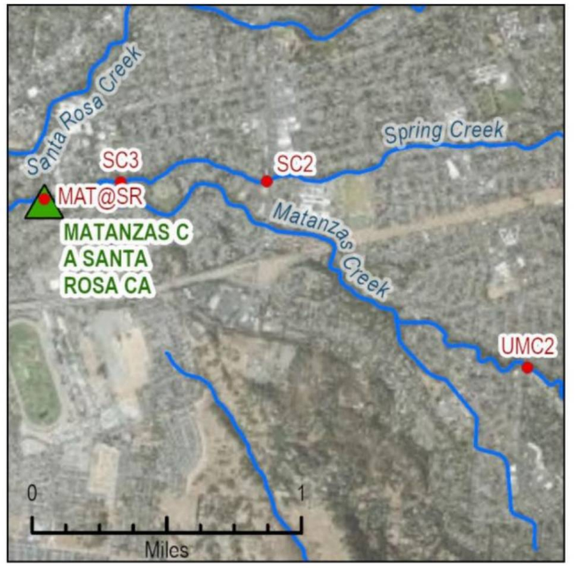


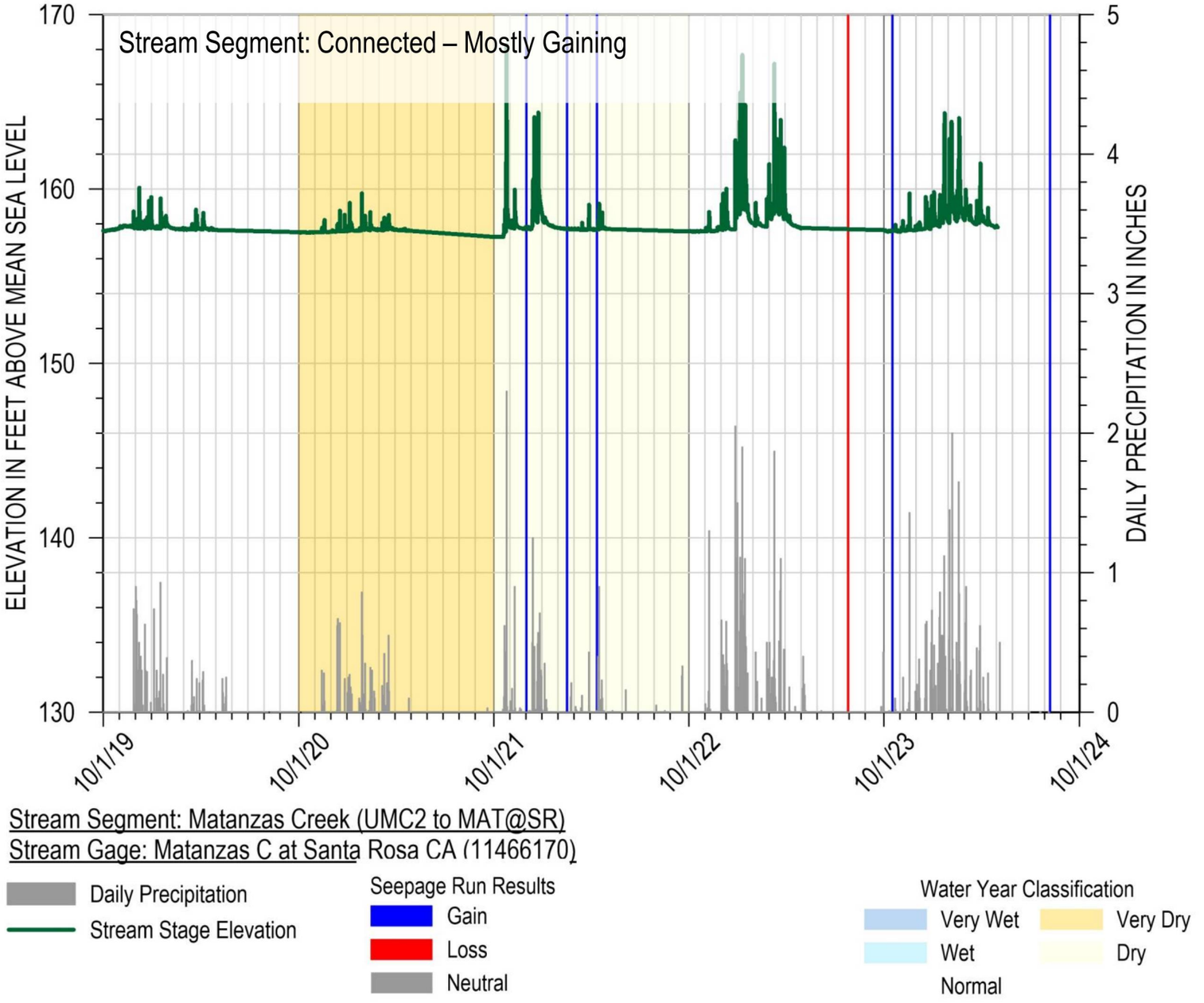
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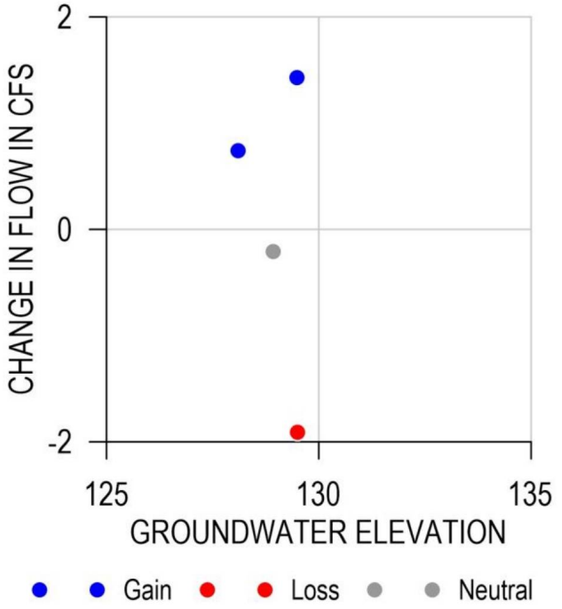
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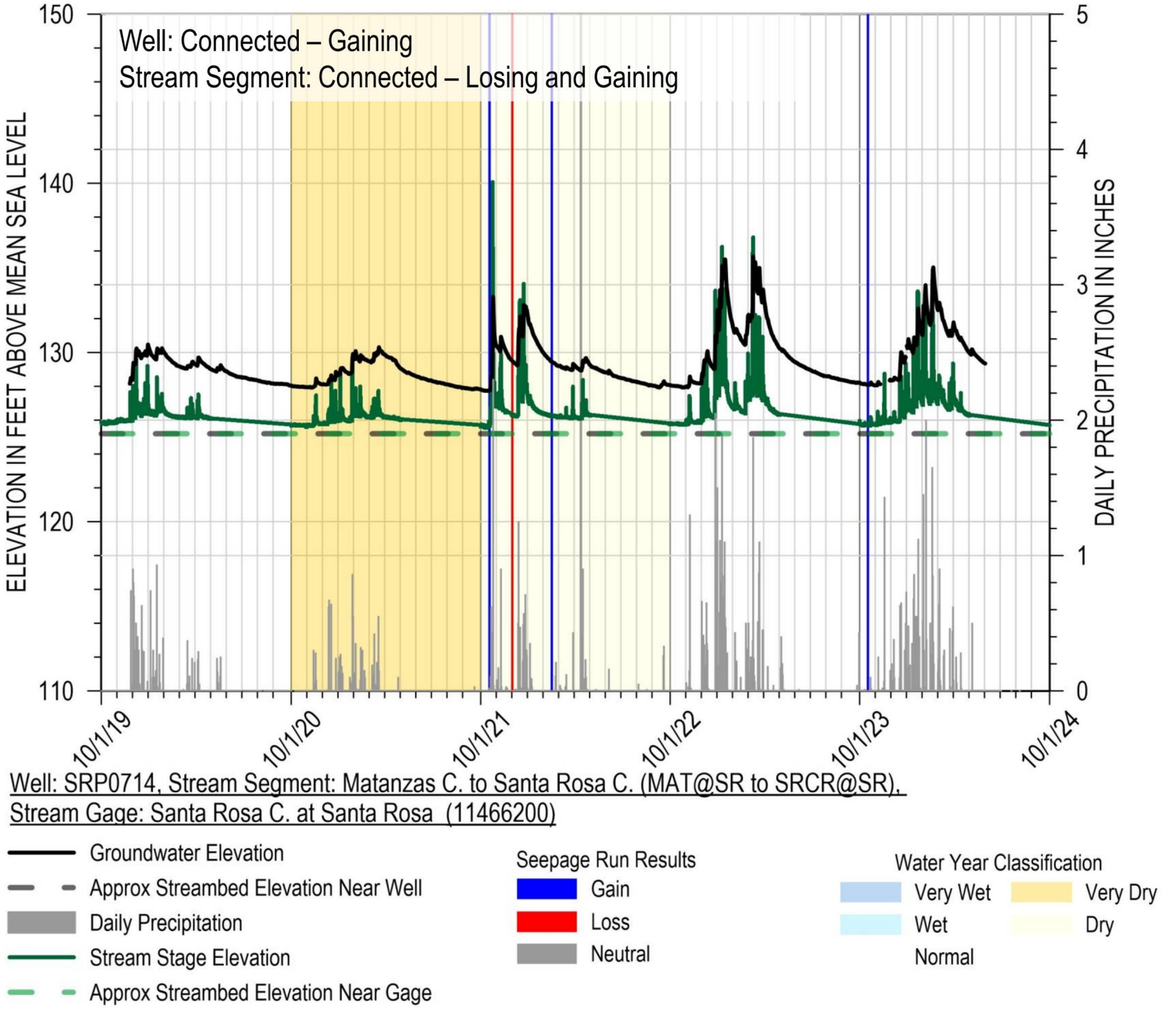




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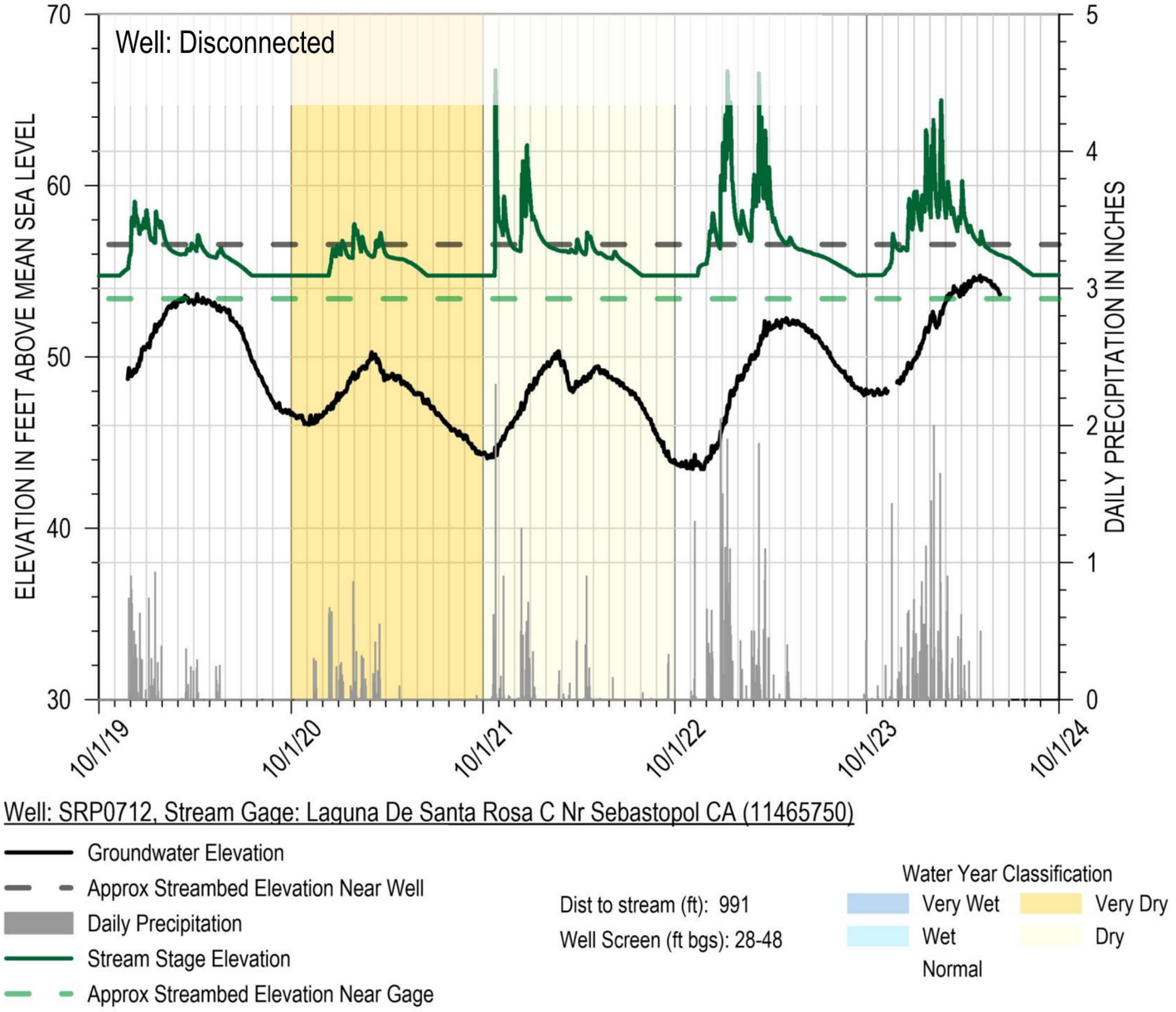




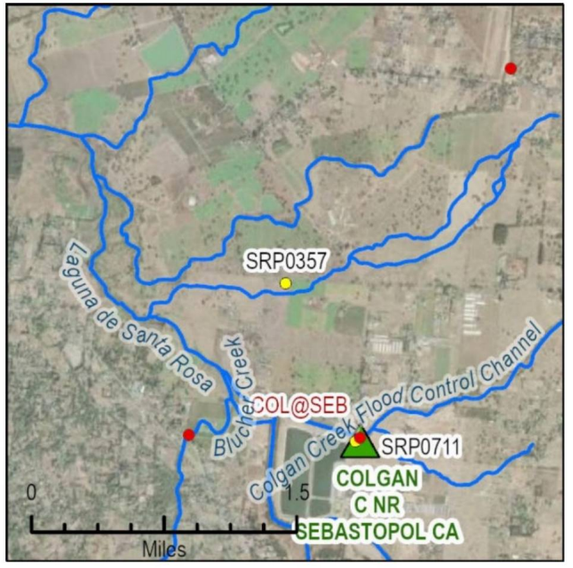


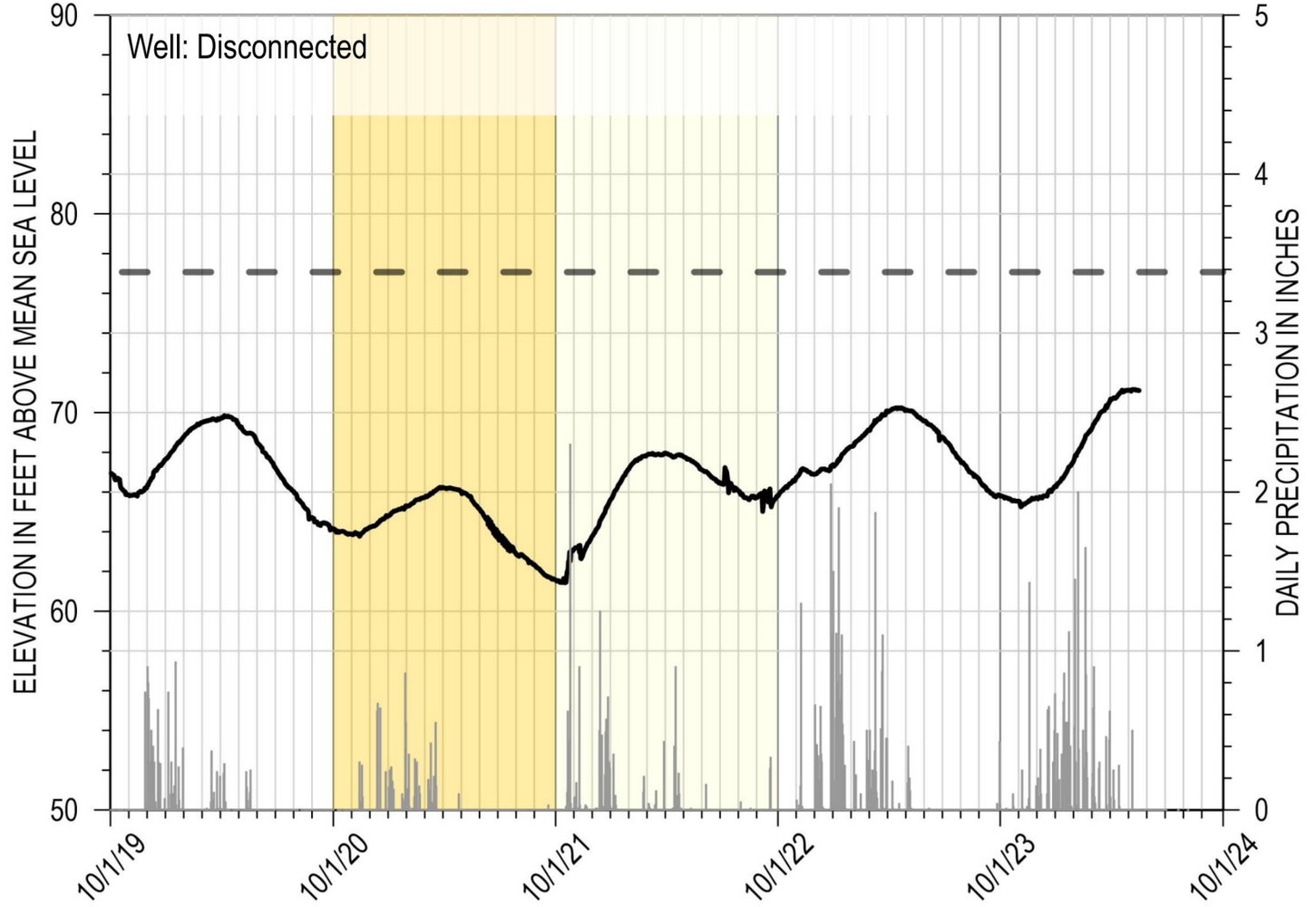
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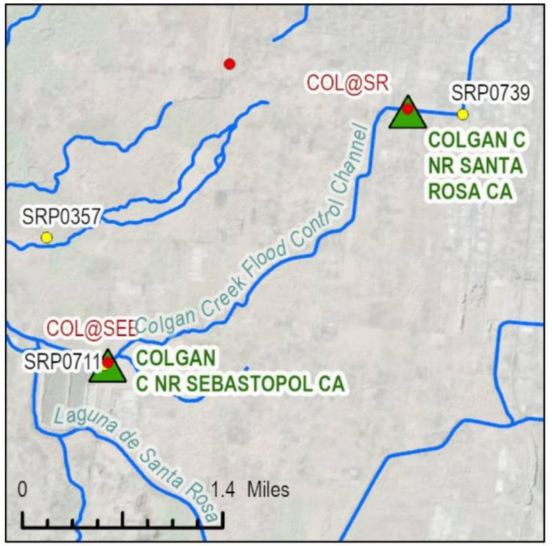
Well: SRP0357, Stream Gage: No Gage Nearby

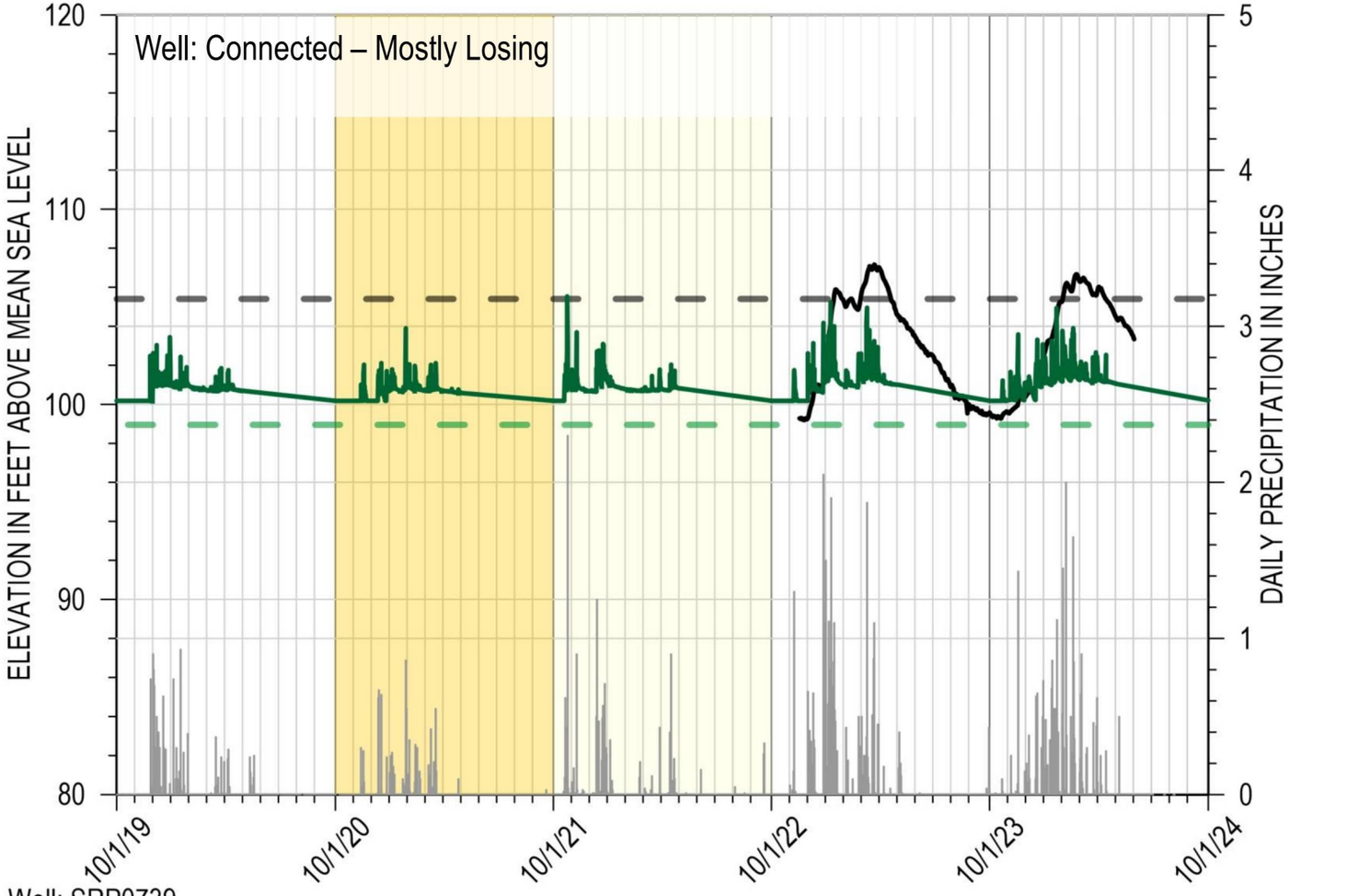
Groundwater Elevation
Daily Precipitation
Approx Streambed Elevation

Dist to stream (ft): 318
Well Screen (ft bgs): 60-80

Water Year Classification
Very Wet
Wet
Normal
Very Dry
Dry

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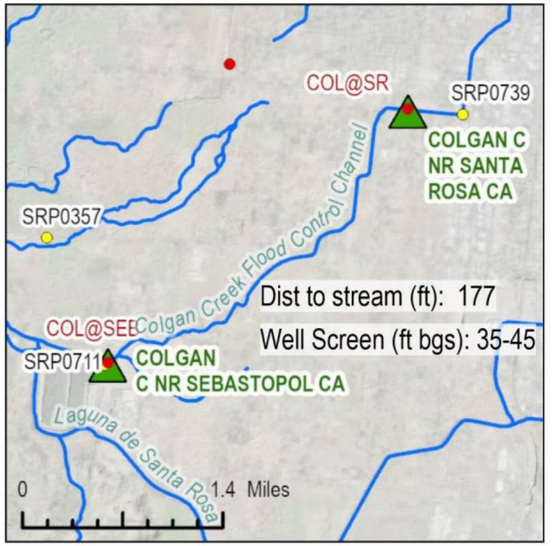
Well: SRP0739
Stream Gage: Colgan C. Nr Santa Rosa (11465690)

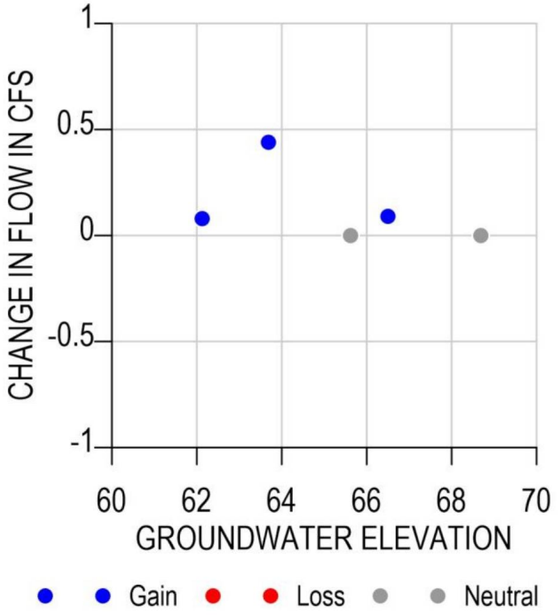
- Groundwater Elevation
- Approx Streambed Elevation
- Daily Precipitation
- Stream Stage Elevation
- Approx Streambed Elevation Near Gage

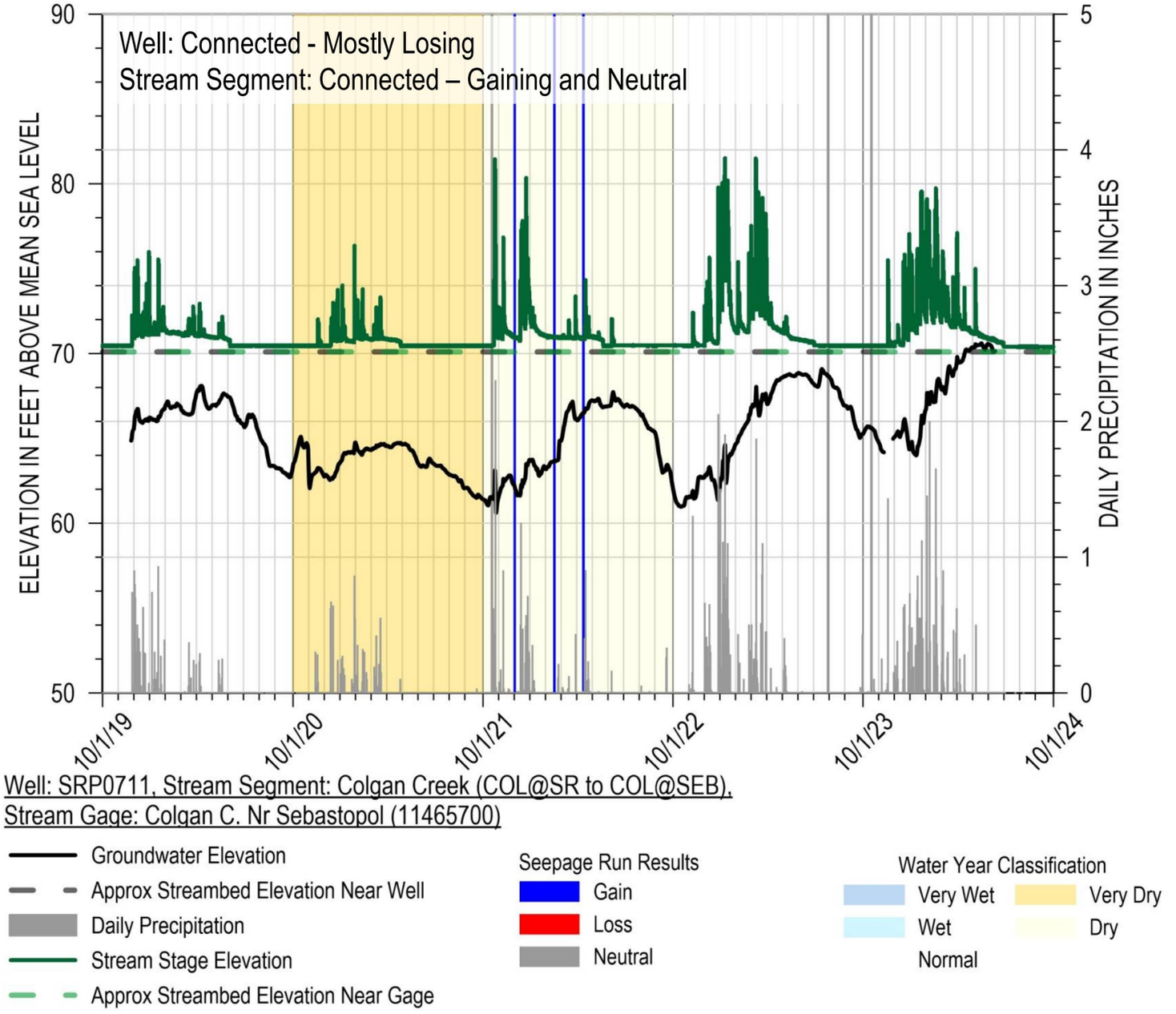
Dist to stream (ft): 70
Well Screen (ft bgs): 72-82

Water Year Classification
- Very Wet
- Wet
- Normal
- Dry
- Very Dry

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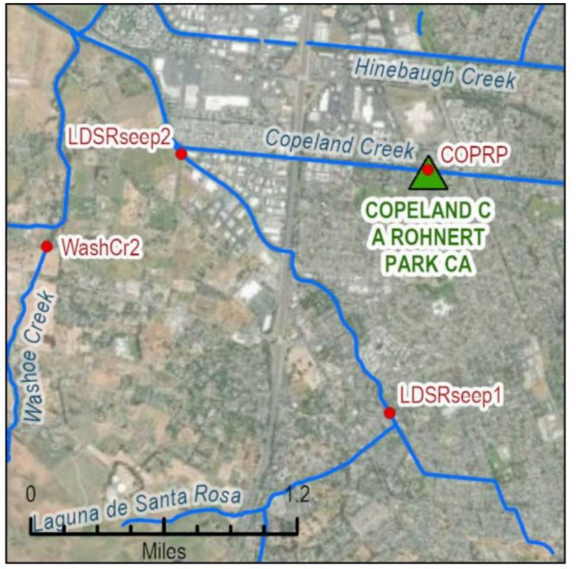
Well: SRP0711, Stream Segment: Colgan Creek (COL@SR to COL@SEB),
Stream Gage: Colgan C. Nr Sebastopol (11465700)

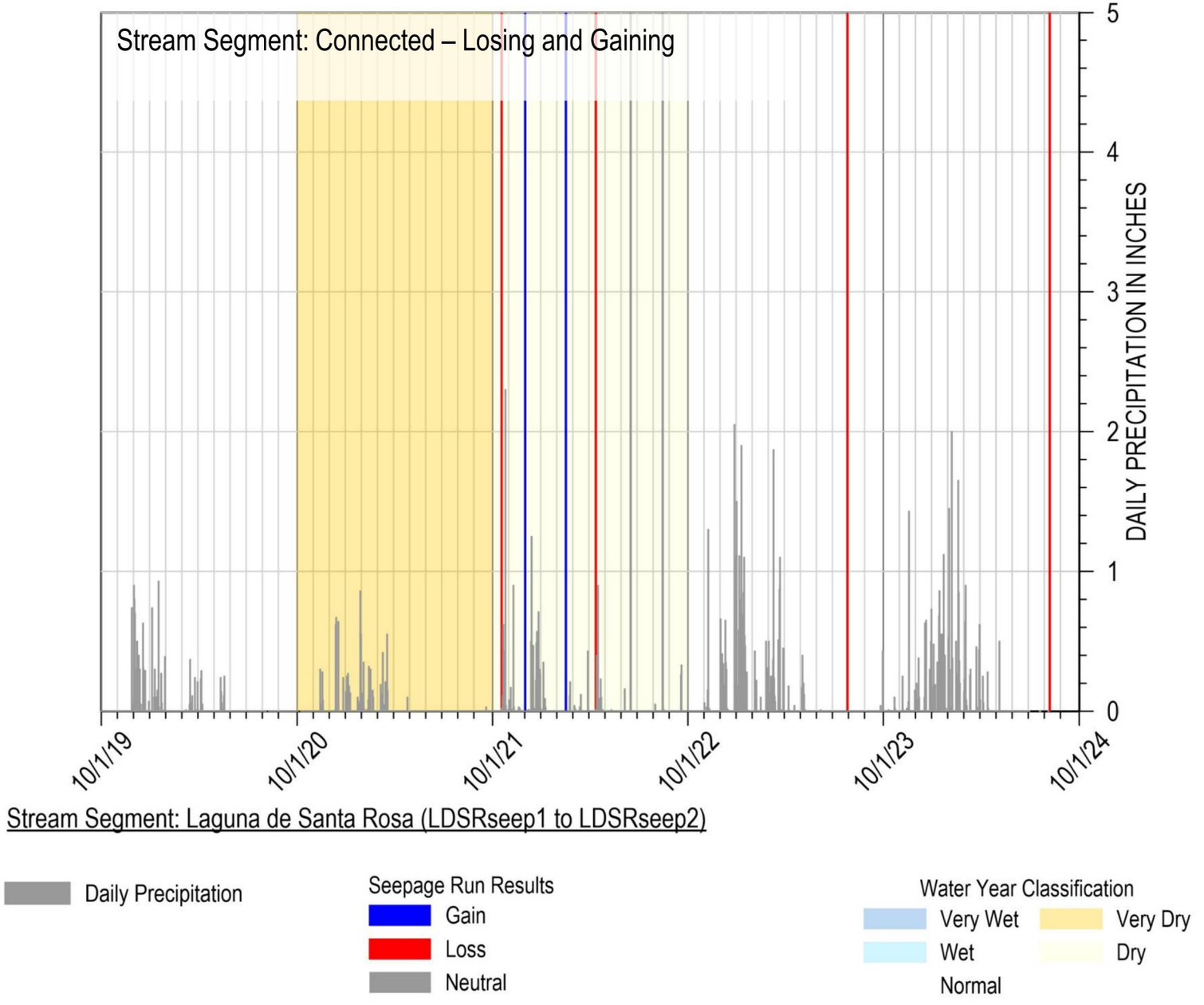
- Groundwater Elevation
- Approx Streambed Elevation Near Well
- Daily Precipitation
- Stream Stage Elevation
- Approx Streambed Elevation Near Gage

Seepage Run Results
- Gain
- Loss
- Neutral

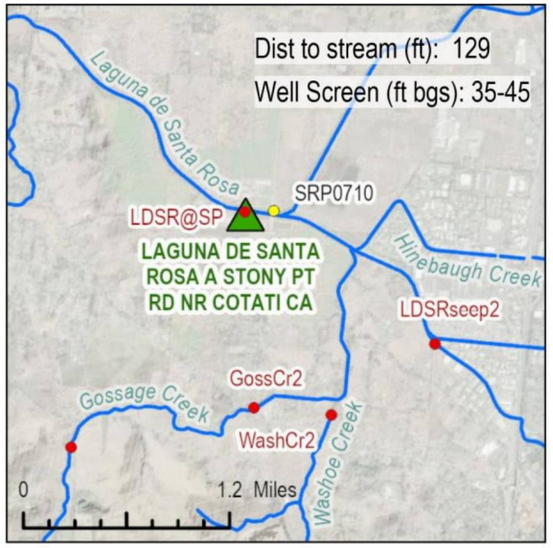
Water Year Classification
- Very Wet
- Very Dry
- Wet
- Dry
- Normal

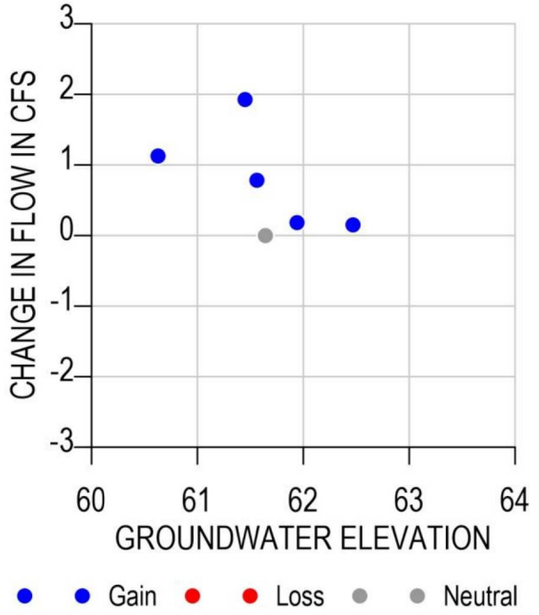
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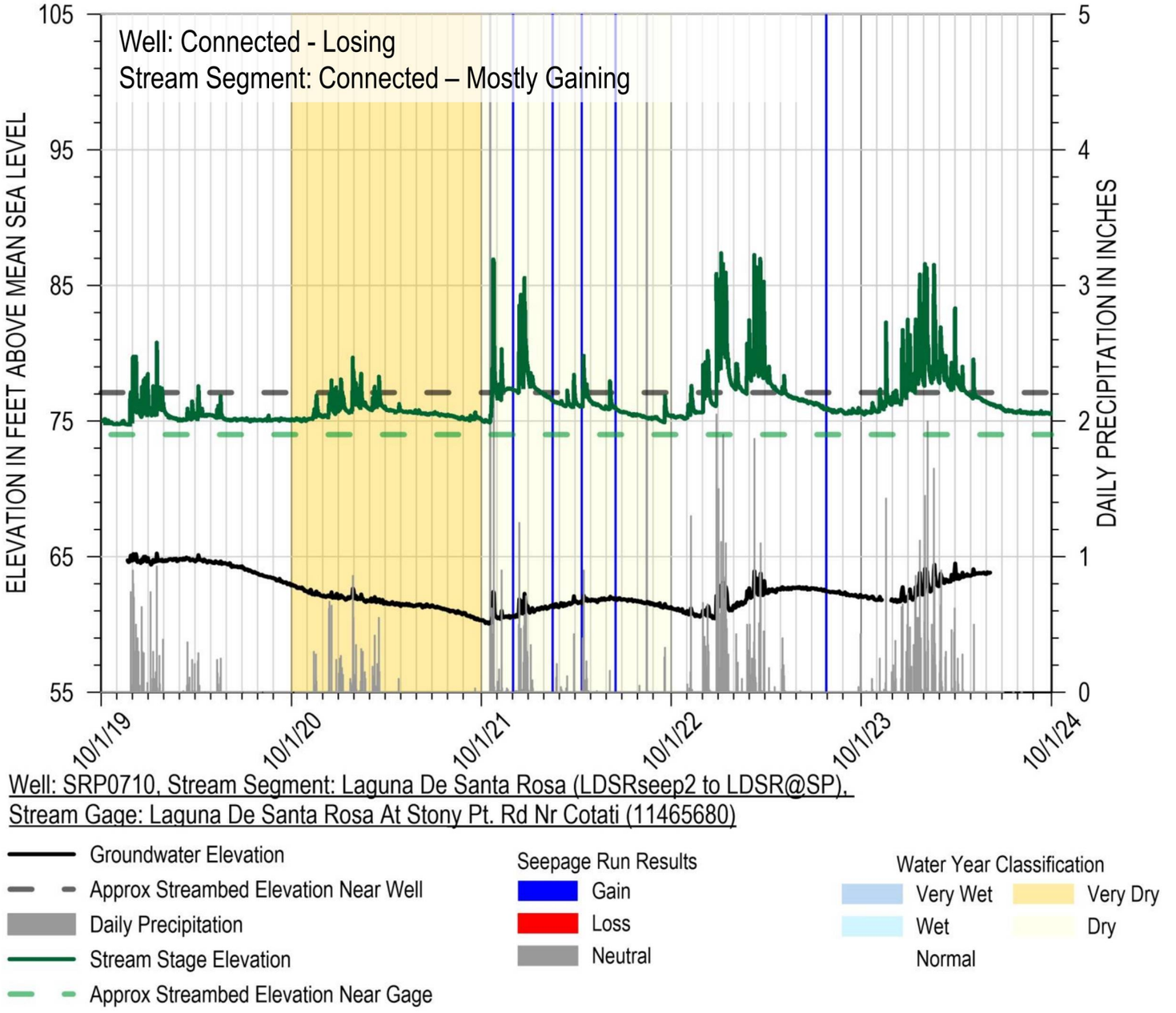




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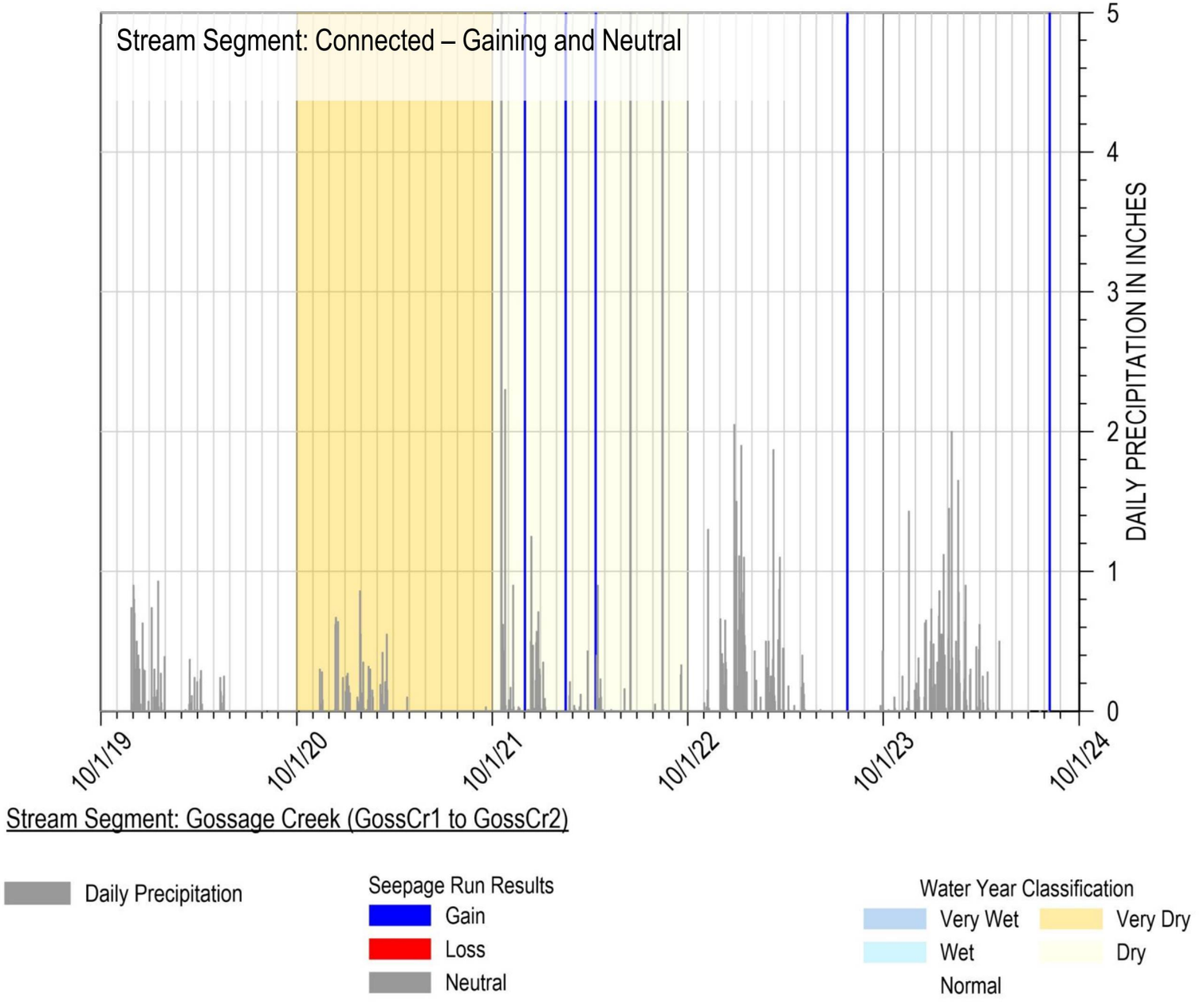






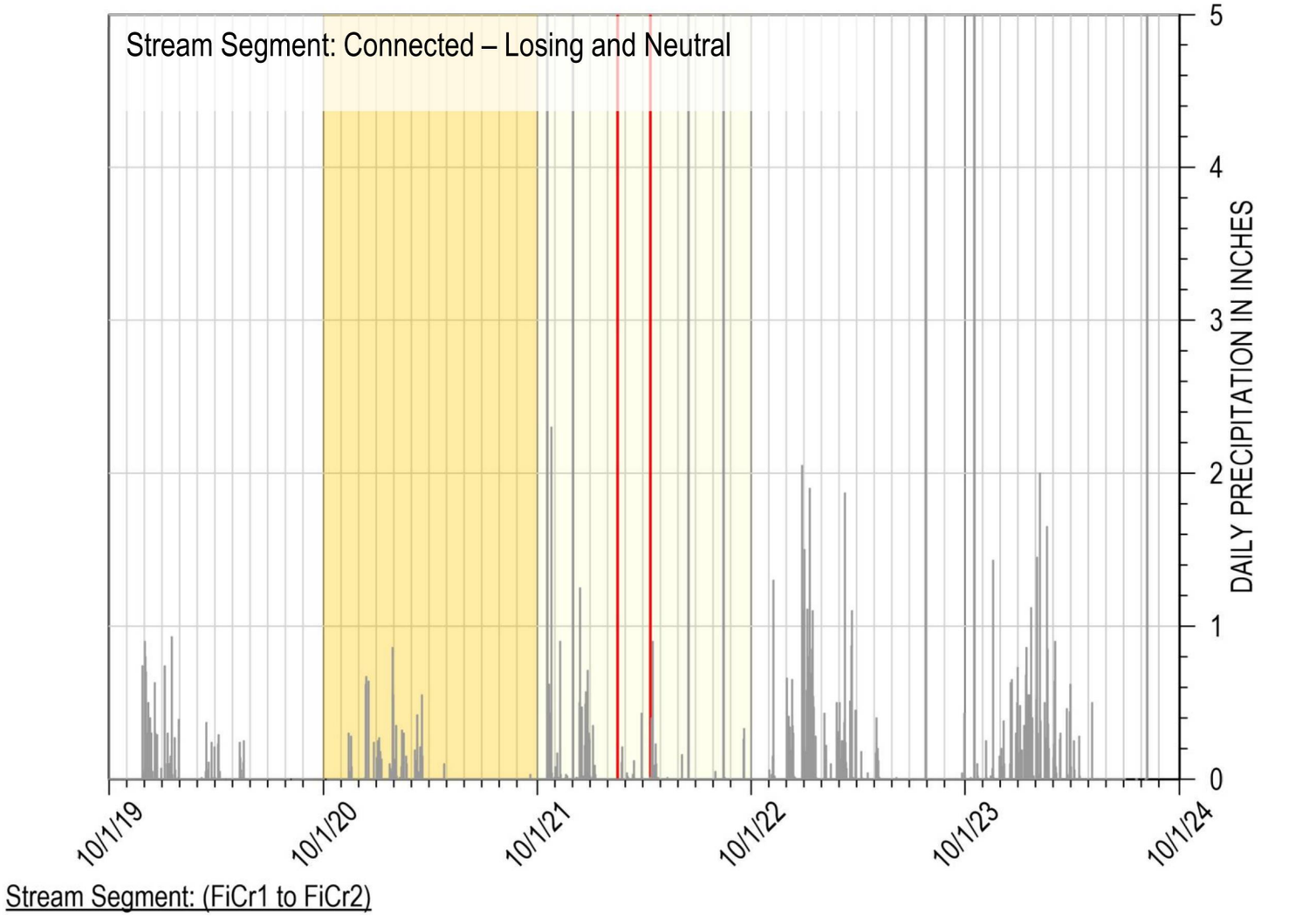
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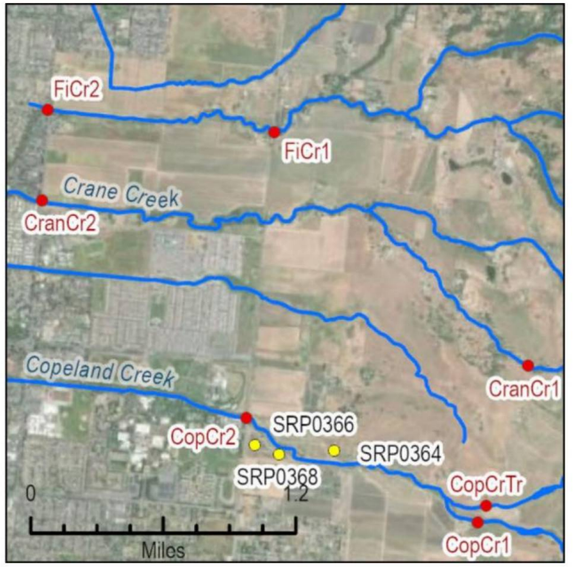


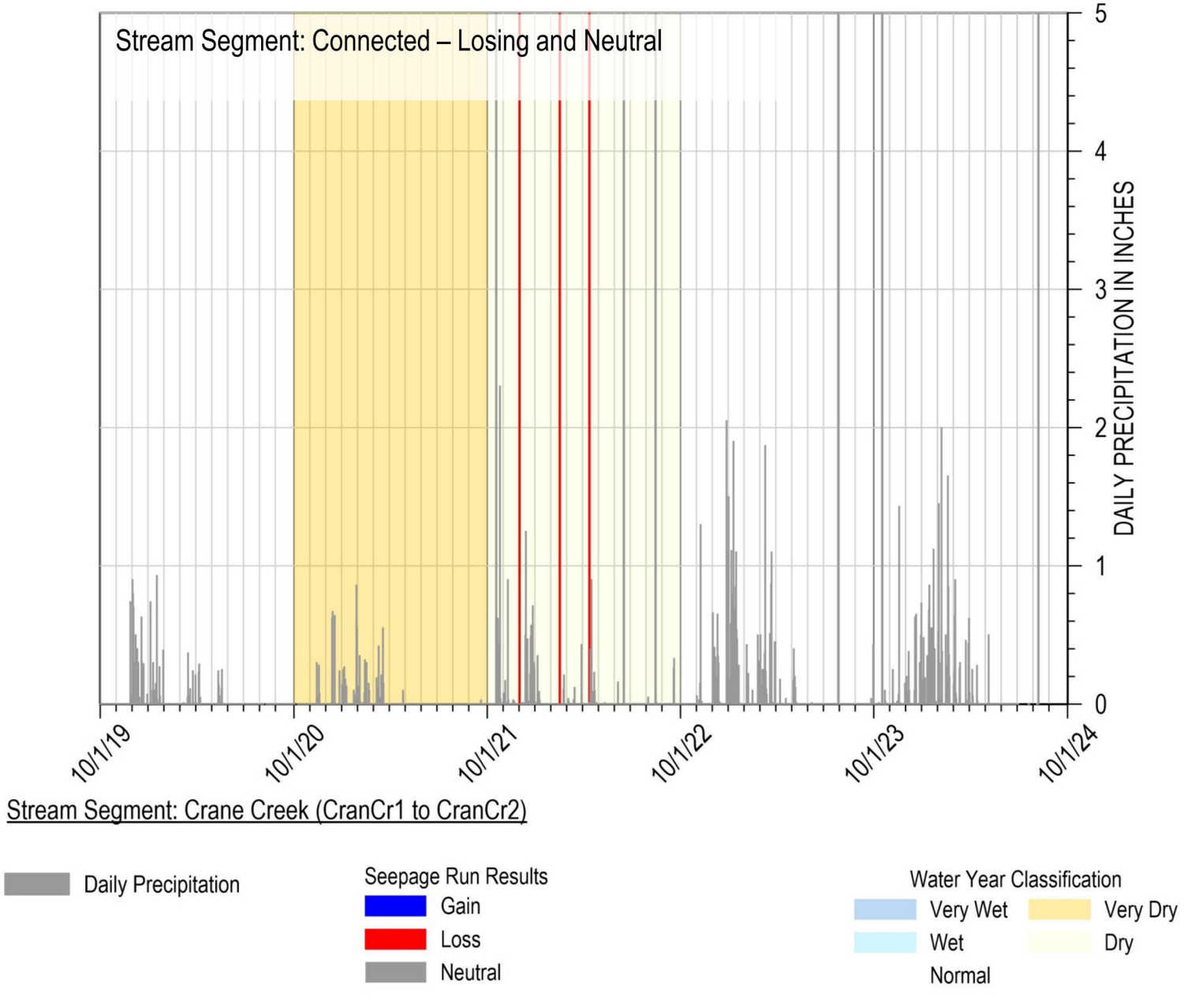
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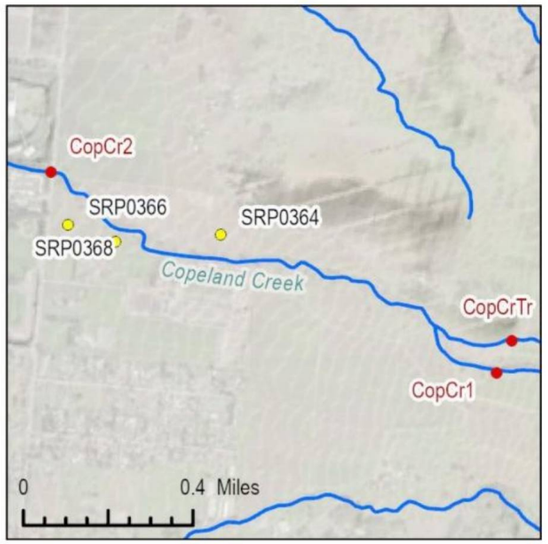


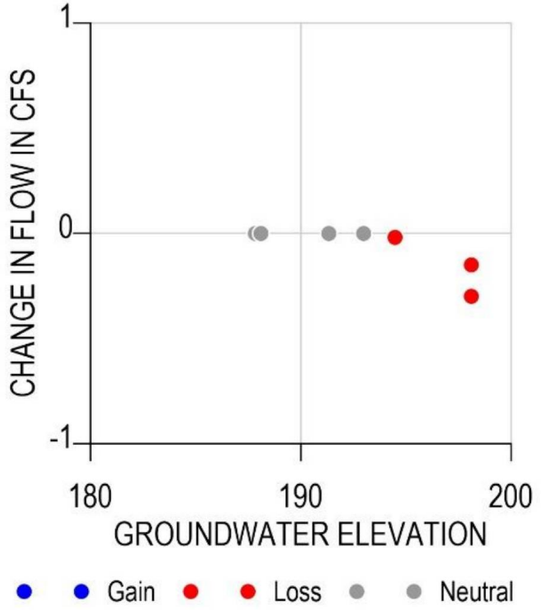
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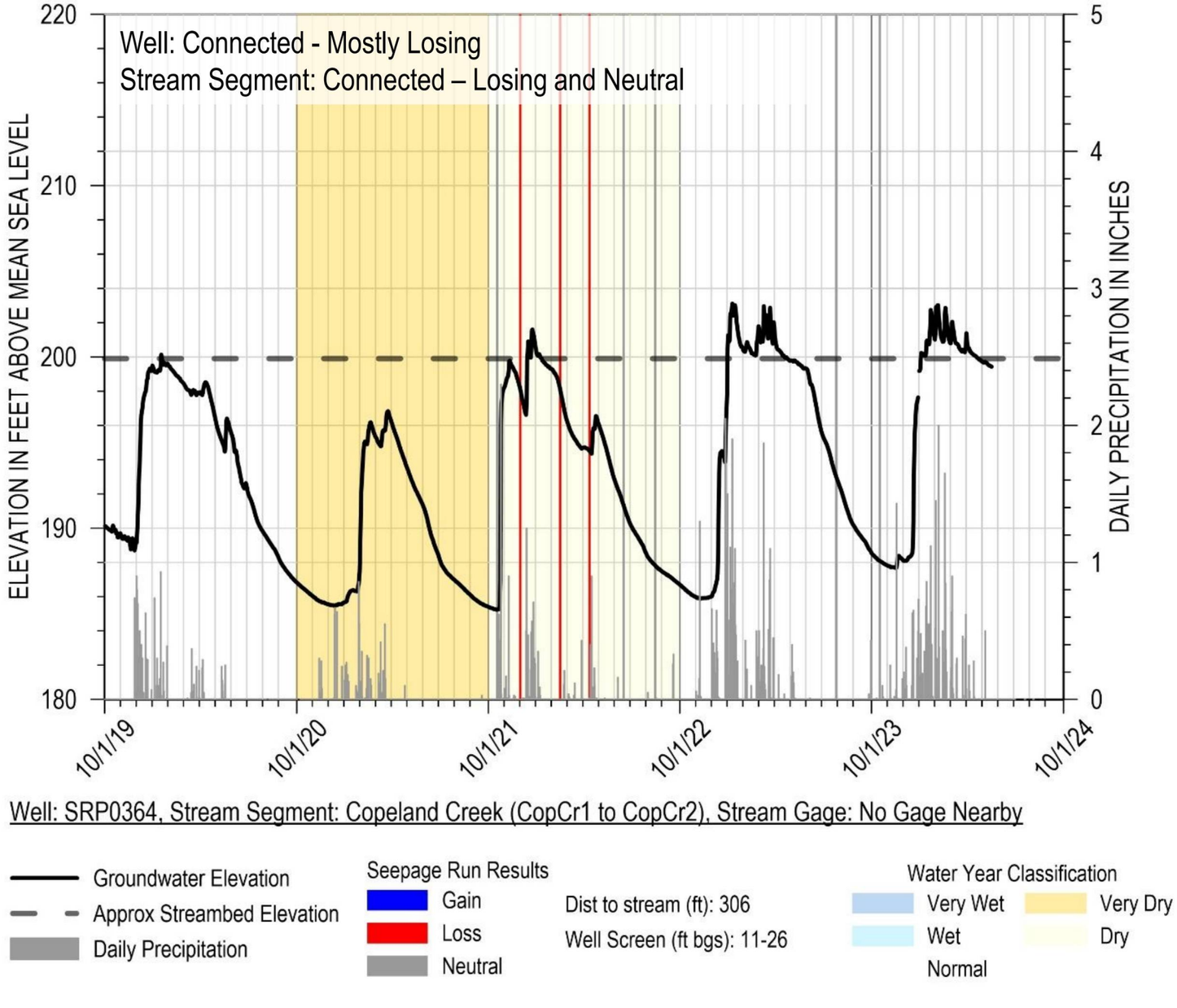




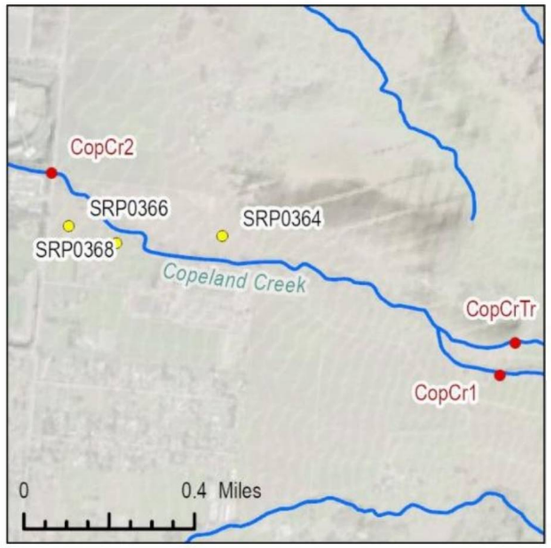
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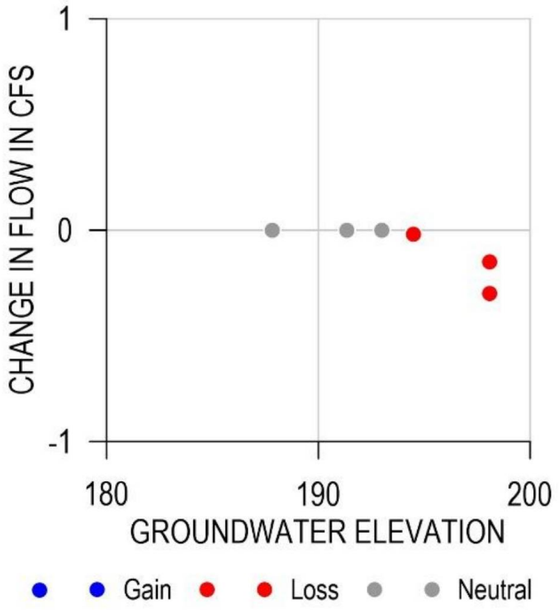


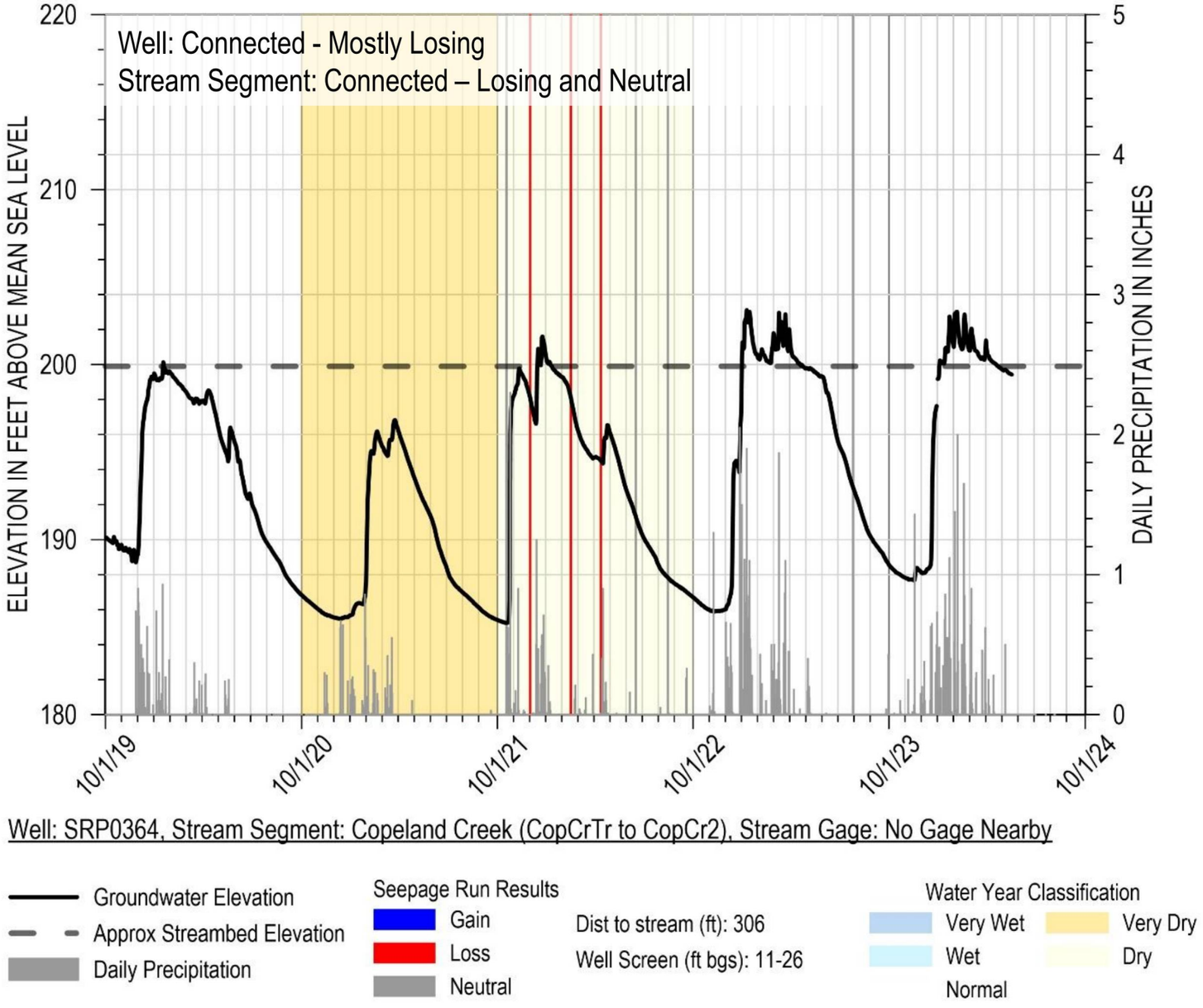




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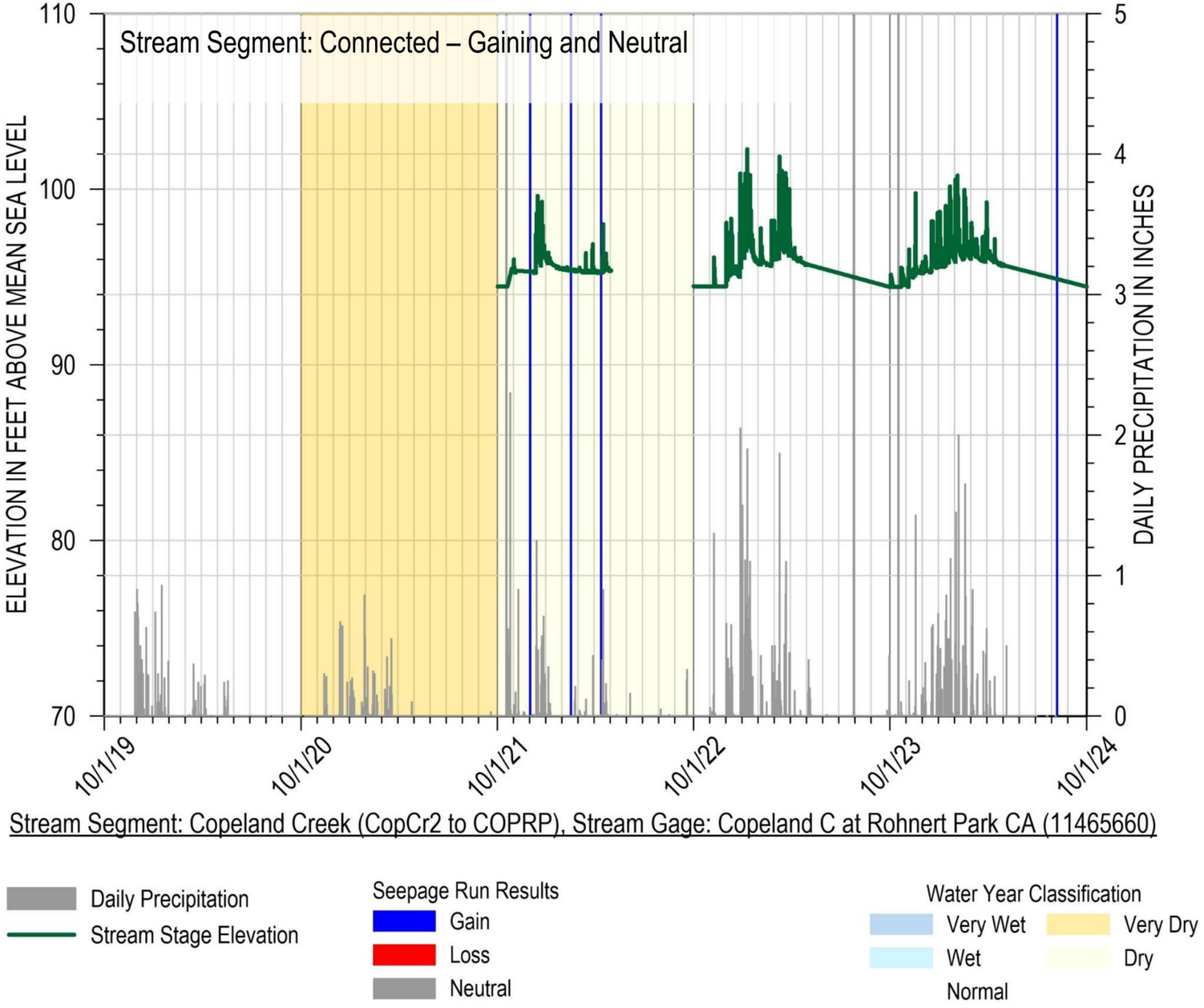






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ATTACHMENT 2

ECOLOGICAL THRESHOLD APPROACH

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ATTACHMENT B
ECOLOGICAL THRESHOLD APPROACH

Introduction

Rohde *et al*. (2024) developed an ecological threshold approach as a method to quantify the groundwater requirements for groundwater dependent ecosystems (GDEs) in California. This approach, which quantifies the depth to groundwater corresponding to adverse vegetation impacts, was trialed in the Santa Rosa Plain Subbasin by evaluating the Normalized Difference Vegetation Index (NDVI), Normalized Difference Moisture Index (NDMI) and Depth to Groundwater (DTG) across all GDEs and specific GDE vegetation groups. The goal of the trial is to determine the effectiveness of using ecological thresholds as part of reevaluating sustainable management criteria (SMC) for the 2027 Groundwater Sustainability Plan Periodic Evaluation.

Data Preparation

GDE polygons identified using Spring 2023 depth to groundwater are used to average NDVI, NDMI, and DTG for each polygon (Figure 1).

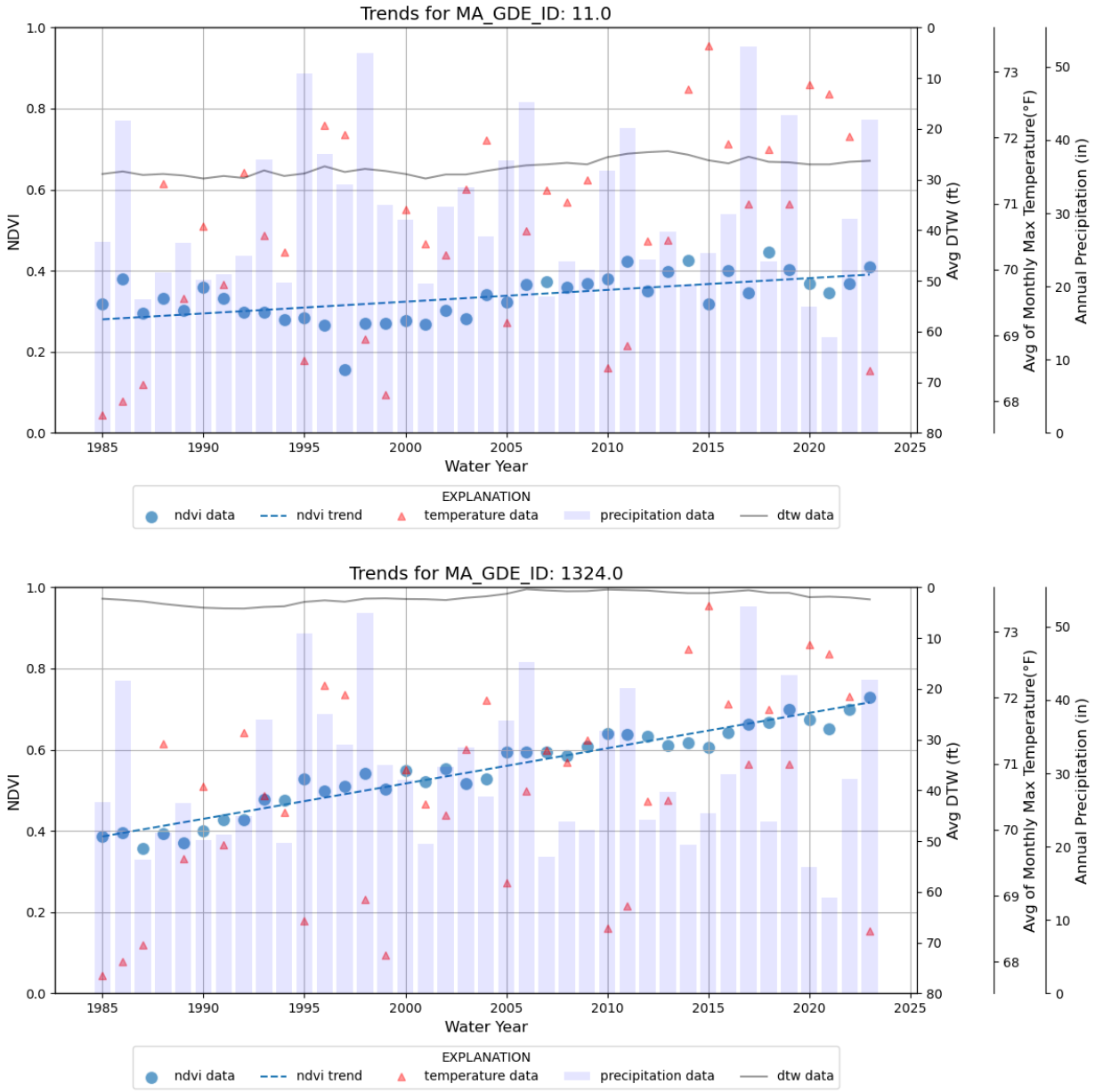


Figure 1. NDVI, DTG, and Climate Timeseries for Example GDE Polygons in Santa Rosa Plain Subbasin

In the Santa Rosa Plain, there are 1,734 GDE polygons (Figure 2). Each polygon has 39 pairs of data for DTG and NDVI corresponding with the number of years from 1985 through 2023 (Figure 3).

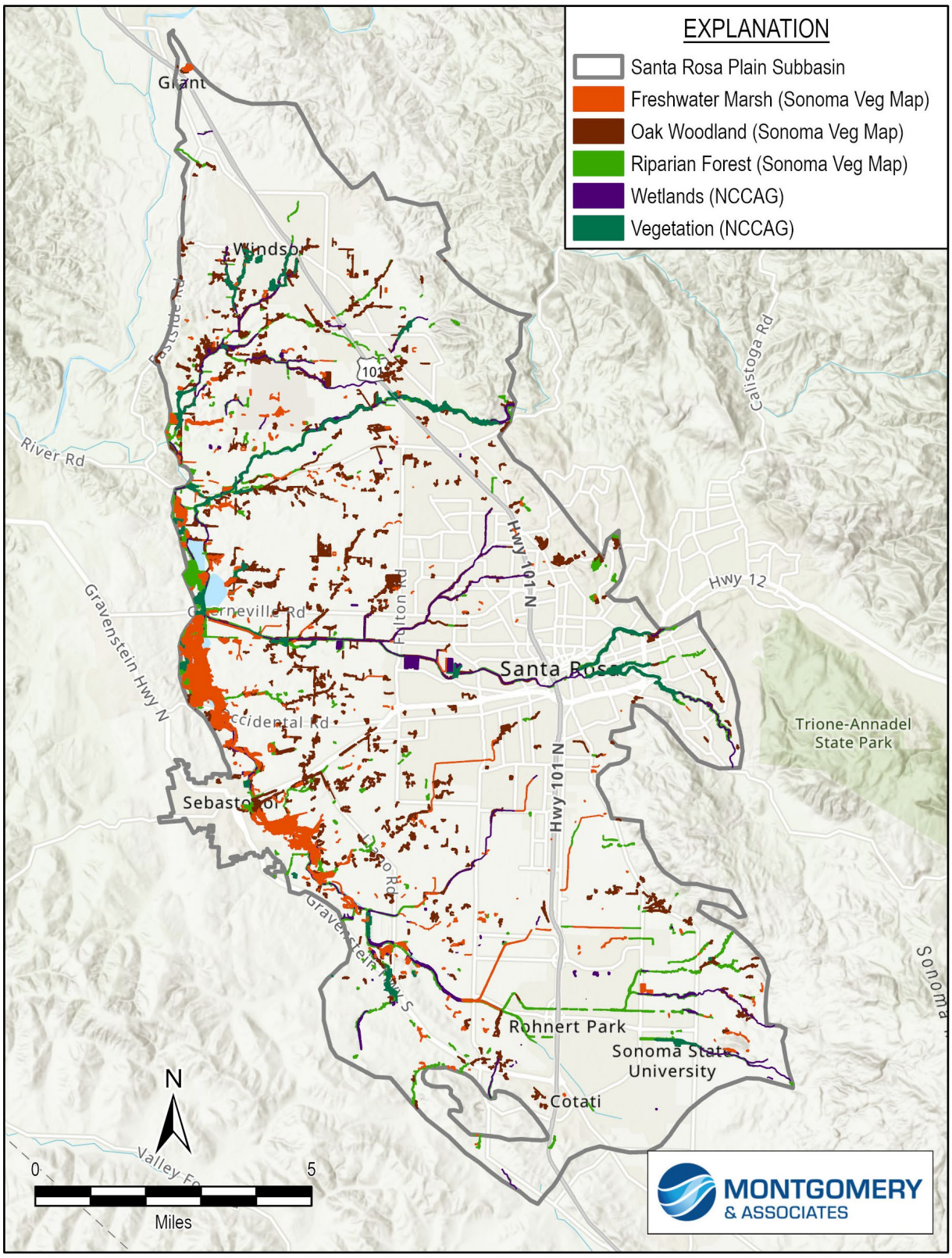


Figure 2. Santa Rosa Plain Subbasin Groundwater Dependant Ecosystems

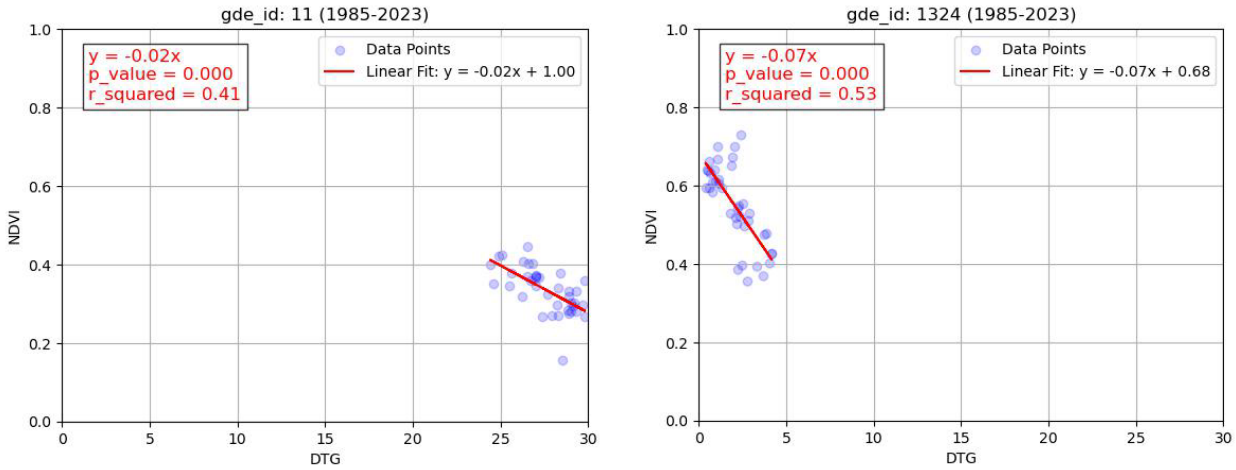


Figure 3. Vegetation NDVI as a Function of DTG for Example GDE Polygons in Santa Rosa Plain Subbasin

Data Standardization

Values of NDVI and DTG are transformed into Z-scores using the set of values for each polygon.

$$Z = \frac{Obs - Mean}{Standard\ Deviation} \qquad (1)$$

Z_{NDVI} are plotted as a function of Z_{DTG} to examine vegetation response to changes in DTG (Figure 4). This can be done at a variety of scales: Z-score plots are developed for each GDE polygon (Figure 5), for each vegetation community, for the entire subbasin, and for distinct geographic areas within the subbasin.

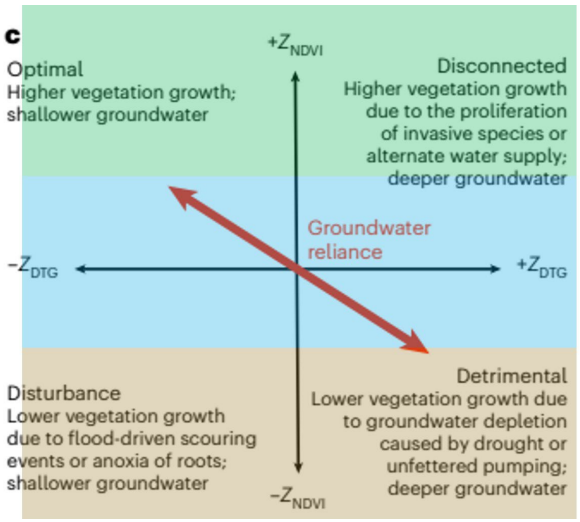


Figure 4. Z-Score Plot Interpretation (Source: Rhode *et al.*, 2024)

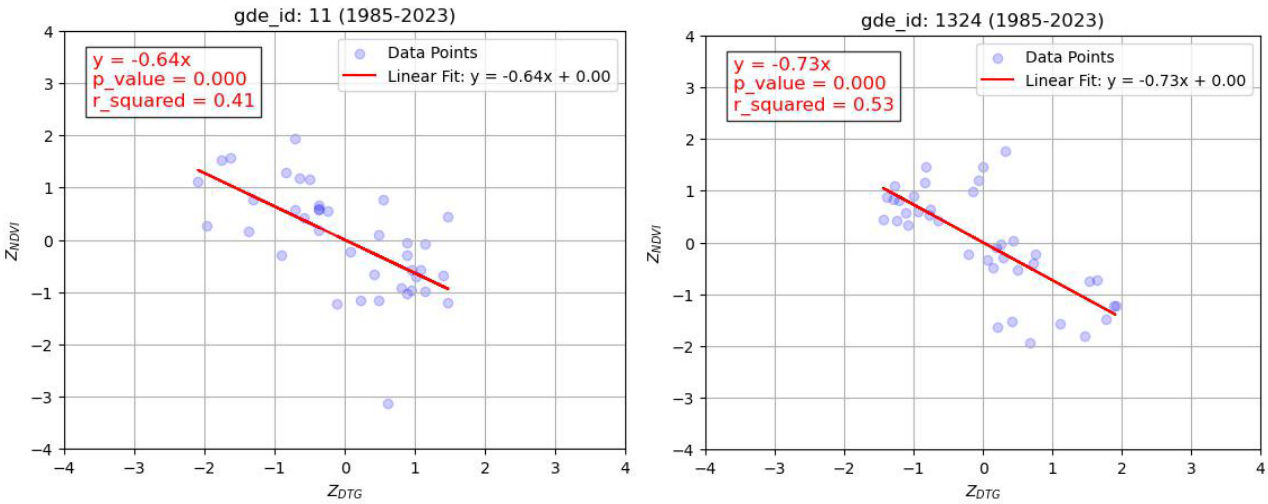


Figure 5. Z-Score Plots for Example GDE Polygons in Santa Rosa Plain Subbasin

Threshold Development

Groundwater thresholds are developed when a significant negative relationship exists between Z_{NDVI} and Z_{DTG} (slope <0; p<0.05). When Z_{NDVI} is equal to -1, this indicates the depth to groundwater resulted in a decline in vegetation greenness (NDVI) by one standard deviation from the mean. Significant relationships are observed at some individual GDE polygons and at various scales within the subbasin. Relationships are evaluated for each vegetation community in the Subbasin (Figure 6) and all GDE vegetation types in the subbasin (Figure 7). This relationship can be evaluated for distinct watersheds or regions within the subbasin; for example, isolating GDE polygons near Sonoma State University along Copeland Creek, Hinebaugh Creek, and Crane Creek (Figure 8).

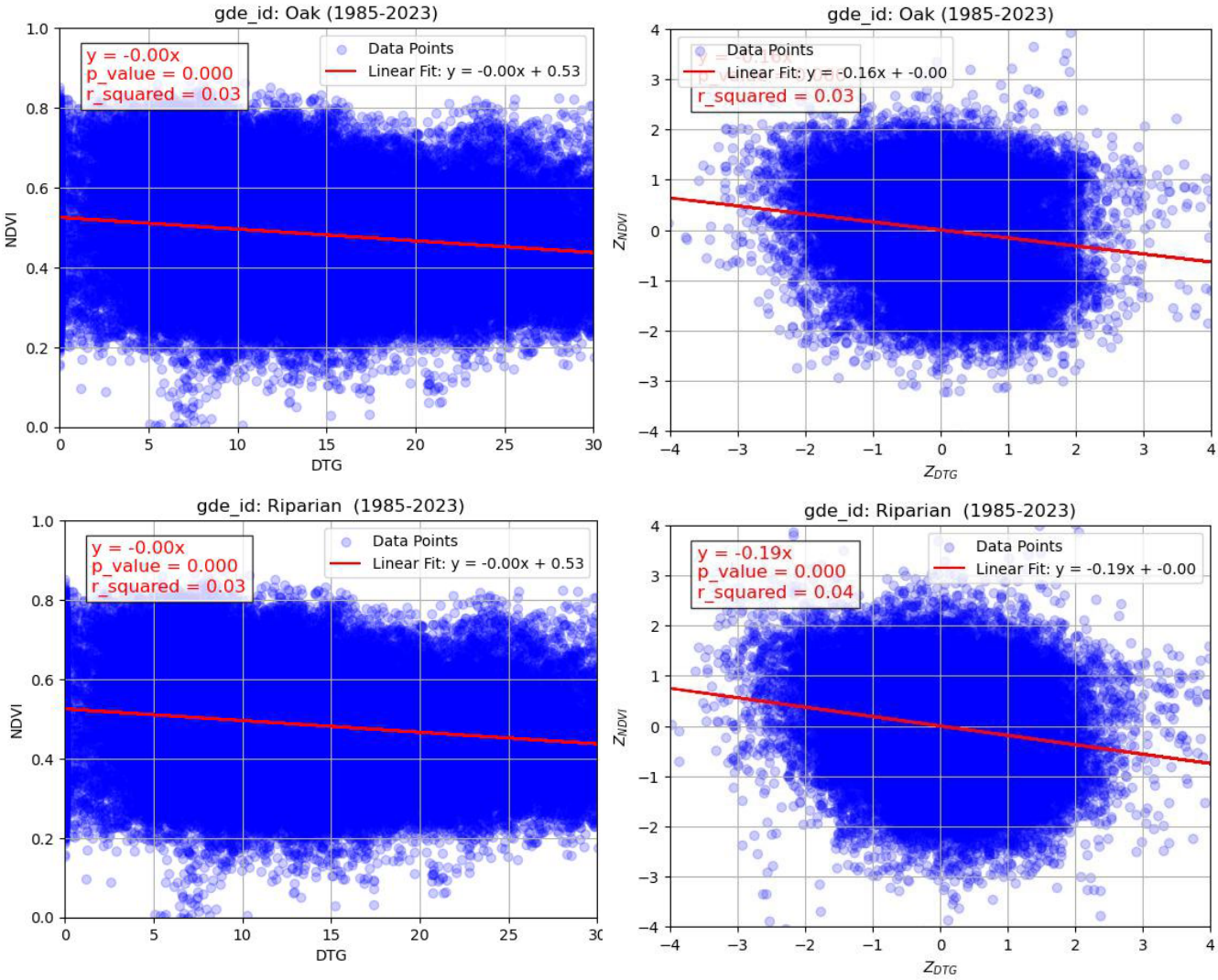


Figure 6. DTG and NDVI Relationships for Oak and Riparian Vegetation Communities (left); Z-Score Relationships (right)

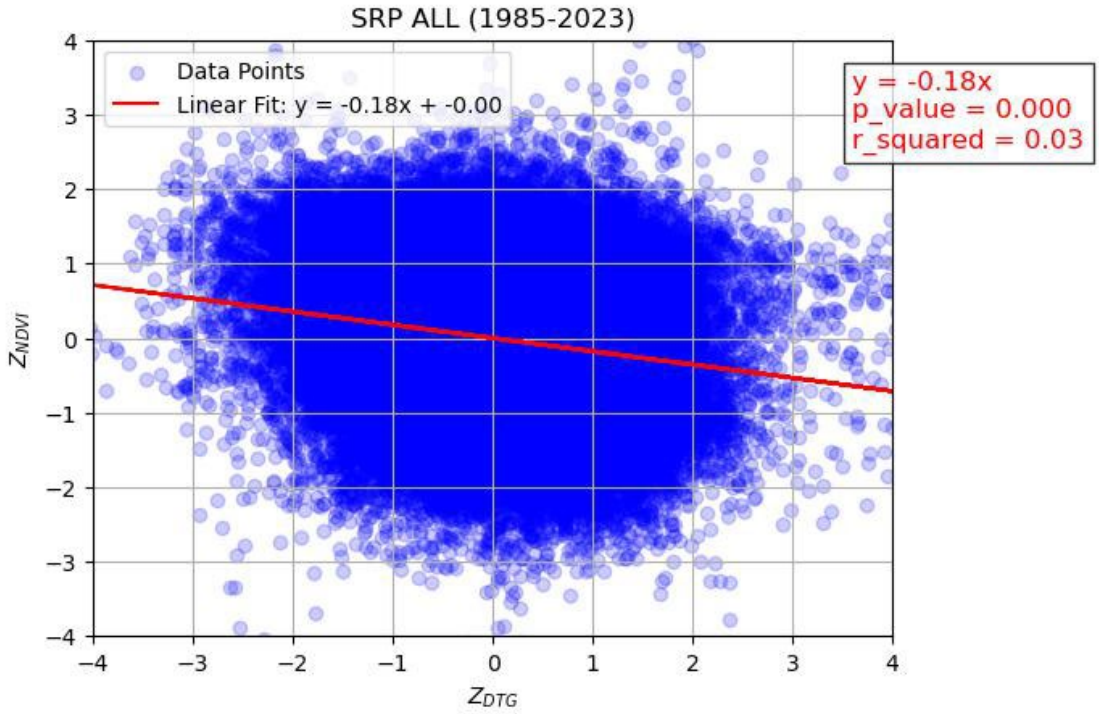


Figure 7. Z-Score Relationship for All GDE Polygons in Santa Rosa Plain Subbasin

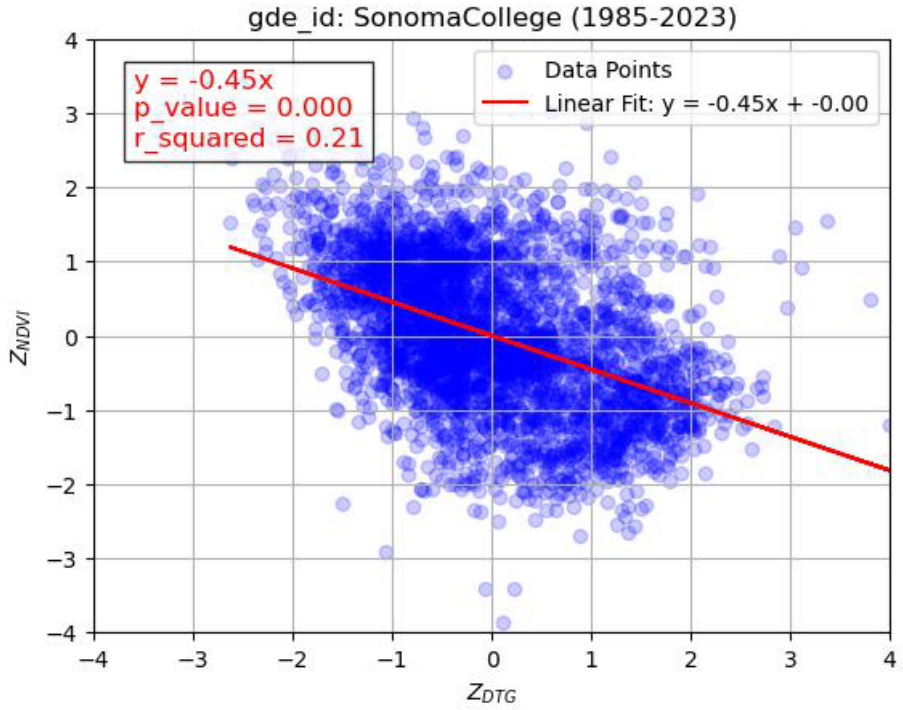


Figure 8. Z-Score Relationship for GDE Polygons near Sonoma State University

In the GDE polygons near Sonoma State University, $Z_{NDVI} = -1$ corresponds to Z_{DTG} of 2.2. Z_{DTG} can be converted back to a threshold depth to groundwater by using the statistics of those polygons (DTG mean = 13.3 feet and DTG standard deviation = 8.2) in Equation 1. In this instance, the ecological threshold for this region would be 31.3 feet DTG compared to an average rooting depth based on known rooting depth of vegetation around 17.7 feet (Figure 10).

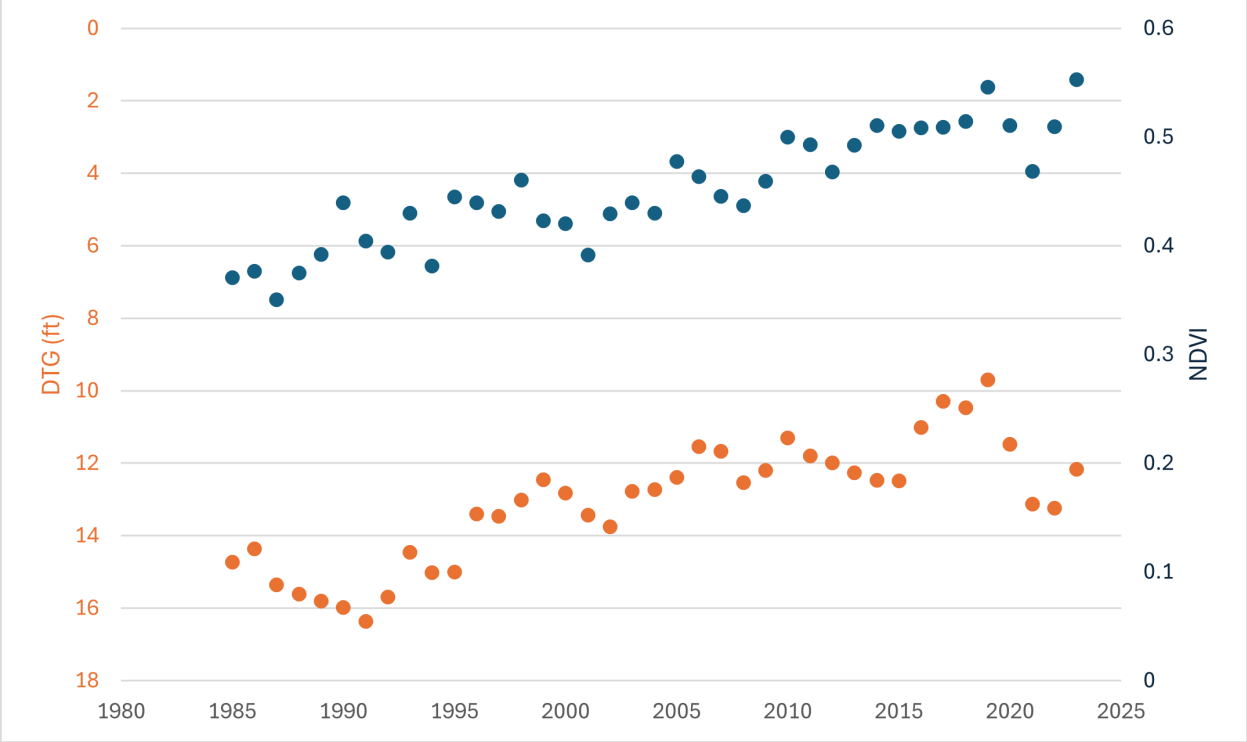


Figure 9. Average DTG and Average NDVI for All GDE Polygons near Sonoma State University

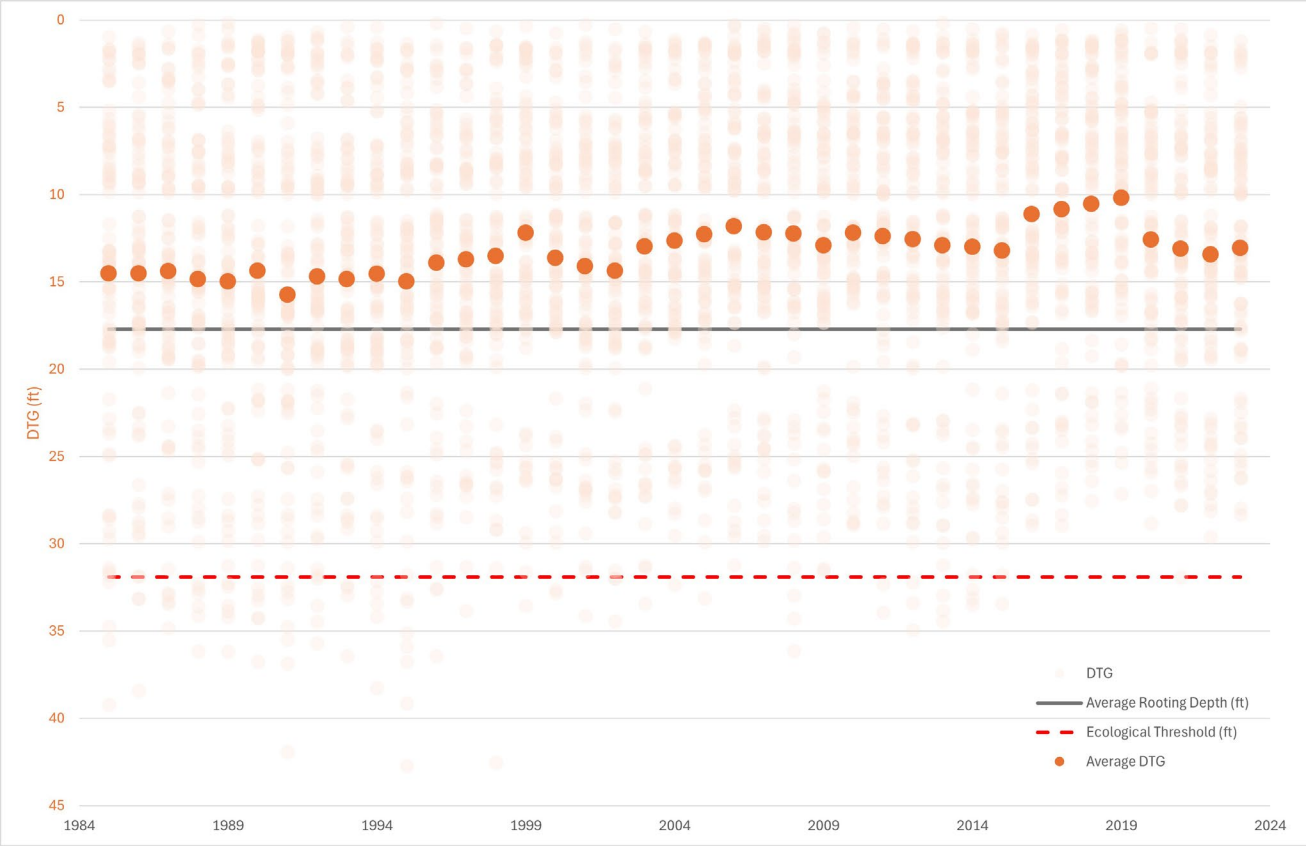


Figure 10. Ecological Threshold with DTG for GDE Polygons near Sonoma State University

Finally, the distribution of DTG for different categories of Z_{NDVI} can provide insight into DTG values for different vegetation health classifications (Table 1). Differences between unhealthy, moderately healthy, and healthy vegetation categories indicate that the relationship between depth to groundwater and vegetation health is present within this subbasin (Figure 11).

Table 1. Vegetation Groups and Corresponding DTG for Different Vegetation Health

Vegetation Group	Rooting Depth (ft)	Unhealthy (Z_{NDVI}<=-1)		Near Baseline (-1<Z_{NDVI}<1)		Healthy (Z_{NDVI}>=1)	
		Average DTG (ft)	25th Percentile DTG (ft)	Average DTG (ft)	25th Percentile DTG (ft)	Average DTG (ft)	25th Percentile DTG (ft)
All	6.9	14.0	8.2	13.4	7.7	13.2	7.6
Oak	28.4	16.5	10.3	16.0	9.9	15.6	9.8
Riparian	10.5	12.5	7.1	11.7	6.7	11.6	6.4

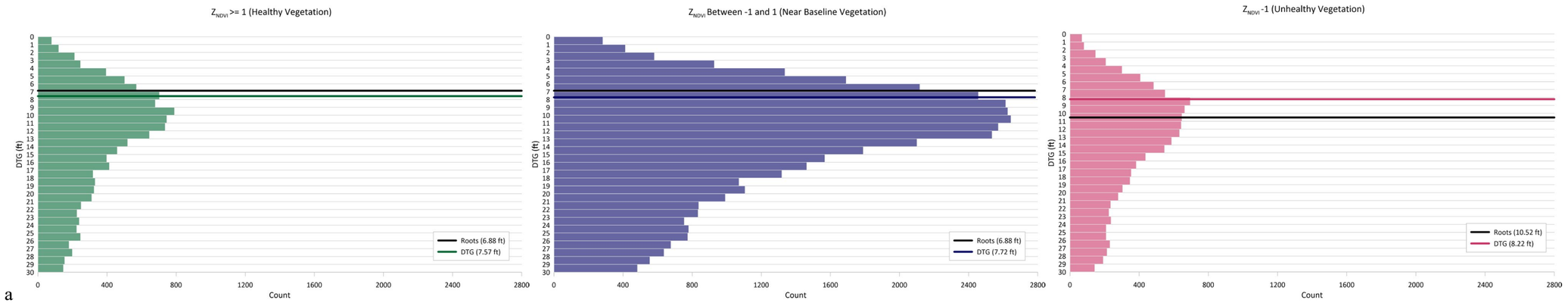


Figure 11. Santa Rosa Plain Subbasin Depth to Groundwater Distribution of Healthy (left), Near Baseline (center), and Unhealthy (right) Vegetation for All Vegetation (a), Oak Woodland (b), and Riparian Vegetation (c)

Findings

Developing ecological thresholds could offer valuable insights when reassessing existing SMC for GDEs within the Subbasin. Rhode *et al.* observed stronger correlations between groundwater depth and vegetation health in the Kern River Preserve (26 GDE polygons). These localized relationships suggest that site-specific applications—where groundwater levels and vegetation health can be directly monitored and verified—may yield the most meaningful results. A similar approach was demonstrated near Sonoma State University, highlighting the potential for targeted ecological threshold development. To effectively implement this approach in the Santa Rosa Plain Subbasin and neighboring basins, further insight into the appropriate scale for groundwater management purposes is needed.

Rhode *et al.* also explored defined links between GDEs and discrete shallow groundwater monitoring locations. While this linkage is implemented at the state level through the GDE Pulse tool, it could be applied more precisely at the subbasin scale by incorporating ongoing local monitoring efforts. To support this, existing and planned monitoring locations should be evaluated in relation to current GDEs.

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ATTACHMENT 3

TECHNICAL MEMORANDUM INTERCONNECTED SURFACE WATER MONITORING CLUSTER INSTALLATION REPORT FOR SANTA ROSA PLAIN SUBBASIN

MONTGOMERY & ASSOCIATES
Water Resource Consultants

Groundwater experts since 1984

TECHNICAL MEMORANDUM

DATE: February 5, 2026

TO: Marcus Trotta, Andy Rich, and Mitch Buttress - Sonoma Water

FROM: Tim Dooley and Pete Dennehy, P.G., C.Hg

REVIEWED BY: Georgina King, P.G., C.Hg

PROJECT: GSP Implementation Technical Support for Sonoma County GSAs

SUBJECT: Interconnected Surface Water (ISW) Monitoring Cluster Installation Report for Santa Rosa Plain Subbasin

INTRODUCTION

The Santa Rosa Plain Subbasin Groundwater Sustainability Agency (GSA) prepared a Groundwater Sustainability Plan (GSP) in 2022 to fulfill the requirements of the Sustainable Groundwater Management Act (SGMA). The GSP identified data gaps related to the analysis and establishment of sustainable management criteria (SMC) for the depletion of interconnected surface water (ISW) sustainability indicator. Montgomery & Associates (M&A) supported Sonoma Water staff on technical analysis to fill these data gaps by the first Periodic Evaluation due in January 2027. This technical memorandum (TM) documents ISW monitoring cluster installations performed in July 2025 to collect additional monitoring data to verify gaining and losing groundwater conditions of interconnected streams.

OVERVIEW

Interconnected stream monitoring clusters were installed at 3 sites in the Santa Rosa Plain Subbasin between July 28 and 31, 2025, as shown on Figure 1:

- Mark West Creek at Fulton Road
- Santa Rosa Creek at Willowside Road
- Copeland Creek at Snyder Lane

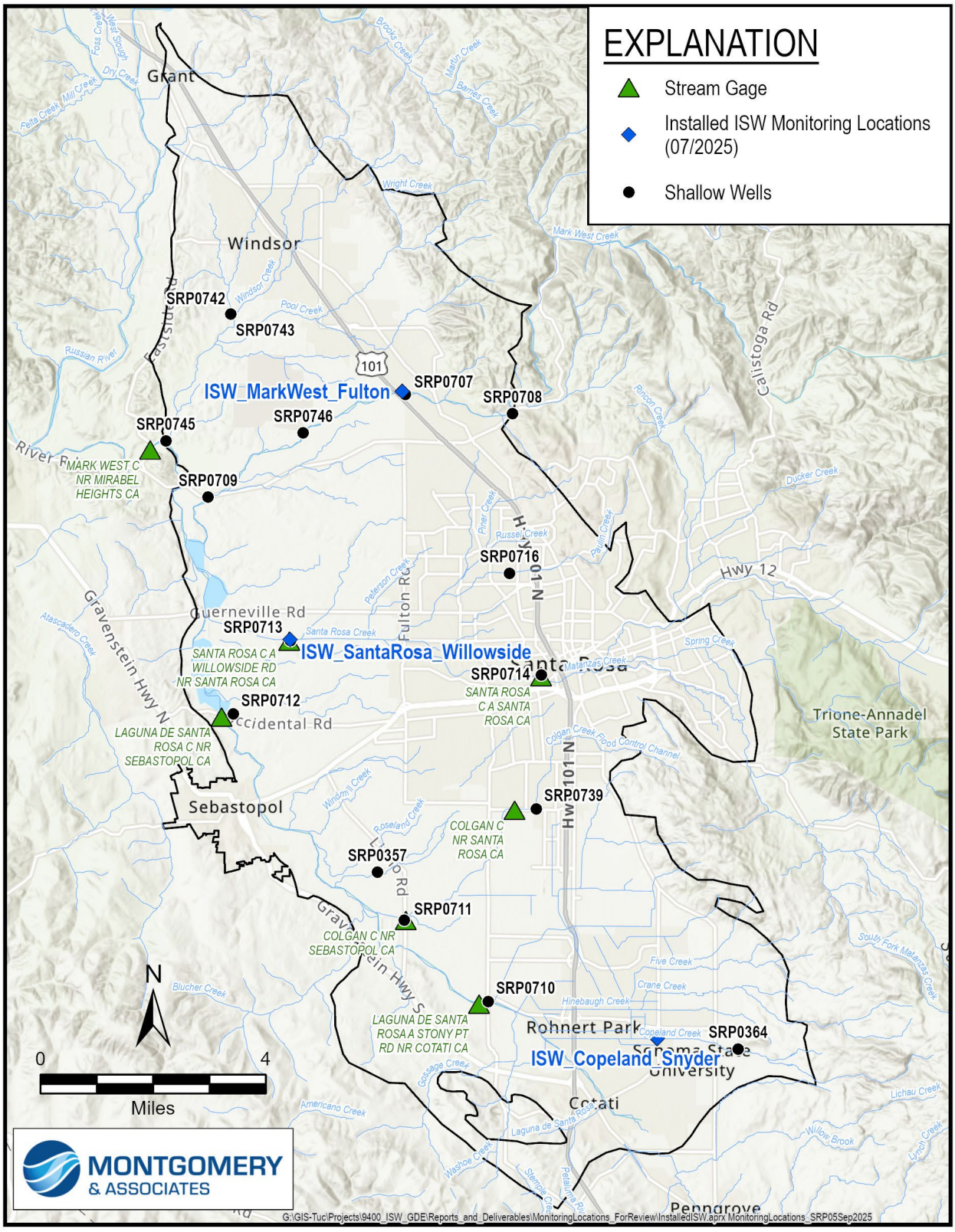


Figure 1. Santa Rosa Plain Subbasin Interconnected Surface Water Monitoring Cluster Locations and Other Related Monitoring Features

The clusters consist of up to 4 monitoring features:

1. Stilling well for monitoring stream stage
2. Streambed piezometer for measuring shallow groundwater levels and gradient below the stream
3. Bank piezometer for measuring shallow groundwater levels and gradient adjacent to the stream
4. Temperature rod (TROD) to profile the thermal gradient beneath the stream

Figure 2 includes a photograph of each feature except for the TROD that is installed underwater, flush with the streambed. Each monitoring feature is equipped with dataloggers to collect and evaluate high frequency data for evaluating pressure and temperature gradients over time. These data will be used to support estimation of the timing and rate of streamflow depletion at specific stream locations.

Figure 3 shows a schematic of the typical stream monitoring cluster.



Figure 2. Bank Piezometer (Left), Stream Bed Piezometer (Middle), and Stilling Well (Right) Installed at Copeland Creek near Snyder Lane

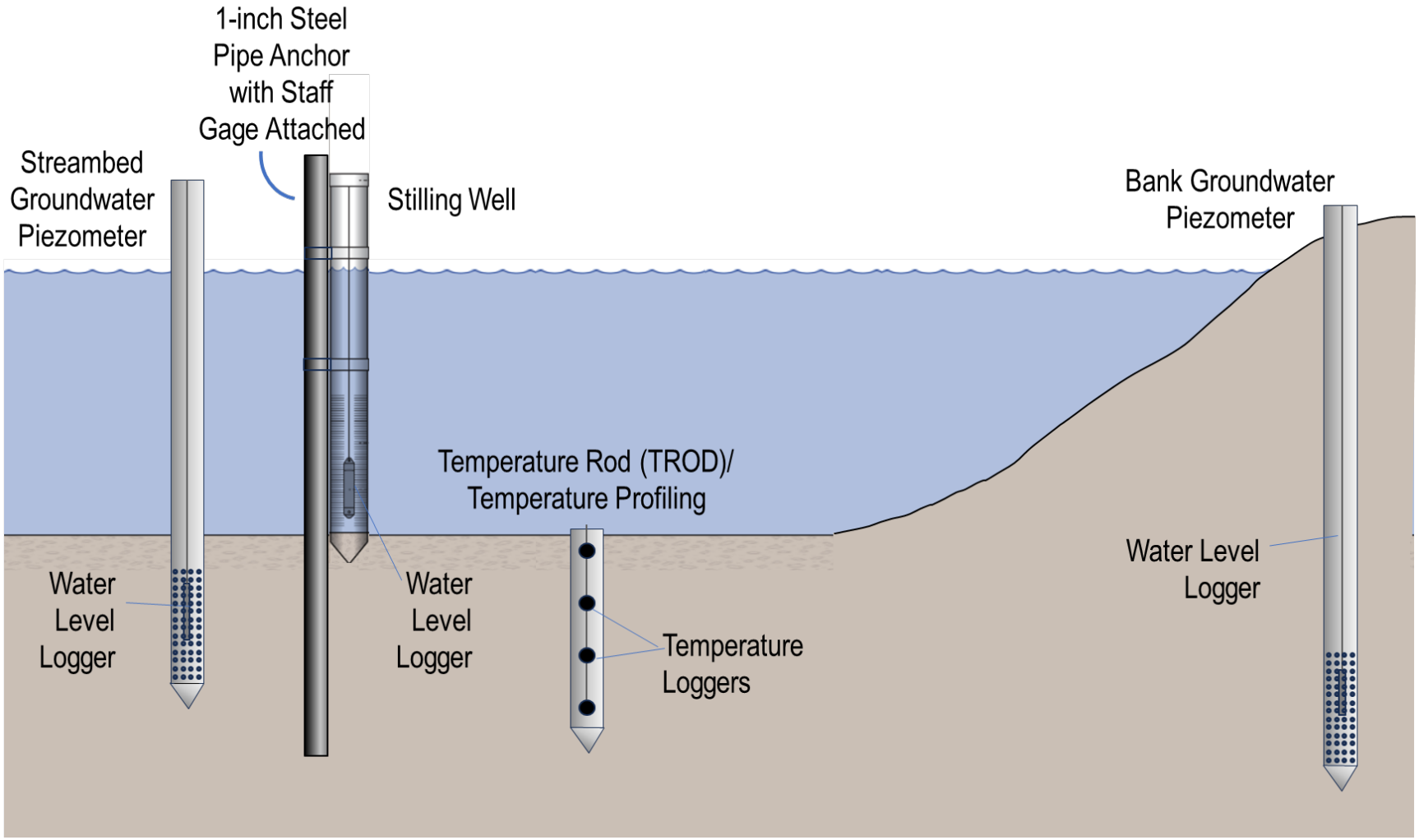


Figure 3. Schematic Diagram of Interconnected Surface Water Monitoring Cluster

FIELD APPROACH

The general field methods and construction specifications for the installed ISW monitoring clusters are described below.

General Specifications

The stilling well and piezometers are constructed with 1-inch diameter, Schedule 40, polyvinyl chloride (PVC) piping, end caps, and 1/8-inch drilled perforations. The piping was installed using a gas powered post-driver (Figure 4).



Figure 4. Sonoma Water Staff Operating a Gas Powered Post Driver to Push the PVC Casing to Depth

Stilling Well Construction Specifications

Each cluster includes a stilling well installed in the stream for measuring stream stage. The perforated PVC pipe rests on the streambed and is anchored to a 6-foot long, 1-inch diameter steel pipe using 3 hose clamps.

Piezometer Construction Specifications

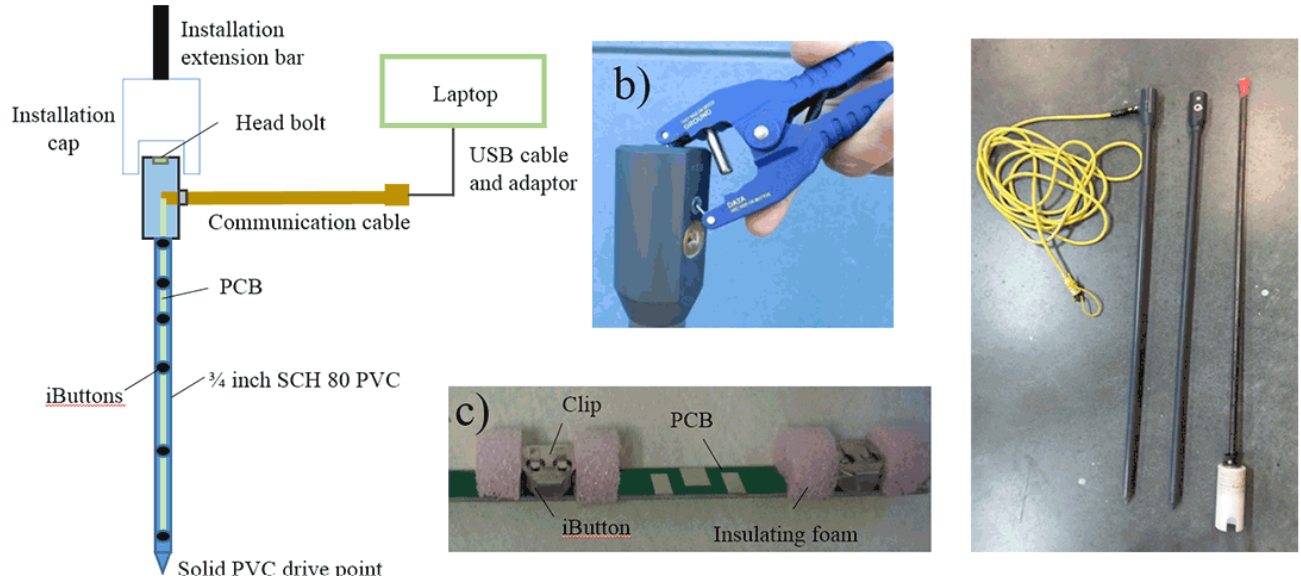
At each site, 2 piezometers were installed in the shallow subsurface for monitoring shallow groundwater levels and groundwater gradients: 1 piezometer was installed in the streambed and 1 was installed on the stream bank (Figure 3). The piezometer perforations were installed at least 6 inches below the streambed to avoid cross-connection between the stream and monitoring point. A PVC drive point was glued to the end of the piezometer to push through and prevent infill with sediments. The piezometers were driven to depth using a post driver. A steel pipe was placed inside the piezometer. Washers were placed around the pipe to centralize it within the PVC casing and prevent damage to the PVC casing while it was being driven. Once the desired depth or refusal was reached, the drive pipe was removed. The piezometer was fitted with a PVC slip cap and a hole was drilled for a 3/8-inch lock shackle.

Stilling Well and Piezometer Monitoring Equipment

The stilling well, stream piezometer, and bank piezometers are equipped with Van Essen Micro-Diver pressure transducers for recording high frequency water level and temperature data. The transducers are hung above the bottom of the monitoring point using a braided stainless-steel cable. The cable is attached to an eye bolt under the slip cap. The transducers are programmed to record measurements every half-hour. Since the transducers are non-vented, they will need to be removed to download data and a barometric compensation applied to account for atmospheric pressure changes. A barometric logger, stored by Sonoma Water in a secure outdoor location, will be used to post-process logger data to compensate for atmospheric pressure.

Temperature Rod Construction Specifications

The TRODs were acquired, programmed, and installed by Sonoma Water. They consist of up to 6 self-logging iButtons placed by the manufacturer (Alpha Mach) at fixed locations inside a ¾-inch diameter schedule 80 PVC pipe with a solid PVC drive point. The rod is capped with a 2-inch diameter, sealed head designed to prevent the ingress of water. The iButtons are connected in series to a heavy-duty submersible communication cable that allows for downloading the temperature data via USB port without removing the equipment. The probes are programmed to record measurements hourly. The TROD assembly is shown on Figure 5.



(https://nevada.usgs.gov/TROD/design.html)

Figure 5. Temperature Rod Assembly

Figure 6 illustrates the following steps used to install the temperature rods:

1. A hole for the TROD was cleared with a 1-inch diameter rock bar. The bar was driven with the gas post driver and removed by rotating with large pipe wrenches and pulled up with a fence post puller.
2. The open hole was filled with bentonite to seal the annulus between the hole and the pipe.
3. The TROD assembly was inserted into the pilot hole.
4. The communications cable was coiled and placed next to the TROD assembly on the stream bank.



(https://nevada.usgs.gov/TROD/installation.html)

Figure 6. Temperature Rod Installation Procedure

Elevation Survey

Piezometer and stilling well casing elevations were surveyed by Sonoma Water using a laser level and rod. A base station was set up emitting a laser in a horizontal plane. A gradated rod was used to measure the relative reference height of each measurement point to the base station. A survey was not performed at the Copeland-Snyder site.

As-Built Construction Details

The as-built construction information, including relative reference height, piezometer length, cable length, and well depth and water level measurements at the time of installation are summarized for each monitoring feature in Table 1. A stilling well was not installed at the Santa Rosa Creek – Willowside site because there is an existing stream gage at this location (Figure 1). The reference height was offset using the known elevation of the stream gage, 58.564 feet relative to mean sea level.

Table 1. As-Built Construction Details

Location Name	Monitoring Feature	Relative Reference Height (feet)	Well Length (feet)	Cable Length (feet)	Tagged Well Bottom (feet below top of casing)	Water Level (feet below top of casing)
Copeland - Snyder	Streambed Piezometer	Not surveyed	5.35	3.66	4.20	1.32
	Bank Piezometer	Not surveyed	5.35	2.94	3.68	1.60
	Stilling Well	Not surveyed	3.40	2.50	3.34	1.78
Mark West - Fulton	Streambed Piezometer	2.901	5.88	5.08	5.50	0.80
	Bank Piezometer	-0.786	5.96	4.79	5.60	4.35
	Stilling Well	2.365	2.60	2.06	2.59	1.30
Santa Rosa - Willowside	Streambed Piezometer	-58.564	5.06	2.71	3.80	0.42
	Bank Piezometer	-61.509	5.35	4.71	5.30	3.46

WELL CLUSTER MANAGEMENT

Sonoma Water has assumed responsibility for monitoring and maintenance of the equipment. The following management approaches help promote collection of good quality data and longevity of the monitoring features:

- Data management – Monitor loggers to ensure sufficient battery and memory are available for data collection.
- Maintenance – Ensure the piezometers are locked to avoid tampering or theft of the transducers. Seasonal removal of equipment and/or monitoring points in streams with high wet season flows or debris that could damage equipment.

MONTGOMERY & ASSOCIATES

ATTACHMENT 4

SONOMA COUNTY GROUNDWATER BASINS VEGETATION SURVEY FOR GROUNDWATER-DEPENDENT ECOSYSTEMS

Groundwater Dependent Ecosystem Characterization and Monitoring for SGMA Implementation

Sonoma County Groundwater Basins

Vegetation Survey for Groundwater-Dependent Ecosystems

Site Name: _____

Site ID: _____

Groundwater Basin: ☐ Santa Rosa Plain ☐ Petaluma ☐ Sonoma

Site Description: _____ ☐ Natural disturbance

_____ ☐ Human disturbance

Coordinates: _____ Survey area (acres):_____

Survey Information

Survey Date: _____ Survey Time: _____

Surveyor(s):_____

Climate Conditions

Weather: ☐ Recent rain ☐ Rain during survey ☐ No current/recent precipitation

Air temperature: _____

Habitat Description

Surface water feature: ☐ Spring ☐ Creek/river ☐ Lake ☐ Dam ☐ Wetland ☐ Other _____

Surface water present and description: ☐ Yes ☐ No

_____

Surrounding land use: ☐ Natural ☐ Urban ☐ Agricultural ☐ Other _____

Presence of phreatophytes: ☐ Willows ☐ Cottonwoods ☐ Oaks ☐ Alder ☐ Ash

☐ Other_____

Observed aquatic and terrestrial fauna: _____

_____

_____

_____

Site ID: _____

Vegetation Assessment

Dominant Species	Species Density [Estimate per square meter/acre]	Plant Health Indicators: [Describe seasonal stage, leaf color, signs of drought stress, and growth patterns]

Non-Native Species: [List invasives if present with estimated density]

_____

_____

_____

_____

Geolocated Photographs

Describe general site photographs taken including location and direction taken.

_____

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List closeup leaf photographs of dominant species. Include scale in leaf photos.

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Other notes: