Identification and Mapping of Groundwater Dependent Ecosystems in the 180/400-Foot Aquifer Subbasin

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Prepared for the Salinas Valley Basin Groundwater Sustainability Agency
Prepared by the Central Coast Wetlands Group

Introduction

The Sustainable Groundwater Management Act (SGMA) requires all beneficial users, including Groundwater Dependent Ecosystems (GDEs), must be considered during development and implementation of Groundwater Sustainability Plans (Water Code § 10723.2). SGMA requires all GDEs within a groundwater basin be identified, monitored and assessed to ensure there are no adverse impacts to these systems due to groundwater conditions.

Identification of Potential Groundwater Dependent Ecosystems

The process for identifying and mapping potential GDEs in the Salinas Valley, including the Upper Valley Aquifer Subbasin, was developed with guidance from documents developed by The Nature Conservancy (TNC) (Rhode et al. 2018, Rhode et al. 2020), TNC staff and San Francisco Estuary Institute (SFEI) staff with subject matter expertise, and Dr. Melissa Rhode. Additionally, this process was developed with feedback from local stakeholders as part of the Salinas Valley Basin Groundwater Sustainability Agency (SVBGSA) convened Groundwater Dependent Ecosystem Working Group, which met seven times between July 2023 - April 2024.

Identification and mapping of potential GDEs in the Upper Valley Aquifer Subbasin was part of a larger identification process for identifying potential GDEs in the Salinas Valley and included a desktop review and analysis of groundwater and habitat datasets.

There are inherent uncertainties in the identification of GDEs due to the difficulty of directly measuring an ecosystem's reliance on groundwater. While there are methods for directly measuring the extent to which vegetation and waterbodies are reliant on groundwater, these methods are highly resource intensive and are not considered a reasonable or necessary approach by subject matter experts. This process instead relied on proxy measures based on the best available science and groundwater and habitat mapping data. If these datasets are updated, so should the identification and mapping of potential GDEs in this subbasin. Due to the inherent uncertainties, this process aimed to err on the side of being more inclusive in the mapping and identification of potential GDEs.

Additionally, the goal of this identification and mapping process was not to identify every plant and waterbody dependent on groundwater but rather ensure there was adequate identification of potential GDEs across the Upper Valley Aquifer Subbasin. This approach takes the perspective that if there are no adverse impacts to identified potential GDEs, then any additional ecosystems missed in the process will also be protected under SVBGSA management activities and decisions. Subject matter experts consulted in the development of this identification process support this perspective and encourage spending enough resources on identification and mapping to get adequate coverage while spending more focus and resources on monitoring and assessment to protect potential GDEs from adverse impacts.

Monitoring and Assessment of Groundwater Dependent Ecosystems

The objective of GDE monitoring and assessment is to detect when the condition of a GDE is declining, where further decline would be expected to result in long-term adverse impacts to the ecosystem. When such declines in condition are detected, the GDE must be flagged for further investigation into the root cause of the decline to determine if it is related to groundwater management activities. For the purposes of GDE monitoring in the Salinas Valley, ecosystem condition is primarily defined through vegetation health and vigor since this metric can be most readily tied to groundwater conditions. If groundwater levels are lowered below a depth that vegetation roots can access, a decline in vegetation vigor due to the loss of the water source would be an expected result and defined as an adverse impact.

The monitoring and assessment protocol for GDEs in the Salinas Valley was developed with guidance from documents developed by TNC (Rhode et al. 2018, Rhode et al. 2020), TNC staff and SFEI staff with subject matter expertise, and Dr. Melissa Rhode. Additionally, as with the identification of potential GDEs in the Salinas Valley, this monitoring protocol was developed with feedback from local stakeholders as part of the SVBGSA Groundwater Dependent Ecosystem Working Group.

Two-pronged Approach

This GDE monitoring methodology uses a two-pronged approach to maximize efficiencies of cost and labor while ensuring GDEs are adequately monitored and assessed to effectively detect adverse impacts. Monitoring includes a desktop-based component and a field-based component. It is recommended that the desktop-based monitoring is conducted annually for all mapped potential GDEs while the field-based monitoring is conducted once every five years at a subset of mapped potential GDEs. Detailed procedures for both monitoring components are described in the following sections, as is the application of this monitoring methodology to potential GDEs identified in the Upper Valley Aquifer Subbasin to establish baseline conditions. As will become clear, while both monitoring components are reasonable and useful tools for monitoring and assessing GDEs, neither can directly relate declining ecosystem condition to decreasing groundwater levels. Making this direct causal connection to groundwater management would need to be a subsequent hydrogeological analysis to investigate groundwater level trends in the area around the GDE. Therefore, all GDEs in the report are described as "potential" GDEs. However, it is important to make informed inference between any declines in GDE condition and groundwater levels wherever possible. To that end this protocol also includes considerations for siting additional shallow water table monitoring wells, appropriate for monitoring groundwater at a depth the roots of groundwater dependent vegetation can reach, to be added to the existing monitoring well network.

Identification and Mapping of Potential GDEs

State and local habitat mapping datasets were filtered to identify where ecosystems potentially dependent on groundwater are located in the subbasin. Groundwater elevation and ground surface elevation data were used to determine how deep the groundwater table was in relation to the ground surface across the subbasin. This depth to groundwater table was layered with the habitat datasets to identify locations in the subbasin where the groundwater table was reasonably high enough to expect the above ecosystem to be able to access groundwater as one of its water sources. The resulting set of ecosystems potentially reliant of groundwater was further filtered to exclude areas overlying non-principal aquifers and corrected as needed for errors in habitat mapping, such as large areas clearly in agricultural production based on aerial imagery.

The datasets used and steps taken to develop a map of potential GDEs in the 180/400 Subbasin are described in more detail in the following sections.

Datasets

The desktop-based process of identifying and mapping potential GDEs in the 180/400-Foot Aquifer Subbasin used local groundwater elevation data, ground surface elevation data, state and local habitat mapping datasets, and TNC guidance on the rooting depth of plant species known to be groundwater dependent.

Habitat Data

Natural Communities Commonly Associate with Groundwater

The Natural Communities Commonly Associated with Groundwater (NCCAG) dataset is a compilation of phreatophytic vegetation, regularly flooded natural wetlands and riverine areas, and seeps and springs identified from 48 publicly available state and federal agency datasets. This dataset does not account for local groundwater elevations and areas identified in the dataset are considered potentially dependent on groundwater. Two potential GDE types are identified in NCCAG, wetlands and terrestrial vegetation (Figure 1). This dataset was developed by a working group comprised of staff from Department of Water Resources, California Department of Fish and Wildlife, and The Nature Conservancy (Klausmeyer et al. 2018). GDE subject matter experts recommend using NCCAG as a starting point for identifying potential GDEs within groundwater subbasins and modifying the dataset based on local habitat and groundwater data.

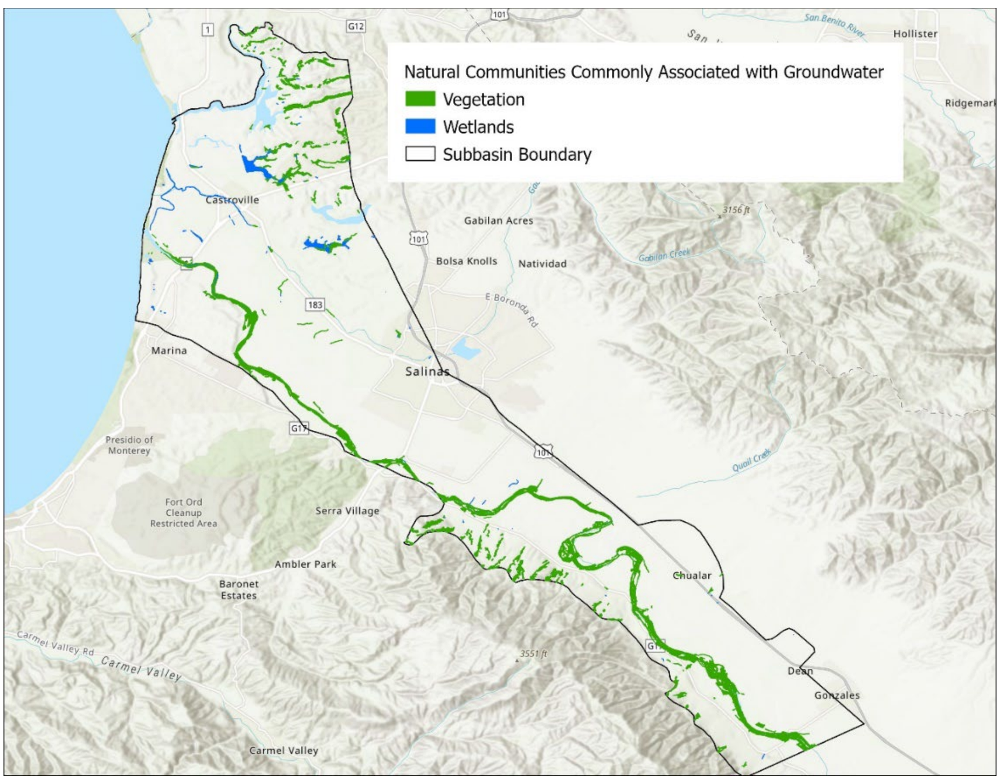

Figure 1. Natural Communities Commonly Associated with Groundwater dataset focused on the 180/400 Foot Aquifer Subbasin (Klausmeyer et al. 2018).

Elkhorn Slough Enhanced Lifeform Habitat Mapping

To supplement NCCAG with local habitat data, the Elkhorn Slough Enhanced Lifeform Habitat Mapping dataset was used in the GDE identification process. The Elkhorn Slough Watershed lifeform mapping was developed by Elkhorn Slough National Estuarine Research Reserve, Elkhorn Slough Foundation, and National Oceanic and Atmospheric Administration (ESF et al. 2020) (Figure 2). This mapping effort includes habitat and land use types not suitable as potential GDEs, such as annual cropland and developed land. Only habitat types determined through best professional judgement to be consistent with the GDE definition were included for further consideration (Table 1) (ESF et al. 2020).

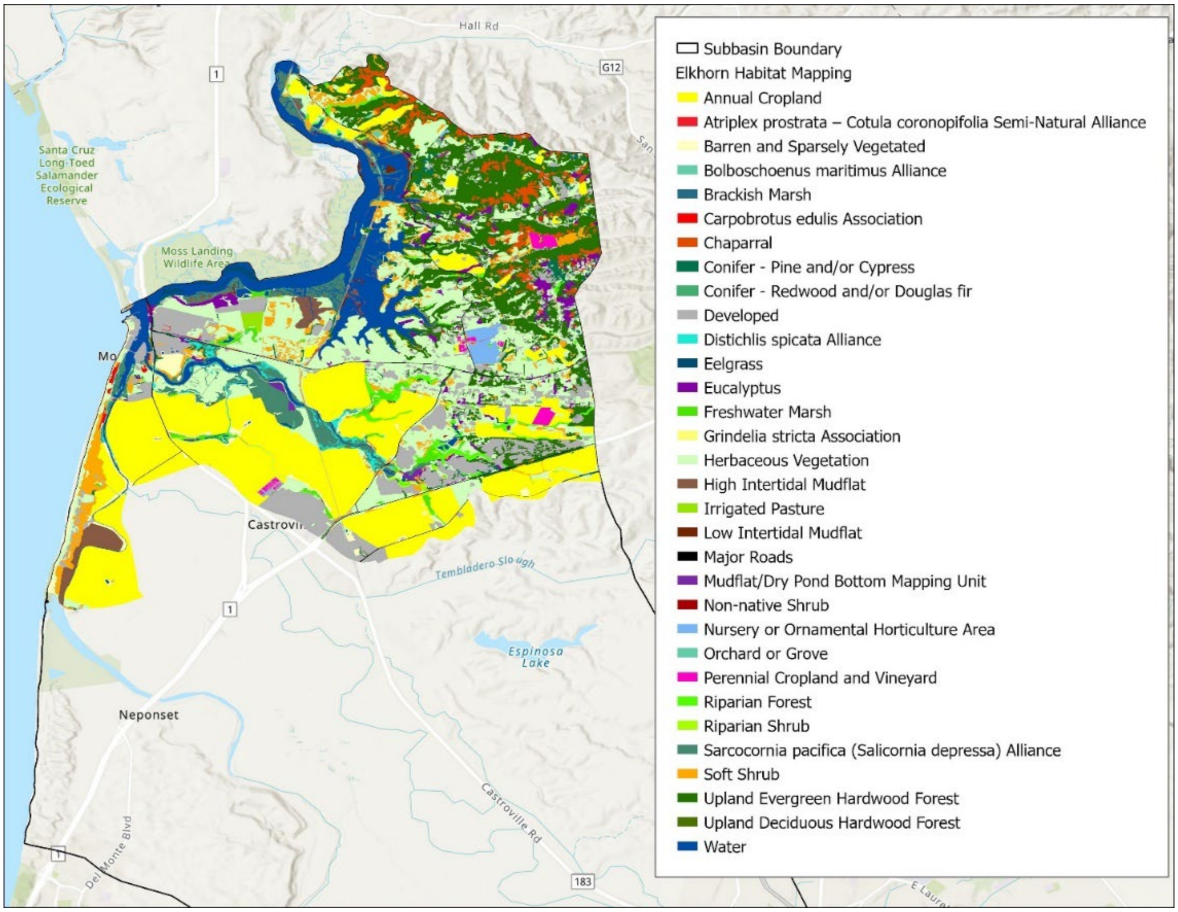

Figure 2. Elkhorn Slough Watershed lifeform mapping (ESF et al. 2020).

Table 1. Elkhorn Slough Watershed lifeform mapping habitat classes retained as potential GDEs and description of retained habitat classes from dataset metadata supporting documentation (ESF et al. 2020).

Habitat Class	Description
Brackish Marsh	Partner designated wetland areas that have been tidal wetland in the past but are no longer exposed to salt water because of diking or dams. Vegetation is primarily freshwater species, but the soil still retains salt.
Saltgrass (*Distichlis spicata*) alliance	Salt and brackish marshes dominated or co-dominated by Distichlis spicata, Frankenia salina and/or Jaumea carnosa. Non-native grasses including Avena spp. and Bromus hordeaceus may have high cover and Sarcocornia pacifica may be present as a sub-dominant.
Freshwater Marsh	Wetland herbaceous vegetation dominated by or characterized by Schoenoplectus, Typha, Bolboschoenus glaucus, Carex barbarae, C. densa, C. nudata, C. serratodens, Cirsium fontinale, Euthamia occidentalis, Hoita orbicularis, Juncus arcticus, Lepidium latifolium, Leymus triticoides, or Mimulus guttatus. Stands are found along streams, ditches, shores, bars, and channels of river mouth estuaries; around ponds and lakes; and in sloughs, swamps, and

	freshwater to brackish marshes as well as settings where saturated soil or standing water throughout the growing season are a characteristic. Absolute tree and/or shrub cover is less than 10%.
Habitat Class	**Description**
Gumplant (Grindelia stricta) alliance	Grindelia stricta dominates or co-dominates with Frankenia salina, Sarcocornia pacifica along upper banks of tidal channels and raised tidal marshes.
Riparian Forest	Areas where woody vegetation >15 feet is at least 10% absolute cover. Areas dominated by riparian tree species that require perennial water, such as species of Alnus, species of Salix, species of Populus, and/or species of Fraxinus.
Riparian Shrub	Short (canopy height <= 15 feet) vegetation dominated by riparian species that require perennial water, such as species of Alnus, species of Salix, species of Populus, and/or species of Fraxinus.
Upland Evergreen Forest	Areas where woody vegetation >15 feet is at least 10% absolute cover; hardwoods strongly dominate the tree canopy (>70% relative tree cover); Deciduous hardwoods dominate or co-dominate the canopy. Upland deciduous hardwoods Include Aesculus californica, Acacia melanoxylon, Juglans californica.

Additional Local Habitat Datasets

If needed or available in the future, additional local habitat datasets can be added to the GDE identification process to supplement and enhance the initial set of ecosystems potentially dependent on groundwater under consideration.

Elevation Data

2019 Fall Groundwater Elevation Contours

Monterey County Water Resources Agency (MCWRA) conducts a groundwater elevation monitoring program in the Salinas Valley and provided the groundwater elevation contour data used for this identification and mapping effort. These data are for all wells monitored by MCWRA, almost all of which are deep irrigation wells in which water levels often differ from the true water table elevation near the ground surface. There are too few true shallow monitoring wells to allow contouring over the full extent of the Subbasin, so the global water-level data set was used as a proxy, recognizing its inherent limitations and potential bias. Fall groundwater elevation contour data from 2019 was used to identify potential groundwater dependent ecosystems in the Upper Valley Aquifer Subbasin (Figure 3). The Shallow Groundwater Contours describe groundwater elevation in relation to sea-level. This was a conservative approach, including the broadest number of potential GDEs in initial identification because 2019 was a wet year with high groundwater elevations post 2014 when SGMA took effect (Figure 10 illustrates this concept). The fall groundwater elevation contours are developed from measurements taken from mid-November to December after the end of the irrigation season and before seasonal recharge from winter precipitation increases groundwater levels.

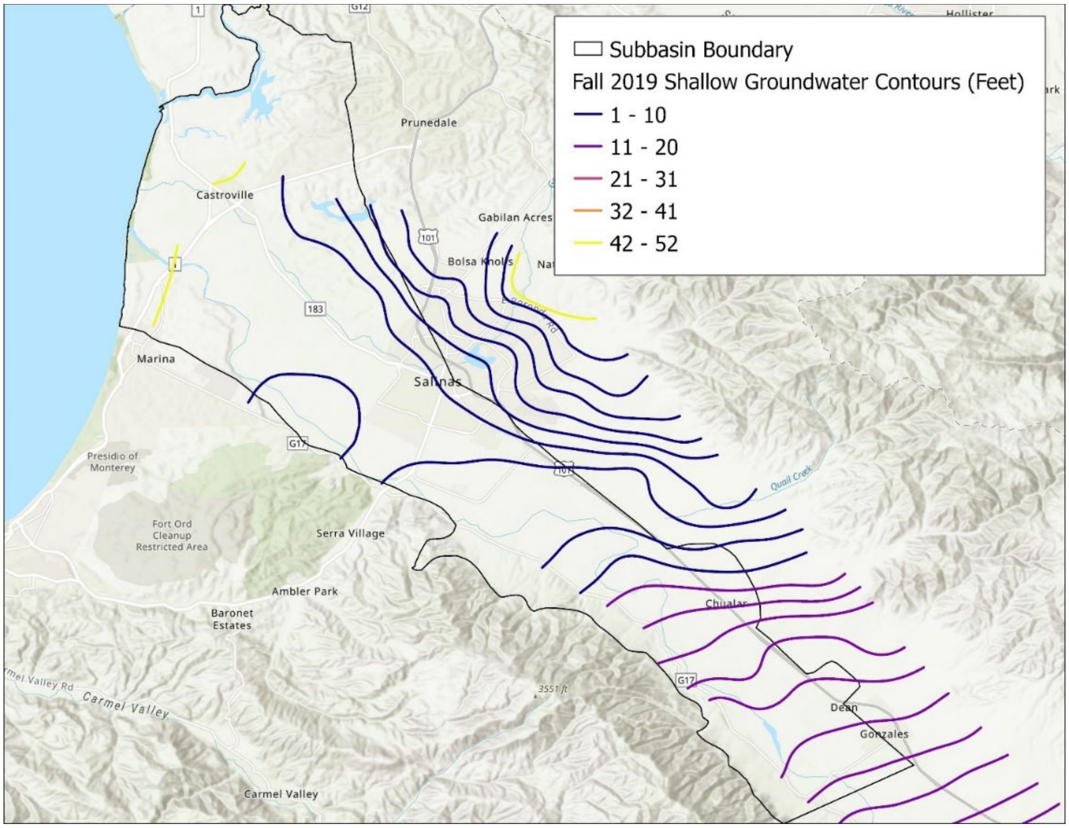

Figure 3. Shallow groundwater elevation contours (feet) based on Fall 2019 MCWRA monitoring.

Digital Elevation Model (DEM) Ground Surface Elevation

A digital elevation model (DEM) is a representation of the bare ground (excluding surface objects such as trees and buildings) topographic surface of the Earth. The DEM used for this identification and mapping effort was developed by the U.S. Geological Survey (USGS) at a 30-meter resolution (USGS 2024).

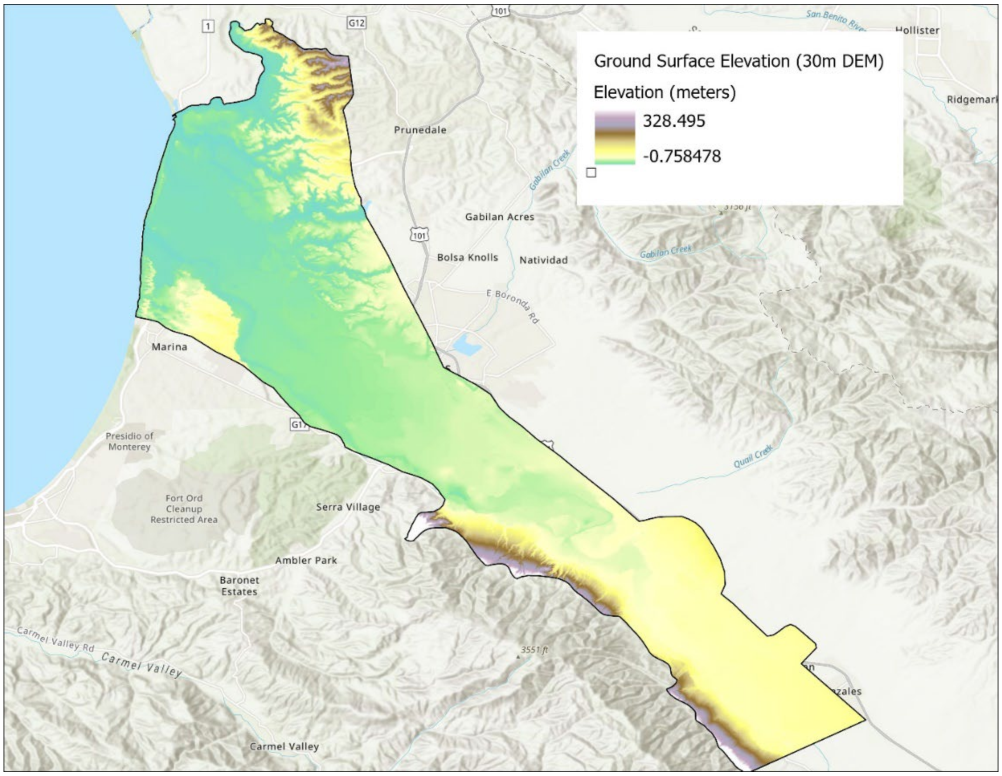

Figure 4. Digital Elevation Model (DEM) ground surface elevation (meters) in the 180/400 Foot Aquifer Subbasin (USGS 2024).

Salinas Valley Aquitard Extent

The Salinas Valley Aquitard is a clay layer that ranges from 25-100 feet thick and is generally found less than 150 feet below the ground surface. The Salinas Valley Aquitard overlies and confines the 180-Foot Aquifer, separating the shallow sediments and groundwater above the aquitard from the 180-Foot Aquifer. Potential GDEs located above the known extent of the Salinas Valley Aquitard were excluded from the map due to being reliant on the groundwater from the shallow sediments above the Salinas Valley Aquitard, which is hydrologically separate from groundwater within the 180-Foot Aquifer. These shallow sediments are not considered a principal aquifer because there is no extraction from the shallow sediments that is “significant and economic” (California Code of Regulations, Title 23 § 351). Based on the best available hydrogeologic data, ecosystems above the shallow sediments are not impacted by groundwater management in principal aquifers in the 180/400 Subbasin.

Hydrogeologists are still updating the geographic extent of the Salinas Valley Aquitard and periodic updates on the boundaries are provided. When these updates occur, the map of potential GDEs will be updated to reflect the best available knowledge.

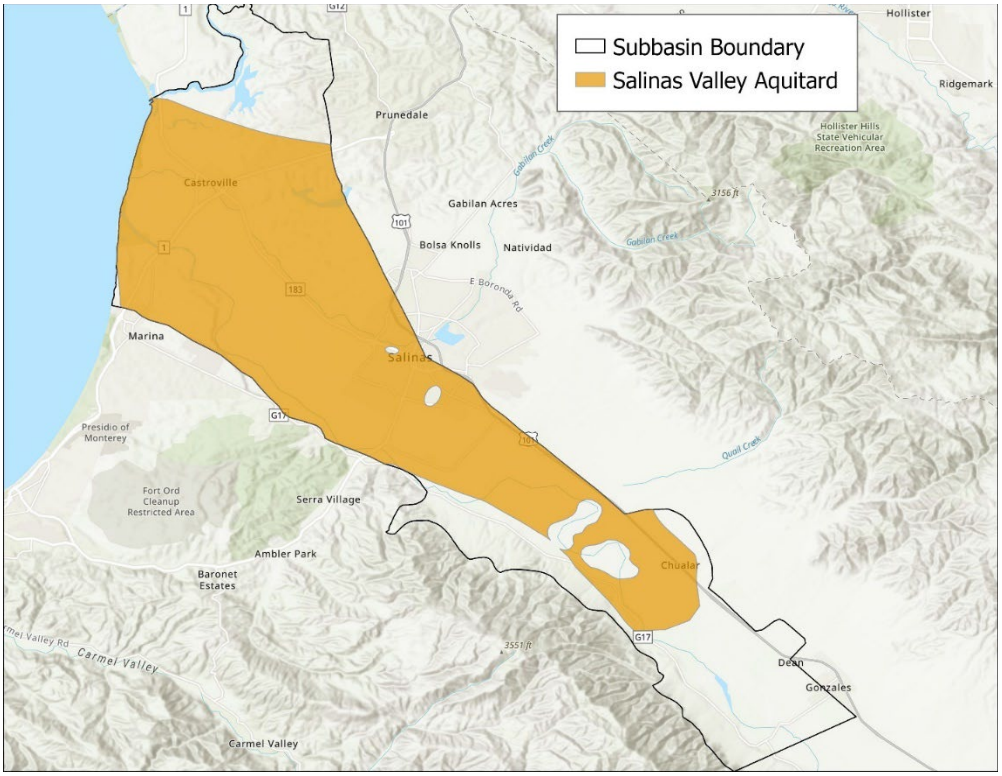

Figure 5. Confirmed extent of Salinas Valley Aquitard as of July 2024.

Verification of Ecosystem Connection to Groundwater

To determine if the starting set of ecosystems potentially dependent on groundwater, based on local and state habitat mapping datasets (Figure 6), are potential GDEs, it is necessary to determine how deep the groundwater table is below the ground surface. If the groundwater table is 200 ft below the ground surface, it is highly unlikely that groundwater is able to support the vegetation or wetland above it. However, if the groundwater table is 5 ft below the ground surface, it is highly likely that groundwater is able to support the above vegetation or wetland. Areas above the current known extent of the Salinas Valley Aquitard are excluded from consideration because the shallow area above the aquitard is not a principle aquifer (Figure 5).

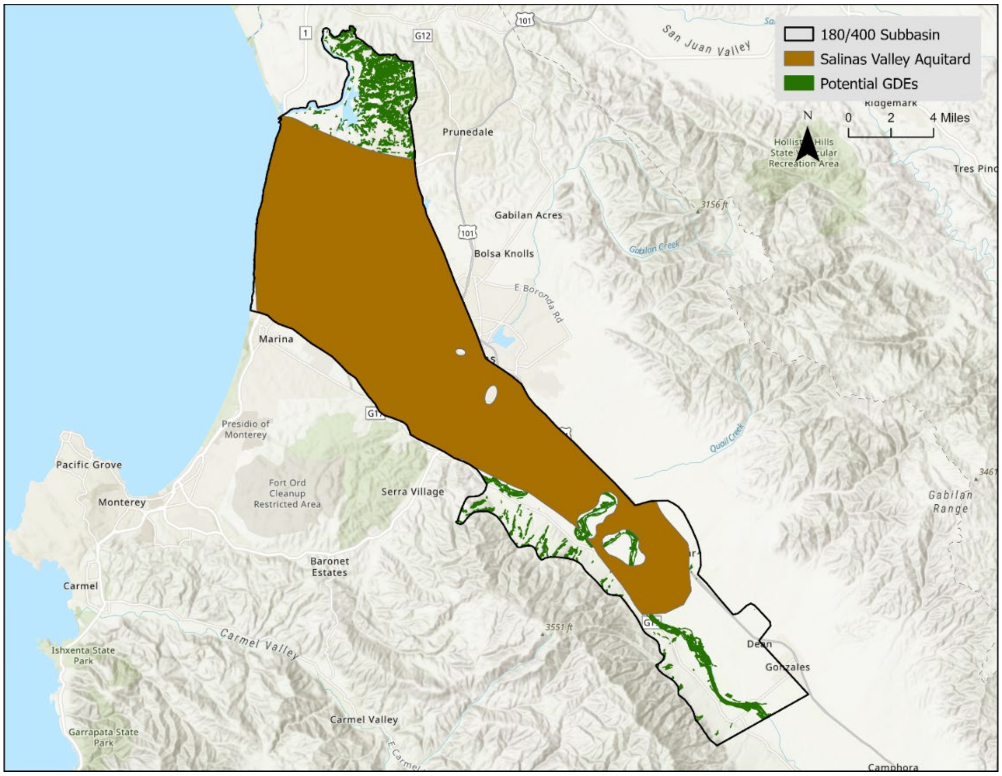

Figure 6. Set of ecosystems potentially dependent on groundwater, based on state and local habitat mapping datasets. Areas above the current known extent of the Salinas Valley Aquitard are excluded from consideration based on a recommendation from the SVBGSA Advisory Committee.

To determine the depth from the surface down to the groundwater table across the 180/400 Foot Aquifer Subbasin, the groundwater elevation (groundwater contours) was subtracted from the ground surface elevation (DEM). However, to complete this subtraction, the groundwater contours, which are provided by MCWRA as topographic lines, had to be turned into a continuous surface to ensure there was a groundwater elevation measurement for every point in the Subbasin. This was accomplished using the Inverse Distance Weighting (IDW) interpolation method to estimate missing data and turn the contours into a continuous surface (Figure 7). Once this layer was created it was subtracted from the ground surface elevation (DEM) to create a complete depth to groundwater map (Figure 8).

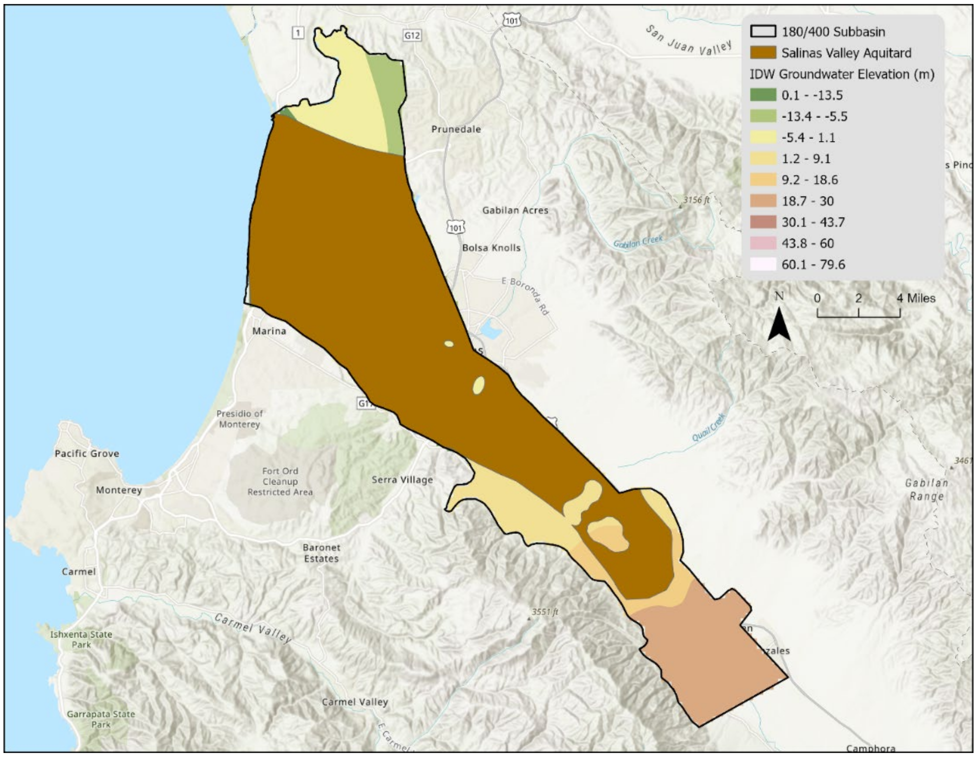

Figure 7. Continuous surface of groundwater elevations. Fall 2019 Shallow Groundwater Contour data provided by MCWRA was interpolated using Inverse Distance Weighting (IDW) to create the continuous surface of groundwater elevations.

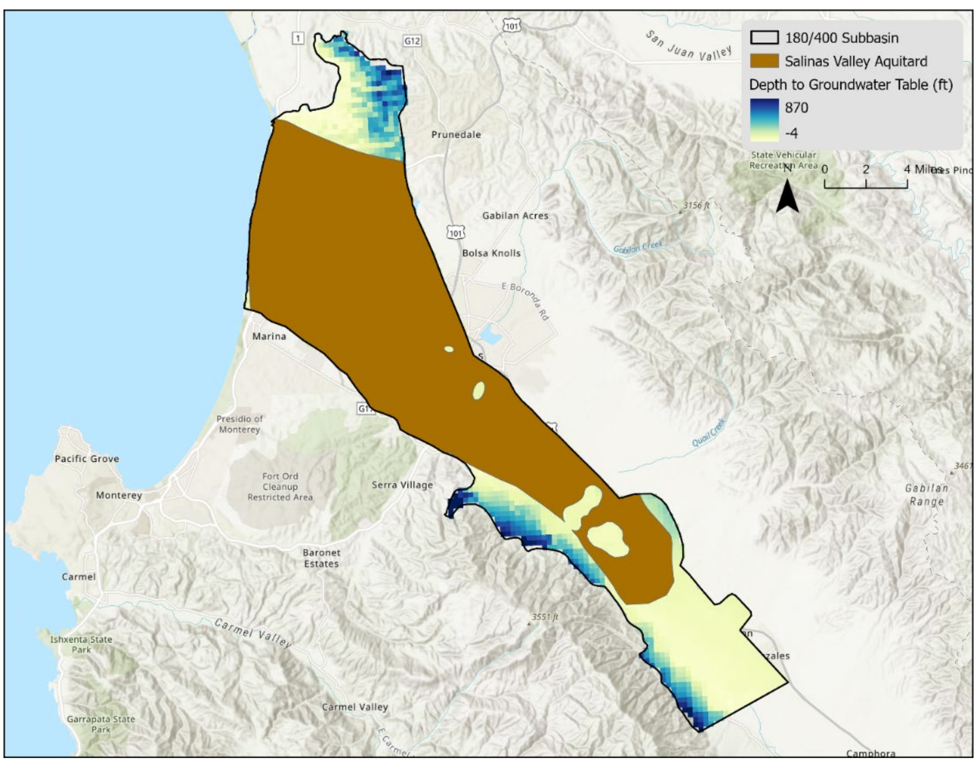

Figure 8. Distance from the ground surface to the groundwater table, or depth to groundwater table (feet).

With depth to groundwater table data for the entire subbasin, the starting set of habitat data can be overlayed to determine where the groundwater table is reasonably high enough to support the above ecosystems. Guidance developed by subject matter experts at The Nature Conservancy was consulted to determine how close to the surface the groundwater table is to be reasonably assumed a water source for the above ecosystem (Rhode et al. 2018). Based on this guidance, if the groundwater table is greater than 30 feet below the ground surface, the ecosystem at the surface is likely not reliant on groundwater. This is because most vegetation does not have roots deep enough to reach the water table below 30 feet. Oak trees are an exception to this generalized rule, as Oak trees have been shown to have roots that reach up to 80 feet below the ground surface (Howard 1992). For this reason, in areas mapped as having Oak trees as the dominant plant species, the depth to groundwater cutoff for including the ecosystem as a GDE was 80 feet. For all other areas the cutoff was 30 feet. Figure 9 shows the resulting map of potential groundwater dependent ecosystems in the 180/400 Foot Aquifer Subbasin.

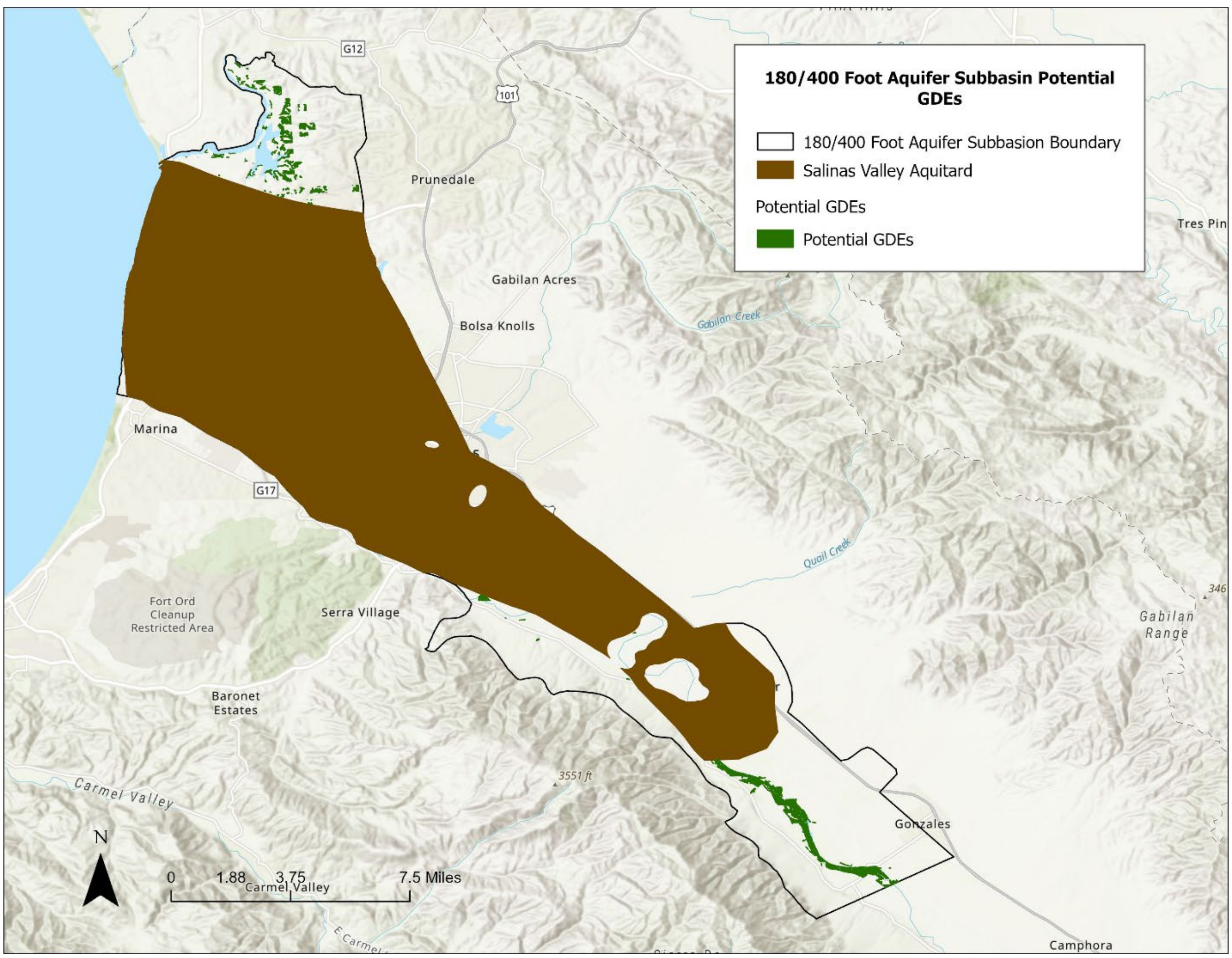

Figure 9. All identified potential GDEs within the 180/400 Foot Aquifer Subbasin, this set of potential GDEs is considered up to date as of June 2026.

Inherent Uncertainty and an Iterative Process

There are inherent uncertainties in the identification of potential GDEs due to the difficulty of directly measuring an ecosystem's reliance on groundwater. The process relies on the best available data and guidance from subject matter experts to develop a map of ecosystems reasonably assumed to be dependent on groundwater as one of their water sources. This identification process does not result in a perfectly accurate map of potential GDEs. However, it does result in a representative and characteristic map of potential GDEs in the 180/400 Subbasin. Subject matter experts consider this a sufficient level of identification from which the SVBGSA can fulfill the GDE monitoring and assessment requirements under SGMA to ensure no adverse impacts to potential GDEs. This process should be considered iterative and subject to updates if additional guidance from the California Department of Water Resources becomes available, or updates to groundwater and/or habitat datasets become available.

Removing large areas of irrigated vegetation (crops or landscaping)

While the goal of this identification and mapping process is not to identify every plant and waterbody dependent on groundwater but ensure adequate identification of potential GDEs across the whole subbasin, one exception to modifying the starting habitat datasets is to correct any large mapping inaccuracies. This includes any large areas of irrigated vegetation such as acreage in agricultural production or large areas of landscaping. The map of identified potential GDEs was visually checked with a satellite imagery basemap for any such areas. No mapping inaccuracies were found in the 180/400 Subbasin at this time. In other words, the NCCAG mapping already excluded agricultural areas.

Adding areas of ecological importance

In acknowledgment of the inherent uncertainty of GDE identification, the Groundwater Dependent Ecosystem Working Group decided to allow for the inclusion of areas in the habitat datasets deemed as ecologically important in the set of potential GDEs even if these ecologically important areas were not identified as a potential GDE through the process outlined here. This allows for ecologically important areas to be monitored for adverse impacts should they be identified as potential GDEs in the future through the iterative identification process.

Examples of areas of ecological importance that could be considered for inclusion in the set of potential GDEs may include, but are not limited to, areas identified as drought refugia, areas known to contain threatened and endangered species or areas identified as critical habitat for any of these species. Drought refugia are areas of habitat that stay wet and/or green for longer than their surroundings. By staying wet and green for longer these refugia continue to provide quality habitat for species when the surrounding areas have become too dry to be suitable habitat, thus providing a resource for maintaining sensitive species' populations through periods of drought. The *Groundwater Dependent Ecosystem Monitoring and Assessment Protocol for the Salinas Valley Basin* describes resources that could be utilized to identify areas of ecological importance for inclusion in the set of potential GDEs.

As of June 2026, this option has not been exercised in the identification of potential GDEs in the 180/400 Foot Aquifer Subbasin.

Categorizing Potential GDEs into Units

The final step in developing a map of potential GDEs in the 180/400 Subbasin was to group the identified potential GDEs into units based on shared hydrogeology and association with the same aquifer (Figure 10). The purpose of grouping potential GDEs into these units is to assist with monitoring and assessment for adverse impacts potential GDEs. If an adverse impact to a GDE within a unit is detected, understanding which additional potential GDEs may be impacted based on a shared relationship to the underlying aquifer can focus and guide monitoring activities. Hydrogeologists familiar with the aquifers and geomorphology of the Salinas Valley Basin were consulted to develop the units for potential GDEs in the 180/400 Subbasin, this resulted in eight GDE units (Figure 11).

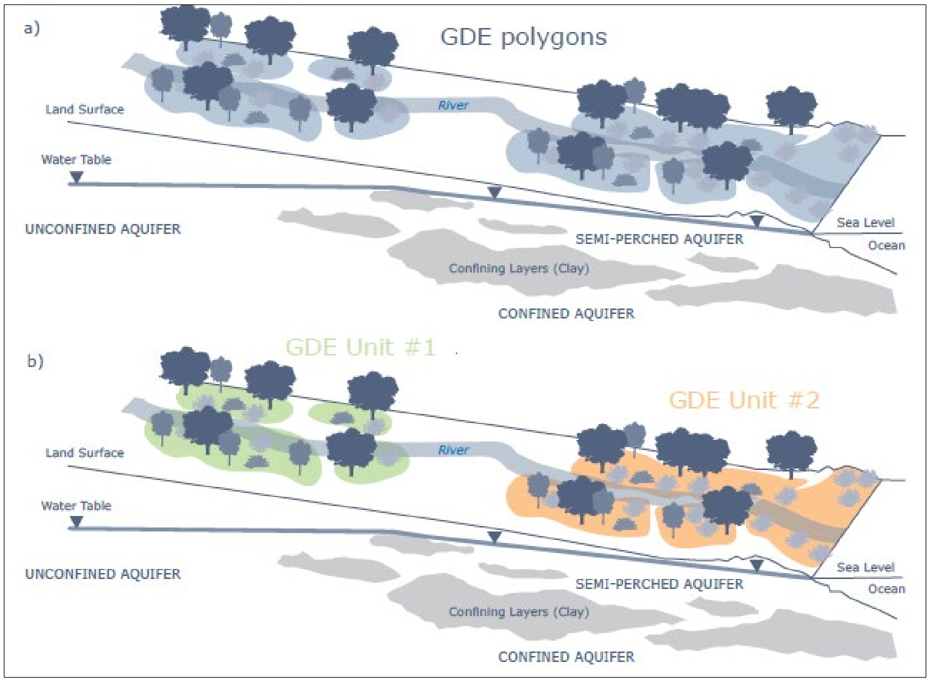

Figure 10. Illustration of grouping potential GDEs into units based on shared association with an aquifer. a) potential GDEs not separated into units, b) potential GDEs separated into two units, Unit #1 is associated with an unconfined aquifer, Unit #2 is associated with a "semi-perched aquifer" above a confined aquifer. Image Credit: Rhode et al. 2018

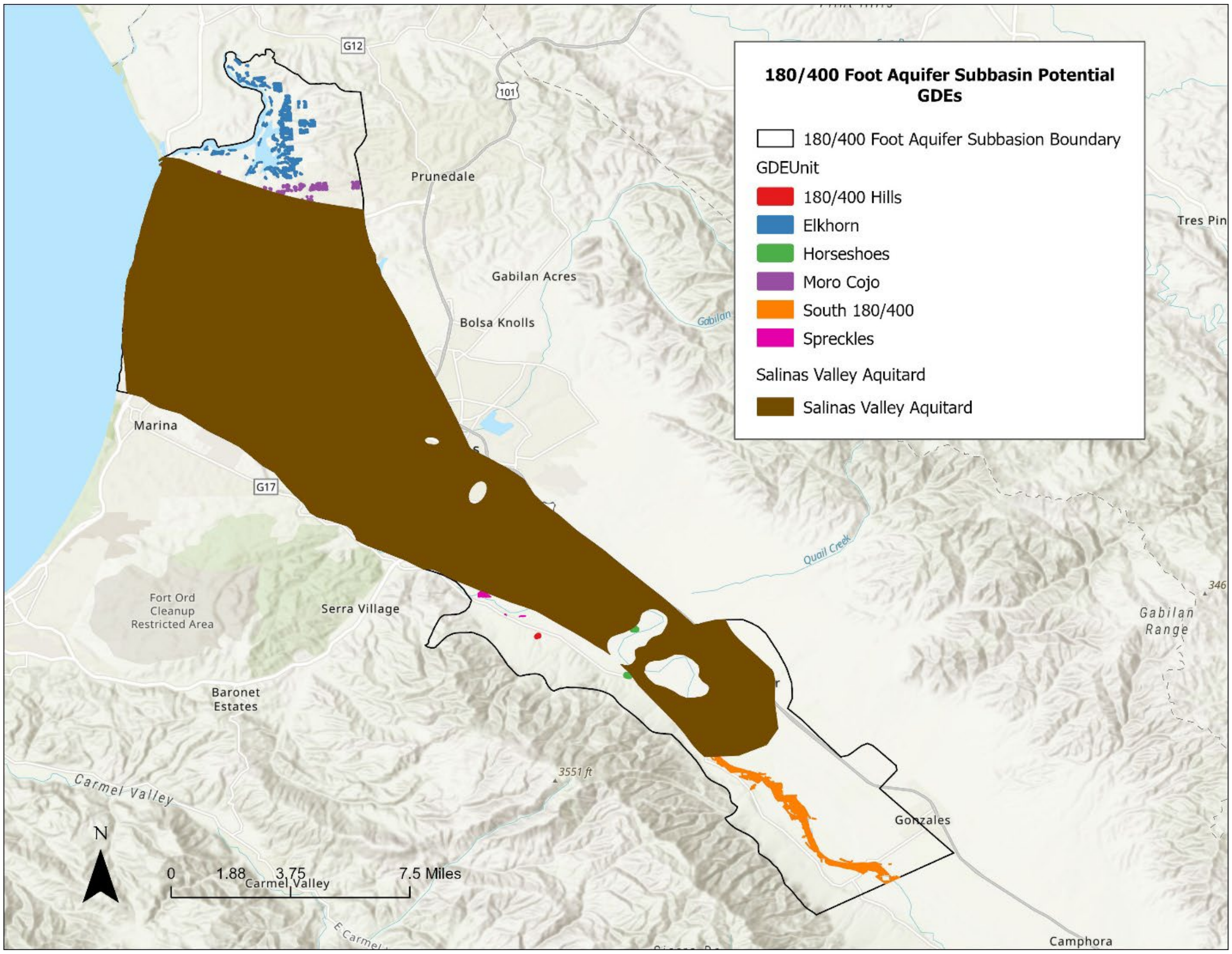

Figure 11. Map of identified potential GDEs, up to date as of June 2026 and including GDE units delineated by hydrogeologists familiar with the Salinas Valley Basin. Potential GDEs are enlarged for visibility here.

Desktop-based Monitoring of Potential GDEs

The desktop-based GDE monitoring methodology follows the approach described in *Establishing ecological thresholds and targets for groundwater management* (Rhode et al. 2024). Rhode et al. (2024) utilized local groundwater elevation data and Normalized Derived Vegetation Index (NDVI) data to establish a unique groundwater threshold for each GDE, below which a GDE is flagged as experiencing adverse impacts. This section details the methods used to develop this approach locally in the Salinas Valley and application of it to potential GDEs identified in the Forebay Aquifer Subbasin. The utilization of satellite imagery from Landsat (to calculate NDVI) and groundwater elevation data that is already collected annually by Monterey County Water Resources Agency (MCWRA) in an automated workflow allows for this monitoring methodology to be conducted annually in a cost-effective manner.

Desktop-based Monitoring Methods

Data Acquisition

The following datasets were used in this desktop-based monitoring methodology:

Normalized Derived Vegetation Index (NDVI) Data

NDVI is a quantified measurement of vegetation greenness that has been demonstrated as a valid proxy for measuring vegetation health and vigor (TNC 2024). TNC has developed an online mapping tool that provides NDVI calculations for potential GDEs across California from 1985 – 2024 and updated annually, called GDE Pulse (TNC 2024). NDVI data in GDE pulse are derived from Landsat satellite imagery with average annual dry-season (July 1st - September 30th) data calculated for all potentially groundwater-dependent ecosystems included in the statewide NCCAG dataset developed by the California Department of Water Resources.

NDVI values are calculated by taking the difference between reflectance in the near-infrared and red spectral bands of satellite imagery and normalizing this difference by their sum. Resulting NDVI values span from −1 to 1. Values approaching 1 reflect dense, healthy green vegetation and values near zero (typically <0.2) correspond to sparse or senescent vegetation or bare soil; negative values generally indicate water surfaces (Roy et al. 2016) (Figure 12).

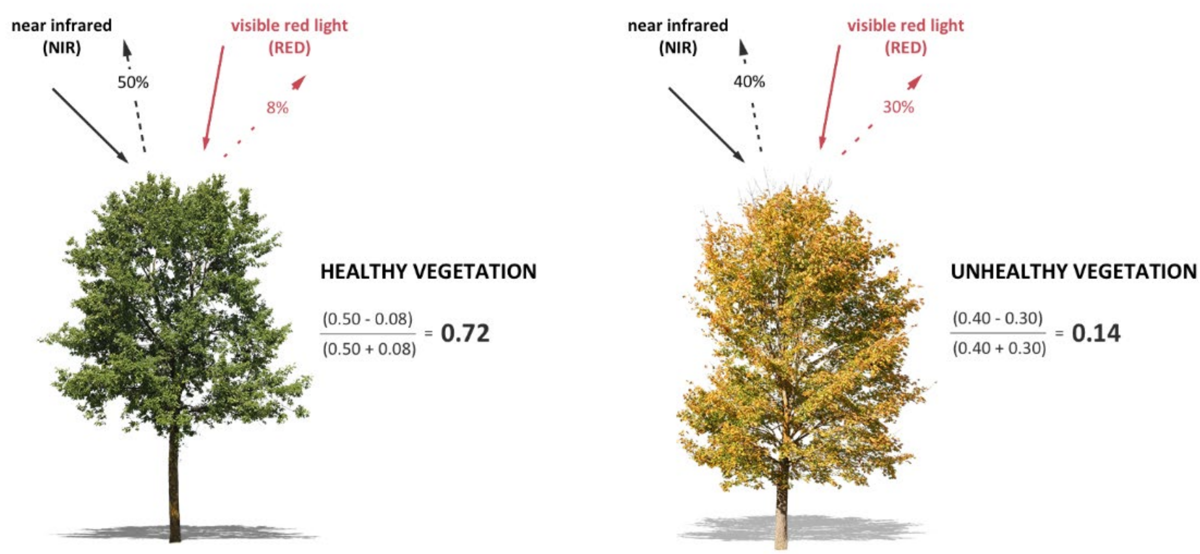

Figure 12. This graphic depicts how NDVI is calculated and gives an example of how much light is absorbed versus reflected by healthy, green vegetation compared to unhealthy, less green vegetation. As vegetation greenness declines, the percentage of reflected light increases (image credit: TNC 2024).

Groundwater Elevation Data

Shallow groundwater elevation contour data were obtained from MCWRA. These contours span a large extent of the Salinas Valley and provide measurements of groundwater depth.

Digital Elevation Model (DEM) Data

Land surface elevations were determined from the US Geological Survey's 1/3 arcsecond digital elevation model dataset. This dataset, along with the groundwater elevation data provided by MCWRA was used to calculate depth to groundwater.

Calculating Depth to Groundwater

As with the identification of potential GDEs in the Salinas Valley, calculating depth to groundwater required interpolating shallow groundwater-level contours for all available years in ArcGIS Pro. Since these contours provide groundwater elevations derived from monitoring wells, each interpolated raster was corrected for land-surface elevation to accurately compute local depth to groundwater (DTG). Local DTG at each location was calculated by subtracting the interpolated groundwater elevation from the corresponding land-surface elevation (Figure 3). For each year (15 years), the mean DTG value was extracted for each GDE (Figure 10).

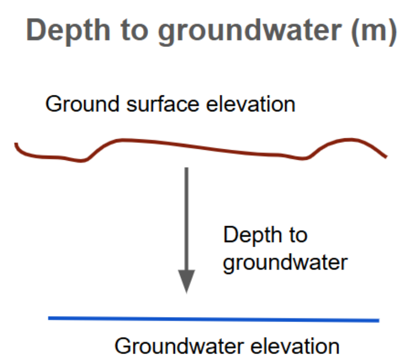

Figure 13. A simplified graphic depicting how depth to groundwater (DTG) is calculated using ground surface and groundwater elevations.

Statistical Analysis

For each potential GDE, the mean and standard deviation of DTG and NDVI were calculated across the full time series, which 15 years of groundwater elevation data for DTG and 39 years of data for NDVI. Annual observations were standardized by computing Z-scores for both DTG and NDVI, this was done only for years where both DTG and NDVI data were available, with DTG as the limiting dataset. Z-scores are a unitless statistical metric used to indicate how many standard deviations an individual observation value is from the mean. Due to this unitless standardization, Z-scores are useful in comparing values from distributions with different units and ranges, such as DTG and NDVI.

The equation for calculating a Z-score is as follows, here the Z-score for DTG in 2024 is used as an example though the equation is the same for any other annual observation of DTG or NDVI, or any other dataset:

$Z_{DTG\ 2024}$ = Annual mean DTG (2024) – Long-term mean DTG (all years) / long term standard deviation DTG (all years)

Using these Z-scores, an ordinary least-squares linear model was fit for each potential GDE to evaluate the relationship between Z_{NDVI} and Z_{DTG} (Figure 13 provides a conceptual example). A unique linear model was created for each potential GDE, describing the relationship between vegetation vigor and depth to the groundwater table for each potential GDE.

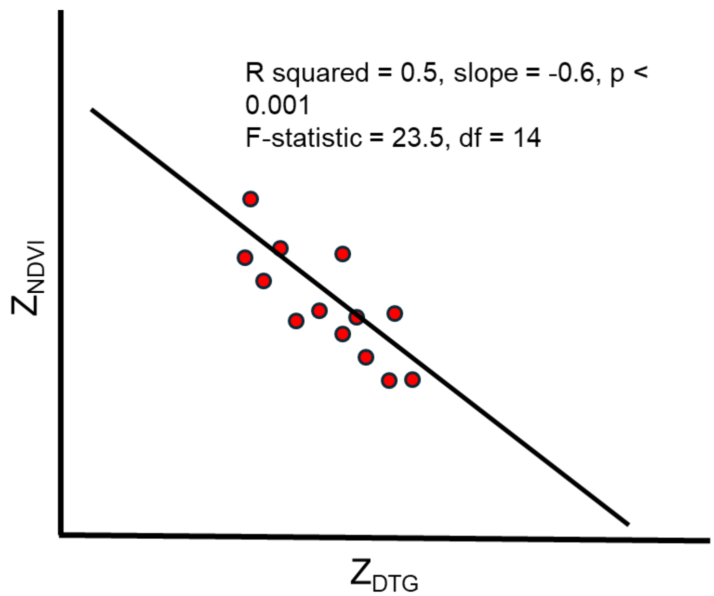

Figure 14. Illustrative example, not based on real data, of the linear model generated for each GDE based on NDVI and DTG Z-scores calculated for each available year (15 years for which data from both datasets were available). This example describes a statistically significant negative relationship between NDVI and DTG, due to the negative slope of the best fit line and a p-value of < 0.001.

Potential GDEs exhibiting a statistically significant negative relationship between Z_{NDVI} and Z_{DTG} based on the linear model were used to calculate a Z_{DTG} threshold for that GDE (Figure 15). Thresholds were not created for potential GDEs exhibiting a non-significant negative relationship, neutral, or positive relationship (NDVI increasing as depth to groundwater increases), since it is assumed, these potential GDEs are not being adversely impacted by declining groundwater levels. The set of potential GDEs for which thresholds are created should not be static but rather reassessed every few years as additional observations (i.e. years) are added to the linear model. It is recommended that this reassessment aligns with the 5-year Periodic Evaluations required by SGMA.

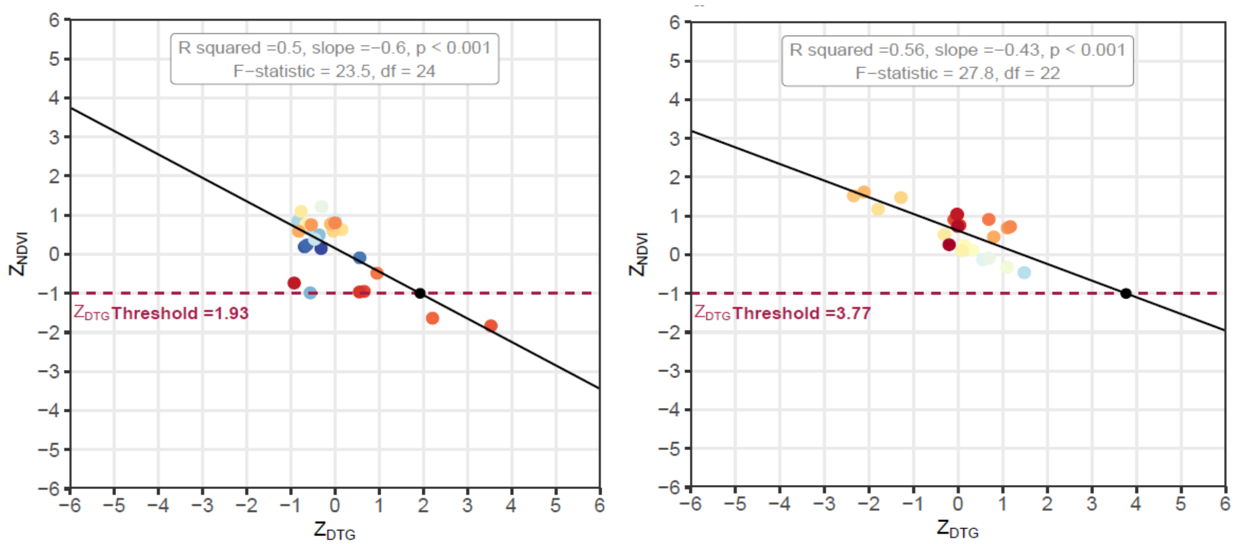

Figure 15. Examples of linear models for two GDEs with a ZDTG threshold set for each based on where ZNDVI = -1 intersects with the linear model. The ZDTG threshold is unique to each GDE, with the threshold = 1.93 for the example on the left, and threshold = 3.77 for the example on the right. (Image credit: Rhode et al. 2024).

The unique thresholds for potential GDEs exhibiting a significant negative relationship between Z_{NDVI} and Z_{DTG} were calculated based on a set Z_{NDVI} threshold of -1. Rhode et al. 2024 chose $Z_{NDVI} = -1$, or an NDVI value of one standard deviation below the average for that GDE, as the set threshold and point at which the reduction in vegetation greenness might point to adverse ecosystem impacts. The Z_{DTG} threshold for each potential GDE was calculated using the following equation:

Z_{DTG} threshold = (Z_{NDVI} threshold (i.e. -1) – linear model intercept)/ linear model slope

A potential GDE should be classified as being ‘of concern’, or experiencing adverse impacts, if for the year of interest the NDVI value and DTG value meet both of the following criteria:

- $Z_{NDVI} \leq -1$
- $Z_{DTG} \geq Z_{NDVI}$

This ‘zone of concern’ identifies an area where, for the year of interest, the vegetation in the potential GDE is less green than one standard deviation below the historical average for that potential GDE, and where the depth to groundwater is deeper than the calculated threshold. Therefore the ‘zone of concern’ identifies years for which lower groundwater levels may be adversely impacting vegetation vigor. Figure 13 illustrates this ‘zone of concern’ for the example GDEs used in Figure 15.

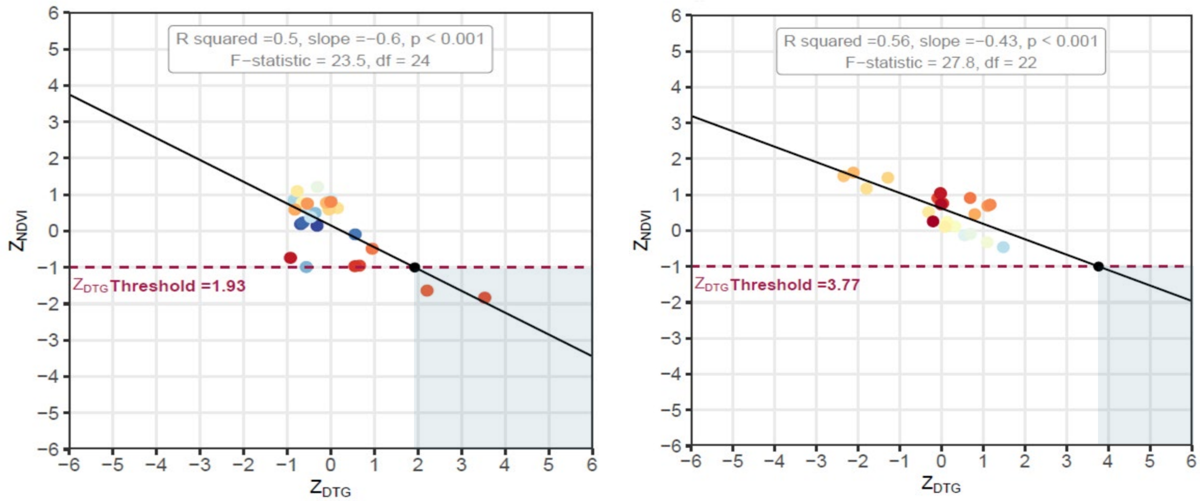

Figure 16. Illustration of the 'zone of concern', the shaded area, for GDE examples used in Figure 15. In the example on the left, two years fall into this zone, while on the right, there were no years for which this GDE was considered 'of concern' (Image credit: Rhode et al.)

The workflow for this analysis was developed in R, making it automated and easily replicable on an annual basis as annual NDVI and groundwater elevation data become available.

Assessment of Potential GDEs Based on Desktop Monitoring Methods

Potential GDEs in the Salinas Valley Basin exhibiting a statistically significant negative relationship between Z_{NDVI} and Z_{DTG} (significant downward trend) based on the linear model over the 15 years that were analyzed are shown in orange in Figure 17.

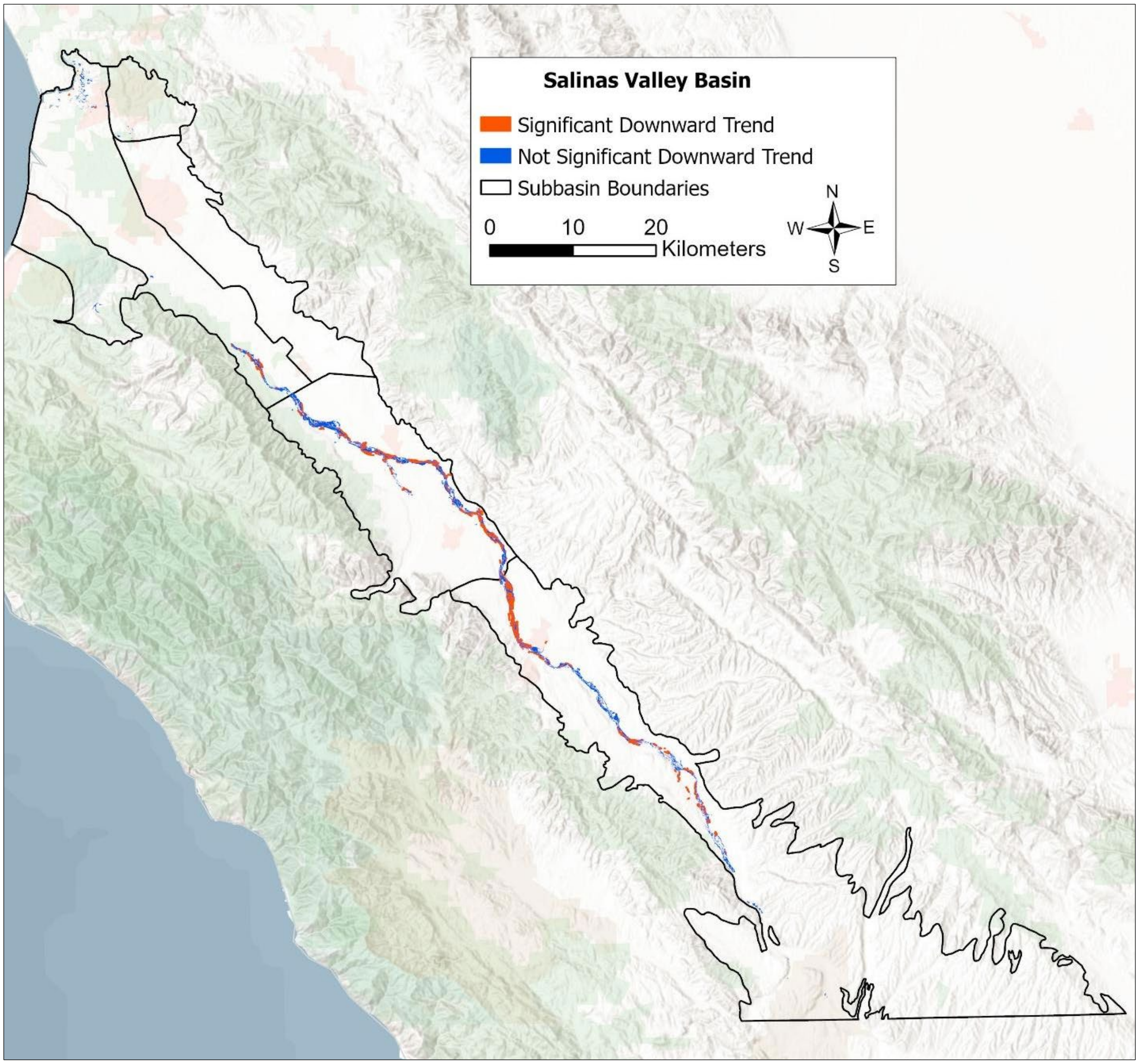

Figure 17. Salinas Valley GDE trends. Potential GDEs with a statistically significant negative relationship between ZNDVI and ZDTG (significant downward trend) are in orange, potential GDEs that did not have a significant downward trend are in blue. The symbology for significant downward trends (orange) is enlarged for visibility.

Figure 18 shows potential GDEs with a significant negative relationship between Z_{NDVI} and Z_{DTG} in the 180/400 Foot Aquifer Subbasin. A threshold value was calculated for each potential GDE with this significant negative relationship and from this threshold, potential GDEs were assessed if they fell below this threshold for a specific year. The results of this analysis are shown for all years for which data were available post the passage of SGMA in 2014 (Figures 16-18, years: 2015, 2019-2024).

Within the 180/400 Foot Aquifer Subbasin, potential GDEs of concern were found to be present in 2015, 2021, 2022, and 2023, though the location of these potential GDEs of concern is not consistent through the years (Figures 19-22). No potential GDEs were found to be of concern in 2019, 2020, or 2024 (Figure 23).

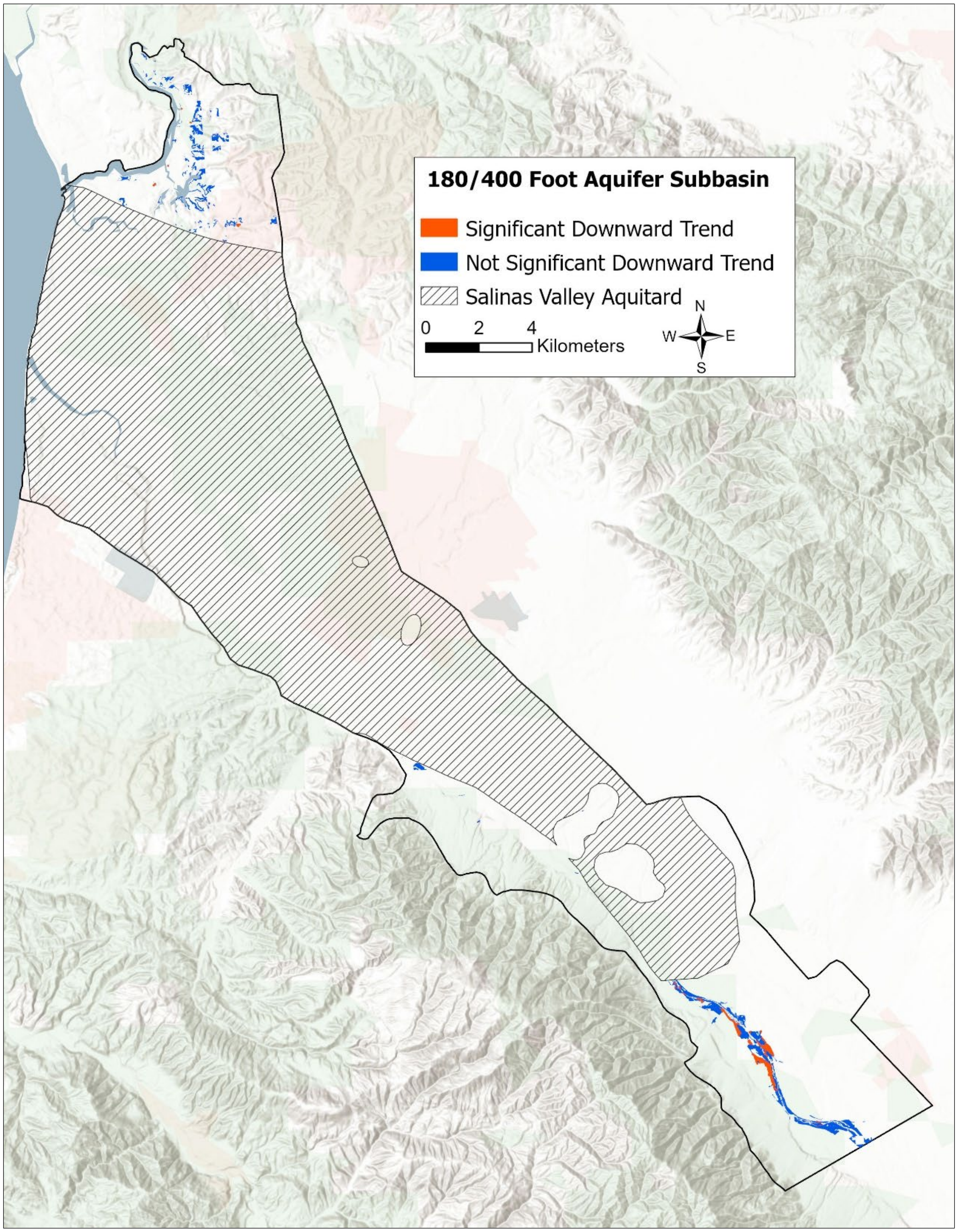

Figure 18. In the 180/400 Foot Aquifer Subbasin, potential GDEs showing a significant negative relationship (significant downward trend) between ZNDVI and ZDTG shown in orange.

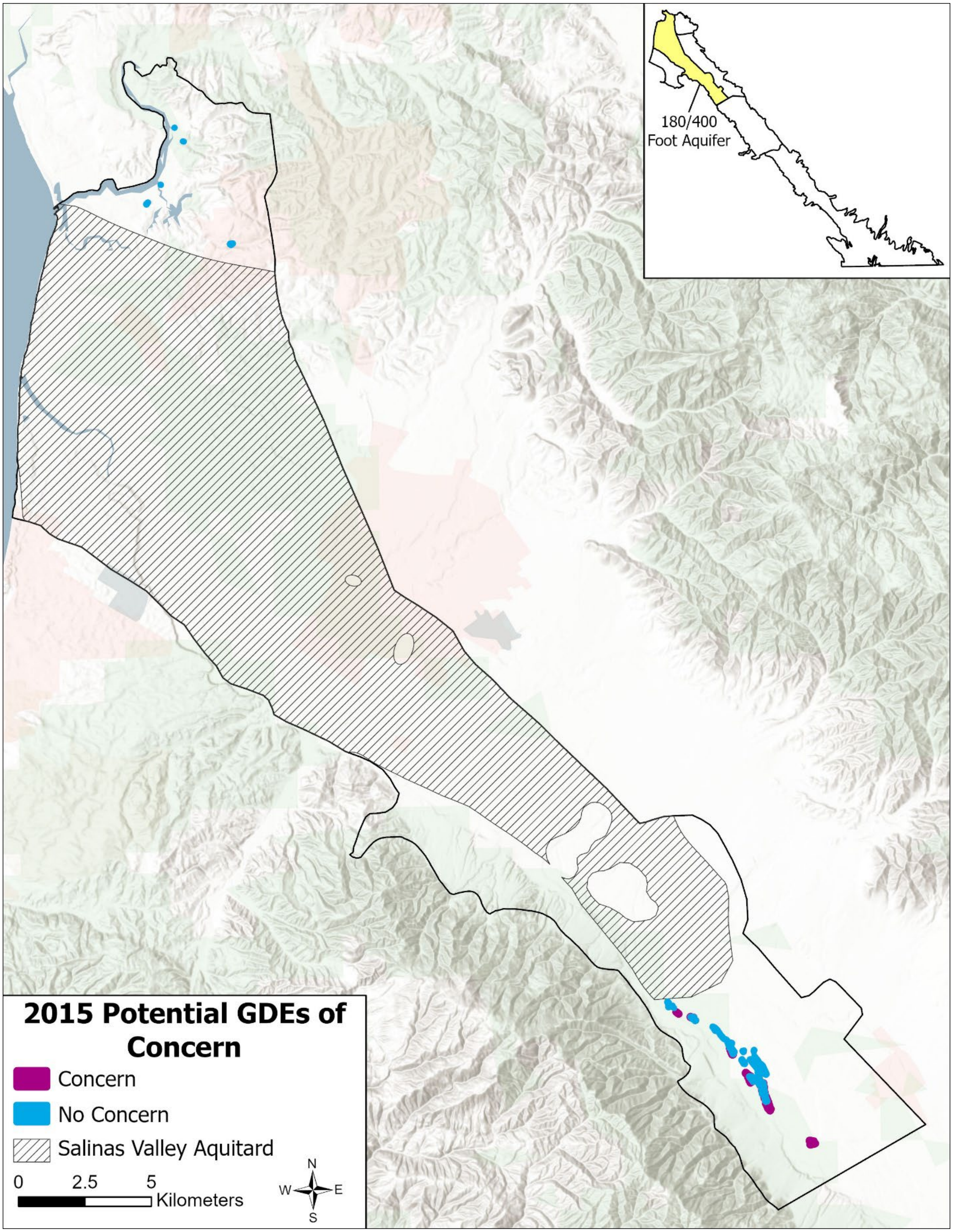

Figure 19. Potential GDEs of concern within the 180/400 Foot Aquifer Subbasin in 2015. All potential GDEs are enlarged for visibility.

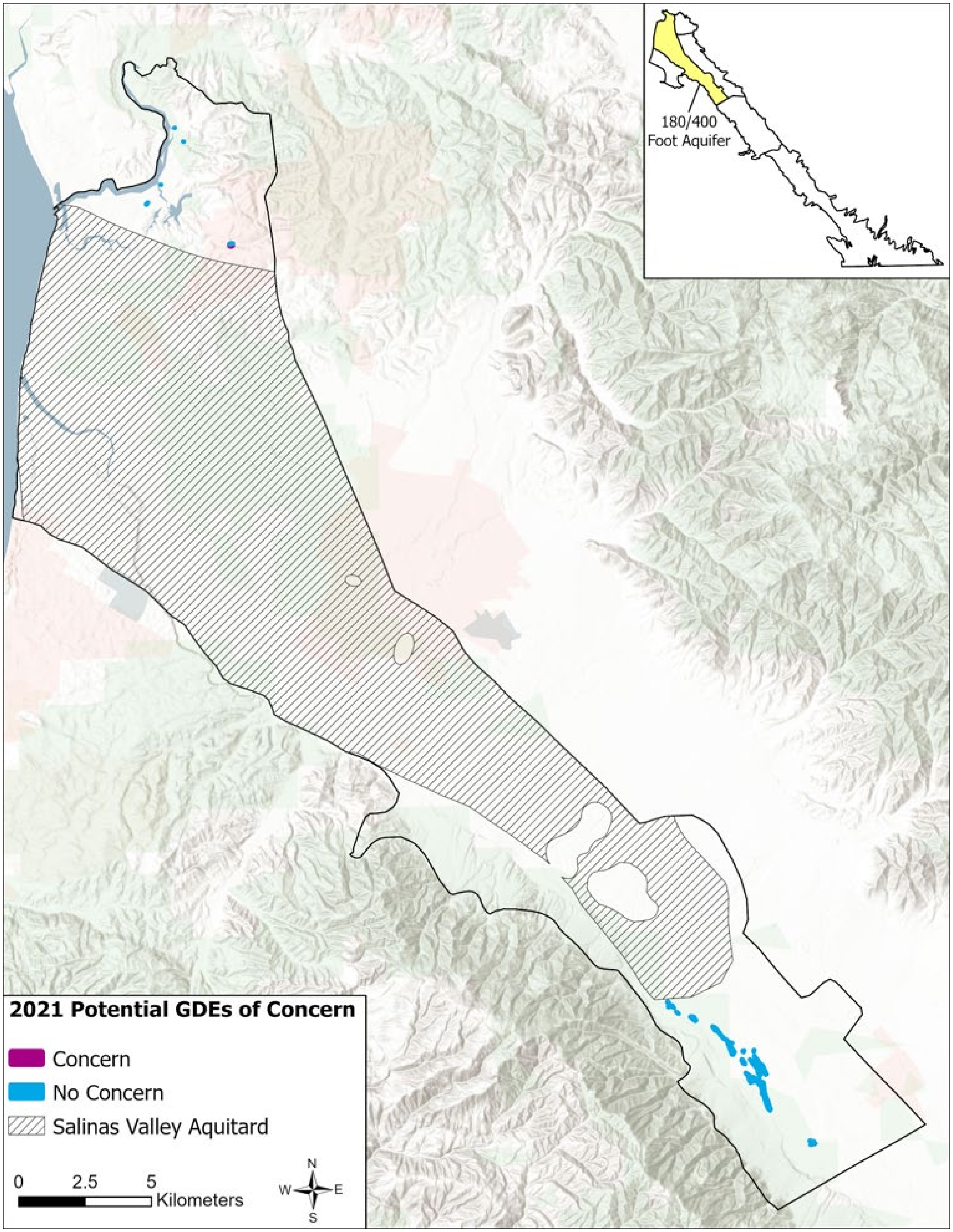

Figure 20. Potential GDEs of concern within the 180/400 Foot Aquifer Subbasin in 2021. All potential GDEs are enlarged for visibility.

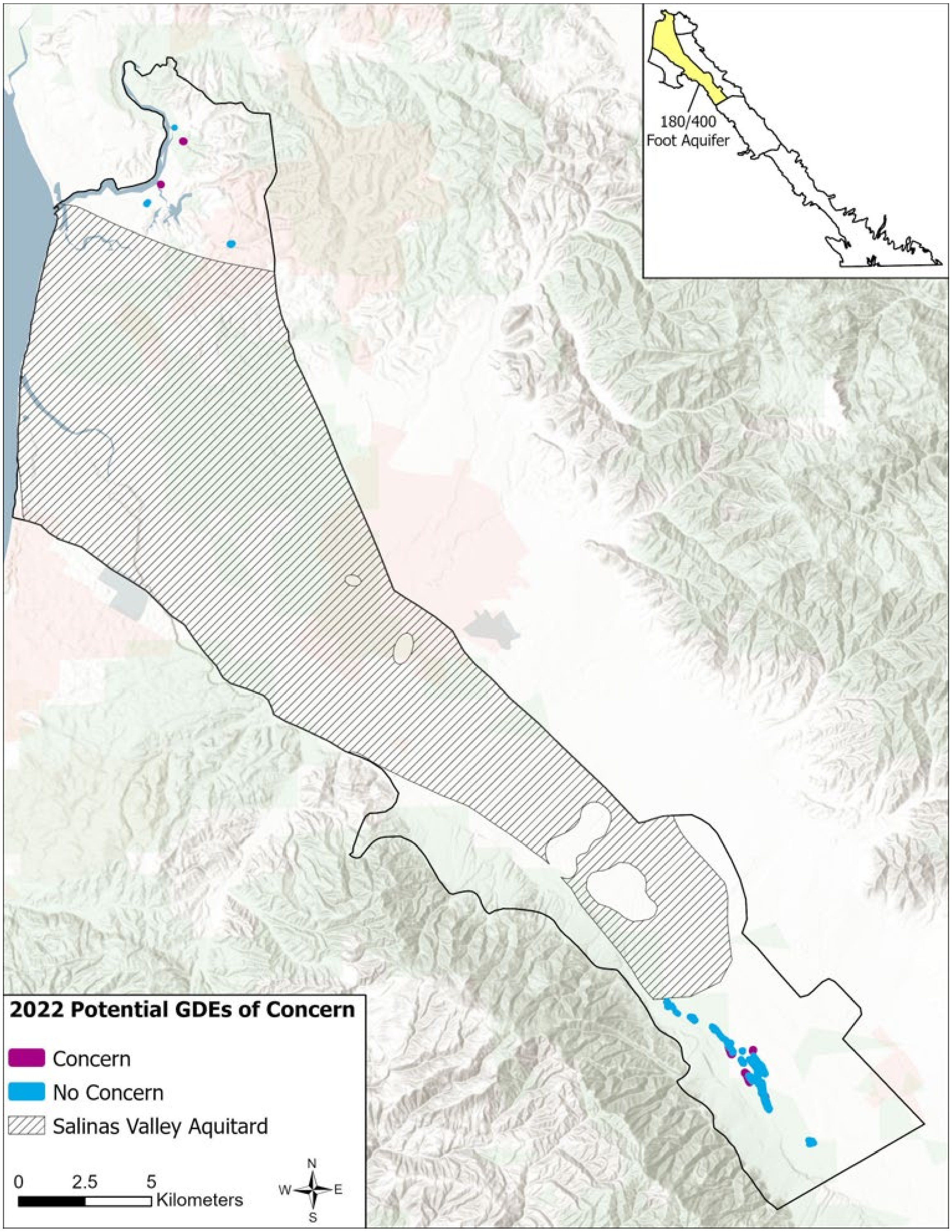

Figure 21. Potential GDEs of concern within the 180/400 Foot Aquifer Subbasin in 2022. All potential GDEs are enlarged for visibility.

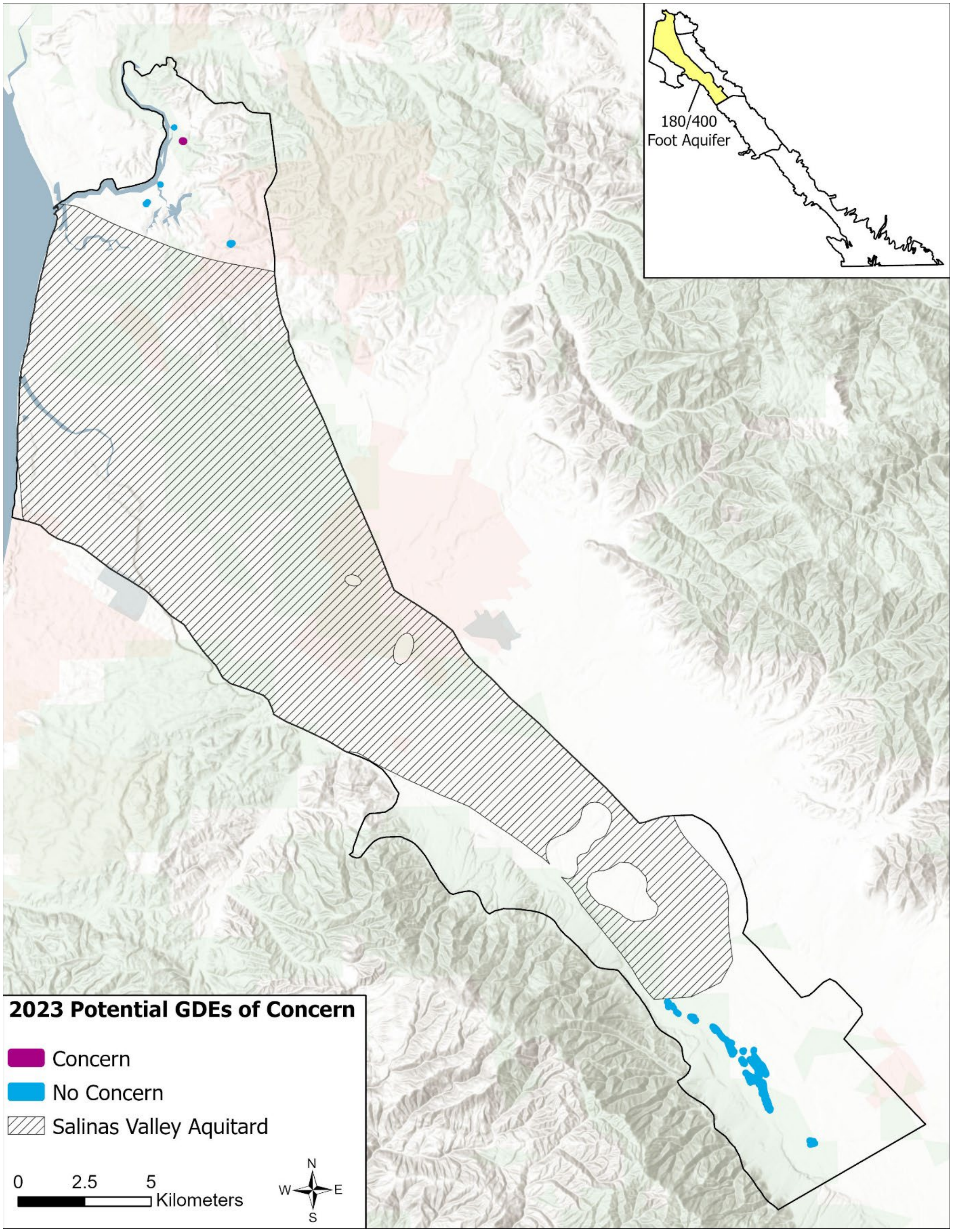

Figure 22. Potential GDEs of concern within the 180/400 Foot Aquifer Subbasin in 2023. All potential GDEs are enlarged for visibility.

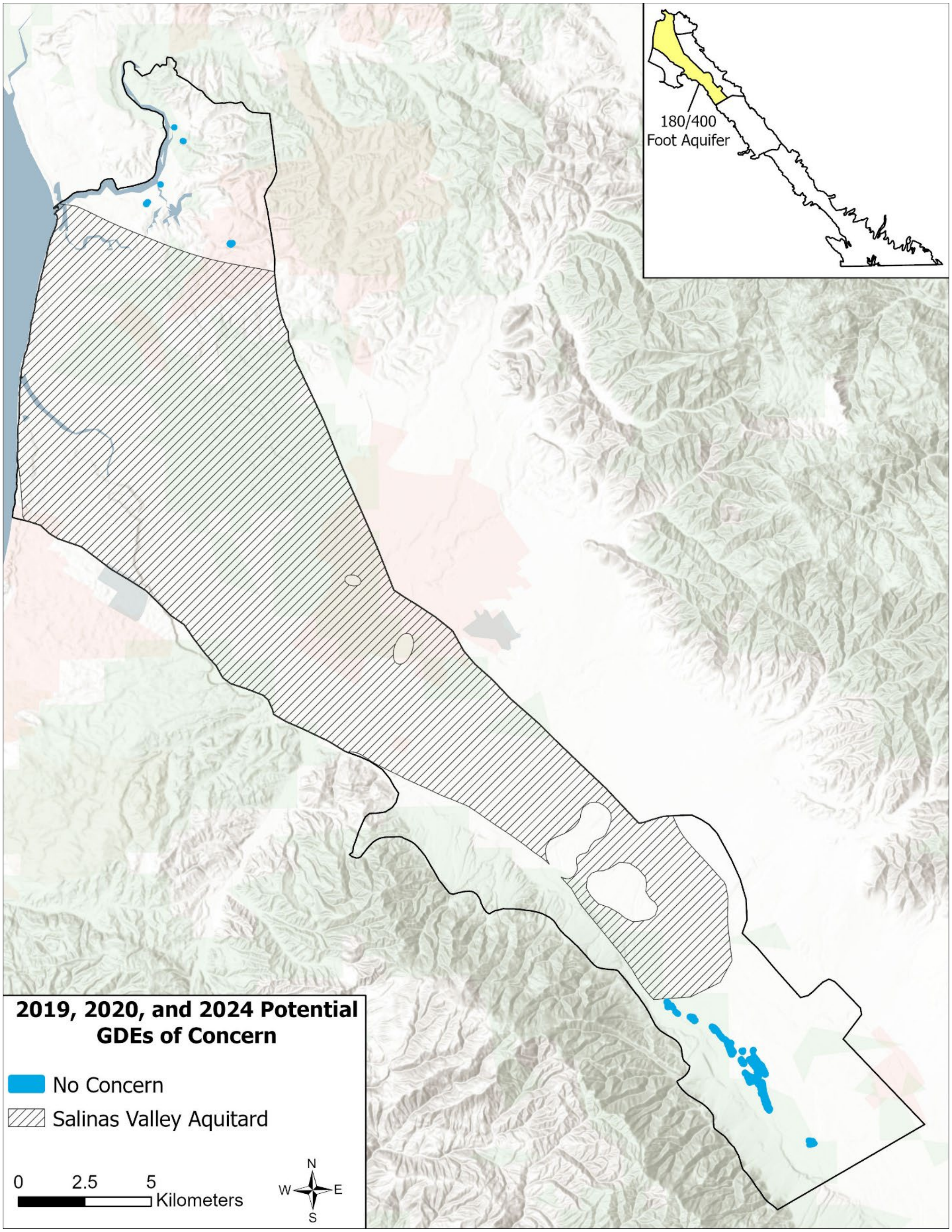

Figure 23. No potential GDEs of concern were found within the 180/400 Foot Aquifer Subbasin in 2019, 2020, or 2024. All potential GDEs are enlarged for visibility.

Field-based Baseline Condition Monitoring of Select Potential GDEs

This field-based baseline condition monitoring of potential GDEs in the 180/400 Foot Aquifer followed the field-based monitoring methods described in the *Groundwater Dependent Ecosystem Monitoring and Assessment Protocol for the Salinas Valley Basin* (Monitoring and Assessment Protocol). For this baseline monitoring, the California Rapid Assessment Method (CRAM) was conducted at 14 sites within areas mapped as potential GDEs in the 180/400 Subbasin. Site selection and the results of those assessments are summarized here.

Site Selection

The site selection guidelines outlined in the Monitoring and Assessment Protocol were followed when selecting a subset of potential GDEs to conduct CRAM assessments including prioritizing ecologically important locations, ensuring the selection is representative of potential GDEs across the subbasin, and selecting potential GDEs close to shallow monitoring wells when possible.

In the 180/400 Subbasin there are three locations identified as drought refugia (Rhode et al. 2024). Drought refugia are areas of habitat that stay wet and/or green for longer than their surroundings. These areas have been classified as ecologically important in the Monitoring and Assessment Protocol. Of the three potential GDES identified as drought refugia, CRAM was conducted at two (Table 2), access permission to conduct the assessment was not secured for the third.

In order to have a subset of potential GDEs that are representative of potential GDEs across the subbasin, the aim was to select two locations for CRAM assessments within each GDE unit (Table 2, Figure 11). This was not always possible due to either the size of the GDE unit – as was the case with the Chualar unit, difficulties securing access permission – as was the case with the Sierra de Salinas Foothills unit, or lack of appropriate sites to conduct CRAM – as was the case with the 180/400 Hills. For situations where there is a lack of appropriate sites: CRAM assessments must be conducted in wetlands, which can include ponds and lakes, riverine systems, seeps and springs, and variety of other habitats. However, potential GDEs are not limited to wetlands and can include terrestrial vegetation with root systems deep enough to reach the water table, such as Oak woodlands. The 180/400 Hills GDE unit consists entirely of Oak woodland habitats, and as such there was no appropriate location to conduct a CRAM assessment within that unit.

Table 2. CRAM assessment locations listed by site number and describing whether the assessment location was within an identified drought refugia, near an appropriate monitoring well, and what GDE unit the assessment location was within. Drought refugia determined by Rhode et al. 2024.

Site	Drought Refugia (Y/N)	GDE Unit	Proximity to Monitoring Well (Y/N)*
1	No	Elkhorn	Yes
2	No	Elkhorn	Yes
3	No	Elkhorn	Yes
4	No	Moro Cojo	Yes
5	No	South 180/400	Yes
6	No	South 180/400	No
7	No	Spreckles	No
8	Yes	Spreckles	No
9	Yes	South 180/400	No
10	No	Sierra de Salinas Foothills – 180/400	Yes
11	No	Moro Cojo	No
12	No	Chualar	No
13	No	Horseshoes	Yes
14	No	Horseshoes	No

* Proximity to monitoring wells marked yes if a well identified as appropriate for monitoring potential GDEs by hydrogeologists was located within 1.5 miles of the CRAM assessment site (distance recommended by Chappelle et al. 2023)

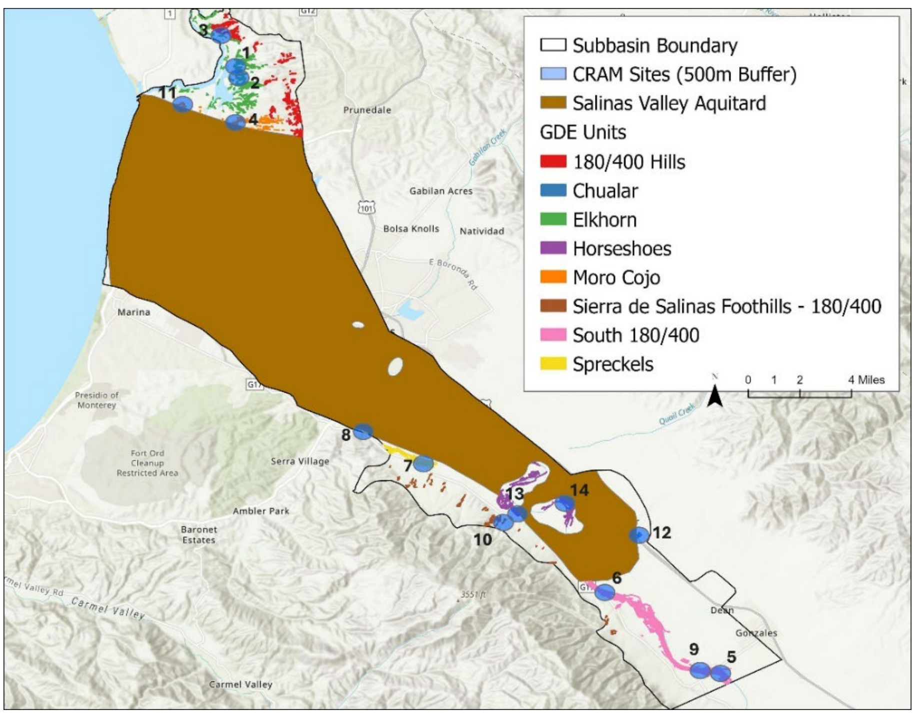

Figure 24. Approximate location of CRAM assessments, sites buffered by 500m circle (blue) to anonymize locations. Numbers indicate site number and correspond to Site in Table 2. Potential GDEs and GDE units shown here are from December 2024 identification and have not been updated in order to reflect where CRAM assessments were conducted during the 2024 assessment period.

Baseline CRAM Scores

Each CRAM assessment area is evaluated according to the four universal attributes and associated metrics/submetrics of CRAM using the correct CRAM module for each GDE. The four universal attributes are:

- **Buffer and Landscape Context** - measured by assessing the quantity and condition of adjacent aquatic areas as well as extent and quality of the buffering environment adjacent to the assessment area (AA).
- **Hydrology** - assesses the sources of water, the stream channel stability, and the hydrologic connectivity of rising flood waters in the stream.
- **Physical Structure** - measured by counting the number of patch types found within the AA and the topographic complexity of the marsh plain.
- **Biotic Structure** - assesses the site based on several factors including the number of plant vertical layers, the number of different species that are commonly found in the marsh, the percent of the common species that are invasive, and the horizontal and vertical heterogeneity of the plant communities.

These four attributes are consistent for all wetland modules of CRAM. Each of the four attribute categories is comprised of a number of metrics and submetrics that are evaluated in the field and scored on a letter grading scale corresponding to a set numeric score: D (3), C (6), B (9), A (12) (Table 3). Each of the four attribute categories are then converted to a scale of 25 through 100, and the average of these four scores is the final CRAM Index score, also ranging on a scale from 25 (lowest possible) to a maximum of 100.

CRAM assessments for selected potential GDEs were conducted between Sept 13 – Nov 1, 2024. Scores are summarized visually in Figures 25 and 26, with all metric, sub-metric, attribute and index scores listed in Table 3. Site photos of each CRAM assessment area are included at the end of this report to provide a sense of each location.

CRAM index scores for the assessed potential GDEs ranged from 40-80 with five of the 14 assessments receiving an index score of 65 (Figure 25). Hydrology and buffer/landscape attribute scores generally higher than biotic structure and physical structure attributes (Figures 26). Eight of the 14 assessment locations were on the main stem of the Salinas River. For these sites it was common for the biotic structure attribute score to be negatively impacted by dense areas of *Arundo donax*, an invasive plant. It was common for the physical structure attribute score to be negatively impacted by the planar nature of the channel of the river, lacking rapids, riffles and deep pools, and it was common for buffer and landscape context attribute score to be positively impacted by the wide floodplain of the Salinas River. These general observations are not true of every assessment area on the Salinas River, and certainly not true of every GDE assessed for this baseline monitoring effort, but they may provide insight into the score ranges and trends.

It is important to note that these CRAM assessments are intended to provide a baseline from which to compare future CRAM assessments. The SVBGSA is not responsible for improving the condition of potential GDEs, rather ensuring groundwater management does not negatively impact these systems.

Following recommendations outlined in the Monitoring and Assessment Protocol, next steps using this baseline data could include, examining groundwater elevation data in monitoring wells near CRAM assessment areas, establishing new shallow monitoring wells near CRAM assessment areas that currently are not within 1.5 miles (distance per recommendation in Chappell et al. 2023) of an appropriate monitoring well, and conducting CRAM assessments in these same assessments areas in 5 years to measure any changes in condition in relation to the baseline established here.

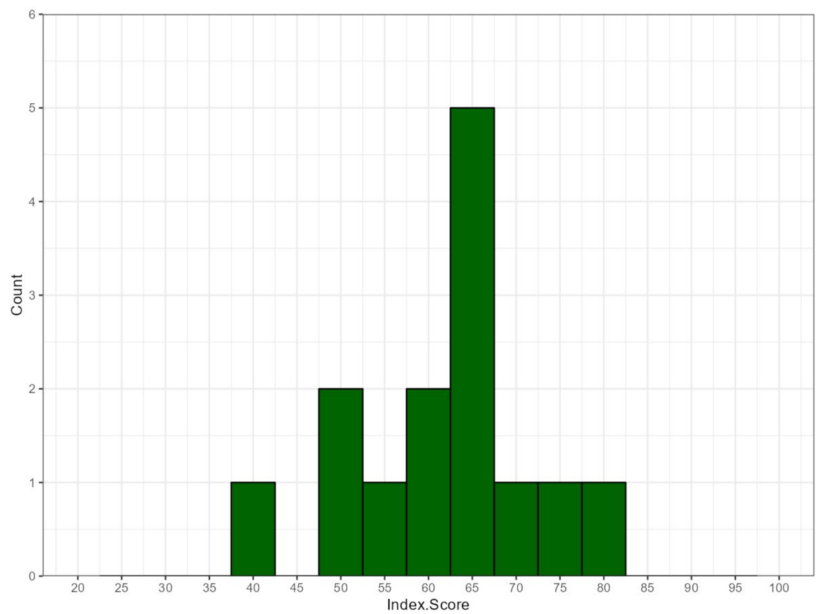

Figure 25. Histogram of CRAM Index Scores for 14 sites assessed for baseline monitoring. CRAM index scores can range from 25-100, y-axis indicates number of sites that received each score.

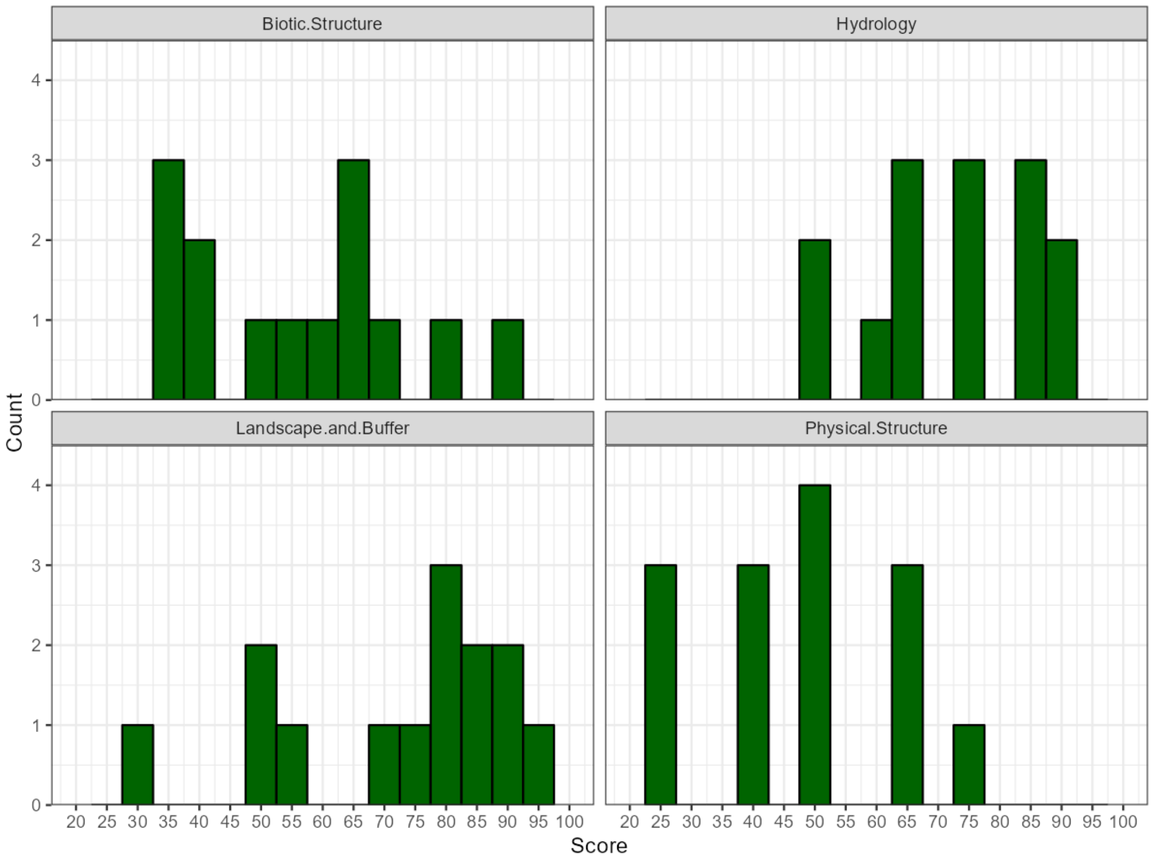

Figure 26. Histograms of scores from 14 assessments for baseline monitoring for each of the four universal CRAM attributes. Scores for each attribute can range from 25-100, y-axis indicates the number of sites that received each score

Table 3. CRAM assessment scores for potential GDEs assessed in the 180/400 Subbasin.

CRAM Attribute	**CRAM Metrics and Sub-metrics**	**Gabilan Watershed GDE CRAM Assessments**													
		Site 1	**Site 2**	**Site 3**	**Site 4**	**Site 5**	**Site 6**	**Site 7**	**Site 8**	**Site 9**	**Site 10**	**Site 11**	**Site 12**	**Site 13**	**Site 14**
Buffer and Landscape Connectivity	Landscape Connectivity	9	6	9	3	12	12	12	12	12	3	3	3	12	12
	% of AA with Buffer	12	12	12	6	12	12	12	12	12	12	12	9	12	12
	Average Buffer Width	12	12	6	9	9	9	9	3	9	9	12	3	3	12
	Buffer Condition	9	9	9	12	9	6	9	9	6	9	6	3	9	9
	Attribute Score	**81**	**68**	**74**	**52**	**90**	**83**	**90**	**81**	**83**	**53**	**48**	**29**	**81**	**93**
Hydrology	Water Source	9	9	9	6	6	6	6	6	6	12	9	6	6	6
	Hydroperiod/ Channel Stability	12	9	12	12	6	9	9	9	9	9	12	6	9	9
	Hydrologic Connectivity	9	9	12	12	6	3	9	9	12	12	9	12	12	6
	Attribute Score	**83**	**75**	**92**	**83**	**50**	**50**	**67**	**67**	**75**	**92**	**83**	**67**	**75**	**58**
Physical Structure	Structural Patch Richness	589	3	9	3	6	3	6	6	6	3	6	3	3	3
	Topographic Complexity	6	6	9	9	9	3	6	9	6	3	6	3	6	6
	Attribute Score	**63**	**38**	**75**	**50**	**63**	**25**	**50**	**63**	**50**	**25**	**50**	**25**	**38**	**38**
Biotic Structure	Number of plant layers	12	9	12	9	9	6	9	9	6	3	12	9	9	12
	Number of co-dominants	9	3	9	3	6	3	6	6	3	3	6	3	3	6
	Percent Invasive plants	9	12	9	12	6	9	12	9	9	12	12	3	9	6
	Horizontal Interspersion	9	6	9	6	6	6	6	6	3	3	9	6	3	9
	Vertical Biotic Structure	6	6	12	9	6	3	3	9	3	3	9	3	3	6
	Attribute Score	**69**	**58**	**88**	**67**	**53**	**42**	**50**	**64**	**33**	**33**	**78**	**39**	**36**	**64**
	Index Score	**74**	**60**	**82**	**63**	**64**	**50**	**64**	**68**	**60**	**51**	**65**	**40**	**57**	**63**

180/400 Subbasin Baseline GDE Monitoring CRAM Site Photos

Site 1

Site 2

Site 3

Site 4

Site 5

GDE 6


Site 7


Site 8


Site 9


Site 10


Site 11


Site 12


Site 13


Site 14

References

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