Appendix 5B

GDE Identification and GDE Monitoring Standard Operating Procedures

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

CCWG
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.

The process for identifying and mapping GDEs in the 180/400-Foot Aquifer Subbasin (180/400 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 GDEs in the 180/400 Subbasin included a desktop review and analysis of groundwater and habitat datasets. Additionally, field-based baseline condition monitoring was conducted for select GDEs identified through the desktop process.

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 GDEs in this subbasin. Due to the inherent uncertainties, this process aimed to be conservative in the identification of GDEs and err on the side of being more inclusive in the mapping of these ecosystems.

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 GDEs across the whole subbasin. This approach takes the perspective that if there are no adverse impacts to identified 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 GDEs from adverse impacts.

Desktop Identification and Mapping

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 nonprincipal 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 GDEs in the 180/400 Subbasin are described in more detail in the following sections.

Datasets

The desktop-based process of identifying and mapping GDEs in the 180/400-Foot Aquifer 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 GDEs within groundwater subbasins and modifying the dataset based on local habitat and groundwater data.

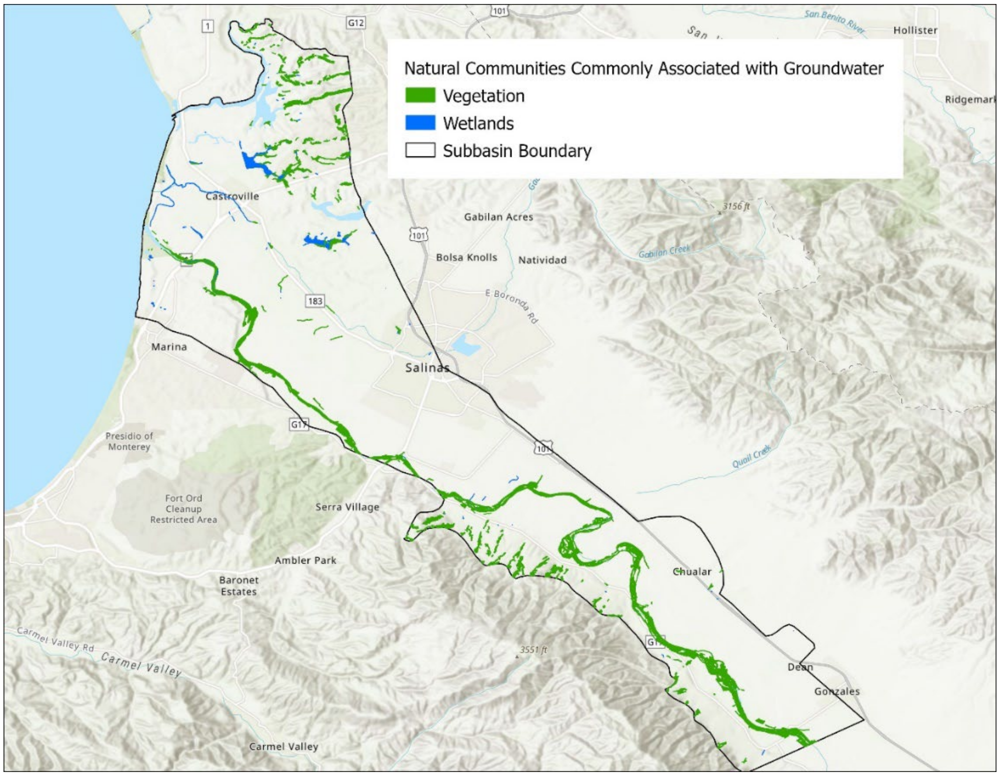

Figure 1. Natural Communities Commonly Associated with Groundwater dataset focused on the 180/400 Subbasin (Klausmeyer et al. 2018).

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).

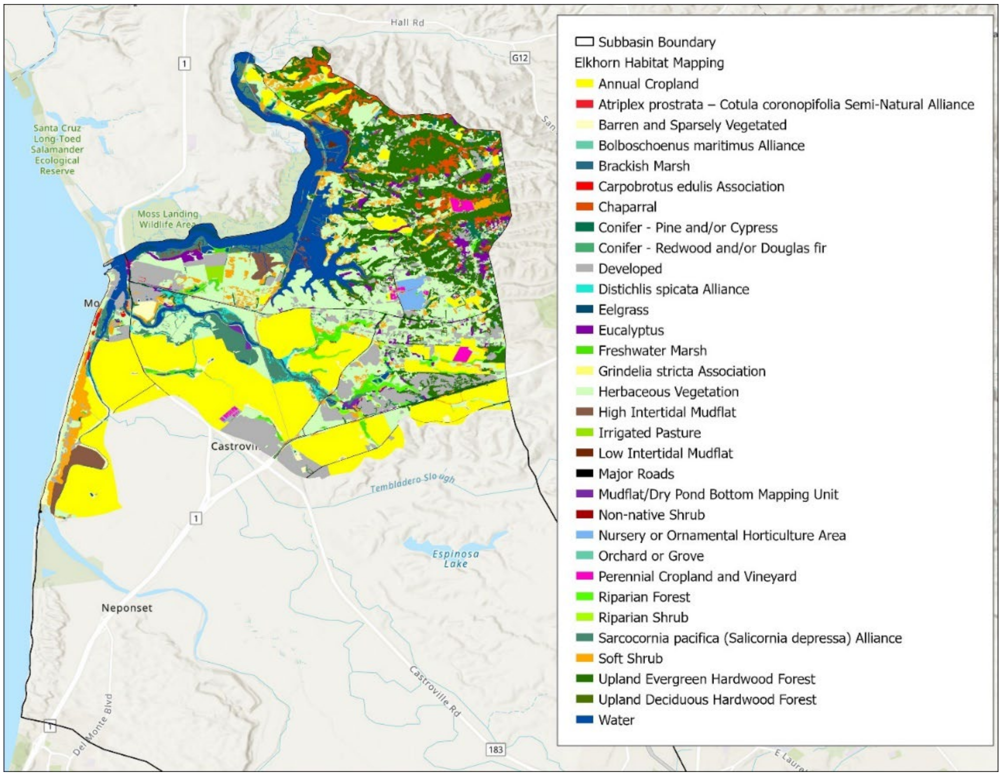

Figure 2. Elkhorn Slough Watershed lifeform mapping (ESF et al. 2020).

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 Shallow Groundwater Elevation Contours

Monterey County Water Resources Agency (MCWRA) conducts a groundwater elevation monitoring programs in the Salinas Valley Groundwater Basin and provided the groundwater elevation contour data used for this identification and mapping effort. Fall shallow groundwater elevation contour data from 2019 was used to identify groundwater dependent ecosystems in the 180/400 Subbasin. This was a conservative approach, including the broadest number of GDEs in initial identification because 2019 was a wet year with high groundwater elevations post 2014 when SGMA took effect. 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; the fall measurements represent the seasonal high.

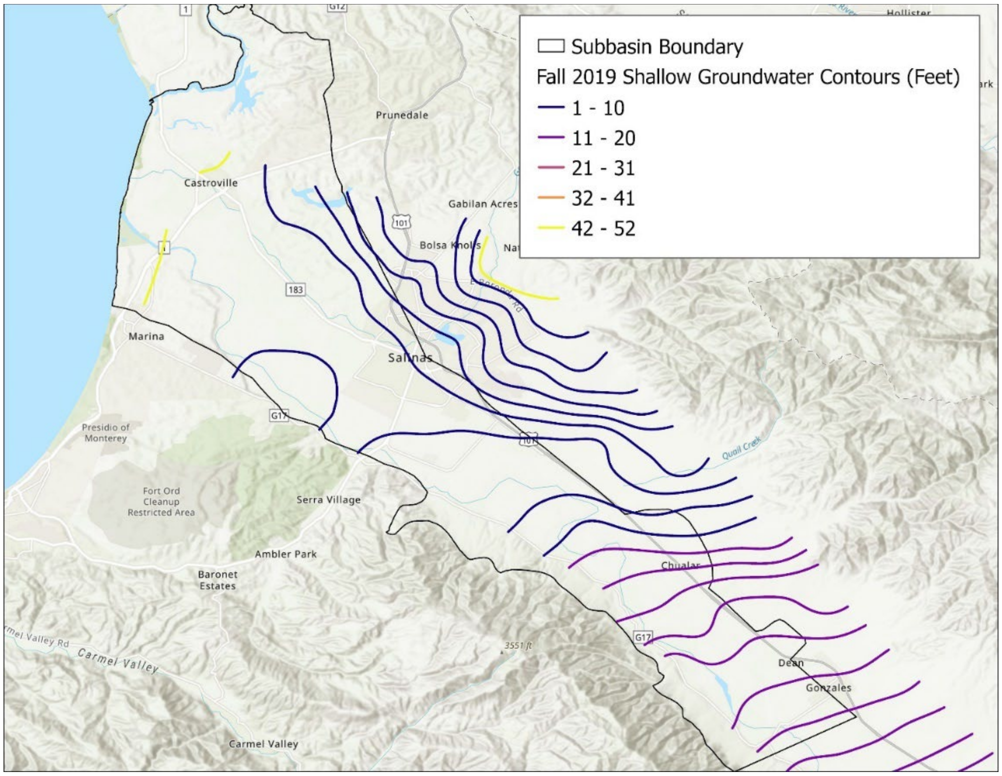

Figure 3. Shallow groundwater elevation contours (feet) based on Fall 2019 MCWRA monitoring.

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).

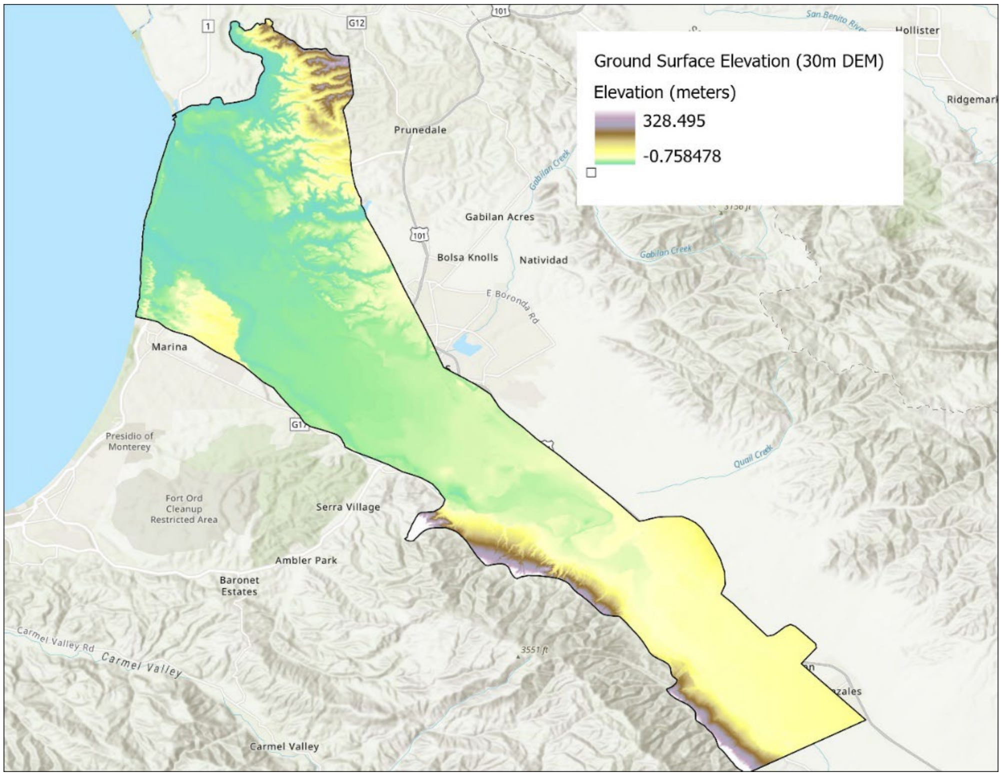

Figure 4. Digital Elevation Model (DEM) ground surface elevation (meters) in the 180/400 Subbasin (USGS 2024).

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 GDEs will be updated to reflect the best available knowledge.

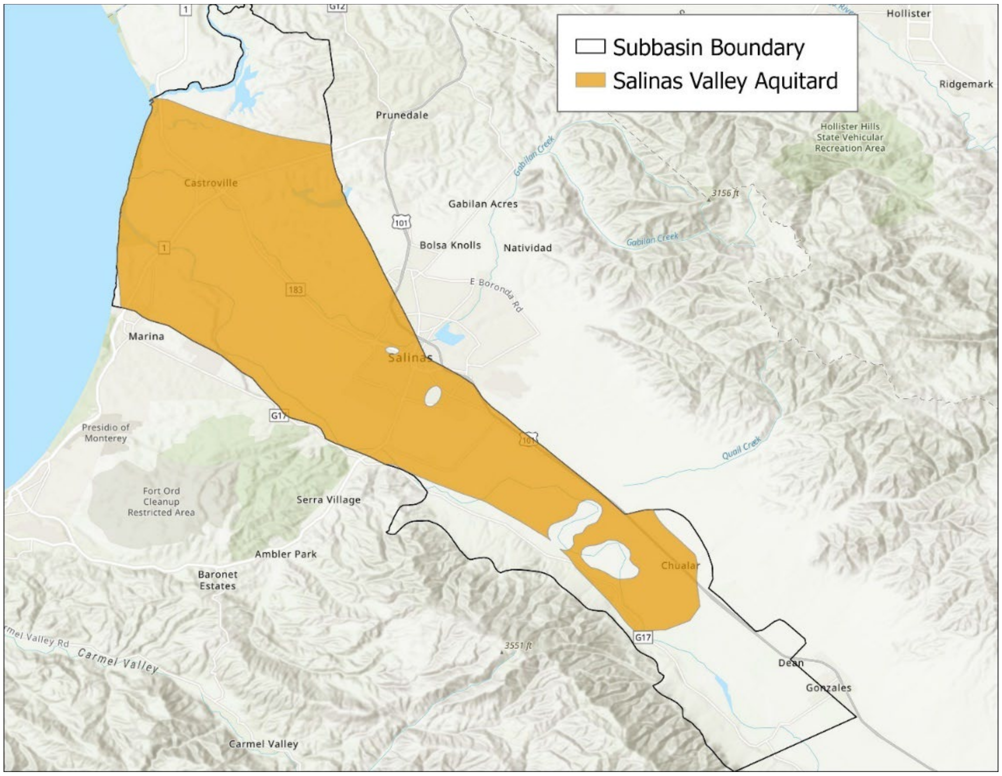

Figure 5. Confirmed extent of Salinas Valley Aquitard as of July 2024.

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 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.

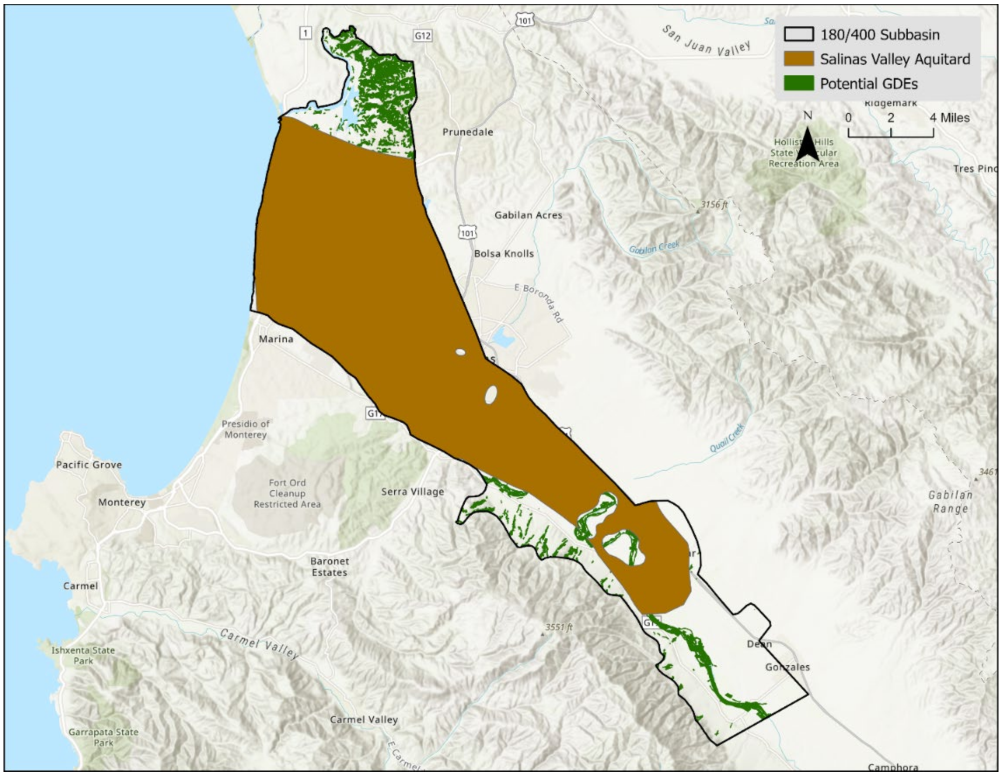

Figure 6. Set of ecosystems potentially dependent on groundwater, based on state and local habitat mapping datasets. Areas above the current known extent of the Salinas Valley Aquitard are excluded from consideration based on a recommendation from the SVBGSA Advisory Committee.

The Fall 2019 Shallow Groundwater Contours describe groundwater elevation in relation to sea-level. The DEM data describes the ground surface elevation in relation to sea-level. To determine the depth from the surface down to the groundwater table across the 180/400 Subbasin, the groundwater elevation (groundwater contours) was subtracted from the ground surface elevation (DEM) (Figure 7). However, in order 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 8).

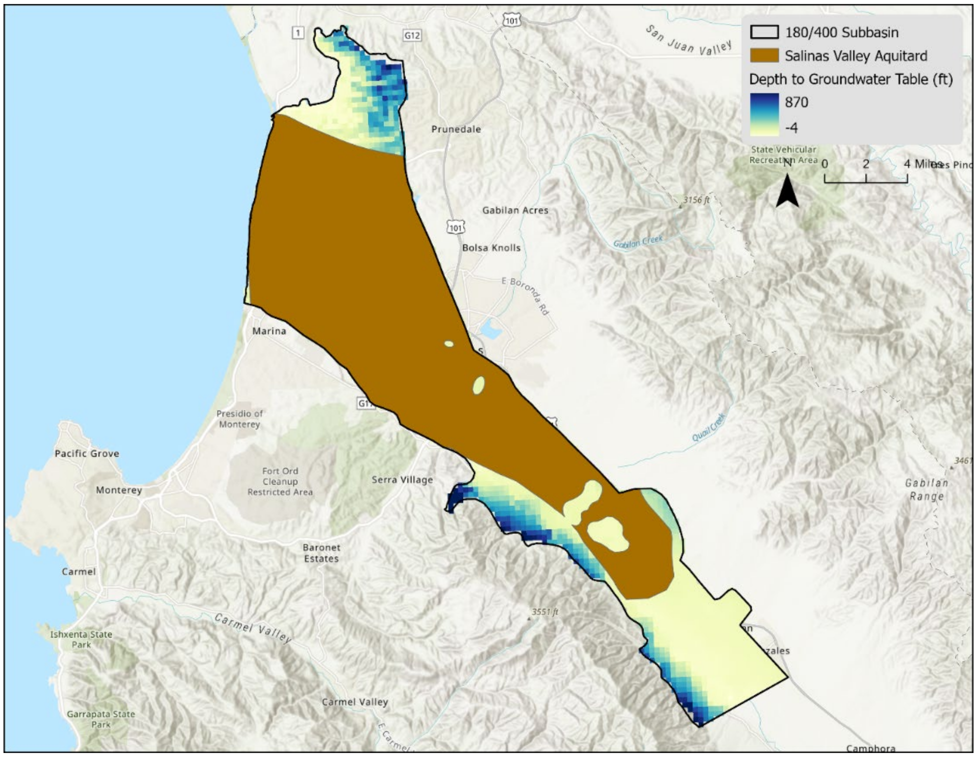

Figure 7. Distance from the ground surface to the groundwater table, or depth to groundwater table (feet).

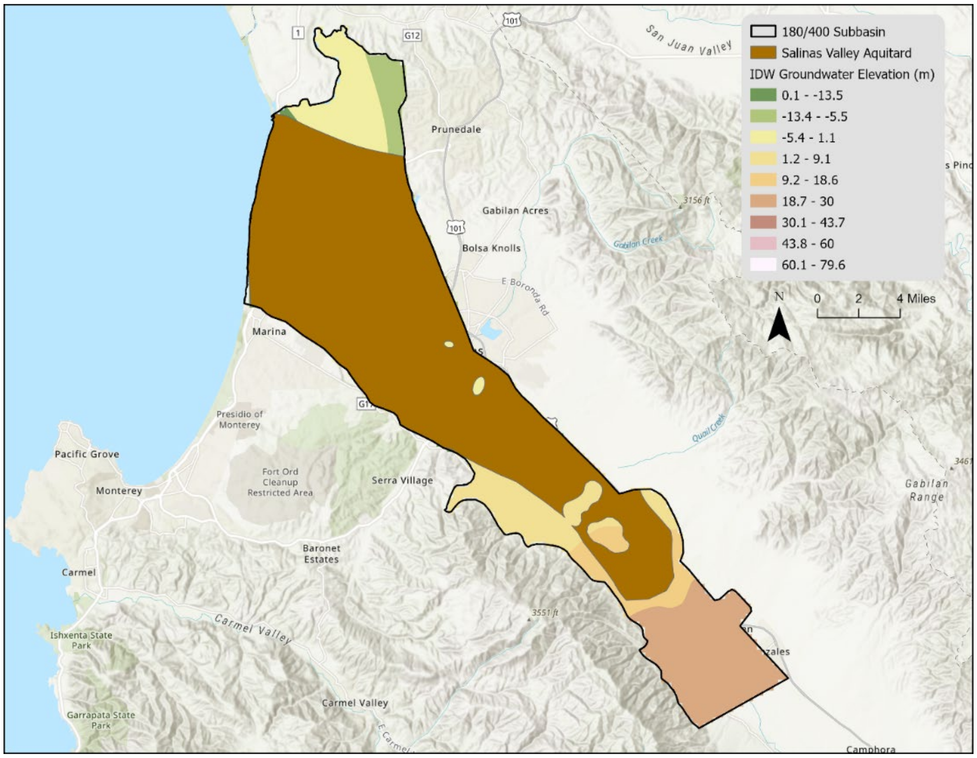

Figure 8. Continuous surface of groundwater elevations. Fall 2019 Shallow Groundwater Contour data provided by MCWRA was interpolated using Inverse Distance Weighting (IDW) to create the continuous surface of groundwater elevations.

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 groundwater dependent ecosystems in the 180/400 Subbasin.

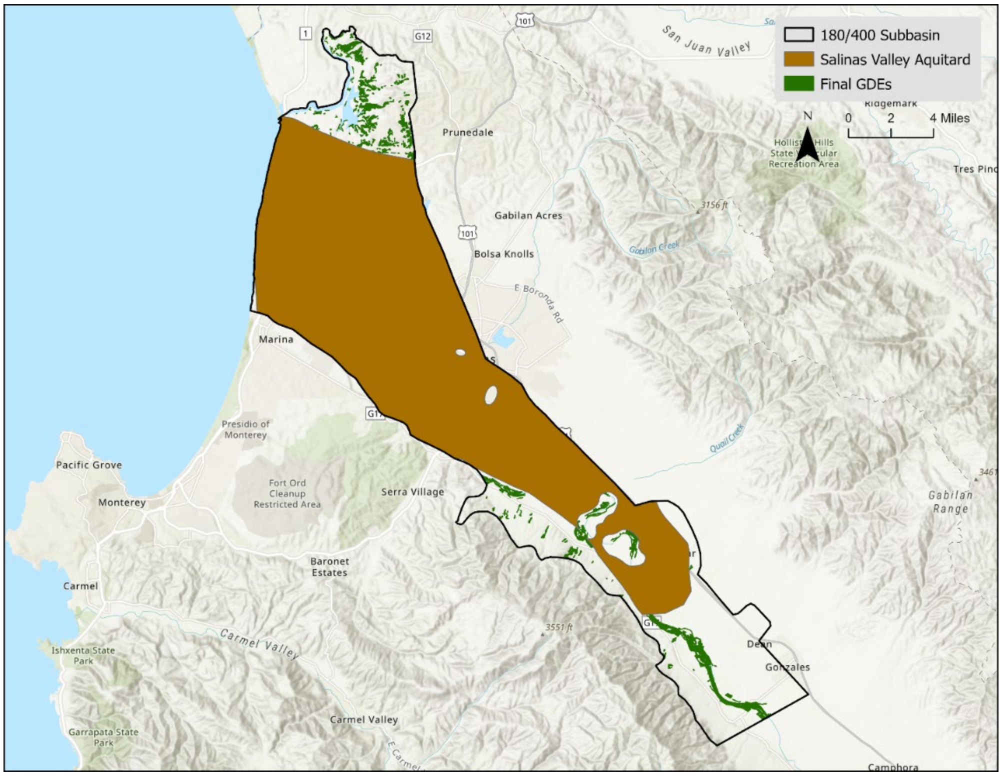

Figure 9. All identified GDEs within the 180/400 Subbasin, this set of GDEs is considered up to date as of November 2024.

Inherent Uncertainty and an Iterative Process

There are inherent uncertainties in the identification of 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 GDEs. However, it does result in a representative and characteristic map of 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 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 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 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.

Categorizing GDEs into Units

The final step in developing a map of GDEs in the 180/400 Subbasin was to group the identified GDEs into units based on shared hydrogeology and association with the same aquifer (Figure 10). The purpose of grouping GDEs into these units is to assist with monitoring and assessment for adverse impacts GDEs. If an adverse impact to a GDE within a unit is detected, understanding which additional 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 GDEs in the 180/400 Subbasin, this resulted in eight GDE units (Figure 11).

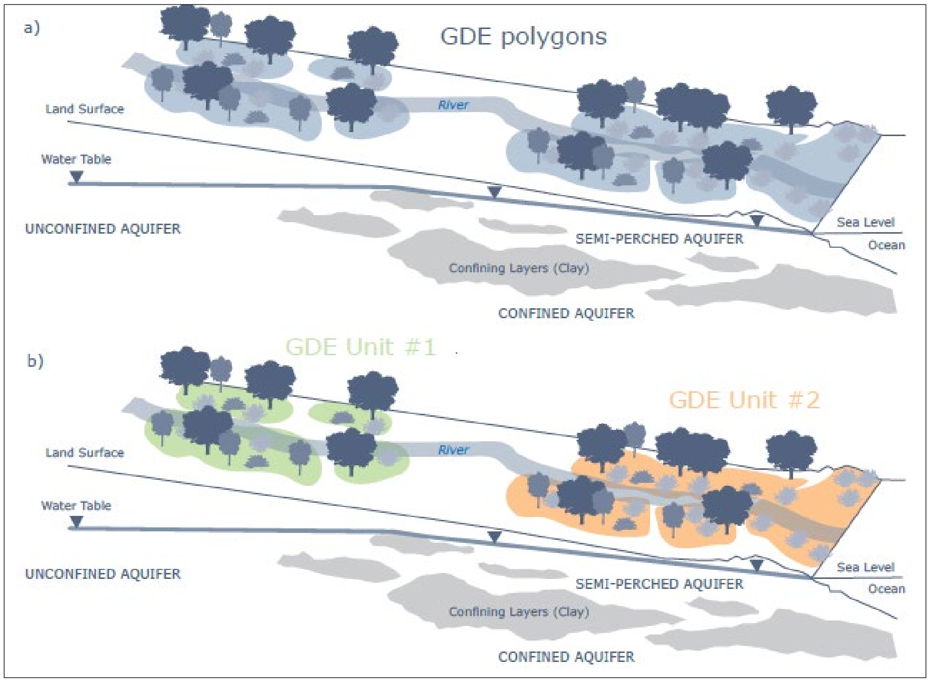

Figure 10. Illustration of grouping GDEs into units based on shared association with an aquifer. a) GDEs not separated into units, b) GDEs separated into two units, Unit #1 is associated with an unconfined aquifer, Unit #2 is associated with a semi-perched aquifer above a confined aquifer. Image Credit: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

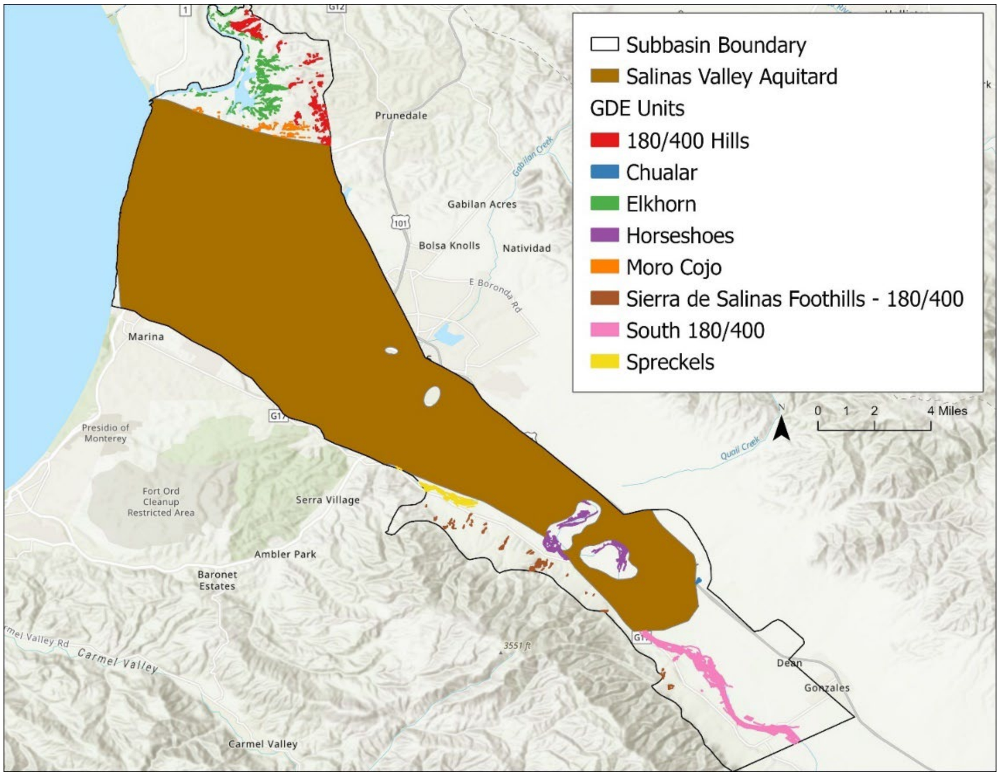

Figure 11. Map of identified GDEs, up to date as of November 2024 and including GDE units delineated by hydrogeologists familiar with the Salinas Valley Basin.

Field-based Baseline Condition Monitoring of Select GDEs

This field-based baseline condition monitoring of 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 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 GDEs to conduct CRAM assessments including prioritizing ecologically important locations, ensuring the selection is representative of GDEs across the subbasin, and selecting 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 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 GDEs that are representative of GDEs across the subbasin, the aim was to select two locations for CRAM assessments within each GDE unit (Table 2, Figure 12). 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, 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 GDEs by hydrogeologists was located within 1.5 miles of the CRAM assessment site (distance recommended by Chappelle et al. 2023)

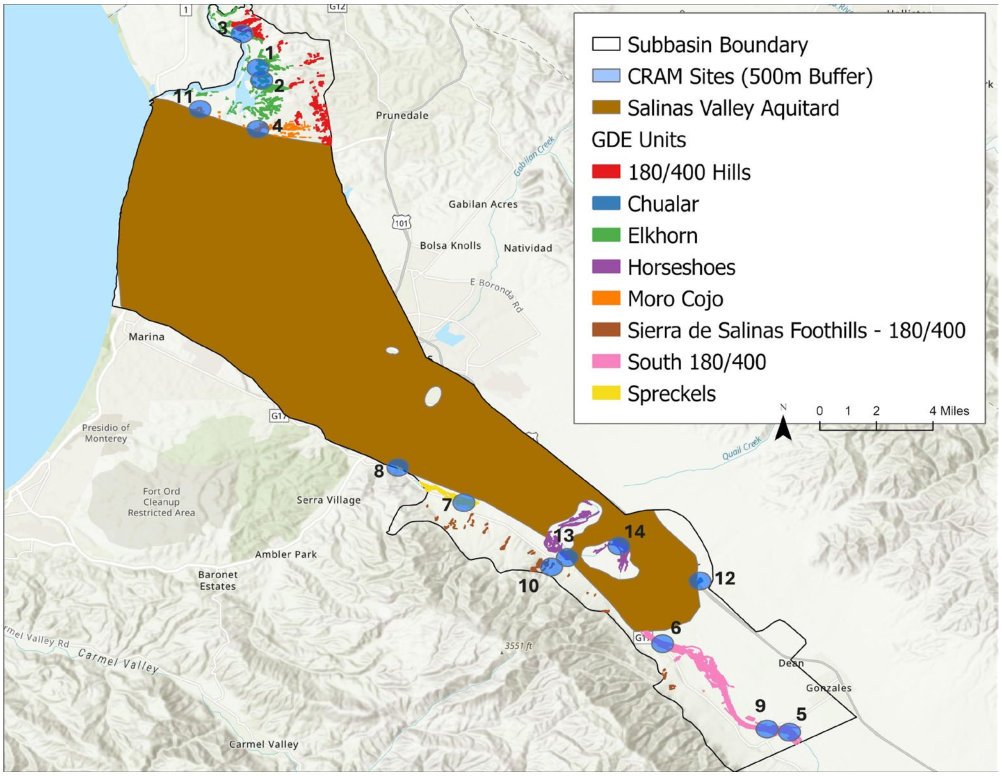

Figure 12. Approximate location of CRAM assessments, sites buffered by 500m circle (blue) to anonymize locations. Numbers indicate site number and correspond to Site in Table 2.

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 GDEs were conducted between Sept 13 – Nov 1, 2024. Scores are summarized visually in Figures 13 and 14, 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 GDEs ranged from 40-80 with five of the 14 assessments receiving an index score of 65 (Figure 13). Hydrology and buffer/landscape attribute scores generally higher than biotic structure and physical structure attributes (Figures 14). 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, but they may provide insight into the score ranges and trends. However, 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 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.

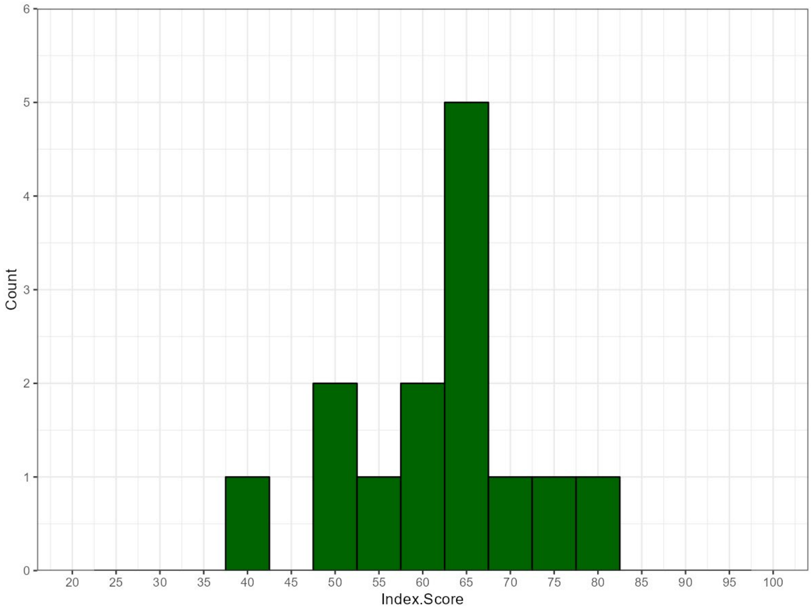

Figure 13. Histogram of CRAM Index Scores for 14 sites assessed for baseline monitoring. CRAM index scores can range from 25-100, y-axis indicates number of sites that received each score.

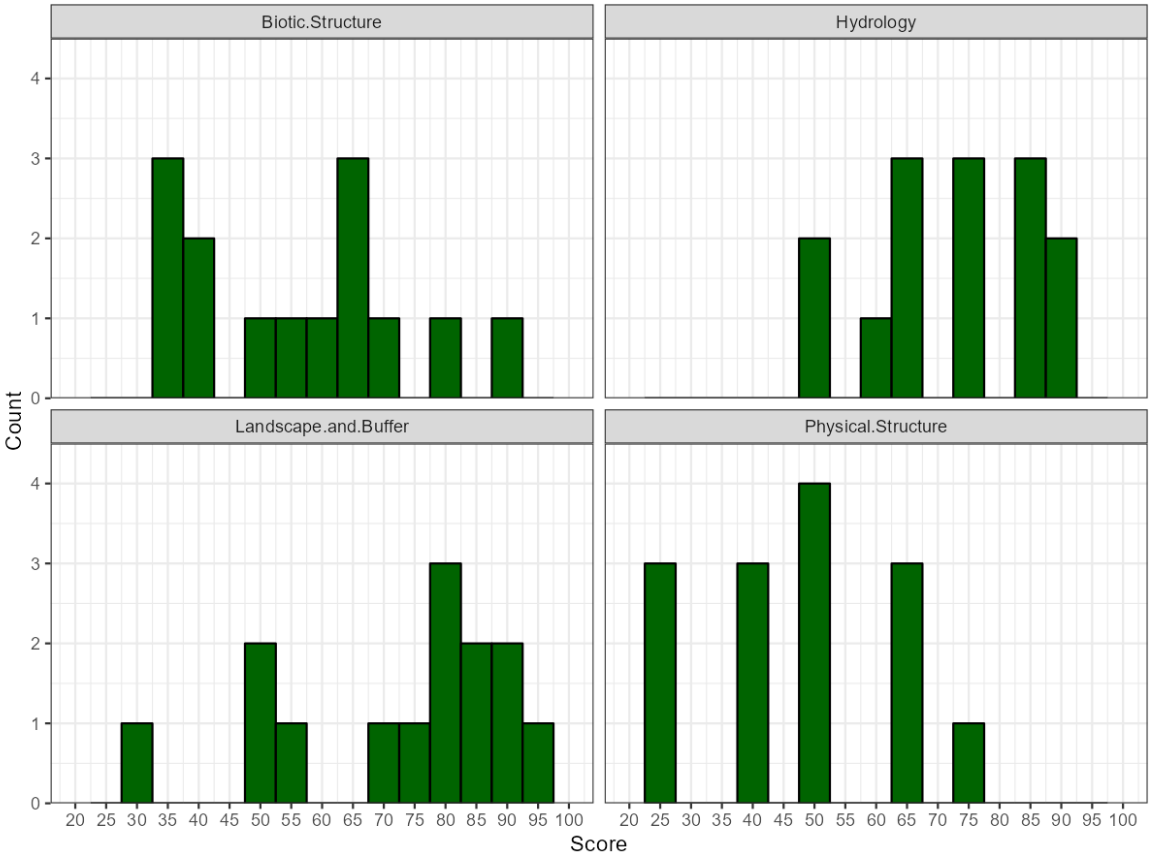

Figure 14. Histograms of scores from 14 assessments for baseline monitoring for each of the four universal CRAM attributes. Scores for each attribute can range from 25-100, y-axis indicates the number of sites that received each score

Table 3. CRAM assessment scores for 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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Groundwater Dependent Ecosystem Monitoring and Assessment Protocol for the Salinas Valley Basin

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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 that 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 to be identified, monitored and assessed to ensure there are no adverse impacts to these systems due to groundwater conditions.

The objective of this monitoring protocol 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, 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.

This monitoring protocol for GDEs in the Salinas Valley Basin 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 monitoring protocol was developed with feedback from local stakeholders as part of the Salinas Valley Basin Groundwater Sustainability Agency (SVBGSA) Groundwater Dependent Ecosystem Working Group, which met seven times between July 2023 - April 2024.

Two-pronged Approach

This GDE monitoring protocol 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. The desktop-based monitoring is conducted annually for all mapped GDEs while the field-based monitoring is conducted once every five years at a subset of mapped GDEs. Detailed procedures for both monitoring components are described in the following sections. 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. 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.

Desktop-Based Monitoring

The desktop-based GDE monitoring consists of monitoring changes over time using a remotely sensed satellite data derived metric named the Normalized Derived Vegetation Index (NDVI). NDVI is a quantified measurement of vegetation greenness and has been demonstrated as a valid proxy for measuring vegetation health and vigor (TNC 2024). NDVI values for a given GDE can be compared over time, and if statistically significant declines are detected, the GDE will be flagged for further investigation into the cause of the declining NDVI values.

Calculating NDVI

NDVI is calculated using near infrared (NIR) and visible red light (red) bands taken from satellite imagery to measure how much of these bands of light are absorbed versus reflected by a surface (Figure 1). The higher the NDVI value, the greener, and healthier, the vegetation. NDVI values range from -1.0 to 1.0, Table 1 provides a general guide to interpreting NDVI values.

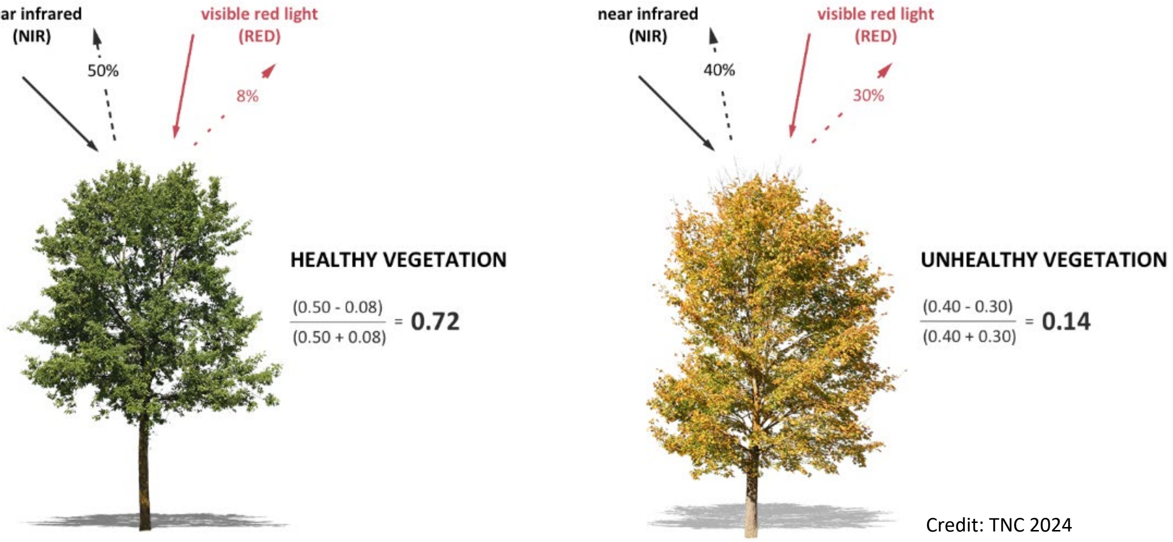

Figure 1. This graphic depicts how NDVI is calculated and gives an example of how much light is absorbed versus reflected by healthy, green vegetation compared to unhealthy, less green vegetation. As vegetation greenness declines, the percentage of reflected light increases (image credit: TNC 2024).

The following equation is used to calculate NDVI values from satellite derived NIR and visible red light (red) bands (Rouse et al. 1974):

$$NDVI = (NIR - red)/ NIR+red$$

Table 1. Guide to interpreting NDVI values, a description of which surfaces correspond to NDVI value ranges (USGS 2018)

NDVI Value Range	Corresponding Surface
-1.0 – 0.1	Areas of barren rock, sand, snow, urban development or any other highly reflective surface
0.1 – 0.5	Sparse or senescing vegetation
0.5 – 1.0	Dense, green vegetation

NDVI values can be calculated for one point in time, based on a single satellite image. However, for monitoring purposes it is more useful to consider the average NDVI value over a period of time to better characterize the vegetation vigor of a GDE rather than rely on a single point in time. The daily NDVI values for a GDE should be averaged annually between June 1 – September 30. This is the driest time of year when GDE vegetation is likely most reliant on groundwater (TNC 2024).

TNC has developed an online mapping tool that provides NDVI calculations for GDEs across California from 1985 – 2022, called GDE Pulse (TNC 2024). GDE Pulse provides a great starting point for desktop-based GDE monitoring. However, additional GDEs have been identified in the Salinas Valley based on local data and therefore, GDE Pulse, using the statewide GDE dataset, is not sufficient for SVBGSA monitoring purposes. It is instead recommended that NDVI values for GDEs be calculated from publicly available Landsat satellite imagery (USGS Earth Explorer) to ensure all GDEs are included in this desktop-based monitoring.

Analyzing and Reporting NDVI

Analysis of NDVI values includes two steps: the first is determining how NDVI are changing over time and if there is an increasing or decreasing trend at each GDE; the second is determining when a decreasing trend in NDVI values is substantial enough to trigger additional investigations into the cause of the declining vegetation vigor.

Assessing NDVI Trends Over Time

The statistical test “Mann Kendall Test for Monotonic Trends” (Mann Kendall Test) should be used to assess how dry season annual average NDVI values change over time. The Mann Kendall Test is a non-parametric test that is not as sensitive to extreme outliers as other statistical tools for assessing trends over time, such as linear regression. Considering there could be large changes in NDVI values from year to year due to rainfall patterns and other climatic variables, the Mann Kendall test is an appropriate test for this application. Additionally, there is local precedent for using the Mann Kendall test for environmental data; Central Coast Water Quality Preservation, Inc. uses the same statistical test to assess trends in their Cooperative Monitoring Program water quality data over time (Central Coast Water Quality Preservation, Inc. et al 2023).

The direct output of the Mann Kendall Test is a statistic called Tau, which can range from -1 to 1. A Tau of -1 indicates an extremely decreasing trend, a Tau of 1 indicates an extremely increasing trend. A p-value is also reported with each Tau; the p-value indicates whether a trend is significant or not (Table 2). The standard practice for determining significance is to check for a p-value of less than 0.05. In this application the standard practice is followed, with a trend classified as significantly increasing or decreasing (depending if the Tau is negative or positive) if the p-value is less than 0.05. However, here it is also of value to determine if NDVI values have a neutral trend over time or an increasing or decreasing trend, even if those trends are not large enough to be significant. Therefore, an additional range of p-values are suggested in Table 2 to classify trends in NDVI values.

Table 2. Classification of p-values into levels of significance. Whether a trend is increasing or decreasing depends on the sign of the Tau statistic (positive = increasing, negative = decreasing).

P-value range	**Trend classification**
0 - 0.05	Significantly increasing or decreasing
0.05 – 0.7	Increasing or decreasing
0.7 – 1.0	Neutral

The Mann Kendall Test should be calculated for NDVI values in a moving window of 5 years. Table 3 gives an example of a moving window of 5-year intervals. This time frame for analysis was chosen since it balances reducing the noise of tracking NDVI values from year to year with picking up on longer term trends, while still remaining sensitive enough to indicate decreasing trends on a time scale that is biologically relevant for GDE vegetation.

Table 3. Example NDVI trend analysis over a 5-year moving window interval using historic NDVI data for GDEs in the Salinas Valley (data provided by TNC, TNC 2024). Example reporting period from 2018-2022.

GDE Unique Identifier	**2013 - 2018**	**2014 - 2019**	**2015 - 2020**	**2016 - 2021**	**2017 - 2022**
29224	Neutral	Neutral	Increasing	Increasing	Increasing
29260	Decreasing	Decreasing	Decreasing	Significantly Decreasing	Decreasing
29424	Decreasing	Decreasing	Significantly Decreasing	Significantly Decreasing	Significantly Decreasing
30912	Neutral	Increasing	Increasing	Increasing	Increasing
37491	Neutral	Increasing	Increasing	Significantly Increasing	Significantly Increasing
37501	Significantly Increasing	Significantly Increasing	Neutral	Neutral	Neutral

Detecting Adverse Impacts with NDVI Values

GDEs should be flagged for further investigation into their condition and possible causes for declining vegetation vigor if NDVI value trends for that GDE meet the following criteria:

- Three consecutive 5-year windows with a Significantly Decreasing trend. As an example, GDE 29424 in Table 3, would be flagged under this criterion. Even if the GDE shows an improving trend in NDVI values in subsequent 5-year windows, it should still be flagged for further investigation.
- Five consecutive 5-year windows with a combination of either a Decreasing or Significantly Decreasing Trend. As an example, GDE 29260 in Table 3 would be flagged under this criterion. If all five 5-year windows for GDE 29260 were Decreasing, this GDE would still be flagged for further investigation.

Flagging a GDE using the above criteria based on NDVI value trends does not automatically mean that GDE is experiencing adverse impacts to ecosystem condition due to declining groundwater levels. Monitoring NDVI values alone is not sufficient for drawing causal conclusions about the impact of groundwater management on GDE condition. Rather sustained trends of decreasing NDVI values are an indicator that the ecosystem is experiencing adverse impacts and further investigation is required to determine the root cause. The criteria for flagging GDEs were defined in an effort to be sensitive to decreases in ecosystem condition while allowing for variation in rainfall patterns and short drought periods vegetation can likely recover from. As with all components of this monitoring protocol, these criteria should be periodically evaluated and modified as necessary to best detect adverse impacts to GDEs.

Field-Based Monitoring

The field-based GDE monitoring consists of monitoring changes in ecosystem condition over time using the California Rapid Assessment Method (CRAM). CRAM is a standardized, scientifically validated, rapid habitat assessment tool for wetland monitoring, developed with support from the US Environmental Protection Agency. It is designed to assess the overall condition of a wetland based on visible indicators relative to the least impacted reference conditions. CRAM is based on the concept that the structure and complexity of a wetland is indicative of its capacity to provide a range of functions and services (Solek et al. 2018). Though CRAM is designed for assessing ambient conditions within watersheds throughout the state, it can also be used to assess changes in habitat condition for locations of interest over time such as GDEs.

While CRAM is designed to be a rapid assessment, because it is a field-based tool it is a more resource-intensive monitoring tool than the desktop-based monitoring of NDVI values over time. For that reason, only a subset of GDEs will be selected for CRAM assessments. Considerations for selecting these GDEs for CRAM assessments are discussed in the following section. The concept for monitoring and assessing GDEs with CRAM is similar to that of monitoring and assessing NDVI values. CRAM assessments will be completed in the same location within each selected GDE, and the scores will be compared over time. If significant declines in CRAM score are detected the GDE will be flagged for further investigation into the cause of the decreasing CRAM score.

Site Selection for CRAM Assessments

There are two main factors to consider when selecting which subset of GDEs will be monitored with CRAM assessments: ecological importance, and proximity to an appropriate monitoring well. In addition, GDEs selected for CRAM assessments should be well distributed across each subbasin to characterize the subbasin as best as possible despite the site-specific nature of CRAM. Also, safety and land access permission must be checked and prioritized when finalizing site selection for CRAM assessments.

Ecological Importance

Since selected GDEs will receive more focused monitoring, with more data to detect adverse impacts, it is appropriate for these sites to have greater habitat value. To determine which GDEs have the greatest habitat value it is recommended to identify which GDEs are drought refugia, have recent observations of threatened and endangered species, and/or are nominated as ecologically important by local subject matter experts.

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. Researchers have developed a robust methodology for identifying drought refugia across California and have made their findings publicly available (Rhode et al. 2024). Wherever drought refugia in this dataset overlap with identified GDEs, those GDEs should be included in the subset for CRAM monitoring.

Ecological importance can also be defined based on recent observations of threatened and endangered species in identified GDEs, or classification of a GDE as critical habitat for one of these species. The California Natural Diversity Database (CNDDB) is an inventory of the status and locations of rare plants and animals across the state and includes identification of critical habitat. This database can be cross referenced with identified GDEs, and areas of overlap should be considered for CRAM monitoring. Additionally, local researchers and subject matter experts should be consulted to identify areas of ecological importance that may not appear in either CNDDB or in the drought refugia dataset.

Water Table Monitoring Wells

While both CRAM and NDVI values can provide valuable information about the condition of GDEs, neither can draw a causal link between declining habitat condition and groundwater levels. To link groundwater levels to changes in habitat condition requires a monitoring well, screened to monitor shallow groundwater, in close proximity to a GDE. One recommendation for measuring proximity to a GDE is if an appropriate monitoring well is within 1.5 miles of an identified GDE (Chappelle et al. 2023), however, whether that distance is appropriate for local use should be assessed further. To maximize the use of CRAM assessment data, GDEs selected for this focused monitoring should be located as close as possible to existing water table monitoring wells, or in locations being considered for the construction of additional water table monitoring wells.

Conducting CRAM Assessments

CRAM assessments must be conducted by two certified CRAM practitioners. Locally held CRAM trainings where new practitioners can become certified are generally offered annually in either Moss Landing or San Jose (https://www.cramwetlands.org/training). The time required to conduct an assessment can range between 2-3.5 hours depending on ease of access and the complexity of the site. For GDE monitoring CRAM assessments should be conducted between June 1 – September 30, as this is the driest time of year when groundwater is likely to be a more prominent water source for supporting vegetation and any surface water present. CRAM monitoring of selected GDEs should be conducted in 5-year intervals. Changes in habitat condition are not likely to be detected if CRAM assessments are conducted on an annual basis, and 5 years is considered both sufficient and relevant for detecting adverse impacts to GDEs (S. Pearce, pers comm).

Additionally, CRAM must be conducted in an area defined as a wetland. To assist in the identification of an area appropriate for conducting a CRAM assessment. The California Rapid Assessment Method for Wetlands User’s Manual (CWMW, 2013) provides the definition of a wetland and riparian under which CRAM was developed and each CRAM Field Guidebook provides a flow chart to ensure practitioners are using the correct module for the wetland type being assessed. While there is a large overlap between the definition of wetland and riparian habitats appropriate for CRAM assessments and the definition of GDEs, the overlap is not complete. Oak woodlands are one habitat type that may be identified as groundwater dependent, but where it may not be appropriate to conduct a CRAM assessment. These habitats generally consist of upland plant species and do not have hydrology or soils that fall under the wetland or riparian definition, however due to the deep rooting systems of Oak trees they may still rely on groundwater for one of their water sources and therefore be classified as a GDE. The inclusion of Oak tree dominated habitats as GDEs is discussed further in the *Identification and Mapping of Groundwater Dependent Ecosystems in the 180/400-Foot Aquifer Subbasin*.

CRAM Score Analysis

Calculating 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 4). 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.

Table 4. Structure of CRAM attributes, metrics, and sub-metrics

Attribute	Metric (m) or Sub-metric (s)
Buffer and Landscape Context	Landscape Connectivity (m)
	Buffer (m)
	Percent of AA with Buffer (s)
	Average Buffer Width (s)
	Buffer Condition (s)
Hydrology	Water Source (m)
	Hydroperiod (m)
	Hydrologic Connectivity (m)
Physical Structure	Structural Patch Richness (m)

	Topographic Complexity (m)
Biotic Structure	Plant Community (m)
	Number of Plant Layers (s)
	Number of Co-dominant Plant Species (s)
	Percent Invasive Plants (s)
	Horizontal Interspersion and Zonation (m)
	Vertical Biotic Structure (m)

Detecting Adverse Impacts with CRAM Scores

When monitoring for changes in habitat condition, it is appropriate to track either the final CRAM Index score or any of the four attribute scores, or all five scores. One key question when monitoring the change in scores over time is how to determine when a change in score is reflective of a true change in habitat condition. CRAM developers acknowledge that a certain amount of variation in scores is expected due to differences in practitioners conducting the assessments. While this is mitigated by requiring all prospective practitioners attend a training to become certified, requiring all CRAM assessments to be conducting by two practitioners, and providing a detailed guidebook for each CRAM module, the tool is not perfectly precise. To understand when a change in score is reflective of a true difference in habitat condition, CRAM developers have created a 90% confidence level for each of the five scores (Table 5) (Solek et al. 2018).

Table 5. Is one score greater than another? This table provides a guide for when two scores can be considered different with 90% confidence (Solek et al. 2018).

Type of Score	**90% Confidence Level**	**Examples**
Index	7 points	You can be 90% sure that one final index score is higher than another if their difference is ≥ 7 points
Buffer and Landscape Condition Attribute	4 points	You can be sure that one final buffer and landscape attribute score is higher than another if their difference is ≥ 4 points
Hydrology Attribute	10 points	You can be sure that one final hydrology attribute score is higher than another if their difference is ≥ 10 points
Physical Structure Attribute	17 points	You can be sure that one final physical attribute score is higher than another if their difference is ≥ 17 points
Biological Structure Attribute	11 points	You can be sure that one final biological attribute score is higher than another if their difference is ≥ 11 points

For the purposes of monitoring GDEs to detect when adverse impacts occur, it is recommended to track all five scores, the Index and four attributes, to monitor for score decreases as specified in Table 5. While a change in score outside of the 90% confidence level for any of the attributes or Index should be flagged for further investigation, particular emphasis should be placed on changes to the Biological Structure Attribute score. Changes in this attribute are most likely to be reflective of changes in the water supply available to support vegetation. Any substantial decrease in scores should not automatically be attributed as an adverse impact due to groundwater management, and instead be considered a flag to investigate the root cause of the decrease.

Next Steps

As stated in the Introduction, the monitoring protocol described here should be considered a foundation from which to build off. The following are identified next steps to continue developing a GDE monitoring and assessment protocol.

Siting Water Table Wells

Siting and installing additional monitoring wells specifically aimed at monitoring the shallow groundwater accessible to roots of groundwater dependent vegetation is a crucial next step in developing an effective GDE monitoring approach. These additional wells will help SVBGSA staff understand when an adverse impact to a GDE is likely due to declining groundwater levels.

Calculating NDVI

While the process of coding and automating the calculation of NDVI values from satellite imagery should be straightforward, the volume of data will be large and require adequate computing power and data storage capacities. Identifying an organization with the computing capacity to process and store large amounts of data is a necessary next step in continuing to develop a GDE monitoring and assessment protocol.

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