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SUSTAINABLE GROUNDWATER MANAGEMENT (SGM) GRANT PROGRAM

OVERVIEW [MM-07 to MM-10]

Sustainability Indicator Improvements – Overview

Project / Action Type	Projects or actions for preventing undesirable effects related to the following groundwater conditions or sustainability indicators: Groundwater and Surface Water Interactions, Seawater Intrusion, Subsidence, and Groundwater Dependent Ecosystems.
Similar / Related Project Types	Typical projects to provide groundwater benefits include groundwater recharge and water demand reduction. Projects or actions that monitor groundwater and surface water levels.
Metric	Groundwater levels. Groundwater storage. Applicable water quality constituents. Ground levels. Change in ground levels. Surface water flow rates. Surface water stage. Groundwater dependent ecosystems (GDE) type and cover.
Measurement Unit	Groundwater levels measured in feet in a consistent vertical datum. Recharge/demand volumes in acre-feet. Concentration or measurement of applicable groundwater quality constituents (typically mg/L). Ground surface elevation measured in feet a consistent vertical datum. Change in surface elevation measured in feet. Salinity/specific conductance concentrations. Surface water flow rate in cubic feet per second (streamflow). Surface water levels in feet (stage/depth, channel elevation). Vegetation vigor and plant surveys (root zone index, wetland species) of GDEs GDEs area of cover in acres.
Beneficial User	Municipal and domestic water supply (MUN) Industrial service supply (IND) Industrial process supply (PROC) Freshwater replenishment to surface waters (FRSH)

Introduction

As part of the Sustainable Groundwater Management Act (SGMA) of 2014, significant decline in groundwater levels, reduction in groundwater storage, seawater intrusion, water quality degradation, land subsidence, and surface water depletion were identified as metrics for managing and using groundwater without causing undesirable results (USGS, 2021). These indicators are referred to as the six sustainability indicators.

The Monitoring Methods presented in this section focus on these sustainability indicators with the addition of groundwater dependent ecosystems (GDE). Although GDE is not a sustainability indicator outlined in SGMA, GDEs can link to the sustainability indicators and are a valuable metric for monitoring benefits and impacts of groundwater use on ecosystem function. The sustainability indicators as laid out in SGMA are geared towards undesirable results; however, these indicators can also be evaluated to show that groundwater systems are improving and that projects/actions are providing benefits to these indicators.

The California Department of Water Resources (DWR) has drafted Best Management Practices (BMPs) for monitoring the sustainability indicators (DWR, 2016). Additional information specific to GSPs can be found under the region's GSA identified at sgma.water.ca.gov.

It is important to note that the term 'sustainability indicator' is not unique to SGMA. The California Water Plan Update 2013 includes a California Water Sustainability Indicators Framework that uses the term 'sustainability indicator' in a way that differs from SGMA. Sustainability indicators in the context of the California Water Plan inform users about the relationship of water system conditions to ecosystems, social systems, and economic systems. For the purpose of these Monitoring Methods, the term sustainability indictor is defined based on SGMA.

Categories of Sustainability Indicators Monitoring Methods

The purpose of this section is to describe the categories used in the accompanying Sustainability Indicator Improvements Monitoring Methods (MM-07 to MM-10) to clarify the similarities and differences between them[1]

The sustainability indicators were generally applied in all four categories for monitoring and management of projects and actions. However, the Monitoring Methods presented in this category specifically focus on three of the six sustainability indicators: interconnected surface water (also referred to as groundwater surface water interaction), seawater intrusion, and subsidence. These three indicators are the most complex to monitor and evaluate and warranted further discussion.

[1] Other project types and actions may exist, but the four categories cover the majority of the sustainability indicators. If a project does not fall directly into the defined categories a combination of the Monitoring Methods could be used.

Groundwater levels and groundwater storage are directly linked where impacts/benefits can be monitored through groundwater levels and recharge volumes. These indicators are standard practice in monitoring benefits for projects and actions, thus it was not necessary to generate a specific Monitoring Method for them. They are discussed as part of the project type-specific monitoring methods (refer to Section 3.1).

Groundwater quality is another approach where monitoring is project specific with selection of specific constituents of concern. Groundwater Recharge (levels and volumes) and Water Quality Improvement Monitoring Methods are provided under the project specific monitoring categories (see MM-01 to MM-06). Groundwater storage is generally related to groundwater levels. For further information on monitoring methods related to these sustainability indicators refer to Section 3.1.

This category also includes a discussion of monitoring for Groundwater Dependent Ecosystems (GDE) [MM-10], which is one of the beneficial users considered under SGMA, to be protected from groundwater depletions. As noted above, although GDEs are not a sustainability indicator per se (as outlined in SGMA) they provide a valuable metric for monitoring benefits and impacts of groundwater use on ecosystem function.

1) **Groundwater and Surface Water Interactions** (MM-07) – Groundwater and surface water are interconnected resources. Much of the flow in streams, and the water in lakes and wetlands, is sustained by the discharge of groundwater, particularly during dry periods. Coordinated measurement and modeling of surface and groundwater conditions generally are needed to estimate surface water changes that result from groundwater development.

   Monitoring – Groundwater levels, surface water flows, and surface water stage (channel elevation)

2) **Seawater Intrusion Management** (MM-08) – Seawater intrusion associated with lowering of groundwater levels is an important issue in many of California's coastal groundwater basins. Quantifying the rate and extent of seawater intrusion involves understanding the aquifer–ocean interconnection and distinguishing among multiple sources of saline water.

   Monitoring – Groundwater quality (chloride concentrations), groundwater levels, and recharge/demand reduction volumes.

3) **Subsidence Management** (MM-09) – Extensive groundwater withdrawals from aquifer systems have caused land subsidence in many California basins. Land subsidence can damage structures such as wells, buildings, and highways. They also can create problems in the design and operation of facilities for drainage, flood protection, and water conveyance.

   Monitoring – Ground surface elevations, change in ground surface elevations and groundwater levels.

4) **Groundwater Dependent Ecosystems** (MM-10) – Are defined as "ecological communities or species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface". GDEs generally include plant and animal communities that rely on shallow groundwater levels or interconnected surface water to meet all or some of their needs.

   Monitoring – Groundwater levels, surface water flows, surface water stage (channel elevation), vegetation vigor and plant surveys (root zone index, wetland species) of GDE habitat, and concentration or measurement of water quality such as nitrate, electrical conductivity, etc.

Implementation

There are three basic functions of sustainability indicators - simplification, quantification, and communication. The use of sustainability indicator monitoring to evaluate project and actions can simplify complex groundwater interactions and allow for quantifiable information that can be communicated across platforms and apply across multiple situations. Applying the Monitoring Methods should help users generate metrics for quantifiable benefits to groundwater and the overall groundwater basin. The Monitoring Methods allow for specific understanding of the benefits a project or action can have across the four categories of Groundwater and Surface Water Interactions (MM-07), Seawater Intrusion Management (MM-08), Subsidence Management (MM-09), and Groundwater Dependent Ecosystems (MM-10).

Sustainability Indicators

The Sustainability Indicators Improvements Monitoring Methods will be applied to projects or actions that impact the six sustainability indicators as defined in the Sustainable Groundwater Management Act (SGMA) is presented in Table MM07/MM10-1.

Table MM07/10-1. Level of Benefit to the Six Sustainability Indicators Outlined in SGMA

	Six Sustainability Indicators Outlined in SGMA	Groundwater Surface Water Interactions	Seawater Intrusion Management	Subsidence Management	Groundwater Dependent Ecosystems
	Depleted Interconnected Surface Water	★★★	★	★	★★★
	Lowered Groundwater Levels	★★	★★	★★	★★★
	Water Quality Degradation		★★		★★
	Subsidence	★	★	★★★	★★
	Reduced Groundwater Storage	★★	★★	★★	★★★
	Seawater Intrusion		★★★	★	★★

*Notes
★★★ = Primary Benefit (High Applicability)
★★ = Secondary Benefit (Medium Applicability)
★ = Situational Benefit (Applicability dependent on Location, Site Characteristics, and Aquifer Condition)

Monitoring Methods

The sustainability indicator Monitoring Methods were separated into categories based on the sustainability indicators that projects are most likely to affect (benefits or impacts) as shown in Table MM07/10-1. Detailed monitoring methods for implementing the sustainability indicators-based projects or actions are provided under the Monitoring Methods for Groundwater and Surface Water Interactions (MM-07), Seawater Intrusion Management (MM-08), Subsidence Management (MM-09), and Groundwater Dependent Ecosystems (MM-10).

Data Standards

The following apply to all sustainability indicator improvement projects or actions:

- Groundwater, surface water, and water quality monitoring data should conform to the technical and reporting standards of the California Water Code (CWC) §352 *et seq*.
- Groundwater levels - Groundwater elevation measurements should be recorded relative to a consistent vertical datum.
- Water quality - Concentrations of water quality constituents of concern should be compared to maximum contaminant levels (MCLs) and other regulatory limits available from the SWRCB.

Source References

United States Geological Survey. 2021. *Sustainable Groundwater Management.* Sacramento (CA): US Department of Interior. [Website]. Viewed online at: https://ca.water.usgs.gov/sustainable-groundwater-management/

California Department of Water Resources. 2016. *Best Management Practices for the Sustainable Management of Groundwater, six-part series (BMP 1 Monitoring Protocols Standards and Sites, BMP 2 Monitoring Networks and Identification of Data Gaps, BMP 3 Hydrogeologic Conceptual Model, BMP 4*

Water Budget, BMP 5 Modeling, and BMP 6 Sustainable Management Criteria DRAFT). Sacramento (CA): California Department of Water Resources. [Website]. Viewed online at: https://water.ca.gov/Programs/Groundwater-Management/SGMA-Groundwater-Management/Best-Management-Practices-and-Guidance-Documents.

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Groundwater Surface Water Interactions Monitoring Method
MONITORING METHOD [MM-07]

MONITORING METHOD [MM-07]

Groundwater Surface Water Interactions Monitoring Method

Project / Action Type	Monitoring streamflow depletions along interconnected surface waters.
Similar / Related Project Types	This Monitoring Method describes monitoring of a specific sustainability indicator for a variety of potential projects, rather than describing a monitoring method for a particular project. Other similar Monitoring Methods include seawater intrusion, groundwater dependent ecosystems, and subsidence.
Metric	Groundwater levels. Surface water flow rates. Surface water stage. Groundwater dependent ecosystems (situationally).
Measurement Unit	Groundwater levels measured in feet in a consistent vertical datum. Surface water flow rate in cubic feet per second (streamflow). Surface water levels in feet (stage/depth, channel elevation). Vegetation vigor and plant surveys (root zone index, wetland species) of groundwater dependent ecosystems habitats.
Beneficial User	Municipal and domestic water supply (MUN) Industrial service supply (IND) Industrial process supply (PROC) Freshwater replenishment to surface waters (FRSH)

Groundwater and Surface Water Interactions Sustainability Indicator Overview

Interconnected surface water (ISW) is a sustainability indicator that can be benefited by projects. ISW is surface water that is hydraulically connected by a continuous saturated zone to the underlying aquifer. If groundwater elevations adjacent to a water body are higher than the water level in the water body, the water body is said to be **gaining** because it gains water from groundwater. If the groundwater elevation adjacent to a water body is lower than the water level in the water body, it is said to be a **losing** water body because it loses water to groundwater (see Figure MM07-1). Interconnected surface water can have both gaining and losing reaches where the gradient between surface water and groundwater is what determines the extent to which water is gained or lost from the streams. Surface water may be intermittently gaining or losing, based on seasonal or climatic changes. The purpose of this Monitoring Method is to provide recommendations for monitoring and reporting on the effectiveness of projects with impacts on groundwater and surface water interactions.

Figure MM07-1. Groundwater-Surface Water Interactions

In some cases, even relatively small gradient shifts can change a gaining stream to a losing stream, and vice versa. Some losing streams are defined as “disconnected”, meaning the groundwater is so far below the surface water that aquifer recharge occurs through an unsaturated zone (the vadose zone) to the water table. In these cases, although water is typically percolating out of the stream down to the underlying groundwater, the rate of loss is not affected by the elevation of the groundwater (i.e., groundwater pumping does not affect the stream any longer). In cases where a water body is periodically connected and disconnected from groundwater, it is still considered ISW because it is not permanently disconnected from groundwater.

Depletion of ISW is related to lowered groundwater levels adjacent to the stream. Conversely, if a project increases groundwater levels near ISW, there could be an increase in groundwater contributions to surface water (larger baseflows) or a decrease in surface water contributions to groundwater (smaller depletion). Monitoring ISW, both groundwater levels and streamflow, can identify benefits or impacts to surface water from projects and groundwater use.

Several types of projects can benefit ISW, such as variations of managed aquifer recharge, indirect potable reuse, and water demand reductions. These project types are discussed in the Groundwater Recharge Projects Monitoring Methods (MM-01 to MM-06) and the Conceptual Monitoring Method for Demand Management (MM-13). This Monitoring Method describes methods specifically for evaluating benefits to ISW.

The groundwater sustainability plan (GSP) Regulations that specify components of GSPs prepared pursuant to the Sustainable Groundwater Management Act (SGMA) require that groundwater sustainability agencies (GSAs) provide explanations of project and management actions (23 CCR § 354.44). Nothing in these Monitoring Methods supersedes the GSP Requirements as related to the development and implementation of GSPs, alternatives to a GSP, coordination agreements, and annual reporting requirements under SGMA.

Monitoring Objectives

This Monitoring Method describes how projects with the goal of benefiting ISW should be monitored to demonstrate expected benefits. Monitoring feature types, methods, and frequency are collectively important for ensuring the appropriate data are collected from which to evaluate project benefits to ISW. Table MM07-1 below identifies the relative impact of ISW mitigation on the six sustainability indicators included in SGMA.

Table MM07-1. Level of Benefit to the Six Sustainability Indicators Outlined in SGMA

	Six Sustainability Indicators Outlined in SGMA	Applicability*
	Depleted Interconnected Surface Water	★★★
	Lowered Groundwater Levels	★★
	Water Quality Degradation	
	Subsidence	★
	Reduced Groundwater Storage	★★
	Seawater Intrusion	

*Notes:
★★★ = Primary Benefit (High Applicability)
★★ = Secondary Benefit (Medium Applicability)
★ = Situational Benefit (Applicability dependent on Location, Site Characteristics, and Aquifer Condition)

Desired Outcomes or Benefits Resulting from Groundwater and Surface Water Interactions

Table MM07-2 shows the potential benefits that monitoring groundwater surface water interactions and avoiding depletion of ISW can have on each of the six SGMA sustainability indicators.

Table MM07-2. Potential Benefits Resulting from Project / Action

	Potential Benefits on SGMA Sustainability Indicators	Benefit / Not Applicable	Description of Benefits
	Depleted interconnected surface water	Benefit	Stated goal of project or action.
	Lowered groundwater levels	Benefit	Raising groundwater levels to avoid depletion of ISW should reduce chronic lowering of groundwater levels that impact streamflows.
	Water quality degradation	Not Applicable	
	Subsidence	Benefit	Raising groundwater levels to avoid depletion of ISW should reduce risk of subsidence where applicable.
	Reduced groundwater storage	Benefit	Raising groundwater levels to avoid depletion of ISW should reduce losses from groundwater in storage where applicable.
	Seawater intrusion	Benefit	Raising groundwater levels to avoid depletion of ISW should reduce risk of seawater intrusion where applicable.

The desired outcome for any project or groundwater management action should be no increased depletion of baseflows. In some cases, the desired outcome will benefit ISW by increasing baseflows.

Potential Impacts

Projects implemented to reduce depletion of ISW would generally not be expected to have significant unintended effects on any of the other sustainability indicators or beneficial users. In extreme cases, projects impacts from increased groundwater levels near surface water features could result from: 1) excessive groundwater level rise that could affect subsurface structures or other sensitive land and water uses; 2) changing natural seasonal fluctuations in streamflow required for some aquatic species, and 3) groundwater quality degradation from mobilization and flushing of chemical constituents (whether applied, such as from previous agricultural land use, legacy contamination, or naturally-occurring minerals in the previously unsaturated zone).

These potential impacts are related to the chronic lowering of groundwater levels, depletion of ISW, reduced groundwater storage, and degraded water quality sustainability indicators. The subsidence or seawater intrusion sustainability indicators would be the most likely to have no impact. Potential impacts resulting from ISW are shown in Table MM07-3.

Table MM07-3. Potential Impacts Resulting from Project / Action

Potential Impacts on SGMA Sustainability Indicators		Impact / Not Applicable	Mitigation Measures to Address Impacts
	Depleted interconnected surface water	Impact	Project changes could result in seasonal changes to the groundwater surface water connections. In limited cases there is the potential for impacts to sensitive species dependant on the parameters for survival. To mitigate for these impacts, monitoring parameters such as flow, temperature and water quality should be done in relation to supporting ecosystems for sensitive, threatened, or endangered species.
	Lowered groundwater levels	Impact	During project feasibility planning, use a numerical model to simulate how high groundwater levels are projected to rise, especially in very wet years.Raising groundwater levels to avoid depletion of ISW should reduce chronic lowering of groundwater levels that impact streamflows. Only allow shallow groundwater levels to rise to a safe level for any surface structures and sensitive land uses. If impacts occur, the project should be managed to reduce the amount of groundwater level rise to a safe level.
	Water quality degradation	Impact	During project feasibility planning, use a numerical model to simulate projected changes in groundwater flow directions and levels in relation to known contamination or naturally occurring water quality issues. Only allow shallow groundwater levels to rise to a safe level for surface structures and sensitive land uses. Raising groundwater levels to avoid depletion of ISW could mobilize shallow contaminants. Evaluation of potential risk and additional monitoring of mobilization would be required. If impacts occur, the project should be managed to reduce the amount of groundwater level rise to a safe level.
	Subsidence	Not Applicable	
	Reduced groundwater storage	Impact	Same as Lowered Groundwater Levels indicator.
	Seawater intrusion	Not Applicable	

Use and Limitations

Depletion of ISW can occur due to factors other than changes to groundwater conditions related to a project or action. Monitoring and analysis efforts should specifically identify groundwater level changes resulting from the project. If groundwater levels are responding to factors other than the project, it may be challenging to evaluate project benefits. Baseline monitoring before the project is implemented and monitored can help evaluate project-specific benefits. Analysis of data collected by the monitoring network may indicate that the data are insufficient to evaluate the groundwater/surface water interaction. An insufficient monitoring network conditions can be addressed by developing and implementing a work plan to install additional streamflow gauges, monitoring wells and/or vadose zone piezometers, which would provide useful hydrogeologic information at targeted locations, as well as providing additional critical monitoring points.

Relationship to Other Monitoring Methods

The ISW Monitoring Method is linked to projects with the potential to influence groundwater levels near identified ISW. Project types that could improve ISW include recharge projects outlined in the Groundwater Recharge Projects Monitoring Methods including Aquifer Storage and Recovery (MM-01), Recharge Ponds (MM-02), Flood-MAR (MM-03), Stormwater Recharge (MM-04), and Indirect Potable Reuse (MM-05) as well as the Conceptual Monitoring Method for Demand Management (MM-13). Even though there may be some overlap in the methods, specific project type Monitoring Methods should be implemented in conjunction with the ISW Monitoring Method.

Groundwater and Surface Water Interactions Monitoring

Management practices to consider for supporting assessment of ISW can be found in California Department of Water Resources' (*DWR's) Best Management Practice (BMP) 2 Monitoring Networks and Identification of Data Gaps* (DWR, 2016). Additional guidance can be found in The Nature Conservancy *Groundwater Dependent Ecosystems under the Sustainable Groundwater Management Act: Guidance for Preparing Groundwater Sustainability Plans* (Rohde et al., 2018) and the Environmental Defense Fund *Addressing Regional Surface Water Depletions in California: A Proposed Approach for Compliance with the Sustainable Groundwater Management Act* (Environmental Defense Fund, 2018).

The project proponent should monitor both surface water and groundwater in the vicinity of potential ISW or known ISW reaches. Monitoring both is needed to fully characterize spatial and temporal exchanges between surface water and groundwater, and to calibrate and apply the tools and methods necessary to calculate depletions of surface water. The combined use of groundwater elevation and streamflow data can allow managers to assess temporal changes in conditions due to variations in stream discharge, natural recharge, and regional groundwater extraction, as well as other factors that may be necessary to identify adverse impacts on beneficial uses of the surface water.

Additional information on tools and monitoring protocols relevant to ISW can be found at DWR's BMP 1 Monitoring Protocols Standards and Sites (DWR, 2016) and the *USGS California Water Science Center* website.

Background and Context

A variety of projects designed to improve groundwater sustainability may reduce depletion of ISW or increase groundwater contributions to baseflow. Monitoring project benefits or impacts on ISW primarily relies on monitoring both groundwater levels and streamflow. The SGMA metric quantifying depletion of ISW is a volume or rate of surface water depletion. This is a difficult metric to quantify since the sustainability indicator of depletion of ISW is specific to depletions caused by groundwater use. Surface water depletions caused by groundwater use can be too small to directly measure through changes in streamflow. SGMA GSP Regulations allow for the use of groundwater elevations as a proxy for volume or rate of surface water depletion. The general approach to demonstrating no increased ISW depletion using groundwater levels instead of a volume or rate of depletion is that if groundwater levels connected to surface water are kept at or above a specified level, then there would not be more surface water depletion than what occurred historically when groundwater levels were at the specified level. Under SGMA, to use groundwater elevations as a proxy, it must be demonstrated that there is a significant correlation between groundwater elevations and volume or rate of surface water depletion. Where changes in streamflow from groundwater extractions cannot be directly measured, changes in depletion flow rate or volume can be demonstrated with a numerical model that has an integrated surface water component calibrated to historical streamflows and/or stage, or other analytical methods.

The established GSP monitoring networks may be suitable for monitoring project impacts or benefits to ISW. However, given the project type, its location and potential influence on groundwater near ISW, additional monitoring points are likely necessary to monitor local ISW impacts. Where possible and appropriate, multi-depth monitoring well clusters should be used for evaluating relationships between shallow groundwater levels and any deeper aquifers where groundwater pumping occurs. The ISW monitoring network should be capable of providing sufficient data for evaluating short-term, seasonal, and long-term trends in groundwater levels.

A Step-by-Step Guide to Applying the Groundwater and Surface Water Interactions Monitoring Method

1. **Safety plan:** All projects with fieldwork related activities should produce a Safety Plan. Planning for fieldwork and availability of access to the site, such as monitoring wells, is necessary to maintain project safety. Projects with an impact on groundwater and surface water interactions may require a Safety Plan to address these and other potential safety concerns.
2. **Groundwater influence area:** Determine the project's area of groundwater influence and determine if the basin's GSP indicates whether groundwater and surface water are connected. If disconnected or unknown, go to Step 3, otherwise go to Step 4.
3. **Identify monitoring network:** Identify locations and extents of ISW in the project area, based on historical measurements of groundwater elevations and streambed elevations, or field-based methods such as:
    a. *Seepage (or Accretion) Measurements*: Field discharge measurements at selected intervals in a creek or river to determine gaining and losing reaches. Often environmental tracers such as temperature and electrical conductivity are used in conjunction with discharge to determine groundwater and surface water exchange.
    b. *Environmental Tracers:* Physical or chemical properties of water, or any substance dissolved in water that can be used to identify the origin or the age of groundwater. Environmental tracers can be used to:
        i. identify if and where groundwater discharge occurs in a surface water body
        ii. estimate the proportion of different sources of water in a water body
        iii. estimate the age and velocity of groundwater
        iv. quantify the groundwater flux to a surface water body.
        v. Examples of environmental tracers are total dissolved solids / electrical conductivity / salinity, temperature, dissolved oxygen, pH, major ions, stable isotopes, radionuclides, and naturally occurring and anthropogenic tracers for groundwater dating such as naturally occurring (14C, 36Cl, 4He) and anthropogenic chlorofluorocarbons (CFCs) and sulfur hexafluoride (SF6) tracers.
    c. *Artificial Tracers*: Analysis of deliberately introduced hydrochemical tracers to identify water sources and groundwater-surface water mixing relationships. Introduced dyes and conservative tracers, typically to surface water, have a wide range of applications in groundwater dependent ecosystem studies, including the identification of groundwater discharge zones and the quantification of groundwater – surface water exchange rates.
    d. *Geophysical Surveys*: Geophysical methods, such as electrical resistivity tomography and electrical magnetism, can provide relatively inexpensive and high-resolution spatial data to identify and map regions of differing soils and water.

4. Install monitoring network:
    a. Identify and/or install stream gauging stations (see Figure MM07-2) along identified connected stream reach or water body. Stream gauging stations should be established based on DWR's BMP 1 Monitoring Protocols Standards and Sites (DWR, 2016) and DWR's BMP 2 Monitoring Networks and Identification of Data Gaps (DWR, 2016).
    b. Identify and/or install shallow groundwater elevation monitoring wells. The well network should be established based on DWR's BMP 2 Monitoring Networks and Identification of Data Gaps (DWR, 2016). Where possible, the wells should be located adjacent to the connected stream or waterbody, and between the stream and project. The established GSP monitoring network may be suitable for monitoring impacts from regional projects; however, additional monitoring sites may be necessary to monitor the benefits of local-scale projects in vicinity of a connected stream. Pairing a groundwater elevation monitoring well with a nearby stream gauge is useful for identifying consistent trends in the datasets that indicate hydraulic connection between the monitoring sites. The location of the monitoring network should be easily accessible such that gaining access to the site does not inhibit gathering and downloading data (refer to Step 1).

Figure MM07-2. Simple stilling well and Staff Gauge Setup (DRW, 2016).

5. **Data collection:** Measure hourly streamflow and hourly or daily groundwater levels to establish baseline characterization of the dynamic connection between groundwater and surface water. Data collected in the summer and fall months when there is no rainfall are easier to evaluate groundwater's contribution to streamflow. It may also be possible to use these data to identify that there are non-groundwater related streamflow influences.
    a. Collect background data. Collecting seasonal data for up to 1 year prior to project implementation is useful for establishing a baseline.
    b. Use baseline monitoring data to determine if there is a correlation between groundwater extraction and shallow groundwater levels adjacent to the ISW and/or streamflow. When possible, estimate depletion of surface water due to pumping using numerical or analytical methods. A groundwater model, calibrated at industry standards to historical groundwater level and streamflow measurements, could be used to simulate conditions with and without groundwater pumping. The difference in streamflow between the two scenarios is depletion due to groundwater pumping. Continue monitoring during project implementation to assess impacts and benefits to ISW, while considering non-project groundwater extraction taking place.
    c. Quantify the volume and timing of groundwater extractions near the ISW. These data are used for estimating depletion of surface water due to groundwater extractions.
    d. Review data at least annually for comparison to any regional based sustainable management criteria generated the project's region GSPs, to evaluate whether undesirable results are being avoided and progress toward measurable objectives is being achieved. If applicable, the GSAs will include this evaluation in its annual report.
6. **Reporting:** Report monitoring data to the basin's GSAs at least twice per year based on SGMA requirements if applicable.
    a. Upload project-specific monitoring data to the DWR SGMA data portal on an annual basis. This step will need to be coordinated with and completed by the GSAs.
    b. Recommend monitoring points to add to the GSP monitoring network if applicable.
    c. Recommend representative monitoring points and associated applicable sustainable management criteria that avoid conditions deemed significant and unreasonable by the GSA.
7. **Adaptive management:** Expand or refine monitoring network adaptively, as needed.

Data and Protocols - Fundamentals

Monitoring ISW involves monitoring both groundwater and streamflow. The primary monitoring requirements and tools include the following:

- Shallow monitoring wells or piezometers co-located with streamflow gauges.
- Multiple shallow monitoring wells or piezometers located perpendicular to the stream.
- Multi-depth monitoring well clusters for understanding the level of connectivity between the shallow aquifer and the deeper aquifer, which may be important in areas with perched groundwater.
- Measurements of streamflow and shallow groundwater levels adjacent to the stream should be measured at least daily to characterize the relationship between surface water and the groundwater system. Groundwater levels farther away from the stream should be measured at least monthly.
- Primary "tools" for measuring groundwater levels include electrical sounders and pressure transducers lowered into and/or installed in monitoring wells (DWR's BMP 1 Monitoring Protocols Standards and Sites [DWR, 2016]). The use of dataloggers in association with pressure transducers allows automated collection and storage of groundwater level measurements at frequent intervals.
- Primary "tools" for measuring streamflow are gauges consisting of a mounted staff plate and pressure transducers installed in a stilling well to measure depth of water (stage); a rating curve for the gauge is required to measure discharge (flow); the use of dataloggers in association with pressure transducers allows automated collection and storage of groundwater level measurements at frequent intervals.

Groundwater levels, streamflow, and stage are primary monitoring requirements that should be supported, where appropriate, with other monitoring methods described above in the Step-by-Step Guide, such as environmental tracers (Step 3b) and geophysical surveys (Step 3d).

Table MM07-4 provides an example of summary parameters to use to monitor groundwater and surface water interactions.

Table MM07-4. Example Data Monitoring Report (Generally Annually)

Annual Monitoring Report	
Groundwater basin	XXX Basin or Subbasin
Surface water body	name of stream, lake, wetland etc.
Percentage of time over the reporting period shallow groundwater elevations adjacent to surface water are higher than the streambed or bed of the surface water body	XX.X percent
Change in reporting period dry season flow compared to pre-construction flows for past similar water year types	XXX cubic feet per second
Estimated increased surface water discharge rate compared to past similar water year types	XX acre-feet
Estimated increased surface water volume compared to past similar water year types	XXX cubic feet per second

Data Standards

Groundwater and surface water monitoring data should conform to the technical and reporting standards of the California Water Code (CWC) §352 *et seq*. Additionally, post-construction monitoring reports must be submitted per grant conditions that quantify benefits or impacts to ISW. Each surface water body benefited/impacted by the project should be reported separately.

Key Protocols

The following protocols should be followed for required ISW monitoring:

- Standard groundwater level measurement protocols as described in DWR's BMP 1 Monitoring Protocols Standards and Sites (DWR, 2016).
- Standard surface water measurements as described in DWR's BMP 1 Monitoring Protocols Standards and Sites (DWR, 2016).
- Technical and reporting standards included in CWC §352 *et seq*.

Additional guidance or references include:

- DWR's BMP 2 Monitoring Networks and Identification of Data Gaps (DWR, 2016) – Describes guidelines for establishing monitoring networks capable of providing sustainable indicator data of sufficient accuracy and quantity to demonstrate sustainable management in the basin and provides information on how to identify and resolve data gaps to reduce uncertainty (DWR, 2016).
- United States Geological Survey Water-Supply Paper on Measurement and Computation of Streamflow: Volume 1. Measurement of Stage and Discharge – Describes standardized stream-gauging procedures (Rantz and others, 1982).
- United States Geological Survey Water-Resources Investigations Report on Standards for the Analysis and Processing of Surface-Water Data and Information Using Electronic Methods – describes standards for surface water computation methods and procedures (Sauer, 2002).

The use of a data management system is required for storing and reporting information relevant to the monitoring of the basin in support of a GSP. Considerations for storing and reporting data are summarized in the Data Management and Monitoring Method (MM-12).

Examples of Groundwater and Surface Water Interactions Monitoring Application

Soquel Creek Monitoring and Adaptive Management Plan

Location: Santa Cruz County, California

Year: 2012 to present

Description and Relevance: Soquel Creek Water District has a Monitoring and Adaptive Management Plan (MAMP) for Soquel Creek. The MAMP was developed to provide data to evaluate potential stream and shallow groundwater level impacts related to deep groundwater pumping near Soquel Creek. The MAMP involves monitoring for impacts on stream baseflow related to pumping in the vicinity of one of the District's production wells and to modify municipal pumping if pumping impacts are detected. As part of the MAMP, the District installed a new shallow monitoring well, weather station, and stream groundwater level gauge (stilling well); and conducts ongoing monitoring of these and other shallow wells and stream level gauges.

Data collected by the MAMP is designed to detect effects on creek levels caused by pumping of groundwater for municipal use. The MAMP monitors creek levels and shallow groundwater levels, supplemented by streamflow measured at the United States Geological Survey gauge on Soquel Creek, municipal production data, and local climate data. The MAMP specifically examines low flow periods when baseflow depletion would be of greatest concern for steelhead habitat. Monitoring data are reported on an annual basis.

Links to Resources: Santa Cruz Mid-County Groundwater Sustainability Plan: https://www.midcountygroundwater.org/sustainability-plan

Humboldt Bay Municipal Water District Ranney Collector Groundwater Study

Location: Humboldt County, California

Year: 2008 to present

Description and Relevance: The Humboldt Bay Municipal Water District used a groundwater model to determine impacts on downstream flows due to groundwater extractions from Ranney Collectors installed in or near the Mad River. The collectors draw water from the aquifer below the river in perforated lateral pipes located approximately 60 to 90 feet beneath the bed of the river. The process of drawing water from the aquifer below the riverbed provides a natural filtration process which results in water that is very high quality. Currently, four Ranney collectors are in operation supplying water to the Humboldt Bay Municipal Water District's domestic system for drinking water purposes.

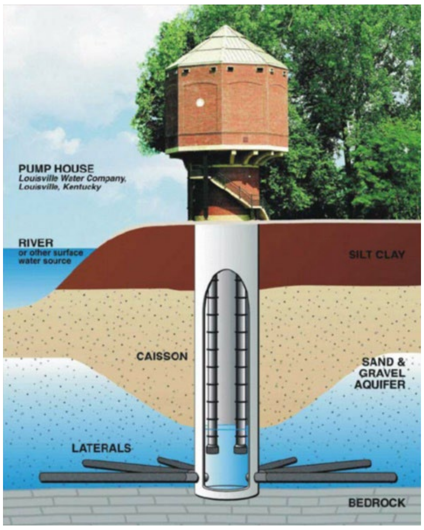

Figure MM07-3. Ranney Intake Well. (Humboldt Bay Municipal Water District, 2008)

The purpose of developing the groundwater model was to provide the operators of the District's groundwater pumping facilities with a management tool that would aid the assessment of interactions and impacts of various pumping scenarios within the groundwater system around the Ranney Collectors. Assessing the downstream impacts on the Mad River due to various pumping scenarios was evaluated using a mass balance approach, based on the calibrated MODFLOW groundwater model developed for the project. The model simulates flow from the river into the groundwater system but is limited in that it does not simulate the hydraulics within the river channel and does not model the induced changes in the river flow. However, the model does report the amount of water that enters the groundwater system through recharge from the river (i.e., seepage) and this can be equated to the change in flow of the river.

Links to Resources: Humboldt Bay Municipal Water District, 2008. Ranney Collector Final Evaluation Report. Winzler & Kelly

Source References

California Department of Water Resources. 2016. *Best Management Practices for the Sustainable Management of Groundwater, six-part series (BMP 1 Monitoring Protocols Standards and Sites, BMP 2 Monitoring Networks and Identification of Data Gaps, BMP 3 Hydrogeologic Conceptual Model, BMP 4 Water Budget, BMP 5 Modeling, and BMP 6 Sustainable Management Criteria DRAFT).* Sacramento (CA): California Department of Water Resources. [Website]. Viewed online at: https://water.ca.gov/Programs/Groundwater-Management/SGMA-Groundwater-Management/Best-Management-Practices-and-Guidance-Documents.

Environmental Defense Fund. 2018. *Addressing Regional Surface Water Depletions in California: A Proposed Approach for Compliance with the Sustainable Groundwater Management Act*. New York (NY): Environmental Defense Fund. [Website]. Viewed online at: https://www.edf.org/sites/default/files/documents/edf_california_sgma_surface_water.pdf

Humboldt Bay Municipal Water District. 2008. Ranney Collector Final Evaluation Report.

Rantz SE and others. 1982a. *Measurement and Computation of Streamflow: Volume 1 Measurement of Stage and Discharge.* Washington, DC: United States Department of the Interior. [Website]. Viewed online at: https://pubs.usgs.gov/wsp/wsp2175/wsp2175.pdf

——. 1982b. *Measurement and Computation of Streamflow: Volume 2 Computation of Discharge*. Washington, DC: United States Department of the Interior. [Website]. Viewed online at: https://pubs.usgs.gov/wsp/wsp2175/wsp2175_vol2.pdf

Rohde MM, Matsumoto S, Howard J, Liu S, Riege L, Remson EJ. 2018. *Groundwater Dependent Ecosystems under the Sustainable Groundwater Management Act*: *Guidance for Preparing Groundwater Sustainability Plans*. San Francisco (CA): The Nature Conservancy. [Website]. Viewed online at: https://www.scienceforconservation.org/assets/downloads/GDEsUnderSGMA.pdf.

Rosenberry DO, and LaBaugh, JW. 2008. *Field Techniques for Estimating Water Fluxes Between Surface Water and Ground Water: U.S. Geological Survey Techniques and Methods 4–D2*. Washington, DC: U.S. Department of the Interior. U.S. Geological Survey. [Website]. Viewed online at: https://pubs.usgs.gov/tm/04d02/.

Sauer VB. 2002, *Standards for the Analysis and Processing of Surface-Water Data and Information Using Electronic Methods: U.S. Geological Survey Water-Resources Investigations Report 01–4044*. Washington, DC: U.S. Department of the Interior. U.S. Geological Survey. [Website]. Viewed online at: https://pubs.usgs.gov/wri/2001/4044/report.pdf.

Seawater Intrusion Management Monitoring Method
MONITORING METHOD [MM-08]

SUSTAINABLE GROUNDWATER MANAGEMENT (SGM) GRANT PROGRAM

MONITORING METHOD [MM-08]

Seawater Intrusion Management Monitoring Method

Project / Action Type	Seawater intrusion management projects with stated goal to prevent undesirable results for seawater intrusion.
Similar / Related Project Types	Typical projects to provide seawater intrusion management include variations of groundwater recharge (including injection barrier), indirect potable reuse, and water demand reduction. Similar Monitoring Methods are those that assess specific sustainability indicators such as subsidence and depletion of interconnected surface water.
Metric	Water quality constituents (chloride concentrations). Groundwater levels. Groundwater storage. Groundwater dependent ecosystems (situationally).
Measurement Unit	Concentration or measurement of applicable groundwater quality constituents, specifically, salinity (mg/L) and specific conductance concentrations (µS/cm at 25 °C). Groundwater levels measured in feet in a consistent vertical datum. Recharge/demand volumes in acre-feet. Vegetation vigor and plant surveys (root zone index, wetland species) of groundwater dependent ecosystems habitats.
Beneficial User	Municipal and domestic water supply (MUN) Industrial service supply (IND) Industrial process supply (PROC) Agricultural water supply (AGR) Freshwater replenishment to surface waters (FRSH)

Seawater Intrusion Management Sustainability Indicator Overview

Seawater intrusion refers to the advancement of seawater into a groundwater supply that results in degradation of water quality in the basin. Seawater intrusion occurs when inland pumping results in lowered groundwater levels, which results in a hydraulic gradient that causes seawater to flow into the freshwater aquifers. Salinity increases in groundwater affecting beneficial uses including drinking water and irrigation.

Seawater intrusion resulting from **groundwater overdraft** is of primary concern in many groundwater basins along the California coast (see Figure MM08-1 for seawater intrusion mechanisms and their effects on the aquifer). Seawater intrusion is a sustainability indicator for which undesirable results should be avoided under the Sustainable Groundwater Management Act (SGMA). The purpose of this Monitoring Method is to provide recommendations for monitoring and reporting on the effectiveness of projects with impacts on seawater intrusion.

KEY TERMS

Seawater intrusion can occur when over pumping results in lowered groundwater levels that pulls in saline water from surface water into the groundwater aquifers.

Groundwater overdraft occurs where the average annual amount of groundwater extraction exceeds the long-term average annual supply of water to the basin.

Isocontours are geographic lines of specified concentrations on a map as they relate to water quality constituents in groundwater, for seawater intrusion, chloride concentrations are generally used.

Several different types of projects can achieve goals to prevent seawater intrusion. These projects include variations of enhancing groundwater recharge (Flood-MAR, recharge ponds, stormwater recharge, and injection well barriers), indirect potable reuse, and water demand reduction, which are discussed in separate Monitoring Methods. This Monitoring Method describes the method specifically for evaluating benefits related to the seawater intrusion sustainability indicator.

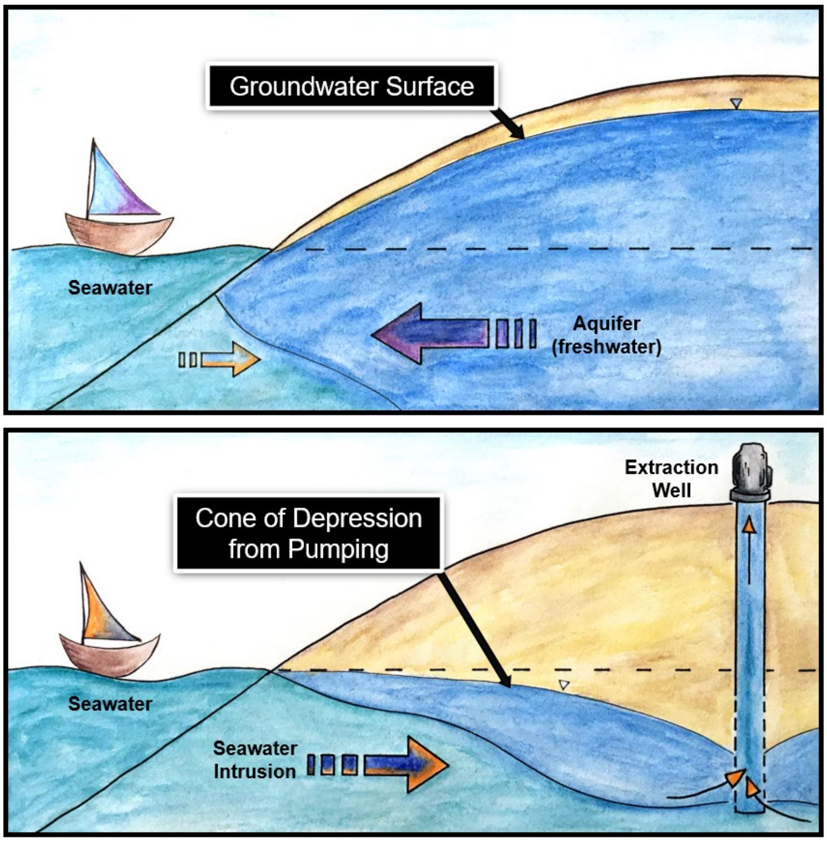

Figure MM08-1. Seawater intrusion mechanisms and effects on aquifer, showing natural conditions (top) and system under groundwater well extractions (bottom).

Evaluating benefits related to a seawater intrusion project involves multiple monitoring programs including those for groundwater quality, groundwater levels, and recharge/demand reduction volumes. One challenge for seawater intrusion evaluation is that it is commonly defined based on mapped **isocontours** prepared from data for a limited number of individual well locations.

The groundwater sustainability plan (GSP) Regulations that specify components of GSPs prepared pursuant to SGMA require that groundwater sustainability agencies (GSAs) provide explanations of project and management actions (23 CCR § 354.44). Nothing in these Monitoring Methods supersedes the GSP Requirements as related to the development and implementation of GSPs, alternatives to a GSP, coordination agreements, and annual reporting requirements under SGMA.

Monitoring Objectives

This method describes how projects with a goal of preventing seawater intrusion should be monitored to demonstrate the benefits from the project for the indicator. Table MM08-1 identifies the relative impact of seawater intrusion mitigation on the six SGMA sustainability indicators.

Table MM08-1. Level of Benefit to the Six Sustainability Indicators Outlined in SGMA

	Six Sustainability Indicators Outlined in SGMA	Applicability*
	Depleted Interconnected Surface Water	★
	Lowered Groundwater Levels	★★
	Water Quality Degradation	★★
	Subsidence	★
	Reduced Groundwater Storage	★★
	Seawater Intrusion	★★★

*Notes:

★★★ = Primary Benefit (High Applicability)

★★ = Secondary Benefit (Medium Applicability)

★ = Situational Benefit (Applicability dependent on Location, Site Characteristics, and Aquifer Condition)

Desired Outcomes or Benefits Resulting from Seawater Intrusion Management

The desired outcome for any project or management plan should be the prevention of seawater intrusion. Table MM08-2 shows the benefits of addressing seawater intrusion on the SGMA sustainability indicators. Prevention of seawater intrusion protects water supplies in coastal basins. Progress toward preventing seawater intrusion is desired.

Table MM08-2. Potential Benefits Resulting from Project / Action

	Potential Benefits on SGMA Sustainability Indicators	Benefit / Not Applicable	Description of Benefits
	Depleted interconnected surface water	Benefit	Raising groundwater levels to prevent seawater intrusion may reduce depletion of interconnected surface water.
	Lowered groundwater levels	Benefit	Raising groundwater levels to prevent seawater intrusion should reduce chronic lowering of groundwater levels that affects groundwater supply.
	Water quality degradation	Benefit	Improved water quality benefits by reducing seawater intrusion.
	Subsidence	Benefit	Raising groundwater levels to prevent seawater intrusion should reduce risk of subsidence where applicable.
	Reduced groundwater storage	Benefit	Implementing projects to increase recharge or reduce pumping to prevent seawater intrusion should help make progress toward achieving sustainable yield and preventing significant and unreasonable reduction of groundwater in storage.
	Seawater intrusion	Benefit	Stated goal of project or action.

Potential Impacts

Projects implemented to prevent seawater intrusion would generally not be expected to have significant unintended effects on any of the other sustainability indicators or beneficial users, except for water quality degradation as shown in Table MM08-3. Raising groundwater levels could mobilize contaminants.

Table MM08-3. Potential Impacts Resulting from Project / Action

Potential Impacts on SGMA Sustainability Indicators	Impact / Not Applicable	Mitigation Measures to Address Impacts
Depleted interconnected surface water	Not Applicable	
Lowered groundwater levels	Not Applicable	
Water quality degradation	Impact	Raising groundwater levels to prevent seawater intrusion could mobilize shallow contaminants. Evaluation of potential risk and additional monitoring of mobilization would be required.
Subsidence	Not Applicable	
Reduced groundwater storage	Not Applicable	
Seawater intrusion	Not Applicable	

Use and Limitations

Challenges include identifying available wells or locations for new wells to monitor groundwater salinity (commonly represented by chloride or total dissolved solids concentrations) and effects from the projects and actions. These challenges can include land acquisition and whether existing well construction (depths and screened intervals) can effectively monitor the depth-dependent saline interface. There also are limitations to the use of wells to monitor changes in groundwater salinity across an area; aerial geophysical surveys (such as airborne electromagnetic surveys) can help overcome this limitation by identifying areas and depths with high salinity.

Other challenges relate to sources of chloride and dissolved salts other than seawater, such as surface application of irrigation water and recharge of surface water or recycled water. Collecting optional data to evaluate cation/anion ratios or minor constituents can help identify the source of salts.

Results of groundwater monitoring using the monitoring network established during project construction may indicate that insufficient data are being obtained to evaluate the effectiveness of the project in relation to the established performance standards and/or that groundwater level rise or groundwater quality impacts may be of concern at or in the vicinity of the facility. These conditions can be addressed by developing and implementing a work plan to install additional monitoring wells and/or vadose zone piezometers, which would provide useful hydrogeologic information at targeted locations, as well as providing additional critical monitoring points.

Relationship to Other Monitoring Methods

Any project and action with a goal of providing seawater intrusion management will require use of additional Monitoring Methods. Project types that could address this sustainability indicator include recharge projects outlined in the Groundwater Recharge Projects Monitoring Methods including Aquifer Storage and Recovery (MM-01), Recharge Ponds (MM-02), Flood-MAR (MM-03), Stormwater Recharge (MM-04), and Indirect Potable Reuse (MM-05) and Groundwater Quality Improvement (MM-06), as well as the Conceptual Monitoring Method for Demand Management (MM-13). The method for the specific project type should be implemented in conjunction with this method.

Monitoring Methods for Groundwater and Surface Water Interactions (MM-07), and Subsidence Management (MM-09) are relevant as they are sustainability indicators for which projects can provide benefits by raising groundwater levels.

Seawater Intrusion Monitoring

A project's ability to prevent undesirable results associated with seawater intrusion can be evaluated based upon changes in salinity at monitoring locations. SGMA requires that the seawater intrusion sustainable management criteria applied under a GSP include a chloride concentration isocontour as a minimum threshold. Therefore, chloride concentrations should be monitored for seawater intrusion for SGMA projects. Groundwater elevation proxies can be included in the seawater intrusion evaluation. Groundwater elevations and recharge/pumping reduction volumes also can be used to demonstrate that progress toward preventing seawater intrusion can be attributed to the project. Other data may be useful to support evaluation of seawater intrusion.

Background and Context

The monitoring method for seawater intrusion management projects evaluates whether seawater intrusion advances and facilitates the evaluation of the effect of the project on preventing significant and unreasonable seawater intrusion. The method includes collection of the following categories of data:

1. **Monitoring should include groundwater salinity data to evaluate seawater intrusion**:
   - SGMA requires a chloride concentration isocontour to be used as management criteria for seawater intrusion. Sampling for chloride concentrations at wells along the isocontour in each principal aquifer is required.
   - A project should identify data gaps for monitoring seawater intrusion. If the project is expected to affect conditions in any of the data gap areas, monitoring points filling those data gaps should be established for the project to demonstrate efficacy.
   - A project may establish groundwater elevation proxies management criteria for seawater intrusion. If so, monitoring of groundwater elevations at monitoring points with groundwater elevation proxies is required.
2. **Monitoring should include additional data to evaluate the benefit of the project**:
   - Monitoring groundwater levels should be conducted to demonstrate that the project or action is successfully preventing or reducing seawater intrusion. Monitoring points should be located between the project location (recharge location or wells with reduced pumping) and the area of seawater intrusion, any representative monitoring points for salinity concentrations, and monitoring points of groundwater elevations.
   - Measurement of **water budget** components (e.g., recharge and pumping volumes) also should be conducted to evaluate a connection between project and action, and groundwater levels or salinity concentrations.
3. **Monitoring may include optional data to support both evaluation of seawater intrusion and associated benefits with the project:**
   - Sampling for general minerals to evaluate cation/anion ratios for changes in groundwater chemistry
   - Sampling for minor constituents such as iodide, bromide, boron, and barium as indicators of seawater intrusion
   - Continuous monitoring of electrical conductivity at wells to track changes in salinity
   - Geophysical surveys at wells to evaluate depth of seawater interface
   - Geophysical surveys to evaluate areal extent and depth of seawater interface.

Water budgets are form of accounting for the total groundwater and surface water entering and leaving a basin including the changes in the amount of water stored.

A Step-by-Step Guide to Applying the Seawater Intrusion Monitoring Method

1. **Area of groundwater influence:** Determine project's area of groundwater influence and determine if a basin's Groundwater Sustainability Plan applies to the project, and if so, whether the Plan indicates if seawater intrusion occurs in the area.
2. **Safety plan:** All projects with fieldwork related activities should produce a Safety Plan. Planning for fieldwork and availability of access to the site, such as monitoring wells, is necessary to maintain project safety. Projects with an impact on seawater intrusion may require a Safety Plan to address these and other potential safety concerns.
3. **Monitoring network:** Identify and/or install groundwater monitoring wells. The well network should be established based on Department of Water Resources (DWR) *BMP 2 Monitoring Networks and Identification of Data Gaps* (DWR, 2016). An established Groundwater Sustainability Plan monitoring network may be suitable for monitoring impacts from regional projects; however, additional monitoring sites may be necessary to monitor the benefits or impacts of local-scale projects. The location of the monitoring network should be easily accessible such that gaining access to the site does not inhibit gathering and downloading data (refer to Step 2).
4. **Data collection:** Conduct "baseline monitoring" in the monitoring wells prior to project commencement to document groundwater levels and trends, and to characterize ambient groundwater quality and trends. While baseline monitoring for groundwater levels and quality should be conducted at a minimum prior to project commencement, collecting baseline monitoring for at least one year before project commencement during prior seasonal low and seasonal high groundwater level periods would provide a more robust dataset to compare to project implementation data should groundwater level or quality impacts occur.
5. **Data analysis:** Implement the monitoring plan to evaluate seawater intrusion isocontours to evaluate project benefits.
   - Generating isocontours involves measuring groundwater salinity, commonly represented by chloride concentrations or other measurements convertible to chloride concentrations, at monitoring wells on a regular basis, at least once annually. Isocontours of the measured salinity concentrations are then prepared using industry standard spatial interpolation techniques. For SGMA projects, each basin's Groundwater Sustainability Plan should identify the chloride isocontour management criteria established for the area. Identify areas and any monitoring points most likely to show benefits from project.
   - Identify data gaps and install new monitoring wells in areas identified to show likely benefits of the project. Implement monitoring at data gaps.
   - Monitor groundwater levels at monitoring wells in the project network to correlate project with effects on groundwater levels and seawater intrusion.
   - Review data at least annually to evaluate whether seawater intrusion is occurring and progress toward preventing seawater intrusion is being achieved. For SGMA projects, the Groundwater Sustainability Agency should include this evaluation in its annual report.
6. **Reporting:** Review and report optional data as planned by project proponent.
   - Upload project-specific monitoring data to the DWR SGMA data portal on an annual basis. For SGMA projects, this step should be coordinated with and completed by the basin's Groundwater Sustainability Agency (See Data Management and Monitoring Method [MM-12]).
7. **Adaptive management**: Expand or refine the monitoring network adaptively, as needed.

Data and Protocols - Fundamentals

Monitoring for seawater intrusion involves monitoring groundwater quality, groundwater levels, and volumes related to the project or action. The primary monitoring requirements and tools include the following:

- Monitoring wells in aquifers near the area of concern for seawater intrusion where groundwater quality can be sampled, and groundwater levels can be monitored.

- For SGMA projects, monitoring wells that allow groundwater quality and groundwater level monitoring in aquifers located between the project or action and the critical chloride isocontour.
- Water quality should be sampled and analyzed at least semi-annually with timing corresponding with seasonal highs and lows in groundwater levels.
- Groundwater levels should be measured at least quarterly.
- Primary "tools" for measuring groundwater quality include pumps, low-flow sampling equipment and passive diffusion samplers as presented in DWR's *Best Management Practice (BMP) 1 Monitoring Protocols Standards and Sites* (DWR, 2016).
- Primary "tools" for measuring groundwater levels include electrical sounders and pressure transducers lowered into and/or installed in monitoring wells (DWR's BMP 1 Monitoring Protocols Standards and Sites, 2016). The use of dataloggers in association with pressure transducers allows automated collection and storage of groundwater level measurements at frequent intervals.
- Primary "tools" for measuring recharge or demand reduction volumes achieved by the project or action are flow meters or other tools described in Monitoring Methods for Groundwater Recharge Project (MM-01 to MM06) and Demand Reduction Monitoring Methods (MM-13) projects.

Table MM08-4 provides an example of summary parameters to use in a monitoring report for seawater intrusion management projects.

Table MM08-4. ***Example Data Monitoring Report (Generally Annually)***

Annual Monitoring Report	
Groundwater Basin Name	XXX
Average change in salinity at monitoring wells	XXX mg/L
Average change in groundwater levels at monitoring wells	XXX feet
Annual change in area of seawater intrusion	XXX square miles

Data Standards

Groundwater, surface water, and water quality monitoring data should conform to the technical and reporting standards of the California Water Code (CWC) §352 *et seq*. Standards for chloride concentration precision and accuracy (+/- 10 mg/L) should be met for measurements close to the threshold isocontour values.

Groundwater elevation measurements should be recorded relative to a consistent **vertical datum.** It is worth noting that the vertical datum recommended by DWR's BMP 1 Monitoring Protocols, Standards, and Sites (DWR, 2016) is the **North American Vertical Datum of 1988 (NAVD88)**, which is 2-4 feet higher than mean sea level along the California coast. This distinction is important for seawater intrusion. Coastal Groundwater Sustainability Agencies may choose to consistently use an alternative vertical datum such as the **National Geodetic Vertical Datum of 1929 (NGVD29)** because it is generally closer to mean sea level.

VERTICAL DATUMS

Along the California coast NAVD88 is 2-4 feet higher than mean sea level. NAVD88 was established in 1991 by the minimum-constraint adjustment of the Canadian-Mexican-United States leveling observations.

NGVD29 is generally closer to mean sea level. Mean sea level was held fixed at the sites of 26 tide gauges across the United States and Canada.

NGVD29 = NAVD88 – 3.6 feet

Key Protocols

The following protocols should be followed for required monitoring:

- Standard water quality sampling protocols as described in DWR's BMP 1 Monitoring Protocols Standards and Sites (DWR, 2016).
- Standard groundwater level measurement protocols as described in DWR's BMP 1 Monitoring Protocols Standards and Sites (DWR, 2016).

- Standard measurements for recharge or demand reduction volumes as described in Monitoring Methods for recharge and demand reduction projects.
- Technical and reporting standards included in CWC §352 *et seq*.

Suggested references for optional data include:

- Evaluating cation/anion ratios as indicators of seawater intrusion (Jones et al., 1999).
- Use of minor constituents as indicators of seawater intrusion (Hem, 1989).
- Areal geophysical surveys (Schamper et al., 2013 and Pidilisecky et al, 2015).

Example of Seawater Intrusion Management Application

Pure Water Soquel

Location: Santa Cruz County, CA

Year: Planned start of Operation as 2023

Description and Relevance: Pure Water Soquel is an indirect potable reuse project that will treat wastewater with advanced purification techniques and injects it into the groundwater basin to prevent seawater intrusion. To meet requirements of the State Water Resources Control Board Prop 1 groundwater quality implementation grant funding the project, Soquel Creek Water District developed a Project Assessment and Evaluation Plan that describes a methodology for preventing the advancement of seawater intrusion in the Santa Cruz Mid-County Basin. The sustainable management criteria include chloride concentrations and groundwater elevation proxies. Effects of the project are evaluated with the recharge amounts and with the groundwater elevation proxies.

Links to Resources: https://www.soquelcreekwater.org/184/Pure-Water-Soquel

Water Replenishment District - Dominguez Gap Barrier Project

Location: Los Angeles, CA

Year: 2006-Present

Description and Relevance: The Water Replenishment District installed 56 injections wells to impede seawater intrusion into the coastal aquifer and to provide potable water for domestic wells. The project involves the delivery of recycled water from the City of Los Angeles Department of Public Works - Bureau of Sanitation, Terminal Island Water Reclamation Plant / Advanced Water Treatment Facility to the Dominguez Gap Barrier. The Water Replenishment District measures and tracks groundwater levels and quality conditions, evaluates potential impact of recycled water on groundwater, and identifies potential problems at monitoring wells before recycled water arrives at any downgradient drinking water wells. An extensive tracer study was performed between February 2006 through the fall of 2010 to determine the extent of travel and movement of the injected recycled water through the aquifers. This study confirmed that adequate blending of recycled water occurs. This indirect potable reuse project will ultimately receive 9.5 million gallons per day of advanced treated wastewater, which will enable the expansion of the existing infrastructure to include a Second Barrier Connection.

Links to Resources: https://www.wrd.org/files/7aa811ec7/WRD+2022+ESR+-+June+v1+%28FINAL%29.pdf

Source References

California Department of Water Resources. 2016. *Best Management Practices for the Sustainable Management of Groundwater, six-part series (BMP 1 Monitoring Protocols Standards and Sites, BMP 2 Monitoring Networks and Identification of Data Gaps, BMP 3 Hydrogeologic Conceptual Model, BMP 4 Water Budget, BMP 5 Modeling, and BMP 6 Sustainable Management Criteria DRAFT).* Sacramento (CA): California Department of Water Resources. [Website]. Viewed online at: https://water.ca.gov/Programs/Groundwater-Management/SGMA-Groundwater-Management/Best-Management-Practices-and-Guidance-Documents

Hem JD. 1989*. Study and Interpretation of the Chemical Characteristics of Natural Water: U.S. Geological Survey Water-Supply Paper 2254 3rd edition*. Washington, DC: U.S. Department of the Interior. U.S. Geological Survey. [Website]. Viewed online at: https://pubs.usgs.gov/wsp/wsp2254/pdf/wsp2254a.pdf

Jones BF, Vengosh A, Rosenthal E, and Yechieli Y. 1999. *Seawater Intrusion in Coastal Aquifers - Concepts, Methods And Practices: Geochemical Investigation*. Dordrecht, The Netherlands: Kluwer Academic Publishers.

Pidlisecky A, Moran T, Hansen B, and Knight R. 2015. *Electrical Resistivity Imaging of Seawater Intrusion Into the Monterey Bay Aquifer System*. [Research Paper]. Groundwater, vol. 54-2, p. 255-261.

Schamper C, Pedersen B, Auken E, Christiansen AV, Vittecoq B, Deparis J, Jaouen T, Lacquement F, Nehlig P, Perrin J, and Reninger PA. 2013. *Airborne Transient EM Methods and Their Applications for Coastal Groundwater Investigations*. Wetzelhuetter C. (eds) Groundwater in the Coastal Zones of Asia-Pacific. Coastal Research Library, vol 7. Springer, Dordrecht.

Subsidence Management Monitoring Method
MONITORING METHOD [MM-09]

SUSTAINABLE GROUNDWATER MANAGEMENT (SGM) GRANT PROGRAM

MONITORING METHOD [MM-09]

Subsidence Management Monitoring Method

Project / Action Type	Subsidence management aims to reduce subsidence through lessening groundwater overdraft.
Similar / Related Project Types	Subsidence could be managed in coordination with groundwater elevation management. Groundwater elevation management is generally the primary benefit, and subsidence management is ancillary.
Metric	Ground levels. Change in ground levels. Groundwater levels.
Measurement Unit	Ground surface elevation measured in feet a consistent vertical datum. Change in surface elevation measured in feet. Groundwater levels measured in feet in a consistent vertical datum.
Beneficial User	Municipal and domestic water supply (MUN) Industrial service supply (IND) Industrial process supply (PROC) Agricultural water supply (AGR)

Subsidence Management Sustainability Indicator Overview

Land **subsidence** is the settling or sinking of the ground surface (see Figure MM09-1). While there may be various subsidence mechanisms, the main cause of subsidence in California is groundwater pumping (USGS, 2021a). Subsidence can cause damage to buildings and infrastructure, increase flood risk in low-lying areas, and result in the permanent reduction of groundwater storage capacity. Subsidence can be elastic or inelastic. **Elastic** subsidence is reversible and **inelastic** subsidence is permanent. The purpose of this Monitoring Method is to provide recommendations for monitoring and reporting on the effectiveness of projects with impacts on subsidence.

KEY TERMS

Subsidence is the settling or sinking of the ground surface or land. Subsidence is determined by the change in ground surface elevation.

Subsidence can be elastic or inelastic.

Elastic subsidence is reversible.

Inelastic subsidence is permanent.

Inelastic land subsidence can be halted or slowed by managing groundwater levels. Therefore, projects designed to manage groundwater levels may have the secondary benefit of controlling subsidence. Often direct measurements of subsidence are correlated with groundwater level data to establish a relationship and causality between groundwater levels and subsidence. Groundwater projects are the only practical means for slowing or halting land subsidence.

This Monitoring Method describes the methods specifically for evaluating benefits and impacts related to projects addressing land subsidence. Examples of projects that might benefit subsidence include groundwater recharge, indirect potable reuse, and water demand reduction. Direct recharge of deep, confined aquifers is an effective approach to reduce subsidence as it targets portions of aquifers below thick clay layers that are often most susceptible to compaction.

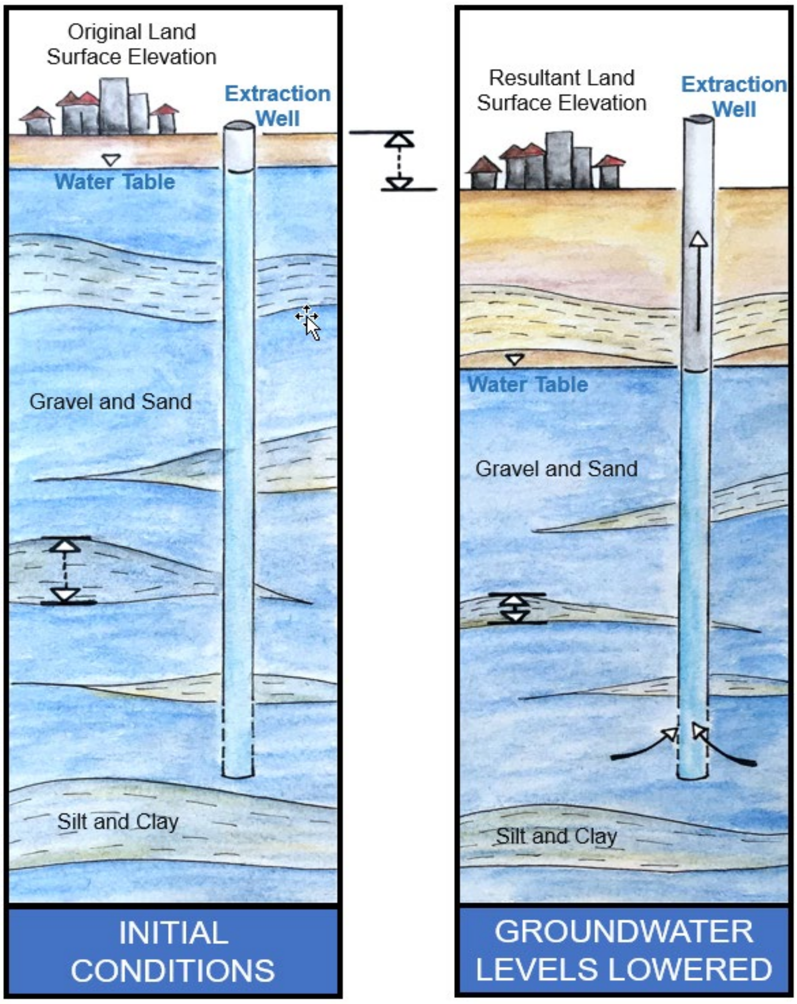

Figure MM09-1. Subsidence Conditions and Potential Effects from Extraction on the Aquifer and Surface Elevation.

The groundwater sustainability plan (GSP) Regulations that specify components of GSPs prepared pursuant to the Sustainable Groundwater Management Act (SGMA) require that groundwater sustainability agencies (GSAs) provide explanations of project and management actions (23 CCR § 354.44). Nothing in these Monitoring Methods supersedes the GSP requirements as related to the development and implementation of GSPs, alternatives to a GSP, coordination agreements, and annual reporting requirements under SGMA.

Monitoring Objectives

This Monitoring Method describes how projects with either a primary or secondary goal of slowing or stopping subsidence should be monitored, and how that monitoring demonstrates the expected benefits. Table MM09-1 below identifies the relative impact of subsidence mitigation on the six sustainability indicators included in SGMA.

Table MM09-1. Level of Benefit to the Six Sustainability Indicators Outlined in SGMA

	Six Sustainability Indicators Outlined in SGMA	Applicability*
	Depleted Interconnected Surface Water	★
	Lowered Groundwater Levels	★★
	Water Quality Degradation	
	Subsidence	★★★
	Reduced Groundwater Storage	★★
	Seawater Intrusion	★

*Notes:

★★★ = Primary Benefit (High Applicability)

★★ = Secondary Benefit (Medium Applicability)

★ = Situational Benefit (Applicability dependent on Location, Site Characteristics, and Aquifer Condition)

Desired Outcomes or Benefits Resulting from Subsidence Management

Table MM09-2 shows the benefits of implementing projects to prevent land subsidence for each of the six SGMA sustainability indicators. Projects implemented to prevent land subsidence would generally reduce and ultimately stop land subsidence.

Table MM09-2. Potential Benefits Resulting from Project / Action

	Potential Benefits on SGMA Sustainability Indicators	Benefit / Not Applicable	Description of Benefits
	Depleted interconnected surface water	Benefit	Stabilizing groundwater levels to prevent subsidence may stabilize or reduce depletion of interconnected surface water.
	Lowered groundwater levels	Benefit	Stabilizing groundwater levels to reduce and/or prevent subsidence should reduce chronic lowering of groundwater levels that affects groundwater supply.
	Water quality degradation	Not Applicable	
	Subsidence	Benefit	Stated goal of project or action.
	Reduced groundwater storage	Benefit	Arresting subsidence prevents permanent loss of aquifer volume available for groundwater storage due to compaction. Implementing projects to increase recharge or reduce pumping in order to mitigate falling or raising groundwater elevations to prevent subsidence should help make progress toward achieving sustainable yield and preventing permanent reduction of groundwater in storage.

	Potential Benefits on SGMA Sustainability Indicators	Benefit / Not Applicable	Description of Benefits
	Seawater intrusion	Benefit	Arresting subsidence in coastal basins reduces the risk of lowered stream thalwegs[2] that allow ocean water to migrate inland, providing a pathway for seawater intrusion. Stabilizing groundwater levels to prevent subsidence could help avoid inland gradients from the coastline that induce seawater intrusion.

Potential Impacts

Projects implemented to prevent land subsidence would generally not be expected to have significant unintended effects on any of the other sustainability indicators or beneficial users, except for water quality, which could be impacted when rising groundwater levels results in mobilization of contaminants. Potential impacts resulting from projects implemented to prevent land subsidence are shown in Table MM09-3.

Table MM09-3. Potential Impacts Resulting from Project / Action

	Potential Impacts on SGMA Sustainability Indicators	Impact / Not Applicable	Mitigation Measures to Address Impacts
	Depleted interconnected surface water	Not Applicable	
	Lowered groundwater levels	Not Applicable	
	Water quality degradation	Impact	Raising groundwater levels to address subsidence could mobilize shallow contaminants. Evaluation of potential risk and additional monitoring of mobilization would be required.
	Subsidence	Not Applicable	
	Reduced groundwater storage	Not Applicable	
	Seawater intrusion	Not Applicable	

Use and Limitations

Monitoring challenges include:

- Identifying available monitoring sites or locations for new sites to monitor ground surface elevation.
- Cost and maintenance of specialized equipment and/or routine surveys.
- Interpreting subsidence data and factoring the uncertainty of monitoring methods.
- Acquiring land for new monitoring sites or access to existing monitoring sites.
- Adequately correlating and establishing causality between ground surface elevation and groundwater elevation data in cases where groundwater elevation data are used as a proxy for subsidence monitoring.
- Addressing delayed, or residual subsidence that can occur for many years after periods of groundwater level declines are mitigated.

Results of subsidence monitoring using the monitoring network established during project implementation may indicate that insufficient data are being obtained to evaluate the effectiveness of the projects in relation

[2] A thalweg is the line of lowest elevation within a watercourse.

to the established performance standards. These conditions can be addressed by developing and implementing a work plan to install additional subsidence monitoring sites, which would provide useful hydrogeologic information at targeted locations.

Relationship to Other Monitoring Methods

Any project and action with a goal of stopping subsidence requires the use of additional Monitoring Methods. Project types that could address this sustainability indicator include recharge outlined in the Groundwater Recharge Projects Monitoring Methods including Aquifer Storage and Recovery (MM-01), Recharge Ponds (MM-02), Flood-MAR (MM-03), Stormwater Recharge (MM-04), and Indirect Potable Reuse (MM-05) as well as the Conceptual Monitoring Method for Demand Management (MM-13). The Monitoring Method for the specific project type should be implemented in conjunction with this method.

Subsidence Management Monitoring

Subsidence is best monitored through direct measurement of ground surface elevation. The rate and extent of subsidence are the most useful parameters to measure. Several techniques may be used to monitor ground surface elevation including the following:

– Conducting **leveling surveys** allow for an impacted area to be tied into known benchmarks. Installing and tracking changes in borehole **extensometers** allow for measurement of compaction of clay layers.
– Portable global position systems (**GPS**) can allow for data collection over a wider area of interest and allow for monitoring of continuous global position systems.
– Analyzing interferometric synthetic aperture radar (**InSAR**) data is a satellite-based method for larger scale monitoring.

Additional information on these methods is described in Department of Water Resources (DWR) Best Management Practice (BMP) 2 Monitoring Networks and Identification of Data Gaps (DWR, 2016).

SUBSIDENCE MONITORING METHODS

Leveling surveys – Routine surveys of benchmarks with known elevation.

Extensometer – Device installed in a well for measuring compaction of subsurface clay layers.

InSAR - Interferometric synthetic aperture radar, satellite-based method implemented by California Department of Water Resources.

GPS – Global position systems, land surveying method. Data can be collected continuously at one location or over a wider area.

Background and Context

Subsidence is defined by a change in ground surface elevation, not absolute ground surface elevation. Subsidence can only be identified after multiple successive ground surface elevation measurements. Therefore, it is necessary to establish a monitoring network and methodology that provide repeatable and definitive data.

While groundwater elevations are the typical cause of subsidence, monitoring groundwater elevations are not always adequate for measuring subsidence. Residual, or delayed, clay compaction leads to subsidence that continues after groundwater elevations have stabilized. Therefore, stable groundwater levels are not an adequate indicator of arrested subsidence.

Ground surface elevation measurements can be collected multiple times throughout the year to identify the presence of cyclic fluctuations due to elastic subsidence. Seasonal pumping for agricultural irrigation often results in corresponding seasonal rises and drops in ground surface elevation. Differentiating between elastic subsidence, which is reversible, and inelastic subsidence, which is permanent, can be difficult. To minimize influences from elastic subsidence, total annual subsidence should be calculated using annual high ground surface elevations. Historical ground surface measurements should be analyzed to identify the potential magnitude and cyclic nature of elastic subsidence.

Areas with a history of subsidence and adequate subsidence and groundwater level data might be used to calibrate subsidence models that estimate the quantity and timing of residual subsidence after groundwater levels have stabilized. However, the model results should still be verified with ground surface elevation measurements. Only areas with unconsolidated clay sediments are prone to subsidence. Areas with consolidated rock aquifers are not at risk for subsidence caused by groundwater overdraft.

A Step-by-Step Guide to Applying the Subsidence Management Monitoring Method

1. **Safety plan:** All projects with fieldwork related activities should produce a Safety Plan. Planning for fieldwork and availability of access to the site, such as monitoring wells, is necessary to maintain project safety. Projects with an impact on subsidence may require a Safety Plan to address these and other potential safety concerns.
2. **Establish baseline conditions:** Thresholds and objectives from the baseline conditions need to be determined. For projects or actions in basins with a GSP, the management criteria identified in the GSP may help and can be used to evaluate outcomes.
   - Use historical subsidence data to develop the baseline conditions.
   - Assess existing subsidence rates and extent, determine if correlation exists with groundwater level declines, and identify any seasonal elastic subsidence.
   - Identify areas where land uses and property interests have been affected or are likely to be affected by land subsidence in the basin.
   - The project proponent should identify areas where the effects of land subsidence have been observed, where risks of damage from subsidence to critical infrastructure such as canals, roads, bridges, buildings, and wells exists, and where geology is conducive to subsidence if groundwater elevations decline.
3. **Identify monitoring network:** Evaluate the necessary subsidence monitoring type, such as extensometers, InSAR, or continuous global position systems (CGPS). Identify monitoring sites in areas at risk from future subsidence and areas likely to show benefits. The location of the monitoring network should be easily accessible such that gaining access to the site does not inhibit gathering and downloading data (refer to Step 1).
4. **Install monitoring network:** Install additional subsidence and groundwater elevation monitoring sites, as necessary. In basins with GSPs, there may be an established GSP monitoring network that could be suitable for monitoring impacts; however, additional monitoring sites may be necessary to monitor conditions in vicinity of subsidence monitoring sites, or on smaller scale projects not yet identified in the GSPs.
   - Implement any optional monitoring to supplement evaluation.
   - More monitoring or different monitoring frequency may be required than that which is required under a GSP.
5. **Collect monitoring data:** Gather, review, and evaluate subsidence and groundwater elevation data.
6. **Data reporting**: Upload project-specific monitoring data to the SGMA Portal following the protocols described in the data monitoring and reporting method.
7. **Refine monitoring method:** Expand or refine monitoring network and data collection, as needed.

Data and Protocols - Fundamentals

Monitoring subsidence primarily includes monitoring ground surface elevations, and often includes monitoring groundwater elevations. Ground surface elevation can be directly monitored using a variety of methods, including:

- Levelling surveys tied to known benchmarks: Levelling surveys use surveying equipment to establish or verify the height of specified points relative to a known benchmark.
- Portable GPS: Portable GPS readers gather data from the U.S. Department of Defense satellite network to estimate a 3-dimensional location on the ground.
- CGPS stations: CGPS stations use the same satellite network as portable GPS systems. CGPS systems, however, are stationary. These stations generally collect position information on a regular interval (such as every 15 seconds) and the measurements are then processed to produce a daily position.
- Borehole extensometer data: Extensometers consist of a pipe or cable anchored at the bottom of a well casing and a recorder that measures the relative distance between the bottom of the borehole and the ground surface. Extensometers are used to measure expansion or compaction of the geologic materials in an aquifer system, measured as displacement at ground surface.
- InSAR data: InSAR is a remote sensing technology that measures ground elevation using microwave satellite imagery data. DWR collects monthly InSAR data mapped over the entire state; these data are publicly available starting in June 2015.

Of these five techniques leveling surveys and extensometers provide the most precise data. The least precise measurements tend to be made by using mobile GPS systems, with CGPS and InSAR measurements falling somewhere in the middle (USGS, 2021b).

Additional considerations for monitoring ground surface elevations include:

- Subsidence is measured as a differential in ground surface elevation between time periods, so it is important that baseline ground surface elevations be collected before a project or action is initiated. Post-project ground surface elevations can then be compared to pre-project ground surface elevations to identify changes in subsidence rates.
- Ground surface elevations should be measured at least quarterly to identify seasonal fluctuations due to elastic subsidence.
- Ground surface elevations should be monitored near critical infrastructure.

Groundwater elevations should be monitored to verify any modelled or estimated correlations between groundwater elevation and subsidence. Considerations for groundwater elevation monitoring include:

- Groundwater elevation measurements should be co-located with extensometers, known benchmarks, or CGPS locations to establish correlations between groundwater elevations and subsidence.
- Groundwater elevation data should be collected near the anticipated area of greatest project impact
- Groundwater elevations should be monitored near critical infrastructure.
- Groundwater elevations should be monitored on the same schedule as ground surface elevations.

Table MM09-4 provides an example of summary parameters to use in a monitoring report for subsidence management projects.

Table MM09-4. Example Data Monitoring Report (Generally Annually)

Monitoring Reporting	
Min / Average / Max Change in Land Surface Elevation	XX X / XXX/ XXX feet
Min / Average/ Max Change in Groundwater Levels	XX X / XXX / XXX feet
Incurred Costs	$XXX

Data Standards

All data should meet the technical and reporting standards included in California Water Code §352 *et seq*. This includes recording ground surface elevation measurements relative to **NAVD88**, with an accuracy of at least 0.01 feet.

VERTICAL DATUMS

NAVD88 was established in 1991 by the minimum-constraint adjustment of the Canadian-Mexican-United States leveling observations. Along the California coast NAVD88 is 2-4 feet higher than mean sea level.

NGVD29 is generally closer to mean sea level. Mean sea level was held fixed at the sites of 26 tide gauges across United State and Canada.

NGVD29 = NAVD88 – 3.6 feet

Key Protocols

The following protocols should be followed for required monitoring:

- Standard protocols for measuring subsidence as described in DWR's BMP 1 Monitoring Protocols Standards and Sites (DWR, 2016).
- Standard protocols for measuring groundwater levels as described in DWR's BMP 1 Monitoring Protocols Standards and Sites (DWR, 2016).
- Technical and reporting standards included in California Water Code §352 *et seq*.

Additional guidance or references include:

- Guidance for monitoring land subsidence in Montgomery County, Texas (Groundwater science Advisory Committee, 2021)
- Land Subsidence from Groundwater Use in California (Luhdorff & Scalmanini, 2014)

Examples of Subsidence Management Applications

Santa Clara Basin Project

Location: Santa Clara County, CA

Year: 1930s – 1970s

Description and Relevance: Excessive pumping of groundwater between about 1915 and 1969 caused the northern portion of Santa Clara County to experience as much as 13 feet of subsidence, impacting more than 100 square miles from San Jose to southern San Francisco Bay. The District implemented a number of measures to halt subsidence and carefully monitors water levels and subsidence to make sure the problem does not reoccur. The subsidence was essentially halted by around 1970, as a result of Valley Water's investments in reservoirs, diverse water supplies, and groundwater recharge, along with management programs, which enable the groundwater conditions to recover.

Valley Water continues to minimize the risk of additional subsidence through careful water management and vigilant monitoring of conditions. Valley Water uses local and imported surface water to recharge the groundwater basin to replenish the groundwater that is withdrawn. Valley Water also reduces the demand on groundwater by providing alternate water supplies and through water conservation and recycling.

Valley Water actively monitors for land subsidence by monitoring hundreds of benchmarks, wells, and extensometers. Valley Water has developed goals and metrics to ensure that any changes in the land surface are within acceptable levels.

Links to Resources: https://www.valleywater.org/your-water/where-your-water-comes/groundwater/subsidence

San Joaquin Valley Basin Project

Location: Kern, Tulare, Kings, Fresno, Merced, Stanislaus, and San Joaquin Counties, CA

Year: 1951 – 1970s

Description and Relevance: The San Joaquin Valley lies between the Sierra Nevada range to the east, the Tehachapi Mountains to the south and the coastal ranges to the west. The basin is comprised of thousands of feet of marine sediments overlain with continental sediments. Groundwater occurs in shallow unconfined or partially confined aquifers and in a deep confined aquifer. Prior to development the alluvial aquifers were recharged primarily by infiltration from stream channels. Irrigated agriculture in the basin began in the 1850's and continues today. Early on, irrigation was primarily through surface diversion but by the early 1900's most of the available surface waters had been diverted and agriculture turned to groundwater as an irrigation source. Around 1930 improvements in pumping technology and rural electrification allowed for the development of deep well groundwater for irrigation.

In the early 1950's the U.S. Bureau of Reclamation completed the Delta-Mendota Canal. Observed subsidence associated with groundwater withdrawal raised concerns about the risk of damage to the canal and potential costly repairs. This began a period of study and evaluation of practices causing groundwater level declines and subsequent land subsidence. By 1960, water levels in the deep aquifer were declining at a rate of 10 feet per year with some regions experiencing more the 100 feet of groundwater level decline. Land subsidence was found to be related (directly or indirectly) to flooding and long-term environmental effects, decreased storage in aquifers, partial or complete submergence of canals and associated bridges and pipe crossings, collapse of well casings, and disruption of collector drains and irrigation ditches. In response, several large State Water Projects were constructed to provided less expensive water for crop irrigation. By 1967 these projects had largely supplanted groundwater use. In a period of 6 years groundwater levels in the deep aquifer increased as much as 200 feet. The observed rate of land subsidence was greatly reduced but still continues, just at a much slower rate. The slow response in land subsidence rate change is likely due to the time it takes for pore-fluid pressures to equilibrate.

Links to Resources:
https://www.researchgate.net/publication/313157507_San_Joaquin_Valley_California_Largest_human_alteration_of_the_Earth's_surface

Source References

California Department of Water Resources. 2016. *Best Management Practices for the Sustainable Management of Groundwater, six-part series (BMP 1 Monitoring Protocols Standards and Sites, BMP 2 Monitoring Networks and Identification of Data Gaps, BMP 3 Hydrogeologic Conceptual Model, BMP 4 Water Budget, BMP 5 Modeling, and BMP 6 Sustainable Management Criteria DRAFT).* Sacramento (CA): California Department of Water Resources. [Website]. Viewed online at: https://water.ca.gov/Programs/Groundwater-Management/SGMA-Groundwater-Management/Best-Management-Practices-and-Guidance-Documents

——. 2019. *The California Aqueduct Subsidence Study: Supplemental Report.* California: Department of Water Resources. [Website]. Viewed online at: https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/Engineering-And-Construction/Files/Subsidence/CASS_Supplement_final_a_1119.pdf

——. 2022. *California’s Groundwater Live: Current Land Subsidence Information*. California: Department of Water Resources. [Website]. Viewed online at: https://sgma.water.ca.gov/CalGWLive/#subsidence

Galloway D, Riley FS. 1999. *San Joaquin Valley, California: Largest human alteration of the Earth's surface*. U.S. Geological Survey Circular 1182. 1182. 23-34.

Groundwater Science Advisory Committee. 2021. *Guidance for Monitoring Land Subsidence in Montgomery County, Texas.* The Woodlands (TX): Houston Advanced Research Center. [Website]. Viewed online at: https://harcresearch.org/wp-content/uploads/2021/06/Guidance-for-Monitoring-Land-Subsidence.pdf

Borchers JW, Carpenter M. 2014. *Land Subsidence from Groundwater Use in California*. Sacramento (CA): California Water Foundation. [Website]. Viewed online at: https://cawaterlibrary.net/wp-content/uploads/2017/04/1397858208-SUBSIDENCEFULLREPORT_FINAL.pdf

United States Geological Survey. 2021a. *Land Subsidence in California*. Viewed online at: https://www.usgs.gov/centers/ca-water-ls. U.S. Geological Survey. [Website]. Viewed online at: https://www.usgs.gov/centers/land-subsidence-in-california

——. 2021b. *Land Subsidence Measuring and Monitoring*. U.S. Geological Survey. [Website]. Viewed online at: https://www.usgs.gov/centers/ca-water-ls/science/measuring-and-monitoring.

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Groundwater Dependent Ecosystems Monitoring Method
MONITORING METHOD [MM-10]

MONITORING METHOD [MM-10]

Groundwater Dependent Ecosystems Monitoring Method

Project / Action Type	Monitoring for general impacts, effects, and connections between the groundwater dependent ecosystems (GDEs) and the sustainability indicators.
Similar / Related Project Types	Interconnected Surface Water
Primary Metric	*Note that not all will apply. Metrics will be region and GDE classification type specific.* GDE type. GDE area of cover. Groundwater levels. Surface water stage. Surface water flow rates. Applicable groundwater/surface water quality constituents.
Measurement Unit	Vegetation vigor and plant surveys (root zone index, wetland species). GDE area of cover in acres. Groundwater levels measured in feet in a consistent vertical datum. Surface water levels in feet (stage/depth, channel elevation). Surface water flow rate in cubic feet per second (streamflow). Concentration or measurement of applicable water quality constituents (typically mg/L), may include nitrate, electrical conductivity, or other constituents of concern.
Beneficial User	*The GDEs are themselves the beneficial users* Freshwater replenishment to surface waters (FRSH)

Groundwater Dependent Ecosystem Overview

The Sustainable Groundwater Management Act (SGMA) defines **Groundwater Dependent Ecosystems (GDEs)** as *"ecological communities or species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface",* which generally includes plant and animal communities that rely on shallow groundwater levels (pressures) or interconnected surface water to meet all or some of their needs (see Figure MM10-1 for an example of a groundwater dependent ecosystem). The purpose of the Monitoring Method is to provide recommendations for monitoring and reporting for activities that could create adverse impacts to GDEs. Unsustainable groundwater conditions related to all six sustainability indicators (refer to Table MM10-1) can have potential impacts on GDEs, which underlines the importance of monitoring GDEs as part of any relevant project.

The groundwater sustainability plan (GSP) regulations that specify components of GSPs prepared pursuant to SGMA require that groundwater sustainability agencies (GSAs) provide explanations of project and management actions (23 CCR § 354.44). Nothing in these Monitoring Methods supersedes the GSP Requirements as related to the development and implementation of GSPs, alternatives to a GSP, coordination agreements, and annual reporting requirements under SGMA.

Groundwater Dependent Ecosystems (GDEs) are ecosystems that rely on groundwater or interconnected surface water to meet all or some of their needs.

Figure MM10-1. Llano Seco Unit of the North Central Valley Wildlife Management Area.
© Teresa Garrison/GHD Inc.

Table MM10-1. Level of Benefit to the Six Sustainability Indicators Outlined in SGMA

	Six Sustainability Indicators Outlined in SGMA	Applicability*
	Depleted Interconnected Surface Water	★★★
	Lowered Groundwater Levels	★★★
	Water Quality Degradation	★★
	Subsidence	★★
	Reduced Groundwater Storage	★★★
	Seawater Intrusion	★★

*Notes:
★★★ = Primary Benefit (High Applicability)
★★ = Secondary Benefit (Medium Applicability)
★ = Situational Benefit (Applicability dependent on Location, Site Characteristics, and Aquifer Condition)

Monitoring Objectives

The objective of monitoring is to understand how projects (directly related to or connected with groundwater) could affect the balance of GDEs as projects are implemented over time. Being able to directly correlate observed impacts to GDEs with changes in sustainability indicators is important because other external factors can affect the balance of GDEs, such as fire, drought, flood, (ecological) disease, non-related activities/projects that have the potential to influence groundwater flow regimes, etc.

Desired Outcomes or Benefit Resulting from GDEs

Projects that can show positive impacts to GDEs (or acceptable impacts) provide beneficial outcomes and are considered supportive of GDEs. Projects that result in a negative impact to GDEs may be considered as causing unsustainable conditions for one of the SGMA sustainability indicators or specified beneficial uses of groundwater.

Potential Impacts

Maintaining or improving groundwater conditions supporting GDEs demonstrates if a project is benefiting GDEs. Declining groundwater levels may indicate a project will cause negative impacts to GDEs if levels (or pressures) decline such that they significantly reduce or limit groundwater available to GDEs. Negative impacts on GDEs from reduced groundwater levels (or pressures) may include:

- Reduced rates of plant reproduction and recruitment
- Reduced tree canopy
- Reduced understory
- Shifts in vegetation type, such as herbaceous species to shrub species
- Shifts in faunal species
- Habitat loss and habitat fragmentation
- Reductions in the area, extent, or duration of surface water at discharge points, such as seeps and springs, rivers and streams, or wetlands
- River or stream reaches become narrower or drier for longer periods due to depletions of surface water.

Groundwater level declines in an area influenced by the project may require further assessment to confirm that potential impacts are project induced and are not being caused by other groundwater use. If there are negative impacts to GDE health without declining groundwater levels, these may be caused by previously mentioned factors, such as fire, drought, flood, (ecological) disease, non-related activities/projects that can also affect GDE health.

Use and Limitations

Changes to groundwater conditions can yield a range of potential effects on GDEs that can be limited or adverse. Data on groundwater conditions supporting a GDE can be insufficient to detect changes from baseline conditions, in which case determining a correlation between the sustainability indicators and the GDE can be challenging. Continued monitoring to fill in data gaps could be required and then the understanding of the system re-evaluated and adaptively managed based on the results of the analysis. Changes to climate, land use and groundwater use activities may impact future groundwater conditions supporting the GDE and should be considered in the evaluation.

Background and Context

SGMA requires that all beneficial uses and users, including GDEs, be considered in the development and implementation of GSPs (California Water Code § 10723.2). The GSP Regulations include specific requirements to identify GDEs and consider them when determining whether groundwater conditions are having potential effects on beneficial uses and users (TNC, 2018). Groundwater sustainability project or actions that effect GDE may fall under the legislative requirements of SGMA and would therefore fall within the requirements of GSPs. A project proponent should determine if their project is regulated under a GSP to better understand what guidelines and regulations the project will need to follow for monitoring.

GDEs serve society by providing a wide range of services, including:

- **Environmental**: ecosystem services including water purification, soil preservation, carbon sequestration, flood risk reduction, species habitat, and ecosystem diversity.
- **Social**: recreation, cultural and spiritual values.
- **Economic**: water supply, industrial, commercial and tourism business continuation

When groundwater is unsustainably managed, GDEs can suffer, compromising these benefits and the social and economic opportunities they provide. Monitoring GDEs in conjunction with groundwater is required to understand the connection groundwater has with the ecosystems and the potential effects groundwater changes may have on them.

Additionally, GDE monitoring may identify areas where management agencies should focus efforts to maintain the ecosystems and the benefits they provide.

Relationship to Other Monitoring Methods

This Monitoring Method is linked to any project type with the potential to influence groundwater in and around GDEs. The Monitoring Method is also linked to the Groundwater and Surface Water Interactions Monitoring Method (MM-07).

Groundwater Dependent Ecosystem Monitoring

Monitoring networks should be designed to detect potential adverse impacts to beneficial uses, including GDEs. Establishing a monitoring network and monitoring method relies on first understanding and mapping the GDEs likely to be impacted by a project. First and foremost, a conceptual groundwater model is needed to document the conceptual understanding of the location of GDEs and inferred interactions between ecosystems and groundwater. If a numerical groundwater model is available, it should be used to simulate the project’s impact on groundwater levels in and around GDEs, based on the conceptual groundwater model developed, thereby focusing monitoring to a specific area.

Monitoring GDEs over time to assess changes in response to changing groundwater conditions is based on a combination of existing available data, field observations, and management criteria specific to the region, and specific types of GDEs. Monitoring of GDEs generally falls under the sustainability indicators measurable thresholds. Methods for monitoring GDEs should be specific to the needs and interconnectivity of different GDEs to the water source. Surface water and groundwater can both play a vital role in GDE maintenance and monitoring of both may be required.

A Step-by-Step Guide to Applying Groundwater Dependent Ecosystem Monitoring Method

A step-by-step guide to apply the monitoring method for assessing project impacts on GDEs is provided below. The steps have been summarized into a method framework or flow chart as shown in Figure MM10- 2.

Although each of the main steps should be followed, there are multiple options available within each step. For example, Step 2 provides several options for desktop analysis and field surveys. Local conditions and available data will dictate the selection of the appropriate options.

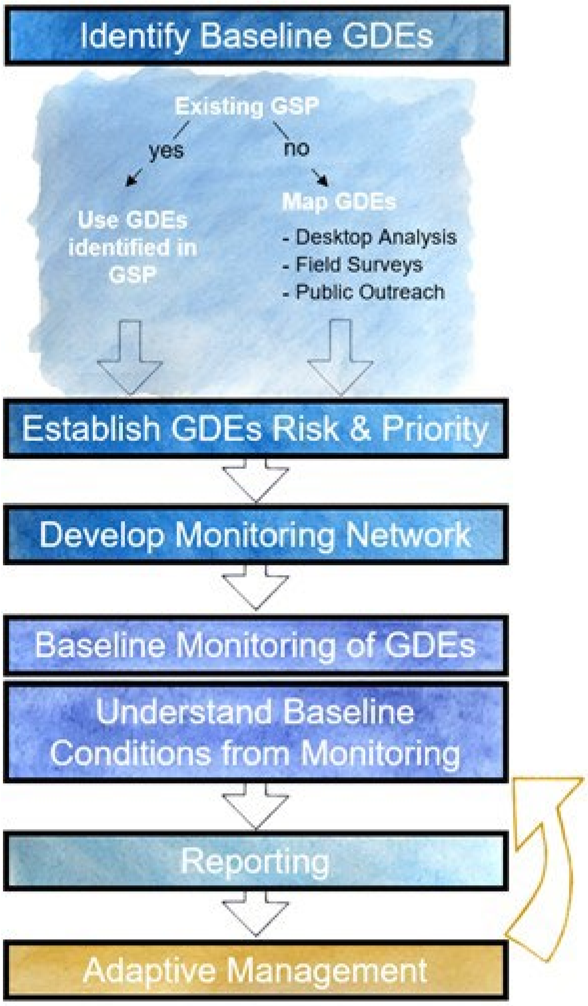

Figure MM10-2. Groundwater Dependent Ecosystem Method framework

1. **Safety plan:** All projects with fieldwork related activities should produce a Safety Plan. Planning for fieldwork and availability of access to the site, such as monitoring wells, is necessary to maintain project safety. Projects which have an impact on groundwater dependent ecosystems may require a Safety Plan to address these and other potential safety concerns.
2. **Identify baseline GDEs -** Identify terrestrial, riparian, and aquatic GDEs and determine a baseline understanding of groundwater and surface water relationships.
    a. Have potential or confirmed GDEs been identified in the area likely to be influenced by the project? If, so use this as a starting point for identifying GDEs.
    b. Map GDEs and characterize GDE condition, using a combination of appropriate options listed below–

Desktop analysis, e.g.:

- **Hydrogeological analysis** to identify conditions where GDEs are most likely to exist. This requires a conceptual understanding of flow between aquifers, and areas of groundwater recharge and discharge. For example, spring-based GDEs occurring at geological contacts, or spring-based and baseflow GDEs supported by the discharge of groundwater along fault lines. Use surface water and groundwater elevation data to understand the nature of groundwater and surface water connectivity, and depth to water to understand terrestrial GDE access to groundwater.
- **Aerial photographs** can be analyzed to map vegetation communities, geology, and geomorphology (see Figure MM10-3). These data are used to determine likely groundwater dependance and need ground-truthing to clarify areas of uncertainty. Unsupervised interpretation, using image analysis software, can translate data from satellites or aircraft into maps of vegetation type, leaf area index, vegetation condition and/or evapotranspiration. The correlation of a GDE with specific geomorphic, hydrogeological, or hydrological conditions that have groundwater dependence in one area may be used to infer the presence and distribution of those GDEs over larger spatial scales.
- **Geographic information systems (GIS) modeling** by overlaying and linking existing spatial datasets, including topographic, soil and geological maps, depth to groundwater, vegetation maps, ground or airborne geophysical surveys, aerial photography and/or satellite imagery etc. GIS analyses are best used when there is good information on specific characteristics of existing GDEs, which can then be extrapolated to infer the location of similar GDEs in other areas.
- **Remote sensing analysis.** Remotely sensed data collected by satellites or aircraft record the radiation absorbed or emitted by the earth surface (including by vegetation). The radiation sensed is processed using different algorithms to develop images of the earth surface that highlight particular landscape features, such as areas of open water, moist or dry soil, presence or absence of vegetation, leaf-area index, and plant productivity. A long-standing and commonly used algorithm is the Normalized Difference Vegetation Index, which uses the ratio of red and infrared bandwidths to produce an Vegetation Index value between -1 and +1 for each pixel of the area being sensed.

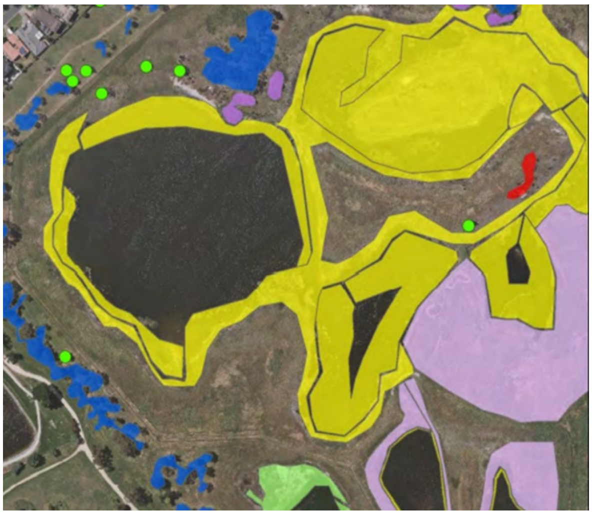

Figure MM10-3. Example Habitat Zone Mapping (AECOM and GHD, 2018)

Figure MM10-4 Example of Benthic Monitoring using a Teledyne Oceanscience Z-Boat. (AECOM and GHD, 2018)

Field surveys, e.g.:

- **GDE field observations**. Field confirmation and photographic record of GDE type and health.
- **GDE surface water observations**. Field observations of surface water flow and water depth, bathymetry surveys (see Figure MM10-4) Field measurements of temperature. See Groundwater and Surface Water Interactions Monitoring Method (MM-07) for streamflow gauging.
- **Seepage (or accretion) measurements** – See Groundwater and Surface Water Interactions Monitoring Method (MM-07).
- **Environmental tracers** – See Groundwater and Surface Water Interactions Monitoring Method (MM-07).
- **Artificial tracers** – See Groundwater and Surface Water Interactions Monitoring Method (MM-07).
- **Geophysical surveys** – See Groundwater and Surface Water Interactions Monitoring Method (MM-07).
- **Ecological indicators**

Public outreach and input

- **Workshops.** Working with the community to understand the historical context of the GDE and how the landscape has changed over time.
- **Transparency.** Providing the community with information that is already available to build relationships and support.

3. **Establish GDE risk and priority**
   a. Establish the ecological significance of the GDEs, i.e., is the site considered to be of local, national, or international importance
   b. Assign ecological values to the GDEs
   c. Establish the priority and risk ranking of the GDEs
4. **Develop monitoring network**
   a. Consider GDE risk levels and existing monitoring networks, establish groundwater (shallow and if relevant, deep wells), surface water (flow and depth), ecological (field observations) and climate (temperature, rainfall, evaporation) monitoring networks. Note that new monitoring features may be required to complete the network (see Figure MM10-5 for an example surface water stage monitoring station). The location of the monitoring network should be easily accessible such that gaining access to the site does not inhibit gathering and downloading data (refer to Step 1).
5. **Baseline monitoring of GDEs** - Establish the specifics of data collection.
   a. Establish and collect data for relevant monitoring parameters to identify potential impacts to GDEs. Parameters could include:
      - Groundwater levels (measured as elevations and depth below natural ground surface)
      - Groundwater quality (e.g., salinity, major ions, nutrients, metals)
      - Surface water levels (measured as elevations and depth below measuring point)
      - Surface water quality (e.g., salinity, major ions, nutrients, metals)
      - Climate (rainfall, temperature, evaporation)

Figure MM10-5. Example surface water stage (level) monitoring. (AECOM and GHD, 2018)

b. Establish monitoring frequency for relevant monitoring parameters to identify potential impacts to GDEs. For example:
   - Groundwater levels – daily
   - Groundwater quality – quarterly
   - Surface water levels– daily
   - Surface water quality– quarterly
   - Climate – as per available NOAA data record

c. Establish monitoring duration to identify potential impacts to GDEs. For example, monitor baseline conditions at least 2 years prior to project implementation or based on GSP requirements.

6. **Understand baseline conditions from monitoring:** Understand the range of conditions at the end of the baseline period.
   a. Establish baseline conditions and variability based on existing conditions. Is there evidence of declining ground/surface water levels and/or quality in any groundwater monitoring points near the GDEs?
   b. Compare baseline conditions to lowered groundwater level and interconnected surface water.
   c. Estimate degree of dependence of the GDE ecology/fauna on groundwater.
   d. Confirm and describe if there is evidence of declining groundwater and/or surface water levels, quality and/or flow.
   e. Establish performance standards (e.g., triggers or conditions that define acceptability or cause undesirable results, may be outline in a regions GSP)
   f. Establish review frequency to assess performance standards.
7. **Reporting:** Report monitoring data is recommend being reported twice per year.
   a. Establish relevant stakeholders.
   b. Establish data management and sharing arrangements.
   c. Recommend monitoring points to add to the monitoring network.
   d. If project falls within a Groundwater Sustainable Agency, then compare monitoring to the requirements of GDEs laid out in the GSP.
8. **Adaptive management:** Expand or refine monitoring network adaptively, as needed.
   a. Review and update monitoring requirements.
   b. Consider relevant impact verification measures.
   c. Consider relevant risk analysis techniques.
   d. Review and update mitigation options assessment, implementation, and validation.

Data and Protocol - Fundamentals

GDE mapping is the first step in identifying the GDEs and understanding their relationship to groundwater sustainability indicators. There are several digital mapping methods available based on the region. The GDE Pulse web app developed by The Nature Conservancy provides data on long-term temporal trends of vegetation vigor based on remote sensing. Aerial photos from the U.S. Department of Agriculture provide free high resolution aerial photography through the National Agriculture Imagery Program. However, digital data should be confirmed with (potentially higher resolution and more reliable) local data. Additional information and cross-referencing can be made using local resource documents or habitat specific monitoring plans prepared by other agencies. Field visits should be conducted in the area likely to be impacted by a groundwater project to confirm remote sensing requirements in assessing GDE locations, GDE type, and current conditions. Public comment and community input also is a key component that needs to be considered. Site specific GDE information should be integrated with available groundwater level (and where relevant, quality) data near the GDEs to assess the relationship between groundwater conditions and GDEs.

Groundwater levels are the primary metric for the groundwater water source for GDEs because they are one of the controlling factors in supporting rooting depths for vegetation based GDEs, and the primary measure used to assess groundwater flow regimes and potential ecosystem connectivity. Remote sensing of vegetation locations for GDEs can be compared over time and areas assessed compared to groundwater levels. However, since aquatic GDEs depend, in part, to groundwater contributions from interconnected surface water, streamflow/stage is another metric, particularly in the summer and fall months before the significant rainfall months.

Similarly, water quality (ground and surface) may be a useful metric for some GDEs, particularly in:

- Assessing surface water quality in the context of vegetation condition.
- Assessing interaction between surface water and groundwater.
- Conceptualizing the hydrological regime.
- Assessing temporal water quality variability and establishing baseline conditions.

Data Standards

Groundwater and surface water monitoring data should conform to the technical and reporting standards of the California Water Code (CW §352 *et seq.*).

Key Protocols

The key protocols for GDEs monitoring are:

- GDE Observations: Locating and identifying ecosystems that are potentially groundwater dependent based on physical parameters such as depth to water table, soils, and vegetation type. Assessing primary productivity, water relations and/or condition of vegetation communities using remotely sensed images to infer use of groundwater (Richardson et al, 2011b).
- Groundwater Levels: Department of Water Resources (DWR) Best Management Practice (BMP) 1 Monitoring Protocols Standards and Sites (DWR, 2016) - describes protocols for measuring groundwater extraction, groundwater levels, and streamflows to assist in the establishment of consistent data collection procedures and processes.
- Water Quality: USGS National Field Manual for the Collection of Water Quality Data (Wilde, 2005) and DWR's BMP 1 Monitoring Protocols Standards and Sites (DWR, 2016).
- Streamflow and Depth: USGS Water Supply Paper 2175, Volume 1 – Measurement of Stage Discharge and Volume 2 – Computation of Discharge. This method is currently being used by both the USGS and DWR for existing streamflow monitoring throughout the State and DWR's BMP 1 Monitoring Protocols Standards and Sites (DWR, 2016). Utilizing computer models for streamflow and depth analysis is a secondary approach given the potential for limited real-time data. For additional information see Groundwater and Surface Water Interactions Monitoring Method (MM-07).

The regional GSP Regulations include specific requirements to identify GDEs and the protocols that should be considered when determining whether groundwater conditions are having potential effects on beneficial uses and users. It is acknowledged that each basin is unique, that not all projects fall under a GSP, and adaptations to the monitoring plan may be needed to meet project specific needs.

Examples of Groundwater Dependent Ecosystem Monitoring Application

Santa Margarita Groundwater Sustainability Plan

Location: The Santa Margarita Basin as defined in DWR Bulletin 118. The Basin is located at the northern end of the Central Coast hydrologic region, in Santa Cruz County to the west of the Santa Cruz Mountains.

Year: November 2021

Description and Relevance: The Santa Margarita GSP has used a methodology to identify and generate a monitoring protocol for the GDEs within the Basin. The GDE were mapped and categorized based on a classification specific to the region. Monitoring parameters and frequencies were applied based on GDE classification. Semi-annual field observation monitoring will measure discharge, water depth, and water quality constituents, record visual observations and photographs. Shallow groundwater levels in dedicated monitoring wells have pressure transducers to continuously monitor groundwater levels. Streamflow is measured in streamflow gauges, many of which, are associated with shallow monitoring wells. Every five-years, changes in vegetation vigor will be analyzed using remotely sensed data and techniques.

Links to Resources: Santa Margarita Groundwater Agency - Groundwater Sustainability Plan

Santa Rosa Plain Groundwater Sustainability Plan

Location: The GSP covers the 80,000-acre Santa Rosa Plain subbasin, which lies within the Coast Ranges geomorphic province and is one of three coastal alluvial subbasins of the Santa Rosa Valley Groundwater Basin in the North Coast Hydrologic Region.

Year: October 2021

Description and Relevance: The Santa Rosa Plain GSP identifies GDEs as in need of protection as beneficial uses. The GDE maps out the GDE and identifies the existing data gaps, where additional monitoring is needed. The GDE presents an adaptive approach to monitoring of the GDE over time based on using groundwater levels as the primary indicator. The adaptive management approach is important as there is often limited data available on GDEs to completely understand their correlation to groundwater.

Links to Resources: Santa Rosa Plain Groundwater Sustainability Agency - GSP

Edithvale Wetlands Groundwater Management

Location: This example relates to an internationally recognized wetland in Edithvale, Victoria, Australia, which was identified as a relevant GDE that could be affected by an urban infrastructure project (the Edithvale and Bonbeach Level Crossing Removal Projects). An environmental impacts assessment was required for the project to assess potential impacts to groundwater levels, groundwater quality and the Edithvale-Seaford Wetlands. It was identified that groundwater levels and quality could be maintained for the project within acceptable thresholds through engineering controls and implementation of specific measures, one of which was the development of a specific Groundwater Monitoring and Management Plan.

Year: December 2021

Description and Relevance: The environmental impacts assessment undertaken involved geotechnical, hydrogeological and environmental investigations undertaken to inform desktop studies and numerical groundwater modelling of potential project impacts. The predictive modelling was used to quantify the potential projects impacts in identifying the potential impact to sensitive receptors. Associated habitat values are depicted in a conceptual model presented in Figure MM10-6. It provides an overview of cell habitat features, key fauna species and indicative levels of groundwater interaction.

The environmental impacts assessment adopted a risk-based approach consistent with international standards, which was used to guide adaptive management (mitigation) requirements.

The purpose of the Groundwater Monitoring and Management Plan is to ensure that the existing groundwater conditions (quality and levels) are not adversely affected by the project i.e., that project conditions show positive impacts to GDEs.

The purpose of the Edithvale Wetlands Monitoring and Mitigation Plan is to identify whether groundwater mounding (as a result of the project) reaches Edithvale Wetland and whether this groundwater increase affects the suitability of the habitat and therefore use of the wetland by birds.

Monitoring is undertaken as per the locations, parameters, frequency, and duration designated in the Groundwater Monitoring and Management Plan. Trigger levels for monitoring were established that defined negative impact to GDEs.

Links to Resources:
Read the EES | Level Crossing Removal Project (levelcrossings.vic.gov.au)

Edithvale and Bonbeach Monitoring and Management Plans and publication of Annual Compliance Report | Level Crossing Removal Project (levelcrossings.vic.gov.au)

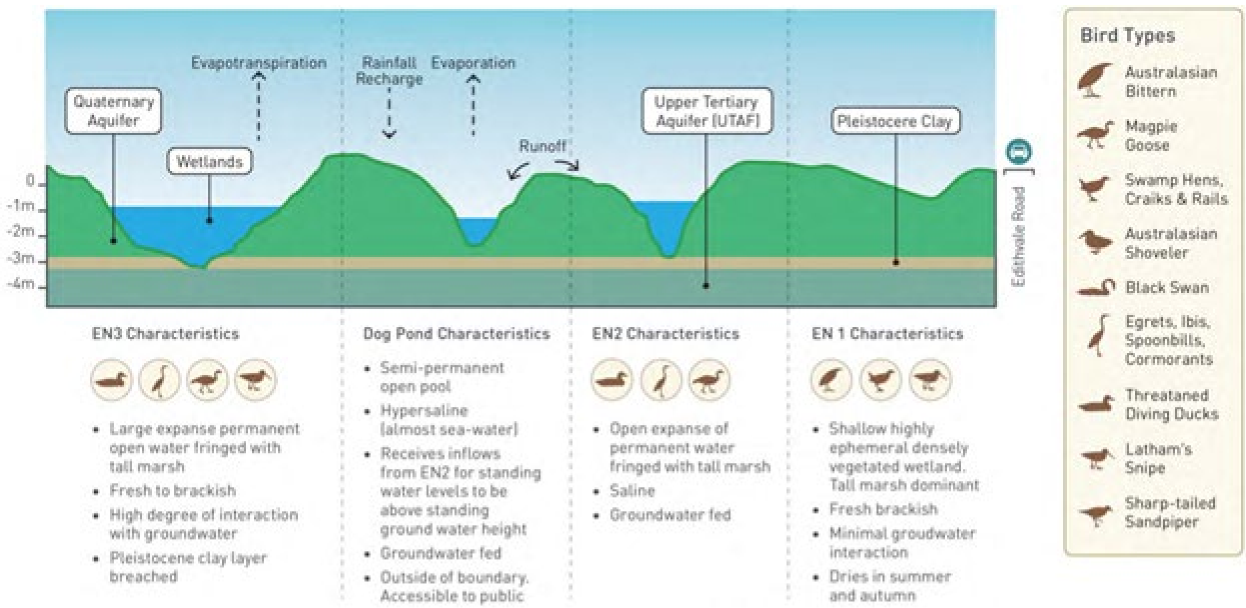

Figure MM10-6. Illustrative depiction of the Edithvale GDEs showing cells with habitat cells, key fauna species and indicative levels of groundwater interactions (AECOM and GHD, 2018).

Source References

Resources

Aerial Photography and Remote Sensing Data

U.S. Department of Agriculture provides freely available high-resolution aerial photography through the National Agriculture Imagery Program.

http://www.fsa.usda.gov/programs-and-services/aerial-photography/imagery-programs/naip-imagery/

The Nature Conservancy's GDE Pulse web app provides users easy access to satellite data to view long term temporal trends of vegetation metrics. These vegetation metrics serve as an indicator of vegetation health for GDEs.

https://gde.codefornature.org/#/home

Areas of Conservation Emphasis

The Areas of Conservation Emphasis (ACE) Project contains spatial data on native species richness, rarity, endemism, and sensitive habitats for six taxonomic groups: birds, fish, amphibians, plants, mammals, and reptiles. Information on the location of four sensitive habitat types (i.e., wetlands, riparian habitat, rare upland natural communities, and high-value salmonid habitat) are also summarized. The ACE dataset is available statewide at a 2.5-square-mile hexagon grid. The ACE spatial data are available online or downloadable for GIS.

https://www.wildlife.ca.gov/Data/Analysis/ACE

Beneficial Use Designations

Regional Water Quality Control Board basin plans contain a list of beneficial uses of surface waters, groundwater, marshes, and wetlands that pertain to water quality objectives. According to the State Water Resources Control Board, "beneficial use designations for any given water body do not rule out the possibility that other beneficial uses exist or have the potential to exist."

http://www.waterboards.ca.gov/plans_policies/#plans

California Protected Areas

The California Protected Areas Data Portal contains spatial information about lands that are protected for open space purposes by more than 1,000 public agencies or non-profit organizations. The Data Portal spatial downloadable GIS data contain shapefiles and geodatabases.

http://www.calands.org/data

California Special Status Species

The California National Diversity Database (CNDDB) contains text and spatial information on California's special status species. The CNDDB spatial data can be downloaded as a shapefile or accessed via the BIOS Data Viewer. Users must have a CNDDB subscription to access RareFind and CNDDB spatial data downloads.

https://www.wildlife.ca.gov/Data/CNDDB/Maps-and-Data#43018407-rarefind-5

Critical Habitat for Threatened and Endangered Species

The Environmental Conservation Online System contains spatial data of critical habitat for threatened and endangered species. The Environmental Conservation Online System spatial data can be downloaded as shapefiles.

http://ecos.fws.gov/ecp/report/table/critical-habitat.html

Groundwater Dependent Ecosystems

The Nature Conservancy (TNC 2018) developed a guidance document for understanding and considering GDEs while preparing Groundwater Sustainability Plans.

https://groundwaterresourcehub.org/

https://groundwaterresourcehub.org/sgma-tools/gsp-guidance-document/

Groundwater Monitoring

California Department of Water Resources (DWR) program for the California Statewide Groundwater Elevation Monitoring (CASGEM) Program provides guidance and procedures for monitoring groundwater levels in their report Procedures for Monitoring Entity Reporting, 2010.

https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/Groundwater-Management/CASGEM/Files/CASGEM-Procedures-for-Monitoring-Entity-Reporting-Final-121610_ay_19.pdf

California Department of Water Resources (DWR) 2016 Best Management Practices for the Sustainable Management of Groundwater, Monitoring Protocols, Standards, and Sites.

https://cawaterlibrary.net/wp-content/uploads/2017/05/BMP_Monitoring_Protocols_Final_2016-12-23.pdf

Wilde, F.D., January 2005. Preparations for water sampling (ver. 2.0): U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A1.

http://water.usgs.gov/owq/FieldManual/compiled/NFM_complete.pdf

References

AECOM and GHD Inc. 2018. *Edithvale and Bonbeach Level Crossing Removal Project, Environmental Effects Statement: Technical Report B: Ecological Impacts Assessment: Wetland and Groundwater Dependent Ecosystems*. Melbourne (Australia): Victoria State Government

The Nature Conservancy. 2018. *Groundwater Dependent Ecosystems under the Sustainable Groundwater Management Act, Guidance for Preparing Groundwater Sustainability Plans*. [Website]. Viewed online at: https://groundwaterresourcehub.org/sgma-tools/gsp-guidance-document/

Richardson S, Irvine E, Froend R, Boon P, Barber S, and Bonneville B. 2011a. *Australian groundwater-dependent ecosystem toolbox part 1: assessment framework.* Canberra (Australia): National Water Commission. [Website]. Viewed online at: http://www.bom.gov.au/water/groundwater/gde/GDEToolbox_PartOne_Assessment-Framework.pdf.

——. 2011b. *Australian groundwater-dependent ecosystems toolbox part 2: assessment tools*. Canberra (Australia): National Water Commission. [Website]. Viewed online at: http://www.bom.gov.au/water/groundwater/gde/GDEToolbox_PartTwo_Assessment-Tools.pdf.

State of California. 2022. *State of California Water Code, Division 6, Conservation, Development, and Utilization of State Water Resources*. [Website]. Viewed online at: https://leginfo.legislature.ca.gov/