Chapter 3 [June 2024 Draft Revision]

Sustainable Management Criteria

3.1 Introduction to Sustainable Management Criteria and Definition of Terms

This section characterizes sustainable groundwater management in the Butte Valley groundwater basin (Basin) through description of an overall sustainability goal for the Basin, and through definition and quantification of sustainable management criteria (SMC) for each of the sustainability indicators. Building on the Basin conditions described in Chapter 2, this section describes the processes and criteria used to define the undesirable results, measurable objectives (MO), and minimum thresholds (MT) for each sustainability indicator.

The following terms, defined below, are used throughout this chapter.

Sustainability Goal: The overarching goal for the Basin with respect to managing groundwater conditions to ensure the absence of undesirable results.

Sustainability Indicators (SI): Six indicators defined under the Sustainable Groundwater Management Act (SGMA): chronic lowering of groundwater levels, reduction of groundwater storage, seawater intrusion, degraded groundwater quality, land subsidence, and depletions of interconnected surface water (ISW). These indicators describe groundwater-related conditions in the Basin and are used to determine occurrence of undesirable results (23 CCR 354.28(b)(1)-(6).).

Sustainable Management Criteria (SMC): Minimum thresholds (MT), measurable objectives (MO), and undesirable results, consistent with the sustainability goal, that must be defined for each sustainability indicator.

Undesirable Results: Conditions, defined under SGMA as:

"… one or more of the following effects caused by groundwater conditions occurring throughout a basin:

1. Chronic lowering of groundwater levels indicating a significant and unreasonable depletion of supply if continued over the planning and implementation horizon [….]
2. Significant and unreasonable reduction of groundwater storage.
3. Significant and unreasonable seawater intrusion.
4. Significant and unreasonable degraded water quality, including the migration of contaminant plumes that impair water supplies.
5. Significant and unreasonable land subsidence that substantially interferes with surface land uses.
6. Depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water." (Wat. Code § 10721(x)(1)-(6).)

Minimum / Maximum Thresholds (MT): a numeric value that defines an undesirable result. Groundwater conditions should not exceed the MT defined in the groundwater sustainability plan (GSP). The term "minimum threshold" is predominantly used in SGMA regulations and applied to most sustainability indicators. The term "maximum threshold" is the equivalent value but used for sustainability indicators with a defined maximum limit (e.g., groundwater quality).

Measurable Objectives (MO): specific and quantifiable goals that are defined to reflect the desired groundwater conditions in the Basin and achieve the sustainability goal within 20 years. MOs are defined in relation to the six undesirable results and use the same metrics as MTs.

Interim Milestones: periodic goals (defined every five years, at minimum), that are used to measure progress in improving or maintaining groundwater conditions and assess progress towards the sustainability goal.

Representative Monitoring Points (RMP): for each sustainability indicator, a subset of the monitoring network, where MTs, MOs, and milestones are defined.

Project and Management Actions (PMAs): creation or modification of a physical structure / infrastructure (project) and creation of policies, procedures, or regulations (management actions) implemented to achieve Basin sustainability.

3.1.1 Updates to Sustainable Management Criteria

The Butte Valley GSA received a determination letter from the California Department of Water Resources (DWR) on January 18, 2024. This letter deemed the Butte Valley Basin GSP, originally submitted on January 28, 2022, incomplete, and identified two deficiencies in the GSP. As a result, Sections of the GSP that relate to the groundwater level sustainability indicator, have been revised to address these deficiencies and corrective actions.

The two potential deficiencies were identified as:

Deficiency 1: The GSP does not include a reasonable assessment of overdraft conditions and reasonable means to mitigate overdraft.

Deficiency 2: The GSP does not establish sustainable management criteria for chronic lowering of groundwater levels in a manner substantially compliant with the GSP regulations.

A full summary of the deficiencies, corrective actions, and how the revisions to the GSP chapters and appendices address each can be found in Appendix 3-D.

3.2 Sustainability Goal

The overall sustainability goal of groundwater management in Butte Valley is to maintain groundwater resources in ways that best support the continued and long-term health of the people, the environment, and the economy in the Basin for generations to come. This includes managing groundwater conditions for each of the applicable sustainability indicators in the Basin so that:

- Groundwater elevations and groundwater storage are not significantly declining below their historically experienced range, protecting the existing well infrastructure from outages, and protecting groundwater dependent ecosystems (GDEs).
- Groundwater quality is suitable for the beneficial uses in the Basin and is not significantly or unreasonably degraded.

- Significant and unreasonable land subsidence is prevented in the Basin. Infrastructure and agricultural production in Butte Valley remain safe from permanent subsidence of land surface elevations.

3.3 Monitoring Networks

The monitoring networks detailed here support data collection to monitor the chronic lowering of groundwater levels, reduction of groundwater in storage, land subsidence, and degraded groundwater quality sustainability indicators. The monitoring networks for each sustainability indicator are critical to demonstrating the Basin's sustainability over time. No monitoring networks are included for the seawater intrusion and ISW sustainability indicators, as they are not applicable in the Basin (see Chapter 2). After data gaps are addressed (see Appendix 3-A and Chapter 4) a monitoring network and SMCs may be set for ISWs.

Per 23 CCR Section 354.34, monitoring networks should be designed to:

- Demonstrate progress towards achieving MOs described in the Plan.
- Monitor impacts to the beneficial uses or users of groundwater.
- Monitor changes in groundwater conditions relative to MOs and minimum or maximum thresholds.
- Quantify annual changes in water budget components.

The monitoring networks for each sustainability indicator are critical to demonstrating the Basin's sustainability over time.

Monitoring networks are required to have sufficient spatial density and temporal resolution to evaluate effects and effectiveness of Plan implementation and represent seasonal, short-term, and long-term trends in groundwater conditions and related surface conditions. Short-term is considered here to be a timespan of 1 to 5 years, and long-term is considered to be 5 to 20 years.

There is no rule for the spatial density and frequency of data measurement required for each monitoring network. These values are specific to monitoring objectives, the parameter to be measured, level of groundwater use, and Basin conditions, among other factors. A description of the existing and planned spatial density and data collection frequency is included for each monitoring network.

Detailed descriptions, assessments and plans for improvement of the monitoring network and protocols for data collection and monitoring are addressed for each sustainability indicator in the following sections.

In summary, there are three monitoring networks: a water level monitoring network, a water quality monitoring network, and a land subsidence monitoring system Figure 3.1. The first two utilize two independent but overlapping networks of wells, the latter utilizes satellite remote sensing. Detailed descriptions, assessments and plans for future improvement of the well monitoring network and protocols for data collection and monitoring are addressed for each sustainability indicator in the following sections.

Table 3.1: Summary of monitoring networks, metrics and number of sites for sustainability indicators.

Sustainability Indicator	Metric	Number of Sites in Current Network
Chronic Lowering of Groundwater Levels	Groundwater level	13
Reduction of Groundwater Storage	Volume of water per year, computed from water level changes	Uses chronic lowering of groundwater levels network
Groundwater Quality	Concentration of selected water quality parameters	7
Land subsidence	Land surface elevation	Spatially continuous

[a] This table only includes monitoring networks used to measure sustainability indicators. It does not include additional monitoring necessary to monitor the various water budget components of the basin, described in Chapter 2, or to monitor the implementation of project and management actions (PMAs), which are described in Chapter 4.

[b] Land surface elevation changes are monitored through satellite remote sensing.

Identification and Evaluation of Potential Data Gaps

Per 23 CCR Section 351, data gaps are defined as, “a lack of information that significantly affects the understanding of the basin setting or evaluation of the efficacy of Plan implementation and could limit the ability to assess whether a basin is being sustainably managed.” A detailed discussion of potential data gaps, and strategies for resolving them, is included as Appendix 3-A. Data gaps are primarily addressed in this chapter through the ‘Assessment and Improvement of Monitoring Networks,’ associated with each sustainability indicator in the Basin. Of particular focus for the monitoring networks are the adequacy of the number of sites, frequency of measurement, and spatial distribution in the Basin. In addition to the monitoring network-specific data gaps, information was identified that would be valuable to collect. This information is valuable to support increased understanding in the Basin setting, understanding of conditions in comparison to the SMCs, data to calibrate or update the model, and to monitor efficacy of PMAs. These additional monitoring or information requirements depend on future availability of funding and are not yet considered among the GSP Representative Monitoring Points (RMPs). They will be considered as potential RMPs and may eventually become part of the GSP network at the five-year GSP update. The list includes:

- Streamflow gauges on ephemeral streams near the Basin Boundaries and Butte Creek, outside the Basin boundaries.
- Groundwater level monitoring wells near potential GDEs and potential ISWs to establish groundwater levels for use in Butte Valley Integrated Hydrogeologic Model (BVIHM) model calibration, as part of GDE/ISW identification and monitoring, and for measuring PMA efficacy.
- Domestic well monitoring for both water quality and groundwater levels.
- Improved estimation of evapotranspiration (ET) from key crops, natural vegetation.
- Additional biological data that would be useful for monitoring and evaluation of GDEs.

Streamflow gages and some more monitoring stations for continuous groundwater levels and rainfall have already been installed as part of the GSP implementation (Figure 2.32). The GSA will be working with a biologist in 2025 to further fill data gaps on existing GDEs in the Basin. Additionally, the GSA will be coordinating with the California Department of Fish and Wildlife (CDFW), and the North Coast Regional Water Quality Control Board (NCRWQCB) throughout this process.

A detailed discussion of these potential data gaps and suggested approach and monitoring prioritization can be found in Appendix 3-A and Chapter 5.

Monitoring Network to Fill Identified Data Gaps

Butte Valley groundwater monitoring includes the California Statewide Groundwater Elevation Monitoring Program (CASGEM) program by the Department of Water Resources (DWR), which maintains periodic records of groundwater elevation since the 1950s. Butte Valley climate monitoring includes one DWR California Irrigation Management Information System (CIMIS) climate station site near Macdoel and two United States National Oceanic and Atmospheric Administration (NOAA) weather stations near Mount Hebron and the City of Dorris. There are no permanent or long-term streamflow gages in the Basin.

To supplement historical monitoring stations, the groundwater sustainability agency (GSA) developed nine locations around Butte Valley to collect continuous groundwater level data, eight sites to collect precipitation data, two sites with soil water content sensors, and one surface water flow station located on Butte Creek just south (outside) of the Basin boundary. Sites are shown on Figure 3.2 and Figure 3.3. The network of continuous wells provides tools and resources for farmers to connect to their own stations using a password protected website.

An evaluation of ET by strawberry grown for propagation in Butte Valley (a major crop in the Basin) is ongoing and the results are anticipated to be published in 2022 or 2023. The eddy covariance-

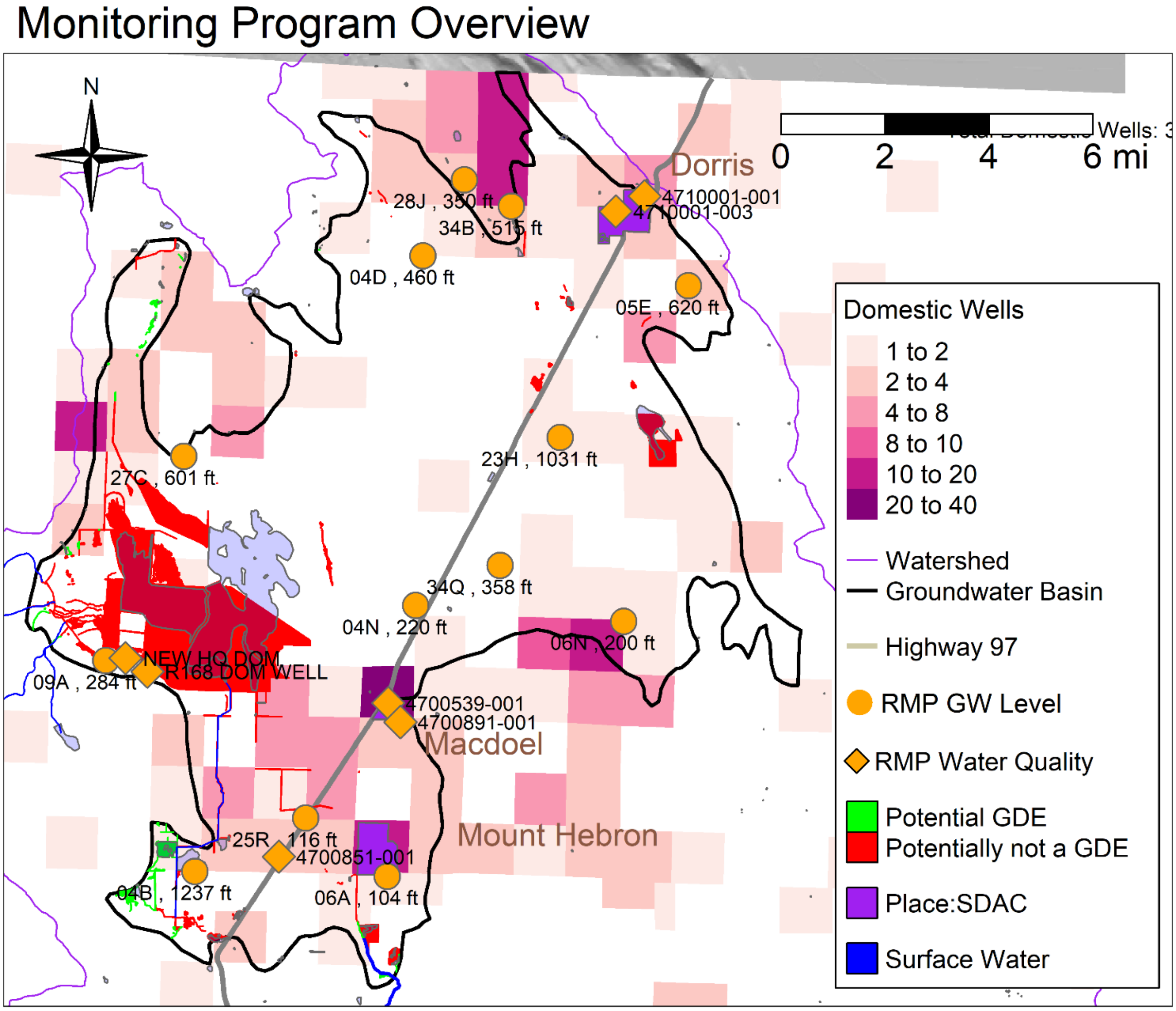


Figure 3.1: The current overall monitoring network in Butte Valley.

and energy balance-based research station used to collect data for the study was deployed during the 2020 and 2021 growing seasons in eastern Butte Valley over a field of drip irrigated strawberry.

Significant data gaps exist in the historical records of flow and surface water conditions. Historical surface water flow observations are from a brief period of record from 1952 through 1960 at a United States Geological Survey (USGS) station along Butte Creek and monthly self-reporting by California State Water Resources Control Board (SWRCB) surface water right appropriation holders. The USGS also maintained a station along Antelope Creek from 1952 to 1979, however Antelope Creek does not flow to Butte Valley.

The GSA received implementation funding to expand monitoring in Butte Valley and the surrounding watershed (Watershed) to resolve data gaps related to groundwater and surface water, and to select the location of a proposed Snow Water Equivalent (SWE) station in the upper watershed.

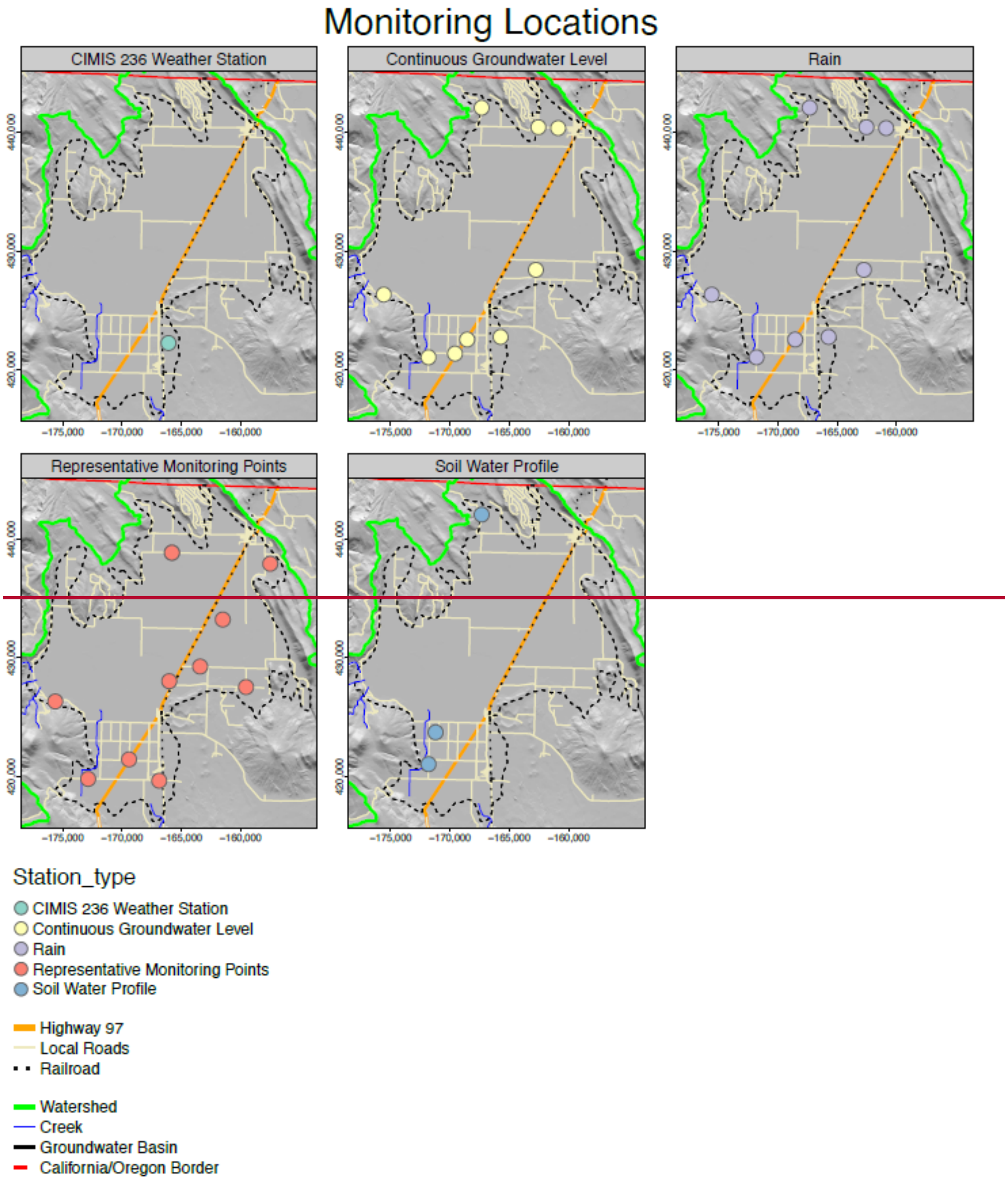
Several data gaps were identified during the GSP development which were intended to be resolved during implementation. Numerous data gaps remain and implementation funding is insufficient to resolve most issues. Identified data gaps and the current status of resolution include:

- Insufficient model inputs used for the geologic model and numerical groundwater model including data quantifying the depth and distribution of key geologic features such as the total depth of alluvial sediment in the basin and the geometry of the sediment in relation to volcanic deposits which likely inter-finger the alluvial deposits.

  To resolve this data gap:
  - The Airborne Electromagnic (AEM) survey data from the Department of Water Resources study was used to improve the geologic model of Butte Valley.
  - The inclusion of significant structural features like faults was improved through improvements in the geologic modeling software Leapfrog Works.
  - Additional historical groundwater observations were located for upland areas in the watershed to improve groundwater numerical model calibration.
  - Groundwater numerical model ~~calibration~~ was further refined with a higher-resolution model moving from 8-layers to 11-layers within the MODFLOW numerical model. The model will be fully calibrated over GSP implementation and results will be included in the 2027 GSP evaluation.
- Insufficient data on climate variables such as site-specific evapotranspiration for unusual crops grown in Butte Valley like high elevation nursery strawberry, precipitation trends across the valley, the lack of a Butte watershed Snow Water Equivalent (SWE) station for accurate hydrologic modeling, and significant data gaps in historical NOAA precipitation data due to variable maintenance over time.

  To resolve this data gap:
  - A multi-season evapotranspiration study of strawberry was conducted in collaboration with the Hydrologic Sciences graduate group of UC Davis
  - Six Davis Instruments rain gauges were installed on volunteer properties throughout the Butte Valley basin to improve understanding of precipitation patterns across the basin.
  - The selection of a new SWE station is ongoing. No new location has been identified.
  - Data analysis of the historical NOAA precipitation data has concluded that due to significant data gaps during high winds and rainy days, the Mount Hebron station currently located at Goosenest Ranger Station may under-count actual precipitation.
- Insufficient data on significant hydraulic and hydrogeologic features, like geochemical and isotope data to quantify the flow paths, ages, and recharge elevations of groundwater, the absence of any surface water flow data since the 1970s, and potential interconnected surface water.

To resolve this data gap:
  - A groundwater sampling study is planned for summer 2024
  - Surface flow stations have been built and are undergoing rating curve development on Harris Creek, Prather Creek, and Butte Creek at existing engineered structures near the basin boundaries. Valid flow data is not yet available due to the field effort required to develop accurate site-specific rating curves.
  - Potential interconnected surface waters should be validated by a combination of field study and advanced desktop analysis. This effort has not begun but is planned for the 2024-2025 water year.
- Insufficient validation of the extent and accuracy of proposed GDE maps and
  To resolve this data gap:
  - Potential interconnected surface waters should be validated by a combination of field study and advanced desktop analysis. This effort has not begun but is planned for the 2024-2025 water year.
- Estimates of groundwater storage require further study. Due to the significant contribution of the surrounding High Cascade Volcanic unit which is not an alluvial deposit in the Bulletin 118 basin boundary, the specific yield and storativity are calculated through calibration of the integrated hydrogeologic model.
  To resolve this data gap:
  - Additional pump test data is required which has not been collected or analyzed.
  - Additional numerical model calibration is required which is ongoing.
- Groundwater extraction is not reported to the GSA so no groundwater extraction data is available for calibration.
  To resolve this data gap:
  - The GSA is continuing outreach and requests to pumpers to voluntarily contribute their groundwater meter data.
- Groundwater quality includes data gaps in both spatial and temporal coverage.
  To resolve this data gap:
  - A groundwater sampling effort is planned for summer 2024.


Monitoring Locations
CIMIS 236 Weather Station
Continuous Groundwater Level
Rain
Representative Monitoring Points
Soil Water Profile
440,000
430,000
420,000
-175,000
-170,000
-165,000
-160,000
Station_type
CIMIS 236 Weather Station
Continuous Groundwater Level
Rain
Representative Monitoring Points
Soil Water Profile
Highway 97
Local Roads
Railroad
Watershed
Creek
Groundwater Basin
California/Oregon Border

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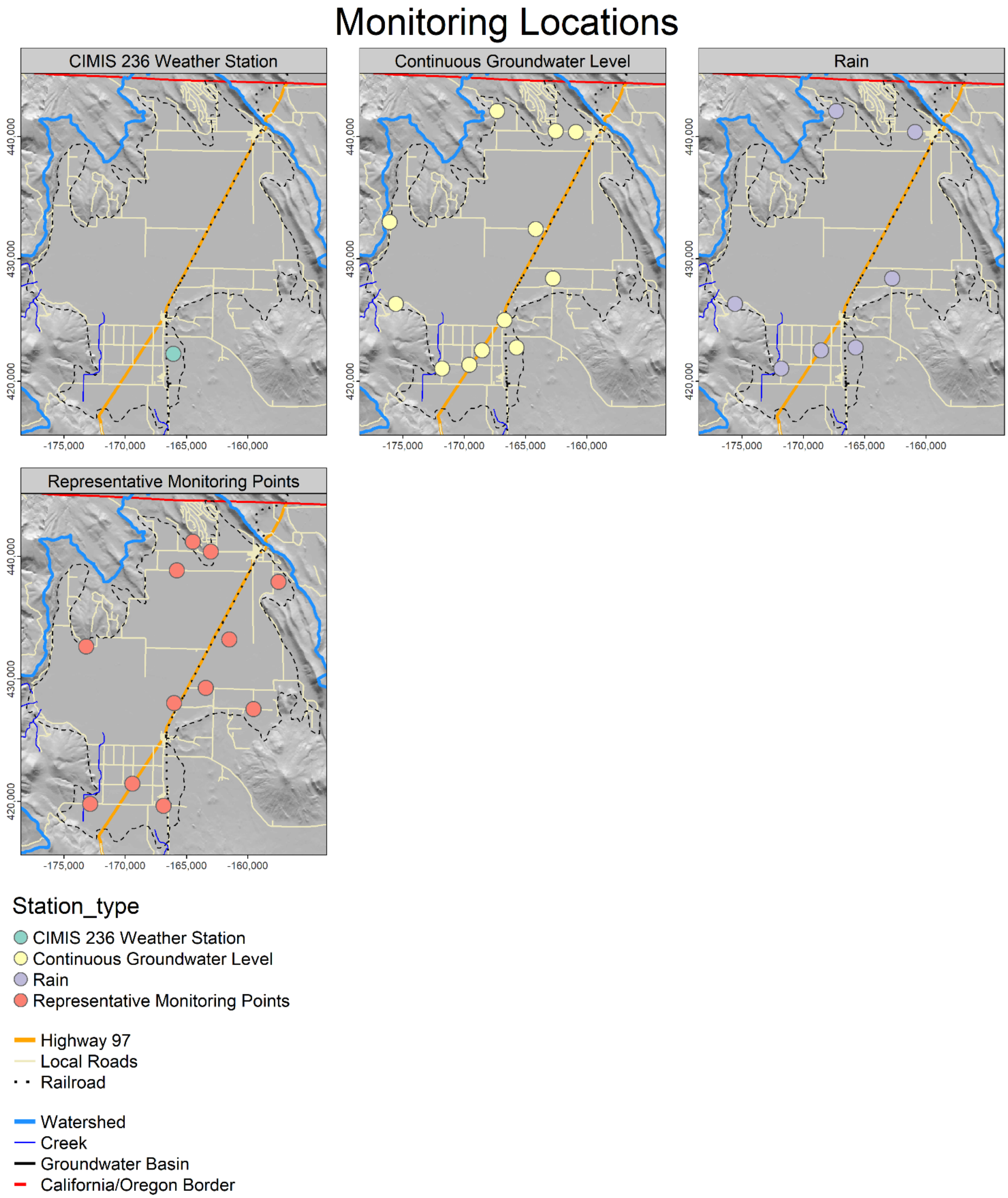
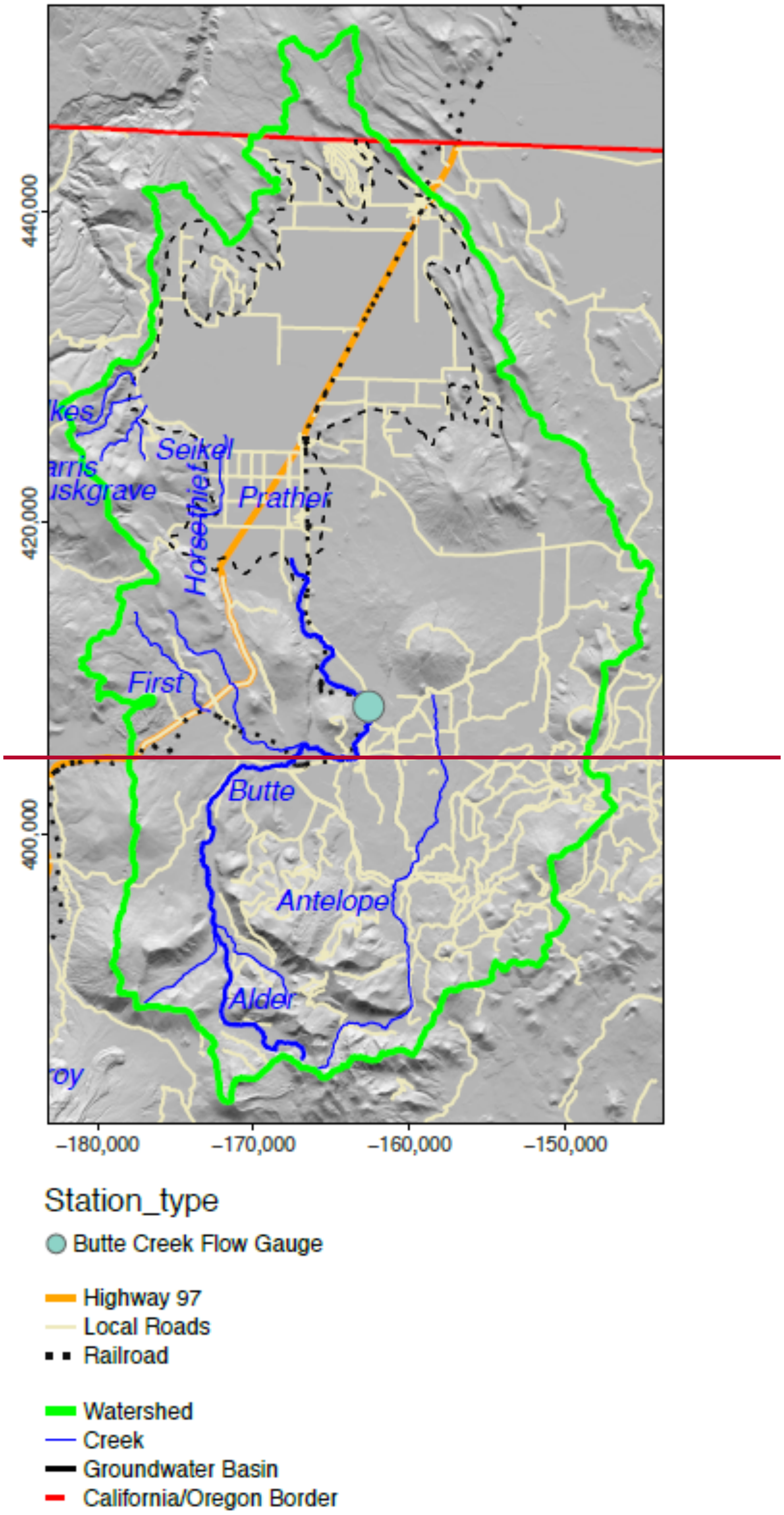


Figure 3.2: The location of continuous monitoring stations in Butte Valley.

Surface Water Monitoring



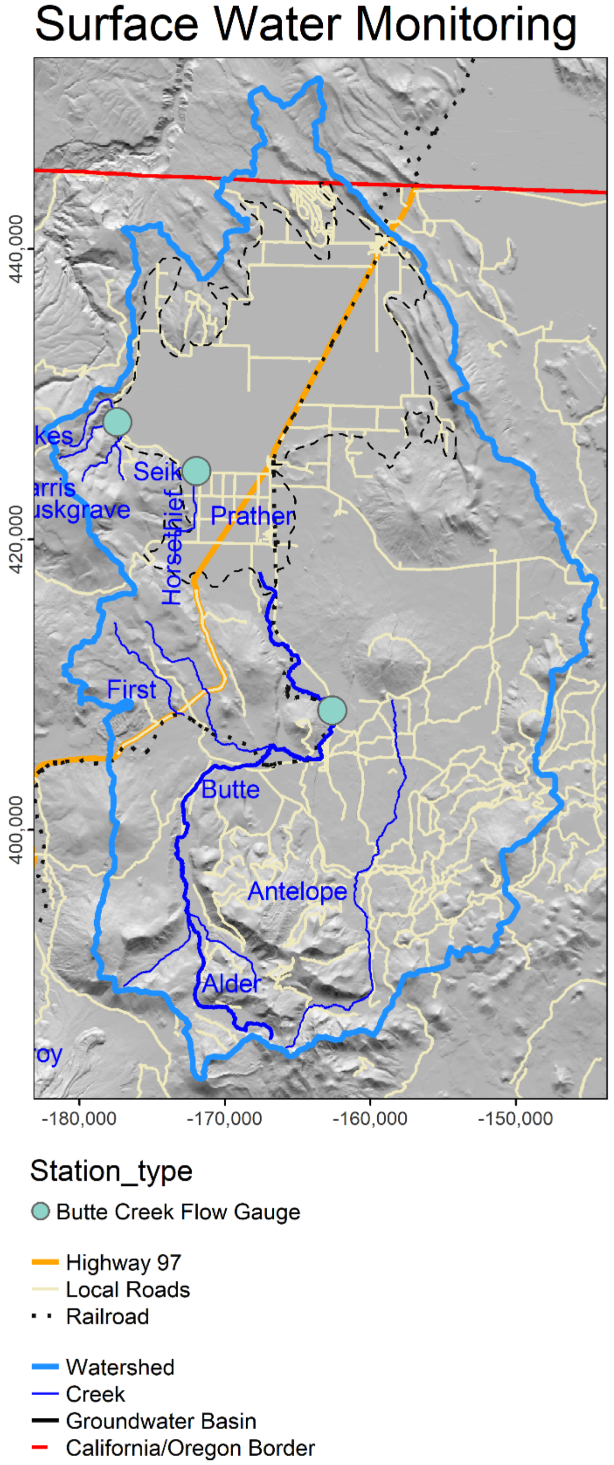


Figure 3.3: The location of continuous surface water monitoring stations in Butte Valley.

Network Enrollment and Expansion

With exception for stream flow and land subsidence, monitoring is done on wells. Some wells will be monitored for water level, some for water quality, some for both. Prior to enrolling wells into the GSA monitoring network, wells will be evaluated, using the selection criteria listed below, to determine suitability. The selection criteria for potential wells to be added to the monitoring network include the following:

- Well location
- Monitoring History
- Well Construction Information
- Well Access

Well Location

The location and design of a well network is important to ensure adequate spatial distribution, coverage and well density. Locations important for groundwater monitoring include sufficient spatial representation of GSP projects and management actions, many of which are Basin-wide. Statistical methods will be used to aid in extrapolating from a limited number of monitoring sites to the entire Basin. Additionally, the network includes the major water bearing formations including the Butte Valley Basalt, Lake Deposits, and High Cascade Volcanics.

Monitoring History

Wells with a long monitoring record provide valuable historical groundwater level or water quality data and enable the assessment of long-term trends.

Well Information

In addition to well location, information about the construction of the well, including the well depth and screened interval(s) provides context, such as which water bearing formation is being sampled. Basin groundwater users tap into three major water-bearing formations, which occur at different depths in separate areas of the Basin. Well information is therefore critical for an effective well network that efficiently monitors groundwater conditions. For wells that are candidates for being added to the well network, the GSA will continue to verify well information, e.g., with well logging.

Well Access / Agency Support

In order to be valuable to the monitoring network, the ability to gain access to the well to collect samples at the required frequency is critical.

Wells in existing monitoring programs are not evenly distributed (e.g., water quality well locations are mostly near population centers), leaving sections of the remainder of the Basin without monitoring data. The planned additional wells are intended to gather groundwater data representative of different land uses and activities and representative of all three geologic units. Such an expansion will improve upon the existing spatial coverage in the Basin. Any wells added to the monitoring network will be evaluated using the criteria listed above to ensure well suitability. The spatial density and monitoring frequency of the monitoring network will be evaluated at least every five years to ensure that the monitoring network is representative of Basin conditions and enables evaluations of seasonal, short-term (1 to 5 years) and long-term (5 to 20 years) trends.

The expansion of the monitoring network will be completed in several steps during GSP implementation. The first step will involve coordination with those agencies already implementing existing monitoring programs in the Basin (see Chapter 2). Wells in these existing monitoring networks (water level or water quality) will be evaluated using the selection criteria and suitable wells will be selected for the GSA Monitoring Network.

The second step will involve identification of additional existing wells in the Basin that could be included in the monitoring network and evaluation of these wells using the selection criteria. Following identification of additional suitable existing wells, analyses will be conducted to determine whether additional wells are required to achieve sufficient spatial density, are representative of land uses in the Basin, and include monitoring in key areas identified by stakeholders. If additional sites are required to ensure sufficient spatial density, then existing wells may be identified, or new wells may be constructed at select locations, as required.

Finally, the monitoring frequency and timing that enable evaluation of seasonal, short-term, and long-term trends will be determined and coordination will be conducted between existing monitoring programs and the GSA to develop an agreement for data collection responsibilities, monitoring protocols and data reporting. With coordination between the GSA and existing monitoring programs (“agencies”), monitoring will be conducted by GSA or agency program staff or their contractors. For water quality, samples are analyzed at contracted analytical labs. To prevent bias, samples will be collected at the same time (i.e., within +/- 30 days) each year.

3.3.1 Groundwater Level Monitoring Network

3.3.1.1 Description of Monitoring Network

This section describes the process used to select wells as potential Representative Monitoring Points (RMPs) for monitoring the groundwater level sustainability indicator. These wells are mapped in Figure 3.4 and listed in Table 3.2.

The objective of the groundwater level monitoring network design is to capture sufficient spatial and temporal detail of groundwater level conditions to assess groundwater level changes over time, groundwater flow directions, and hydraulic gradients between aquifers and surface water features. The monitoring network is critical for the GSA to show compliance with SGMA and quantitatively show the absence of or improvement of undesirable results. The design of the monitoring network must enable adequate spatial coverage (distribution, density) to describe groundwater level conditions at a local and Basin-wide scale for all beneficial uses. Revisions to the monitoring network and schedule will be considered after review of the initial five years of monitoring data and as part of any future GSP updates and as necessary with changes to landowner participation. ~~.~~

Monitoring Network Development

Considerations for making the RMP selections include, in order of priority: spatial coverage, date of last water level observation, and inclusion in existing monitoring programs (such as CASGEM or the continuous transducer measurement network).

Spatial coverage criteria

DWR guidance on monitoring networks (DWR 2016d) recommends a range of well densities to adequately monitor groundwater resources, with a minimum of 0.2 wells and a maximum of 10 wells per 100 sq mi (259 sq km). Because the Basin covers approximately 125 sq mi (326 sq km), these recommendations would translate directly into a range from 1 to 13 RMP wells, evenly spaced in the Basin. To provide some continuity with previous monitoring efforts, and to provide some redundancy in the event of inaccessible wells, a network of potential RMPs was selected using a coverage radius of 1.25 mi (2.0 km).

Measurement schedule

The water elevation in RMP wells will be measured, at a minimum, twice per year to capture the fall low and spring high water levels (Table 3.2). In some wells, transducers may provide daily or higher resolution water elevation measurements.

For wells to be future candidates for the RMP network, at least 10 years of data must be collected, especially when those data are used to adopt future changes in SMC levels (e.g., to fill data gaps for GDEs, see Chapter 2). This ensures a minimum baseline for the well and is consistent with 23 CCR Section 358.2(c)(3), which requires alternative GSPs to have operated sustainably for at least 10 years and include data covering at least 10 years.

Selected groundwater level RMP network

Existing wells considered for the RMP network were public supply wells, and CASGEM wells that include agriculture and domestic wells. Wells selected as RMP candidates (Table 3.2) had a minimum of 10 years of mostly continuous (twice annual) water level measurements. To achieve sufficient spatial coverage, the 5-square mile buffer zone (1.25 mile radius) was mapped around each selected well. The final groundwater level RMP network provides broad coverage of the Basin (Figure 3.4). The groundwater level well network has excellent coverage, especially of the most developed areas of the Basin. But data gaps exist in some of the less developed areas of the Basin, in Sam’s Neck, Butte Valley Wildlife Area (BVWA), and Butte Valley National Grasslands. Additionally, very few wells are located near creeks, lakes, and other surface water bodies mostly near the southern boundary of the Basin.

Table 3.2: Existing and planned elements of the groundwater level monitoring network.

Name of Network	Well Name	State Well Number	Map Name	Target Area	Geologic Formation	Sample Schedule
CASGEM	418948N1220832W001	47N02W27C001M	27C	Meiss Lake	Deep Lake Sediment, High Cascade Volcanics	Twice Annual
CASGEM	417786N1220041W001	45N01W06A001M	06A	Mount Hebron	Butte Valley Basalt	Twice Annual
CASGEM	417789N1220759W001	45N02W04B001M	04B	South West Butte Valley	Data Gap	Twice Annual
CASGEM	417944N1220350W001	46N02W25R002M	25R	Butte Valley Irrigation District	Butte Valley Basalt	Twice Annual
CASGEM	418544N1219958W001	46N01W04N002M	04N	South Mid Valley	Lake Deposits	Twice Annual
CASGEM	418661N1219587W001	47N01W34Q001M	34Q	South Mid Valley	Lake Deposits	Twice Annual
CASGEM	418512N1219183W001	46N01E06N001M	06N	East Valley	Lake Deposits	Twice Annual
Municipal	NA	NA	NA	City of Dorris Well #6	High Cascade Volcanics	Monthly*
CASGEM	419662N1219633W001	48N01W34B001M	34B	West of City of Dorris	High Cascade Volcanics	Twice Annual
CASGEM	419755N1219785W001	48N01W28J001M	28J	NW Butte, Mahogany Mtn F.Z.	High Cascade Volcanics	Twice Annual
CASGEM	419519N1219958W001	47N01W04D002M	04D	North Mid Valley Nested	Lake Deposits	Twice Annual
CASGEM	419520N1219959W001	47N01W04D001M	04D	North Mid Valley Nested	Lake Deposits	Twice Annual
CASGEM	418371N1221105W001	NA	09A	Meiss Lake	Alluvium and High Cascade Volcanics	Twice Annual*
CASGEM	419451N1218967W001	47N01E05E001M	05E	East of Dorris	Data Gap	Twice Annual
CASGEM	419021N1219431W001	47N01W23H002M	23H	East Valley	Data Gap	Twice Annual
Expanded GSA Monitoring Network	TBA	TBA	TBA	Sam’s Neck, National Grasslands, Butte Valley Wildlife Area, Butte Creek, Prather Creek, Meiss Lake		Twice Annual

Note:

(*) The well began groundwater level measurements in 2015 and SMC cannot be set until 10 years of data is available (2025)

3.3.1.2 Assessment and Improvement of Monitoring Network

The very small number of monitoring wells near surface water bodies, including Meiss Lake, Butte Creek, Prather Creek, Ikes, Harris, and Muskgrave Creeks, and various springs leaves significant uncertainty about the hydraulic gradients between the groundwater aquifer and surface water features in the Basin. Based on current knowledge and groundwater depths in nearby wells, these surface water bodies are either losing streams or disconnected from groundwater, in some cases possibly sustained via perched aquifers (see Section 2.2.2.6). Expanding the network to include representative wells adjacent to key surface water bodies would close data gaps regarding the connection of surface water to the groundwater aquifer in the Basin.

Water level measurements near potential GDEs in the Basin are also lacking. The potential GDEs in Butte Valley are relatively small and exist on the Basin edges and areas not covered by the current network. The connection of these potential GDEs to the Basin aquifer and therefore their GDE status is a major data gap (see Section 2.2.2.7).

As the existing monitoring network has data gaps in several key areas of the Basin, an expansion of the network is required to adequately characterize and monitor groundwater levels in the Basin. Data gaps exist in spatial coverage, well information and representation of all land uses and beneficial uses and users in the Basin. Expansion of the network will be informed by the process outlined in Section 3.3.1.1. The current biannual monitoring schedules are sufficient to evaluate seasonal trends, though installation of data loggers could produce monthly or daily data that could be valuable in the evaluation of some PMA pilots. An assessment and expansion of the monitoring network is planned within the first five years of GSP implementation, and repeated evaluations of the network will occur on a five-year basis.

3.3.1.3 Monitoring Protocols for Data Collection and Monitoring

Groundwater level data collection may be conducted remotely via telemetry equipment or with an in-person field crew. Appendix 3-B provides the monitoring protocols for groundwater level data collection. Establishment of these protocols will ensure that data collected for groundwater levels are accurate, representative, reproducible, and contain all required information. All groundwater level data collection in support of this GSP is required to follow the established protocols for consistency throughout the Basin and over time. These monitoring protocols will be updated as necessary and will be re-evaluated every five years.

3.3.2 Groundwater Storage Monitoring Network

This GSP will adopt groundwater levels as a proxy for groundwater storage. The groundwater level network described in Section 3.3.1., will also serve as the groundwater storage monitoring network. The network currently provides reasonable coverage of the major water-bearing formations in the Basin and will provide reasonable estimates of groundwater storage. The network also includes municipal, agricultural, and municipal wells of shallow to deep depths.

Expansion of the network to close data gaps will benefit the characterization of both the groundwater level and storage sustainability indicators.

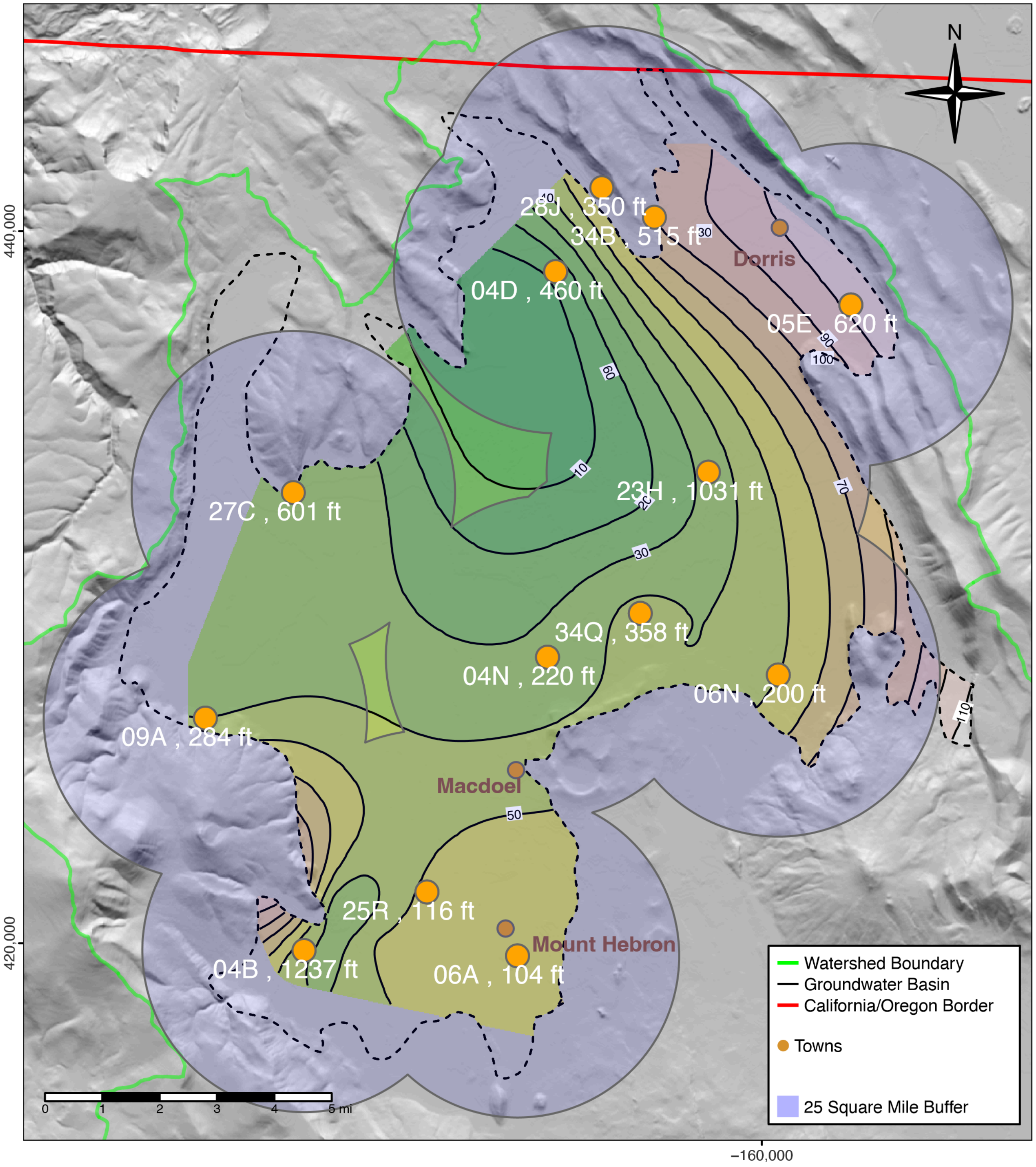


Figure 3.4: Representative monitoring points (RMP) in the water level monitoring network. Well names corresponding to the shorthand names on the map are shown in Table 2.

Historic groundwater storage changes are computed with BVIHM (see Chapter 2.2.3). Throughout the implementation period of this Plan, updates of BVIHM provide updated time series of groundwater storage changes at least every five years.

The change in observed groundwater level data is used to obtain groundwater storage changes for the most recent, non-simulated period. The change in groundwater level is calculated at wells with measurements in the spring season from the previous year to the current year. These wells have water level data collected through the biannual DWR measurement collection, continuous data loggers, and locally collected manual measurements. The locations of these wells is used to identify Thiessen polygons which define the areal extent which is closest to a given well rather than any other well. The Theissen polygons are then cropped to the extent of the Bulletin 118 groundwater basin to calculate storage change for the Butte groundwater basin. The average specific yield of the Bulletin 118 groundwater basin is used to inform the storativity of the aquifer system where the water level change occurs. The change in saturated aquifer thickness is calculated by multiplying the change in water level at each well by its area of influence, i.e. Thiessen polygon. The change in groundwater storage is then calculated by multiplying the change in saturated thickness by the specific yield. Further explanation of this method, and a~~A~~ conceptual illustration of measured wells with their identified Thiessen polygons in Butte Valley groundwater basin is shown in **Chapter 2.2.2**.

~~To obtain groundwater storage changes for the most recent, non-simulated period (currently 2018~~

~~water storage change, $\Delta\Delta STORAGE = intersect + slope * \Delta WL$STORAGE, as a function of~~

~~the year-specific average BVIHM-simulatedΔ Δ to 2021), the latest version of BVIHM, currently,~~

~~for example, simulating the period 1991 to 2018, is used to establish a linear regression equation~~

~~of year-specific spring-to-spring Basin groundgroundwater level change, WL, at the RMP locations~~

~~of the groundwater level network:~~

~~tistical analysis of ΔSTORAGE and WL during the simulation period. The regression analysis is~~

~~where “intersect” and “slope” are parameters of the linear regression equation, obtained from sta-~~

~~performed using the specific, actual monitoring locations available each year for spring-to-spring water level change observations. The “intersect” and “slope” parameters in the above equation can be updated when new, updated, or re-calibrated versions of BVIHM become available, or when individual RMSPs in the water level monitoring network are added or removed.~~

~~The above equation is then used to annually compute groundwater storage change using the actually measured average change in groundwater levels within the Basin’s groundwater level monitoring network. The resulting estimate of annual groundwater storage change (in units of thousandacre-feet, positive or negative) is then summed with previous year’s estimates and combined with the simulated groundwater storage change timeline for the historic period (see Section 2.2.3).~~

~~This regression-based method allows for computation of groundwater storage change from measured groundwater level monitoring for the years between the end of the simulation period (to be updated at least every five years, currently 2018) and the current reporting year (currently 2021). As BVIHM is updated in the future, regression-based estimates of groundwater storage change for a given year (e.g., for 2021) may be replaced with the simulated BVIHM groundwater storage changes for the same year.~~

~~In summary, the combination of simulated groundwater storage change in BVIHM and regressionestimated groundwater storage changes for the post-simulation period provides a time series of cumulative groundwater storage change for the entire period from 1991 to present time (where “present time” is the most recent year in the GSP implementation).~~

3.3.3 Groundwater Quality Monitoring Network

3.3.3.1 Description of Monitoring Network

The objective of the groundwater quality monitoring network design is to capture sufficient spatial and temporal detail to measure groundwater conditions and assess groundwater quality changes over time. The monitoring network is critical for the GSA to show compliance with SGMA and quantitatively show the absence or improvement of undesirable results. The network data will provide a continuous water quality record for future assessments of groundwater quality.

Existing wells used for monitoring groundwater quality in the Basin include public water supply wells and monitoring wells from DWR, California Department of Fish and Wildlife (CDFW), and SWRCB, which are shown in Figure 3.5. However, wells in these existing networks do not cover the entire Basin. Areas of the Basin with no representative wells, such as Sam’s Neck and the middle of the Basin, are data gaps. However, historic and current land use (natural vegetation, some irrigated forage) does not pose significant known risks for groundwater contamination. Existing wells in those areas can be added to the network if well information such as the well depth and well screen dimensions are also known. Well logging or a camera inspection, where a camera is lowered into the well, may be used to obtain unknown well construction information.

The initial groundwater quality well network relies primarily on existing programs that are located within and near the semi-urban areas of the Basin. Initially, the groundwater quality monitoring network is based on wells that are regularly sampled as part of existing monitoring programs for the constituents for which SMCs are set: arsenic, nitrate, and specific conductivity (Table 3.3). Data from these existing programs are not representative of groundwater quality associated with agricultural irrigation, or stock watering (the basin has no or insignificant groundwater discharge to streams). The locations of the existing wells in the proposed well network are shown in Figure 3.5, with details in Table 3.3. Initial monitoring schedules are shown in Table 3.3.

With improvements (Section 3.3.3.2), the design of the monitoring network will eventually enable adequate spatial coverage (distribution, density) to describe groundwater quality conditions at a local and Basin-wide scale for all beneficial uses.

Table 3.3: Existing and planned elements of the groundwater level monitoring network.

Name of Network	Agency	Well Name	Constituent	Frequency
Municipal / Public Supply	City of Dorris	4710001-001, 4710001-003	Arsenic	Every 9 yrs
			Nitrate	Every 9 yrs Annually
			Specific Conductivity	Every 9 yrs
	Goosenest District Office (USFS)	4700851-001	Nitrate	Annually
			Specific Conductivity	No official monitoring schedule
	Macdoel Waterworks	4700539-001	Nitrate	Annually
			Specific Conductivity	No official monitoring schedule
	Juniper Village Farm Labor Housing	4700891-001	Nitrate	Annually
Domestic Well	Butte Valley Wildlife Area (CDFW)	NEW HQ DOM, R168 DOM WELL	Nitrate	Annually
			Specific Conductivity	Annually
Expanded GSA Monitoring Network	GSA	A minimum of 3 wells; sites to be determined	Nitrate, Specific Conductivity	Frequency to be determined.

3.3.3.2 Assessment and Improvement of Monitoring Network

As the existing monitoring network has limited spatial coverage and is not representative of all land uses in the Basin, an expansion of the network is required to adequately characterize and monitor groundwater quality in the Basin. An assessment and expansion of the monitoring network is planned within the first five years of GSP implementation. An expanded monitoring network will occur through a combination of adding suitable existing wells and construction of new wells. Further evaluations of the monitoring network will be conducted on a five-year basis, at minimum, particularly with regard to the sufficiency of the monitoring network in meeting the monitoring objectives.

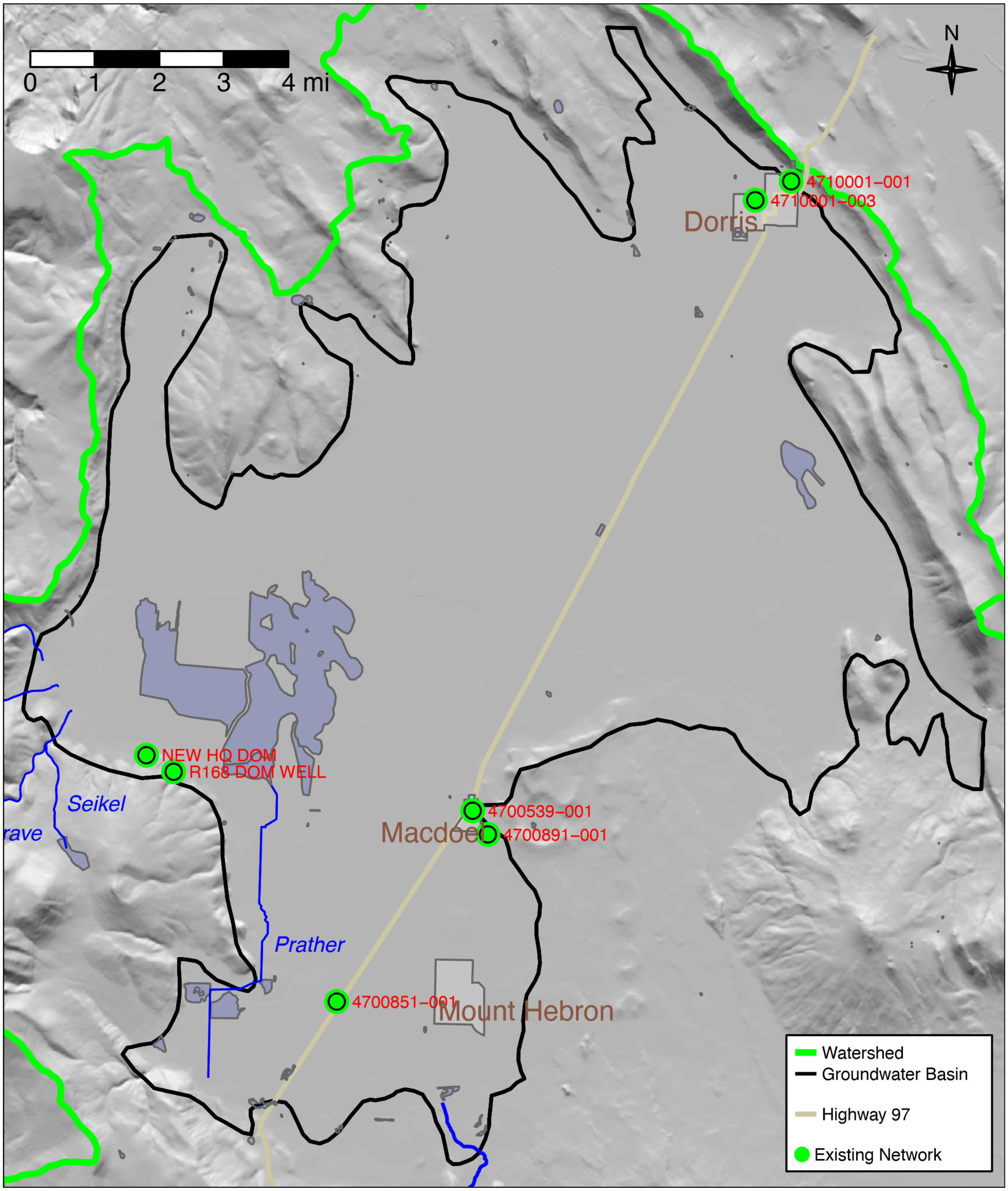


Figure 3.5: Existing water quality monitoring network. Wells along Highway 97 are public supply wells and wells near Meiss Lake are wells volunteered by CDFW. This current monitoring network is planned to be expanded.

An evaluation of the monitoring network, for both spatial density and monitoring frequency suitability will be included in the design of the monitoring network, as discussed in Section 3.3.1. Data gaps have been identified, particularly in spatial coverage, well information and representation of all land uses and beneficial uses and users in the Basin. These data gaps will be resolved through well logging, addition of suitable existing wells, and construction of new wells. The location and number of these wells will be informed by the evaluation completed as part of the monitoring network design.

3.3.3.3 Monitoring Protocols for Data Collection and Monitoring

Sample collection will follow the *USGS National Field Manual for the Collection of Water Quality Data* (Wilde 2008; USGS 2015) and *Standard Methods for the Examination of Water and Wastewater* (Rice, Bridgewater, and American Public Health Association 2012), as applicable, in addition to the general sampling protocols listed in Appendix 3-B.

3.3.4 Subsidence Monitoring Network

3.3.4.1 Description of Monitoring Network

Interferometric Synthetic Aperture Radar (InSAR) is a satellite-based remote sensing technique that measures vertical ground surface displacement changes at high degrees of measurement resolution and spatial detail. DWR provides vertical displacement estimates derived from InSAR data collected by the European Space Agency Sentinal-1A satellite and processed under contract by TRE ALTAMIRA Inc. The InSAR dataset has spatial coverage for much of the Basin and consists of two data forms: point data and a Geographic Information System (GIS) raster, which is point data interpolated into a continuous image or map. The point data are the observed average vertical displacements within a 100 by 100 m area. The InSAR data covers the majority of the Basin as point data and entirely as an interpreted raster dataset. The dataset provides good temporal coverage for the Basin with annual rasters (beginning and ending on each month of the coverage year from 2015 to 2019), cumulative rasters, and monthly time series data for each point data location. These temporal frequencies are adequate for understanding short-term, seasonal, and long-term trends in land subsidence.

Representative Monitoring

The DWR / TRE ALTAMIRA InSAR data will be used to monitor subsidence in Butte Valley. There are no explicitly identified representative subsidence sites because the satellite data consists of thousands of points. Figure 2.25 shows the coverage of the subsidence monitoring network, which will monitor potential surface deformation trends related to subsidence. Data from the subsidence monitoring network will be reviewed annually. The subsidence monitoring network allows sufficient monitoring both spatially and temporally to adequately assess that the measurable objective is being met.

3.3.4.2 Assessment and Improvement of Monitoring Network

It is currently sufficient for the monitoring network to be based on InSAR data from DWR / TRE ALTAMIRA, which adequately resolves land subsidence estimates in the Basin spatially and temporally. However, data gaps exist in the subsidence network, including the lack of data prior to 2015 and no Continuous Global Positioning System (CGPS) stations to ground-truth the satellite data. The DWR/TRE ALTAMIRA InSAR dataset is the only subsidence dataset currently available for the Basin and only has data extending back to 2015. Historical subsidence data prior to 2015 is currently unavailable. Compared to satellite data, CGPS stations offer greater accuracy and higher frequency and provide a ground-truth check on satellite data. However, there are no CGPS or borehole extensometer stations located within or near the Basin boundary. Due to lack of subsidence since 2015 (see Section 2.2.2.5), no future CGPS or borehole extensometer stations are proposed for the Basin at this time. If subsidence becomes a concern in the future, then installation of CGPS stations and/or borehole extensometers can be proposed. The subsidence monitoring network will be used to determine if and where future CGPS or ground-based elevation surveys would be installed. In addition, if subsidence anomalies are detected in the subsidence monitoring network, ground truthing, elevation surveying, and GPS studies may be conducted.

3.3.4.3 Monitoring Protocols for Data Collection and Monitoring

The subsidence monitoring network currently depends on data provided by DWR through the TRE ALTAMIRA InSAR Subsidence Dataset. Appendix 3-B describes the data collection and monitoring completed by DWR contractors to develop the dataset. The GSA will monitor all subsidence data annually. If any additional data become available, they will be evaluated and incorporated into the GSP implementation. If the annual subsidence rate is greater than minimum threshold, further study will be needed.

3.4 Sustainable Management Criteria

3.4.1 Groundwater Elevation

3.4.1.1 Identification of Undesirable Results

SGMA defines undesirable results related to groundwater levels as chronic lowering of groundwater levels indicating a significant and unreasonable depletion of supply if continued over the GSP planning and implementation horizon. Lowering of water levels during a period of drought is not the same as (and does not constitute) chronic lowering of groundwater levels “if extractions and groundwater recharge are managed as necessary to ensure that reductions in groundwater levels or storage during a period of drought are offset by increases in groundwater levels or storage during other periods” (California Water Code 10721(x)(1)).

~~Chronic lowering of groundwater levels is considered significant and unreasonable when a significant number of private, agricultural, industrial, and municipal production wells can no longer provide enough groundwater to supply beneficial uses. SGMA defines undesirable results related to groundwater levels as chronic lowering of groundwater levels indicating a significant and unreasonable depletion of supply if continued over the planning and implementation horizon. Lowering of water levels during a period of drought is not the same as (and does not constitute) chronic lowering of groundwater levels “if extractions and groundwater recharge are managed as necessary to ensure that reductions in groundwater levels or storage during a period of drought~~

~~are offset by increases in groundwater levels or storage during other periods" (California Water Code 10721 (x)(1)).~~

Multiple ~~D~~discussions, driven by stakeholders and with input from technical advisors, the GSA, and members of the public, were used to define what constitutes an undesirable result due to the chronic lowering of groundwater levels. ~~Potential impacts and the extent to which they are considered significant and unreasonable were determined by the GSA with input by technical advisors and members of the public.~~ During development of the GSP, ~~potential undesirable results~~concerns that were identified by stakeholders and the advisory committee related to groundwater level decline included~~ include~~ ~~a significant and unreasonable~~:

- ~~Excessive~~ The number of domestic, ~~domestic,~~ public~~,~~ or agricultural wells going dry.
- ~~Excessive~~ The reduction in the pumping capacity of existing wells.
- ~~Excessive increase in pumping costs due to greater lift.~~
- ~~Excessive~~ The need for deeper well installations or lowering of pumps.
- ~~Excessive financial burden from the above undesirable results.concerns~~
- ~~Adverse iImpacts t~~The significant reduction in spatial coverage and/or health of GDEs in the Basin~~o~~ ~~environmental uses and users, including ISWs and GDEs.~~

Based on additional recent input from stakeholders, the advisory committee, and the GSA identified the undesirable result as a significant, non-mitigatable long-term reduction in the viability of groundwater to support environmental uses and users or to supply private, agricultural, industrial, and municipal production wells over the planning and implementation period of this GSP. Domestic wells were identified as the wells most vulnerable to well failure. Specifically, the failure of more than 20% of domestic wells (more than approximately 40-50 domestic wells) over the planning and implementation period of this GSP was identified as a non-mitigable outcome.

The sustainability goal and the undesirable results above provide the qualitative basis for the **quantitative identification of undesirable results**, which must be based on evaluating conditions at individual representative monitoring sites in the Basin, as described in **Section 3.3.1**:

Operationally, an undesirable result for groundwater levels occurs if the fall low water level observation (i.e., the minimum elevation in any given water year) in 25% (more than 3 wells with the current monitoring network) of the representative monitoring sites in the Basin fall below their respective minimum thresholds (MT) over two consecutive years. Groundwater levels that fall below the MT repeatedly would indicate the failure of a succession of projects and management actions (PMAs; see Chapter 5) over a significant area of the basin.

No other federal, state, or local standards exist for chronic lowering of groundwater elevations.

The operational, quantitative definition of the undesirable result considers short-term climate and hydrologic variability and focuses on longer-term trends in groundwater levels outside of individual water year types. The 25% threshold means that undesirable results would occur when more than three of the representative monitoring points fall below their minimum thresholds over two consecutive years. Using a value of more than three wells in the definition ensures consideration of conditions at multiple locations in the Basin, as opposed to localized changes in groundwater levels. Defining undesirable results as occurrences over a timespan longer than one year focuses the definition on persistent declines in groundwater levels as opposed to an isolated event. A singular year of lowering of groundwater levels during dry or critically dry conditions is not considered significant and unreasonable if precipitation conditions, or implementation of project and management actions recover groundwater levels in the subsequent year or years.

Additionally, the representative monitoring points used to define an undesirable result have varying well depths. There are large variations in the depths of groundwater wells in the RMP network, ranging from 104 to 1,237 ft, with some at unknown depths. This variation in well depth may result in some wells going dry as isolated occurrences, as opposed to being reflective of Basin-wide conditions. As minimum thresholds for groundwater levels are defined at individual sites (see **Section 3.3.1**), isolated areas may experience temporary decreases below the minimum threshold that are not representative of overall conditions in the Basin.

This quantitative definition of undesirable results was determined following discussions during advisory committee and Board meetings, with input from committee members, members of the public, and technical advisors. The definition of undesirable results considers the ability of the GSA to mitigate for individual wells going dry. The mitigation is designed to avoid detrimental economic impacts on users that rely on groundwater. The GSA is also aware of the need to maintain the Human Right to Water (AB 685), i.e. the right to safe, clean, affordable, and accessible water. Consideration of impacts to domestic well users, and the GSA's ability to mitigate impacts to domestic wells is a major component of both the qualitative and quantitative undesirable result definitions.

The GSA recognizes that under this definition, individual wells may still go dry without an undesirable result occurring. From 2015 through 2042, based on the well outage analysis included as Appendix 3-C, 12 percent of all domestic wells or 28 domestic wells that were not already dry in 2015, may be at risk of going dry if water levels across the Basin fall to the minimum threshold. This is well below the fraction of total domestic wells (20%, or 48 wells, see above) identified as the maximum domestic well outages that can reasonably be mitigated by the GSA. Many of the shallowest wells are private domestic wells. Using one or several shallow domestic wells to indicate the occurrence of undesirable results in the Basin is impractical in the SGMA context, and not an accurate reflection of overall Basin conditions. On the other hand, private shallow domestic wells may fail for a variety of reasons, including deterioration due to age, equipment exceeding its useful life, or a drop in groundwater level below the screened portion of the well. . Private wells which are adversely impacted by a lowering of groundwater levels may be mitigated through well deepening or construction of a deeper well to ensure a continued viable water supply.

To address the issue of wells going dry, the GSA is developing a well mitigation program to address impacts to domestic and municipal well owners. The development and implementation of this plan will be managed by a Domestic Well Advisory Group, a subcommittee that will work closely with the Butte Valley Advisory Committee and the GSA. Details on the progress and overall timeline for this effort can be found under **Chapter 4: Project and Management Actions.** The GSA will be working with the Office of Emergency Services and other relevant local, state and federal agencies to develop and acquire revenue sources to assist well owners in mitigating well outages. Based on the revised well failure analysis (see Appendix 3-C), a total of 14 domestic wells from 2023 to 2042 are estimated to be at risk of well outages if groundwater levels fall to the minimum threshold. If assumed to occur gradually over this entire 19-year period, that would equate to around one well per year falling dry, a number that the GSA considers reasonable to mitigate.

Undesirable results were defined to consider all beneficial uses and users, including the agricultural users that form the foundation of the economy in the Basin. Defining undesirable results to occur with a single well going dry would result in detrimental impacts to these users, and consequently to the Basin’s economy, T~~t~~herefore the advisory committee and the GSA Board agreed to define the undesirable result associated with groundwater levels as more than 25% of the RMPs falling below their minimum thresholds.

Undesirable results have been defined based on a consideration of social, environmental, and economic perspectives and were designed with consideration for agricultural, municipal, and environmental uses and users in the Basin. The sustainable management criteria are defined in a way that allows groundwater levels to decline from current conditions temporarily during the GSP implementation period, with the ultimate objective of long-term maintenance of groundwater levels within the measurable objective range. The gap between minimum thresholds and measurable objectives is designed to allow operational flexibility for droughts and provide time to see benefits from implemented PMAs. The minimum thresholds and measurable objectives are described in detail in subsequent sections

Potential Causes of Undesirable Results

Basin’s groundwater pumping currently ~~does not exceed the~~slightly exceeds the estimated sustainable yield of the Basin (see updated sustainable yield discussion in ~~i.e., pumping does not exceed recharge;~~ Chapter 2.2.5). The long-term, multi-decadal decline in water levels in the Basin has several possible causes other than pumping in excess of recharge that would continue to lower water levels and cause undesirable results if continued into the future:

- A significant (continued) increase in Basin pumping volumes, forcing the groundwater system to a new dynamic equilibrium, that is causing water levels to fluctuate around a larger mean depth (lower mean water level), but following similar seasonal and interannual (dry year/wet year) patterns (see Chapter 2).
- A significant reduction in natural recharge as a result of climate change, or other sources that reduce groundwater inflow, forcing the groundwater system to a new dynamic equilibrium at a lower range of water levels.

- A significant reduction in groundwater inflow from surrounding volcanic uplands as a result of reduced recharge across the watershed, forcing the groundwater system to a new dynamic equilibrium at a lower range of water levels.
- A significant lowering of water levels in the downgradient regions of the Basin, i.e., in areas to the east and northeast of the Mahogany range, increasing the groundwater outflow from the Basin to downgradient regions. This also forces the groundwater system to a new dynamic equilibrium at a lower range of water levels.

Changes in pumping distribution and volume may occur due to significant rural residential, agricultural, and urban growth that depend on groundwater as a water supply. Climate change or an extended drought can lead to rainfall reductions, prolonged periods of lowered groundwater levels, and reduced recharge.

Reductions in groundwater flowing into the Basin may also result from expansion of groundwater wells outside the Basin border, within the larger watershed upgradient and downgradient from the Basin. Relevant policies regarding management of groundwater outside the Basin are discussed in Section 2.1.4.

The Basin is significantly interconnected with the volcanic groundwater system of the surrounding Watershed. Most precipitation in the larger watershed occurs to the south and southwest of the Basin and flows via recharge and groundwater rather than in streams toward and into the Basin. Groundwater not used for consumptive use in the Basin is discharging via the subsurface to the east and northeast of the Basin into the adjacent volcanic groundwater system and out of the Watershed. Water levels in the Basin are therefore significantly controlled by groundwater recharge into the volcanic groundwater system upgradient and downgradient of the Basin (Chapter 2).

Climate change is expected to raise average annual temperatures and intensify rainfall periods while extending dry periods. Together with resulting vegetation changes in surrounding uplands, climate change may significantly increase or decrease recharge compared to historic conditions (Figure 3.9; see CDWR 2021). If climate change were to lead to reduced recharge in surrounding uplands, upgradient and downgradient from the Basin, upgradient groundwater inflow to the Basin and water levels downgradient of the Basin will be lower, thus reducing the equilibrium water level in the Basin. On the other hand, if climate change leads to future increased recharge in the surrounding uplands, this would be raising water levels in the Basin.

The GSA will coordinate with relevant agencies and stakeholders within the Basin and the larger Watershed to implement PMAs to sustainably manage groundwater levels in the Basin.

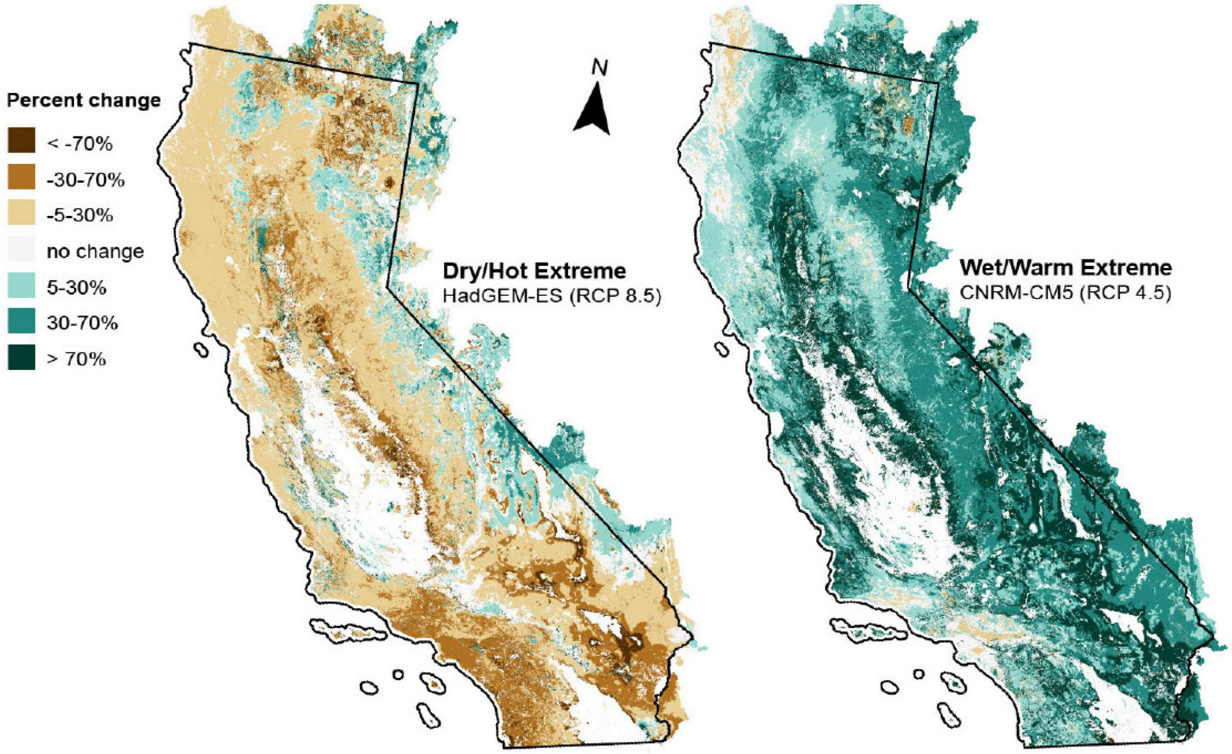


Figure 3.6: Relative change in average annual natural recharge, not accounting for irrigation return flows, under two possible future climate scenarios (CDWR 2021).

Potential Effects of Undesirable Results on Beneficial Uses and Users of Groundwater

Undesirable results associated with chronic lowering of groundwater levels primarily impact groundwater users and environmental users such as groundwater dependent ecosystems.

- **Municipal Drinking Water Users** - Undesirable results due to declining groundwater levels can adversely affect current and projected municipal users, causing increased costs for potable water supplies.
- **Rural and/or Agricultural Residential Drinking Water Users** - Falling groundwater levels can cause shallow domestic and stock wells to go dry, which may require well owners to drill deeper wells or lower pumps, both of which may pose financial burdens to well owners. Under undesirable result conditions, based on the well outage analysis (Appendix 3-C), 12 percent of wells (currently estimated as 28 domestic wells, given the number of domestic and "missing" planned use wells identified in DWR's OSWCR database) may be impacted by well outages. Additionally, the lowering of the water table may lead to decreased groundwater quality drinking water wells.
- **Agricultural Users** - Excessive lowering of groundwater levels could necessitate changes in irrigation practices and crops grown and could cause adverse effects to property values and the regional economy.
- **Environmental Uses** – Lowered groundwater levels may result in a significant -reduction of groundwater supply to GDEs. This may result in insufficient connection of GDEs to groundwater which may result in impaired GDE health or overall reduction of spatial coverage

in the Basin. There are no streams within the Butte Valley basin, and the spatial extent of GDEs is not fully defined at this time.

Undesirable results associated with chronic lowering of groundwater levels were defined to avoid the impacts listed above. Impacts to beneficial users in the first three groups above, at the MT, will be addressed through project and management actions, including development of a well mitigation program (see Chapter 4). To avoid undesirable results to environmental uses, the GSA will expand upon historic monitoring and assessment efforts to fill data gaps, and then adjust the definition of undesirable result, as necessary to include metrics for GDEs. A key component of implementation slated for the first five years of GSP implementation includes working with biologists to clarify GDE location and spatial extent, and to identify key metrics for tracking GDE health. Groundwater level monitoring sites as well as stream gages have already been added in areas identified as potential GDEs in Chapter 2, as shown in Figure 2.3.2 to ensure tracking of groundwater conditions and inflow from the watershed in these areas

3.4.1.2 Minimum Threshold

The GSP regulations define minimum thresholds for chronic lowering of groundwater levels as “the groundwater level indicating a depletion of supply at a given location that may lead to undesirable results” and shall be supported by “the rate of groundwater elevation decline based on historical trends, water year type, and projected water use in the basin” and “potential effects on other sustainability indicators”. (23 CCR § 354.28)

Minimum thresholds (MT) for groundwater levels in the Basin are defined using existing groundwater level data, have been developed in consultation with the GSA advisory committee and stakeholders. This definition stems from the goal of slowing (and stopping/improving by 2042) current groundwater decline and providing operational flexibility in the implementation period, with the ultimate goal of reaching and sustaining groundwater levels at the measurable objective (MO).

The~~Resulting from this process,~~ MTs are set using a combination of historical measured water level depths, to enable a~~n~~ “~~extended~~ soft landing” by the year 2042. ~~The “extended soft landing” is defined as 15 feet below a conceptual “soft landing” approach (see below). The “soft landing” approach to managing water levels is analogous to smoothly landing a plane at a moderate, controlled speed.~~ Groundwater levels might decline beyond baseline (pre-2015) levels but remain above the MT while PMAs are implemented to achieve the measurable objective (MO). PMAs for groundwater levels are described in Chapter 4.

MTs are tailored to each individual well in the representative monitoring network, to accommodate differences in groundwater conditions across the Basin. Well hydrograph models projected 2042 groundwater elevations based on a selected base period (1999 to 2014), as shown in Figure 3.8. The ~~RMS~~RMP hydrographs are included in Appendix 3-C. All MTs were chosen to account for the natural delayed response of groundwater levels to PMAs (Figure 3.7).

Thresholds were set after an analysis of projected well outages (see Section 3.4.1.5). A well outage is defined by the inability to pump groundwater from the affected well due to declining groundwater levels. Results from the well outage analysis indicate that if water levels across the Basin fall to the MT, only 12 percent of shallow domestic wells in the Basin may be at risk for well outages, 10 total agricultural wells, and no public supply wells will be at risk of a well outage.

The ~~“soft landing” trigger and the “extended soft landing”~~ MTs are specific to each RMP. The following mathematical method was used to set the MT at each RMP in a hydrologically consistent manner such that the undesirable results identified above are avoided when water levels are at the MT:

A regression line is fitted to the fall water level measurements at the RMP for the 15-year period from fall 1999 to fall 2014. The slope or beta (β) of the regression line corresponds to the average rate of decline in fall water levels, measured in feet per year, over this 15-year period. The water level depth of the regression line in fall 2014 is denoted as “WL_Depth_Regression_F2014” in the equation below (Figure 3.8).

The ~~soft-landing trigger~~MT is computed by extending the regression line to 2042, then “bending” it to a flattening landing approach by allowing for ~~only~~ at most 75% of the total decline that the regression curve provides for the 27-year period from fall 2014 to fall 2041 (immediately prior to the January 1, 2042 SGMA compliance date):

= MT(measured as water depth) = WL Depth Regression F2014~~$soft$~~ ~~(measured as water level depth~~$[ft] + 0.75 * \beta[ft/yr] * 27[yr])$ ~~]~~

~~WL Depth Regression F2014~~

The 75% value (0.75 in the above equation) was selected such that the undesirable result identified above is avoided at the MT. Specifically, using this value avoids the mitigation of 12~~15~~% or more of existing domestic wells due to wells going dry, well below the threshold set for allowable mitigation of dry wells (20% of wells, see description of undesirable results above). At the same time, t~~T~~he ~~soft-landing trigger~~MTs ~~must~~ allow for operational flexibility when water levels fall below~~between~~ the MOs to implement project and management actions in a timely manner to avoid significant and unreasonable undesirable results from occurring within the planning horizon.~~and MTs that cause undesirable results (see below).~~ ~~If~~ For sufficient~~the~~ operational flexibility, ~~or~~ the difference between the ~~soft-landing trigger~~MT and minimum MO (see below), is set to be at least~~less than~~ 5 feet (ft)~~using the above method, the softlanding trigger~~ MT ~~is lowered to 5 feet below the minimum MO~~. Additionally, for wells where the MT ~~is~~based on the approach would be below the screen depth, the MT is set at 5 ft above the total well depth.

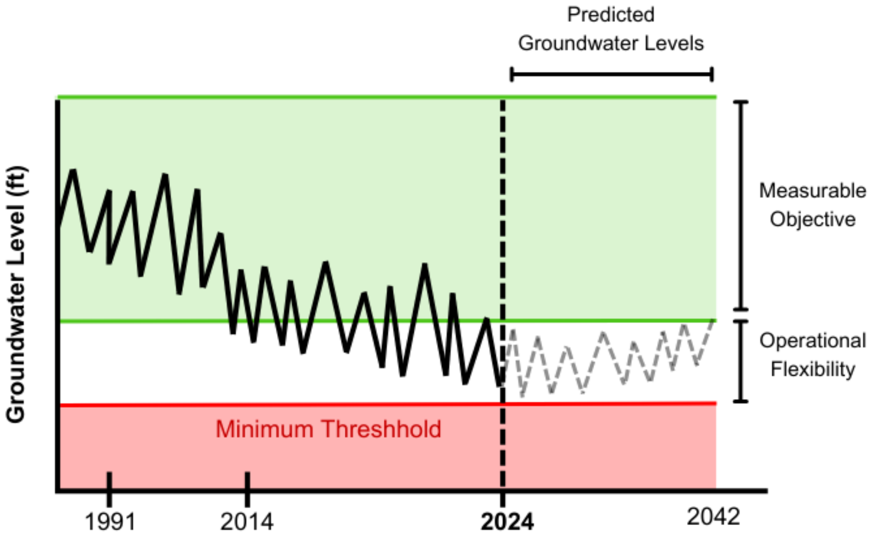
The well failure analysis (see Appendix 3-C) estimates the number of well outages. It was conducted first through an evaluation of reported wells from DWR's OSWCR in Butte Valley groundwater basin. Then, domestic and public well outages are estimated using the most available well construction information (i.e., well depth, top of perforation) and groundwater levels at the reported well locations, which are interpolated using groundwater level measurements across the basin. A well outage was defined as less than 10 ft of the wet depth to bottom of well. The analysis shows that the estimated number of domestic well outage in 2015 is 45 out of the total 247 domestic and public wells identified from OSWCR. The estimated additional domestic well outages from 2015 to 2023 is 14 (6% of the total), and the estimated additional domestic well outages after 2023 to minimum threshold levels is 14 (6% of the total). Ten additional agricultural well outages compared to the condition in 2015 are anticipated if the groundwater levels fall to the minimum threshold. No public supply well outages are anticipated if groundwater levels fall to the minimum threshold.

~~The main undesirable result that will be avoided by the soft-landing trigger are well outages and the cost of drilling deeper wells.~~

~~The "extended soft-landing" MT is a constant additional depth added to the soft-landing trigger, regardless of the RMP. The MT is selected to be 15 feet below the soft-landing trigger. Hence the final MT at a representative monitoring point is:~~ ~~$MT_{extended} = T_{soft} + 15[ft]$~~

~~The extended MT provides the GSA and groundwater users additional operational flexibility, without incurring permanent undesirable results, to address potential consequences of climate change, allowing for some adjustment of the dynamic equilibrium in water levels that occur as a result of lower recharge in the surrounding Watershed, while allowing for continued, full groundwater use. Importantly, maintaining water levels above the MT also avoids conditions of chronic lowering of water levels due to future conditions of overdraft that may result from drastic reductions in Watershed-wide recharge (Figure 3.9).~~

Table 3.4 shows, for each ~~RMPRMS~~RMP, the most recent fall water level (2020), the lowest historic water level measurement and the year of that observation, the value of the regression line in fall 2014 (“*WL_Depth_Regression_F2014*”), the slope (β) of the regression line, the depth of the ~~soft-landing trigger (“*T_soft*”),~~MT the final MT, and the ~~(“*MT_extended*”), and~~ MO.



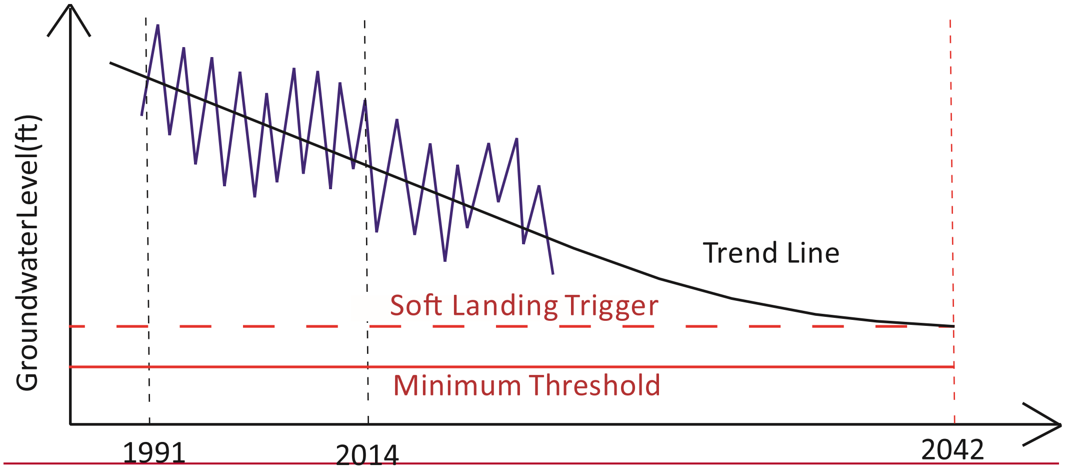
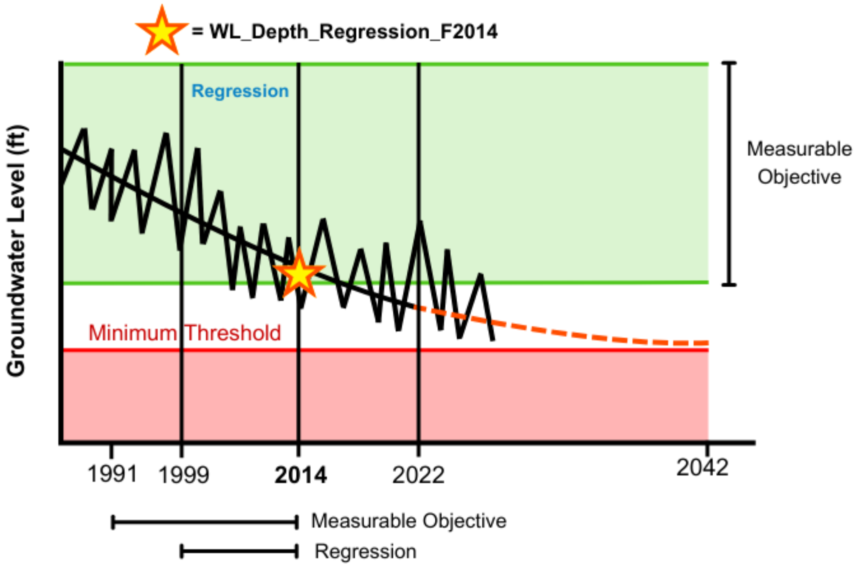


Figure 3.7: The goal for groundwater levels is to slow any groundwater level decline~~ down to the soft-landing trigger and no lower~~during GSP implementation, with the ultimate objective of increasing levels to the MO. The ~~soft-landing trigger~~MT initiates strict management actions to prevent further decline~~ to the MT~~.



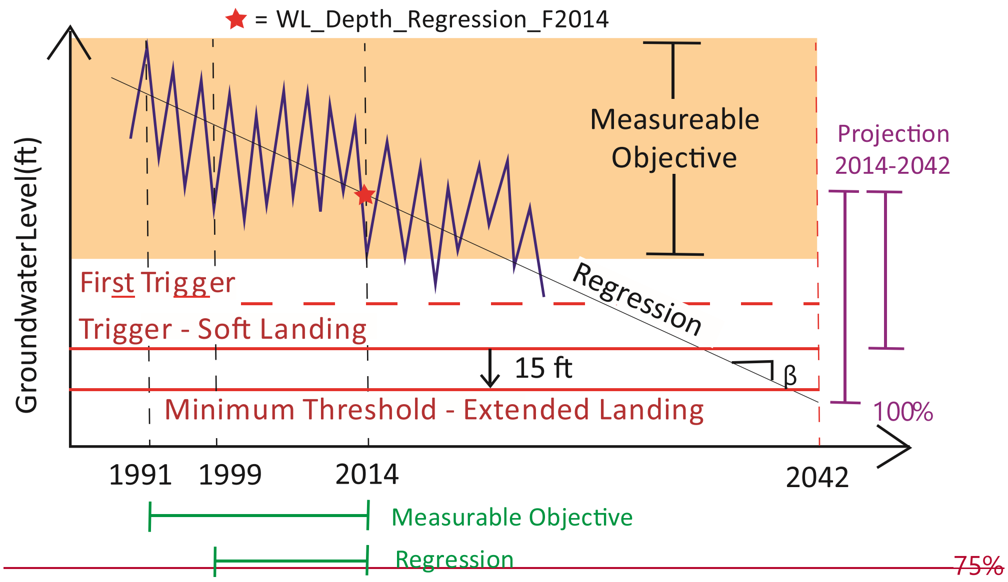


Figure 3.8: Visual description of the MT ~~and soft landing trigger~~ on a hydrograph.

Table 3.4: Groundwater level (WL) minimum thresholds (MT), with units of feet above mean sea level (ft amsl). Abbreviations: minimum threshold (MT), measurable objective (MO), water level (WL), trigger (T), minimum (Min), and maximum (Max).

Representative Monitoring Point/Well	**Fall 2020 WL**	**Historic Low WL (Year)**	**WL Depth Regression F2014**	**Regression Slope (ß) (ft/yr)**	**MT~~T_soft~~**	**~~MT_extended~~**	**MO Min**	**MO Max**
417786N1220041W001	4182.78	4181 (2014)	4181	-1.7954	4163**~~4145~~	~~4130~~	4181	4225
417789N1220759W001	4211.91	4202 (2016)	4215	-0.5916	4203	~~4188~~	4213	4237
417944N1220350W001	4207.83	4184 (2015)	4200	-0.5218	4185***	~~4170**~~	4190	4225
418512N1219183W001	NA*	4190 (2018)	4195	-0.6810	4181	~~4166~~	4193	4214
418544N1219958W001	4208.32	4208 (2019)	4211	-0.8111	4195	~~4180~~	4211	4224
418661N1219587W001	NA*	4186 (2014)	4186	-1.1004	4163	~~4148~~	4186	4214
418948N1220832W001	NA*	4189 (1996)	4193	-1.1538	4170	~~4155~~	4193	4216
419021N1219431W001	NA*	4202 (2015)	4204	-0.7407	4189	~~4174~~	4203	4216
419451N1218967W001	4143.53	4129 (2009)	4145	-0.1611	4124~~4129~~***	~~4114**~~	4129	4158
419519N1219958W001	4226.49	4227 (2018)	4229	-0.3302	4223	~~4208~~	4229	4237
419520N1219959W001	4230.34	4231 (2020)	4232	-0.3095	4226	~~4211~~	4231	4242
419662N1219633W001	4161.66	4162 (2020)	4166	-1.3362	4139	~~4124~~	4161	4199
419755N1219785W001	4168.5	4169 (2020)	4192	-1.0284	4171	~~4156~~	4187	4217

Note:

(*) No fall measurements in 2019 and 2020.

(**) The MT was moved to 5 feet above its bottom of well screen (104 feet below ground surface, 4158 feet above mean sea level).

(***) The ~~soft-landing~~ MT was moved to 5 feet below the MO.

~~Method for Quantitative Measurement of Minimum Thresholds~~

~~MTs and triggers are tailored to each individual well in the representative monitoring network, to accommodate differences in groundwater conditions across the Basin. Well hydrograph models projected 2042 groundwater elevations based on a selected base period (1999 to 2014), as shown in Figure 3.8. The RMP hydrographs are included in Appendix 3-C.~~

~~Thresholds were set after an analysis of projected well outages (see Section 3.4.1.5). A well outage is defined by the inability to pump groundwater from the affected well due to declining groundwater levels. Baseline conditions include well outages that seasonally may occur when groundwater levels are within the MO. For example, wells that tap into the Butte Valley Basalt water-bearing formation sometimes go dry in the summer and fall, under conditions when groundwater levels are within the MO.~~

~~Lastly, thresholds are also set to avoid undesirable results for neighboring groundwater basins. Significant adverse effects to the Lower Klamath Basin, northeast of the Basin are avoided at the current "extended soft landing" MT.~~

3.4.1.3 Measurable Objectives

MOs are defined under SGMA as described above in Section 3.1. Within the Basin, the MOs for groundwater levels are established to provide an indication of desired levels that are sufficiently protective of beneficial uses and users. MOs are defined on a well-specific basis, with consideration for historical groundwater level data.

The MO is defined separately for each RMP, as shown in Figure 3.8. The MO is a range of water levels rather than a single threshold. The upper limit of the MO is the highest observed water level at a RMP in the period from years 1991 to 2014 and the lower limit of the MO is the lowest observed water level at a RMP in the period 1991 to 2014, regardless of whether the water level was observed in the spring or fall season. This will eliminate the threat of well outages and protect beneficial uses in the Basin. MOs are shown in Table 3.4.

The difference in groundwater levels between the lower limit of the MO and MT gives a margin of operational flexibility, or margin of safety, for variation in groundwater levels due to seasonal, annual, or drought variations. Groundwater levels might drop in drought years but rise in wet years to recharge the aquifer and offset drought years. The operational flexibility is shown in Table 3.5. As can be seen from this table, the minimum MO (the lowest historically observed water level depth) is less than 30 feet above the selected MT for most RMP.

~~Management Action Triggers~~

~~If falling groundwater levels activate defined triggers, the GSA will use MAs to proactively avoid the occurrence of undesirable results, as defined in Chapter 4. Triggers are tailored to each representative monitoring point (RMP) based on historical groundwater level trends, and the defined MTs and MOs. The triggers for individual wells in the representative monitoring network are shown in Table 3.5.~~

~~Trigger levels at each RMP are used to gradually increase the intensity of PMAs. The first trigger is exactly halfway between the MO minimum and the soft-landing trigger level. If groundwater elevations fall to this depth, the GSA will initiate MAs to halt further decline. Exceedances of the first trigger level at a single RMP may require only localized management to address falling groundwater levels. If widespread exceedance of the first trigger level occurs, the GSA will initiate more extensive MAs. It will also initiate planning for a well outage program. More rigorous MAs will be activated if groundwater levels fall to the second trigger, the "soft landing" trigger (Chapter 4). MAs will be tailored to avoid reaching the MT ("extended soft landing").~~

3.4.1.4 Path to Achieve Measurable Objectives

The GSA will support achievement of the MOs by reducing the amount of groundwater pumping to the sustainable yield to a not to exceed 65 TAF per year as identified in Chapter 2.2.5 by monitoring groundwater levels and coordinating with agencies and stakeholders within the Basin to implement PMAs. The GSA will also monitor compliance with this identified sustainable yield, to the extent possible, through collection of groundwater extraction data through flowmeters on representative wells. The GSA will review and analyze groundwater level data to evaluate any changes in groundwater levels resulting from groundwater pumping or from PMAs. Using monitoring data collected as part of GSP implementation, the GSA will develop information (e.g., hydrograph plots, BVIHM model information) to demonstrate that PMAs are operating to maintain or improve groundwater level conditions in the Basin and to avoid unreasonable groundwater levels. Should groundwater levels drop to a trigger or MT as the result of GSA project implementation, the GSA will implement measures to address this occurrence. This process is illustrated in Figure 3.9.

To manage groundwater levels, the GSA will partner with local agencies and stakeholders to implement PMAs. PMAs are presented in further detail in Chapter 4. Implementation timelines and approximate costs are discussed in Chapter 5. Examples of possible GSA actions include stakeholder education, ~~and~~ outreach and support for impacted stakeholders, development and implementation of a well mitigation program, groundwater demand management, and development of a preliminary groundwater allocation program.

Where the cause of groundwater level decline is unknown, the GSA may choose to conduct additional or more frequent monitoring and initiate additional groundwater modeling. The need for additional studies on groundwater levels will be assessed throughout GSP implementation. The GSA may identify knowledge requirements, seek funding, and help to implement additional studies.

Table 3.5: Operational flexibility for each representative monitoring well and MA triggers, with units of feet above mean sea level (ft amsl).

Representative Monitoring Point/Well	Top of Screen (ft)	Bottom of Screen (ft)	Measurable Objective Maximum (MO max) (ft)	Measurable Objective Minimum (MO Min) (ft)	~~First Man-agement action Trigger (ft)~~	Minimum Threshold (MT) (ft)~~Soft Landing Trigger (ft)~~	~~Extended Minimum Threshold~~	Operational Flexibility (MO min - MT~~MO - T_soft~~) (ft)	~~Operational Flexibility (MO - MT_Extended) (ft)~~
417786N1220041W001	4222	4158	4225	4181	~~4163.0~~	4163~~4145~~	~~4130~~	18~~36~~	~~51~~
417789N1220759W001	Data Gap	Data Gap	4237	4213	~~4208.0~~	4203	~~4188~~	10	~~25~~
417944N1220350W001	4190~~70~~	4144~~116~~	4225	4190	~~4187.5~~	4185	~~4170~~	5	~~20~~
418512N1219183W001	4216	4096	4214	4193	~~4187.0~~	4181	~~4166~~	12	~~27~~
418544N1219958W001	Data Gap	Data Gap	4224	4211	~~4203.0~~	4195	~~4180~~	16	~~31~~
418661N1219587W001	4181	3937	4214	4186	~~4174.5~~	4163	~~4148~~	23	~~38~~
418948N1220832W001	4079	3829	4216	4193	~~4181.5~~	4170	~~4155~~	23	~~38~~
419021N1219431W001	Data Gap	Data Gap	4216	4203	~~4196.0~~	4189	~~4174~~	14	~~29~~
419451N1218967W001	4167~~87~~	4069~~185~~	4158	4129	~~4126.5~~	4124	~~4109~~	5	~~20~~
419519N1219958W001	Data Gap~~4245~~	4045	4237	4229	~~4226.0~~	4223	~~4208~~	6	~~21~~
419520N1219959W001	Data Gap~~4045~~	3785	4242	4231	~~4228.5~~	4226	~~4211~~	5	~~20~~
419662N1219633W001	4222	3745	4199	4161	~~4150.0~~	4139	~~4124~~	22	~~37~~
419755N1219785W001	4079	4019	4217	4187	~~4179.0~~	4171	~~4156~~	16	~~31~~

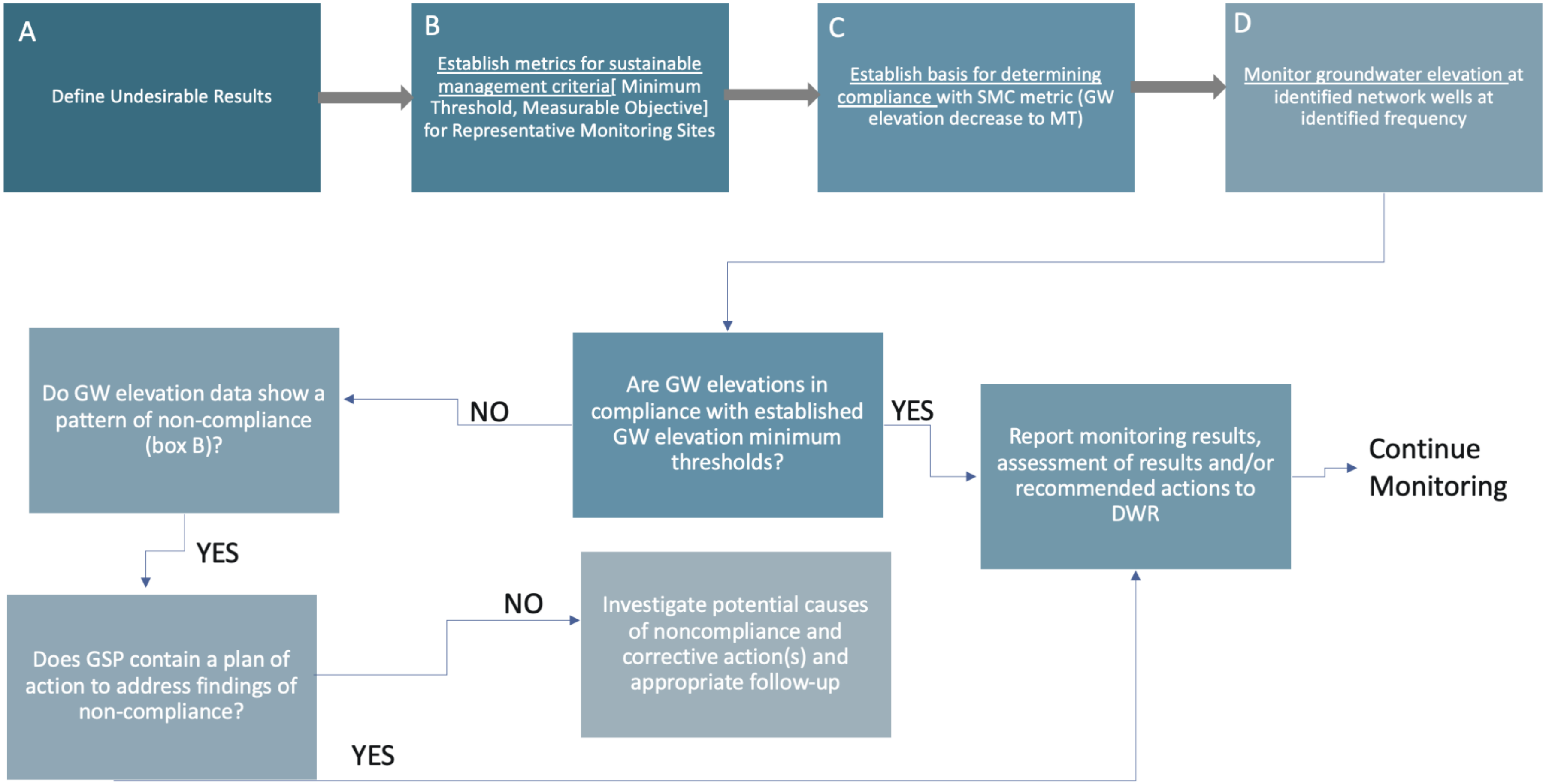
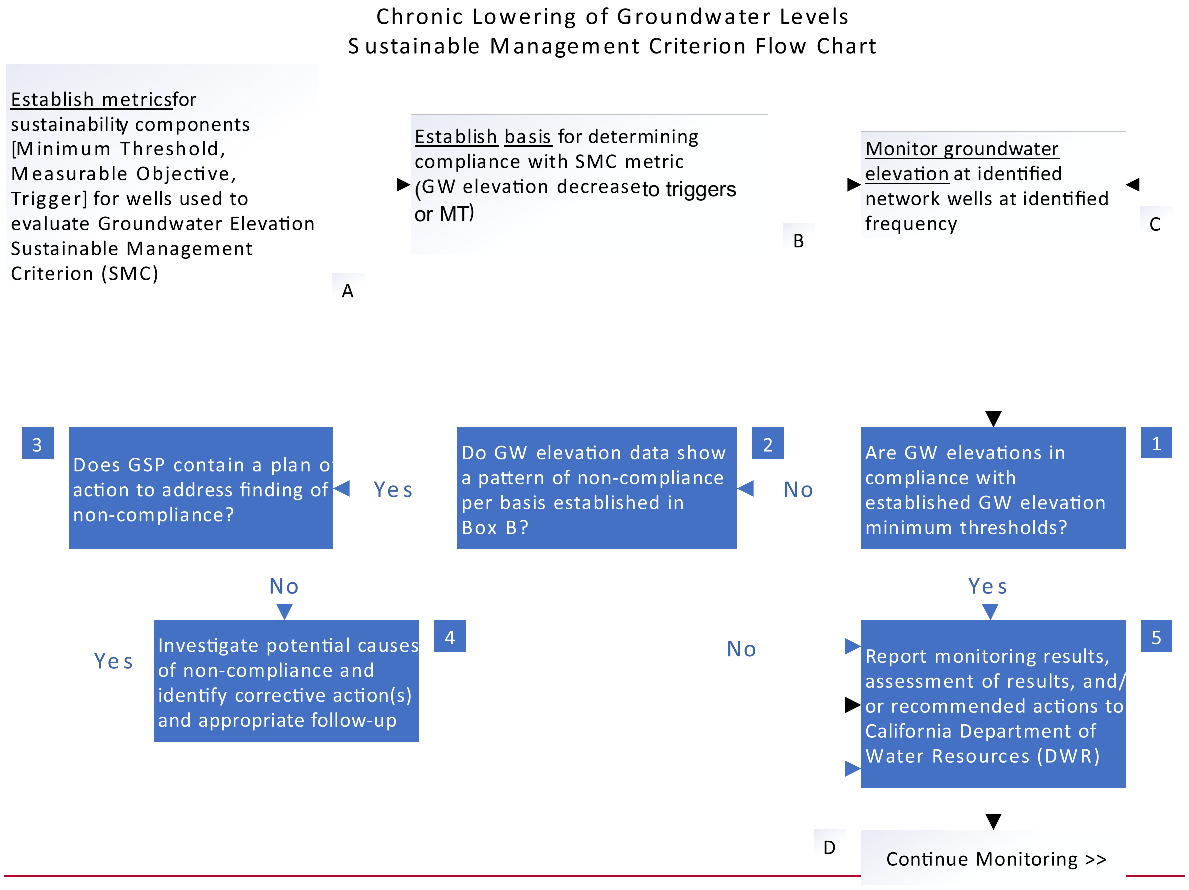


Figure 3.9: Groundwater level SMC flow chart. The flow chart depicts the high-level decision making that goes into developing SMCs, monitoring to determine if criteria are met, and actions to be taken based on monitoring results. Actions are described in Chapter 5.

962



~~Figure 3.9: Groundwater level SMC flow chart. The flow chart depicts the high-level decision making that goes into developing SMCs, monitoring to determine if criteria are met, and actions to be taken based on monitoring results. Actions are described in Chapter 5.~~

Interim Milestones

Groundwater levels are managed to reach the MO by 2042. Interim milestones for groundwater levels were established through review and evaluation of measured groundwater level data and future projected fluctuations in groundwater levels and planned implementation of PMAs. Based on the historical groundwater levels presented in Appendix 3-C, where most hydrographs show leveling off of groundwater decline from 2014 to 2020, all interim milestones are set simply to remain within the MO for each RMP. This interim milestone is already met by most RMP. Remaining wells are expected to reach MO through MAs. At future five-year assessments, the GSA will evaluate if these interim milestones need to be adjusted based on observed groundwater conditions.

3.4.1.5 Minimum Threshold Effects on Beneficial Uses and Users

~~The MT will prevent undesirable results in form of significant numbers of private, agricultural, industrial, and/or municipal production well outages~~Groundwater level MT will primarily impact beneficial uses and users reliant on groundwater and environmental users such as GDEs. ~~Even above the MT, some wells may experience temporary or permanent outages, requiring drilling of deeper wells. This may constitute an undesirable result, as it would effectively increase the cost of using groundwater as a water source to a user, most commonly domestic well users.~~

To better understand the effect on beneficial uses and users, specifically domestic well users, a well failure risk analysis was performed, which is presented in Appendix 3-C. The analysis provides an estimate of the undesirable result that would occur if water levels declined to the MT. Due to data gaps related to well construction details and groundwater levels, the well failure risk analysis focuses on interpolated groundwater elevation data to assess the aggregated risk of wells not being able to pump water due to low water levels ("well outages"). Groundwater levels were interpolated for fall 2015 (dry year) and fall ~~2017~~ 2023 (~~wet year~~most recent fall conditions). Wells were classified by well type (public and~~,~~ domestic~~, agriculture~~) and the ~~dominant~~ geologic formation identified at the bottom of the perforated interval. Results indicate that if water levels were lowered to ~~soft landing trigger level~~MT throughout the Basin, about ~~45~~ 40 to ~~120~~ 120 wells out of approximately 1,000 wells would be at risk of well outage. ~~If water levels will fall to the extended MT across the basin, an additional 15 feet decline at each RMP~~RMS~~, an additional 45 to 120 wells may be at risk of well outage.~~ Well outage risk may also be unevenly distributed across the basin due to varying well characteristics between geologic formations and varying water level declines.

The following provides greater detail regarding the potential impact of poor groundwater level on several major classes of beneficial users:

- **Municipal Drinking Water Users** - ~~Undesirable results due to declining~~declining groundwater levels can adversely affect current and projected municipal users, causing increased costs for potable water supplies.
- **Rural and/or Agricultural Residential Drinking Water Users** - Falling groundwater levels can cause shallow domestic and stock wells to go dry, which may require well owners to drill deeper wells. ~~The MT is expected to cause as much as~~The well outage analysis shows, at the minimum threshold, 12% of domestic/shallow wells in the Basin would be susceptible to well outages. Additionally, the lowering of the water table may lead to decreased groundwater quality in drinking water wells.
- **Agricultural Users** - Excessive lowering of groundwater levels could necessitate changes in irrigation practices and crops grown and could cause adverse effects to property values and the regional economy.
- **Environmental Uses** - Deep groundwater levels may result in significant and unreasonable reduction of groundwater flow toward ~~streams and~~ GDEs, which may adversely impact ecological habitat and resident species, resulting in reduced spatial coverage and/or health. There are no streams entering into the Basin (as the Butte Creek flow is diverted toward Red Rock Valley) and surface water bodies are limited to Meiss Lake, a managed wetland, and several spring-fed creeks. Currently, in the Basin the location of GDEs is a data gap that will be addressed by PMAs including the development of data and mitigation strategies to achieve ~~at~~ the MT.

To avoid undesirable outcomes to the first three beneficial user groups, to the degree they occur at water levels above the MT, the GSA will develop a well ~~replacement~~ mitigation program (Chapter 4). To avoid undesirable outcomes to the fourth group of beneficial uses, the GSA will expand upon historic monitoring and assessment efforts to fill data gaps, then develop mitigation programs or~~then~~ adjust MTs at relevant RMP~~S~~ in future updates to the GSP as needed. The MO is already protective of GDEs, where they exist, as it preserves baseline water levels.

3.4.1.6 Relationship to Other Sustainability Indicators

MTs are selected to also avoid undesirable results for other sustainability indicators. In the Basin, groundwater levels are directly related to groundwater storage and GDEs outside of streams. The relationship between groundwater level MTs and MTs for other sustainability indicators are discussed below.

- **Groundwater Storage** - Groundwater levels are closely tied to groundwater storage, with high groundwater levels related to high groundwater storage. The groundwater storage MTs use the water level MTs as a proxy.
- **Groundwater Quality** - Protecting groundwater quality is critically important to all who depend upon the groundwater resource. A significant and unreasonable condition for degraded water quality is exceeding drinking water standards for constituents of concern in supply wells due to PMAs proposed in the GSP. Groundwater quality could potentially be affected by PMA induced changes in groundwater elevations and gradients. These changes could potentially cause poor quality groundwater to flow towards supply wells that would not have otherwise been impacted.
- **Subsidence** - The MT for land subsidence is to not cause significant additional land subsidence. The water level MT (“extended soft landing”) prevents the subsidence MT from being exceeded.

3.4.1.7 Information and Methodology Used to Establish Minimum Thresholds and Measurable Objectives

The MTs were selected based on historical groundwater level trends and stakeholder input. A detailed discussion of groundwater level trends and current conditions is described in Section 2.2.2.1. In establishing MTs for groundwater levels, the following information was considered:

- Feedback about groundwater level concerns from stakeholders.
- An assessment of available historical and current groundwater level data from wells in the Basin.
- An assessment of potential well outages based on possible MTs.
- Collection of well information regarding water bearing formation, depth, and screen characteristics.
- Results of the completed numerical groundwater model, BVIHM, indicating groundwater flow conditions (Chapter 2).

- Input from stakeholders resulting from the consideration of the above information in the form of recommendations regarding MTs and associated MAs.
- The model and resulting future water budget indicates and supports the finding that the basin is not in overdraft. Management changes that would require significant reductions in groundwater usage are not anticipated at this time.

Based on a review of these data, Basin water needs, and information from stakeholders, the GSA reached the determination to set two tiers – a trigger level and an "extended soft landing" MT. The two tiers give the GSA time to implement PMAs to meet the MO, while addressing anticipated well outages as groundwater levels continue to decline.

3.4.2 Groundwater Storage

Groundwater levels are selected as the proxy for groundwater storage. Hence, the SMCs are identical (Section 3.4.1). According to the USGS, estimates of groundwater storage rely on groundwater level data and sufficiently accurate knowledge of hydrogeologic properties of the aquifer. Direct measurements of groundwater levels can be used to estimate changes in groundwater storage (USGS 2021). As groundwater levels fall or rise, the volume of groundwater storage changes accordingly, where unacceptable groundwater decline indicates unacceptable storage loss. The hydrogeologic model outlined in Chapter 2 provides the needed hydrogeologic properties of the aquifer.

Protecting against chronic lowering of groundwater levels will directly protect against the chronic reduction of groundwater storage as the lowering of groundwater levels would directly lead to the reduction of groundwater storage. There cannot be a reduction in groundwater storage without a commensurate, observable reduction in water levels. There are currently no other state, federal, or local standards that relate to this sustainability indicator in the Basin.

An undesirable result from the reduction of groundwater in storage occurs when reduction of groundwater in storage interferes with beneficial uses of groundwater in the Basin. Since groundwater levels are being used as a proxy, the undesirable result for this sustainability indicator occurs when groundwater levels drop below the extended MT (Table 3.5), as defined by the undesirable result for the chronic lowering of groundwater levels. This should avoid significant and unreasonable changes to groundwater storage, including long-term reduction in groundwater storage or interference with the other sustainability indicators. Possible causes of undesirable reductions in groundwater storage are increases in well density or groundwater extraction or increases in frequency or duration of drought conditions.

The MT for groundwater storage for this GSP is the MT for groundwater levels. Information used to establish MTs and MOs for groundwater levels can be found in Section 3.4.1. Since groundwater storage is defined in terms of water level, Section 3.4.1.2 for the water level indicator equally applies to define the relationship of the groundwater storage SMC to other sustainability indicators.

The MO for groundwater storage is the MO for groundwater levels as detailed in Section 3.4.1.3. The path to achieve MOs and interim milestones for the reduction in groundwater storage sustainability indicator are the same MOs and interim milestones as for the chronic lowering of groundwater levels sustainability indicator detailed in Section 3.4.1.4.

3.4.3 Degraded Groundwater Quality

Groundwater quality in the Basin is generally well-suited for the municipal, domestic, agricultural, and other existing and potential beneficial uses designated for groundwater in the Water Quality Control Plan for the North Coast Region (Basin Plan). Existing groundwater quality concerns within the Basin are identified in Section 2.2.2.3 and the corresponding water quality figures and detailed water quality assessment are included in Appendix 2-B. In Section 2.2.2.3, constituents that are identified as groundwater quality concerns include 1,2 Dibromoethane (ethylene dibromide; EDB), arsenic, benzene, boron, nitrate, and specific conductivity.

SMCs will be defined for a select group of constituents: arsenic, nitrate, and specific conductivity. 1,2 Dibromoethane (ethylene dibromide; EDB) and benzene are already being monitored and managed by the NCRWQCB through the Leaking Underground Storage Tank (LUST) program.

Boron is naturally occurring. As such, SMC for EDB, benzene and boron are not needed. An SMC is defined for arsenic because, while it can be naturally occurring, there is arsenic contamination near Dorris from an unknown historical industrial source. Due to the localized contamination, arsenic SMCs are only defined for wells near Dorris. The GSA will monitor the naturally occurring constituents to track any possible mobilization of elevated concentrations.

The role of the GSA is to provide additional local oversight of groundwater quality, collaborate with appropriate parties to implement water quality projects and actions, and to evaluate and monitor, as needed, water quality effects of projects and actions implemented to meet the requirements of other SMCs. All future PMAs implemented by the GSA will be evaluated and designed to avoid causing undesirable groundwater quality outcomes. Federal and state standards for water quality, water quality objectives defined in the Basin Plan, and the management of known and suspected contaminated sites within the Basin will continue to be managed by the relevant agency. Groundwater in the Basin is used for a variety of beneficial uses which are protected by the NCRWQCB through the water quality objectives adopted in the Basin Plan.

Available historic and current groundwater quality monitoring data and reporting efforts have been used to establish and document conditions in the Basin, as discussed in Section 2.2.2.3. These conditions provide a baseline to compare with future groundwater quality and identify any changes observed, including those due to GSP implementation.

Groundwater quality monitoring in the Basin in support of the GSP will rely on the monitoring network described in Section 3.3.3. Groundwater quality samples will be collected and analyzed in accordance with the monitoring protocols outlined in Section 3.3.3.3. The monitoring network will use information from existing programs in the Basin that already monitor for the constituents of concern, and programs where constituents could be added as part of routine monitoring efforts in support of the GSP. New wells will be incorporated into the network as necessary to fill data gaps.

Because water quality degradation is typically associated with increasing rather than decreasing concentration of constituents, the GSA has decided to not use the term “minimum threshold” in the context of water quality, but instead use the term “maximum threshold.” The use of the term maximum threshold for the water quality SMC in this GSP is equivalent to the use of the term MT in other SMCs or in the SGMA regulations.

3.4.3.1 Undesirable Results

Degraded groundwater quality is considered an undesirable result if concentrations of constituents of concern exceed defined MTs or if a significant trend of groundwater quality degradation is observed for the identified constituents of concern. Groundwater quality changes that occur due to SGMA activities, including current groundwater use and management, may constitute an undesirable result.

For purposes of quantifying and evaluating the occurrence of an undesirable result, the concentration data are aggregated by statistical analysis to obtain spatial distributions and temporal trends. Specifically, statistical analysis is performed to determine the ten-year linear trend in concentration

the $75 conc75$th percentile, $trend75_{10year}$, is obtained. Similarly, the moving two-year average

con-th at each well. This trend is expressed unitless as percent relative concentration change per

year. From the cumulative distribution of all 10-year trends observed across the monitoring

network,

$_{2year}$, is obtained. Concentrations are expressed in their respective concentration units centrations are computed at each well, and from their cumulative distribution the 75 percentile, (μg/L, mg/L, or micromhos). For purposes of this GSP, a “water quality value” is defined by com-

bining the measures of trend and concentration.

$$Water\ quality\ value = Maximum(trend75_{10year} - 15\%, conc75_{2year} - MT)$$

The undesirable result is quantitatively defined as:

$$Water\ quality\ value\ is > 0$$

This quantitative measure assures that water quality remains constant and does not increase by more than 15% per year, on average over ten years, in more than 25% of wells in the monitoring network. Mathematically this can be expressed by the following equation: $trend75_{10year}[\%] - 15\% \leq 0$

It also assures that water quality does not exceed MTs for concentration in more than 25% of wells in the monitoring network. Values for MTs are defined in Section 3.4.3.4. Mathematically, this

second condition can be expressed by the following equation: $conc75_{2year} - MT \leq 0$

The water quality value is the maximum of the two terms on the left-hand side of the above two equations. If either of them exceeds zero, that is, if either of them does not meet the desired condition, then the water quality value is larger than zero and quantitatively indicates an undesirable result.

MTs align with applicable water quality regulations. Groundwater regulatory thresholds are defined by federal and state drinking water standards and Basin Plan water quality objectives. Due to emphasis on local governance, Basin Plan water quality objectives are considered in addition to state or federal drinking water standards. The Basin Plan may set more stringent standards to address local water quality issues or set separate less stringent water standards depending on the beneficial uses (e.g., for agricultural irrigation and stock watering vs. drinking water). With the current Basin Plan, the Butte Valley groundwater aquifer is designated with the beneficial use Municipal and Domestic Supply (MUN) but use of irrigation wells can be managed so that the Basin Plan groundwater water quality objectives are not applicable: if irrigation occurs at agronomic rates (tracked by the user), the irrigation water is only enough for the crops and will not reach the underlying groundwater to cause or contribute to a water quality problem. Then water quality is only evaluated based on values that are harmful to the crop being irrigated.

Due to limited surface water resources in the Basin, groundwater has an important role in supporting beneficial uses including agriculture (a significant part of the local economy), domestic use and municipal water supply. Groundwater is also an important component of streamflow and its water quality benefits instream environmental resources and wildlife. These beneficial uses, among others, are protected by the NCRWQCB through the water quality objectives adopted in the Basin Plan. The Basin Plan defines the existing beneficial uses of groundwater in the Basin: Municipal and Domestic Supply (MUN), Agricultural Supply (AGR), Industrial Service Supply (IND), and Native American Culture (CUL). Potential beneficial uses include Industrial Process Supply (PRO) and Aquaculture (AQUA).

Significant and unreasonable degradation of groundwater quality is the degradation of water quality that would impair beneficial uses of groundwater within the Basin or result in failure to comply with groundwater regulatory thresholds including state and federal drinking water standards and Basin Plan water quality objectives. Based on the State’s 1968 antidegradation policy, water quality degradation that is not consistent with the provisions of Resolution No. 68-16 is degradation determined to be significant and unreasonable. Furthermore, the violation of water quality objectives is significant and unreasonable under the State’s antidegradation policy. The NCRWQCB and the State Water Board are the two entities that determine if degradation is inconsistent with Resolution No. 68-16.

Federal and state standards for water quality, water quality objectives defined in the Basin Plan, and the management of known and suspected contaminated sites within the Basin will continue to be managed by the relevant agency. The role of the GSA is to provide additional local oversight of groundwater quality, collaborate with appropriate parties to implement water quality projects and actions, and to evaluate and monitor, as needed, water quality effects of projects and actions implemented to meet the requirements of other SMCs.

Sustainable management of groundwater quality includes maintenance of water quality within regulatory and programmatic limits (Section 2.2.2.3) while executing GSP PMAs. To achieve this goal, the GSA will coordinate with the regulatory agencies that are currently authorized to maintain and improve groundwater quality within the Basin. This includes informing the NCRWQCB of any issues that arise and working with NCRWQCB to rectify the problem. All future PMAs implemented by the GSA will be evaluated and designed to avoid causing undesirable groundwater quality outcomes. Historic and current groundwater quality monitoring data and reporting efforts have been used to establish and document conditions in the Basin, as discussed in Section 2.2.2.3. These conditions provide a baseline to compare with future groundwater quality and identify any changes observed due to GSP implementation.

Potential Causes of Undesirable Results

Future GSA activities with potential to affect water quality will be monitored and may include changes in location and magnitude of basin pumping, declining groundwater levels and changes to both planned and incidental groundwater recharge mechanisms. Altering the location or rate of groundwater pumping could change the direction of groundwater flow which may result in a change in the overall direction in which existing or future contaminant plumes move thus potentially compromising ongoing remediation efforts. Similarly, recharge activities could alter hydraulic gradients and result in the downward movement of contaminants into groundwater or move groundwater contaminant plumes towards supply wells.

Land use activities that may lead to undesirable groundwater quality include industrial contamination, pesticides, sewage, animal waste, and other wastewaters, and natural causes. Industrial application of wood preservatives can elevate arsenic. Fertilizers and other agricultural activities can elevate analytes such as nitrate and specific conductivity. Wastewater and animal waste can elevate nitrate, and specific conductivity. The GSA cannot control and is not responsible for natural causes of groundwater contamination but is responsible for how PMAs may impact groundwater quality (e.g., through mobilization of naturally occurring contaminants). Natural causes (e.g., local geology and soils) can elevate analytes such as arsenic and specific conductivity. For further detail, see Section 2.2.2.3.

Groundwater quality degradation associated with known sources will be primarily managed by the entity currently overseeing these sites, the NCRWQCB. In the Basin, existing leaks from underground storage tanks (USTs) are currently being managed, and though additional degradation is not anticipated from known sources, new leaks may cause undesirable results due to constituents that, depending on the contents of an UST, may include petroleum hydrocarbons, solvents, or other contaminants.

Agricultural activities in the Basin are dominated by alfalfa, grain and hay, and strawberry. Alfalfa and pasture production have low risk for fertilizer-associated nitrate leaching into the groundwater (Harter et al. 2017). Grain production is rotated with alfalfa production, usually for one year, after which alfalfa is replanted. Grain production also does not pose a significant nitrate-leaching risk. Animal farming, a common source of nitrate pollution in large, confined animal farming operations, is also present in Butte Valley, but not at stocking densities of major concern (Harter et al. 2017). Strawberry production has a potentially high risk for nitrate leaching (Harter et al. 2017) even using advanced irrigation methods due to its shallow rooting depth (Gardenas et al. 2005; Zaragosa et al. 2017). In Butte Valley, strawberry production focuses on plant propagation of daughter plants, which differs in management from berry production. They are regularly grown in a three-year rotation with a grain crop (low nitrate leaching risk) and fallowing (low nitrate leaching risk). With respect to arsenic, a DWR study suggested that the contamination near Dorris stemmed from an unknown historical industrial source (DWR 1968).

3.4.3.2 Maximum Thresholds

MTs for groundwater quality in the Basin were defined using existing groundwater quality data, beneficial uses of groundwater in the basin, existing regulations, including water quality objectives under the Basin Plan, Title 22 Primary Maximum contaminant levels (MCLs), and Secondary MCLs, and consultation with the GSA advisory committee and stakeholders (see Section 2.2.2.3.). Resulting from this process, SMCs were developed for three constituents of concern in the Basin: arsenic, nitrate, and specific conductivity. Although 1,2 Dibromoethane (ethylene dibromide; EDB) and benzene are identified as a potential constituent of concern in Section 2.2.2.3, no SMC is defined for either constituent as current 1,2 Dibromoethane and benzene data are associated with leaking underground storage tanks (LUST) where the source is known and monitoring and remediation are in progress. These sites will be taken into consideration with PMAs undertaken by the GSA, as applicable. Boron does not have an SMC because it is naturally occurring.

The selected MTs for the concentration of each of the three constituents of concern and their associated regulatory thresholds are shown in Table 3.6.

Triggers

The GSA will use concentrations of the identified constituents of concern as triggers for preventive action, in order to proactively avoid the occurrence of undesirable results. Trigger values and associated definitions for specific conductivity are the values and definitions listed in the Basin Plan. The Basin Plan specifies two upper limits for specific conductivity, a 50% upper limit, or 50 percentile value of the monthly means for a calendar year and a 90% upper limit or 90 percentile values for a calendar year. The Title 22 water quality objectives for the remaining analytes are incorporated by reference into the Basin Plan and the triggers provided in Table 3.6 correspond to half and 90% of the Title 22 MCL.

Method for Quantitative Measurement of Maximum Thresholds

Groundwater quality will be measured in representative monitoring wells as discussed in Section 3.3.3. Statistical evaluation of groundwater quality data obtained from available water quality data obtained from the monitoring network will be performed and evaluated using a water quality value using the equation above. The MT for concentration values are shown in Table 3.6. Figure 3.10 shows example “thermometers” for each of the identified constituents of concern in Butte Valley groundwater basin with the associated MT, range of MO, and triggers.

Table 3.6: Constituents of concern and the associated maximum thresholds. Maximum thresholds also include a 15 percent average increase per year over 10 years in no more than 25 percent of wells, and no more than 25 percent of wells exceeding the MT for the concentration listed here.

Constituent	Maximum Threshold	Regulatory Threshold
Arsenic (only wells near Dorris)	5 µg/L, trigger only	10 µg/L (Title 22)
	9 µg/L, trigger only	
	10 µg/L, MT	
Nitrate as Nitrogen	5 mg/L, trigger only	10 mg/L (Title 22)
	9 mg/L, trigger only	
	10 mg/L, MT	
Specific Conductivity	250 micromhos, trigger only	250 micromhos (Basin Plan Upper Limit – 50% of monthly means in a calendar year must be less or equal to 250 micromhos)
	500 micromhos, trigger only	500 micromhos (Basin Plan Upper Limit - 90% of samples in a calendar year must be less or equal to 500 micromhos)
	900 micromhos, MT	900 micromhos (Title 22)

3.4.3.3 Measurable Objectives

MOs are defined under SGMA as described above in Section 3.1. Within the Basin, the MOs for water quality are established to provide an indication of desired water quality at levels that are sufficiently protective of beneficial uses and users. MOs are defined on a well-specific basis, with consideration for historical water quality data.

Description of Measurable Objectives

The groundwater quality MOs for wells within the GSA monitoring network, where the concentrations of constituents of concern historically have been below the MTs for water quality in recent years, is to continue to maintain concentrations at or below the current range, as measured by longterm trends. To establish a quantitative MO that protects uses and users from unreasonable water quality degradation, the GSA has decided to establish a list of constituents of concern (COCs). The MO is defined using those COCs, which include arsenic, nitrate, and specific conductivity.

Specifically, for these COCs, the MO is to maintain groundwater quality at a minimum of 75% of wells monitored for water quality within the range of the water quality levels measured over the past 30 years (1990 to 2020). In addition, no significant increasing long-term trends should be observed in levels of constituents of concern.

3.4.3.4 Path to Achieve Measurable Objectives

The GSA will support the protection of groundwater quality by monitoring groundwater quality conditions and coordinating with other regulatory agencies that work to maintain and improve the groundwater quality in the Basin. All future PMAs implemented by the GSA will comply with State and Federal water quality standards and Basin Plan water quality objectives and will be designed to maintain groundwater quality for all uses and users and avoid causing unreasonable groundwater quality degradation. The GSA will review and analyze groundwater monitoring data as part of GSP implementation in order to evaluate any changes in groundwater quality resulting from groundwater pumping or recharge projects (anthropogenic recharge) in the Basin. The need for additional studies on groundwater quality will be assessed throughout GSP implementation. The GSA may identify knowledge requirements, seek funding, and help to implement additional studies.

Using monitoring data collected as part of project implementation, the GSA will develop information (e.g., time-series plots of water quality constituents) to demonstrate that PMAs are operating to maintain or improve groundwater quality conditions in the Basin and to avoid unreasonable groundwater quality degradation. Should the concentration of a constituent of interest increase to its MO (or a trigger value below that objective specifically designated by the GSA) as the result of GSA project implementation, the GSA will implement measures to address this occurrence. This process is illustrated in Figure 3.11.

If a degraded water quality trigger is exceeded, the GSA will investigate the cause and source and implement MAs as appropriate. Where the cause is known, PMAs with stakeholder education and outreach will be implemented. Examples of possible GSA actions include notification and outreach with impacted stakeholders, alternative placement of groundwater recharge projects, and coordination with the appropriate water quality regulation agency. PMAs are presented in further detail in Chapter 4.

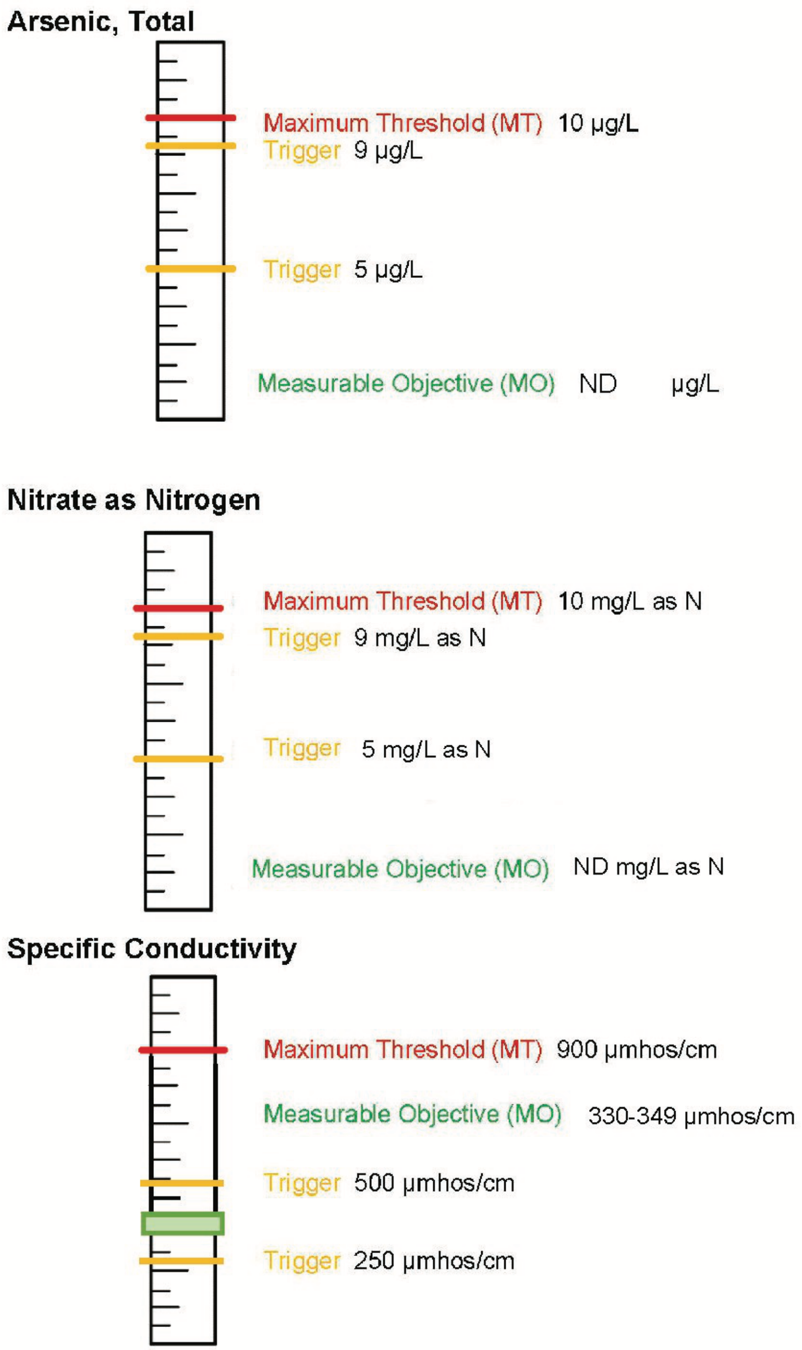


Figure 3.10: Visual Representation of the SMCs of Arsenic, Nitrate, and Specific Conductivity for Well 4710001-003 of the Monitoring Network. MOs are specific to each well in the monitoring network. If the measurable objective is higher than one of the triggers, then that particular trigger is not applicable to that well.

Exceedances of arsenic, nitrate, and specific conductivity will be referred to the NCRWQCB. Where the cause of an exceedance is unknown, the GSA may choose to conduct additional or more frequent monitoring.

Interim Milestones

As existing groundwater quality data indicate that groundwater in the Basin generally meets applicable state and federal water quality standards, the objective is to maintain existing groundwater quality. Interim milestones are therefore set equivalent to the MOs with the goal of maintaining water quality within the historical range of values.

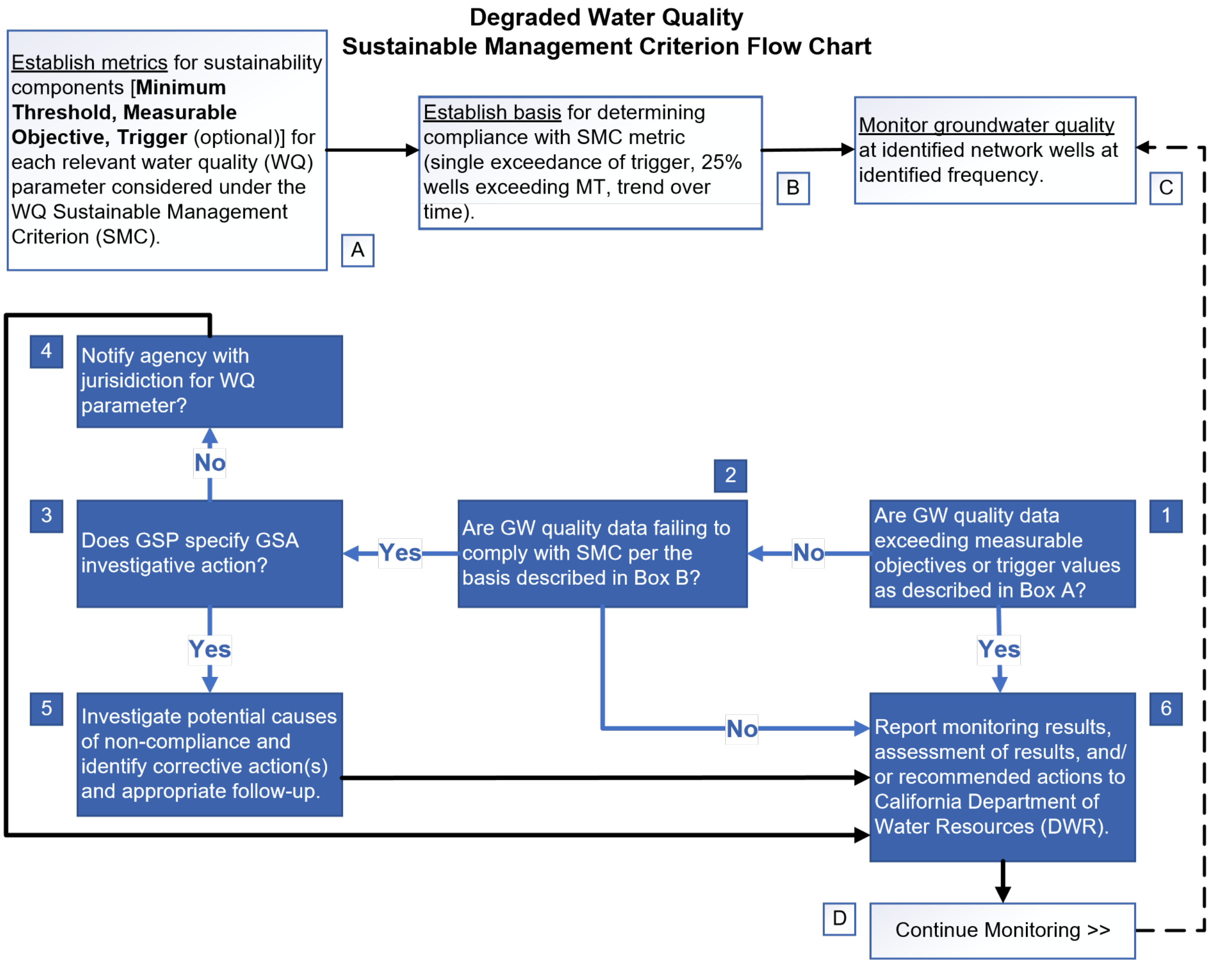


Figure 3.11: Degraded SMC criteria flow chart. The flow chart depicts the high-level decision making that goes into developing SMC, monitoring to determine if criteria are met, and actions to be taken based on monitoring results.

3.4.3.5 Effects on Beneficial Uses and Users

Concerns over potential or actual non-attainment of the beneficial uses designated for groundwater in the Basin are and will continue to be related to certain constituents measured at elevated or increasing concentrations, and the potential local or regional effects that degraded water quality have on such beneficial uses.

The following provides greater detail regarding the potential impact of poor groundwater quality on several major classes of beneficial users:

- **Municipal Drinking Water Users** - Under California law, agencies that provide drinking water are required to routinely sample groundwater from their wells and compare the results to state and federal drinking water standards for individual chemicals. Groundwater quality that does not meet state drinking water standards may render the water unusable or may cause increased costs for treatment. For one municipal supplier in the Basin, shallow impacted wells forced the city to develop a new supply well to access deep unaffected groundwater (Bray & Associates 2015).
- **Rural and/or Agricultural Residential Drinking Water Users** - Residential structures not located within the service areas of the local municipal water agency will typically have private domestic groundwater wells. Such wells may not be monitored routinely and groundwater quality from those wells may be unknown unless the landowner has initiated testing and shared the data with other entities. Degraded water quality in such wells can lead to rural residential use of groundwater that does not meet potable water standards and results in the need for installation of new or modified domestic wells and/or well-head treatment that will provide groundwater of acceptable quality.
- **Agricultural Users** - Irrigation water quality is an important factor in crop production and has a variable impact on agriculture due to different crop sensitivities. Impacts from poor water quality may include declines in crop yields, crop damage, or alter which crops can be grown in the area.
- **Environmental Uses** - Poor quality groundwater may result in migration of contaminants which could impact GDEs or instream environments, and their resident species, to which groundwater contributes.

3.4.3.6 Relationship to Other Sustainability Indicators

Groundwater quality cannot typically be used to predict responses of other sustainability indicators. However, groundwater quality may be affected by groundwater levels and reductions in groundwater storage. In addition, certain implementation actions may be limited by the need to achieve MTs for other sustainability indicators.

- **Groundwater Levels** - Declining water levels can potentially lead to increased concentrations of constituents of concern in groundwater and may alter the existing hydraulic gradient and result in movement of contaminated groundwater. Changes in water levels may also mobilize contaminants that may be present in unsaturated soils. The MTs established for groundwater quality may influence groundwater level MTs by affecting the location or number of projects, such as groundwater recharge, in order to avoid degradation of groundwater quality.
- **Groundwater Storage** - The groundwater quality MTs will not cause groundwater pumping to exceed the sustainability yield and therefore will not cause exceedances of the groundwater storage MTs.
- **Depletion of Interconnected Surface Waters** - The groundwater quality MT does not promote additional pumping or lower groundwater levels near interconnected surface waters. The groundwater quality MT does not negatively affect ISWs.

- **Seawater Intrusion** - This sustainability indicator is not applicable in this Basin.
- **Subsidence** - The groundwater quality MT does not promote additional pumping or lower groundwater levels and therefore does not interfere with the subsidence MT.

3.4.3.7 Information and Methodology Used to Establish Maximum Thresholds and Measurable Objectives

The constituents for which SMC were considered were specifically selected due to measured exceedances in the past 30 years, known groundwater contamination at LUST sites, and/or stakeholder input and prevalence as a groundwater contaminant in California. A detailed discussion of the concerns associated with elevated levels of each constituent of interest is described in Section 2.2.2.3. As the constituents of concern were identified using current and historical groundwater quality data, this list may be reevaluated during future GSP updates. In establishing MT for groundwater quality, the following information was considered:

- Feedback about water quality concerns from stakeholders.
- An assessment of available historical and current groundwater quality data from production and monitoring wells in the Basin.
- An assessment of historical compliance with Federal and state drinking water quality standards and water quality objectives.
- An assessment of trends in groundwater quality at selected wells with adequate data to perform the assessment.
- Information regarding sources, control options and regulatory jurisdiction pertaining to constituents of concern.
- Input from stakeholders resulting from the consideration of the above information in the form of recommendations regarding MTs and associated MAs.

The historical and current groundwater quality data used in the effort to establish groundwater quality MTs are discussed in Section 2.2.2.3. Based on a review of these data, applicable water quality regulations, Basin water quality needs, and information from stakeholders, the GSA reached a determination that the state drinking water standards (MCLs and water quality objectives [WQOs]) are appropriate to define MTs for groundwater quality. These MTs are summarized in Table 3.6. The established MTs for groundwater quality protect and maintain groundwater quality for existing or potential beneficial uses and users. For most analytes, the MTs align with the state standards listed in Title 22 of the California Code of Regulations (CCR), which lists the state regulations for drinking water.

New constituents of concern may be added with changing conditions and as new information becomes available.

3.4.4 Subsidence

3.4.4.1 Undesirable Results

An undesirable result occurs when subsidence substantially interferes with beneficial uses of groundwater and land uses. Subsidence occurs as a result of compaction of fine-grained aquifer materials (i.e., clay) due to the overdraft of groundwater. The fine-grained sediment in the lake deposits may have some land subsidence risk when groundwater levels drop. Undesirable results would occur when substantial interference with land use occurs, including significant damage to critical infrastructure such as canals, pipes, or other water conveyance facilities, including flooding agricultural practices. As there has not been any historical documentation of subsidence in the Basin, it is reasonable to declare that measurable land subsidence caused by the chronic lowering of groundwater levels occurring in the Basin would be considered an unreasonable result. This is quantified as pumping induced subsidence greater than the minimum threshold of 0.1 feet (0.03 meters) in any single year, essentially zero subsidence accounting for measurement error.

3.4.4.2 Minimum Thresholds

The MT for land subsidence in the Basin is set at no more than 0.1 feet (0.03 meters) in any single year, resulting in no long-term permanent subsidence. This is set at the same magnitude of estimated error in the InSAR data (+/- 0.1 feet [0.03 meters]), which is currently the only tool available for measuring basin-wide land subsidence consistently each year in the Basin.

The MTs selected for land subsidence for the Basin area were selected as a preventative measure to ensure the maintenance of current ground surface elevations and as an added safety measure for potential future impacts not currently present in the Basin and nearby groundwater Basins. This avoids significant and unreasonable rates of land subsidence in the Basin, which are those that would lead to a permanent subsidence of land surface elevations that would impact infrastructure and agricultural production in Butte Valley and neighboring groundwater Basins. There are currently no other state, federal, or local standards that relate to this sustainability indicator in the Basin.

3.4.4.3 Measurable Objectives

MOs are defined under SGMA as described above in Section 3.1. Within the Basin, the MO for subsidence is established to protect beneficial uses and users. The guiding MO of this GSP for land subsidence in the Basin is the maintenance of current ground surface elevations. This MO avoids significant and unreasonable rates of land subsidence in the Basin, which are those that lead to a permanent subsidence of land surface elevations that impact infrastructure and agricultural production.

The lake sediments in Butte Valley offer some land subsidence risk; however, there is no historical record of subsidence in the Basin (see Section 2.2.2.5). Recent InSAR data show no significant subsidence occurring during the period of mid-June 2015 to mid-September 2019 (see Figure 2.25 in Chapter 2).

Land subsidence in the Basin is expected to be managed through the implementation period via the sustainable management of groundwater pumping through the groundwater level MO, MT, and interim milestones. The margin of safety for the subsidence MO was established by setting a MO to maintain current land surface elevations and opting to monitor subsidence throughout the GSP implementation period. This is a reasonable margin of safety based on the past and current aquifer conditions (see Section 2.2.2.5).

3.4.4.4 Path to Achieve Measurable Objectives

Land subsidence in the Basin will be quantitatively measured by use of InSAR data (DWR-funded TRE ALTAMIRA or other similar data products). If there are areas of concern for inelastic subsidence in the Basin (i.e., exceedance of MTs) observed in the InSAR data, then ground-truthing studies could be conducted to determine if the signal is potentially related to changes in land use or agricultural practices, or from groundwater extraction. If subsidence is determined to result from groundwater extraction, then ground-based elevation surveys might be needed to monitor the situation more closely. At each interim milestone, subsidence data will be reviewed for yearly and five-year subsidence rates to assess continued compliance with the MT.

3.4.4.5 Effects of Undesirable Results on Beneficial Uses and Users

Subsidence can result in substantial interference with land use including significant damage to critical infrastructure such as canals, pipes, or other water conveyance facilities, as well as breaking of building foundations and tilting of structures. Other effects include flooding of land, including residential and commercial properties, and negative impacts on agricultural operations. Subsidence is closely linked with declining groundwater levels: a decline in groundwater levels can trigger land subsidence.

3.4.4.6 Relationship to Other Sustainability Indicators

Managing groundwater pumping and avoiding the undesirable result of chronic lowering of groundwater levels will reduce the risk of land subsidence. Additionally, land subsidence directly causes a reduction in groundwater storage.