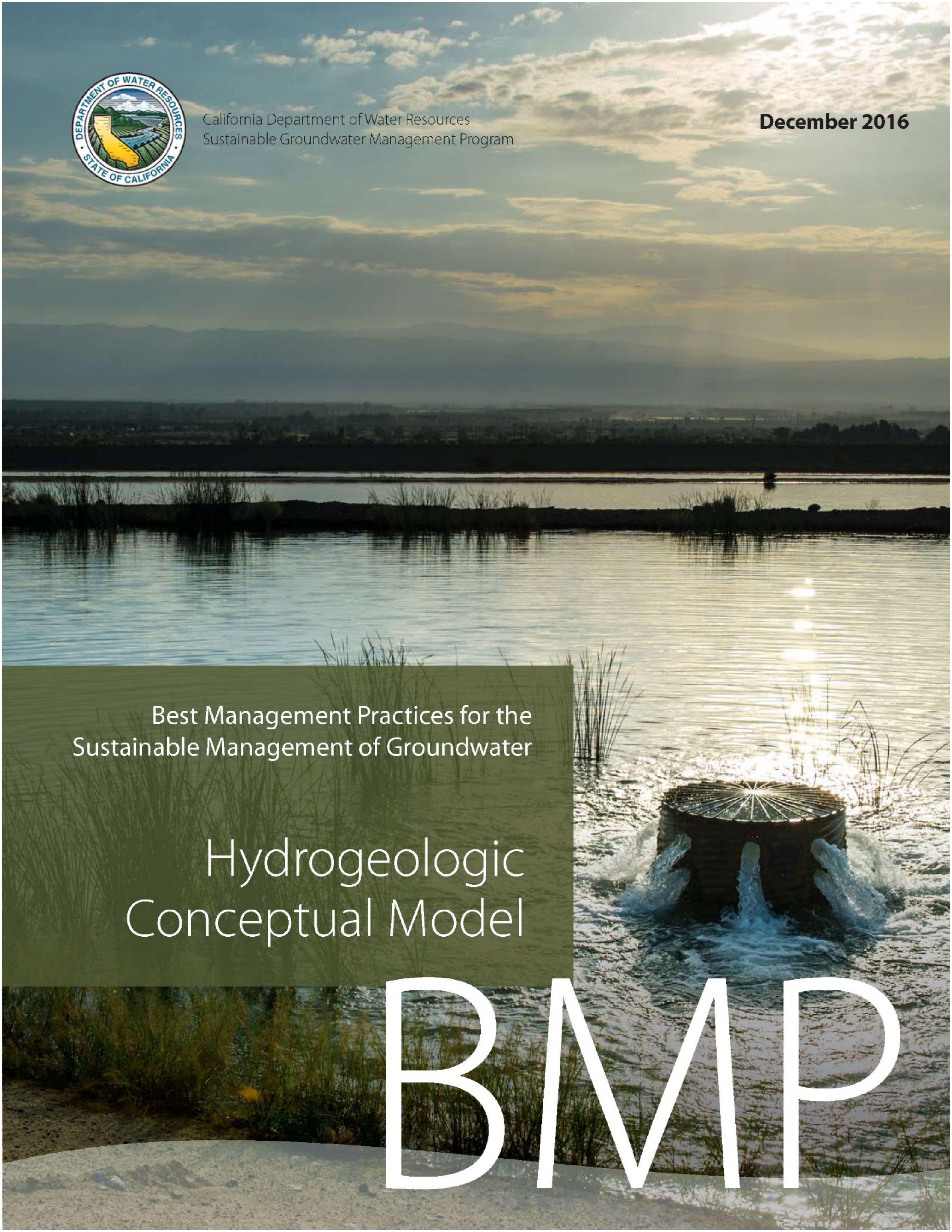

California Department of Water Resources
Sustainable Groundwater Management Program

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Best Management Practices for the Sustainable Management of Groundwater

# Hydrogeologic Conceptual Model

# BMP

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# Hydrogeologic Conceptual Model
# Best Management Practice

## 1. Objective

The objective of this Best Management Practice (BMP) is to assist in the use and development of *hydrogeologic conceptual models* (HCM). The California Department of Water Resources (the Department or DWR) has developed this document as part of the obligation in the Technical Assistance Chapter (Chapter 7) of the Sustainable Groundwater Management Act (SGMA) to support the long-term sustainability of California's groundwater *basins*. Information provided in this BMP is meant to provide support to Groundwater Sustainability Agencies (GSAs) when developing a HCM in accordance with the Groundwater Sustainability Plan (GSP) Emergency Regulations (GSP Regulations). This BMP identifies available resources to support development of HCMs.

This BMP includes the following sections:

1. Objective. The objective and brief description of the contents of this BMP.
2. Use and Limitations. A brief description of the use and limitations of this BMP.
3. HCM Fundamentals. A description of HCM fundamental concepts.
4. Relationship of HCM to other BMPs. A description of how the HCM relates to other BMPs and is the basis for development of other GSP requirements.
5. Technical Assistance. A description of technical assistance to support the development of a HCM and potential sources of information and relevant datasets that can be used to further define each component.
6. Key Definitions. Definitions relevant for this BMP as provided in the GSP and Basin Boundary Regulations and in SGMA.
7. Related Materials. References and other materials that provide supporting information related to the development of HCMs.

## 2. Use and Limitations

BMPs developed by the Department are intended to provide technical guidance to GSAs and other stakeholders. Practices described in these BMPs do not replace or serve as a substitute for the GSP Regulations, nor do they create new requirements or obligations for GSAs or other stakeholders. While the use of BMPs is encouraged, use and/or adoption of BMPs does not equate to an approval determination by the Department. All references to GSP Regulations relate to Title 23 of the California Code of Regulations (CCR), Division 2, Chapter 1.5, and Subchapter 2. All references to SGMA relate to California Water Code sections in Division 6, Part 2.74.

## 3. HCM FUNDAMENTALS

A HCM:

1. Provides an understanding of the general physical characteristics related to regional hydrology, land use, geology and geologic structure, water quality, *principal aquifers*, and principal aquitards of the *basin setting*;
2. Provides the context to develop water budgets, mathematical (analytical or numerical) models, and monitoring networks; and
3. Provides a tool for stakeholder outreach and communication.

A HCM should be further developed and periodically updated as part of an iterative process as *data gaps* are addressed and new information becomes available. A HCM also serves as a foundation for understanding potential uncertainties of the physical characteristics of a basin which can be useful for identifying *data gaps* necessary to further refine the understanding of the hydrogeologic setting. An example of a HCM depicted as a three-dimensional block diagram is shown in **Figure 1**.

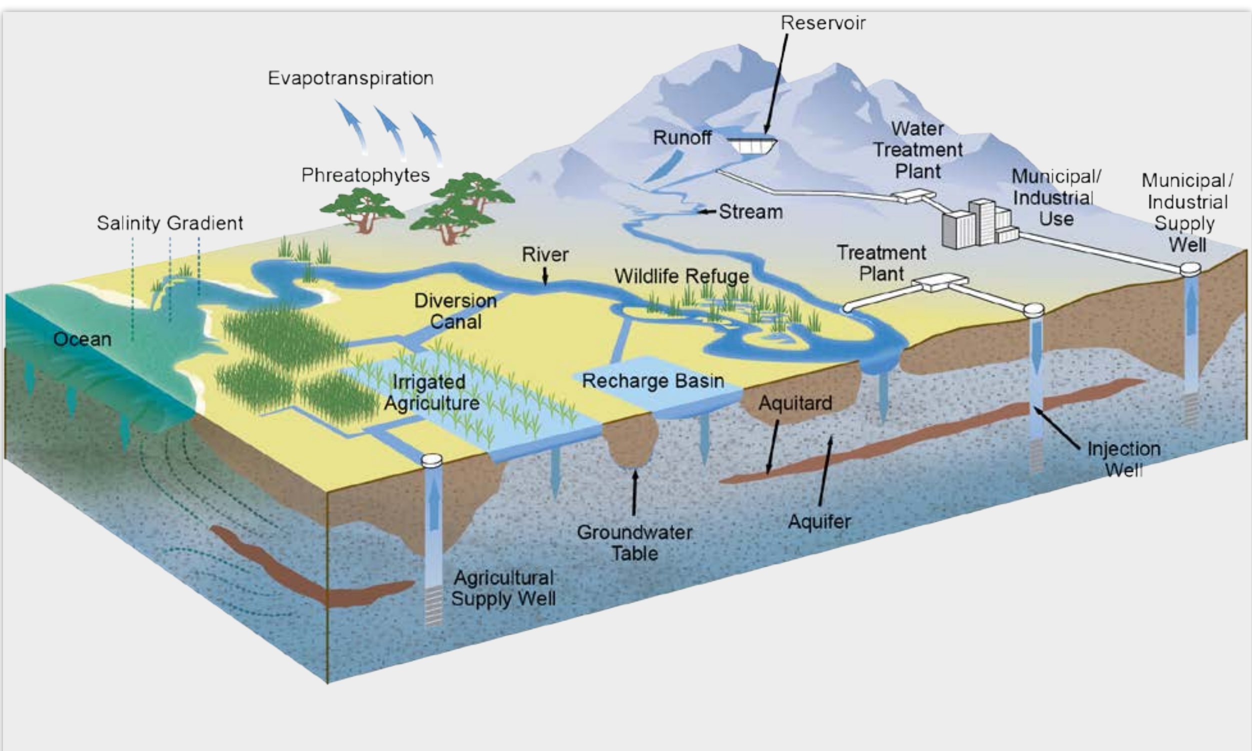


**Figure 1 – Example 3-D Graphic Representing a HCM**

## COMMON HCM USES

The following provides a limited list of common HCM uses:

- Develop an understanding and description of the basin to be managed, specifically the structural and physical characteristics that control the flow, storage, and quality of surface and groundwater
- Identify general water budget components
- Identify areas that are not well understood (*data gaps*)
- Inform monitoring requirements
- Facilitate or serve as the basis for the development, construction, and application of a mathematical (analytical or numerical) model
- Refine the understanding of basin characteristics over time, as new information is acquired from field investigation activities, monitoring networks, and modeling results
- Provide often highly-technical information in a format more easily understood to aid in stakeholder outreach and communication of the basin characteristics to local water users
- Help identify potential projects and management actions to achieve the sustainability goal within the basin

## HCM IN REFERENCE TO THE GSP REGULATIONS

*23 CCR §354.14 (a): Each Plan shall include a descriptive hydrogeologic conceptual model of the basin based on technical studies and qualified maps that characterizes the physical components and interaction of the surface water and groundwater systems in the basin.*

GSP Regulations[1] require that each GSP include a HCM for the basin reported in a narrative and graphical form that provides an overview of the physical basin characteristics, uses of groundwater in the basin, and sets the stage for the *basin setting* (GSP §354.14(a)). The GSP Regulations identify the level of detail to be included for the HCM to aid in describing the *basin setting* for the GSP development and sustainability analysis.

[1] http://www.water.ca.gov/groundwater/sgm/pdfs/GSP_Emergency_Regulations.pdf

The HCM requirements outlined pertain to two main types of information:

1. The narrative description is accompanied by a graphical representation of the basin that clearly portrays the geographic setting, regional geology, basin geometry, general water quality, and consumptive water uses in the basin.
2. A series of geographic maps and scaled cross-sections to provide a vertical layering representation and a geographic view of individual datasets including the topography, geology, soils, *recharge* and discharge areas, source and point of delivery of imported water supplies, and surface water systems that are significant to management of the basin.

A HCM differs from a mathematical (analytical or numerical) model in that it does not compute specific quantities of water flowing through or moving into or out of a basin, but rather provides a general understanding of the physical setting, characteristics, and processes that govern groundwater occurrence within the basin. In that sense, the HCM forms the basis for mathematical (analytical or numerical) model development, and sets the stage for further quantification of the water budget components.

The intent of requiring HCMs in the GSP Regulations is not to provide a direct measure of sustainability, but rather to provide a useful tool for GSAs to develop their GSP and meet other requirements of SGMA.

## 4. RELATIONSHIP OF HCM TO OTHER BMPS

The purposes of the HCM in the broader context of SGMA implementation include:

- Supporting the evaluation of sustainability indicators, assessing the potential for undesirable results, and development of minimum thresholds;
- Supporting identification and development of potential projects and management actions to address undesirable results that exist or are likely to exist in the future; and
- Supporting the development of monitoring protocols, networks, and strategies to evaluate the sustainability of the basin over time.

The HCM is also linked to other related BMPs as illustrated in **Figure 2**. This figure provides the context of the BMPs as they relate to various steps to sustainability as outlined in the GSP Regulations. The HCM BMP is part of the *Basin Setting* development step in the GSP Regulations.

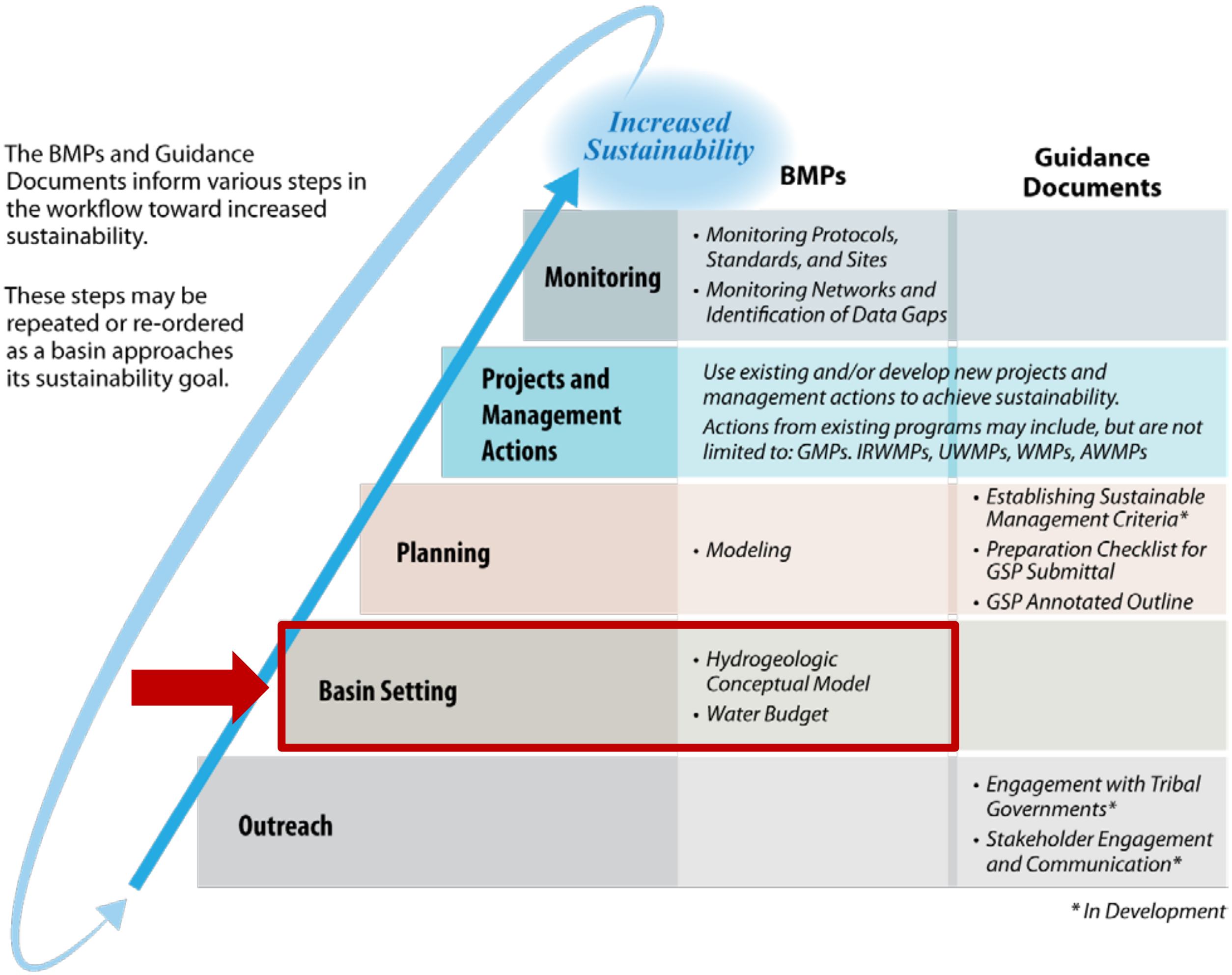


**Figure 2 – Logical Progression of Basin Activities Needed to Increase Basin Sustainability**

HCM development is the first step to understanding and conveying the GSP *basin setting*. The HCM is also linked to other GSP components (and applicable related BMPs) as illustrated **Figure 3**. For example, the HCM supports the development of the monitoring networks and activities needed to better understand the distribution and movement of water within a basin, which leads to the initial development and quantification of a water budget. Once the HCM and water budget have been developed, a mathematical (analytical or numerical) model may be built to further evaluate sustainability indicators, assess the probability of future undesirable results, and support basin management decisions as necessary to avoid the occurrence of undesirable results.

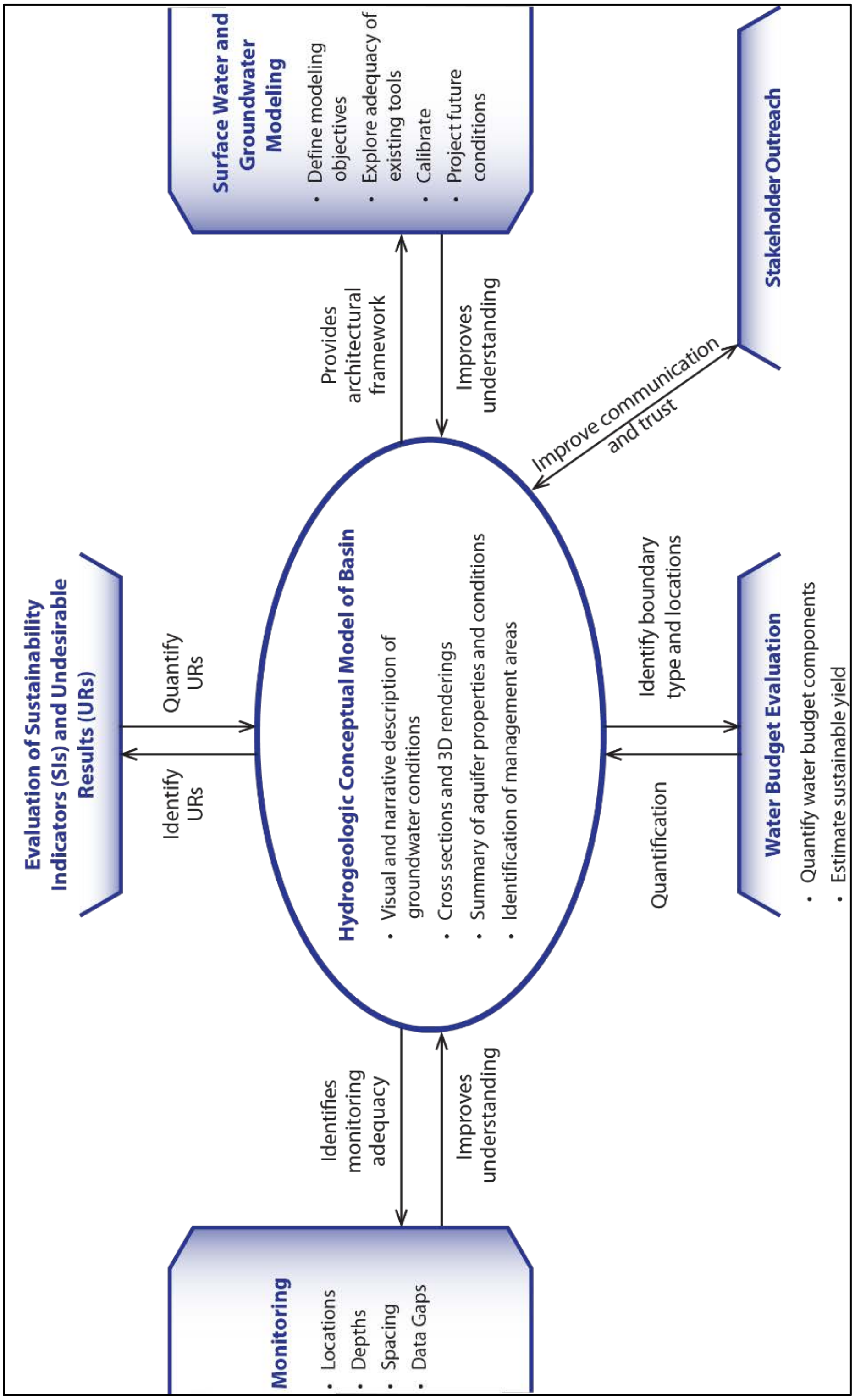


**Figure 3 – Interrelationship between HCM and Other BMPs and Guidance Documents**

## 5. Technical Assistance

This section provides technical assistance to support the development of a basin HCM including potential sources of information and relevant datasets that can be used to develop each HCM requirement. As described in the GSP Regulations Section 354.12, the Basin Setting shall be prepared by or under the direction of a professional geologist or professional engineer.

### CHARACTERIZING THE PHYSICAL COMPONENTS

Each section below is related to the specific GSP Regulation requirements and provides additional technical assistance for the GSA's consideration.

*23 CCR §354.14 (b)(1): The regional geologic and structural setting of the basin including the immediate surrounding area, as necessary for geologic consistency.*

The regional geologic and structural setting of a basin describes the distribution, extent, and characteristics of the geologic materials present in the basin along with the location and nature of significant structural features such as faults and bedrock outcrops that can influence groundwater behavior in the basin.

This type of information can often be found in existing geologic maps and documents published by the Department (specifically Bulletin 118 and 160), the United States Geological Survey (USGS), and other local government agencies (references are also provided in Section 7). Groundwater Management Plans and other technical reports prepared for the basin may also include information of this type.

*23 CCR §354.14 (b)(2): Lateral basin boundaries, including major geologic features that significantly affect groundwater flow.*

Basin boundaries are often geologically controlled and may include bedrock boundaries that define the margins of the alluvial groundwater *aquifer* system, and therefore represent barriers to groundwater flow. For a map of the Department's Bulletin 118 groundwater basins and subbasins refer to the Department's basin boundary website.

Other basin boundaries may include rivers and streams, or structural features such as faults. Additionally, basins on the coast can be subject to seawater intrusion, which creates another type of boundary to the freshwater basin. Information on these types of boundaries can also be found in reports prepared by State (California Geological Survey) or federal agencies (USGS) or by local agencies or districts. In addition, the presence of seawater along the coastal margin can also reflect the boundary of a coastal basin.

*23 CCR §354.14 (b)(3): Definable bottom of the basin.*

Several different techniques or types of existing information can be used in the evaluation of the definable bottom of the basin and extent of freshwater.

*Defining the Basin Bottom based on Physical Properties*

The bottom of the basin may be defined as the depth to bedrock also recognized as the top of bedrock below which no significant groundwater movement occurs. This type of information may be found from reviewing geologic logs from wells drilled for water extraction, as well as from oil and gas exploration wells which tend to be drilled deeper than usable aquifer systems.

*Defining the Basin Bottom based on Geochemical Properties*

In many basins of the Central Valley, freshwater is underlain by saltier or brackish water that is a remnant of the marine conditions that were present when the Valley was flooded in the geologic past. Several standards exist that can be used to define the base of freshwater and the bottom of the basin in the Central Valley:

- Base of freshwater maps in the Central Valley published by the Department and by USGS
- United States Environmental Protection Agency (US EPA) definition for Underground Source of Drinking Water (USDW)

The Department plans to release a freshwater map for the Central Valley that depicts the useable bottom of the alluvial aquifer. This map assumes that the base of freshwater is defined by the Title 22 State Water Resources Control Board (SWRCB) upper secondary maximum contaminant level recommendation of 1,000 milligrams per liter (mg/L) total dissolved solids (TDS).

The USGS has two base of fresh water maps available in the Central Valley based on 3,000 mg/L TDS.

An alternative threshold available to define the bottom of the groundwater basin is the US EPA USDW standard of less than 10,000 mg/L TDS. In some basins, oil and gas *aquifers* underlie the potable alluvial *aquifer* or USDW (defined as less than 10,000 mg/L TDS in Title 40, Section 144.3, of the Code of Federal Regulations). In basins where produced water from underlying oil and gas operations is beneficially used within the basin, or injected into the basin's USDW, the HCM can further characterize the geologic boundaries that separate the USDW from the oil and gas *aquifers*, and identify the "exempted *aquifer*" portion of the groundwater basin that has been permitted for underground injection control by the SWRCB Oil and Gas Monitoring Program or the Division of Oil, Gas and Geothermal Resources (DOGGR).

It should be noted that the definable bottom of the basin should be at least as deep as the deepest groundwater extractions; however, this may not be an appropriate method if it conflicts with other local, State, or Federal programs or ordinances. Finally, consideration should be given to how the bottom of the basin is defined in hydraulically-connected adjacent basins, as this could create additional complexity when developing and implementing GSPs.

*Defining the Basin Bottom based on Field Techniques*

Common field techniques used to define the bottom of alluvial basins can be subdivided into techniques utilizing direct measurements and those utilizing indirect measurements. The most common ones are listed below.

**Direct measurement** approaches typically involve drilling of multiple wells through the freshwater-bearing alluvial aquifer sediments and into the underlying lithologic units, whether it is bedrock or alluvium, containing groundwater that does not meet the criteria for potable water or an USDW. Once each borehole has been constructed, several different approaches can be taken to estimate the depth to the basin bottom at that location. Compilation of data from multiple wells can then be used to prepare a contour map of the depth to the basin bottom. Typical direct techniques include:

- Installation of multi-port well systems or installation of a nested well array
- Continuous profiling of lithology/groundwater quality using TDS, conductivity, or other downhole geophysical techniques
- Mapping depth to bedrock from borehole

**Indirect measurement** approaches are typically employed along the ground surface or from helicopters or fixed-wing aircraft. The most common methods used are geophysical techniques or surveys. Typical geophysical techniques that can be used to estimate bedrock depth or groundwater quality profiles include:

- Seismic refraction/reflection surveys
- Gravity surveys
- Magnetic surveys
- Resistivity surveys
- Radar, including ground penetrating radar
- Other Electromagnetic techniques

*23 CCR §354.14 (b)(4): Principal aquifers and aquitards, including the following information:*
*(A) Formation names, if defined.*
*(B) Physical properties of aquifers and aquitards, including the vertical and lateral extent, hydraulic conductivity, and storativity, which may be based on existing technical studies or other best available information.*
*(C) Structural properties of the basin that restrict groundwater flow within the principal aquifers, including information regarding stratigraphic changes, truncation of units, or other features.*
*(D) General water quality of the principal aquifers, which may be based on information derived from existing technical studies or regulatory programs.*
*(E) Identification of the primary use or uses of each aquifer, such as domestic, irrigation, or municipal water supply.*

*Aquifer* information is available in geologic reports from the Department and USGS, such as Bulletin 118, and local groundwater management plans and studies. Links to applicable reports are provided below. The USGS maintains very detailed reports and datasets for groundwater quality throughout the state that can be downloaded from their California Water Science Website (http://ca.water.usgs.gov/). The SWRCB also collects and maintains groundwater quality data, accessible through their GeoTracker GAMA website. (http://www.waterboards.ca.gov/gama/geotracker_gama.shtml)

In addition, the Regional Water Quality Control Boards, with coordination from the SWRCB, manage groundwater quality programs and data related to the Irrigated Lands Regulatory Program (http://www.swrcb.ca.gov/water_issues/programs/agriculture/). These programs are in the early phases of development, and data are being collected by local entities. As groundwater quality data become available through these programs, they may be a good source of information for HCM and GSP development. The Central Valley Regional Water Quality Control Board and SWRCB, in cooperation with stakeholders and the Central Valley Salinity Coalition, collaborate to review and update the basin plans for the Sacramento and San Joaquin river basins, the Tulare Lake Basin, and the Delta Plan for salinity management. As part of this program, technical reports are being developed and groundwater quality data are being collected in the Central Valley aquifer that provide other sources of information for those basins (http://www.cvsalinity.org/).

Uses of groundwater can be found within water quality control plans (known as basin plans), agricultural water management plans (AWMP) and urban water management plans (UWMP), which detail the use of water by agency and by types of beneficial uses. In addition, basin plans describe the water quality objectives and beneficial uses to be protected, with a program of implementation to achieve those objectives.

> 23 CCR §354.14 (b)(5): *Identification of data gaps and uncertainty within the hydrogeologic conceptual model.*

An assessment of the uncertainty in the HCM components, along with the identification of data gaps of the physical system and water use practices in the basin, are all necessary elements of the HCM. Typical data gaps and uncertainties related to the HCM include the hydraulic properties of the aquifer and aquitard materials, the depth and thickness of various geologic layers, and adequate geographic distribution of groundwater quality data, among others. It is important to adequately evaluate data gaps and uncertainties within a HCM as these data gaps often drive the types and locations of monitoring that should be conducted to reduce uncertainties in these conceptual model components.

For example, a portion of a groundwater basin may not be well characterized from previous studies and historic monitoring activities; therefore, there is less readily-available information to define the HCM in that portion of the basin. Specific data collection activities to address these *data gaps* could then be considered in the development of the GSP.

## GRAPHICAL AND MAPPING REQUIREMENTS

> *23 CCR §354.14 (c): The hydrogeologic conceptual model shall be represented graphically by at least two scaled cross-sections that display the information required by this section and are sufficient to depict major stratigraphic and structural features in the basin.*

In addition to the narrative description of the HCM, another necessary element of a HCM is a graphical representation of the HCM components in the form of at least two geologic cross-sections. A cross-section depicts the vertical layering of the geology and major subsurface structural features in a basin, in addition, but not limited to, other HCM features such as the general location and depth of existing monitoring and production wells and the interaction of streams with the aquifer.

The locations selected for cross-section development in a basin are best informed by the sustainability indicators most critical to that basin, as well as the potential for undesirable results to occur. For example, if subsidence is a known issue in a basin, construction of cross-section(s) may be focused in areas where subsidence has occurred or is at risk of occurring. An example of a scaled cross-section is provided in **Figure 4**.

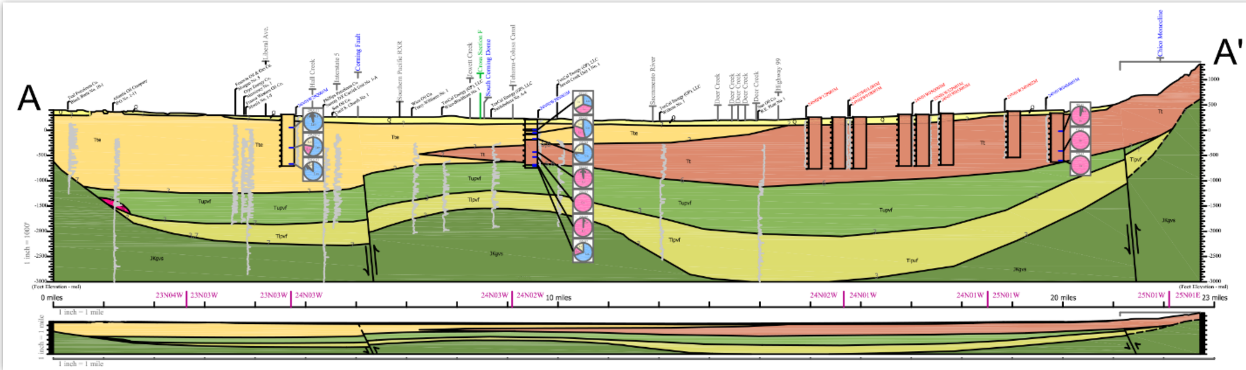


**Figure 4 – Example Scaled Cross-Section**

Geologic cross-sections should be constructed by a professional geologist, or a person knowledgeable of geologic principles such as the Laws of Superposition, Original Horizontality, cross-cutting relationships, and Walther's Law. The type of cross-section ranges from "conceptual to highly detailed", depending on the intended use. The type of cross-section also depends on the type of subsurface data that is available and the reliability of that data. A full understanding of, and appreciation for, the variety of depositional environments, like sequence stratigraphy, is needed to construct accurate geological cross sections. Cross-section construction considerations include, but are not limited to, the following:

- Geologic cross-sections are often oriented perpendicular to the strike of the regional bedding. If a line of section oblique to the strike of regional bedding is selected, apparent dip of bedding and structural features should be computed and included in the geologic cross-section. It is important to choose a geologically relevant orientation with respect to strike and dip (and to note whether any of the selected orientations depict an apparent dip much different than the true dip).

- The geologic cross-section should not change trend direction, or bend significantly as this can change the relationship of the deposition direction. North and east should be on the right side of the page. If wells logs are projected onto the section the distance they are projected from the section line should be noted.

- The location and orientation of the line of geologic cross-section should be presented in plan view on a geologic map. The horizontal distance between boreholes, geologic contacts, structural features, and surface features is interpreted from the scale of the geologic map. The horizontal scale can be enlarged or reduced, preserving the relative distances, based on cross-section size. The vertical scale of the cross-section can exceed the horizontal scale (vertical exaggeration) in order to more clearly present the subsurface data. However, the scale should be chosen without undue vertical exaggeration.

- Subsurface lithology and structural features should be projected from surface contacts at the dip angle (or apparent dip) reported on the geologic map. Subsurface contacts may be correlated/interpreted between boreholes based on available lithologic logs and professional judgement. The cross-sections should be tied where they cross and to the geologic map at formation contacts.

- Cross-sections should include major aquifer and aquitard units, but it may not be necessary to include all lithologic beds on the cross-section.

- The geologic cross-section should include information provided on lithologic logs for boreholes along the line of section. Information for wells off-set from the line of section can be projected onto the cross-section. The maximum distance for projection of data onto the cross-section will be dependent upon the scale; professional judgement should be used in the selection of the maximum projection distance. The distance for projection of data should be somewhat dependent on the reasonableness one can infer that the units or features continue with some level of certainty. Conversely, if there is uncertainty, dashed lines or question marks are often applied to denote uncertainty.

- The level of detail and quality of available subsurface lithologic logs will vary between boreholes. The quality of individual lithologic logs should be considered when correlating subsurface borehole information.

- Where two cross-section lines intersect, the subsurface interpretations presented on the geologic cross-sections should be consistent at the intersection.

- The data used for horizon boundaries should be shown and posted for reference; and any references used to depict the cross-sections should be cited.

If known, other details should also be included in hydrogeologic cross sections, such as: (1) static water level of each *aquifer*; (2) screened intervals; (3) total depth of the boring/well; (4) availability of geophysical logs; and (5) type of drilling method. Additional notation on the cross-section may also be helpful for illustration.

*23 CCR §354.14 (d) Physical characteristics of the basin shall be represented on one or more maps that depict the following:*
*(1) Topographic information derived from the U.S. Geological Survey or another reliable source.*
*(2) Surficial geology derived from a qualified map including the locations of cross sections required by this Section.*
*(3) Soil characteristics as described by the appropriate Natural Resources Conservation Service soil survey or other applicable studies.*
*(4) Delineation of existing recharge areas that substantially contribute to the replenishment of the basin, potential recharge areas, and discharge areas, including significant active springs, seeps, and wetlands within or adjacent to the basin.*
*(5) Surface water bodies that are significant to the management of the basin.*
*(6) The source and point of delivery for imported water supplies.*

Geographical representations of the distribution of major data elements in a groundwater basin in map form help illustrate the layout of data and information presented in the HCM. The data for these maps are generally available from various sources such as GIS Shapefiles that can be overlain on a basin-wide base map.

As stated in the GSP Regulations, physical characteristics of the basin need to be displayed on maps. Information is provided on the types of datasets readily available for mapping.

- Topographic information can be found from online USGS topographic maps or more detailed high resolution Digital Elevation Model (DEM) mapping GIS datasets. There are several sources of topographic and DEMs available online, such as the ones provided in Section 7.

- In addition, the ESRI ArcGIS platform also includes DEM data available for use in conjunction with the ESRI GIS software.

- Surficial Geologic information can be downloaded from the California Geological Survey (CGS) and USGS from their interactive mapping tool.
    - CGS - http://maps.conservation.ca.gov/cgs/gmc/
    - USGS - http://ngmdb.usgs.gov/ngmdb/ngmdb_home.html

  The map that is produced to illustrate the surficial geology of the basin should also include the location of the cross-sections.

- The National Resource Conservation Service (NRCS) maintains soil data and Shapefiles nationwide on a county basis available at their website: http://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx.
  For additional related soil characteristics in California, see the UC Davis soil interactive maps (http://casoilresource.lawr.ucdavis.edu/).

- *Recharge* and discharge areas of groundwater are generally not well mapped. This type of information may be available from local and regional groundwater management planning documents, or larger reports form the Department and USGS. Additional *recharge* maps in California have been developed by the California Soil Resource Lab at UC Davis – The following link is to their Soil Agricultural Groundwater Banking Index (SAGBI): http://casoilresource.lawr.ucdavis.edu/sagbi/

- Surface water mapping data can be downloaded from ESRI base maps within ArcGIS, or downloaded from the National Hydrography Datasets (NHD) datasets: http://viewer.nationalmap.gov/viewer/nhd.html?p=nhd

- Water supplies imported into a basin from state, federal, or local projects need to be mapped for the HCM. This information is generally available from the major suppliers of surface water such as the Department, United States Bureau of Reclamation (USBR), and local water and irrigation districts.

Additional useful information to be mapped may include:

- Groundwater elevation contour maps show the spatial distribution of groundwater elevations and help identify areas of low and high groundwater level areas within a basin. Elevation contour maps can be created from water level data collected from wells that are screened within the same principal aquifers. Information on water level data interpolation to create contour maps can be found in Tonkin et. al (2002).

- Land use maps detail the agricultural and urban land uses, and the distribution of natural vegetation, including potentially groundwater-dependent ecosystems. Land use maps shall use the Department land use classification scheme and maps provided by the Department.

An example of a geologic map is provided in **Figure 5**.

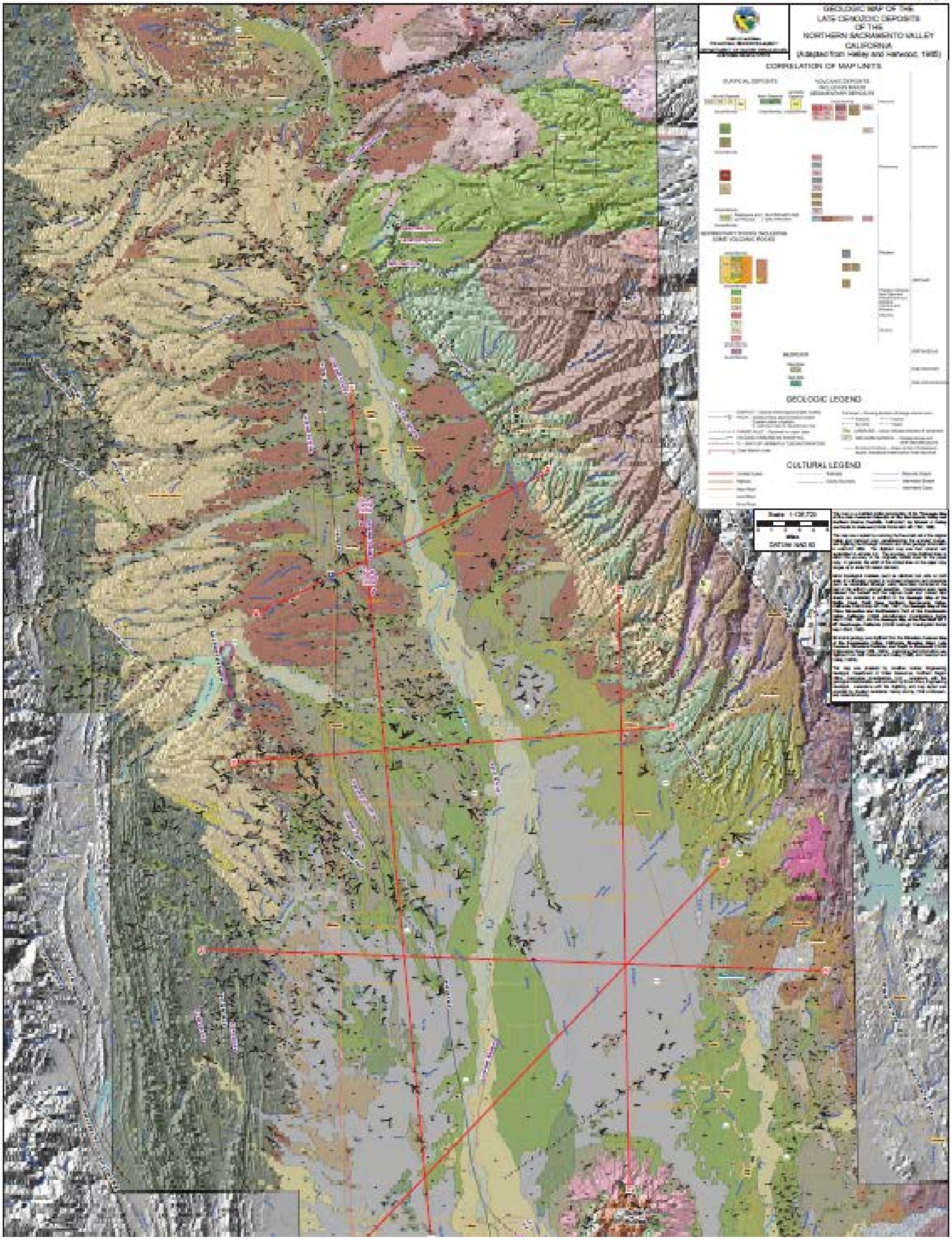


**Figure 5 – Example Geologic [Map](#)**

## TYPICAL FLOW OF GRAPHICAL HCM DEVELOPMENT

The HCM requirements outlined in the GSP Regulations pertain to two main types of information:

1. Narrative description of the basin, which can be accompanied by a three-dimensional graphic illustration of the HCM to complement the narrative; and
2. At least two scaled cross-sections and geographic maps to provide vertical layering representation and a geographic view of individual datasets, respectively.

The typical flow of graphical HCM development is presented in **Figure 6**. This figure shows the level of technical representation and detail, from basic cartoon-type representation, to a geographic representation map, to a scaled vertical cross-section that provides more subsurface detail for the HCM.

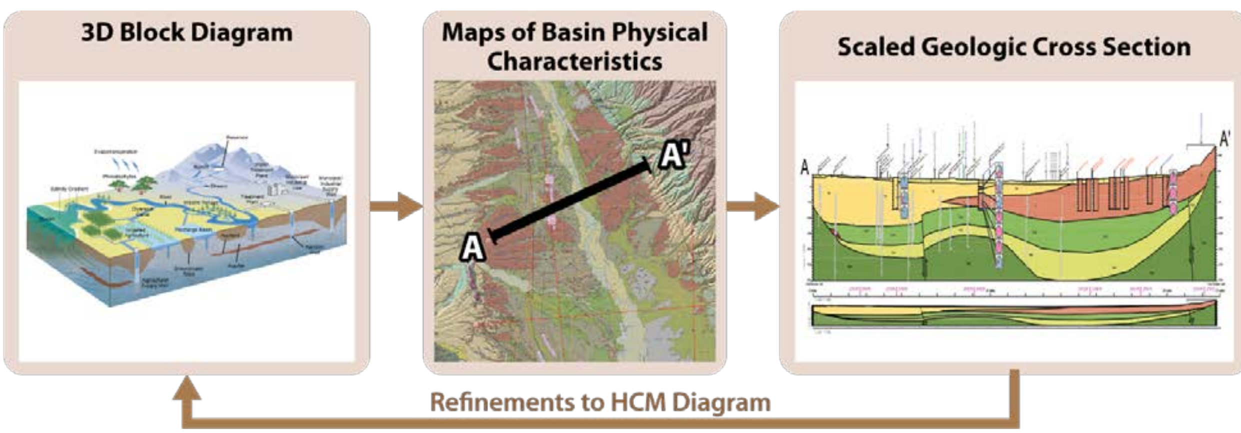


**Figure 6 – Steps to Developing Graphic Representations of the HCM**

## 6. Key Definitions

The key definitions related to HCM development outlined in applicable SGMA code and regulations are provided below for reference.

**SGMA Definitions (California Water Code §10721)**

- "Groundwater recharge" or "recharge" means the augmentation of groundwater by natural or artificial means.

- "Recharge area" means the area that supplies water to an aquifer in a groundwater basin.

**Groundwater Basin Boundaries Regulations (California Code of Regulations §341)**

- "Aquifer" refers to a three-dimensional body of porous and permeable sediment or sedimentary rock that contains sufficient saturated material to yield significant quantities of groundwater to wells and springs, as further defined or characterized in Bulletin 118.

- "Hydrogeologic conceptual model" means a description of the geologic and hydrologic framework governing the occurrence of groundwater and its flow through and across the boundaries of a basin and the general groundwater conditions in a basin or subbasin.

- "Qualified map" means a geologic map of a scale no smaller than 1:250,000 that is published by the U. S. Geological Survey or the California Geological Survey, or is a map published as part of a geologic investigation conducted by a state or federal agency, or is a geologic map prepared and signed by a Professional Geologist that is acceptable to the Department.

- "Technical study" means a geologic or hydrologic report prepared and published by a state or federal agency, or a study published in a peer-reviewed scientific journal, or a report prepared and signed by a Professional Geologist or by a Professional Engineer.

**Groundwater Sustainability Plan Regulations (California Code of Regulations §351)**

- "Basin setting" refers to the information about the physical setting, characteristics, and current conditions of the basin as described by the Agency in the hydrogeologic conceptual model, the groundwater conditions, and the water budget, pursuant to Subarticle 2 of Article 5.

- "Best available science" refers to the use of sufficient and credible information and data, specific to the decision being made and the time frame available for making that decision, that is consistent with scientific and engineering professional standards of practice.

- "Data gap" refers to 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.

- "Principal aquifers" refer to aquifers or aquifer systems that store, transmit, and yield significant or economic quantities of groundwater to wells, springs, or surface water systems.

- "Uncertainty" refers to a lack of understanding of the basin setting that significantly affects an Agency's ability to develop sustainable management criteria and appropriate projects and management actions in a Plan, or to evaluate the efficacy of Plan implementation, and therefore may limit the ability to assess whether a basin is being sustainably managed.

- "Water source type" represents the source from which water is derived to meet the applied beneficial uses, including groundwater, recycled water, reused water, and surface water sources identified as Central Valley Project, the State Water Project, the Colorado River Project, local supplies, and local imported supplies.

- "Water use sector" refers to categories of water demand based on the general land uses to which the water is applied, including urban, industrial, agricultural, managed wetlands, managed *recharge*, and native vegetation.

# 7. Related Materials

This section provides a list of related materials including general references, standards, guidance documents, and selected case studies and examples pertinent to the development of HCMs. For the items identified, available links to access the materials are also provided. In addition, common data sources and links to web-materials are also provided. By providing these links, DWR neither implies approval, nor expressly approves of these documents.

It should also be noted that existing Groundwater Management Plans (GMP), Salt & Nutrient Management Plans (SNMP), Urban Water Management Plans (UWMP), Drinking Water Source Assessment Plans (DWSAP), Agricultural Water Management Plans (AWMP), and Integrated Regional Water Management Plans (IRWMP) may be useful references in the development of HCMs. To the extent practicable, GSAs should utilize and build on available information.

## STANDARDS

- ASTM D5979 – 96 (2014) Standard Guide for Conceptualization and Characterization of Groundwater Systems

## REFERENCES FOR FURTHER GUIDANCE

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Fulton, J.W., et. al. 2005. *Hydrogeologic Setting and Conceptual Hydrologic Model of the Spring Creek Basin, Centre County, Pennsylvania, June 2005.* USGS Scientific Investigation Report 2005-5091.
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http://maps.conservation.ca.gov/cgs/gmc/ *Accessed December 2016.*

Groundwater Ambient Monitoring and Assessment Program (GAMA) web page. State Water Resources Control Board.
http://www.waterboards.ca.gov/gama/geotracker_gama.shtml *Accessed December 2016.*

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http://earthquake.usgs.gov/hazards/qfaults/map/#qfaults *Accessed December 2016.*

Irrigated Lands Regulatory Program web page. State Water Resources Control Board.
http://www.swrcb.ca.gov/water_issues/programs/agriculture/ *Accessed December 2016.*

National Geologic Map Database. U.S. Geological Survey.
https://ngmdb.usgs.gov/ngmdb/ngmdb_home.html *Accessed December 2016.*

National Map Hydrography. U.S. Geological Survey.
https://viewer.nationalmap.gov/viewer/nhd.html?p=nhd *Accessed December 2016.*

Oil and Gas Monitoring Program web page. State Water Resources Control Board.
http://www.waterboards.ca.gov/water_issues/programs/groundwater/sb4/index.shtml
*Accessed December 2016.*

Teresita Betancur V., Carlos Alberto Palacio T. and John Fernando Escobar M. 2012. *Conceptual Models in Hydrogeology, Methodology and Results - A Global Perspective*, Dr. Gholam A. Kazemi (Ed.), ISBN: 978-953-51-0048-5, InTech, Available from: http://www.intechopen.com/books/hydrogeology-a-globalperspective/conceptual-models-in-hydrogeology-methodologies-and-results

Tonkin, M. and Larson, S. 2002. *Kriging Water Levels with a Regional-Linear and Point-Logarithmic Drift*, Ground Water, March-April 2002.

Toth, J. 1970. *A conceptual model of the groundwater regime and the hydrogeologic environment.* Journal Of Hydrology, Volume 10, Issue 1. February. doi:10.1016/0022-1694(70)90186-1

Web Soil Survey. U.S. Department of Agriculture Natural Resources Conservation Service. http://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx *Accessed December 2016.*

**REFERENCES FOR CROSS SECTIONS**

Suggestions to Authors of the Reports of the United States Geological Survey, Seventh Edition, 1991. See Section named Cross Sections and Stratigraphic Sections and Preparing Maps and Other Illustrations, with a subsection titled Cross Sections.

Manual of Field Geology, Robert Compton, 1962. Chapter 11, Preparing Geologic Reports, Section 11-10 Detailed Geologic Maps and Cross Sections.

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Reading, H.G. (editor), 1978, Sedimentary Environments and Facies, Elsevier Press New York, 569 pages.

Krumbein, K.C. and L.L. Sloss. 1963, Stratigraphy and Sedimentation, W.H. Freeman and Company, San Francisco, 660 pages.

## DATA SOURCES

**Geology reports**:

**Geology of the Northern Sacramento Valley, CA:**
http://www.water.ca.gov/pubs/geology/geology_of_the_northern_sacramento_valley__california__june_2014-web/geology_of_the_northern_sacramento_valley__california__june_2014__updated_09_22_2014__website_copy_.pdf

**Digital Elevation Models (DEMs)**:

- http://www.opendem.info/opendem_client.html
- http://viewer.nationalmap.gov/basic/?basemap=b1&category=ned,nedsrc&title=3DEP%20View
- http://www.brenorbrophy.com/California-DEM.htm.