Butte County
CALIFORNIA

Technical Collaboration on Interconnected Subbasins to Advance Sustainable Groundwater Management:

Assessment of INTERCONNECTED SUBBASINS

June 2017

Prepared By:

RMC water and environment

WOODARD & CURRAN

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National Experience. Local Focus.

June 30, 2017

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Finally, the authors would like to thank the Water Foundation, an initiative of the Resources Legacy Fund, for their generous support.

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List of Abbreviations

BBGM	Butte Basin Groundwater Model
BMP	Best Management Practice
C2VSim	California Central Valley Groundwater-Surface Water Simulation Model
CASGEM	California Statewide Groundwater Elevation Monitoring
CVHM	Central Valley Hydrologic Model
DWR	California Department of Water Resources
GSA	Groundwater Sustainability Agency
GSP	Groundwater Sustainability Plan
IDC	IWFM Demand Calculator
IGSM	Integrated Groundwater and Surface-Water Model
InSAR	interferometric synthetic aperture radar
IWFM	Integrated Water Flow Model
MODFLOW-FMP	MODFLOW Farm Process
NSVIRWM	Northern Sacramento Valley Integrated Regional Water Management
SACFEM	Sacramento Valley Finite Element Groundwater Model
SCF Model	Stony Creek Fan Model
SGMA	Sustainable Groundwater Management Act
SVSim	Sacramento Valley Simulation Model
TAC	NSVIRWM Technical Advisory Committee
TC	Technical Collaborators
USGS	United Stated Geological Survey

Executive Summary

Background

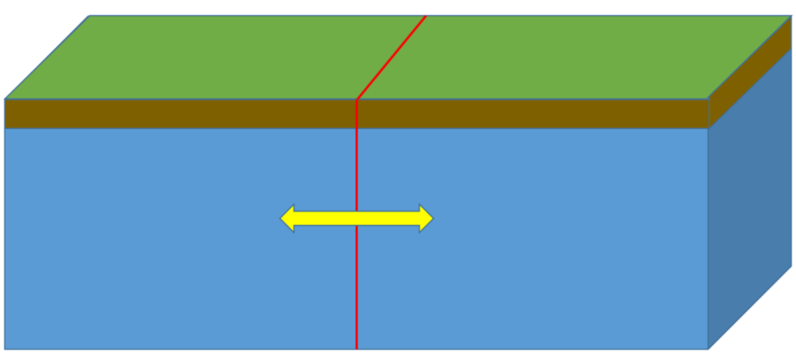
The Sustainable Groundwater Management Act (SGMA) requires groundwater sustainability agencies (GSAs) to develop groundwater sustainability plans (GSPs) that achieve sustainable groundwater management within 20 years of adoption. All critically overdrafted basins must adopt GSPs by January 31, 2020; all other medium and high priority basins must complete GSPs by January 31, 2022. Since many subbasins are hydrologically connected to adjoining subbasins, sustainable groundwater management will require accounting for groundwater interactions with adjoining subbasins. Often, adjoining subbasins will use different analytical methods or apply different levels of technical rigor. Many GSAs are concerned that different methodologies for developing interbasin flows can lead to different results that will call into question the ability to achieve sustainability and would potentially create issues with SGMA compliance.

This effort evaluated opportunities and barriers for agencies to account for interconnected basin dynamics through the collaboration of technical experts focused on a portion of the northern Sacramento Valley Integrated Regional Water Management (NSVIRWM) Plan area. As interbasin flows (i.e., groundwater flow between interconnected basins) cannot be directly measured, the project reviewed available tools to investigate how they may or may not be suitable for use in estimating interbasin flows within the region. This process highlighted areas for local agencies to consider in addressing interbasin issues, developed a framework for analysis in other areas of the state, and identified areas where the state and federal government can assist local agencies implementing SGMA. This report is developed to provide summary level information appropriate for decision makers, with more detailed technical information and examples provided in the appendices or by reference.

Interbasin flow is groundwater entering or exiting a defined subbasin through its boundaries in the subsurface (Figure ES.1) and may vary significantly in space and time based on the dynamics of inflow and outflow from the basins. Interbasin flows are driven by differences in groundwater levels (i.e. head gradients) across the basin boundary. Groundwater levels are, in turn, impacted by processes on the land surface. Land use and crop acreages drive water demand in a subbasin and indirectly drive groundwater pumping, which has a direct effect on groundwater levels (i.e., groundwater heads). The direction and magnitude of interbasin flow depends on the groundwater head gradient across the basin boundary and the conductivity of the aquifer materials.

It is widely recognized that the groundwater subbasins in the Sacramento Valley, and throughout the Central Valley, are interconnected to varying degrees. The Sacramento Valley Groundwater Basin includes many subbasins, extends over a wide geographic area, and includes numerous established and eligible GSAs. With interconnected subbasins, management decisions and actions in one subbasin may influence one or more adjoining subbasins. Such influence may positively or negatively impact sustainability. Thus, interbasin flows become critical to both GSAs' development of GSPs and to DWR reviewing GSPs.

Figure ES.1: Simple Representation of Interbasin Flow



Project Goal and Development

This project sets out to build technical capacity and local ownership of a methodology to assess and account for groundwater flow between interconnected subbasins among GSAs in the northern Sacramento Valley region. It also serves to provide recommendations to GSAs regarding available modeling tools and their appropriate use during GSP development and implementation. In addition, findings from a case study within the northern Sacramento Valley provide an example approach and lessons-learned for other subbasins in California that are faced with understanding interconnected groundwater flows.

Discussions by a group of Technical Collaborators (TCs) generated the findings and recommendations of this report. The TC members (Table 1 in Section 1.5) were federal, state, local, and consulting water resources scientists and engineers familiar with the northern Sacramento Valley and/or existing technical tools.

The project was made possible through the Water Foundation Program of the Resources Legacy Fund.

Findings

The complexity of processes affecting interbasin groundwater flows makes groundwater models effective and necessary tools for quantifying these flows. Surface layer models and integrated groundwater-surface water models (groundwater models) have been developed to account for complex processes and to estimate water budgets in the northern Sacramento Valley. In one of its five SGMA Best Management Practice documents developed in December 2016, the California Department of Water Resources (DWR) describes a model as

> *any computational method that represents an approximation of the hydrologic system. While models are, by definition, a simplification of a more complex reality, they have proven to be useful tools over several decades for addressing a range of groundwater problems and supporting the decision-making process. Models can be useful tools for estimating the potential hydrologic effects of proposed water management activities.*

While surface layer models and other water budget approaches are valuable planning and operations tools for local agencies, they generally do not calculate interbasin flows or groundwater-surface water interaction and are generally not well suited for predictive simulation. SGMA does not legally require the use of a groundwater model. Yet, successfully avoiding the six Undesirable Results defined by SGMA will require accounting for a complete surface water and groundwater budget and the ability to evaluate the effects of changes in the water budget (e.g., increased pumping or increased recharge) on groundwater conditions over time. Water budgets must account for interbasin flows and groundwater-surface water interaction. Since groundwater modeling will be a part of our future under SGMA, it will be key to leverage local data sets and knowledge to improve existing groundwater models or to develop new ones.

Several regional and local surface water/groundwater models are available that cover all or parts of the NSVIRWM plan area (Table ES.1). Two Central Valley-wide models (C2VSim and CVHM) are being updated with planned releases in late 2017 or early 2018. One local model covering four subbasins in the northern Sacramento Valley is being finalized (BBGM). A Sacramento Valley-wide model is also under development (SVSim). These models quantify various components of the water budget and groundwater interbasin flows within each model domain.

Table ES.1: Regional and Local Models Covering All or Parts of the NSVIRWM Plan Area

Model	Organization
BBGM – Butte Basin Groundwater Model	Butte County
C2VSim – California Central Valley Groundwater-Surface Water Simulation Model	DWR
CVHM – Central Valley Hydrologic Model	USGS
SVSim – Sacramento Valley Simulation Model	DWR

The following highlights important ideas and recommendations generated by discussions of the TC for GSAs to consider when developing GSPs and technical tools to support sustainable groundwater management.

Perspectives on Models

1. SGMA does not require the use of a groundwater model. However, integrated groundwater-surface water modeling is necessary in the northern Sacramento Valley to sufficiently answer the questions posed by SGMA. Models provide a relatively transparent, internally consistent method that is grounded on available data and allows for simulation of future conditions under different management scenarios.
2. Use of a groundwater model is the best approach to quantify and evaluate interbasin groundwater flows given the complex spatial and temporal variations in basin water budget components (e.g., groundwater pumping, recharge, groundwater-surface water interactions). A major shortfall of approaches that do not use groundwater models is an inability to adequately evaluate basin conditions and interbasin flows under future water resources conditions or effects of potential projects needed for sustainability of the basin.
3. If an existing groundwater model does not adequately represent local conditions, revisions or updates to the model are required to incorporate important aspects of the system rather than abandoning modeling all together. It should be expected that models will always be in some state of update as the inputs and representation of reality continue to be refined. Yet, they can also be useful tools in the meantime, even with their limitations.
4. Groundwater models are more reliable in characterizing relative changes between two possible scenarios (e.g., estimated water level increase of 10-15 feet), rather than predicting the absolute conditions resulting from a particular scenario (e.g., groundwater levels estimated to be 25 feet below ground surface).
5. A significant degree of uncertainty exists in modeling complex systems. Sources of uncertainty may involve missing elements in the mathematical model so the system is not yet modeled in its entirety. Uncertainty may be related to limited data or the quality of available data. Other sources or contributors to uncertainty might be data gaps in field data to assist calibration.
6. Adaptive management will be important since groundwater models should not be expected to tell decision makers precisely what should be done and what the outcome will be, but instead can be expected to provide information and greater understanding of the system to help inform management actions and promising solutions. As model results change because understanding changes and new data is incorporated in the models, managers should be prepared to increase or reduce actions depending on system response to management actions. The uncertainty inherent in models needs to be anticipated and accounted for when making decisions based on their results.
7. Different models will not perfectly agree. For example, differences in estimated interbasin flows will need to be discussed and, if both models are deemed reasonable, accepted and managed accordingly. In some cases, these differences reflect our level of uncertainty and provide reasonable bounds. GSAs should recognize how management in the adjacent subbasin may change groundwater conditions in their area.
8. Acknowledge that there is no "right model." Groundwater modelers are fond of quoting statistician George Box, who wrote "all models are wrong; some models are useful." It is critical to consider the use of the model when assessing the model and to determine what is important for getting to useful, sufficiently reliable answers.

Model Comparison and Selection

1. It is not immediately obvious which of the identified, existing Central Valley-wide models is better-suited for SGMA application in the northern Sacramento Valley area. Both CVHM and C2VSim were developed prior to SGMA for different purposes. Differences in crop acreage and water budget estimates between the models suggests that each subbasin/GSA needs to evaluate how their area is represented in each model and select the one that best aligns with local data and knowledge to support evaluation of local conditions.
2. Significant differences exist in water budget component estimates between existing regional models. This is, in part, due to differences in land use and crop acreage input data of the two models as well as to differences in terminology and definitions. Both the C2VSim and CVHM models are undergoing respective updates, and the presented water budgets (Appendix D) are subject to change. Additional clarity from the model developers on how to compare water budget components between models would assist GSAs in understanding the differences in these models.
3. Significant differences exist in simulated groundwater levels compared to historical data between these two models (Appendix F). Simulated groundwater elevations near the boundaries have the most effect on quantifying interbasin groundwater flows, therefore evaluating a model's representation of groundwater levels in comparison to historical data is important, particularly in the areas along subbasin boundaries.
4. Reporting of model outputs differ spatially, with depth, in terminology, and even in what is reported. A deep understanding of what is reported in model output files, how it is reported, and the definition of the terminology is critical to compare models and their results to support local planning and management.
5. Often basin boundaries are along rivers, complicating quantification of stream recharge calculations for adjoining basins. CVHM and C2VSim account for stream recharge differently in their model water budgets (see Appendix D for more information). Special care should be taken when comparing surface water budgets and interbasin flows along a boundary with a river or stream.

Local Investment in Tools

1. GSAs should consider the following question when selecting a groundwater model: **How well does the model match my current understanding of the surface layer and groundwater budget in my area?** This question can be answered by considering the input data, water supply and demand, boundary conditions, water balance, and calibration, including whether aquifer parameters are realistic. Compare the model inputs and results to historical data, if possible.
2. Early cooperation with neighboring subbasins to compare interbasin flow estimates and reconcile significant differences in flow and magnitude or direction is very important. Although the exact values may be different, the interbasin flow magnitude and direction should be similar. The differences in part reflect the uncertainty in the modeled systems.
3. GSAs may consider development of a local model to provide finer detail on the groundwater or surface water system. If new local models are to be developed, it is recommended that the local model be based on the regional models and that the local model inform the regional models to improve regional consistency.
4. GSPs should address how to incorporate updated models or new models into management. Inevitably, updates or new models will produce different results to some degree. GSPs should recognize this reality of the incorporation of new data and new techniques into the model and allow for the inclusion of improved data over time rather than being forced to stay with an outdated model for the sake of consistency. The key is to allow for incorporation of the new information without resulting in sudden and disruptive shifts in management actions. In the end, the model is a tool to achieve management objectives based on real data. Proper planning can allow for using the best available science while maintaining a groundwater management structure

that is not destabilized by changes in the model and its results.

Recommendations for GSAs in the Northern Sacramento Valley

GSP development will require technical analysis and organization of existing data. Although regional and local datasets and groundwater models exist in the region, significant effort will be required to identify and develop the tools needed to accomplish the analysis required for sustainable management. The following recommendations describe possible steps by GSAs. These could also be incorporated as tasks into grant applications for GSP development.

1. At the time of GSP development, the most current available version of the C2VSim and CVHM models should be considered for development of water budgets including estimation of interbasin flows. If SVSim becomes available in time, it should also be considered. In cases where local groundwater models exist and can provide a complete water budget including interbasin flows, they are likely preferable.
2. If a detailed, locally-accepted surface layer model exists, the results of this model can be compared to the corresponding results of the available groundwater models to see which regional model more closely resembles the local understanding of those components of the water budget, focusing on recent periods.
3. A surface layer model or other water budget datasets should be used only to assist in selecting the appropriate groundwater model. It is not appropriate to mix output from the groundwater model with other local water budget sources. Groundwater model results should be presented in full to keep the results internally consistent since different water budget components can influence each other.
4. Over time, local knowledge and water budgets from surface layer models should be incorporated into the selected regional groundwater model through cooperation with DWR and/or USGS. Providing more detailed data such as crop types and water operations can greatly improve the usefulness of the regional groundwater models.
5. For selection of a groundwater model:
    a. GSAs should consider what crops are grown in their area and how well the different models represent the crops grown in that area. This is particularly true for areas growing rice and for the representation of total irrigated agricultural acreage, notably newly irrigated areas. The comparison may be performed visually with maps, through analysis of total acreage, and/or through analysis of estimated per-acre water use.
    b. Areas that have experienced changes in irrigation practices should analyze whether the model properly represents the crop demand and recharge by reviewing the irrigation efficiency values within the model.
    c. GSAs should consider how adequately the models represent complex surface water supplies. Analysis of surface water representation in the models can be done through comparing diversion and surface water use data from the models to local data, focusing on recent periods.
    d. GSAs should evaluate whether the regional models simulate the rivers and streams considered important to their area and consider the calibration of the surface water flows and nearby groundwater elevations. Localized studies of stream losses or gains can be compared to model results, but note that such studies are not typically available in most areas.
    e. GSAs should consider the extent to which the models represent subsurface flows from outside the model boundary and incorporate near-basin recent agricultural development, associated groundwater use, and the impact on groundwater inflows. If significant

increases in groundwater production outside of the alluvial aquifer system is anticipated in the future, the GSA should assess the ability of the models to incorporate associated boundary flow changes to the basin.

6. Ultimately the modeling process will be easier if neighboring subbasins select and collaborate in developing the same model. Coordination with neighbors may allow for, all things being equal, selection of a common model for analysis.
7. Other existing groundwater models (i.e., SACFEM2013, Stony Creek Fan IGSM, described in Section 3.2.1) may be valuable sources of data or understanding that could be incorporated into local or regional models selected for GSP development.

Recommendations for DWR and USGS providing technical assistance to GSAs

It is recognized that neither CVHM nor C2VSim were originally developed with the purpose of supporting local compliance with SGMA as these models preceded SGMA by many years. While the current revisions to both models are anticipated to provide more detailed and more accurate results, the following are recommended as part of the continued improvement and updates to these models, allowing them to serve as useful tools for GSAs within the northern Sacramento Valley and across the Central Valley.

1. Develop guidance on developing water budgets, specifically
   a) Terminology linkages between CVHM and C2VSim to allow for comparable water budgets.
   b) Methods for developing water budgets where subbasin boundaries are defined by rivers or streams.
2. Refine the models and develop post-processing tools to allow reporting of water budgets and simulated heads at the subbasin level, GSA level, or management zone level.
3. Move towards common datasets between CVHM and C2VSim with regular updates, notably land use, actual evapotranspiration, land subsidence based on InSAR and extensometers, stream gages, and aquifer structure.
4. Develop a process by which local agencies can submit data to inform regional models.
5. Develop guidance on how to use these regional models to address the six SGMA Undesirable Results.
6. Improve the ability to simulate interconnected surface waters by assessing need for grid cell size reduction near rivers and streams, surveying existing surface water stage gages and verifying the stage-discharge relation, reviewing available surface water interconnection studies (e.g., isotope studies) and assessing the ability to incorporate results into the models.
7. Develop guidance for quantifying uncertainty (monitoring, water budget, modeling) and how to utilize uncertainty estimates as part of modeling predictions to support sound decision-making.

Section 1 Background

The Sustainable Groundwater Management Act (SGMA) requires groundwater sustainability agencies (GSAs) to develop groundwater sustainability plans (GSPs) that achieve sustainable groundwater management within 20 years of adoption. All critically overdrafted basins must adopt GSPs by January 31, 2020; all other medium and high priority basins must complete GSPs by January 31, 2022. Since many subbasins are hydrologically connected to adjoining subbasins, sustainable groundwater management will require accounting for groundwater interactions with adjoining subbasins. Often, adjoining subbasins will use different analytical methods or apply different levels of technical rigor. Many GSAs are concerned that different methodologies for developing interbasin flows can lead to different results that will call into question the ability to achieve sustainability and would potentially create issues with SGMA compliance.

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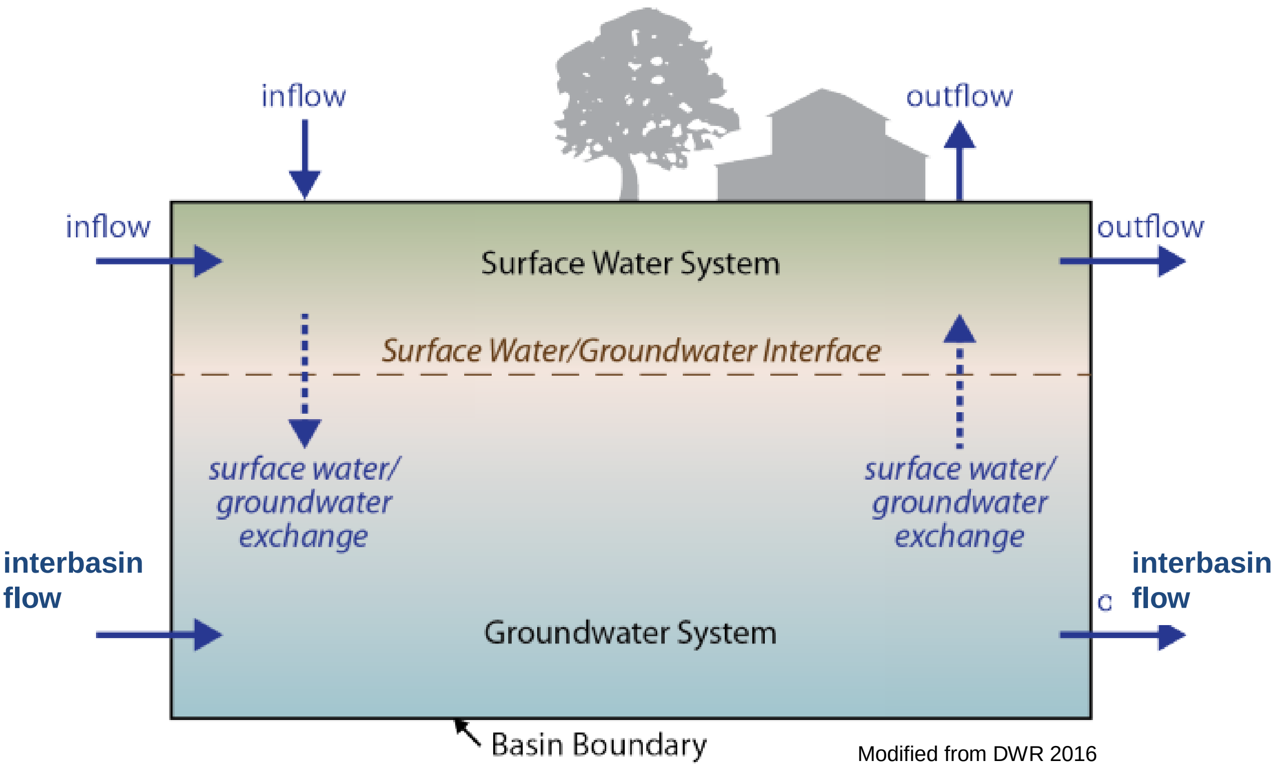
The NSVIRWM was formed through the history of collaboration between the six counties in the plan area—Butte, Colusa, Glenn, part of Shasta, Sutter, and Tehama—in the northernmost part of California's Central Valley. The NSVIRWM has committed to be the regional forum for SGMA collaboration and has delegated the responsibility to their NSVIRWM Technical Advisory Committee (TAC), which meets monthly.

Figure 1: Interbasin Flows as Part of the Groundwater Budget



Modified from DWR 2016

A portion of the NSVIRWM area constitutes the study area (Figure 2) including the area bounded to the north, west, and east by the extent of the Sacramento Valley Groundwater Basin and to the south by the Sutter Buttes. This study area focuses on a portion within the NSVIRWM region where subbasins are recognized as interconnected to varying degrees and relationships among water managers are well-established.

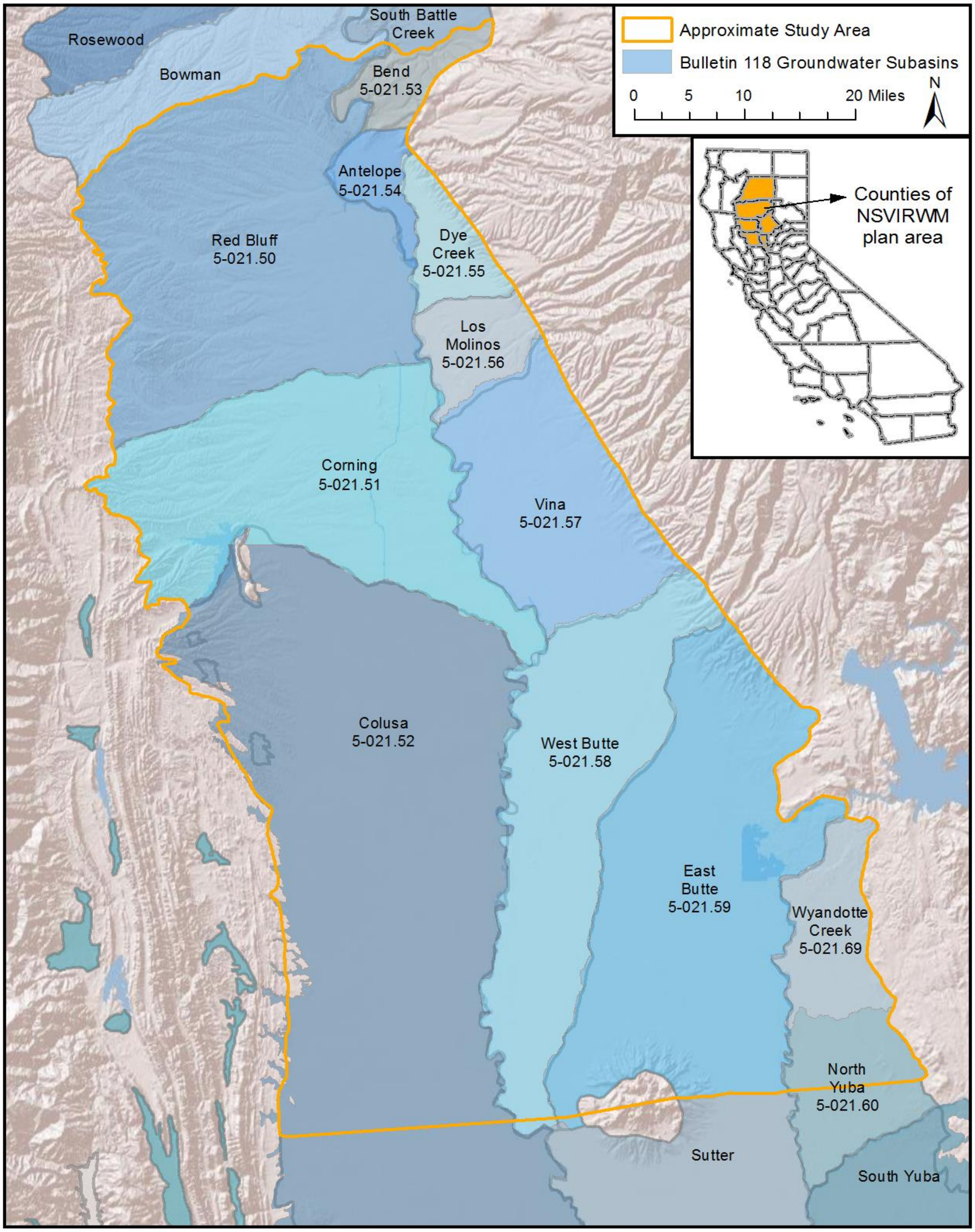
Twelve groundwater subbasins (all part of the Sacramento Valley Groundwater Basin) are the focus of interbasin flows in the study:

- Red Bluff (5-21.50)
- Corning (5-21.51)
- Colusa (5-21.52)
- Bend (5-21.53)
- Antelope (5-21.54)
- Dye Creek (5-21.55)
- Los Molinos (5-21.56)
- Vina (5-21.57)
- West Butte (5-21.58)
- East Butte (5-21.59)
- Wyandotte Creek (5-21.69)
- North Yuba (5-21.60)

These groundwater subbasins are also shown in Figure 2. All the subbasins, except for Bend, were categorized as either being medium or high priority under the California Statewide Groundwater Elevation Monitoring (CASGEM) program in June 2014. None of the subbasins were designated as critically overdrafted by the DWR as of January 2016.

The study area contains all the subbasin connections for the subbasins listed above (e.g., Corning–Red Bluff, Corning–Los Molinos, Corning–Vina, Corning–West Butte, Corning–Colusa, etc.).

Figure 2: Groundwater Subbasins in Study Area



Section 2 Project Goal and Development

The project goal for the Technical Collaboration on Interconnected Subbasins to Advance Sustainable Groundwater Management Project was to build technical capacity of the methodology for assessing interbasin flows, leading to process recommendations that allow for local ownership of future interbasin flow assessments. Goals also included:

- Providing recommendations to GSAs within the study area on methodologies for accounting for interbasin interaction in their GSPs.
- Documenting recommended methodologies to aid DWR in their evaluation of whether one GSP adversely affects the ability of an adjacent basin to achieve sustainability.
- Providing a case study within the northern Sacramento Valley that will provide an approach and example ("lessons learned") for other subbasins that are faced with interconnected subbasin issues.

Numerical groundwater models were focused on as potential tools to meet the project goals. Approaches other than groundwater modeling, were also considered and are discussed in Section 3.1. The results of this project will be used by the northern Sacramento Valley GSAs as they move forward developing GSPs under the SGMA schedule. The methodology for assessing interbasin flows developed during this project will be useful in GSP development. Furthermore, results may aid other GSAs developing GSPs for hydraulically connected subbasins, as well as DWR during GSP review.

This project relied on the input and recommendations from a group of Technical Collaborators (TCs) listed in Table 1. TCs are federal, state, local, and consulting water resources scientists and engineers familiar with the study area subbasins and existing technical tools, including individuals who have experience in assessing interbasin interactions primarily through groundwater modeling. Several TCs are also members of the NSVIRWM TAC.

Table 1: Project Technical Collaborators

Name	Organization	NSVIRWM TAC Member
Charles Brush	DWR Bay-Delta Office, Modeling Support Branch	
Christina Buck	Butte County Department of Water and Resource Conservation	
Grant Davids	Davids Engineering, Inc.	
Bill Ehorn	DWR Northern Region Office	✓
Claudia Faunt	United States Geological Survey	
Allan Fulton	University of California, Cooperative Extension	✓
Thomas Harter	University of California, Davis	
Peter Lawson	CH2M	
Steffen Mehl	California State University, Chico	
Vickie Newlin	Butte County Department of Water and Resource Conservation	✓
Ben Pennock	Glenn Colusa Irrigation District (Retired)	✓
Steve Phillips	United States Geological Survey	
Mary Randall	DWR Northern Region Office	
Oscar Serrano	Colusa Indian Community Council	✓
Ali Taghavi	RMC, a Woodard & Curran Company	

The TCs were engaged throughout the project by a series of five TC meetings and by providing direction and comments on draft materials. The TC meetings were held in 2016 and 2017 at the Sacramento offices of RMC, a Woodard & Curran Company. The meeting topics were selected to take full advantage of the extensive knowledge of the TC, with discussions directed by the project team but with a goal of stimulating discussions and ideas from the TC. The five meetings are briefly summarized in Table 2, with the full presentation slides contained in Appendix A and meeting notes contained in Appendix B.

The project was made possible through the Water Foundation Program of the Resources Legacy Fund.

Table 2: Summary of Technical Collaborator Meetings

Meeting No.	Meeting Date	Primary Topics
1	July 26, 2016	• Define project objectives • Identify and describe available models • Define project outcomes
2	September 6, 2016	• Discuss criteria and approaches for model comparison • Determine ability to provide recommendations on appropriate models • Identify refinement needs in existing models
3	March 7, 2017	• Discuss details on differences in key input data between CVHM and C2VSim • Discuss details on calibration differences between CVHM and C2VSim
4	April 12, 2017	• Discuss the approach and outline for the report • Gain input from the TC on key items and conclusions for the report
5	April 26, 2017	• Receive input on the draft report • Discuss next steps beyond this report

Section 3 Findings

Several regional and local surface water/groundwater models are available that cover all or parts of the NSVIRWM plan area (Section 3.2.1 and Appendix C). These models quantify various components of the water budget and groundwater interbasin flows within each model domain.

The regional and local models introduced in Section 3.2.1 are similar in solving the fundamental surface water and groundwater flow equations[1]; however, representation of surface layer processes and the subsurface system can vary between models. Each model uses its own methodology for developing input data and processing model results. Different conceptualizations of hydrologic processes as well as different input data sources in some cases can lead to significantly different estimates of water budgets components and simulated groundwater level conditions. The more the input data used in these models align, the more the differences in model results reflect the uncertainty inherent to modeling complex systems. Differences in results from two or more models where the input data align closely may provide reasonable bounds on water budget component values.

The assessment of the regional and local models was mainly based on comparison of input data and results of these models. The details of this assessment are presented in the Technical Collaborators presentation slides and meeting summaries provided in Appendices A and B and in the following subsections.

3.1 Perspectives on Models

Integrated groundwater-surface water models are focused on in this report as an important tool in SGMA compliance and overall groundwater management, including the understanding of interbasin flows. The benefits of groundwater models, along with limitations, is acknowledged by DWR, which included it as one of five SGMA Best Management Practice developed in December 2016. In the BMP, DWR (2016a) described groundwater models as follows:

> *As modified from Barnett and others (2012), a model is any computational method that represents an approximation of the hydrologic system. While models are, by definition, a simplification of a more complex reality, they have proven to be useful tools over several decades for addressing a range of groundwater problems and supporting the decision-making process. Models can be useful tools for estimating the potential hydrologic effects of proposed water management activities.*

And, DWR summarized the application of groundwater models to SGMA as follows:

> *Models provide insight into the complex system behavior and (when appropriately designed) can assist in developing conceptual understanding. Models provide an important framework that brings together conceptual understanding, data, and science in a hydrologically and geologically consistent manner. In addition, models can estimate and reasonably bound future groundwater conditions, support decision-making about monitoring networks and management actions, and allow the exploration of alternative management approaches. However, there should be no expectation that a single 'true' model exists. All models and model results will have some level of uncertainty. Models can provide decision makers an estimate of the predictive uncertainty that exists in model forecasts. By gaining a sense of the magnitude of the uncertainty in model predictions, decision makers can better accommodate the reality that all model results are imperfect forecasts and actual basin responses to management actions will vary from those predicted by modeling.*

[1] This report does not cover analysis of model codes. Previous work on this subject has been performed by others, notably: Harter T. and H. Morel-Seytoux, 2013. Peer Review of the IWFM, MODFLOW and HGS Model Codes: Potential for Water Management Applications in California's Central Valley and Other Irrigated Groundwater Basins. Final Report, California Water and Environmental Modeling Forum, August 2013, Sacramento, 58 pages. http://www.cwemf.org.

Although the Central Valley-wide models generally simulate the same region using similar processes, significant differences in model results can occur because of differences in how the system is represented and quantified and because input data can be developed from different sources. Understanding these differences is important for accurate comparison and interpretation of results. DWR and USGS, as respective model owners of CVHM and C2VSim, have an important role to play in defining comparable terms and water budget outputs from these models.

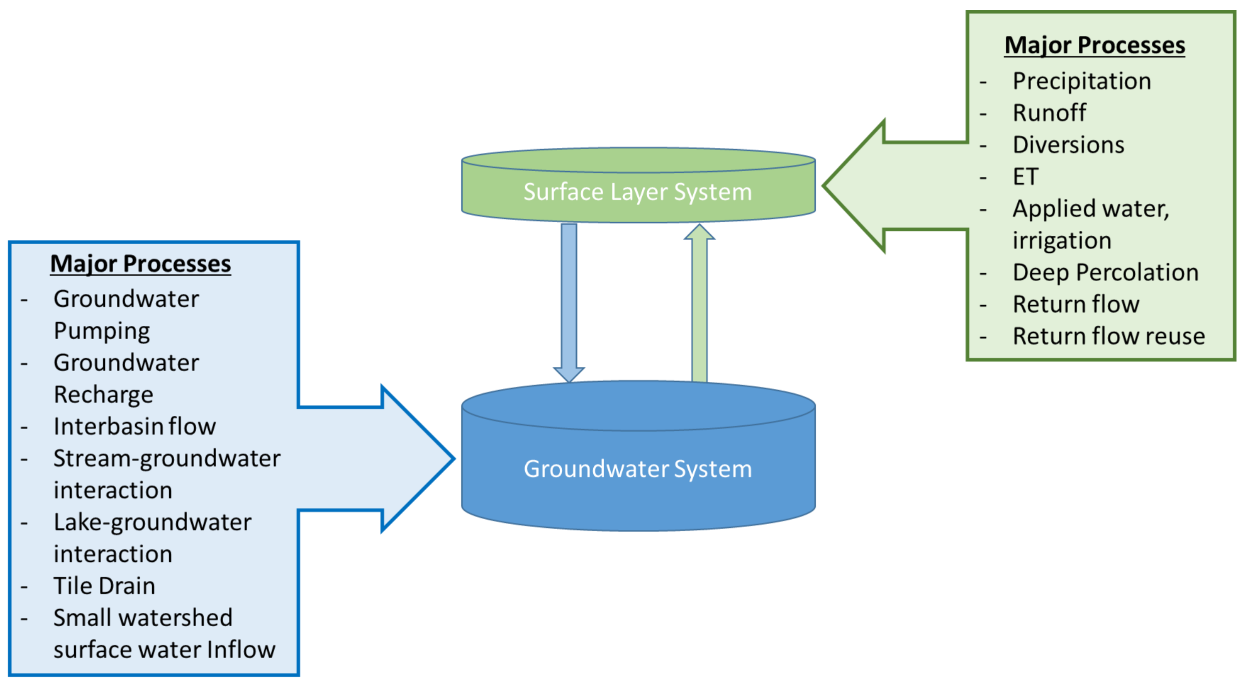
Major components of the available models for the NSVIRWM Plan area, as shown in Figure 4, consist of:

- Surface layer system
- Groundwater system

Each model consists of several hydrological processes for simulating water flow on the land surface, in the surface layer system, and in the groundwater system. Each process requires a significant amount of data which are usually obtained from various sources with different levels of availability, consistency, and accuracy. As an example, land use data from three different sources have been used in CVHM and C2VSim. Land use data from DWR are available by parcel but not for every year while county agricultural commissioners publish annual crop acreages without reference to any specific parcel. Satellite land use data are available at frequent intervals but with some uncertainty about specific land use and only for more recent years.

Additional details on terminology associated with crops and water budgets from CVHM and C2VSim are described in Section 3.2.3.

Figure 4: Major Components and Processes of Models for the NSVIRWM Plan Area



In the absence of a suitable integrated groundwater-surface water model for a subbasin in Sacramento Valley, other approaches might be considered to estimate interbasin groundwater flows. Analytical modeling approaches are primarily based on estimating groundwater elevation gradient across a subbasin boundary. Using Darcy's Law, the interbasin groundwater flows could be estimated by the following equation:

$$Q = q\,A = -\,K\,A\,dh/dl$$

Where,

Q = Interbasin groundwater flow in ft^3/day
q = Interbasin groundwater flow in ft/day
K = Hydraulic conductivity of aquifer material at the subbasin boundary (ft/day)
A = Cross-sectional area of the aquifer perpendicular to groundwater flow direction (ft^2)
dh = head difference between two wells, one on each side of the subbasin boundary (ft)
dl = distance between two wells used for dh calculation (ft)
dh/dl = groundwater head gradient across the subbasin boundary (ft/ft)

SGMA regulations do not require the use of a groundwater model to quantify and evaluate interbasin groundwater flows. However, if a model is not used, an equally effective approach should be substituted. For groundwater basins with complex spatial and temporal variations in water budget components, it is not recommended to estimate interbasin groundwater flows without use of an integrated groundwater-surface water model. Using Darcy's Law is based on historical groundwater elevation data and average aquifer properties. Incorporation of the detailed variations in aquifer properties and basin boundary configuration in this approach is challenging. Averaging the conditions at the basin boundaries may result in missing seasonal and annual variations in aquifer processes. Additionally, a major shortfall of this approach is the inability to predict basin conditions and interbasin flows under future water resources conditions of the basin and SGMA projects needed for sustainability of the basin.

3.2 Model Comparison and Selection

3.2.1 Existing Tools

Numerical hydrologic models capable of simulating interbasin groundwater flow were inventoried to identify options available for use in estimating interbasin flows and to direct the analysis work of the project. Groundwater models which cover the entire Sacramento Valley are the California Central Valley Groundwater-Surface Water Simulation Model (C2VSim; Brush et al. 2013), Central Valley Hydrologic Model (CVHM; Faunt 2009), and Sacramento Valley Finite Element Groundwater Model (SACFEM2013; CH2M Hill and MBK Engineers 2015). C2VSim and CVHM cover the entire Central Valley. The Butte Basin Groundwater Model (BBGM; CDM 2008) administered by Butte County and the Stony Creek Fan Model (SCF Model; WRIME, Inc. [now RMC, a Woodard & Curran Company] 2003) developed by the Stony Creek Fan Partners and DWR cover smaller regions within the northern Sacramento Valley. The spatial extent for each of the models in the study area is shown in Figure 3. A summary of the model features relevant to the simulation of interbasin groundwater flow is shown on Table 3. None of these tools were developed for the purposes of groundwater management under SGMA; although useful, they each have limitations related to SGMA needs.

Note that this analysis focuses on models that were available for this project. New models and updates of existing models are being developed; however, these models were not available and were not applied and evaluated in this project. Some of the ongoing modeling efforts include the following:

- DWR is developing a new model of the Sacramento Valley, named the Sacramento Valley Simulation Model (SVSim). SVSim is being developed primarily to evaluate water transfer projects in the Sacramento Valley and will be more refined than the fine grid version of C2VSim, both in terms of horizontal and vertical discretization and input datasets. It may also be more broadly applicable for evaluation of stream-aquifer interaction.

- C2VSim and CVHM are being updated by DWR and USGS, respectively. The updates include extending input data to include recent extreme hydrological conditions.
- Recent updates to the BBGM include refining land use from the subregion scale to the element scale, extending input data to 2014, and migrating the model code to IWFM-2015 using version 4.0 of IDC and the stream package. Model calibration and documentation is underway in 2017 with a public version intended to be made available in early 2018.

Appendix C contains an inventory of numerical hydrologic models capable of simulating interbasin groundwater flow in the NSVIRWM plan area. Background information is provided for each model.

The inventory of groundwater models indicated that local models are in the process of being updated (BBGM) or are not up-to-date (SCF). SacFEM is not up-to-date and is proprietary. In addition, rather than being an integrated groundwater-surface water model, it couples a surface layer model (IDC) with a groundwater model (MicroFEM). As a result, it is limited in simulating the interconnected nature of stream-aquifer interactions, which will be important for management under SGMA. So, SacFEM is not recommended as a principle model to assess interbasin flows. Despite limitations, these local models can provide useful information for ongoing management or modeling activities. For instance, SacFEM contains transient monthly stream stages and wet-dry seasonal flow timing (ephemeral streams), flood bypass geometry and inundation areas under variable monthly stream flows, transient monthly mountain front recharge rates based on drainage area and historic precipitation patterns, and aquifer transmissivity distribution based on measured well specific capacity. While recognizing the potential utility of other existing models, this effort focused on the existing versions of the two regional models, CVHM and C2VSim, and their application to interbasin flows under SGMA.

Figure 3: Groundwater Model Grids

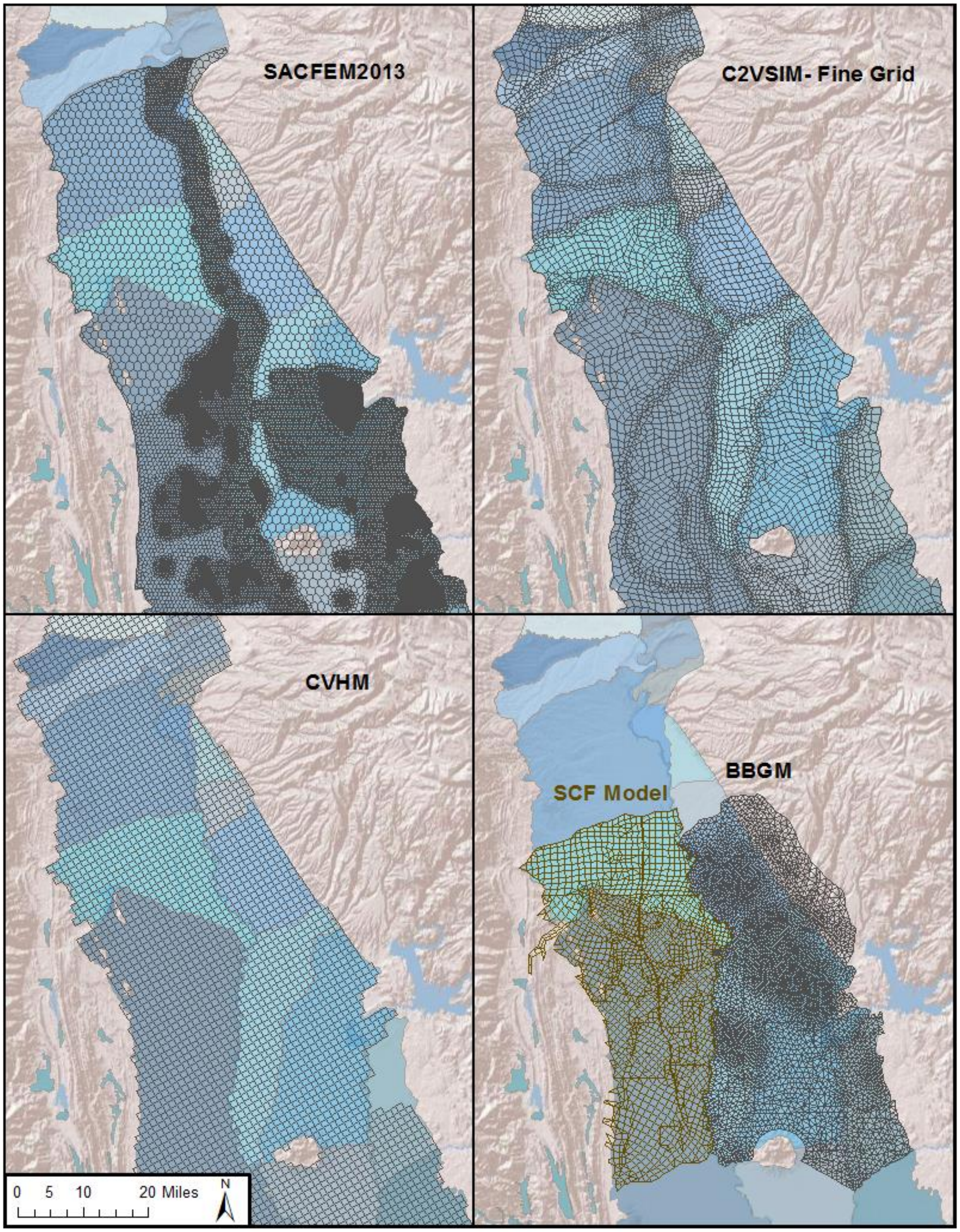


Table 3: Comparison of Components of Available Models

Key Feature	C2VSim	CVHM	SACFEM2013	BBGM 2008	SCF Model
Code Platform	IWFM	MODFLOW-FMP	IDC coupled with MicroFEM	IWFM	IGSM
Public Domain Code	Yes	Yes	Yes for IDC; MicroFEM is proprietary	Yes	Yes
Model Ownership	DWR	USGS	US Bureau of Reclamation	Butte County	DWR
Availability	Coarse grid: DWR website Fine grid: upon request to DWR	USGS website	Uncertain	Upon request to Butte County	Upon request to DWR
Documentation	Brush, et al, 2013	Faunt, et al. 2009	Perry, 2016	Butte County, 2008	WRIME, 2003
Integrated Model	Yes	Yes	Partially: two separate codes used to simulate hydrologic processes	Yes	Yes
Geographic Area	Central Valley	Central Valley	Sacramento Valley Groundwater Basin	Groundwater Subbasins in Butte County	Corning and northern Colusa Subbasins
Simulation Period (Water Years)	1921 - 2009	1961 - 2003	1970 - 2010	1970 - 2014	1970 - 2000
Number of Layers	3	10	7	9	4
Geologic Formations Represented in the Model	Generalized upper unconfined aquifer, confined production zone, Corcoran Clay in the San Joaquin Valley, deep confined zone	Layers not explicitly tied to hydrogeologic units except for Corcoran Clay in the San Joaquin Valley, remainder based on sediment texture model	Layers not explicitly tied to hydrogeologic units except for portions of the Tuscan Formation	Holocene basin deposits, Alluvium, Sutter/Laguna Formation, Tehama Formation, Tuscan C/B/A Formations, older marine (Neroly, Upper Princeton Gorge, Ione)	Alluvial and basin deposits, Tehama Formation, Upper Tuscan Formation, and Lower Tuscan Formation
Agricultural Demand Estimation Method	Integrated methodology using IDC	Integrated methodology using the Farm Process	Calculated externally by IDC	Integrated methodology using IDC	Integrated methodology using IGSM Ag Demand Package
Stream-Aquifer Interaction Method	Integrated methodology using IWFM Stream Package	Integrated methodology using MODFLOW Streamflow Routing Package	Limited; fixed head boundary condition for river stages	Integrated methodology using IWFM Stream Package	Integrated methodology using IGSM Stream Package

Note: Descriptions in this table may not reflect ongoing, unpublished updates to these models.

3.2.2 Role of Local Models

While this analysis and report focused on regional models, local models can play a role in SGMA modeling by being the primary modeling platform for SGMA analysis or by allowing for detailed local analysis while feeding data upward into regional models for regional analysis. In many circumstances, local conditions may require the use of a detailed local model. The need to represent complex conditions or management actions, including water transfers, surface water/groundwater interaction, or the need for costly major projects are examples of potential needs for local models.

In the first iteration of GSPs, different modeling tools may be used by GSAs for quantifying interbasin flows by neighboring subbasins. This may result in different estimates of interbasin flows. While DWR and the State Water Resources Control Board are the final arbiters under SGMA, some level of difference should be acceptable. As more and better local model data and information are incorporated into the regional models, estimates of the interbasin flows will improve and become more similar. Early cooperation with neighboring subbasins to compare interbasin flow estimates and reconcile significant differences in flow and magnitude or direction is very important. Although the exact numbers may be different, the goal is that trends in magnitude and direction should be similar. The differences in part reflect the uncertainty in the modeled systems. Uncertainties in water budget components including interbasin flows, should be acknowledged and, to the extent feasible, estimated.

3.2.3 Comparing Regional Models

Data Inputs (Land Use and Crop Acreage)

Interbasin flows are dependent on groundwater head gradients across the basin boundary. Groundwater heads are, in turn, impacted by processes on the land surface. Land use such as crop type and acreages drive the quantity of water needed to meet the water demand in a subbasin. Depending on availability of surface water, all or part of the water demand may be met by groundwater. Agricultural groundwater extractions, not measured in most cases, are estimated based on estimates of total water demand and available surface water supplies. The difference is assumed to be met by groundwater pumping. Groundwater extractions result in changes in groundwater heads, impacting the interbasin flow rates. As such, an accurate representation of land use and crop acreages is critical for a reliable estimate of groundwater extraction and therefore interbasin flows.

Differences were seen in the representation of crop types and acreage by CVHM and C2VSim, with the models agreeing more closely in recent years (Table 4). The more recent-year agreement is valuable for confidence in the development of baseline scenarios necessary to simulate effects of future groundwater management. Still, the differences in crops between the models suggests that each subbasin/GSA needs to evaluate how their area is represented in the available regional models and select the one that best aligns with local data and knowledge. A challenge with comparing crop types and acreages is the different categories of crops contained within CVHM and C2VSim (Table 5). GSAs should seek guidance from the USGS and DWR on how to appropriately compare the two datasets.

Table 4: Total and Agricultural Area for CVHM and C2VSim in the Sacramento Valley

Year	Agricultural Area (thousands of acres)	
	CVHM[1]	C2VSim[2]
1960	2,015	994
1973	2,171	1,547
1992	2,489	1,550
1998	2,385	1,712
2000	1,726	1,746

Notes:
1. CVHM total area: 3,804 thousand acres
2. C2VSim total area: 3,772 thousand acres

Table 5: Land Use Categories of CVHM and C2VSim

CVHM	C2VSim
Citrus and sub-tropical	Alfalfa
Cotton	Citrus and Olives
Cropland	Cotton
Cropland and pasture	Field crops
Deciduous fruits and nuts	Grains
Developed	Native Vegetation
Field crops	Orchard
Grains and hay crops	Pasture
Idle/fallow	Rice
Irrigated row and field crops	Riparian Vegetation
Native Classes	Sugar beet
Orchards, groves, and vineyards	Tomato
Pasture	Tomato (hand-picked)
Pasture/hay	Tomato (machine picked)
Rice	Truck crops
Row crops	Urban
Semi-agriculture	Vineyard
Small grains	
Truck, nursery, and berry crops	
Urban	
Vineyards	
Water	

Water Budgets

Water budgets are useful tools for water resources management and are now a required component for groundwater management under SGMA. However, significant data collection and analysis are needed to develop a reliable and representative water budget for a subbasin. One or more of the available models could be used to develop water budgets for various areas of the Sacramento Valley including groundwater subbasins or GSA areas. As shown in Figure 8, C2VSim and CVHM were developed based on similar subregions in the Sacramento Valley. Water budgets can be extracted from these models for any of the model subregions. Tools are available for extracting water budget components from these models for other defined zones (i.e., GSA area or subbasin). Extraction of model budgets from both CVHM and C2VSim can be a relatively low-cost method to provide an initial range of values for components of the water budget as a starting point for more detailed analyses. Comparison of results to local data will help identify a potential reasonable range for values of the water budget.

For comparison purposes, water budgets for subregions 2, 3, 4, and 5 were extracted out of C2VSim and CVHM and are summarized in Table 6. Table 6 is not a comprehensive water budget; however, it includes the long-term averages (1961-2003) of major components of the water budget for the four selected subregions. As shown in Table 6, significant differences exist in estimation of the average values of five water budget components by these two models. The differences in Table 6 are, in part, due to differences in land use and crop acreage input data of the two models as well as to differences in terminology and definitions. These differences underline the importance of developing method to ensure consistent "apples to apples" comparisons between models as well as the importance of using common and consistent datasets between models.

Both C2VSim and CVHM models are undergoing updates and the presented water budgets are subject to change. Additional clarity from the model developers on how to compare water budget components between models would assist GSAs in understanding the differences in these models, and is included in the Conclusions and Recommendations section. Additional details discussion on the case study analysis are provided in Appendices A and D.

This analysis suggests that 1) there is not a model that is obviously better-suited for SGMA application in the northern Sacramento Valley area and that 2) each subbasin/GSA needs to evaluate how their area is represented in available regional models and select the one that best aligns with local data and knowledge. It is recommended that before using CVHM and C2VSim models with newer input data for development of more current water budgets for various parts of the Sacramento Valley, one or more of these models should be employed with pre-existing input data to generate water budgets for comparison against the local data and knowledge of groundwater and surface system in the water budget area. The model that reflects land use and generates water budgets that compares most favorably with local data and knowledge may be the most appropriate model to select and invest in for future modeling.

Figure 8: Shared CVHM and C2VSim Subregions
(Note: Water Budget of Table 6 is for Subregions 2,3,4, and 5)

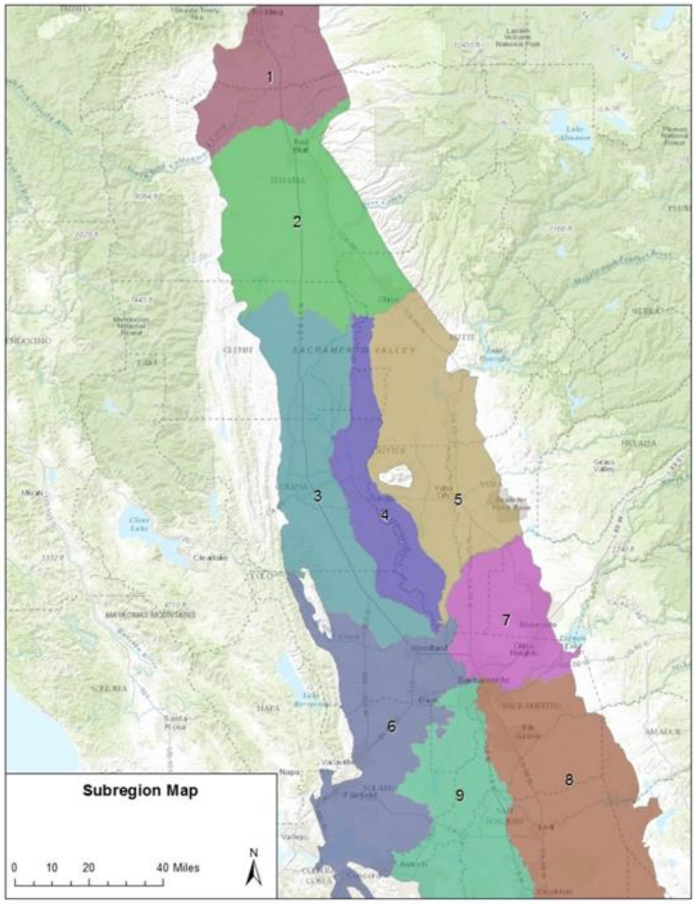


Table 6: Long-Term (1961-2003) Average Water Budget for Selected Components, Subregions 2, 3, 4, and 5

Water Budget Component	Basis in Model	Long Term Average Volume Subregions 2, 3, 4, and 5 (see Figure 8) (thousand acre-feet per year)
CVHM *note: differences in C2VSim and CVHM water budgets are largely due to both differences in data and terminology*		
Ag Water Required	Final Total Farm Delivery Requirement	1,928
Surface Diversion	Routed and Nonrouted Surface-Water Delivery	1,339
Pumping	Multi-Node Wells and Farm Wells	1,853
Groundwater Recharge	Net Farm Recharge	2,384
Stream Recharge*	Stream Leakage	-1,021
C2VSim *note: differences in C2VSim and CVHM water budgets are largely due to both differences in data and in terminology*		
Ag Water Required	Agricultural Supply Requirement	3,491
Surface Diversion	Agricultural Diversion, Urban Diversion	3,126
Pumping	Agricultural Pumping, Urban Pumping	948
Groundwater Recharge	Net Deep Percolation and Recharge	876
Stream Recharge*	Gain from Stream	-338

Note: Negative values for stream recharge in this table indicates stream is gaining (groundwater flows into stream).

Calibration

Simulated groundwater elevations have the most effect on quantifying interbasin groundwater flows because groundwater flows from higher to lower elevations or head. Therefore evaluating a model's representation of groundwater levels in comparison to historical data is important, particularly in the areas along subbasin boundaries. This section presents a comparison of the two models' calibration for groundwater elevations in the Sacramento Valley. Surface water and groundwater model calibration usually involves modifying estimated model parameters, such as hydraulic conductivity, until an acceptable match of model simulated and observed groundwater levels and/or streamflows are obtained. Availability of observed data and the level of understanding of the flow system in the modeled basin are the two main factors in achieving a good model calibration. Model areas with few or no monitoring wells or insufficient number of observed water levels will result in poor model calibration. Similarly, models of basins with unknown or poorly understood faults will be very difficult to calibrate.

C2VSim and CVHM were calibrated using historical data for streamflows and groundwater elevations. Figure 9 shows the location of wells used for calibration of C2VSim and CVHM models. The calibration wells that are common between the two models are shown by red dots. There are 79 and 291 calibration wells in the CVHM and C2VSim models in the Sacramento Valley area, respectively. There are 28 common wells used by both models. Hydrographs of simulated heads and observed heads for three of the common wells are presented in Figures 10, 11, and 12. Hydrographs of several other calibration wells are provided in Appendix F. As shown in Figure 10, CVHM has a better match with the observed water levels of this well and is more responsive to seasonal fluctuations. C2VSim shows a better match with the observed water levels of the wells in Figures 11. In Figure 12, C2VSim provides a better match with observed water levels on an average basis, but CVHM provides a better match of the trend over time.

It is highly recommended that when using models for estimating interbasin flows, the calibration status of the model in areas near the basin boundaries be carefully reviewed. If the model overestimates the hydraulic gradient across the boundary, then the model interbasin flows would be larger than the actual interbasin flows. In contrast, if the model underestimates the hydraulic gradient across the boundary, then the model interbasin flows would be smaller than the actual interbasin flows. The errors in model estimated interbasin flows could be significant for SGMA planning work, as the models may underestimate or overestimate the effectiveness of planned groundwater management in the basin. However, this is expected to improve as the models are updated and GSAs apply models more consistently and routinely during the 25-year time span for achieving sustainability under SGMA.

Figure 9: Location of CVHM and C2VSim Calibration Wells

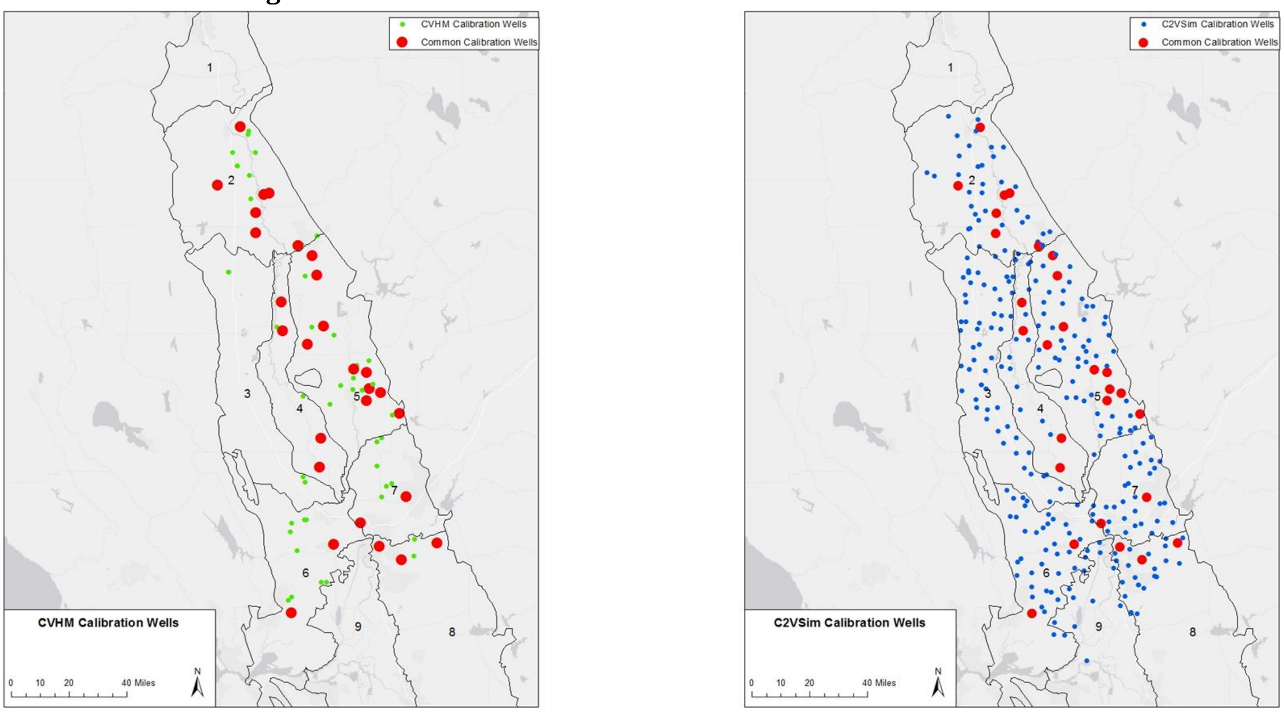
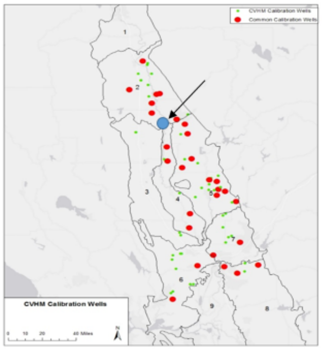


Figure 10: Simulated and Observed Water levels for a Representative Shallow Calibration Well (23N02W16B001)

- Active Irrigation
- Shallow (100 – 120 ft)



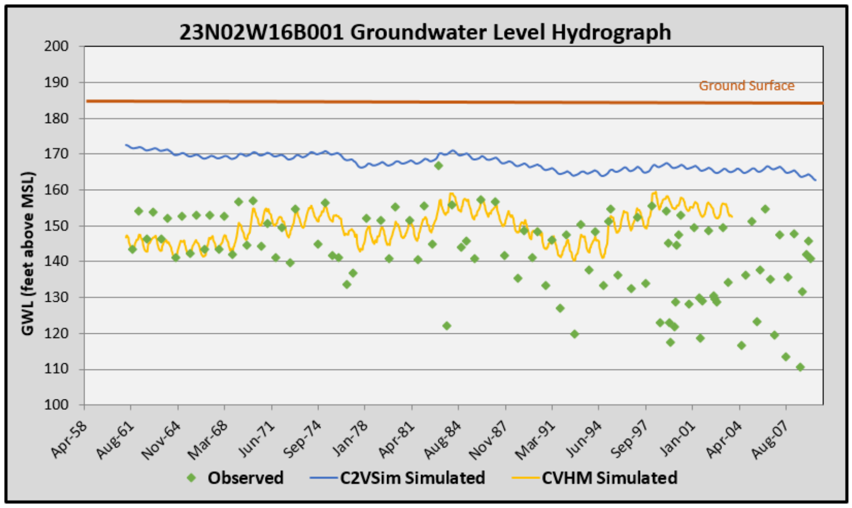
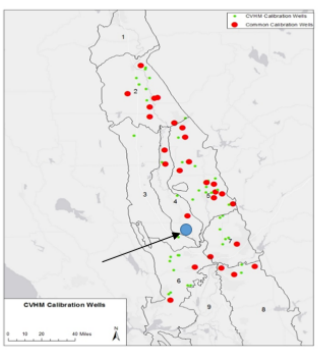


Figure 11: Simulated and Observed Water levels for a Representative Intermediate Calibration Well (12N02E20P001)

- Active, unknown type
- Intermediate (Total Depth – 500 ft)



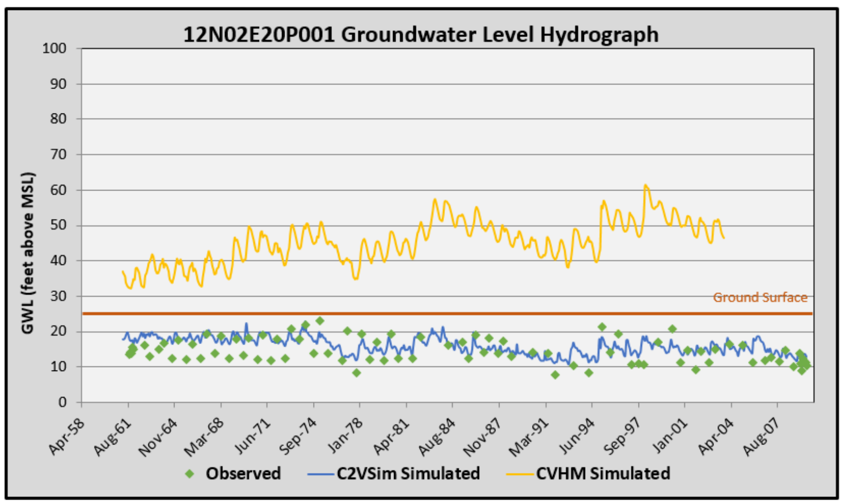
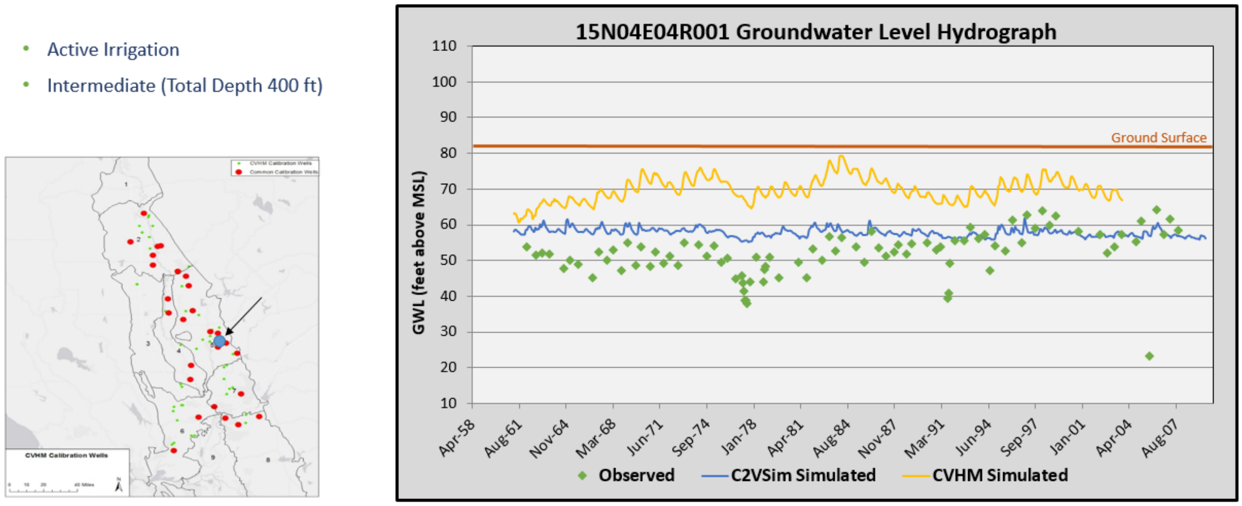


Figure 12: Simulated and Observed Water levels for a Representative Intermediate Calibration Well (15N04E04R001)

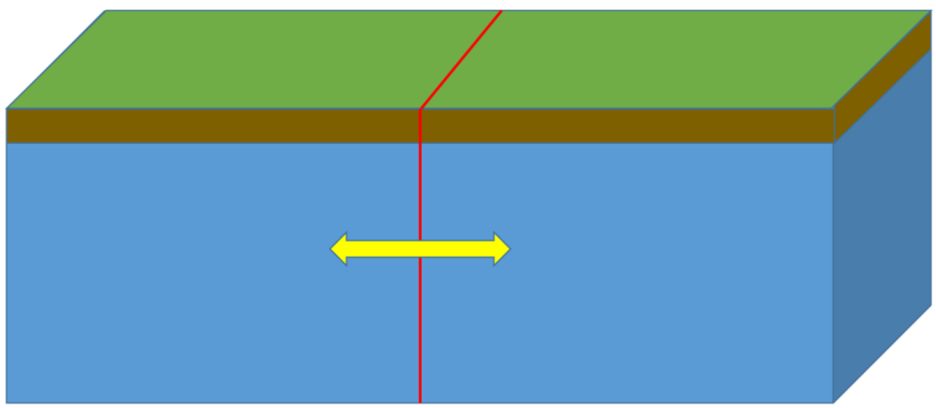


Section 4 Accounting for Interbasin Flows Example

As discussed in Section 1, interbasin flow is groundwater entering or exiting a defined region through its boundaries in the subsurface. Figure 5 shows a simple representation of interbasin flow across two adjacent basins. The red line represents the boundary of two adjacent hydraulically connected basins. The yellow arrow represents the two-way flow of groundwater into and out of the basins. The direction and quantity of interbasin flow depends on the groundwater head gradient across the basin boundary.

Often basins are divided along rivers resulting in complications of quantifying stream recharge entering each adjoining basin. Different models have different methods of accounting for stream recharge in model water budgets. C2VSim assigns the rivers to model cell boundaries while CVHM assigns the rivers to areas within model cells. This results in differences in accounting of stream-aquifer interaction. River recharge within C2VSim will be split between subregions on either side of the river, while CVHM will show river recharge within the subregion on one side of the river, with associated changes in interbasin flows. Guidance from DWR and USGS would help GSAs to appropriately and consistently account for this difference in their water budget development. Additional information on stream-aquifer interaction at model boundaries are provided in Appendix E.

Figure 5: Simple Representation of Interbasin Flow



Interbasin flows at any given basin boundary may vary significantly in space and time based on the dynamics of inflow and outflow components of the basins. Groundwater pumping in one basin could bring the groundwater levels down resulting in the gradient at the boundary to be towards the pumping area and increased interbasin flow to this basin. Other basin processes such as artificial recharge, irrigation, and changes in climate could result in changing the gradient at the boundary and interbasin flow rates.

Groundwater models presented in Section 3.2.1 could be used to quantify interbasin flows at subbasin boundaries in the NSVIRWM Plan area. As an example, the C2VSim model was used to quantify interbasin flows in the Vina subbasin. The Vina subbasin was split into two hypothetical subbasins along the Tehama and Butte county line: North Vina and South Vina subbasins (Figure 6). Water budget information for these two subbasins as well as interbasin flows between the two subbasins and the adjacent basins (Corning and West Butte) were extracted from the C2VSim model.

The C2VSim budget output showed a complex system with boundary flow magnitudes and directions that change over time due to changes in groundwater heads that are driven by groundwater pumping, surface water use, and recharge dynamics. Interbasin flow directions are generally from the Corning and North Vina into South Vina and from South Vina to West Butte. In later years of the C2VSim simulation (after

2005), almost 50 TAF per year of interbasin flows enter South Vina while about 10 TAF per year flow into West Butte subbasin.

Other components of water budgets (groundwater pumping, etc.) were also obtained from C2VSim for the South Vina subbasin. Figure 7 shows a comparison of the interbasin flows of the South Vina subbasin from the three adjacent subbasins to the total groundwater budget quantities, shown in gray. Comparison of interbasin flow rates with the overall inflows and outflows can give an assessment of scale of the overall importance of interbasin flows, i.e., whether they are a significant part of the groundwater budget or not.

As shown in the example for South Vina subbasin, the available models for the NSVIRWM Plan area can generate estimates of interbasin flows over time and in relation to total inflows and outflows from the subbasin. However, as shown in previous sections, representation of the local conditions by these models may not be very accurate and groundwater budgets and interbasin flows contain a certain degree of uncertainty and error. Appendix E provides additional information on accounting for interbasin interaction.

Figure 6: Hypothetical North and South Vina Subbasin

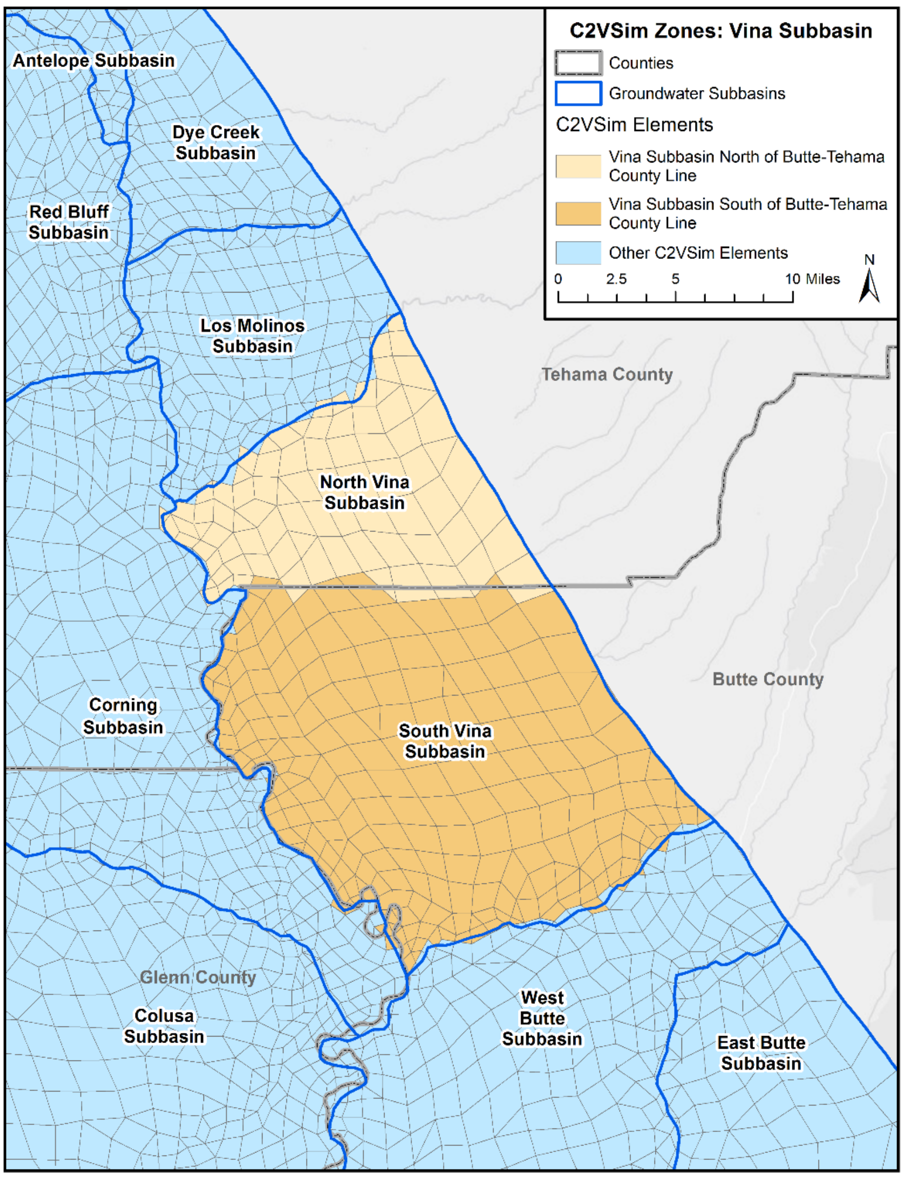
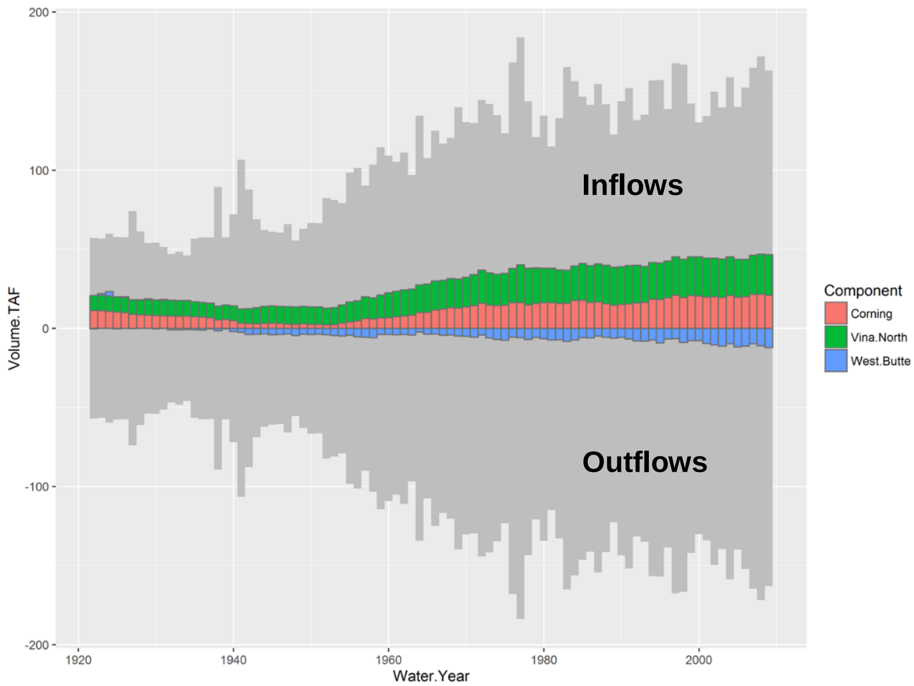


Figure 7: C2VSim Model Results of Interbasin Flows from South Vina to or from Corning, North Vina and West Butte Subbasins Relative to Total Inflows and Outflows



Section 5 Recommendations

This effort presented considerations for local agencies and GSAs on whether and how to utilize the existing integrated surface water and groundwater models in support of their efforts to prepare GSPs. Ultimately, the lack of a clearly more suitable groundwater model and the unique conditions and needs of local areas resulted in the TC not recommending a single groundwater model for the northern Sacramento Valley. Each GSA will need to go through a process to consider the most appropriate approach for their local area. The following conclusions and recommendations are provided to assist in developing that process and are presented specifically for the northern Sacramento Valley, for Statewide use, and for DWR and USGS, as the developers and caretakers of the two existing Central Valley groundwater models.

GSAs, based on their in-depth knowledge of their basins, should review the available models for their basin. The existing models include uncertainty and require updating as more data become available and understanding of the basin is improved or additional hydrologic processes need to be simulated by the model. As the best available tools, the existing models may be used in their current state for SGMA purposes. GSAs should identify the shortcomings of the existing models based on the modeling needs for development of their GSPs. The existing models could then be improved through collaboration between GSAs, DWR, and/or USGS. GSAs could then use the updated models for the next iteration of GSPs for their five year updates over the course of the plan implementation and reporting period.

5.1 Recommendations for GSAs in the Northern Sacramento Valley

The northern Sacramento Valley has several unique characteristics and needs that should be considered when selecting a model to account for interbasin flows between the hydraulically connected subbasins. The area is covered by two Central Valley models, both of which are being updated; one local model that is being finalized; and one Sacramento Valley model which is in development. In addition to the numerical groundwater models, the area also has several local surface layer models that have proved useful for water management. At the land use level, the area has highly varied cropping patterns, with crops with very different water usage requirements. Many of these crops are irrigated with the region's extensive surface water supplies that have been implemented over time. As the area does not have the severity of overdraft conditions seen in other parts of the state, interconnected surface water systems may be more important for SGMA compliance. Finally, the area has areas of agricultural expansion and increased groundwater use in areas near the boundaries of the defined Bulletin 118 groundwater basins.

5.1.1 Available Groundwater Models

At the time of GSP development, the most current available version of the C2VSim and CVHM models should be considered for development of water budgets including estimation of interbasin flows. If SVSim becomes available in time, it should also be considered. In cases where local groundwater models exist and can provide a complete water budget including interbasin flows using more detailed data, they are likely preferable.

5.1.2 Selection of a Groundwater Model

In addition to the more general statewide selection process described in Section 5.2, it is recommended that the northern Sacramento Valley GSAs consider the following question when selecting a groundwater model: **How well does the model match my current understanding of the surface layer and groundwater budget in my area?** This question can be answered by considering the input data, supply and demand, boundary conditions, water balance, and calibration, including whether parameters are realistic.

Consider beginning by extracting readily available model input and water budget output data

Extraction of available data within the existing CVHM and C2VSim can help provide initial estimates and may define reasonable bounds for interbasin flows and other components of the water budgets. This includes input data (such as crop acreage or ET estimates) and output data (such as estimates of groundwater pumping, recharge, etc.). Such an effort is likely to be relatively low cost, particularly if the USGS and DWR can provide tools or information to facilitate this exercise (see Section 5.3).

Consider surface layer models.

Many areas within the northern Sacramento Valley have surface layer models that calculate a portion of the groundwater budget. These budgets are valuable planning and operations tools for local agencies. While they generally are not adequate to calculate interbasin flows or groundwater/surface water interaction and are generally not well suited for predictive simulation, they do often incorporate a detailed understanding of water deliveries and crop water use. If a detailed, locally-accepted surface layer model exists, the results of this model can be compared to the corresponding results of the available groundwater models to see which model more closely resembles the local understanding of those components of the groundwater budget, focusing on recent periods.

Note that the surface layer model should be used only to assist in selecting the appropriate groundwater model, and that it is not appropriate to mix output from the groundwater model with other local water budget sources. Groundwater model results should be presented in full to keep the results internally consistent.

Consider cropping patterns.

The crops grown in the northern Sacramento Valley have highly different water demands. Northern Sacramento Valley GSAs should consider what crops are grown in their area and how well the different models represent the crops grown in that area. This is particularly true for areas growing rice and for the representation of total irrigated agricultural acreage, notably newly irrigated areas. The comparison may be performed visually with maps, through analysis of total acreage, and/or through analysis of estimated per-acre water use.

Consider crop irrigation

Agricultural irrigation has been shifting over time towards higher efficiency systems such as drip or low-energy micro-sprinklers. Different irrigation techniques impact water demands and groundwater recharge. Areas that have experienced changes in irrigation techniques should analyze whether the model properly represents the crop demand and recharge by reviewing the irrigation efficiency values within the model.

Consider complex surface water systems

The northern Sacramento Valley is rich in water resources, and many areas utilize surface water for irrigation. These systems are complex and have changed over time. Additional complexity is added through water transfer programs, which are common in the area and can include land fallowing or increased pumping to allow for use of local surface water resources by others within and outside the region. Northern Sacramento Valley GSAs should consider how adequately the models represent complex surface water supplies. For areas with extensive groundwater substitution transfers, it is possible that a more refined local model may be necessary to capture the finer details of changes in the groundwater and surface water systems. Analysis of surface water representation in the models can be done through comparing diversion and surface water use data from the models to local data, focusing on recent periods.

Consider interconnected surface water

SGMA drivers for the northern Sacramento Valley are likely to be based around maintaining sustainable connections between surface water in rivers and streams with groundwater in aquifers rather than on changes in groundwater storage. As such, the representation of this interface is important for model selection. Ultimately there are little data on groundwater-surface water interaction, and assessments of the models will need to be based on data that can be compared to historical data: surface water flows and groundwater elevations. GSAs should consider if the models simulate the rivers and streams considered important to their area and the level of calibration of the surface water flows and nearby groundwater elevations. Localized studies of stream losses or gains can be compared to model results, but note that such studies are not typically available in most areas.

Consider foothill groundwater use

Many areas of the northern Sacramento Valley are adjacent to areas outside of groundwater basins but that still have substantial groundwater resources. Often these groundwater resources provide subsurface inflows into the groundwater subbasins of the northern Sacramento Valley. GSAs should consider the extent to which the models represent flows from outside the model boundary and incorporate recent agricultural development, associated groundwater use, and the impact on groundwater inflows. This assessment may be performed through analysis of groundwater elevation data at wells near areas of increased groundwater use. If significant future increases in groundwater production outside of the alluvial aquifer system is anticipated, the GSA should assess the ability of the models to incorporate associated changes in inflows to the basin.

Consider what your neighbors are using

Ultimately the modeling process will be easier if neighboring subbasins use the same model. Coordination with neighbors may allow for, all things being equal, selection of a common model for analysis.

Consider working with DWR and USGS to improve regional models

Local data and understanding can improve regional models through cooperatively working with DWR and USGS. Notably, providing more detailed data such as crop types and water operations can greatly improve the usefulness of the regional groundwater models.

5.2 Recommendations for GSAs Statewide

While focused on the northern Sacramento Valley, much of the work performed in this study is applicable to all of the Central Valley and other groundwater basins in the state.

5.2.1 Project Approach

The approach to identifying models used in this effort is one that can be adopted and modified for use by others. This effort used the following steps:

1. Form group of Technical Collaborators (preferably with representatives from adjacent subbasins where applicable)
2. Identify needs
3. Identify models
4. Extract readily available simulated data to analyze models
5. Select integrated model and approach to long-term modeling

Form group of Technical Collaborators

A group of technical collaborators or local experts are critical to support and guide an interbasin groundwater flow study or model selection process. Collaborators should be consulted on major project decisions and guide the process from planning through to completion. The collaborators, through attending meetings and reviewing study results, provided vital input to:

- Identify characteristics necessary in a groundwater model and approach to modeling that reflects and is suitable for local conditions, needs, and is appropriately transparent.
- Select the model or models, and approach that appears to be most cost effective, accurate, adaptable, and repeatable.
- Review modeling materials produced often and carefully to accurately convey the process and

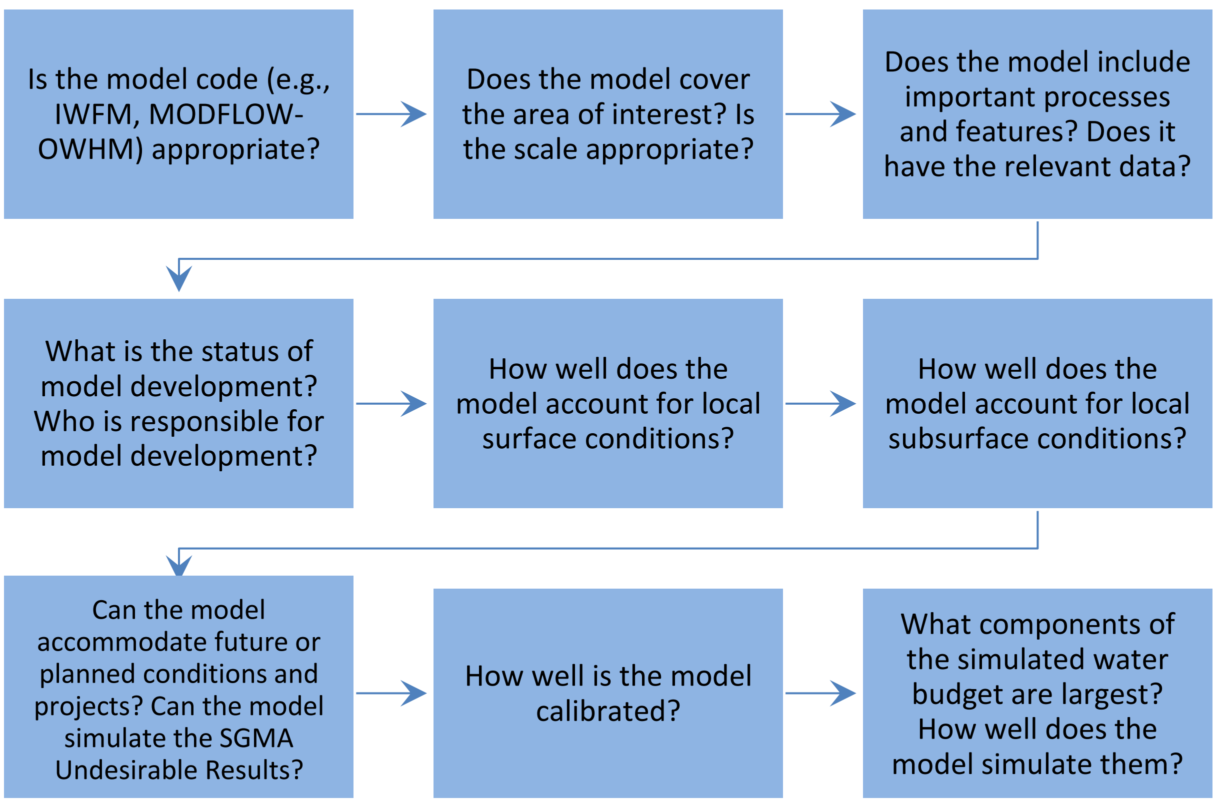
results to a broad audience of technical and non-technical readers.

Identify needs
Collaborators will also help identify and clarify modeling, goals, objectives, and outcomes. Each area will have unique characteristics that cause differences in the analysis of hydraulically connected subbasins. As described above, evaluation of interconnected surface waters will be an important aspect of successful sustainable management in the NSVIRWM area. Other areas of the state may place higher priority on groundwater levels, storage, quality, seawater intrusion, land subsidence, or faults that act as flow barriers.

Identify models
An inventory of models used within the local area is important to understand what tools are available and what sort of model selection decisions and obstacles have already been identified. The model inventory should include information on the models, including a summary of their use, as well as details on how they are utilized, especially regarding approaches to interbasin interactions.

Analyze models
Identified models can then be analyzed for the specific study area. To determine whether a groundwater model is appropriate for interbasin flow analysis in the study area, the flowpath in Figure 13 may be considered as broad categories when selecting a model to analyze interbasin groundwater flows.

Figure 13: Model Selection Criteria Based on Local Data and Knowledge and Pathway for Long-term Modeling to Support Sustainable Groundwater Management



This step is complex, and the technical analysis must be paired with stakeholder outreach to gain broad acceptance needed for ultimate implementation of policies based on model results. The next section contains several recommendations to direct the analysis of the models.

Select approach

With the guidance of the technical collaborators, an approach to analyzing interbasin groundwater flow is selected and integrated groundwater modeling work can begin. An integrated groundwater model such as C2VSim or CVHM is recommended over only using simpler analytical models (page 9) based on Darcey's Law. The complexity of interbasin groundwater interactions and the need to analyze future management actions limits the effectiveness of these simpler analysis methods.

5.2.2 Model Analysis Recommendations

Recommendations are provided for several aspects of model analysis:

1) Identify what is important for groundwater flow. Which components are most important to the groundwater system and which components are most likely to be different in the groundwater models? For instance, precipitation is important to models, but is unlikely to vary significantly between models due to the general availability of precipitation data. Some areas may know that agricultural groundwater use is a large component of the groundwater system but has little quantitative data. Other areas may be highly urbanized but with highly uncertain stream losses contributing greatly to the aquifer system.

2) Develop cost-effective methods to compare readily extractable data across more than one groundwater model. Reporting from models is different spatially, with depth, in terminology, and even in what is reported. A deep understanding of what is reported, how it is reported, and the definition of the terminology is critical to comparing across models. Potential comparisons include land use, agricultural water use, overall water budgets, groundwater heads, streamflows, surface water groundwater interaction, and others. Special care is needed when comparing stream groundwater budgets and boundary flows because of differences in how the modeling codes represent streams (see Appendix E for details).

3) Compare the models back to historical data, if possible. Identifying differences in models is valuable, but more valuable is identifying which model has the best data and more closely simulates conditions in an area of interest, and thus which may be better suited for simulating future conditions.

4) Acknowledge that there is no "right model." Groundwater modelers are fond of quoting statistician George Box, who wrote, "all models are wrong; some models are useful." It is critical to consider the use of the model when assessing the model and to determine what is important for getting to useful answers.

   Determination of what is useful will depend on local conditions and local needs. For the northern Sacramento Valley, components like simulating interconnected surface water will likely be important while simulating seawater intrusion will not be important. Simulation of groundwater elevations will likely be important for all groundwater basins in the state, but accuracy may be more important in areas of GSAs with more intensive use or areas that may change over time.

5) Utilize baseline simulations. The models are likely to be used to consider different water management scenarios, whether they will achieve sustainability, and how they can be implemented. The models are likely to be run with a baseline simulation representing current or future land and water use conditions. Thus, differences in older data may impact older calibration results, but will have less impacts on the baseline analysis.

6) Recognize uncertainty and incorporate into adaptive management, particularly in absolute groundwater elevations. SGMA will likely require that the models be used for estimation of both absolute measurements and relative groundwater elevations. Absolute groundwater elevations, such as estimates of sustainable pumping levels, are more prone to error and differences between models than relative measurements, such as quantifying the benefit of a project compared to a no-

project condition. While this presents a challenge for implementing agencies not wanting to underestimate or overestimate sustainable pumping, the SGMA process that allows an adaptive management approach. The selected model will support management efforts to allow reaching defined, measurable targets. This allows for adjustments in management actions moving forward. If the model underestimates the need for action, then additional activities can be taken on when targets are not met. Similarly, if the model results lead to overly-aggressive actions, then these can be ramped back in the future. Managers should consider this uncertainty when developing management actions and be prepared to increase or reduce actions depending on system response to management actions.

7) Accept that different models will not perfectly agree. Differences in interbasin flows will need to be discussed and, if both models are deemed reasonable, accepted and managed. GSAs should recognize how management in the adjacent subbasin may change groundwater conditions in their area. For instance, if management in the adjacent basin is expected to lower groundwater elevations by 10 feet along a boundary, this condition should be transferred into the adjacent model to the extent feasible, by incorporating changes in management in the adjacent area or modifying boundary conditions. In this way, the relative change in groundwater elevations is consistent across the models.

8) Recognize modeling is necessary to answering the questions posed by SGMA. Integrated models provide a relatively transparent, internally consistent method that is grounded on available data and allows for simulation of future conditions under different management scenarios. If an existing groundwater model does not adequately represent local conditions, revisions or updates to the model are required to incorporate important aspects of the system rather than abandoning modeling all together. It should be expected that models always be in some state of update as the inputs and representation of reality continue to be refined. Yet, they can also be useful tools in the meantime, even with their limitations.

9) Update the model and revisit the decision on the most appropriate model. GSAs should consider how to incorporate updated models or new models into management. Inevitably, updates or new models will result in different results to some degree. GSAs should recognize this reality of the incorporation of new data and new techniques into model and allow for the inclusion of improved data rather than being forced to stay with an outdated model due to consistency. The key is to allow for incorporation of the new information without resulting in sudden and disruptive shifts in management actions. In the end, the model is a tool to achieve management objectives based on real data. Proper planning can allow for using the best available science while maintaining a groundwater management structure that is not destabilized by changes in the model and its results.

5.3 Recommendations for DWR and USGS for Providing Technical Assistance to GSAs

It is recognized that neither CVHM nor C2VSim were developed with the purpose of complying with SGMA because they preceded SGMA by many years. While the current revisions to both models are anticipated to provide more detailed and more accurate results, the following are recommended as part of the continued improvement and updates to the model, allowing them to serve as useful tools for GSAs within the northern Sacramento Valley and across the Central Valley. Timely and quality refinements will allow for more accurate and efficient completion of GSPs by the GSAs.

1. Move towards common datasets between CVHM and C2VSim, with regular updates, notably land use, actual evapotranspiration, land subsidence based on InSAR and extensometers, stream gages, and aquifer structure.
2. Develop post-processing tools to assist GSAs in developing information needed for SGMA, such

as

- Extracting pre-set or pre-existing (readily available) input data (i.e. crop types, acreages, water use efficiency, etc…)
- Extracting water budgets for specific GSAs
- Extracting simulated heads at given locations
- Developing sustainability estimates.

3. Develop guidance on developing water budgets, specifically
    - Terminology linkages between CVHM and C2VSim to allow for comparable water budgets
    - Methods for developing water budgets where boundaries are defined by a stream
4. Refine the models or develop tools to allow reporting of water budgets at the subbasin level, GSA level, or management zone level.
5. Develop a process by which local agencies can submit data to inform regional models
6. Develop guidance for quantifying acceptable levels of uncertainty (monitoring, water budget, modeling) and how to utilize uncertainty estimates as part of modeling predictions to support decision-making
7. Develop guidance on how to use these regional models to address the six SGMA Undesirable Results.
8. As new models are developed by DWR or USGS, such as SVSim, develop guidance on suitability for use with SGMA and differences between existing models.
9. Provide technical support and training to local agencies to assist in their use of modeling tools.
10. Develop guidance for expected cost and investment into the refinement of groundwater models to meet SGMA and GSA requirements.
11. Improve ability to simulate interconnected surface waters by
    - Assessing need for grid cell size reduction near rivers and streams (e.g., as performed in RMC, 2016)
    - Surveying existing surface water stage gages and verifying stage-discharge relation
    - Reviewing available surface water interconnection studies (e.g., isotope studies) and assessing the ability to incorporate results into the models.
12. Incorporate operation of water transfers, including fallowing and pumping increases, into models, if not already present.
13. Assess water use by rice, including tailwater reuse

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Appendix A - Technical Collaborators Presentation Slides

Butte County
CALIFORNIA

Interbasin GROUNDWATER FLOW Evaluation Project

Technical Collaborators Meeting 1

July 27, 2016

Meeting Outline

- Introductions
- Project Objectives
- Roles
- Model Inventory
- Questions for Discussion

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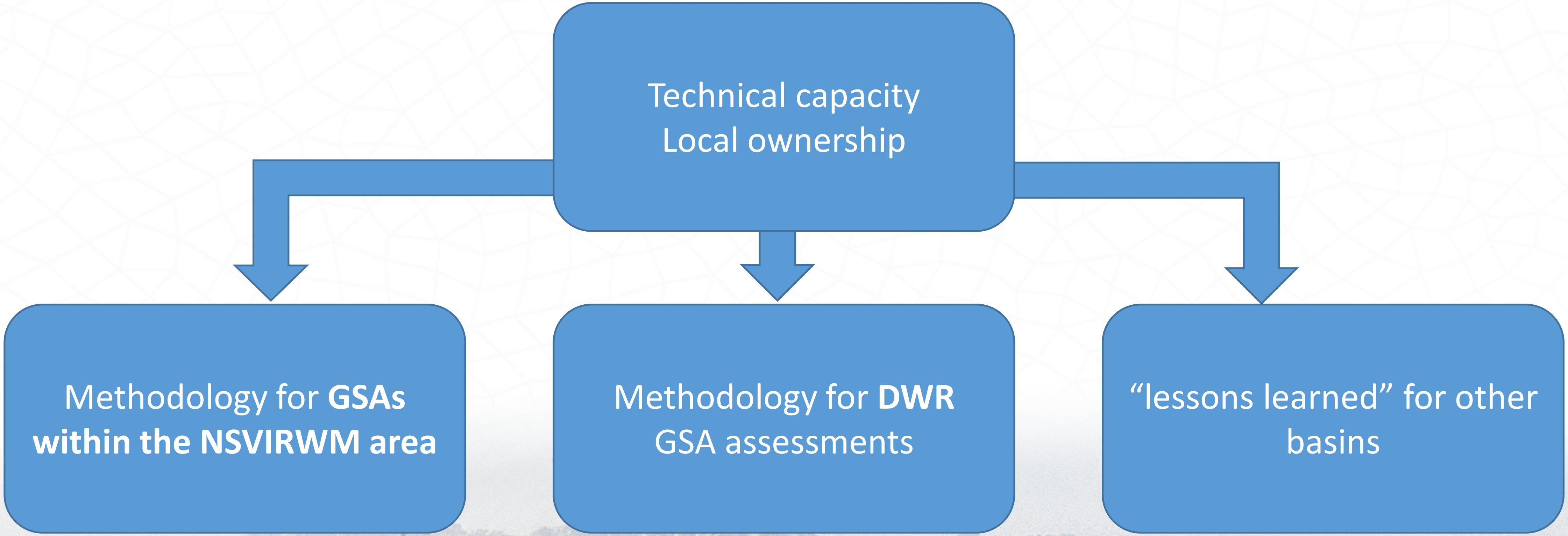
Project Objectives

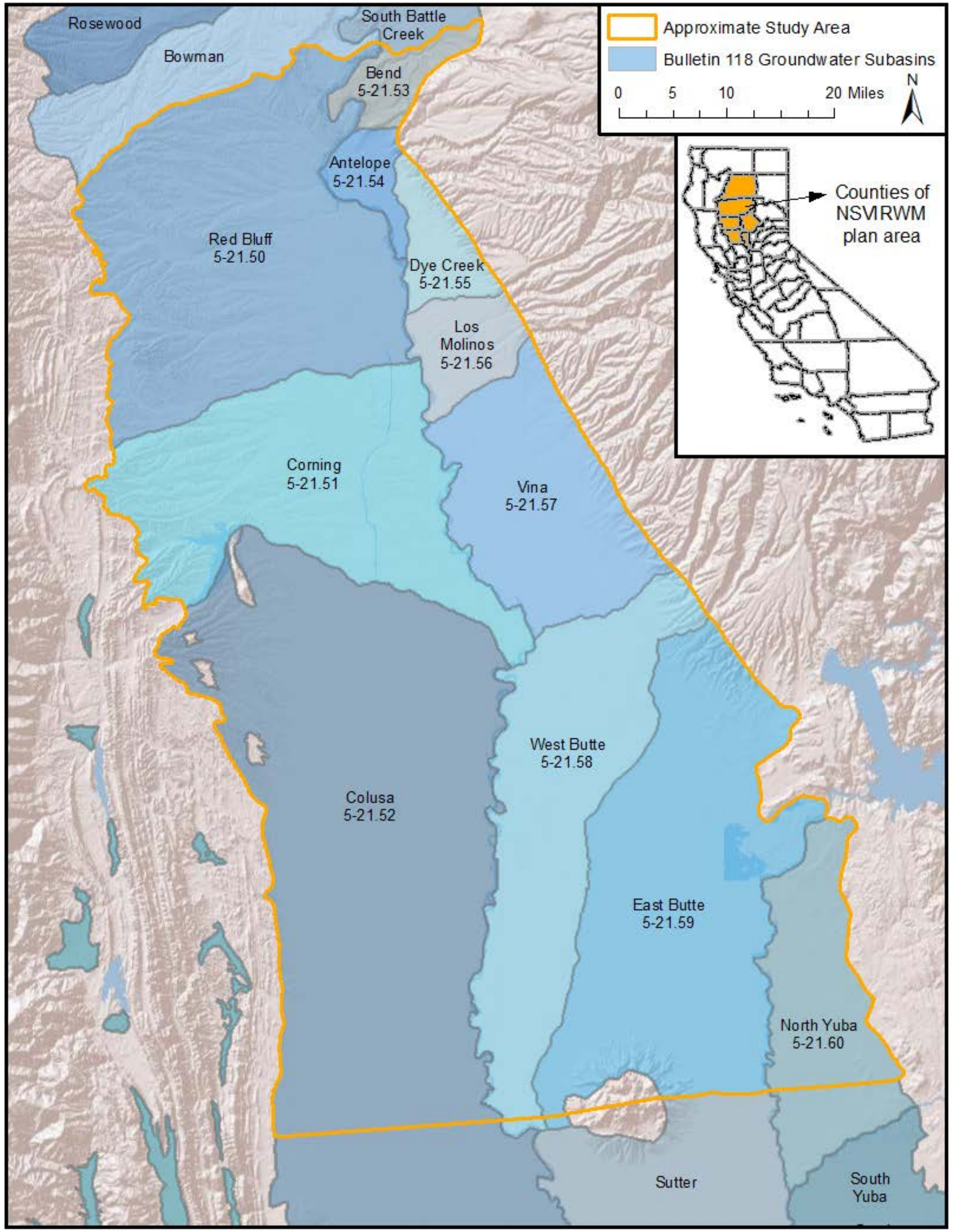
A methodology to assess **interbasin flows**



Study Area

Study Area Groundwater Subbasins:

- Red Bluff (5-21.50)
- Corning (5-21.51)
- Colusa (5-21.52)
- Bend (5-21.53)
- Antelope (5-21.54)
- Dye Creek (5-21.55)
- Los Molinos (5-21.56)
- Vina (5-21.57)
- West Butte (5-21.58)
- East Butte (5-21.59)
- North Yuba (5-21.60)



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Role of the Technical Collaborators

- Guide the
  - Identification of characteristics necessary to quantify interbasin flows
  - Development of an approach to identify model(s) or other techniques best suited for a local area
  - Application of the technique for the NSVIRWM area for this use
- Attend five Technical Collaborator meetings (July 2016-April 2017)
- Review and provide feedback on materials developed

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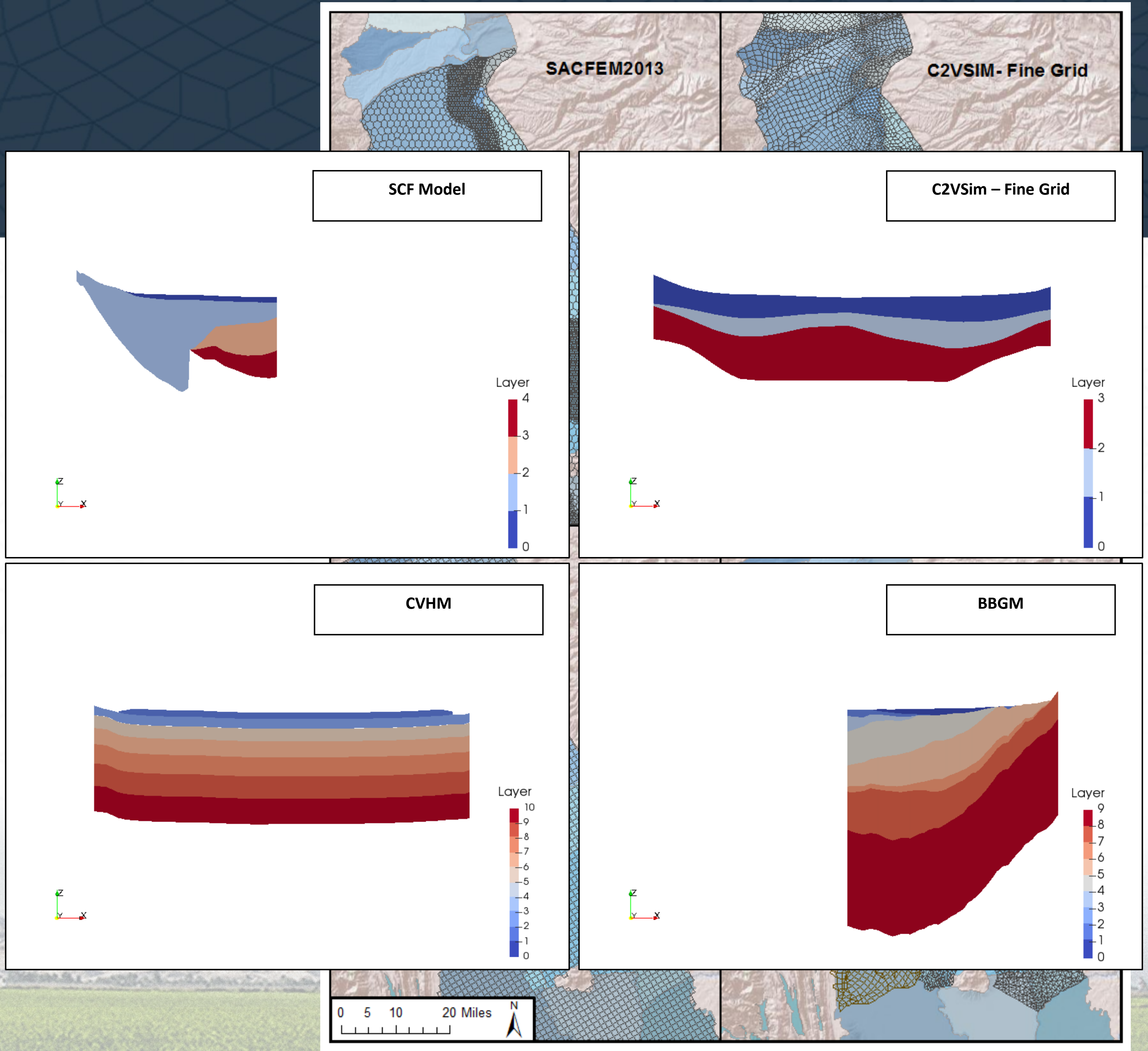
Project Timeline

- Jul 2016: Draft Model Inventory Memo and ***TC Meeting #1***
- Sept 2016: TC Meeting #2 (Focus on Regional Models) and Finalize Model Inventory Memo
- Jan 2017: TC Meeting #3 (Focus on Local Models)
- Feb 2017: TC Meeting #4 (Summary of Findings)
- Mar 2017: Draft Project Report
- Apr 2017: TC Meeting #5 (Comments on Draft Project Report)
- May 2017: Finalize Project Report and Present to NSVIRWM Board

Model Inventory

- Five models identified
- Consideration of horizontal and vertical extent and discretization
- Parties responsible for development
- Agencies actively using the models



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Model Features Comparison Table (see handout)

Key Feature	C2VSim	CVHM	SACFEM2013	BBGM	SCF Model
Code Platform	IWFM	MODFLOW-FMP	IDC coupled with MicroFEM	IWFM	IGSM
Public Domain Code	Yes	Yes	Yes for IDC; MicroFEM is proprietary	Yes	Yes
Model Ownership	DWR	USGS	Reclamation	Butte County	DWR
Availability	Course grid available on DWR website and fine grid available upon request to DWR	Available on USGS website	Uncertain	Available upon request to Butte County	Available upon request to DWR
Documentation	Available on DWR website	Available on USGS website	Available online	Available on Butte County website	Available upon request to DWR
Integrated Model	Yes	Yes	Partially: two separate codes used to simulate hydrologic processes	Yes	Yes
Geographic Area	Central Valley	Central Valley	Sacramento Valley Groundwater Basin	Groundwater Subbasins in Butte County (including East Butte, West Butte, Vina, portions of North Yuba and Sutter)	Corning Subbasin and northern Colusa Subbasin
Simulation Period (Water Years)	1921 - 2009	1961 - 2003	1970 - 2010	1970 - 1999	1970 - 2000
Number of Layers	3	10	7	9	4
Geologic Formations Represented in the Model	Generalized upper unconfined aquifer, confined production zone, deep confined zone	Layers not explicitly tied to hydrogeologic units except for Corcoran Clay in the San Joaquin Valley, remainder based on sediment texture model	Layers not explicitly tied to hydrogeologic units except for portions of the Tuscan Formation	Holocene basin deposits, Alluvium, Sutter/Laguna Formation, Tehama Formation, Tuscan C/B/A Formations, older marine (Neroly, Upper Princeton Gorge, Ione)	Alluvial and basin deposits, Tehama Formation, Upper Tuscan Formation, and Lower Tuscan Formation
Agricultural Demand Estimation Method	Integrated methodology using IDC	Integrated methodology using the Farm Process	Calculated externally by IDC	Integrated methodology using IDC	Integrated methodology using IGSM Ag Demand Package
Stream-Aquifer Interaction Method	Integrated methodology using IWFM Stream Package	Integrated methodology using MODFLOW Streamflow Routing Package	Limited; fixed head boundary condition for river stages	Integrated methodology using IWFM Stream Package	Integrated methodology using IGSM Stream Package

Note: Descriptions in this table may not reflect ongoing, unpublished updates to these models.

Model Inventory

- Are there any other model applications in the NSV area that should be considered? Should any of the models we are considering be removed?
- Are there any other key features that should be included in the inventory memo?
- Are any local agencies planning to generate interbasin flow estimates without the use of a numerical model?

Discussion

Our next two meetings will focus on regional and local models, respectively. Some questions we'll evaluate include:

- How do the models compare in their conceptual model for the region and groundwater flows between subbasins? Are any major physical features missing from the models?
- How does each model quantify the interconnectedness of adjoining subbasins? Will the information generated be sufficient for SGMA purposes?
- What updates to the models would increase confidence in their interbasin flow estimates?

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Discussion

- Could the models be used to evaluate impacts of ‘undesirable results’? Can models without the ability to explicitly simulate a process (e.g., subsidence or solute transport) still be used to help evaluate the potential for those processes?
- Does it matter if a model is in the public domain or proprietary? How will members of the public be enabled to evaluate models developed with proprietary software?
- What data gaps exist? Should common datasets be developed or hosted for the benefit of all model users/applications in a study area?

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Thank You

Butte County
CALIFORNIA

Interbasin GROUNDWATER FLOW Evaluation Project

Technical Collaborators Meeting 2

September 6, 2016

Meeting Outline

- Recap of Meeting #1
- Overview and Discussion of Potential Project Outcomes
- Discussion of a Model Selection and Evaluation Process
- Discussion of Water Budgets and How to Compare Between Different Models
- Define the Problem of Interbasin Flow Determination When Boundary is a Stream
- Discussion of Data Gaps
- Example of Interbasin Flow Budget Generation (if time allows)

Meeting #1 Recap

- Project objectives:
  - Local ownership of the interbasin flow evaluation process in the NSV Area
  - “Lessons learned” to DWR and others in the state
- Overview of models likely to be considered for this study
  - Regional: CVHM, C2VSim, SacFEM 2013
  - Local: Butte Basin Groundwater Model, Stony Creek Fan IGSM
- Certain tools identified as being unsuited for future use by GSAs, though they likely contain useful information that shouldn’t be lost
  - SacFEM 2013, Stony Creek Fan IGSM
- Initial discussion of project outcomes

Project Outcomes

- Primary:
  1. Does the TC group feel comfortable identifying which regional model (CVHM or C2VSim) is most appropriate for determination of interbasin flow budget component of GSPs ***at this place and in this time?***
- Other/Secondary Outcomes:
  2. Define the most important components (e.g., simulated heads, water budget) that GSA's should focus on when evaluating which model to use
  3. Describe a process for comparing water budget information generated by different models and codes (e.g., do we need to combine terms from one model to compare outputs from another model?)

Project Outcomes

- Other/Secondary Outcomes:
  4. Describe the challenges and a process for evaluating interbasin flows where the boundary is defined by a river/stream
  5. Describe non-modeling approaches, if recommended, or why the TC does not recommend using them
  6. Describe data gaps that exist ***at this time*** in the models being considered for use. Also describe those updates that are highest priority to increase confidence in interbasin flows
  7. Describe a process for feedback between local and regional modeling efforts
  8. How can regional models be used to evaluate undesirable results

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2. Important Components for Model Selection

Is the model code (e.g., IWFM, MODFLOW-OWHM) appropriate?

- Generally, no code is universally “better”
- However, the codes simulate some processes differently – do local conditions warrant a particular code?

Does the model cover my area of interest?

- Basin/subbasin of the GSA
- Adjacent, hydraulically connected basins/subbasins

Does the model include important processes and features?

- What’s important will vary by area
- Rely on local knowledge and expertise
- If something is missing, can the model be updated to include it?

2. Important Components for Model Selection (continued)

What is the status of model development?

- If the application has been "sitting on the shelf" will it require significant updates?
- If the application is under development will it be ready in time for SGMA needs?

Who is responsible for model development?

- If development is not led by the GSA, is the agency responsible for development going to continue providing support?
- Who will develop baseline and future conditions runs?

How well does the model account for local conditions (surface)?

- Is the scale of water use representation (e.g., surface water delivery, land use) sufficient relative to the GSA area?

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2. Important Components for Model Selection (continued)

How well does the model account for local conditions (subsurface)?

- Is the groundwater portion of the model based on a sound conceptual model, as will be required for SGMA?

How well is the model calibrated?

- Does the historical period of record capture periods of stress?
- What types of observations (head, stream and drain flow, stage, subsidence, head differences, etc.)?

What does the simulated water budget indicate?

- How much interbasin flow occurs?
- How does it vary temporally and spatially?
- How important is it relative to other components of the water budget?

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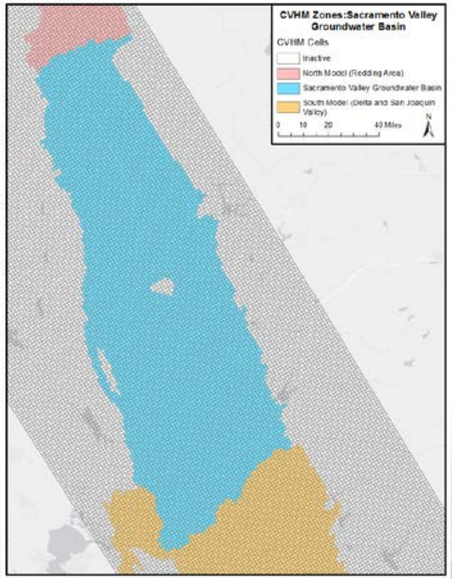
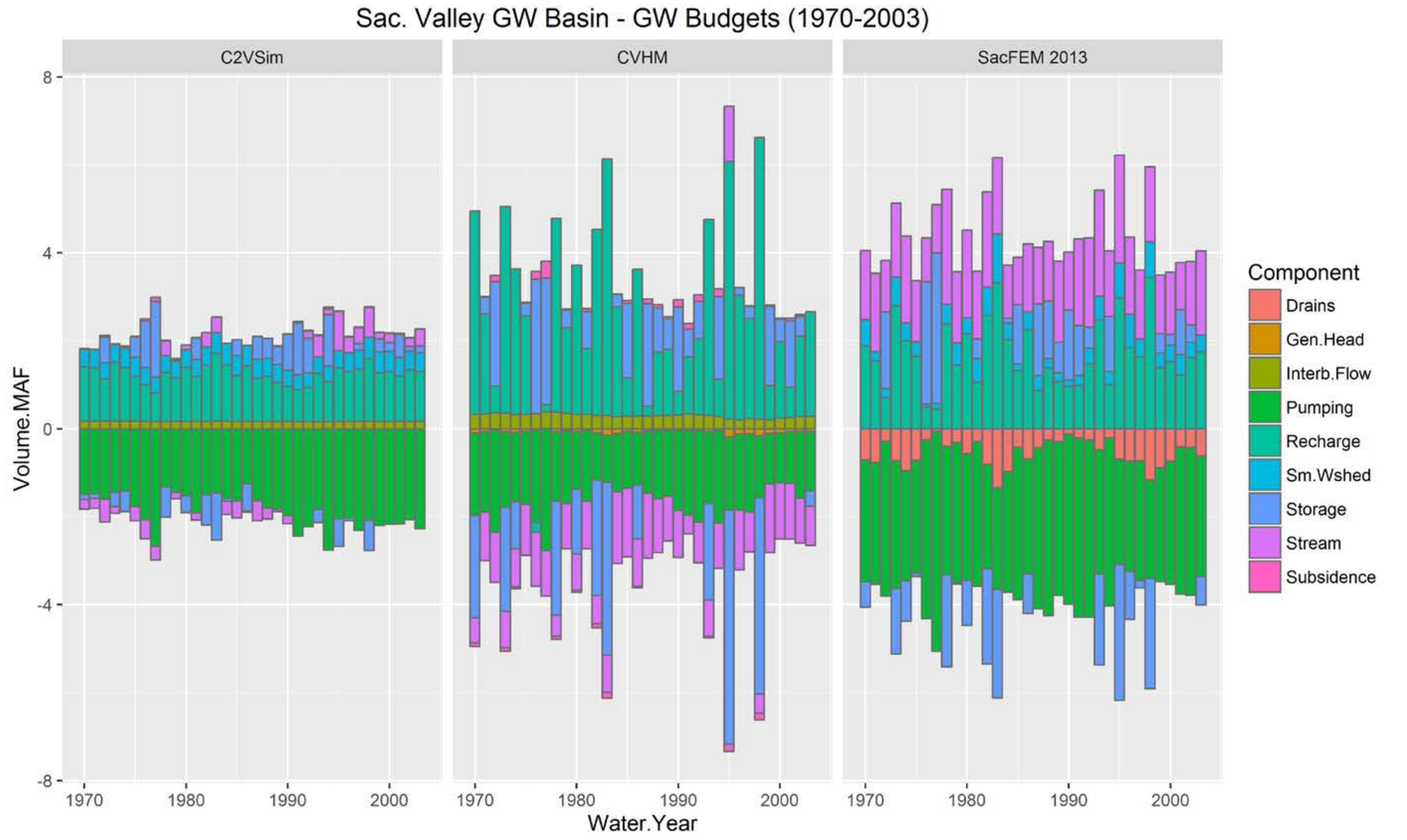
3. Process for Water Budget Comparison

- If more than one model is suitable, how should we compare them?





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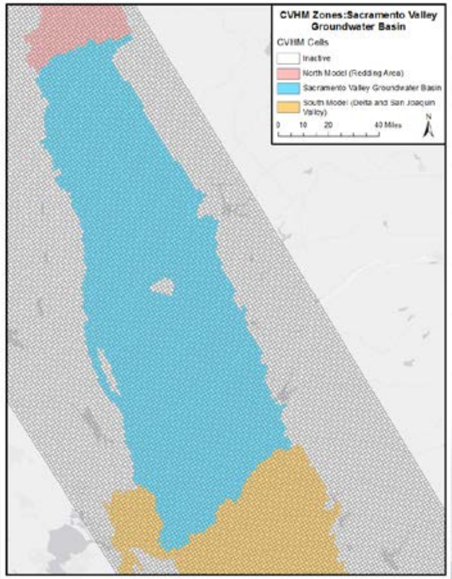
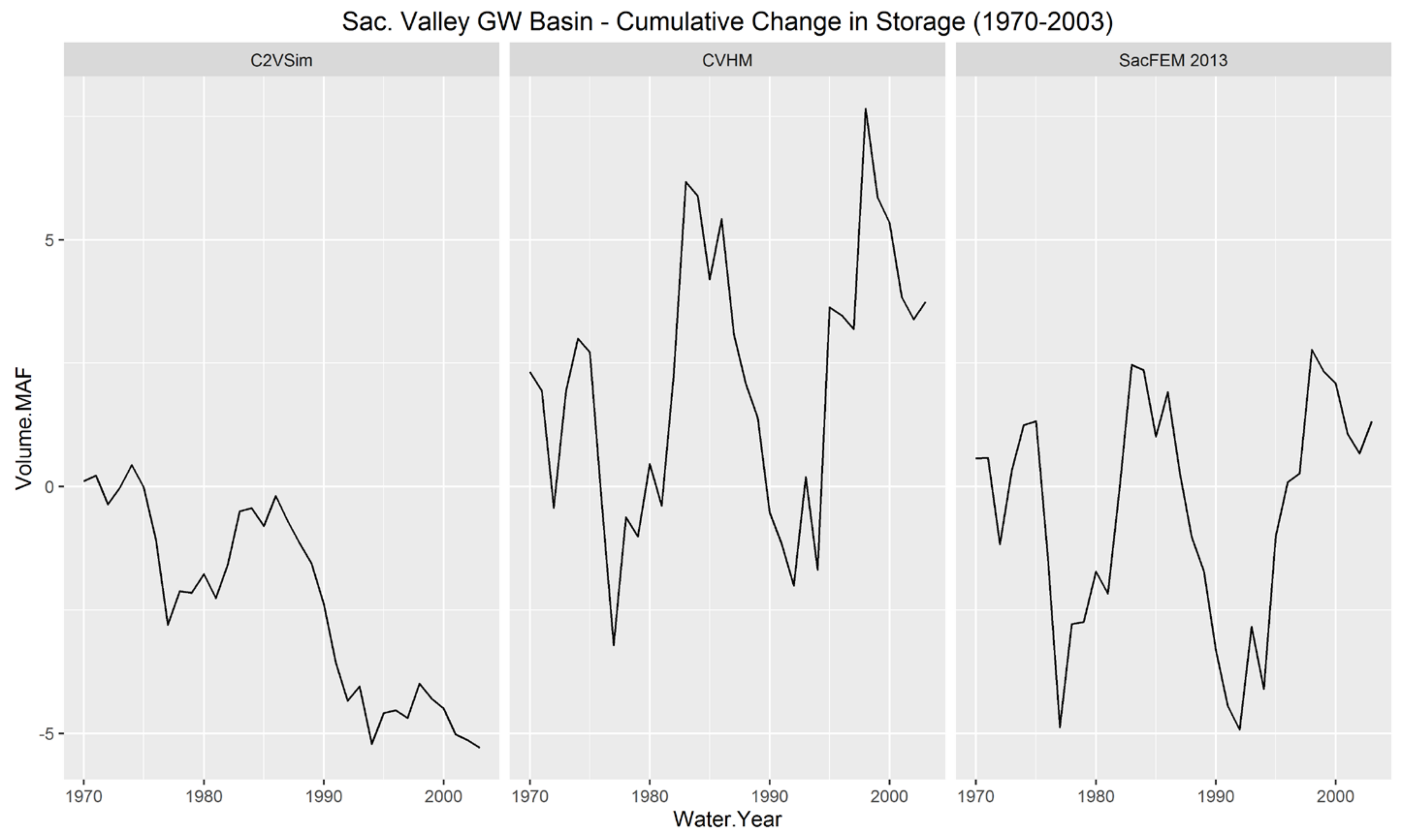
3. Process for Water Budget Comparison

- If more than one model is suitable, how should we compare them?





3. Process for Water Budget Comparison

- Describe best practices for comparing modeled water budgets
  - Which components are directly comparable
  - Which to aggregate
  - How to handle processes simulated by one model but not another

	C2VSim	CVHM2
Storage	GW STORAGE	STORAGE
Recharge	NET DEEP PERCOLATION + (?) DIVERSION RECOVERABLE LOSS + *(?) BYPASS RECOVERABLE LOSS*	FARM_NETRECHARGE
Pumping	PUMPING BY ELEMENT + PUMPING BY WELL	MNW2 + *FARM_WELLS*
Streams	STREAMS	STREAM_LEAKAGE
Small Watersheds	SMALL WATERSHED BASEFLOW + SMALL WATERSHED PERCOLATION	(?) SPECIFIED_FLOWS
Subsidence	SUBSIDENCE	INST_IB_STORAGE + DELAY_IB_STORAGE
Drains	*TILE DRAINS*	*DRAINS*
Interbasin Flow	FLOW FROM ZONE XXX / FLOW TO ZONE XXX	FLOW FROM ZONE XXX / FLOW TO ZONE XXX
Other Boundaries		HEAD_DEP_BOUNDS + *CONSTANT_HEAD*

Note: items in *Gray Italics* are not simulated in the Sacramento Valley GW Basin for these models

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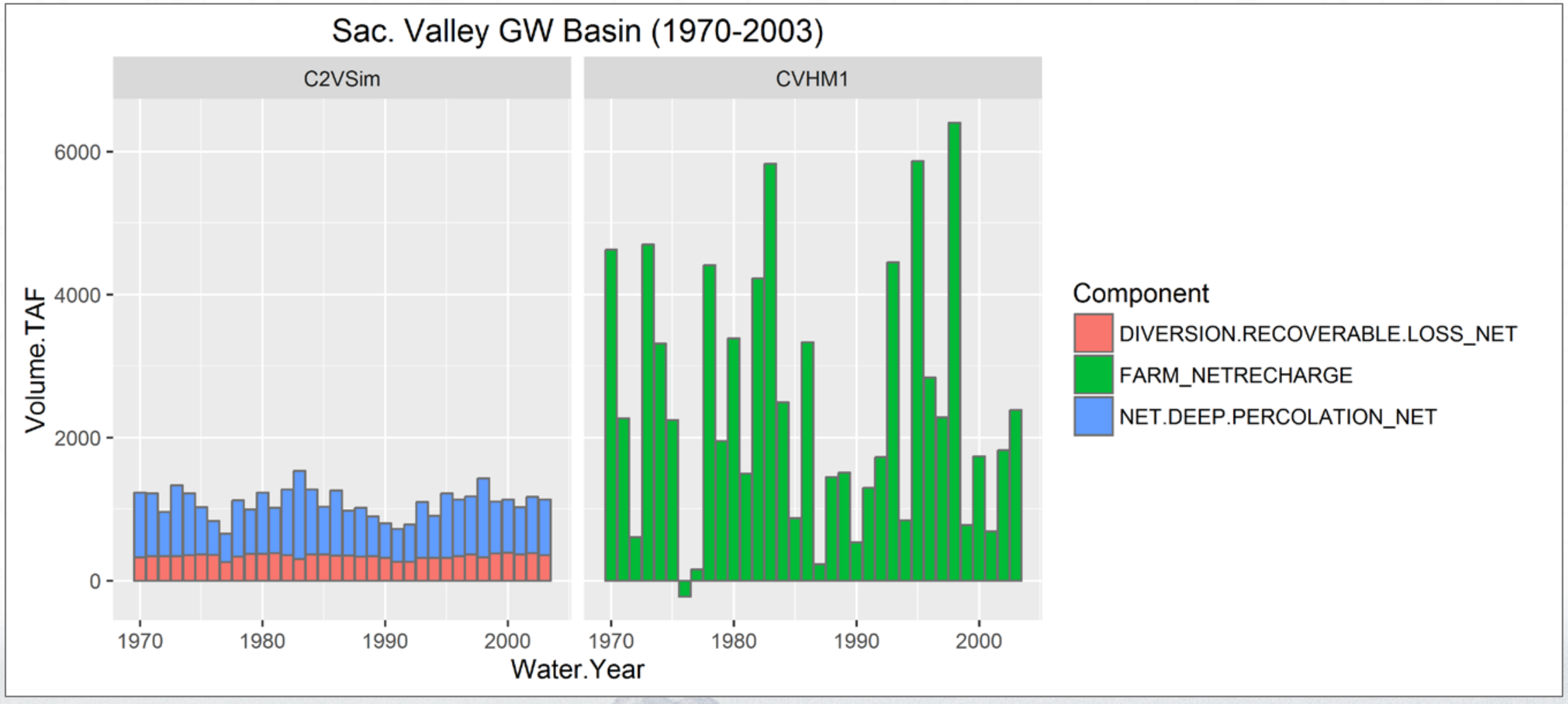
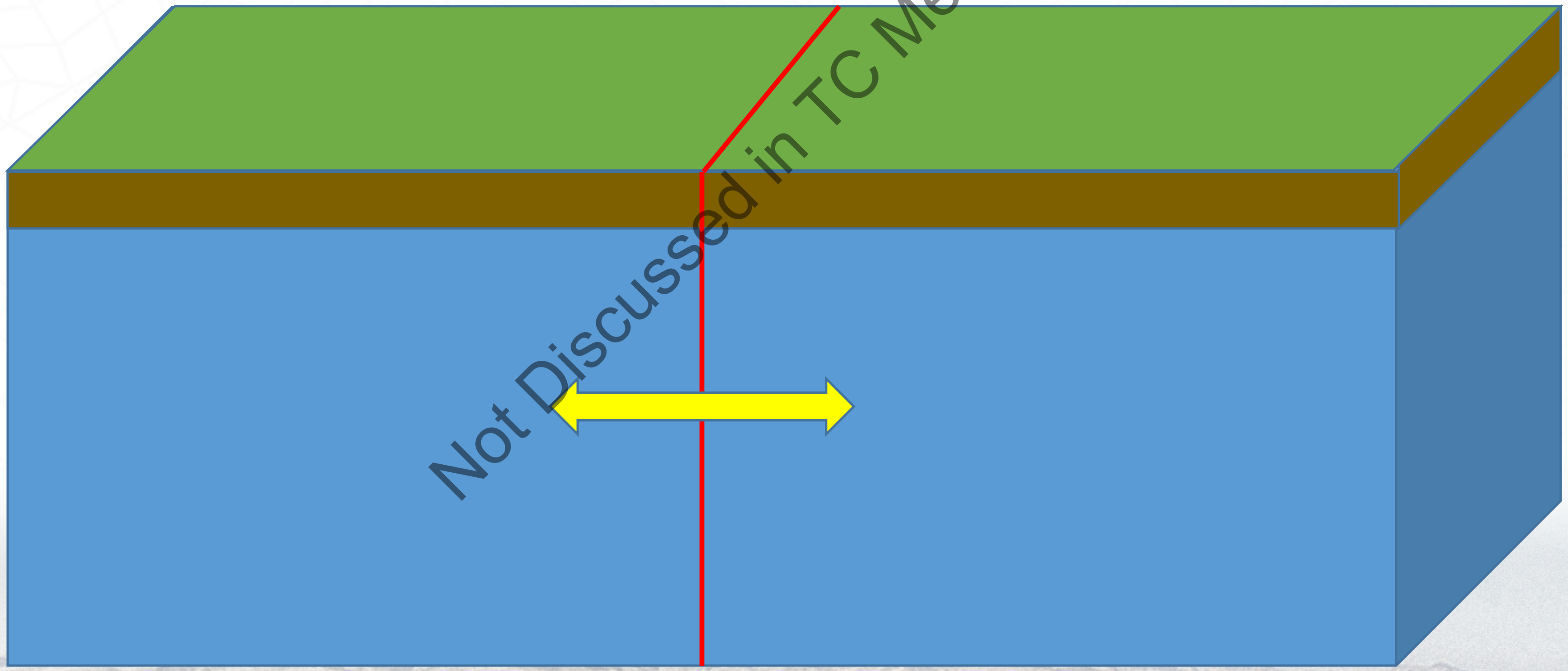
3. Process for Water Budget Comparison



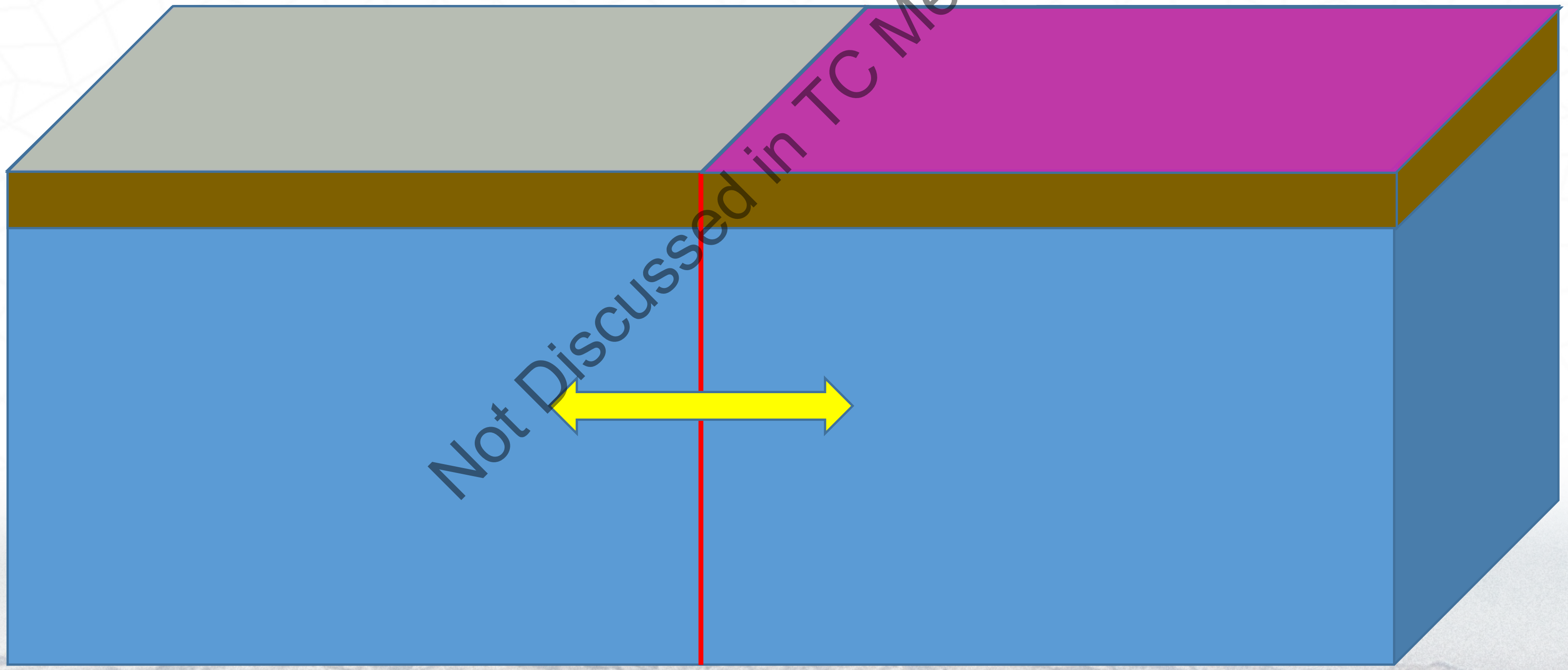
4. Evaluating Interbasin Flows Where the Boundary is Defined by a River/Stream

- Interbasin flow, generally, is the flow entering or leaving a (sub)basin from an adjacent, hydraulically connected (sub)basin



RMC water and environment

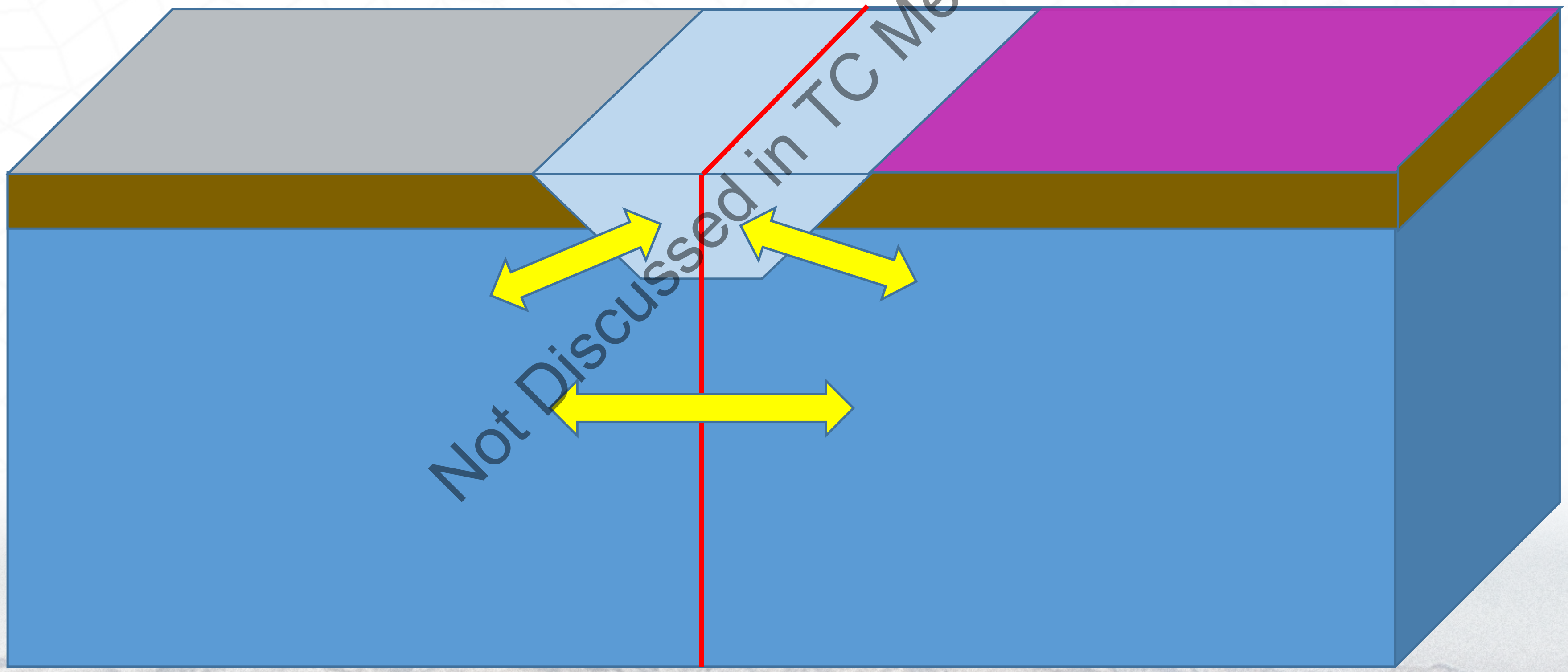
4. Evaluating Interbasin Flows Where the Boundary is Defined by a River/Stream



Not Discussed in TC Meeting #2

4. Evaluating Interbasin Flows Where the Boundary is Defined by a River/Stream

- Boundaries aligned with rivers and streams (as many in the state are) complicates the quantification of these flows



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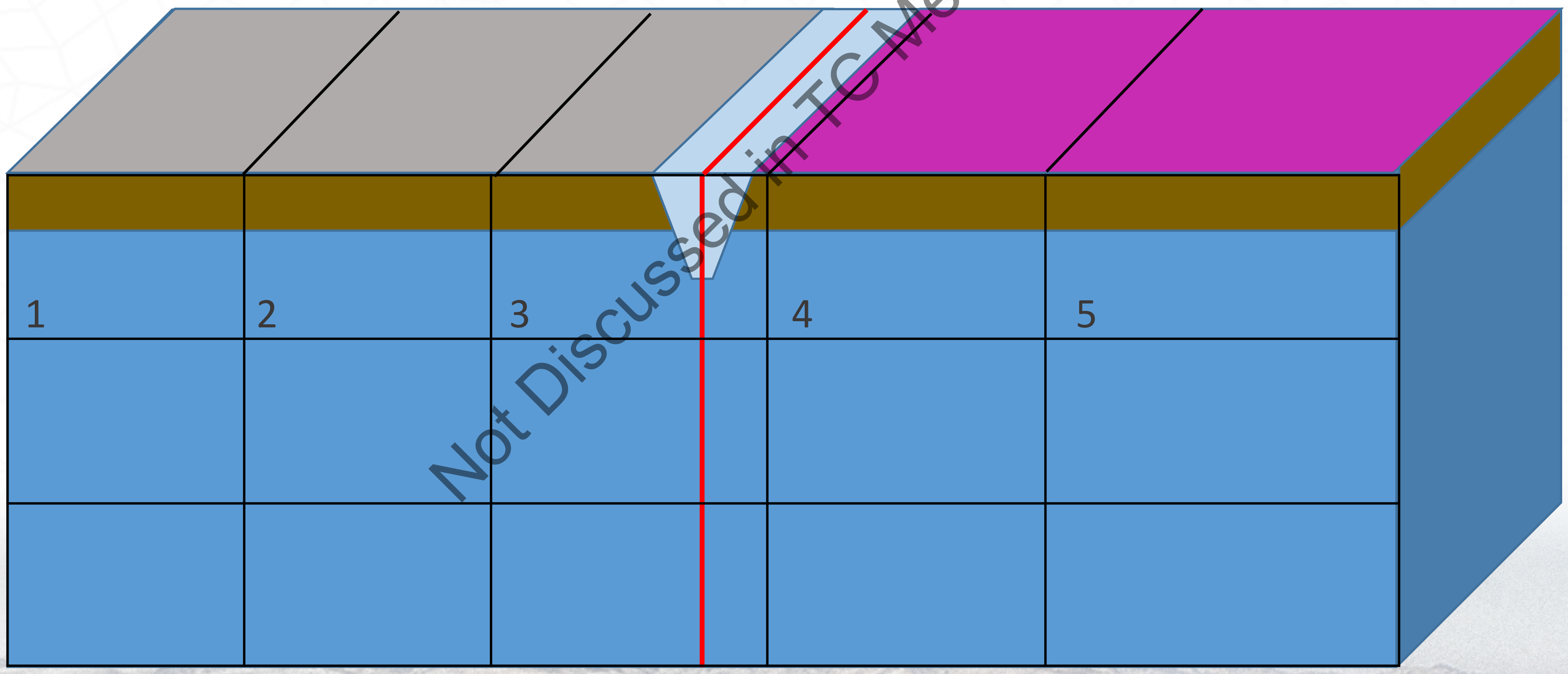

RMC water and environment

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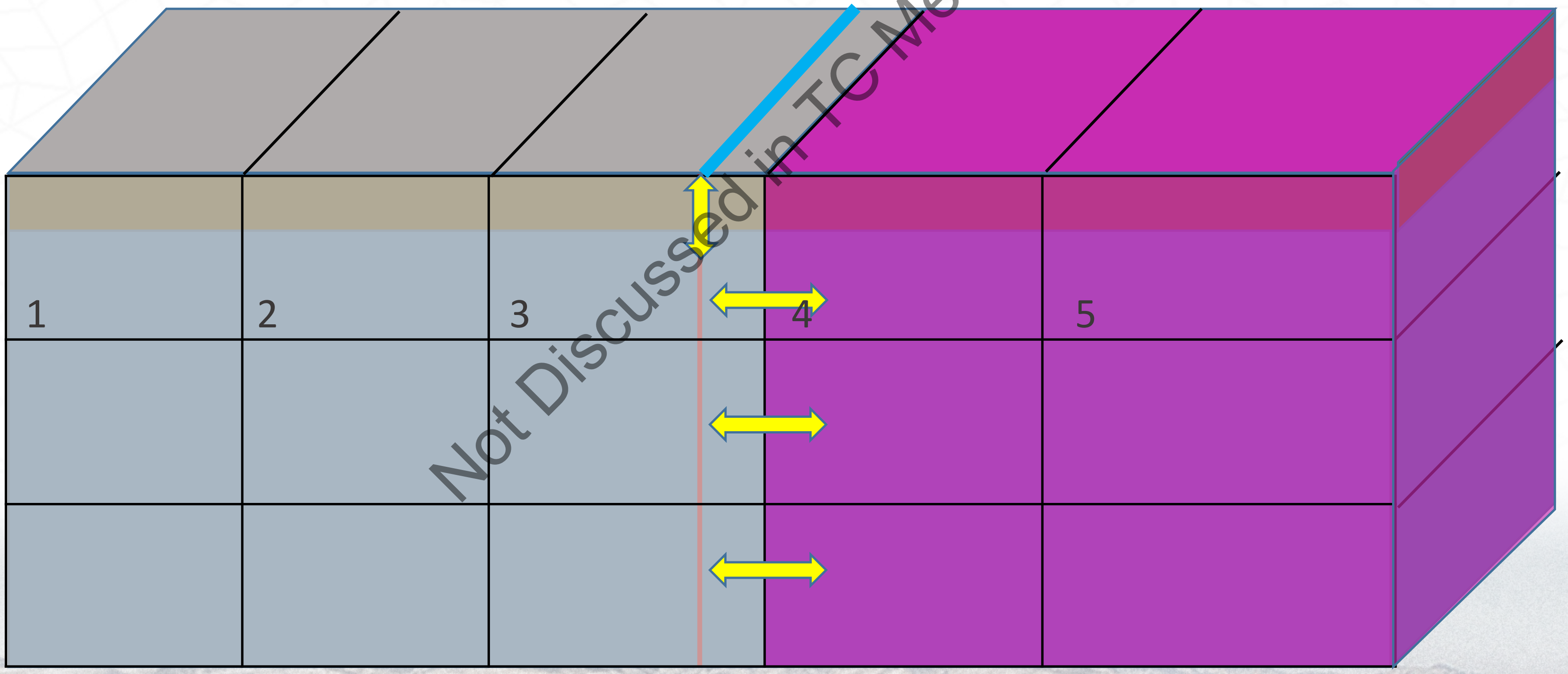


$Q_{str} = 0$

6. Data Gaps and Needed Improvements

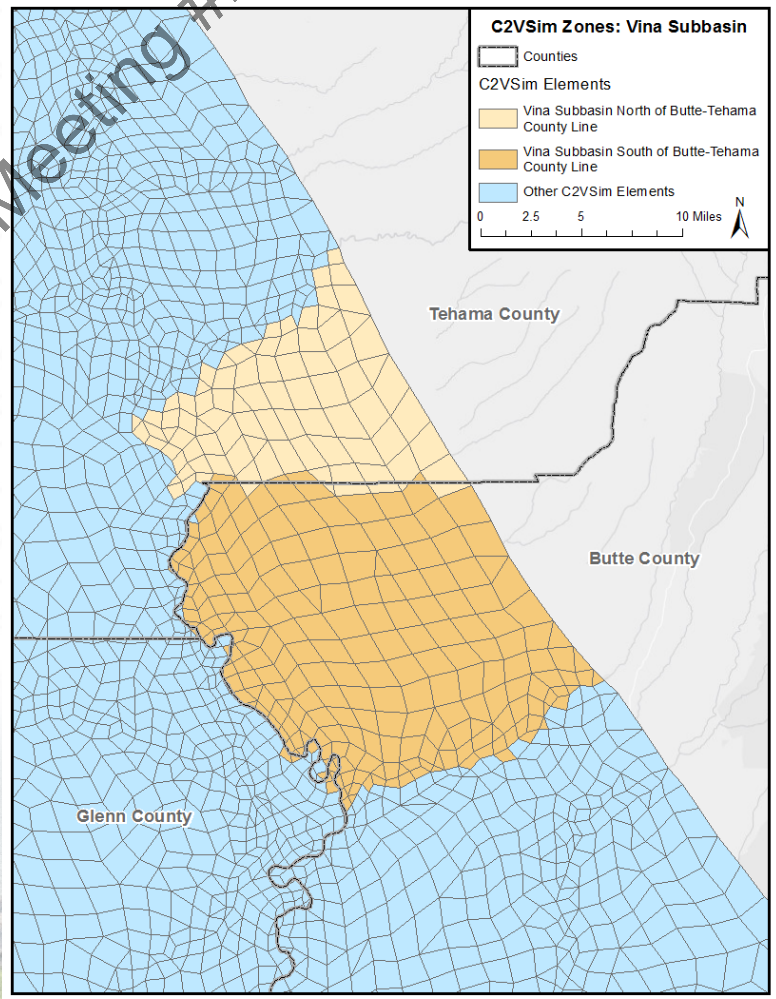
- C2VSim and CVHM are both being updated and are likely be considered by GSAs when developing interbasin components of water budgets
- What data gaps could be filled, or improvements made, to increase confidence and reliability of interbasin flow estimates
  - Model Features
  - Calibration
  - Analysis Tools
  - Documentation/Information

Not Discussed in TC Meeting #2

RMC water and environment

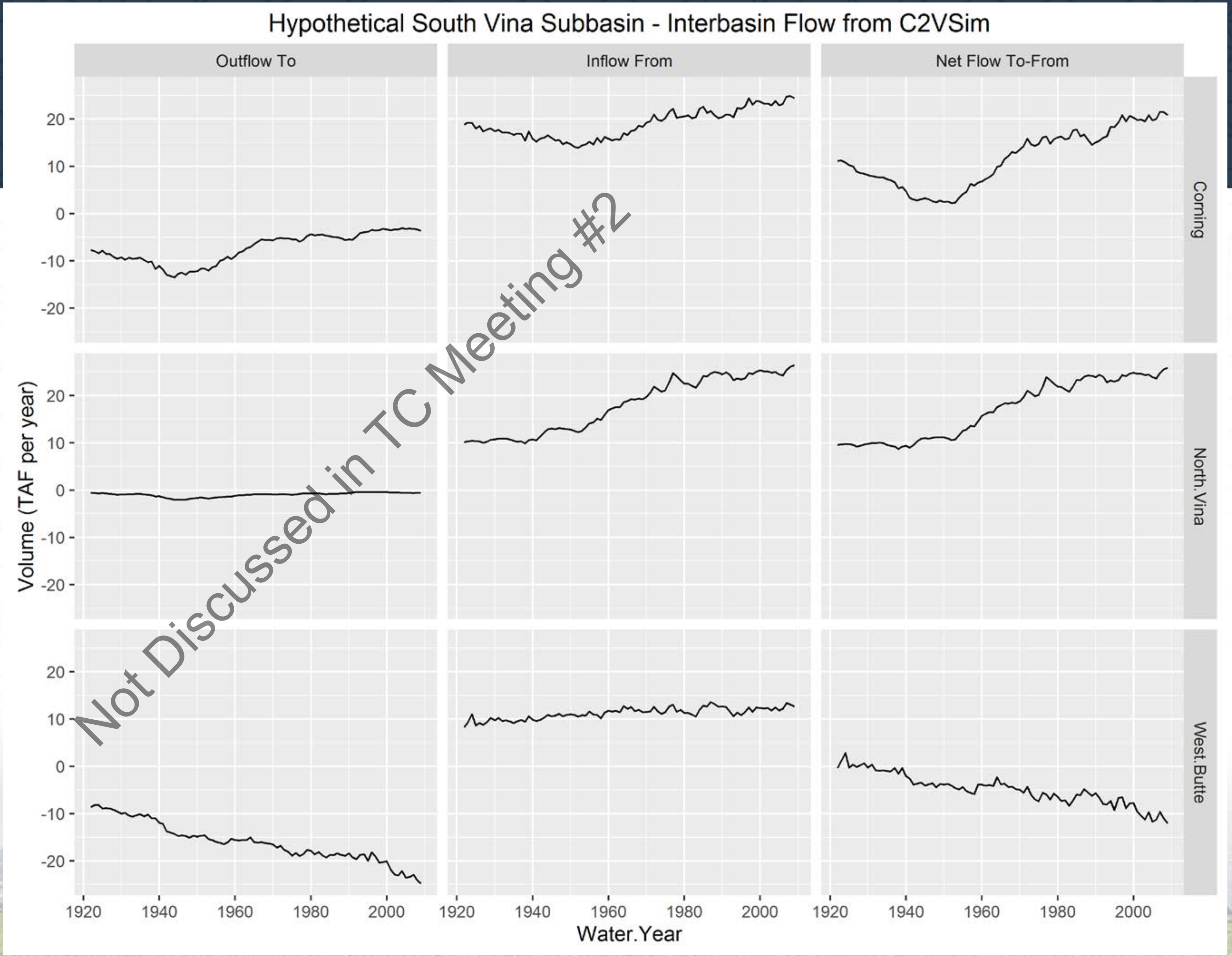
Example of Interbasin Flow Budget Information

- Using C2VSim
- Split Vina Subbasin into two hypothetical subbasins along county line -> North Vina and South Vina
- Budget information presented below is from the perspective of South Vina (darker orange area on figure to the left)



RMC water and environment

- Evaluated subsurface inflow and outflow, by layer, into/out of hypothetical South Vina Subbasin from:
  - Corning
  - North Vina
  - West Butte



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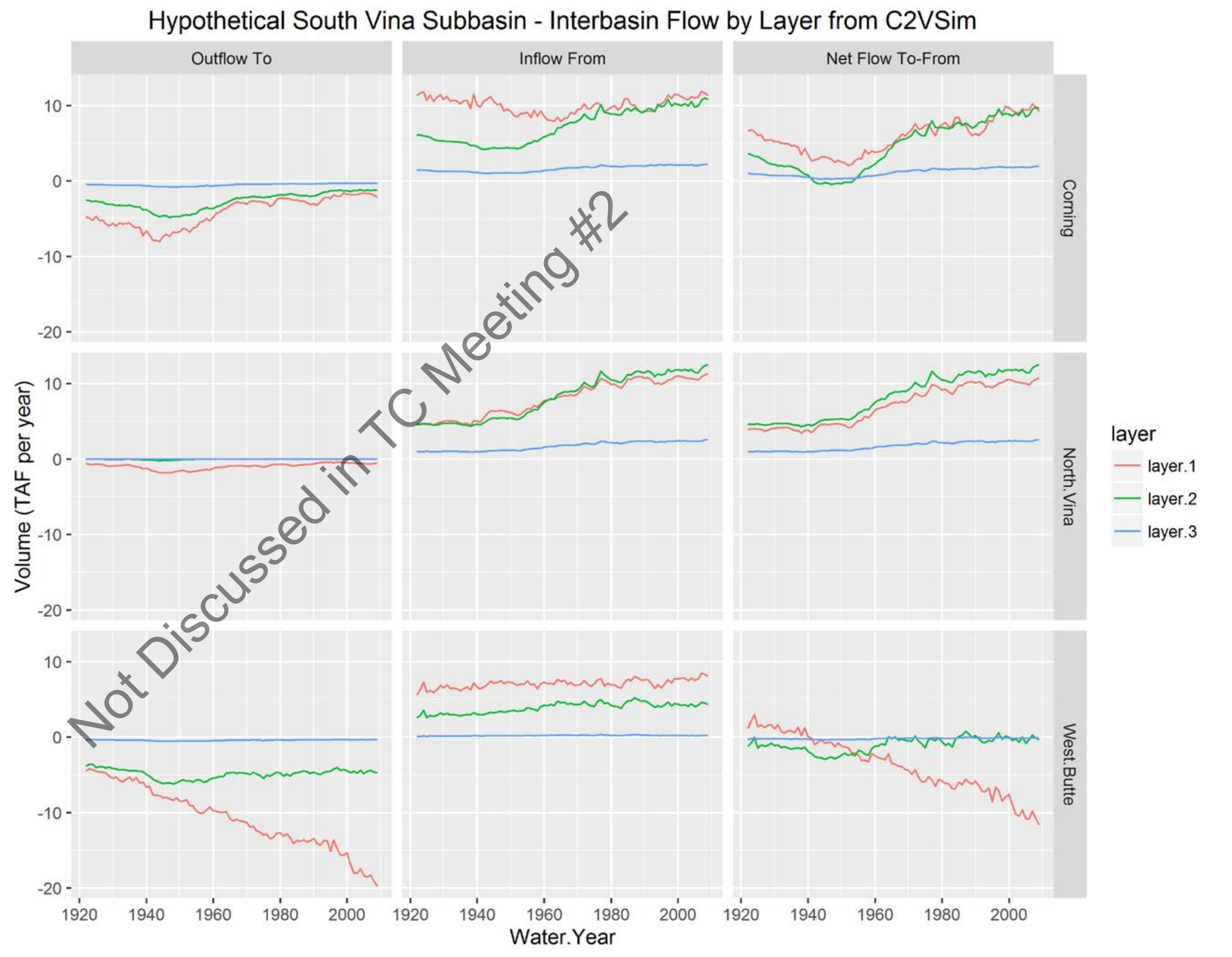
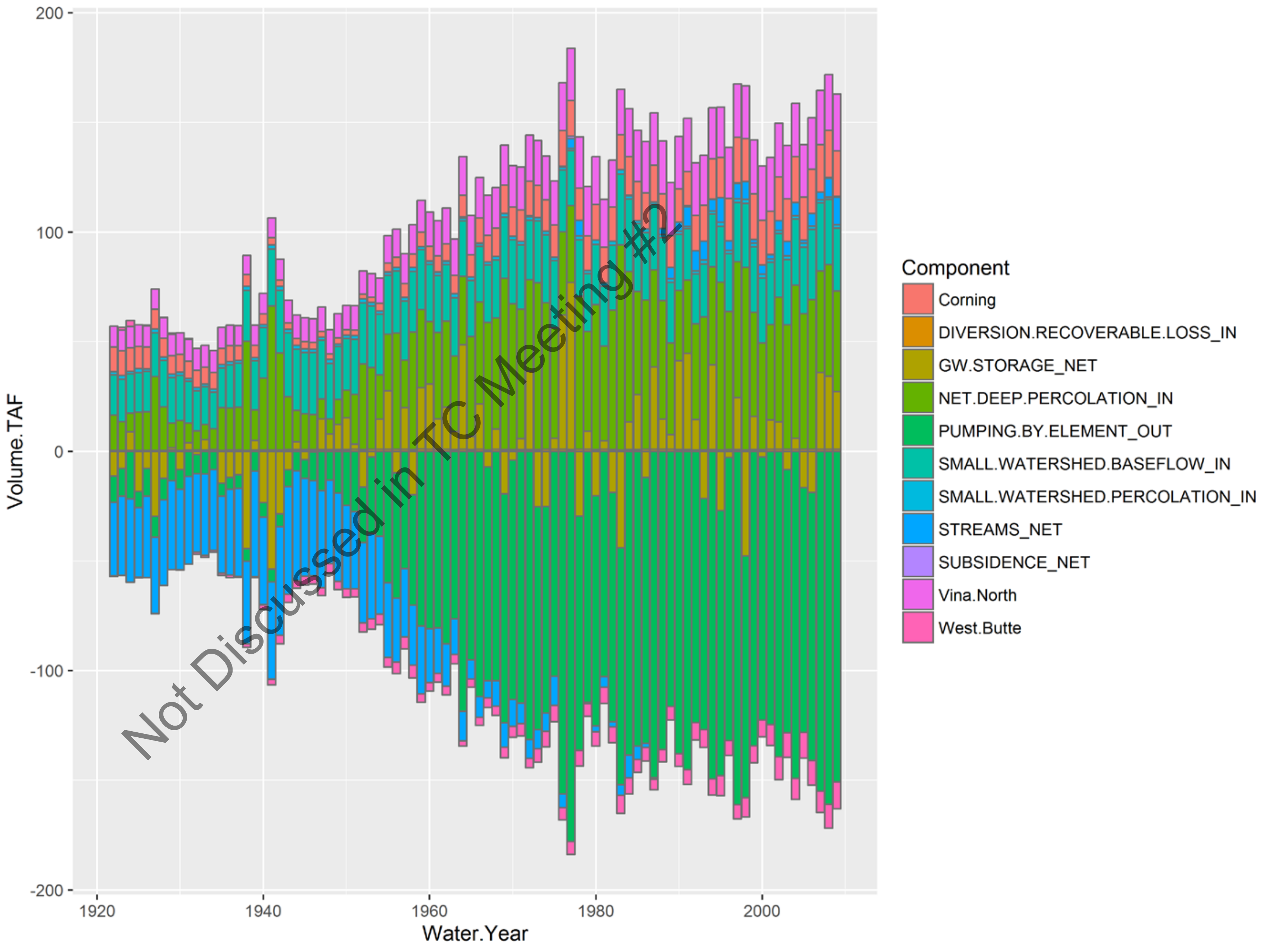


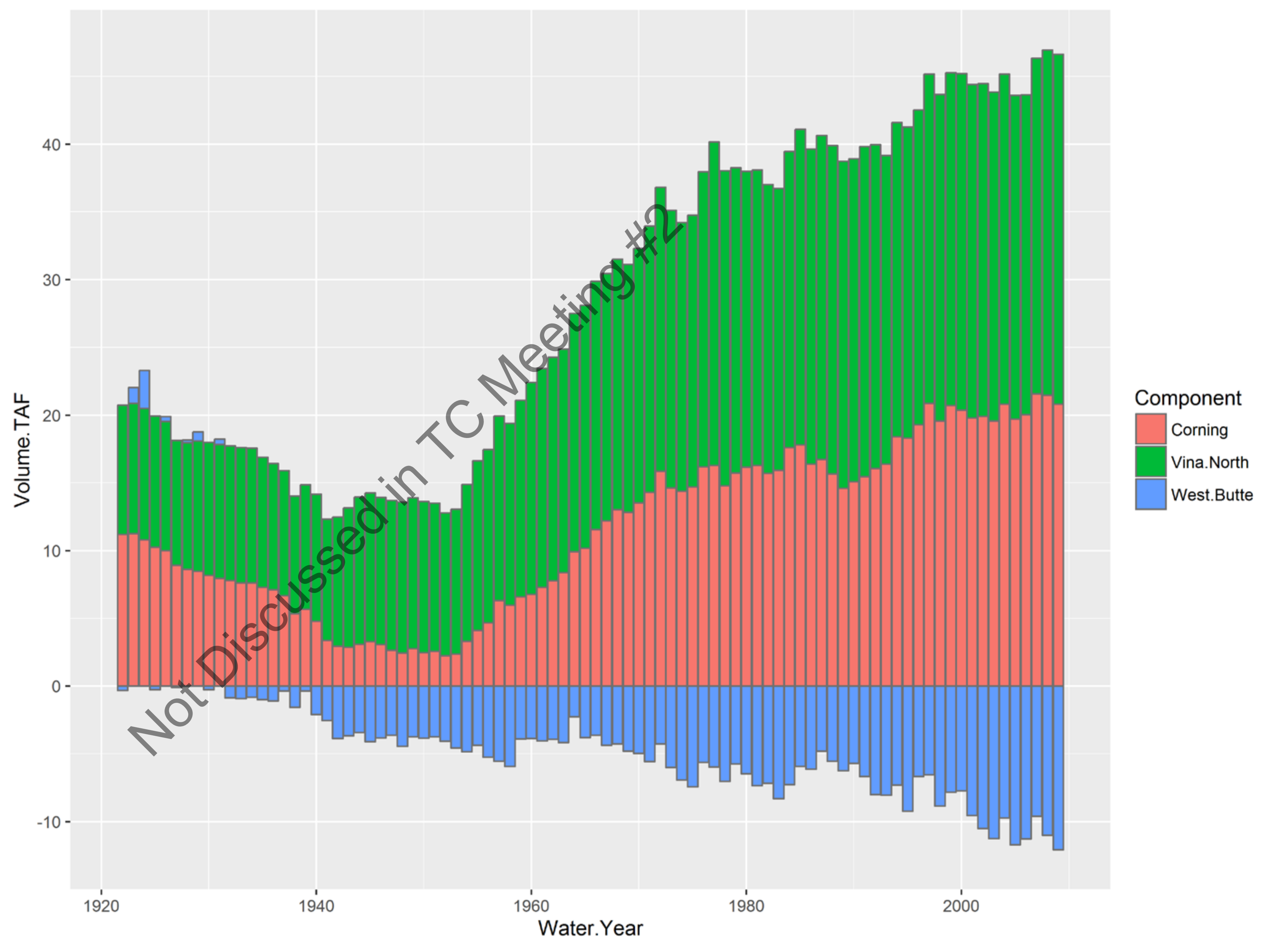
RMC water and environment

Hypothetical South Vina Subbasin Total GW Budget



RMC water and environment

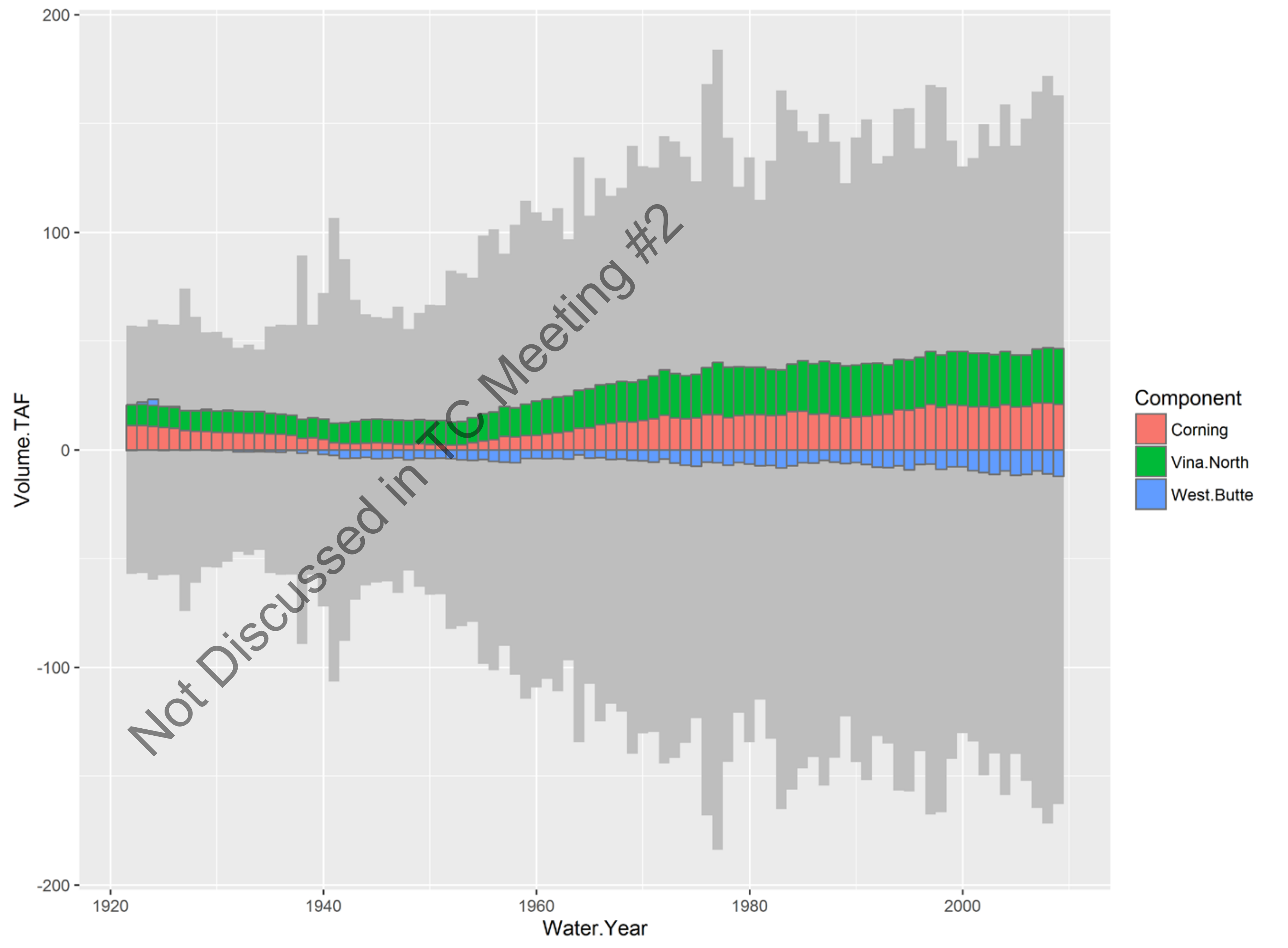
Hypothetical South Vina Subbasin Interbasin Flows



Hypothetical

South Vina Subbasin

Interbasin Flows Relative to Total Groundwater Budget



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Wrap Up

- Next meeting will focus on local models and how feedback between local and regional models could occur
- Deliverable for this project is the Interbasin Flow Evaluation Report
  - Scheduled to begin after completion of next meeting (Jan. 2017)
  - Report will address the project outcomes we discussed earlier
  - Next meeting will include discussion of the report outline

Thank You

RMC water and environment

Interbasin

GROUNDWATER FLOW

Evaluation Project

Technical Collaborators Meeting 3

March 7, 2017

Agenda

- Recap of previous meetings
- Model comparison
  - Land use / cropping
  - Water budget
    - Ag water demand
    - Water supply
    - Recharge
    - Stream seepage
  - Surface water inflows
  - Calibration
    - Hydrographs at selected wells
- Discussion
  - Model recommendations or assistance in model recommendations

Agenda

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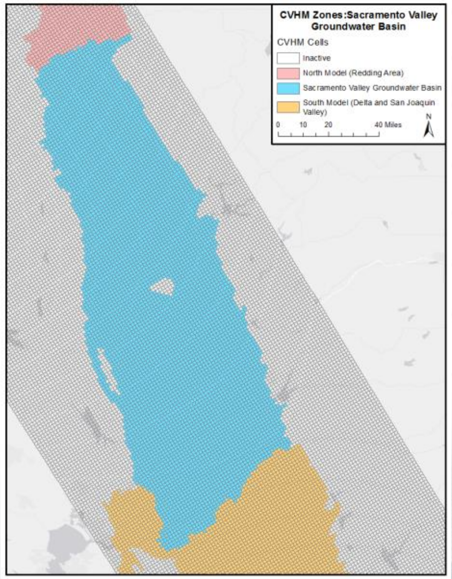
Meeting #1 Recap

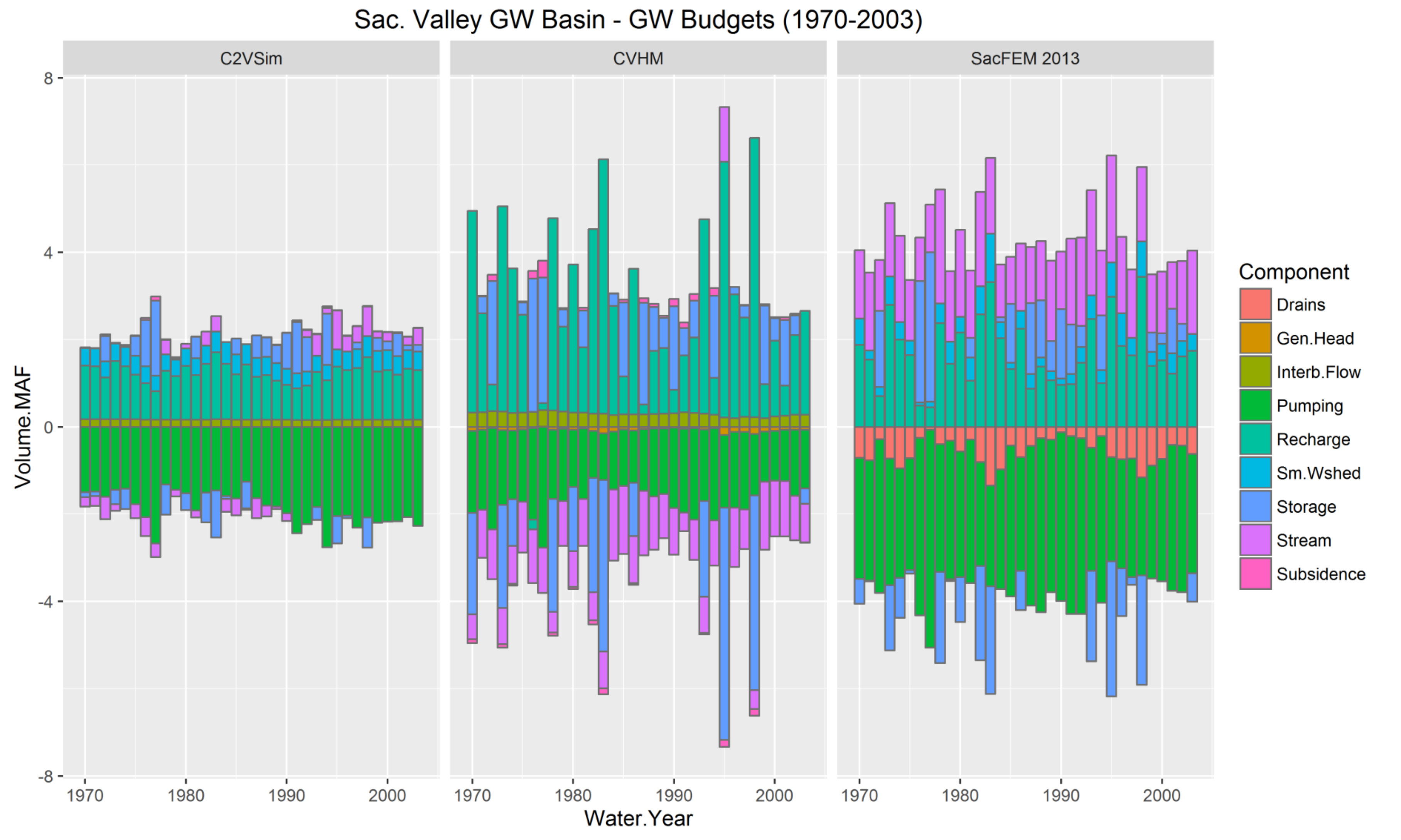
- Project objectives:
  - Local ownership of the interbasin flow evaluation process in the NSV Area
  - “Lessons learned” to DWR and others in the state
- Overview of models likely to be considered for this study
  - Regional: CVHM, C2VSim, SacFEM 2013
  - Local: Butte Basin Groundwater Model, Stony Creek Fan IGSM
- Certain tools identified as being unsuited for future use by GSAs, though they likely contain useful information that shouldn’t be lost
  - SacFEM 2013, Stony Creek Fan IGSM
- Initial discussion of project outcomes

Meeting #2 Recap

- **Model Selection:**
  - Up to GSAs to decide what model is best for what they want to do. Existing models provide bookends and a range of interbasin flows.
  - Model criteria (qualitative and quantitative) will lead evaluation of regional models
  - Define flowpath for selection, incorporating 6 Undesirable Results
- **Model Refinements:**
  - Existing models weren't designed for use in GSPs. Needs for improvement of regional models can help guide future refinement to meet needs under SGMA.
  - Local models can build off regional models
- **Model Analysis:**
  - Differences exist in definitions, methodologies, and water budgets
  - Additional information needed to guide decisions: inputs, calibration, spatially detailed water budgets

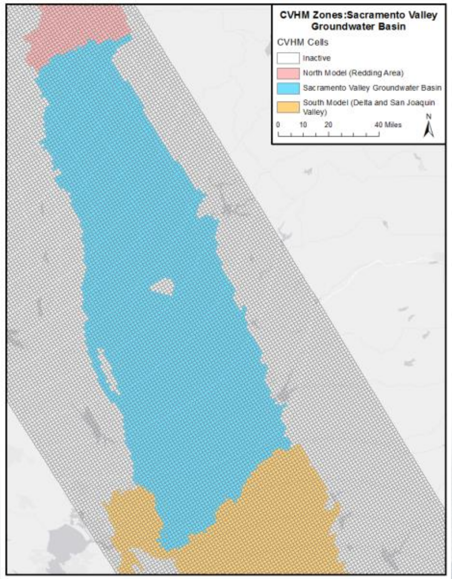
Recall: Water Budget Comparison

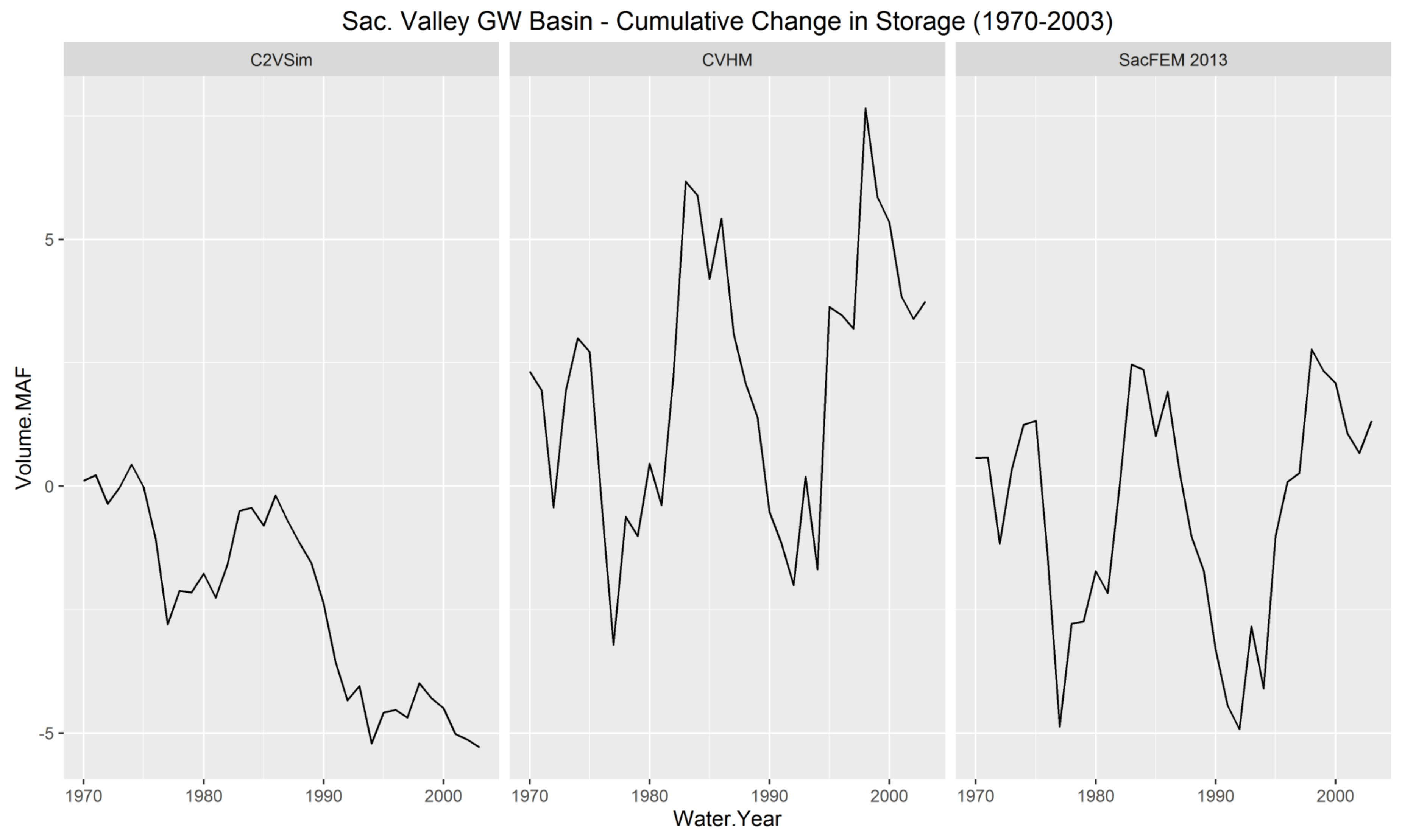




National Experience. Local Focus.

Recall: Water Budget Comparison





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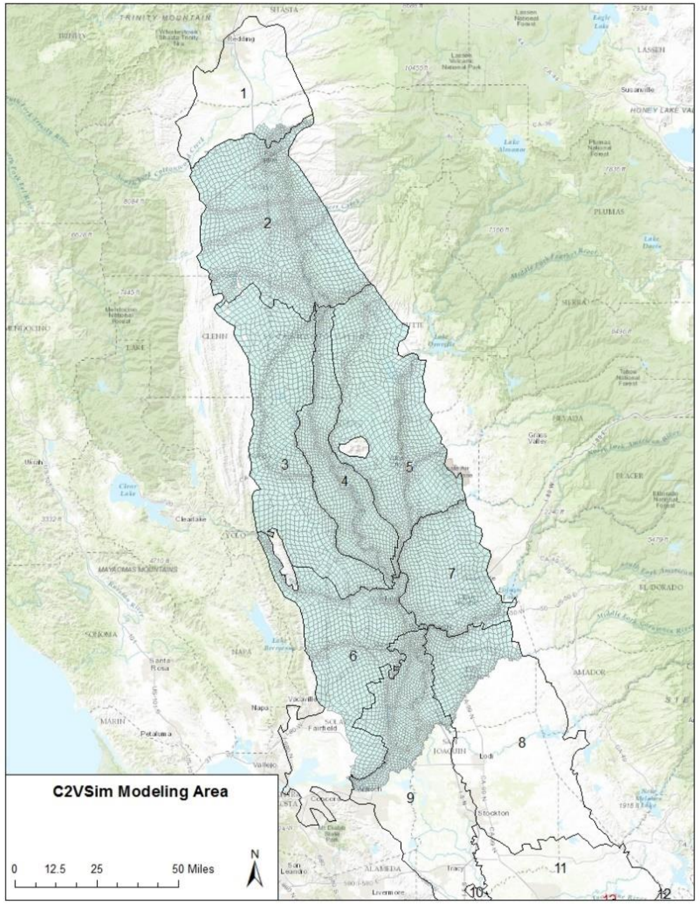
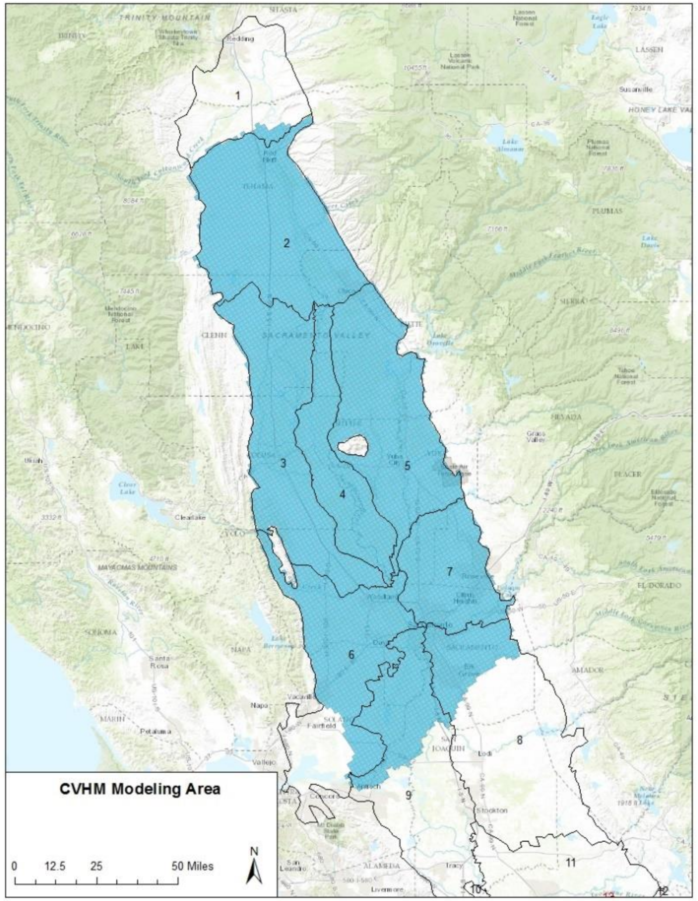
Study Area

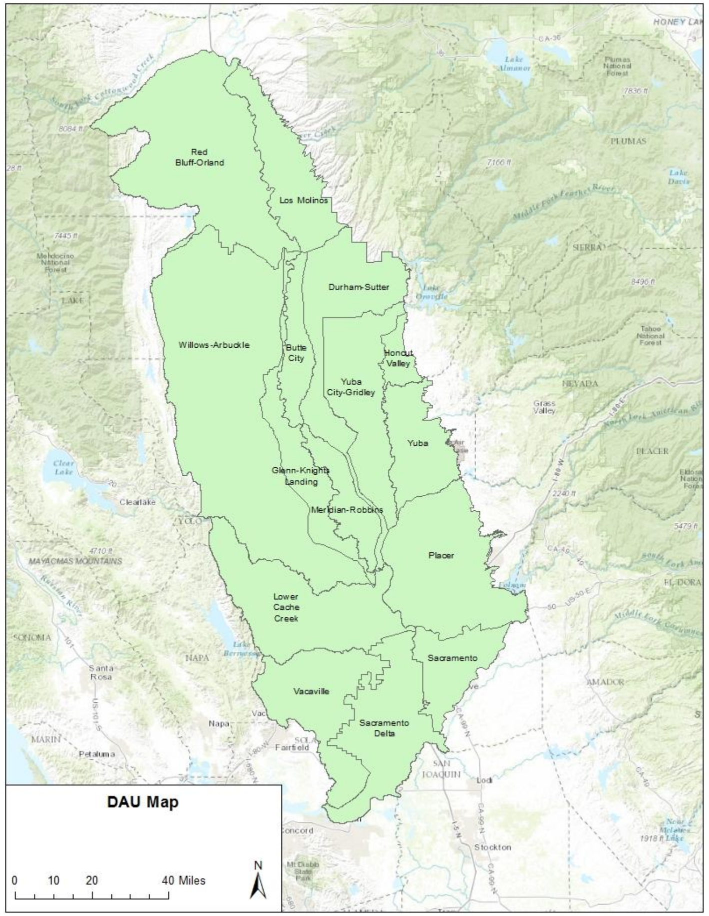
C2VSim



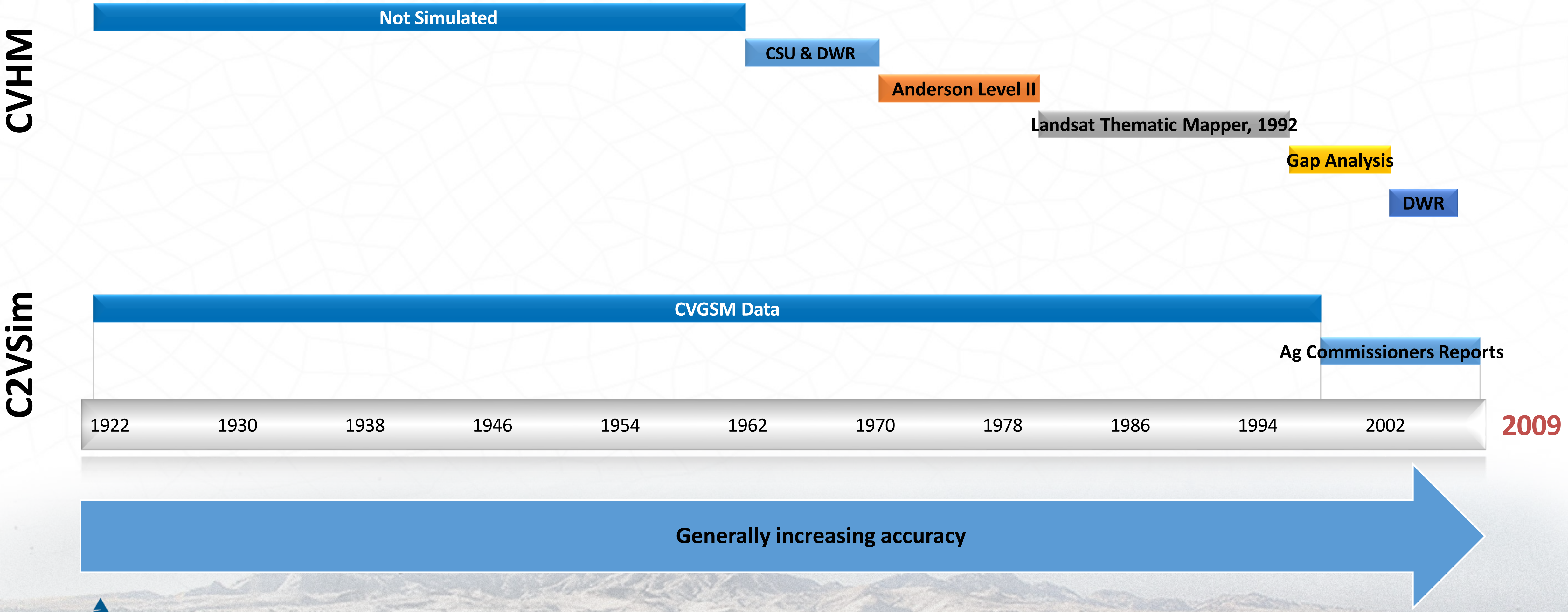
CVHM



DAU



CVHM and C2VSim Land Use Data Sources



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Detailed Analysis Unit (DAU)
Ag Land and Water Use Estimates

- DWR estimates applied water (AW) for 20 crop categories each year.
- AW estimates reflect:
  - Irrigation efficiencies
  - Cultural practices
    - Ponding of water in rice fields
    - Leaching of accumulated salts
    - Etc.

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Land Use Type Mapping

CVHM
Water
Urban
Native Classes
Orchards, groves, and vineyards
Pasture/hay
Row crops
Small grains
Idle/fallow
Truck, nursery, and berry crops
Citrus and sub-tropical
Field crops
Vineyards
Pasture
Grains and hay crops
Semi-agriculture
Deciduous fruits and nuts
Rice
Cotton
Developed
Cropland and pasture
Cropland
Irrigated row and field crops

C2VSim
Pasture
Alfalfa
Sugar beet
Field crops
Rice
Truck crops
Tomato
Tomato (hand picked)
Tomato (machine picked)
Orchard
Grains
Vineyard
Cotton
Citrus and Olives
Urban
Native Vegetation
Riparian Vegetation

Land Use Type Mapping

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Vineyards
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Semi-agriculture
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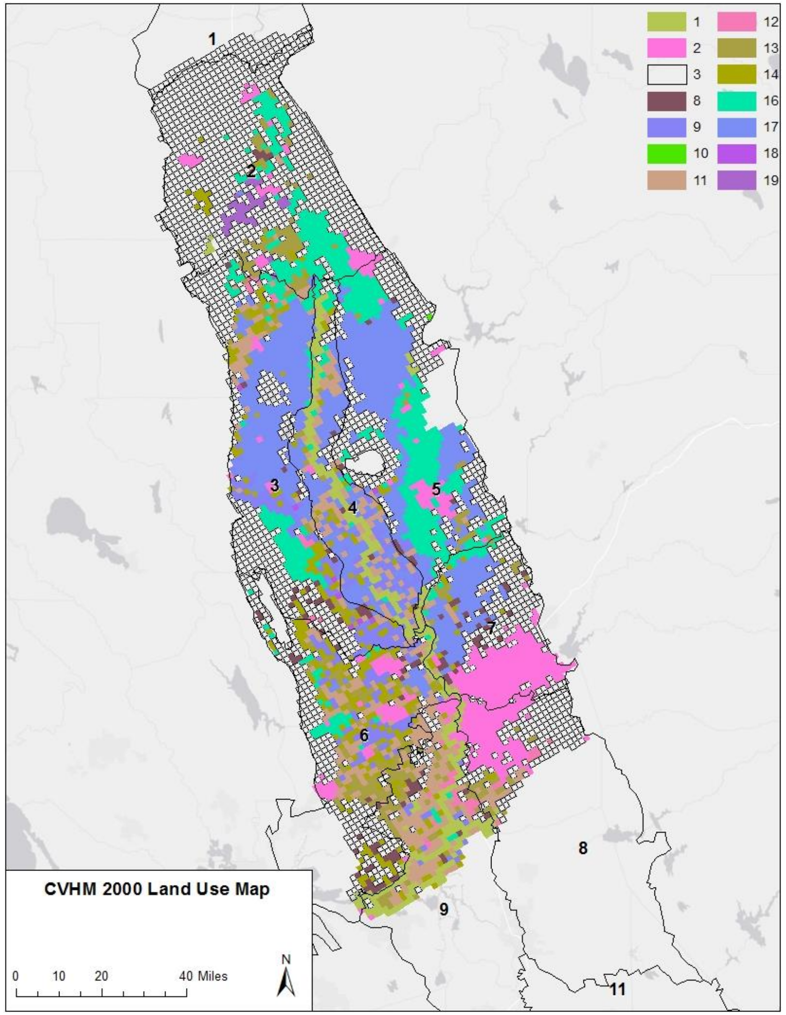
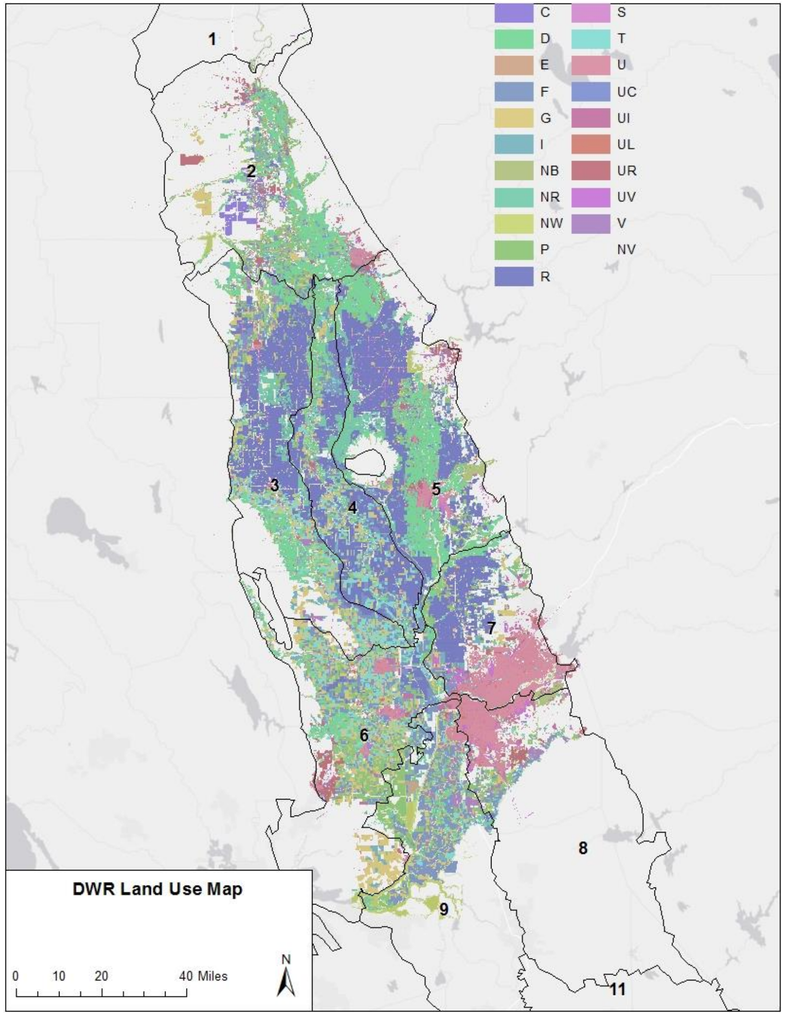
Rice
Cotton
Developed
Cropland and pasture
Cropland
Irrigated row and field crops

Common
Water
Urban
Native Classes
Orchards, groves, vineyards, deciduous fruits and nuts
Pasture/hay
Grains and hay
Truck, nursery, and berry crops
Citrus and sub-tropical
Field crops
Rice
Cotton
Other

C2VSim
Pasture
Alfalfa
Sugar beet
Field crops
Rice
Truck crops
Tomato
Tomato (hand picked)
Tomato (machine picked)
Orchard
Grains
Vineyard
Cotton
Citrus and Olives
Urban
Native Vegetation
Riparian Vegetation

Land Use Map





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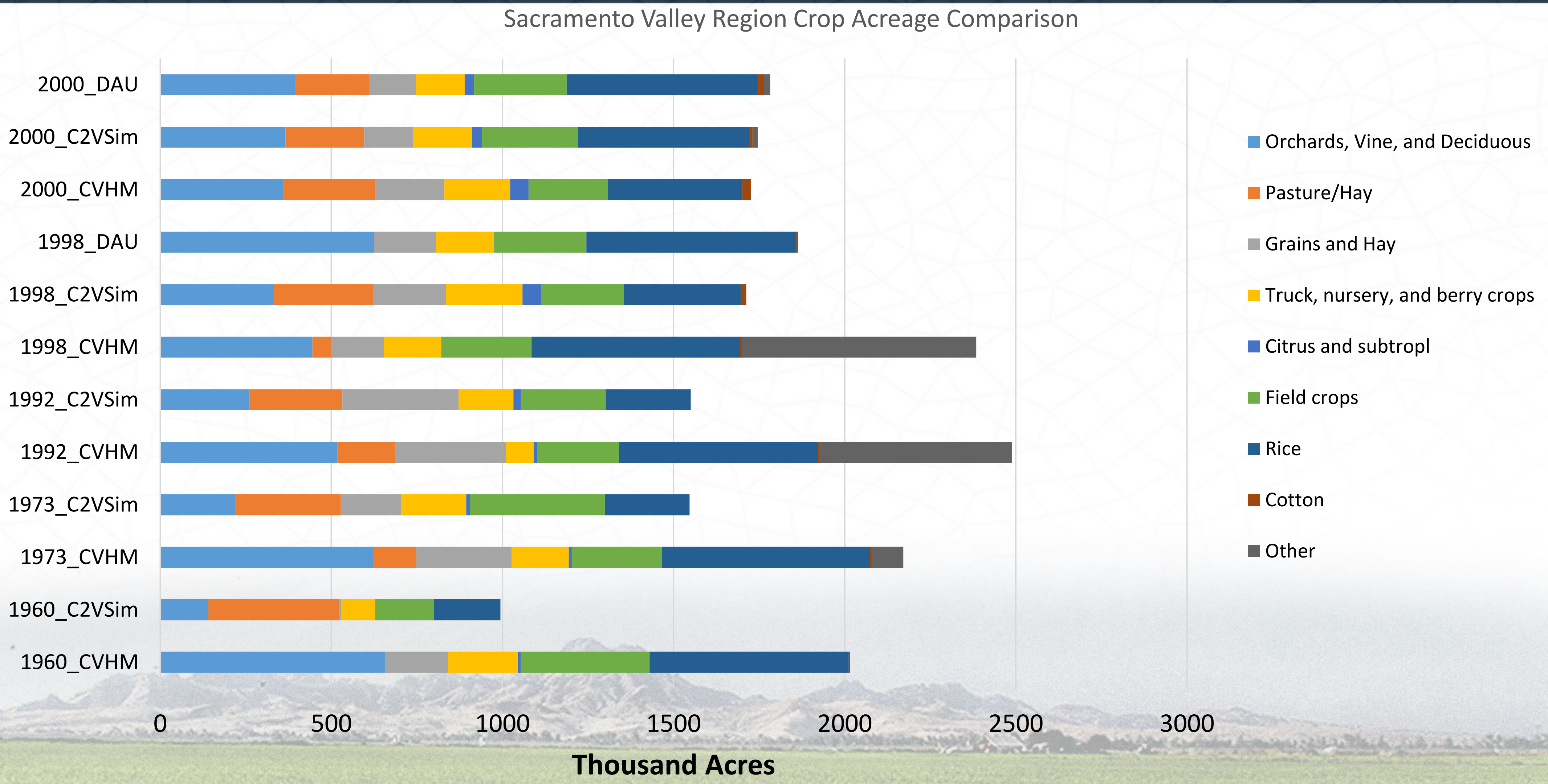
Land Use/Crop Acreages for Sacramento Valley Region



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Land Use/Crop Acreages for Sacramento Valley Region

CVHM	C2VSim
Orchards, groves, and vineyards	Pasture
Pasture/Hay	Alfalfa
Row Crops	Sugar Beet
Small Grains	Field Crops
Truck, nursery, and berry crops	Rice
Citrus and subtropl	Truck Crops
Field crops	Tomato
Vineyards	Grains
Pasture	Vineyards
Grain and hay crops	Cotton
Semiagricultural	Citrus and Olives
Deciduous fruits and nuts	
Rice	
Cotton	
Cropland and pasture	
Cropland	
Irrigated Row and Field Crops	

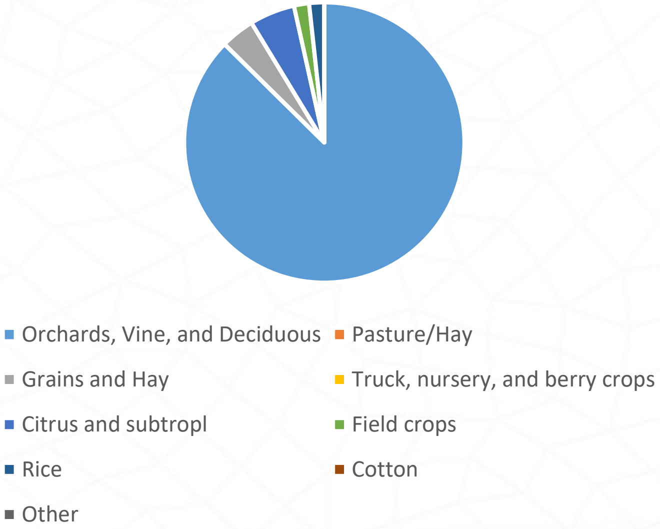
	CVHM	CVHM Ag Acreage	C2VSim	C2VSim Ag Acreage
1960	3,804	2,015	3,772	994
1973	3,804	2,171	3,772	1,547
1992	3,804	2,489	3,772	1,550
1998	3,804	2,385	3,772	1,712
2000	3,804	1,726	3,772	1,746

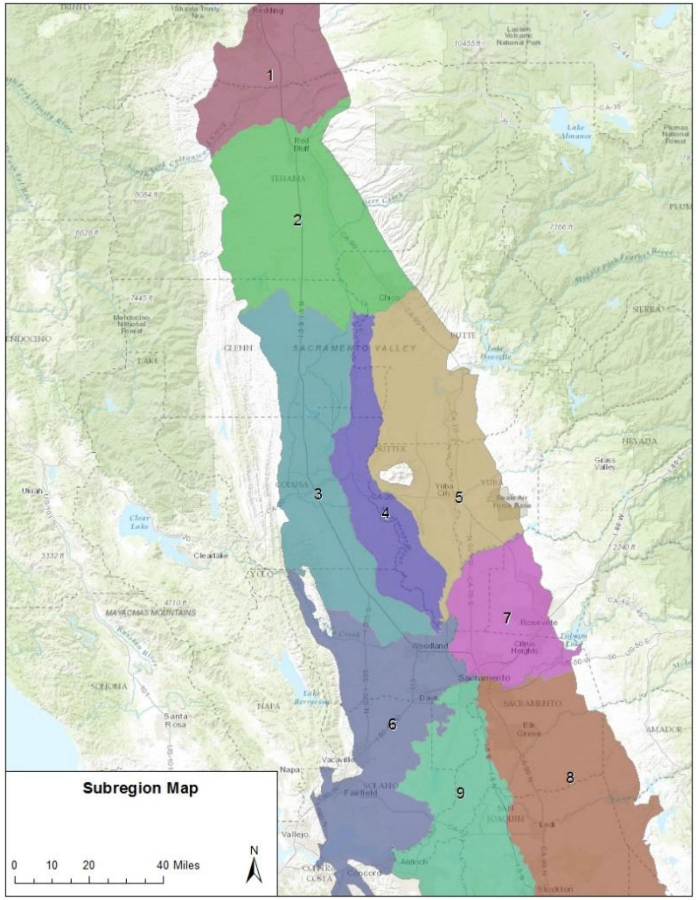
Units: Thousand Acres

Note: Water, Urban, Native Classes, Idle/Fallow, and Developed acreages are excluded from the CVHM Ag Acreage

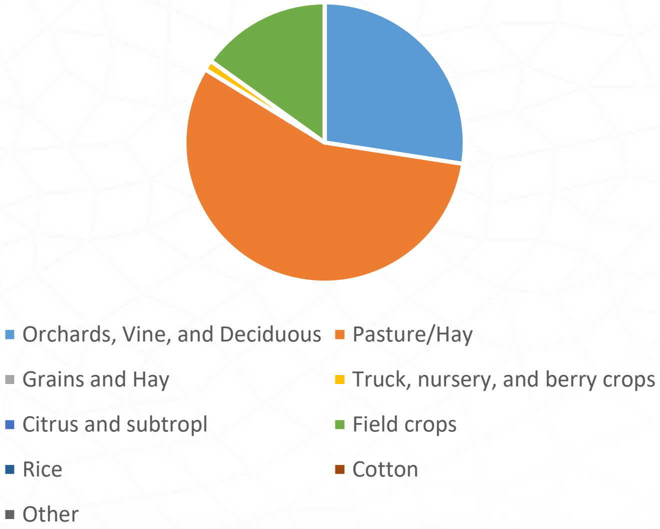
Agricultural Land Use
Subregion 2 - 1960

CVHM

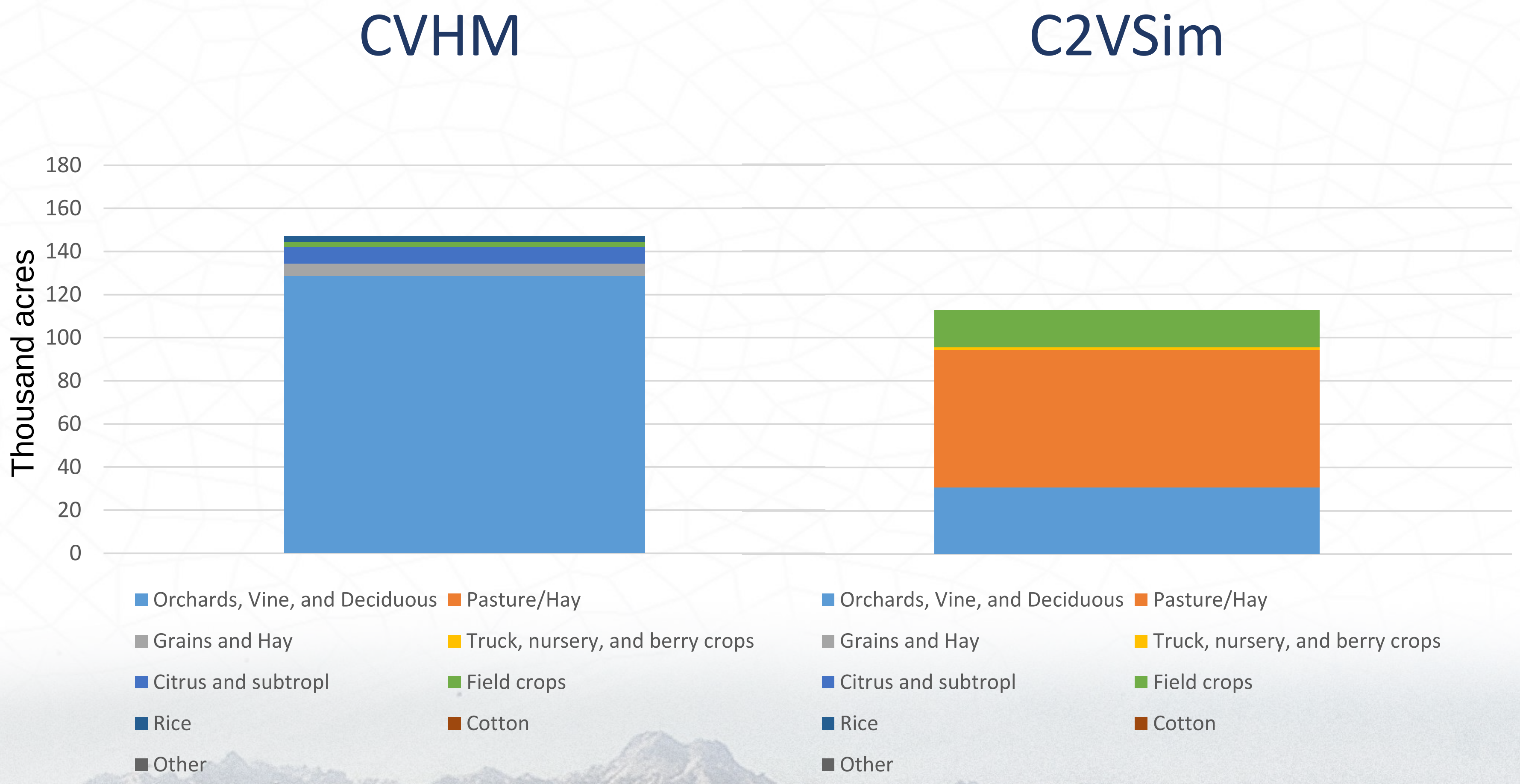




C2VSim



Agricultural Land Use
Subregion 2 - 1960



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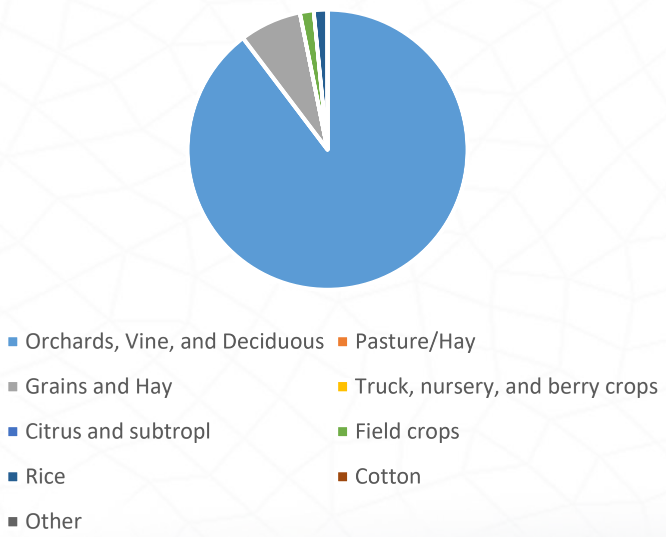
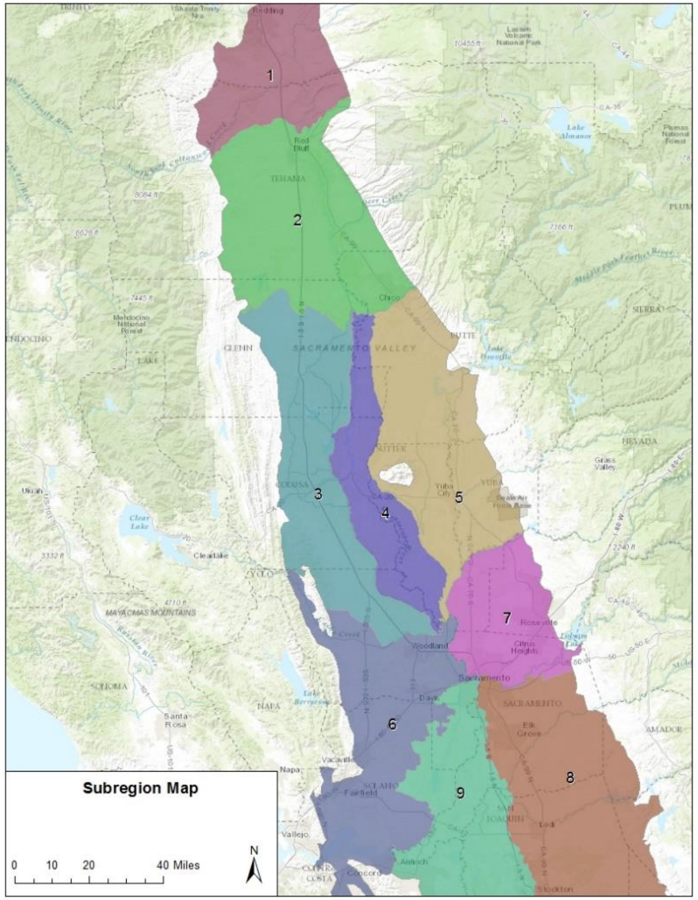
Agricultural Land Use
Subregion 2 - 2000

CVHM





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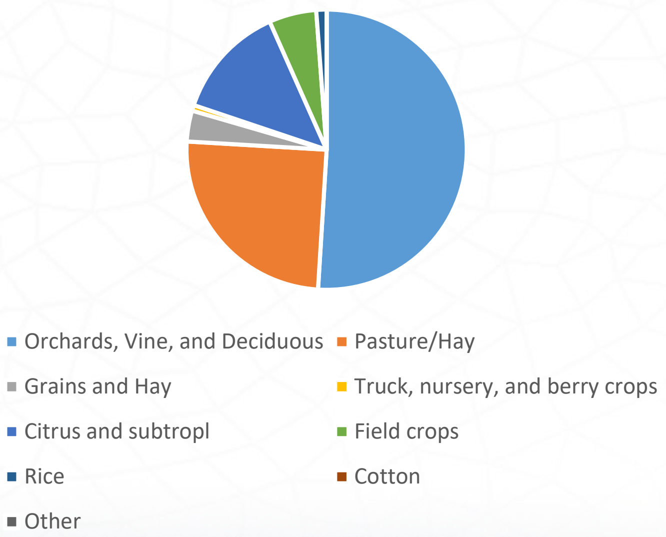
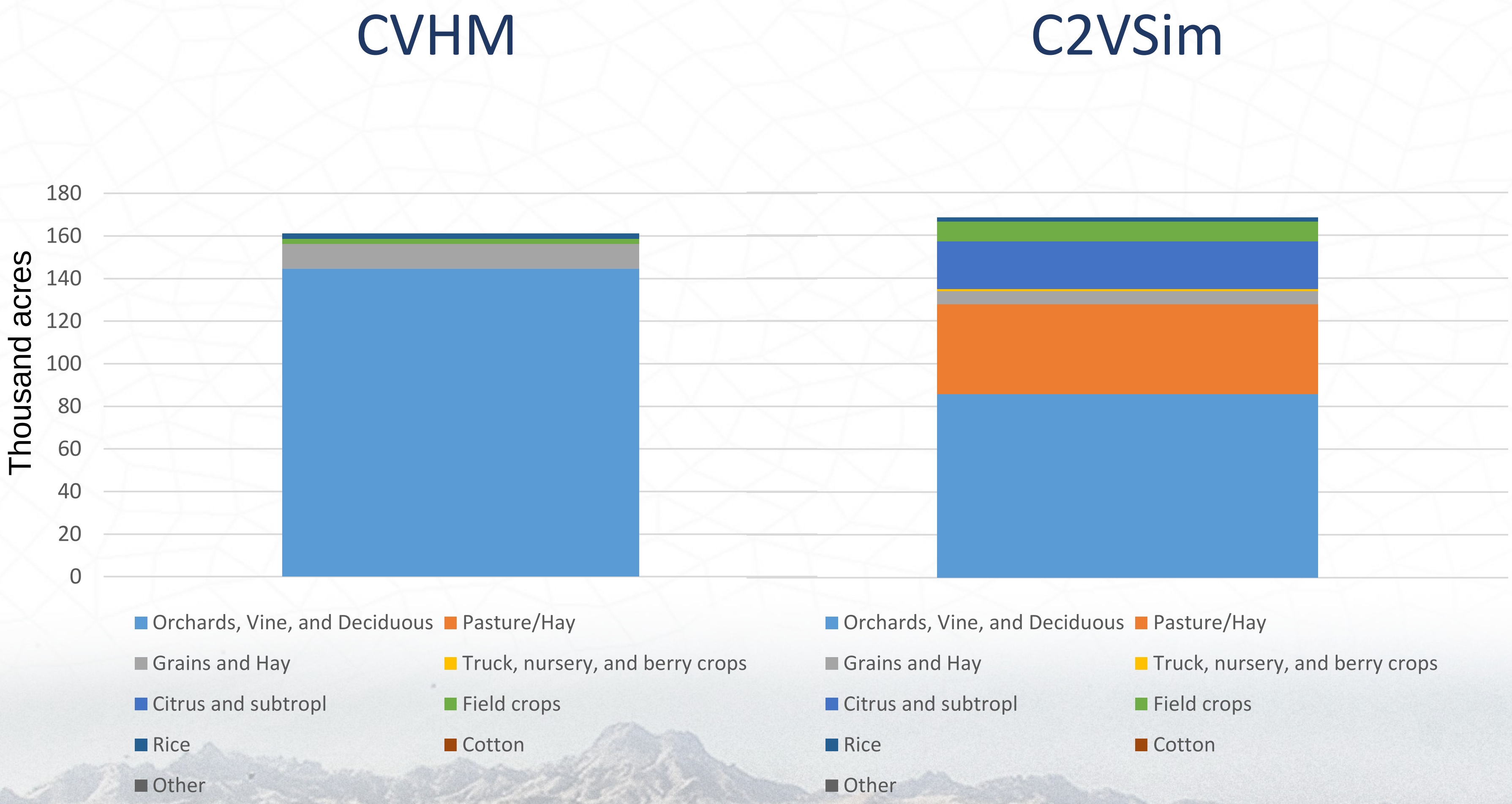
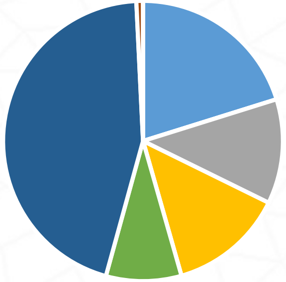


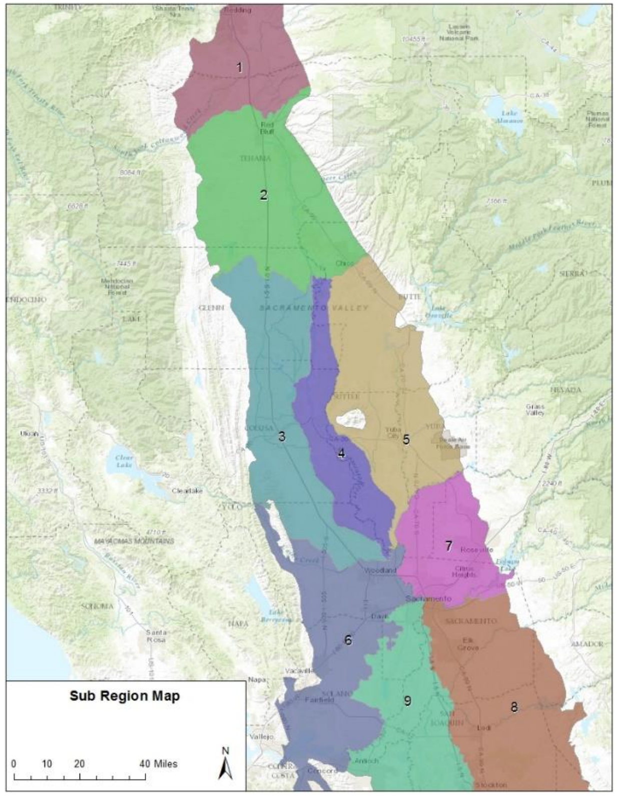
Agricultural Land Use
Subregion 2 - 2000



Subregion 3 - 1960

CVHM





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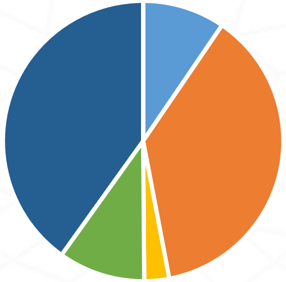
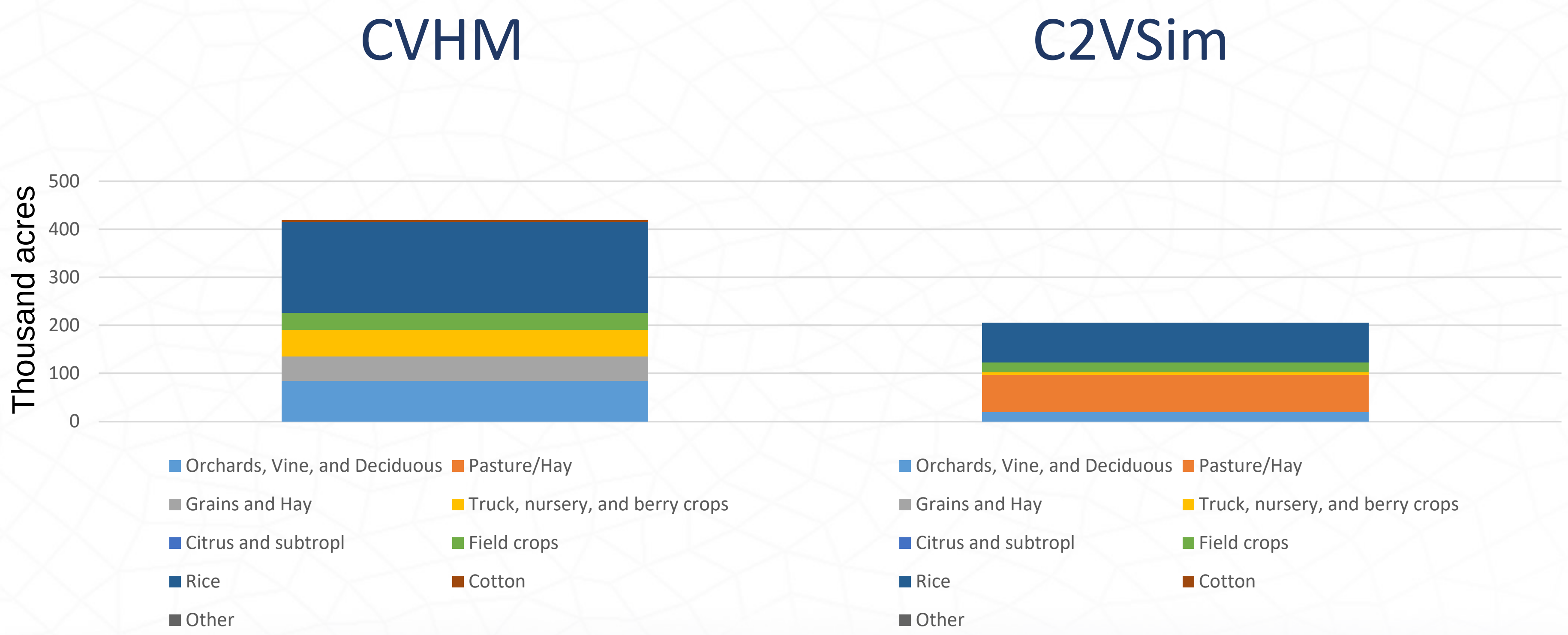
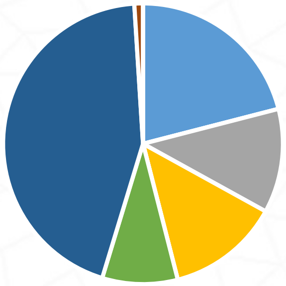


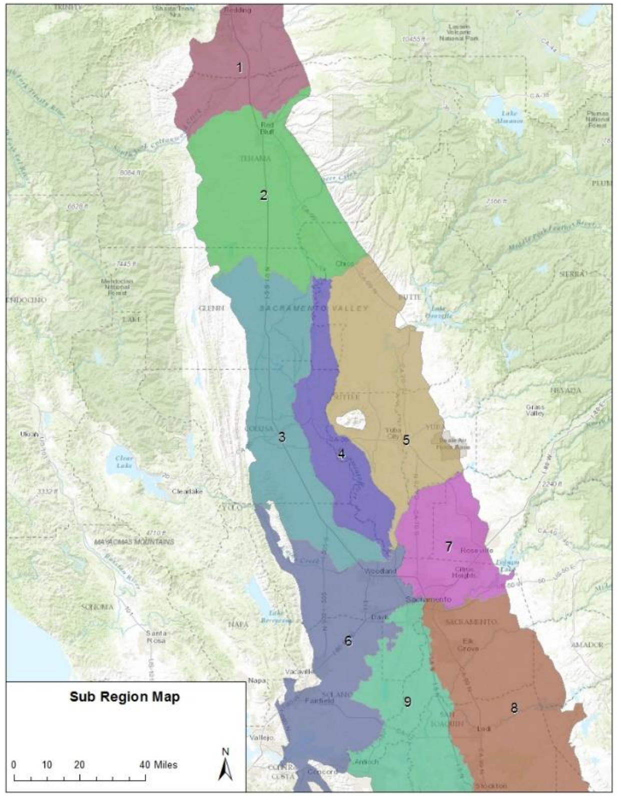
Subregion 3 - 1960



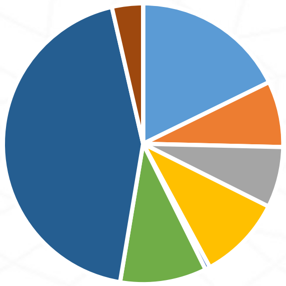
Subregion 3 - 2000

CVHM





C2VSim



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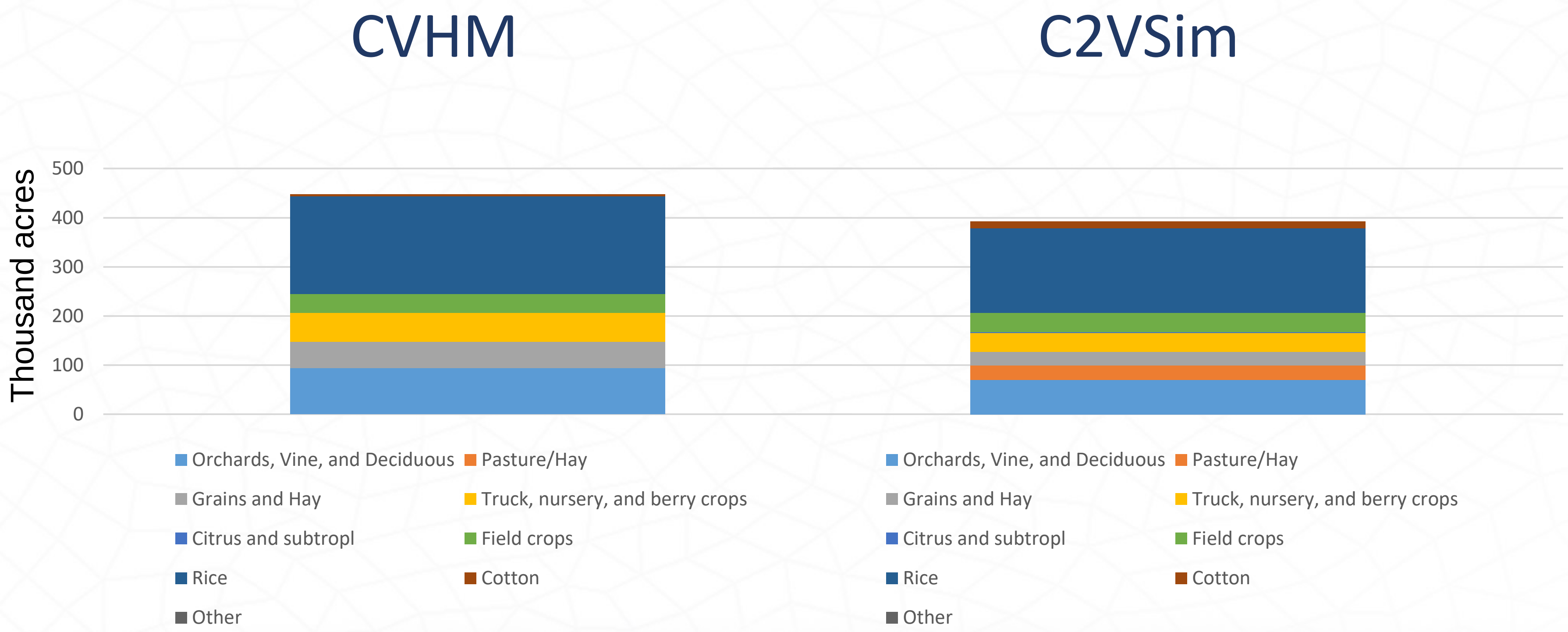
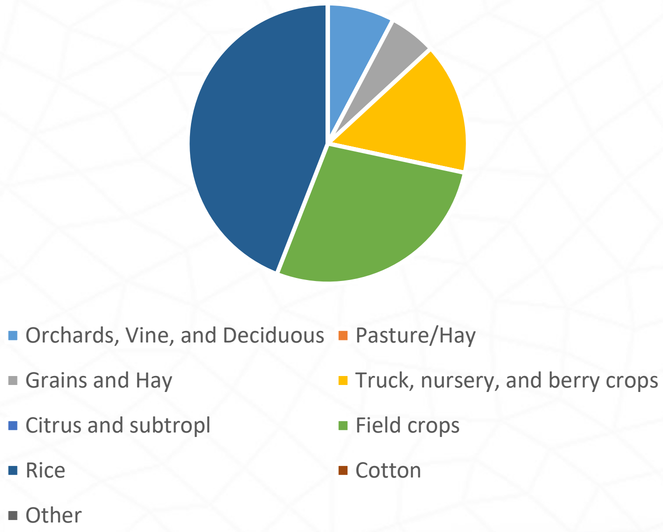
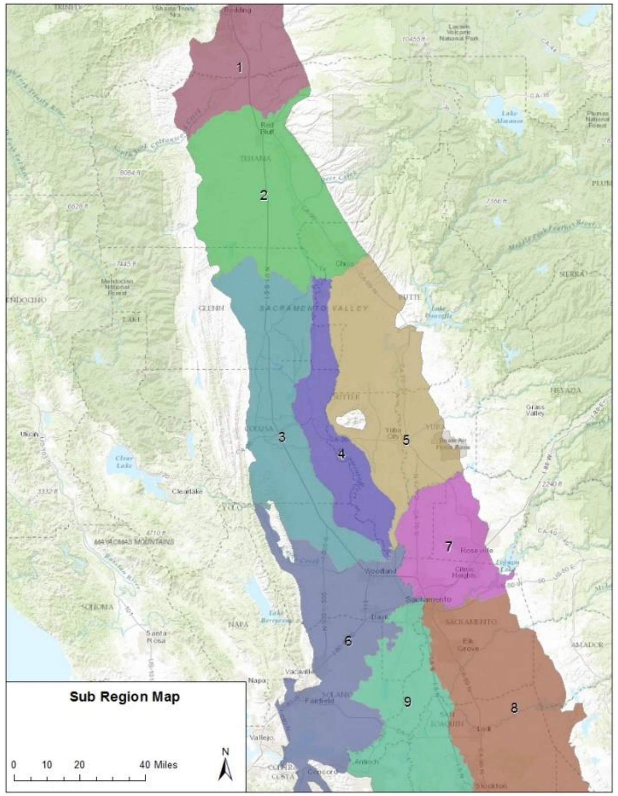
Subregion 3 - 2000



Subregion 4 - 1960

CVHM





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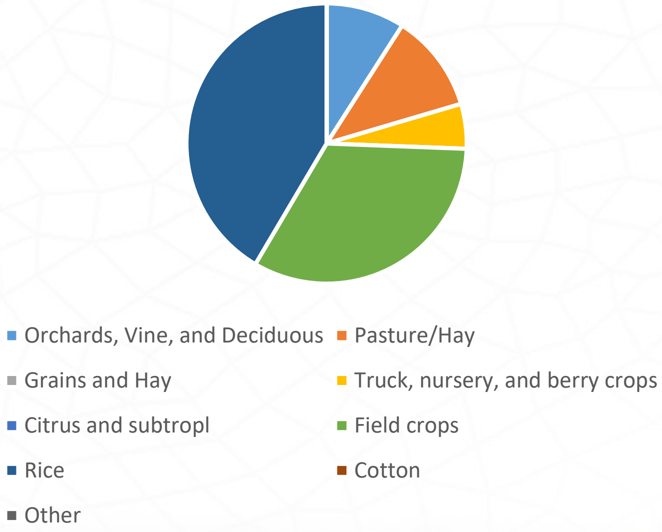
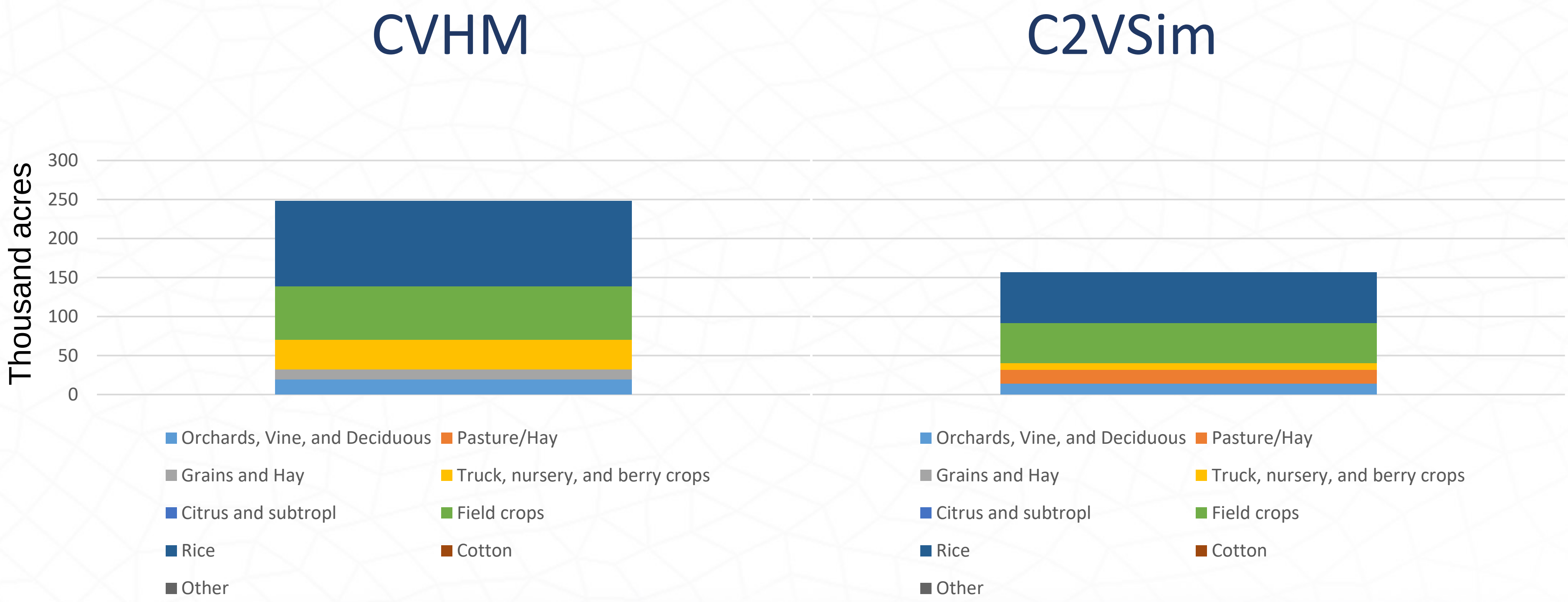
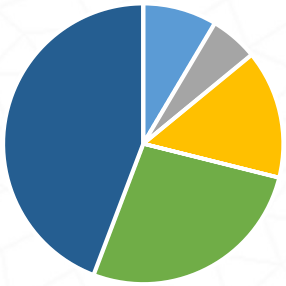


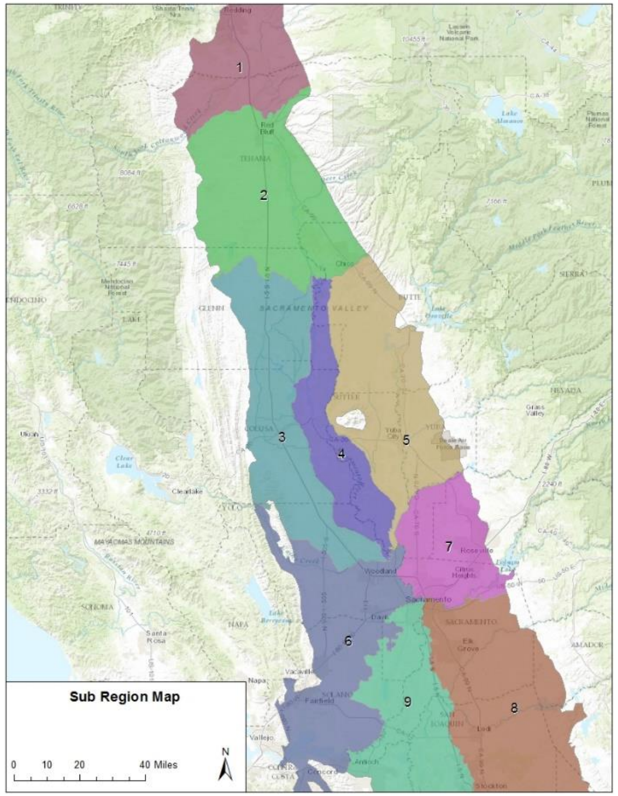
Subregion 4 - 1960



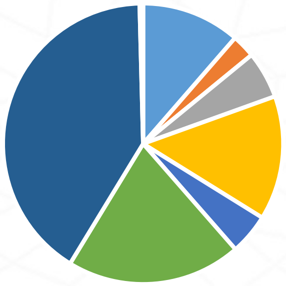
Subregion 4 - 2000

CVHM



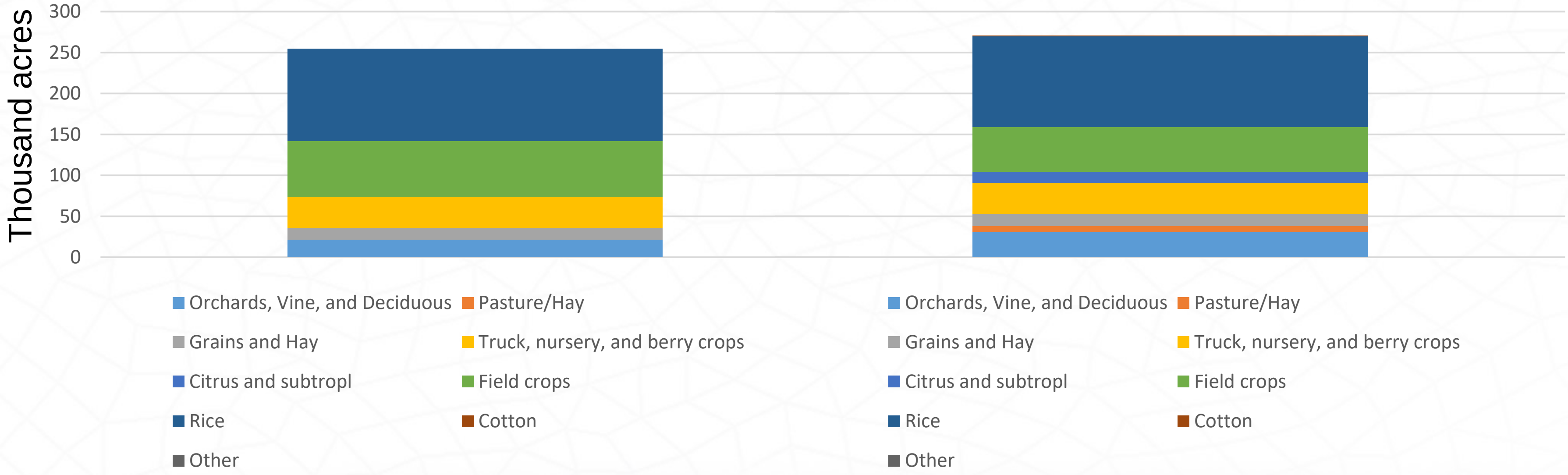


C2VSim



Subregion 4 - 2000

CVHM C2VSim



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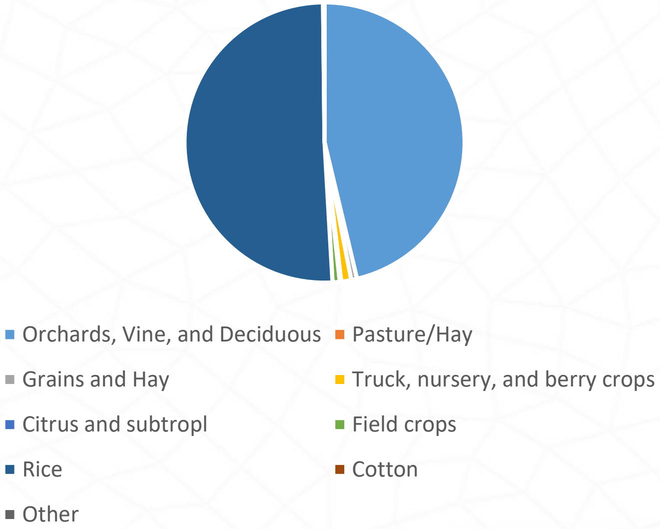
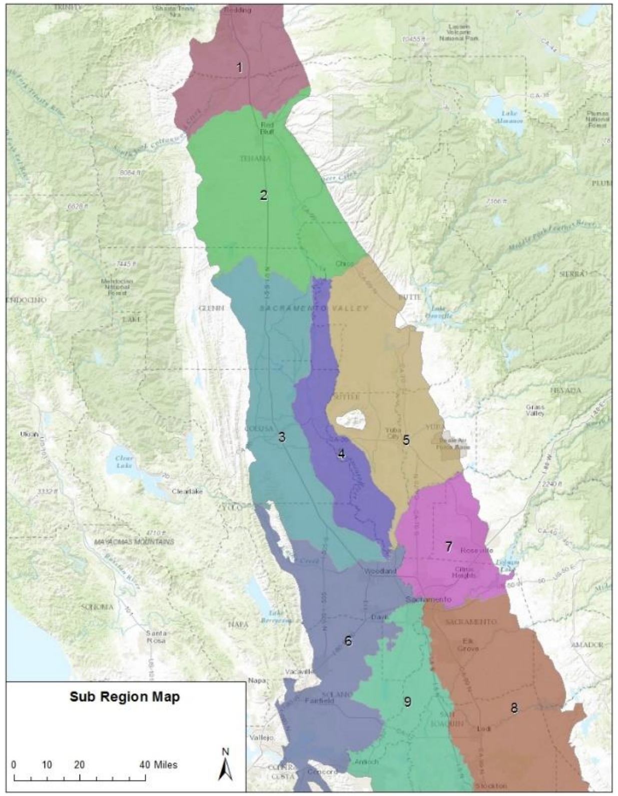
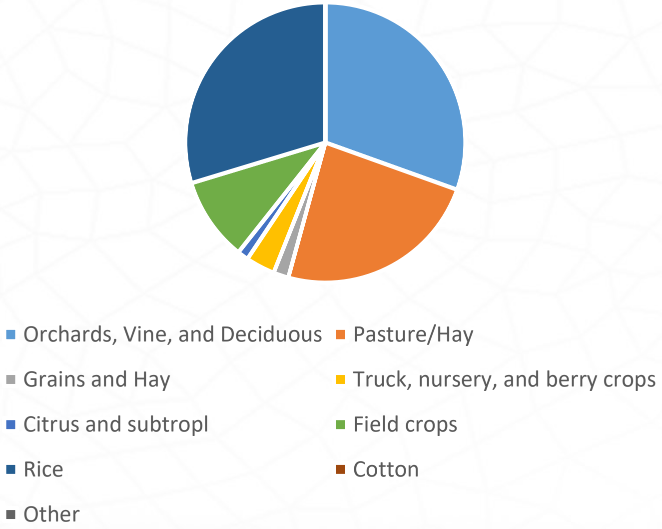
Subregion 5 - 1960

CVHM

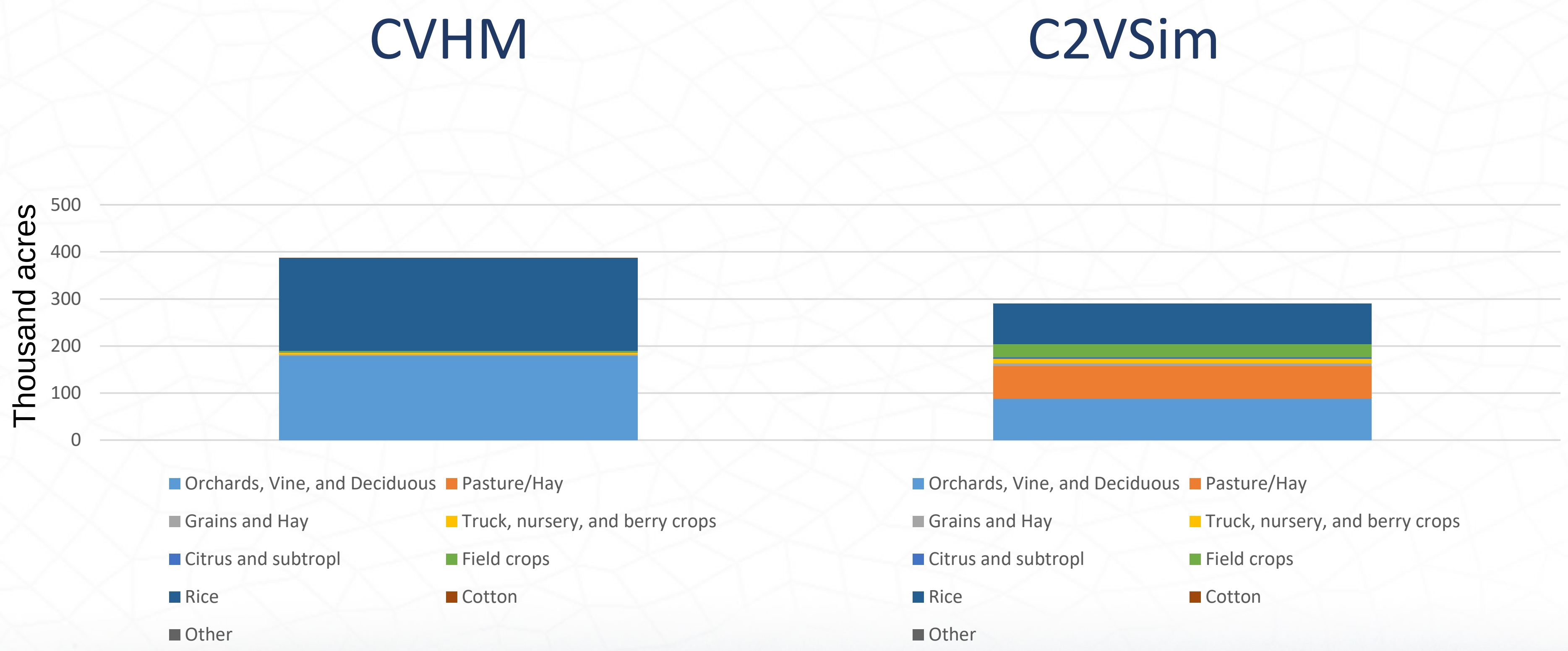




C2VSim

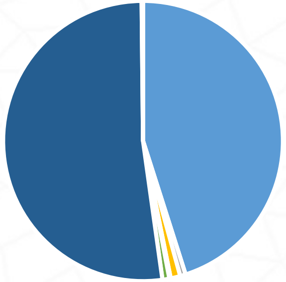


Subregion 5 - 1960

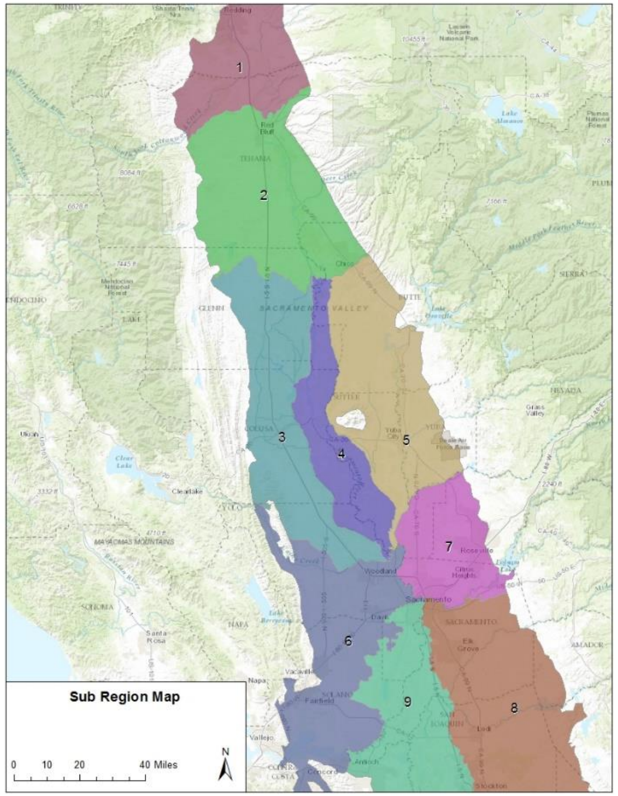


Subregion 5 - 2000

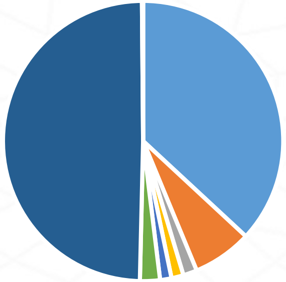
CVHM



- Orchards, Vine, and Deciduous
- Pasture/Hay
- Grains and Hay
- Truck, nursery, and berry crops
- Citrus and subtropl
- Field crops
- Rice
- Cotton
- Other

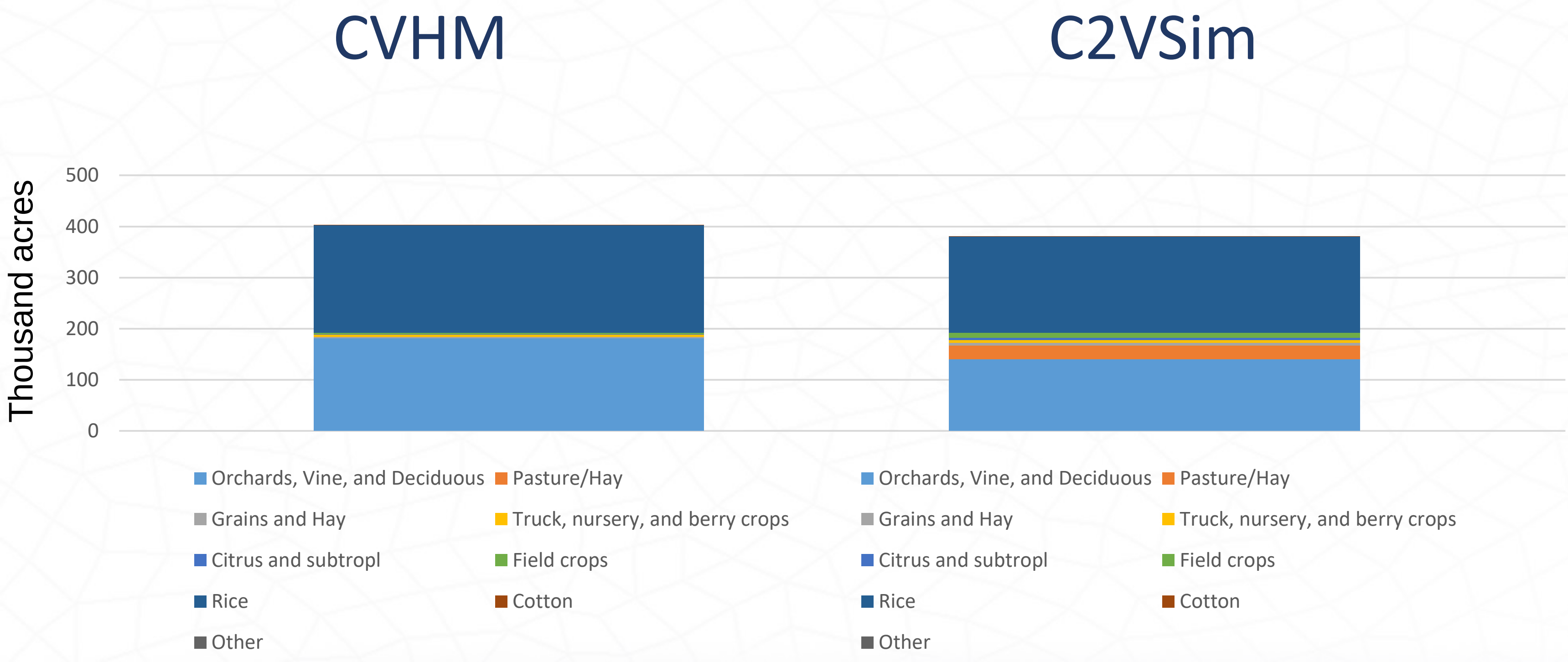


C2VSim



- Orchards, Vine, and Deciduous
- Pasture/Hay
- Grains and Hay
- Truck, nursery, and berry crops
- Citrus and subtropl
- Field crops
- Rice
- Cotton
- Other

Subregion 5 - 2000



Subregion Crop Acreage Comparison - 2000

	CVHM			C2VSim			DAU		
Subregion No.	Subregion Area	Crop Acreages	% Ag	Subregion Area	Crop Acreage	% Ag	DAU Area	Crop Acreage	%
2	745	161	22%	737	168	23%	759	174	23%
3	669	448	67%	662	393	59%	913	375	41%
4	354	255	72%	351	271	77%	350	269	77%
5	688	403	59%	687	381	55%	732	368	50%
6	503	240	48%	497	186	37%	612	259	42%
7	367	113	31%	361	123	34%	379	106	28%
8	184	61	33%	183	61	33%	142	14	10%
9	275	183	67%	276	126	46%	280	165	59%

Thousand Acres

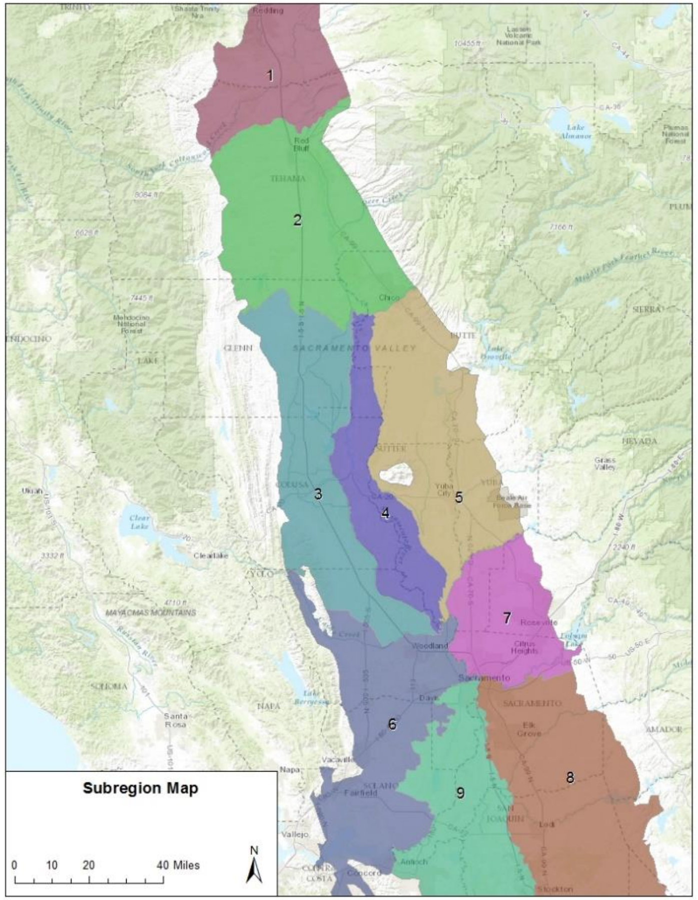
Agenda

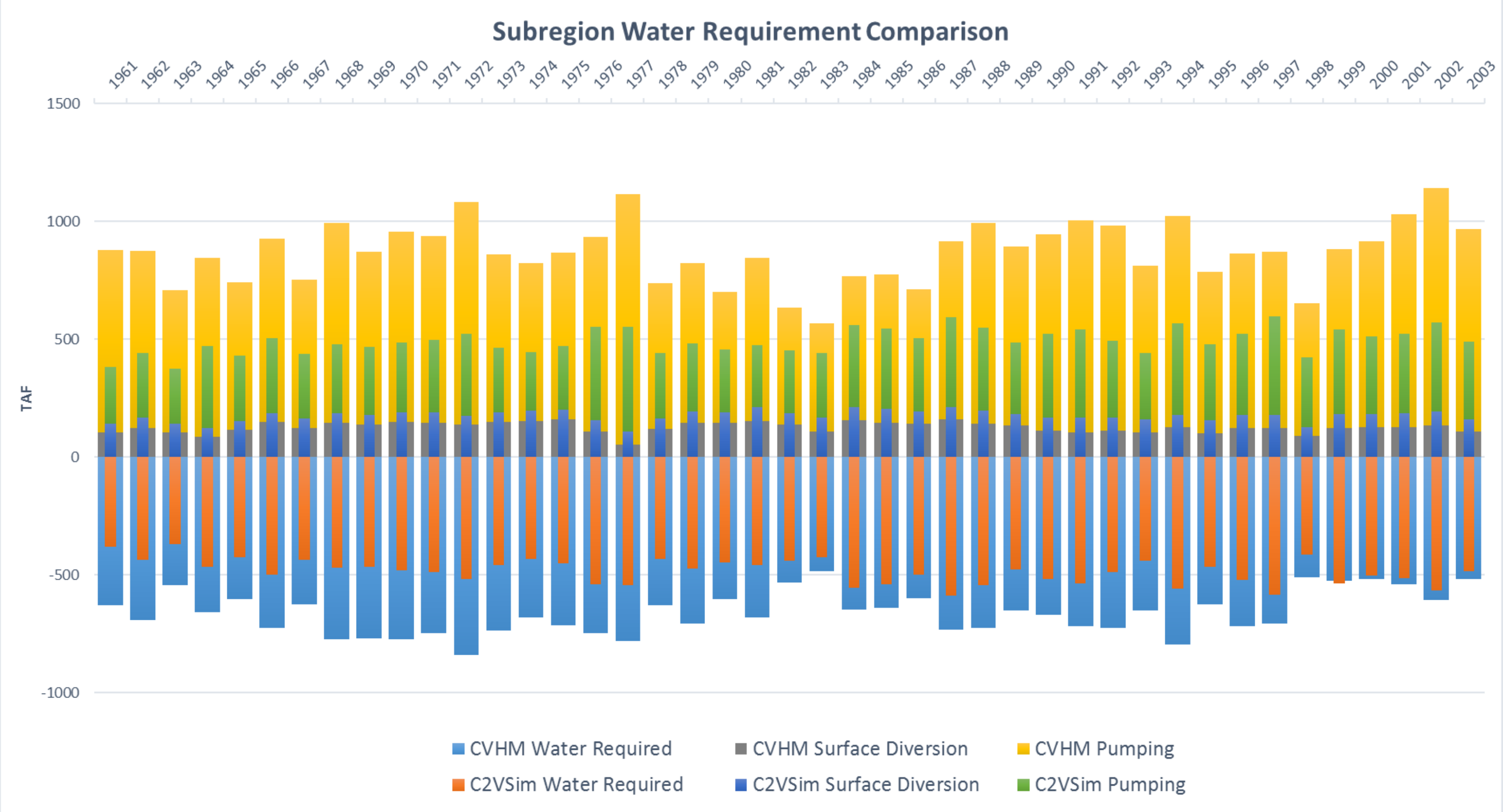
- Recap of previous meetings
- **Model comparison**
  - Land use / cropping
  - **Water budget**
    - **Ag water demand**
    - **Water supply**
    - **Recharge**
    - **Stream seepage**
  - Surface water inflows
  - Calibration
    - Hydrographs at selected wells
- Discussion
  - Model recommendations or assistance in model recommendations

Water Budget Sources

- CVHM
  - Water Required (FDS.OUT file, TFDR-FIN column)
  - Surface Water Diversion (FDS.OUT file, R-SWD-FIN and NR-SWD-FIN columns)
  - Pumping (Compq_bc.in & Compq_bc.out files, Multi Node Well and Farm Wells columns)
  - Steam Leakage (Compq_bc.out & Compq_bc.in files, Stream Leakage column)
  - Farm Recharge (Compq_bc.out & Compq_bc.in files, Net Farm Recharge column)
- C2VSim
  - Water Required (CVLandwater.BUD file, Agricultural Supply Requirement column)
  - Surface Diversion (CVLandwater.BUD file, Agricultural Diversion + Urban Diversion columns)
  - Pumping (CVLandwater.BUD file, Agricultural Pumping + Urban Pumping columns)
  - Stream Leakage (CVGround.BUD, Gain from Stream column)
  - Recharge (CVGround.BUD, Net Deep Percolation & Recharge columns)
- DAU
  - AW (applied water)

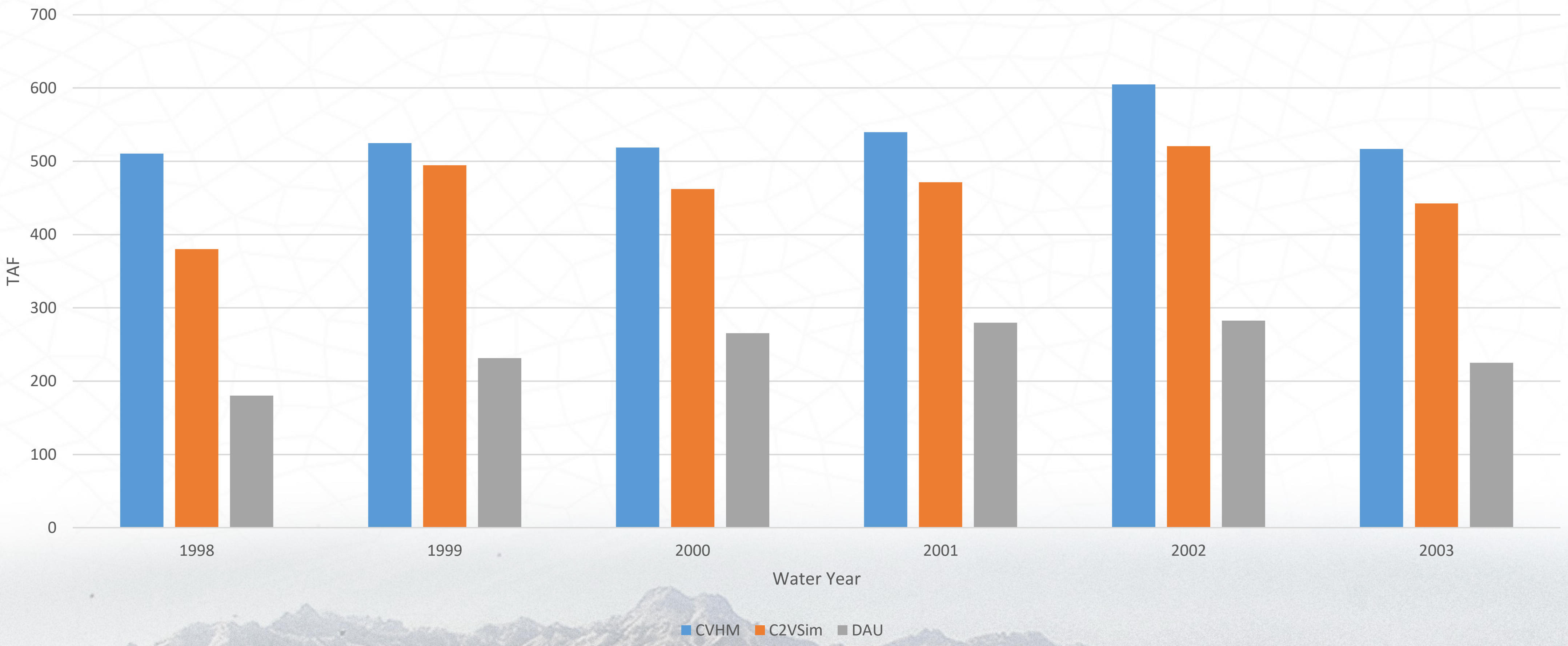
Water Budget: Subregion 2



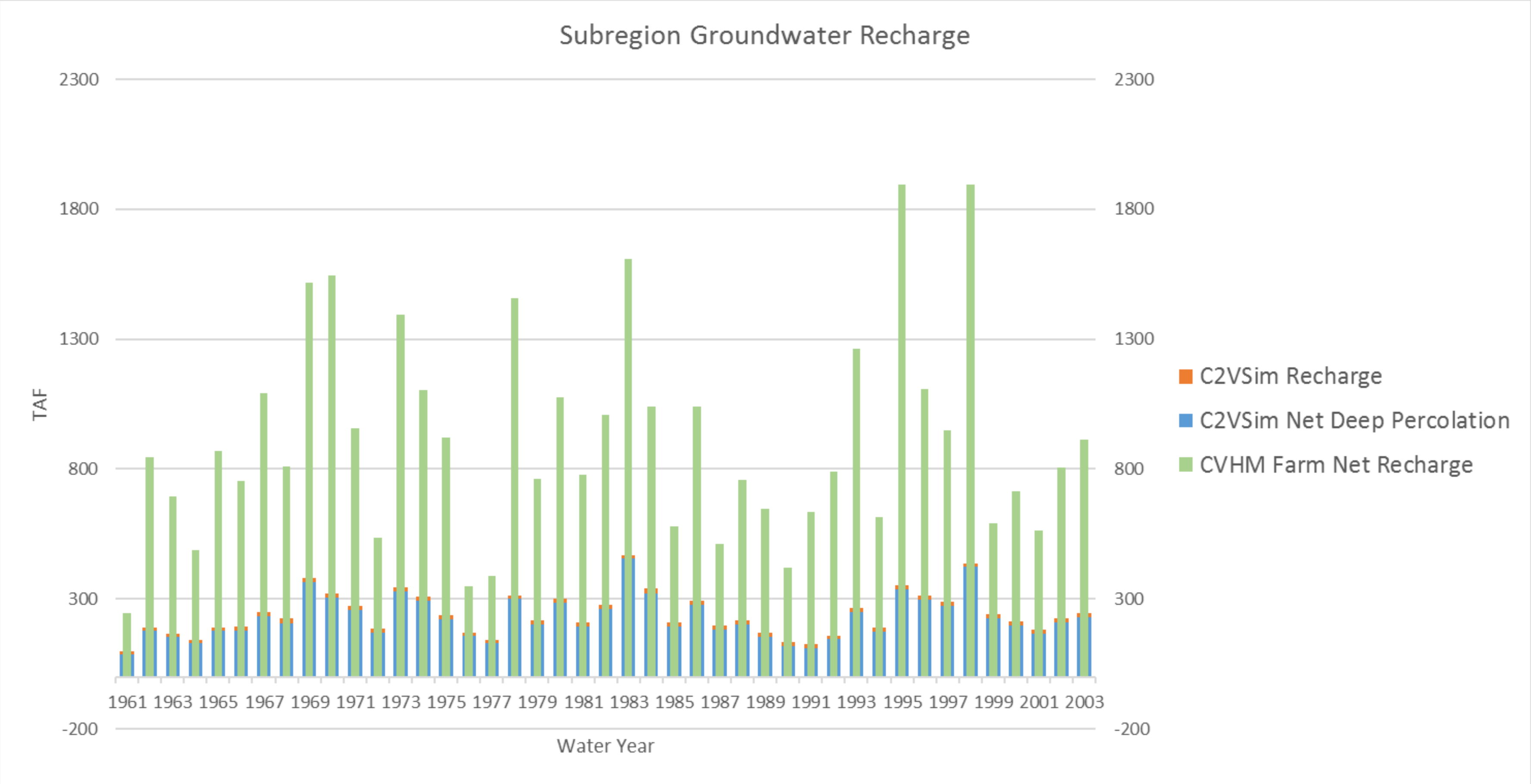


RMC water and environment
WOODARD & CURRAN
National Experience. Local Focus.

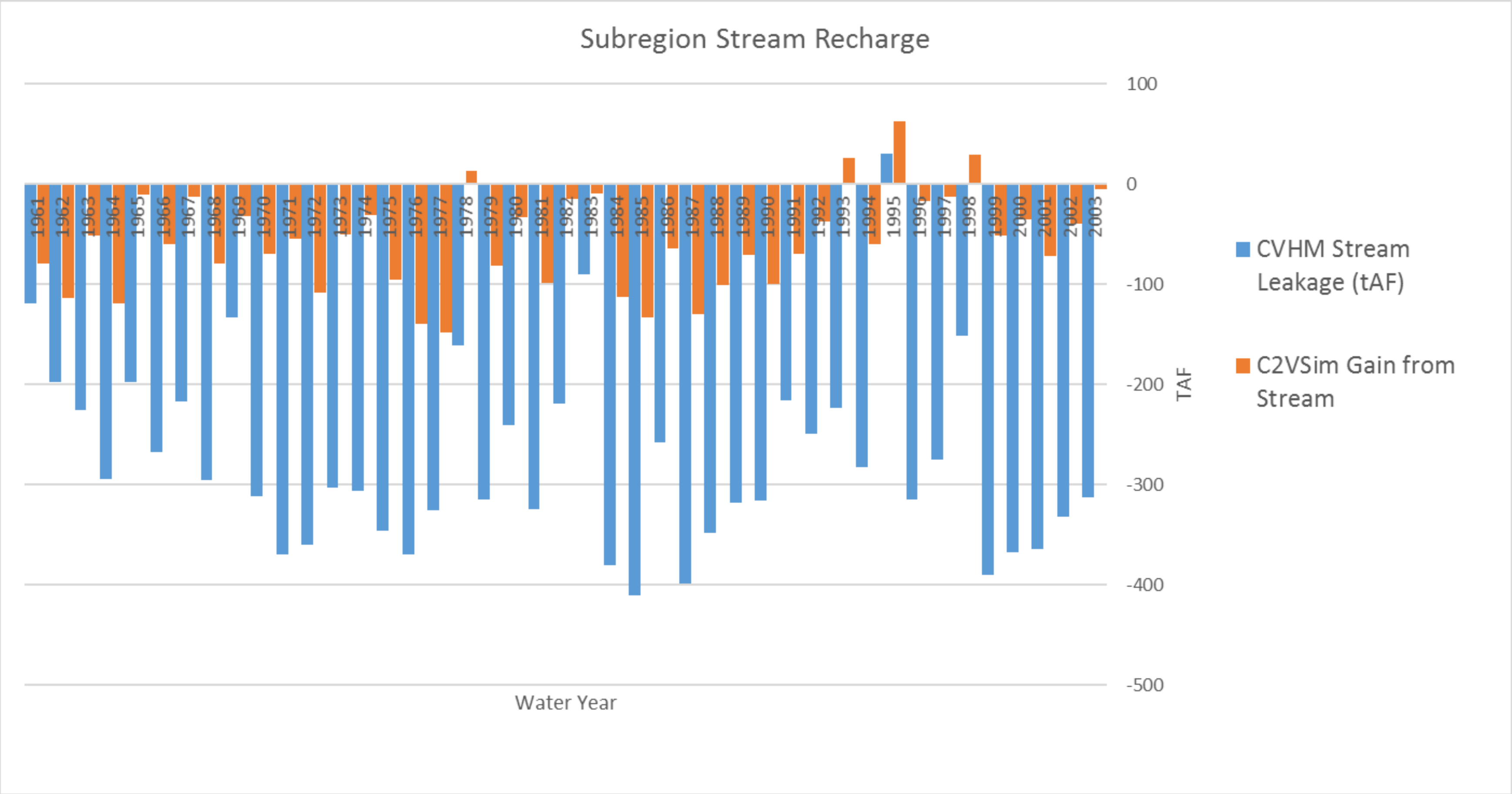
Water Budget: Subregion 2
CVHM(TFDR-FIN), C2VSim(Ag Supply Req), DAU(AW)



Water Budget: Subregion 2



Water Budget: Subregion 2



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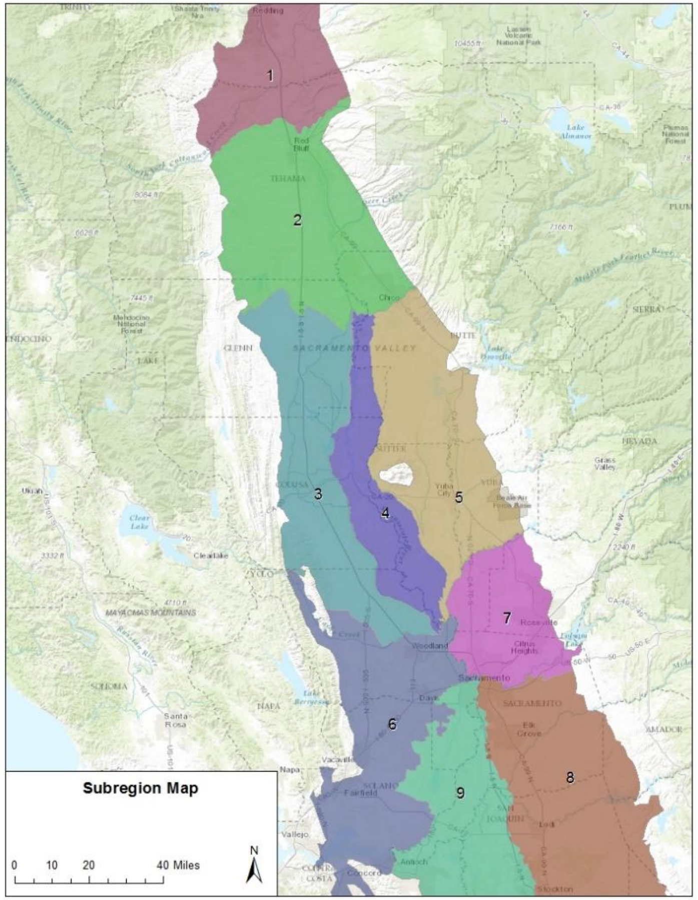
Water Budget: Subregion 2

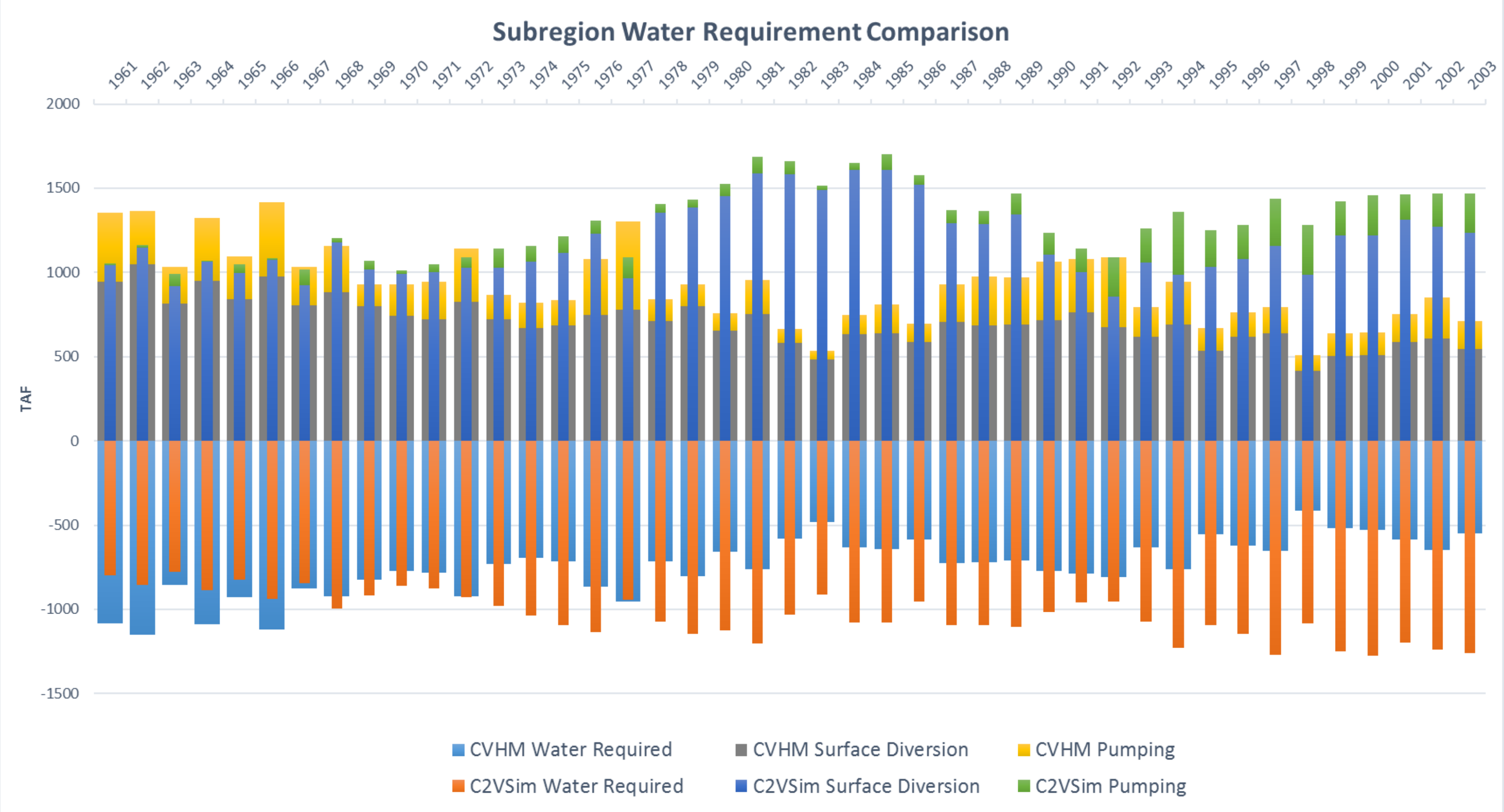
	CVHM	C2VSim
Average Water Required	663	486
Average Surface Diversion	126	174
Average Pumping	743	317

	CVHM	C2VSim
Average GW Recharge	905	242
Average Stream Recharge	-276	-58

Units: TAF

Water Budget: Subregion 3





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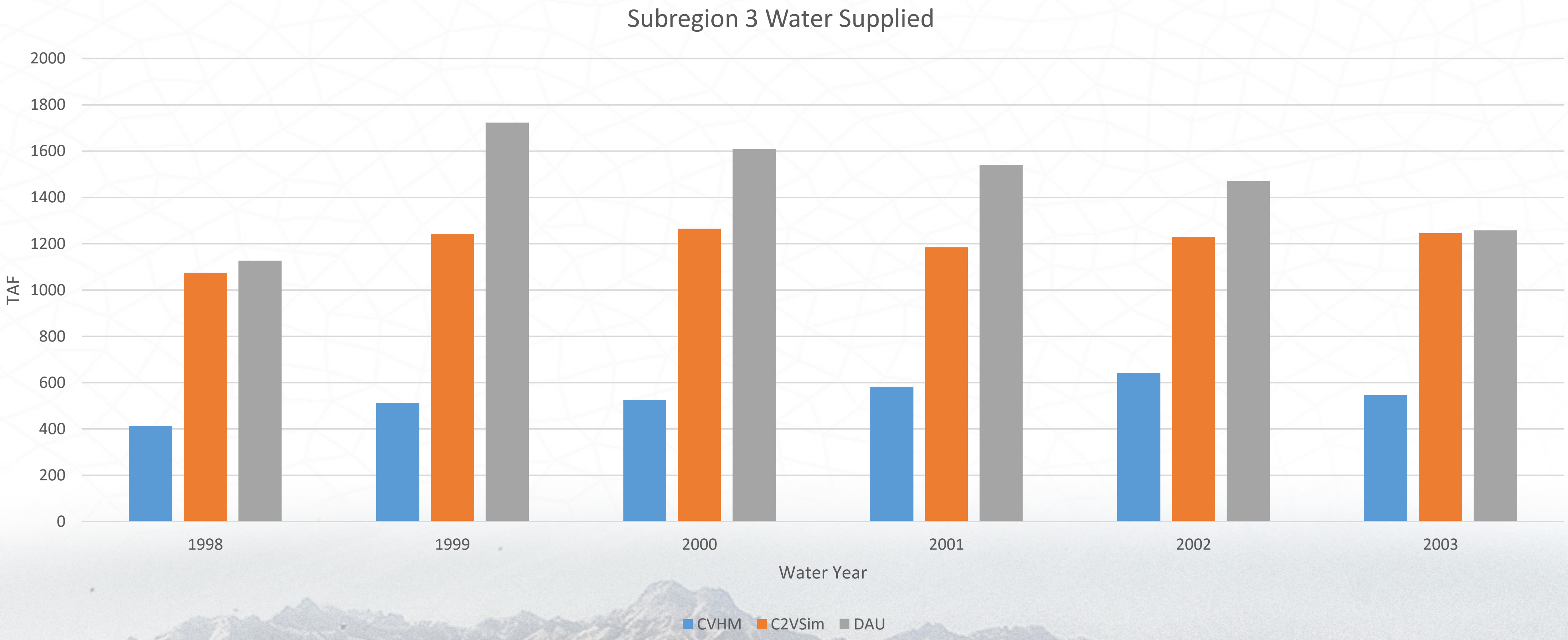
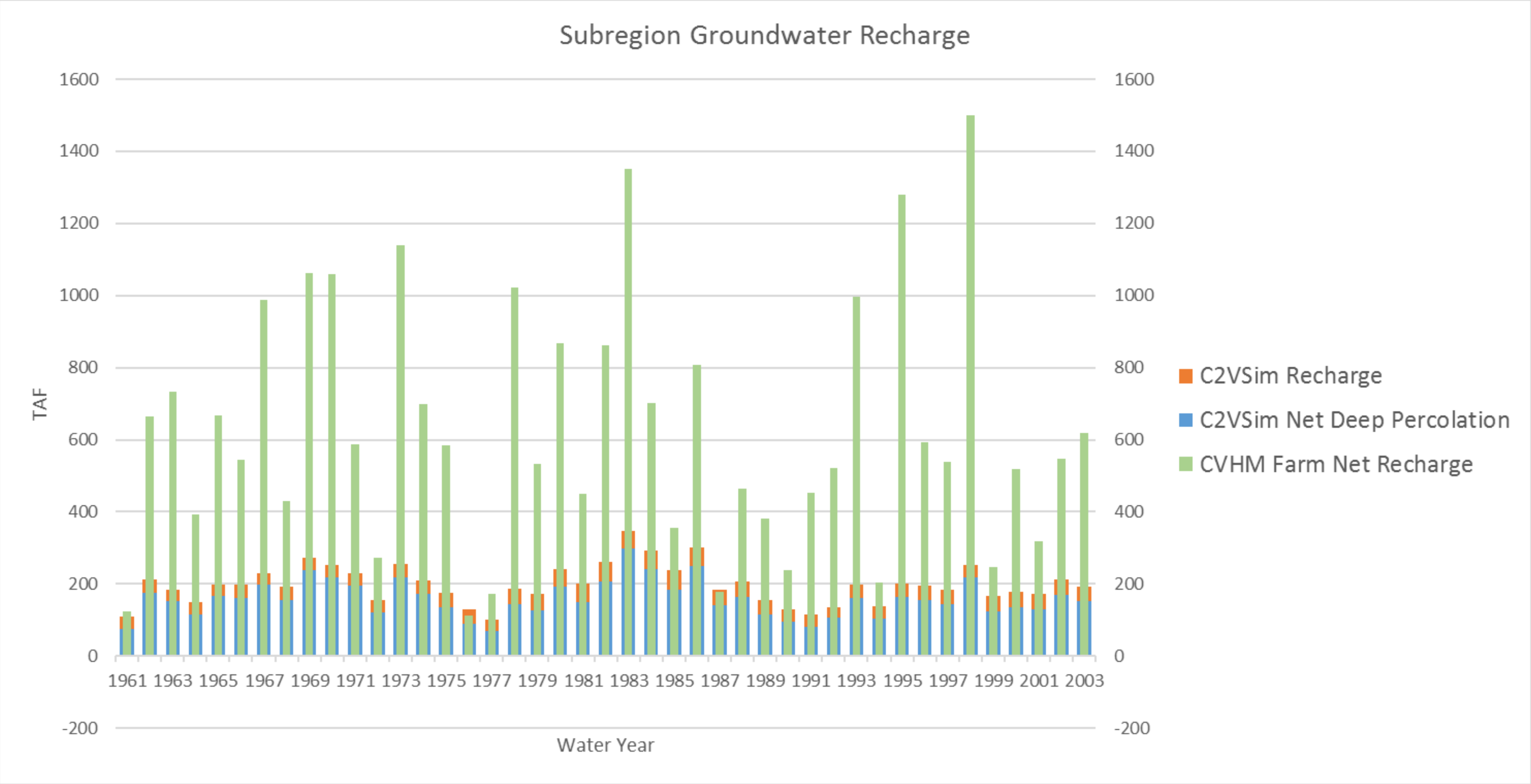
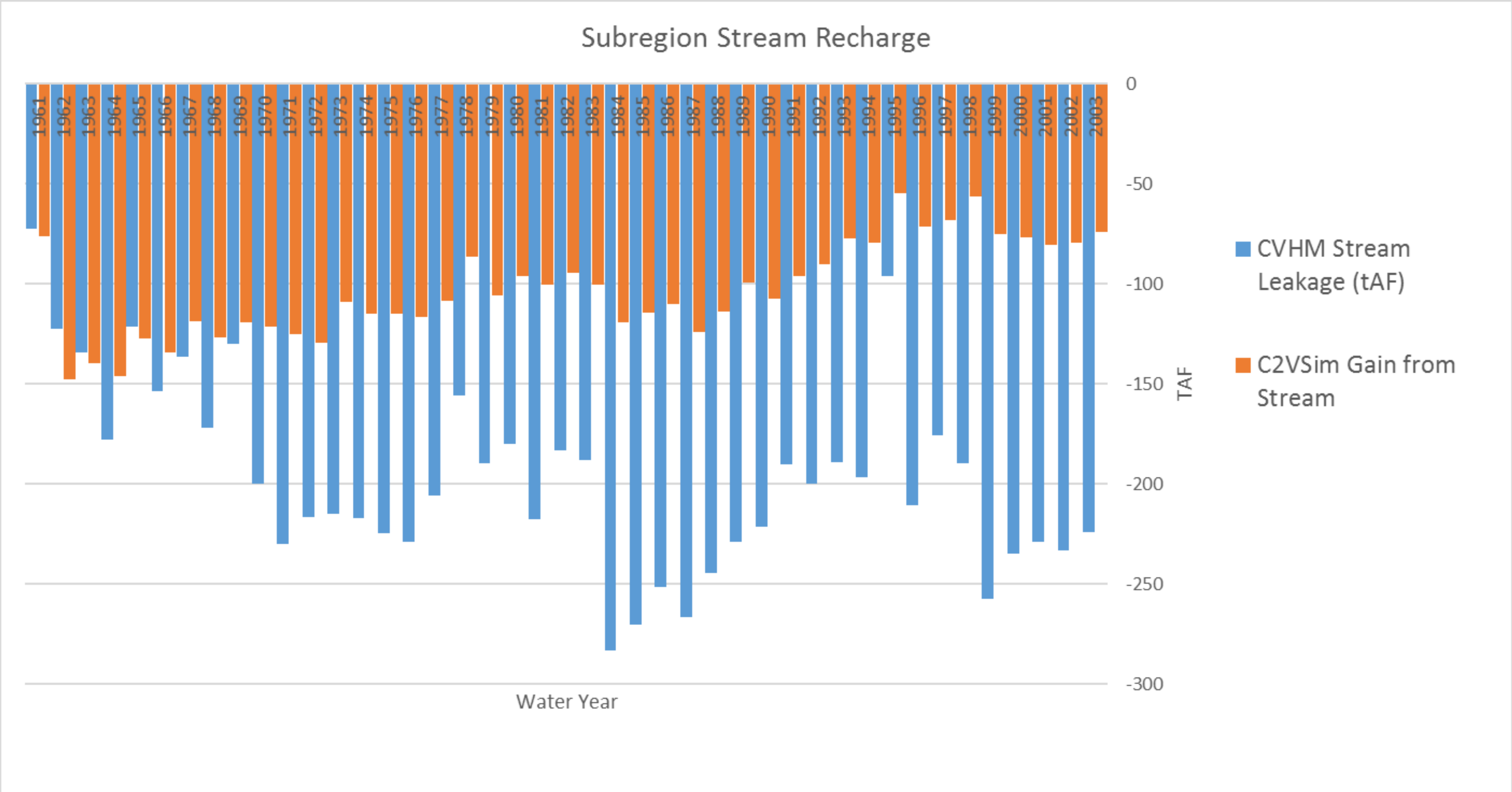
Water Budget: Subregion 3



Water Budget: Subregion 3



Water Budget: Subregion 3



Water Budget: Subregion 3

	CVHM	C2VSim
Average Water Required	747	1,037
Average Surface Diversion	703	1,181
Average Pumping	220	114

	CVHM	C2VSim
Average GW Recharge	623	198
Average Stream Recharge	-197	-103

Units: TAF

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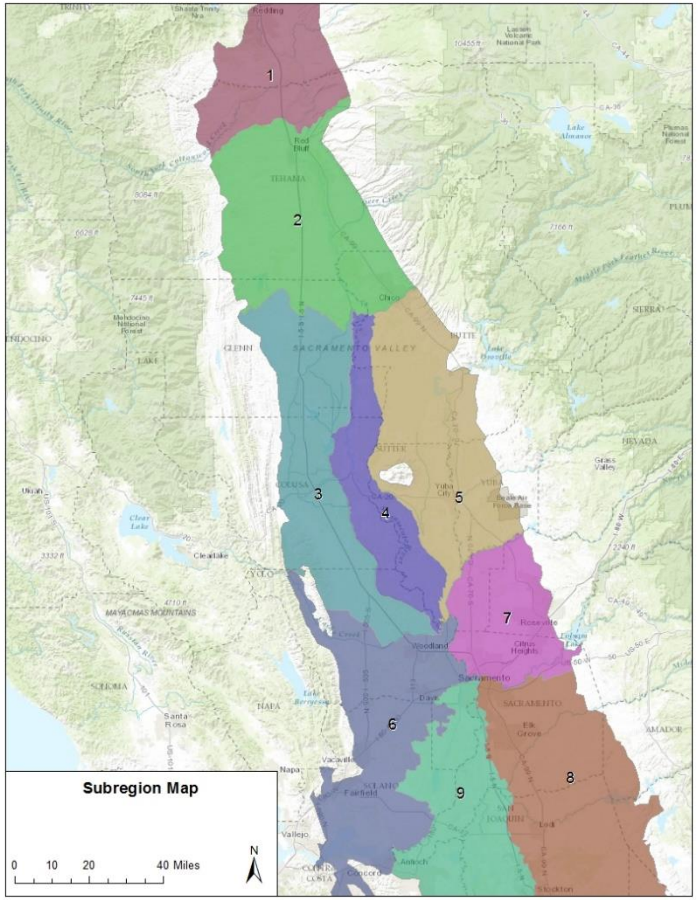
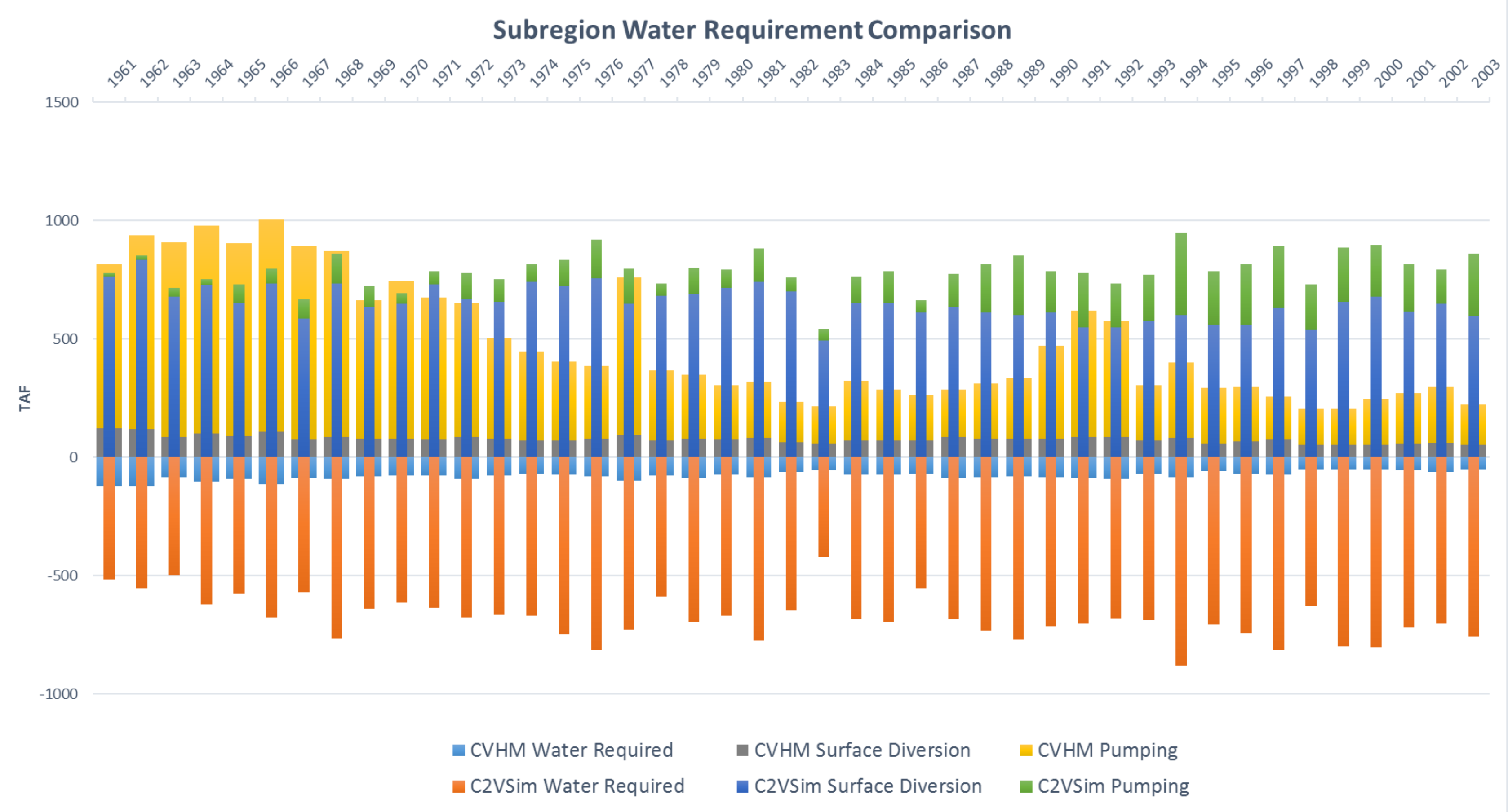
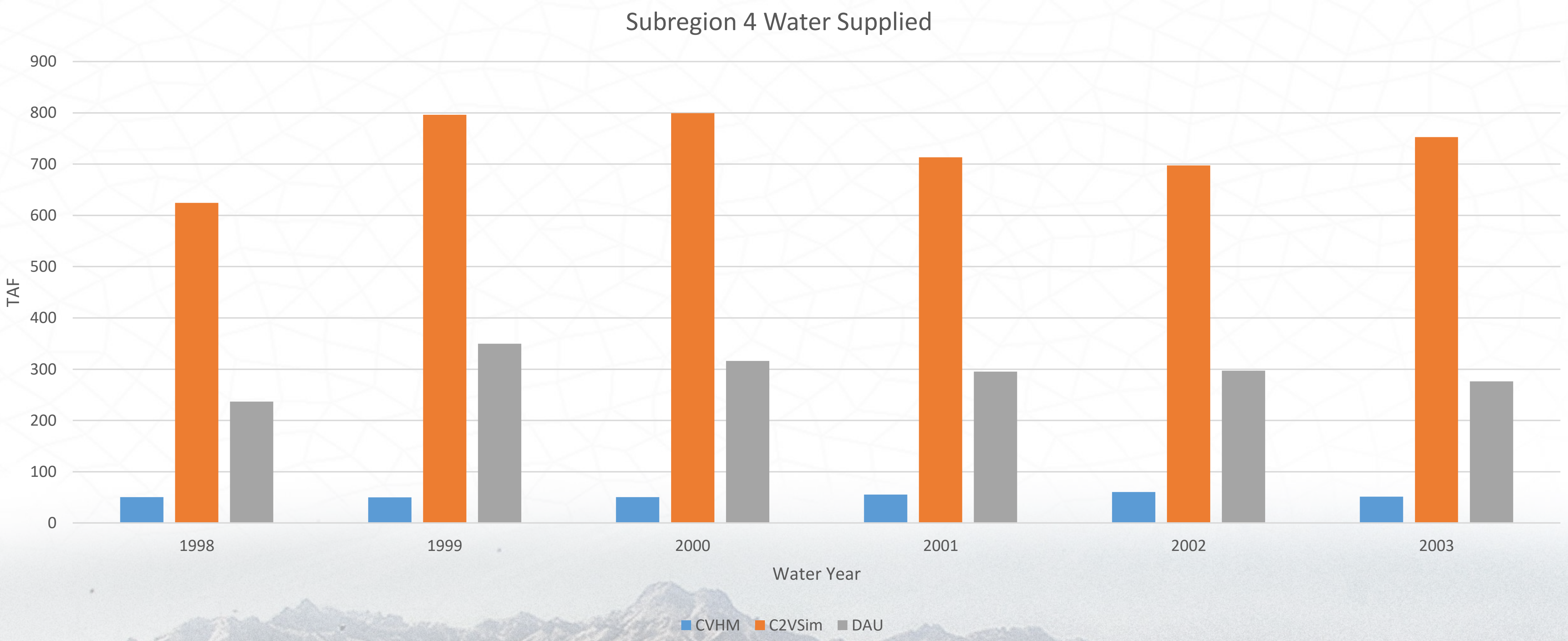
Water Budget: Subregion 4





Water Budget: Subregion 4



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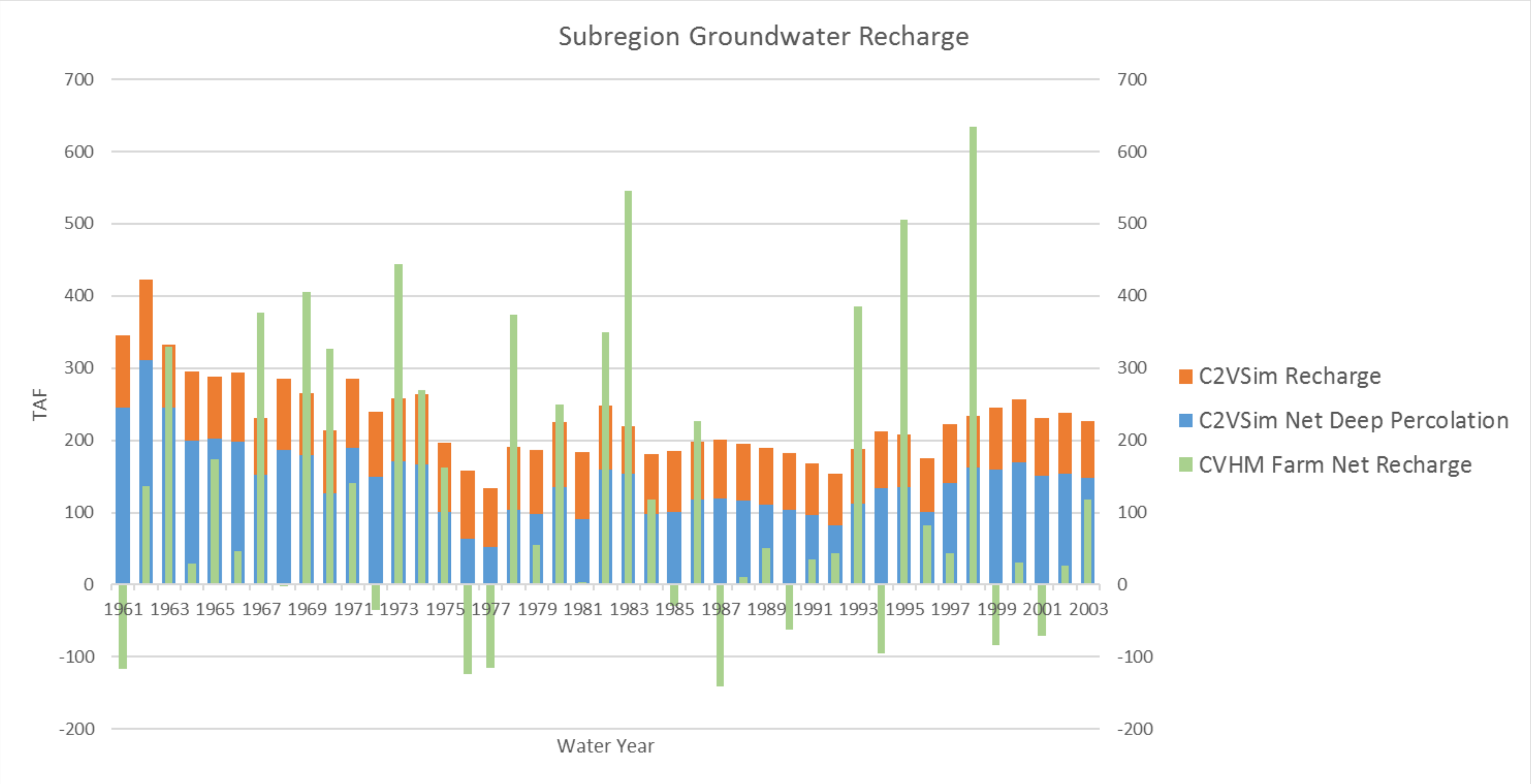
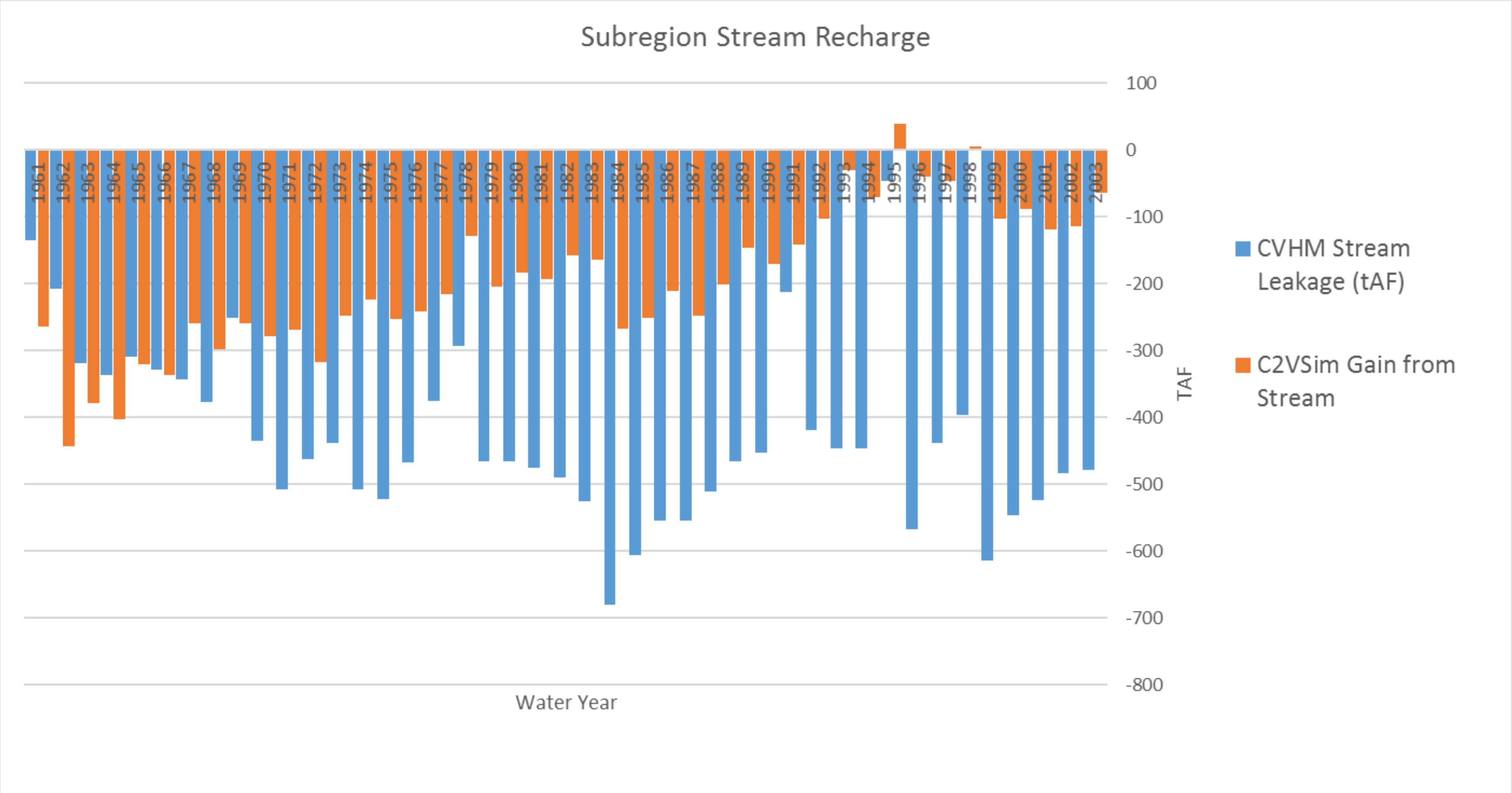
Water Budget: Subregion 4



Water Budget: Subregion 4



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Water Budget: Subregion 4

	CVHM	C2VSim
Average Water Required	79	680
Average Surface Diversion	76	652
Average Pumping	407	135

	CVHM	C2VSim
Average GW Recharge	136	229
Average Stream Recharge	-430	-196

Units: TAF

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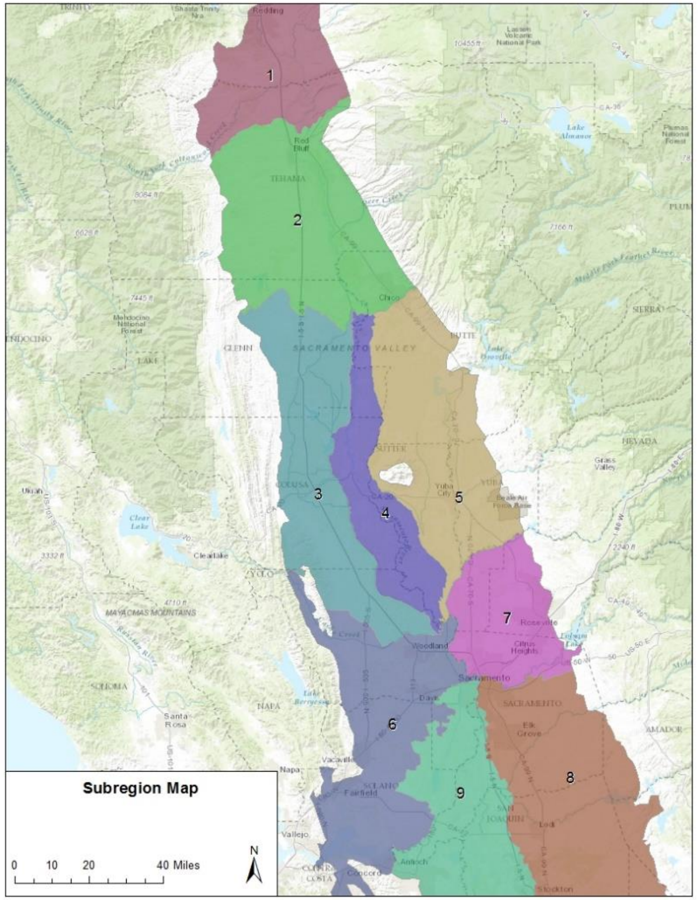
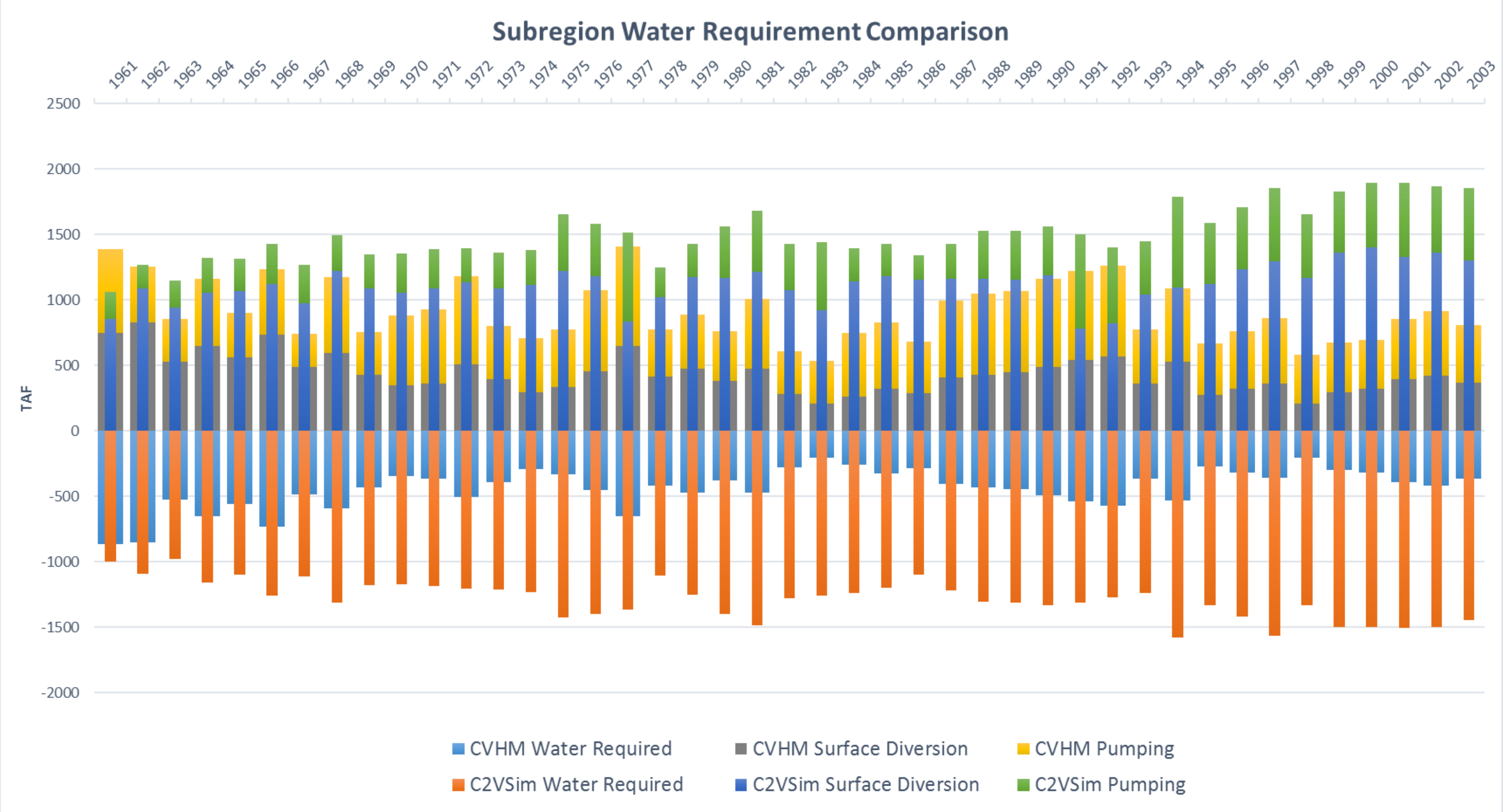
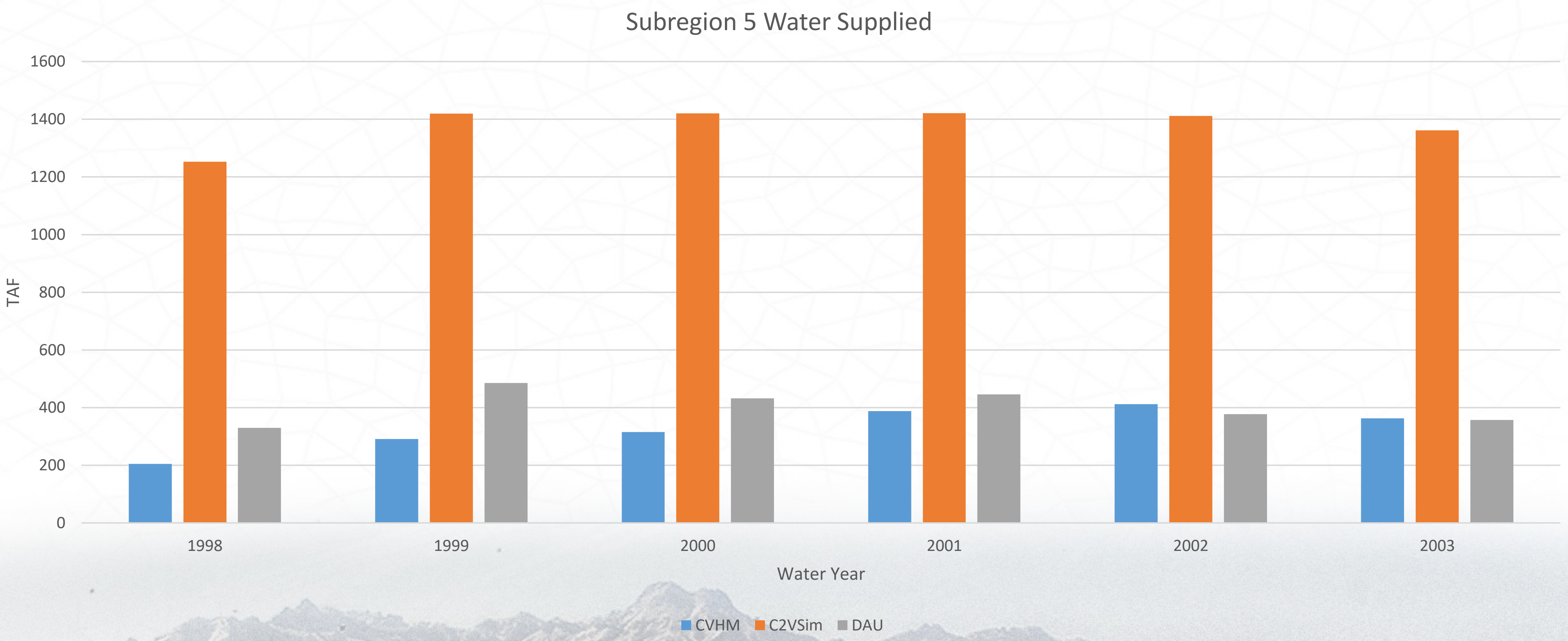
Water Budget: Subregion 5

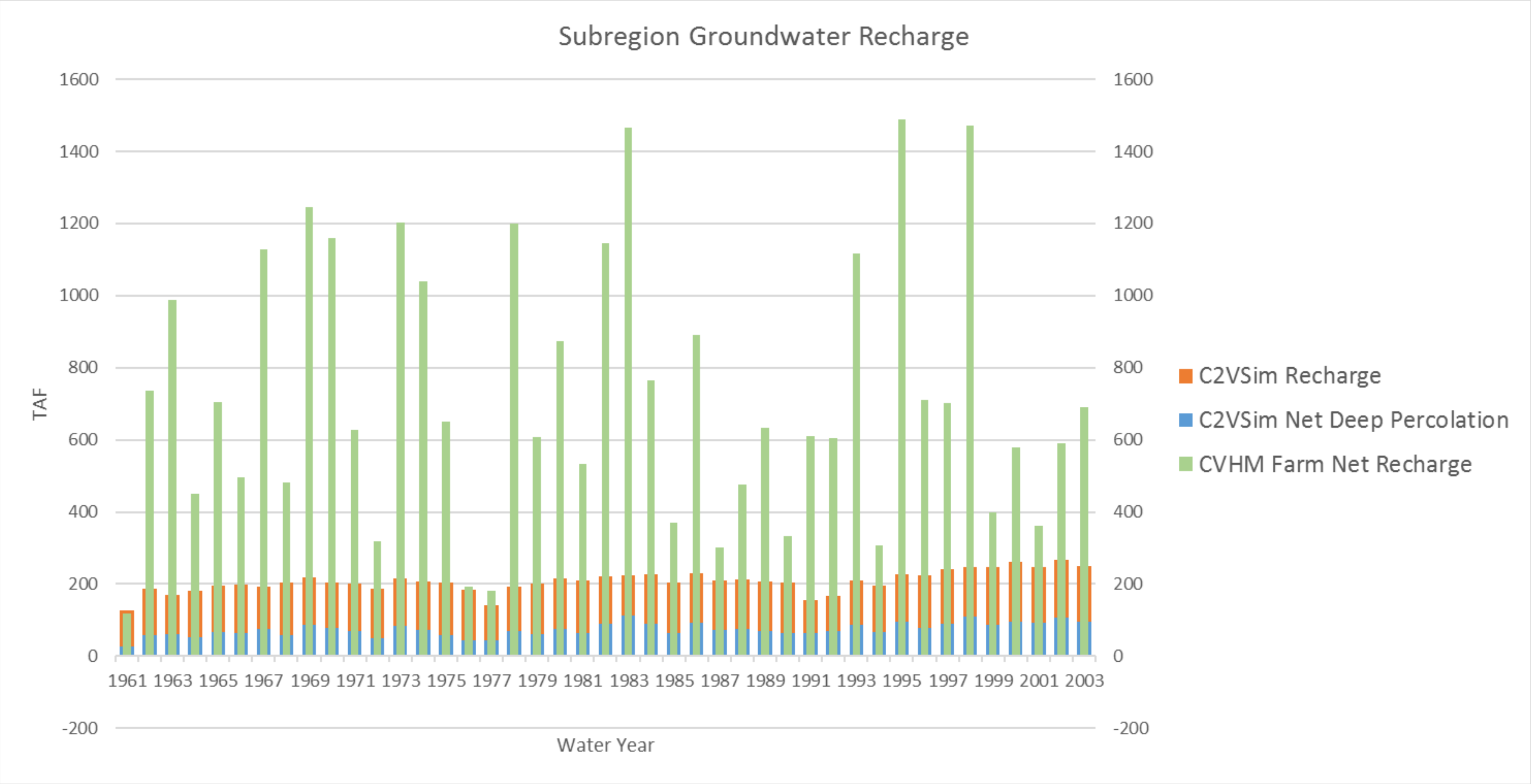




Water Budget: Subregion 5



Water Budget: Subregion 5



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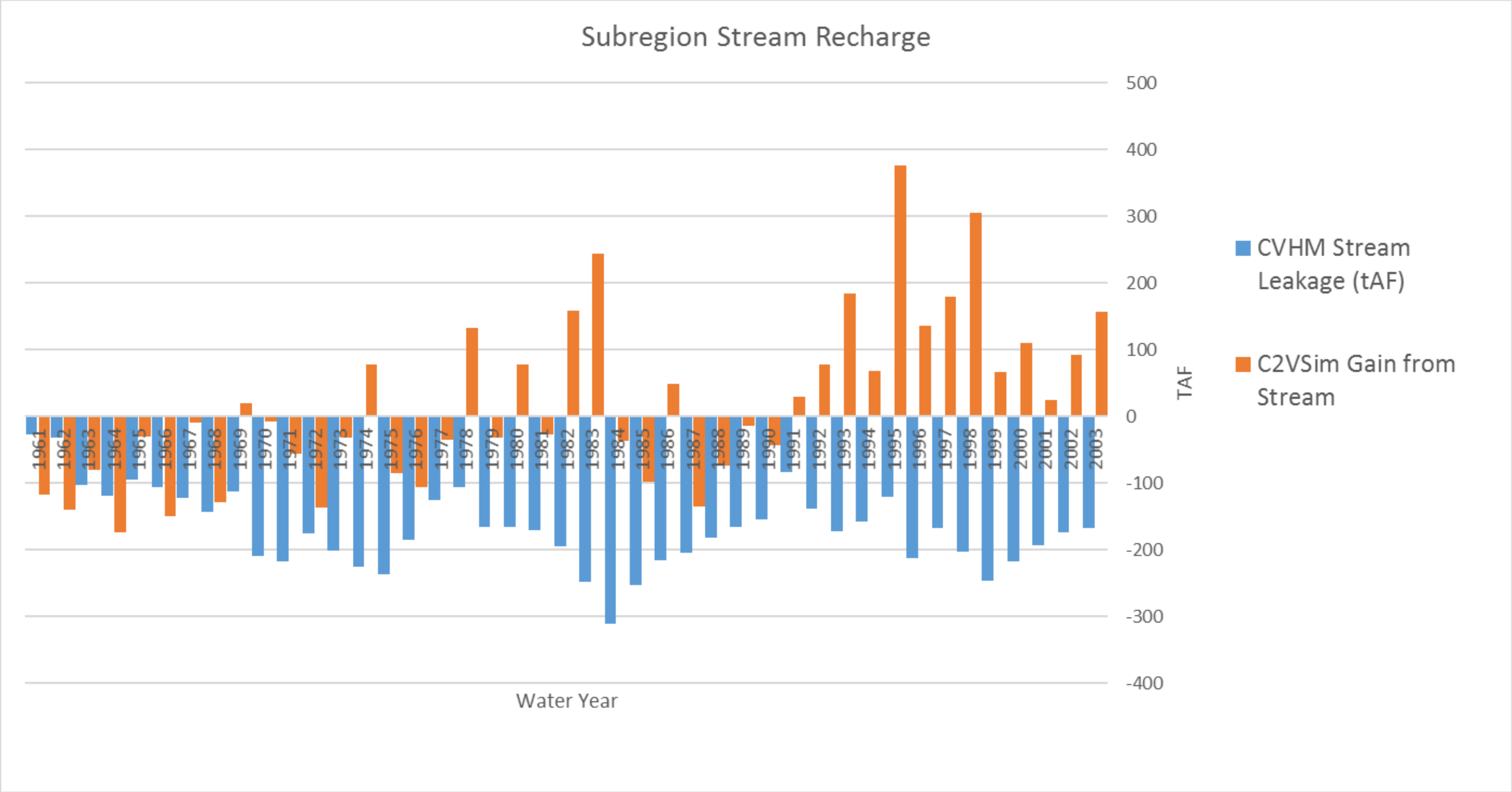
Water Budget: Subregion 5



RMC water and environment
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Water Budget: Subregion 5

	CVHM	C2VSim
Average Water Required	439	1,288
Average Surface Diversion	434	1,119
Average Pumping	483	382

	CVHM	C2VSim
Average GW Recharge	720	207
Average Stream Recharge	-168	-19

Units: TAF

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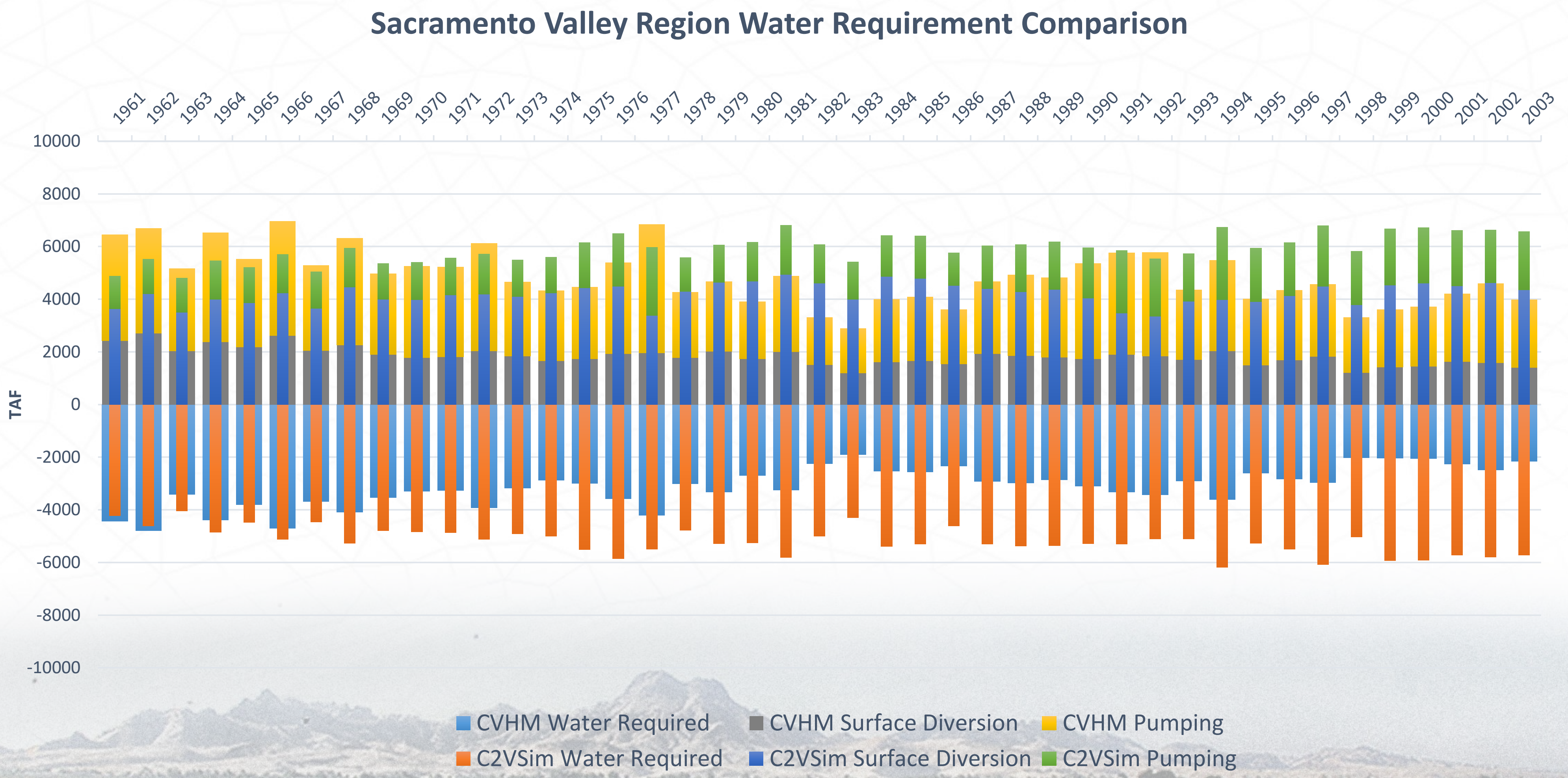
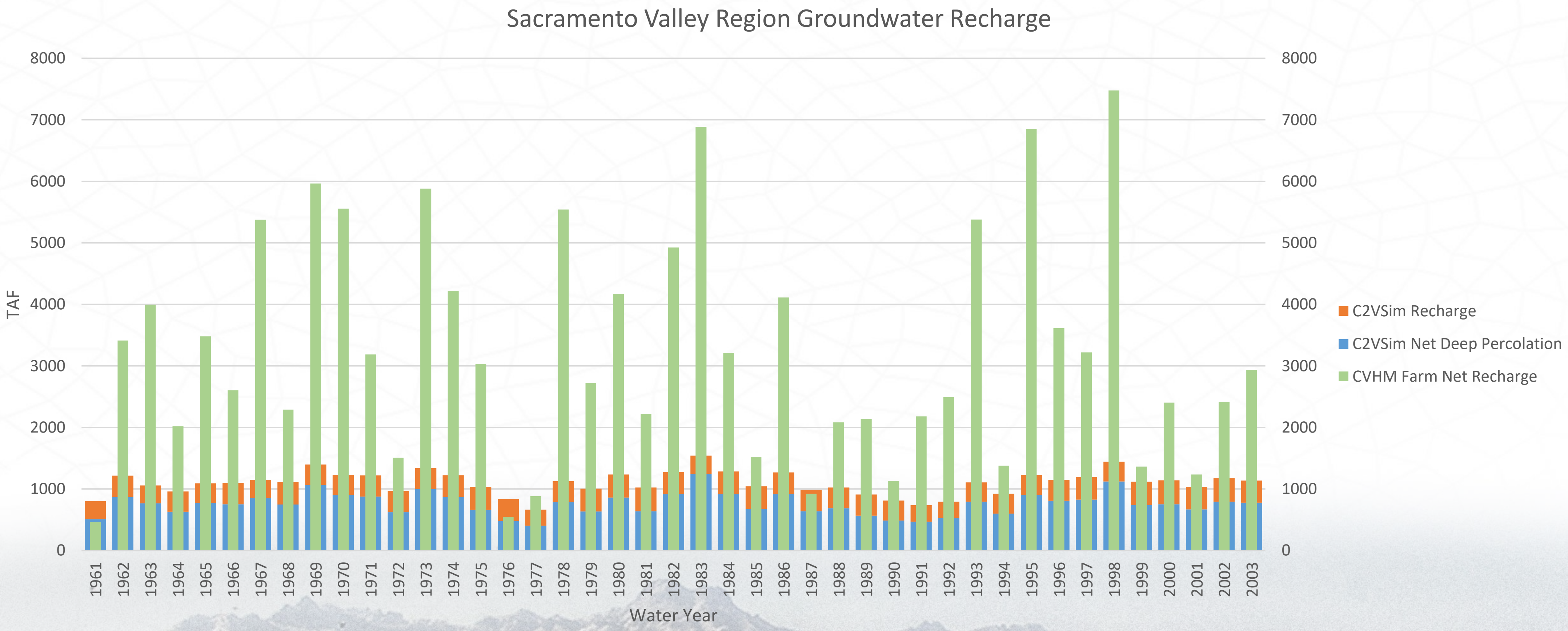
National Experience. Local Focus.

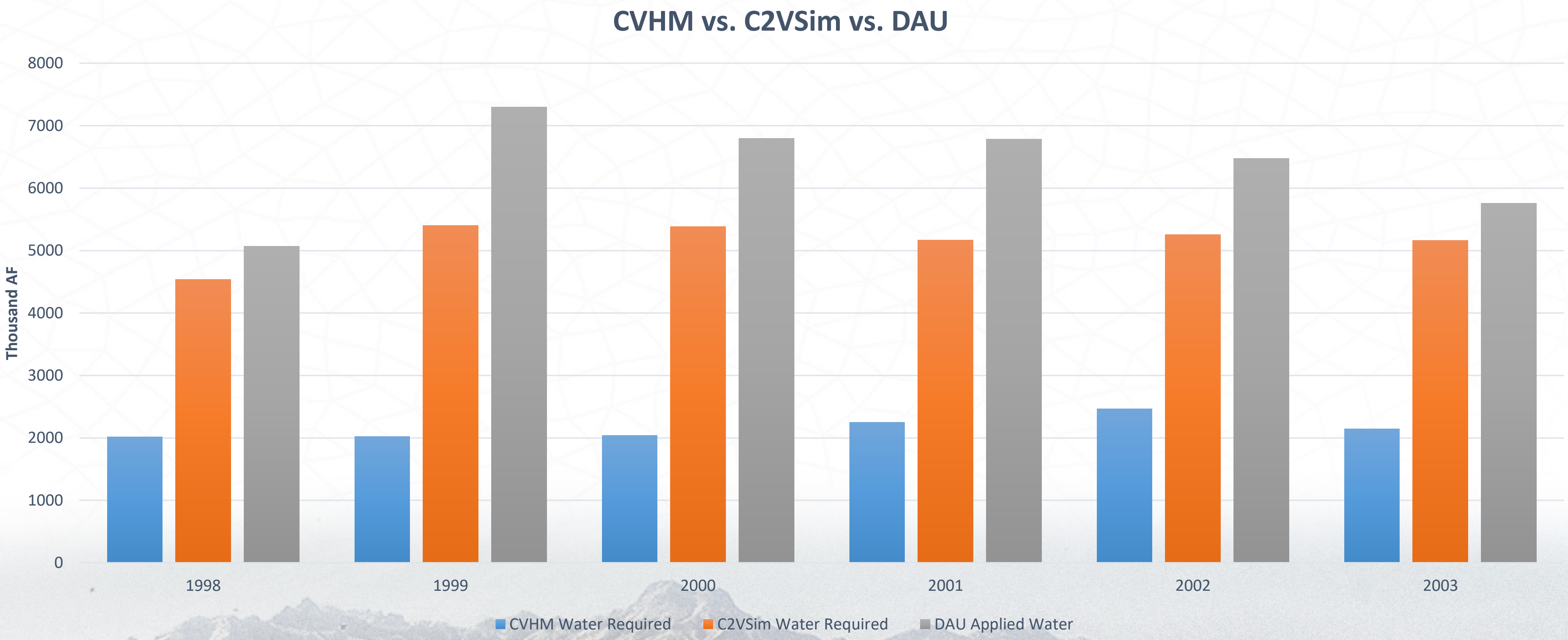
Sacramento Valley Region Agricultural Water Demand



Sacramento Valley Region Groundwater Recharge



Water Budget: Sacramento Valley Region CVHM(TFDR-FIN), C2VSim(Ag Supply Req), DAU(AW)



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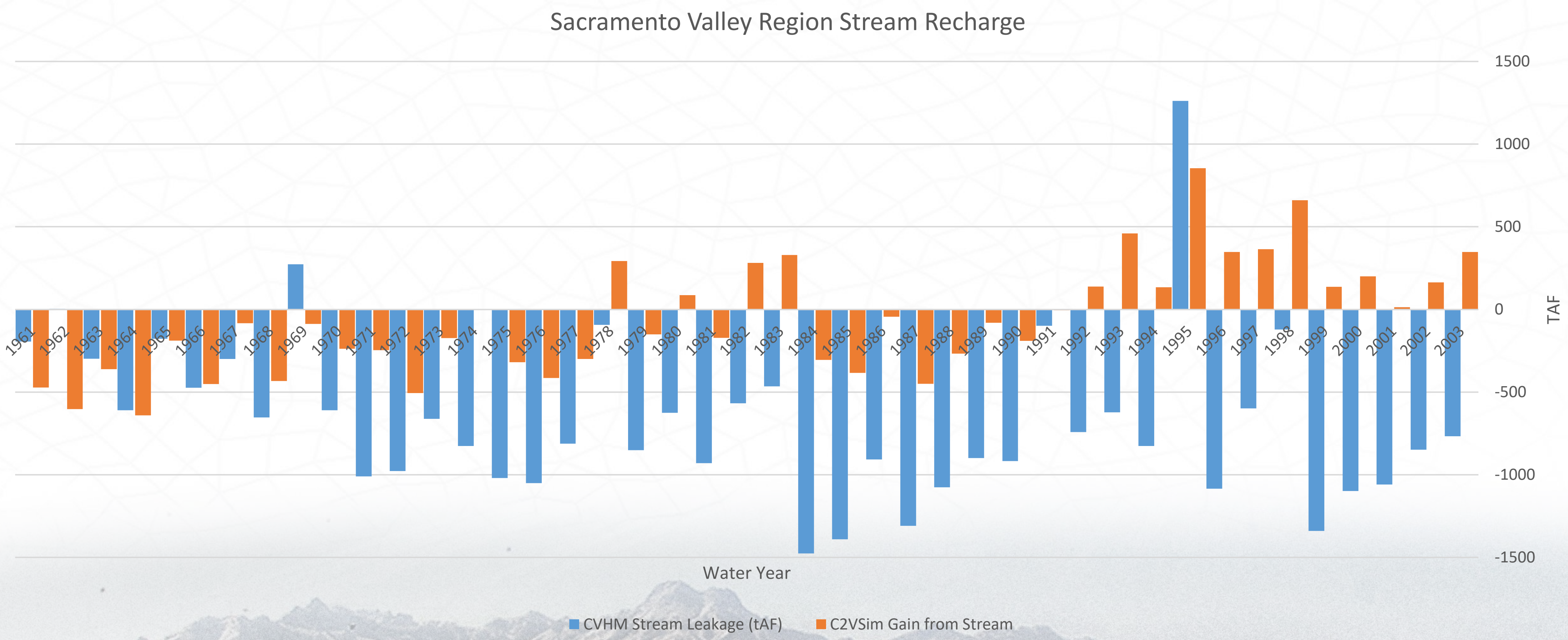
Sacramento Valley Region Stream Recharge



Water Budget: Sacramento Valley
(Subregions 2, 3, 4, and 5)

	CVHM	C2VSim
Average Water Required	1,928	3,491
Average Surface Diversion	1,339	3,126
Average Pumping	1,853	948

	CVHM	C2VSim
Average GW Recharge	2,384	876
Average Stream Recharge	-1,021	-338

Units: TAF

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Water Budget: Sacramento Valley

	CVHM	C2VSim
Average Water Required	3,130	5,190
Average Surface Diversion	1,835	4,200
Average Pumping	3,030	1,732

	CVHM	C2VSim
Average GW Recharge	3,231	1,095
Average Stream Recharge	-671	-64

Units: TAF

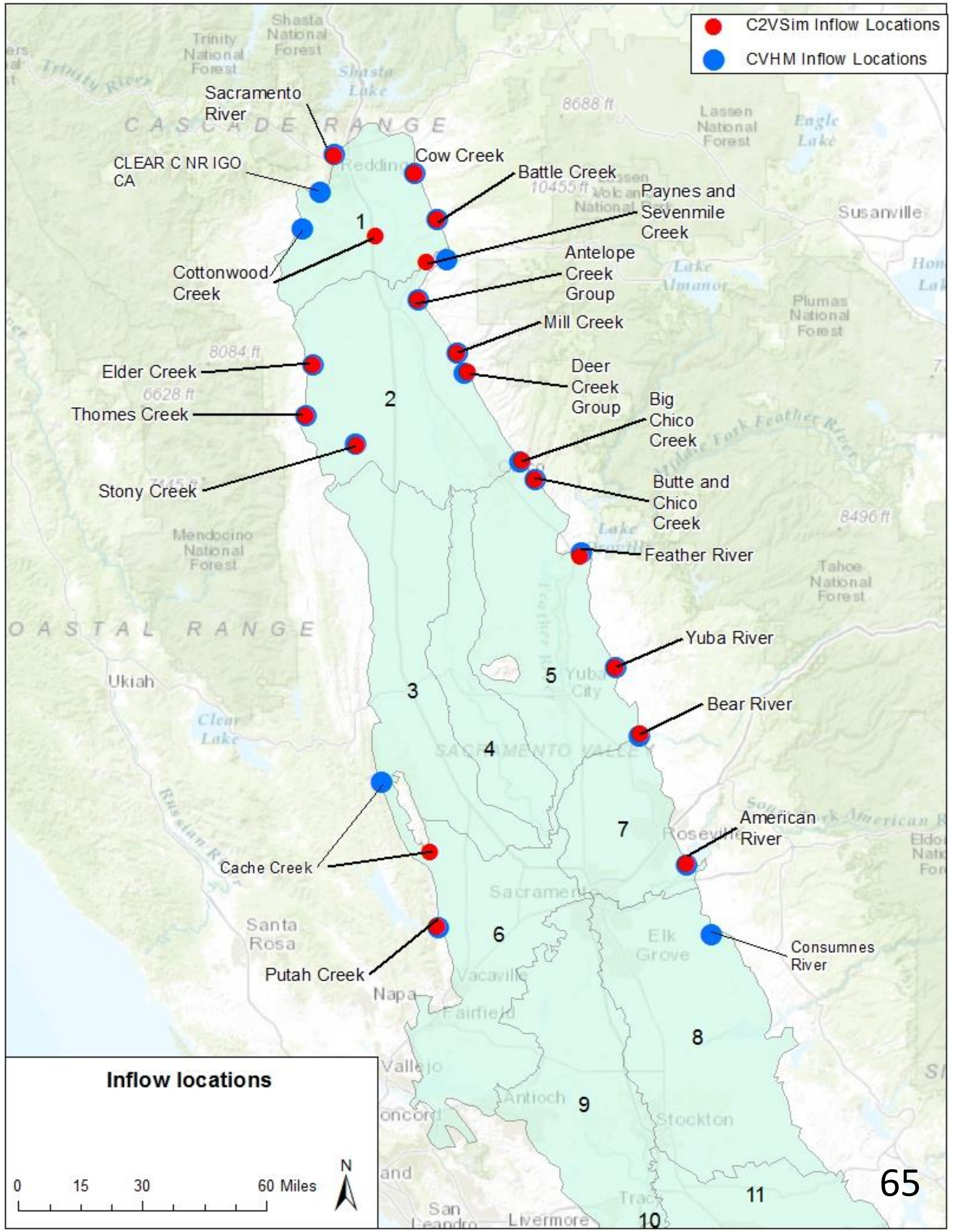
Agenda

- Recap of previous meetings
- Models Comparison
  - Land use / Cropping
  - Water Budget
    - Ag Water Demand
    - Water Supply
    - Recharge
    - Stream Seepage
  - **Surface Water Inflows**
  - Calibration
    - Hydrographs at selected wells
- Discussion
  - Model recommendations or assistance in model recommendations

Source of Data

- C2VSim
  - CVinflow.dat file (river names, and monthly inflow data 1921 to 2009)
- CVHM
  - SFR.txt file (river names, inflow location, and monthly inflow 1961 to 2003)

Stream Inflow Location



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Stream Inflow Data Comparison

Average Annual Inflow between Water Year 1962&2003					
	CVHM	C2VSim		CVHM	C2VSim
1962	15.29	14.57	1983	46.71	43.49
1963	24.05	23.34	1984	27.45	26.14
1964	14.37	12.82	1985	16.08	13.30
1965	27.27	27.06	1986	27.68	26.49
1966	16.30	15.38	1987	12.83	11.51
1967	27.54	26.69	1988	12.87	11.27
1968	16.26	14.42	1989	14.41	13.25
1969	29.15	26.99	1990	12.20	11.12
1970	28.91	27.45	1991	9.61	8.75
1971	25.25	24.16	1992	10.40	9.10
1972	15.80	14.31	1993	18.41	19.24
1973	23.38	21.73	1994	12.53	10.74
1974	38.05	36.64	1995	36.44	34.53
1975	22.10	20.59	1996	27.25	24.68
1976	13.76	12.92	1997	30.93	29.47
1977	8.52	7.51	1998	36.03	33.17
1978	19.87	18.26	1999	24.62	23.14
1979	15.46	13.40	2000	22.28	20.60
1980	24.98	24.00	2001	13.23	11.51
1981	14.66	12.43	2002	15.02	13.52
1982	36.83	34.24	2003	19.50	18.25
Units:	mAFY				

Average Stream Inflow Comparison (million AF/year) 1961-2003

River	CVHM	C2VSim	River	CVHM	C2VSim
Sacramento River	7.34	7.36	Antelope Creek Group	0.23	0.23
Clear Creek	0.13	#N/A	Mill Creek	0.23	0.23
Cottonwood Creek	0.66	0.67	Deer Creek Group	0.42	0.41
Elder Creek	0.14	0.08	Big Chico Creek	0.11	0.11
Thomes Creek	0.26	0.24	Butte and Chico Creek	0.39	0.39
Stony Creek	0.48	0.42	Feather River	4.20	3.58
Cache Creek	0.56	0.34	Yuba River	1.86	1.90
Putah Creek	0.35	0.35	Bear Creek Group	0.07	0.07
Cow Creek	0.51	0.51	American River	2.75	2.72
Battle Creek	0.37	0.37	Cosumnes River	0.40	#N/A
Paynes and Sevenmile Creek	0.06	0.06	Units:	mAFY	

Agenda

- Recap of previous meetings
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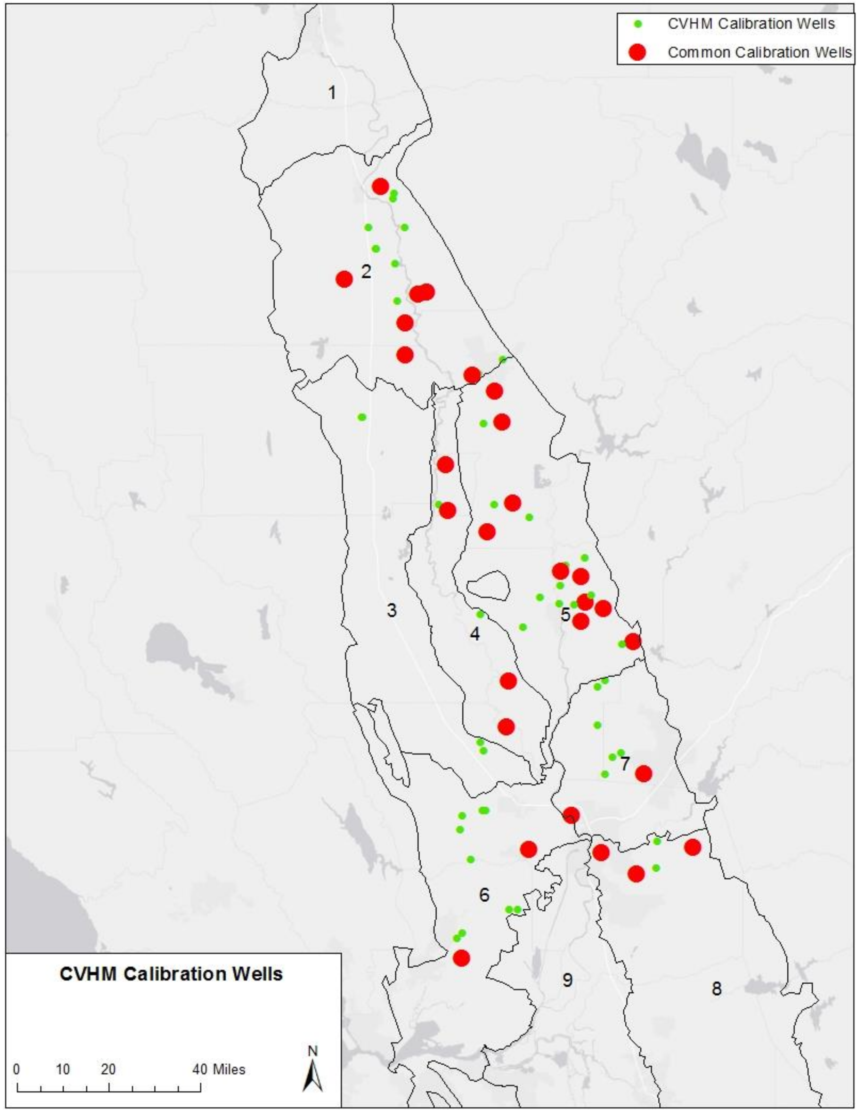
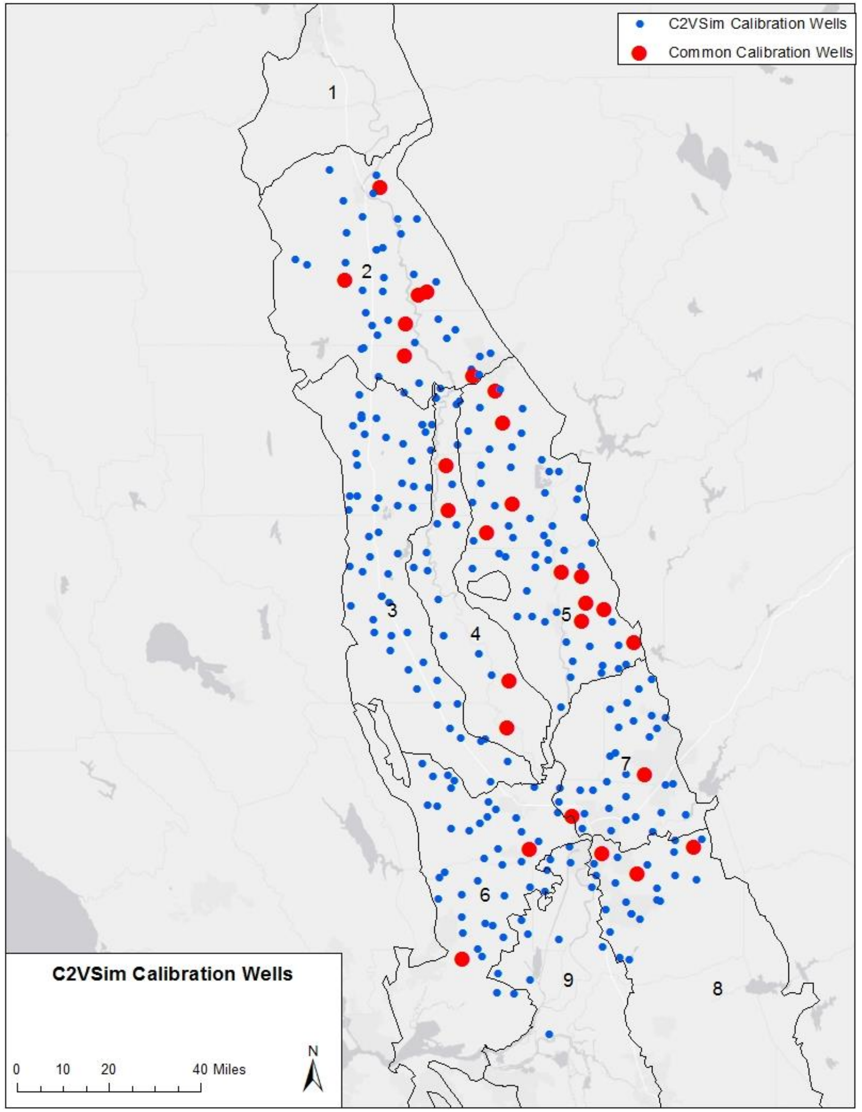
    - Water Supply
    - Recharge
    - Stream Seepage
  - Surface Water Inflows
  - **Calibration**
    - **Hydrographs at selected wells**
- Discussion
  - Model recommendations or assistance in model recommendations

Model Calibration
Source of Data

- C2VSim
  - Cvprint.dat (wells names and locations)
  - CVGWhyd.out (monthly simulated groundwater levels)
- CVHM
  - HYDMOD.txt (wells names and locations)
  - Hydro2.gwh (monthly simulated groundwater levels)
- Ground Surface Elevations
  - Google Earth

Model Calibration



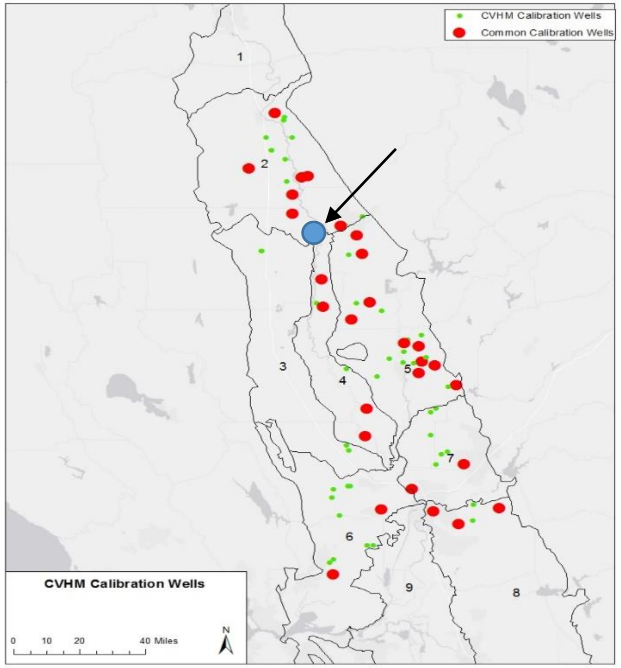


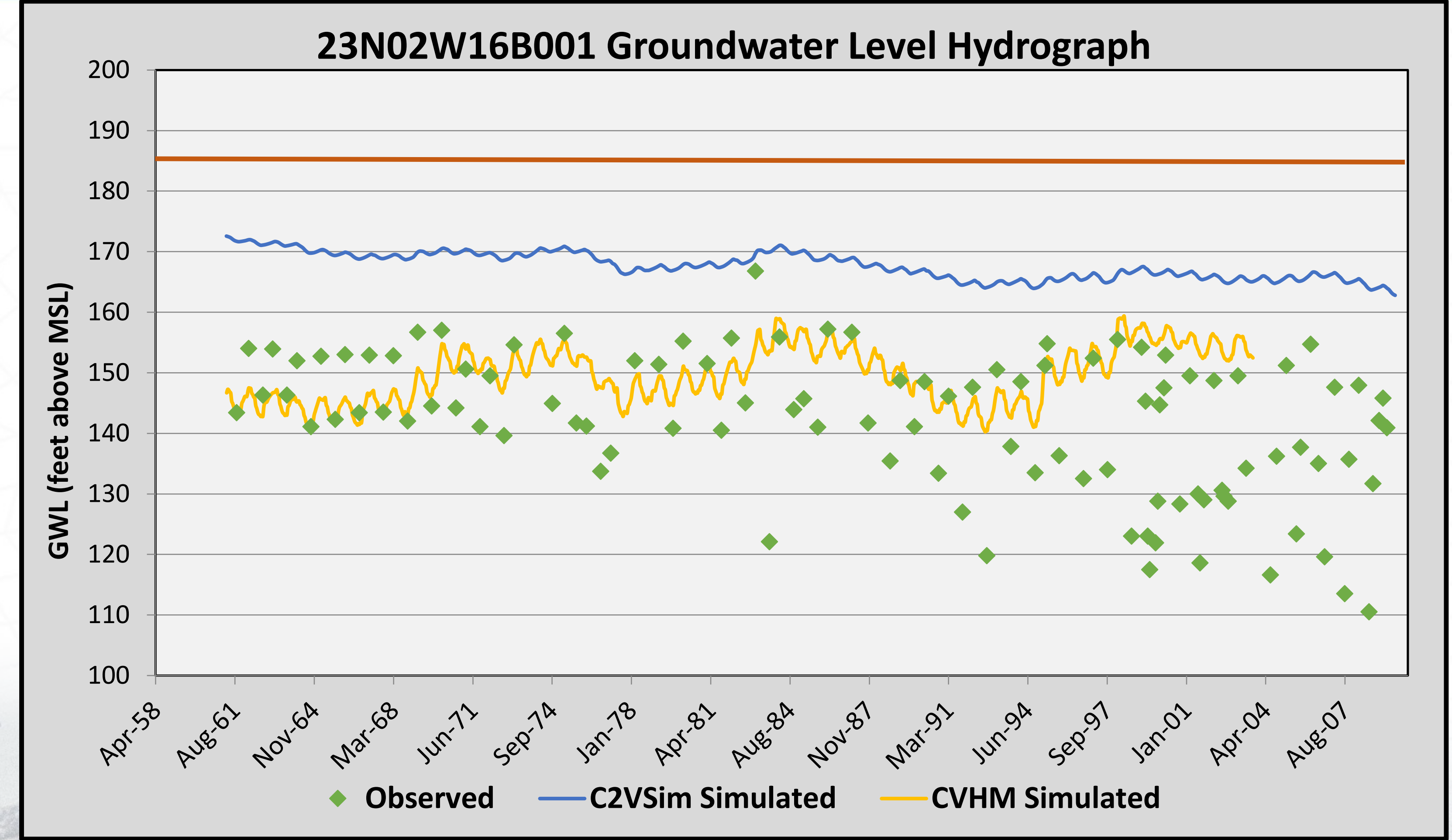
RMC water and environment

National Experience. Lo

Model Calibration

- Active Irrigation
- Shallow (100 – 120 ft)





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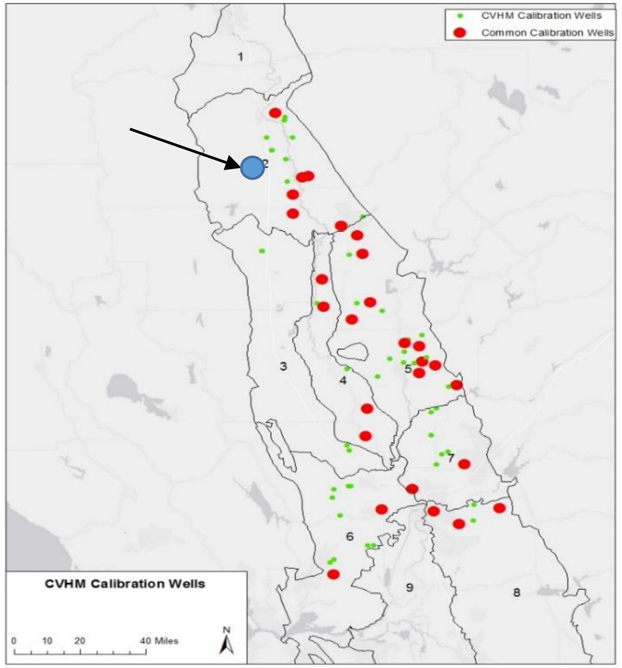
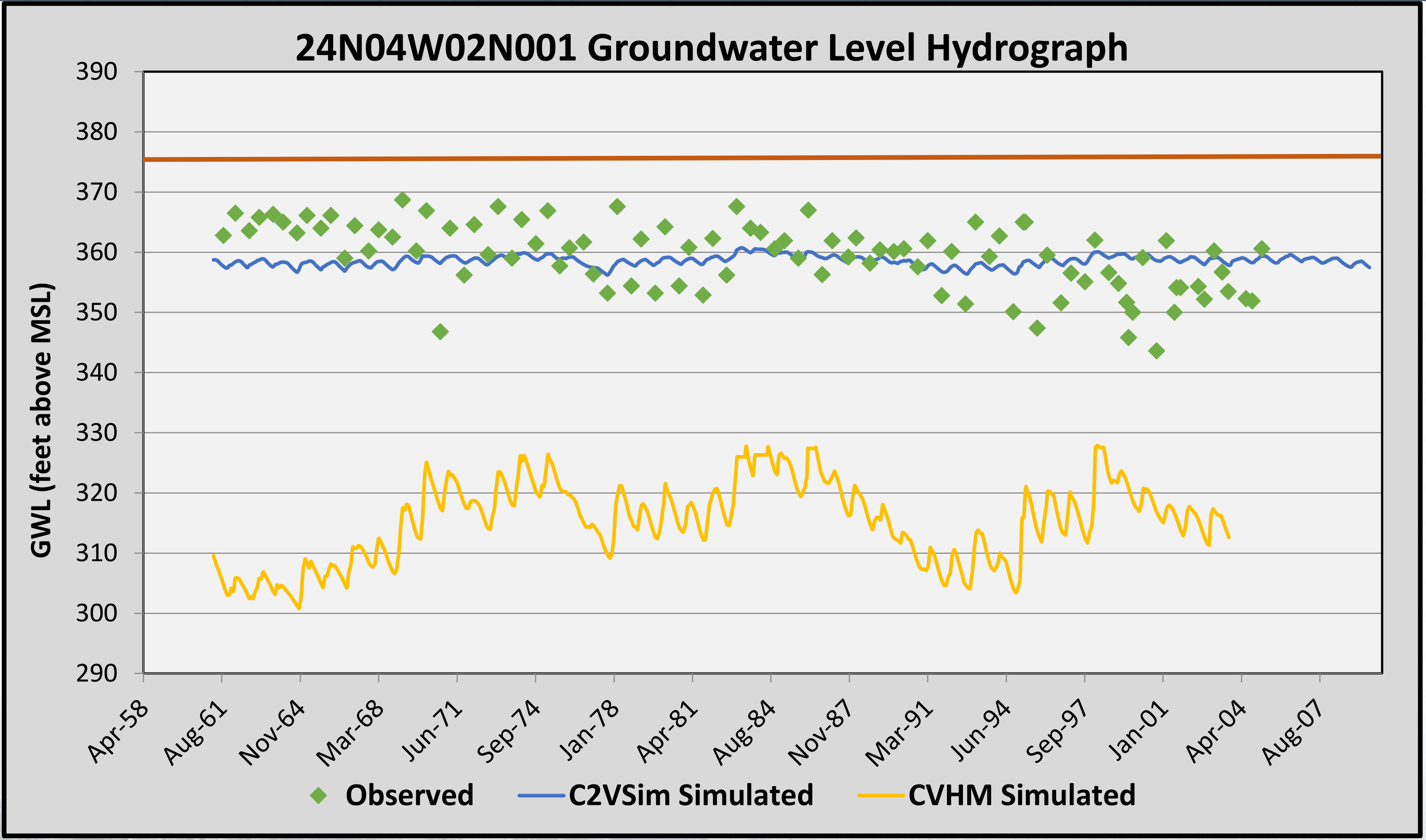
Model Calibration

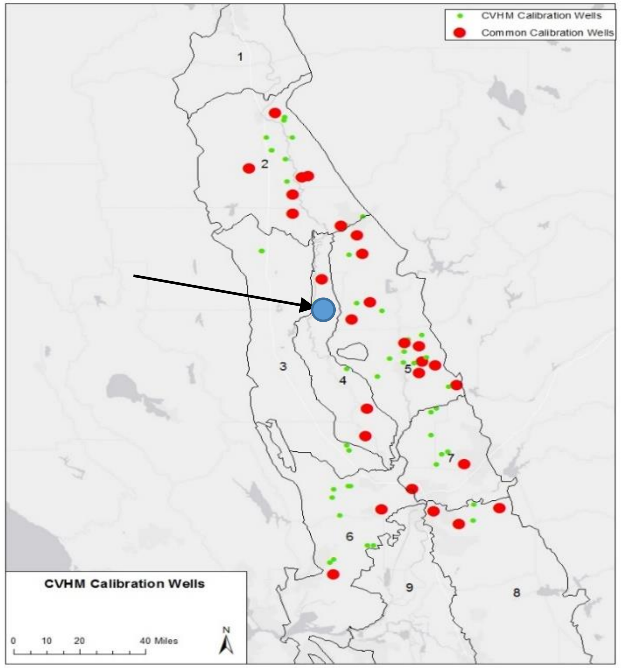
- Inactive Residential
- Shallow (30 – 90 ft)

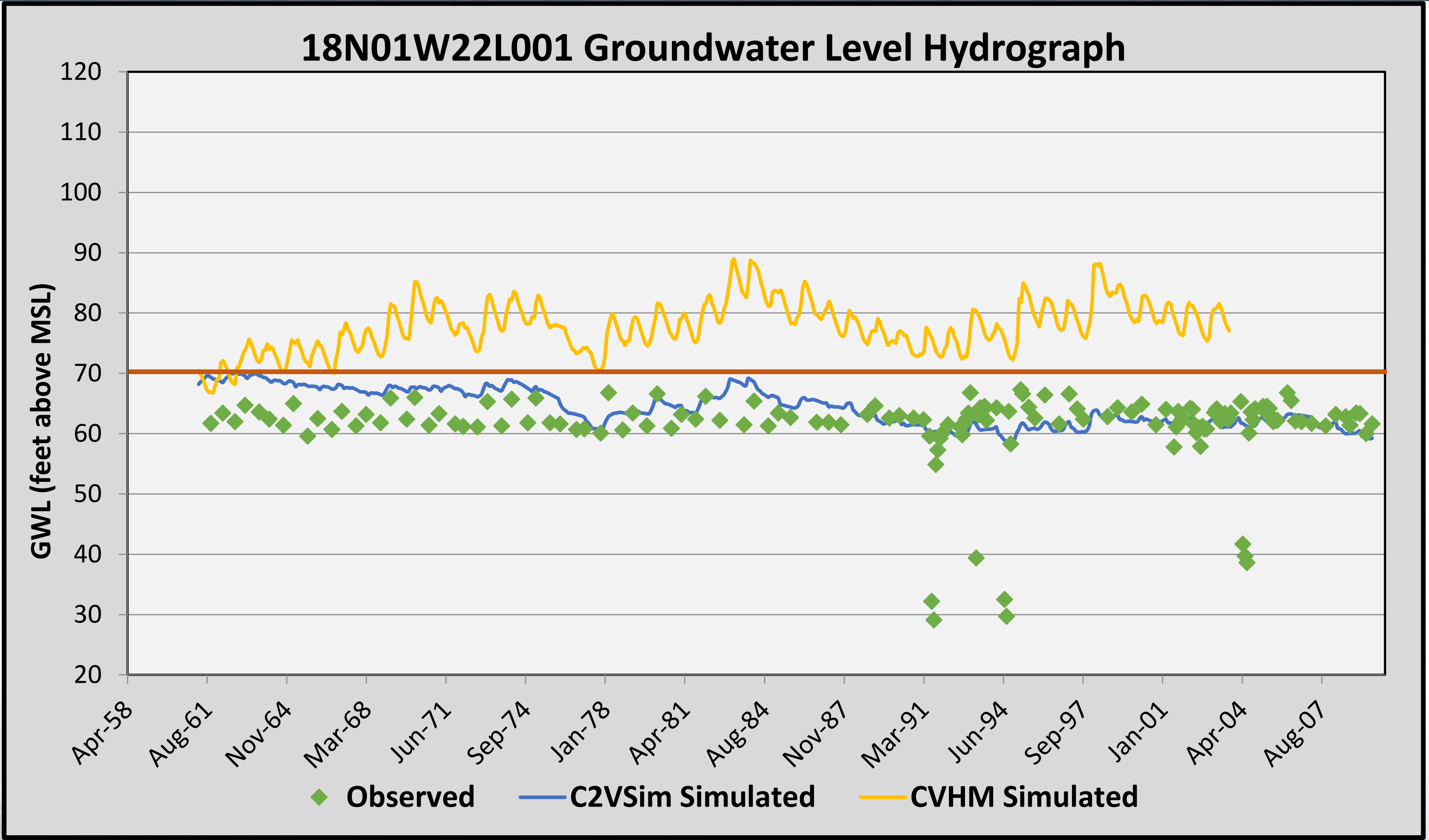




Model Calibration

- Active Irrigation
- Shallow (76 – 92 ft, 108 – 124 ft)





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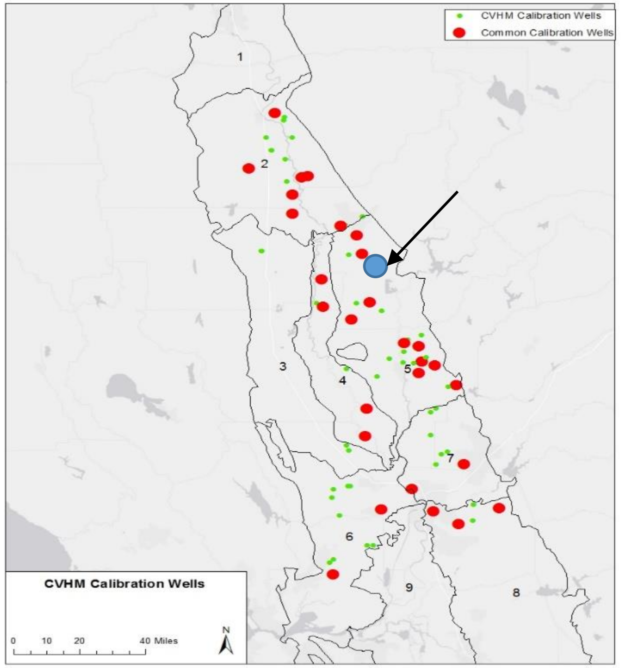
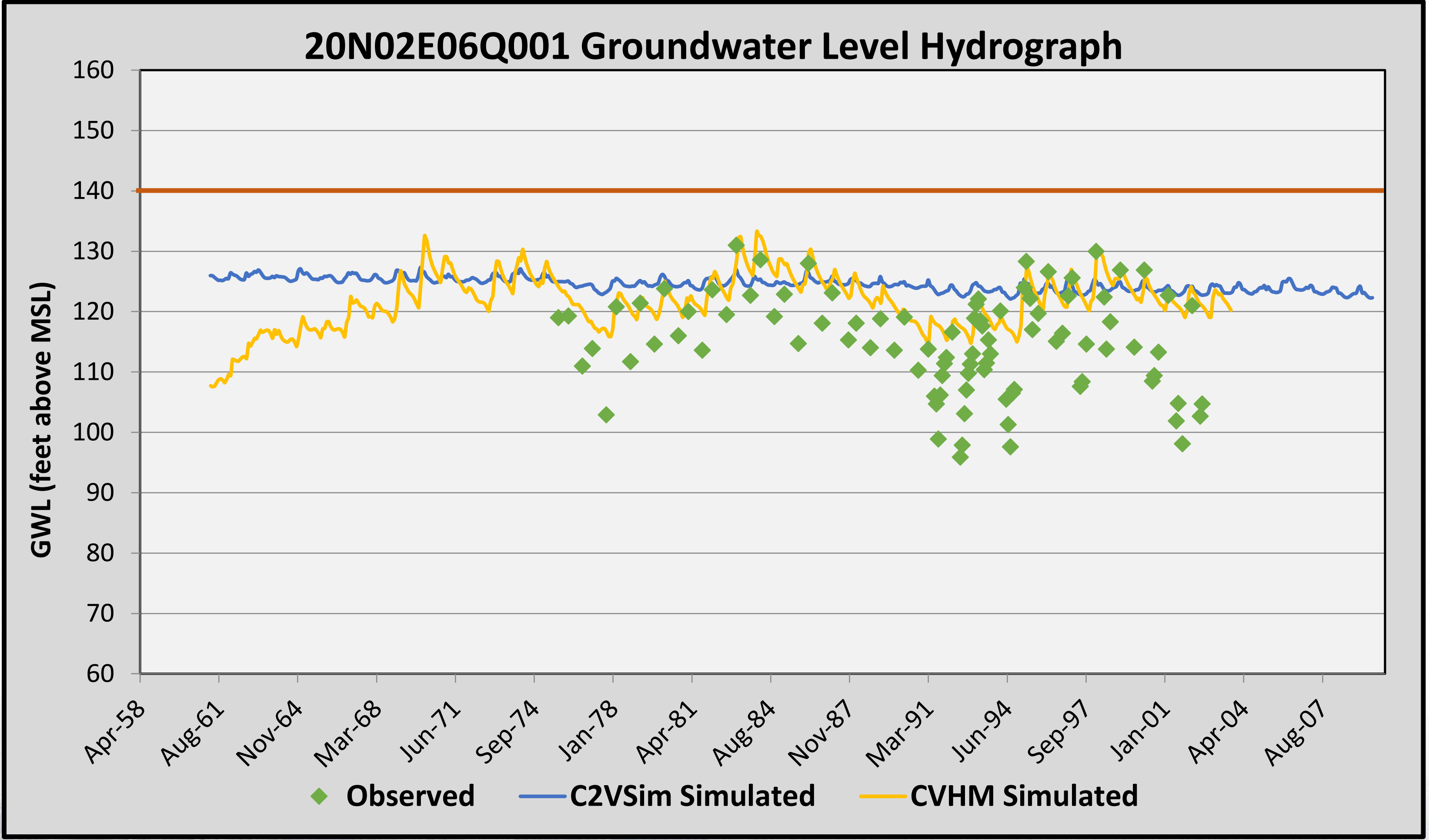
Model Calibration

- Active Irrigation
- Shallow (10 – 44 ft)

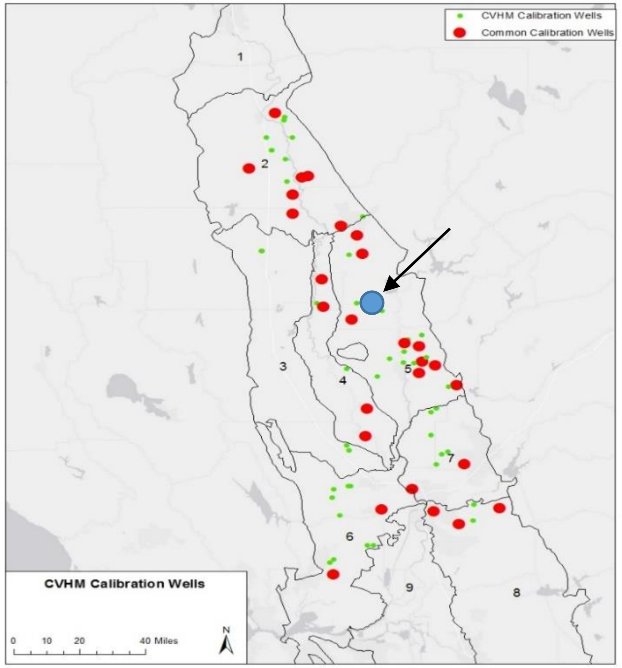


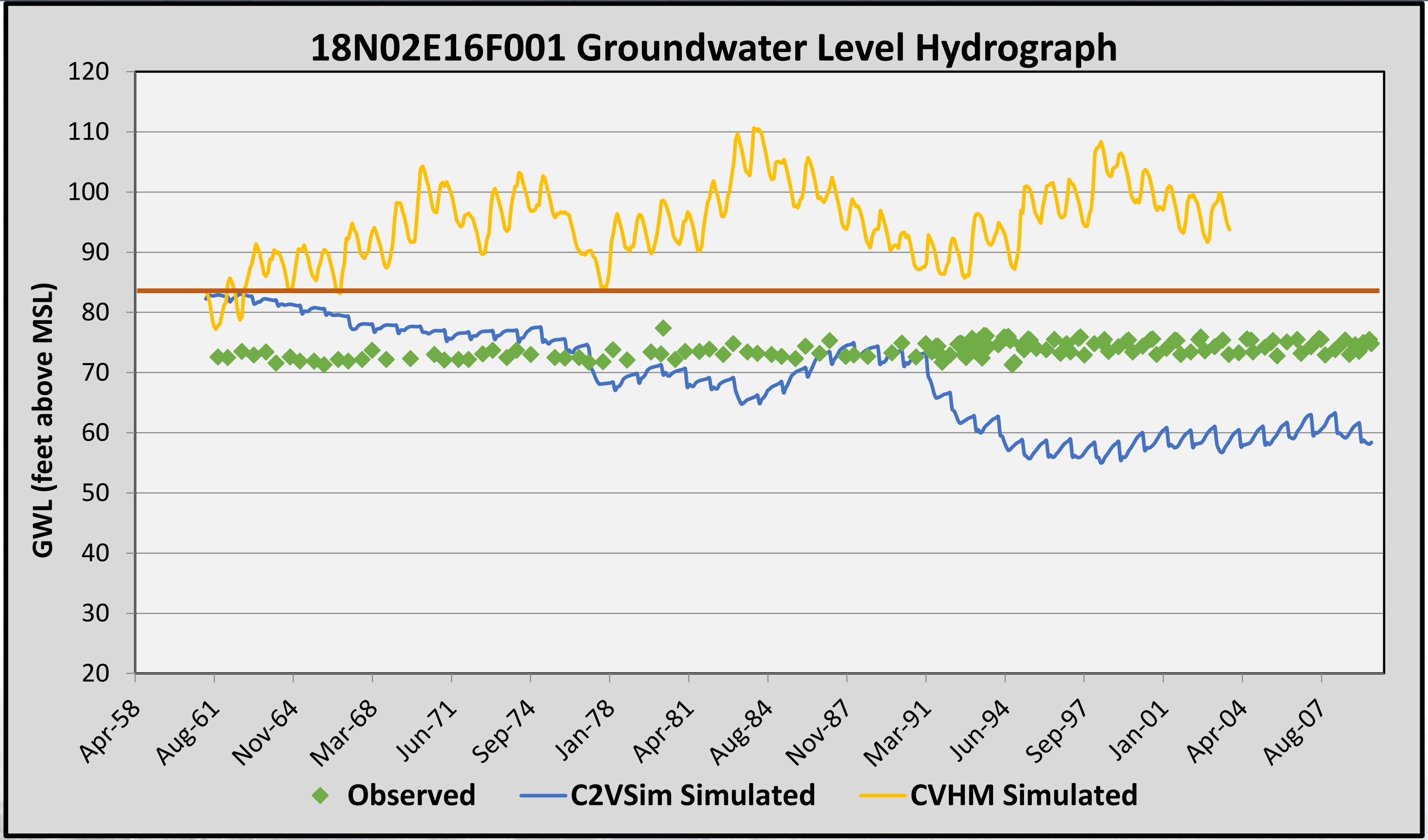


National Experience. Local Focus.

Model Calibration

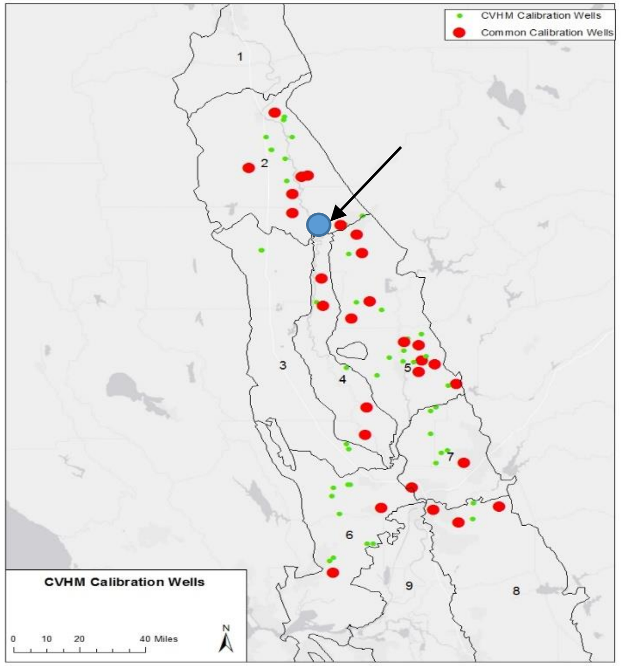
- Active Irrigation
- Shallow (20 – 60 ft)

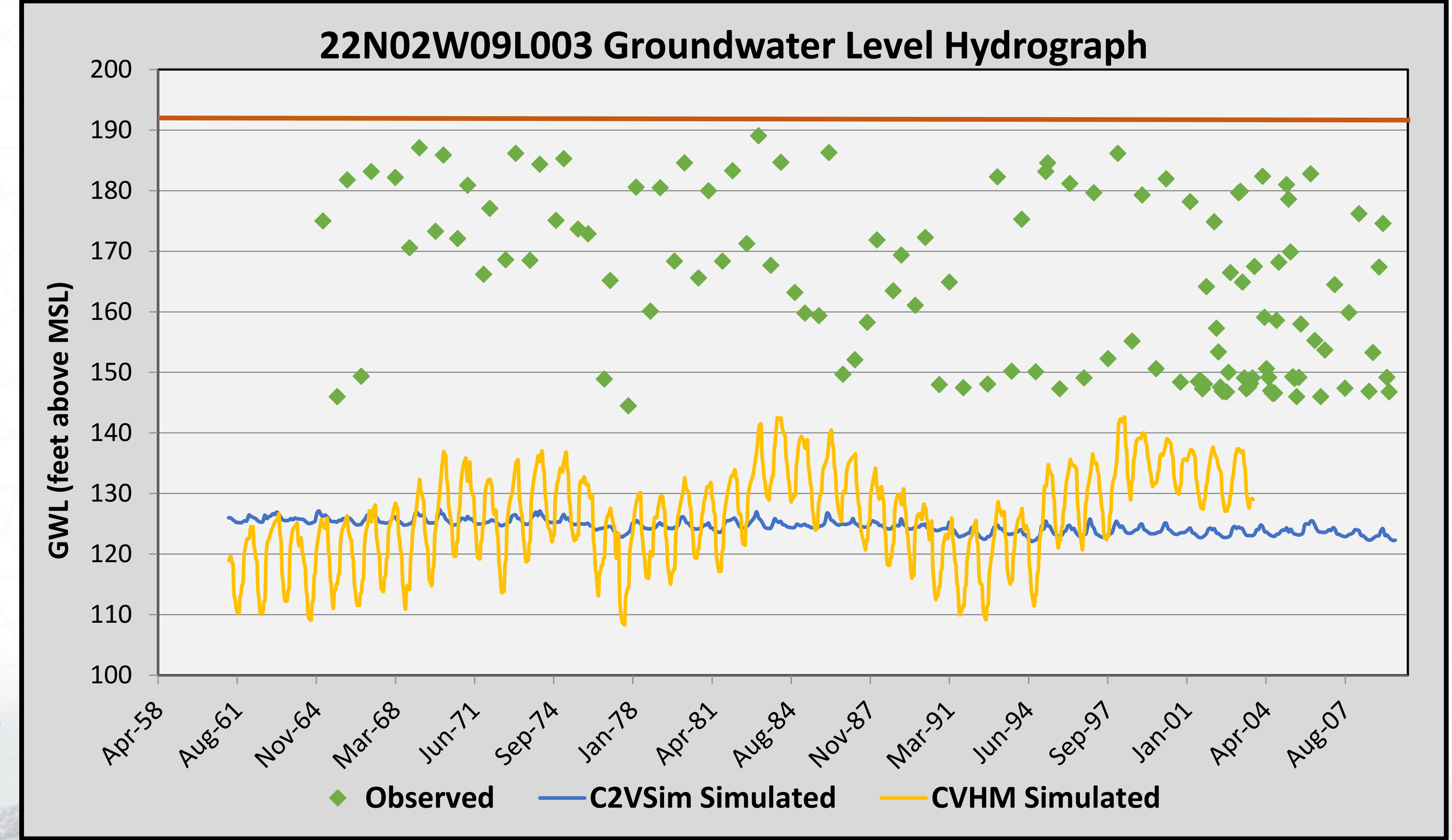




Model Calibration

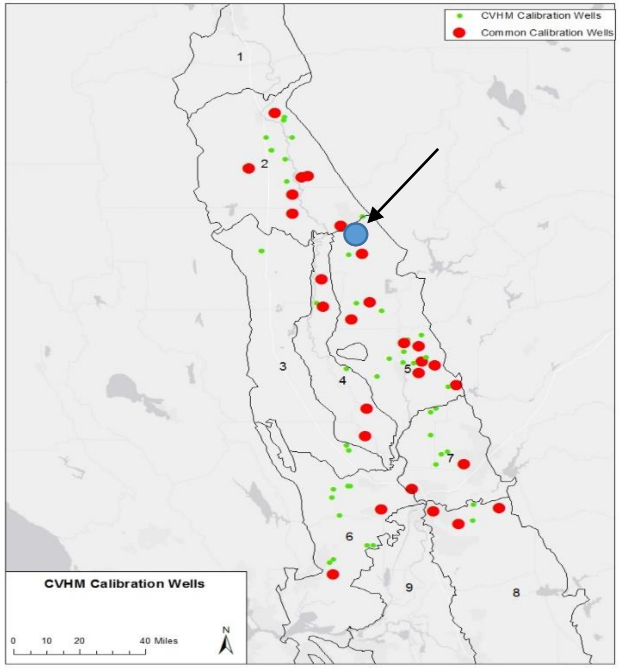
- Active Irrigation
- Intermediate

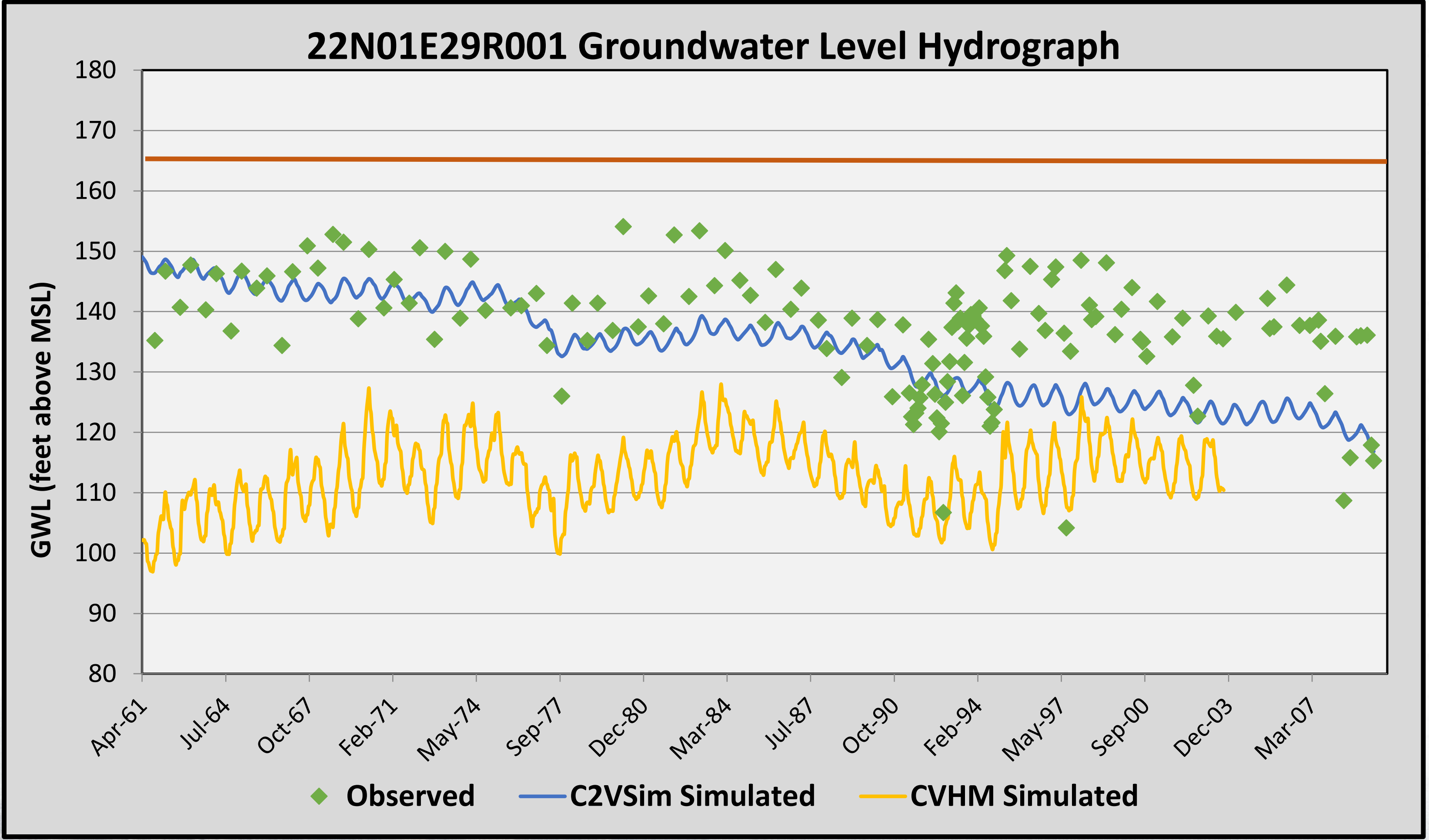




Model Calibration

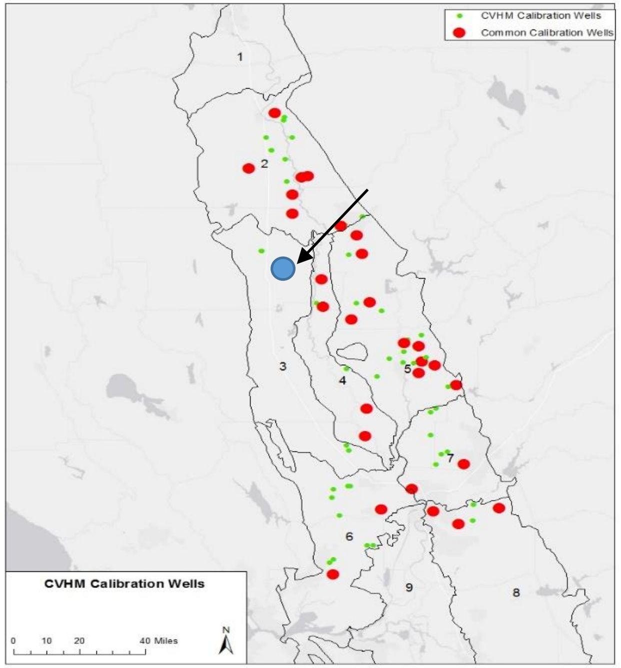
- 22N01E28J001 was used for CVHM
- Observation
- Intermediate (460 – 559 ft)

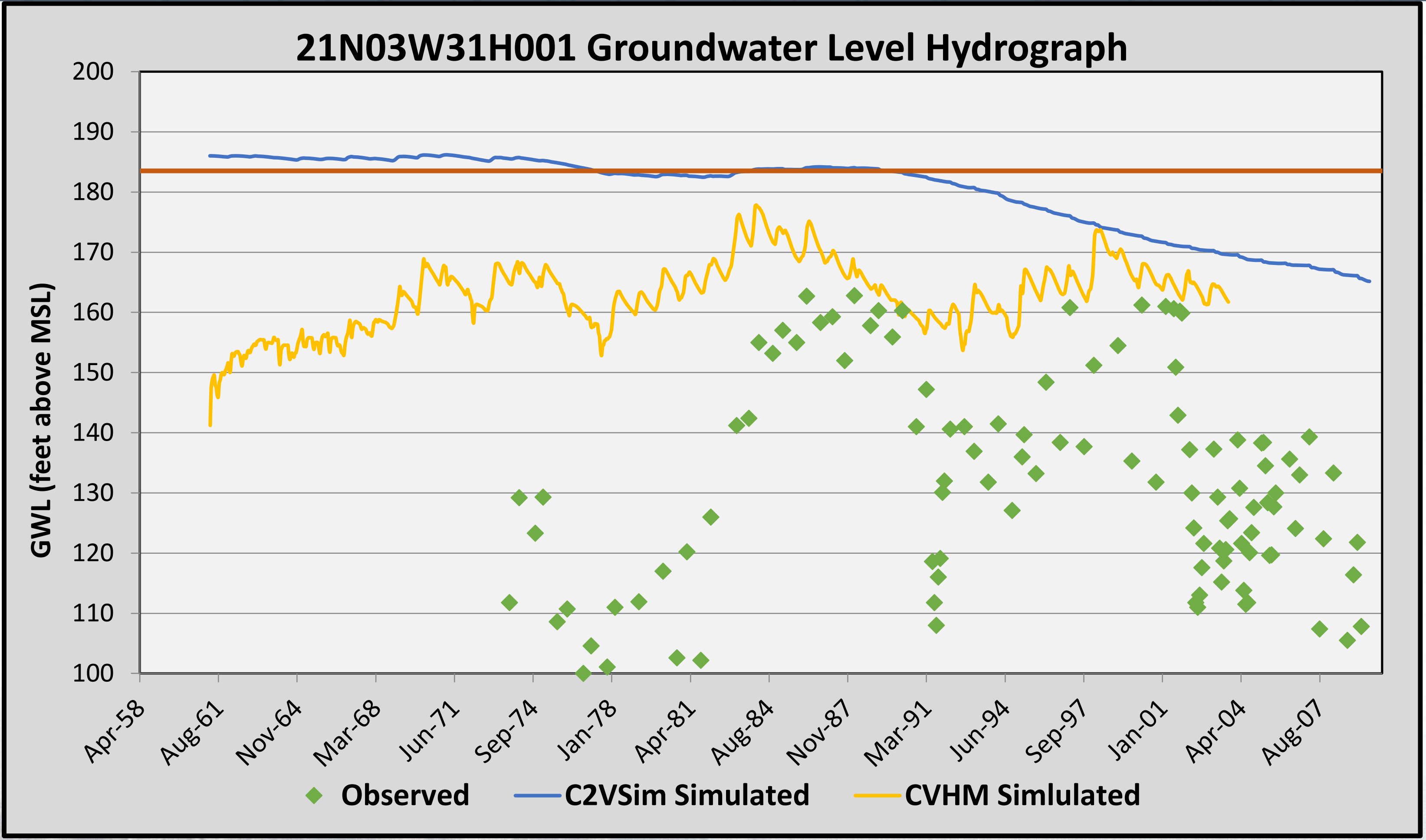




Model Calibration

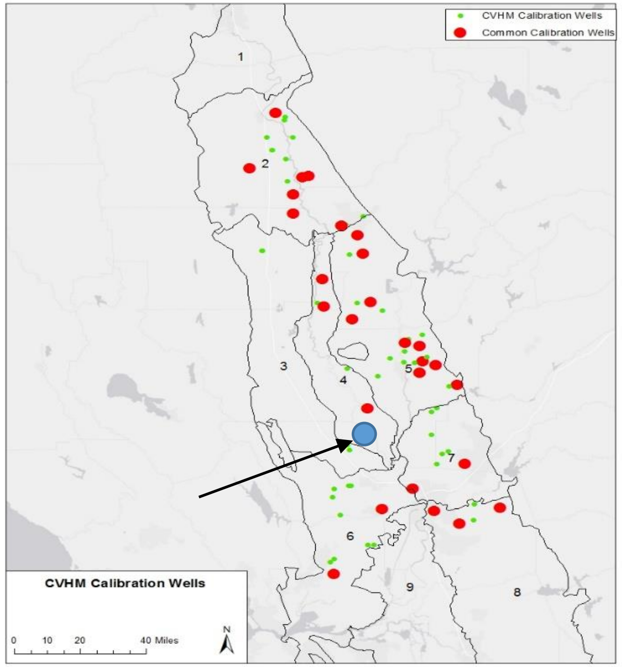
- 21N03W31R002 was used for CVHM
- Inactive, unknown type
- Intermediate (270 – 410 ft)

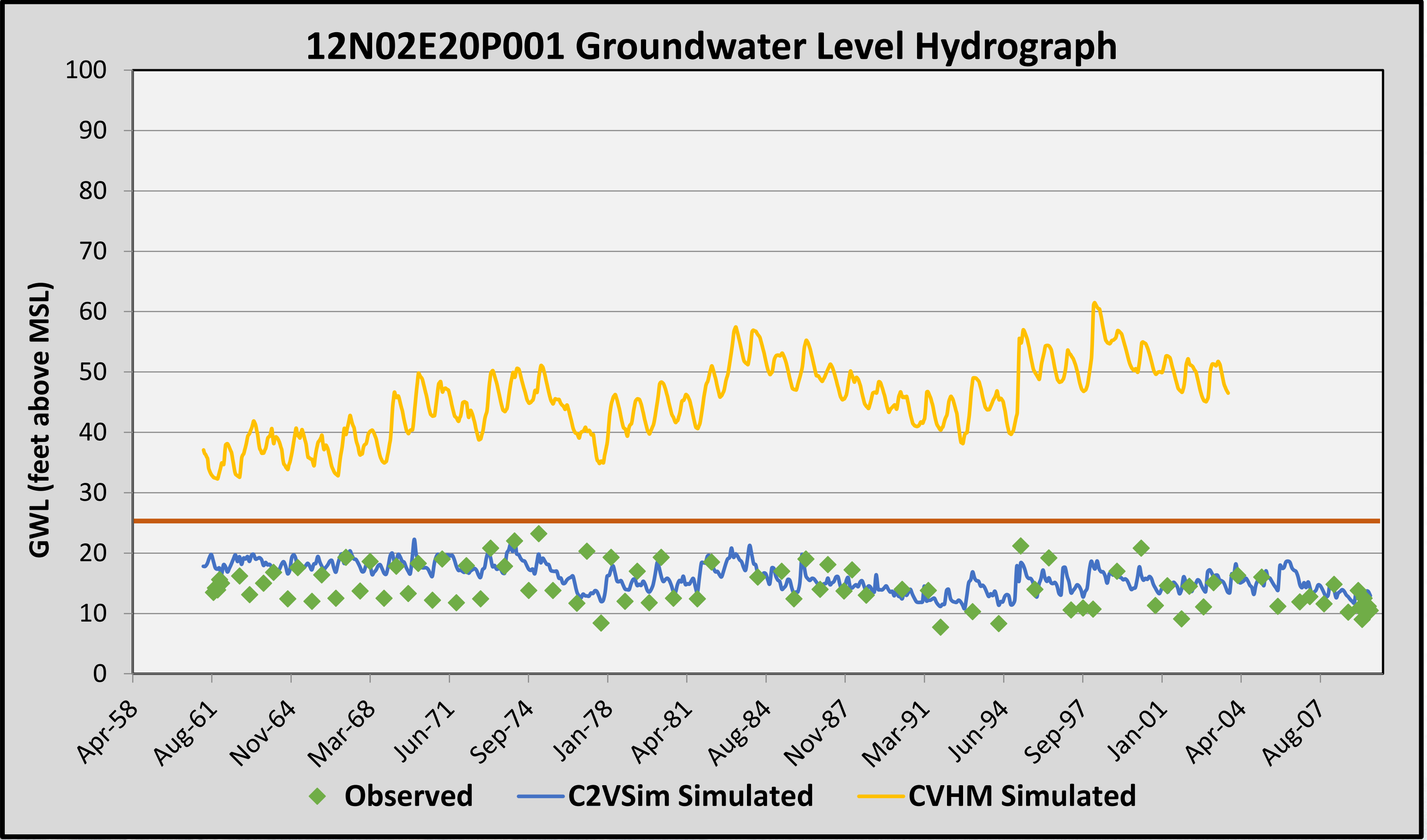




Model Calibration

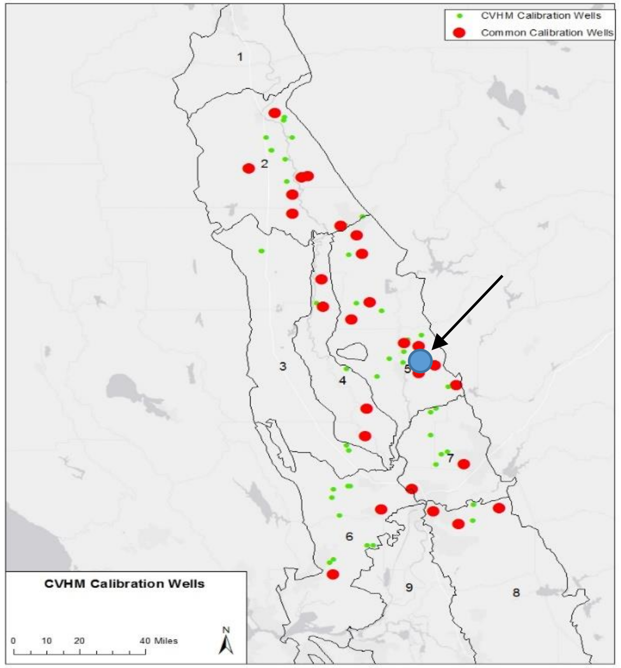
- Active, unknown type
- Intermediate (Total Depth – 500 ft)

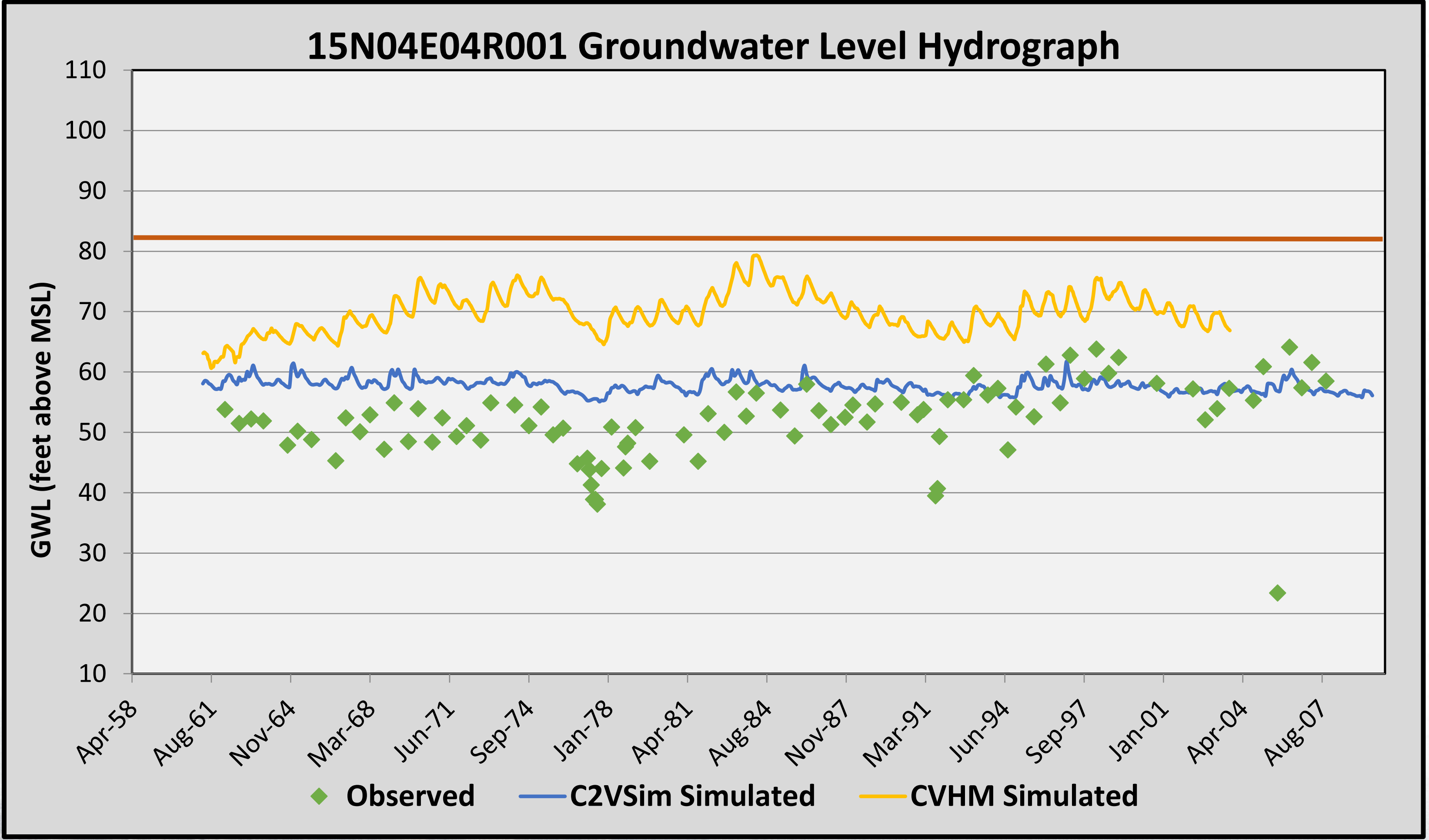




Model Calibration

- Active Irrigation
- Intermediate (Total Depth 400 ft)





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Agenda

- Recap of previous meetings
- Models Comparison
  - Land use / Cropping
  - Water Budget
    - Ag Water Demand
    - Water Supply
    - Recharge
    - Stream Seepage
  - Surface Water Inflows
  - Calibration
    - Hydrographs at selected wells
- **Discussion**
  - **Model recommendations or assistance in model recommendations**

Model recommendations or assistance in model recommendations?

- Can we provide a recommendation?
  - Of a model?
  - Of an approach?
  - Of focus areas?
- How do you see a GSA coming to a conclusion on model selection?

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Thank you.

Interbasin

GROUNDWATER FLOW

Evaluation Project

Technical Collaborators Meeting 4

April 13, 2017

Agenda

- Recap of previous meetings
- Report approach and contents

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Meeting #1 Recap

- **Project objectives:**
  - Local ownership of the interbasin flow evaluation process in the NSV Area
  - "Lessons learned" to DWR and others in the state
- **Overview of models** likely to be considered for this study
  - Regional: CVHM, C2VSim, SacFEM 2013
  - Local: Butte Basin Groundwater Model, Stony Creek Fan IGSM
- Certain **tools** identified as being unsuited for future use by GSAs, though they likely contain useful information that shouldn't be lost
  - SacFEM 2013, Stony Creek Fan IGSM
- Initial discussion of **project outcomes**

Project Objectives

A methodology to assess **interbasin flows**

Technical capacity
Local ownership

Methodology for **GSAs within the NSVIRWM area**

Methodology for **DWR** GSA assessments

“lessons learned” for other basins

Meeting #2 Recap

- **Model Selection:**
  - Up to GSAs to decide what model is best for what they want to do. Existing models provide bookends and a range of interbasin flows.
  - Model criteria (qualitative and quantitative) will lead evaluation of regional models
  - Define flowpath for selection, incorporating 6 Undesirable Results
- **Model Refinements:**
  - Existing models weren't designed for use in GSPs. Needs for improvement of regional models can help guide future refinement to meet needs under SGMA.
  - Local models can build off regional models
- **Model Analysis:**
  - Differences exist in definitions, methodologies, and water budgets
  - Additional information needed to guide decisions: inputs, calibration, spatially detailed water budgets

Meeting #3 Recap

- **Land Use Classifications**
  - Due to varying aggregation methods, CVHM and C2VSim have a different number of land use categories, further groupings were completed for comparative purposes.
  - The group recommends local agencies should review both models in their subregion as early records show significant differences.
- **Water Budget Comparison**
  - Budget component definitions should be reviewed for consistency across two models.
  - Large scale updates and calibrations for both models are currently underway and may address existing issues.
- **Recommendations**
  - Modeling needs are outstripping capacity, additional support and data are needed.
  - The committee recommends to USGS and DWR to formally request specific updates to each model based on local expectations and to formally document model differences.

Report Approach

- High level summary of approach and results
- Easily digestible
- Suitable for decision makers and stakeholders
- 10-20 pages
- More detailed technical information in appendices or by reference
- Executive summary to be considered

Report Approach – TC Participation

- Google Docs – Allowing TC member to provide early input
  - Initial direction / bullets,
  - Identification of appendices, and/or
  - Initial review and comment
- Entire document – All TC members
  - Review and comment

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Report Outline

- Executive Summary (tentative)
- Introduction
- Inventory of Groundwater Models
- Assessment of Regional and Local Models
- Conclusions and Recommendations

Introduction

- Motivation
- Project Goals
- Interbasin Flows
- NSVIRWM Region
- Use of Information
- Technical Collaborators

Introduction

- Motivation
- Project Goals
- Interbasin Flows
- NSVIRWM Region
- Use of Information
- Technical Collaborators

<u>Volunteers</u>
Familiarity with NSV
Familiarity with SGMA

Inventory of Groundwater Models

- No subsections
- Briefly summarizes the existing TM
- TM to be included in the appendix

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Inventory of Groundwater Models

- No subsections
- Briefly summarizes the existing TM
- TM to be included in the appendix

<u>Volunteers</u>
Familiarity with models

National Experience. Local Focus.

Assessment of Regional and Local Models

- Terminology
- Effective Accounting of Interbasin Flows
- Water Budget Comparison
- Calibration
- Baselines
- Role of Local Models
- Issues with Non-Modeling Approaches
- Guidance on Selecting a Model for Addressing SGMA Needs

Assessment of Regional and Local Models

- Terminology
- Effective Accounting of Interbasin Flows
- Water Budget Comparison
- Calibration
- Baselines
- Role of Local Models
- Issues with Non-Modeling Approaches
- Guidance on Selecting a Model for Addressing SGMA Needs

Questions

How to present existing analysis?

Assessment of Regional and Local Models

- Terminology
- Effective Accounting of Interbasin Flows
- Water Budget Comparison
- Calibration
- Baselines
- Role of Local Models
- Issues with Non-Modeling Approaches
- Guidance on Selecting a Model for Addressing SGMA Needs

Questions
If leaving to locals, can we provide things like land use and water budget equivalents?

Assessment of Regional and Local Models

- Terminology
- Effective Accounting of Interbasin Flows
- Water Budget Comparison
- Calibration
- Baselines
- Role of Local Models
- Issues with Non-Modeling Approaches
- Guidance on Selecting a Model for Addressing SGMA Needs

Questions

Appendix materials here will be critical. What do we include?

- Stream budget block diagrams
- Vina example
- etc.

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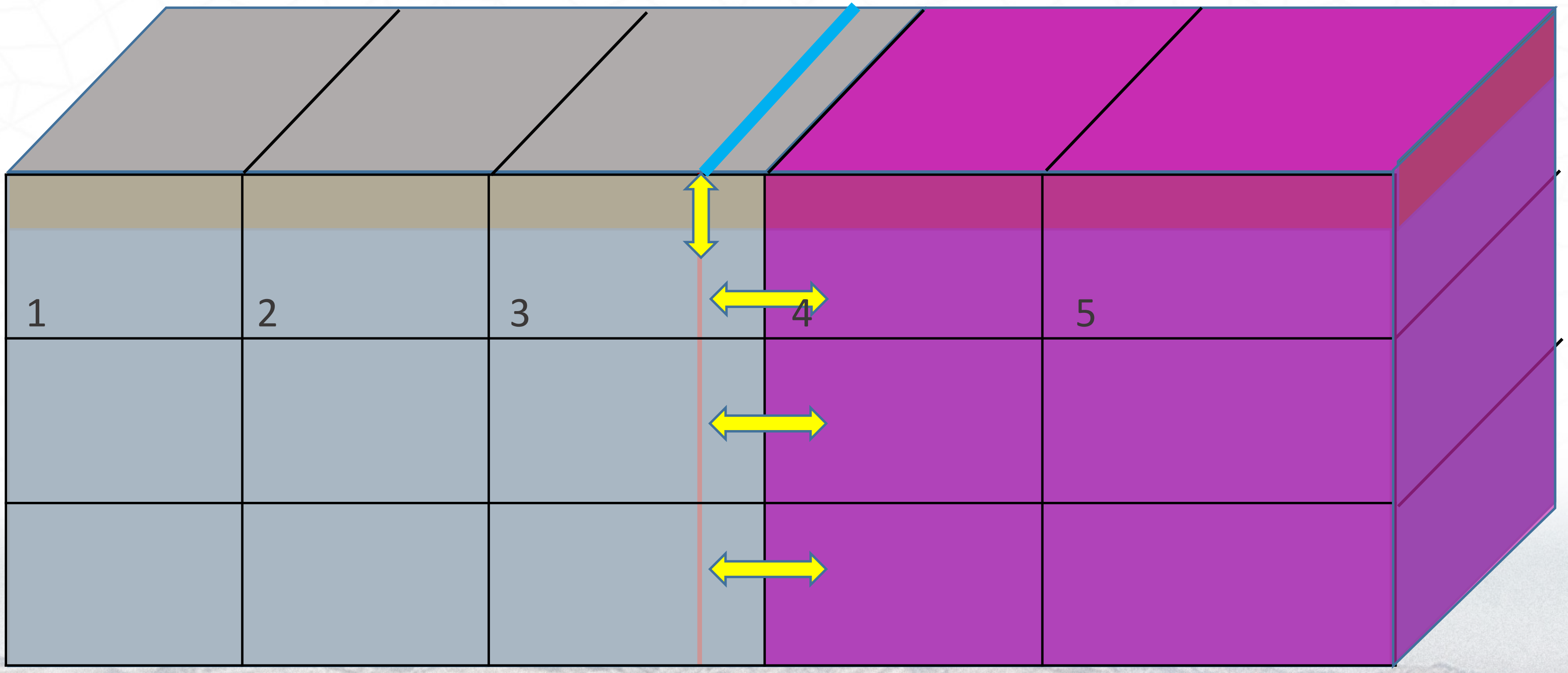
Evaluating Interbasin Flows Where the Boundary is Defined by a River/Stream

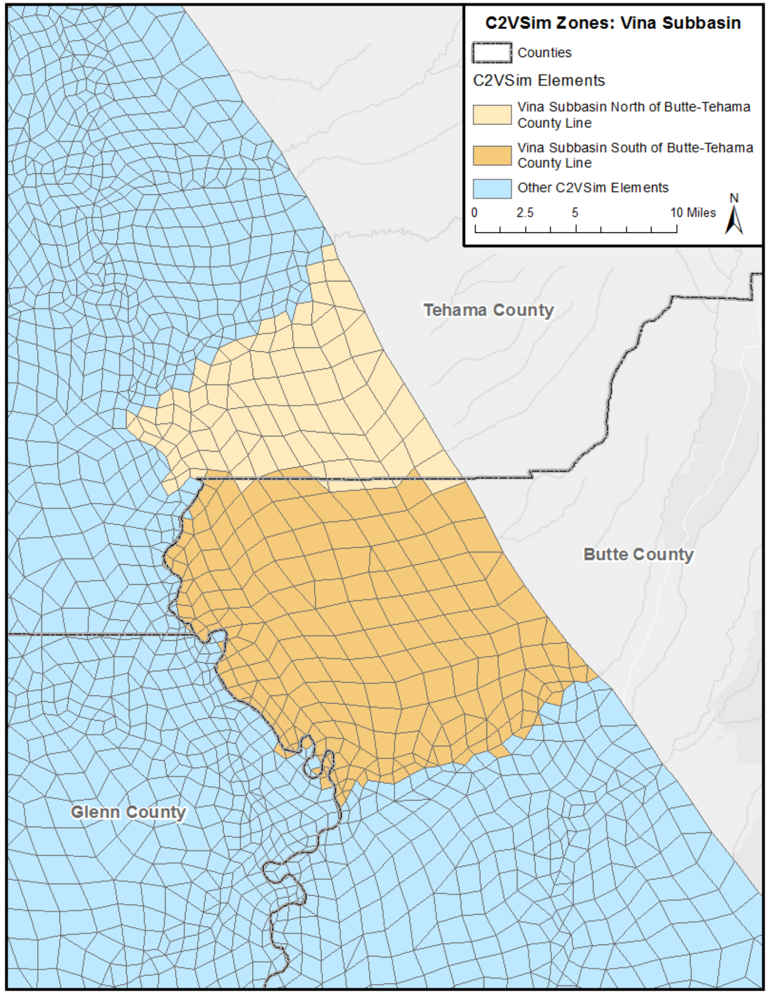
- Boundaries aligned with rivers and streams (as many in the state are) complicates the quantification of these flows



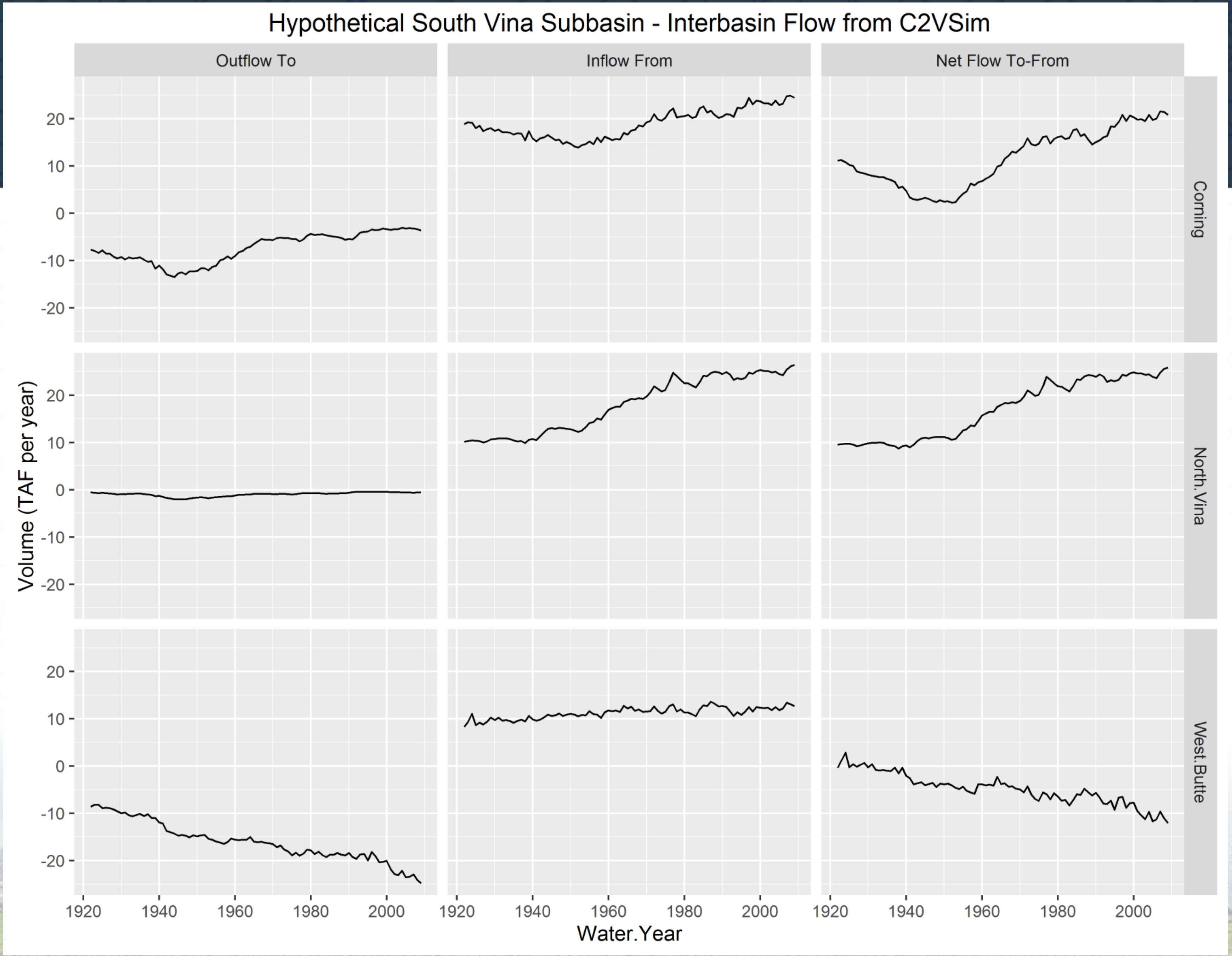
$Q_{str} = 0$

Example of Interbasin Flow Budget Information

- Using C2VSim
- Split Vina Subbasin into two hypothetical subbasins along county line -> North Vina and South Vina
- Budget information presented below is from the perspective of South Vina (darker orange area on figure to the left)



- Evaluated subsurface inflow and outflow, by layer, into/out of hypothetical South Vina Subbasin from:
  - Corning
  - North Vina
  - West Butte



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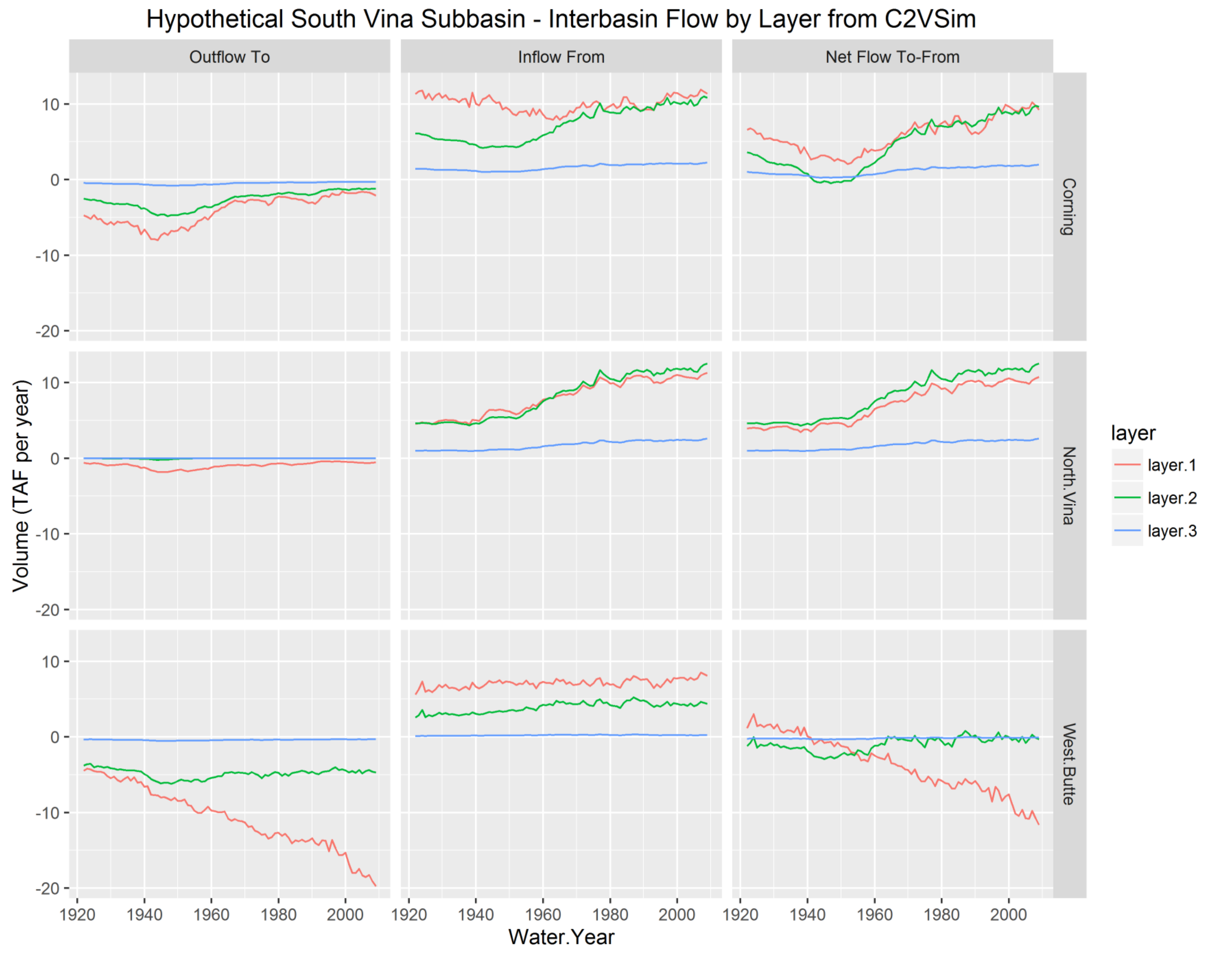
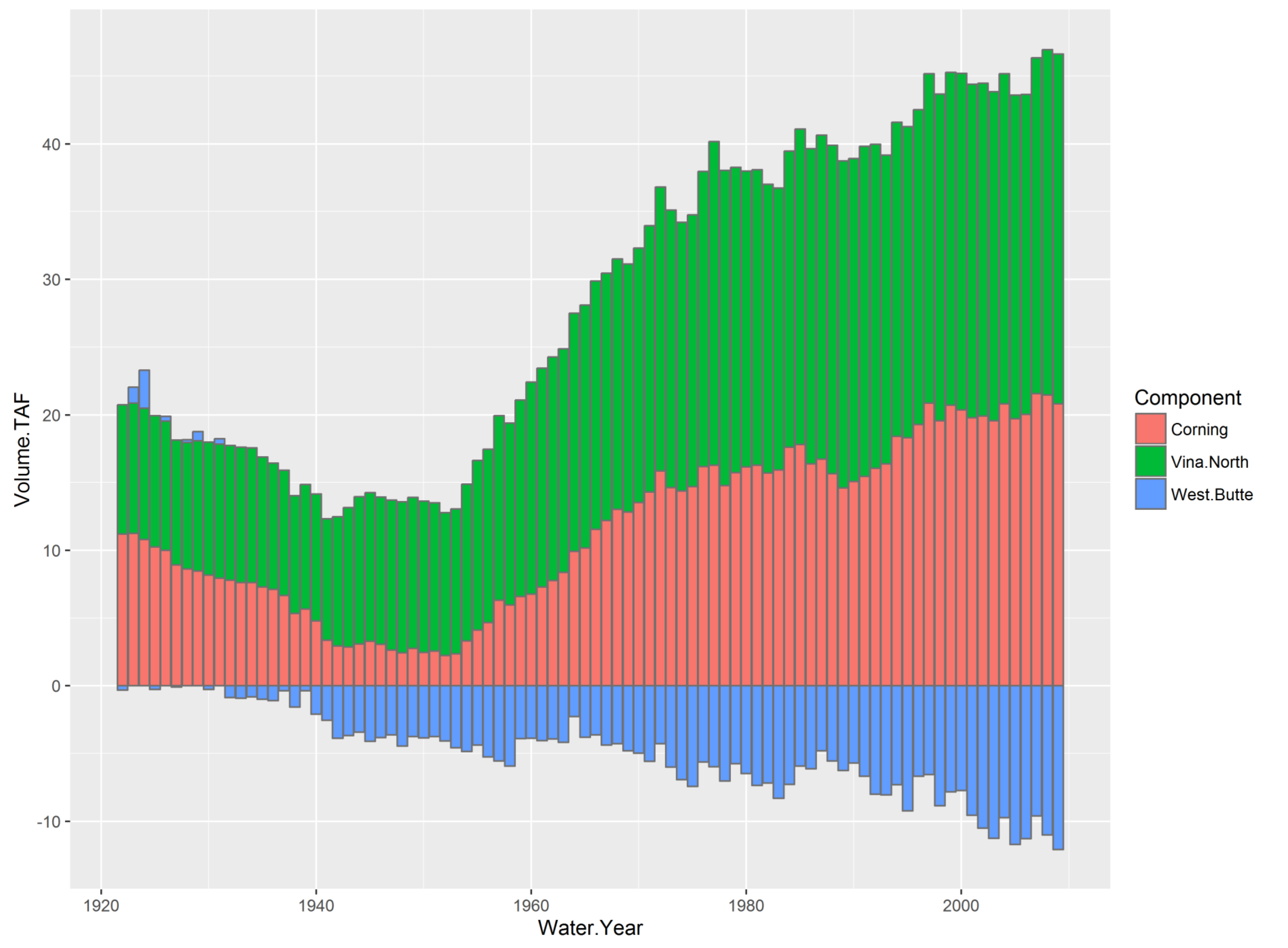
  - North Vina
  - West Butte



Hypothetical South Vina Subbasin Total GW Budget

Hypothetical South Vina Subbasin Interbasin Flows



Hypothetical

South Vina Subbasin

Interbasin Flows Relative to Total Groundwater Budget

Assessment of Regional and Local Models

- Terminology
- Effective Accounting of Interbasin Flows
- Water Budget Comparison
- Calibration
- Baselines
- Role of Local Models
- Issues with Non-Modeling Approaches
- Guidance on Selecting a Model for Addressing SGMA Needs

Volunteers
Modelers

Conclusions and Recommendations

- North Valley Specific
- General Technical Issues (Statewide Application)
- Recommendations for DWR and USGS (Expectations and Desires of Local Agencies for Available Models)

Conclusions and Recommendations

- No qualified or unqualified model recommendation
- No model was developed with SGMA in mind and all models require some kind of refinement to be truly suitable for use in SGMA

Conclusions and Recommendations: North Valley Specific

- NSV-specific data gaps
- NSV-specific needs for refinements for C2VSim and CVHM.
- Utilizing data from SacFEM and Stony Creek Fan models
- Use of local models like Butte Basin
- Consideration of future models, such as SVSim, and updated regional models in the NSV

Conclusions and Recommendations: General Technical Issues (statewide application)

- Overall approach (TC, needs assessment, model ID, model analysis, model selection)
- Specific technical approaches within analysis and selection
  - Process for evaluating multiple modeling tools (water budgets, gw heads)
  - Process for comparing water budgets (which components, and reconciling terminologies/differing approaches)
  - Approach for streams at the boundary for comparing boundary flows in the water budgets.
- Approach to boundaries of GSPs using different models

Conclusions and Recommendations: Recommendations for DWR and USGS

- Enhance the utility, reliability, and ultimately acceptability of the models for SGMA use
- Specific needs
  - Standard data inputs (eg land use refinements)
  - Comparable water budgets
  - Tools for extracting water budgets for specific GSA area
  - Tools for extracting simulated heads at given locations
  - Guidance for using the models by GSAs with respect to each of 6 undesirable results

Conclusions and Recommendations

- North Valley Specific
- General Technical Issues (Statewide Application)
- Recommendations for DWR and USGS (Expectations and Desires of Local Agencies for Available Models)

Volunteers
Anyone/Everyone

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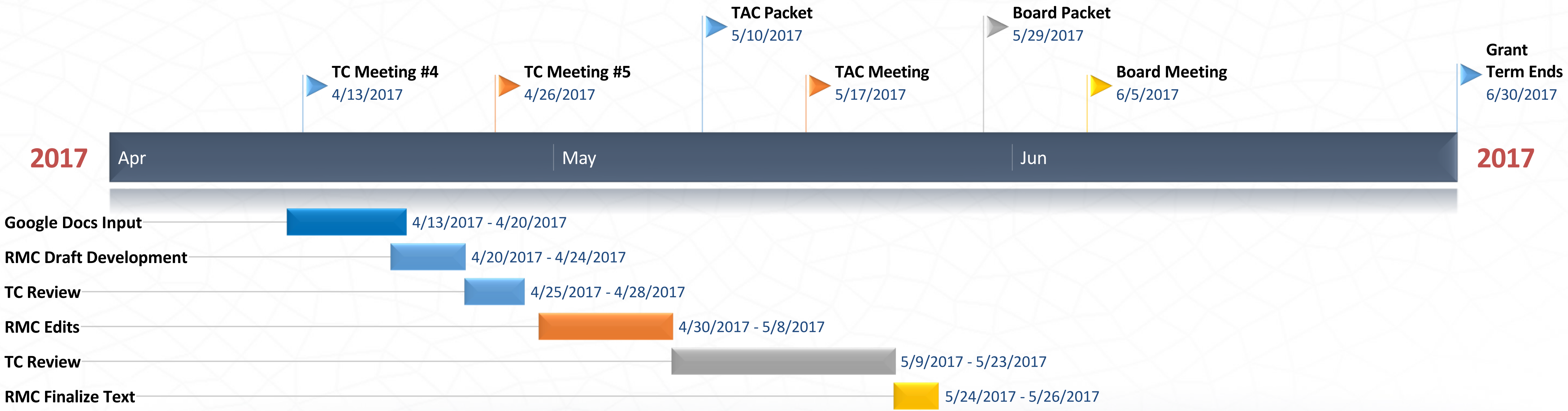
Next Steps / Schedule



Discussion

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Next Steps / Schedule

Early input provided April 20 (Google Docs)
Draft text provided April 24
TC Meeting #5 Wednesday April 26, 10 am-noon
TC review by April 28
Revised document by May 8
May 17 TAC (May 10 TAC packet)
TC review May 9-23
Incorporate comments, May 23 – May 26
Board meeting June 5 (May 29 Board packet)
Grant term ends June 30

Next Steps / Schedule

Early input provided April 20 (Google Docs)
Draft text provided April 24
TC Meeting #5 Wednesday April 26, 10 am-noon
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TC review May 9-23
Incorporate comments, May 23 – May 26
Board meeting June 5 (May 29 Board packet)
Grant term ends June 30

Butte County
CALIFORNIA

Interbasin GROUNDWATER FLOW Evaluation Project

Technical Collaborators Meeting 5

April 26, 2017

Agenda

- Recap of previous meeting
- Report discussion
- Next Steps

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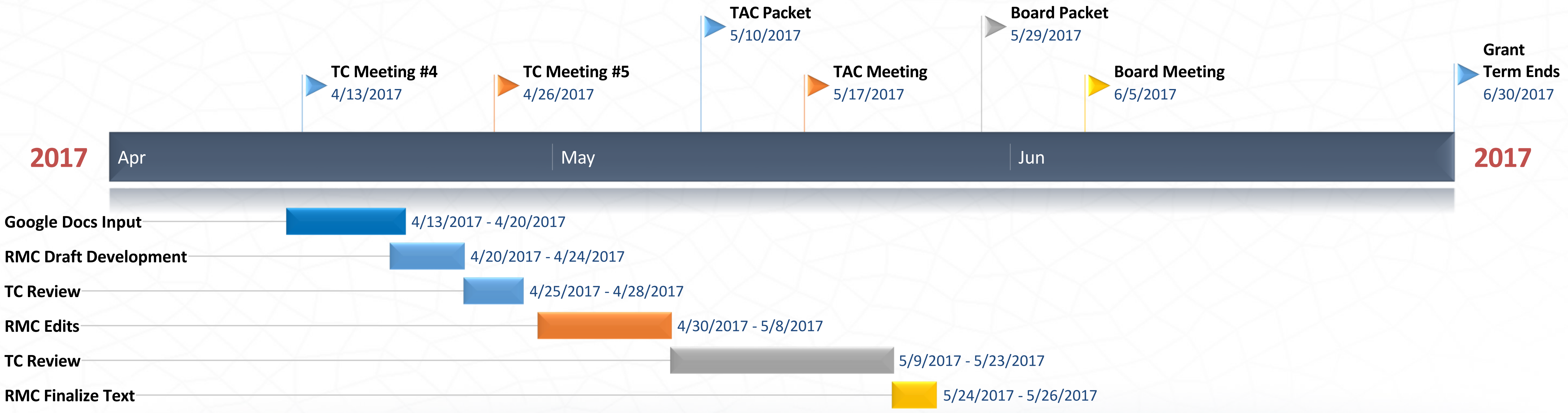
Meeting #4 Recap

- **Report Outline**
  - Aim to have a concise, high level report with technical analysis in appendices
    - Executive Summary
    - Introduction
    - Inventory of Groundwater Models
    - Assessment of Regional and Local Models
    - Conclusions and Recommendations
    - Appendices
  - All TC members may contribute via Google Document link
- **Discussion Highlights**
  - No model recommendation. No model was developed with SGMA in mind and all models require refinement to be truly suitable for use in SGMA.
    - Model uncertainty and risk
    - Tabulated model differences/methodologies
  - Relative differences between scenarios more useful than absolute values
  - Have specific recommendations for approach by sustainability indicator (matrix)
- **Conclusions and Recommendations**
  - Specific recommendations geared toward North Sacramento Valley, statewide application, and DWR/USGS

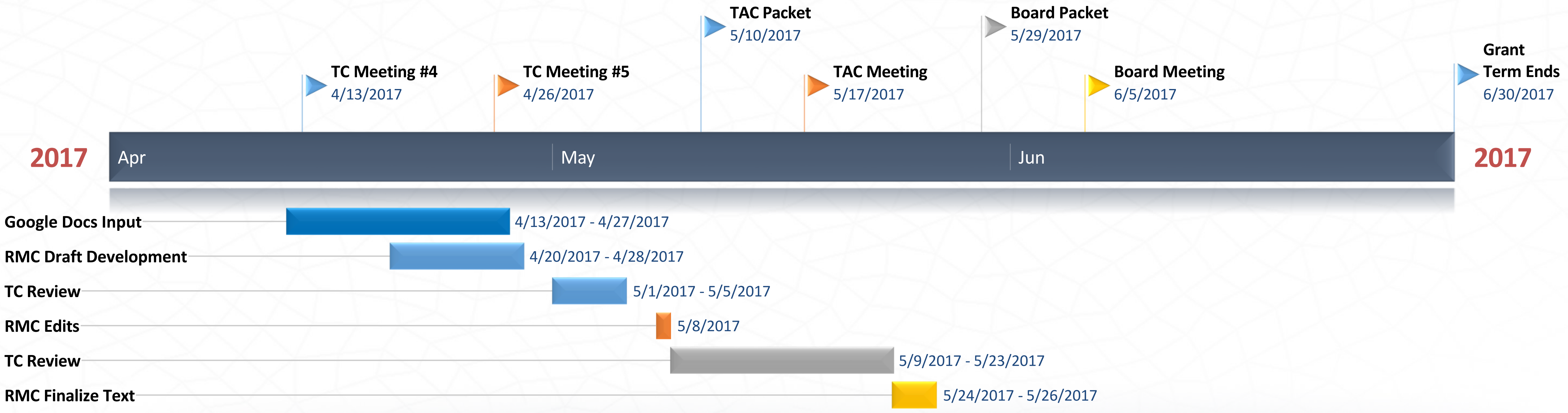
Report Discussion

Next Steps / Schedule



National Experience. Local Focus.

Next Steps / Schedule



Appendix B - Technical Collaborators Meeting Summaries

Meeting Summary

Interbasin Groundwater Flow Evaluation Project

Subject: Technical Collaborators Meeting #1

Prepared By: Craig Altare

Date/Time: July 27, 2016
10:00am-12:00pm

Location: RMC Water and Environement
1545 River Park Drive, Suite 425
Sacramento, CA 95815

Meeting Attendance

• Technical Collaborators: ○ Grant Davids (Davids Engineering) ○ Steve Phillips (USGS) ○ Ali Taghavi (RMC) ○ Claudia Faunt (USGS) ○ Mary Randall (DWR) ○ Oscar Serrano (Colusa Indian Community Council, NSVIRWM TAC) ○ Ben Pennock (Glenn Colusa ID, NSVIRWM TAC) ○ Bill Ehorn (DWR, NSVIRWM TAC) ○ Vickie Newlin (Butte County, NSVIRWM TAC Chair) ○ Allan Fulton (UC Cooperative Extension, NSVIRWM TAC) ○ Steffen Mehl (CSU Chico) ○ Christina Buck (Butte County) ○ Peter Lawson (CH2M Hill) ○ Charlie Brush (DWR) ○ Thomas Harter (UC Davis, on phone)	• Other: ○ Jim Blanke (RMC) ○ Craig Altare (RMC) ○ Sara Miller (RMC)

Meeting Objectives

- Kick off the Interbasin Groundwater Flow Evaluation Project
- Familiarize Technical Collaborator (TC) members with the motivation for the Project
- Inform TC Members of models being considered for interbasin groundwater flow evaluation for the North Sacramento Valley Integrated Regional Water Management (NSVIRWM) area
- Solicit feedback from TC members on draft Tech Memo, e.g. additional models or methods to consider
- Discuss Project timelines

Discussion Summary

1. Project objectives:
    a. Develop methodology to assess interbasin flows for GSAs in the NSVIRWM area

   b. Develop methodology to assess interbasin flows for DWR GSA assessments
   c. Develop "lessons learned" for other basins
2. Draft Model Inventory Tech Memo:
   a. 5 models: 3 regional (C2VSim, CVHM, SACFEM2013) and 2 local (BBGM, SCF Model)
      i. Code platforms:
         1. IWFM (C2VSim, BBGM)
         2. MODFLOW-FMP (CVHM)
         3. MicroFEM with IDC (SACFEM2013)
         4. IGSM (SCF Model)
   b. Other methodologies/models to discuss?
      i. Use field observations for verification
      ii. Sacramento Valley Simulation Model (SVSim) – add to inventory to track it, even though all of the details aren't available
      iii. Age dating/GAMA (Christina Buck mentioned Jean Moran at Lawrence Livermore and Claudia Faunt mentioned USGS studying Fresno area)
3. Suggestions for study:
   a. Members of the TC noted that SACFEM2013 (propriertary and not fully integrated MicroFEM code) and SCF Model (IGSM is predessessor to IWFM and not maintained) are not the path forward, but may contain useful information that could be retained for future efforts.
   b. Considerations when analyzing regional and local models:
      i. Focus on assumptions behind data rather than model numbers
      ii. Consider how differences in discretizations may drive differences in model results
      iii. Consider where boundaries are drawn (e.g., subbasin boundaries usually at streams), especially with regards to differences in finite element (IWFM, MicroFEM, and IGSM), and finite difference (MODFLOW-FMP) models
         1. If keep analysis boundaries at streams, likely need to subtract the stream reach budget from interbasin flows for CVHM
      iv. Include analysis of how different models simulate boundary inflows
      v. For regional models, look at northern Sacramento Valley basin-wide water budgets and how they compare in magnitude
      vi. Consider including an appendix listing the different terminology used for water budget components in each model and how they compare
      vii. Stay closer to a current time period (last ~20 years)
      viii. Consider hydrogeology and how it is implemented in the models (e.g., consider focusing on Tuscan Formation and above, or on primary production zones)
      ix. Most important to compare magnitudes and flow directions across boundaries
      x. Suggestion to focus on one or two boundaries for analysis (consider with/without streams, wet/dry periods, east-west/north-south flow, etc.)
         1. Butte-Tehama County line across Vina subbasin
         2. Tehama-Glenn County line within Stony Creek Fan

Action Items

1. Thomas Harter to send IWFM v.s. MODFLOW-FMP peer review to group
2. Grant Davids to send study comparing C2VSim and CVHM that determined interbasin flow magnitudes often accounted for up to 20% of total water budget
3. RMC to revise draft Tech Memo:
    a. Add to table:
        i. General level of calibration, if possible focusing on the Sacramento Valley
        ii. Stress period and time step for each model
    b. Add information for the upcoming Sacramento Valley Simulation Model (SVSim)
4. Next meeting (September 2016) will focus on regional models
    a. Look at region-wide water budgets and two boundaries (one across a stream and one away from a stream). Boundary water budgets to focus on C2VSim and CVHM.
    b. Continue discussion regarding end products that will be most helpfulto the NSV region and to others throughout the State.

Meeting Summary

Interbasin Groundwater Flow Evaluation Project

Subject: Technical Collaborators Meeting #2
Prepared By: Craig Altare
Date/Time: September 6, 2016
10:00am-12:00pm

Location: RMC Water and Environment
1545 River Park Drive, Suite 425
Sacramento, CA 95815

Meeting Attendance

• Technical Collaborators: o Charlie Brush (DWR) o Christina Buck (Butte County) o Grant Davids (Davids Engineering) o Bill Ehorn (DWR, NSVIRWM TAC) o Claudia Faunt (USGS) o Allan Fulton (UC Cooperative Extension, NSVIRWM TAC) o Thomas Harter (UC Davis) o Peter Lawson (CH2M Hill) o Steffen Mehl (CSU Chico) o Vickie Newlin (Butte County, NSVIRWM TAC Chair) o Ben Pennock (Glenn Colusa ID, NSVIRWM TAC) o Steve Phillips (USGS) o Mary Randall (DWR) o Oscar Serrano (Colusa Indian Community Council, NSVIRWM TAC) o Ali Taghavi (RMC)	• Other: o Jim Blanke (RMC) o Craig Altare (RMC) o Sara Miller (RMC)

Meeting Objectives

- Primary: Obtain feedback from the Technical Collaborators (TC) regarding project outcomes:
  - What types of recommendations does the group feel comfortable committing to?
  - Based on that, what are the action items for the TC and consultants?
- Secondary:
  - Bring members of the TC up to speed on regional modeling tools, the water budget information they generate, current status, and applicability to determination of interbasin flows in the NSV

Discussion Summary

1. Recap of TC Meeting #1:
   a. Project objectives: local ownership of interbasin flow evaluation process in the NSV Area and "lessons learned" to DWR and others in state

   b. SacFEM and Stony Creek Fan not suited for use by GSAs, but still contain useful information
2. Project Outcomes:
   a. Discussion question posed: Does the TC group feel comfortable identifying which regional model (CVHM or C2VSim) is the most appropriate for determination of interbasin flow budget components of GSPs *at this place and in this time*?
      i. "At this time"- Consultants would need model and time to develop GSP well before GSPs due in 2022 (estimated about 2017-2018 with preliminary model development work beginning now)
      ii. Consensus: Up to GSAs to decide what model is best for what they want to do. These models provide bookends and a range of interbasin flows.
   b. TC group could provide input for model development as CVHM and C2VSim continue updating
      i. Since the regional models were never developed for use by GSAs for GSPs, the TC group could recommend improvements to meet the needs of GSAs that may be able to implemented in the models by 2018.
         1. Develop criteria of what would want model to have
      ii. Regional models were never intended for anything other than regional answers. Local models use regional models to develop boundary conditions.
   c. Summary: Model criteria (i.e., qualitative and quantitative components of model that augment the work of GSAs and for GSPs) will lead evaluation of regional models and may help modelers with ideas for how to better support GSPs and GSAs
      i. Criteria would help other GSAs (i.e., evaluate now so others don't have it) and enhance defensibility of modeling for GSPs (i.e., list of criteria met by model). Look at improvements in data and data gaps.
3. Components of Model Selection:
   a. Presentation of flowpath of things considered by water manager to determine model to use
      i. Add to criteria: How well does model work for projects planned?
      ii. Add information about 6 undesirable results from GSP
      iii. May need to be tweaked depending on different critical criteria in each area (e.g., stream-aquifer interaction important in NSV Area)
   b. Discussion:
      i. DWR will do technical evaluation of tools (e.g., model) that go into GSPs. If interbasin flow values from two adjacent basins are largely off, the basins will have to work together to resolve the issue.
      ii. GSAs are only held to sustainability factors and not to the model (model is just how sustainability factors were evaluated and how determined what projects will help)
      iii. Ranges of numbers are a reality that people will have to get used to
4. Regional Model Results for Sacramento Valley Groundwater Basin:
   a. Groundwater budget results across entire Sacramento Valley Groundwater Basin may only come out to a difference between models of about 1-2 AF for each acre
   b. Summary of budget components:
      i. Drains—SacFEM's groundwater discharge to land surface

1. Add to discharge to streams (i.e., reduces stream component of groundwater budget)

ii. General head—CVHM only (in Delta area)

iii. Interbasin flows—coming from north or going to south, SacFEM doesn't have (only has a boundary condition at Delta for outflow)

iv. Recharge—ET from groundwater taken out of recharge component in CVHM (i.e., reason for negative farm net recharge)

v. Small watershed—not in 2009 version of CVHM

c. Beauty of SGMA is that locals define the surface water system and then use groundwater stratigraphy from CVHM or C2VSim. This iterative process lets locals improve the regional models with accurate local surface water data.

d. Boundary conditions between the models are different and drive the differences in results

5. Direction for Analysis and Next Meeting:

a. Next meeting in January

b. Have defined data gaps and specifics about what models may improve (i.e., criteria ideas)

c. Focus on local models and subbasin-scale water budgets in order to help hammer out criteria

d. Develop framework for report

Meeting Summary

National Experience. Local Focus.

Interbasin Groundwater Flow Evaluation Project

Subject: Technical Collaborators Meeting #3

Prepared By: Dominick Amador

Date/Time: March 7, 2017
10:00am-12:00pm

Location: RMC, a Woodard and Curran Company
1545 River Park Drive, Suite 425
Sacramento, CA 95815

Meeting Attendance

• Technical Collaborators: ○ Grant Davids (Davids Engineering) ○ Ali Taghavi (RMC) ○ Claudia Faunt (USGS) ○ Oscar Serrano (Colusa Indian Community Council, NSVIRWM TAC) ○ Ben Pennock (Glenn Colusa ID, NSVIRWM TAC) ○ Vickie Newlin (Butte County, NSVIRWM TAC Chair) ○ Allan Fulton (UC Cooperative Extension, NSVIRWM TAC) ○ Steffen Mehl (CSU Chico) ○ Christina Buck (Butte County) ○ Peter Lawson (CH2M) ○ Charlie Brush (DWR)	• Other: ○ Jim Blanke (RMC) ○ Reza Namvar (RMC) ○ Dominick Amador (RMC)

Meeting Objectives

Obtain feedback from the Technical Collaborators (TC) regarding project outcomes:

- Review of C2VSim and CVHM model input and output.
  - Note any discrepancies in model classifications or budgetary definitions during comparison.
  - Note any additional areas of needed review or refinement to the analysis.
- Determine general recommendations for local agencies looking to use a regional model in support of SGMA and GSA governance.
- Based on meeting discussions, what are the action items for the TC and consultants?

Discussion Summary

Model Comparison

1. Land Use / Cropping Patterns
    a. CVHM operates with 22 land use categories, compared to the 17 of C2VSim. To directly compare the two models, categories were aggregated into 12 common groups.
        i. Claudia and Charlie have offered to assist classification mapping as some of the miscellaneous categories may be misrepresented (ex: developed and semi-agricultural) in the initial analysis.
        ii. Earlier years show greater degrees of model differences, particularly in 1960 and 1992 where CVHM has nearly 1,000,000 acres of additional irrigated cropland. The group notes that this may be caused by methodology, and recommends that calibration is weighted towards later years in the simulation.
    b. Subregional Comparison
        i. Individual subregions should be reviewed by local agencies to determine which model may better represent their area with greater accuracy.
        ii. The group recommends that local agencies look at the total consumptive use, applied water, and surface water diversions rather than only land use. Differences in crop classifications may not make significant changes to the water budget.
2. Water Budget
    a. Initial review of comparative water budgets show significant differences; additional review should be undertaken to ensure that budgetary item definitions are comparative.
        i. Water Demand Required – Claudia indicated that the CVHM ET demand includes ET from precipitation, ET from groundwater, and ET from applied water (Claudia to verify), whereas C2VSim is ET from applied water as read from the L&WU budget.
    b. Subregional water budgets and calibration:
        i. C2VSim Calibration – In IWFM 3.02 stream nodes are given a subregional delineation and all flows from stream-groundwater interaction are applied in that specific subregion. Because of this, certain subregions with large streams on the boundary are showing inaccurate stream seepage depending on the nodal classification. C2VSim is currently being updated to the IFWM 2015 framework, where this will no longer be an issue.
        ii. CVHM Calibration - Subregion 3 is not calibrated very well and has very high water levels, this may be the reason for lower surface water diversions (GCID delivers 800 TAF of and CVHM only shows 700 TAF for the entire subregion).
        iii. CVHM Calibration – CVHM is calibrated more towards storage changes over time and capturing trends rather than matching groundwater elevations.
        iv. Groundwater calibration analysis should take into consideration the scale of the model element and the variation in ground surface elevation and water surface elevation within that model element. These factors can result in what appears to be a mismatch in measured versus simulated groundwater elevations.
        v. There is a fundamental need for consistency between model budget components and there needs to be additional coordination between DWR and USGS about their modeling efforts.
        vi. Models need to be able to be upgraded or fine-tuned at a local level.

Recommendations

1. Regional models are a good starting point for local refinement but even though local agencies would like to be able to pick up either model and use it as-is for their water budgets, the group does not recommend this approach.
    a. Local agencies should look specifically at their area and review both models for accuracy.
    b. Regional models were not developed or calibrated for use in GSA governance.
    c. If local stakeholders want something that can be used off-the-shelf they need to provide additional data and coordinate with the DWR and USGS. This process may include changes to reporting units within the models (e.g. subbasins).
2. The committee recommends that they develop a recommendation to USGS and DWR to formally request specific updates to each model based on local expectations.
    a. SGMA - Develop a guideline on how to use these regional models to address the six SGMA parameters and how a numerical model would assess those conditions.
    b. Cost - The DWR and/or State Board should develop guidelines for expected cost and investment into the refinement of groundwater models to meet SGMA and GSA requirements.
3. Areas for review and additional discussion on the regional models
    a. Development – Modeling needs are outstripping capacity. C2VSim and CVHM were not designed for local SGMA use, and there needs to be development support to allow them to grow into this new capacity.
    b. Model Differentiation – As there are large differences in the regional models within the Sacramento Valley, there needs to be some formal explanation as to why the two models vary to such a degree.
    c. Processing Tools – More materials should be available for a lay-person to understand models and their output, specifically relating to budget output. Review additional utilities that can provide large benefit for minimal effort, potentially a comparison tool for model output.

Action Items

1. Claudia and Charlie to coordinate on an aggregated land use classification for model comparison.
2. Claudia and Charlie to review water budgets to ensure equivalent definition of budgetary items.
3. Everyone to send Jim final thoughts, recommendations, comments, concerns, and questions.
4. Jim to begin develop draft documentation of project findings for discuss at next meeting.

Meeting Summary

National Experience. Local Focus.

Interbasin Groundwater Flow Evaluation Project

Subject: Technical Collaborators Meeting #4
Prepared By: Sara Miller
Date/Time: April 13, 2017
10:00am-12:00pm
Location: RMC Water and Environment
1545 River Park Drive, Suite 425
Sacramento, CA 95815

Meeting Attendance

• Technical Collaborators: o Grant Davids (Davids Engineering) o Steve Phillips (USGS) o Mary Randall (DWR) o Ben Pennock (Glenn Colusa ID, NSVIRWM TAC) o Bill Ehorn (DWR, NSVIRWM TAC) o Vickie Newlin (Butte County, NSVIRWM TAC Chair) o Allan Fulton (UC Cooperative Extension, NSVIRWM TAC) o Christina Buck (Butte County) o Charlie Brush (DWR) o Thomas Harter (UC Davis) o **Phone** Peter Lawson (CH2M Hill) • Absent: o Ali Taghavi (RMC) o Claudia Faunt (USGS) o Oscar Serrano (Colusa Indian Community Council, NSVIRWM TAC) o Steffen Mehl (CSU Chico)	• Other: o Jim Blanke (RMC) o **Phone** Reza Namvar (RMC) o Sara Miller (RMC)

Meeting Objectives

- Receive input from TC on the content of the draft report and on TC participation during the drafting of the report

Discussion Summary

Recap of Previous TC Meetings

1. Meeting #1
    a. Project Objectives:
        i. Local ownership of the interbasin flow evaluation project in the NSV Area (a methodology to assess interbasin flows)

    ii. "Lessons learned" to DWR and others in the state

  b. Overview of models to be considered for this study and decision that some tools are unsuited for future use by GSAs, though still contain useful information that should be preserved (SacFEM 2013, Stony Creek Fan IGSM)

2. Meeting #2
   a. Model selection- Existing models provide bookends and a range of interbasin flows. Model criteria will lead evaluation of regional models
   b. Model refinements- Existing regional models weren't designed for SGMA and need improvement
   c. Model analysis- Differences exist in definitions, methodologies, and water budgets
3. Meeting #3
   a. Analysis of land use classifications and water budget comparisons between CVHM and C2VSim
   b. Recommendations: Specific updates for CVHM and C2VSim

Report Approach

4. Aim to have a concise, high level report with executive summary and technical analysis included in appendices
5. All TC members may contribute to report via Google Document link
6. Target audiences include local agencies (county supervisors, etc.), DWR and USGS, and possibly consultants
7. No model recommendation. No model was developed with SGMA in mind and all models require refinement to be truly suitable for use in SGMA.
   a. Model uncertainty and risk: Acknowledge and deal with uncertainties in model results/GSPs. Need work to get models better over time (i.e., feed information up and down from state to local models and vice versa).
      i. Ultimate goal of model is to evaluate how well a project will do (and with what uncertainty risk) (i.e., sensitivity analysis)
   b. Both C2VSim and CVHM coming out with updates soon, though differences highlighted during TC meetings will remain in updated versions. Updated model releases: SVSim by end of 2017, C2VSim CG by summer 2017 and FG likely early 2018, and CVHM waiting on MODFLOW release (likely summer 2017)
   c. Tabulated model differences/methodologies in report
   d. To minimize conflict in numbers, consider using same model as neighboring subbasins
8. Example of interbasin flows across county line (Vina subbasin) included in appendix to provide an example of how to look at data and will focus on the differences between interbasin flows
9. Relative differences between scenarios more useful than absolute values
10. Include specific recommendations (for local agencies) for approach by sustainability indicator (represent information in a matrix)
11. Conclusions and Recommendations
    a. Specific recommendations geared toward North Sacramento Valley, statewide application, and DWR/USGS
    b. Northern Sacramento Valley highlights:
       i. Significant foothill groundwater use
       ii. Consider:

1. Compare local surface layer model (i.e., water budget model) to C2VSim/CVHM
2. Local groundwater model (e.g., Butte basin)
3. SVSim conceptual model and texture model

iii. Don't mix and match groundwater model/local data
iv. Interbasin flows driven by pumping, climate, crop, transfers, etc.
v. 5 sustainability indicators (salt water intrusion not an issue)

c. Statewide application highlights:
   i. Model differences vs. absolute numbers (risk tolerance/adaptive management, sensitivity analysis)
   ii. Model status- CVHM (late summer), C2VSim (FG early 2018, CG summer), SVSim (late 2017)
   iii. Consider how to deal with disagreement in models (e.g. boundaries)
   iv. Water budgets by water year type
   v. How to include information from existing tools (e.g. G-C ID)
   vi. USGS natural recharge model
   vii. Consider what model your neighbor is using

d. Recommendations for DWR/USGS highlights:
   i. Support funding- legislature, justification (local needs and support of 2 models)
   ii. Provide a workplan
   iii. Continuous updating and long-term improvement
   iv. Linkage with local models- Process for local data submittal and for inclusion in models or SGMA group
   v. Groundwater/surface water interaction- Update gage surveys for stage to minimize uncertainty

Project Schedule

1. Last TC meeting (Meeting #5) in 2 weeks on April 26, 2017
2. Complete TC review of report by late May
3. Report presented to NSV IRWM board meeting on June 5, 2017
4. Project continues through June 30, 2017 to allow for final edits after board meeting

Meeting Summary

Interbasin Groundwater Flow Evaluation Project

Subject: Technical Collaborators Meeting #5

Prepared By: Dominick Amador

Date/Time: April 26, 2017
10:00am-12:00pm

Location: RMC Water and Environment
1545 River Park Drive, Suite 425
Sacramento, CA 95815

Meeting Attendance

• Technical Collaborators: o Charlie Brush (DWR) o Christina Buck (Butte County) o Bill Ehorn (DWR, NSVIRWM TAC) o Allan Fulton (UC Cooperative Extension, NSVIRWM TAC) o Thomas Harter (UC Davis) o Peter Lawson (CH2M Hill) o Vickie Newlin (Butte County, NSVIRWM TAC Chair) o Ben Pennock (Glenn Colusa ID, NSVIRWM TAC) o Steve Phillips (USGS) o Mary Randall (DWR) o Ali Taghavi (RMC) o **Phone -** Claudia Faunt (USGS) o **Phone -** Oscar Serrano (Colusa Indian Community Council, NSVIRWM TAC) • Absent: o Grant Davids (Davids Engineering) o Steffen Mehl (CSU Chico)	• Other: o Jim Blanke (RMC) o Reza Namvar (RMC) o Dominick Amador (RMC)

Meeting Objectives

- Receive input from TC on the content of the draft report.

Discussion Summary

Recap of Previous TC Meetings

1. Report Outline
    a. Aim to have a concise, high level report with technical analysis in appendices
    b. All TC members may contribute via Google Document link
2. Discussion Highlights

    a. No model recommendation. No model was developed with SGMA in mind and all models require refinement to be truly suitable for use in SGMA.
    b. Relative differences between scenarios more useful than absolute values.
    c. Have specific recommendations for approach by sustainability indicator (matrix).
3. Conclusions and Recommendations
    a. Specific recommendations geared toward North Sacramento Valley, statewide application, and DWR/USGS

Report Discussion

4. How to handle multiple models
    a. It is important for local agencies to acknowledge that differing models may show conflicting results but this does not mean that a specific model is incorrect.
    b. The DWR and USGS are currently working together to develop common terminology across modeling platforms, particularly as it pertains to model output.
    c. The committee recommends that the DWR and USGS develop water budgets for each published version of their regional models to assist with local agency consumption.
5. Uncertainty in groundwater modeling
    a. Model development and future updates carry a degree of variance and may change local water budget components.
        i. Most modeling updates are due to improvements in available data rather than changes numerical processes.
        ii. The committee encourages open communication between local agencies and model developers. Sharing high-quality data will improve accuracy and lower the costs of needed refinement.
    b. Local agencies should acknowledge that there is a degree of uncertainty associated with any modeling effort, and plan accordingly.
        i. The committee recommends that the report include a section on uncertainty analysis; what it is, why it is important, and when it should be done. Particularly highlighting how uncertainty should feed into basin management.
        ii. Modeling the groundwater system and working towards sustainability is an iterative process and agencies should utilize adaptive management practices.
6. Local modeling efforts
    a. Coordination between local agencies and the DWR/USGS may be needed to understand the interaction between conflicting models, particularly when simulating boundary conditions.
        i. Charlie recommends the use of boundary flows rather than general head boundary conditions. Models using similar heads can have significant variance in flow and when calibrating to specified flow, it is important to include simulated heads in the analysis.
        ii. Due to the nature of conflicting modeling results, local Groundwater Sustainability Plans (GSPs) should account for levels of uncertainty when developing their management practices and plan for an iterative process through adaptive management.
7. Comments on the Project Report were discussed and will be considered.

Schedule Adjustments

8. 04/28/2017 The current phase of commenting and direct editing of the report though Google Documents will be completed by the Technical Collaborators.
9. 05/05/2017 RMC to have incorporated all suggested comments for further review by the Technical Advisory Committee (TAC).
10. 05/19/2017 Christina will summarize all TAC comments and provide them to RMC by close of business.
11. 05/27/2017 RMC to review and address additional comments suggested by the TAC and provide a draft report to the Technical Collaborators for review and consideration.

Appendix C - Inventory of Groundwater Models Technical Memorandum

Technical Memorandum

Interbasin Groundwater Flow Evaluation

Subject:	**Inventory of Groundwater Models**
Prepared For:	Butte County Department of Water and Resource Conservation
Prepared by:	Sara Miller and Craig Altare, P.G.
Reviewed by:	Jim Blanke, P.E., P.G., C.Hg.
Date:	September 21, 2016
Reference:	

This Technical Memorandum (Tech Memo) contains an inventory of numerical hydrologic models capable of simulating interbasin groundwater flow in the Northern Sacramento Valley Integrated Regional Water Management (NSVIRWM) plan area.

1 Study Area

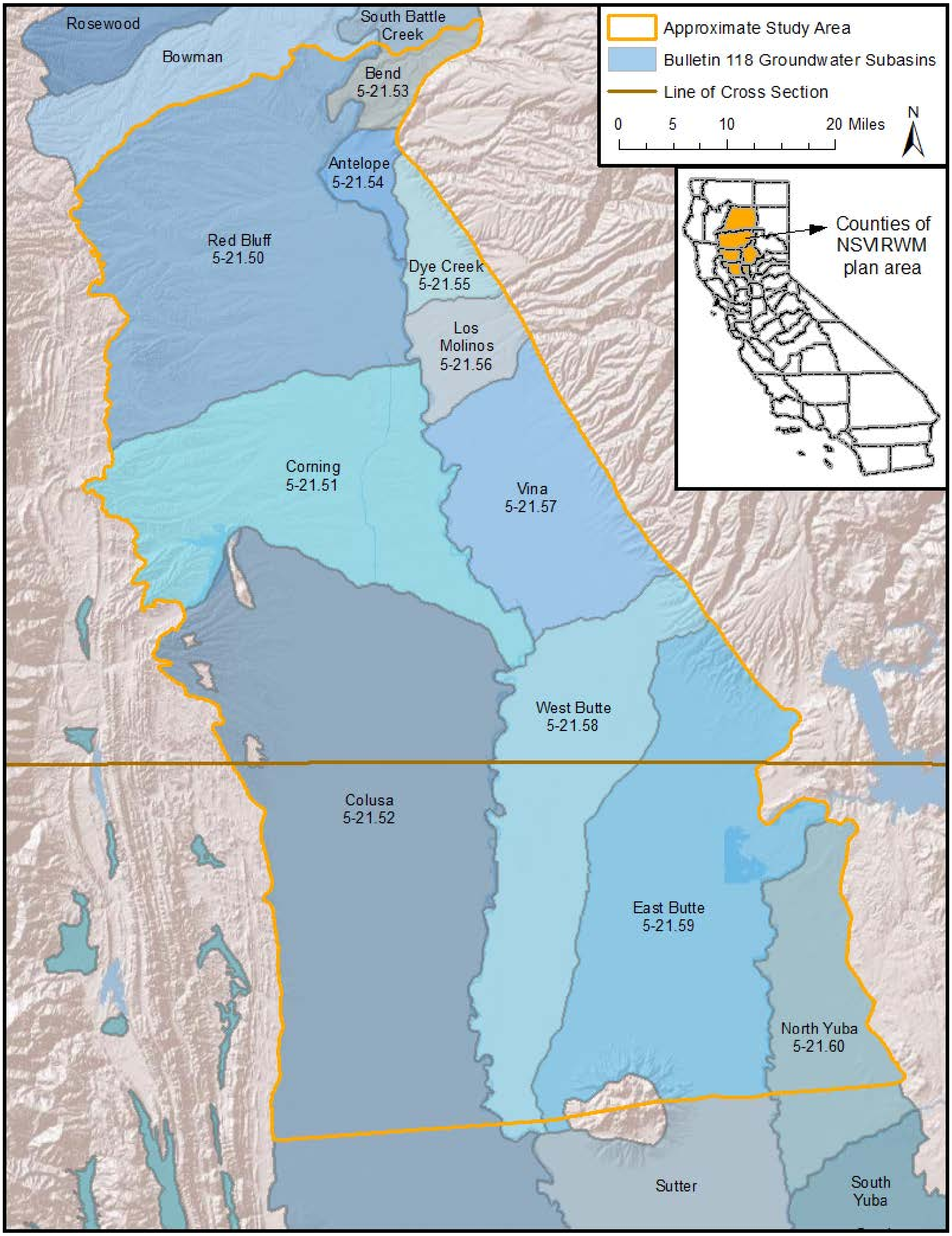
The NSVIRWM plan area is made up of six counties—Butte, Colusa, Glenn, part of Shasta, Sutter, and Tehama—in the northernmost part of California's Central Valley (inset in Figure 1). A portion of the NSVIRWM Area constitutes the study area and includes the area bounded to the north, west, and east by the extent of the Sacramento Valley Groundwater Basin and to the south by the Sutter Buttes. Eleven groundwater subbasins (all part of the Sacramento Valley Groundwater Basin) underlie the study area and are the focus of interbasin flows in the study:

1. Red Bluff (5-21.50)
2. Corning (5-21.51)
3. Colusa (5-21.52)
4. Bend (5-21.53)
5. Antelope (5-21.54)
6. Dye Creek (5-21.55)
7. Los Molinos (5-21.56)
8. Vina (5-21.57)
9. West Butte (5-21.58)
10. East Butte (5-21.59)
11. North Yuba (5-21.60)

These groundwater subbasins are shown in Figure 1. All of the subbasins, except for Bend, were categorized as either being medium or high priority under the California Statewide Groundwater Elevation Monitoring (CASGEM) program in June 2014. None of the subbasins were designated as critically overdrafted by the Department of Water Resources (DWR) as of January 2016.

Figure 1 also shows the approximate bounds of the study area. The study area contains all of the subbasin connections for the subbasins listed above (e.g., Corning–Red Bluff, Corning–Los Molinos, Corning–Vina, Corning–West Butte, Corning–Colusa, etc.).

Figure 1: Groundwater Subbasins in Study Area



2 Interbasin Groundwater Flow and the Sustainable Groundwater Management Act

The 2014 Sustainable Groundwater Management Act (SGMA) established new requirements for groundwater management of medium and high priority groundwater basins or subbasins (referred to hereafter collectively as basins). All critically overdrafted basins (i.e., none of the study area subbasins) must have Groundwater Sustainability Plans (GSPs) by January 31, 2020; all other medium and high priority basins must complete GSPs by January 31, 2022.

In the GSP regulations[1], DWR recognizes that groundwater conditions in one basin may be affected by groundwater management practices in adjacent, hydrologically-connected basins. Each GSP must demonstrate that management activities within a basin will have no adverse impacts on sustainable management of adjacent basins. Therefore, it is important that agencies planning to develop and execute GSPs understand the hydrologic connections between adjacent groundwater basins and how different groundwater models deal with subsurface flows across those boundaries.

Article 8 of the GSP regulations describes interbasin agreements, which are optional interagency agreements for hydrologically connected basins. These interbasin agreements are to include an estimate of groundwater flow across basin boundaries developed using consistent and coordinated data, methods and assumptions; estimates of stream-aquifer interactions at the boundary; and a common understanding of the hydrogeology and hydrology of the basins. Though they are optional, it is likely that DWR will view them favorably when evaluating the interaction of multiple GSPs in adjacent basins.

3 Models Selected to Evaluate Interbasin Groundwater Flow

The first task in the Interbasin Groundwater Flow Evaluation Project is an inventory of numerical hydrologic models capable of simulating interbasin groundwater flow. The models are generally categorized as either regional or local. For this study, regional models are those covering at least an entire Bulletin 118 groundwater basin. Examples include the California Central Valley Groundwater-Surface Water Simulation Model (C2VSim), Central Valley Hydrologic Model (CVHM), and Sacramento Valley Finite Element Groundwater Model (SACFEM2013), all of which cover the Sacramento Valley Groundwater Basin at a minimum. Local models are those simulating only a portion of a groundwater basin, for example several subbasins within and adjacent to a given county. Examples of local models include the Butte Basin Groundwater Model (BBGM) developed by Butte County and the Stony Creek Fan Model (SCF Model) developed by DWR. The horizontal extent of the active domain for each of the models in the study area is shown in Figure 2. Cross sections through all models except SACFEM2013 are shown on Figure 3 (see Figure 1 for line of section). Each cross section shown on Figure 3 uses a consistent camera origin and focal point, which results in a consistent perspective and vertical axis for each pane of the figure. This allows for comparison between models (e.g., to show that the BBGM extends to a greater depth than the other models included for comparison).

A brief description of each model described above is provided below, including the historical calibration period, horizontal and vertical extent and discretization, and modeling code and packages used. Each description includes details on model features relevant to the simulation of interbasin groundwater flow and a summary of those features are shown on Table 1 for all the models. Note that this inventory report is not an exhaustive review and comparison of each model. However, we have included references to the most recent development information and reports for each model. Also note that this analysis focuses on models

[1] http://www.water.ca.gov/groundwater/sgm/pdfs/Proposed_GSP_Regs_2016_05_10.pdf

that are complete as of the time this memo was developed. DWR is developing a new model of the Sacrament Valley, named the Sacramento Valley Simulation Model (SVSim), but it is not complete. SVSim is being developed to evaluate water transfer projects in the Sacramento Valley, and will be more refined than the fine grid version of C2VSim, both in terms of horizontal and vertical discretization and input datasets.

Figure 2. Groundwater Model Grids

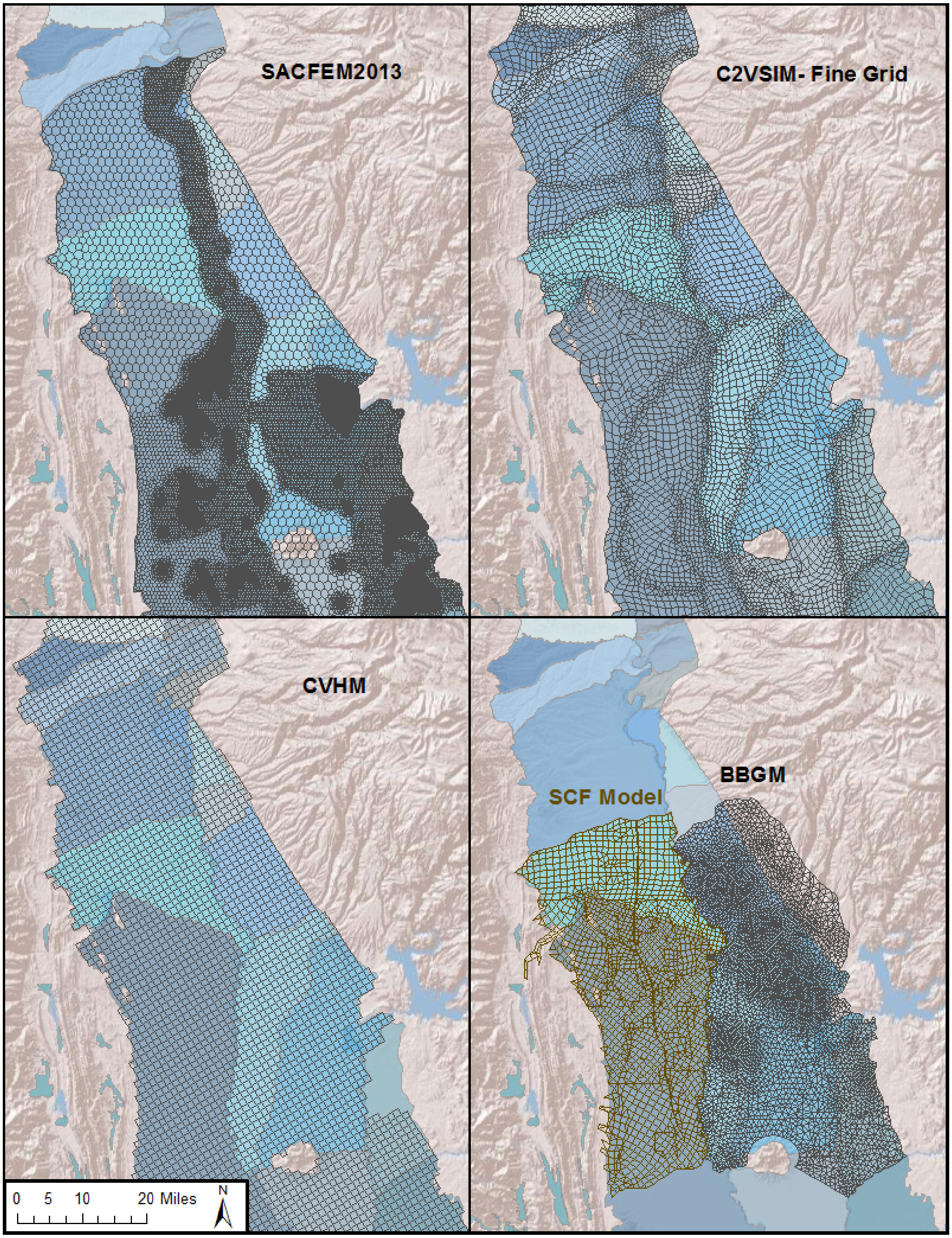
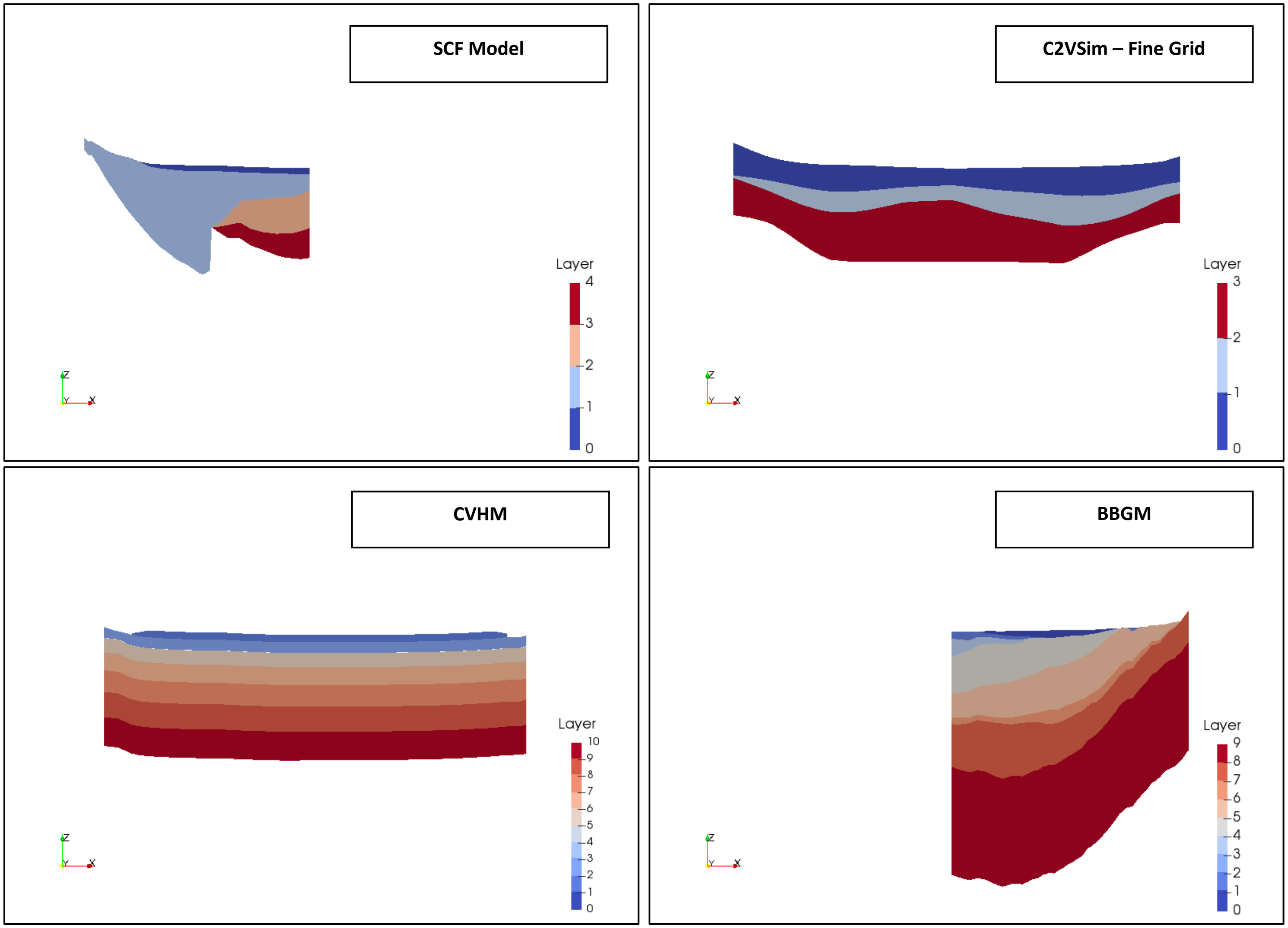


Figure 3. Model Cross Sections



Note: See Figure 1 for line of section. Viewing direction is to the north. Camera origin and focal point are the same for each figure, resulting in a consistent vertical scale for each pane of the figure

Table 1: Study Area Model Components

Key Feature	C2VSim	CVHM	SACFEM2013	BBGM	SCF Model
Code Platform	IWFM	MODFLOW-FMP	IDC coupled with MicroFEM	IWFM	IGSM
Public Domain Code	Yes	Yes	Yes for IDC; MicroFEM is proprietary	Yes	Yes
Model Ownership	DWR	USGS	Reclamation	Butte County	DWR
Availability	Course grid available on DWR website and fine grid available upon request to DWR	Available on USGS website	Uncertain	Available upon request to Butte County	Available upon request to DWR
Documentation	Available on DWR website	Available on USGS website	Available online	Available on Butte County website	Available upon request to DWR
Integrated Model	Yes	Yes	Partially: two separate codes used to simulate hydrologic processes	Yes	Yes
Geographic Area	Central Valley	Central Valley	Sacramento Valley Groundwater Basin	Groundwater Subbasins in Butte County (including East Butte, West Butte, Vina, North Yuba, and portions of Sutter)	Corning Subbasin and northern Colusa Subbasin
Simulation Period (Water Years)	1921 - 2009	1961 - 2003	1970 - 2010	1970 - 2014	1970 - 2000
Number of Layers	3	10	7	9	4

Key Feature	C2VSim	CVHM	SACFEM2013	BBGM	SCF Model
Geologic Formations Represented in the Model	Generalized upper unconfined aquifer, confined production zone, deep confined zone	Layers not explicitly tied to hydrogeologic units except for Corcoran Clay in the San Joaquin Valley, remainder based on sediment texture model	Layers not explicitly tied to hydrogeologic units except for portions of the Tuscan Formation	Holocene basin deposits, Alluvium, Sutter/Laguna Formation, Tehama Formation, Tuscan C/B/A Formations, older marine (Neroly, Upper Princeton Gorge, Ione)	Alluvial and basin deposits, Tehama Formation, Upper Tuscan Formation, and Lower Tuscan Formation
Agricultural Demand Estimation Method	Integrated methodology using IDC	Integrated methodology using the Farm Process	Calculated externally by IDC	Integrated methodology using IDC	Integrated methodology using IGSM Ag Demand Package
Stream-Aquifer Interaction Method	Integrated methodology using IWFM Stream Package	Integrated methodology using MODFLOW Streamflow Routing Package	Limited; fixed head boundary condition for river stages	Integrated methodology using IWFM Stream Package	Integrated methodology using IGSM Stream Package

Note: Descriptions in this table may not reflect ongoing, unpublished updates to these models.

3.1 C2VSim

C2VSim[2] is a regional numerical hydrologic model covering the approximately 20,000 square miles (i.e. 12.8 million acres) of California's Central Valley. C2VSim was originally developed in 1990 for DWR, U. S. Bureau of Reclamation, and the State Water Resources Control Board as the Central Valley Groundwater and Surface water Model (CVGSM). The model was upgraded in 2005 to the public domain IWFM platform and was renamed C2VSim. IWFM, also developed by DWR, is an open source finite element simulation code that supports triangular and quadrilateral elements. C2VSim has been used in numerous applications, including planning studies, climate change assessments, improved understanding of stream–groundwater flows, groundwater storage investigations, ecosystem enhancement scenarios, infrastructure improvements, and Delta flows specific studies. IWFM and C2VSim are both specifically designated as useful in developing water budgets for SGMA compliance, though other models or codes may be used.

There are two versions of C2VSim maintained by DWR, a coarse-grid version (C2VSim-CG) and a fine-grid version (C2VSim-FG). C2VSim-CG is publically available for download from DWR, while C2VSim-FG is under refinement and calibration. Both versions are currently being updated through 2015.

[2] http://baydeltaoffice.water.ca.gov/modeling/hydrology/C2VSim/index_C2VSIM.cfm

This Tech Memo will focus on the fine-grid version of C2VSim; all references to C2VSim hereafter refer to C2VSim-FG.

C2VSim currently contains monthly historical stream inflows, surface water diversions, precipitation, land use, and crop acreages from October 1921 through September 2009. C2VSim dynamically calculates crop water demands; allocates contributions from precipitation, soil moisture, and surface water diversions; and calculates groundwater pumping required to meet the remaining demand. The model simulates the historical response of the Central Valley's groundwater and surface water flow system to historical stresses.

The C2VSim grid has more than 32,000 elements and 30,000 nodes, with an average element area of approximately 400 acres. The C2VSim model grid, which covers the entire Central Valley, is shown for the study area in Figure 2. C2VSim is vertically discretized into 3 aquifer layers and 1 aquiclude with a generalized upper unconfined aquifer, a confined production zone, and a deep confined zone. Additional details of C2VSim are provided in Table 1.

3.2 CVHM

CVHM[3] is a regional model developed by the U.S. Geological Survey (USGS) to simulate historical hydrology and groundwater conditions of California's Central Valley. Some applications have included simulating land subsidence, determining groundwater availability in the Central Valley, and evaluating the effect of climate change on streamflow, demands, and other hydrology. CVHM utilizes USGS' open source MODFLOW code plus the Farm Process Package, Stream Flow Routing, Basin Characteristics Model, Subsidence, and Flow Barriers modules and simulates conditions from October 1961 through September 2003. CVHM, like C2VSim, accounts for historical stream inflows, surface water diversions, precipitation, land use, and crop acreages. USGS developed a Central Valley sediment texture model to account for the heterogeneous distributions of fine and coarse grained materials that control groundwater flow. Although not yet released, USGS is reportedly updating CVHM to simulate recent conditions and to use a new simulation code, MODFLOW-One Water Hydrologic Model (OWHM).

CVHM contains about 20,000 elements with a uniform cell size of 640 acres (i.e., 1 square mile) and covers approximately 20,000 square miles (12.8 million acres) of the Central Valley. The subsurface is simulated using 10 layers. Additional details of CVHM are provided in Table 1.

3.3 SACFEM2013

SACFEM2013[4] is a regional model that uses the proprietary MicroFEM model for simulation of groundwater flow and the IWFM Demand Calculator model (IDC) for simulation of land surface processes. SACFEM2013, originally developed in 2008, links the groundwater model with the surface water budget and root zone model (i.e., IDC model) to estimate deep percolation and agricultural pumping on a node by node basis from October 1969 through September 2010. SACFEM2013 was primarily developed as a tool to estimate the impact of conjunctive water management projects on surface water and groundwater resources within the Sacramento Valley. RMC performed a peer review of SACFEM in 2011[5]. SACFEM2013 was used to evaluate water transfers to mitigate Central Valley Project supply shortages for

[3] http://ca.water.usgs.gov/projects/central-valley/central-valley-hydrologic-model.html

[4] SACFEM2013: Sacramento Valley Finite Element Groundwater Flow Model User's Manual, February 2015. Prepared for U.S. Bureau of Reclamation by CH2M HILL and MBK Engineers, Inc.

[5] Technical Memorandum: Peer Review of Sacramento Valley Finite Element Groundwater Model (SACFEM), October 2011. Prepared for U.S. Bureau of Reclamation by WRIME, Inc. (now RMC).

the Long-Term Water Transfers Environmental Impact Statement/Environmental Impact Report (EIS/EIR) in 2014[6]. It was also reviewed as a part of the Review and Comments for the EIS/EIR.

SACFEM2013 covers the entirety of the Sacramento Valley Groundwater Basin (i.e., almost 6,000 square miles) and contains about 150,000 nodes and over 300,000 elements. Spacing between the nodes is as large as 3,300 feet and as small as 410 feet. The subsurface is simulated using 7 layers. Additional details of SACFEM2013 are provided in Table 1.

3.4 BBGM

BBGM[7] is a local model that uses the public domain IWFM code to simulate surface water and groundwater conditions in Butte County and selected surrounding areas from October 1970 through September 2014. Applications have included evaluating project feasibility, determining water budgets by model subregion, estimating changes to surface water availability, modeling climate change effects and system vulnerabilities, and assessing the effects of changing future demands. The model is a successor to the earlier Butte Basin Water Users Association Groundwater Model developed using the FEMFLOW3D code. Butte County staff and their consultants are currently updating the BBGM to utilize a newer version of IWFM. The update will allow for representation of additional complexity, including elemental land use distributions and details of water use for ponded crops (e.g., water use changes associated with laser levelling of rice fields).

The boundaries of the model are Deer Creek to the north, Sacramento River to the west, the Sutter Buttes and Yuba River to the south, and foothills to the east. The model covers about 1,200 square miles with nodes spaced between 2,500 and 5,000 feet that form over 7200 elements. The average element size is 112 acres and the model has 9 layers. BBGM contains portions of the Sacramento Valley Groundwater Basin—the Vina, West Butte, East Butte, Sutter, and North Yuba subbasins. Additional details of BBGM are provided in Table 1.

3.5 SCF Model

The SCF Model[8] is a local model developed for DWR and local program sponsors in 2003 to study Stony Creek Fan, a geologic feature in Glenn and Tehama Counties. The model has been used to evaluate changes in land and water use and make assumptions about the availability of water supply. The SCF Model is a comprehensive hydrologic model that simulates the surface water and groundwater flow systems using the public domain Integrated Groundwater-Surface Water (IGSM) code, which is a predecessor code to DWR's IWFM. The historical simulation period of the SCF Model is from 1970 through 2000. An extensive geologic analysis was conducted to develop model layering and parameters. The model simulates conditions in the Corning and northern Colusa groundwater subbasins, and includes the Tehama, Upper, and Lower Tuscan Formations. The calibration period of the model has not been updated since 2003 and we are not aware of any ongoing efforts to update this model.

At its largest points, the model extends about 30 miles from west to east and about 70 miles from north to south to cover an area of about 1,000 square miles covering the Corning groundwater subbasin and a portion

[6] http://www.usbr.gov/mp/nepa/nepa_projdetails.cfm?Project_ID=18361

[7] https://www.buttecounty.net/waterresourceconservation/Groundwater.aspx

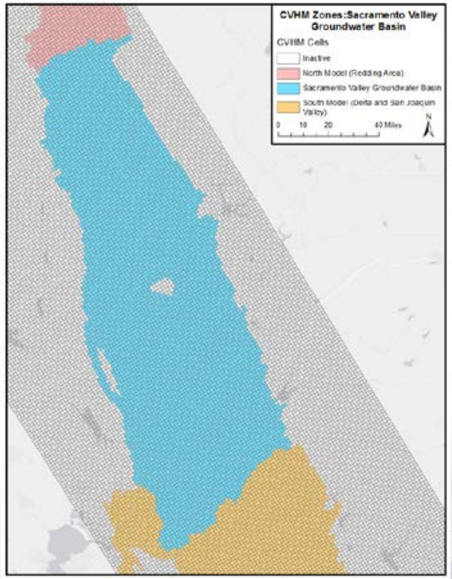
[8] Stony Creek Fan Integrated Groundwater and Surface Water Model (SCFIGSM): Model Development and Calibration Baseline Analysis, Volume 3 of 4, May 2003. Prepared for Glenn-Colusa Irrigation District, Orland-Artois Water District, and Orland Unit Water Users' Association by WRIME, Inc. (now RMC) in coordination with DWR.

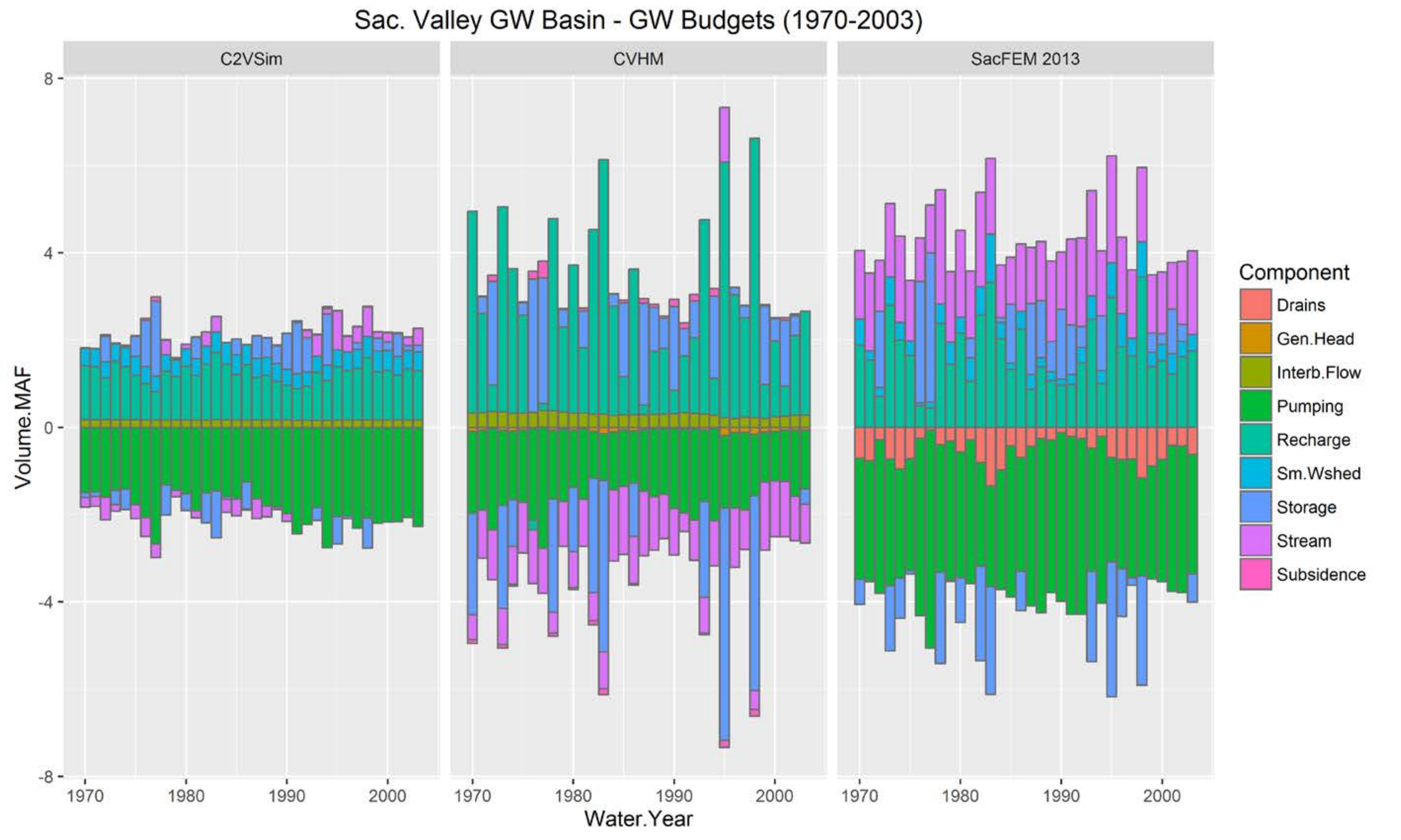
of the Colusa subbasin (i.e., approximately the same portion within the study area). The SCF Model grid is made up of over 2,000 elements and approximately 1,800 nodes. The subsurface is modeled using 4 layers. Additional details of the SCF Model are provided in Table 1.

Appendix D - Water Budget Assessment

3. Process for Water Budget Comparison

- If more than one model is suitable, how should we compare them?





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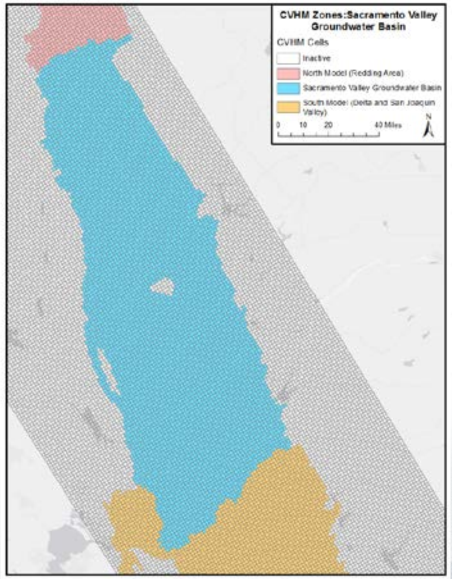
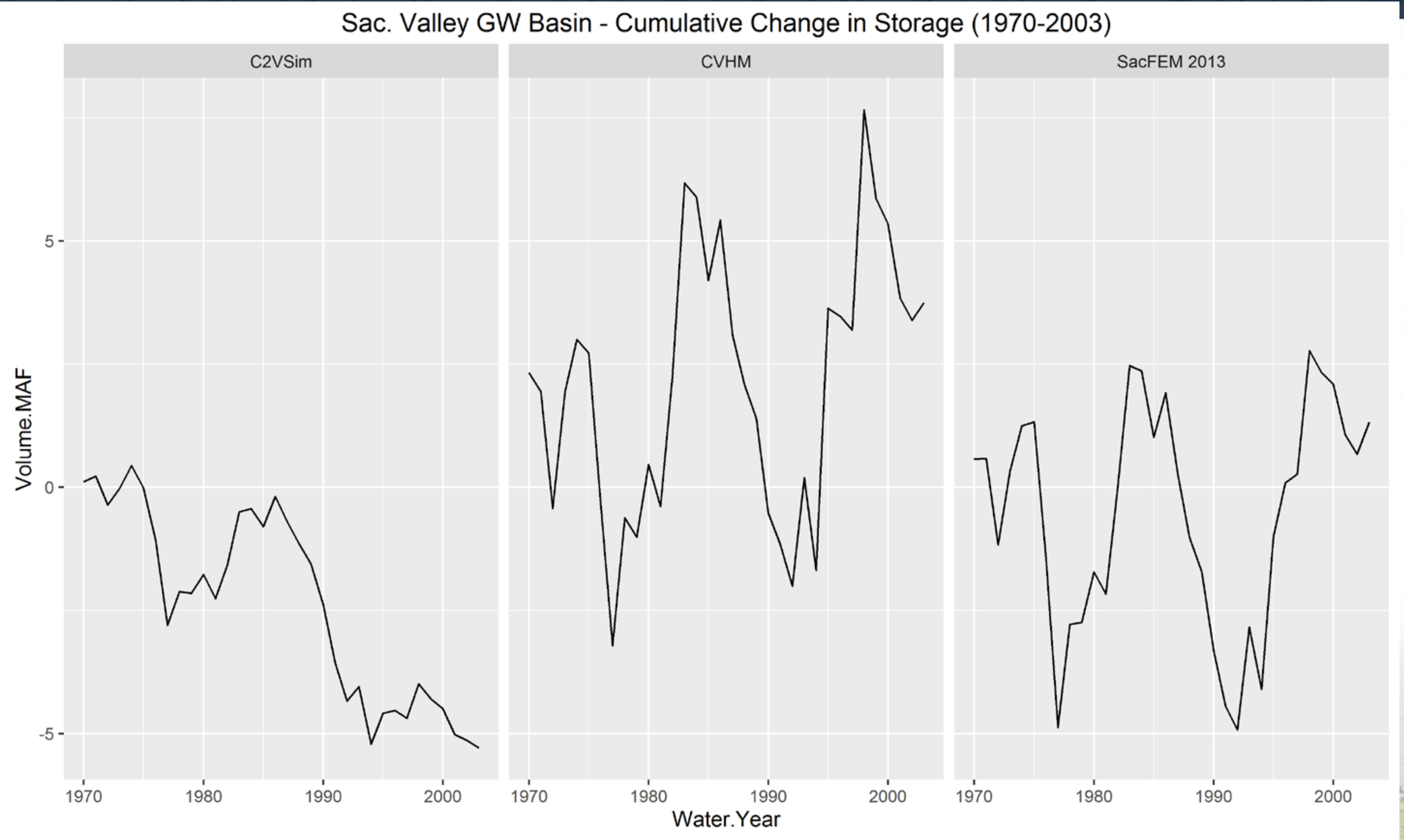
3. Process for Water Budget Comparison

- If more than one model is suitable, how should we compare them?





3. Process for Water Budget Comparison

- Describe best practices for comparing modeled water budgets
  - Which components are directly comparable
  - Which to aggregate
  - How to handle processes simulated by one model but not another

	C2VSim	CVHM2
Storage	GW STORAGE	STORAGE
Recharge	NET DEEP PERCOLATION + (?) DIVERSION RECOVERABLE LOSS + *(?) BYPASS RECOVERABLE LOSS*	FARM_NETRECHARGE
Pumping	PUMPING BY ELEMENT + PUMPING BY WELL	MNW2 + *FARM_WELLS*
Streams	STREAMS	STREAM_LEAKAGE
Small Watersheds	SMALL WATERSHED BASEFLOW + SMALL WATERSHED PERCOLATION	(?) SPECIFIED_FLOWS
Subsidence	SUBSIDENCE	INST_IB_STORAGE + DELAY_IB_STORAGE
Drains	*TILE DRAINS*	*DRAINS*
Interbasin Flow	FLOW FROM ZONE XXX / FLOW TO ZONE XXX	FLOW FROM ZONE XXX / FLOW TO ZONE XXX
Other Boundaries		HEAD_DEP_BOUNDS + *CONSTANT_HEAD*

Note: items in *Gray Italics* are not simulated in the Sacramento Valley GW Basin for these models

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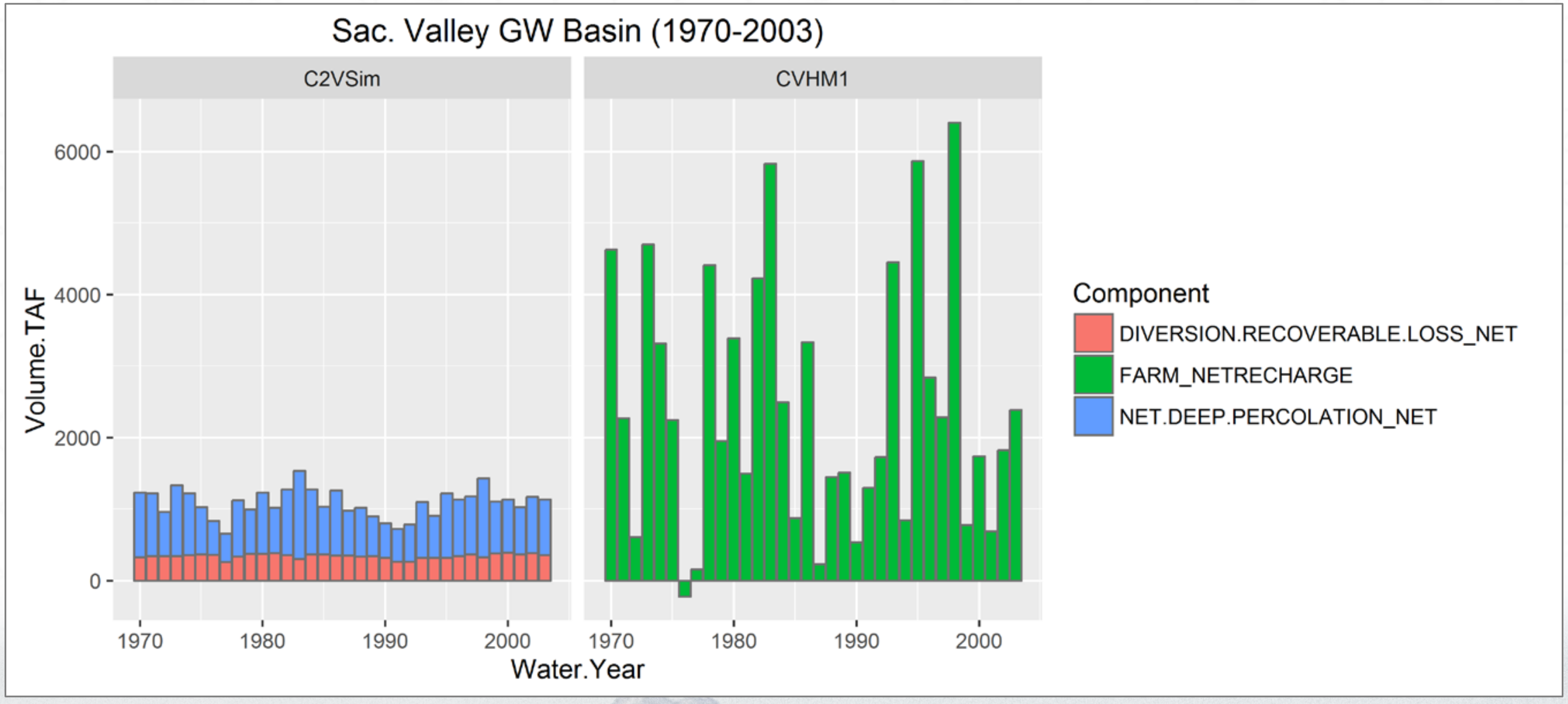
3. Process for Water Budget Comparison



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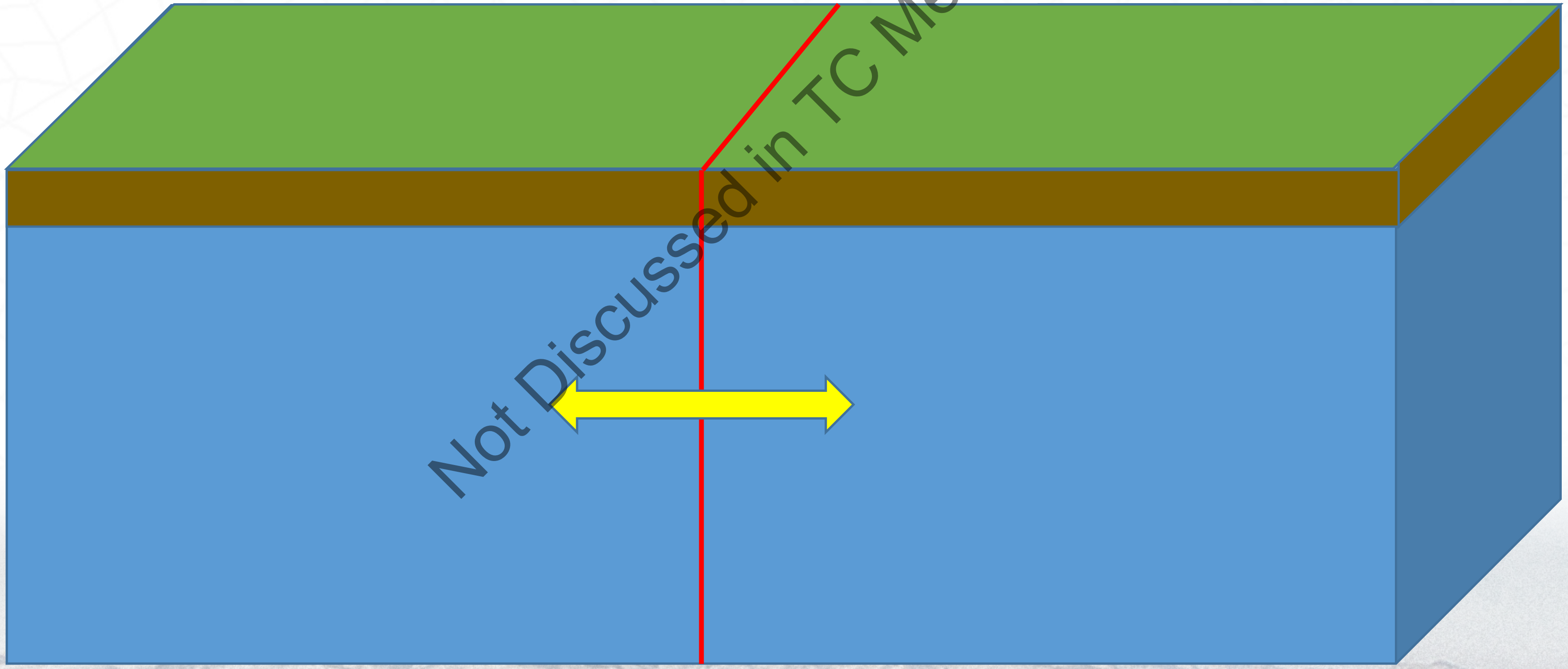
Appendix E - Interbasin Groundwater Flow Assessment

4. Evaluating Interbasin Flows Where the Boundary is Defined by a River/Stream

- Interbasin flow, generally, is the flow entering or leaving a (sub)basin from an adjacent, hydraulically connected (sub)basin



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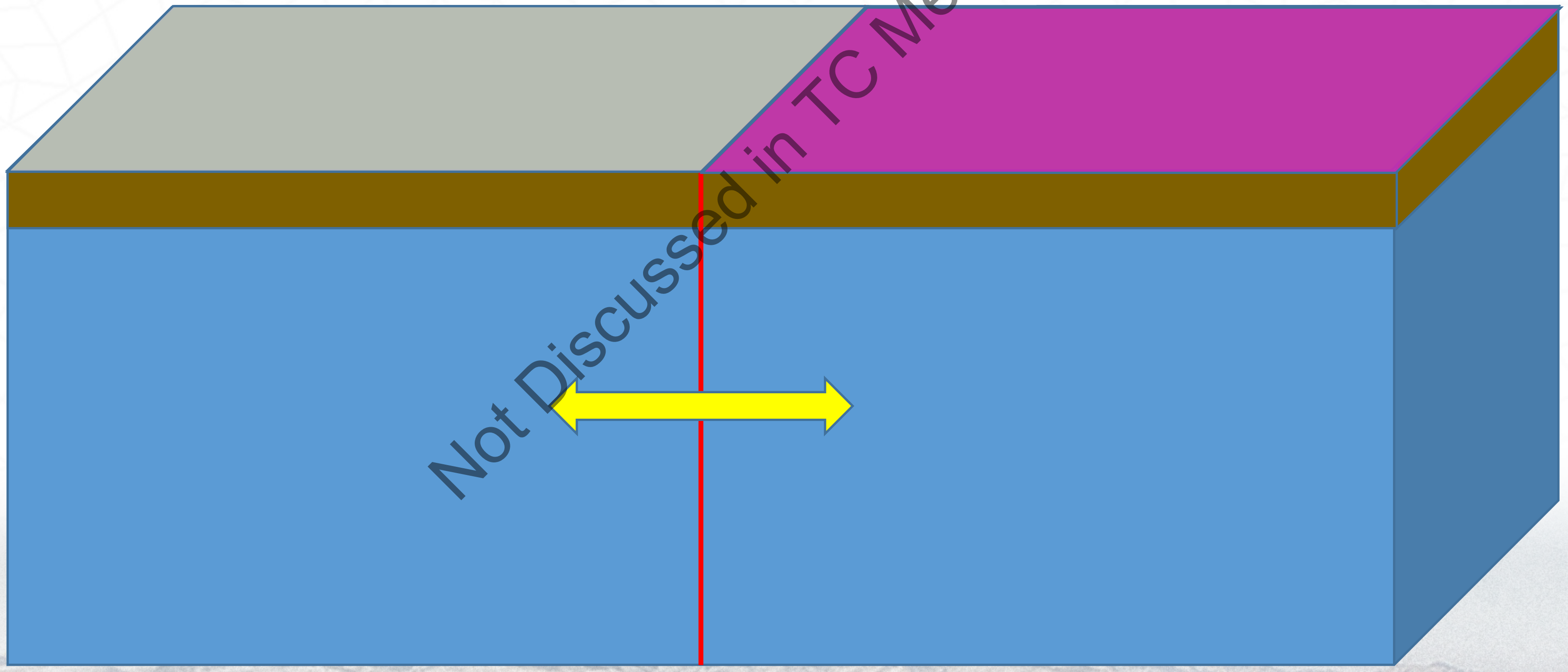
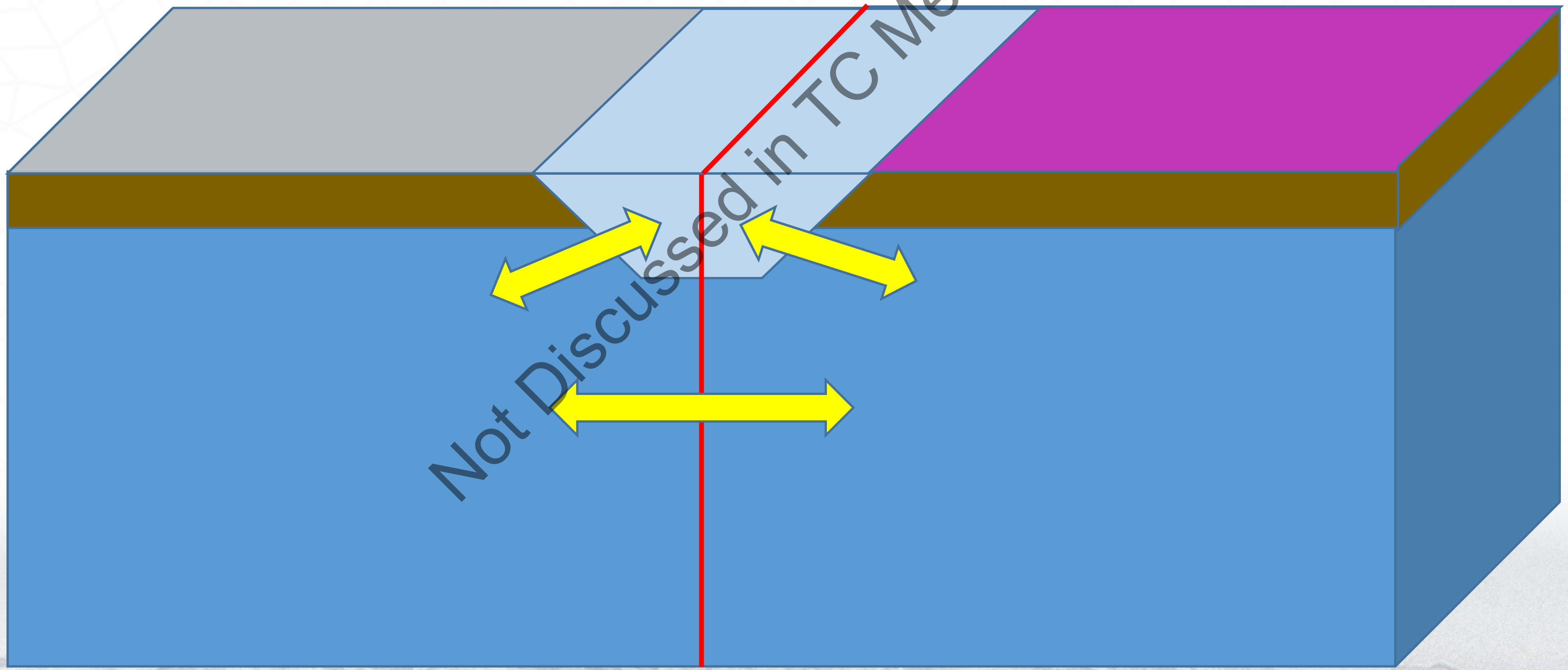
4. Evaluating Interbasin Flows Where the Boundary is Defined by a River/Stream

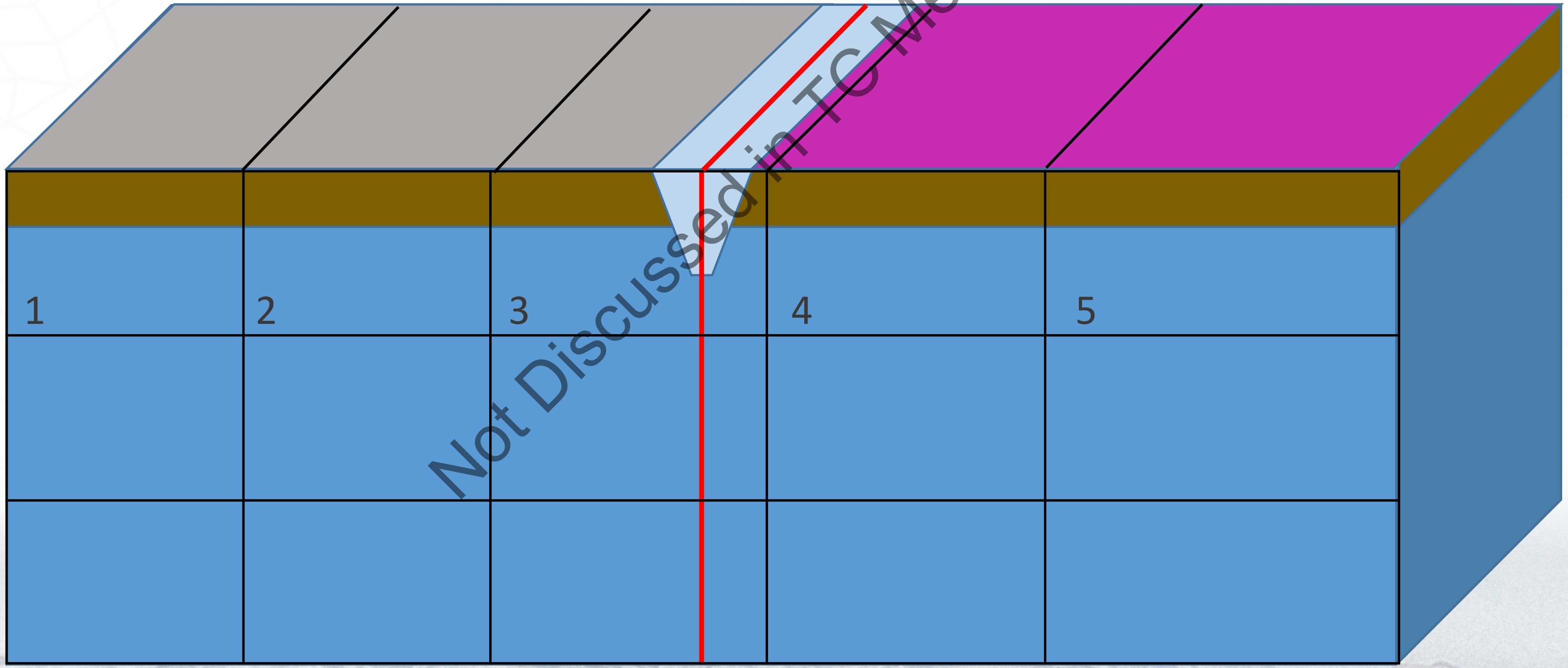


4. Evaluating Interbasin Flows Where the Boundary is Defined by a River/Stream

- Boundaries aligned with rivers and streams (as many in the state are) complicates the quantification of these flows



4. Evaluating Interbasin Flows Where the Boundary is Defined by a River/Stream



4. Evaluating Interbasin Flows Where the Boundary is Defined by a River/Stream

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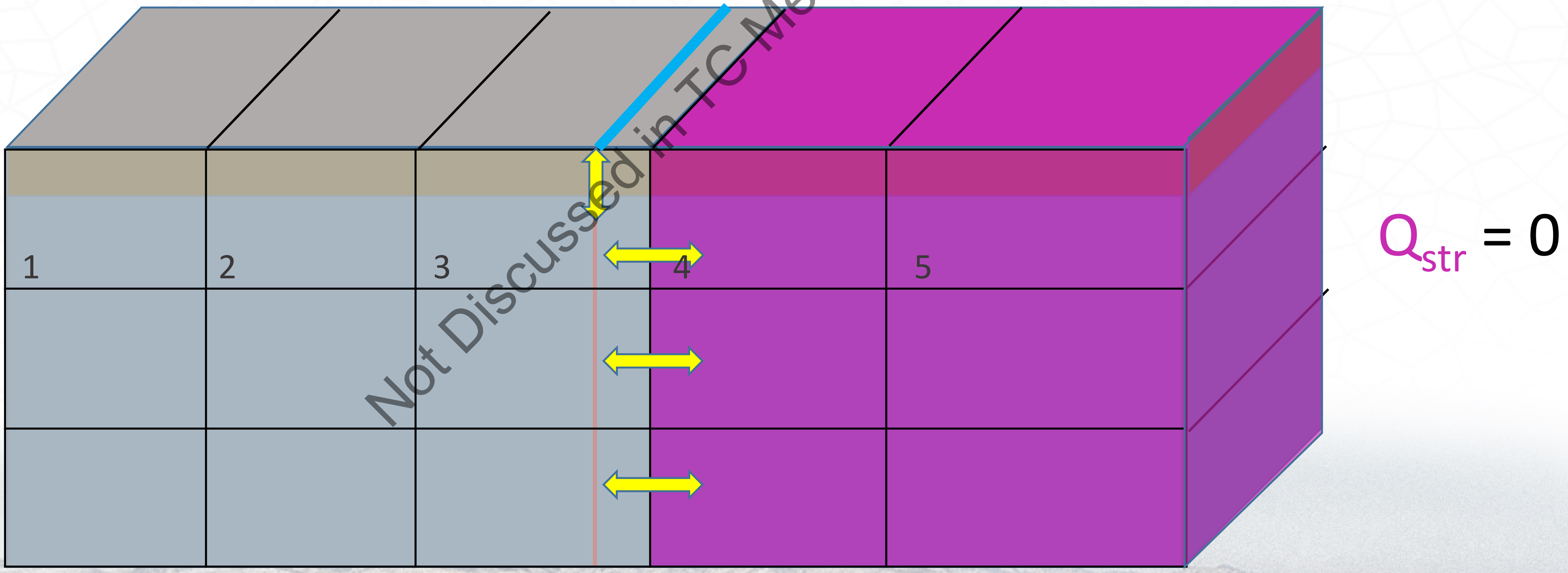

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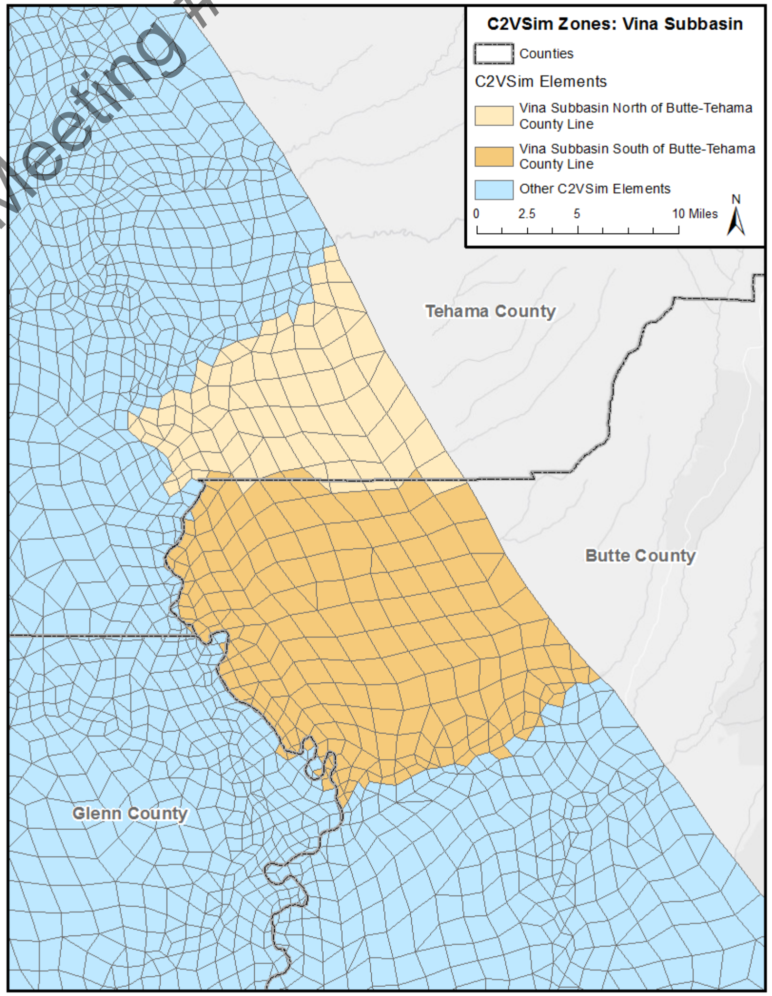
Example of Interbasin Flow Budget Information

- Using C2VSim
- Split Vina Subbasin into two hypothetical subbasins along county line -> North Vina and South Vina
- Budget information presented below is from the perspective of South Vina (darker orange area on figure to the left)



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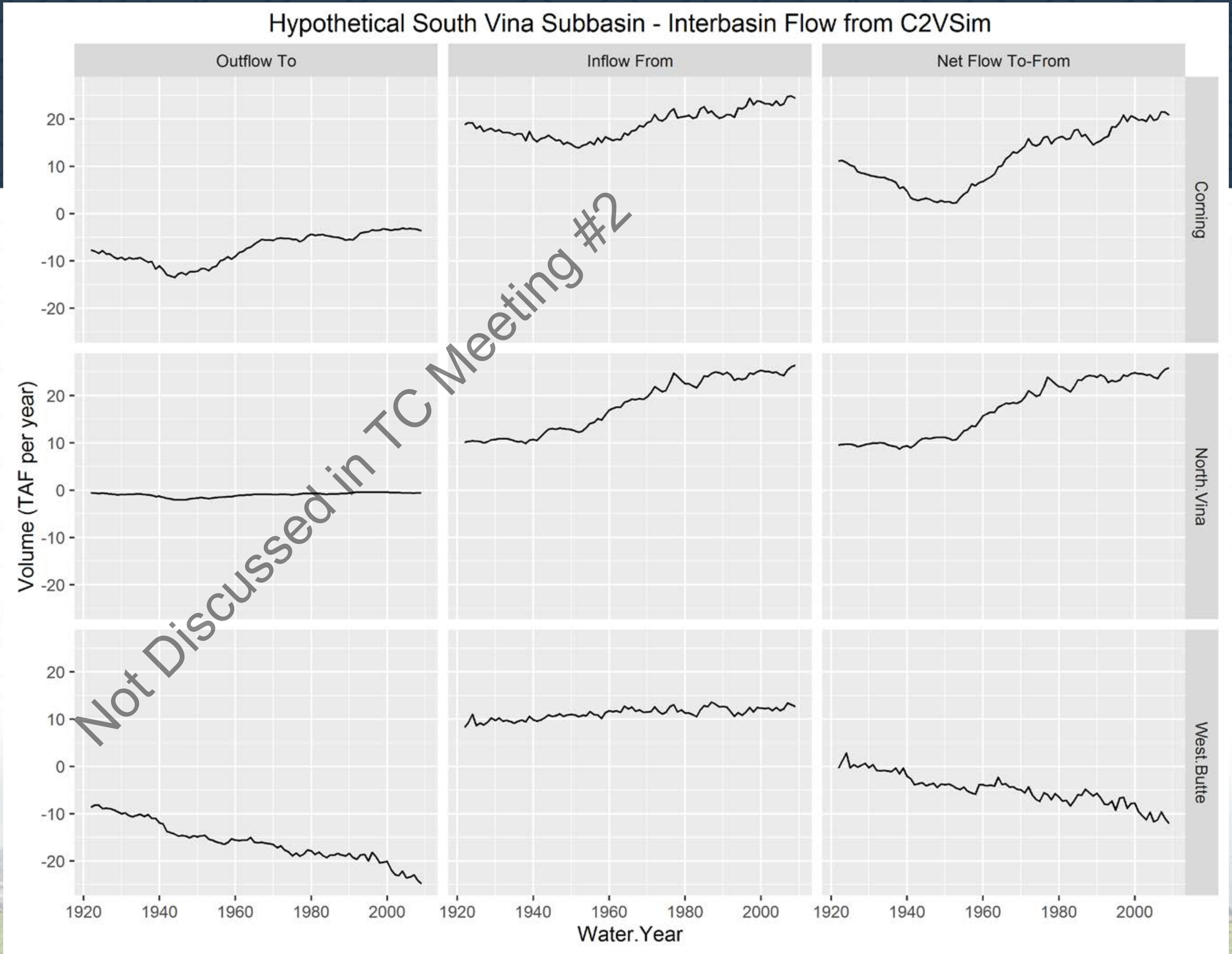
- Evaluated subsurface inflow and outflow, by layer, into/out of hypothetical South Vina Subbasin from:
  - Corning
  - North Vina
  - West Butte



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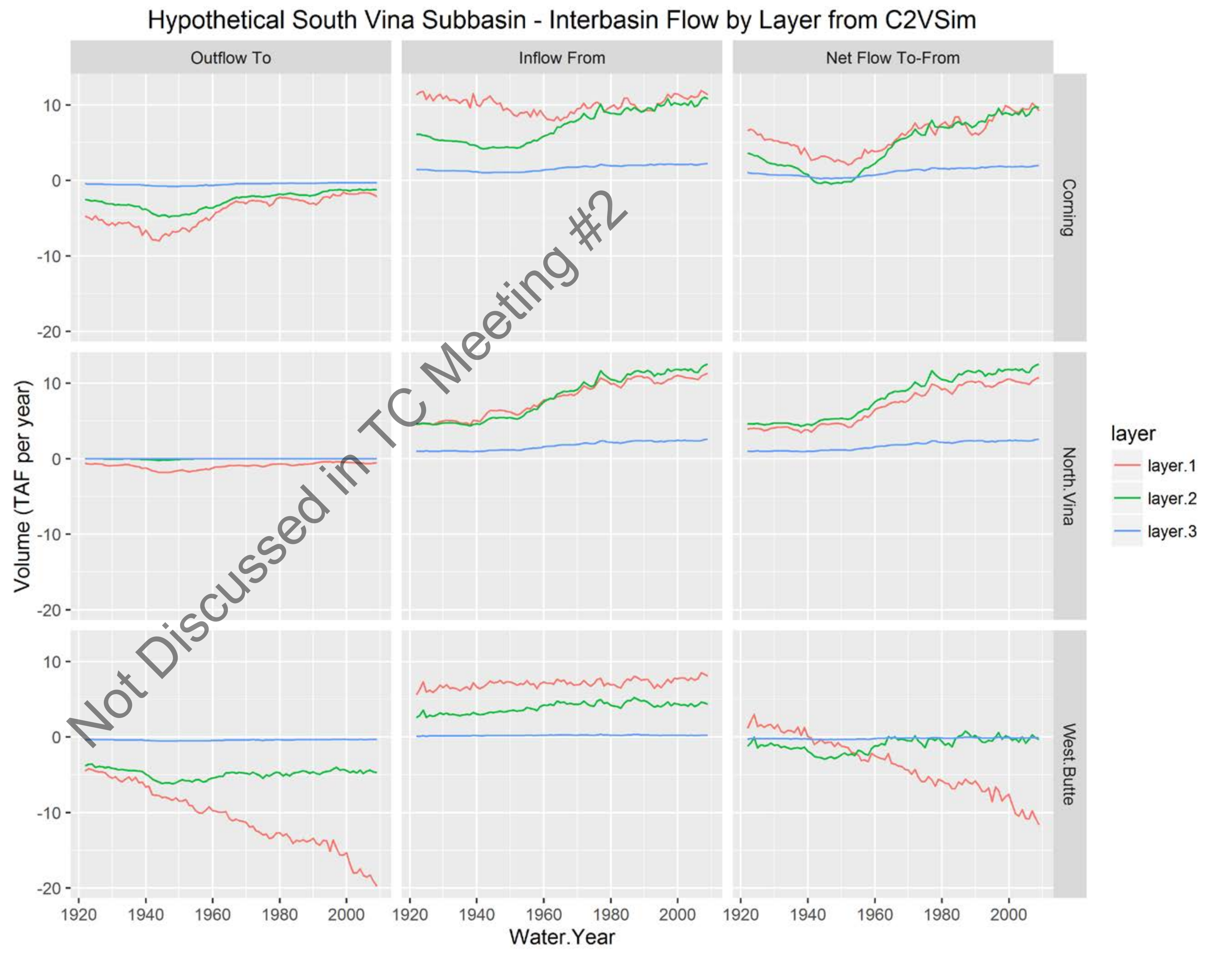
- Evaluated subsurface inflow and outflow, by layer, into/out of hypothetical South Vina Subbasin from:
  - Corning
  - North Vina
  - West Butte



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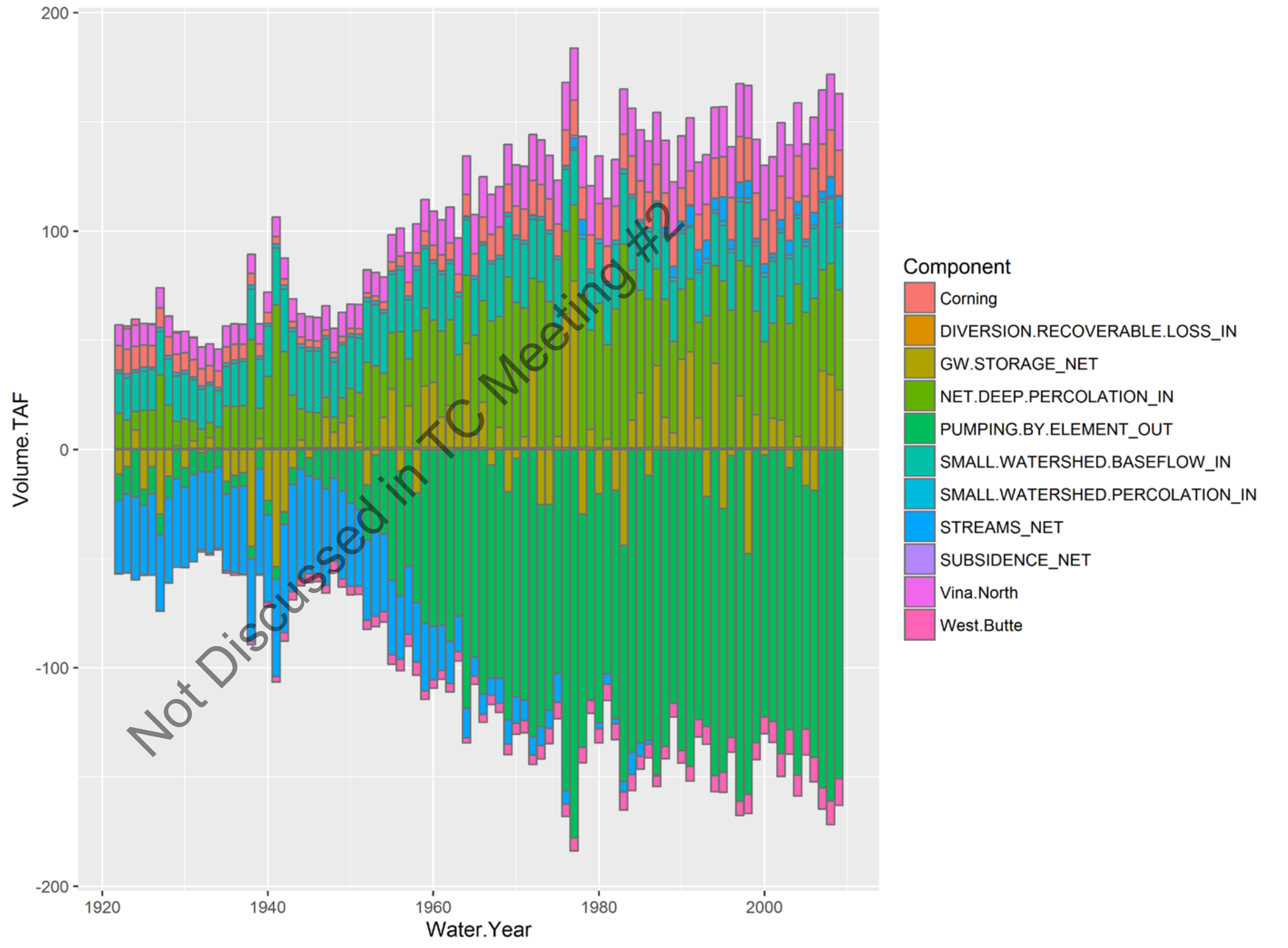
Hypothetical South Vina Subbasin Total GW Budget



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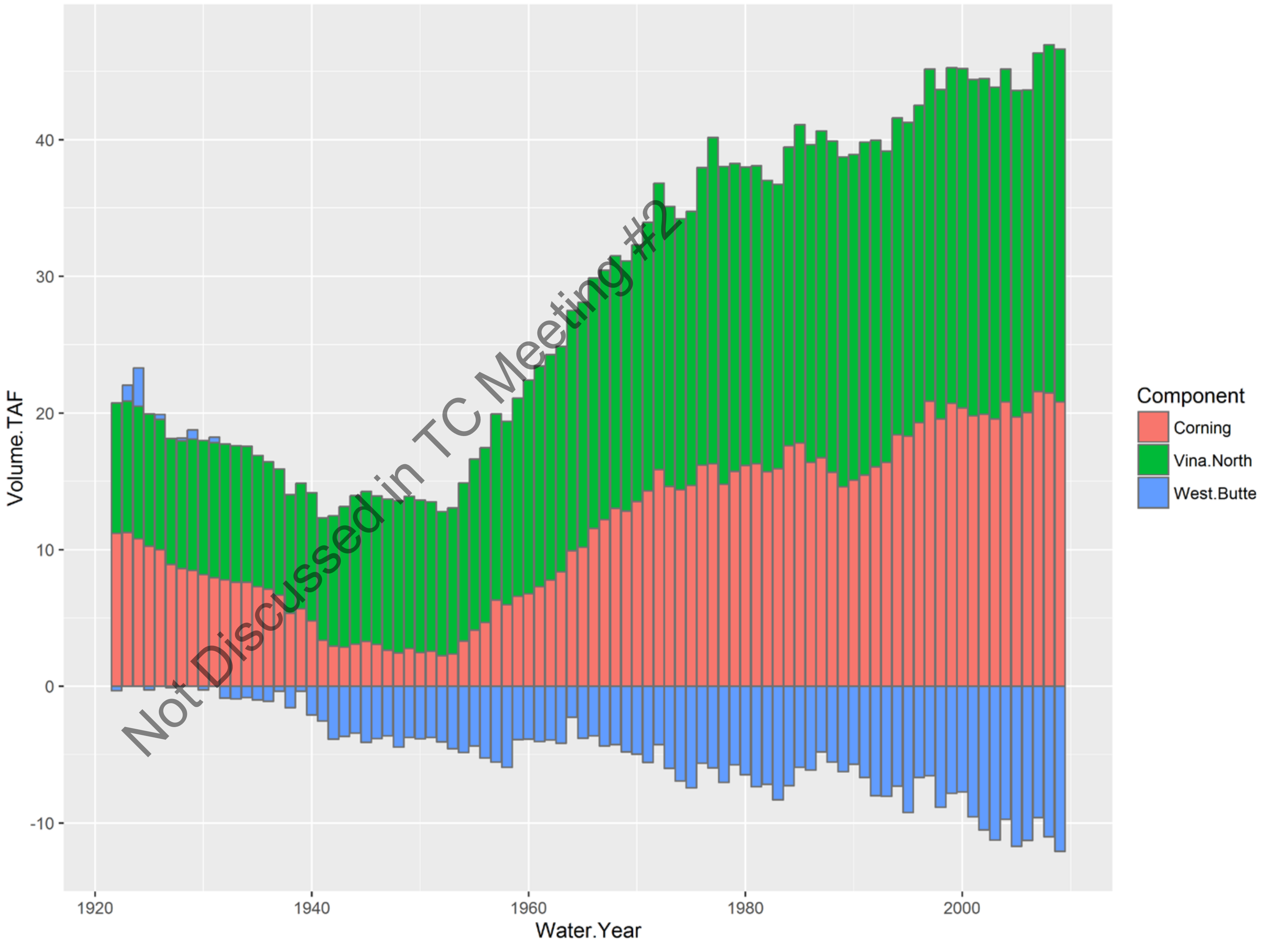
Hypothetical South Vina Subbasin Interbasin Flows



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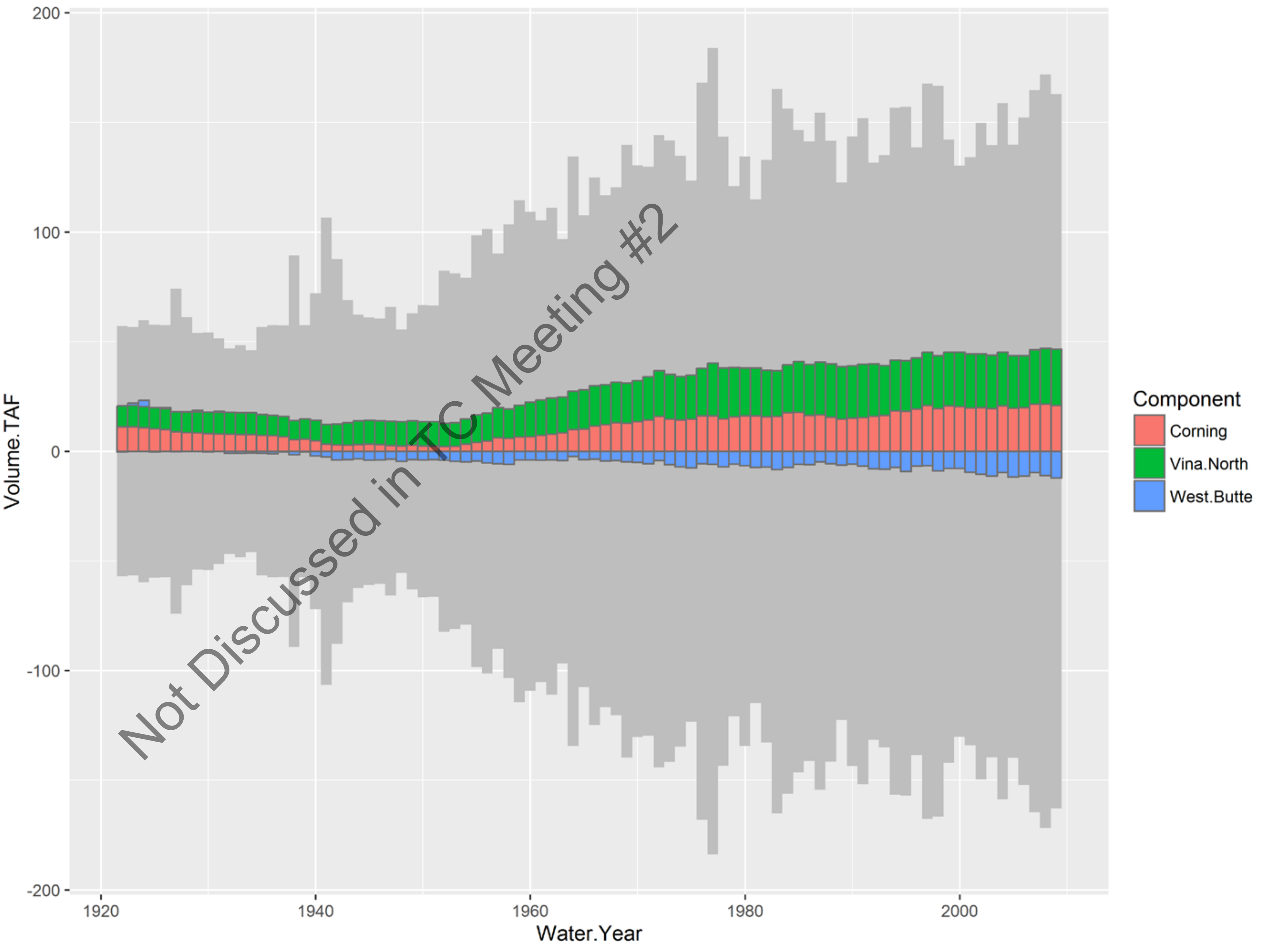
Hypothetical

South Vina Subbasin

Interbasin Flows Relative to Total Groundwater Budget



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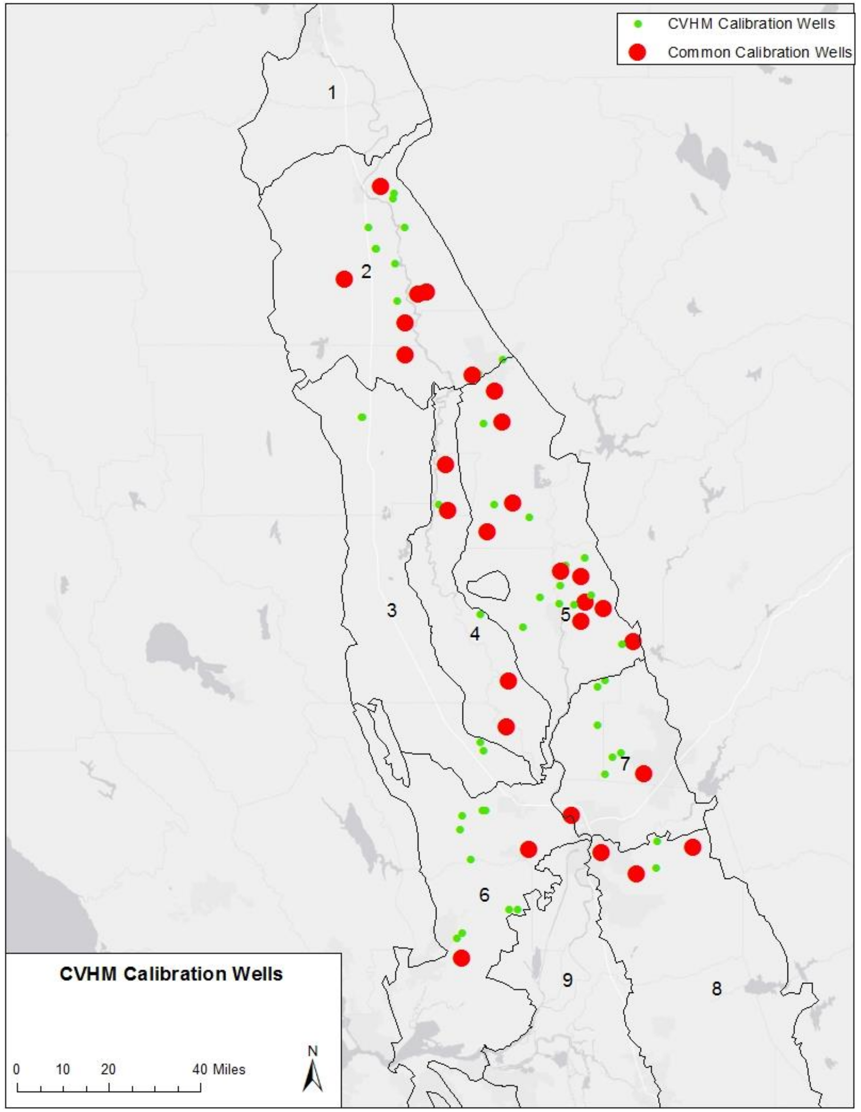
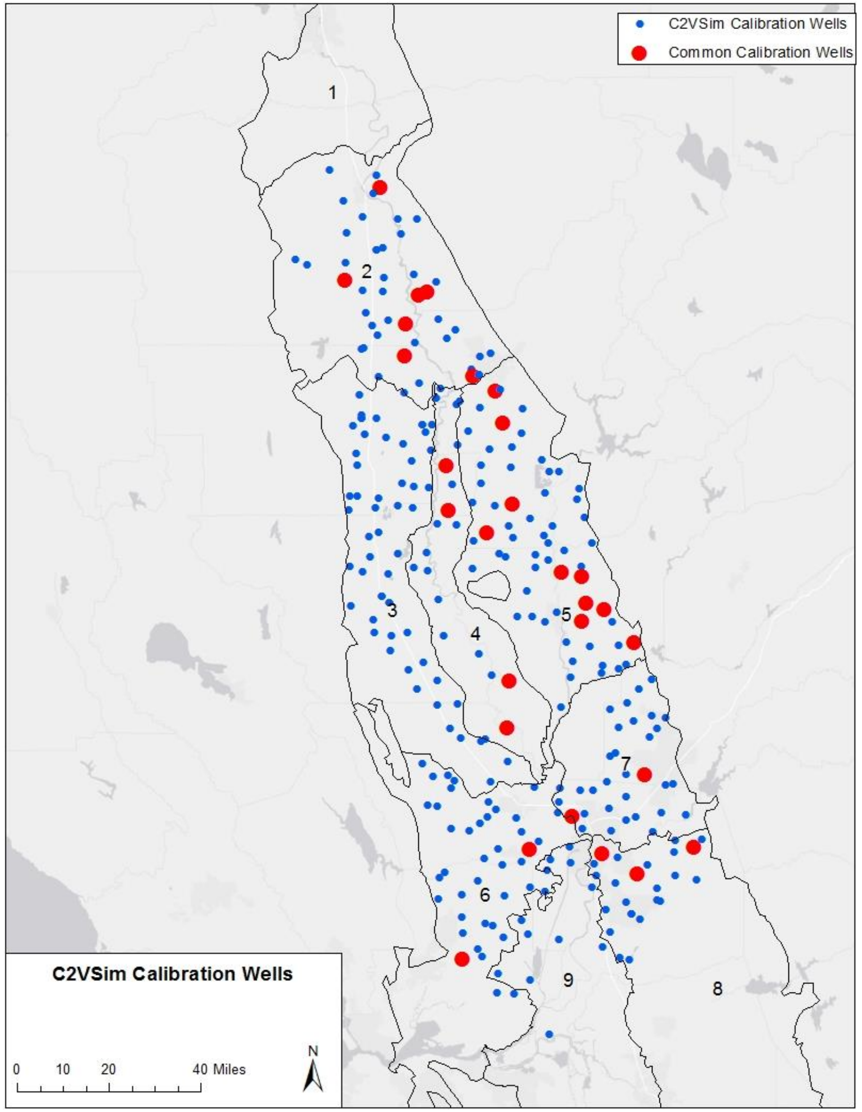
Appendix F - Model Calibration Hydrographs

Model Calibration
Source of Data

- C2VSim
  - Cvprint.dat (wells names and locations)
  - CVGWhyd.out (monthly simulated groundwater levels)
- CVHM
  - HYDMOD.txt (wells names and locations)
  - Hydro2.gwh (monthly simulated groundwater levels)
- Ground Surface Elevations
  - Google Earth

Model Calibration





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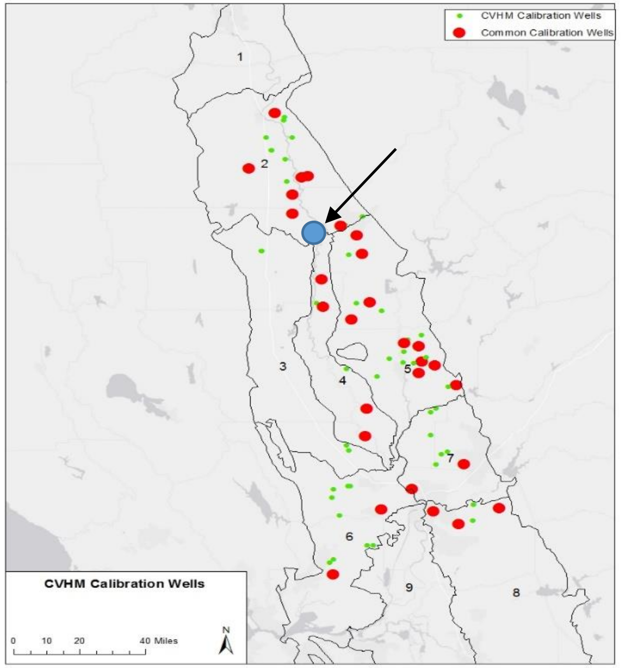
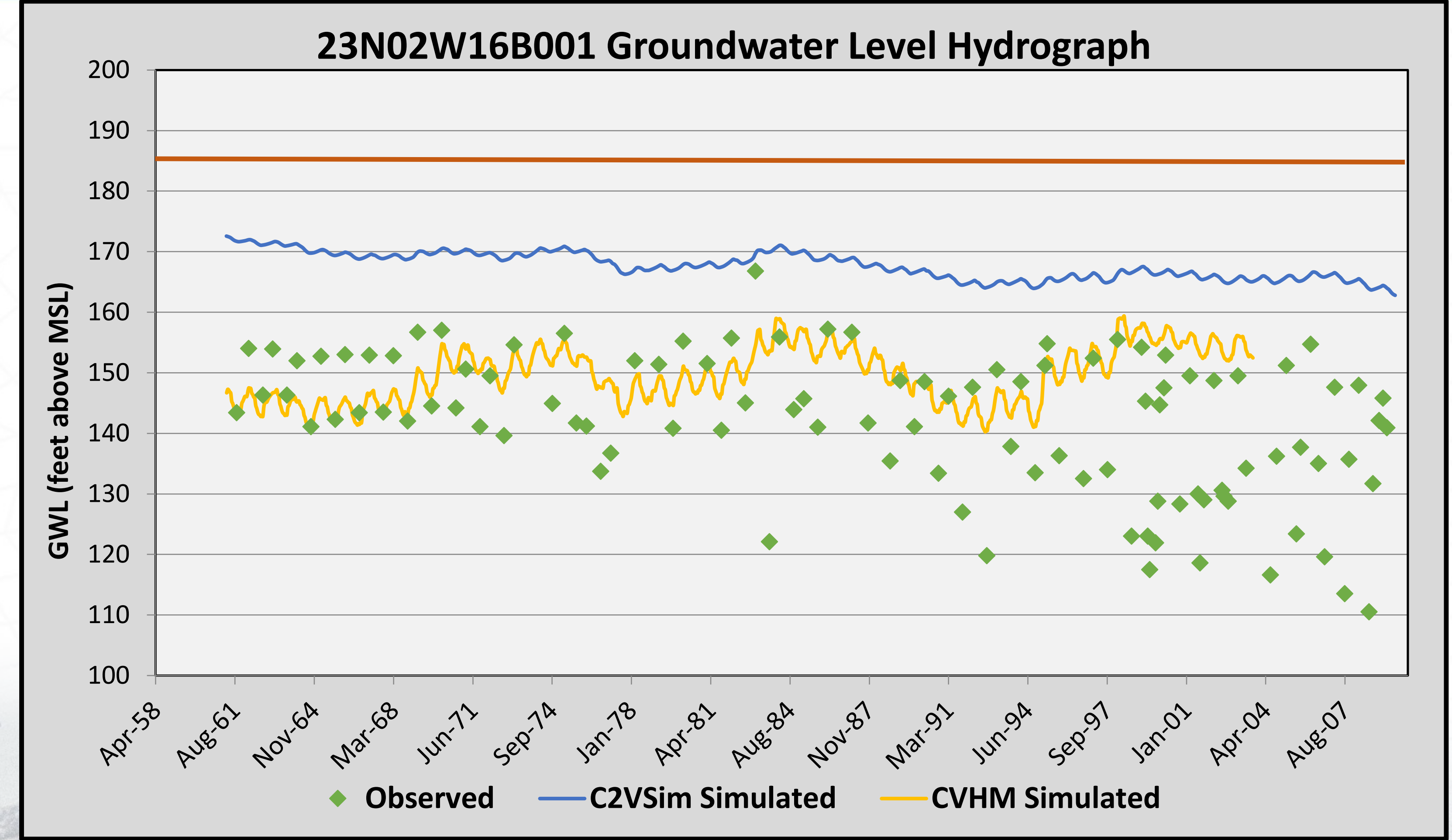
Model Calibration

- Active Irrigation
- Shallow (100 – 120 ft)





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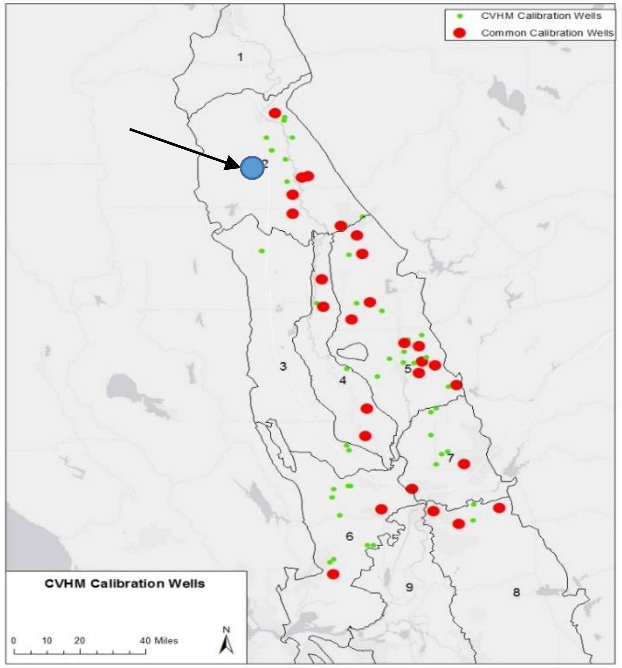
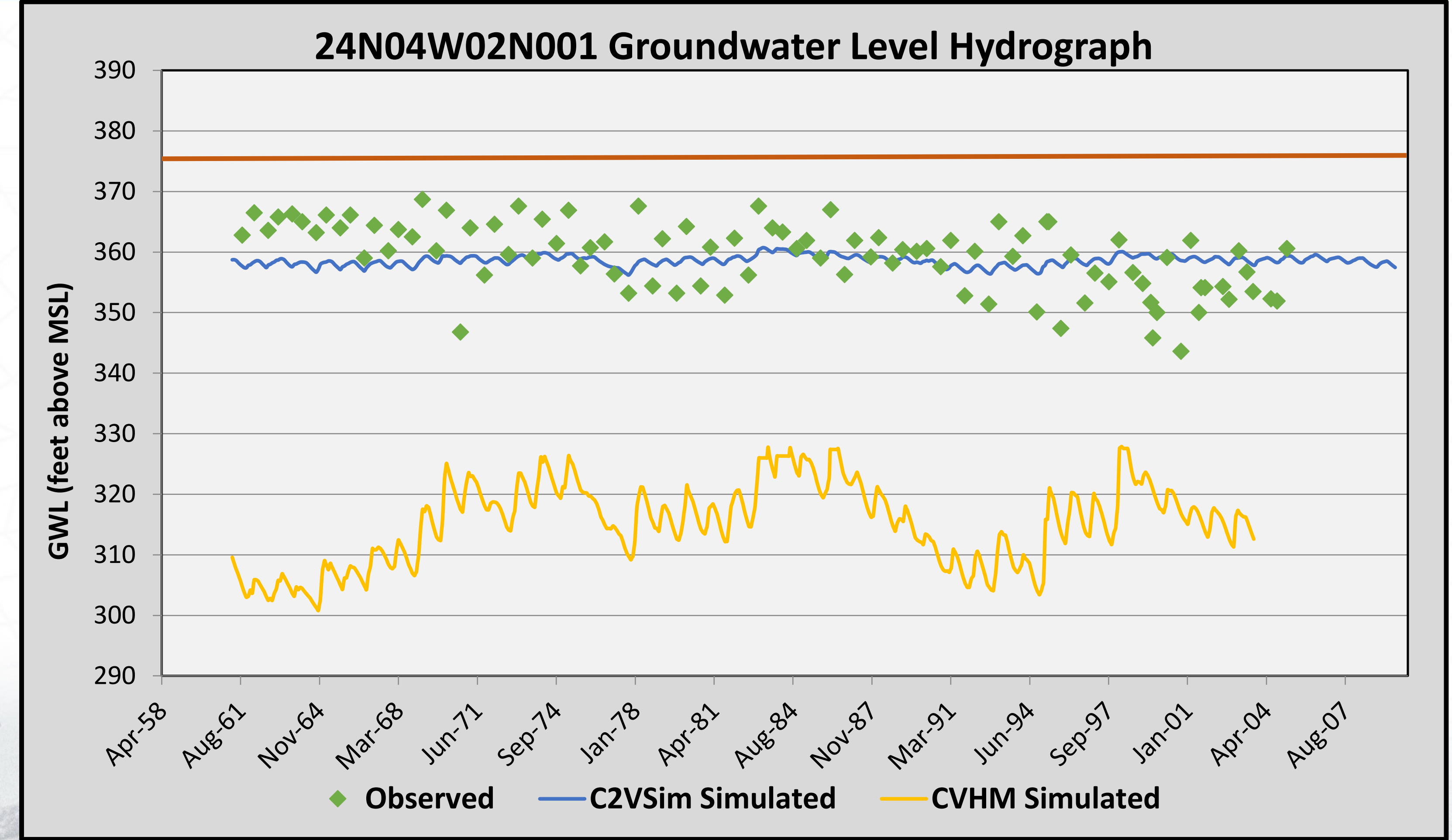
Model Calibration

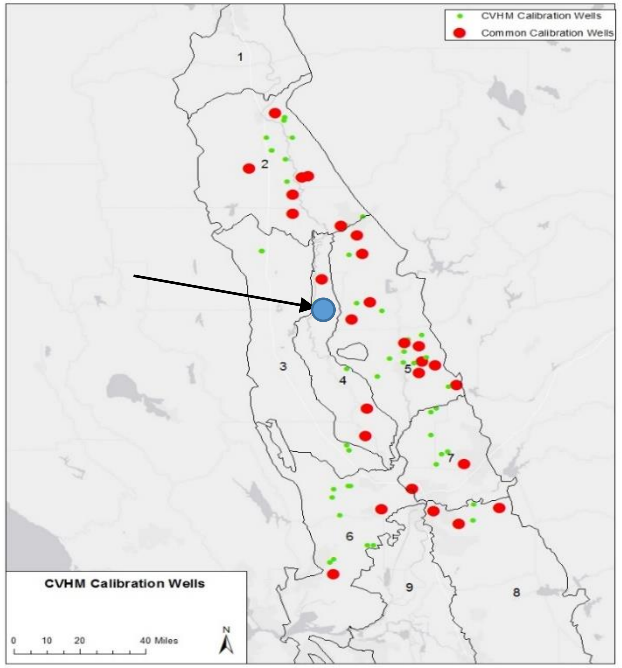
- Inactive Residential
- Shallow (30 – 90 ft)

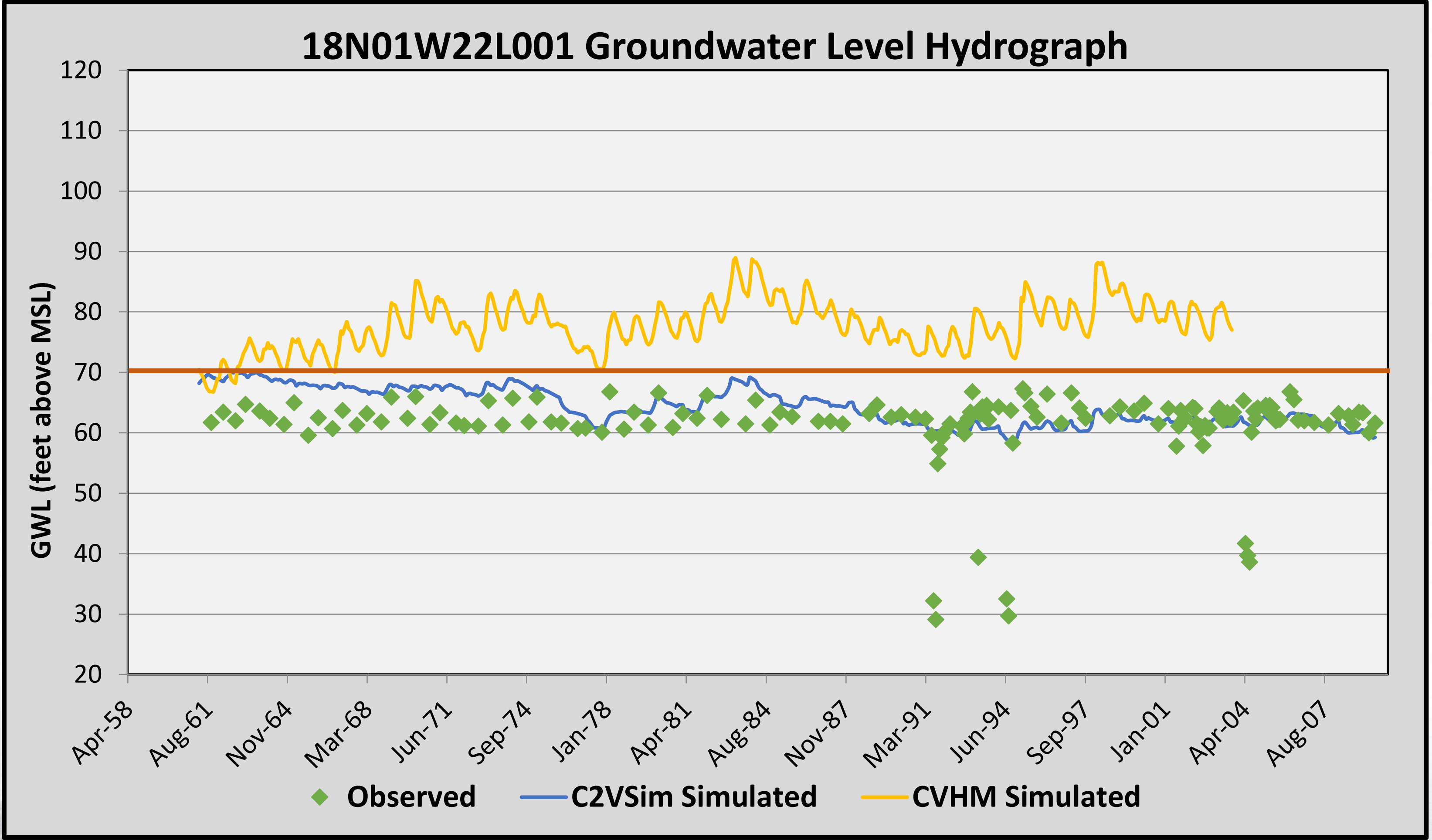




Model Calibration

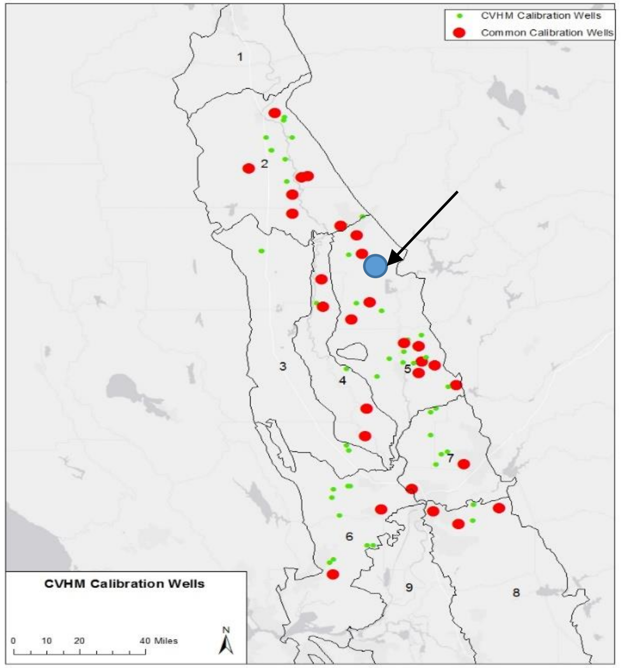
- Active Irrigation
- Shallow (76 – 92 ft, 108 – 124 ft)

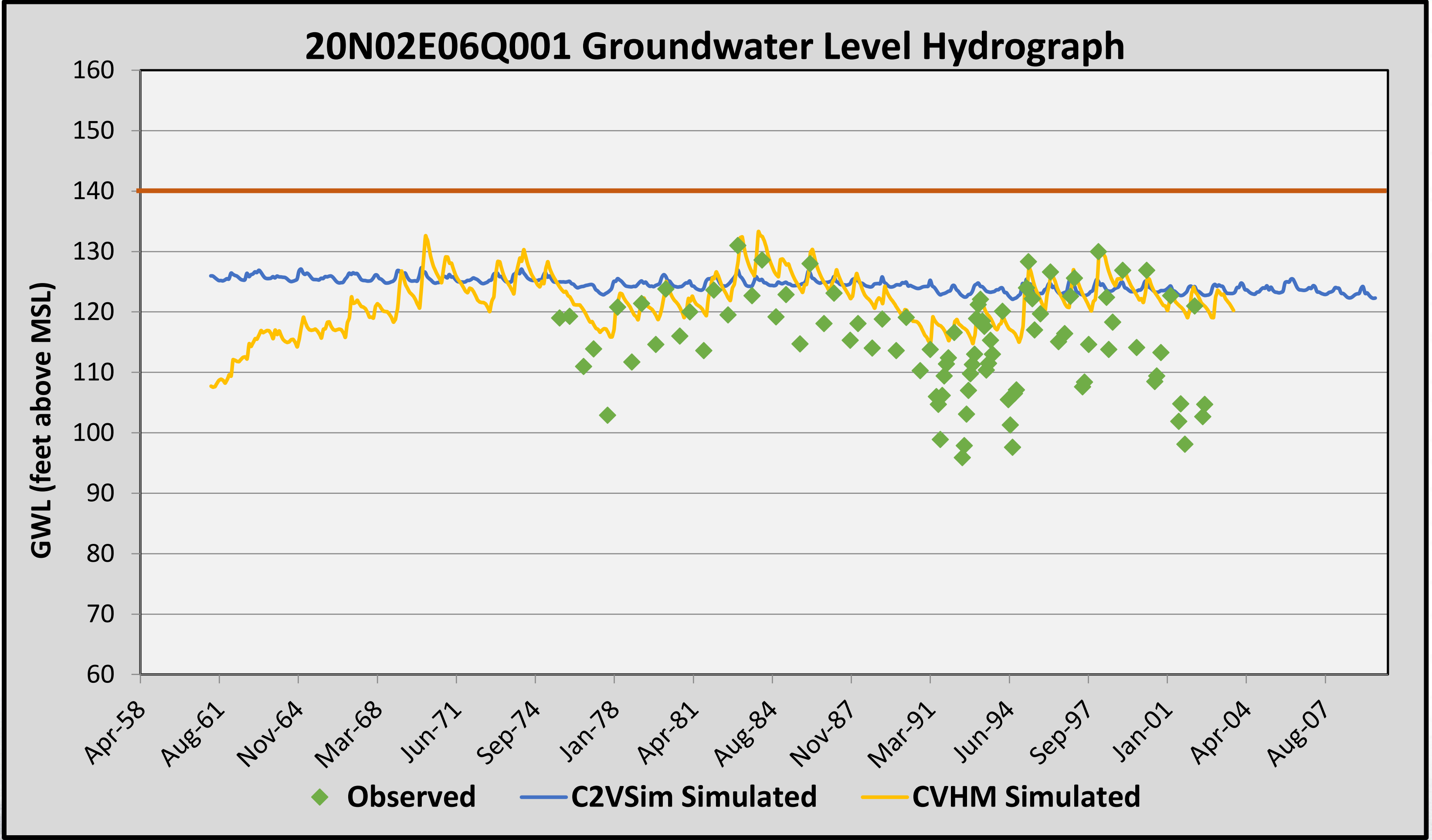




Model Calibration

- Active Irrigation
- Shallow (10 – 44 ft)





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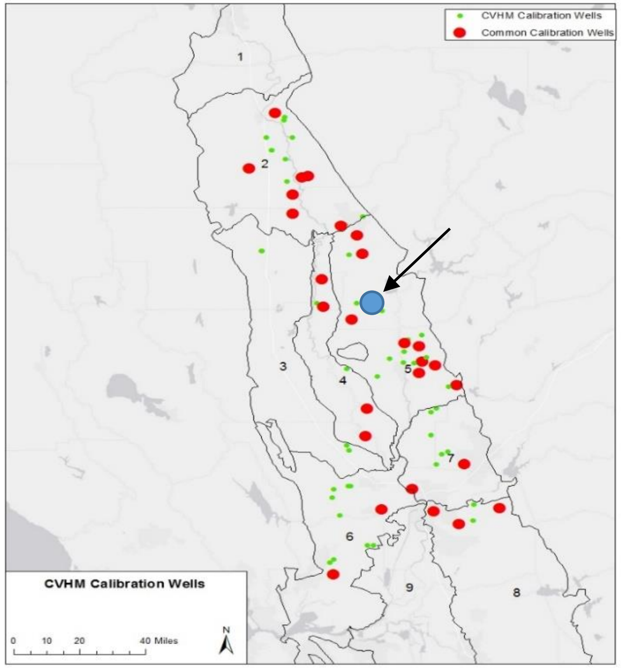
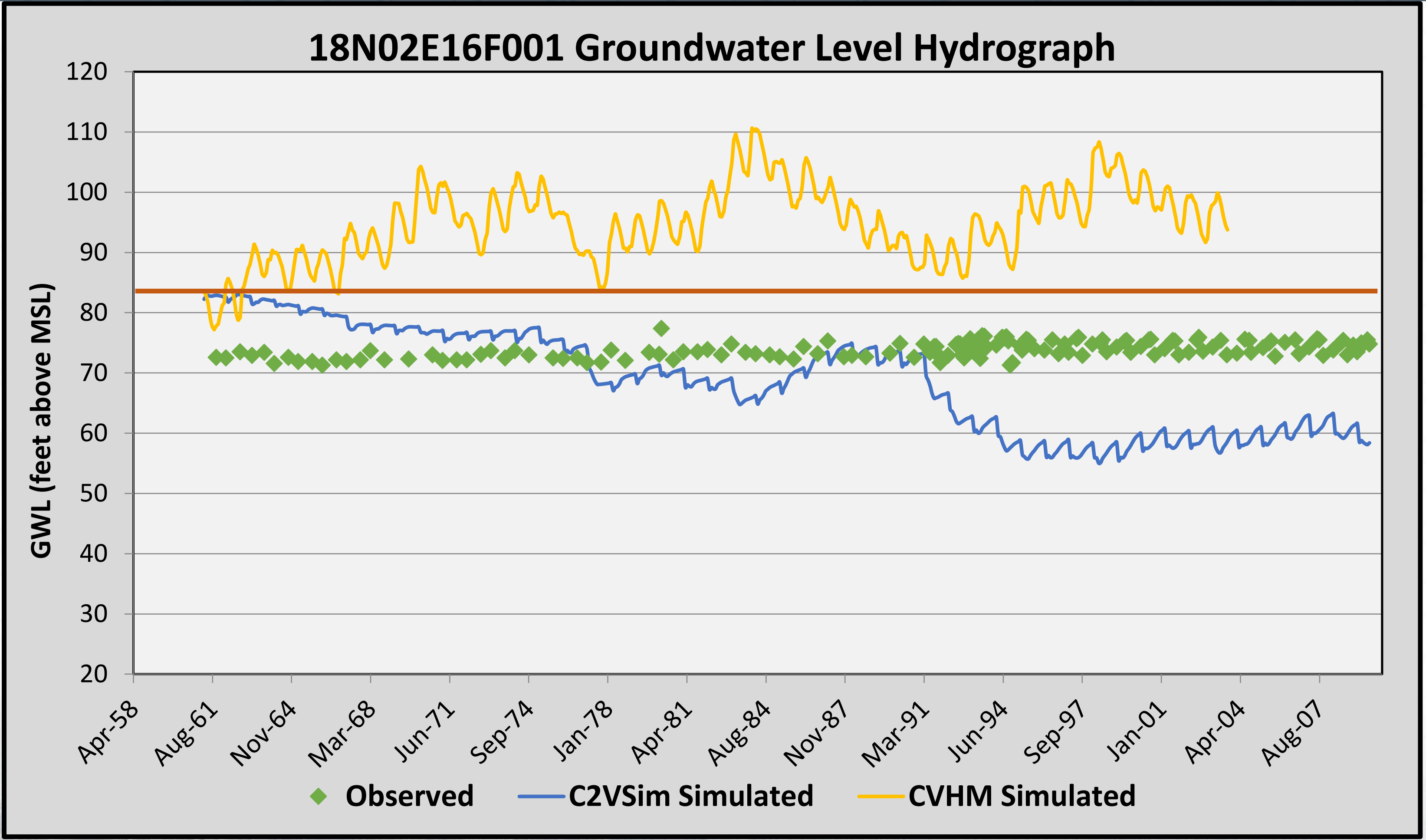
Model Calibration

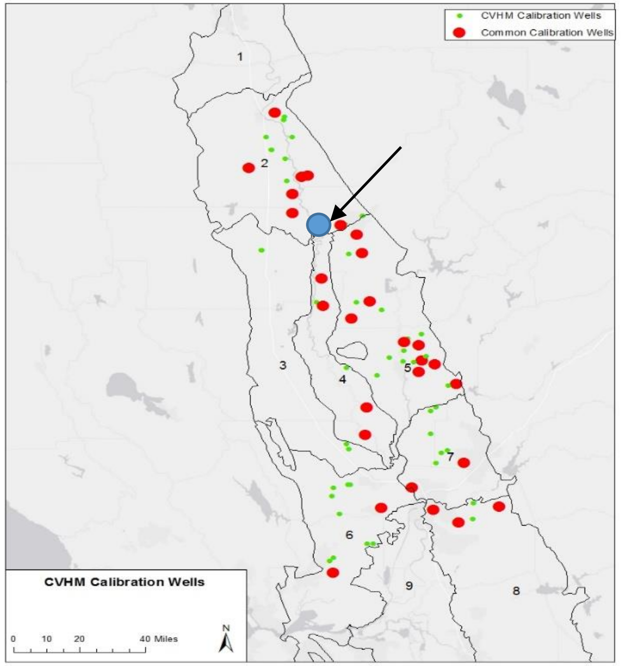
- Active Irrigation
- Shallow (20 – 60 ft)

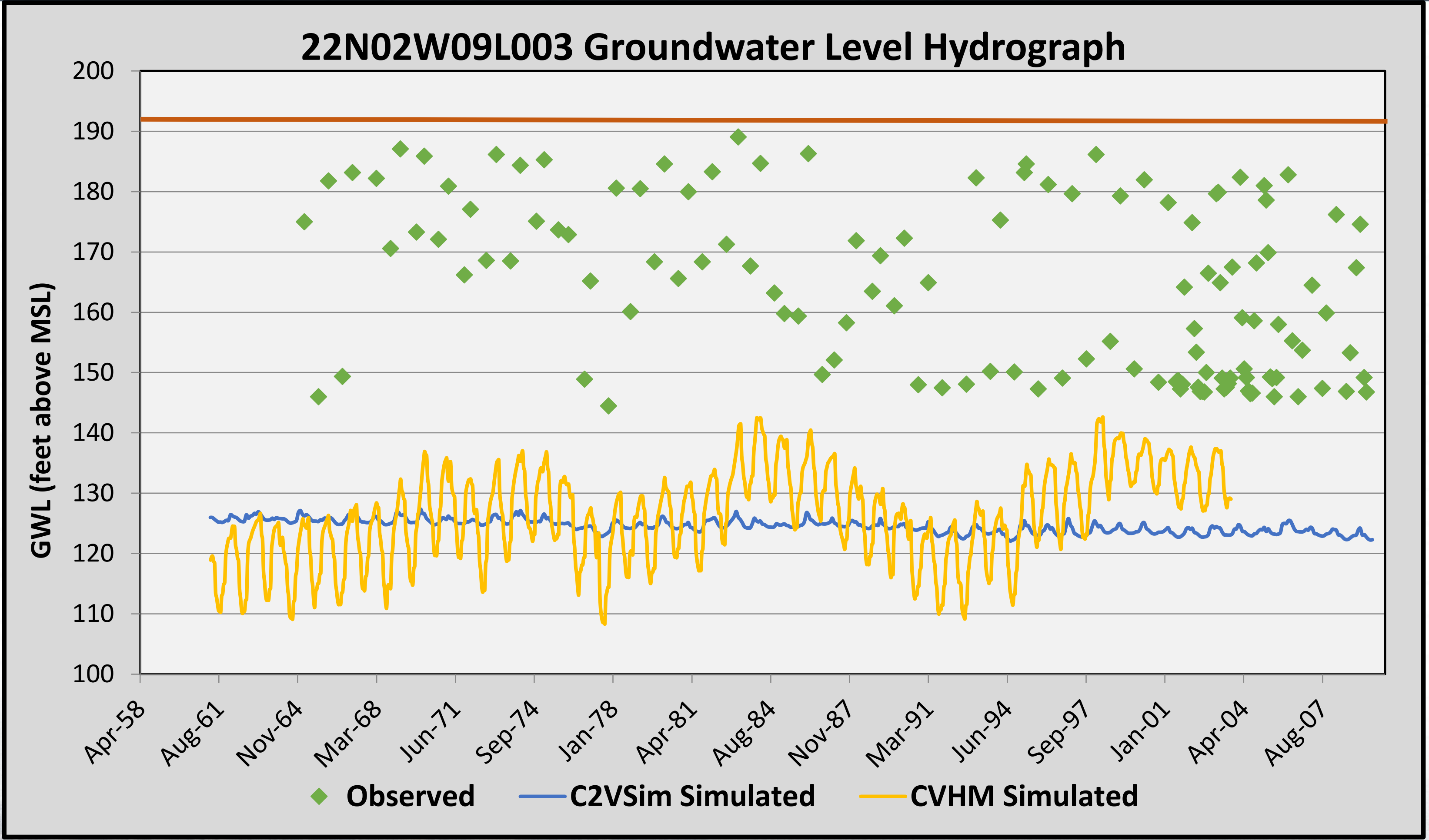




Model Calibration

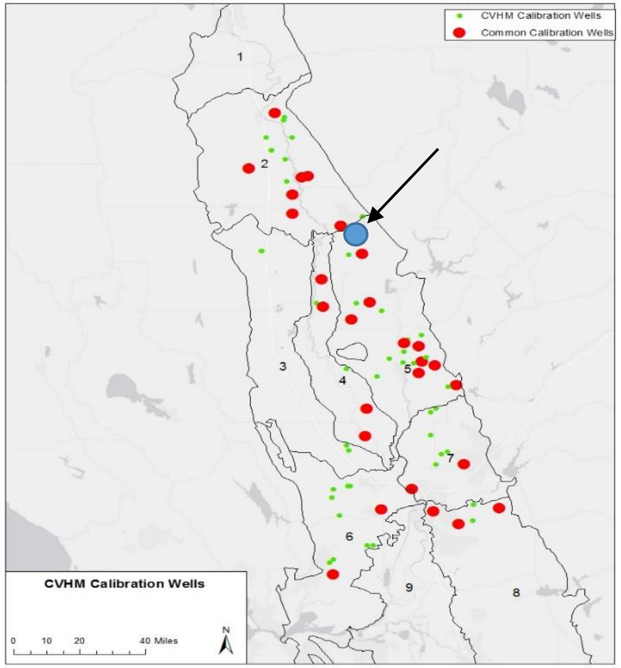
- Active Irrigation
- Intermediate

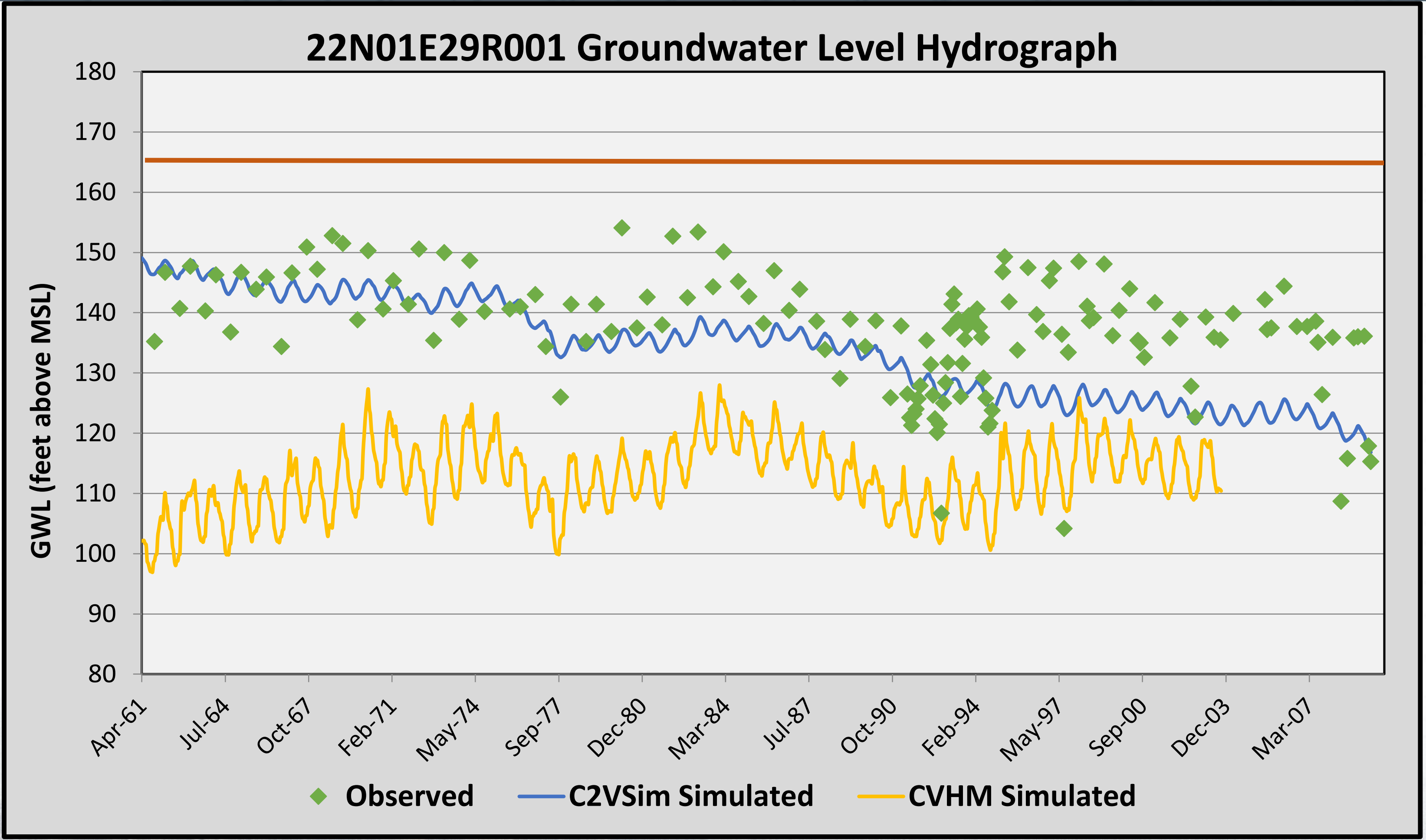




Model Calibration

- 22N01E28J001 was used for CVHM
- Observation
- Intermediate (460 – 559 ft)





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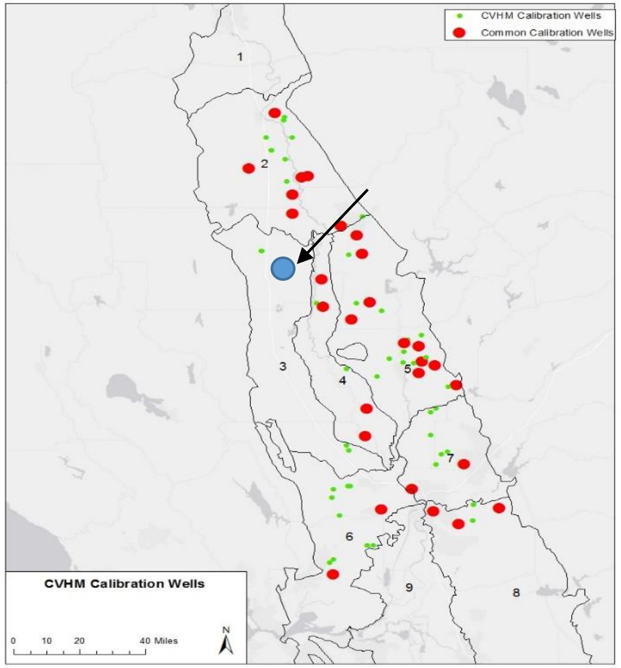
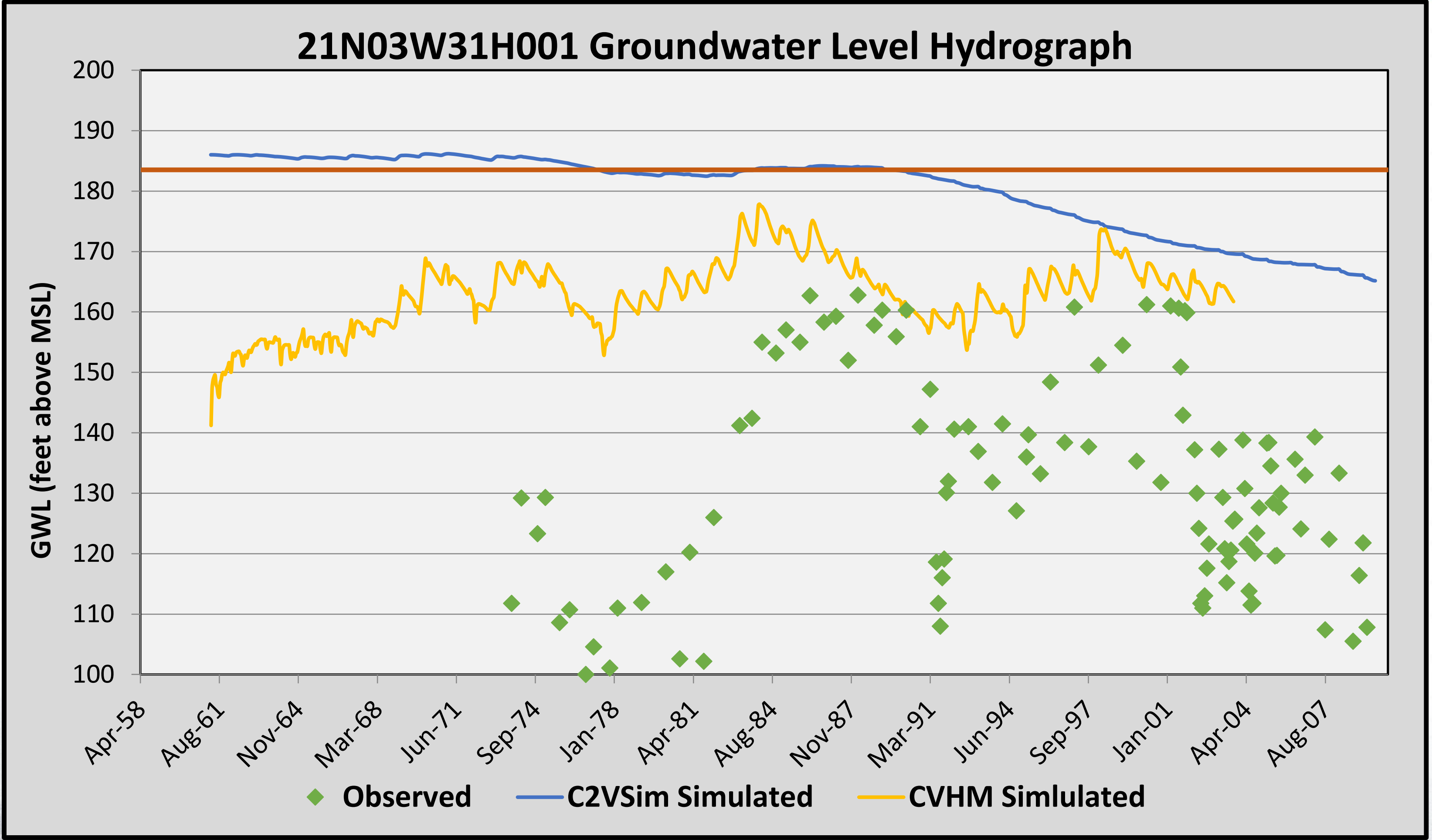
Model Calibration

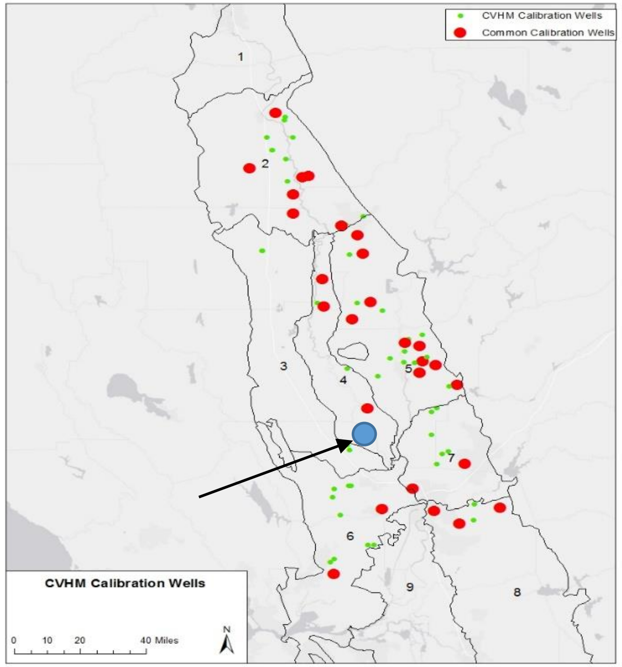
- 21N03W31R002 was used for CVHM
- Inactive, unknown type
- Intermediate (270 – 410 ft)

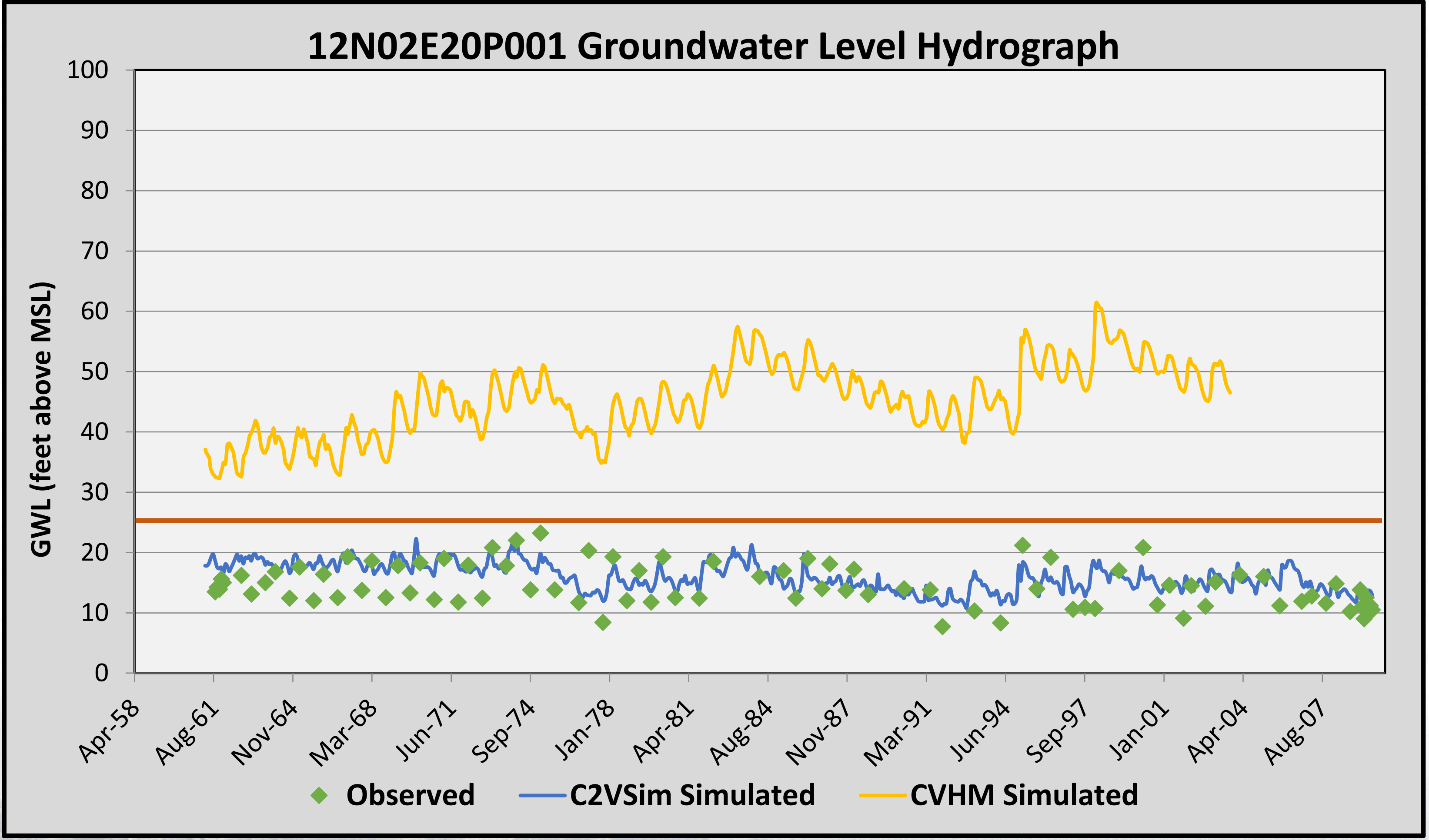




Model Calibration

- Active, unknown type
- Intermediate (Total Depth – 500 ft)





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Model Calibration

- Active Irrigation
- Intermediate (Total Depth 400 ft)