



Beyond the Numbers:

The Future of Sustainable Groundwater Management Through Data-Driven Implementation

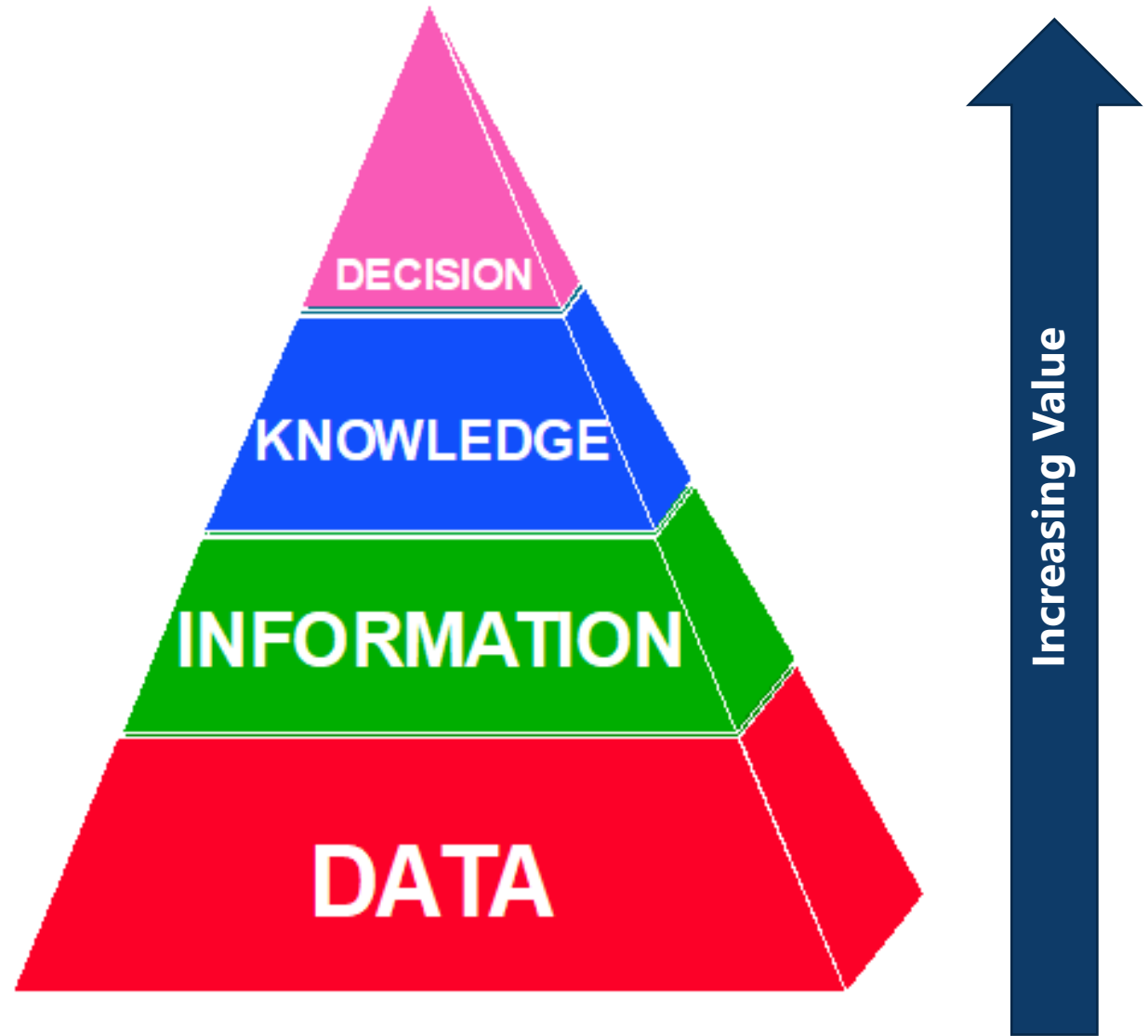
Presented by Saquib Najmus, Ph.D., P.E., PMP

Collaborators: Josh Uecker, M.S. and Frank Qian, M.S., P.E.



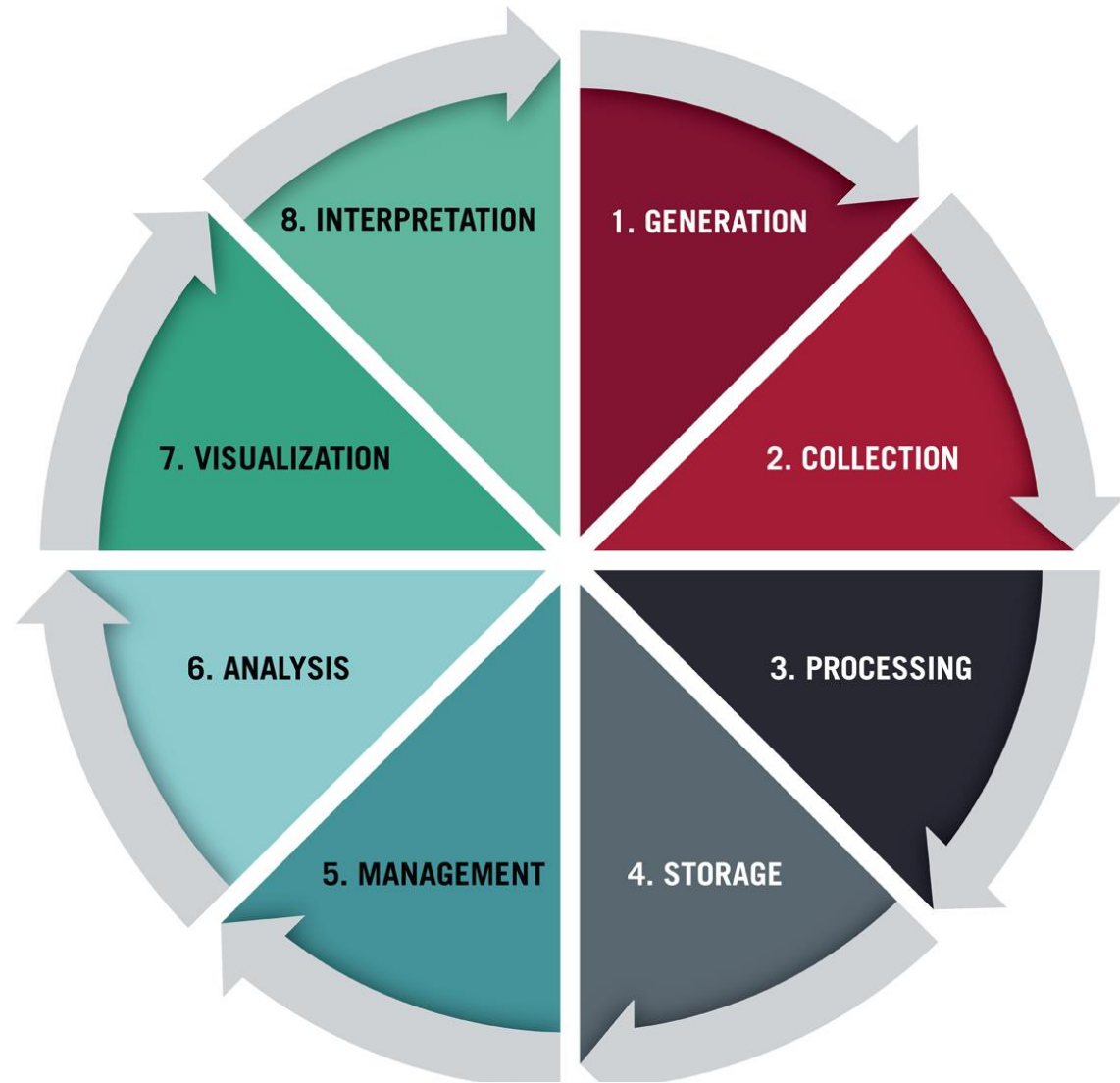
**Woodard
& Curran**

We are drowning in data, but starved for knowledge

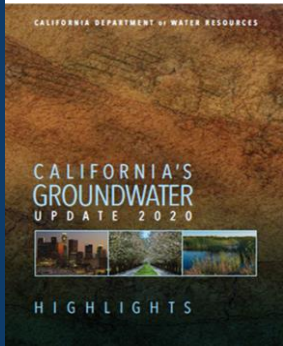




Beyond the Numbers: Making the Invisible, Visible



DATA LIFE CYCLE

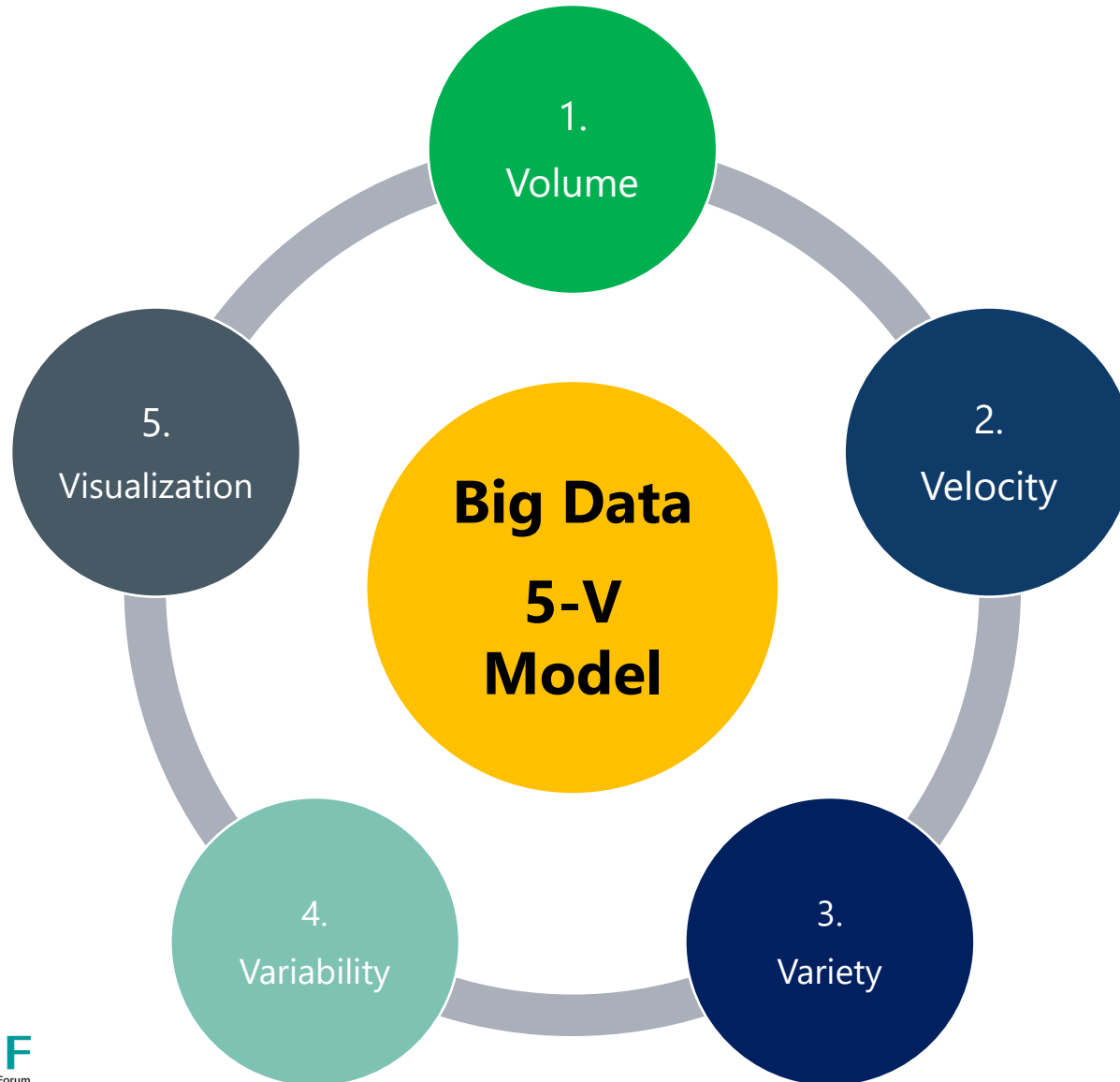


Advancing Data Driven Decisions is a Key Recommendation of CalGW 2020 (Bulletin 118)



- 1** Strengthen and support long-term groundwater data collection programs at State, local, and regional levels ...
- 2** Enhance SGMA reporting systems and align them with the Open and Transparent Water Data Act (AB 1755) ...
- 3** Develop and enhance analysis methods, standards, and modeling tools ...
- 4** Build upon B-118 legacy by collaborating with local agencies on the application of new technology and tools ...

Groundwater Data has entered “Big Data” Era



GAMA Database:

290,000 wells

87 million analytical results

Water Data Library:

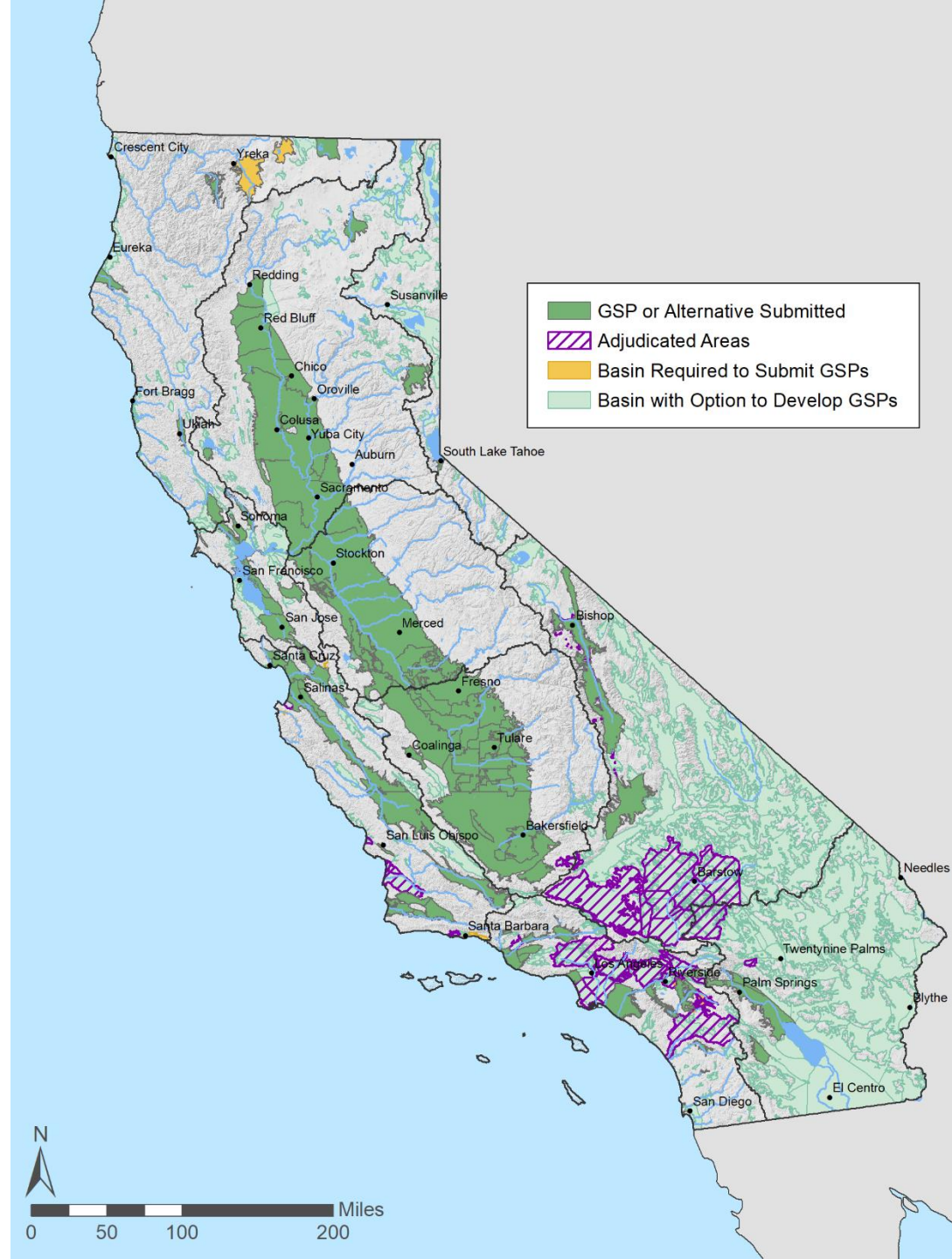
35,000 wells

Pre-SGMA: State of Groundwater Data

- ❑ Isolated/Siloed
- ❑ Infrequent reporting
- ❑ Inconsistency in reporting
- ❑ Various methods and standards

Local Agencies Driving Data Growth

- Data from GSAs will cover significant portions of the state
- 98% of groundwater use covered by a GSP or adjudication

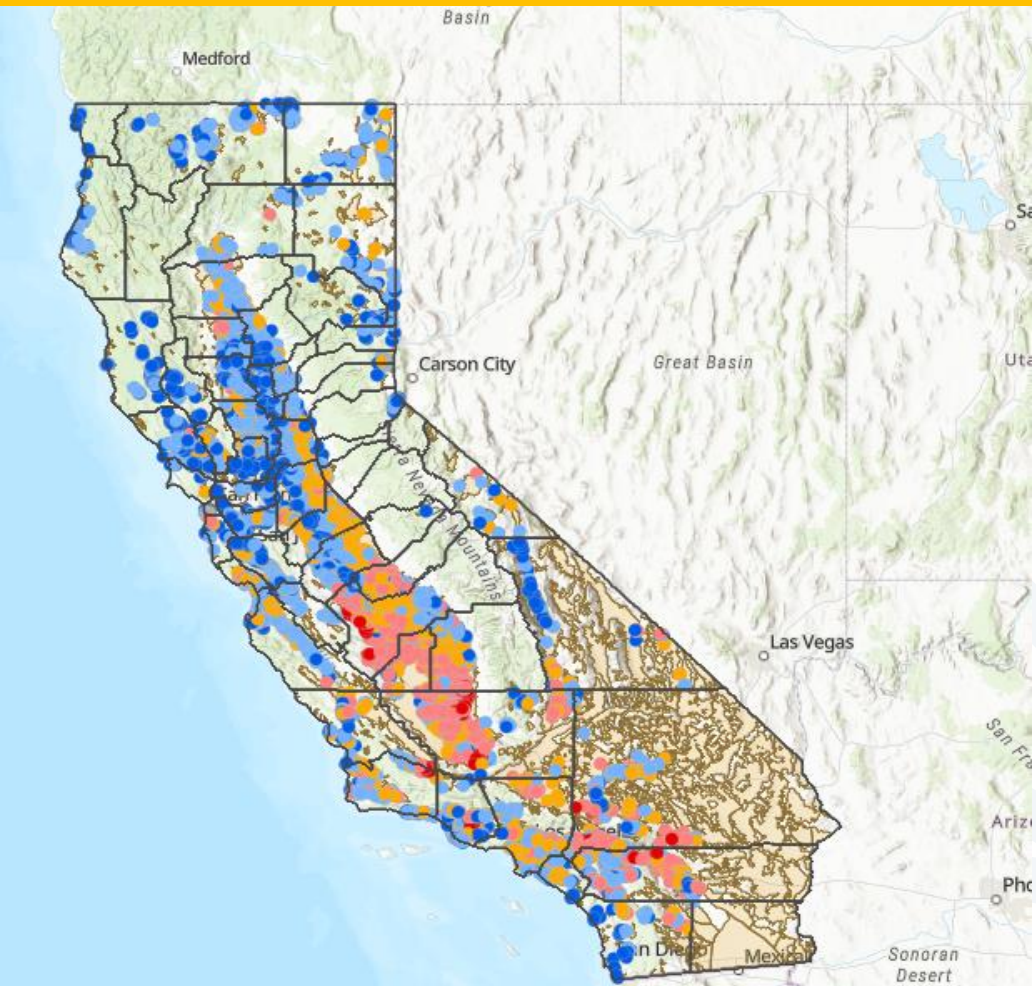


Volume and Velocity have Increased

4,800 Wells with GW Level Data for past 20 years



8,400 Wells with GW Level data in past 18 months



Variety has Also Increased

Figure 5-1 Groundwater Level Monitoring Wells by Monitoring Program (2015–2018)

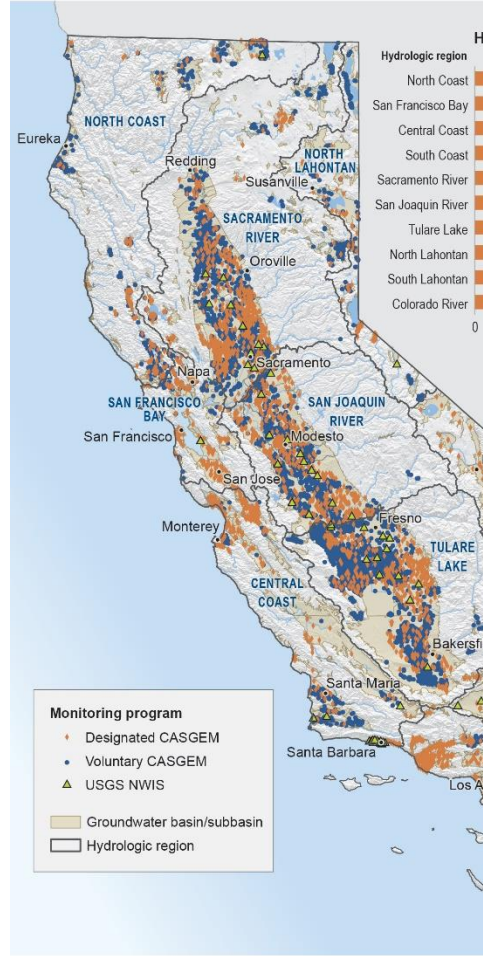


Figure 5-6 Groundwater Quality Monitoring Stations in the Groundwater Ambient Monitoring Assessment (GAMA) Database (as of July 2020)

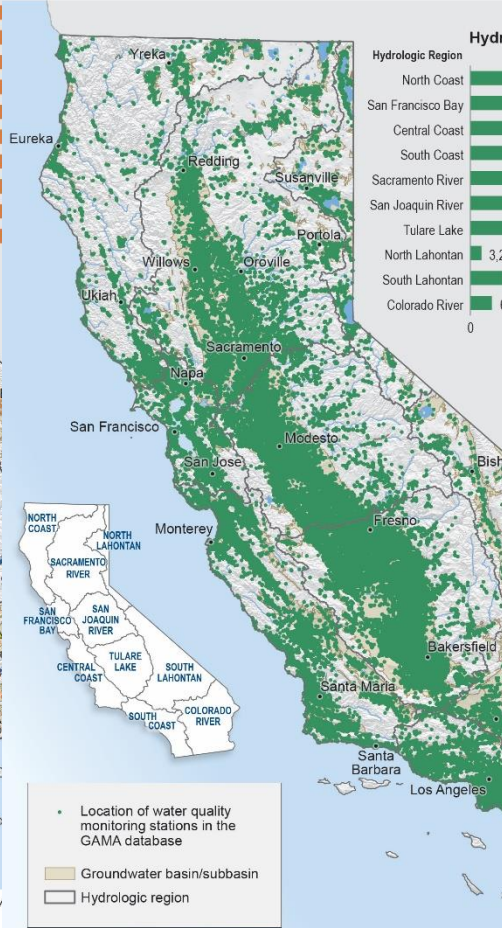


Figure 5-7 Distribution of Continuous GPS Stations, Borehole Extensometers, InSAR Data Coverage, and Regional Subsidence Networks

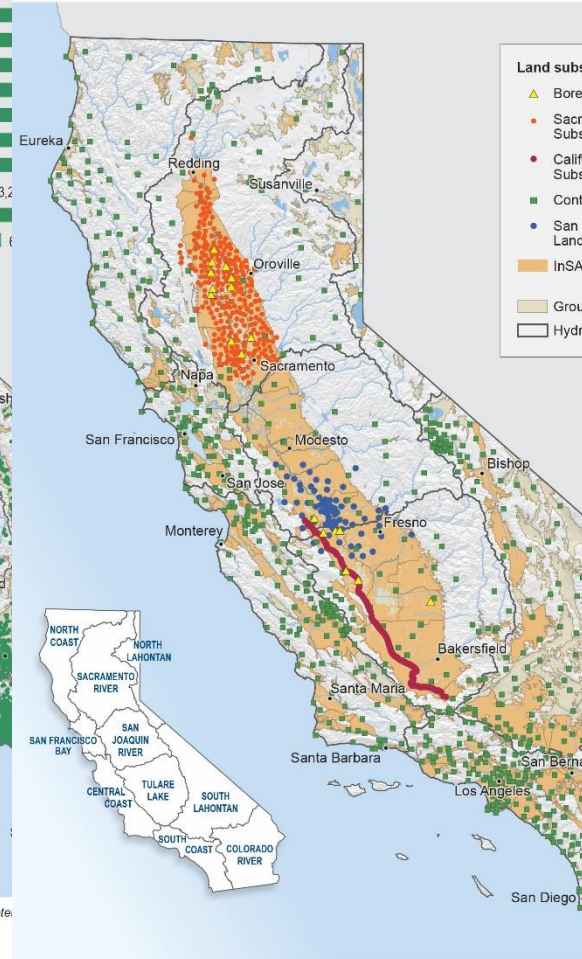
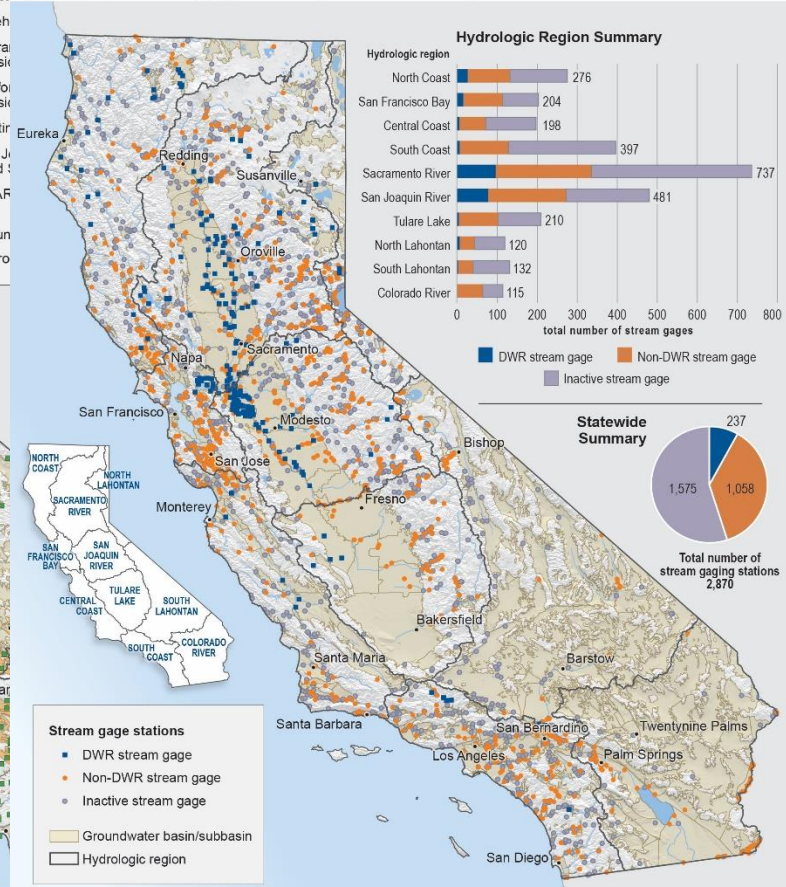


Figure 5-8 Stream Gaging Stations (as of March 2020)

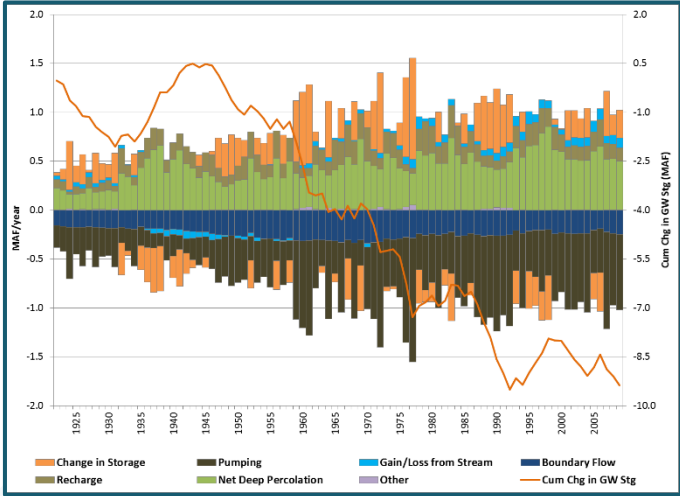
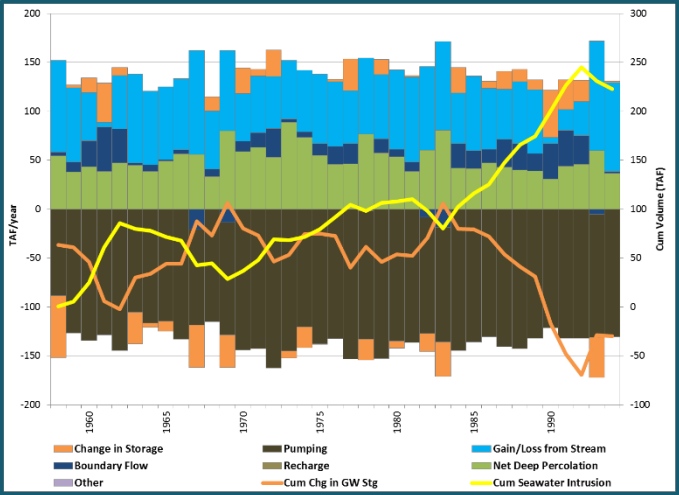
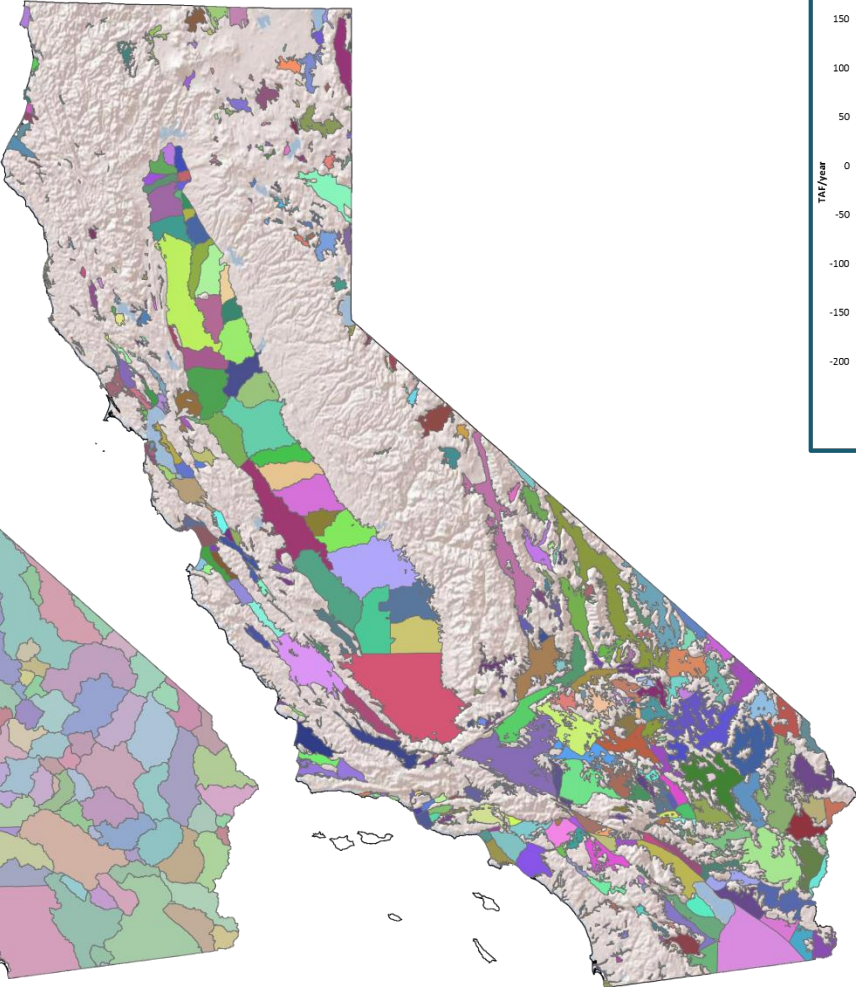


Variability has Multiplied: Spatial and Temporal

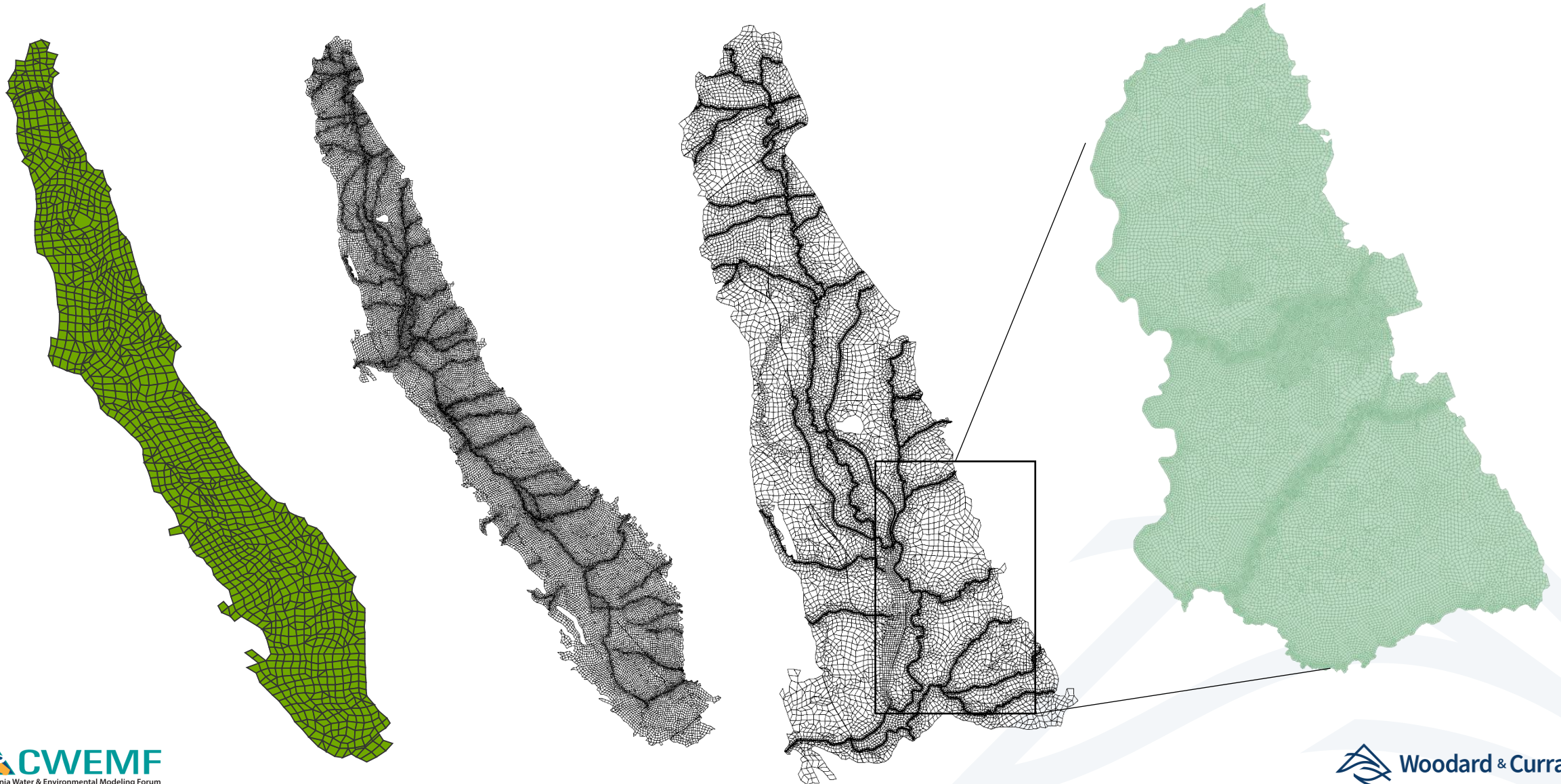
479 DAUs



515 Groundwater Basins

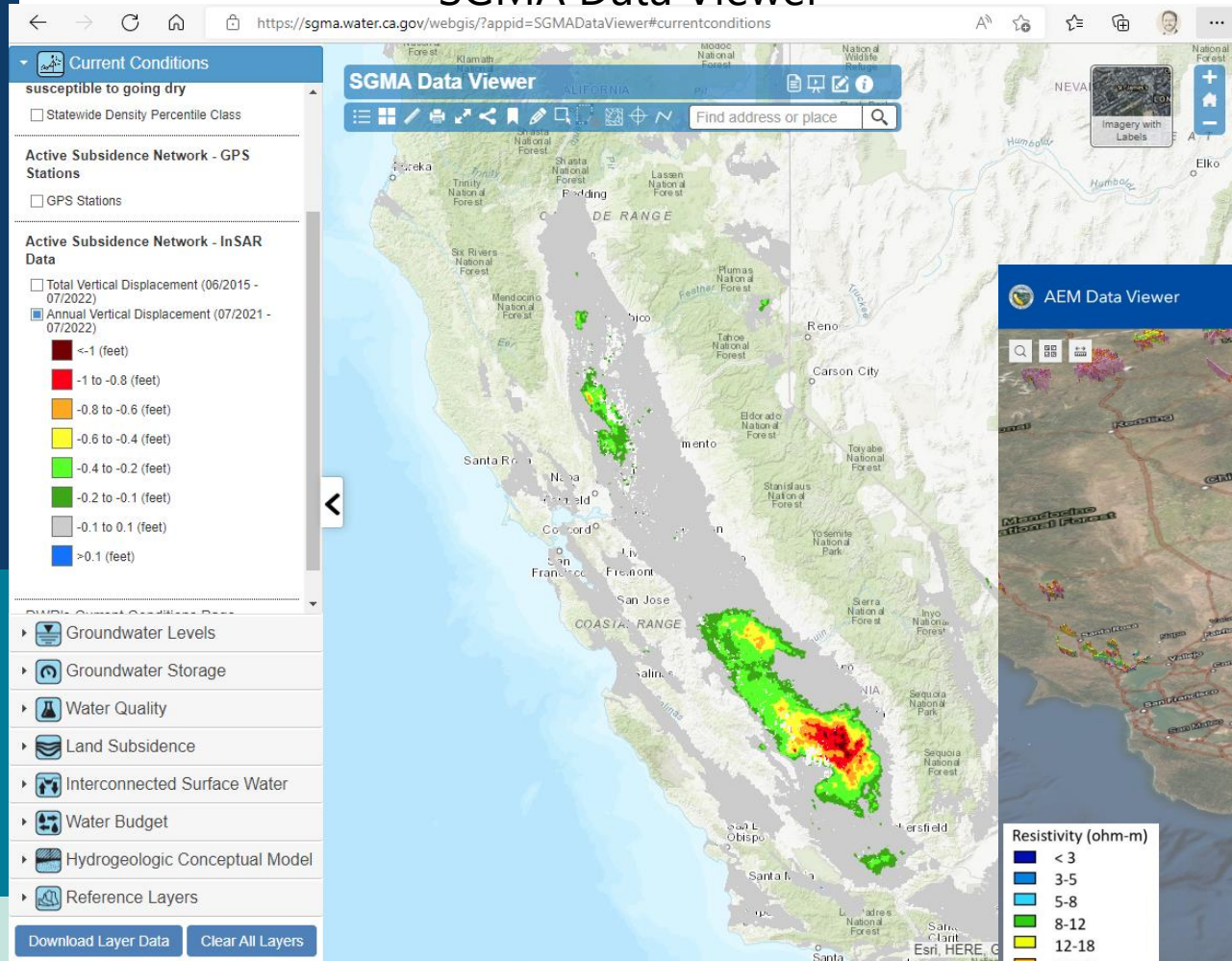


Model Enhancement Adding to Spatial Variability

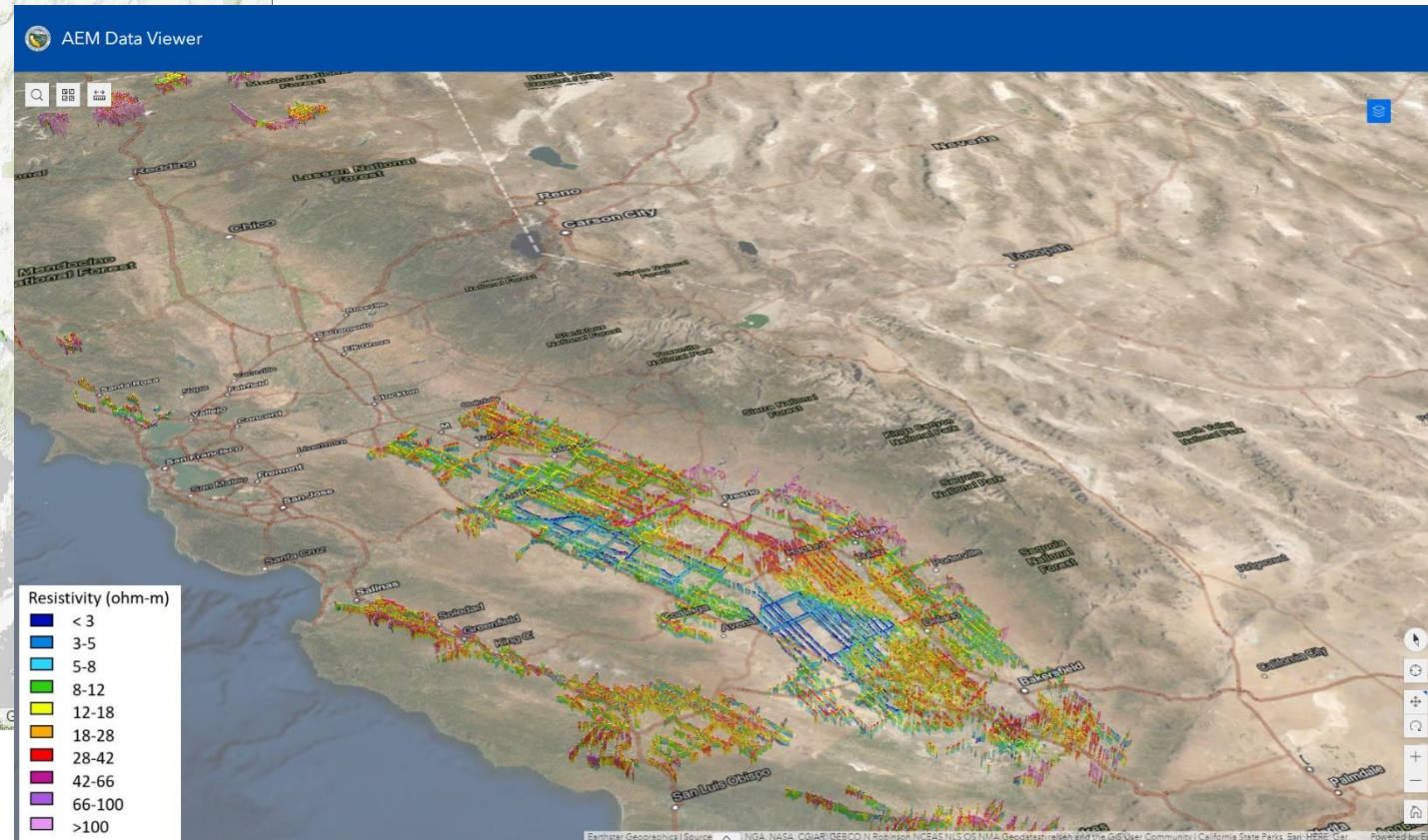


Visualization has Enabled Complex Analysis

SGMA Data Viewer



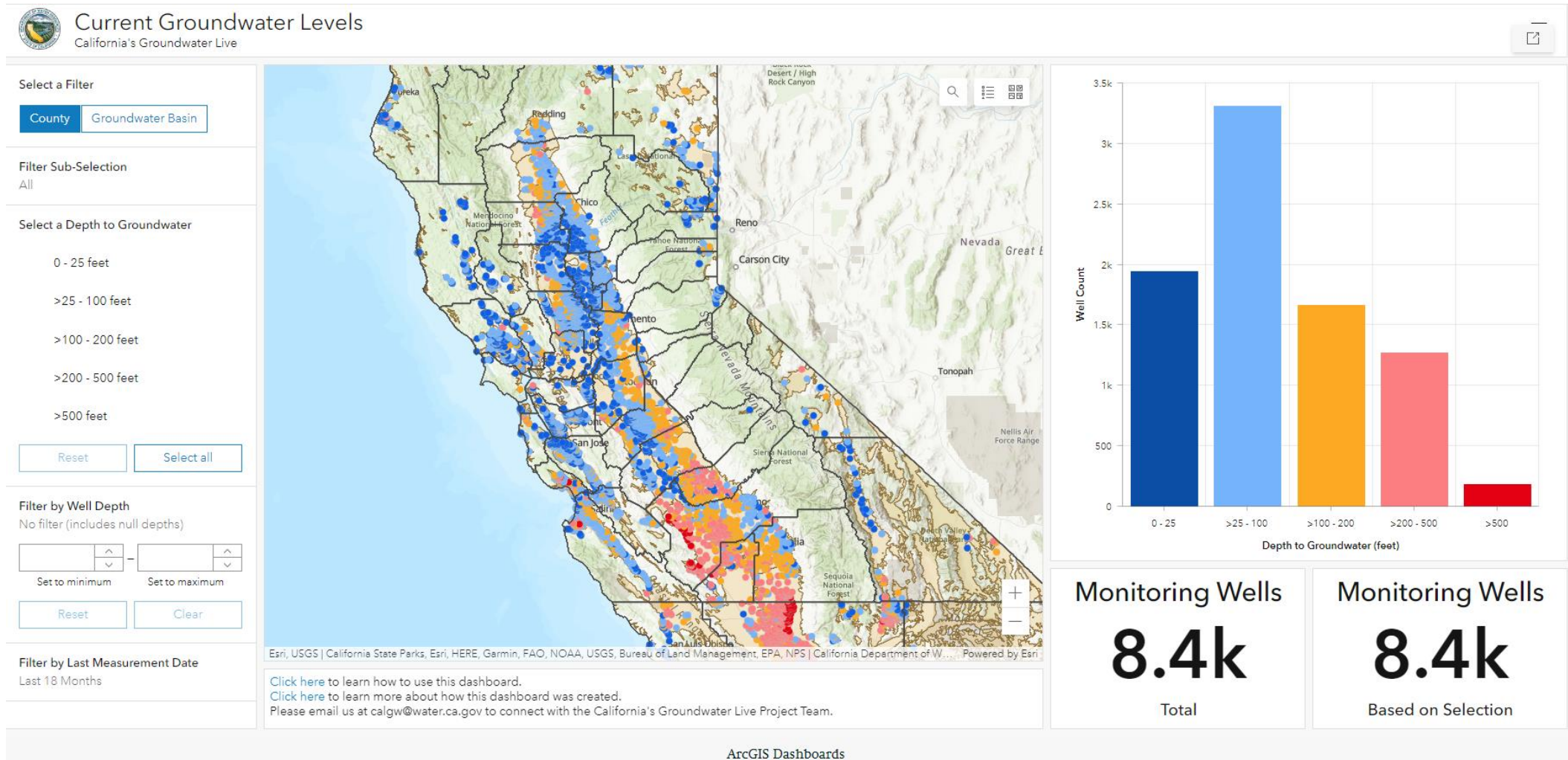
AEM Data Viewer



New Tools: Real-time Data Visualization

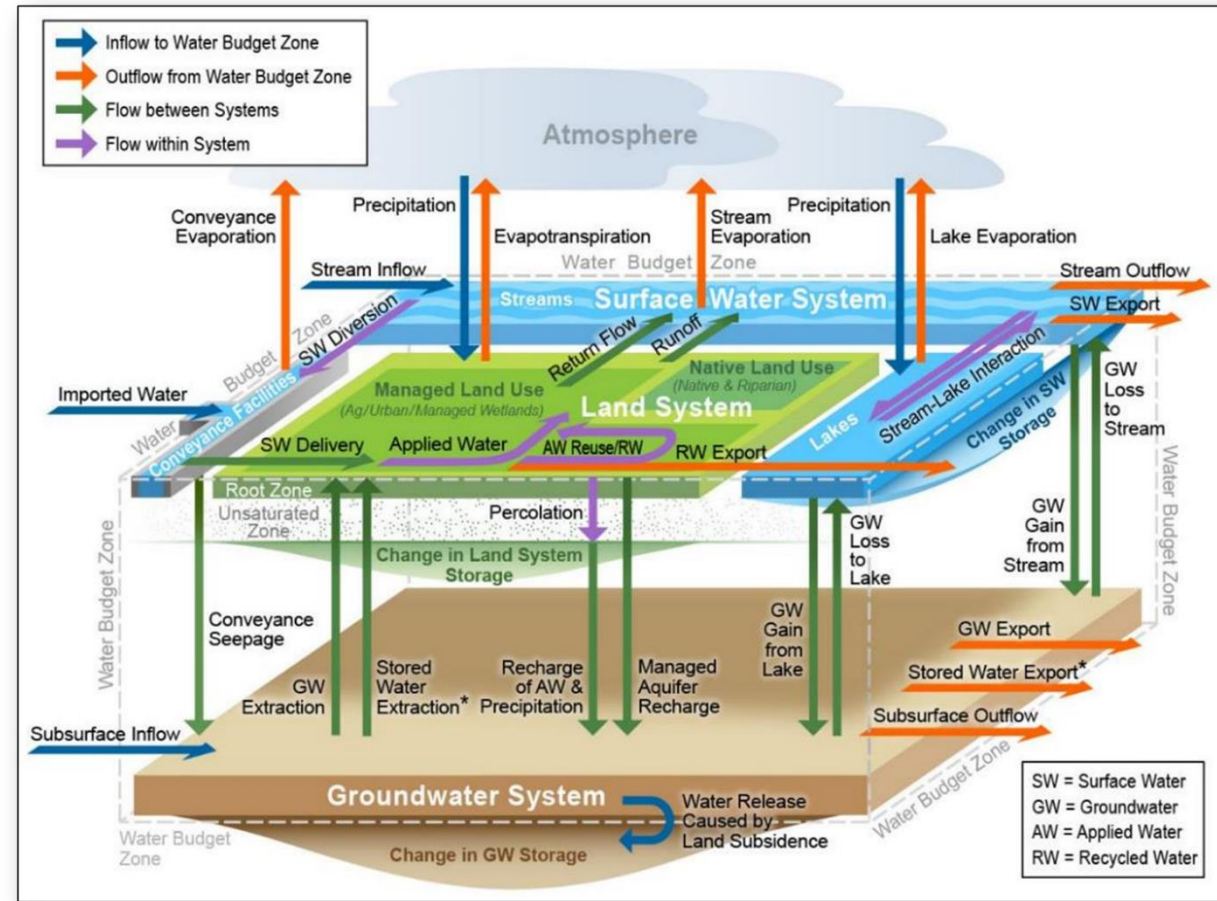
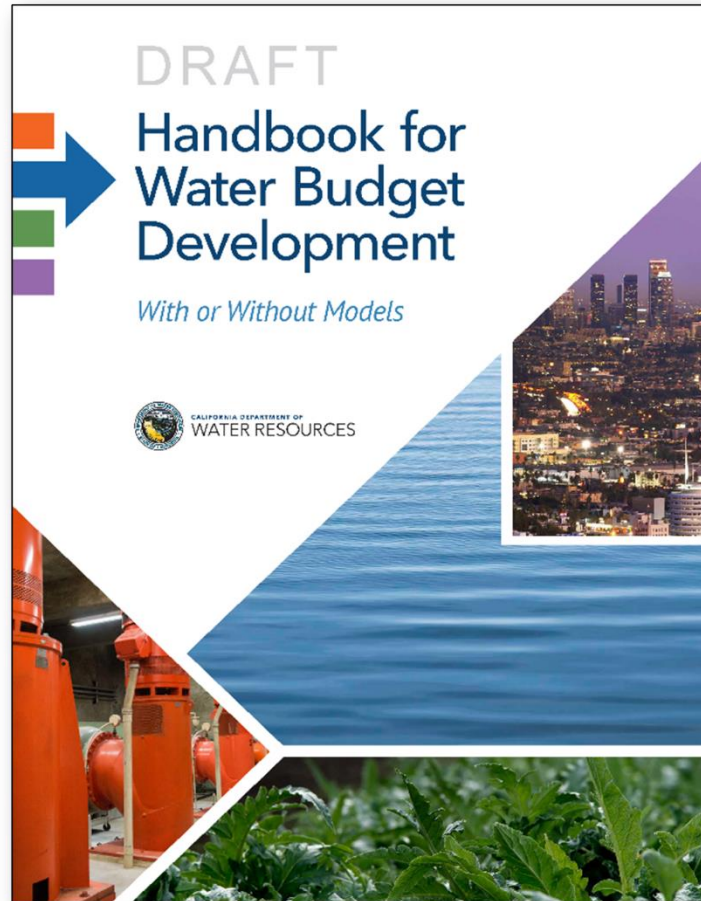
The screenshot shows a web browser window with the URL <https://sgma.water.ca.gov/CalGWLive/>. The page features a blue header with the California's Groundwater Live logo and navigation links for Current Conditions, Groundwater Levels, Well Infrastructure, and Land Subsidence. The main content area has a dark background with an aerial view of agricultural fields. It includes the title "California's Groundwater Live" and the subtitle "CALIFORNIA'S LATEST GROUNDWATER INFORMATION AND CONDITIONS". Below this is the Department of Water Resources logo for the State of California. A "SECTIONS" menu contains four buttons: CURRENT CONDITIONS, GROUNDWATER LEVELS, WELL INFRASTRUCTURE, and LAND SUBSIDENCE. The footer includes links for About, How to access data, and Questions/Feedback: calgw@water.ca.gov.

New Tools: Real-time Data Visualization



New Handbook: Data Ingestion

Established Common Vocabulary, Water Budget Framework, and Standard Templates



New Handbook: Data Ingestion

Established Common Vocabulary, Water Budget Framework, and Standard Templates

LAND SYSTEM WATER BUDGET

HANDBOOK FOR WATER BUDGET DEVELOPMENT

Table 1-2 Water Budget Accounting Template

- Color Key:
- Inflow to Water Budget Zone
 - Outflow from Water Budget Zone
 - Flow between Systems
 - Flow within Systems

LAND SYSTEM WATER BUDGET		
Component	Credit/Debit	Relationship with Other Systems
INFLOWS		
Precipitation	+	
Surface Water Delivery	+	Equal to the Surface Water Delivery term in the surface water system outflow
Groundwater Extraction	+	Equal to the Groundwater Extraction term in the groundwater system outflow
Stored Water Extraction	+	Equal to the Stored Water Extraction term in the groundwater system outflow
Applied Water	+	Sum of Surface Water Delivery, Groundwater Extraction, Stored Water Extraction, and Applied Water Recharge/Recycled Water
OUTFLOWS		
Evapotranspiration	-	Precipitation plus Surface Water Delivery plus Groundwater Extraction plus Stored Water Extraction
Rainfall	-	Equal to the Rainfall term in Surface Water System*
Return Flow	-	Equal to the Return Flow term in Surface Water System*
Recharge of Applied Water	-	Equal to the Recharge of Applied Water term in the groundwater system
Recharge of Precipitation	-	Equal to the Recharge of Precipitation term in the groundwater system
Managed Aquifer Recharge	-	Equal to the Managed Aquifer Recharge term in the groundwater system
Recycled Water Export	-	
	Total Outflow	Evapotranspiration plus Rainfall plus Return Flow plus Recharge of Applied Water plus Recharge of Precipitation plus Managed Aquifer Recharge plus Recycled Water Export
STORAGE CHANGE		
Change in Land System Storage		
Land System Mass Balance Error		
*For cases where the surface water system is outside the water budget zone, some of these components will require additional consideration to characterize correctly.		

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SURFACE WATER SYSTEM WATER BUDGET

SURFACE WATER SYSTEM WATER BUDGET		
Component	Credit/Debit	Relationship with Other Systems
INFLOWS		
Precipitation on Land System	+	Equal to the Precipitation term in the land system
Precipitation on Lakes	+	Equal to the Precipitation on Lakes term in the surface water system
Stream Inflow	+	Equal to the Stream Inflow term in the surface water system
Imported Water	+	Equal to the Imported Water term in the surface water system
Subsurface Inflow	+	Equal to the Subsurface Inflow term in the groundwater system
Water Release Caused by Land Subsidence	+	Equal to the Water Release Caused by Land Subsidence term in the groundwater system
OUTFLOWS		
Evapotranspiration from Land System	-	Precipitation on Land System plus Precipitation on Lakes plus Stream Inflow plus Imported Water plus Subsurface Inflow
Stream Evaporation	-	Equal to the Stream Evaporation term in the surface water system
Lake Evaporation	-	Equal to the Lake Evaporation term in the surface water system
Convergence Evaporation	-	Equal to the Convergence Evaporation term in the surface water system
Stream Outflow	-	Equal to the Stream Outflow term in the surface water system
Subsurface Outflow	-	Equal to the Subsurface Outflow term in the groundwater system
Groundwater Export	-	Equal to the Groundwater Export term in the groundwater system
Recycled Water Export	-	Equal to the Recycled Water Export term in the land system
Convergence Evaporation from Land System	-	Evapotranspiration from Land System plus Stream Evaporation plus Lake Evaporation plus Convergence Evaporation plus Stream Outflow plus Subsurface Outflow plus Groundwater Export plus Recycled Water Export
STORAGE CHANGE		
Change in Surface Water Storage		
Surface Water System Mass Balance Error		
*For cases where the surface water system is outside the water budget zone, some of these components will require additional consideration to characterize correctly.		

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GROUNDWATER SYSTEM WATER BUDGET

HANDBOOK FOR WATER BUDGET DEVELOPMENT

GROUNDWATER SYSTEM WATER BUDGET		
Component	Credit/Debit	Relationship with Other Systems
INFLOWS		
Recharge of Applied Water	+	Equal to the Recharge of Applied Water term in the land system
Recharge of Precipitation	+	Equal to the Recharge of Precipitation term in the land system
Managed Aquifer Recharge	+	Equal to the Managed Aquifer Recharge term in the land system
Groundwater Gain from Streams	+	Equal to the Stream Loss to Groundwater term in the surface water system
Groundwater Gain from Lakes	+	Equal to the Lake Loss to Groundwater term in the surface water system
Convergence Seepage	+	Equal to the Convergence Seepage term in the surface water system
OUTFLOWS		
Recharge of Applied Water plus Recharge of Precipitation plus Managed Aquifer Recharge plus Groundwater Gain from Streams plus Groundwater Gain from Lakes plus Convergence Seepage plus Subsurface Inflow plus Water Release Caused by Land Subsidence	-	
Groundwater Extraction	-	Equal to the Groundwater Extraction term in the land system
Stored Water Extraction	-	Equal to the Stored Water Extraction term in the land system
Stream Loss to Stream	-	Equal to the Stream Gain from Groundwater term in the surface water system
Loss to Lake from Groundwater	-	Equal to the Lake Gain from Groundwater term in the surface water system
Convergence Seepage	-	Equal to the Convergence Seepage term in the surface water system
Subsurface Outflow	-	Equal to the Subsurface Outflow term in the groundwater system
Groundwater Export	-	Equal to the Groundwater Export term in the groundwater system
Recycled Water Export	-	Equal to the Recycled Water Export term in the land system
STORAGE CHANGE		
Change in Groundwater Storage		
Groundwater System Mass Balance Error		
*For cases where the surface water system is outside the water budget zone, some of these components will require additional consideration to characterize correctly.		

HANDBOOK FOR WATER BUDGET DEVELOPMENT

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Precipitation on Lakes	+	Equal to the Precipitation on Lakes term in the surface water system
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Water Release Caused by Land Subsidence	+	Equal to the Water Release Caused by Land Subsidence term in the groundwater system
OUTFLOWS		
Evapotranspiration from Land System	-	Precipitation on Land System plus Precipitation on Lakes plus Stream Inflow plus Imported Water plus Subsurface Inflow
Stream Evaporation	-	Equal to the Stream Evaporation term in the surface water system
Lake Evaporation	-	Equal to the Lake Evaporation term in the surface water system
Convergence Evaporation	-	Equal to the Convergence Evaporation term in the surface water system
Stream Outflow	-	Equal to the Stream Outflow term in the surface water system
Subsurface Outflow	-	Equal to the Subsurface Outflow term in the groundwater system
Groundwater Export	-	Equal to the Groundwater Export term in the groundwater system
Recycled Water Export	-	Equal to the Recycled Water Export term in the land system
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STORAGE CHANGE		
Change in Surface Water Storage		
Surface Water System Mass Balance Error		
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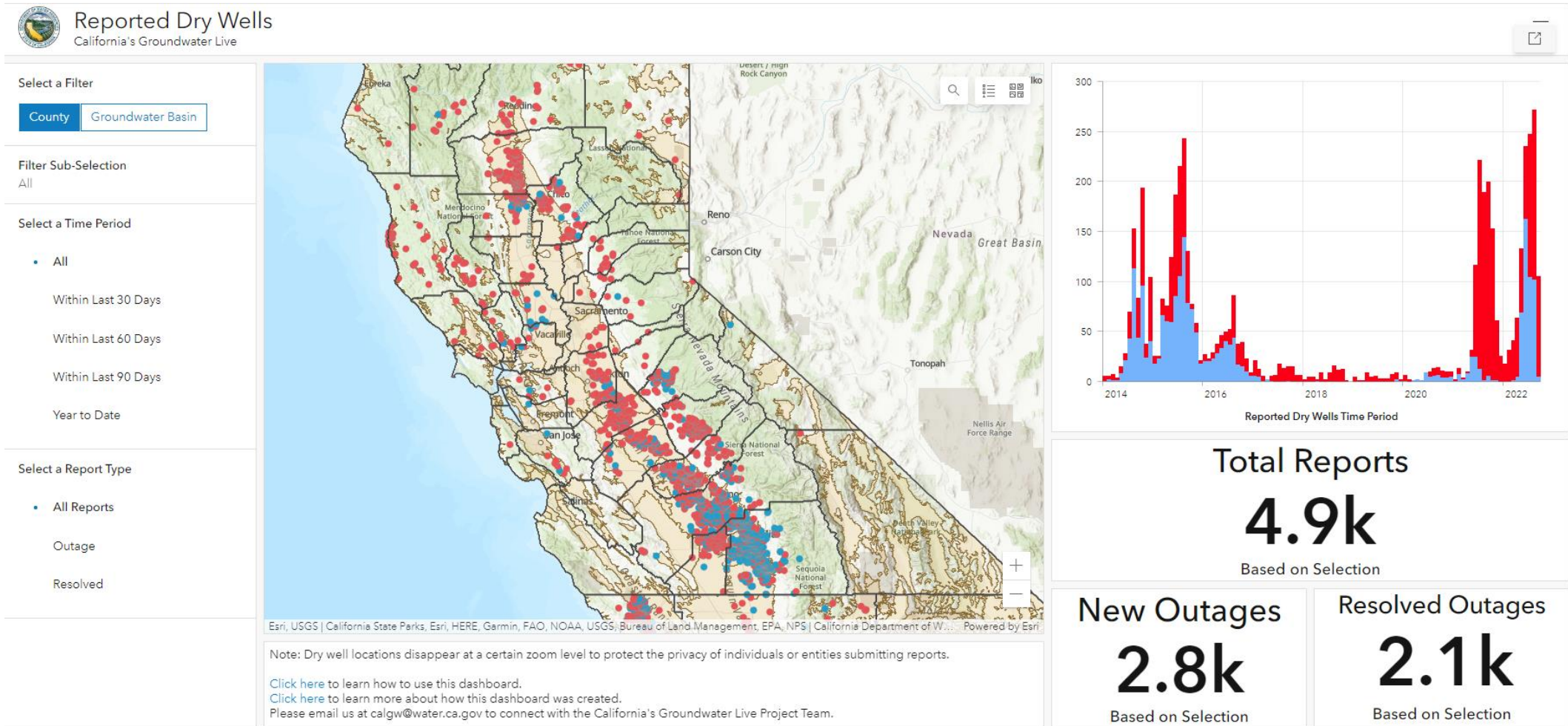
TOTAL WATER BUDGET

HANDBOOK FOR WATER BUDGET DEVELOPMENT

TOTAL WATER BUDGET		
Component	Credit/Debit	Relationship with Other Systems
INFLOWS		
Precipitation on Land System	+	Equal to the Precipitation term in the land system
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Imported Water	+	Equal to the Imported Water term in the surface water system
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Water Release Caused by Land Subsidence	+	Equal to the Water Release Caused by Land Subsidence term in the groundwater system
OUTFLOWS		
Evapotranspiration from Land System	-	Precipitation on Land System plus Precipitation on Lakes plus Stream Inflow plus Imported Water plus Subsurface Inflow
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STORAGE CHANGE		
Change in Land System Storage		
Land System Mass Balance Error		
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New Data and Tools: Drought Response and Preparedness



New Data and Tools: Drought Response and Preparedness



Dry Domestic Well Susceptibility within Groundwater Basins
California's Groundwater Live



Select a Filter

County Groundwater Basin

Filter Sub-Selection

All

Select Susceptible Well Density

(0=Low to 100=High)



To get started:

- Search for an address or area of interest (County or groundwater basin)
- View the legend to see what data are being presented
- Overlay additional layers to inform your decisions
- Change the basemap

Background:

This dashboard estimates dry domestic well susceptibility within groundwater basins. The results are created by combining the latest information on domestic well locations, depths, and local groundwater level conditions. This dashboard has been created for informational purposes only and is not intended to be a prediction of when and where specific domestic wells will go dry. The information is intended to help local, state, and federal partners understand areas of highest dry well susceptibility in California in order to prepare and respond to ongoing drought conditions. For more information please visit the [California Natural Resource Agency Open Data Platform](#) or review the [Fact Sheet](#).

The map includes the locations of reported dry wells based from Department of Water Resources' (DWR) [Dry Well Reporting System](#) and a series of reference layers applicable to dry domestic well susceptibility. These layers include important boundaries including [Disadvantaged Communities](#), [Groundwater Basins](#), [Counties](#), [State Water Resources Control Board California Drinking Water System Areas](#), and [Office of Environmental Health Hazard Assessment's CalEnviroScreen 4.0 Results](#).

If you are currently experiencing a dry domestic well, you can report that to DWR's [Dry Well Reporting System](#) which will connect you with available local assistance.

Use Disclaimer:

DWR makes no warranties or guarantees – either expressed or implied – as to the completeness, accuracy, or correctness of the data. DWR neither accepts nor assumes liability arising from or for any incorrect, incomplete, or misleading subject data.

This dashboard and the underlying analysis provide a density map of domestic wells that are susceptible.

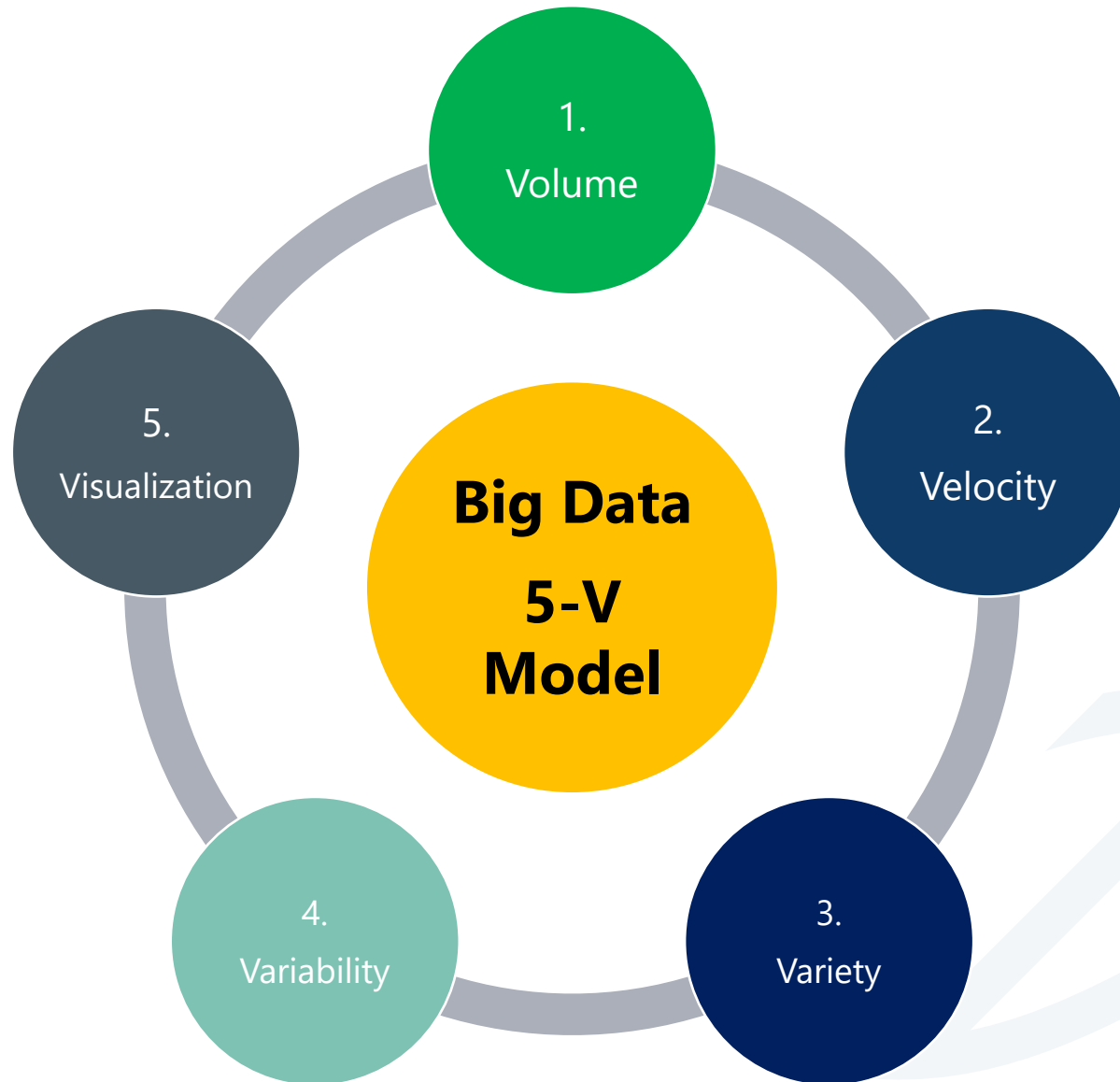
Dry Well Susceptibility Dashboard

Using Data to Solve Problems

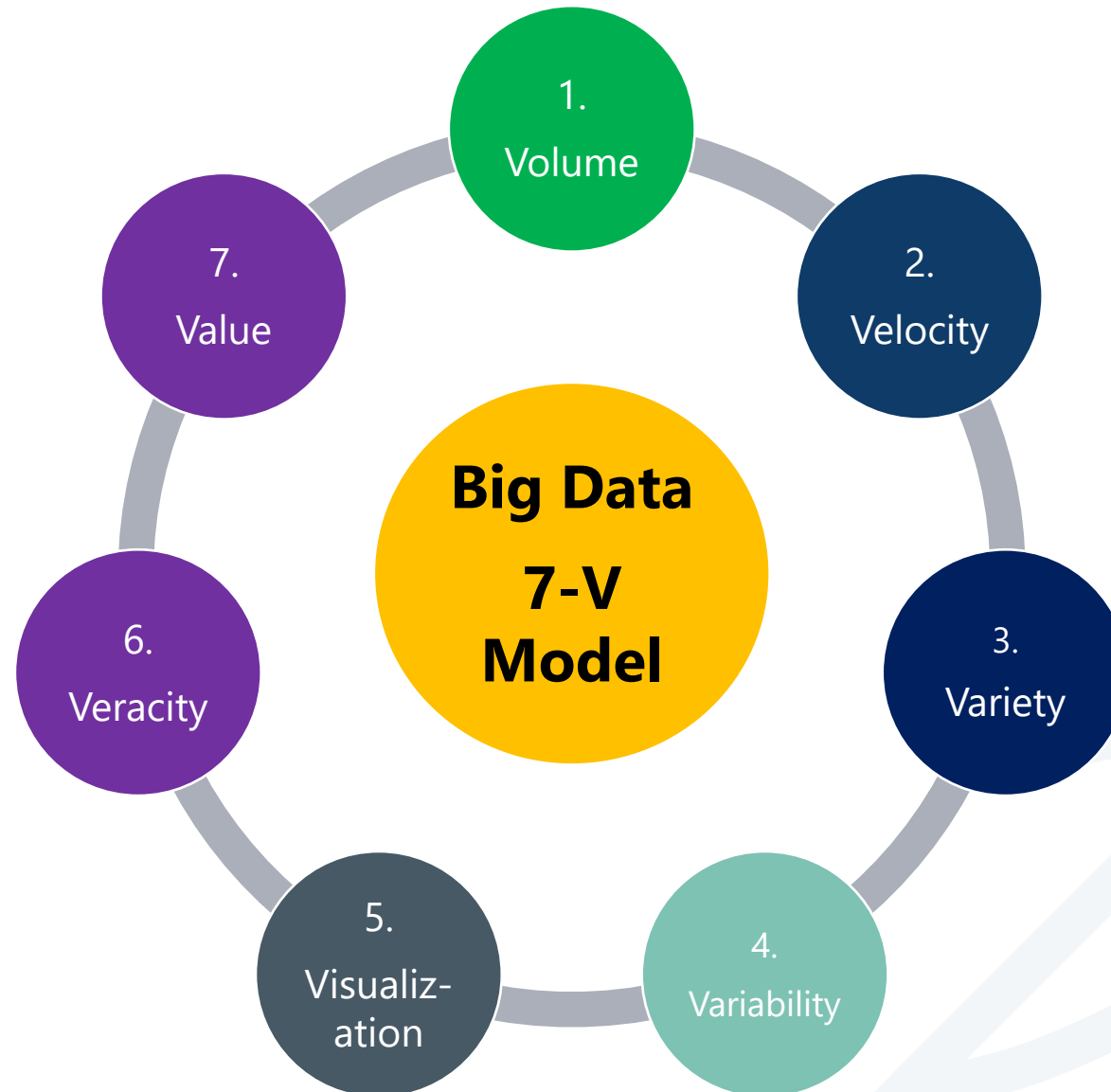
Ocean of Data



Big Data Journey from 5-V Model to 7-V Model



Big Data Journey from 5-V Model to 7-V Model



Hype or Hope?!

Forbes

Feb 8, 2019, 06:00am EST

CRYPTO & BLOCKCHAIN

IBM Pilots Blockchain and IoT Sensor Solution To Track Sustainable Groundwater Usage In California

Colorado senator wants to study blockchain for water rights management

March 7, 2019 - 10:41 am

Front. Environ. Sci., 15 June 2022
Sec. Water and Wastewater Management
<https://doi.org/10.3389/fenvs.2022.909606>

A Framework of Blockchain Technology in Intelligent Water Management

Special issue: [Recent advances in drought and water scarcity monitoring...](#)

Research article | 03 Dec 2021

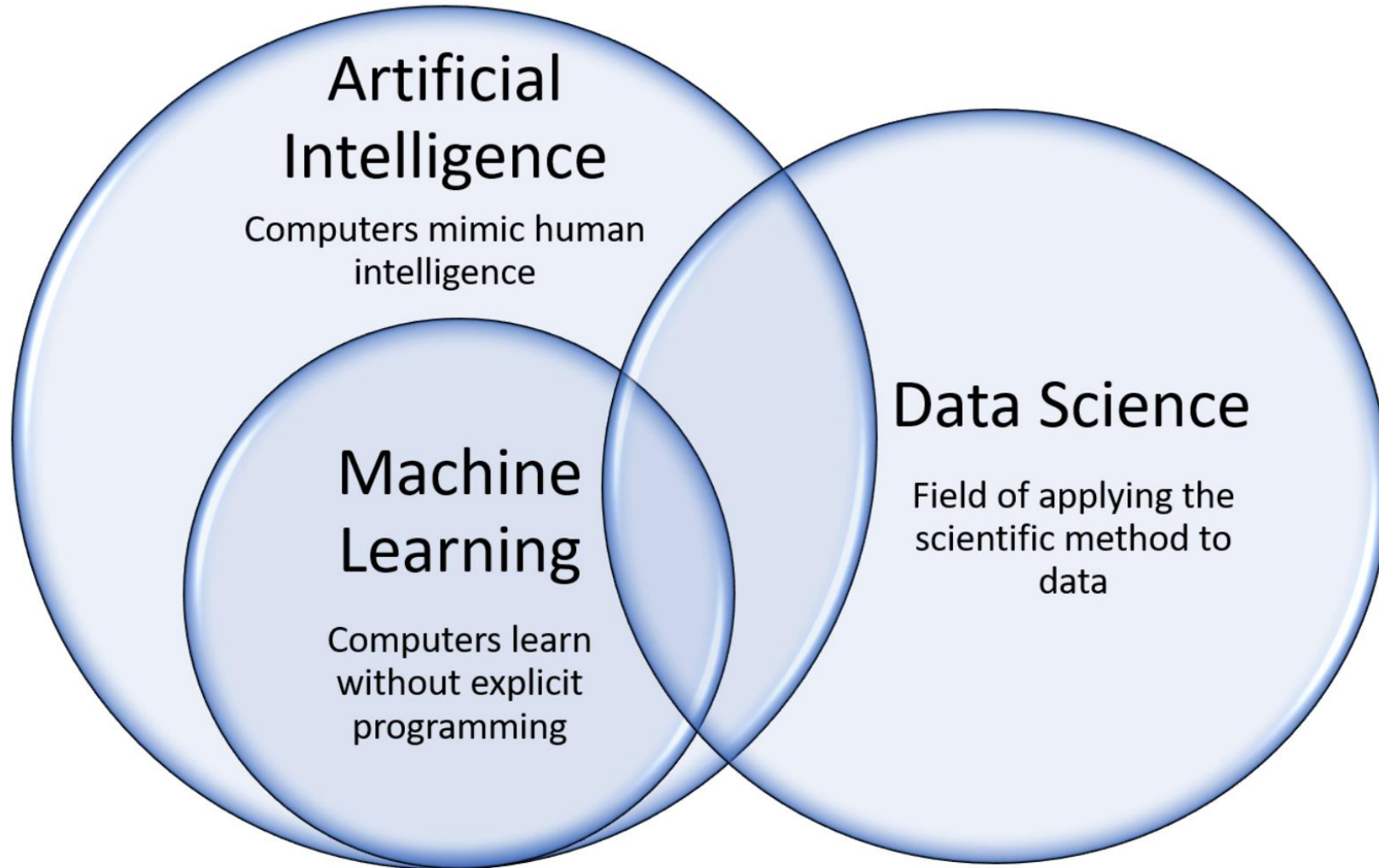
Applying machine learning for drought prediction in a perfect model framework using data from a large ensemble of climate simulations

Elizaveta Felsche and Ralf Ludwig

[Show author details](#)

New Tools for Handling Big Data:

AI, Machine Learning, and Data Science



Applications of Big Data Tools in Groundwater



Fig. 2. Arithmetical conceptualization of growth observed in GWL research using AI based model during 2008–2020.

Big data offers promise of better groundwater management in California

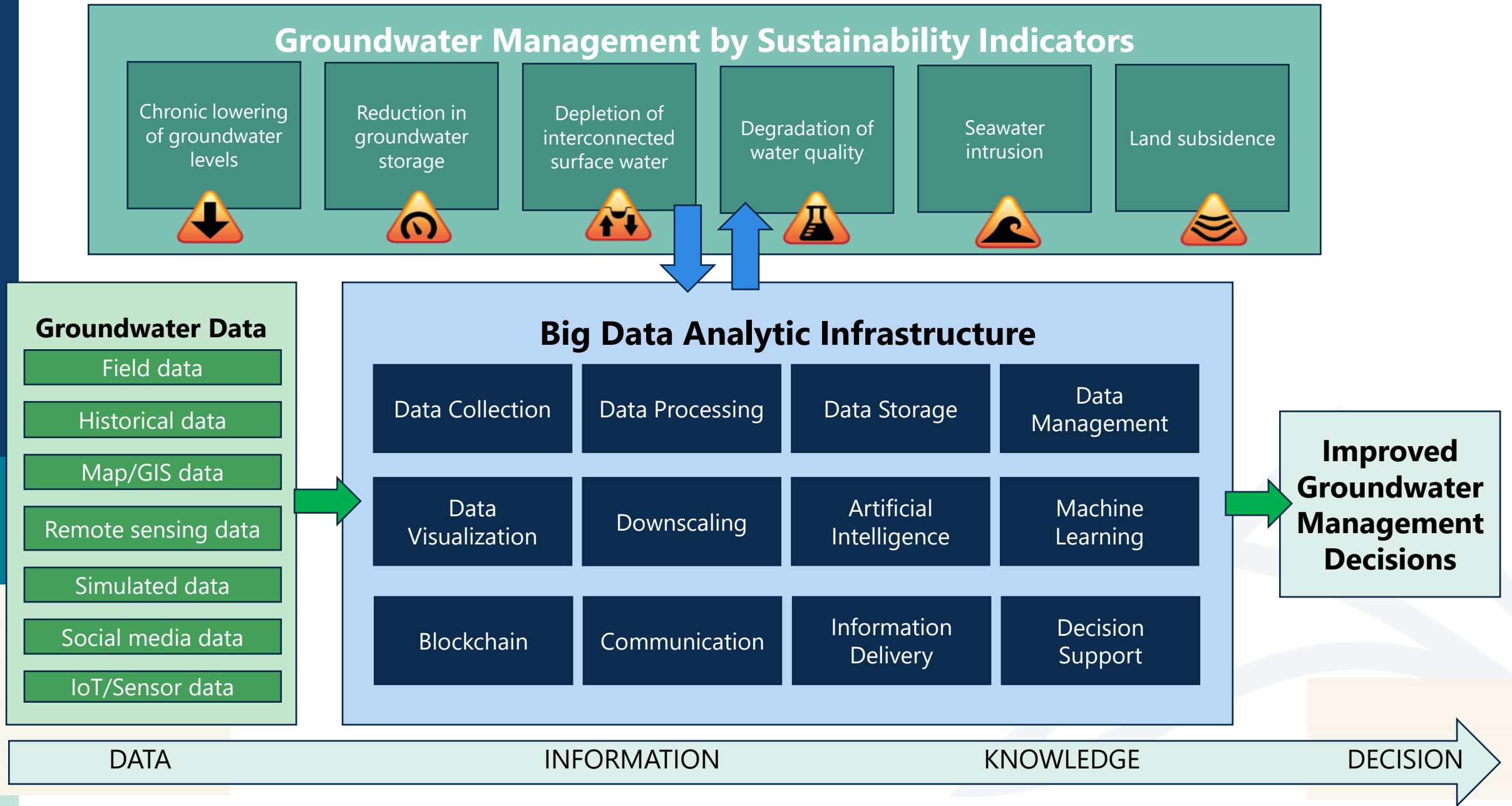
Analysis of 200,000 groundwater samples reveals major mismatch in California groundwater data

Date: December 9, 2020

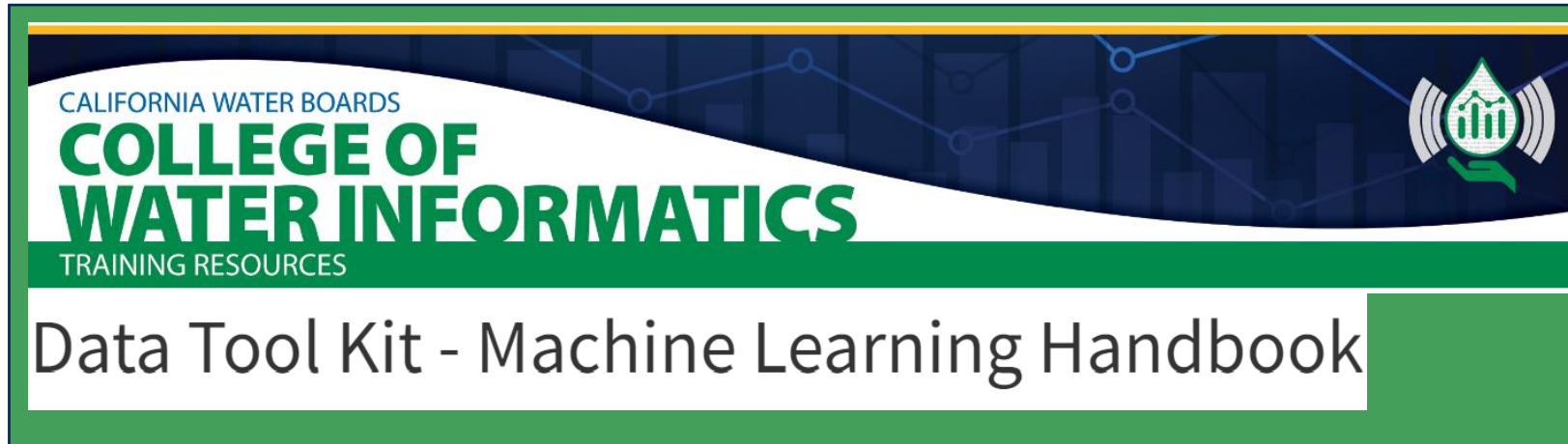
Source: McGill University

Summary: A research team has analyzed big data of more than 200,000 groundwater samples taken from across the state and found that there are problems with the guidelines used for groundwater management. Known as the 'Base of Fresh Water', the guidelines are close to fifty years old and don't reflect current uses, knowledge, concerns or technologies related to managing groundwater in this coastal state with a multi-billion-dollar agricultural industry.

A Theoretical Framework for Big Data in Groundwater



Capacity Building: Skills are Necessary



CALIFORNIA WATER BOARDS
**COLLEGE OF
WATER INFORMATICS**
TRAINING RESOURCES

Data Tool Kit - Machine Learning Handbook

The banner features a dark blue background with a white wavy shape on the left containing the text. On the right, there is a green and white logo of a water drop with a bar chart inside, held by a hand. The background also has faint blue lines and bar charts.



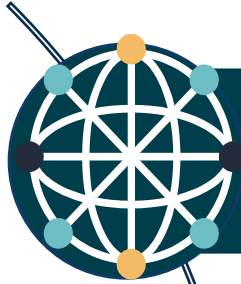
ONLINE COURSE

Machine Learning:
From Data to Decisions

The banner has a dark blue background with a white and blue circuit-like pattern on the right side. The text is in white and blue.

The Value Proposition

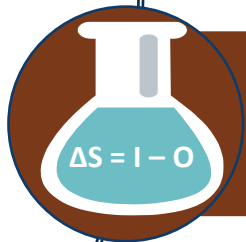
A Vision for the Future: From Extraction to Stewardship



California's water data is integrated and accessible to all to support decision making for long-term resiliency and sustainability



California's suite of water models and tools use data from the same source and provide the output to the same source for use by state, local, and federal agencies, and stakeholders



Water budgets are developed and used for long-term planning, drought resiliency, and water marketing using common vocabulary and integrated sources of data and suite of models



Decision making is supported by a reliable and robust data/information base that is up-to-date



**Woodard
& Curran**

Thank You!

Saquib Najmus

Senior Technical Leader

snajmus@woodardcurran.com

916-806-8360

woodardcurran.com

