Agenda #3: Presentation Overview for Hydrologic Region Reports

Presentation Content:

- Well Infrastructure and Distribution
- Monitoring Well Information
- Basin Prioritization
- Groundwater Quality
- Groundwater Supply
- Aquifer Conditions
- Groundwater Management

Organized by:

- Statewide Overview
- Tulare Lake HR
- San Joaquin River HR
- Central Coast HR

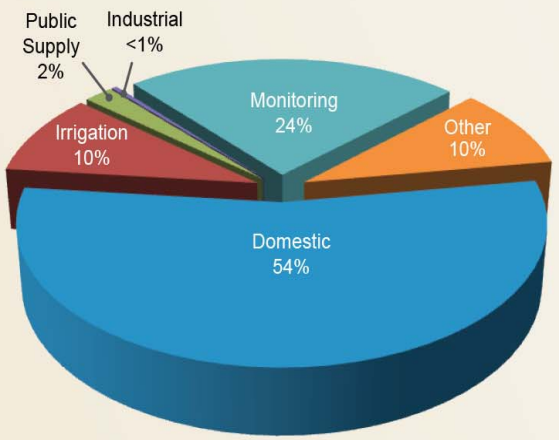
See HR Chapters for Details:

- Alluvial Aquifers
- Land Subsidence
- Other GW Management Information

Well Infrastructure and Distribution
Statewide

Wells completed between 1977 and 2010:

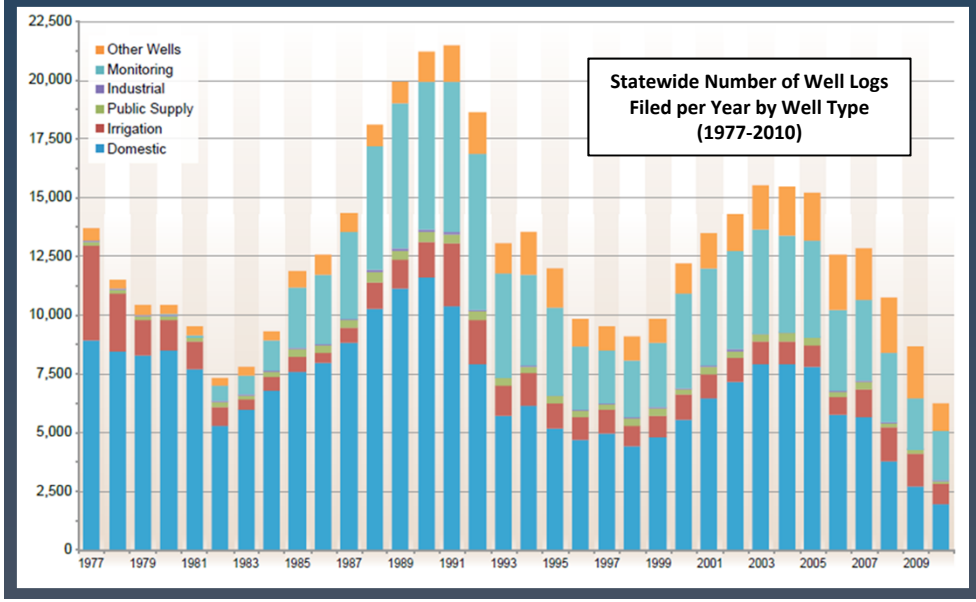
- Based on WCR records
- Total number: 432,500
- Low of 4,100 wells in North Lahontan HR
- High of 108,300 wells in Sacramento River HR

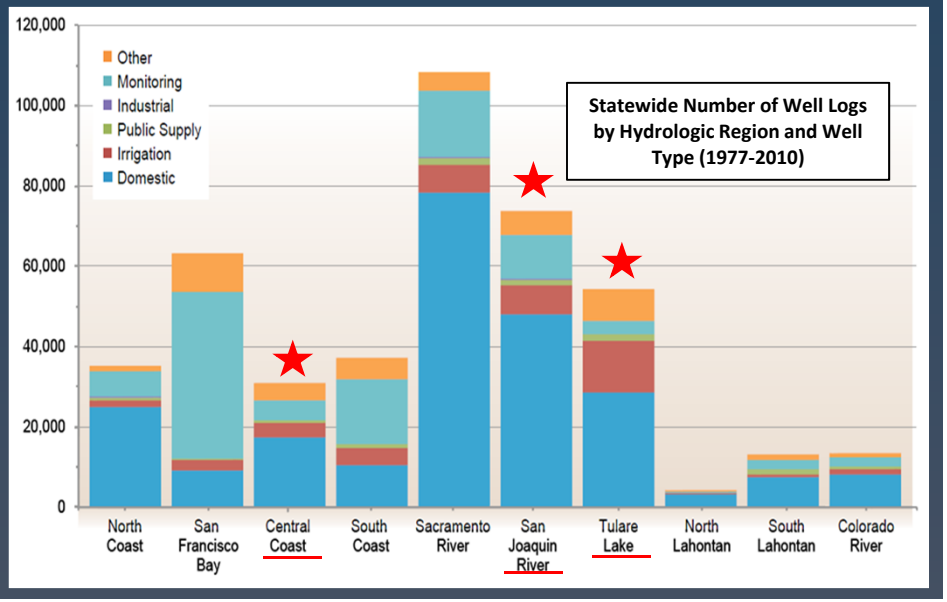


Statewide Well Logs Summary by Well Type

Well Type	Number of Well Logs
Domestic	234,281
Irrigation	41,526
Public Supply	9,077
Industrial	1,739
Monitoring	104,200
Other	41,646
Total	**432,469**

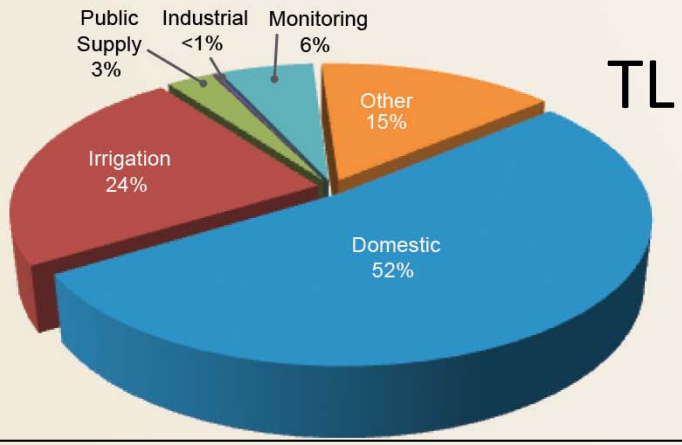
Prepared by California Department of Water Resources for California's Groundwater Update 2013





Well Logs by Well Type

- 1977-2010
- Water Code Section 13751
- Drillers have been required to submit WCRs to State since 1949
- Details vary on WCRs
- "Other wells"
  - Stock wells
  - Test wells
  - Unidentified Wells



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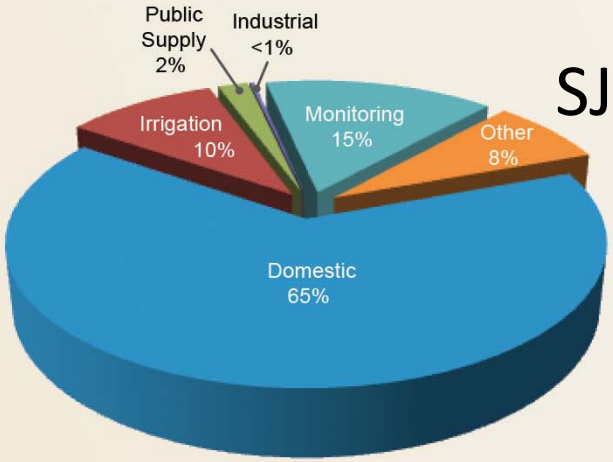
Tulare Lake Well Logs Summary by Well Type

Well Type	Number of Well Logs
Domestic	28,466
Irrigation	12,786
Public Supply	1,581
Industrial	181
Monitoring	3,211
Other	8,097
Total	**54,322**



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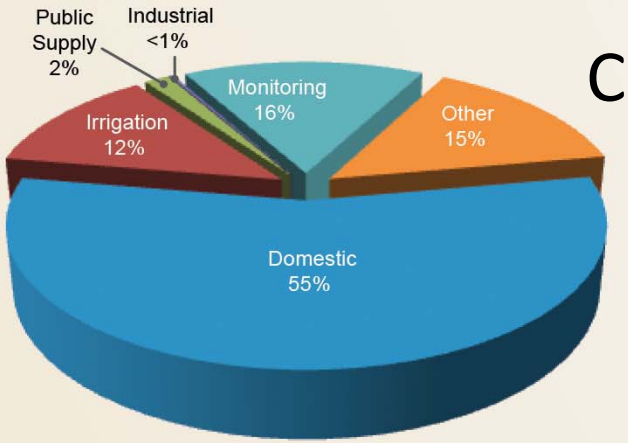
San Joaquin River Well Logs Summary by Well Type

Well Type	Number of Well Logs
Domestic	47,789
Irrigation	7,280
Public Supply	1,461
Industrial	225
Monitoring	11,031
Other	5,661
Total	**73,447**



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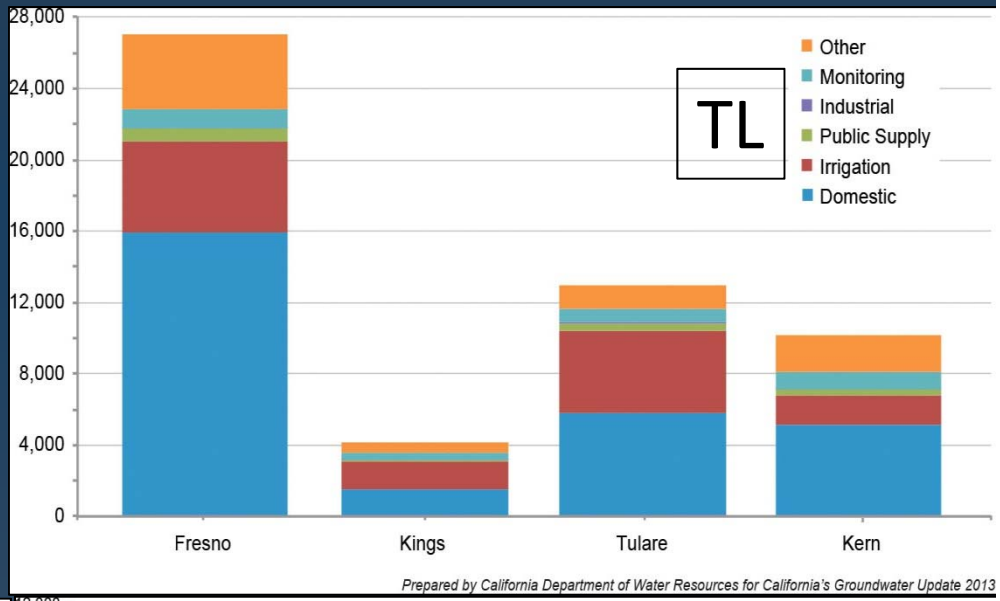
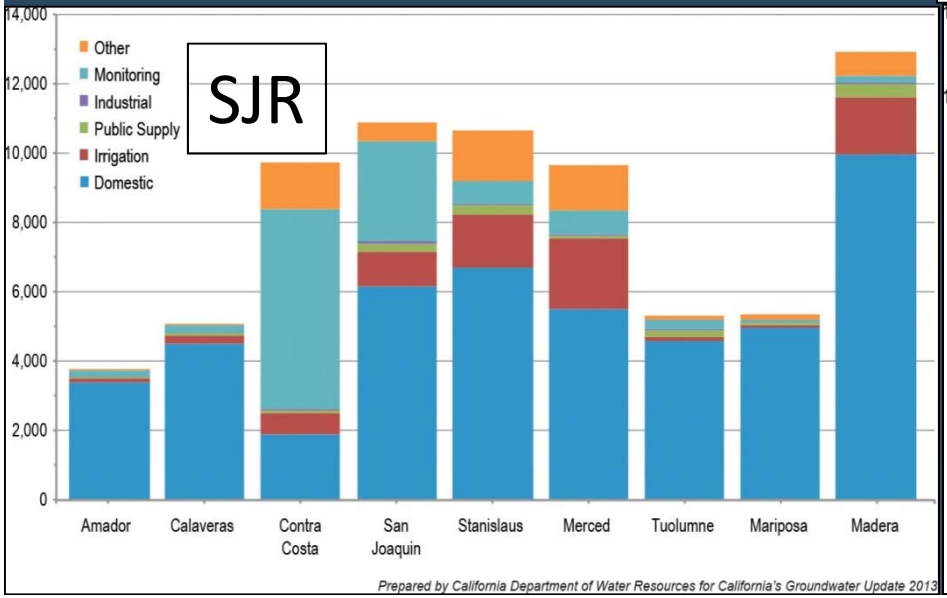
Central Coast Well Logs Summary by Well Type

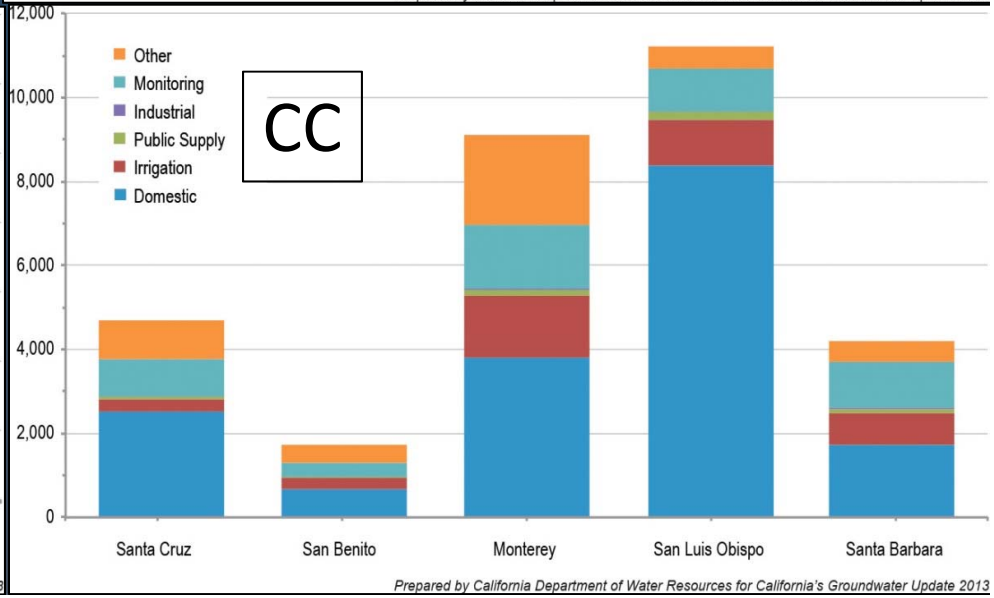
Well Type	Number of Well Logs
Domestic	17,137
Irrigation	3,849
Public Supply	501
Industrial	80
Monitoring	4,880
Other	4,480
Total	**30,927**

Prepared by California Department of Water Resources for California's Groundwater Update 2013

Well Logs by Well Type by County

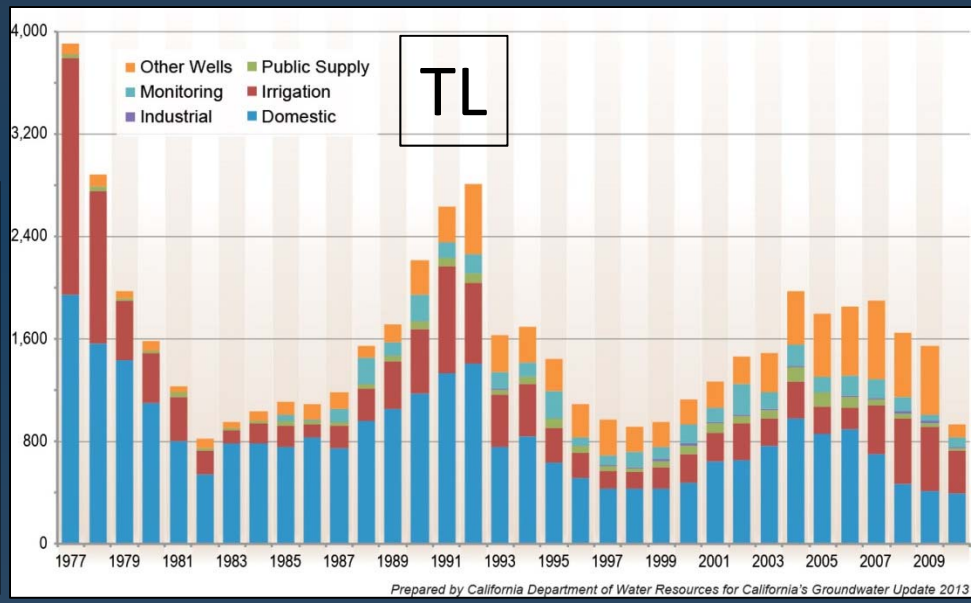


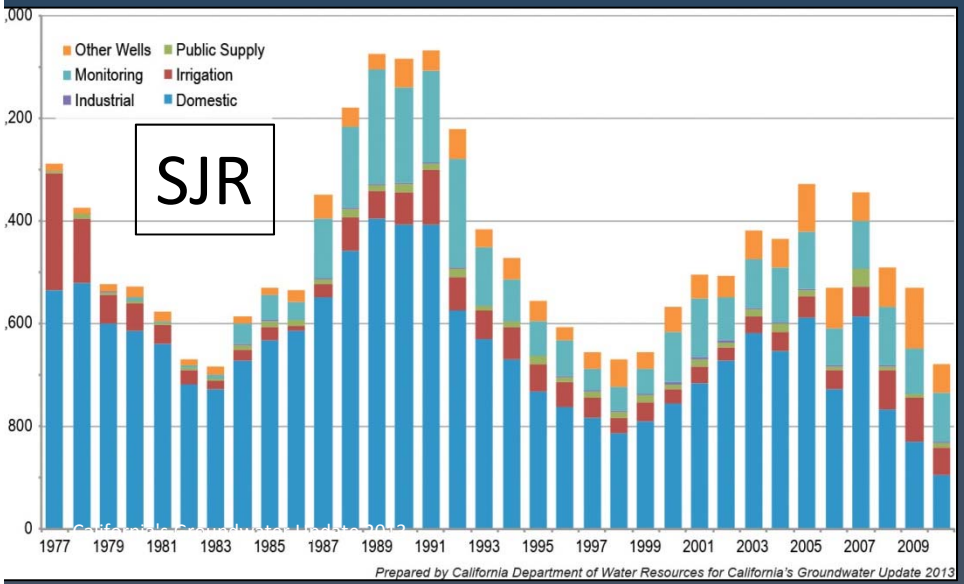


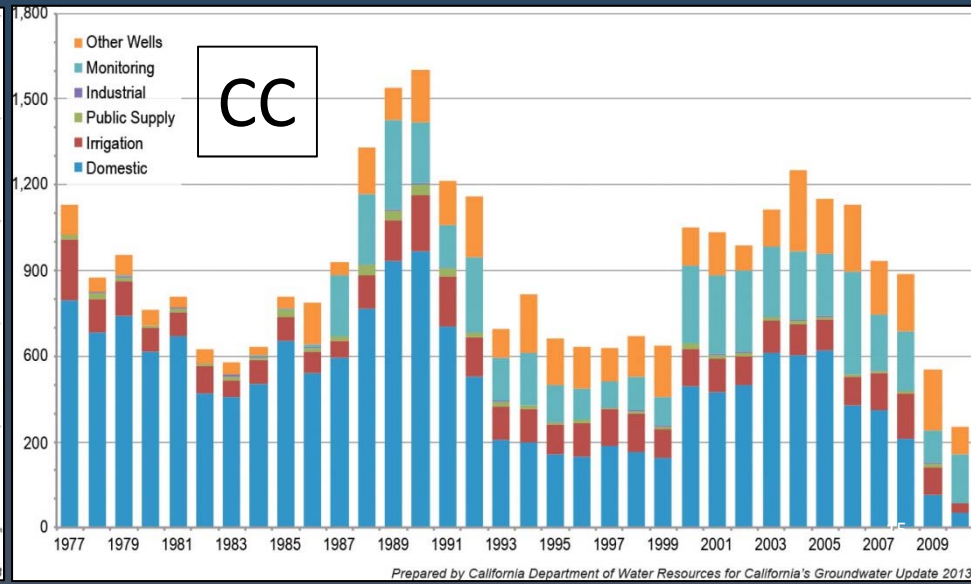


Well Logs by Well Type and Year Installed

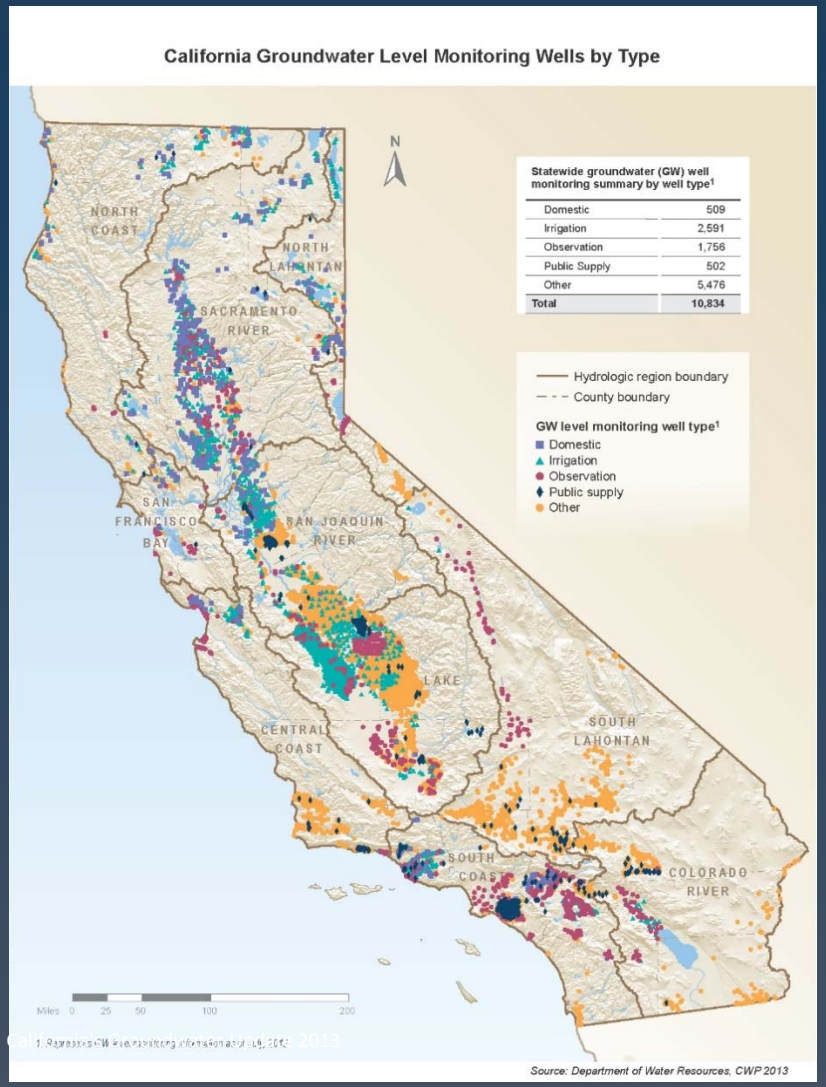
- Increase of domestic and irrigation wells in drought years
- 2009-2010 have incomplete records

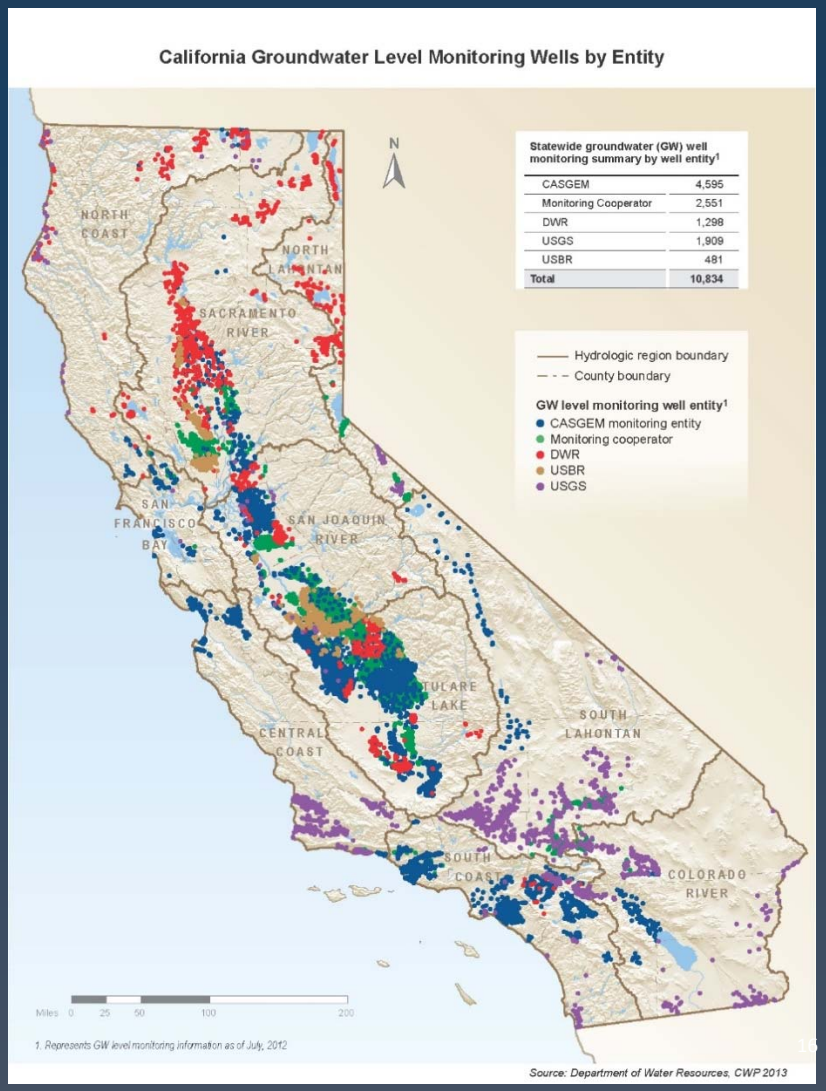






Groundwater Level Monitoring Wells
Statewide



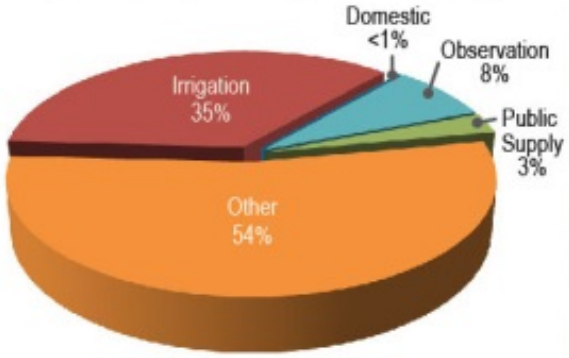


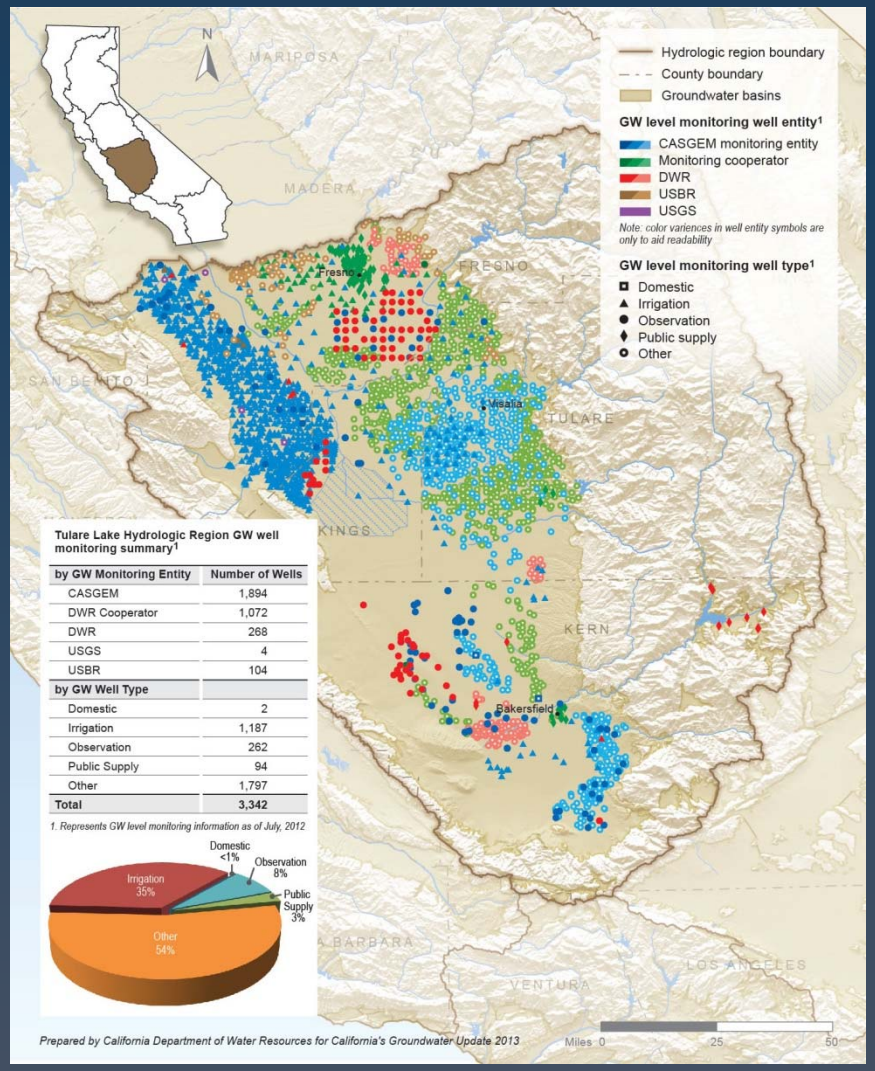
Groundwater Level Monitoring Wells
Tulare Lake HR

Tulare Lake Hydrologic Region GW well monitoring summary[1]

by GW Monitoring Entity	Number of Wells
CASGEM	1,894
DWR Cooperator	1,072
DWR	268
USGS	4
USBR	104
by GW Well Type	
Domestic	2
Irrigation	1,187
Observation	262
Public Supply	94
Other	1,797
Total	**3,342**

1. Represents GW level monitoring information as of July, 2012





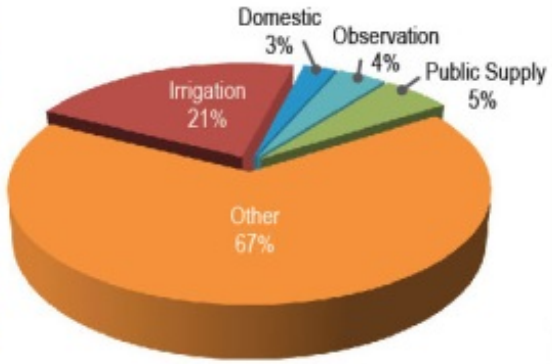
Groundwater Level Monitoring Wells

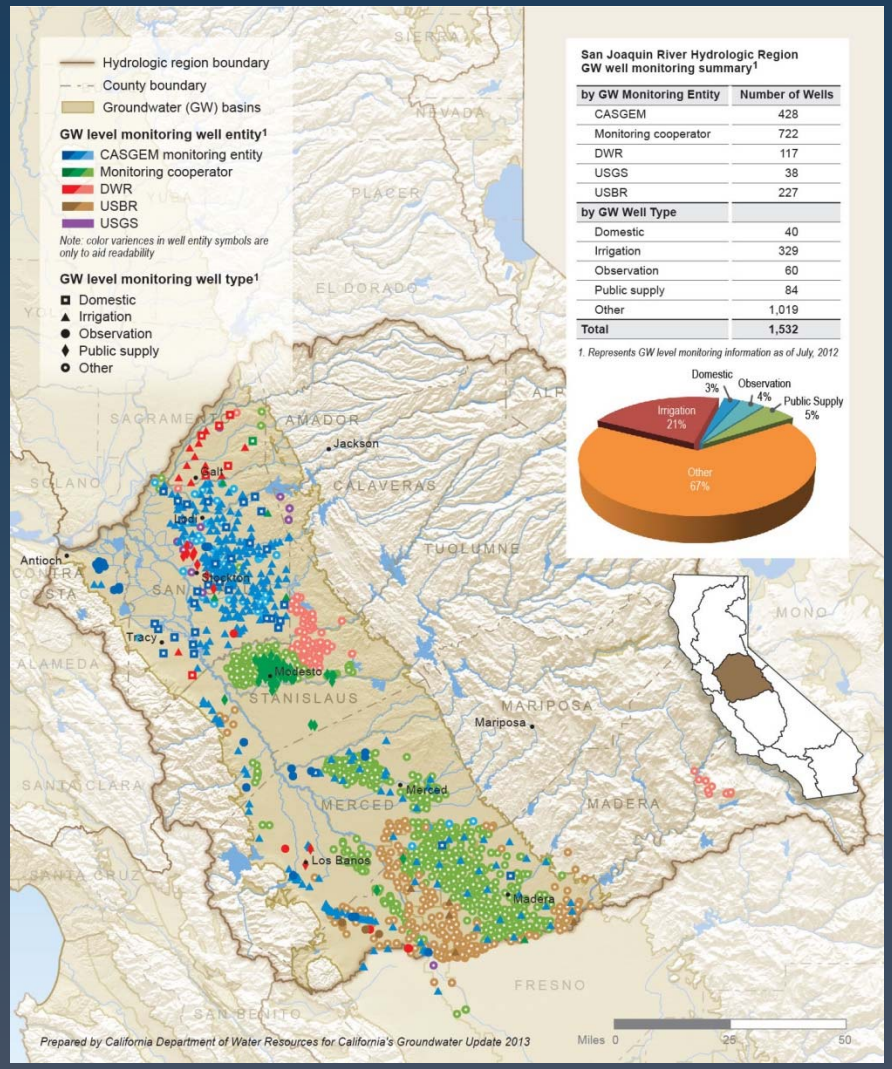
San Joaquin River HR

San Joaquin River Hydrologic Region GW well monitoring summary[1]

by GW Monitoring Entity	Number of Wells
CASGEM	428
Monitoring cooperator	722
DWR	117
USGS	38
USBR	227
by GW Well Type	
Domestic	40
Irrigation	329
Observation	60
Public supply	84
Other	1,019
Total	**1,532**

1. Represents GW level monitoring information as of July, 2012



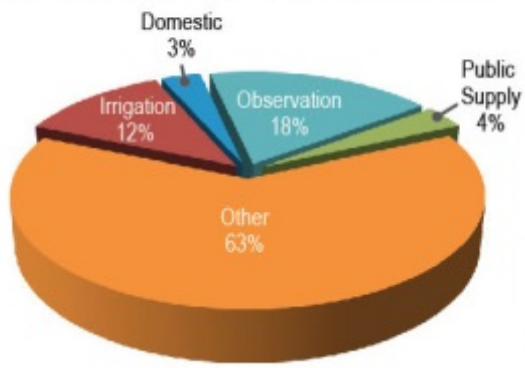


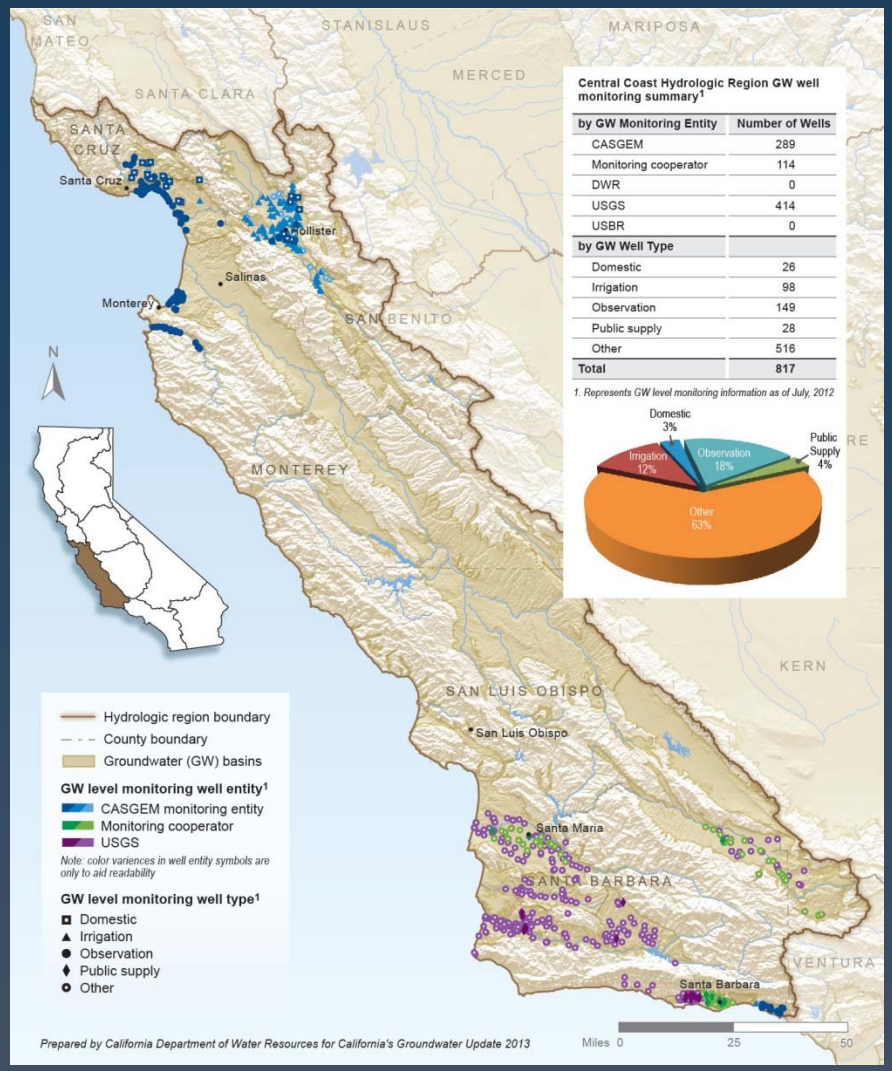
Groundwater Level Monitoring Wells
Central Coast HR

Central Coast Hydrologic Region GW well monitoring summary[1]

by GW Monitoring Entity	Number of Wells
CASGEM	289
Monitoring cooperator	114
DWR	0
USGS	414
USBR	0
by GW Well Type	
Domestic	26
Irrigation	98
Observation	149
Public supply	28
Other	516
Total	**817**

1. Represents GW level monitoring information as of July, 2012





Central Coast Hydrologic Region GW well monitoring summary[1]

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Monitoring cooperator	114
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by GW Well Type	
Domestic	26
Irrigation	98
Observation	149
Public supply	28
Other	516
Total	**817**

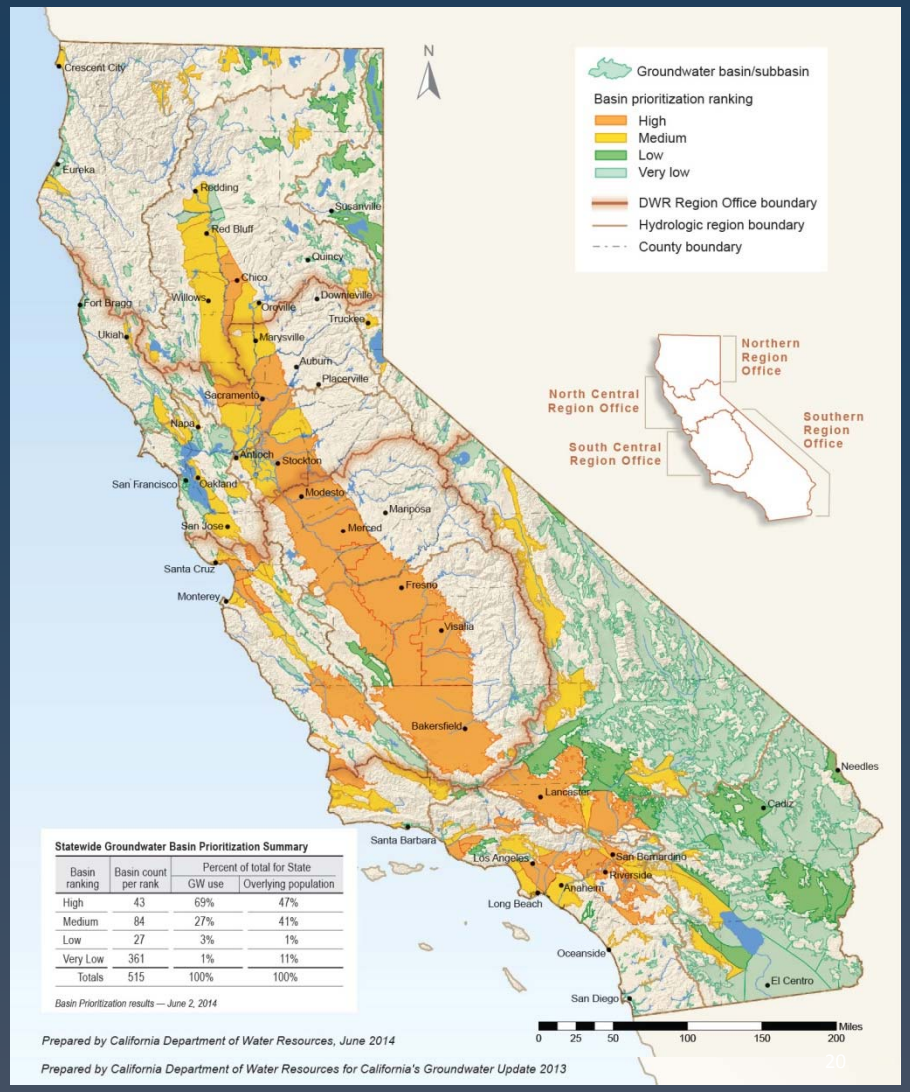
1. Represents GW level monitoring information as of July, 2012

CASGEM Basin Prioritization
Statewide

- 515 alluvial basins/subbasins underlying 61,900 square miles
- 127 high & medium priority basins account for:
  - 96% of average annual GW supply
  - 88% of 2010 population overlying basin area
  - Required to address SGMA!

BASIN RANKING	BASIN COUNT	PERCENT OF TOTAL FOR STATE	
		GW USE	POPULATION
High	43	69%	47%
Medium	84	27%	41%
Low	27	3%	1%
Very Low	361	1%	11%
Totals	515	100%	100%

Basin Prioritization Results – June 2, 2014

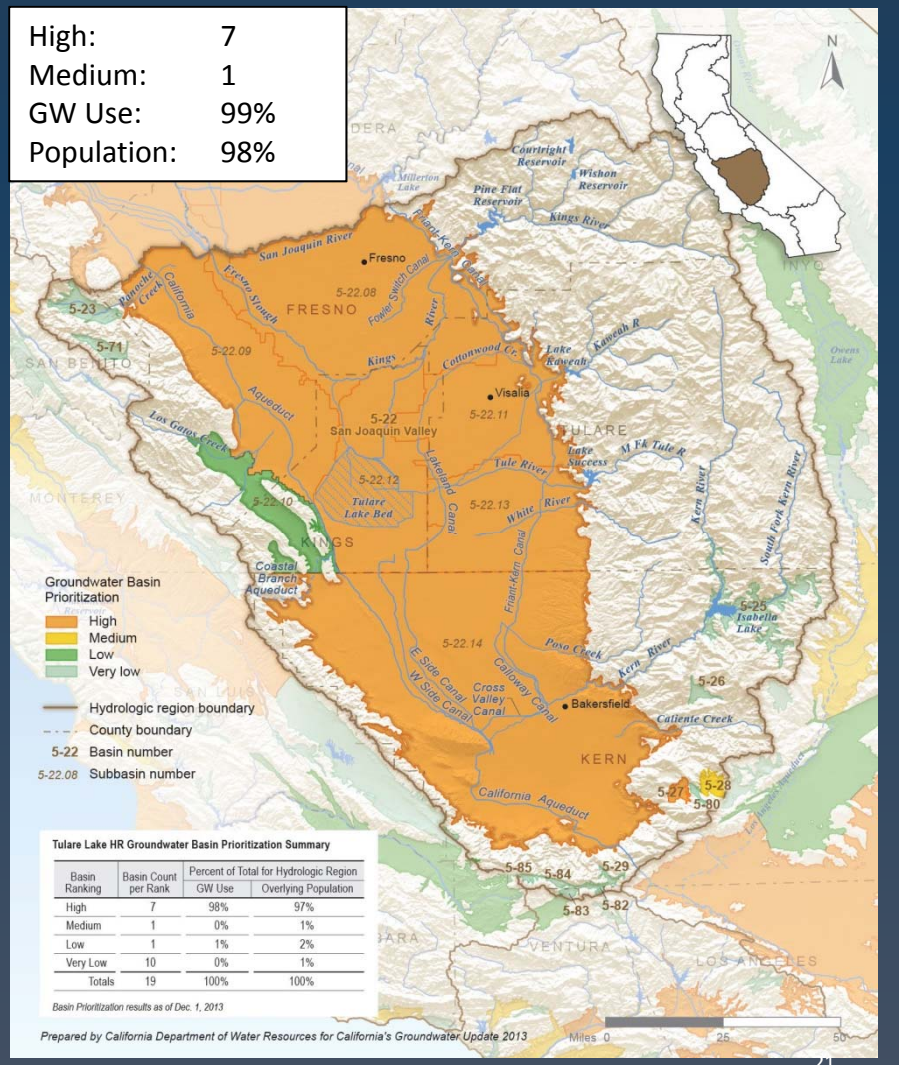


Basin Prioritization
Tulare Lake HR

California Water Code Section 10933(b):

- The population overlying the basin.
- The rate of current and projected growth of the population.
- The number of public supply wells.
- The total number of wells.
- The irrigated acreage.
- The degree to which persons rely on groundwater as their primary source of water.
- Any documented impacts on the groundwater, including overdraft, subsidence, saline intrusion, and other water quality degradation.
- Any other information determined to be relevant by the Department, including adverse impacts on local habitat and local stream flows.

High:	7
Medium:	1
GW Use:	99%
Population:	98%



Basin Ranking	Basin Count per Rank	Percent of Total for Hydrologic Region	
		GW Use	Overlying Population
High	7	98%	97%
Medium	1	0%	1%
Low	1	1%	2%
Very Low	10	0%	1%
Totals	19	100%	100%

Basin Prioritization results as of Dec. 1, 2013

Basin Prioritization
San Joaquin River HR

California Water Code Section 10933(b):

- The population overlying the basin.
- The rate of current and projected growth of the population.
- The number of public supply wells.
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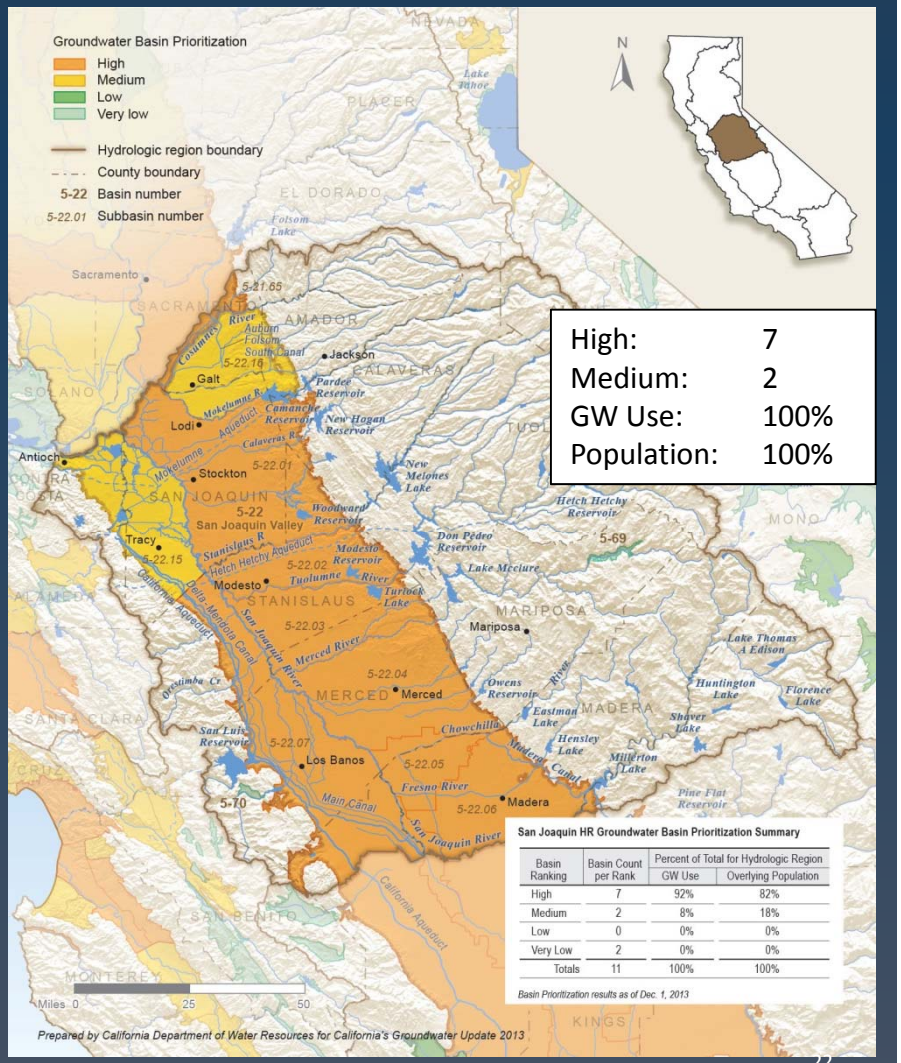

Basin Prioritization
Central Coast HR

California Water Code Section 10933(b):

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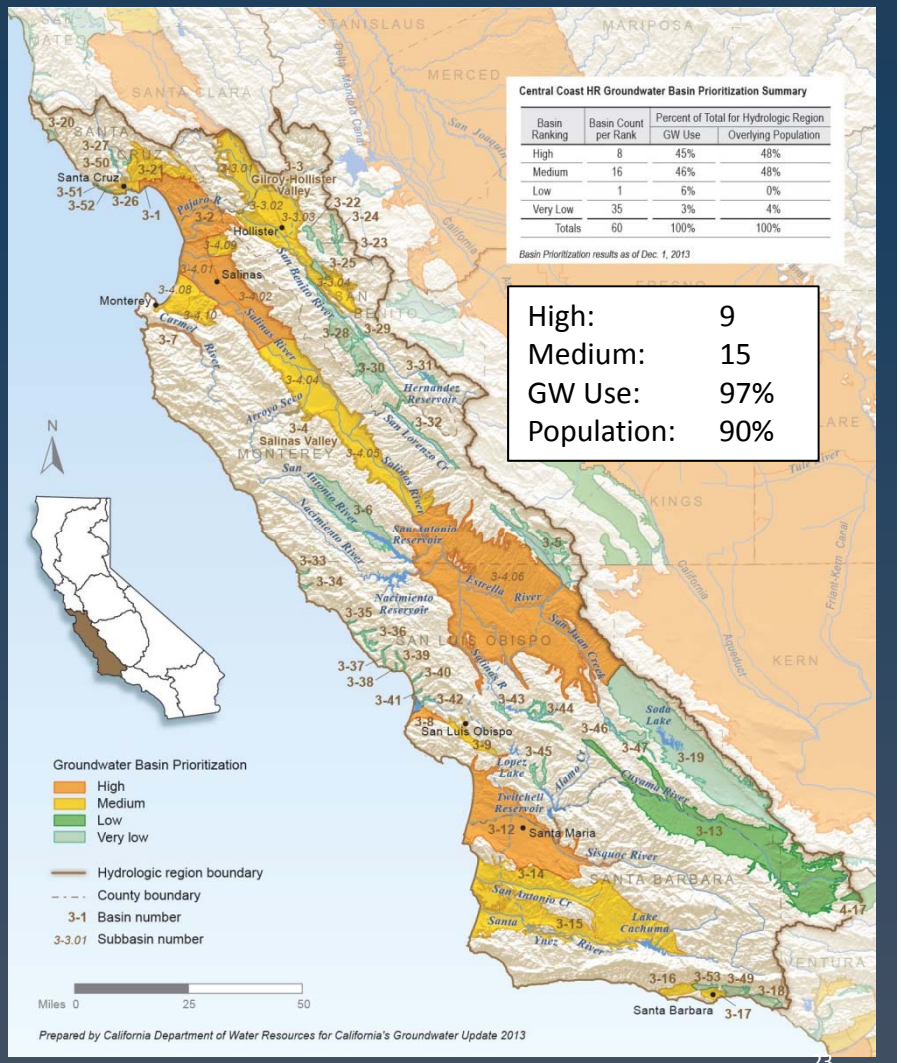


Groundwater Quality
Information in All HR Chapters

Information compiled by Regional Water Quality Control Boards

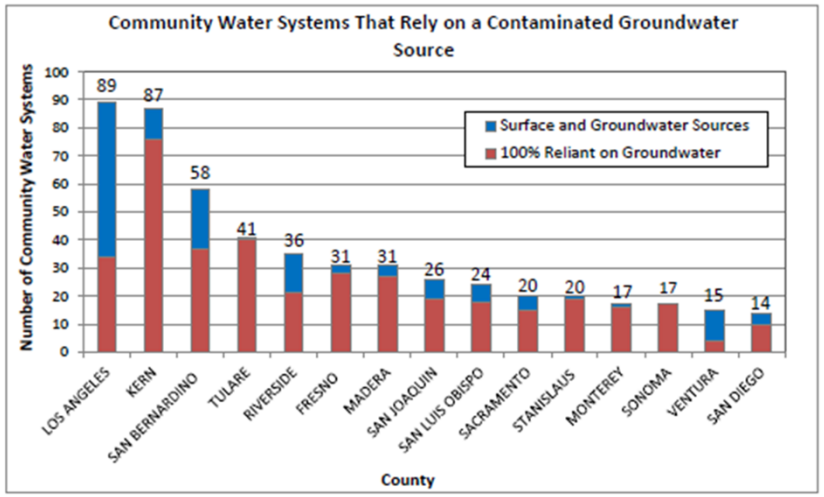
- Table of Data Sources
- Quality at Community Drinking Water Wells
- GAMA Priority Basin Project
- Groundwater Quality at Domestic Wells
- Groundwater Quality Protection
  - Regional Protection Strategy
  - Salt and Nutrient Management Plans
- DWR WDL Water Quality Data

Ten Most Frequently Detected Principle Contaminants in Community Water System Wells

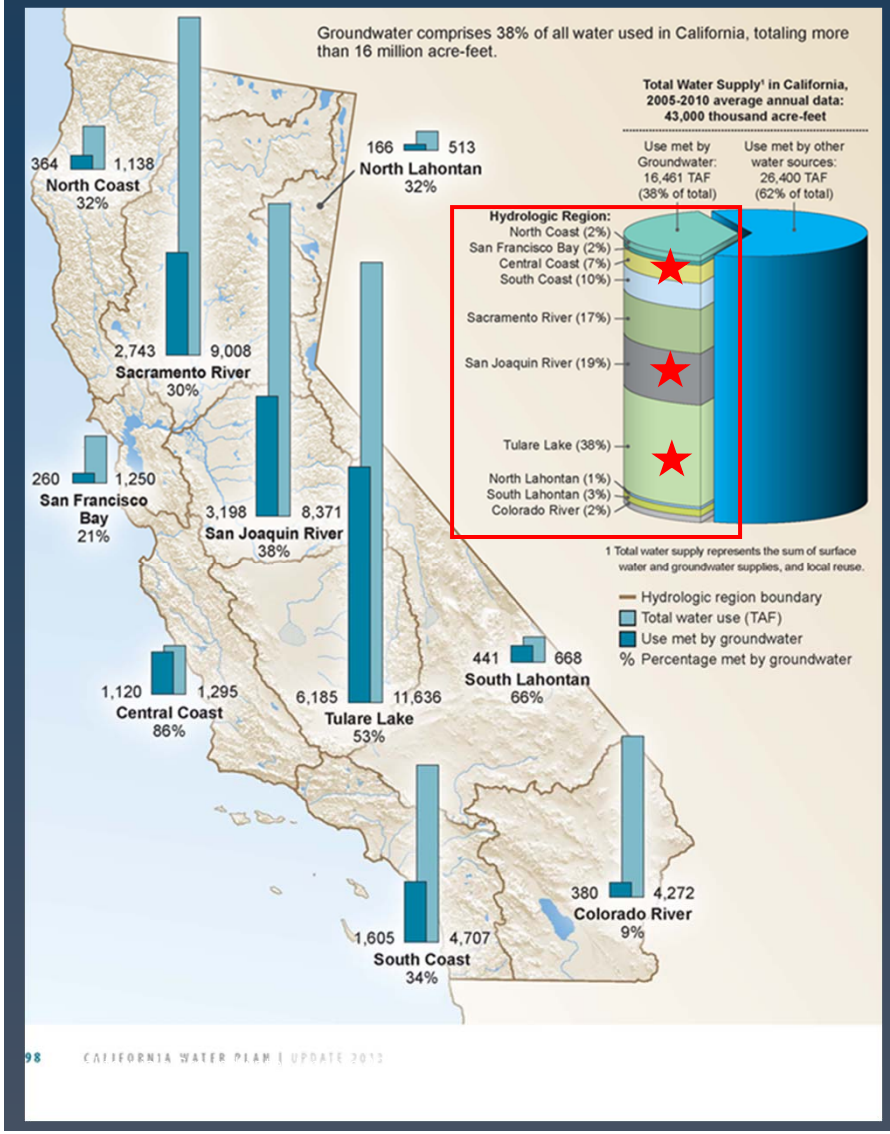
Principal Contaminant	Number of Wells	Number of Community Water Systems	Type of Contaminant
Arsenic	587	287	Naturally occurring
Nitrate	451	205	Anthropogenic nutrient[1]
Gross alpha activity	333	182	Naturally occurring
Perchlorate	179	57	Industrial/military use[1]
Tetrachloroethylene (PCE)	168	60	Solvent
Trichloroethylene (TCE)	159	44	Solvent
Uranium	157	89	Naturally occurring
1,2-dibromo-3-chlropropane (DBCP)	118	36	Legacy pesticide
Fluoride	79	41	Naturally occurring
Carbon tetrachloride	52	17	Solvent

Notes:
1. Also can be naturally occurring, but typically at levels below maximum contaminant level.

Source: SWRCB, 2013, Communities that Rely on a Contaminated Source for Drinking Water



Groundwater Supply Data 2005-2010 Average



TOTAL SUPPLY

- 43 maf (43,000 taf)

GROUNDWATER SUPPLY

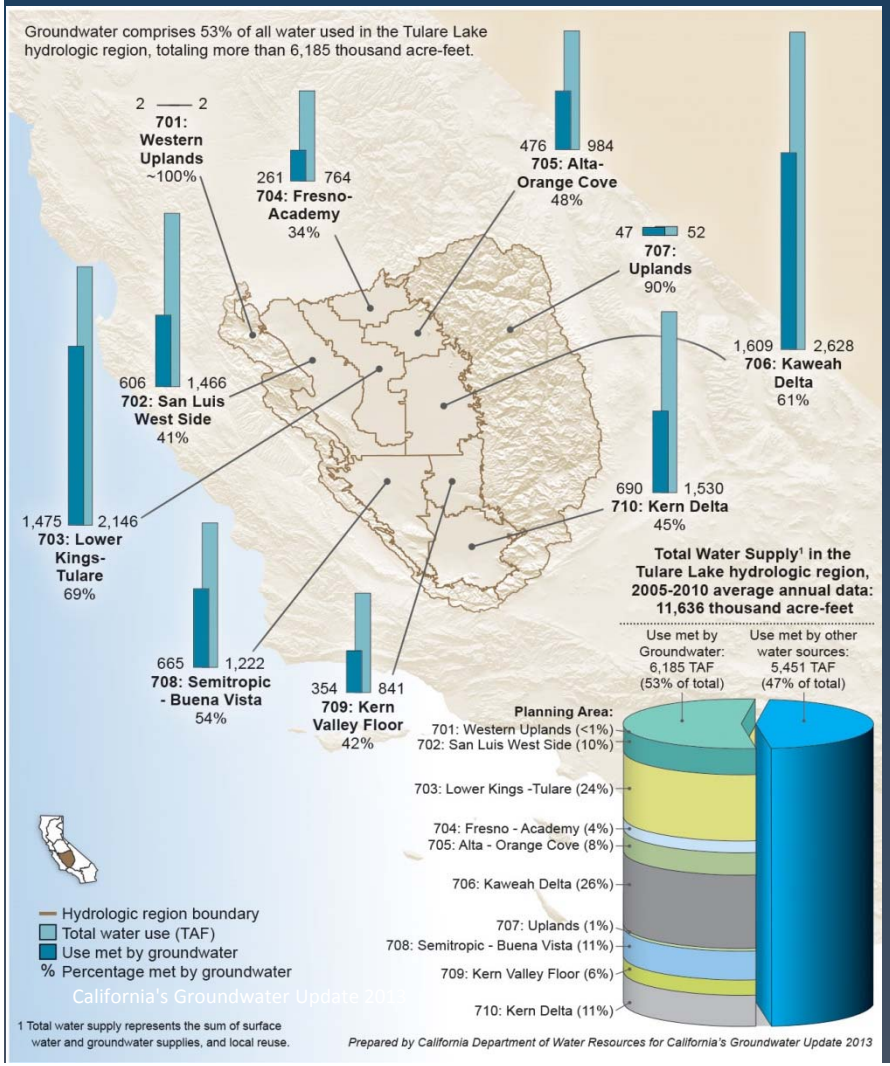
- 16.5 maf (16,461 taf)
- 38% of total supply

➢ GW Meets 39% of Total Agricultural Use
➢ GW Meets 41% of Total Urban Use

Average Annual Groundwater Use and Percent of Total Supply Met by Groundwater, by Hydrologic Region and by Type of Use (2005-2010)

Hydrologic Region	Agriculture Use Met by Groundwater		Urban Use Met by Groundwater		Managed Wetlands Use Met by Groundwater		Total Water Use Met by Groundwater	
	taf	%	taf	%	taf	%	taf	%
North Coast	301.3	41%	60.3	41%	2.5	1%	364.0	32%
San Francisco	76.1	74%	183.5	16%	0.0	0%	259.5	21%
Central Coast	906.1	91%	213.3	71%	0.0	0%	1,119.5	86%
South Coast	385.4	54%	1,219.6	31%	0.0	0%	1,605.0	34%
Sacramento River	2,294.2	30%	428.6	47%	20.1	4%	2,742.9	30%
San Joaquin	2,591.8	36%	415.9	58%	190.7	38%	3,198.4	38%
Tulare Lake	5,551.8	51%	604.0	82%	28.9	37%	6,184.8	53%
North Lahontan	118.4	27%	37.1	84%	10.7	48%	166.2	32%
South Lahontan	270.6	72%	170.3	58%	0.0	0%	440.9	66%
Colorado River	50.1	1%	329.7	53%	0.0	0%	379.7	9%
2005-2010 annual average California total:	12,545.7	39%	3,662.2	41%	252.9	18%	16,460.8	38%

Groundwater Supply (2005-2010)
Tulare Lake HR



TOTAL WATER SUPPLY

- 11,636 taf = 11.636 maf

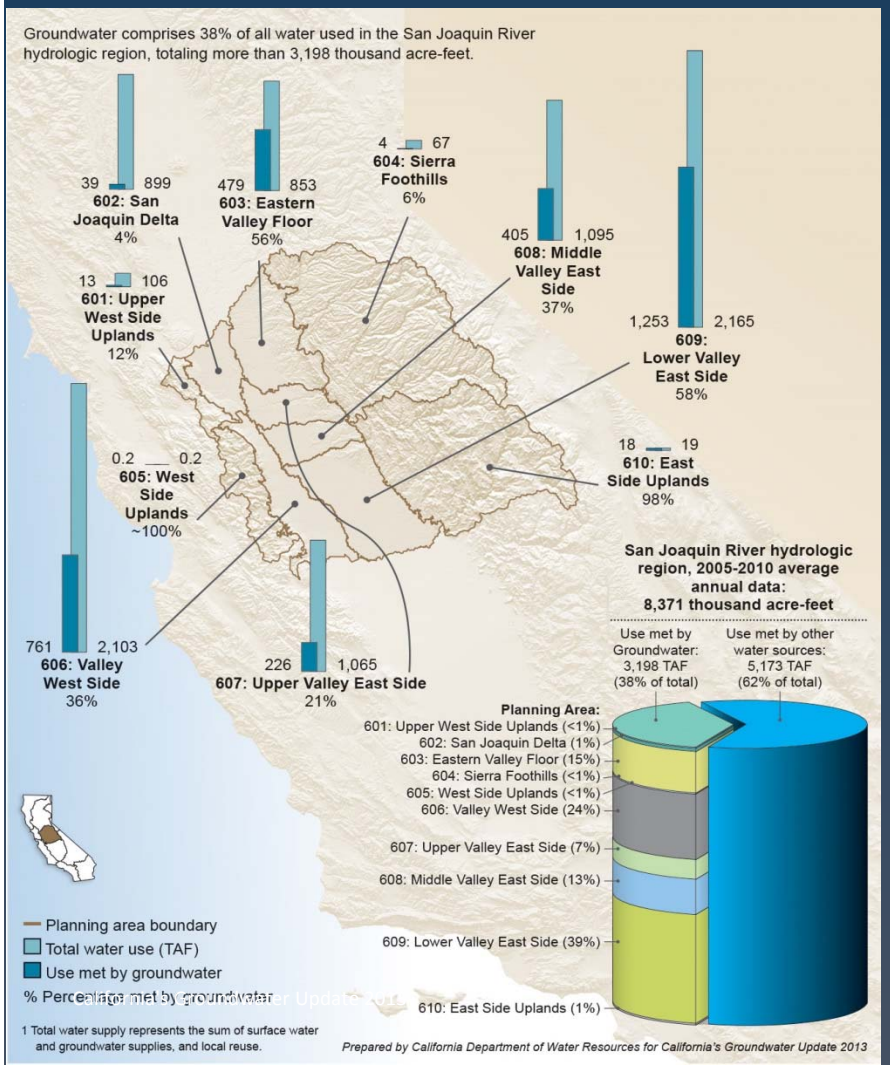
USE MET BY GROUNDWATER

- 6,185 taf
- 53 percent of total supply

8 Planning Areas

Largest user of groundwater

Groundwater Supply (2005-2010)
San Joaquin River HR



TOTAL WATER SUPPLY

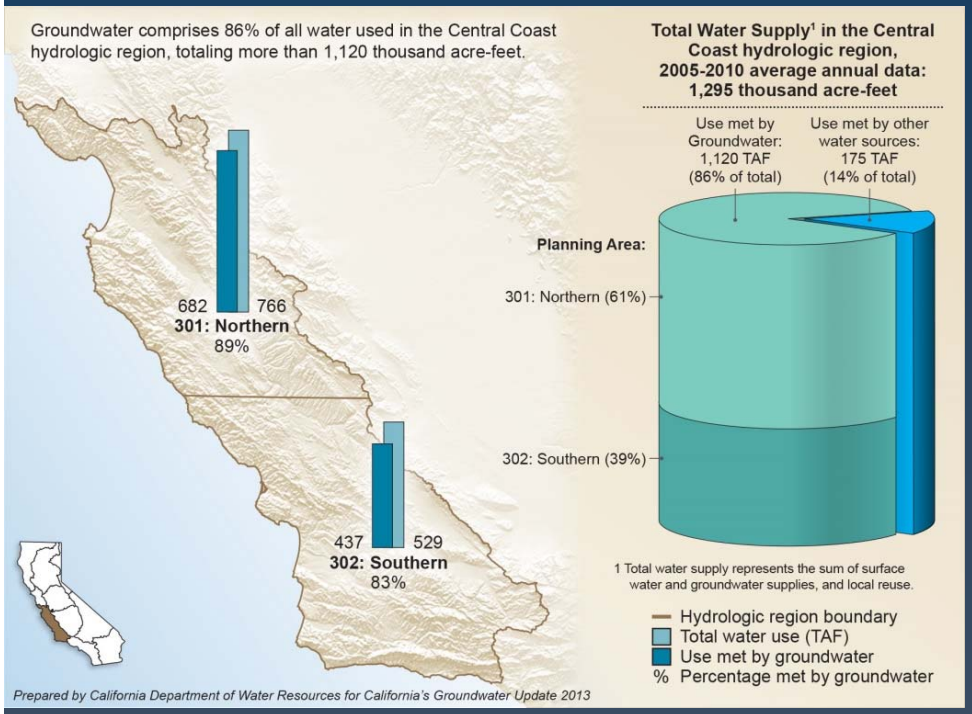
- 8,371 taf = 8.371 maf

USE MET BY GROUNDWATER

- 3,198 taf
- 38 percent of total supply

7 Planning Areas

Groundwater Supply (2005-2010)
Central Coast HR



TOTAL WATER SUPPLY

- 1,295 taf = 1.295 maf

USE MET BY GROUNDWATER

- 1,120 taf
- 86 percent of total supply

2 Planning Areas

Most reliant upon groundwater

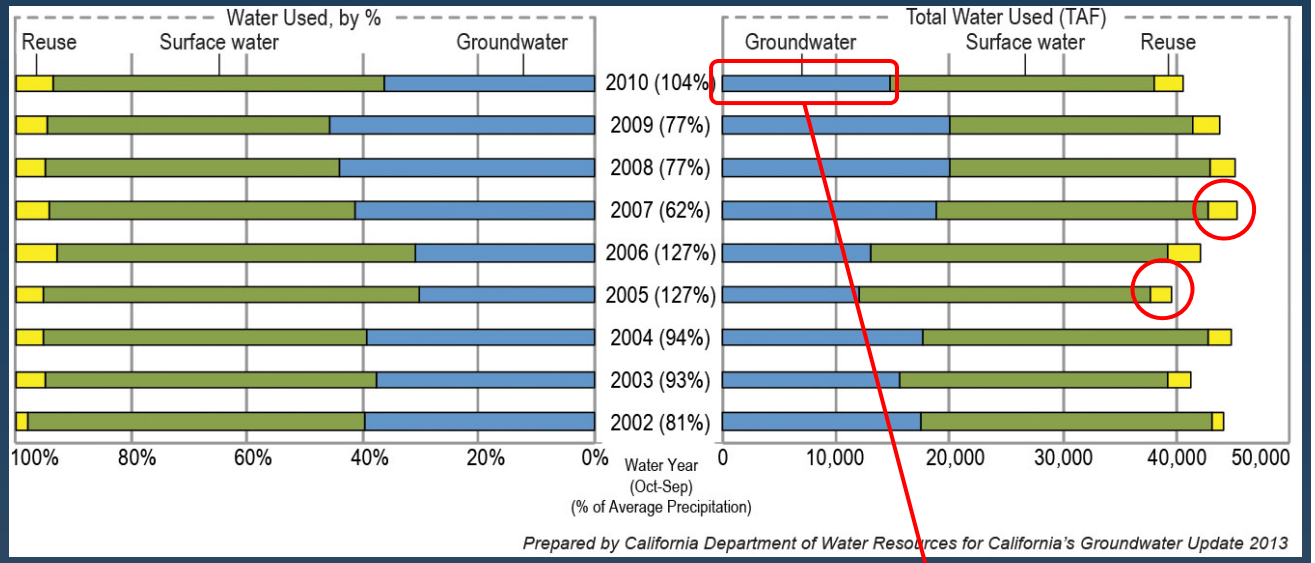
Water Supply Trend (2002-2010)
Statewide

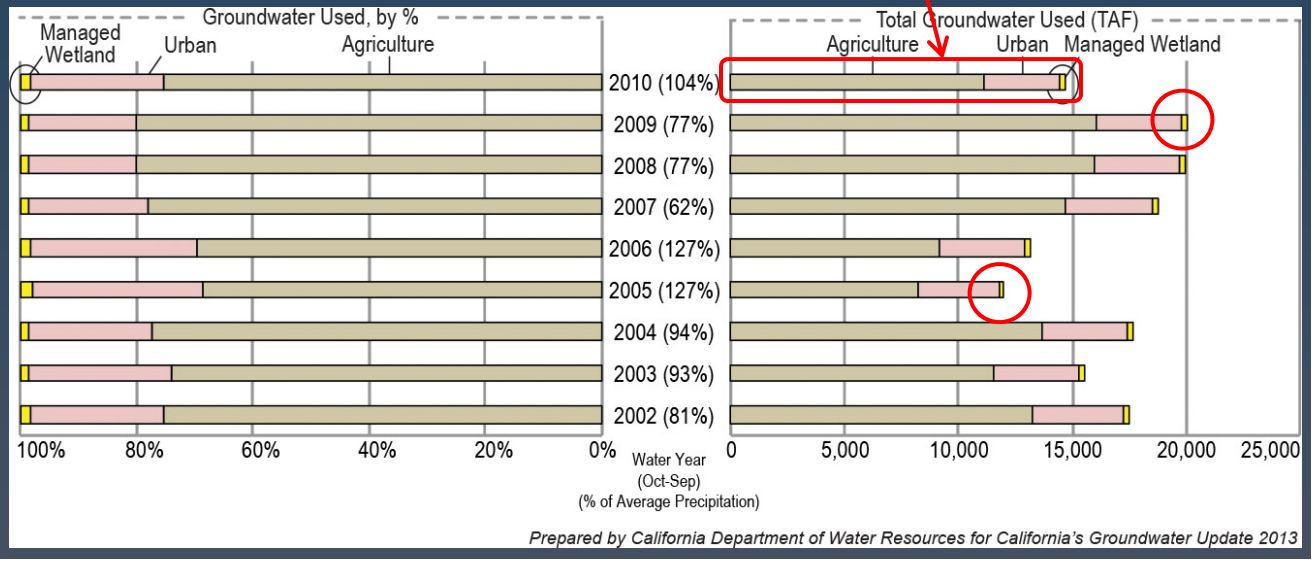
TOTAL WATER SUPPLY

- High of 45.5 maf
  - 2007 (62%)
- Low of 39.7 maf
  - 2005 (127%)

GROUNDWATER SUPPLY

- High of 20.1 maf
  - 2009 (77%)
  - 46% of total supply
- Low of 12 maf
  - 2005 (127%)
  - 30% of total supply





Total Water Supply Trend (2002-2010)

Water Year (% Precipitation)
Blue = groundwater
Green = surface water
Yellow = reuse water

Right Side:
- Total Water Used by Supply
- *Note: Charts do not use same horizontal scale*

Left Side:
- Water Used by Percent by Supply

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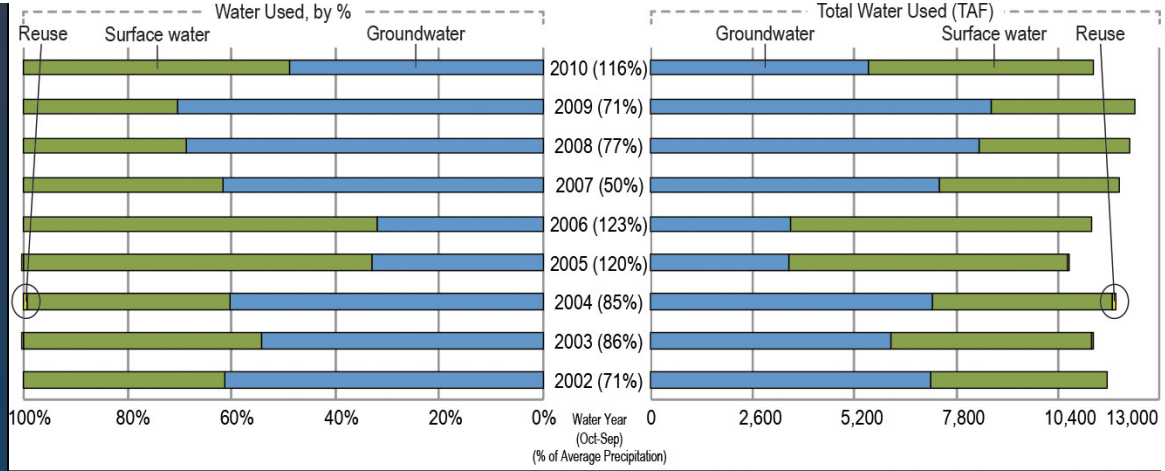

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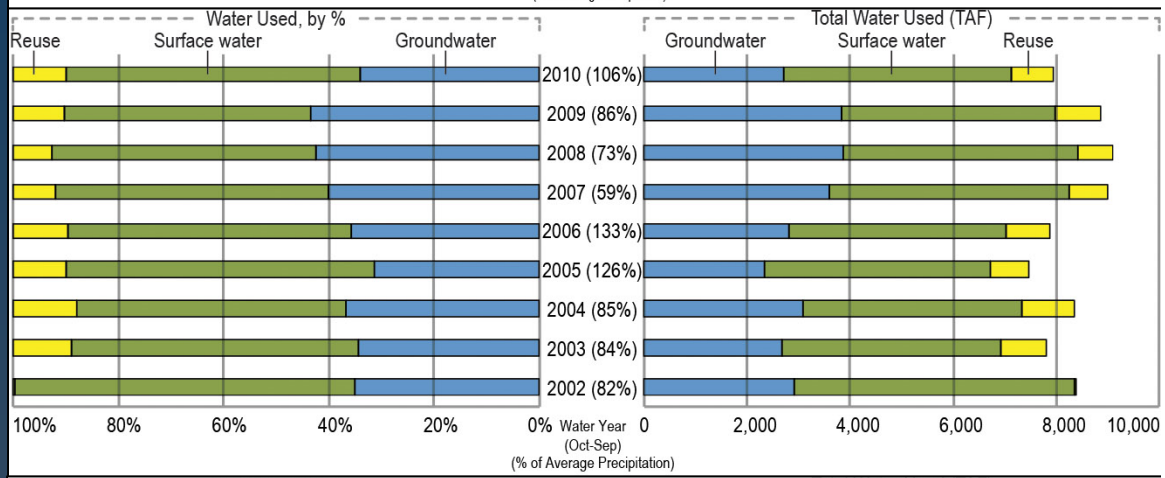

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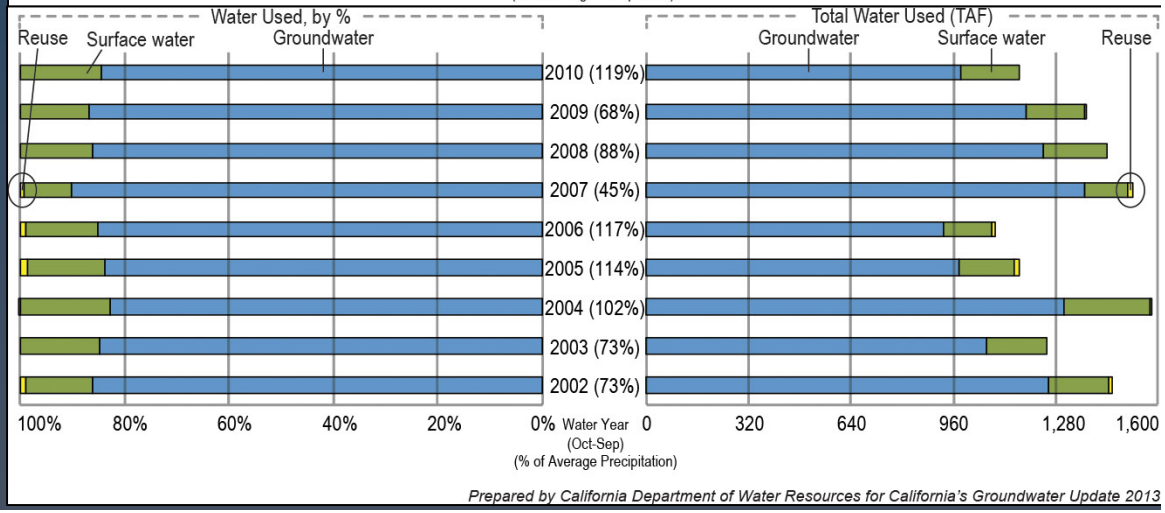

Groundwater Supply Trend (2002-2010)

Water Year (% Precipitation)
Brown = agriculture
Pink = urban
Yellow = managed wetlands

Right Side:
- Total Groundwater Used by Type
- *Note: Charts do not use same horizontal scale*

Left Side:
- Groundwater Used by Percent by Type

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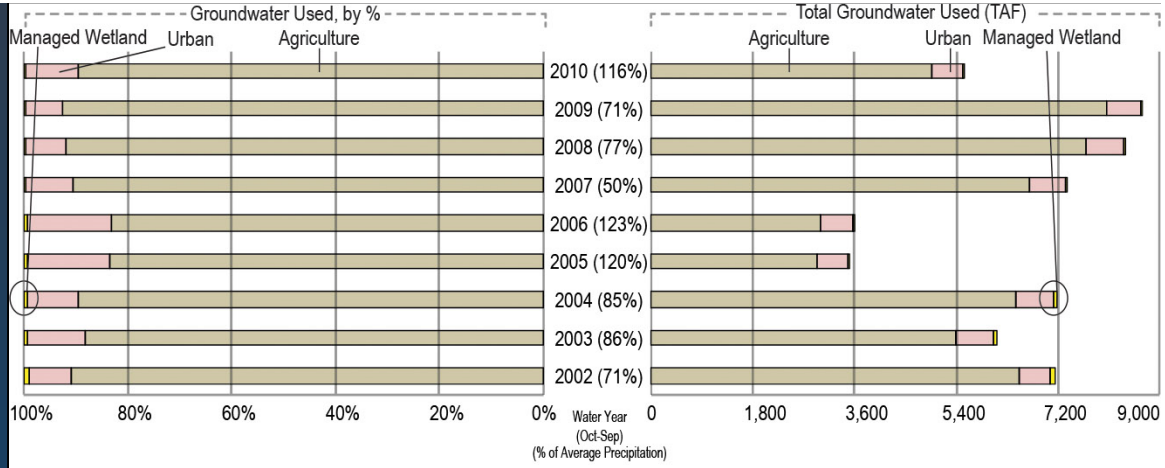

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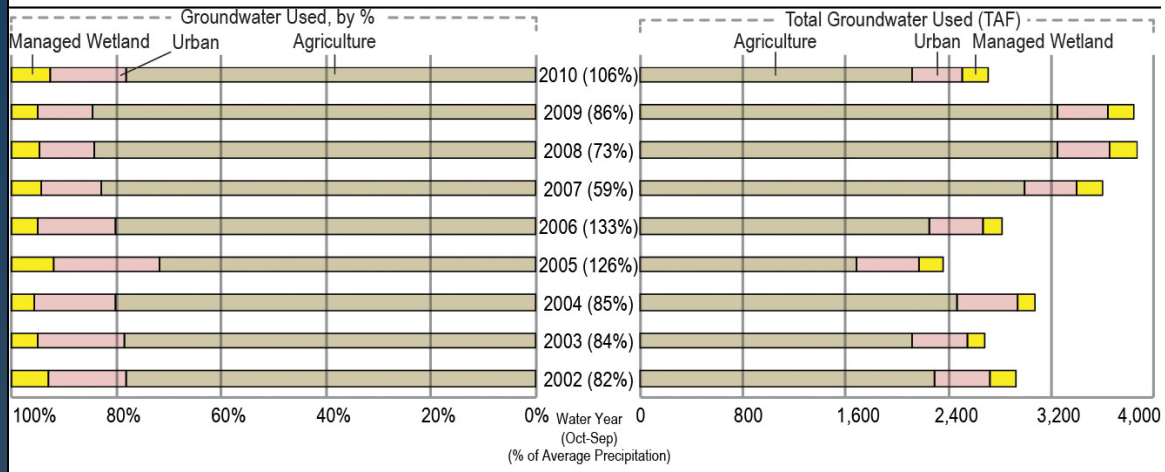

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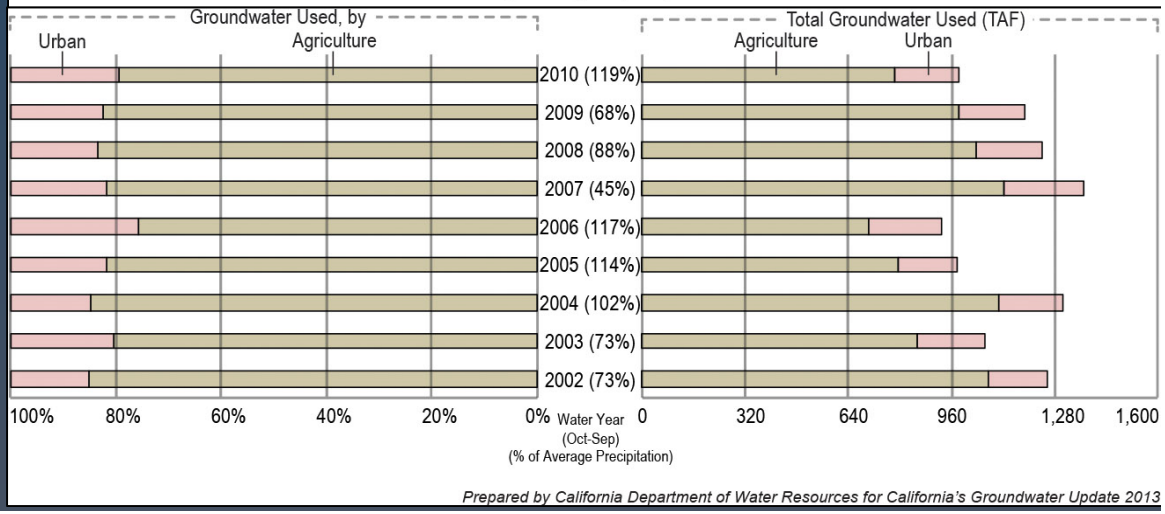
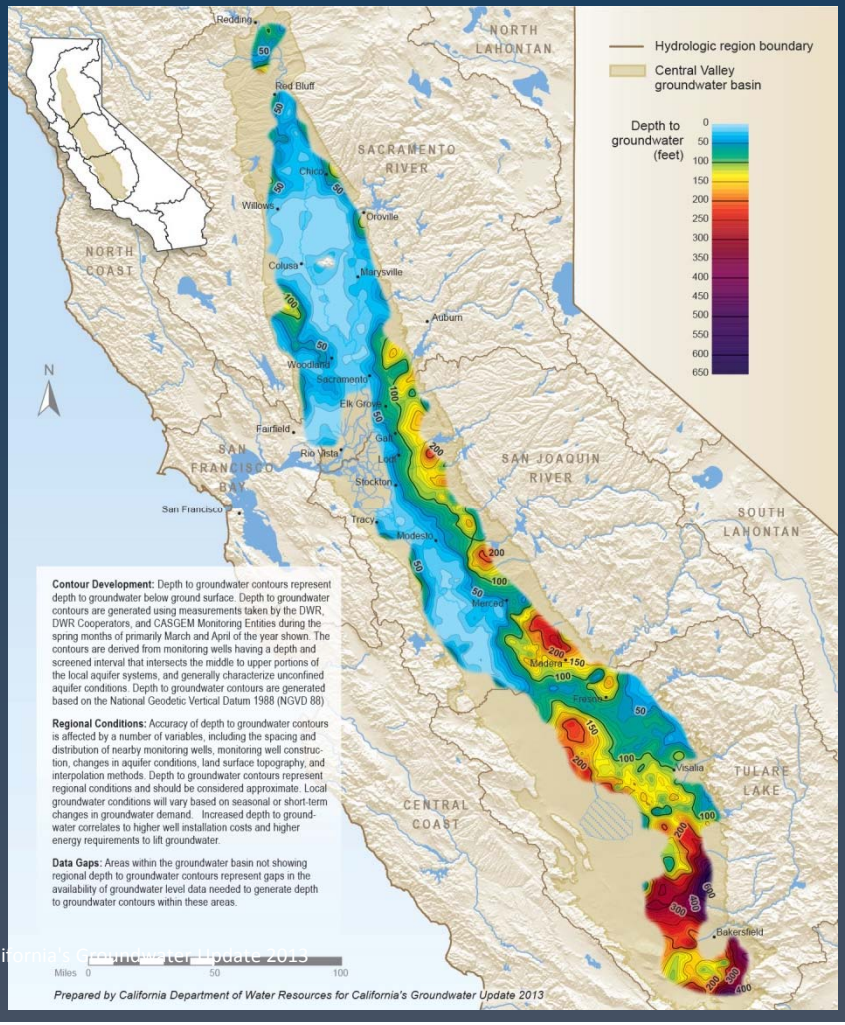
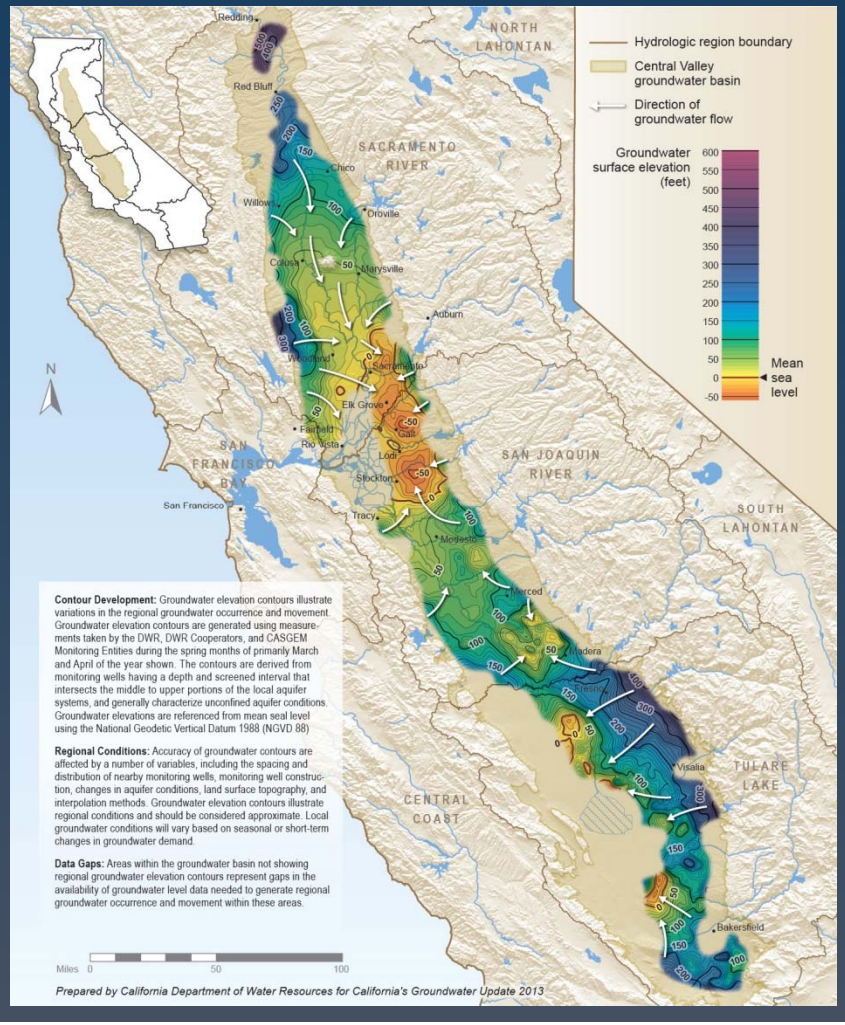


Central Valley Aquifer Conditions
Spring 2010 Groundwater Contours

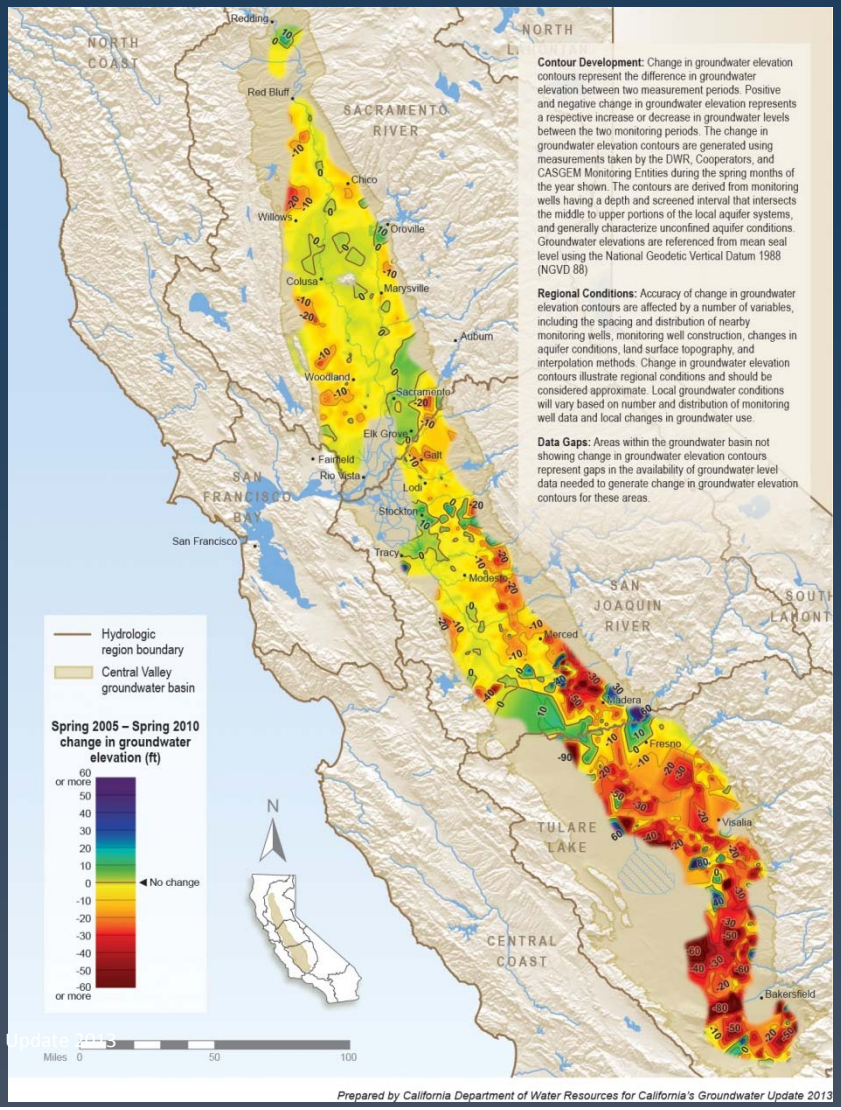
Depth to Groundwater

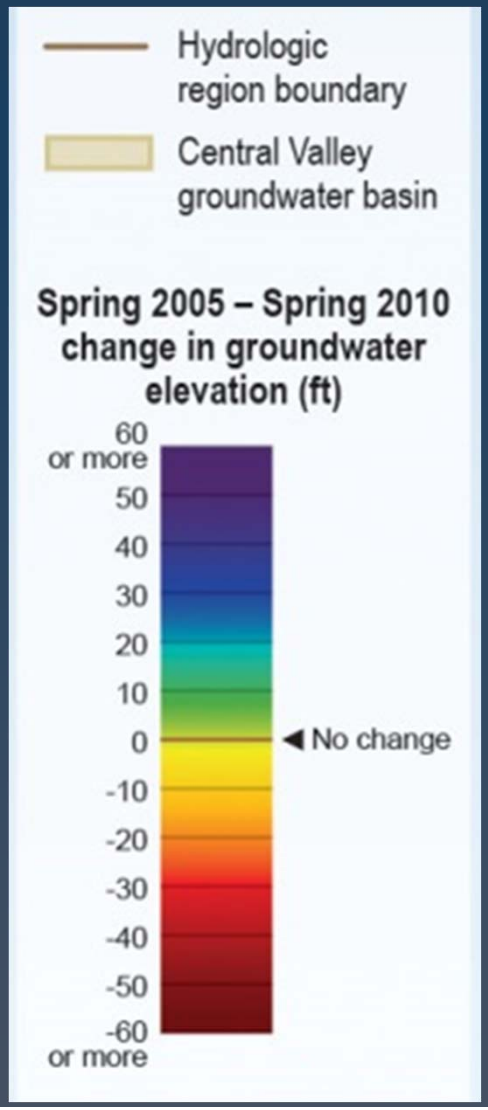


Groundwater Elevation

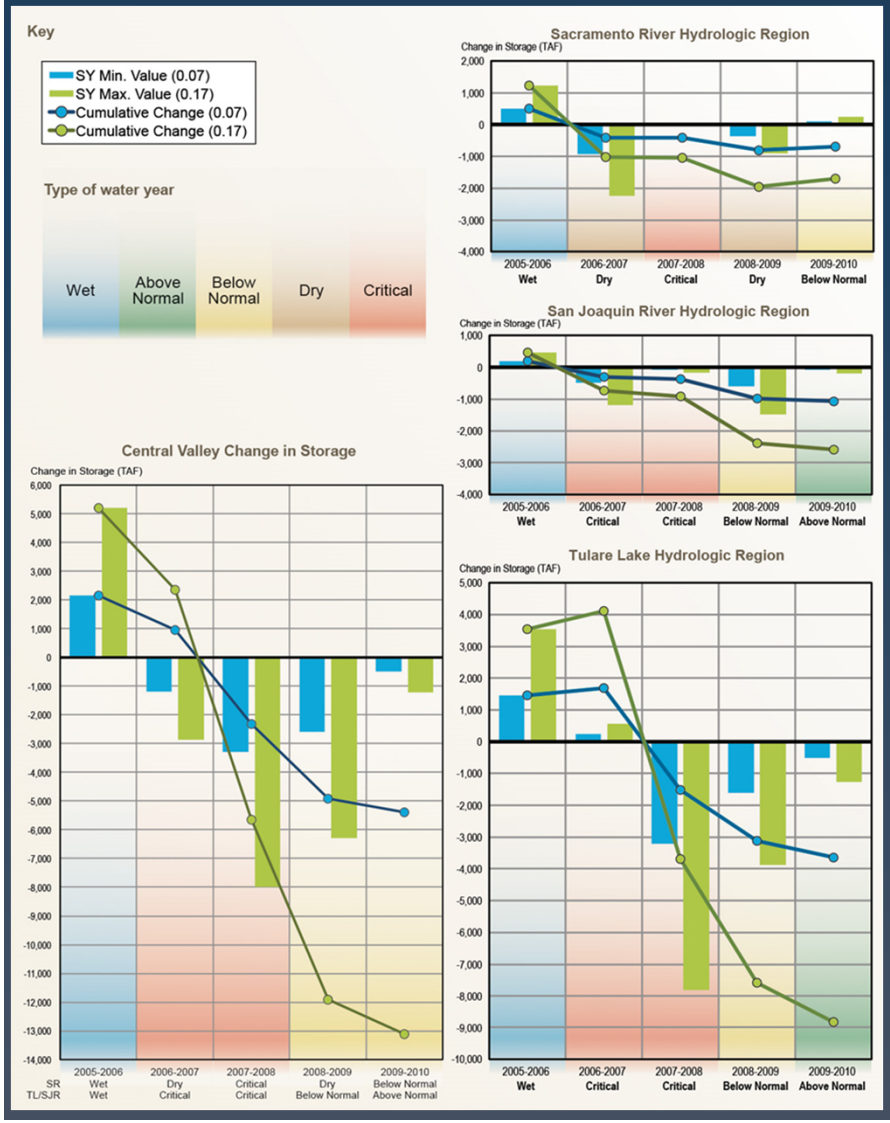


Central Valley Aquifer Conditions
Change in GW Elevation(2005-2010)





Central Valley Aquifer Conditions
Change in GW in Storage (2005-2010)



- GIS Change in Storage Tool
- Change in Groundwater in Storage for Central Valley
  - Total GW Storage Decline
    - 5.4 maf to 13.1 maf
  - Avg. Annual GW Storage Decline
    - 1.1 maf to 2.6 maf per year

Change in Elevations and Groundwater in Storage for California's Central Valley (Spring 2005 – Spring 2010)

Period Spring/Spring	Average change in groundwater elevation (ft)	Estimated Change in Storage in taf	
		Assuming Specific Yield = 0.07	Assuming Specific Yield = 0.17
2005-2006	3.6	2,148	5,218
2006-2007	-2.0	-1,179	-2,863
2007-2008	-5.5	-3,288	-7,984
2008-2009	-4.3	-2,584	-6,276
2009-2010	-0.8	-497	-1,209
Total (2005-2010)	-9.0	-5,400	-13,114

Notes:
1. taf = thousand acre feet
2. ft = feet
3. GW elevation and change in storage is estimates are calculated within reporting area only
4. Reporting Area (Acres): 8,588,247
5. Non-Reporting Area (Acres): 4,232,587

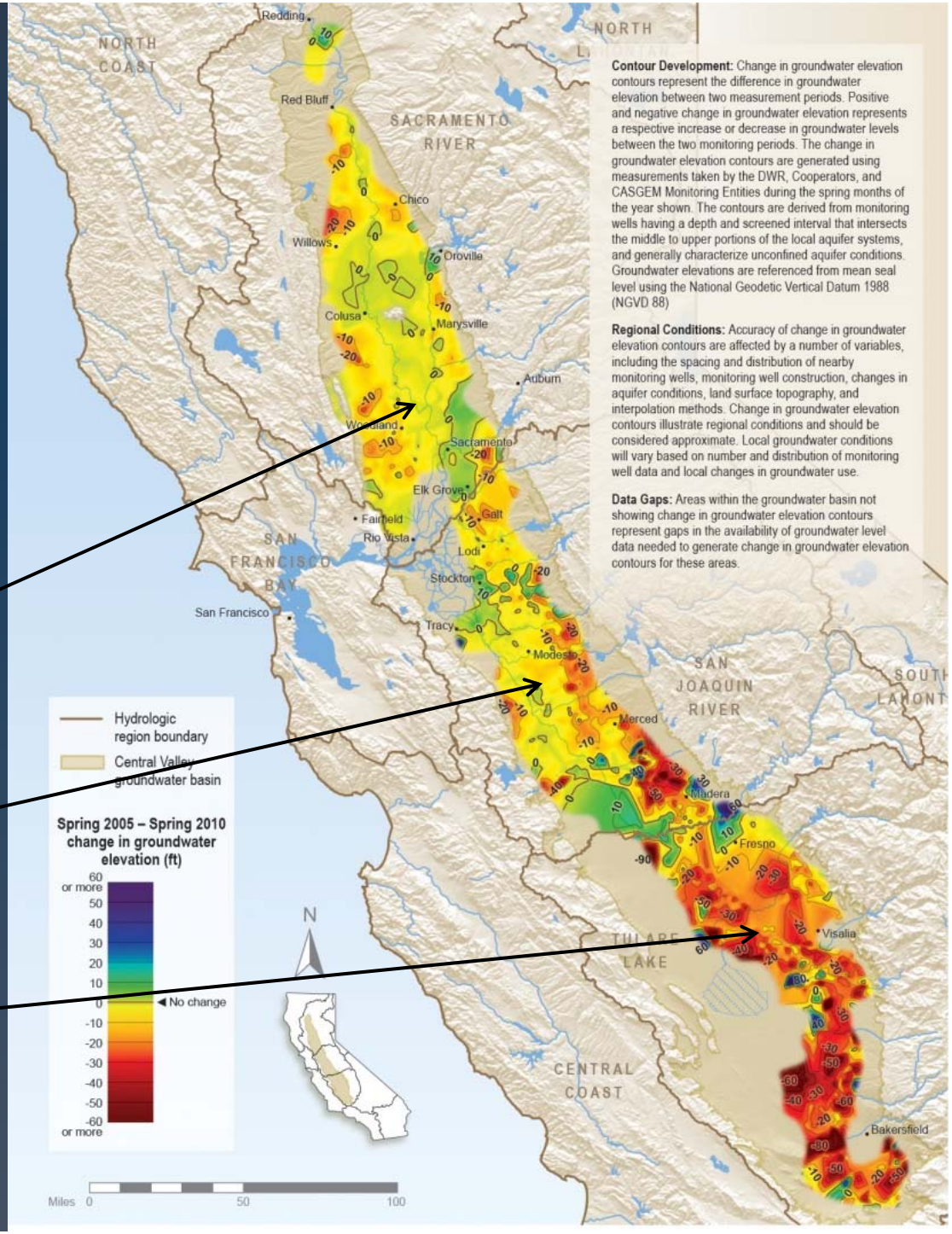
Central Valley Aquifer Conditions

Change in GW in Storage (2005-2010)

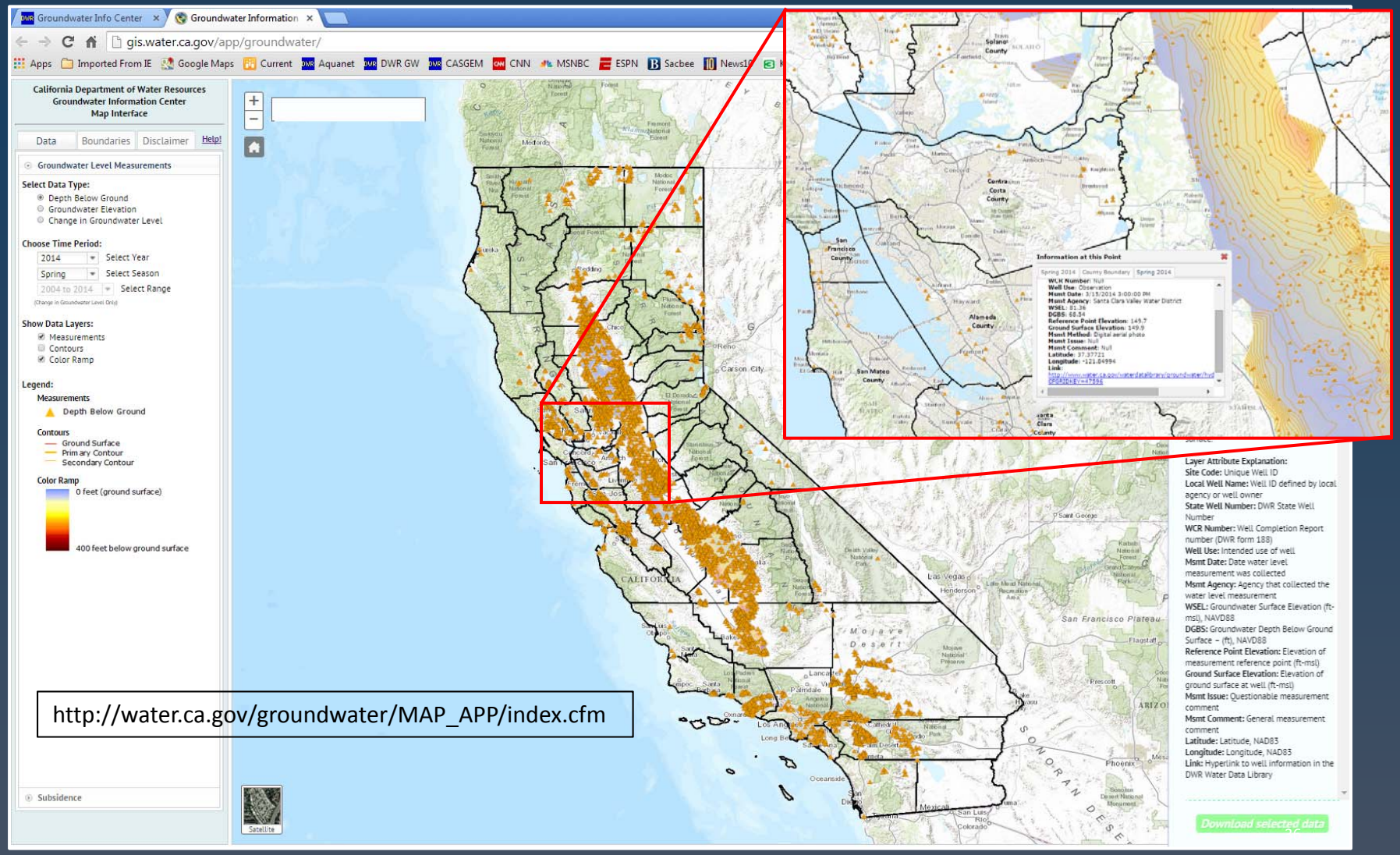
Sacramento River HR
GW Storage Reduction:
0.8 to 1.8 maf

San Joaquin River HR
GW Storage Reduction:
1.1 to 2.6 maf

Tulare Lake HR
GW Storage Reduction:
3.6 to 8.8 maf



Groundwater Information Center
GIS Map Interface – GW Level Data



http://water.ca.gov/groundwater/MAP_APP/index.cfm

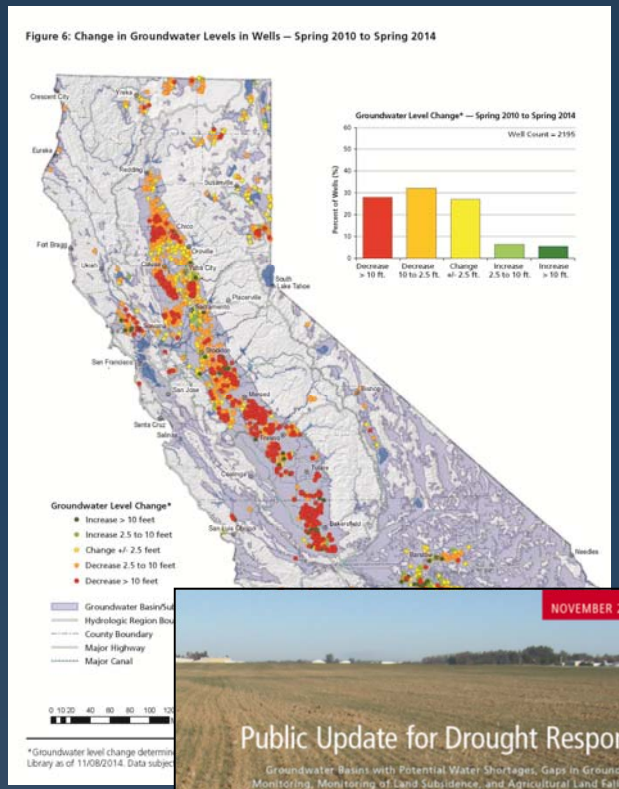
Updated Drought Information - 2014

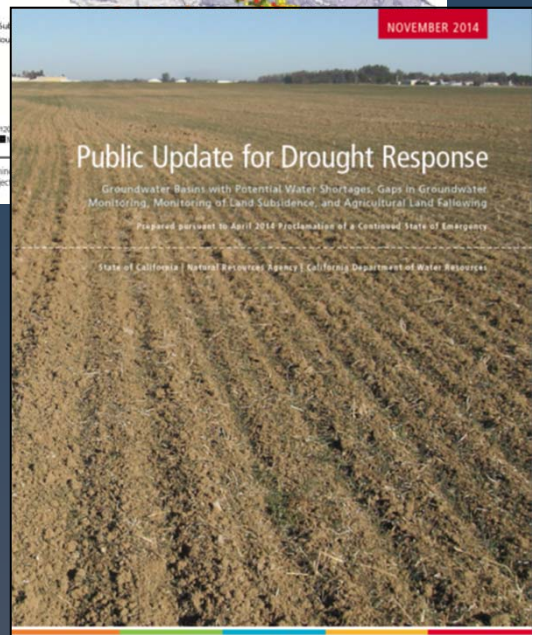
- CA GW Update 2013 data is presented through 2010
- CWP efforts helped facilitate presentation of data in 2014 Drought Updates
- Drought Updates contain data up to 2014
- Reports available on DWR's Groundwater Information Center Web site

http://www.water.ca.gov/groundwater/gwinfo/index.cfm

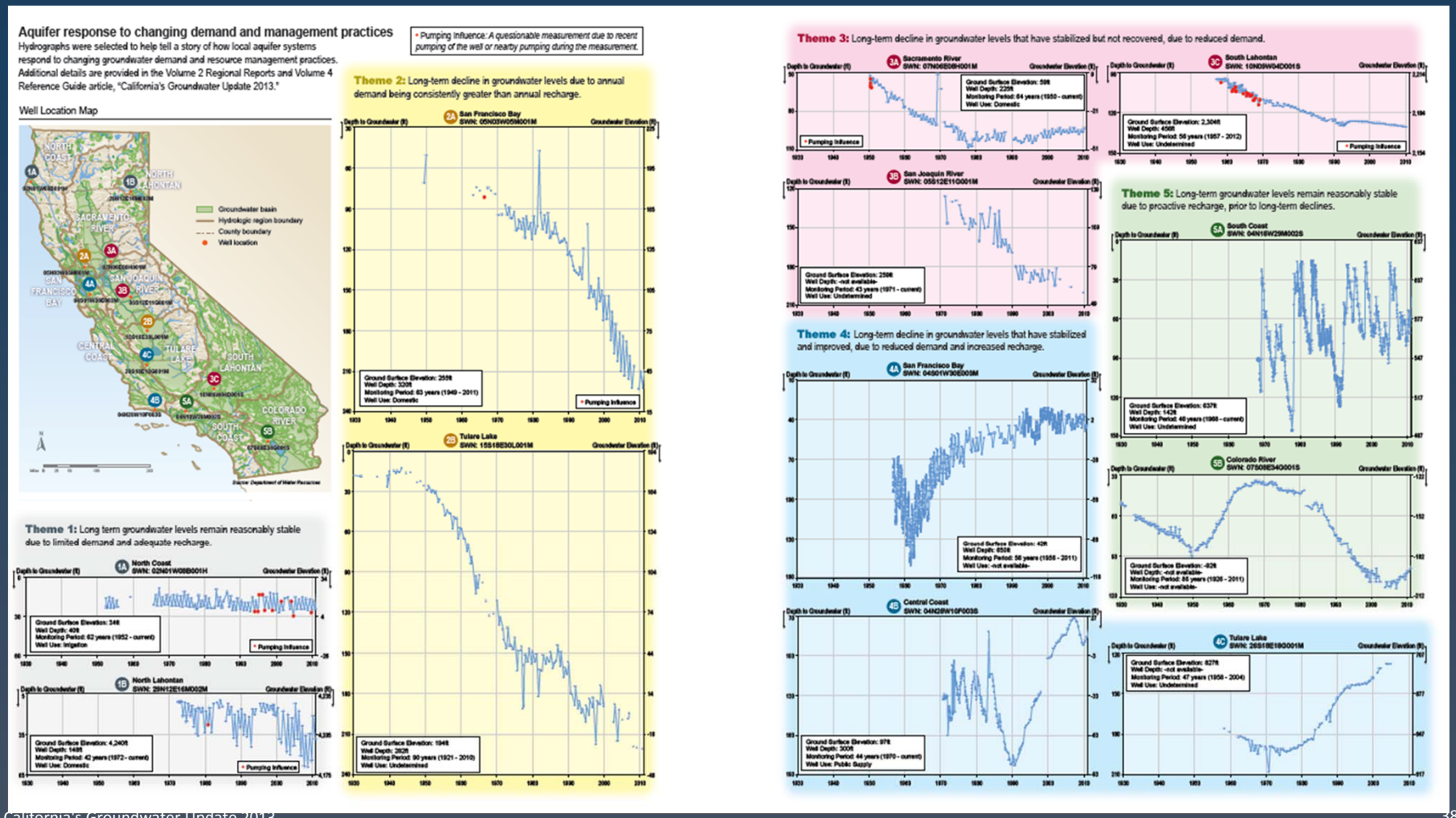
- DWR's Drought Information Web Site

http://www.water.ca.gov/waterconditions/





Long-term Groundwater Level Trends
Tell-a-Story Hydrographs: 5 Themes

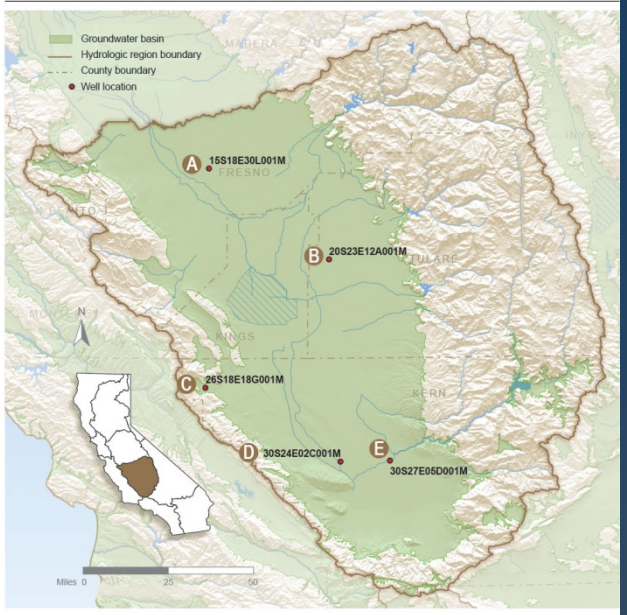


Tell-a-Story Hydrographs
Tulare Lake HR

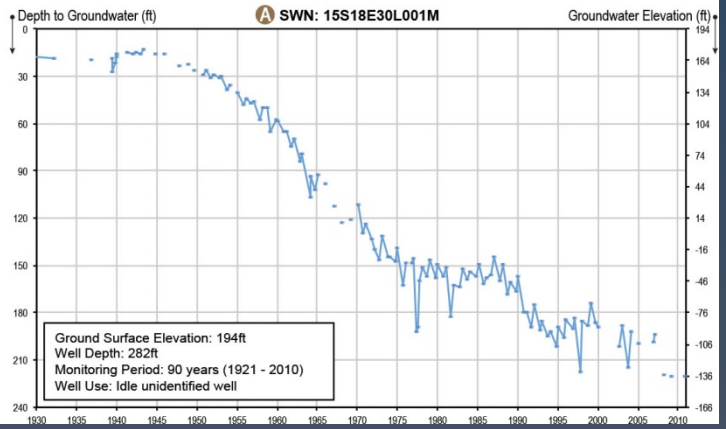
Aquifer response to changing demand and management practices

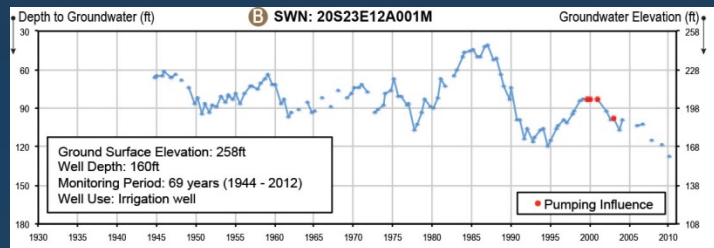
Hydrographs were selected to help tell a story of how local aquifer systems respond to changing groundwater demand and resource management practices. Additional detail is provided within the main text of the report.

Regional locator map

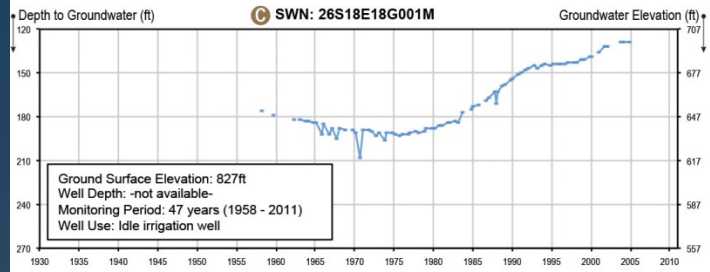


A Hydrograph 15S18E30L001M: shows an imbalance between aquifer recharge and groundwater extraction as a result of unsustainable reliance on the local groundwater resources.

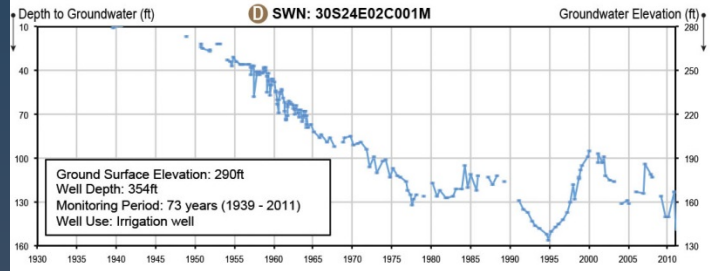




B Hydrograph 20S23E12A001M: illustrates the local aquifer response to changes in aquifer recharge and groundwater extraction, due to changes in precipitation and surface water supply deliveries.



C Hydrograph 26S18E18G001M: highlights recovering groundwater levels associated with the introduction of imported surface water from the California Aqueduct, which resulted in decreasing groundwater demand and facilitating in-lieu groundwater recharge.



D, E Hydrographs 30S24E02C001M and 30S27E05D001M: illustrate the successful stabilization of sharply declining groundwater levels through conjunctive management of surface water and groundwater supplies.

Tell-a-Story Hydrographs
San Joaquin River HR

Aquifer response to changing demand and management practices

Hydrographs were selected to help tell a story of how local aquifer systems respond to changing groundwater demand and resource management practices. Additional detail is provided within the main text of the report.

A Hydrograph 05S09E07B001M: illustrates an example of a typical well in the western portion of the Turlock Groundwater Basin. The wells extract water from the shallow unconfined to semi-confined aquifers which readily respond to the local hydrologic conditions.

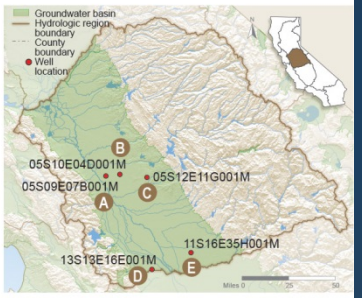
B Hydrograph 05S10E04D001M: highlights the successful role of conjunctive management of surface water and groundwater supplies in meeting the increasing urban water demands while keeping the long-term aquifer conditions stable.

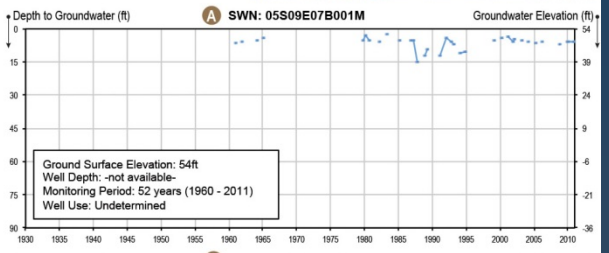
C Hydrograph 05S12E11G001M: shows the successful stabilization of declining groundwater levels associated with the technological advancement in the irrigation systems. The declining trend resumed, however, due to expansion of agricultural lands into previously non-irrigated lands.

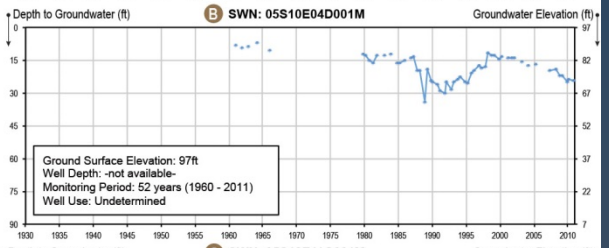
D Hydrographs 13S13E16E001M: highlights the successful recovery of declining groundwater conditions associated with the introduction of imported water.

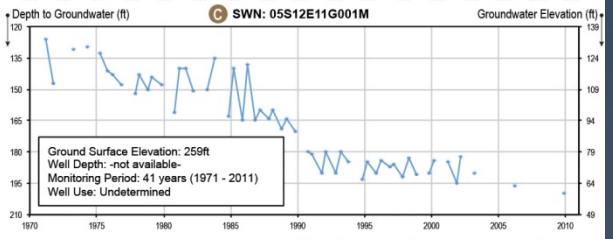
E Hydrographs 11S16E35H001M: shows an imbalance between aquifer recharge and groundwater extraction as a result of unsustainable reliance on the local groundwater resources in absence of surface water supplies.

Regional locator map

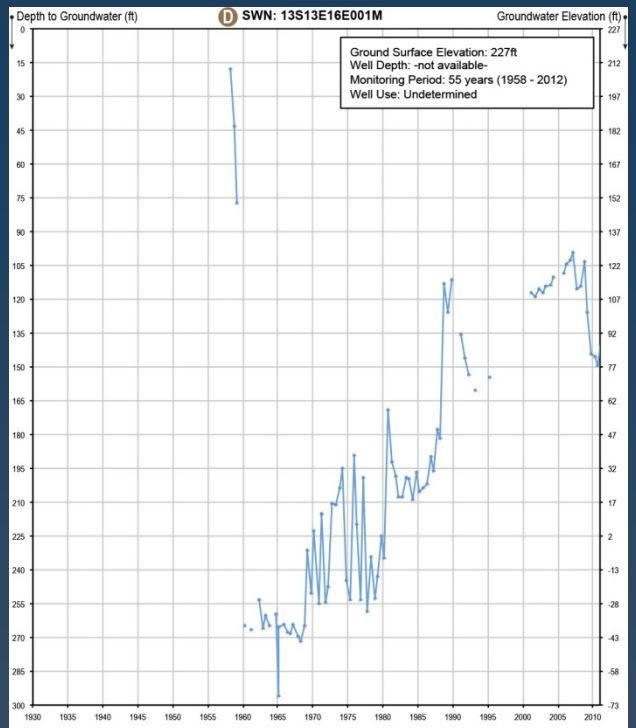


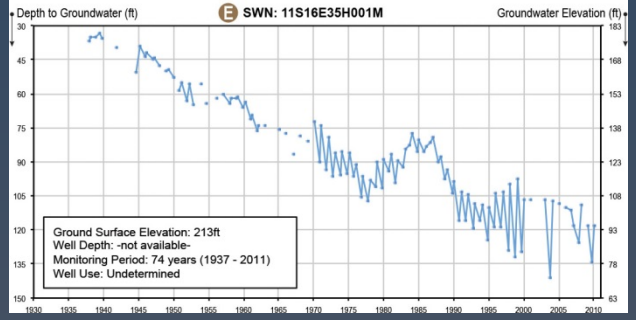






Prepared by California Department of Water Resources for California's Groundwater Update 2013



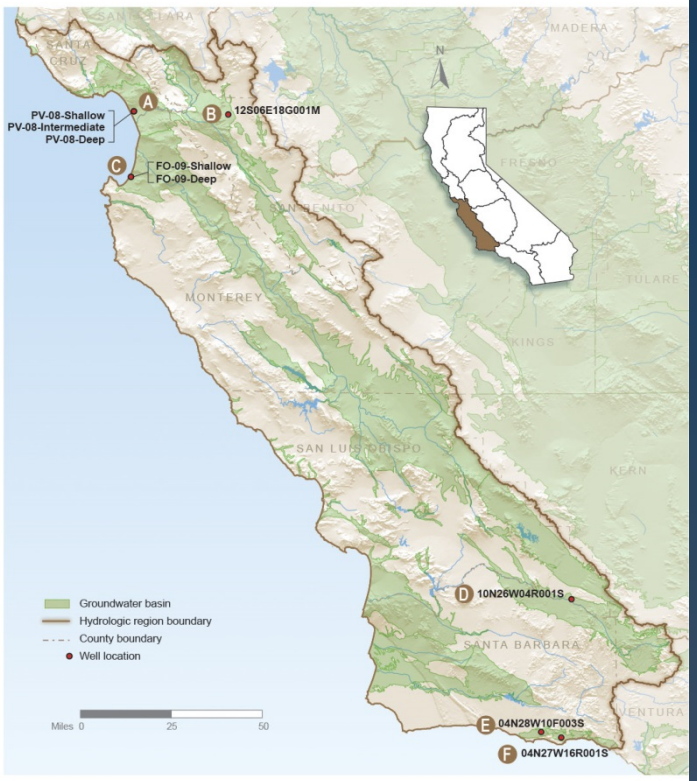


Tell-a-Story Hydrographs
Central Coast HR

Aquifer response to changing demand and management practices

Hydrographs were selected to help tell a story of how local aquifer systems respond to changing groundwater demand and resource management practices. Additional detail is provided within the main text of the report.

Regional locator map



A Hydrograph Local Well No. PV-08-Shallow/ Intermediate/ Deep: shows a well with relatively stable groundwater levels despite significant withdrawal for urban and agricultural uses. The limited seasonal change is due to seawater intrusion into the aquifer formation.

B Hydrograph 12S06E18G001M: highlights the improvement of groundwater aquifer conditions associated with shifting water source from groundwater to surface water supplies, thereby, reducing the stress on groundwater pumping.

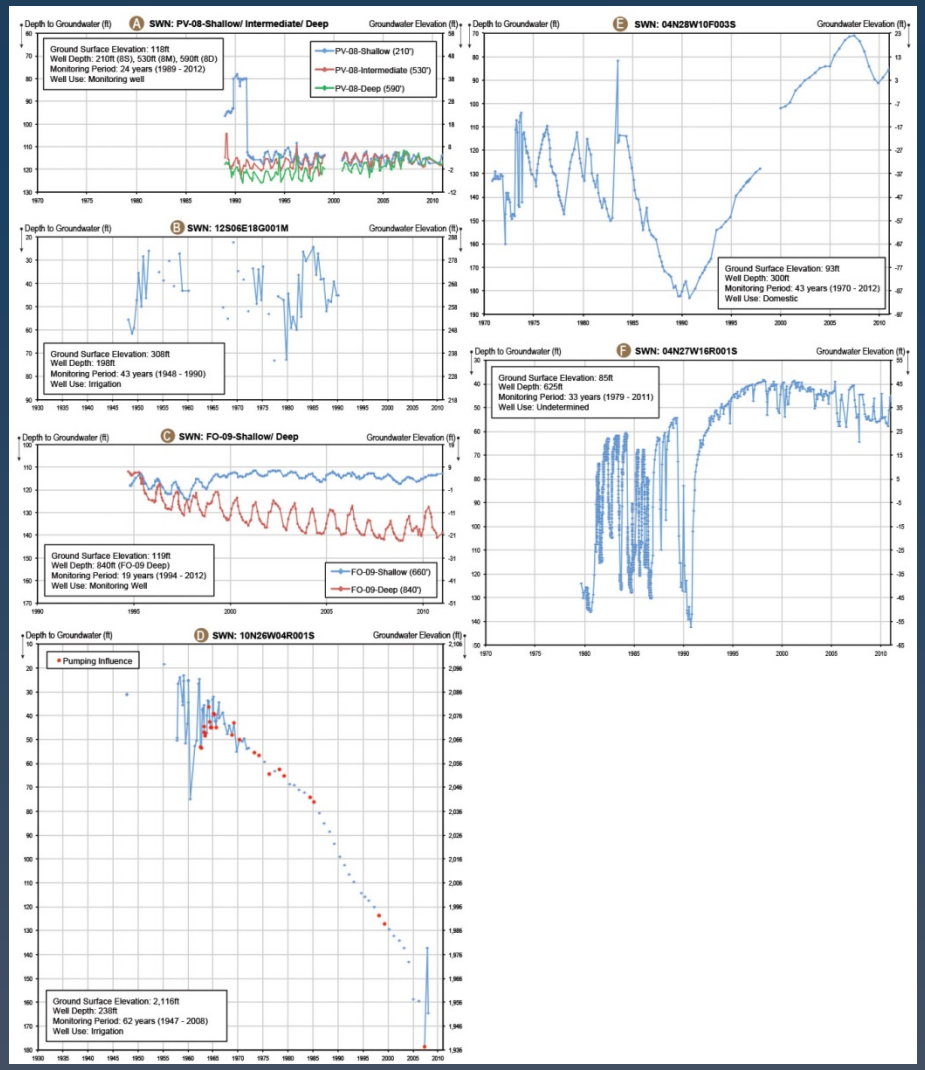
C Hydrograph Local Well No. FO-09-Shallow/ Deep: shows the aquifer response to the long-term hydrologic cycles and season variations associated with local precipitation conditions. The increase in the groundwater elevation in the shallow well is most likely due to seawater intrusion into the shallower aquifer.

D Hydrograph 10N26W04R001S: illustrates a well with a long-term declining groundwater level trend.

E Hydrograph 04N28W10F003S: highlights the recovery and stabilization of groundwater aquifer associated with the 1989 Wright Judgment, a groundwater basin adjudication entitlement pertaining to the Goleta Basin which triggered a series of groundwater management practices such as using recycled water for irrigation use and importing more SWP water.

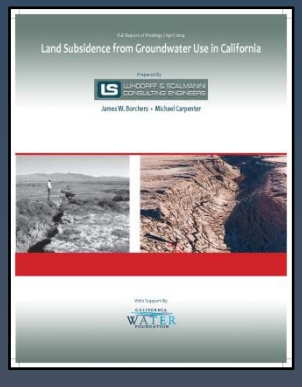
F Hydrograph 04N27W16R001S: illustrates the rapid recovery of groundwater aquifer followed by a period of relatively stable groundwater levels as a result of improved groundwater management practices, in addition to the availability of SWP water beginning 1997.

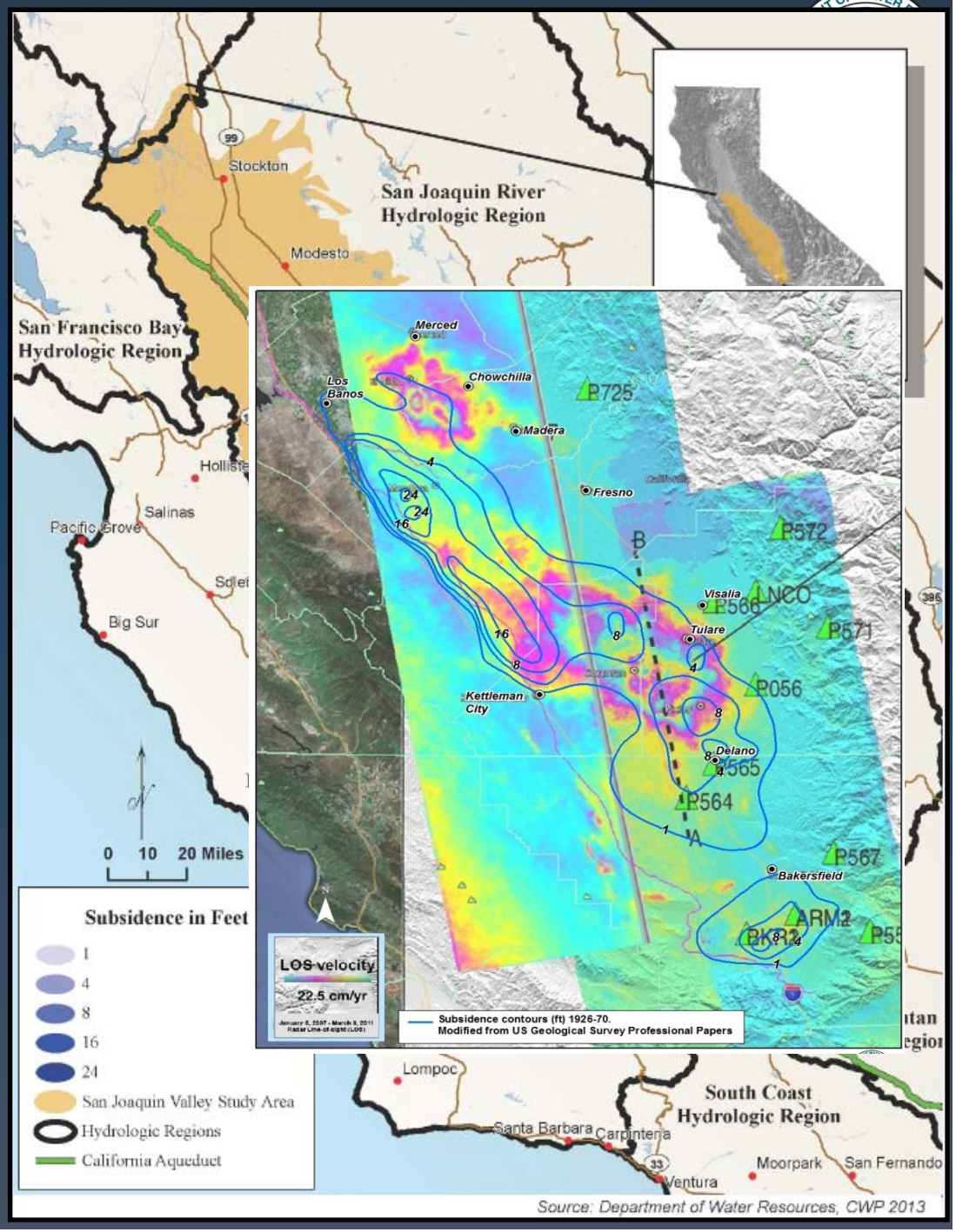
Prepared by California Department of Water Resources for California's Groundwater Update 2013



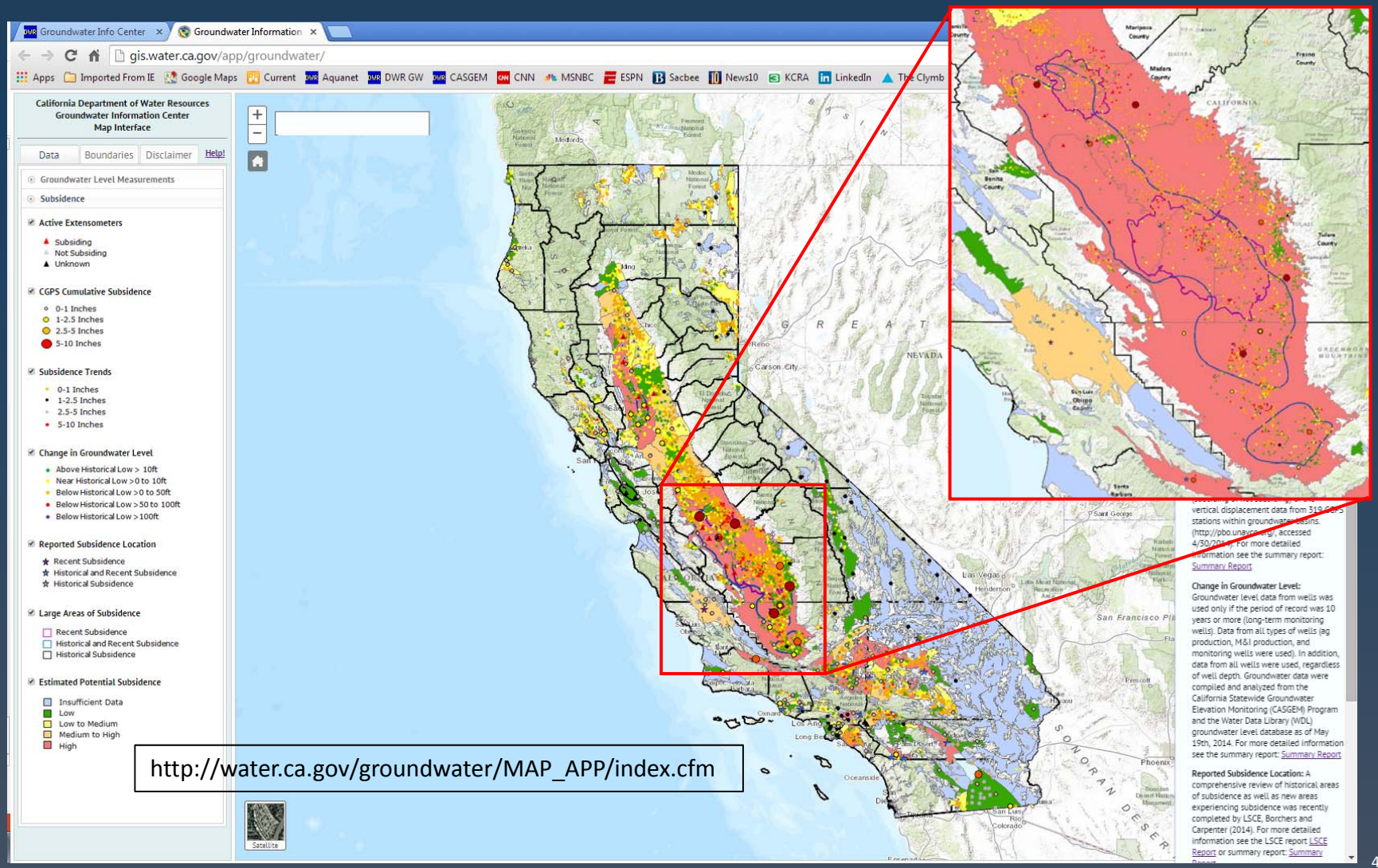
Land Subsidence

- Between 1926 and 1970 there was more than 24 feet of land subsidence in some areas (Ireland, 1984)
- Recent studies show renewed land subsidence rates as high as 1 foot per year (USGS)
- Appendix F references the 2014 LSCE & CWF subsidence report and 2014 DWR Report on Subsidence Potential





Groundwater Information Center
GIS Map Interface – Land Subsidence



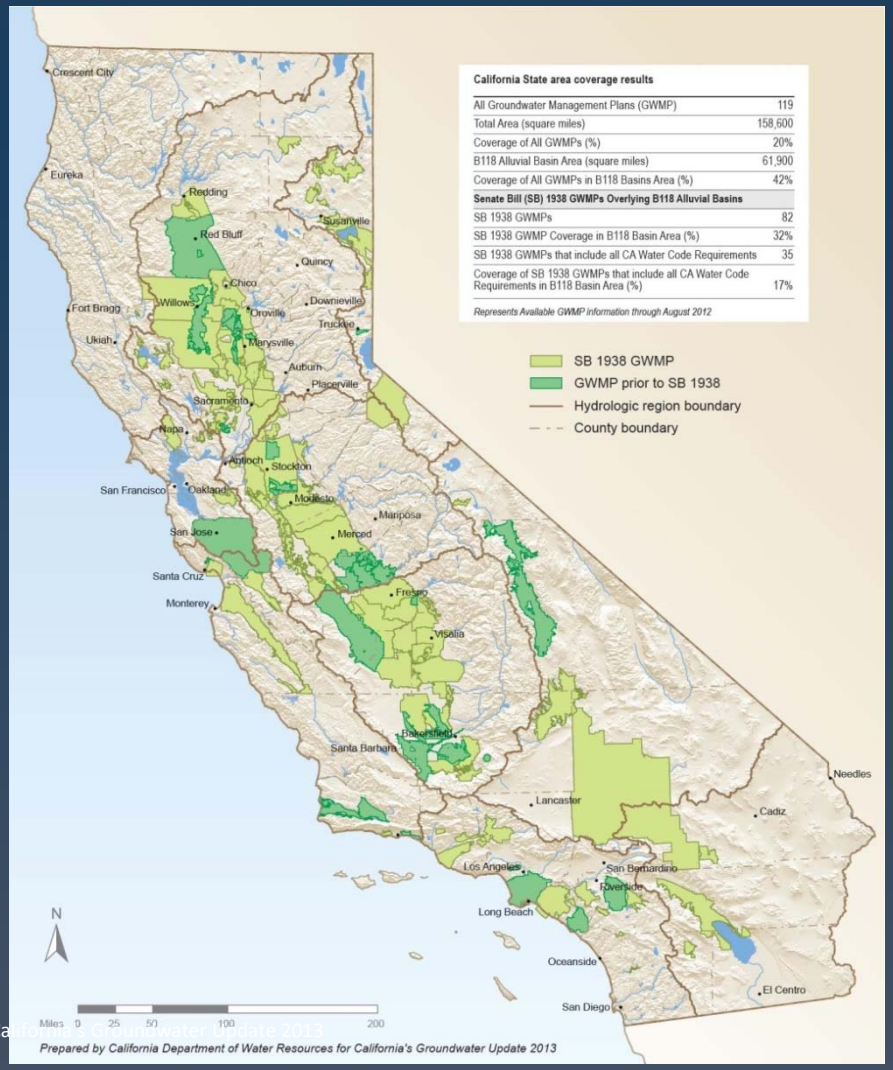
http://water.ca.gov/groundwater/MAP_APP/index.cfm

Groundwater Management
Legislation

California Water Code Sections, Part 2.74

- 1992: AB 3030 – Groundwater Management Plans (GWMP)
- 2000: AB 303 – Local Groundwater Assistance grants
- 2002: SB 1938 – Required specific elements in GWMPs to be eligible for grant funds
- 2009: SBx7-6 (CASGEM) – Statewide seasonal and long-term groundwater elevation monitoring
- 2011: AB 359 – Requires groundwater recharge mapping
- 2014: Sustainable Groundwater Management Act (SGMA)
  - SB 1168, AB 1739, SB 1319

Groundwater Management Plan
Statewide Inventory and Assessment



California State area coverage results

All Groundwater Management Plans (GWMP)	119
Total Area (square miles)	158,600
Coverage of All GWMPs (%)	20%
B118 Alluvial Basin Area (square miles)	61,900
Coverage of All GWMPs in B118 Basins Area (%)	42%
Senate Bill (SB) 1938 GWMPs Overlying B118 Alluvial Basins	
SB 1938 GWMPs	82
SB 1938 GWMP Coverage in B118 Basin Area (%)	32%
SB 1938 GWMPs that include all CA Water Code Requirements	35
Coverage of SB 1938 GWMPs that include all CA Water Code Requirements in B118 Basin Area (%)	17%

Represents Available GWMP information through August 2012

California State area coverage results

All Groundwater Management Plans (GWMP)	119
Total Area (square miles)	158,600
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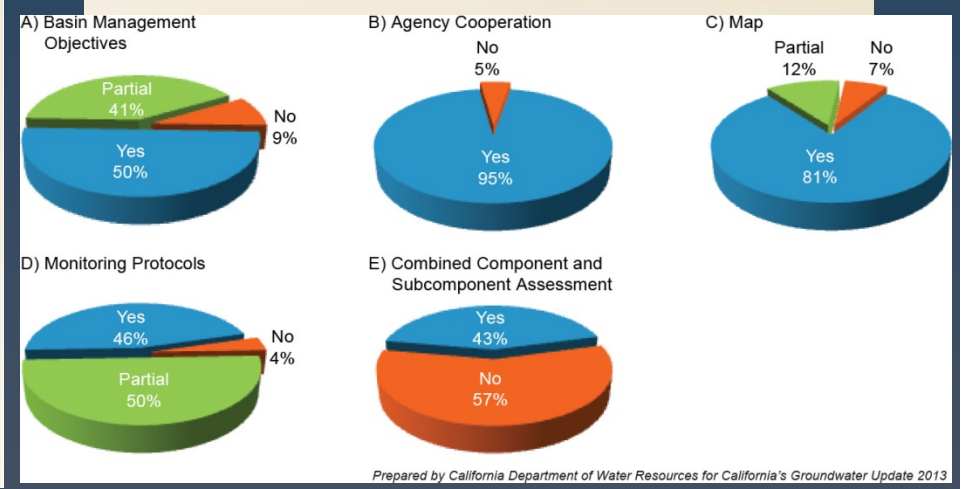
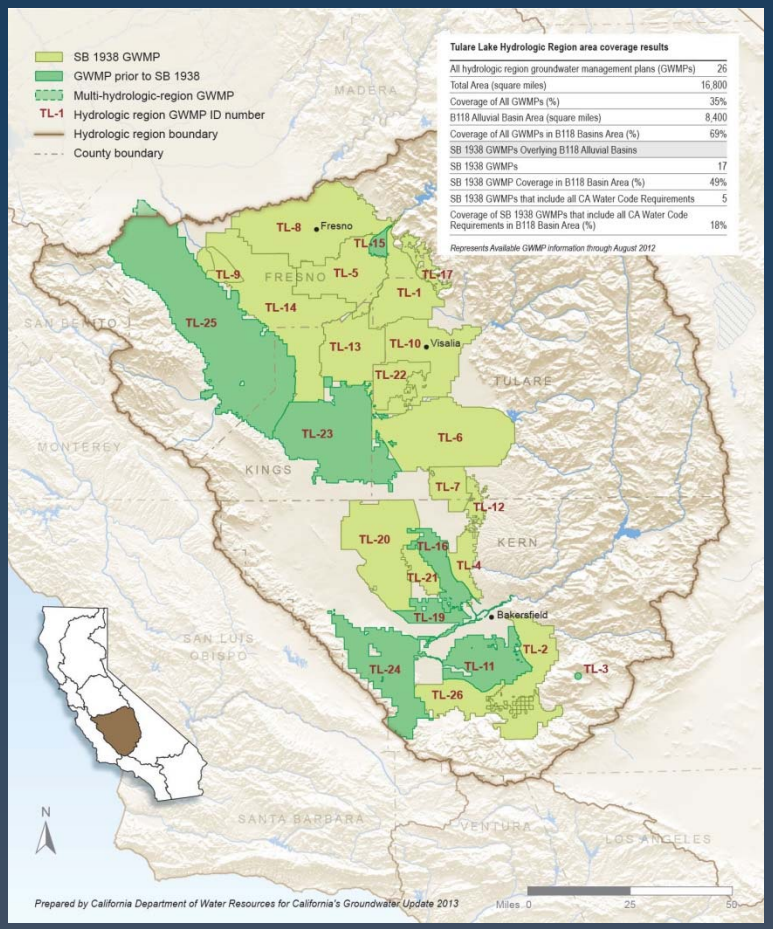
Represents Available GWMP information through August 2012



Groundwater Management Plans
Tulare Lake HR

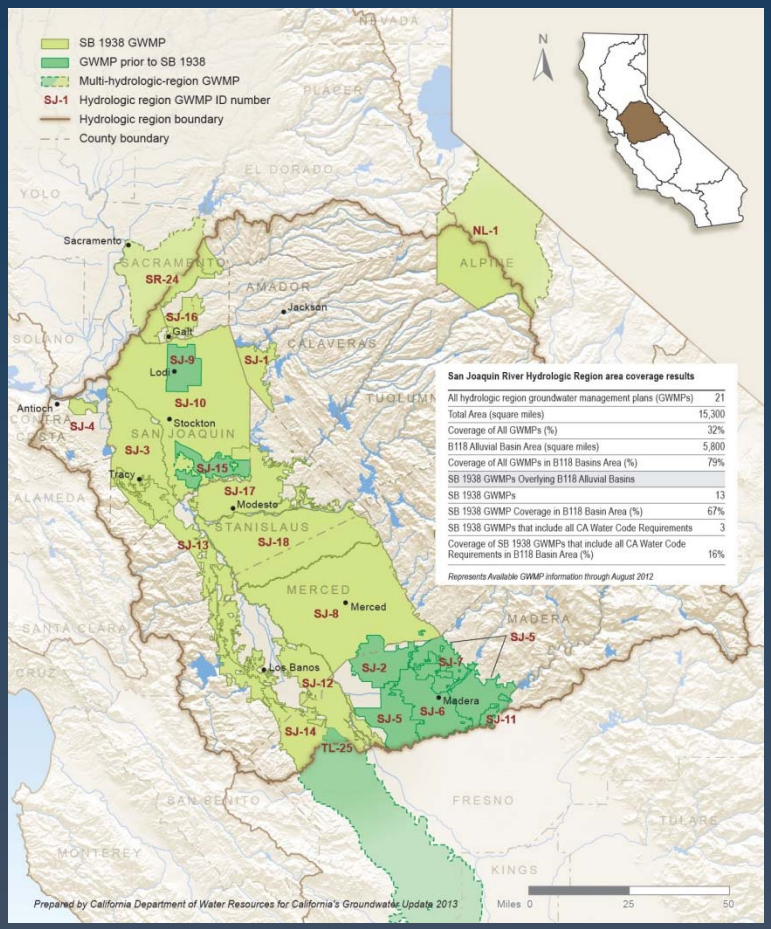


Tulare Lake Hydrologic Region area coverage results

All hydrologic region groundwater management plans (GWMPs)	26
Total Area (square miles)	16,800
Coverage of All GWMPs (%)	35%
B118 Alluvial Basin Area (square miles)	8,400
Coverage of All GWMPs in B118 Basins Area (%)	69%
SB 1938 GWMPs Overlying B118 Alluvial Basins	
SB 1938 GWMPs	17
SB 1938 GWMP Coverage in B118 Basin Area (%)	49%
SB 1938 GWMPs that include all CA Water Code Requirements	5
Coverage of SB 1938 GWMPs that include all CA Water Code Requirements in B118 Basin Area (%)	18%

Represents Available GWMP information through August 2012

Groundwater Management Plans
San Joaquin River HR

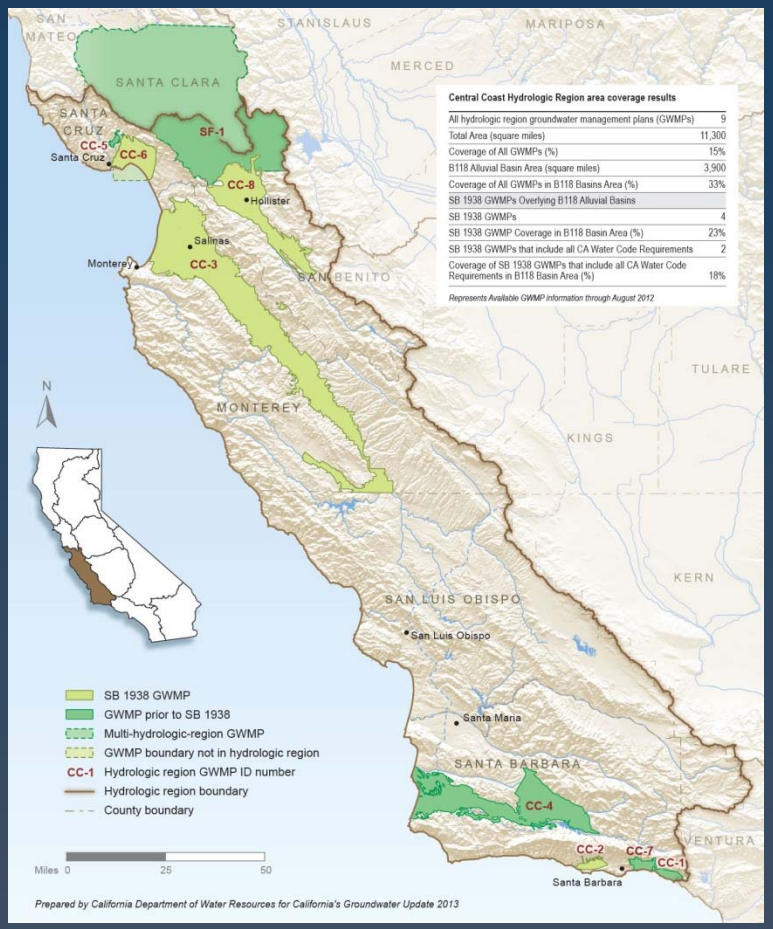


San Joaquin River Hydrologic Region area coverage results

All hydrologic region groundwater management plans (GWMPs)	21
Total Area (square miles)	15,300
Coverage of All GWMPs (%)	32%
B118 Alluvial Basin Area (square miles)	5,800
Coverage of All GWMPs in B118 Basins Area (%)	79%
SB 1938 GWMPs Overlying B118 Alluvial Basins	
SB 1938 GWMPs	13
SB 1938 GWMP Coverage in B118 Basin Area (%)	67%
SB 1938 GWMPs that include all CA Water Code Requirements	3
Coverage of SB 1938 GWMPs that include all CA Water Code Requirements in B118 Basin Area (%)	16%

Represents Available GWMP information through August 2012

Groundwater Management Plans
Central Coast HR



Central Coast Hydrologic Region area coverage results

All hydrologic region groundwater management plans (GWMPs)	9
Total Area (square miles)	11,300
Coverage of All GWMPs (%)	15%
B118 Alluvial Basin Area (square miles)	3,900
Coverage of All GWMPs in B118 Basins Area (%)	33%
SB 1938 GWMPs Overlying B118 Alluvial Basins	
SB 1938 GWMPs	4
SB 1938 GWMP Coverage in B118 Basin Area (%)	23%
SB 1938 GWMPs that include all CA Water Code Requirements	2
Coverage of SB 1938 GWMPs that include all CA Water Code Requirements in B118 Basin Area (%)	18%

Represents Available GWMP information through August 2012

Other Groundwater Management Planning Efforts

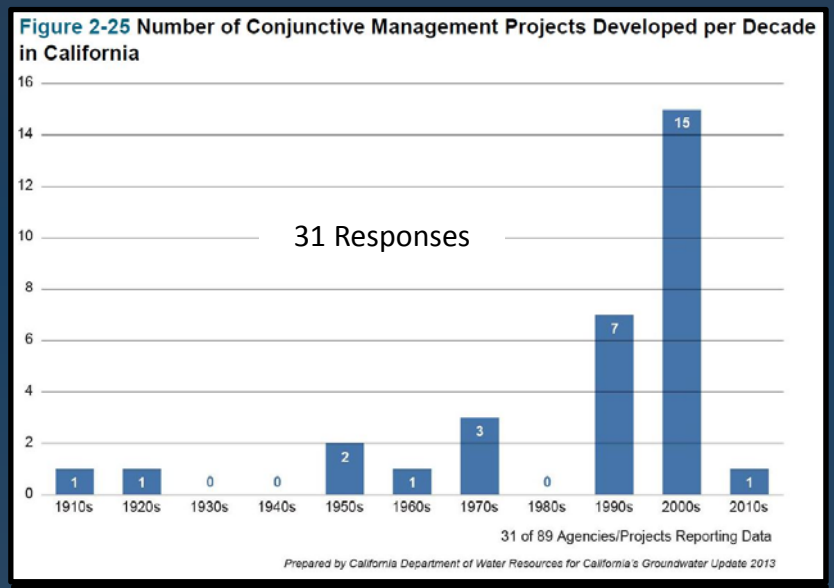
- Groundwater Ordinances
- Special Act Districts
- Groundwater Adjudications
- Other Groundwater Management Efforts
  - Integrated Regional Water Management Plans
  - Urban Water Management Plans
  - Agricultural Water Management Plans

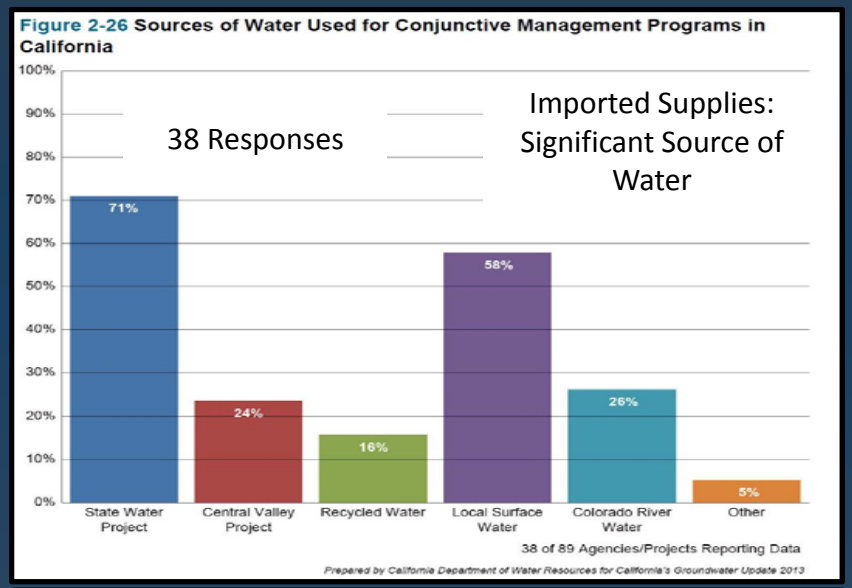
Conjunctive Management Inventory

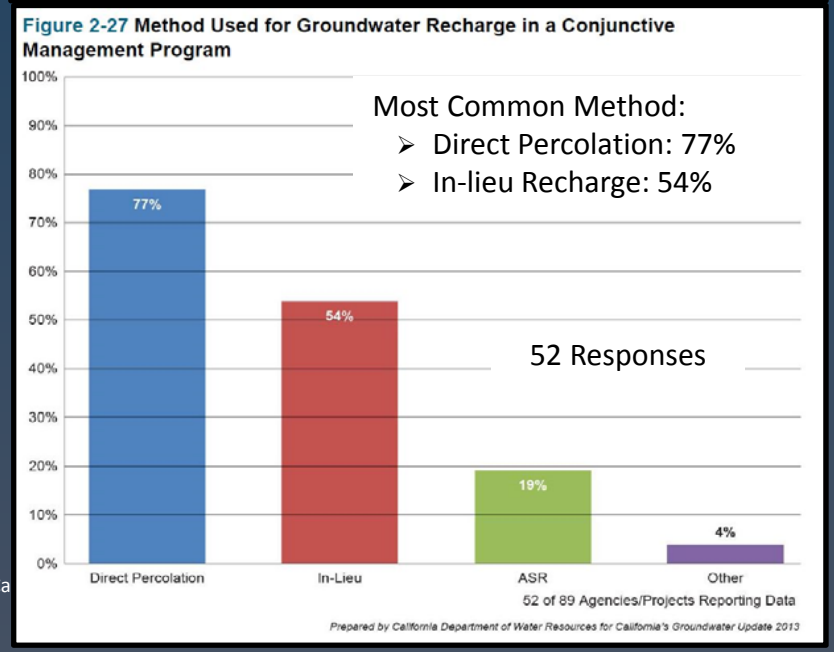
- Location of project
- Year project was developed
- Capital costs
- Annual operating cost
- Administrator/operator
- Capacity in units of acre-feet
- Source of water received
- Put and take capacity
- Type of project
- Program goals and objectives
- Constraints on development of program

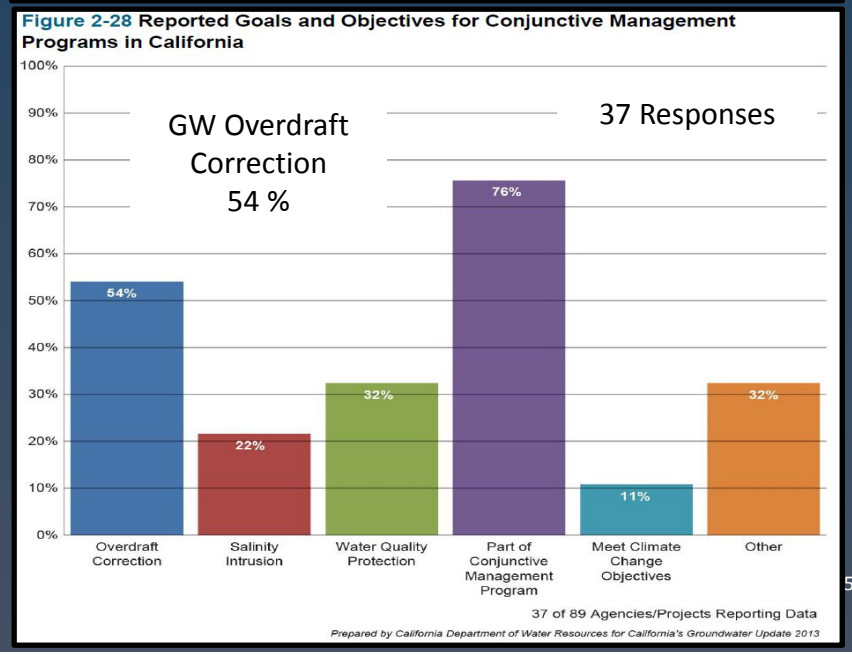
Table of 89 survey responses will be included as Appendix D

Conjunctive Management Inventory









California's Groundwater Update 2013
Statewide Recommendations

1. Promote public education about groundwater.
2. Improve collaboration, coordination, and alignment among agencies.
3. Develop a statewide groundwater management planning Web site to promote easy access to groundwater information.
4. Improve essential data to enable sustainable groundwater management by expanding and funding the CASGEM Program.
5. Improve understanding of California's high- and medium- priority groundwater basins by conducting groundwater basin assessments.
6. Develop a groundwater sustainability plan evaluation and implementation process.
7. Advance sustainable groundwater management within the framework of integrated water management.
8. Review and assist local agencies in developing improved analytical tools to assess conjunctive management and groundwater management strategies.
9. Increase local and regional groundwater recharge and storage.

California's Groundwater Update 2013
Hydrologic Region Recommendations

- Findings
  - Groundwater Supply and Development
  - Groundwater Use and Aquifer Conditions
  - Groundwater Monitoring Efforts
  - Groundwater Management and Conjunctive Management
- Data Gaps
  - Data Collection and Analysis
  - Basin Assessments
  - Sustainable Management
- Recommendations
  - Similar to Statewide recommendations but HR specific

California's Groundwater Update 2013

California's Groundwater Update 2013

California's Groundwater Update 2013: A Compilation of Enhanced Content for California Water Plan Update 2013 compiles and analyzes readily-available groundwater information to characterize California's groundwater basins, aquifers, and well infrastructure.

Although previous California Water Plan Updates had included groundwater-related resource management strategies, feedback from advisory committees and other stakeholder groups highlighted the lack of hydrologic region-specific groundwater information in the California Water Plan.

The Update expands and enhances baseline groundwater information on a regional scale, identifies challenges associated with sustainable groundwater management and helps guide implementation of diverse resource management strategies. Statewide and regional findings, data gaps and recommendations to improve groundwater management also are included.

The report is organized into the following components:

California's Groundwater Update

- Front Cover
- Director's Foreword
- Front Matter and Table of Contents
- Statewide Findings, Data Gaps and Recommendations
- Introduction, Scope and Future Directions (Chapter 1)
- Statewide Groundwater Update (Chapter 2)
- Back Cover

Hydrologic Region Groundwater Update

- North Coast Hydrologic Region (Chapter 3)
- San Francisco Bay Hydrologic Region(Chapter 4)
- Central Coast Hydrologic Region (Chapter 5)
- South Coast Hydrologic Region (Chapter 6)
- Sacramento River Hydrologic Region (Chapter 7)
- San Joaquin River Hydrologic Region (Chapter 8)
- Tulare Lake Hydrologic Region (Chapter 9)
- North Lahontan Hydrologic Region (Chapter 10)
- South Lahontan Hydrologic Region (Chapter 11)
- Colorado River Hydrologic Region(Chapter 12)

Appendices:

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- Appendix B: California Statewide Groundwater Elevation Monitoring (CASGEM) Basin Prioritization
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Available Online At:

http://www.waterplan.water.ca.gov/topics/groundwater/index.cfm

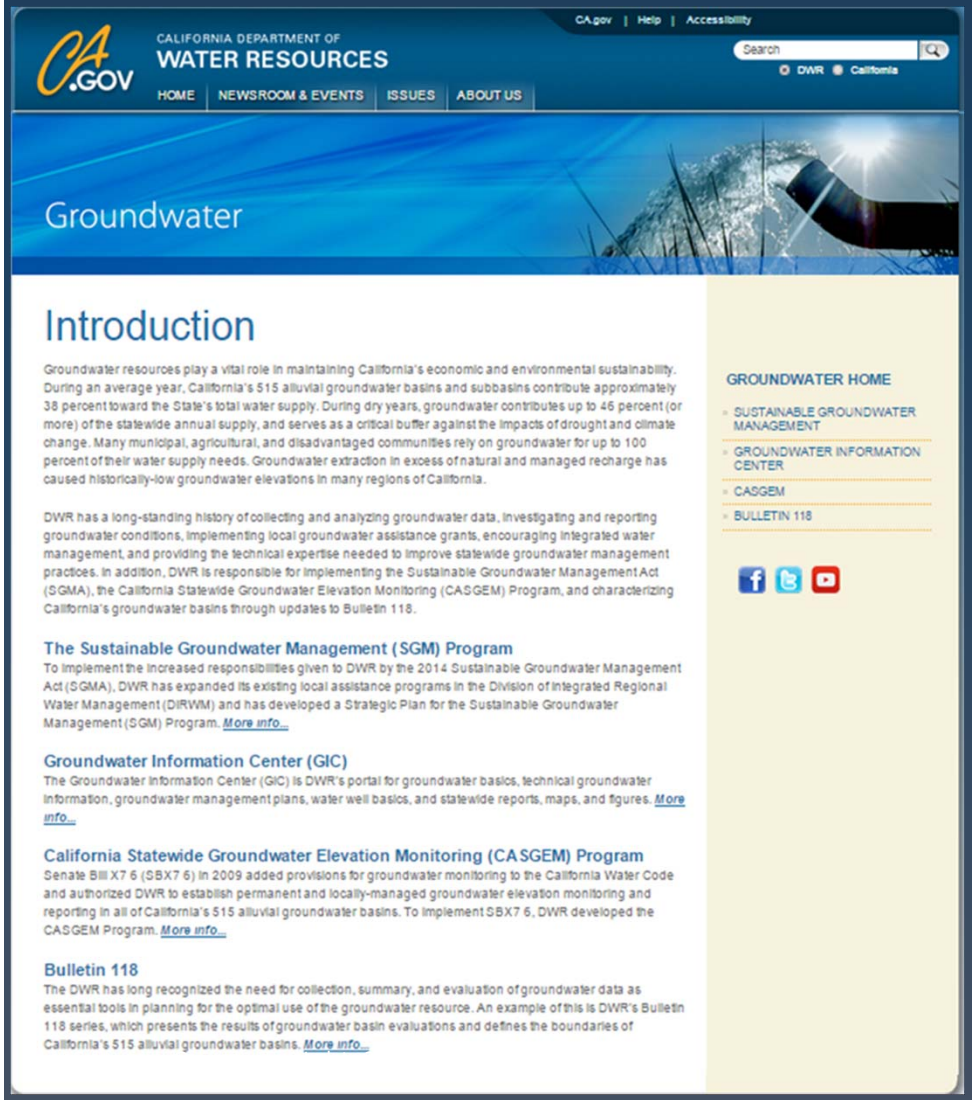
California Water Plan eNews:

https://listserv.state.ca.gov/wa.exe?SUBED1=DWR_CWP_eNews&A=1

CALIFORNIA
WATER PLAN eNEWS

DWR Groundwater Information

http://water.ca.gov/groundwater/



DWR's GROUNDWATER WEBSITE

- Sustainable Groundwater Management (SGM) Program
- Groundwater Information Center (GIC)
- CASGEM Program
- Bulletin 118

Sustainable Groundwater Management Act (SGMA)

- http://www.groundwater.ca.gov/

California's Groundwater Update 2013
Webinars

1st Hydrologic Region Webinar: June 4, 2015

- Tulare Lake, San Joaquin River, Central Coast

2nd Hydrologic Region Webinar: July 27, 2015

- Sacramento River, San Francisco Bay, South Coast

3rd Hydrologic Region Webinar and Technical Appendices Webinar: August 26, 2015

- North Coast, Colorado River, North & South Lahontan and Technical Appendices