PRELIMINARY FINDINGS FROM REVIEW OF USGS STUDY IN CUYAMA VALLEY BASIN

PRESENTED TO: CUYAMA BASIN GSA

7 FEBRUARY 2018

eki environment & water

AGENDA

- Overview of the Cuyama Valley Groundwater Basin
- Review of the USGS Report - Summary of Key Findings
- Implications for SGMA Implementation

eki

CUYAMA VALLEY GROUNDWATER BASIN – QUICK FACTS

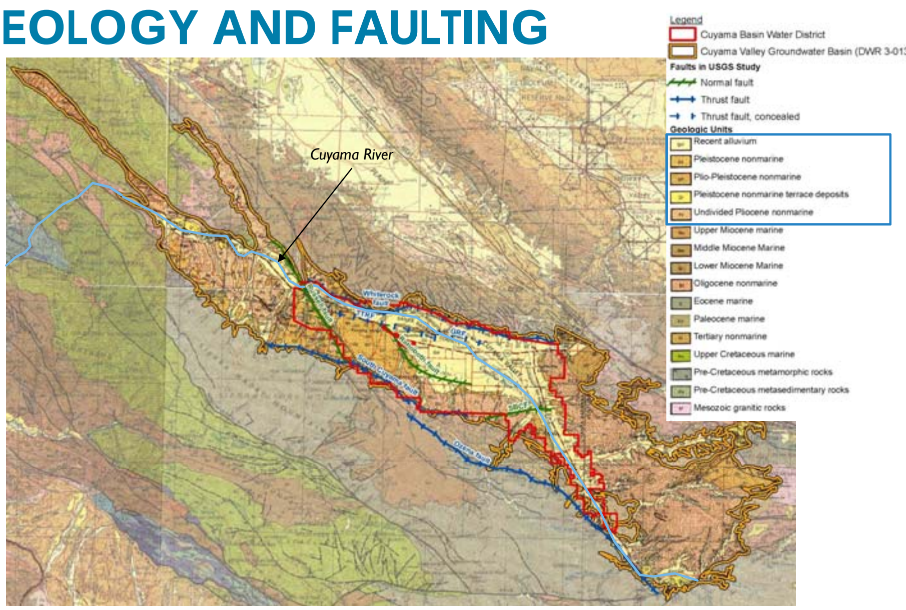
- Geography / Physical
  - Basin Area: 378 sq mi
    - including contributing watersheds: 798 sq mi
  - Population (2010): 1,236
  - Counties: Kern, SLO, SB, Ventura
- SGMA / Regulatory Status
  - DWR Basin Number: 3-013
  - Final CASGEM Ranking: Medium
  - Critical Overdraft Status: Yes
  - GSA Coverage: Cuyama Basin GSA (CBWD, CCSD, SBCWA, Kern, SLO, Ventura) (posted 6/12/2017)

eki

Source: http://www.water.ca.gov/groundwater/casgem/pdfs/PubRel_BasinRank_by_HR_5-18-15.xlsx

COMPLEX GEOLOGY AND FAULTING

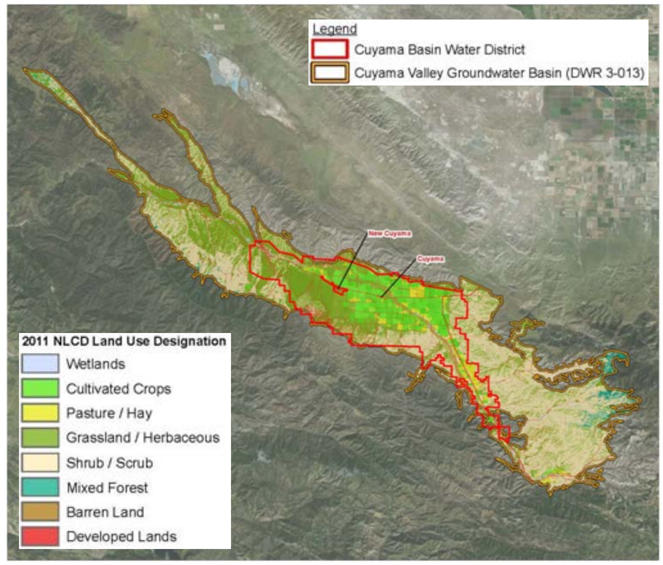
- Major Faults:
  - Russel
  - Rehoboth
  - South Cuyama
  - Whiterock
  - Morales
  - Graveyard Ridge
  - Turkey Trap Ridge
  - Santa Barbara Canyon
  - Ozena
- Topographic range: >8,800' (Mt. Pinos) to <1,500' (NW "finger")
- Cuyama River flows from uplands in southeast to northwest



eki

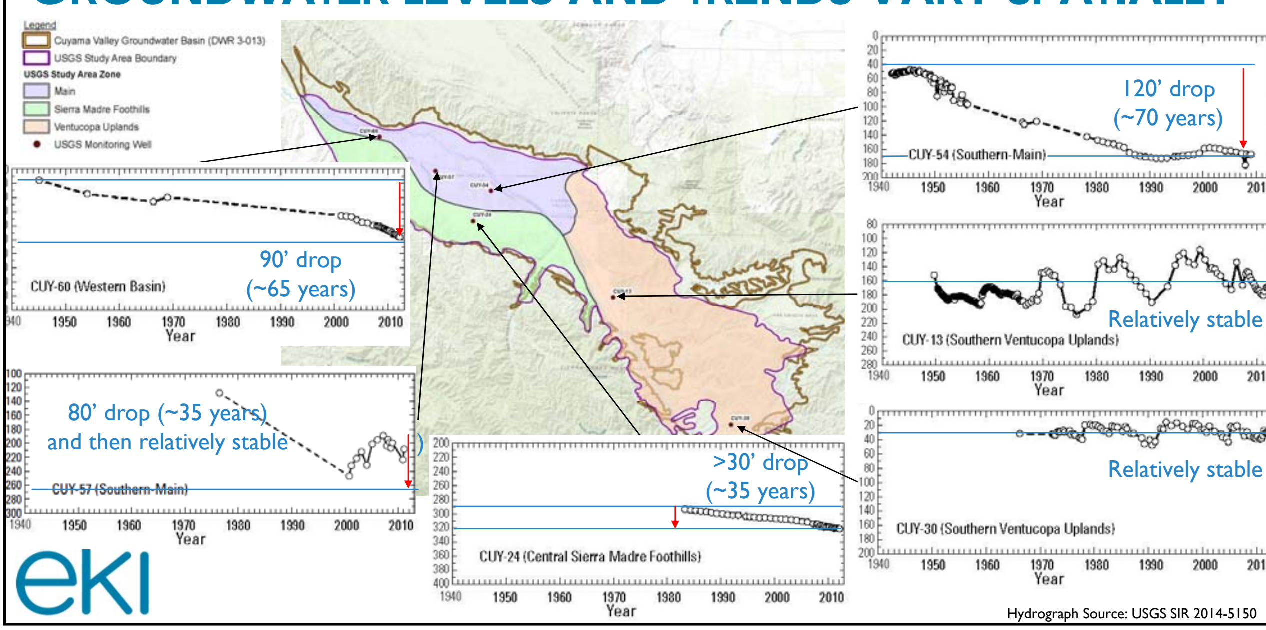
LAND USE – AGRICULTURE AND NATIVE VEGETATION

- 65% Native Vegetation
  - Mostly grassland/herbaceous and shrub/scrub
- 35% Agricultural
  - Mostly carrots and grains
  - Focused in center of Basin
- 1% Urban
  - Majority in Cuyama and New Cuyama
  - Other residences scattered throughout basin
- Some historical oil and gas development



Reported statistics are from Hanson et. al (2014)

GROUNDWATER LEVELS AND TRENDS VARY SPATIALLY



Hydrograph Source: USGS SIR 2014-5150

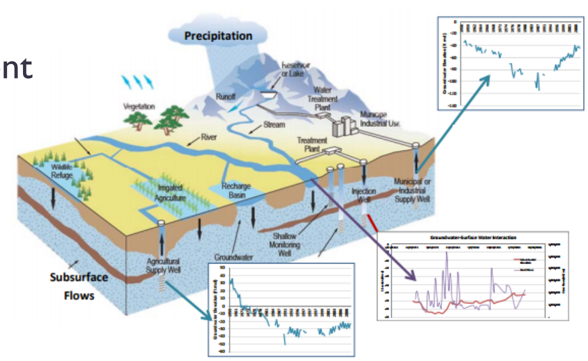
KEY ISSUES INFORMING DWR'S BASIN PRIORITIZATION AND SGMA RESPONSE

- Basin classified as Medium Priority and in a conditions of "Critical Overdraft"
  - *"Local salinity and TDS impairments in basin (B-118)"*
  - *"Declining Groundwater levels of 150-300' over the last 40-50 years (DWR, 1998). Conservation Assessment by TNC (2009) indicates annual GW budget deficit of ~ 28,500 af"*
- SGMA Implications:
  - Requires Groundwater Sustainability Plan (GSP) development by 2020
  - Basin Sustainability by 2040

The Six SGMA "Undesirable Results"

KEY SGMA REQUIREMENTS – GROUNDWATER SUSTAINABILITY PLANS (GSP)

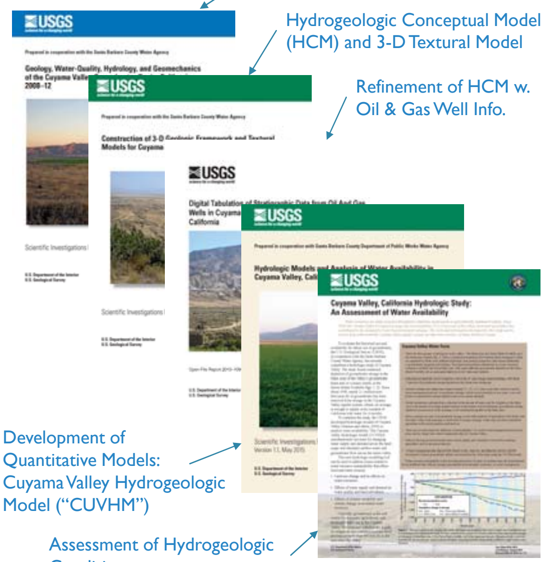
- Data Management System
- Groundwater Conditions Assessment
- Hydrogeological Conceptual Model (HCM)
- Water Budget
- Sustainability Criteria
- Monitoring Network
- Projects & Management Actions



* 23-CCR Sections 354.16-20; www.water.ca.gov/groundwater/sgm/gsp.cfm

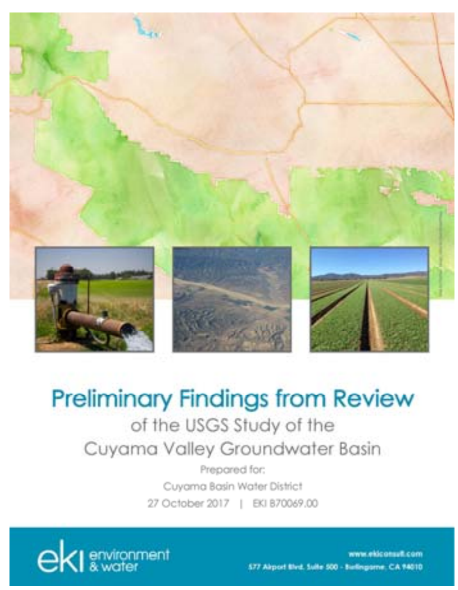
THE "USGS STUDY" – 2008-2014

- Everett, R.R., Gibbs, D.R., Hanson, R.T., Sweetkind, D.S., Brandt, J.T., Falk, S.E. and Harich, C.R., 2013, *Geology, water-quality, hydrology, and geomechanics of the Cuyama Valley groundwater basin, California, 2008–12*: U.S. Geological Survey Scientific Investigations Report 2013–5108, 62 p.
- Sweetkind, D.S., Faunt, C.C., and Hanson, R.T., 2013, *Construction of 3-D geologic framework and textural models for Cuyama Valley groundwater basin, California*: U.S. Geological Survey Scientific Investigations Report 2013–5127, 46 p.
- Sweetkind, D.S., Bova, S.C., Langenheim, V.E., Shumaker, L.E., and Scheirer, D.S., 2013, *Digital tabulation of stratigraphic data from oil and gas wells in Cuyama Valley and surrounding areas, central California*: U.S. Geological Survey Open-File Report 2013–1084, 44 p.
- Hanson, R.T., Flint, L.E., Faunt, C.C., Gibbs, D., and Schmid, Wolfgang, 2014, *Hydrologic models and analysis of water availability in Cuyama Valley, California*: U.S. Geological Survey Scientific Investigations Report 2014–5150, 150 p.
- Hanson, Randall T., and Sweetkind, Donald, 2014, *Cuyama Valley, California hydrologic study—An assessment of water availability*: U.S. Geological Survey Fact Sheet 2014-3075, 4 p.



EKI TEAM'S ROLE IN PEER REVIEW

- Performed detailed review of USGS reports and supporting data
- Assessed the USGS Groundwater Model (CUVHM) for reproducibility, transparency, performance, and reliability



KEY QUESTIONS

- How does this work support SGMA compliance in the Basin?
- Are the key assumptions and findings of the USGS Study with respect to groundwater conditions in the Basin valid?
- What potential flaws, inconsistencies, or data gaps may influence the Basin water budget and HCM developed by the USGS?
- Is the numerical model CUVHM developed by the USGS adequate to reasonably estimate the Basin water budget?

eki

SUMMARY OF KEY FINDINGS

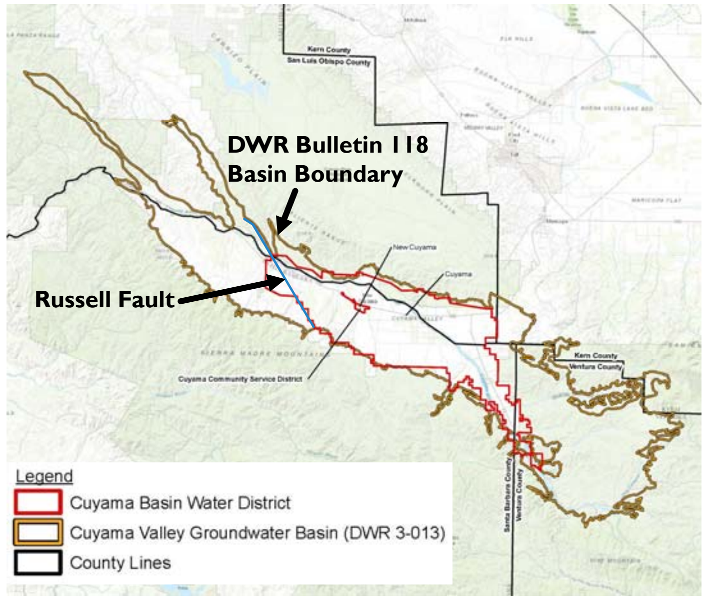
- The USGS Study represents a significant body of work that can provide foundational data and information to inform the development of the Cuyama Basin GSP.

- However, this was a pre-SGMA effort -

- The USGS Study does not encompass all of the DWR-defined Cuyama Basin and is therefore insufficient as the sole basis to fulfill any SGMA requirements.
- The USGS-defined basin "subdivisions" need further evaluation to assess their validity and to assess their value as the potential basis for basin "management areas" under SGMA.
- Results of USGS numerical model and simulated water budget are non-unique and not reproducible.

eki

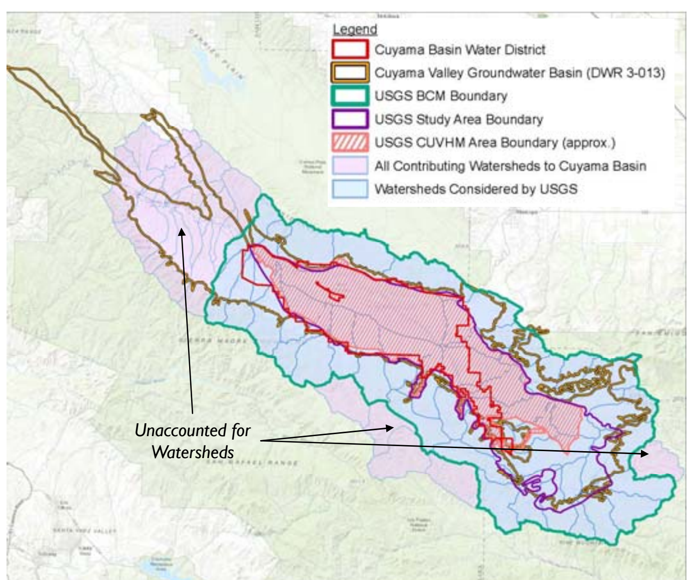
SGMA REQUIRES FULL COVERAGE OF DWR-DEFINED BASINS



- DWR mapped the basin based on the extent of unconsolidated alluvial sediments
- The 2016 attempt to subdivide the basin along the Russel fault was denied by DWR

eki

THE USGS STUDY AND MODEL ONLY CONSIDERS PART OF THE BASIN



- USGS Study (and associate HCM) only considers 61% of the Basin area
- The USGS numerical model (and associated water budget) only covers 44% of the Basin area
- Only 41 out of 58 contributing watersheds are accounted for

eki

SGMA IMPLICATIONS: USGS STUDY ALONE IS INSUFFICIENT

- SMGA requires that, among other things, the technical GSP elements (the "Basin Setting" and "Sustainable Management Criteria") be developed with respect to the DWR-defined basin boundaries
- Given its limited spatial scale, the USGS Study alone is insufficient to rely on to inform key technical elements of the Cuyama Basin GSP

eki

"MANAGEMENT AREAS" MAY BE APPROPRIATE FOR SUSTAINABLE MANAGEMENT OF THE BASIN

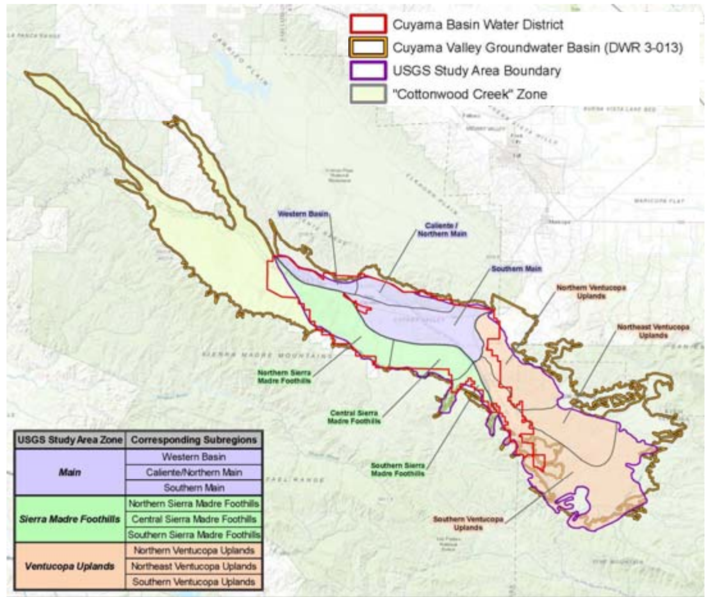
- SGMA regulations permit GSAs to:

  "*define one or more management areas within a basin if the [Groundwater Sustainability] Agency has determined that creation of management areas will facilitate implementation of the [Groundwater Sustainability] Plan. Management areas may define different minimum thresholds and be operated to different measurable objectives than the basin at large, provided that undesirable results are defined consistently throughout the basin" (23-CCR §354.20(a)).*
- Given Basin complexity, delineation of management areas will likely be important to GSP development and implementation
- Management area delineation should be systematic and logical to avoid adding even greater complexity

eki

USGS SUBDIVIDED THE BASIN INTO 4 "ZONES" AND 9 "SUBREGIONS"

- Three sub-regions of USGS-defined "Cuyama Basin":
  - Ventucopa Uplands
  - Sierra Madre Foothills
  - Main basin
- Area outside of USGS "Cuyama Basin":
  - "Cottonwood Creek" Zone*

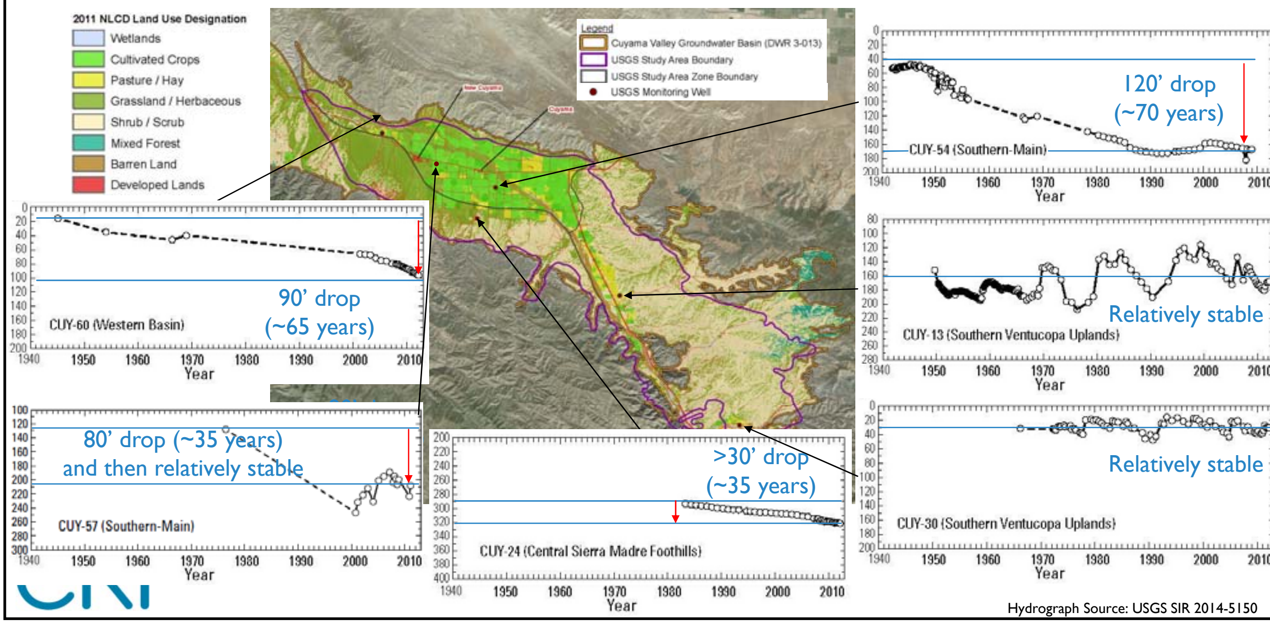


* Referred to as the "Chalk Mountain" area in the *2016 Basin Boundary Modification Request.*

USGS ZONES AS MANAGEMENT AREAS?

- USGS-defined "zones" and/or "subregions" could potentially be used as the basis for management areas
- According to USGS, the "zone" and "subregion" delineations were defined by "hydrogeologic features"
- However, close investigation of the purported basis for the zone delineations unveiled some internal inconsistencies

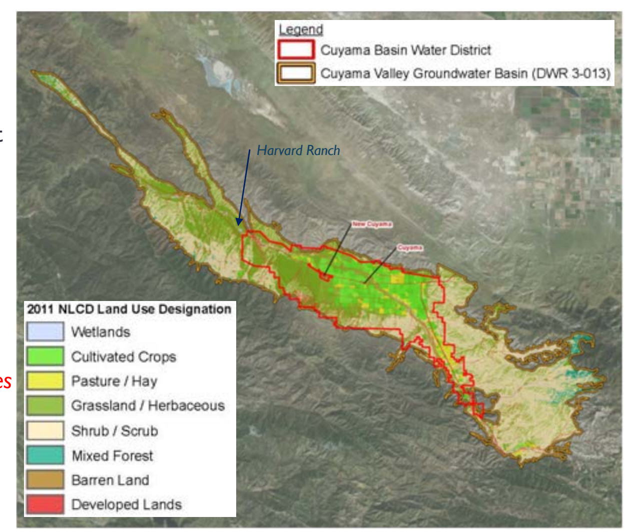
GROUNDWATER LEVELS AND TRENDS VARY SPATIALLY



Hydrograph Source: USGS SIR 2014-5150

LAND USE APPEARS TO BE A KEY DRIVER FOR GROUNDWATER CONDITIONS

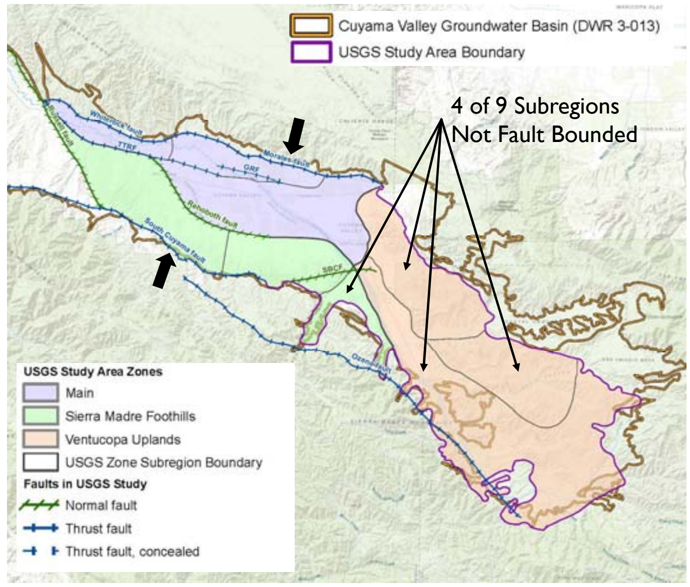
- Cottonwood Creek, Sierra Madre Foothills, and large portions of the Ventucopa Uplands areas are undeveloped
- Main area includes significant agricultural development
- Annual pumpage differs significantly between areas*
  - Main Zone: 57,000 AFY
  - Ventucopa Uplands: 7,400 AFY
  - Sierra Madre Foothills: 900 AFY
- Land uses are not static (e.g., Harvard Ranch development)
- *Differences in land use in addition to hydrogeologic features likely influence observed patterns of groundwater trends and movement*



* Reported values are from CUVHM 1950 – 2010 simulation results

NOT ALL SUBREGIONS ARE FAULT BOUNDED

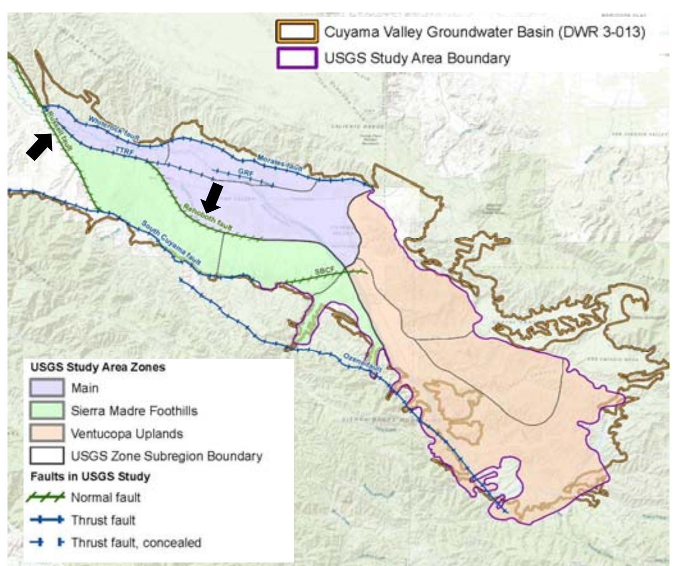
- USGS Study states that hydrologic subregions "are fault bounded" (Hanson et al., 2014), but that is actually only the case for some



eki

FAULTS PROPERTIES ARE NOT APPLIED CONSISTENTLY

- Russell fault and Rehoboth fault have been modeled as barriers to flow in the USGS model (Hanson et al., 2014).
- The HCM states the Russell fault and Rehoboth (Farms) fault "did **not** appear to be acting as a contributing barrier to groundwater flow" (Everett et al., 2013)
- DWR denied the 2016 Basin Boundary Modification Request because "it was not demonstrated that the Russell Fault is a hydrogeologic barrier to groundwater flow"*

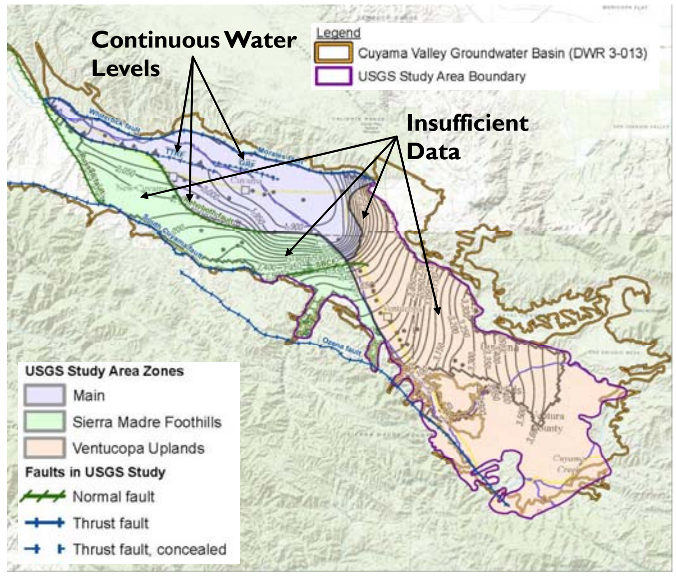


eki

*http://water.ca.gov/groundwater/sgm/pdfs/Final_Basin_Boundary_Modifications.pdf

GROUNDWATER GRADIENTS ARE NOT ADEQUATELY CHARACTERIZED

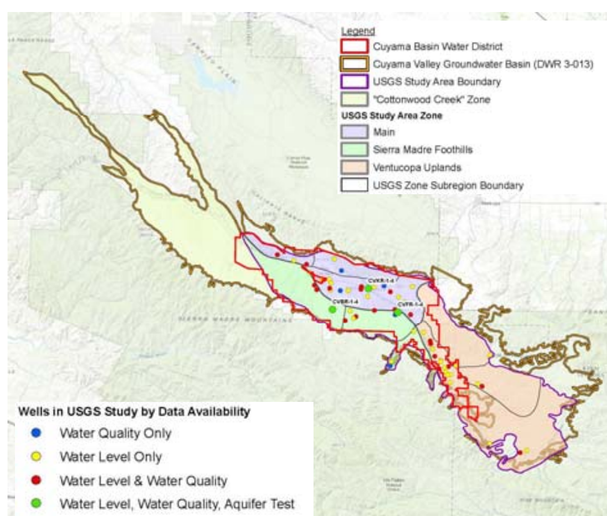
- Data gaps exist in characterization of groundwater-flow conditions in many areas of the Cuyama Basin:
  - Northern Ventucopa Uplands
  - Sierra Madre Foothills
- Fault parameterization (as barriers to flow) is often not supported by data - continuous groundwater level conditions exist across:
  - Rehoboth fault
  - Turkey Trap fault
  - Graveyard Ridge fault



eki

WATER QUALITY DIFFERENCES BETWEEN USGS ZONES VARY, BUT NOT DEFINITIVELY

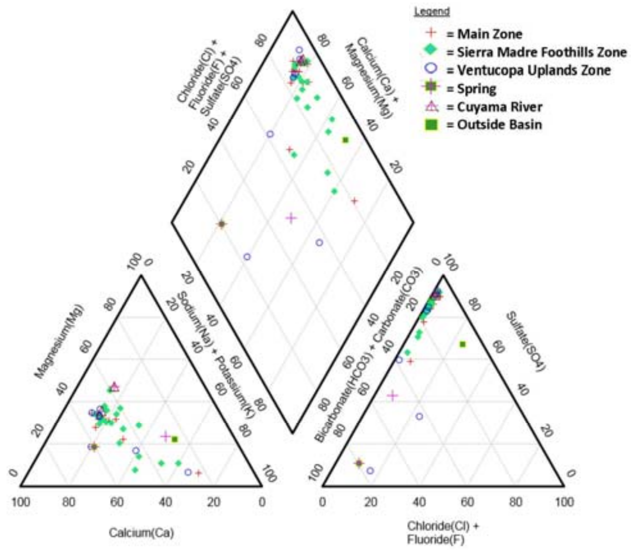
- The USGS study relied on “different water quality characteristics” (Hanson et al., 2014) to delineate between zones and hydraulic subregions.
- Water quality samples collected from 39 wells and analyzed for up to 53 constituents
- However, examination of these water quality and stable isotope data reveals that these differences are unclear



eki

PIPER DIAGRAMS DO NOT INDICATE DISTINCT WATER TYPES

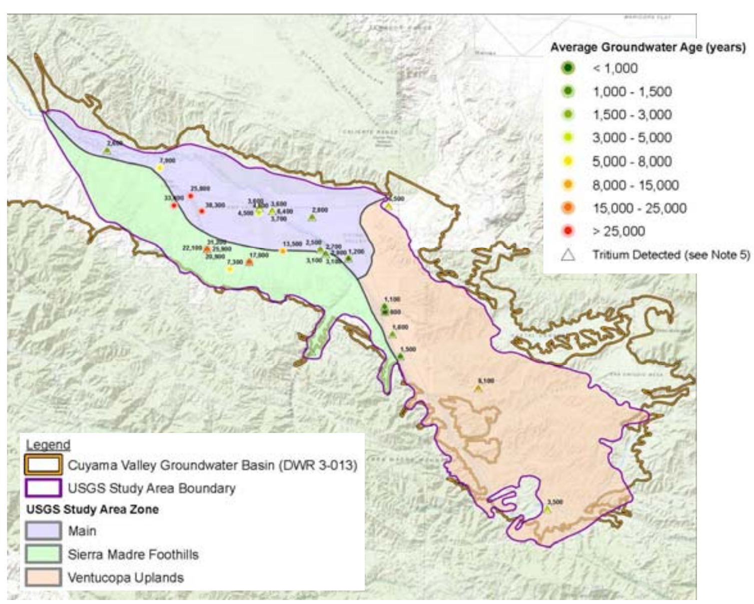
- Significant variability existed from sample to sample
- Most water characterized as "calcium-magnesium sulfate waters"
- Plotting of major cation data on Piper diagrams does not indicate distinct water types between the multiple zones



eki

WATER AGE VARIES IN RELATION TO PROXIMITY TO THE RIVER

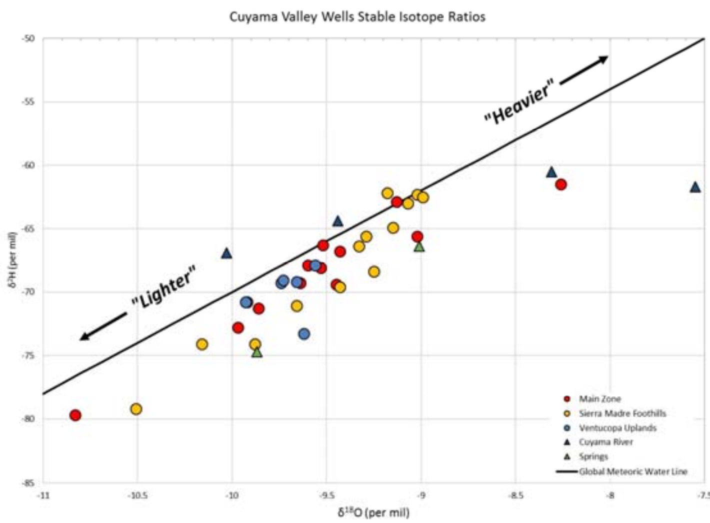
- Analysis of tritium and carbon-14 in Cuyama Basin groundwater samples indicates significant groundwater age variability
- Younger waters found in shallow wells close to Cuyama River
- Older waters found in deeper wells away from Cuyama River



eki

OXYGEN AND HYDROGEN ISOTOPES RATIOS SUGGEST COMMON RECHARGE SOURCES

- Recharge from Cuyama River expected to have "lighter" isotope ratio
- Recharge from direct precipitation expected to have "heavier" isotope ratio
- Plotting of stable isotopes of oxygen and hydrogen by zone shows very little distinction in isotope ratios between zones



eki

SGMA IMPLICATIONS: FURTHER EVALUATION OF GROUNDWATER CONDITIONS WILL BE NECESSARY

- USGS Study's delineation of hydraulic "zones" and "subregions" is not entirely consistent with information presented in the study
- Further refinement of the hydrogeologic and anthropogenic drivers causing the variability within the Basin will be necessary in order to provide a strong basis for the formation of management areas
- Tradeoffs associated with actions within each proposed management area must be evaluated to determine the correct balance of local versus Basin-wide management approaches within the Cuyama Basin

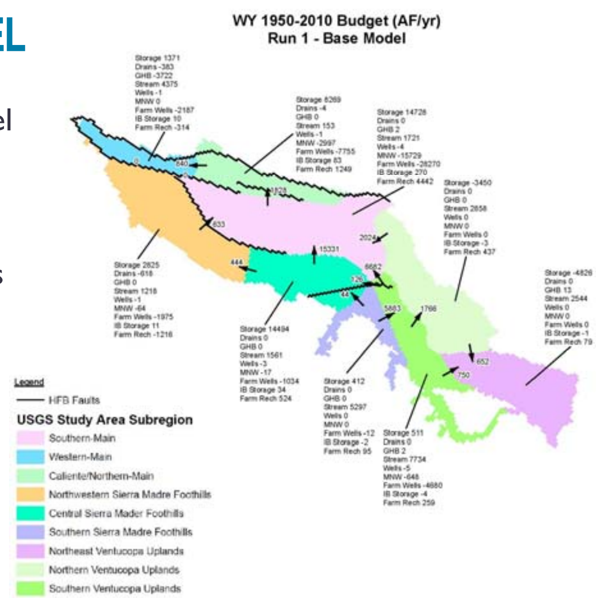
eki

MODELING IS KEY TO SGMA IMPLEMENTATION

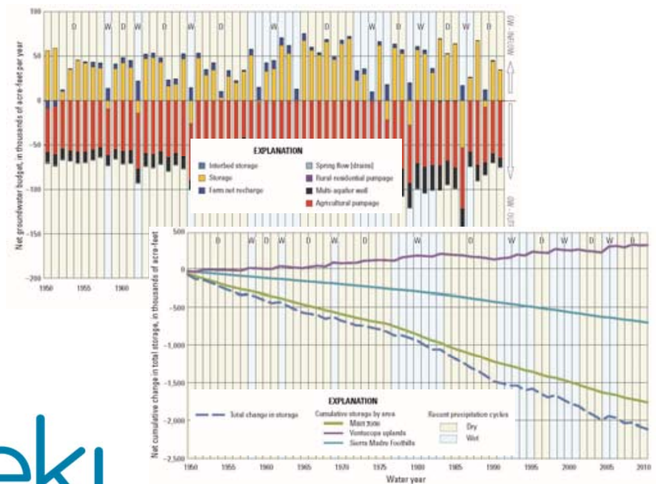
- In the context of SGMA, the purpose of modeling is to provide knowledge related to:
  - past and present behavior of the surface and groundwater system
  - the likely response to future changes
  - uncertainty over the 50-year time horizon
- Any model must be accurate, adaptable, representative, and transferrable

USGS NUMERICAL MODEL

- The USGS developed a numerical model (CUVHM) to quantitatively represent the Cuyama Basin
- The numerical model was calibrated to historical water and land use conditions and then used to assess the use and movement of groundwater throughout the valley and to quantify a water budget.
- However, the numerical model and simulated water budget are not reproducible and not necessarily accurate



USGS WATER BUDGET INDICATES SUBSTANTIAL OVERDRAFT CONDITIONS EXIST



Source	Valley Wide	Main zone	Ventucopa Uplands	Sierra Madre Foothills
Time period (Water years)	2000–2010[5]	2000–2010	2000–2010	2000–2010
Inflows:				
Storage depletion:	34,800	27,500	0	13,800
Direct infiltration (DI)[7]	3,100	700	1,500	900
Streamflow infiltration (SI)	30,300	8,300	20,500	1,600
Total recharge (DI+SI):	33,400	9,000	22,000	2,500
Total inflows:	68,200	36,500	22,000	16,300
Outflows:				
Storage accretion:	0	0	6,000	0
Underflow (GU):	3,100	3,200	15	0
Springs as drains:	600	600	0	0
Domestic pumpage:	10	6	8	2
Water-supply pumpage:	190	190	0	0
Agricultural pumpage:	68,100	56,700	10,000	1,400
Total pumpage:	68,300	56,900	10,000	1,400
Total outflows:	68,900	57,500	16,000	1,400
Inflows - Outflows =	−700[8]	−21,000[8]	6,000[9]	−14,900[8]

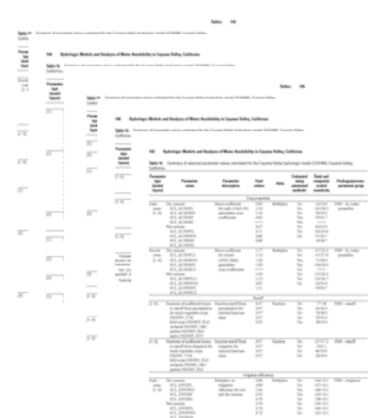
eki

INPUT PARAMETERS COULD NOT BE INDEPENDENTLY VERIFIED

- Model documentation does not describe quality assurance procedures undertaken to verify the "several hundred" input parameters used in the numerical model, including:
  - Monthly rainfall and temperature
  - Land use information
  - Spatially variable soil types
  - Processes like subsidence and faulting
- 65 parameters calibrated:

"A total of 200 parameters were initially created to facilitate model calibration, but this number was reduced to 65 parameters after initial global sensitivity and calibration analysis (table 14)." (Hanson, 2014a)

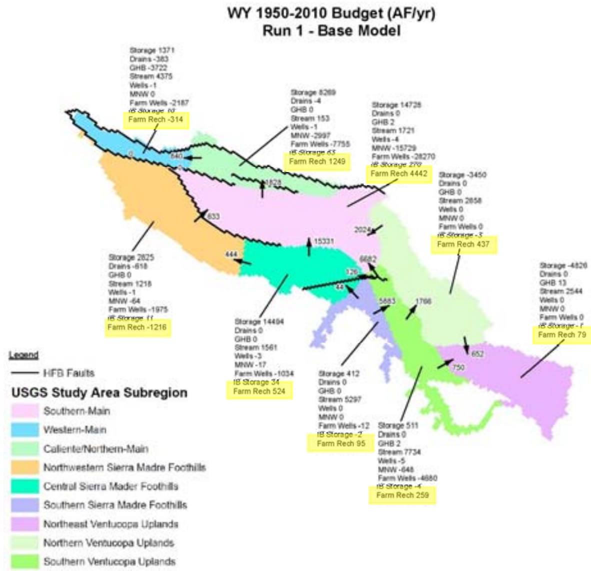
- Lack of verification, and the large number of input parameters, and the complexity of land and water processes represented by the model create uncertainty



eki

DISCREPANCIES EXIST BETWEEN USGS STUDY AND ARCHIVED MODELS

- The EKI Team ran the numerical model (obtained from the USGS Model Archive) and compared results to the corresponding output from the USGS Model Archive
- Model-calculated and archived water levels agreed, but discrepancies exist between the water budgets, with most of the discrepancy attributable to "**Farm Recharge**"
- These discrepancies indicate that the numerical model results reported in the USGS Study are not reproducible



eki

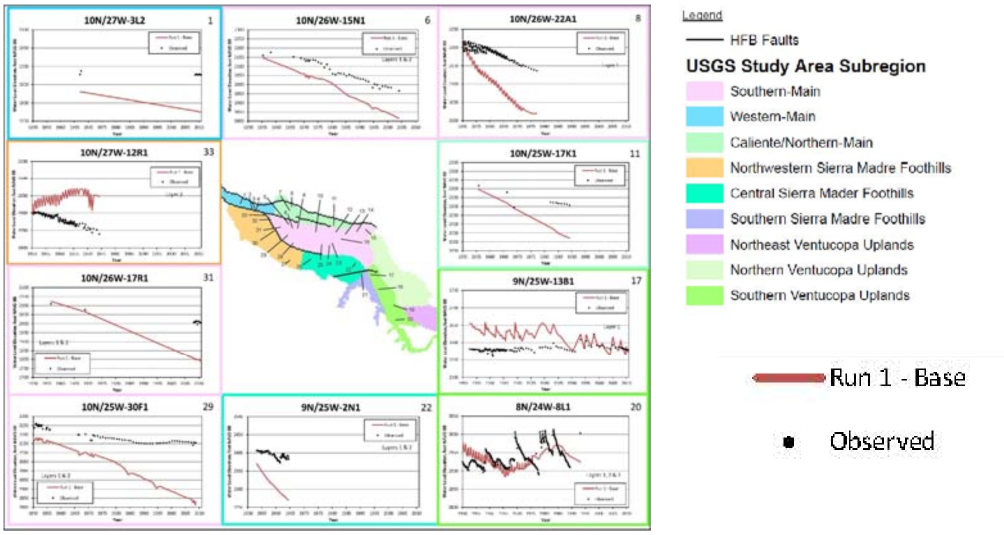
MODEL RESULTS ARE NON-UNIQUE

	Subregion / Water Budget Component	Northeast Ventucopa Uplands	Southern Ventucopa Uplands	Northern Ventucopa Uplands	Southern Sierra Madre Foothills	Central Sierra Madre Foothills	Northwestern Sierra Madre Foothills	Southern Main	Caliente/ Northern Main	Western Main
Water Budget Components Internal to Subregion	Storage	0%	37%	2%	106%	-1%	8%	-3%	-1%	-13%
	Drains	both zero	both zero	both zero	both zero	both zero	-8%	both zero	no change	26%
	GHB	no change	no change	both zero	both zero	both zero	both zero	-100%	both zero	3%
	Stream	no change	0%	no change	2%	-3%	7%	0%	-1%	-3%
	Wells	both zero	no change	both zero	both zero	no change	no change	no change	no change	no change
	MNW	both zero	no change	both zero	both zero	no change	no change	0%	-1%	both zero
	Farm Wells	both zero	0%	both zero	no change	no change	0%	0%	0%	1%
	IB Storage	no change	no change	33%	-50%	-6%	18%	-4%	-8%	-30%
	Farm Rech	no change	0%	0%	8%	3%	-17%	0%	-1%	23%
Fluxes Between Subregions	From Northeast Ventucopa Uplands	--	no change	no change	both zero	both zero	both zero	both zero	both zero	both zero
	From Southern Ventucopa Uplands	no change	--	-1%	-5%	-46%	both zero	no change	both zero	both zero
	From Northern Ventucopa Uplands	no change	-1%	--	both zero	both zero	both zero	-4%	both zero	both zero
	From Southern Sierra Madre Foothills	both zero	-5%	both zero	--	1875%	both zero	both zero	both zero	both zero
	From Central Sierra Madre Foothills	both zero	-46%	both zero	1875%	--	1%	4%	both zero	both zero
	From Northwestern Sierra Madre Foothills	both zero	both zero	both zero	both zero	1%	--	-3%	both zero	100%
	From Southern Main	both zero	no change	-4%	both zero	4%	-3%	--	3%	both zero
	From Caliente/Northern Main	both zero	both zero	both zero	both zero	both zero	both zero	3%	--	-6%
	From Western Main	both zero	both zero	both zero	both zero	both zero	100%	both zero	-6%	--

- Increasing fault conductance affected the subsurface flux rates between some subregions with shared fault boundaries, but flux remained unchanged in other cases
- Increasing fault conductance improved comparisons between measured and model-calculated water levels, suggesting that the USGS Study model solution is "non-unique" and can be improved

eki

USGS MODEL GENERALLY OVER-ESTIMATES WATER LEVEL DECLINES



MODEL RESULTS ARE HIGHLY VARIABLE AT SMALL TEMPORAL & SPATIAL SCALES

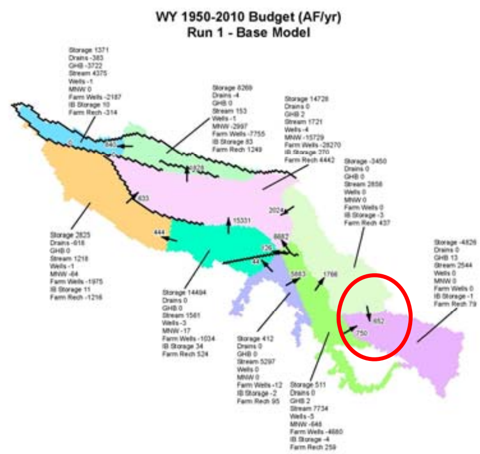
- Considerable mass balance error exists:
  - Within subregional water budgets of the CUVHM
  - Within individual simulation years of the basin-wide model
- The USGS Study notes that

"the conceptual and numerical models were developed on the basis of assumptions and simplifications that may restrict the use of the model to regional and subregional levels of spatial analysis within seasonal to interannual temporal scales… In particular, the distribution and change in land-use patterns needs to be improved to annual or even monthly scales to significantly increase accuracy of the simulation, [as] many of the stresses that are driven by these land uses varied throughout the simulation period at higher frequencies than the multi-year estimates of most of the historical land use." (Hanson et al., 2014)

- Use of the model at small spatiotemporal scales could prove problematic

NUMERICAL MODEL: ADDITIONAL ISSUES

- Additional issues of concern were identified while testing the USGS model:
  - Uncertainty exists in modeled values of rainfall runoff
  - 8,000 AFY of annual groundwater storage accretion in the Ventucopa Uplands Zone may be anomalous
  - Subsurface flows between the Northeast Ventucopa Uplands and the Northern and Southern Ventucopa Uplands are not supported by data
  - Many land- and water-related parameters used to estimate calculate pumping are estimated, assumed, or calibrated



eki

SMGA IMPLICATIONS: USGS NUMERICAL MODEL IS INCOMPLETE, BUT VALUABLE

- In its present form, the USGS numerical model is not adequate to use in support of GSP development
- Foundational information can be used to support model refinement or transition to:
  1. Expand boundaries to represent the entire DWR-defined Cuyama Basin
  2. Improve transparency and reproducibility of calibration, verification of model results, expansion of data collection, and improvement of the site characterization

eki

IMPLICATIONS FOR SGMA COMPLIANCE

- The USGS Study alone cannot be used as the sole basis for GSP development for the Cuyama Basin
- However, the USGS study and multiple independent studies conclude that Guyama Basin is operating in deficit

Study	Method	Time Period	Annual Net Recharge	Annual Net Usage	Deficit/Surplus	CUVHM Deficit/ Surplus
Singer & Swarzenski, 1970	Mass Balance	1939-1946	16,000 AFY	18,000 AFY	-2,000 AFY	N/A
Singer & Swarzenski, 1970	Mass Balance	1947-1966	12,000 AFY	33,000 AFY	-21,000 AFY	-32,851 AFY[1]
SBCWA, 1977	Mass Balance	1966-1975	13,000 AFY	51,000 AFY	-38,000 AFY	-24,099 AFY
USDA, 1988	Safe Yield	1975-1986	26,500 AFY	56,800 AFY	-30,300 AFY	-39,596 AFY
DWR, 1998	Specific Yield	1982-1993	N/A	N/A	-14,600 AFY	-44,098 AFY
TNC, 2008	Mass Balance	2008	11,500 AFY	42,000 AFY	-30,500 AFY	-9,301 AFY
USGS, 2014 (CUVHM)	Numerical Model	2000-2010	N/A[2]	N/A[2]	-33,912 AFY	
USGS, 2014 (CUVHM)	Numerical Model	1950-2010	N/A[2]	N/A[2]	-34,166 AFY	

[1] USGS-CUVHM simulation period begins in 1950
[2] Analogous values for net recharge and net usage cannot be readily extracted from USGS model outputs due to the complex methodology used in deriving water balance estimates

eki

NO DENYING THAT SIGNIFICANT ISSUES WILL HAVE TO BE ADDRESSED

- Multiple entities have evaluated the Basin over the years and reached similar conclusions that groundwater pumping was exceeding recharge
- Water quality and water levels will have to be managed to avoid undesirable results
- Determine sustainability criteria
- Refine the water budget and other basin information to reflect complete data and basin information
- Develop appropriate management actions and projects

eki

QUESTIONS?

Anona Dutton, P.G., C.Hg.

adutton@ekiconsult.com

650-292-9100

eki

www.ekiconsult.com
Burlingame, CA | Los Angeles, CA
Oakland, CA | Centennial, CO

eki

41