Addressing Hydrogeologic Conceptual Model Uncertainty within the SGMA Planning Framework

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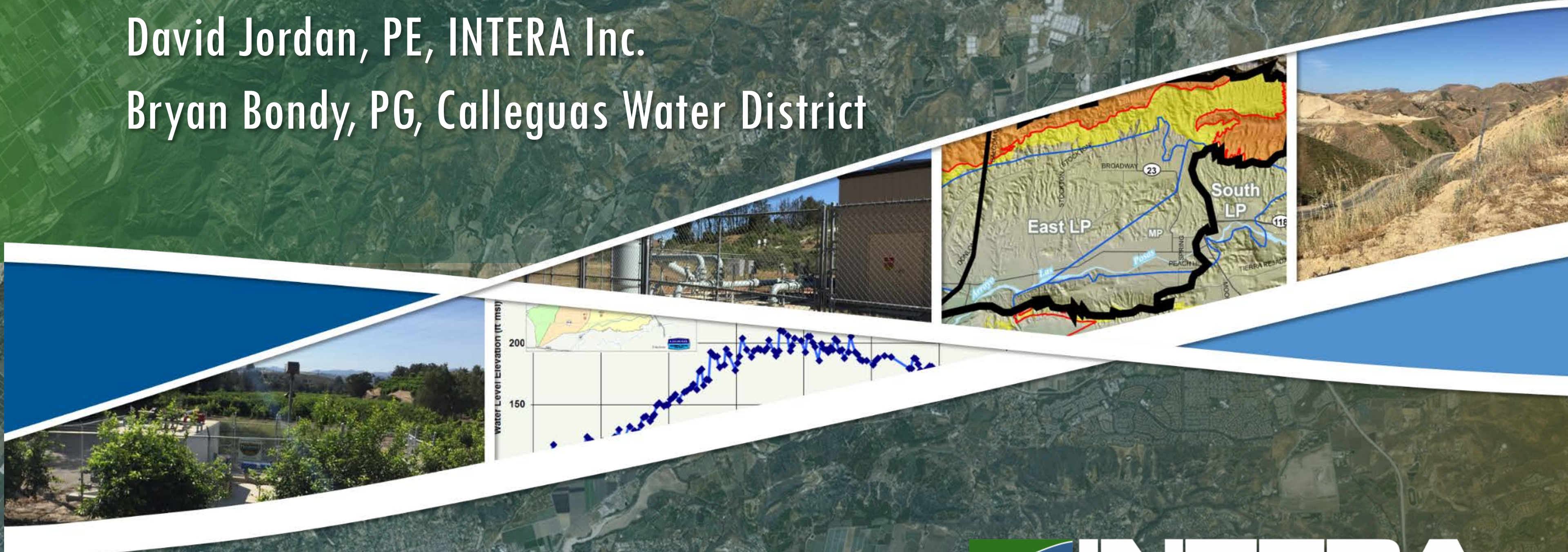

INTERA

GEOSCIENCE & ENGINEERING SOLUTIONS

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Groundwater Resources Association of California

Outline

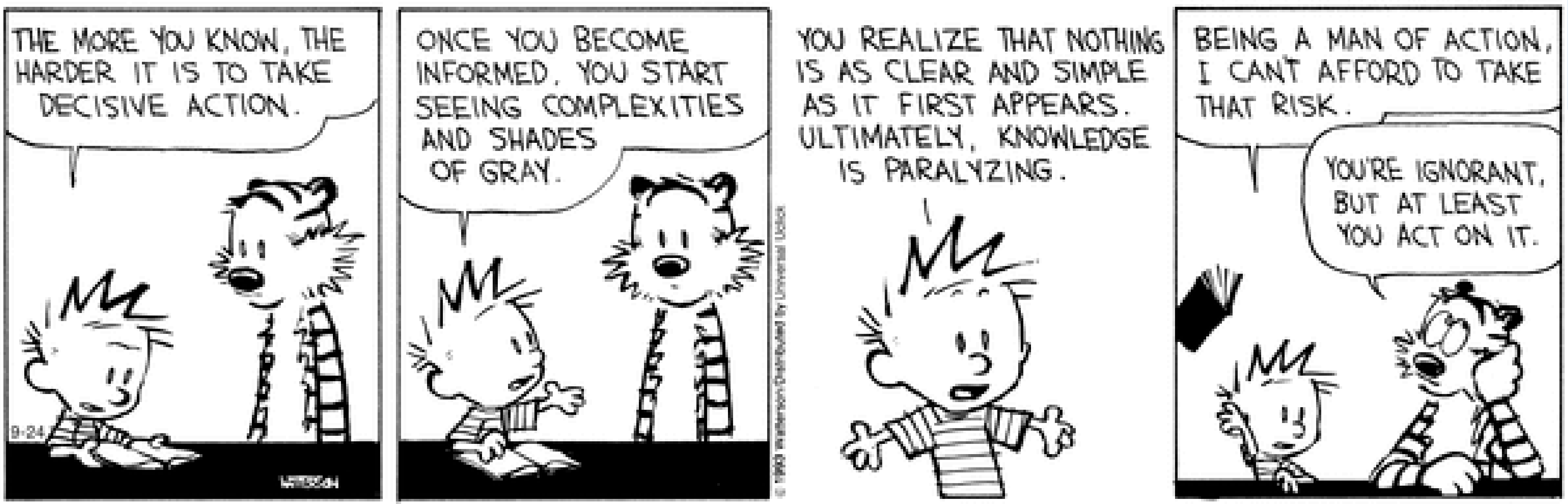
- Planning under uncertainty
- Uncertainty within the SGMA Planning Framework
- 5-steps for uncertainty assessment
- Case-Study
- Summary & Conclusions

Planning under uncertainty

- Planning *with* certainty is a rare luxury
- Planning under uncertainty is the norm

Planning under uncertainty

- **Alternatives:**
  - **Account for uncertainty**
  - **Ignore uncertainty**



SGMA Planning under Uncertainty

CALIFORNIA CODE OF REGULATIONS

TITLE 23. WATERS

DIVISION 2. DEPARTMENT OF WATER RESOURCES

CHAPTER 1.5. GROUNDWATER MANAGEMENT

SUBCHAPTER 2. GROUNDWATER SUSTAINABILITY PLANS

(d) Sustainable management criteria and projects and management actions shall be commensurate with the level of understanding of the basin setting, based on the level of uncertainty and data gaps, as reflected in the Plan.

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

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SUBARTICLE 2. Basin Setting

§ 354.12. Introduction to Basin Setting

This Subarticle describes the information about the physical setting and characteristics of the basin and current conditions of the basin that shall be part of each Plan, including the identification of data gaps and levels of uncertainty, which comprise the basin setting that serves as the basis for defining and assessing reasonable sustainable management criteria and projects and management actions. Information provided pursuant to this Subarticle shall be prepared by or under the direction of a professional geologist or professional engineer.

§ 354.14. Hydrogeologic Conceptual Model

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

(b) The hydrogeologic conceptual model shall be summarized in a written description that includes the following:

(1) The regional geologic and structural setting of the basin including the immediate surrounding area, as necessary for geologic consistency.

(2) Lateral basin boundaries, including major geologic features that significantly affect groundwater flow.

(3) The definable bottom of the basin.

(4) Principal aquifers and aquitards, including the following information:

(5) Identification of data gaps and uncertainty within the hydrogeologic conceptual model

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§ 354.18. Water Budget

(3) Projected water budgets shall be used to estimate future baseline conditions of supply, demand, and aquifer response to Plan implementation, and to identify the uncertainties of these projected water budget components. The projected water budget shall utilize the following methodologies and assumptions to estimate future baseline conditions concerning hydrology, water demand and surface water supply availability or reliability over the planning and implementation horizon:

(A) Projected hydrology shall utilize 50 years of historical precipitation, evapotranspiration, and streamflow information as the baseline condition for estimating future hydrology. The projected hydrology information shall also be applied as the baseline condition used to evaluate future scenarios of hydrologic uncertainty associated with projections of climate change and sea level rise.

(B) Projected water demand shall utilize the most recent land use, evapotranspiration, and crop coefficient information as the baseline condition for estimating future water demand. The projected water demand information shall also be applied as the baseline condition used to evaluate future scenarios of water demand uncertainty associated with projected changes in local land use planning, population growth, and climate.

(C) Projected surface water supply shall utilize the most recent water supply information as the baseline condition for estimating future surface water supply. The projected surface water supply shall also be applied as the baseline condition used to evaluate future scenarios of surface water supply availability and reliability as a function of the historical surface water supply identified in Section 354.18(c)(2)(A), and the projected changes in local land use planning, population growth, and climate.

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§ 354.28. Minimum Thresholds

(a) Each Agency in its Plan shall establish minimum thresholds that quantify groundwater conditions for each applicable sustainability indicator at each monitoring site or representative monitoring site established pursuant to Section 354.36. The numeric value used to define minimum thresholds shall represent a point in the basin that, if exceeded, may cause undesirable results as described in Section 354.26.

(b) The description of minimum thresholds shall include the following:

(1) The information and criteria relied upon to establish and justify the minimum thresholds for each sustainability indicator. The justification for the minimum threshold shall be supported by information provided in the basin setting, and other data or models as appropriate, and qualified by uncertainty in the understanding of the basin setting.

§ 354.30. Measurable Objectives

(a) Each Agency shall establish measurable objectives, including interim milestones in increments of five years, to achieve the sustainability goal for the basin within 20 years of Plan implementation and to continue to sustainably manage the groundwater basin over the planning and implementation horizon.

(b) Measurable objectives shall be established for each sustainability indicator, based on quantitative values using the same metrics and monitoring sites as are used to define the minimum thresholds.

(c) Measurable objectives shall provide a reasonable margin of operational flexibility under adverse conditions which shall take into consideration components such as historical water budgets, seasonal and long-term trends, and periods of drought, and be commensurate with levels of uncertainty.

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FIGURE 1 – Measureable Objectives and Interim Milestones are Necessary to Reduce Uncertainty and Achieve or Maintain Groundwater Basin Sustainability

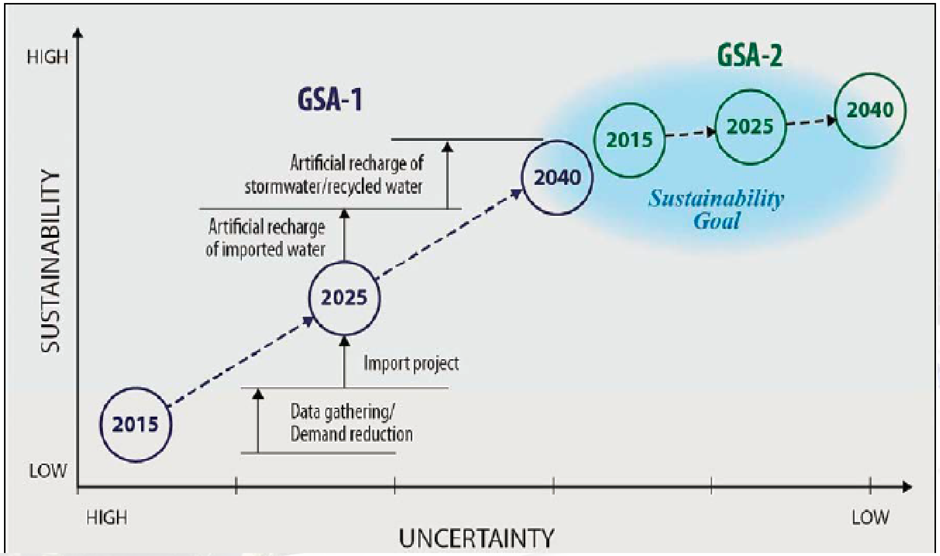
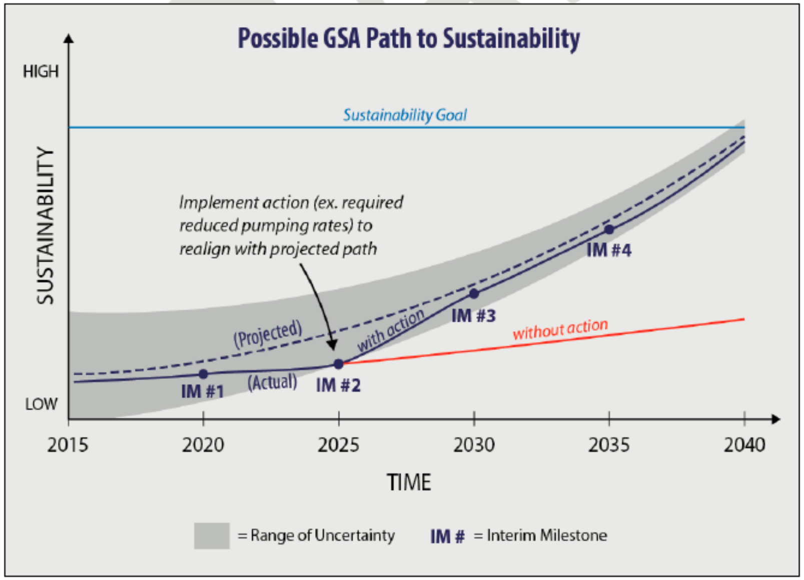


FIGURE 2 – Interim Milestones are Necessary to Trigger Actions if Measurable Objectives are not Being Achieved as Planned



SGMA Planning under Uncertainty

§ 354.38. Assessment and Improvement of Monitoring Network

(a) Each Agency shall review the monitoring network and include an evaluation in the Plan and each five-year assessment, including a determination of uncertainty and whether there are data gaps that could affect the ability of the Plan to achieve the sustainability goal for the basin.

§ 354.44. Projects and Management Actions

(d) An Agency shall take into account the level of uncertainty associated with the basin setting when developing projects or management actions.

5-Step Program for Uncertainty Assessment

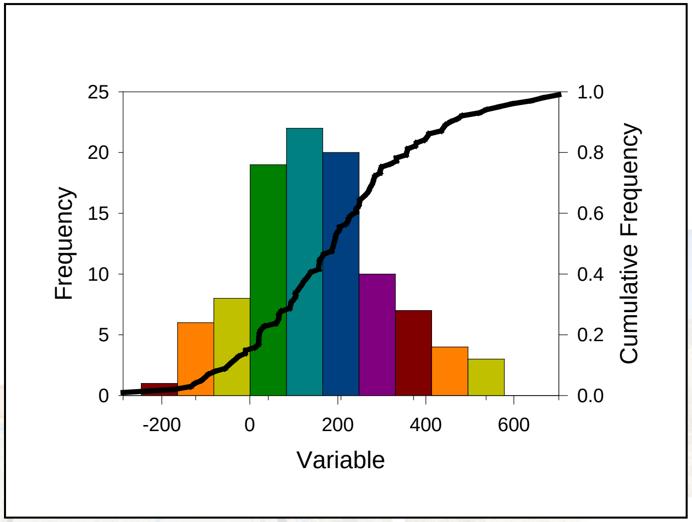
1. Uncertainty Identification
2. Uncertainty Characterization
3. Uncertainty Propagation
4. Uncertainty Importance Analysis
5. Uncertainty Reduction

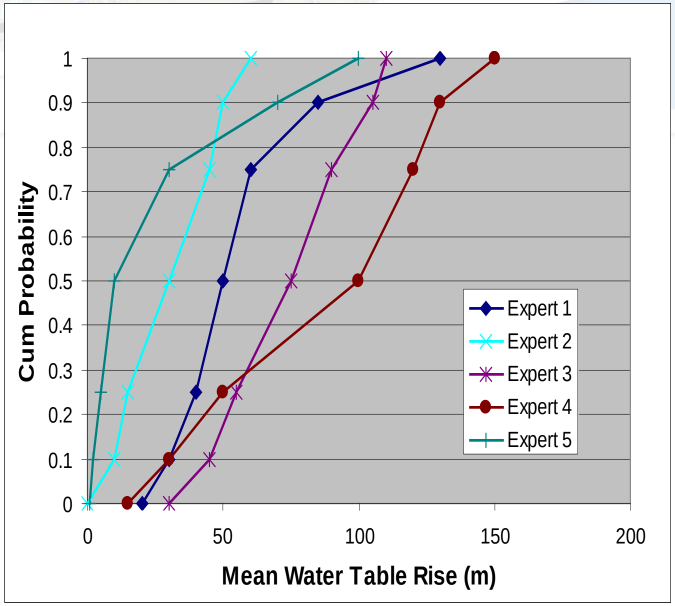
Uncertainty Identification

- Recognize and articulate key uncertainties
  - Hydrogeology, hydrology, water budget, water supplies, water demands…
- Engage and involve stakeholders, subject/policy experts, planners
- Process of moving ‘unknown unknowns’ to ‘known unknowns’
  - Multiple perspectives are critical
- <u>Conceptual water budget is a good place to start</u>

Uncertainty Characterization

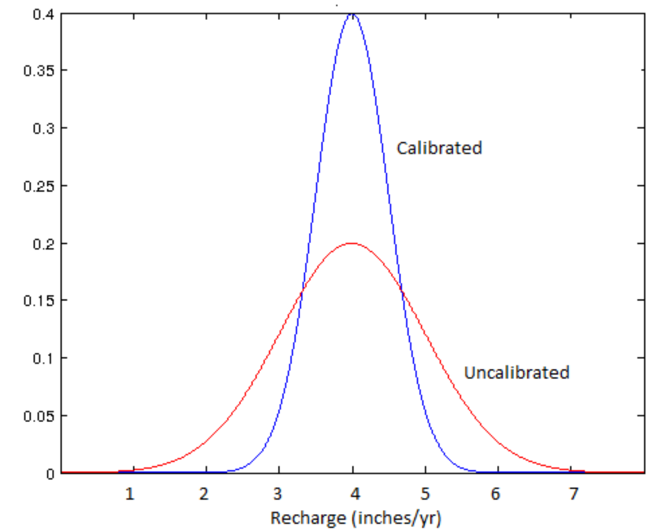
- Develop plausible ranges/ distributions for uncertain terms
  - Recharge is 7% - 15% of precip.
- Use existing data combined with graphical or regression techniques
  - Analogous sites can be useful
- Assess ranges/distributions using formal expert elicitation protocols





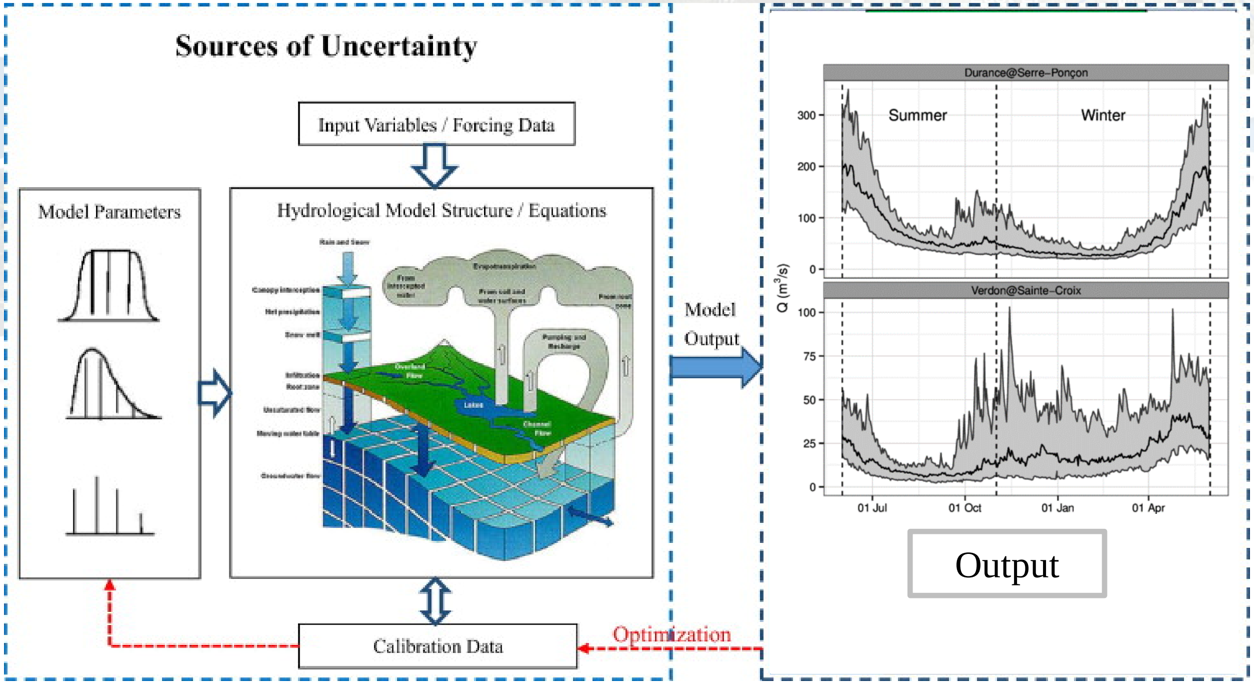
Uncertainty Characterization

- Constrain ranges using expert judgment and/or model
  - Model incorporates physical processes
  - Calibration reduces uncertainty by conditioning to data
- Use model to test prior assumptions for uncertain variables
  - Does 15% of precip. as recharge lead to unreasonably high water levels?
- Use model to understand relationships between uncertain variables



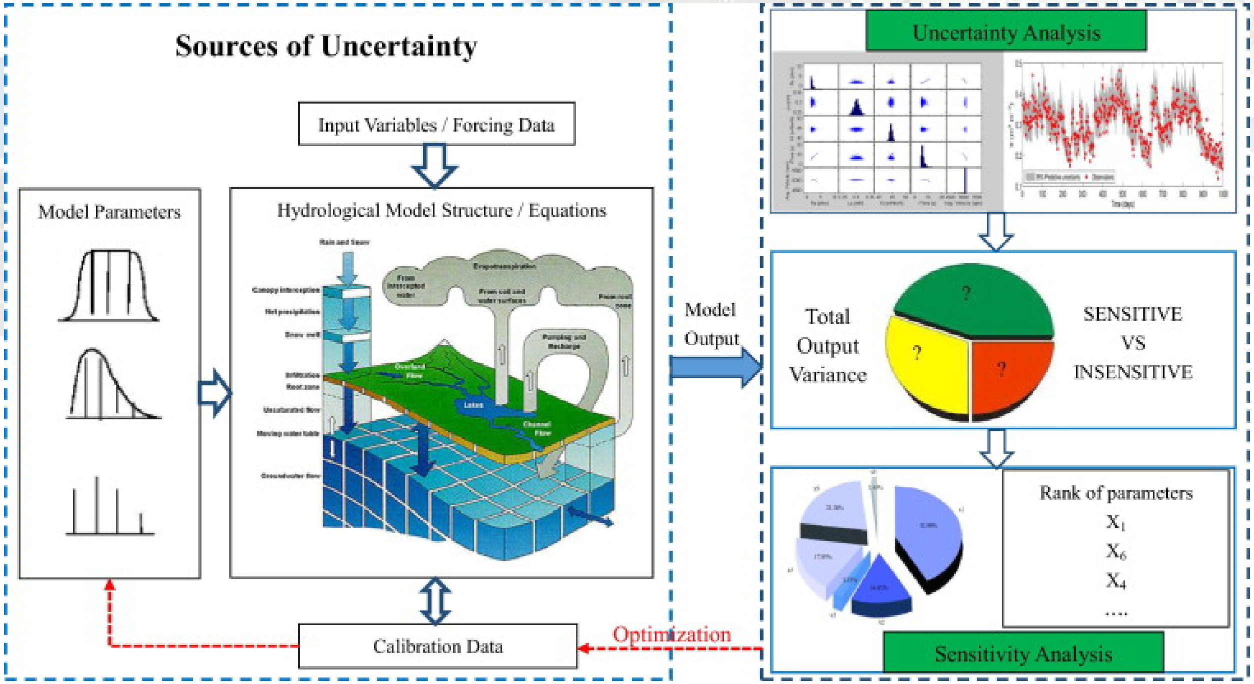
Uncertainty Propagation

- Translate uncertain variables to system metrics (water budget terms, sustainability indicators)
- Typically use models to propagate uncertainty



Uncertainty Importance Analysis

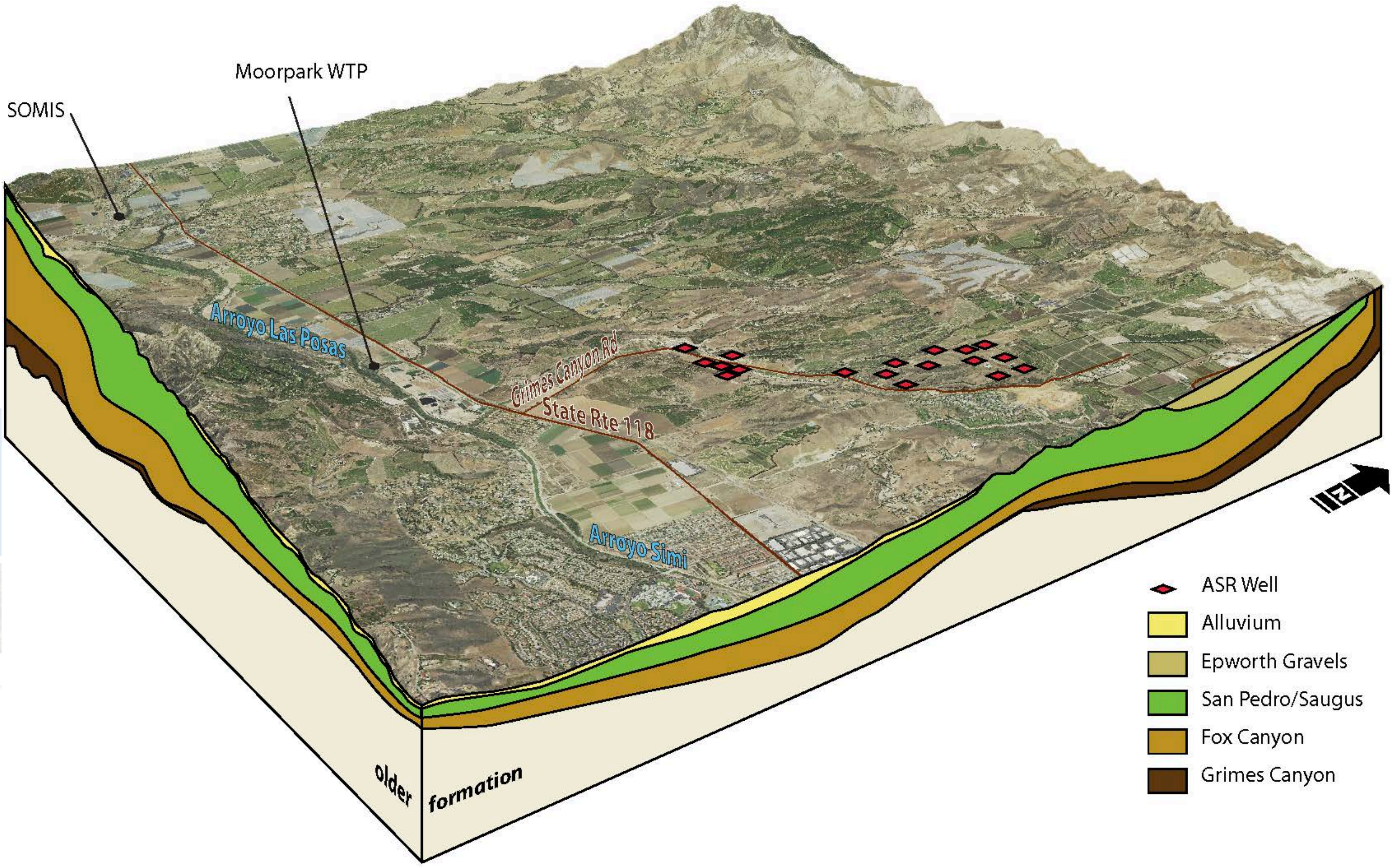
- Assess which uncertain variables, system metrics (sustainability indicators) are most sensitive to
- Vary uncertain parameter(s) over their range and evaluate impact on given output metric
  - Assess correlations between uncertain parameters



Uncertainty Reduction

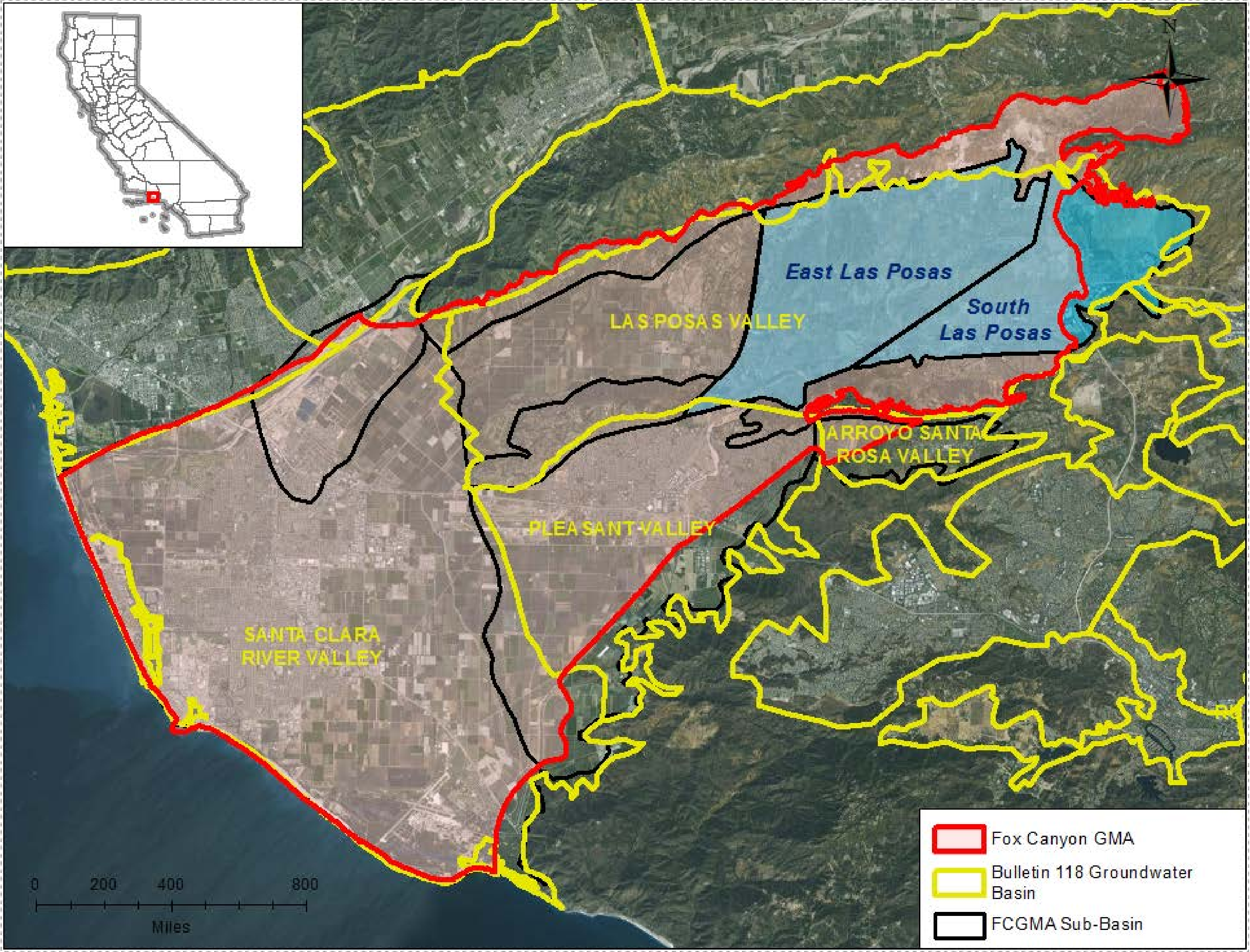
- Key uncertainties can be reduced by collecting more data
- Model can be used to develop and optimize data-collection efforts
- Additional data can be used to a) refine prior uncertainty distributions, and b) calibrate model and reduce predictive uncertainty

Case Study

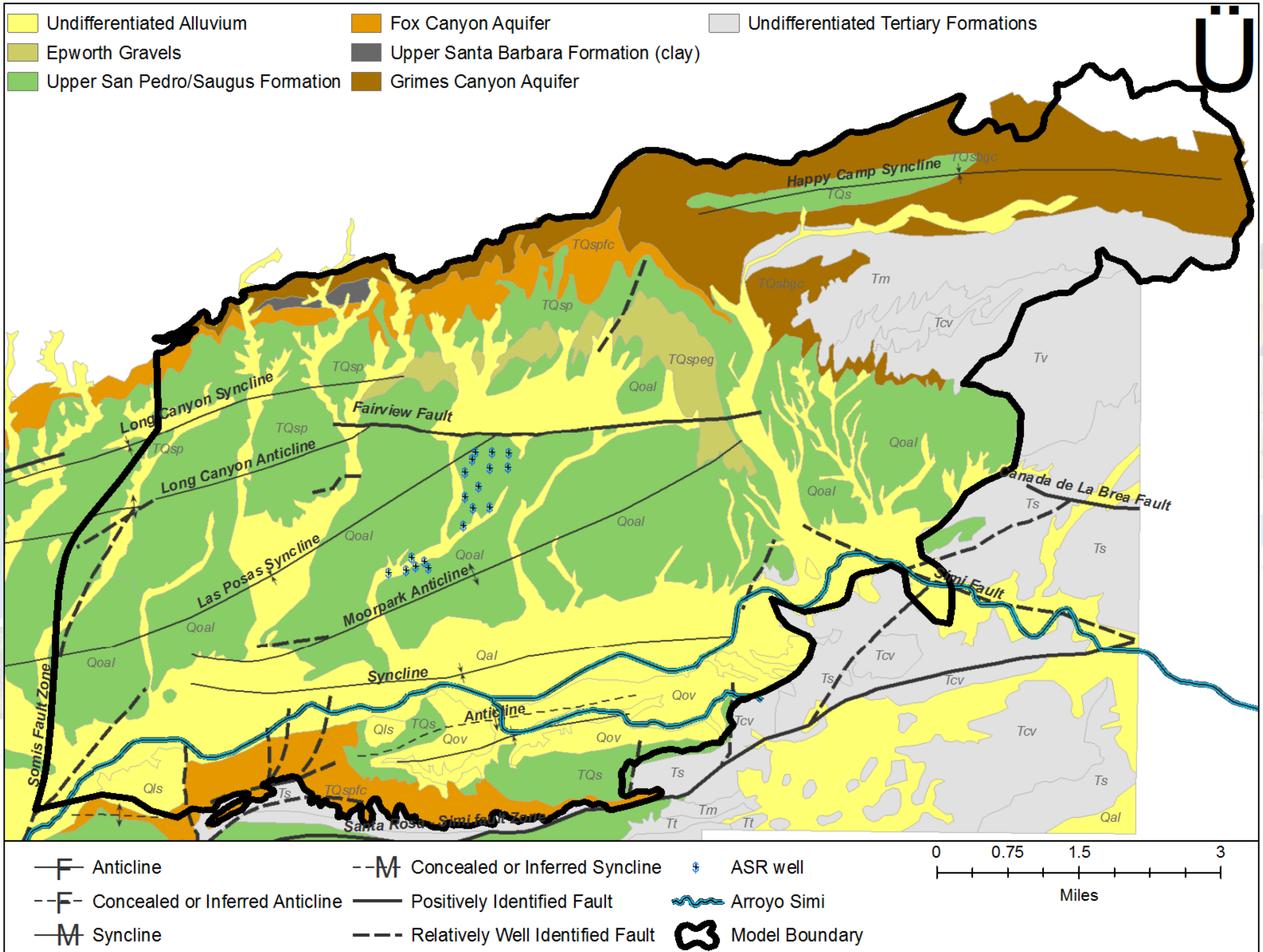


Moorpark WTP
SOMIS
Arroyo Las Posas
Grimes Canyon Rd
State Rte 118
Arroyo Simi
N
older formation
ASR Well
Alluvium
Epworth Gravels
San Pedro/Saugus
Fox Canyon
Grimes Canyon

Study Area

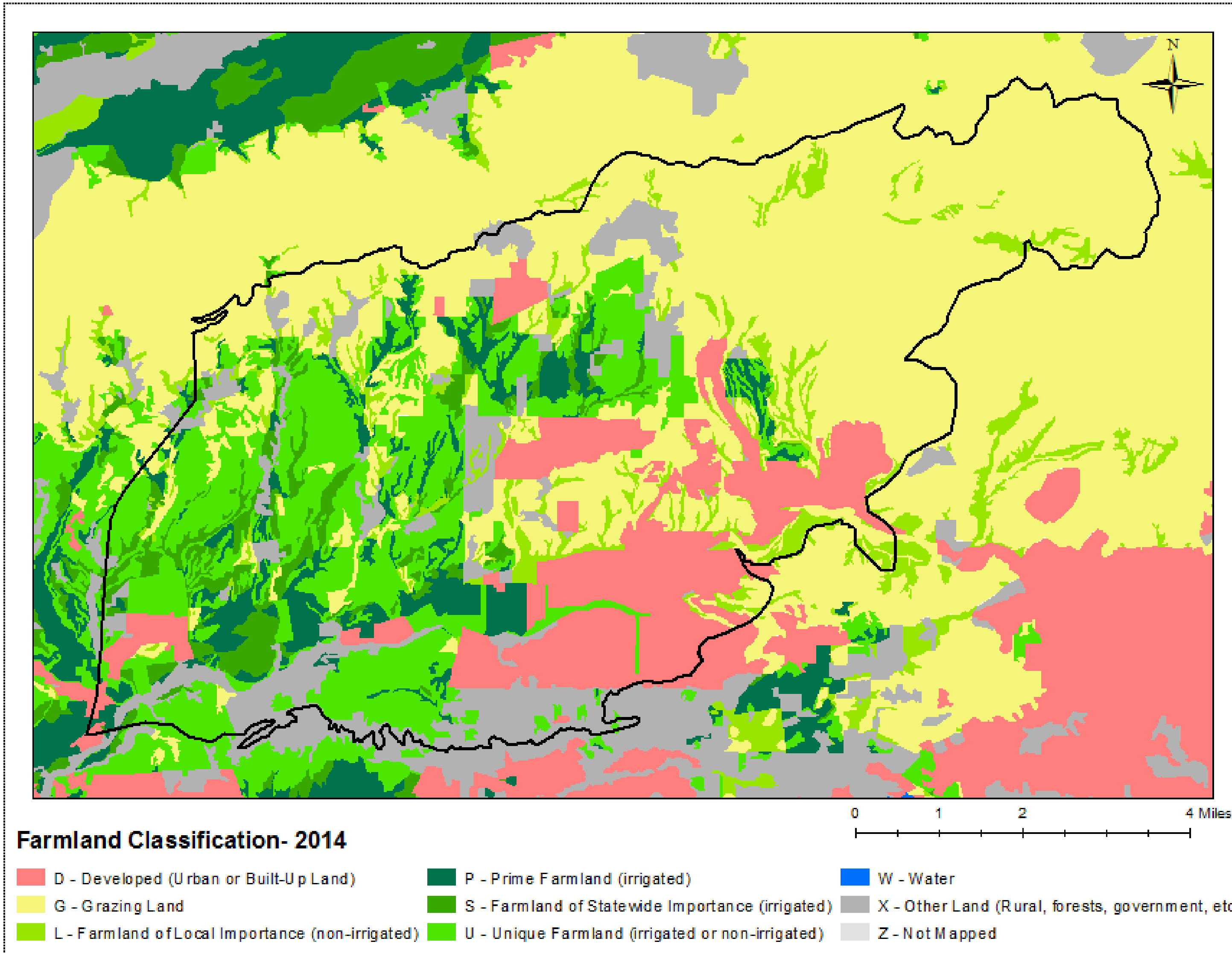

East Las Posas
South Las Posas
LAS POSAS VALLEY
ARROYO SANTA ROSA VALLEY
PLEASANT VALLEY
SANTA CLARA RIVER VALLEY
N
0 200 400 800
Miles
Fox Canyon GMA
Bulletin 118 Groundwater Basin
FCGMA Sub-Basin

Surface Geology

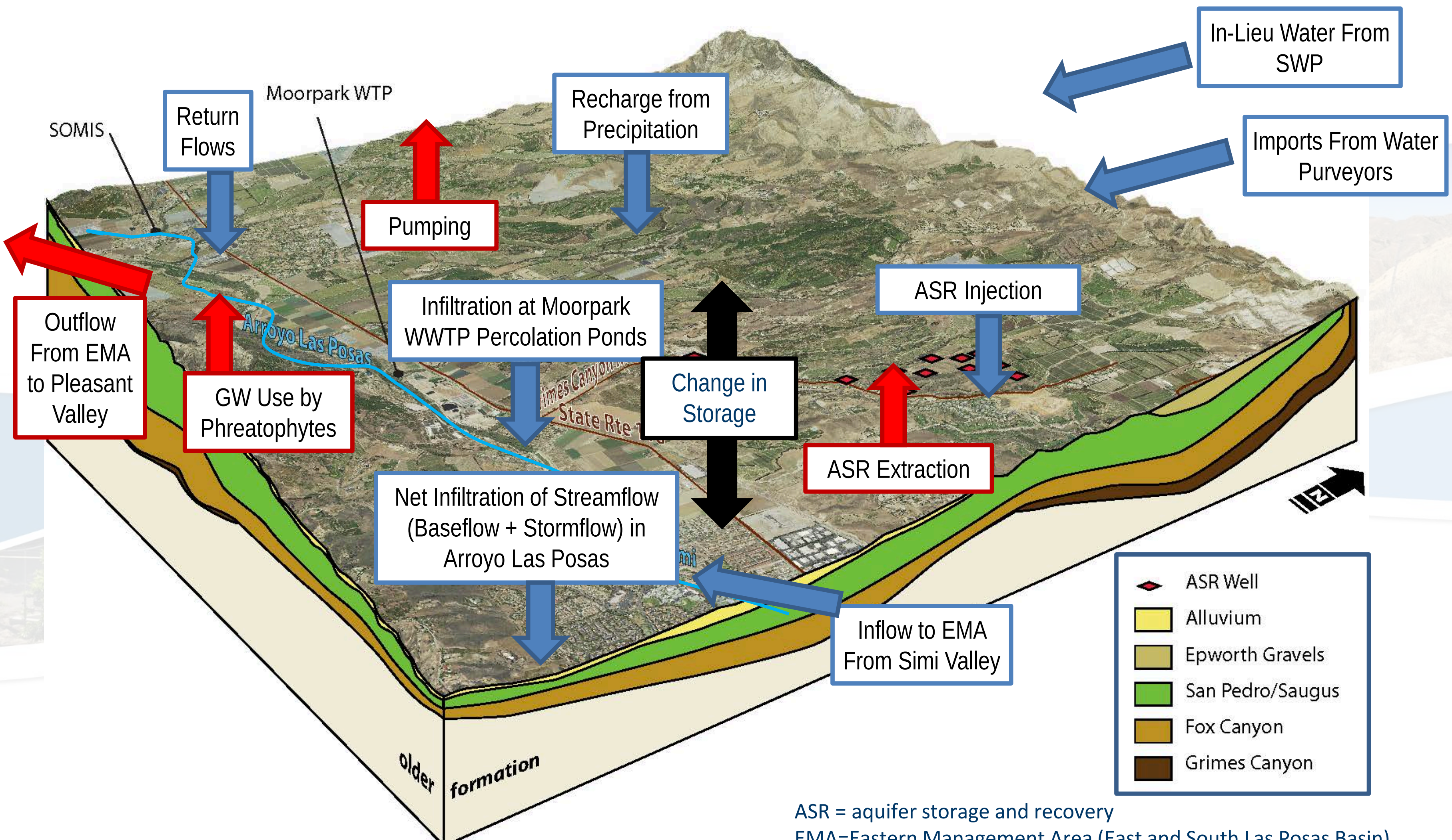


Study Area Proposed Stratigraphic Column[5]
Undifferentiated Alluvium (Qal)[8]
Epworth Gravels (Qseg) *(where present)*
Upper San Pedro/Saugus Formation (Qs) *(may contain localized water bearing zones, to be evaluated in later stages of project)*
Clay Marker Bed (CL)
Fox Canyon Aquifer (Qlpfc)
Upper Santa Barbara Formation (clay-rich) (Qsb)
Grimes Canyon Aquifer (Qsbfc)
Undifferentiated Tertiary Formation (Effective Base of Fresh Water)

Land Use


N
0
1
2
4 Miles
Farmland Classification- 2014
D - Developed (Urban or Built-Up Land)
G - Grazing Land
L - Farmland of Local Importance (non-irrigated)
P - Prime Farmland (irrigated)
S - Farmland of Statewide Importance (irrigated)
U - Unique Farmland (irrigated or non-irrigated)
W - Water
X - Other Land (Rural, forests, government, etc.)
Z - Not Mapped

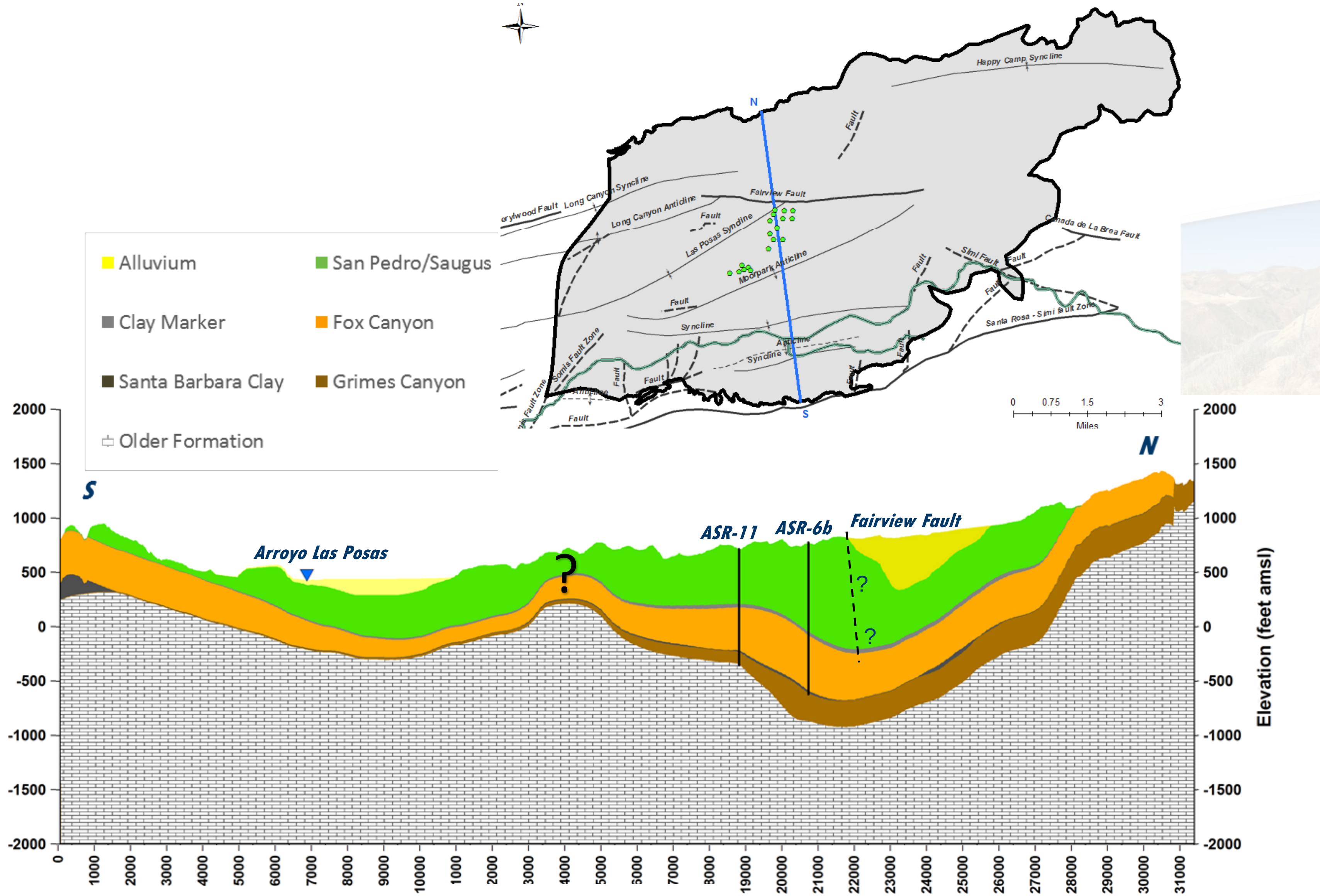
Conceptual Illustration of Water Budget



ASR = aquifer storage and recovery
EMA=Eastern Management Area (East and South Las Posas Basin)
GW=groundwater; SWP = state water project
WWTP = wastewater treatment plant

Change in Storage = Inflows - Outflows

Geologic Cross-Sections



1:3 Vertical Exaggeration

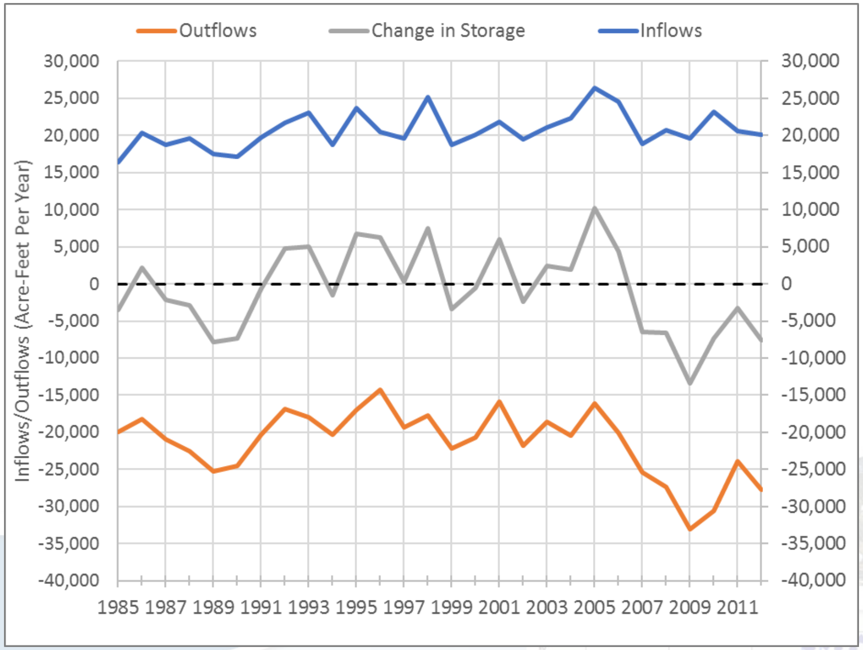
Key Questions

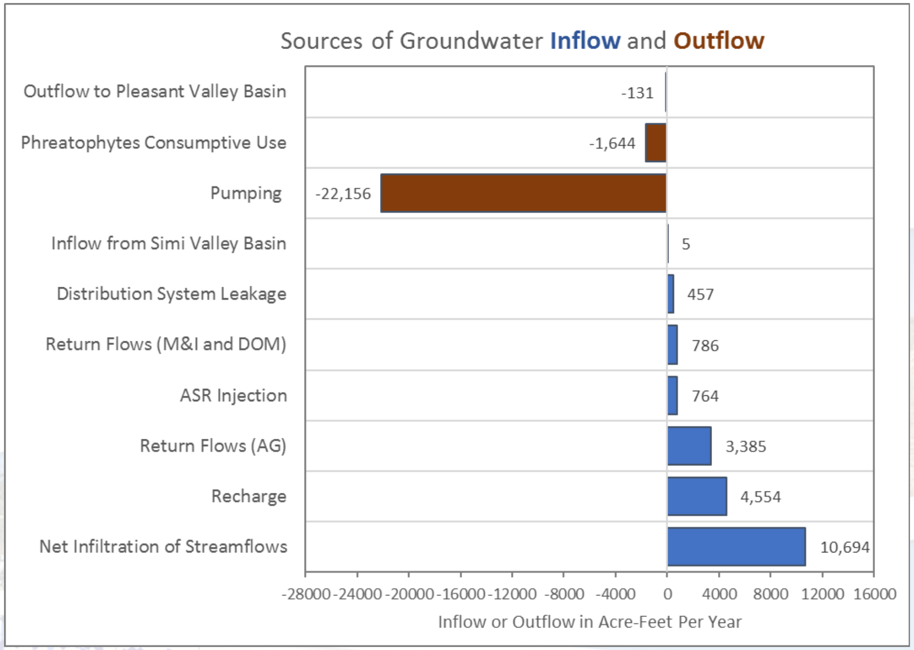
- How much streamflow percolates to the shallow/Fox Canyon aquifers?
  - How much percolation occurred under ephemeral flow conditions?
- What is the ET demand from the phreatophytes?
- What is the leakage from the San Pedro into the Fox Canyon Aquifer?
- Is there flow across the Somis Fault zone in the upper units?
- How much outflow occurs from the basin to the Pleasant Valley basin under current and historical conditions?
- Is there a connection between the ASR well-field and the Arroyo?
  - Does the anticline restrict flow under low-water level conditions?
- Have return flows from agriculture arrived at the water table?

Water Budget Approach

- Focus on:
  - Water budget terms that can be reasonably estimated from data
  - Larger water budget terms, of significance for groundwater flow model
  - Water budget terms that can be simulated or constrained by the flow model
- Recognize diminishing returns to reducing uncertainty for smaller water budget terms
- Use range over time to bound average conditions
- Use different methodologies or different data for an “independent” estimate
- Use physical constraints/relationships to develop bounds
- Use rules of thumb for measurement errors

Water Budget

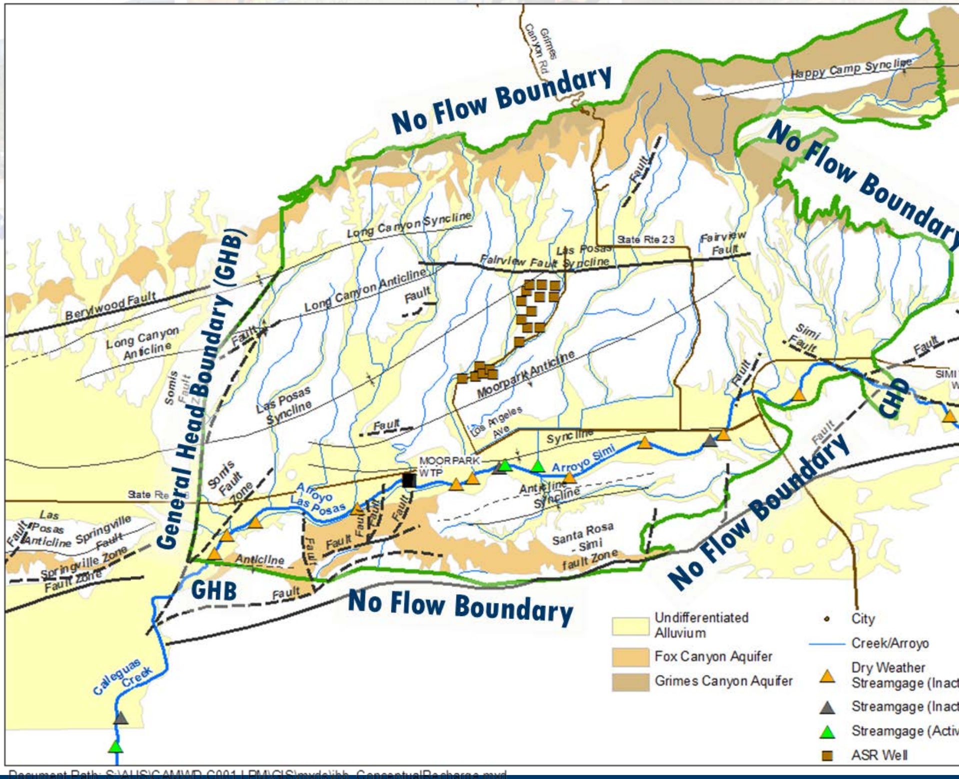




Average of Current Conditions				
Water Budget Term	Best Estimate[1] (AFY)	Lower Bound (AFY)	Upper Bound (AFY)	Approach
Recharge	3,330	824	6,758	range
Net Infiltration of Streamflow to Arroyo Las Posas (excludes stormflow)	10,452	7,755	15,000	physical constraint for upper bound; 20% measurement error
Groundwater ET	1,723	1,514	5,953	“independent”

Groundwater Model

- Groundwater model is being built in MODFLOW-NWT (may need to switch to MODFLOW-USG
- Currently working on calibrating numerical model
  - Water budget is being used to constrain calibration
- Heterogeneous/transient dataset used for calibration
- Areas with uncertain stratigraphy being varied to evaluate impact on flows
- Uncertain boundary conditions being varied to assess impact on calibration



Summary & Conclusions

- SGMA-related groundwater planning entails accounting for uncertainty in a) hydrogeologic conceptual model, b) current and future water budgets
- Measurable objectives, minimum thresholds, monitoring network, and management actions need to account for uncertainty
  - A flexible/adaptive approach reduces exposure to future risks
- 5-step approach to incorporating uncertainty into planning
  - Stakeholder driven process to identify and assess uncertainties
- Work on the Las Posas Basin Model exemplifies approach
  - Range of water budget terms developed using best available data and expert judgment
  - Model used to validate and reduce uncertainty in water budget

Planning under Uncertainty

We can do better!

"Political and economic uncertainty make long term planning difficult. Let's stick to ordering lunch."