East Bay Plain GSP Progress Update

TAC Meeting 27 Jan 2021

Subtask 4.2 TM and Groundwater Model Development and Calibration

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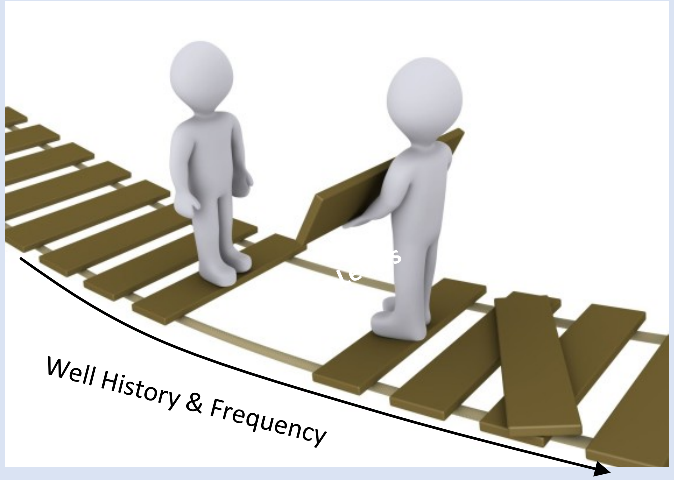
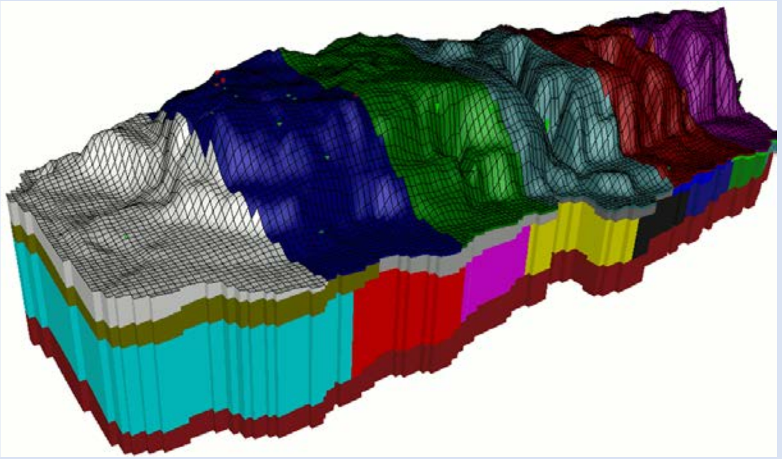
Completed Tasks

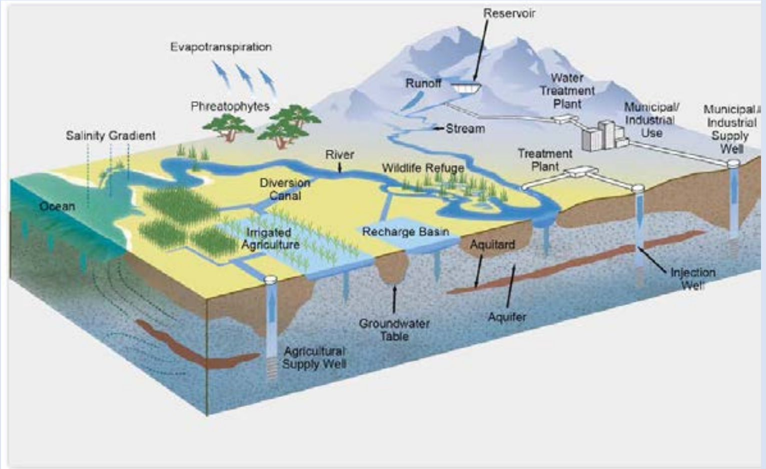
Subtask 4.1
Data Compilation and Data Gap Analysis



Subtask 4.3
Model Objectives and Model Selection



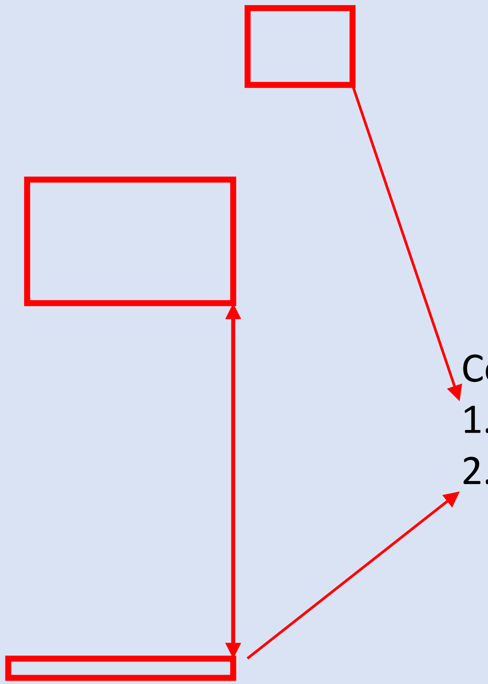
Subtask 4.2
Hydrogeologic Conceptual Model



Subtask 4.2 TM TAC Review – Responses to Major Comments

B

B’



Comments/Questions:

1. Why is this labeled as “Thin Sandstone Beds”?
2. Why is lithology on well logs labeled as “Gravel Cobbles Rock”, but interpreted to be Bedrock?

Subtask 4.2 TM TAC Review – Responses to Major Comments

B

B’

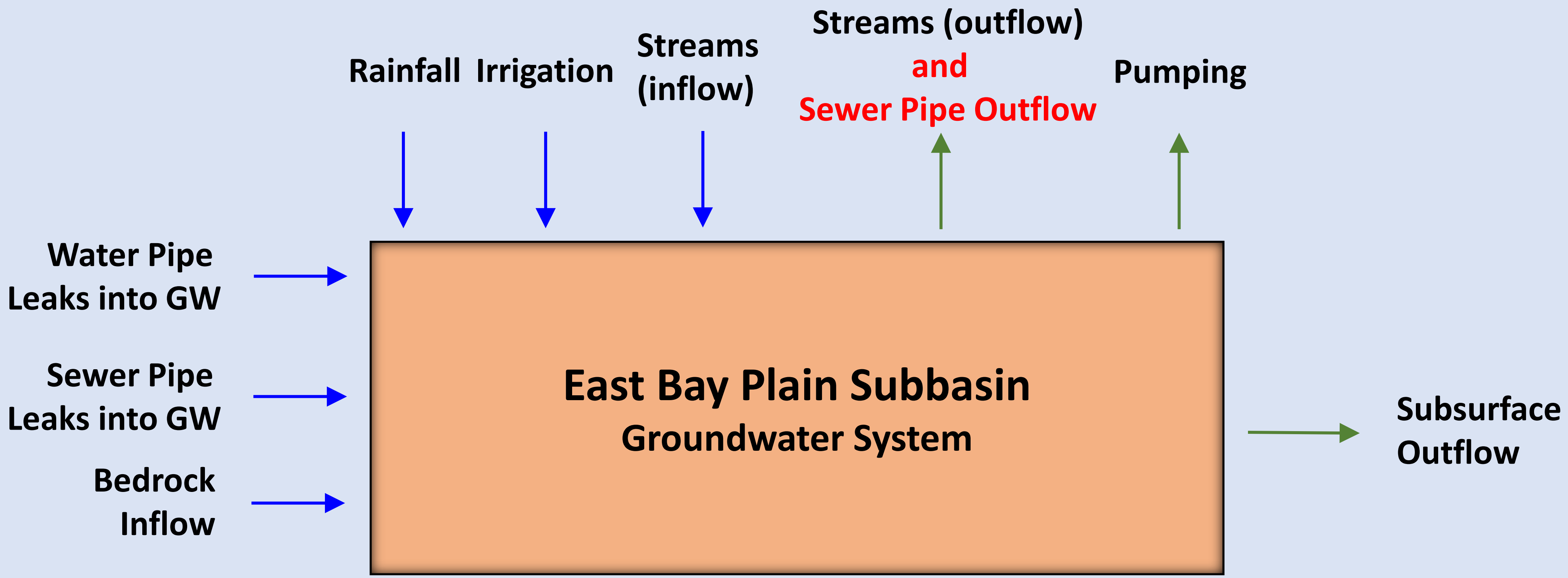
Responses:

1. Review of WCRs used in this cross-section indicate "Clay with thin gravel layers" as opposed to "Thin Sandstone Layers".
2. WCR shows “Rock” in this interval, which is included in the lumped category of “Gravel Cobbles Rock”. In this case, LSCE geologist interpreted “Rock” to be bedrock.

Subtask 4.2 TM TAC Review – Responses to Major Comments

Comments/Questions:

1. Is sewer pipe outflow (referred to as I & I) considered in the water balance? It is not shown on the water balance diagram in the November 2020 TAC Meeting presentation.
2. Does EBMUD WWTP have data pertaining to sewer outflow/I & I/exfiltration?



Subtask 4.2 TM TAC Review – Responses to Major Comments

Recharge Component to GW	Amount (AFY)	Comments
Precipitation	4,800	4% of total rainfall
Irrigation	2,350	Includes large parcels and residential
Water Pipe Leaks into GW	4,350	
Sewer Pipe Leaks into GW	3,000	
Stream Infiltration into GW	2,350	12 streams evaluated
Bedrock Inflow	2,600	
Total	19,450	Annual Average for 1990 to 2015

Discharge Component	Amount (AFY)	Comments
Groundwater Pumping	3,150	Relatively consistent since 1990's
Subsurface Outflow	13,500	Flow towards SF Bay
Stream/Sewer Pipe Outflow	2,800	Residual of water balance
Total	19,450	Annual Average for 1990 to 2015

Responses:

1. Sewer pipe outflow is included with stream discharge as part of the residual of the water balance.
2. EBMUD WWTP data were reviewed but are not sufficiently detailed to distinguish the groundwater component. Additional review of this water balance component will be conducted as part of future model refinement efforts.

Model Development TAC Review - Borehole Data Kv Averaging

TAC member suggested using Harmonic Mean to average borehole data for Vertical Hydraulic Conductivity (Kv)

<u>Additional conducted analysis of data from borehole logs as suggested</u>

- Previously used arithmetic and geometric means
- Conducted additional analyses using harmonic mean for Kv
  - Kv values calculated for each of the 12-layers and each aquifer interval (Shallow, Intermediate, and Deep)

Model Development TAC Review - Borehole Data Kv Averaging

Kv values calculated using the Harmonic Mean of estimated values for 5 ft intervals based on boring logs.

Harmonic Mean

$$K_v = \frac{d}{\sum_{i=1}^{n} d_i/K_i}$$

d is total thickness,
d_i is thickness of each interval (5 ft), and
K_i is the calculated Kv for each 5 ft interval

- The harmonic mean **more heavily weights low Kv values** in a **vertical stratigraphic sequence**.
- **Most appropriate** for a geologic setting with **continuous layers** (**Fig 1**); **less appropriate** for **heterogenous alluvial deposits** (**Fig 2**).
- Best use as a lower bookend for Kv values, and for qualitative assessment of geographic variation of Kv values.

Fig 1

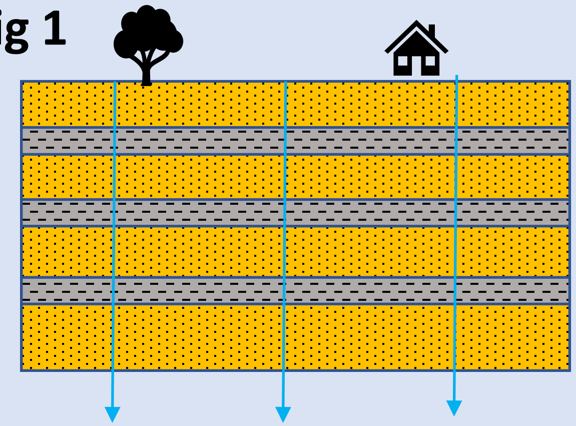
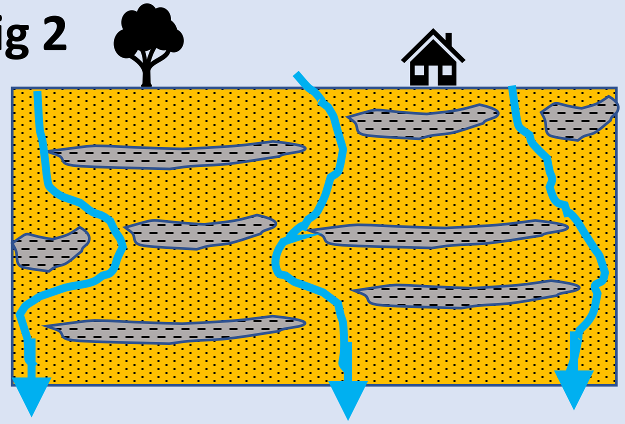
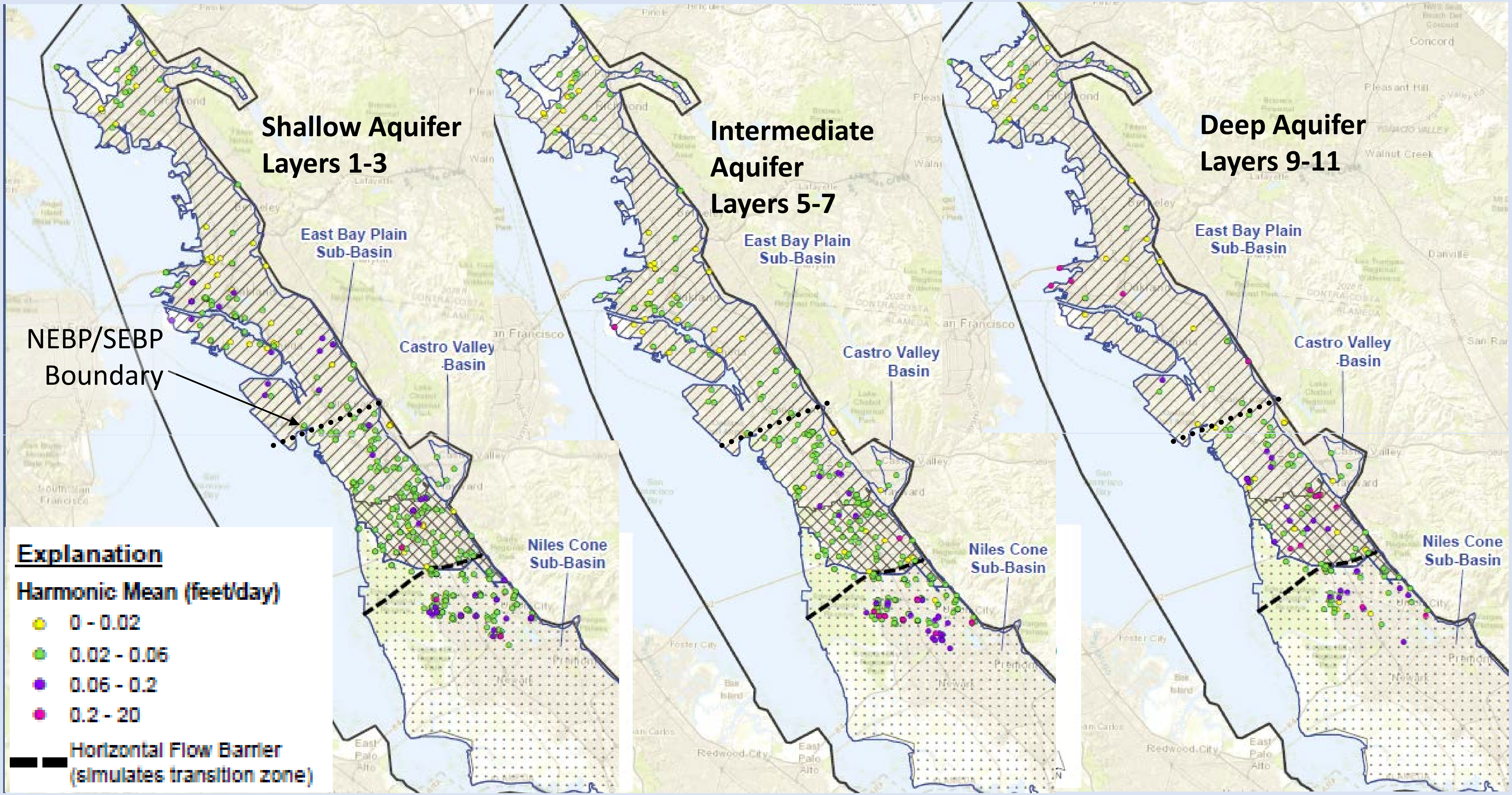


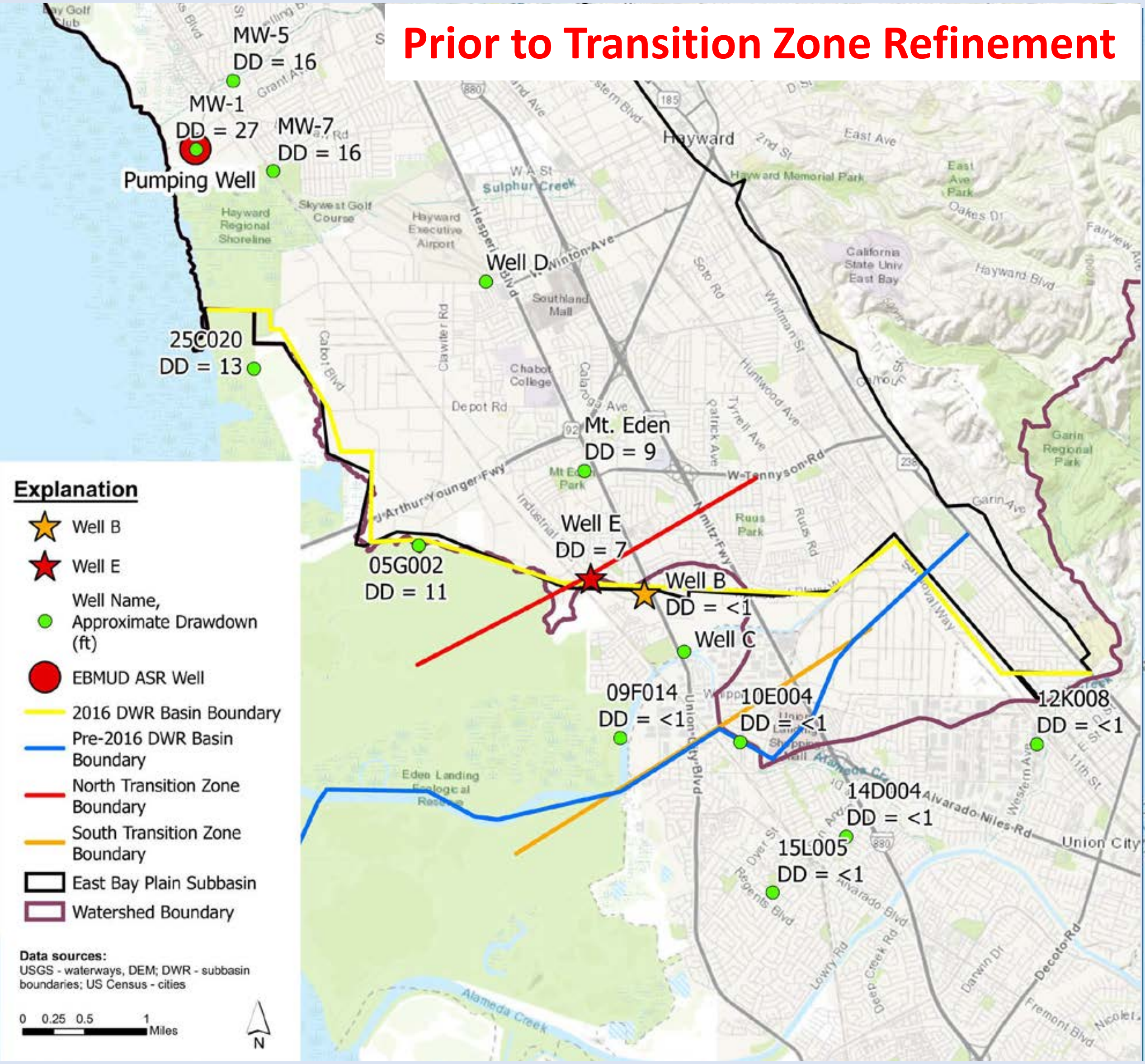
Fig 2

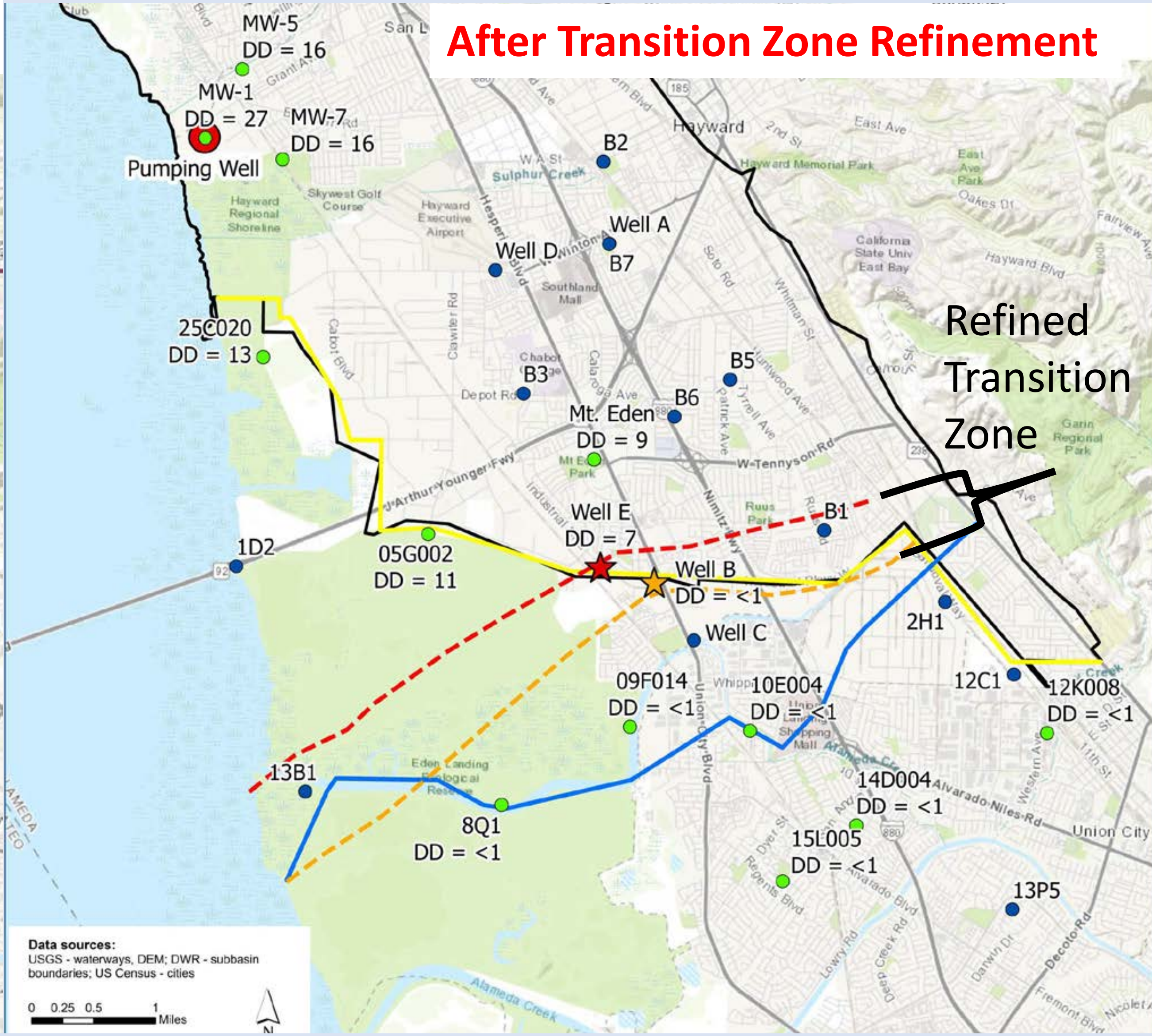


Model Development TAC Review - Borehole Data Kv Averaging



Subtask 4.2 TM - Transition Zone Refinement





Questions or Comments

TM 4.2 HCM and Previous TAC Meeting

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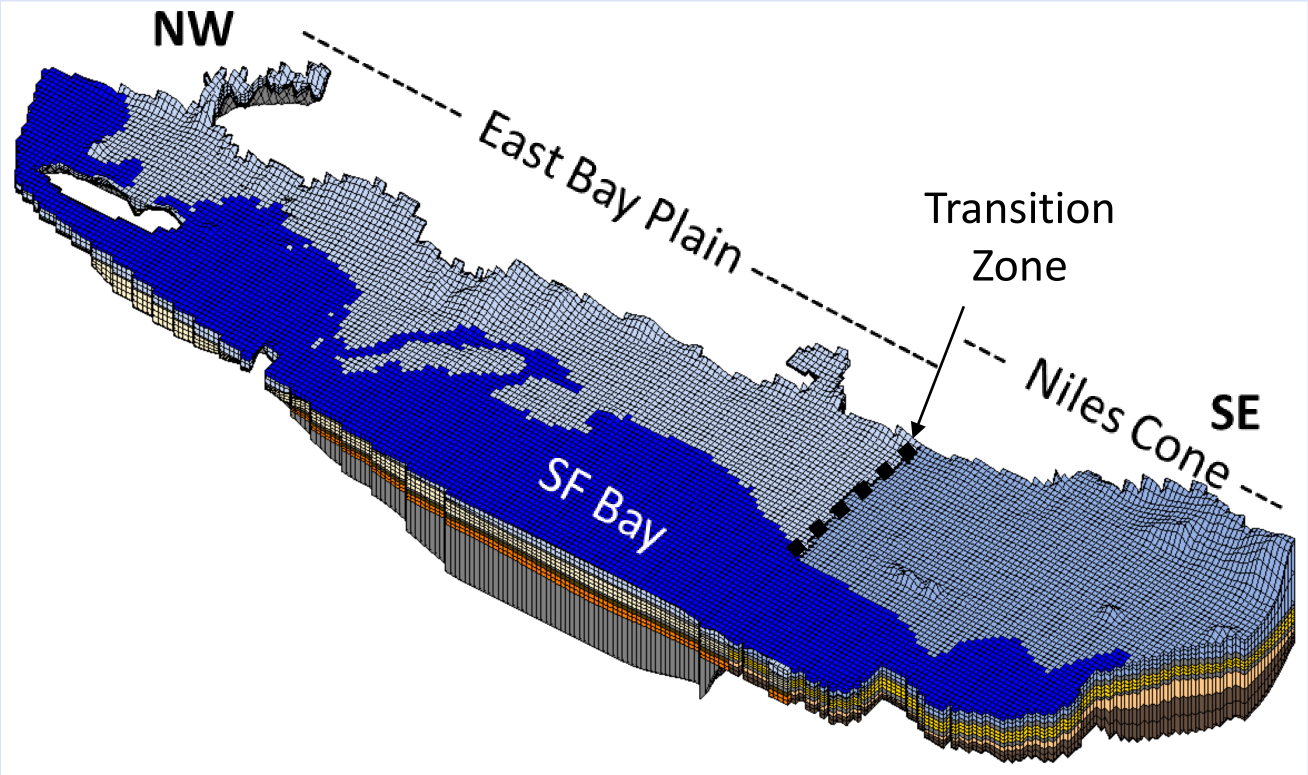
We welcome your questions and feedback.

Subtask 4.4 Progress Update

Groundwater Model Development and Calibration

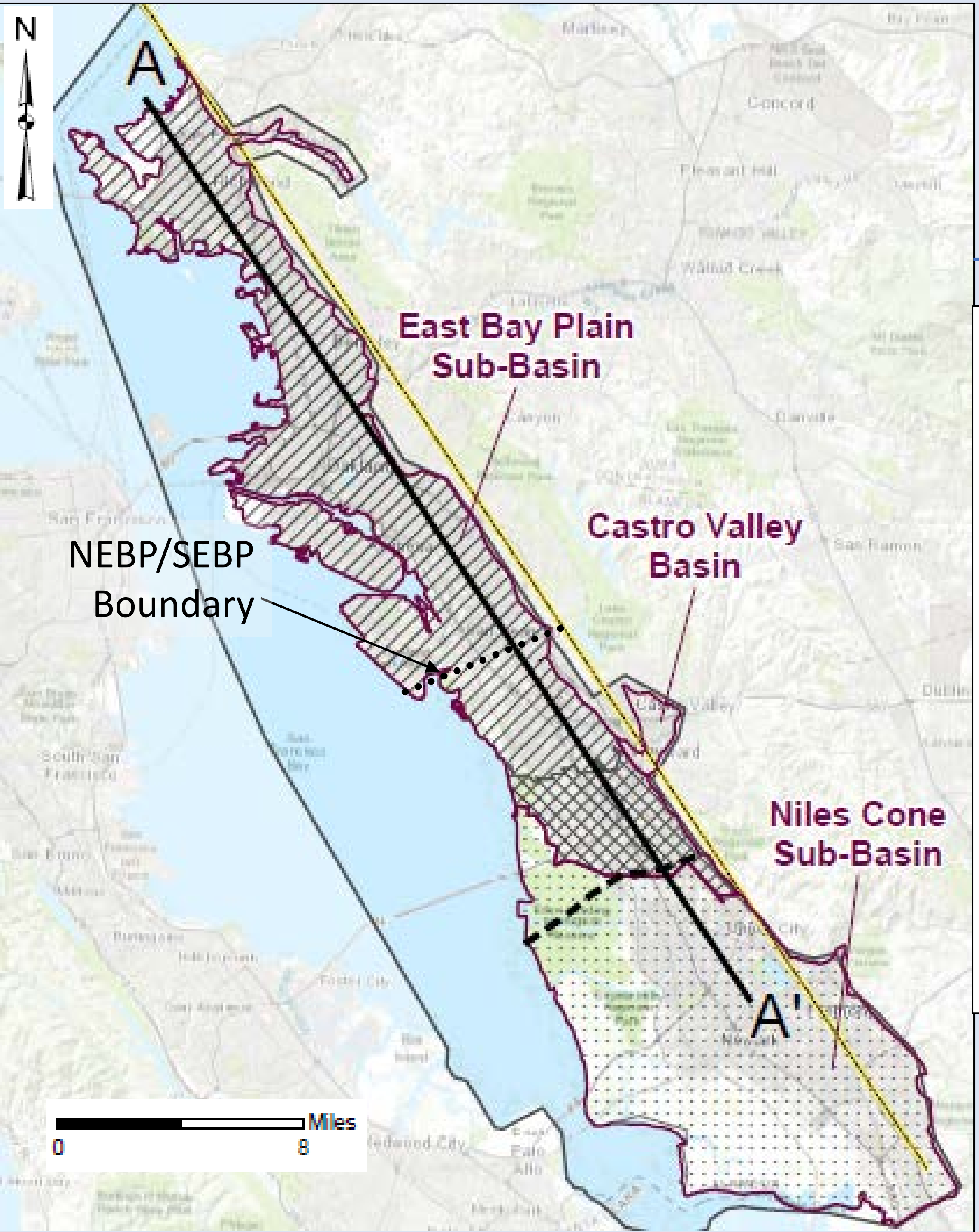
- Purpose of Groundwater Model
- Design Updates
- Calibration

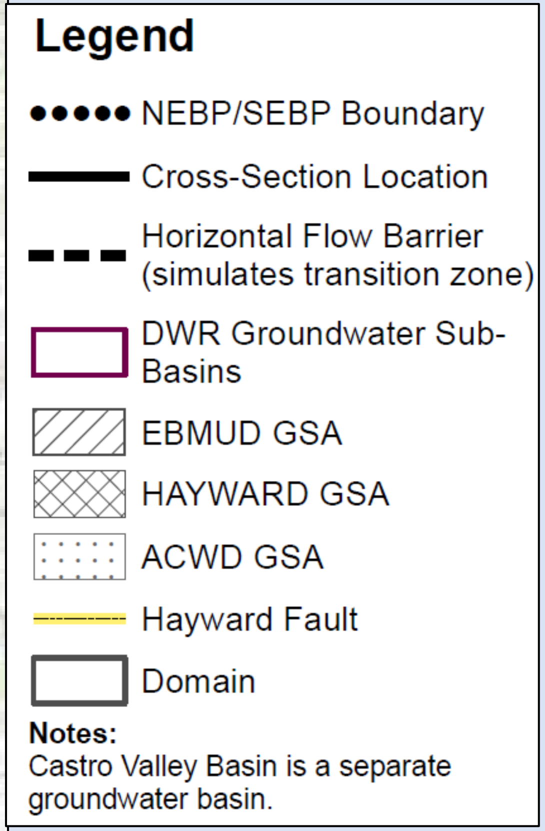


Purpose of the Groundwater Model

- Quantify water budget
  - Outflow to Bay
  - Recharge
  - Groundwater – Surface Water interaction
- Estimate sustainable yield
- Evaluate potential projects and management actions
- Develop monitoring criteria for sustainable management
  - Protect from **overdraft**
  - Protect **water quality** (e.g., saltwater intrusion)
  - Protect groundwater dependent **ecosystems**
  - Evaluate relationship with **adjacent sub-basins** and basins

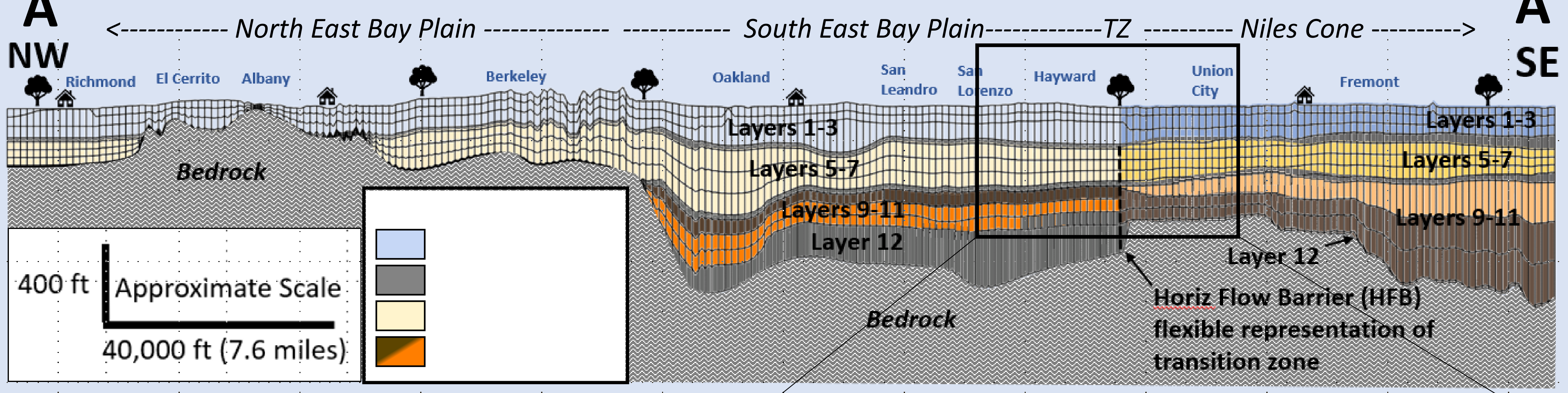
Updates to Model Domain and Layering



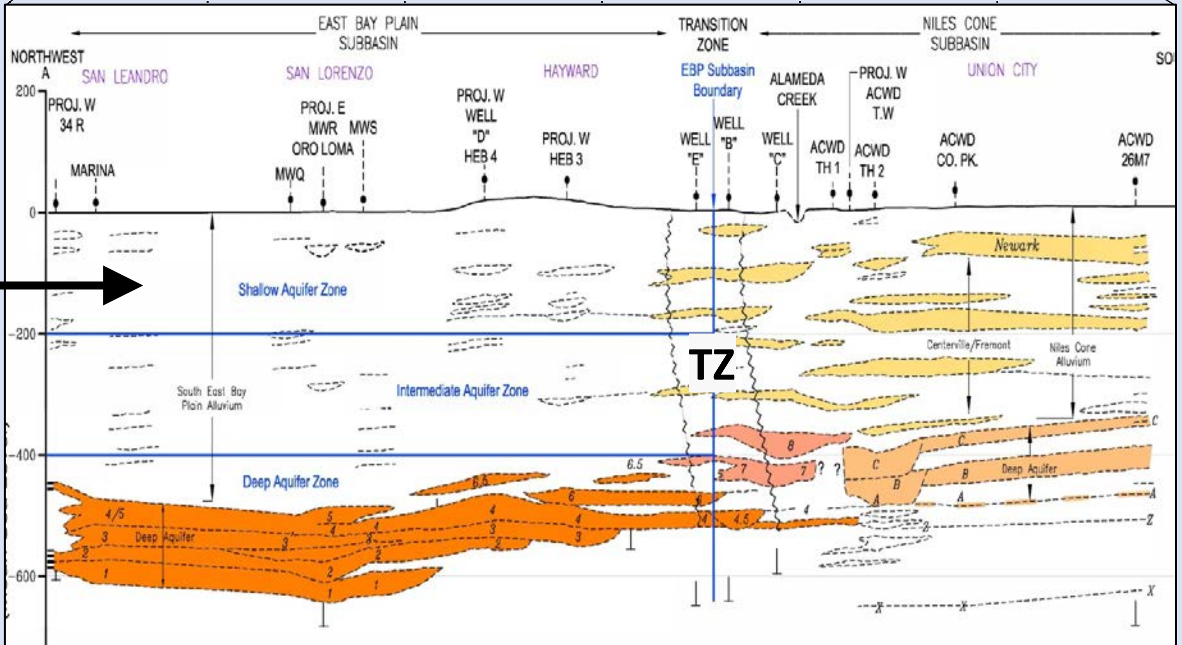


- 1000 by 1000 ft grid cells
- 12 Layers
- 10,930 cells per layer
- 131,160 cells total

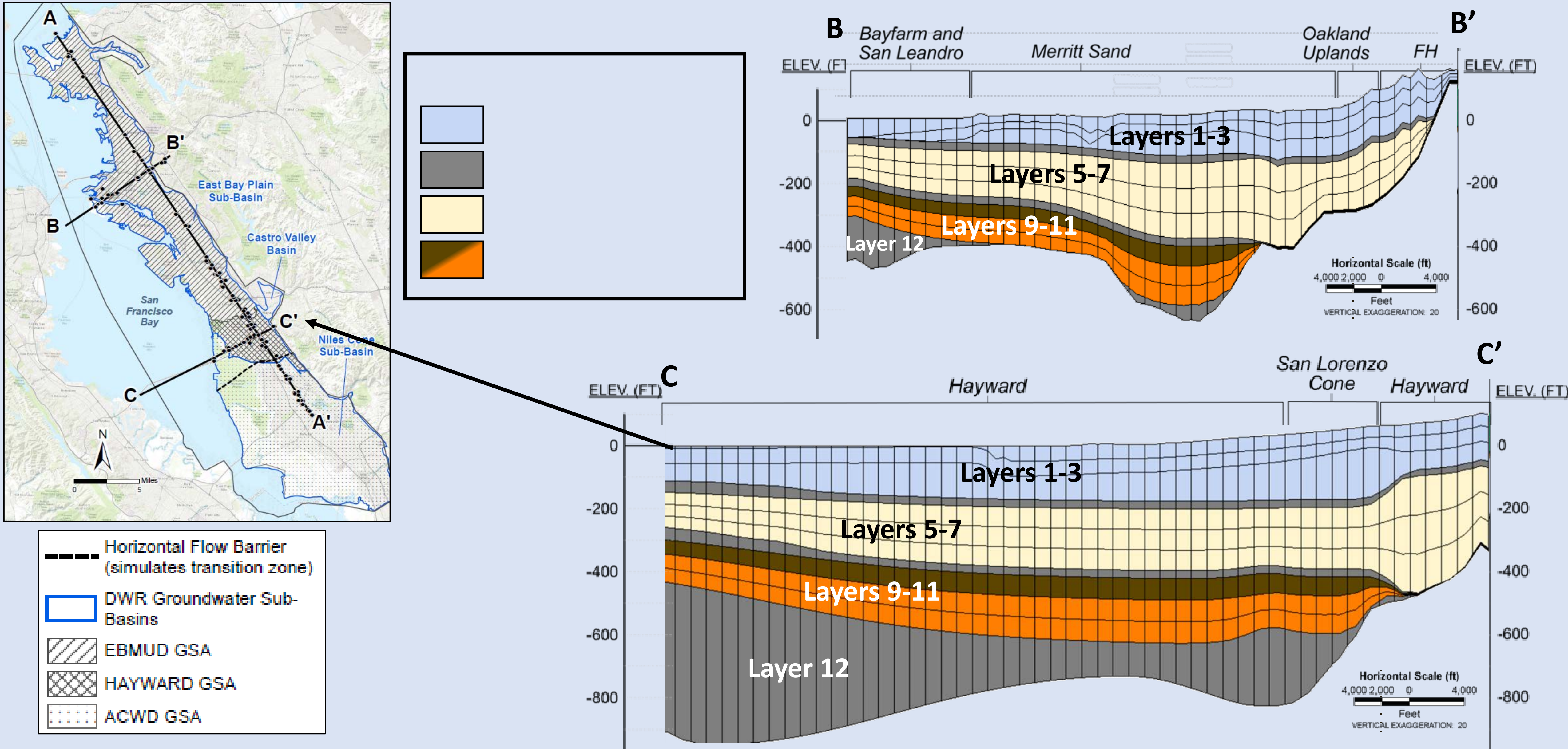
Cross-Section Slice Through the New 12-Layer Model



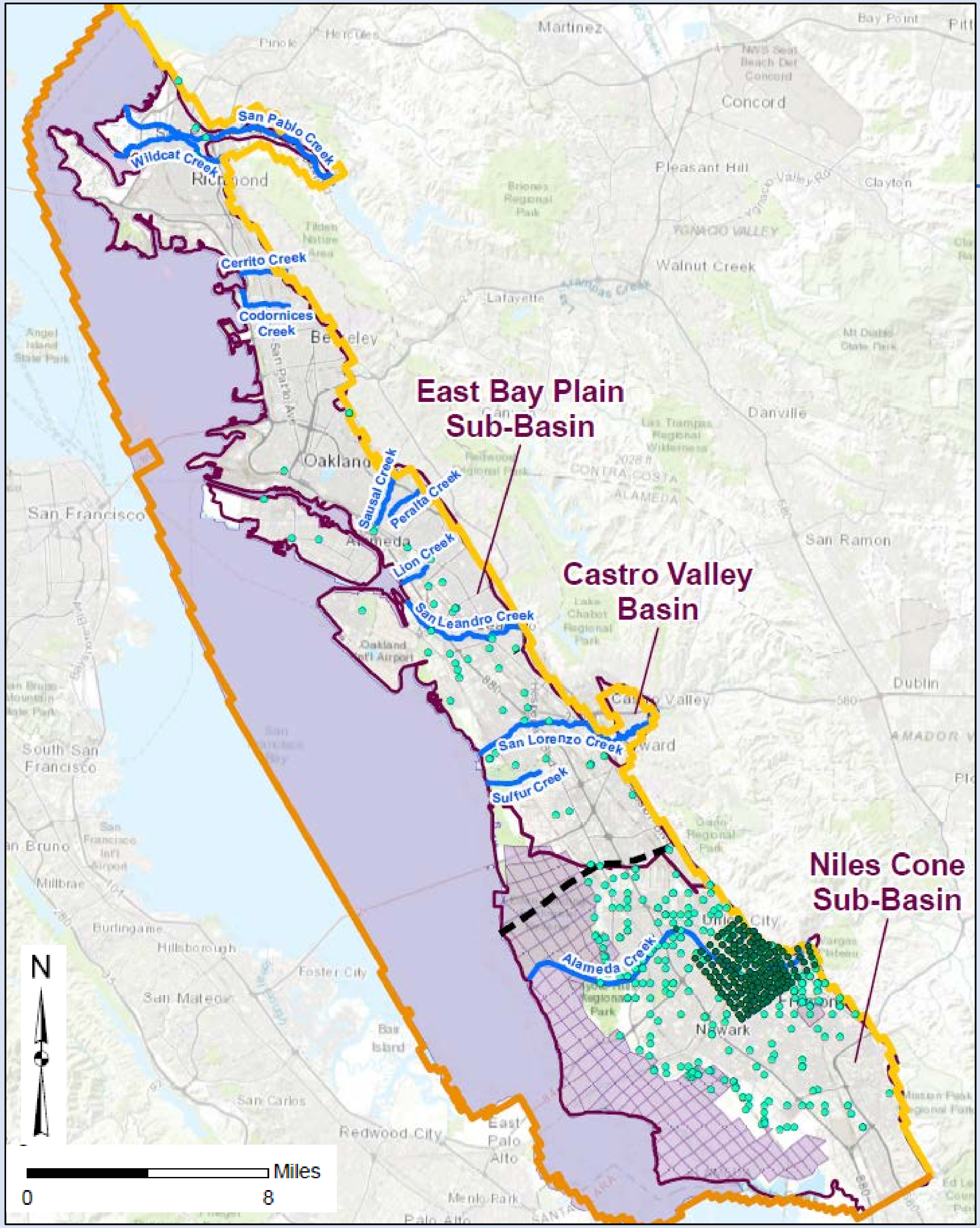
- **Three Aquifer Zones** (depth intervals)
- Transition zone (**TZ**) represented by a Horizontal Flow Barrier (**HFB**)
- The **location** and **conductance** of the HFB can be **varied**.
- The **geologic cross-section** (LSCE, HCM, Task 4.2, **2020**), here, includes updates to the previous version (**LSCE, 2003**).
- **Width of TZ** between NC and EBP **decreased** from >2 to ~1/2 mile.
- **Data constrain** the **width** of the **partial hydraulic barrier** between NC and EBP, locally to **<1000 ft**.



Updates to Model Domain and Layering



Boundary Conditions



Legend

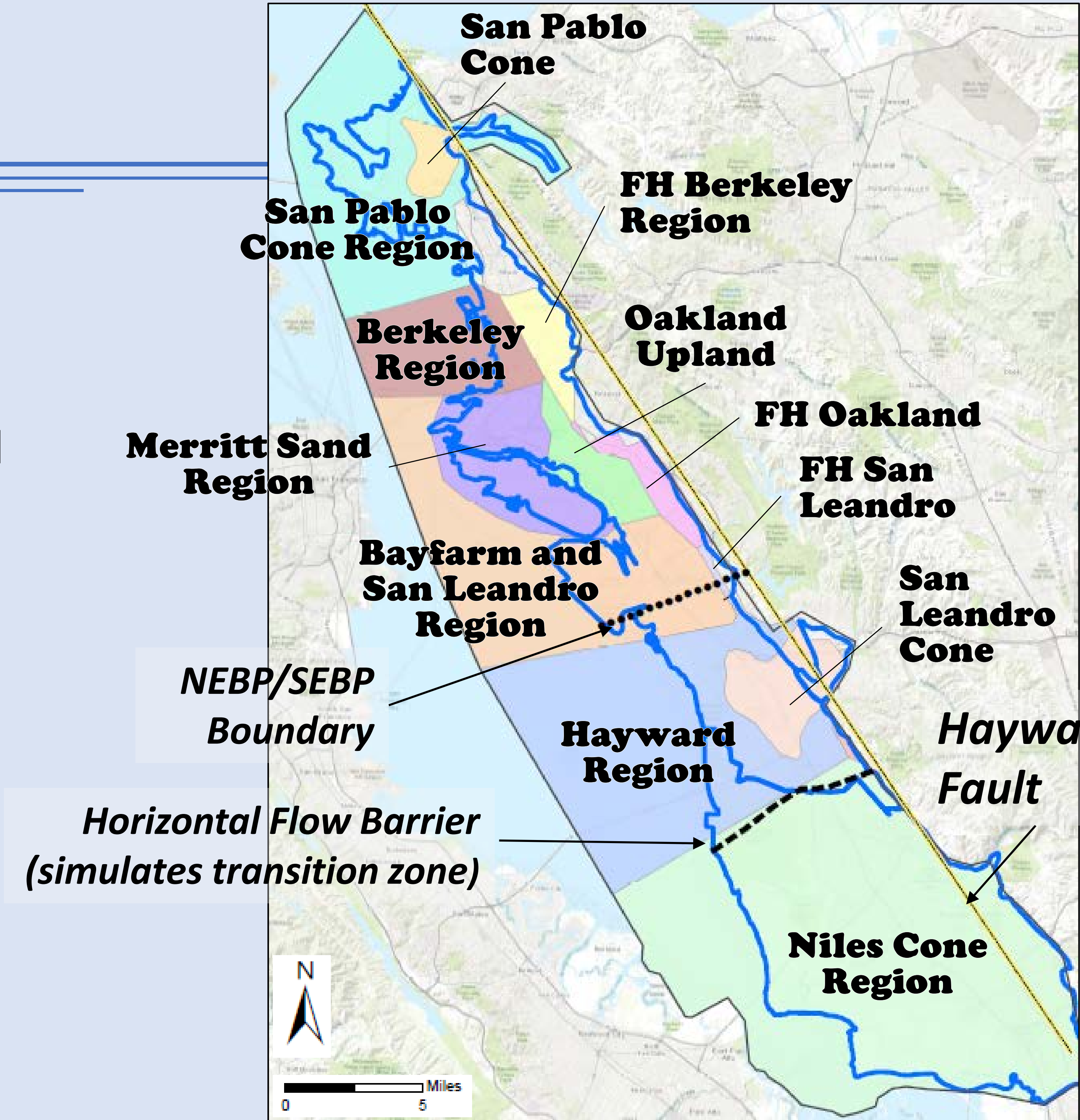
- Injection Wells*
- Production Wells**
- Eastern Margin Inflow
- No Flow Boundary
- Streams
- Horizontal Flow Barrier (simulates transition zone)
- General Head Boundary
- DWR Groundwater Sub-Basins

*Artificial recharge in Niles Cone was previously modeled as a patch of injection wells; this was retained since the GSP is for the EBP Subbasin.

** Includes production wells active (or partially active) during 1990 – 2015 period.

Geographic Areas

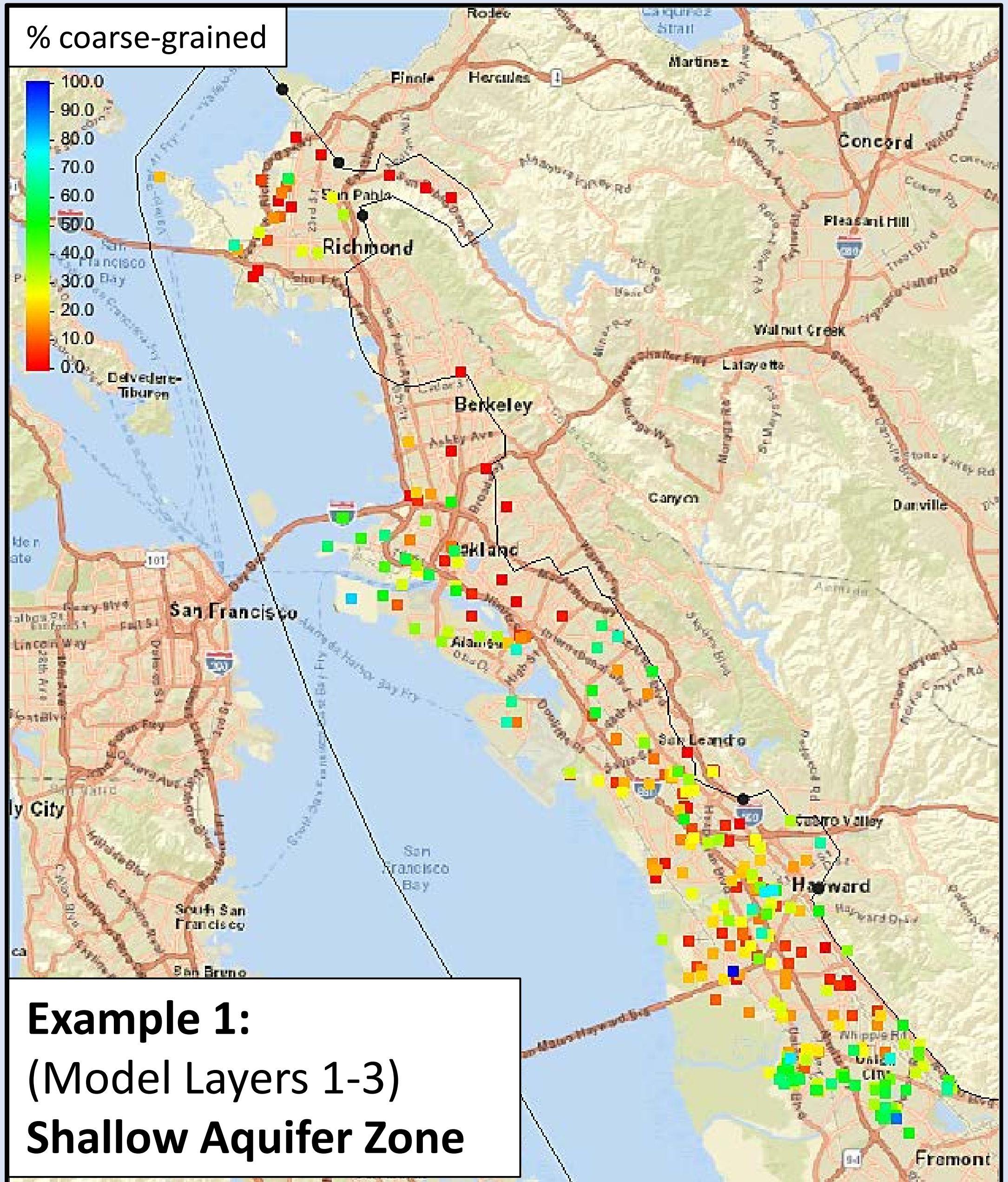
- Defined regional areas (zones) based on geography and hydrogeology
- Ranges of aquifer properties established for each zone for calibration

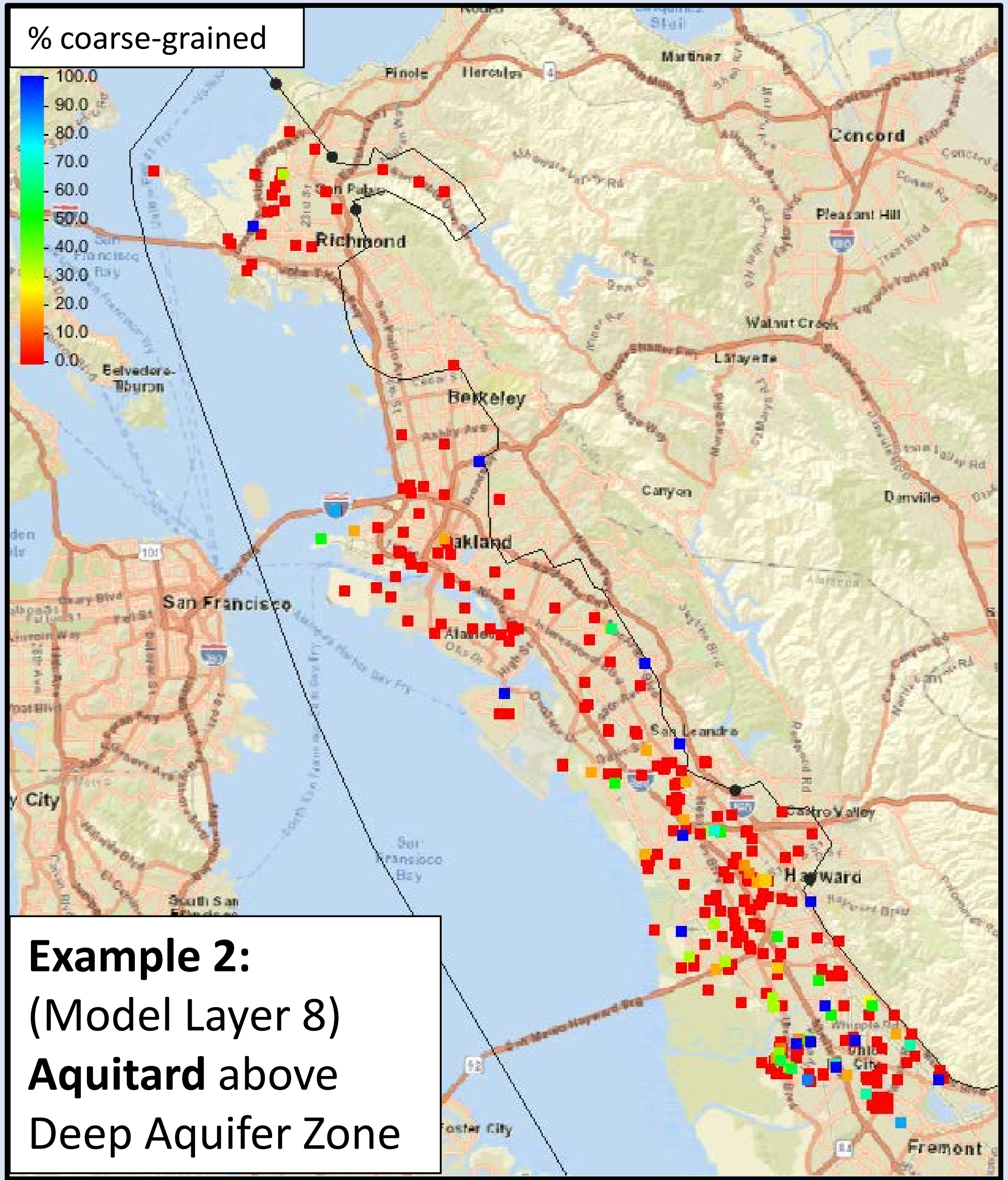


Initial Properties and Range for Calibration

- HCM (TM 4.2)
- NEBMODFLOW 2013 and existing models
- Geophysical logs
- Boring logs
  - compiled boring log info for 5-ft intervals
  - estimated soil textures (% coarse), and
    horizontal and vertical hydraulic conductivity (Kh and Kv)

Boring Log Data Compilation





Questions or Comments on *Groundwater Model Updates*

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We welcome your questions and feedback.

Groundwater Model Calibration Overview (slide 1 of 4)

Adjustment of model properties to obtain **acceptable match** between model-**predicted** and **observed** (“target”) **values** (e.g. GW elevations).

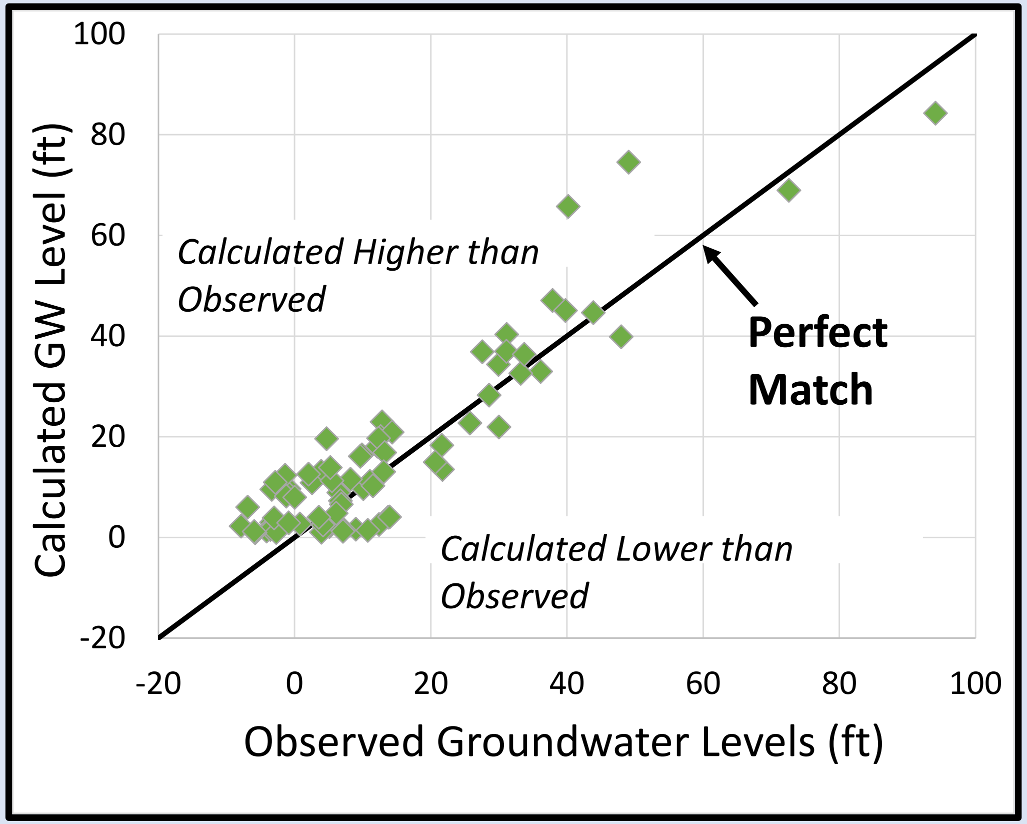
Both automated and by-hand **iterative adjustment** are common.

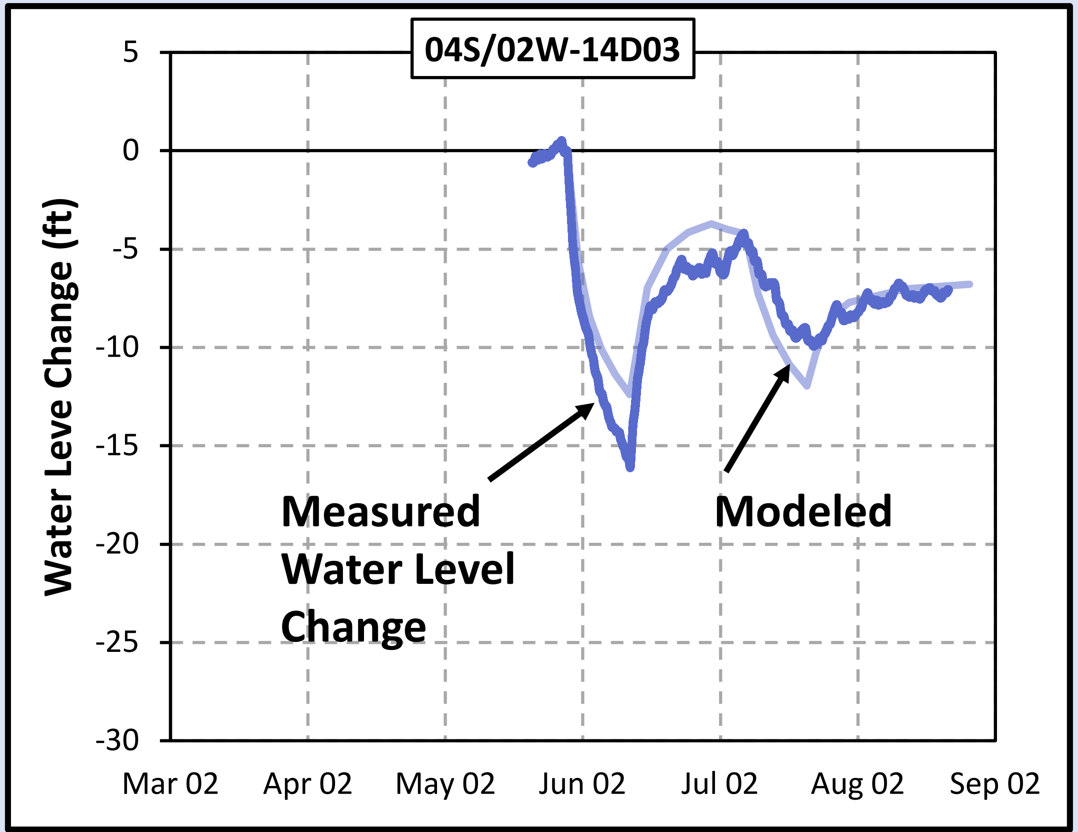
Data Type Examples	Examples of Sources of Target Values
Groundwater (GW) elevations (hydraulic head)	• GW level monitoring data
Change in GW levels	• Aquifer testing data • Aquifer storage estimates.
Hydraulic gradient distribution	Contour maps of GW elevation
Water balance *Flow in, Flow out, Change in Storage*	Compilation of measured and estimated inflow and outflow values: • pumping rates, • recharge, • rainfall, ET, • storage
GW flow rate (Travel Time)	Estimated hydraulic properties and GW level data
Water Quality	Chemical concentration data
Known relationships between data	• Pumping rates and drawdown in well. • Surface water (SW) levels and GW levels • SW flow rates and GW levels • Change in storage and pumping

Groundwater Model Calibration Overview (slide 2 of 4)

Graphical illustrations of calibration include

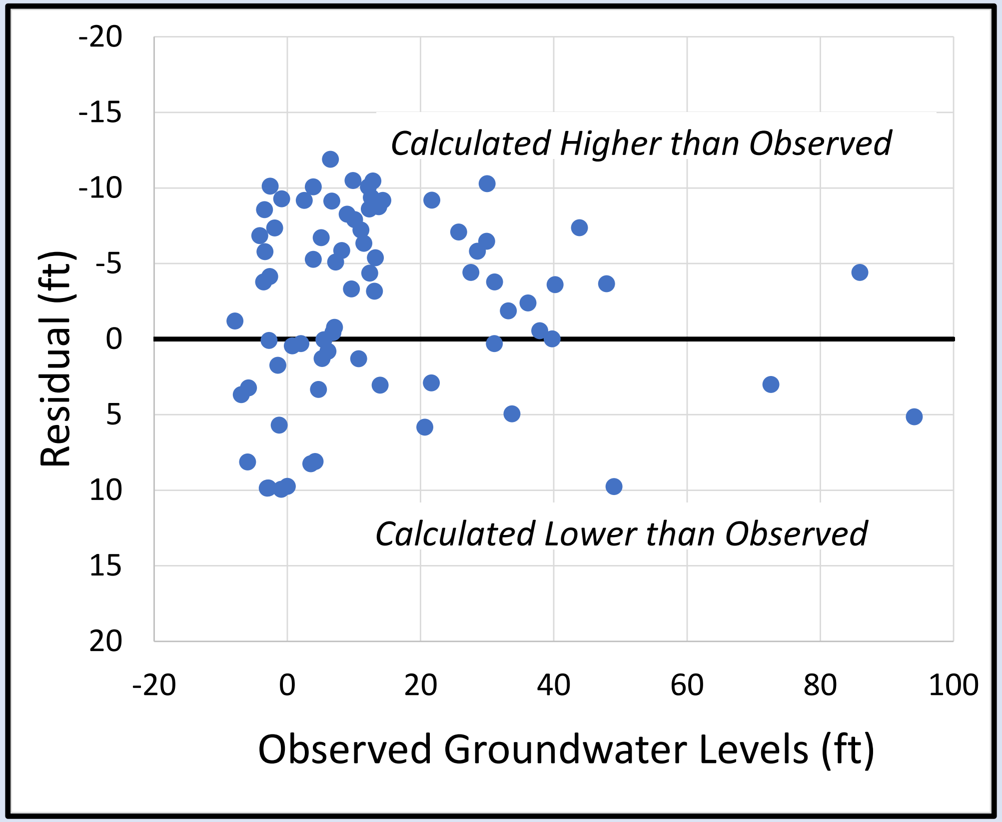
- Comparisons observed (actual) and modeled (calculated) values:
  - Scatter plots
  - Hydrographs (variation with time of groundwater elevations)

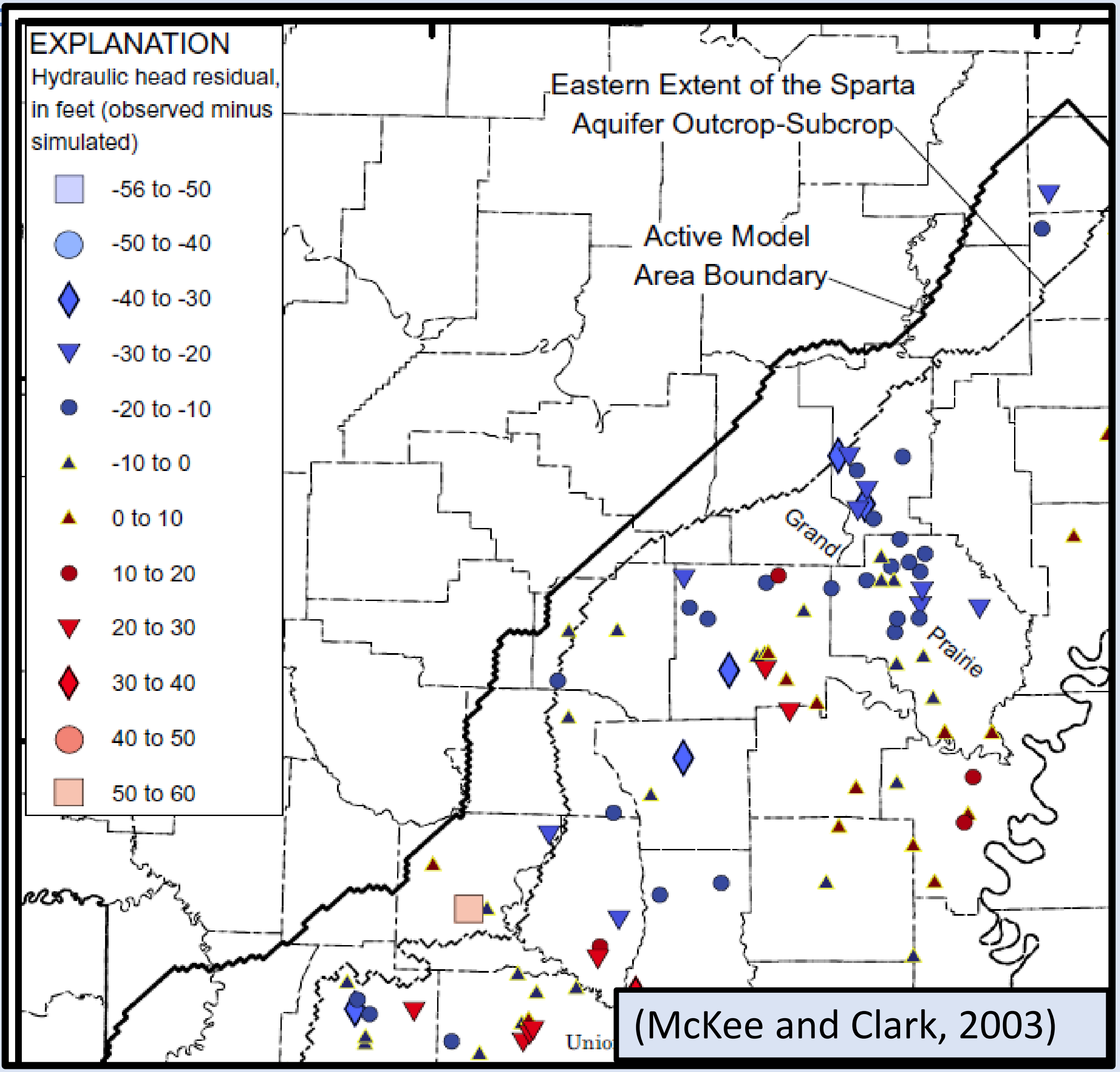




Groundwater Model Calibration Overview (slide 3 of 4)

- Plots to evaluate residuals (errors)
  - Scatter plots
  - Plots of observed values vs residuals
  - Maps of distribution of residuals
  - Graphs of residual statistics with time



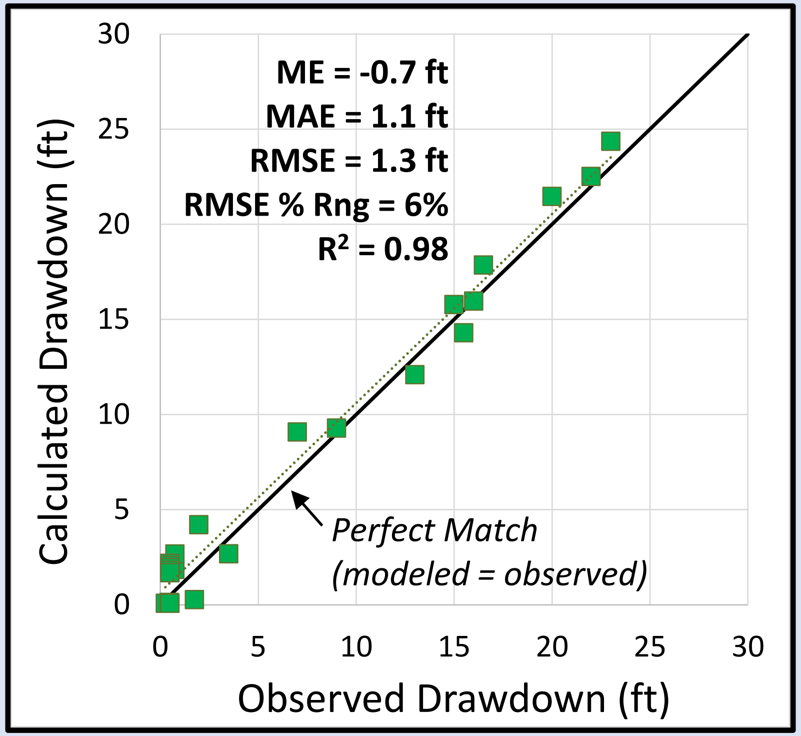


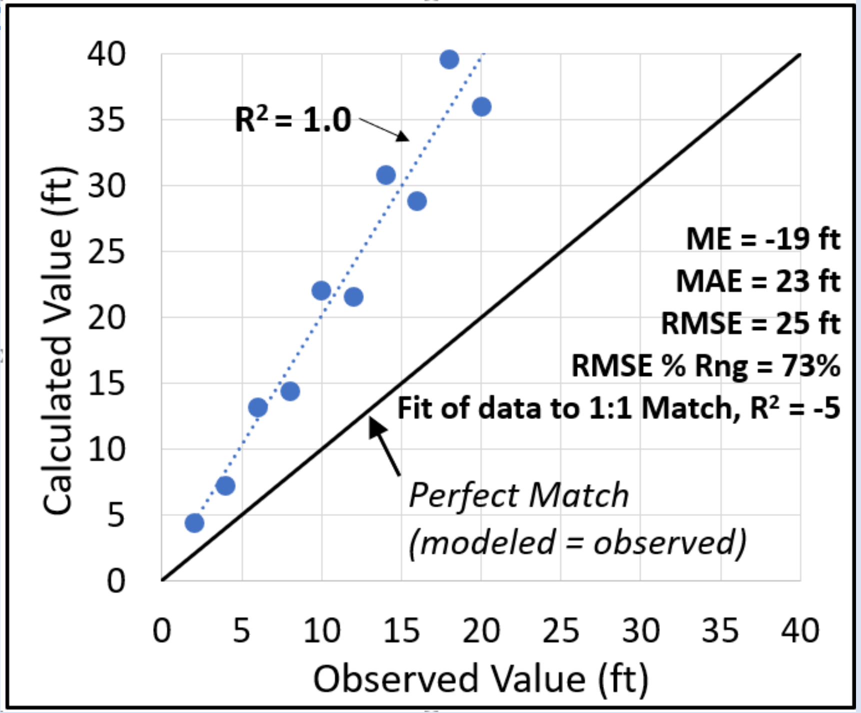
(McKee and Clark, 2003)

Groundwater Model Calibration Overview (slide 4 of 4)

Statistics to quantify residuals

- mean error (ME)
- mean absolute error (MAE)
- root mean standard error (RMSE)
- RMSE as percent of range of observed data*
- Coefficient of determination (R^2)





R^2 for the fit of the dashed line to the data is not the same as the R^2 value for the fit of the data to a perfect match for calculated and observed values.

RMSE is a more commonly used statistic for comparison between observed and modeled values.

$$RMSE = \sqrt{\frac{1}{N}\sum_{t=1}^{N}(observed_t - predicted_t)^2}$$

Calibration Guidance for GSPs (Modeling BMP, DWR 2016)

- Calibration **scatter plots** comparing observed and modeled groundwater levels for each aquifer.
- **Maps** of calibrations **residuals** in each hydrostratigraphic unit.
- **R^2 value > 0.9** indicates an **excellent match** match of obs & calc values
- **“No model is perfectly calibrated”**
- “Establishing desired calibration accuracy a priori is difficult.”
- “**If a more accurate model does not change the decision a GSA would make, then additional calibration is not necessary**.”

*For example, **reliability** of estimated **sustainable yield** of the EBP for the Hayward and EBMUD GSAs*

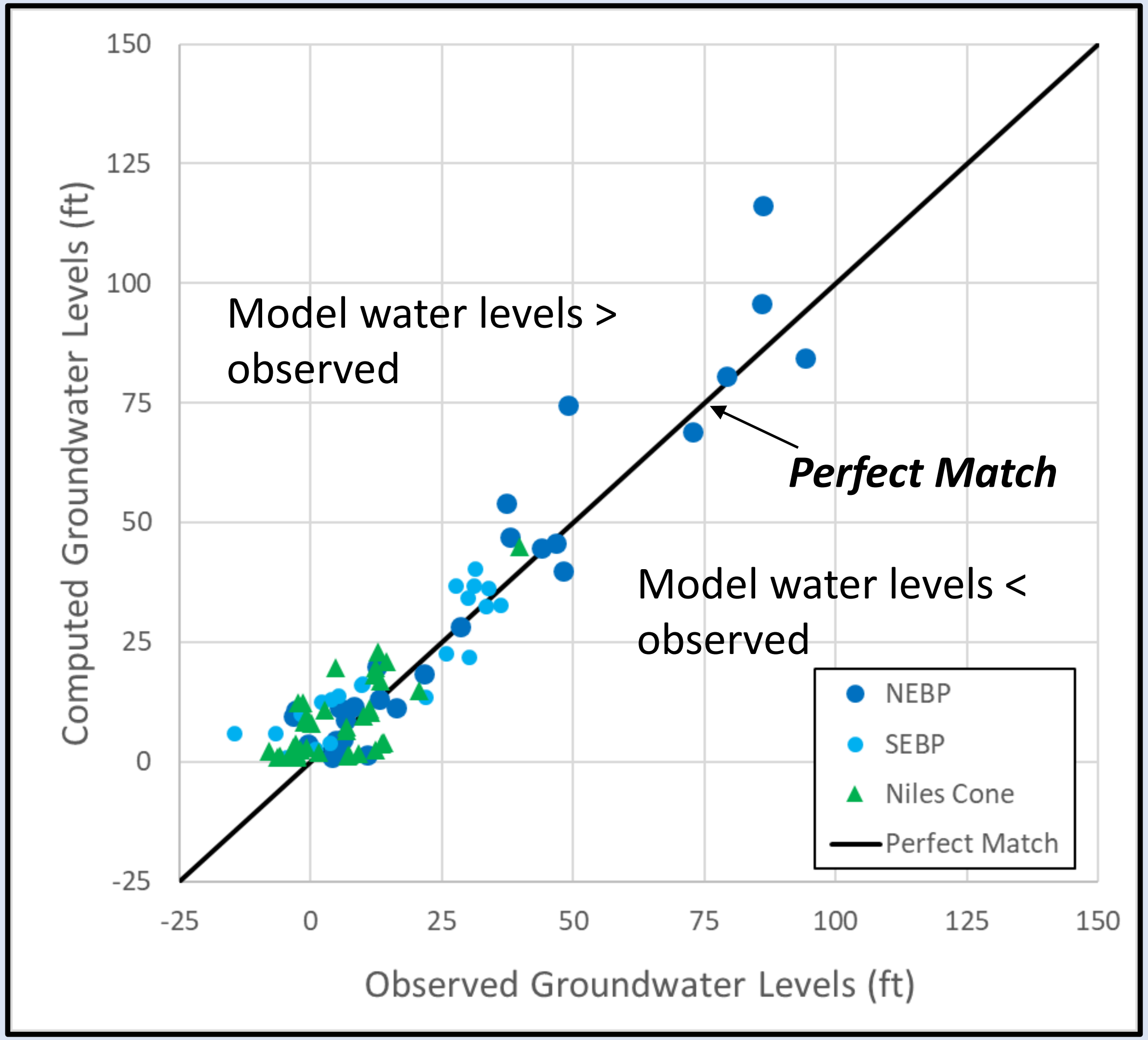
Properties Adjusted for Model Calibration

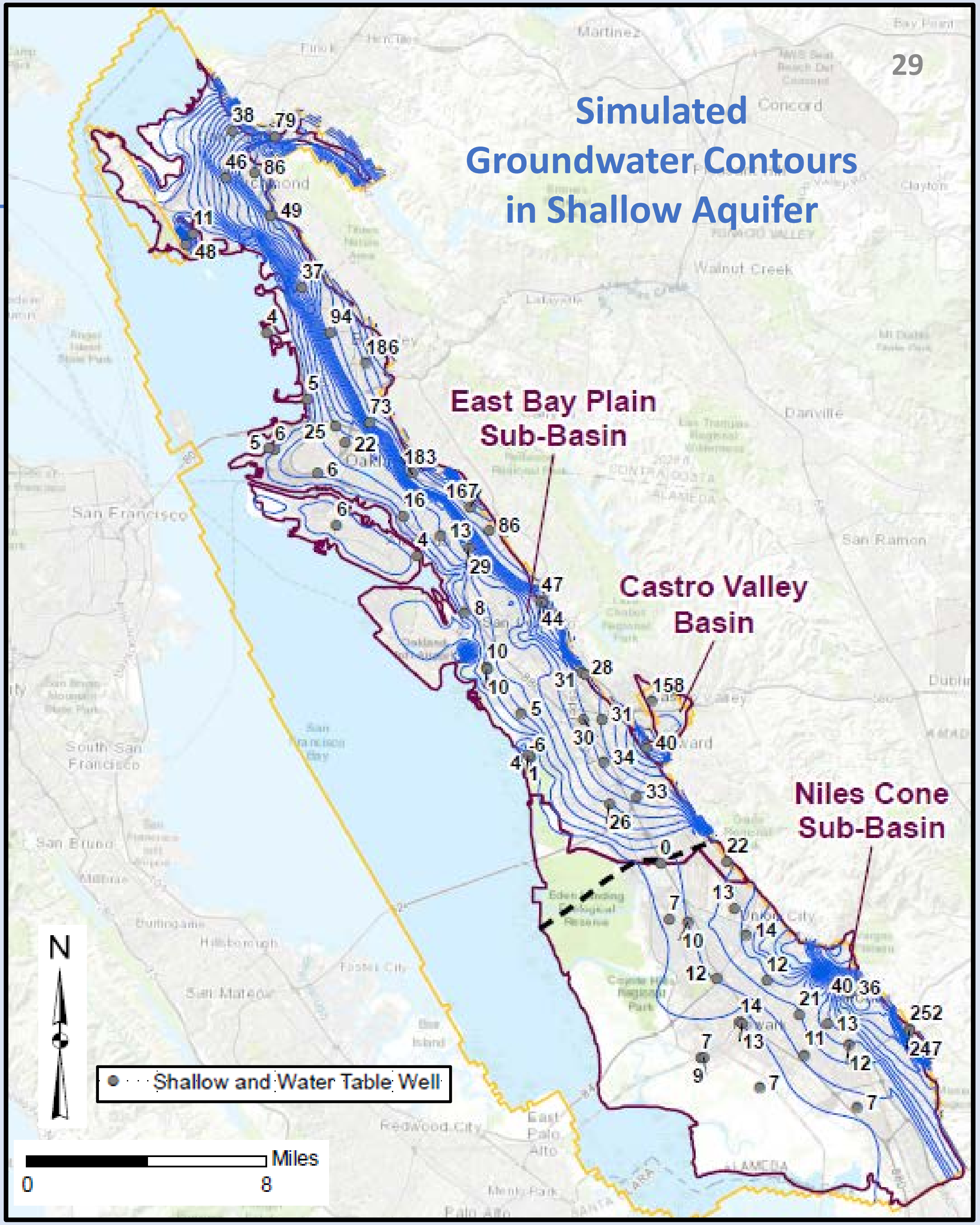
- Horizontal and vertical hydraulic conductivity (**Kh and Kv**) in model layers and subareas.
- Recharge
- **Inflow** from bedrock in East Bay Hills
- Hydraulic **conductance** of **SF Bay floor** and **stream beds**
- Hydraulic **conductance** of **partial hydraulic barrier** between the **Niles Cone** (ACWD & Hayward) and **East Bay Plain** (Hayward & EBMUD)
- **Storage** coefficients

The Model Calibration Process

	Name	Calibration Dataset	Purpose
1	Steady State **Average Baseline** Conditions	Average water levels (2000 -2015) at **90 wells**	Calibration to **recent average conditions**
2	**Historical Transient** Model	Water levels at **90 wells** (1990 – 2015)	Calibration to **historical data** set in accordance with **SGMA guidelines**
3	Bayside Well **8-week** Aquifer Pumping Test	Water level fluctuations at **26 wells** in response to **8-week** pumping **test**	Calibration of properties most relevant to **production potential** in south portion of EBP, and **hydraulic communication** between **NC and EBP**
4	**Hayward Wells C and E** Aquifer Pumping Tests	Water level fluctuations at **18 wells** in response to **two 2-week** pumping **tests**	**Validation** and **refinement of calibration** in vicinity of **transition zone** between **NC and EBP**

1. Steady State Calibration
Average Conditions (2000-2015)



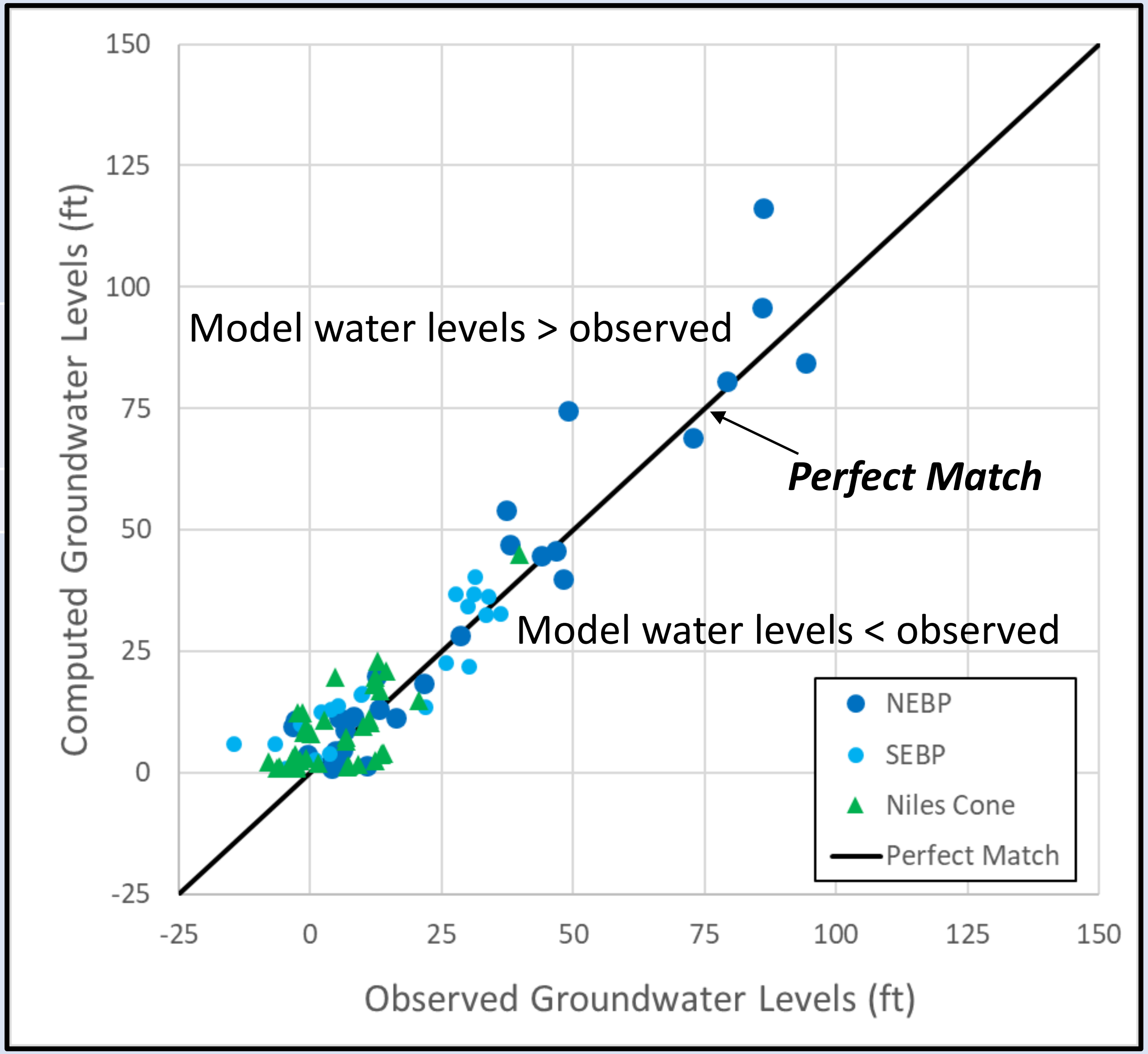


1. Steady State Calibration
Average Conditions (2000-2015)

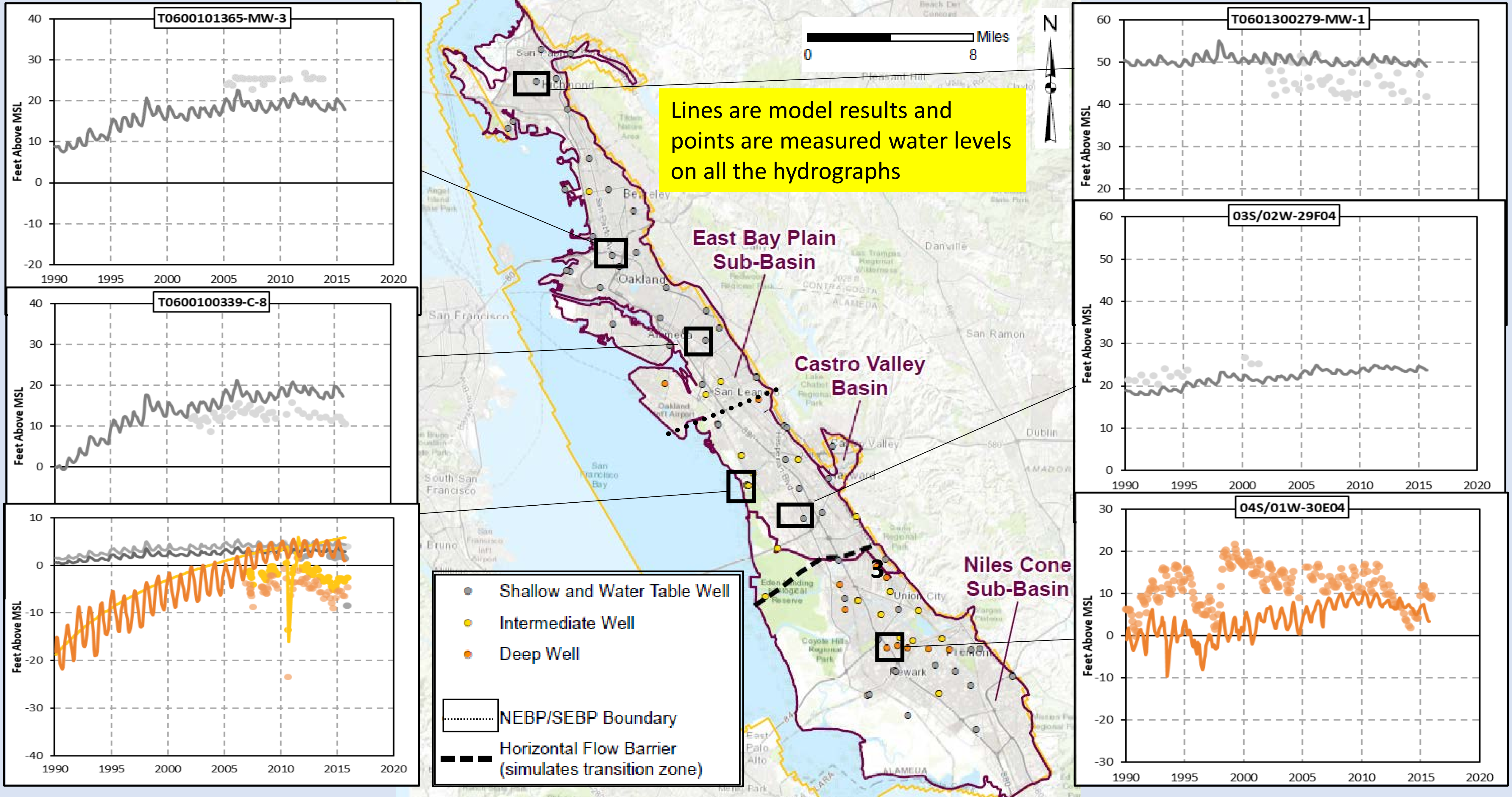
Calibration Statistics

Number of Obs	Range of Obs (ft)	ME (ft) (mean error)	MAE (ft) (mean abs error)	RMSE (ft)	RMSE (% Range)	R^2
90	109	-3.8	7.0	9.0	8%	0.86

N = number of values (observed and calculated)
Obs = observed
ME = mean error
MAE = mean absolute error
RMSE = root mean standard error
RMSE % Range is the RMSE divided by the range of observed values
R^2 Coefficient of determination

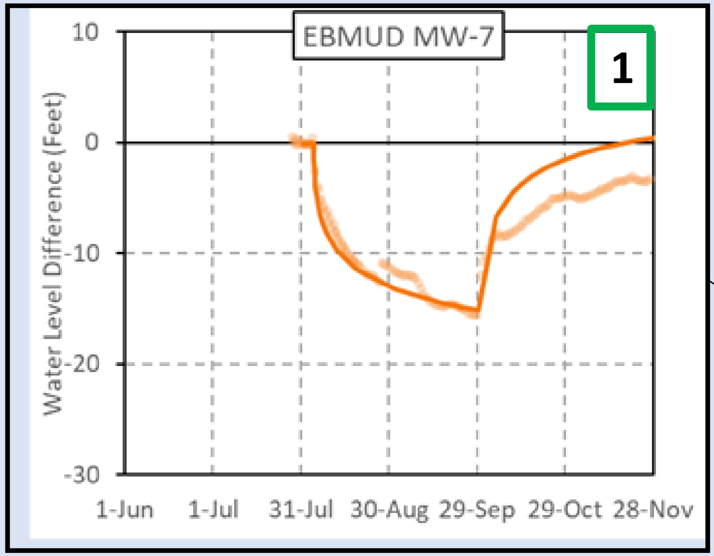


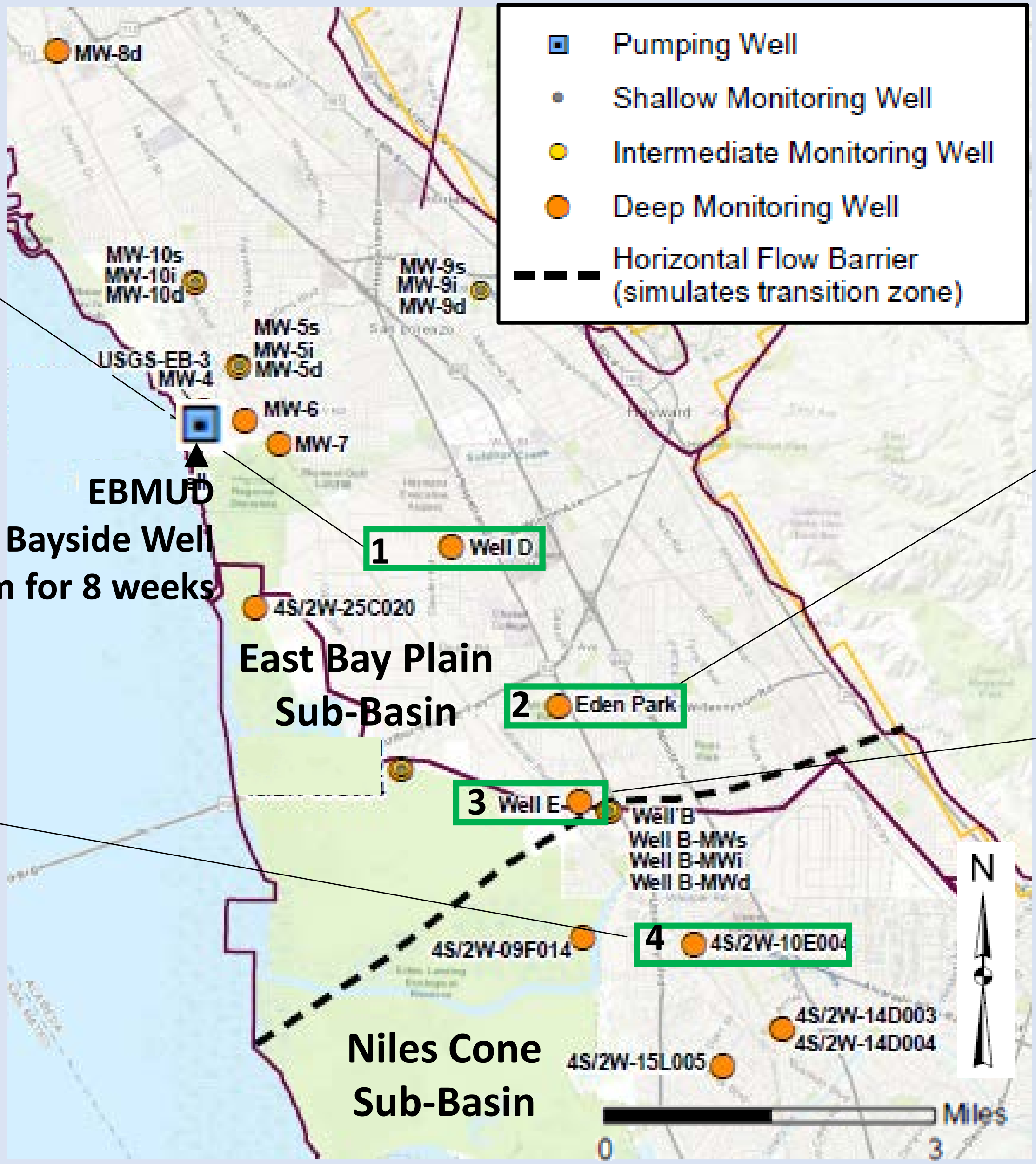
2. Calibration to 1990 – 2015 Groundwater Elevations

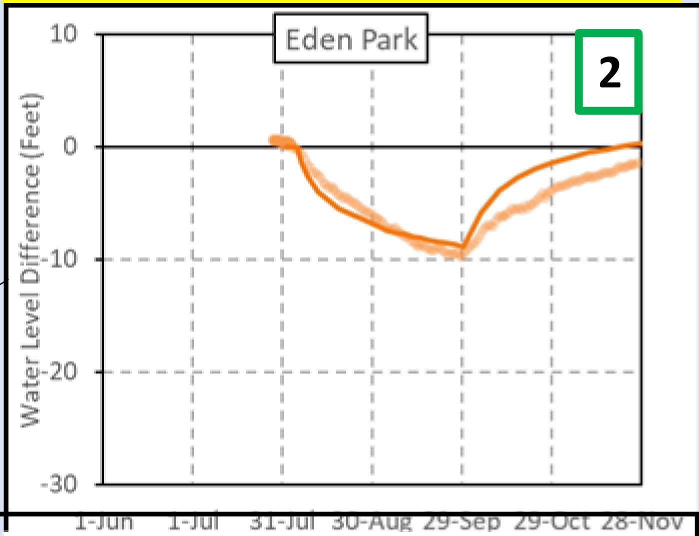


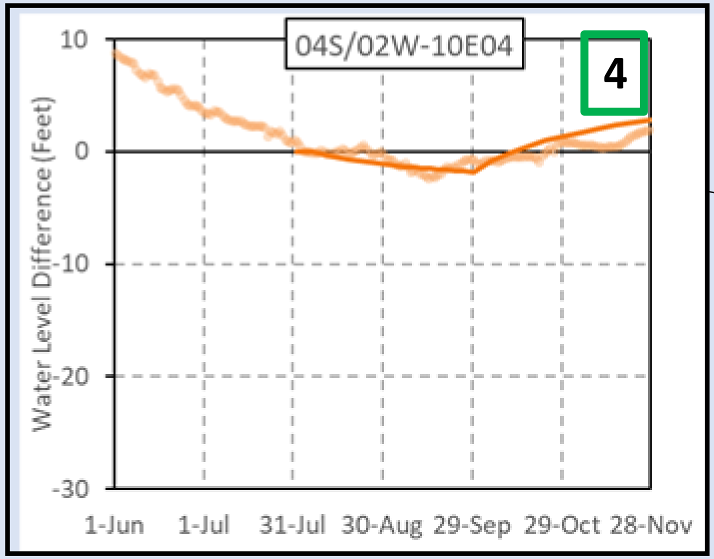
3. Calibration to 8-Week Bayside Well Aquifer Test (Slide 1 of 2)

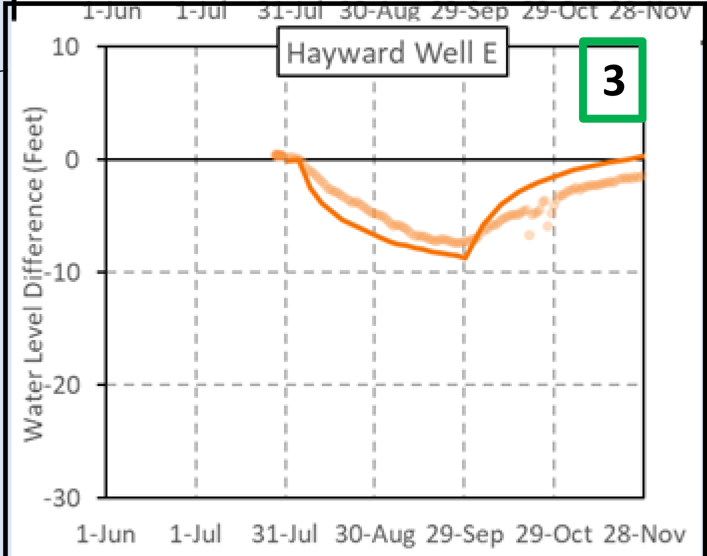
Dark lines are model results and paler points are the water levels recorded during the aquifer test on all the hydrographs



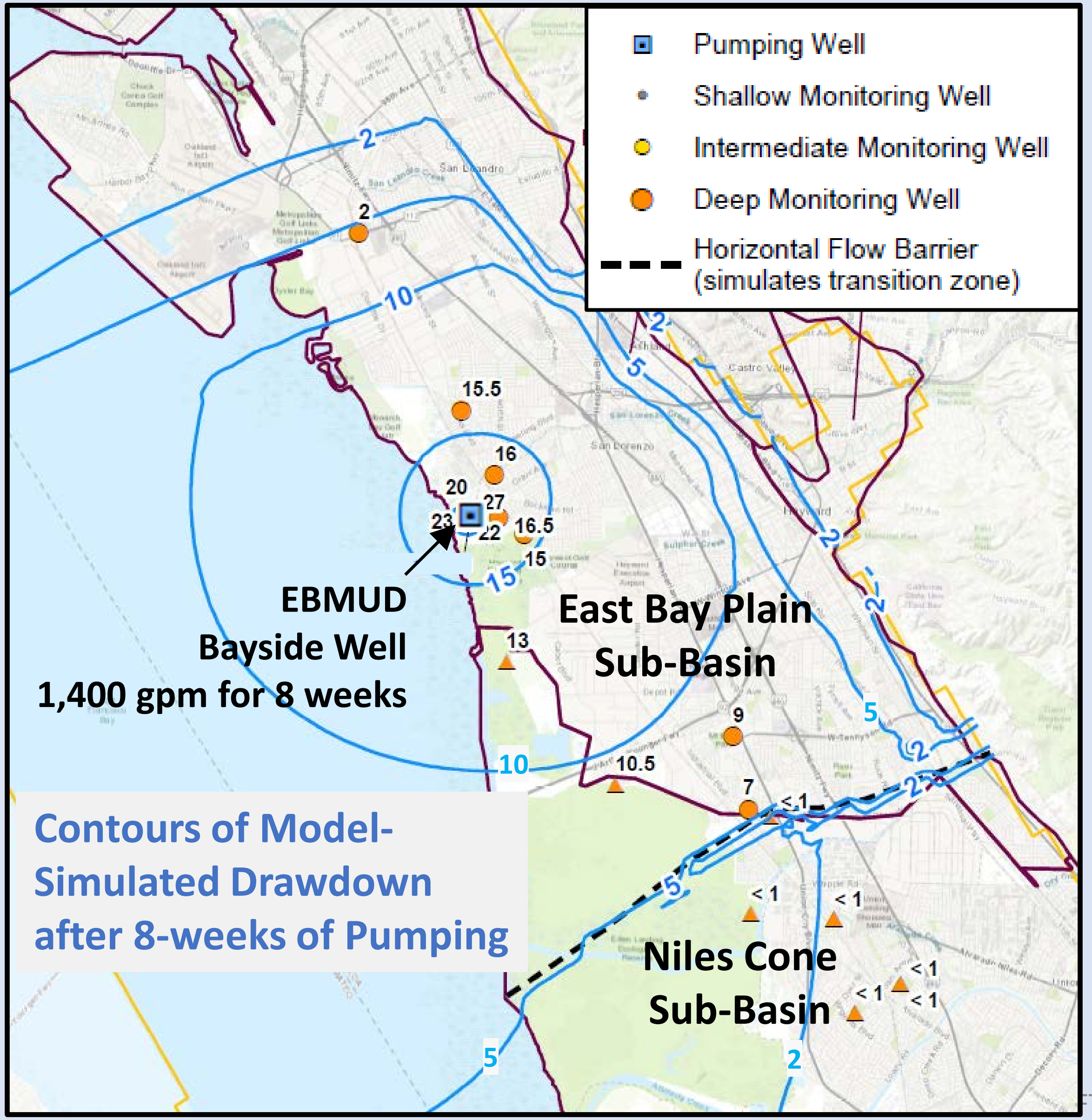


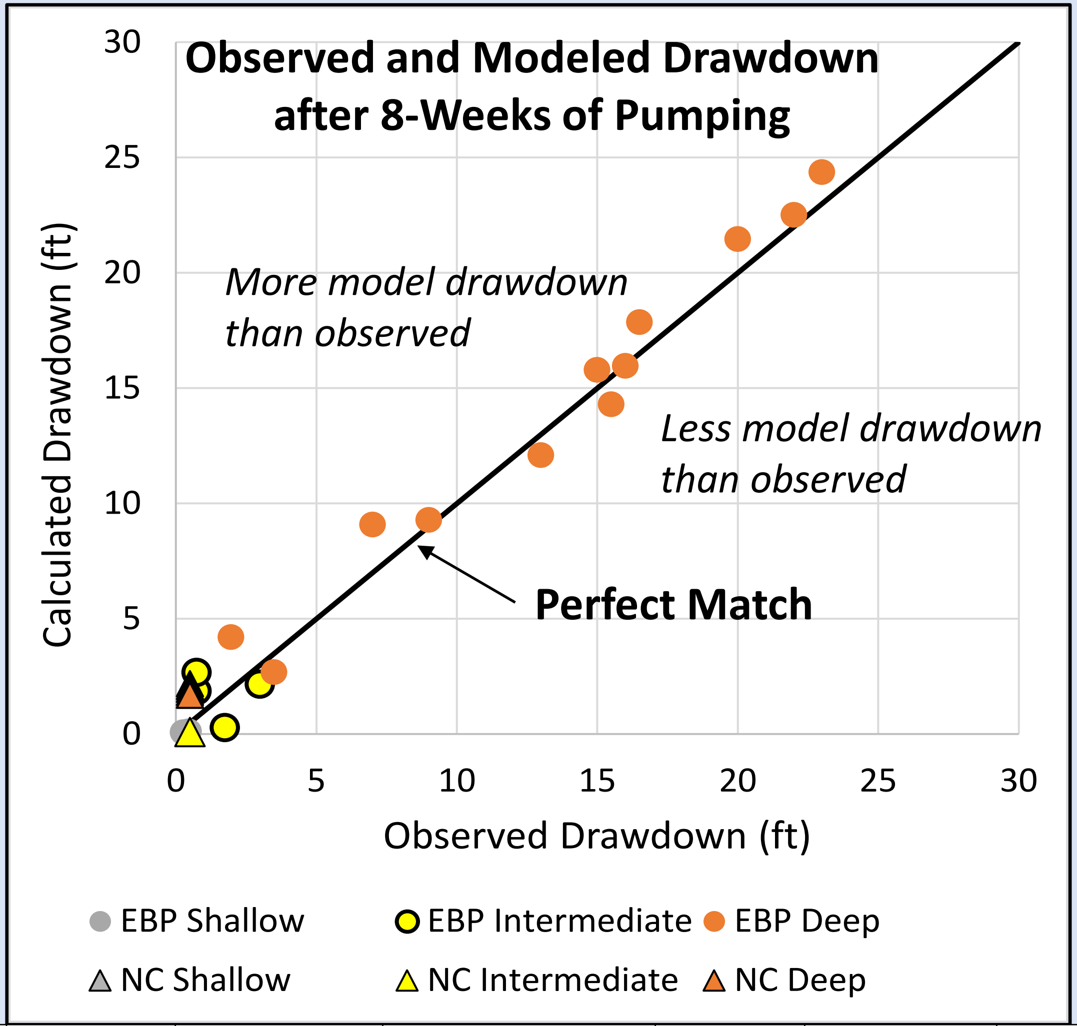






3. Calibration to 8-Week Bayside Well Aquifer Test (Slide 2 of 2)



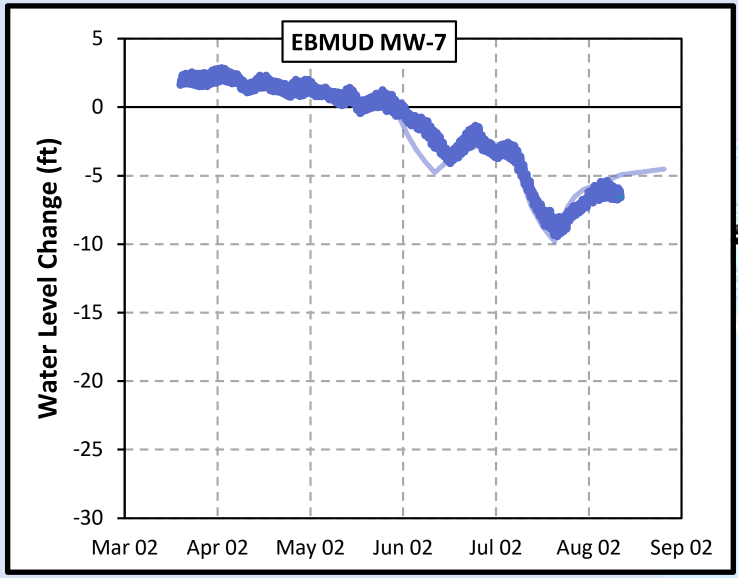


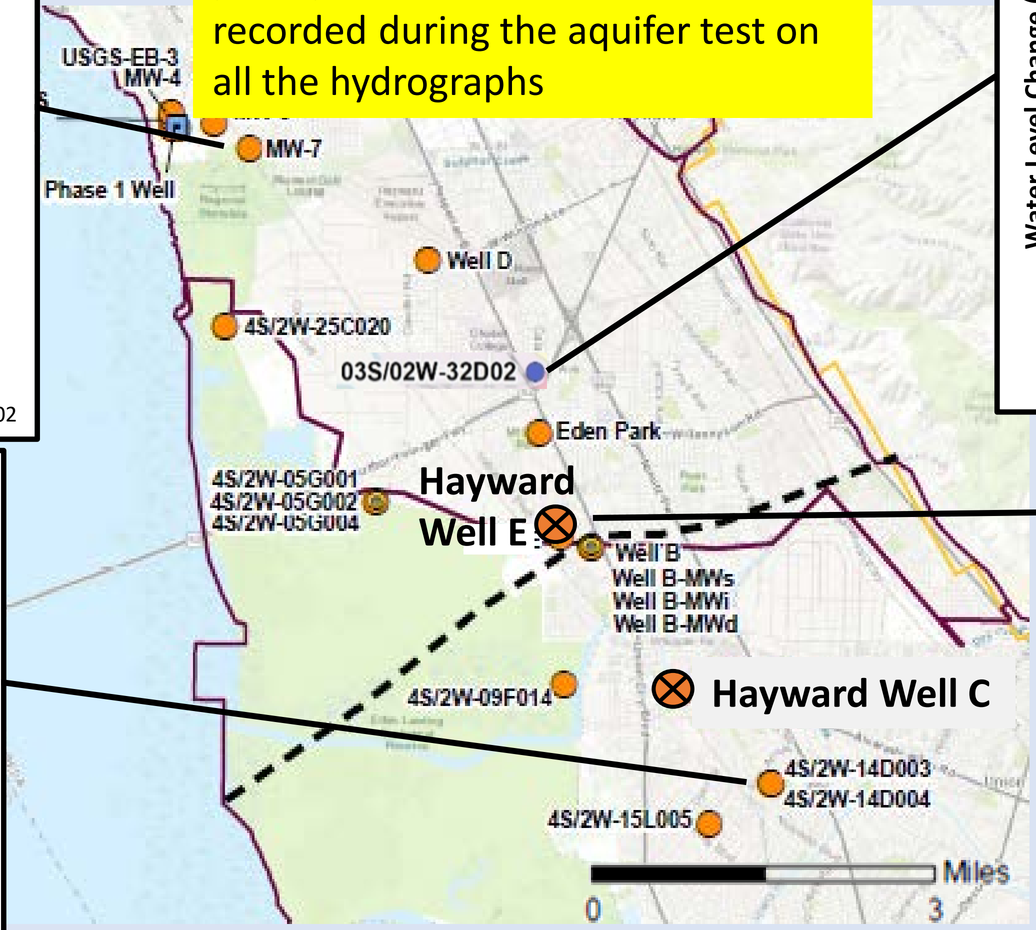
N	Range of Obs (ft)	ME (ft) (mean error)	MAE (ft) (mean abs error)	RMSE (ft)	RMSE (% Range)	R^2
26	22.7	-0.27	1.3	1.2	5%	0.97

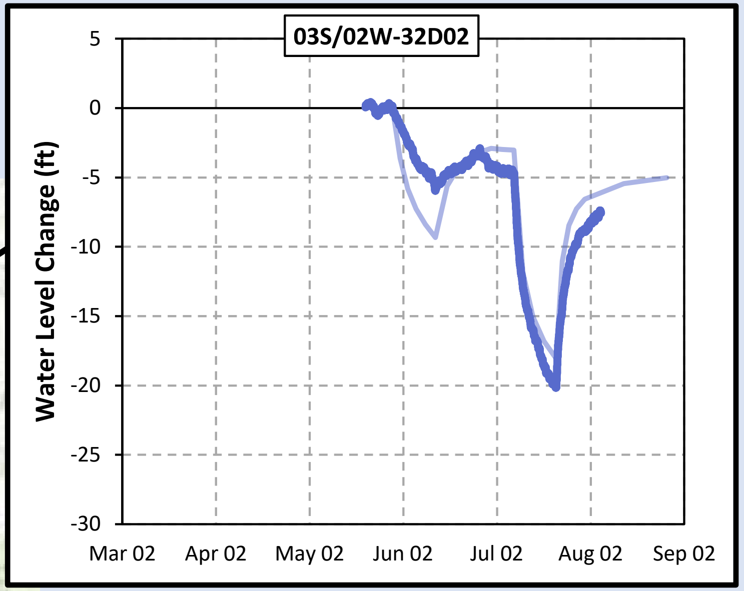
4. Simulation of Aquifer Pumping Tests at Hayward Wells

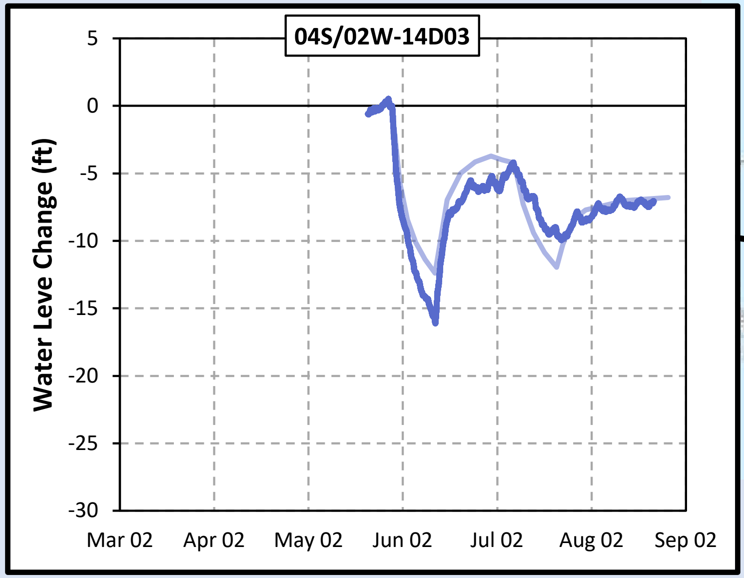
2 Weeks of pumping at **3,300 gpm** from **Well C** followed by **2 weeks** at **2,200 gpm** from **Well E**

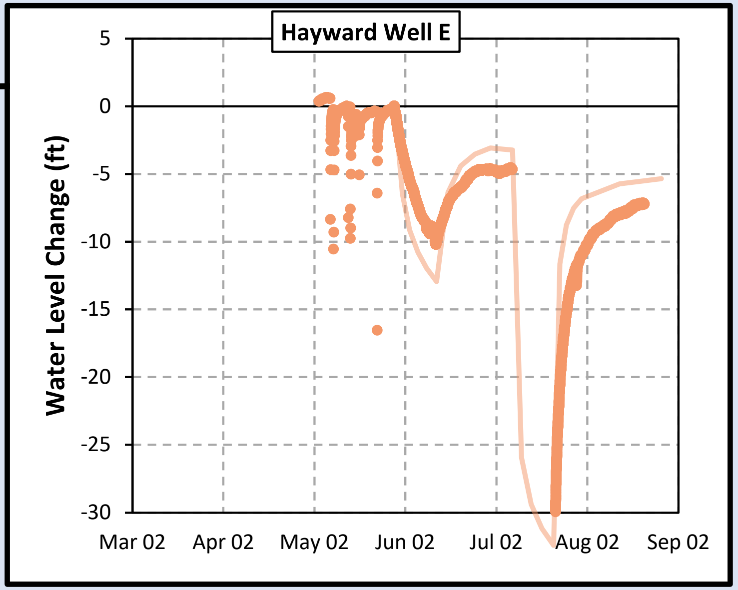
Dark lines are model results and paler points are the water levels recorded during the aquifer test on all the hydrographs





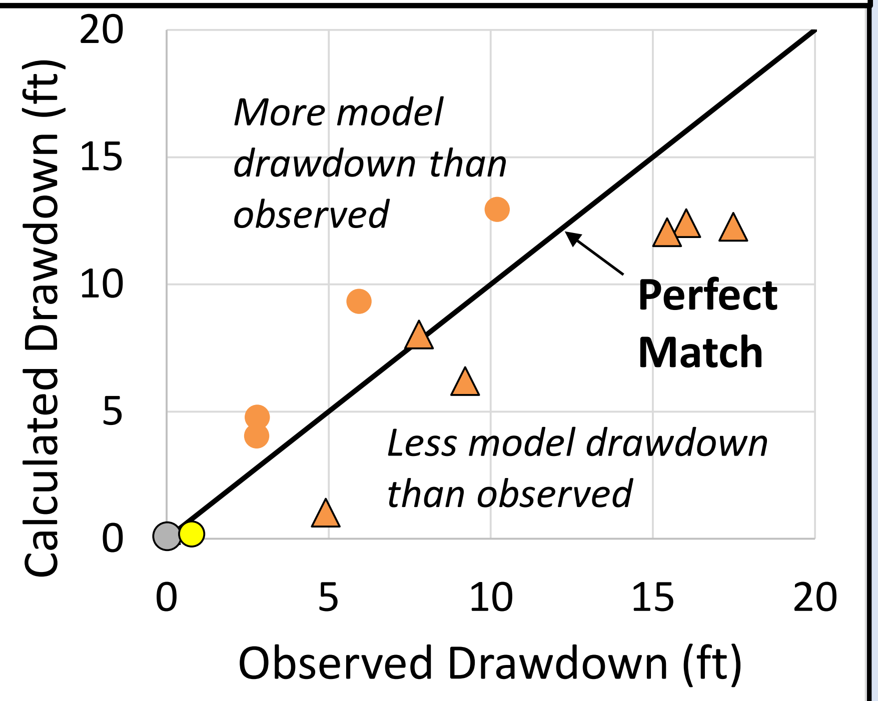






4. Simulation of Aquifer Pumping Tests at Hayward Wells

Observed vs Calculated response **to 2 Weeks** of **3,300 gpm** from **Well C**

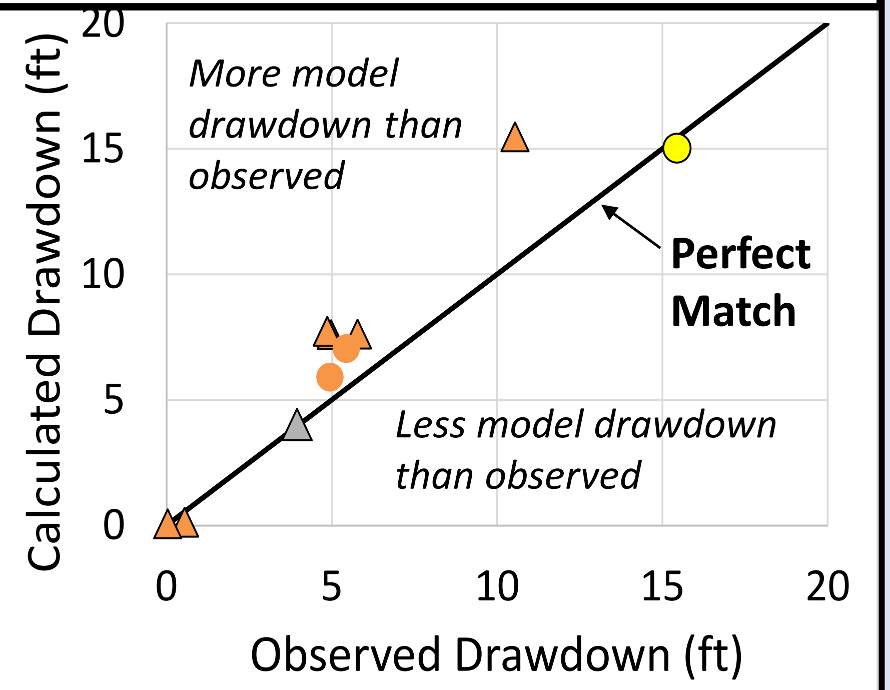


Well C in Niles Cone

Well E in East Bay Plain

- EBP Shallow
- NC Shallow
- EBP Intermediate
- NC Intermediate
- EBP Deep
- NC Deep

Observed vs Calculated response to **2 weeks** of **2,200 gpm** from **Well E**



Calibration Statistics

	Number of Obs	Range of Obs (ft)	ME (ft) (mean error)	MAE (ft) (mean abs error)	RMSE (ft)	RMSE (% Range)	R^2
Well C Test	14	20.2	1.2	2.6	3.3	16%	0.8
Well E Test	13	15.5	-0.9	1.4	1.7	11%	0.8

Questions or Comments *Calibration*

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We welcome your questions and feedback.

Future Groundwater Model Tasks

- Subtask 4.4 Model Update and Calibration
    1. Local refinements of calibration and finalize baseline model
    2. Water balance
    3. Groundwater – surface water interaction
- Subtask 4.5 Application of the Model
    1. Simulations of pumping in the 1960s
    2. Sustainable yield evaluations
    3. Simulation of potential projects
    4. Groundwater dependent ecosystems
    5. Monitoring criteria for sustainable management
- Subtask 4.6 Documentation

Summary

✓Model update complete

- expanded domain and 12-Layers

✓Calibration generally meets standard guidelines

- e.g. USGS, SGMA, ASTM
- excellent match between simulated and observed response to pumping in the SEBP, and in TZ between NC and SEBP
  (Important for reliable simulations of potential groundwater production)

✓The model is ready as a tool for the Hayward and EBMUD GSAs

- sustainable yield evaluations and sensitivity analyses
- simulate potential projects

✓The model is living tool and refinements will continue

Analyzing Project Scenarios

- Municipal water supply projects
- In-lieu projects
- Local groundwater Extraction
- Groundwater Recharge Sources
- Environmental water use and other beneficial uses such as GDE
- Climate change induced impacts to groundwater such as sea level rise
- Potential impacts to groundwater quality

Discussion of Project Scenarios

Contacted Entities	Projects (Yes/No/TBD)	Additional Info
11 Cities	Yes (El Cerrito, San Pablo, Hayward)	Pumping data
2 Counties	Bioretention Basins	Functionality, sizes and locations
3 Agencies	No	
10 other entities	Yes (Metropolitan Golf Link, Salesian High School)	Pumping data

Upcoming Schedule

Groups	Meeting Dates	Purposes
General Stakeholders	February	GSP status update
General Stakeholders/TAC	April	Scenario Run results
TAC	June	Sustainable Management Criteria development
General Stakeholders/TAC	August	Sustainable Management Criteria Update
General Stakeholders	October	Draft GSP

- **Public Notification: Sept 2021**
- **Board/City Council hearings: Dec 2021**

Questions or Comments *Scenarios/Next Steps*

We welcome your questions and feedback.