

# Groundwater Modeling Support at Removal and Remedial Sites

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# Modeling Support

- ▶ Model Review:
  - ▶ PRP Consultant; and
  - ▶ EPA Contractor.
- ▶ CSM Development and Model; and Implementation.

# General Issues with PRP Models

- ▶ Proprietary, not widely used codes;
- ▶ Code and Model Assumptions: Strong PRP bias;
- ▶ Modeling process not fully transparent; and
- ▶ In adequate modeling process documentation.

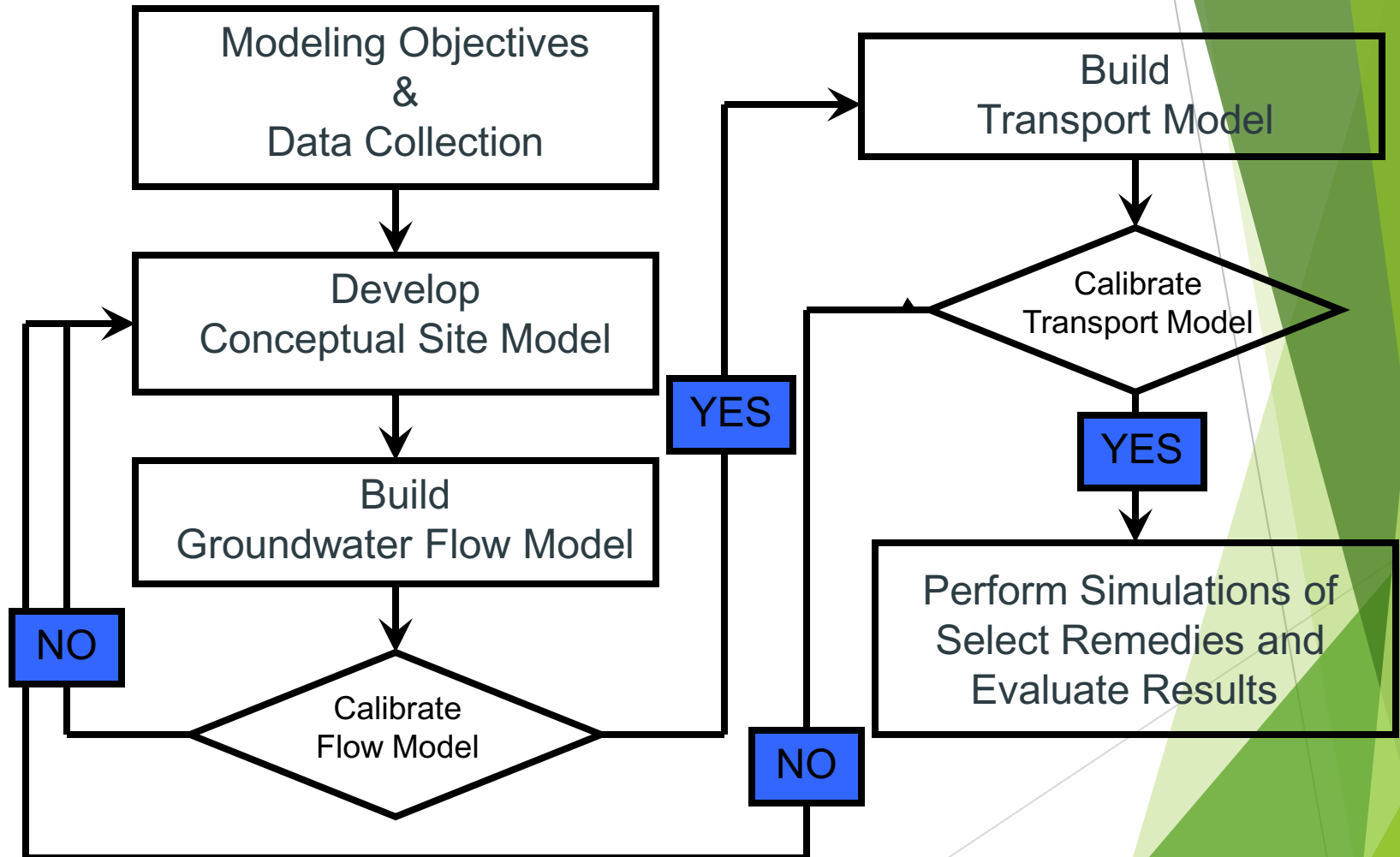
# General Issues with EPA Models

- ▶ Inexperienced Modelers;
- ▶ Modeling process not fully transparent; and
- ▶ Inadequate modeling process documentation.

# Modeling Support: Groundwater Modeling

- ▶ Site dependent with clearly defined objective;
- ▶ Generally 3D Groundwater Flow and Transport; and
- ▶ Will summarize with one model applications.

# Generalized Modeling Flow Chart



The background features abstract, overlapping green geometric shapes in various shades, creating a modern and professional look. The shapes are primarily triangles and polygons, some with gradients, set against a white background.

# **Modeling Groundwater Flow and Contaminant Transport at the Billings PCE Site**

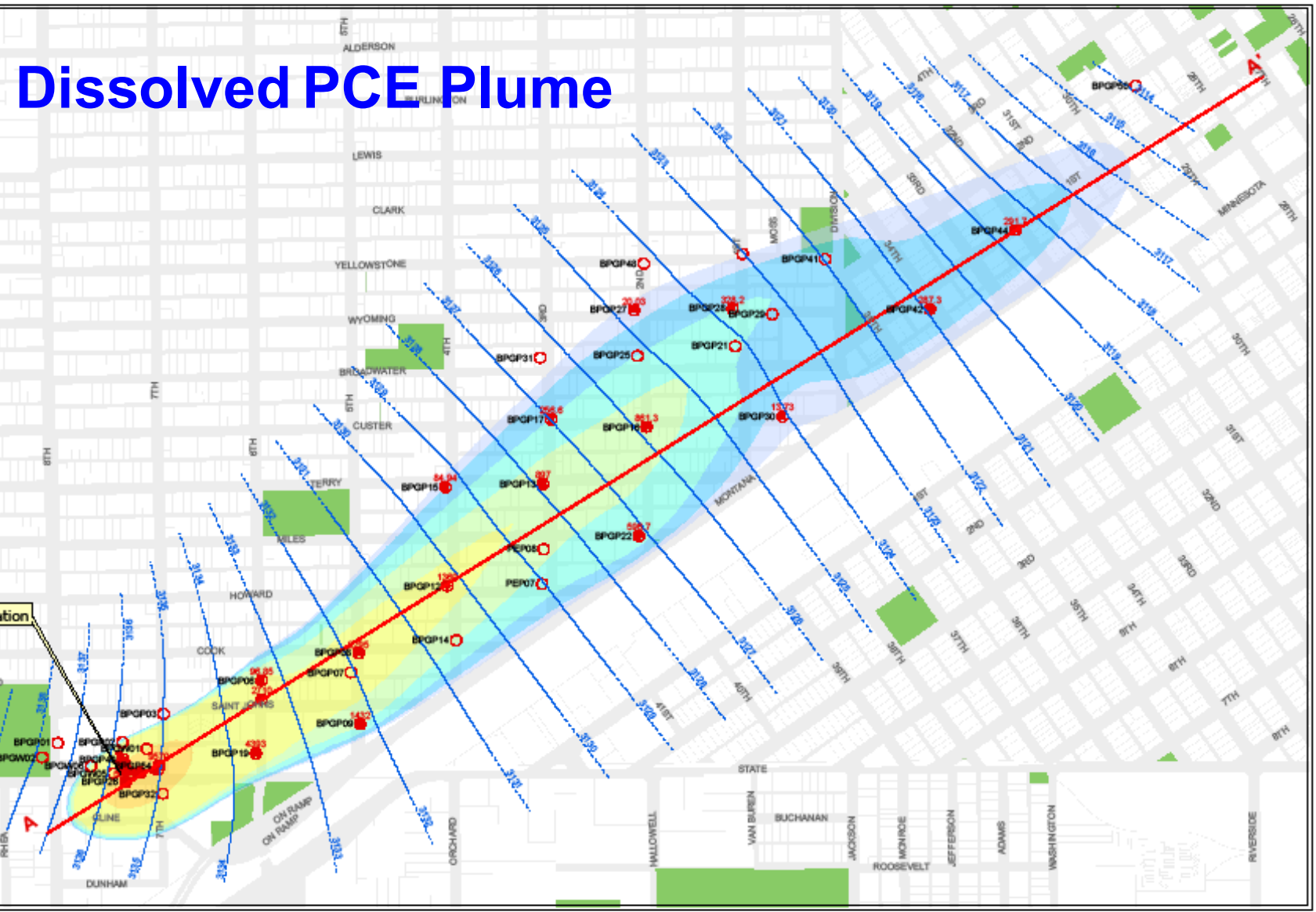


# Background Data

- ▶ Elevated PCE vapors discovered indoors in a residential neighborhood in the City of Billings;
- ▶ Subsequent investigation identified an up to 1,000-ft wide by 10,000-ft long PCE plume in the underlying, shallow unconfined aquifer;
- ▶ Dissolved PCE concentrations range up to 33,100 ug/L.
- ▶ The likely source is vadose zone PCE DNAPL from the Big Sky Linen Dry Cleaners; and
- ▶ Site History indicates the plume is 30 to 40 years old.

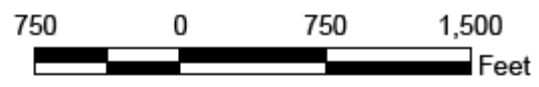


# Dissolved PCE Plume

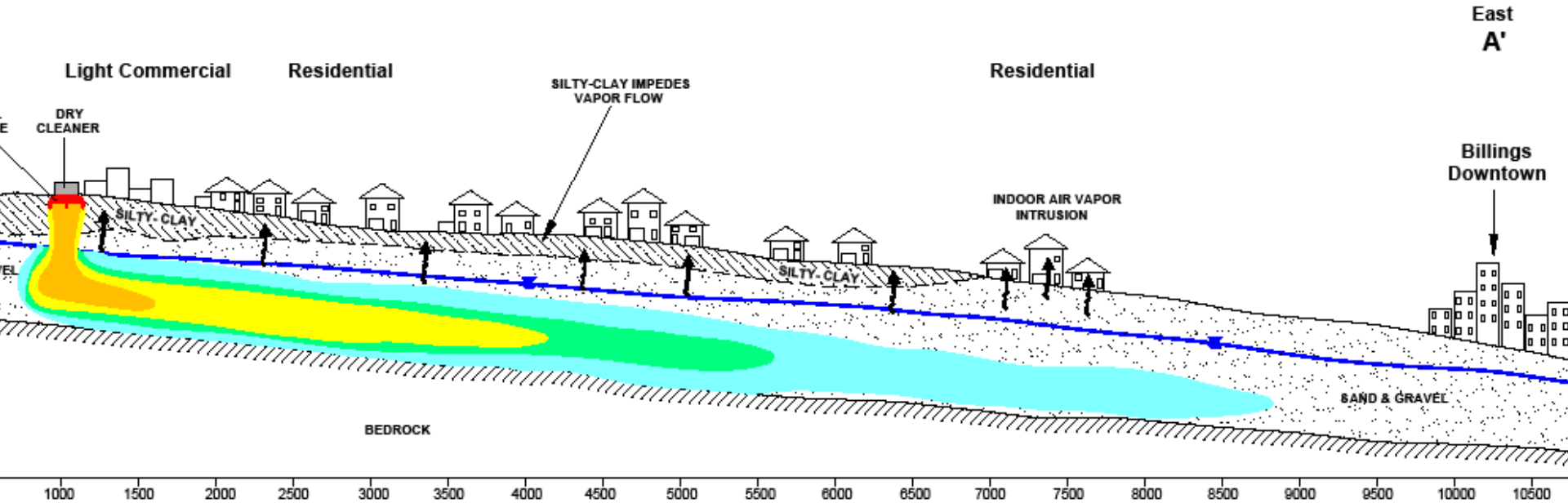


## Legend

- Long - Section
  - Groundwater
  - - - Dashed white
  - Sample Location
  - Sample Location
  - Private
  - Right of Way
  - Government
- Groundwater PCE**  
ug/L = micrograms per liter
- 10 - 100
  - 100 - 300
  - 300 - 600
  - 600 - 1,000
  - 1,000 - 5,000
  - 5,000 - 10,000
  - 10,000 - 20,000
  - 20,000 - 40,000

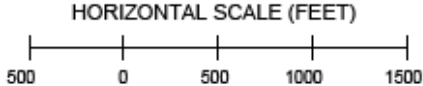


# PCE Plume Cross Section



Looking Northwest

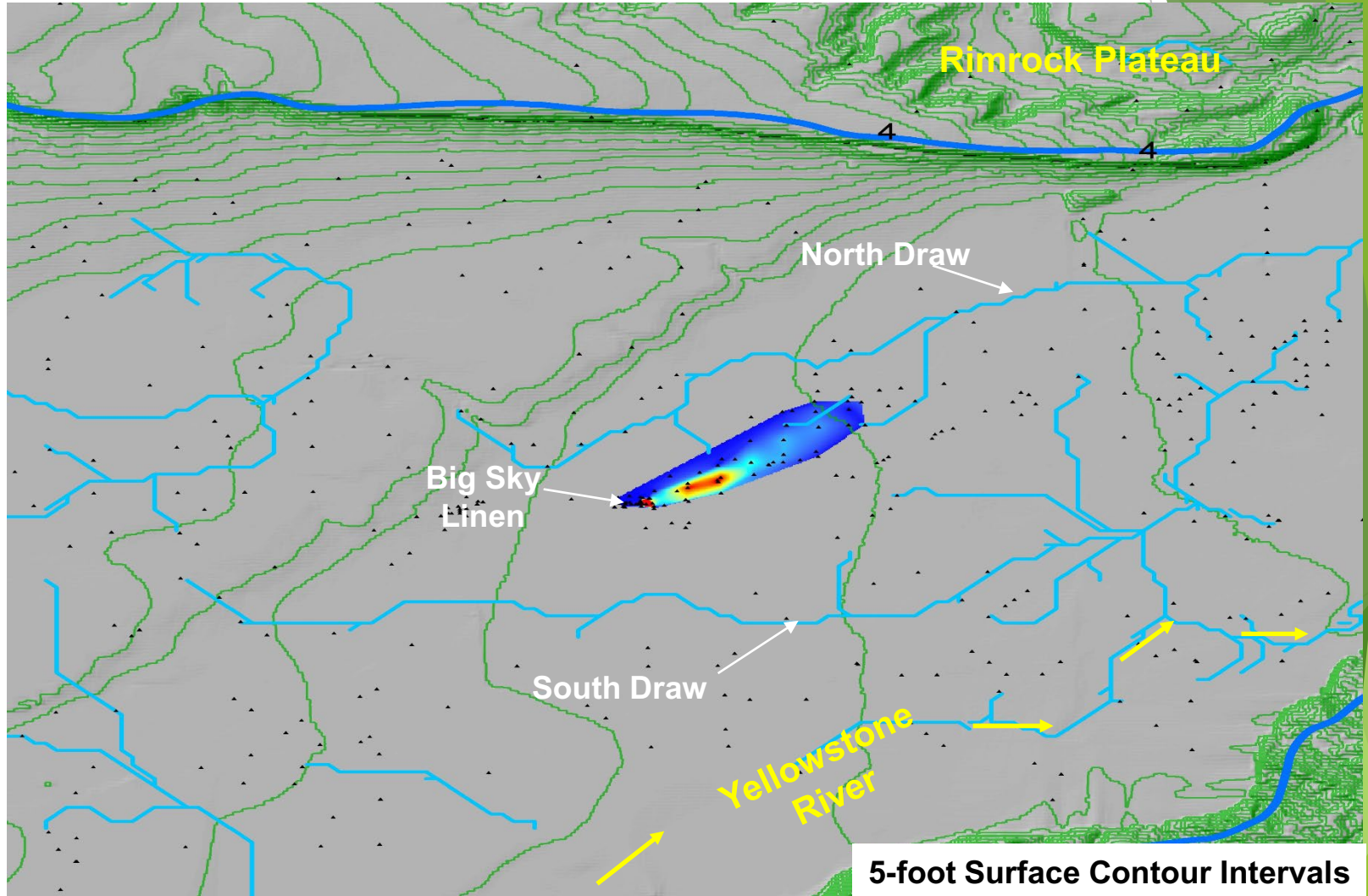
- LEGEND**
- GROUNDWATER PLUME
  - VOC VAPOR FLOW
  - WATER LEVEL



# Modeling Objectives

- ▶ Implement the CSM to improve the understanding of site conditions and identify data gaps;
- ▶ Evaluate plume stability (i.e., is the plume at steady state or getting larger/smaller); and
- ▶ Evaluate various remedial options.

# PCE Plume August 2007 and Surface Drainage Model



# Conceptual Site Model

- ▶ A CSM of the Billings basin watershed (80 sq. mi.) was developed;
- ▶ The 1/3 sq. mi. Site is within the watershed;
- ▶ Surface recharge to the aquifer is primarily from direct rainfall:
  - ▶ average rainfall is 13 in/yr, and
  - ▶ Recharge is greater in undeveloped areas opposed to urban (developed) areas;

# CSM (cont'd)

- ▶ Regional Surface Water Hydrology

- ▶ The Yellowstone River (YSR) is the primary hydrogeologic feature within the watershed:
  - ▶ drains the watershed and defines the southern boundary of the flow model,
  - ▶ daily flow rates range from 3 to 27 billion cu. ft/day;

# CSM (cont'd)

- **Regional Physiography:** site is surrounded by topographic highs that define the natural hydrogeologic boundaries of the watershed;
- **Relief:** elevations in the Billings basin range from 3,080 to 3,850 feet above msl with a regional slope to the east;
- **Regional Geology:** unconsolidated alluvium overlies massive bedrock.



# Model Construction

- ▶ **The CSM is used to construct site specific numerical models using 3D software:**
  - ▶ MODFLOW: groundwater flow; and
  - ▶ MT3D: contaminant transport.



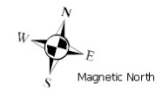
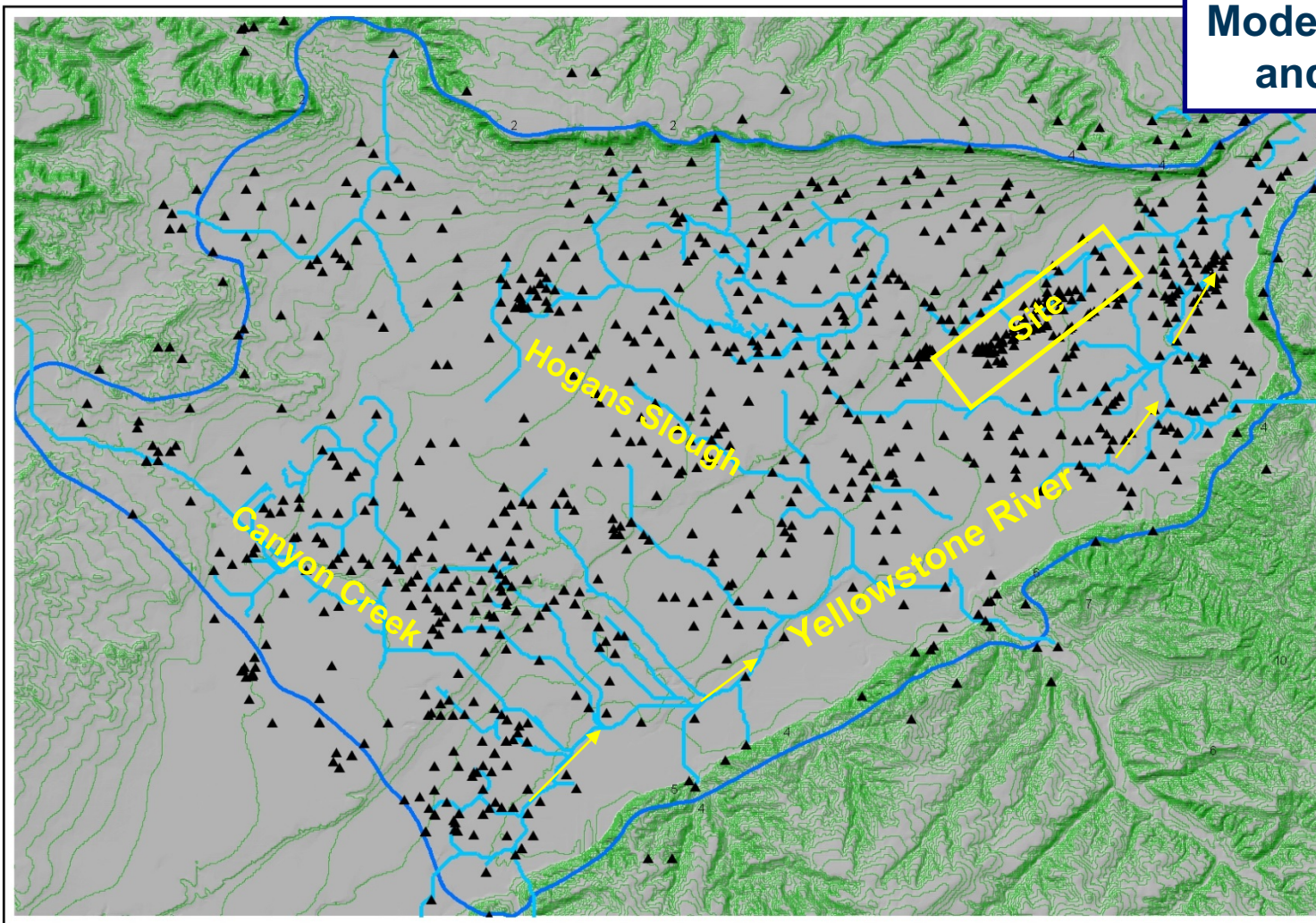
# Flow Model Assumptions

- Groundwater system is **unconfined**;
- Recharge is **constant**;
- Groundwater flow is **steady-state**;
- Hydraulic conductivity field is **heterogeneous, isotropic horizontally and anisotropic vertically**; and
- YSR defined as a **constant head boundary** (i.e., complete hydraulic connectivity with saturated zone).

# Flow Model Inputs

- ▶ Ground topography;
- ▶ Watershed boundaries;
- ▶ Geologic unit hydraulic conductivities;
- ▶ Surface hydrologic features:
  - ▶ Drainage network
  - ▶ Surface recharge.

# Model Topography and Drainages



## About This Map:

This map was generated using national elevation data (NED) provided by USGS. A flow model was used to highlight the surface flow paths in the study area.

Well locations were collected from MBMC.

Surface elevations generated using national elevation data (NED) from the USGS. NED is 1/3 arc second, or 10m horizontal resolution.

## Websites:

MBMC: [http://www.mbmtech.edu/mbmg\\_default.htm](http://www.mbmtech.edu/mbmg_default.htm)

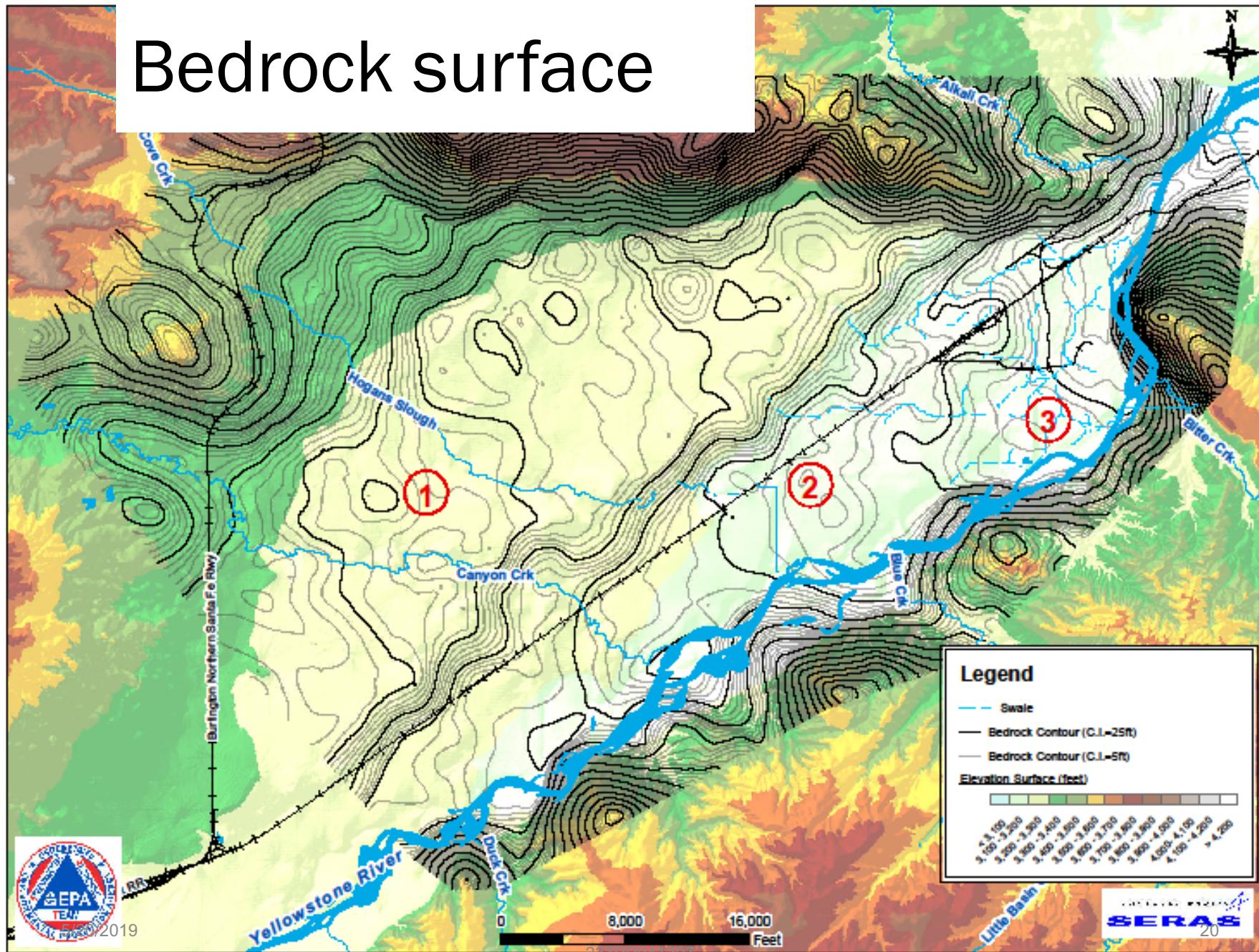
USGS: <http://www.usgs.gov>



## Legend

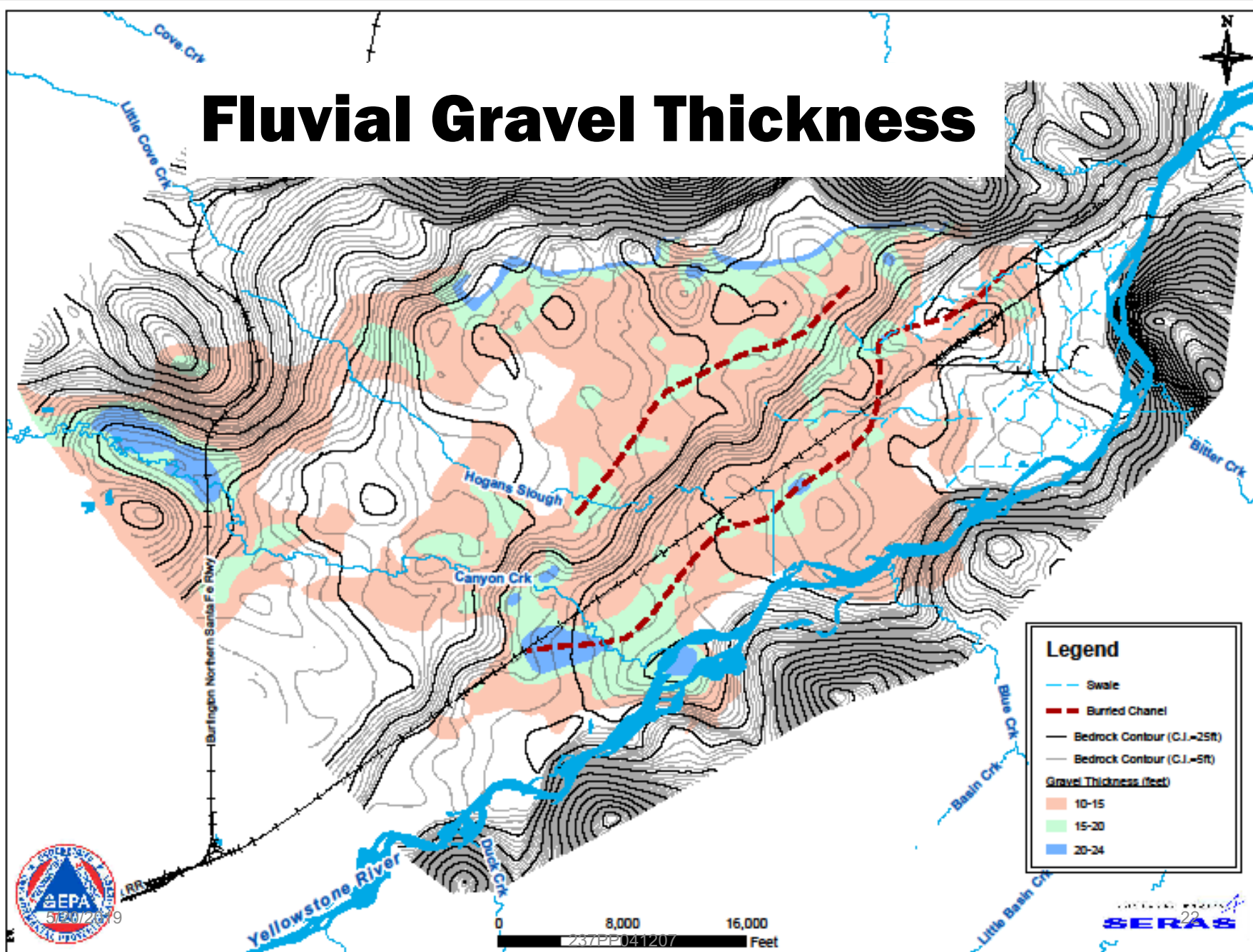
- ▲ Well Location
- Modeled Stream Channel
- Contour Elevation  
*Interval = 20 feet*
- Model Extents

# Bedrock surface

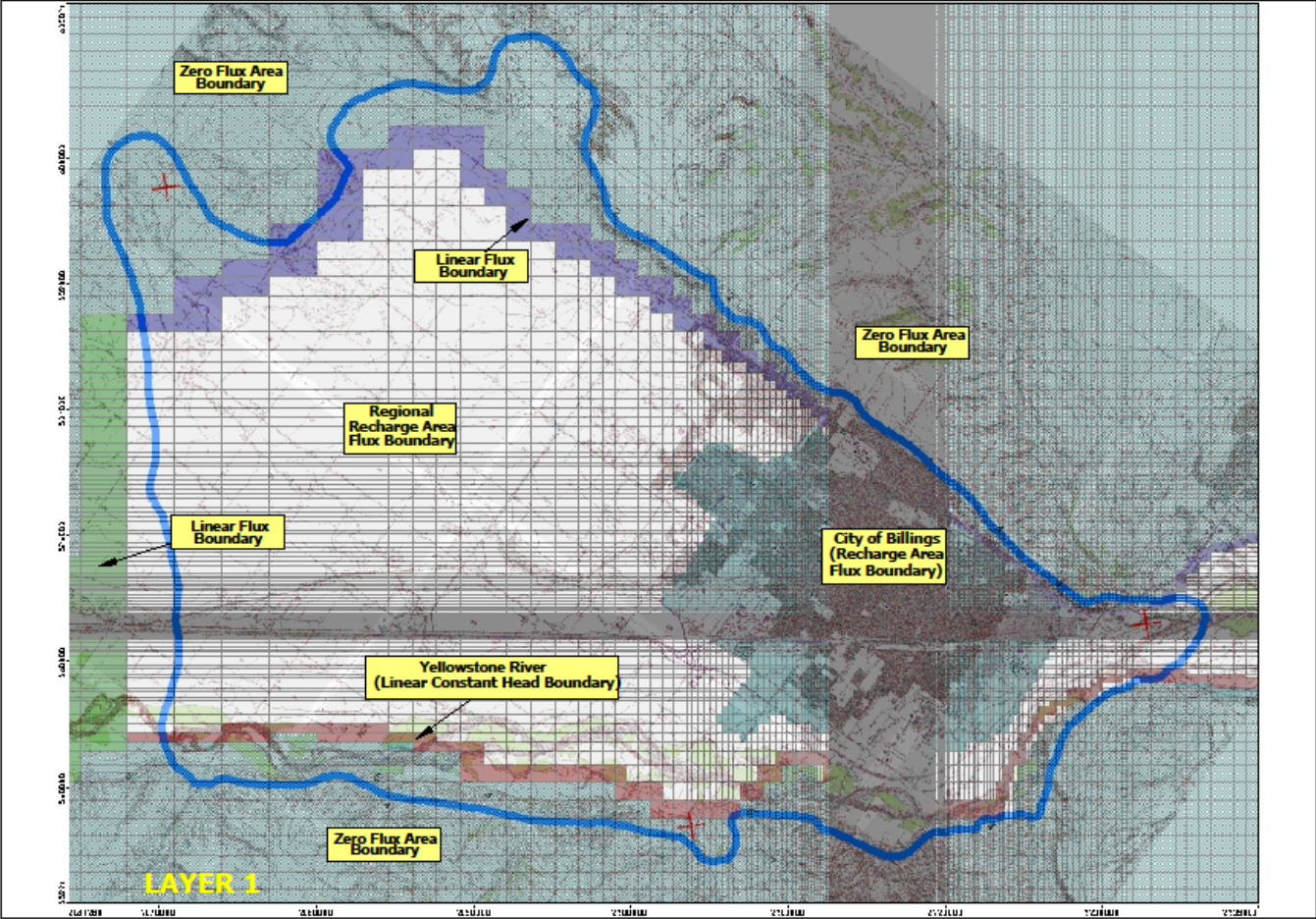




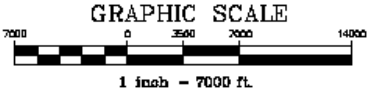
# Fluvial Gravel Thickness



# Surface Boundary Conditions



- MODEL DISCRETIZATION**
- \* 4 LAYERS
  - \* 185 ROWS PER LAYER
  - \* 377 COLUMNS PER LAYER
  - \* 69,745 CELLS PER LAYER



U.S. EPA ENVIRONMENTAL RESPONSE TEAM  
 RESPONSE ENGINEERING AND ANALYTICAL CONTRACT  
 EP-C-04-032  
 W.A.# 0 - 141



E07\_EV\_Mapping\_of\_FL\_Boundaries/Layer1\_Boundaries 06/2003

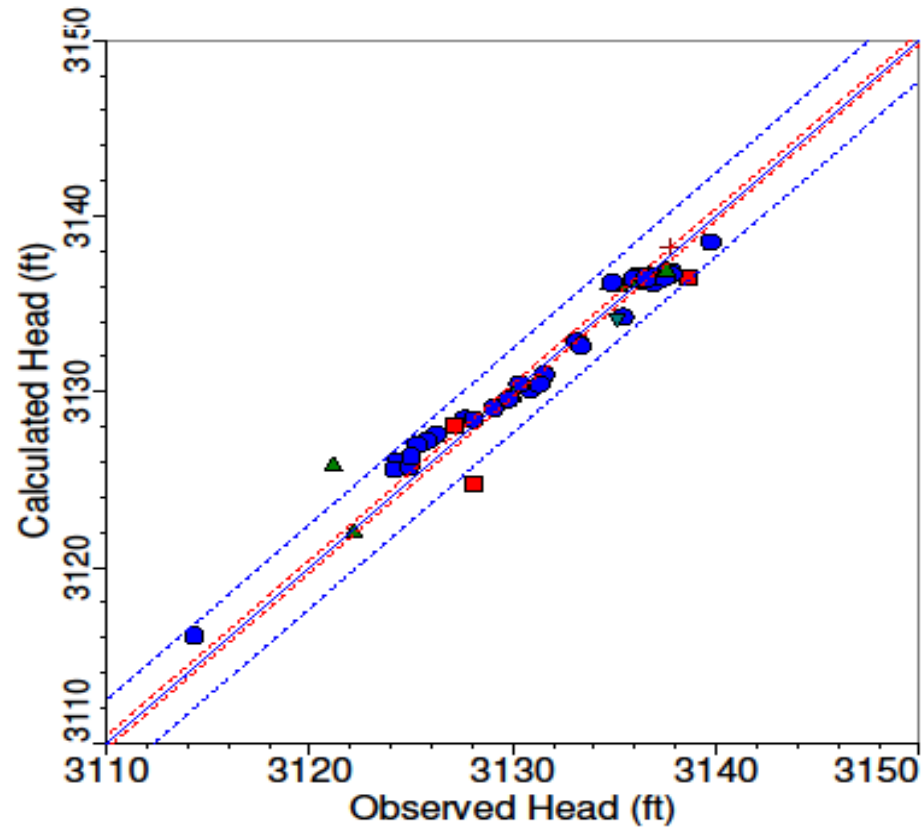


# Flow Model Calibration

- ▶ Builds model credibility (reality based);
- ▶ Model calibrated to groundwater elevation data collected on;
- ▶ Calibration criteria: normalized RMS <10% and correlation coefficient greater than 90%; and
- ▶ Calibrated Model: normalized RMS 1.4%; and correlation coefficient 99%.



# Flow Model Calibration Result



- Layer #2
- Layer #3
- ▲ Layer #4
- ▼ Layer #5
- + Layer #7
- 95% confidence interval
- 95% interval

Max. Residual: 4.695 (ft) at BPGP47/A  
Min. Residual: -0.001 (ft) at BPGP13/A  
Residual Mean : 0.071 (ft)  
Abs. Residual Mean : 0.873 (ft)

Num. of Data Points : 54  
Standard Error of the Estimate : 0.164 (ft)  
Root Mean Squared : 1.193 (ft)  
Normalized RMS : 4.688 ( % )  
Correlation Coefficient : 0.98



# Obj. #1: CSM and Data Gaps

## ▶ CSM

- ▶ Model indicated high groundwater velocity (3 to 10 ft/day); and
- ▶ North and South draw directions plume migration subparallel to YSR.

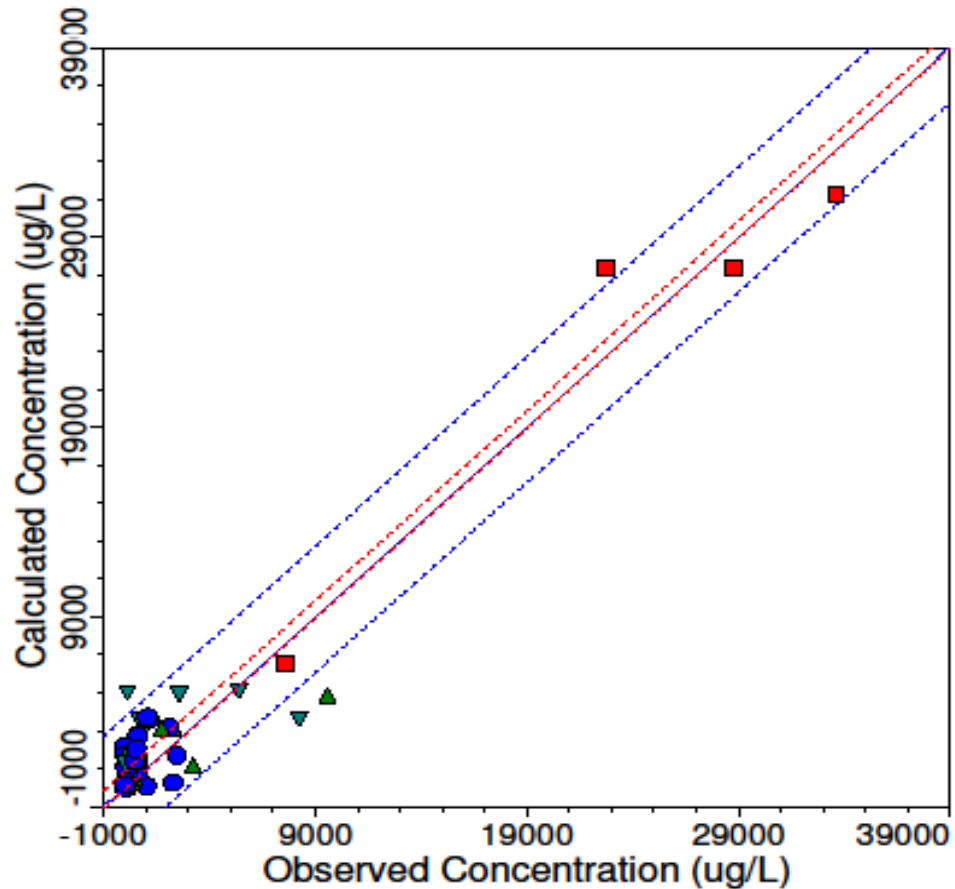
## ▶ Data Gaps

- ▶ More site representative hydraulic conductivity data needed: Conducted additional aquifer testing; and
- ▶ Identified areas near the site where better hydraulic control was needed: Installed additional wells.

# Transport Model Calibration

- ▶ Compare model predicted concentrations after 35 years to current dissolved concentrations; and
- ▶ Calibrated Model: Normalized RMS of 3.4%, and correlation coefficient of 99%.

# Transport Model Calibration Result

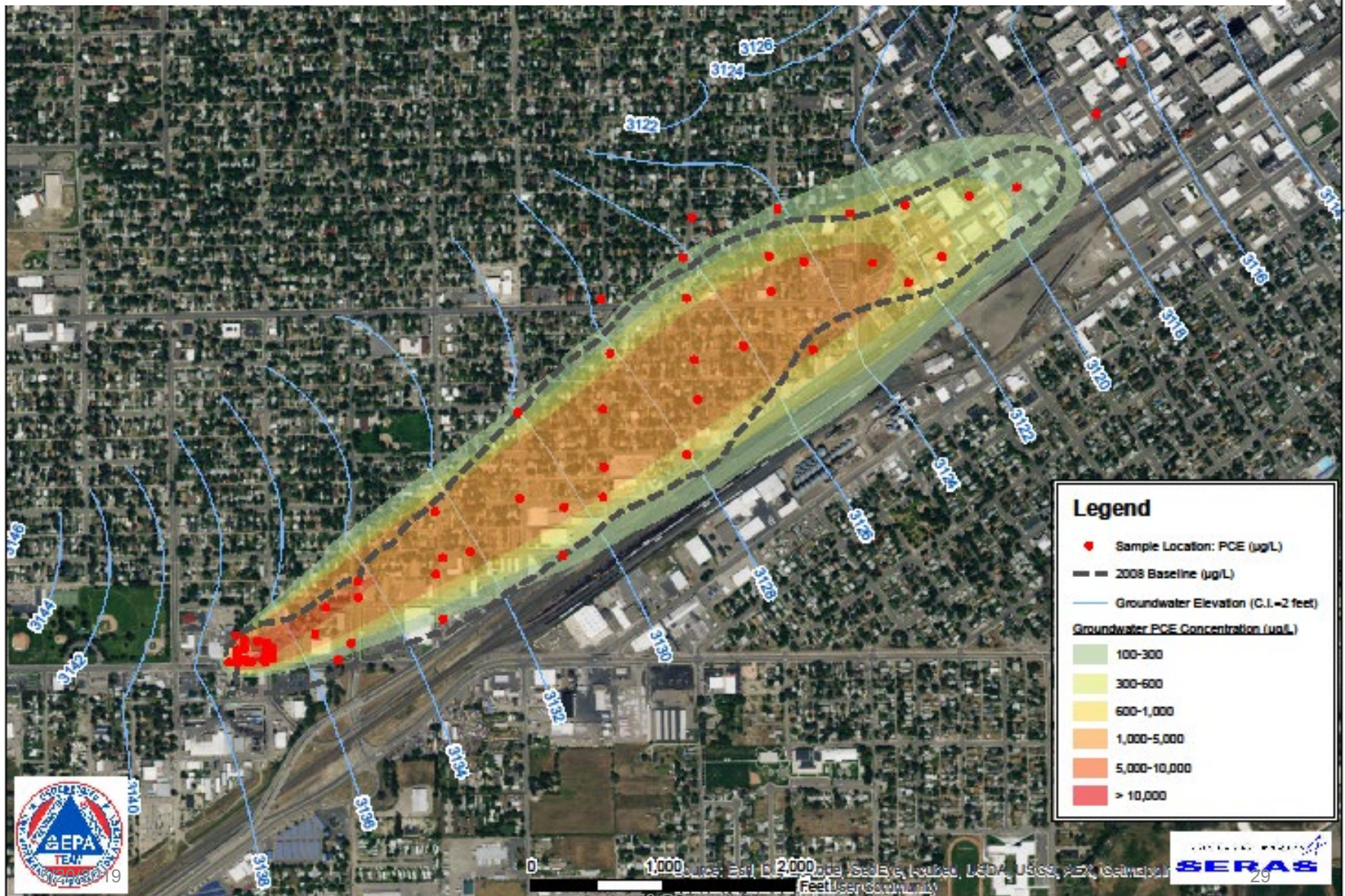


- Layer #2 : PCE
- Layer #3 : PCE
- ▲ Layer #4 : PCE
- ▼ Layer #5 : PCE
- + Layer #7 : PCE
- 95% confidence interval
- 95% interval

Max. Residual: 4924.075 (ug/L) at BPGP06/A  
 Min. Residual: 0 (ug/L) at BPGW03/A  
 Residual Mean : 423.448 (ug/L)  
 Abs. Residual Mean : 1115.405 (ug/L)

Num. of Data Points : 58  
 Standard Error of the Estimate : 217.734 (ug/L)  
 Root Mean Squared : 1697.522 (ug/L)  
 Normalized RMS : 5.051 (%)  
 Correlation Coefficient : 0.967

# Calibrated and Observed PCE Plume at 35 yrs



# Obj. #2: Plume Stability Evaluation

- ▶ Plume is at quasi steady state; i.e., not growing; and
- ▶ No additional receptors threatened.

# Obj. #3: Evaluation of Removal Options

- ▶ Options Simulated: source containment (sheet pile wall); source reduction (excavation); groundwater pump and treat; Reactive permeable barriers (PRB).

# Obj. #3: Removal Action

- ▶ Source containment (sheet piling), ISCO and source removal on Central Ave; and
- ▶ ISCO and source removal in alley.





**Post Removal Evaluation;  
Billings PCE Site**

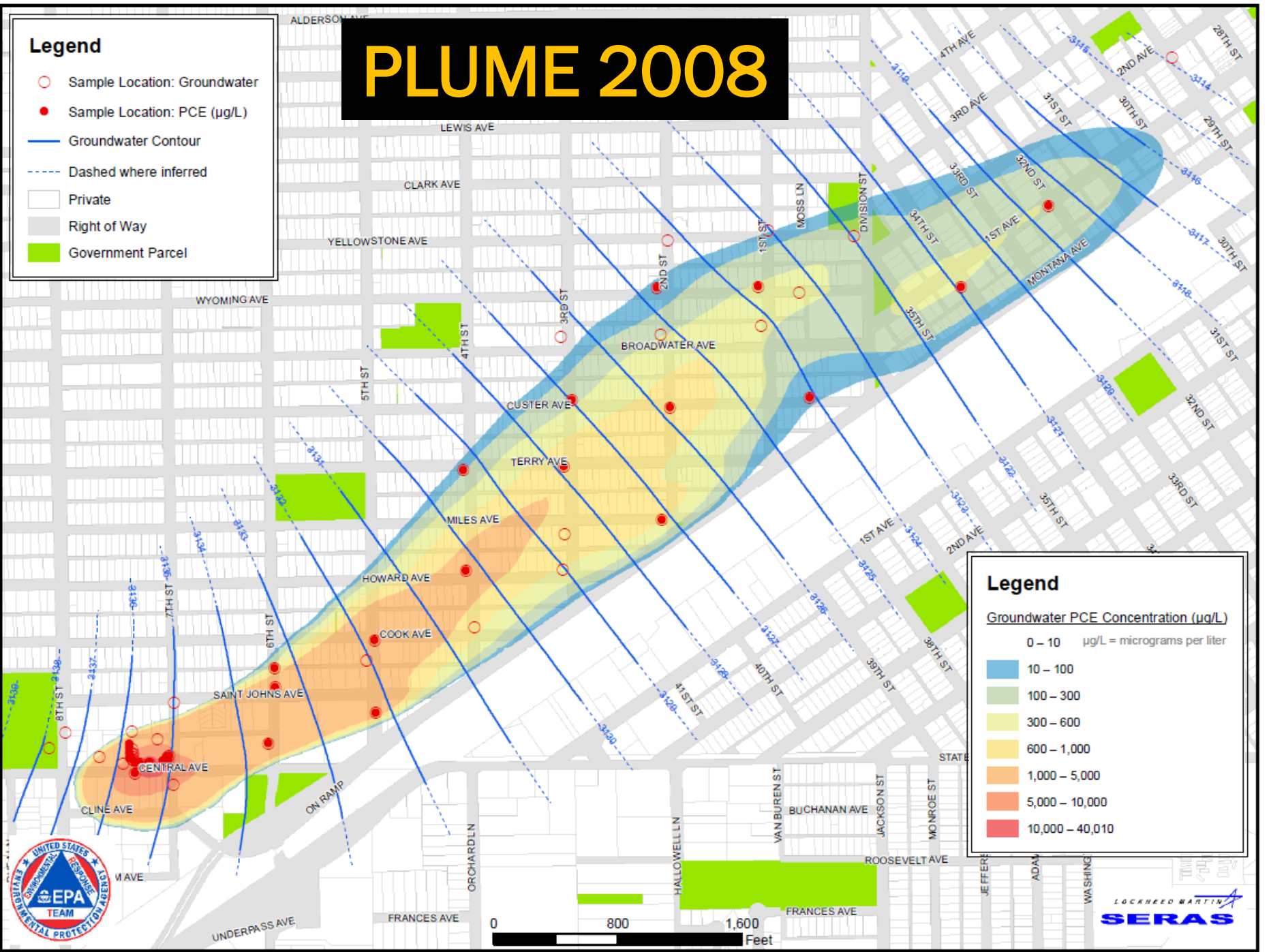
**Billings, MT**

**02/10/15**

# PLUME 2008

**Legend**

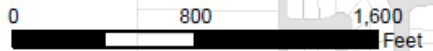
- Sample Location: Groundwater
- Sample Location: PCE (µg/L)
- Groundwater Contour
- - - Dashed where inferred
- Private
- ▒ Right of Way
- Government Parcel



**Legend**

Groundwater PCE Concentration (µg/L)

0 - 10	µg/L = micrograms per liter
10 - 100	
100 - 300	
300 - 600	
600 - 1,000	
1,000 - 5,000	
5,000 - 10,000	
10,000 - 40,010	



# PLUME 2014

## Legend

- Sample Location: Groundwater
- Sample Location: PCE (µg/L)
- Groundwater Contour
- - - Dashed where inferred
- Private
- Right of Way
- Government Parcel

## Legend

### Groundwater PCE Concentration (µg/L)

0 - 10 µg/L = micrograms per liter

- 10 - 100
- 100 - 300
- 300 - 600
- 600 - 1,000
- 1,000 - 5,000
- 5,000 - 10,000
- 10,000 - 60,000

