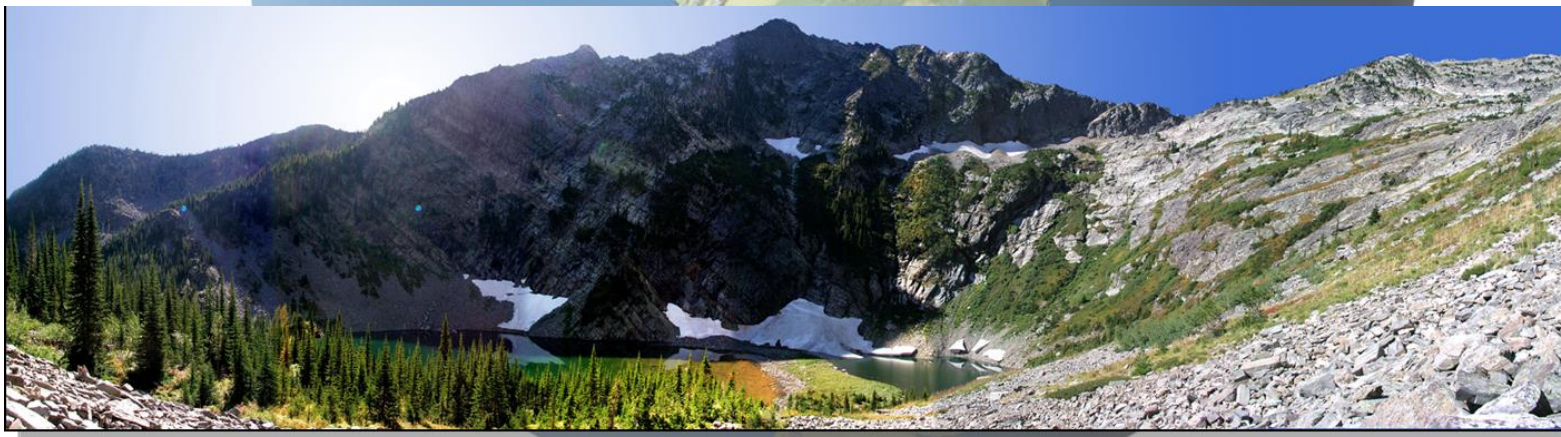


NewFields

Modeling Effects of Underground Mine Depressurization on Water Resources for the Proposed Montanore Mine, Lincoln and Sanders Counties, Montana.

A. Campbell Stringer, P.G., Amelia Tallman (NewFields); and Eric Klepfer (Klepfer Mining Services LLC).

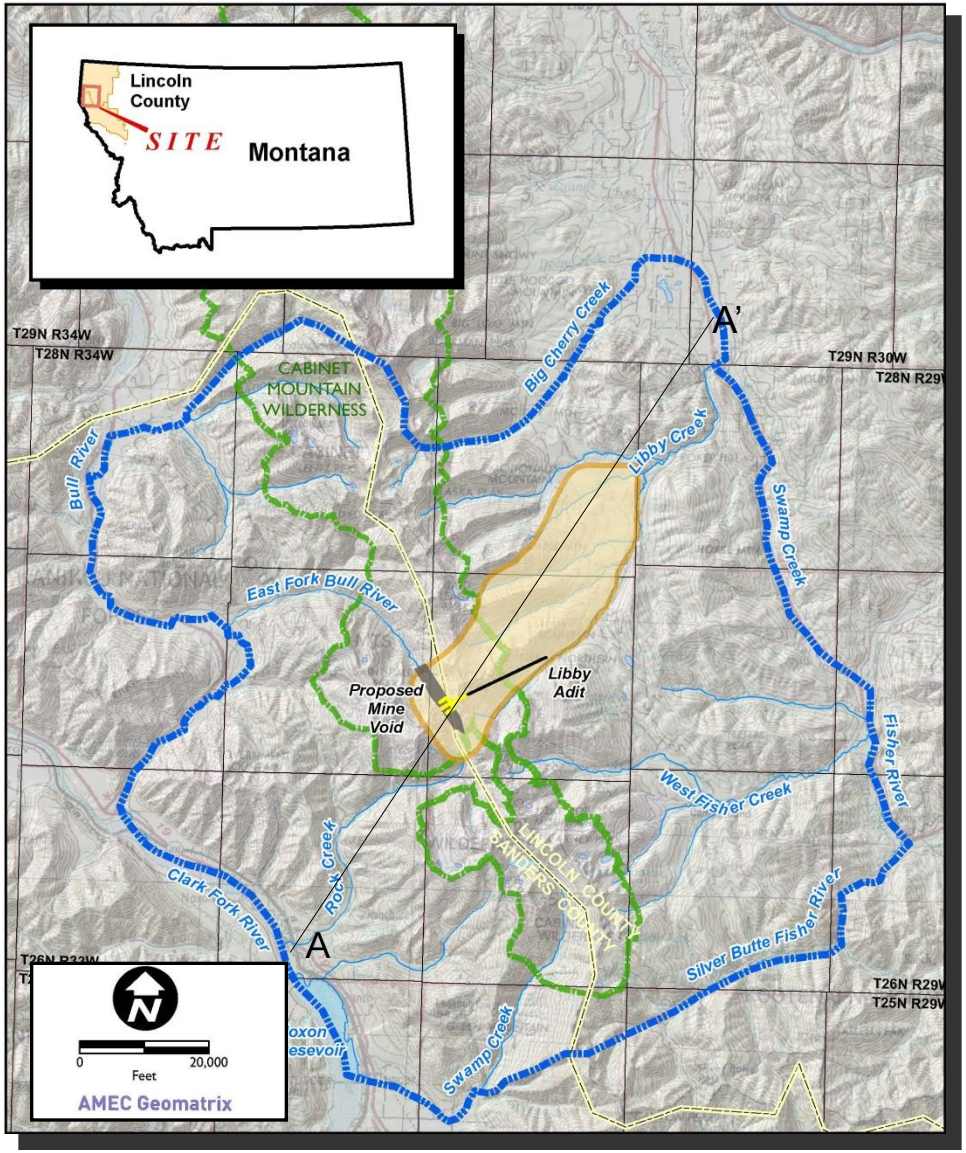
Background

- Proposed Silver and Copper Mine beneath the Cabinet Mountain Wilderness Area
- NEPA/MEPA analysis
- Final EIS anticipated in 2013.
- USFS and MDEQ are lead agencies for EIS
- Concerns regarding potential impacts to alpine lakes and streams

Location

Partially within the Cabinet Mountain Wilderness Area

Crosses a major hydrologic divide in the upper catchments for the Clark Fork River and the Kootenai River

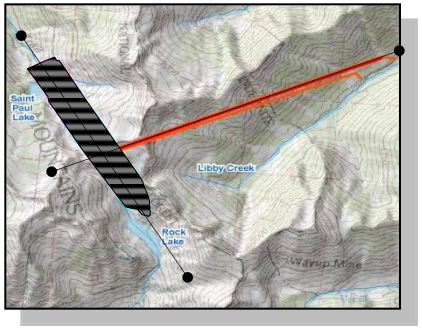


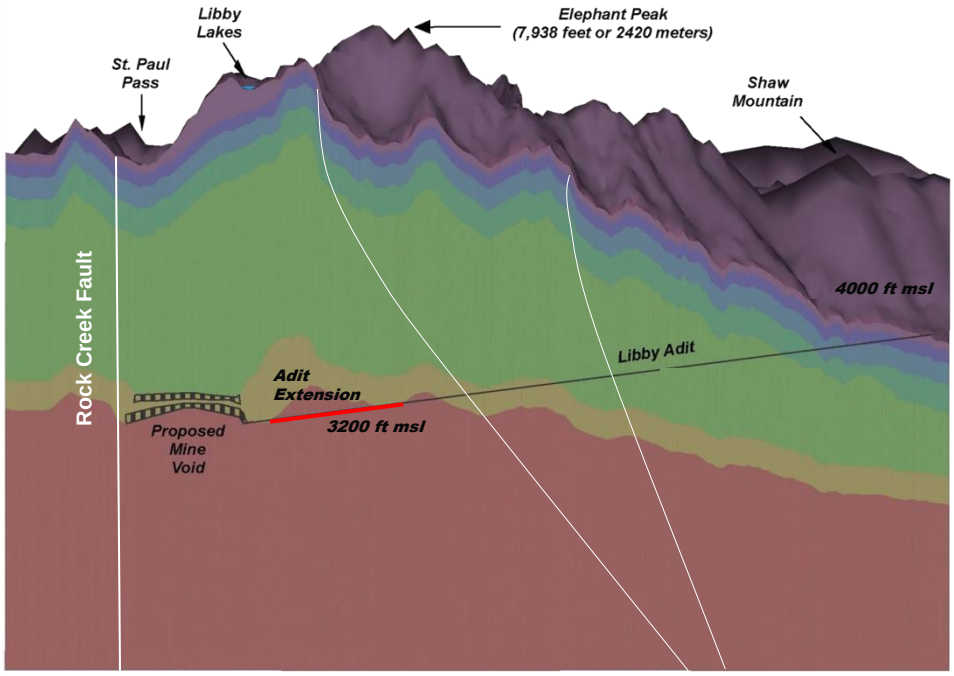
Mine Plan

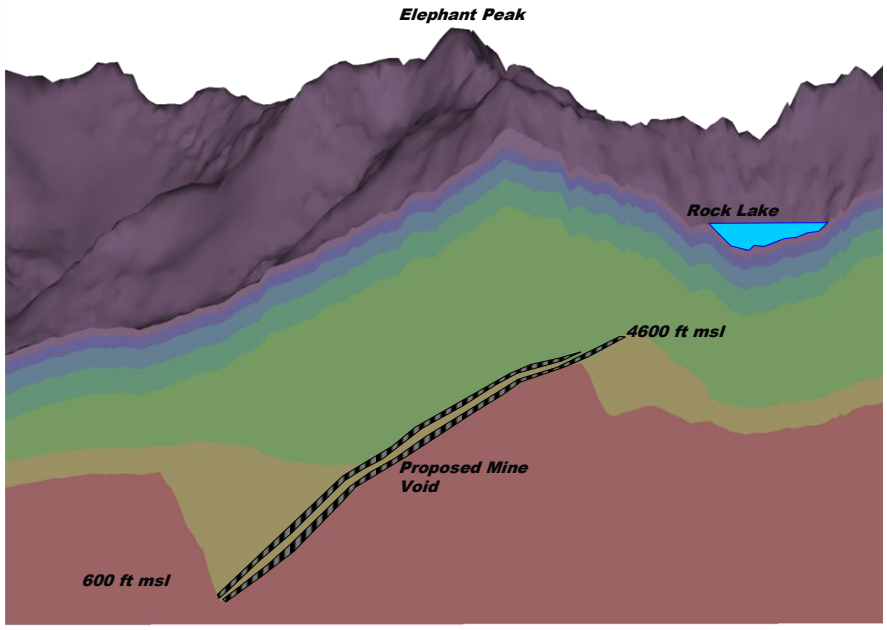
Existing:

- 14,000-ft long exploration adit

- Plans for :
  - 3,000-ft Adit Extension
  - Two additional adits
    Two layered mine voids
  - Mine voids plunge 4000 ft







Factors Leading to 3D Model Development

- **2D model initially developed for impact analysis was insufficient for simulating 3D flow and testing conceptual models.**
- **Uncertainty regarding degree of hydraulic communication between surface water and deep bedrock**
- **Hydraulic characteristics of faults not well understood. Concern that Rock Lake fault is a conduit to flow that could result in draining of Rock Lake**
- **Led to alternative conceptual models.**
- **Decision to develop 3D model.**

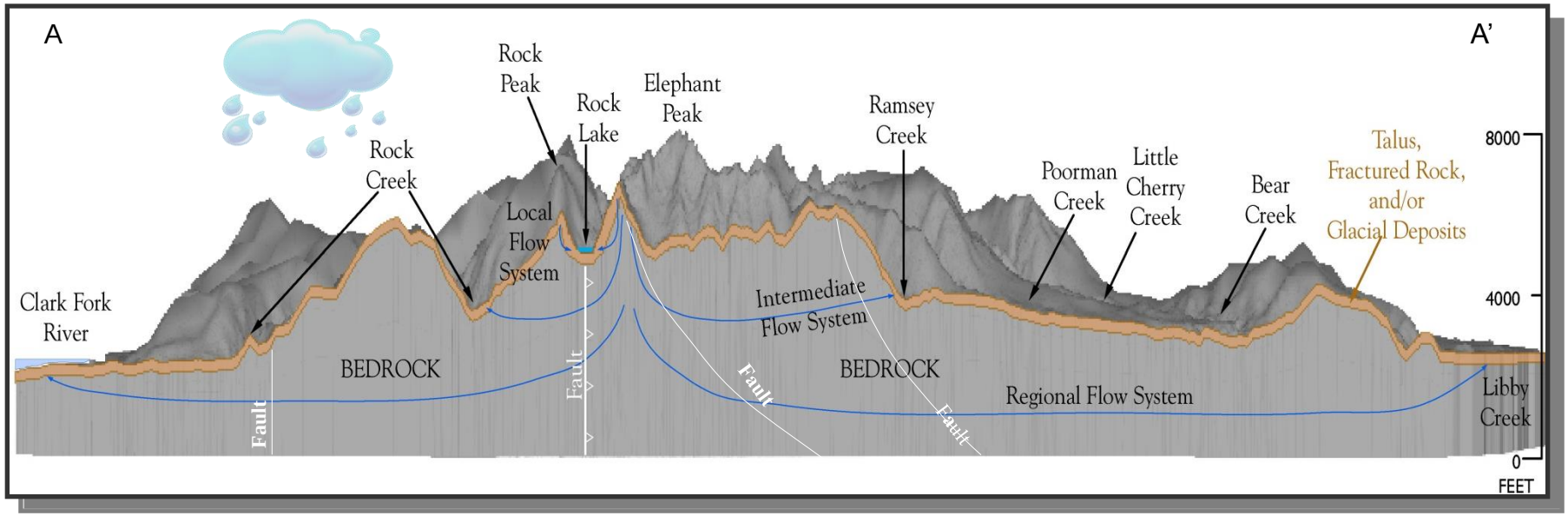
Background Information

- Site specific hydrologic data available from mine area:
  - Libby Adit: mapped fractures, measured flows, hydraulic test data.
  - Sparse head data from exploration boreholes, on-site wells and GWIC
  - Stream flow data for Bull River, CFR, Rock Creek, Libby Creek

Conceptual Model

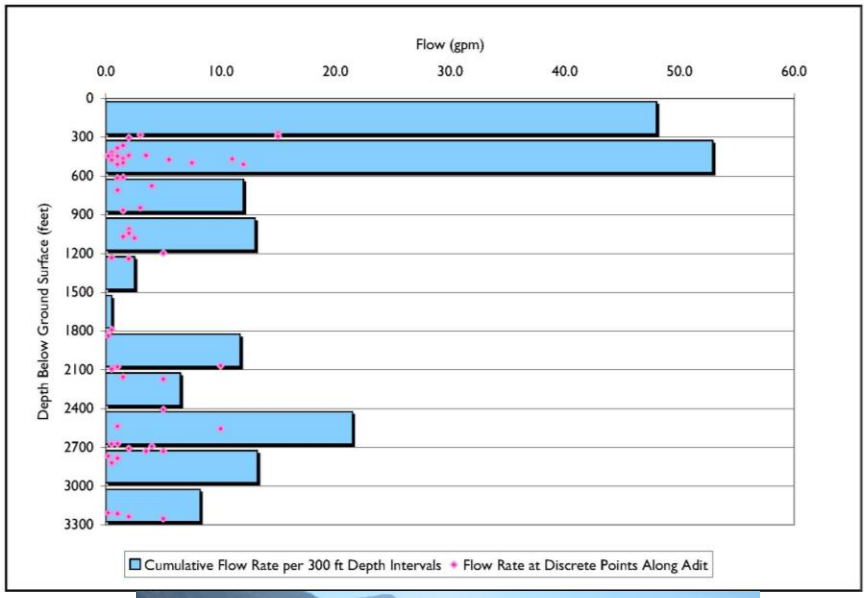
Flow Systems

- **Local**- rapid shallow groundwater flow through talus and shallow fractured bedrock into alpine lakes and streams.
- **Intermediate**- groundwater flow through fractured bedrock flowing into perennial streams.
- **Regional**- deep groundwater flow through fractured bedrock into major drainages.

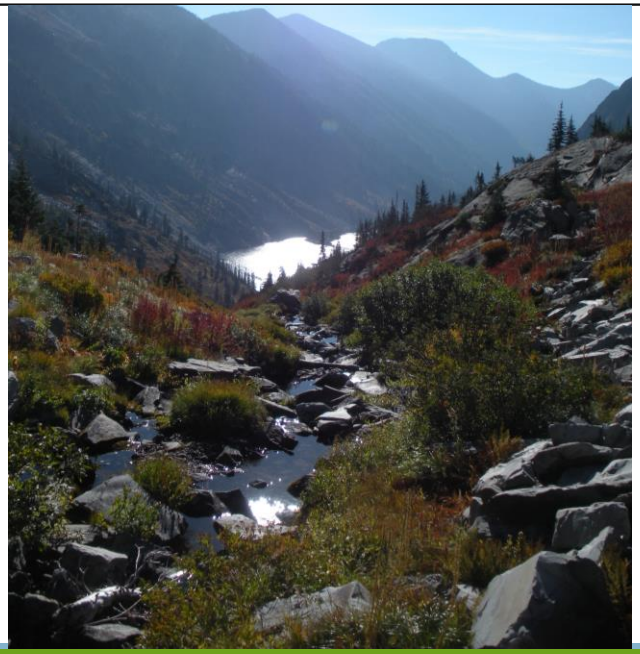


Conceptual Issues

- Decreasing permeability with depth



- Are headwater streams sustained by regional groundwater or by snowmelt and localized/perched flow systems?



Model Design

Finite Element - FEFLOW

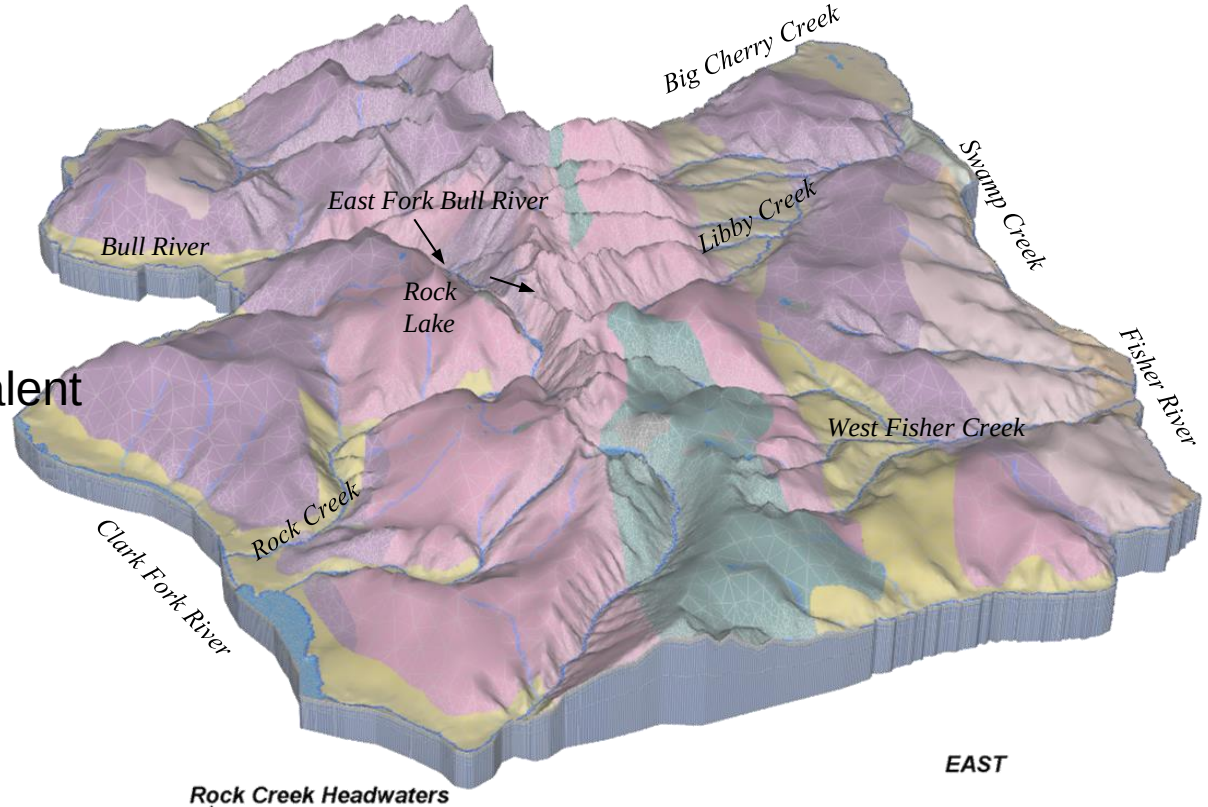
370 square mile model domain

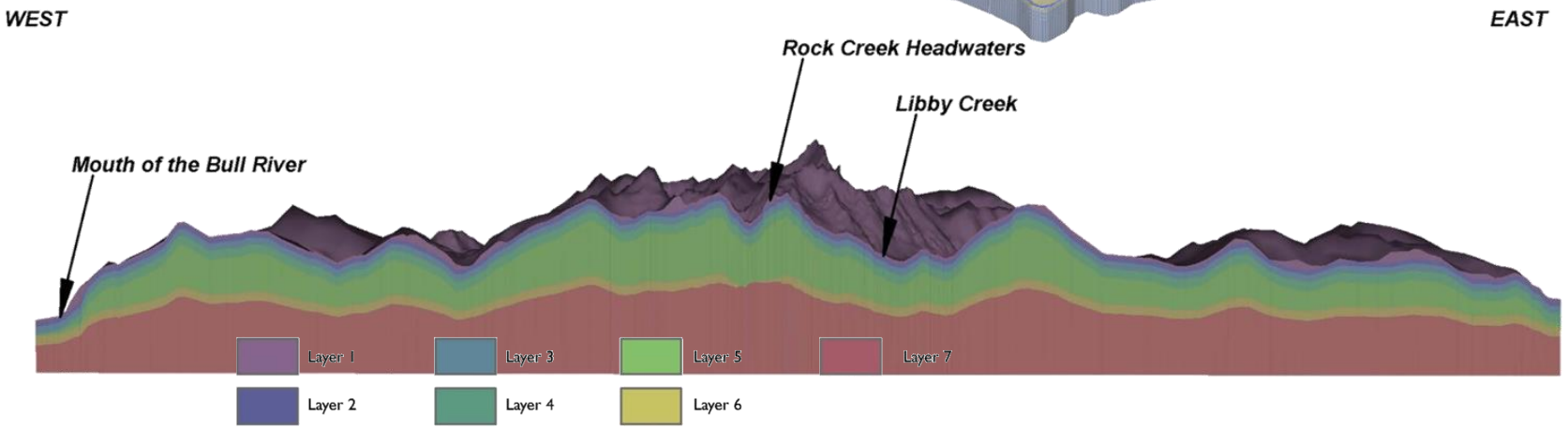
7 layers

Discrete fracture flow and equivalent porous media fracture flow

Boundary Conditions

- Streams
- Underflow
- Recharge





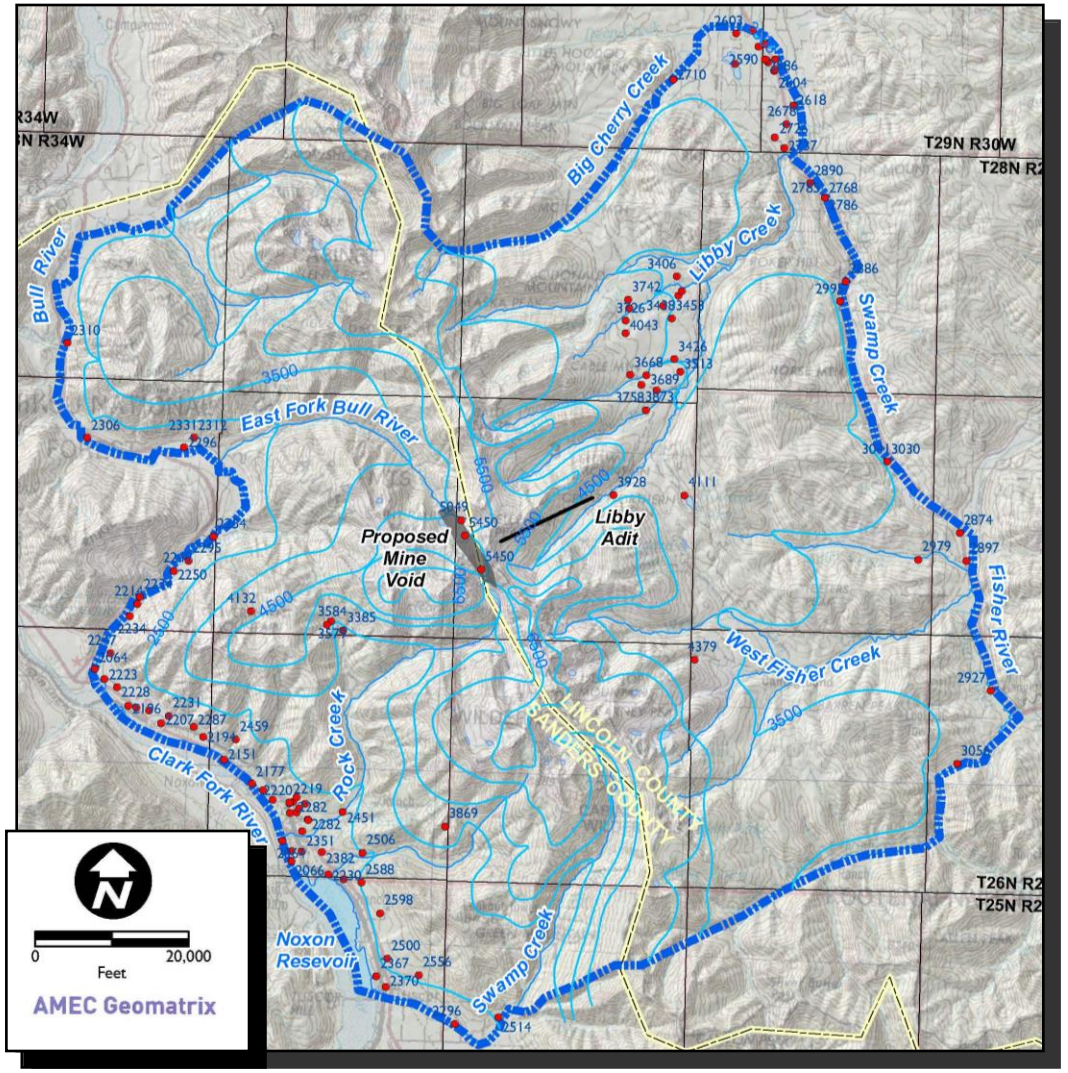
Steady-State Calibration

Head Targets

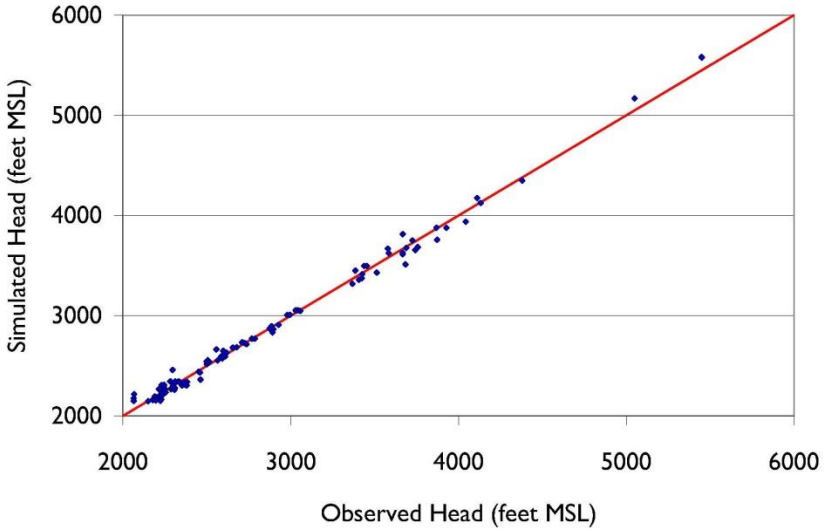
- 112 head targets

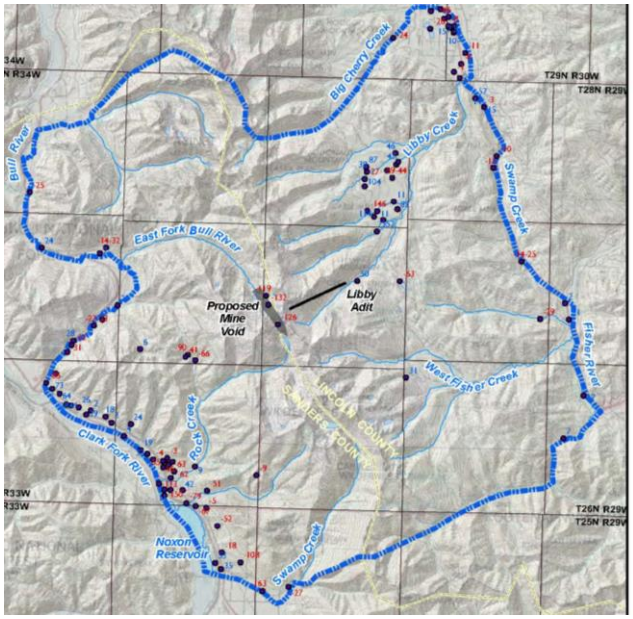
Flux Data

- USGS and USFS Stream Flow from lower reaches



Steady State Results



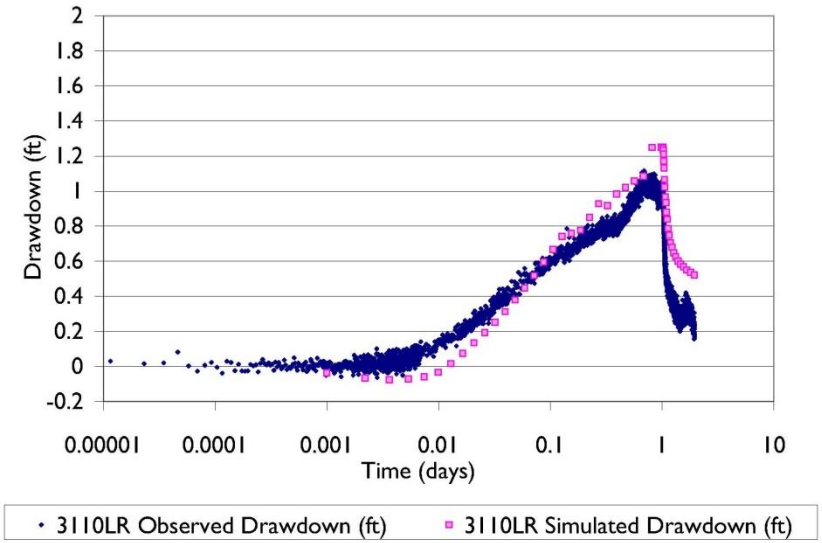


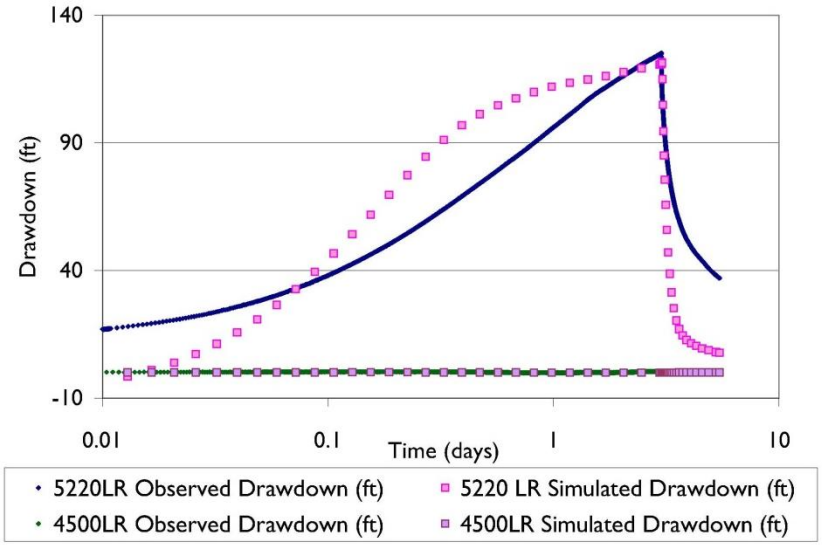
residual standard deviation /range of observed heads – 0.017

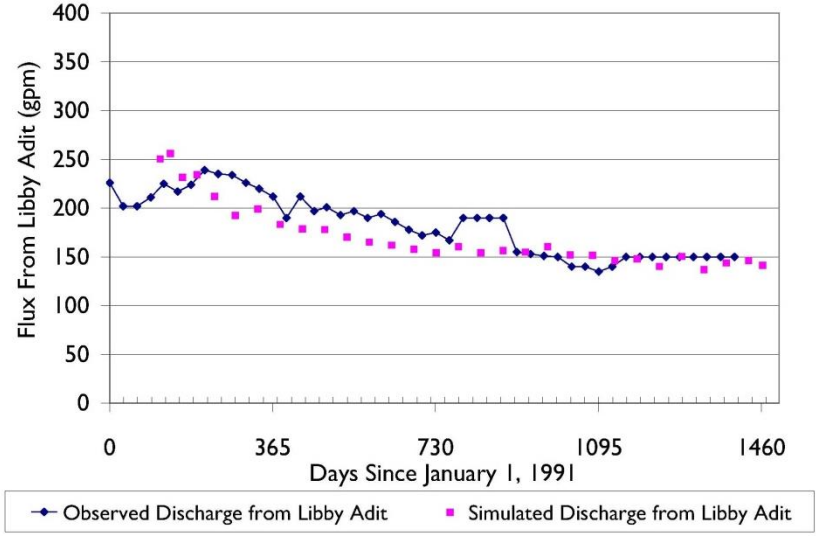
absolute residual mean = 46 feet (13 meters).

Transient Calibration

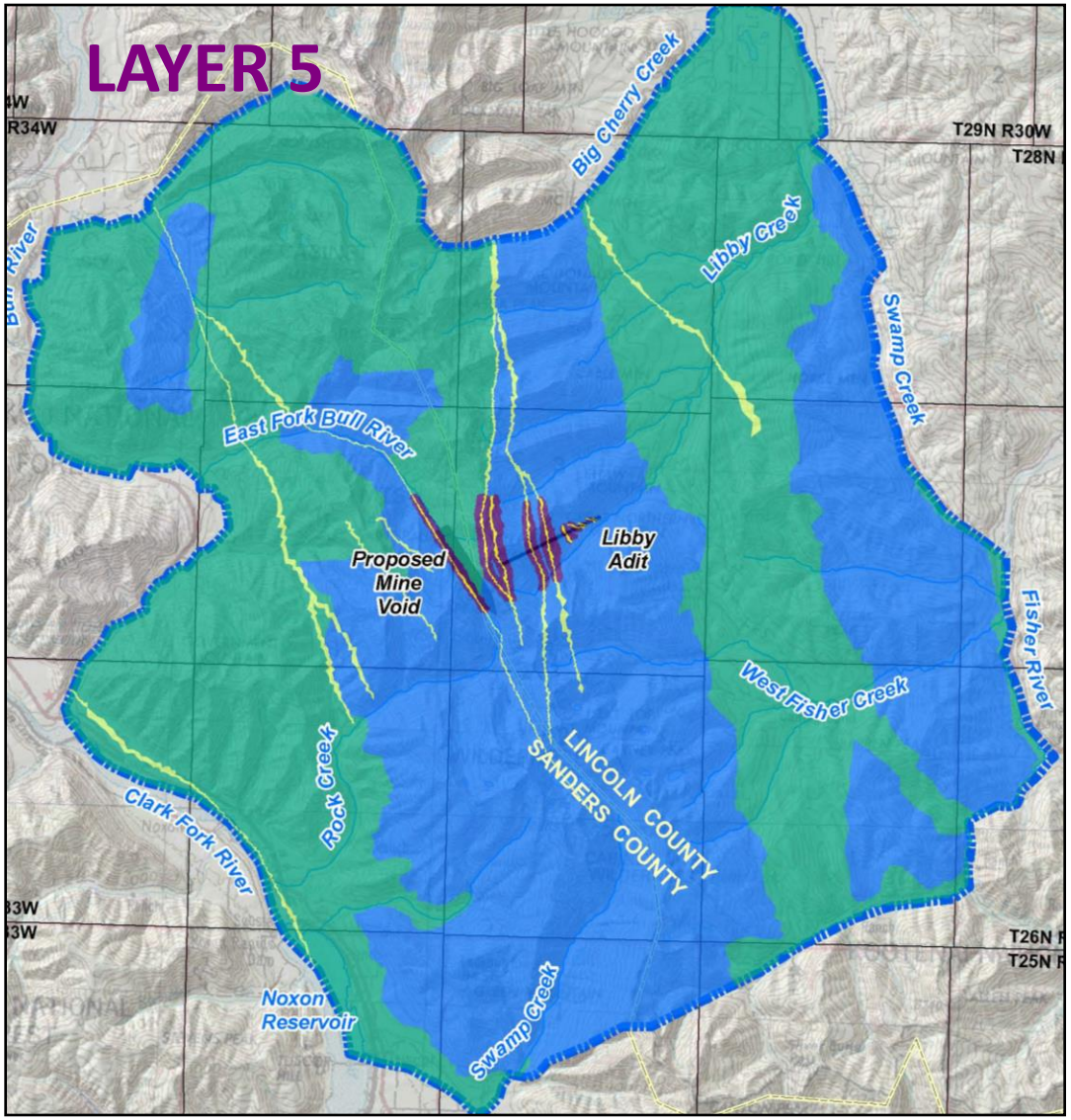
- Short-Term: Calibrated to time-drawdown from hydraulic testing in Libby Adit
- Long-Term: Calibrated to 4-years of dewatering rates from Libby Adit





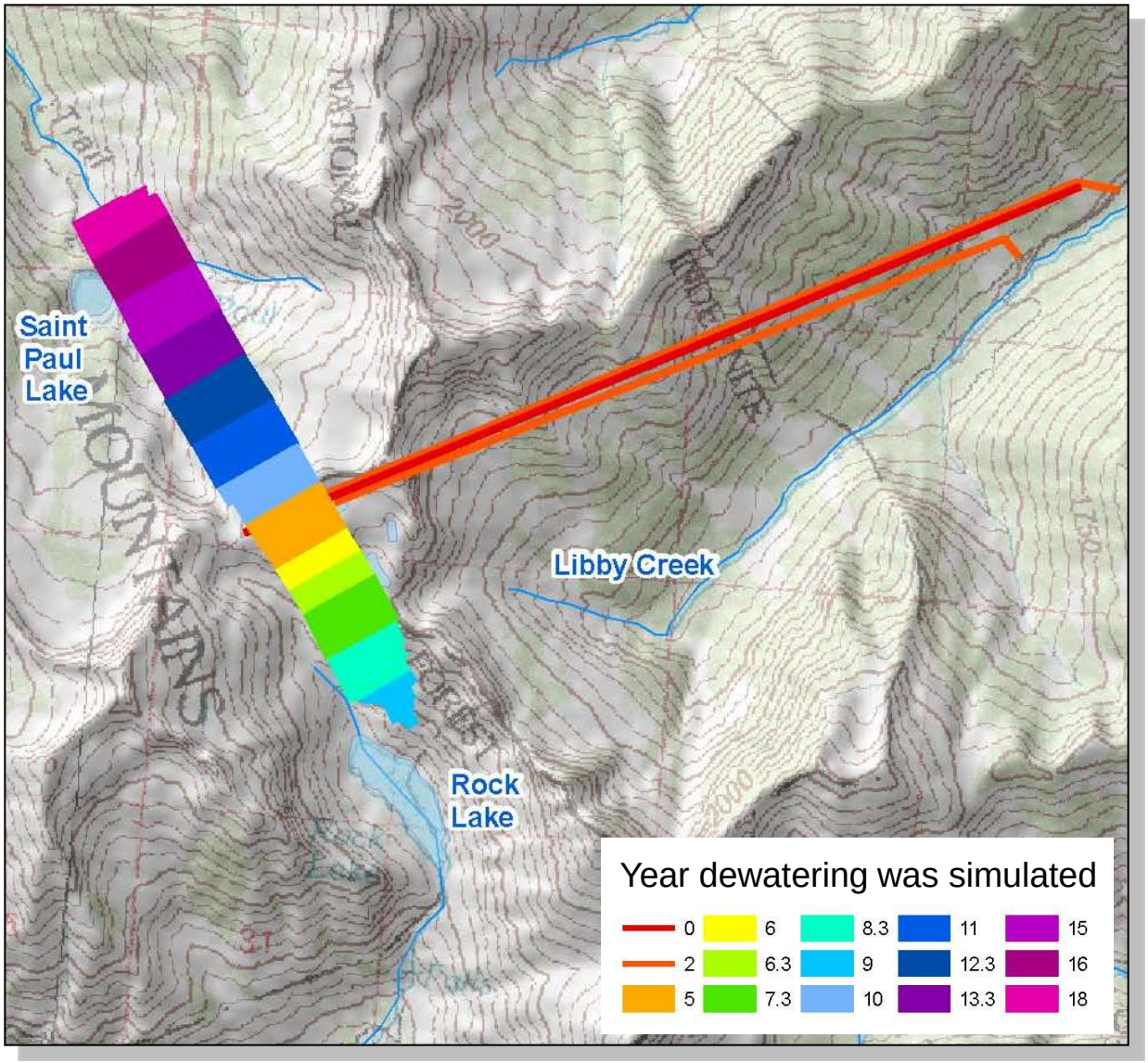


Resulting Hydraulic Conductivity Distribution



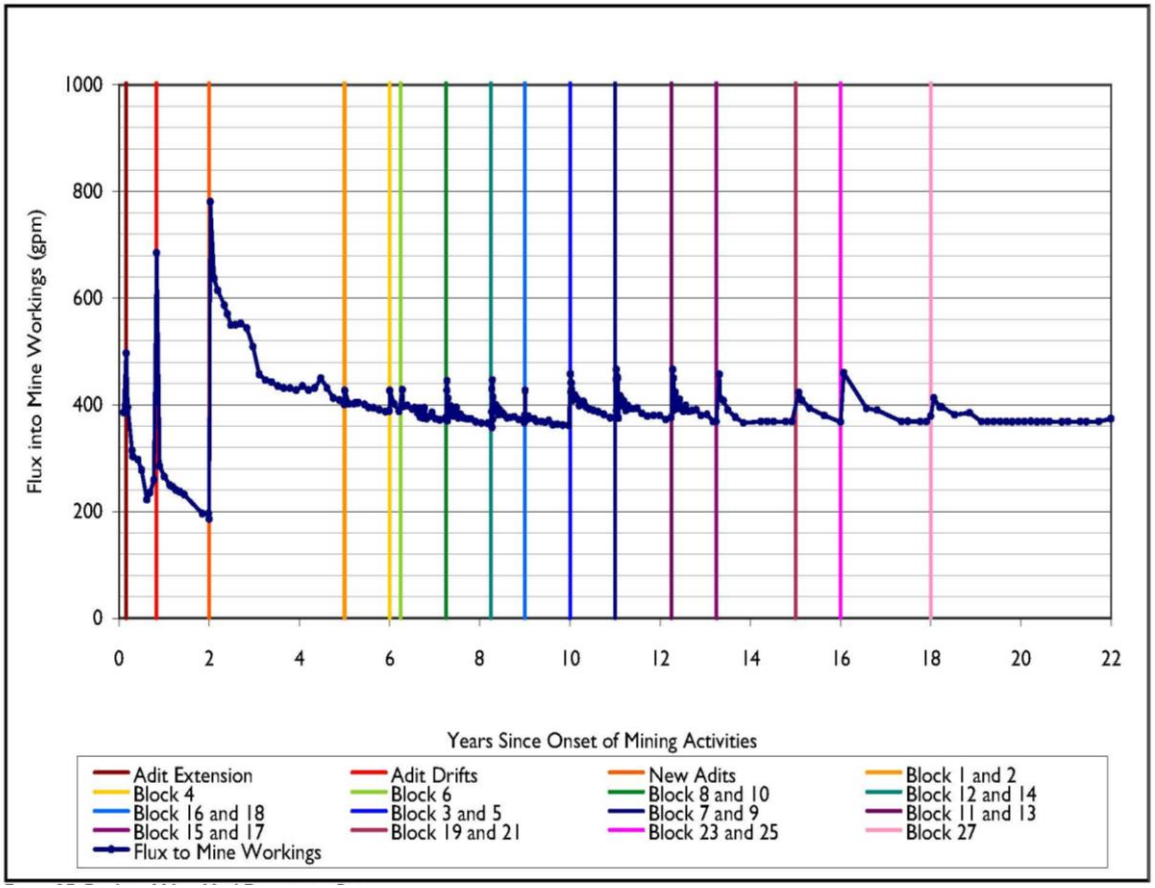
Mining Simulation

Mine features simulated with time-variant specified head boundaries



Dewatering rates

Predicted long term rates are approximately 380 gpm

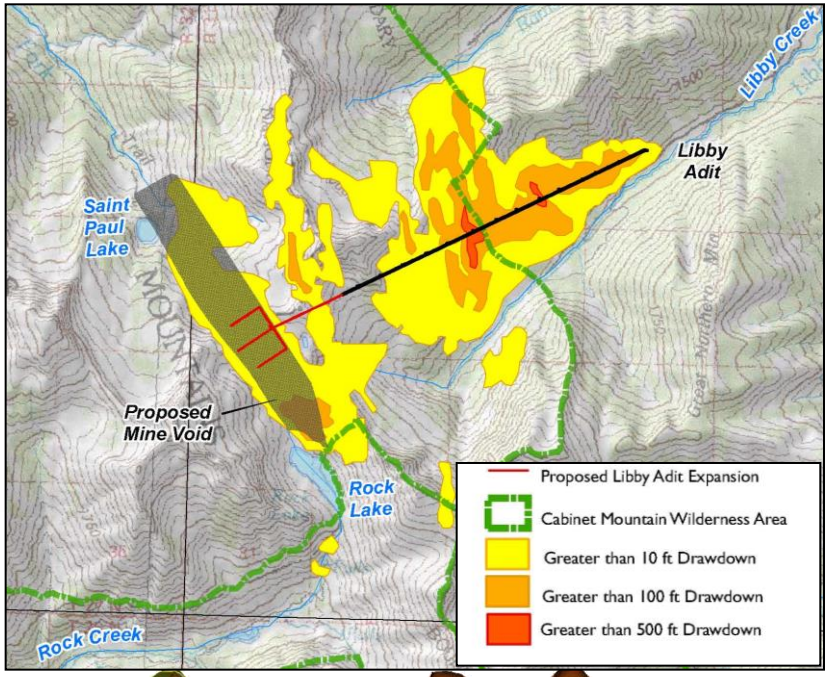


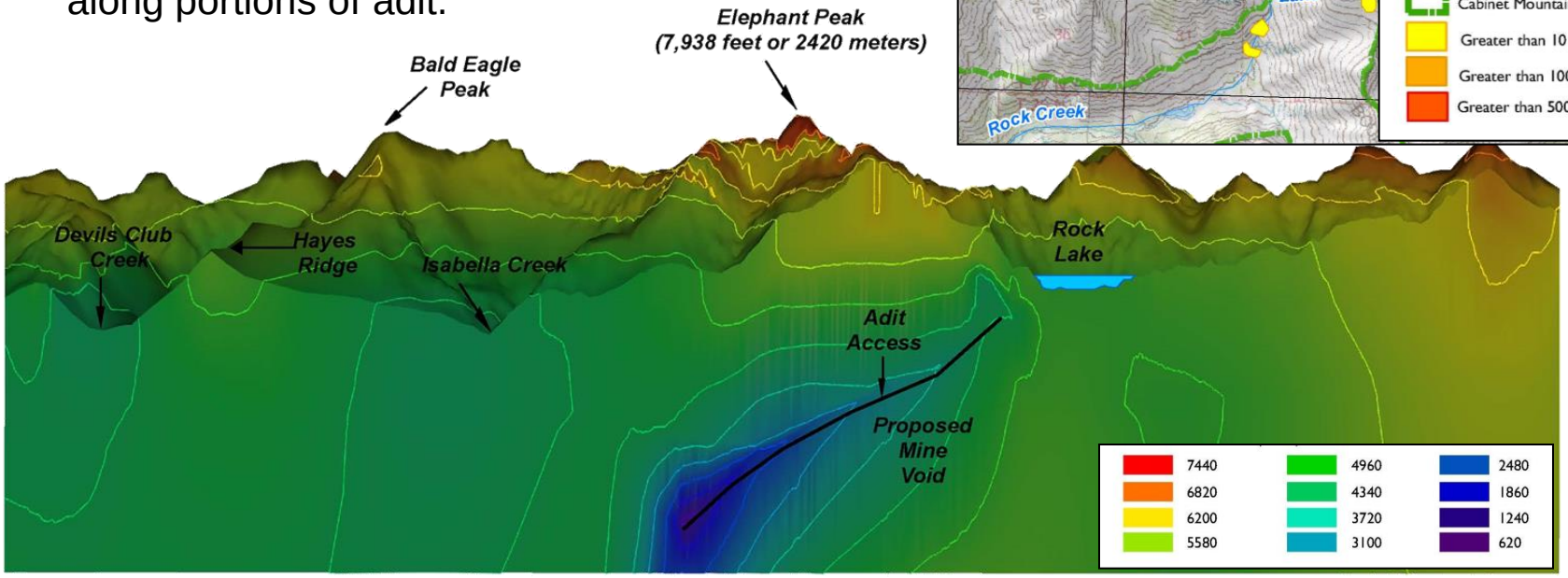
Predicted Drawdown

Drawdown will expand radially up to the water table.

Model suggests that where fractures connect mine workings to the surface, there will be greater water table drawdown.

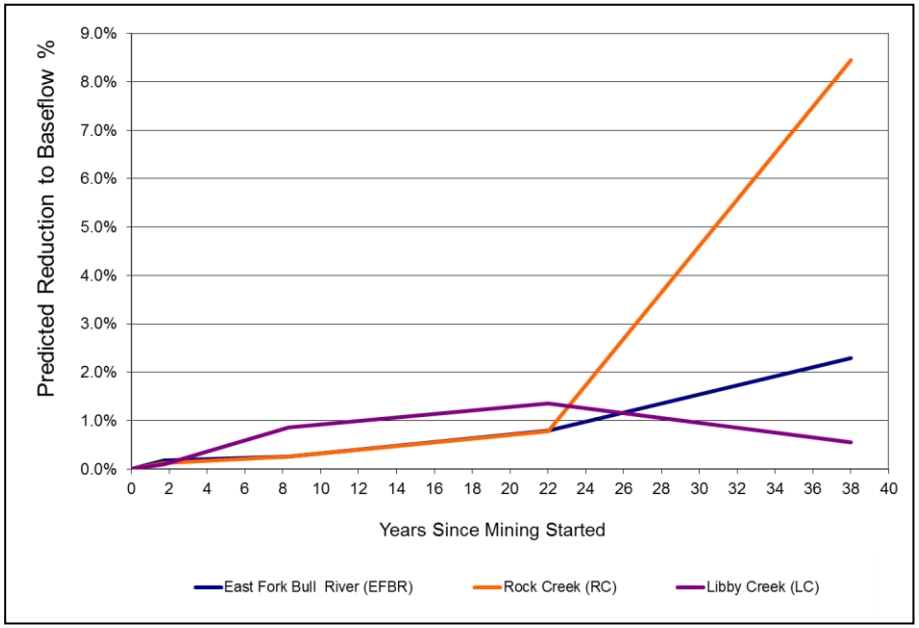
Greatest water table drawdown will occur above the upper end of mine void and along portions of adit.

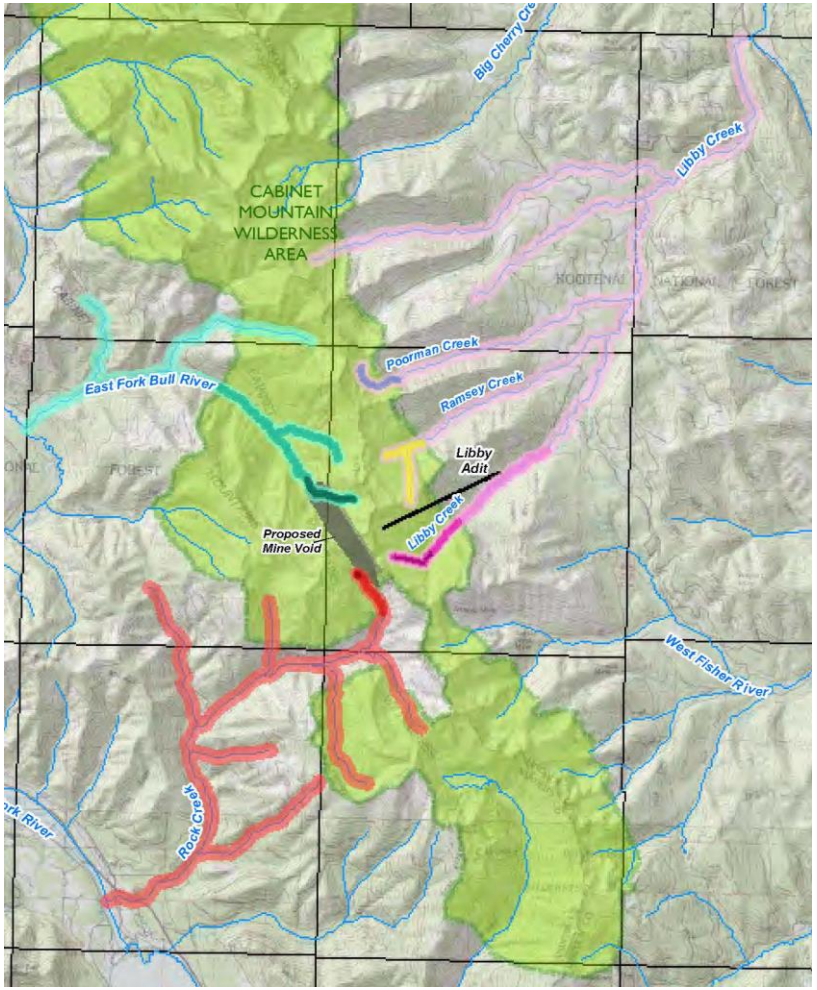




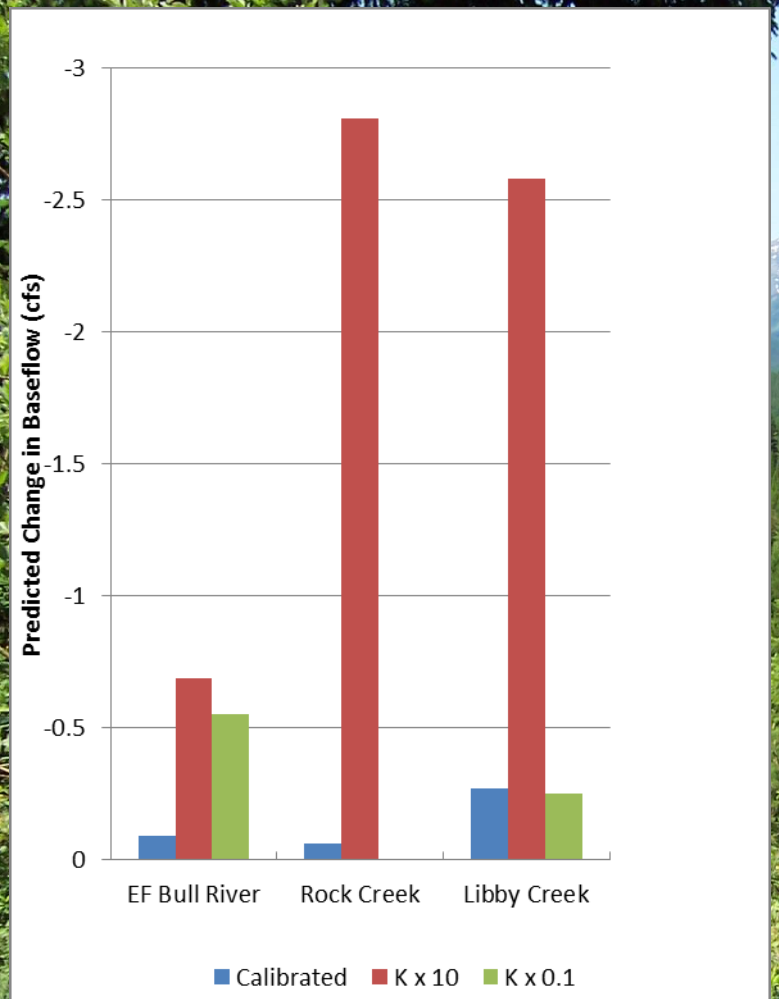
Predicted Stream Flow Depletion

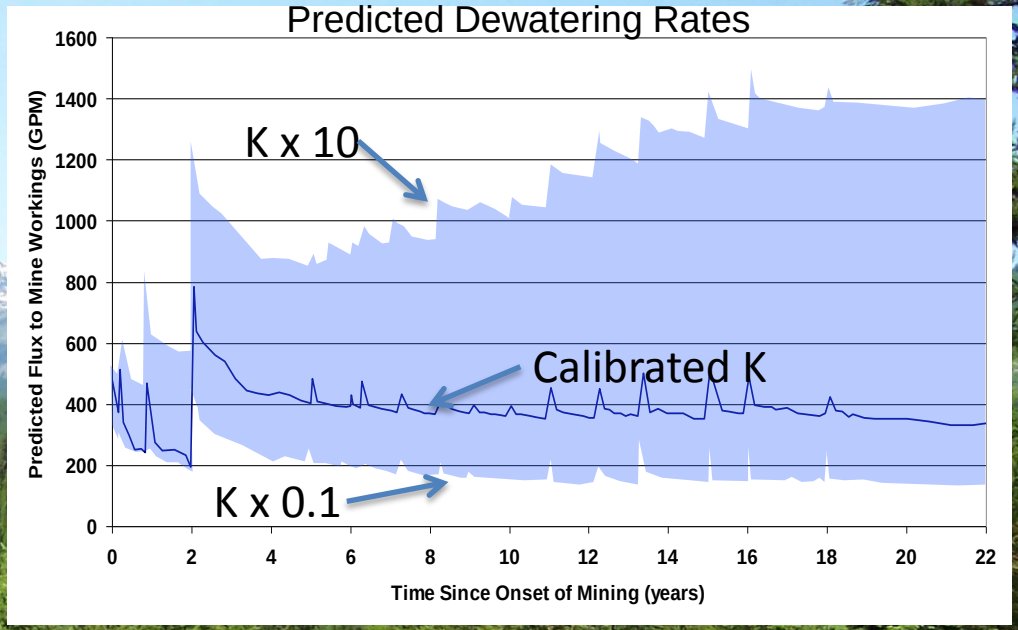
- Base flow predictions for main stems within measurement error.
- Reduction in outflow from Rock lake is <0.5 %, annually
- Depletions predicted in headwaters streams (some > 20%) – quantities uncertain





Uncertainty Analysis





- Varied hydraulic conductivity within a reasonable range
- Removed low K zones around faults and fractures
- Produced a range of predicted impacts.

Uncertainty and Appropriate Use of Model in NEPA Analysis

Originally presented predictions for major streams and tributaries, where we had data for base flow calibration.

Due to stakeholder concerns, asked to predict stream flow depletion in headwaters streams.

- Minimal base flow data for headwaters streams available for calibration.
- Extent of perennial reaches unknown. Some streams are intermittent in late summer.

Model predicted > 20% base flow reduction in some headwaters streams.

- Uncertainty associated with these predictions is large and difficult to quantify.
- Difficult to evaluate the accuracy of predictions

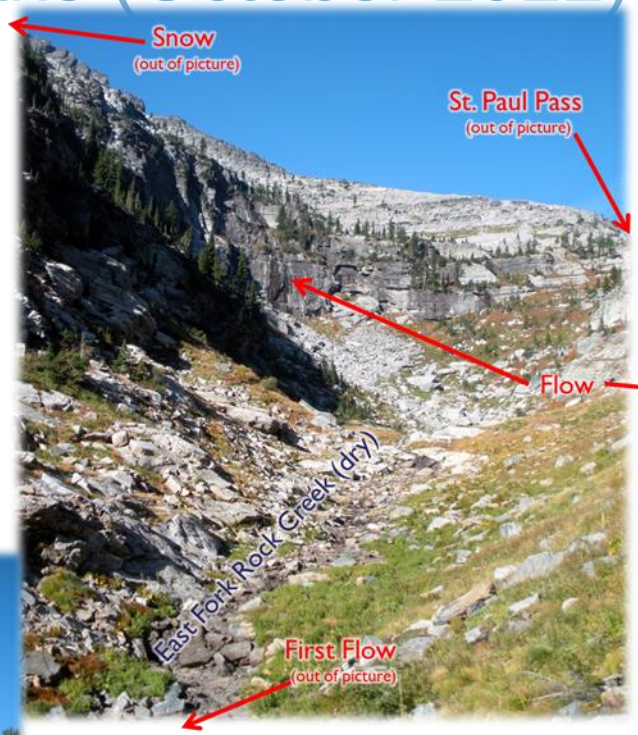
2012 Additional Analyses

Mitigation: model simulations indicate that impacts to stream flow could be reduced by grouting of fractures in the mine workings.

Alternative conceptualization of groundwater surface water:

- Added mapped colluvium/alluvium zones to upper Rock Creek
- Increased Recharge and Storage
- Decreased vertical K
- Resulted in reduced stream flow depletions

Subsequent Field Investigation – Upstream of Rock Lake (October 2012)



Limitations

- Model simulates fully saturated conditions – does not allow for development of “perched” groundwater
  - Could over-predict communication between deep bedrock and surface
- Regional model is not capable of accurately predicting changes in headwaters stream flow
  - Highly localized systems

Conclusions

- The model is a good tool for EIS analysis even with limited site specific data.
- Model is capable of simulating groundwater flow within a reasonable range of error.
- Predictions are sensitive to permeability of major fault zones.
- Headwaters streams may not rely on regional groundwater system for baseflow
- Maximum stream flow reductions in Rock Creek and East Fork Bull River - 16 years after mine closure.

Conclusions (continued)

- The model provides a tool for water management and evaluating mitigation options.
- Model can be used to evaluate appropriate locations of surface water monitoring sites.
- Model will be recalibrated after exploration adit is advanced; drilling and testing will provide further empirical data.