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Groundwater Model - An Essential Tool for Mining Operations

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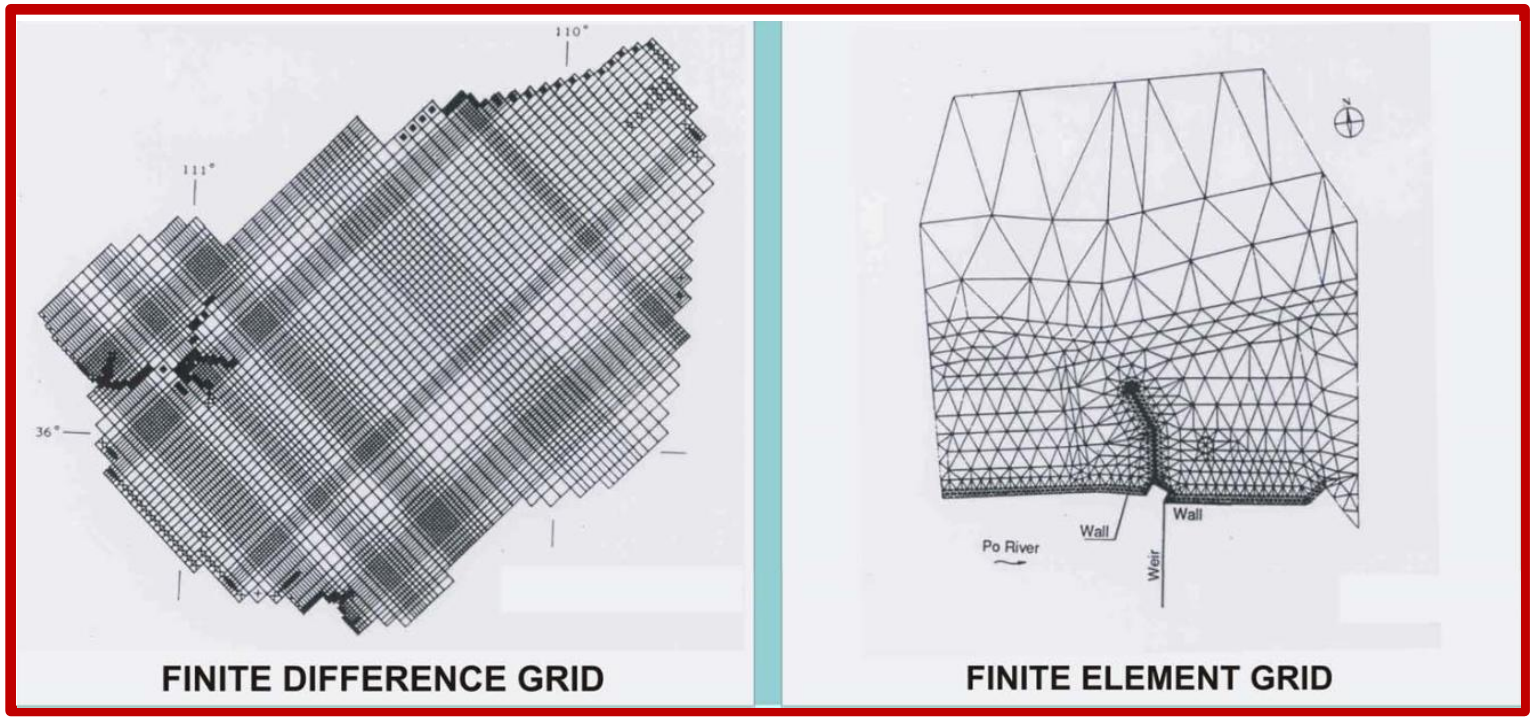
Presentation Contents

1. What Is a Model
2. Why Model
3. How to Model
4. Case Study– Barrick Goldstrike Mine
5. Conclusions

1. What Is a Model

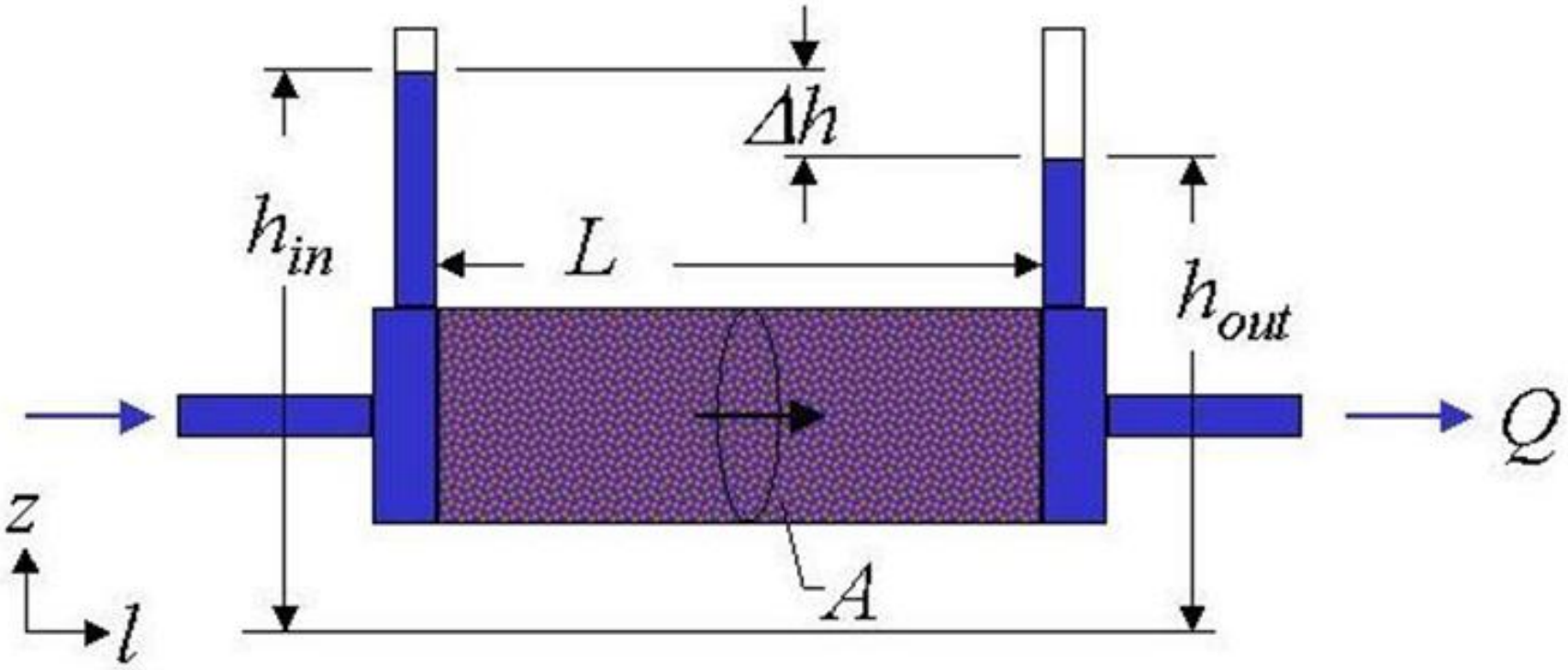
Mathematical representation of a real physical **system** and **processes**



Darcy's Flow – A Model Example

Process: Water flow due to energy gradients - Darcy's Law

$$Q = K * A * \frac{\Delta h}{L}$$



A Groundwater Flow Model

Governing Equation

= Darcy's law + water balance equation

For a transient, heterogeneous and anisotropic condition

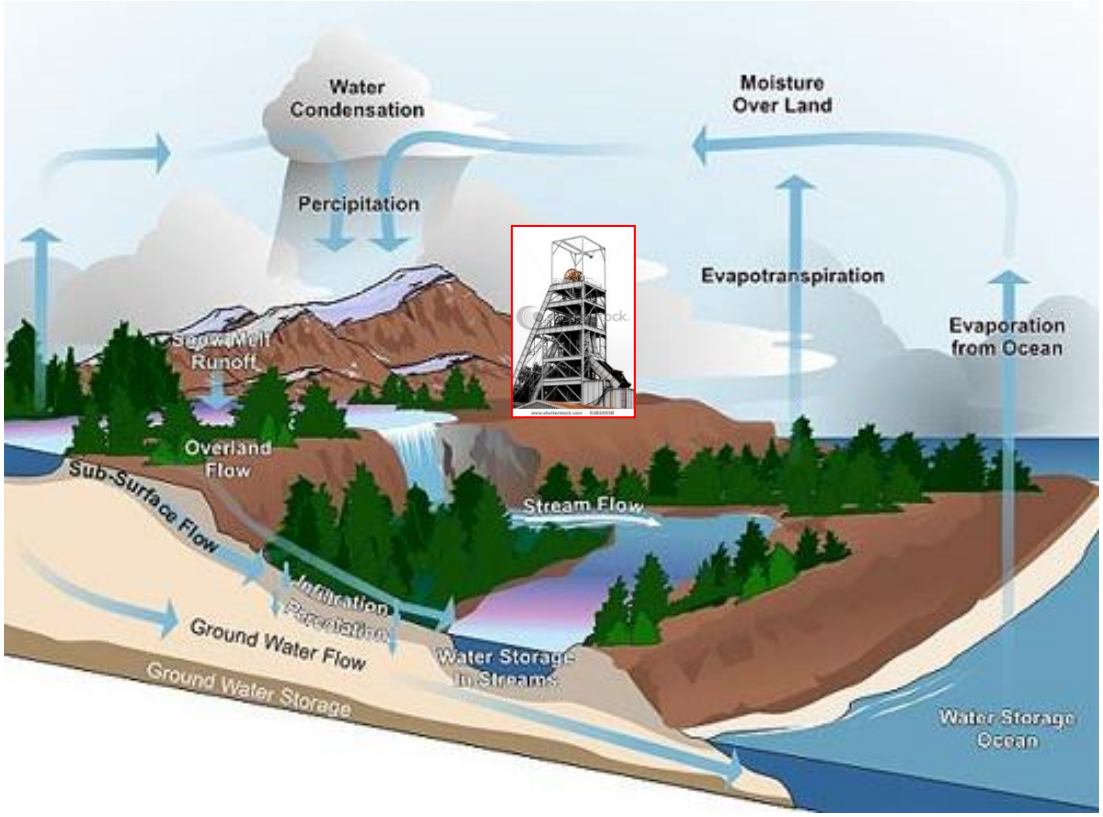
$$\frac{\partial}{\partial x}\left(K_x \frac{\partial h}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_y \frac{\partial h}{\partial y}\right) + \frac{\partial}{\partial z}\left(K_z \frac{\partial h}{\partial z}\right) = S_s \frac{\partial h}{\partial t} - R^*$$

Specific storage

Recharge or sink

Components of a Flow Model

- Governing Equation
- Boundary Conditions
- Initial Conditions (for transient problems)

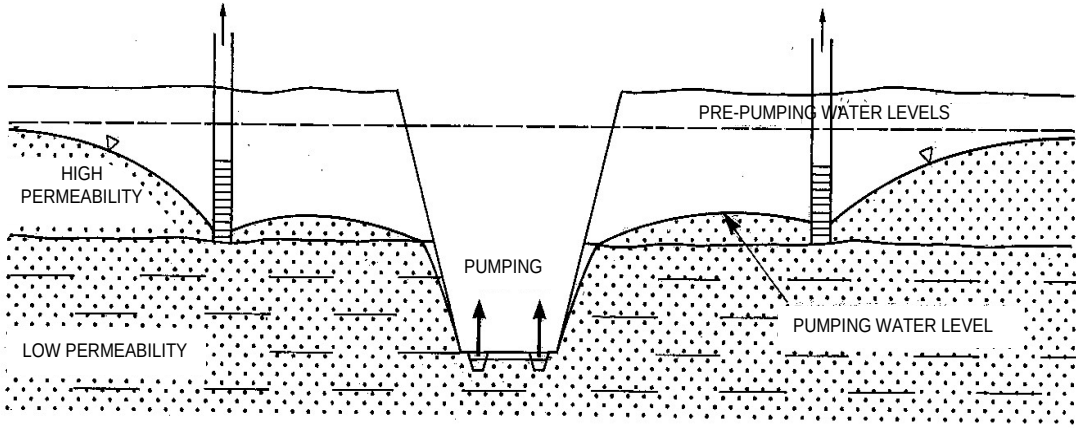


2. Why Model

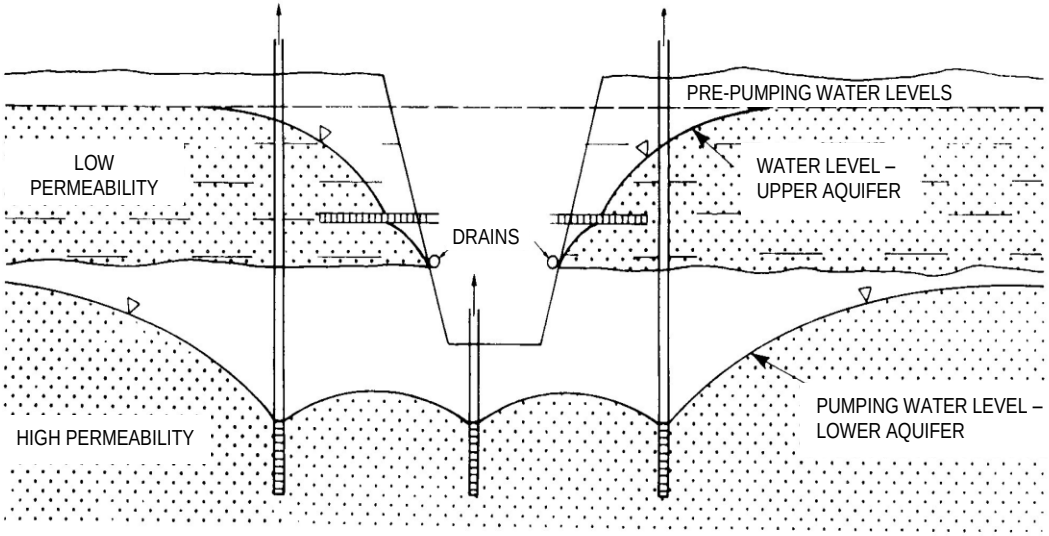
- Understand or discover flow system
- Compare alternatives
- Make quantitative predictions

- Maintain a dry working environment
- Ensure geotechnical stability
- Understand/remediate impacts associated with mine water management and post mining recovery

Guide Dewatering/Depressurization Program



Multiple aquifers: high K over low K



Multiple aquifers: low K over high K

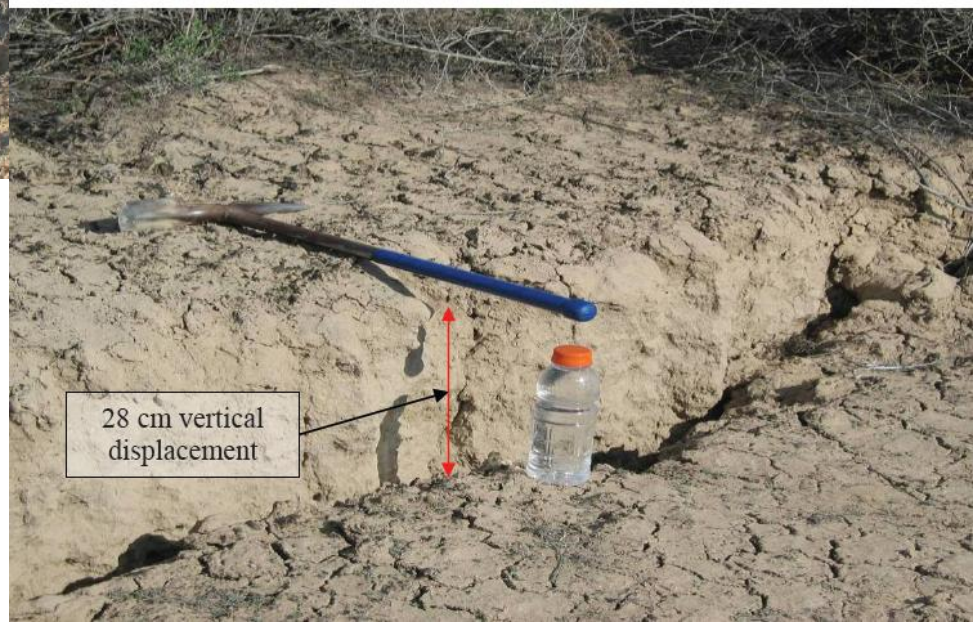
Otherwise

Without Dewatering
- Flooded Open Pit

Without Depressurization
- Unstable pit wall

Drawdown Cone Extent and Impact

Horizontal displacement due to mine dewatering



Vertical displacement due to mine dewatering

From Jon Price's photo archive

3. How to Model

- Model needs to answer specific questions
- Model needs to be a simplified abstraction of a complex reality
- Too many details can make it impossible to interpolate the results

How Not to Model

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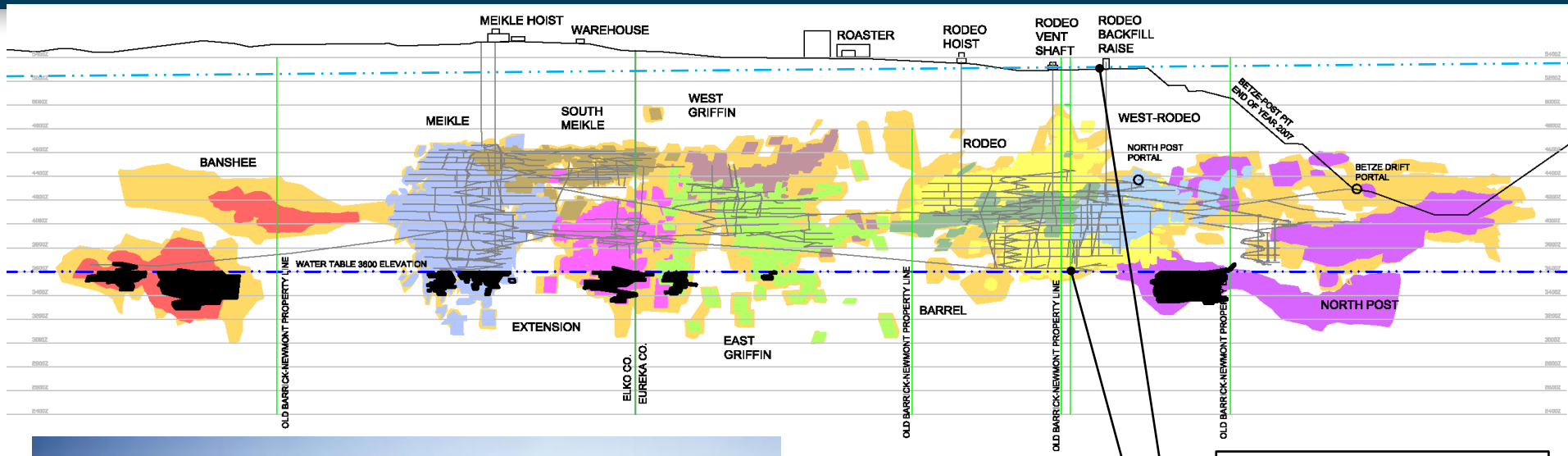
- Dump all data into the model and hope the model gets the results magically
- Remember that model is just a big calculator – do not expect model to do the thinking for you

Conceptual Model Is Critical

- Start with cartoon picture in mind
- Start with a guess
- Start simple

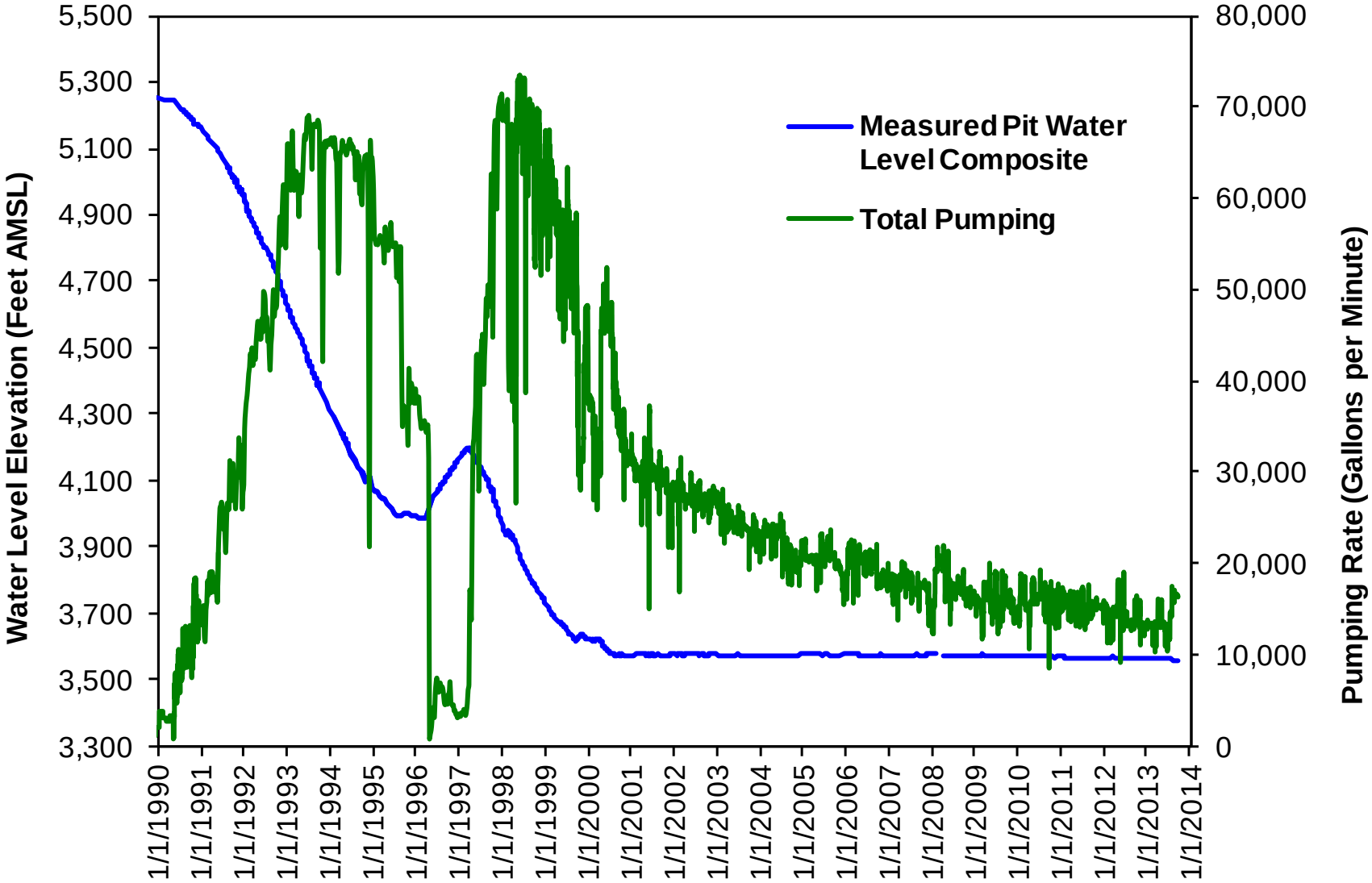
4. Case Study– Barrick Goldstrike Mine



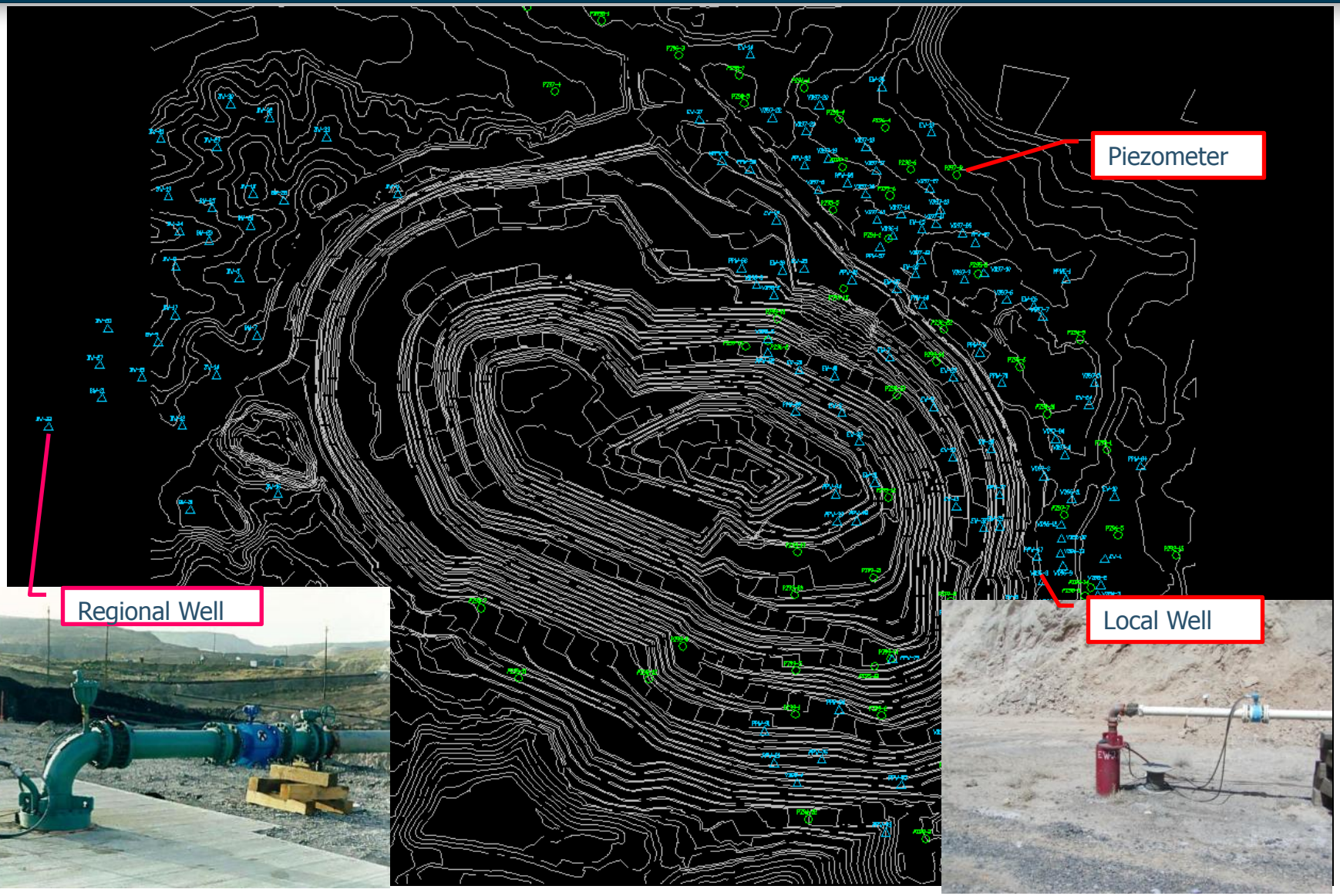
Pre-mining water table
5300 ft amsl

Current water table
3600 ft amsl
with a drawdown of 1700 ft

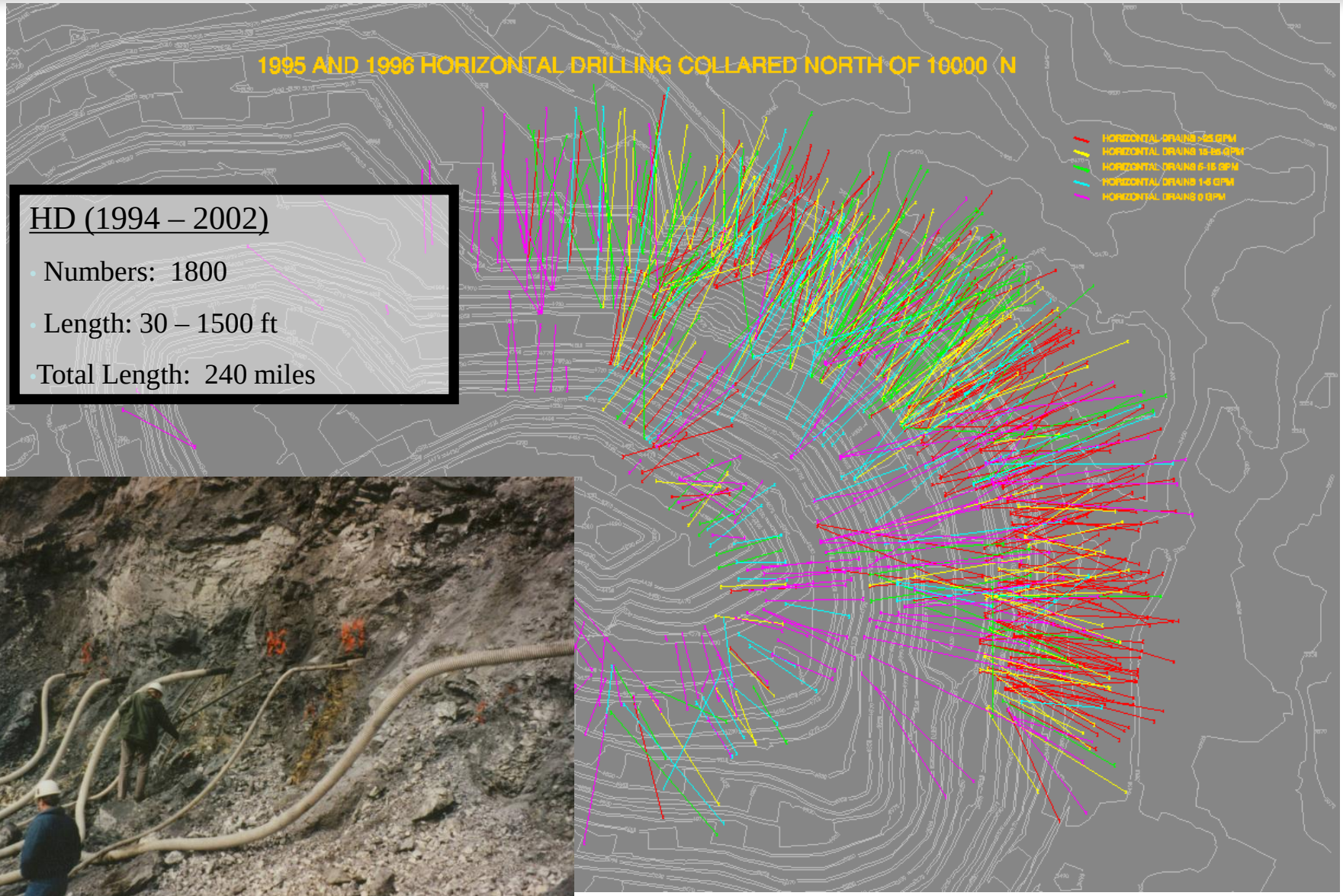
Dewatering Progress



Dewatering System - Active



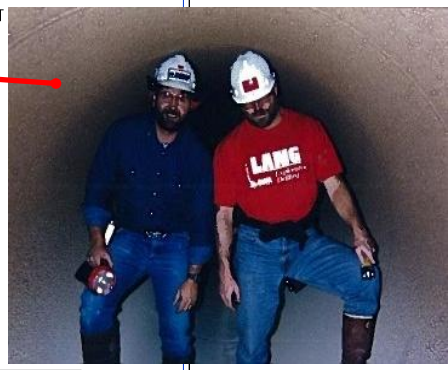
Dewatering System - Passive



HD (1994 – 2002)

- Numbers: 1800
- Length: 30 – 1500 ft
- Total Length: 240 miles

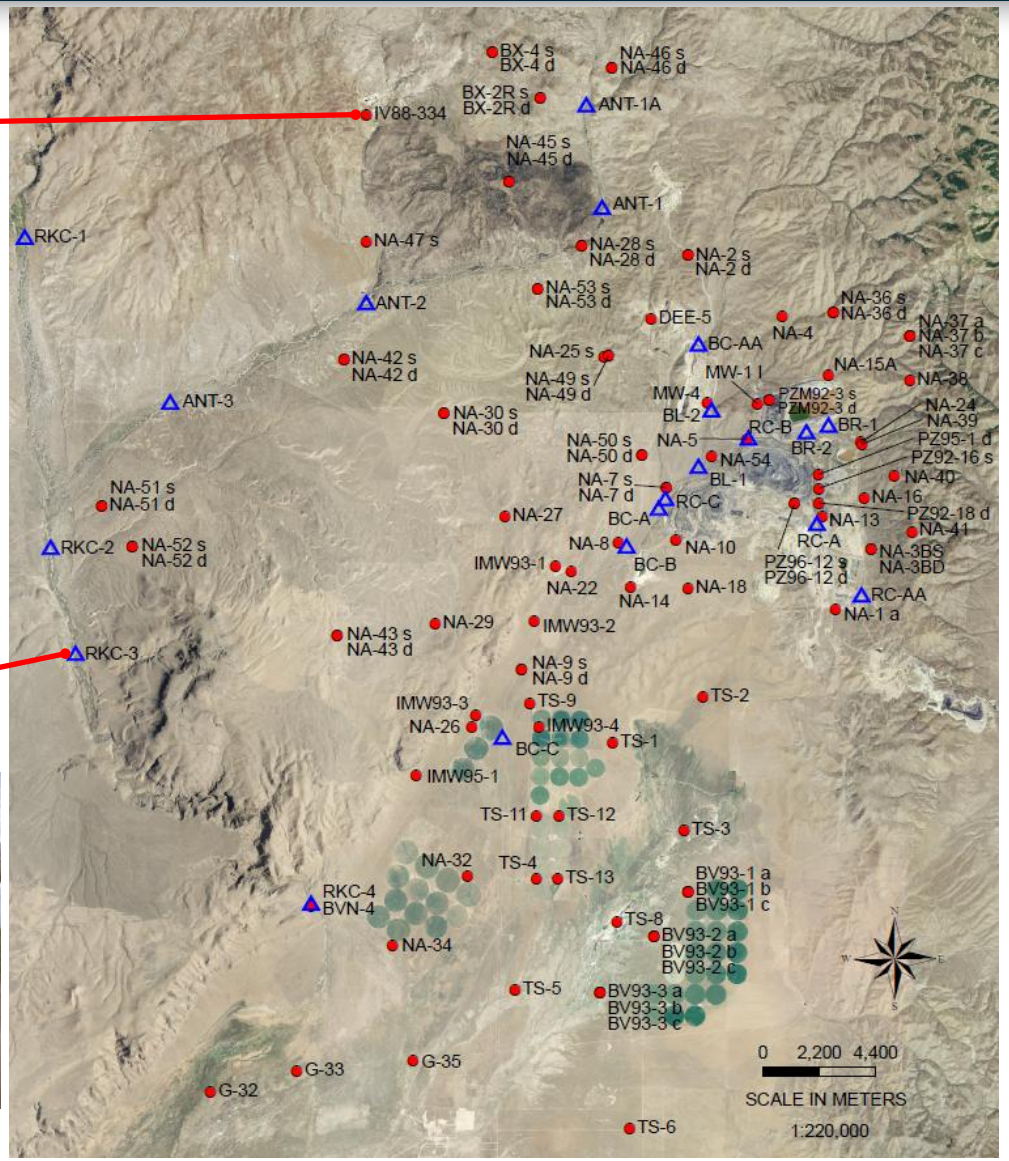
Water Management System



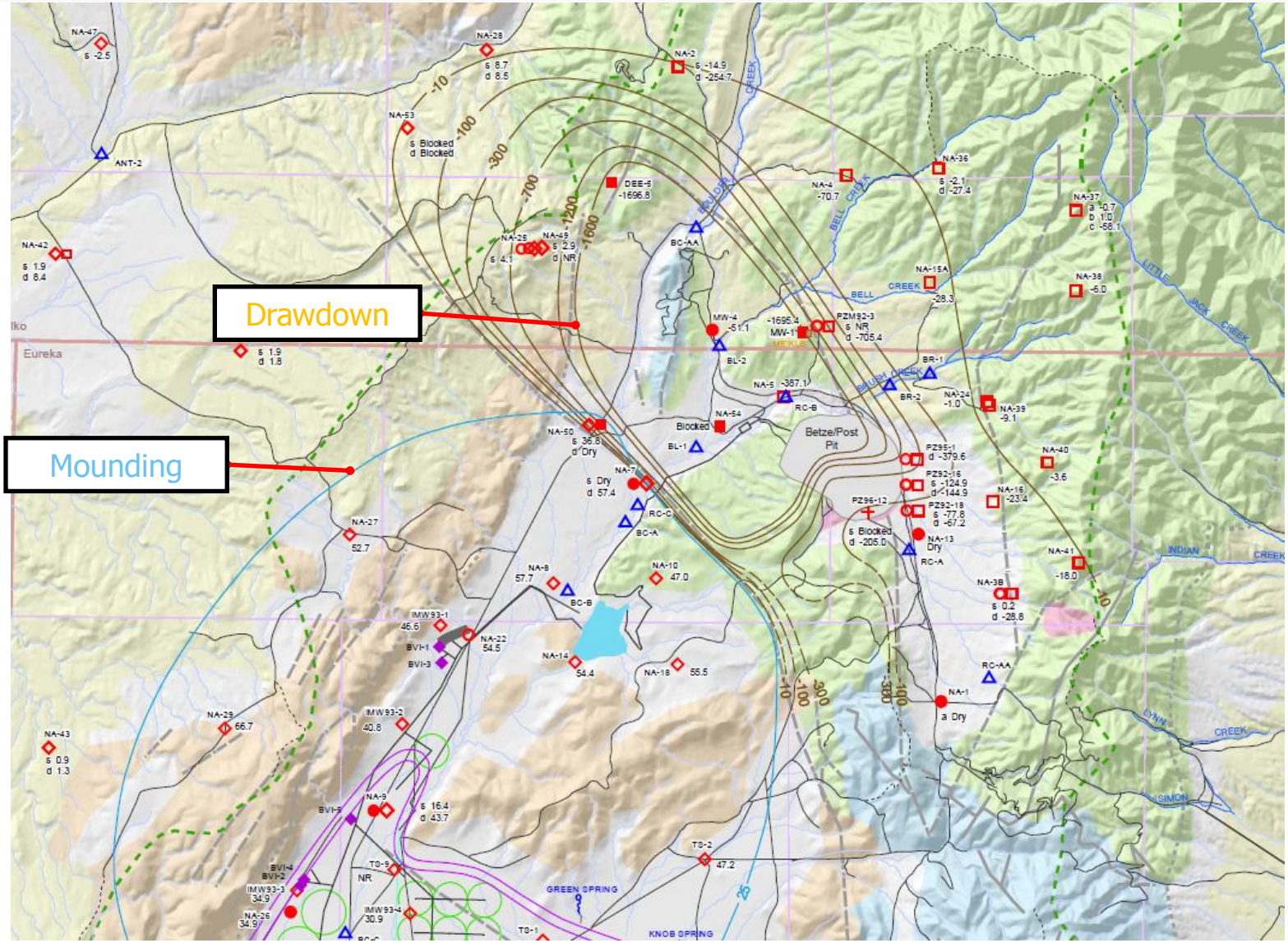
Monitoring System – 600 Mile²

Manual/Automatic Groundwater Monitoring

Manual/Automatic Surface Water Monitoring



Water Level Change To-Date



Ground Deformation – InSAR Results

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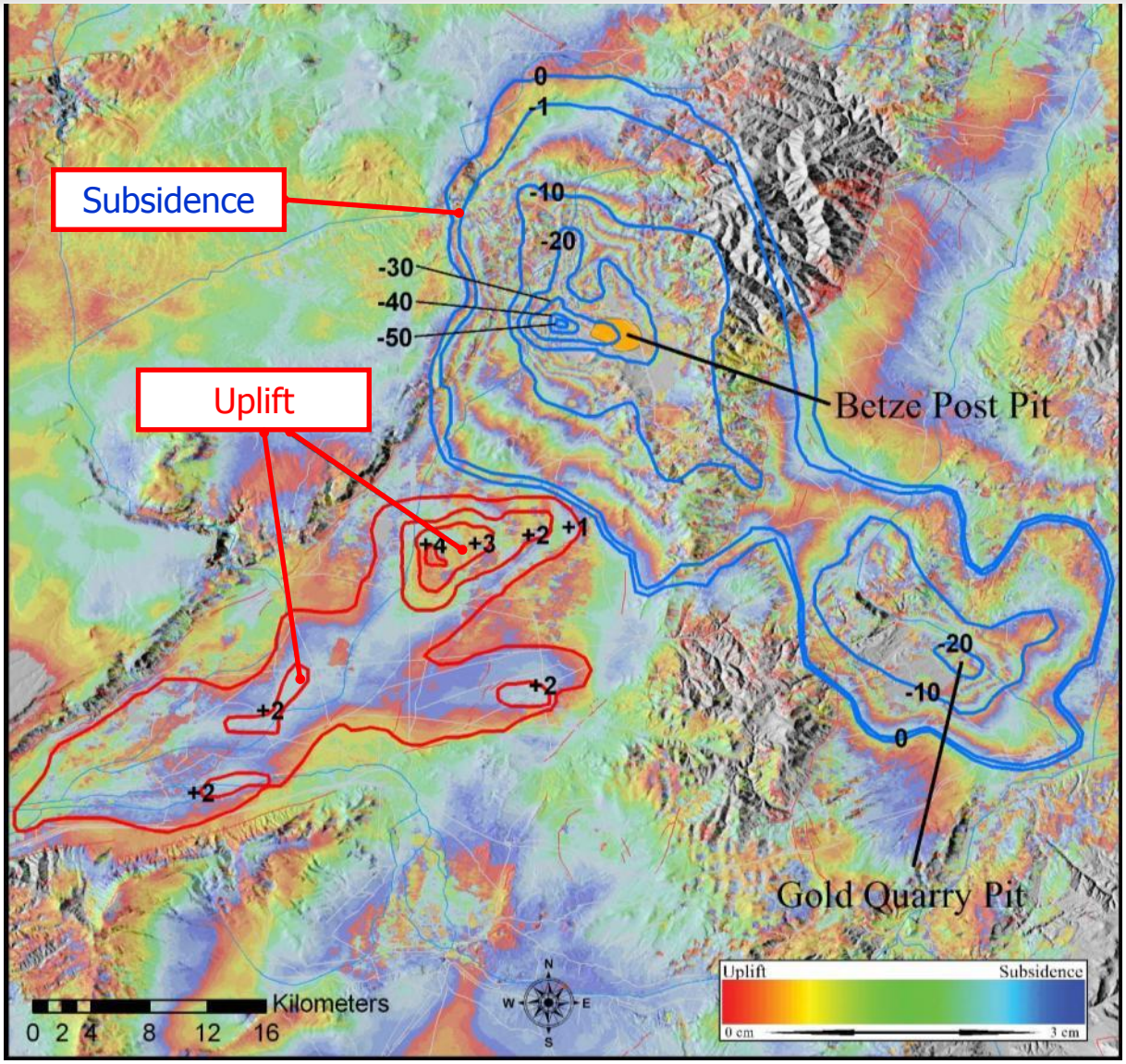
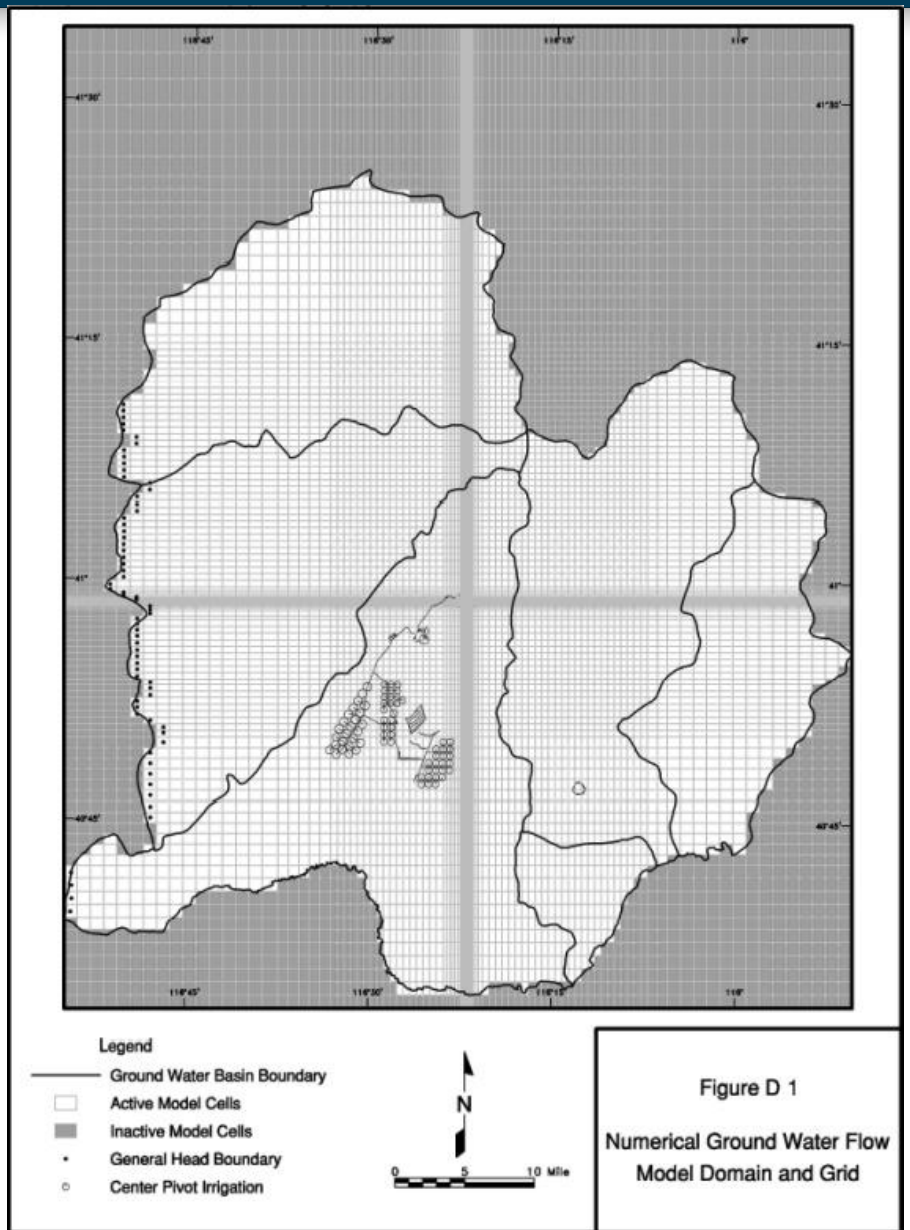
Subsidence and Uplift
June 1, 1992 – Nov 26, 2000

From Katzenstein, 2008

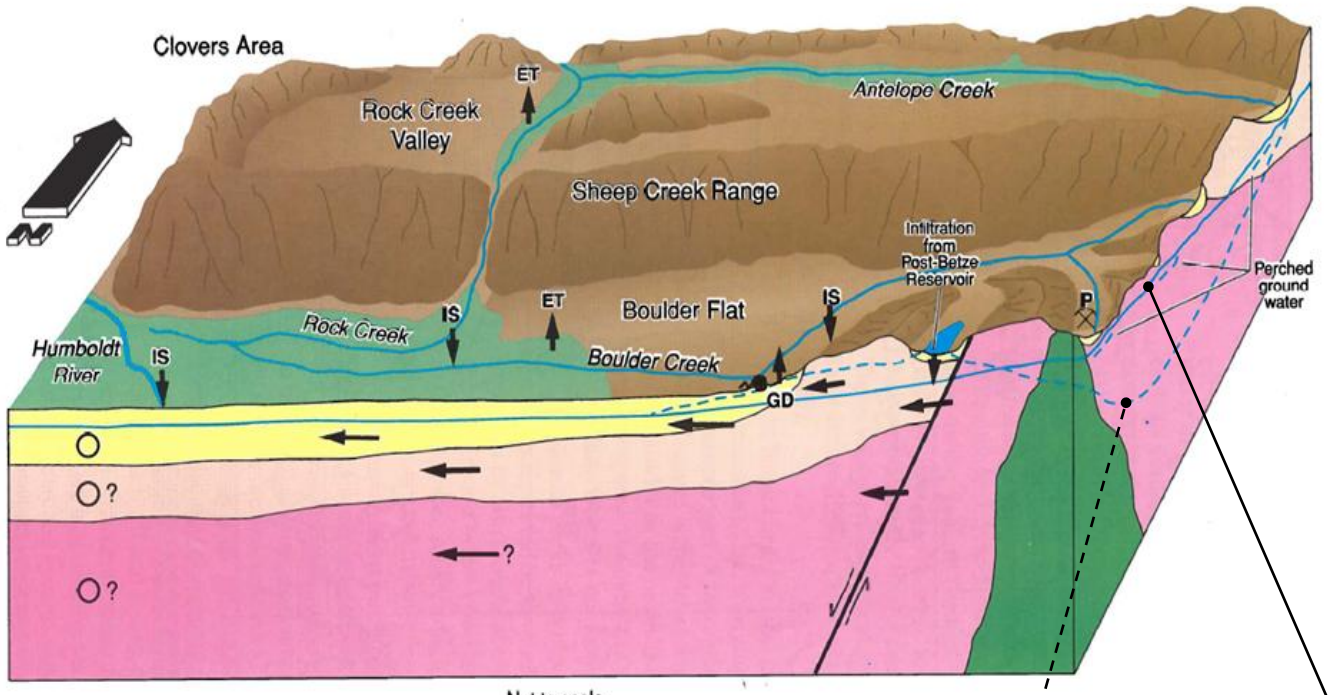


Flow Model



MODFLOW Model Grids

Conceptual Flow Model



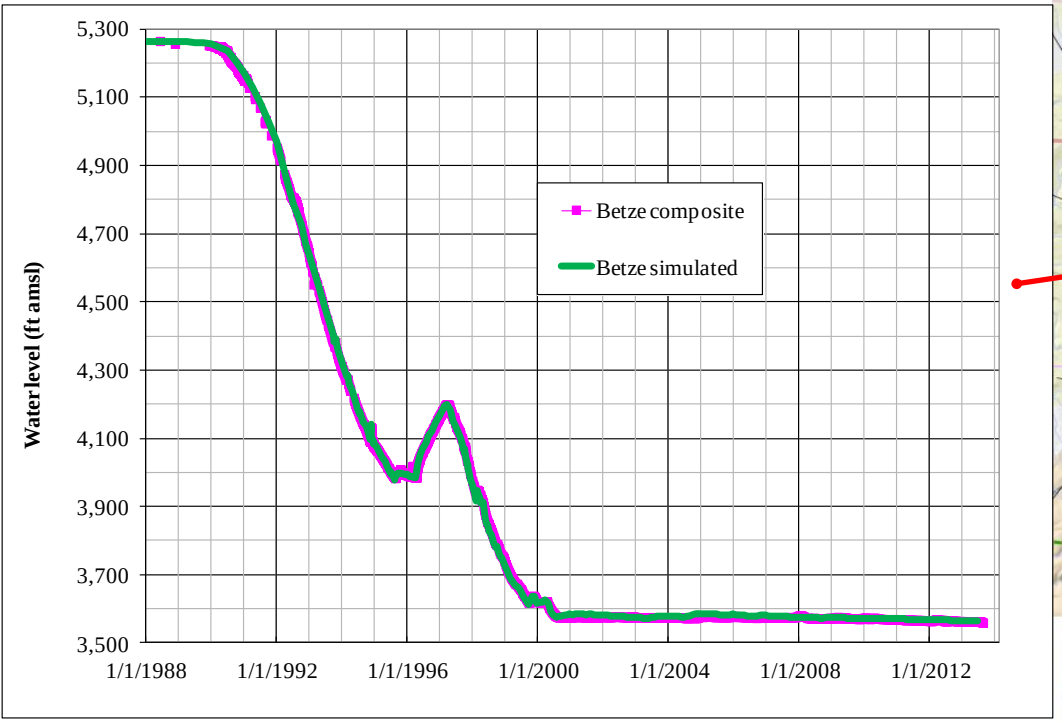
EXPLANATION

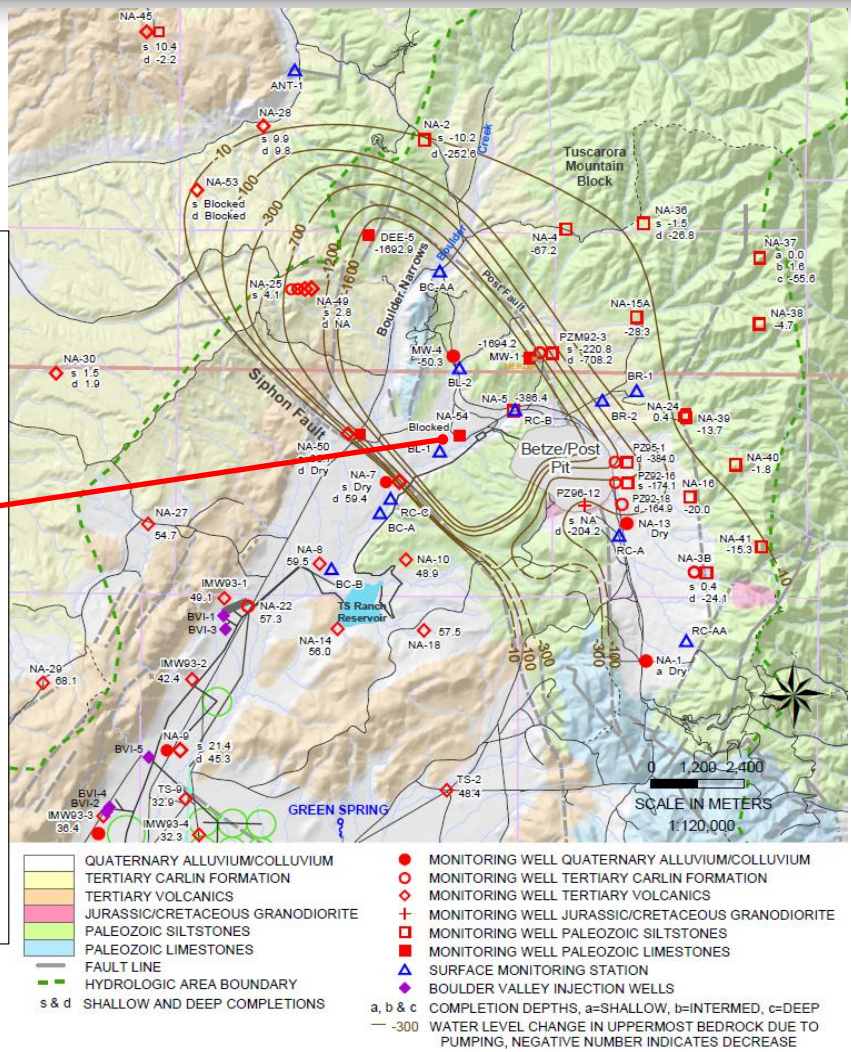
- Basin-fill deposits
- Volcanic rocks
- Granitic rocks
- Siltstones and carbonate rocks
- Phreatophytes—Area of ground-water discharge by evapotranspiration
- High-angle fault—Arrows indicate direction of relative movement
- ? Water table in 1990—Queried where uncertain
- ? Water table in 1993—Queried where uncertain
- ? Ground-water flowline—Queried where direction or amount of flow uncertain
- Ground-water flowline—Generalized direction of ground-water flow is toward viewer
- Ground-water flowline—Generalized direction of ground-water flow is away from viewer. Queried where uncertain
- ET Ground-water discharge by evapotranspiration
- GD Ground-water discharge as inflow to stream channel or as springflow
- IS Ground-water recharge as infiltration of streamflow
- Spring
- P Open-pit mine—Gold Quarry mine (Q) in Maggie Creek Area and Post-Betze mine (P) in Boulder Flat

Current water table

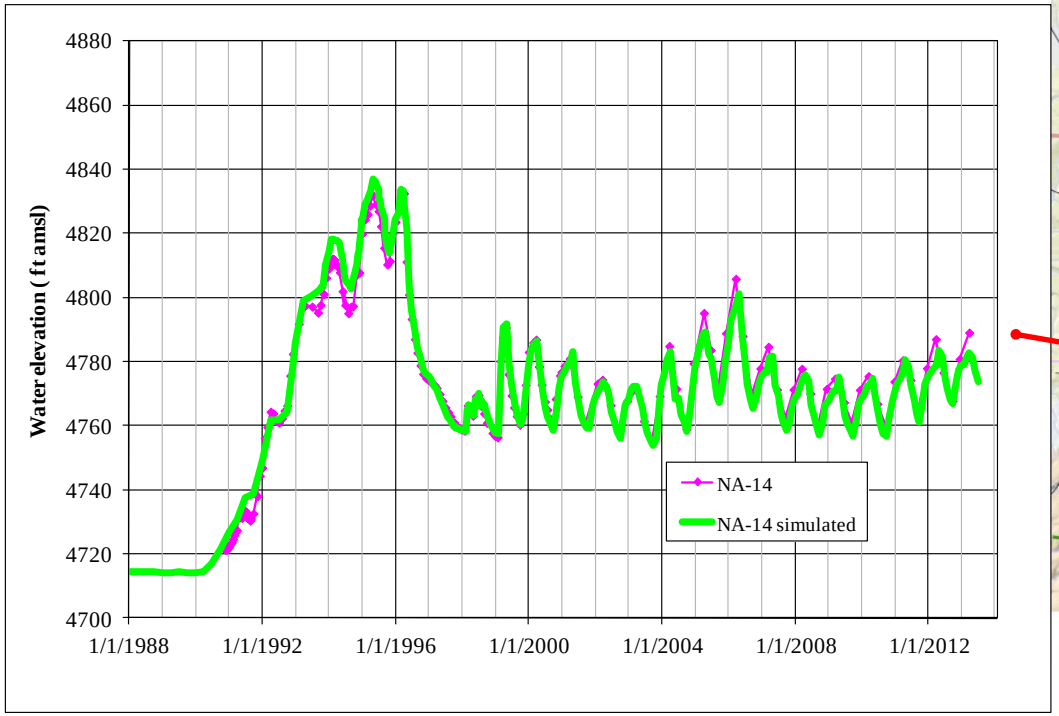
Pre-mining water table

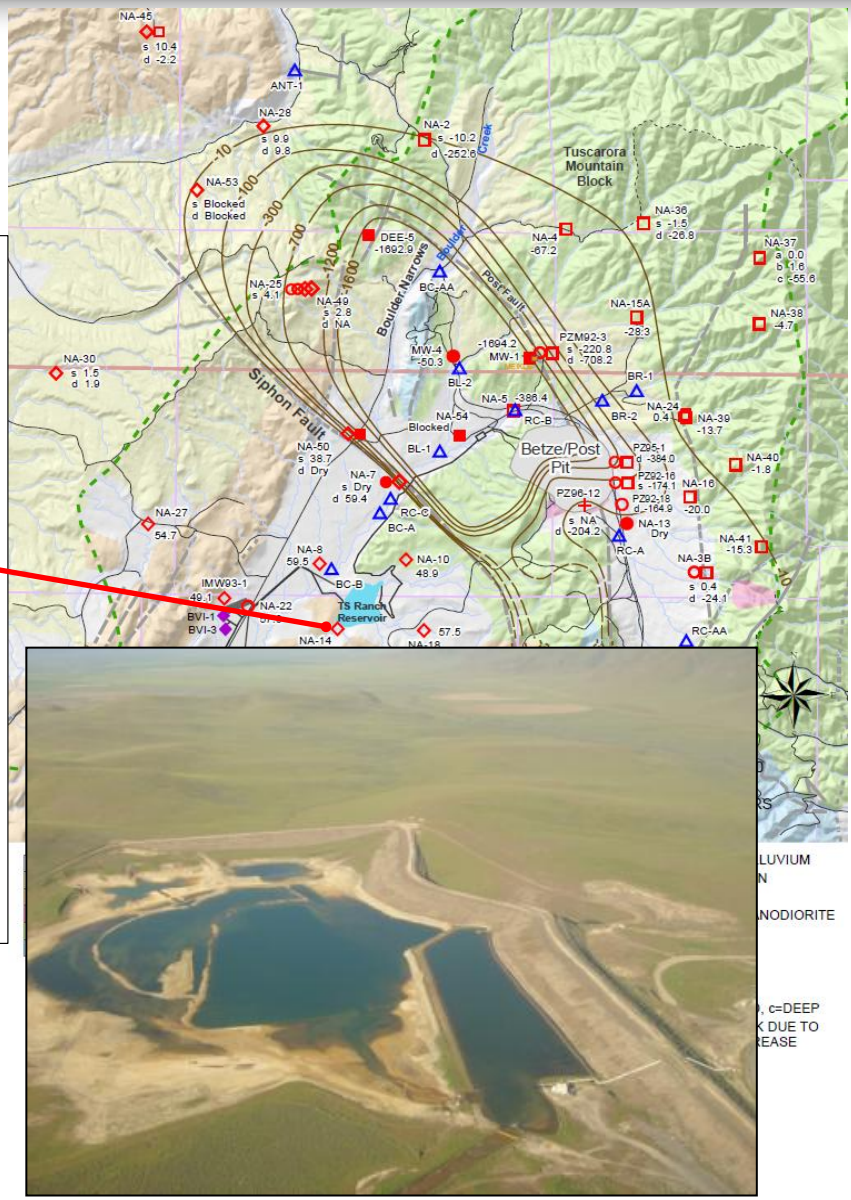
Flow Model – Transient (Pit Area)





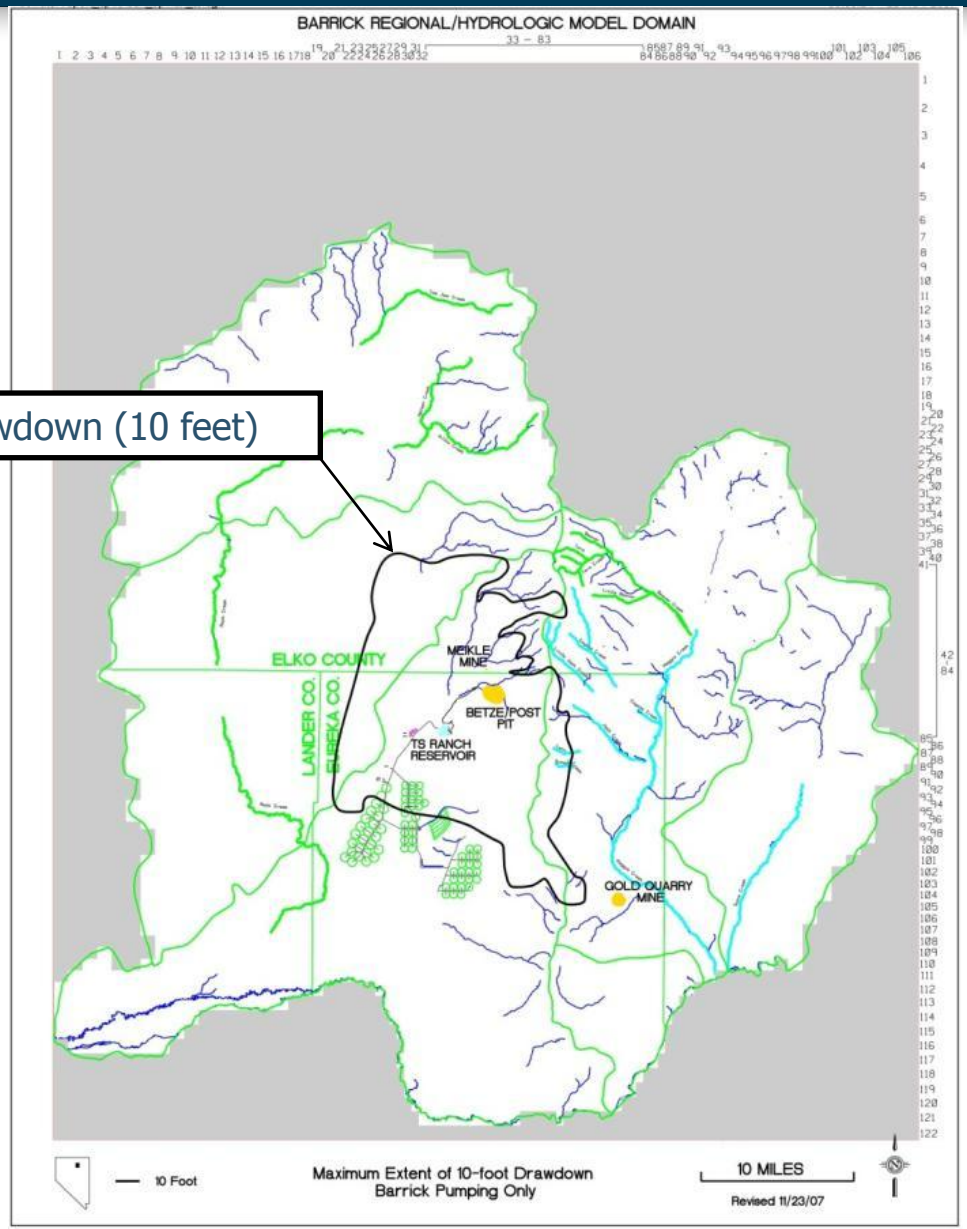
Flow Model – Transient (RIB Area)





Flow Model – Projection

Simulated Maximum Drawdown (10 feet)



5. Conclusions

A numerical model is an essential tool for

- permitting a mine
- safely operating a mine
- economically running a mine, and
- determining the environmental impacts of a mine