Effective Application of Groundwater Modeling to Design Construction Dewatering and Water Treatment Infrastructure

23rd Annual Mine Design, Operations, and Closure Conference
May 2015

McLaren Tailings Presentation Overview

- History
- Project Setting
- Challenges
- Design Approach
- Construction
- Results

History

New World Mining District

Near Cooke City and Northeast Entrance to Yellowstone National Park
Site of Crown Butte $65 M Buyout in 1997 and USFS $30 M Cleanup

McLaren Mill

Processed Au and Cu ore from 1933 - 1953
Tailings impoundment grew over Soda Butte Creek and Miller Creek
1950 tailings release mapped to the Lamar River

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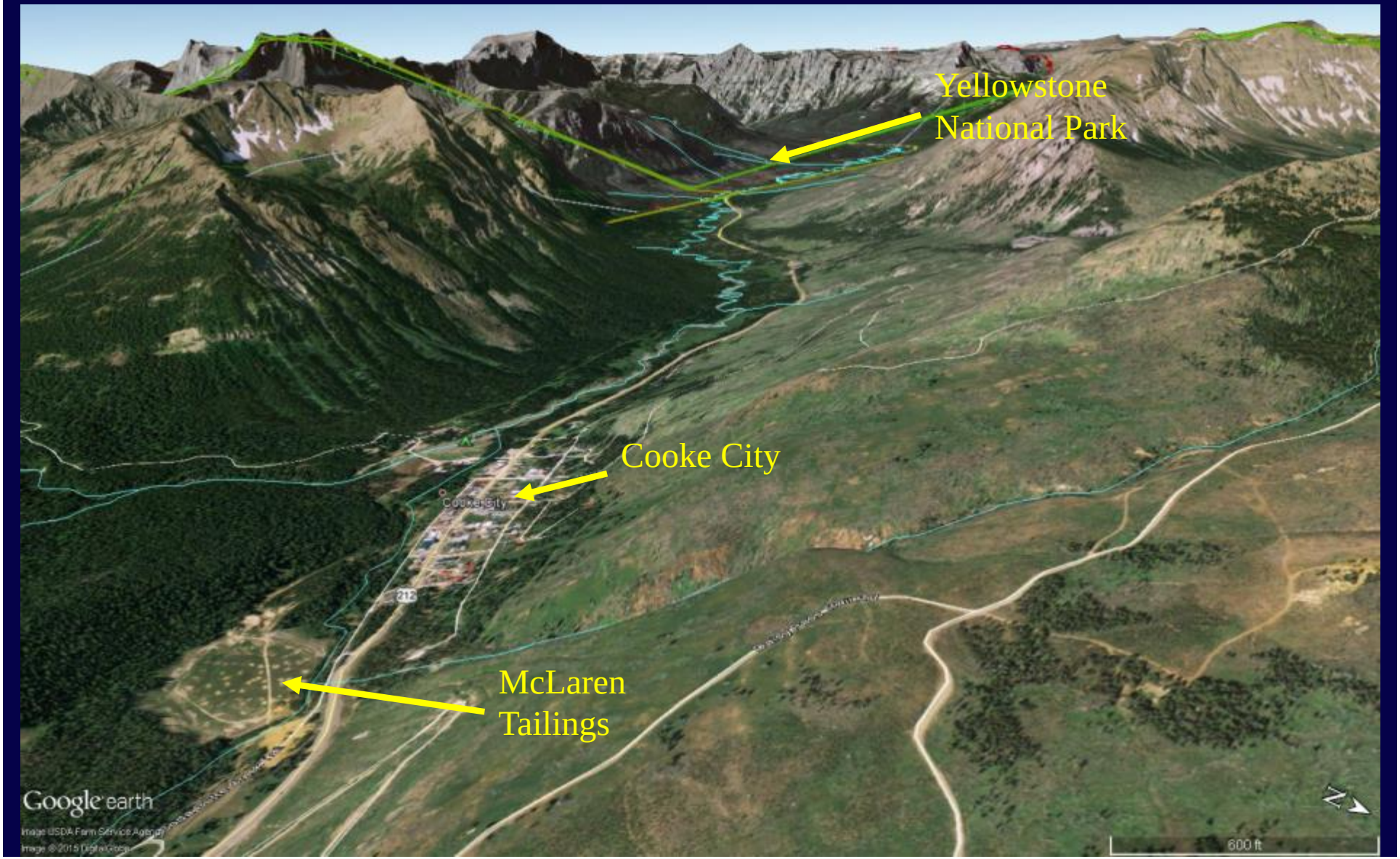
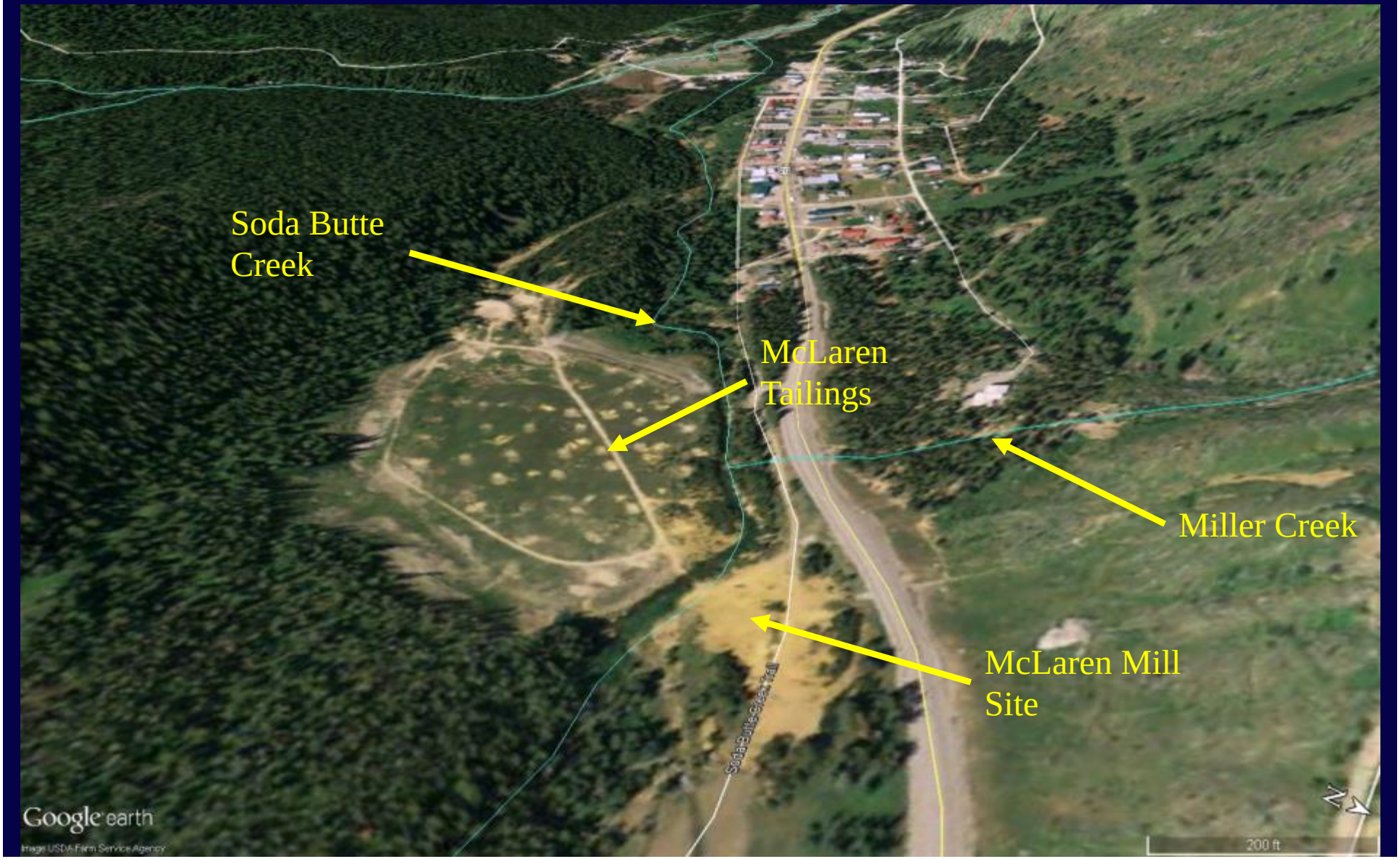
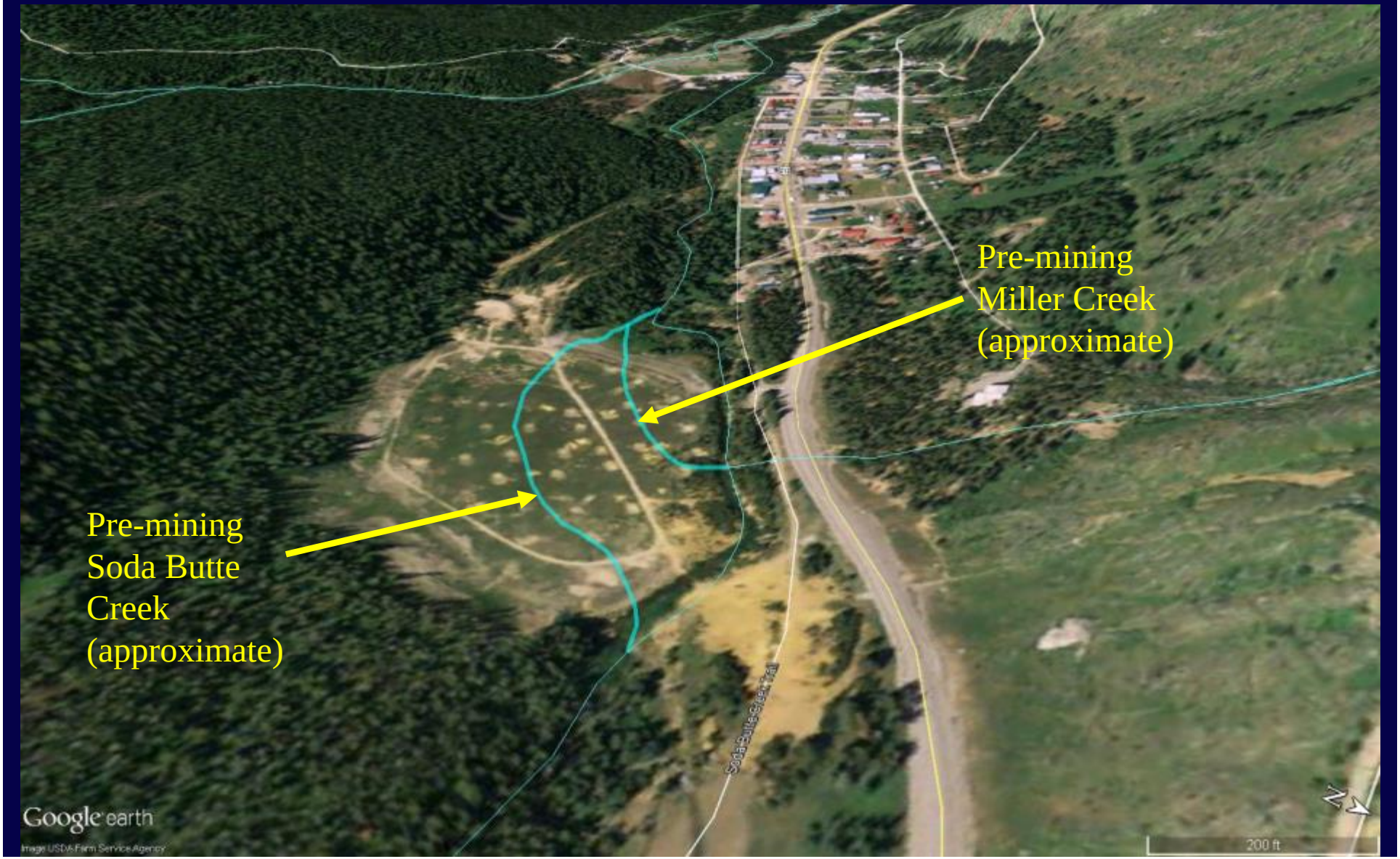
Project Setting



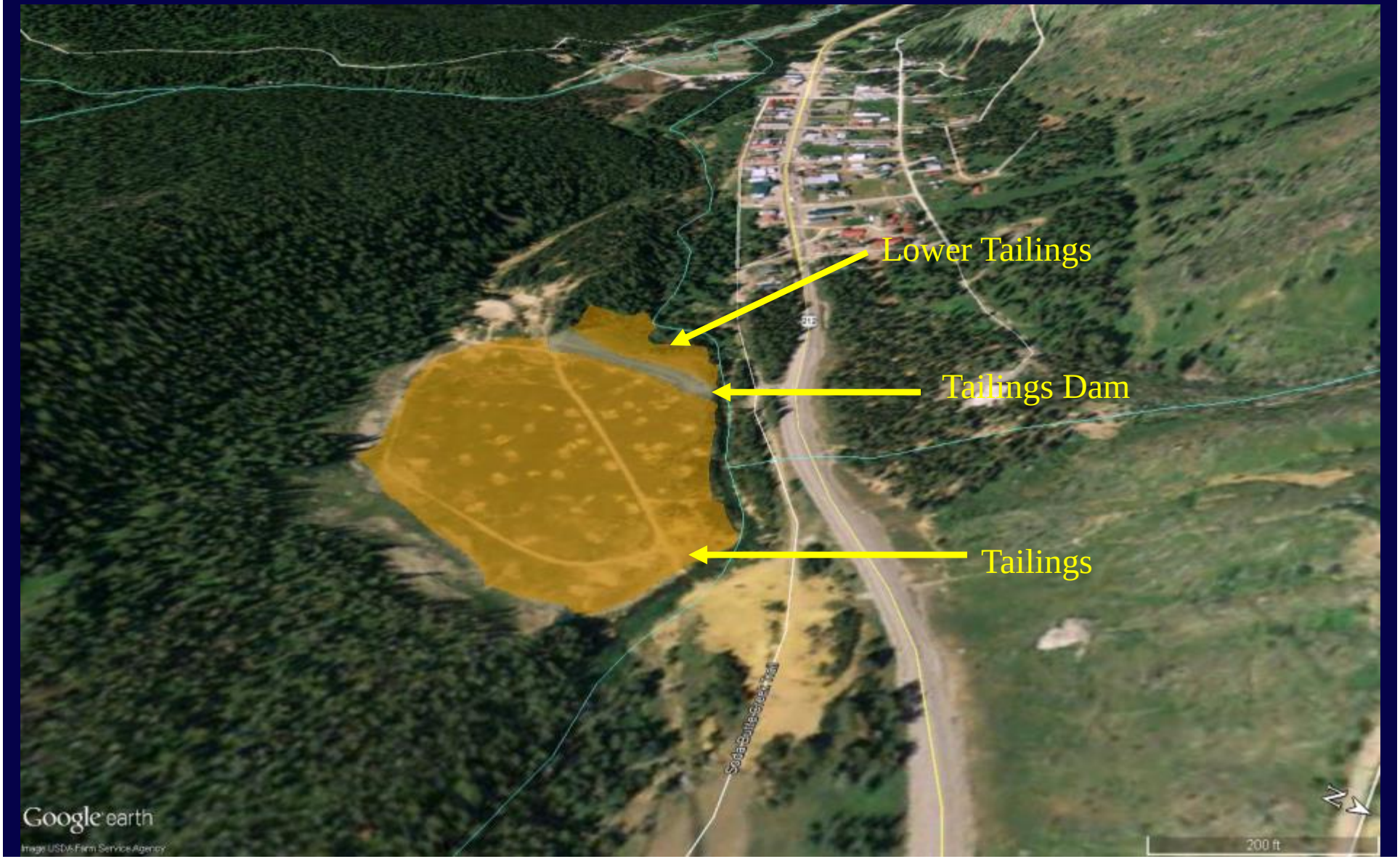
McLaren Mill and Tailings



Approximate Pre-Mining Creek Locations



Tailings Impoundment



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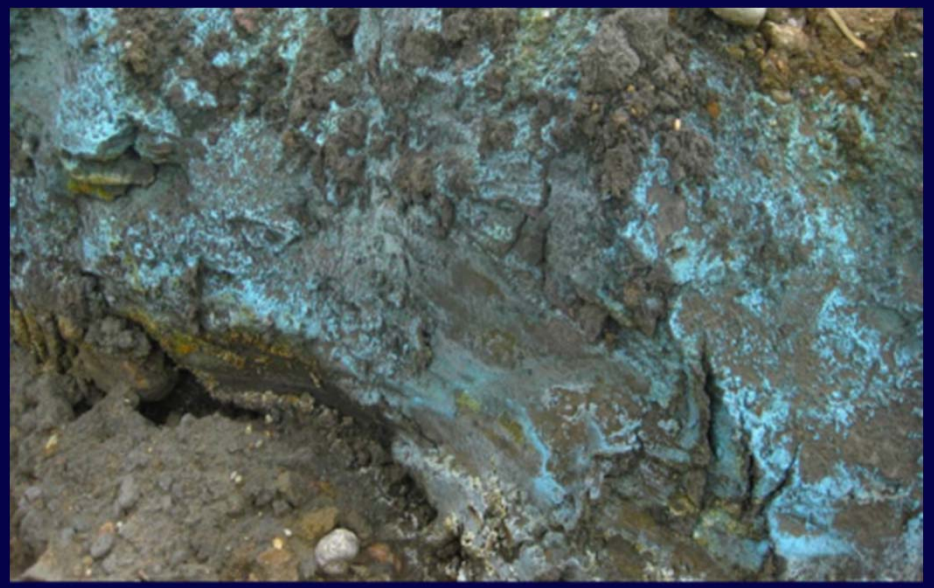
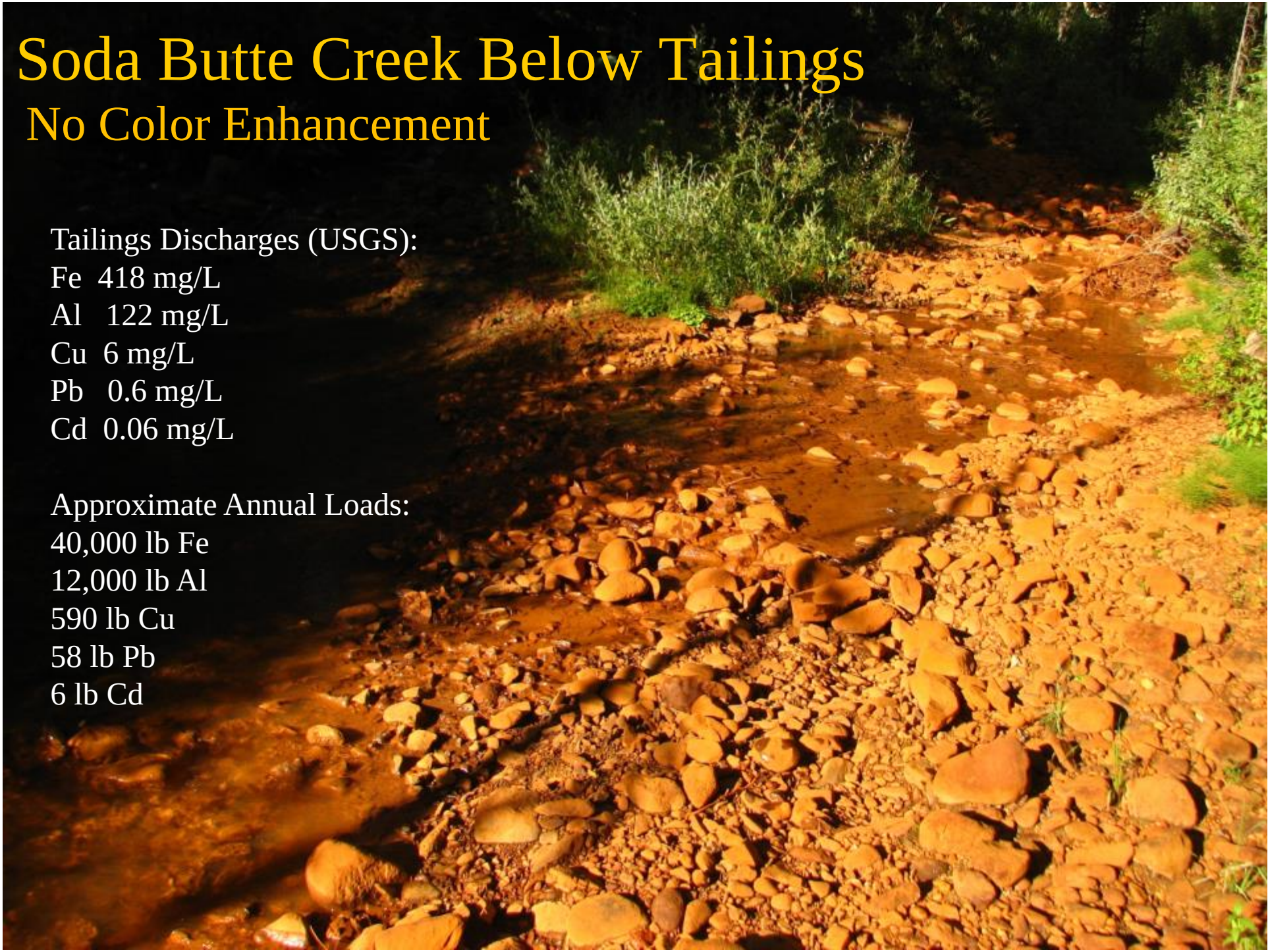
Challenges

- Environmental Issues
  - Dam failure - seismic stability
  - Flooding/erosion of tailings impoundment
  - Perpetual contamination to Soda Butte Creek: 303(d) impaired water body



Soda Butte Creek Below Tailings

No Color Enhancement



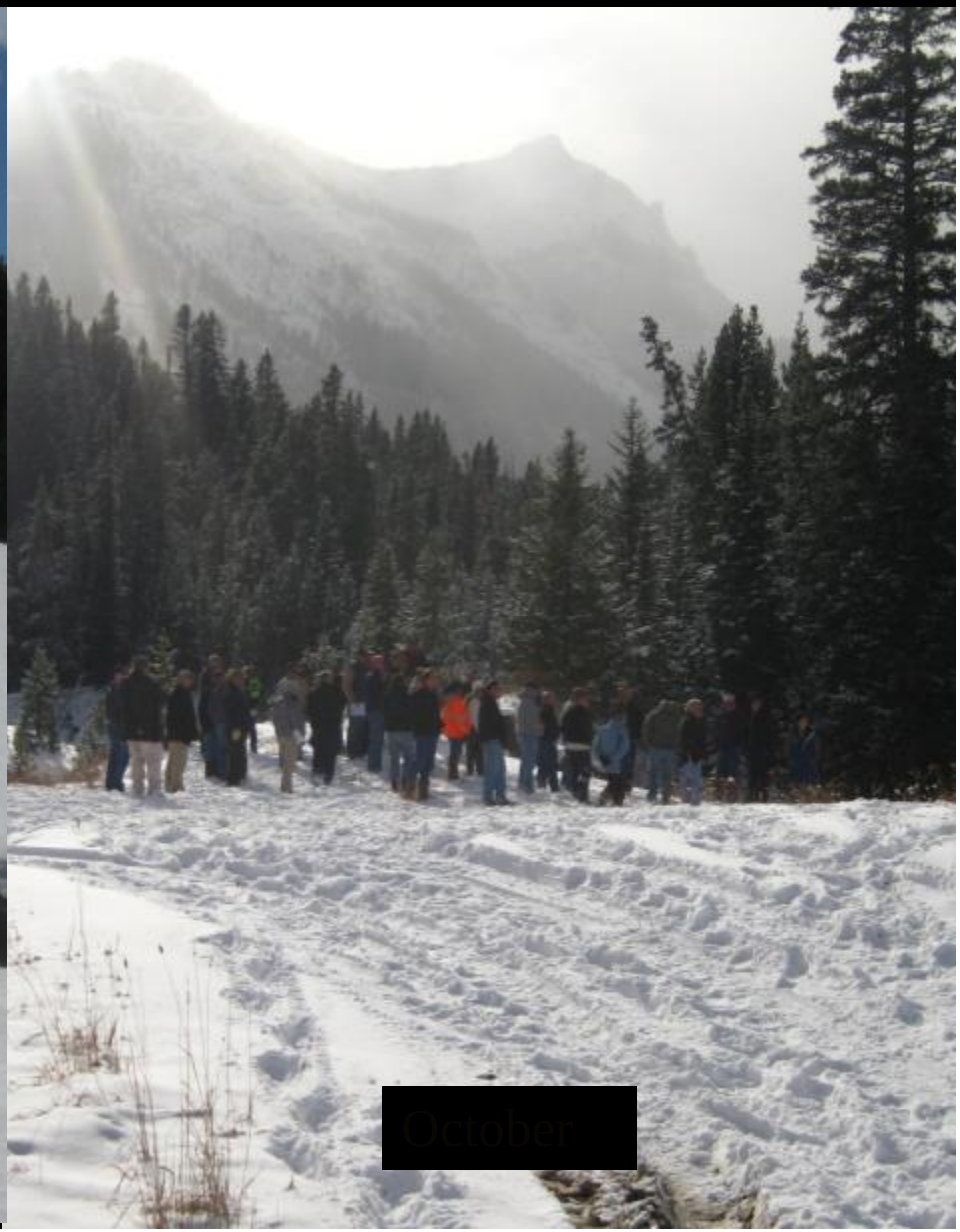
Tailings Discharges (USGS):
Fe 418 mg/L
Al 122 mg/L
Cu 6 mg/L
Pb 0.6 mg/L
Cd 0.06 mg/L

Approximate Annual Loads:
40,000 lb Fe
12,000 lb Al
590 lb Cu
58 lb Pb
6 lb Cd

Challenges

- Environmental Issues
  - Dam failure - seismic stability
  - Flooding/erosion of tailings impoundment
  - Perpetual contamination to Soda Butte Creek: 303(d) impaired water body

Climate - Offseason



Challenges

- Environmental Issues
  - Dam failure - seismic stability
  - Flooding/erosion of tailings impoundment
  - Perpetual contamination to Soda Butte Creek: 303(d) impaired water body
- Climate/Remoteness

Materials Instability

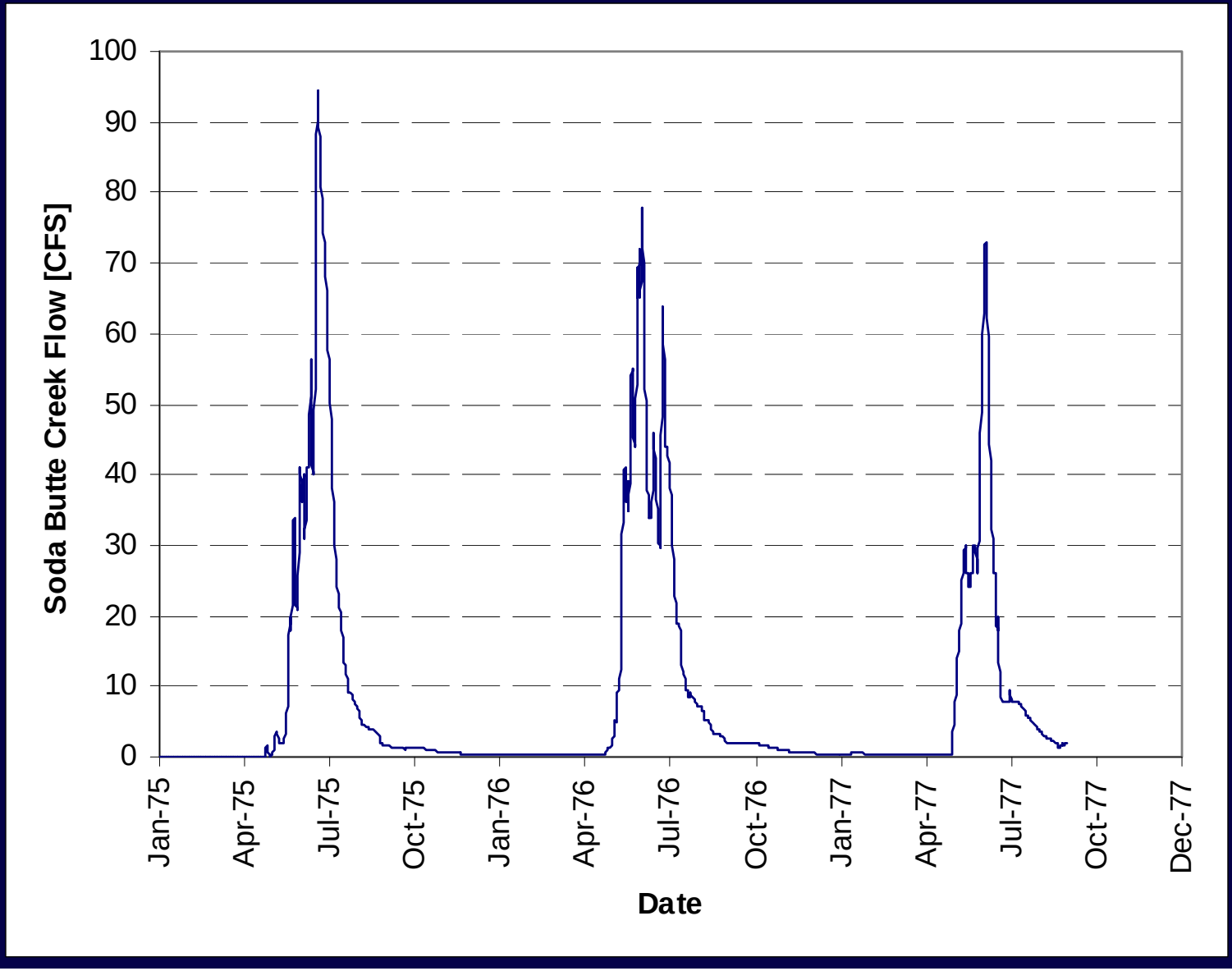
Water Saturated Tailings

Challenges

- Environmental Issues
  - Dam failure - seismic stability
  - Flooding/erosion of tailings impoundment
  - Perpetual contamination to Soda Butte Creek: 303(d) impaired water body
- Climate/Remoteness
- Materials stability of wet tailings is very poor
- Groundwater/Surface Water
  - Groundwater fluctuates 14 to 16 feet annually
  - Artesian conditions in the spring

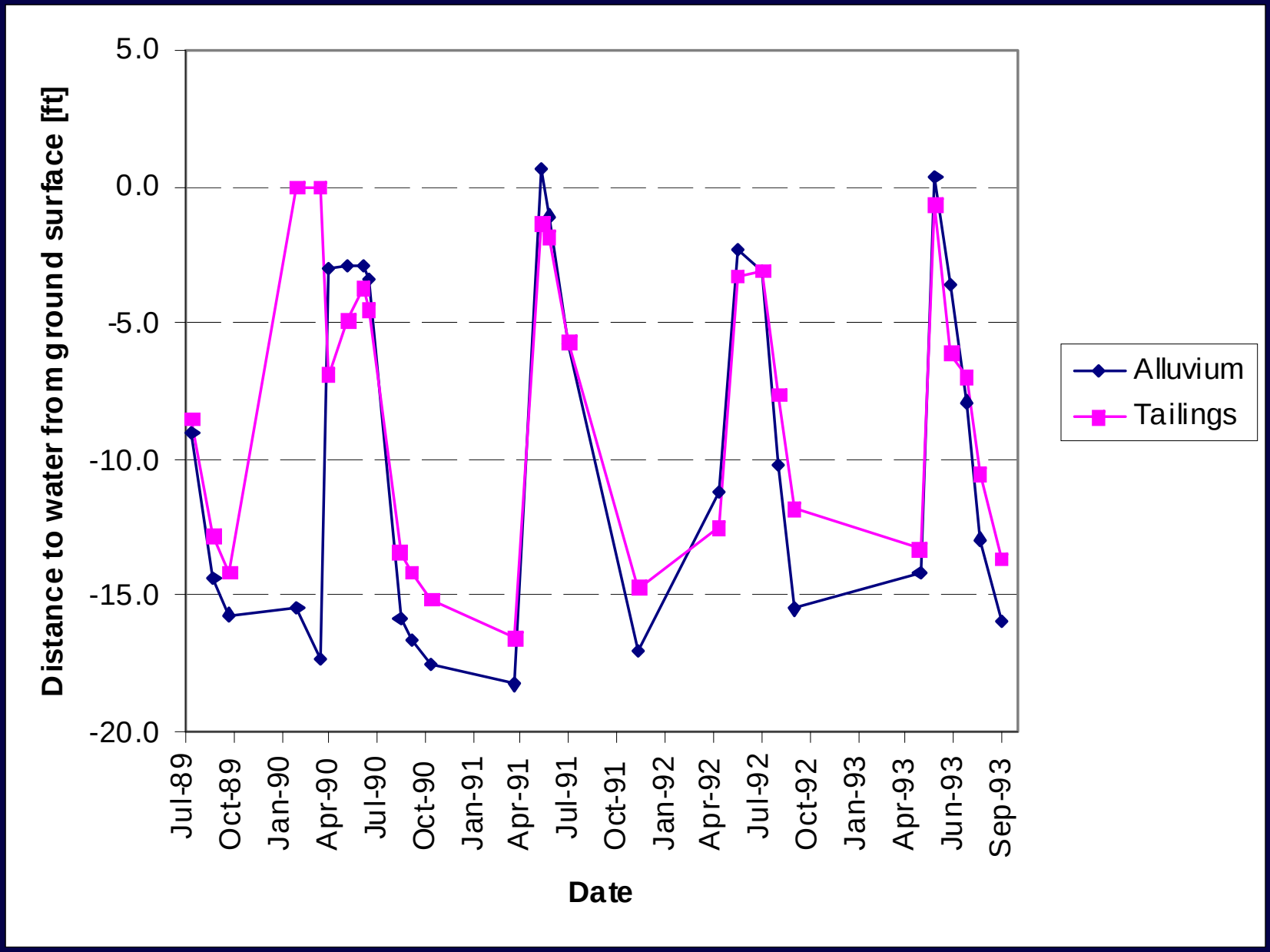
Surface Water - Soda Butte Creek

Soda Butte Creek at Cooke City 1975-1977



Artesian/Confined Aquifer Below Impoundment

EPA Fluid Level Data 1989-1993



Subsurface Recharge

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  - Conduct Pilot Dewatering Test and Extended Monitoring
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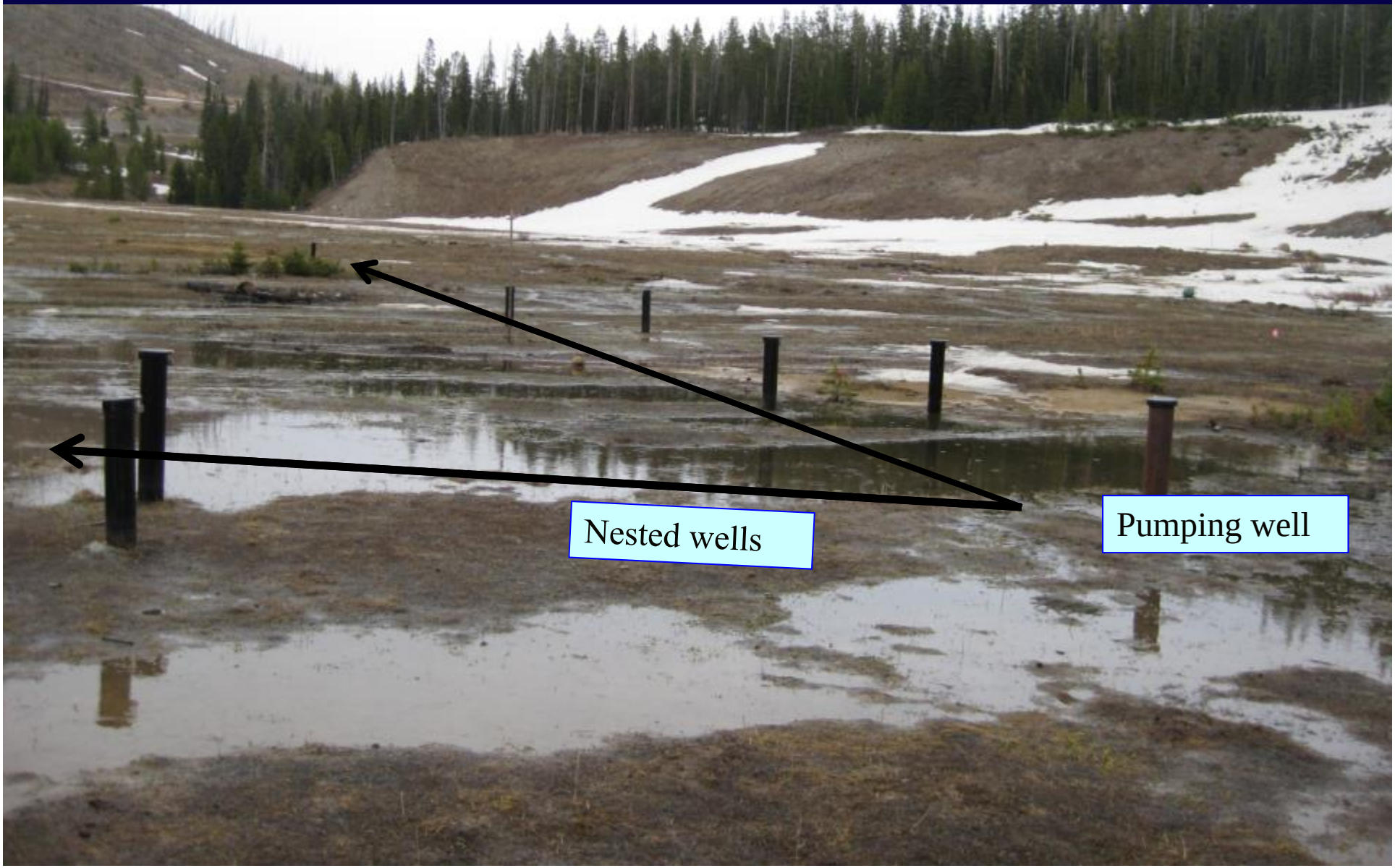
Pilot Dewatering Test

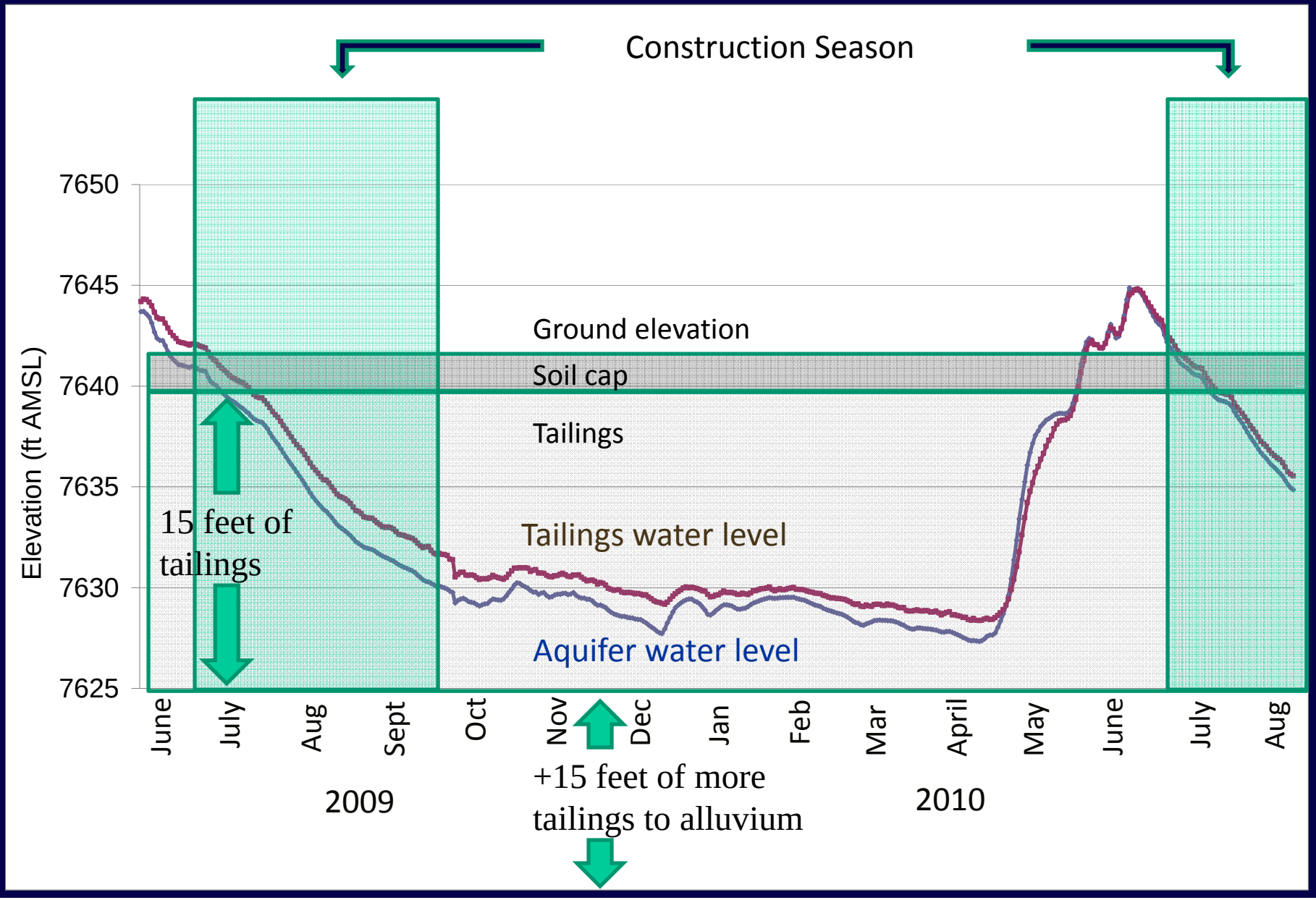


Pilot Dewatering Test

Pumping Test Results

- Aquifer characterized as “leaky-confined”
- Hydraulic conductivity (K) :
  - In underlying alluvium, 25 to 125 feet per day (ft/day).
  - In tailings, 0.0045 ft/day.
- Results from deep piezometers identify general location of historic Soda Butte Creek Channel.
- Minor pumping test effected groundwater over a significant portion of the site.
- Drawdown observed in shallow piezometers show tailings can be dewatered by pumping the alluvium.

Monitoring - Groundwater Seasonality



Test Findings

- Much of the tailings impoundment is perpetually water saturated
- Large contact area (12 acres) between high conductivity alluvial aquifer and low conductivity tailings
- Underlying alluvium and tailings respond together
- Tailings can’t be dewatered separately from underlying aquifer
- Conductive cobble/boulder lenses associated with historic flow channels in alluvial aquifer

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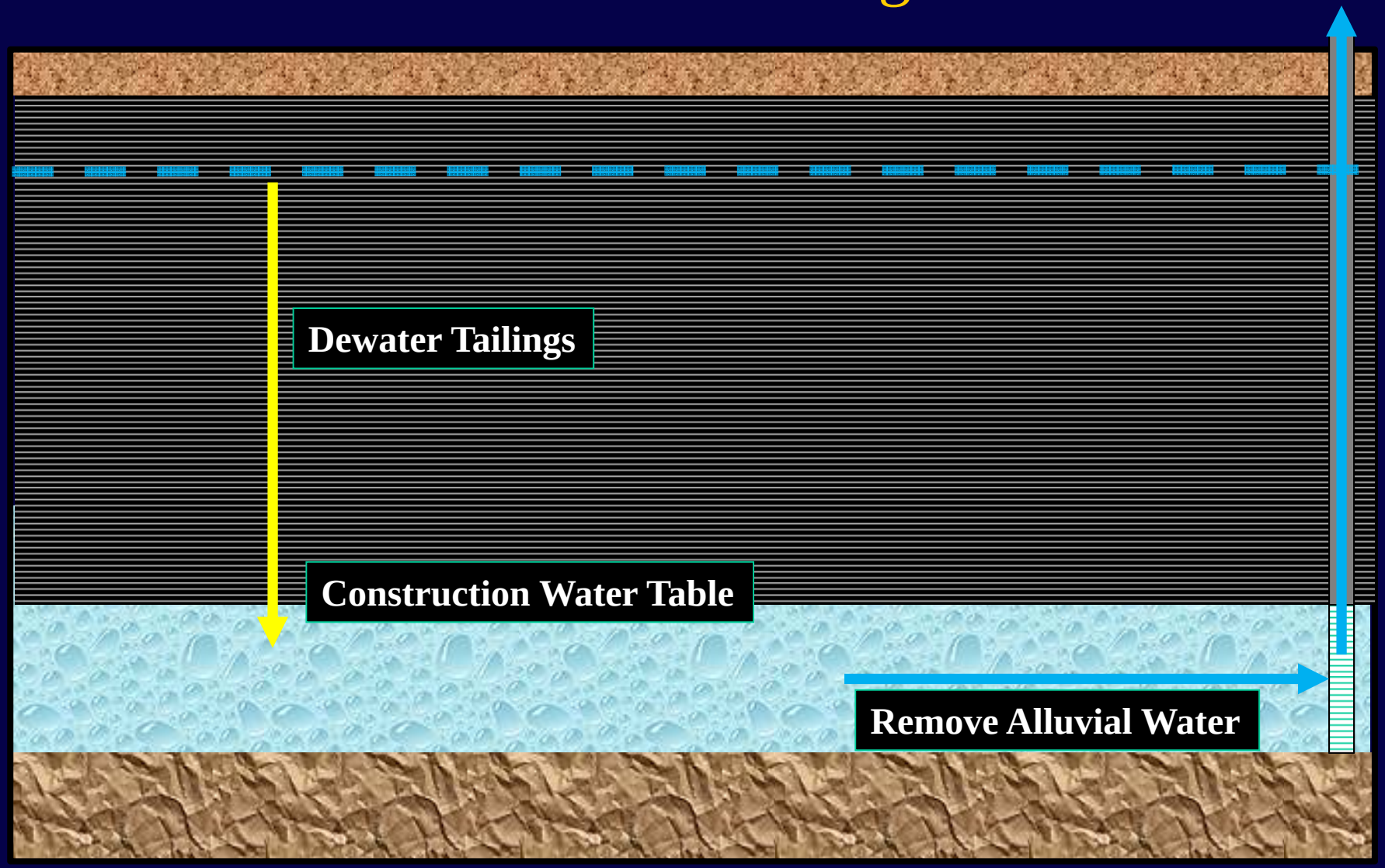
Objectives and Conceptual Construction Dewatering Design

- Minimal materials stability in tailings
  - Accommodate using pumping wells instead of dewatering trenches
- Excessive alluvial depth
  - Not cost effective to use a cutoff wall in the northeast corner to minimize incoming groundwater
- Accommodate Winter conditions
  - Design system for operation during freezing weather
- Anticipate Extreme Spring Conditions (14 to 16 ft Groundwater Fluctuations)
  - Pump perimeter wells (no treatment) to reduce annual spike
  - Requires design of system for year-round operation
- Utilize Underlying Alluvium to Dewater Tailings
  - Screen construction wells in underlying alluvium

Utilize Underlying Alluvium to Dewater Tailings



Objectives and Conceptual Construction Dewatering Design

- Minimize treatment of contaminated water
  - Intercept clean water with pumping wells around upgradient perimeter
  - Remove tailings water with central pumping wells
  - Treat diluted tailings water
- Offset Buoyancy of Treatment Pond Buoyancy during spring
  - Maintain flow through lined sediment pond during winter
  - Requires design of system for year-round operation

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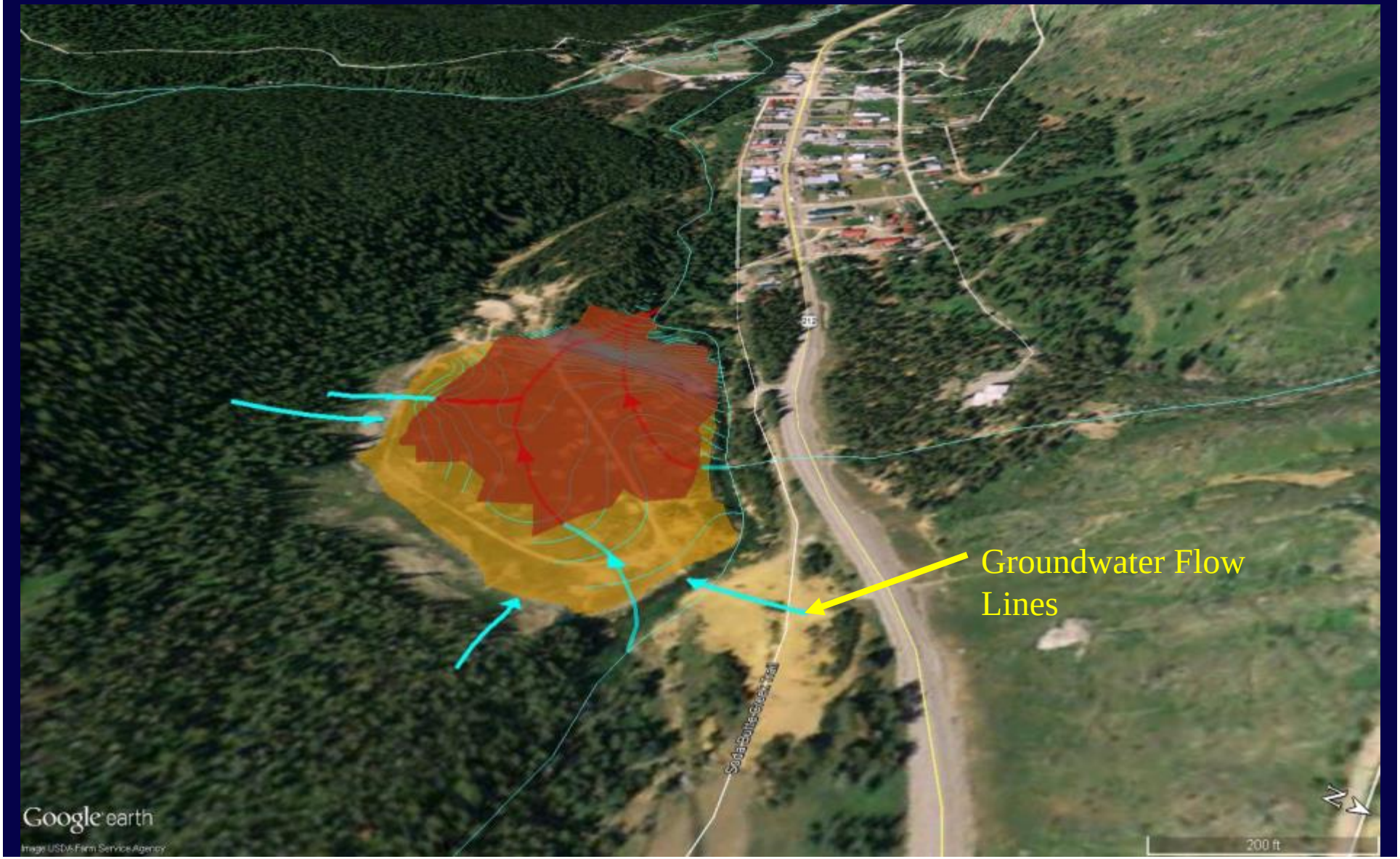
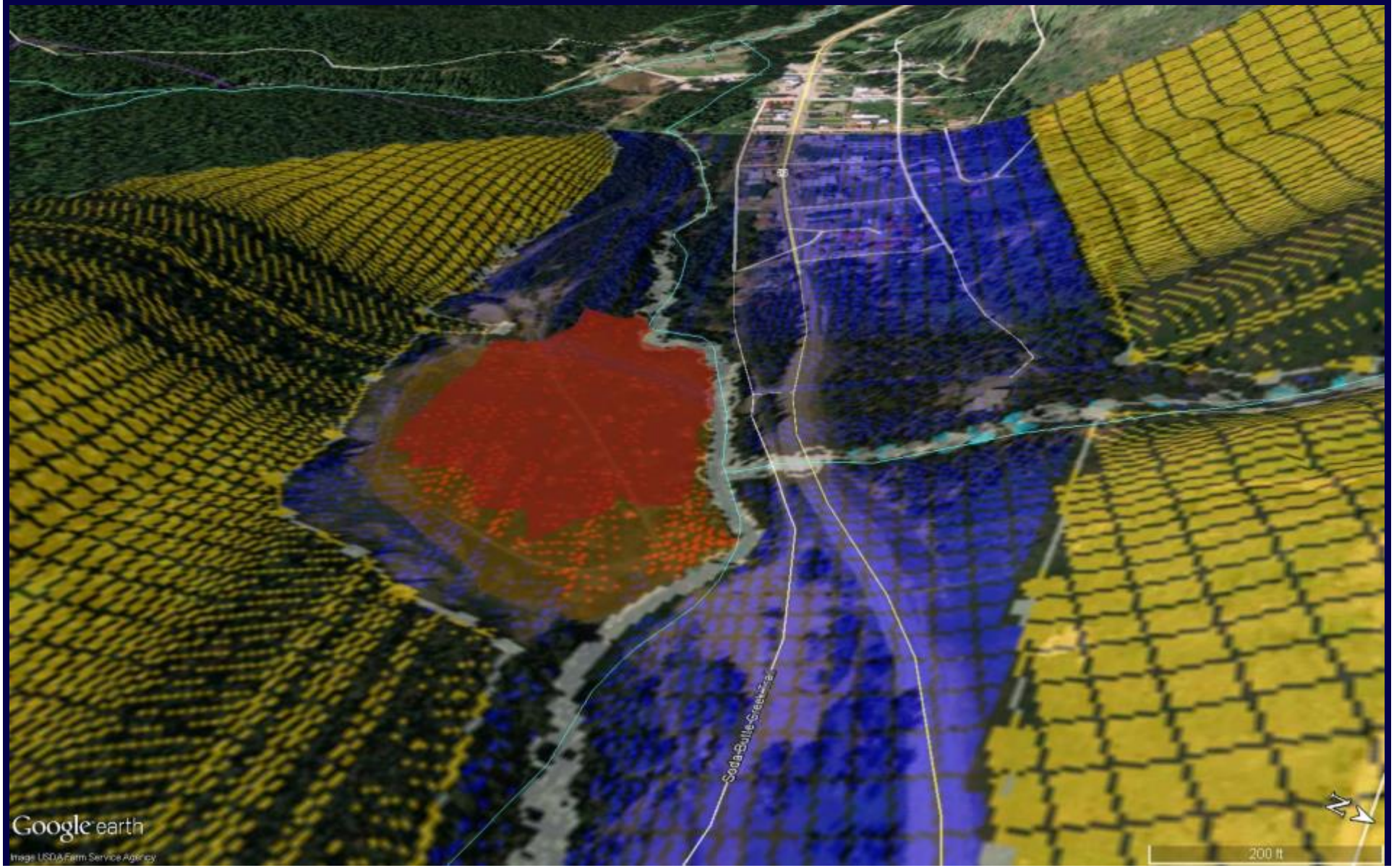
  - Optimize Construction Dewatering with Groundwater Model
    - Estimate optimal pumping rate
    - Optimal pumping well locations while minimizing volume of treated water

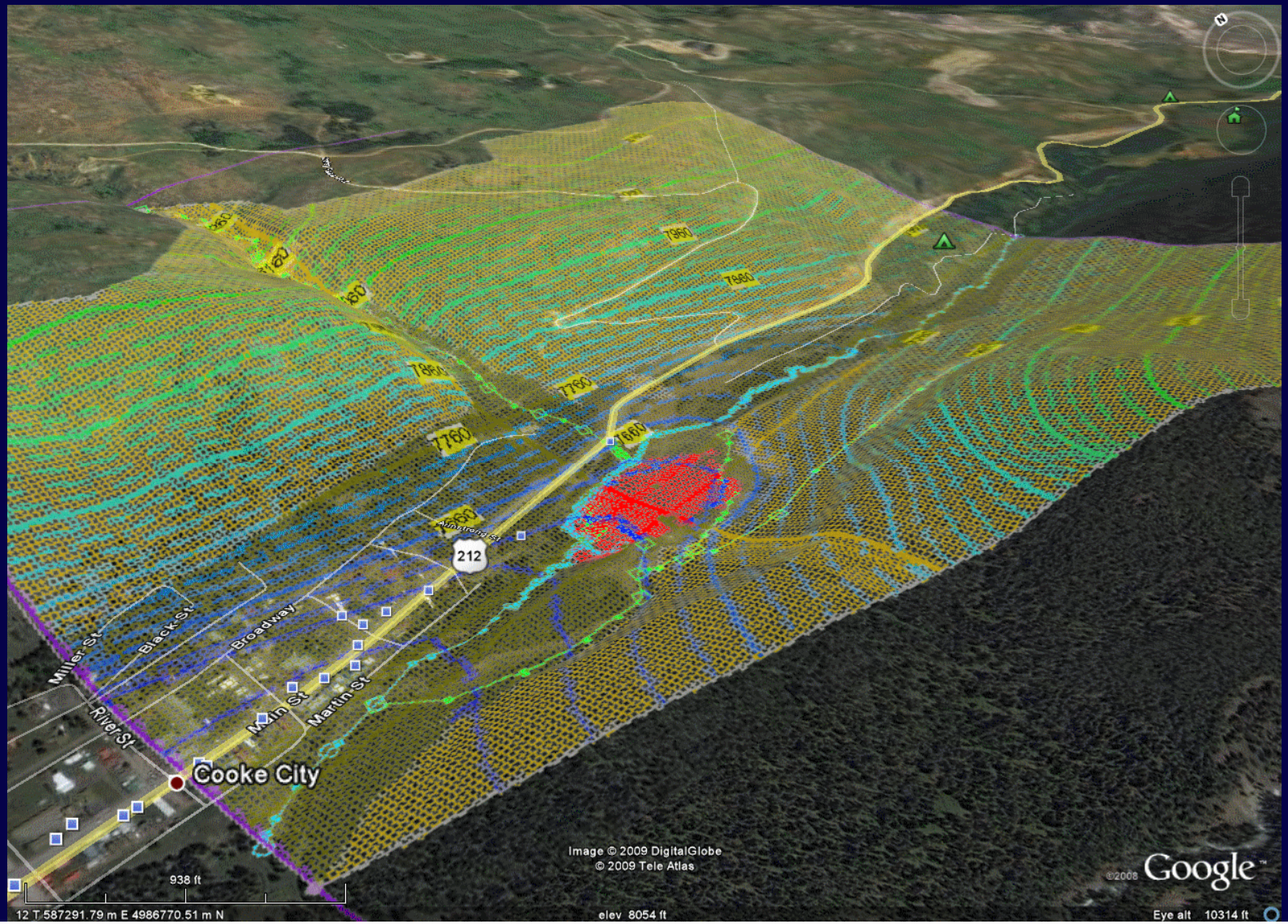
1. Estimate Optimal Pumping Rate



1. Estimate Optimal Pumping Rate
Construct Groundwater Model



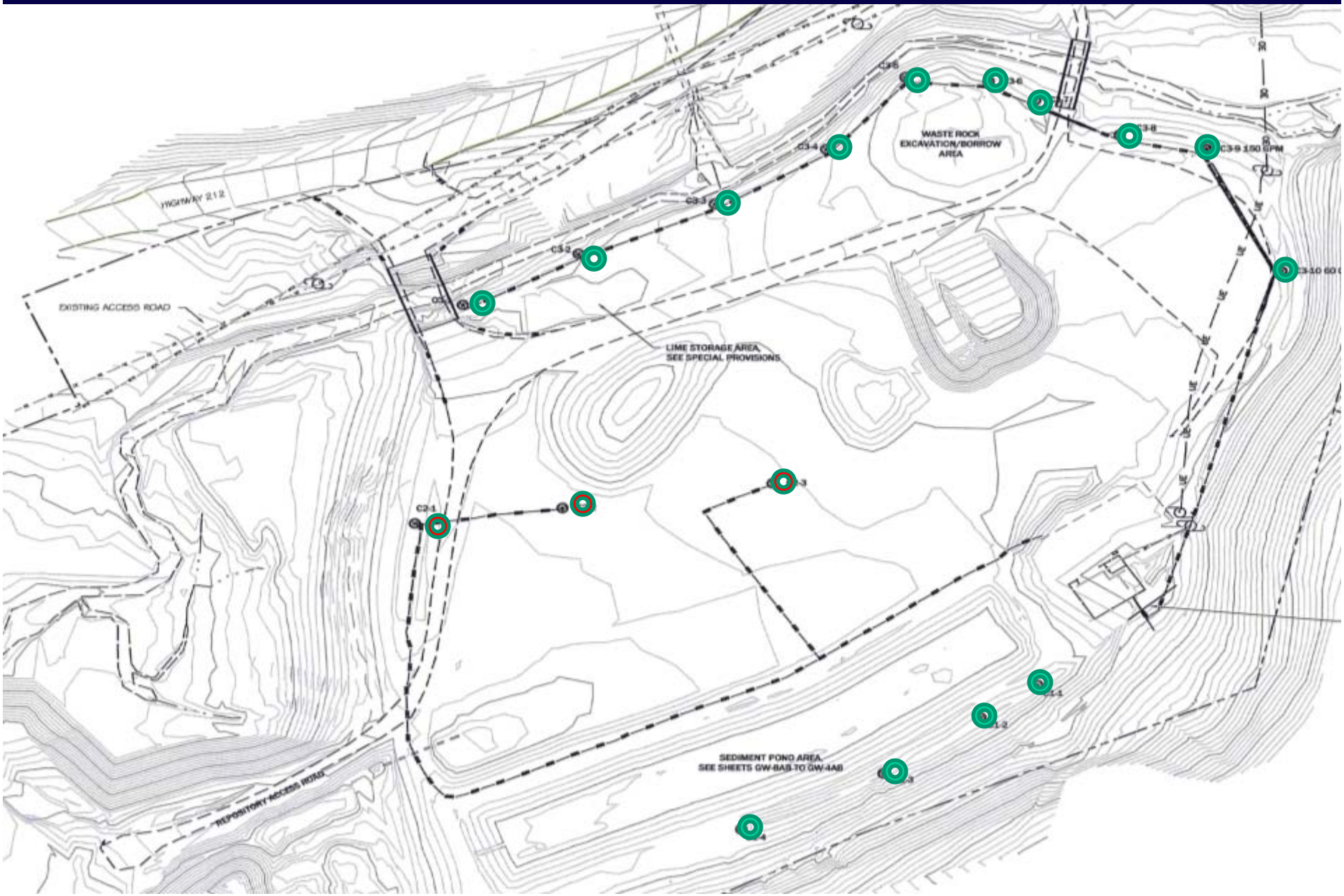
Groundwater Model: Oblique View



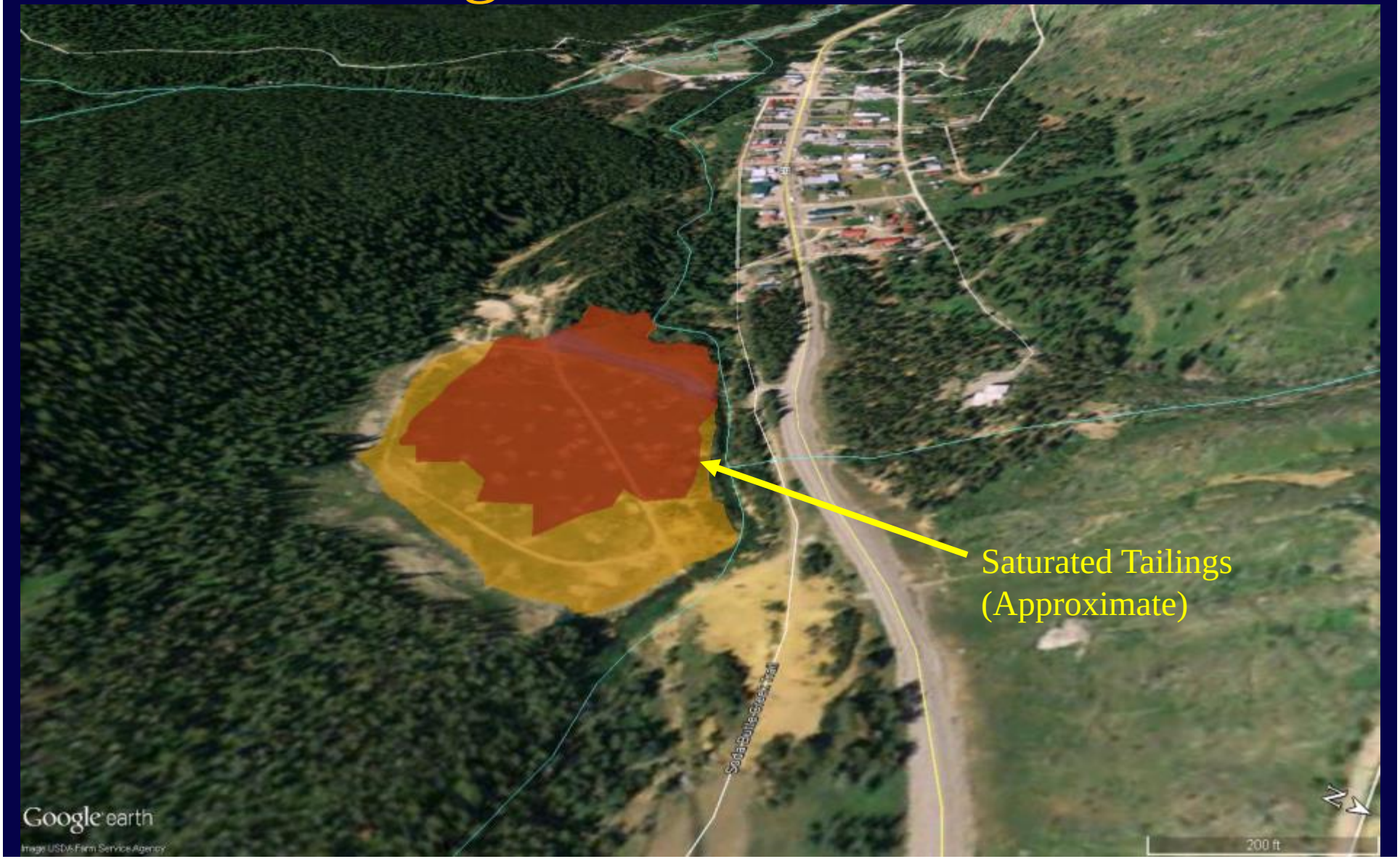
1. Estimate Optimal Pumping Rate

- Typical flow underneath tailings impoundment
  - 600 to 700 gallons per minute (gpm)
  - To design system, separated flow into six zones.
- Simulate construction dewatering
  - Pumping of storage
  - Accommodate high water conditions
  - +300 gpm to construction dewatering system
- Add localized dewatering needs and safety factor
  - +500 gpm to construction dewatering system
- Estimated 1,500 gpm total

Pumping Well Locations



2. Optimize pumping well locations while minimizing volume of treated water



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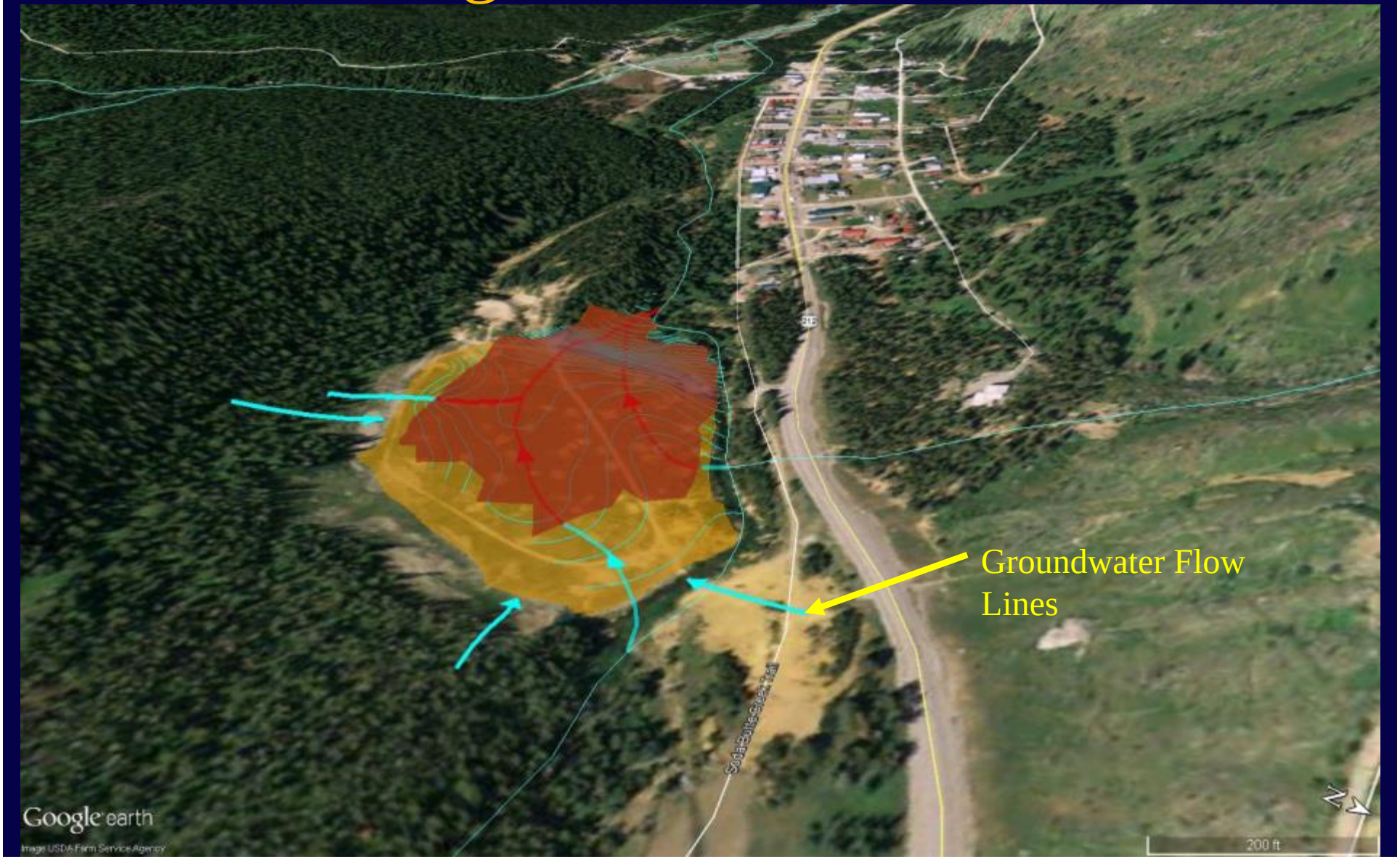

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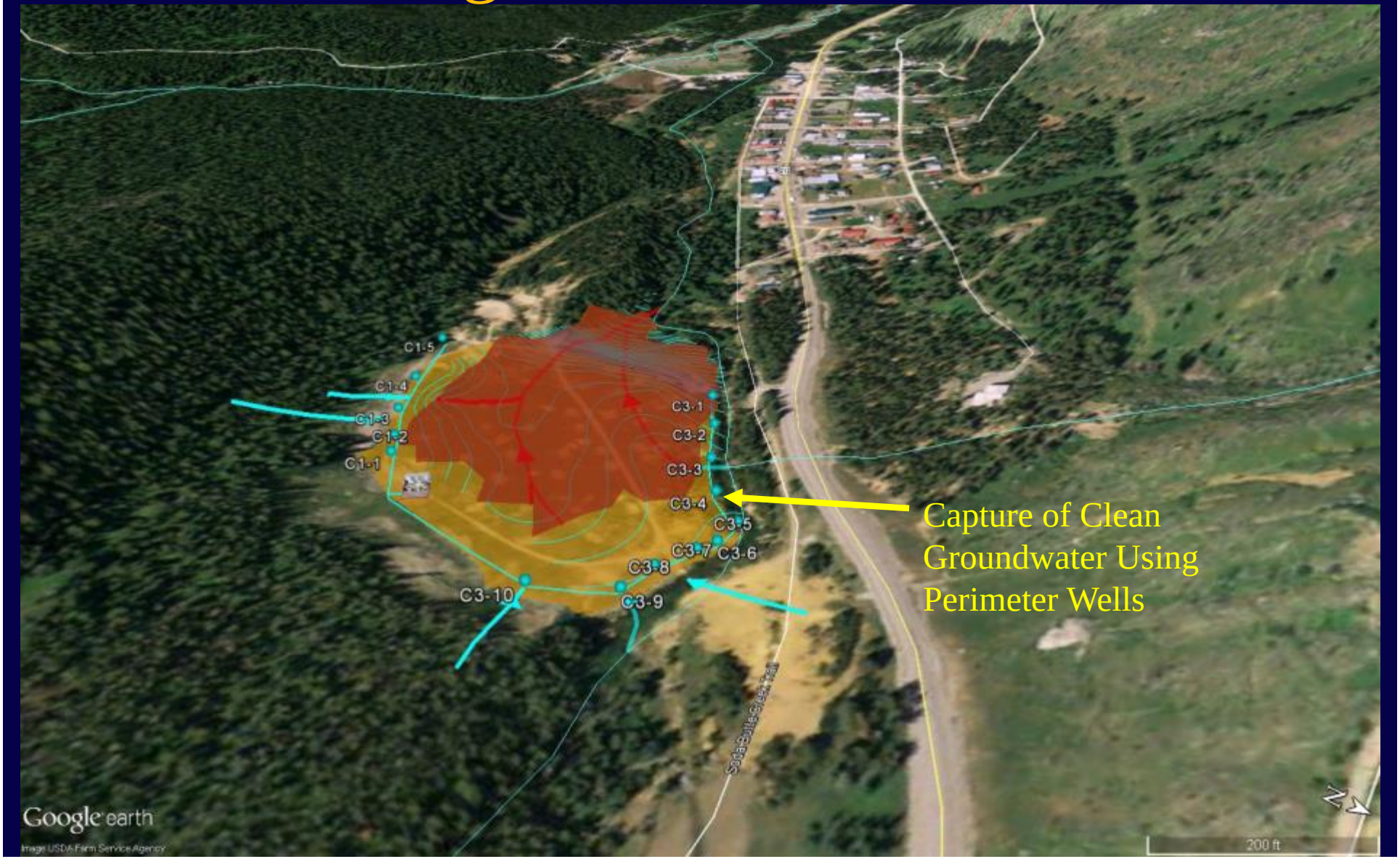

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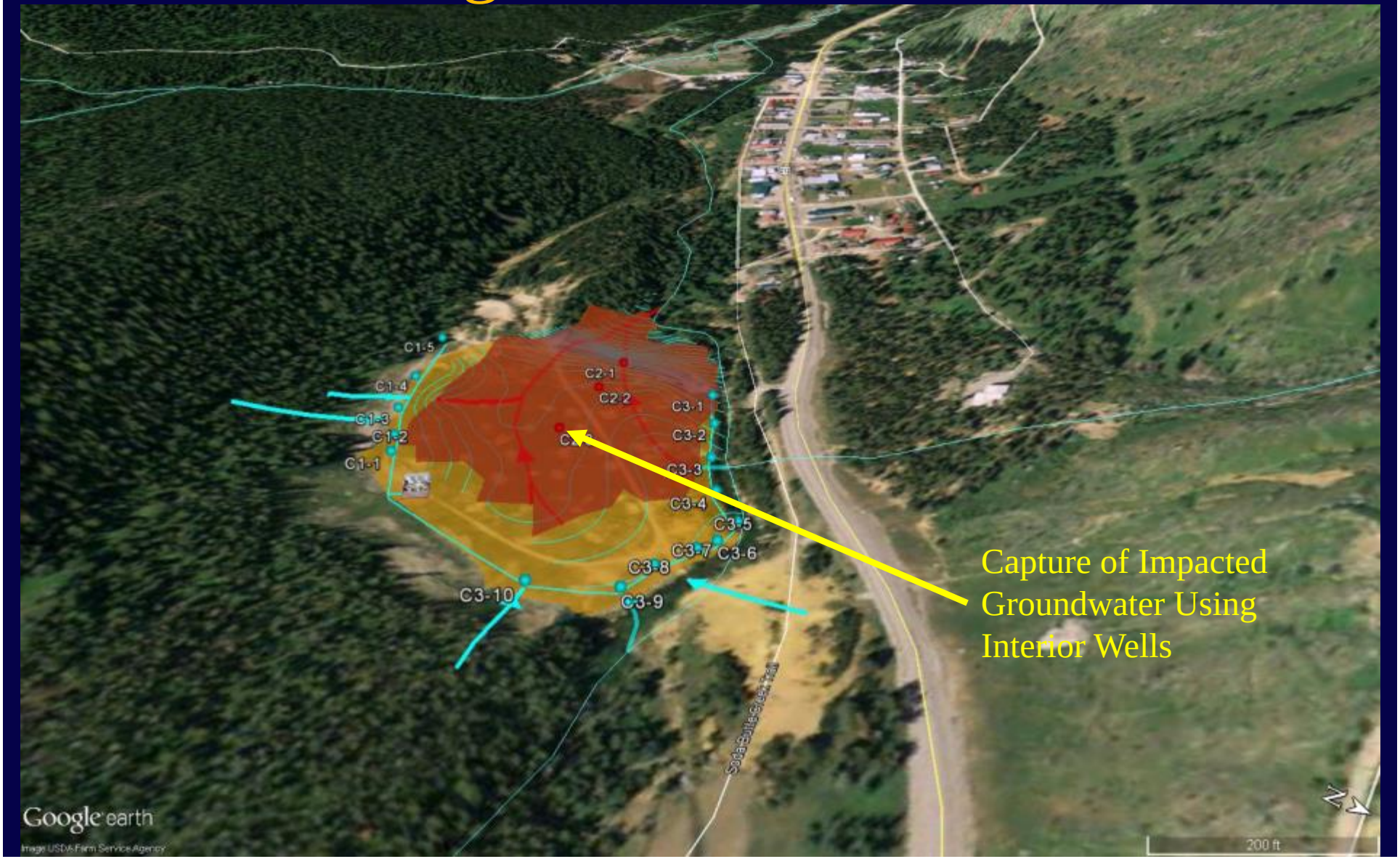

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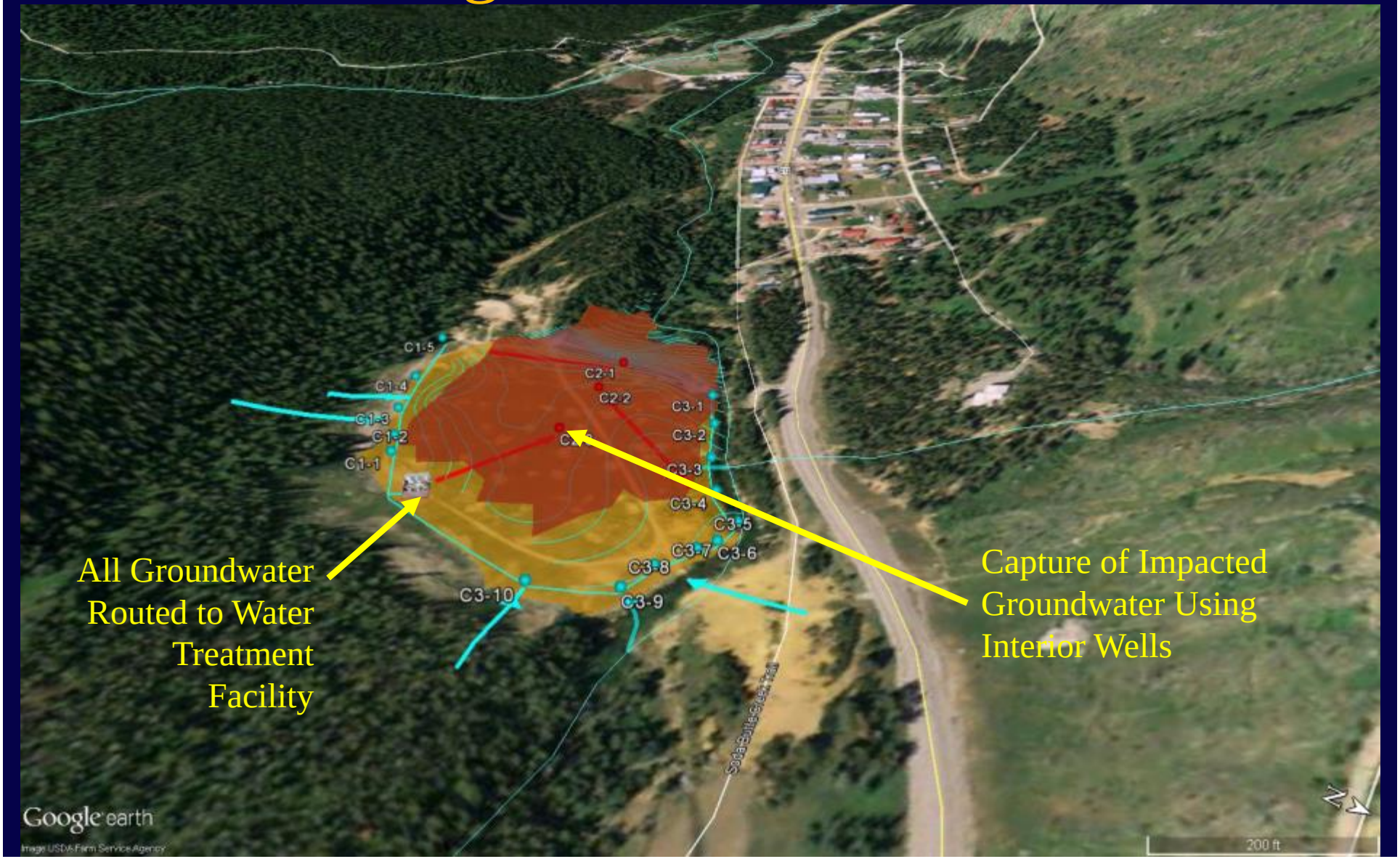

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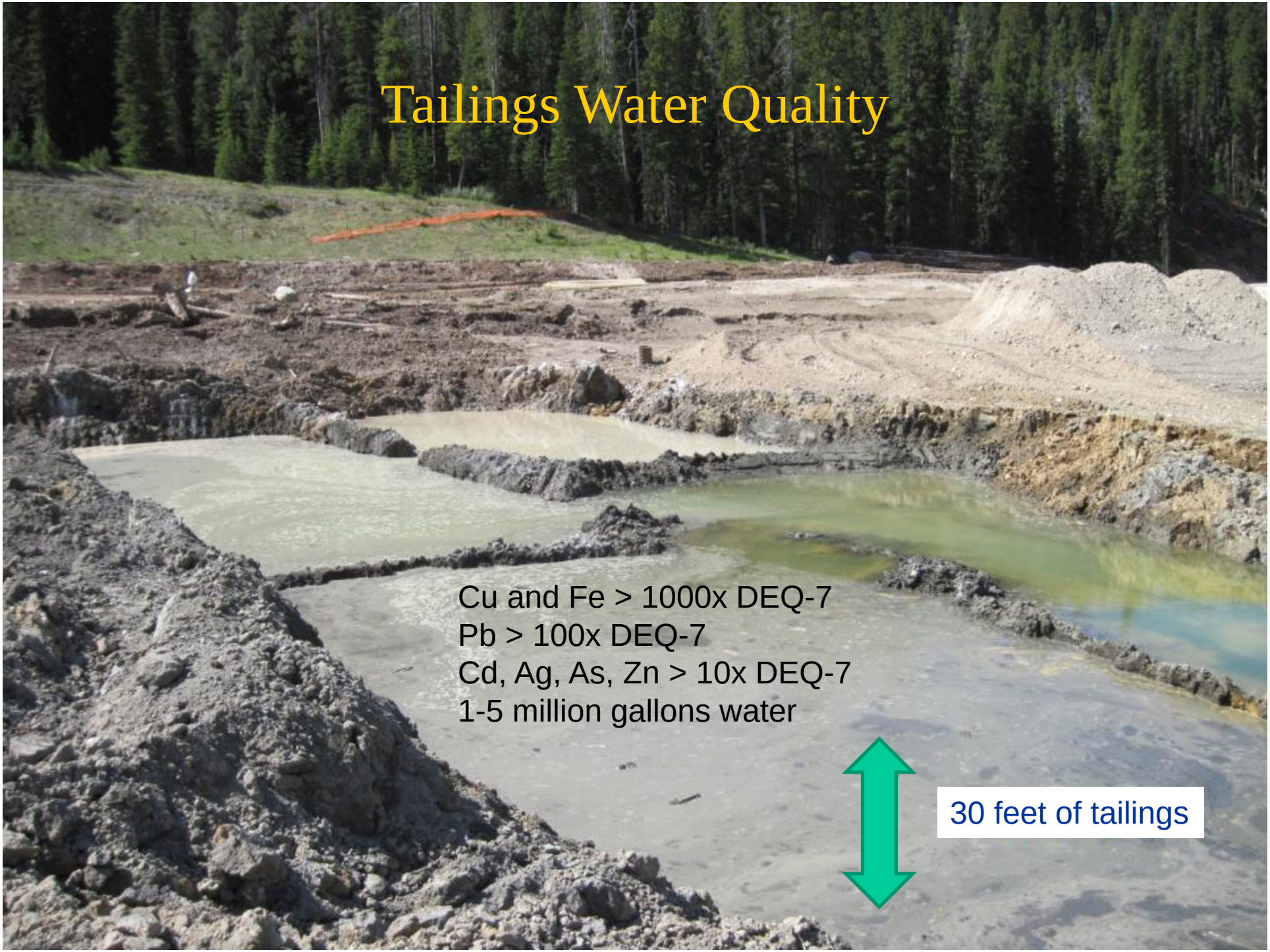
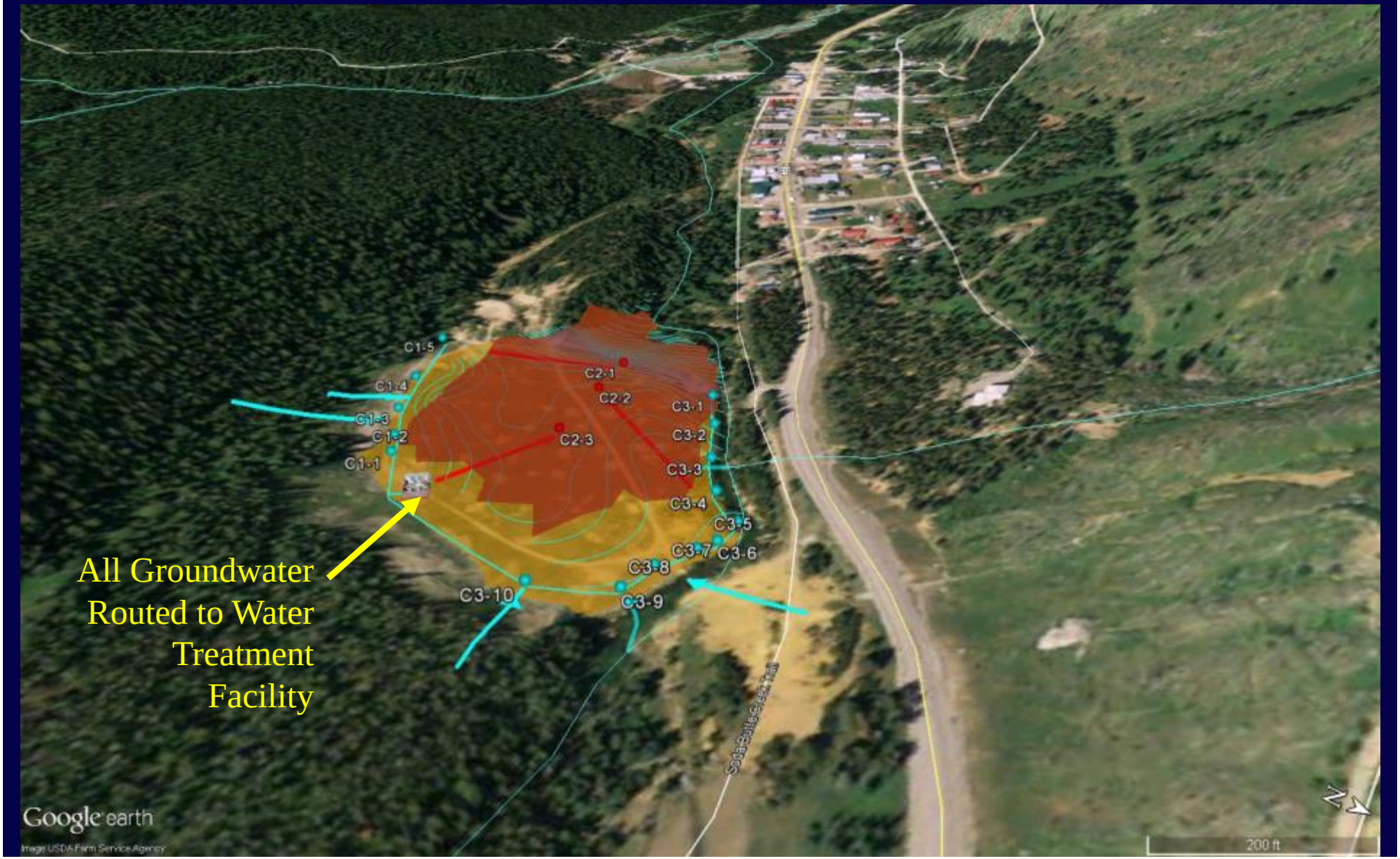
Tailings Water Quality



Water Treatment Facility



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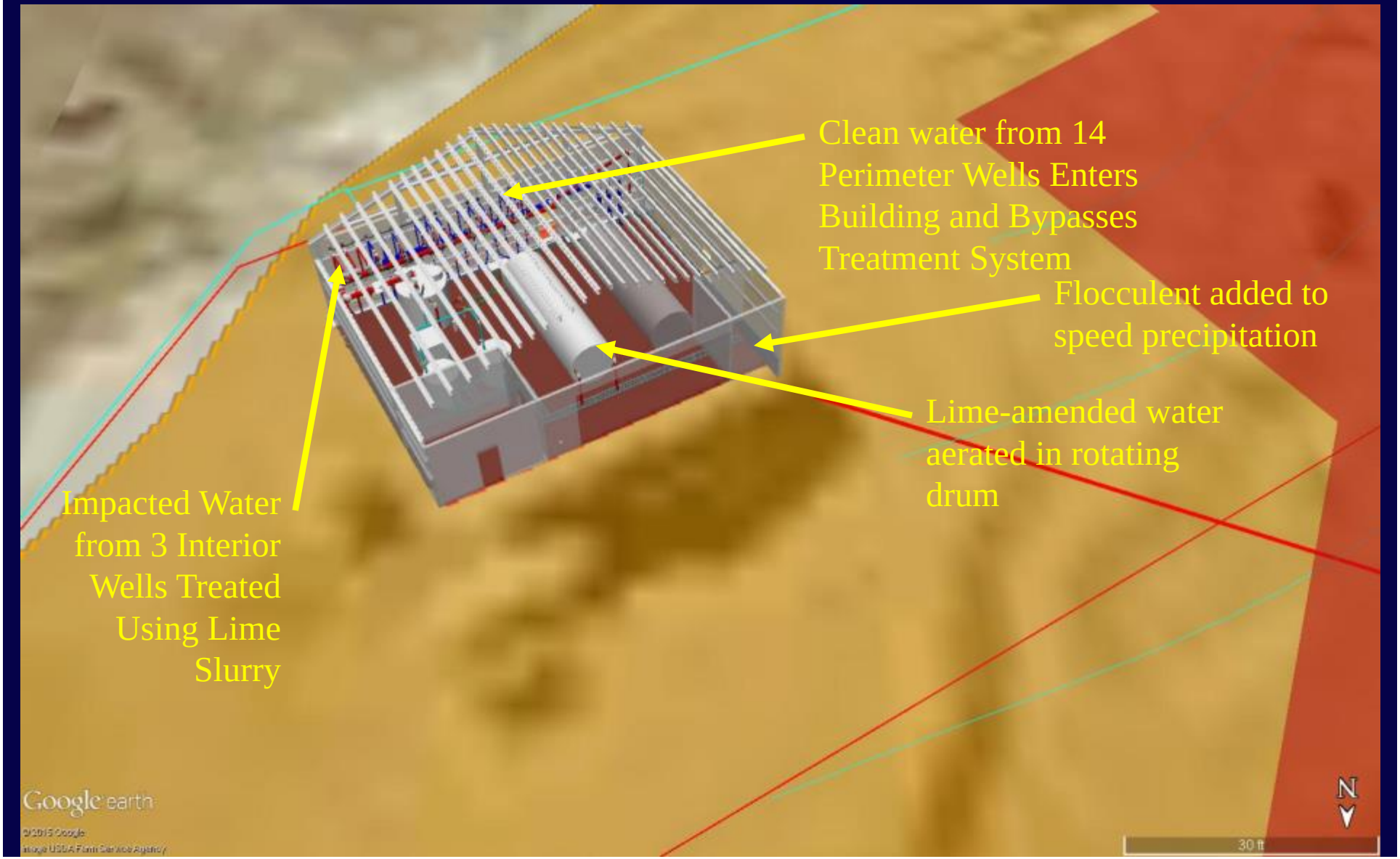

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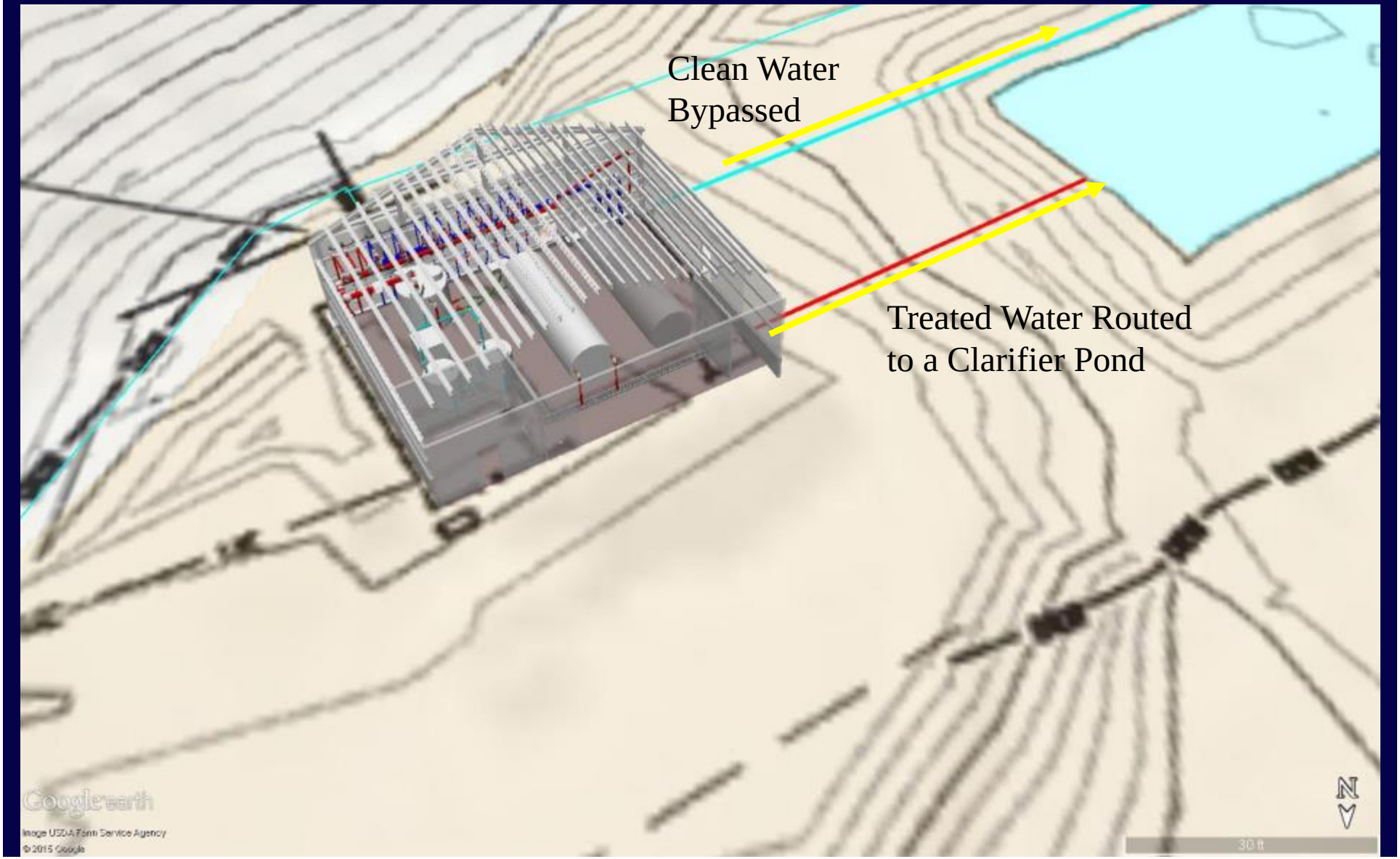

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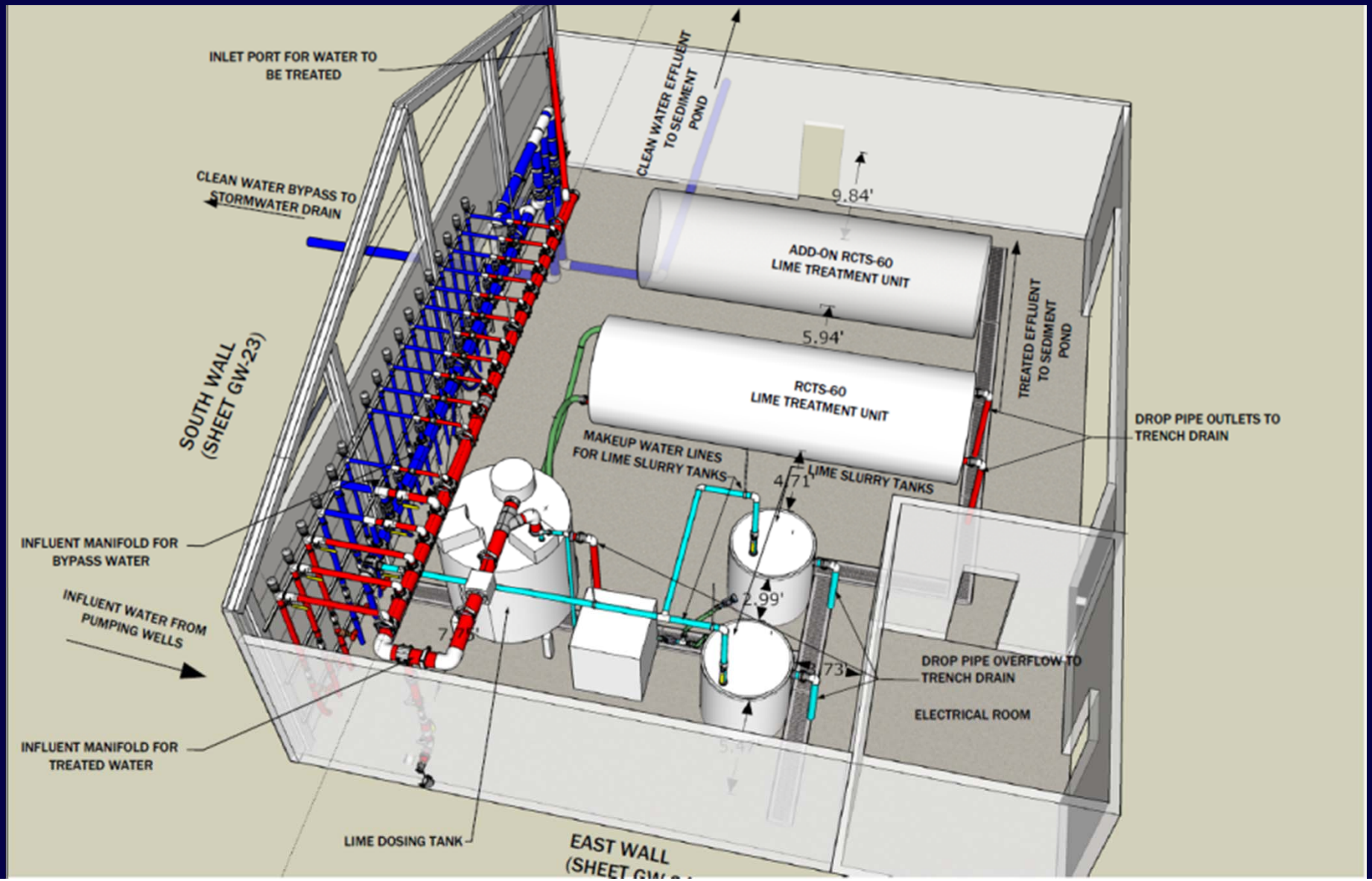

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Construction of Dewatering Wells

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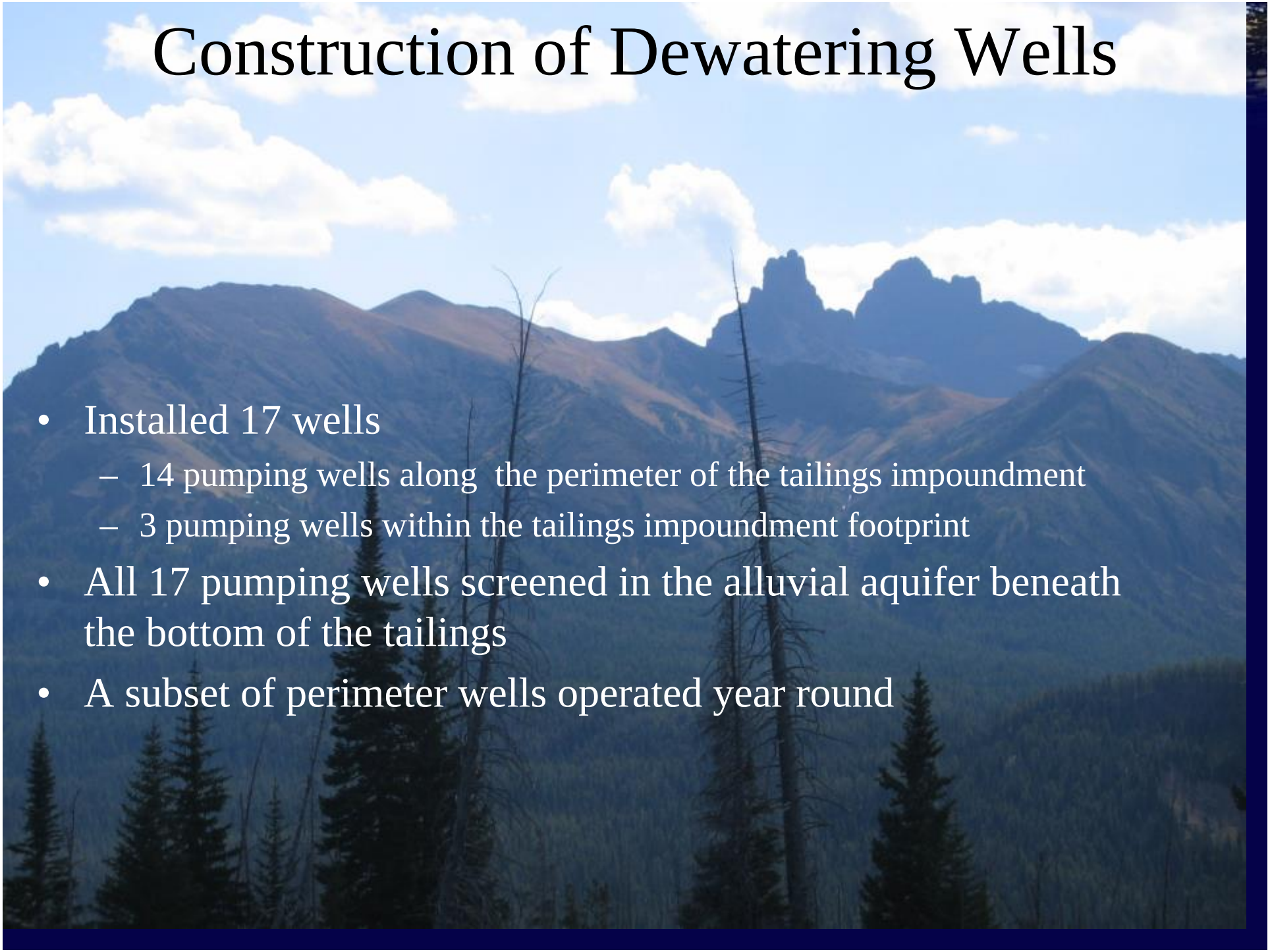


- Installed 17 wells
  - 14 pumping wells along the perimeter of the tailings impoundment
  - 3 pumping wells within the tailings impoundment footprint
- All 17 pumping wells screened in the alluvial aquifer beneath the bottom of the tailings
- A subset of perimeter wells operated year round

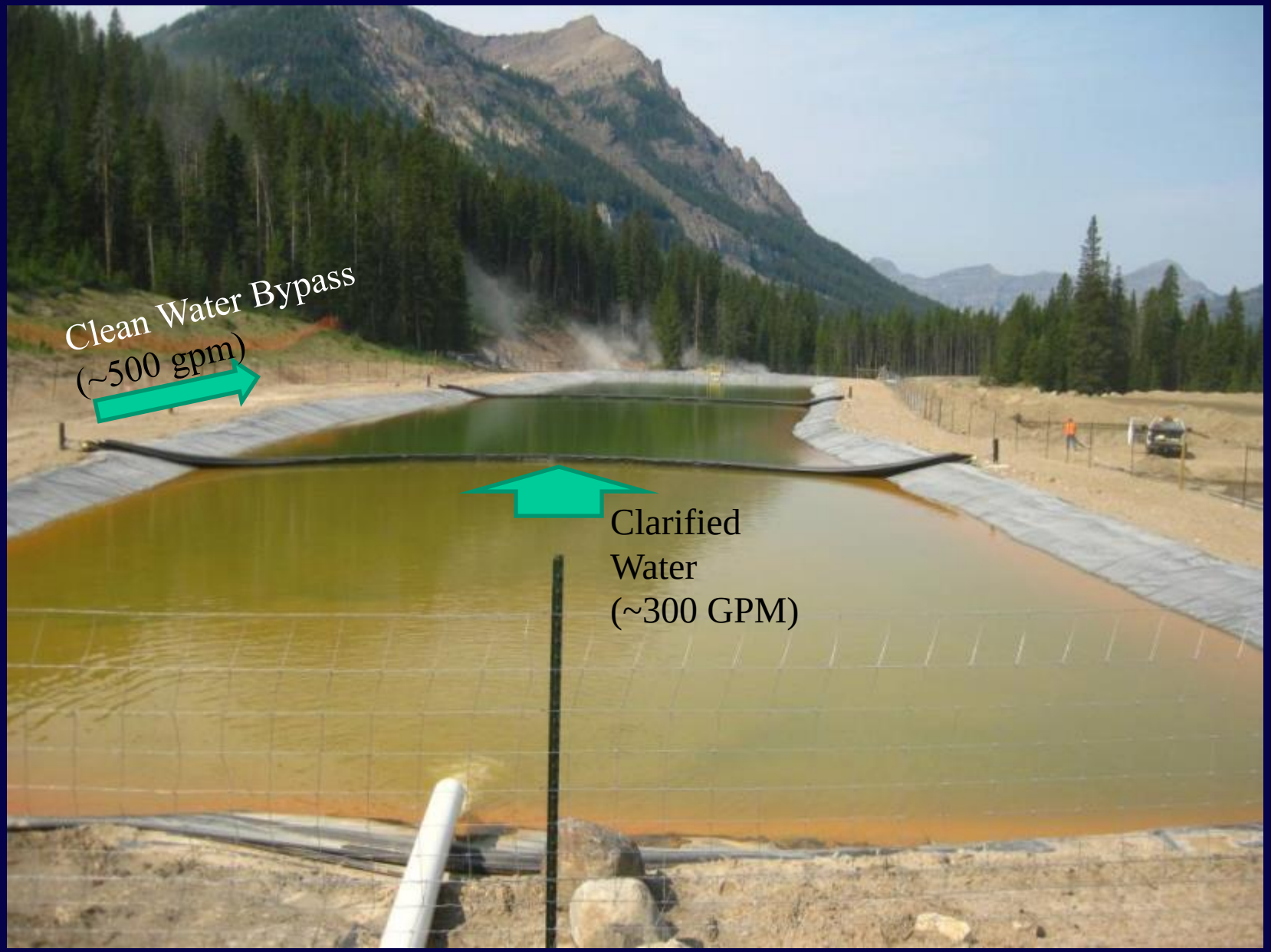
2011 Construction Season
(Prior to use of Dewatering Wells)

2012 Summer Construction Dewatering

- Three pumping wells under the tailings activated
- Approximately 300 gallons per minute water piped to water treatment plant and treated
- Weekly laboratory analysis of water quality throughout treatment process
- Comparison of 2010 and 2012 fluid levels indicates 25 – 30 feet of drawdown achieved in the three pumping wells

Water Treatment Facility

Clarification Pond and Clean Water Bypass



2012 Clarification Pond

Construction Dewatering - Effectiveness

Photo taken July 11, 2012

Construction Dewatering August 2012

Dewatered AMD Seeps

BEFORE:

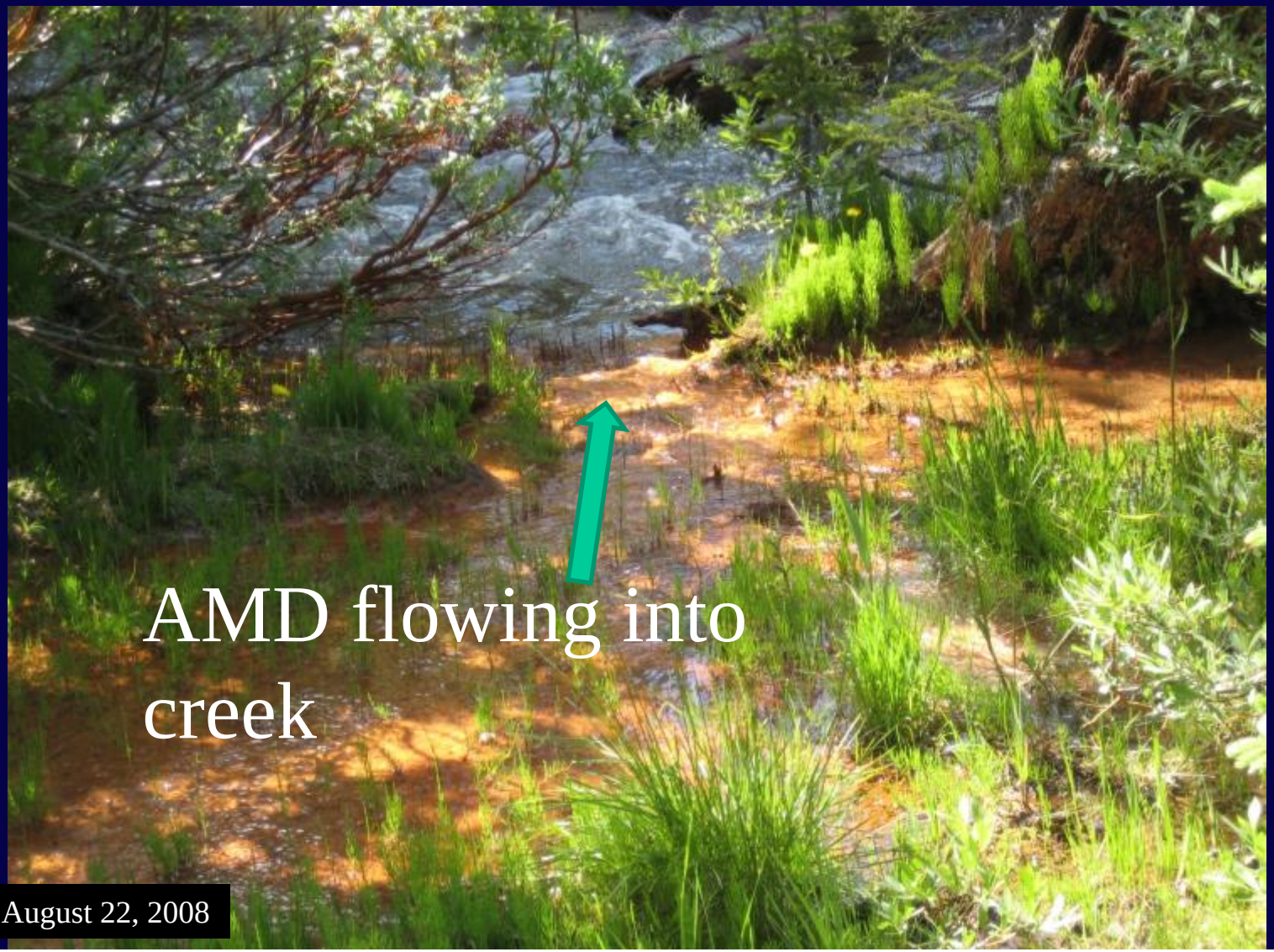
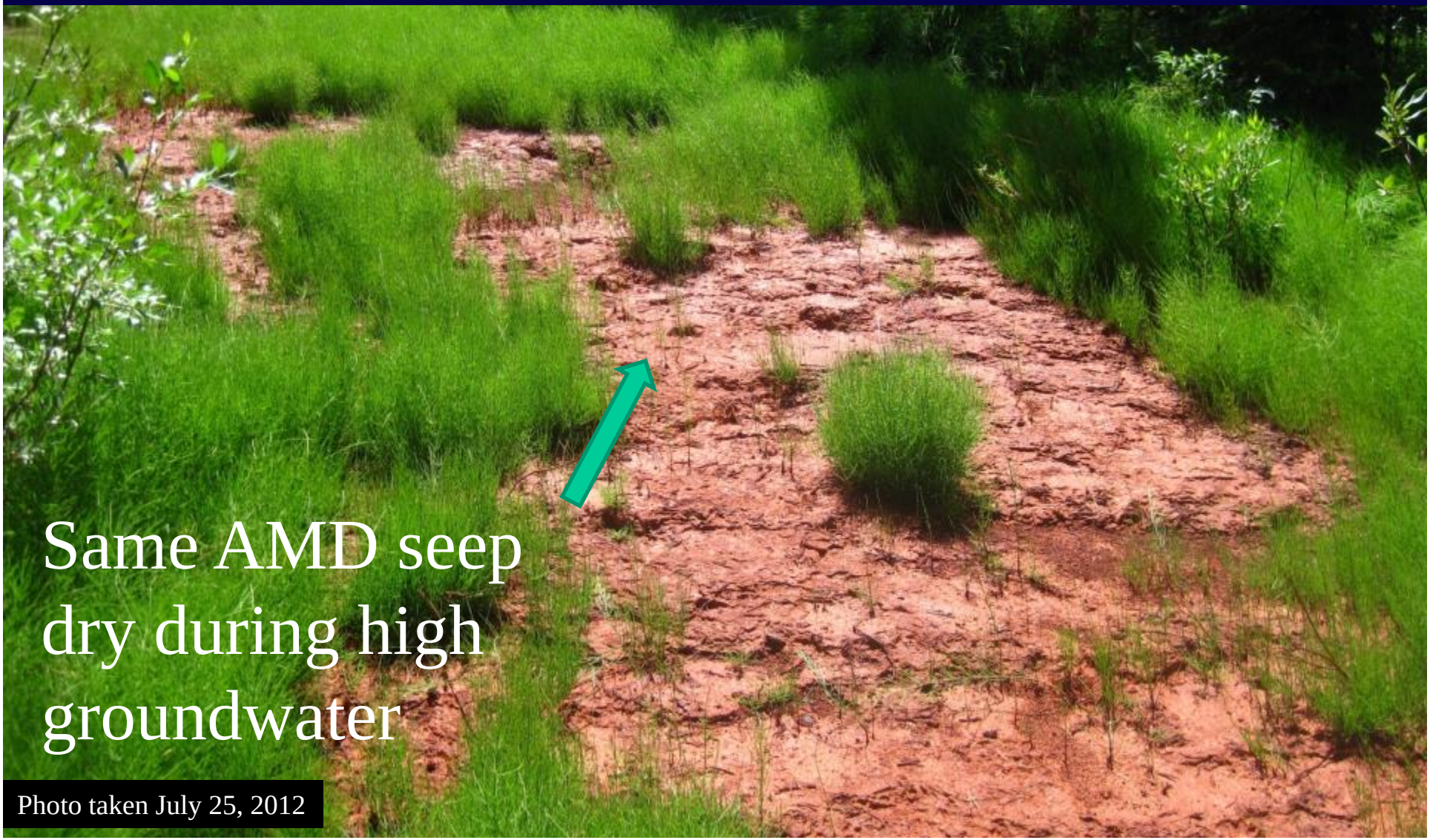


Photo taken August 22, 2008

Dewatered AMD Seeps

AFTER:



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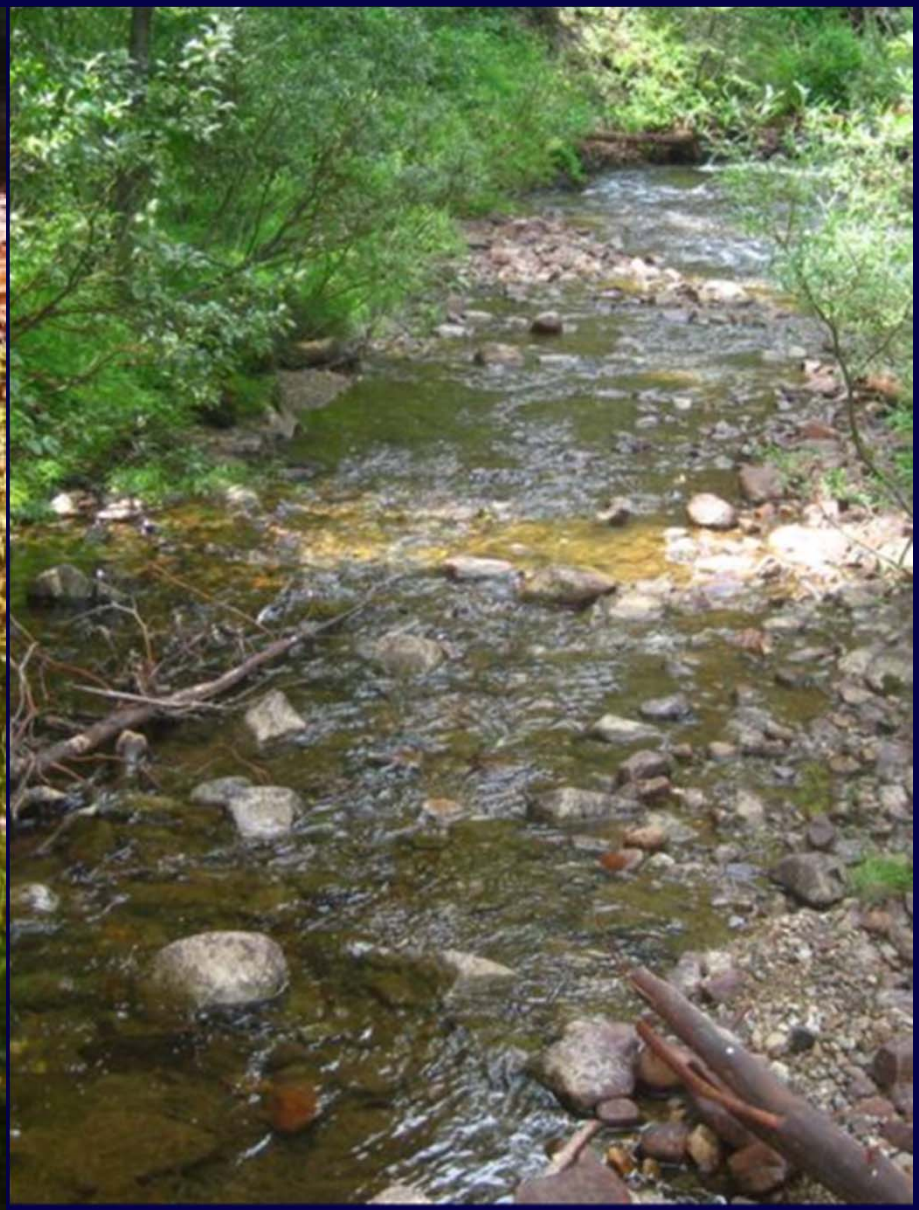
Results

- Detailed site investigation data critical to develop conceptual and numerical models
- System design not possible without numerical modeling
- Successes of the dewatering system:
  - Put the project one year ahead of schedule;
  - Significantly reduced lime costs; and
  - Allowed systematic and complete excavation of tailings 20 feet below pre-system groundwater elevation
- Water quality on reconstructed channels of Soda Butte and Miller Creeks complies with DEQ-7

Soda Butte Creek

2008



2013

Awards

- 2015 National Recognition Award from American Council of Engineering Companies

- Montana Contractors Construction Excellence Award
  - Overall Excellence Award
  - Special Recognition – Water Quality


Questions?

Objectives for Construction Dewatering Design

- **Criteria:**
  - Efficiency
  - Cost-Effective, and
  - Feasibility
- **Develop Feasibility Considerations:** for Construction Dewatering Design
- **Identify :** Key aspects of the conceptual dewatering design

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  - Cost-Effective, and
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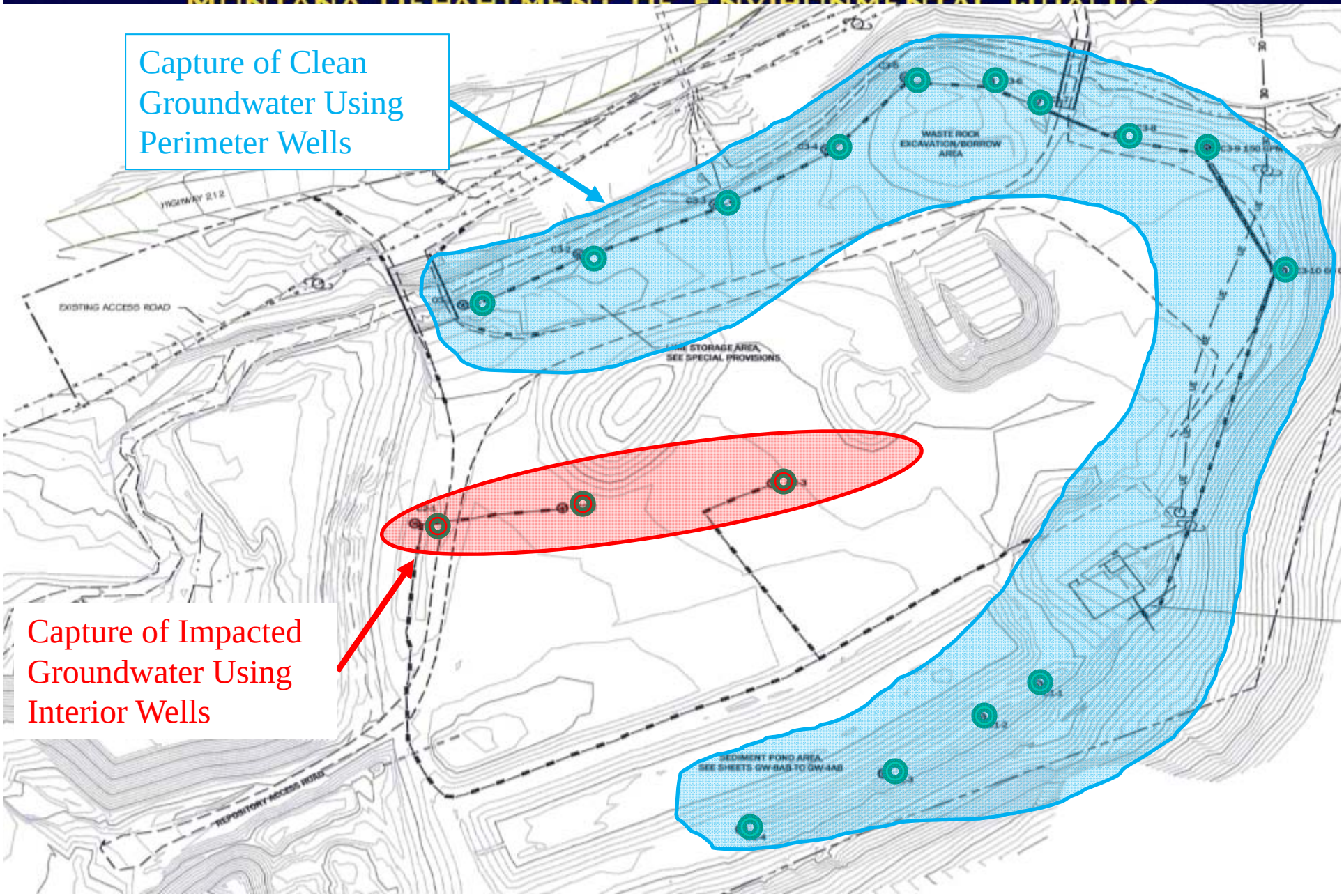
Final Pumping Well Design Locations



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