Jamestown Mine
Harvard Pit
Water Balance Model

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Characterizing, Predicting and Modeling Water at
Mine Sites
SWRCB Training Academy Short Course

Jamestown, CA
Water Waste & Land
Time-Step Water Balance Model

- \( V_t = V_{t-1} + 2(GW + \text{runoff} + \text{precip}) - \text{evap} \)
- Assumed groundwater inflow would equal dewatering rates.
- Does not account for the increase in pit area as mine depth increased.
- Linear Regression calculation based solely on dry season inflow.
- Wet season dewatering rates ignored.
- Resulted in underestimation of groundwater contribution to refill of HP.
- Model predicted 1,270 elevation reached in 2025
Water Waste & Land vs Observed

WWL Model Predictions versus Observed
1990 through 2007

- Observed Harvard Pit Elevations
- WWL Predicted Elevations

Date

Harvard Pit Water Elevation (ft mean)

900 1000 1100 1200 1300

Brown & Caldwell
Similar to WWL Model

- Precipitation used Monte Carlo simulation
- GW inflow used Jacob-Lohman constant drawdown equation to model HP as large diameter well
- Produced higher, flatter curve.
- B&C used 1,340 as pre-mining water level
- Model did not account for pre-mining hydraulic gradient
Brown & Caldwell vs Observed

B & C Model Predictions versus Observed
2001 through 2007

Harvard Pit Water Elevation (ft msl)
Date

- Observed Harvard Pit Elevations
- B & C Predicted Elevations
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Harvard Pit Refilling Model

- Conceptualization
  - Visual MODFLOW (VMF) V. 4.2
  - HP - surface water body, simulated by creation of 2 highly conductive zones (10cm/s)
  - Bedrock - 4 hydrologic zones
Model Construction

- Model domain - 2x length by 3x width of HP
- Domain separated into 6 hydrologic zones
  - (4) Gabbro, serpentine, phyllite & schist
  - (2) Open HP & northern backfilled HP
- Model consists of 8 individual layers
- HP modeled by high conductivity zones
Model Construction

GW flow - anisotropic

Boundaries:
- Top & bottom - constant head recharge boundaries
- Sides - no flow
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Harvard Pit Refilling Model

- Model Construction
- TMF transfer
- Modeled as injection well
- Turned on, October 2006
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Harvard Pit Refilling Model

- **Model Construction**
  - Precipitation - Sonora ranger stn, avg monthly rain fall
  - Runoff – 30%
  - Evaporation – New Melones dam, pan coefficient 0.72
  - Recharge to GW – 14.77% of precipitation.
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Harvard Pit Refilling Model

**Calibration** – primarily trial & error

- Initial run, 3,652 days, 1/1/1998 to 12/31/2007 to calibrate
- Model Runs (2) -
  - 23 years 1/1/1998 to 12/31/2020
  - 53 years 1/1/1998 to 12/31/2050
- Observation wells – 10 + Harvard Pit; head observations plus initial head.
Sensitivity Analysis

Hydraulic conductivity, Y direction
largest effect on model results
Harvard Pit Refilling Model vs Observed
Shaw E & I
Harvard Pit Refilling Model

Results

- 1,320 elevation by December 2015
- 1,330 by February 2018
- GW flow 0 to 12 gpm
- 1,358 by February 2029 spill over
- Surface flow 0 to 200+ gpm to Woods Creek
- TMF – 1,320 reached 2 yrs earlier
Harvard Pit Refilling Model
1,320 elevation by December 2015
Harvard Pit Refilling Model
1,358 by February 2029 spill over
Harvard Pit Over Flowing

- MODFLOW predicts pit will fill to 1320 ft msl in 2015.
- Flow through bedrock into Woods Creek and affect water quality.
- Flow increases to 12 gpm until level reaches spillover of 1358 ft msl in 2029.
- Flow over southern wall into creek.
- Rate to creek varies by season from 0 gpm to 200 gpm in rainy season.
Over Flow Point

HARVARD PIT

WOODS CREEK

PLAN VIEW

CROSS-SECTION A-A'

Q = 0 to 202 gpm

Q = 0 to 13 gpm
Harvard Pit Treatment

- Trees (phytohydraulics) up-gradient in Crystalline Pit, to reduce GW inflow.
- 650 mature trees equals 20 gpm, initially plant 5,000 small trees.
- Extract 55 million gallons per year.
- Pit contains over 2,500 mg/L TDS, mostly Ca and Mg sulfates.
- As removed by ferrous/ferric iron or GeoBind™ blended MgO.
- TDS by reverse osmosis (RO).
Harvard Pit Treatment Options

- Ultra filtration/reverse osmosis (UF/RO) system – UF/RO 55% clean water discharge to creek. Concentrate to pit.
- Dry season evaporation ponds (with/without treatment) – 60-acre evap. pond on TMF fill April to Oct., concentrate to pit. Treat to remove As, lowering risk in creek.
- Enhanced spray evaporation with treatment – Spray Evap units increase evaporation with smaller ponds. Treat to remove As, operate April to Oct, concentrate to pit.
- Wet season discharge to Woods Creek – During high creek flow treat to remove As. Treated water contains high sulfates, discharge fixed to creek flow.
Treatment Costs

- **UF/RO** - Capital cost is $3,390,000; O&M is $543,000/yr; 10-year capital and O&M is $8,820,000.

- **Dry season evap. with treatment** - Capitol cost is $9,650,000; O&M is $556,000/yr; 10-year capital and O&M is $15,210,000.

- **Dry season evap. no treatment** - Capital cost is $5,700,000, O&M is $234,000/yr; 10-year capital and O&M is $8,040,000.

- **Spray evap. with treatment** - Capital cost is $3,750,000; O&M is $398,000/yr; 10-year capital and O&M is $7,730,000.

- **Wet season discharge with treatment** - Capital cost is $3,200,000; O&M is $351,000/yr; 10-year capital and O&M is $6,710,000.

Note: *** indicates preferred option
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