# MINE WATER MANAGEMENT AT A LIMITED-DISCHARGE POTASH MINE IN SASKATCHEWAN

**JEFF GRINSEL**

**ART KALMES**

**SETH ANDERSON**

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# MINE WATER MANAGEMENT AT A LIMITED DISCHARGE POTASH MINE IN SASKATCHEWAN

- DEFINITIONS
- REGULATIONS & GUIDELINES
- METEOROLOGY
- MODELING
- TAKE HOME MESSAGE
- QUESTIONS

# HOW DO WE HANDLE MINE SITE STORMWATER RUNOFF?

- ZERO DISCHARGE MINE
  - PLANT INTAKE / RECLAIM
  - EVAPORATION
- LIMITED DISCHARGE MINE
  - INJECTION
  - WATER TREATMENT AND DISCHARGE TO SURFACE WATER
- FREE DISCHARGE MINE
  - DISCHARGE TO SURFACE WATER

    (RUNOFF IS INERT, NOT AN ENVIRONMENTAL HAZARD)

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# REGULATIONS & GUIDELINES

- REQUIRES CONTROL OF RUNOFF FROM AN **EVENT**
  - **100-YEAR, 24-HOUR STORM**
  - **300mm, 24-HOUR STORM**
    - *HISTORICAL DESIGN STORM FOR POTASH MINES IN SASKATCHEWAN*
  - **1000-YEAR, 24-HOUR STORM**
  - **PROBABLE MAXIMUM FLOOD (PMF)**
  - **COMBINATION OF 1000-YEAR & PMF (2/3 BETWEEN 1000-YEAR AND PMF)**
    - *CDA DAM SAFETY GUIDELINES, HIGH DAM CLASSIFICATION*

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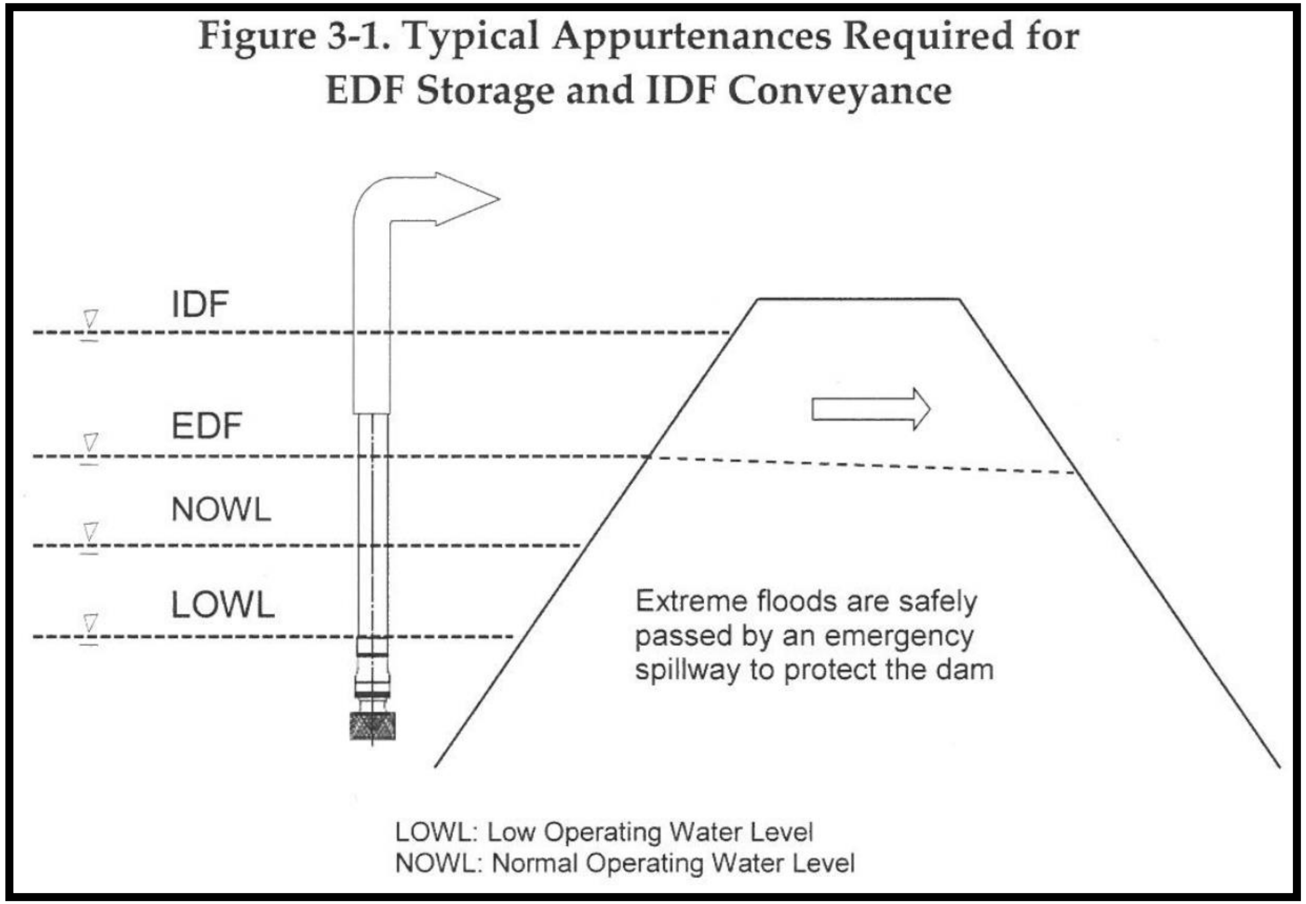
# REGULATIONS & GUIDELINES




EXCERPT FROM CDA TECHNICAL BULLETIN
*"MINING DAMS: APPLICATION OF 2007 DAM SAFETY GUIDELINES TO MINING DAMS"*

- **LOWL: LOW OPERATING WATER LEVEL**
- **NOWL: NORMAL OPERATING WATER LEVEL**
- **EDF: ENVIRONMENTAL DESIGN FLOOD**

  "THE *EDF* IS THE *MOST SEVER FLOOD TO BE MANAGED WITHOUT RELEASE OF UNTREATED WATER TO THE ENVIRONMENT"*

- **IDF: INFLOW DESIGN FLOOD**

  *"THE IDF IS THE MOST SEVERE INFLOW FOR WHICH A DAM AND ITS ASSOCIATED FACILITIES ARE TO BE DESIGNED"*

- **FREEBOARD**

  ACCOUNTS FOR WAVE ACTION & RUNUP GENERATED DURING A HIGH WIND EVENT

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# WHAT ABOUT OTHER **METEOROLOGICAL** CONSIDERATIONS?

- EQUIVALENT MULTI-DAY DURATION STORM EVENTS (SASKATOON)

| STORM EVENT 1 | RAINFALL DEPTH (mm) | STORM EVENT 2 | RAINFALL DEPTH (mm) |
|---|---|---|---|
| 50 YEAR, 24 HR | $80_1$ | 10 YEAR, 4 DAY | 85 |
| 100 YEAR, 24 HR | $94_1$ - $95_2$ | 5 YEAR, 10 DAY | 93 |
| 1000 YEAR, 24 HR | $121_3$ | 25 YEAR, 10 DAY | 132 |
| 300mm, 24 HR | 300 | 25 YEAR, 60 DAY | 295 |

1: ENVIRONMENT CANADA, SHORT DURATION INTENSITY-DURATION-FREQUENCY DATA , SASKATOON, SK (SASKATOON DIEFENBAKER INT'L AIRPORT)

2: ENVIRONMENT CANADA & R.F. HOPKINSON, POINT PROBABLE MAXIMUM PRECIPITATION FOR THE PRAIRIE PROVINCES (1999), SASKATOON, SK

3: BARR ENGINEERING ESTIMATE BASED ON DAILY PRECIPITATION DATA BETWEEN 1926 – 2011 USING EXTREME VALUE TYPE 1 DISTRIBUTION

- BEST PRACTICE: EVALUATION OF MULTI-DAY EVENTS NECESSARY FOR COMPLETE ASSESSMENT AT ***ZERO DISCHARGE*** AND ***LIMITED DISCHARGE*** MINES

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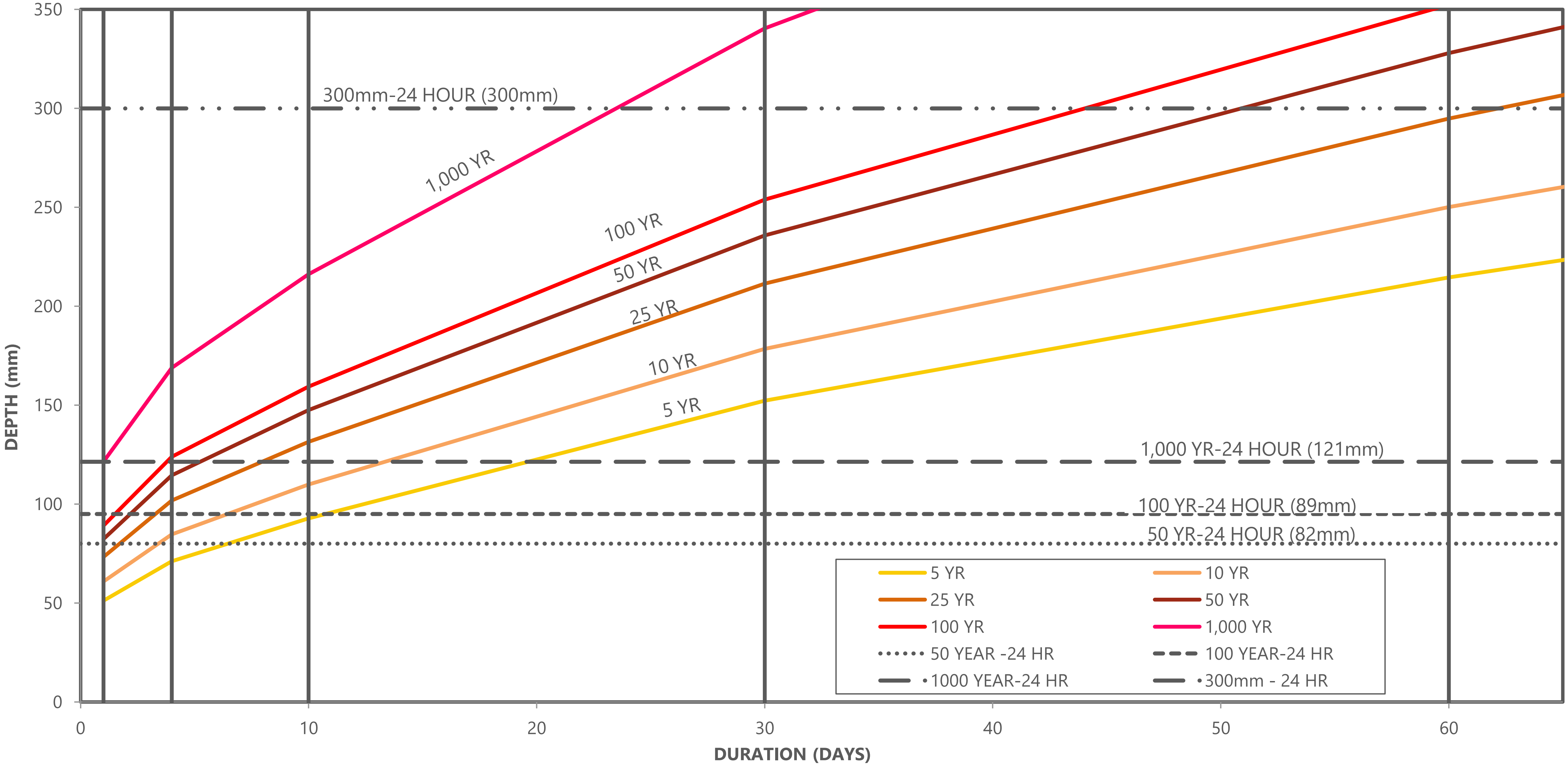
# WHAT ABOUT OTHER **METEOROLOGICAL** CONSIDERATIONS?

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# WHAT ABOUT OTHER **METEOROLOGICAL** CONSIDERATIONS?

- REGULATORY GUIDELINES ADDRESS STORMWATER RUNOFF
- WHAT ABOUT **DROUGHT** CONDITIONS?
  - NOT REGULATED BY A GOVERNING AGENCY
  - CRITICAL FROM AN OPERATIONS PERSPECTIVE
    - POND SIZING
    - STAGE STORAGE
    - INTAKE PUMP INVERT ELEVATION

*WHAT IF THIS WAS A MINE WATER STORAGE AREA?*

# WHAT ABOUT OTHER **METEOROLOGICAL** CONSIDERATIONS?

CONSIDERATIONS

- REGULATIONS & GUIDELINES
- LONG DURATION STORMS
- DRY / DROUGHT CONDITIONS
- FACILITY OPERATION CHANGES

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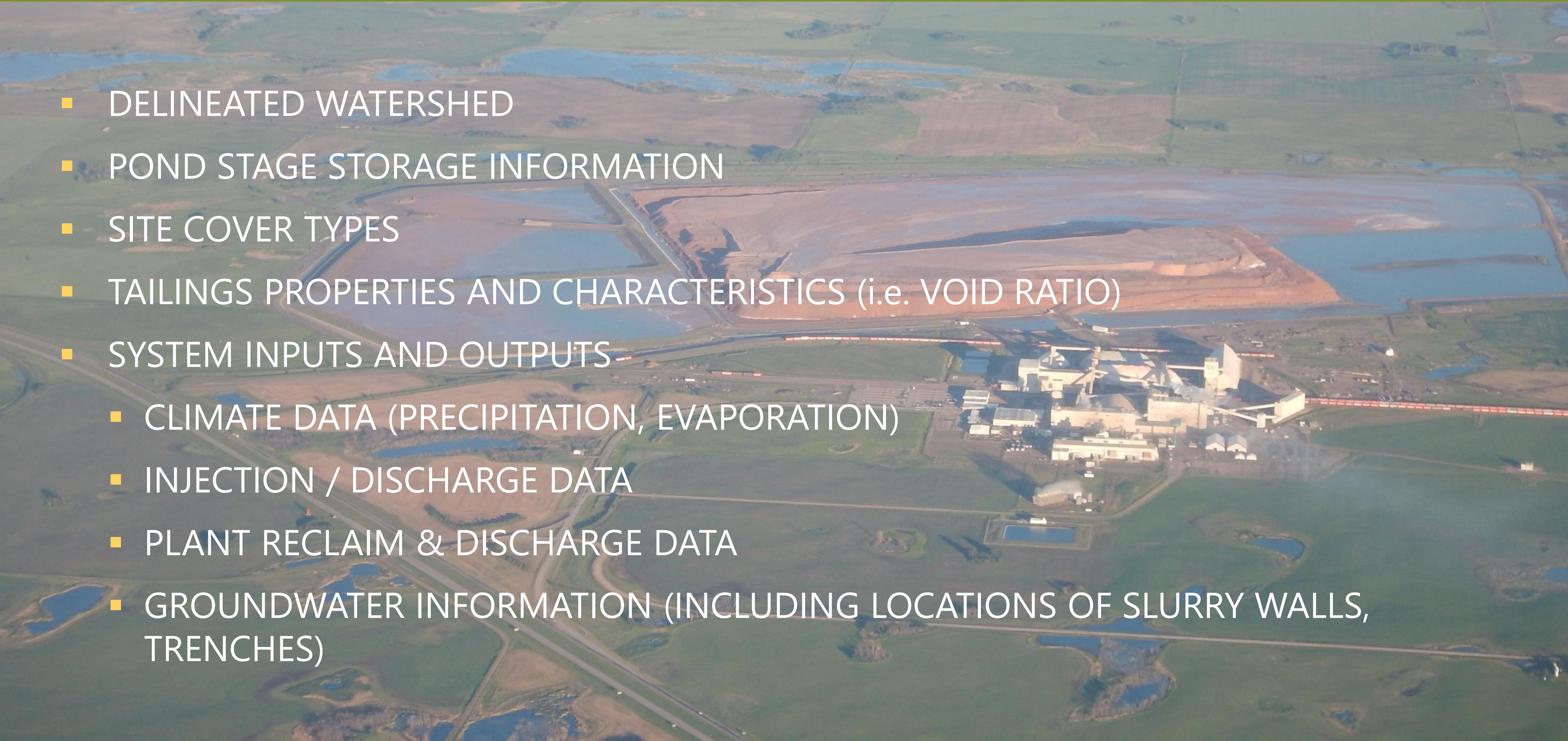
# WATER BALANCE MODELING

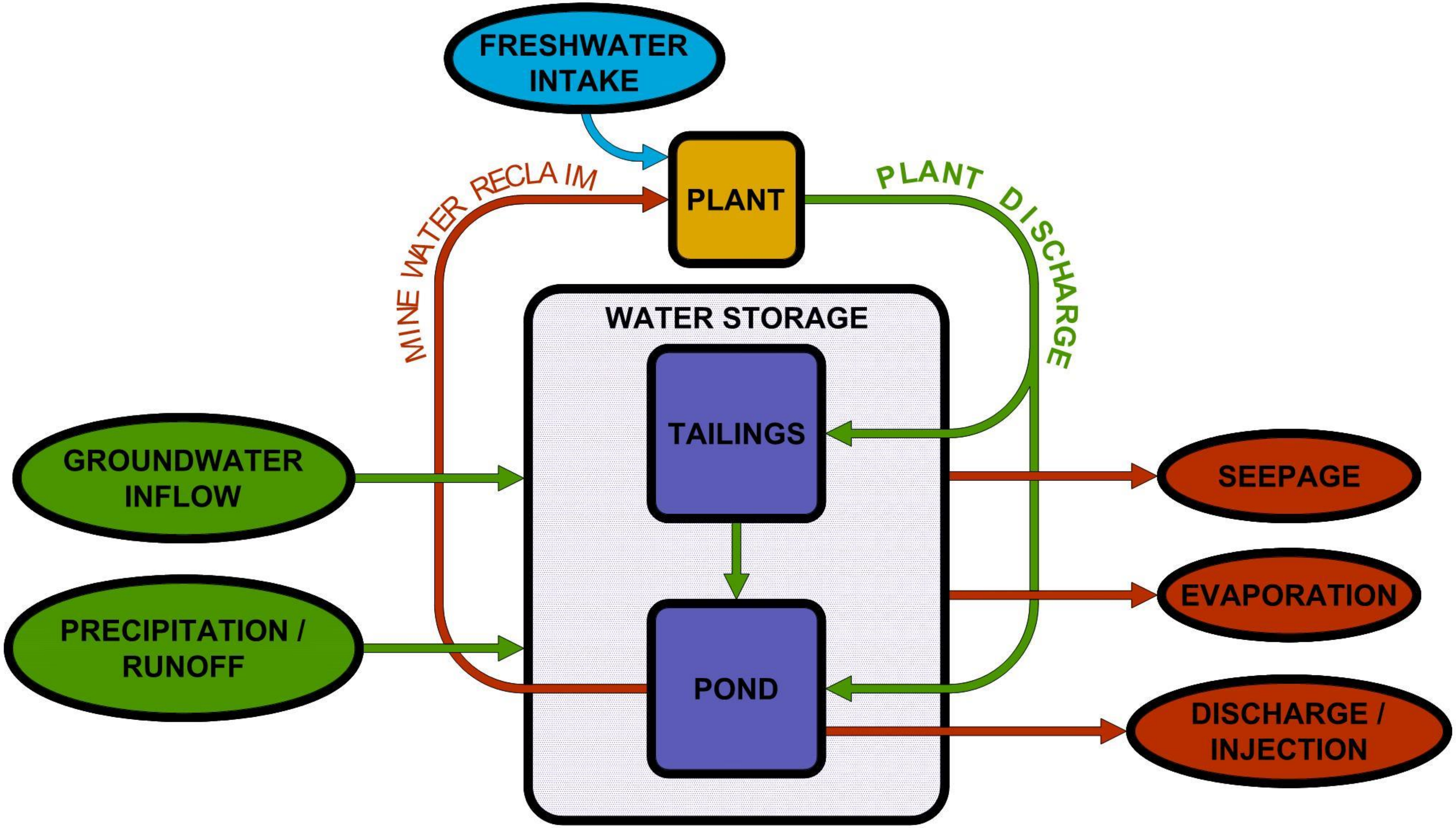
- PURPOSE
  - SUPPLEMENT EVENT BASED MODELS
  - EVALUATE PERFORMANCE DURING A VARIETY OF SEASONAL WEATHER PATTERNS
  - ADDRESS FACILITY OPERATION CHANGES
  - HELP MINE STAFF MAKE INFORMED OPERATING DECISIONS
- MODEL TYPES
  - SPREADSHEETS
    - EASY TO USE
    - READILY AVAILABLE
    - KNOWLEDGE TRANSFER BETWEEN CLIENT AND CONSULTANT
  - GOLDSIM MODEL
    - RISK ANALYSIS / MONTECARLO SIMULATION

# WATER BALANCE MODELING
## (MODEL NEEDS)



- DELINEATED WATERSHED
- POND STAGE STORAGE INFORMATION
- SITE COVER TYPES
- TAILINGS PROPERTIES AND CHARACTERISTICS (i.e. VOID RATIO)
- SYSTEM INPUTS AND OUTPUTS
  - CLIMATE DATA (PRECIPITATION, EVAPORATION)
  - INJECTION / DISCHARGE DATA
  - PLANT RECLAIM & DISCHARGE DATA
  - GROUNDWATER INFORMATION (INCLUDING LOCATIONS OF SLURRY WALLS, TRENCHES)

# WATER BALANCE MODELING – SYSTEM INPUTS & OUTPUTS

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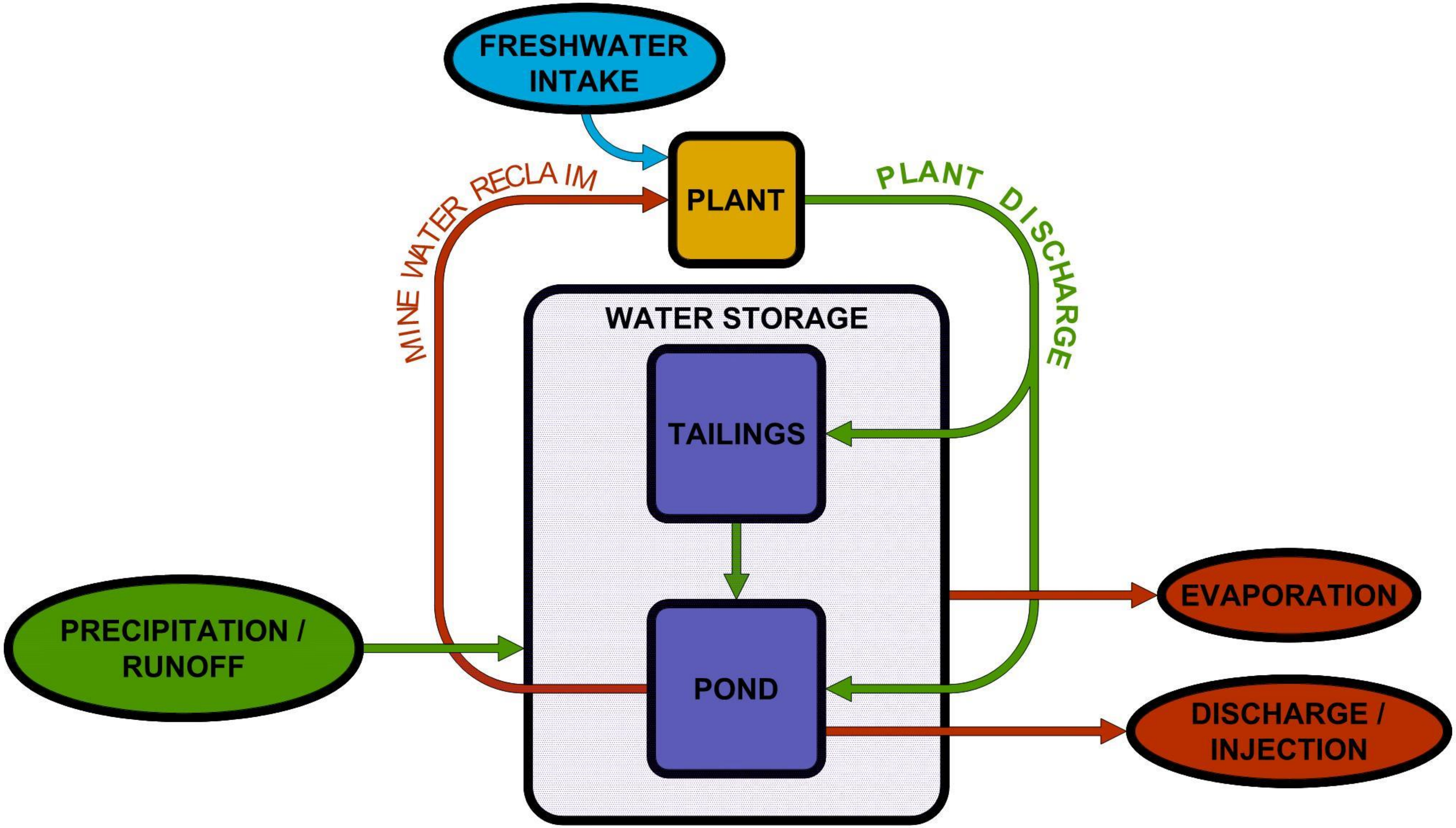
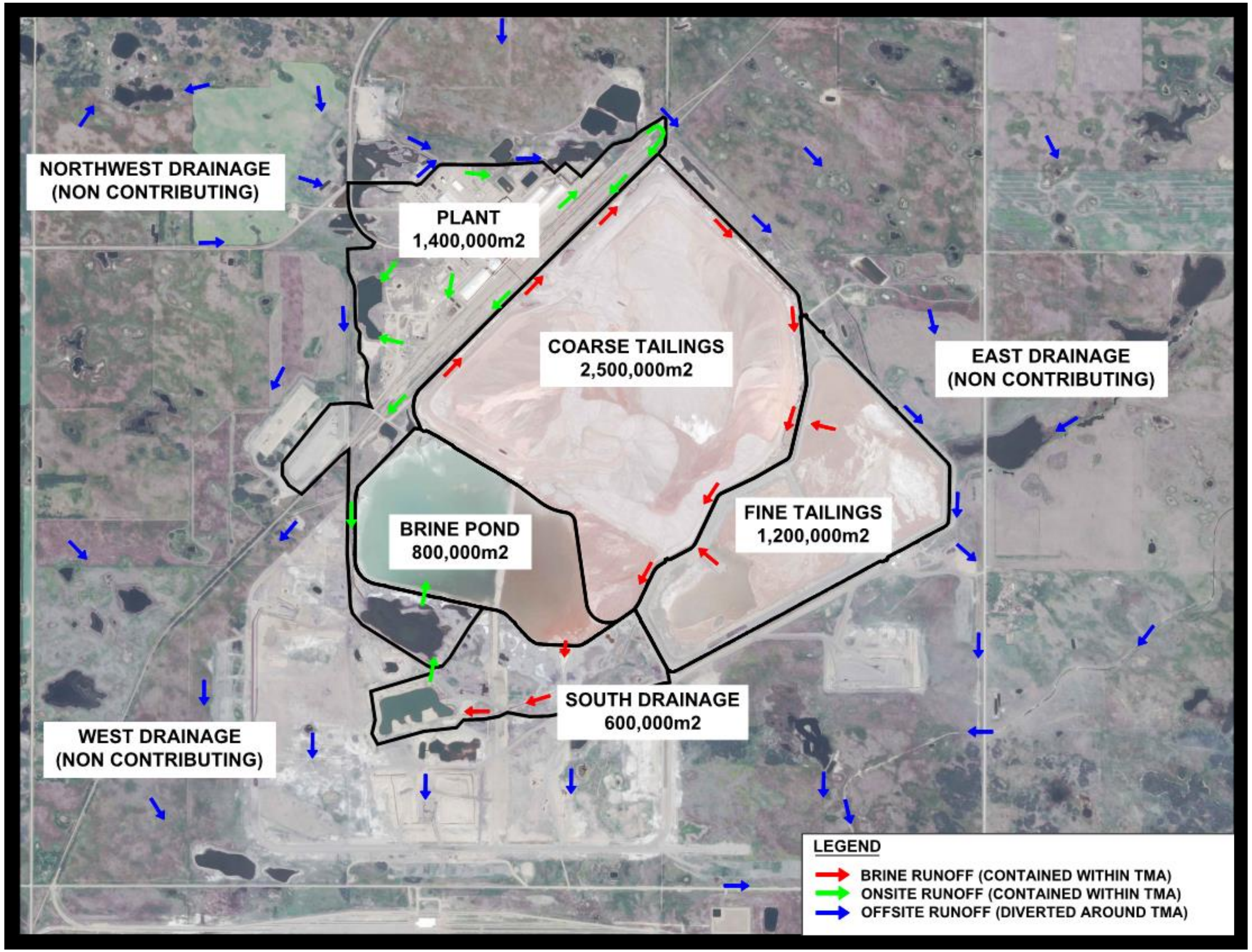
# WATER BALANCE MODELING – SYSTEM INPUTS & OUTPUTS (EXAMPLE)



# WATER BALANCE MODELING – PRECIPITATION / RUNOFF

- WHERE DOES THE WATER GO?
- HOW BIG ARE THE CONTRIBUTING WATERSHEDS?
- WHAT ARE THE COVER TYPES?

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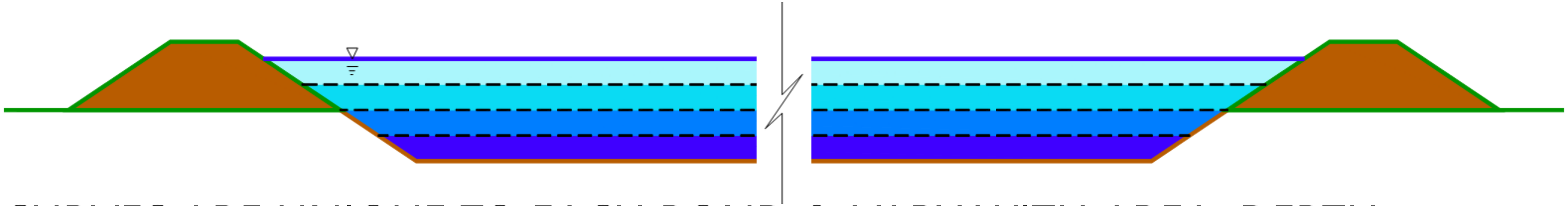
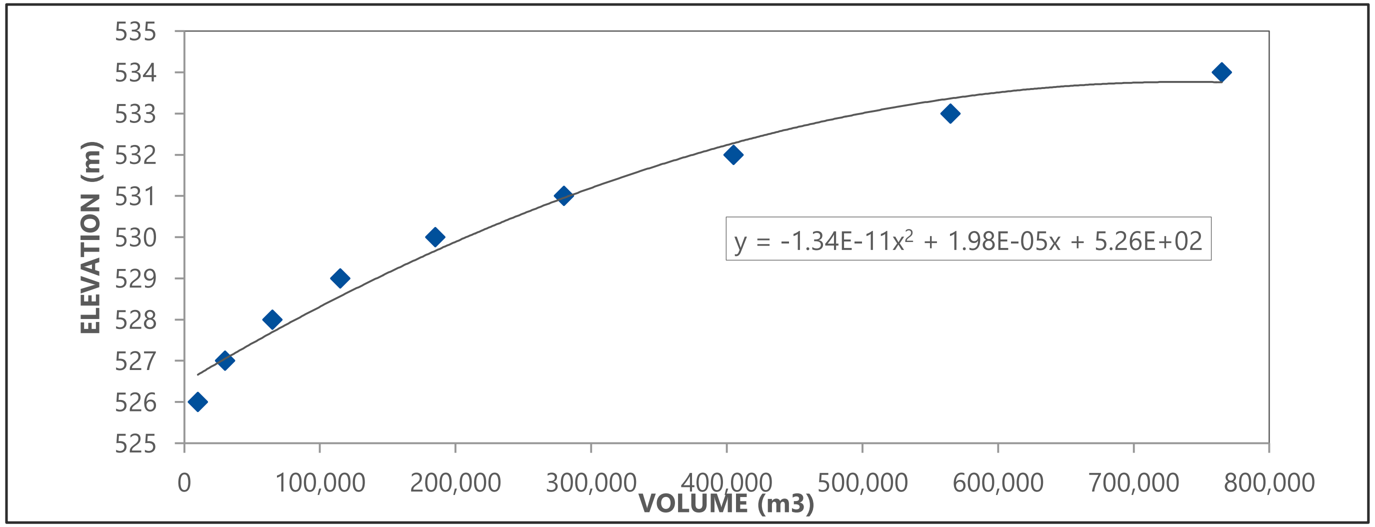
# WATER BALANCE MODELING –STORAGE

- TAILINGS STORAGE
- POND STORAGE
  - A STAGE STORAGE CURVE RELATES VOLUME TO ELEVATION



  - CURVES ARE UNIQUE TO EACH POND & VARY WITH AREA, DEPTH
    - y = POND ELEVATION
    - x = POND VOLUME

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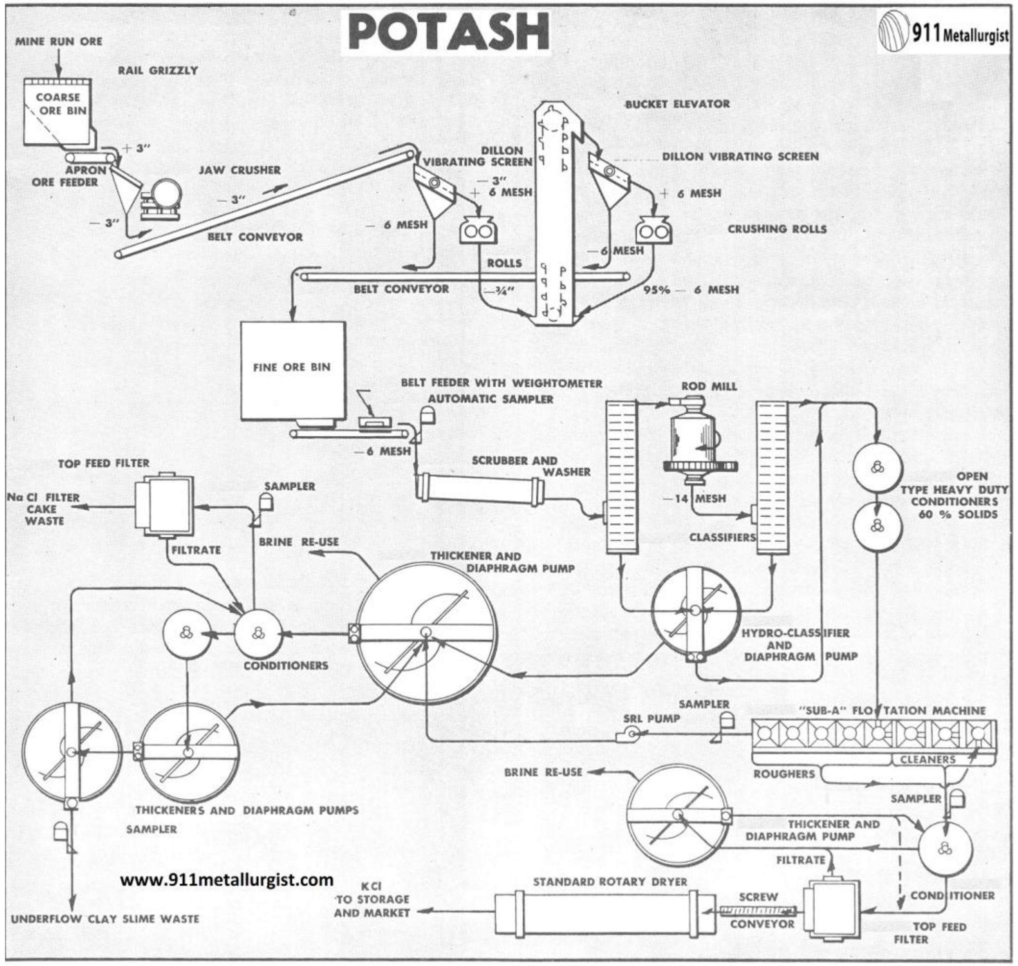
# WATER BALANCE MODELING – INPUTS AND OUTPUTS

- INPUTS (WATER ADDITIONS)
  - PRECIPITATION
    - 74 YEARS OF *DAILY* PRECIPITATION *(SOURCE INFO FROM ENVIRONMENT CANADA)*
  - PLANT DISCHARGE
    - FACILITY RECORDS
    - MEASURE FLOWS AT PIPE OUTLETS
    - CALIBRATION USING KNOWN INPUTS AND OUTPUTS

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# WATER BALANCE MODELING – INPUTS AND OUTPUTS

- SYSTEM OUTPUTS (LOSSES)
  - EVAPORATION
    - DAILY DATA OBTAINED TO ESTIMATE POND LOSSES *(SOURCE INFO FROM ENVIRONMENT CANADA)*
    - OVER 20mm DAILY EVAPORATION POSSIBLE IN SUMMER MONTHS
  - BRINE INJECTION
    - HISTORICAL INJECTION RATES REFERENCED IN MODEL

# WATER BALANCE MODELING

INPUTS - EXISTING CONDITIONS

| | | | |
|---|---|---|---|
| Precipitation Factor | | 1.15 | …s brine (Golder and Associates, 2009 |
| Evaporation Factor | | 0.6 | …*(Conversion of EVAPfresh to EVAPbrine) = (0.7)*(0.8) |
| | | | …ce / Department of Fisheries and the environment |
| $DATE_{start}$ | mm/dd | 299 | …vaporation of Brine Solutions Under Controlled Laboratory Conditions (1968 |
| $V_{start}$ | $m^3$ | | |

| REGION | | BRINE PND | COARSE TP | FT CELLS | RUNOFF | RECLAIMED | 0.0254 | METERS / INCH |
|---|---|---|---|---|---|---|---|---|
| AREA | $m^2$ | 912,000 | 2,458,000 | 1,206,000 | 1,742,000 | - | FOR RUNOFF CALCULATION | |

…ap & Plnt to TMA" tab

- CONVERSION FACTORS
- ADJUSTMENT FACTORS
- WATERSHED AREAS
- RUNOFF CALCULATION COEFFICIENTS

| INJECTION CRITERIA | | 60% Trigger | 80% Trigger | 100% Trigger |
|---|---|---|---|---|
| Brine Pond Elevation | (m) | 531.1 | 531.3 | 531.5 |
| Injection Volume | ($m^3$) | 7800 | 11700 | 15600 |

See "L-Injection Criteria" for injection …

*Brine Pond Elevation = .000001*(Volume)+529.8 - Brine Pond Elevation vs. Volume Equation from "Re…

| | | | |
|---|---|---|---|
| High Operating Level | 531.90 | m | Design Flood Level |
| Low Operating Level | 530.80 | m | Top of Dyke |
| Top of Dyke | 533.75 | m | |

(Set according to HydroCAD Event Based Water Balance)

- INJECTION CRITERIA

DAILY INPUTS

-DATE
-PRECIPITATION DEPTH
-EVAPORATION DEPTH

SUM OF LOSSES (m3) + SUM OF ADDITIONS (m3) = NET VOL CHANGE (m3)

- POND VOLUME (m3)
- POND ELEVATION

INJECTION ???

| Month | Day | Value | Avg Tmp | Precip | Precip* | Evap | Date | Losses: Evaporation | Losses: Tailings Storage | Losses Total | Additions: Net Plant to TMA | Additions: Precipitation | Additions Total | Net Volume Change | Brine Pond Volume* | Brine Pond Elevation* | Injection Required | Injection Capacity |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (°C) | (mm) | (in) | (mm) | | ($m^3$/day) | ($m^3$/day) | ($m^3$/day) | ($m^3$/day) | ($m^3$/day) | ($m^3$/day) | ($m^3$/day) | ($m^3$) | (m) | ($m^3$) | % |
| 1 | 1 | 1 | [illegible] | [illegible] | 0.000 | 0.000 | 1/1/1926 | 0 | [illegible] | 1,151 | 11,560 | [illegible] | 11,560 | 10,409 | 1,051,000 | 531.80 | [illegible] | [illegible] |
| 1 | 2 | 2 | -4.8 | 0 | 0.000 | 0.000 | 1/2/1926 | 0 | 1,151 | 1,151 | 11,560 | 0 | 11,560 | [illegible] | [illegible] | [illegible] | 15600 | 80% |
| 1 | 3 | 3 | -7.8 | 0 | 0.000 | 0.000 | 1/3/1926 | 0 | 1,151 | 1,151 | 11,560 | 0 | 11,560 | 10,409 | 1,051,000 | 531.80 | 15600 | 80% |
| 1 | 4 | 4 | -5.9 | [illegible] | 0.051 | 0.000 | 1/4/1926 | 0 | 1,151 | 1,151 | 11,560 | 3,501 | 15,061 | 13,910 | 1,051,000 | 531.80 | 15600 | 80% |
| 1 | 5 | 5 | [illegible] | [illegible] | [illegible] | 0.000 | 1/5/1926 | 0 | 1,151 | 1,151 | 11,560 | 3,293 | 14,853 | 13,702 | 1,051,000 | 531.80 | 15600 | 80% |
| 1 | 6 | 6 | [illegible] | [illegible] | [illegible] | 0.000 | 1/6/1926 | 0 | 1,151 | 1,151 | 11,560 | 0 | 11,560 | 10,409 | [illegible] | [illegible] | 15600 | 80% |
| 1 | 7 | 7 | -4.2 | 0 | 0.000 | 0.000 | 1/7/1926 | 0 | 1,151 | 1,151 | 11,560 | 0 | 11,560 | 10,409 | 1,051,000 | 531.80 | 15600 | 80% |
| 1 | 8 | 8 | -6.7 | 0 | 0.000 | 0.000 | 1/8/1926 | 0 | 1,151 | 1,151 | 11,560 | 0 | 11,560 | 10,409 | [illegible] | [illegible] | 15600 | 80% |
| 1 | 9 | 9 | -0.6 | 0 | 0.000 | 0.000 | 1/9/1926 | 0 | 1,151 | 1,151 | 11,560 | 0 | 11,560 | 10,409 | 1,051,000 | 531.80 | 15600 | 80% |
| 1 | 10 | 10 | -9.2 | 0 | 0.000 | 0.000 | 1/10/1926 | 0 | 1,151 | 1,151 | 11,560 | 0 | 11,560 | 10,409 | 1,051,000 | 531.80 | 15600 | 80% |
| 1 | 11 | 11 | -10.6 | 0 | 0.000 | 0.000 | 1/11/1926 | 0 | 1,151 | 1,151 | 11,560 | 0 | 11,560 | 10,409 | 1,051,000 | 531.80 | 15600 | 80% |
| 1 | 12 | 12 | -2.5 | 0 | 0.000 | 0.000 | 1/12/1926 | 0 | 1,151 | 1,151 | 11,560 | 0 | 11,560 | 10,409 | 1,051,000 | 531.80 | 15600 | 80% |
| 1 | 13 | 13 | -1.2 | 0 | 0.000 | 0.000 | 1/13/1926 | 0 | 1,151 | 1,151 | 11,560 | 0 | 11,560 | 10,409 | 1,051,000 | 531.80 | 15600 | 80% |
| 1 | 14 | 14 | -3.6 | 0 | 0.000 | 0.000 | 1/14/1926 | 0 | 1,151 | 1,151 | 11,560 | 0 | 11,560 | 10,409 | 1,051,000 | 531.80 | 15600 | 80% |
| 1 | 15 | 15 | -0.9 | 0 | 0.000 | 0.000 | 1/15/1926 | 0 | 1,151 | 1,151 | 11,560 | 0 | 11,560 | 10,409 | 1,051,000 | 531.80 | 15600 | 80% |
| 1 | 16 | 16 | -3.4 | 0 | 0.000 | 0.000 | 1/16/1926 | 0 | 1,151 | 1,151 | 11,560 | 0 | 11,560 | 10,409 | 1,051,000 | 531.80 | 15600 | 80% |
| 1 | 17 | 17 | -11.1 | 7.6 | 0.299 | 0.000 | 1/17/1926 | 0 | 1,151 | 1,151 | 11,560 | 24,819 | 36,379 | 35,229 | 1,051,000 | 531.80 | 15600 | 80% |
| 1 | 18 | 18 | -21.7 | 0 | 0.000 | 0.000 | 1/18/1926 | 0 | 1,151 | 1,151 | 11,560 | 0 | 11,560 | 10,409 | 1,051,000 | 531.80 | 15600 | 80% |
| 1 | 19 | 19 | -25.3 | 0 | 0.000 | 0.000 | 1/19/1926 | 0 | 1,151 | 1,151 | 11,560 | 0 | 11,560 | 10,409 | 1,051,000 | 531.80 | 15600 | 80% |
| 1 | 20 | 20 | -22.5 | 0 | 0.000 | 0.000 | 1/20/1926 | 0 | 1,151 | 1,151 | 11,560 | 0 | 11,560 | 10,409 | 1,051,000 | 531.80 | 15600 | 80% |
| 1 | 21 | 21 | -22.5 | 0 | 0.000 | 0.000 | 1/21/1926 | 0 | 1,151 | 1,151 | 11,560 | 0 | 11,560 | 10,409 | 1,051,000 | 531.80 | 15600 | 80% |
| 1 | 22 | 22 | -18.9 | 0 | 0.000 | 0.000 | 1/22/1926 | 0 | 1,151 | 1,151 | 11,560 | 0 | 11,560 | 10,409 | 1,051,000 | 531.80 | 15600 | 80% |
| 1 | 23 | 23 | -13.6 | 0 | 0.000 | 0.000 | 1/23/1926 | 0 | 1,151 | 1,151 | 11,560 | 0 | 11,560 | 10,409 | 1,051,000 | 531.80 | 15600 | 80% |
| 1 | 24 | 24 | -11.4 | 0 | 0.000 | 0.000 | 1/24/1926 | 0 | 1,151 | 1,151 | 11,560 | 0 | 11,560 | 10,409 | 1,051,000 | 531.80 | 15600 | 80% |
| 1 | 25 | 25 | -7.5 | 0 | 0.000 | 0.000 | 1/25/1926 | 0 | 1,151 | 1,151 | 11,560 | 0 | 11,560 | 10,409 | 1,051,000 | 531.80 | 15600 | 80% |
| 1 | 26 | 26 | -16.4 | 0 | 0.000 | 0.000 | 1/26/1926 | 0 | 1,151 | 1,151 | 11,560 | 0 | 11,560 | 10,409 | 1,051,000 | 531.80 | 15600 | 80% |
| 1 | 27 | 27 | -21.1 | 0 | 0.000 | 0.000 | 1/27/1926 | 0 | 1,151 | 1,151 | 11,560 | 0 | 11,560 | 10,409 | 1,051,000 | 531.80 | 15600 | 80% |
| 1 | 28 | 28 | -18.1 | 0 | 0.000 | 0.000 | 1/28/1926 | 0 | 1,151 | 1,151 | 11,560 | 0 | 11,560 | 10,409 | 1,051,000 | 531.80 | 15600 | 80% |
| 1 | 29 | 29 | -10.3 | 2.5 | 0.098 | 0.000 | 1/29/1926 | 0 | 1,151 | 1,151 | 11,560 | 5,517 | 17,077 | 15,926 | 1,051,000 | 531.80 | 15600 | 80% |
| 1 | 30 | 30 | -13.9 | 0 | 0.000 | 0.000 | 1/30/1926 | 0 | 1,151 | 1,151 | 11,560 | 0 | 11,560 | 10,409 | 1,051,000 | 531.80 | 15600 | 80% |
| 1 | 31 | 31 | -15 | 0 | 0.000 | 0.000 | 1/31/1926 | 0 | 1,151 | 1,151 | 11,560 | 0 | 11,560 | 10,409 | 1,051,000 | 531.80 | 15600 | 80% |

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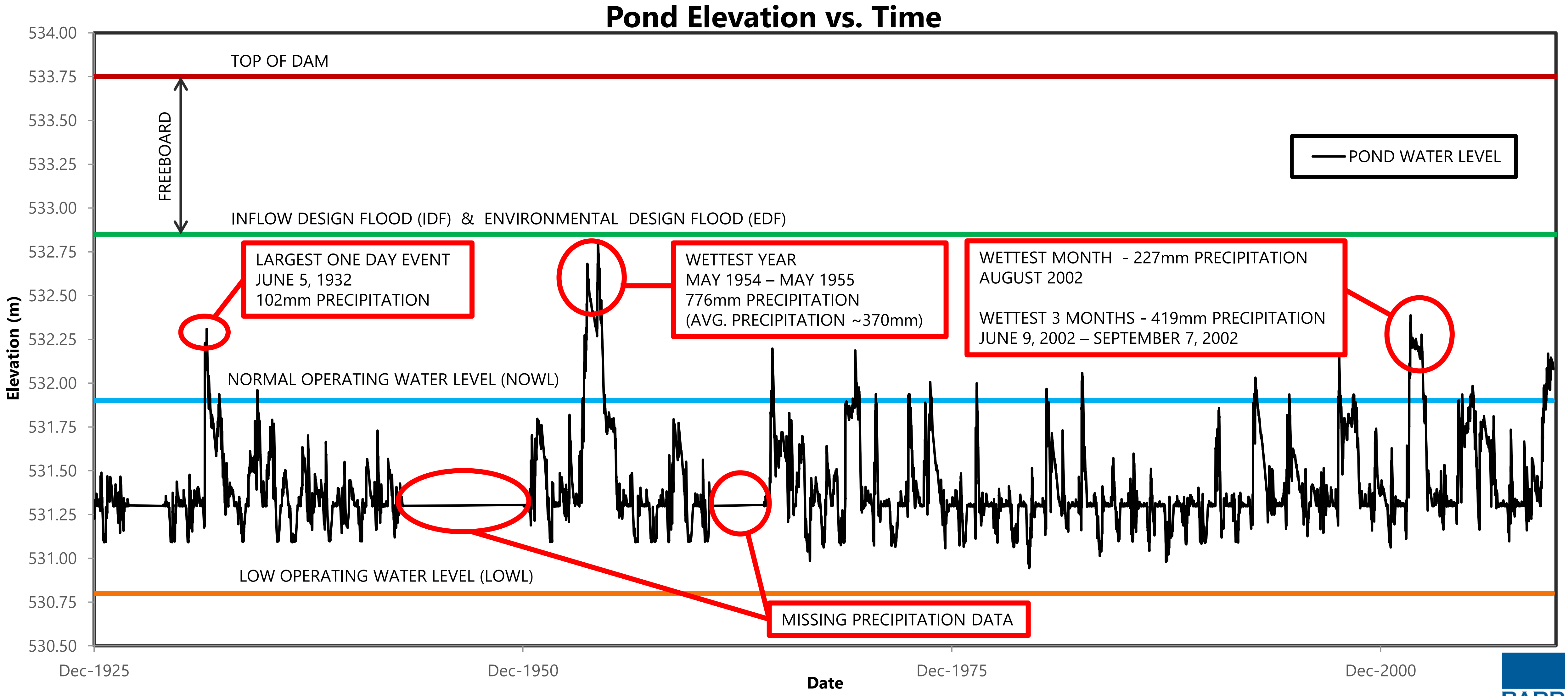
# DAILY WATER BALANCE MODELING – MODEL OUTPUT

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# WATER BALANCE MODELING – PRACTICAL APPLICATION

- MINE STAFF CAN USE MODEL TO ASSIST WITH DAILY OPERATIONS

***BRINE POND EVALUATION MODEL***

**RELEASE DATE: January 5, 2015**

This worksheet is intended to assist in managing the existing Brine Pond by assesing the potential for deviation from designated operating levels.
User inputs date, Brine Pond elevation, and injection criteria (yellow cells, Pond Evaluation worksheet). All other cells have been locked from editing.
Model outputs are days above the high operating level, days below the low operating level, and extreme elevations (green cells).
This model considers available historic daily precipitation (74 years) and evaporation data (40 years)

***USER INPUTS***

| | | |
|---|---|---|
| **DATE** | MM/DD/YYYY | 10/26/2016 |
| **BRINE POND ELEVATION** | masl | 531.80 |
| MONTH | - | 10 |
| DAY | - | 26 |
| VALUE | - | 299 |
| BRINE POND VOLUME | $m^3$ | 1,051,000 |

| **ELEVATION** | | | **INJECTION RATE** |
|---|---|---|---|
| 531.1 | and BELOW | | 0% |
| 531.1 | to | 531.3 | 40% |
| 531.3 | to | 531.5 | 60% |
| 531.5 | and ABOVE | | 80% |

***MODEL OUTPUTS***

| | | | | | |
|---|---|---|---|---|---|
| HIGH OPERATING LEVEL = 531.90 | | | | | |
| LOW OPERATING LEVEL = 530.80 | | | | | |
| BRINE POND **ABOVE** HIGH OPERATING LEVEL FOR | **28** | DAYS | of | **4,901** | DAYS |
| BRINE POND **BELOW** LOW OPERATING LEVEL FOR | **0** | DAYS | of | **4,901** | DAYS |
| MAX BRINE ELEV THROUGH REMAINDER OF YEAR = | **531.94** | | DATE | **11/21/41** | |
| MIN BRINE ELEV THROUGH REMAINDER OF YEAR = | **531.45** | | DATE | **12/31/61** | |

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# MINE WATER MANAGEMENT – TAKE HOME POINTS

- REGULATORY GUIDELINES REQUIRE CONSIDERATION OF A SINGLE PRECIPITATION EVENT; HOWEVER, SINGLE EVENTS DO NOT ALWAYS TELL THE FULL STORY.
- AT **LIMITED DISCHARGE FACILITIES**, MORE FREQUENT, EXTENDED-DURATION PRECIPITATION EVENTS CAN RESULT IN LARGER RUNOFF VOLUMES THAN SINGLE DAY PRECIPITATION EVENTS.
- CONSIDERATION OF DROUGHT AND / OR DRY SEASONS IS NEEDED TO ENSURE MINING PROCESSES ARE NOT INTERRUPTED.

# MINE WATER MANAGEMENT – TAKE HOME POINTS

- DAILY WATER BALANCE MODELING IS A GREAT TOOL FOR SUPPLEMENTING EVENT BASED MODELS BY EVALUATING LONG-TERM CLIMATE PATTERNS.

- CALIBRATION OF HISTORIC POND DATA CAN HELP AVOID CREATING OVERLY COMPLEX MODELS THAT CONSIDERS ALL OF THE PLANT PROCESS FLOWS.

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# MINE WATER MANAGEMENT – QUESTIONS?