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A suggested methodology for pore pressure model reliability check - two case studies.

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Background and Problem Statement

Background

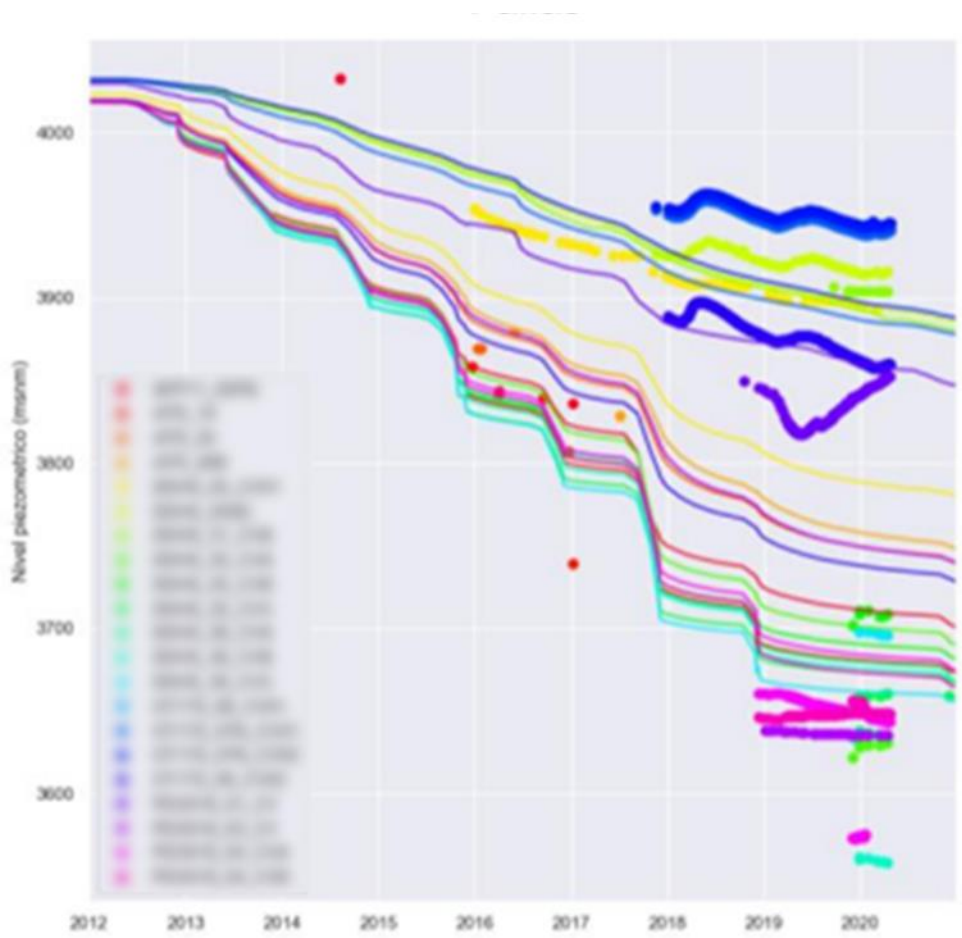
- Increasing need for better pore pressure inputs
- Many operations posses robust monitoring networks

However

- Difficult to reproduce data in groundwater flow models
- Variable calibration within modeled domain
- Incorporated into geotechnical models without evaluation

Need for a tool that can

- **Systematically evaluate pore pressure outputs, and**
- **Inform geotechnical modelers how to best use them**



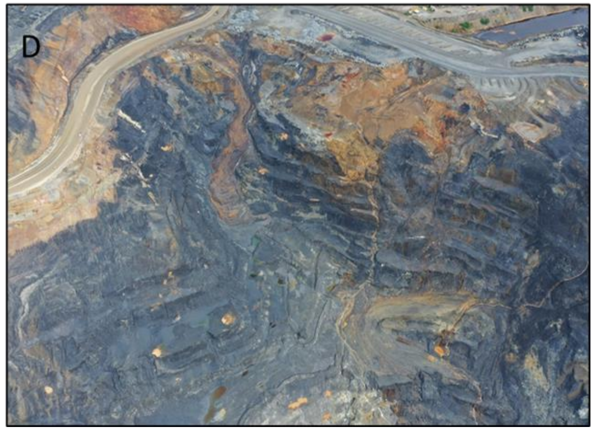
Two real-world case studies were used to develop the proposed methodology

Compañia Minera Antapaccay (CMA), Glencore, Peru:

- Copper mine 160 km SE of Cusco
- Elevations between 3,900 - 4,100 mamsl
- MAP of 710 mm/yr
- Topographical low, regional runoff *towards* the mine
- NW/SE Porphyry intruded host carbonate rocks
- Low permeability
- Flow controlled by structures and karstic features
- FEFLOW 3D flow model with 293 observation points

Pueblo Viejo Dominicana, Corp (PVDC), Barrick Gold, DR:

- Gold mine 100 km north of Santo Domingo
- Elevations between 100 - 600 mamsl
- MAP of 2000 mm/yr
- Topographical high, regional runoff *away* from mine
- Andesites and tuffs overlain by carbonaceous sediments
- Low permeability
- Flow controlled by structures
- MINEDW 3D flow with 397 observation points



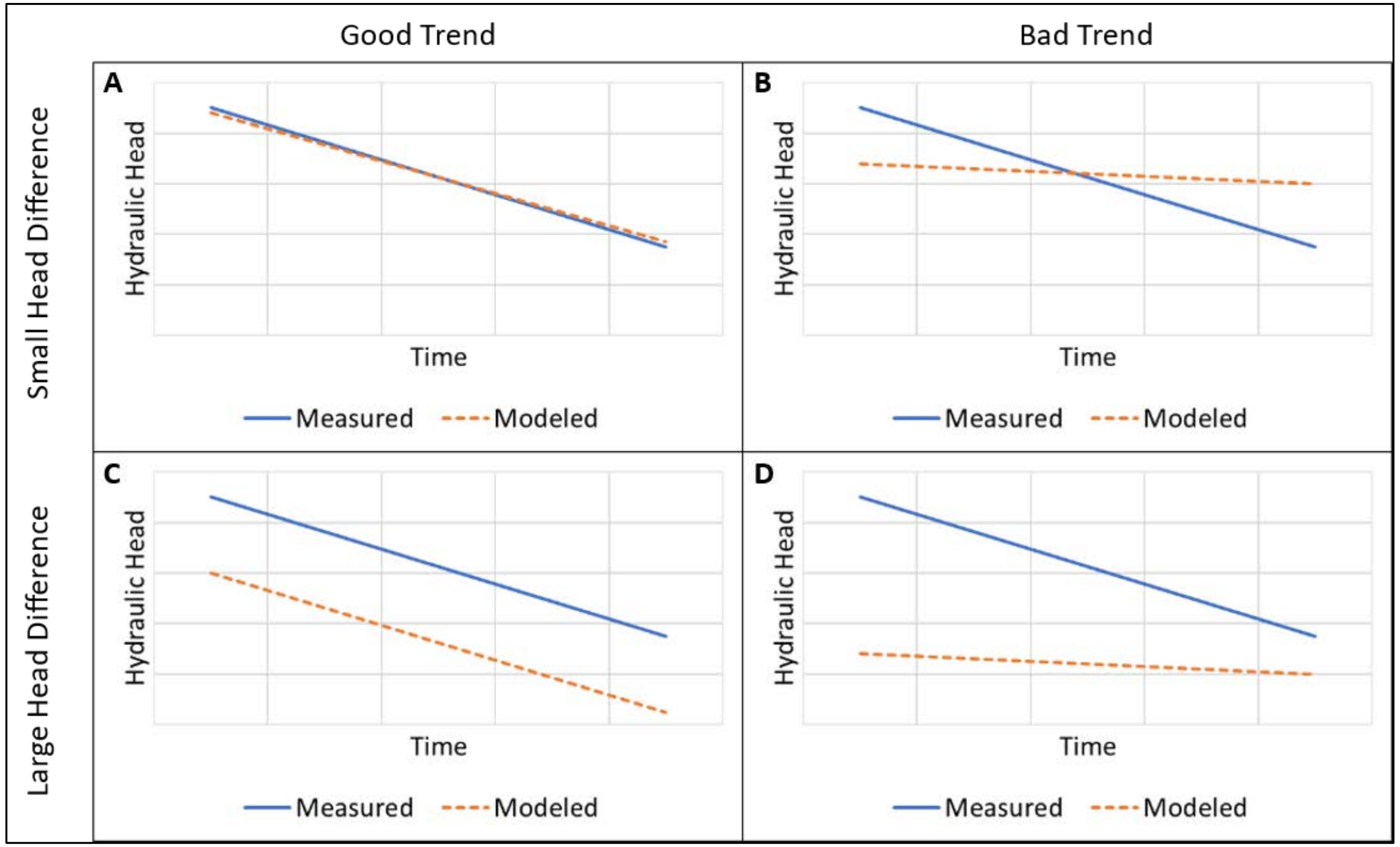
Proposed Methodology

Objective

Quantify **validity, usefulness, and reliability** of pore pressure outputs for their use in slope stability analyses

Three step approach

1. Model characteristics and architecture
2. Calibration and behaviour
3. Pore Pressure Reliability Score



Focus on the correct representation of absolute water levels (“hydraulic heads”, or “heads”) and water levels changes in time (“trends”)

Step 1: Interrogation of model architecture

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- Critique of numerical modeling approach
- Highlight inconsistencies and systematic bias
- Static Components:
  - Meshing
  - Node and Elements
  - Dimensions
  - Zonation
  - Hydraulic Parameters
- Dynamic Components
  - Temporality
  - Boundary conditions
  - Initial conditions
  - Mining
  - Dewatering
  - Water Balance

Assessment criteria

Judgement	Description
Valid	Component is hydrogeologically sound. No evident conflict with modeling objectives
Questionable	Theoretically questionable. Effects on outputs are uncertain
Invalid	Modeled erroneously. Could render outputa invalid

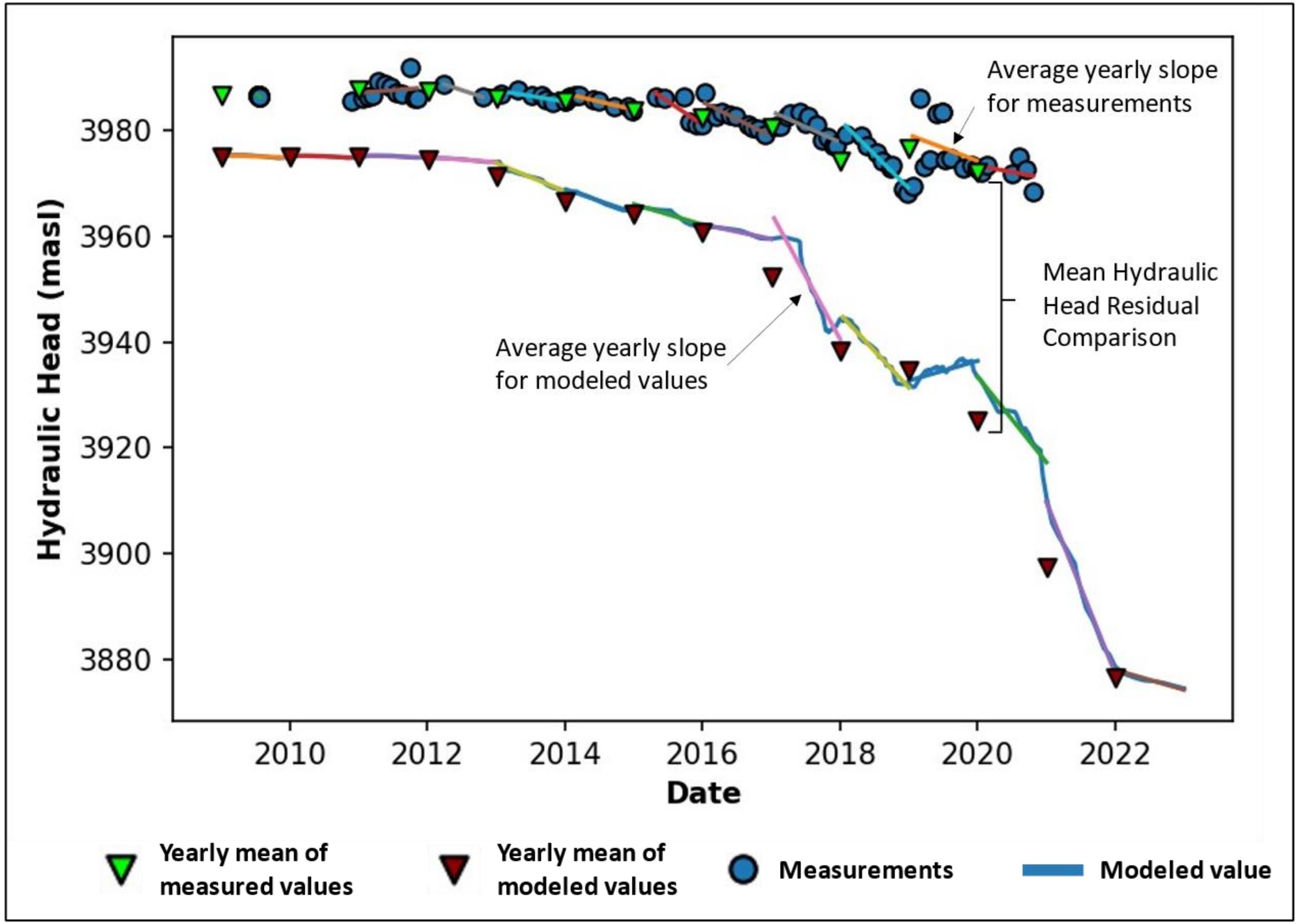
The objective is to validate inputs, raise awareness of possible problems, and identify critical issues

srk 50 YEARS

Step 2A: Calibration and model behavior

- Specialized code used to contrast measured and modeled values.

- User must define:
  - Time interval length
  - Analysis period
  - Excluded observations
  - Category ranges



Step 2B: Definition of category ranges

- Heart of the methodology
- Assign a qualitative assesment to pore pressure outputs
- Transform numerical residuals into simple categories
- Can use site specific targets and criteria to establish reliability

Parameter	Category Value	Category Descriptor	Criteria Used for Residual (Category Ranges)	
			CMA (based on geotechnical requirements)	PVDC (based on % pit wall saturated thickness)
Hydraulic Head	1	Adequate	<10 m	< 5 m (5%)
	2	Acceptable	10-20 m	5-10 m (10%)
	3	Deficient	20-30 m	10-20 m (20%)
	4	Inadequate	>30 m	>20 m (> 20%)
Average Trend	1	Adequate	<0.025 m/d	< 0.015 m/d
	2	Acceptable	0.025 – 0.05 m/d	0.015 – 0.025 m/d
	3	Deficient	0.05 – 0.1 m/d	0.025 – 0.05 m/d
	4	Inadequate	>0.1 m/d	>0.05 m/d

Step 3: Pore Pressure Reliability (PPR) score

$$CV_H * CV_T * W = PPR$$

Where

CV_h corresponds to the hydraulic head category value

CV_s corresponds to the average trend category value

W corresponds to the weight value from relative geomechanical importance

PPR corresponds to the pore pressure reliability score.

Afterwards, each observation with its PPR is linked to its placement in 3D space and interpolated into volumes.

PPR	Qualifier
<0	Inconsequential
0-2	Adequate
2-6	Acceptable
6-9	Tolerable
9-12	Deficient
>12	Inadequate

Case study results: Architecture & statistics

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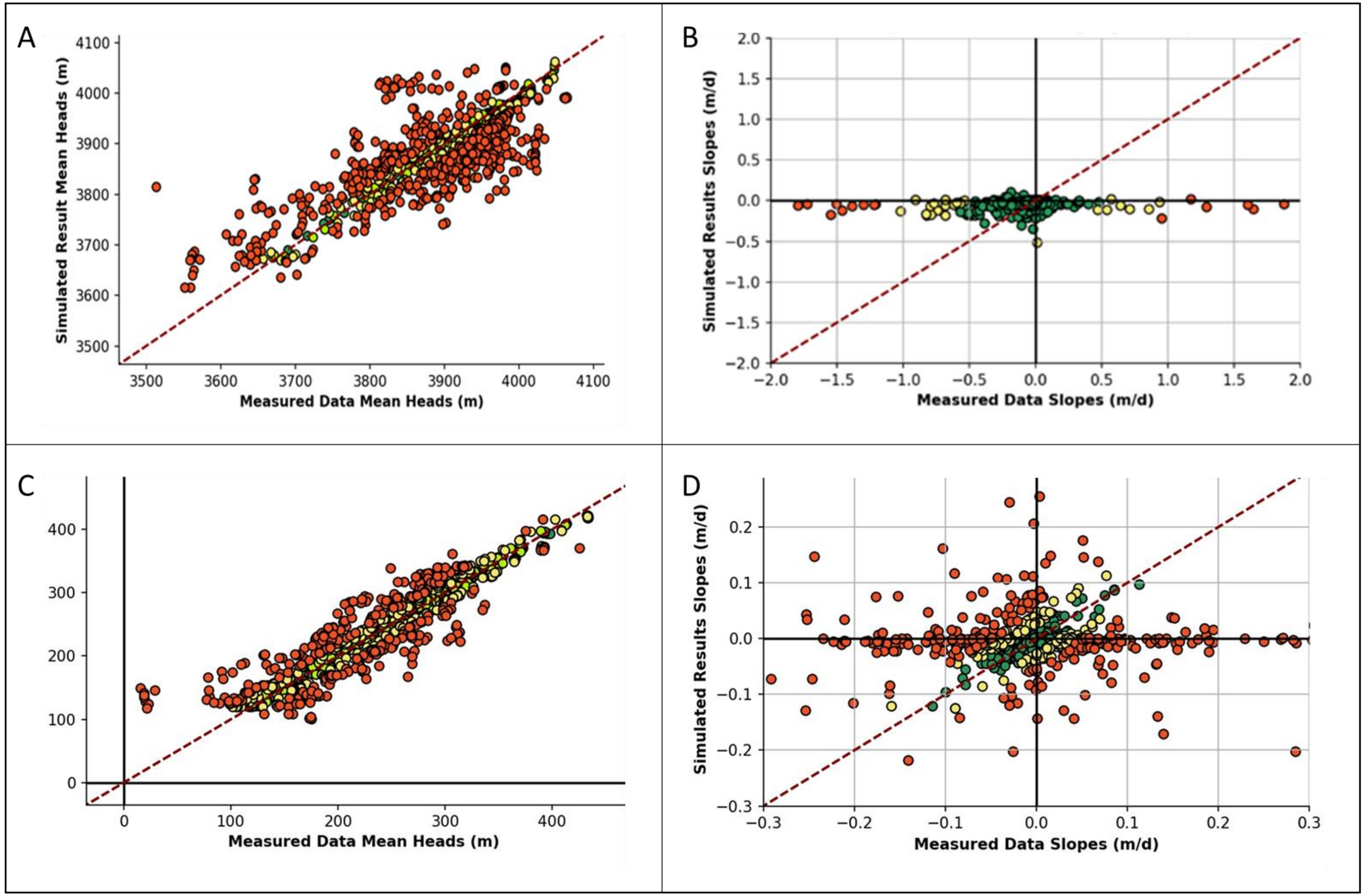
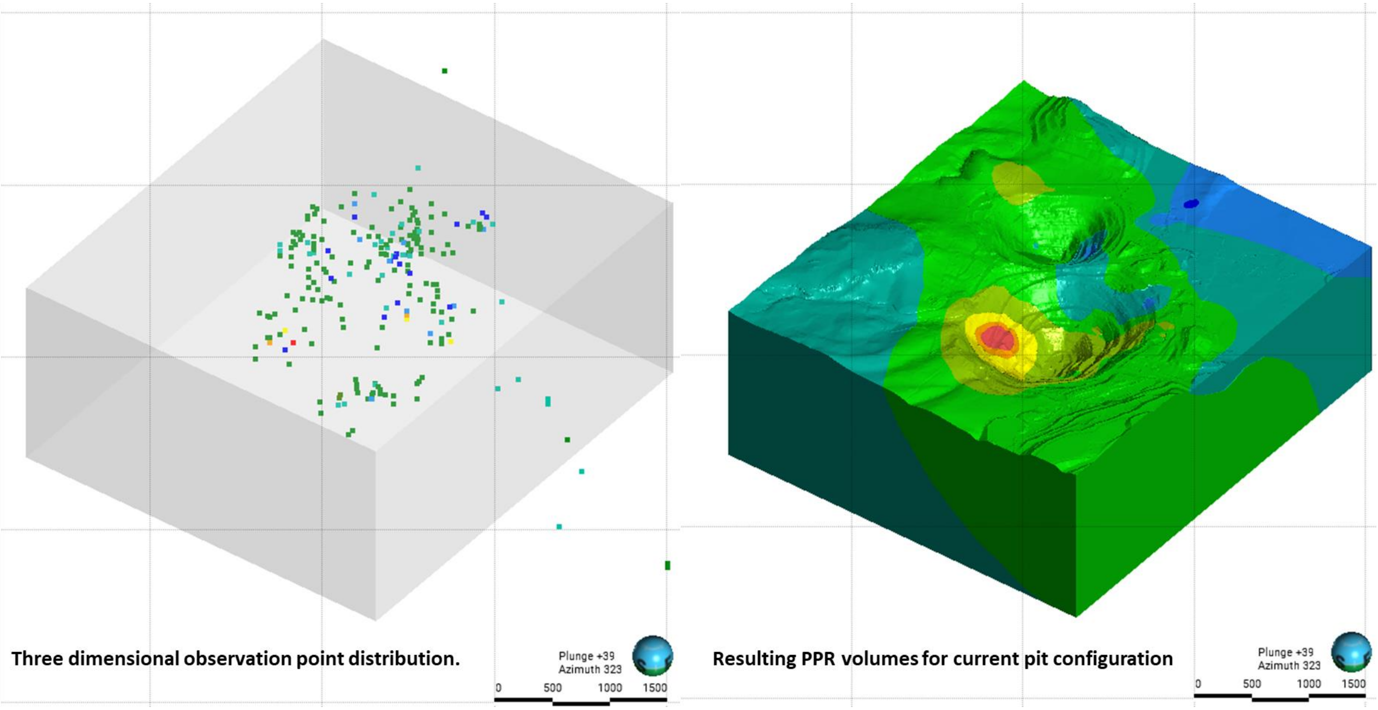
Type	Modeling Element	CMA	PVDC
Static	Mesh Gradation, Horizontal & Vertical Discretization	Valid	Valid
	Node & Element Number	Valid	Valid
	Topography, Model Thickness & Width	Valid	Valid
	Hydrogeological Units	Questionable	Valid
	Hydraulic Parameters	Questionable	Questionable
Dynamic	Temporal Discretization	Valid	Valid
	Boundary Conditions	Questionable	Valid
	Initial Water Levels	Valid	Valid
	Mining Representation	Valid	Valid
	Dewatering Infrastructure	Questionable	Questionable
	Water Balance Components	Valid	Valid

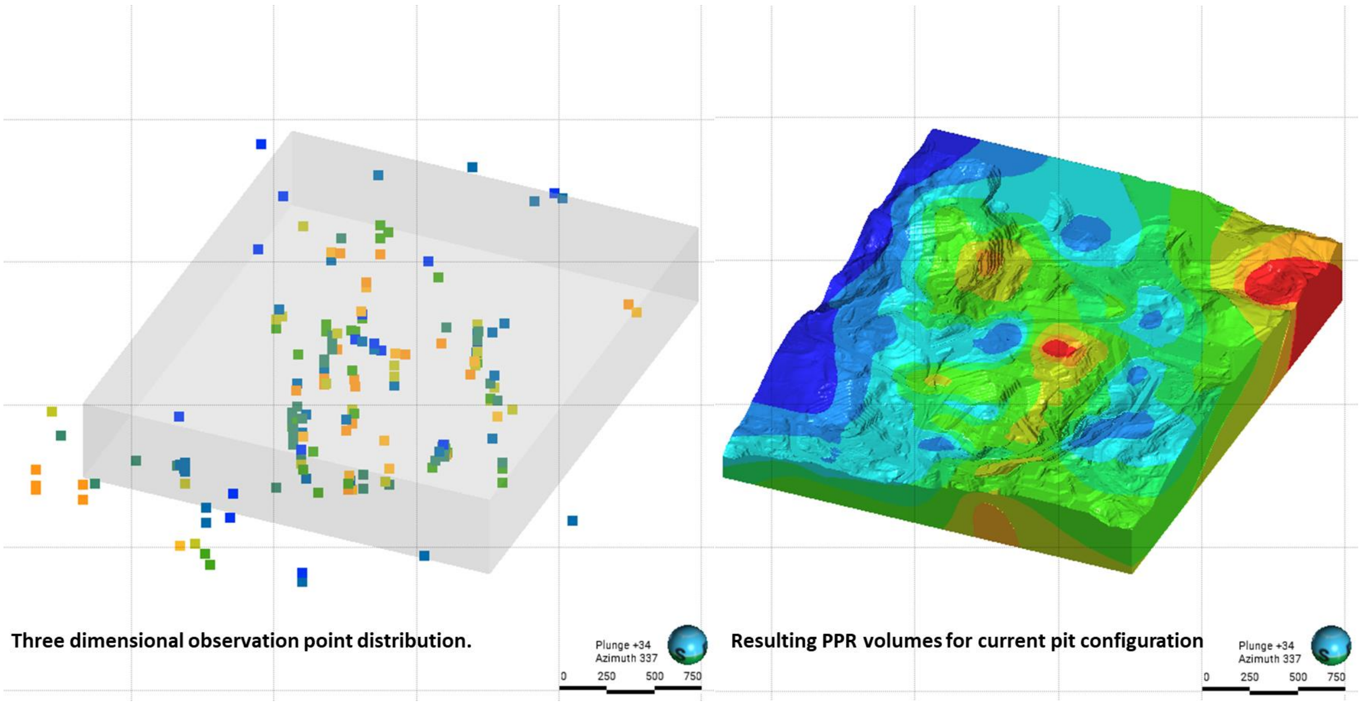


Case study results: PPR volumes

- Pore pressure realiabity scores are clearly distinguished for each pit, sector and slope
- CMA interpolation through ID2, while PVDC incorporated lithological anisotropy



CMA



PVDC

Conclusions

- The methodology developed could succesfully quantify reliability of pore pressure model outputs in a way that is:
  - Site specific,
  - Quick, and
  - Flexible.

- Direct interaction between the geotechnical and hydrogeological teams is key

- Pore pressure deviations can mean different things for different slopes

- Results should be used in conjunction with other analyses (kinematic, structural, lithological) for better use of pore pressures in slope stability analyses

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