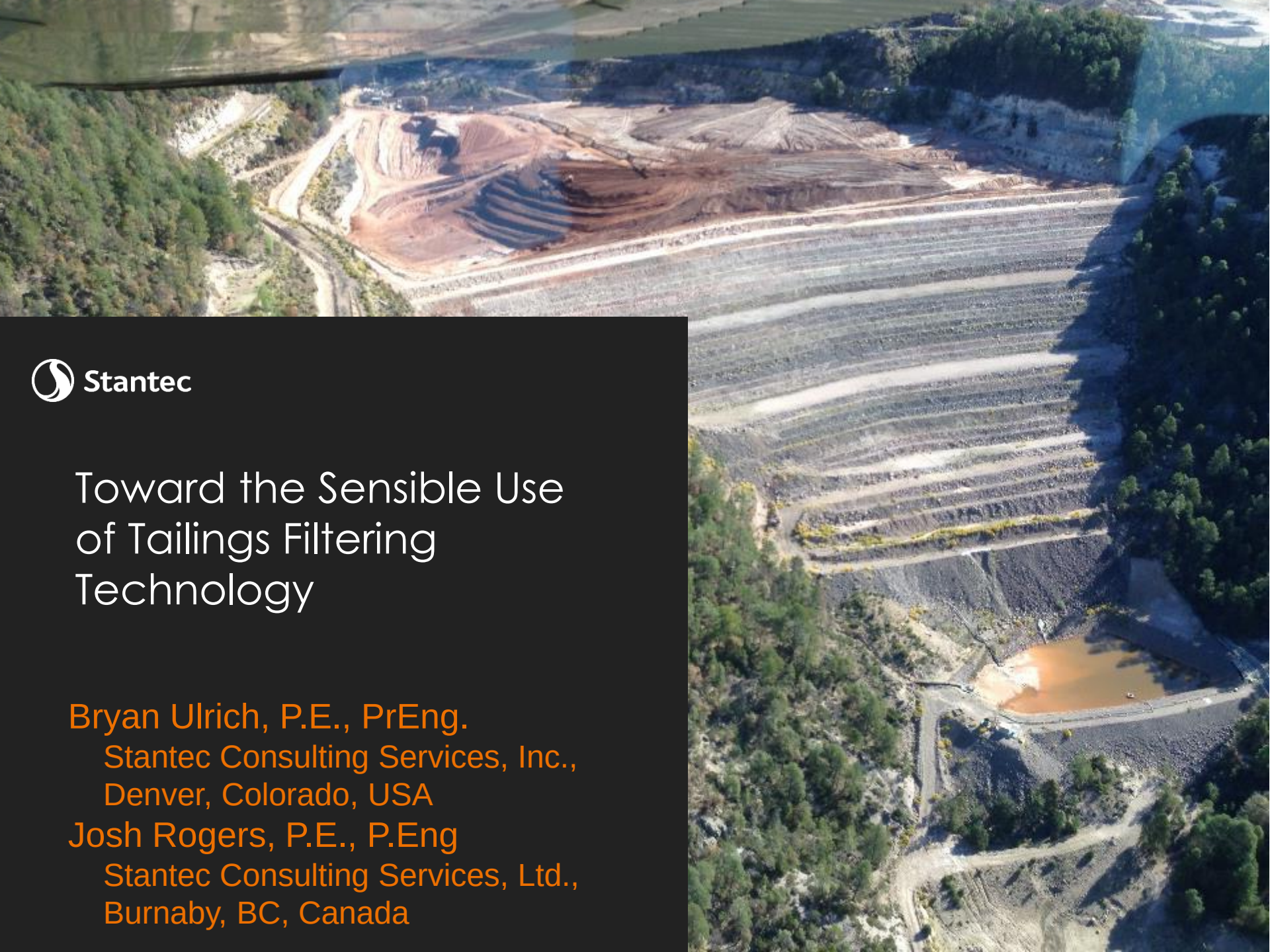

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Toward the Sensible Use of Tailings Filtering Technology

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Outline

1. Safety Share
2. Tailing Disposal Methods and Classification
3. Selecting a Preferred Disposal Alternative
4. Target Moisture Content for Clayey Tailings
5. Water, Water Everywhere?
6. Structural Requirements?
7. Q and A

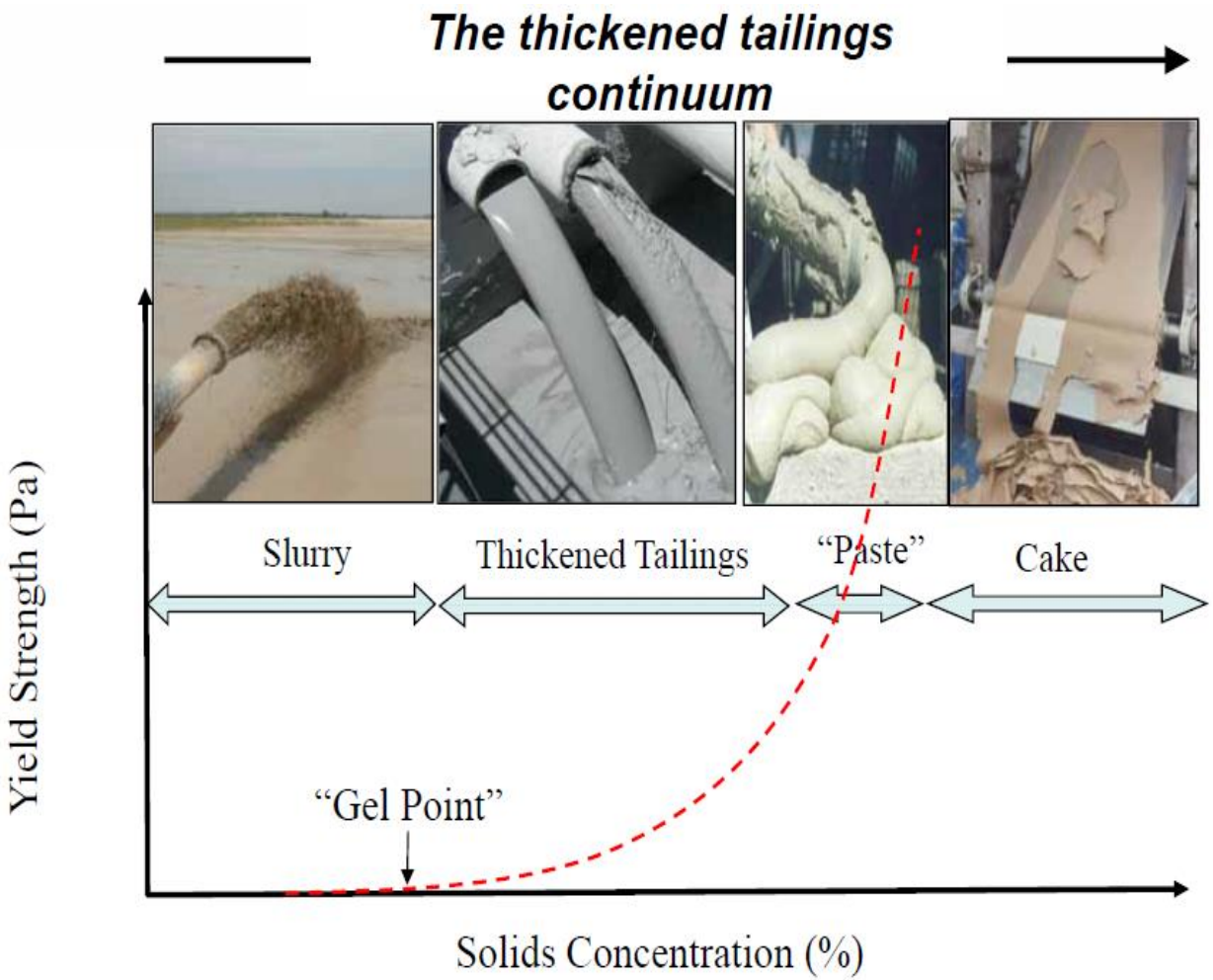
Safety
Moment

Watch for Motorcycles
Share the Road

BACKGROUND:

Tailings Disposal Methods and Definitions

Deposition Method Classification



From: Jewell & Fourie (2006)

Deposition Method Classification

Common Yield Stress and Percent Solid Ranges per Tailings Deposition Method

Tailings Classification	Yield Stress[1] (Pascals)	Typical Percent Solids (%)
Conventional Tailings	<5 to 20	<50
Thickened Tailings[2]	20 - 100	50-70
Paste Tailings	100-800	70-85
Filtered Tailings	>800	>85

NOTE:
1. As measured at the point of deposition using a shear vane device.
2. Often also defined by non-segregating behavior at deposition.

(After Cooke, R. 2010. MWH Short Course: Improved Water Recovery Through Implementation of Alternative Tailing Disposal Methods. *Short Course for the 2010 Tailings and Mine Waste Conference*. Vail, Colorado.)

- Based on depositional characteristics
- Helpful to define likely behavior
- Remove confusion surrounding what is being produced ("conventional thickened" vs. "high-density thickened")

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- Accounts for stresses induced through the transportation system – intent is to classify by depositional characteristics

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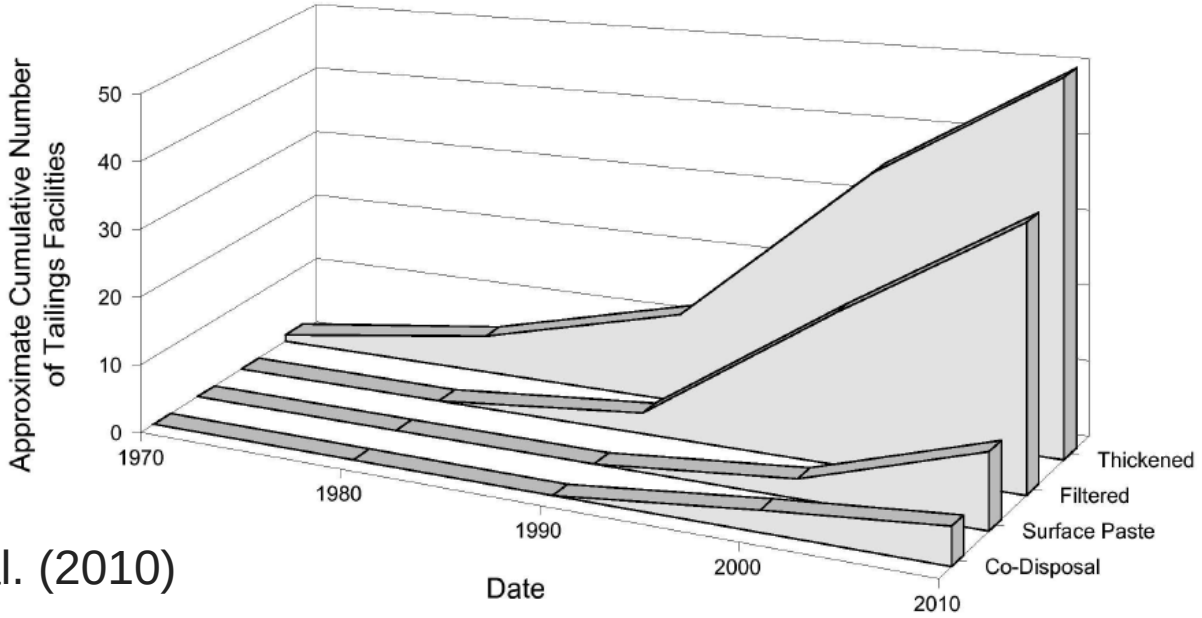
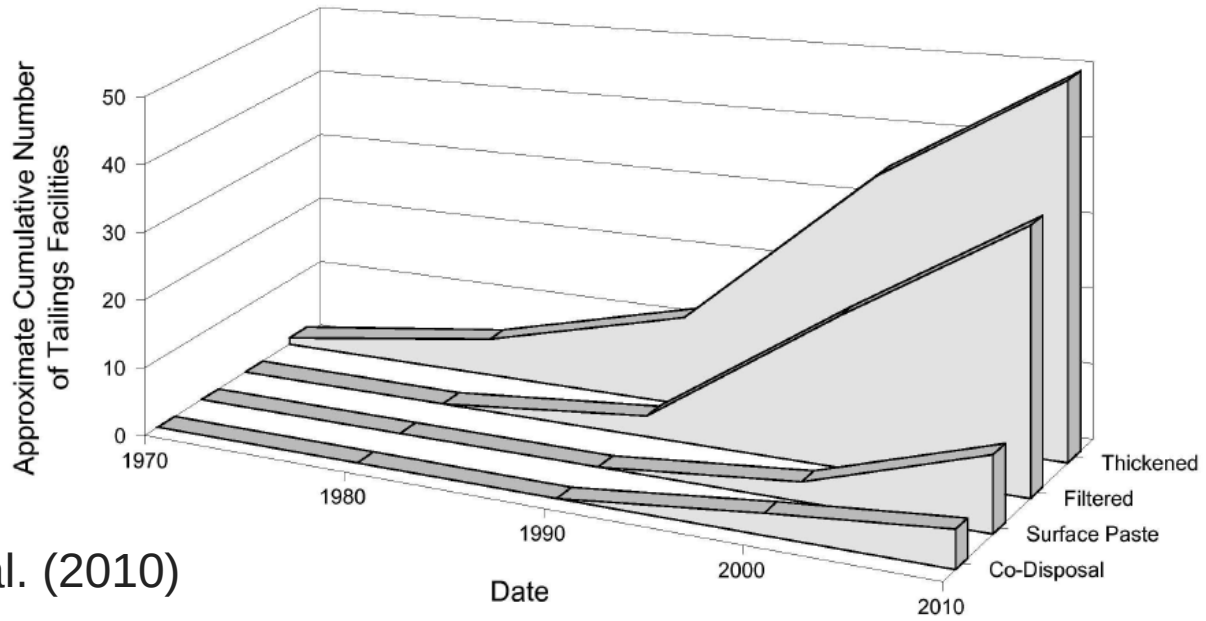
Industry Precedent for Deposition Methods

- Martin and Davies (2000) estimated there were approximately 3,500 tailings facilities in operation worldwide as of 2000
- In 2010, Davies, et al. estimated that only approximately 100 facilities were using alternative disposal methods (co-disposal, surface paste, filtered, thickened)
- Conventional disposal still comprises the vast majority of all tailings operations world wide (perhaps 3,400 of 3,500)



From: Davies et al. (2010)

- However - alternative deposition methods are increasingly being adopted
  - Increased regulatory scrutiny
  - Description of filtered tailings as "Best Available Technology"
  - Increasing corporate focus on failure consequences, water and social license to operate, etc.



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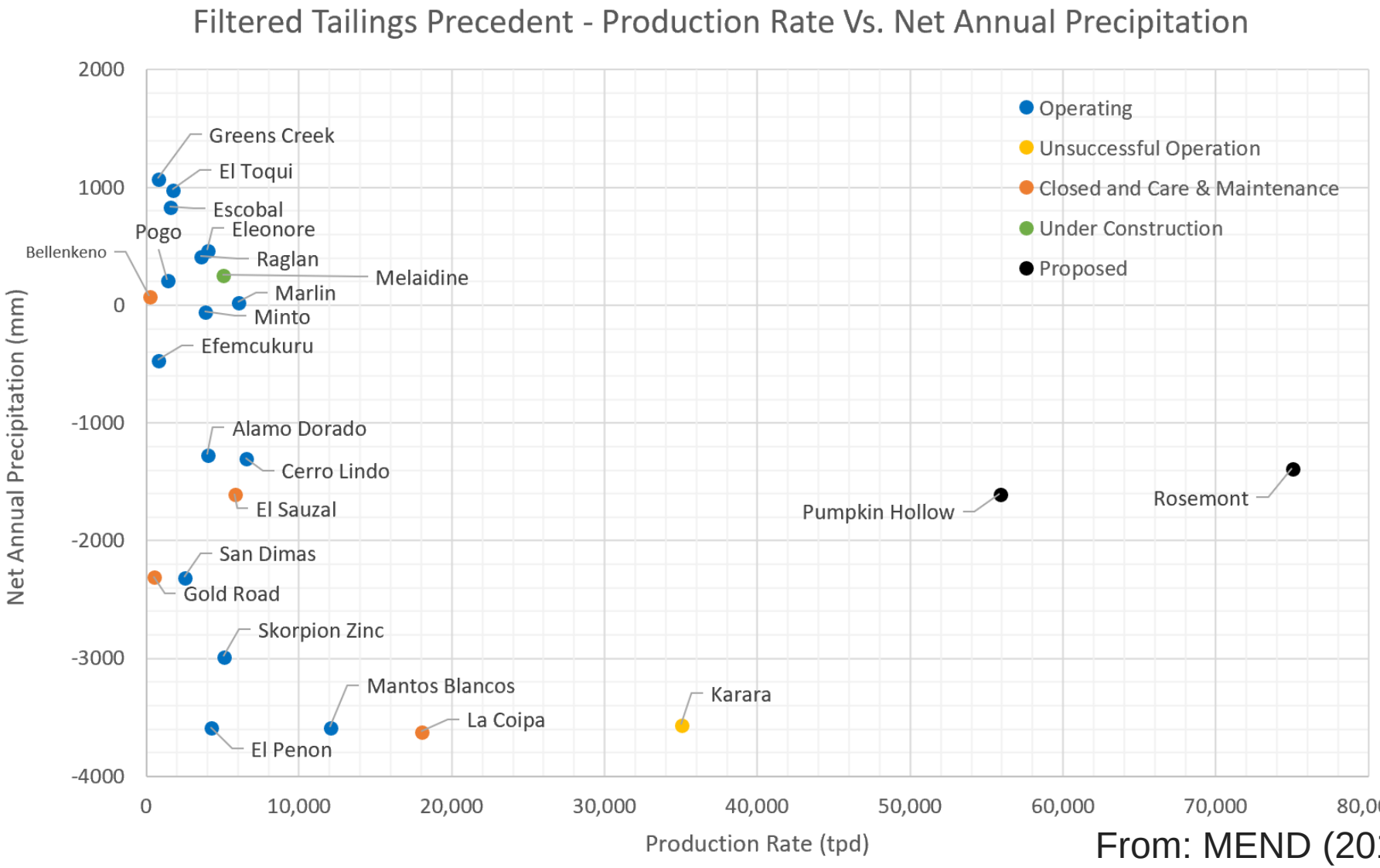
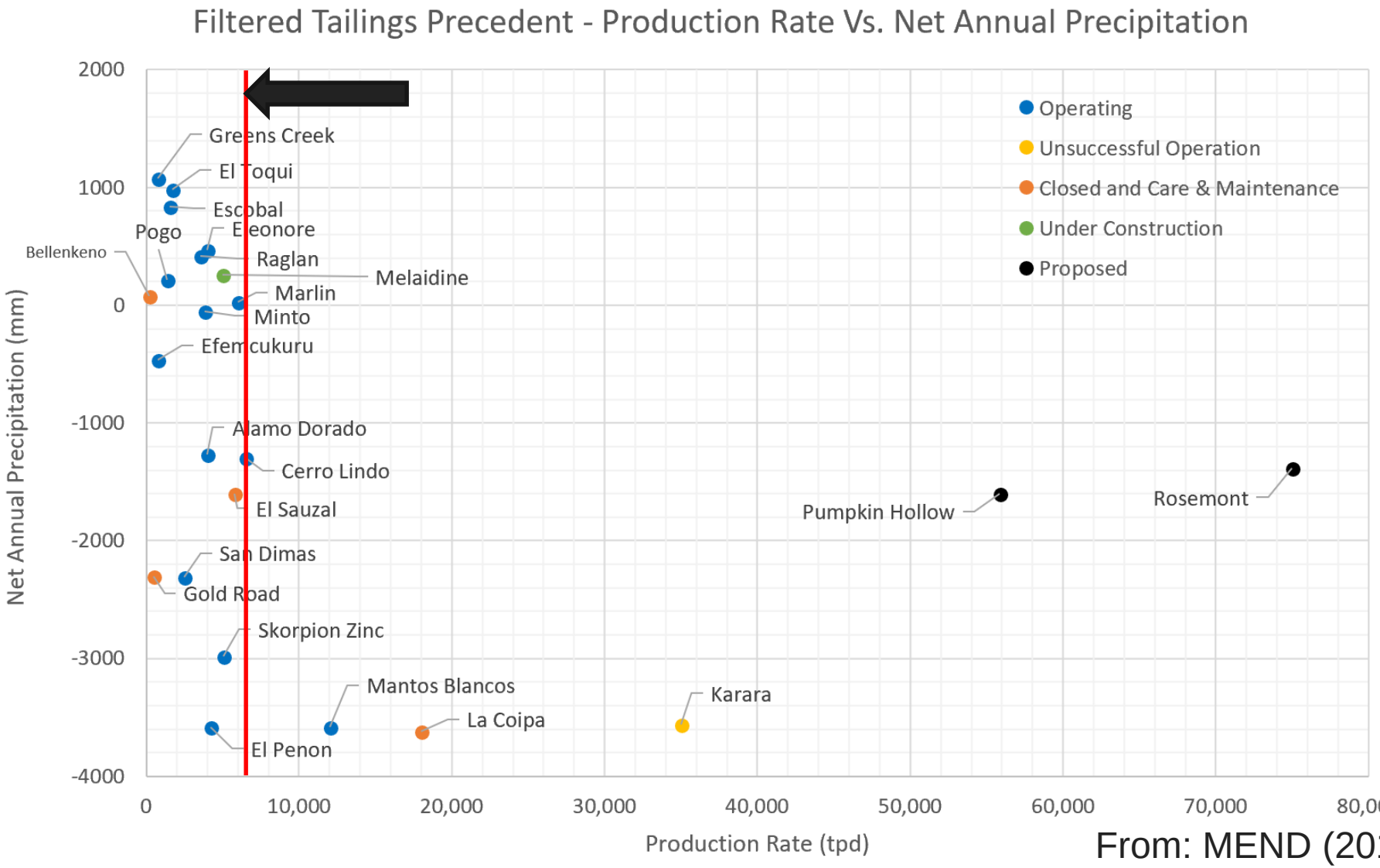
Industry Precedent for Deposition Methods



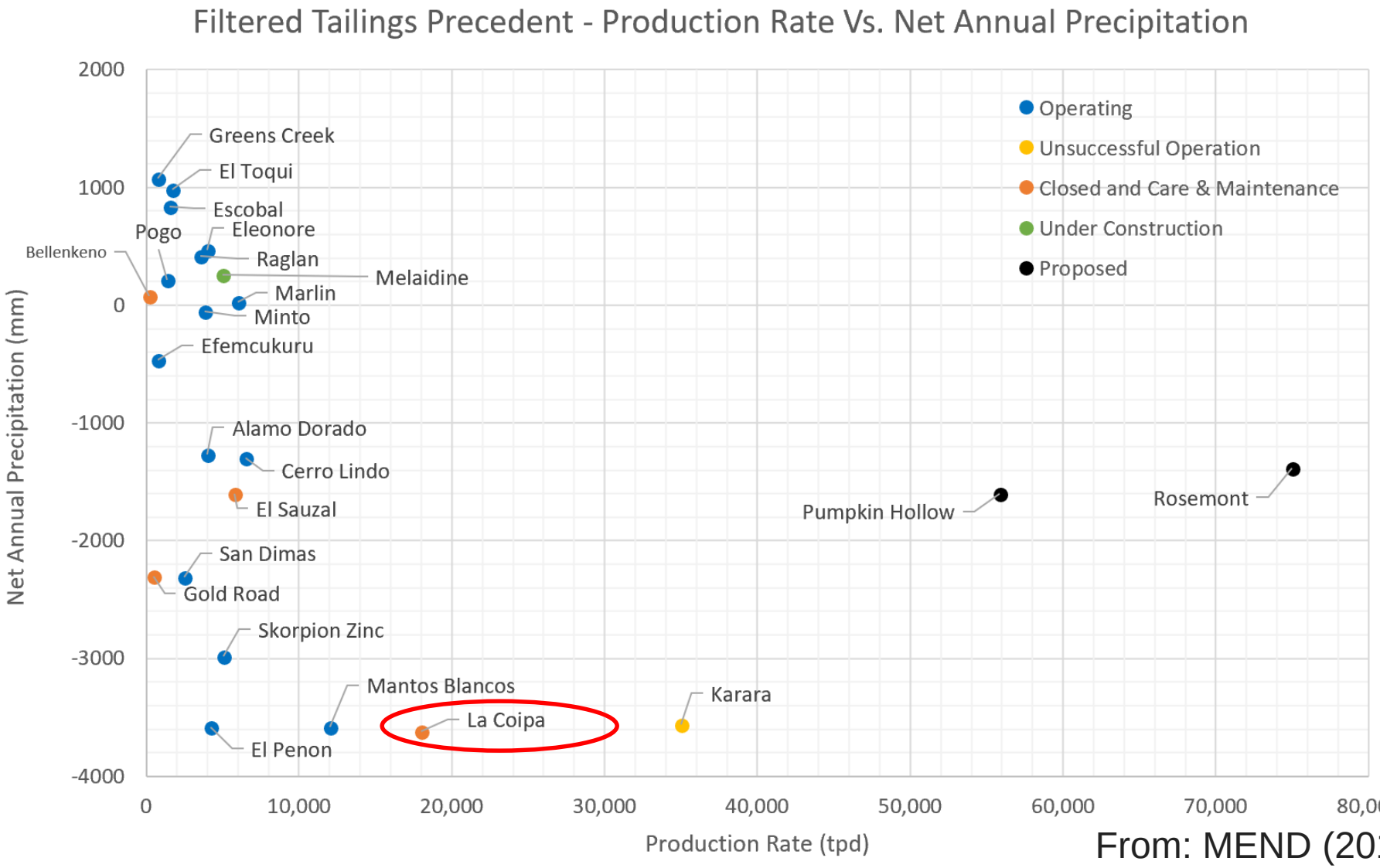
From: MEND (2017)

- For filtered tailings, precedent remains at
  - relatively low production rate facilities (6,500 tpd)
  - often in relatively arid regions



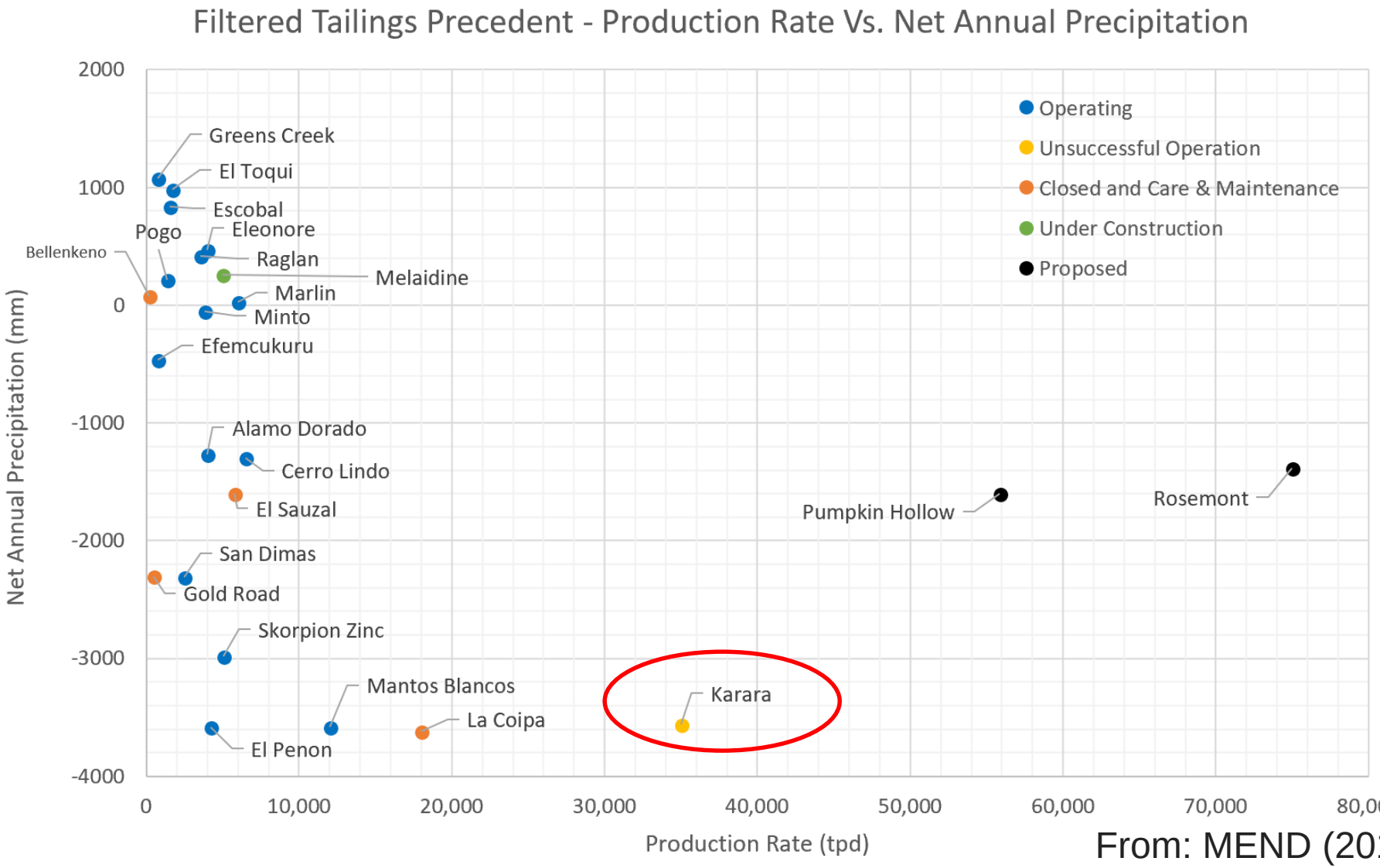
From: MEND (2017)

- Highest production rate successfully commissioned filtered facility to date known to the authors is La Coipa (15 to 18 ktpd)
  - Wet cake, climatic drying



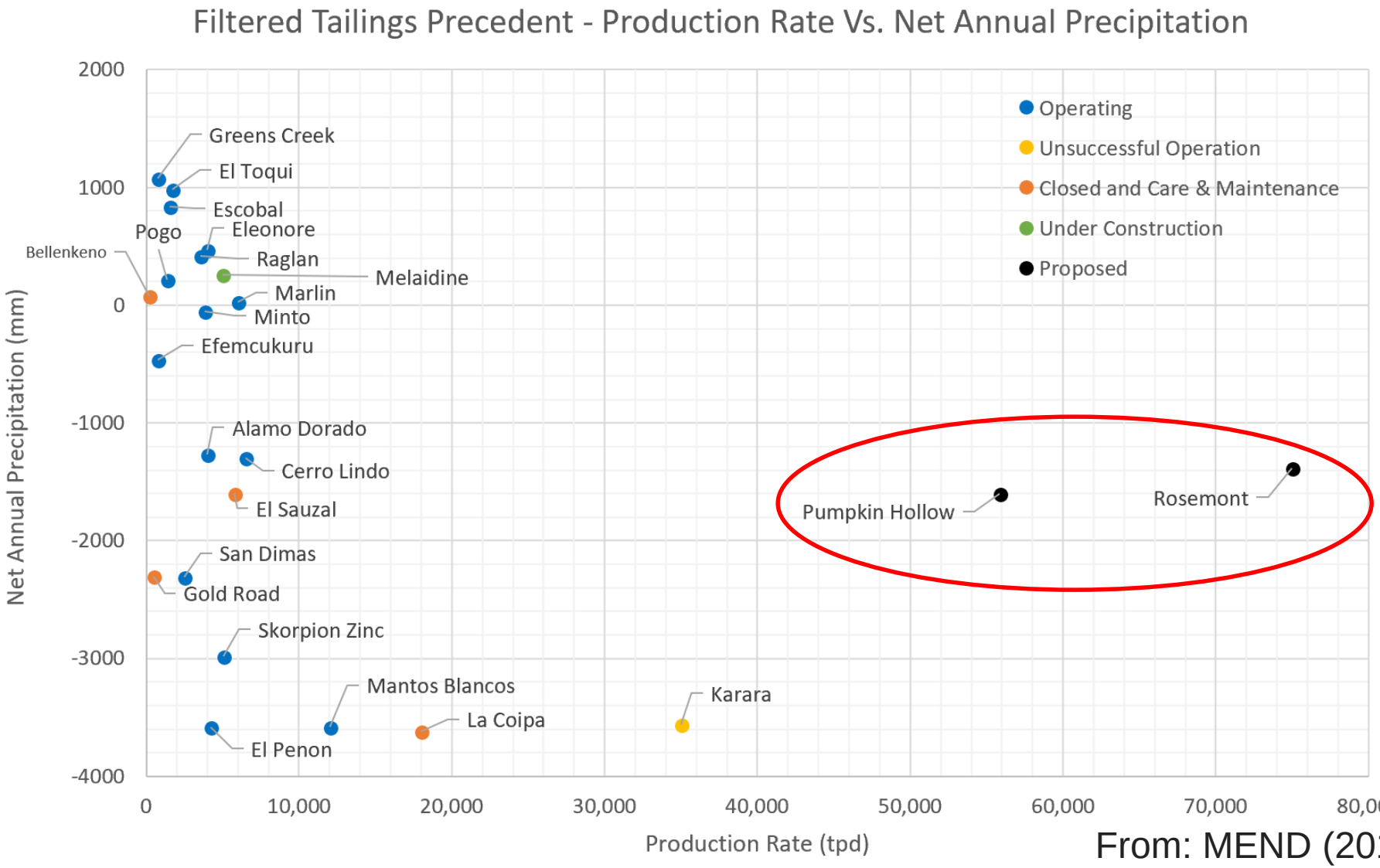
From: MEND (2017)

- Understand that Karara experienced difficulties in achieving the full production rate



From: MEND (2017)

- High production rate facilities have been proposed or are being trialled (>50 ktpd)
- These would represent a significant step forward in precedent and may initiate a significant change in the industry if successful



From: MEND (2017)

PRIMARY OBJECTIVE:

Selecting a Preferred Disposal Alternative

Selecting a Preferred Disposal Alternative

Rule #1:

There are no Panaceas

Rule #2:

There is only one Rule

Selecting a Preferred Disposal Alternative

A2 APPENDIX 2: BEST AVAILABLE TECHNOLOGY AND BEST AVAILABLE/APPLICABLE PRACTICE

Appendix 2: Best Available Technology and Best Available/ Applicable Practice

Best Available Technology, or BAT, is the site-specific combination of technologies and techniques that is economically achievable and that most effectively reduces the physical, geochemical, ecological, social, financial and reputational risks associated with tailings management to an acceptable level during all phases of the life cycle, and supports an environmentally and economically viable mining operation.

Selecting a Preferred Disposal Alternative

- Location?
- Technology?
- Variety of impacts, stakeholders, technical disciplines

Selecting a Preferred Disposal Alternative

- Multiple Accounts Analysis (MAA) methodology discussed by Robertson and Shaw (1999)
- Adapted by Environment and Climate Change Canada (ECCC) – *Guidelines for the Assessment of Alternatives for Mine Waste Disposal*
- MAA methodology and ECCC Guidelines referenced in Mining Association of Canada (MAC) *A Guide to the Management of Tailings Facilities* (Third Edition)

Selecting a Preferred Disposal Alternative

A Guide to the

Management of Tailings Facilities

THIRD EDITION

A3 APPENDIX 3: ASSESSMENT OF ALTERNATIVES

Appendix 3: Assessment of Alternatives

Multiple Accounts Analysis

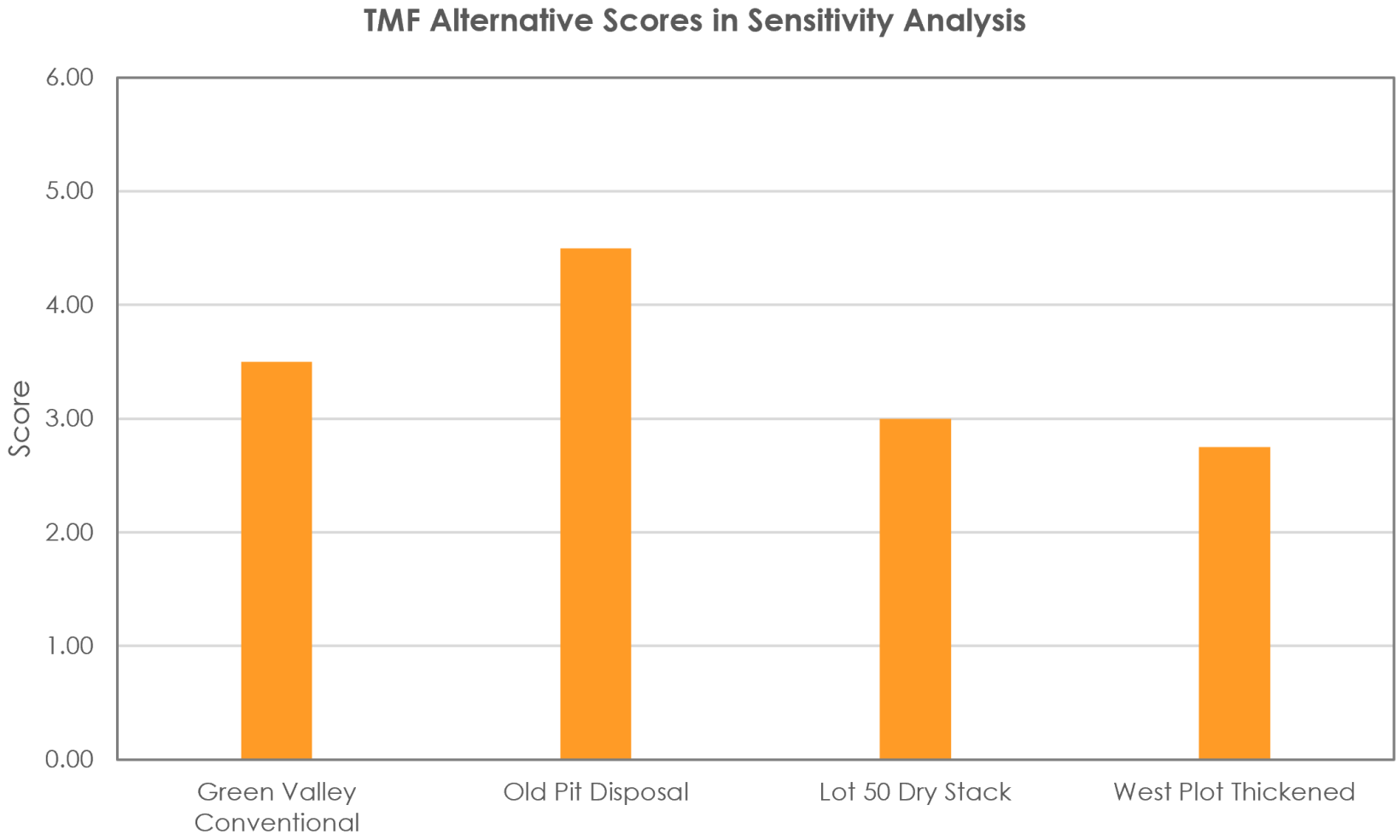
Multiple accounts analysis (MAA) is a tool that is used to support decision-making, including for tailings management. There are a number of good, structured decision-making tools available to assist the tailings planning and design process. Since the federal regulator in Canada mandates the use of MAA, it is given additional focus here. This approach was described in *A Multiple Accounts Analysis for Tailings Site Selection*.[5] It was expanded upon by Environment and Climate Change Canada in its *Guidelines for the Assessment of Alternatives for Mine Waste Disposal* (2011). This discussion is based on the approach as described in these documents.

Selecting a Preferred Disposal Alternative

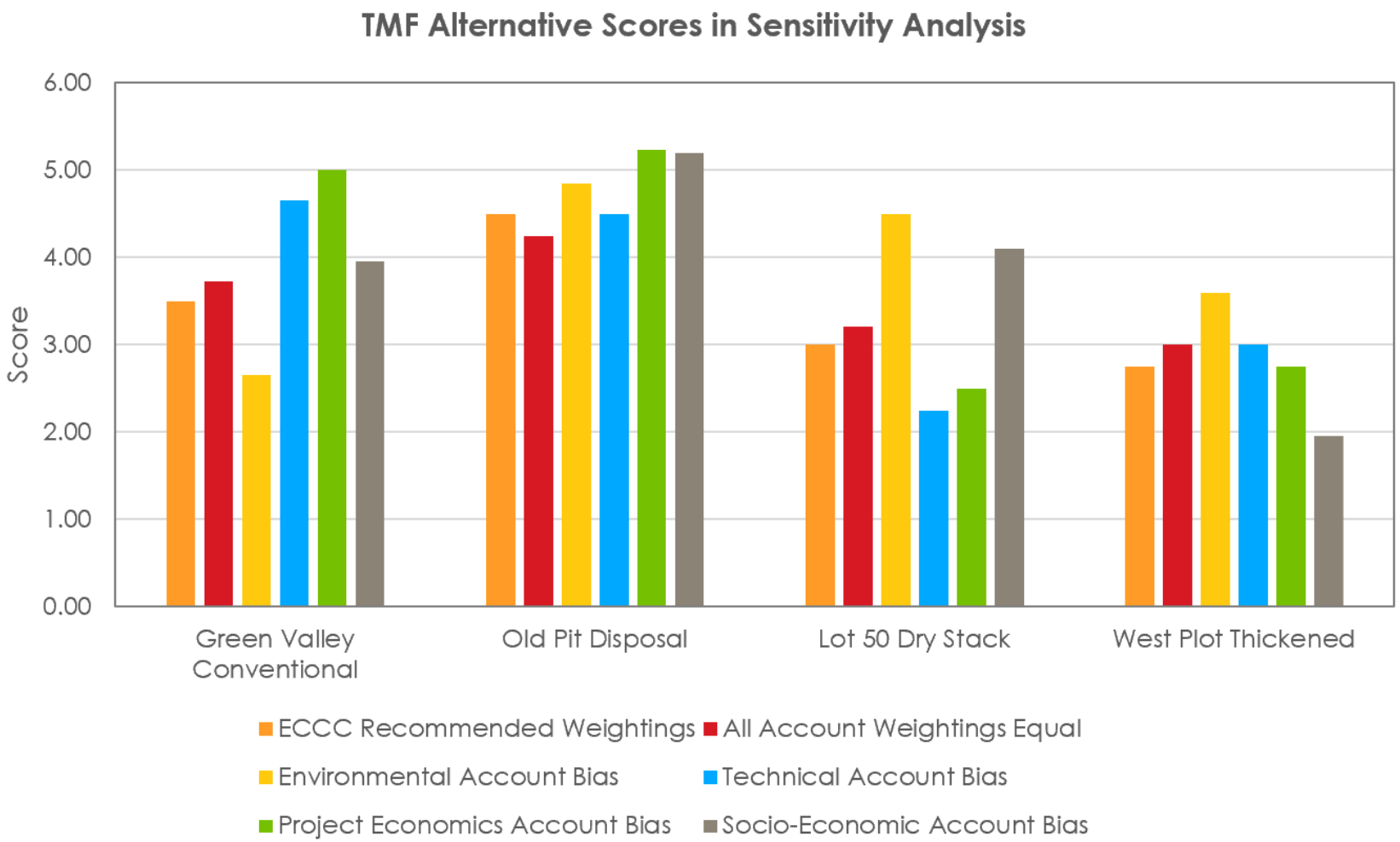
Guidelines for the Assessment of Alternatives for Mine Waste Disposal

- Seven Step Process:
  1. Identify Candidate Alternatives
  2. Pre-Screening Assessment
  3. Alternative Characterization
  4. Multiple Accounts Ledger
  5. Value-Based Decision Process
  6. Sensitivity Analysis
  7. Document Results

Selecting a Preferred Disposal Alternative



Selecting a Preferred Disposal Alternative



IF FILTERED TAILINGS IS THE MOST FAVORABLE TECHNOLOGY:

Some Rules of Thumb…

DESIGN CONSIDERATION:

Target Moisture Content for Clayey Tailings: How about Trafficability as a Guideline?

How about Trafficability as a Guideline?

Atterberg Limits and Tailings Filtration

For clayey tailings, the filter cake is often produced at a moisture content somewhere between its Liquid and Plastic Limits.

Let’s look there for guidance.

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How about Trafficability as a Guideline?

Based on a database of 641 fall cone test results from 101 cohesive soil samples at Bristol and Cambridge…

An updated correlation between the undrained shear strength of a soil (C_u) and its liquidity index (LI) was developed:

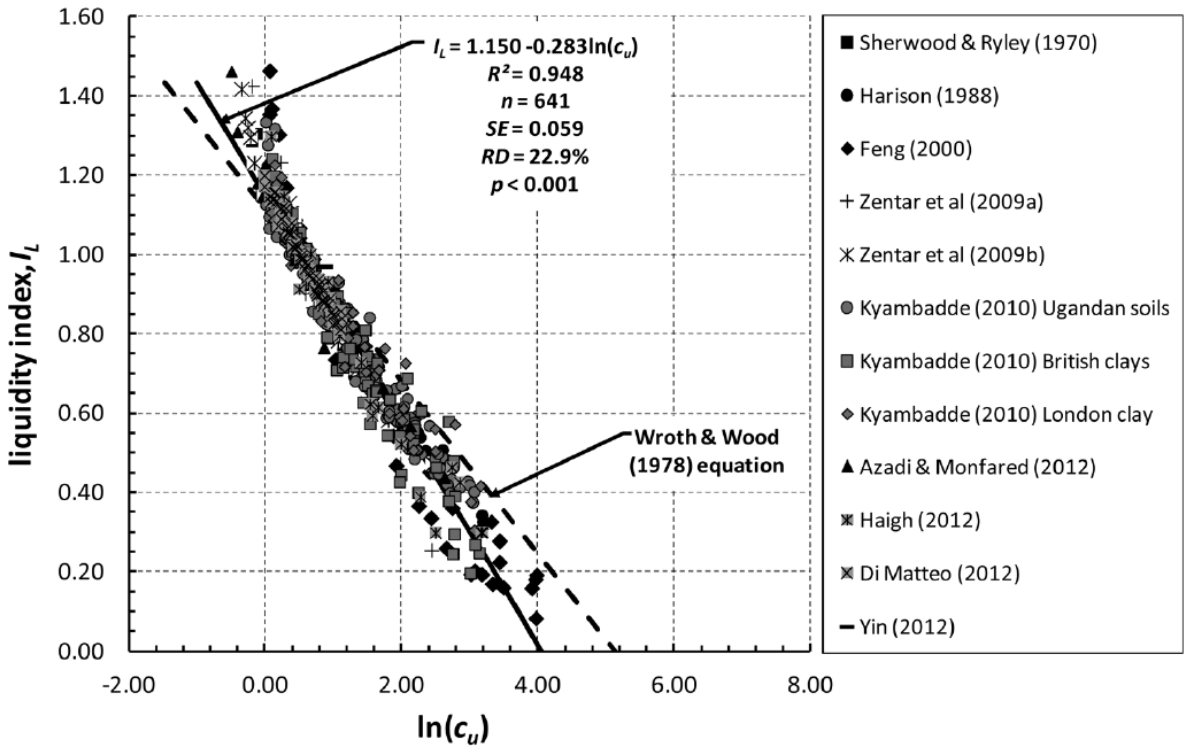
$$C_u = 1.7 * 35^{(1 - LI)} \quad \text{kPa} \quad \text{for } 0.2 < LI < 1.1$$

Where: $LI = (w - PL) / (LL - PL)$

Vardanega and Haigh (2014)

How about Trafficability as a Guideline?

Fig. 4. Natural logarithm of undrained shear strength plotted against liquidity index: resulting regression shown.



From: Vardanega and Haigh (2014)

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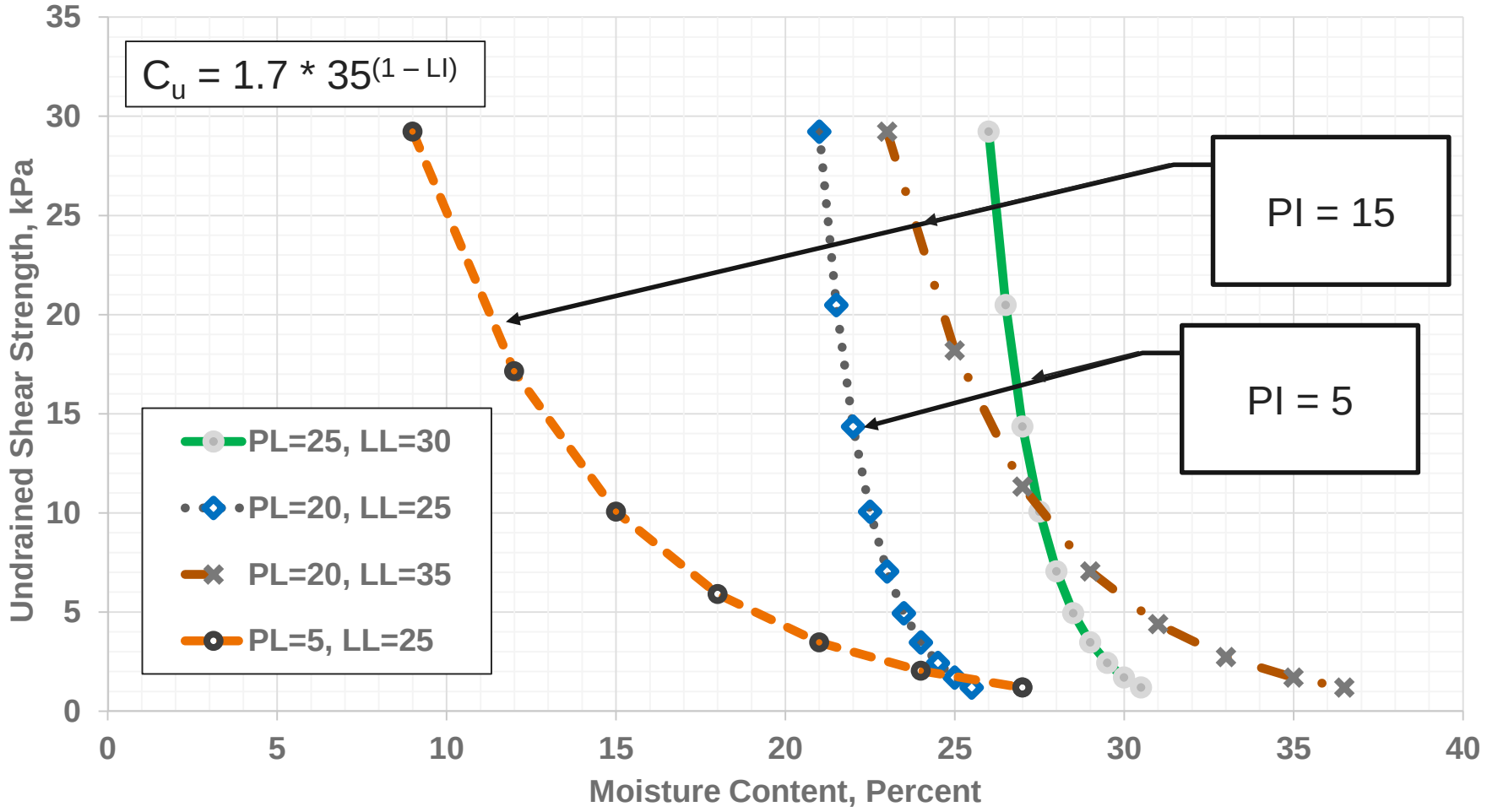
How about Trafficability as a Guideline?



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How about Trafficability as a Guideline?

$C_u = 1.7 * 35^{(1 - LI)}$ kPa for $0.2 < LI < 1.1$

Where: $LI = (w - PL) / (LL - PL)$

If $w = LL$, then $LI = 1$ and $C_u = 2$ kPa

If $w = PL$, then $LI = 0$ and $C_u = 60$ kPa

Vardanega and Haigh (2014)

How about Trafficability as a Guideline?

$$C_u = 1.7 * 35^{(1 - LI)} \quad \text{kPa} \quad \text{for } 0.2 < LI < 1.1$$

Where: $LI = (w - PL) / (LL - PL)$

Using Terzaghi's Bearing Capacity Equations:

Moisture Content	Bearing Capacity (kPa)	
	q_{ult}	q_{all}
w = PL	260	90
w = LL	70	20

Vardanega and Haigh (2014)

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How about Trafficability as a Guideline?

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Approximate example ground pressures:

A Typical Person ~ 40 kPa

D6 Low Ground Pressure Dozer ~ 30 kPa

320D Excavator ~ 40 kPa

Articulated Trucks ~ 400 kPa

(Caterpillar, 2012)

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DESIGN CONSIDERATION:

Water, Water Everywhere?

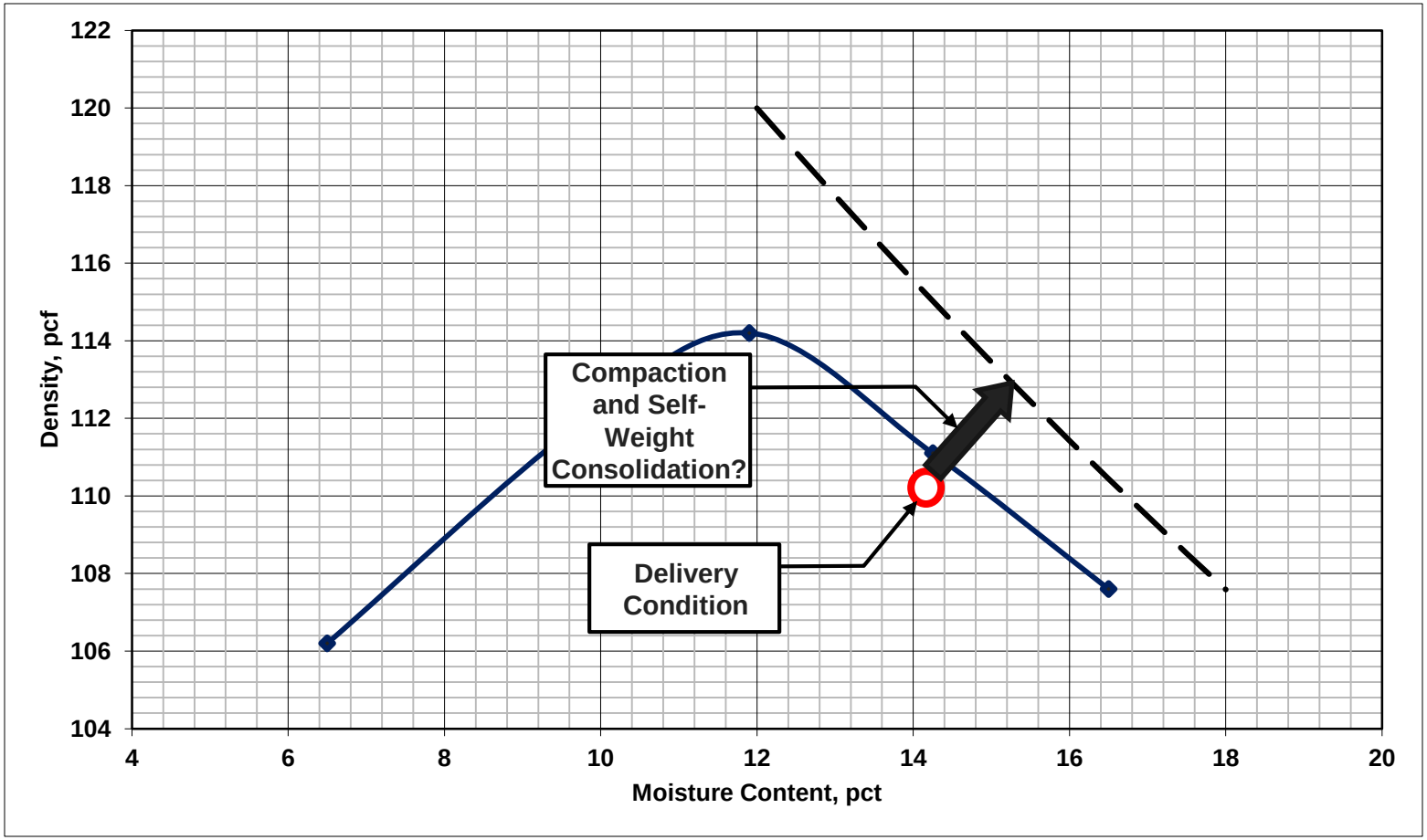
Water, Water Everywhere?

Other Sources of Water (or Pore Pressure):

- Plant upset conditions
- Precipitation
- Self-weight consolidation
- Construction-induced pore pressure

How about some underdrains?

Water, Water Everywhere?



How about some underdrains?

Structural Requirements?:

Accommodating Varying Tailings Characteristics

Accommodating Varying Tailings Characteristics

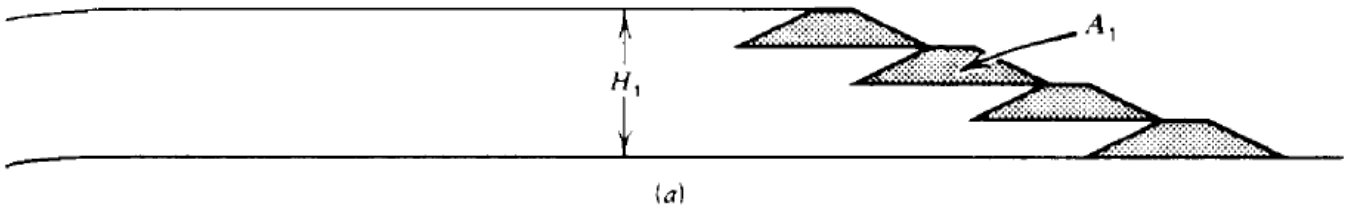
Structural Requirements for:

- Static Loading
- Earthquake Loading

Consider:

- Increased Pore Pressures (Including Construction Induced)
- Decreased Shear Strength
- Cyclic Softening
- Liquefaction

Accommodating Varying Tailings Characteristics



(Illustration Source: Vick 1990)

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Q and...A?

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