INTEGRATED MINE CLOSURE I

UNIVERSITY OF ALBERTA

"uplifting the whole people"

— HENRY MARSHALL TORY, FOUNDING PRESIDENT, 1908

WHY DO MINES CLOSE?

1. Depletion of mineable reserves, resulting from total extraction within deposit or mine limits
2. Unexpected deterioration in geologic condition
3. Deterioration of market condition
4. Changes in other external market conditions that make the project un-workable (i.e. changes in liability or regulation)
5. Financial non-viability of company or parent company
6. Adverse environmental conditions
7. Adverse political or social conditions

* Some of these we have control over

** Can also result in suspension of mining / "care & maintenance"

WHY IS IT IMPORTANT?

There can be little difference between “care & maintenance” (level varies) and closure.

Short notice if closure is unexpected

- Without planning for closure, legacy sites are created
- Few mines have an emergency closure plan which is updated regularly
- Entire communities can be left with water & air pollution, and without an income stream
- Governments can be left with an expensive mess to reclaim
- Mining corporations can have their credibility and future projects at stake, and subsequent legal action.

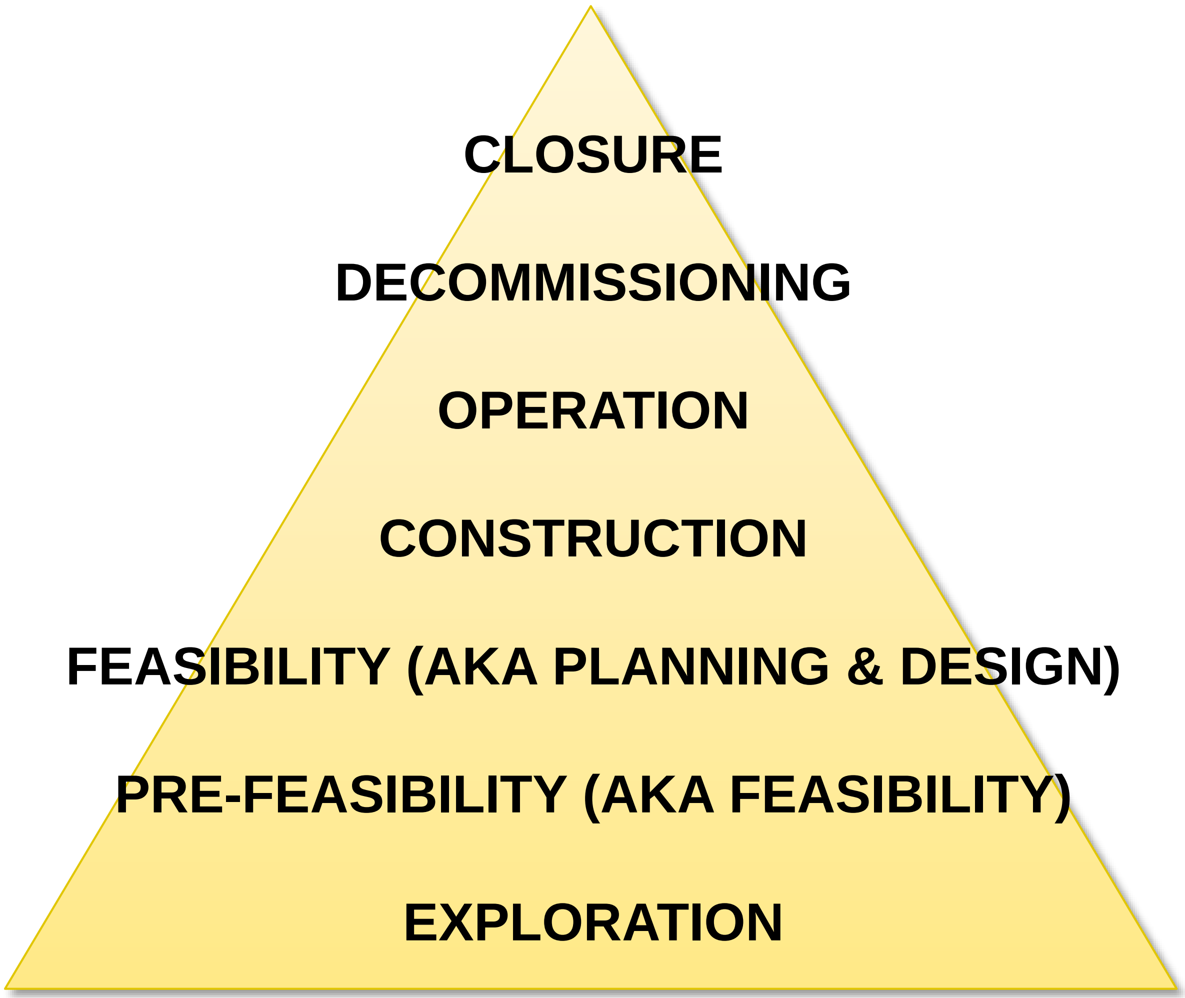
MINING FOR CLOSURE

The life of any mine can be guessed, but is never guaranteed.

The only guarantee is that sooner or later that mine will close.

Be prepared. Plan early.

CONVENTIONAL

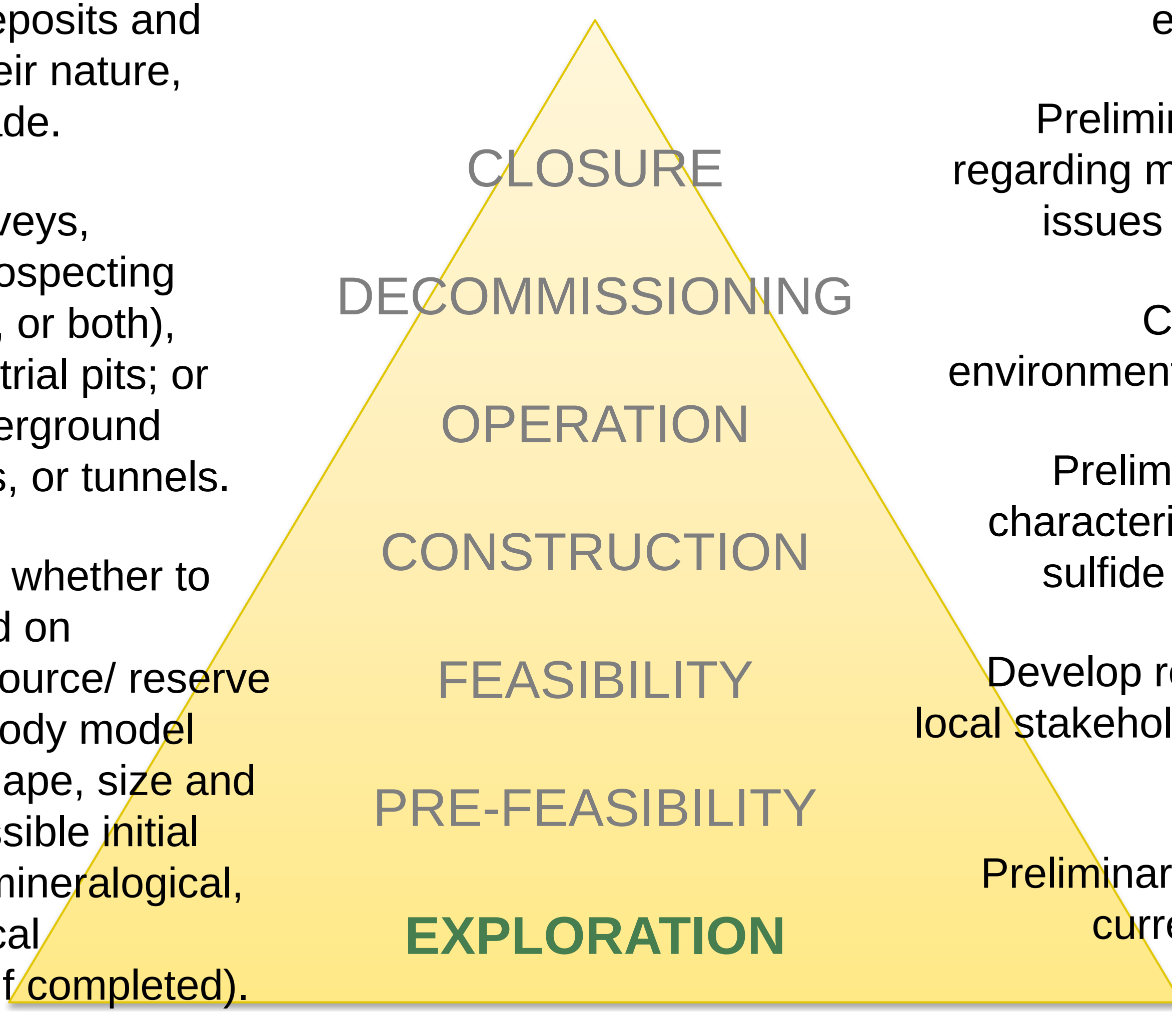


INTEGRATED

Aims at locating the presence of economic deposits and establishing their nature, shape, and grade.

Geological surveys, geophysical prospecting (ground, aerial, or both), boreholes and trial pits; or surface or underground headings, drifts, or tunnels.

Decision made whether to progress based on preliminary resource/ reserve report, an orebody model showing the shape, size and grade, and possible initial geotechnical, mineralogical, and metallurgical assessments (if completed).



Develop a community engagement plan

Preliminary discussions regarding mine concept and issues to be addressed

Collection of early environmental baseline data

Preliminary waste rock characterization, including sulfide testing and ABA

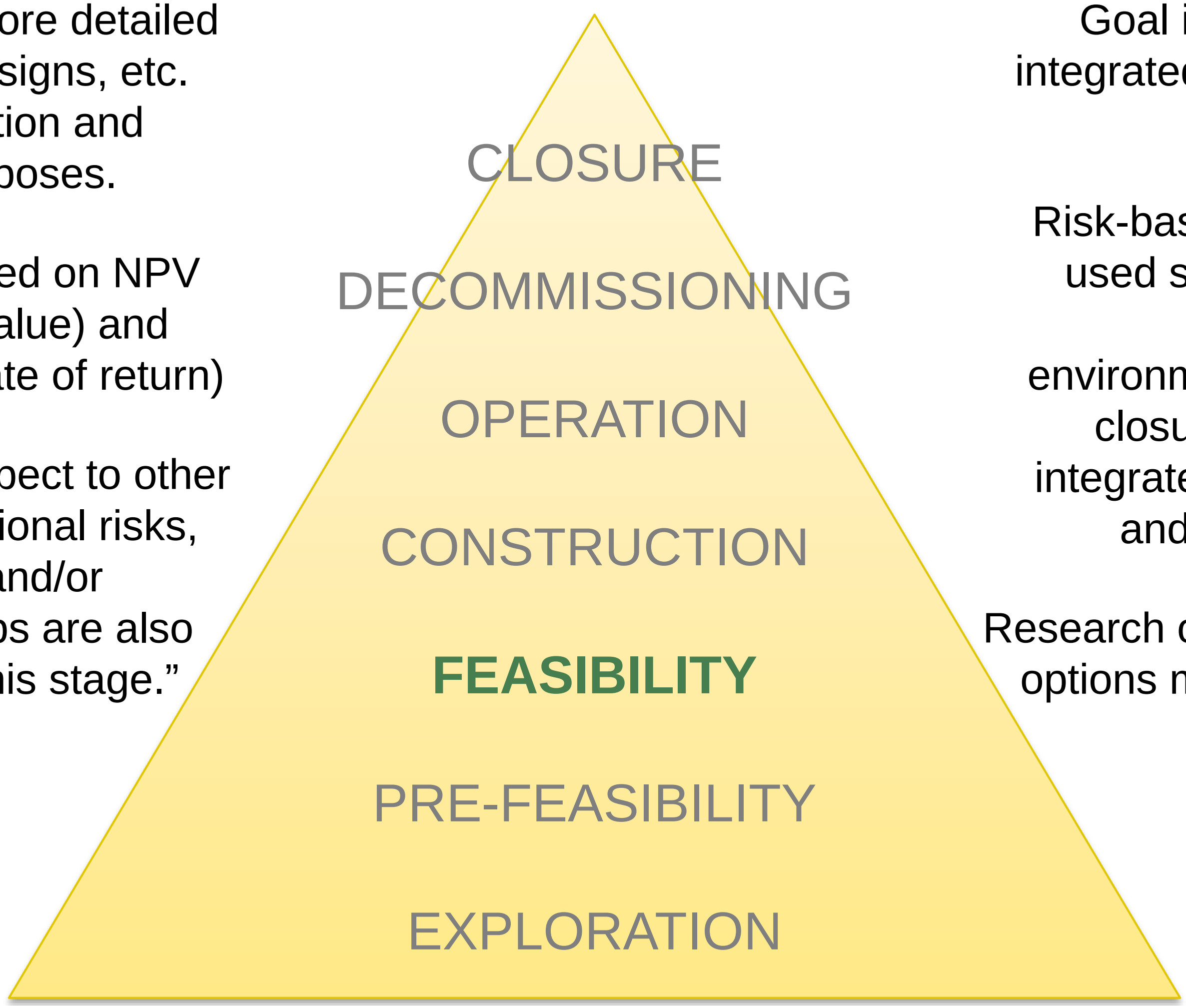
Develop relationships with local stakeholders, regulators, and community

Preliminary assessment of current land use and ownership.

Collection of more detailed information, designs, etc. for cost estimation and scheduling purposes.

Planning focused on NPV (Net Present Value) and IRR (internal rate of return)

Vague with respect to other aspects: "Additional risks, opportunities, and/or information gaps are also addressed in this stage."



Goal is to achieve an integrated mine systems design

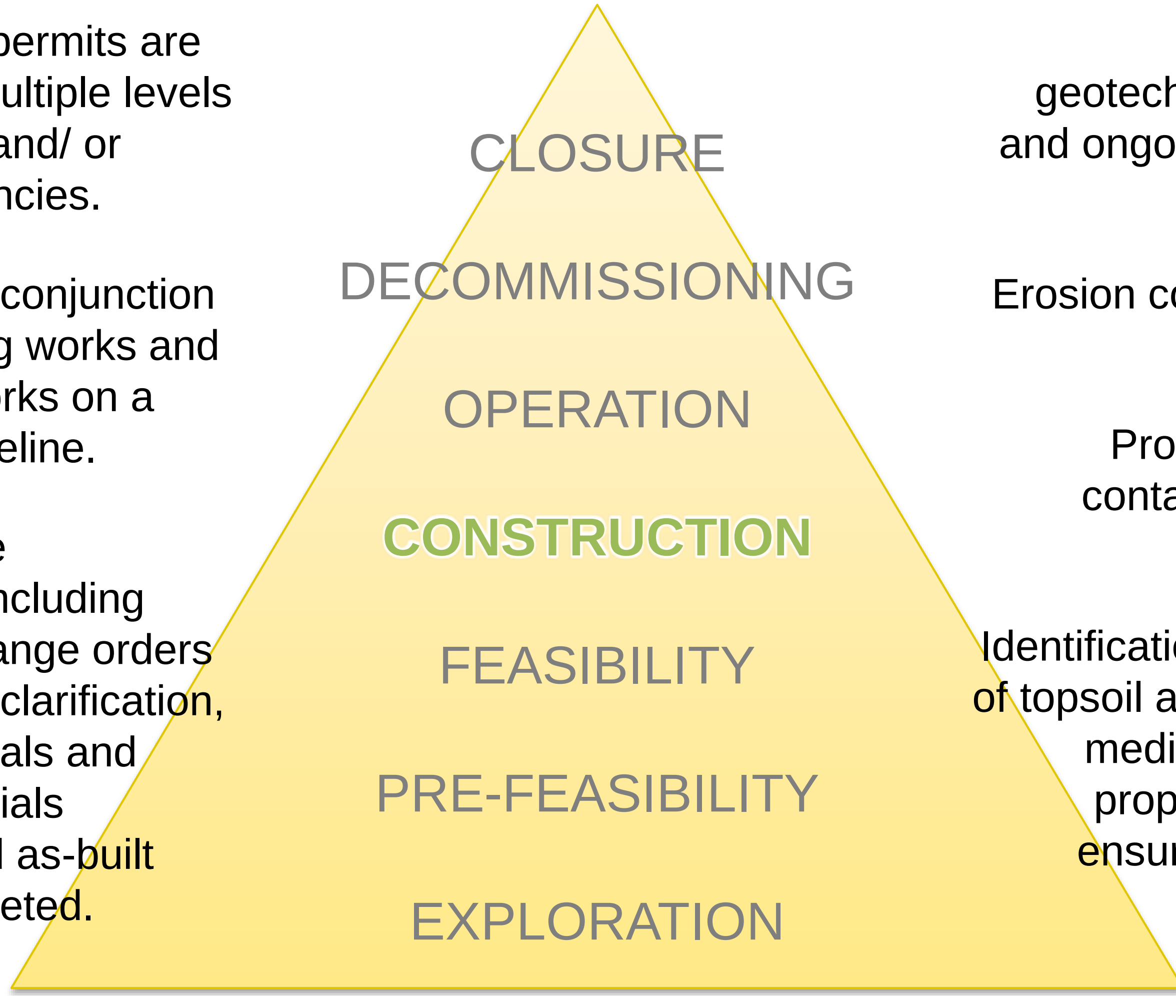
Risk-based approach is used so that business risks, long-term environmental risks and closure liabilities are integrated into planning and cost estimated

Research on rehabilitation options may be required

Approvals and permits are attained from multiple levels of government and/ or associated agencies.

Construction in conjunction with engineering works and architectural works on a coordinated timeline.

Building of mine infrastructure, including inspections, change orders or specification clarification, operating manuals and other site materials assembled, and as-built drawings completed.



Verification of geotechnical properties and ongoing construction inspections

Erosion control measures put in place

Proper storage and containment of fuels, lubricants, etc.

Identification and handling of topsoil and other growth media. Removal and proper stockpiling to ensure viability for its future use

Operation and production includes the mining, milling, and processing of the metal, ore or diamonds.

Mine life (length of time a mine is in production) depends on the quantity of reserves and quality (grade) of the mineral, metal or gems and whether the operation is still profitable.

Mining works may result in small adjustments to the design as required.

Closure planning begins nearing the end of operation.

CLOSURE

DECOMMISSIONING

OPERATION

CONSTRUCTION

FEASIBILITY

PRE-FEASSIBILITY

EXPLORATION

Focus on long-term goals and working towards final landscape

On-going refinement of information and closure plan response to updated information

Progressive implementation of reclamation and closure works

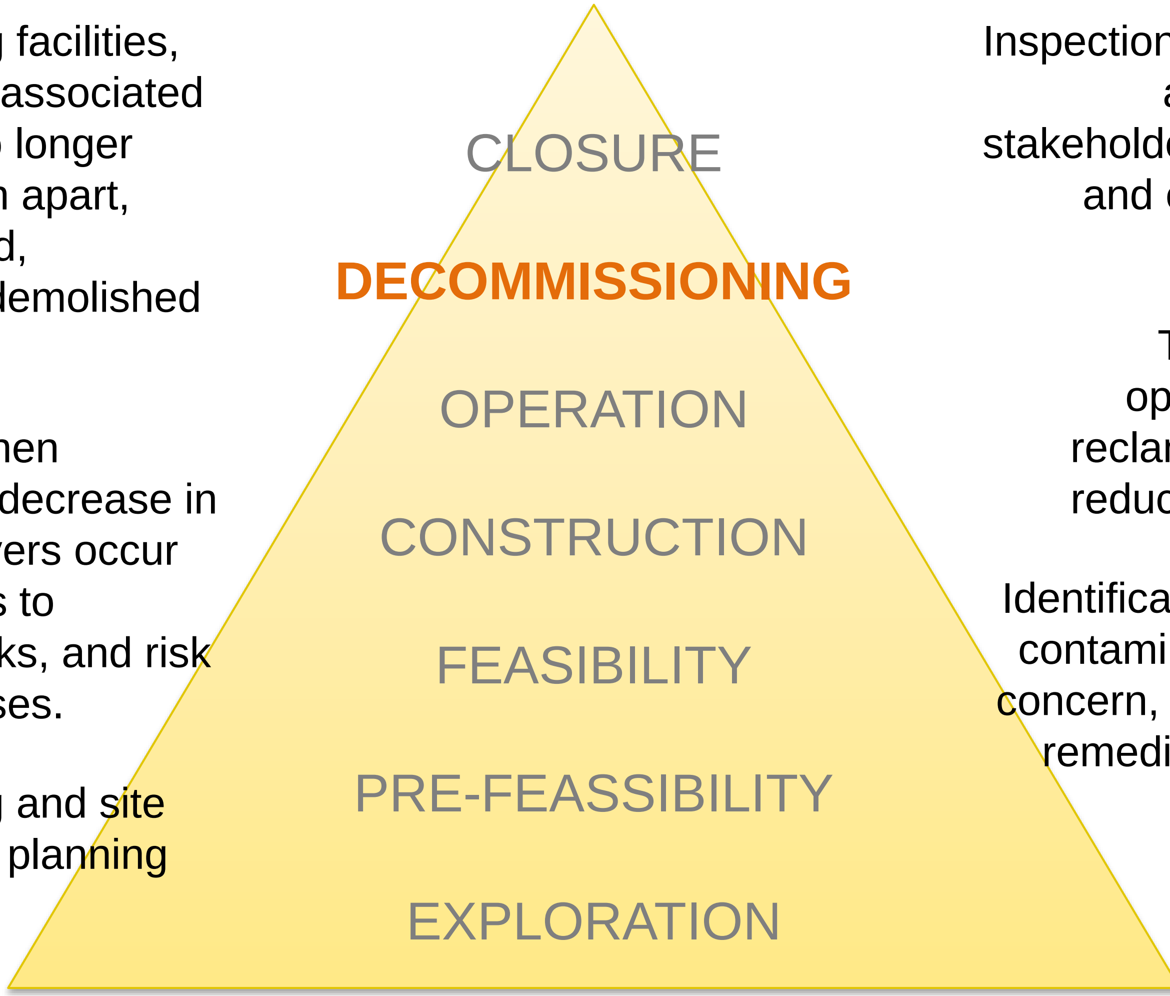
Ongoing engagement with community and stakeholders with regard to status and reclamation works

Allocation of finances and engaging experienced professionals for closure

Mine processing facilities, equipment, and associated infrastructure no longer required is taken apart, cleaned and sold, repurposed, or demolished and disposed.

This is a time when operations staff decrease in numbers, turnovers occur from mine works to reclamation works, and risk of failure increases.

Required testing and site trials for closure planning occur.



Inspections, consultation, and reporting to stakeholders on progress and end-of-mine-life conditions

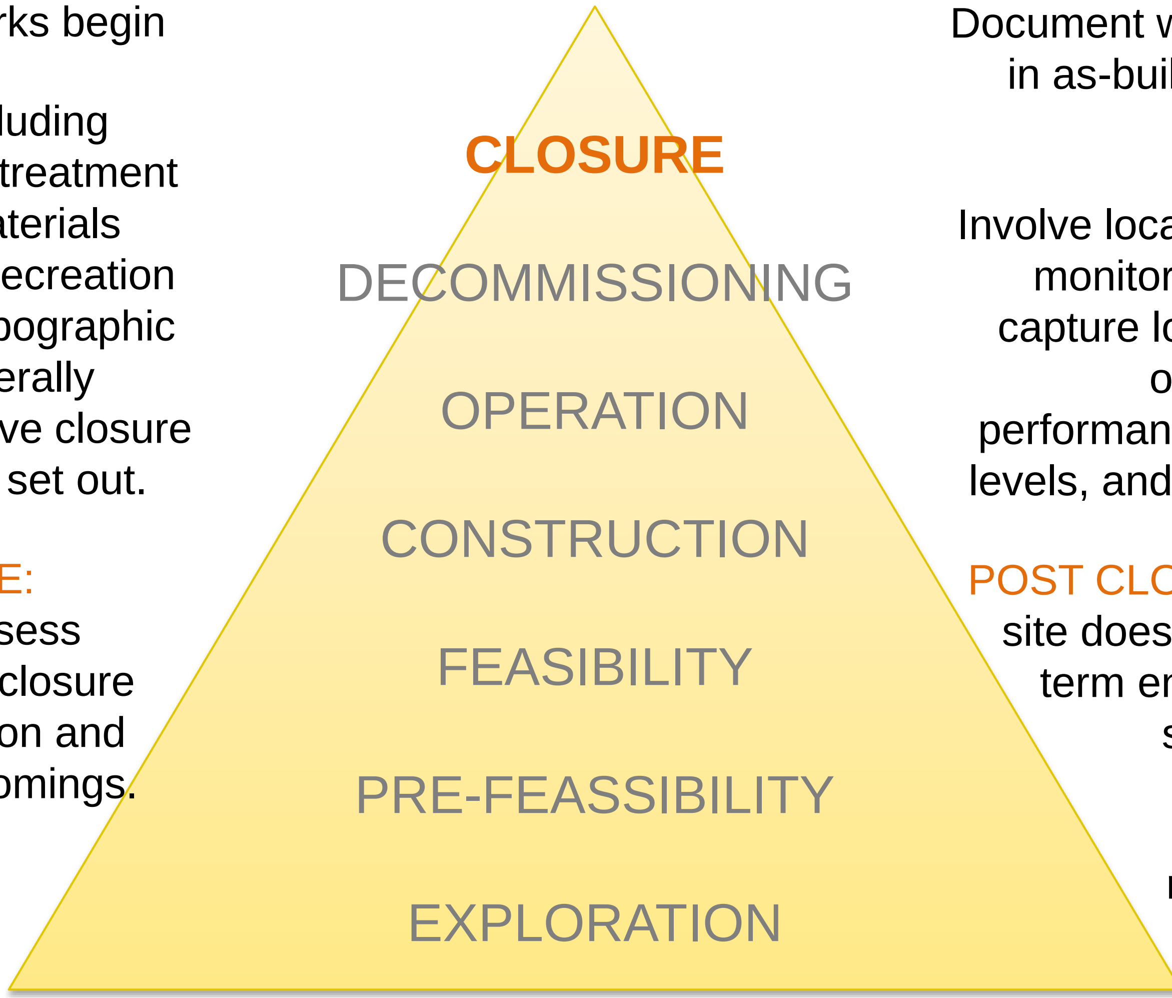
Training of mine operations staff in reclamation works to reduce staff turnover

Identification of potential contamination, areas of concern, etc., to develop remediation strategies

Reclamation works begin

Construction including removal and/ or treatment of hazardous materials and chemicals, recreation of soil profile, topographic design, and generally working to achieve closure goals previously set out.

POST CLOSURE: monitoring to assess effectiveness of closure work. Identification and rectifying shortcomings.



Document work completed in as-built drawings and reports

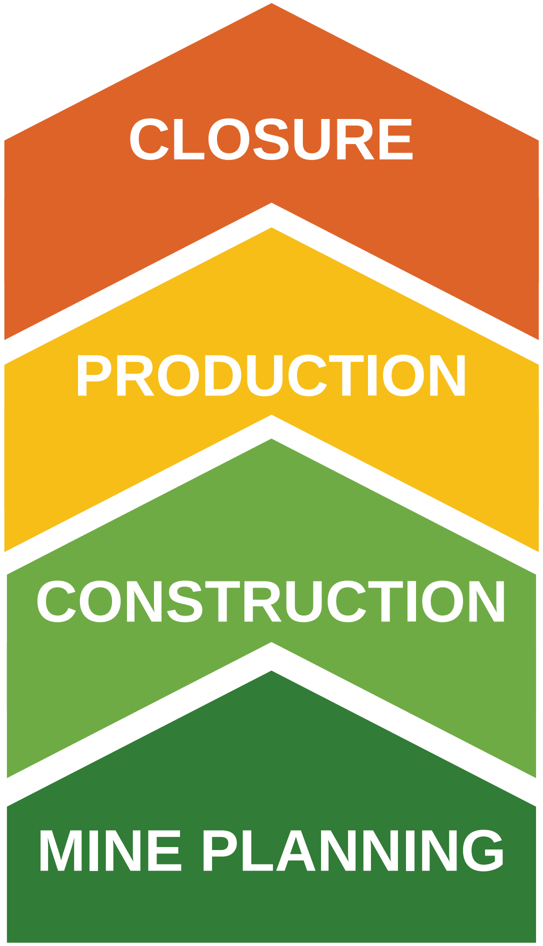
Involve local community in monitoring activities to capture local knowledge on environment, performance, biodiversity levels, and cultural issues

POST CLOSURE: ensure site does not have long-term environmental or social liabilities.

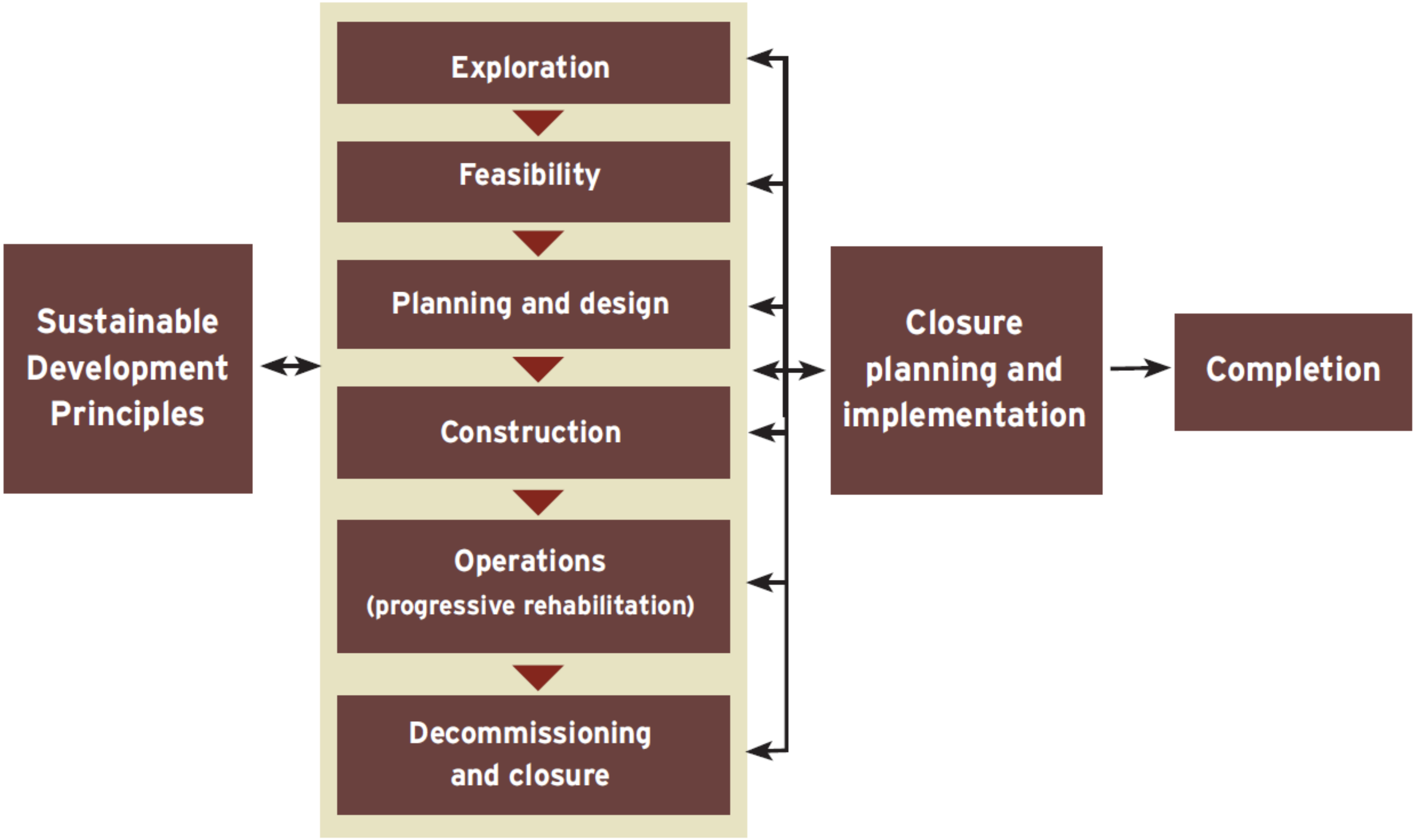
Mine lease relinquishment.

CONVENTIONAL PLANNING APPROACH

- Work completed in silos – little overlap or forethought outside of mine planning & optimization
- NPV dominated decision making
- Little time to identify & solve closure-related challenges
- Extensive earth movement /waste relocation
- Geochemical & geotechnical challenges
- Increased reclamation costs
- Low closure success rates, etc.



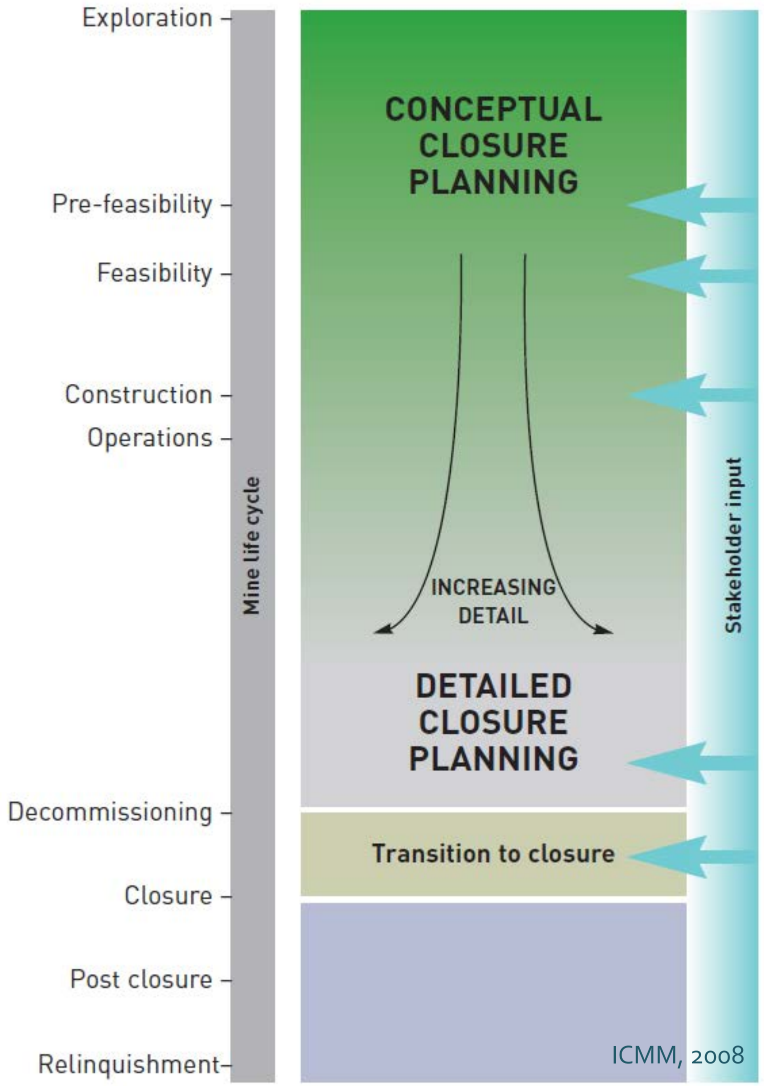
Ultimate result: Liability

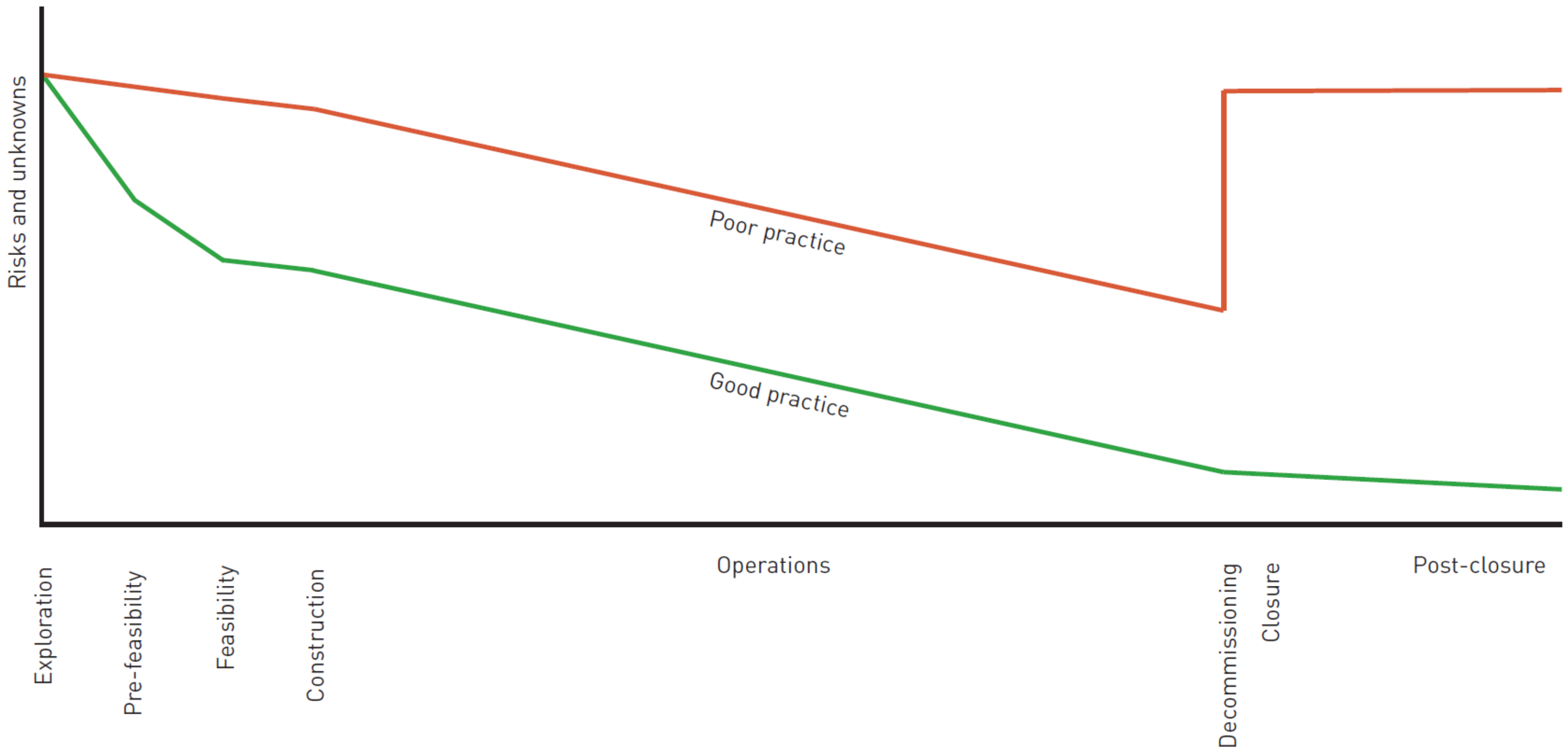


Australian Government, 2006

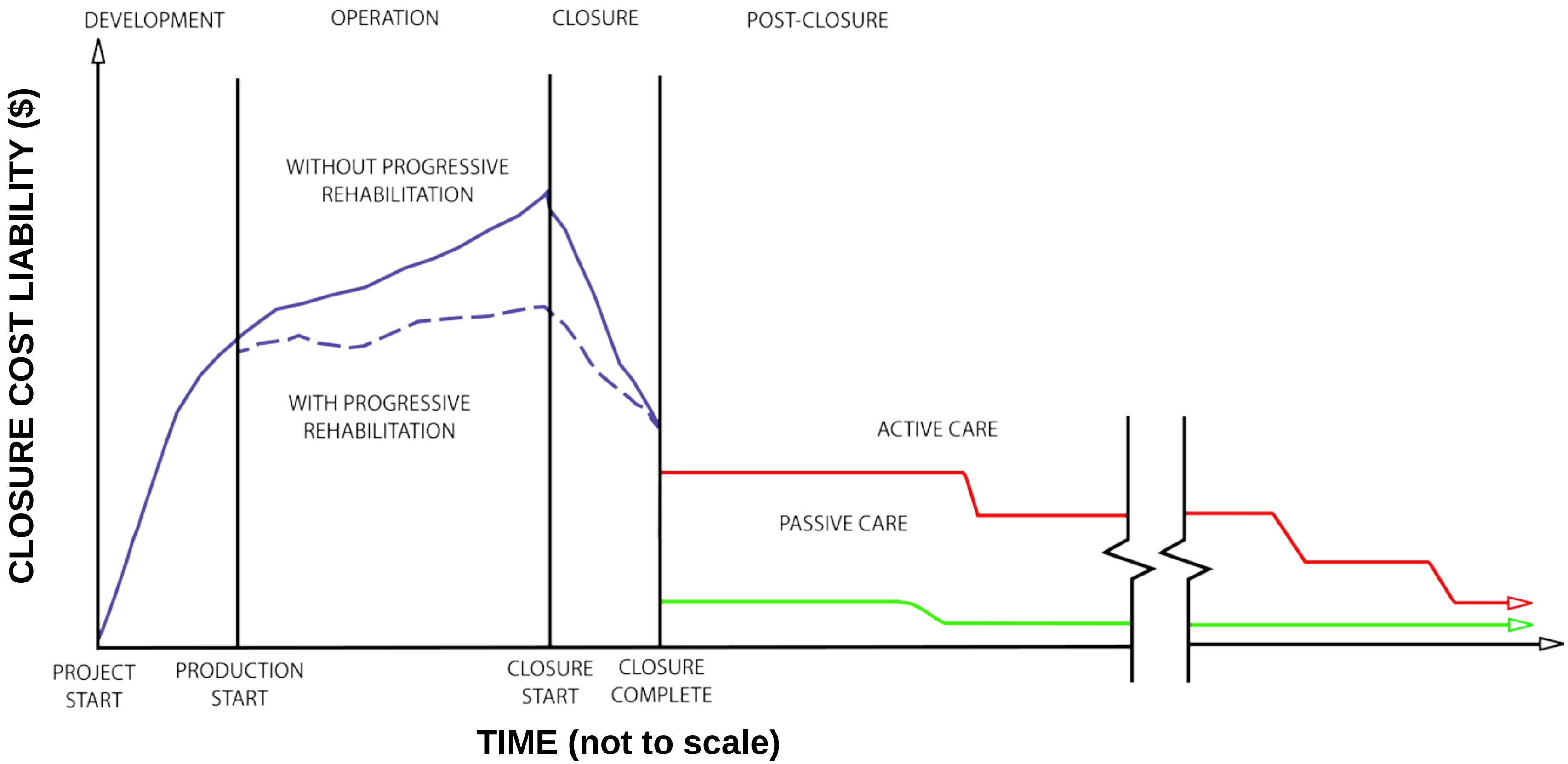
These new approaches are all slightly different in their presentation, but the core value and objective is the same:

- Work with the people (communities, stakeholders, "rights-holders", government, etc.)
- Characterize the rock and waste early.
- Plan for closure up front with mine planning
- Progressively reclaim where possible




Risks and unknowns
Poor practice
Good practice
Exploration
Pre-feasibility
Feasibility
Construction
Operations
Decommissioning
Closure
Post-closure

ICMM, 2008

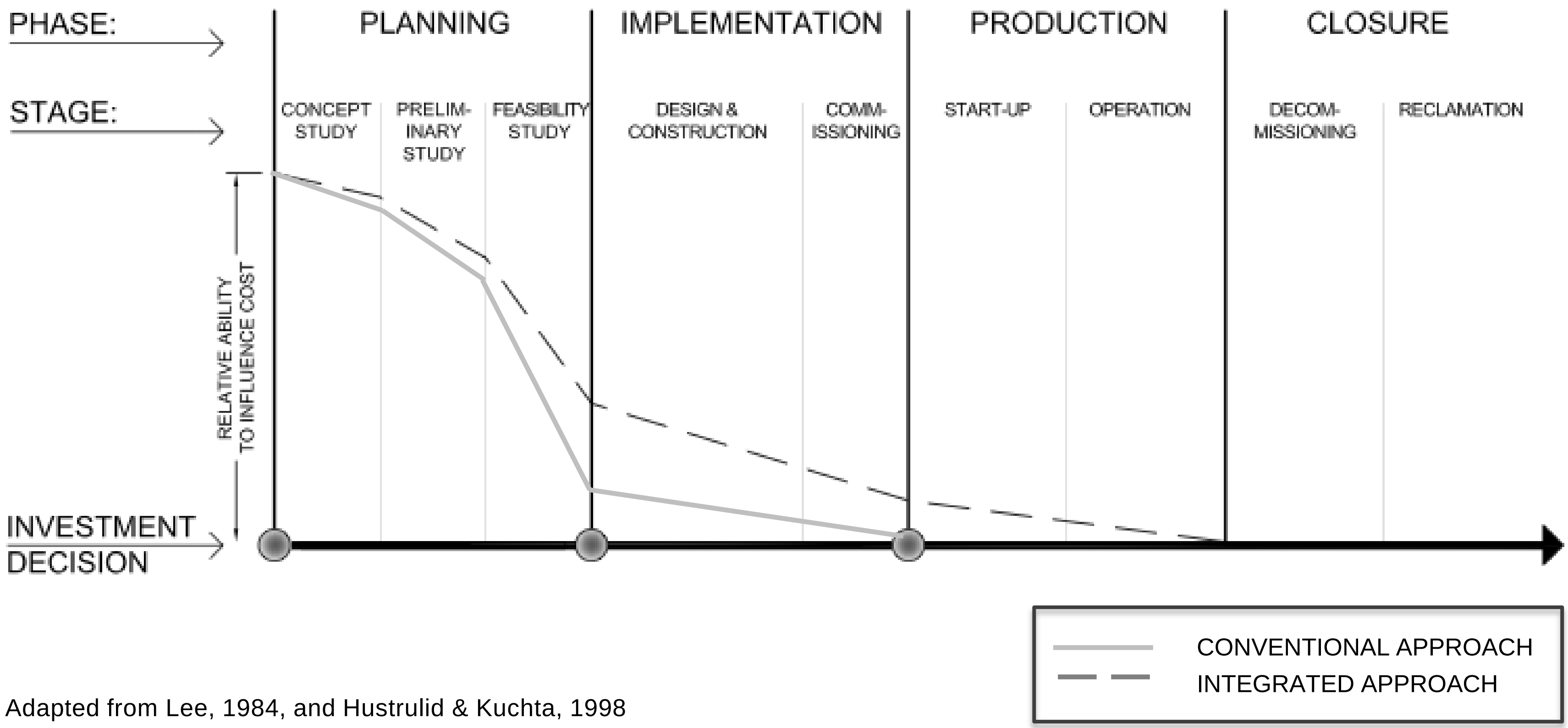


NOTES

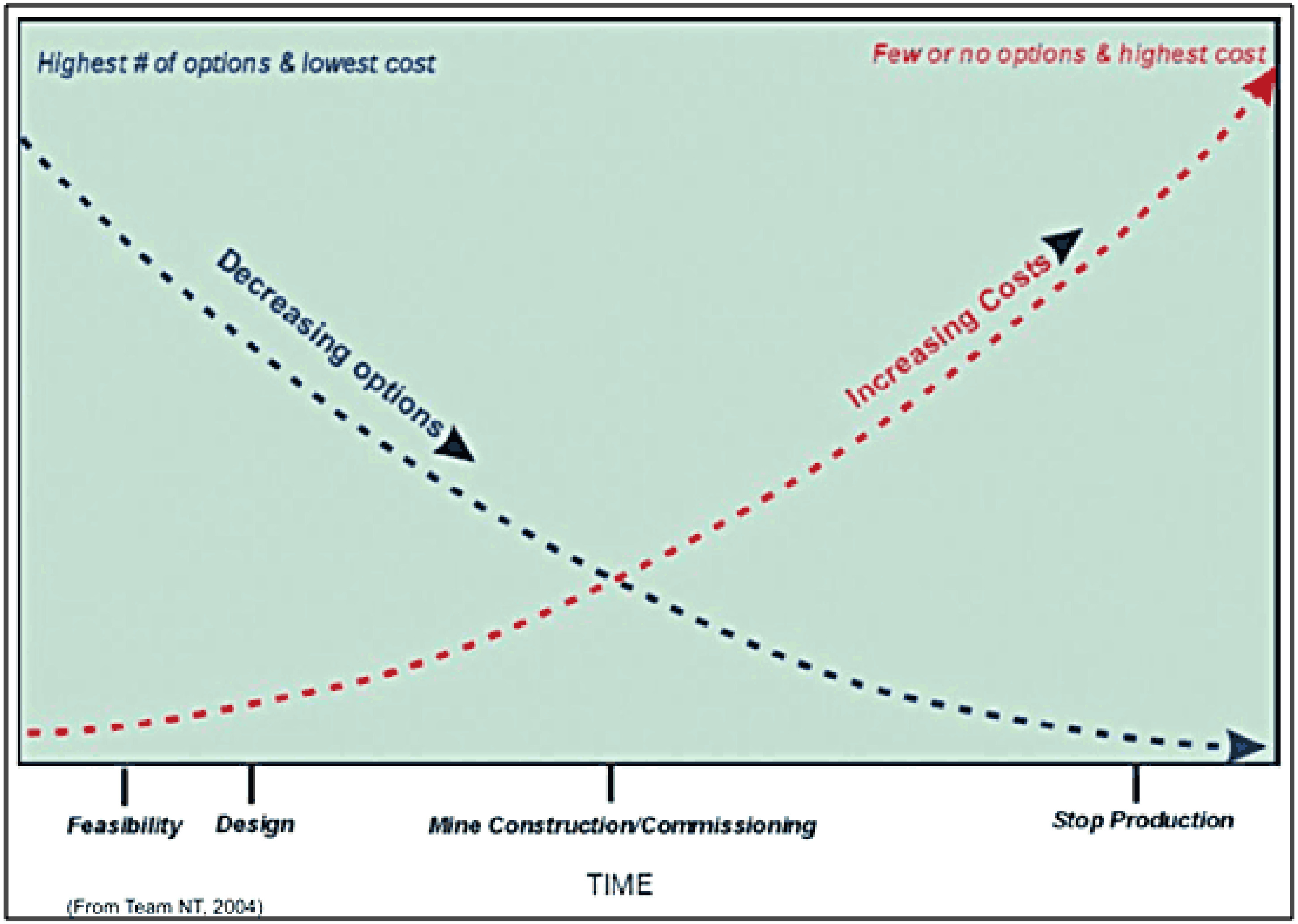
1) FIGURE MODIFIED FIGURE FROM THE "REHABILITATION OF MINES GUIDELINES FOR PROPONENTS" ONTARIO MINISTRY OF NORTHERN DEVELOPMENT AND MINES. OCTOBER 1994.
2) IN SOME CASES TECHNICAL WALK AWAY MAY NOT BE ACHIEVABLE AND PASSIVE CARE MAY BE REQUIRED FOREVER

After Bocking, 2010.

INTEGRATED MINE CLOSURE I



Adapted from Lee, 1984, and Hustrulid & Kuchta, 1998


Highest # of options & lowest cost
Few or no options & highest cost
Decreasing options
Increasing Costs
Feasibility
Design
Mine Construction/Commissioning
Stop Production
TIME
(From Team NT, 2004)

INAP, 2009

THEORY:

- Efficiency over mine life
- Earlier:
  - Identification/resolution of reclamation challenges
  - Closure cost estimation
  - (& more productive) community engagement
- Greater social licence
- Design subsoil

LANDFORM CREATION:
REALITY 1/5

Ideal:

Lab testing and field scale trials are completed prior to finalizing processing methods, in order to characterize construction materials.

http://www.hoskin.ca/catalog/images/ELE_Tri-Flex%202%20Permeability%20Test%20System.jpg

LANDFORM CREATION:
REALITY 2/5

Ideal:

Fine tune processing methods to avoid creating problematic waste products

http://www.businessinsider.com/photos-destructive-canada-oil-sands-2012-10?op=1

http://www.constructionphotography.com

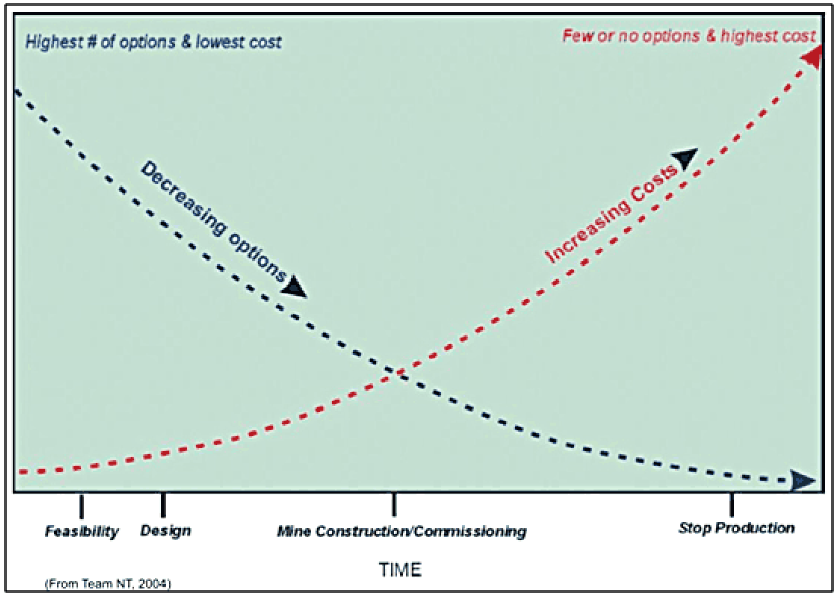
Ideal:
Fine tune
processing

LANDFORM CREATION:
REALITY 3/5

Ideal:

Waste characterization, ARD mitigation scenario testing, and a finalized mitigation plan are developed prior to mine operations.

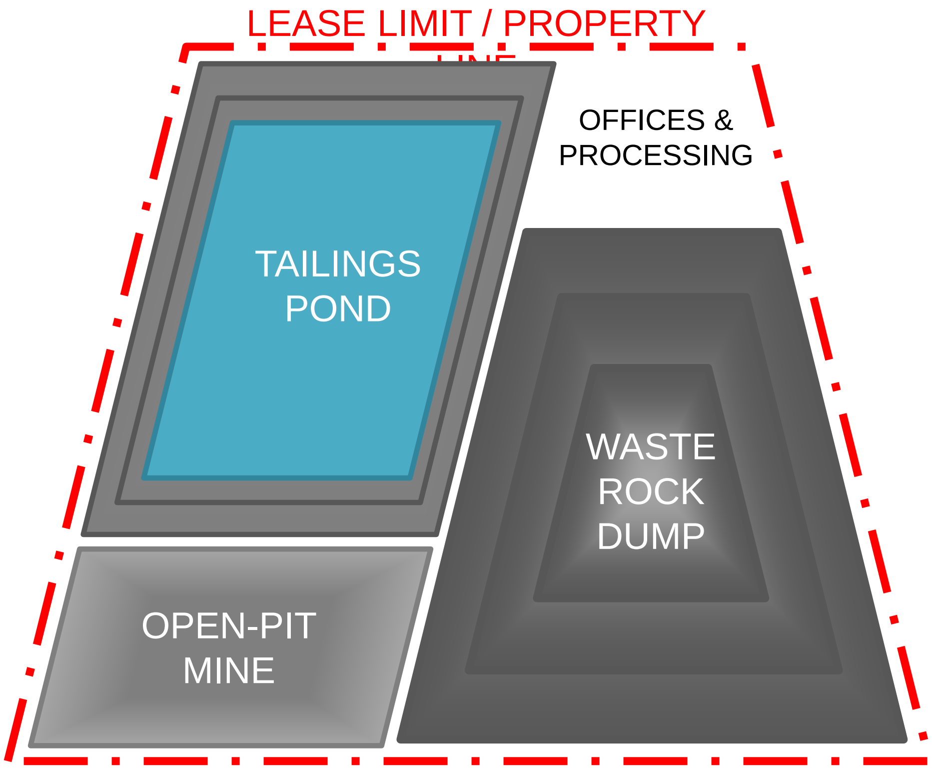
Image from GARD Guide (INAP, 2009)



LANDFORM CREATION: REALITY 4/5

Ideal:

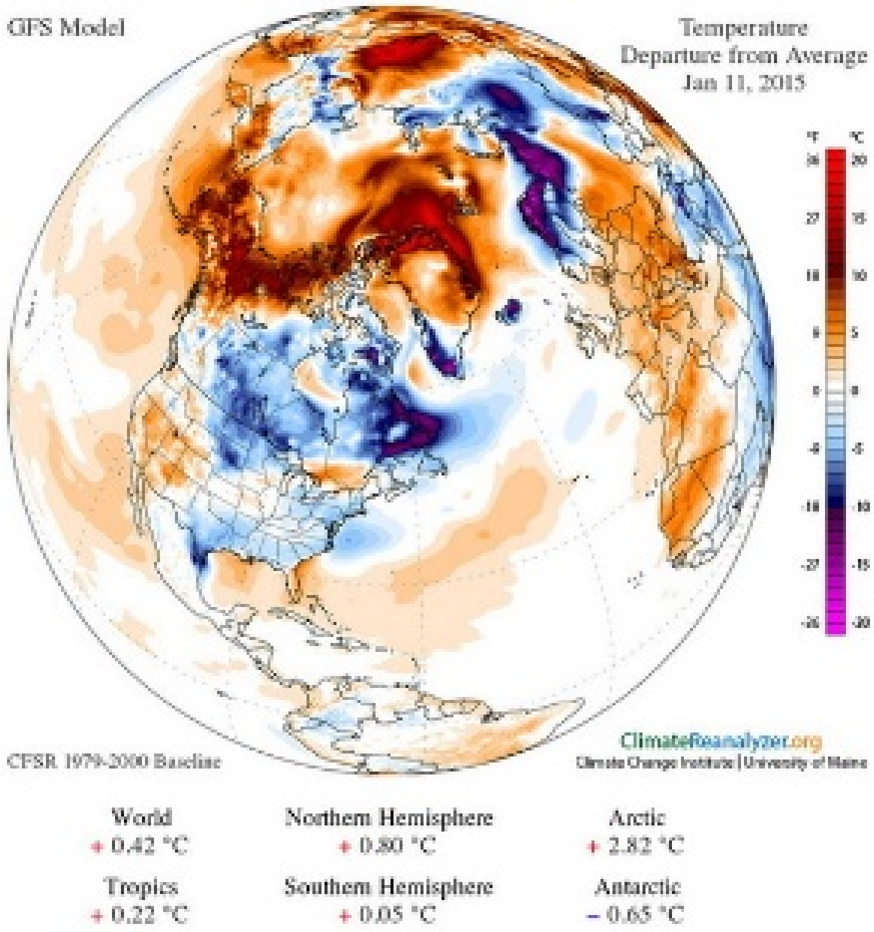
Design landforms using a natural analogue and geomorphic principles.



LANDFORM CREATION:
REALITY 5/5

Ideal:

Design with time in mind, to probable maximum precipitation levels / storm events and consideration of climate change.



http://images.huffingtonpost.com/2015-01-12-anomaltempjan112014-thumb.jpg.

LAND-USE PLANNING APPROACH: WHY?

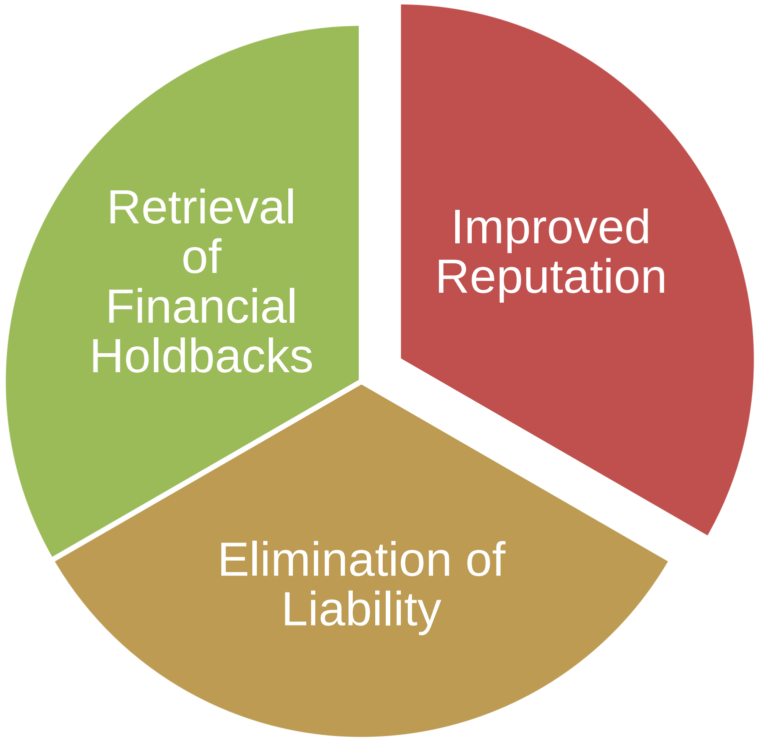
Social license: Take emphasis off the hole in the ground and on to the end landscape

Processing guided by desired end materials = easier/ cheaper/ faster reclamation

Efficiencies, etc.

www.cosia.ca

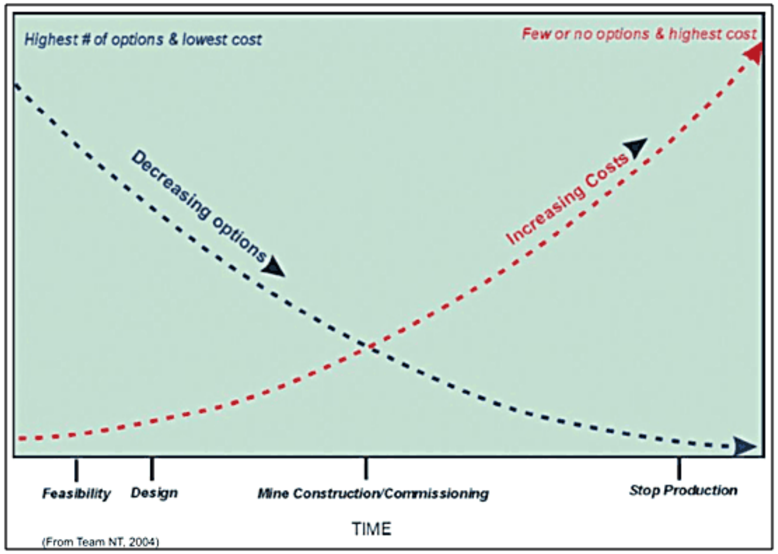
LAND-USE PLANNING APPROACH: PROGRESS?

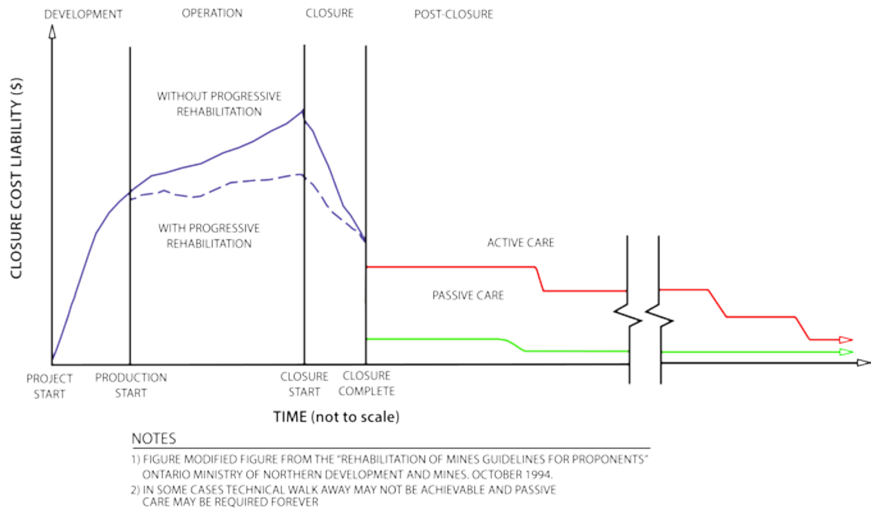


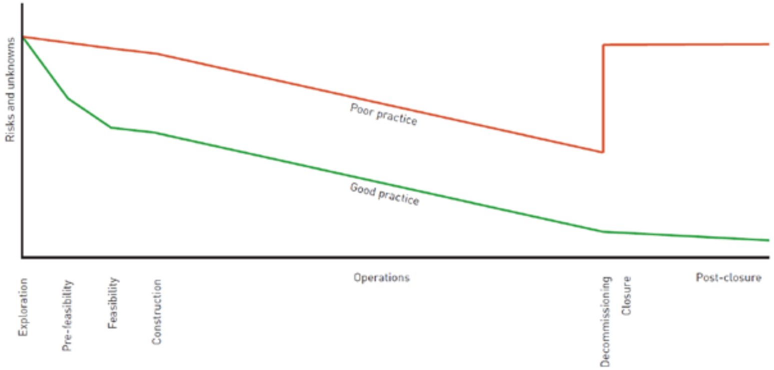
quantifiable

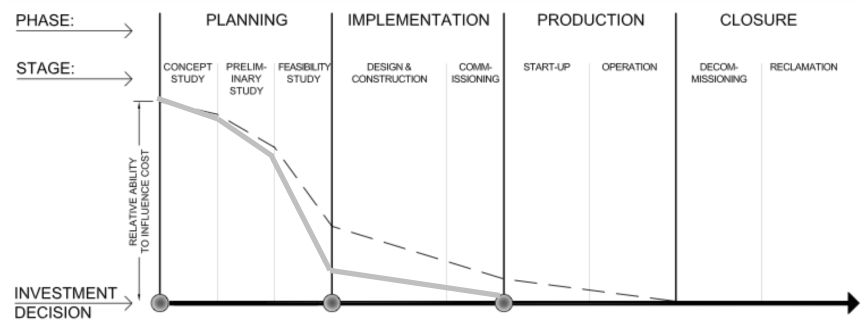
... Not enough incentive!

INTEGRATED MINE CLOSURE I









INAP, 2009

INTEGRATED MINE CLOSURE I - WAIHI GOLD MINE, NEW ZEALAND

INTEGRATED MINE CLOSURE I - WAIHI GOLD MINE, NEW ZEALAND

http://www.waihigold.co.nz/environment/rehabilitation/

Aerial photo from Google Maps

INTEGRATED MINE CLOSURE I - WAIHI GOLD MINE, NEW ZEALAND

INTEGRATED MINE CLOSURE I - WAIHI GOLD MINE, NEW ZEALAND

http://2.bp.blogspot.com/_1mnWZVP2CBY/S9TDlqnxvqI/AAAAAAAAAWw/q5LHrdHQtLM/s1600/IMG_1843_L.jpg

WHO IS THIS?

http://garden-ramblings.blogspot.ca/2011/02/waihi-gold-mining-town.html

IMPORTANCE OF EARLY GOAL IDENTIFICATION

- Something to work towards
- Distributes closure costs over life of mine, reduces overall cost
- Early public license:
  - Shifts focus from current state to the future state of land
  - Builds confidence in company
- End land use dictates:
  - Topography
  - Location of permanent features
- Forces earlier & more accurate closure cost estimation

ASSESSMENT OF CLOSURE / RECLAMATION GOALS

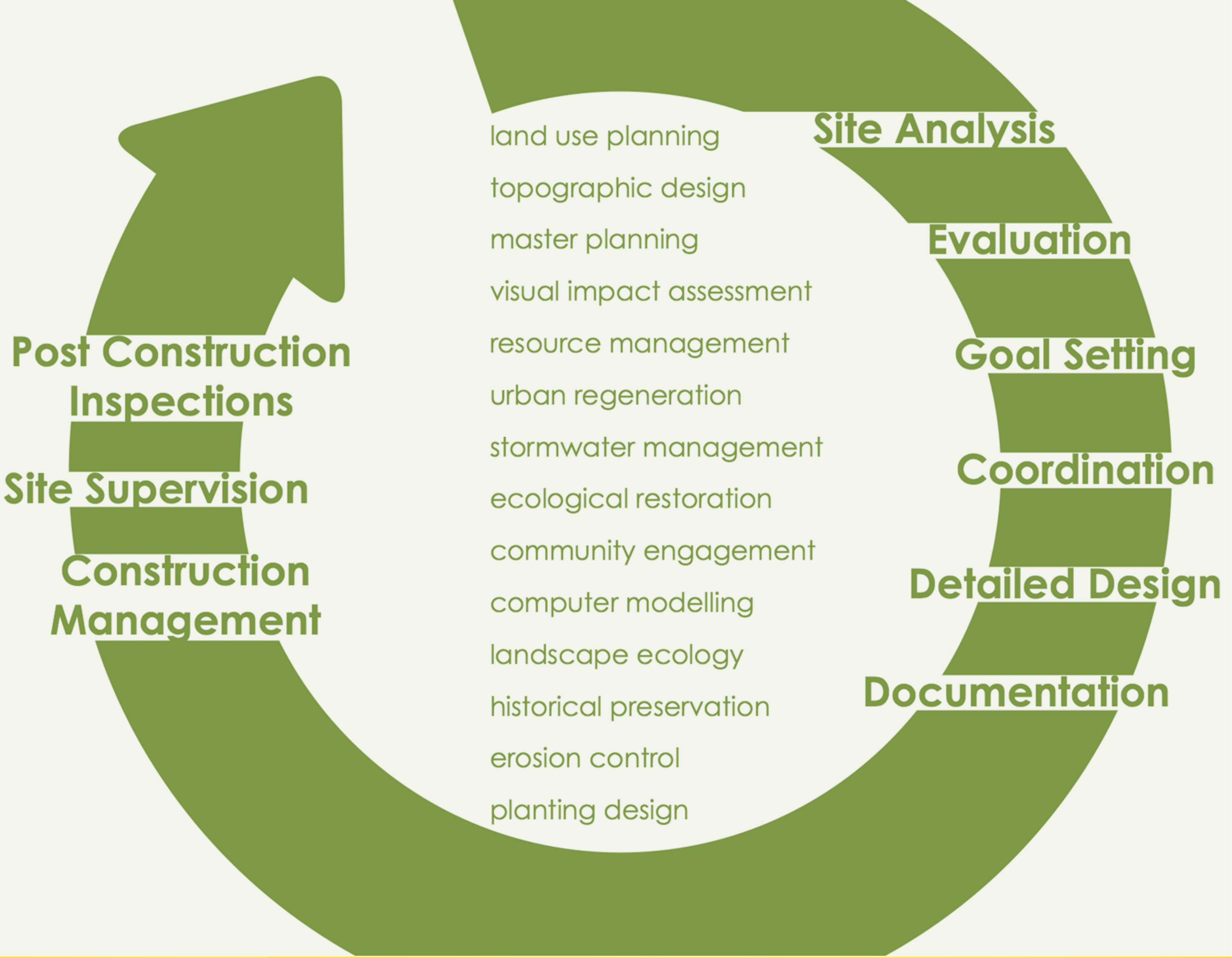
- Geotechnical stability
- Geochemical stability
- Erosion and sedimentation control
- Environmental sustainability
- Etc.

Broad goals with little tangible meaning without going into specifics

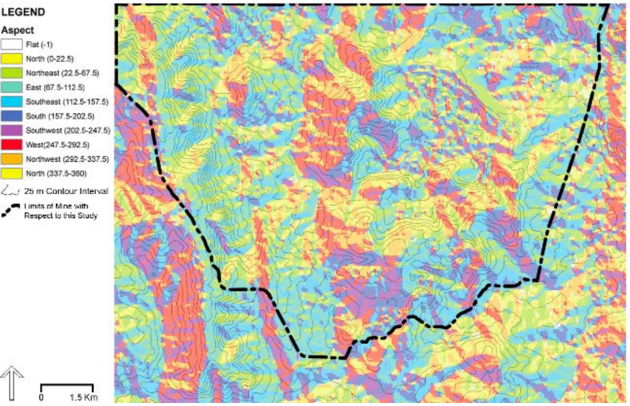
All important.

All require very specific testing and design.

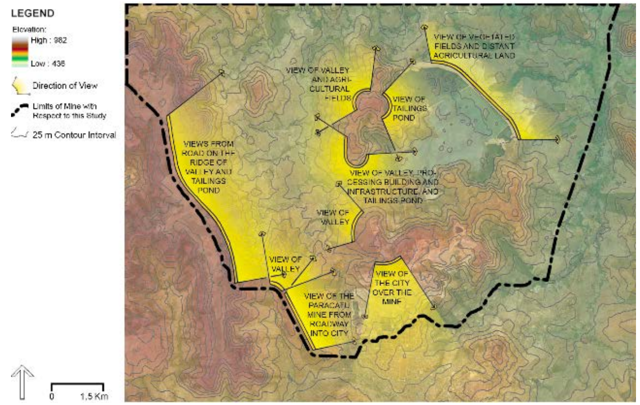
How do we get to this point?


Site Analysis
Evaluation
Goal Setting
Coordination
Detailed Design
Documentation
Construction Management
Site Supervision
Post Construction Inspections
land use planning
topographic design
master planning
visual impact assessment
resource management
urban regeneration
stormwater management
ecological restoration
community engagement
computer modelling
landscape ecology
historical preservation
erosion control
planting design

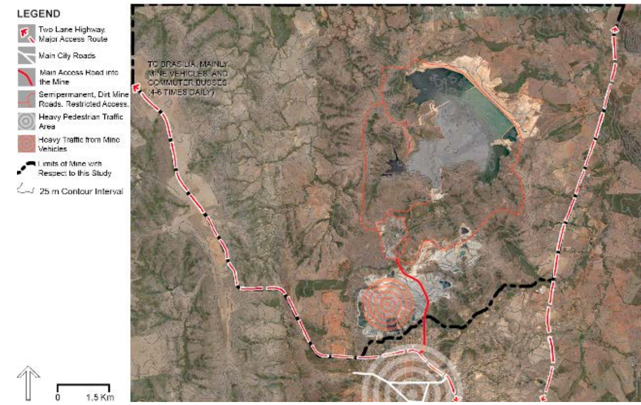
SITE INVENTORY, GEOTECHNICAL/ GEOCHEMICAL INVENTORY



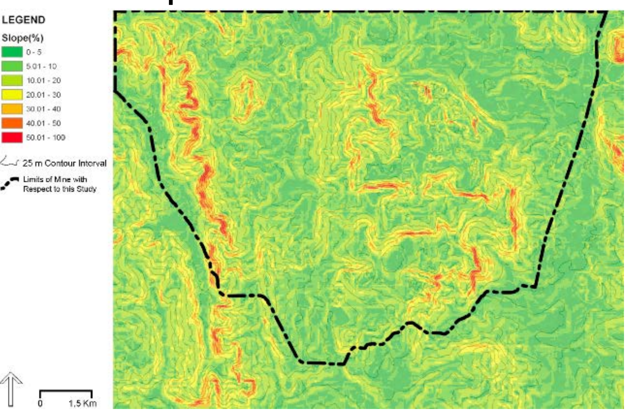
Aspect



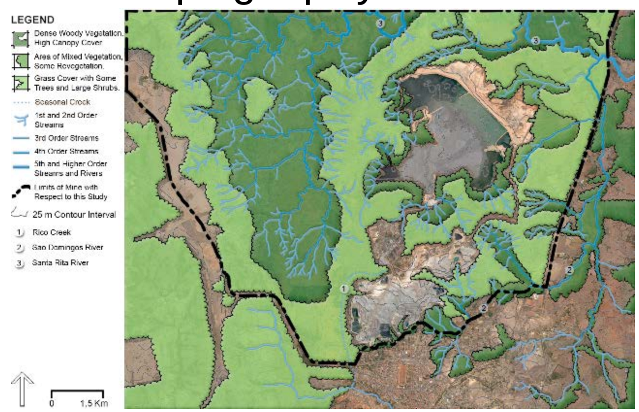
Topography & Viewsheds



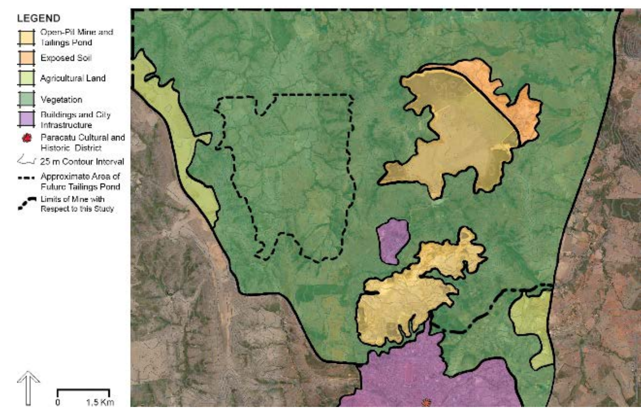
Circulation Patterns



Slope

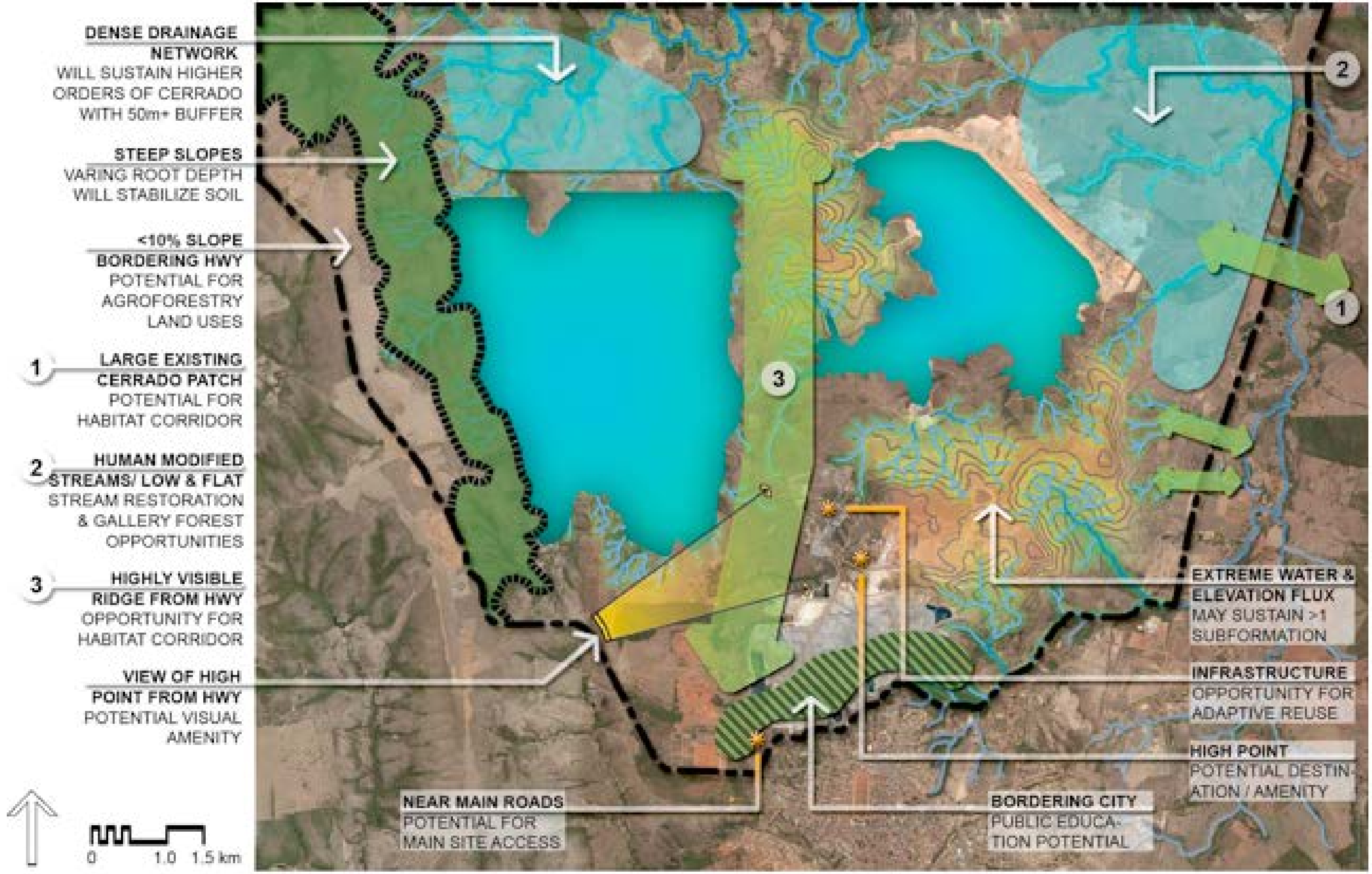


Vegetation & Hydrology

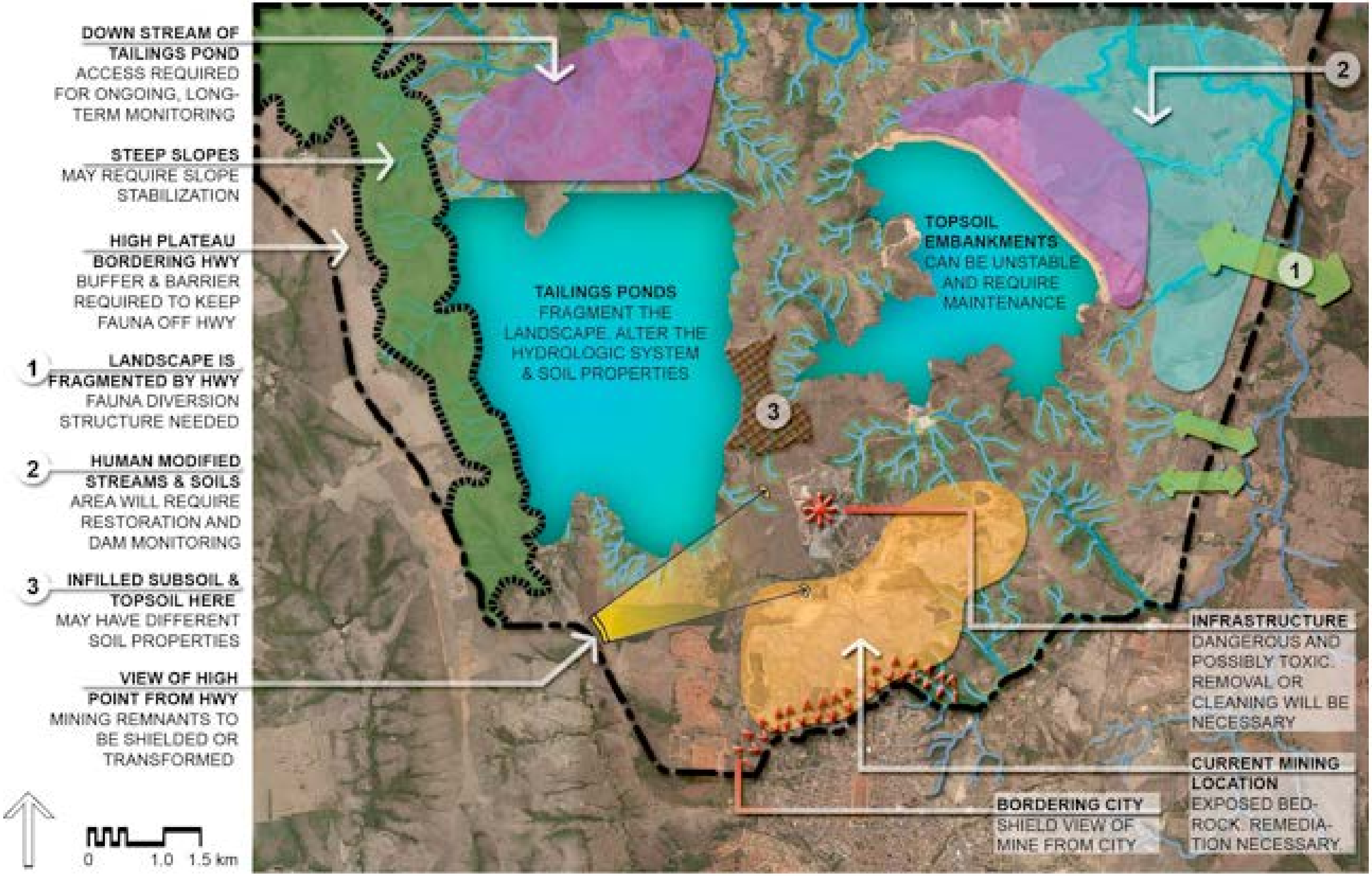


Land Use

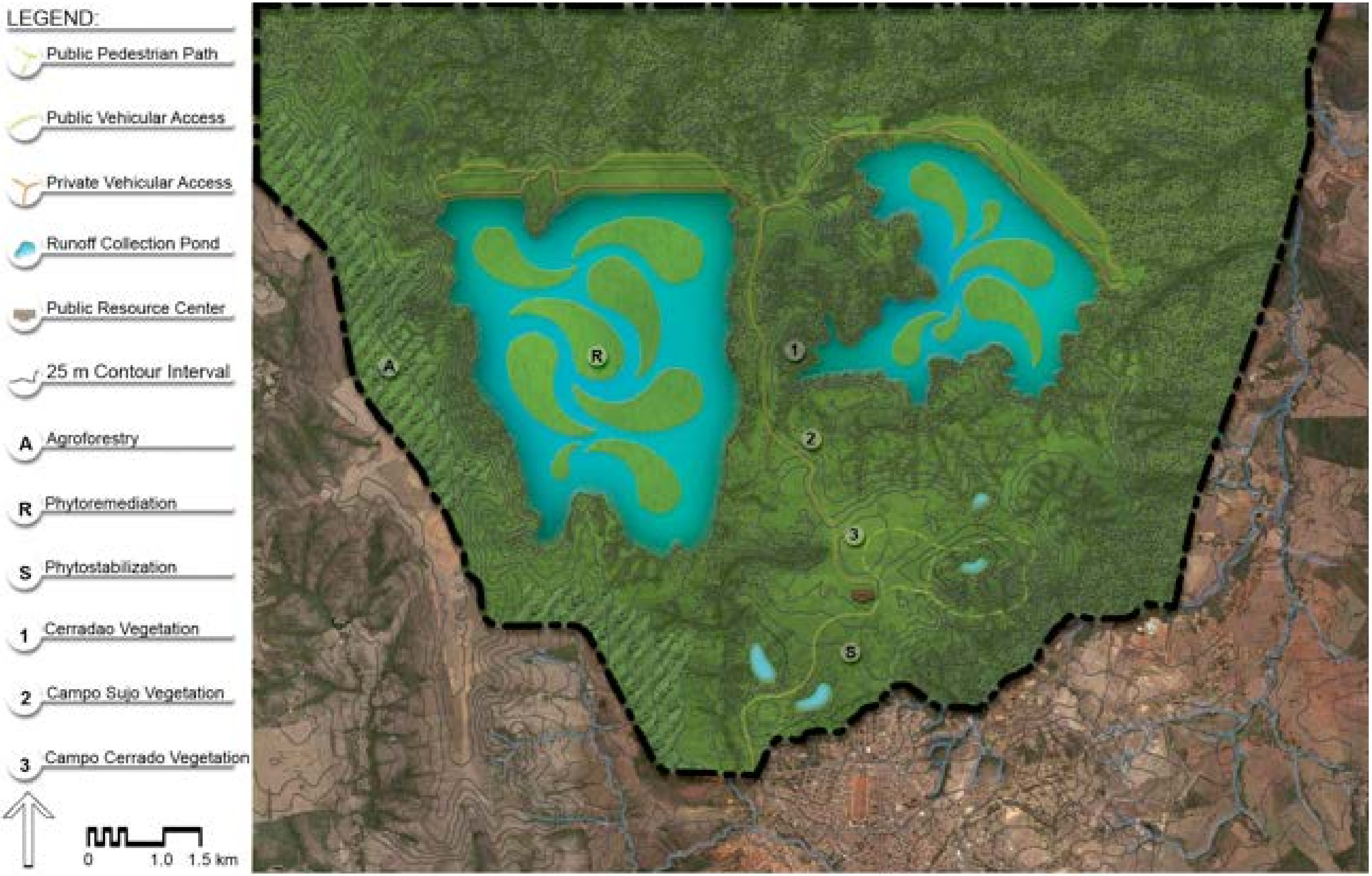
OPPORTUNITIES MAP:



CONSTRAINTS MAP:



LAND USE LEADS TO GOAL SETTING



INFORMATION MANAGEMENT

Environmental & socio-economic decisions are:

- Complex
- Multi-faceted

They require multi-disciplinary knowledge bases:

- Natural & physical sciences
- Social sciences
- Politics
- Ethics, etc.

Information comes in different formats:

- Modelling & monitoring data
- Risk analyses
- Cost estimates & cost-benefit analyses
- Stakeholder preferences

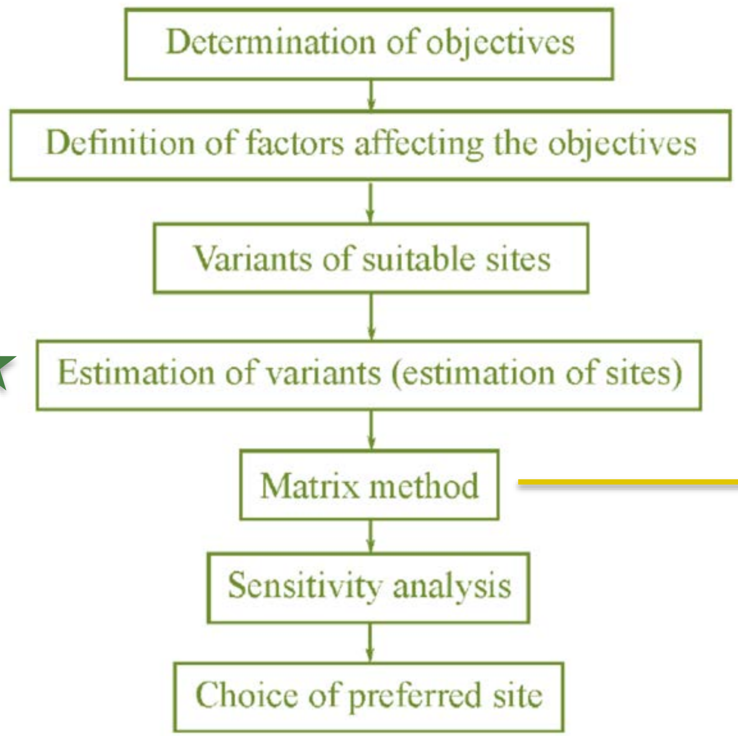
Structured vs. Unstructured

Tangible vs. Intangible

Qualitative vs. Quantitative

INFORMATION MANAGEMENT

Example: Choosing the best waste rock dump location at the Central Iron Mine of Iran.



From Osanloo & Ataei, 2003

TABLE 2. Weight Number of Each Objective

Objective	WN
Decrease in haulage distance	0.20
Increase in dump capacity	0.25
Diminution in the rate of environmental disturbance and pollution	0.30
Reduction in stockpiling cost	0.25

TABLE 1. Matrix Procedure of Estimation of Rock-Dump Sites

Object	Distance of rock haulage, WN = 0.2	Dump capacity, WN = 0.25	Environmental disturbance, WN = 0.3	Rock stockpiling cost, WN = 0.25
Site 1	4	2	4	4
Site 2	1	2	2	3
Site 3	2	3	1	2
Site 4	3	1	3	1
Total classification				
Site 1	0.2×4+0.25×2+0.3×4+0.25×4=3.5	The most preferred variant		
Site 2	0.2×1+0.25×2+0.3×2+0.25×3=2.05	Good variant		
Site 3	0.2×2+0.25×3×+0.3×1+0.25×2=1.95	The least preferred variant		
Site 4	0.2×3×+0.25×1+0.3×3+0.25×1=2	Mean variant		

WHAT MAKES A GOOD CLOSURE GOAL?

Specific

Measurable

Attainable

Realistic

Time-oriented

Don’t forget to outline: Who, What, Where, When, and Why?

EXAMPLE: SMART GOALS

"I will finish the first draft of topographic design for Area X by noon today."

Specific – vagueness won't help

- *Who? What? Why?.*

Measurable – can you actually determine if this was accomplished?

- Ex. *I will finish the first draft of topographic design for Area X by noon today.*

Attainable – Is this something you are capable of doing?

- Do I have everything I need to complete this task? Do I have time?

Realistic – Is this something we will actually do?

- Ex. I have a meeting that *may* interfere with the deadline.

Time dependant – "No timeline, no rush to get it done!"

- Ex. *I will finish the first draft of topographic design for Area X by noon today.*

FINAL THOUGHTS

Design for a built landscape, not for a closed mine.

UNIVERSITY OF ALBERTA