SOURCE - PATHWAY - RECEPTOR MODELLING

Institute of Waste Management of Southern Africa

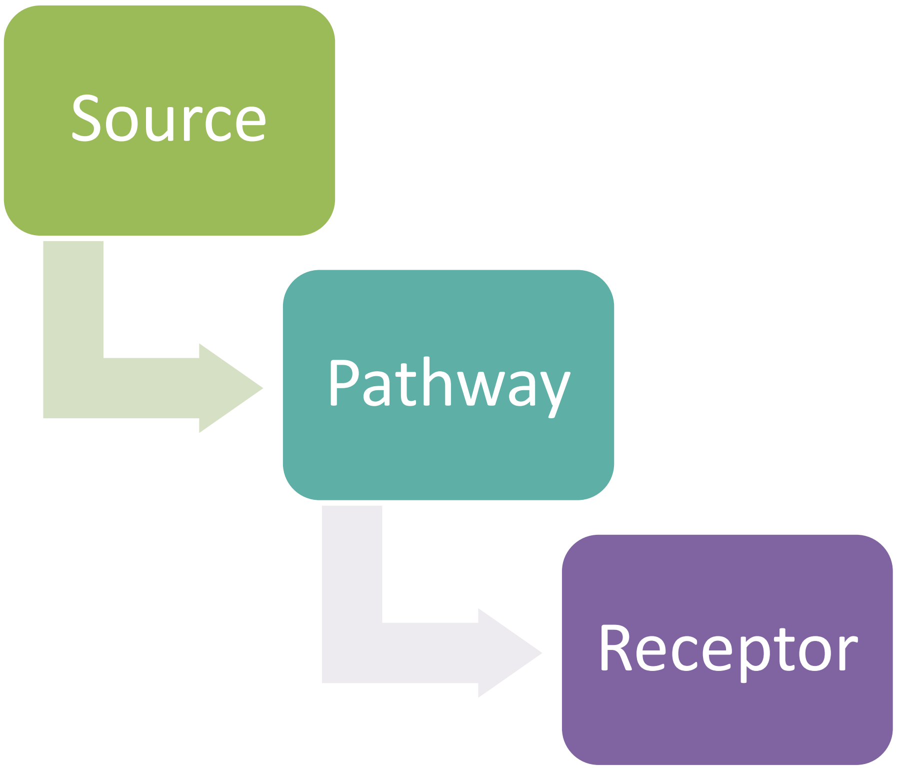
Golder Associates

OVERVIEW

- Source-Pathway-Receptor assessment
- Field investigations
- Conceptual site models
- Numerical modelling
- Outcomes and managing uncertainty

SOURCE-PATHWAY-RECEPTOR ASSESSMENT

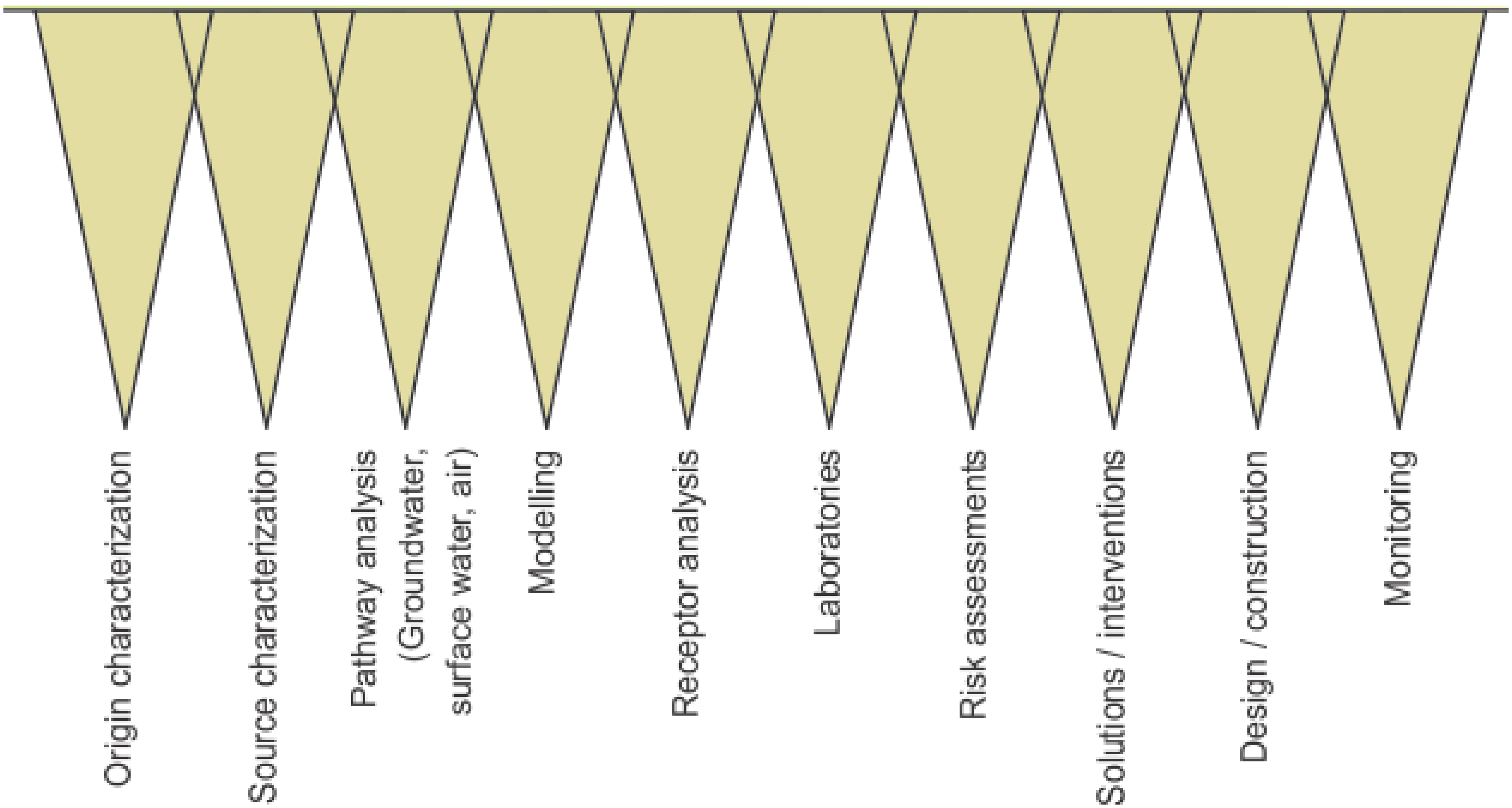
S-P-R connection



- Current and potential contamination sources
- Pathways that go all the way from the sources to the receptors
- Who and what will be impacted (receptors)

Significance/impact

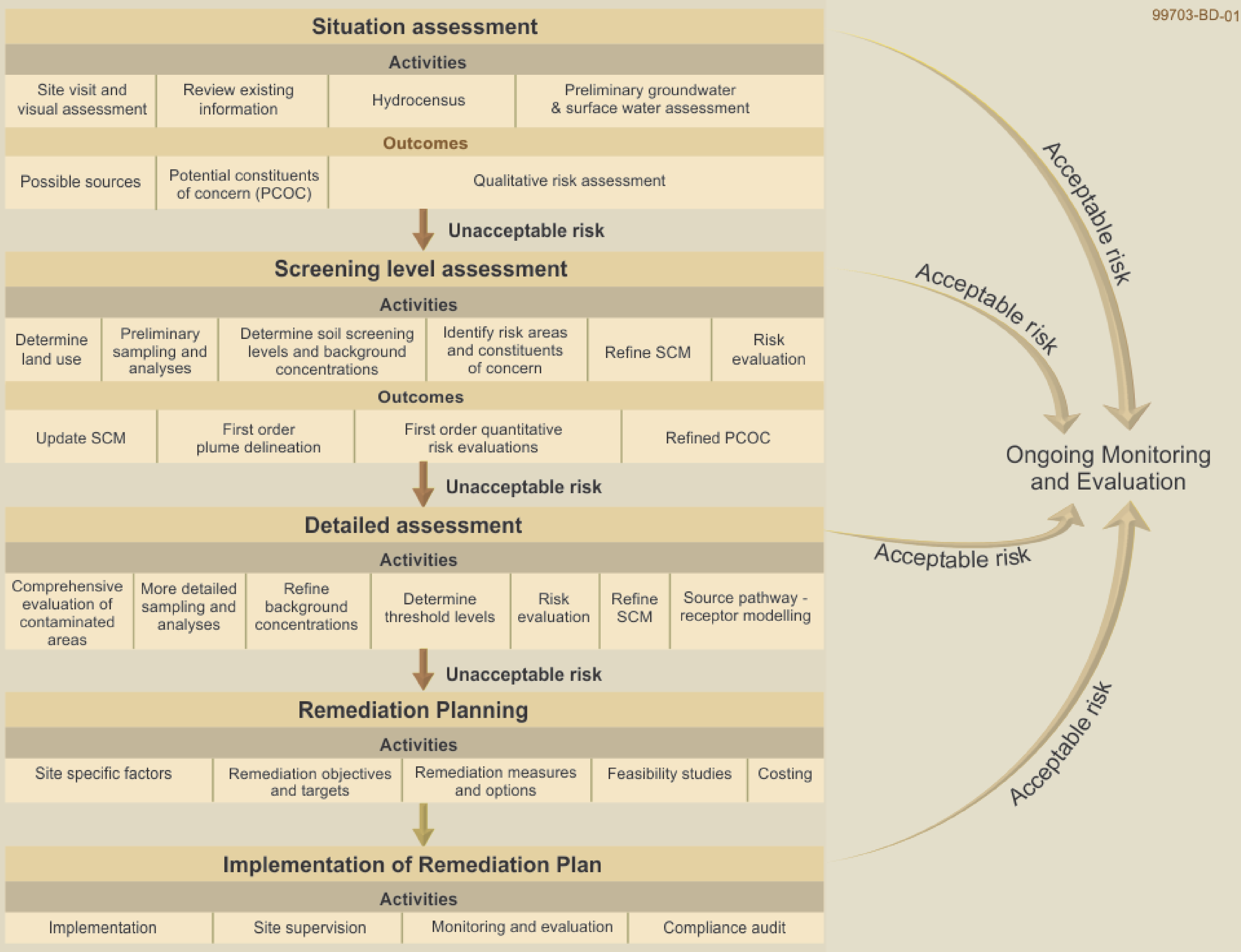
SPR: Fit for purpose



Multi- and transdisciplinary solutions

FIELD INVESTIGATIONS

The results are only as good as the weakest link in the chain of characterization, which is often the sampling



99703-BD-01
Situation assessment
Activities
Site visit and visual assessment
Review existing information
Hydrocensus
Preliminary groundwater & surface water assessment
Outcomes
Possible sources
Potential constituents of concern (PCOC)
Qualitative risk assessment
Unacceptable risk
Screening level assessment
Activities
Determine land use
Preliminary sampling and analyses
Determine soil screening levels and background concentrations
Identify risk areas and constituents of concern
Refine SCM
Risk evaluation
Outcomes
Update SCM
First order plume delineation
First order quantitative risk evaluations
Refined PCOC
Unacceptable risk
Detailed assessment
Activities
Comprehensive evaluation of contaminated areas
More detailed sampling and analyses
Refine background concentrations
Determine threshold levels
Risk evaluation
Refine SCM
Source pathway - receptor modelling
Unacceptable risk
Remediation Planning
Activities
Site specific factors
Remediation objectives and targets
Remediation measures and options
Feasibility studies
Costing
Implementation of Remediation Plan
Activities
Implementation
Site supervision
Monitoring and evaluation
Compliance audit
Acceptable risk
Acceptable risk
Acceptable risk
Acceptable risk
Ongoing Monitoring and Evaluation

Statistical fundamentals for sampling

- Accuracy – how close a measured value is to the true value
- Precision – measure of variability
- Sampling procedure
  - Haphazard sampling
    - Based on convenience
    - Fundamentally flawed
  - Search sampling
    - Know history of site
  - Judgement (biased) sampling
    - Sampling is random – but not statistically random
    - Sampling units are chosen based on what appears to be representative
    - Often more representative than probability sampling when n is small (1-3)
  - Probability sampling
    - Samples have an equal change of being chosen
    - Good for source materials, such as soils and sludges

Non intrusive investigations

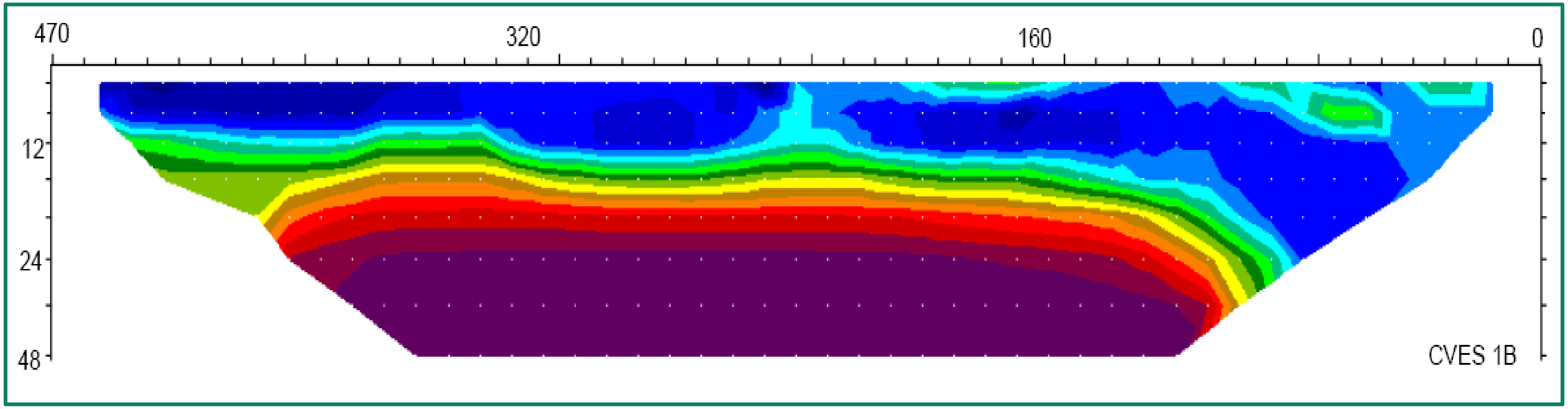
- **Soil vapour survey** (volatile compounds)-VOCs that were released into the subsurface will volatilise into soil gas and can, under favourable conditions, be detected through a soil vapour survey. Although an indirect method, can be an important tool in selecting soil and groundwater sample positions to delineate the contaminant plumes
    - Rapid surveys using Photo Ionisation Detector (PID)
    - Thermal Desorption Tubes (TDT's)

Non intrusive investigations

Geophysical Surveys for optimal positioning of monitoring boreholes

Magnetic, electromagnetic, high resolution resistivity and gravity aiming to map subsurface structures.

The geophysical data is incorporated into the site conceptual model, which will guide the positions of intrusive investigative points.



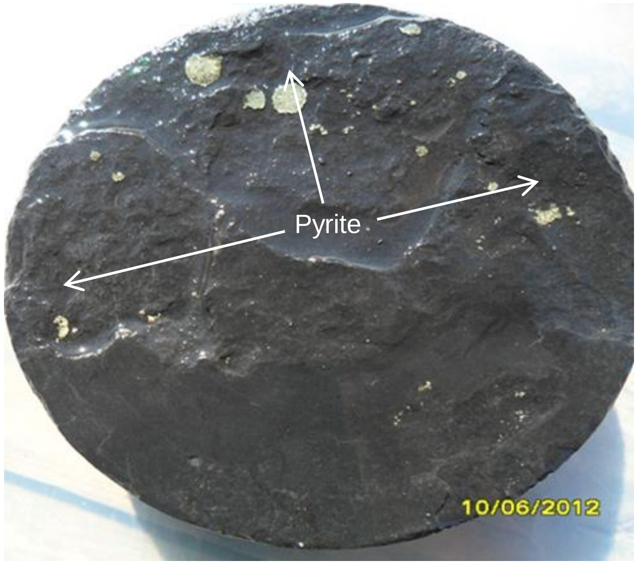
Intrusive assessments

- Site specific field investigations are the basis of any detailed site conceptual model and the monitoring and measurement of certain parameters (i.e. hydraulic conductivity and seasonal water level response) are crucial in understanding site conditions and designing remedial/management options.
- A screening/detailed site investigation phase is conducted to fill gaps and delineate contaminant plumes



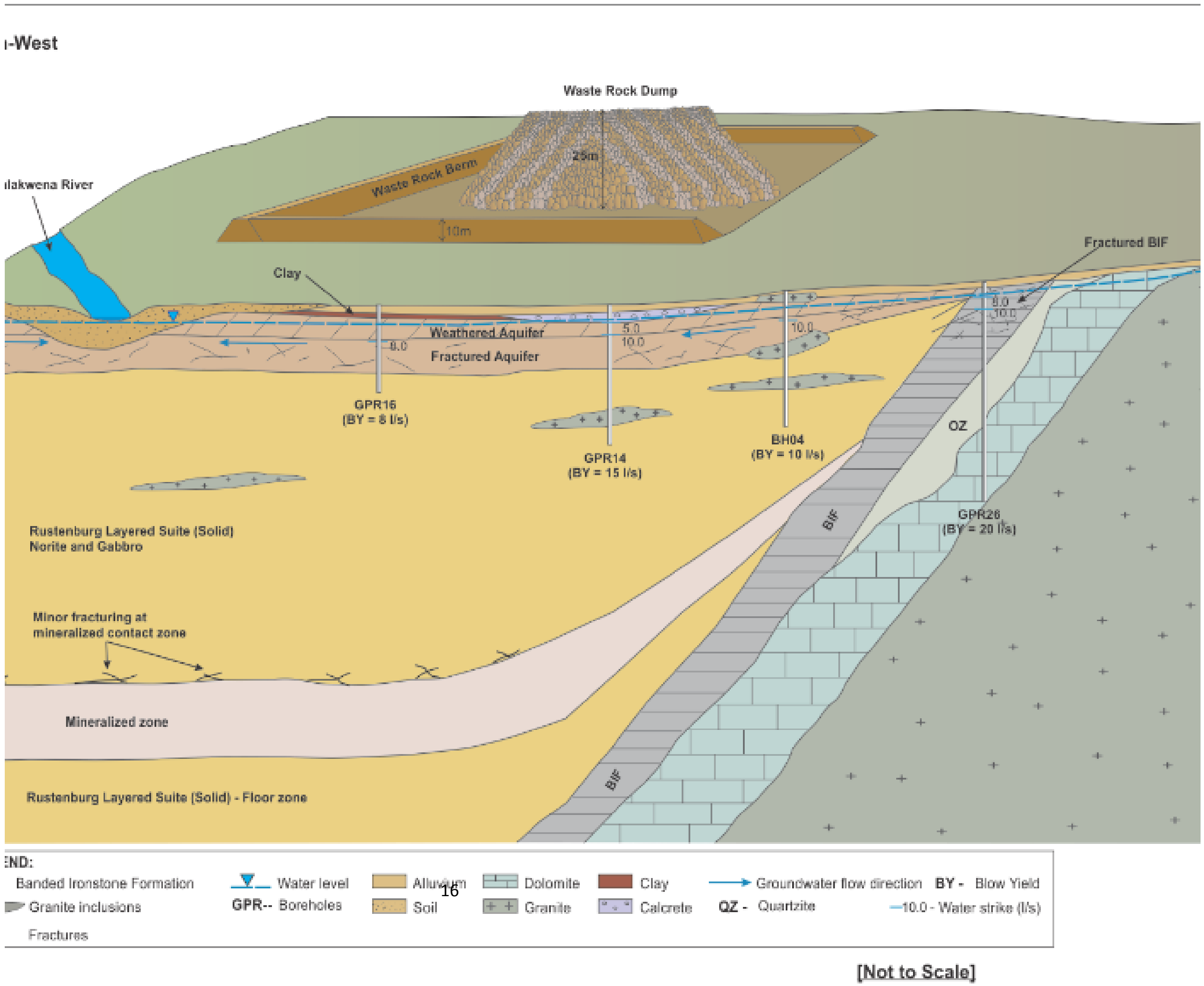

Geochemistry

- Sampling strategy/Material representatively
- Laboratory testwork
- Pit water quality predictions
- In-pit disposal of discard
- Co-disposal facilities
- Storage of tailing/water underground



Geochemistry - Engineering

- Groundwater Risk Assessment for liner relaxation GN. R. 632
- Engineering liner design



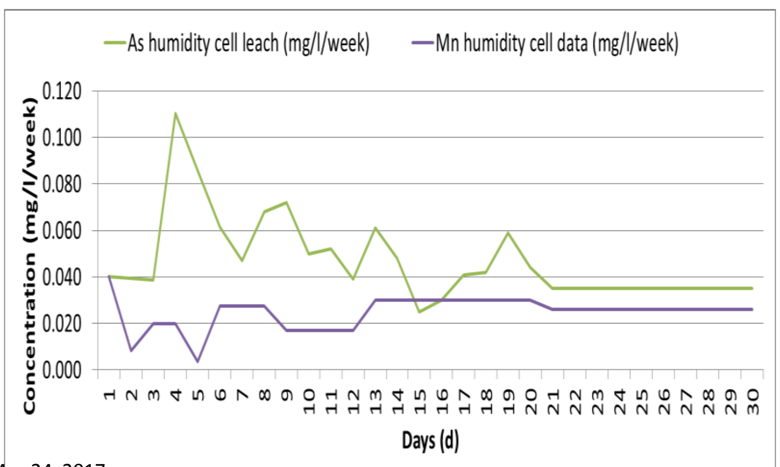
Geochemistry - Engineering

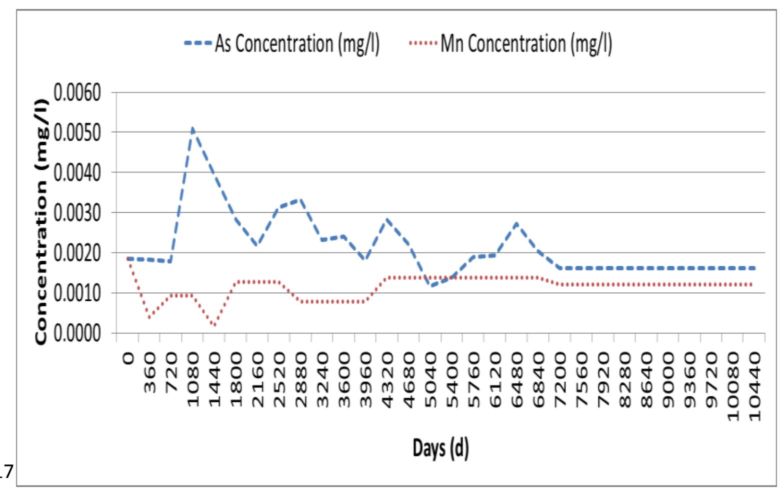
- Type 3 waste (GN R.635) lower risk as LCT ≤ LCT0
- Unsaturated flow modelling

Table 1: Seepage volume to groundwater as a function of compacted layer hydraulic conductivity

Scenario	K (cm/s)	K (m/day)	Seepage as % of MAP
1	1.0×10^{-6}	8.22×10^{-4}	16
2	1.0×10^{-7}	8.22×10^{-5}	4.5

- Source-term modelling of As & Mn concentrations
- Groundwater contaminant transport modelling to quantify impacts

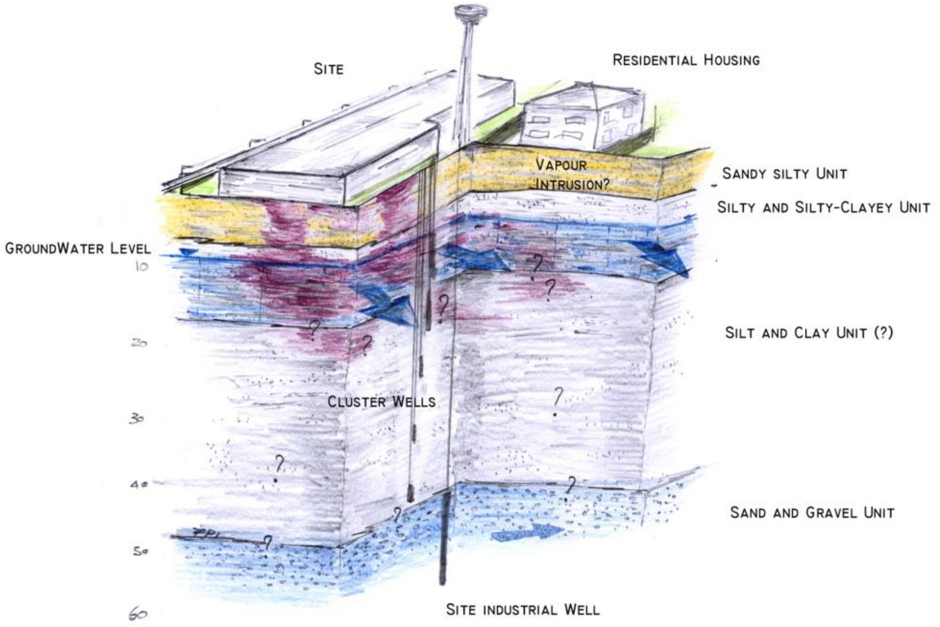




CONCEPTUAL SITE MODELS

Why do we need a Conceptual Site Model?

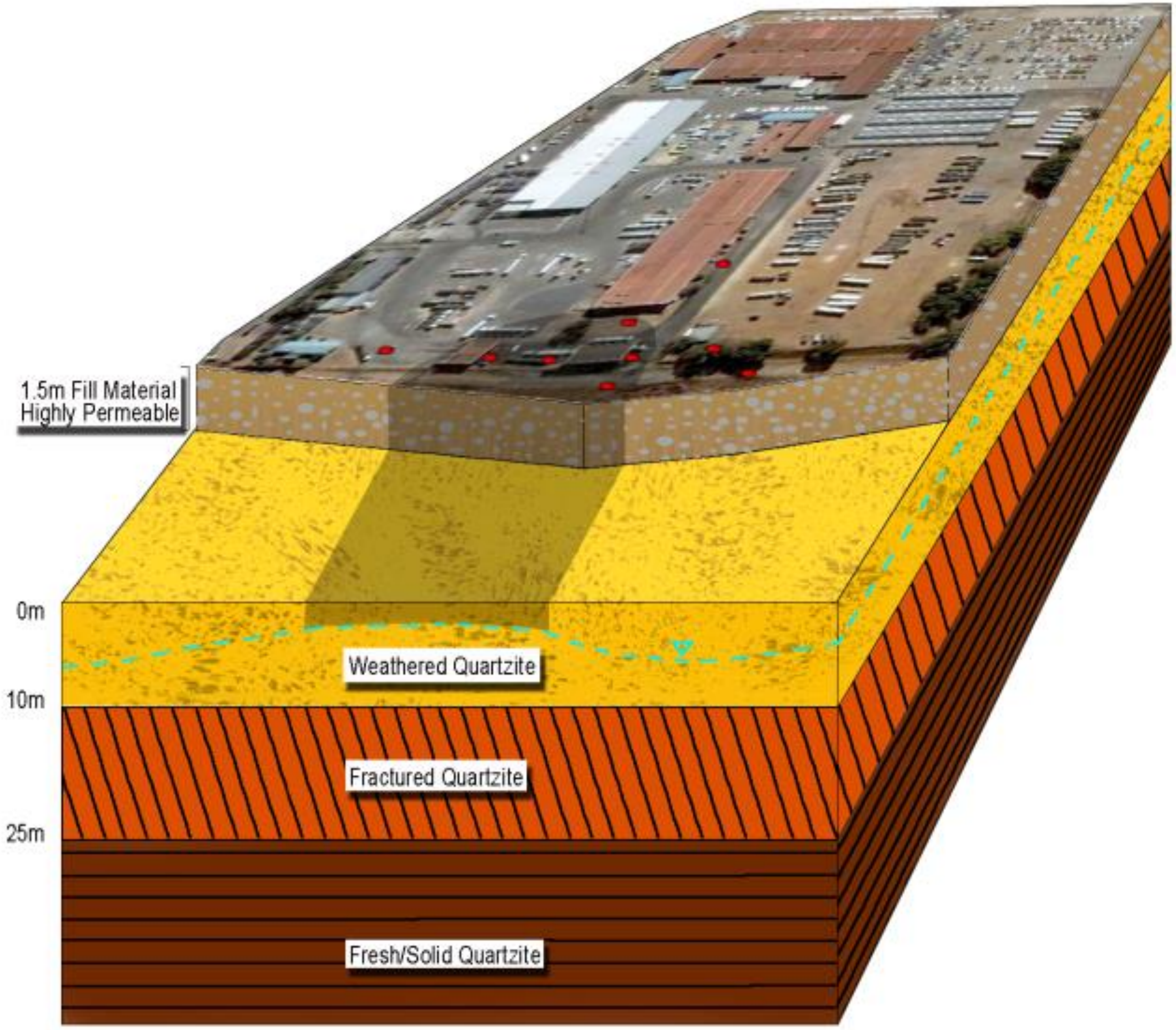
- Stimulate discussion amongst team members
- Simple and made to be understood
- Explain complex problems, dividing them into pieces
- Updated as new information becomes available
- Necessary base for any remedial design
- If NMA is an option a CSM is needed that stands the test of time



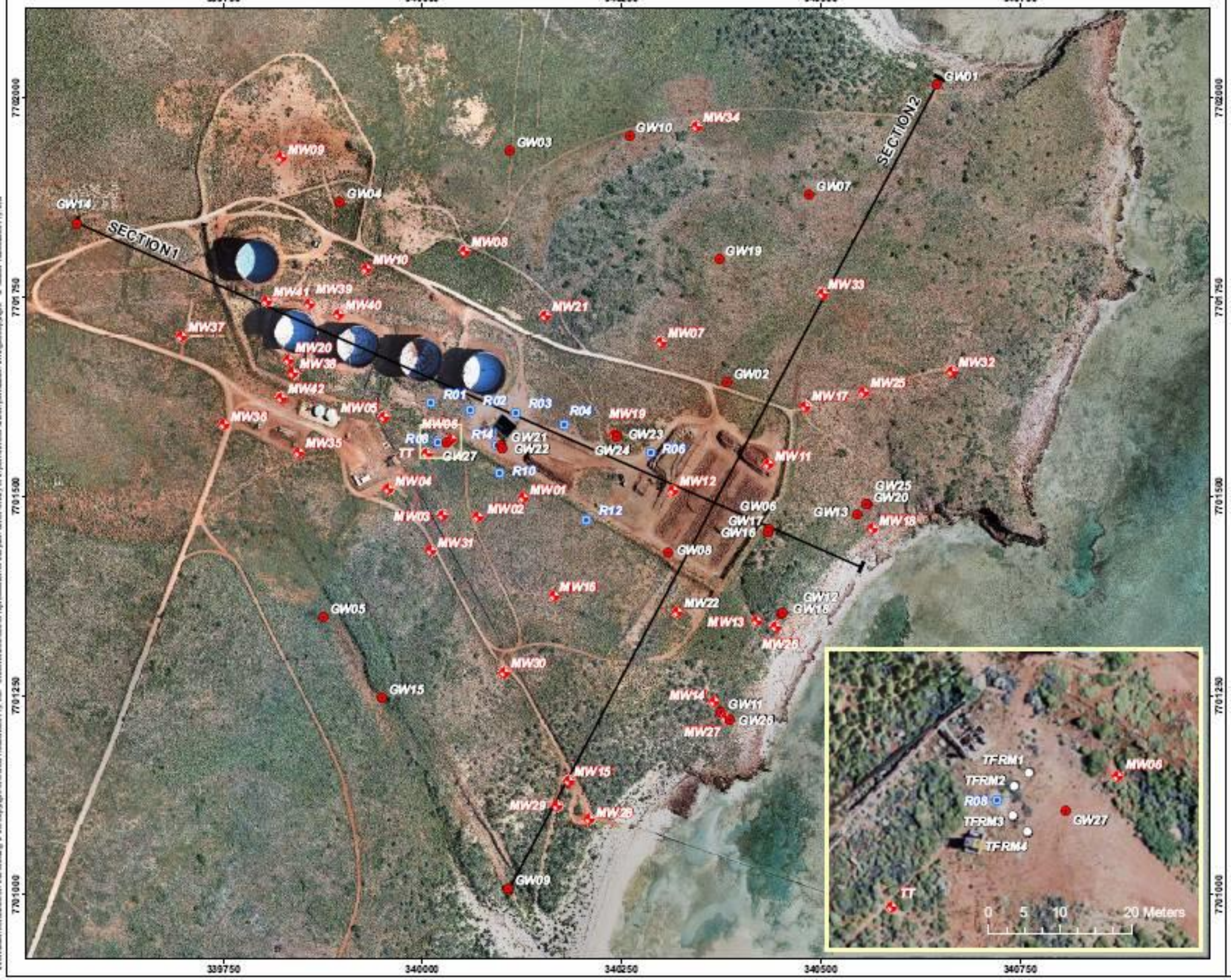
Key Elements of a Conceptual Site Model

- Site history
- Potential source zones and contaminants of concern
- Pathways for contaminant transport
- Receptors
- Geology and stratigraphy
- Aquifers and aquitards
- Groundwater levels and elevations
- Hydraulic gradients
- Physical and hydrogeological Boundaries
- Contaminated soil levels
- Plumes of contamination

SCM



1.5m Fill Material
Highly Permeable
0m
Weathered Quartzite
10m
Fractured Quartzite
25m
Fresh/Solid Quartzite


SECTION1
SECTION2
GW01
GW02
GW03
GW04
GW05
GW06
GW07
GW08
GW09
GW10
GW11
GW12
GW13
GW14
GW15
GW16
GW17
GW18
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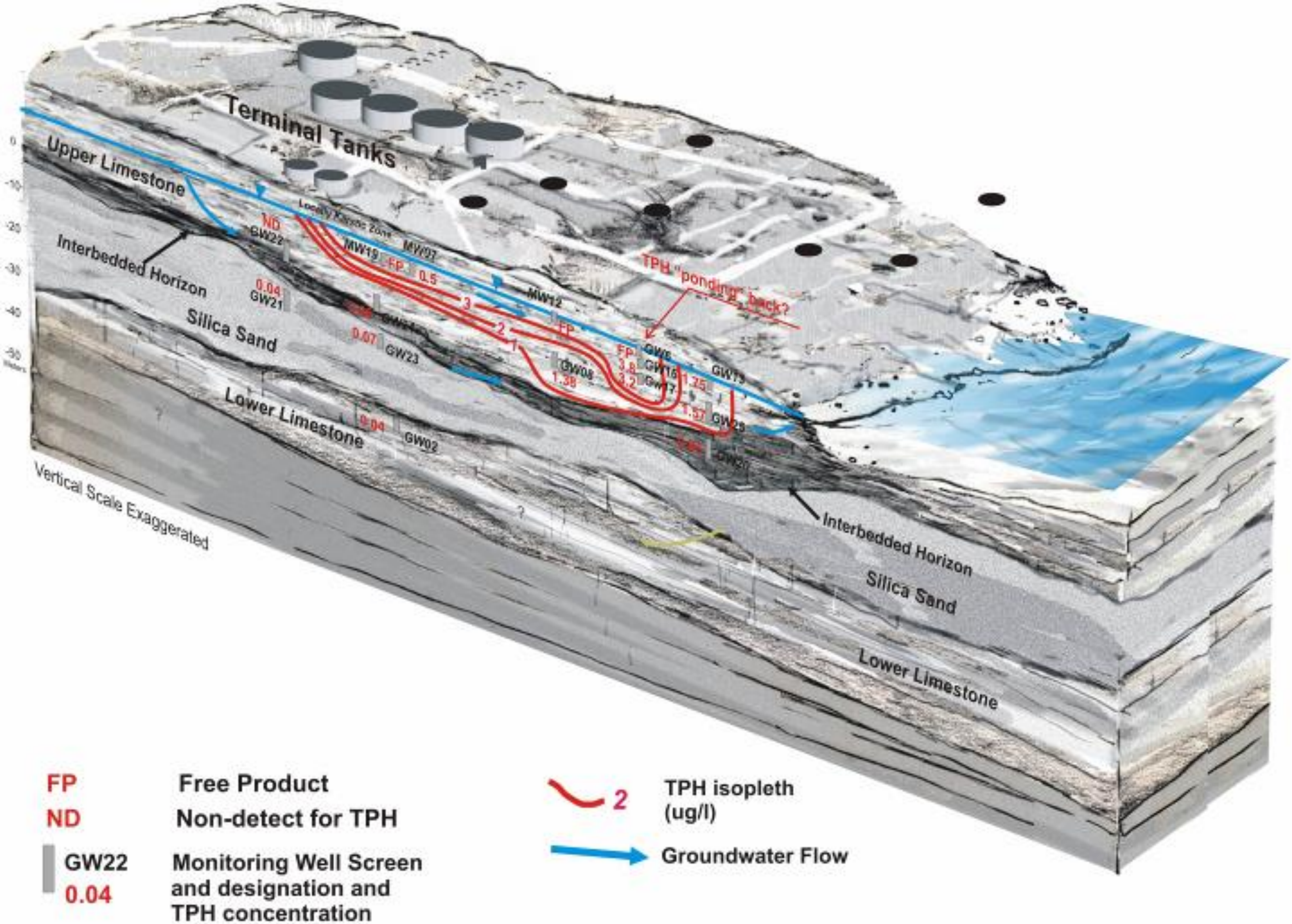
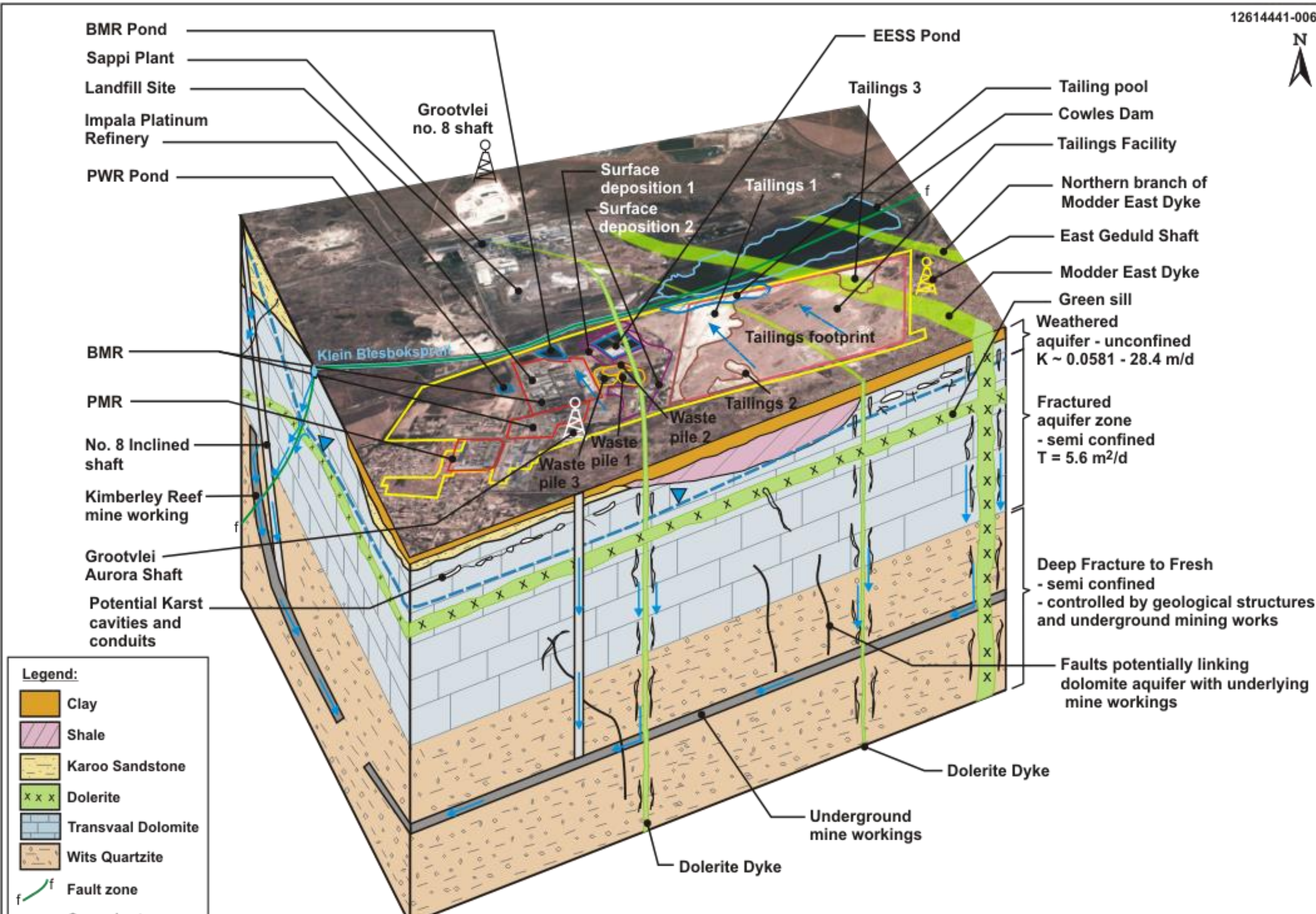
MW40
MW41
MW42
R01
R02
R03
R04
R06
R08
R10
R12
R14
TT
TFRM1
TFRM2
TFRM3
TFRM4
0 5 10 20 Meters
339750
340000
340250
340500
340750
7702000
7701750
7701500
7701250
7701000

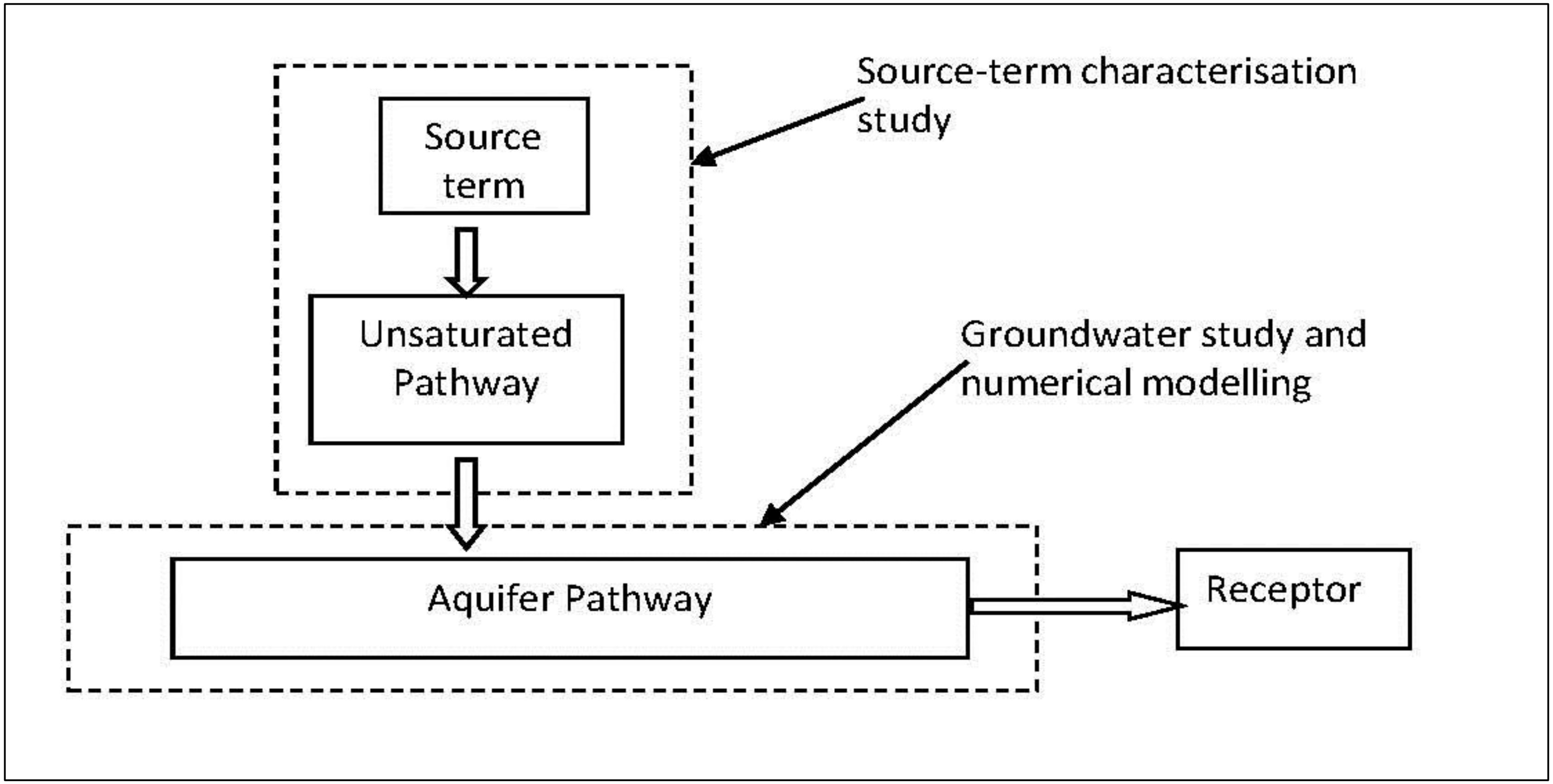

Terminal Tanks
Upper Limestone
Interbedded Horizon
Silica Sand
Lower Limestone
Vertical Scale Exaggerated
TPH "ponding" back?
ND
GW22
0.04
GW21
MW19
FP
0.5
MW07
MW12
0.07
GW23
GW08
1.38
FP
3.8
3.2
GW15
GW17
1.75
GW13
1.57
GW28
0.04
GW02
Interbedded Horizon
Silica Sand
Lower Limestone
FP Free Product
ND Non-detect for TPH
GW22 0.04 Monitoring Well Screen and designation and TPH concentration
2 TPH isopleth (ug/l)
Groundwater Flow



Groundwater Conceptual Model

NUMERICAL MODELLING

Source-term characterisation link to groundwater and receptor study



Numerical modelling: Source

	Input	Model Component	Output
Source	• Area and height estimates low, likely or high (m^2) for different areas • Recharge rate (m^3/year) 5th, 50th and 95th from output • Total (mg/kg) and soluble (mg/l) quality for F^- of soil and waste material.	**Probabilistic unsaturated flow and transport modelling – Consim and SVFlux:** • Area A • Plant • Waste sites	• Declining seepage quality • Volume (m^3) and mass (tons) estimates for each facility. • Loads (kg/year) to the environment from $time_0$ to $time_1$
	• Rainfall data for (mm) more than one weather stations	**Cross-correlated probabilistic modelling to generate rainfall sequences**	• Cross-correlated rainfall sequences (mm/day and mm/month) for 5th, 50th and 95th percentile years.

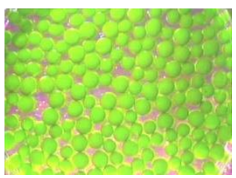
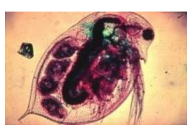
Numerical modelling: Pathway

	Input	Model Component	Output
Pathway	• Cross-correlated rainfall sequences (mm/day and mm/month) for 5th, 50th and 95th for typical years. • Groundwater concentrations for CoCs (mg/l).	**Recharge calculation** - Calculate site specific recharge.	• Recharge rate (m^3/year) for 5th, 50th and 95th percentile estimate.
	• Recharge rate (m^3/year) for 50th percentile. • Conceptual understanding of lithology. • Hydraulic properties of geological lithology layers (m/s). • Declining seepage loads of CoC for each facility (kg/year) from $time_0$ to $time_1$. • Groundwater borehole water levels (masl). • Groundwater quality concentrations (mg/l).	**Groundwater flow and transport – FEFLOW**	• Loads reporting to the receptor for CoC (mg/l) for likely case. • Predicted borehole concentrations (mg/l).
	• Sediment quality in storm water system (mg/kg) • Water quality in storm water system (mg/l). • Receptor sediment quality (mg/kg). • Receptor dimensions height, width and length (m).	**Surface water quality evaluation**	• Contribution to water quality at receptor for CoC (mg/l). • Potential contribution to sediment quality (mg/kg).

Numerical modelling: Receptor

Receptor	• Groundwater loads reporting to the receptor over time • Contribution of surface water to water quality at receptor for CoC. • Potential contribution of sediment loss from the site to sediment quality in receptor (mg/kg) • Aquatic toxicity tests results. • Sediment toxicity screening tests. • Sediment quality (mg/kg). • Receptor water quality (mg/l).	**Ecological impact characterisation and prediction in the receptor.**	• Ecological characterization. • Potential future ecological hazard rating.

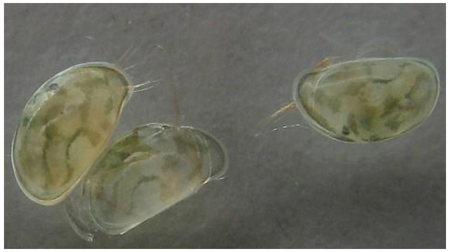
Aquatic bioassays (battery of tests)

Toxicity test		**Effect period**	**Exposure period**	**Endpoint**	**Detection limit (%)**	**Standard**
Vibrio fischeri luminescence bacterial test		Acute/ Short term	30 minutes	% growth inhibition or stimulation, EC20 and EC50 value	20	EN ISO
Selenastrum capricornutum (algal) growth inhibition test		Acute/ Short term	72 h	% growth inhibition or stimulation, EC20 and EC50 value	20	OECD
Daphnia pulex (waterflea) lethality test		Acute/ Short-term	24 and 48 h	% lethality, LC10 and LC50 value	10	US EPA
Poecilia reticulata (fish) lethality test		Acute/ Short-term	96 h	% lethality, LC10 and LC50 value	10	USEPA

Sediment Bioassays

- *Heterocypris incongruens*: Ostracod crustaceans are ecologically important members of the meiofauna of freshwater sediments. Has a cosmopolitan distribution and can be found in diverse freshwater benthic habitats in all continents.
- *Chironomus caffrarius*: Indigenous species found through out South Africa. Tolerant of contaminated sediments and low dissolved oxygen environments. Utilises a stable laboratory monoculture.

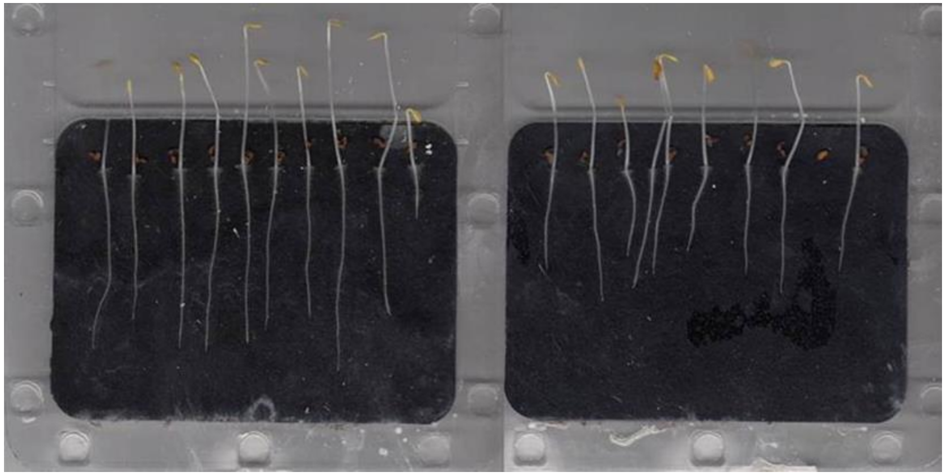
- Direct contact with sediment: Burrowing and ingestion = Bioavailable fraction assessment



Terrestrial Bioassays

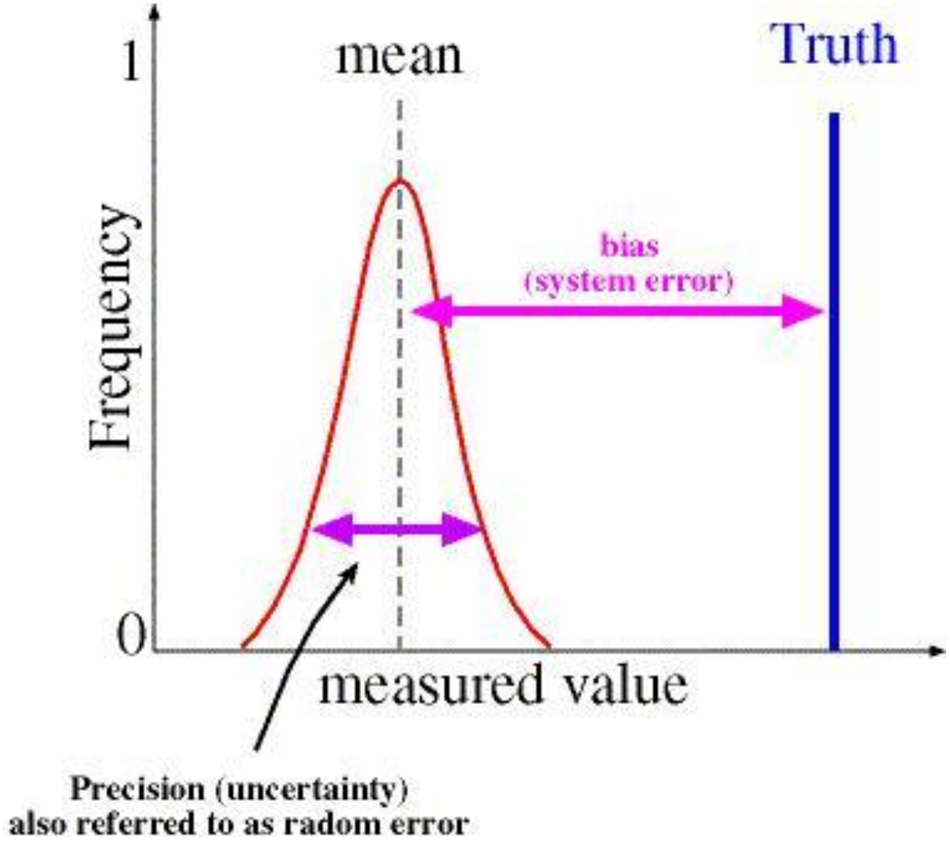
Three commercially important test species have been selected for the bioassay due to their rapid germination and growth of roots and shoots, which allow observations and scoring after only 3 days.

- *Lepidium sativum* (Water cress)
- *Sinapis alba* (White Mustard)
- *Sorghum saccharatum* (Sorghum)
- Indication of soil, contaminated waste etc effect on seed germination and growth



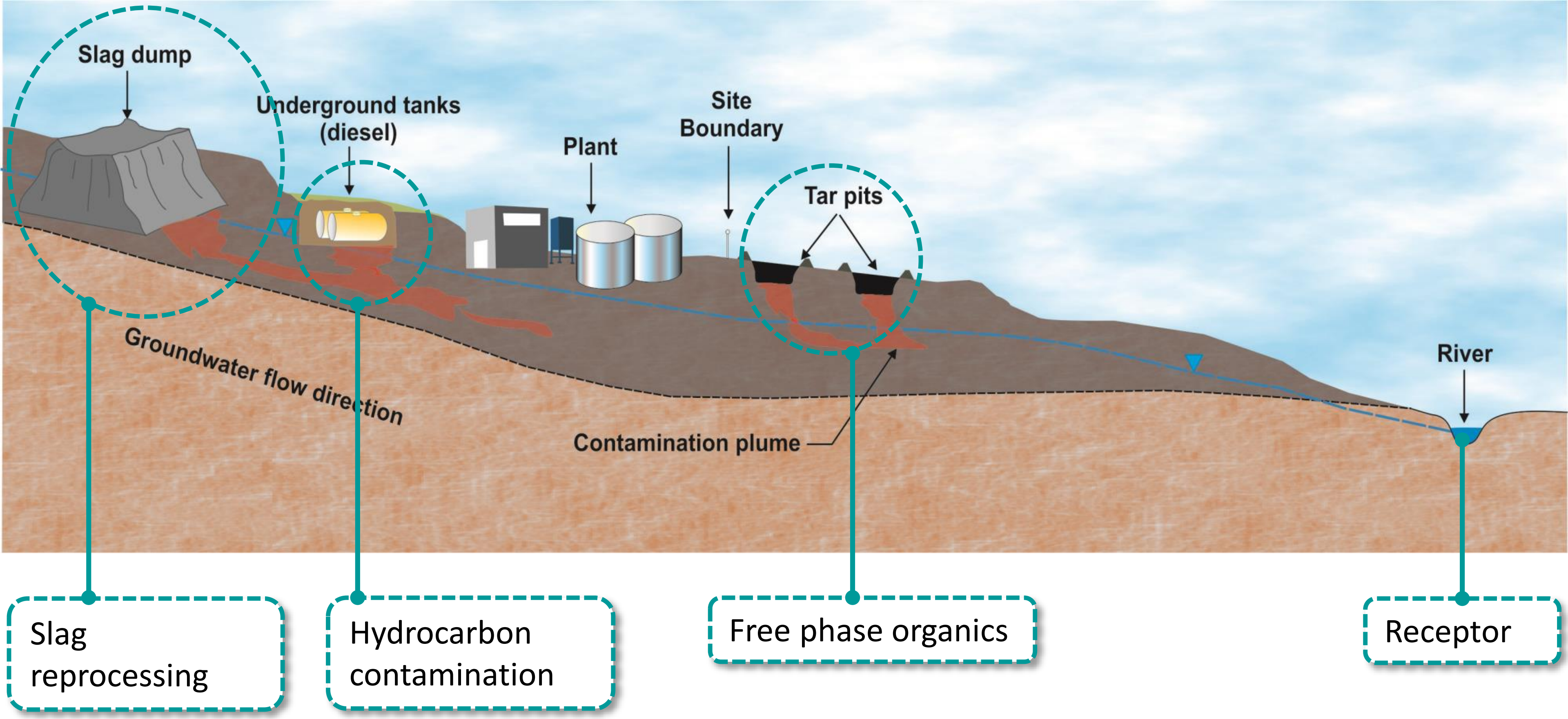
OUTCOMES AND MANAGING UNCERTAINTY

Uncertainty

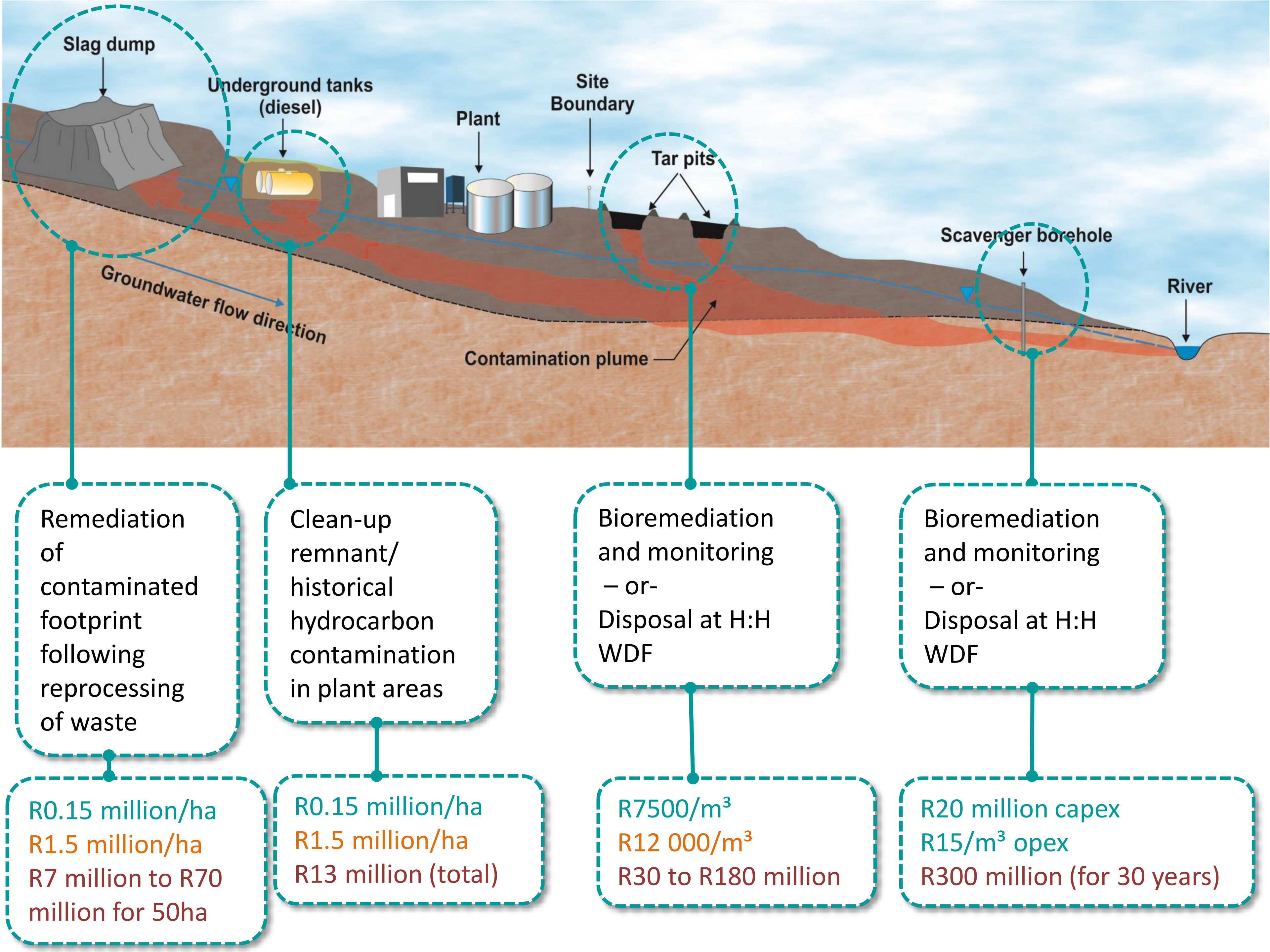


Reality – Complex Problems

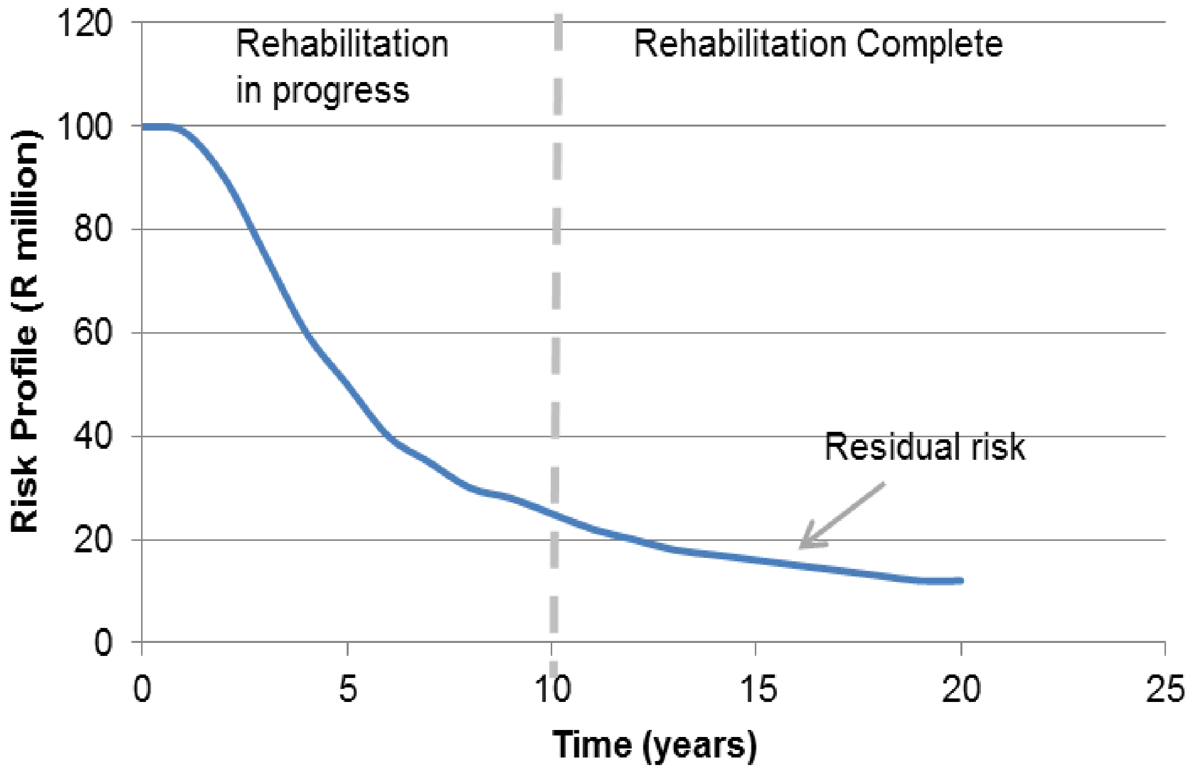
Surviving progress – Directed by Harold Crooks and Mathiue Roy, 2011. Canada



Slag dump
Underground tanks (diesel)
Plant
Site Boundary
Tar pits
River
Groundwater flow direction
Contamination plume
Slag reprocessing
Hydrocarbon contamination
Free phase organics
Receptor


Slag dump
Underground tanks (diesel)
Plant
Site Boundary
Tar pits
Scavenger borehole
River
Groundwater flow direction
Contamination plume
Remediation of contaminated footprint following reprocessing of waste
Clean-up remnant/ historical hydrocarbon contamination in plant areas
Bioremediation and monitoring – or- Disposal at H:H WDF
Bioremediation and monitoring – or- Disposal at H:H WDF
R0.15 million/ha
R1.5 million/ha
R7 million to R70 million for 50ha
R0.15 million/ha
R1.5 million/ha
R13 million (total)
R7500/m³
R12 000/m³
R30 to R180 million
R20 million capex
R15/m³ opex
R300 million (for 30 years)

Residual risk



THANK YOU

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