PARSONS

CHALLENGES IN DEVELOPMENT AND APPLICATION OF REMEDIAL GUIDELINES

Yong Li, P. Geo
Anne Way, P. Chem.
Parsons, Calgary Alberta, Canada
October 16, 2024

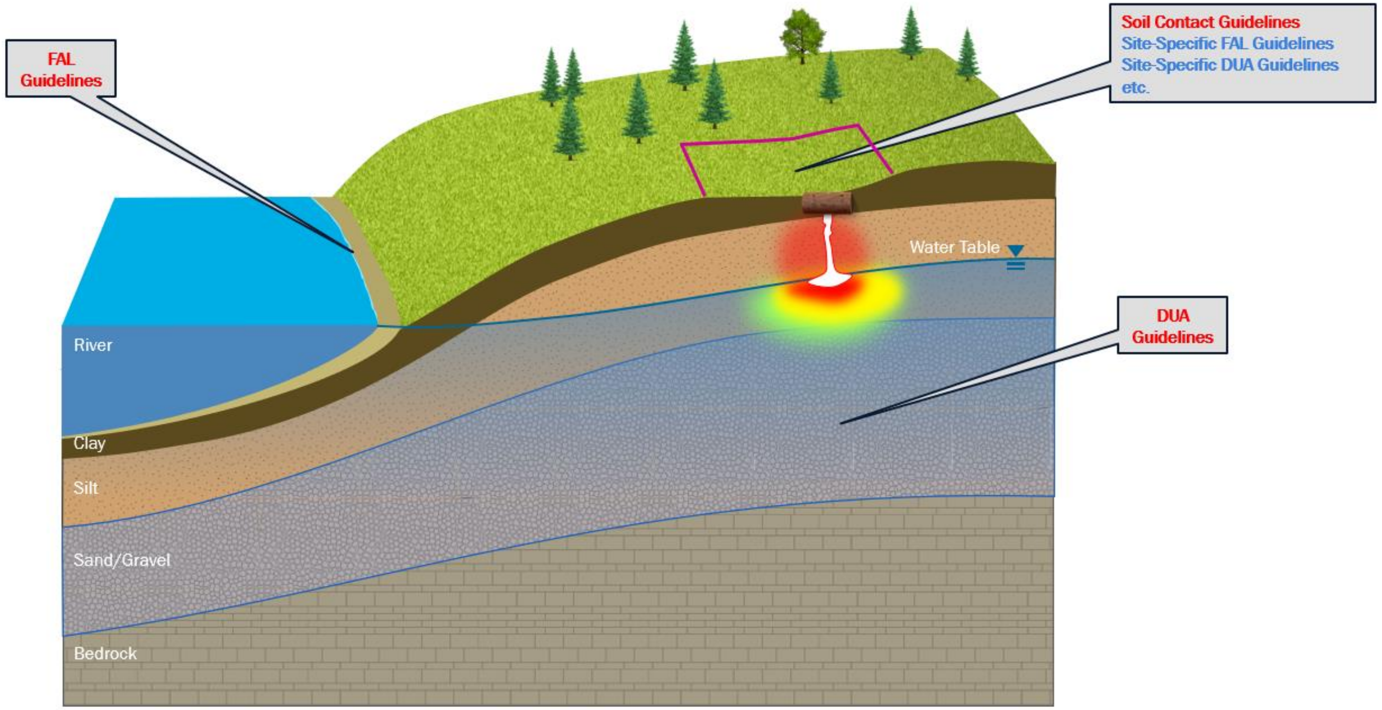
OUTLINE

1. Review of guideline concepts
2. Challenges in guideline development and application
3. Statistical review/application of guidelines
4. Do we really need remedial guidelines to plan remedial actions?

CONCEPTS OF GUIDELINES

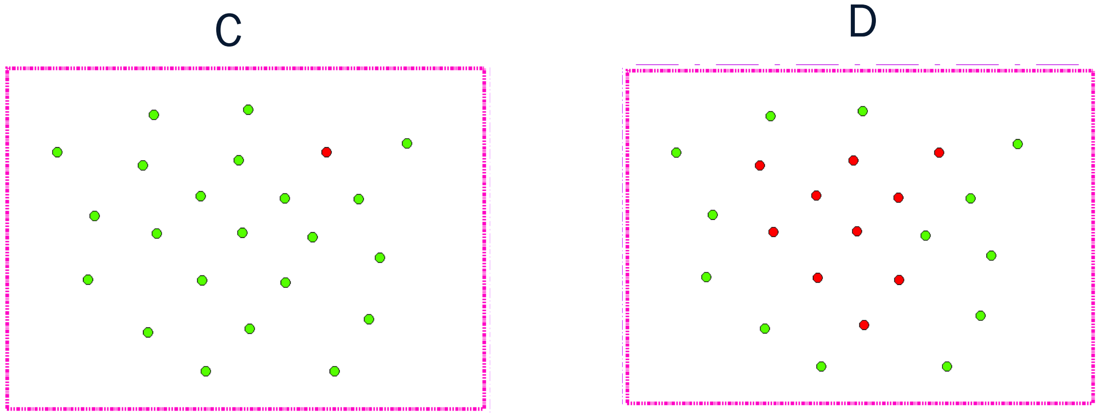
Guidelines for Contaminated Sites

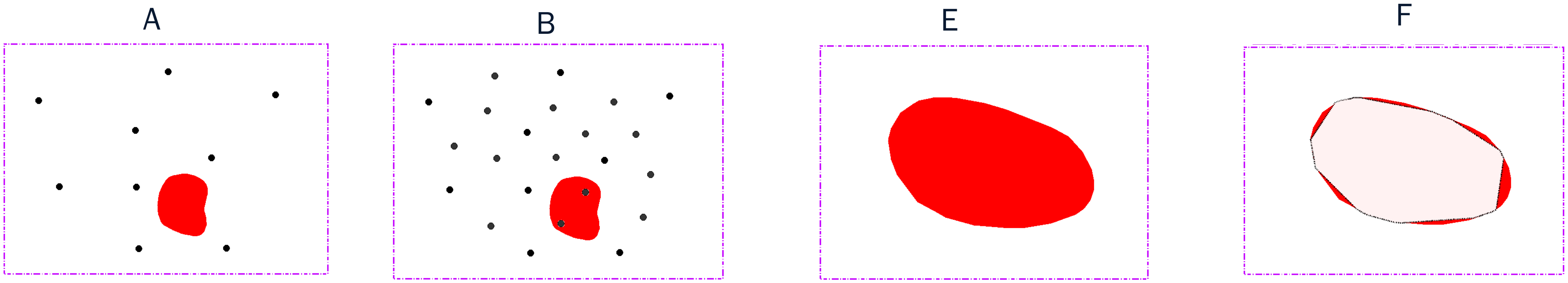
- Endpoint Guidelines
  - Guidelines at receptors (DUA, FAL, Indoor inhalation, human or eco soil contact, etc.)
  - Commonly calculated using toxicological information and estimates of chemical doses to potential receptors (for example, AEPA 2024 guidelines)
  - Could be modified through SSRA
- Remedial Guidelines
  - Remedial objectives at site to direct risk assessment and remediation
  - Some are same as endpoint guidelines (such as human or eco soil contact.)
  - Some can be same (Tier 1 guidelines) or different (Tier 2 or site-specific guidelines for DUA, FAL, inhalation pathways)



CHALLENGES FOR GUIDELINE APPLICATIONS

- Many challenges are related to how to assess risks varied with contaminant mass volume, frequency of occurrence and distribution
  - Some small footprints of impacts are always missed (A and B)
  - Soil lead exceeding 140 mg/kg in 1 out of 100 samples versus 50 out of 100 (C and D)
  - Isolated exceedances at excavation wall and base versus pre-excavation exceeded volume (F and E)





STATISTICAL VIEW OF GUIDELINE APPLICATIONS

Consider the contaminant concentration distribution and associated volume (Gemperline, 2019)

- Concept of the smallest volume of contaminated soil that could both reasonably exist and also result in an unacceptable risk the human or environmental health
- Use a probability density function and area-fraction function to define the **“smallest consequential quantity of contamination”**

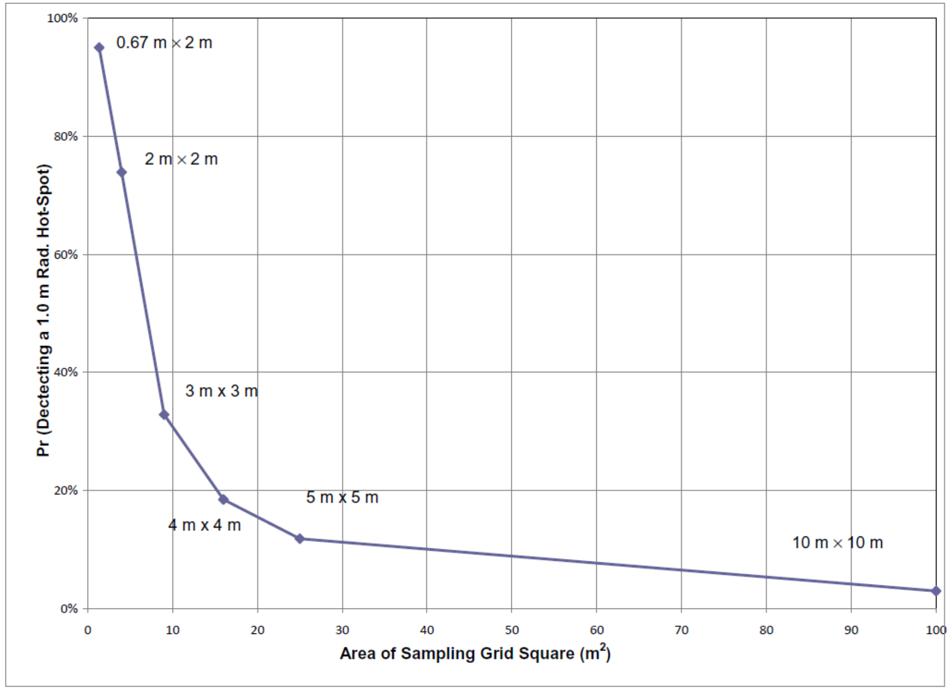
$$f(C) = \frac{2\left(1 - \frac{c}{C_{max}}\right)}{C_{max}} \qquad \frac{A_{SCF}}{A_C} = \frac{3 \times C_{index}}{C_{max}}$$

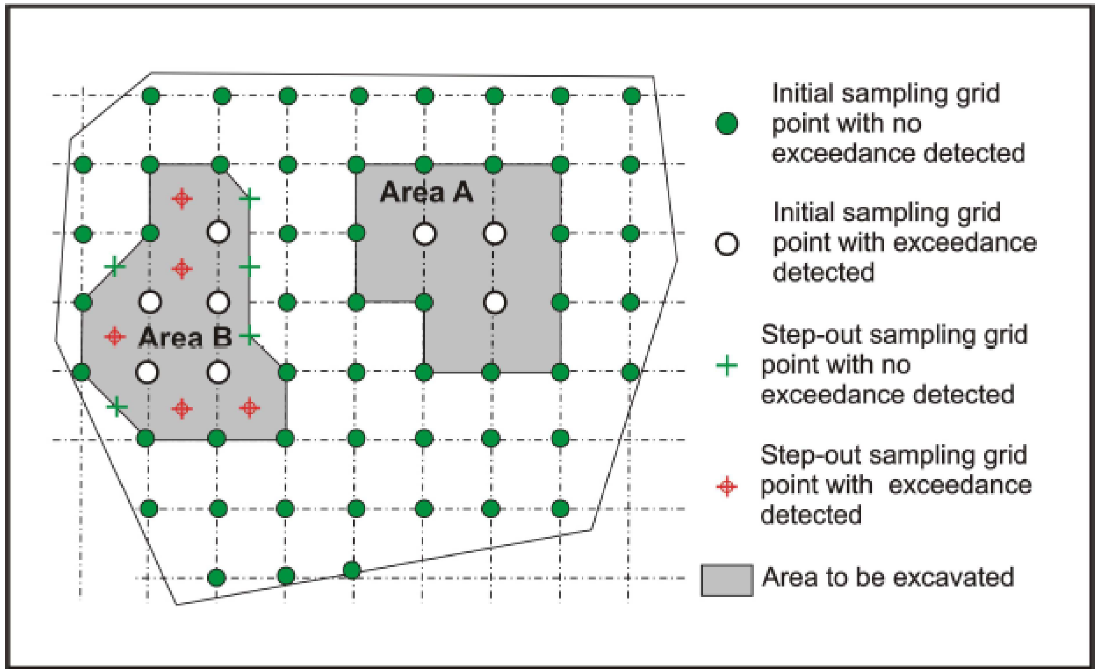
Gemperline, M.C. 2019..Responding to the Smallest Consequential Quantity of Soil Contamination. *J. Hazard. Toxic Radioact. Waste, 23(2).*

STATISTICAL VIEW OF GUIDELINE APPLICATIONS

Use probability-based sampling plans

- Probability-based sampling plans yield an acceptable chance of responding to the smallest consequential quantity of contamination
- Applied at a site in Calgary. Used VSP to delineate lead hotspots ≥ 1m radius at a high level of confidence (90%)
  - Used prior knowledge of the frequency distribution of lead soil impacts to further refine estimate of detectable **hot spot** size



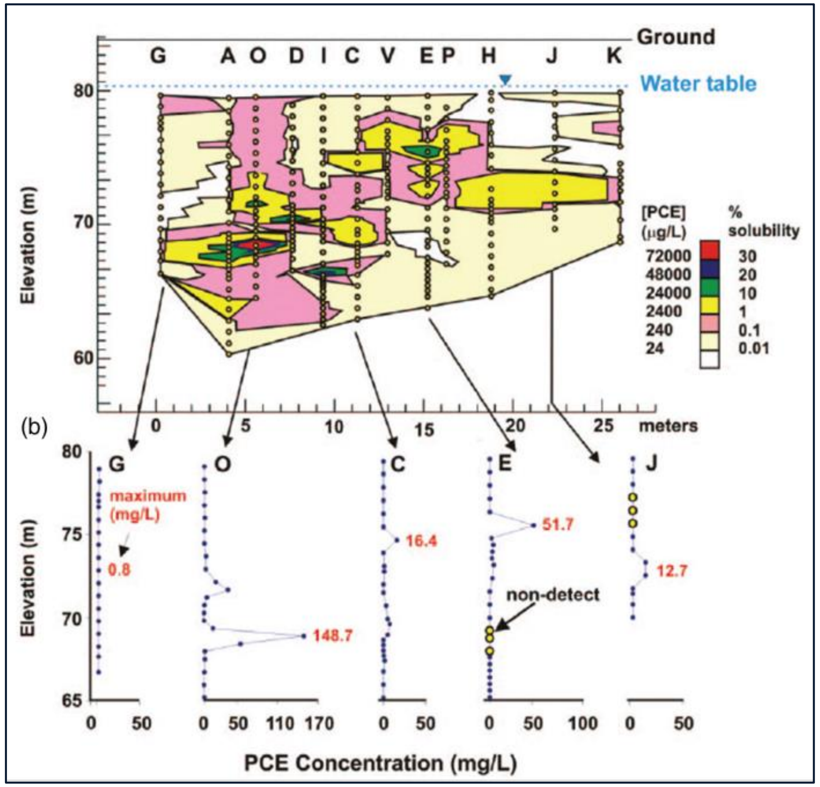


Vickers, A.G.L., Kindzierski, W.B., Wong, T.T., Carss, J.G., Agar, J.G. 2008. Implication of data uncertainty in geo-environmental site assessment. In *Proceedings of the 61st Canadian Geotechnical Conference and 9th Joint CGS/IAH-CNC Groundwater Conference*. Edmonton, pp. 871-878.

STATISTICAL VIEW OF GUIDELINE APPLICATIONS

Consider contaminant mass and flux for groundwater (Einarson, 2017)

- Advocates for use of a spatially-averaged, flow-weighted concentration regulatory limit for groundwater
- Gives more significance to where the contaminant mass is distributed, and the mass that resides in higher flow zones
- Involves modification of the mass discharge equation
- Contaminant mass discharge and flow-rate must be known or can be estimated



Einarson, M. 2017. Spatially Averaged, Flow-Weighted Concentrations – A More Relevant Regulatory Metric for Groundwater Cleanup. Groundwater Monitoring & Remediation 37, no. 4/ Fall 2017.

STATISTICAL VIEW OF GUIDELINE APPLICATIONS

Other statistical views of guidelines

- Regulator pre-defined sampling frequency (e.g., 1 sample per 100 m^3, 10 m or 5 m linear spacing, implicitly define accepted missing quantity of contamination)
- 95^{th} percentile of background values (97.5^{th} percentile, calculated based normal or lognormal distribution in different jurisdictions, accepting some impacts above background)
- Determine COPCs based on exceedance % (e.g., 95 %) in defined areas (accepted by regulators historically at some sites)

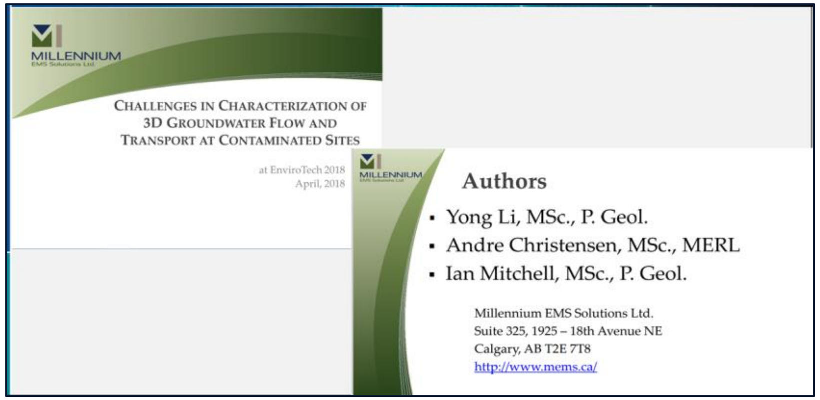
Challenges

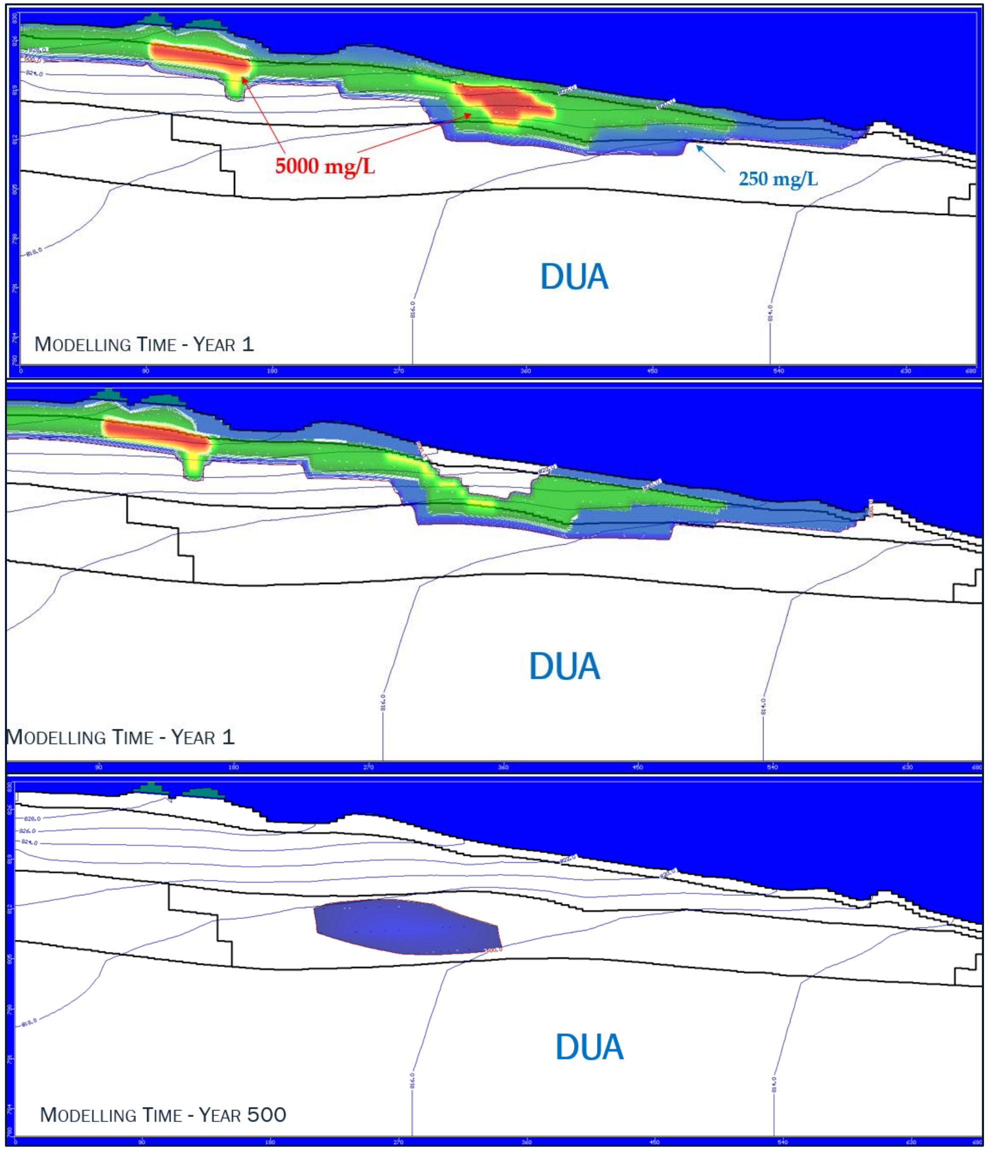
- Lack of consistent and complete guidance (e.g., confirmation sampling vs delineation sampling)
- Lack of technical rationales behind the proposed numbers
- Generally, lack of documented regulatory guidance for statistical application of guidelines (e.g., 95^{th} percentile rule not documented in SCARG, definition of hotspot, when and how to use 95% rule for COPCs)

GUIDELINE FOR DIFFERENT MASS DISTRIBUTIONS

Do we need to remove the contaminant mass based on the same concentration cut-off value to protect a receptor?

- The answer is NO
- A 2018 EnviroTech presentation showed modelling results at a site
  - Groundwater sulphate concentrations showed two elevated clusters (> 5000 mg/L)
  - Only one cluster needs to be removed to protect both DUA and FAL receptors



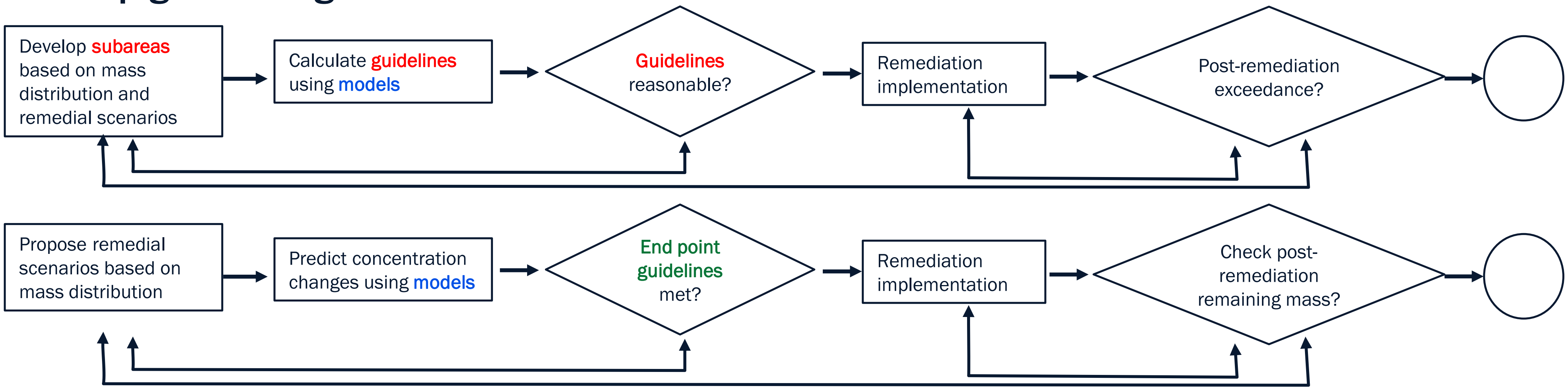


GUIDELINE FOR DIFFERENT MASS DISTRIBUTIONS

Tier 2 Site-specific guidelines can change with mass distributions

- Tier 2 FAL guidelines change with distances to the receptor
- Latest SST allows up to 5 subareas
  - Different guidelines for different subareas
  - Guidelines can change if contaminant mass is reduced (by assumed excavation)
  - However, there are some limitations using 5 subareas to represent mass distributions at a complex site
  - It frequently becomes a time-consuming process to adjust, test and review subarea arrangement for different remedial scenarios and post-remediation confirmation

Can we skip guideline generation?

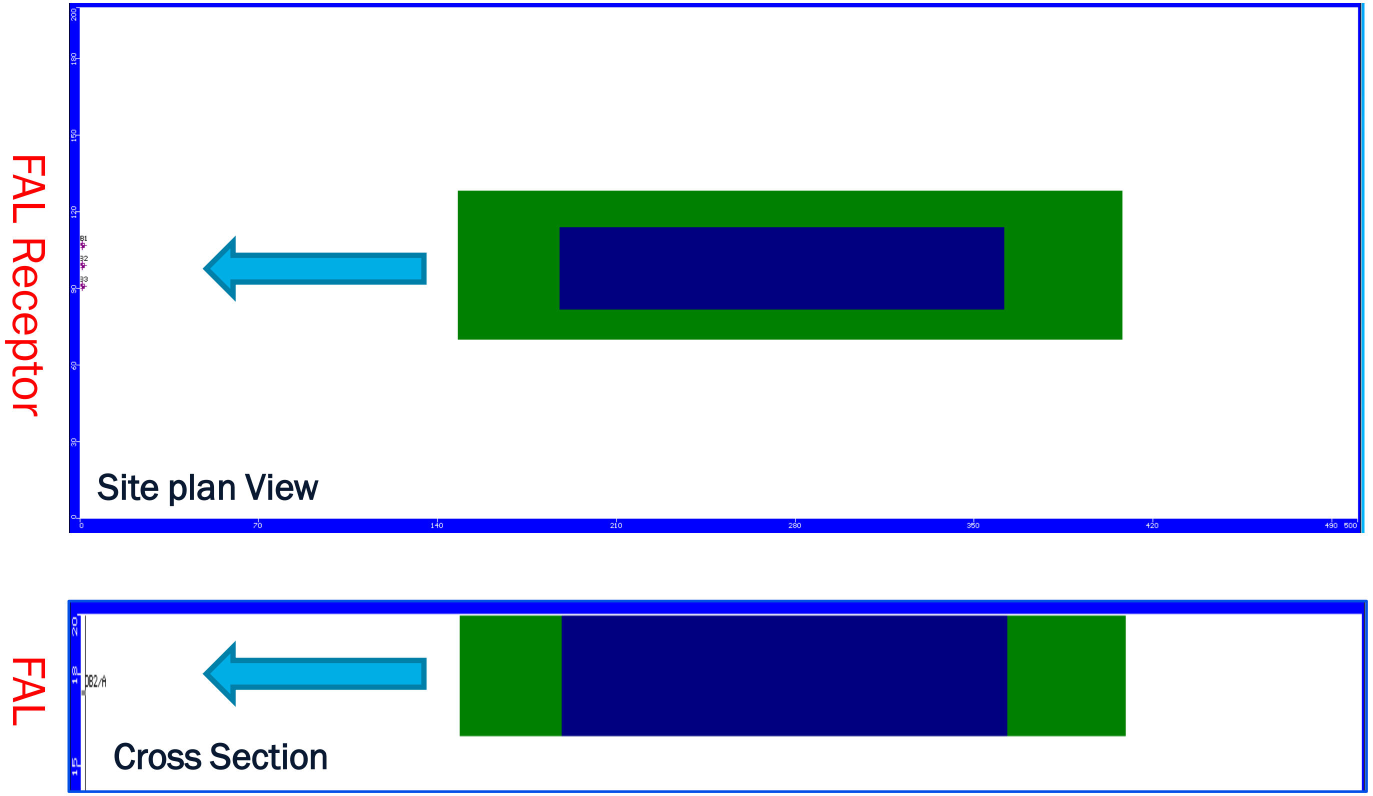


A MASS REMOVAL EXPERIMENT

A numerical experiment for mass removal to protect FAL receptor

- Model setup (pre-remediation)
    - Groundwater impacted by chloride at concentrations 500 – 1000 mg/L, exceeding FAL guideline (120 mg/L)
    - Plume is 250 m long, 50 wide and 4 m deep
    - Groundwater flows to the FAL receptor 150 m away from edge of plume
    - A rainfall infiltration rate of 6 mm/year is assumed
    - Three observation wells set to monitor concentration changes at FAL receptor

Initial Concentration



Zone		Conc001 [mg/L]
1	(white)	0
2	(blue)	1000
3	(green)	500

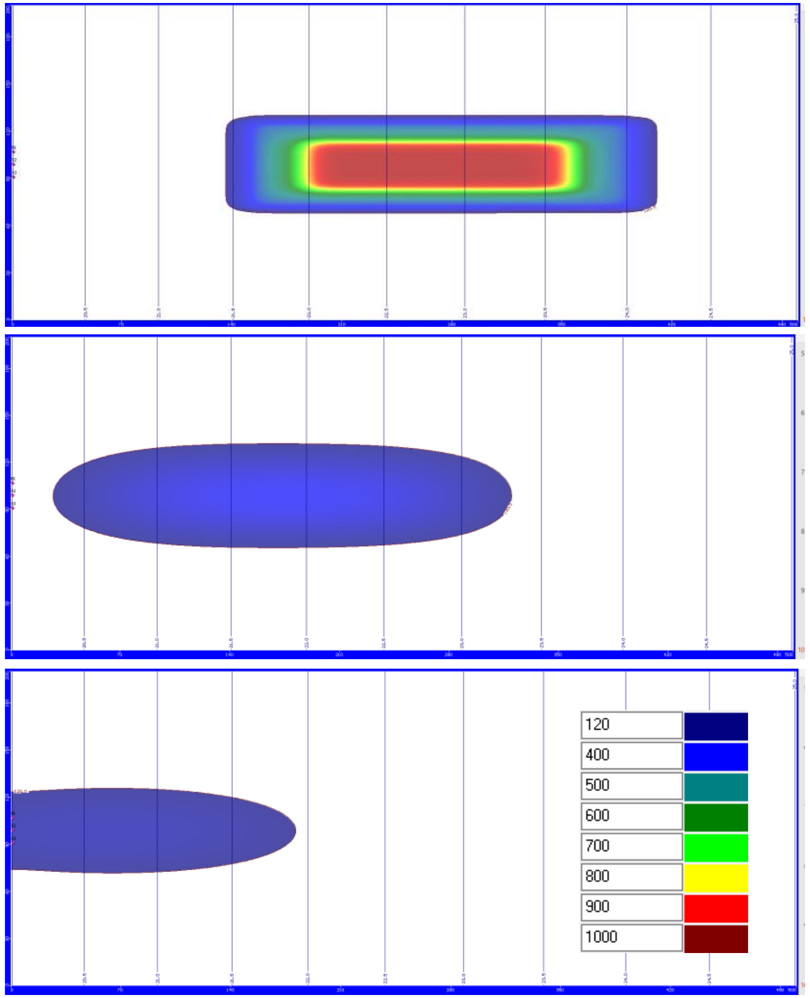
A MASS REMOVAL EXPERIMENT

- Concentrations will exceed FAL guideline at receptor

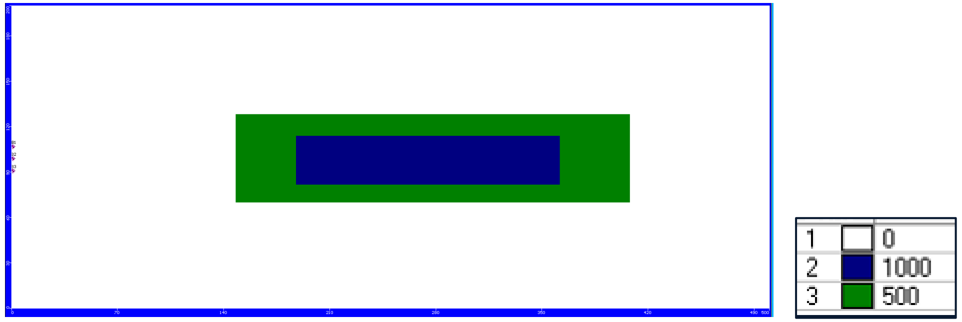
Year 1

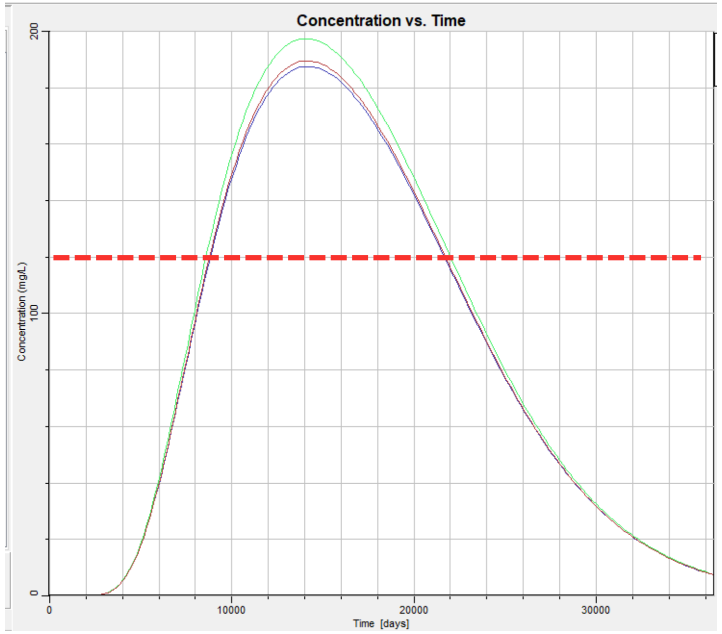
Year 20

Year 40



Pre-remediation

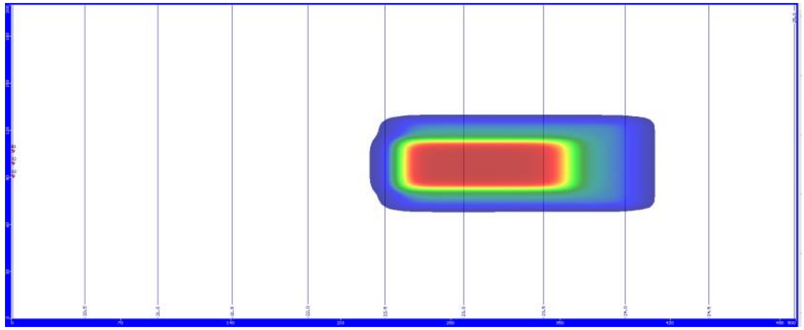




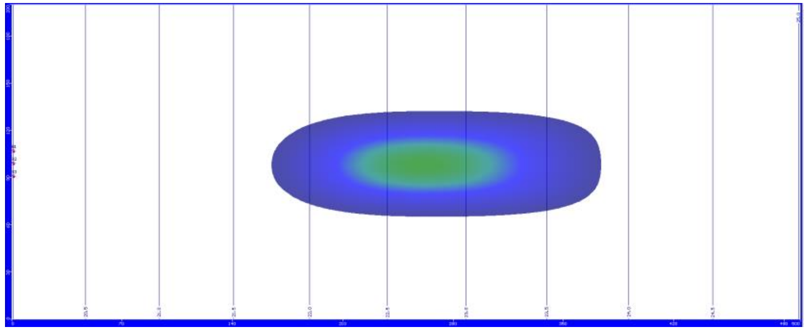
A MASS REMOVAL EXPERIMENT

- Remove some mass at near receptor side to meet the endpoint guideline

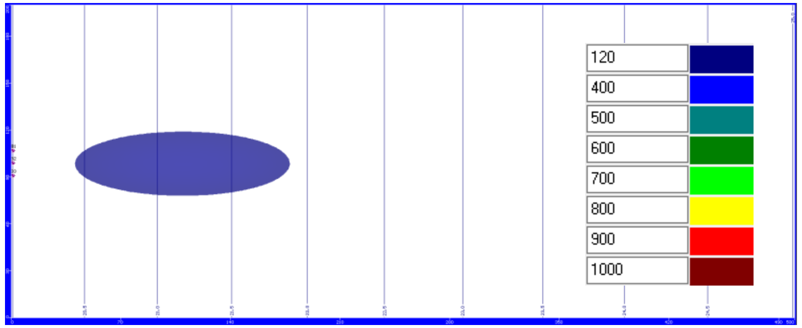
Year 1



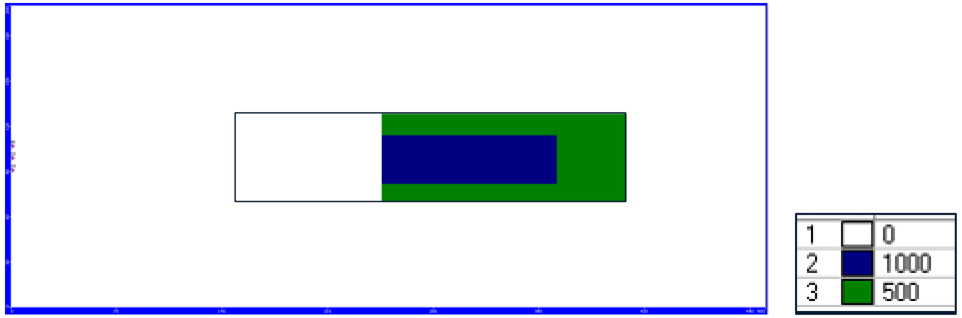
Year 20

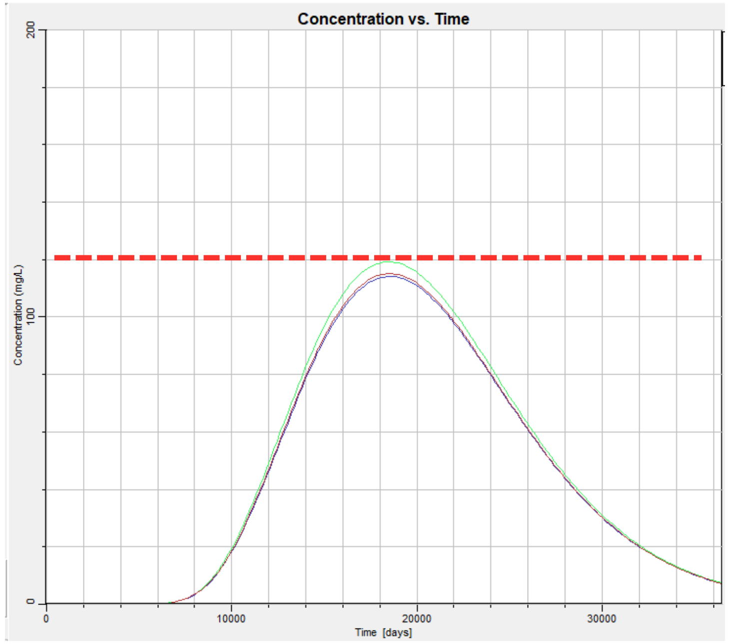


Year 40



Mass Removal Scenario 1

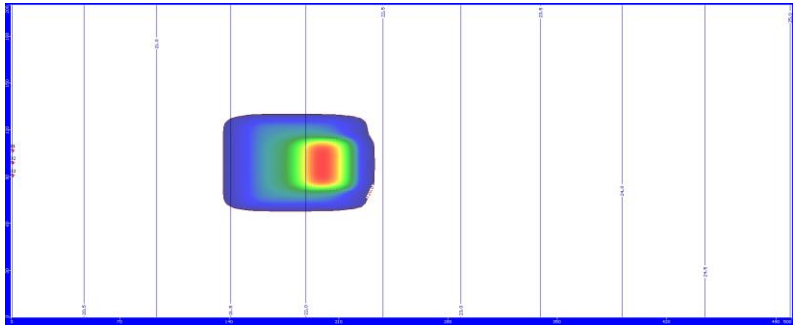




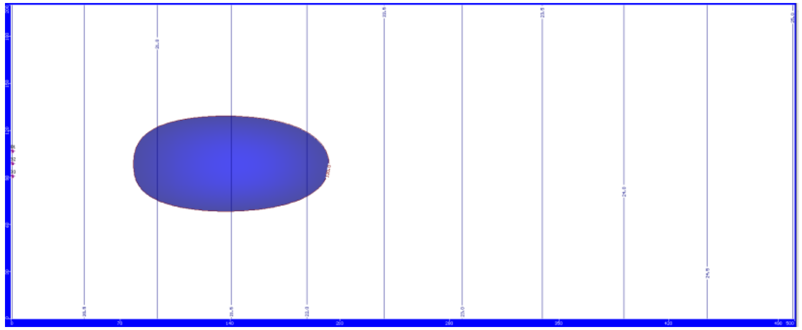
A MASS REMOVAL EXPERIMENT

- Remove some mass at far end (double the volume)

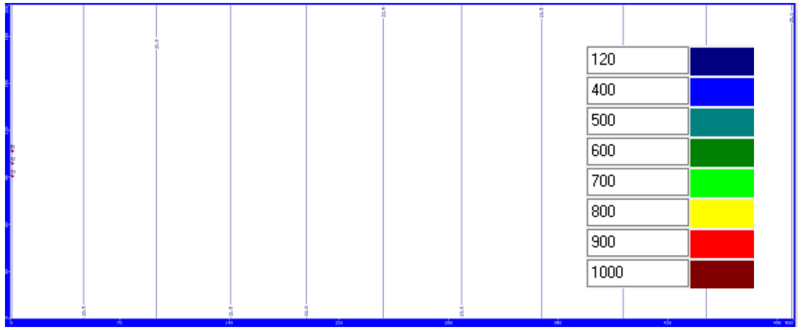
Year 1



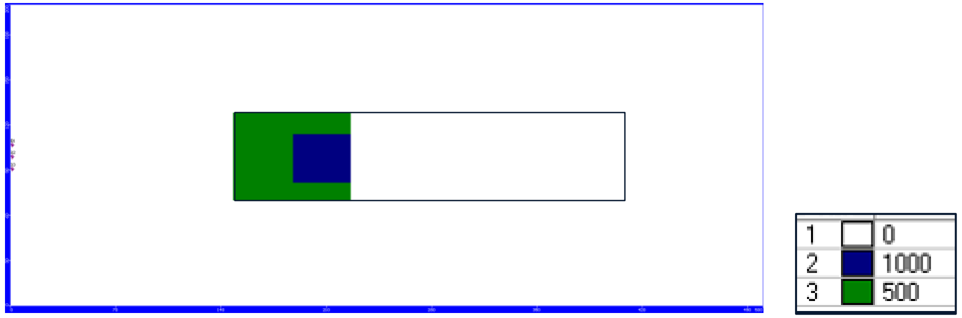
Year 20

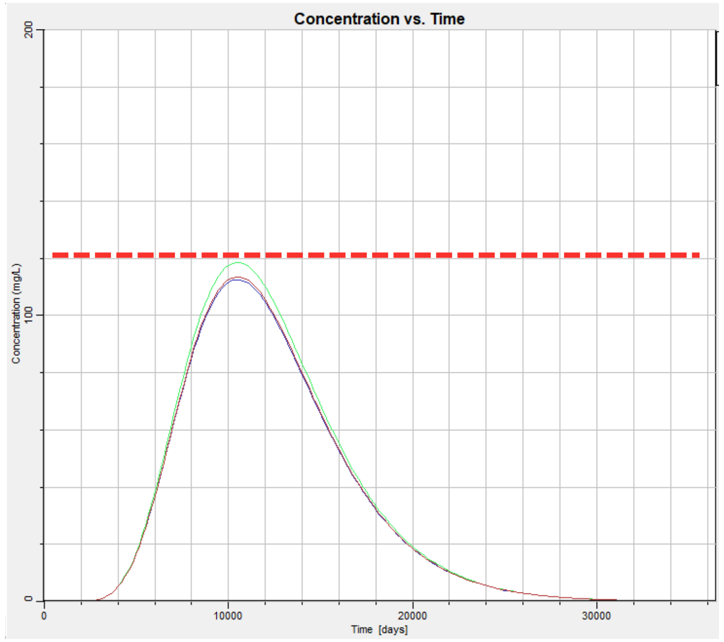


Year 40



Mass Removal Scenario 2

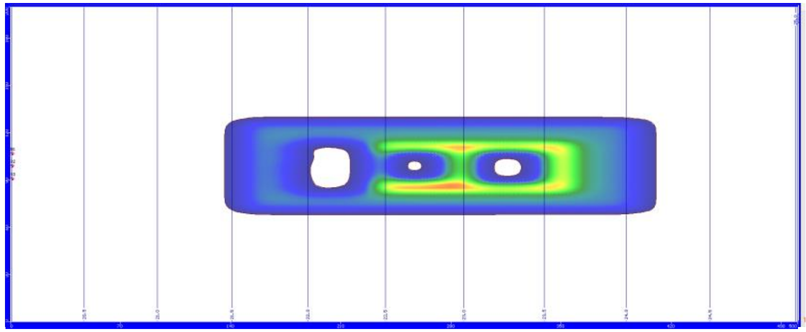




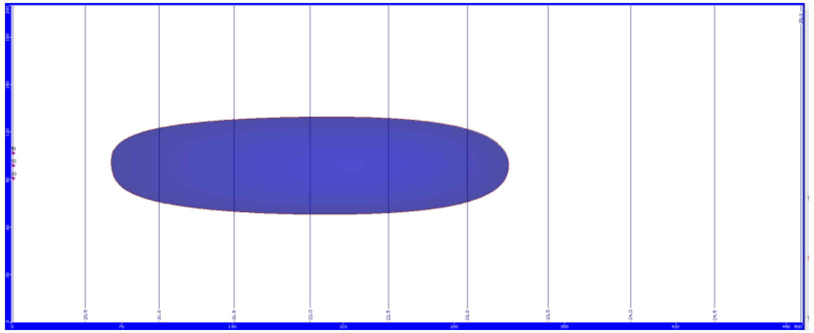
A MASS REMOVAL EXPERIMENT

- Remove some mass in middle high concentration areas (note that some remaining high concentrations left at boundaries or between)

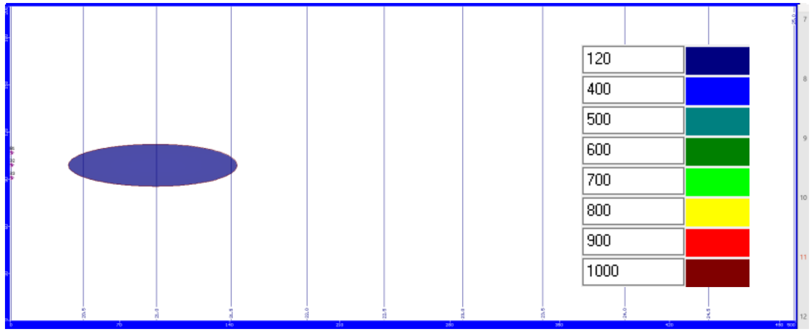
Year 1



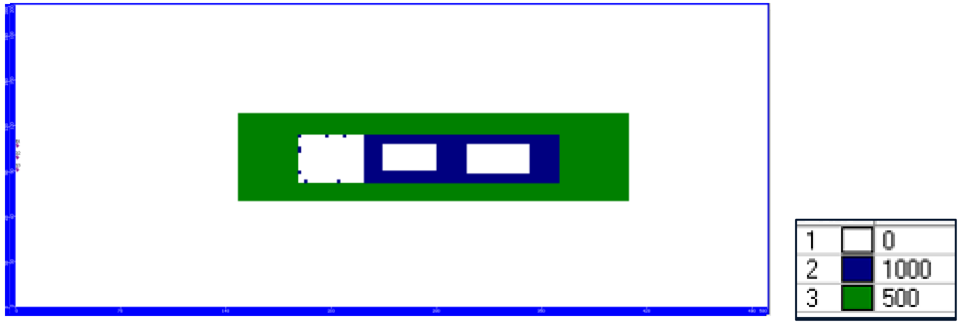
Year 20

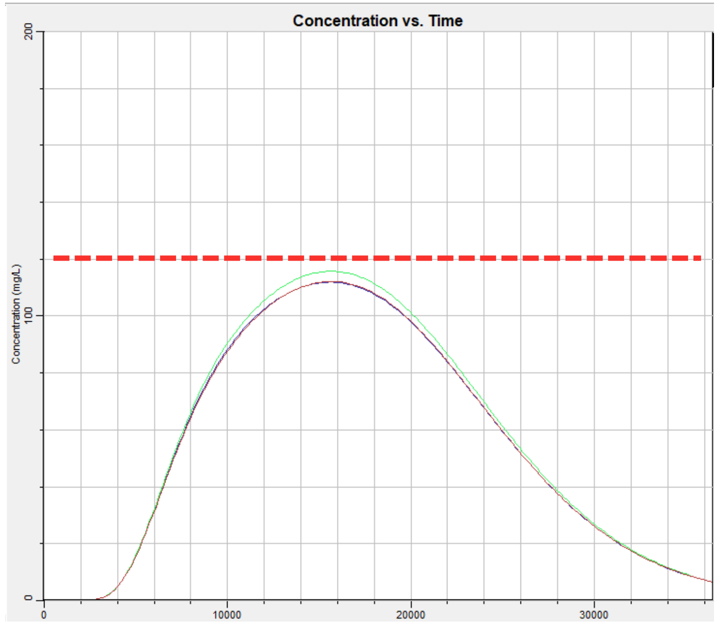


Year 40



Mass Removal Scenario 3

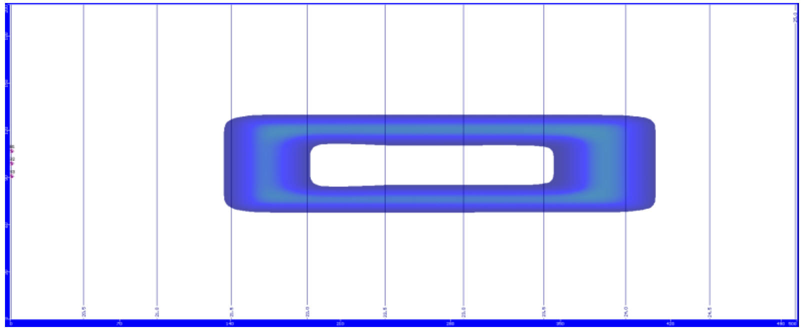




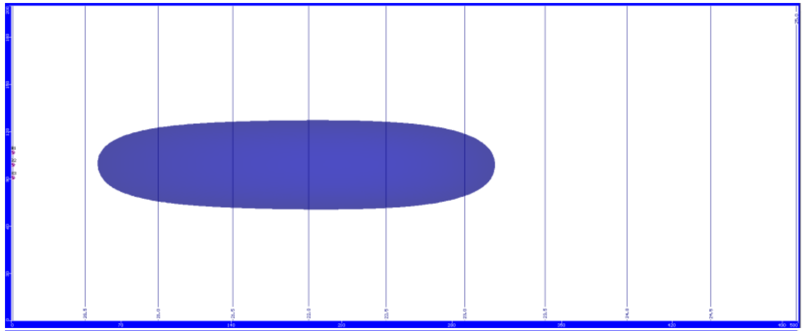
A MASS REMOVAL EXPERIMENT

- Remove some shallow impact (simulate some practical considerations)

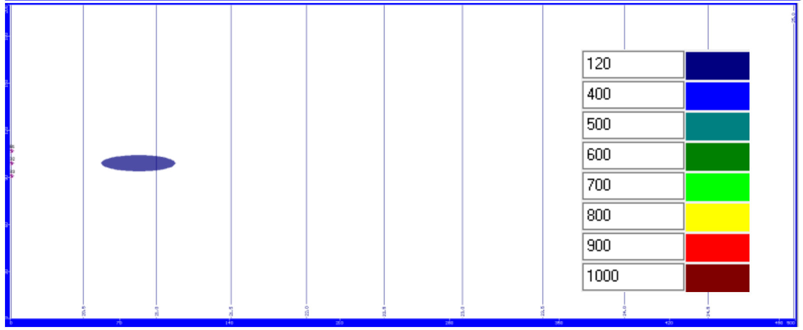
Year 1



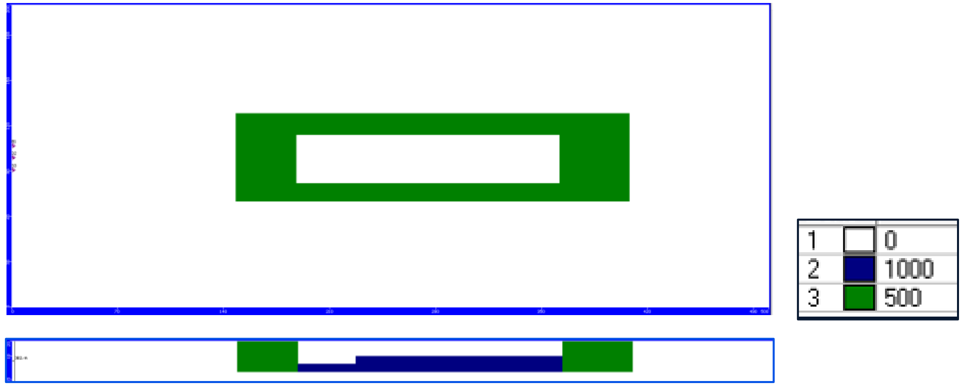
Year 20

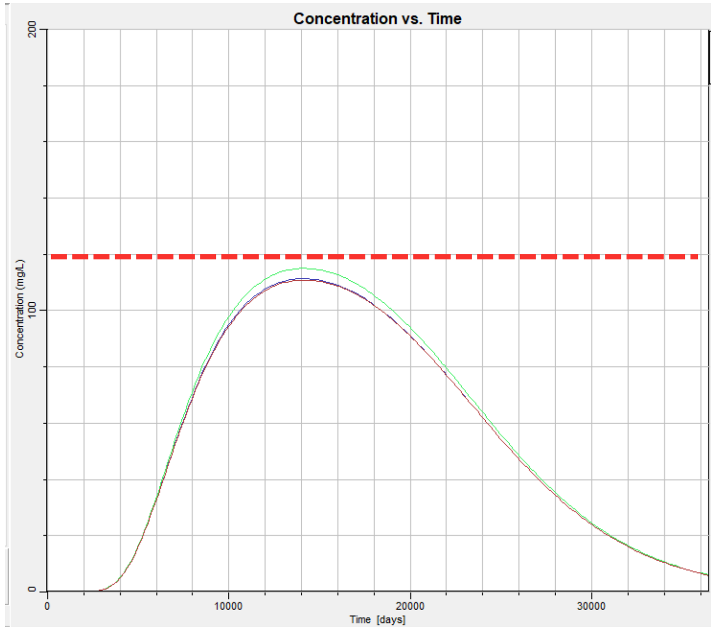


Year 40



Mass Removal Scenario 4

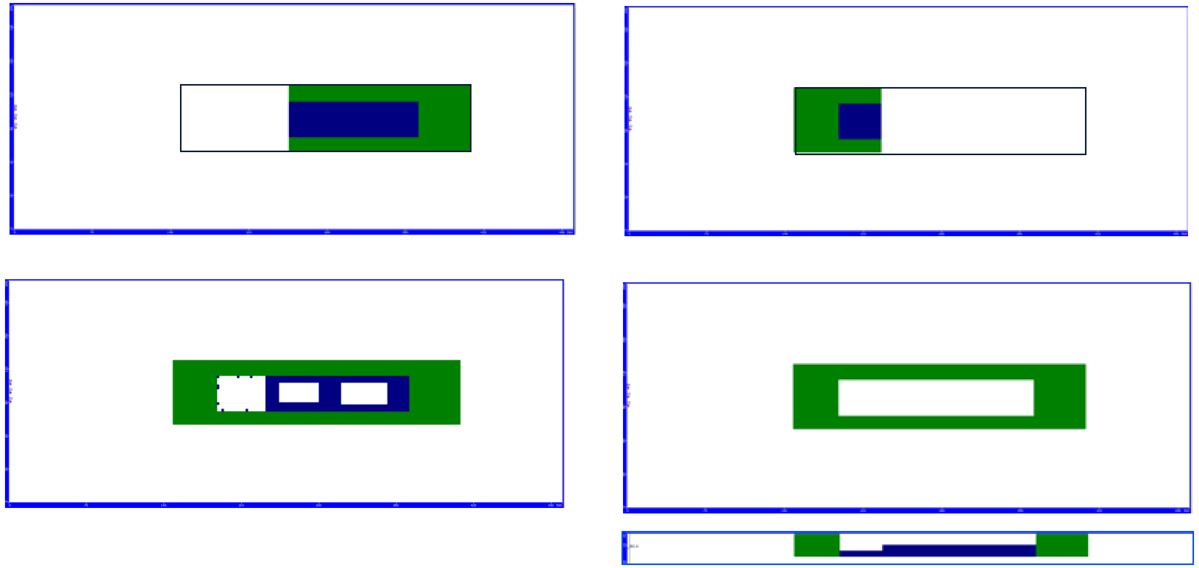




A MASS REMOVAL EXPERIMENT

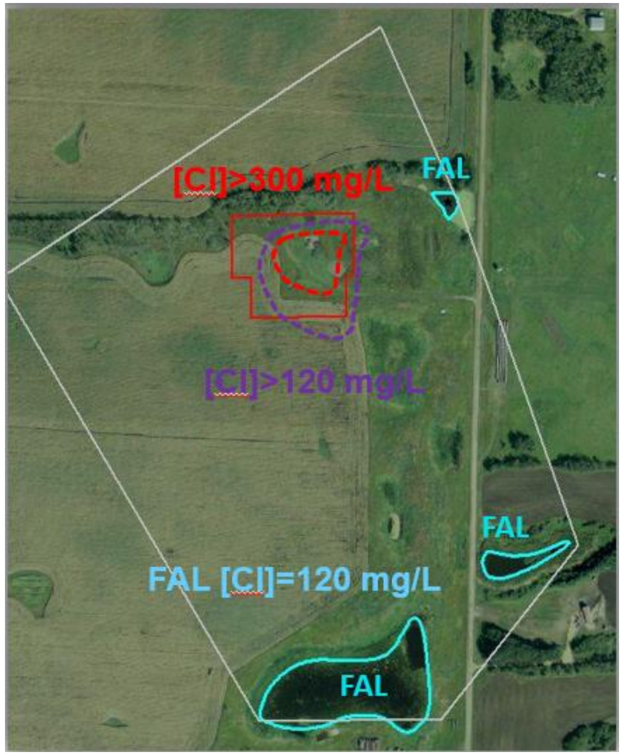
Summary

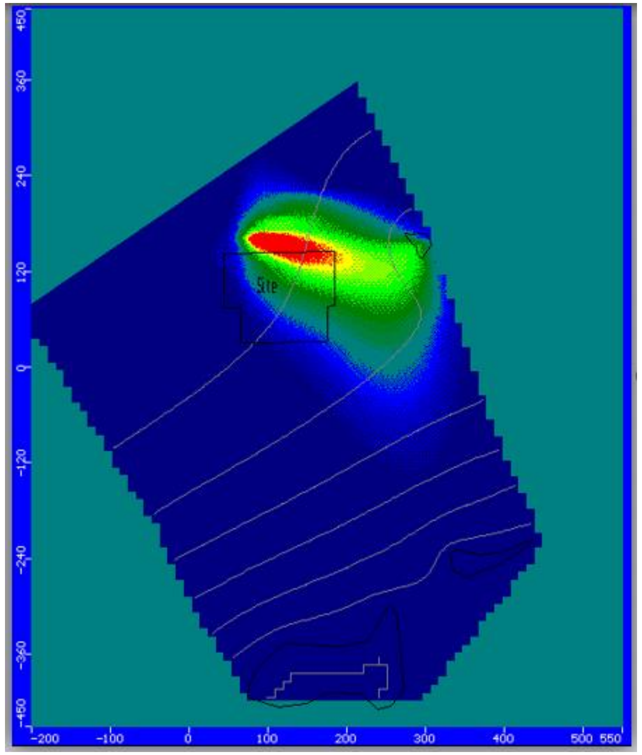
- There are many ways to remove mass for protection of FAL receptor
- Mass removal design not constrained by concentrations (remedial guidelines are not required)
- May be a much efficient way to design remediation based on practical considerations
- Would work for any contaminant transport related pathways and receptors
  - FAL
  - DUA
  - Vapour migration
  - Salt uptake from subsoil to root zone
- Require modelling



CHALLENGES FOR "REAL SITE" MODELLING

- Challenges in presenting site conditions in model and determination of site-specific input parameters
  - Rainfall infiltration rates
  - Dispersion coefficients
  - Geological and hydrogeological conditions between the site and FAL receptors
- General lack of data for model calibration, particularly for transport model calibration
- Difficult to justify modelling effort and cost particularly at small and simple sites
- Longer time for regulatory review
- May be asked for long-term monitoring to verify modelling prediction (unreasonable at most sites)

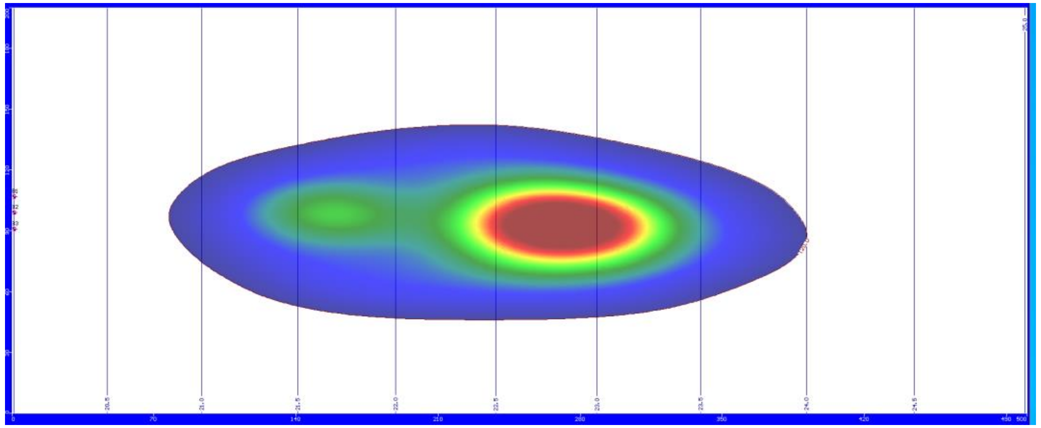


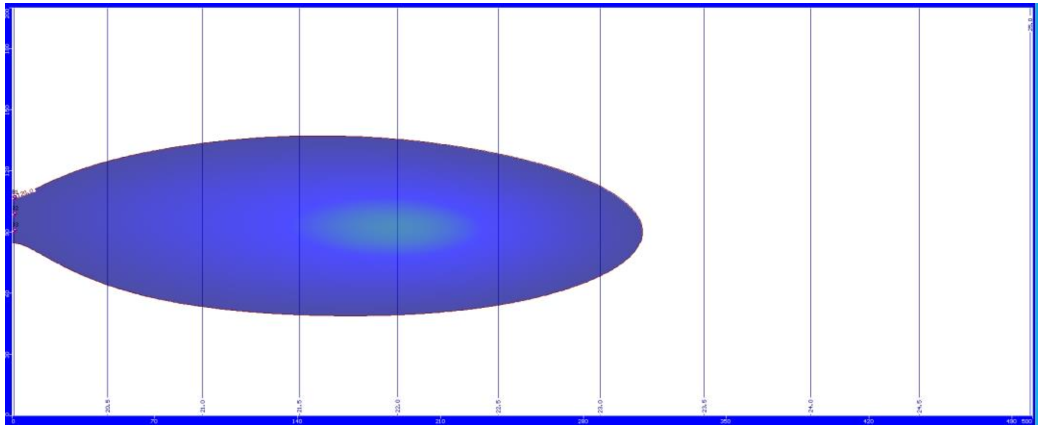


PROPOSE TIER 2 LEVEL REMEDIATION DESIGN TOOLS

Numerical models to represent Tier 2 assumptions + 3D input for mass distribution

- Conceptually, SST added with 3D input
- Need to be based on commonly used modelling packages
- Require some research to present Tier 2 assumptions using numerical models (not a trivial task)
- Need a standardized modelling procedure
- Need testing for a right level of conservatism
- Interaction with regulators is absolutely necessary





TAKEAWAY MESSAGE

Statistic approaches may be required for guideline applications

- Replace single guideline value checking approach

Remedial guidelines may not be required for remedial design

- Propose mass-based remedial design tools

CLOSING

Thank you!

Questions?