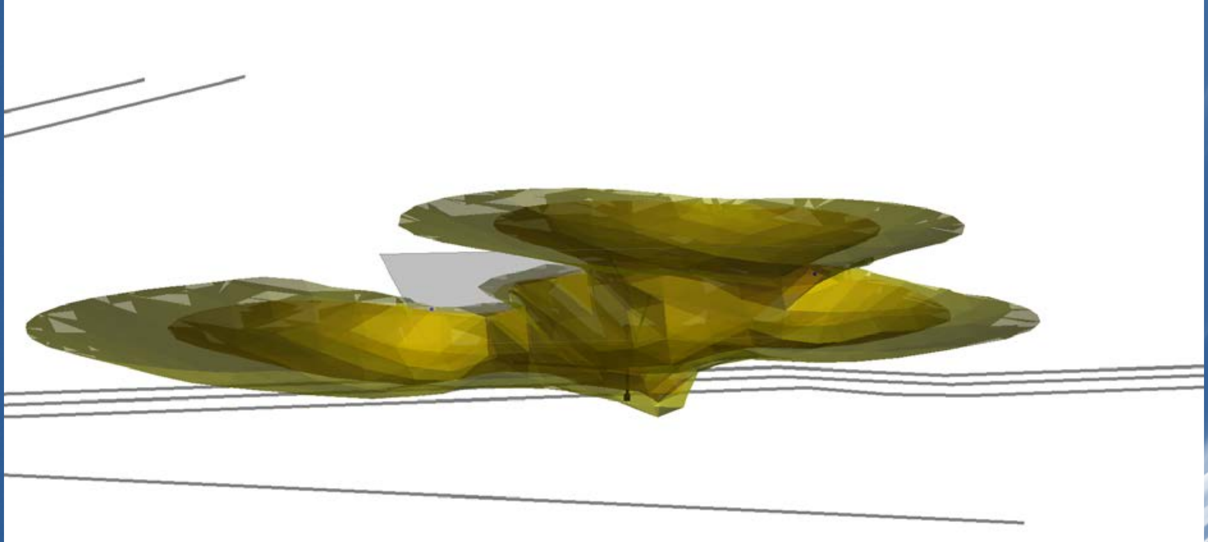
MODELING ASSISTED EVALUATION OF SALINITY REMEDIATION APPROACHES



Understanding chloride remediation in soils

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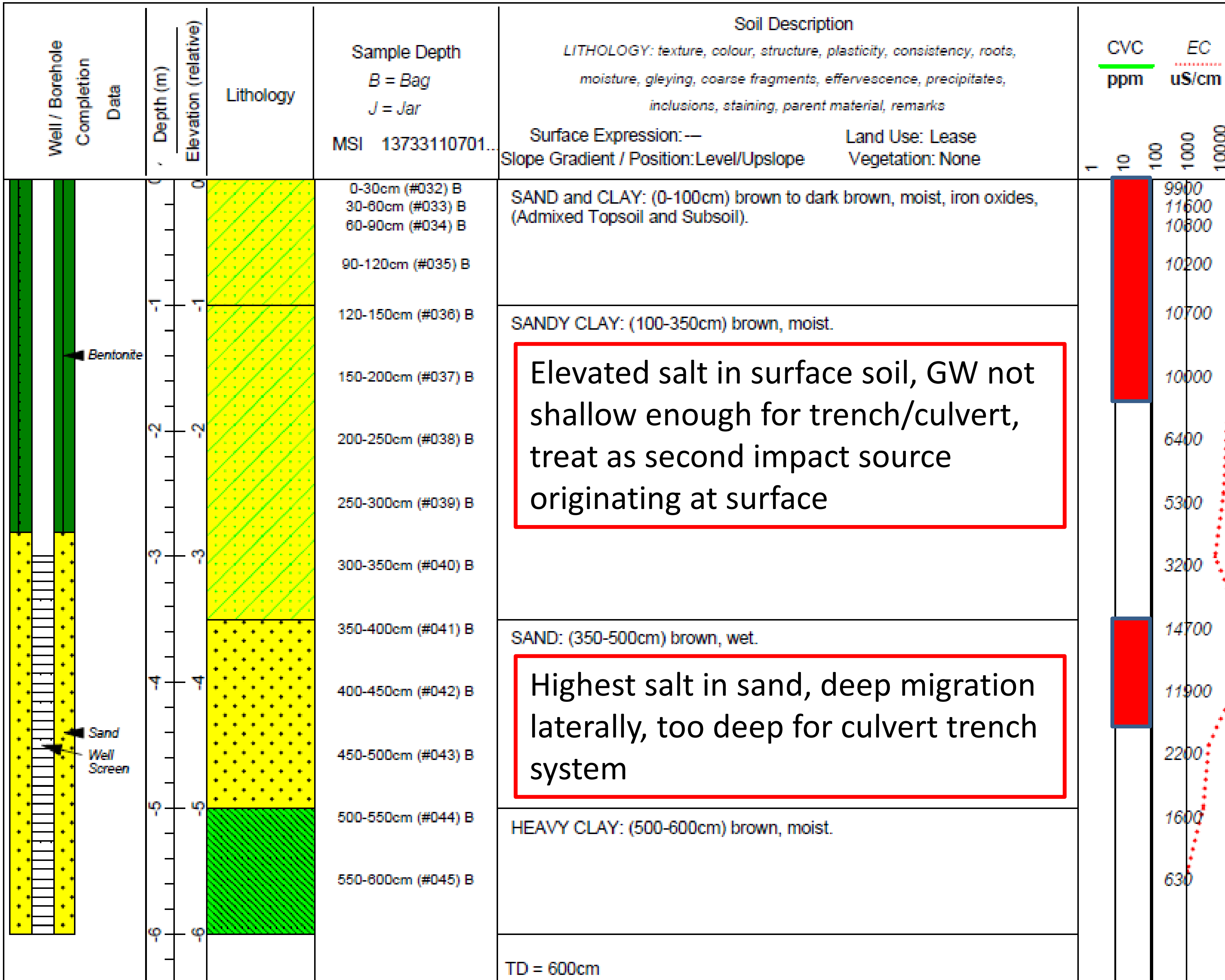
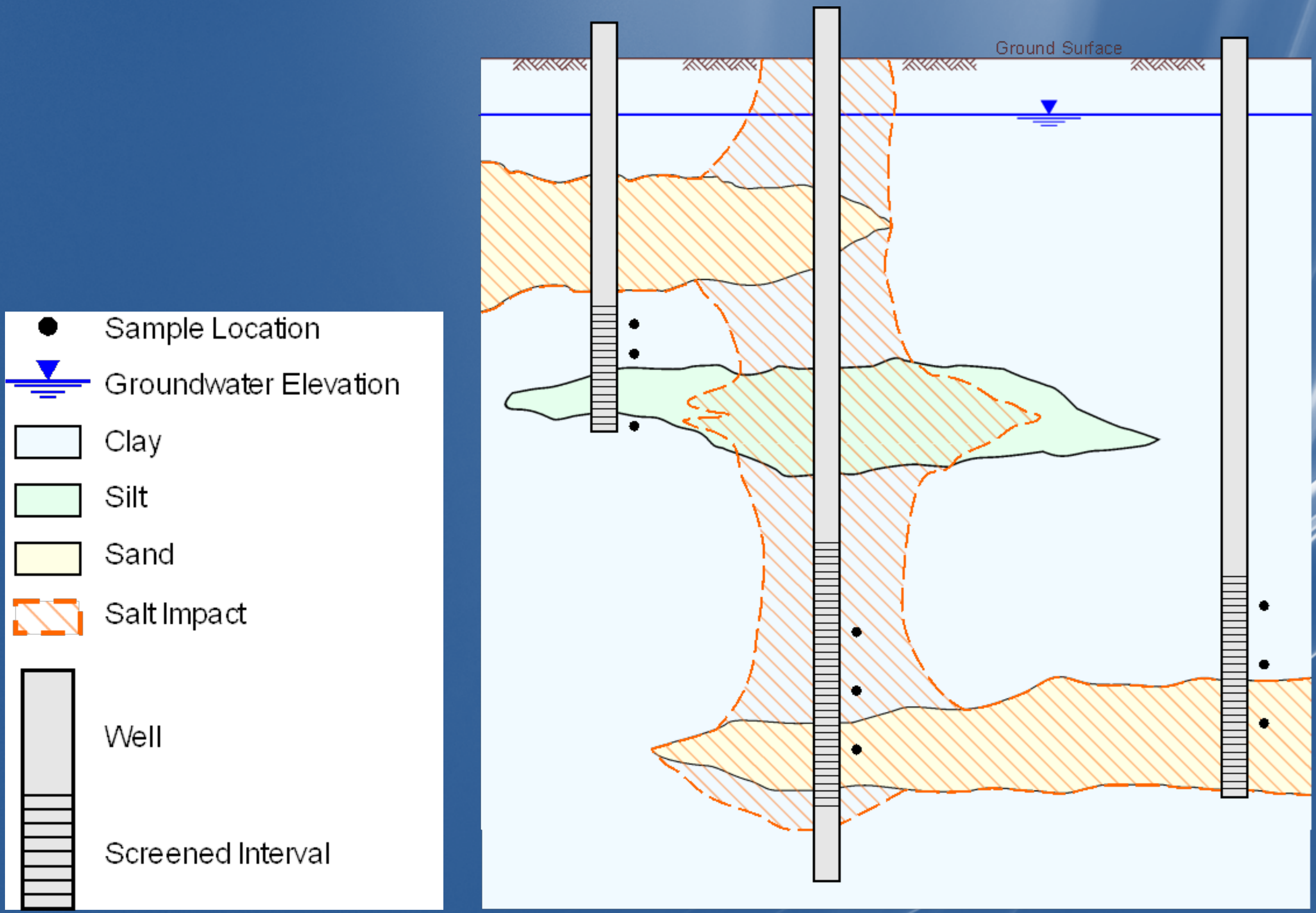
OUTLINE

1. Soil Salinity Relationships
   - Relating field parameter to concentrations
2. Feasibility of “Soil Washing”
3. Prairie Case Study
   - Mass distribution (samples → 3D distribution)
   - Remediation Considerations
   - Existing System Design – typical approach
   - Simulation Tools
     - Approach
     - Options Evaluation (effectiveness and cost)
   - Collaborative Research

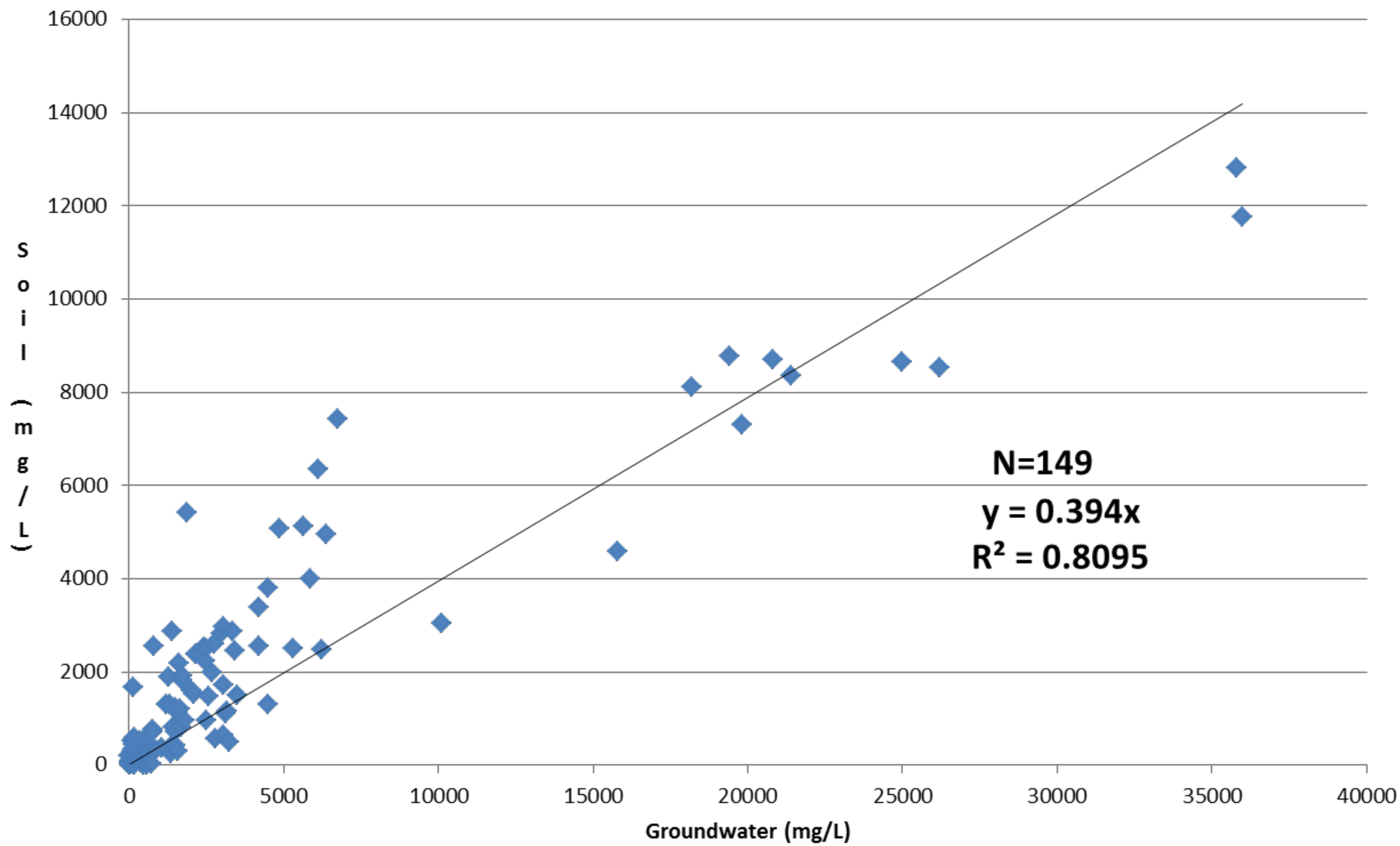


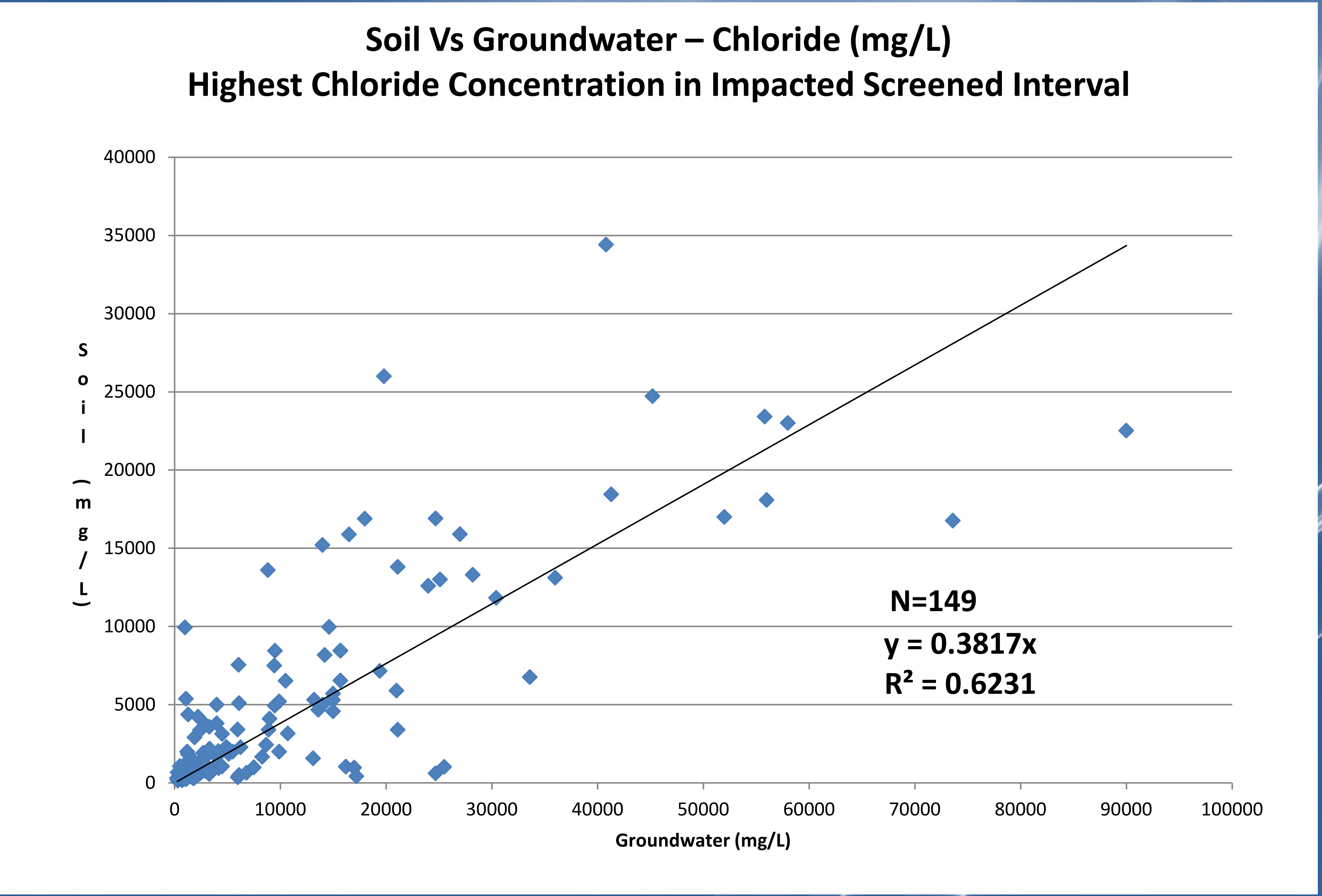
Well / Borehole Completion Data
Depth (m)
Elevation (relative)
Lithology
Sample Depth
B = Bag
J = Jar
MSI 13733110701...
Soil Description
LITHOLOGY: texture, colour, structure, plasticity, consistency, roots, moisture, gleying, coarse fragments, effervescence, precipitates, inclusions, staining, parent material, remarks
Surface Expression: --
Land Use: Lease
Slope Gradient / Position: Level/Upslope
Vegetation: None
CVC
ppm
EC
uS/cm
1
10
100
1000
10000
Bentonite
Sand
Well Screen
0-30cm (#032) B
30-60cm (#033) B
60-90cm (#034) B
90-120cm (#035) B
120-150cm (#036) B
150-200cm (#037) B
200-250cm (#038) B
250-300cm (#039) B
300-350cm (#040) B
350-400cm (#041) B
400-450cm (#042) B
450-500cm (#043) B
500-550cm (#044) B
550-600cm (#045) B
SAND and CLAY: (0-100cm) brown to dark brown, moist, iron oxides, (Admixed Topsoil and Subsoil).
SANDY CLAY: (100-350cm) brown, moist.
Elevated salt in surface soil, GW not shallow enough for trench/culvert, treat as second impact source originating at surface
SAND: (350-500cm) brown, wet.
Highest salt in sand, deep migration laterally, too deep for culvert trench system
HEAVY CLAY: (500-600cm) brown, moist.
TD = 600cm
9900
11600
10800
10200
10700
10000
6400
5300
3200
14700
11900
2200
1600
630

SAMPLING INFLUENCE ON GW AND SOIL CHLORIDE CONCENTRATION RELATIONSHIP

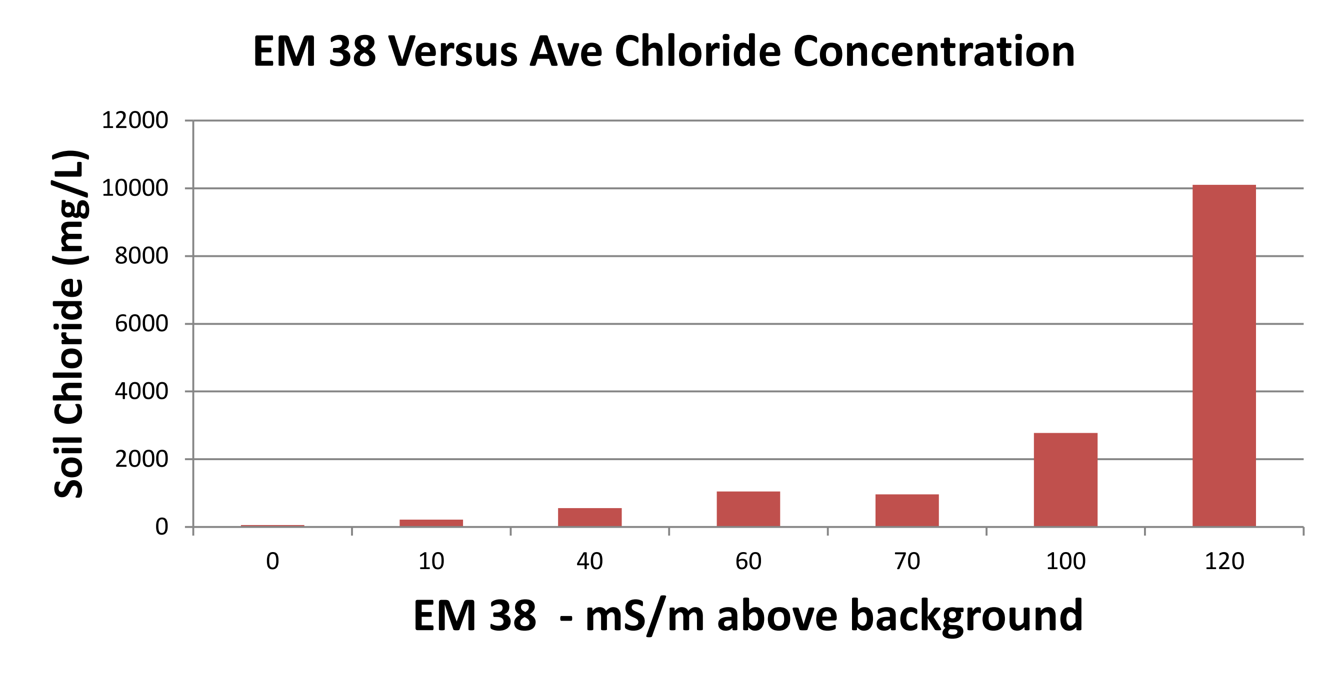


Soil Vs Groundwater - SO4 (> 250 mg/L Cl)
Highest Chloride Concentration in Impacted Screened Interval

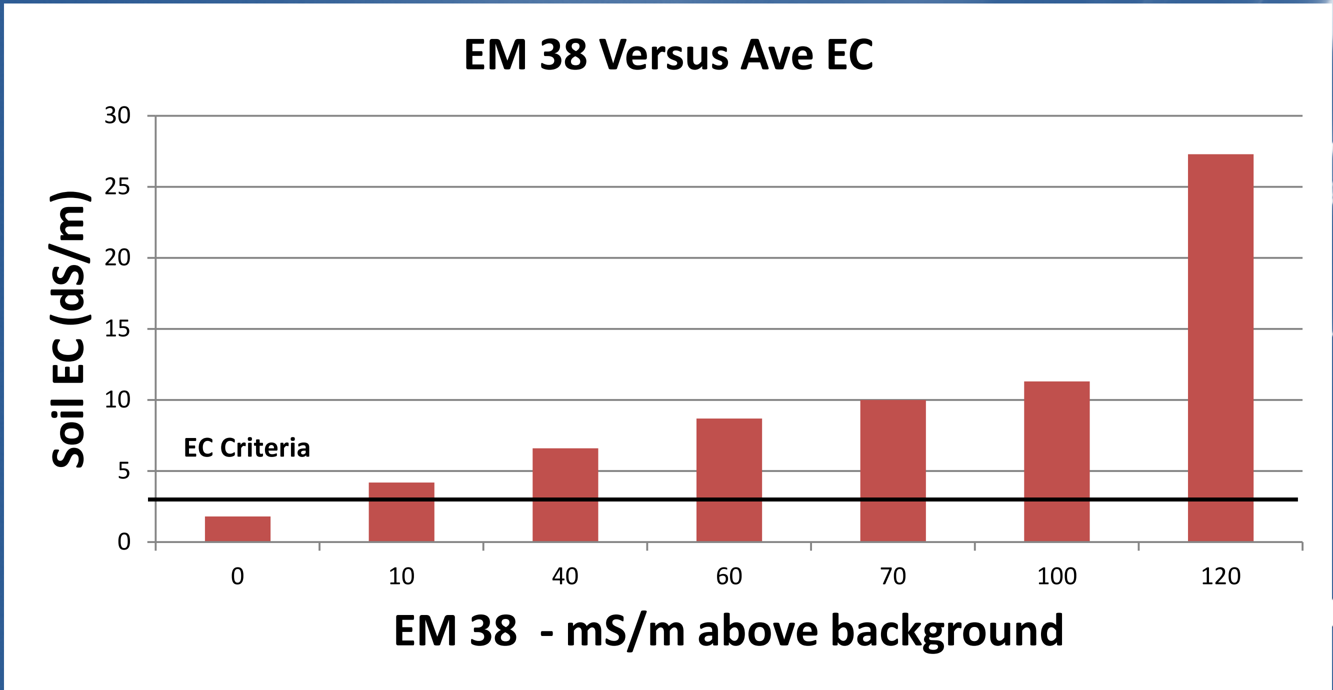




Soil Vs Groundwater – Chloride (mg/L)
Highest Chloride Concentration in Impacted Screened Interval
40000
35000
30000
25000
20000
15000
10000
5000
0
Soil (mg/L)
0
10000
20000
30000
40000
50000
60000
70000
80000
90000
100000
Groundwater (mg/L)
N=149
y = 0.3817x
R² = 0.6231



EM 38 Versus Ave Chloride Concentration
Soil Chloride (mg/L)
12000
10000
8000
6000
4000
2000
0
0
10
40
60
70
100
120
EM 38 - mS/m above background



EM 38 Versus Ave EC
Soil EC (dS/m)
30
25
20
15
10
5
0
EC Criteria
0
10
40
60
70
100
120
EM 38 - mS/m above background

SEQUENTIAL SOIL WASHING AND SATURATED PASTE SQUEEZE

LABORATORY SALT REMOVAL TEST RUN

Water Used to Soil Wash - (10,000 mg/L Cl Spill)			
Soil Type	Initial 1st Wash EC (dS/m)	Soil Wash Iterations to Criteria	Ratio H_2O to Soil (m^3 H2O/m^3 impacted soil)
Peat Soil	11.2	3	1.8
Clay	13.1	4	4.9
Sandy Clay Loam	8.6	3	2.8
Sandy Loam	11.4	4	3.0
Impacted Top Soil	15.3	4	3.0

Water Used to Sat Paste Squeeze Soil - (10,000 mg/L Cl Spill)			
Soil Type	**Initial 1st Wash EC (dS/m)**	**Soil Squeeze Iterations to Criteria**	**Ratio H_2O to Soil (m^3 H2O/m^3 impacted soil)**
Peat Soil	35.3	5	1.4
Clay	31.1	6	3.4
Sandy Clay Loam	23.5	6	2.6
Sandy Loam	24.3	6	1.8
Impacted Top Soil	34.1	7	1.8

SUMMARY POINTS

- Minor increases in clay content lead to increased water used more so than decreased sand for squeeze
- Higher EC starting point (background) increased water use more for washing than squeezing
- Although water washing requires much more water there is significantly less work events

PRAIRIE SPILL – 3D VISUALIZATION OF PRODUCED WATER IMPACT AREA

STANDARD CULVERT-TILE GW RECOVERY STRATEGY FOR LONG TERM REMEDIATION

Groundwater Recovery	Tile Length (m)	Vol GW recovered (m^3/year)	Cl Removal Rate (kg/year)	Mass Chloride (kg)	Mass Chloride in Hot Spot	Years for 50% Reduction	Years for 50% Reduction of Hot Spot	Additional Tile for 50% Reduction of Hot Spot in 10 Years (m)
	80	305	2480	177,000	93,000	36	19	151

TRANSPORT MODELLING EXAMPLE APPLICATION

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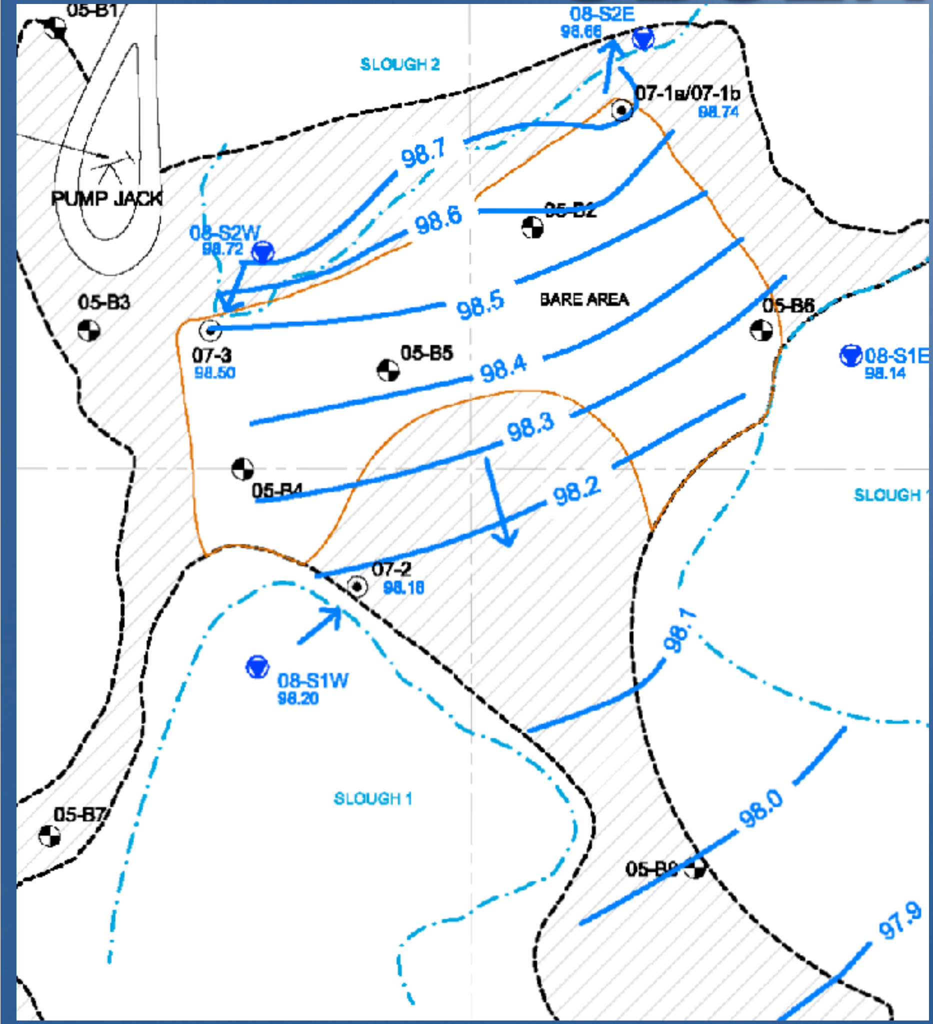
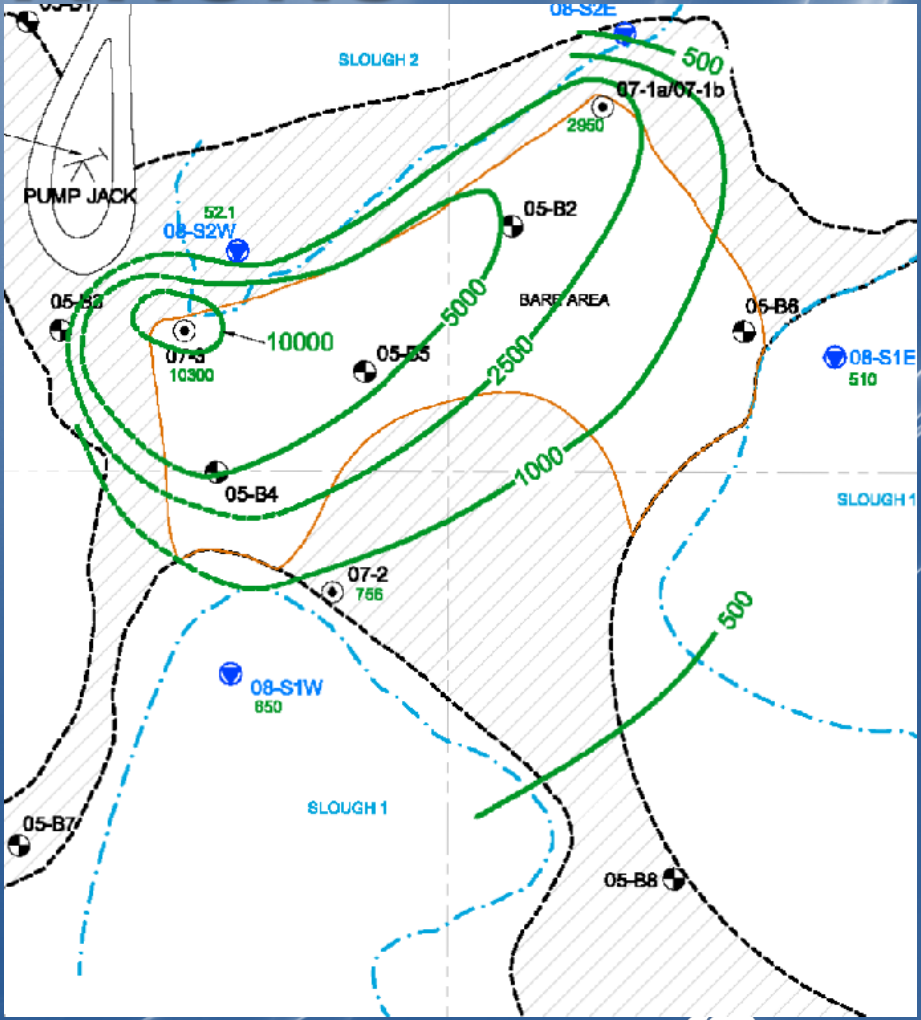
NUMERICAL MODELLING

- Purpose
  - Evaluate Groundwater flow and Transport of Saline Process Water
  - Evaluate Remediation Alternatives
- Scope
  - Numerical Model with Simplified Parameters
  - Evaluate effectiveness of multiple trench and drain designs
  - Cost benefit analysis

FLOW & TRANSPORT OBSERVATIONS





REMEDIATION OPTIONS

1. Do nothing / natural attenuation (dispersion)
2. Extraction trenches (multiple designs)
   a) Single trench
   b) Multiple trenches
3. Root zone excavation
   a) independent
   b) with extraction trenches
4. Extraction / re-infiltration systems

1. NATURAL ATTENUATION

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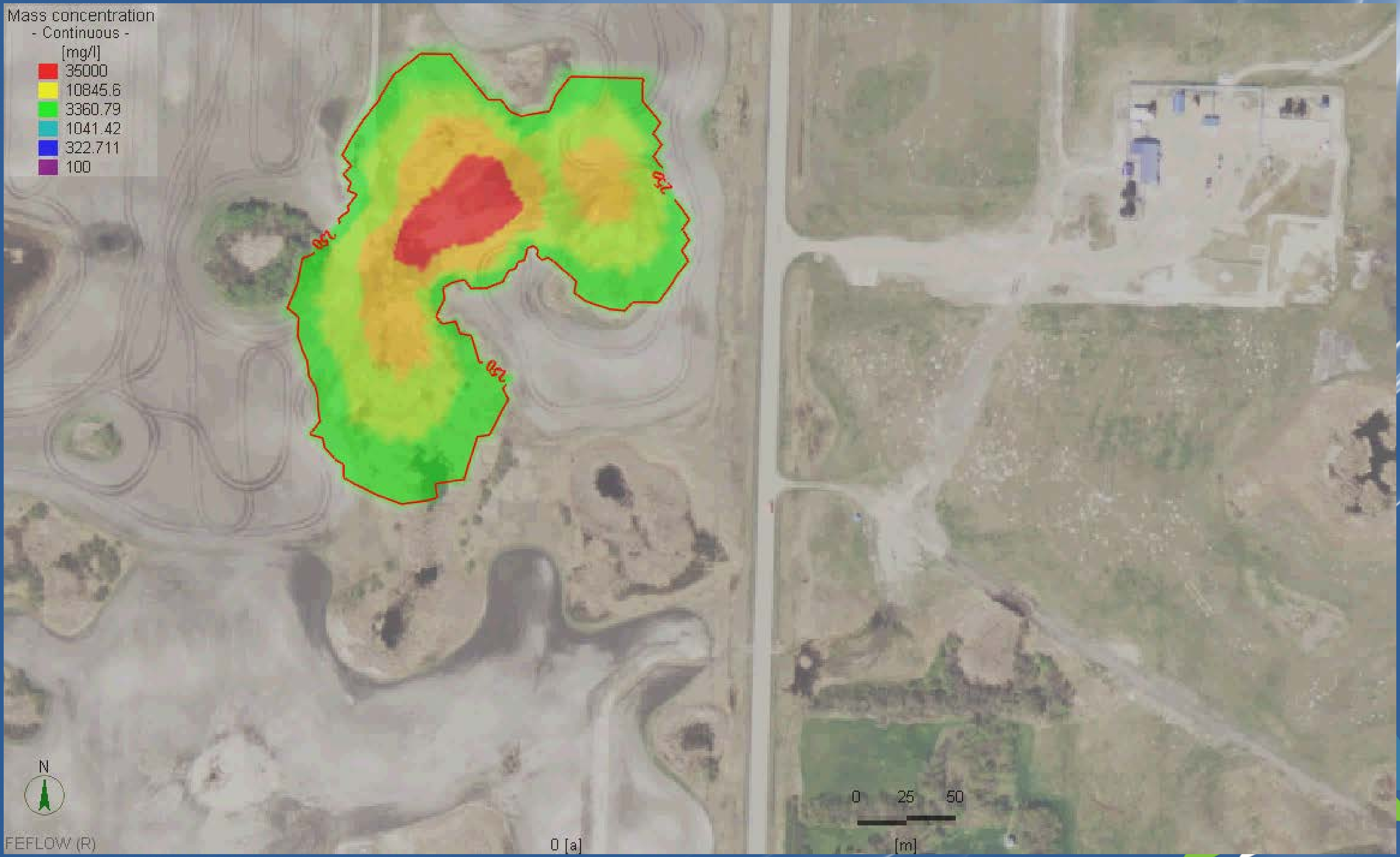
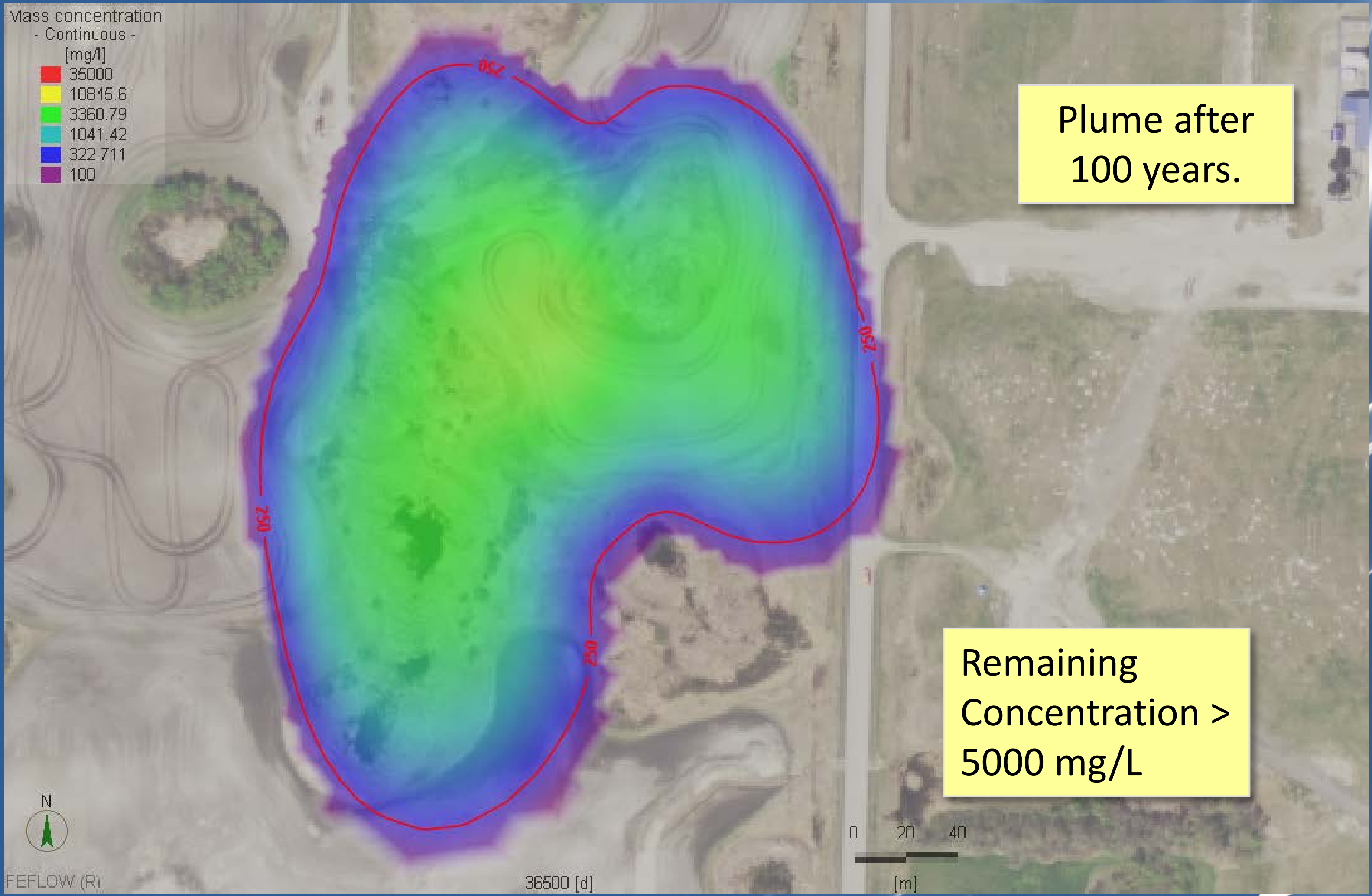
PREDICTED PLUME MIGRATION WITHOUT ACTIVE REMEDIATION

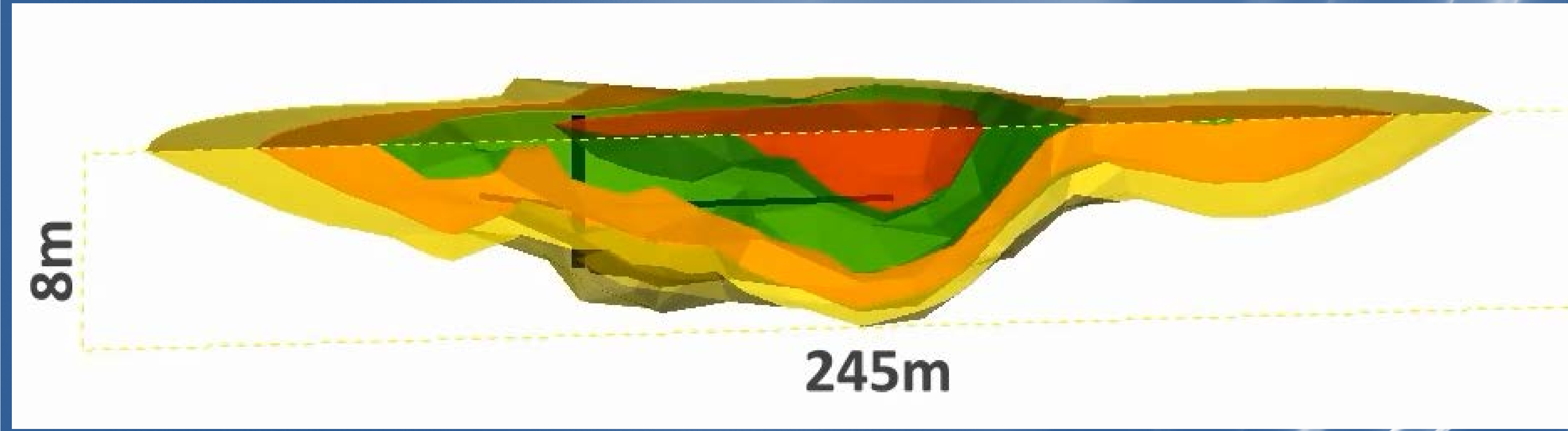


PREDICTED PLUME MIGRATION WITHOUT ACTIVE REMEDIATION



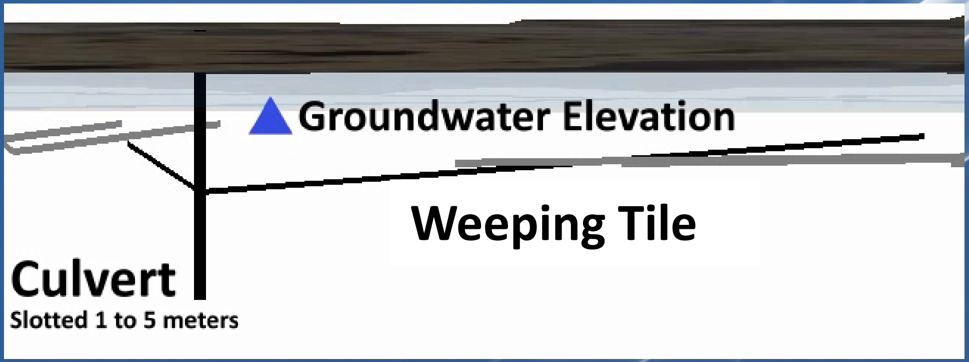
2A. SINGLE EXTRACTION TRENCH

2. EXTRACTION TRENCH



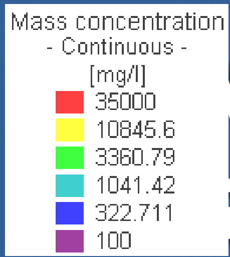
Weeping Tile Connected to a Vertical Culvert

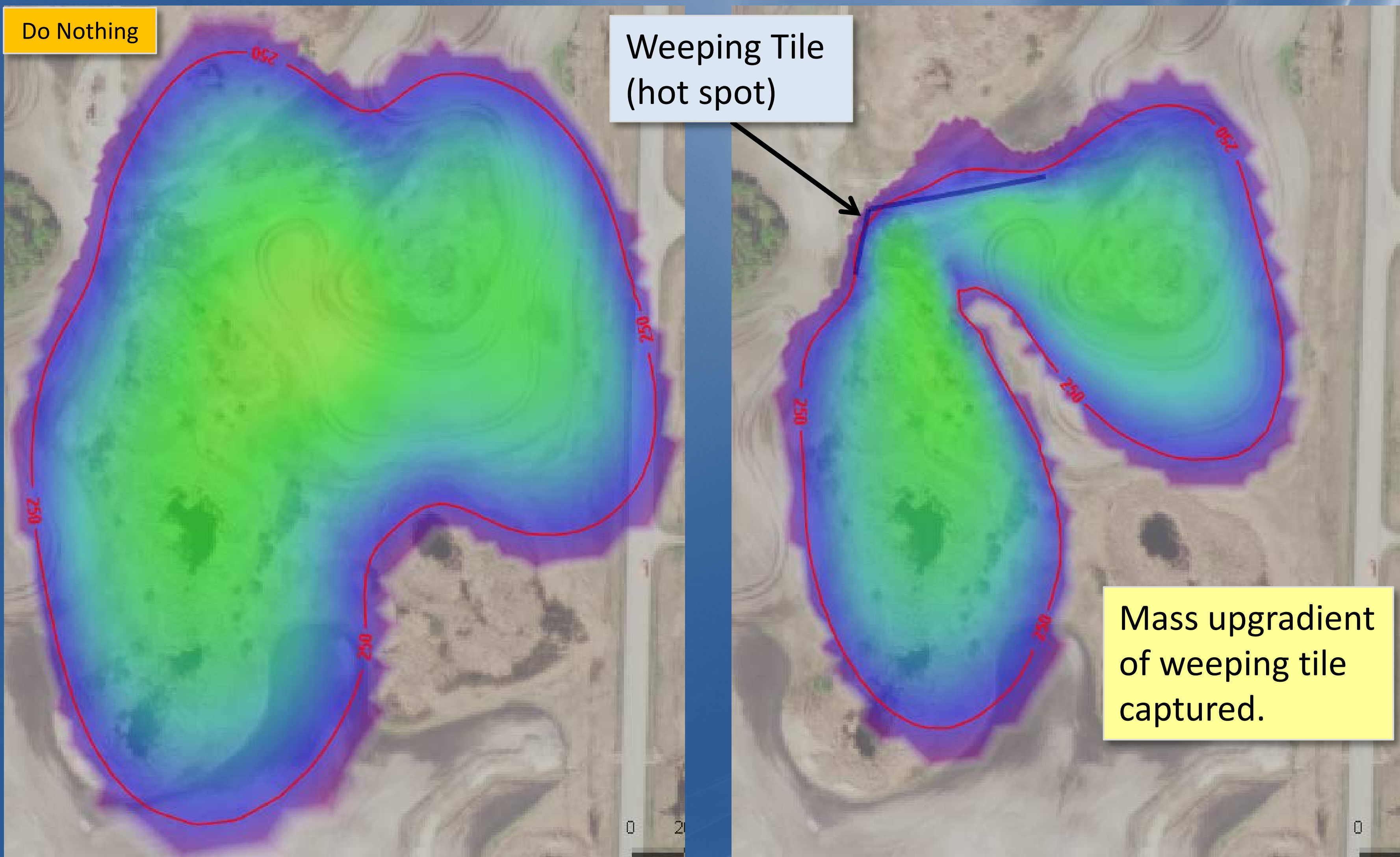
Assumptions
- Head at culvert maintained at 2 m below watertable.
- Weeping tile allows water and mass to freely flow toward the culvert.



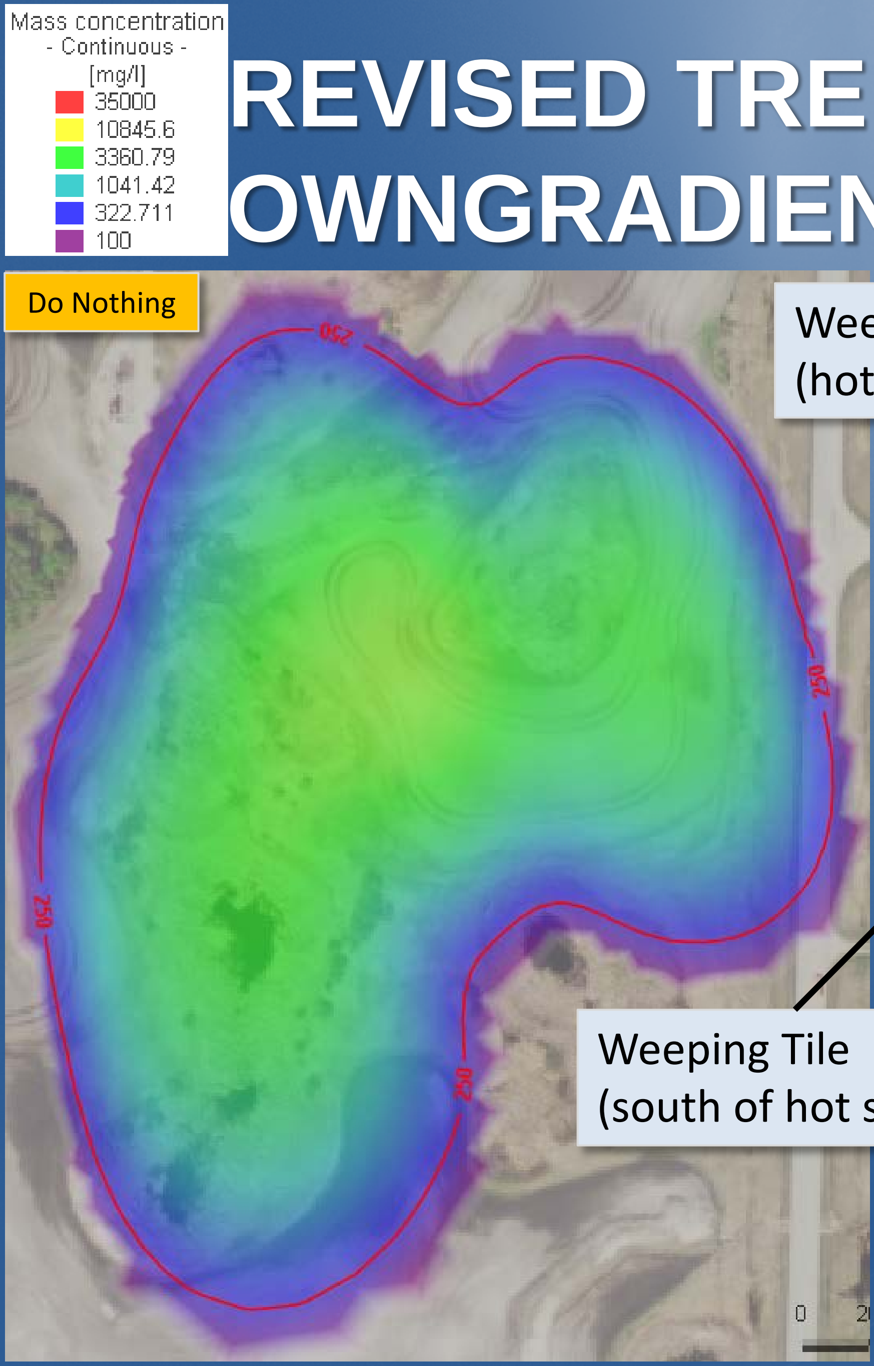
PREDICTED PLUME MIGRATION WITH SINGLE EXTRACTION TRENCH

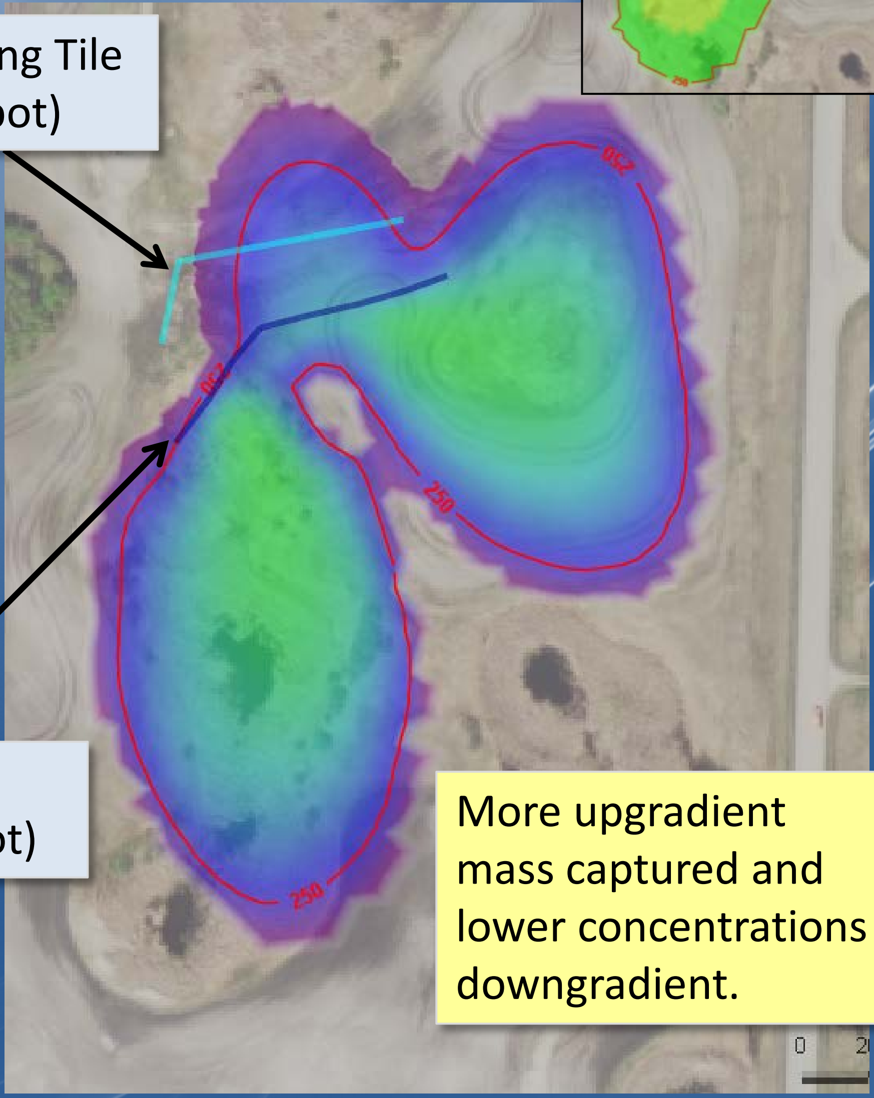
MAINING PLUME AFTER 100 YRS
INGLE EXTRACTION TRENCH

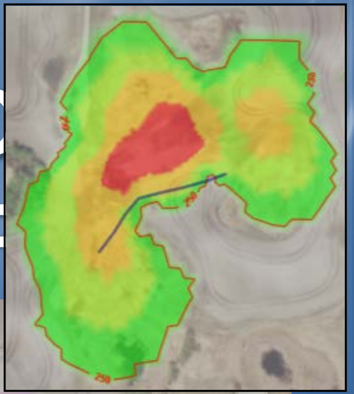




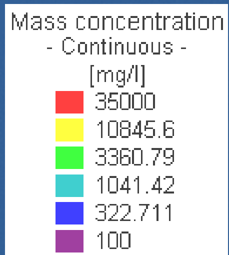
REVISED TRENCH LOCATIO… OWNGRADIENT OF HOT SP…



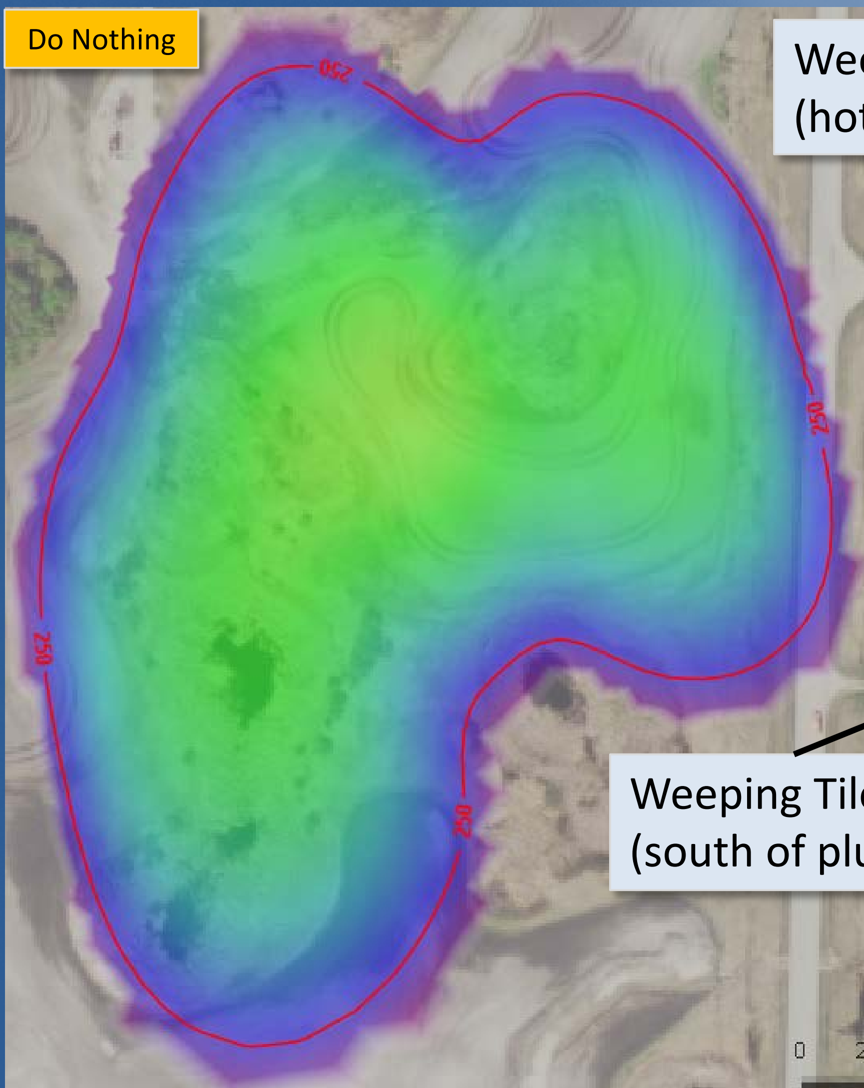


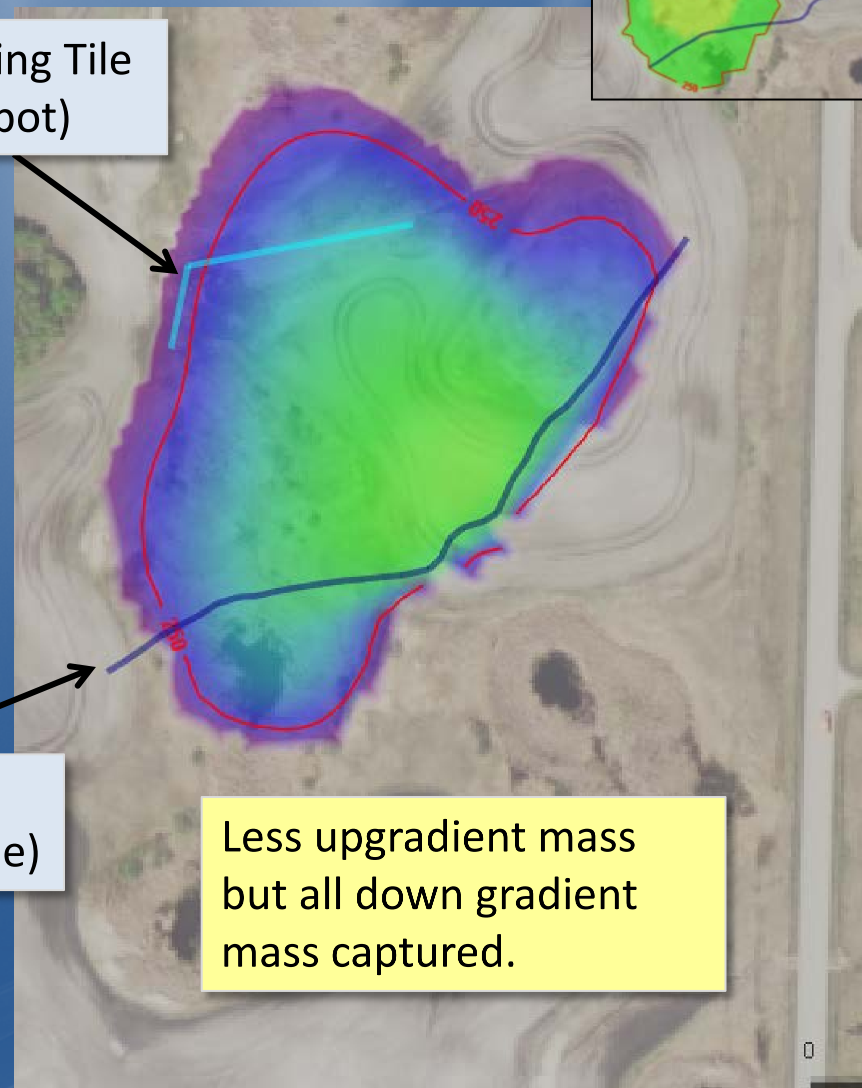


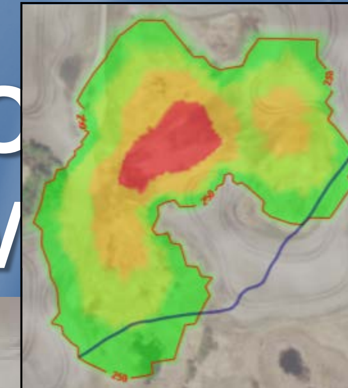
More upgradient mass captured and lower concentrations downgradient.



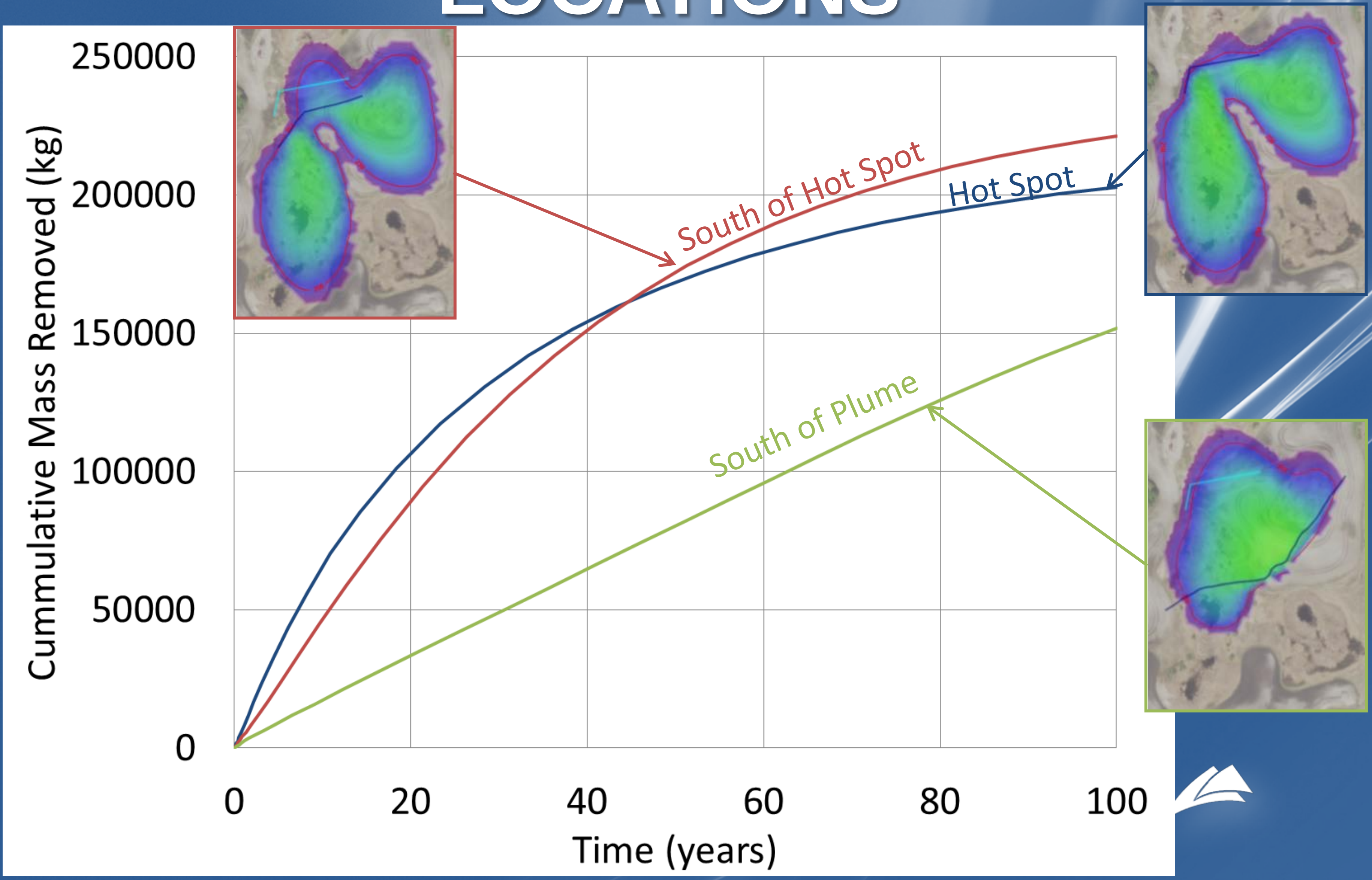
REVISED TRENCH LOCATIO DOWNGRADIENT OF PLUM



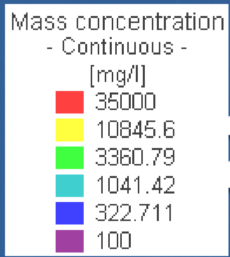




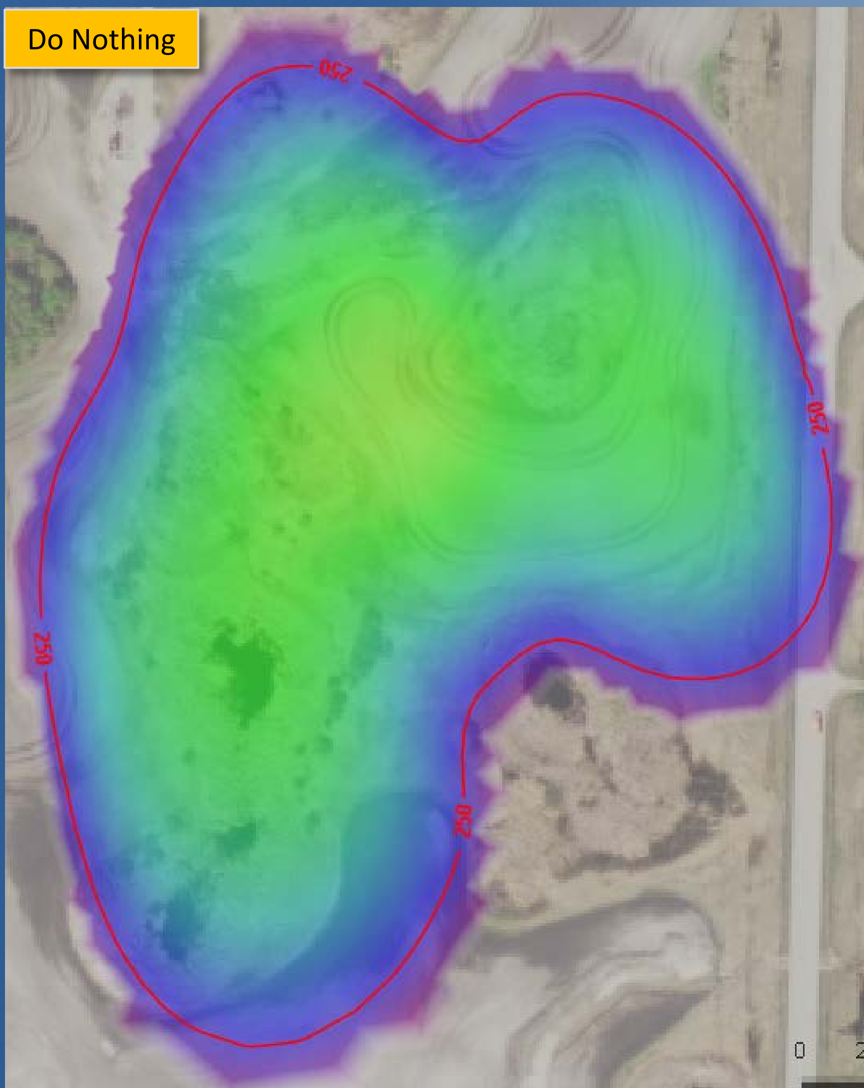
COMPARISON OF TRENCH LOCATIONS

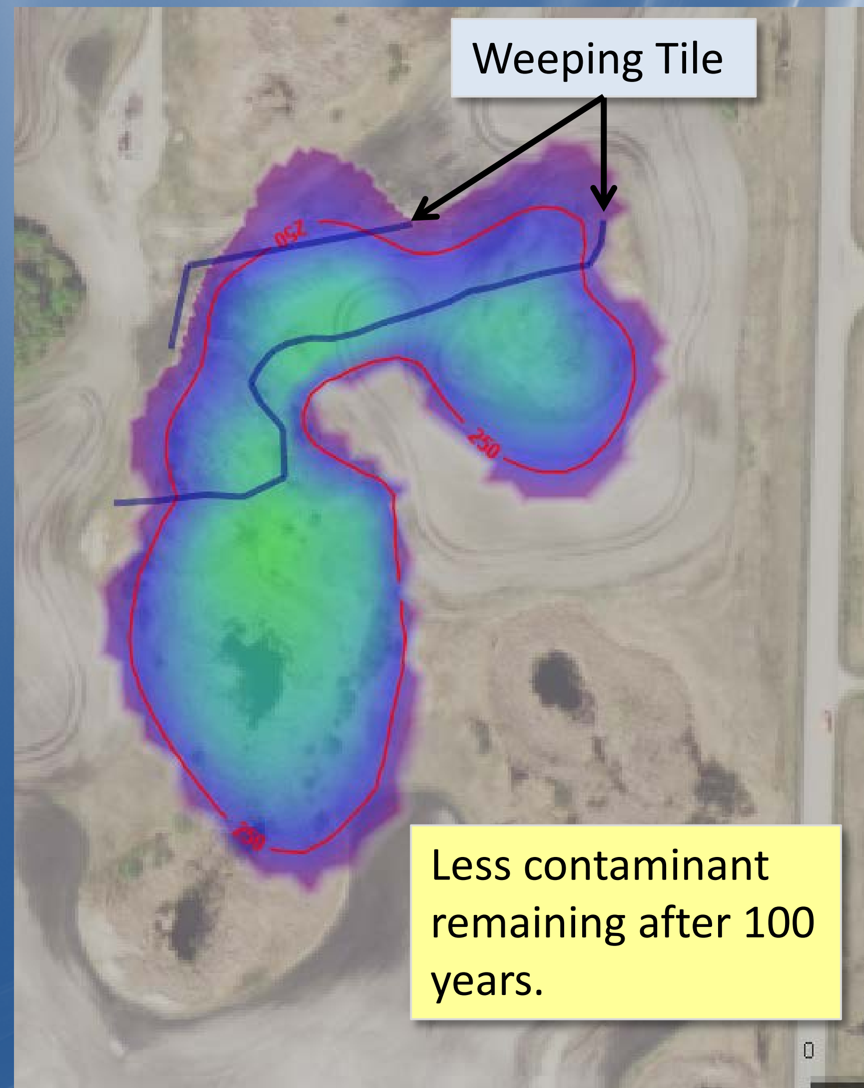


2B. MULTIPLE EXTRACTION TRENCHES

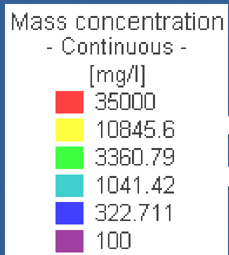


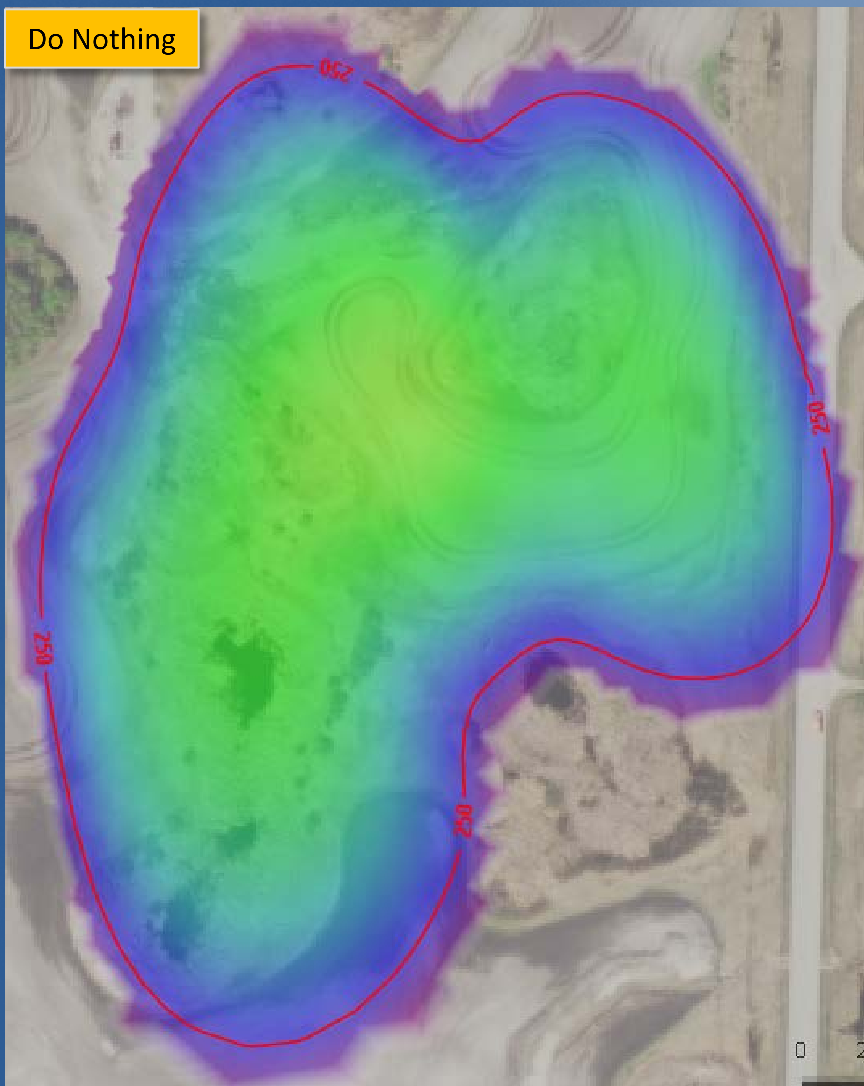
2 EXTRACTION TRENCHES

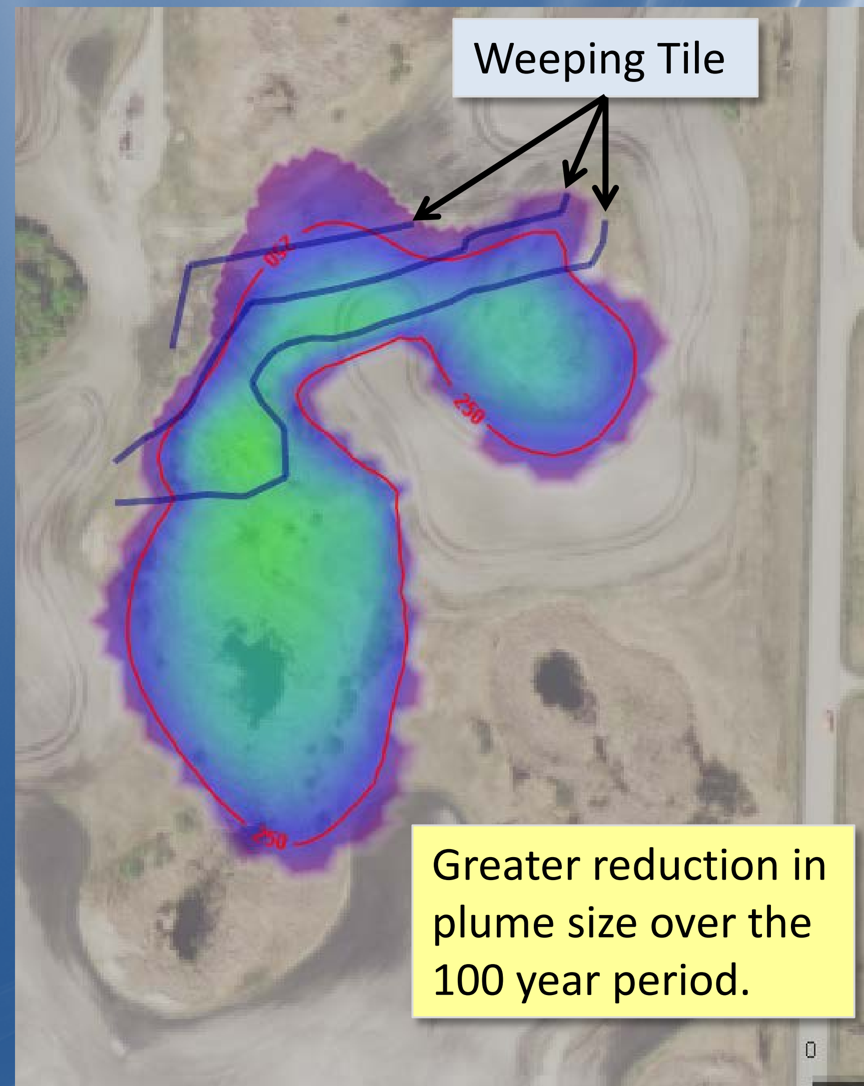


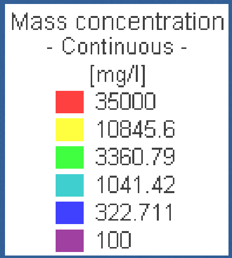


3 EXTRACTION TRENCHES

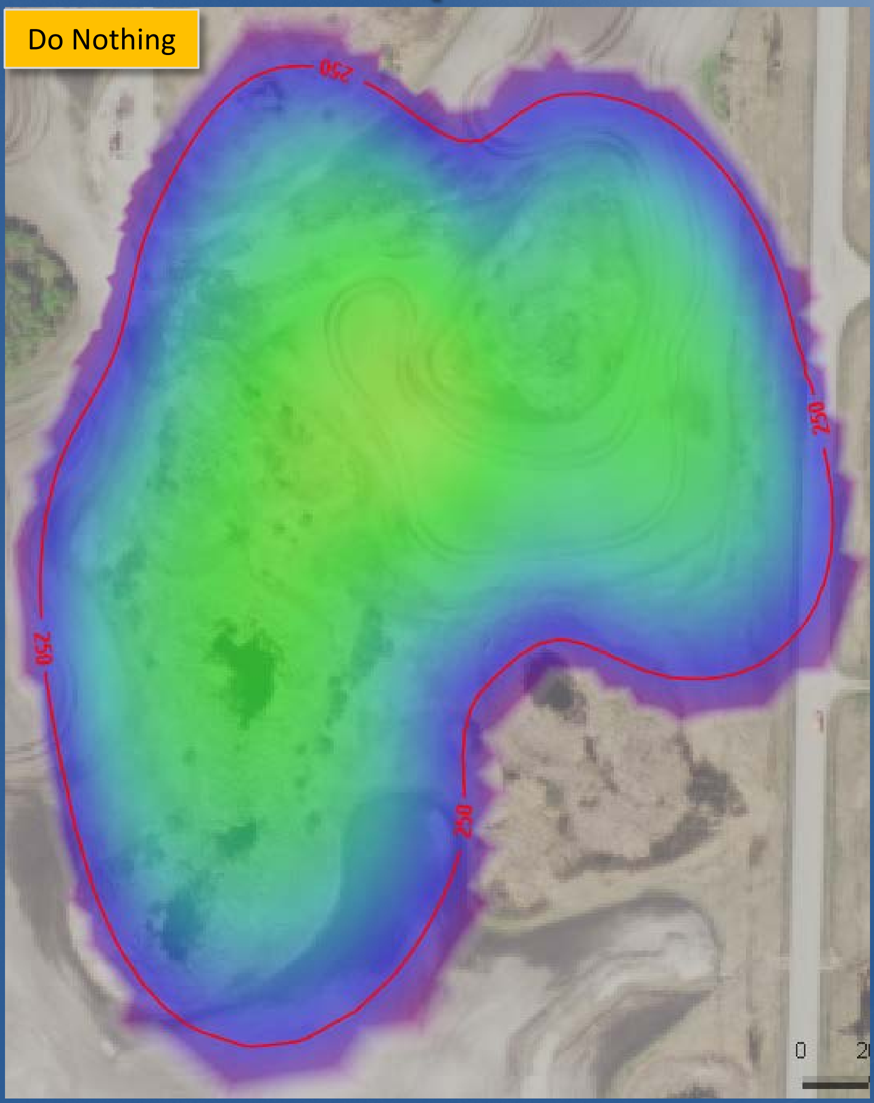


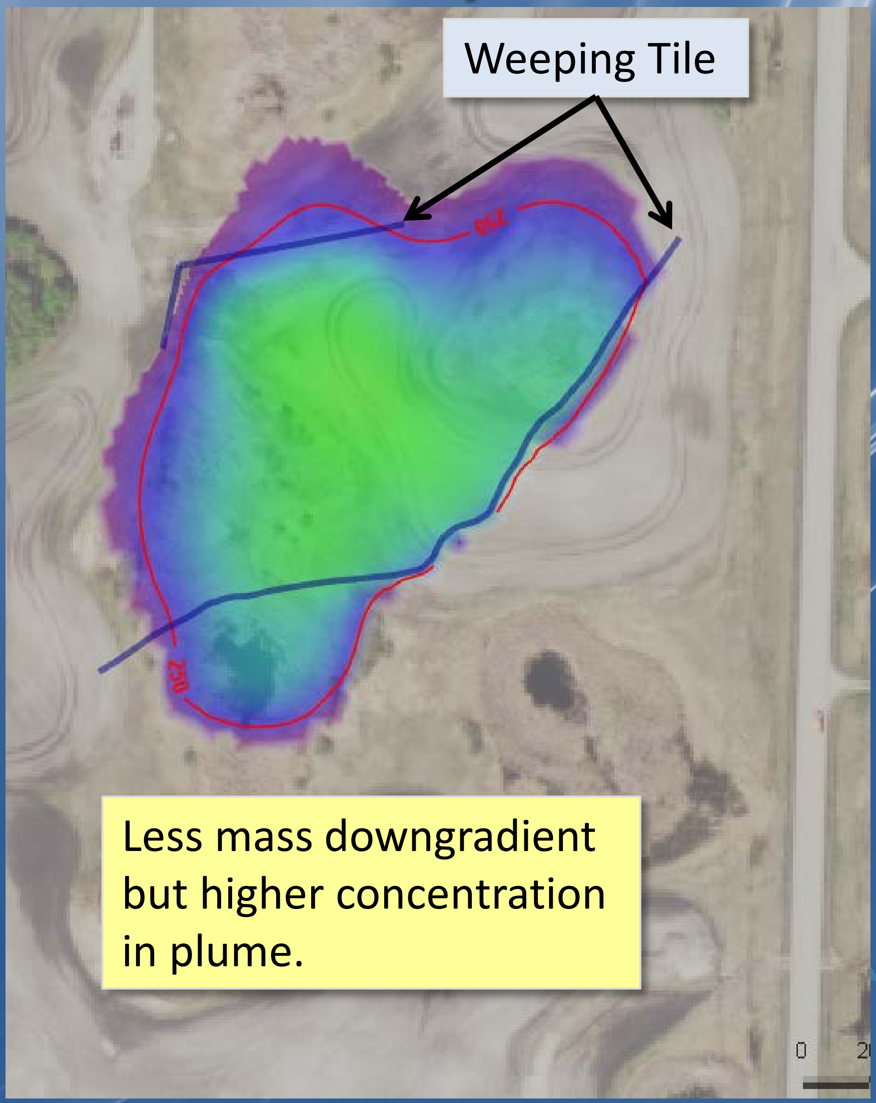






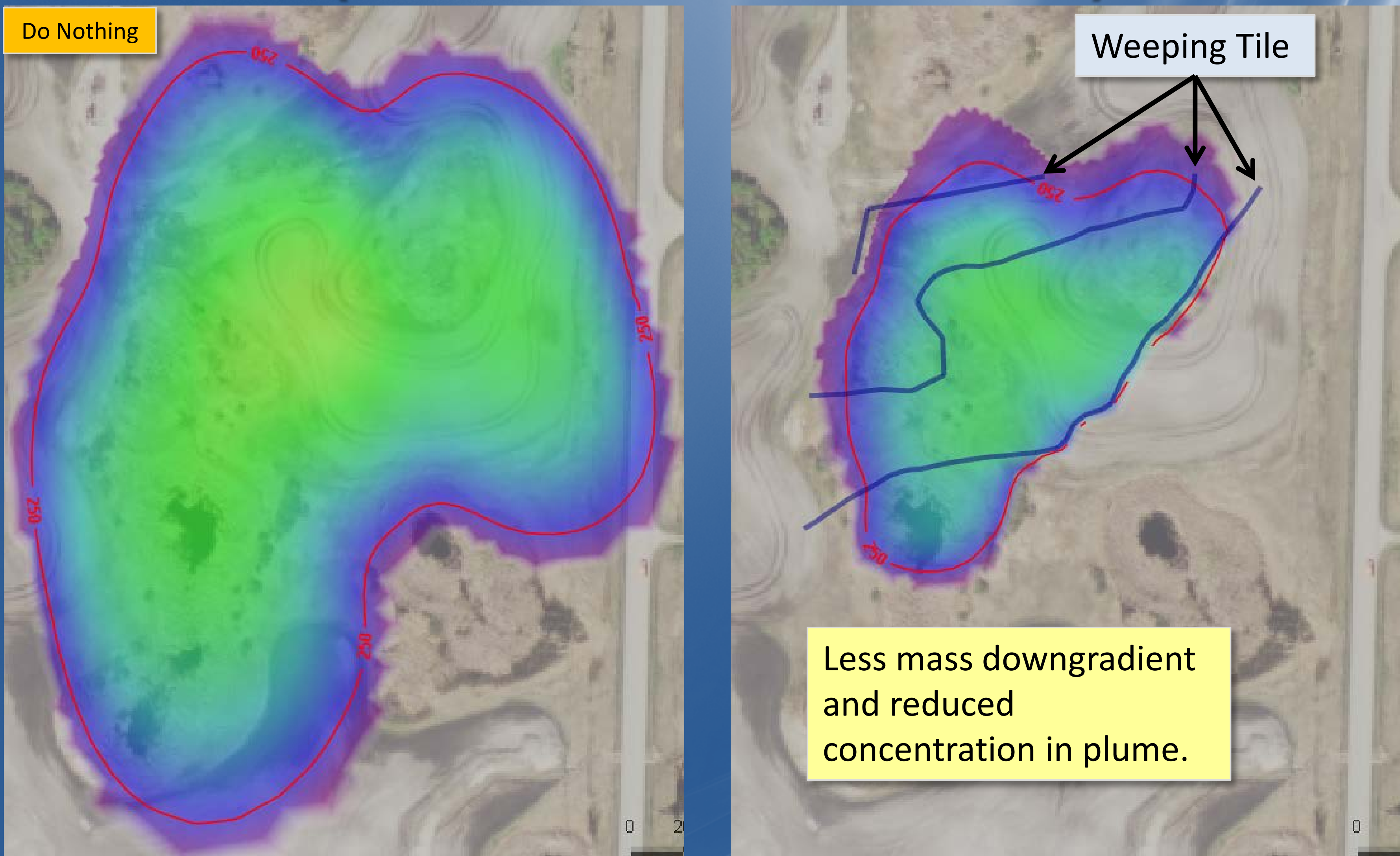
2 EXTRACTION TRENCHES (1 SOUTH OF PLUME)



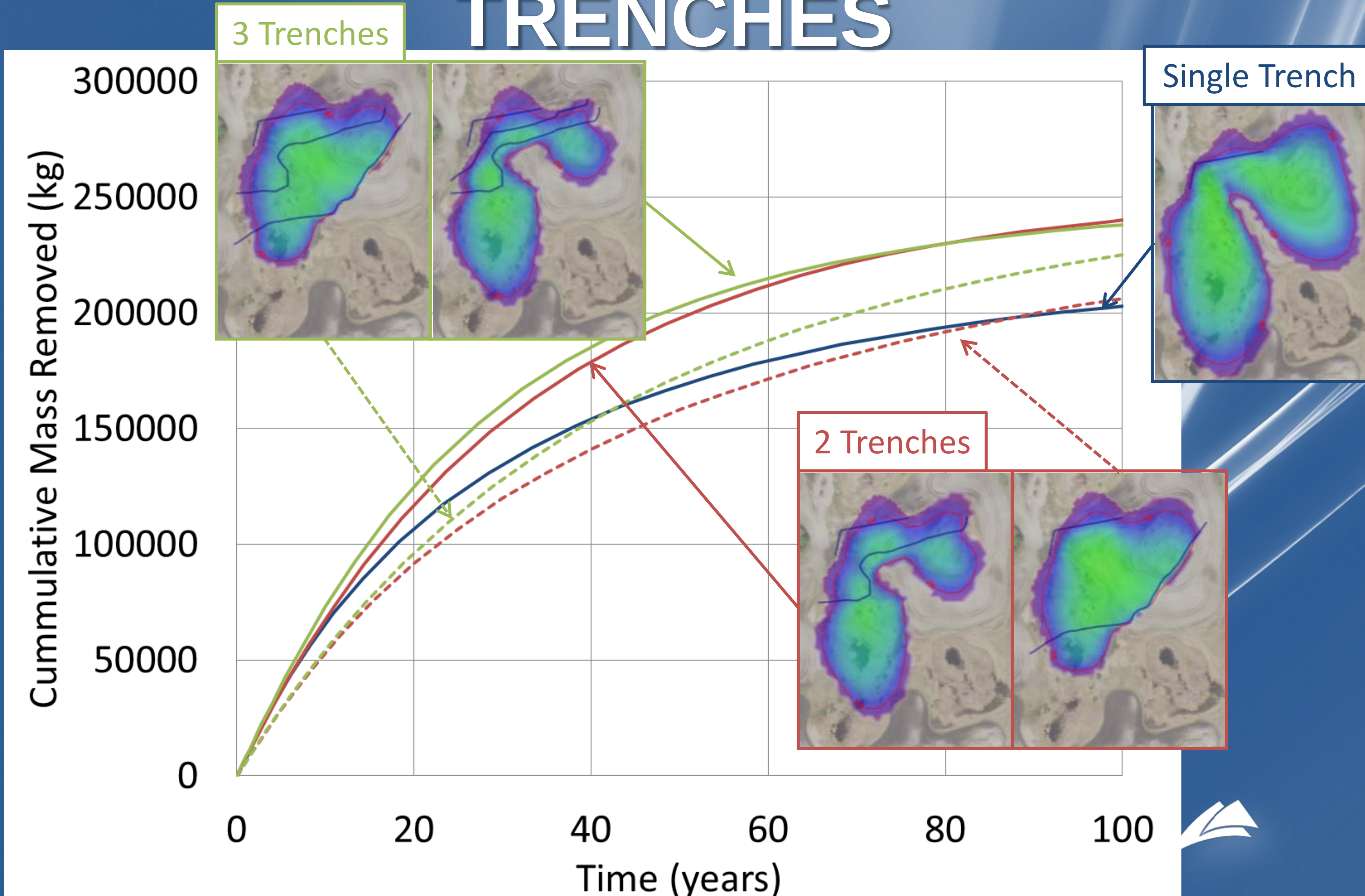


3 EXTRACTION TRENCHES (1 SOUTH OF PLUME)

Mass concentration
- Continuous -
[mg/l]
35000
10845.6
3360.79
1041.42
322.711
100



COMPARISON OF MULTIPLE TRENCHES



3A. ROOT ZONE EXCAVATION

Extraction of upper 1.5 m across footprint of impacted area.

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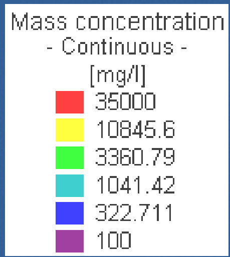
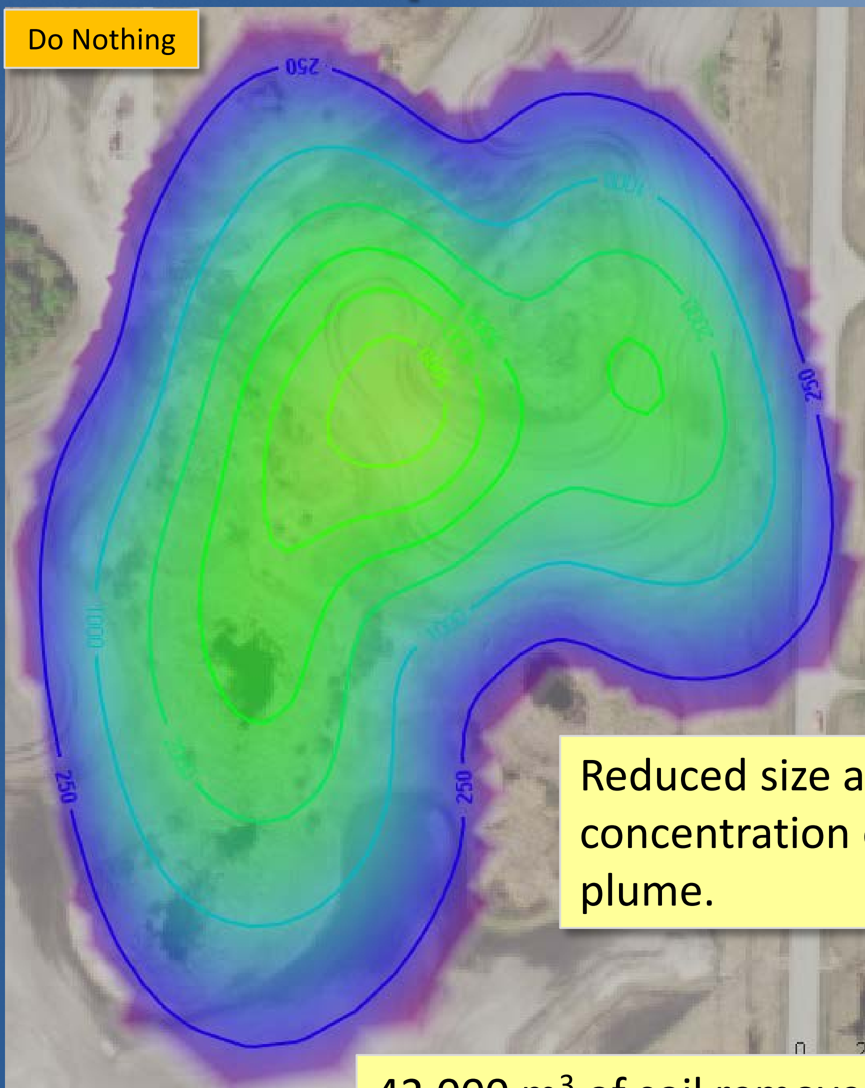
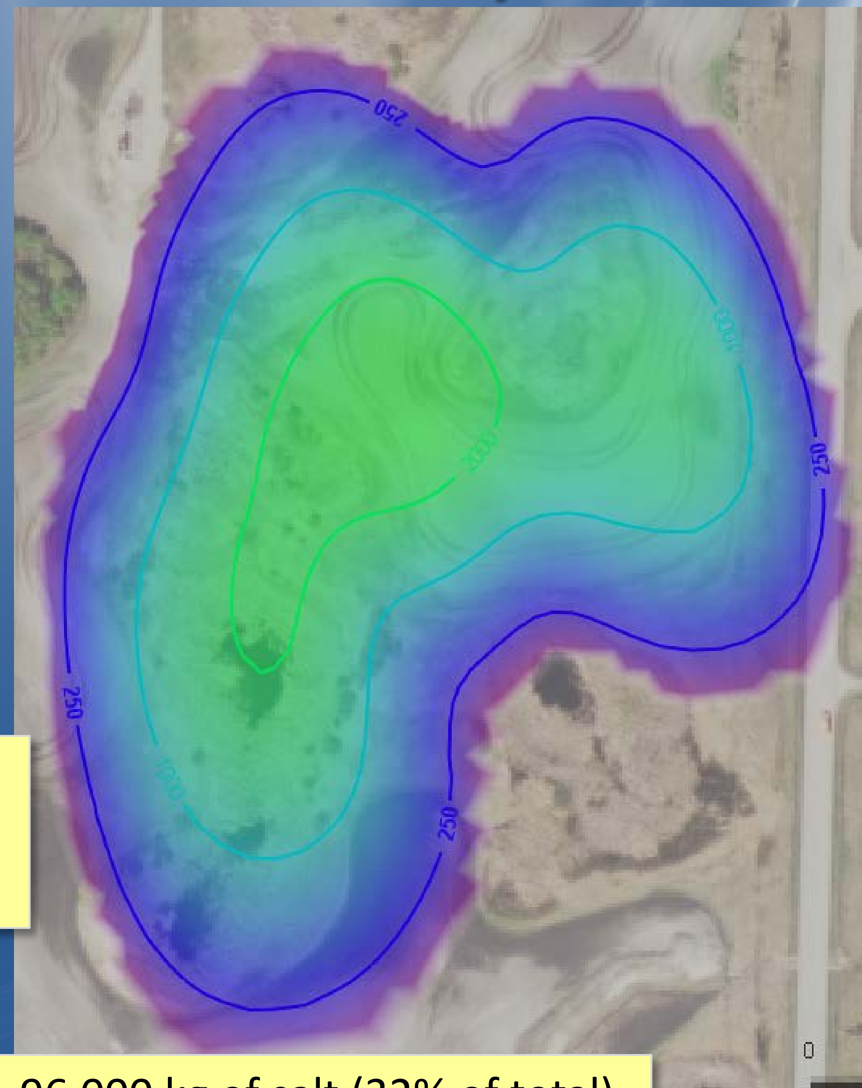


ROOT ZONE EXCAVATION (TOP 1.5 M OF PLUME)

Do Nothing

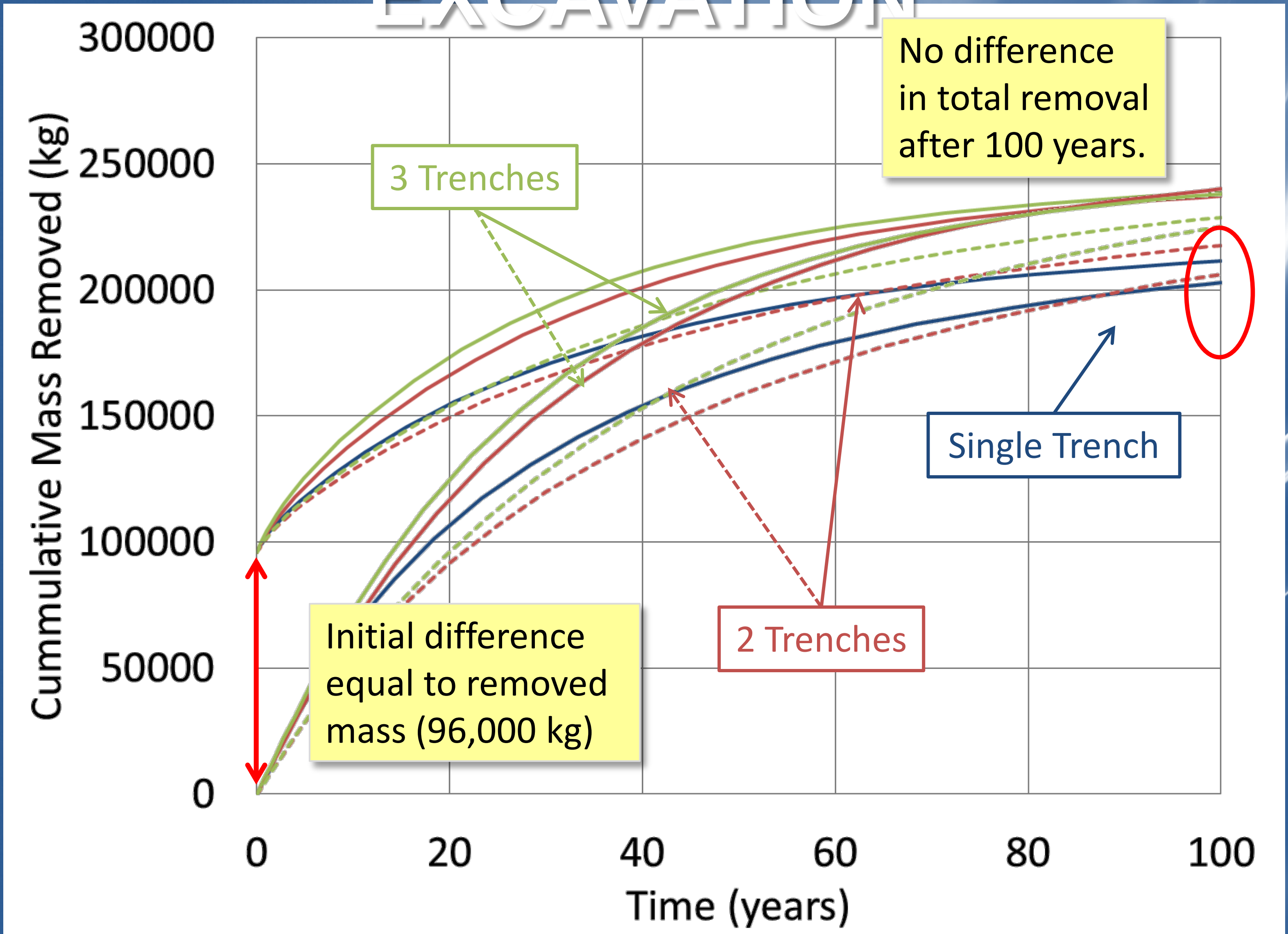




Reduced size and concentration of plume.

42,000 m^3 of soil removed = 96,000 kg of salt (32% of total)

COMPARISON OF ROOT ZONE EXCAVATION



4. EXTRACTION / RE-INFILTRATION

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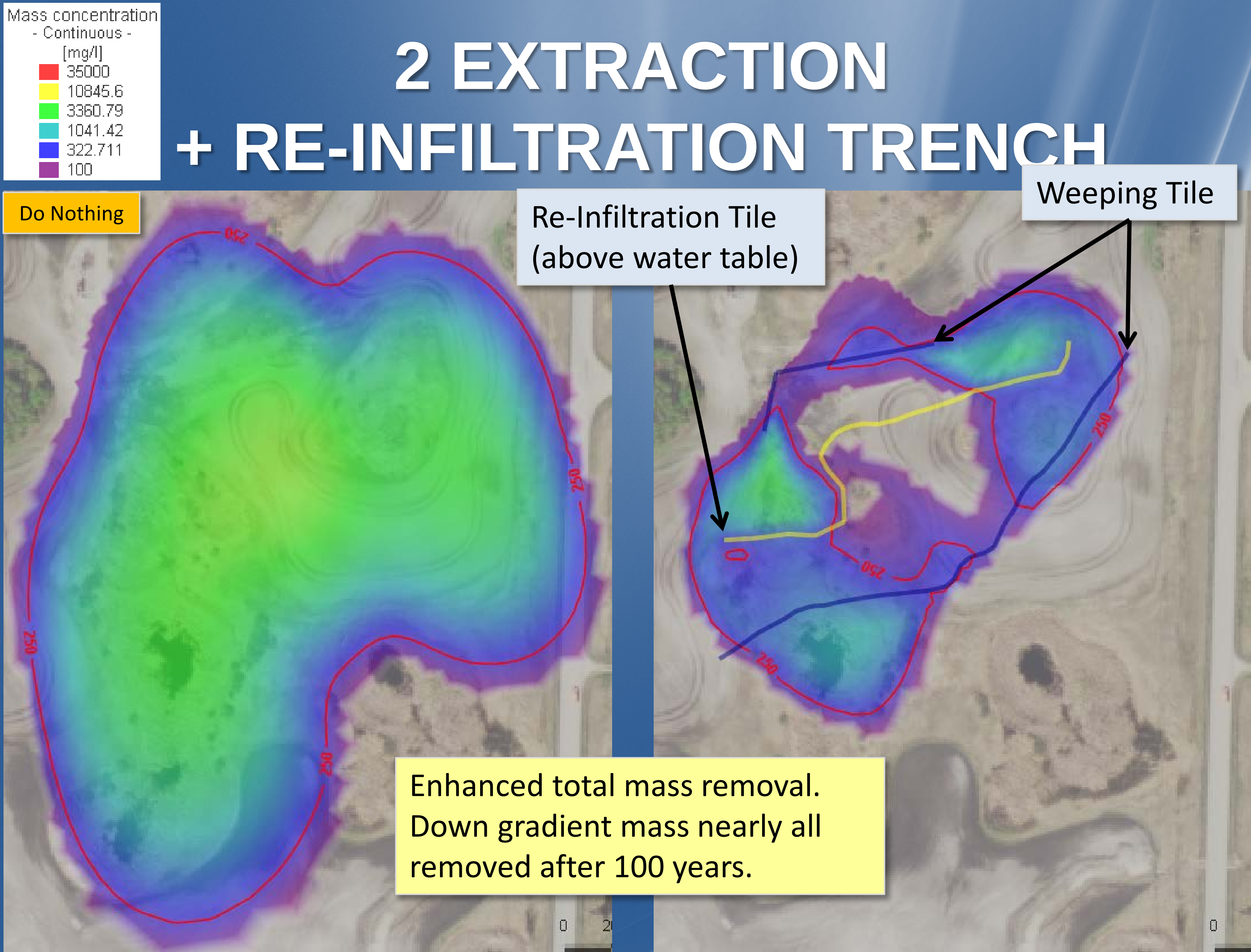
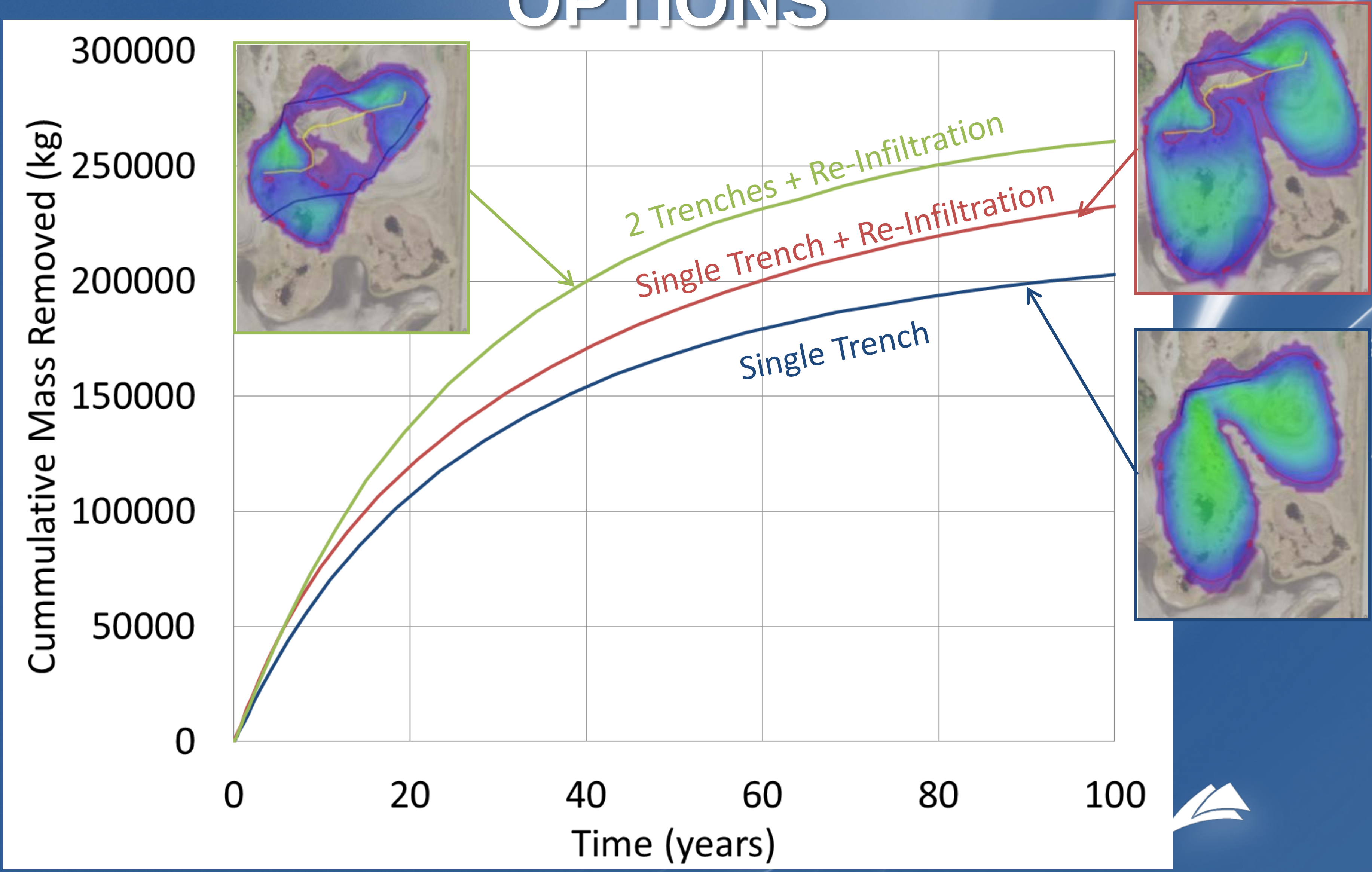
2 EXTRACTION + RE-INFILTRATION TRENCH



Enhanced total mass removal. Down gradient mass nearly all removed after 100 years.

COMPARISON OF RE-INFILTRATION OPTIONS



COST / BENEFIT ANALYSIS