Using Novel Geophysical Techniques to Relate Surface Coal Mining Fill Characteristics to Effluent Stream Quality

June 5, 2018 – Kathryn L. Little[1]
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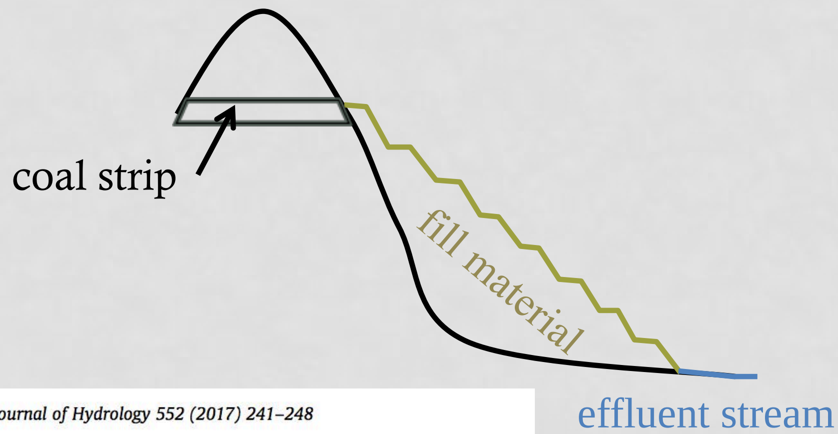
THE LEGACY OF SURFACE COAL MINES

- Coal mining in Appalachia
- Site reclamation
- Valley fills
- Hydrologic patterns
- Preferential flow



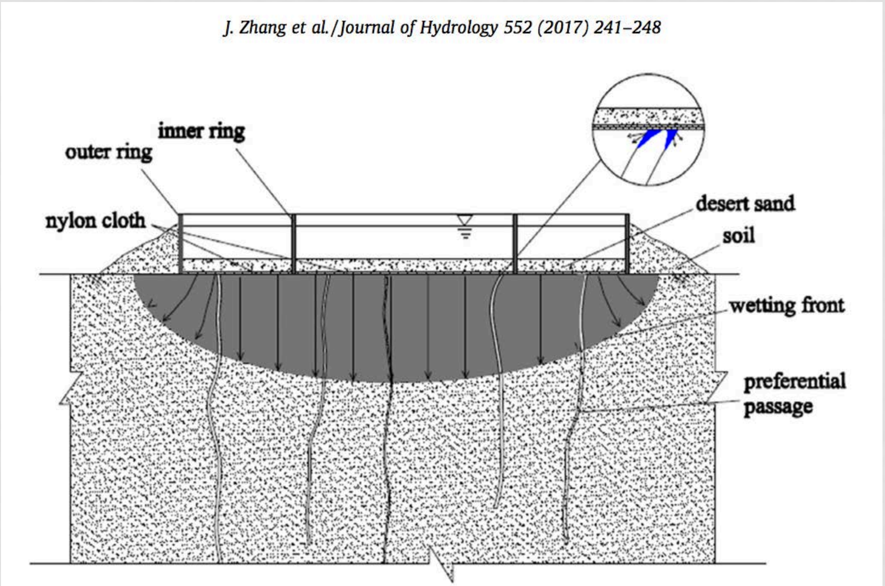


Fig. 1. Schematic of the theoretic concept to measure matrix infiltration.

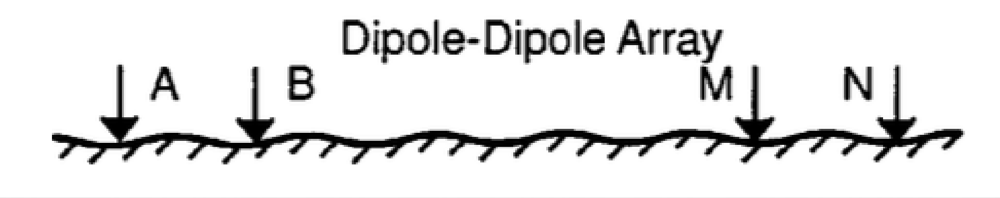
The Legacy of Surface Coal Mines

- Effluent streams - total dissolved solids (TDS)
  - Specific conductance (SC) as proxy

- How are different fill properties related to preferential flow and TDS?
  - Valley fill & drainage basin size
  - Age since reclamation/vegetation
  - Construction method

Electrical Resistivity Imaging

- Resistivity
- Electrodes



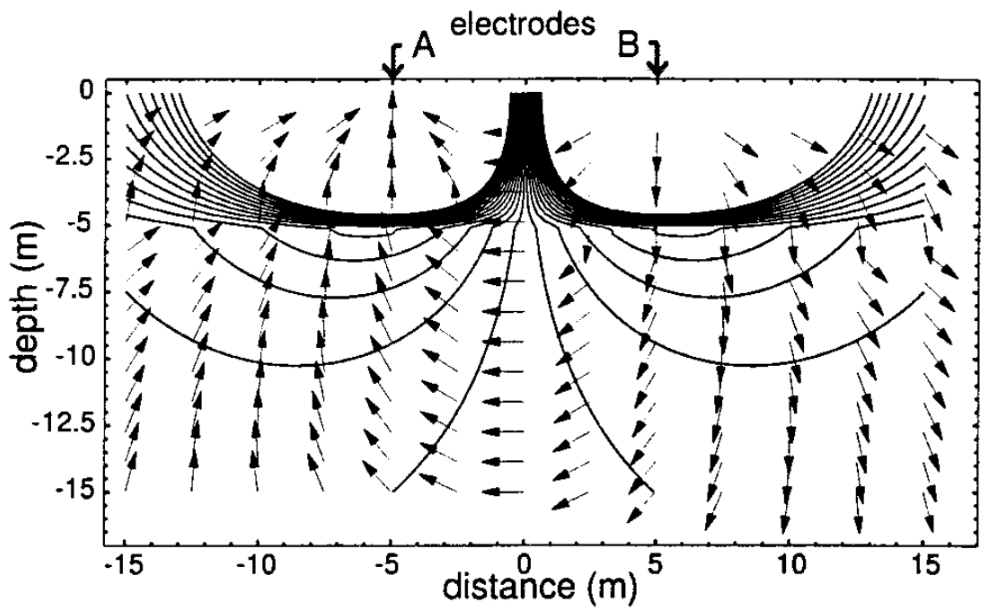


Fig. 3. Current flow and equipotential surfaces between two electrodes in a level field with inhomogeneous subsurface structure. The boundary between the two materials in this example is at a depth of $z = 5$ m.

$$R = \frac{\Delta V}{I}$$

Source: Herman, An introduction to electrical resistivity in geophysics (2001)

Electrical Resistivity Imaging

- Image underground coal mines
  - Das et al., Krishnamurthy et al.
- Infiltration and subsurface flow
  - Bass et al., Hübner et al., Scaini et al. – hillslopes
  - Clémence et al. – streambed
  - Fernández de Vera et al. – brownfield
  - Travelletti et al. – landslide site
- Infiltration on coal mine valley fills
  - Greer et al.

Objectives and Field Methods

Research Objectives

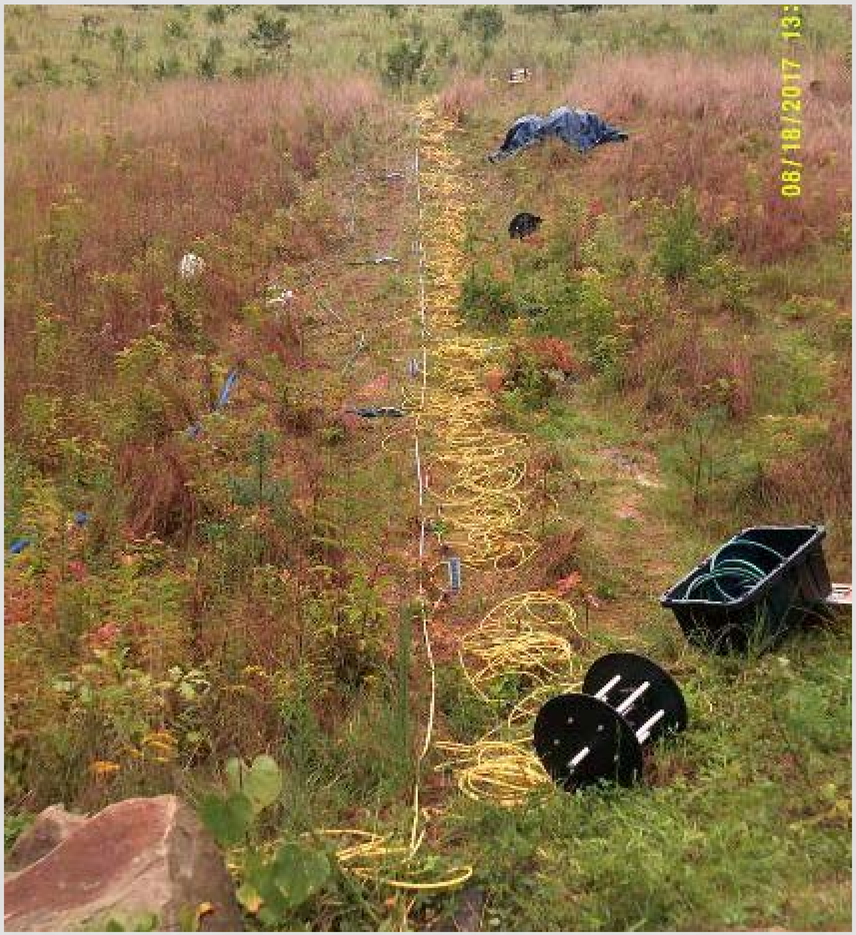
1) Survey and evaluate the variability of subsurface structure of a series of valley fills
2) Locate preferential flowpaths in the subsurface of valley fills
3) Estimate lengths, flow velocities, and transit times of flowpaths
4) Verify ERI result interpretations using conventional geophysical techniques

FIELD SITES

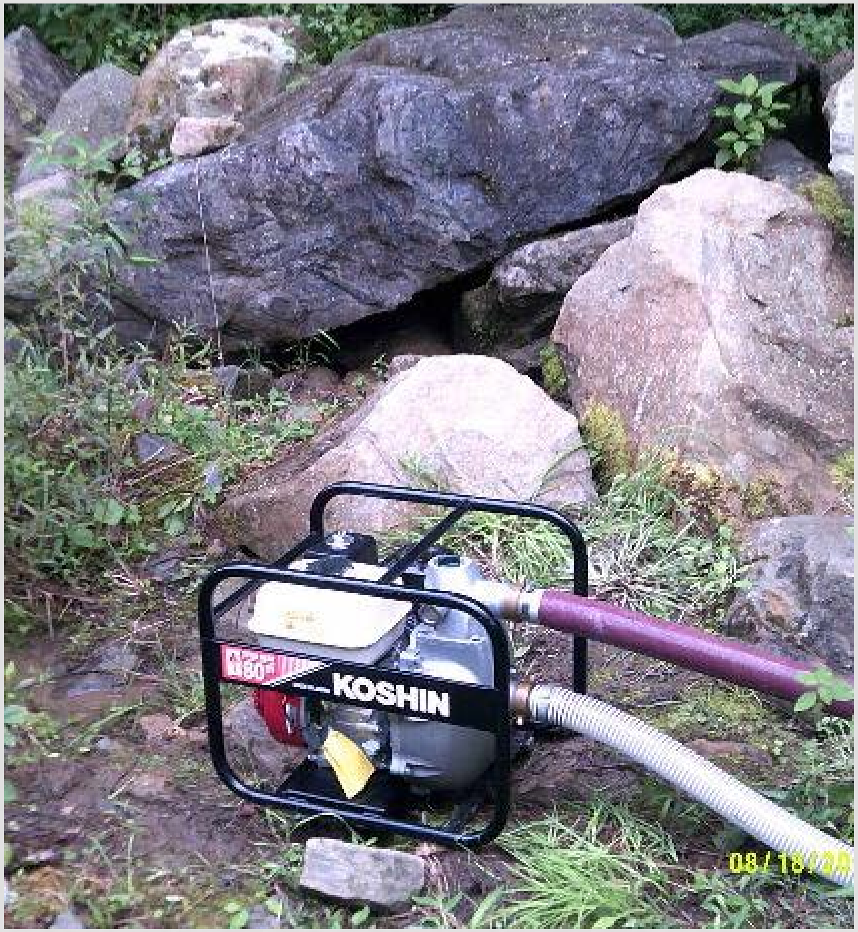
Fill	Age (yr)	Land Cover	Construction Method	Size (ha)
Bearwallow	10	mixed	loose-dump	large (15)
Office Fill	8	mixed	loose-dump	small (2.8)
End Fill	21	forest	loose-dump	small (2)
Barton Hollow	1	grass	experimental (thin lifts w/compaction)	medium (7)
Powell River (Greer et. al 2017)	6	grass	loose-dump	small-medium (4.5)

Source: Google Maps

Electrical Resistivity Imaging



Artificial Rainfall



Results

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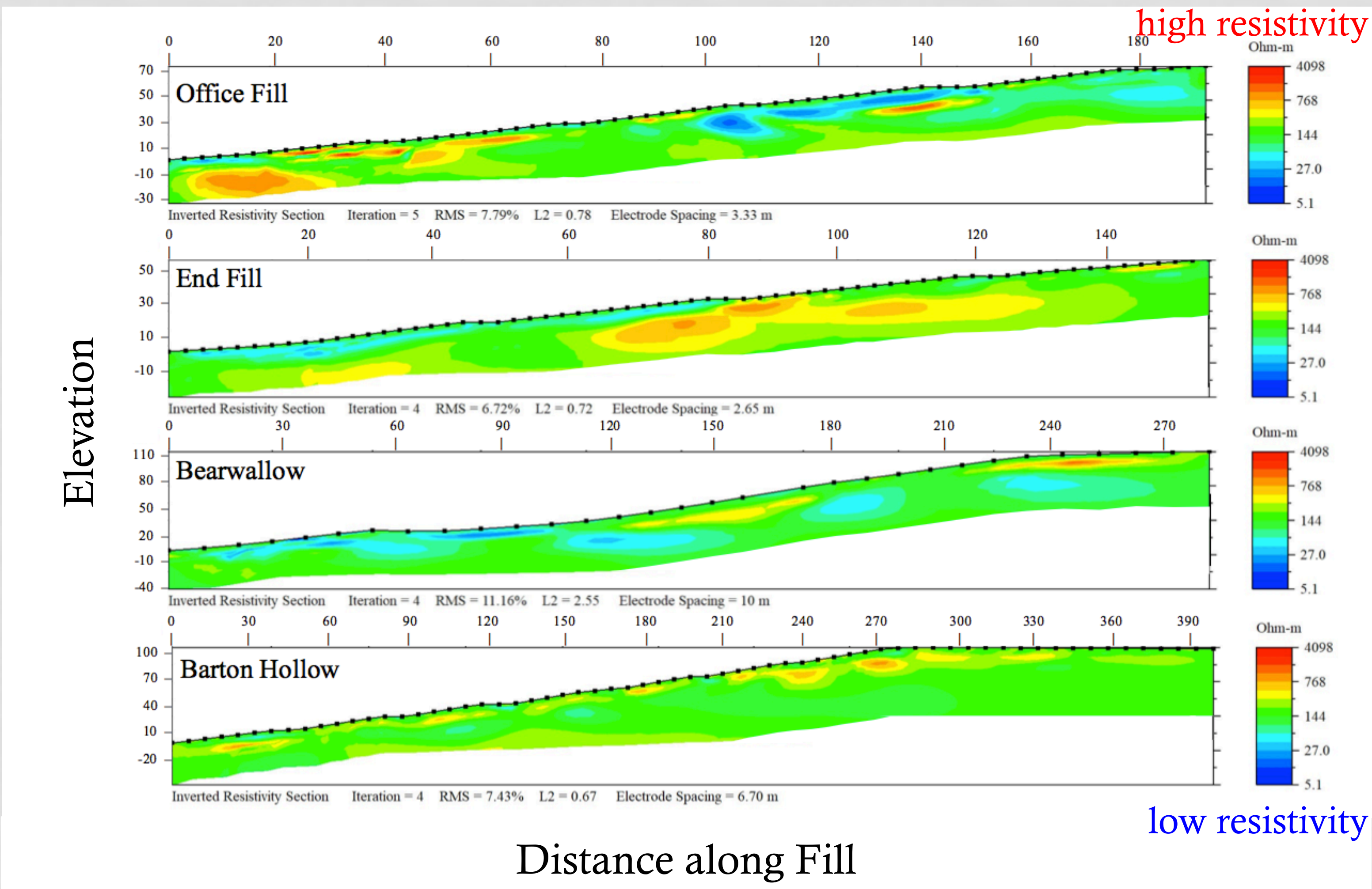
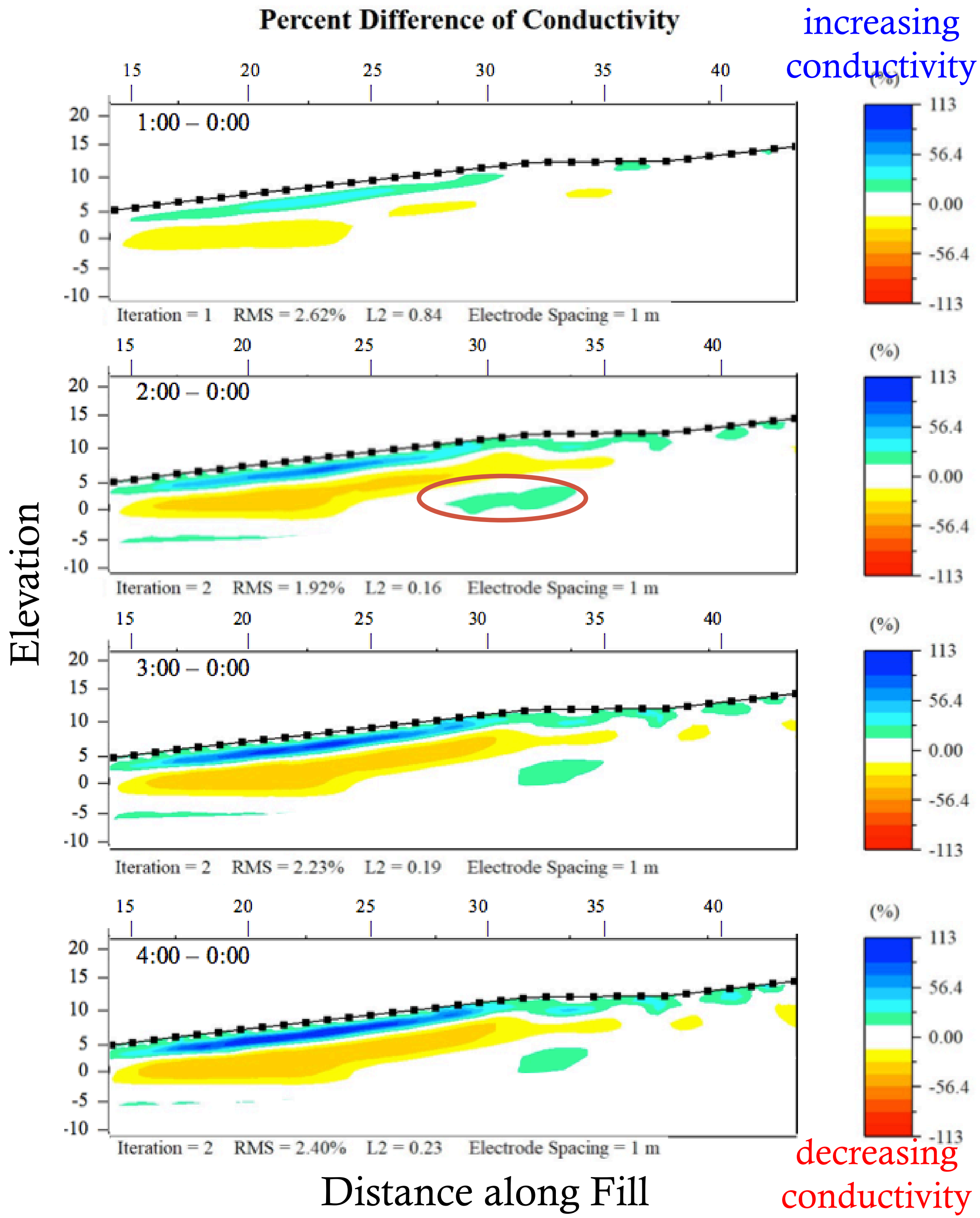
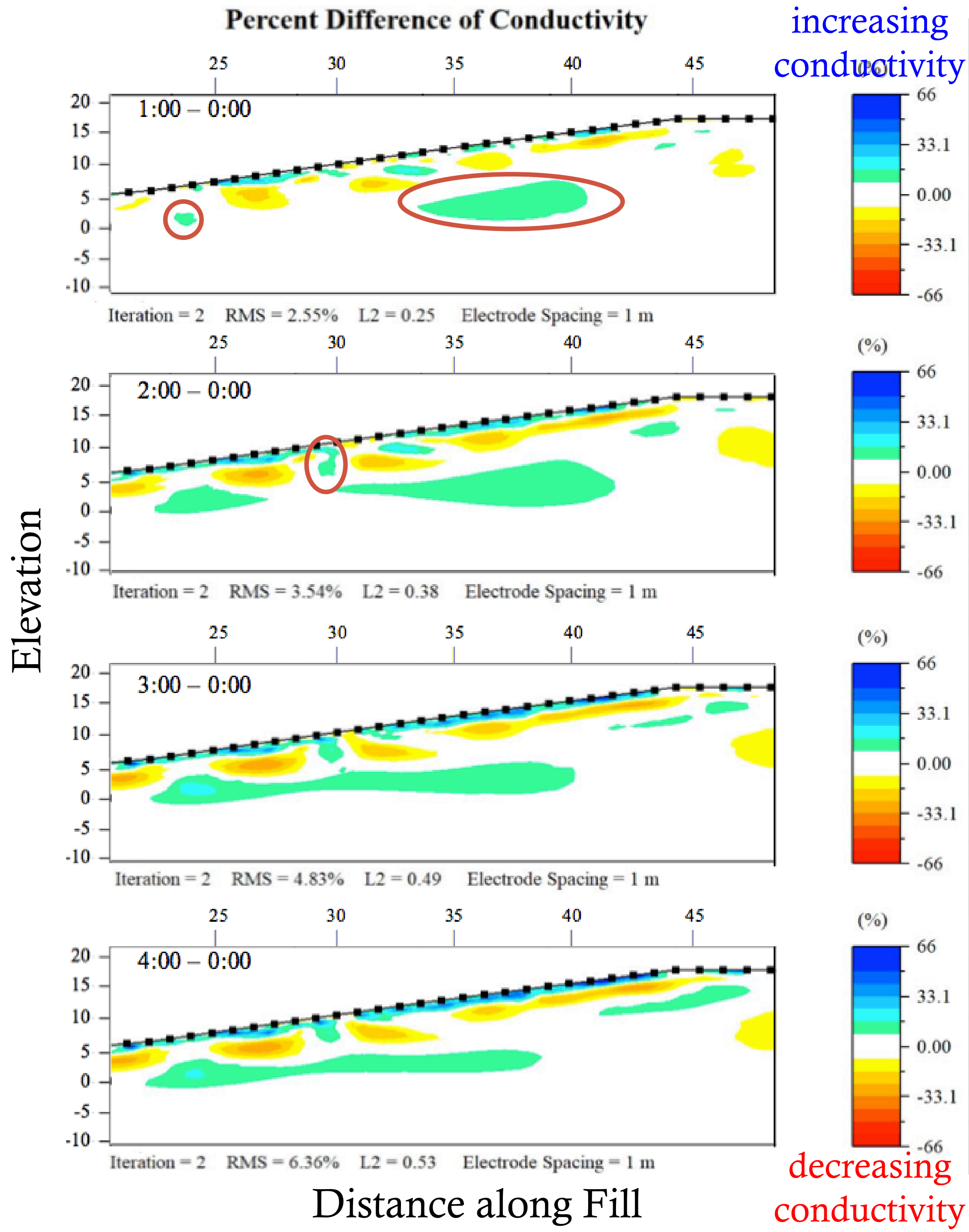
LONG DRY SURVEYS





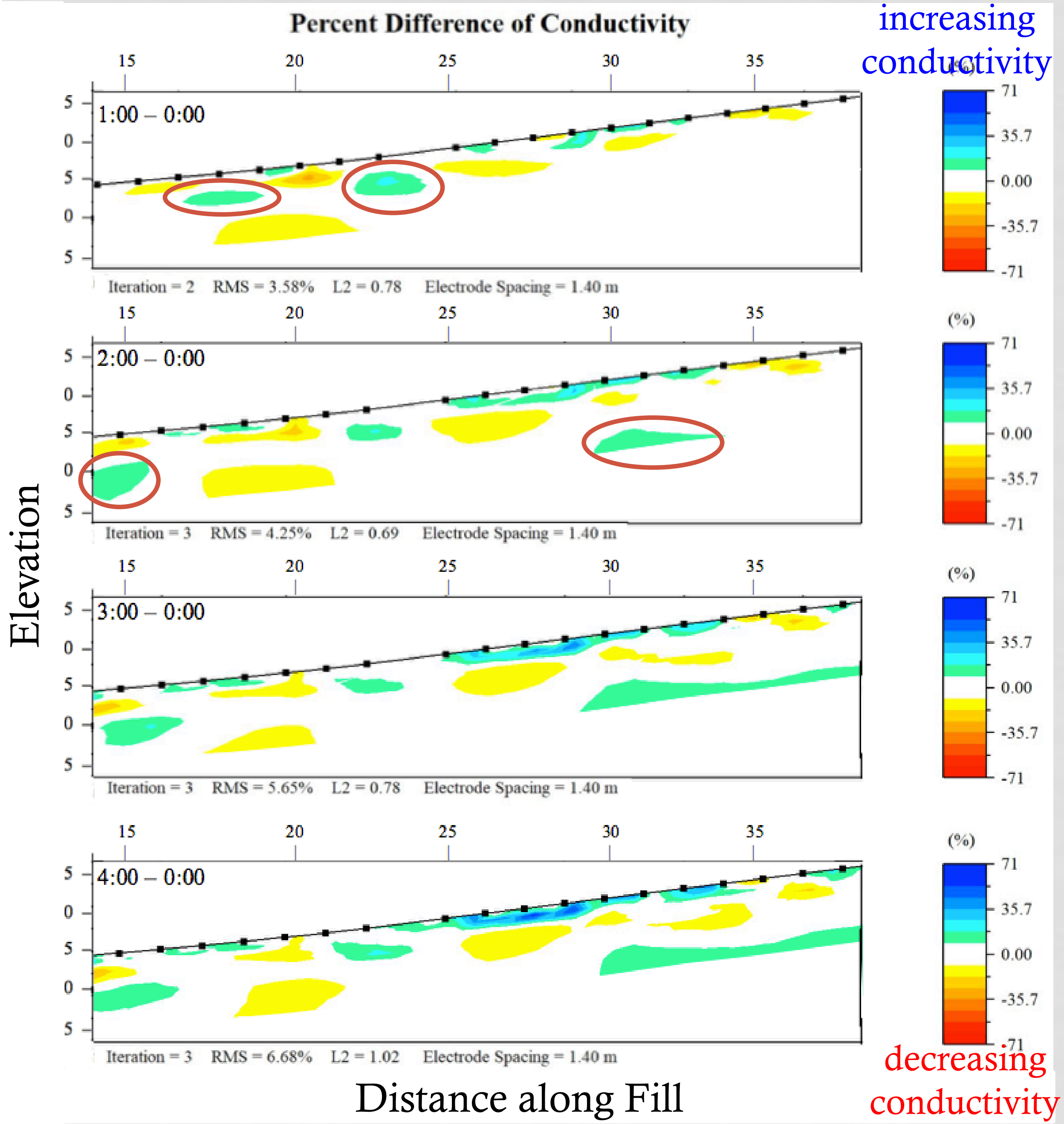
OFFICE FILL

- Layer of increasing conductivity
- Accumulation zone – 33 m



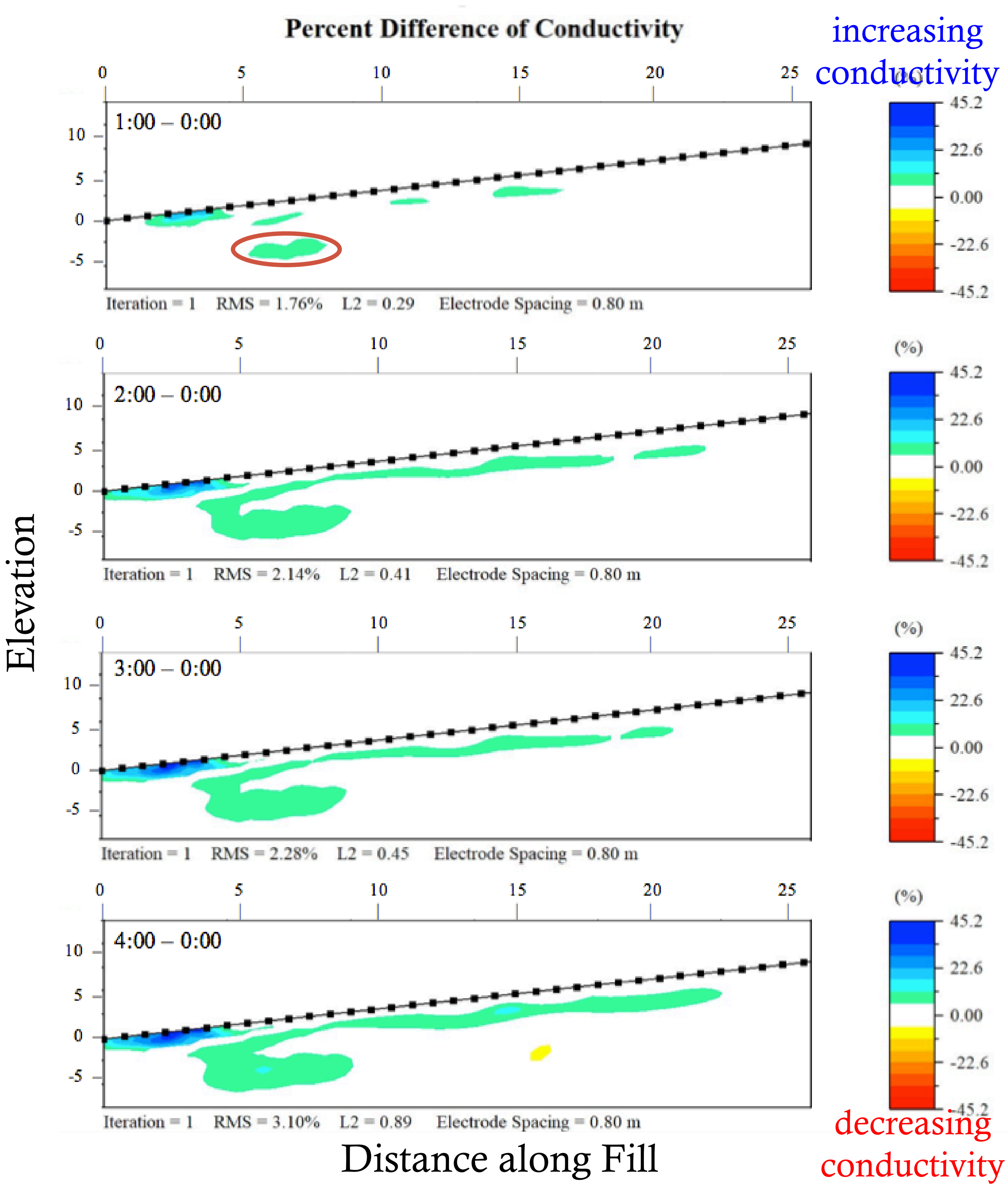
END FILL

- Similar shallow blue regions
- Possible visible vertical flowpath – 30 m
- Accumulation zones – 24 m and 37 m



Bearwallow

- Limited shallow accumulation
- Accumulation zones – 23 m, 17.5 m, 32 m, and 15.5 m



Barton Hollow

- Most conductivity increases within a few meters of surface
- Fewer accumulation zones (7 m)
  - Construction method?
  - Vegetation?

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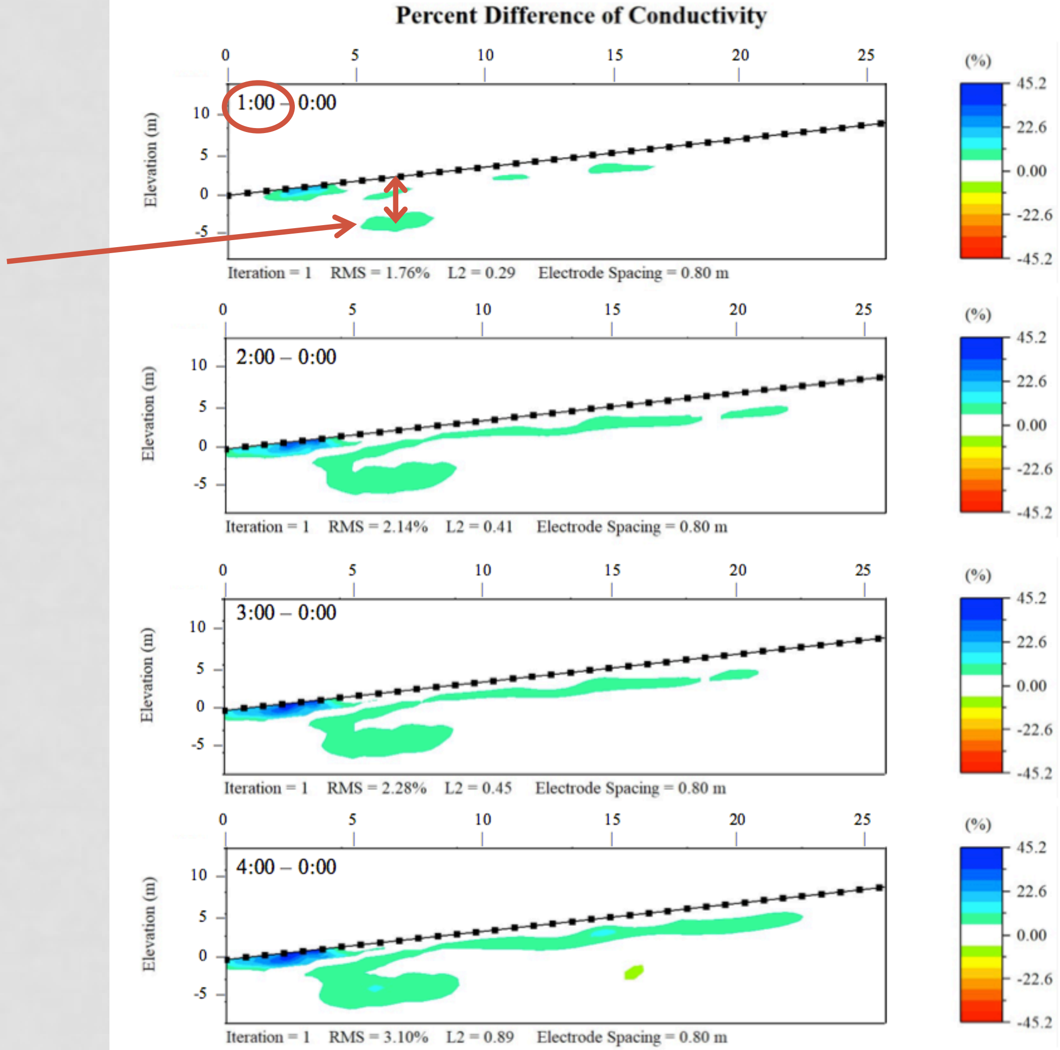
FLOWPATH PROPERTIES



Flowpath Properties

Fill (Figure)	Horizontal Location (m)	Time to First Appearance, or Flowpath Transit Time (h)	Approximate Vertical Depth from Surface, or Flowpath Length (m)	Approximate Linear Water Velocity along Flowpath (m/h)
Office Fill	33.0	2	10.5	5.25
End Fill	23.5	1	5.5	5.5
End Fill	37.0	1	10.5	10.5
Bearwallow	23.0	1	3.5	3.5
Bearwallow	17.5	1	3.0	3.0
Bearwallow	32.0	2	9.0	4.5
Bearwallow	15.5	2	5.0	2.5
Barton Hollow	7.0	1	6.0	6.0
Average		**1.4**	**6.6**	**5.1**

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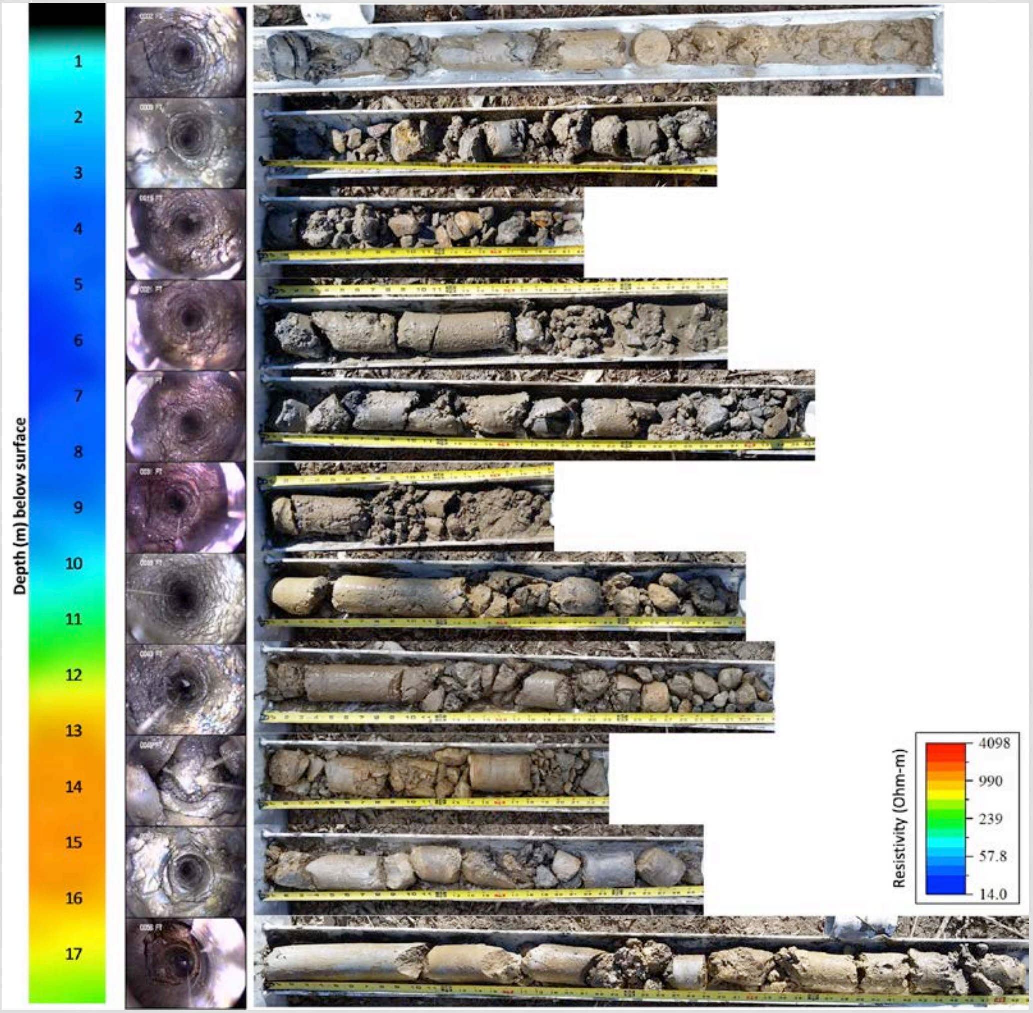
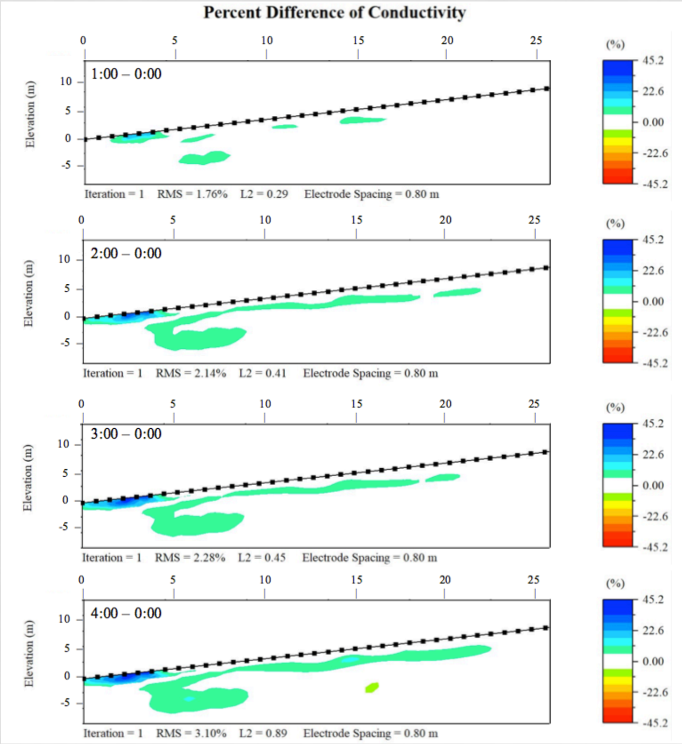
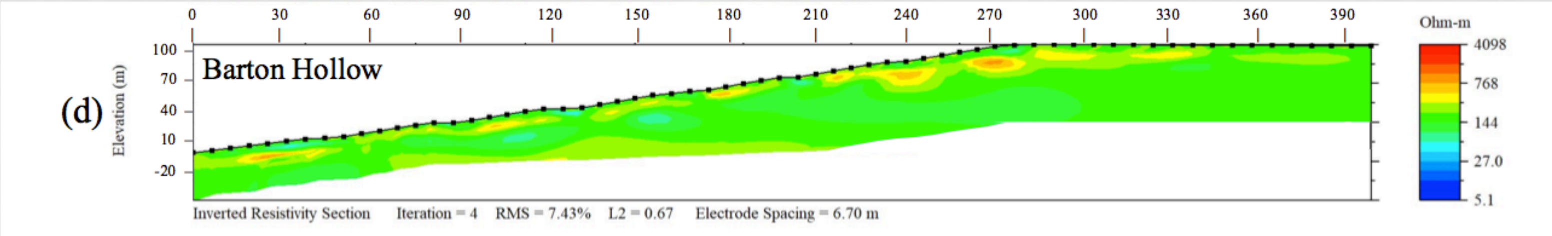
Verification: Borehole



FINDINGS

- Significant variation among fills
- Preferential flowpaths
- Borehole observations corroborate ERI interpretations





Future Study Suggestions

- Future fill designs
  - Thin-lift with compaction, like Barton Hollow
  - New experimental designs
- ERI of new experimental fills
- Comparison of two similar fills differing only in construction method
- Rainfall experiments at high temporal resolution

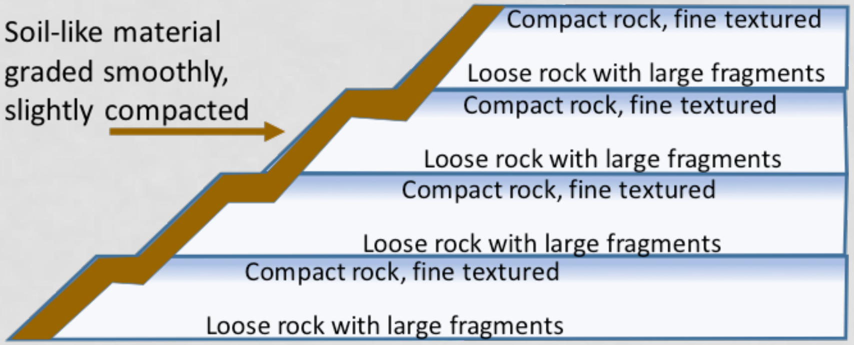
Thank You to…

- Dr. Erich Hester, Dr. Tom Burbey, Dr. Carl Zipper, and Dr. Mark Widdowson for support and direction; Virginia Tech
- Joe Buckwalter for project collaboration
- Dylan Honardoust for field assistance
- Breeyn Greer for field guidance
- OSMRE
- ASMR
- Mining company engineers, AGI
- You for your attention and questions!

Sources: www.osmre.gov,
www.facebook.com/AmericanSocietyMiningReclamation/

REFERENCE MATERIAL

Independent Variable	Dependent Variable	R^2
Fill area (ha)	Transit time (h)	0.12
Fill area (ha)	Flowpath length (m)	0.20
Fill area (ha)	Flowpath velocity (m/h)	0.52
Drainage area (ha)	Transit time (h)	0.01
Drainage area (ha)	Flowpath length (m)	0.06
Drainage area (ha)	Flowpath velocity (m/h)	0.01
Age (yr)	Transit time (h)	0.00
Age (yr)	Flowpath length (m)	0.03
Age (yr)	Flowpath velocity (m/h)	0.03
Fill area (ha)	Mean SC (µS/cm)	0.00
Drainage area (ha)	Mean SC (µS/cm)	0.11
Age (yr)	Mean SC (µS/cm)	0.03
Transit time (h)	Mean SC (µS/cm)	0.41
Flowpath length (m)	Mean SC (µS/cm)	0.04
Flowpath velocity (m/h)	Mean SC (µS/cm)	0.15

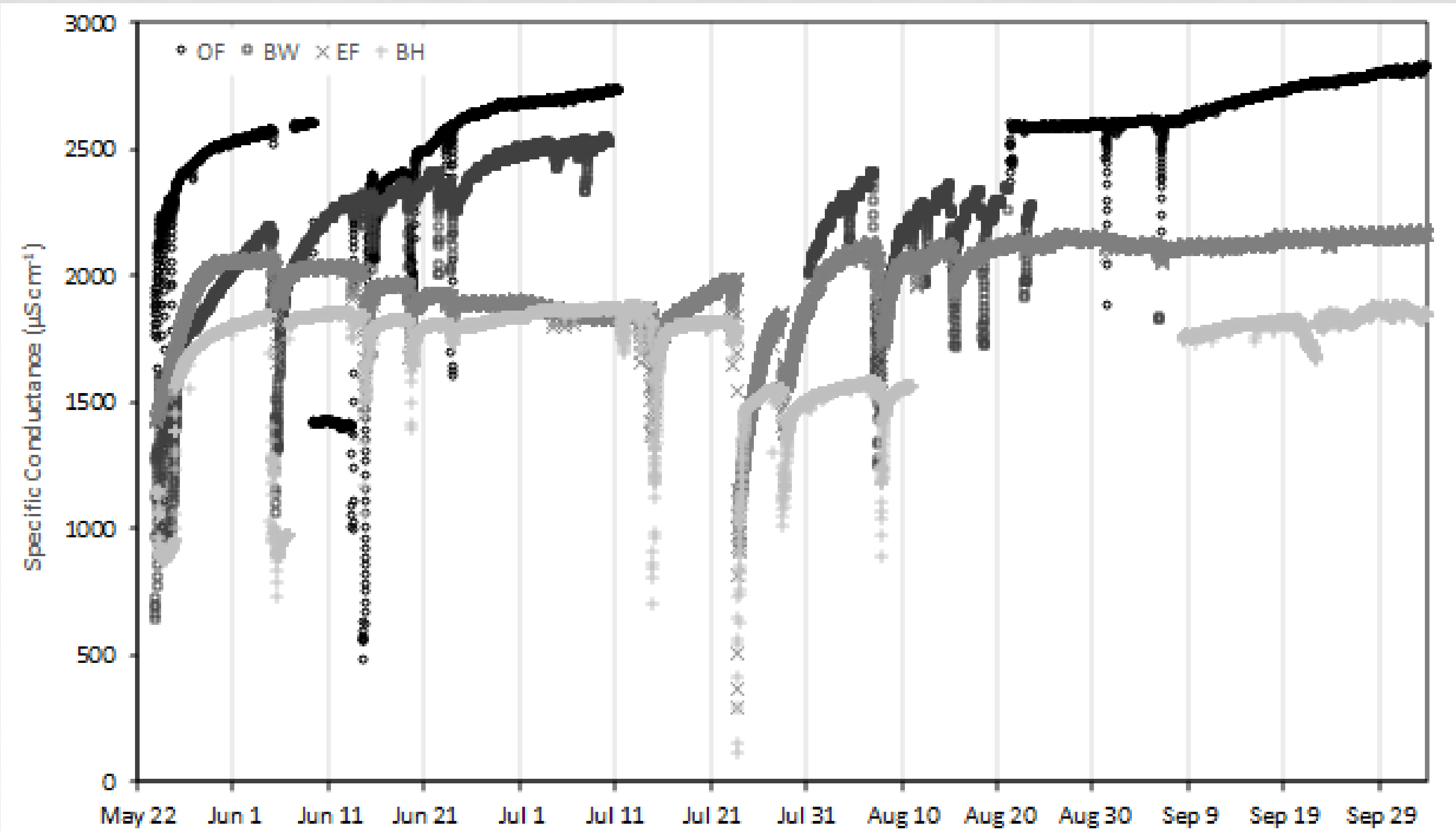


Reference Material

Date	Fill	Transect Length (m)	Electrode Spacing (m)	Days since Last Rainfall*
06/12/2017	Barton Hollow	422.1	6.7	7
07/12/2017	Office Fill	210	3.33	6
08/25/2017	End Fill	167	2.65	2
10/03/2017	Bearwallow	310	10.0	19

Date	Fill	Transect Length (m)	Electrode Spacing (m)	Length of Fire Hose (m)	Total Length of Garden Hose (all branches, m)	Average Rainfall Intensity (cm/h)	Days since Last Rainfall*	Average SC of Pumped Water* (µS/cm)
08/18/2017	Barton Hollow	50.4	0.8	45.7	17	1.04	2	1519
08/21/2017	Office Fill	63	1.0	30.5	17	1.04	3	2508
08/26/2017	End Fill	63	1.0	83.8	17	1.12	3	2151
09/22/2017	Bearwallow	43.4	1.4	45.7	18.8	2.82	8	988

Reference Material



Reference Material