Oak Ridge National Laboratory

The Use of Terrestrial Laser Scanning to Assess the Mobilization of Contaminated Creekbank Soils in Oak Ridge, Tennessee

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Contents

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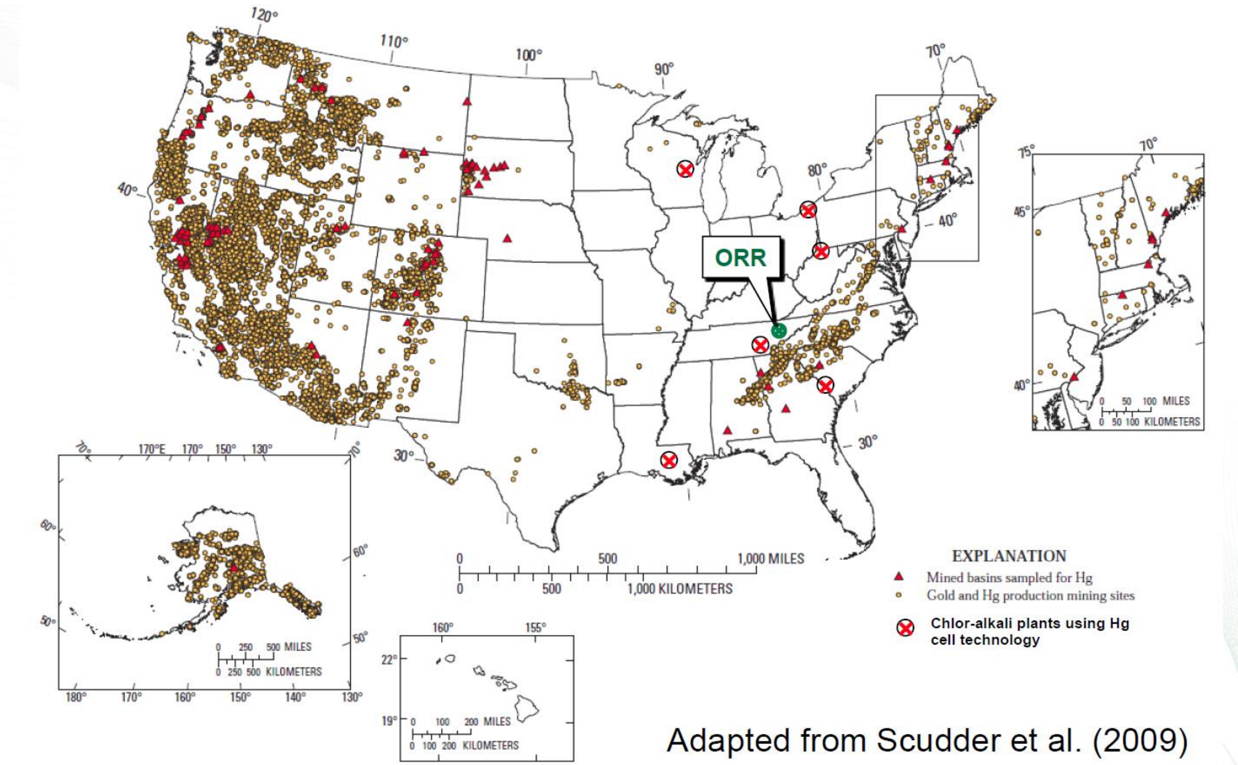
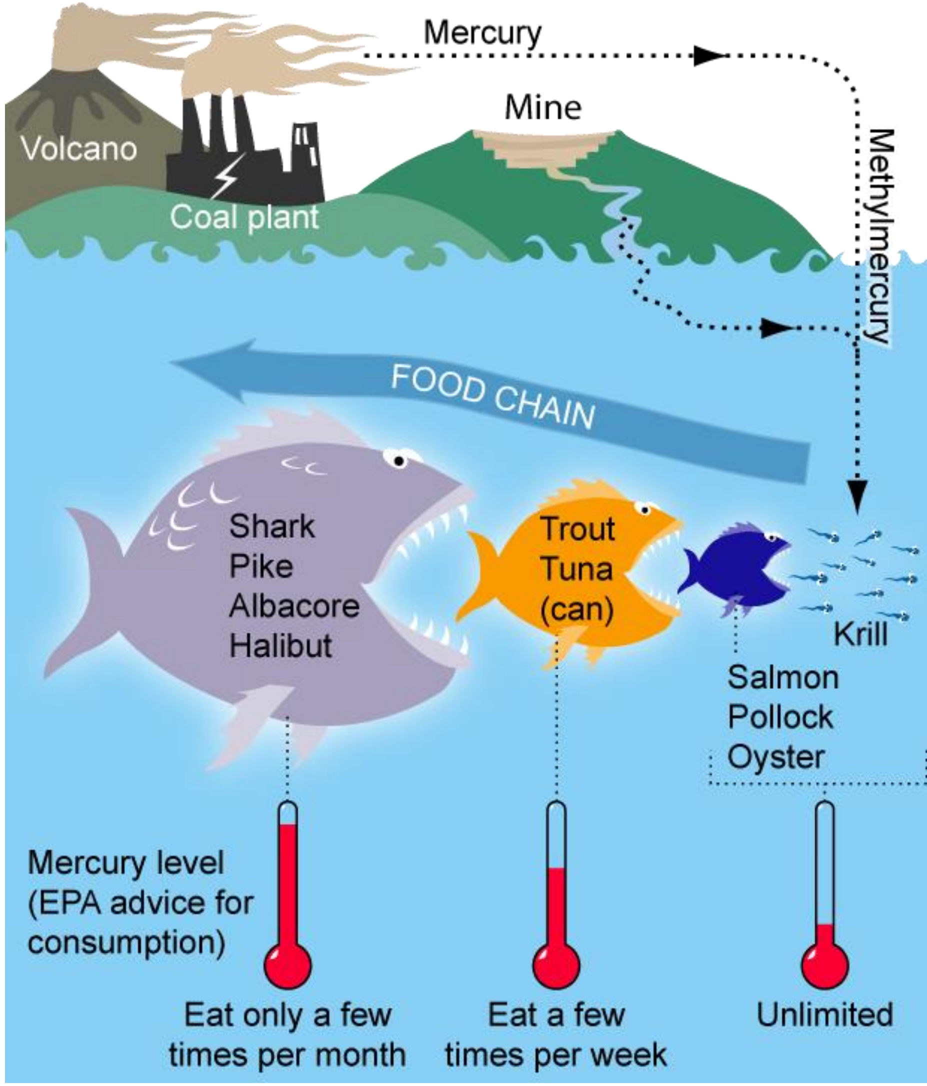
Mercury: A legacy pollutant

- Sources include natural (volcanoes) and anthropogenic
- Toxic on its own, anaerobic bacteria can methylate
  - Component of periphyton and sediments
- Strong biomagnification (100 million x)
- Why mercury in Oak Ridge?



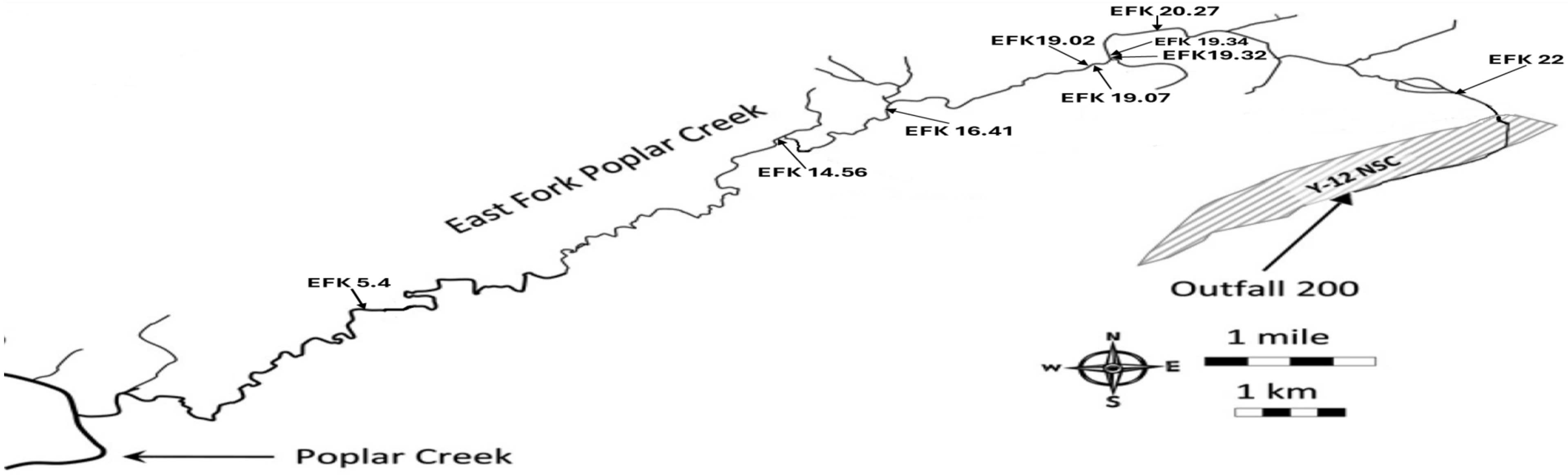
Adapted from Scudder et al. (2009)



EPA, 2017

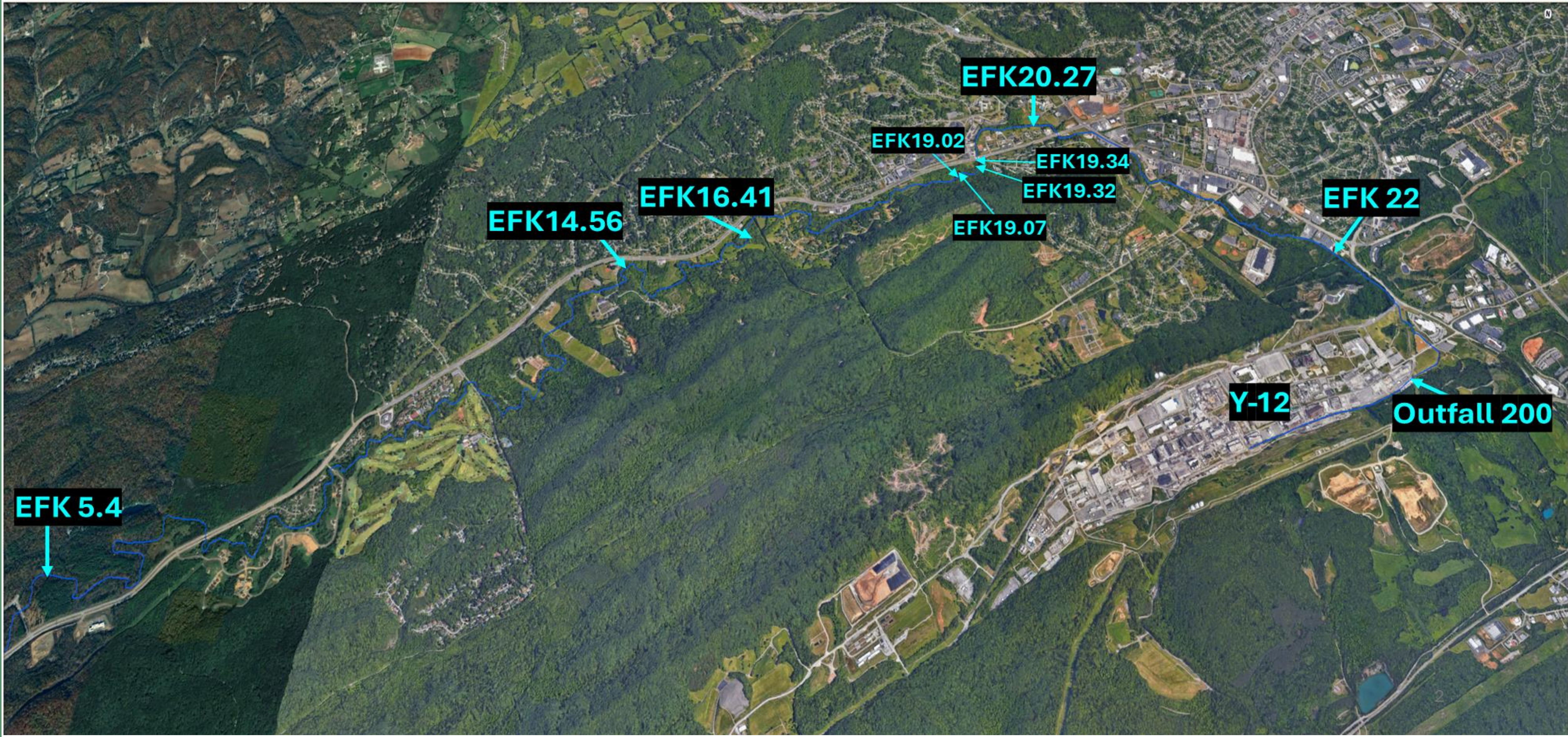
History of Mercury Pollution

- 11 million kilograms used in production at Y-12
- ~350,000 kg lost,128,000 discharged, 85% incorporated
- East Fork Poplar Creek
- Regulatory parameters (TDEC:51 ng/L, 200 ng/L Hg in water)
- 9 field sites designated by km from confluence of creek (EFK)



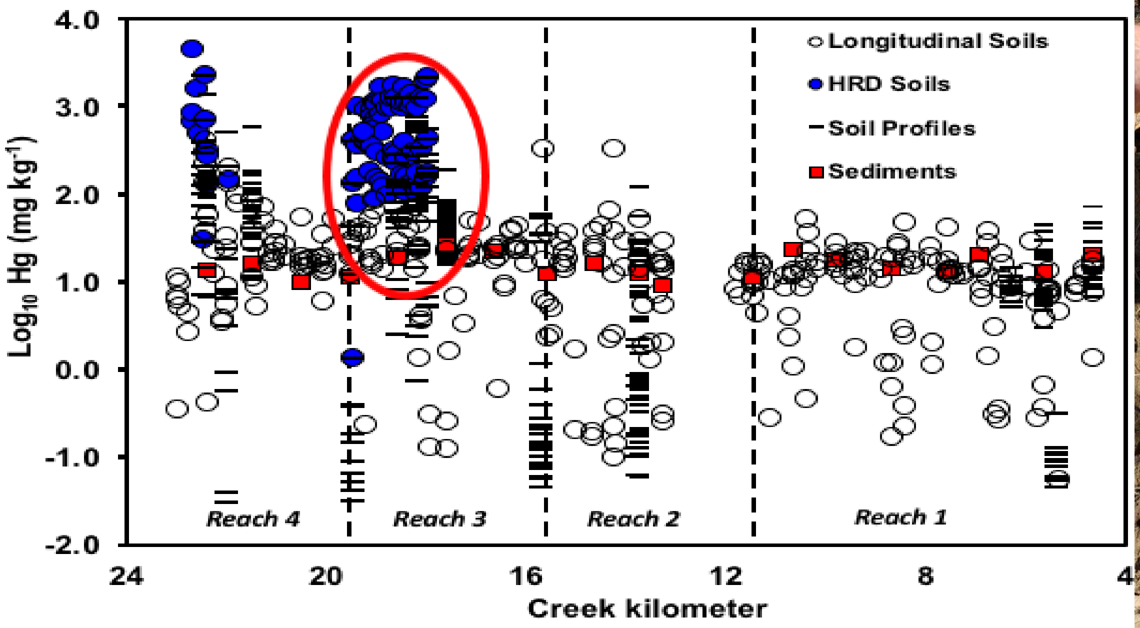
Brooks, S. C. and G. R. Southworth. History of mercury use and environmental contamination at the Oak Ridge Y-12 Plant. Environmental Pollution. 159 (2011)

Overhead of Scan sites



Soil and sediment contamination and project terminology

- EFPC bank soil analysis taken
- Average of 126.39 mg/kg Hg and 5.38 µg/kg MeHg in soils
  - Historical Release Deposit (HRD), EFK17.5-19.3
  - 4590 mg/kg Hg and 60.48 µg /kg MeHg in the HRD layer
- Total Hg in sediment down 67% since 1984, trend is slowing
- But mercury still being added to creek from erosion



Dickson, J. O., Mayes, M. A., Brooks, S. C., Mehlhorn, T. L., Lowe, K. A., Earles, J. K., Goñez-Rodriguez, L., Watson, D. B., & Peterson, M. J. (2019). Source relationships between streambank soils and streambed sediments in a mercury-contaminated stream. *Journal of Soils and Sediments*, *19*(4), 2007–2019. https://doi.org/10.1007/s11368-018-2183-0

Goals and Objectives

Goals

- Identify erosion and mercury flux trends in EFPC
- Understand erosion dynamics to assess remediation allocation

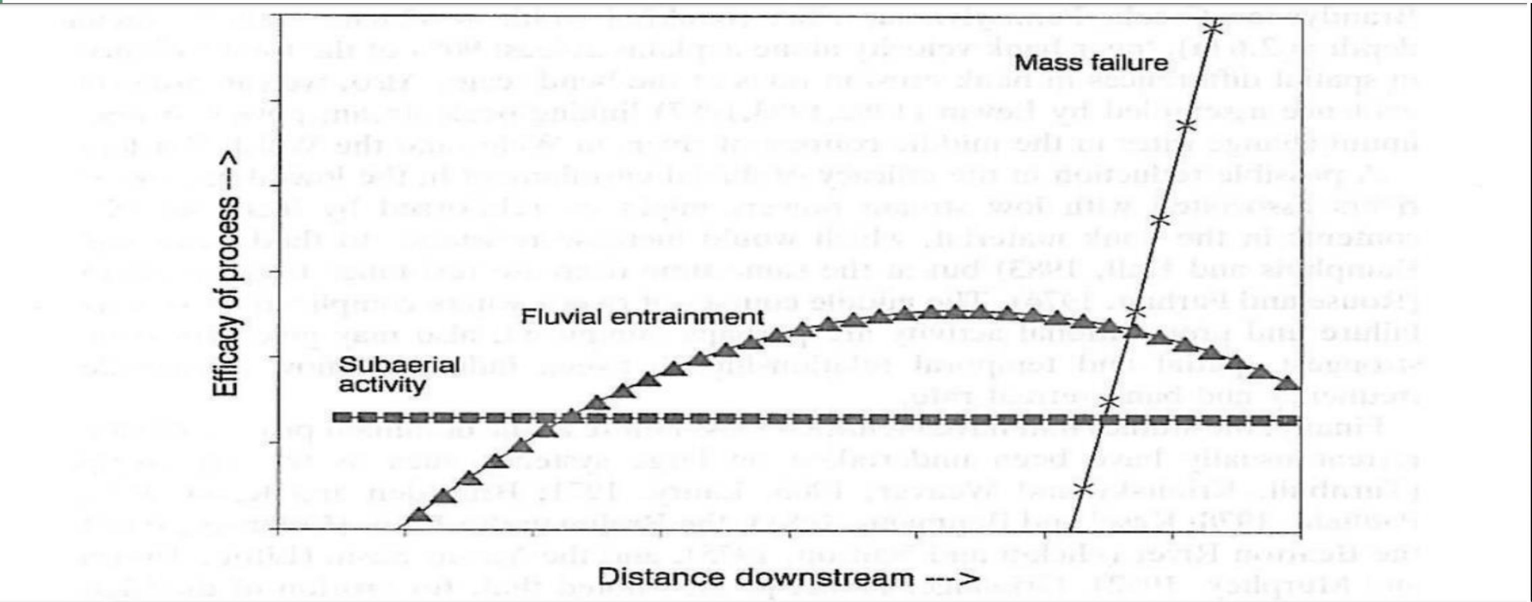
Objectives

- High-resolution point clouds of creek banks over time using Terrestrial Laser Scanning (TLS)
- Establish a consistent workflow for processing of Light Detection and Ranging (LiDAR) scans
- Quantify erosion and deposition rates, can be used to quantify flux
- Identify major factors driving erosion in EFPC

Processes Contributing to Erosion

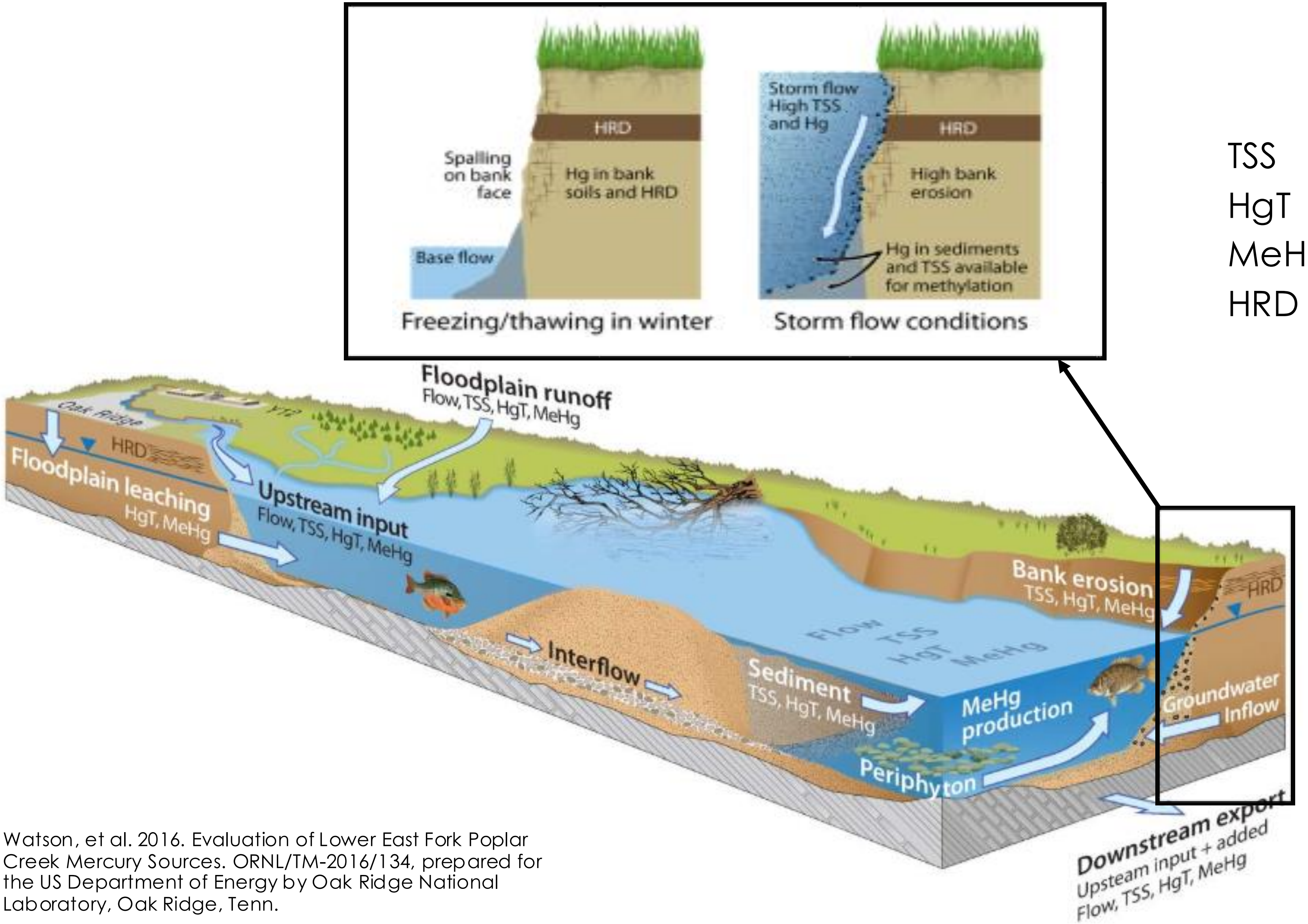
- Y-12 discharge baseflow and flash-flooding, impact determined by streambank factors
- Study in South River, Virginia found four primary modes of channel change
  - 26% from bends, 15% from straight reaches
- Determining the dominant longitudinal erosional process is important
  - Processes can be split into domains: subaerial activity, fluvial entrainment, mass failure (upstream to downstream)
- Time lag of mass failure leads to longer downstream erosion season
- Desiccation (drying of soil moisture) can be a significant driver of mass-wasting

A. Simon et. al, 2000



T. Wynn et. al, 2014

Hg mobilization in soil & groundwater



TSS	Total suspended solid
HgT	Total mercury
MeHg	Methylmercury
HRD	Historical release deposit

Watson, et al. 2016. Evaluation of Lower East Fork Poplar Creek Mercury Sources. ORNL/TM-2016/134, prepared for the US Department of Energy by Oak Ridge National Laboratory, Oak Ridge, Tenn.

Site Introduction

EFK 5.4

EFK 19.07

EFK 20.27

Introduction to TLS

- TLS is preferred for this research over Airborne Laser Scanning (ALS)
- The LiDAR system is mounted on a leveled tripod
- Product of scan is a point cloud
- Point clouds from different sampling times are superimposed and compared using registration software, resulting in volume calculations
- Georeferencing being added to improve overlap
- Site-specific variables will be utilized to assess dominant erosional processes

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TLS Materials

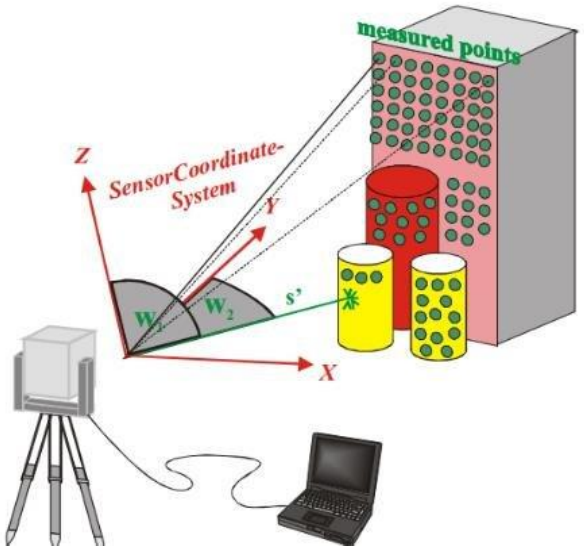
STTL, 2016

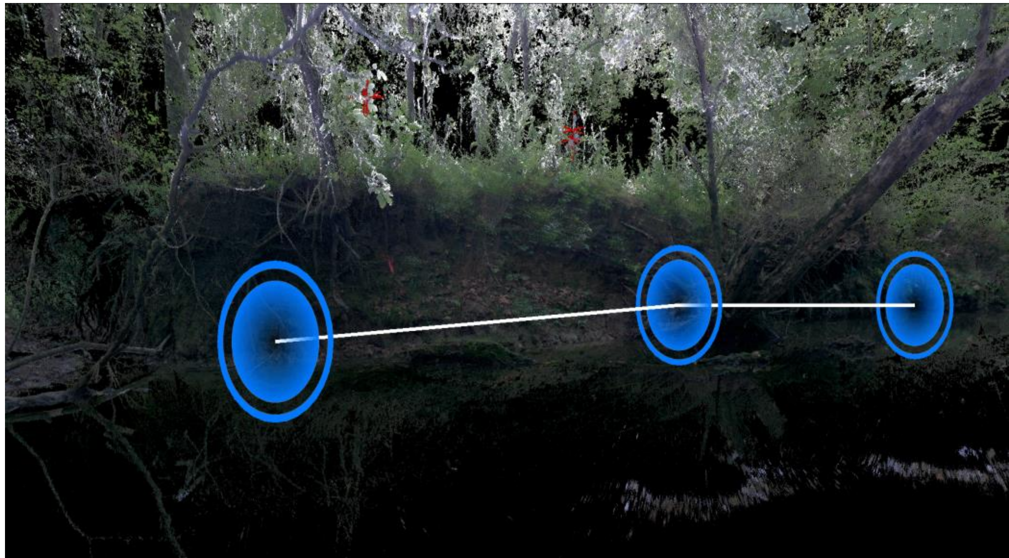
Cyclone
REGISTER 360

LiDAR Scanning and Procedure

- Scanner is leveled and set up on tripod in creek
- Scanner is moved to 3 locations to collect scans of a creek bank section
- Registration of 1 merged point cloud and georeferencing
- The merged point cloud is reduced to just the bank and exported for volume calculations
- Moving cloud is compared to reference cloud to calculate volume
- 9 sites, 3-6 months between

Khomsin, et al, 2019



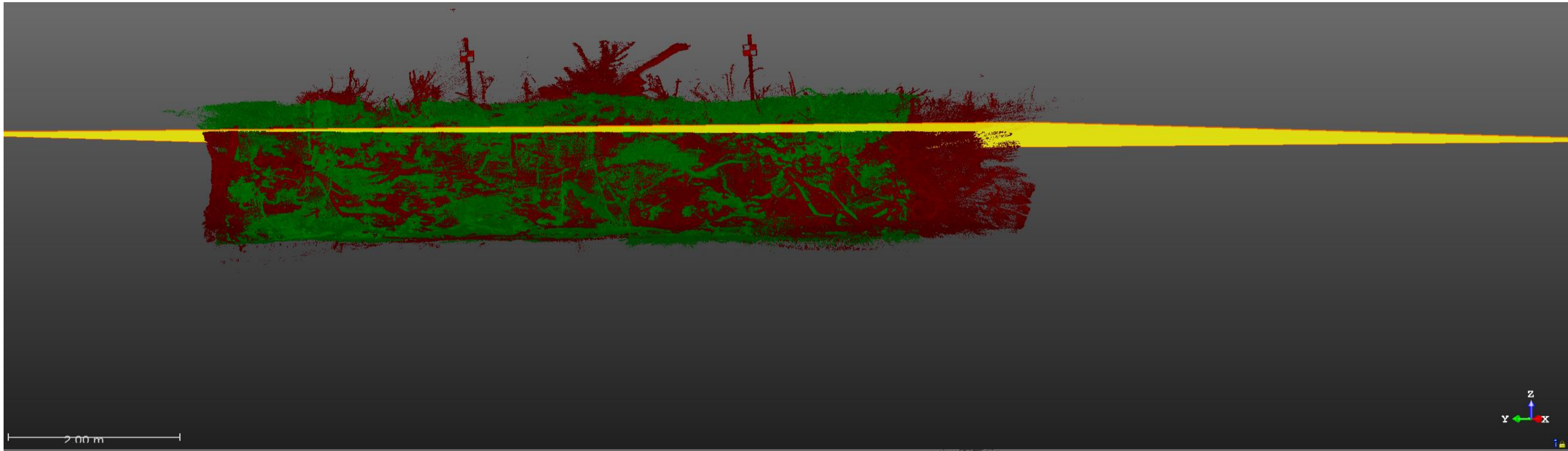


Scanning site-> point cloud comparison

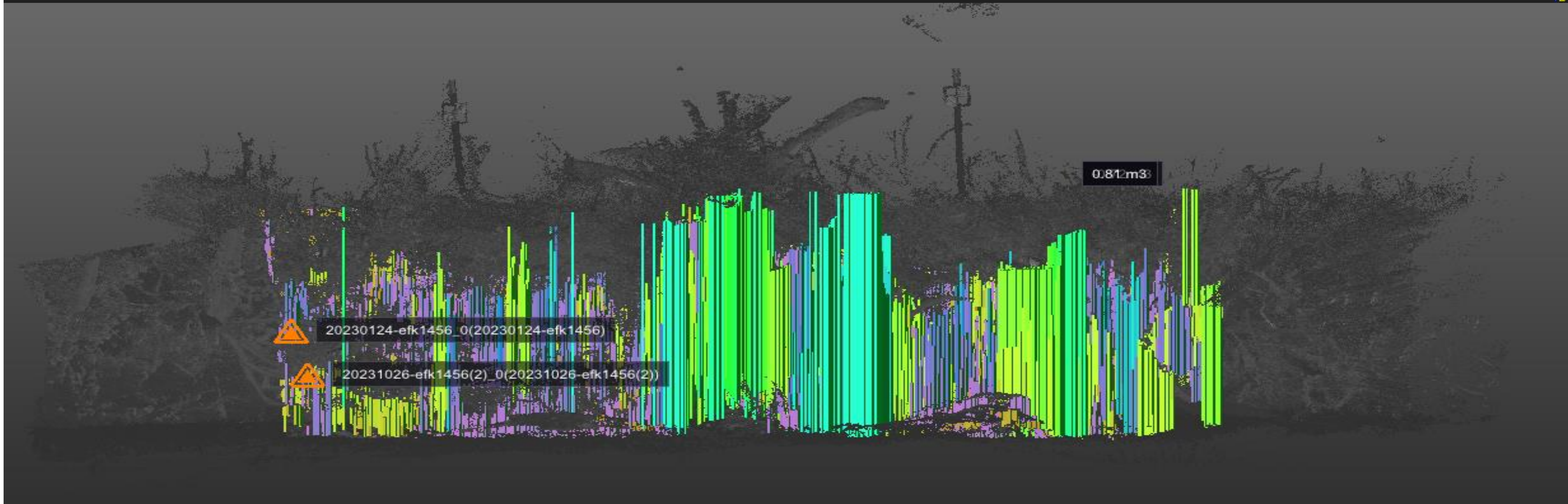
EFK 14.56 (targets circled)

Point Cloud: Close Look

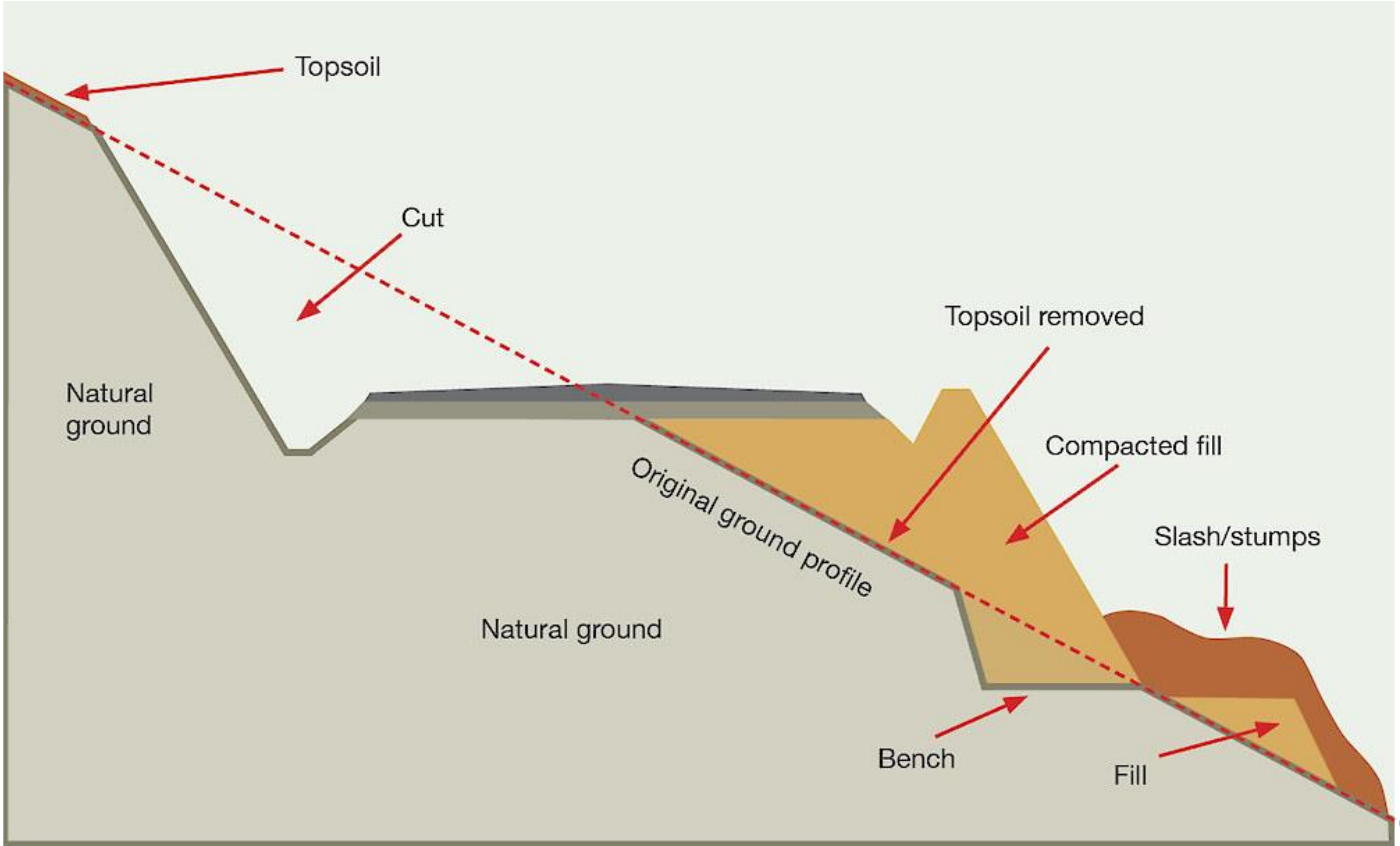
Moving=Red
Reference=Green



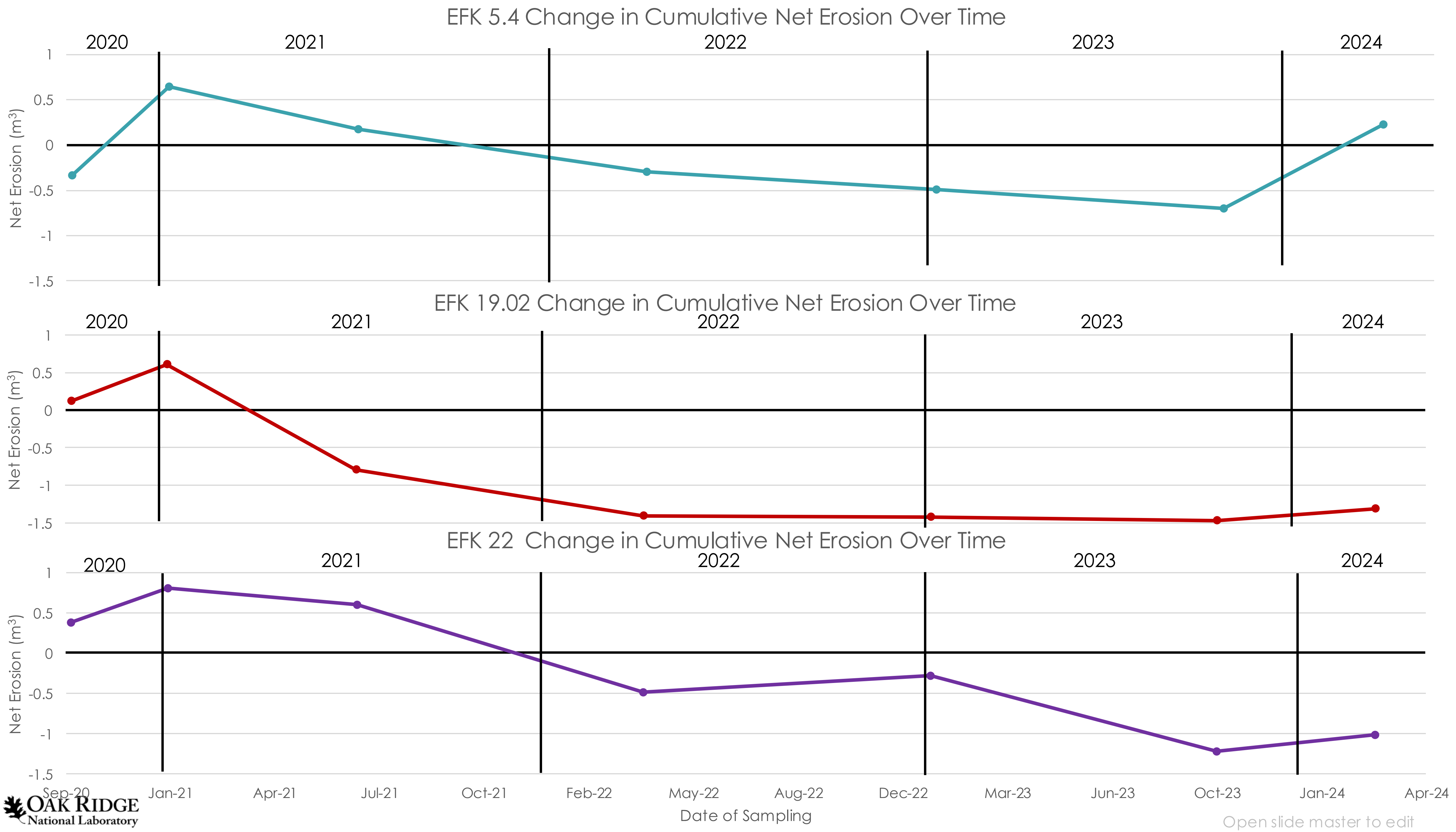
Green-Teal: Erosion
Purple-Light Blue: Deposition



Data Legend



Topsoil
Cut
Natural ground
Topsoil removed
Compacted fill
Original ground profile
Slash/stumps
Natural ground
Bench
Fill



EFK 5.4 Change in Cumulative Net Erosion Over Time
2020
2021
2022
2023
2024
Net Erosion (m3)
1
0.5
0
-0.5
-1
-1.5
EFK 19.02 Change in Cumulative Net Erosion Over Time
2020
2021
2022
2023
2024
Net Erosion (m3)
1
0.5
0
-0.5
-1
-1.5
EFK 22 Change in Cumulative Net Erosion Over Time
2020
2021
2022
2023
2024
Net Erosion (m3)
1
0.5
0
-0.5
-1
-1.5
Sep-20
Jan-21
Apr-21
Jul-21
Oct-21
Feb-22
May-22
Aug-22
Dec-22
Mar-23
Jun-23
Oct-23
Jan-24
Apr-24
Date of Sampling

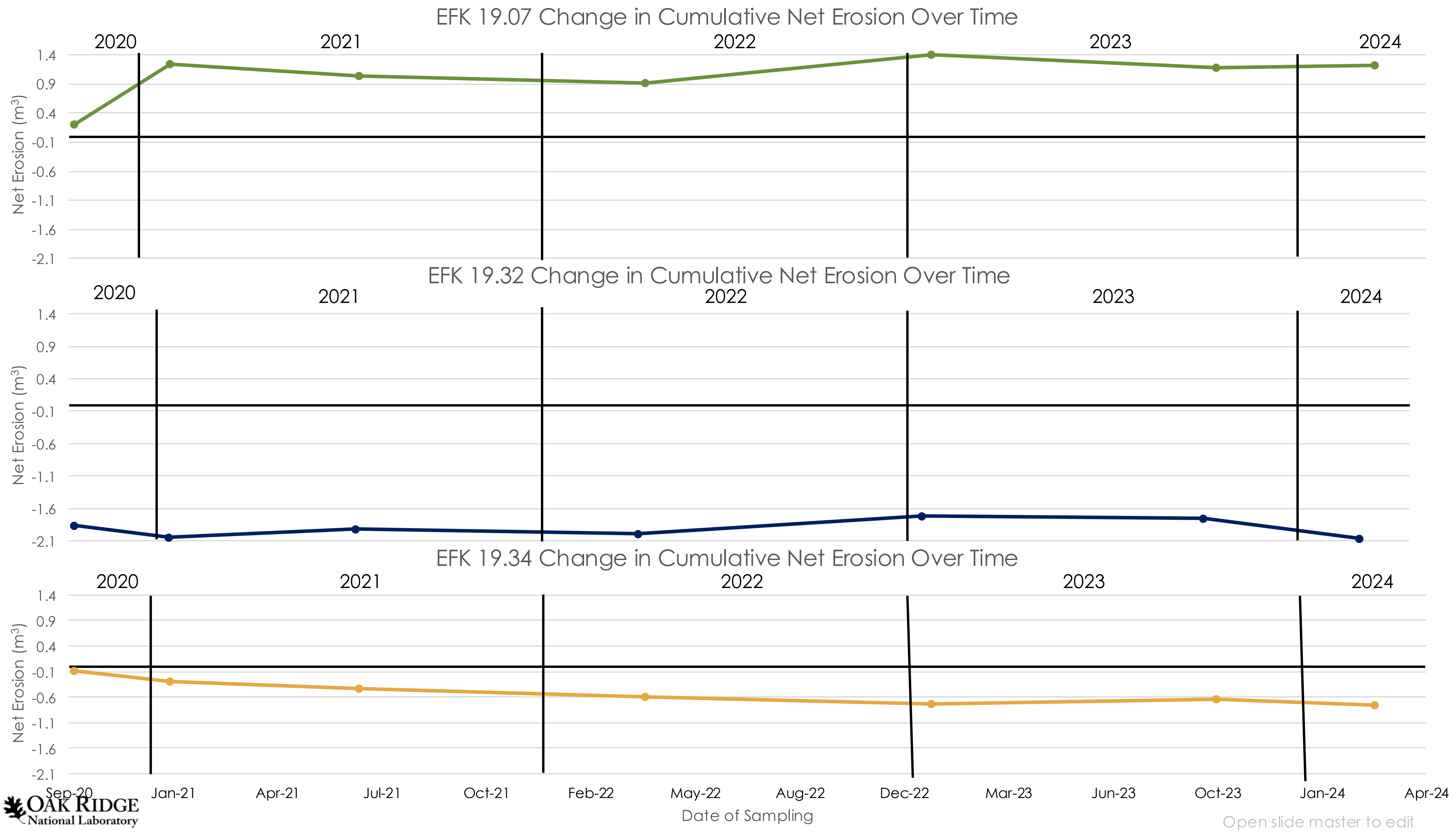
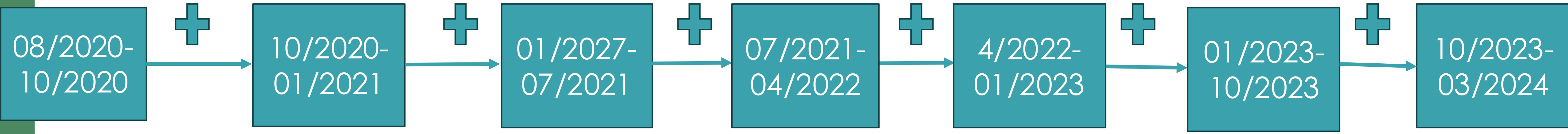

EFK 19.07 Change in Cumulative Net Erosion Over Time
2020
2021
2022
2023
2024
Net Erosion (m³)
1.4
0.9
0.4
-0.1
-0.6
-1.1
-1.6
-2.1
EFK 19.32 Change in Cumulative Net Erosion Over Time
EFK 19.34 Change in Cumulative Net Erosion Over Time
Sep-20
Jan-21
Apr-21
Jul-21
Oct-21
Feb-22
May-22
Aug-22
Dec-22
Mar-23
Jun-23
Oct-23
Jan-24
Apr-24
Date of Sampling

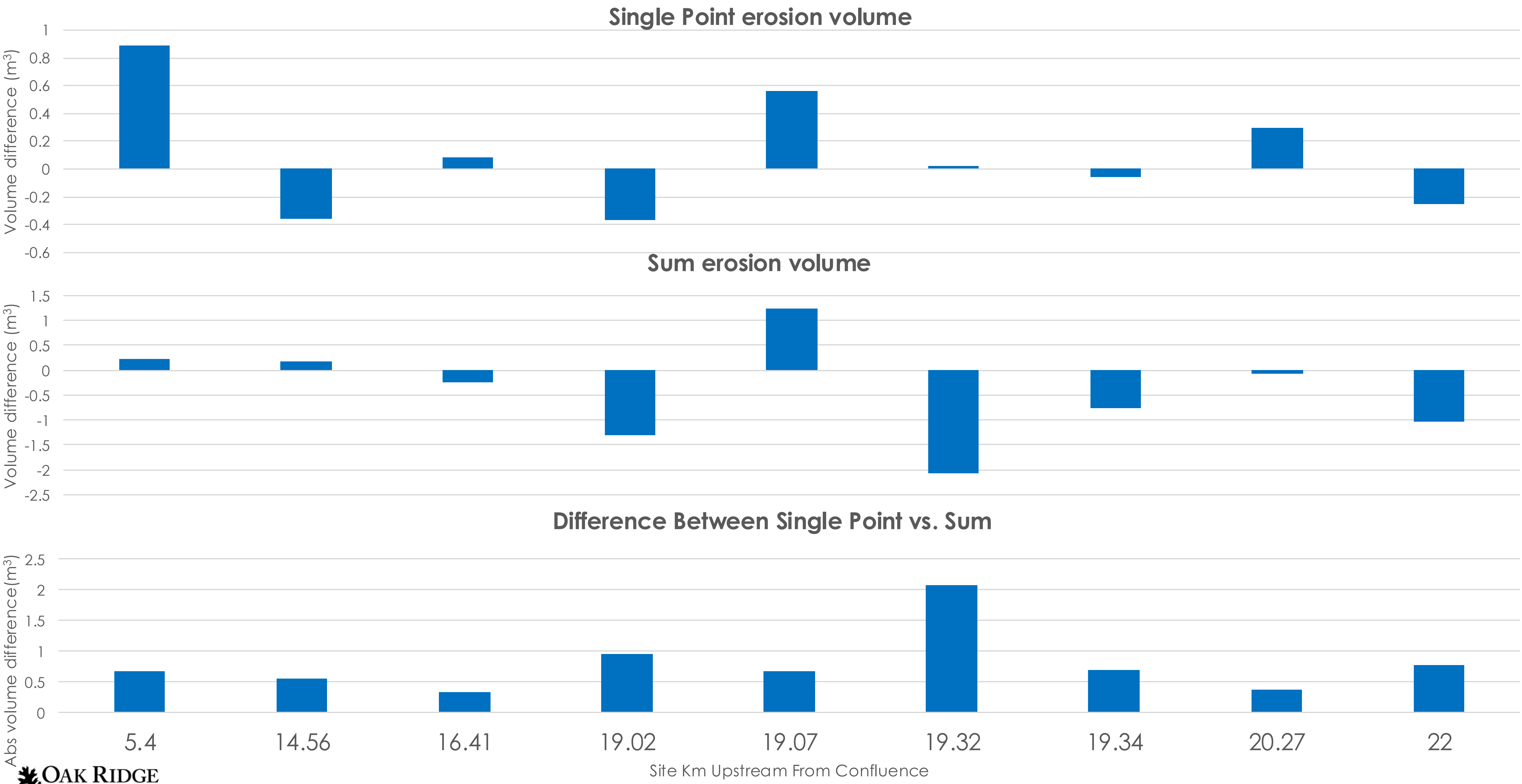
Diagram of data comparison for 2020-2024

Single Point Erosion

Sum Erosion



Net Erosion Volumes 2020-2024



Discussion of Trends

- Smallest differences between methods found at 16.41 and 20.27
- The biggest differences between methods found at 19.02, and 19.32
- Issues caused by mixture of heavy vegetation, overhanging banks and unremarkable features (bare banks)

EFK 20.27

EFK 19.32

EFK 19.07

Moving Forward

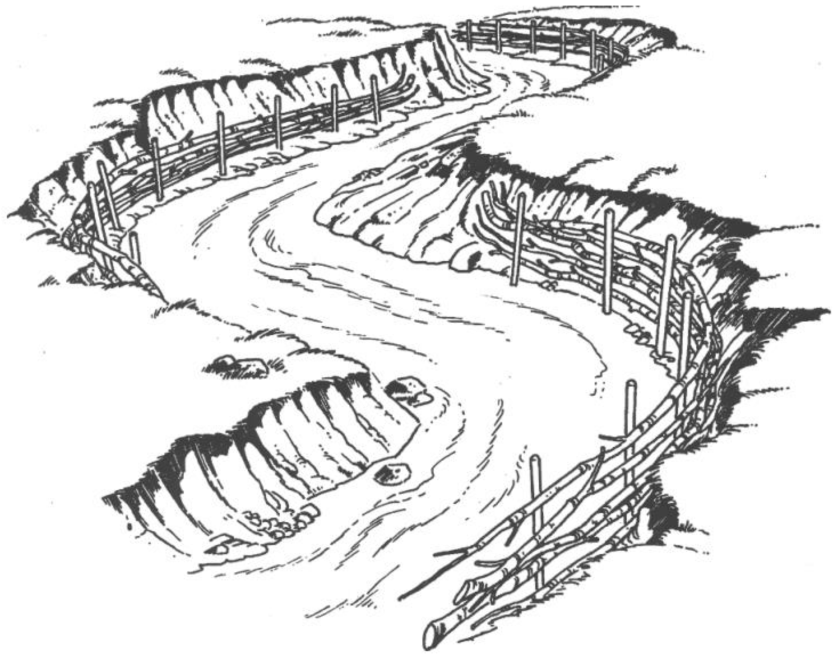
- Creating error estimates for data points
- Analysis of data to add sample sites
- Ensure same area is used for calculation
- Capturing flow rate at all available sites

USGS, 2018

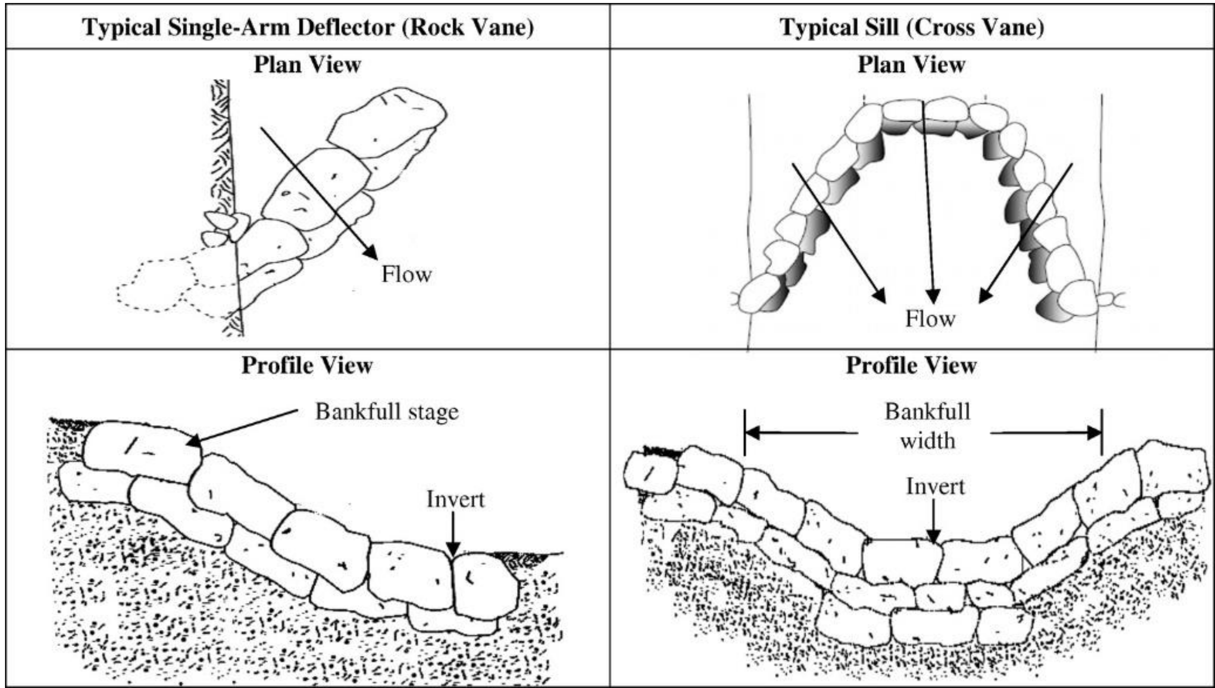
Outcomes

- Establish workflow for erosion detection
- Find the site-specific drivers of erosion
- Will lead to useful information for remediation of the creekbank soils in EFPC
- Will identify erosion rates and Hg and MeHg flux rates along EFPC

David F. Polster, 2002



R.R Radspinner et al, 2010



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Lessons Learned

- How to develop a process for ideal data collection
- How to work with consultants and task members
- How to be a graduate academic

Acknowledgements

- ORNL (UT-Battelle, LLC) and members of the mercury TD project, UCOR, DOE-EM (Sponsor)
- University of Tennessee, Knoxville
- F. Loeffler, J.M. Hathaway, D. Yoder, J. Martinez Collado (UTK)
- D. Duran, C. Kercheval (consultants)

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All Site Photos

EFK 5.4

EFK 14.56

EFK 16.41

EFK 19.02

EFK 19.07

EFK 19.32

EFK 19.34

EFK 20.27

EFK 22

Sum data compilation

Volume Differences Over Time (m^3)

	202008-202010	202010-202101	202101-202107	202107-202204	202204-202301	202301-202310	202310-202402
5.4	-0.33	0.98	-0.47	-0.47	-0.2	-0.21	0.92
14.56		-0.52	0.84	-0.08	-0.03	0.08	-0.11
16.41	-0.11	0.13	-0.31	-0.12	0.12	0.08	-0.03
19.02	0.12	0.49	-1.4	-0.62	-0.01	-0.05	0.16
19.07	0.2	1.04	-0.19	-0.14	0.5	-0.22	0.04
19.32	-1.87	-0.17	0.13	-0.08	0.27	-0.04	-0.3
19.34	-0.08	-0.22	-0.14	-0.16	-0.14	0.09	-0.1
20.27	-0.37	0.2	0.04	-0.39	0.15	0.07	0.23
22	0.37	0.44	-0.22	-1.08	0.21	-0.94	0.2

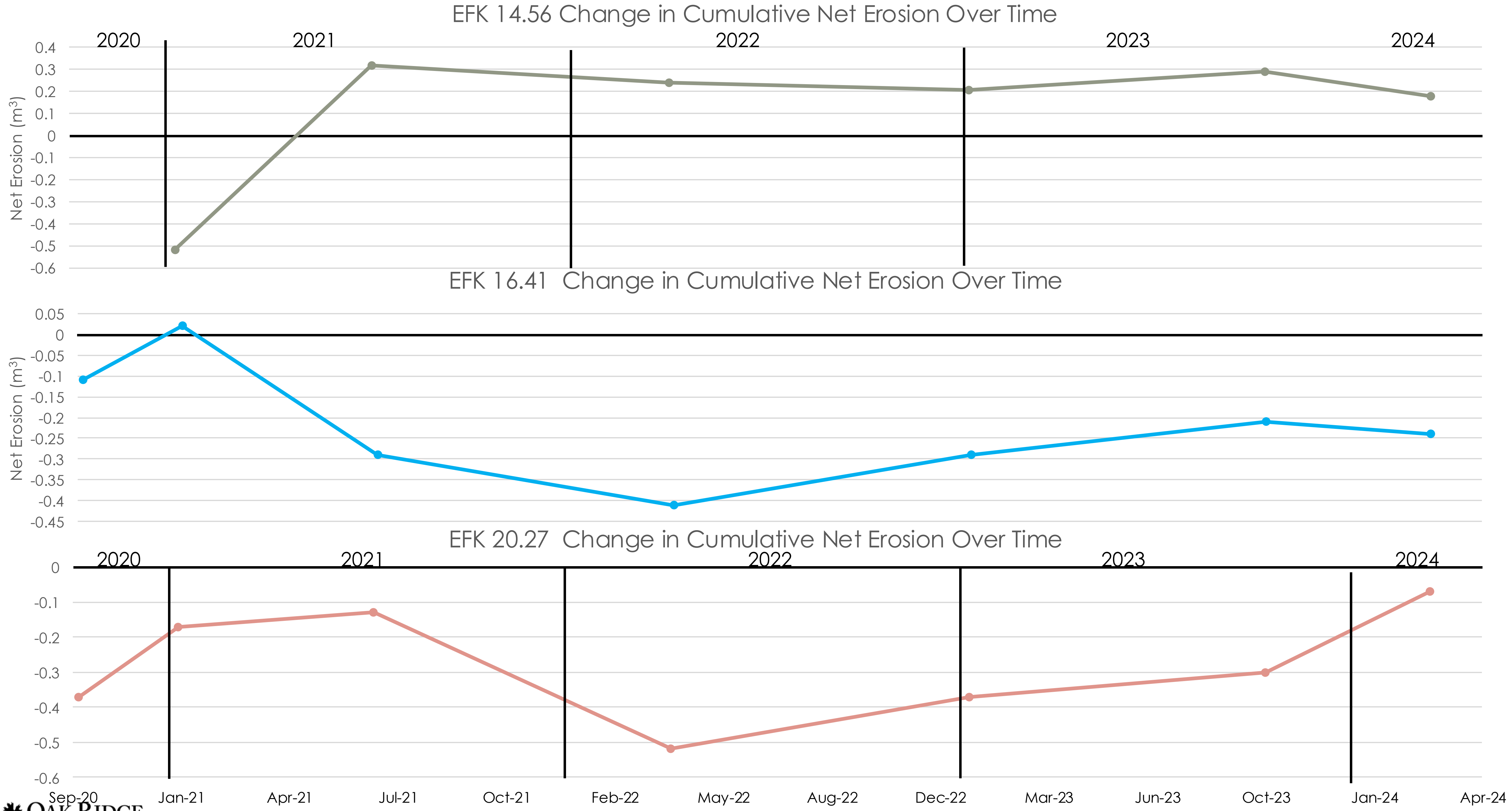
Georeferencing results (in progress)

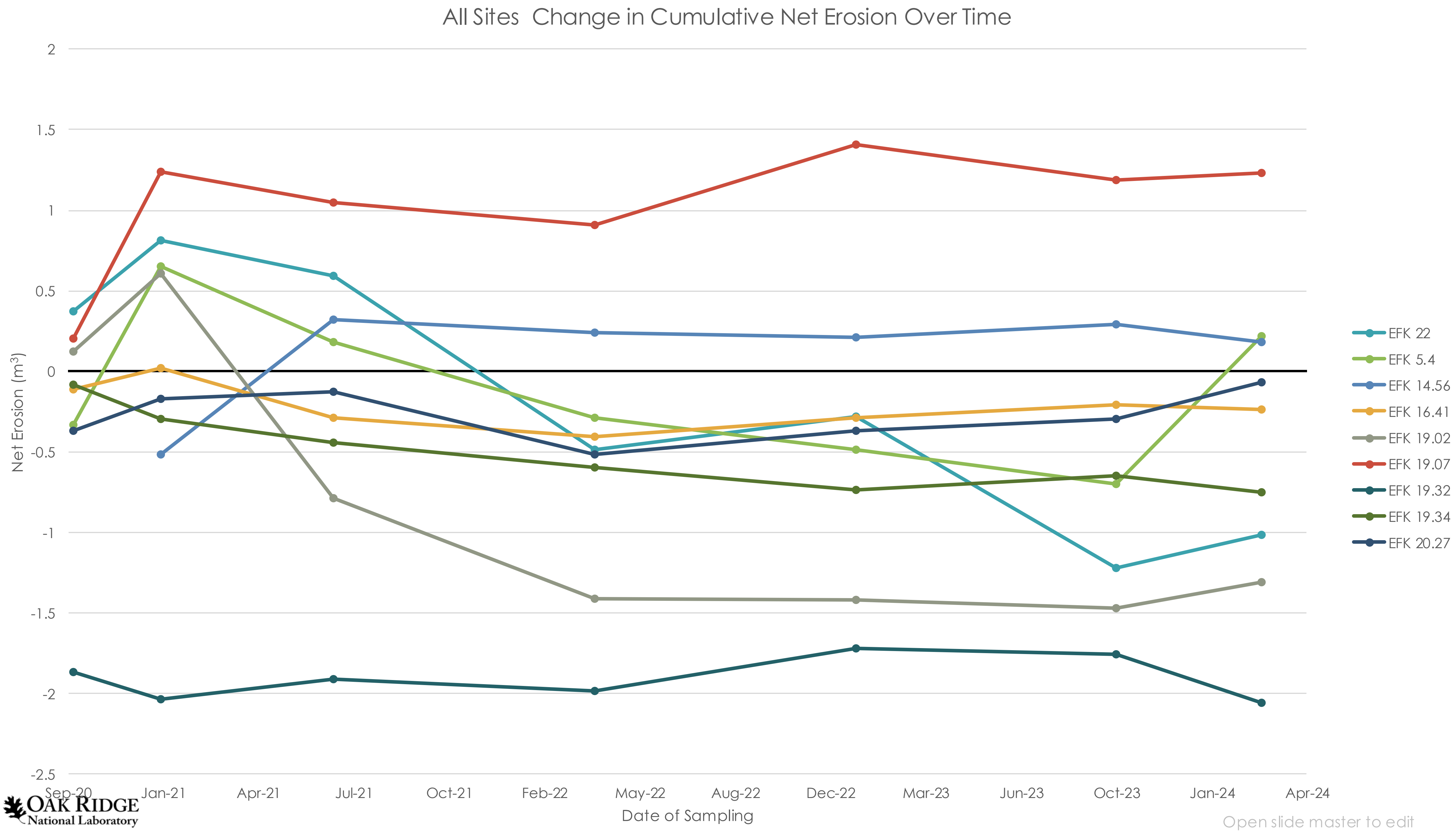
Volume Differences Over Time (m³)

	202008-202010	202010-202101	202101-202107	202107-202204	202204-202301	202301-202310	202310-202402
5.4	0.04	0.8	-0.6	-0.57	-0.1	0.2	0.47
14.56		0.85	-0.19	-0.32	-0.04	0.17	-0.08
16.41	0.07	0.06	0.21	-0.32	-0.01	0.02	-0.01
19.02	0.3	-0.56	-0.1	0.41	-0.19	-0.16	-0.19
19.07	0.47	0.47	-0.36	-0.21	0.37	0.41	0.92
19.32	0.14	0.16	-0.01	-0.05	0.15	-0.09	0.45

Procedure

- Leica Work
- Trimble work
- Erosion Pin measurement


EFK 14.56 Change in Cumulative Net Erosion Over Time
2020
2021
2022
2023
2024
Net Erosion (m³)
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
EFK 16.41 Change in Cumulative Net Erosion Over Time
Net Erosion (m³)
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
-0.3
-0.35
-0.4
-0.45
EFK 20.27 Change in Cumulative Net Erosion Over Time
2020
2021
2022
2023
2024
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
Sep-20
Jan-21
Apr-21
Jul-21
Oct-21
Feb-22
May-22
Aug-22
Dec-22
Mar-23
Jun-23
Oct-23
Jan-24
Apr-24


All Sites Change in Cumulative Net Erosion Over Time
Net Erosion (m³)
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
Sep-20
Jan-21
Apr-21
Jul-21
Oct-21
Feb-22
May-22
Aug-22
Dec-22
Mar-23
Jun-23
Oct-23
Jan-24
Apr-24
Date of Sampling
EFK 22
EFK 5.4
EFK 14.56
EFK 16.41
EFK 19.02
EFK 19.07
EFK 19.32
EFK 19.34
EFK 20.27

Remediation Goals

- TDEC water quality target: 51 ng/L (TDEC 2008)
- Interim cleanup goal for Hg in EFPC headwaters: 200 ng/L
- National (EPA) Recommended Aquatic Life Criteria:
    - Mercury acute: 1.4 µg/L
    - Mercury chronic: 0.77 µg/L
    - Marked as a priority pollutant (EPA 2015)
- EPA methylmercury criterion for human health: 0.3 mg/kg in fish tissue (EPA 2001)

TENNESSEE DEPARTMENT OF ENVIRONMENT AND CONSERVATION

EPA

Procedure

- Leica Work
- Trimble work
- Erosion Pin measurement

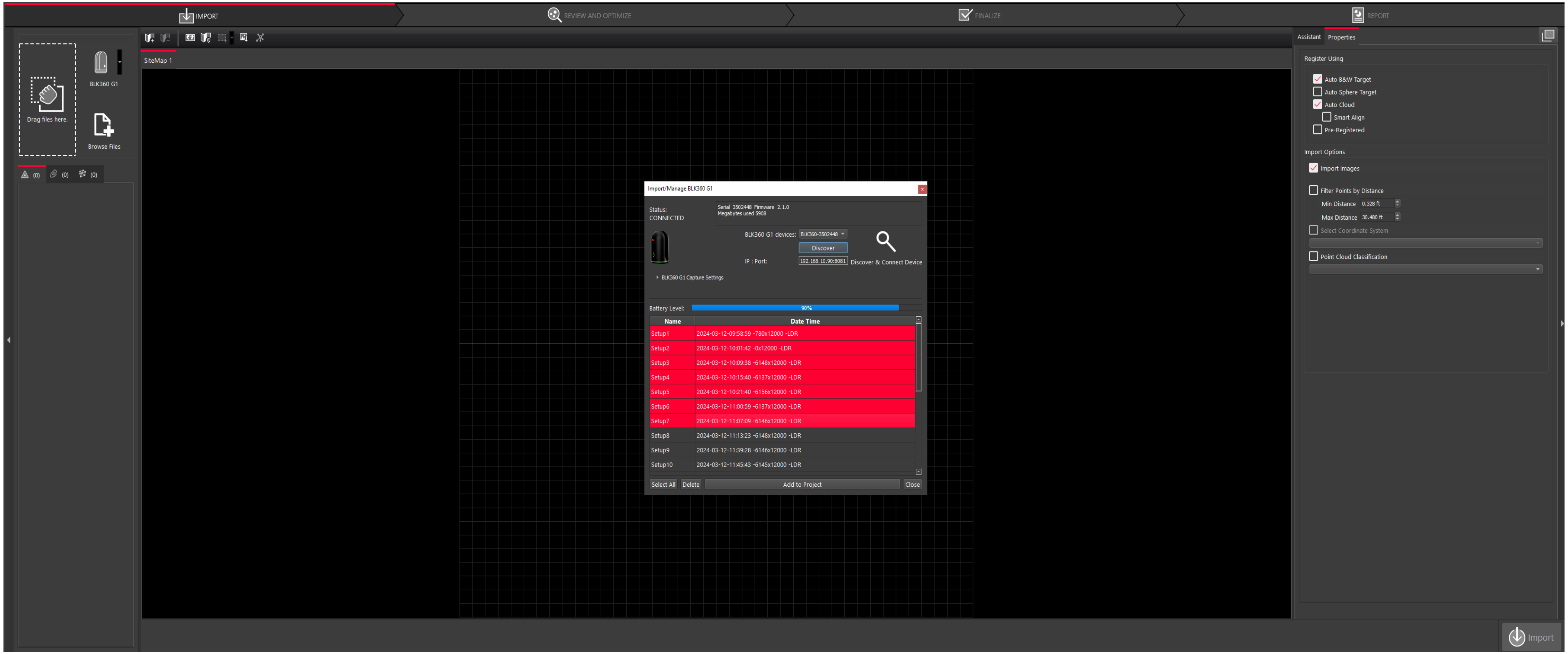
Scanning

OAK RIDGE
National Laboratory

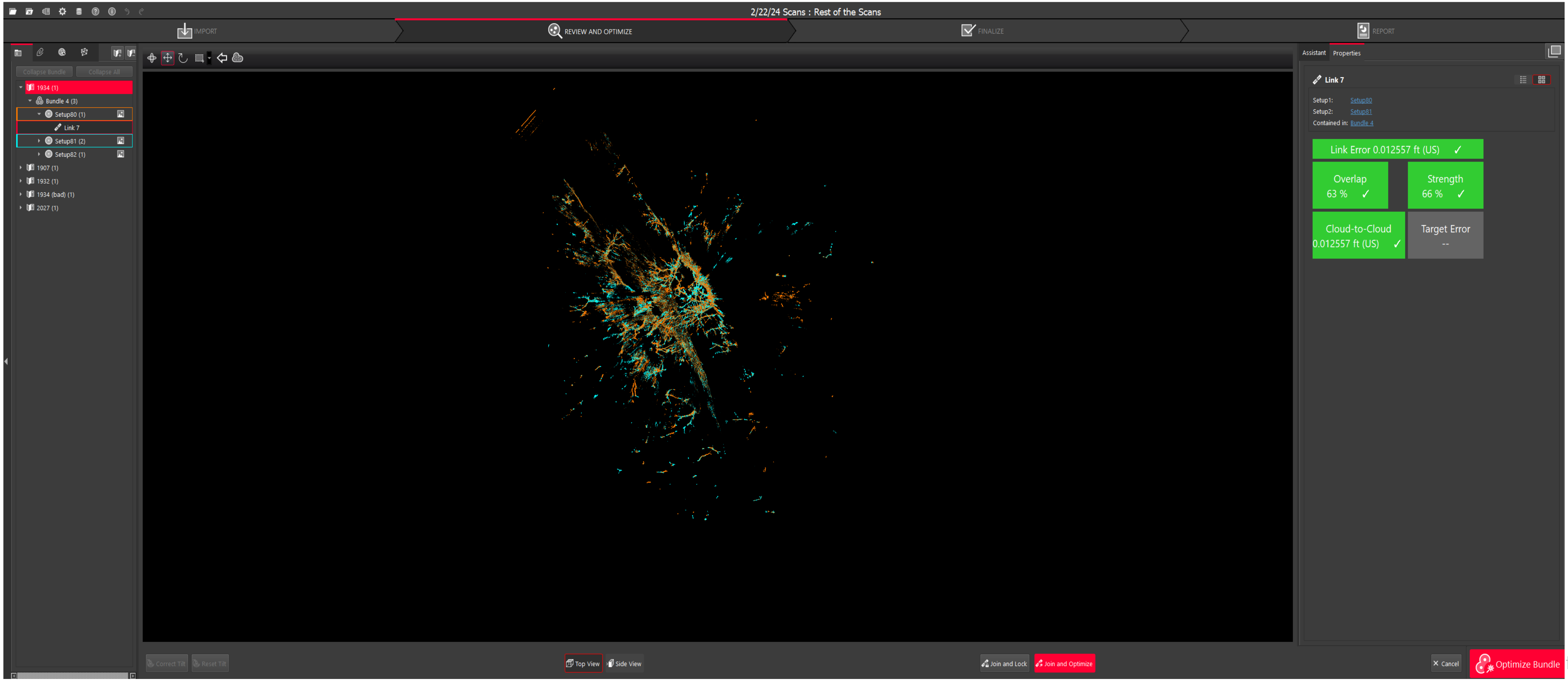
Leica Cyclone 360 Plus (BLK Edition)

Import and Scan Registration

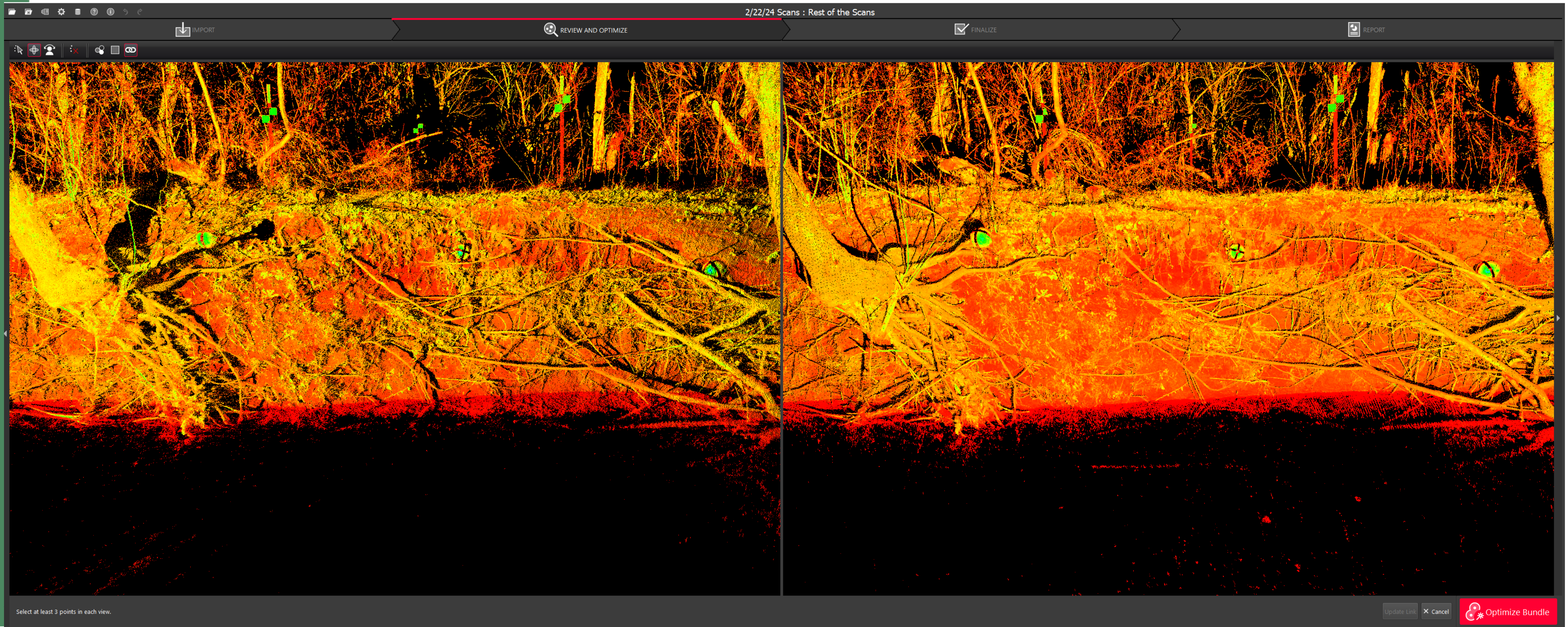
Importing into Cyclone



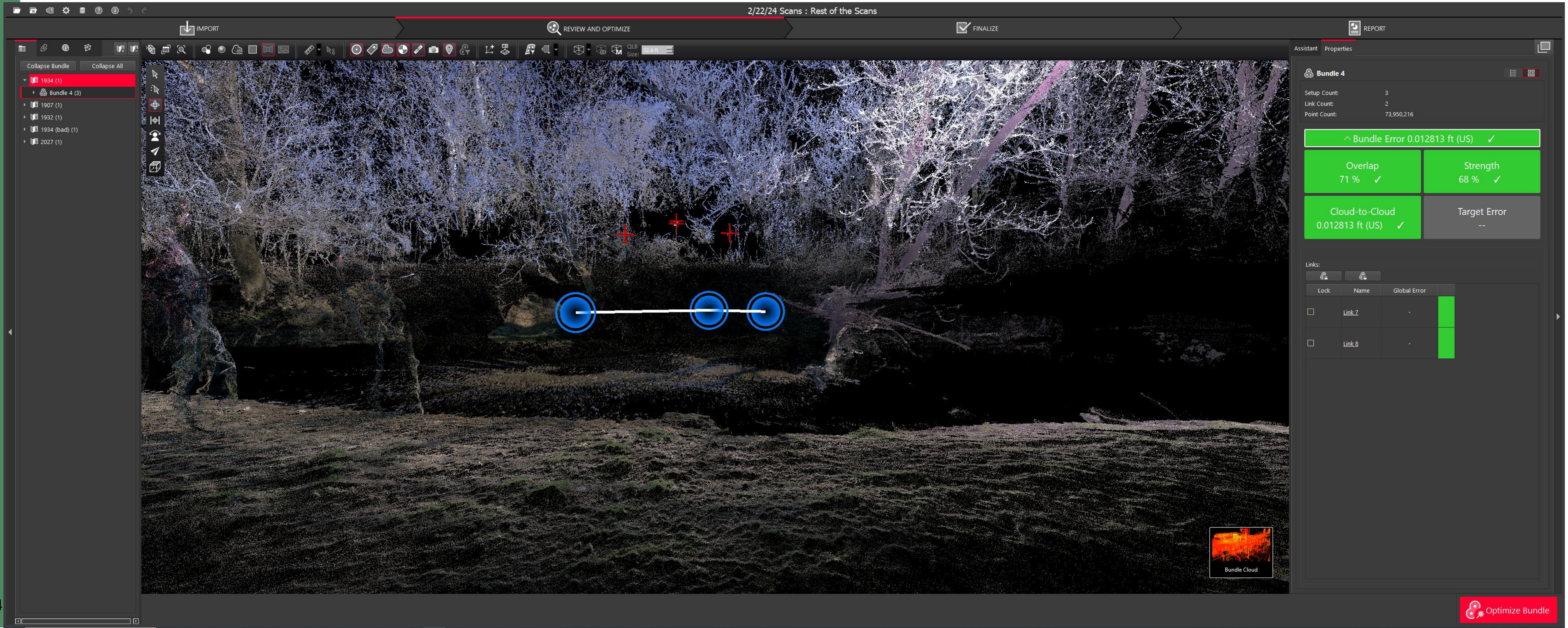
Establishing links



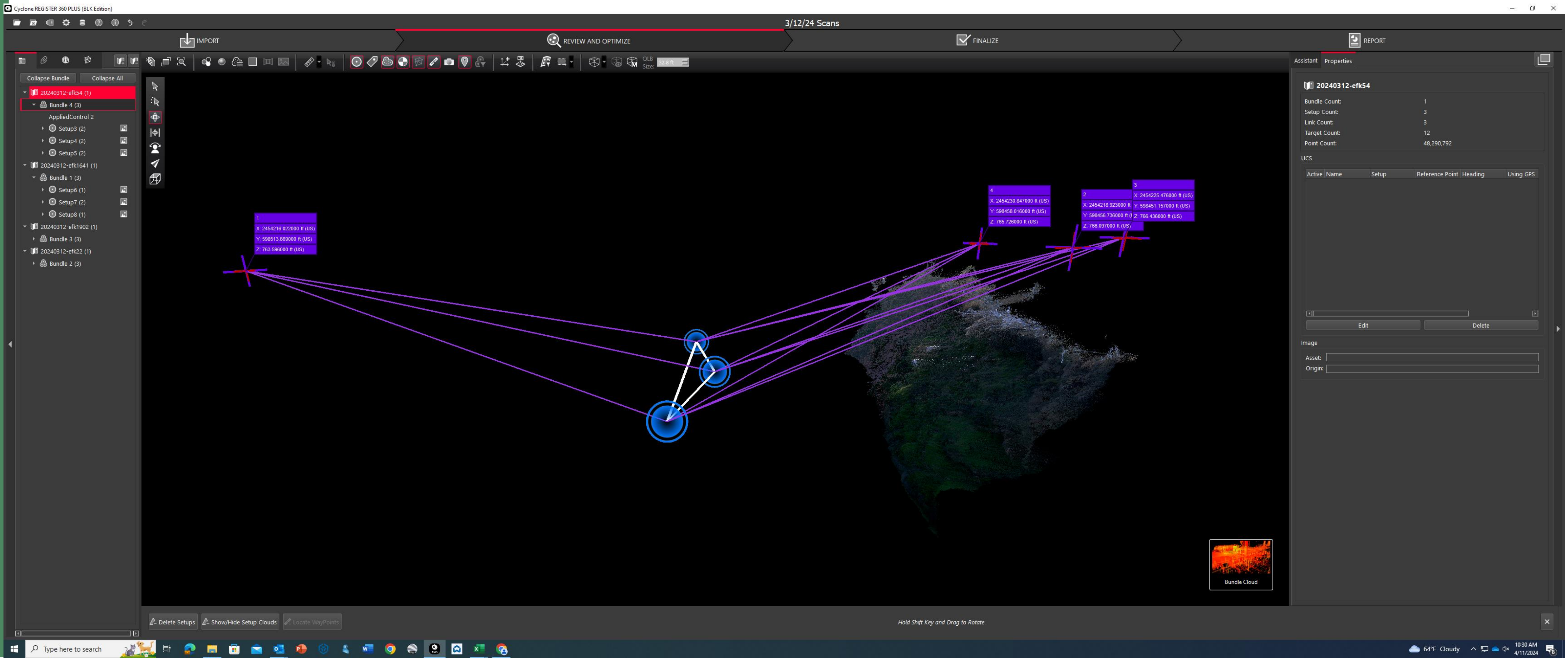
Establishing links cont.



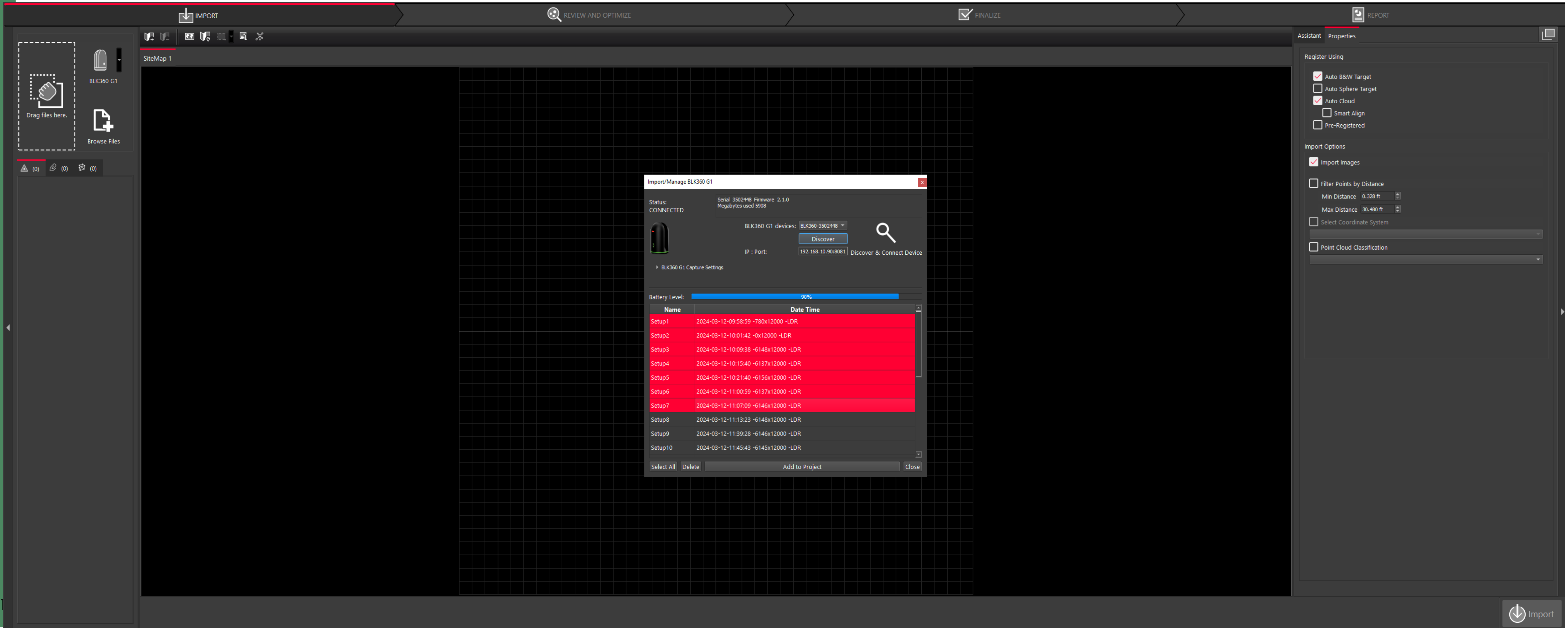
Trimming the bank



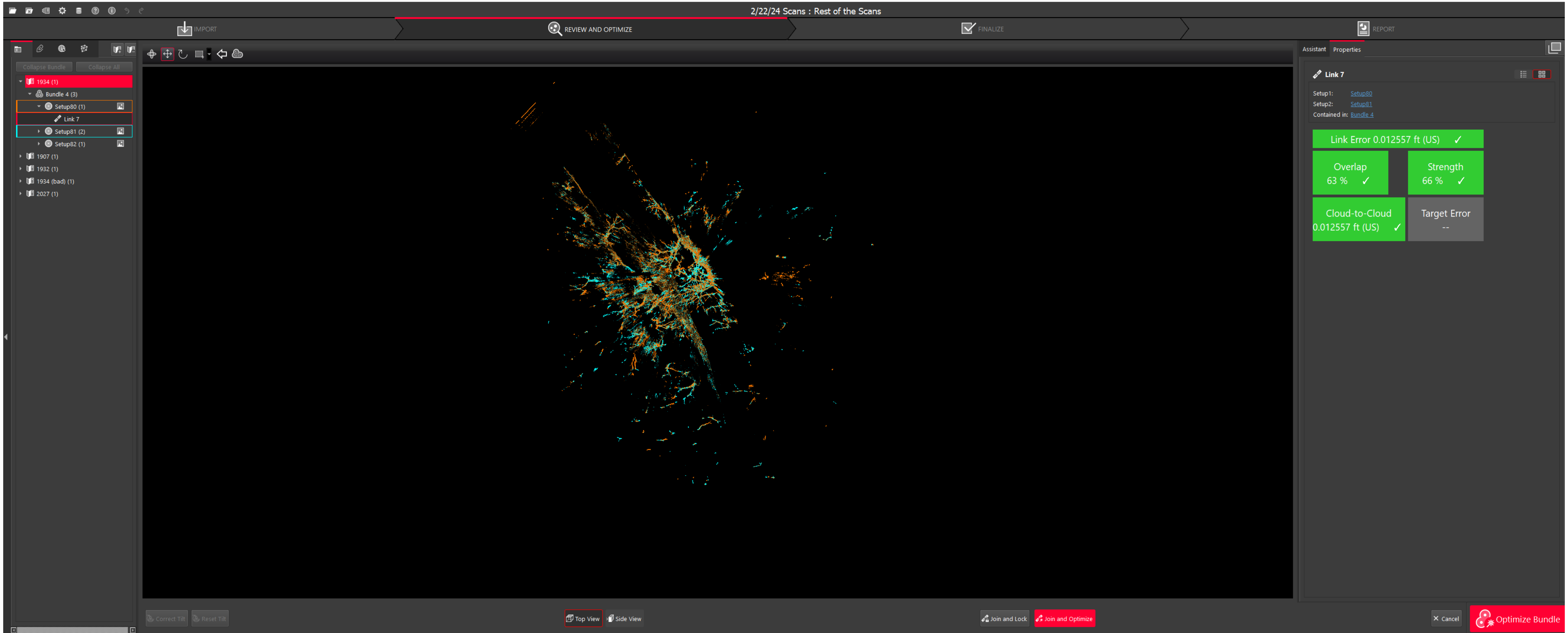
Apply Control



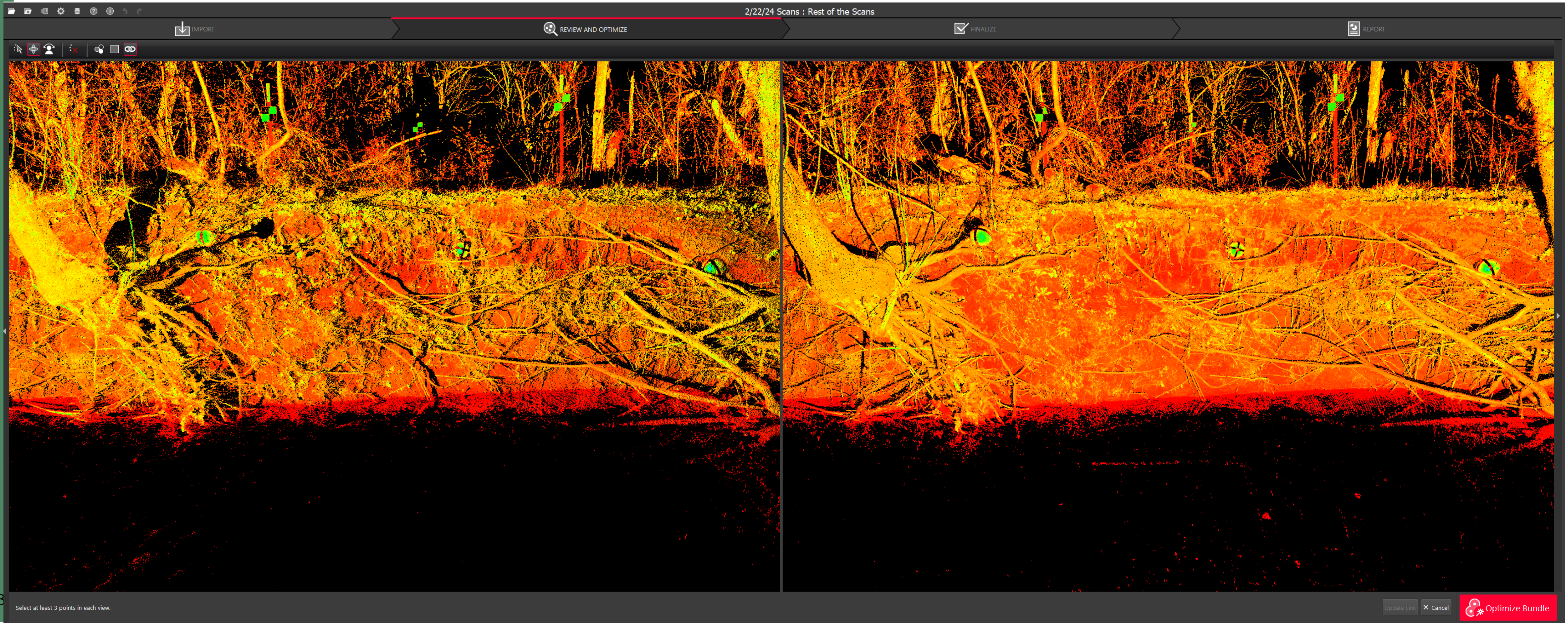
Trimming the bank cont.



Finalize


2/22/24 Scans : Rest of the Scans
IMPORT
REVIEW AND OPTIMIZE
FINALIZE
REPORT
Collapse Bundle
Collapse All
1934 (1)
Bundle 4 (3)
Setup80 (1)
Link 7
Setup81 (2)
Setup82 (1)
1907 (1)
1932 (1)
1934 (bad) (1)
2027 (1)
Assistant
Properties
Link 7
Setup1: Setup80
Setup2: Setup81
Contained in: Bundle 4
Link Error 0.012557 ft (US) ✓
Overlap 63 % ✓
Strength 66 % ✓
Cloud-to-Cloud 0.012557 ft (US) ✓
Target Error --
Correct Tilt
Reset Tilt
Top View
Side View
Join and Lock
Join and Optimize
Cancel
Optimize Bundle

Publish

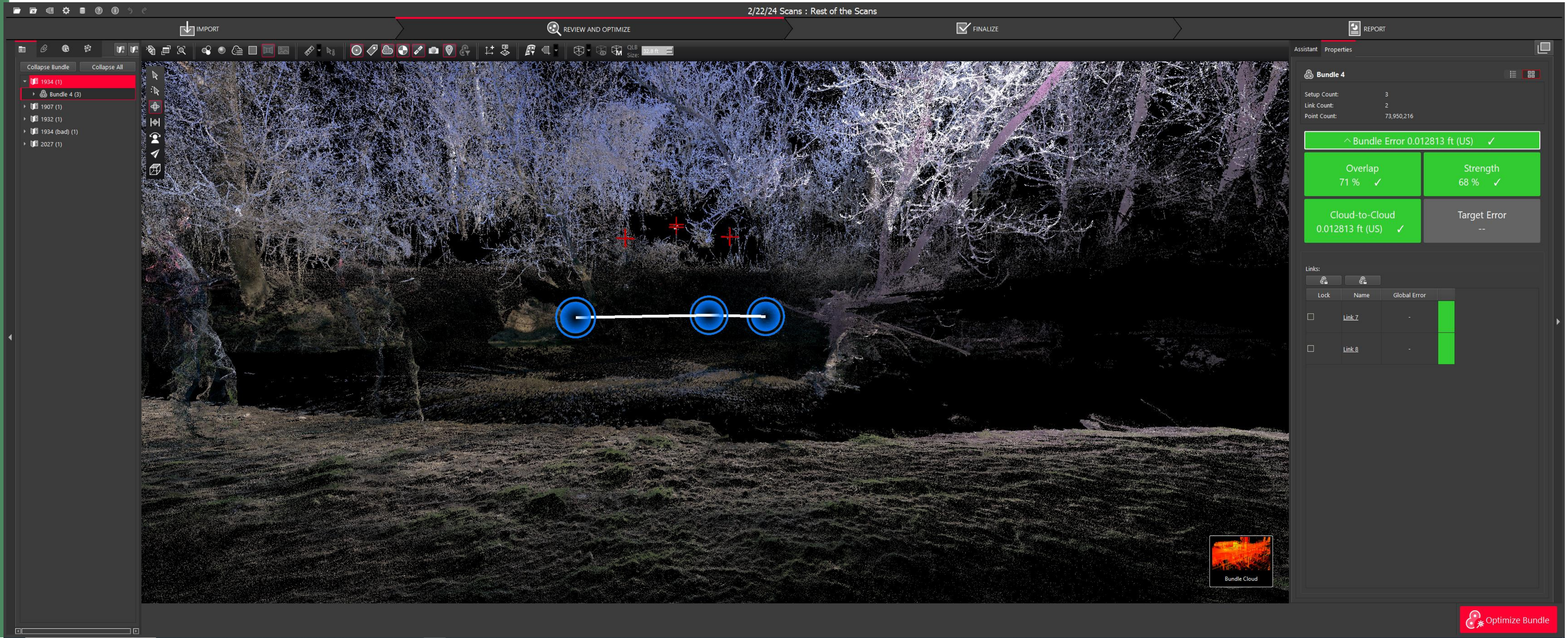


2/22/24 Scans : Rest of the Scans
IMPORT
REVIEW AND OPTIMIZE
FINALIZE
REPORT
Select at least 3 points in each view.
Update Link
Cancel
Optimize Bundle

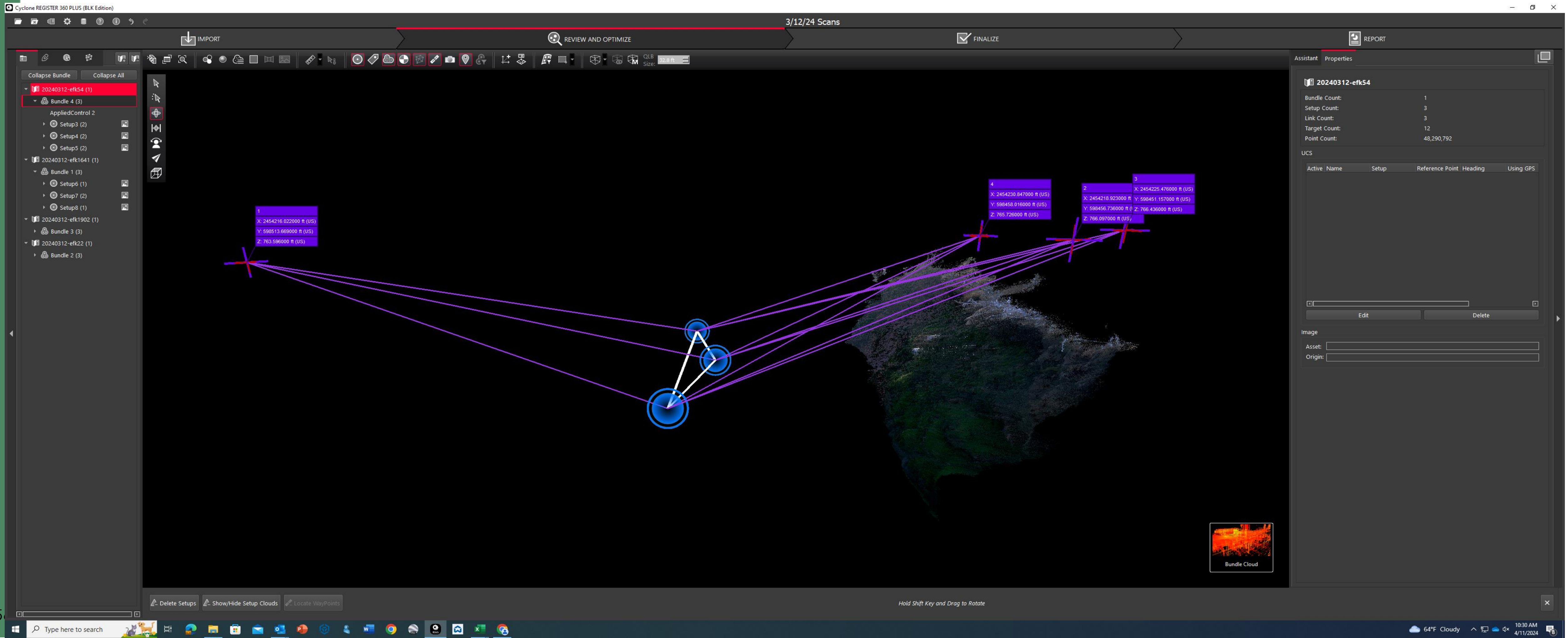
Trimble Realworks

Importing pts files and Calculation Erosion Volume

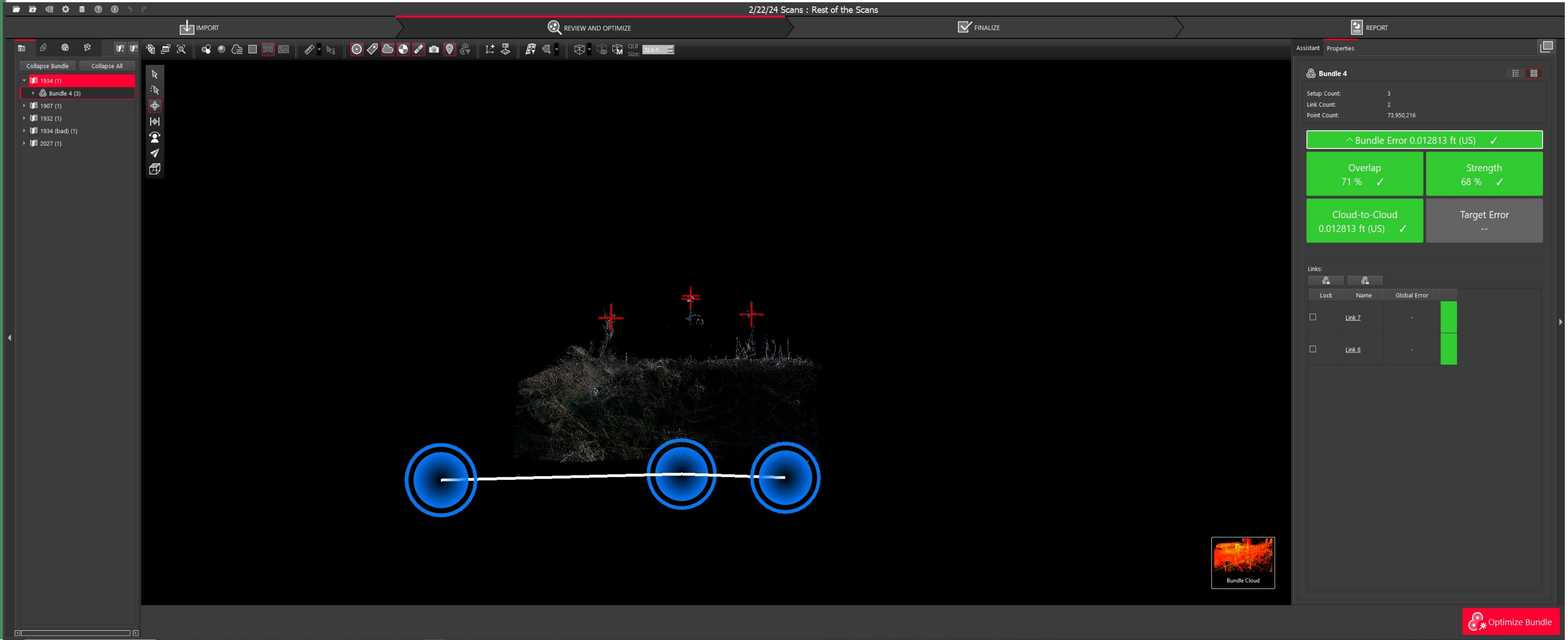
Import and Conversion



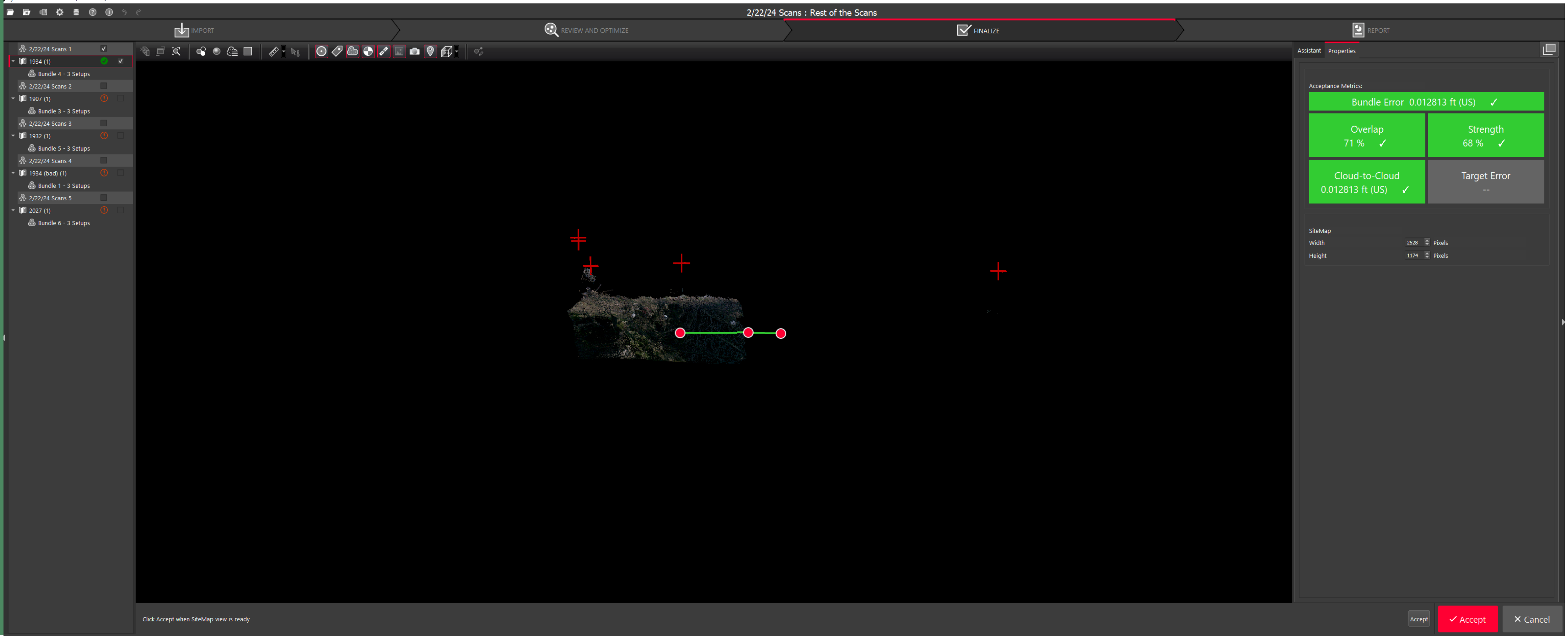
Import of Scans



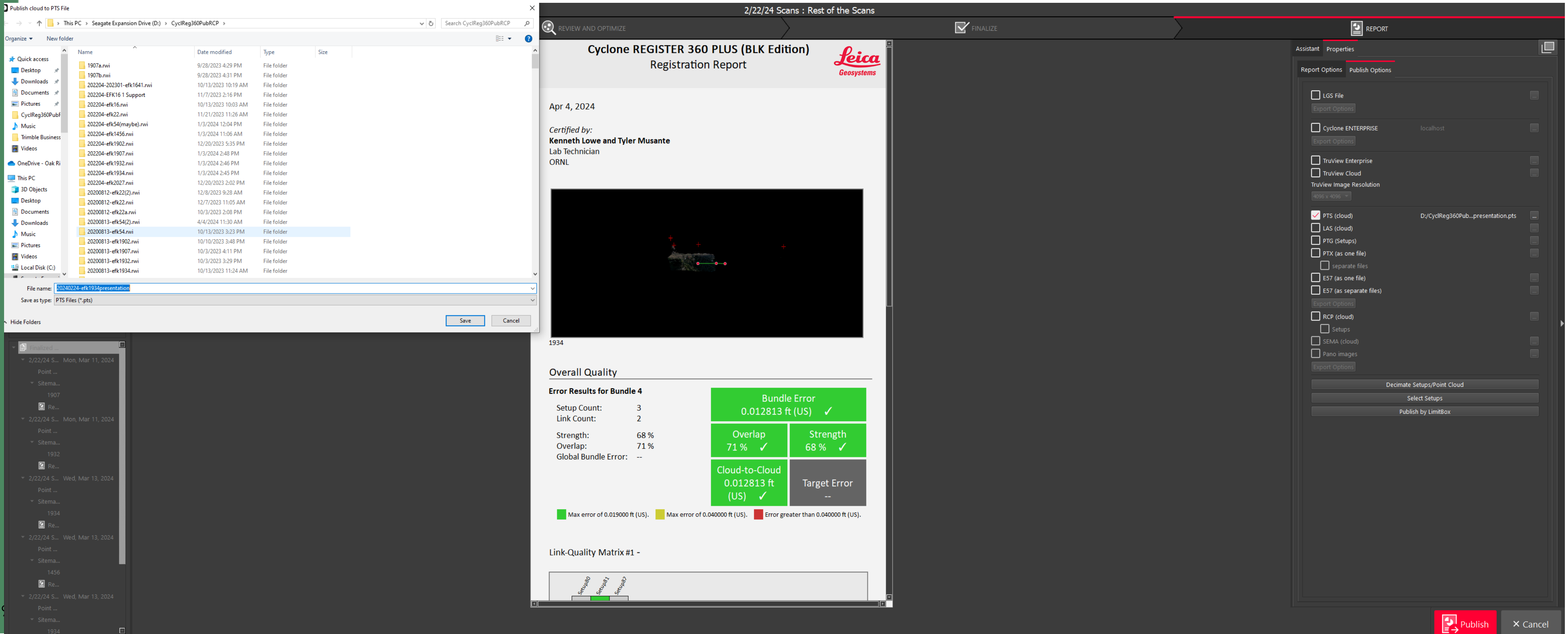
Registration in Trimble



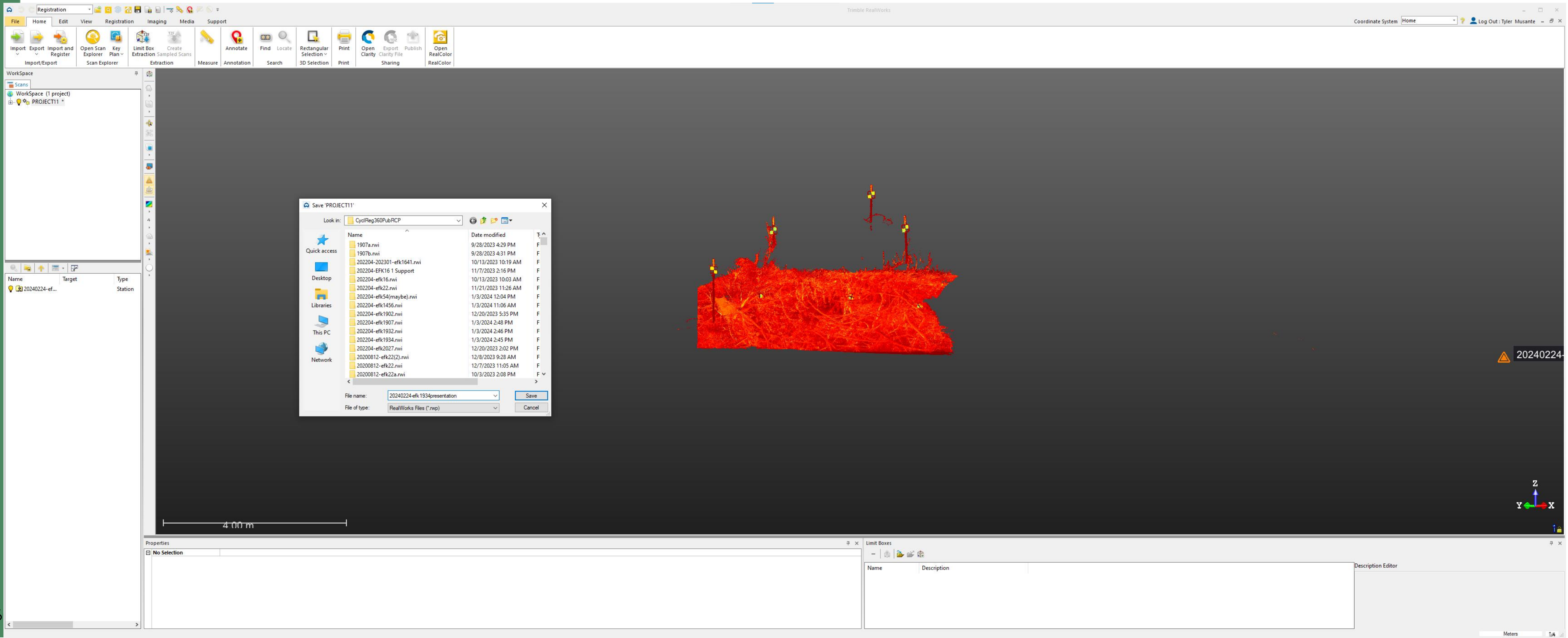
Create Scan-Based Sampling Layer



Reduce Area of Consideration



Calculate Erosion



Save the calculations and Volume Breakdown Layers