PHASE 1 EROSION STUDIES
STUDY 1 – TERRAIN ANALYSIS
FINAL REPORT

Volume II: Appendices

WEST VALLEY DEMONSTRATION PROJECT AND WESTERN NEW YORK NUCLEAR SERVICE CENTER

Prepared for:

United States Department of Energy, and
New York State Energy Research and Development Authority

Prepared By:

WVDP EROSION WORKING GROUP
Enviro Compliance Solutions, Inc. (ECS) Contract Number DE-EM0002446/0920/13/DE-DT0005364/001

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February, 2018

Phase 1 Erosion Studies
Study 1 – Terrain Analysis
Draft Report

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APPENDIX A1
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APPENDIX A2
Annotated Bibliography

List of NUREG-CR Documents Pertaining to WVDP

Title: Hydrogeologic Performance Assessment Analysis of the Commercial Low-Level Radioactive Waste Disposal Facility near West Valley, NY

Year: April 1991

URL: http://pbadupws.nrc.gov/docs/ML0037/ML003726086.pdf

Author(s): M. P. Bergeron, J. L. Smoot, M. L. Kemner, W. E. Cronin

Abstract / Summary:

A hydrogeologic performance assessment of the commercial low-level waste site near West Valley, New York, was performed for two pathways: a shallow lateral path way where trench water can potentially migrate laterally through fractured and weathered till to nearby streams and a deep vertical pathway where leachate can migrate downward through un-weathered till and laterally offsite in a lacustrine unit. Along the shallow pathway, little physical site evidence is available to indicate what the degree of lateral migration can be. Past modeling showed that overflowing trench water would migrate laterally some distance before migrating downward into the un-weathered till. If water did reach a nearby stream, calculations show that decay, adsorption, and stream dilution would reduce leachate concentration to acceptable levels. Within the deep pathway, tritium and ^{14}C were the only radionuclides released in any significant concentrations. Predicted tritium levels are well below regulatory limits; however, predicted peak ^{14}C concentrations, while meeting the 25 mrem/yr limit using the drinking-water-only exposure scenario, exceed the limit for the full garden scenario. Site Information on ^{14}C release rates and geochemical behavior has considerable uncertainty and would need to be more fully evaluated in a licensing situation.

Title: NRC Staff Guidance for Activities Related to U.S. Department of Energy Waste Determinations

Year: August 2007

URL: http://pbadupws.nrc.gov/docs/ML0723/ML072360184.pdf

Author(s):

H. Arle, A. Bradford, N. Devaser, D. Esh, M. Fuller, A. Ridge (NRC)

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Abstract / Summary:

This document provides U.S. Nuclear Regulatory Commission (NRC) staff guidance for conducting activities related to waste determinations. Waste determinations are evaluations

performed by the U.S. Department of Energy and are used to assess whether certain wastes resulting from the reprocessing of spent nuclear fuel can be considered low-level waste and managed accordingly. This guidance document applies to NRC activities that may be conducted for the Savannah River Site (SRS) in South Carolina and the Idaho National Laboratory (INL) in Idaho pursuant to the Ronald W. Reagan National Defense Authorization Act for Fiscal Year 2005 (NDAA), as well as the Hanford site in Washington and the West Valley site in New York. The guidance document discusses the background and history of waste determinations, the different applicable criteria and how they are applied and evaluated, the review of associated performance assessments and inadvertent intruder analyses, the removal of highly radioactive radionuclides, and NRC's monitoring activities that will be performed at SRS and INL in accordance with the NDAA.

Title: Survey of Waste Solidification Process Technologies

Year: January 2001

URL: http://pbadupws.nrc.gov/docs/ML0104/ML010460184.pdf

Author(s): V. Jain

Abstract / Summary:

This report provides a current status of the high-temperature solidification technologies that have been used or proposed in the United States and abroad. The technologies presented in this report can be broadly classified into the following categories: Inconel-based, joule heated melters; high-temperature, joule-heated melters; induction melters; cold-crucible induction melters; plasma melters; combustion melters; microwave melters; molten metal technology; and Synroc technology. The operating experience and safety issues associated with major solidification technologies are summarized.

Title: Ground-Water Protection Activities of the U.S. Nuclear Regulatory Commission

Year: November 1986

URL: http://pbadupws.nrc.gov/docs/ML1015/ML101550111.pdf

Author(s): “Ground-Water Protection Group”

Abstract / Summary:

The U.S. Nuclear Regulatory Commission (NRC) provides for ground-water protection through regulations and licensing conditions that require prevention, detection, and correction of ground-water contamination. Prepared by the interoffice Ground-water Protection Group, this report evaluates the internal consistency of NRC's ground-water protection programs. These programs have evolved consistently with growing public concerns about the significance of ground-water contamination and environmental impacts. Early NRC programs provided for protection of the public health and safety by minimizing releases of radionuclides. More recent programs have included provisions for minimizing releases of nonradiological constituents, mitigating environmental impacts, and correcting groundwater contamination. NRC's ground-water protection programs are categorized according to program areas, including nuclear materials and waste management (NMSS), nuclear reactor operation (NRR), confirmatory research and standards development (RES), inspection and enforcement (IE), and agreement state programs (SP). Based on analysis of existing ground-water protection programs within NRC, the interoffice Ground-water Protection Group has identified several inconsistencies between and within program areas. These inconsistencies include: (1) different definitions of the term "ground-water," (2) variable regulation of nonradiological constituents in ground water, (3) different design periods for groundwater protection, and (4) different scopes and rigor of ground-water assessments. The second inconsistency stems from differences in statutory authority granted to the NRC. The third inconsistency is rationalized by recognizing differences in perceived risks associated with nuclear facilities. The Ground-water Protection Group will document its analysis of the remaining inconsistencies and make recommendations to reconcile or eliminate them in a subsequent report.

Title: Public Information Circular For Shipments of Irradiated Reactor Fuel

Year: January 2010

URL: http://pbadupws.nrc.gov/docs/ML1013/ML101390089.pdf

Author(s): A. G. Garrett, S. L. Garrett, R. G. Ostler

Abstract / Summary:

This report provides information on the shipment of irradiated reactor fuel (spent fuel) subject to regulation by the U.S. Nuclear Regulatory Commission (NRC). It briefly describes spent fuel shipment safety and safeguards requirements of general interest, summarizes data for highway and railway shipments from 1979 - 2007, and lists, by State, recent highway and railway shipment routes. This circular does not include 'Department of Defense and Department of Energy spent fuel shipments. The enclosed route information reflects specific NRC approvals that the agency has granted in response to requests for shipments of spent fuel. This publication does not constitute authority for carriers or other persons to use the routes to ship spent fuel, other categories of nuclear waste, or other materials.

Title: Hanford Tank Waste Remediation System Pretreatment Chemistry and Technology

Year: September 2000

URL: http://pbadupws.nrc.gov/docs/ML0126/ML012690529.pdf

Author(s): R. T. Pabalan, V. Jain, R. F. Vance, S. Ioannidis, D. A. Pickett, C. S. Brazel, J. T. Persyn, E. J. Taylor, M. E. Inman

Abstract / Summary:

The U.S. Department of Energy (DOE) will remediate the high-level radioactive wastes (HLWs) stored in 177 aging underground storage tanks at the Hanford, Washington site. The retrieved wastes will be separated into a HLW stream containing most of the radionuclides and a low-activity waste (LAW) stream containing the bulk of the nonradioactive chemicals and the soluble components of the tank waste. Both waste streams will be vitrified. Pretreatment of the LAW stream is required to remove cesium-137, strontium-90, technetium-99, and transuranic elements. This report provides information useful to U.S. Nuclear Regulatory Commission staff for understanding the technical bases of the pretreatment technologies proposed by DOE privatization contractors and for identifying potential hazards associated with those technologies. A review of publicly available information on the chemistry and technology of unit operations proposed by BNFL Inc. and by Lockheed Martin Advanced Environmental Systems is presented. These unit operations are sludge washing, ion exchange, electrochemical methods, organic destruction, and precipitation/filtration. The physicochemical bases of the unit operations and published experimental studies involving alkaline tank wastes are discussed. The proposed pretreatment technology is discussed in the context of its application to Hanford wastes, including operational and safety considerations.

Title: Status of the Decommissioning Program

Year: December 2006

URL: http://pbadupws.nrc.gov/docs/ML0706/ML070600680.pdf

Author(s): J. Buckley

Abstract / Summary:

This report provides a comprehensive overview of the U.S. Nuclear Regulatory Commission's (NRC's) decommissioning program. Its purpose is to provide a stand-alone reference document that describes the decommissioning process and summarizes the status of decommissioning activities, under NRC jurisdiction, through September 30, 2006. This includes the decommissioning of complex decommissioning sites, commercial reactors, research and test reactors, uranium recovery facilities, and fuel cycle facilities. In addition, this report discusses accomplishments of the decommissioning program in fiscal year (FY) 2006; identifies the key decommissioning program issues that the staff will address in FY 2007; and provides information Agreement States have supplied on decommissioning in their States.

Title: Status of the Decommissioning Program

Year: February 2009

URL: http://pbadupws.nrc.gov/docs/ML0905/ML090500375.pdf

Author(s): R. Chang, G. Gnugnoli

Abstract / Summary:

This report provides a comprehensive overview of the Decommissioning Program of the U.S. Nuclear Regulatory Commission (NRC). Its purpose is to provide a stand-alone reference document that describes the decommissioning process and summarizes the status of decommissioning activities, under NRC and Agreement State jurisdiction, from October 1, 2007, through September 30, 2008.

Title: A Performance Assessment Methodology for Low-Level Waste Facilities

Year: June 1990

URL: http://pbadupws.nrc.gov/docs/ML1112/ML11126A298.pdf

Author(s): M. W. Kozak, M. S. Y. Chu, P. A. Mattingly

Abstract / Summary:

A performance assessment methodology has been developed for use by the U.S. Nuclear Regulatory Commission in evaluating license applications for low-level waste disposal facilities. This report provides a summary of background reports on the development of the methodology and an overview of the models and codes selected for the methodology. The overview includes discussions of the philosophy and structure of the methodology and a sequential procedure for applying the methodology. Discussions are provided of models and associated assumptions that are appropriate for each phase of the methodology, the goals of each phase, data required to implement the models, significant sources of uncertainty associated with each phase, and the computer codes used to implement the appropriate models. In addition, a sample demonstration of the methodology is presented for a simple conceptual model.

Title: Public Information Circular for Shipments of Irradiated Reactor Fuel

Year: September 2006

URL: http://pbadupws.nrc.gov/docs/ML0629/ML062910052.pdf

Author(s): A. Giantelli, S. Bagley

Abstract / Summary:

This report provides information on the shipment of irradiated reactor fuel (spent fuel) subject to regulation by the U.S. Nuclear Regulatory Commission (NRC). It briefly describes spent fuel shipment safety and safeguards requirements of general interest, summarizes data for highway and railway shipments from 1979-2005, and lists, by State, recent highway and railway shipment routes. This circular does not include Department of Defense and Department of Energy spent fuel shipments. The enclosed route information reflects specific NRC approvals that the agency has granted in response to requests for shipments of spent fuel. This publication does not constitute authority for carriers or other persons to use the routes to ship spent fuel, other categories of nuclear waste, or other materials.

Title: Data Base for Radioactive Waste Management

Year: August 1981

URL: http://pbadupws.nrc.gov/docs/ML0920/ML092010352.pdf

Author(s): O. I. Oztunali, G. C. Re, P. M. Moskowitz, E. D. Picazo, C. J. Pitt

Abstract / Summary:

This report presents the methodologies utilized to calculate potential impacts resulting from the management of low level radioactive waste (LLW). The report considers three phases of waste management that may result in various types of impacts: (1) processing of the waste at the generation source or at a centralized location prior to disposal, (2) transportation of the waste from the generation source to the disposal location, and (3) disposal of the waste. Potential impacts resulting from the management and disposal of LLW are expressed through "impact measures." Five quantifiable impact measures have been selected for treatment in this report: dose to the members of the public, occupational exposures, costs, energy use, and land use. Other impact measures may be quantified; however, the above five measures have been selected since they implicitly reflect many of the other impact measures.

Title: Proceedings of the Workshop on Engineered Barrier Performance Related to Low-Level Radioactive Waste, Decommissioning, and Uranium Mill Tailings Facilities

Year: June 2011

URL: http://pbadupws.nrc.gov/docs/ML1123/ML11238A056.pdf

Author(s): T. J. Nicholson, H. D. Arlt

Abstract / Summary:

NRC's Offices of Nuclear Regulatory Research (RES) and Federal and State Materials and Environmental Management Programs (FSME) organized this *Workshop on Engineered Barrier Performance Related to Low-Level Radioactive Waste, Decommissioning, and Uranium Mill Tailings Facilities*. The workshop was held August 3–5, 2010 at the U.S. Nuclear Regulatory Commission (NRC) Headquarters Auditorium, 11545 Rockville Pike, Rockville, Maryland. The Workshop was coordinated with the States (i.e., Texas, South Carolina, Utah, Colorado, Washington, and New York), Tribal Nations (Navajo, Umatilla and Nez Perce), and Federal agencies (e.g., U.S. Department of Energy [DOE], U.S. Environmental Protection Agency [EPA], U.S. Department of Agriculture's Agricultural Research Service [USDA/ARS], U.S. Geological Survey [USGS], and DOE National Laboratories). The workshop technical topics focused on engineered surface covers and bottom liners designed to isolate waste by impeding surface-water infiltration into the waste systems and mitigating the migration of contaminants from the waste disposal site. Topics included engineered barrier performance, modeling, monitoring, and regulatory experiences at low-level radioactive waste, decommissioning, and uranium mill tailings sites. The workshop objectives included: (1) facilitation of communication among Federal and State staff and contractors and selected experts on current engineered barrier issues and technical and regulatory experiences; (2) discussion of lessons learned and approaches for monitoring and modeling; (3) preparation of recommendations to address maintenance of engineered barrier performance over time; and (4) identification of topics for future research and the potential need to update technical guidance. Recommendations and insights given during session presentations, panel debates, and the discussions that followed were documented by the session reporters and are included in this report.

Title: A Performance Assessment Methodology for Low-Level Radioactive Waste Disposal Facilities

Year: October 2000

URL: http://pbadupws.nrc.gov/docs/ML0037/ML003770778.pdf

Author(s): N/A

Abstract / Summary:

The relationships between the overall 10 CFR Part 61 data and design requirements, and detailed low-level radioactive waste (LLW) performance assessment needs, are not directly apparent from the existing U.S. Nuclear Regulatory Commission (NRC) guidance documents. To address this concern, NRC's Performance Assessment Working Group (PAWG) has prepared this technical report as a means of providing information and recommendations on performance assessment methodology as it relates to the objective concerned with the radiological protection of the general public - 10 CFR 61.41. Specifically, this information includes the PAWG's views on: (a) an acceptable approach for systematically integrating site characterization, facility design, and performance modeling into a single performance assessment process; (b) five principal regulatory issues regarding interpreting and implementing Part 61 performance objectives and technical requirements integral to an LLW performance assessment; and (c) implementation of NRC's performance assessment methodology. Moreover, the PAWG does not expect separate intruder scenario dose analyses would be included in an LLW performance assessment because 10 CFR 61.13(b) requires that analyses of the protection of individuals from inadvertent intrusion must include a demonstration that there is reasonable assurance the waste classification and segregation requirements will be met and that adequate barriers to inadvertent intrusion will be provided. Finally, this technical report attempts to share with the Agreement States and LLW disposal facility developers some of the PAWG's experience and insights, as they relate to the use of LLW performance assessments. In this regard, these groups may also find this technical report useful, as they proceed with the implementation of their respective programs.

From Alternative Online Sources

Title: Geotechnical Analysis of Soil Samples from Test Trench at Western New York Nuclear Service Center, West Valley, New York

Year: January 1979

URL: http://babel.hathitrust.org/cgi/pt?id=mdp.39015038541739;view=1up;seq=5

Author(s): R. H. Fickies, R. H. Fakundiny

Abstract / Summary:

In July 1977, a deep research trench was excavated and soil samples collected at the Western New York Nuclear Services Center, West Valley, N.Y. The glacial till horizons sampled are considered to be representative of the till serving as a burial medium at the nearby low-level radioactive waste burial ground. A series of laboratory tests were conducted consisting of unit weight, moisture content, Atterberg limits, unconfined compression, dispersion, swell, permeability, and consolidation. These laboratory analyses and field observations indicate that the till exposed in the research trench is a generally dense mixture of silt and clay of low to medium plasticity, with minor amounts of fine to coarse sand and fine gravel. The till has a generally low coefficient of permeability in the range of 10^{-7} cm/sec horizontal and 10^{-8} cm/sec vertical. A network of vertical fractures exists in the upper 15 feet of “weathered” till which may allow some downward percolation of surface runoff. The test data indicates that the maximum depth to which these fractures could possibly penetrate is 50 feet.

Documents Available On Share-File

Title: Ground-Water Flow Near Two Radioactive-Waste Disposal Areas at the Western New York Nuclear Service Center, Cattaraugus County, New York - - Results of Flow Simulation

Year: April 20th, 1988

Author(s): Marcel P. Bergeron

Abstract / Summary:

Two adjacent burial areas are excavated in a clay-rich till at a radioactive-waste-disposal site near West Valley in Cattaraugus County, N.Y. One of the burial grounds, which contains mainly low-level radioactive wastes generated onsite by a nuclear-fuel-reprocessing plant, has been in operation since 1966. The other, which contains commercial low-level-radioactive wastes, was operated during 1963-75. Ground water below the upper 3 meters of till generally moves downward through a 20- to 30-meter-thick sequence of tills underlain by lacustrine and kame-delta deposits of fine sand and silt. Ground water in the weathered, upper 3 meters of till can move laterally for several meters before either moving downward into the kame-delta deposits or discharging to land surface.
A two-dimensional finite-element model that simulates two vertical sections was used to evaluate hydrologic factors that control ground-water flow in the till. Conditions observed during March 1983 were reproduced accurately in steady-state simulations that used four isotropic units of differing hydraulic conductivity to represent two fractured and weathered till units near land surface, an intermediate group of isolated till zones that contain significant amounts of fine

sand and silt, and a sequence of till units at depth that have been consolidated by overburden pressure.
Recharge rates used in the best-fit simulation ranged from 1.4 centimeters per year along smooth, sloping or compacted surfaces to 3.8 centimeters per year near swampy areas. Values of hydraulic conductivity and infiltration used in the calibrated best-fit model were nearly identical to values used in a previous model analysis of the nearby commercial-waste burial area.
Results of model simulations of a burial pit assumed to be filled with water indicate that water near the bottom of the burial pit would migrate laterally in the shallow, weathered till for 5 to 6 meters before moving downward into the unweathered till, and water near the top of the pit would move laterally less than 20 meters before moving downward into the unweathered till. These results indicate that subsurface migration of radionuclides in ground water to points of discharge to land surface is unlikely as long as the water level does not rise into the reworked cover material.

Title: Geomorphic Processes and Evolution of Buttermilk Valley and Selected Tributaries; West Valley, New York

Year: July, 1982

Author(s): Jon C. Boothroyd, Barry S. Timson, Lorie A. Dunne

Abstract / Summary:

Repetitive bar and channel mapping at several scales, clast sire and movement measurements, suspended-sediment sampling, and stream gaging of a 5 km reach of Buttermilk Creek and selected tributaries at West Valley, New York, have been carried out to determine short-term depositional and erosional processes as well as long-term valley changes adjacent to the low-level nuclear waste disposal site and other areas of the Western New York Nuclear Service Center.

Changes to bar-and-channel geometry in Buttermilk Creek are the result of migration of large transverse bars in equilibrium with large floods, such as occurred during Hurricane Fredric, September 1979. Large amounts of lower terrace gravel are also recycled during these events.

Downslope movement of landslides by slumping and earthflow appears to be a continuous process (1.5 m^3yr^{-1}). Volumetrically it is a small sediment source except when sudden failure by block gliding deposits a large mass in Buttermilk Creek.

Quantitative values of bedload transport, suspended-load sediment transport, and reservoir infill rates compare well with a simple denudation rate (6600 m^3yr^{-1}), a preliminary estimate, was calculated by dividing the volume of sediment removed by the number of years since initial incision (9920 +/- 240 BP).

The middle-to high-level fluvial terraces in Buttermilk Creek are either adjacent to tributary confluences and preserved by an excess of bedload over transport capacity, or survive because the channel is stable on the opposite side of the valley for unknown reasons.

The convex longitudinal profile of Franks Creek/Erdman Brook suggests that it is unstable and will continue to downcut rapidly. Valley widening will occur by parallel retreat of slopes.

The future lowering of Buttermilk Creek is controlled by bedrock floors in Cattaraugus Creek and lower Buttermilk Creek. However, tributary lowering and widening will continue independent of a change in base-level of Buttermilk Creek.

(Includes Scanned Plates)

Title: Report, Seismo-Tectonics, Proposed Expansion, Nuclear Spent Fuel Reprocessing Facility, West Valley, New York, Nuclear Fuel Services, Incorporated.

Year: July 16th, 1970

Author(s): “Dames and Moore”

Abstract / Summary:

The report presents the results of seismo-tectonic studies conducted for the proposed expansion of an existing nuclear spent fuels reprocessing facility in West Valley, New York. The proposed expansion will be designed and constructed by Blaw-Knox Chemical Plants, Incorporated. The purpose of these studies were to: investigate and evaluate the geologic tectonic characteristics of the side and environs, and to develop seismic criteria for use in the design of critical units to resist earthquake ground motion.

Title: Geologic Study of the Burial Medium at a Low-Level Radioactive Waste Burial Site at West Valley, New York

Year: February 9th, 1979

Author(s): R. H. Dana, Jr., R. H. Fakundiny, R. G. LaFleur, S. A. Molello, P. R. Whitney

Abstract / Summary:

This report is one in a series of related reports presenting the results of a three-year study to evaluate the containment ability of a low-level solid radioactive waste burial ground at West Valley, New York.

The trenches of the low-level radioactive waste burial site at West Valley, New York, are emplaced in surficial glacial deposits (Lavery, Late Wisconsinan) consisting of a clayey silt till approximately 30m thick. These deposits overlie lacustrine deposits and till (Kent, Late Wisconsinan) which in turn are inferred to overlie tills and lacustrine deposits (Olean, Late (?) Wisconsinan) which are not exposed in the area of the site. The burial till contains discontinuous, randomly-distributed, distorted, silt, sand and gravel pods and lenses. Because of the discontinuous distribution of these pods within the enclosing very low-permeability clayey silt they do not appear to form preferential permeability systems for ground-water movement.

Systematically oriented (northeast and northwest) vertical fractures, believed to be inherited from the joint patterns of underlying bedrock, occur in the upper part of the burial till. Water flow through these till fractures is too slow to be measured by dye movement with any meaningful results. The deepest observed fracture was 4.5 m deep. Theoretical maximum fracture depth is 15m.

The trench caps show extensive cracking of the compacted till material used as covering for the trenches. It is not practical to measure the depths of the cracks, but some are believed to extend completely through the trench caps and to provide open paths for the movement of gas and water between the surface and the trench wastes. The mapped density of cracks in the cover material is not necessarily related to crack depth but appears to be greatly influenced by the underlying trenches. The dense zone of cracks commonly follow trench sides and trench center lines on the crests of the mounded cap material.

The burial till is of very low permeability with vertical permeabilities ranging from 1.25×10^{-8} cm/sec to 4.33×10^{-8} cm/sec and horizontal permeabilities of 3.72×10^{-7} and 7.46×10^{-7} cm/sec. Landslide and slope-failures exist in the general area and small-scale slope movements occur in man-made ground on the margins of the site.

Title: Surface-Water Hydrology of the Western New York Nuclear Service Center, Cattaraugus County, New York

Year: 1987

Author(s): William M. Kappel, William E. Harding

Abstract / Summary:

This report describes the relationships between precipitation and surface-water runoff at the burial ground and reprocessing-plant areas and includes analyses of streamflow and precipitation data, seepage measurements from springs, and estimates of evapotranspiration. Four appendixes present (1) precipitation records, (2) stream discharge at three gaged sites, (3) seepage discharge at 19 seeps along the edge of the reprocessing-plant area, and (4) water levels measured during 1982-83 in wells around the reprocessing-plant area.

Title: Erosion Frame Monitoring; Progress Report

Year: September, 2001

Author(s): URS Corp.

Abstract / Summary:

The purpose of the report is to update the information that was gathered during the initial monitoring program, which ran from September 1990 through April 1992. Results of the initial monitoring are contained in Environmental Information Document Volume III, Hydrology, Part 3: Erosion and Mass Wasting[1]. In the initial program, erosion frames were installed at various locations that are representative of the overall site topography to provide measurements of soil gain or loss (e.g., aggradation or degradation), from which the amount and rate of change can be calculated. Comparison of these aggradation or degradation data with fluctuations in precipitation and stream discharge may reveal how precipitation affects the rate and amount of erosion over a given time at these locations.

Title: Environmental Information Document Volume 1

Year: April 1st, 1993

Author(s): West Valley Nuclear Services, Inc.

Abstract / Summary:

The following exposition of regional geology is based on a general review of the literature, including summaries of regional geology compiled for and presented in documents specifically pertaining to the Western New York Nuclear Service Center (WNYNSC) and the West Valley Demonstration Project (WVDP).

Title: Report of the 1982 Cooperative Drilling Project at the Western New York Nuclear Service Center West Valley, New York

Year: 1982

Author(s): S. M. Potter, J. R. Albanese, S. L. Anderson, L. F. Whitbeck

Abstract / Summary:

The NYSGS-USGS cooperative drilling program of fall 1982 installed 17 test holes adjacent to the U.S. Nuclear Regulatory Commission-licensed burial area at the Western New York Nuclear Service Center (WNYNSC) near West Valley, New York. The program was part of a continuing effort to define the geology and subsurface hydrology, and to examine the possibility of radioisotope migration at the WNYNSC. Test holes 15.2, 12.2, and 6.2 m (50, 40, and 20 ft) deep were drilled in five clusters around the burial area, and deeper holes 26.8 and 28 m in depth (88 and 92 ft), were drilled at its western and southern borders. This report presents lithologic descriptions and preliminary geologic interpretations of the cores obtained. Further work with these samples is planned to refine the understanding of the site stratigraphy and hydrology. Results of tritium analyses of core and water samples are also presented. Concentrations of tritium are below detectable limits except near the surface, within weathered sediment. Additional radioisotope analyses will be performed. The holes were finished as piezometers, and water levels within them will be used to extend the hydrologic model, developed by the USGS, of the adjacent New York State-licensed burial area, into the area of the USNRC burial pits.

Title: Estimation of Source Term for Hulls and Ends Burial Ground at West Valley

Year: December, 1983

Author(s): N. J. Dayem, J. D. Price, J. E. Hammelman

Abstract / Summary:

Approximately 150,000 ft^3 of waste is buried in the burial ground. Review of the burial logs allowed us to identify the principal categories and quantities of waste. The principal constituents

in the burial ground were summarized in Table 2.2. The basis for calling a specific category a principal constituent for the major isotopes are the volume and/or the curie content of the category at burial. Table 3.4 shows the curie content at burial and estimated curie content in September, 1983. The major isotopes at present are estimated to be Cs(Ba), Sr(Y), H-3, and Pu making up approximately 10, 20, 30, and 40 percent of the total activity, respectively. The tritium and Pu are primarily contained in the hulls.

Several sources of information concerning the chemical composition of the waste in the burial grounds were reviewed and no chemicals with the exception of spent solvent, were noted that could present a potential for increased mobility of the radioisotopes. The spent solvent is identified as TBP. By our best estimate, the TBP burials are in three burial holes. The TBP can significantly enhance the mobility of Pu, U, Zr, Nb, and Ru isotopes. For Cs and Sr isotopes TBP may slightly enhance their mobility.

Title: Low Level Waste Burial Data

Year: March, 1975

Author(s): Various

Abstract / Summary:

Log of burial data containing the following fields: Shipment Number, Customer, Date Received, H&S Rep., Cubic Feet, Date Buried, Location Buried, Location Buried, Container Type, Curies Per Load, SNM Decon Spec. Hand

Title: Procedures Used in the 1983 Cooperative USGS-NYSGS Drilling Projects at the Western New York Nuclear Service Center, West Valley, New York

Year: 1983

Author(s): S. M. Potter, S. L. Anderson, L. F. Whitbeck

Abstract / Summary:

In the spring of 1983 the USGS and USDOE deepened two holes drilled near the NRC-licensed burial area at the WNYNSC, and drilled five more holes to the west. The NYSGS assisted in geologic logging of the cores. The drilling and sampling procedures were similar to those used in 1982 in the USGS-NYSGS drilling project. In the summer of 1983 the USGS and NYSGS cooperated in drilling a hole on the North Plateau, using a contracted drilling rig. The procedures used were different from those used in 1982, but allowed the project to go to greater depth. Together these holes added substantially to knowledge of the character and extent of lithologic units at the WNYNSC. The North Plateau hole penetrates a pre-Kent (?) lacustrine sequence and an underlying till. Neither of these units had been identified in any holes drilled previously at the site.

Title: Summary of U.S. Geological Survey Drilling Activities for the NRC Disposal Area Drilling Program

Year: October, 1983

Author(s): USGS

Abstract / Summary:

In late April 1983, the U.S. Geological Survey (USGS) was funded by the U.S. Department of Energy to complete a number of tasks in an effort to provide baseline geologic and hydrologic data of subsurface materials in an area southwest of the present NRC disposal area. These tasks are as follows: Drill and complete 5 borings at the Western New York Nuclear Service Center site. Complete these borings as piezometers. Drilling specifications, sampling, and the well completion program should be identical to the drilling program completed at the site in 1982 by the USGS. All casing and piezometer equipment is to be included. Subsequently, the USGS will perform gamma ray and neutron logging of these borings. This report summarizes USGS activities in relation to this program and includes geologic descriptions of materials penetrated, locations and depths of each test boring, construction details of wells installed, and natural gamma and neutron profiles done on selected holes.

Title: Core Sampling Beneath Low-Level Radioactive-Waste Burial Trenches, West Valley, Cattaraugus County, New York

Year: 1979

Author(s): David E. Prudic

Abstract / Summary:

A technique was developed for collecting cores for radiometric analysis from beneath a low-level radioactive-waste landfill to determine the rates of downward radionuclide migration below the trenches. A closed pipe was driven through the buried waste, and a removable point withdrawn. The hole was then advanced by alternately pushing a coring device, then driving an inner casing to the depth reached by the coring device and cleaning out cuttings from within the casing. The effectiveness of the technique was limited by inability to predict the location of impenetrable objects within the waste in some parts of the burial ground and difficulty in detecting when the end of the pipe first penetrated undisturbed material beneath the trench floor. Geophysical logs of the completed hole were used to help determine the trench-floor depth.

Title: Waste Burial Log

Year: 1967 - 1970

Author(s): Various

Abstract / Summary:

A hand-written log of the waste buried at the site between the aforementioned years.

Title: Waste Burial Log

Year: 1972 - 1976

Author(s): Various

Abstract / Summary:

A hand-written log of the waste buried at the site between the aforementioned years.

Documents Yet to be Digitized (Physical Copy Available)

Title: Geologic and Hydrologic Research at the Western New York Nuclear Service Center West Valley, New York

Year: August 1979 – July 1981

Author(s): J. R. Albanese, L. A. Dunne, W. B. Rogers, S. M. Potter

Abstract / Summary:

During August 1979, the NYSGS began the first part of a USNRC-funded study of 1354 hectare of the Western New York Nuclear Service Center. The goal of this study is to learn enough about the natural processes at work to evaluate the adequacy of the present containment capabilities and the probable life span of the radioactive waste burial sites at West Valley. This study will define the surface and subsurface geologic and hydrologic characteristics of these sites and the surrounding areas to determine the potential for radionuclide migration off site.

This broader study is a logical extension of the studies done by the NYSGS which focused on the New York State licensed burial trenches.

As in the past, the NYSGS is cooperating with the USGS, which is investigating site hydrology and handling the logistics of the drilling programs, and the Radiological Sciences Laboratory of the New York State Department of Health (RSL) which is providing the radiochemical analyses of water and sediment samples.

The integration of the information generated by each of these studies forms the basis of this first phase of the site-wide investigation. As this investigation continues an overview of the North

Plateau area which contains the underground high-level radioactive liquid waste storage tanks and the NRC burial will emerge. This will result, when combined with earlier studies, in a complete geologic and hydrologic characterization of the area occupied by the Western New York Nuclear Service Center.

Title: An Update of the Structural Geology in the Vicinity of the Western New York Nuclear Service Center, West Valley, New York

Year: May, 2002

Author(s): URS Corporation

Abstract / Summary:

This document presents an updated review of the regional structural geology in the vicinity of the 3,340 acre Western New York Nuclear Service Center (WNYNSC) near West Valley, New York. A review of the regional geology of western New York was included in the draft environmental impact statement (DEIS) for the WVDP and the WNYNSC that was prepared jointly by the DOE and NYSERDA (U.S. Department of Energy and New York State Energy Research and Development Authority January 1996). However, additional information concerning regional structural geology, such as the recently completed WVDP seismic reflection survey has become available since the publication of the DEIS.

Title: Practical Applications of Geological Methods at the West Valley Low-Level Radioactive Waste Burial Ground, Western New York

Year: 1985

Author(s): Robert H. Fakundiny

Abstract / Summary:

This paper describes the physical setting of the burial area and summarizes results of the areal geologic studies, vertical geologic studies, soil studies, geomorphologic studies, subtrench coring, ground-water studies, trench-gas studies, surface-water studies, biological pathway studies, and computer modeling studies of ground-water migration routes. Each section states the study rationale and scope, describes the experimental approach, presents results, and summarizes the major conclusions.

Title: Ground-Water Hydrology and Subsurface Migration of Radionuclides at a Commercial Radioactive-Waste Burial Site, West Valley, Cattaraugus County, New York

Year: 1986

Author(s): David E. Prudic

Abstract / Summary:

This report is a summary of the U.S. Geological Survey study at the burial site from 1975 through 1980. The report has fourfold purpose. First, it describes the general geohydrologic setting in the vicinity of the burial site, including climate, streamflow, geology, ground-water movement, and ground-water quality. Second, it describes the history of the site, including the types of waste buried and the method of burying the wastes. Third, it describes in detail the ground-water hydrology and geology at the burial site, including the periodic rise of water within some of the trenches. Fourth, it evaluates the potential for subsurface migration of radionuclides from the trenches to the land surface.

Title: Stability Evaluations of Slopes Adjoining the New York State-Licensed Disposal Area (SDA) Western New York Nuclear Service Center (WNYNSC) West Valley, New York

Year: June, 1992

Author(s): D. L. Aloysius, A. J. Nello

Abstract / Summary:

In September 1991 the New York State Energy Research and Development Authority (NYSERDA) requested that the WVNS Safety and Environmental Assessment Department (Dames and Moore) investigate and evaluate the stability of selected slopes adjoining the New York State-licensed disposal area (SDA). This report describes the subsequent investigation by Dames and Moore, and the resulting recommendations.

Two general areas of potential slope instability had been noted in the course of routine surveillances of the SDA: The west bank of Frank’s Creek on the eastern border of the SDA and the south bank of Erdman Brook on the north border of the SDA (Fig. 1). The following report characterizes surficial conditions, surrounding topography, previous literature, soil data, and boring data and a computer code (SB-Slope, version 3.0) used for detailed slope stability analysis to produce recommendations for retaining slope configurations and reducing erosion.

Title: Glacial Geology and Stratigraphy of Western New York Nuclear Service Center and Vicinity, Cattaraugus and Erie Counties, New York

Year: 1979

Author(s): Robert G. Lafleur

Abstract / Summary:

A detailed glacial geologic map at a scale of 1:24,000, embracing a 165 square-mile area in Erie and Cattaraugus Counties, N.Y., shows 27 mapping units, including the till complex in which the West Valley radioactive-waste burial site is located. Stratigraphic relationships at 24 boreholes at the burial site and 6 newly described exposures indicate the age of the till complex to be early late Woodfordian (post-Kent, pre-Lake Escarpment [Valley Heads]), equivalent to the Lavery

glacial advance. Correlations of mapping units and measured sections with Woodfordian and older glacial and deglacial episodes are proposed.

Title: Geologic and Hydrologic Research at the Western New York Nuclear Service Center West Valley, New York

Year: August 1981 – July 1982

Author(s): J. R. Albanese, S. L. Anderson, L. A. Dunne, B. A. Weir

Abstract / Summary:

This report details the research accomplished during the second part of the New York State Geological Survey's (NYSGS) three part program of geologic and hydrologic investigations at the Western New York Nuclear Service Center (WNYNSC) at West Valley, New York. During this reporting period, July 1981 – July 1982, the surficial gravel and the underlying till surface of the North Plateau area were measured using core log data and seismic techniques. Contour and isopach maps are included and show the superficial gravel layer to be lenticular in cross section and approximately 40 feet thick at its center. The history of drilling at the site and all available subsurface information pertaining to the site stratigraphy has been compiled and standardized. Geologic sections based upon the locations of all the wells and their geologic logs show that a sandy stratum, previously reported to extend under the entire site at an elevation of 1350 feet, is not a continuous layer. Grain size analyses of gravel samples from the North Plateau indicate the two genetically different gravels have similar particle size distributions. Analyses of surface and subsurface till samples show that Lavery Till can be subdivided into three subfacies using grain size distributions and the Kent Till can be distinguished from it by its higher silt content. Initial measurements for movement determination on two landslides yield an average downslope movement rate of 0.23 meters/year. A site slope domain map, establishing five domains of varying sliding potential, has been compiled from aerial photos and field mapping. The final phase of the Buttermilk Creek investigation and the study of the erosional history of the Cattaraugus Creek drainage basin have been initiated. Data collection for the cooperative for the USG-NYSGS surface water and ground water studies, initiated during the earlier programs, is continuing. A preliminary characterization of the relationship between precipitation and runoff on the North Plateau shows the income to outflow ratio is 3:1 during the summer and nearly equal to one in the winter.

Title: Geomorphic and Erosion Studies at the Western New York Nuclear Service Center, West Valley, New York

Year: June 1984

Author(s): J. C. Boothroyd, B. S. Timson, R. H. Dana, Jr.

Abstract / Summary:

This report is the last in a series by the New York State Geological Survey on studies funded by the U.S. Nuclear Regulatory Commission. The report covers five important aspects of the

geology and hydrology of the Western New York Nuclear Service Center, near West Valley, New York: geomorphology, stratigraphy, sedimentology, surface water, and radionuclide analyses. We reviewed pas research on these subjects and present new data obtained in the final phase of NYSGS research at the site. Also presented are up-to-date summaries of the present knowledge of geomorphology and stratigraphy.

Title: Errata Sheet for Geomorphic and Erosion Studies at the Western New York Nuclear Service Center West Valley, New York (**for previously listed document**)

Year: February 26th, 1980

Author(s): NYSGS

Abstract / Summary:

Document containing 5 plates that were omitted from the original document (NUREG/CR-0795).

Title: Sedimentologic and Geomorphic Processes and Evolution of Buttermilk Valley, West Valley, NY

Year: (Unlisted; post-1981)

Author(s): Jon C. Boothroyd, Barry S. Timson, Lorie A. Dunne

Abstract / Summary:

The purpose of this trip is to investigate the sedimentologic and geomorphic processes active in a small non-glacial gravel stream and on adjacent valley walls and tributaries. The work that led to this field trip is part of a larger geologic and hydrologic study by the New York State Geological Survey of the low-level nuclear waste disposal site and other use areas of the West Valley Nuclear Service Center. The geomorphic study is being done to determine, as accurately as possible, the denudation rate in the Buttermilk drainage basin, and to estimate rate and magnitude of morphologic changes to the waste-burial site.

Though designed for a field trip, the document contains a number of useful references as well as figures and descriptive text that offers insight towards Buttermilk Creek and its many tributaries.

Title: Geologic and Hydrologic Research at the Western New York Nuclear Service Center West Valley, New York

Year: August 1982 – December 1983

Author(s): J. R. Albanese, S. L. Anderson, R. H. Fakundiny, S. M. Potter, W. B. Rogers, L. F. Whitbeck

Abstract / Summary:

This report is the last in a series of progress, annual, and topical reports from the New York State Geological Survey (NYSGS) on geologic and hydrologic research at the Western New York Nuclear Service Center (WNYNSC) near West Valley, New York. The NYSGS has been involved with the studies at the site since 1975, often in cooperation with the United States Geological Survey (USGS) Water Resources Division, and the Radiological Sciences Laboratory (RSL) of the New York State Department of Health (NYSDOH).

The primary interests of the NYSGS have been geomorphology, stratigraphy, sedimentology, and surface water hydrology. The NYSGS also has participated with the USGS in a cooperative program to study groundwater hydrology, and with the USGS and RSL in studies related to radionuclide migration and pathways and monitoring.

In this final report we present new data from the past year and a half of research. We also provide summaries of past research on several topics. Finally, we present up-to-date interpretations of several aspects of the geology. The extensive list of references and the historical summaries can be used as a guide to a majority of the scientific studies that have been done at the site.

Title: Environmental Information Document Volume III; Hydrology: Part 1. Geomorphology of Stream Valleys

Year: January 29th, 1993

Author(s): B. M. Beyer

Abstract / Summary:

Geomorphological studies identifying the processes affecting the surficial geology and/or topography of the WVDP site and the surrounding area have focused on Buttermilk Creek and its tributaries. These studies include investigations of geomorphological and surficial characteristics of the sire, longitudinal profiles of stream channels, and ages of stream terraces.

Title: Environmental Information Document Volume III; Hydrology: Part 2. Surface Water Hydrology

Year: January 29th, 1993

Author(s): F. A. O'Connor

Abstract / Summary:

Decommissioning of the Project requires assurance that future erosional processes in the Buttermilk Creek drainage basin probably will not result in release and migration of radioactivity. Because potential sources of radioactivity are located in Frank's Creek watershed, which drains to Buttermilk Creek and thence to Cattaraugus Creek, erosional processes in the Frank's Creek watershed are of major interest, as are the overall watershed characteristics. Since previous

investigations had indicated that "whether actively slumping, slowly creeping or currently stationary, nearly all the ravine walls in the Buttermilk Creek Drainage Basin are unstable" (Nicholson and Hurt 1985), additional study of Frank's Creek and its tributaries was necessary. Specifically, the hydrologic and hydraulic conditions responsible for stream erosion on-site needed to be understood in order to estimate the long-term stability of sensitive areas.

Title: Environmental Information Document Volume III; Hydrology: Part 3. Erosion and Mass Wasting Processes

Year: January 29th, 1993

Author(s): B. M. Beyer

Abstract / Summary:

The West Valley Demonstration Project (WVDP) and former Nuclear Fuel Services (NFS) facilities are located on a plateau that is bounded and encroached upon by a number of stream channels and gullies. The stream valleys vary in depth from 0.3 meters (one foot) or less along their upper reaches to more than 27.5 meters (90 feet) at the outfall of the site watershed. The site's location on this plateau and its proximity to the streams is cause for concern regarding the effects of erosion on the long-term integrity of the site.

The plateau that the site is located on is bisected into north and south plateaus by Erdman Brook. The overall plateau has an average drop in elevation of approximately 27.4 meters (90 feet) over its 914 meters (3,000-foot) length (3% grade). Bedrock below the site exists from within 1.5 meters (5 feet) of the surface at Rock Springs Road to more than 39.5 meters (130 feet) below near the waste burial areas.

Past erosion studies primarily focused on the State-licensed Disposal Area (SDA) and characterization of Buttermilk Creek. Current erosion studies have concentrated on the local stream channels in the vicinity of the site since these could likely affect the integrity of site facilities to some degree in the future. The streams investigated include: Erdman Brook, Quarry Creek, and Frank's Creek.

APPENDIX B
Pebble Count Data

Pebble Count Compilation, West Valley Geologic Study (Revised February 22, 2017)

Spreadsheet Explanation:

Pebble counts of the various sedimentary units encountered in the field were measured in order to more accurately determine the potential sources and/or genesis of the different fluvial and glacial deposits. This was done especially with the goal of distinguishing among the potential origins of horizontal to semi-horizontal geomorphic surfaces along the sides of Buttermilk Creek valley. It is not always obvious whether such surfaces might be fluvial terraces, glacial marginal deposits such as kame terraces, alluvial fans (glacial or post-glacial), and/or more recent landslide slump blocks.

The accompanying Excel spreadsheet records the 76 pebble (clast) counts performed on various sedimentological units in the Buttermilk Creek drainage basin near the WVDP site. Clast counts generally consisted of 100 clasts. Sometimes only 50 clasts were collected and identified where the genesis of the deposit seemed obvious. It was determined that counts of 50 clasts gave essentially the same results as the 100-clast samples. Some samples contained more or less than 100 clasts, all of which were converted to percentages for the compilation on the spreadsheet.

The background spreadsheet colors signify the following subdivisions:

White or yellow signifies fluvial deposits of existing creeks or their ancestral terraces.
The yellow samples are simply locations where multiple samples were taken close together within the same sedimentary setting to provide a more detailed comparison, as well as to demonstrate the relative consistency of the results. The four "WP9" nine samples (yellow) were measured to test whether numbers greater than 100, or different particle size intervals would produce a significantly different result. Normally the individual clasts ranged from 1 to 2 inches in diameter, with pebbles as small as ½ inch utilized where clasts were limited in number, such as in some till samples only accessible from limited backhoe excavations.

Gray signifies glacial till samples.

Pink signifies samples that are probably glacial outwash or ice contact sediments, such as ablation till.

Green signifies samples that are either alluvial fans, or locations where the distal margins of alluvial fans may interfinger with adjacent stream terrace gravels.

The column labeled, PERSONS, indicates which two individuals completed and/or supervised the clast identifications.

Y=Young, W= Wilson, B=Butzer, D=daSilva, Z=Zerfas, H=Hristodoulou, Hs=Hess

The following generalities are obvious from the data collected:

1) The major differences between the fluvial, generally southerly derived gravels and the glacial, northerly derived deposits are best documented by the clearly different percentages of local Devonian sandstone (generally grayish to brownish in color) and carbonates, which crop out in the Onondaga Limestone and Lockport Dolostone escarpments to the north of Cattaraugus Creek. The Buttermilk Creek fluvial and terrace deposits have 80 to 98 percent locally or southerly derived sandstone and siltstone clasts, but limestones are relatively uncommon, never exceeding 4% (most

probably derived from local reworking of till). Of the 42 fluvial gravel samples analyzed, 35 (83%) contained no limestone clasts, due both to the northerly location of the bedrock outcrops and the tendency for such softer lithologies to be eliminated by abrasion during fluvial transport.

2) By comparison, the glacial till component of sandstone and siltstone is noticeably lower, ranging from 28 to 79 percent. The glacial till carbonate clast percentages are higher, ranging from 7 to 28 percent.

3) Not surprisingly, glacial outwash gravels and ablation tills, whose subtle differences are sometimes difficult to accurately distinguish, have compositions more similar to the glacial tills. The fewer samples examined from these less well represented environments contained 55 to 86 percent sandstone and 5 to 23 percent carbonates (only one such sample exhibited no carbonate clasts).

4) Shale, a relatively more friable rock type, is nearly absent from most of the fluvial deposits, except where adjacent tributaries (such as Heinz Creek) contributed locally derived clasts. Such locally derived shale clasts have not been transported sufficient distances to have all disintegrated. In contrast, the tills contained 3 to 34 percent shale clasts, and shale was missing in only one till sample. Shale clasts are more common in tills lowest in the stratigraphic sections, presumable because such shale clasts have not been glacially transported as far from the underlying bedrock sources.

5) Quartzite percentages are more difficult to accurately assess because some clasts identified as “quartzite” may be simply hard Devonian sandstones. Without a microscope or thin section the metamorphic fabric of a true quartzite is difficult to determine. Thus some of the clasts identified as “quartzite” may actually belong in the sandstone/siltstone column. This difficulty would only impact a small number of clasts, and does not change the basic conclusions listed above.

Elevations are approximate.

In summary, these pebble counts are a very useful and reliable method of providing a greater degree of confidence for assessing the different origins of the sedimentary gravel deposits, and for specifically documenting the identification of fluvial terraces related to the incision history of Buttermilk Creek, as opposed to glacially derived gravels.

No.	LOCATION, TRENCH No., etc.	GRAY/BROWN SS, SLTST	Red SS (Grimsby?)	LIMESTONE/DOLO	CHERT	SHALE	META/IGNEOUS	QTZITE	OTHER	No. of CLASTS	FEATURE, COMMENTS	ELEV ft	PERSONS	LAT/LONG	LOCATION, TRENCH No., etc.	No.
1	**Heinz a**	94	0	0	4	0	2	0	0	100	terrace	1265	YD	42.452/78.642	**Heinz a**	1
2	**Heinz b**	91	2	0	2	2	1	2	0	100	terrace	1265	YD	42.452/78.642	**Heinz b**	2
3	**Heinz c**	94	2	0	1	2	0	1	0	100	terrace	1253	YD	42.452/78.642	**Heinz c**	3
4	**Heinz d**	92	4	0	0	0	2	2	0	50	terrace	1253	YD	42.452/78.642	**Heinz d**	4
5	**Heinz e**	88	0	0	0	2	6	4	0	50	terrace	1260	YD	42.452/78.642	**Heinz e**	5
6	**Heinz f**	98	0	0	0	0	2	0	0	50	terrace	1260	YD	42.452/78.642	**Heinz f**	6
7	**Heinz g**	94	4	0	0	0	0	2	0	50	terrace	1233	YD	42.452/78.642	**Heinz g**	7
8	**Heinz h**	94	4	2	0	0	0	0	0	50	terrace	1233	YD	42.452/78.642	**Heinz h**	8
9	**Heinz i**	84	4	2	6	0	2	2	0	50	terrace	1257	YD	42.452/78.642	**Heinz i**	9
10	**Heinz j**	94	2	0	3	0	0	1	0	100	terrace	1241	WB	42.452/78.642	**Heinz j**	10
11	**Heinz k**	87	5	0	2	2	1	3	0	100	alluvial fan	1253	WB	42.452/78.642	**Heinz k**	11
12	**Heinz l**	93	0	0	3	0	2	2	0	100	terrace	1273	WB	42.452/78.642	**Heinz l**	12
13	**Heinz m**	79	0	7	6	6	2	1	0	102	creek channel	1240	WB	42.452/78.642	**Heinz m**	13
14	**Heinz n**	78	0	5	0	10	3	4	0	100	creek channel	1240	WB	42.452/78.642	**Heinz n**	14
15	**Heinz 0**	64	5	4	2	20	3	2	0	100	creek channel	1245	YD	42.452/78.642	**Heinz 0**	15
16	**Heinz p**	69	1	12	2	15	0	1	0	100	creek channel	1245	YD	42.452/78.642	**Heinz p**	16
17	**Heinz q (confluence with B.Ck.)**	80	2	10	0	3	2	3	0	100	Buttermilk Heinz Confluence	1226	YD	42.452/78.642	**Heinz q (confluence with B. Ck.)**	17
18	**Heinz r**	92	3	0	4	0	0	1	0	100	terrace	1251	WB	42.452/78.642	**Heinz r**	18
19	**Upper Heinz (pit at tree throw)**	97	1	0	1	0	1	0	0	100	terrace(?)	1387	WB	42.452/78.638	**Upper Heinz (pit at tree throw)**	19
20	**WP9 "O" > 1cm**	93.5	combined w/ gray	0	2	0	2	2	0	140	terrace south of meander	1320	YD	42.458/78.648	**WP9 "O" > 1cm (1st tests)**	20
21	**WP9 "O" < 1cm**	90	combined w/ gray	0	3	0	1	6	0	218	terrace south of meander	1320	YD	42.485/78.648	**WP9 "O" < 1cm (1st tests)**	21
22	**WP9 "O" >22mm**	84	5	0	0	0	3	8	0	107	terrace south of meander	1320	YD	42.485/78.648	**WP9 "O" >22mm (1st tests)**	22
23	**WP9 "O" <22mm**	85	5	0	3	0	2	5	0	347	terrace south of meander	1320	YD	42.485/78.648	**WP9 "O" <22mm (1st tests)**	23
24	**WP2 (Buttermilk Creek)**	81	7	4	1	0	6	1	0	101	BUttermilk Creek (toe slide)	1220	YD	42.451/78.643	**WP2 (Buttermilk Creek)**	24
25	**WP1 landslide top**	43	10	27	1	8	8	3	0	117	Lavery(?) till	1340	YD	42.450/78.643	**WP1 landslide top**	25
26	**WP5,6 at Creek**	61	11	14	2	3	2	7	0	100	lower till	1250	YD	42.443/78.641	**WP5,6 at Creek**	26
27	**Abandoned meander till**	61	5.5	6.5	1	22	4	0	0	108	South gully till	1280	YD	42.458/78.650	**Abandoned meander till**	27
28	**Abandoned meander bog**	79	9	7	2	0	3	0	0	100	Wood till (Pit 2)	1340	DZ	42.458/78.650	**Abandoned meander bog**	28
29	**Abandoned meander bog**	55	10	23	5	2	3	2	0	100	Outwash (Pit 1)	1340	DZ	42.458/78.650	**Abandoned meander bog**	29
30	**Abandoned meander bog**	65	4	21	4	4	2	0	0	110	Outwash (Pit 2)	1340	DZ	42.458/78.650	**Abandoned meander bog**	30
31	**Lowest meander channel-MT30**	86	2	0	1	2	2	7	0	100	Channel gravel	1287	DH	42.458/78.649	**Lowest meander channel-MT30**	31
32	**Lowest meander channel-MT31**	87	4	0	0	1	3	5	0	100	Channel gravel	1287	DH	42.458/78.649	**Lowest meander channel-MT31**	32
33	**Lowest meander channel-MT35**	89	0	0	0	4	4	3	0	100	Channel gravel	1291	DH	42.458/78.649	**Lowest meander channel-MT35**	33
34	**Lowest meander channel-MT36**	86	6	0	1	2	3	2	0	100	Channel gravel	1291	DH	42.458/78.649	**Lowest meander channel-MT36**	34
35	**Lowest meander channel-MT37**	83	0	0	4	0	8	5	0	100	Channel gravel	1292	DH	42.458/78.649	**Lowest meander channel-MT37**	35
36	**Below large landslide WP 20**	91	4	1	0	0	2	2	0	100	Buttermilk Ck channel bar	1230	YD	42.451/78.644	**Below large landslide WP 20**	36
37	**Below large landslide WP 2**	81	7	4	1	0	6	1	0	100	Buttermilk Ck channel bar	1230	YD	42.451/78.638	**Below large landslide WP 2**	37
38	**Heinz Ck. till on bedrock**	28	9	28	0	34	1	0	0	100	Heinz Creek (on bedrock)	1330	YD	42.453/78.638	**Heinz Ck. till on bedrock**	38
39	**Buttermilk Ck till WP25**	54	5	28	0	9	2	2	0	100	Till 1-4 ft above water	1240	YD	42.447/78.641	**Buttermilk Ck till WP25**	39
40	**Buttermilk Ck till WP25**	52	10	22	3	9	4	0	0	100	Till 27 ft above water	1260	YD	42.447/78.641	**Buttermilk Ck till WP25**	40
41	**Buttermilk Ck till WP5,6 (log 1)**	61	11	14	2	3	2	7	0	100	Till 3 ft above water	1250	YD	42.447/78.641	**Buttermilk Ck till WP5,6 (log 1)**	41
42	**Gully area bet. Beta Gamma**	58	8	14	3	0	8	9	0	97	Outwash(?)between tills	1320	YD	42.444/78.643	**Gully area bet. Beta Gamma**	42
43	**Intertill sequence (waterfall)**	74	5	10	6	0	4	1	0	100	Ablation till? (west gully site)	1330	YH	42.443/78.642	**Intertill sequence (waterfall)**	43
44	**Meander highest terrace north**	93	2	0	2	0	2	1	0	100	Terrace gravel GPR 5/6	1335	YD	42.459/78.651	**Meander highest terrace north**	44
45	**Meander Hill near parking WP31**	90	2	0	6	0	0	2	0	50	Terrace fluvial gravel	1371	DZ	42.457/78.649	**Meander Hill near parking WP31**	45
46	**Meander Trench 8**	81	12	0	1	1	2	3	0	100	Terrace fluvial gravel	1344	DZ	42.458/78.649	**Meander Trench 8**	46
47	**Meander Trench 9 (GPR 7A)**	89	6	0	0	1	3	1	0	100	Terrace fluvial gravel	1346	DZ	42.458/78.649	**Meander Trench 9 (GPR 7A)**	47
48	**Meander Trench 10 (GPR 6B)**	78	9	0	5	1	4	3	0	100	Terrace fluvial gravel	1335	DZ	42.458/78.649	**Meander Trench 10 (GPR 6B)**	48
49	**Meander Trench 12 (GPR 16)**	75	8	4	6	1	6	0	0	100	Till at base of trench	1335	YD	42.458/78.649	**Meander Trench 12 (GPR 16)**	49
50	**Meander Trench 13**	81	6	0	5	0	4	4	0	100	Terrace fluvial gravel?	1350	DH	42.458/78.648	**Meander Trench 13**	50
51	**Meander Trench 17**	90	6	0	0	0	2	2	0	100	Kettle south of bog site	1358	DH	42.458/78.648	**Meander Trench 17**	51
52	**Meander Trench 18**	86	6	0	0	1	7	0	0	103	Terrace fluvial gravel?	1355	DH	42.457/78.650	**Meander Trench 18**	52
53	**Meander Trench 18**	59	4	8		25	3	1	0	111	Till below fluvial gravel	1355	DH	42,457/78.650	**Meander Trench 18**	53
54	**Meander Trench 19**	80	5	5	6	1	2	1	0	100	Lower gravel (outwash?)	1345	DH	42.458/78.648	**Meander Trench 19**	54

No.	LOCATION, TRENCH No., etc.	GRAY/BROWN SS, SLTST	Red SS (Grimsby?)	LIMESTONE/DOLO	CHERT	SHALE	META/IGNEOUS	QTZITE	OTHER	No. of CLASTS	FEATURE, COMMENTS	ELEV ft	PERSONS	LAT/LONG	LOCATION, TRENCH No., etc.	No.
55	**Meander Trench 19**	86	5	0	5	1	2	1	0	100	Upper gravel (outwash?)	1345	YH	42.458/78.648	**Meander Trench 19**	55
56	**UHT1**	90	1	0	4	0	2	3	0	100	Gravel above till, genesis?	1388	HHs	42.452/78.638	**UHT1**	56
57	**UHT3**	87	1	0	1	0	4	7	0	100	Gravel above till, genesis?	1339	HHs	42.452/78.638	**UHT3**	57
58	**UTH5**	93	4	0	2	0	0	1	0	100	gravel below till(?) genesis?	1403		42.452/78.638	**UTH5**	58
59	**UHT4**	82	0	9	0	0	2	7	0	100	Ice contact(?) gravel on till	1389	HHs	42.452/78.638	**UHT4**	59
60	**HT1**	88	6	0	0	0	2	4	0	50	Terrace fluvial gravel on till	1235	DH	42.452/78.642	**HT1**	60
61	**HT8**	80	0	0	2	0	12	6	0	50	Terrace fluvial gravel on till	1241	DH	42.452/78.642	**HT8**	61
62	**HT13**	92	2	0	2	0	0	4	0	50	Terrace fluvial gravel on till	1252	DH	42.452/78.642	**HT13**	62
63	**HT15**	88	0	0	0	2	10	0	0	50	Terrace fluvial gravel on till	1260	DH	42.452/78.642	**HT15**	63
64	**HT17 (possible alluvial fan?)**	92	1	0	4	0	3	0	0	100	Fan(?) gravel on till	1279	DHHs	42.452/78.642	**HT17**	64
65	**HT20**	81	1	0	1	9	7	1	0	100	Terrace fluvial gravel on till	1270	HHs	42.452/78.642	**HT20**	65
66	**HT21**	79	2	0	2	10	6	1	0	100	Fan from Heinz Ck	1270	HHs	42.452/78.642	**HT21**	66
67	**HT23**	87	0	0	6	3	4	0	0	100	Fan distal(?) from Heinz Ck	1265	HHs	42.452/78.642	**HT23**	67
68	**HT25**	84	1	0	3	3	4	5	0	100	Terrace fluvial gravel on till	1225?	HHs	42.452/78.642	**HT25**	68
69	**HT31**	90	2	0	1	2	3	2	0	100	Terrace fluvial gravel on till	1237	DHs	42.452/78.642	**HT31**	69
70	**HT33**	91	0	0	2	1	2	4	0	100	Gravel below wood sample	1227	DHs	42.452/78.642	**HT33**	70
71	**FT4**	85	3	0	0	7	1	4	0	100	Terrace fluvial gravel on till	1190	DHs	42.452/78.642	**FT4**	71
72	**FT8**	89	1	0	2	2	2	4	0	100	Terrace fluvial gravel on till	1175	HHs	42.452/78.642	**FT8**	72
73	**FT9**	91	0	0	0	2	1	6	0	100	Terrace fluvial gravel on till	1177	HHs	42.452/78.642	**FT9**	73
74	**FT17**	86	1	0	7	2	0	4	0	100	Terrace fluvial gravel on till	1158	DH	42.452/78.642	**FT17**	74
75	**FT19**	98	0	0	0	1	1	0	0	100	Terrace fluvial gravel on till	1149	DH	42.452/78.642	**FT19**	75
76	**FT26 (landslide)**	65	6	11	0	6	5	7	0	100	Till in landslide	1200	DH	42.474/78.668	**FT26 (landslide)**	76
	LOCATION, Trench no., etc.	**GRAY/BROWN SS, SLTST**	**Red SS (Grimsby?)**	**LIMESTONE/DOLO**	**CHERT**	**SHALE**	**META/IGNEOUS**	**QTZITE**	**OTHER**	**No. of CLASTS**	**FEATURE, COMMENTS**	**ELEV ft**	**PERSONS**	**LAT/LONG**	**LOCATION**	

APPENDIX C
Reconnaissance Field Summaries

Activity Notes:

August 26th, 2014

Dave Butzer and Mike Wilson

Field work accomplished: August 26th, 2014
Notes written: August 28th through September 1st, 2014

Over the course of the warm, humid, mostly sunny day, we all stayed within eye-sight or worked alongside each other for most of the time. In order to cover more ground, Young and Dasilva would occasionally examine features out of sight being 50 or more yards away from Wilson and Butzer. Our paths also varied slightly when traveling between locations in order to cover different areas and attain additional perspectives. Walkie-talkies were used to maintain communication between the two groups. The locations visited and information gathered afforded us the foundation needed to continue this phase of Study 1. Safety issues were discussed several times during the morning and afternoon. Communication with Chris and key access went smoothly.

Previous week

The previous week (Thursday, 8-21-14) our group (Study 1) traveled to the "race track" (an abandoned, high-elevation meander) and to the large landslide on the west bank of Buttermilk Creek (adjacent to the east side of the SDA). On that recon we were led by Lee Gordon and Zintar Zadins. During that investigation we looked at: (a) several LiDAR-identified terraces north of the race-track meander, (b) the meander itself and its included small alluvial fan on its west side (presumably left-bank), and (c) several bogs south of the race-track meander. The bog area was tentatively identified as a stream terrace at the same general elevation as the race-track meander, but with an apparent dip southward (rather than an anticipated northward dip in concert with the modern Buttermilk gradient).

From this prior trip (8-21-14) we identified **Action Items** for our trip of 8-26-14: (1) follow the communication cable to Buttermilk Creek; (2) return to the high terrace (?) bogs near the race track for further investigation; and (3) request that Lee provide more information on access to the region, such as gates, roads, etc.

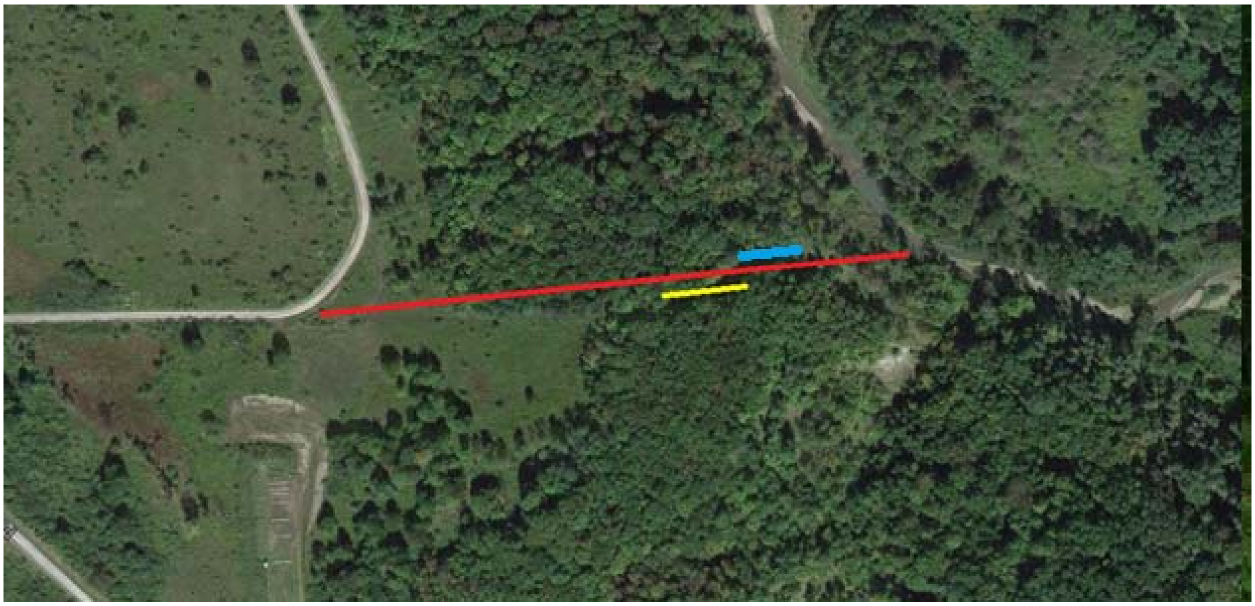
Notes from geographic areas of activity from 8-26-14

The following pages provide notes from our recon on 8-26-14 in the temporal sequence for that day.

Area 1: Telecommunications Road

Taking the advice of Lee Gordon (NYSERDA), we followed the telecommunications line from Buttermilk Road to where it intersects Buttermilk creek:

Figure 1-



The overhead-cable access-route (most likely constructed during the installation of that cable, the telecommunications line) has since undergone erosion and gullying. The red line in figure 1 shows the general path taken to reach Buttermilk Creek, beginning at our start point on Buttermilk road. Figures 2-6 were obtained along the yellow line and figures 7-10 taken along the blue line in figure 1.

Figure 2-

Photo looks east to west. Both red arrows denote the formation of two separate gullies, where the yellow arrow shows an area of land raised in elevation. The gully on the left can be referred to as the southern gully, whereas the one on the right the northern. The land (berm to the right, north, of yellow arrow) may have been artificially raised during the construction of the telecommunication line.

Figure 3-

Figure 3 shows the depth of the southern gully as compared to the average height of the path. Note the aforementioned elevated terrain can be seen in the right-center margin of figure 3. Dick Young is on the left and Mike Wilson on the right.

Figure 4-

The northern gully is shown in figure 4; the banks are much steeper than the southern gully.

Figure 5-

Figure 5 shows another angle of the northern gully; note the steep banks continue for an appreciable distance.

Figure 6-

The unstable slope can be seen in figure 6; this is also an image of the northern gully.

The destabilization of the landscape caused by the advancement of the gullies was made evident as we continued down the path. A third gully forming near the center of the telecommunications path is expected to grow substantially in a relatively short period of time; the formation of slide blocks near the gully-head shows that the landscape is currently in motion and can be expected to change significantly.

Figure 7-

The eroding landscape has revealed a cable in figure 7 that may have been previously buried.

Figure 8-

The red lines in figure 8 emphasize the tops of two slide blocks that are advancing towards the gully. Wilson stands on top of a third slice of this rotational failure, which extends upslope.

Figure 9-

Figure 9 shows a different angle of the gully, highlighting the location of the slide blocks (rotational slices) with respect to the gully's location. Note: the northern gully can be seen in the background (past the tree line).

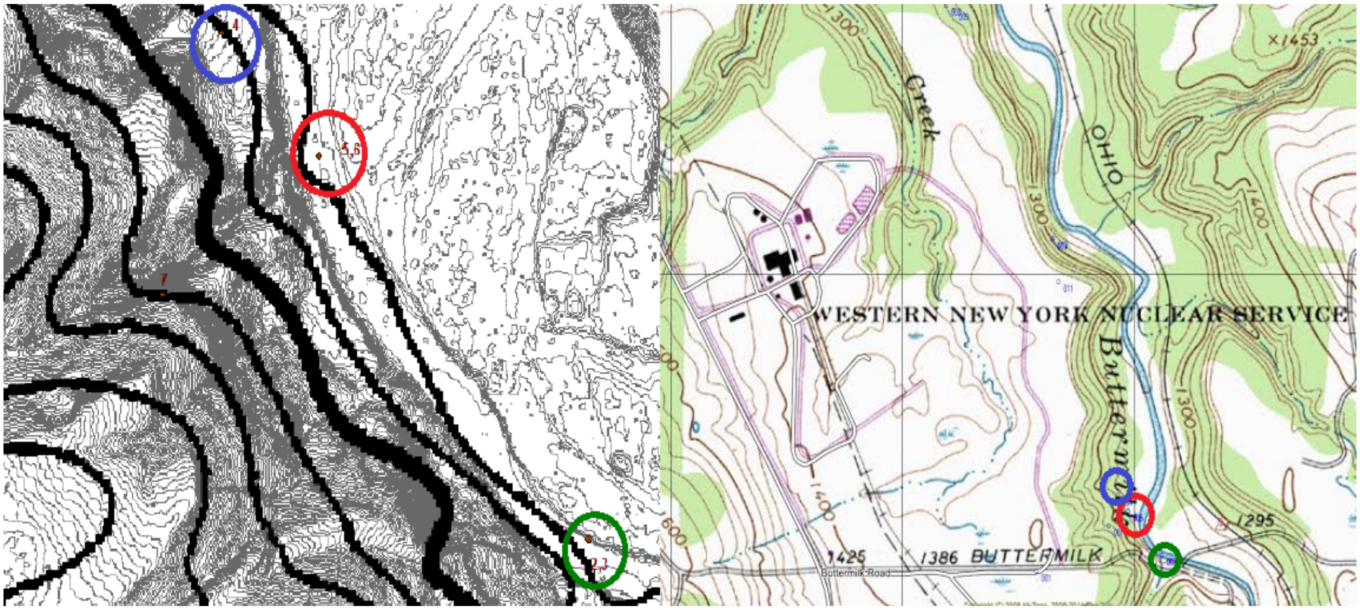
Figure 10-

Yet another angle of the gully is shown in figure 10, with the exposed cable in the foreground. The land beginning where Wilson is standing is unstable and likely in motion, at least during wet periods such as the month of March each year.

Action Item from 8-26-14 Area #1, for future work, is:
Investigate the history of this area for the past two centuries to discern erosion or landscape history as they relate to these potentially dateable features (e.g. when was the right-of-way cut? Ground cable laid? Communication lines with poles placed? Etc.).

Area 2: Buttermilk Creek

Figure 11-



The Buttermilk Creek intersection with the elevated cable is marked by the green circle in figure 11. The creek was traveled downstream until point 4 was reached, where Young and Dasilva noted a visible contact of alluvium over till occurred 4 feet above the creek (figure 11, blue circle). The red circle and points 5 and 6 in figure 11 show where Wilson and Butzer noted two logs approximately 50 yards apart on the left (west) bank of Buttermilk creek, occurring at the same stratigraphic level within alluvium over glacial till, and being about 8 feet above the creek.

Figure 12-

Dr. Young and Alex at waypoint 4

Figure 13-

Shown in figure 13 is one of the two logs located on the west bank of Buttermilk Creek. The logs were located using binoculars while standing on the opposite (i.e., right or east) creek bank.

Figure 14-

The second log (figure 14, yellow circle) was discovered to be partially buried.

Figure 15-

Picture of second log with auger for scale

Figure 16-

Picture of second log with auger for scale (zoomed)

Figure 17-

Similar to the piece taken to be C14 dated

Figure 18-

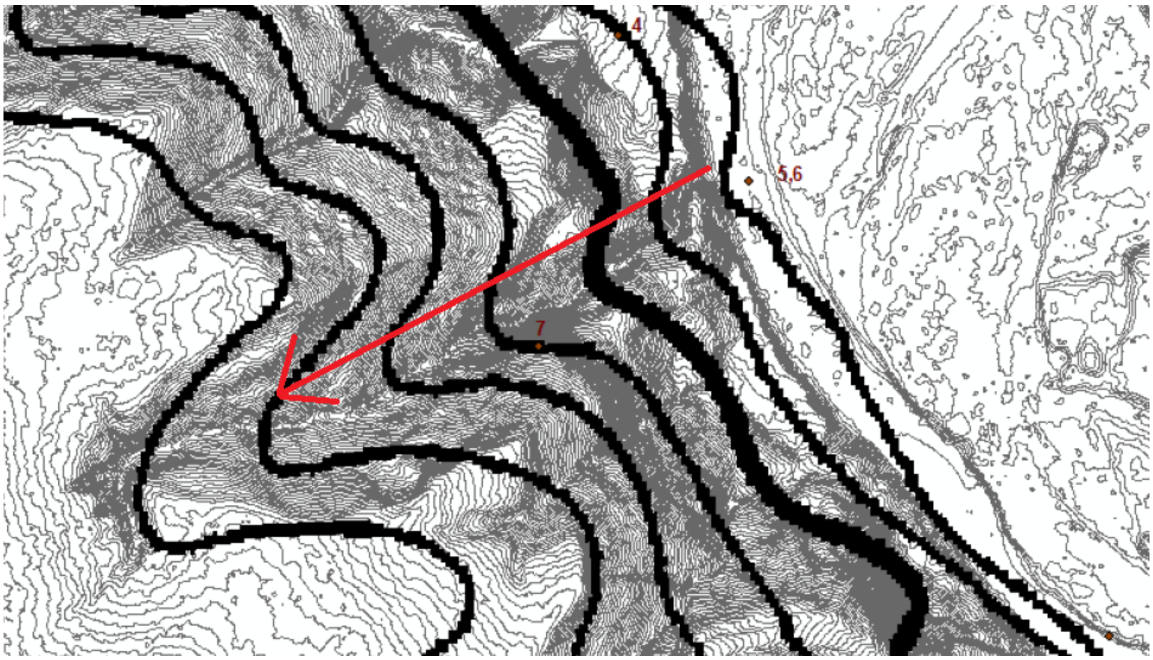
Dr. Young with actual C14 sample in-hand, wrapped in aluminum foil

The second log proved to be more accessible than the first one found, and thus was sampled to be later dated. Though two large logs were found at the same stratigraphic level, fine organics such as leaves were not found. Assuming a worst-case scenario, that this log was recycled, this log could provide a minimum age for the alluvium, and may be stratigraphically similar to logs found by Lee Gordon in Buttermilk or adjacent drainages.

Action Item from 8-26-14 for Area #2 is:
Compare to other lowland sites and get date(s) if warranted.

Area 3: Prominent Gully and Bog 1

Figure 19-



From the previous location, we headed uphill in the general direction shown in figure 19 (note the locations of waypoints 5 and 6). We chose this path to further investigate the gully (shown prominently on figure 19); the path of Wilson and Butzer differed slightly from Young and Dasilva at this time. Wilson and Butzer traversed the ridge on the north flank (watershed divide above left bank) of the gully, while Young and Dasilva traveled to the south and west.

Figure 20-

Several (unpaired?) terraces were found to border the gully at the location shown in figure 20.

Figure 21-

The aforementioned terraces (Fig. 20) can be seen in figure 21. There are at least two terraces in figure 21, the highest being in the foreground, and lowest in the center background (behind and below Wilson). Tentatively, these terraces are thought to be unpaired with any others in the area.

Figure 22-

The observed slope in figure 22 was roughly determined to be 26 degrees, which is consistent with previous literature.

Figure 23-

Another angle of the hill slide, which slopes to the gully. Approx. 26º slope observed.

Figure 24-

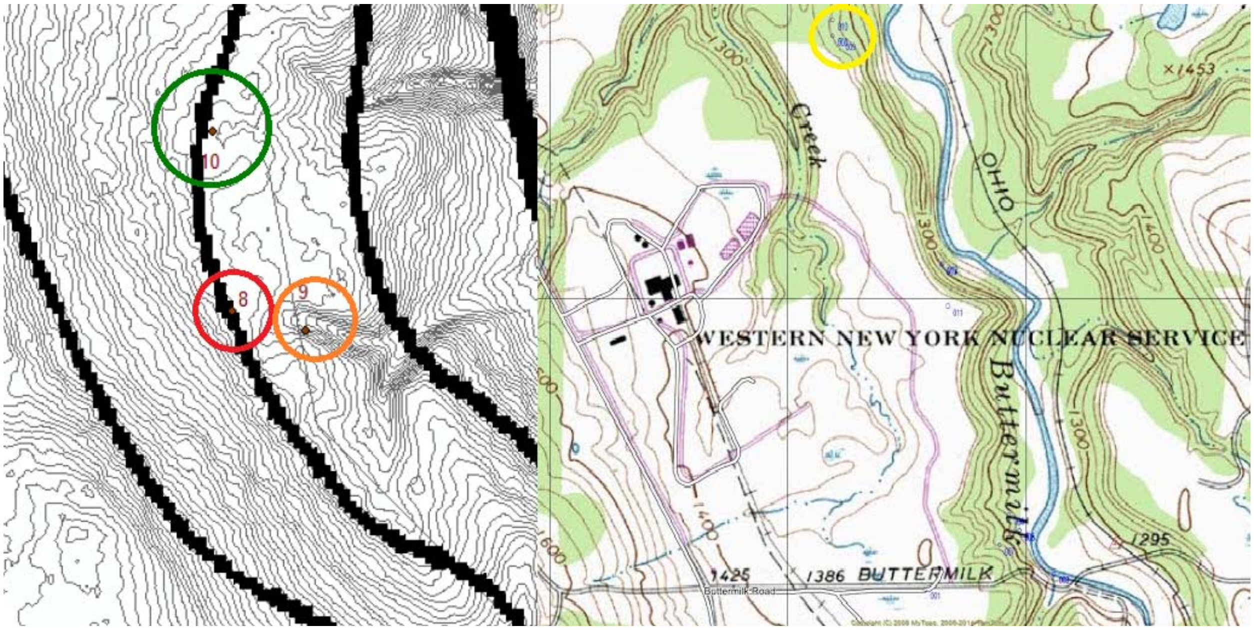
Continuing up the hill, we discovered an area with a perched water table that we tentatively named "bog 1". The exact location can be observed in figure 24. Samples were collected using the hand-auger and one was taken to the lab for study (Sample #1, Bog #1). The auger we were using was a traditional Oakfield sampler, an auger that takes an approximately 0.1 ft diameter and 1 ft long sample by pushing the open-sided tube (Figs. 15-16) into the soil. Reentry of the bore-hole can be repeated, but sampling stops when a firm object is encountered (such as a log or coarse gravel).

The site in figure 24 (Bog 1) contained about 0.5 to 1.0 ft of wet peat grading into wet organic clay (with a trace of sand and pebbles when the sample was washed and reviewed under magnification in the lab), above an unknown substrate. This substrate refused the auger in several places for an unknown reason (gravel, wood, other?).

Action Items from 8-26-14 for Area #3 are:
(a) Look for other terraces at similar elevations to challenge the hypothesis of these terraces being unpaired.
(b) Systematically hand-auger bogs on a transect sampling plan using snowshoes or similar supports.

Area 4: High Terrace

Figure 25-



The fourth location visited was the high terrace south of the abandoned meander; this location is emphasized in figure 25 by the yellow circle. At point 8 (red circle), a sample was collected via hand auger (labeled Bog 2, Sample 2) for further analysis. A sample (labeled Bog 2, Sample 3) was similarly collected at point 10 (green circle). A gravel sample was collected by Dick Young at point 9 (orange circle) and later analyzed by Alex Dasilva in the lab for shape and lithology.

Figure 26-

Collection of Bog 2 Sample 3 using hand auger

The terrace and bogs south of the race-track meander tend to slope to the south, however we would expect them to dip towards the north due to the northerly direction of ice retreat and the direction of Buttermilk Creek drainage. Several working hypotheses have been proposed to explain this anomaly: (1) partial in- on- or under-ice deposition, (2) Holocene gulley-head advance into the southerly area of the bogs, (3) the top of a large landslide, (4) lake or proglacial lake beach, and (5) anthropologic influences, such as farming or logging.

An old partly-tree-covered road was discovered northeast of the abandoned metal building (near the tree line) that leads to the race-track terrace; this path can be potentially used as an access route for equipment.

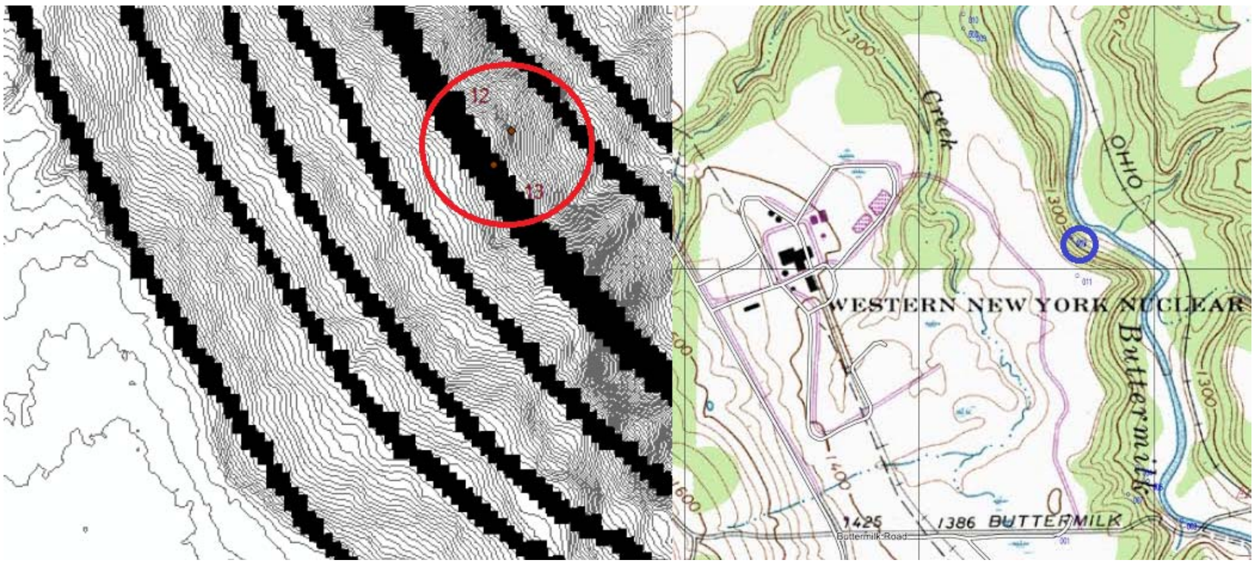
In the field, several bogs were augered to depths of one or two feet encountering thin peats (0.5 ft) or organic clays near bog margins and 1 ft of more of peat and organic clay when more interior to the bogs. Below the organic soils (which contained less than expected woody material) were soft tills (or pebbly lake clays). Gravels occurred between bogs. Thus the terrace surface is composed of alternating lateral sequences of organic clay versus gravel, both underlain by till (or pebbly lake clay), along the south-sloping terrace length.

In the lab, bog samples were examined, and then washed and the remaining coarse particles examined. Bog #2 Sample #2 (way point 9) contained approximately 95% peat, organic-clay, and dark gray till. The till contained a trace of silt and sand with about 5% pebbles in clay. The residual material after washing was composed of 9 fine pebbles and 2 coarse pebbles. The coarse pebbles were one gneiss and one sandstone; the fine pebbles were composed of 4 sandstone, 4 shale, and one chert. All pebbles were very angular. Two fine pebbles were elongate; all others were compact. The organic soils were black to dark gray in color (Munsell color 2.5Y-3/2) and the underlying tills were dark to medium gray (Munsell color 2.5Y- 4/1 or 5/1 and 4/4) with olive brown mottling, indicative of reducing water-logged conditions with occasional drying (mottled colors). Bog #2 Sample #3 (way point # 10) contained similar materials and colors, but no pebbles.

Action Items from 8-26-14 for Area #4 are:
(a) Systematically hand-auger transects of all bogs (in advance of trenching and sampling?).
(b) Examine the laterally intermittent nature of the gravel-bog sequences.
(c) Examine the up and down-slope edges of the terrace.

Area 5: Landslide

Figure 27-



The final location visited was the landslide (blue circle, figure 27), where we examined stratified, coarse sediment lenses located within (?) the tills on the northern edge (figure 27, points 12 and 13 circled in red). At point 12 (also in figure 28), a sample of sand was obtained to be later studied. There are three hypotheses for the origin of these sands:
(1) semi-continuous laterally-extensive deposition (hypothesis of earlier workers);
(2) englacial transport of blocks (likely frozen?) (hypothesis of Lee Gordon and others);
(3) ice-contact deposits with ice-melt deformation (hypothesis of M. Wilson)

Action Item from 8-26-14 for Area #5 is:
Approach the deposit from below and examine with binoculars and telephoto lens.

Figure 28-

Sand was sampled to be later analyzed.

Activity Notes:
September 2nd, 2014

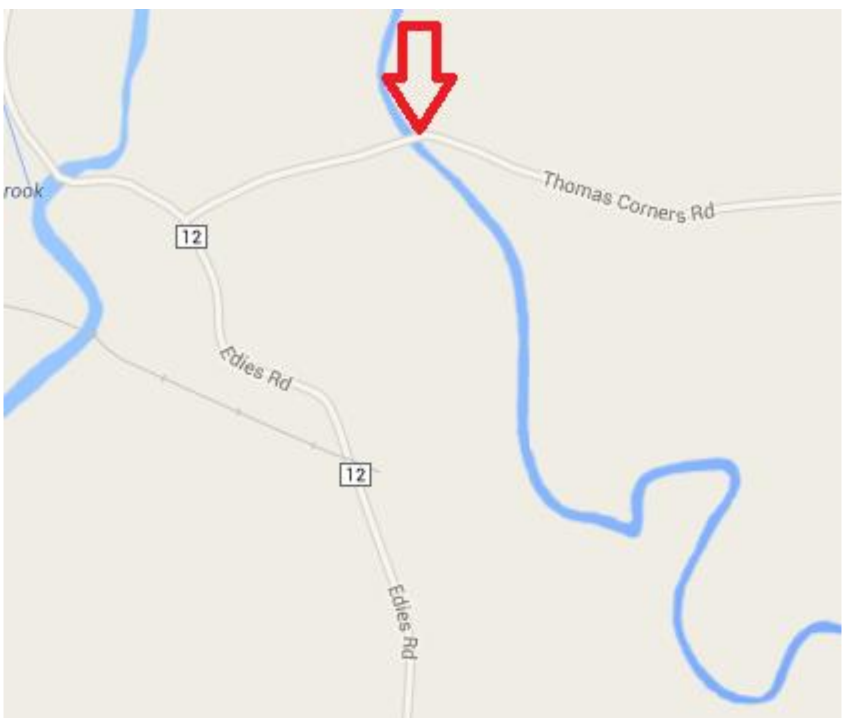
Dave Butzer and Mike Wilson

Field work accomplished: September 2nd, 2014
Notes Written: September 3rd – September 5th , 2014

Over the course of the day, Lee Gordon accompanied Butzer, Wilson, Young, and Dasilva while traversing Buttermilk Creek at points downstream of the West Valley Nuclear plant. In addition to the information recorded in these notes, Young and Dasilva have extensive photos and location points that are also available. Rainfall the night before had only modest effects on the stream velocity and depth as the stream flowed clear; the weather throughout the day was mostly cloudy and humid. Bedrock was exposed at multiple points along the left (west) bank of Buttermilk creek, where terraces (lake or stream) were located on the right (east) bank. Exposed banks of till and clay were located at two notable points along Buttermilk creek. The importance of both, along with additional information attained during the day, will be described herein.

Buttermilk Creek was entered where intersected by Thomas Corners Road; the location of which is shown by the red arrow in figure 1.

Figure 1-



Initially, the left (west) and right (east) banks (till exposed in addition to alluvium) were of relatively equal elevation. As we continued upstream however, the left (west) bank grew in elevation at a higher rate than that of the right bank. Exposed bedrock began to line the left (west) bank of Buttermilk Creek (figure 2, outlined in red), and quickly grew to heights of approximately 40 feet above the base of the stream channel.

Figure 2-

This bedrock acted to control the maximum horizontal distance the stream could migrate towards the left bank. Terraces were found via LiDAR to exist on the right (east) bank at multiple elevations, and a major reason to initially recon this area was to visit these terraces. The lower terraces could potentially be stream terraces, where the upper terraces could be lake or stream terraces; many of the terraces could have been controlled by events in the Cattaraugus Creek valley, such as lakes or landslides, in addition to elevation control by variation in cutting rates in the bedrock. Obtaining dates along these terraces could enlighten us towards understanding the downcutting history of Buttermilk creek over time, if additional research allows us to assess the origin (e.g. stream or lake) of the terraces. Excavation of the terraces with machinery would not be difficult, as they are accessible through the creek. After a light rainfall, the creek was approximately 1 – 2 feet deep (maximum depth ~3 feet) which can be easily traversed by large equipment.

Continuing upstream (southerly), we were faced with a very steep right (east) bank with an opposing gradual western bank. Buttermilk meandered away from the aforementioned steep west banks (located downstream), and has since cut into the east bank. The aerial view in figure 3 shows this meander, and the yellow arrow shows the steep east bank cliff; creek flows to left.

Figure 3-

A ground-level photograph shown in figure 4 shows the cliff from ground level; yellow arrow in figure 3 points north to right-bank cliff (obscured by overhanging trees).

Figure 4-

The large size and steep slope of the cliff can be better seen from this photograph. The exposed cliff extended approximately 150 feet past the view of this photo (view is blocked by the tree on the right-hand side of the frame). Also just out of frame (on the right-hand side of the photograph) and just past the sediment cliff was a large landslide, also on the right bank. The slide was very large and in soft clay (that contained layers with and without clasts). This material could have been either till or lake sediments, or both. The material was apparently lateral to the big-cliff sands, gravels, and possible tills, as if one large section of the modern valley-wall was a buried valley deposit adjacent to (cross-cutting) the other section of wall. The contact deserves further evaluation, as does the layering in the cliffs.

In the synoptic view (photographer far away), one can still make out several different layers that can be seen in the cliff-side in figure 4. To better emphasize the layers, a photo enlargement was taken and is displayed in figure 5. The cliff is composed of layers of gravel, till, and lake sediments, and contains at least two large cut-and-fill structures. One of the cut-and-fill structures (not clearly seen in these photos; mostly out of view) is abnormally deep (approximately 12 to 20 feet) compared to width (approximately 10 to 15 feet); it could potentially be a subglacial tunnel deposit or be of other distinctive origin. Several strata are present in the cliff, but resolving them into a coherent history with attendant strata descriptions may be impossible without top-down roping.

Figure 5-

The sediment cliff towards the bottom of figures 4 and 5 was covered with a veneer of loose debris from above which partly masks the lower slope. The blue circle highlights an interesting exposed feature of the cliff that may be an old stream channel (which is the smaller and shallower of the two cut and fill structures). Additional research might allow us to definitively determine whether or not it was a Buttermilk Creek tributary or a glacier stream (such as a tunnel or crevasse, etc.); the cliff-side location may prove too difficult to access, however. A close-up picture of the clay-till matrix with inclusions is shown in figure 6 (below); the base of a hoe is shown for scale. This cobble of till indicates that the till can be eroded and transported as a cobble with other rock cobbles.

Figure 6-

Upstream from the cliff was an old bridge that has since washed out. This bridge (figure 7) is however interesting in its own right as it shows the evolution of the stream channel since its construction. This bridge could likely be dated from local historic records or photos to help make an anthropogenic history of erosion of the region.

Figure 7-

A significant portion of the bridge was washed downstream in an assumed storm event that occurred in the past. Figure 7 shows the location of the washed out portion with respect to the actual structure, as well as the scale. The yellow circle is the washed out portion, and the red circle is the actual structure (red circle is upstream; yellow is downstream).

Figure 7-

As the threat of rain and thunderstorms was increasing, we headed out of the creek and began walking out via the old decommissioned railroad tracks. Along these tracks, we noticed an area where gully advance threatened to wash out a section of the old rail bed completely. An aerial view (with coordinates of the location) is shown in figure 8 below.

Figure 8-

The banks on either side of the gully in figure 9 are not vegetated, and signs of aggressive erosion were noted. Remnants of an already washed out bridge or possibly failed erosion control measures can be seen.

Figure 9-

The scale of the slope can be seen in figure 10 below:

Figure 10-

A close up view of the debris, including what appears to be a drainage pipe can be seen below:

Figure 11-

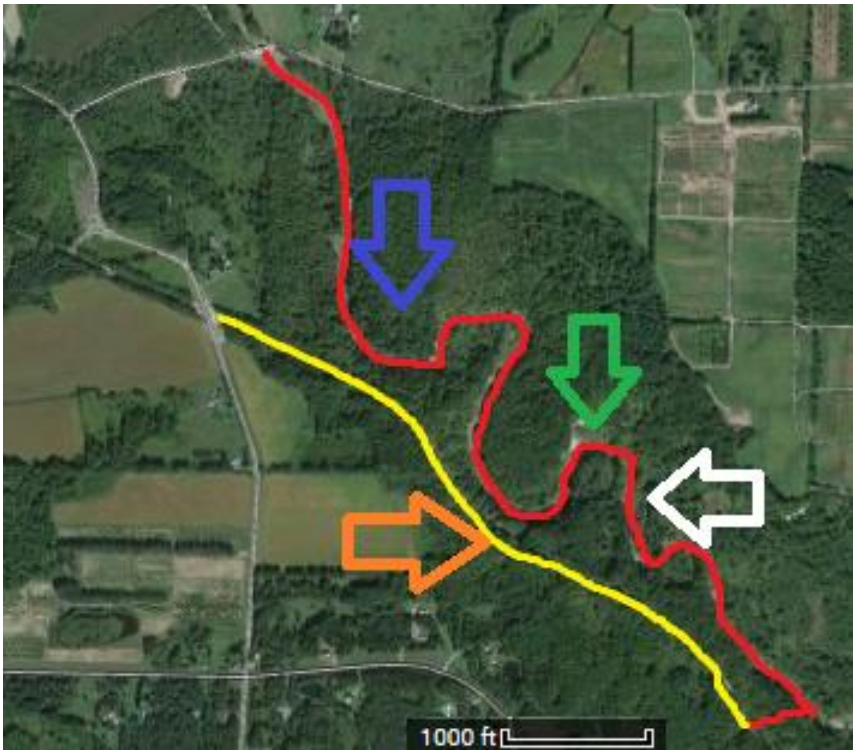
Figure 12 demonstrates the area behind the bridge where Dr. Wilson was shown standing. Though it is difficult to see, there was running water when the image was captured:

Figure 12-

It is also important to note that Lee pointed out a distinct reach of the creek (along blue arrow in figure 13) where large boulders occurred in the stream bed, as opposed to most of Buttermilk Creek where very large boulders (meter and more in diameter) do not occur or are infrequent. Wilson responded that similar restricted occurrences are found in other valleys such as in northern Chautauqua County, and that these locations are where the Lake Escarpment End Moraines cross the drainages in those other locations.

To properly conclude, the final figure 13 has been introduced to provide a logistical sense of where each of the features were discovered in respect to each other:

Figure 13-



The red line represents the path we traveled upstream, and the yellow path represents the path we took to leave along the old decommissioned railroad track. The blue arrow represents where terraces were observed along the east bank, where the banks were steep along the west bank. The green arrow represents the exposed cliff along the east bank. The white arrow represents the area where we observed the old bridge. Finally, the orange arrow shows the location along the old railway tracks where erosion caused by gully advancement threatens to overtake the railway.

<u>Reconnaissance Survey Fieldwork: August-September, 2014</u>, West Valley Demonstration Project, ECS R.A. Young Notes.

August 21, 2014
Mike Wilson, Lee Gordon, Alex daSilva, Dick Young, Dave Butzer, Zintars Zadins

Arrived NYSERDA 9:30 AM (66 miles one way).
Conference Room: Distributed and discussed LaFleur colored geologic maps.

Planned for day visits to sites near abandoned meander and Buttermilk Ck. confluence with Cattaraugus Ck. Set handheld GPS to record tracks and Waypoints as necessary.

Drove to WV site, entered at Buttermilk Road gate.
Proceeded to abandoned meander; reviewed Lee's previous excavation sites.
Hiked to two higher terraces (D, B of map plan) on north edge of meander. Gravel apparent at surface of both terraces (could it be winnowed till?).

Climbed out of meander to van for brief lunch. (Zintars returned to office)

Examined small horizontal bench (terrace O of map plan) southeast of meander. Rounded gravel apparent in subtle channel at surface. Headward erosion of channel by intersecting gullies is apparent. Headward erosion by modern downslope gullies appears to be a plausible cause of the terrace surfaces not having a simple northward slope. It seems unlikely that these benches (terraces) are old shorelines of glacial lakes due to their elevation below the walls of the large abandoned (postglacial) meander. While landslide dams may have created local postglacial lakes within Buttermilk Creek, I assume such lakes would not be long lasting, and shoreline gravels might be more compatible with till pebble composition.

Stopped at active landslide to show assistants Alex and Dave the location and current conditions.

Lee pointed out powerline (communication cable?) route into Buttermilk Ck. to be explored Tuesday (26th). There appear to be two "powerlines" leading east into Buttermilke Ck.

Left WV site and drove south around road leading north up east side of Buttermilk Creek to become familiar with main access roads to Creek.

Drove to Buttermilk-Cattaraugus Ck. confluence; checked exposures along abandoned RR leading to old trestle. Could dig shallow trenches along SW side of RR right-of-way, but appears to be essentially till.
Adjacent farm field to SW could also be access for drilling when harvest is over.

Lee offered use of ArcGIS laptop with Lidar imagery for future fieldwork.

Returned to NYSERDA offices. Conferred about Tuesday plans for additional reconnaissance.
Powerline (cable line) near south end of trench burial area into Buttermilk will provide access to Creek exposures.

Discussed plan for hike up Buttermilk Ck. With Lee on September 2 (walking in creek required).

Left NYSERDA for Geneseo at 4 PM (66 x 2 = 132 miles roundtrip)


Headward rosion of "terrace O" by gully (pebble collection location, 8/26/14)

August 26, 2014
Mike, Dave , Alex, Dick (Arrived WV gate at 9:15 AM).

Got key for Buttermilk gate, parked near communication cable line at WP 1.
Hiked down communication cable route to Buttermilk Creek (WP 2,3). (Waypoints duplicated by mistake).
Vegetation cover this summer is lush and obscures access and contacts along creek banks to some degree.

Located Qal/till contact at WP 4 about 4 feet above low water level (creek was 4-6 inches deep).
Qal = standard notation for "Quaternary alluvium".

Located and sampled large log buried immediately above Qal/till contact at WP 5,6. Contact is 8 feet above Creek. Wood sample labeled B-1, dried in oven and stored at Geneseo. Should return to this site to uncover deeper portion of log for better 14C sample and to take companion OSL sample (good exposure of contact).

Hiked out of Creek through WP 7 where we examined 5-foot section of outwash(?) gravel or ice-contact lens in till. Lower till contact obscured, but till visible above gravel contained striated pebbles.

Brief lunch in field at 12:30 PM

Drove back to old meander site to sample. Viewed high level terrace gravel SE of meander (WP 9). Collected random surficial gravel sample while Mike and Dave cored boggy areas of old channel (WP 8,10). Channel is being headwardly eroded by two downslope gullies. Site could be efficiently trenched by starting at downslope end to create self-draining excavation. Should return to this site to collect better (deeper) gravel sample to use as potential "standard" for terrace gravels.

Drove back to WP 1 to find more southern entry to Buttermilk. Realized cable line access is only one route (actual powerline is located further north).

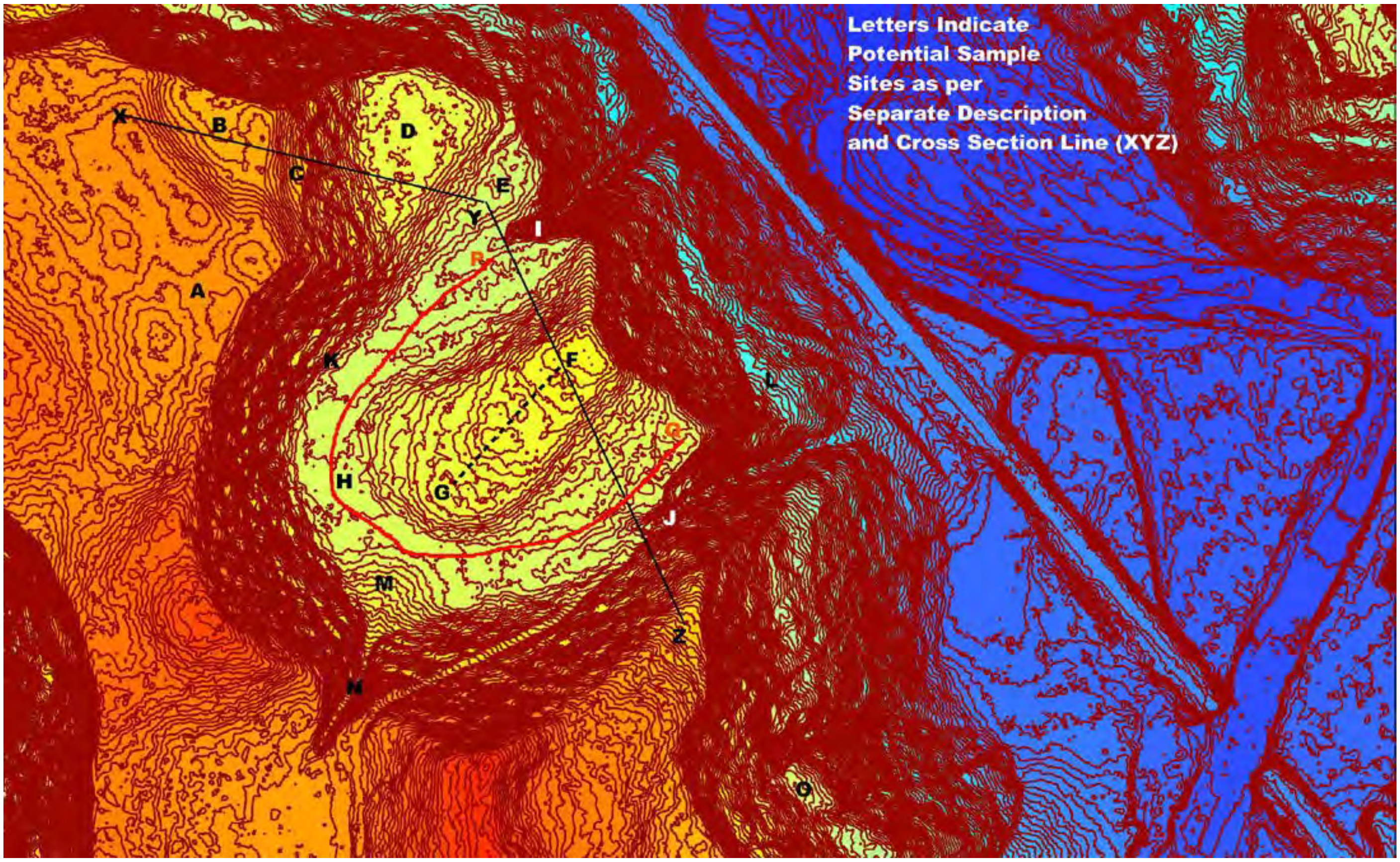
Drove to north end of active landslide to examine stratified sediments visible at north end (parked at WP 11). Climbed around on upper active north end of slide and examined well oxidized sand/gravel lenses in till near top (WP 12, 13). Dave sampled sands.

Returned to surrender gate key at 4:15 as insufficient time remained for another climb down into Buttermilk Ck.

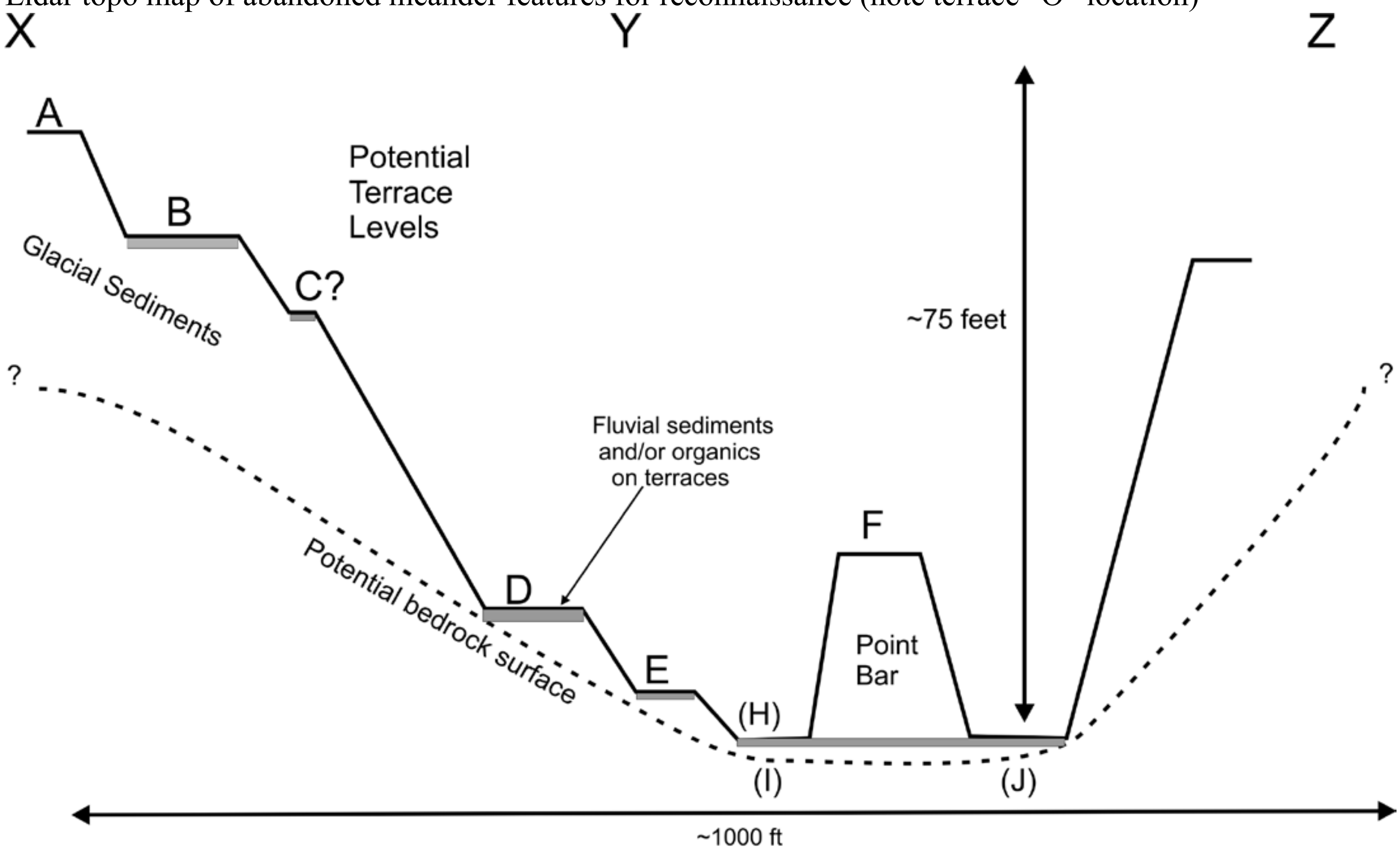
Additional Tasks Completed

8/27/2014 Spent I hour creating lidar/topo map of Waypoints and sorting photo documentation.
Waypoint lat/long recorded in field notes.

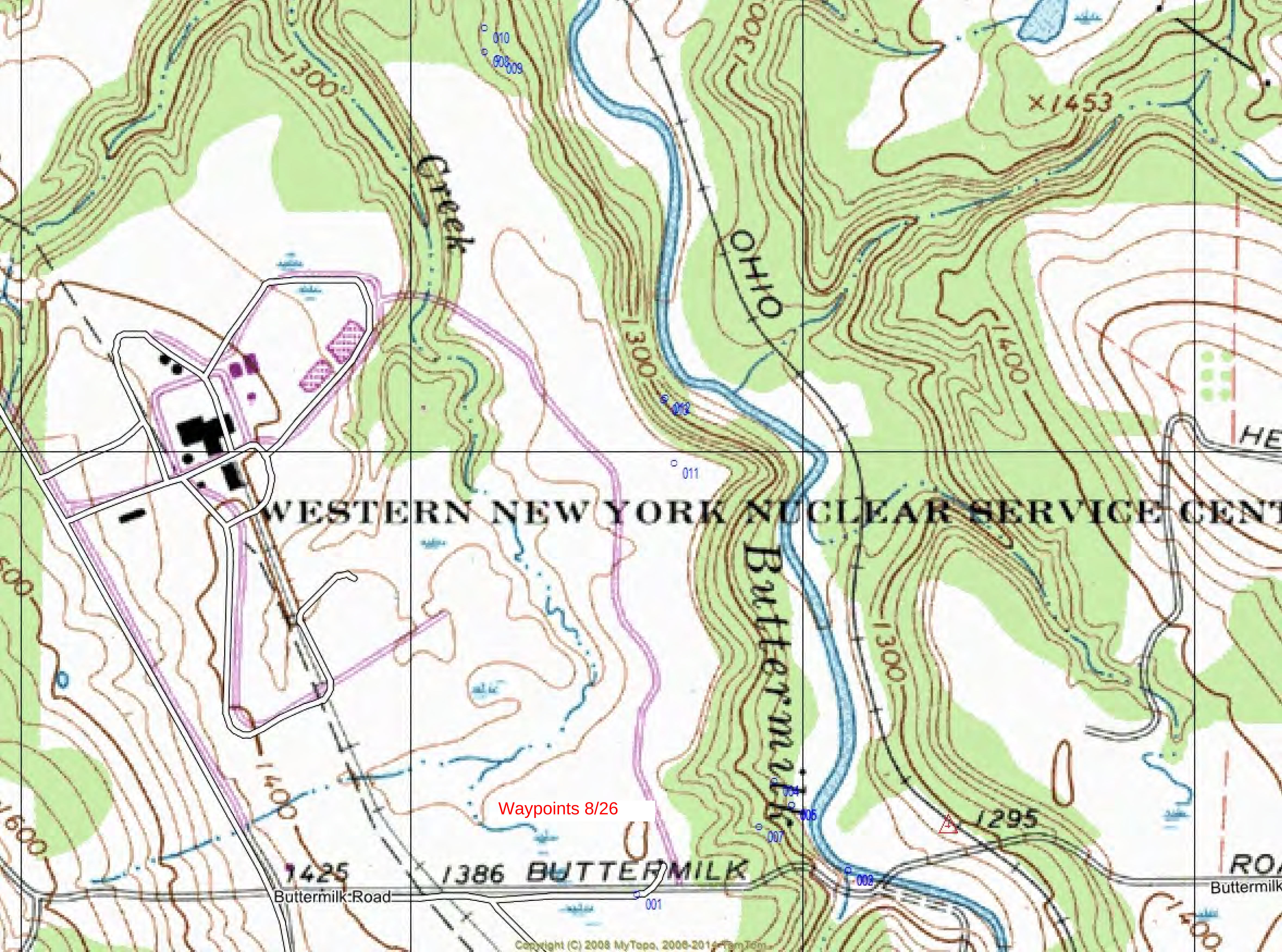
8/28/2014 Alex completed pebble identification/count on terrace gravel sample from WP 9.
Sent brief account and photos of reconnaissance results to other 3 geologists, M. Wolff, and Lee Gordon.



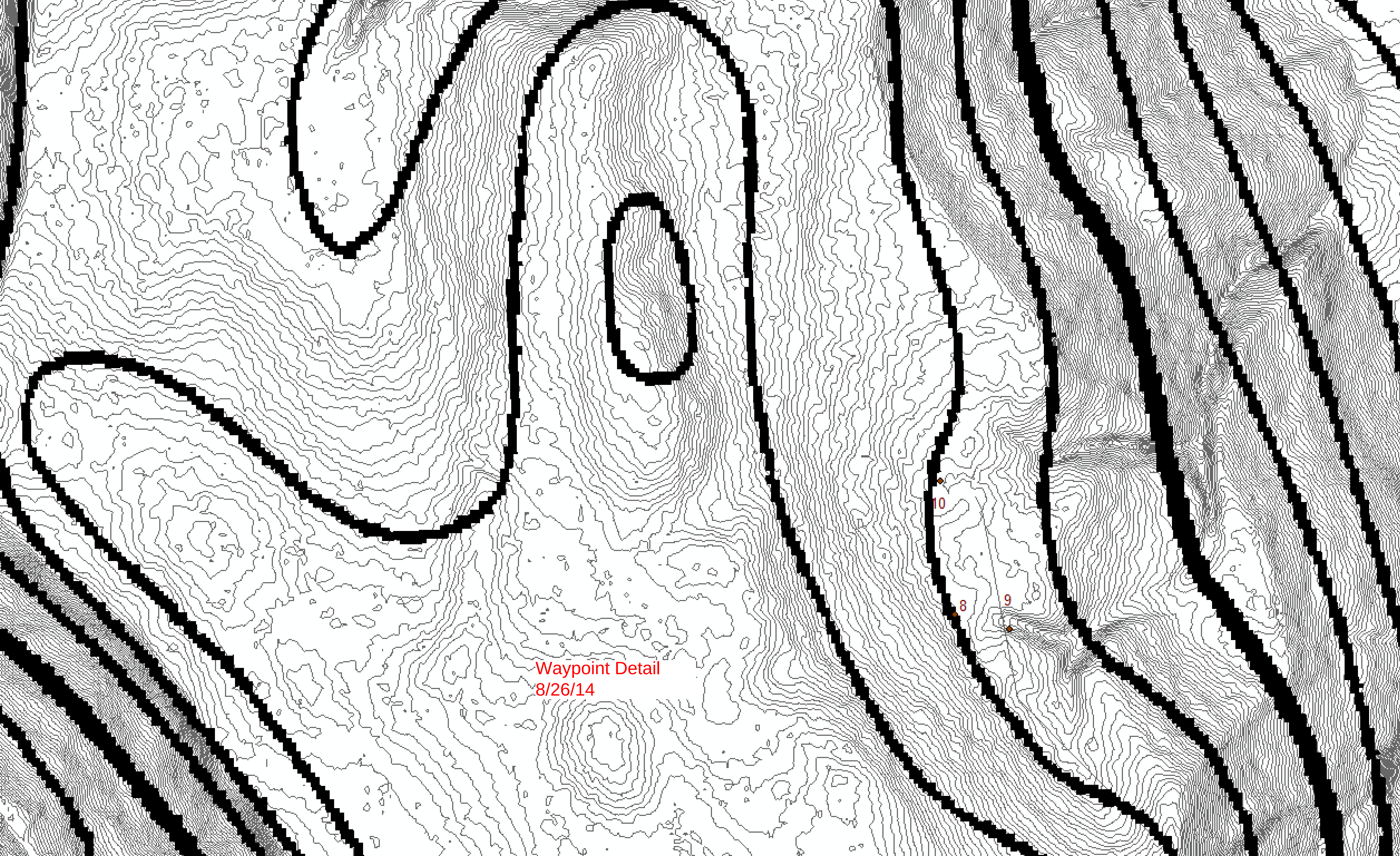
Lidar topo map of abandoned meander features for reconnaissance (note terrace "O" location)

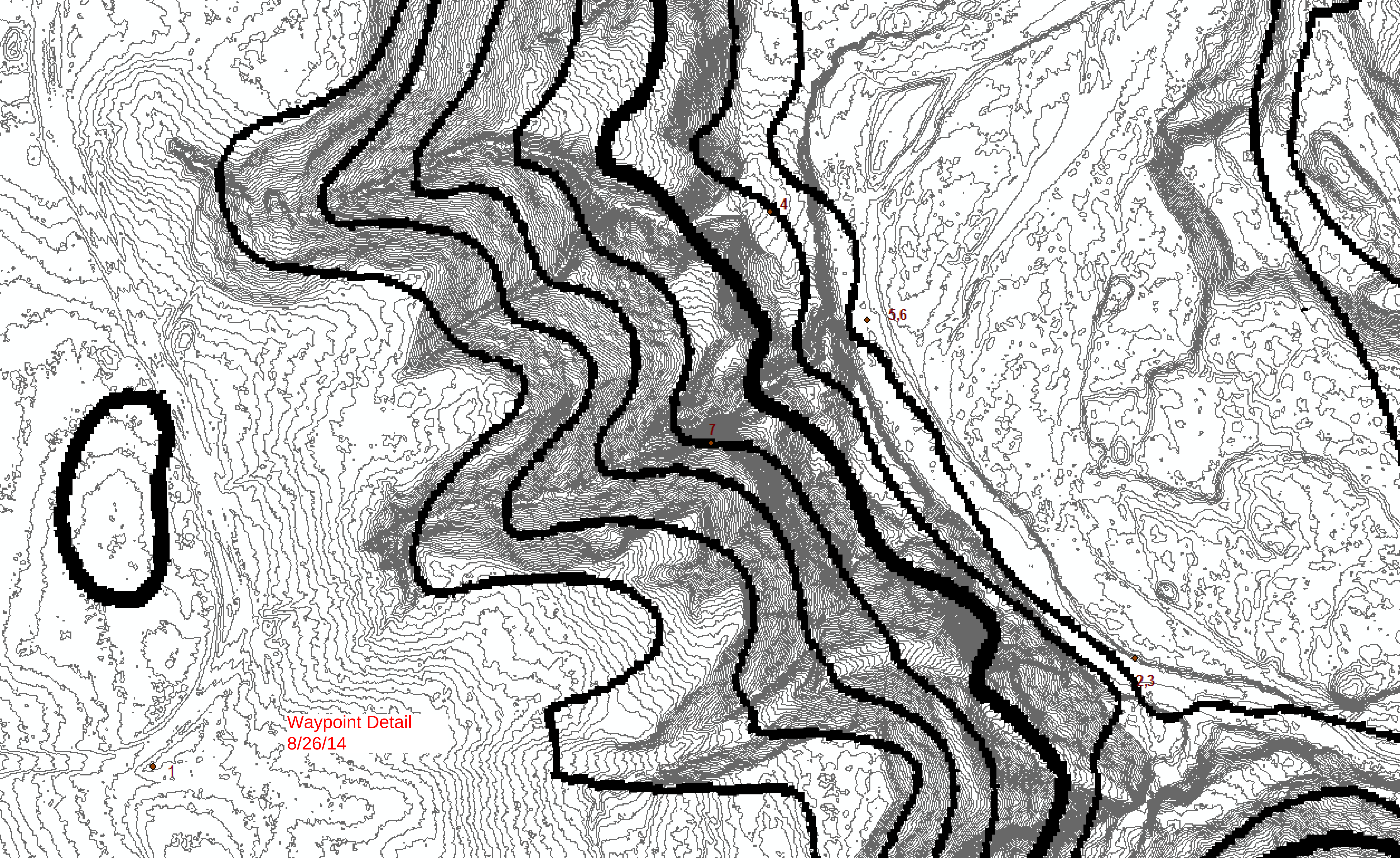


Diagrammatic, Hypothetical Profile XYZ at Abandoned Meander Channel
Diagrammatic only; Not to Scale



Waypoints 8/26
WESTERN NEW YORK NUCLEAR SERVICE CENT
Creek
OHIO
Buttermilk
BUTTERMILK
Buttermilk Road
Buttermilk
ROA
HE
×1453
1300
1400
1295
1425
1386
010
008
009
011
012
004
005
007
002
001
Copyright (C) 2008 MyTopo, 2006-2014 TomTom


10
8
9
Waypoint Detail
8/26/14


Waypoint Detail
8/26/14
1
2,3
4
5,6
7

September 2, 2014. Lower Buttermilk Hike with Lee, Mike, Alex, Dave, R. Young

Met with Lee Gorden at NYSERDA at 9:30 and drove to Buttermilk confluence.

Hiked up Buttermilk approx. 1.6 miles to check exposures, ease of access to terraces by backhoe, etc.

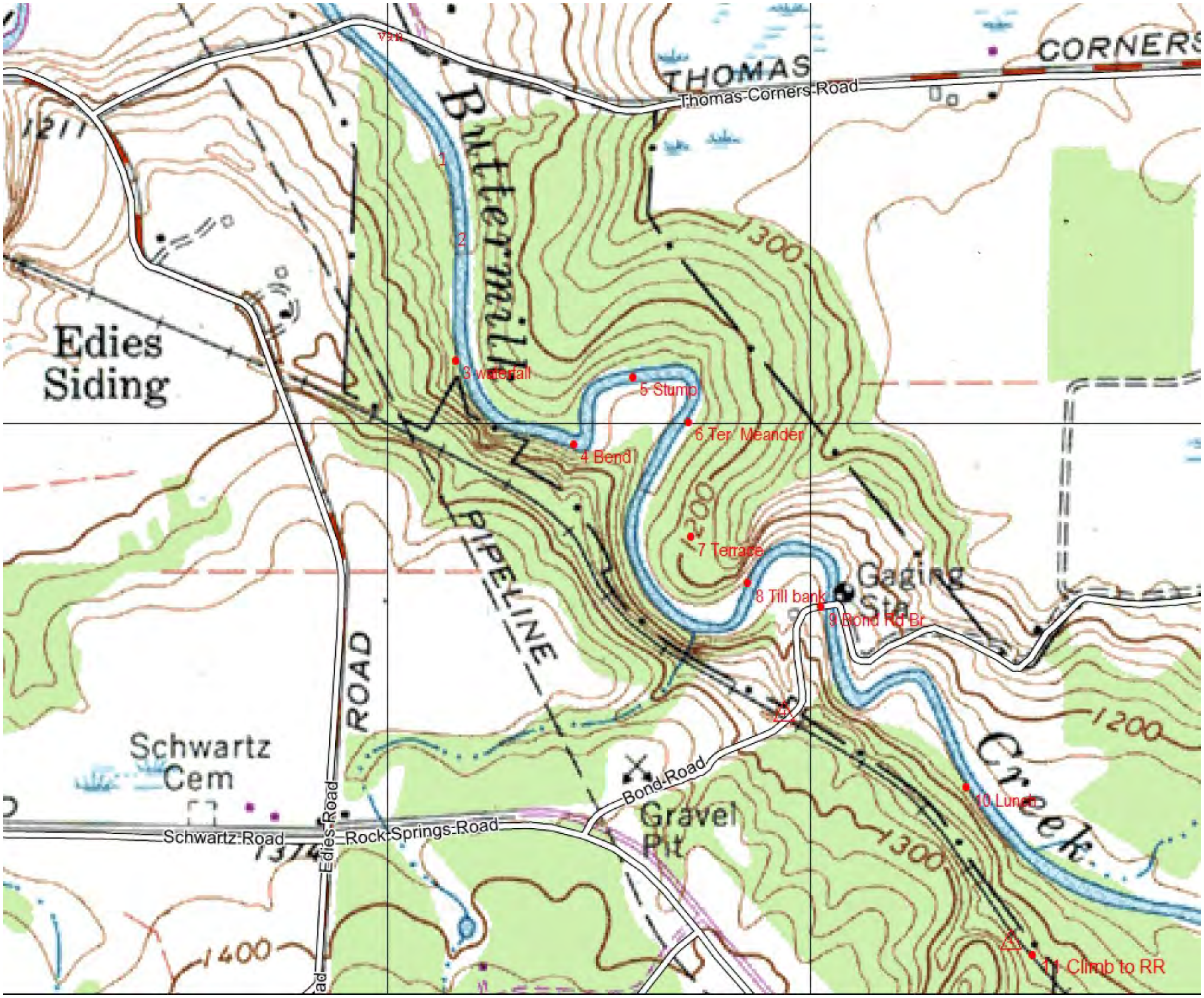
Recorded 11 waypoints (attached) and associated digital images. WP 1 and 2 not recorded on GPS?

Located large rooted stump in riverbed about 1 km upstream from Thomas Corners Rd bridge at WP 5. (stump photo and WP map attached).

Ascertained that multiple terraces at meander bend (WP 6, 7) should be readily accessible for vehicles such as back hoe, at low river stage. Solid gravel riverbed, little mud present. Water generally was less than 1 foot deep, gravel banks exposed (photos of riverbed saved and available, see below images).

Till bank (WP 8) mapped by LaFLeur as Lavery till over Kent till. Uppermost sand and gravel layers in or between till sheets might be suitable for OSL sampling. Possibly Lavery recession was oscillatory, so late "outwash" age could be close to time of final ice recession?

Lavery/Kent till outwash interface(?) WP 8



Waypoints 1 and 2 are approximated (GPS data apparently not recorded).


Photo of rooted stump at WP 5.


Photo of terraces near WP 6-7 on meander (point bar) bend.

Brief lunch stop at WP 10.

Hiked out along RR from WP 11.

Light intermittent rain began during return.

Went to abandoned meander to recollect undisturbed sample of high terrace "O" gravels at WP 9 of Aug. 26 reconnaissance. Dug 1 foot into terrace to collect sample. New sample (pebble count) is not appreciably different from previous surface grab sample (data attached). Roundness of pebbles and sandstone-dominated lithology suggest fluvial origin, rather than immature beach winnowed from valley wall material. Additional pebble counts on diverse deposits, features, and locations should address these issues more fully.

Returned badges at WV site, and departed at 3:30PM, just as very heavy rain started. Heavy rain continued during entire return to Geneseo.

Below are 4 images of typical conditions along Buttermilk Creek that would be encountered by equipment needing to access meander at WP 6-7 area.

Lower Buttermilk Creek bed between WP 1, 2, 3.


Buttermilk Creek bed between WP 3-4


Buttermilk Creek below bend near WP 4


Upstream from bend near WP 4, viewed looking downstream

Random (large) pebble count from channel gravel on high terrace SE of abandoned meander (8/26/14)

Location: WP 9 (coarse fraction of same sample below)

Diameter range 1-6.5 cm (moderate to well rounded; few subangular)

ROCK TYPES	NO.	PERCENT
Igneous/metamorphic	3	2%
Shale	0	0%
Chert	3	2%
Limestone	0	0%
Dolostone	0	0%
"Quartzite(?)"	3	2%
Sandstone + siltstone	131	93.5%
	140 pebbles	99.5%

Random (small) pebble count from channel gravel on high terrace SE of abandoned meander (8/26/14).

Location: WP 9 (from same sample as larger diameter pebble count above)

Diameter range 1-2 cm (rounded to subangular). Appears somewhat more angular than large pebbles.

ROCK TYPES	NO.	PERCENT
Igneous/metamorphic	2	0.9%
Shale	0	0%
Chert	6	2.8%
Limestone	0	0%
Dolostone	0	0%
"Quartzite(?)"	13	6%
Sandstone + siltstone	192	88.15%
Unidentifiable	5	2.3%
	218 pebbles	100.1%

Channel gravel pebble count #2: High level terrace "O" SE of abandoned meander (9/2/2014)
(Divided sample into large and small sizes using 7/8" screen = 22.6 mm) Eliminated < 1 cm sizes.
Dug into gravel layer approximately 1 foot. Maximum pebble size = 11 cm.

Large sizes (>7/8" screen; 22.6 mm) Total pebbles = 107

Rock type	Count	Percent
Medium gray sandstone	47	44
Darker gray sandstone	32	30
Reddish sandstone	5	4.7
Siltstone (& v. fine sandstone?)	11	10………………..88.7 subtotal sandstone + siltstone
Meta/igneous	3	2.8
"Quartzite"	9	8.5 (difficult to distinguish true quartzite from sandstone)
Chert	0	0
Limestone	0	0
	107	100 %

Small Sizes (< 7/8") Total pebbles = 347 (cut off = 1 cm)

Rock type	Count	Percent
Medium gray sandstone	138	39.7
Darker gray sandstone	109	31.4
Reddish sandstone	16	4.6
Siltstone (& v. fine sandstone?)	48	13.8……………..89.5 subtotal sandstone + siltstone
Meta/igneous	9	2.6
"Quartzite"	17	4.9 (difficult to distinguish true quartzite from sandstone)
Chert	10	2.9
Limestone	0	0
	347	99.9%

Percentage rock type counts differ very little regardless of using large or small sizes.
Therefore, it is reasonable to use larger sizes (>7/8" screen) to estimate percentages accurately.

/2YLJl-NJʎă2ƴ2Ŧ Terrace "O" gravel samples : Percentage of rock types greater than 1 cm in diameter (High terrace near ~1280ft, SE of abandoned meander)

	<u>Surface grab sample</u> (358 count) (6.5 cm = largest size)	<u>1 ft. Deep Sample</u> (454 count) (11 cm = largest size)
Limestone or dolostone	None	None
Shale	None	None
Sandstone and siltstone	91%	89%
"Quartzite"	4%	6.5%
Chert	2.4%	1.4%
Igneous + Metamorphic	<u>1.5%</u>	<u>2.7%</u>
	98.9%	99.6%

There is also no significant compositional difference when comparing large and small pebbles using 7/8 in (22.6 mm) screen as an arbitrary size separation criterion.

High sandstone content and percentage of well rounded clasts suggest these gravels are fluvial, derived from upstream abundance of Conneaunt and Canadaway Group grayish sandstones, rather than being winnowed mainly from glacial till, outwash, or related to local till and bedrock-derived alluvial fans. Stream energy is apparently very efficient at breaking down and removing shale component of local and southern bedrock.

I anticipate that till and glacial outwash clast analyses would be more angular and show more obvious component of Canadian Shield erratics, carbonates, reddish sandstones (Grimsby/Queenston), and local shales that crop out between Ontario lakeshore and Cattaraugus Creek.

These data suggest that surface grab sample of 100 or more pebbles should be adequate to verify the presence of rounded fluvial terrace gravels directly related to the evolution of Buttermilk Creek. In other words, the prominent horizontal benches along the valley sides, those that are not obvious slumps, can be demonstrated to be fluvial terrace remnants if such gravel deposits are preserved.

Glacial till clast and local glacial outwash samples should be analyzed and compared to further test this hypothesis. Additional terrace gravels from lower terraces should also be sampled.

R. A. Young
9/4/2014

Waypoints 8-26-2014   Reconnaissance and log sample (WPs 1-13)

1. Parked car

2, 3. Buttermilk Creek at former Buttermilke Rd. crossing (communication cable)

4. Contact visible (Qal over till; contact 4 feet above creek)

5, 6. Potential ^{14}C log sample (large log located just above contact of Qal over glacial till; contact 8 ft above creek). (Lat/Long = 42 26.670; 78 38.498) Sample B-1 (Buttermilk 1). Oven dried 8/27/14. Photo and map attached.

7. 5- foot bed of gravel in till exposed in steep hillside.

8, 10. Probe coring of sediment/organics on high terrace south of abandoned meander. Wilson sampled.

9. Random gravel sample collected at surface for lithologies, roundness analysis; dug into about 10" of gravel to verify in base of small headward eroding channel junction. Left pink flagging with date near location.

11. Parked for landslide visit.

12, 13. Examined sediment lenses in landslide tills on north edge of landslide. Dave sampled sand.

Three maps made of waypoint locations completed using topographic 1:24,000 map contours overlain on lidar 1-ft contour map by R. Young. Waypoint lat/long recorded in field notes.

R. Young email 9-4-14

Mike and all:

We had a productive reconnaissance trip with Lee Gordon walking about 1.6 miles up Buttermilk Creek from Thomas Corners Rd. on Tuesday (see waypoint map attached). We ascertained that the creek bed is readily accessible to ATVs or basic construction equipment such as a backhoe (as far as terraced meander, Site 8, Appendix A, Figure A-1 of "Target Study Locations"). This multi-terraced meander (as many as 10 to 11 benches) is approximately 3300 feet upstream from the Thomas Corners Road bridge. The wide channel bed of Buttermilk Ck. is surfaced largely with thick sandstone-dominated gravel and is relatively flat in most places (see images attached). There are very few larger boulders, which do not seem to present serious vehicle obstacles. The water depth on this wet year (including 1.5 inches of rain over the weekend) varied up to a maximum of about 18 inches in a few short reaches where a vehicle would have to transit. Many of the flat gravel bars were fully exposed or had only a few inches of water cover (see images attached). There are few sections where relatively thin muddy sediment is present, and this would not seem to present serious obstacles to vehicle passage. There were recent 4-wheel ATV tracks most of the way up the Creek to our exit point (also a beaver trying to build a new dam near old Bond Road crossing). Access up onto the meander terraces would require some minor excavation to breach the slight vertical rise at the channel margin. Much of the gradually sloping meander terrace area is open and clear of undergrowth, much like the terrain near the old abandoned meander that Lee and others have investigated. The meander terraces (WP 6-7 area on attached map; see image) contain gravel layers and obvious channel features. This area has the potential for providing age data for an interesting sequence of terraces reaching up to about 40 feet above modern stream level.
There is a large multi-layer till exposure at WP 8 that LaFleur mapped as including both Kent and Lavery tills (with intervening outwash gravels; see image).

We also located a large tree stump in growth position (see stump image) on a bar in the center of the channel (WP 5). This could provide an interesting bit of data on how long the creek has been near this level, especially if it has a relatively old age. However, due to the restriction on sampling at channel and modern floodplain level downstream of Franks Creek, we were not able to obtain a good sample of this stump (a shame). It seems a bit pointless that we are allowed to tramp through the flowing stream in normal boots and clothing, examine any number of rock samples and debris, but cannot put said objects into a sample bag for dating or pebble counts. It would be a real missed opportunity if this stump is either buried by a major flow, or eroded away before we are permitted to sample it.

We also obtained a second, larger sample of high terrace channel gravel at the old abandoned meander for a pebble count. I think such pebble counts will be useful in establishing that the various terraces actually are stream features, rather than small slumps. A heavy downpour began immediately after we finished collecting the gravel at around 3:30 PM. Rain was very heavy and steady continuously from West Valley to Geneseo, with warnings on the weather channels.

Other items we might discuss on the next call (tomorrow?) are the work limitations due to NYSERDA schedules. We cannot be onsite if no one from NYSERDA is there to check us in and out (via telephone). This means no work on weekends or every other Friday, even though we could gain access via the DOE gate security. We were also advised we need either an enhanced NY driver's license (regular license not sufficient) or passport every time we enter the site through various gates, and we need to wear badges, which had not been the case previously. This meant that Alex could not work Thursday without a passport (they let him work Tuesday with regular NY license, but only allow one such exception per individual). We cancelled Thursday 1/2 day trip do to inability to officially collect samples along Buttermilk Ck. and to Mike Wilson's feeling out of sorts.

At some point we need to obtain some of the minor equipment we have previously discussed, such as a camera, small tools, emergency medical kit, misc. supplies, etc. to replace the personal items we have been using to date. Also should make decision on vehicles when Lee is no long available or willing to assist with his van on short notice.

Dick Young

Reconnaissance Fieldwork (and current thoughts), West Valley, ECS
September 9, 2014, R. A. Young
Pebble Counts and log resample.
Personnel: Young, Wilson, DaSilva, Butzer, Zadins

Arrived West Valley 9AM
Obtained gate key and met Zintars at Buttermilk Rd. gate.
Parked at landslide overlook to Buttermilk Ck.

Mike and Dave with Zintars hiked into Buttermilk Creek with Wilson and Butzer to recon terraces, etc.

Young and DaSilva started till pebble count at top of landslide, south end.
Count 1 = till approximately 50 feet below top of slide on south edge of slide (photo 6); Assumed to be Lavery till (WP 1). As anticipated, this till contains abundant dark limestones and "Grimsby type" red sandstones derived from bedrock outcrops to the north (see pebble count attached). The till pebble sample is very different from typical Buttermilk Creek gravel, mainly with regard to content of coarse red sandstones (Grimsby?), abundant dark limestones (northerly outcrop derivation), and shale. See image #1 below.

It appears reasonable, based on till pebble count below, to readily distinguish between former Buttermilk stream gravels located on higher terraces and other types of gravel deposits more likely to have been winnowed or locally derived more directly from till, such as: shorelines, alluvial fans, colluvium. The "Grimsby" red sandstone in the till is dark red and relatively coarse grained. Some reddish sandstone also are present in the Buttermilk Creek gravel, but the color is often not as distinctly "Grimsby color", and the grain size often is finer. Obviously, *some* component of Grimsby and other till lithology pebble types should be expected to be reworked into terrace or modern stream gravels. See example of till clasts in image #1 below.

Pebble Count 2 = Buttermilk Creek gravel bar immediately downstream from landslide (WP 2). Three photos taken, 2 of gravel bar collection site; one looking back at landslide from WP 2. Completed both pebble counts onsite after washing clasts in creek. Photos 5,6,8.
Results of pebble counts included below. Admittedly limited data so far, but clast compositions appear distinctive.

Brief lunch at Creek.

Radio contact with Wilson and Butzer: Proposed Young and DaSilva return to log site (WP 5,6) of 8/26/14 to excavate more of log and obtain better ^{14}C sample. Also to collect till clast sample at Creek level at same location (WP 5,6), as well as from "intertill" gravel at WP 7 of 8/26/14. (See image #1 of representative till clasts.)

Returned to communication cable access and proceeded down into Buttermilk Creek. Stopped at former WP 7 to collect pebble clast sample from "intertill" gravel. Proglacial outwash(?) or ice-contact gravel(?). Gravel may have formed in ice stagnation conditions (close to ice) as matrix contains significant clay (gravels not washed clean; clay till matrix is stuck to pebbles), as opposed to "cleaner" proglacial outwash expected at a greater distance from ice front. Would expect true proglacial outwash to consist of clean gravel without so much clay sticking to pebbles. Also, imbrication indicates diverse flow directions, some to north, as if complex local ice stagnation topography were controlling deposition. Images 3 &4 of outcrop attached. Sample yet to be analyzed.

Dug out more of log buried at Qal/till contact (WP 5,6; 8/26/14). Log total length preserved is approx 10 feet; est. 8-10 inch diameter. Root is missing from exposed downstream end. Log is badly decomposed for most of length. Obtained much better (less decomposed) sample from exposed larger end of log (see photo 7). Log is associated with relatively large (5-8 inch) clasts in Qal, suggesting significant flood event associated with log burial. Existence of such a large tree suggests little reworking or complex transport history for tree. See image #7 of extracted wood sample. Completed second till clast collection at same location as log at Creek level (yet to be analyzed).

Finished 3PM; Met and updated Lee Gorden; Waited for Wilson, Butzer to return, returned key at 4:30 PM (Six hours worked).

OVERVIEW

The two wood samples located to date (log at WP 5,6 and the stump in the creek bed in lower Buttermilk Ck. in growth position) have the potential either to support the current interpretations, or to provide a renewed and improved perspective concerning erosion rates and longer-term chronology.

The location of the as yet unsampled, rooted stump in lower Buttermilk Creek might provide improved data concerning the rate of recent base level lowering. If the stump turned out to be quite old (say 2000 to 5000 years, for example), it could document an obvious slowing of vertical incision rates at a location clearly marking the modern creek bed. If it is much younger (say 500 to 1000 years), it would still imply relative stability in vertical incision rates in the lower part of the main channel. The location and in situ growth position provide more conclusive information than previous wood fragments imbedded in the floodplain gravels or low terraces, whose ages involve greater uncertainty, due to required assumptions.

The buried log at WP 5,6, located at the Qal/till interface and close to the west valley wall, might provide similar information, either a confirmation of Lee Gordon's work and ideas to date, or a pushing back further of the time when vertical incision reached an elevation close to the modern Creek (approximately 8 feet above Creek level). The location and condition of this large log seem to imply there is no significant reworking (log buried in situ shortly after dying?, or possibly knocked down and buried during large flood event?). The till surface below presumably represents the channel base at that time.

In other words, relatively old ages on either of these wood samples might provide an improved perspective concerning vertical incision rates.

If these two samples could be dated soon (this season), the results could have a significant impact in shaping our future planning for continued reconnaissance and/or the focus of early excavations. With any luck, some higher and intermediate terrace excavations might also result in an expanded ^{14}C chronology for the time sequence of vertical incision.

The distinct difference in the pebble counts we have made in different types of deposits also implies that we have an additional tool with which to better characterize and select excavation sites, especially regarding our ability to distinguish between fluvial terraces and other "terrace- like" topographic features possibly created by slumping along the valley sides.

1) Lavery(?) till pebble count (WP 1) at landslide Location

* Pebble types not as abundant in Buttermilk Creek gravel.

Lithology	Number	Percent
Red sandstone (probably Grimsby)	*12 (mostly coarse grained, darker red)	10.2
Gray sandstone	42	35.8
Siltstone	8	6.8
Shale (blackish)	*10	8.5
Limestone/Dolostone	*24 black, 8 gray (most striated)	27.4
Meta/igneous	9	7.6
"Quartzite"	3	2.5
Chert	1	0.9
	117	99.7

2) Buttermilk Creek Pebble Count, gravel bar downstream from landslide (WP 2) (compare terrace "O"sample)

Lithology	Number	Percent
Red sandstone (not all Grimsby?)	7 (some finer grained/lighter colored)	6.9
Gray sandstone	74	73.3
Gray siltstone	8	7.9
Shale	0	0
Limestone/dolostone	4 (light gray, not striated)	3.9
Meta/igneous	6	5.9
"Quartzite"	1 (white)	0.99
Chert	1	0.99
	101	99.9

#) Terrace "O" deep sample (combined large and small sizes, for comparison with modern Buttermilk Creek)

Red sandstone	4.6%
Gray sandstone	71.7%
Gray siltstone	13%
Shale	0%
Limestone/dolo.	0%
Meta/igneous	2.6%
"Quartzite"	5.7%
Chert	2.2%
	99.8%

1. Representative till clasts from log site (WP 5,6). Generally more angular than stream and terrace clasts.

2. Representative terrace "O" gravel (larger clasts only). Mostly sandstone, more rounded than above. Quarter in center for scale.


3. “Intertill” gravel (many clasts have clay attached and imbrication is somewhat variable) WP 7, 8/26/14

.

4. Closer view of above. Till is present above and below gravel. WP 7 of 8/26/14

5. Buttermilk Ck. gravel sample site (WP 2), downstream from landslide. 9/9/14 (As below)

6. Landslide till sample site (WP 1, upper left) as viewed from downstream gravel site (WP 2) in foreground.

7. Resampled log segment from site WP 5,6 of 8/26/14. Excellent condition, no modern rootlet penetration. Exposed and recollected 9/9/14. Log at Qal/till contact in river gravel.

8. Buttermilk Ck. gravel bar, WP 2 9/9/14 Dominated by rounded, gray sandstone and siltstone.

ISSUES RELATING TO RADIOCARBON DATING OF ORGANICS IN FLUVIAL AND GLACIAL ENVIRONMENTS: TENTATIVE THOUGHTS ON PRELIMINARY DATA FROM WEST VALLEY, NY. R.A. Young, December 22, 2015

There are two major issues that are probably most important in the evaluation and dating of organic samples in fluvial and glacial environments.

1) What is the nature of the depositional process and what was the natural environment (ie. What is the origin and nature of the organic material and how did it arrive at its current burial position?). Is reworking a plausible assumption?

2) What is the likelihood and potential magnitude of contamination by older or younger introduced carbon?

Some of the contamination issues can be minimized by careful sample treatment and use of the AMS method; others depend significantly upon the interpretation of the sample context as carefully observed in the field.

BURIAL AND PRESERVATION EVIDENCE

There are some straightforward observations that can be used to simplify the potential circumstances:

A) Old wood samples can be reworked and redeposited in younger sediments (the "reworking" issue). However, younger samples cannot be found in truly older sediments (unless contamination has occurred by penetration of rootlets, fungi, etc.). The reworking issue is predominantly one where old (dead) trees or branches are buried, reexposed, broken into smaller pieces, and redeposited one or more times during major flood events. This is common in fluvial floodplain situations. Therefore, this issue is problematic when a relatively small, isolated wood sample (broken fragment) is found or collected, and its decomposition and potential multi-stage burial history are uncertain.

B) All dead or uprooted wood is susceptible to relatively rapid decay and disintegration when exposed at the ground surface, or when buried in permeable sediments that are above the local groundwater table. Conversely, wood samples can be amazingly well preserved for extended times below the water table, especially when the enclosing sediments are fine grained (silt and clay). Proof of this is shown in Figure 1, a circa 48,000-year-old sample of spruce wood preserved in mid-Wisconsin glacial till in the Genesee Valley (Young and Burr, 2006). Many similar samples were collected at this site.

Figure 1. Spruce wood preservation in Genesee Valley, NY (~48,000 calendar years). Young & Burr, 2006.

The reason for the unusual preservation of wood below the water table is the relative absence of air, insects, and fungi, and the relatively slow operation of bacteria in this environment. Studies of old wooden construction piles at building sites in Boston, MA, (Lambrechts, 2008) and in European countries have recently demonstrated the significance of above vs below water table environments for wood preservation at the multi-century scale (Klaassen, 2015). Also attachment.

In addition, my own 50-year experience with extensive firewood cutting, storage, and use has shown me just how rapidly hardwood trees disintegrate when exposed to air. Even when carefully stacked above ground, hardwoods such as oak decompose significantly in this climate in 4 to 5 years, to the extent that the wood looses much of its heating value. Decomposition is mainly due to fungal, bacterial, and insect activity, as well as normal atmospheric oxidation processes. For these reasons, wood exposed in the open and on the surface is highly unlikely to survive for more than a decade and end up buried in a pristine, undecomposed state. In other words, if an old sample of buried wood (log or stump) is found to be in good to excellent condition (little or no obvious decomposition), it can be assumed that: 1) the sample has been preserved below the water table for most of its history, and/or 2) the specimen did not sit on the surface for a lengthy period of time (probably less than a decade).

CONTAMINATION ISSUES

There is a fairly comprehensive discussion of relevant ^{14}C dating issues at:
https://en.wikipedia.org/wiki/Radiocarbon_dating

One of the main conclusions to be drawn from this and other similar discussions is that the cellulose extraction method or treatment, when used with AMS (accelerator mass spectrometry) dating, should allow for most contamination issues to be eliminated, or at least better resolved. In addition, AMS dates, unlike the older generation methods, allow discrete counting of individual atomic species (isotopes), such that contamination issues can be better defined.

Another factor to be considered is that even when contamination is present, a small amount of contamination does not necessarily mean that a date is completely worthless (depending on the age of the sample and the amount of contamination). A sample with small amounts of contamination can still provide a useful approximate age (as indicated by examples in the Wikipedia site above; Example: 1% contamination of 17,000-year-old sample produces a 600-year error, which is not that different from discrepancies encountered along some portions of the ^{14}C calibration curve).

RELEVANCE TO BUTTERMILK CREEK SAMPLES

It is clear that we will be collecting more samples from Buttermilk Creek environments during the course of the present study. However, as a preliminary evaluation, I am formally summarizing my thoughts concerning two of the wood samples analyzed to date from near the Buttermilk channel, while the pertinent information is fresh in my mind.

Buried Stump Sample (WV-BC-C14-S1; age 1960±30 BP) from Buttermilk Creek channel

This stump (Figure 2) appears to be in a normal growth position, well preserved, and was as "hard" as modern wood, in so far as the strength required to detach a sample with a sharp-edged mattock. From these conditions it can be inferred that the ~2000-year-old specimen was not exposed to the atmosphere (uprooted) for any significant period of time (as inferred from discussion above). This implies that it has been beneath the water table (at or near stream channel elevation) throughout its burial/growth history. The most logical way to interpret the environment is that of a rooted tree stump in its original growth position. Only further excavation could verify this reasonable assumption.

Consider the alternative possibility. Suppose such a tree were growing on the adjacent flood plain some distance upstream. Such a large tree would either be toppled by the wind, by a major flood event, by disease, or by gradual encroachment of the channel so as to undercut the root ball. Regardless of how such a relatively large tree might eventually fall, the root would likely be attached to the trunk at that time (in order that the roots be lifted from their original growth position, as seen in locally uprooted trees). If such an exposed rooted stump somehow were to be separated from the trunk, carried further downstream, and reburied, the following would have to occur. The root and stump would have to become quickly separated from the trunk. This is difficult to envision without allowing the entire tree to be exposed to the elements and the natural decay process described above for several years. However, the separation somehow would have to occur in a manner such that the stump is still well preserved (not compatible with several years of weathering above ground or above the water table) prior to subsequent burial.

The normal position for stumps seen along such floodplains is: 1) attached to a significant portion of the original trunk and caught in a tangle of other flood debris; or 2) present as a stump (often debris left from logging or clearing operations), but typically tipped on its side with the stump end tilted downwards (due to larger diameter of attached root structure). It seems unlikely that a stump with a large root system could be uprooted, separated from the trunk, transported a short distance, and reburied without noticeable "weathering or decomposition" in such an upright position. If such conditions were to be met, it certainly would have to occur over a short time frame following the tree's demise, in order to explain the relatively pristine condition of the wood comprising the stump.

Alternatively, if the stump (and trunk?) were originally buried for some unknown time (possibly above the water table), then re-exposed and/or reburied by another flood, there would have to be more significant effects of decomposition evident. So, reworking and/or gradual reburial do not seem to be reasonable assumptions for this well-preserved specimen (in addition to its upright position).

Figure 2. Rooted(?) stump in gravel bar along Buttermilk Creek (WV-BC-C14-S1)

If the above analysis is reasonably accurate, it implies that the channel of Buttermilk Creek was lowered to near its current elevation at this location by approximately 2000 years ago, perhaps even earlier if vertical incision has been slowed effectively by the bedrock knickpoint immediately downstream. Obviously,we will need additional supportive evidence to properly evaluate the issue of age and depth of incision along Buttermilk Creek. However, the presence of this rooted stump, in its present condition, would seem to be potentially more instructive than a random fragment of wood, with the attendant uncertainties that are attached to such occurrences.

BURIED LOG AT FLUVIAL/TILL CONTACT (WV-BC-C14-S2; Age: 1860+30 YBP)

The buried log shown in Figures 3a-3d has a less certain interpretive and "weathering" history than stump sample S1. The log is preserved resting at the contact between glacial till and overlying fluvial sediments , which varies from 4 to 8 feet above the local stream level. The log is in a state of intermediate decomposition (not completely decomposed or disintegrated). Its total length and connection to an original root structure is undetermined. Although it is above the current water table at present, it has been gradually exposed by the lateral (westward) migration of the Buttermilk channel. When it was located further from the channel, the till directly below may have served to maintain a perched water table, which could have slowed the rate of decomposition of the log for some unknown period of time.

Figure 3a. Log protruding from contact of fluvial sediment over glacial till.

Figure 3b. Contact of fine-grained fluvial sediment over glacial till. Log is located immediately to left of this view.

Figure 3c. Wood sample dislocated from downstream (north) end of main log.

Figure 3d. Collected log sample after drying at 90^{o}C (WV-BC-C14-S2).

The visible portion of the partially buried log is a minimum of 10 feet long, and it is estimated to have been 8-10 inches in diameter at its largest preserved end. The downstream root end is missing, and the best sample (no visible rootlet penetration) was extracted from this lower end. It was possible to extract and submit a smaller sample from relatively deep within the collected specimen to the Beta lab, so that external contamination is even less likely.

The elevation of the log sample above the modern channel appears to be at or close to the approximate elevation of the modern floodplain elsewhere along Buttermilk Creek (occupied during moderate to high flood stages). My working assumption for this location is that the log was deposited during a flood-stage event on a surface that had been scoured down to the till, either during the same flood or during an unknown earlier event. Because the log is not totally decomposed it is assumed that it died or was felled and could not have remained exposed on the surface for much more than a decade. It must have been transported onto the till surface during a flood event. The fluvial sediment was either deposited at nearly the same time or somewhat later. As it must have been buried at or near the local water table at the time, it did not totally disintegrate during the approximately 1900 years since its measured growing period.

Trees of this size are moved by extreme flood events, but generally do not travel far (not miles) before becoming entangled with other similar obstacles in the floodway channel, or getting lodged against other trees still standing on the floodplain. For these reasons, and the relatively well preserved condition of the relatively large log, it can be assumed that it has not been exhumed, exposed, and reburied two or more times. Based on these reasonable assumptions, I assume it came to rest in its present position not more than a decade or so after its demise.

Based on these simplistic assumptions, and the evidence from the downstream stump, that Buttermilk Creek was near its present channel elevation by ~2000 years ago (or earlier), it is reasonable to surmise that this log is additional evidence for the elevation of the Buttermilk channel close to the time of the log's "death" and original burial. This must have been soon enough that the log did not entirely disintegrate. So it is reasonable to assume (conservatively) that the burial situation occurred within 100 years or less of the tree falling. Otherwise, if left on the surface for several decades, the log should have disintegrated and not been moved as a large intact object by flood conditions.

I would exclude the tree simply falling and being buried (in place) on a vegetated floodpain shortly thereafter by a large flood event, because it is resting on an apparently scoured till surface, which is unlike the nature of the vegetated floodplain surface seen across the adjacent terrain. Transport and burial of the recently fallen tree, some 1900 years ago, without significant time elapsing for decomposition seems to best fit the observed conditions. Even if slightly more time might have elapsed prior to transport and/or burial, the circumstances imply that the modern creek was near its present channel elevation within this approximate time frame. An OSL age determination on the fluvial sediments at this log site should be an important target for next field season. The site is upstream from the "exclusion" zone for the floodplain, which is located mostly downstream from the Franks Creek confluence.

TENTATIVE CONSCLUSION

The evidence based on the two wood samples could mean that the erosion of Buttermilk Creek was rather rapid at first, but has slowed in recent time, presumably due to reduction in gradient and associated development of equilibrium conditions along much of the channel, possibly associated with one or more bedrock knickpoints. This might imply that valley widening and tributary erosion (headward erosion) are currently more important processes than main channel incision.

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ATTACHMENTS

(http://www.irccdd.com/building_division/R319.pdf)

SECTION R319
PROTECTION AGAINST DECAY

R319.1 Location required.

In areas subject to decay damage as established by Table R301.2(1), the following locations shall require the use of an approved species and grade of lumber, pressure treated in accordance with AWPA C1, C2, C3, C4, C9, C15, C18, C22, C23, C24, C28, C31, C33, P1, P2 and P3, or decay-resistant heartwood of redwood, black locust, or cedars.

1. Wood joists or the bottom of a wood structural floor when closer than 18 inches (457 mm) or wood girders when closer than 12 inches (305 mm) to the exposed ground in crawl spaces or unexcavated area located within the periphery of the building foundation.
2. All wood framing members that rest on concrete or masonry exterior foundation walls and are less than 8 inches (203 mm) from the exposed ground.
3. Sills and sleepers on a concrete or masonry slab that is in direct contact with the ground unless separated from such slab by an impervious moisture barrier.
4. The ends of wood girders entering exterior masonry or concrete walls having clearances of less than 0.5 inch (12.7 mm) on tops, sides and ends.
5. Wood siding, sheathing and wall framing on the exterior of a building having a clearance of less than 6 inches (152 mm) from the ground.
6. Wood structural members supporting moisture-permeable floors or roofs that are exposed to the weather, such as concrete or masonry slabs, unless separated from such floors or roofs by an impervious moisture barrier.
7. Wood furring strips or other wood framing members attached directly to the interior of exterior masonry walls or concrete walls below grade except where an approved vapor retarder is applied between the wall and the furring strips or framing members.

R319.1.1 Ground contact.

All wood in contact with the ground and that supports permanent structures intended for human occupancy shall be approved pressure preservative treated wood suitable for ground contact use, except untreated wood may be used where entirely below groundwater level or continuously submerged in fresh water.

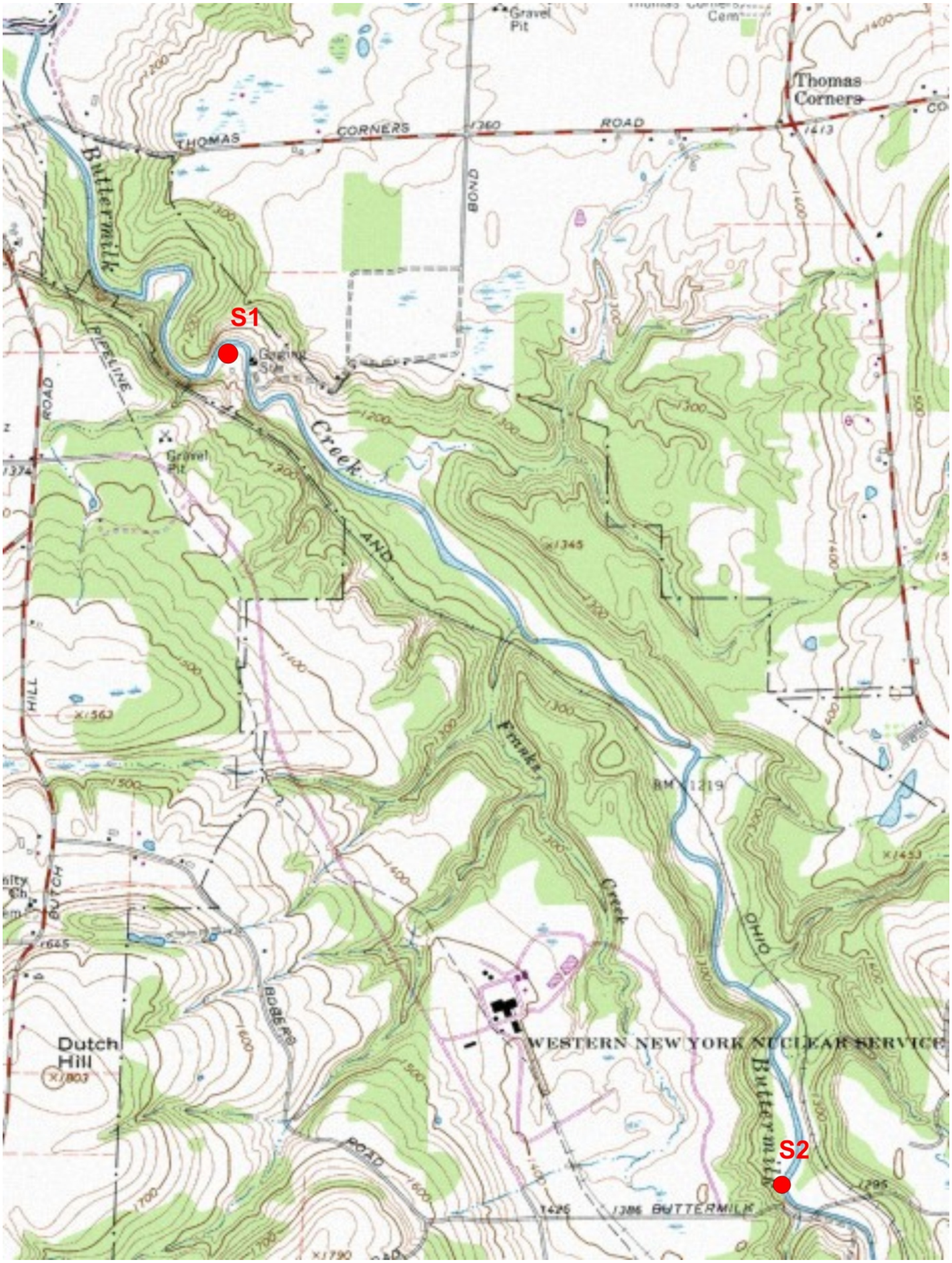
R319.1.2 Geographical areas.

Approved naturally durable or pressure preservatively treated wood shall be used for those portions of wood members that form the structural supports of buildings, balconies, porches or similar permanent building appurtenances when such members are exposed to the weather without adequate protection from a roof, eave, overhang or other covering that would prevent moisture or water accumulation on the surface or at joints between members. Depending on local experience, such members may include:

1. Horizontal members such as girders, joists and decking.
2. Vertical members such as posts, poles and columns.
3. Both horizontal and vertical members.

R319.1.3 Posts, poles and columns.

Posts, poles and columns supporting permanent structures that are embedded in concrete in direct contact with the ground or embedded in concrete exposed to the weather shall be approved pressure preservatively treated wood suitable for ground contact use.



Map for locations of Samples WV-BC-C14-S1 and S2

Notes for Joint ECS/DOE/NYSERDA Reconnaissance: West Valley project fieldtrip on July 31, 2015 (9 AM – 4 PM)

Participants: Young, Wilson, deSilva, Butzer, Feldman, Frank, Zadins (compiled by R.A. Young)

Partial record of route shown by waypoints WP 3-23 (black letters and symbols added to topographic maps)

1. Met for orientation by Feldman at WVDP parking lot (9 AM)

2. Discussion and handouts by R. Young for (A) abandoned meander site (Fig.1) and (B) multi-terrace meander reconnaissance on east side of Buttermilk Ck. off Thomas Corners Rd. at tree farm property (WP 3-8; Figs. 7,8). Wilson and Butzer discussed Heinz Creek and other reconnaissance locations on east side of Buttermilk Ck. for afternoon (WP 14-23, Fig. 9).

3. a)Walked abandoned meander site (no WPs recorded) and discussed location of trenches, appropriate type of equipment (tracked trenching machine as per attached CAT, Fig.2), potential trench locations, procedures, access routes, ground penetrating radar (GPR) and portable groundwater pump/generator (see Fig. 1 with cross section).

b) Access appears clearly possible and relatively straightforward with small tracked vehicle from existing (abandoned) road, then across meander channel and proceeding upwards to highest north-side terrace (B) as per 2014 plan, (this includes surfaces B thru H on cross section of Fig. 1; surface A appears to be till of original glacial topography, but should be trenched to confirm). Access to highest potential terrace (B) from slope below might be the only issue, but surfaces A and B also could be accessed from above, if necessary. Removal of fallen trees will be required for access to some locations, and possibly minor removal of a few live trees or brush. Many smaller fallen trees can obviously be dragged out of the way by hand. Surface testing of terraces with hand shovel showed shallow rounded fluvial gravel (sandstone clasts dominate) on all terrace levels (B-H) as per Figure 1 (fluvial sandstone clasts also are obvious in overturned root balls of fallen trees).

c) Discussed dewatering concepts and preferred GPR locations. Recommended two long (NE-SW) parallel GPR profiles along length of meander point bar (likely location to show most detailed stratification, sites for best trenching locations, and possibility of shallow bedrock). However, typical unweathered gray till is currently exposed in floor of gully (N, Fig. 1) leading down to head of alluvial fan, M (no evidence of bedrock at N). Alluvial fan area (M) has standing water due to recent rainy spring & summer. Possibility for leaving fan trenching to potentially dryer period in Fall (alternatively, could attempt individual trench to run from low to high elevation to create self-draining condition). Wilson suggested two GPR lines be located on each terrace at right angles to maximize potential to best capture variable bedding trends. Where individual terraces have minor variable relief, GPR might be best run along highest (driest) locations to avoid muddy conditions and redeposition of recent sediment in gentle swales.

d) Wilson discussed advisability for staff of USGS OSL lab to visit site for familiarity with project conditions and requirements, as well as to demonstrate best practices for OSL sample acquisition (one interested staff member is student of Greg Tucker). Wilson has explored interest in such a USGS visit with head of Denver lab.

e) Walkover with potential contractors will clarify any additional issues overlooked by participants.

4. Lunch 12-1 PM

5. Reconvened at Buttermilk Gate to visit multi-terraced meander at tree farm (Fig. 8, WP 3-8). House at property access is not currently occupied by land owner; appears to be tenant. Adjacent tree farm land recently sold to alternative owner and most existing trees currently are being cleared/removed.

6. Tree farm stop: Drove to top of ridge (WP 7) and walked down to highest terrace level (WPs 3-6, ca. 1200 ft elev.). Access by similar tracked excavator along ridge "trail" and nearby segments of old logging or farm roads and slump benches seems relatively straightforward and entirely feasible. At one location trees block short segment of ridge crest trail. However, numerous parallel routes through relatively open forest are available by traversing back and forth among trees and parallel to slump block surfaces (forest cover shown in Fig. 4). Assuming owner's permission, access to this important multi-terrace site from above should not be an issue. Figures 5 & 6 show steep erosional cliff on southeast side of ridge. Figure 7 (black hachured line) includes an approximation of the potential access route via a "switchback" approach.

7. Drove to Heinz Road to investigate access to Heinz Creek terraces and fans mapped by Wilson and Butzer in 2014 (Figure 10). Vegetation was too dense for easy access given time available (see black dot WPs 14-16 on Figure 9). Drove through tall grass from WP 14 to 15, then attempted walk toward Heinz Creek. It would be useful if improved access could be "bush hogged" further across level field to WP 15 (near site of former farm building foundations) and then as far as possible toward Heinz Creek in the general direction of WP 16. Grass and vegetation is currently more than waist high in much of the unforested area, but terrain is generally level if a visible grass track were opened up.

8. Drove south to abandoned Buttermilk Road to determine potential access to abandoned RR bed along Buttermilk Creek. Parked at WP 18 (Fig. 9) and walked down old roadbed to RR, and then as far north as WP 21, where Buttermilk Ck has eroded close to the old RR route (Figs. 11, 12). Access via 4-wheel drive is clearly feasible if the road bed were bush hogged down to and along the old RR. North side of steepest portion of road on hill leading down to RR is gullied to depths of between 1-2 feet locally, especially near WP 22, but there is room to straddle the main gully or bypass it along the south edge of the old roadbed if visibility were improved (grass and weeds cut). This important route would provide the best overall vehicle and walking access to Buttermilk Creek for nearly all fieldwork upstream from the Frank's Creek confluence, as it avoids the need to repeatedly transport personnel and gear by foot down the steep slopes on the west side of Buttermilk Ck. near the main WVDP. Maintaining this access, including possible filling of hillslope gullys along a short segment of the former Buttermilk roadbed, should be given a high priority because of the easy access it could provide for much of the Buttermilk Creek area that will be the focus of geologic studies. It would allow the conveyance of miscellaneous gear and bulky or heavy equipment to river level as a flexible base of daily operations to work on foot both upstream and downstream in critical areas on both sides of Buttermilk Creek. At one point just above (east) of the junction of Buttermilk Road with the railroad there is thick outcrop of crushed stone ballast (south side of road) that was probably emplaced for RR maintenance and might currently be used to fill the existing short stretch of gully erosion noted above (optional).   Finished tour and left final site at 4 PM.

Significant Conclusions:

A) Access by personnel and tracked excavation equipment and/or 4-wheel drive vehicles into these critical areas for the present geologic studies and mechanized sampling appears feasible from both the east and west sides of Buttermilk Creek valley, without requiring vehicle access along the river channel, especially if additional bush hogging is completed through the eastern Heinz and Buttermilk Road access points.

B) General access to the Buttermilk Creek valley for fieldwork on either side of valley (other than the uplands) appears to be most efficient via the old Buttermilk Road and east-side abandoned railroad bed as far north as Heinz Creek. This will allow personnel and/or equipment to be transported most quickly and efficiently to points where fieldwork on foot and sample collection could be efficiently staged for either side of the valley.

NOTE: Figures 1-12 are not all to scale or "planimetric". Some are slightly distorted to fit them conveniently on pages.

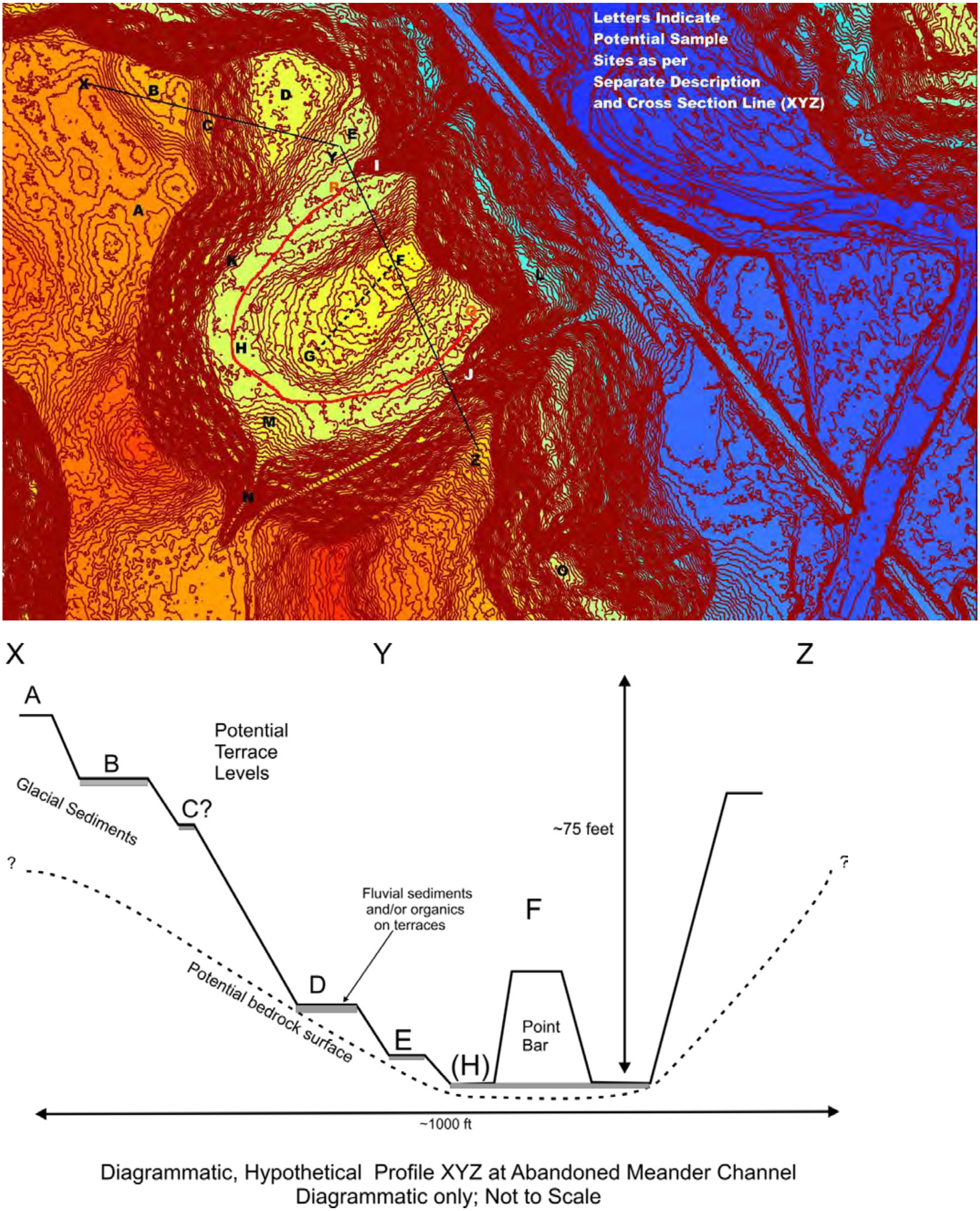


Fig. 1. Abandoned meander channel site topography and cross section at high-level abandoned meander. Approximate traverse route on 7/31/15 was via N,M,G,E,D,C,B,X

Fig. 2. Example of potential type of small tracked excavation equipment (CAT brand) required/envisioned.

Fig. 3. Intermediate terrace with open forest at multi-terrace site, east side Buttermilk Ck, in 2014 photo; see Fig. 7.

Fig. 4. Open forest cover and gradually sloping terrain near top of multi-terrace ridge near tree farm access.

Fig. 5. Steep erosional cliff and vertical drop-off at till cliff on southwest side of ridge at multi-terrace site near tree farm.

Fig. 6. Near vertical till face forming SW edge of multi-terrace meander as seen from below in 2014.

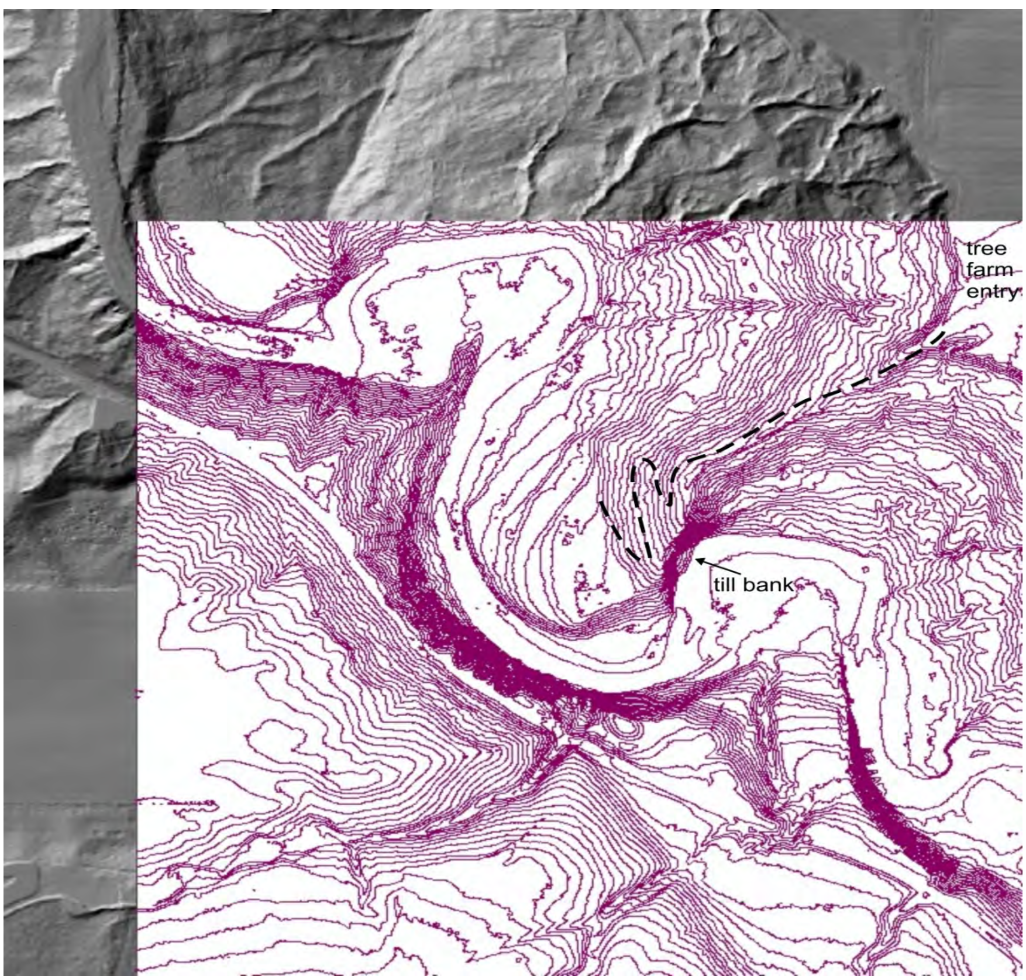


Fig. 7. Multi-terrace meander access from tree farm, WP 7, Figure 8 (approximate route). 5-foot contours.

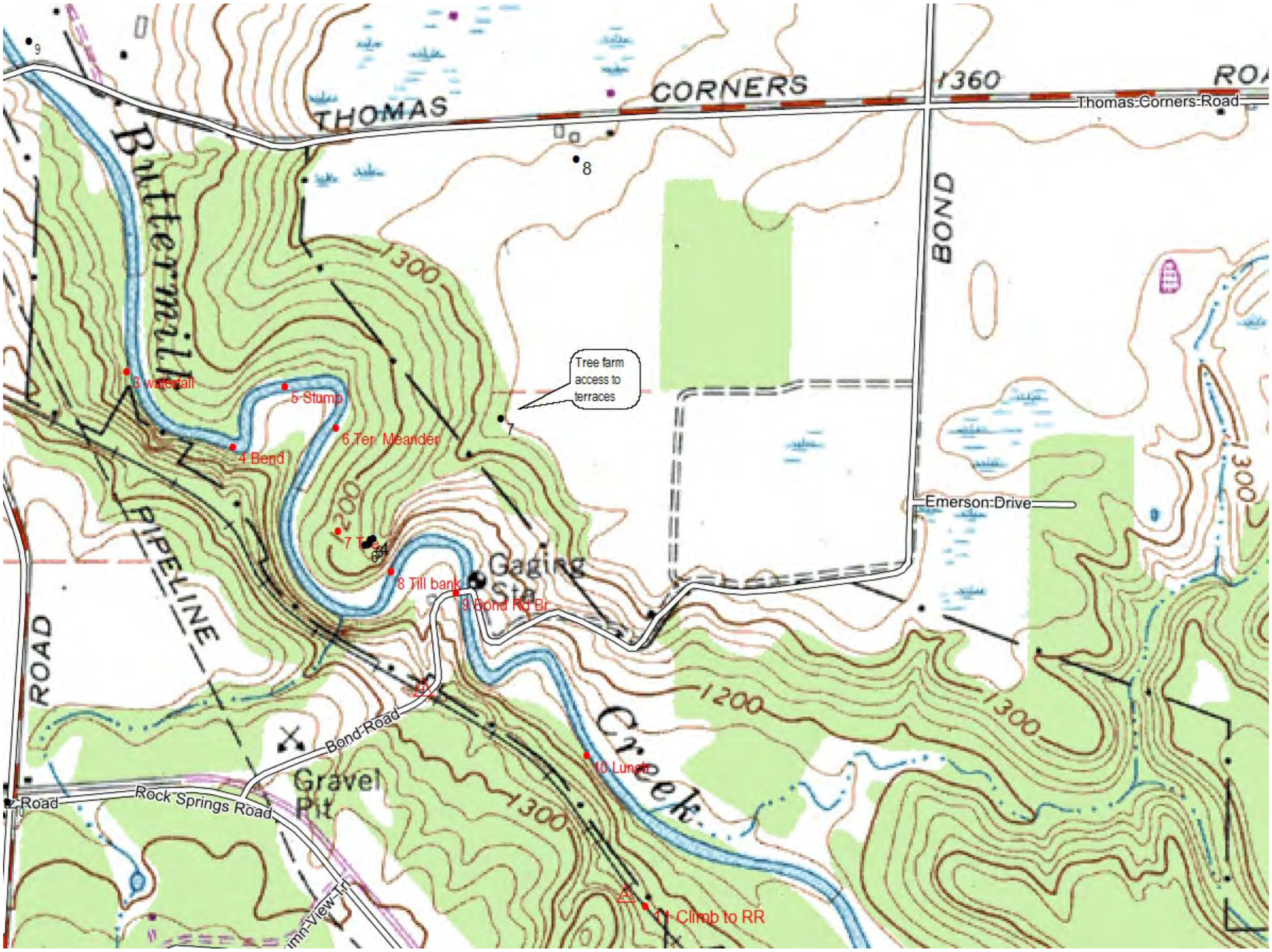


Fig. 8. Tree farm access to multi-terrace meander off Thomas Corners Road. July 31, 2015 waypoints are black numbers and dots. Tree farm buildings (rental property?) are near WP8. Vehicle was driven along farm access road and parked at WP7. Participants hiked to WP3-6 along ridge to SE end of meander where upper terrace was visible (see example of terrace in Figure 3, taken during 2014 visit). Note: WPs 3-6 are closely bunched together on map to right of 1200 ft. elevation label. Red numbers and WPs are from 2014 trip up Buttermilk Creek.

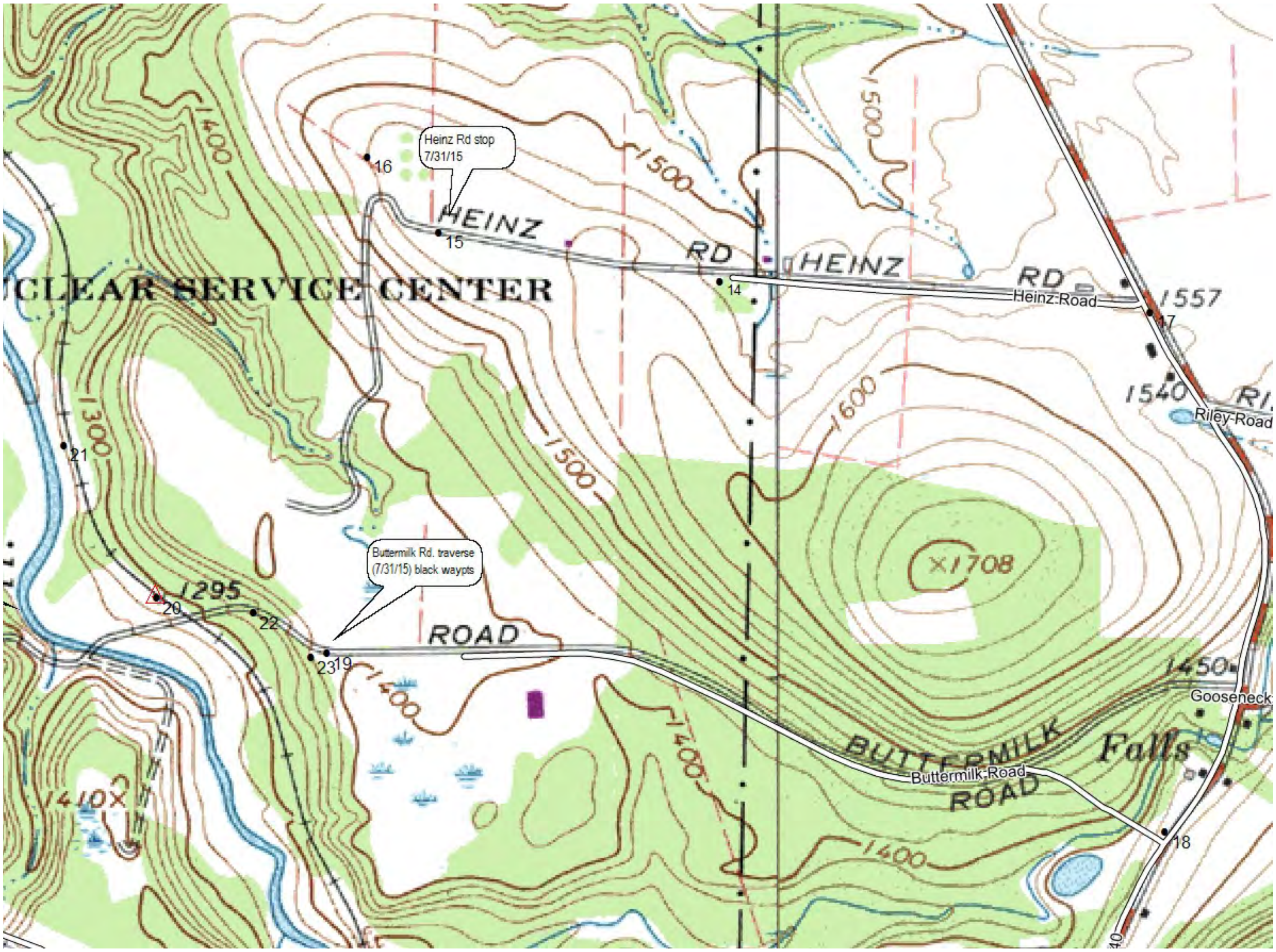


Fig. 9. Afternoon reconnaissance waypoints (black dots and numbers 14-21) via Heinz Creek Rd. and railroad via Buttermilk Rd. Heinz Creek mouth is at upper left corner. Figures 10 & 11 images are located along former RR bed at WP 21 (near 1300 contour label). Old road bed is moderately gullied on north edge near WP 22, but is passable with 4-wheel drive if bush hogged to improve visibility.

Fig. 10. Heinz Creek mouth area landforms mapped by Wilson/Butzer in 2014. See Wilson report for explanation and legend.

Fig. 11. Erosion of Buttermilk at abandoned RR bed near WP 21. Culvert pipe gives approximate distance of recent erosion. West side of RR bed has been partially eroded in the same area, but room is sufficient to bypass the eroded section with a 4-wheel drive vehicle, and to proceed closer to Heinz Creek, where old RR bridge is impassable.

Fig. 12. Typical view of existing RR bed (at narrowest location, WP 21) that could be bush hogged for best access to Heinz Creek and to much of Buttermilk Valley from the east side.

Activity Notes regarding Recon 10-19-2015 through 10-22-2015; M. Wilson and D. Butzer.

Wilson and Butzer visited the lower Heinz Creek area on Monday 10-19-15 and Tuesday 10-20-15, with Young and DaSilva. Wilson and Butzer previously traversed part of this Heinz Creek area in autumn 2014 and reported those observations at that time with notes, photos, maps and cross-sections. The need was stated at that time for more recon, further review of the fan and terrace features, the desire to observe the bedrock contact with valley-fill (sediment) indicated by LaFleur's mapping, and the need to test the hypothesis that old trees are available to indicate minimum ages for terraces near creeks, among other concerns.

During this time period (10-19-15 through 10-22-15) we also tested modes of transportation (and continue to do so). After several trips to the vehicle rental facility during the previous week and a delay by them the morning of the 19th, Wilson decided to use his own vehicle for the remainder of the 19th, and transported the four researchers to the east side of Buttermilk valley. We also had to walk a considerable distance to access the areas near lower Heinz Creek, as the abandoned access road and rail tracks were not conducive to driving with personal vehicles. Later that afternoon Wilson returned to the vehicle rental business and obtained a four-wheel drive Tahoe.

[Note: The vehicle rental facility agreed to look for a smaller 4-wheel drive model, and located one (a Jeep) about two weeks later. The Tahoe served us well when we accessed the high abandoned-meander ("race track") via brush-hogged gentle terrain with wide turn-around spaces. But our more recent rental, a Jeep Cherokee, was more effective in the restricted spaces, poor tracks, and steep terrain of the Heinz Creek area, so Wilson rented the Jeep for a month and the rental facility provided a reduced cost.]

During our limited field time on the afternoon of the 19th Wilson and Butzer re-familiarized ourselves with the region and reaffirmed our observations (2014) of the Heinz area and found no differences of opinion regarding our previous year observations or conclusions. We brought a set of laminated maps, sections, and notes from the 2014 work for re-familiarization purposes, and a second set was provided to Young and DaSilva. We also looked for the site previously used by Tucker and Doty to sample for OSL. We were able to generally find the terrace bank they used and the location of their coordinates, but could not be sure of their exact location (their excavation) without their photographic or other local documentation (which became available on a later date and Young then used to find the location). Lastly, we extracted and documented one tree core.

On Tuesday 10-20-15 we extracted cores from 8 trees on lowest terraces and fans in the Heinz and Buttermilk confluence area. The tree cores are being dried, mounted, sanded and examined at Wilson's home. In addition, we traveled up Heinz Creek with Young and DaSilva to look at the bedrock-sediment contact. Young and DaSilva next continued up-creek to recon the extent of bedrock and position of the upstream rock-sediment contact and nature of sediment above that contact. Meanwhile, Wilson and Butzer examined rock structures such as joints and their relationship to stream channel character; we also examined flow history of the July 2015 storm from various hydraulic indicators (between the bedrock section and the abandoned railroad bridge).

Wilson and Butzer visited the Buttermilk high terrace on the soil plateau near the WVDP facilities, also known as the "race track", with Young and DaSilva, on Wednesday 10-21-15 and Thursday 10-22-15. Dennis Feldman joined us for the morning of 10-22-15, Thursday. During the two days we probed with a small augur all the terraces marked for radar and several other terraces and features above and below the marked terraces. Nearly all of the probes encountered either large roots or gravel within one foot of the surface; while the gravel detection by hand-augur was and will be helpful, the roots and gravel will prevent hand-augur methods in most locations on terraces or fans from detecting materials at even two or three foot depths. The roots also make hand-dug pits laborious; mechanical trenching and drilling are needed. Never-the-less, each terrace was verified at five to ten locations to contain near-surface gravel.

At the southeast end of the race track meander, we examined the OSL site previously used by Tucker and Doty. We suggest it be resampled for OSL as a type of blind duplicate (nearly or approximately a duplicate). This location provided a view of the terrace material in a cross-section approximately 1 to 3 meters vertical and 7 meters horizontal, partially scraped by us, and exhibiting coarse gravel and sand.

We collected a tree core (tree core #10) in the gulley head of the gulley that cut the OSL sample site and that cuts the bed of the SE end of the race-track meander.

A straight, N-S oriented, topographic ridge approximately 150 meters (500 feet) in length was examined and probed; it was gravel bearing in top-soil exposures, a shovel pit, and probes. The feature lies directly south of the center of the race-track meander and north of a likely kettle. This feature is tentatively considered an ice disintegration feature (crevasse filling, esker, other?). It would be helpful to trench this feature longitudinally and transversely at one or more locations. An OSL date(s) from it could be much older than a date from the race-track bed or point-bar terrace immediately north.

Another interesting feature was discovered at a terrace south of the race-track meander; this terrace lies north of and about 10 to 15 feet above, the terraces probed in 2014. This terrace is mostly surfaced with sand in mounds, giving the appearance of aeolian or fluvial dunes, however the close spacing argues against these origins and an origin from a sheet of sand let-down by underlying glacial-ice melt is also considered, as is cryogenic patterned ground. The "dunes" are about 2 or 3 feet in height, several feet in width and 10 or more feet in length, form hummocky ground, and are composed of sand as indicated by successful probing with hand augur. The depressions between the sand "dunes" are underlain by gravel and sand. This location provides another interesting site for trenching and possible OSL dating.

Stream character vs. substrate features at the bedrock contact in Heinz Creek:

This section provides observations and analysis of the bedrock section in lower Heinz Creek that was visited on 10-20-15. It is a shale dominated section with sandstones (siltstones are included with sandstones in this discussion because in this region most sandstones are similar to the siltstones in color and fossils, etc.; the sandstones are relatively fine grained; both rock types act similarly to retard erosion; literature mostly refers to these rocks in this region as sandstones). Waterfalls in this section of Heinz Creek are capped with sandstones or are located where joints are more numerous (closely spaced); sandstone caprock is typical of waterfalls in southwestern NY, closely spaced joints are not.

Joint sets in this Heinz Creek section occur with strikes that are dominantly NNW and form steps approximately perpendicular to stream flow; another joint set is oriented ENE that parallels stream flow. The ENE joints are fewer and longer than northerly joints, and individual ENE joints sometimes form the Heinz channel wall for distances of 50 ft. These long ENE joints are the younger set (i.e., terminate against NNW joints). [Terminology for joint orientations such as ENE is based on the practice of only using the north half of the compass for strikes.]

The Heinz Creek bedrock-channel profile measured by pace in the field consists of several stream reaches separated by small waterfalls, with the following waterfall distribution (bedrock knickpoint profile) in the mid to lowest portion of the bedrock reach (F for fall in feet and H for horizontal distance in feet): F=8, H=70, F=4, H=70, F=1, H=20, F=2, H=20, F=4, H=20, F=4, H=20, sediment encountered. The LiDAR of the same reach, beginning at the “8-foot drop”, shows a distribution of: F=7, H=70, F=2, H=70, F=1, H=20, F=2, H=20, F=2, and then the contours show about 3 to 4 feet of elevation change over about 40 feet horizontal. These observations predict that the 2015 LiDAR will show profile changes from the 2010 LiDAR for the Heinz Creek bedrock section, that the changes will show erosion, that how much erosion might be attributed to the 2015 July storm cannot be differentiated from other erosion during the 5-year time period using LiDAR evidence alone. However, the lack of shale in the stream sediments indicates that the July storm did not move much shale or the shale residue from shale disintegration would be present in October.

Paleohydraulics of Heinz Creek, July 2015 storm:

There were two notable storms in the region in recent decades as noted by workers at the West Valley SDA and NDA sites as well as local residents; these storms were in September 2009 and July 2015. While some of the effects of the 2009 storm may be present, we suggest that the high-water marks (floatsome, lag-gravel, and erosion scars) we observed in October are from the 2015 storm. These high water marks are lower than we expected from a storm reputed to be a 200-year recurrence interval rainfall event, but no higher water marks were found.

Our velocity and discharge analysis follows the same approach commonly used in studies ranging from paleohydraulic analysis of late Pleistocene floods or modern dam bursts, to studies by Wilson of modern flows in western NY. For a location in Heinz Creek channel between approximately 200 to 300 feet upstream of the abandoned railroad bridge, the floatsome and channel bed indicated a channel that we have divided into two transverse subsections based on depth, one about 2 ft deep and 15 ft wide and the other about 3 ft deep and 15 ft wide (dimensions estimated from pace and eye-height). The shallower section was left bank, and deeper section was right bank and outside of meander. Upstream bar was somewhat mid-channel rather than just inside of curve, was composed of cobbles and boulders, and boulders were mostly sandstone slabs one to two feet across. The bar position was somewhat different than the 2010 LiDAR shape (more mid-channel) and so indicates that the 2015 storm moderately rearranged the 2009 storm channel features.

The Manning Equation is used for "paleo-hydraulic" calculation here (as was also used in the report on Frank's Creek and Erdmann Brook dated 9-18-15). Velocity = 1.49/n (R to 2/3 power) x (S to ½ power). The 1.49 is for use with American Practical Units such as feet. Using an n = 0.04, R is approximated by depth = 2 ft (from field observation) and S = 0.02 (from LiDAR and field observation), for the left-bank subsection, while R = 3 ft and S = 0.02 for the right-bank subsection (using same observation sources). **Velocity** = [37 x 1.6 x 0.14] in the left subsection, and [37 x 2.1 x 0.14] in the right subsection, or velocity = **8.3 ft/s** left bank subsection and **10.9 ft/s** right bank subsection. **Discharge** = (8.3 ft/s) (30 ft^2) on left, plus (10.9 ft/s) (45 ft^2) on right. Discharge was approx 250 cfs on left side of channel and approx. 490 cfs on right side; the two subsections conveyed roughly **740 cfs**.

A note about the Manning Roughness. There are several reasons for choosing 0.04. First, many researchers have chosen 0.04 as the go-to value for paleohydraulic calculations. Second, the value is appropriate relative to the USGS book of field-derived Manning "n" values (Water Supply Paper #1849). Third, the value is appropriate to the special volume of USGS field-derived values for New York State. Fourth, Wilson's experience suggests 0.04 is a good value for the site characteristics. And fifth, one is not likely to choose a value below 0.03 or above 0.05, and those values result in only about a 10% difference in velocity or discharge from that calculated.

Conclusion regarding the July 2015 storm: the discharges of the three watersheds at the locations visited (9-17-15 and 10-20-15) indicate similar flows for different sizes of watersheds, explainable by different land uses among the watersheds (different "c" values in the simplest of watershed models, Q=cia).

Geologic reconnaissance at West Valley, November 3-4, 2015 (R.A. Young and A. deSilva)
By R.A. Young, November 5, 2015
Nov. 3, 2015

Purpose and Plan: Characterize gravel content and nature of multiple surfaces (1-10) in lower Heinz Creek area mapped by Wilson and Butzer in 2014. Determine potential for future access for trenching.

Arrived at West Valley site at 9:00 AM, Tuesday.
Repacked rental 4-wheel drive, checked in with D. Feldman, and departed for Heinz Creek-old Buttermilk Road access to railroad bed. Removed a few small bushes and fallen trees that were blocking RR right of way, so as to provide convenient access as far as abandoned RR bridge at Heinz Creek worksite. This extends convenient access approximately 1 km along the abandoned railroad bed to the approximate location of the large documented landslide on the opposite (west) side of Buttermilk Creek. Deteriorating Heinz Creek bridge has concrete barriers and chain link fencing and prevents further northward access.

Young and daSilva worked with Wilson and Butzer initially to complete 4 diagnostic clast counts (100 clasts each) along lower Heinz Creek immediately above RR bridge for characterization of Heinz Creek bedload. These measurements are for the purpose of demonstrating specific differences between clast populations of potential Heinz Creek fan deposits and terrace deposits (old channel gravels) of Buttermilk Creek. Nineteen clast count results (a-r) are listed on attached spreadsheet, with approximate locations marked on attached 2-foot contour Lidar map.

Young and daSilva completed pebble counts on two more major “terrace surfaces” in vicinity of OSL 2A site excavated during previous studies. We were able to locate the original excavation (shallow slope depression) for the actual OSL 2A sample using photos supplied by Sandi and Greg. Two separate clast counts were made on this terrace, which has an estimated present elevation of 1265±1 ft (lidar map data). This terrace is surface 5 on Wilson reconnaissance map of 2014. All clast collections were bagged and carried back to Heinz Creek for washing, accurate identification, and final counting. Excavated samples of gravel on terraces are generally coated with silt and/or clay from weathering in situ that needs to be removed. Each clast is split open to expose a fresh surface for more accurate identification. Terraces are generally covered with 6 to 8 inches of recent organic-rich topsoil underlain by either brown sand or gravel, so more than one attempt is sometimes needed to locate a near-surface gravel exposure with a sufficient numbers of clasts.

An additional clast count was performed on a lower terrace about 110 feet further north from the bridge along the RR. This is surface 10 on Wilson reconnaissance map of 2014 (surface elevation estimated at 1254±1 foot from Lidar 1-foot contour map attached).

Preliminary assessment indicates that Buttermilk Creek terrace deposits are distinctly different from Heinz Creek bedload gravels, in that Buttermilk terrace clast counts typically have 90% or higher well rounded, sandstone and/or siltstone clasts, with limited, durable, accessory rock types, such as quartzite, chert, and/or igneous & metamorphic lithologies. Shale or limestone clasts are generally rare or absent in Buttermilk Creek terrace gravels, as previously noted in most modern Buttermilk channel bar gravels. Photos attached show representative clast collections; some larger clasts were purposely broken to reduce size during collection. Buttermilk samples are generally well rounded but many have low sphericity.

Young and deSilva rejoined Wilson and Butzer at vehicle and returned to West Valley south parking lot at 4:30PM
Stayed at Microtel in Springville Tuesday night.

November 4, 2015, Wednesday
Plan: Continue characterization of multiple Heinz Creek area surfaces; check abandoned road access from east for potential excavation equipment in future.

Met at West Valley south parking lot at 8:30 AM, joined D. Feldman for trip to Heinz Creek railroad bridge site as on previous day. Feldman joined group until noon, walked out.

Incomplete clast counts remaining from the previous day were finalized.

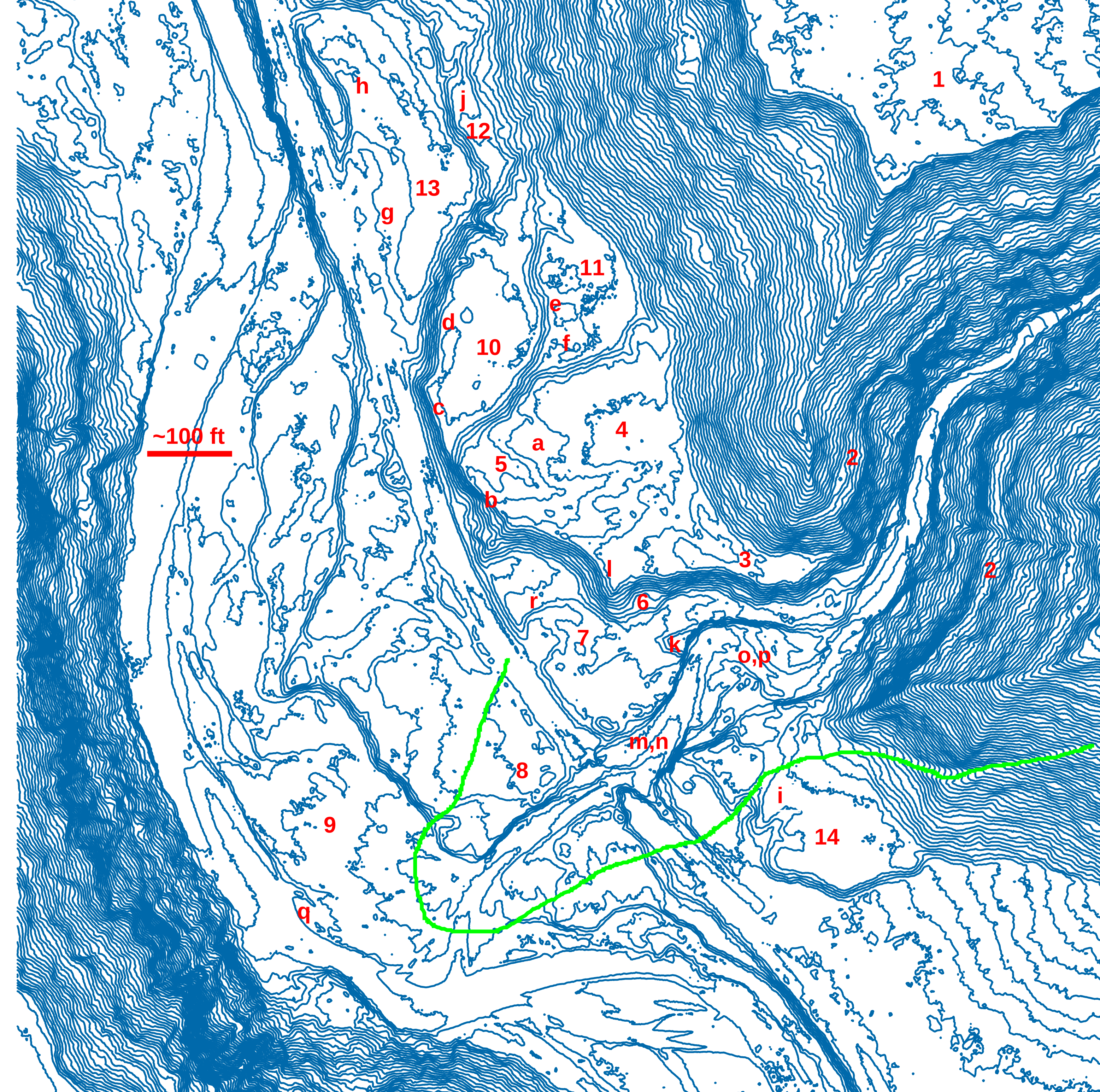
Young and deSilva performed a clast count on Buttermilk Creek channel gravel immediately downstream from Heinz Creek-Buttermilk Creek confluence (q on map) to determine how the influx of Heinz Creek bedload changes the average composition of Buttermilk Creek channel gravels closest to the Heinz Creek source. As anticipated, the downstream Buttermilk Creek bedload reflects a local and measurable addition of typical Heinz Creek clasts (especially shale and limestone), but this relatively subtle change may not persist very far downstream. The Heinz-Buttermilk confluence is important because Heinz Creek is one of the largest Buttermilk tributaries. Many small side tributaries are assumed to have little measurable impact on the average composition of Buttermilk bedload gravel.

The rest of day 2 was spent locating, collecting, washing, and completing 6 more clast counts (2 per surface) on other Heinz Creek area surfaces located at different elevations, four of which are not specifically labeled on the original 2014 Wilson/Butzer reconnaissance map. The new attached map adds surfaces labeled 11 through 14 to the ten originally shown on the Wilson map. On this new map all clast counts are designated by letters, as listed on the accompanying spreadsheet. Designations for clast counts from Wilson and Butzer are included, but differ from field identification numbers initially applied by Wilson. The map locations of the samples suffice to accurately distinguish and identify the numerous samples. It is now deemed adequate to use only 50 clasts as a means of determining whether a specific surface is likely to be a former Buttermilk Creek related surface (ie. terrace, abandoned floodplain, channel, or slough).

Rejoined Wilson and Butzer and returned to south parking lot at 4:30 PM.

General Conclusions and Observations:

Based on clast counts to date, it appears that the various surfaces near the mouth of Heinz Creek are most likely the result of the normal lateral migration of the Buttermilk Creek channel during its postglacial incision. Heinz Creek channel inputs seem to have little connection to the preserved topography. For this reason the surfaces mapped (approximate elevations between 1273 and 1233 ft) would be good targets for OSL and/or 14C age determinations as a continuation of the abandoned meander terraces, which end at elevation 1295 ft. If successful, the chronologic data from the two areas could provide a potential record of incision from elevation 1345 down to 1233 within this 1.2 km reach of Buttermilk Creek.
Much of the old road access along the south side of Heinz Creek seems to be reasonably preserved, so the issue would be crossing the abandoned railroad bed and clearing an access path for a small excavator across the low relief near the confluence with Buttermilk Creek and then back up to the railroad on the north side of the abandoned bridge. See green line on attached map as approximation for potential access route (depending on connection to roads further east).



1
h
j
12
13
g
11
e
d
10
f
c
4
a
5
~100 ft
2
b
3
l
2
r
6
7
k
o,p
m,n
8
i
9
14
q

PEBBLE COUNTS HEINZ CREEK AREA [Column p (ave.) is average of 4 Heinz channel counts highlighted in yellow]

COUNT (label) a-r (See map)	**a**	**b**	**c**	**d**	e	f	g	h	i	j
Sandstone/Siltstone (Gray to Br.) %	94	91	94	92	88	98	94	94	84	94
Sandstone (Red) %		2	2	4			4	4	4	2
Shale %		2	2		2					
Limestone/Dolostone %								2	2	
Igneous/Meta/Vein qtz %	2	1		2	6	2			2	
Quartzite(?) %		2	1	2	4		2		2	1
Chert/flint %	4	2	1						6	3
Other (misc.) %										
Total clasts actually counted	100	100	100	50	50	50	50	50	50	100
Surface Number (1-14) See map	5	5	10	10	11	11	13	13	14	12
Elevation (Estimated ±1 ft) Lidar	1265	1265	1253	1253	1260	1260	1233	1233	1257	1241
Probable Origin? (Fluvial/Glacial)	F	F	F	F	F	F	F	F	F	F
Geomorphic feature?	Terrace	Terrace	Terrace	Terrace	Terrace	Terrace	Terrace	Terrace	Terrace	Terrace
Personnel (Young/Wilson)	Y	Y	Y	Y	Y	Y	Y	Y	Y	W

Percentage of common lithologies in clast samples

PEBBLE COUNTS HEINZ CREEK AREA [Column p (ave.) is average of 4 Heinz channel counts highlighted in yellow]

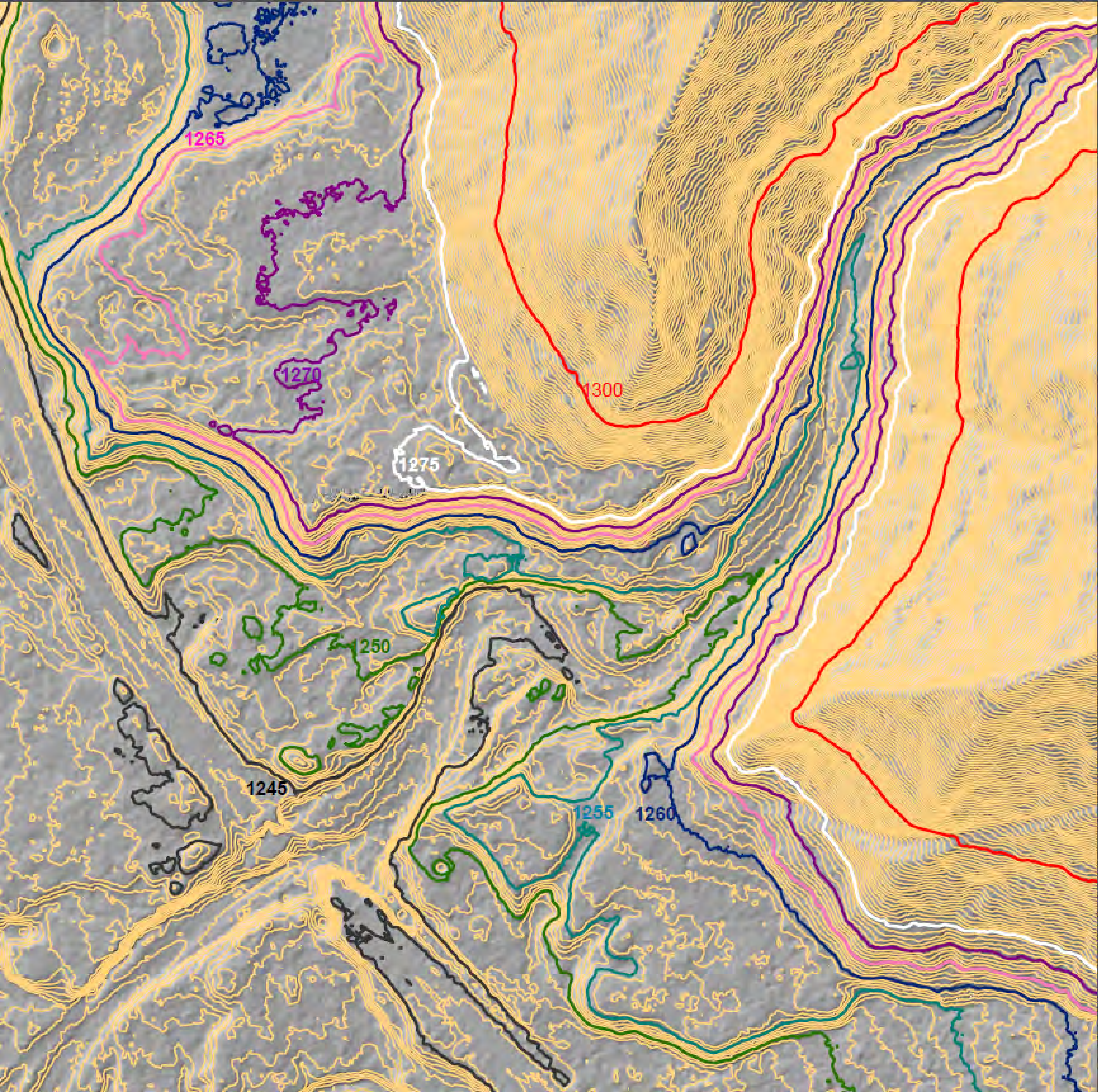
k	l	m	n	o	p (ave.)	q	r	**Lithology**	Misc.
87	93	79	78	64	69 (72.5)	80	92	**SS**	97
5		0	0	5	1 (1.5)	2	3	**Red SS**	1
2		6	10	20	15 (12.75)	3		**Shale**	
		7	5	4	12 (7)	10		**LS/Dolo**	
1	2	2	3	3	0 (2)	2		**Ig/Meta**	1
3	2	1	4	2	1 (2)	3	1	**Qtzite**	
2	3	6	0	2	2 (2)		4	**Chert**	1
100	100	102	100	100	100	100	100		100
6	4	Channel	Channel	Channel	Channel	Buttermlk	7		high surf.
1253	1273	1240	1240	1245	1245	1226	1251		?
F	F	Heinz Ck	Heinz Ck	Heinz Ck	Heinz Ck	Confluenc	Terrace		F
HK Fan?	Terrace	Channel	Channel	Channel	Channel	Channel	Terrace		Terrace
W	W	W	W	Y	Y	Y	W		W

Percentage of common lithologies in clast samples

Sample A

Sample F

Sample Q


1265
1270
1275
1300
1250
1245
1255
1260

Activity Notes regarding Recon on 11-3-15 and 11-4-15; M. Wilson and D. Butzer

Wilson and Butzer visited the lower Heinz Creek area on November 3 and 4, 2015, with Young and DaSilva. For the morning into early afternoon of November 4, Feldman paired with Wilson and Butzer to recon the potential use of a road for access to the Heinz area in future work, as well as look at geologic features immediately south and southeast of Heinz Creek.

On 11-3-15, we found that the old rail line was more easily reached by use of the Jeep than had been true of the Tahoe, but there were several impassable sections of old railroad embankment due to vegetation. We opted to remove the vegetation and successfully negotiated the rail line all the way to the Heinz Creek bridge. (While much of the morning was used to remove the vegetation, previously requested by the team, walking time was saved by gaining better vehicle access for each day.) This travel route to lower Heinz Creek offers a future option for access by trenching or drilling equipment, however there are two points (head of a Buttermilk-instigated landslide and sinkholes over a deteriorated culvert) where maintenance will be required; increased deterioration was apparent between last year and this year.

We began the field data collection in late morning and early afternoon on 11-3-15 with pebble counts to obtain some QA-QC background data. Wilson and Butzer collected two separate samples of pebbles in Heinz Creek near the rail line while Young and DaSilva did the same activity several hundred feet upstream, the two groups out of view of each other. The comparative results are presented in the Young-DaSilva activity report.

Wilson and Butzer worked on a pair of terraces in afternoon of 11-3-15 that were identified in 2014 and labeled in green and #6 on their 2014 map (these are not the possible paired terraces of 2014, vermillion color, cross-section B-B'; these are lower and not in the 2014 cross-sections). These features were/are thought to be terrace or fan remnants of Heinz Creek. Several locations were attempted for digging shallow pits to retrieve pebbles for counts, but roots and cobbles made retrieval difficult. The northerly of the two paired-terraces did not yield a pebble count in the time available but did show at several points a layering of about 4 inches of organic-rich top soil, over 16 inches of sand, over cobbles. This surface sand deposit (or other surface sands such as the sands found previously in the "race track" meander area) should be discussed with OSL personnel regarding OSL dating. A sand layer was not found on the southerly terrace-fan remnant (which does not of itself eliminate these deposits as "paired"). The southerly remnant yielded a sandstone-dominated pebble count and the sediment sizes and lithologies encountered generally matched the exposed sediments we examined in the adjacent high-bank of Heinz Creek. All pebble counts by Wilson and Butzer from 11-3 and 11-4-15 are presented in Young and DaSilva's report tabulation.

On 11-4-15, Wilson and Butzer worked both north and south of Heinz Creek, including features at both relatively low and high elevations. Young and DaSilva opted to continue pebble counts on low to moderate height terraces of Heinz Creek and Buttermilk Creek, allowing testing of many terraces. We parked the Jeep at the Heinz Creek crossing of the old railroad bridge as a meeting point for lunch or later. Walkie-talkies and cell phones were used for communication (cell phone reception has been good throughout the SDA region thus far).

While not obvious on some imagery due to tree canopy or other influences, part of the old road grade south of Heinz Creek is clearly observable on LiDAR contours. On the morning and into early afternoon of the 4th, Wilson, Butzer and Feldman reconnoitered this potential access road and investigated several geologic features south of Heinz Creek. Feldman also evaluated this possible access road above these geologic features while Wilson and Butzer continued to study the geology and topography. The access road is in surprisingly good condition with minimal erosion or vegetative obstacles. Feldman will continue to evaluate ownership and how this old road connects to other roads for access. This road could offer access to upper terraces and features of interest via the rail line access if the rail embankment is maintained, or offer a completely new access replacing the rail line corridor. Care will be needed to avoid initiating gullies in this old road.

The 2015 map (Figure 1 of this report) shows a high level terrace SE of Heinz Creek and E of Buttermilk Creek that we investigated on 11-4-15 with Feldman while traversing the possible access road. This surface has several exposures due to headward erosion of a gulley network. The surface, at about 1390 to 1420 ft, was mapped by LaFleur as till; the gulley heads expose till underlain by soft lacustrine clay and sand. Butzer suggested that the sand might be of a quality compatible with OSL dating; Wilson wondered if the sand was thick enough; and so these are the kinds of questions for our several OSL experts to discuss and ultimately we may have to try blind duplicates or experimentation to get a good answer.

Much of this surface (all?) appears veneered with sand and gravel rather than till (gravel exposed in several places). We obtained a pebble count (97 sandstones, 1 red sandstone, 1 chert, and 1 gneiss) at a pit opened naturally by a large root-ball of a toppled tree (# ? 11-4-15 in Young's data). The surface is also veneered with muck deposits in shallow depressions above the heads of gullies. The gulley heads are mostly, and obviously, terminated in the terrace surface. The appearance is one of a steep hillside with its steep water table above the terrace then intersecting the perched water table on the terrace gravel, muck, till and lake clay. This terrace is either the glacier-withdrawal outwash or a very high Buttermilk or tributary terrace. Below the terrace in several places are the tops of rotational landslide blocks, some very large (length of arcuate head-scarp in plan-view up to 50 of meters; scarp height 5 meters).

Wilson discussed with Feldman several reasons for trenching or drilling at this location in order to further illustrate needs for vehicle access. In the following sentences we enlarge upon the discussion with Feldman. There are currently three locations receiving special consideration for study: 1) the "race track" abandoned meander and its associated terraces because it has shown promise of C-14 and OSL dating due to previous dates, and it is one of the sites located close to the WVDP facilities; 2) the Heinz Creek juncture with Buttermilk because this area contains geologic features whose ages define the dates when the valley fills were eroded below and upstream of the WVDP facilities (transmittance of base level changes), and because this area contains a potentially-complete record of erosional events, and because the growth of the

Heinz Creek fan has repeatedly or continuously forced Buttermilk Creek to migrate westward against the WDVP soil plateau, and because that migration will lead to gullying that captures Franks Creek and hastens loss of the WVDP facilities; and 3) terraces near the juncture of Buttermilk Creek with Cattaraugus Creek to learn of base level changes that may have been transmitted upstream. In addition to these features, there needs to be identification of geologic layering properties and thicknesses and locations that control erosion rates for local or global computer models or other models, and there needs to be dates on some of these layers to determine if any episodes of valley cutting and refilling have occurred. Drilling will likely be needed, in addition to observing stratigraphic sections in gullies or elsewhere, so as to increase certainty of subsurface information as compared to landslide corrupted information.

During the afternoon Feldman returned to office tasks and Wilson and Butzer examined terraces to the north of Heinz Creek (mostly terraces that we had not visited previously). These terraces were mostly terraces of Buttermilk as indicated by ghost channel dimensions, radius of curvature of ghost channel meanders, exposed materials such as sand and gravel, etc. Pebble counts were taken and the results provided to Young.

Draft of 11-15-15

Activity Notes regarding Recon on 11-3-15 and 11-4-15; M. Wilson and D. Butzer

Wilson and Butzer visited the lower Heinz Creek area on November 3 and 4, 2015, with Young and DaSilva. For the morning into early afternoon of November 4, Feldman paired with Wilson and Butzer to recon the potential use of a road for access to the Heinz area in future work, as well as look at geologic features immediately south and southeast of Heinz Creek.

On 11-3-15, we found that the old rail line was more easily reached by use of the Jeep than had been true of the Tahoe, but there were several impassable sections of old railroad embankment due to vegetation. We opted to remove the vegetation and successfully negotiated the rail line all the way to the Heinz Creek bridge. (While much of the morning was used to remove the vegetation, previously requested by the team, walking time was saved by gaining better vehicle access for each day.) This travel route to lower Heinz Creek offers a future option for access by trenching or drilling equipment, however there are two locations (head of a Buttermilk-instigated landslide and sinkholes over a deteriorated culvert) where maintenance will be required; increased deterioration was apparent between last year and this year.

We began the field data collection in late morning and early afternoon on 11-3-15 with pebble counts to obtain some QA-QC background data. Wilson and Butzer collected two separate samples of pebbles in Heinz Creek near the rail line while Young and DaSilva did the same activity several hundred feet upstream, the two groups out of view of each other. The comparative results are presented in the Young-DaSilva activity report.

Wilson and Butzer worked on a pair of terraces during the afternoon of 11-3-15 that were identified in 2014 and labeled in **green** and **#6** on their map in the 2014 report (these paired terraces are at lower elevation than paired terraces of 2014 shown in **vermillion** color on 2014 map and 2014 cross-section B-B'; these terraces are green on 2014 map and not in the 2014 cross-sections). These features were and are thought to be terrace or fan remnants of Heinz Creek. Several locations were attempted for digging shallow pits to retrieve pebbles for counts, but roots and cobbles made retrieval difficult. The northerly of the two paired-terraces (green on 2014 map and approximately south of "Q" in figure 1 of this report) did not yield a pebble count in the time available but did show at several points a layering of about 4 inches of organic-rich top soil, over 16 inches of sand, over cobbles.

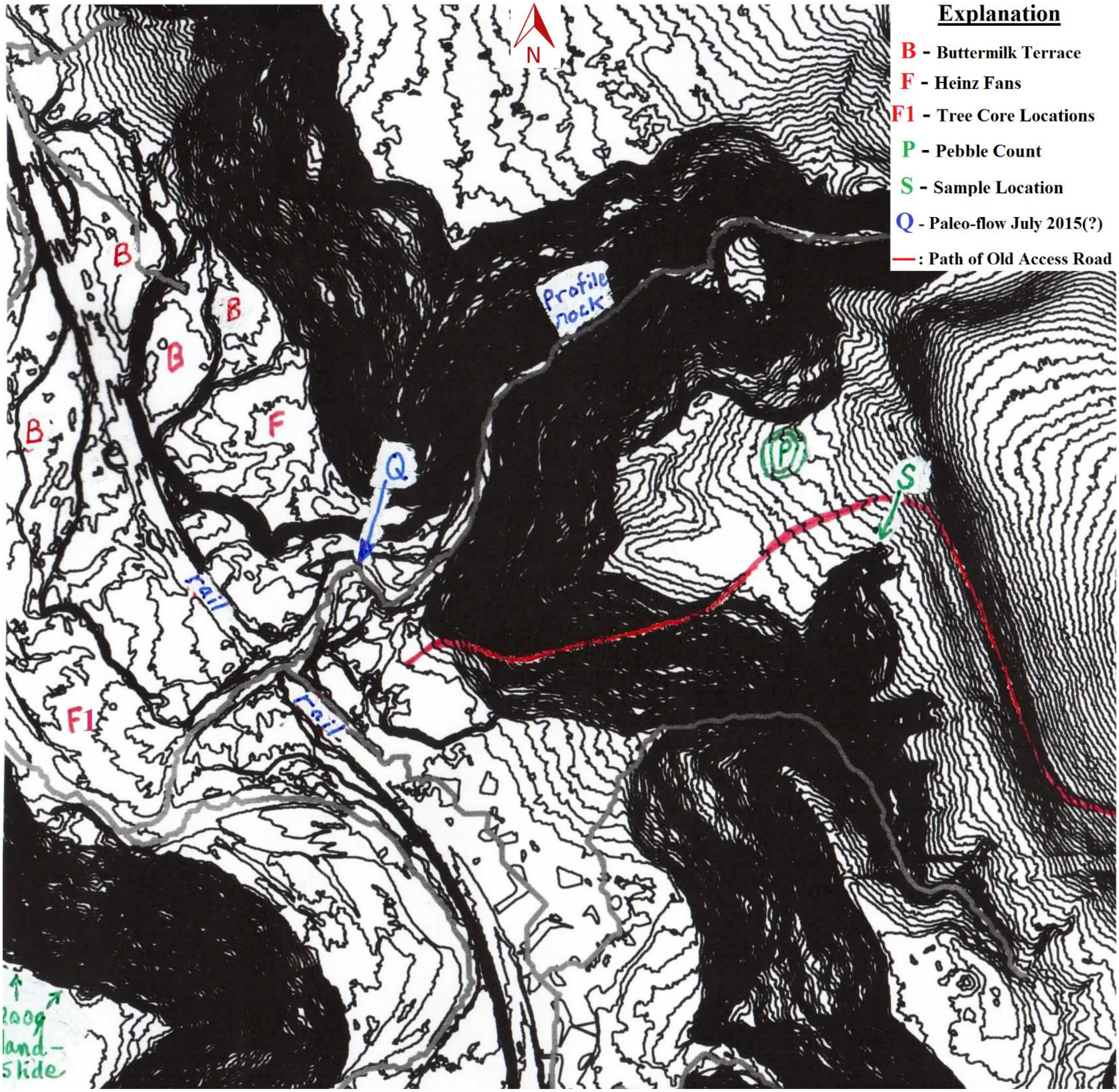


Figure 1- Labeled map of the area where reconnaissance took place on November 3rd and 4th 2015. Several locations mentioned in the text refer back to areas that are labeled on this image. Notes: a) "F1" is fan area where three Sycamore trees were cored 10-19 to 10-20-15; b) "Q" is location of previous Manning velocity and discharge estimation; c) "profile – rock" is where previous profiles by LiDAR and pace methods were graphed; d) "P" is location of pebble count on high terrace; and e) and "S" is location of gully head sampled for OSL and C-14. Map details on sample sheets.

Figure 2- Hand auger sample showing the depth of the sand layer upon removing the topsoil with a shovel; large cobbles prevented the hand auger from penetrating deeper. Because of the fine sand that was discovered in the upper layer, OSL sampling should be considered for this area.

Deposits of surface sands, such as the sands (Figure 2 above) found on the terrace near “Q” in Figure 1, or previously found in the “race track” meander area, should be discussed with OSL personnel regarding OSL dating. The southerly remnant of the paired terraces investigated in 2014 and again 2015 (figure 3 below and green on 2014 map) yielded a sandstone-dominated pebble count and the sediment sizes and lithologies encountered (and contributed to data base maintained by Young) matched the exposed sediments we examined in the adjacent near-vertical, exposed high-bank of Heinz Creek.

Figure 3- Pictured is the southern paired terrace, the closer of the two to Heinz Creek. A pebble count was accomplished at this location, however it was an extremely laborious exercise as the area was thickly covered in roots.

All pebble counts by Wilson and Butzer from 11-3 and 11-4-15 are presented in Young and DaSilva's report tabulation.

On 11-4-15, Wilson and Butzer worked both north and south of Heinz Creek, including features at both relatively low and high elevations. Young and DaSilva opted to continue pebble counts on low to moderate height terraces of Heinz Creek and Buttermilk Creek, allowing testing of many terraces when the two groups' data are combined. We parked the Jeep at the Heinz Creek crossing of the old railroad bridge as a meeting point for lunch or later. Walkie-talkies and cell phones were used for communication (cell phone reception has been very good throughout the five square miles of state-owned region thus far).

While not obvious on some imagery due to tree canopy or other influences, part of the old road grade south of Heinz Creek is clearly observable on LiDAR contours. On the morning and into early afternoon of the 4th, Wilson, Butzer and Feldman reconnoitered this potential access road and investigated several geologic features south of Heinz Creek. Feldman also evaluated this possible access road above these geologic features while Wilson and Butzer continued to study the geology and topography. The access road is in surprisingly good condition with minimal erosion or vegetative obstacles. Feldman will continue to evaluate ownership and how this old road connects to other roads for access. This road could offer access to upper terraces and features of interest via the rail line access if the rail embankment is maintained, or offer a completely new access replacing the rail line corridor. Care will be needed to avoid initiating gullies in this old road.

The 2015 map (Figure 1 areas of "P" and "S" of this report) shows a high level terrace SE of Heinz Creek and E of Buttermilk Creek that we investigated on 11-4-15 with Feldman while traversing the possible access road. This surface has several exposures due to head-ward erosion of a gulley network. The surface, at about 1390 to 1420 ft, was mapped by LaFleur as till; the gulley heads expose till underlain by soft lacustrine clay and sand. Butzer suggested that the sand might be of a quality compatible with OSL dating; Wilson wondered if the sand was thick enough; and so these are the kinds of questions for our several OSL experts to discuss and ultimately we may have to try blind duplicates or experimentation to get a good answer.

Much of this high topographic surface (all of it?) appears veneered with sand and gravel rather than till (gravel exposed in several places). We obtained a pebble count (97 sandstones, 1 red sandstone, 1 chert, and 1 gneiss) at a pit opened naturally (figure 3) by a large root-ball of a toppled tree.

Figure 4- The uprooted tree created a natural pit which allowed us access to numerous pebbles; a pebble count was thus accomplished at this location.

This high surface is also veneered with muck deposits in shallow depressions above the heads of gullies. The gulley heads are mostly, and obviously, terminated in the terrace surface. The appearance is one of a steep hillside with its steep water table above the terrace then intersecting the perched water table on the terrace gravel, muck, till and lake clay. This terrace is either the glacier-withdrawal outwash or a very high Buttermilk or tributary terrace. Below the terrace in several places are the tops of rotational landslide blocks, some very large (length of arcuate head-scarp in plan-view up to 50 meters; exposed top-scarp height 5 meters).

Wilson discussed with Feldman several reasons for trenching or drilling at this location and above in order to further illustrate causes for vehicle access. In the following sentences we enlarge upon the discussion with Feldman. There are currently three locations receiving special consideration for study: 1) the “race track” abandoned meander and its associated terraces because it has shown promise of C-14 and OSL dating due to previous dates, and it is one of the sites located close to the WVDP facilities; 2) the Heinz Creek juncture with Buttermilk because this area contains geologic features whose ages define the dates when the valley fills were eroded below and upstream of the WVDP facilities (transmittance of base level changes), and because this area contains a potentially-complete record of erosional events, and because the growth of the Heinz Creek fan has repeatedly or continuously forced Buttermilk Creek to migrate westward against the WVDP soil plateau, and because that migration will lead to gullying that captures Franks Creek and hastens loss of the WVDP facilities; and 3) terraces near the juncture of Buttermilk Creek with Cattaraugus Creek to learn of base level changes that may have been transmitted upstream. There needs to be identification of geologic layering properties and thicknesses and locations for obtaining dates or that control erosion rates for local or global computer models or other models, and there needs to be dates on some of these layers to determine if any episodes of valley cutting and refilling have occurred. Drilling will likely be needed, in addition to observing stratigraphic sections in gullies or elsewhere, so as to increase certainty of subsurface information as compared to landslide corrupted information.

During the afternoon Feldman returned to office tasks and Wilson and Butzer examined terraces to the north of Heinz Creek (mostly terraces that we had not visited previously). These terraces (figures 5 and 6) were mostly terraces of Buttermilk as indicated by ghost channel dimensions, radius of curvature of ghost channel meanders, exposed materials such as sand and gravel, and so forth. Pebble counts were taken and the results provided to Young.

Draft of 11-15-15; figures added 12-11-15.

Detailed information for Figure 5: view is looking northward from terrace above, then across next lower terrace, and toward Buttermilk Creek in far distance and below and out of sight. Buttermilk Creek is in the far background (flows left to right) and a higher terrace is under the photographer and also to the right in the photo. The foreground is a portion of the abandoned channel of Buttermilk, with large radius of curvature compared to Heinz. The channel in foreground flowed left to right and the broad sunlit ground-surface (abandoned Buttermilk point bar) is sloped eastward toward the photographer.

Figure 5- Photograph of one of the numerous Buttermilk terraces that was discovered during recon on 11-5-15. See text above for more detailed discussion.

Figure 6- One of the many terraces located along the Heinz/Buttermilk confluence.

Activity Notes Regarding Trenching on 11-17-15 and 11-18-15; M. Wilson and D. Butzer

On 11-17-15 Wilson and Butzer joined Young, DaSilva, Feldman, Huot and employees of J. D. Northrup, Inc. (Ed and Matt) for trenching w. small tracked excavator with approx. 1.5 foot (0.5 meter) bucket at sites along the previously located radar lines, or nearby, in the area of the "racetrack" abandoned high-meander and adjacent terraces. On 11-18-15 the group was joined by H. Gray for more trenching and sampling at the racetrack site.

From about 10:30 to 12:30 on the 18th, Wilson, Butzer, Huot and Gray visited a gulley head (previously visited by Wilson, Butzer and Feldman on 11-4-15, figure #1 map in the report for 11-3/4-15) in a high terrace on the east side of Buttermilk valley and south of Heinz Creek. OSL and C-14 samples were taken there.

In the pages that follow are four "Sample Description Forms" which contain field notes for:
1) OSL sample "WV T1 S1" clay till sampled as a block in a trench on the south side of the racetrack meander;
2) OSL sample "WV T1 S2" gravel sampled under tarp in a trench on the south side of the racetrack meander and above sample WV-T1-S1;
3) Partial description of weathering conditions in Trench 4 (Munsell colors) on west side of the racetrack meander;
4) OSL and C-14 samples labeled "Heinz 11-18-15-1" sampled in a gully cut into a high terrace east of Buttermilk Creek and south of Heinz Creek.

The "Sample Description Forms" contain maps, sections, and related information. Related photographs follow each form.

Brief summary of OSL sample extraction methods:
With leadership from Huot we discussed or used a variety of OSL sample extraction techniques as we encountered various geologic conditions in the trenches or outcrops . . .
a) use 2-inch diameter PVC tube hammered into thick sand . . . did not happen at our site except possibly for Trench 3 (sand was somewhat thin in Trench 3, i.e., not ideal thickness);
b) use several thin tubes oriented parallel to each other and parallel to layer top and bottom (this is preferred method for a thin layer), however use a thick tube if you mark the orientation of the tube (such as a line along the top of the tube); we used the marked oriented tube method at the gully wall south of Heinz Creek;
c) cut a block of clay or silt from lake or till sediment; we used this method in Trench 1 bottom;
d) sample coarse sand and gravel into a tube under an opaque tarp in darkness (orange-light headlamp preferred); we used this method in Trench 1 gravel above the till;
e) sample coarse sand and gravel with a hammered tube, which was done in most of our trenches, but this method is suspect because the sampled materials may shift or mix in the tube, especially if the gravel diameter is large relative to the tube diameter; improve this method by using artificial inserts as pistons (such as 5mm-thick plastic wafers).

Sample Description Form: Radiocarbon and/or OSL and field notes **Collected By:** Sebastien Huot, M. Wilson, D. Young, D. Butzer and all

^{14}C______ **OSL** ✓ **Sample Designation (#)** WVT1 S1 "Till" **Date** 11-17-15

Description of location: near-bottom in wall of trench #1; high, abandoned meander "racetrack"; Trench was about 8 ft deep w. sloped walls top of lowest terrace, north bank of south side of meander

Lat/Long (GPS) Lat: 42.45842 **Photos:** Butzer photos show layer contacts, oxidation, colors, setting, people, etc.

Long: 78.64849

Elevation of ground surface 1294' from LiDAR

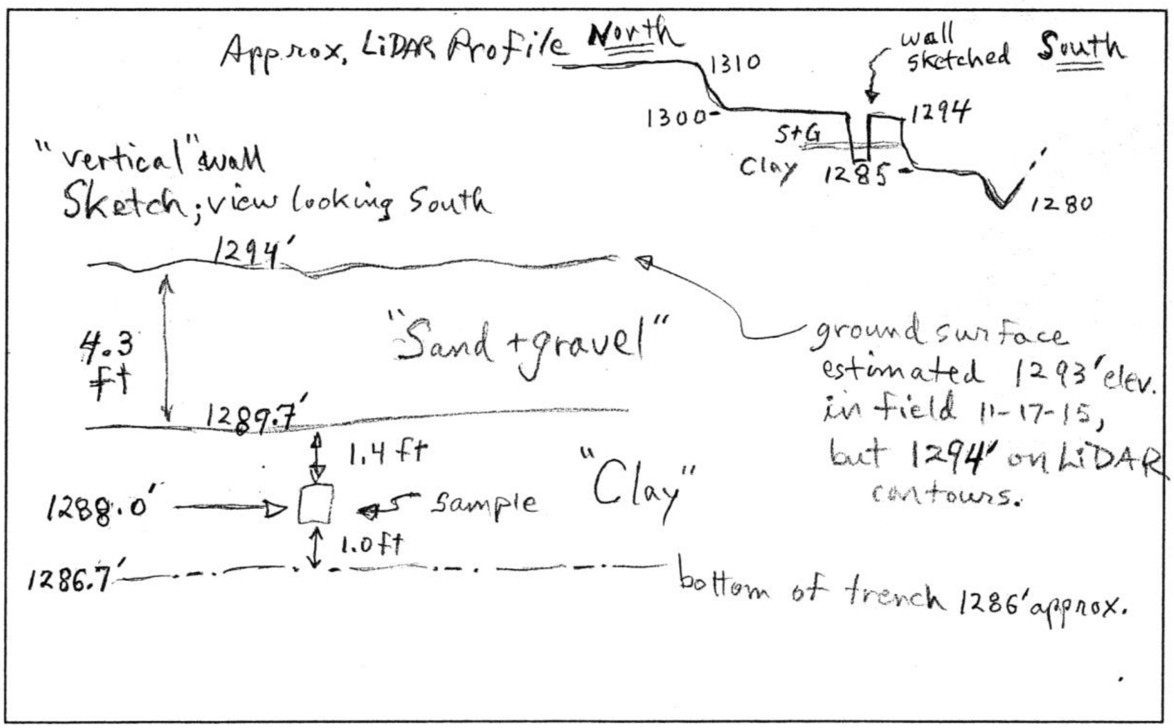
Type of sample: Wood Peat Leaves Nut Seed **Sediment** Other clay Till (pebbly lake clay) +gravelly

Description of sample:
pebbly gravelly clay (Till or lake) likely Lavery or similar, below gravel of terrace on N. side of gulley; block approx 7×7×7 inches cut from excavator chunk. (0.6 ft per side)

Elevation of ground surface 1294'; elev of sample block center 1288.0'

Saturation History: [to be estimated from Wilson 1983, 1974, etc.]

Sketch of Location (geologic cross section) and/or Plan view "map"



Sample Description Form: Radiocarbon and/or OSL Collected By: Huot and Butzer w. help and field notes from all

^{14}C______ ~~OSL~~ (circled) ✓ Sample Designation (#) WV-T1-S2 Date 11-17-15

Description of location: same trench and profile as sketched for WV-T1-S1 clay

Lat/Long (GPS) Lat: 42.45842 Photos: same as WV T1 S1; also Young photos (#98).

Long: 78.64849

Elevation of Ground Surface 1294' from LiDAR

Type of sample: Wood Peat Leaves Nut Seed **Sediment** (circled) Other Sand from S+G layer

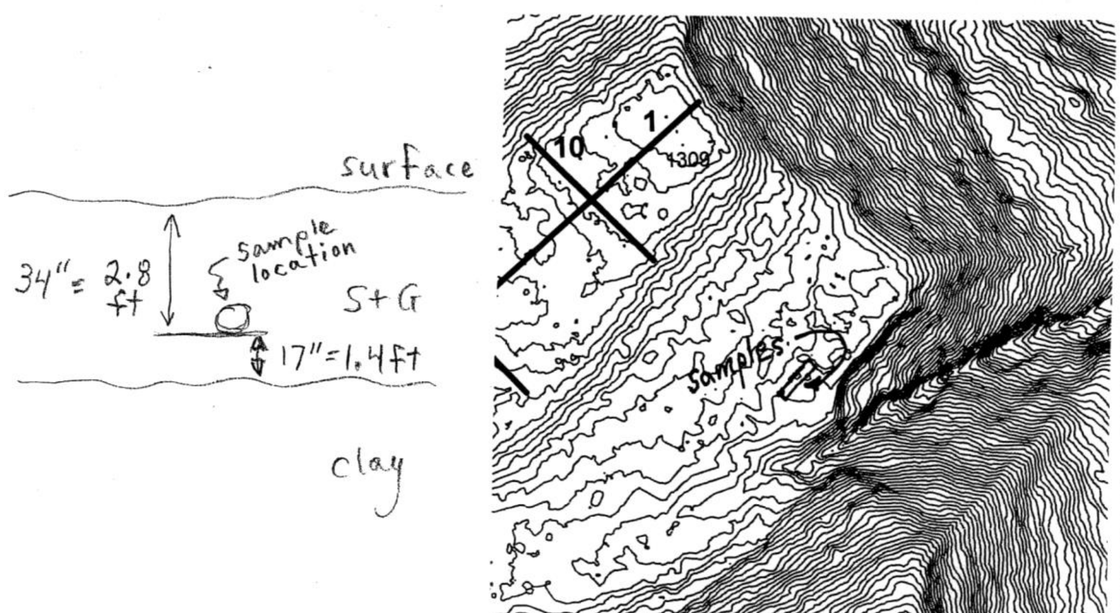
Description of sampling:

- a tube of sand was collected from the S+G terrace layer while in darkness under 2 layers of 16'x20' opaque-lined tarps
- one bag of S+G representative of the unit was collected

Saturation (water content) History [to be estimated from Crain, 1960's; Wilson various dates]

Sketch of Location (geologic cross section) and/or Plan view "map"

See also information for WV-T1-S1 "Till"



The S&G sample was removed from the trench wall 2.8 feet below the surface, or 1.4 feet (17 inches) above the clay. The black arrow shows the location where the sample was retrieved. Because it was a bulk collection, the trench was covered by two tarps which eliminated most of the light during the collection phase.

Sample Description Form: Radiocarbon and/or OSL Collected By: Wilson and Butzer

^{14}C______ OSL ______ Sample Designation (#)____________________ Date 11-18-15

Other ✓ Purpose collect additional data while pit is open.

Description of location: Trench #4 on SW edge of point bar of abandoned meander ("race track" meander) map below; trench oriented approx EW and this data collected in N face (N wall)

Lat/Long (GPS) Lat: 42.458974 Photos: Butzer took photos 11-17-15 and 11-18-15

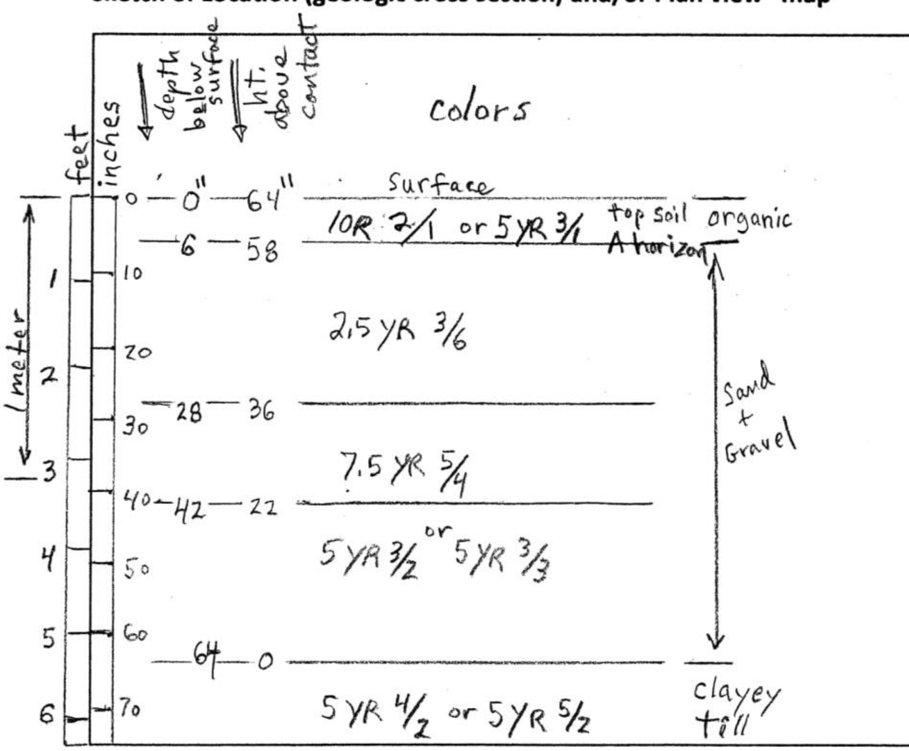
Long: 78.649810

Type of ~~sample~~: Wood Peat Leaves Nut Seed Sediment Other color and acid response

Description of ~~sample~~: data:

- acid response – no response at 5% HCl solution (need to use 10%). lack of acid response may reflect both too weak an acid and lack of carbonates in trench wall S+G and depth of weathering.
- color data are below in sketch space; using Munsell system soil charts.
- initially upon excavation no water flowed into this pit but clay was wet and gravel at base wet, and wet to moist above throughout section.

Sketch of Location (geologic cross section) and/or Plan view "map"



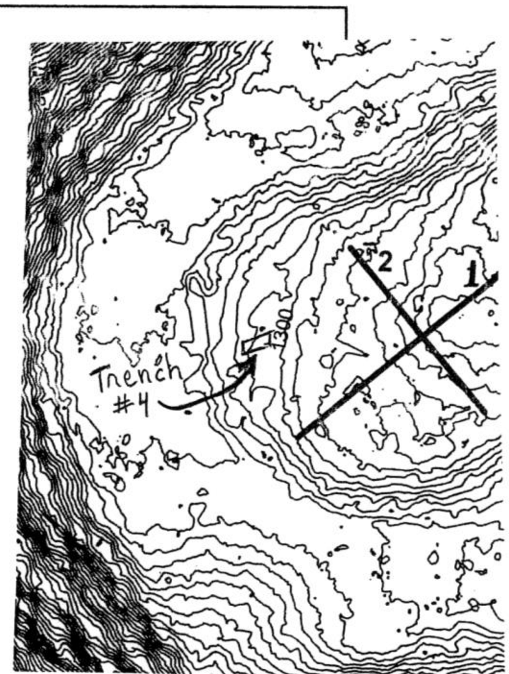


*Photo of pit wall colors related to weathering and Munsell notations in Trench 4 [**to be added**].*

Sample Description Form: Radiocarbon and/or OSL **Collected By:** Butzer, Wilson, Huot, Gray

^{14}C ✓ and **OSL** ✓ **Sample Designation (#)** Heinz 111815 1 **Date** 11-18-15

Description of location: near base of gulley wall (left bank; south bank) south of Heinz Creek and south of proposed (old) access road shown on map below (LiDAR)

Saturation History: position and color indicate always saturated (will analyze further for water content).

Lat/Long (GPS) Lat: ______ **Photos:** Butzer has photos.

Long: ______

Elevation ground surface 1298.5 ft; top of sand 1288.6'; bottom of sand 1288.0'; from LiDAR; center of sample 1288.3 ft. (ie, center of pvc tube)

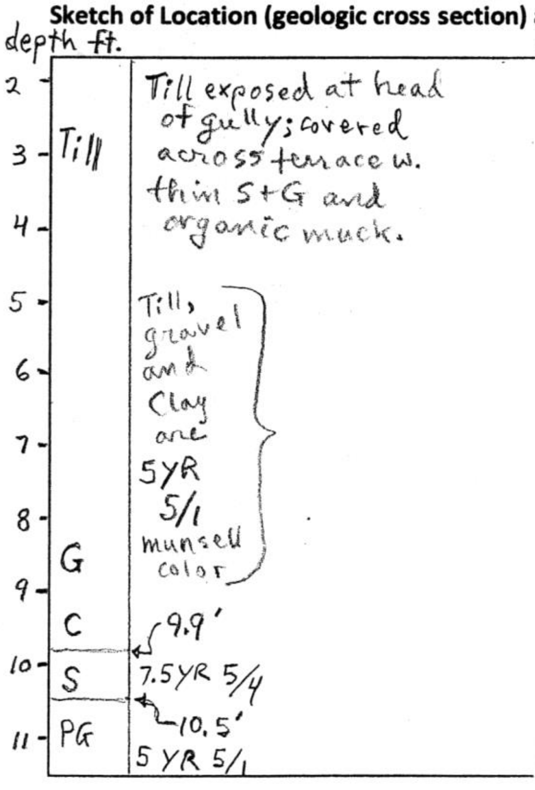
Type of sample: **Wood** **Peat** (C-14) **Leaves** (C-14) **Nut** **Seed** **Sediment** (OSL) ~~**Other**~~

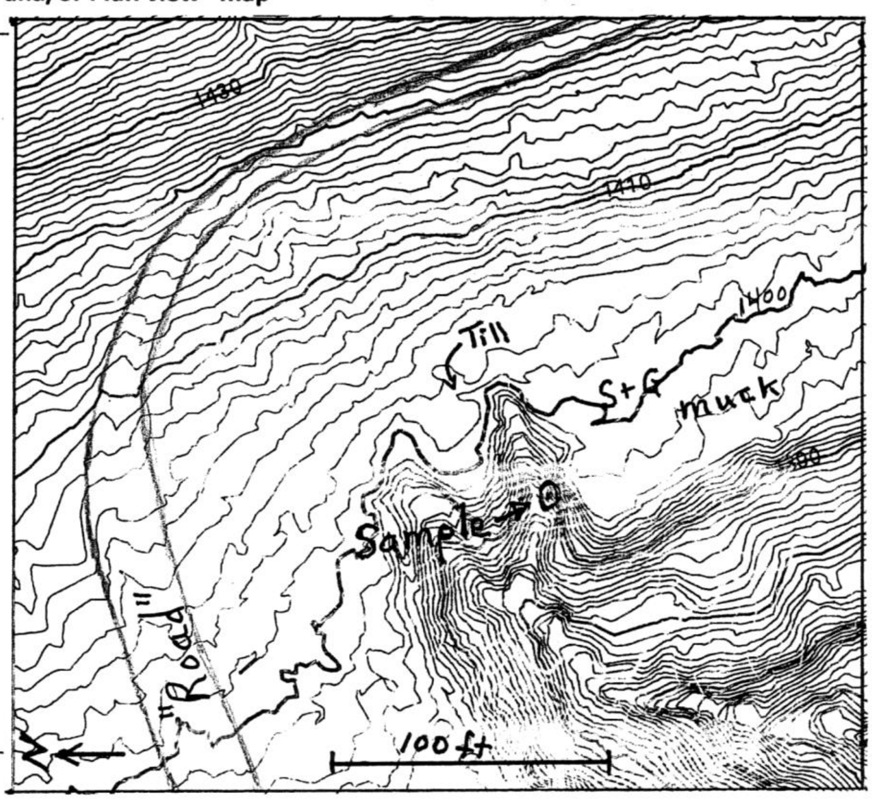
Description of sample:

Column	
Till gray w. stones; Till about 8ft thick	C-14 from top of clay, base of overlying gravel
G gravel gray	
C clay gray no rhythmites	
S Sand bedding millimeters in thickness	OSL from middle of Sand
pG pebbles & gravel; gray	2" pvc tube

OSL reference samples (two) one each collected in S+G above and below pvc sample.

Sketch of Location (geologic cross section) and/or Plan view "map"





Red rectangle shows organics used for C14; yellow rectangle shows area where OSL sample was collected.

General Comparison of Pebble Counts to Date from Glacial and Fluvial Environments
R.A. Young, West Valley Studies, 2014-2015, January, 5, 2016

Tentative Implications:

The attached spreadsheet includes the average percentages of the majority of the pebble counts completed to date in the vicinity of Buttermilk Creek. The numbers of individual pebble counts are indicated by the numbers in parentheses at the top of each column. Minor decimal percentages have been rounded off in some cases, so not all columns total to exactly 100%.

The gray shaded columns indicate the locations that are assumed to be most representative of the modern Buttermilk Creek channel and/or its inferred former terraces. One site (Column 2) is from the modern Buttermilk channel immediately downstream from the large active landslide, and therefore should be expected to contain a larger percentage of till derived clasts.

The following general conclusions are tentatively drawn from a review of these data:

1) Glacial and fluvial deposits can be readily distinguished by their comparative clast lithologies, as well as by the obviously greater “roundness” (but not sphericity) of the fluvial samples. The textural differences with regard to the tills are, of course, obvious.

2) The more fluvially worked samples from ancestral (terraces) and modern Buttermilk Creek are highly enriched (>90%) in rounded sandstone clasts derived from the local upstream bedrock and reworked glacial tills. The southerly derived fluvial samples contain little or no shale and few carbonate clasts, which indicates those less competent lithologies, when present, are relatively efficiently removed by fluvial transport and by abrasion caused by interaction with the more resistant clasts during bedload transport.

3) The glacial till clast compositions are relatively consistent for tills that are not located close to the bedrock surface, and exhibit three diagnostic lithologic differences that make them distinctive when compared to the fluvial gravels (in addition to their obvious till textures). The tills have significantly higher percentages of shale and carbonate clasts and a correspondingly lower number of sandstone clasts.

4) Tills sampled immediately above the bedrock contact (although only represented by one sample from Heinz Creek) appear to have a notably higher shale content, presumably because the basal till has not been transported as far from the bedrock source as the overlying material. Studies have shown that less competent clasts derived directly from bedrock by glacial action do not survive far in transport due to the mechanical disintegration and abrasion which characterize that glacial environment.

5) The glacial outwash has an intermediate composition between the tills and fluvial samples. The most obvious difference between the till and outwash is the obvious loss of shale clasts, presumably due to their relatively rapid physical disintegration by strong or prolonged current transport.

6) The lithologic differences between the fluvial and glacial deposits also are reflected by the obvious differences in the bedrock composition from north to south, as implied by the small percentage of Grimsby and Queenston sandstones that are more prevalent in the northerly derived glacial deposits. A small percentage of these competent reddish pebble types would be expected to show up in the fluvial deposits from reworking of the glacial drift into the Buttermilk channel. Carbonate bedrock is also more common to the north.

Implications:

All of the above observations are basically textbook examples of what one might predict in such an environment, given the nature and distribution of bedrock types in the study area. The important conclusion for the present study is that it should be possible to identify fluvial terraces along the slopes of Buttermilk Creek that are the product of the gradual incision history of Buttermilk Creek preserved in this major valley. From the perspective of ^{14}C or OSL dating of such sediments the problems appear to be twofold:

1) The coarse nature of much of the terrace sand and gravels examined to date probably has allowed oxidation to remove most of the organic materials that originally might have been present. Some organic material may still be located in portions of the broader terraces where low swampy conditions have prevailed, or where fine-grained sediments might have been preserved below the local (perched?) water table(s).

2) For optimal OSL samples it will be preferable to find locations where finer sands have been preserved, and/or to collect the sediments in relative darkness by covering trenches with tarps during sampling activities.

Key Pebble Counts and Averages from Buttermilk Creek Basin
West Valley Demonstration Project, 2014-2015

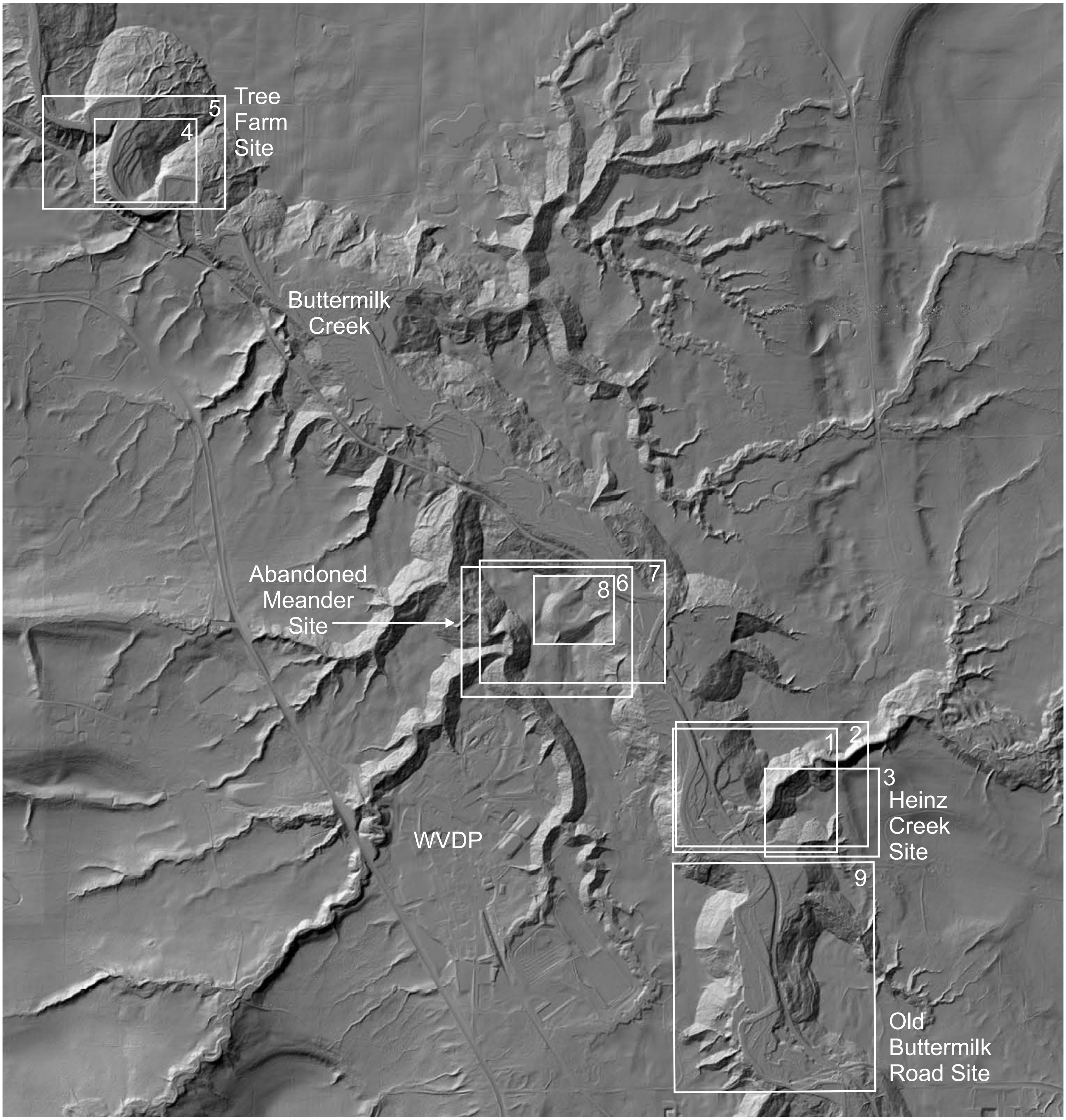
Clast Lithology	Buttermilk Ck channel (1)	Buttermilk Ck Bar (1)	Heinz Ck area terraces (12)	Abandoned Meander (2)	Misc. Till Samples (5)	Till on Bedrock @ Heinz Ck (1)	Glacial Outwash (1)
Sandstone (gray/brown)	91	81	92	90.5	51	28	58
Sandstone (red)	4	7	2	2	9	9	8
Shale	0	0	0.5	0	11	34	0
LS/Dolostone	1	4	0.33	0	22	28	14
Igneous/metamorphic	2	6	1.5	1	6	1	8
Quartzite	2	1	1.5	1.5	1	0	9
Chert	0	1	2	2.7	1	0	3
	(Upstream of Heinz Ck)	(At landslide site =	(Buttermilk channel	(Buttermilk channel	(Not close to bedrock)	(Shale better represented	(Near log site - S2)
		greater contribution	former terraces?)	former terraces?)		closest to bedrock?)	(Note loss of shale
		from till ?)					relative to till)
	All numbers are average		Minor decimal places are				
	percent of total pebble		rounded off for some %ages				
	count (100 or 50 pebbles)		to simplify columns.				
	Parentheses are total						
	number of sample counts						

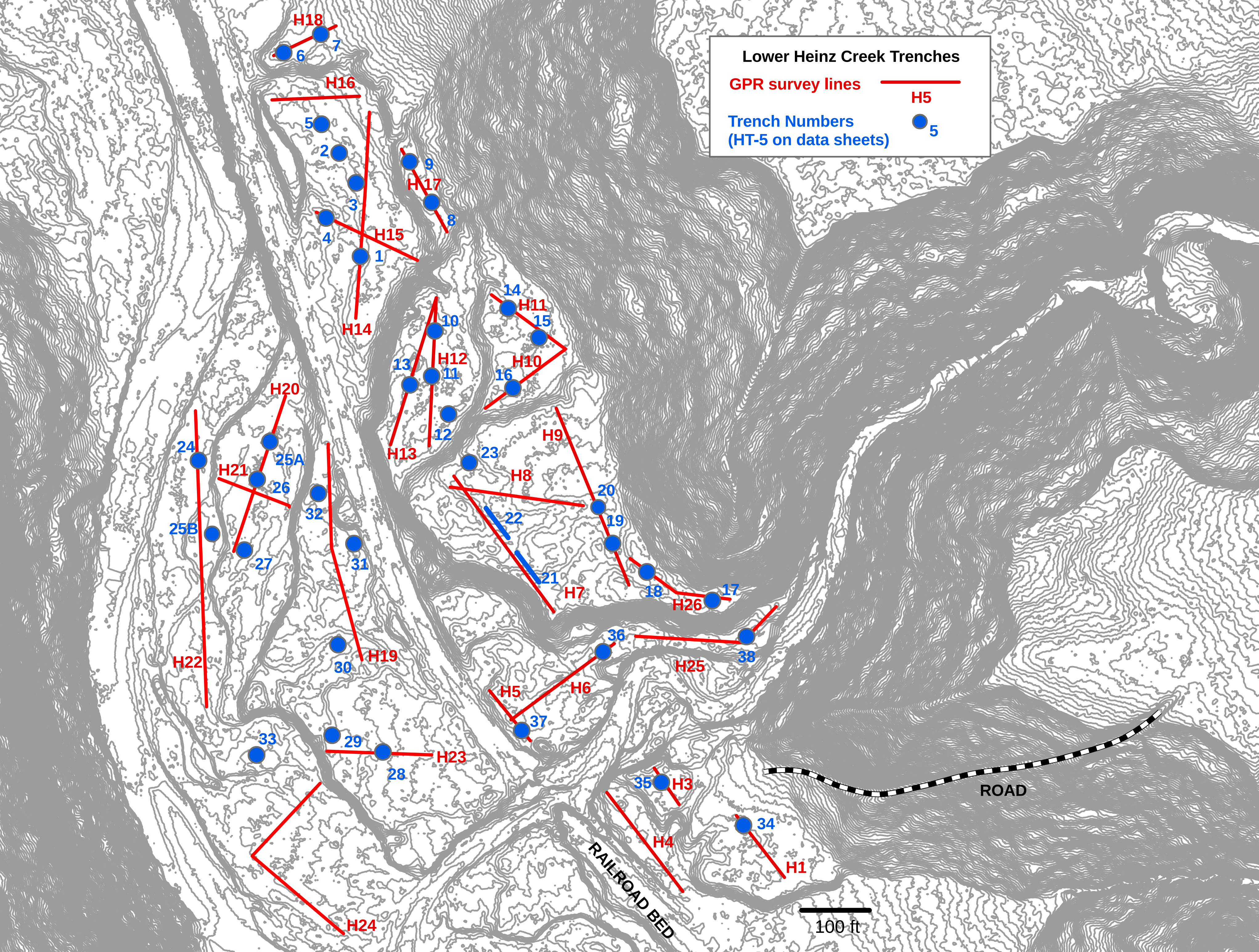
APPENDIX D
Maps of GPR and Exploratory Excavation Locations

Map Index

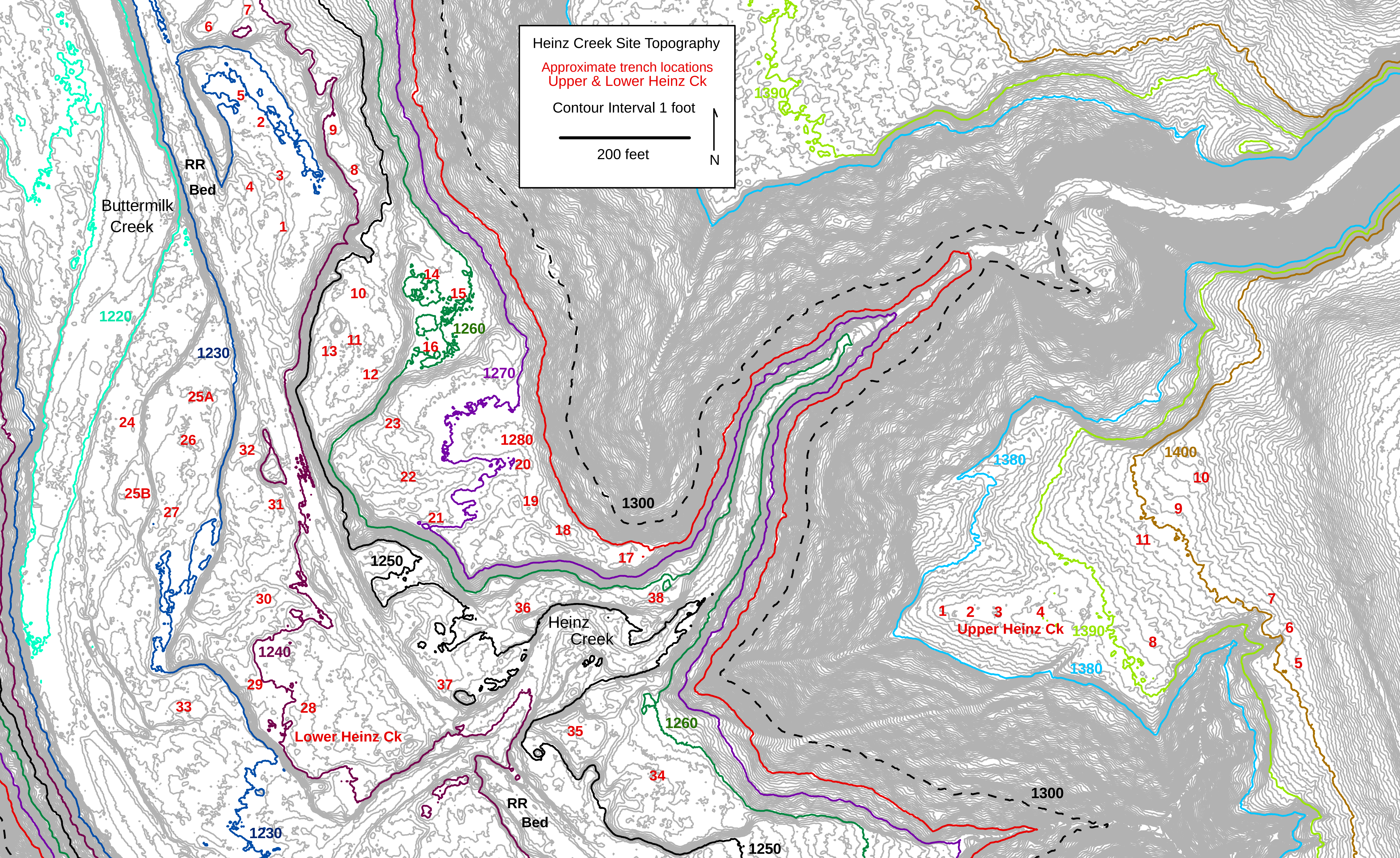
[Figures (1-9) locations outlined by white boxes on hillshade map.]

1. GPR lines and trench locations for lower Heinz Creek site
2. Topography with trench locations for lower and upper Heinz sites
3. GPR lines and trench locations for upper Heinz site
4. GPR lines and trench locations for Tree Farm site
5. Topography and trench locations for Tree Farm site
6. GPR lines and trench locations for main abandoned meander site
7. Topography and trench locations for all abandoned meander sites
8. Trench locations for lowest abandoned meander channel
9. Sample locations for Old Buttermilk Road/Landslide site reach

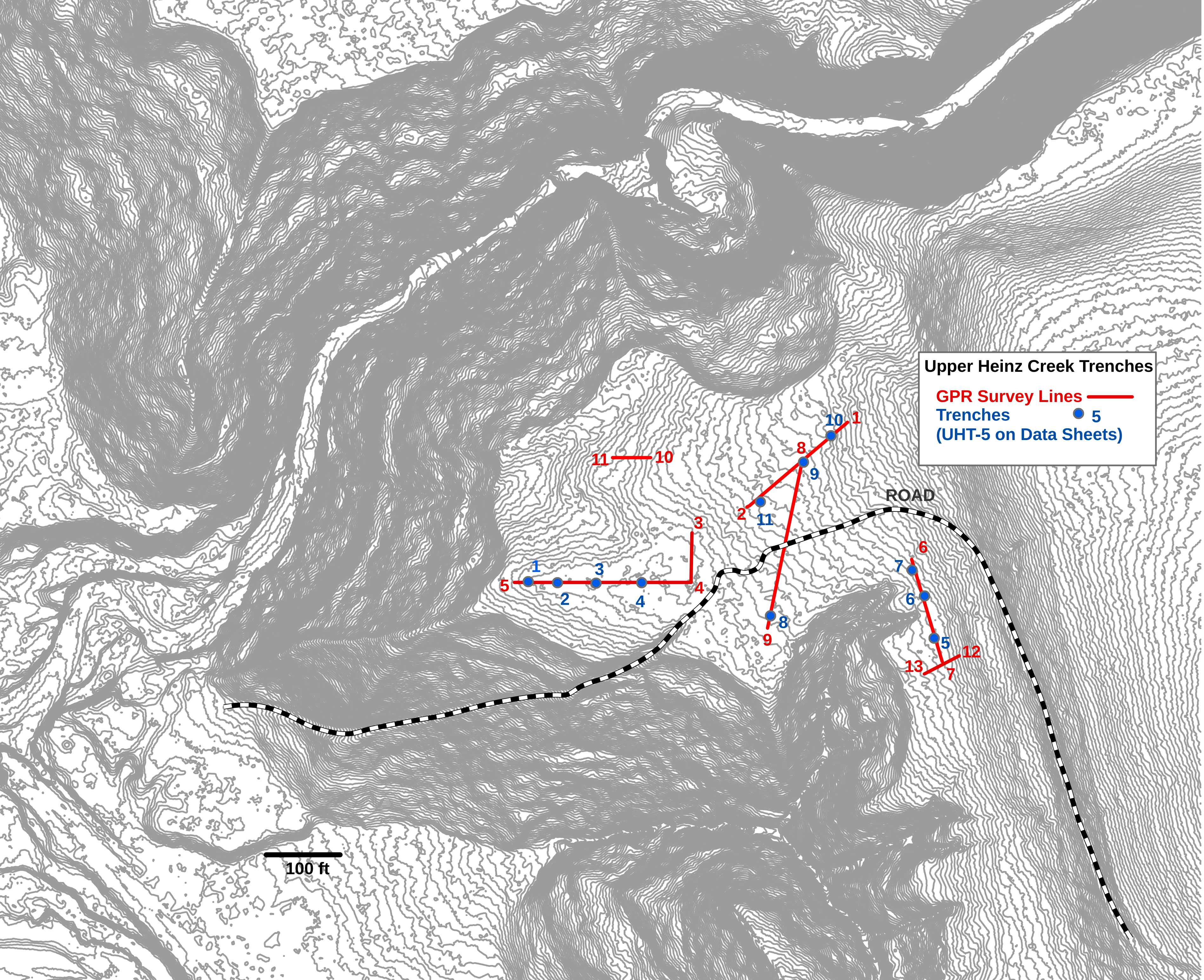

Tree
Farm
Site
5
4
Buttermilk
Creek
Abandoned
Meander
Site
7
6
8
1
2
3
Heinz
Creek
Site
WVDP
9
Old
Buttermilk
Road Site

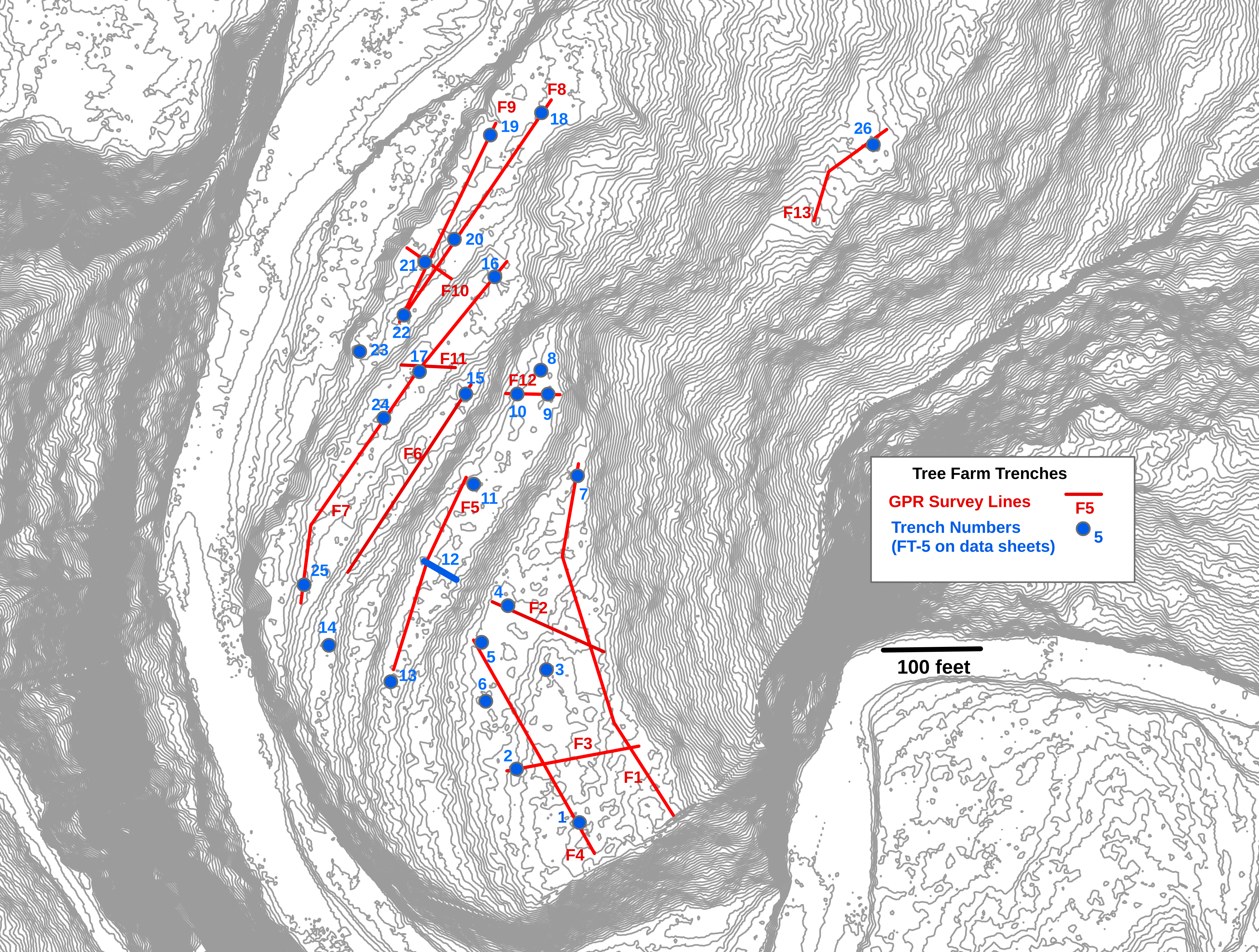


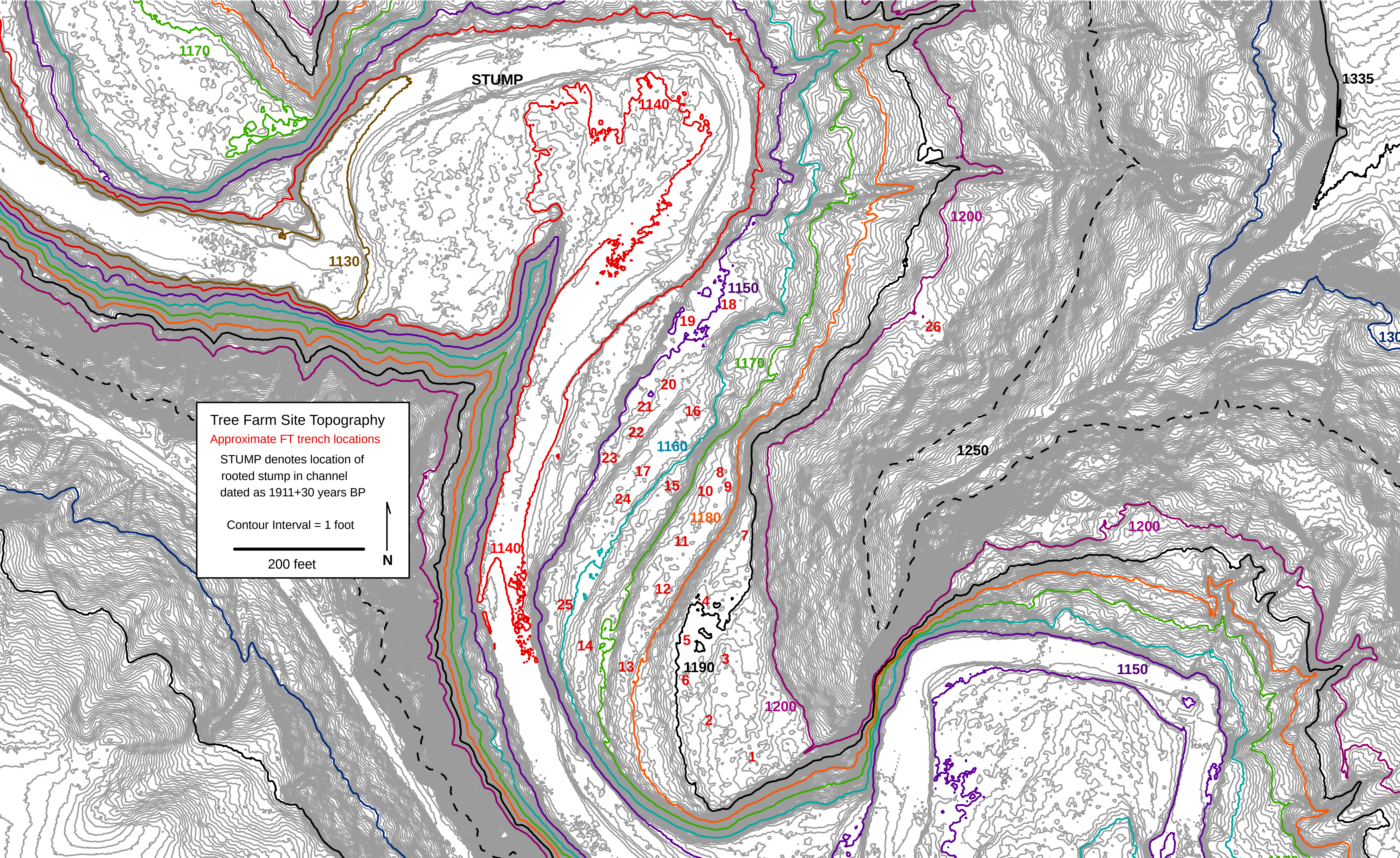
Lower Heinz Creek Trenches
GPR survey lines
H5
Trench Numbers
(HT-5 on data sheets)
5
H18
7
6
H16
5
2
3
4
H15
1
H14
9
H17
8
14
H11
15
10
H12
13
11
H10
16
12
H13
H20
24
25A
H21
26
32
25B
27
31
23
H9
H8
20
22
19
21
H7
18
17
H26
36
38
H25
30
H19
H22
H5
H6
37
33
29
28
H23
35
H3
34
H4
H1
H24
RAILROAD BED
ROAD
100 ft



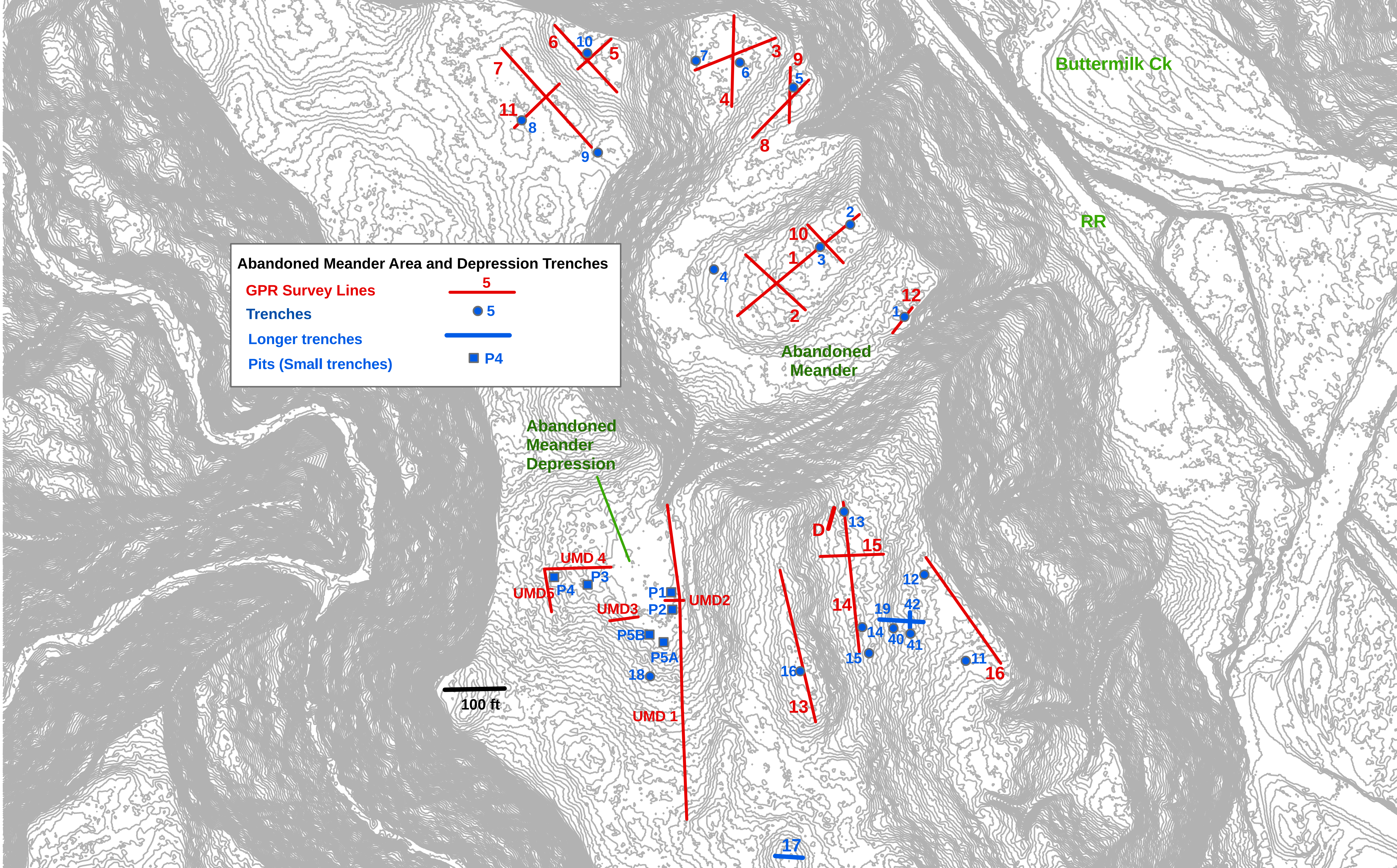
Heinz Creek Site Topography
Approximate trench locations
Upper & Lower Heinz Ck
Contour Interval 1 foot
200 feet
N
Buttermilk Creek
RR Bed
Heinz Creek
Upper Heinz Ck
Lower Heinz Ck
1220
1230
1240
1250
1260
1270
1280
1300
1380
1390
1400


Upper Heinz Creek Trenches
GPR Survey Lines
Trenches 5
(UHT-5 on Data Sheets)
ROAD
100 ft
1
2
3
4
5
6
7
8
9
10
11
12
13

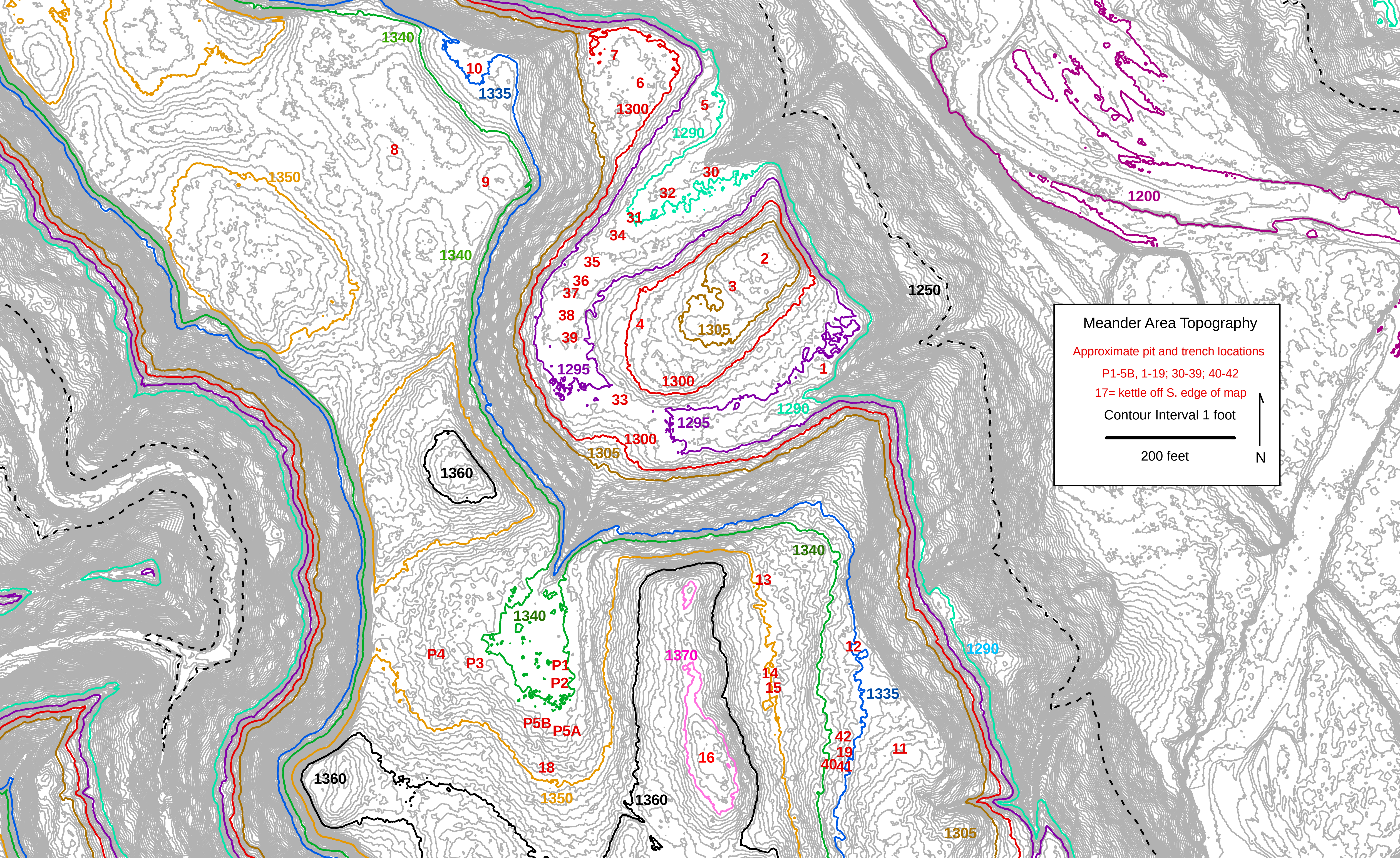

Tree Farm Trenches
GPR Survey Lines
F5
Trench Numbers
(FT-5 on data sheets)
5
100 feet
F1
F2
F3
F4
F5
F6
F7
F8
F9
F10
F11
F12
F13
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26

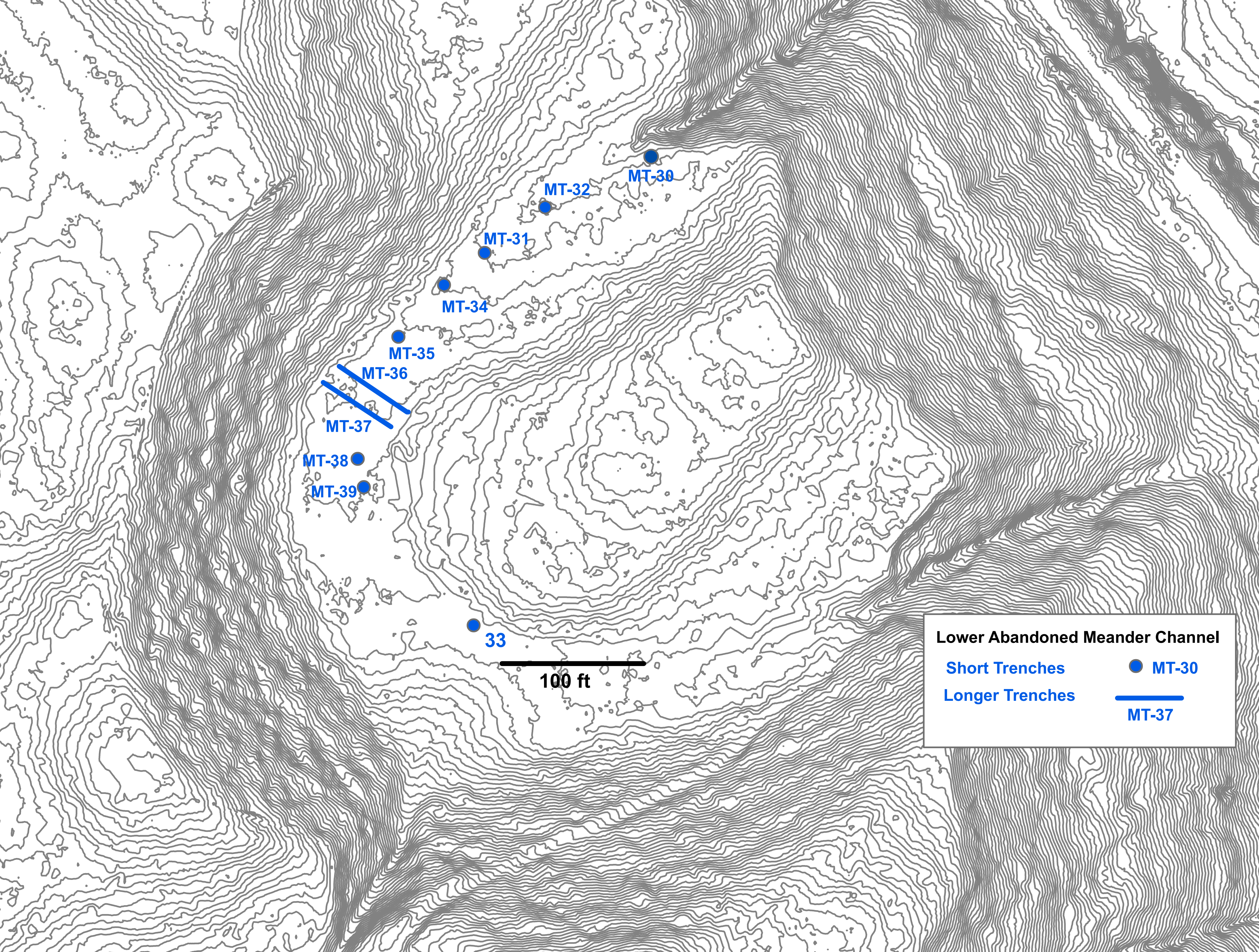


Tree Farm Site Topography
Approximate FT trench locations
STUMP denotes location of
rooted stump in channel
dated as 1911+30 years BP
Contour Interval = 1 foot
200 feet
N
STUMP
1130
1140
1150
1160
1170
1180
1190
1200
1250
1335
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26

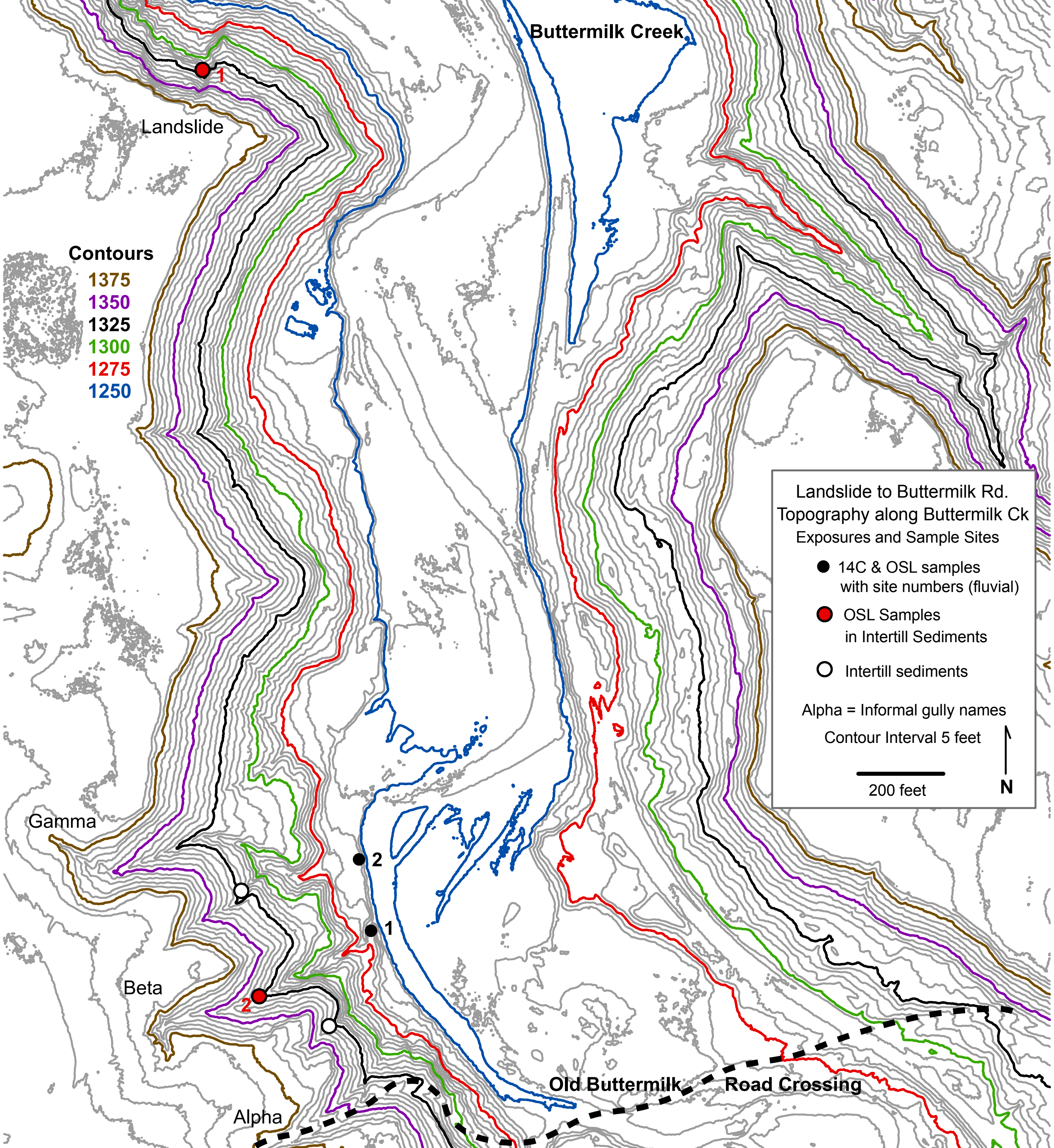


Abandoned Meander Area and Depression Trenches
GPR Survey Lines
Trenches
Longer trenches
Pits (Small trenches)
P4
Buttermilk Ck
RR
Abandoned Meander
Abandoned Meander Depression
UMD 4
UMD5
UMD3
UMD2
UMD 1
P1
P2
P3
P4
P5B
P5A
D
100 ft


Meander Area Topography
Approximate pit and trench locations
P1-5B, 1-19; 30-39; 40-42
17= kettle off S. edge of map
Contour Interval 1 foot
200 feet
N
1340
1335
1350
1300
1305
1290
1295
1250
1200
1360
1370
P1
P2
P3
P4
P5A
P5B



MT-30
MT-32
MT-31
MT-34
MT-35
MT-36
MT-37
MT-38
MT-39
33
100 ft
Lower Abandoned Meander Channel
Short Trenches
MT-30
Longer Trenches
MT-37


Buttermilk Creek
Landslide
Contours
1375
1350
1325
1300
1275
1250
Landslide to Buttermilk Rd.
Topography along Buttermilk Ck
Exposures and Sample Sites
14C & OSL samples with site numbers (fluvial)
OSL Samples in Intertill Sediments
Intertill sediments
Alpha = Informal gully names
Contour Interval 5 feet
200 feet
N
Gamma
Beta
Alpha
1
2
Old Buttermilk Road Crossing

APPENDIX E
Ground Penetrating Radar Results

GEOPHYSICAL SERVICES REPORT

New York State Energy Research and Development Authority Property Adjacent to the West Valley Demonstration Project
10282 Rock Springs Road
West Valley, New York

Schnabel Reference 15615028
November 25, 2015

Schnabel
ENGINEERING

November 25, 2015

Mr. David Butzer
Enviro Compliance Solutions Inc.
1571 Parkway Loop, Suite B
Tustin, CA 92780

Subject: **Project 15615028 Task 01, Geophysical Services, New York State Energy Research and Development Authority Property, Adjacent to the West Valley Demonstration Project, 10282 Rock Springs Road, West Valley, New York**

Dear Mr. Butzer:

SCHNABEL ENGINEERING OF NEW YORK (Schnabel) is pleased to submit our geophysical services report for this project. This study was performed in accordance with our proposal dated November 6 2015, as authorized by Mr. Michael Wolff on November 9, 2015.

SCOPE OF SERVICES

Our proposal dated November 6, 2015, defines the scope of services for this project. The scope of services includes the following: a ground penetrating radar (GPR) geophysical survey to identify the depth to an interface between sands and gravels overlying clayey glacial till along traverses you identified at the project area.

PROJECT DESCRIPTION

Schnabel obtained the project description information from our discussions with you, Dr. Richard Young, and Dr. Michael Wilson. A Site Vicinity Map is included as Figure 1.

The project area is located on New York State Energy Research and Development Authority (NYSERDA) property adjacent to the West Valley Demonstration Project (WVDP) site. The WVDP is a former nuclear reprocessing and disposal site that was active from 1966 to 1975. Activities at the site since 1975 have focused on clean-up and containment of the nuclear materials and characterizing the hydrogeologic system at and around the site.

The site is located in the glaciated Allegheny Plateau of New York State. The project area is located in the Buttermilk Creek Valley, an incised valley through complex layers of till, stream and glacial lake terrace deposits, and reworked sands and gravels.

We understand that an erosion study is currently ongoing to predict the future long-term sediment erosion at and near the WVDP. As part of that study, you are interested in characterizing sand and gravel layers along select traverses across several terraces, an old stream meander, and point bar. The project area has been preliminarily interpreted into regions consisting of a Point Bar, Terraces 1, 2 and 3, the Oldest Surface (a possible terrace), and the Area South of the Meander. The approximate boundaries of these areas were provided to us by Dr. Young and are included on Figure 2, Approximate GPR Traverse Locations.

SUBSURFACE INVESTIGATION PROGRAM

Schnabel personnel visited the site and conducted the geophysical data collection in the project area on November 16, 2015. The Enviro Compliance Solutions Inc. (ECS) team on site through the duration of the GPR survey consisted of you, Dr. Young, Dr. Wilson and Mr. Alex DaSilva.

Location Information

The ECS team had identified 10 GPR traverse locations prior to November 16, 2015. Throughout our field day 8 traverses were added, for a total of 18 traverses. Sixteen of these are labeled as Lines 1 through 16, and two traverses are labeled uniquely as “uphill” and “low-high.”

The traverses were identified by labeled pink flagging tape attached to trees. Each traverse had the starting point designated as “A” and the direction of travel was to location “B”; for example, “Line 1A” was the start of Line 1. Several traverses were labeled with additional trees marked “B,” “C,” and “D” depending on the lengths and the number of trees along the traverse. The locations between the marked trees were measured by the ECS team using a laser distance sensor.

Table 1 provides the distances between the marked trees of each traverse, and the approximate locations of the traverse and the starting points are shown on Figure 2.

Table 1: Traverse Lengths

Location	Traverse	Distance A to B (ft)	Distance B to C (ft)	Distance C to D (ft)	Total Length (ft)
Point Bar	**Line 1**	87	101	92	**280**
	Line 2	122	126	81	**329**
	Line 10	109	118	-	**227**
	Line 12	90	-	-	**90**
Terrace 1	**Line 5**	82	-	-	**82**
	Line 6	114	-	-	**114**
Between Terrace 1 and 2	**uphill**	160	-	-	**160**
Terrace 2	**Line 3**	153	-	-	**153**
	Line 4	111	-	-	**111**
Terrace 3	**Line 8**	140	-	-	**140**
	Line 9	125	-	-	**125**
Oldest Surface	**Line 7**	207	-	-	**207**
	Line 11	142	-	-	**142**
South of the Meander	**Line 13**	158	-	-	**158**
	Line 14	32	115	50	**197**
	Line 15	78	-	-	**78**
	Line 16	152	-	-	**152**
	low-high	35	-	-	**35**

Ground Penetrating Radar (GPR) Data Collection

We used a Geophysical Survey Systems, Inc. (GSSI) SIR-3000 GPR system with a 400 MHz antenna to collect GPR data along the traverses. We established range and gain settings in the Point Bar to optimize depth of investigation and resolution. Line 12 in the Point Bar was located approximately 10 ft from the edge of an erosional surface exposing the sand/gravel overlying the till.

We used a range setting of 90 nS for all traverses (except the “low-high” traverse), which we refer to as the “primary data files.” In addition, we collected supplemental data along several traverses using two different range settings (50 and 120 nS). The supplemental data was collected with a range of 50 nS in the vicinity of the “low-high” traverse in the area South of the Meander, with the purpose of providing higher resolution in the shallower portion of the hummocky terrain localized near the “low-high” traverse. The supplemental data was collected with a range of 120 nS along traverses where the interface between the sands/gravel and clayey till was not immediately apparent in the data, in the Terraces and Oldest Surface.

All GPR files in *.dzt and pdf format are provided to you in electronic format. Copies of the GPR profiles are included in Appendix B. Tables 2 and 3 include file inventories.

Table 2: File Inventory, Primary Files

Range (nS)	Location	Traverse ID	GPR File	Starting Location	Direction Heading
90	Point Bar	**Line 1**	**9**	1A	W
			10	1B	
			11	1C	
		Line 2	**12**	2A	N
			13	2B	
			14	2C	
		Line 10	**15**	10A	N
			16	10B	
		Line 12	**33**	12A	NE
	Terrace 1	**Line 5**	**26**	5A	SW
		Line 6	**25**	6A	NW
	Between Terrace 1 and 2	**uphill**	**24**	3B, uphill S	N
	Terrace 2	**Line 3**	**20**	3A	W
		Line 4	**19**	4A	N
	Terrace 3	**Line 8**	**18**	8A	S
		Line 9	**17**	9A	N
	Oldest Surface	**Line 7**	**30**	7A	NW
		Line 11	**31**	11A	S
	South of the Meander	**Line 13**	**34**	13A	NE
		Line 14	**38**	14A	N/NE
			39	14B	
			40	14C	
		Line 15	**41**	15A	N/NE
		Line 16	**48**	16A	S

Table 3: File Inventory, Supplemental Files

Range (nS)	Location	Traverse ID	GPR File	Starting Location	Direction Heading
50	South of the Meander	**Line 14**	**42**	14A	N/NE
			43	14 no mark	
			44	14B	
			45	14C	
		Line 15	**47**	15A	E
		low-high	**46**	low-high N	SW
120	Terrace 1	**Line 5**	**28**	5A	SW
		Line 6	**27**	6A	NW
	Terrace 2	**Line 3**	**22**	3A	W
		Line 4	**23**	4A	N
	Oldest Surface	**Line 7**	**29**	7A	NW
		Line 11	**32**	11A	S
	South of the Meander	**Line 13**	**35**	13A	NE
			36	13B	
			37	13C	

Ground Penetrating Radar (GPR) Data Analysis

We performed processing and analysis using GSSI's RADAN software. Figure 3 includes examples of files showing the processing steps. The initial processing step was to normalize the ground surface reflection to zero on the time axis, and then we applied a background removal to reduce horizontal banding. We then identified reflections from the sand/gravel and till interface.

We applied a migration to several profiles to remove the diffraction patterns that are inherent where the GPR passes over point objects (such as gravel pieces within sand), and to calculate the GPR signal velocity through those materials. The migrated files visually appeared less noisy, though the contrast between the sand/gravel and till is not as readily apparent. The final processed files in Appendix B do not include the migration.

RADAN has a semi-automatic picking routine that adds discrete points in the profiles and outputs the distance and depth (in nS). We used this picking routine to estimate the bottom of the sand/gravel and top of till. There is variability along the interface because the interface is not one discrete continuous layer. We plotted these points in Excel and added a moving average curve to estimate the interface. The Excel plots with the estimated interface are included in Appendix A.

Conversion from Time to Depth

GPR data is collected as profiles with the vertical axis in time (in nS). The time represents how long the radar waves took to pass downward into the subsurface, reflect off an object or interface, and then return to the antenna. Time can be converted to depth by multiplying it by its signal velocity. We estimate the signal velocity by correlation with features of a known depth or calculating it through migration processing. You provided us with preliminary depth information from trenching that was conducted the day after the

GPR survey, and we also measured the migration velocity in the files at several locations in the sand/gravel.

There is a range in the dielectric constants we calculated because: the exact location of the trenches along the GPR traverses is unknown, there is variability in the depth to the till along the traverses, and because the sand and gravel is non-homogeneous. We estimated dielectric constants between 11.7 and 20.9 based on both the trenching results and the migration velocities. We performed depth calculations on all the data using an average dielectric constant of 16.9.

GSSI states the depth accuracy of the SIR-3000 System is no better than 5% of the calculated depth; however, because of the range in the estimated dielectric constants, we calculated the depth accuracy to be about 14% of the depth. This means that a calculated depth of about 5 ft may be within about ±0.7 ft.

We applied the average dielectric constant to the entire data set. The depth accuracy could be improved for a particular location by estimating and applying a more localized dielectric constant: either by having trenching information at a precise known location along the GPR traverse, and/or by measuring the migration velocity within the sand/gravel in that local area.

Location Accuracy

We used a GSSI survey wheel attached to the data collection cart to trigger the GPR data collection and to correlate the data with distance. We calibrated the survey wheel to the site ground surface conditions over a length of 50 ft. GSSI states that the variation from point to point within each GPR line is less than 2% of the distance point to point. We estimate that the traverse lines are located about 1-3 ft from the flagged trees, and may vary from a straight line because we did not move in an exact straight line due to the irregular ground surface and small obstacles along the lines (such as cobbles and trees).

RESULTS

The primary data files provide the desired information (i.e., the interface between sand and gravel overlying clayey glacial till), and therefore the primary files are the focus of this report. We grouped the GPR results into three groups based on the character of the primary data profiles. Appendices B1, B2, and B3 contain these files.

The supplemental files are also provided for your information and use in Appendix B4.

Group 1: Point Bar and Terraces 2 and 3

The interface between sand/gravel and till was clearly visible in the GPR data during data collection and processing, particularly in the Point Bar and Terrace 3 areas. The GPR profiles show strong radar signal penetration through the interpreted sand/gravel, with a stronger amplitude reflector at what we interpret to be the base of the sand/gravel and top of the clayey glacial till. Beneath this stronger reflector, the radar signal significantly attenuates, as is typical in clayey soils. The sand/gravel appears to be poorly sorted, as there are many individual reflectors which indicate gravel or cobbles within the sandy matrix.

In addition, along Lines 1, 2, and 10 in the Point Bar, we identified an interlayer. This interlayer appears to indicate a composition interface, possibly between the poorly sorted sand/gravel above and more well-sorted material with a more clayey composition below.

Appendix B1 includes these files.

Group 2: Terrace 1 and Between Terraces 1 and 2 and Oldest Surface

The Uphill line started on Terrace 2 at the end of Line 3, moved across Terrace 2, up the steep slope, and moved across Terrace 1. The interface between sand/gravel and till was clearly visible in the GPR profile as being thicker while on the Terraces, and appearing to pinch out in the middle of the profile, which was on the steep slope.

The interface between sand/gravel and till is visible in the GPR profiles on Terrace 1 and the Oldest Surface, though the stronger amplitude reflector is lacking in these areas. We interpreted the interface to be between the section of the profile showing strong radar signal penetration and the section of the profile where the signal significantly attenuates. Also, the profile indicates the interpreted sand/gravel has more larger point features than observed in the Point Bar and at Terraces 2 and 3; we interpret these to be either cobbles or boulders.

In addition, along Lines 5, 7, and 11 we identified an interlayer. This interlayer appears to indicate a composition interface, possibly between the poorly sorted sand/gravel above and more well-sorted material with a more clayey composition below.

Appendix B2 includes these files.

Group 3: South of the Meander

The GPR data collected at the area South of the Meander has a similar appearance to the data collected in Group 2 in that there is no strong interface reflector. We interpreted the interface to be between the section of the profile showing strong radar signal penetration and the section of the profile where the signal significantly attenuates.

The depth to the interface along Line 16 is shallower than the other locations observed during this project, in some locations as shallow as 12 inches. Depths this shallow may indicate that what we identified as the sand/gravel and till interface is actually the forest duff/topsoil over till interface.

In addition, along Lines 13 and 14 we identified an interlayer. This interlayer appears to indicate a composition interface, possibly between the poorly sorted sand/gravel above and more well-sorted material with a more clayey composition below. The interlayer along Line 13 is more pronounced and thicker than the other interlayers observed during this project.

Appendix B3 includes these files.

Summary

Table 4 contains the calculated minimum and maximum depths of the interlayers and interface between sand/gravel and till. Appendix A contains plots of the interlayers and interface depths along the profile lines. Appendix B contains the GPR profiles.

Table 4: Calculated Depths

Location	Traverse ID	Minimum Interlayer Depth (inch)	Maximum Interlayer Depth (inch)	Minimum Depth to Sand/Gravel and Till Interface (inch)	Maximum Depth to Sand/Gravel and Till Interface (inch)
Point bar	1	36	68	30	85
	2	31	57	10	90
	10	5	55	18	80
	12	-	-	31	71
Terrace 1	5	28	71	41	94
	6	-	-	39	102
Between Terrace 1-2	uphill	-	-	11	70
Terrace 2	3	-	-	38	80
	4	-	-	46	75
Terrace 3	8	-	-	31	59
	9	-	-	18	55
Oldest	7	24	60	56	106
	11	26	43	68	109
South	13	22	53	28	112
	14	10	43	28	88
	15	-	-	47	94
	16	-	-	12	42

Note: Depth accuracy is expected to be up to about 14% of the depth, as explained above.

LIMITATIONS

Geophysical data depict an estimate of actual subsurface conditions based on secondary parameters (e.g., GPR reflections and signal velocity). Correlation of this data with intrusive method data may show some variance due to the nature of measured geophysical properties and variation in personnel and methods used to describe the intrusive investigation findings. Also, the resolution of the geophysical methods may be such as to not detect potentially significant small features. Discussion of the results, including annotations on the figures, represents our interpretation of the data. As such, some amount of variation in the actual field conditions should be expected.

We based the interpretations submitted in this report on the geophysical data obtained during the investigation, general observations of the conditions while on site, and information provided to us.

This report has been prepared to aid in the evaluation of this site. It is intended for use concerning this specific project. We based our analysis on information on the site as described in this report. Substantial changes should be brought to our attention so we can modify our analysis as needed.

We have endeavored to complete the services identified herein in a manner consistent with that level of care and skill ordinarily exercised by members of the profession currently practicing in the same locality and under similar conditions as this project. No other representation, express or implied, is included or intended, and no warranty or guarantee is included or intended in this report, or other instrument of service. We appreciate the opportunity to be of service for this project. Please call Mia Painter at 610-656-5536 if you have any questions regarding this report.

Sincerely,

SCHNABEL ENGINEERING CONSULTANTS, INC.

Mia A. Painter, PG
Senior Geologist

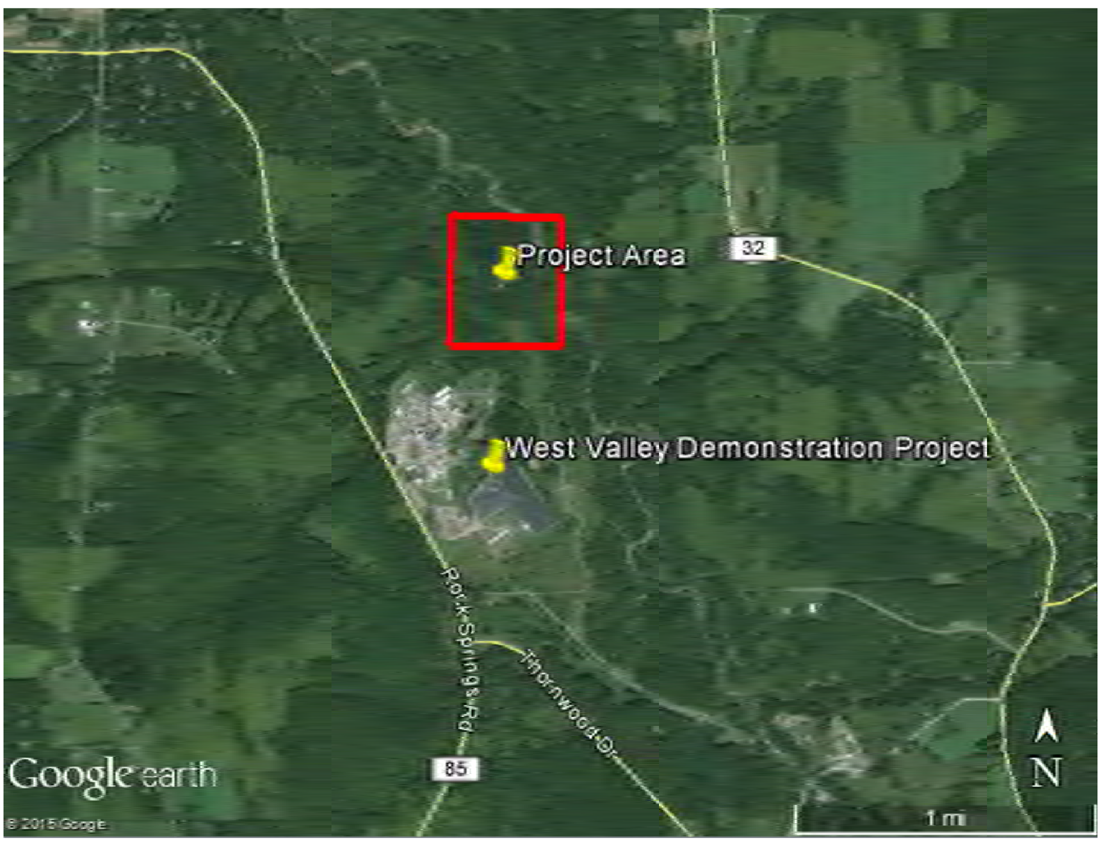
MAP:MHD:jlc

Figures
Appendix A: Excel Plots of Interlayer and Interface Depths
Appendix B: GPR Data Files

Electronic Files (sent separately)
- *.dzt files of raw data
- *.dzt files of processed data
- Excel spreadsheet containing the Appendix A charts and conversions from time to depth
- *.pdf files of each GPR data file
  - -black and white
  - -black and white with interlayers and interfaces (same as in Appendix B)
  - -color scale highlighting sand and gravel

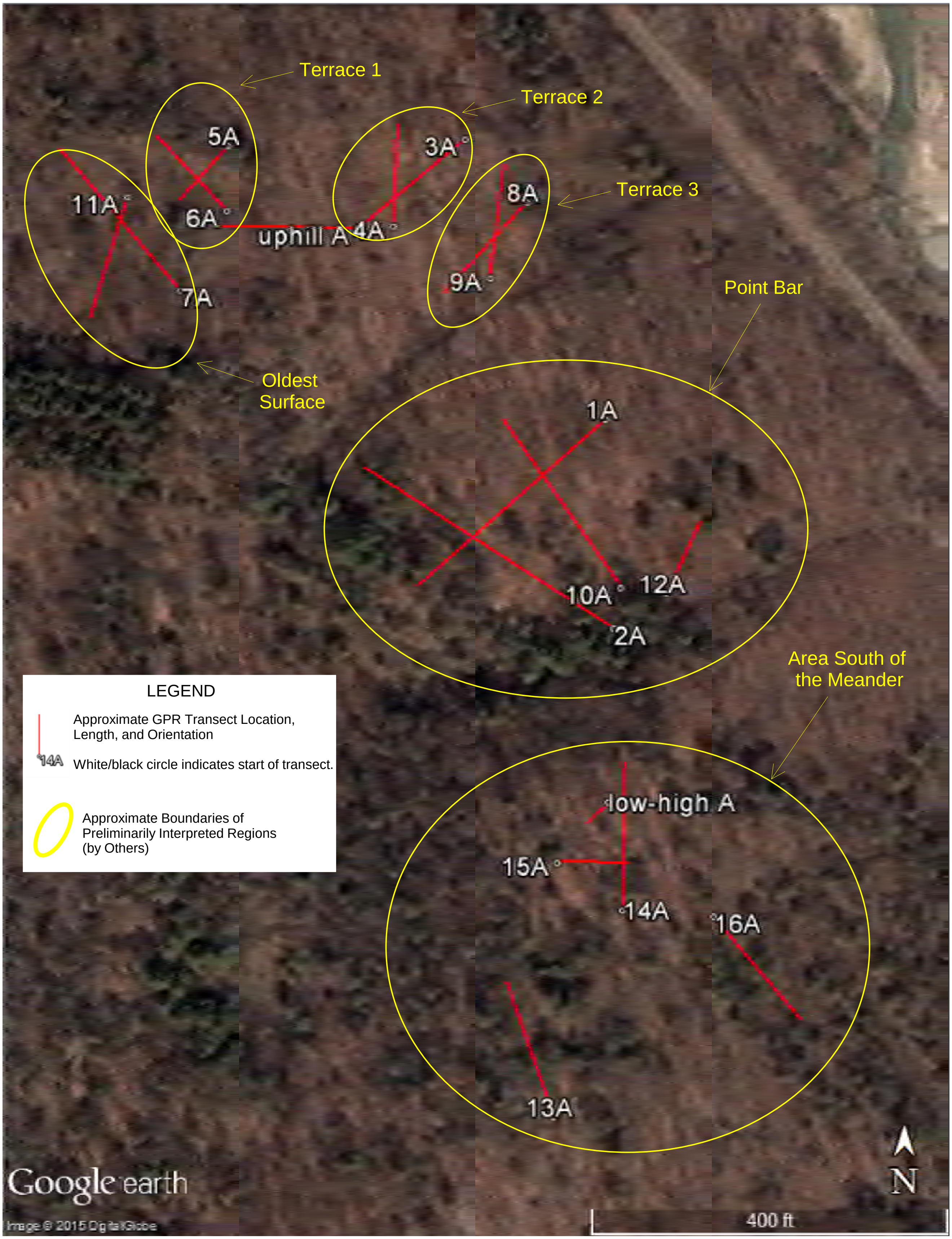
Distribution:
Enviro Compliance Solutions Inc. (email only)
Attn: Mr. Dave Butzer
Attn: Mr. Michael Wolff
Attn: Mr. Michael Wilson
Attn: Mr. Richard Young

FIGURES



Aerial photograph from Google Earth Pro; scale as shown.

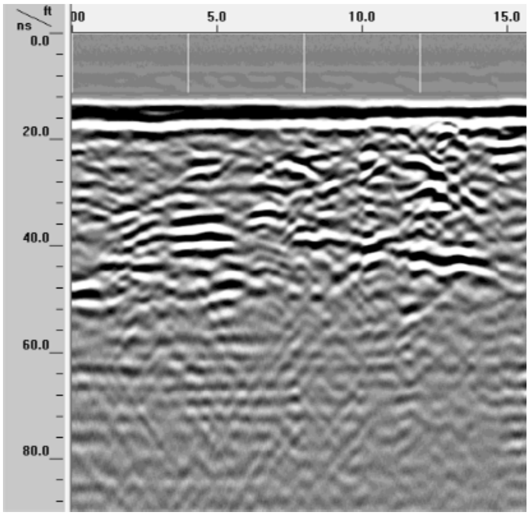
Schnabel ENGINEERING	NYSERDA PROPERTY ADJACENT TO THE WVDP 10282 ROCK SPRINGS ROAD WEST VALLEY, NEW YORK PROJECT NO. 15615028 TASK 01	SITE VICINITY MAP FIGURE 1



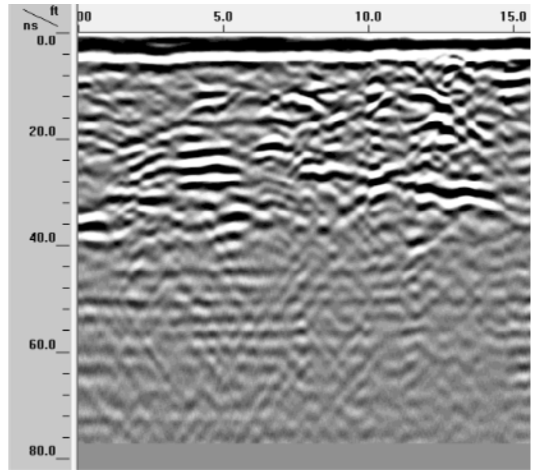
Aerial photograph from Google Earth Pro; scale as shown.

Schnabel ENGINEERING	NYSERDA PROPERTY ADJACENT TO THE WVDP 10282 ROCK SPRINGS ROAD WEST VALLEY, NEW YORK PROJECT NO. 15615028 TASK 01	APPROXIMATE GPR TRAVERSE LOCATIONS FIGURE 2

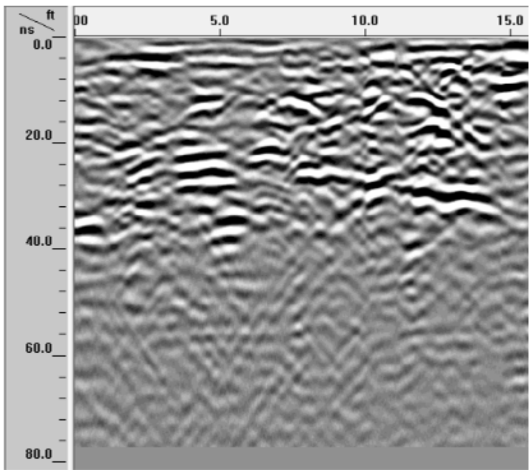
LINE 1, FILE 10
"RAW" FILE



LINE 1, FILE 10
GROUND SURFACE NORMALIZED TO ZERO



LINE 1, FILE 10
BACKGROUND REMOVAL APPLIED



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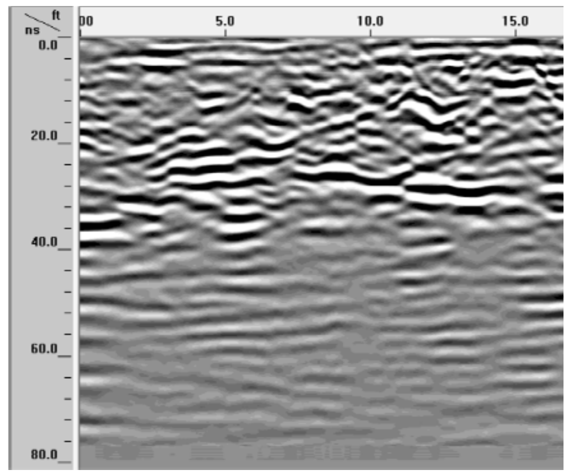
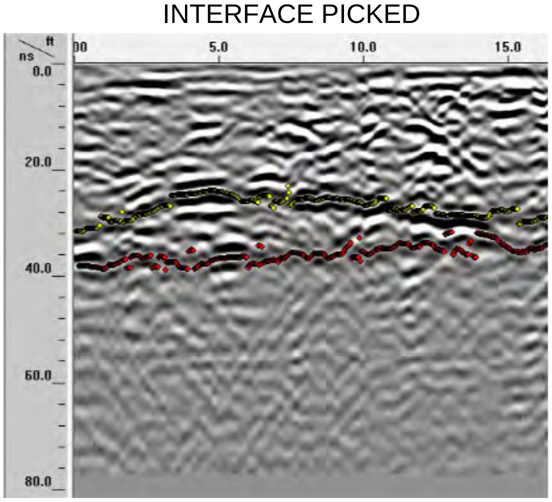
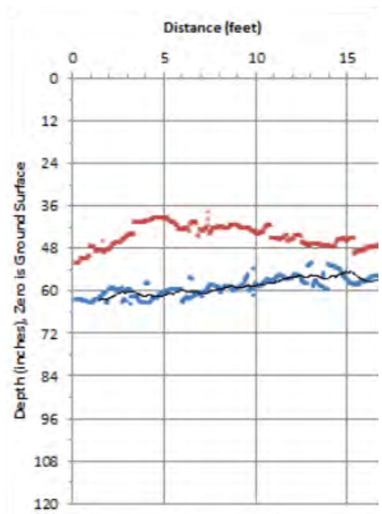
MIGRATED FILE



LINE 1, FILE 10
INTERFACE PICKED



LINE 1, FILE 10
EXCEL PLOT



Schnabel ENGINEERING

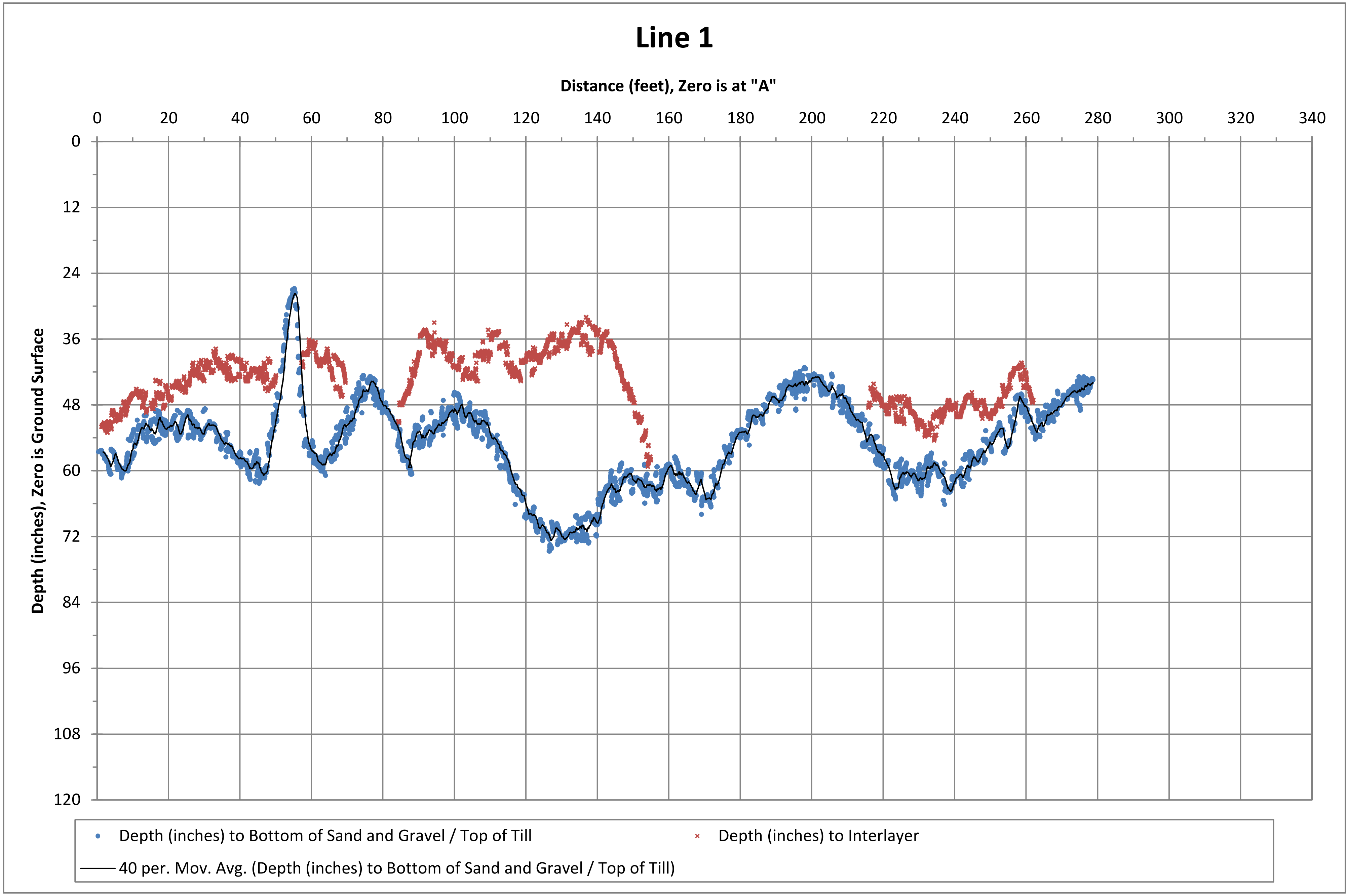
NYSERDA PROPERTY
ADJACENT TO THE WVDP
10282 ROCK SPRINGS ROAD
WEST VALLEY, NEW YORK
PROJECT NO. 15615028 TASK 01

GPR PROCESSING STEPS

FIGURE 3

APPENDIX A

EXCEL PLOTS OF INTERLAYER AND INTERFACE DEPTHS



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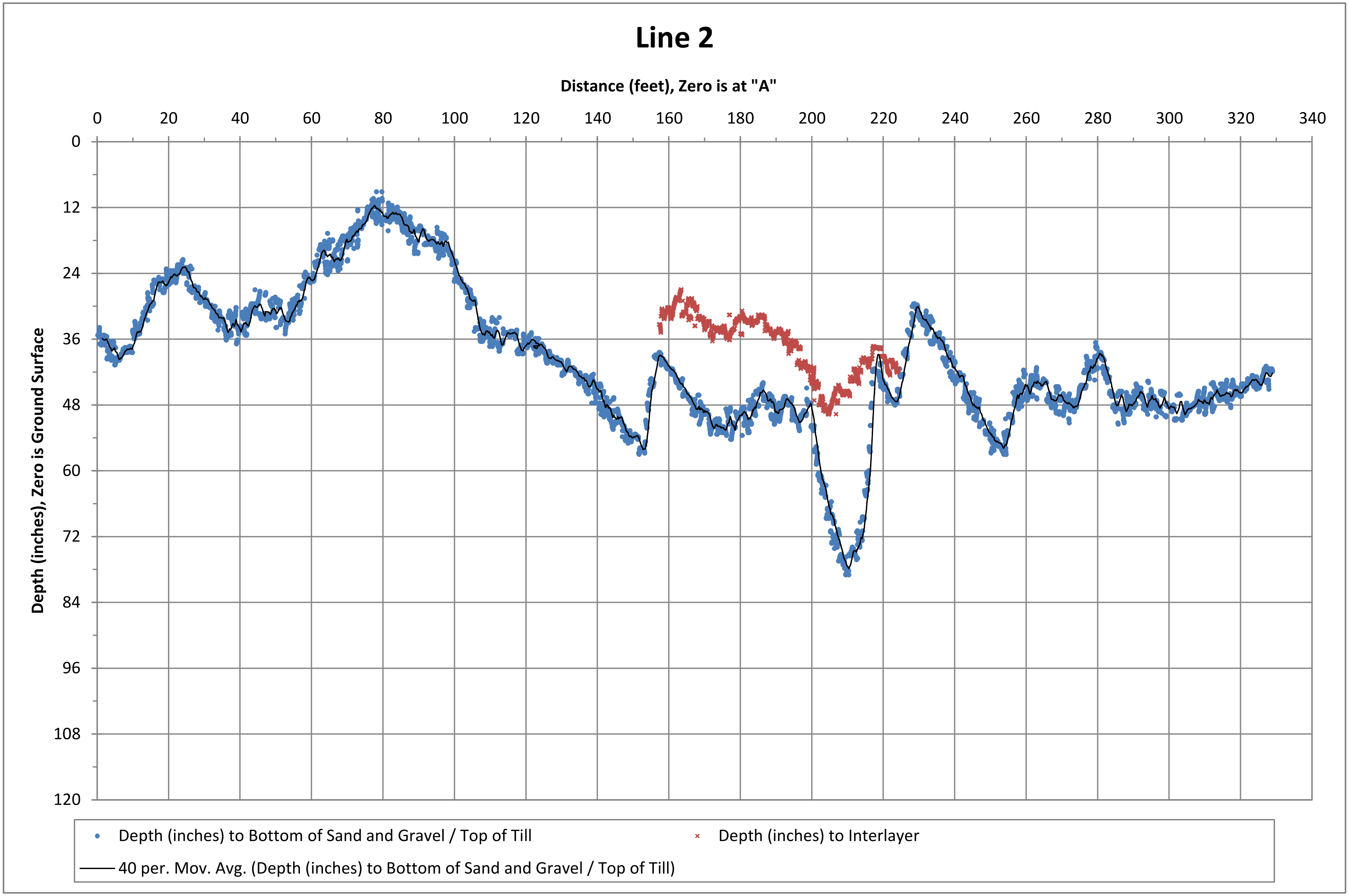
Depth (inches), Zero is Ground Surface
Depth (inches) to Bottom of Sand and Gravel / Top of Till
Depth (inches) to Interlayer
40 per. Mov. Avg. (Depth (inches) to Bottom of Sand and Gravel / Top of Till)



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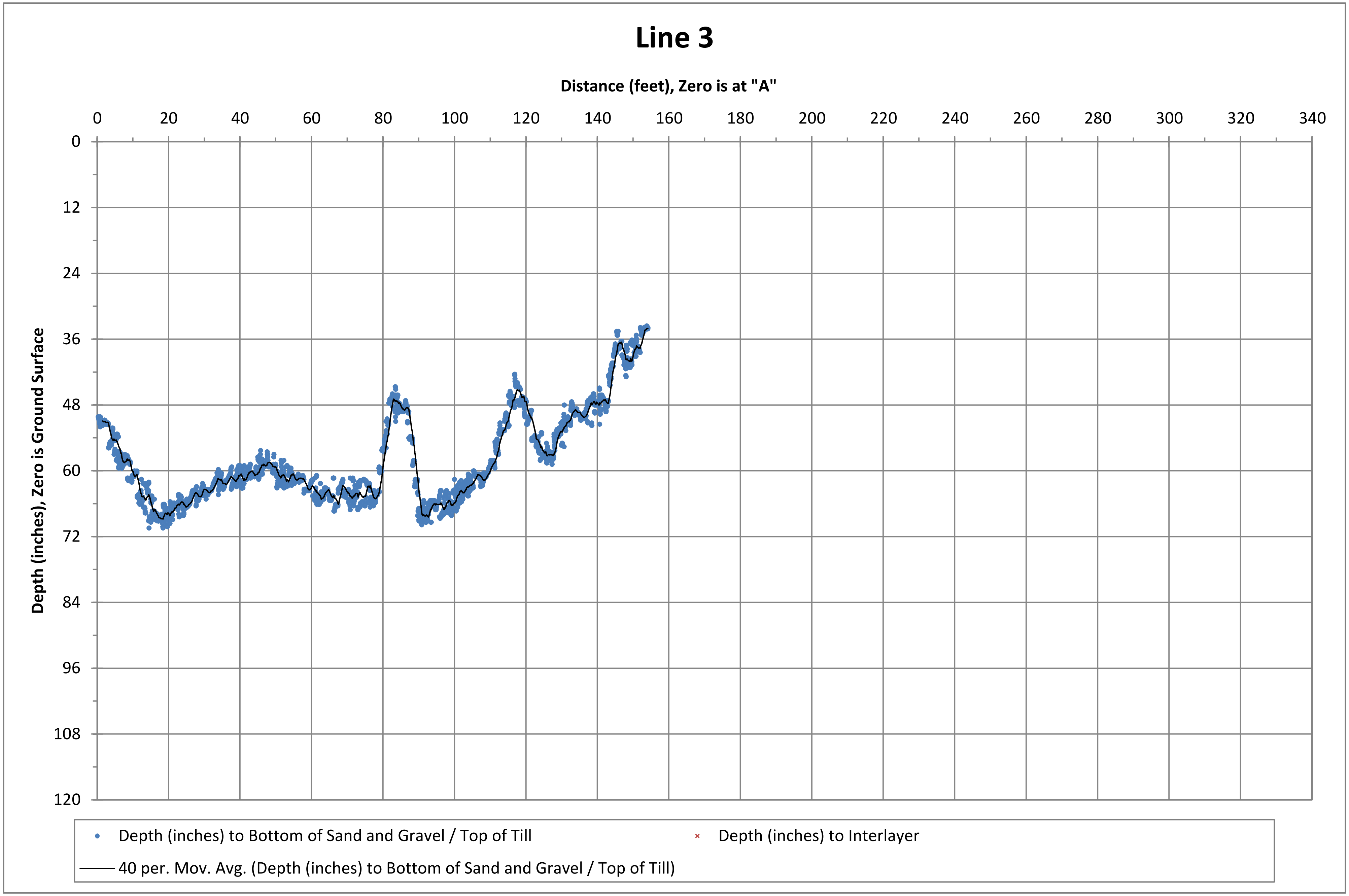
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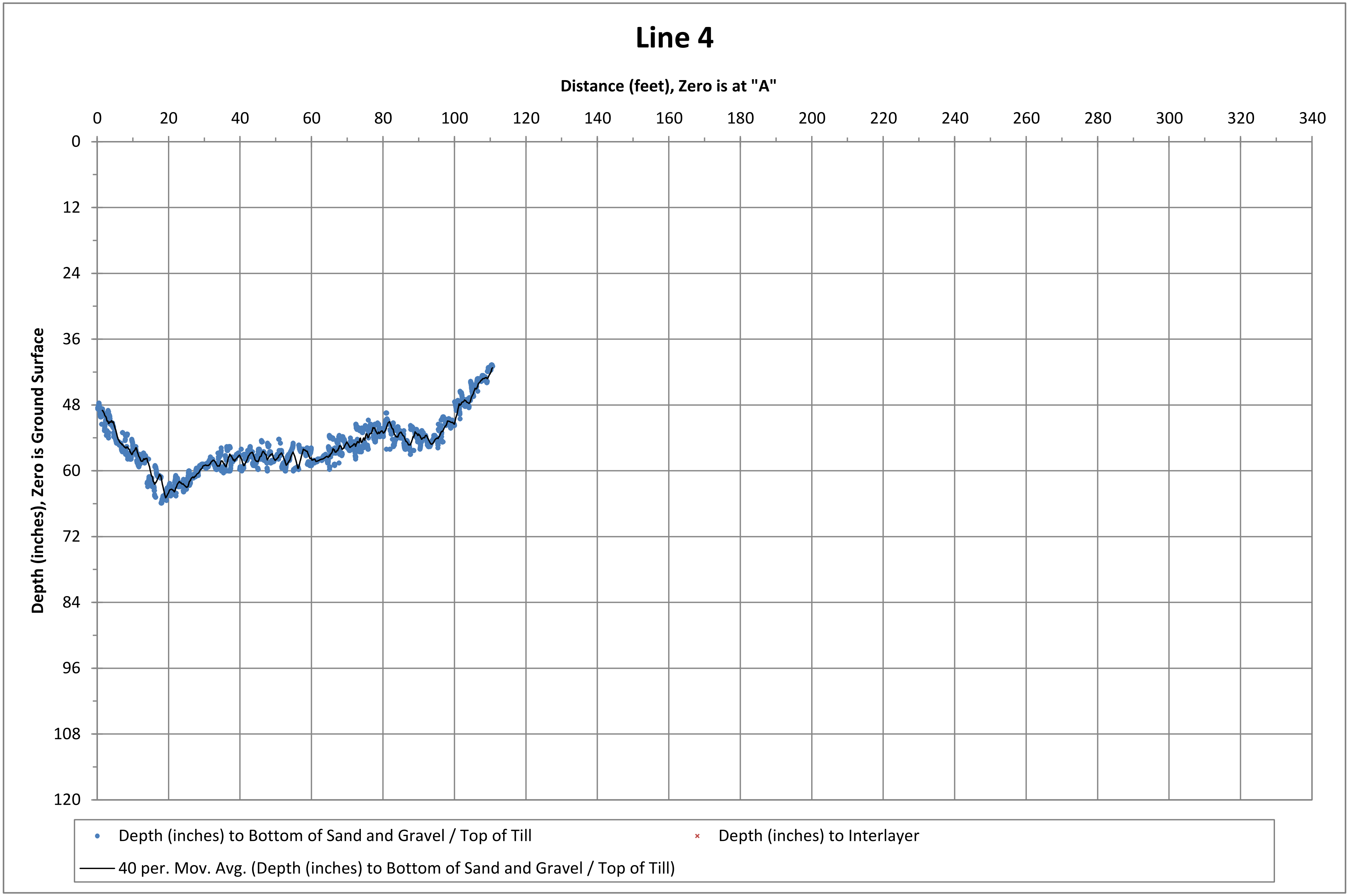
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Depth (inches) to Bottom of Sand and Gravel / Top of Till
Depth (inches) to Interlayer
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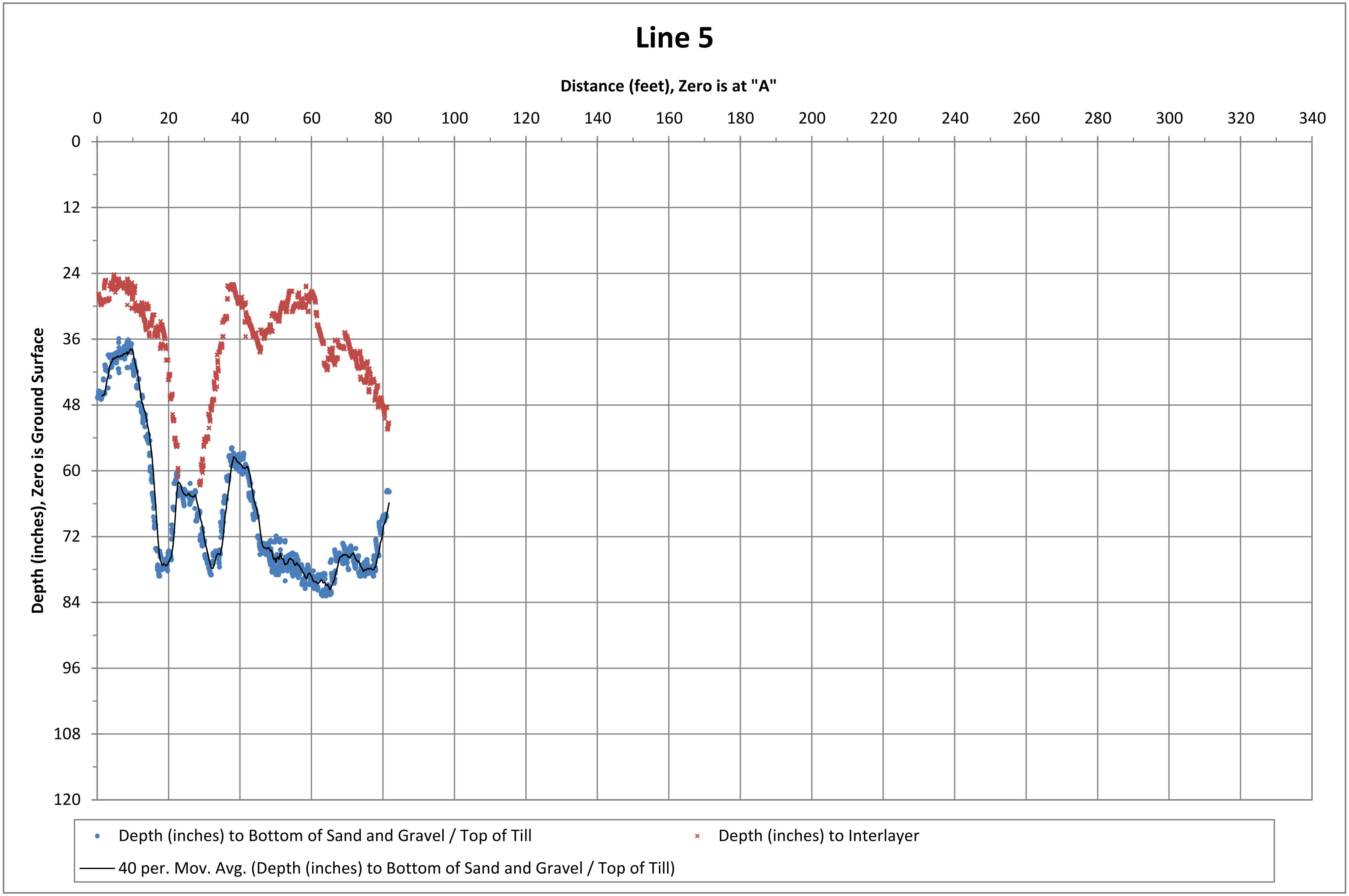
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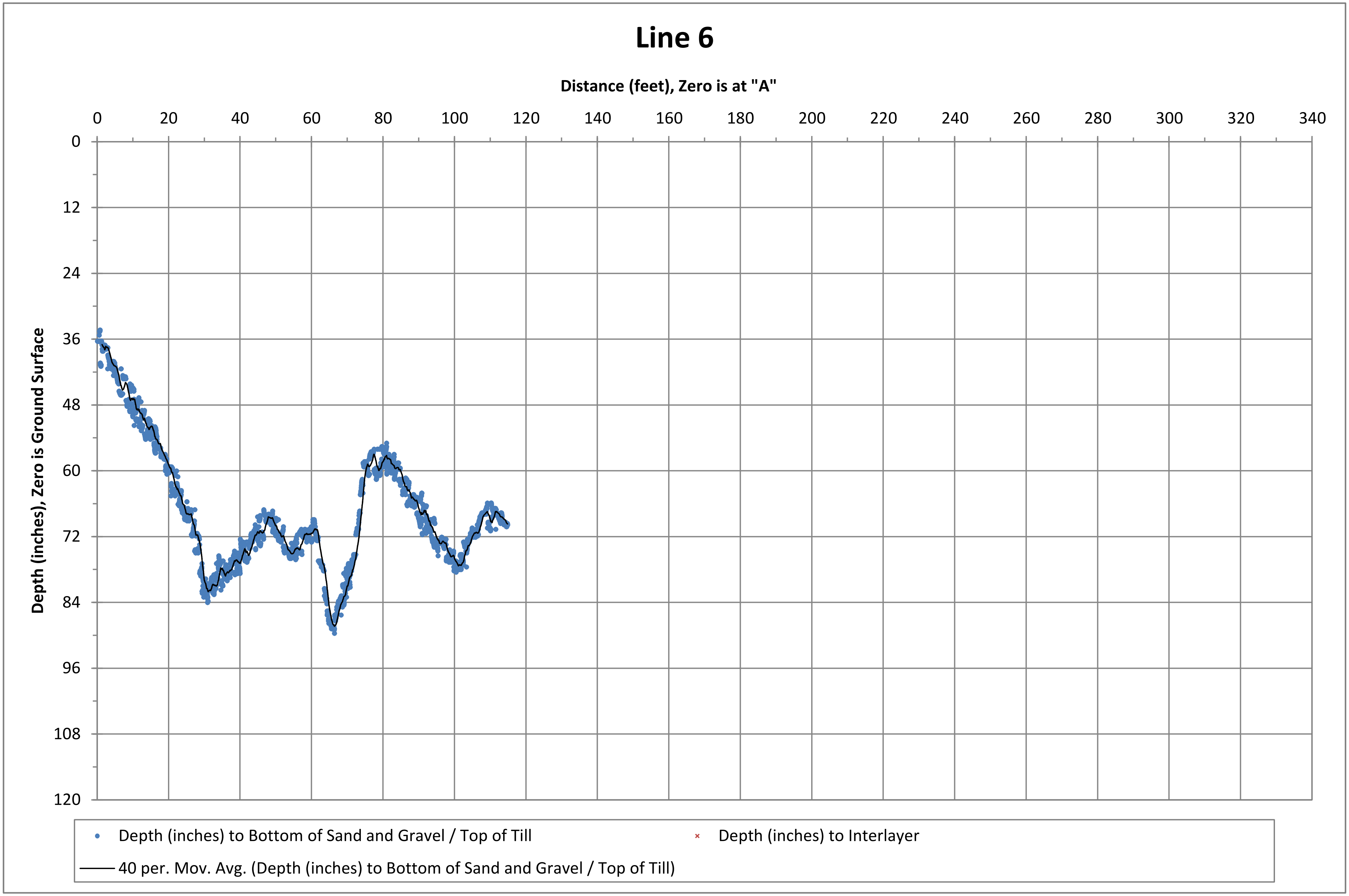

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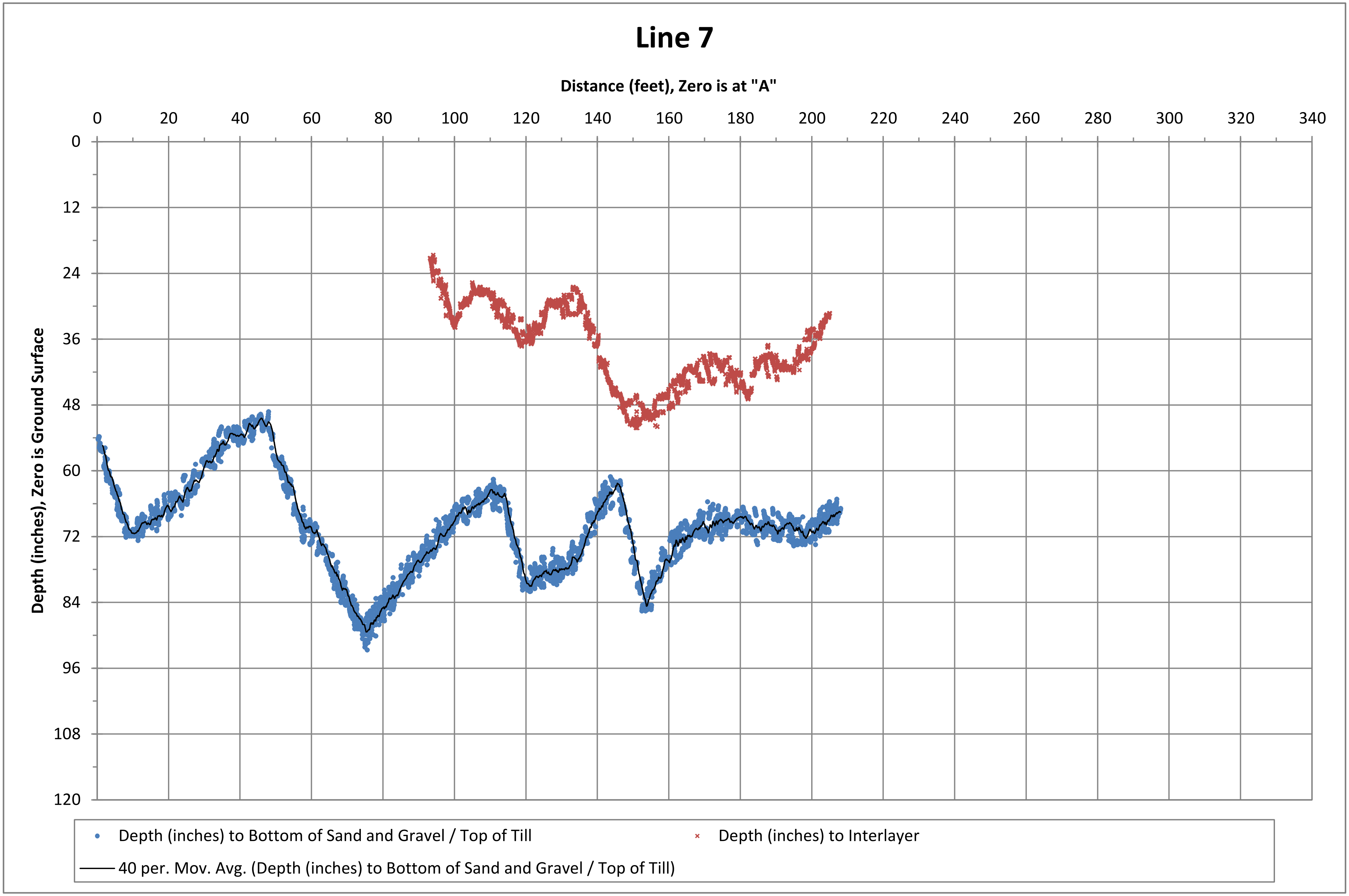
Depth (inches) to Interlayer
40 per. Mov. Avg. (Depth (inches) to Bottom of Sand and Gravel / Top of Till)



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Depth (inches) to Interlayer
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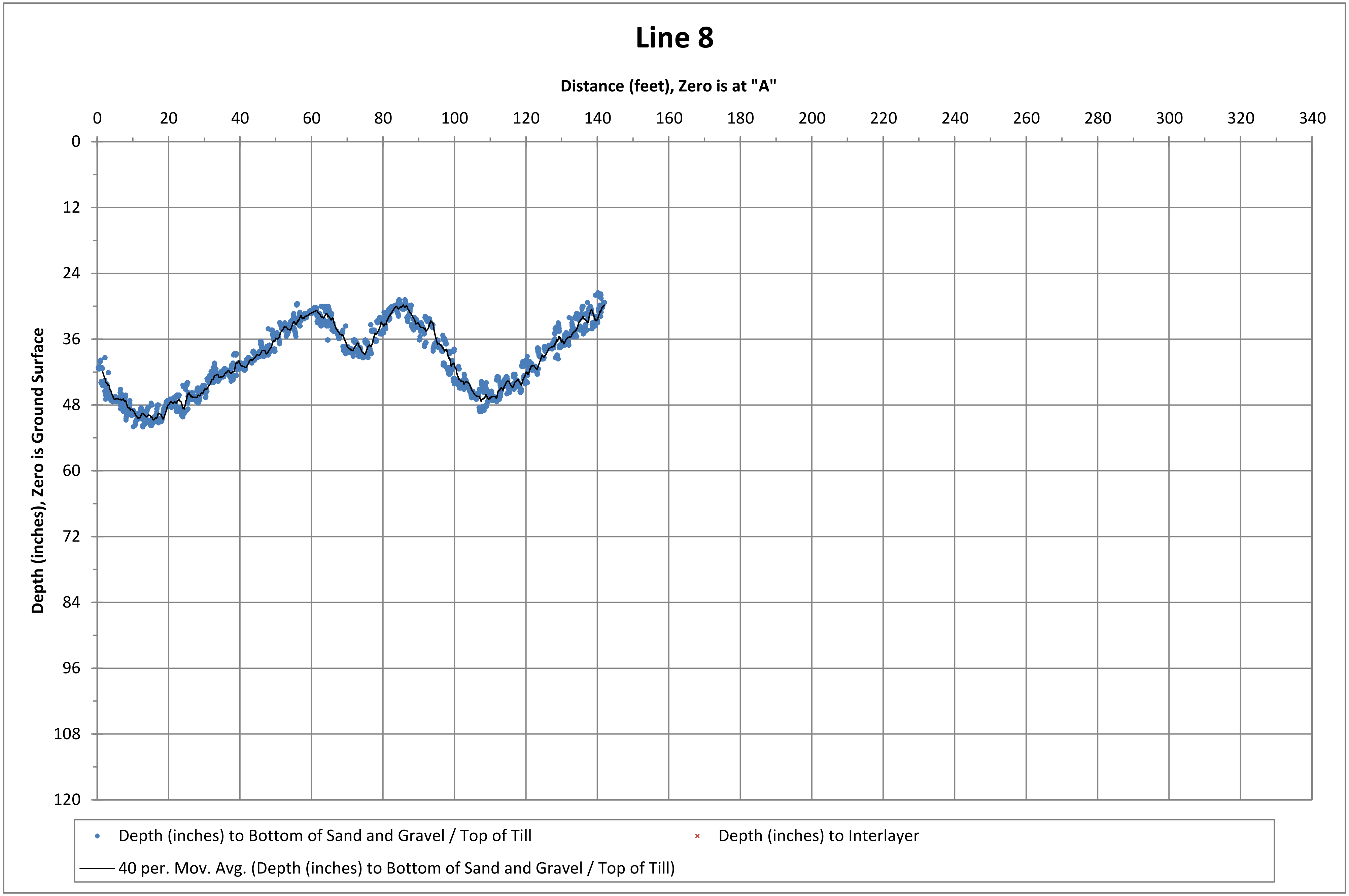

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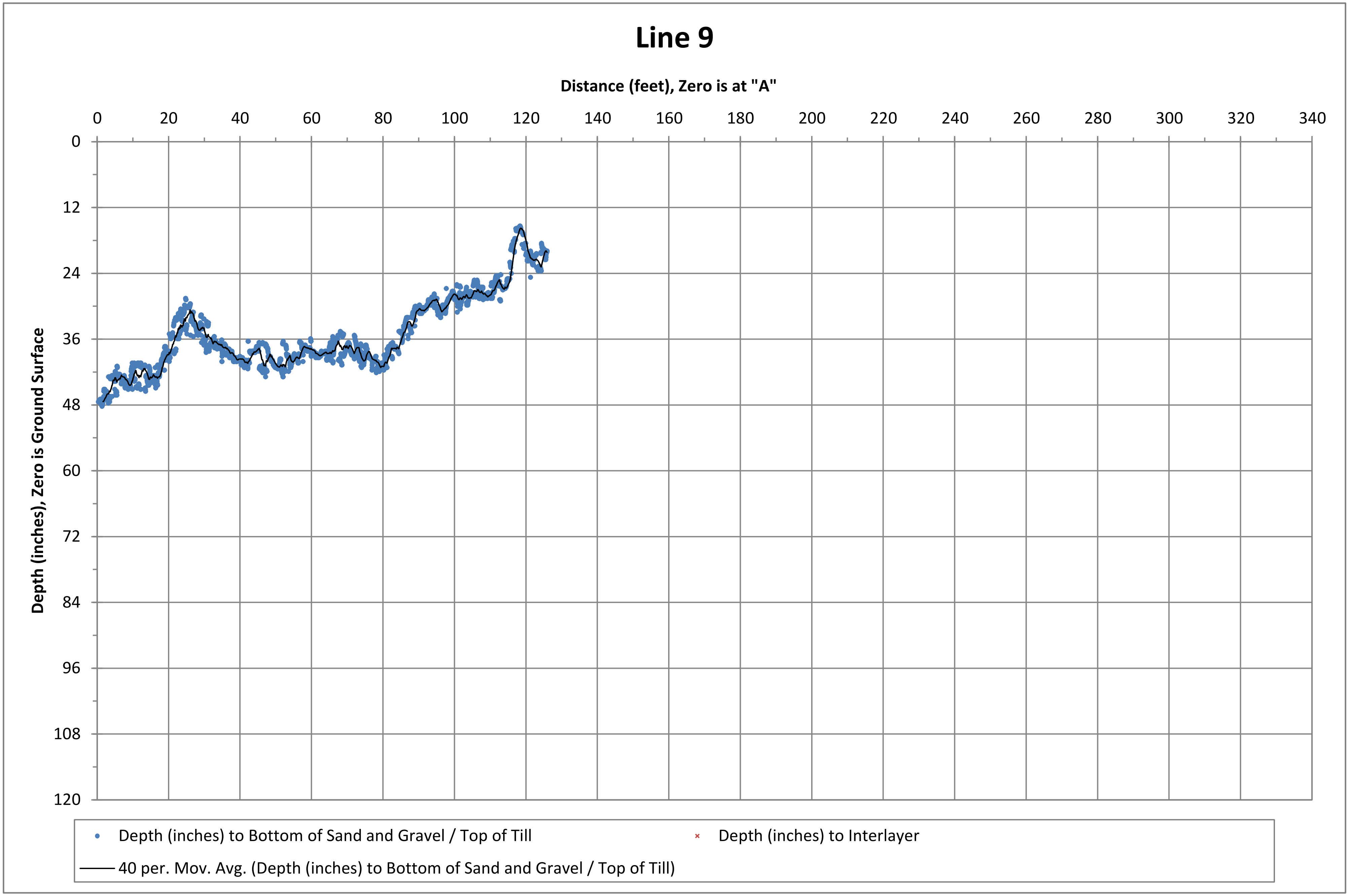
Depth (inches) to Interlayer
40 per. Mov. Avg. (Depth (inches) to Bottom of Sand and Gravel / Top of Till)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Depth (inches) to Interlayer
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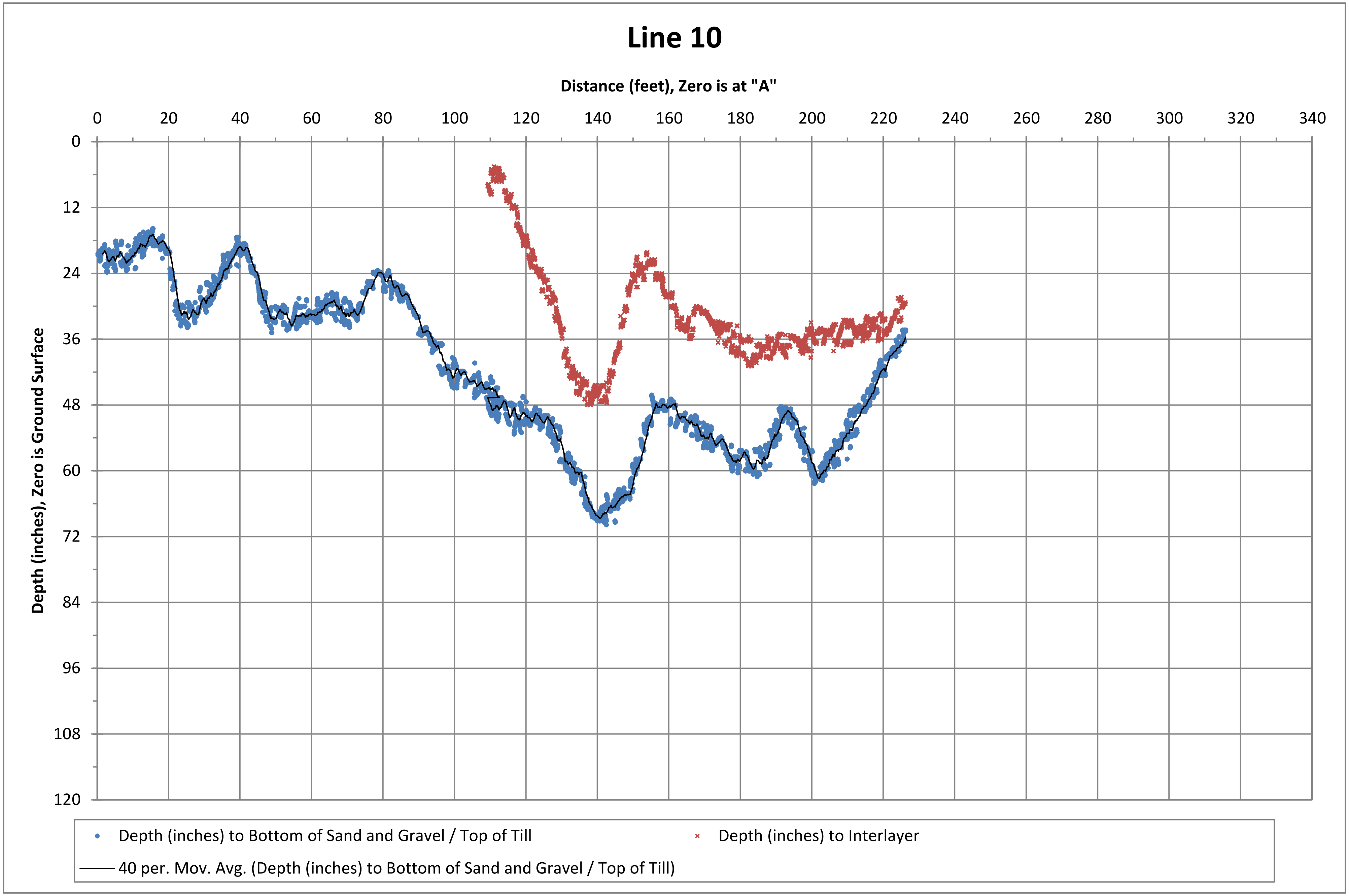

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Depth (inches) to Interlayer
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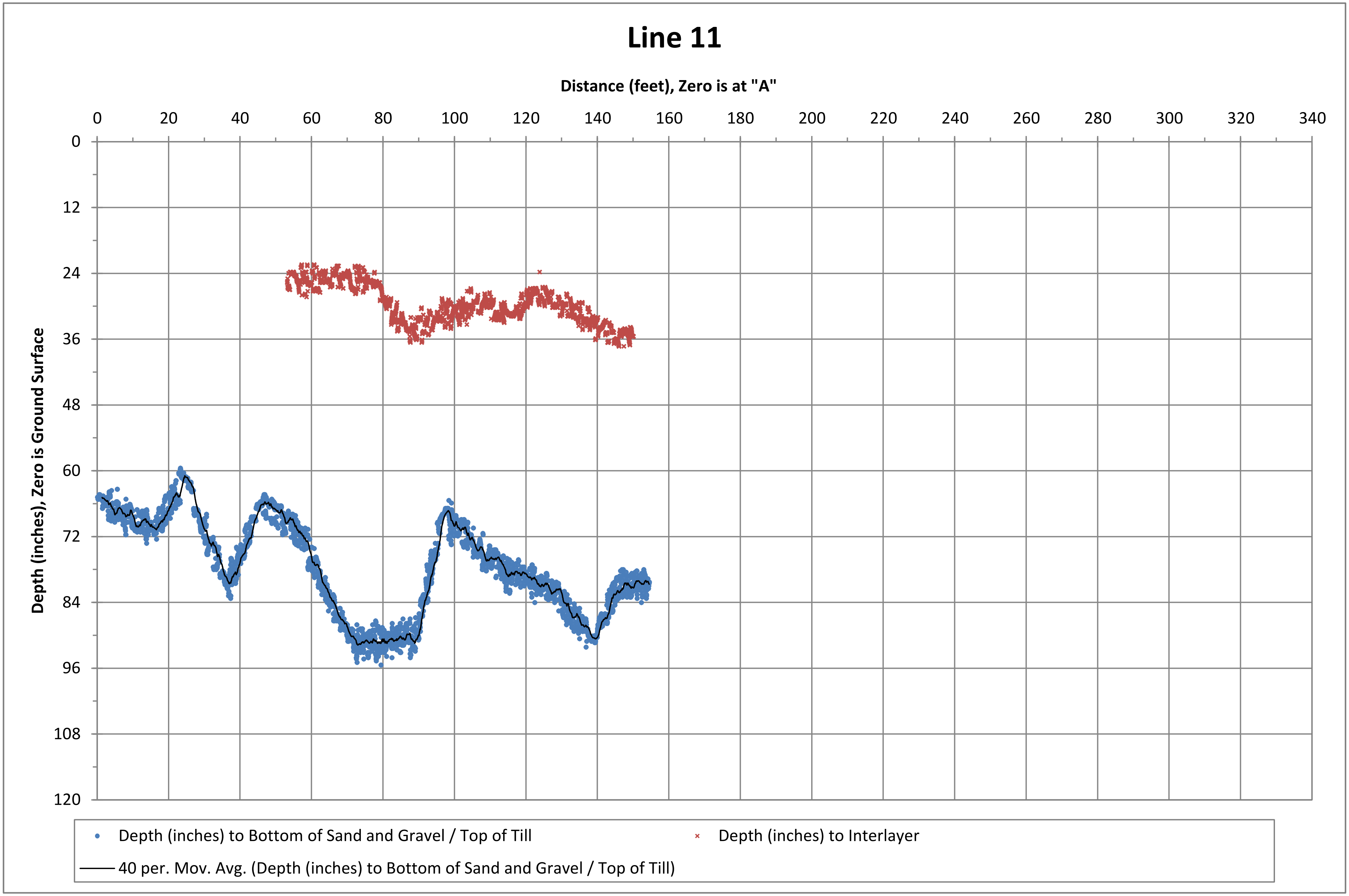

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Depth (inches) to Bottom of Sand and Gravel / Top of Till
Depth (inches) to Interlayer
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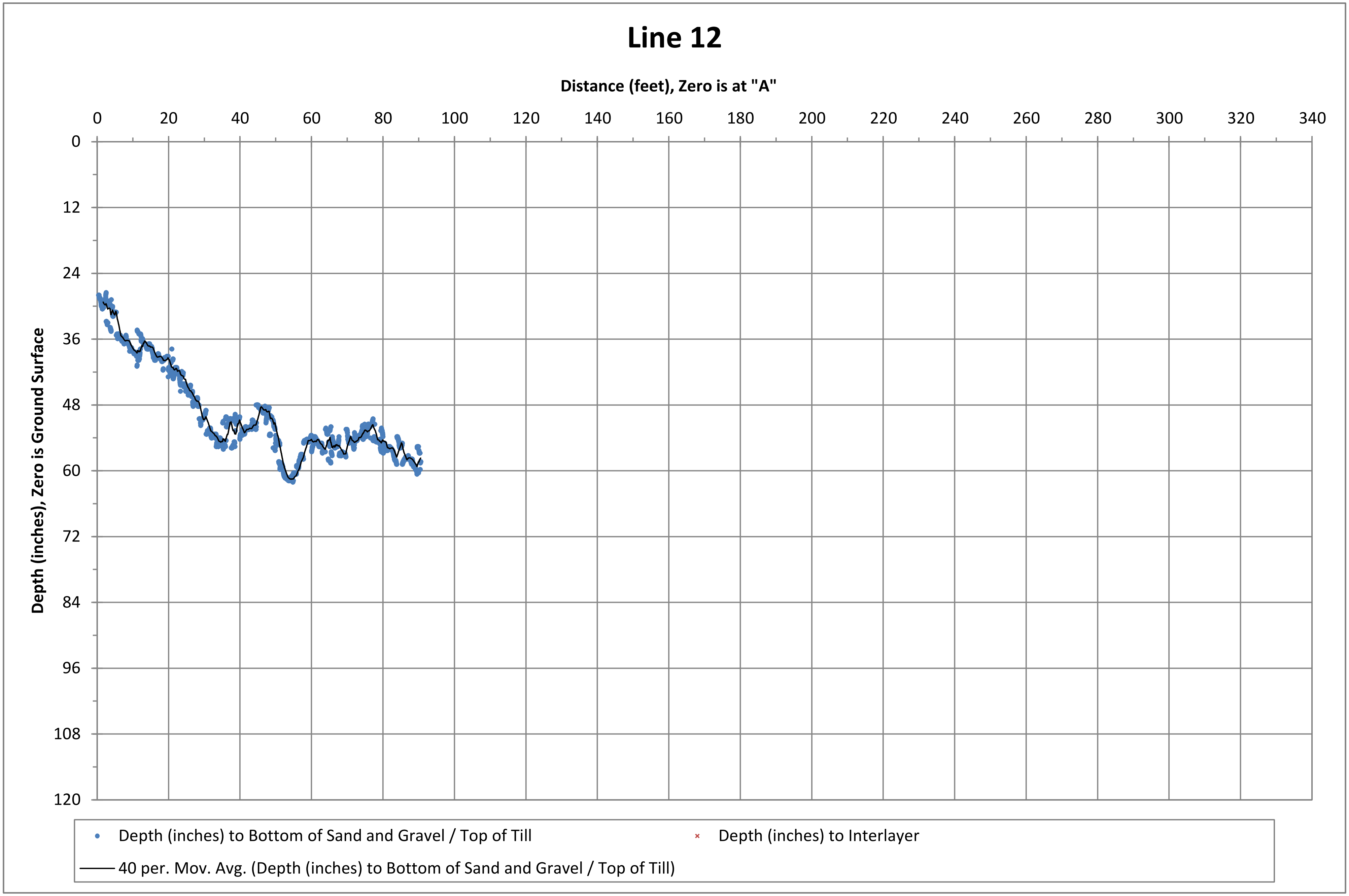

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Depth (inches) to Bottom of Sand and Gravel / Top of Till
Depth (inches) to Interlayer
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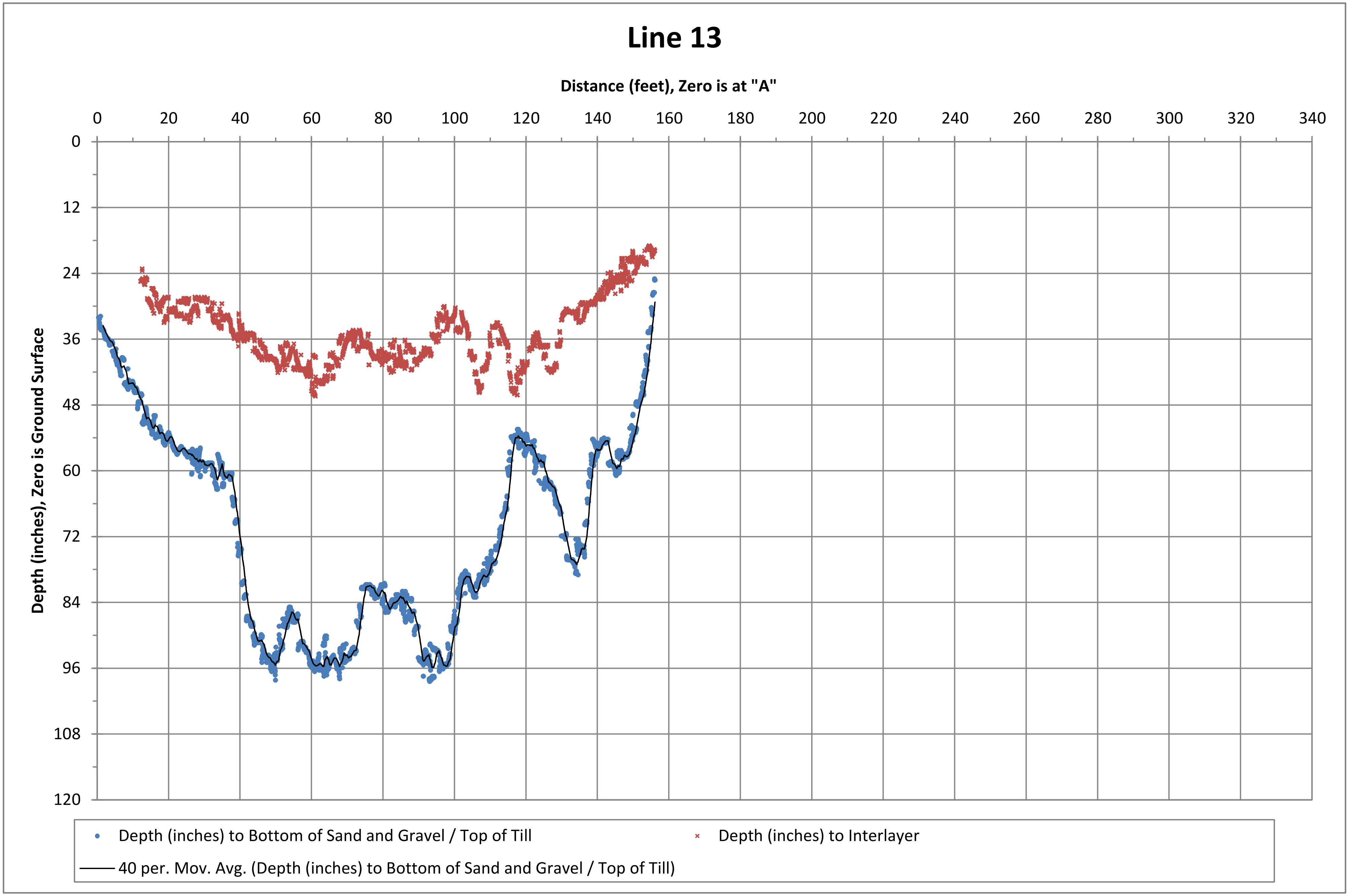

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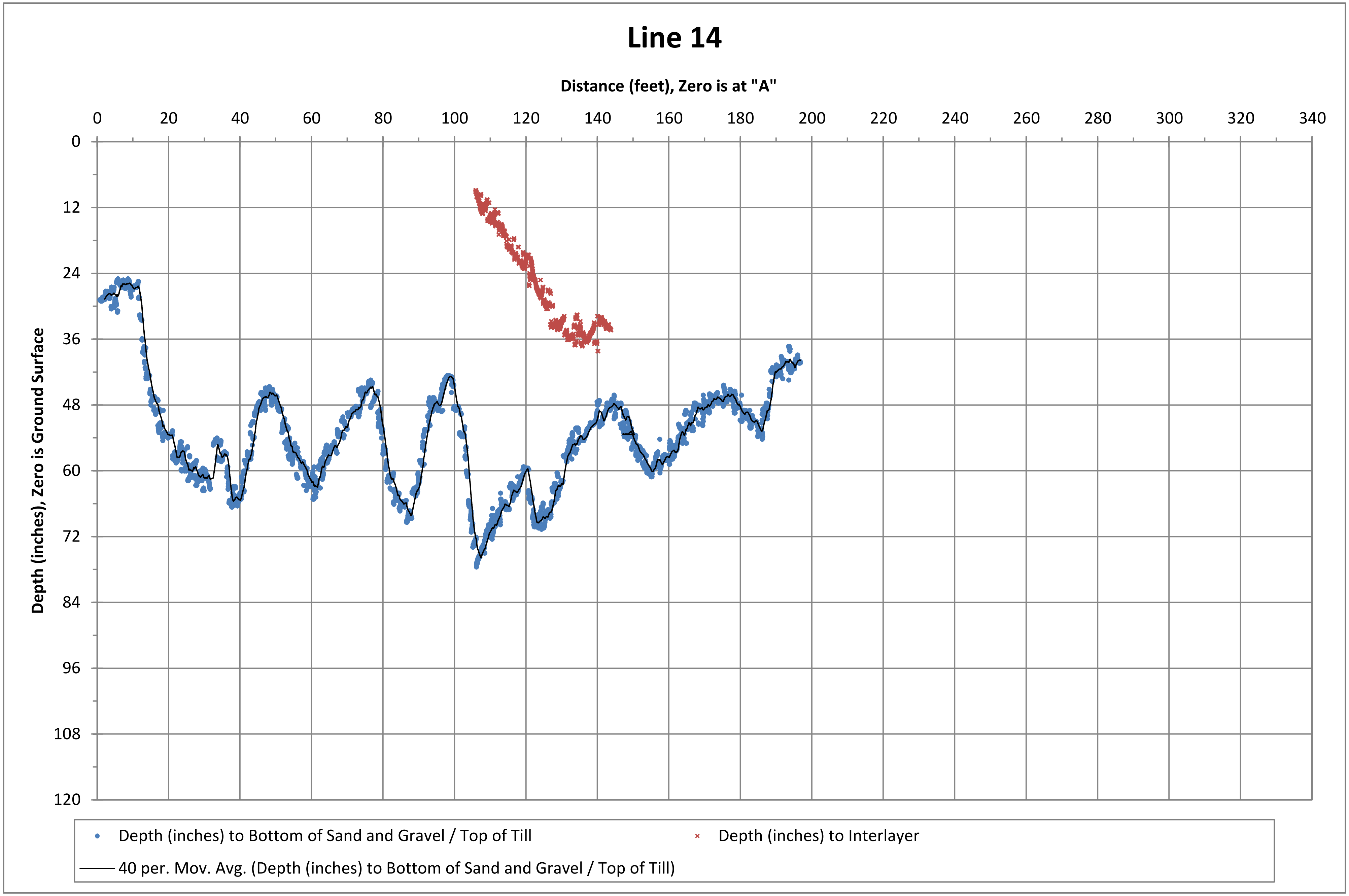
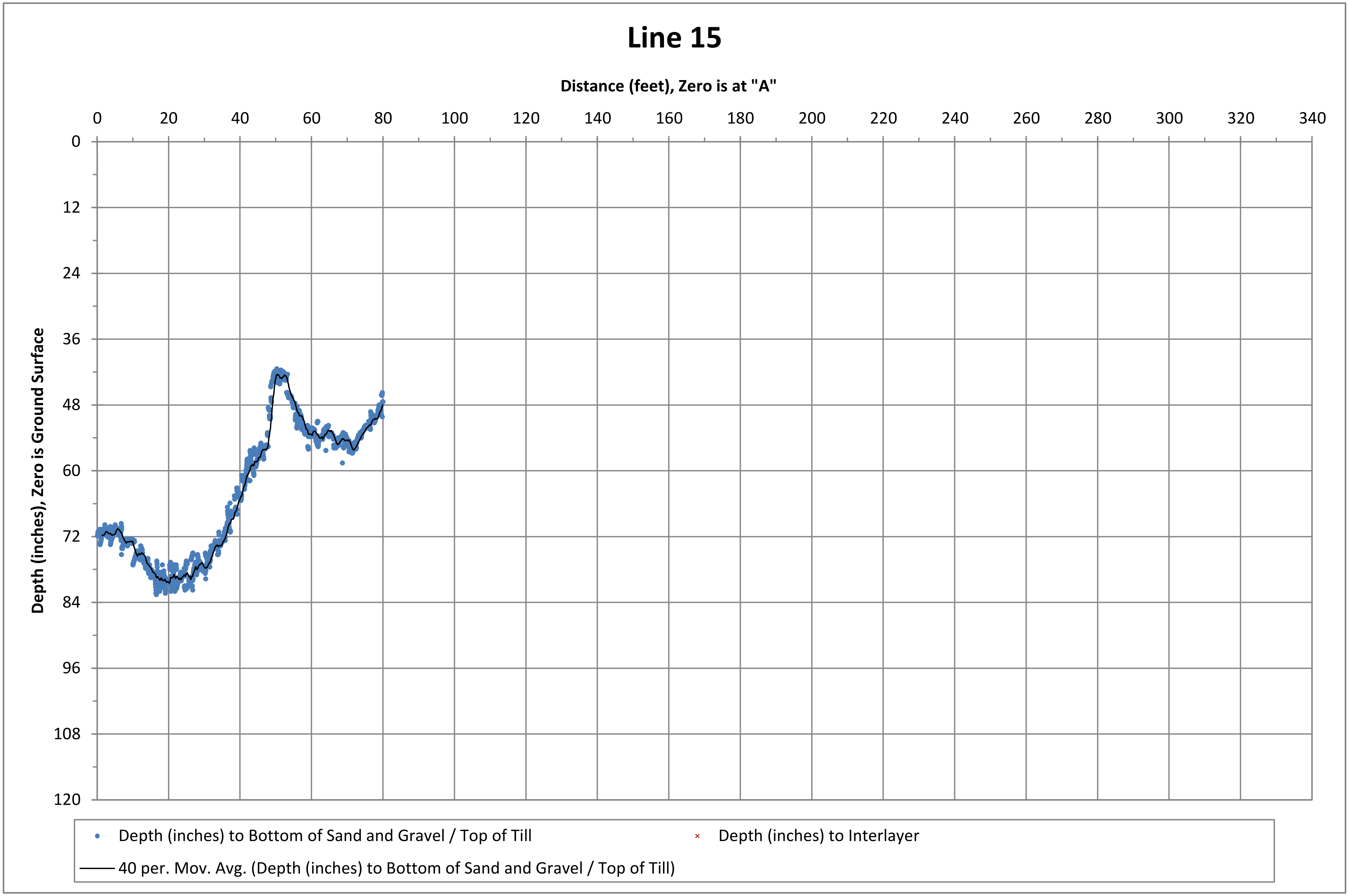
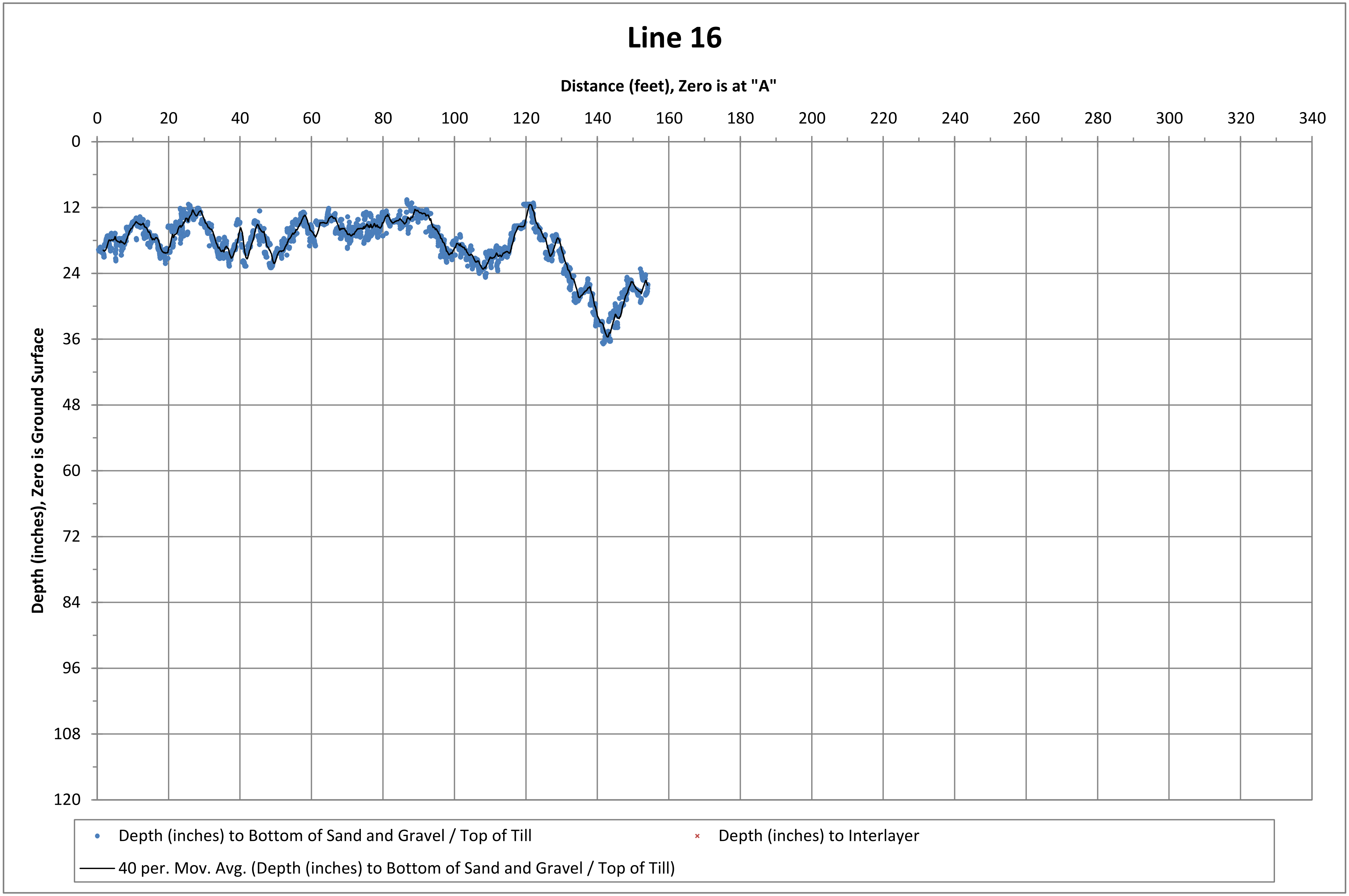
60
72
84
96
108
120
Depth (inches), Zero is Ground Surface
Depth (inches) to Bottom of Sand and Gravel / Top of Till
Depth (inches) to Interlayer
40 per. Mov. Avg. (Depth (inches) to Bottom of Sand and Gravel / Top of Till)

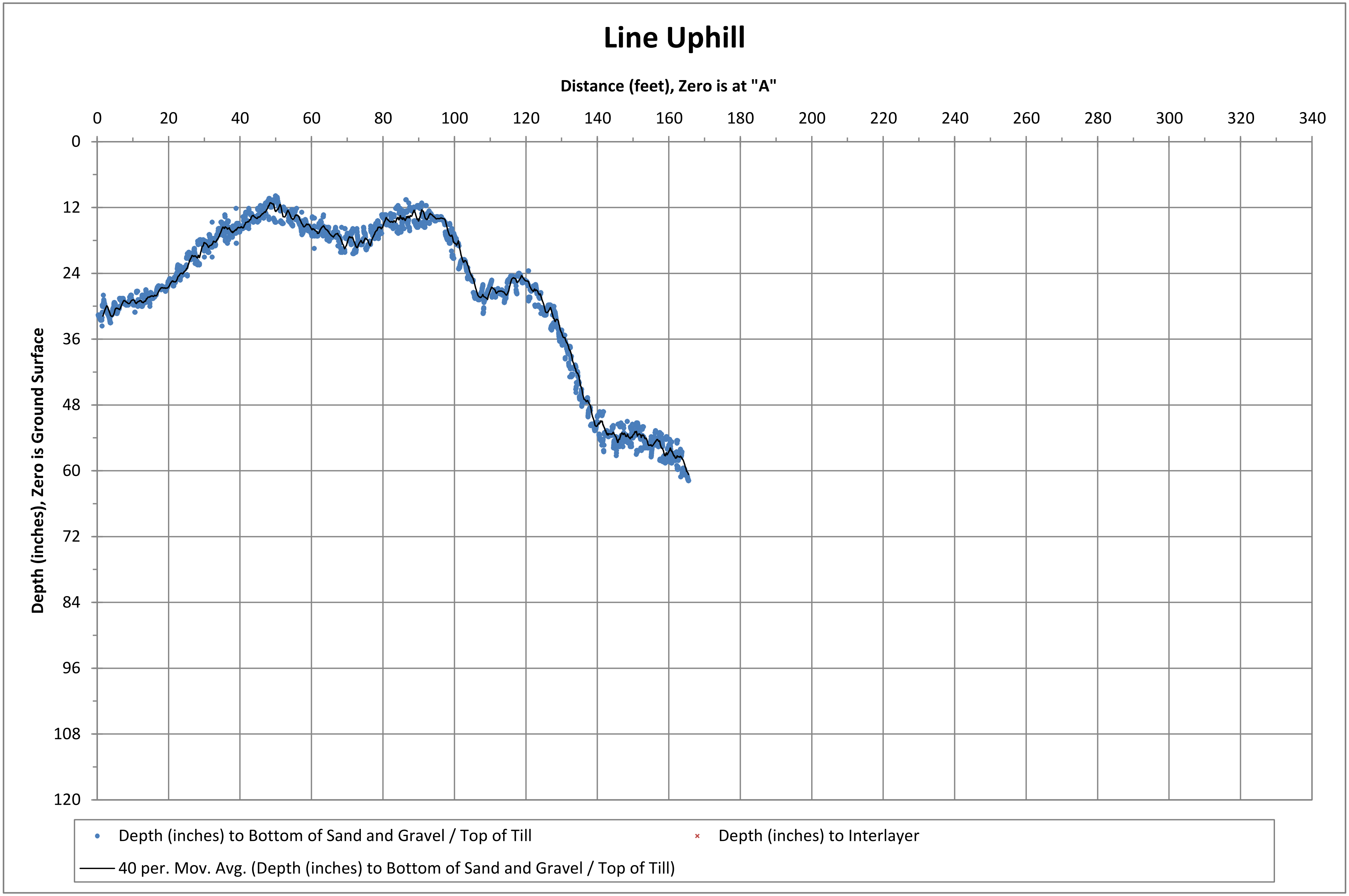


Line 14
Distance (feet), Zero is at "A"
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
0
12
24
36
48
60
72
84
96
108
120
Depth (inches), Zero is Ground Surface
Depth (inches) to Bottom of Sand and Gravel / Top of Till
Depth (inches) to Interlayer
40 per. Mov. Avg. (Depth (inches) to Bottom of Sand and Gravel / Top of Till)



Line 15
Distance (feet), Zero is at "A"
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
Depth (inches), Zero is Ground Surface
0
12
24
36
48
60
72
84
96
108
120
Depth (inches) to Bottom of Sand and Gravel / Top of Till
Depth (inches) to Interlayer
40 per. Mov. Avg. (Depth (inches) to Bottom of Sand and Gravel / Top of Till)


Line 16
Distance (feet), Zero is at "A"
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
Depth (inches), Zero is Ground Surface
0
12
24
36
48
60
72
84
96
108
120
Depth (inches) to Bottom of Sand and Gravel / Top of Till
Depth (inches) to Interlayer
40 per. Mov. Avg. (Depth (inches) to Bottom of Sand and Gravel / Top of Till)



Line Uphill
Distance (feet), Zero is at "A"
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
0
12
24
36
48
60
72
84
96
108
120
Depth (inches), Zero is Ground Surface
Depth (inches) to Bottom of Sand and Gravel / Top of Till
Depth (inches) to Interlayer
40 per. Mov. Avg. (Depth (inches) to Bottom of Sand and Gravel / Top of Till)

APPENDIX B

GPR DATA FILES

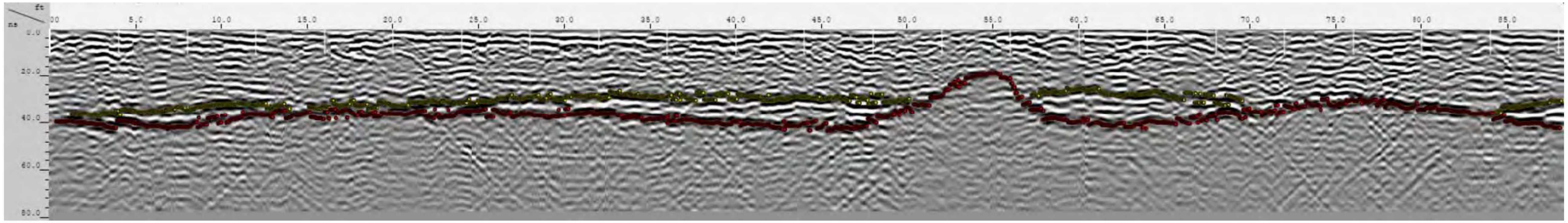
APPENDIX B1

GROUP 1: POINT BAR AND TERRACES 2 AND 3

LINE 1

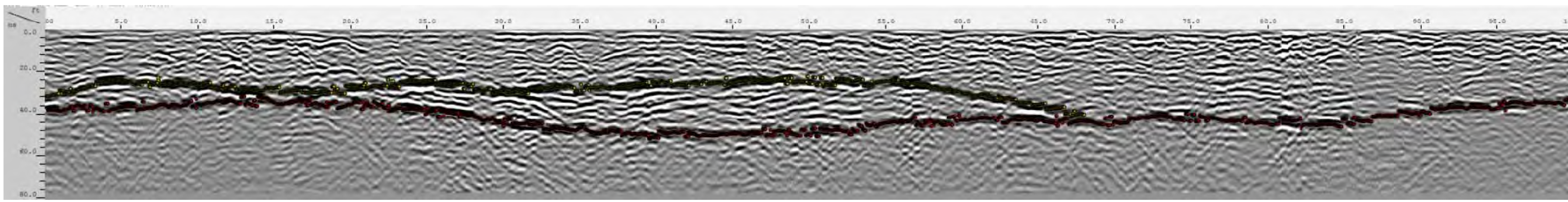
FILE 9
Starts at 1A

Ends at 1B



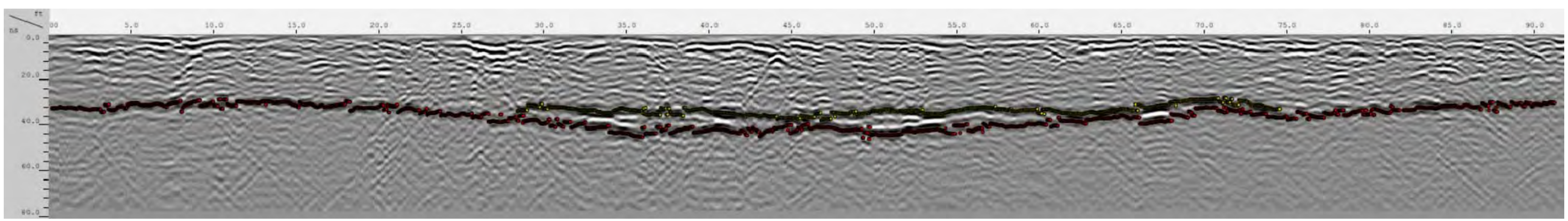
FILE 10
Starts at 1B

Ends at 1C



FILE 11
Starts at 1C

Ends at 1D



Legend

- Interpreted Interlayer Within Sand/Gravel
- Interpreted Interface Between Sand/Gravel and Till

Schnabel ENGINEERING

NYSERDA PROPERTY
ADJACENT TO THE WVDP
10282 ROCK SPRINGS ROAD
WEST VALLEY, NEW YORK
PROJECT NO. 15615028 TASK 01

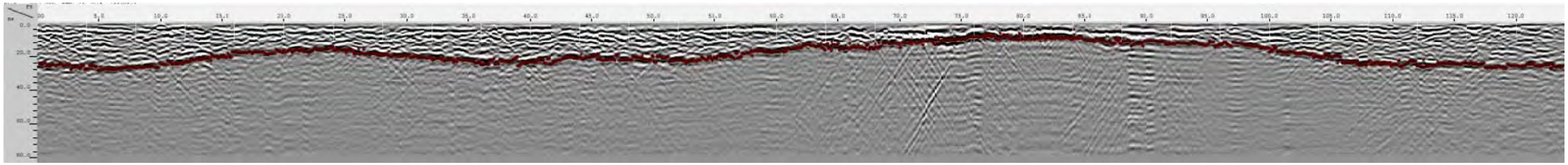
POINT BAR GPR DATA
LINE 1

FIGURE B1-1

LINE 2

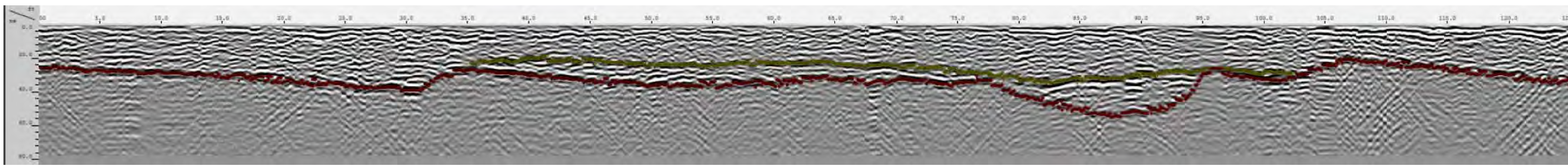
FILE 12
Starts at 2A

Ends at 2B



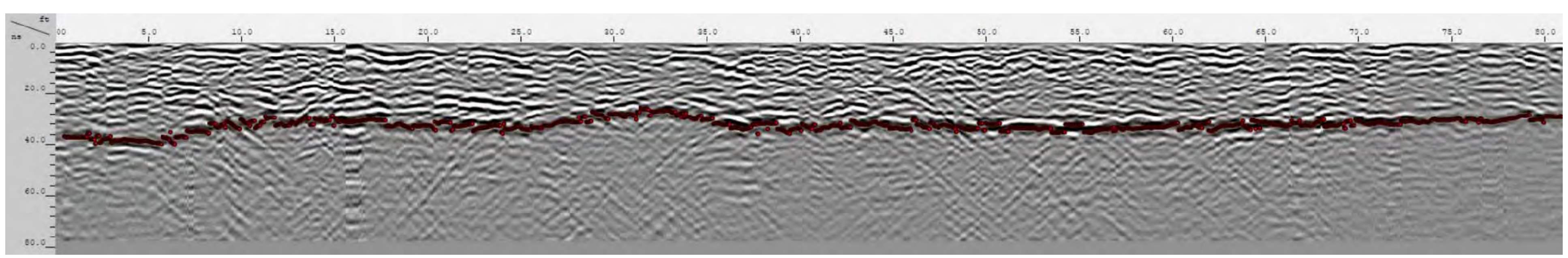
FILE 13
Starts at 2B

Ends at 2C



FILE 14
Starts at 2C

Ends at 2D



Legend

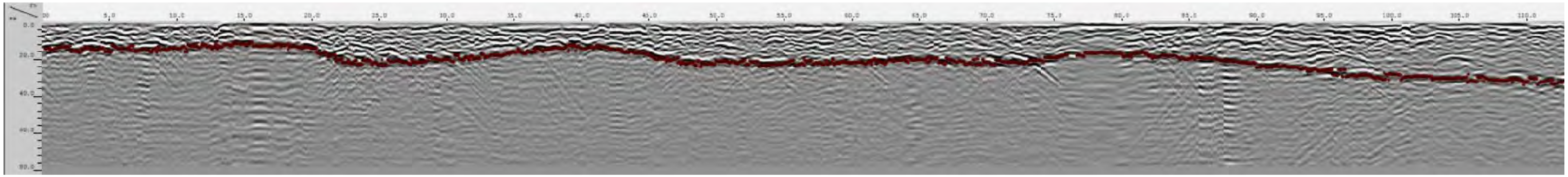
- Interpreted Interlayer Within Sand/Gravel
- Interpreted Interface Between Sand/Gravel and Till

Schnabel ENGINEERING	NYSERDA PROPERTY ADJACENT TO THE WVDP 10282 ROCK SPRINGS ROAD WEST VALLEY, NEW YORK PROJECT NO. 15615028 TASK 01	POINT BAR GPR DATA LINE 2 FIGURE B1-2

LINE 10

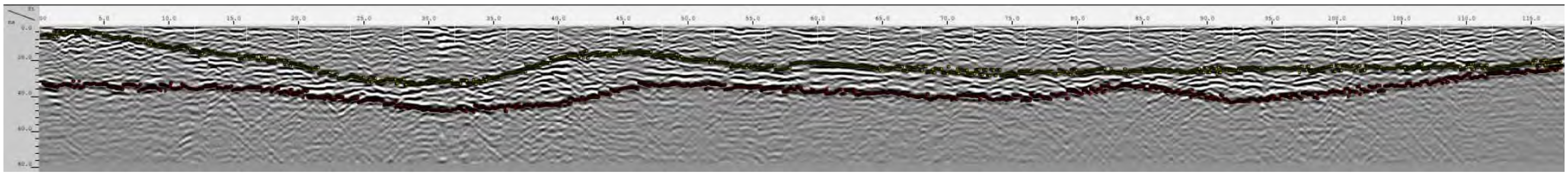
FILE 15
Starts at 10A

Ends at 10B



FILE 16
Starts at 10B

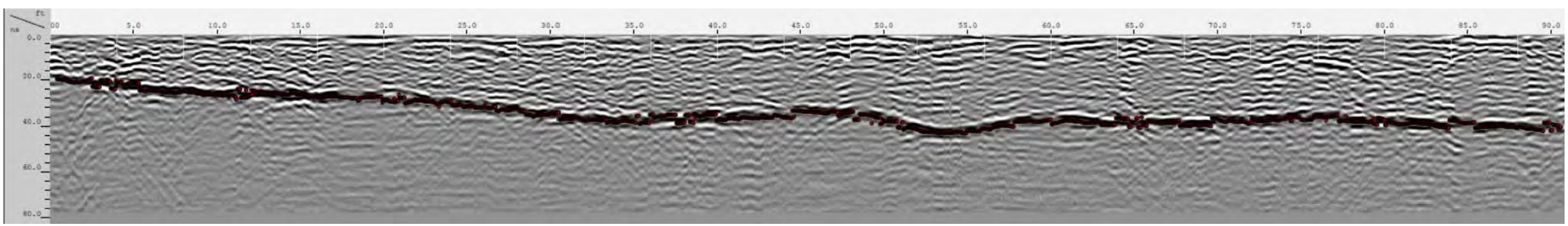
Ends at 10C



LINE 12

FILE 33
Starts at 12A

Ends at 12B



Legend

- Interpreted Interlayer Within Sand/Gravel (green)
- Interpreted Interface Between Sand/Gravel and Till (red)

Schnabel ENGINEERING

NYSERDA PROPERTY
ADJACENT TO THE WVDP
10282 ROCK SPRINGS ROAD
WEST VALLEY, NEW YORK
PROJECT NO. 15615028 TASK 01

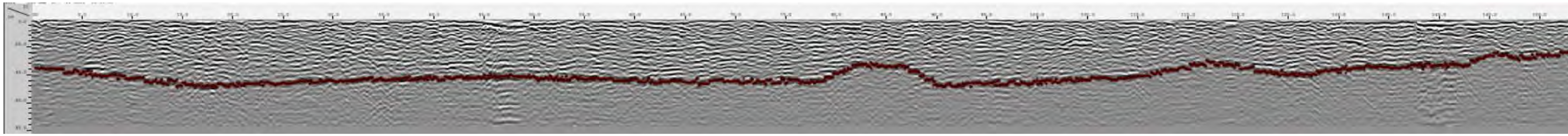
POINT BAR GPR DATA
LINES 10 & 12

FIGURE B1-3

LINE 3

FILE 20
Starts at 3A

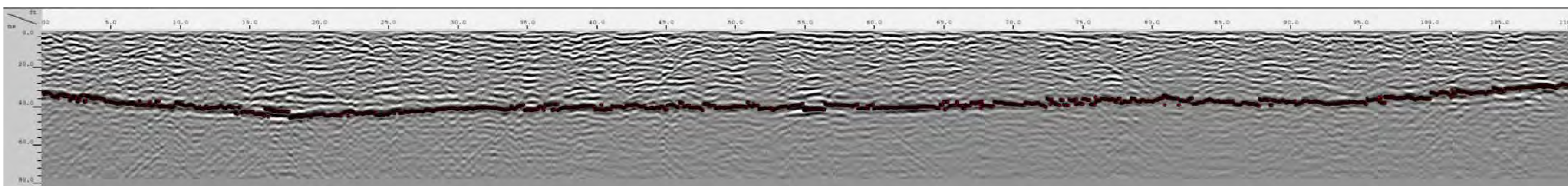
Ends at 3B



LINE 4

FILE 19
Starts at 4A

Ends at 4B



Legend

- Interpreted Interlayer Within Sand/Gravel
- Interpreted Interface Between Sand/Gravel and Till

Schnabel ENGINEERING

NYSERDA PROPERTY
ADJACENT TO THE WVDP
10282 ROCK SPRINGS ROAD
WEST VALLEY, NEW YORK
PROJECT NO. 15615028 TASK 01

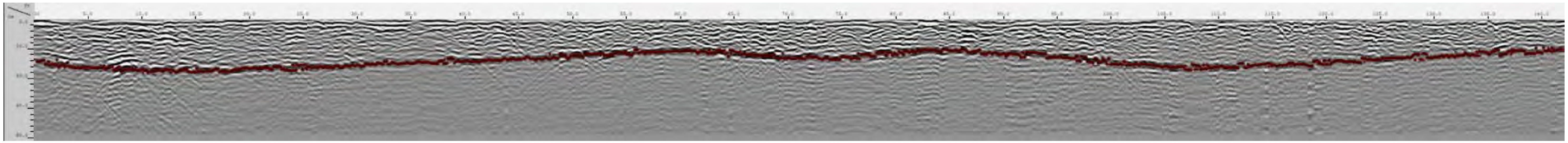
TERRACE 2 GPR DATA
LINES 3 & 4

FIGURE B1-4

LINE 8

FILE 18
Starts at 8A

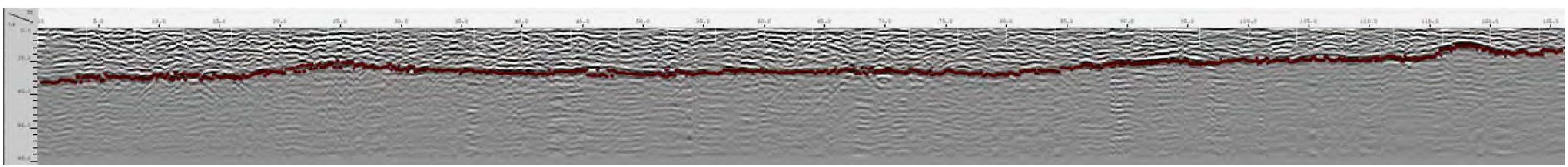
Ends at 8B



LINE 9

FILE 17
Starts at 9A

Ends at 9B



Legend

- Interpreted Interlayer Within Sand/Gravel
- Interpreted Interface Between Sand/Gravel and Till

Schnabel ENGINEERING

NYSERDA PROPERTY
ADJACENT TO THE WVDP
10282 ROCK SPRINGS ROAD
WEST VALLEY, NEW YORK
PROJECT NO. 15615028 TASK 01

TERRACE 3 GPR DATA
LINES 8 & 9

FIGURE B1-5

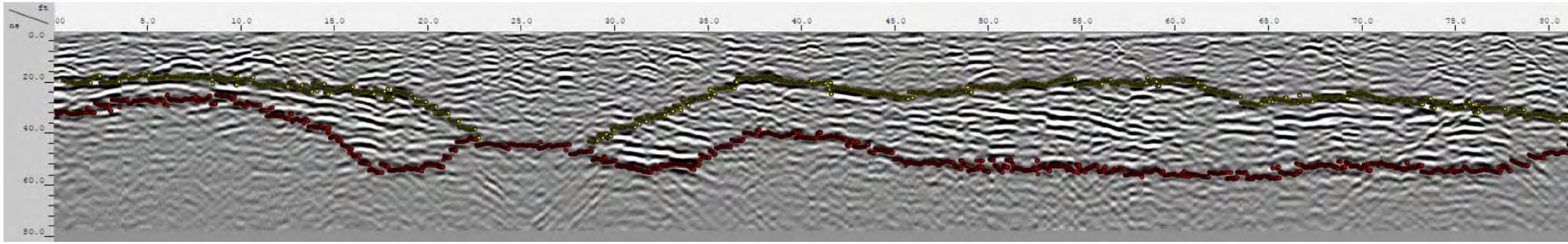
APPENDIX B2

GROUP 2: TERRACE 1 AND BETWEEN TERRACES 1 AND 2 AND OLDEST SURFACE

LINE 5

FILE 26
Starts at 5A

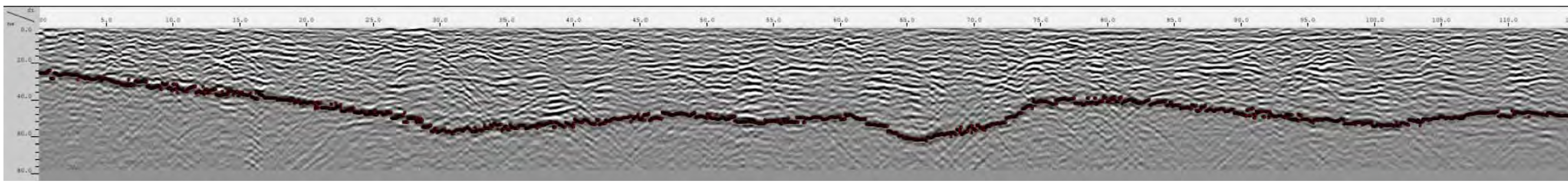
Ends at 5B



LINE 6

FILE 25
Starts at 6A

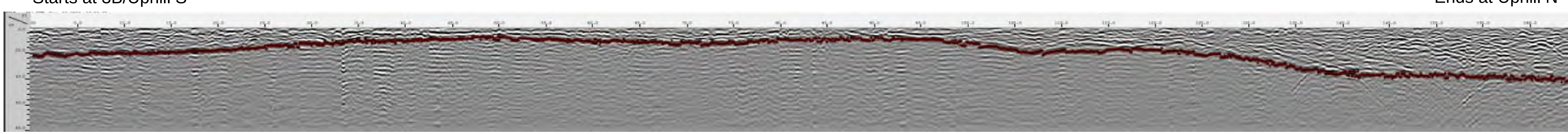
Ends at 6B



LINE Uphill

FILE 24
Starts at 3B/Uphill S

Ends at Uphill N



Legend

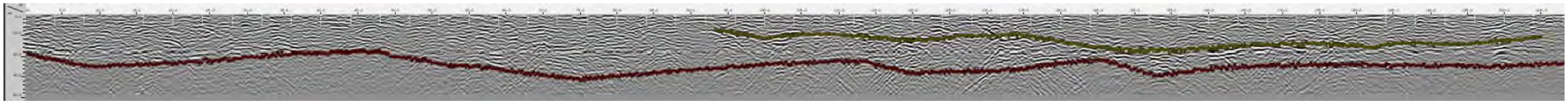
- Interpreted Interlayer Within Sand/Gravel
- Interpreted Interface Between Sand/Gravel and Till

Schnabel ENGINEERING	NYSERDA PROPERTY ADJACENT TO THE WVDP 10282 ROCK SPRINGS ROAD WEST VALLEY, NEW YORK PROJECT NO. 15615028 TASK 01	TERRACE 1 AND BETWEEN TERRACE 1 & 2 GPR DATA LINES 5 & 6 & UPHILL FIGURE B2-1

LINE 7

FILE 30
Starts at 7A

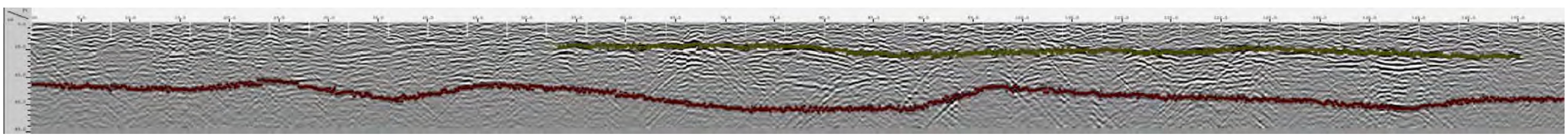
Ends at 7B



LINE 11

FILE 31
Starts at 11A

Ends at 11B



Legend

- Interpreted Interlayer Within Sand/Gravel
- Interpreted Interface Between Sand/Gravel and Till

Schnabel ENGINEERING

NYSERDA PROPERTY
ADJACENT TO THE WVDP
10282 ROCK SPRINGS ROAD
WEST VALLEY, NEW YORK
PROJECT NO. 15615028 TASK 01

OLDEST SURFACE GPR DATA
LINES 7 & 11

FIGURE B2-2

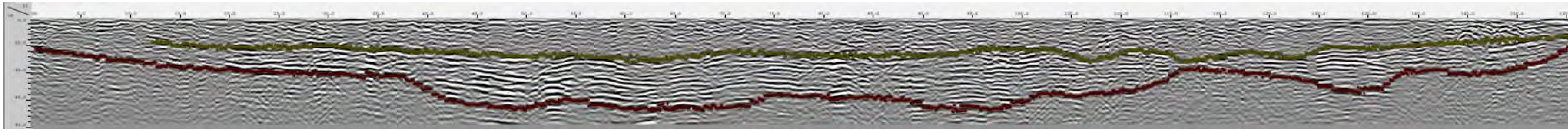
APPENDIX B3

GROUP 3: SOUTH OF THE MEANDER

LINE 13

FILE 34
Starts at 13A

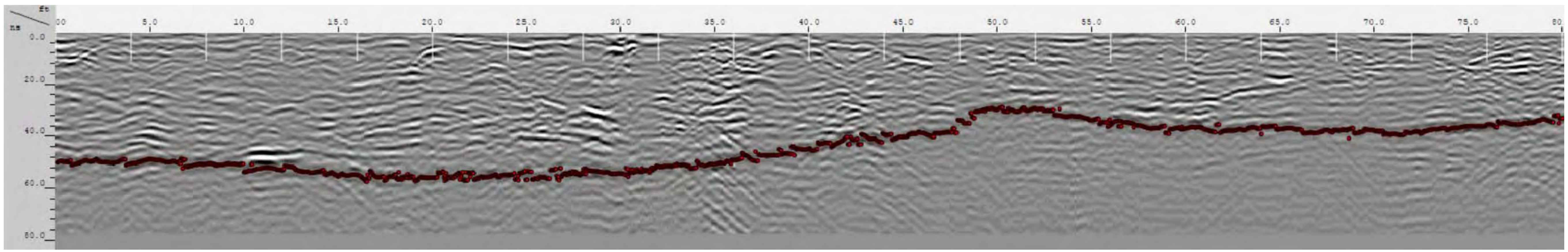
Ends at 13B



LINE 15

FILE 41
Starts at 15A

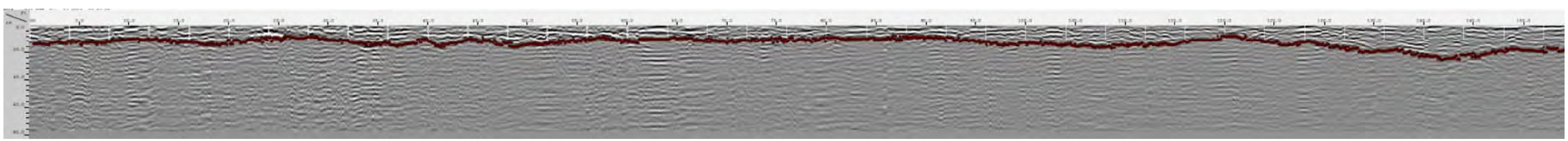
Ends at 15B



LINE 16

FILE 48
Starts at 16A

Ends at 16B



Legend

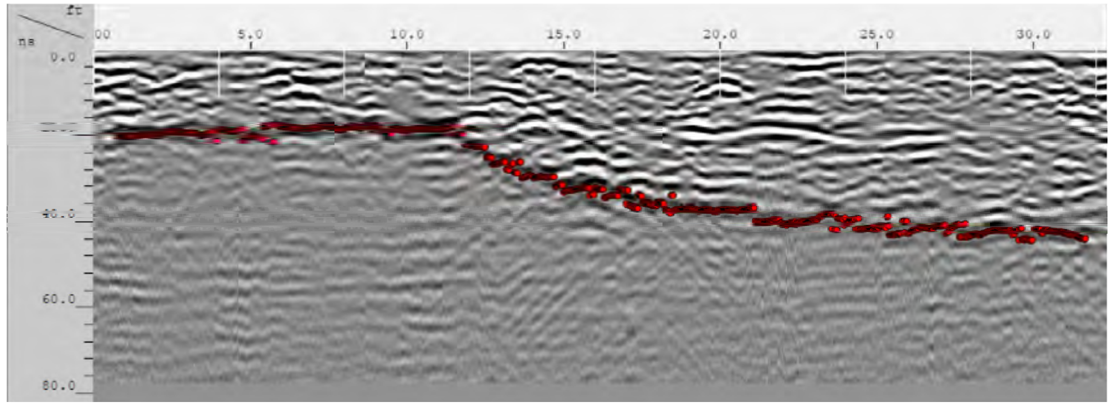
- Interpreted Interlayer Within Sand/Gravel
- Interpreted Interface Between Sand/Gravel and Till

Schnabel ENGINEERING	NYSERDA PROPERTY ADJACENT TO THE WVDP 10282 ROCK SPRINGS ROAD WEST VALLEY, NEW YORK PROJECT NO. 15615028 TASK 01	SOUTH OF THE MEANDER GPR DATA LINES 13 & 15 & 16 FIGURE B3-1

LINE 14

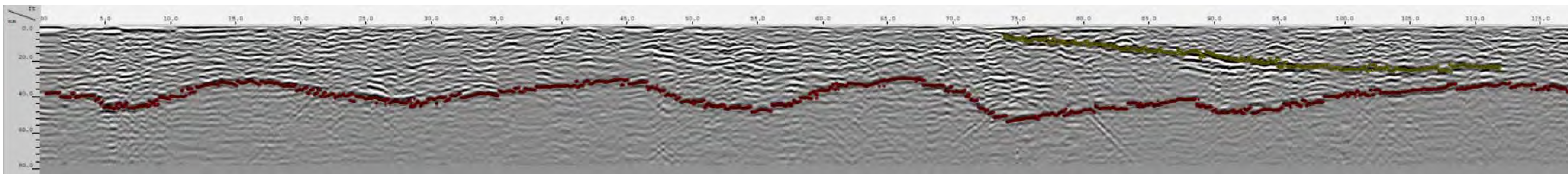
FILE 38
Starts at 14A

Ends at 14B



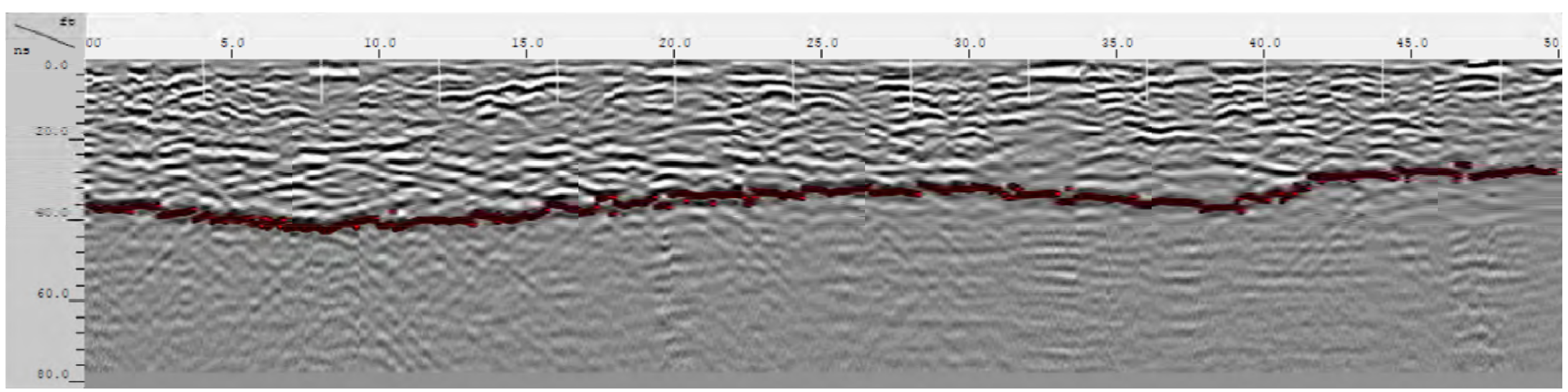
FILE 39
Starts at 14B

Ends at 14C



FILE 40
Starts at 14C

Ends at 14D



Legend

- Interpreted Interlayer Within Sand/Gravel
- Interpreted Interface Between Sand/Gravel and Till

Schnabel ENGINEERING

NYSERDA PROPERTY
ADJACENT TO THE WVDP
10282 ROCK SPRINGS ROAD
WEST VALLEY, NEW YORK
PROJECT NO. 15615028 TASK 01

SOUTH OF THE MEANDER
GPR DATA
LINE 14

FIGURE B3-2

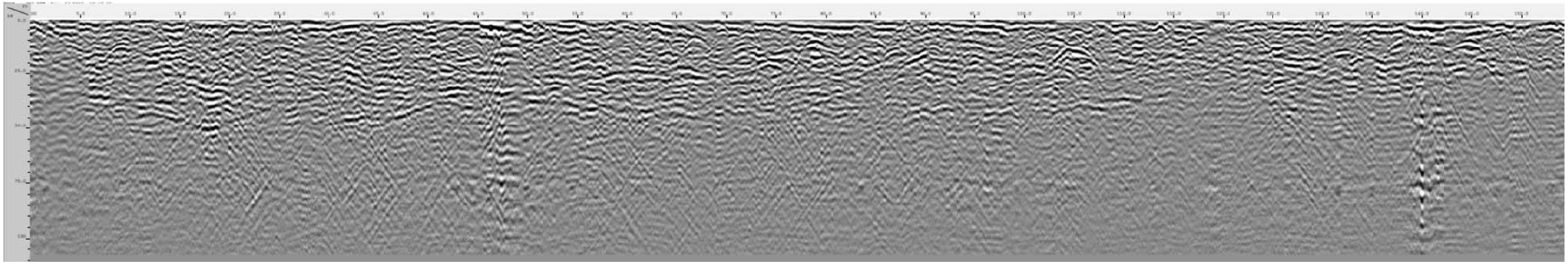
APPENDIX B4

SUPPLEMENTAL FILES

LINE 3

FILE 22
Starts at 3A

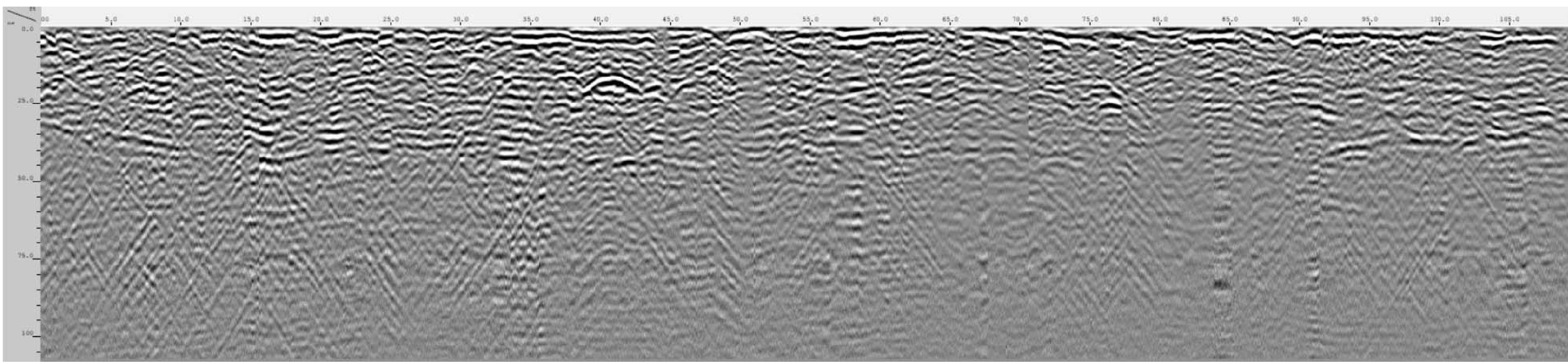
Ends at 3B



LINE 4

FILE 23
Starts at 4A

Ends at 4B

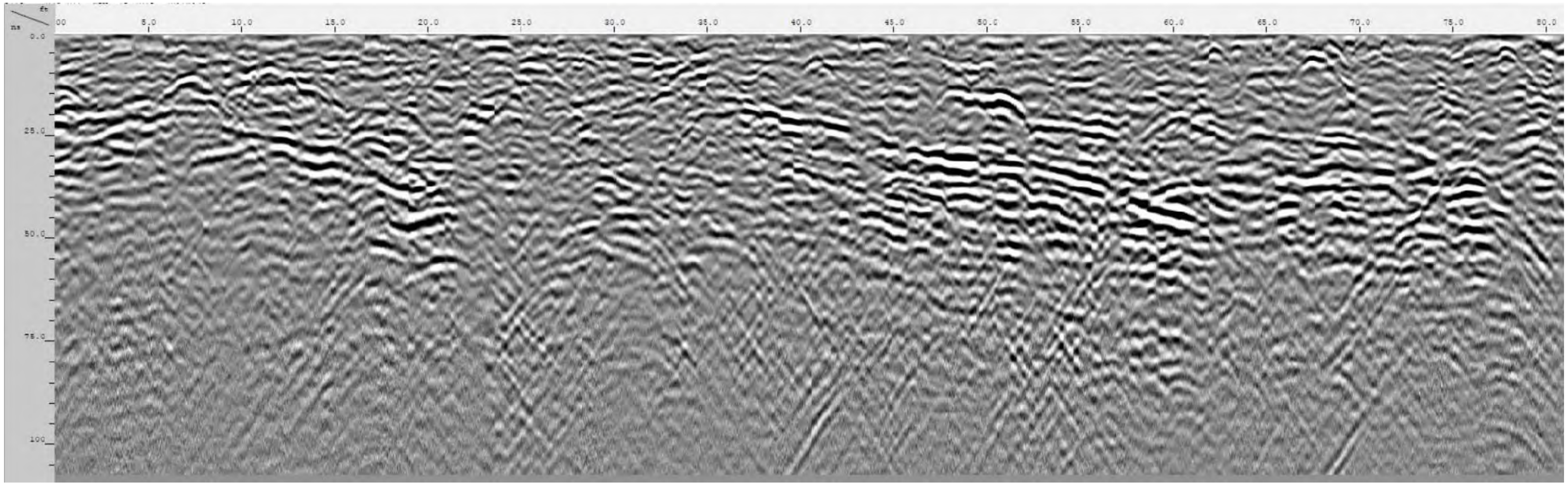


Schnabel ENGINEERING	NYSERDA PROPERTY ADJACENT TO THE WVDP 10282 ROCK SPRINGS ROAD WEST VALLEY, NEW YORK PROJECT NO. 15615028 TASK 01	SUPPLEMENTAL FILES GPR DATA LINES 3 & 4 FIGURE B4-1

FILE 28
Starts at 5A

LINE 5

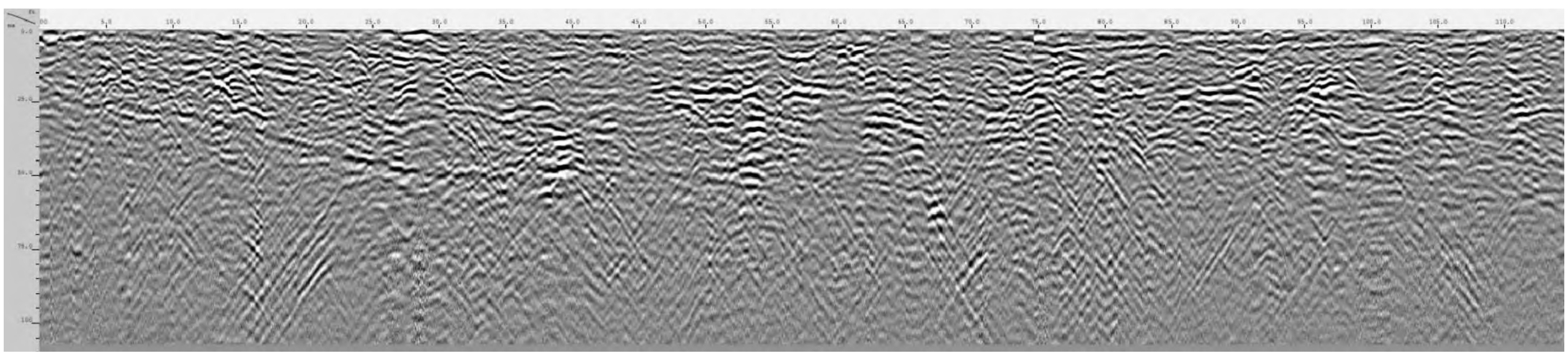
Ends at 5B



FILE 27
Starts at 6A

LINE 6

Ends at 6B

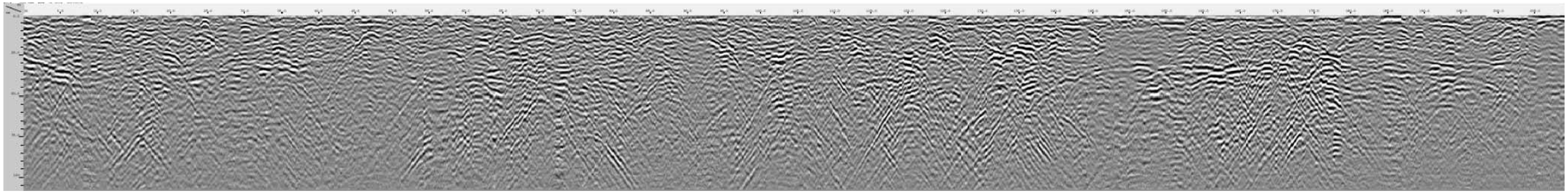


Schnabel ENGINEERING	NYSERDA PROPERTY ADJACENT TO THE WVDP 10282 ROCK SPRINGS ROAD WEST VALLEY, NEW YORK PROJECT NO. 15615028 TASK 01	SUPPLEMENTAL FILES GPR DATA LINES 5 & 6 FIGURE B4-2

LINE 7

FILE 29
Starts at 7A

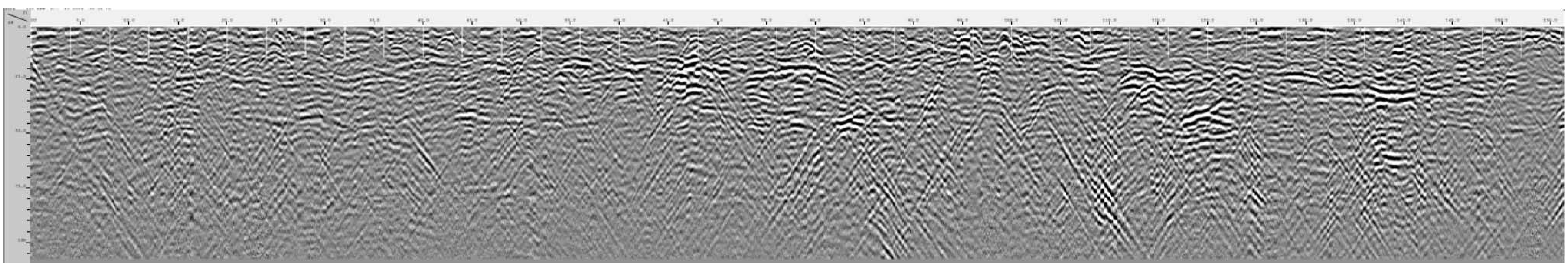
Ends at 7B



LINE 11

FILE 32
Starts at 11A

Ends at 11B

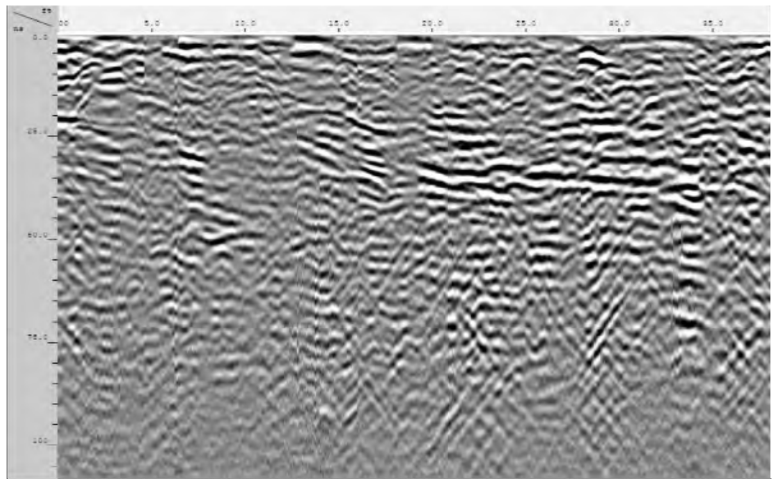


Schnabel ENGINEERING

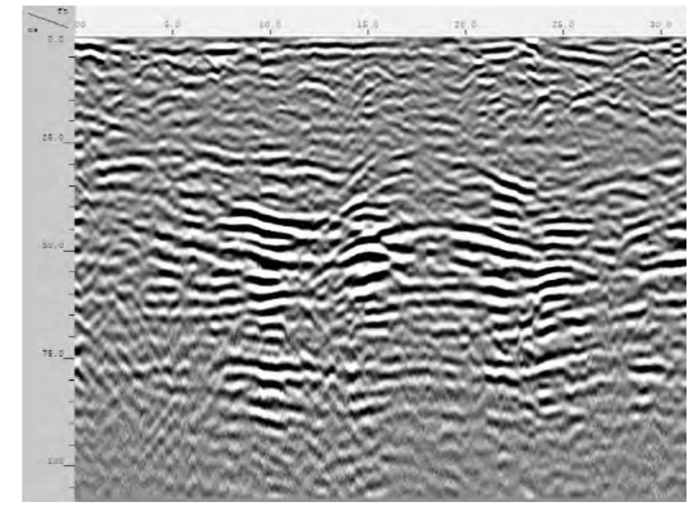
NYSERDA PROPERTY ADJACENT TO THE WVDP 10282 ROCK SPRINGS ROAD WEST VALLEY, NEW YORK PROJECT NO. 15615028 TASK 01	SUPPLEMENTAL FILES GPR DATA LINES 7 & 11 FIGURE B4-3

LINE 13

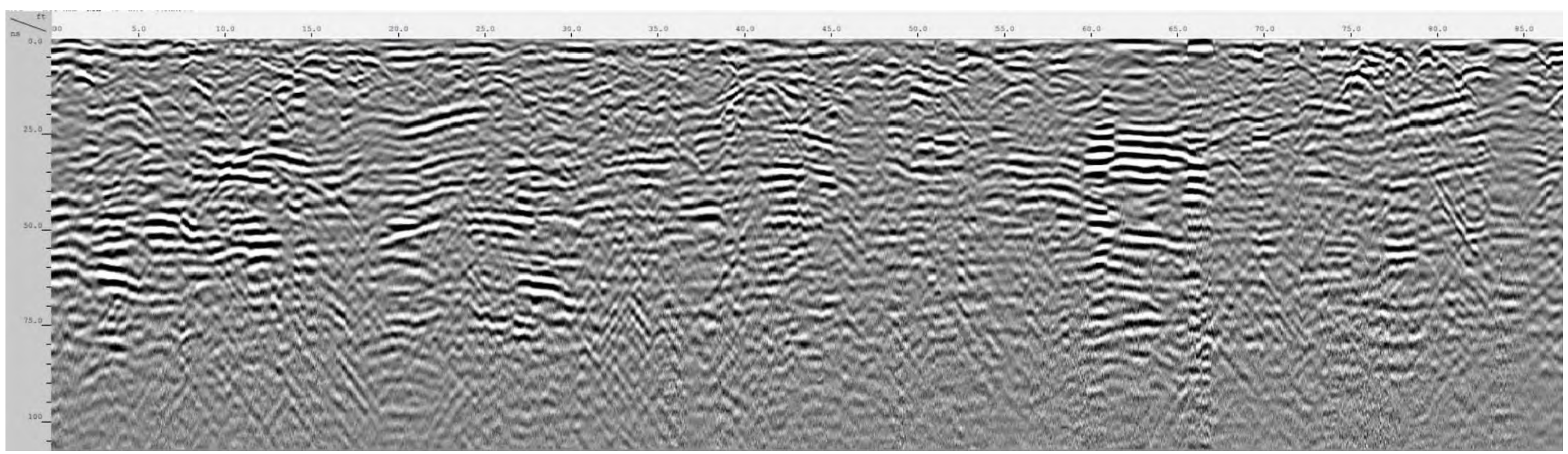
FILE 35
Starts at 13A
Ends at 13B



FILE 36
Starts at 13B
Ends at 13C



FILE 37
Starts at 13C
Ends at 13D



Schnabel ENGINEERING

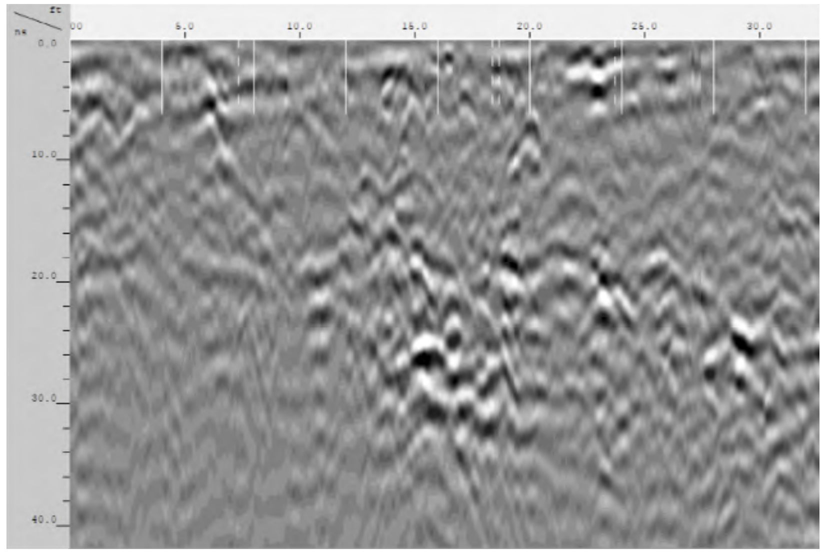
NYSERDA PROPERTY
ADJACENT TO THE WVDP
10282 ROCK SPRINGS ROAD
WEST VALLEY, NEW YORK
PROJECT NO. 15615028 TASK 01

SUPPLEMENTAL FILES
GPR DATA
LINE 13

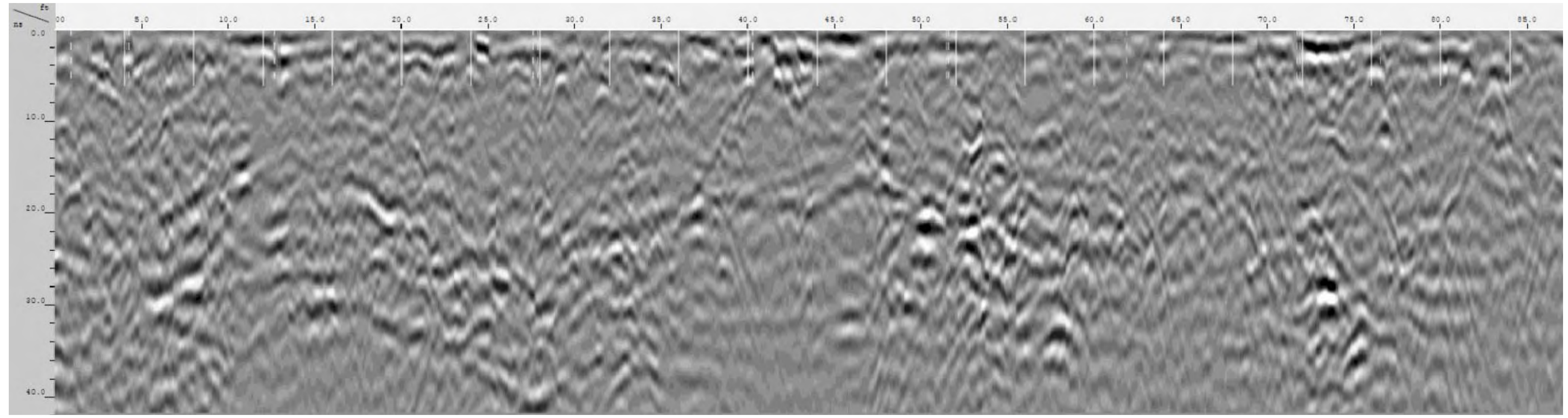
FIGURE B4-4

LINE 14

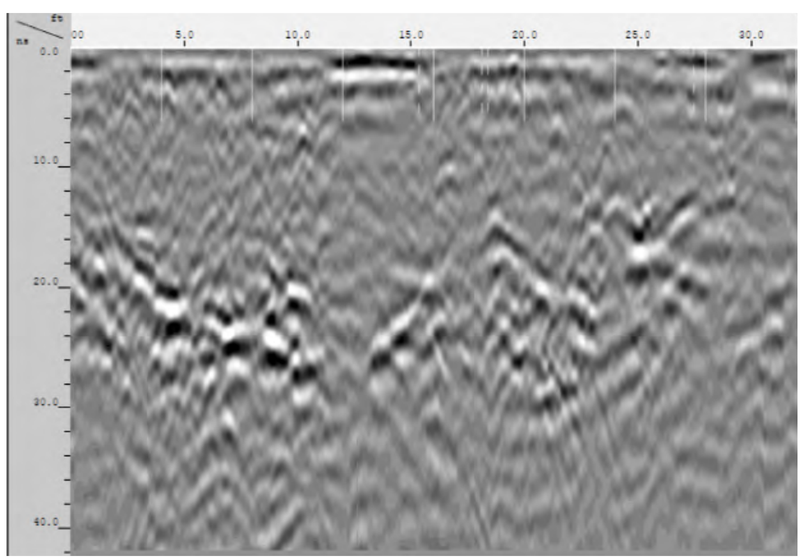
FILE 42
Starts at 14A
Ends at 14 not marked



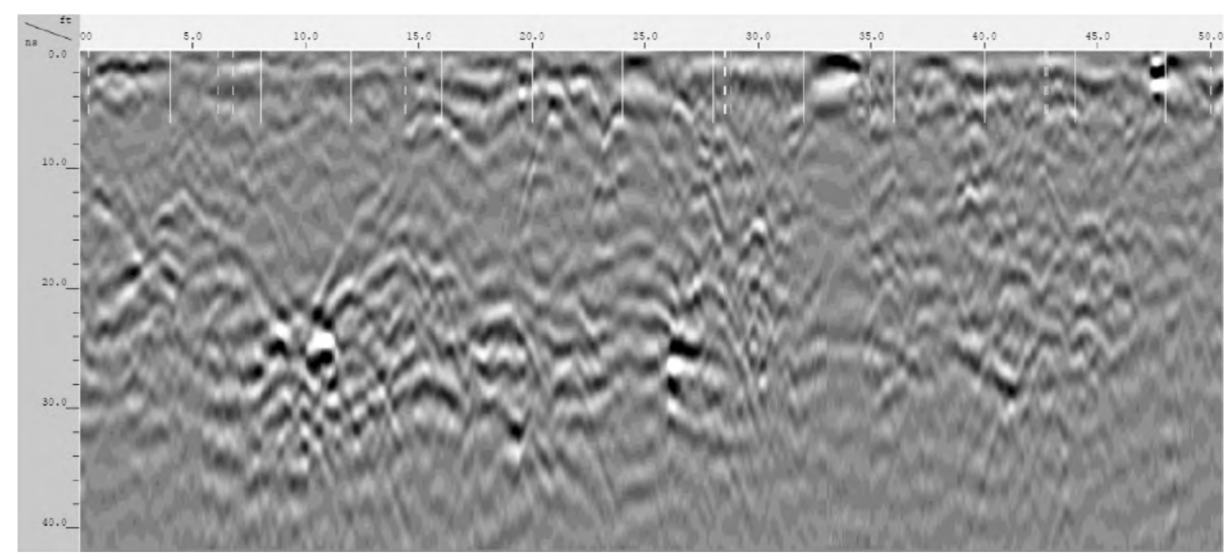
FILE 43
Starts at 14 not marked
Ends at 14 not marked



FILE 44
Starts at 14 not marked
Ends at 14C



FILE 45
Starts at 14C
Ends at 14D

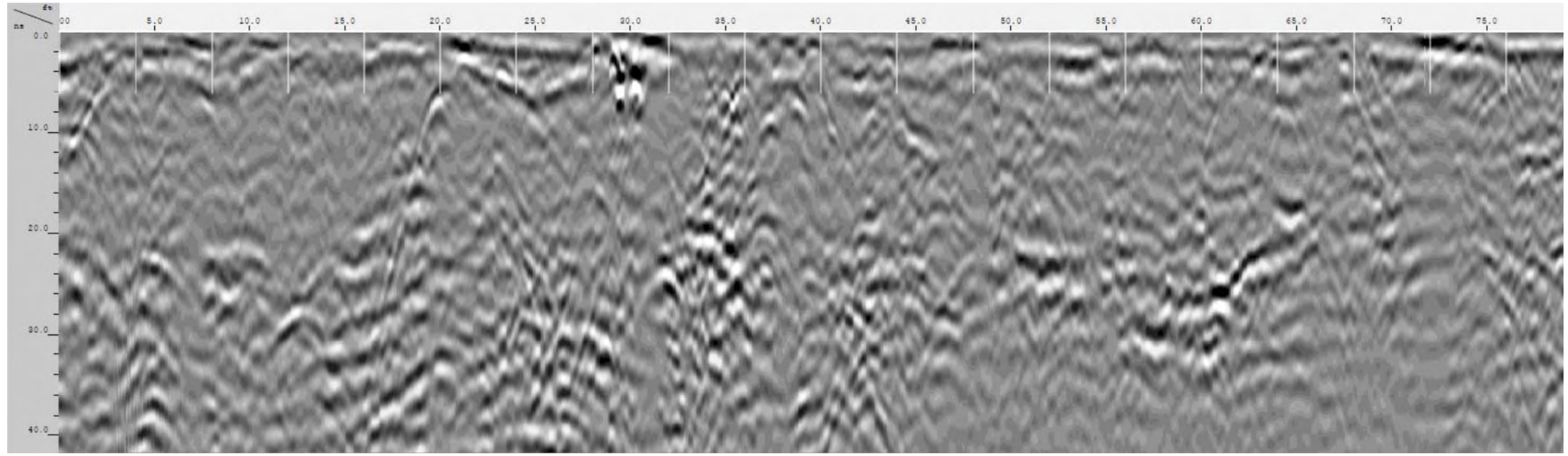


Schnabel ENGINEERING	NYSERDA PROPERTY ADJACENT TO THE WVDP 10282 ROCK SPRINGS ROAD WEST VALLEY, NEW YORK PROJECT NO. 15615028 TASK 01	SUPPLEMENTAL FILES GPR DATA LINE 14 FIGURE B4-5

LINE 15

FILE 47
Starts at 15A

Ends at 15B



LINE Low-High

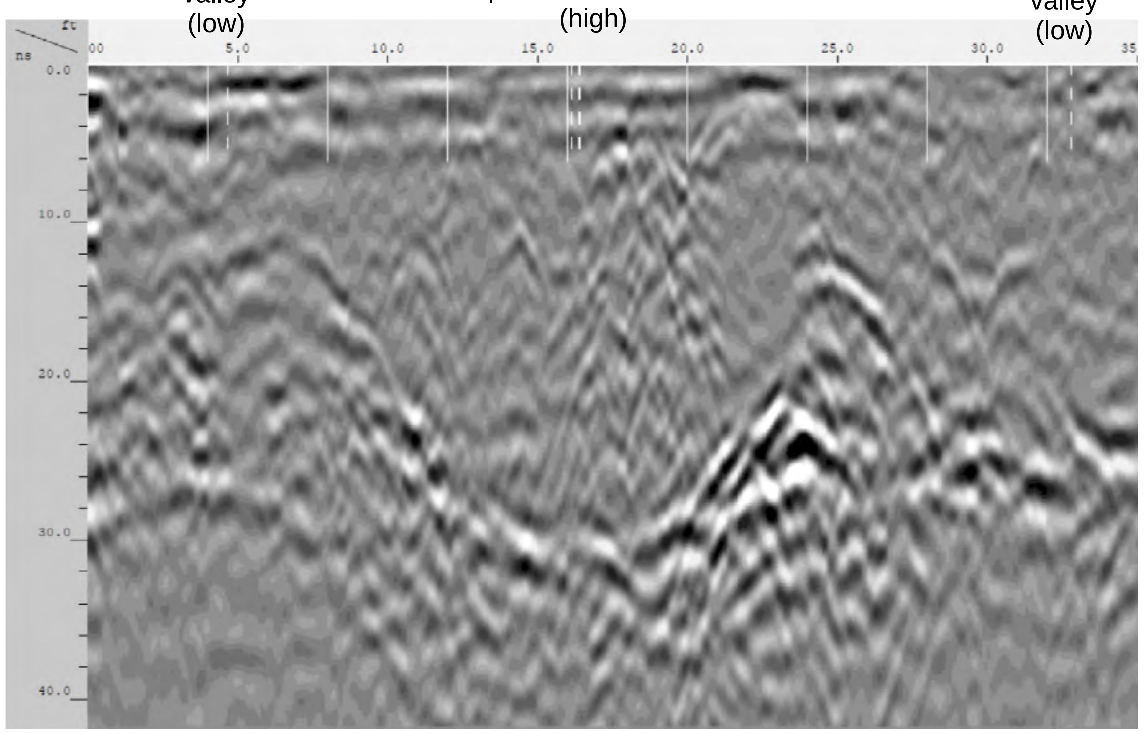
FILE 46
Starts at Low-High N

Ends at Low-High S

valley (low)

peak of hummock (high)

valley (low)



Schnabel ENGINEERING

NYSERDA PROPERTY
ADJACENT TO THE WVDP
10282 ROCK SPRINGS ROAD
WEST VALLEY, NEW YORK
PROJECT NO. 15615028 TASK 01

SUPPLEMENTAL FILES
GPR DATA
LINES 15 & Low-High

FIGURE B4-6

APPENDIX F
Field Progress Reports

Brief Summary of Field Work at West Valley, May 9-12, 2016

R. Young and M. Wilson (with Feldman, Butzer, daSilva, Zerfas)

Monday, May 9 (Tent station at meander depression, south end of abandoned meander)

Arrived at 8:30 AM. Signed documents at storage container with Feldman. Proceeded to abandoned meander depression site with equipment and aid of Tim's ATV and trailer (Figure 1). Cleared part of road (downed trees; Figure 2). Set up tent shelter (Figure 3). Started proposed gravity drainage trench at north end of bog depression adjacent to south end of abandoned meander. Encountered more tight clay sediment at shallow depth than expected; tried feeder trenches to remove more surface water (Figure 4). The peat and organic muck of the top layer of the bog held a large amount of water that drained too slowly into the feeder trenches to accomplish the dewatering we wanted. We noted that the clay below the bog organic soils in the exploration trenches in the following days was gray in color fully upward to the base of the organic topsoil, but that the clay in the wall of the drainage trench at the top of the outlet gully was mottled in color (browns and grays) due to fluctuating water table below the organic bog soil in the gully-head area. Tim and Alex tagged last year's GPR lines (1-16) with permanent metal tags.

Cleared pathway in afternoon along ridge to west and moved excavator to two highest meander terraces left unfinished last fall. Excavated trenches 8 and 9 on highest terrace (GPR lines 7, 11; Figure 5); these gravels were coarse, dry and the most deeply oxidized (2.5 YR 4 /5) of all the meander terraces. Took two OSL samples from each trench. Moved down to next lower terrace and excavated trench 10 (GPR lines 5,6). Taped off all three trenches as per safety regulations. Returned to bog depression to attempt more adequate drainage. Finished 4:30 PM.

Tuesday, May 10 (8:30 AM)

Moved to east side of depression, constructed log platform for excavator, and began excavation of Pit 1 (Figure 6). Returned to trenches T8, T9 to collect OSL samples (2 each pit). Alex and Tim collected and analyzed three 100-clast gravel samples from trenches 8, 9, 10. Returned to depression bog for lunch (south of and above Meander). Pit 1 encountered wood layer in apparent stony clay till (tentative identification) layer immediately below thin modern bog deposits (Figure 7). Bog deposit is only about ¾ to 1 foot thick. Wood imbedded in "till" below is at depth of approximately 1.5 feet. Collected 5 samples of wood from Pit 1 till for potential 14C dating (samples labeled WV-MD-S1, 2, 3, 5, 6). Took OSL sample in sandy layer below wood till layer at approximately 4 ft depth. Also collected gravel (glacial outwash?) sample (100 clasts) in excavation at 3 ft depth just below wood till for pebble count (Figure 8).

Returned to Trench 10 to collect two more OSL samples (drove sampler into same hole; Figure 9). Then returned to the bog area and constructed a log platform ("corduroy") for planned work on second pit (Pit 2) on Tuesday.

Shaved and split ^{14}C samples for shipment. Carbon 14 samples were transported and kept in their original foil and bags in a dark cooler and refrigerated at Wilson's home office until 5-12-16; then on 5-12-16 samples continued to be kept in their original field foil and bags and packed in a cooler with chiller packs; shipped by Wilson from "Box Monkey – Pack and Ship" in Dunkirk, NY on Thursday 5-12-16 and received by BETA on Friday, May 13, 2016; copies of BETA sample forms were retained in our files. R. Young will dry and store sample splits. Wilson will also have splits but some of his splits may be further examined and potentially destroyed in the process. BETA will archive portions of all samples not consumed through the dating prep and measurement processes. Finished 4:30 PM.

Wednesday, May 11 (8:30 AM)

Excavated Pit 2 at west edge of bog depression about 36 feet south of Pit 1. Encountered same sequence of wood bearing till at shallow depth (Figure 10). Wood is at about 3 ft depth (Figure 11). Collected samples for ^{14}C dating. Collected 100 clasts from within till layer immediately at and below wood horizon for pebble count. A sand and gravel layer occurs below wood till near 3.5 ft, then more clay, thickening below. Collected 100 gravel clasts from glacial outwash(?) gravel at depth of 6-7 feet, immediately below thicker basal clay unit. Took 2 OSL samples in sandy layer below wood till at depth near 4.5 ft. Lower clay unit thickens abruptly to the west to nearly 7 ft depth in this small excavation (Figures 12, 13). Lower gray gravel layer at base of excavation has irregular oxidized zones (brown) that appear to be coarser (Figure 13). Basal gray gravel has apparent clay/silt matrix in places where oxidation has not occurred. It is possible that overriding ice may have forces clay sediments into gravel in an irregular fashion, thus creating pockets of reduced permeability (thus the gray color; not oxidized).

Spent significant time examining units in pit, taking measurements (Torvane), and discussing significance of section.

Moved directly west across main bog depression to excavate Pit 3 (Figure 14) immediately above current water elevation in bog (to avoid trencher sinking in muck). Found single wood sample in similar till(?) at similar depth as in Pits 1 and 2 (Figure 15). The "wood till" here is about 2 feet thick beneath a thinner surface soil (i.e., the bog organic soil, or "topsoil", is thinner in Pit 3 than in Pits 1 or 2), and is underlain by gravel. Saved wood sample (WV-MD-P3-S1A) for ^{14}C dating.

Excavated Pit 4 (Figure 16) a short distance upslope (west) of Pit 3. Encountered thin organic topsoil over gravel, and the gravel rests on a well-laminated lacustrine, brown sandy-silty clay which was in-turn over more massive gray clay, but no obvious wood layer. As section is relatively more oxidized, if wood had been present, preservation would be less likely above water table.

A generalized stratigraphy across all the Pits going from 1 and 2 to 3 to 4 has organic bog soil over wood-bearing till, over sand and gravel with disrupted layers and variable amounts of fines, over well-laminated lacustrine clay (locally). However, a more complex stratigraphy than is inferred here might be present between the separated pits.

Finished 5 PM . . . [Carbon14 samples from this date 5-11-16 were also shipped on 5-12-16 in the same cooler with samples from 5-10-16, and received by BETA on 5-13-16; following our routine of splits, storage, and cold transport described above for 5-10-16.]

Thursday, May 12 (8:30 AM)

Drove to Heinz Creek access road (Figure 17) and proceeded to gully head that was site of problematic ^{14}C sample last fall (Figure 18). Alex and Tim cleared outcrop for more thorough stratigraphic examination by Wilson and Young. Collected medium-sized log (root?) for potential repeat of ^{14}C date. Note: Carbon 14 sample was sent to BETA on 5-12-16, same day as collected; this sample was packed separately because it was sent at end of day while previous samples were already sent early in day; all samples were received by BETA on 5-13-16.

Continued to Heinz Creek terraces and marked all 25 GPR lines with metal tags. Also tagged several planned radar lines on upper Heinz terrace in vicinity of 2015 pebble count, in vicinity of Carbon 14 gully sampling, and in vicinity of possible analog gully-heads (Sean Bennett study).

Returned to leave equipment at storage shed at 1:30 PM. [Note: Torvane shear strength data and pebble counts are being compiled in separate files.]

Figures:

Figure 1. Tim's vehicles unloading at head of road into abandoned meander.

Figure 2. Clearing recently fallen trees on way to meander depression site.

Figure 3. Alex setting up work shelter at depression.

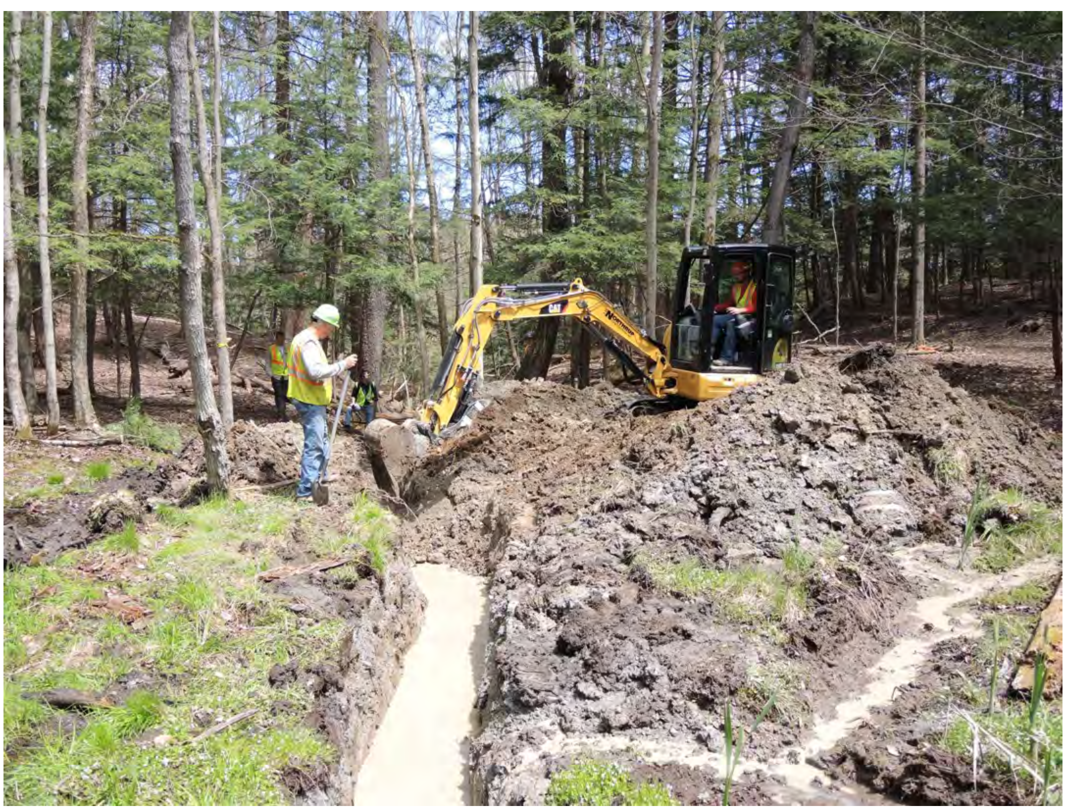


Figure 4. Ditching to attempt to drain meander depression (bog) at head of existing gully.

Figure 5. Trench 8 at GPR lines 7,11 on highest surface north of abandoned meander.

Figure 6. Wilson and Young sampling wood layer at Pit 1, meander depression.
Note blue submersible pump at lower right.

Figure 7. Clay impregnated wood from shallow till(?) layer at Pit 1 of meander depression, east side.

Figure 8. Alex and Tim completing clast counts from till(?) and gravel.

Figure 9. Wilson and Butzer sampling for OSL at Trench 10 on meander terrace (GPR lines 5,6).

Figure 10. Wood till layer in Pit 2. Partial log is exposed near left center.

Figure 11. Darker organic (wood) layer at 3-foot depth running across center of image (above shovel) in Pit 2.

Figure 12. Final depth of Pit two (7 feet) with vertical clay unit forming entire vertical back wall (west side).

Figure 13. Enlargement of center of Figure 12 exposing only clay on left of image, but gray and brown gravel on right (hole is from pebble collection). Clay over gravel contact dives steeply from upper right of view to lower center. Gravel continues and underlies pit floor.

Figure 14. Pit 3 at meander depression on west side of bog, directly across bog from Pits 1 and 2.

Figure 15. Wilson measures depth of wood sample in Pit 3 at meander depression. Note gravel and groundwater in lower part of view.

Figure 16. Pit 4 on west side of meander depression. Drier, no organic layer encountered.

Figure 17. Improved access road at Heinz Creek, south side.

Figure 18. Clearing stratigraphic section at gully head; site of young ^{14}C age from 2015 season.

Brief Summary of Field Work at West Valley, May 23-25, 2016

M. P. Wilson and R. A. Young . . . with Zerfas, Feldman, DaSilva, Hess, Hristodoulou, and Painter

The purpose of our work this week was straight forward: support Mia Painter of Schnabel Inc. to acquire GPR (radar) data from lines previously mapped and tagged at the abandoned meander, Heinz Creek, and the former Tree Farm (Buttermilk-Cattaraugus Creek confluence areas), and to add any additional lines we thought important. We also wanted to probe deeper with a second larger antenna if time permitted. We worked at the site Monday 8:30 AM – 4:30 PM, Tuesday 8 AM – 3:30 PM, and Wednesday 8:30 AM – 3 PM. A working dinner to discuss progress and plans was attended by all participants except Tim Zerfas in Springville on Monday evening. The weather was glorious all three days. Owing to prior commitments Young and DaSilva were not available Wednesday. We spent Monday at the Heinz site and Tuesday at the Tree Farm site; Wednesday was spent completing radar lines at the abandoned meander site to add lines near our recent, wood-bearing trenches, and time was spent to obtain deeper-probing radar lines in the area of upper Heinz Creek terraces and at Bennett's possible analog gullies.

Mia Painter reported that she collected 107 files, approximately a half dozen of which were required for calibration and testing. All lines that we previously marked were completed as well as several that were added as work progressed. In addition to using the standard antenna, we were also able to conduct deeper probes with a heavier antenna at about 35 of our prepared locations. Our preparation by clearing lines of large logs, as well as small limbs and related trash, worked very well and greatly improved Mia's ability to obtain the relatively large number of records in only 2.5 days. Opportunity was available for minor additional recon in the immediate areas of the radar work as the radar work proceeded.

Wilson and Young were able to spend time on their phones while radar calibration was underway to track down the most recent results for ^{14}C and preliminary OSL dates from the respective labs. Both labs reported progress on dating and provided several dates of each type. Most of the dates relate well to each other and support our needs for additional detailed information regarding fluvial incision rates.

Preliminary radar results are expected from Schnabel as plotted radar sections by approximately June 8 or 9, with a more formal report completed about a week later. No field work is anticipated by us until we have the chance to look at the radar sections and consider the dating results in greater detail. We plan to arrive on site to continue trenching at 9 AM on June 13 and to use the basic radar plots to focus those excavations on sites that show the greatest detail, as well as potentially higher groundwater tables . We plan to continue working 3 to 4 days per week for the weeks of June 13 and June 20. During that time, as results become apparent, we will make plans for the next most appropriate phase of field work. We have requested that Feldman secure Northrup's excavator and crew for weeks of June 13 and 20, and we have secured lodging for the first week.

Figures of GPR Activities attached below.

Figure 1. Improved road access at Tree Farm site. Hard rains might easily erode this access.

Figure 2. Climbing terraces to the next GPR lines with "porters" carrying required accessories and field gear.

Figure 3. Coordination and location of GPR lines.

Figure 4. GPR line marking method with permanent aluminum tags; harder to relocate as trees gradually leaf out.

Figure 5. Wet swales on terraces like this hold promise higher water tables and better ^{14}C organic samples.

Figure 6. Three terrace levels at the Tree Farm site are visible in the center of this image.

Figure 7. Brief lunch on the fly!

Figure 8. Calibrating larger antenna; must be dragged by hand.

Figure 9 Dragging large GPR antenna along prepared and previously cleared route. Gee haw!

Figure 10. Ongoing bank slumpage at upstream end of steep bank below Tree Farm access road.

Brief Summary of Field Work at West Valley, May 23-25, 2016 <u>Draft Report</u>

M. P. Wilson and R. A. Young . . . with Zerfas, Feldman, DaSilva, Hess, Hristodoulou, and Painter

The purpose of our work this week was straight forward: support Mia Painter of Schnabel Inc. to acquirer GPR (radar) data from lines previously mapped and tagged in the Meander, Heinz and Tree Farm (Buttermilk-Cattaraugus Creek confluence) areas, and add any additional lines we thought important. We also wanted to probe deeper with a second antenna if time permitted. We worked at the site Monday 8:30 AM – 4:30 PM, Tuesday 8 AM – 3:30 PM, and Wednesday 8:30 AM – 3 PM. The weather was glorious all three days. Owing to prior commitments Young and DaSilva were away Wednesday. We spent Monday at the Heinz sites and Tuesday at the Tree Farm sites; Wednesday was spent completing radar lines at the Meander site to add lines near our recent trenches, and time was spent to obtain deep-probing radar lines in the area of upper Heinz terraces and Bennett's possible analog gullies.

Mia Painter reported that she collected 107 files, approximately a half dozen of which were for calibration and testing. All lines that we previously identified were completed as well as several added as we worked. In addition to using the standard antenna, we were also able to conduct deeper probes with a heavier antenna at about 35 of our prepared locations. Our preparation of clearing lines worked very well and greatly intensified Mia's ability to obtain numerous records.

Wilson and Young were able to spend time on their phones when radar calibration was underway and track down the most recent results for C-14 and OSL dates from the respective labs. Both labs reported progress on dating and provided several dates of each type; the dates related well to each other and support our needs for information.

Opportunity was available for minor additional recon in the immediate areas of the radar work as the radar work proceeded.

Radar results are expected from Schnabel as basic radar sections approximately June 8 or 9, with a more formal report about a week later. No field work is anticipated by us until we have the chance to look at the radar sections. We plan to arrive on site to continue trenching 9 AM June 13 and use the basic radar sections during that trenching. We plan to continue 3 or 4 days per each week June 13 and June 20 and during that time make plans for continued trenching thereafter. We have requested that Feldman secure Northrup's excavator and crew for weeks of June 13 and 20, and we have secured lodging for those weeks.

Brief Summary of Geologic Fieldwork at West Valley, June 13-15, 2016

Monday, June 13 (Young, Wilson, Feldman, Zerfas, daSilva, Hristodoulou, Hess)

Arrived 9:00 AM; cool and sunny. Drove to Heinz Creek site where excavator crew was constructing crossing to north side of creek for access to main terrace areas (Figure 1). Tim transported field gear to railroad bed in UTV trailer and assistants set up tent base camp at former Heinz Creek RR bridge. Excavator moved to GPR line 14; chosen as long and most readily accessible lower terrace on east side of RR right-of-way. Terrace believed to have promise for 14C sampling due to low wet areas with dark organic soils at surface.

Zerfas, daSilva, and Hristodoulou made reconnaissance trip to multi-landslide feature in upper Heinz Creek to check for possible future accessibility and possible fresh exposures along current channel. Fresh exposures not obvious, but access from east via agricultural fields and gas pipeline route seems feasible (Figures 2 and 3 from Zerfas). Hess worked with Wilson and Young to learn how trenching and sampling are done.

Completed Trenches Ht-1 through HT-4 in vicinity of GPR line 14. Took 2 OSL samples from trench HT-2 (Figure 4). Progress was a bit slower than anticipated as protocols were worked out for most efficient sampling and signage. Finished and returned to trailer at 4:30 PM

Tuesday, June 14 (same personnel)

Arrived 8:00 AM; sunny and warm. Retrieved equipment from trailer and proceeded to Heinz Creek site of Trench HT-4 to sample cross-bedded sand (Figure 5). Excavated Trench HT-5 and found buried tree branch and leaf sample for 14C dating (Figures 6, 7). Wilson and 2 assistants moved to GPR line 18, about 12 feet higher than GPR line 14, to complete Trenches HT-6 and HT-7 at north end of terrace sequence. Located what appeared to be flattened and possibly burned(?) log sample (Figures 8, 9).

Excavated Trench HT-8 along GPR line 17 (no samples). Moved to Trench HT-9 near B end of GPR line 17 and took OSL sample. Began Trench HT-10, which contained fluvial gravel (Figure 10) to depth of 9.2 feet (depth limit for excavator). Prepared and labeled 3 samples for Wilson to mail for 14C analysis. Stored equipment and finished at 5:00 PM.

Wednesday, June 15 (same personnel, except Hess)

Arrived 8:00 AM, sunny and warm. Young and daSilva returned to Buttermilk Creek log sites to obtain sediment samples of all sedimentary units above and below OSL samples, as requested by Sebastien Huot. Sebastien prefers to sample all different sedimentary environments within 20-inch radius of samples to analyze for potential impact on OSL ages.

Met Sean Bennett and assistants at parking area for Heinz Creek, then Joined Wilson and others completing Trench HT-10, followed by HT-11 through HT-16. Collected several additional OSL samples and two pebble counts (50 clasts each) from coarse fluvial gravel units. Collected three additional 14C samples from surficial organic unit at Trench HT-16 (Figures 11, 12). Packed up a bit early to allow for transport of all personnel and equipment of Young, Wilson, and Bennett parties out of area by deadline; left trenches open for Bennett. Distance from parking area to work area (terrace at GPR line 18) is slightly over 1 mile. Finished at 4:00 PM; light rain began in Springville around 5:00 PM. Cancelled excavation work for Thursday due to rain/lightening forecast. Wilson mailed all 14C samples on Thursday to arrive at lab Friday. Transport of Wilson, Young, and Bennett personnel and equipment with UTV may potentially slow progress in future, especially at larger Heinz Creek site. Diagrammatic stratigraphic section for terraces (approximate only) is shown following Figure 12.

Figures

Figure 1. Excavator completing north side of Heinz Creek crossing. UTV in foreground.

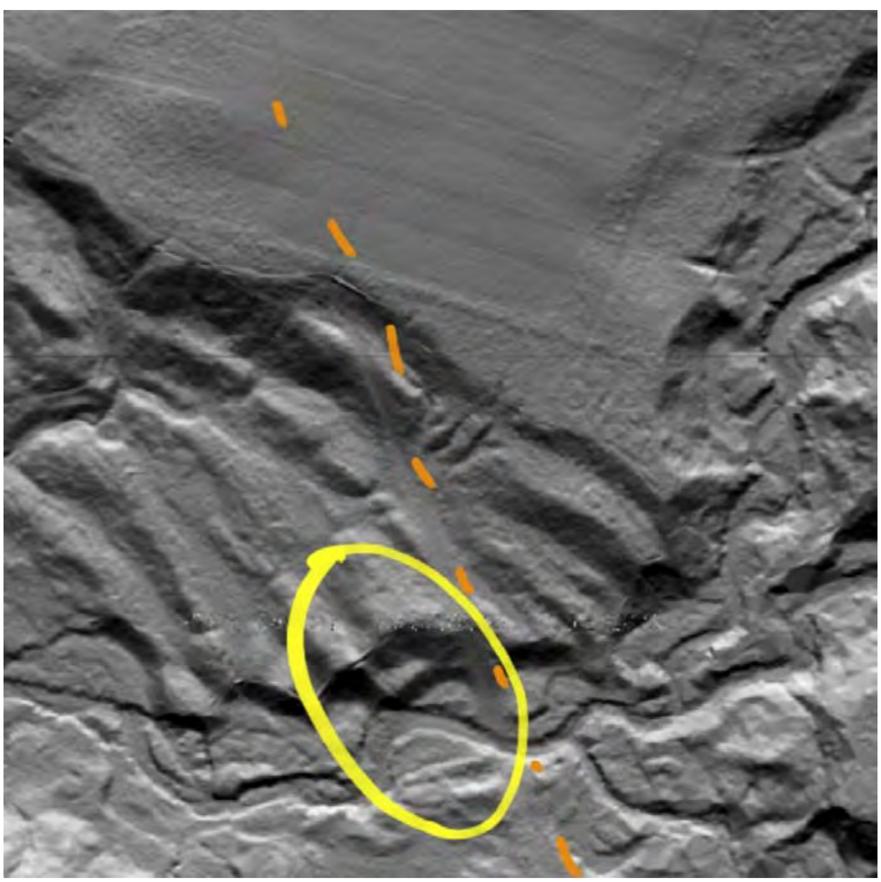


Figure 2. Multislide reconnaissance area with gas pipeline route in orange dashes.

Figure 3. Portion of multi slide area as circled on Figure 2 (photo by Zerfas).

Figure 4. Organic soil and finer fluvial unit over coarse fluvial gravel with Trench HT-2 identification information.

Figure 5. Cross-bedded coarse fluvial sand unit below ID label in Trench HT-4.

Figure 6. Tree branch (bark attached) ^{14}C sample buried in upper fine-grained fluvial unit.

Figure 7. Leaf (lower left) collect from same stratigraphic position as branch shown in Figure 6.

Figure 8. Wilson with hand at level of burned(?) log sample in Trench HT-7. See close-up in Figure 9.

Figure 9. Charcoal-like remnants of flattened(?) or burned(?) log .

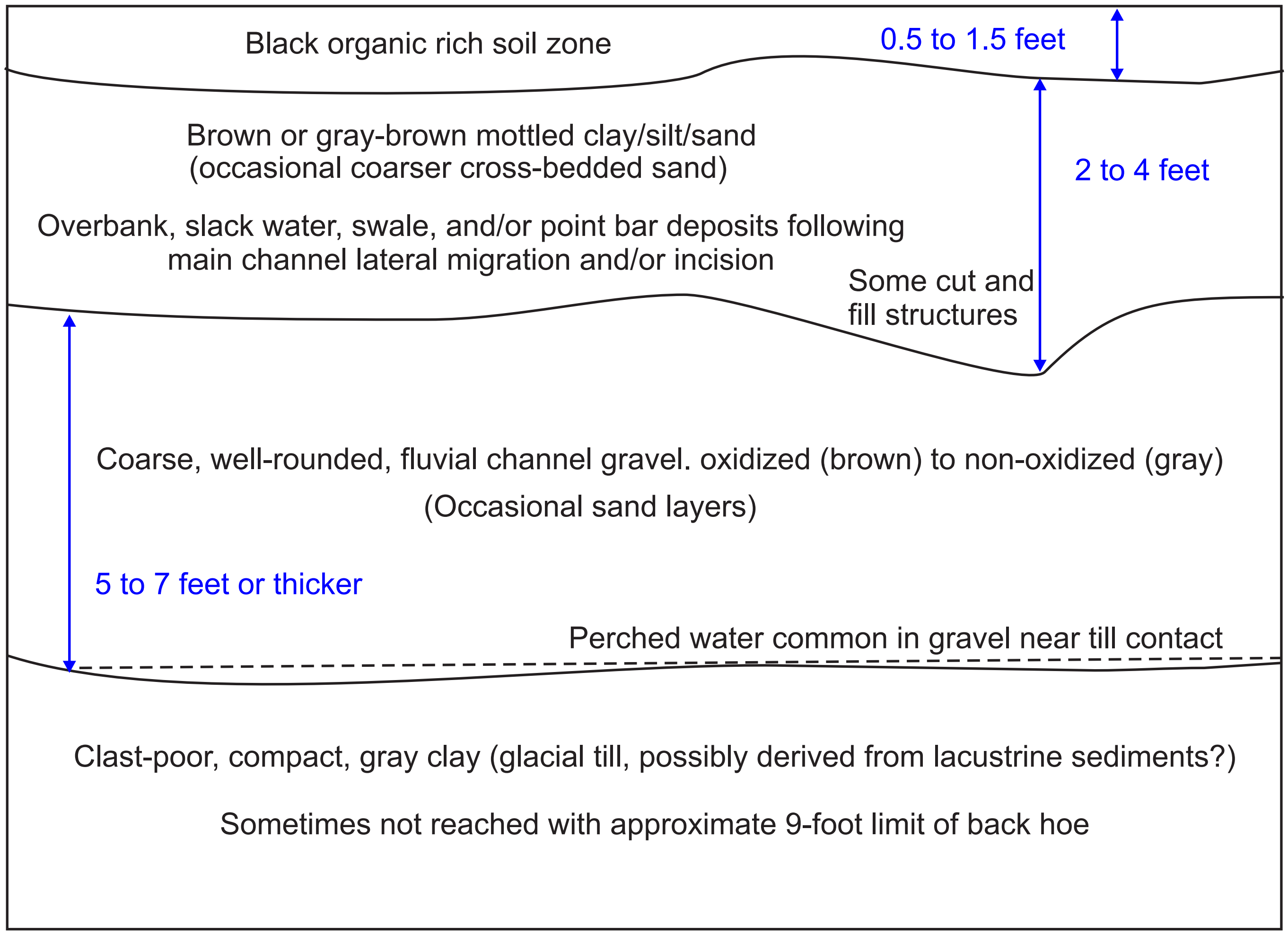
Figure 10. Trench HT-10 showing depth of coarse fluvial gravel (collapsed area) to 9.2 feet (no till encountered).

Figure 11. Organic soil layer at surface and location of wood and leaf samples at Trench HT-16.

Figure 12. Closer view of organic horizon that produced wood and leaves at Trench site HT-16.
One wood sample and leaf litter were at base of organic unit, wood with bark was near middle.

GENERALIZED GEOLOGIC SECTION, LOWER HEINZ CK TERRACES EAST OF RAILROAD

Typical thicknesses



Brief Summary of Geologic Fieldwork at WVDP for the weeks of June 20 and June 27, 2016, for ECS, Inc. Submitted by R. Young on behalf of R. Young and M. Wilson, July 1, 2016

Work has been essentially completed for trenching of the terrace and alluvial fan surfaces in the lower and upper Heinz Creek area. The Upper Heinz Creek area seems to be mainly underlain by glacial tills with a relatively thin cover of younger soil or mass wasting sediment. Trenches were left open to allow further evaluation of the geologic implications. Mike Wilson (currently on vacation) will review the trenching done in his absence (June 27-July 7). In addition to some hiking reconnaissance of nearby areas, the trenching work was moved to the Tree Farm site on June 29, and two days were spent examining the surficial geology of the two upper terraces. A new base camp was set up close to the center of this 2nd terrace site on GPR line F5.

Monday, June 20 (9 AM)

Met with Sean Bennett, then returned to finish work at trench HT-16 at the Heinz site. Moved to GPR line 26 and found coarse alluvial fan gravel in trench HT-17 resting on a few glacial varves(?) and gray clay till (Fig. 1). Took clast count (100) from three foot depth and collected dark layer from varve couplet to try for ^{14}C age (Fig. 2). Darker "varve" layer had some small black specks. Also collected an OSL sample. Tim worked most of day hauling water for Sean's group, but trailer was damaged due to heavy weight of water container and rough terrain. Completed trenches HT-17 and HT-18 on GPR line 26 plus HT-19 and Ht-20 on GPR line 9. Moved to GPR line 7 for long trench HT-21 to intersect apparent radar change in layering indicated from higher to lower topography (Fig. 3). Left at 4 PM to walk out due to lack of trailer transport. Note: H8 GPR line ends at H9.

Tuesday, June 21 (8AM)

Met with Lee Gordon at Heinz parking area and were told to ignore pending sirens for safety drill at WVDP plant area. Loaded gear at tent camp and proceeded to lengthen trench HT-20 to check radar profiles. Subsequently completed trenches HT-21 through Ht-23. It seems that much of surface at SE ends of GPR lines H9 and H7 is covered with coarse alluvial fan deposits (sourced from Heinz Creek). Trench HT-29 suggests transition back to alluvial deposits of Buttermilk Ck. (also NW end of GPR line H9). Moved to west side of abandoned RR bed for trench HT-24 and found coal in this location on GPR line 22 at depth of 2.8 feet. This indicates that deposition on this low terrace (approx. 5 ft above Buttermilk Creek) is probably mostly historic (postdates RR operations). Decided not to continue multiple trenches along this radar line. While working on trench HT-25, we received notification to evacuate site as part of WVDP safety drill (despite earlier assurances to the contrary). Evacuated starting at 2:30 PM and left NYSERDA property at 3:30 PM. Had to take remaining equipment (not left at tent) to motel, due to area roads near WVDP being closed for safety drill.

Wednesday, June 22 (8AM)

Arrived at Heinz Ck. parking area and proceeded to Upper Heinz Creek GPR lines. Excavated 4 trenches (UHT-1 to UHT-4) on GPR line 4-5, and 3 trenches (UHT- 5 through UTH-7) along GPR line 6-7. Obtained three pebble counts in these Upper Heinz area trenches and collected two ^{14}C samples from trench UTH-6 from what appears to be relatively shallow post-glacial sediments (Fig. 4). It appears that most of the sediments in the Upper Heinz area are glacial tills, possibly veneered only with thin soils and postglacial mass wasting debris (Fig. 5). Will complete more trenches in area next week. Put radios on charge and left storage site at 4:45PM.

Thursday, June 23 (8AM)

Met at trailer storage, provided detailed maps for Tim, then proceeded to Heinz Ck parking area. Obtained new ATV and returned to trench HT-25 to finish sampling (Fig. 6). Completed trenches HT-26 to Ht-29 and took several OSL samples, but found no useful ^{14}C samples. Z. Hess left at 2:30 PM. Young and Hristodoulou left at 3:30PM for storage trailer to inventory all current OSL samples. Completed OSL inventory at 5PM. Workers this week: Young, Wilson, Feldman, Zerfas, Hess, Hristodoulou, (daSilva on Monday only).

Monday, June 27 (9AM)
Rained off and on en route to Springville. Picked up equipment and radios at trailer storage; parties met with Feldman to discuss work plans. Met Tim at Heinz Ck parking area to transport equipment to tent base camp on RR bed. Revisited trench HT-29 to complete work started on June 23. Took OSL sample and moved to trench site for HT-30 on GPR line 19 at C end. Site produced only coarse gravel, so no OSL sample taken. Trench HT-31 on GPR line 19 near B end exposed similar coarse gravel. Took clast count, then moved to start trench HT-32 near north end of GPR line H19. Obtained 2 OSL samples in sandy sediment at HT-32.
Moved to trench HT-33 (Fig. 7) just NW of GPR line H24. Site is on small terrace(?) surface slightly above most of GPR line H24. This slightly off-line trench location choice turned out to be fortuitous as organics were encountered at contact of fluvial sand (Fig. 8) over gravel at depth of approximately 5.5 feet. Two large weathered pieces of wood (Fig. 26; possible reworked root fragments ?) fell into trench when contact was excavated. It appears that the two pieces of wood were located right at the contact between the upper sand and lower gravel units, but it is unclear which of the two units the wood may have actually been located in (whether they were located in the very base of the sand or the very top of the gravel). Within the stratification at the base of the sand unit close examination showed some discontinuous thin black layers of compressed organic material (possibly compressed leaf litter?). Samples were collected from two locations along this thin, discontinuous layer. Materials from these four samples were mailed and have been received by Beta Analytics.
Other activities: During the morning Tim and Alex hiked up "Sean's Gully" (just south of Heinz Ck) to attempt reconnaissance mapping of the geology. They encountered only limited till exposures within the channel and numerous small slides present along the gully side slopes. The many channel log jams present made for difficult access.

During the afternoon Tim and Zakk hiked up Heinz Creek to better locate geologic contacts, and to investigate a water line route access for Sean's water supply. They located an interesting glacial section in a relatively fresh landslide (Fig. 9), which included stratified sediments interbedded with apparent tills (visited next day by Young; Figs. 10, 11, 12). Tim and Zakk also found and collected wood buried in the surface sediments at a second landslide (relationship to slide unclear). (Young subsequently visited Tuesday to examine). Saved wood for potential dating.

Moved south of Heinz Creek to trench HT-34 on GPR line H1 (NW end). Produced thickest section of fluvial silty sand (some clay?) yet measured. Roped off site for continuation of work Tuesday; left samples and equipment at trailer storage; finished work at 4:30 PM. Weather cleared during day and was generally better than rainy forecast; deer flies very annoying.

Tuesday, June 28 (8AM)
Collected equipment and radios from storage and met at Heinz terrace site to finish investigation of trench HT-34. Completed new trench HT-35 on GPR line H3, and after lunch Alex and Zakk supervised excavation of 4 Upper Heinz Creek trenches (UHT8 through UHT-11) on GPR lines 1-2 and 3-4, while Tim and Eraklis accompanied Young to review reconnaissance of Tim and Zakk from Monday along upper Heinz Creek channel. Wood in landslide may not be truly embedded in base of slide (due to ongoing surficial mass wasting?). Interesting glacial stratigraphy at newer slide was also investigated, described, and photographed (Figs. 10-12). Two OSL samples were obtained from the finer sands. On return along Heinz Ck to Upper Heinz trenching site, a log was found protruding from a larger, older slide along Heinz Ck (Fig. 13). Top of slide scarp has obvious slip face of 10 to 15 feet. Took ^{14}C sample for possible dating. Log was probably at edge of Heinz Creek when slide occurred, so could be reworked and of limited value for interpretation of slide timing.

Returned to Upper Heinz Creek to take note on results of trenches UTH-8 to UTH-11. Convened meeting with Denny and group to discuss tentative move to Tree Farm site on Wednesday. Discussed need for second tent to provide for base camps for both Sean's group and Tree Farm site. (Later decided one tent would suffice, with Sean's agreement.) Also plan to continue recon of gullies leading to Buttermilk Creek using detailed topographic maps. Late in the day Tim and Alex did additional recon of south branch of "Sean's Gully", but found only till as noted on earlier gully recon trip. Stored equipment and finished at 4:30 PM.

Wednesday, June 29 (8AM)
Acquired radios and equipment from trailer storage and met group at Heinz parking area to collect all gear and tent for move to Tree Farm site (Fig. 14). Drove to Tree Farm site with equipment and set up tent base camp near center of GPR line F5 (Fig. 15). Excavated trenches FT-1 through FT-7 on main high terrace (GPR lines F1 thru F4) during the remainder of the day. Geology is similar throughout this terrace and consists of very coarse brown fluvial gravel overlying hard gray stony till (Figs. 16, 17; many large angular clasts seen in both units). Stony till nature (and large angular clasts) may reflect bedrock outcrops known to exist a short distance to the north (as per LaFLeur maps). Due to the coarse nature of the surficial fluvial unit, we took two OSL samples at trenches FT3 & FT4 using a double tarp covering in the dark and using red safety headlamps (Fig. 22, plus one standard OSL tube sample. Acquired a pebble count from gravel at trench FT-4 at same horizon as OSL sample under tarp. Finished at 4:45 PM. Absent ^{14}C material, an accurate OSL date on this high terrace would be critical to determining a potential Buttermilk Creek elevation at an intermediate time

Thursday, June 30 (8AM) (daSilva absent Thursday due to SUNY Buffalo training session)
Collected radios and equipment at storage trailer and met group at Heinz parking lot. Denny ferried Zakk and Eraklis to Buttermilk Creek log site to reacquire additional organic layer sample needed by Sebastien Huot. Young continued trenching at Tree Farm site with Tim. Began excavation of FT-8 on second terrace down at north end in apparent fluvial swale with obvious thin surficial organics (damp muddy area; Fig. 23). Exposed 1 to 2 feet of gray clay under dark organic surface layer in swale. Below the clay the fluvial gravel is saturated and very "soupy" to excavate.

Tim and Young went to recon Tim's proposed water source (Figs. 18-21; spring fed) for when Sean moves to Tree Farm site. Returned to FT-8 trench site and collected six small wood fragments from lower contact of surficial organic layer (Fig. 27). Moved to excavate FT-9 trench further south in the same low swale and uncovered similar section as in FT-8. Moved to higher ground slightly west of FT-8 and FT-9 for trench FT-10 and encountered brown fluvial sand (possible point bar deposit related to swale area?). Dug shallow trench to connect trenches Ft-8 and FT-10 to trace facies relationships (Fig. 23). Took video of general area and trench relationships. Took clast counts in underlying fluvial gravel at FT-8 and FT-9 to verify fluvial classification (Fig. 24). At this location the felling of a dead tree for safety reasons caused a significant pile of sand to be brought up onto the surface by the root ball; an example of how shallow sediments can be naturally disturbed, materials possibly inverted (Fig. 25). Moved south along GPR line F5 for trench FT-11 excavation on slightly higher ground. Encountered coarse fluvial gravel, so no OSL sample taken.
Cleaned up and roped off sites, stored equipment in tent for long July 4th weekend absence (July 1 through 5). Returned to trailer storage and inventoried newly obtained OSL samples. Finished work at 3:30 PM. Workers for week: Eraklis absent Monday; daSilva absent Thursday.

Figures (1-27)

Figure 1. Trench HT-17 in coarse alluvial fan material near north side of Heinz Creek .

Figure 2. Apparent varved sediments in trench HT-17 as noted in text.

Figure 3. Trench HT-21 on GPR line 7 dug to trace apparent facies changes on radar.

Figure 4. Organic horizon (base of soil unit) at UHT-6 trench. ^{14}C samples were located near center of view near contact of gray clay with overlying organic soil unit.

Figure 5. Trench UHT-3 at Upper Heinz Ck site is mostly glacial till or ice-contact deposits.

Figure 6. Typical fine alluvium over coarser fluvial gravel (HT-25) seen in many Heinz Ck terrace trenches.

Figure 7. Trench HT-33, source of organics at 5.5 feet between upper fine and lower coarse fluvial units.


Figure 8. Lower contact of stratified, upper, fine-grained fluvial unit in Trench HT-33 (organic zone).

Figure 9. Recent slide in Heinz Ck with stratification shown in Figures 10, 11, and 12.

Figure 10. Till at base overlain by thin stratified sand with possible “ablation till” above exposed at slide of Fig. 8. Yellow layer is oxidation and bleaching of clay in lower till unit under permeable sand.


Figure 11. View of ablation till between two thin stratified sand units of Figs. 10 and 12.


Figure 12. Location of OSL sample tube driven into top sand unit of Figure 11.

Figure 13. Log in base of slide on upper Heinz Creek, possibly fluvially reworked, then buried by slide.

Figure 14. Equipment loaded for delivery to Tree Farm base camp on Tim's UTV and repaired trailer.

Figure 15. New base camp at Tree Farm site on terrace of GPR line F-5.

Figure 16. Coarse fluvial gravels encountered throughout surface on Tree Farm upper terrace.


Figure 17. Unusually large boulders located on upper Tree Farm terrace.


Figure 18. Spring source for water line locate by Tim Zerfas.

Figure 19. Water flowing from three springs to form permanent flow for potential dam and water source.

Figure 20. Tim at site chosen for dam to supply water for S. Bennett tests.


Figure 21. Auger post installation in gully by Tim and Eraklis to support eventual dam construction.


Figure 22. Obtaining tarp sample in darkness from coarse sediments at site of trenches FT-3 and 4.

Figure 23. Trench leading from swale trench HT-8 (foreground) to Trench FT-10 (point bar?).

Figure 24. Pebble clast count from trench FT-9 to verify fluvial origin (as opposed to glacial outwash). Note obvious rounding and lack of limestone clasts of northern derivation.

Figure 25. Large sand "pile" naturally brought to surface by tree knocked over during site preparation. Demonstrates how materials can be stratigraphically mixed (pile was spread by back hoe from original shape).

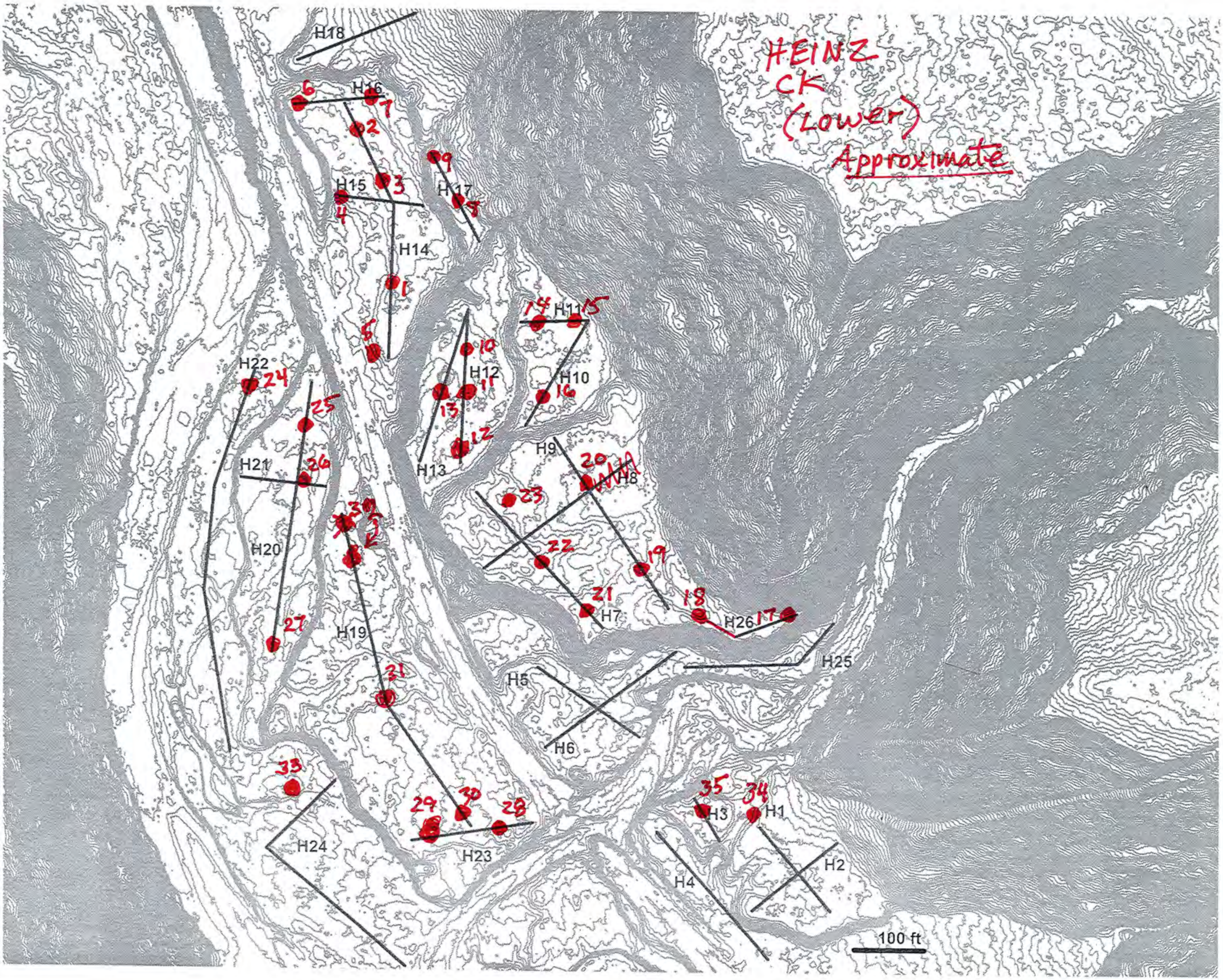
FIGURE 26. Two large wood samples from HT-33 at 5.5 feet; sent pieces for 14C age determination. Smaller, thin debris layers were too small to save splits.

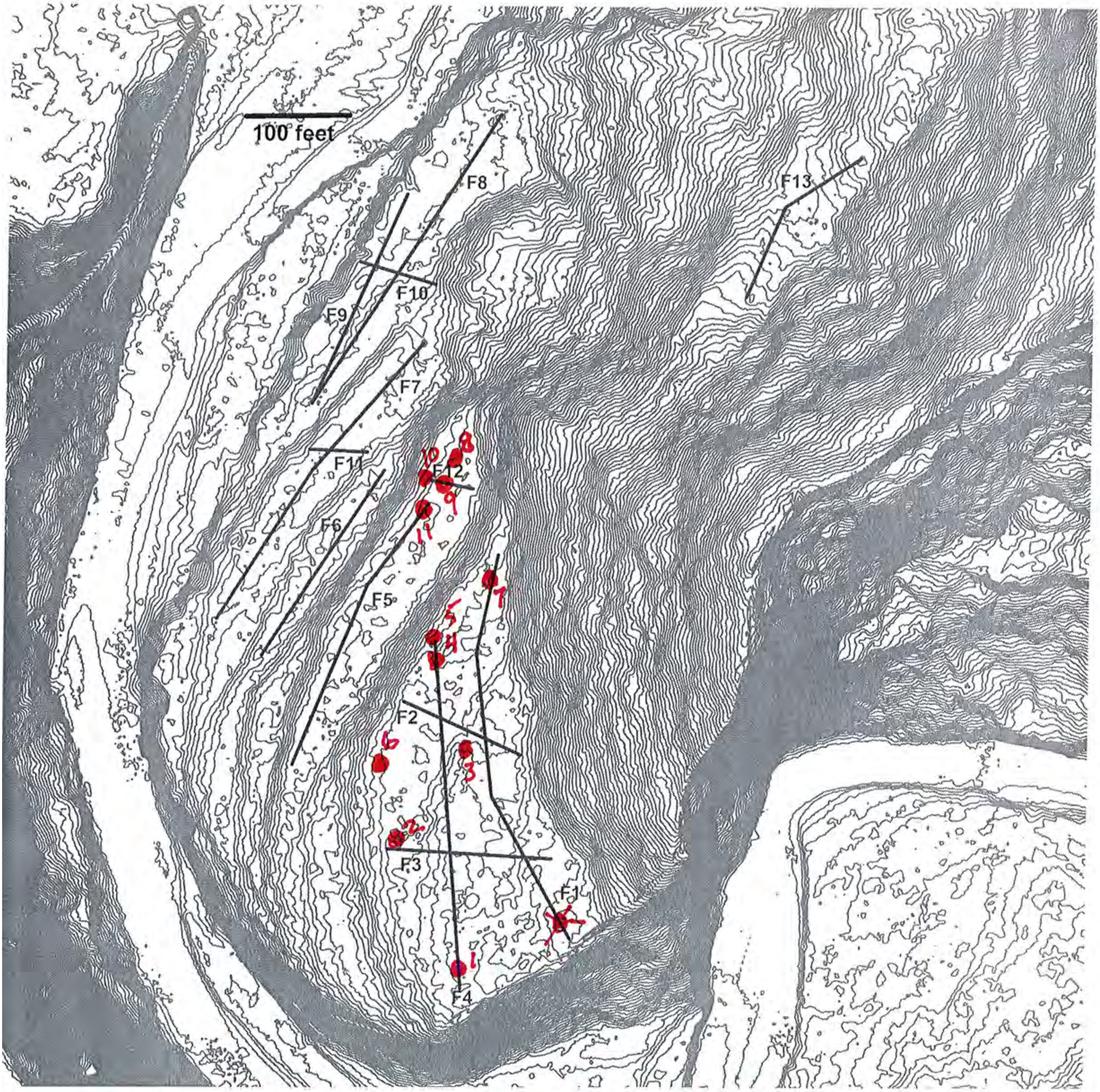
Figure 27. Six different wood samples from base of organic soil at trench FT-8. Sent 1, 4, and 6 for dates. Most probably have been reworked (abraded), but youngest age may put upper limit on terrace age.

TRENCH MAPS ATTACHED

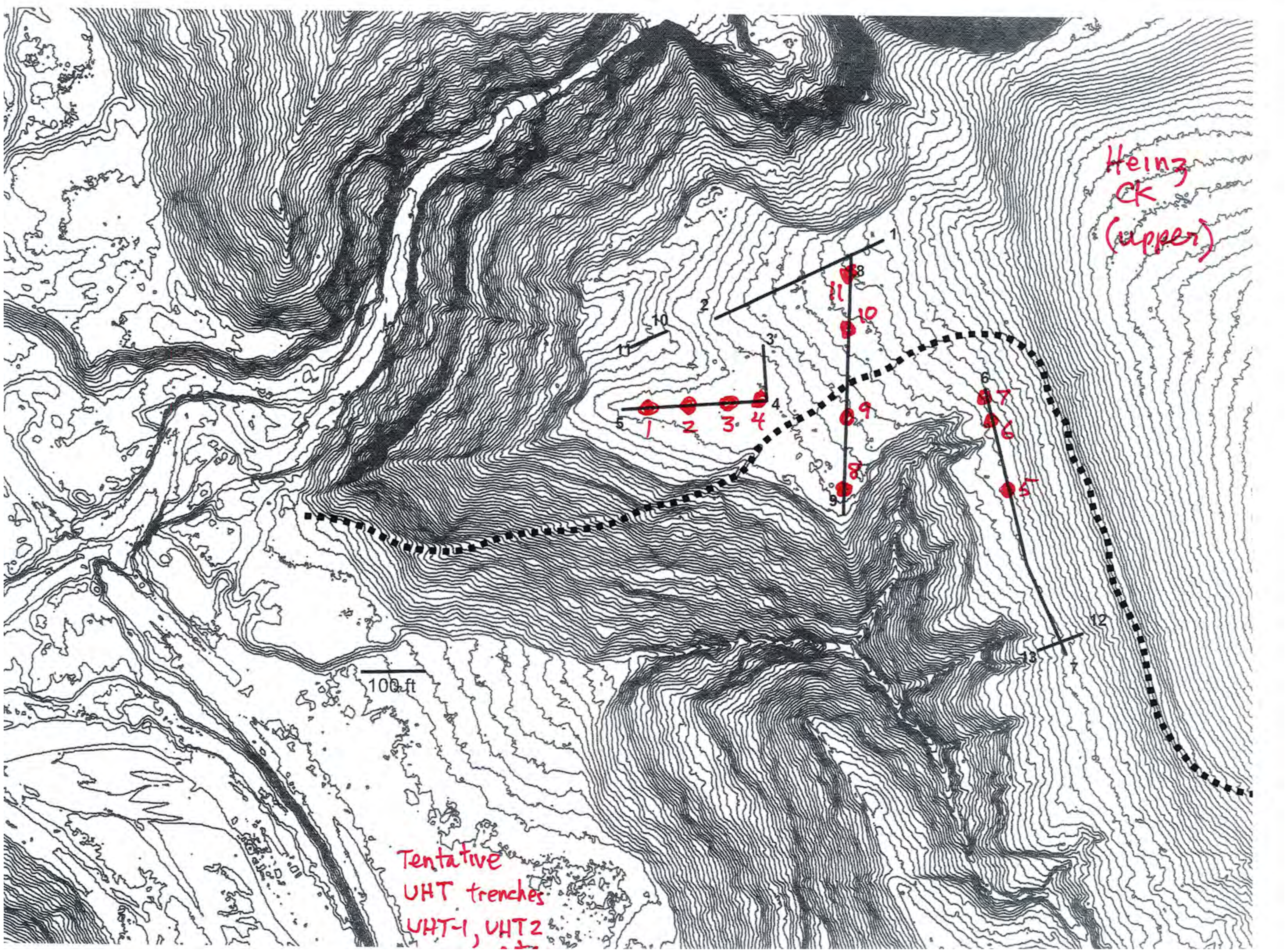
The three maps attached show the APPROXIMATE locations of the trenches completed through June 30, 2016. The locations are approximate because the GPR lines (black lines) are also approximate. In addition, some of the data sheets are in the possession of Mike Wilson, who is on vacation. Young and Wilson have not had a chance to compare all their notes on the excavations that each person may have recorded, when one person was occasionally working on other aspects of the study, or coordinating assistant's activities. These maps will be corrected and updated in the near future. All trenches in the three areas are currently open for further inspection, and are clearly marked with tape and metal ID tags, should anyone need to locate them accurately in the field. The locations are presented in this draft form to allow ECS and EWG people to follow the brief discussion of progress in the accompanying text.
R.A. Young

H-1
H-2
etc


HEINZ
CK
(Lower)
Approximate
H1
H2
H3
H4
H5
H6
H7
H8
H9
H10
H11
H12
H13
H14
H15
H16
H17
H18
H19
H20
H21
H22
H23
H24
H25
H26
100 ft



Approximate Tree farm Trenches   F-1, F-2, etc


Heinz
Ck
(upper)
100 ft
Tentative
UHT trenches
UHT-1, UHT2
1
2
3
4
5
6
7
8
9
10
11

Brief Summary of Geologic Fieldwork for the weeks of July 6-7, and July 11-13, 2016 at West Valley (WVDP) Site
R.A. Young (DRAFT), July 14, 2016 (Wilson on vacation July 6-7)

Wednesday, July 6. (Zerfas, Young, daSilva, Hristodoulou) 9:00AM-4:00PM

Picked up radios and equipment and met Denny Feldman at trailer for day's work plan. Drove UTV to meander bog to dig up (by hand) clay till that Sebastien Huot requested for background information for OSL analysis. Relocated till/wood layer between former Pits 1 and 2, and collected till sample. Drove back to sites of three major gullies between landslide and old Buttermilk Road river crossing (west side Buttermilk Ck). Labeled these gullies informally as: alpha, beta, gamma for reconnaissance purposes. Started in south branch of gamma gully and located sand and lacustrine sequence near tributary junction at approximately 1300 foot elevation (Figs. 2-5). Assumed Lavery till above with Kent till below (from LaFLeur mapping). Unable to find four multi-layered outcrops that laFLeur extrapolated from outcrops he mapped near old Buttermilk Road crossing. The upper till unit was confirmed on the opposite (north) side of the main gully. Tim, Alex and Eraklis continued 3-gully reconnaissance and found lacustrine beds, sand, or ice-contact gravel (ablation till?) in all gullies at or slightly above the 1300 ft elevation (approx. 1300 to 1325 ft) (Figs.6-8). Took pebble count of apparent ablation till "gravel". One site is where Young and Alex previously found good exposure of ice-contact gravel and took pebble count (previous field season). That exposure has since been destroyed by small slide, including large tree falls. It is becoming more obvious that small landslides and accompanying tree falls are a relatively active process on steep gully slopes (Figs.9-10). How does this impact erosion modeling?

Thursday, July 7. (Zerfas, Young, Hristoloudou, Hess) 8:00 AM – 2:00PM

Met at trailer for radios and equipment; drove to Heinz parking area to meet Denny and Tim. Loaded UTV and proceeded to upper Heinz Creek trenching site (Sean B. also working there; Figure 11). Confirmed former trench numbers and locations for UHT-8 through UHT-11. Assistants began detailed record of GPR line locations for all trenches at upper and lower Heinz sites, using accurate laser distances and marking accurately on Mia Painter's preliminary radar plots for future reference or relocation. Completed aluminum tag markings for trenches not previously so marked. Moved to west side of Buttermilk Creek in afternoon to store materials in trailer and revisit parts of alpha, beta, and gamma gullies to more closely examine sedimentary hiatus between tills. Took OSL and pebble counts from appropriate units (Figs. 7-8). Data and locations marked on 2-foot lidar generated topographic map of gullies. Terminated work at 2:00 PM due to sound of thunder occurring in area (as contract requires).

Monday, July 11. (Young, Wilson, Zerfas, Hess, DaSilva, Hristodoulou) 9:00AM-4:30PM

Met at trailer to pick up charged radios and miscellaneous equipment not able to be left in unsecured field tent storage. Drove to Tree Farm site to meet Northrup trenching folks and began with new trench FT-12. Completed trenches Ft-12, 13, 14 and recorded similar stratigraphy of fine alluvium (overbank?) over coarser fluvial gravel resting on gray glacial till (Figs. 12, 13, 16). FT-14 is on small intermediate terrace between GPR lines F5 and F6. FT-13 encountered "hardest" till yet; appears to be true lodgement till with no exotics; mainly local bedrock (sandstone). Finished excavations at trench FT-14 (no OSL sample). Took one OSL sample each at FT-12, FT-13 (Fig. 13). Eraklis, Alex, and Zakk continued accurate recording of trench locations on GPR maps with laser; also measured gradients of terraces. Taped off all new excavations and installed aluminum ID tags. Plan to mark all prime trench locations and GPR lines with fluorescent (orange) marking paint to make them all easier to relocate, especially if yellow flagging tape should be inadvertently removed. Returned to storage trailer to store new samples and equipment; put radios on charger.

Tuesday, July 12. 8:00AM- 4:30PM

Gathered radios and field equipment and drove to Tree Farm site. Drove to tent storage in UTV and began excavation (trench FT-15). Found three pieces of wood in overbank(?) sediments at 17-inch depth; also took OSL. Assistants worked on: 1) taping remaining trenches and labeling, 2) confirming longitudinal gradients of terraces with laser transit loaned by Eric (Norton employee) (Fig. 14). This is a repeat of hand leveling work from previous day to test accuracy of methods. Terrace gradients will be compared with modern Buttermilk Creek gradient, and 3) plotting new trench locations accurately on GPR lines. Finished trenches FT-16 to Ft-20 (wood also located in trench FT-17; Figure 17).

Collected seven new 14C samples this day; split samples and packaged for Wilson to send to BETA lab. Rode UTV out with equipment and returned materials and OSL samples to trailer storage at Buttermilk gate.

Wednesday, July 13. (8:00AM – 5:00PM)

Proceeded from storage trailer to Tree Farm, then UTV trip to begin trenching. Completed trenches FT-21 to FT-25. FT-22 had vertical tree section preserved in clay (no root connection; strange finding, strange orientation for isolated tree); sending for 14C dating; took OSL sample from correlative horizon. Trenches Ft-23 to Ft-25 revealed no useful organic samples. Tim worked with S. Bennet's group on water supply and equipment issues, which he has assisted with periodically (Figures 19-23).

Moved to highest GPR line F-13 to complete trench FT-26 late in the day. Found three semi-vertical tree remnants and two associated organic debris layers within 4.5 feet of surface in clay beneath organic soil in low wet area. Spent rest of afternoon closely examining and recording organic remains located within what clearly appears to be a compact clay till containing abundant clasts, including rounded limestone. This site may be the companion to the meander bog site on the west side of Buttermilk Creek)where we have dated 13,000- to 14,000-year-old wood in till (same glacial advance?). We have collected and preserved numerous organic samples from this location, and we will be revisiting next week to take further notes, additional photographs, and collect more samples. This site (as well as FT-22) contains materials that should be examined and identified by Carol Griggs at the Cornell tree ring lab, and might benefit from being looked at by a palynologist to potentially confirm glacial environment. The case appears to be strengthening for a late glacial advance into this area.

Figures:

Figure 1. Tim's donation on hottest day (temperature in 90s). 2.

Figure 2. UTV transport facilitated transport of people and equipment to gully sites.


Figure 3. Stratified section between tills in northernmost gully (gamma).

Figure 4. Examining stratigraphic interval in gully slope.

Figure 5. Torvane measurements being taken.

Figure 6. Ablation till or ice contact deposition zone sediments in gully knickpoint.

Figure 7. Pebble clast count from location in Figure 6 (20% carbonate, chert, and red sandstone of northern derivation).


Figure 8. Stratified sand zone between tills in gully. Site of OSL sample.


Figure9. Tree fall tangle in gully; typical of some tree fall and landslide conditions.

Figure 10. Difficulties of field work access conditions in some steep gullies (as Figure 9 above).

Figure 11. Zakk Hess watching Bennett crew test operations.

Figure 12. Typical trench (FT-12) at Tree Farm terrace site: fine alluvium over coarser gravel; clay till at base.

Figure 13. Taking OSL sample with steel tube and rubber hammer in alluvium at trench FT-13.

Figure 14. Using laser transit to confirm terrace channel gradients.


Figure 15. Example of terrace feature considered for channel gradient measurements.

Figure 16. Examining fine alluvium contact with coarser fluvial gravel at trench FT-14.

Figure 17. Wood from trench FT-17 in overbank sediments. Probably reworked.

Figure 18. Vertical tree section removed from trench FT-22. Specimen was not attached to root.

Figure 19. Tim completing water delivery system for S. Bennett move to Tree Farm site.

Figure 20. Diversion of spring flow from upstream through PVC pipe.

Figure 21. Gravity flow from upstream diversion of spring flow through PVC pipe fills white storage tank.


Figure 22. Example of Tim's earlier water supply delivery system installation at Heinz Creek site.


Figure 23. Water pressure tank and generator for pump.

Figure 24. Tree impression (below hand) after removal from till at trench FT-26 (GPR line F13, Tree Farm site). Note darker horizontal organic layer below tree impression near top of gray colored zone (arrow).

Figure 25. Wider view of darker organic layer in till at arrow, following slightly more excavation of tree impression.

Brief Summary of Geologic Fieldwork at West Valley, July 18-20, 2016
(R.A. Young for M. Wilson and R. Young; Visit by R. Fakundiny). July 21, 2016

Monday, July 18, 2016 (9:00 AM- 3:00/5:00 PM)

Arrived at ECS storage shed during sporadic showers and loaded gear and radios for work at Tree Farm and Heinz sites. Met at Tree Farm area with Feldman, Zerfas, Wilson, and assistants, including Sean Bennett's workers, to be ferried to work sites. Light showers cleared after about ½ hour. Young and 2 assistants returned to trench TF-26 for further collecting of organic samples and OSL samples from till locality, while Wilson, Zerfas, and Hess, visited Heinz Creek area to measure terrace (channel) gradients, and to relocate and measure cored trees. Tim drained trench FT-26 of accumulated water with garden hose siphon. Till pebble count was also collected at trench FT-26 (location of wood and organic layer in glacial till) for comparison with earlier results from other till exposures (Figures 1-3). Young group finished work and finished storing materials at storage trailer at 3 PM, Wilson group worked at Heinz site until 5 PM. Went to dinner and were joined by R. Fakundiny around 8:30 to discuss Tuesday plans.

Tuesday, July 19, 2016 (8:00 AM – 5:00 PM)

Acquired equipment and radios at storage trailer; met at Tree Farm site with Bob Fakundiny. Wilson and Young (with assistants) guided Fakundiny on tour of Tree Farm trenches and stratigraphy, beginning with the FT-26 trench containing wood and organic layer in till. Also visited work sites of Bennett group so Bob could observe both jet and infiltration tests in progress (Figures 4-7). Located new wood sample at top of gravel at trench FT-18 that was apparently uncovered by collapse of trench wall by filling with water (Figures 8-10). Lee Gordon and Paul Bembia visited in late morning for update on work in progress; also viewed water delivery system organized by T. Zerfas. Entire group moved to Heinz Creek area and spent rest of afternoon on tour of lower and upper Heinz Creek trenches. Discussions occurred throughout visits to both trench areas concerning the stratigraphy and suggestions from R. Fakundiny about significance of findings and possible options. Returned to storage trailer to charge radios and store valuable equipment; left at 5:00 PM.

Wednesday, July 20, 2016 (8:00 AM – 4:30 PM)

Retreived radios and equipment at storage trailer and used both UTVs to move parties to abandoned meander site. Re-exposed wood-bearing till in vicinity of bog Pits 1 and 2 at abandoned meander depression for Fakundiny (by hand digging). Measured mapped locations for all relevant bog area pits and continued with tour of remaining filled trench locations in the abandoned meander area. Showed Fakundiny location of stratigraphic section where Greg and Sandy probably took OSL samples at abandoned meander. Assistants completed marker paint and aluminum tagging of necessary radar line and trench locations, as needed (as also done on previous two days).

Moved to large landslide site on west side of Buttermilk Creek to check for evidence of recent changes. Assistants located and documented a well exposed section of glaciofluvial and/or glaciolacustrine sediments about 50 feet below top of landslide that may mark the glacial recession prior to Lavery till deposition (see images). Assistants collected two OSL samples from this sedimentary sequence. Assistants returned to abandoned meander site to finish final marking of trench locations and radar lines. Wilson, Fakundiny, and Young engaged in lengthy discussion of project progress and issues to be discussed during Friday phone conference. Returned to store equipment and radios and finished at 4:30 PM. Returned Fakundiny to Microtel for Thursday departure to Albany.

Figures:

Figure 1. Work at wood in till site (trench FT-26) following draining of water and construction of wood platform.

Figure 2. Sloping organic layer (between arrows) in till at FT-26; note wood fragment projecting at lower arrow. 1 foot scale at right.

Figure 3. Pebble count of till in progress at trench Ft-26.

Figure 4. Wilson describing stratigraphy during Fakundiny tour.

Figure 5. One of few fluvial gravel deposits showing well developed variety of stratification (trench HT-32).

Figure 6. Fakundiny and Wilson viewing Bennett group's jet test setup at Tree Farm site.

Figure 7. Infiltration test in progress at Tree Farm trench.

Figure 8. Wood unexpectedly exposed(?) in trench FT-18 by gravel collapse into water (see Figure 9 below).

Figure 9. Wood found apparently protruding from gravel in trench FT-18 following collapse. Wood is seldom preserved in gravel exposures due to relatively greater degree of oxidation in permeable strata.

Figure 10. Wood sent for dating from trench FT-18.

Figure 11. Assistants examining stratified sequence between thick tills at large Buttermilk landslide. (See several following images.)

Figure 12. Sediments located between landslide tills after exposing (scraping) with hoe and trowels.

Figure 13. Cross-bedded sediments in section shown above (brown is sand; gray is clay).

Figure 14. Liquefaction related deformation (flame structures) in interbedded sands and clays.

Figure 15. Extraction of OSL samples taken from stratified sediments between tills at landslide location.

Brief Summary of Geologic Fieldwork for ECS, Inc. West Valley Project, July 25-27, 2016
R.A. Young (for M. Wilson and R. Young) (DRAFT) July 28, 2016 (Lewis Owen visit and tour)

Monday, July 25, 2016

Arrived at storage shed at 9:00AM amid scattered showers and rain effecting most of western NY. Showers returned to site about 9:15AM. Drove to Microtel for planning meeting and to await break in weather. Reviewed maps and photographs from existing trenches and explained geology to Lewis Owen. Rain broke about 11:30; proceeded to Tree Farm site for 1.5 hours during break between lines of east-moving thunderstorms. Showed Owen trench FT-26 with wood in glacial till (Fig.1); visited two other trenches near tent storage. Evacuated at sound of thunder and arrived back at cars at beginning of continuing thunderstorms. Went to lunch in Springville for further discussion and to wait for possible afternoon clearing.

Due to uncertain weather forecast it was decided to conduct a tour of portions of Buttermilk and nearby Cattaraugus Creek basins; stopped to view Cattaraugus Creek channel near Scobie Dam. Drove to far SE corner of Ashford Hollow Quadrangle (Tim Zerfas family property) to check geology of pond site where Tim's family uncovered wood about 25 years ago. Also viewed till exposure near another Zerfas farm pond that had recently undergone some renovation work. While conversing with family members, Tim's uncle offered to dig a pit with his large excavator in a depression in an adjacent field to examine glacial stratigraphy, and to expose gray clay till he thought would be close to the surface (see photos and maps attached). On what LaFleur mapped as Wisconsin end moraine (Wem) or "Kent moraine" according to his geologic sketch map (LaFLeur, 1979, USGS Open-File Report 79-989, p. 6) the pit excavated for us by Tim's uncle encountered wood imbedded in gray till (Figs. 2-10). Several of the preserved wood fragments were imbedded approximately 0.5 feet in the top of the till, which was overlain by thick organic deposits. The wood was a yellowish color upon initial excavation (Figs 4-5), but rapidly turned gray, then black, upon exposure to the air. Wilson also collected samples from a layer of "peat" that had a slightly different appearance from the surrounding organics Figs. 7-8). Several samples were collected for ^{14}C dating. These fortuitous findings would probably not have occurred had it not rained, and had the impromptu tour not encountered helpful members of the Zerfas clan (Fig. 10). Dates on these wood samples might provide one of the first accurate dates for the Kent advance in New York State, as well as confirm LaFleur's interpretation of key morphostratigraphic mapping units. Finished work at 5 PM and met for dinner discussion of day's events and plans for Tuesday.

Tuesday, July 26, 2016

Met at trailer storage at 8:00AM to obtain equipment and radios. Drove to Heinz Creek to continue tour for Lewis Owen (Zerfas, Wilson, Young). Other assistants went to begin geologic reconnaissance of first large eastern tributary to Buttermilk Creek south of Heinz Creek. L. Owen gave advice concerning optimal grain size needed for best OSL results and noted that some the layers we have sampled might be slightly too fine-grained for optimal analysis (Fig. 11). However, we have collected (conservatively) many more samples than will be actually submitted for dating, so have many choices that eventually will be prioritized. We resampled trench HF-16 on Lewis's advice, and with his supervision in order to verify our procedures. We then visited the large Buttermilk Creek landslide to show Lewis Owen the glaciofluvial and/or glaciolacustrine interval between the two main tills exposed there (sampled for OSL last week). The tour continued on to the abandoned meander site to view briefly the trench locations. The small gas-powered auger from the storage trailer was used to try and explore shallow groundwater and geologic conditions for planned Wednesday trenching operations (Fig. 12). Groundwater conditions in the lowest (youngest) meander channel did not seem to be as unfavorable as we might have encountered, although it was decided Norton folks should bring a pump to avoid unacceptable trench flooding. Returned equipment to storage trailer and finished at 4:30PM.

Wednesday, July 27, 2016

Retrieved radios and equipment from storage trailer and went to abandoned meander site in Denny's truck and one UTV. Other UTV was delivered to Sean's group. Tim and L. Owen went to Tree Farm site to collect additional OSL samples and Beryllium10 boulder samples for potential surface exposure age analysis. Three assistants began geologic reconnaissance of two gullies leading eastward down to Buttermilk Creek from the lowest abandoned meander channel. Wilson and Young began trenching along lowest abandoned meander channel. Trench numbering system was restarted as trench number MT-30. Trench MT-32 provided many wood and other organic samples (including leaves) at the top of a gray clay immediately below the organic surface layer (Figs. 13-14). The gray clay does not appear to be glacial till, and the organics collected were largely those that appeared to be slightly imbedded in the top of the shallow clay layer. Completed trenches MT-30 to MT-32; broke briefly for lunch and to confer upon return of Tim and Lewis from Tree Farm site.

Began trench MT-33 at base of small alluvial fan leading into abandoned meander channel from adjacent depression (site of earlier excavated Pits 1 and 2 containing wood in till). Immediately encountered multiple wood (medium-sized log fragments) and organic samples (Fig. 15). Several medium-sized log fragments were oriented approximately vertically in a clay layer below the organic soil. One such log ended at the contact between clay and older gravel, but both ends were "broken" and showed no root structure (no root structure was noted on any of the log samples). The gravel extended downward an additional 5 feet from the lower end of this log fragment (Fig. 16), and till was encountered at the base of the gravel (8 ft. depth). Water began to accumulate in the base of the trench, presumably due to the impermeability of the till below. Much of the afternoon was spent extracting and documenting log fragments and other organic remains from trench MT-33, and samples were prioritized for Wilson to mail to Beta Labs on Thursday. One of the non-wood samples was from a thin, darker, organic-rich clay interval near the base of the vertical log (see Fig. 16).

Broke off trenching operations about 3:00PM to locate and mark trench sites on the upper plateau surface south of the landslide and gas line for sampling of Lavery till and access for Sean's next round of jet and infiltration testing. Marked 7 potential trench sites with orange painted stakes and measured their relative locations with the laser distance device. These 7 sites need to be approved by DOE and/or NYSERDA as being outside any areas of concern (wetlands, etc.). Returned to storage trailer with samples and equipment and left at 4:30. Will work 2 days next week (Monday-Tuesday) due to M. Wilson's other commitments.

FIGURES:

Figure 1. Mike conferring with L. Owen at Tree Farm “wood in till” trench FT-26.

Figure 2. Tim Zerfas’s uncle digging pit on Kent moraine in SE corner of Ashford Hollow quadrangle.

Figure 3. Pit in Kent moraine after removing wood on top of till.

Figure 4. Fragments of wood found right on top of till on east side of pit; unclear whether wood was at base of organics or on top of till, before west side of pit was excavated.

Figure 5. Wood clearly embedded at least 6 inches in gray till on west side of pit. Wood began to turn dark gray Immediately upon exposure to air. Brown organic layer is on right.

Figure 6. Left (west) and right (east) sections of pit shown here. Wood embedded in till was located.

at slightly lower excavated level of till near arrow. Figures are standing in west side of pit.

Figure 7. North face of east pit section showing peat layer near center at arrow.

Figure 8. Eraklis collecting peat sample (between arrows) from east section of pit.

Figure 9. View of east wall of east pit section. West pit partially visible in lower left corner of image. Morainal topography visible beyond pit.

Figure 10. Moraine collecting team: Wilson, Tim, Tim's uncle (wood in hand), Eraklis, Zakk, and Lewis Owen. DeSilva and Young out of view.

Figure 11. Lewis Owen viewing trench HT-7 at lower Heinz site.

Figure 12. Tim and Alex testing new auger at abandoned meander lowest channel.

Figure 13. View eastward from trench MT-32 toward trench MT-30 in distance. Most wood was collected from level of arrow below the base of the organic layer, but enclosed by an inch or more in the clay below.

Figure 14. View westward from trench MT-32 toward trench MT-31 along abandoned meander channel.

Figure 15. Shallow log (arrow) found protruding from clay at alluvial fan site, trench MT-33.

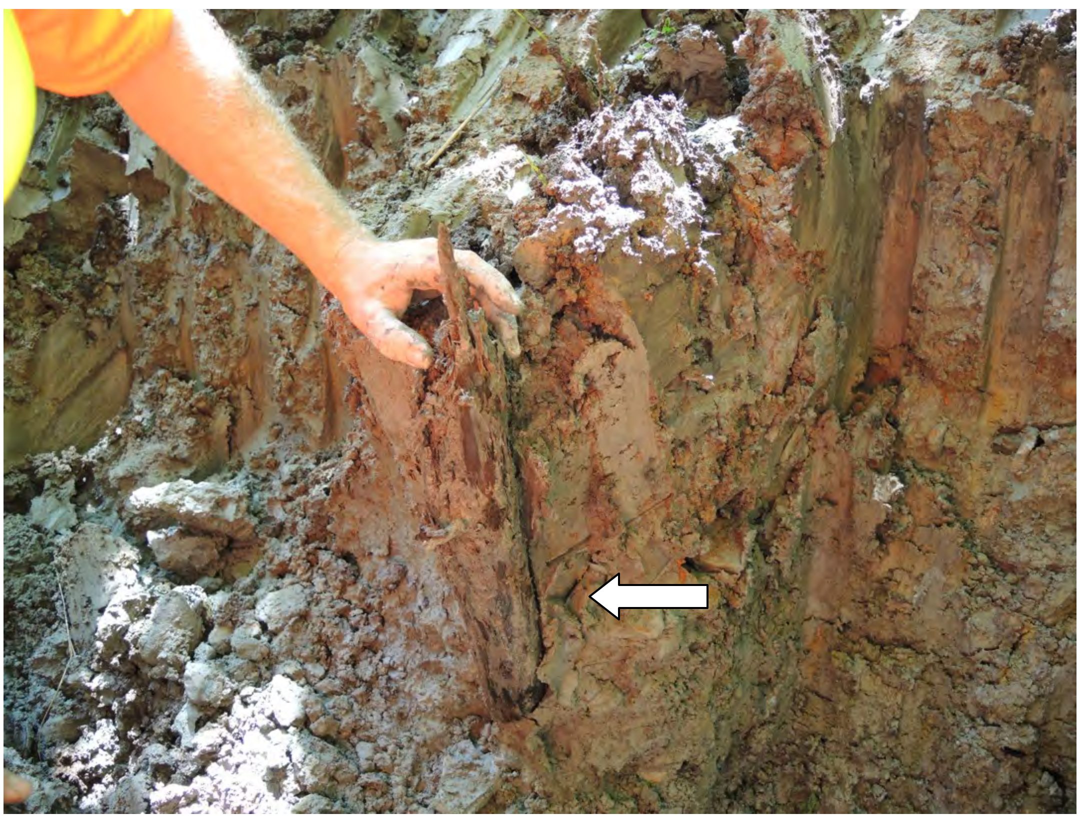
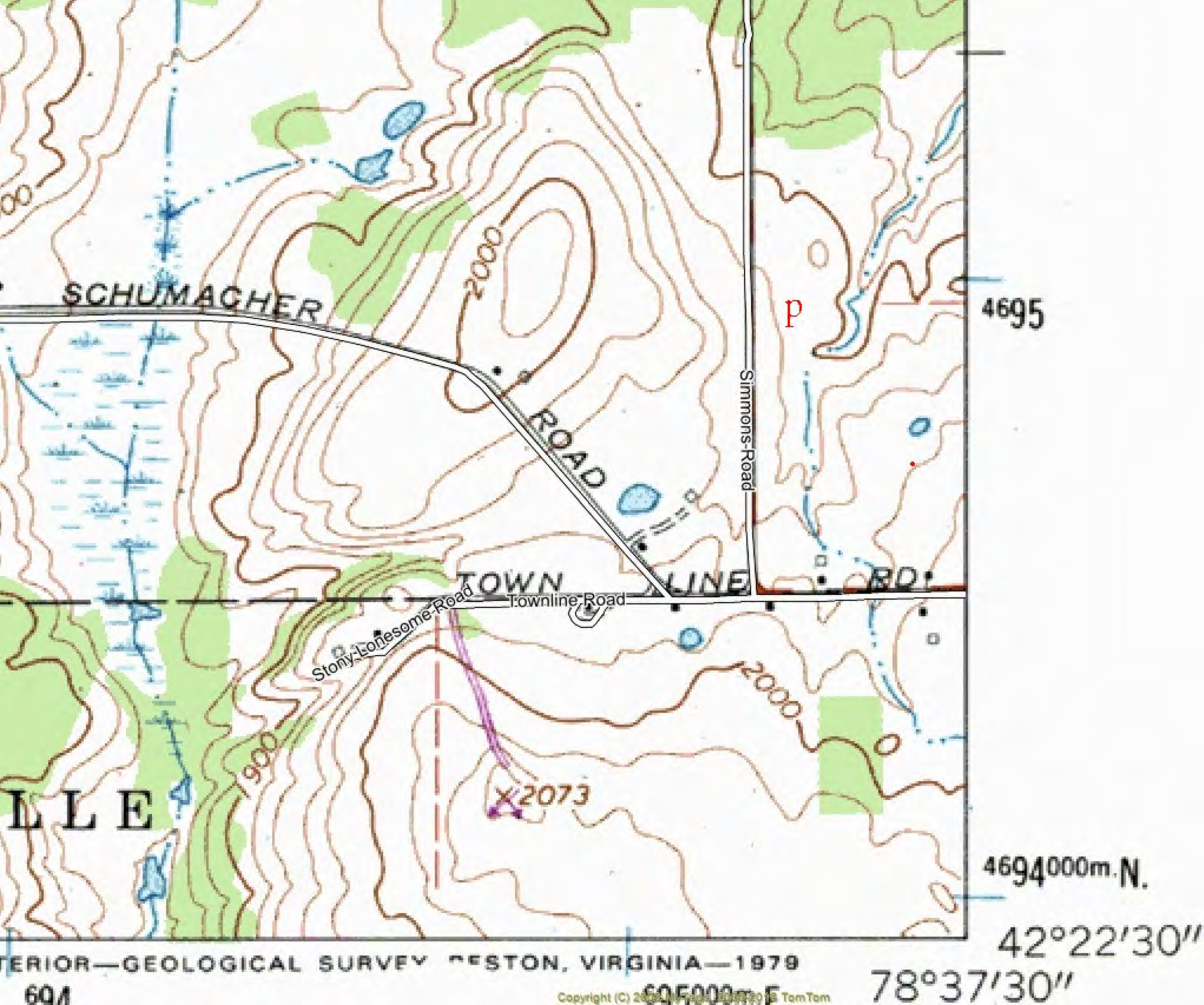


Figure 16. Log segment in clay with lower end resting on contact with gravel at 3 foot depth. A thin organic horizon in the clay was sampled for ^{14}C dating at approximate level of arrow.

Maps and photo following show location of Kent moraine pit on Zerfas property as "P"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ROAD
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LINE
RD
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2000
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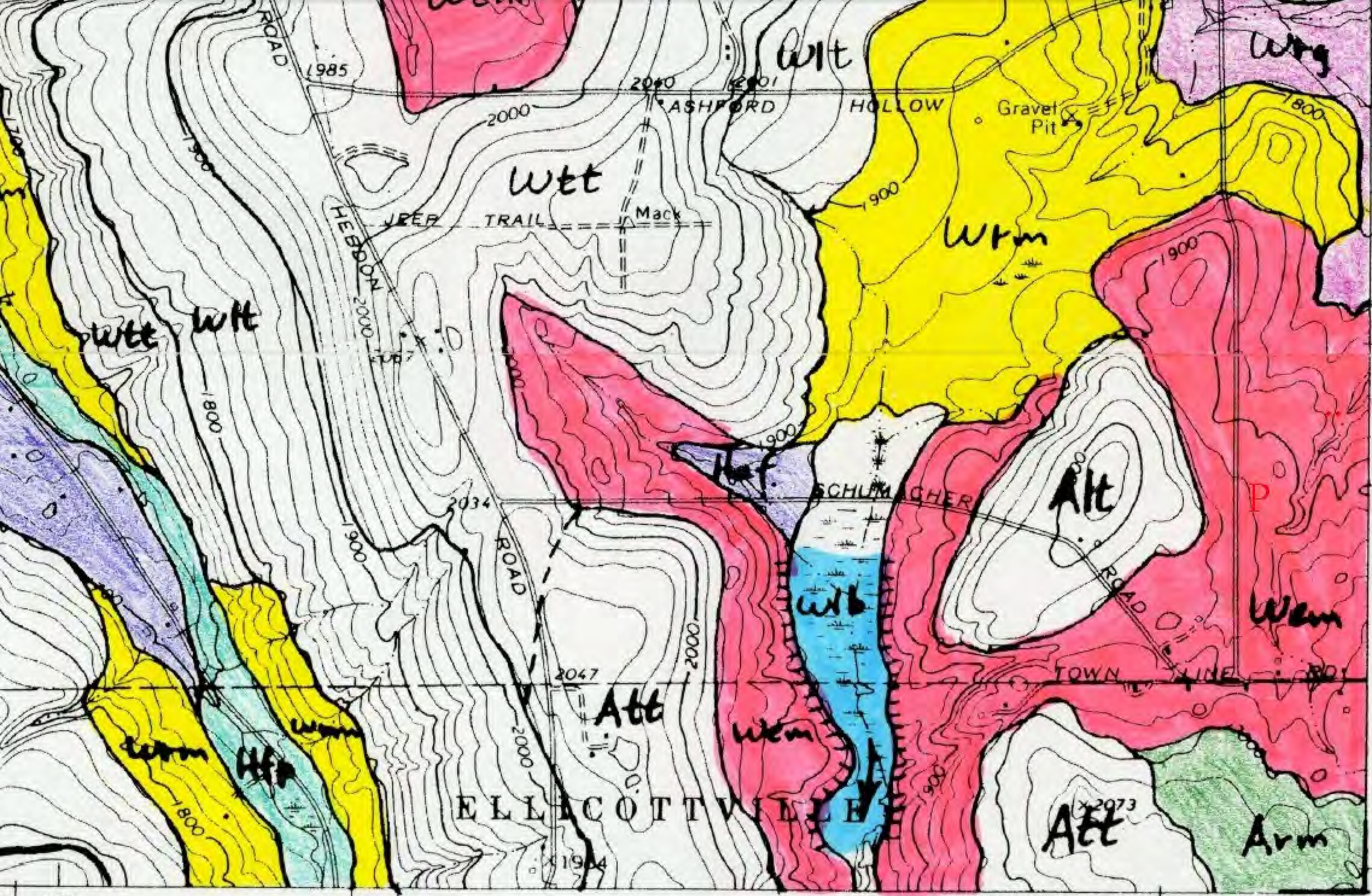
TERIOR—GEOLOGICAL SURVEY RESTON, VIRGINIA—1979
694



GEOLOGY BY R. G. LAFLEUR, 1975

P
© 2016 Google
227 ft
Google earth
N

APPENDIX

LAFLEUR GEOLOGIC MAP (PORTION)

(R. Young notation 7/29/16) Kent moraine highlighted in yellow; red circle is general location of the Zerfas property where the pit was dug last Monday (7/25/16).

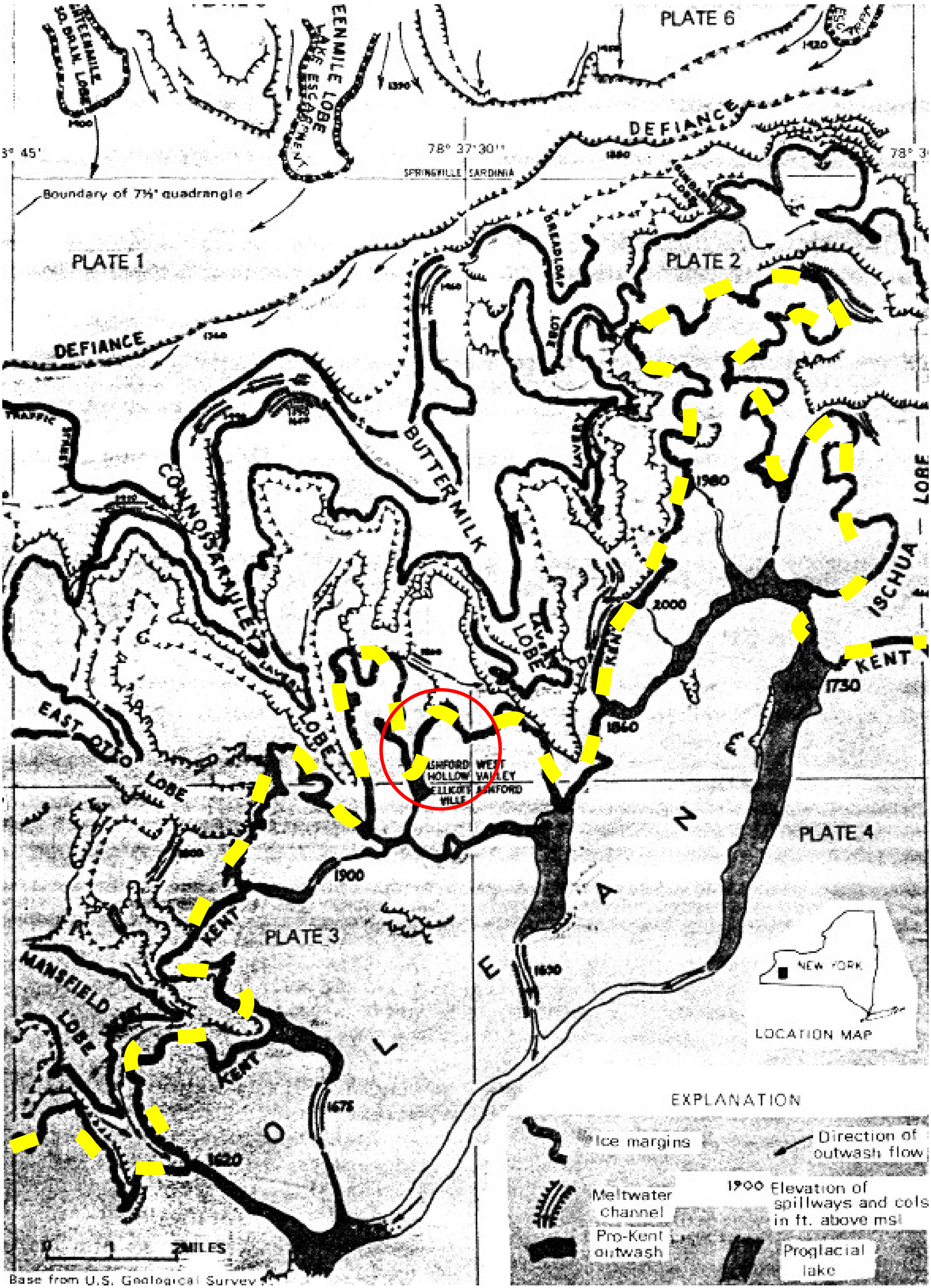


PLATE 6
DEFIANCE
78° 37'30''
SPRINGVILLE SARDINIA
Boundary of 7½' quadrangle
PLATE 1
PLATE 2
DEFIANCE
BUTTERMILK
LOBE
ISCHUA
LOBE
KENT
1980
2000
1730
1860
ASHFORD HOLLOW
WEST VALLEY
ELLICOTTVILLE
ASHFORD
EAST OTTO
LOBE
PLATE 4
PLATE 3
1900
KENT
MANSFIELD
LOBE
KENT
1675
1620
NEW YORK
LOCATION MAP
EXPLANATION
Ice margins
Direction of outwash flow
Meltwater channel
1900 Elevation of spillways and cols in ft. above msl
Pro-Kent outwash
Proglacial lake
0 1 2 MILES
Base from U.S. Geological Survey

Brief Summary of Geologic Fieldwork for ECS, Inc. West Valley Project, August 1-2, 2016
R.A. Young (for M. Wilson and R. Young) (DRAFT) August 4, 2016

Monday, August 1st (9:00AM)

Met at storage trailer (Feldman, Wilson, Zerfas, Young, daSilva, Hess, Hristodoulou). Proceeded from storage trailer to abandoned meander; let off assistants on route to survey 7 staked locations for plateau trenches south of landslide area (laser measurements made to verify approximate cell phone coordinates from previous week). At meander site trench MT-33 was pumped dry to verify that till had been encountered at base of excavation. Completed trench MT-34 and MT-35 in the lowest (youngest) channel of abandoned meander, proceeding along the channel from east to west (Fig. 1). Trench MT-34 provided wood samples in the upper clay and organic horizons; no samples collected from MT-35. Wilson and assistants went to measure channel gradients on terrace remnants to the north of the racetrack. Alex and Eraklis completed pebble count in fluvial gravel above basal till. Tim led survey to determine how to bring water up from Buttermilk Creek to the meander area and to the proposed plateau sites. Began long cross-section trench of entire channel width at MT-36. Collected wood samples at base of organic unit near south end of trench. Took two OSL samples in only sand unit encountered so far (medium to coarse sand). Prepared two carbon 14 samples of wood for Wilson to mail to Beta. Returned to storage trailer and finished at 4:30 PM.

Tuesday, August 2nd (8:00 AM)

Same crew as previous day, except Wilson absent due to commitment for Cincinnati meeting. Returned to lower abandoned meander channel to continue trenching. Began trench MT-37 (Fig. 5) as a second full-channel cross section directly adjacent to (west of) MT-36. Located abundant wood in and near base of a 3.4 foot thick organic surface layer. Encountered 1.5 feet of clay below the organics on top of gray, saturated fluvial gravel. While continuing to excavate the fluvial gravel, a 2-foot long log segment (with bark attached) was encountered completely encased in the gravel. The 2-foot log extended vertically from 8 inches below the top of the gravel down to the top of the underlying till (Fig. 2). The log was carefully excavated from the gravel by hand to search for an expected root (none found). However, this log could not be the result of a larger tree fall driving one of its branches deep into the gravel, as the gravel is much too compact and dense. It was very difficult to excavate the specimen. This implies that the log, entirely encased within the gravel, was associated with fluvial deposition at the time this lowest meander channel was actively transporting its normal gravel bedload. This appears to be the first good wood specimen we have encountered that may provide a reasonable date for the age of this active channel, and the approximate time when the meander was abandoned. Assistants worked on 4 more pebble counts in adjacent trenches to verify the nature of the gravel unit and to confirm its similarity to modern Buttermilk Creek deposits.

Began trench MT-38 immediately west of MT-37. Wood was abundant in the shallow organic layer, underlain by a thin clay unit. More importantly, two additional wood samples were associated directly with the underlying fluvial gravel. One short log extended at an angle of approximately 30 degrees from the thin clay layer for about 6 inches down into the underlying gravel (Fig. 3). This specimen could(?) possibly have been emplaced by a large tree fall (bark intact, but removed during excavation). However, the second wood specimen was clearly located 1.5 feet down into the gravel, but fell out during trench excavation (Fig. 4). Both of these samples associated with the gravel layer have been sent to Beta for dating. The lower wood specimen, located entirely within the gravel, should provide a second opportunity to accurately confirm the age of the active channel, similar to the sample obtained at trench MT-37. Trench MT-39 was shallow and provided no additional useful samples. Received safety briefing from Denny, and left around 3 PM to pack up and return to storage trailer. Worked until 4:30 completing inventory of OSL samples stored in trailer.

FIGURES

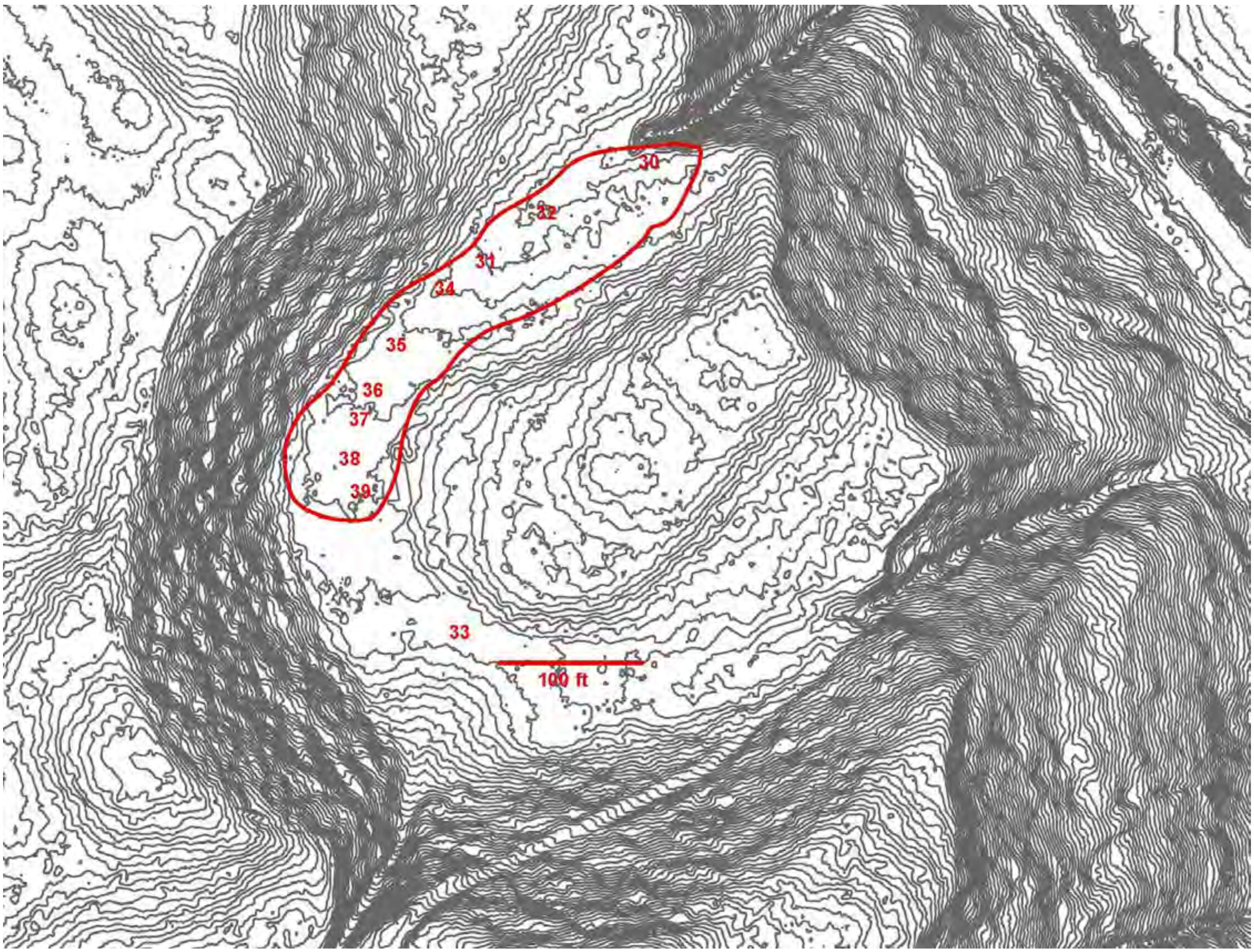


Figure 1. Approximate locations of trenches (MT-30 to MT-39) completed at lower meander channel during past two weeks. Trenches 36 and 37 extended entirely across width of channel.

Figure 2. Two-foot vertical log segment enclosed entirely by fluvial gravel in trench MT-37, during removal. Log segment extended from approximately 5.5 to 7.5 feet below surface.

Figure 3. Log segment extending at ~30 degree angle from clay for about 6 inches into fluvial gravel at trench MT-38. Log has been rotated and bark removed, but is in place.

Figure 4. Location of wood (was in circle) in trench MT-38 after fragment was dislodged during excavation. Wood was located approximately 1.5 feet down within gravel unit.

Figure 5. Lengthwise view of trench MT-37 just prior to completion. Two-foot log segment was excavated from trench close to bottom of image.

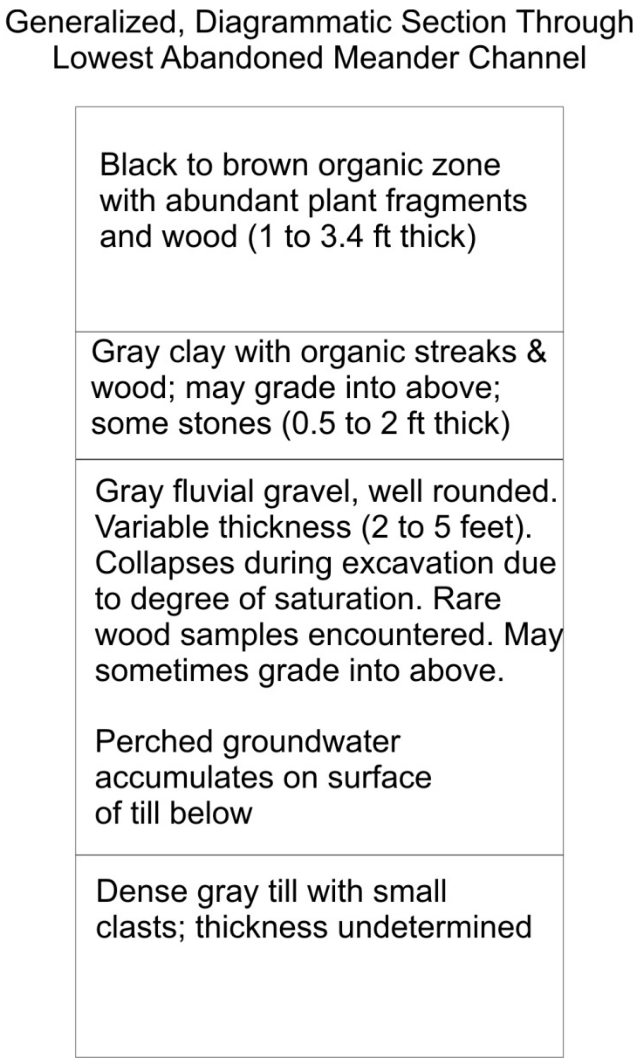


Figure 6. Generalized stratigraphic section encountered along north side of lowest abandoned meander channel. Contacts between three upper units are not always sharp or distinct.

Progress Report: Geologic studies near the WVDP site in the Ashford Hollow Quadrangle (DRAFT)

Objectives and Methods

The basic objectives relating to the geologic fieldwork for the Phase 1 studies involve reviewing all of the previously available geologic information and attempting to improve on the identification of geomorphic landforms with the ultimate goal of improving the late glacial and postglacial chronology. This is in support of the efforts to accurate model the past and future evolution of the topography associated with the Buttermilk Creek drainage system. Phase 1 studies have been greatly enhanced by the availability of detailed lidar imagery, the most recent advance in the detailed analysis of geomorphic landforms. The review of landforms visible on the lidar imagery allows an order of magnitude improvement in the ability to identify small-scale landforms that cannot be resolved on existing 1:24,000 scale topographic maps, and that were not adequately identified during previous geologic mapping studies.

A basic comparision of the new lidar imagery with the geologic maps of LaFleur reveals that many useful landforms exhibiting subtle topographic relief are not adequately depicted on, nor could they be inferred from, the LaFleur maps. This especially includes features such as small individual landslides, fluvial terraces, small alluvial fans, abandoned stream channels, and subtle landforms formed during the last glacial recession. Given the extraordinary level of new detail now visible on the lidar imagery, it is not feasible to accurately remap the large area covered by LaFLeur's maps. This is in part due to the need to verify the identification of many small-scale features in the field.

As a result of our preliminary lidar analysis, we located a number of glacial and fluvial landforms in close proximity to the WVDP that were the most likely to provide information of chronologic value, assuming that appropriate samples have been preserved within such deposits. The landforms considered to be most relevant to such studies are the stream terraces and remnants of former stream channels or deposits that have been preserved over a significant range of elevations. However, the identification of a specific landform must be verified by field inspection. One of the critical issues for such field validation is the ability to make distinctions among fluvial, mass wasting, and glacial landforms. All three processes may produce step-like surfaces along valley margins that record entirely different events in time and space.

We were able to successfully identify three promising areas that appear to record flights of terraced surfaces attributable to fluvial processes, both channel forms (terraces) and low-gradient alluvial fans. Furthermore, our initial field observations were able to distinguish between glacial and fluvial deposits by conducting pebble counts (analysis of 50 to 100 clasts) at all the critical sites. In short, the northerly derived glaciofluvial deposits and tills contain a significant proportion of carbonate clasts, derived from bedrock formations that crop out only north of Cattaraugus Creek. In contrast, the deposits of modern Buttermilk Creek and its predecessors are dominated by the sandstone clasts from bedrock exposed to the south. Locally derived landforms have more complex compositions that can be demonstrably tied to the nearby geology.

The two initial methods for dating fluvial and glacial landforms were assumed to be: 1) radiocarbon dating, good for organic matierials up to 50,000 years old, and 2) optically stimulated luminescence (OSL), a newer method that has evolved rapidly and gained acceptance over the past two decades, but that is very time consuming and labor intensive. Because organic remains are seldom preserved for very long in near-surface, oxidizing environments the OSL method fills an important gap that has long been unavailable. A third method of dating known as "surface exposure dating" utilizes beryllium-10 and aluminum-26 that are produced by the cosmic ray exposure of quartz in boulders exposed at the land surface. This method requires the existence of very large boulders that must not have been moved or rolled over during their recent history. Therefore, this method was initially not considered to be applicable to most Buttermilk Creek sites under consideration. One potential site for application of this technique to alluvial fan deposits has since been located at the mouth of Heinz Creek.

Field Operations and Progress

The three primary sites for chronologic analysis that we have focused on are:

1) The multiple terraces located at the so-called "racetrack" or abandoned meander located a short distance south of the confluence of Franks Creek and Buttermilk Creek at an elevation near 1300 feet, approximately 100 feet above the modern Buttermilk Creek channel. A series of at least 6 fluvial terraces are present, ranging from 1290 to 1350 feet in elevation. An apparent glacial "kettle" depression with significant organic remains preserved is also present directly adjacent to the abandoned meander. The racetrack site was previously recognized as a former Buttermilk Creek channel, and the lowest channel segment as well as the glacial kettle are the locations of earlier limited chronologic studies.

2) A series of fluvial terraces and alluvial fans at the confluence of Heinz Creek and Buttermilk Creek, approximately across from the large active landslide, long monitored at the WVDP. This area contains a series of at least 9 different surfaces, including alluvial fans grading into stream terraces. Further upstream along Heinz Creek are a series of three or more terrace-like features of probable fluvial and glacial origin. The total elevation range at this site is approximately from 1250 to 1420 feet.

3) A series of at least 10 fluvial terraces, some transitional with alluvial fan deposits, located about 1.5 miles north of the abandoned meander site, on the east side of Buttermilk Creek, on a meander a short distance north of the former USGS stream gage. At this so-called "Tree Farm" site the elevations range between 1140 and 1200 feet.

Approximately 115 trenches have been excavated at these three general locations in order to locate and collect radiocarbon samples or OSL sediments. Radiocarbon samples would be the preferred and least expensive method of dating the terrace surfaces. However, organic materials are seldom preserved for hundreds or thousands of years in sediments subject to oxidizing conditions. Oxidization above the local water table is the rule, rather than the exception in this climatic zone. Most of the terrace trench site that were determined to contain coarse and/or permeable sediments were generally oxidized to depths of 3 to 7 feet. Therefore, preferred sites were chosen for trenching that contained shallow depressions with obvious organic sediments at the surface. Because organic remains were not always present at depth, OSL samples were collected from approximately half of the excavations. This approach was deliberately planned as an alternative to radiocarbon dating, once the success of the radiocarbon dating could be determined. An excess of OSL samples was collected, realizing that only a small portion of such samples might ultimately be processed. This is in part due to the lengthy process involved in obtaining such dates, as well as the greater cost. However, a successful program of dating a sufficient number of terraces at each site is dependent upon using OSL samples to fill in for critical surfaces (elevations) where no organic materials were found, or where the radiocarbon results produced only ages that are likely from materials deposited long after the river terraces were abandoned by Buttermilk Creek.

Tentative Results

Approximately 60 radiocarbon dates have been acquired at present. Approximately one quarter of these dates are relatively young, and were acquired near the base of the 1 to 2-foot thick upper organic sediment zone. The original assumption was that some of these samples might have resulted from deposition during stream downcutting immediately after the fluvial terrace was abandoned,. However, it appears that there was a period of reforestation following the original land clearing and agricultural activity. This reforestation has apparently produced much of the shallow organic soil layer (leaf litter, etc.), and produces dates generally in the range from 80 to 150 years old.

The remaining 45 or so ages have produced a very interesting and useful array of ages that revise both the late glacial history and the incomplete record of regional stream dissection. One of the prime questions for the modeling effort has long been the time at which the last glacial recession produced the landscape upon which Buttermilk Creek and its tributaries began the current cycle of erosion. We now believe we have documented this last glacial recession event as having occurred between 13,500 and 14,000 years ago (final conclusion subject to further analysis). We also tentatively conclude that the simplistic maps of the last few glacial advances and recessions, marked by the supposed Kent advance and Kent moraine, and followed by deposition of the Lavery till and the younger Defiance glaciation (LaFLeur, 1980, p. 15) are probably incorrect. As a result of our radiocarbon results, the several moraines mapped by LaFleur now seem to all be sandwiched into a much narrower time frame for the glacial events that have previously been proposed on the maps of the Ashford Hollow Quadrangle.

Regarding the fluvial chronology that relates to the postglacial downcutting rate of Buttermilk Creek and its tributaries, we tentatively have bracketed the age and active time span for the abandoned meander ("racetrack") as having potentially extended from approximately 9500 to 5600 years ago, with the potential for a complex history of erosion and deposition. These results are very recent and we need more time and pending data to draw more definitive conclusions and to explore alternative explanations.

The results of the radiocarbon age data for the rest of the terraces at the Heinz and Tree Farm sites, as well as data from the low terraces along Buttermilk Creek are not as complete or as definitive. There is reasonable evidence that Buttermilk Creek may have already reached its present elevation nearly 2000 years ago. The radiocarbon data for terraces at the Tree Farm have documented landslide activity as old as 3600 years. This places a constraint on the minimum depth of the valley at that time. Additional data from the Tree Farm site needs to be viewed in light of potential OSL ages, which we presumed would be forthcoming this fall.

At the Heinz Creek site, we have evidence from one OSL age and one C14 age that deposition was occurring near elevations of 1400 feet between 7000 and 9900 years ago, which is in reasonable accord with the preliminary data from the racetrack site. One intermediate Heinz terrace has wood that dates from 3785 BP near an elevation of 1240 feet. This age should be compared with an OSL sample from the same trench to determine its relevance.

Most of the prominent terraces on the east side of Buttermilk Creek at the Heinz and Tree Farm sites should be better dated using the OSL samples we have collected. It would be reasonable to select a minimum number of OSL samples from a high, intermediate, and low terrace at each of these sites. This would provide a much more definitive means of determining the incision rate of Buttermilk Creek for the 2000 to 6000 year (BP) time frame, and indicate whether the rate was linear or nonlinear, an important issue.

Unfortunately, the higher terraces above the abandoned meander (racetrack) are relatively coarse grained, and do not have sufficient materials in the optimum sand size range. S. Huot has obtained preliminary results from two of these samples, but is not satisfied the results are meaningful. He has offered to substitute other samples for these poor results at no additional charge. Most of the other seven OSL samples completed by S, Huot are reasonably compatible with our initial C14 analyses (oral conversation).

Conclusions and Recommendations

The results of our radiocarbon analyses to date have provided important and significant additions and changes to the formerly proposed glacial and postglacial chronology on the Buttermilk Creek basin. These promising results would be greatly improved by adding a reasonable number of OSL age determinations spread across the surfaces for which we were unable to acquire definitive C14 ages. This should be somewhere in the range of 10 to 15 age determinations (minimum). In addition, it would be prudent to pair a couple of the OSL age determinations with the best of our C14 ages, as a check on the compatibility of the two methods. Furthermore, the large monitored landslide on the west side of the valley has exposed a fluviolacustrine section of stratified sediments between two glacial tills, purported to be the Lavery and Kent tills. If our revision of the nature and age of these major glacial events is correct, based on our new C14 dates, it would be appropriate to date this critical time interval near the WVDP site with OSL chronology.

In summary, we have tentatively established the following:

1) The glacial history for the region south of Cattaraugus Creek on the Ashford Hollow Quadrangle is much younger and more compressed in time than has been previously appreciated. We now know the age of the last glacial recession with a reasonable degree of accuracy.

2) The more precise ages of several significant geomorphic features, mainly terraces, have been determined (or revised).

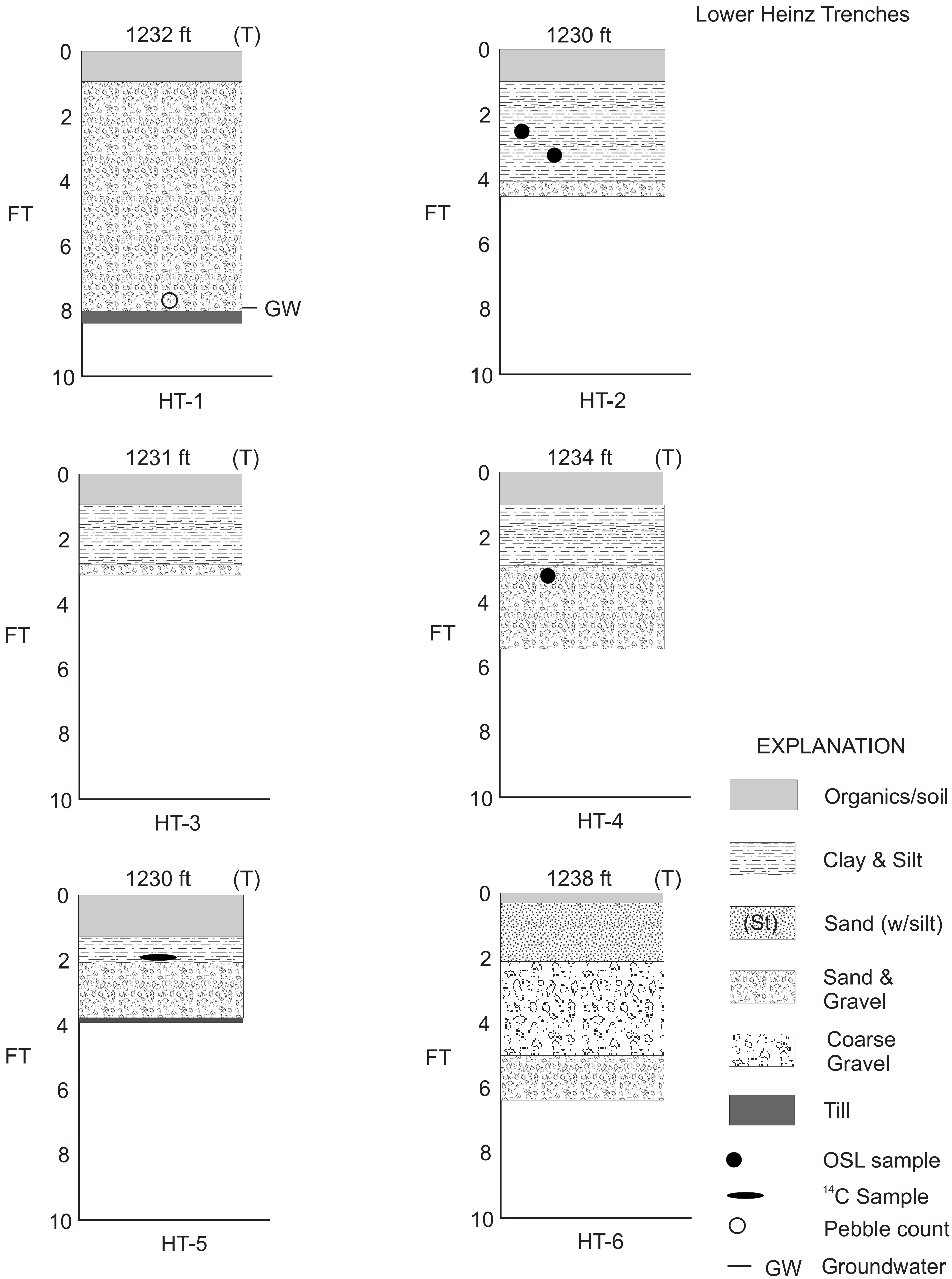
3) An apparent slowing of the rate of stream incision for Buttermilk Creek may have occurred during the past 2000 years, based on the apparent age of the lowest terrace deposits within a few feet of the modern channel. This may be due to the presence of bedrock along the lower reach of Buttermilk Creek near its junction with Cattaraugus Creek.

4) A much more complete incision history for Buttermilk Creek is clearly within reach if a reasonable number of OSL age determinations can be obtained to complement the impressive number of useful radiocarbon ages that have been obtained so far.

5) Results to date are directly relevant and critical for the modeling effort to follow.

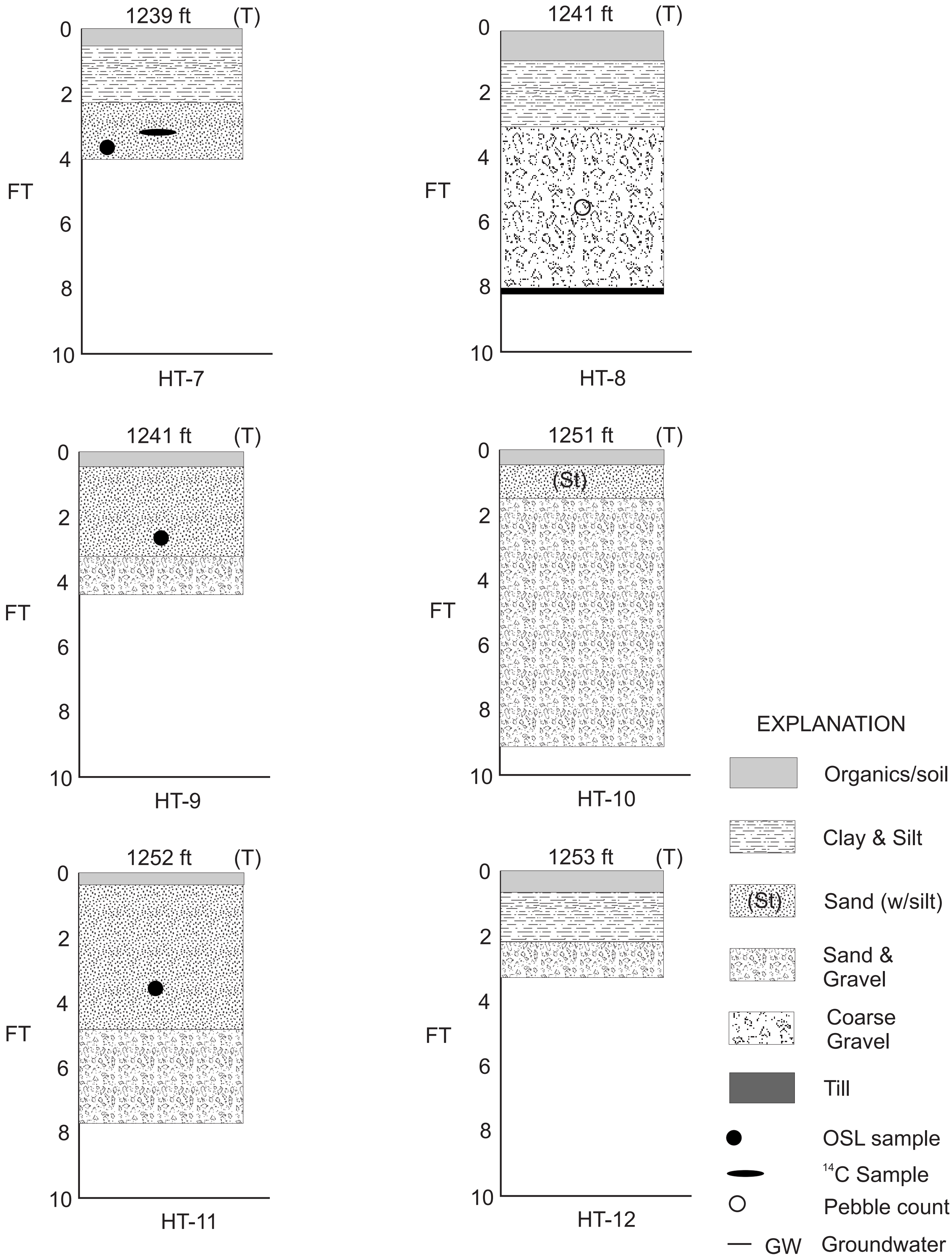
6) Much of the extensive work and positive results briefly summarized here were only possible as a result of the relatively dry weather during the spring and summer seasons, as well as the efficiently coordinated efforts of a dedicated group of competent assistants and efficient contractors.

APPENDIX G
Trench Stratigraphic Logs



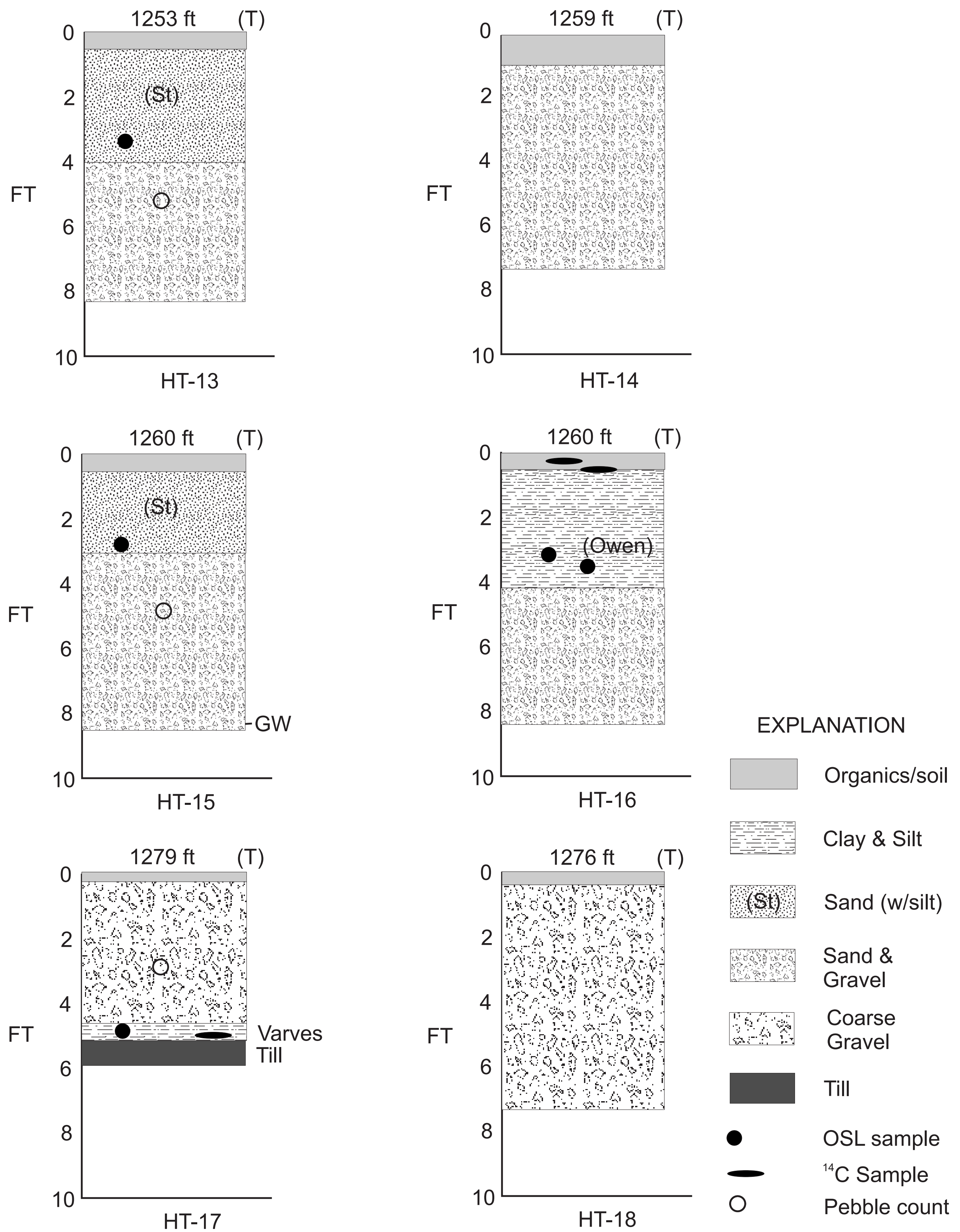
(T) = Torvane measurements available from one or more levels

Lower Heinz Trenches

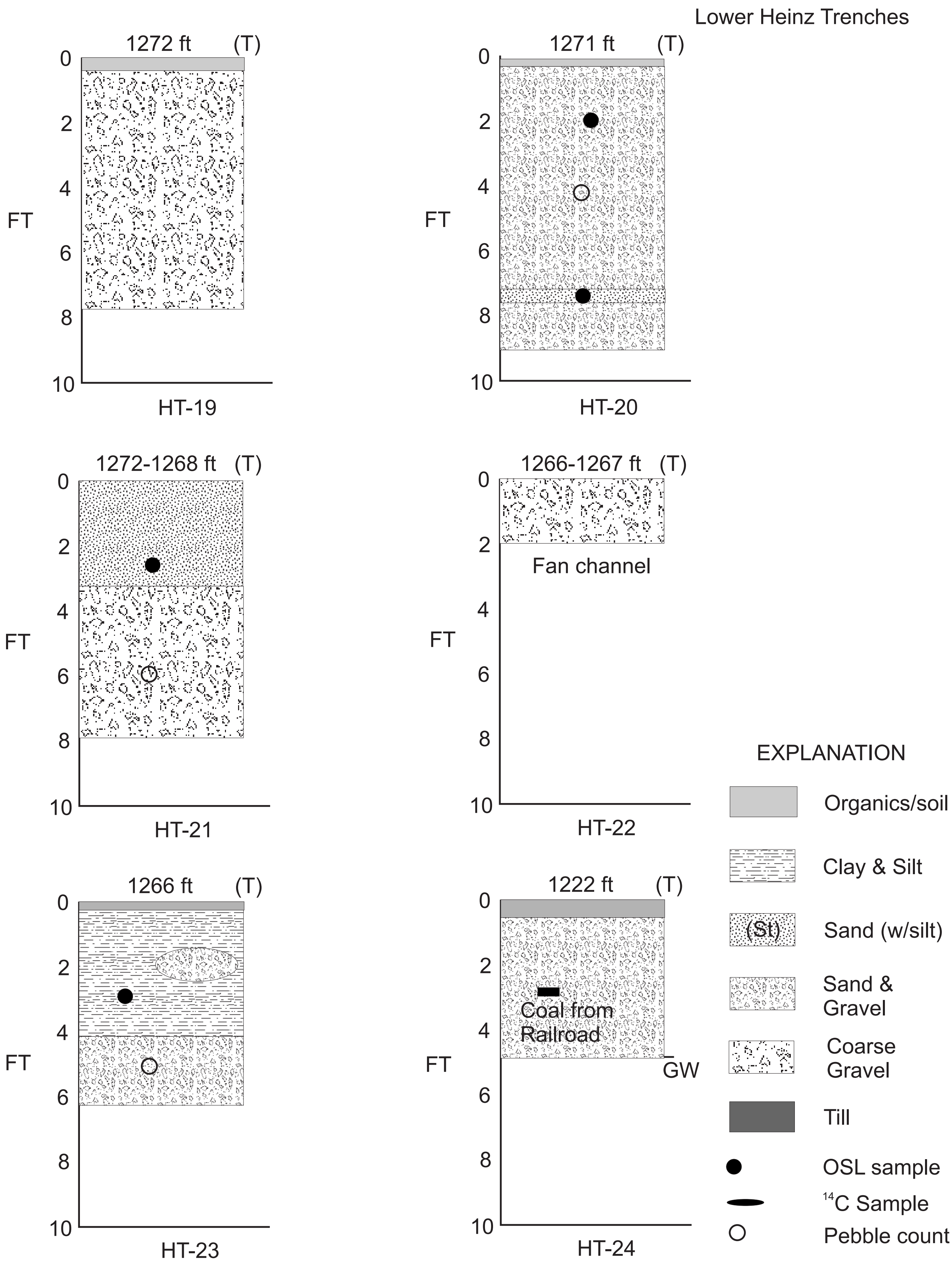


(T) = Torvane measurements available from one or more levels

Lower Heinz Trenches

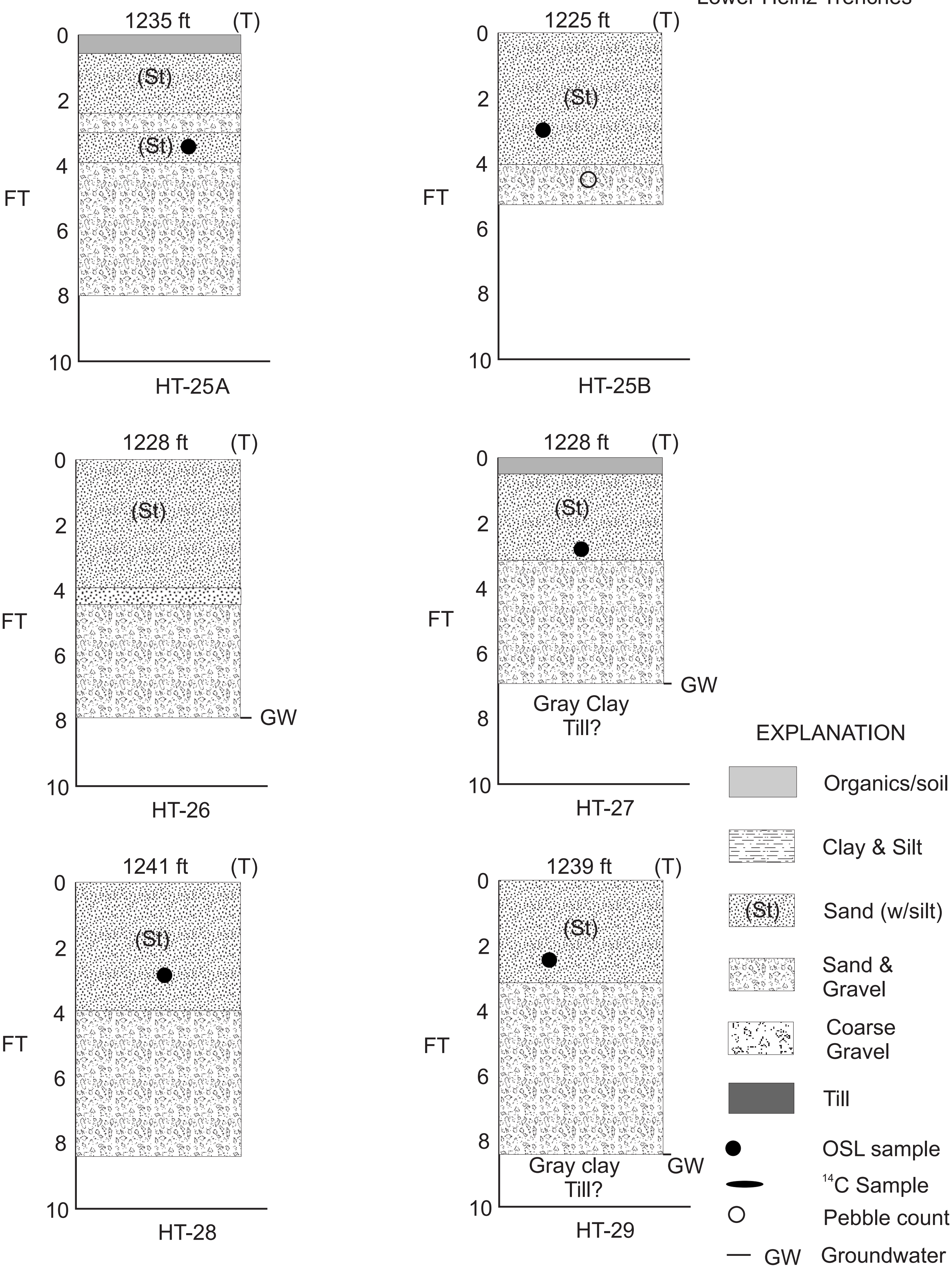


(T) = Torvane measurements available from one or more levels



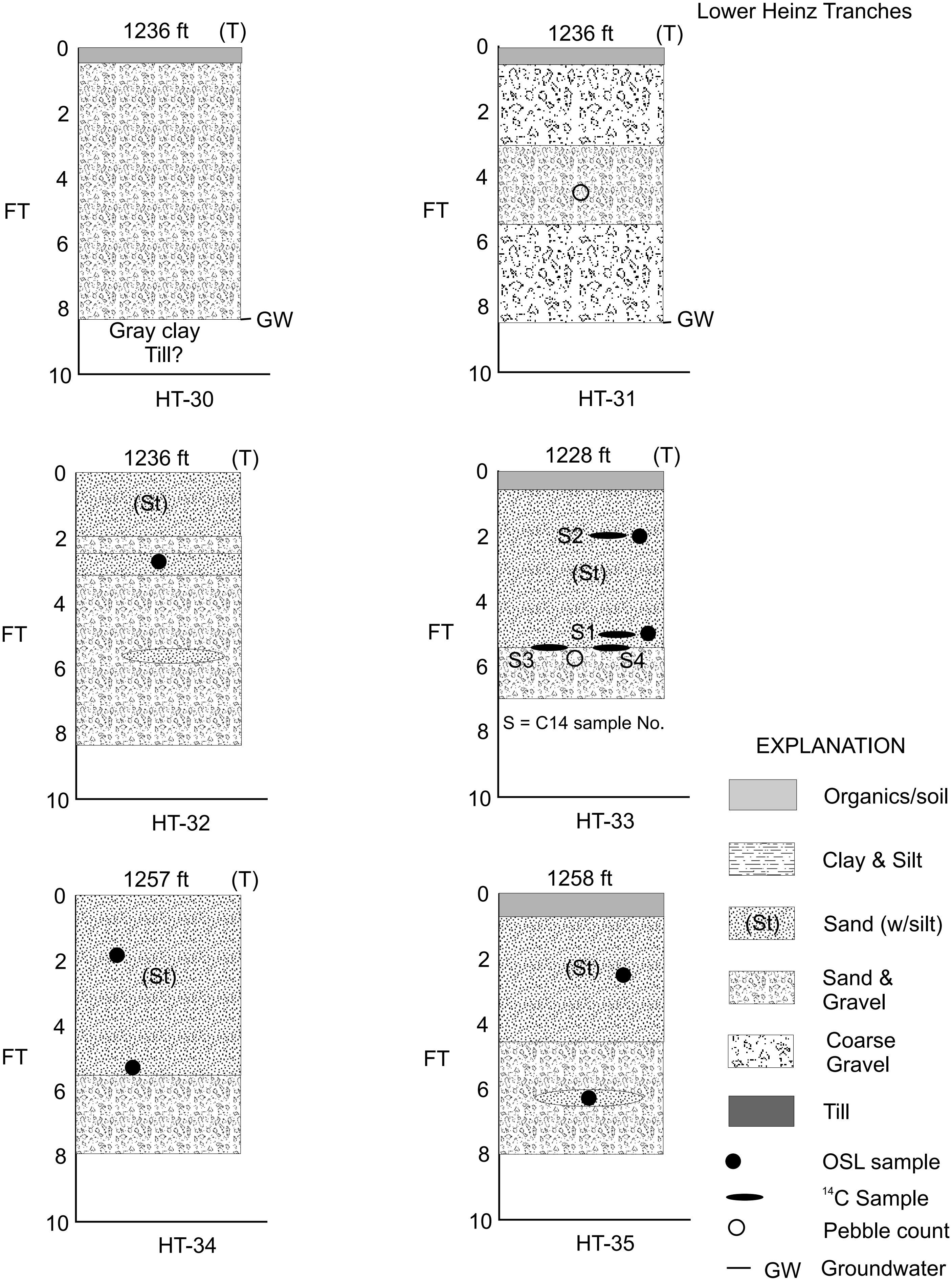
(T) = Torvane measurements available from one or more levels

Lower Heinz Trenches



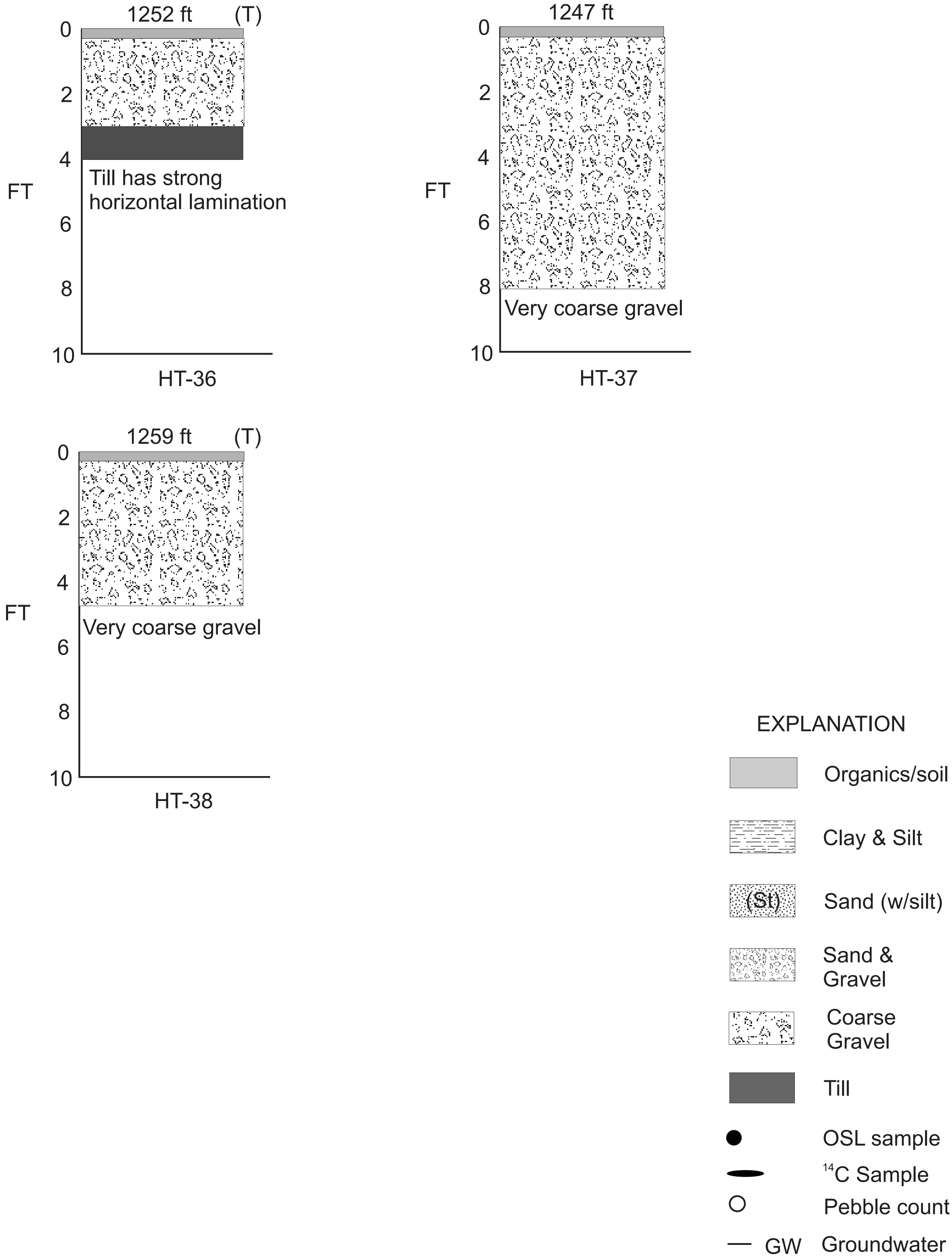
(T) = Torvane measurements available from one or more levels

Lower Heinz Tranches



(T) = Torvane measurements available from one or more levels

Lower Heinz Trenches



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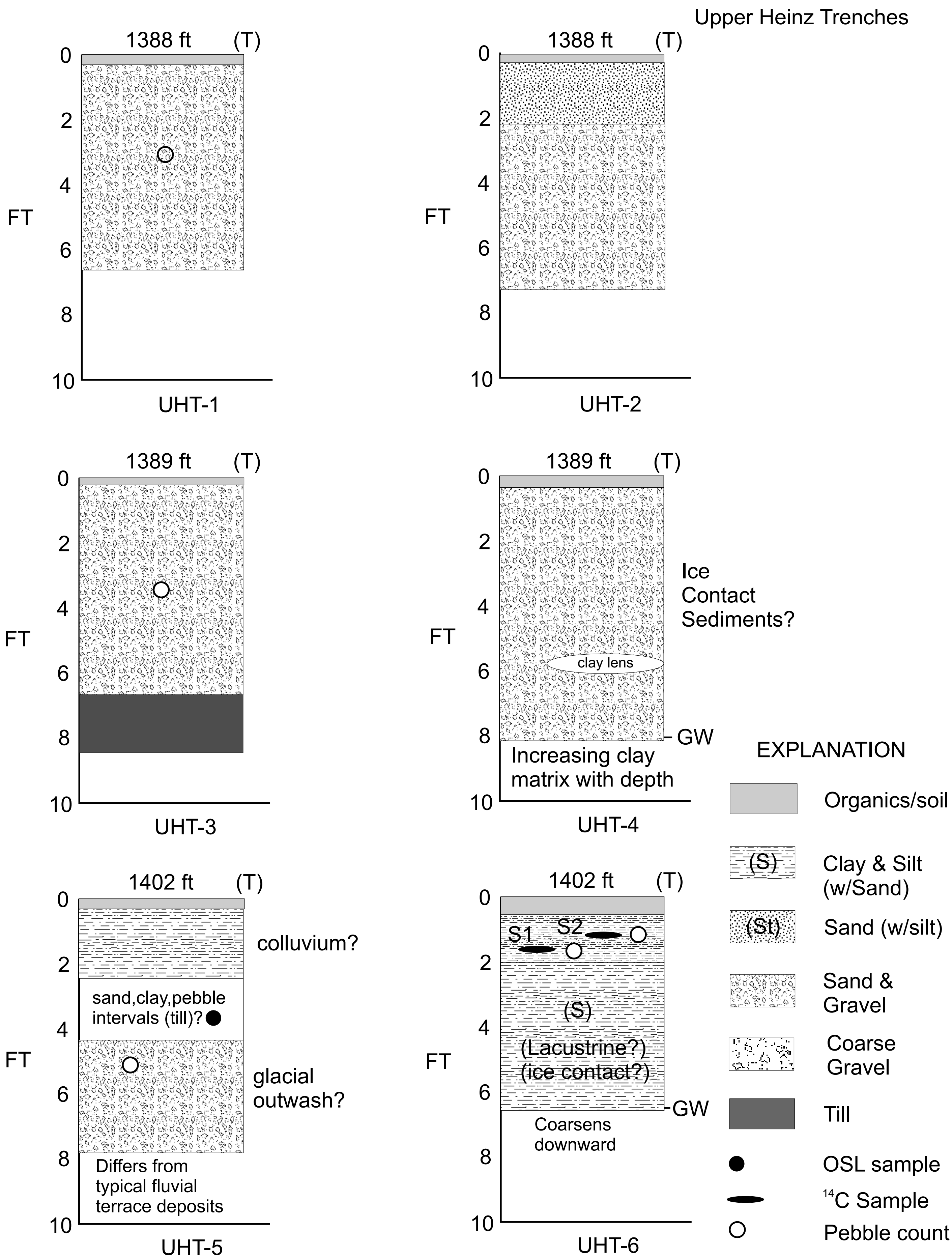

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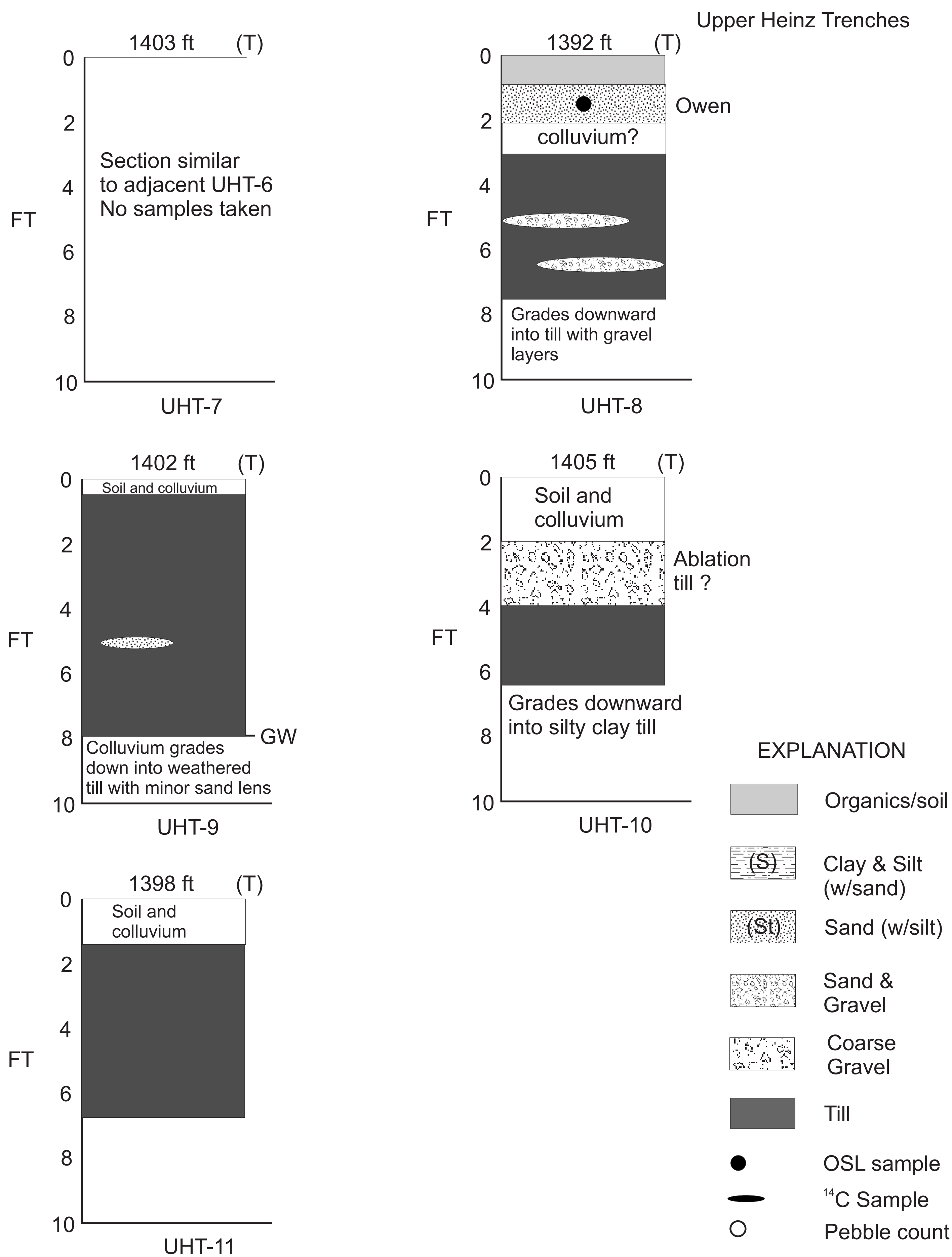
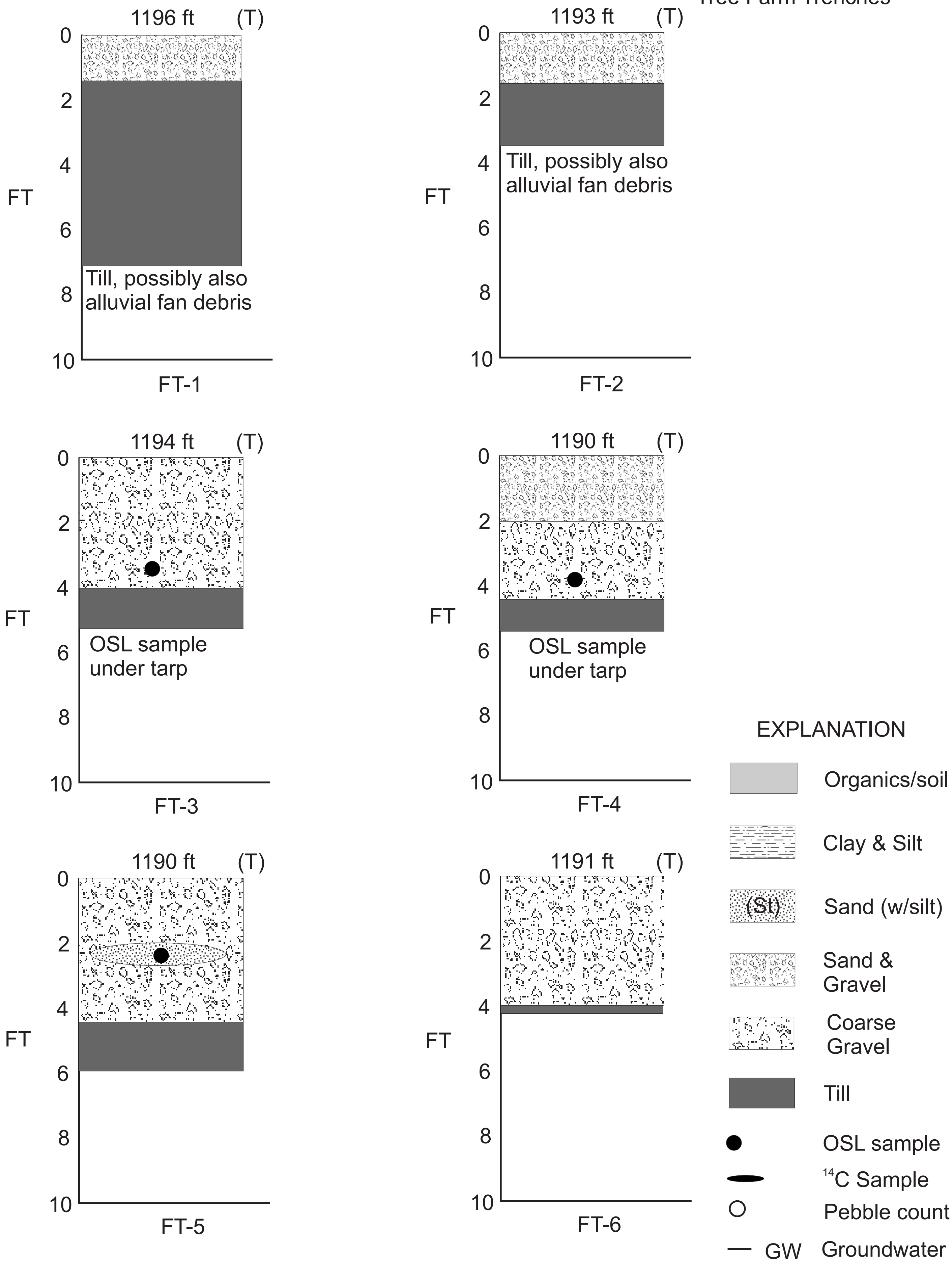


(T) = Torvane measurements available for one or more levels

Tree Farm Trenches



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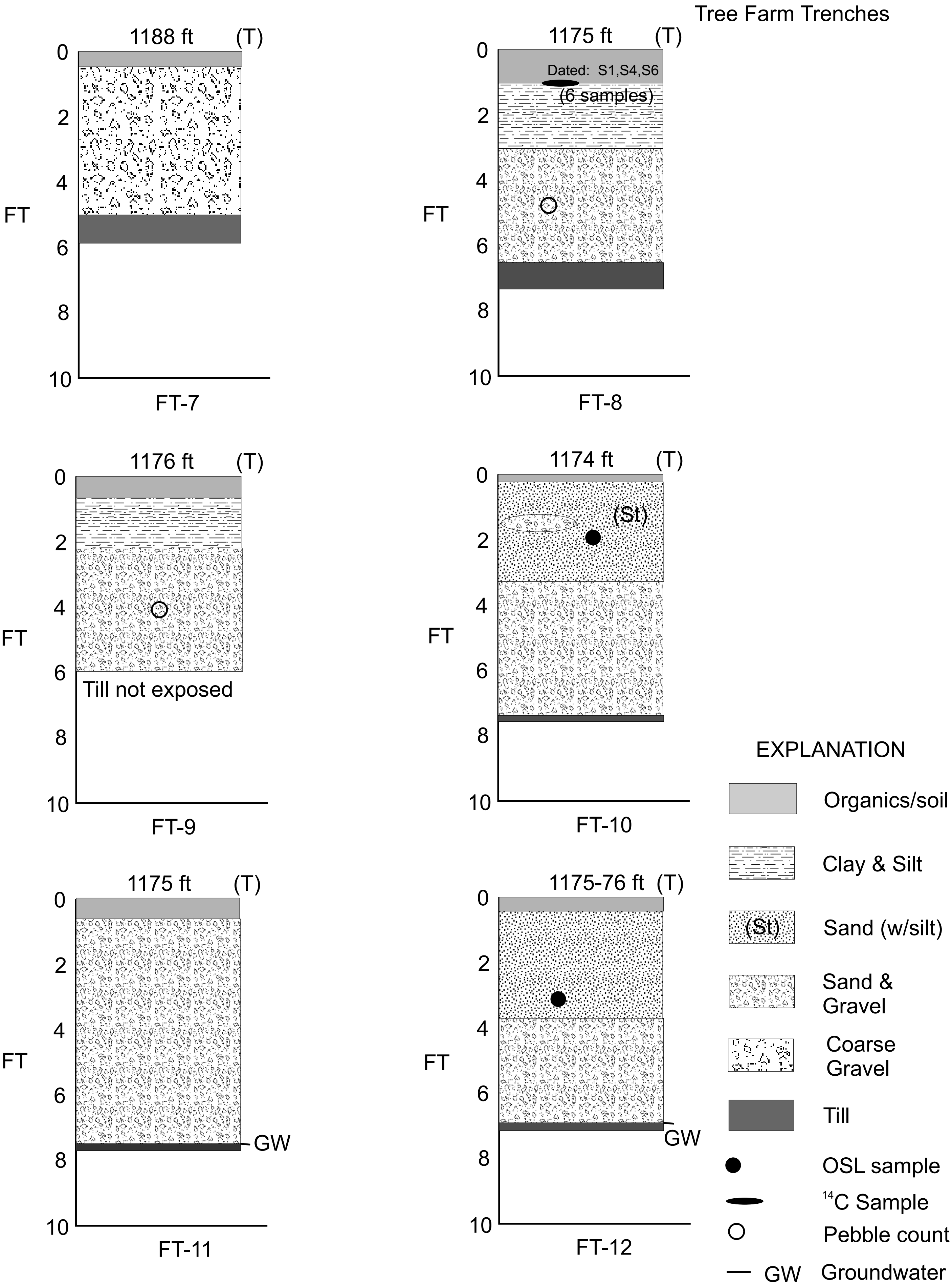

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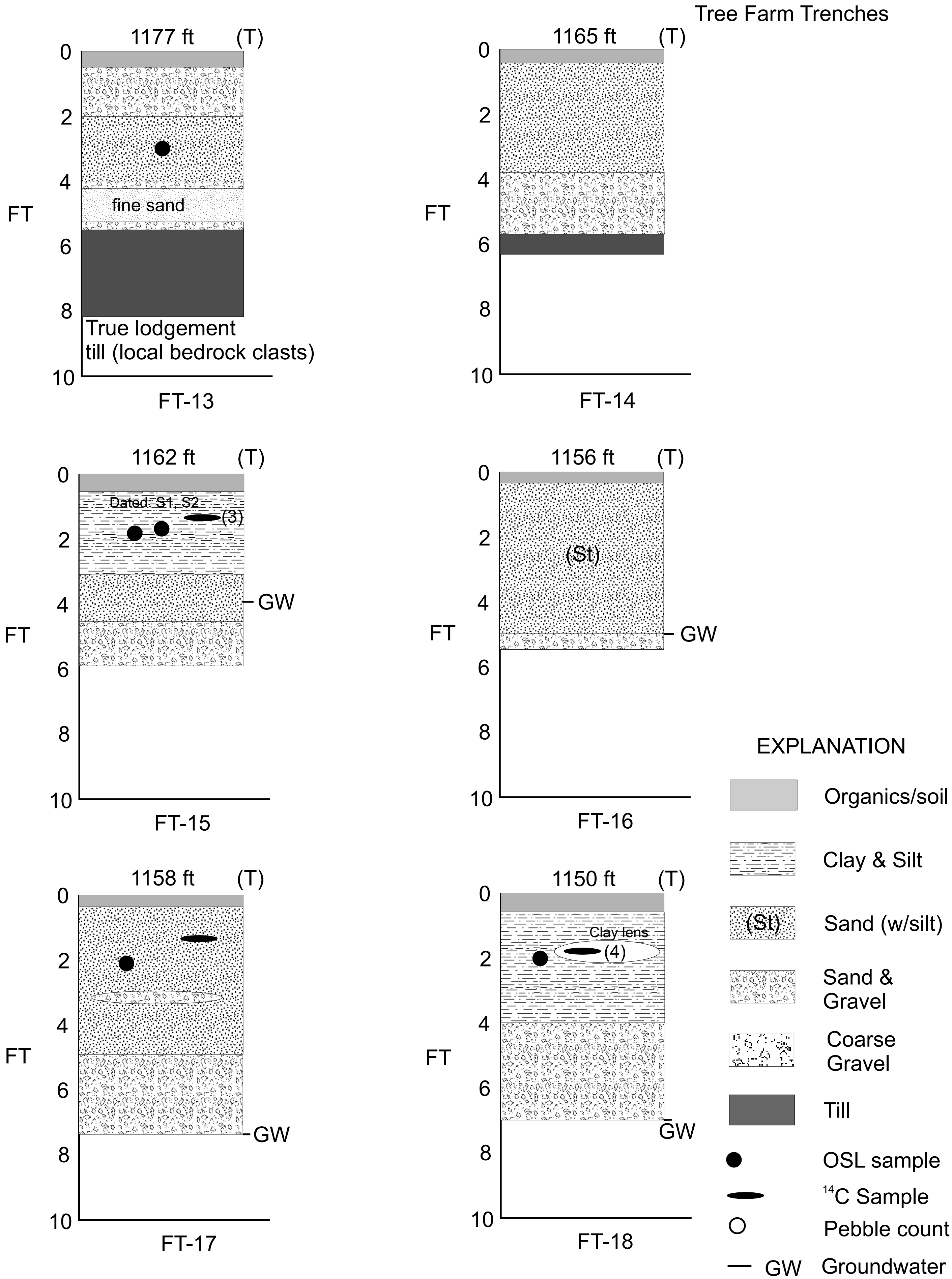

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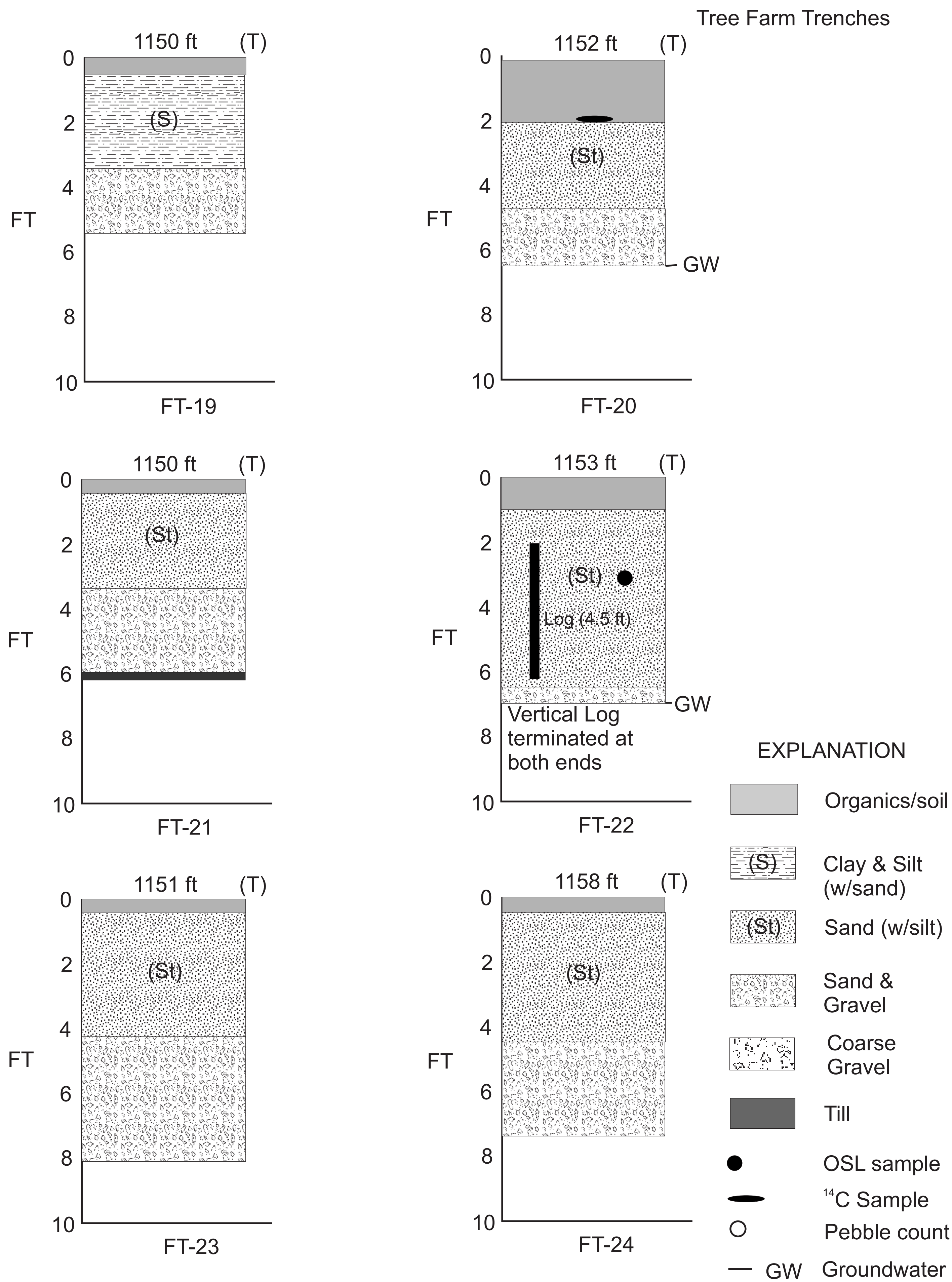

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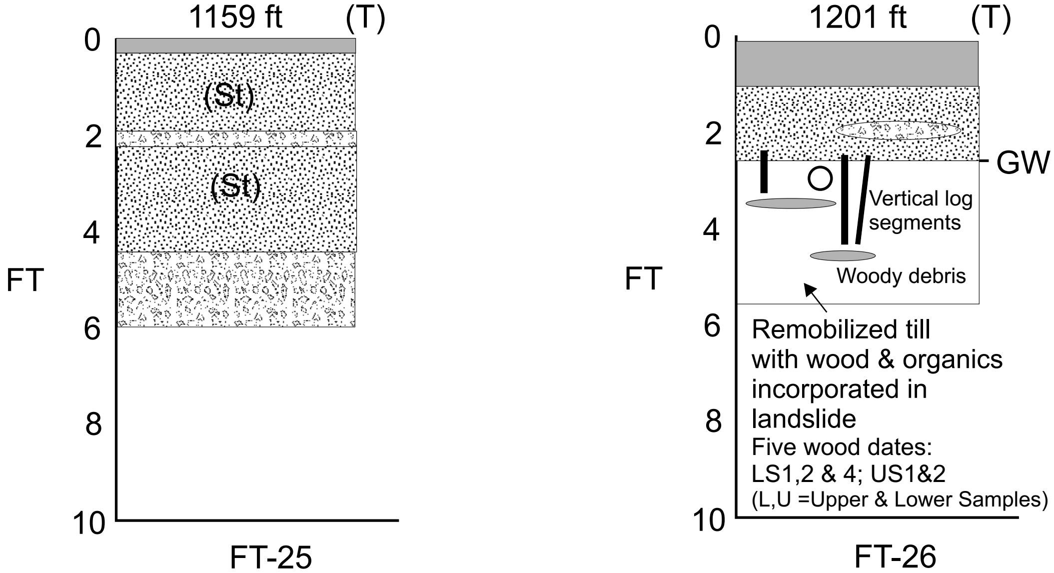
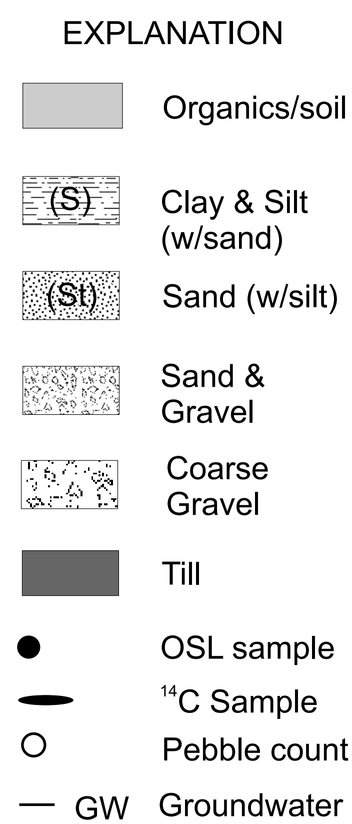
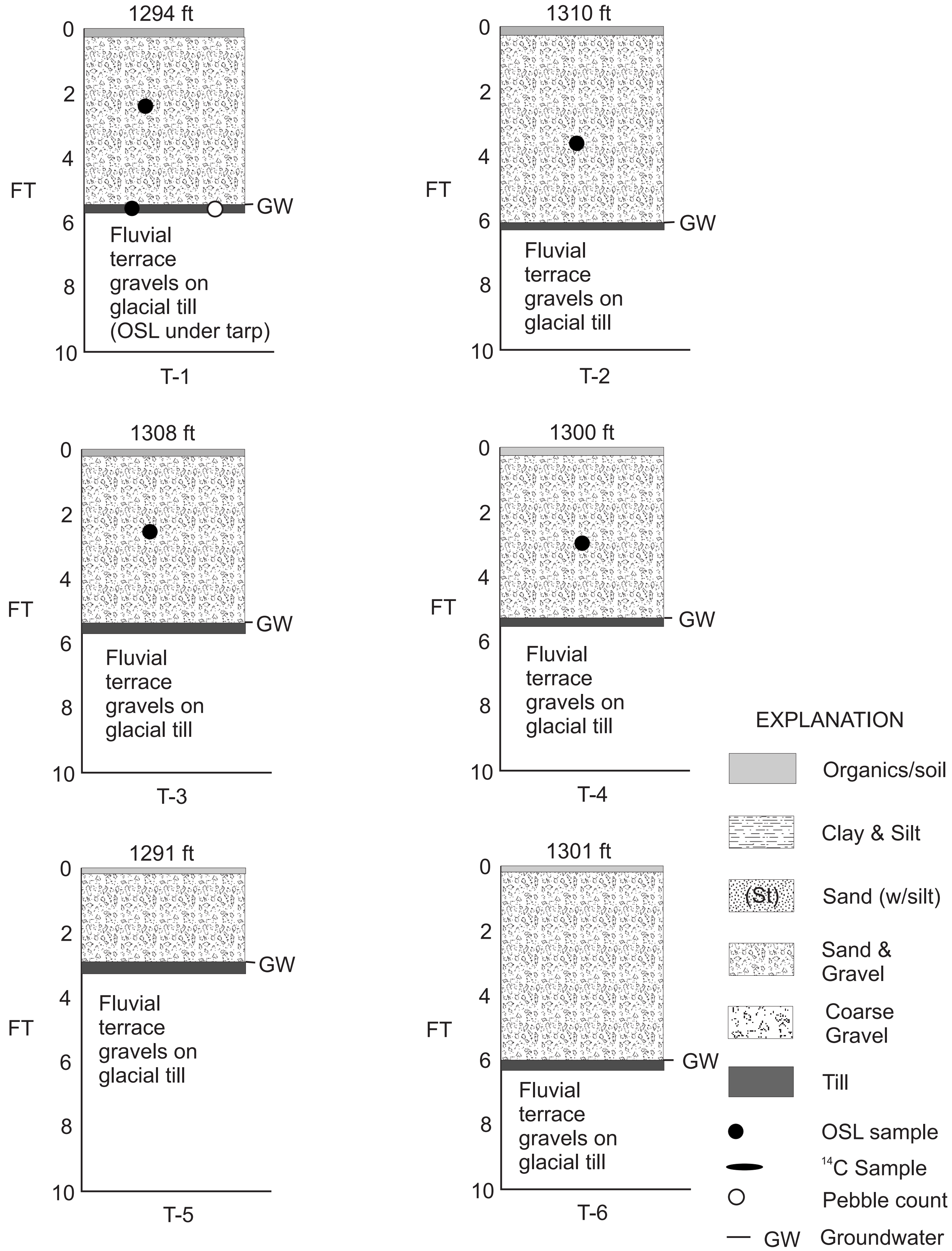
Tree Farm Trenches

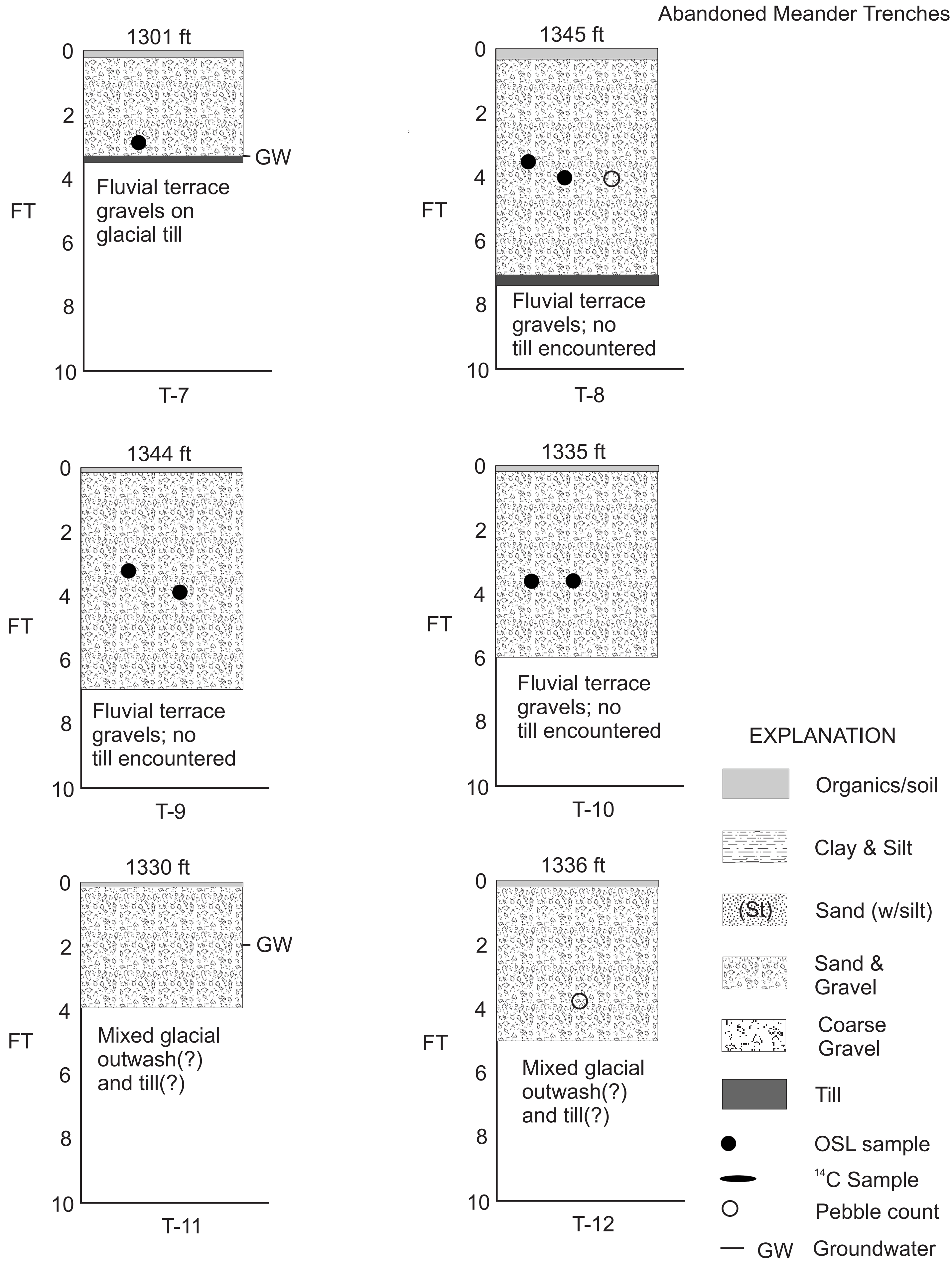


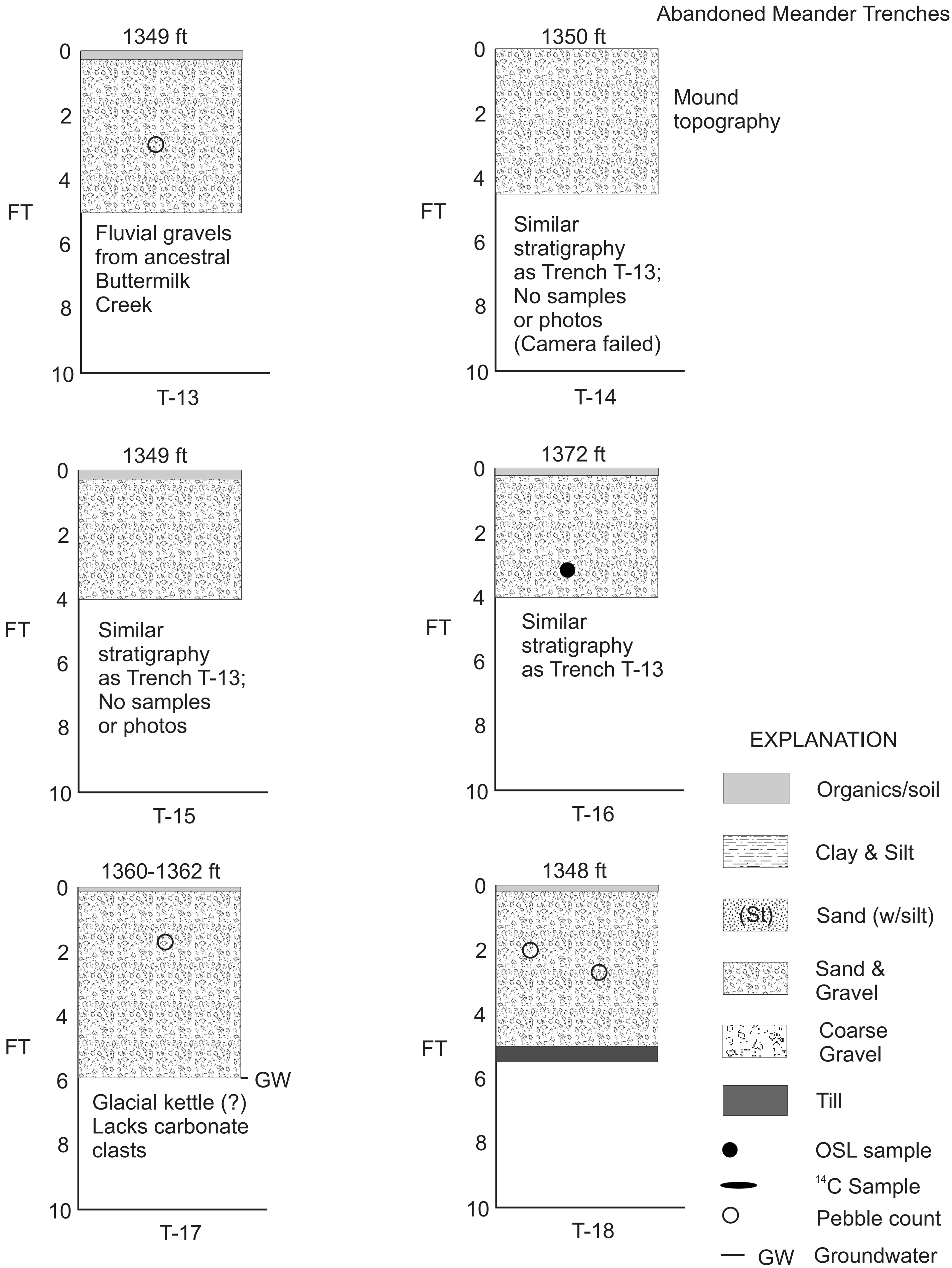


(T) = Torvane measurements available from one or more levels

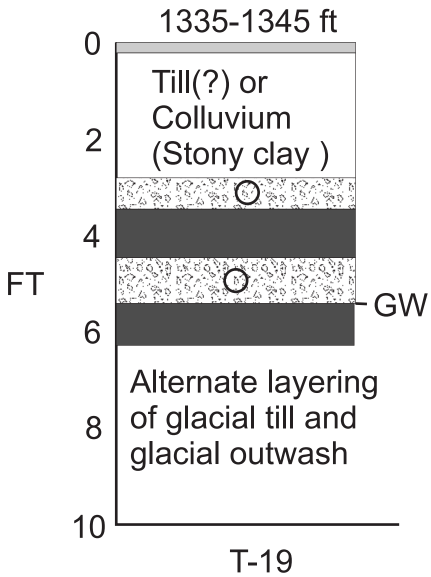
Abandoned Meander Trenches

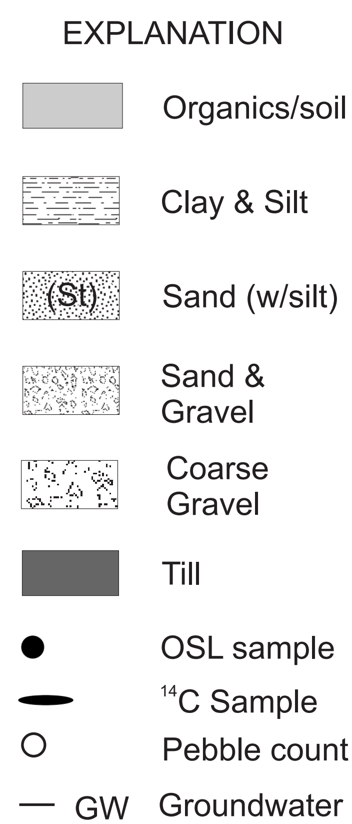


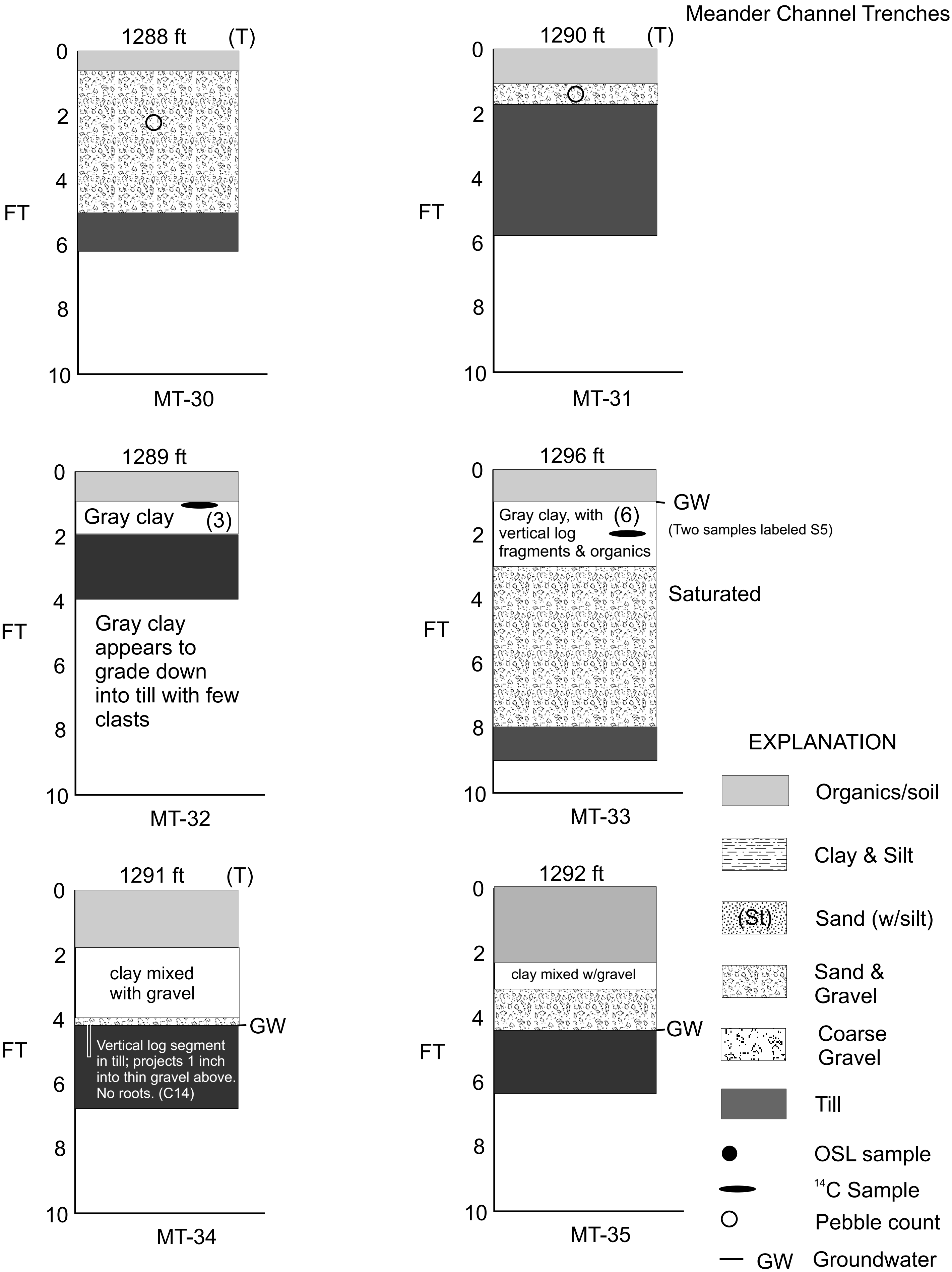

Abandoned Meander Trenches
1301 ft
0
2
4
6
8
10
FT
GW
Fluvial terrace gravels on glacial till
T-7
1345 ft
0
2
4
6
8
10
FT
Fluvial terrace gravels; no till encountered
T-8
1344 ft
0
2
4
6
8
10
FT
Fluvial terrace gravels; no till encountered
T-9
1335 ft
0
2
4
6
8
10
FT
Fluvial terrace gravels; no till encountered
T-10
1330 ft
0
2
4
6
8
10
FT
GW
Mixed glacial outwash(?) and till(?)
T-11
1336 ft
0
2
4
6
8
10
FT
Mixed glacial outwash(?) and till(?)
T-12
EXPLANATION
Organics/soil
Clay & Silt
(St)
Sand (w/silt)
Sand & Gravel
Coarse Gravel
Till
OSL sample
14C Sample
Pebble count
GW Groundwater


Abandoned Meander Trenches
1349 ft
FT
Fluvial gravels from ancestral Buttermilk Creek
T-13
1350 ft
Mound topography
Similar stratigraphy as Trench T-13; No samples or photos (Camera failed)
T-14
1349 ft
Similar stratigraphy as Trench T-13; No samples or photos
T-15
1372 ft
Similar stratigraphy as Trench T-13
T-16
1360-1362 ft
GW
Glacial kettle (?) Lacks carbonate clasts
T-17
1348 ft
T-18
EXPLANATION
Organics/soil
Clay & Silt
(St)
Sand (w/silt)
Sand & Gravel
Coarse Gravel
Till
OSL sample
14C Sample
Pebble count
GW Groundwater

Abandoned Meander Trenches

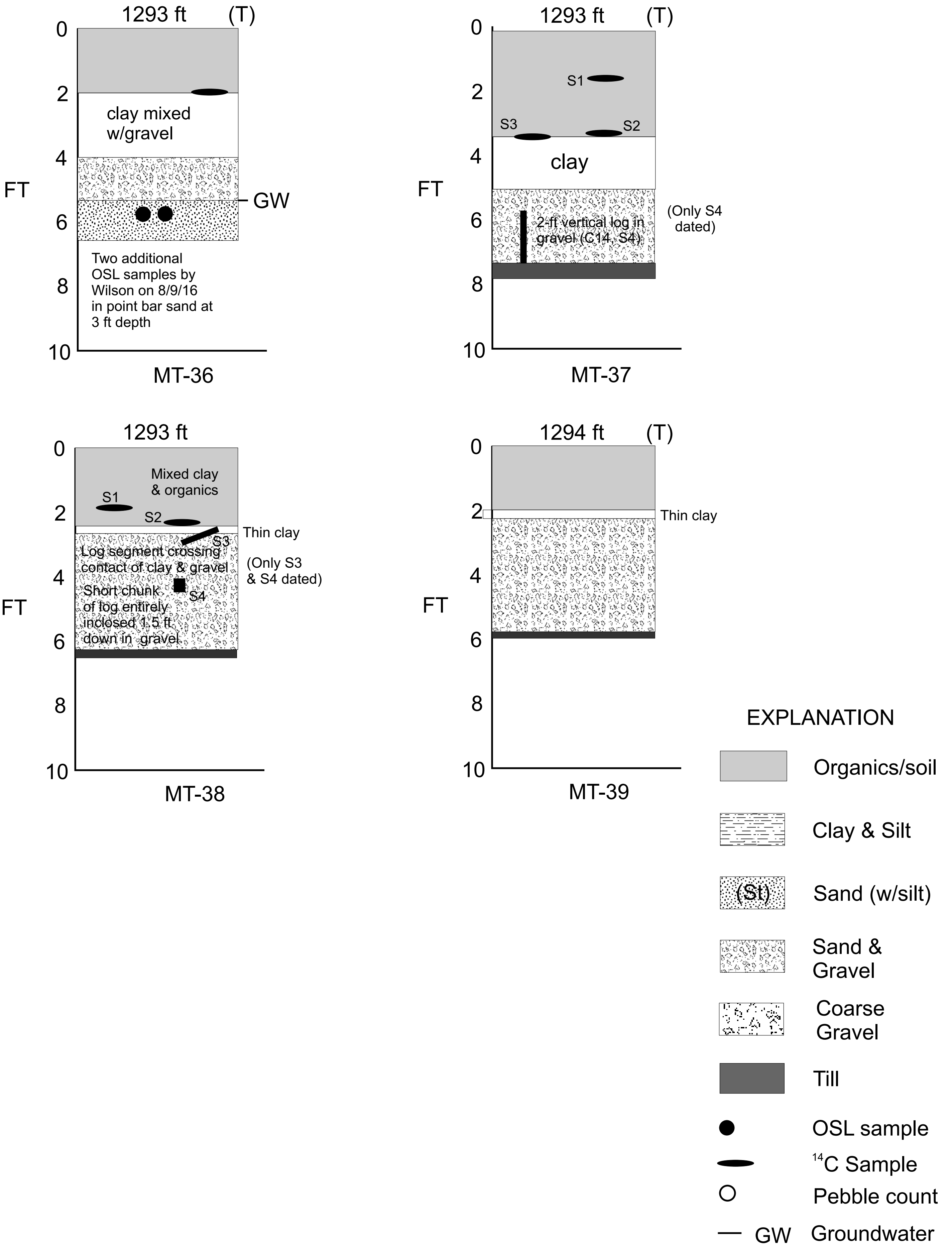




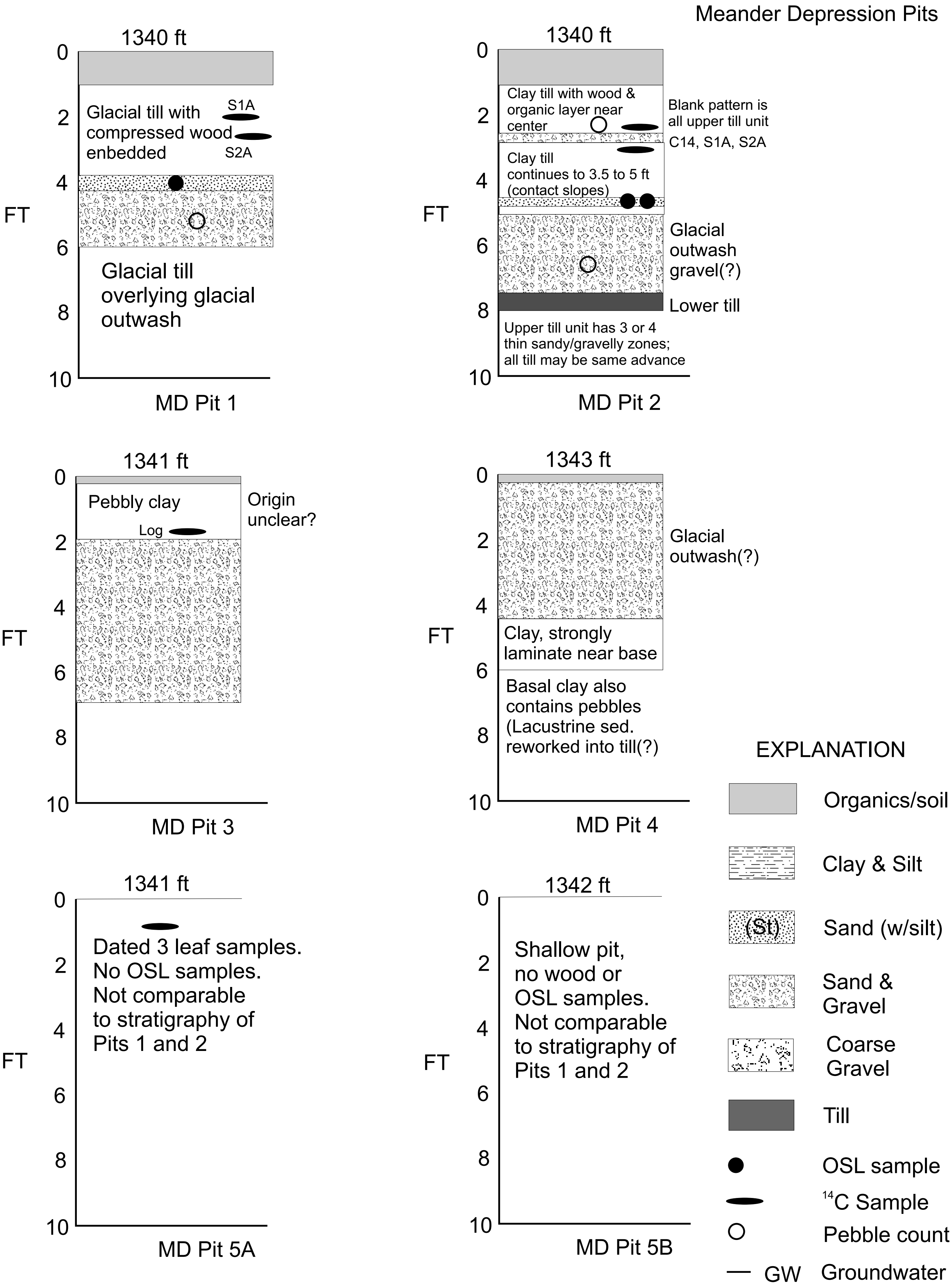


(T) = Torvane measurements available from one or more levels

Meander Channel Trenches



(T) = Torvane measurements available from one or more levels


Meander Depression Pits
1340 ft
Glacial till with compressed wood enbedded
S1A
S2A
Glacial till overlying glacial outwash
MD Pit 1
1340 ft
Clay till with wood & organic layer near center
Blank pattern is all upper till unit
C14, S1A, S2A
Clay till continues to 3.5 to 5 ft (contact slopes)
Glacial outwash gravel(?)
Lower till
Upper till unit has 3 or 4 thin sandy/gravelly zones; all till may be same advance
MD Pit 2
1341 ft
Pebbly clay
Log
Origin unclear?
MD Pit 3
1343 ft
Glacial outwash(?)
Clay, strongly laminate near base
Basal clay also contains pebbles (Lacustrine sed. reworked into till(?)
MD Pit 4
1341 ft
Dated 3 leaf samples. No OSL samples. Not comparable to stratigraphy of Pits 1 and 2
MD Pit 5A
1342 ft
Shallow pit, no wood or OSL samples. Not comparable to stratigraphy of Pits 1 and 2
MD Pit 5B
FT
0
2
4
6
8
10
EXPLANATION
Organics/soil
Clay & Silt
(St)
Sand (w/silt)
Sand & Gravel
Coarse Gravel
Till
OSL sample
^{14}C Sample
Pebble count
GW Groundwater

APPENDIX H
Field Torvane Data

SHEAR STRESS DATA

Date	Location	Trench ID	Depth (ft)	Shear Stress Kg/cm2					Average	Material	Note
		FT-17	3.7	0.000	0.000	0.000	0.000	0.000	0.000	Sand	
7/21/2016	Tree Farm	FT-17	4.6	0.000	0.000	0.000	0.000	0.000	0.000	Sand and Gravel	
		FT-25	2.2	0.000	0.000	0.000	0.000	0.000	0.000	coarse sand	
		FT-11	1.0	0.025	0.050	0.000	0.025	0.075	0.035	Silty Sand	
7/21/2016	Tree Farm	FT-15	4.0	0.025	0.000	0.050	0.050	0.050	0.035	Blue Sandy Clay	
7/21/2016	Tree Farm	FT-4	2.3	0.050	0.025	0.050	0.050	0.050	0.045	Coarse Gravel	
7/21/2016	Tree Farm	FT-10	1.8	0.050	0.025	0.075	0.050	0.050	0.050	Silty Sand	
7/21/2016	Tree Farm	FT-10	4.0	0.025	0.025	0.075	0.050	0.075	0.050	Sand and Gravel	
		FT-20	5.0	0.000	0.050	0.075	0.050	0.075	0.050	Coarse Sand	
7/21/2016	Tree Farm	FT-6	2.9	0.050	0.050	0.050	0.075	0.050	0.055	Sand and Gravel	
7/21/2016	Tree Farm	FT-11	3.5	0.025	0.050	0.050	0.050	0.100	0.055	Fine Gravel/Sand	Vertical Accretion
7/21/2016	Tree Farm	FT-12	4.5	0.125	0.050	0.000	0.075	0.100	0.070	Coarse Gravel and Sand	
		FT-7	1.5	0.100	0.075	0.050	0.150	0.075	0.090	Sand and Gravel	
		FT-25	1.7	0.050	0.050	0.175	0.200	0.125	0.120	silty sand	
7/21/2016	Tree Farm	FT-6	1.1	0.150	0.150	0.150	0.075	0.100	0.125	Sand and Gravel	
		FT-12	3.3	0.100	0.150	0.100	0.150	0.150	0.130	Silty Sand	Taken from bench directly below jet test site
7/21/2016	Tree Farm	FT-13	3.0	0.200	0.150	0.150	0.150	0.100	0.150		Taken From Jet Test Site
		FT-13	2.2	0.325	0.250	0.075	0.175	0.075	0.180	Sand	
7/21/2016	Tree Farm	FT-16	0.3	0.150	0.200	0.100	0.250	0.250	0.190	organics	
		FT-14	4.0	0.300	0.175	0.300	0.100	0.175	0.210	Silty Sand	
	Tree Farm	FT-20	3.1	0.100	0.150	0.200	0.200	0.500	0.230	Silty Sand	
		FT-24	0.4	0.250	0.300	0.200	0.200	0.200	0.230	organics	
		FT-16	1.0	0.250	0.300	0.250	0.250	0.200	0.250	silty sand	
		FT-19	3.0	0.250	0.250	0.200	0.250	0.350	0.260	Silty sand	
		FT-14	2.1	0.300	0.250	0.250	0.250	0.250	0.260	Silty Sand	
		FT-19	0.6	0.225	0.200	0.300	0.350	0.250	0.265	Organics	
		FT-5	6.0	0.300	0.200	0.300	0.350	0.200	0.270	Clay Diamect	
		FT-17	2.0	0.225	0.375	0.225	0.225	0.325	0.275	Silty Sand	
		FT-24	1.2	0.425	0.200	0.150	0.300	0.300	0.275	Clayey Silty Sand	
		FT-21	2.0	0.225	0.325	0.375	0.300	0.200	0.285	Silty Fine sand	
		FT-8	2.0	0.250	0.250	0.250	0.350	0.400	0.300	Clayey/silty sand	
		FT-18	1.9	0.200	0.300	0.150	0.450	0.425	0.305	Sandy, Silty Clay	
		FT-9	2.5	0.250	0.300	0.325	0.300	0.500	0.335	Clayey/silty sand	
		FT-15	2.0	0.300	0.350	0.400	0.350	0.350	0.350	Sandy Clay	
		FT-1	6.0	0.350	0.400	0.400	0.400	0.400	0.390	Clay Diamict	
		FT-23	2.0	0.300	0.525	0.525	0.350	0.375	0.415	Silty Sand	Personal Dissagreance/Human Error
		FT-23	4.2	0.500	0.100	0.475	0.500	0.550	0.425	sandy clay	
		FT-9	2.0	0.700	0.400	0.400	0.200	0.500	0.440	Clayey sand	
		FT-26	1.5	0.750	0.625	0.313	0.500	0.250	0.488	Clay	OSL taken on same horizon in same material
		FT-9	1.4	0.675	0.500	0.300	0.400	0.650	0.505	Clayey/silty sand	Small Torvane Head (readings x 2.5)
		FT-3	4.5	0.600	0.400	0.550	0.500	0.550	0.520	Clay Diamict	
		FT-17	4.0	0.600	0.450	0.550	0.600	0.475	0.535	Silty Sand	Personal Dissagreance/Human Error
		FT-13	4.5	0.350	0.650	0.450	0.550	0.850	0.570		
		FT-26	1.5	0.725	0.525	0.800	0.450	0.800	0.660	Clay	
		FT-19	1.5	0.700	0.800	0.725	0.700	0.600	0.705	Silty Clay	Taken from same location but with fixed head
		FT-13	5.5	1.000	0.875	1.375	0.875	1.563	1.138	Lodgment Till	
		FT-1	2.6	1.063	1.563	1.250	1.125	1.063	1.213	Clay Diamict	Small Torvane Head (readings X 2.5)
		FT-2	1.5	1.313	1.438	1.125	1.625	1.125	1.325	Clay Diamict	

Location	Trench ID	Depth (ft)	Shear Stress Kg/cm2					Average	Material	Note
Lower Heinz	HT-4	0.5	0	0	0	0	0	0	Sand	
	HT-4	3.5	0	0	0	0	0	0	Lateral Accrection	
	HT-24	2.5	0	0	0	0	0	0	fine gravel	
	HT-32	2.9	0	0	0	0	0	0	coarse sand	
	HT-31	2.9	0.1	0.05	0.05	0.05	0	0.05	sand and gravel	
	HT-17	1.4	0.05	0.075	0.075	0.05	0.05	0.06	sand and fine gravel	
	HT-26	4.5	0.05	0.125	0.05	0.1	0.025	0.07	coarse sand	
	HT-31	1.3	0.05	0.075	0.075	0.125	0.1	0.085	sand and gravel	
	HT-25A	3.3	0.05	0.05	0.15	0.1	0.175	0.105	clayey silty sand	
	HT-9	0.9	0.1	0.075	0.1	0.15	0.125	0.11	Silty Sand	
	HT-25B	1.8	0.2	0.1	0.1	0.1	0.05	0.11	silty sand	
	HT-28	0.7	0.15	0.2	0.05	0.05	0.125	0.115	silty sand	
	HT-27	1.0	0.1	0.1	0.075	0.2	0.175	0.13		
	HT-3	1.9	0.1	0.15	0.175	0.1	0.225	0.15	Sandy Silty Clay	
	HT-33	4.4	0.15	0.175	0.15	0.2	0.15	0.165	clayey silty sand	
	HT-26	1.9	0.125	0.175	0.225	0.125	0.2	0.17	silty sand	
	HT-14	1.0	0.25	0.175	0.15	0.2	0.1	0.175	Silty Sand	
	HT-33	2.0	0.175	0.15	0.15	0.35	0.05	0.175	silty sand	
	HT-11	0.5	0.15	0.175	0.15	0.175	0.25	0.18	Organics	
	HT-19	1.0	0.175	0.25	0.15	0.2	0.3	0.215	silty sand	
	HT-9	1.8	0.2	0.2	0.25	0.2	0.25	0.22	Silty Sand	
	HT-10	0.7	0.35	0.1	0.15	0.05	0.45	0.22	Clayey Silty Sand	
	HT-18	2.0	0.175	0.3	0.2	0.2	0.275	0.23	clayey silty sand	
	HT-32	1.0	0.35	0.2	0.05	0.2	0.35	0.23	silty sand	
	HT-20	3.4	0.375	0.15	0.15	0.35	0.2	0.245	silty sand	
	HT-5	2.3	0.275	0.25	0.2	0.275	0.225	0.245	Clayey Sand	
Lower Heinz	HT-3	1.1	0.2	0.2	0.3	0.25	0.3	0.25	Organics	
	HT-24	1.0	0.25	0.4	0.3	0.25	0.1	0.26	silty sand	
	HT-16	3.0	0.3	0.275	0.275	0.275	0.2	0.265	Clayey Silty Sand	OSL Location
	HT-8	1.8	0.275	0.3	0.2	0.3	0.275	0.27	Silty Sandy Clay with Gravel	
	HT-25B	3.0	0.35	0.3	0.25	0.2	0.35	0.29	clayey sand	
	HT-28	2.6	0.25	0.375	0.45	0.35	0.05	0.295	silty sand	
	HT-10	2.8	0.2	0.225	0.425	0.4	0.275	0.305	Sily Sand	
	HT-25A	0.5	0.35	0.3	0.325	0.35	0.225	0.31	organics	
	HT-27	3.1	0.3	0.35	0.25	0.325	0.35	0.315		
	HT-10	4.4	0.55	0.25	0.25	0.225	0.3	0.315	Clayey Sand	
	HT-8	0.8	0.325	0.225	0.275	0.45	0.35	0.325	Organics Zone	
	HT-21	1.6	0.35	0.275	0.45	0.325	0.3	0.34	silty sand	
	HT-12	1.4	0.35	0.3	0.4	0.45	0.275	0.355	Clayey Silty Sand	
	HT-30	1.5	0.45	0.35	0.275	0.4	0.325	0.36	silty sand	
	HT-35	2.5	0.4	0.275	0.5	0.25	0.375	0.36	silty sand	
Lower Heinz	HT-1	1.5	0.15	0.2	0.375	0.65	0.5	0.375	Silty Sand	
	HT-29	2.0	0.3	0.55	0.45	0.3	0.3	0.38	clayey silty sand	
	HT-22	1.8	0.5	0.475	0.45	0.275	0.525	0.445	clayey silty sand	
Lower Heinz	HT-5	0.5	0.55	0.425	0.45	0.45	0.475	0.47	Organics	
	HT-6	1.5	0.45	0.45	0.55	0.4	0.5	0.47	Silty Sand	
	HT-23	2.5	0.425	0.6	0.55	0.425	0.5	0.5	clayey silty sand	
	HT-38A	2.3	0.5	0.625	0.5	0.55	0.35	0.505	silty sandy clay	
	HT-29	5.2	0.55	0.7	0.375	0.2	0.775	0.52	silty sandy clay	
	HT-34	1.9	0.575	0.7	0.275	0.475	0.7	0.545	silty clayey sand	
	HT-13	2.8	0.625	0.25	0.75	0.65	0.5	0.555	Silty Clay	
	HT-35	4.0	0.175	0.35	0.775	0.775	0.775	0.57	clayey sand	
	HT-11	2.7	0.475	0.575	0.55	0.65	0.65	0.58	Clayey Silty Sand	
	HT-34	4.8	0.7	0.625	0.5	0.65	0.75	0.645	clayey sand	
	HT-17	4.3	0.475	0.7	0.65	0.725	0.7	0.65	laminated clay	Clay shows lamination
	HT-15	2.4	0.75	0.5	0.75	0.75		0.6875	Clay with fine sand	small head (readings x 2.5)
	HT-30	6.0	0.6125	0.6875	0.8125	0.875	1	0.7975	Till	
	HT-36	3.0	0.9375	0.8125	0.9375	0.75	0.75	0.8375	clay	small torvane head used (readings x 2.5)
	HT-36	3.0	0.95	0.8	0.85	0.95	0.875	0.885	clay	same location as first but without small head
	HT-7	2.2	1	1.3125	0.8125	1.375	0.875	1.075	Grey Clay	Small Head (readings x 2.5)

Trench ID	Depth (ft)			Shear Stress Kg/cm2			Average	Material	Note
UHT-1	3.6	0.03	0.03	0.00	0.08	0.08	0.04	Sandy Gravel	
UHT-5	5.0	0.08	0.08	0.10	0.05	0.08	0.08	Gravel	
UHT-1	1.5	0.10	0.05	0.08	0.10	0.05	0.08	Colluvium	
UHT-3	1.8	0.10	0.05	0.10	0.10	0.15	0.10	Colluvium	
UHT-2	4.2	0.20	0.08	0.15	0.08	0.10	0.12	Sandy Gravel	
UHT-8	5.5	0.35	0.10	0.05	0.08	0.10	0.14	Coarse Sand and Gravel	
UHT-2	1.5	0.23	0.10	0.15	0.15	0.08	0.14	Colluvium	
UHT-5	3.8	0.30	0.20	0.20	0.25	0.02	0.19	Fine Gravel + Sand	
UHT-4	2.5	0.35	0.25	0.28	0.25	0.10	0.25	Silty Sand	
UHT-10	2.0	0.23	0.43	0.48	0.33	0.25	0.34	Colluvium	
UHT-9	2.7	0.25	0.15	0.55	0.35	0.45	0.35	Colluvium	
UHT-6	2.0	0.35	0.65	0.43	0.35	0.35	0.43	Sandy Silty Clay	Spotty Oxidation
UHT-7	2.0	0.50	0.35	0.50	0.68	0.48	0.50	Colluvium	
UHT-6	4.6	0.60	0.50	0.50	0.70	0.60	0.58	Sandy Gravel in Clay	
UHT-9	5.0	0.60	0.53	0.58	0.65	0.60	0.59	Sandy Clay	
UHT-5	2.5	0.70	0.75	0.55	0.55	0.55	0.62	Colluvium	
UHT-10	4.7	0.68	0.60	0.70	0.53	0.63	0.63	Sandy Gravely Clay	
UHT-11	5.2	0.73	0.85	0.70	0.73	0.90	0.78	Sandy Clay	
UHT-11	2.9	0.73	0.83	0.95	0.83	0.75	0.82	Sandy Clay	
UHT-8	4.2	0.95	0.80	0.95	0.80	0.90	0.88	Brown Clay	
UHT-8	2.0	0.95	0.95	0.95	0.90	0.95	0.94	Sandy Silty Clay	Shelby Tube Locations Also OSL Locations
UHT-3	5.7	1.75	1.75	1.50	1.38	1.81	1.64	Diamict	Small Torvane Head Used (Reading X 2.5)

Location	Trench ID	Depth (ft)	Shear Stress Kg/cm2					Average	Material	Note
Meander	MT-30	0.7	0.250	0.150	0.125	0.350	0.150	0.205	Organics	
	MT-31	0.7	0.100	0.175	0.100	0.150	0.125	0.130	Organics	
		3.8	1.250	1.438	1.125	1.188	1.000	1.200	Till	
	MT-34	1.5	0.100	0.100	0.125	0.150	0.100	0.115	organcis	Readings x 2.5
		4.2	0.750	0.875	0.875	0.625	0.500	0.725	Till	
	MT-36	2.1	0.225	0.225	0.225	0.300	0.275	0.250	Point Bar	
		2	0.500	0.425	0.575	0.225	0.500	0.445	sandy clay	
		4.3	0.813	0.875	0.750	1.063	1.063	0.913	Till	readings x 2.5
	MT-37	2.6	0.475	0.475	0.475	0.425	0.400	0.450	gravely clay	
		1	0.450	0.350	0.500	0.325	0.500	0.425	organics	
	MT-39	2	0.200	0.350	0.200	0.275	0.275	0.260	sandy clay	
		3.2	0.125	0.100	0.100	0.100	0.125	0.110	sandy clay	
		4.7	1.000	0.875	1.125	0.625	0.625	0.850	clay/till	readings x 2.5
	40	0.9	0.275	0.075	0.150	0.075	0.100	0.135	organics	
		1.8	1.500	1.750	1.000	1.250	0.875	1.275	clay	readings x 2.5
	41	2.2	0.450	0.500	0.500	0.450	0.550	0.490	silty sand	
		4.5	0.750	0.825	0.650	0.750	0.700	0.735	clayey	
	42	0.5	0.225	0.300	0.200	0.100	0.225	0.210	organics	
		2.5	0.050	0.050	0.200	0.050	0.050	0.080	gravely clay	

Date	Location	Trench ID	Depth	Material	Shear Stress In TSF (1 Revolution=1-TSF)					Average	Note
5/17/2016	Buttermilk 2nd Log Site	N/A	1.0-2.0m	Mix of Brown sand with wilt and clay with occasional grey organic layers	0.6	0.575	0.56	0.45	0.55	0.55	2.5m thick unit above OSL and C-14 samples
5/17/2016	Buttermilk 2nd Log Site	N/A	2.75m	3" thick sand layer between coarse fluvial gravel and clay, wood, organics layer	0.19	0.15	0.19			0.18	
5/17/2016	Buttermilk 2nd Log Site	N/A	N/A	Till 20" thick exposed above water level in creek	0.56	0.65	0.5	0.6		0.58	refer to field notes

TORVANE DATA

Date	Location	Trench ID	Depth (ft)	Shear Stress Kg/cm2					Average	Material	Note
7/21/2016	Tree Farm	FT-1	6.0	0.350	0.400	0.400	0.400	0.400	0.390	"Till"	
7/21/2016	Tree Farm	FT-3	4.5	0.600	0.400	0.550	0.500	0.550	0.520	"Till"	
7/21/2016	Tree Farm	FT-4	2.3	0.050	0.025	0.050	0.050	0.050	0.045	Coarse Gravel	
7/21/2016	Tree Farm	FT-5	6.0	0.300	0.200	0.300	0.350	0.200	0.270	"Till"	
7/21/2016	Tree Farm	FT-6	1.1	0.150	0.150	0.150	0.075	0.100	0.125	Sand and Gravel	
			2.9	0.050	0.050	0.050	0.075	0.050	0.055	Sand and Gravel	
7/21/2016	Tree Farm	FT-7	1.5	0.100	0.075	0.050	0.150	0.075	0.090	Sand and Gravel	
7/21/2016	Tree Farm	FT-8	2.0	0.250	0.250	0.250	0.350	0.400	0.300	Clayey/silty sand	
7/21/2016	Tree Farm	FT-9	1.4	0.675	0.500	0.300	0.400	0.650	0.505	Clayey/silty sand	
			2.0	0.700	0.400	0.400	0.200	0.500	0.440	Clayey sand	OSL taken on same horizon in same material
			2.5	0.250	0.300	0.325	0.300	0.500	0.335	Clayey/silty sand	
7/21/2016	Tree Farm	FT-10	1.8	0.050	0.025	0.075	0.050	0.050	0.050	Silty Sand	
			4.0	0.025	0.025	0.075	0.050	0.075	0.050	Sand and Gravel	
7/21/2016	Tree Farm	FT-11	1.0	0.025	0.050	0.000	0.025	0.075	0.035	Silty Sand	
			3.5	0.025	0.050	0.050	0.050	0.100	0.055	Fine Gravel/Sand	Vertical Accretion
7/21/2016	Tree Farm	FT-12	3.3	0.100	0.150	0.100	0.150	0.150	0.130	Silty Sand	Taken from bench directly below jet test site
			4.5	0.125	0.050	0.000	0.075	0.100	0.070	Coarse Gravel and Sand	
	Tree Farm	FT-13	2.2	0.325	0.250	0.075	0.175	0.075	0.180	Sand	
			3.0	0.200	0.150	0.150	0.150	0.100	0.150		Taken From Jet Test Site
			4.5	0.350	0.650	0.450	0.550	0.850	0.570		
			5.5	1.000	0.875	1.375	0.875	1.563	1.138	Lodgment Till	Small Torvane Head (readings X 2.5)
		FT-14	2.1	0.300	0.250	0.250	0.250	0.250	0.260	Silty Sand	
			4.0	0.300	0.175	0.300	0.100	0.175	0.210	Silty Sand	
		FT-15	2.0	0.300	0.350	0.400	0.350	0.350	0.350	Sandy Clay	
			4.0	0.025	0.000	0.050	0.050	0.050	0.035	Blue Sandy Clay	
		FT-16	0.3	0.150	0.200	0.100	0.250	0.250	0.190	organics	
			1.0	0.250	0.300	0.250	0.250	0.200	0.250	silty sand	
		FT-17	2.0	0.225	0.375	0.225	0.225	0.325	0.275	Silty Sand	
			3.7	0.000	0.000	0.000	0.000	0.000	0.000	Sand	
			4.0	0.600	0.450	0.550	0.600	0.475	0.535	Silty Sand	
			4.6	0.000	0.000	0.000	0.000	0.000	0.000	Sand and Gravel	
		FT-18	1.9	0.200	0.300	0.150	0.450	0.425	0.305	Sandy, Silty Clay	
		FT-19	0.6	0.225	0.200	0.300	0.350	0.250	0.265	Organics	
			1.5	0.700	0.800	0.725	0.700	0.600	0.705	Silty Clay	
			3.0	0.250	0.250	0.200	0.250	0.350	0.260	Silty sand	
		FT-20	3.1	0.100	0.150	0.200	0.200	0.500	0.230	Silty Sand	
			5.0	0.000	0.050	0.075	0.050	0.075	0.050	Coarse Sand	
		FT-21	2.0	0.225	0.325	0.375	0.300	0.200	0.285	Silty Fine sand	
		FT-23	2.0	0.300	0.525	0.525	0.350	0.375	0.415	Silty Sand	
			4.2	0.500	0.100	0.475	0.500	0.550	0.425	sandy clay	
		FT-24	0.4	0.250	0.300	0.200	0.200	0.200	0.230	organics	
			1.2	0.425	0.200	0.150	0.300	0.300	0.275	Sandy Silty Clay	
		FT-25	1.7	0.050	0.050	0.175	0.200	0.125	0.120	silty sand	
			2.2	0.000	0.000	0.000	0.000	0.000	0.000	coars sand	
		FT-26	1.5	0.750	0.625	0.313	0.500	0.250	0.488	Clay	Small Torvane Head (readings x 2.5)
			1.5	0.725	0.525	0.800	0.450	0.800	0.660	Clay	Taken from same location but with fixed head

Location	Trench ID	Depth (ft)	Material	Shear Stress Kg/cm2					Average	Note
Lower Heinz	HT-1	1.5	Silty Sand	0.15	0.2	0.375	0.65	0.5	0.375	
Lower Heinz	HT-3	1.1	Organics	0.2	0.2	0.3	0.25	0.3	0.25	
		1.9	Sandy Silty Clay	0.1	0.15	0.175	0.1	0.225	0.15	
Lower Heinz	HT-4	0.5	Sand	0	0	0	0	0	0	
		3.5	Lateral Accrection	0	0	0	0	0	0	
Lower Heinz	HT-5	0.5	Organics	0.55	0.425	0.45	0.45	0.475	0.47	
		2.3	Clayey Sand	0.275	0.25	0.2	0.275	0.225	0.245	
	HT-6	1.5	Silty Sand	0.45	0.45	0.55	0.4	0.5	0.47	
	HT-7	2.2	Grey Clay	1	1.3125	0.8125	1.375	0.875	1.075	Small Head (readings x 2.5)
	HT-8	0.8	Organics Zone	0.325	0.225	0.275	0.45	0.35	0.325	
		1.8	Silty Sandy Clay with Gravel	0.275	0.3	0.2	0.3	0.275	0.27	
	HT-9	0.9	Silty Sand	0.1	0.075	0.1	0.15	0.125	0.11	
		1.8	Silty Sand	0.2	0.2	0.25	0.2	0.25	0.22	
	HT-10	0.7	Clayey Silty Sand	0.35	0.1	0.15	0.05	0.45	0.22	
		2.8	Sily Sand	0.2	0.225	0.425	0.4	0.275	0.305	
		4.4	Clayey Sand	0.55	0.25	0.25	0.225	0.3	0.315	
	HT-11	0.5	Organics	0.15	0.175	0.15	0.175	0.25	0.18	
		2.7	Clayey Silty Sand	0.475	0.575	0.55	0.65	0.65	0.58	
	HT-12	1.4	Clayey Silty Sand	0.35	0.3	0.4	0.45	0.275	0.355	
	HT-13	2.8	Silty Clay	0.625	0.25	0.75	0.65	0.5	0.555	
	HT-14	1.0	Silty Sand	0.25	0.175	0.15	0.2	0.1	0.175	
	HT-15	2.4	Clay with fine sand	0.75	0.5	0.75	0.75		0.6875	small head (readings x 2.5)
	HT-16	3.0	Clayey Silty Sand	0.3	0.275	0.275	0.275	0.2	0.265	OSL Location
	HT-17	1.4	sand and fine gravel	0.05	0.075	0.075	0.05	0.05	0.06	
		4.3	laminate clay	0.475	0.7	0.65	0.725	0.7	0.65	Clay shows lamination
	HT-18	2.0	clayey silty sand	0.175	0.3	0.2	0.2	0.275	0.23	
	HT-19	1.0	silty sand	0.175	0.25	0.15	0.2	0.3	0.215	
	HT-20	3.4	silty sand	0.375	0.15	0.15	0.35	0.2	0.245	
	HT-21	1.6	silty sand	0.35	0.275	0.45	0.325	0.3	0.34	
	HT-22	1.8	clayey silty sand	0.5	0.475	0.45	0.275	0.525	0.445	
	HT-23	2.5	clayey silty sand	0.425	0.6	0.55	0.425	0.5	0.5	
	HT-24	1.0	silty sand	0.25	0.4	0.3	0.25	0.1	0.26	
		2.5	fine gravel	0	0	0	0	0	0	
	HT-25A	0.5	organics	0.35	0.3	0.325	0.35	0.225	0.31	
		3.3	clayey silty sand	0.05	0.05	0.15	0.1	0.175	0.105	
	HT-25B	1.8	silty sand	0.2	0.1	0.1	0.1	0.05	0.11	
		3.0	clayey sand	0.35	0.3	0.25	0.2	0.35	0.29	
	HT-26	1.9	silty sand	0.125	0.175	0.225	0.125	0.2	0.17	
		4.5	coarse sand	0.05	0.125	0.05	0.1	0.025	0.07	
	HT-27	1.0		0.1	0.1	0.075	0.2	0.175	0.13	
		3.1		0.3	0.35	0.25	0.325	0.35	0.315	
	HT-28	0.7	silty sand	0.15	0.2	0.05	0.05	0.125	0.115	
		2.6	silty sand	0.25	0.375	0.45	0.35	0.05	0.295	
	HT-29	2.0	clayey silty sand	0.3	0.55	0.45	0.3	0.3	0.38	
		5.2	silty sandy clay	0.55	0.7	0.375	0.2	0.775	0.52	
	HT-30	1.5	silty sand	0.45	0.35	0.275	0.4	0.325	0.36	
		6.0	Till	0.6125	0.6875	0.8125	0.875	1	0.7975	
	HT-31	1.3	sand and gravel	0.05	0.075	0.075	0.125	0.1	0.085	
		2.9	sand and gravel	0.1	0.05	0.05	0.05	0	0.05	
	HT-32	1.0	silty sand	0.35	0.2	0.05	0.2	0.35	0.23	
		2.9	coarse sand	0	0	0	0	0	0	
	HT-33	2.0	silty sand	0.175	0.15	0.15	0.35	0.05	0.175	
		4.4	clayey silty sand	0.15	0.175	0.15	0.2	0.15	0.165	
	HT-34	1.9	silty clayey sand	0.575	0.7	0.275	0.475	0.7	0.545	
		4.8	clayey sand	0.7	0.625	0.5	0.65	0.75	0.645	
	HT-35	2.5	silty sand	0.4	0.275	0.5	0.25	0.375	0.36	
		4.0	clayey sand	0.175	0.35	0.775	0.775	0.775	0.57	
	HT-36	3.0	clay	0.9375	0.8125	0.9375	0.75	0.75	0.8375	small torvane head used (readings x 2.5)
		3.0	clay	0.95	0.8	0.85	0.95	0.875	0.885	same location as first but without small head
	HT-38A	2.3	silty sandy clay	0.5	0.625	0.5	0.55	0.35	0.505	

Trench ID	Depth (ft)	Shear Stress Kg/cm2					Average	Material	Note
UHT-1	1.5	0.10	0.05	0.08	0.10	0.05	0.08	Colluvium	
	3.6	0.03	0.03	0.00	0.08	0.08	0.04	Sandy Gravel	
UHT-2	1.5	0.23	0.10	0.15	0.15	0.08	0.14	Colluvium	
	4.2	0.20	0.08	0.15	0.08	0.10	0.12	Sandy Gravel	
UHT-3	1.8	0.10	0.05	0.10	0.10	0.15	0.10	Colluvium	
	5.7	1.75	1.75	1.50	1.38	1.81	1.64	Diamict	Small Torvane Head Used (Reading X 2.5)
UHT-4	2.5	0.35	0.25	0.28	0.25	0.10	0.25	Silty Sand	
UHT-5	2.5	0.70	0.75	0.55	0.55	0.55	0.62	Colluvium	
	3.8	0.30	0.20	0.20	0.25	0.02	0.19	Fine Gravel + Sand	
	5.0	0.08	0.08	0.10	0.05	0.08	0.08	Gravel	
UHT-6	2.0	0.35	0.65	0.43	0.35	0.35	0.43	Sandy Silty Clay	Spotty Oxidation
	4.6	0.60	0.50	0.50	0.70	0.60	0.58	Sandy Gravel in Clay	
UHT-7	2.0	0.50	0.35	0.50	0.68	0.48	0.50	Colluvium	
UHT-8	2.0	0.95	0.95	0.95	0.90	0.95	0.94	Sandy Silty Clay	Shelby Tube Locations Also OSL Locations
	4.2	0.95	0.80	0.95	0.80	0.90	0.88	Brown Clay	
	5.5	0.35	0.10	0.05	0.08	0.10	0.14	Coarse Sand and Gravel	
UHT-9	2.7	0.25	0.15	0.55	0.35	0.45	0.35	Colluvium	
	5.0	0.60	0.53	0.58	0.65	0.60	0.59	Sandy Clay	
UHT-10	2.0	0.23	0.43	0.48	0.33	0.25	0.34	Colluvium	
	4.7	0.68	0.60	0.70	0.53	0.63	0.63	Sandy Gravely Clay	
UHT-11	2.9	0.73	0.83	0.95	0.83	0.75	0.82	Sandy Clay	
	5.2	0.73	0.85	0.70	0.73	0.90	0.78	Sandy Clay	

Location	Trench ID	Depth (ft)	Shear Stress Kg/cm2					Average	Material	Note
Meander	MT-30	0.7	0.250	0.150	0.125	0.350	0.150	0.205	Organics	
	MT-31	0.7	0.100	0.175	0.100	0.150	0.125	0.130	Organics	
		3.8	1.250	1.438	1.125	1.188	1.000	1.200	Till	
	MT-34	1.5	0.100	0.100	0.125	0.150	0.100	0.115	organcis	Readings x 2.5
		4.2	0.750	0.875	0.875	0.625	0.500	0.725	Till	
	MT-36	2.1	0.225	0.225	0.225	0.300	0.275	0.250	Point Bar	
		2	0.500	0.425	0.575	0.225	0.500	0.445	sandy clay	
		4.3	0.813	0.875	0.750	1.063	1.063	0.913	Till	readings x 2.5
	MT-37	2.6	0.475	0.475	0.475	0.425	0.400	0.450	gravely clay	
		1	0.450	0.350	0.500	0.325	0.500	0.425	organics	
	MT-39	2	0.200	0.350	0.200	0.275	0.275	0.260	sandy clay	
		3.2	0.125	0.100	0.100	0.100	0.125	0.110	sandy clay	
		4.7	1.000	0.875	1.125	0.625	0.625	0.850	clay/till	readings x 2.5
	40	0.9	0.275	0.075	0.150	0.075	0.100	0.135	organics	
		1.8	1.500	1.750	1.000	1.250	0.875	1.275	clay	readings x 2.5
	41	2.2	0.450	0.500	0.500	0.450	0.550	0.490	silty sand	
		4.5	0.750	0.825	0.650	0.750	0.700	0.735	clayey	
	42	0.5	0.225	0.300	0.200	0.100	0.225	0.210	organics	
		2.5	0.050	0.050	0.200	0.050	0.050	0.080	gravely clay	

Date	Location	Trench ID	Depth	Material	Shear Stress In TSF (1 Revolution=1-TSF)					Average	Note
5/17/2016	Buttermilk 2nd Log Site	N/A	1.0-2.0m	Mix of Brown sand with wilt and clay with occasional grey organic layers	0.6	0.575	0.56	0.45	0.55	0.55	2.5m thick unit above OSL and C-14 samples
5/17/2016	Buttermilk 2nd Log Site	N/A	2.75m	3" thick sand layer between coarse fluvial gravel and clay, wood, organics layer	0.19	0.15	0.19			0.18	
5/17/2016	Buttermilk 2nd Log Site	N/A	N/A	Till 20" thick exposed above water level in creek	0.56	0.65	0.5	0.6		0.58	refer to field notes

APPENDIX I
Radiocarbon Dating Results

BETA #	SUBMITTER NO	TRENCH or place	(MATERIAL): PRETREATMENT	CONVENTIONAL AGE	CALENDAR AGE BP(1Σ mean)	1 SIGMA (Σ) RANGE BP	d13C	INTERPRETATION (Tentative)	LATITUDE/LONGITUDE
443610	C14-MT32-S84A seed	MT32	(plant): acid/alkali/acid	102.9 +/- 0.3 BP	NA	NA	-23.2	Recent	42.45867/78.64970
443301	C14-MT33-S5	MT33	(plant): acid/alkali/acid	1640 +/- 30 BP	1544 +/- 30	1445-1596	-23.7	Post-glacial bog	42.45867/78.64970
442968	C14MT38S4	MT38	(wood): acid/alkali/acid	4890 +/- 60 BP	5632 +/- 60	5585-5710	-26.1	In active channel gravel	42.45867/78.64970
442967	C14MT38S3	MT38	(wood): acid/alkali/acid	3170 +/- 30 BP	3397 +/- 30	3366-3443	-25.7	Post-glacial bog; intrusive into gravel	42.45867/78.64970
442966	C14MT37S4	MT37	(wood): acid/alkali/acid	5940 +/- 30 BP	6764 +/- 30	6720-6797	-25	In active channel gravel	42.45867/78.64970
442849	C14-MT36-S1	MT36	(wood): acid/alkali/acid	770 +/- 30 BP	697 +/- 30	675-725	-22.8	Post-glacial bog	42.45867/78.64970
442848	C14-MT34-S1	MT34	(wood): acid/alkali/acid	8470 +/- 30 BP	9495 +/- 30	9477-9917	-23	Till/gravel contact, base of channel age	42.45867/78.64970
442543	Old Zerfas #1	Zerfas	(wood): acid/alkali/acid	11080 +/- 30 BP	12955 +/- 30	12897-13028	-24.8	Old pond excavation ?	42.37919/78.62615
442542	C14-ZP-S5A	Zerfas	(peat?): acid/alkali/acid	11280 +/- 40 BP	13130 +/- 40	13083-13162		Base post-glacial bog	42.38273/78.62809
442541	C14-ZP-S4A	Zerfas	(wood): acid/alkali/acid	12140 +/- 30 BP	14030 +/- 30	13975-14090	-25.9	Wood in till (ice advance)	42.38273/78.62809
442540	C14-ZP-S3A	Zerfas	(wood): acid/alkali/acid	11940 +/- 50 BP	13770 +/- 50	13708-13937	-24.3	Wood in till (ice advance)	42.38273/78.62809
442539	C14-ZP-S2A	Zerfas	(wood): acid/alkali/acid	12390 +/- 40 BP	14438 +/- 40	14251-14590	-24.7	Wood in till (ice advance)	42.38273/78.62809
442538	C14-ZP-S1A	Zerfas	(wood): acid/alkali/acid	12370 +/- 50 BP	14402 +/- 50	14198-14546	-24.6	Wood in till (ice advance)	42.38273/78.62809
442537	C14-MT33-S5	MT33	(sediment): acid washes	5310 +/- 30 BP	6087 +/- 30	6008-6178	-26.1	Organic layer; in clay on gravel	42.45867/78.64970
442536	C14-MT32-S84A leaf	MT32	(plant): acid/alkali/acid	103.2 +/- 0.3	NA		-29.2	Recent bog	42.45867/78.64970
442535	C14-MT32-S1A	MT32	(plant): acid/alkali/acid	102.5 +/- 0.3 pMC	NA		-30.3	Recent bog	42.45867/78.64970
442117	C14-FT18-S10A	FT18	(wood): acid/alkali/acid	129.9 +/- 0.3 pMC	NA		-26	Recent organics	42.47346/78.66898
442102	FT20-F8B-1	FT20	(plant): acid/alkali/acid	115.8 +/- 0.3 pMC	NA		-27.7	Recent organics	42.47346/78.66898
442101	FT20-F8B-1	FT20	(wood): acid/alkali/acid	107.2 +/- 0.3 pMC	NA		-28	Recent organics	42.47346/78.66898
441598	C14-FT26-US2	FT26	(wood): acid/alkali/acid	2350 +/- 30 BP	2357 +/- 30	2334-2402	-23.9	Landslide (2nd event?)	42.47346/78.66898
441597	C14-FT26-US1	FT26	(wood): acid/alkali/acid	3450 +/- 30 BP	3712 +/- 30	3643-3819	-26.4	Landslide debris	42.47346/78.66898
441596	C14-FT26-LS4	FT26	(wood): acid/alkali/acid	3490 +/- 30 BP	3712 +/- 30	3643-3819	-27.1	Landslide debris	42.47346/78.66898
441595	C14-FT26-LS2	FT26	(wood): acid/alkali/acid	3510 +/- 30 BP	3777 +/- 30	3723-3836	-25.2	Landslide debris	42.47346/78.66898
441594	C14-FT26-LS1	FT26	(wood): acid/alkali/acid	3520 +/- 30 BP	3785 +/- 30	3724-3843	-24.9	Landslide debris	42.47346/78.66898
441593	C14-FT22-S1	FT22	(wood): acid/alkali/acid	1740 +/- 30 BP	1653 +/- 30	1614-1698	-22	Post channel?	42.47346/78.66898
441456	FT20-F8B-1	FT20	(sediment): acid washes	1230 +/- 30 BP	1165 +/- 30	1084-1235	-24.8	Post channel?	42.47346/78.66898
441455	FT18-S4A	FT18	(wood): acid/alkali/acid	1140 +/- 30 BP	1040 +/- 30	981-1070	-25.3	Post channel?	42.47346/78.66898
441454	FT18-S3A	FT18	(wood): acid/alkali/acid	1140 +/- 30 BP	1040 +/- 30	981-1070	-25.7	Post channel?	42.47346/78.66898
441453	FT18-S2A	FT18	(wood): acid/alkali/acid	130 +/- 30 BP	NA		-23.5	Recent soil	42.47346/78.66898
441452	FT18-S1A	FT18	(wood): acid/alkali/acid	210 +/- 30 BP	NA		-26.5	Recent soil	42.47346/78.66898
441451	FT17-S1A	FT17	(wood): acid/alkali/acid	250 +/- 30 BP	NA		-24.4	Recent soil	42.47346/78.66898
441450	FT15-S2A	FT15	(wood): acid/alkali/acid	590 +/- 30 BP	604 +/- 30	547-637	-24.2	Post channel fill	42.47346/78.66898
441449	FT15-S1A	FT15	(wood): acid/alkali/acid	600 +/- 30 BP	604 +/- 30	552-642	-23.4	Post channel fill	42.47346/78.66898
440738	C14-FT8-S6	FT8	(wood): acid/alkali/acid	1880 +/- 30 BP	1828 +/- 30	1742-1876	-26.4	Post channel fill?	42.47346/78.66898
440737	C14-FT8-S4	FT8	(wood): acid/alkali/acid	1880 +/- 30 BP	1828 +/- 30	1742-1876	-26.1	Post channel fill?	42.47346/78.66898
440736	C14-FT8-S1	FT8	(wood): acid/alkali/acid	1910 +/- 30 BP	1857 +/- 30	1824-1883	-24.5	Post channel fill?	42.47346/78.66898
440518	C14-HT33-S4	HT33	(wood): acid/alkali/acid	960 +/- 30 BP	856 +/- 30	800-926	-23.7	contact bet. overbank and gravel @ 5.5'	42.45245/78.64210
440517	C14-HT33-S3	HT33	(wood): acid/alkali/acid	2140 +/- 30 BP	2128 +/- 30	2062-2293	-24	reworked(?) wood (older than S4)	42.45245/78.64210
440516	C14-HT33-S2	HT33	(sediment): acid washes	1170 +/- 30 BP	1101 +/- 30	1057-1173	-27	black horizon in sand just above gravel	42.45245/78.64210
440515	C14-HT33-S1	HT33	(sediment): acid washes	1270 +/- 30 BP	1225 +/- 30	1182-1263	-26.5	black horizon in sand just above gravel	42.45245/78.64210
440217	UHT6-S2	UHT6	(sediment): acid washes	8960 +/- 40 BP	10129 +/- 40	9948-10211	-25.7	Clay below organic soil (landslide?)	42.45252/78.63817
440216	UHT6-S1	UHT6	(sediment): acid washes	4360 +/- 30 BP	4922 +/- 30	4866-4960	-24.9	Clay below organic soil (landslide?)	42.45252/78.63817
440138	C14-HT17-S1	HT17	(material): acid washes	24620 +/- 100 BP	28658 +/-100	28539-28782	-28	Organic horizon in varves on till	42.45245/78.64210
439758	HT7GPR18B	HT7	(charcoal): acid/alkali/acid	3520 +/- 30 BP	3785 +/- 30	3724-3843	-24.9	Overbank sediment; charcoal fire?	42.45245/78.64210
439757	HT614161	? (Wilson)	(wood): acid/alkali/acid	126.5 +/- 0.3 pMC	NA		-26.2	Recent	42.45245/78.64210
439756	HT5-leaf	HT5	(plant): acid/alkali/acid	103.2 +/- 0.3 pMC	NA		-27.6	Recent	42.45245/78.64210

BETA #	SUBMITTER NO	TRENCH or place	(MATERIAL): PRETREATMENT	CONVENTIONAL AGE	CALENDAR AGE BP(1Σ mean)	1 SIGMA (Σ) RANGE BP	d13C	INTERPRETATION (Tentative)	LATITUDE/LONGITUDE
439755	C14-HT16-S3	HT16	(plant): acid/alkali/acid	115.8 +/- 0.2 pMC	NA		-27.9	Recent	42.45245/78.64210
439754	C14-HT16-S2	HT16	(wood): acid/alkali/acid	104.2 +/- 0.3 pMC	NA		-26.5	Recent	42.45245/78.64210
439753	C14-HT16-S1	HT16	(wood): acid/alkali/acid	90 +/- 30 BP	NA		-23.3	Recent	42.45245/78.64210
438214	WV-Pit 5-Leaf - part 3	Pit 5	(plant): acid/alkali/acid	2420 +/- 30 BP	2446 +/- 30	2360-2485	-27.3	Post-glacial bog	42.45768/78.65031
438213	WV-Pit 5-Leaf - part 2	Pit5	(plant): acid/alkali/acid	860 +/- 30 BP	765 +/- 30	732-790	-26.1	Post-glacial bog	42.45768/78.65031
437717	WV-Pit 5-Leaf - part 1	Pit5	(plant): acid/alkali/acid	2630 +/- 30 BP	2756 +/- 30	2744-2764	-24.2	Post-glacial bog	42.45768/78.65031
437716	WV-BC-W14C-S4A	BC log site 2	(wood): acid/alkali/acid	1390 +/- 30 BP	1305 +/- 30	1286-1319	-25	1st Buttermilk terrace (4 ft above water)	42.44395/78.64141
437603	WV-BC-W14C-S3A	BC log site 2	(wood): acid/alkali/acid	1210 +/- 30 BP	1134 +/- 30	1078-1179	-23.5	Log in Butter terrace as above	42.44395/78.64141
437602	WV-BC-W14C-S2A	BC log site 2	(wood): acid/alkali/acid	940 +/- 30 BP	853 +/- 30	799-915	-24.9	1st Buttermilk terrace (4 ft above water)	42.44395/78.64141
437601	WV-BC-W14C-S1A	BC log site 2	(wood): acid/alkali/acid	1010 +/- 30 BP	933 +/- 30	919-958	-26.3	1st Buttermilk terrace (4 ft above water)	42.44395/78.64141
437412	MH512161	? (Wilson)	(wood): acid/alkali/acid	160 +/- 30 BP	NA		-23.5	Recent	42.45252/78.63817
437411	WV-MD-P3-S1A	Pit3	(wood): acid/alkali/acid	3550 +/- 30 BP	3834 +/- 30	3734-3893	-25.5	Post-glacial bog	42.45768/78.65031
437410	WV-MD-P2-S2A	Pit2	(wood): acid/alkali/acid	11630 +/- 40 BP	13462 +/- 40	13416-13537	-26.1	Wood in till (ice advance)	42.45768/78.65031
437409	WV-MD-P2-S1A	Pit2	(wood): acid/alkali/acid	12280 +/- 40 BP	14192 +/- 40	14099-14260	-25.7	Wood in till (ice advance)	42.45768/78.65031
437408	WV-MD-S2A	Pit1	(wood): acid/alkali/acid	12220 +/- 40 BP	14114 +/- 40	14048-14174	-25.8	Wood in till (ice advance)	42.45768/78.65031
437407	WV-MD-S1A	Pit1	(wood): acid/alkali/acid	12250 +/- 50 BP	14155 +/- 50	14064-14228	-24.9	Wood in till (ice advance)	42.45768/78.65031
425137	WV-BC-C14-S2	BC log site 1	(wood): acid/alkali/acid	1860 +/- 30 BP	1796 +/- 30	1736-1861	-26.3	Log in floodplain	42.44395/78.64141
425136	WV-BC-C14-S1	BC log site 1	(wood): acid/alkali/acid	1960 +/- 30 BP	1911 +/- 30	1877-1943	-27.6	Stump; growth position; Buttermilk Ck	42.44395/78.64141

APPENDIX J
Previous Radiocarbon Dating Results by Dr. Lee Gordon

Hindcasting, forecasting, and controlling erosion at the Western New York Nuclear Service Center

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INTRODUCTION

The Western New York Nuclear Service Center (Center), comprising 3,340 acres approximately 30 miles southeast of Buffalo, New York (Figure 1), is the site of the only commercial nuclear fuel reprocessing facility that has operated in the United States. As a result of reprocessing activities and shallow-land disposal of radioactive waste, significant inventories of long-lived radioactive materials are present at the site. Although significant decontamination and decommissioning of site facilities has occurred over the past two decades and continues today, the state and federal agencies managing the site are evaluating a range of options between in-place closure and removal of the remaining facilities and contamination. In order to evaluate decommissioning options for the site, the agencies are working to better understand how erosion has shaped the site in the past and how it will continue to do so far into the future. Given inherent uncertainties in hindcasting/forecasting of erosion and the dynamic nature of the local upland stream systems, it is appropriate that the current focus of erosion controls be on the near-term (decades) in areas close to critical site facilities.

GLACIAL GEOLOGY

The Center is located almost entirely within the 29 mi^2 watershed of Buttermilk Creek (Figure 1), a tributary to Cattaraugus Creek that empties into Lake Erie approximately 40 miles downstream of the Center. The watershed generally occupies a shale and sandstone valley scoured by glaciation of the area. Repeated glaciations have veneered and filled the valley with tills, lacustrine sediments, morainal deposits and outwash. The till buries the bedrock valley to a depth of up to 500 ft (150 m) along the valley axis. The till is thinner on the hillsides and bedrock is nearly exposed on the hill summits peripheral to the watershed.

THE ONSET OF INCISION

Post-glacial incision of Buttermilk Creek and its tributaries is thought to have begun in the Late Wisconsinan, shortly after the retreat of the Lavery ice, although direct evidence obtained in the vicinity of the Center has been elusive. Lafleur (1979) dated a high stream terrace suggesting incision of Buttermilk Creek was underway by about 11,500 years before present (YBP). Organic material associated with Defiance-Lake Escarpment outwash to the north of the Center suggests final ice retreat in the area occurred no later than 17,700 YBP (Calkin and Miller, 1977; note ^{14}C [radiocarbon] years are corrected to calendar years before present following Fairbanks et al., 2005). Recently, wood fragments found near the surface of the till plateau adjacent to Buttermilk Creek (Figure 2) indicate a meltwater environment may have still been present until about 14,000 - 14, 600 YBP. These particular wood fragments were not found in fluvial deposits; they were located approximately 0.5 - 1.0m below the surface within homogenous clay deposits. The wood fragments were colocated with very thin, horizontal deciduous leaf mats, suggesting deposition in meltwater/backwater. Once the ice retreated, thus opening northern (Buttermilk Creek) drainage, it is unclear what other mechanism could have emplaced these materials in such a manner at this particular location. Given this information, the onset of incision of Buttermilk Creek may have occurred between 14,000 and 15,000 YBP. As ice retreated further out of the Erie and Ontario Basins, the lowering lake levels would have occasioned the final dissection of the regional plateau drainage by the west-flowing Cattaraugus Creek, which serves as the current local baselevel for the Buttermilk system.

DENUDATION RATE(S)

The timing of ice retreat and onset of incision of Buttermilk creek is important to understanding downcutting rates within the system. Buttermilk Creek has eroded approximately 55m (180 ft) near its confluence with Cattaraugus Creek. Previous estimates using Lafleur's (1979) radiocarbon date of a high stream terrace put average downcutting at approximately 4.8 m/1,000 yr. Given the upper bound date described above (~14,500 YBP) yields a slower average rate of 3.7 m/1,000 yr. These limited data, while constraining to some degree the timing of incision onset, provide no information about changes in the incision rate through time, possible variability in incision rate throughout different parts of the watershed, or about the watershed's baselevel history near its confluence with Cattaraugus Creek (Trip Stop 6). While the existing conceptual model for landscape evolution at the site assumes a constant rate of downcutting, Lafleur (1979) notes that incision rates are expected to slow over time, particularly in reaches where the glacial sediment substrate becomes increasingly armored by clast lag buildup. Further, quartz-based optically stimulated luminescence (OSL) data collected at various terrace elevations along Buttermilk Creek suggest the incision of Buttermilk Creek was much more rapid early in its development (as much as 20x as rapid) than occurs today (USDOE, 2010).

A prominent feature of the Buttermilk Creek watershed topography is a hanging abandoned meander on the west side of the valley near the Center, ~ 20m below the till plateau and ~30m above the valley floor (Trip stop 5, Figure 2). The elevation of the meander suggests it represents a point in time when approximately 40% of the total incision observed today had occurred. OSL dated samples from the top of the till plateau and within the abandoned meander date both features to ~17,000 YBP. Recently collected ^{14}C samples date the top of the plateau at ~14,000 YBP and the meander at ~5,200 YBP. While the OSL data implausibly suggest the first 40% of incision occurred instantaneously, the ^{14}C data suggest the first 40% of incision occurred over a 9,000-year timeframe, the remaining 60% of incision having occurred in the last 5,000 years. It is obvious that additional dating studies are needed to better constrain both the onset of incision and changes in the incision rate over time and space. Samples near the watershed outlet could be particularly valuable for understanding baselevel history.

AGGRADING AND DEGRADING STREAM TERRACES

An interesting follow on discussion is the apparent absence of any net incision at locations within the Buttermilk Creek watershed and neighboring Connoisarauley Creek watershed over the past 1,000 to 2,000 years. This conclusion is drawn from age-dating a number of eroding stream terraces at the valley floor. As the channel sweeps laterally within the valley, remnant stream terraces are exposed and eroded. Within these terraces, exposed wood at the present day level of the stream consistently dates to approximately 1,000 to 2,000 YBP (Trip Stop 7, Figures 4 and 5), indicating that while the stream system may have migrated laterally a great deal during that timeframe, it has not appreciably incised (net incision). Moreover, the terraces being eroded at present stream level appear to be of a much larger scale than those being created within the system at present (Figure 6). These eroding terraces appear to be valley-filling aggradational units of sorted fluvial material, suggesting that while these materials were deposited by flowing water (not landslide or mudflow deposits) it was deposited in a fluvial regime not resembling the one we see today.

DISPOSAL AREA IMPLICATIONS

The large tributaries to Buttermilk Creek have dissected and incised the Lavery till plateau and generally occupy steep, deep V-shaped valleys lacking any floodplain. The discussion that follows focuses on the large Buttermilk Creek tributary known as Frank's Creek and its smaller tributary Erdman Brook (Figure 7). The convex longitudinal profile of Frank's Creek/Erdman Brook (Figure 8) is interpreted to mean that the system is inherently unstable and will continue to incise even if the baselevel at the confluence does not change. The instability is evidenced by the continued headward incision and dissection of the landscape, coupled with valley widening. The development and migration of knickpoints appear to drive much of the development of Buttermilk Creek's tributaries. As knickpoints incise the stream, adjacent slopes are over-steepened, and mass wasting in the form of small slides, slumps, and rotational failure serves to widen the valley (Trip Stop 4 to active landslide).

Near the headwaters of many of Buttermilk's tributaries, there is a sharp transition from a deep V-shaped valley to a more broad U-shaped valley, which coincides with a change in the longitudinal profile of the stream to a gentler grade (Figure 8). In Erdman Brook and Frank's creek, this transition has generally mirrored the location of large knickpoints (Trip Stops 2 and 3, Figures 11 and 12). Upstream of the transition/knickpoints, the floodplains occupy a wide, flat valley bottom, and in many cases (typically in wetland areas), a defined stream channel is not evident. While the V-shaped reaches are incised in Lavery till, the upland U-shaped reaches have been filled with 1 m to 3 m of fine-grained sediment in the recent past, evidently by beaver dams (Figures 11 and 12). Beaver dams are common in the area and effectively result in deposition of large amounts of sediment in these upland stream reaches. Beaver dams/ponds also serve as a natural means of erosion protection, providing grade control and energy dissipation. In order to monitor and manage the streams in a stable condition, beavers (and their dams) have been removed from Frank's Creek and Erdman Brook since the development of the Center (1960s). In the absence of beaver dams to hold the deposited sediments in place, knickpoints moving upstream out of the V-shaped reaches have encountered the highly erodible deposits, and over the past ~50 years have incised more than 100 m of both Erdman Brook and Frank's Creek. As these knickpoints have moved closer to the radioactive waste disposal areas, the state and federal agencies managing the site have taken steps to control the erosion.

On both Erdman Brook and Frank's Creek a number of grade-control structures have been installed during 2009-2013. The structures are typically based on a pool-riffle design with incorporated anchored grade control (Trip Stops 2 and 3, Figures 13 and 14). At knickpoint brinkpoints, interlocking subsurface concrete block walls have been installed perpendicular to the stream valley and keyed into the Lavery till that underlies the more erodible surface deposits. These walls extend outward from the center of the valley to the extent of the 100-year floodplain. Immediately downstream of these grade-control walls, the knickpoint scour pools have been reshaped and armored, and designed to outflow into engineered rock riffles. These structures, while relatively new, have functioned as designed with minimal maintenance, and should protect these localized reaches from erosion over the next several decades -- an appropriate nearby and near-term focus for erosion control, absent a better understanding of the system over millennial timeframes.

CONCLUSION

Converging lines of evidence suggest the existing simple conceptual model of Holocene landscape development may not adequately describe the evolution of the Buttermilk valley in a manner that allows for meaningful long-term erosion forecasts. As the state and federal agencies at West Valley continue to safely manage the site and conduct decommissioning activities, we are also focusing effort on developing a better understanding of the history of the Buttermilk Creek basin. This work may eventually lead to the development of longer-term, basin wide erosion forecasts and broader erosion control strategies. In the meantime, the agencies will continue to deploy, monitor, and maintain decade-scale, local controls, which are proving to be effective at mitigating erosion in the tributaries adjacent to critical site facilities

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United States Department of Energy, 2010. Final Environmental Impact Statement For Decommissioning and/or Long-Term Stewardship at the West Valley Demonstration Project and Western New York Nuclear Service Center (DOE/EIS-0226).

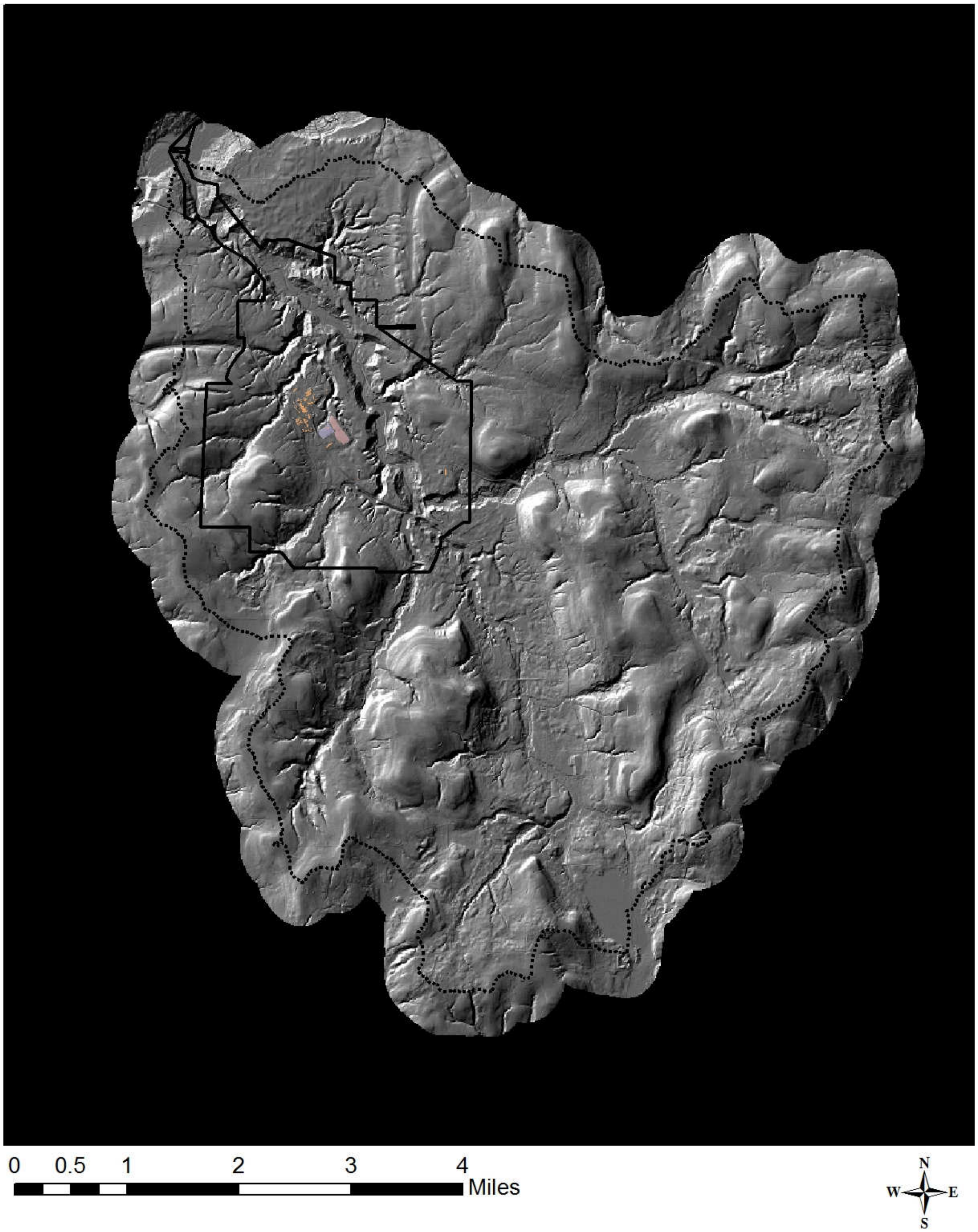

Figure 1: LiDAR-derived hillshade relief of Buttermik Creek watershed (outer dashed line) and Western New York Nuclear Service Center (inner solid line).

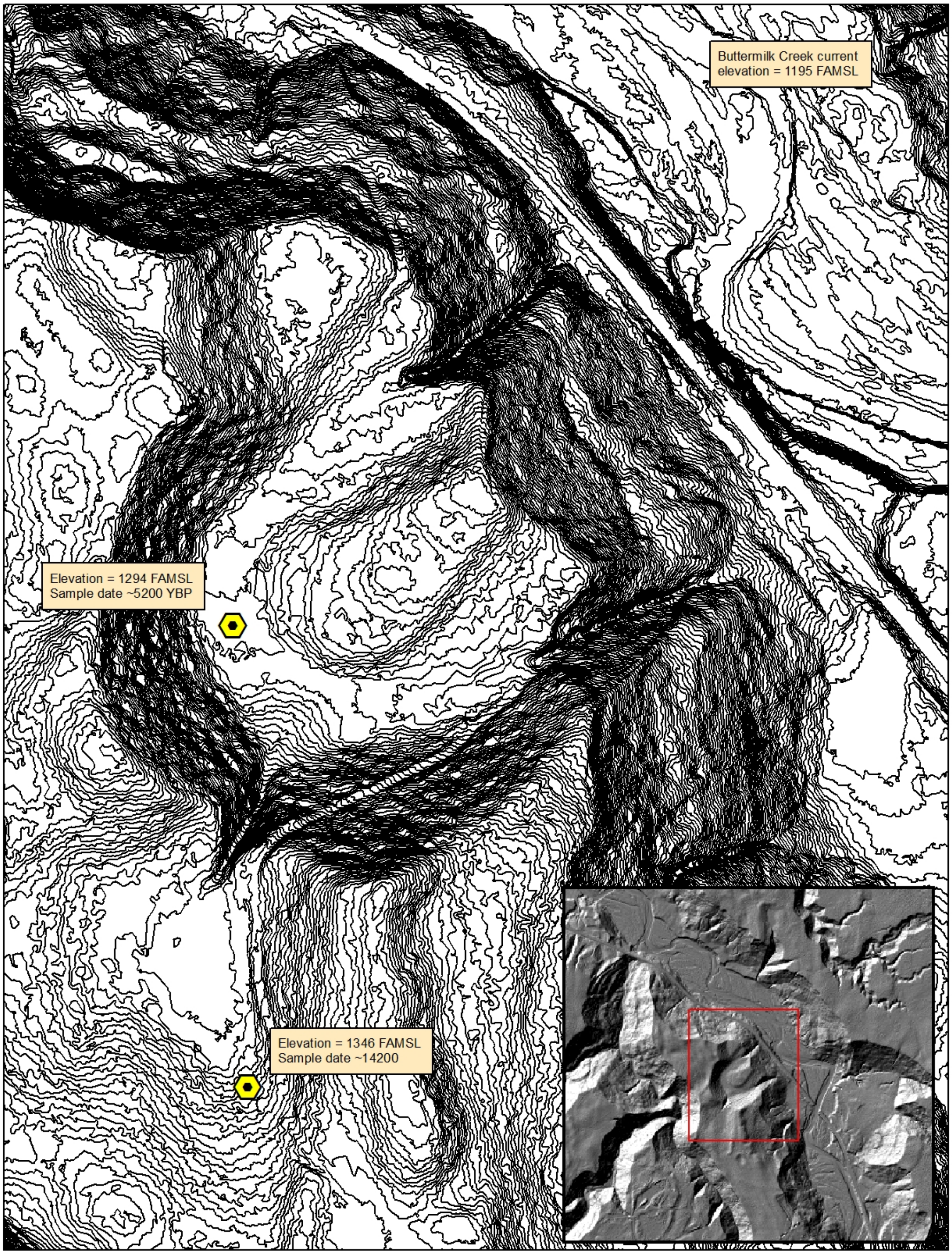

Figure 2 - LiDAR 1.0ft contour lines depicting hanging cutoff meander on Buttermilk Creek valley wall. Two dated wood sample locations are identified.

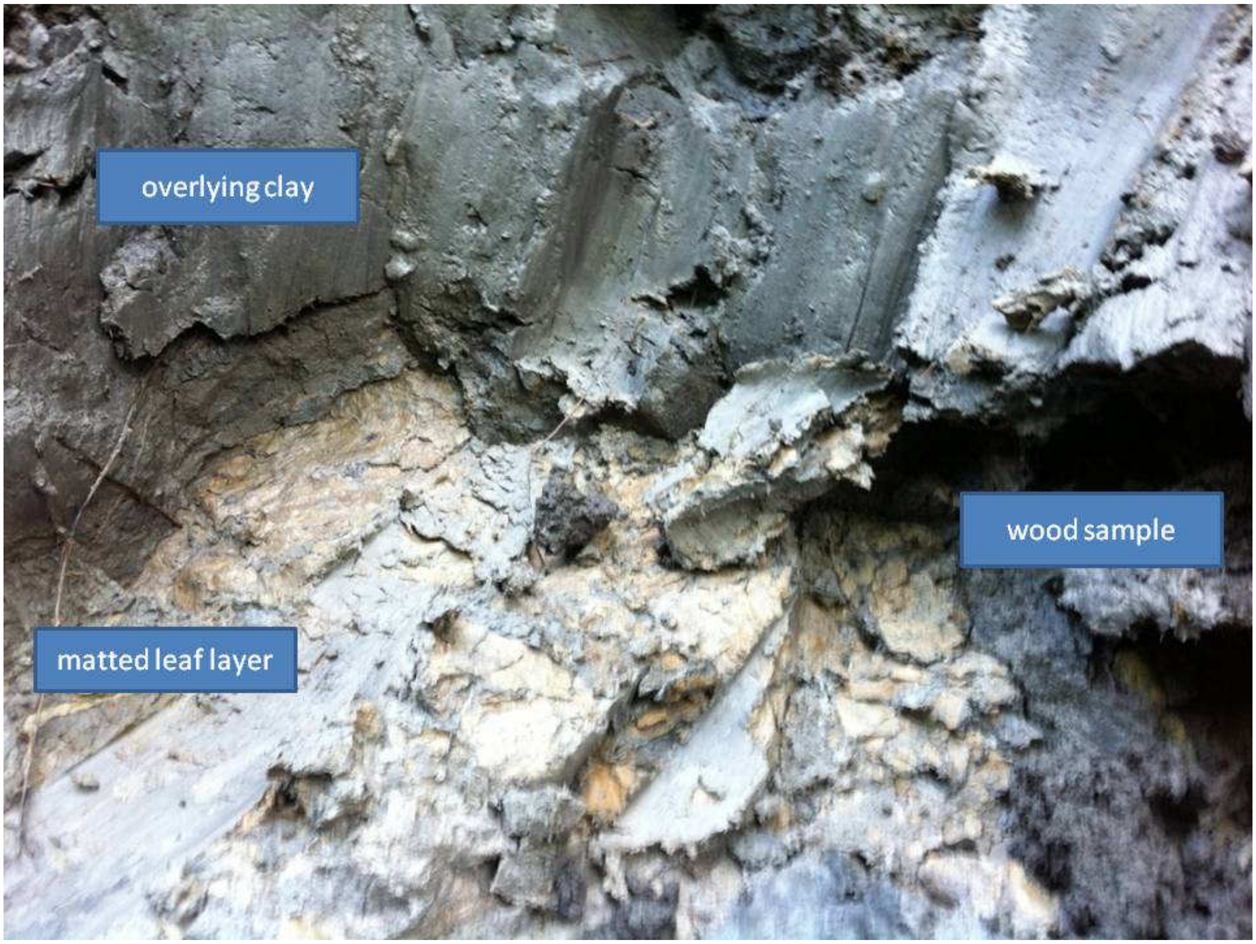

Figure 3 - Wood sample collected near top of till plateau at 0.89m deep (bottom). Samples were found in homogenous clay deposits colocated with mats of deciduous leaves. Three samples date to ~14,200 YBP.

Figure 4 - Large wood sample at base of ~3m terrace at interface between Lavery till and fluvial cobbles. Wood sample dated to ~2,300 YBP. Sample in Connoisarauley Creek, which occupies the next watershed to the west of Buttermilk Creek.

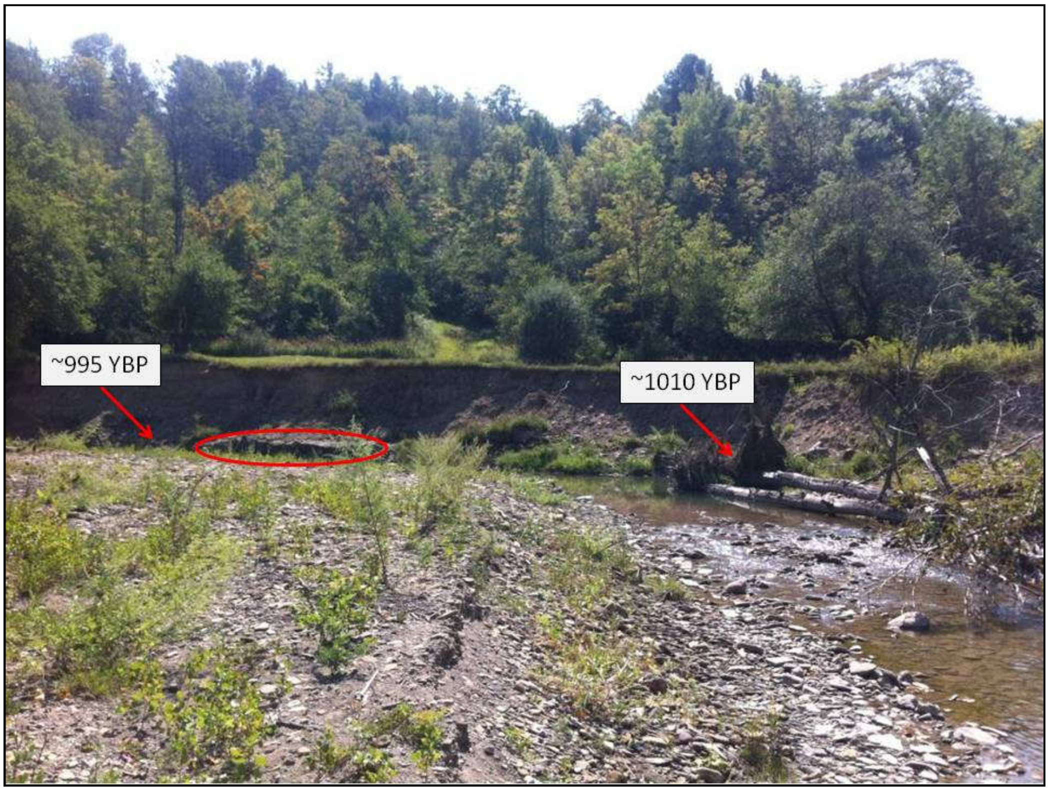

Figure 5 - Eroding terrace in Connoisarauley Creek. Two wood samples from the base of the terrace date to ~995 YBP and ~1010 YBP. A Lavery till outcrop is circled.

Figure 6 - "Valley-filling" fluvial terrace on Buttermilk Creek, a ~4.0m high aggradational feature. Intact lavery till can be found at the base of the terrace. A wood sample excavated at the base of the red pole dates to ~520 YBP.

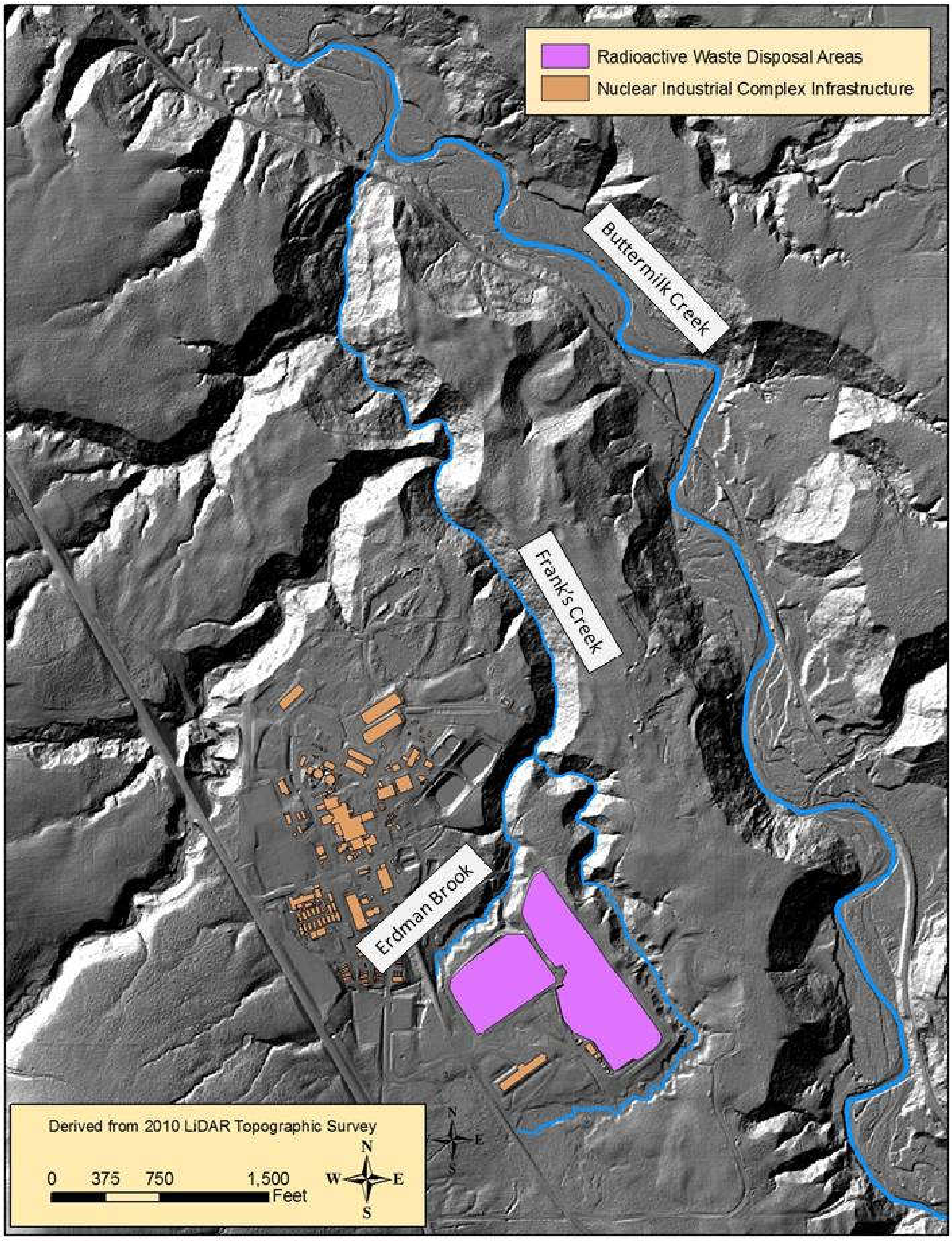

Figure 7 - Hillshade topography highlighting Buttermilk Creek and tributaries Frank's Creek and Erdman Brook and their proximity to the radioactive waste disposal areas and the infrastructure of the industrial complex

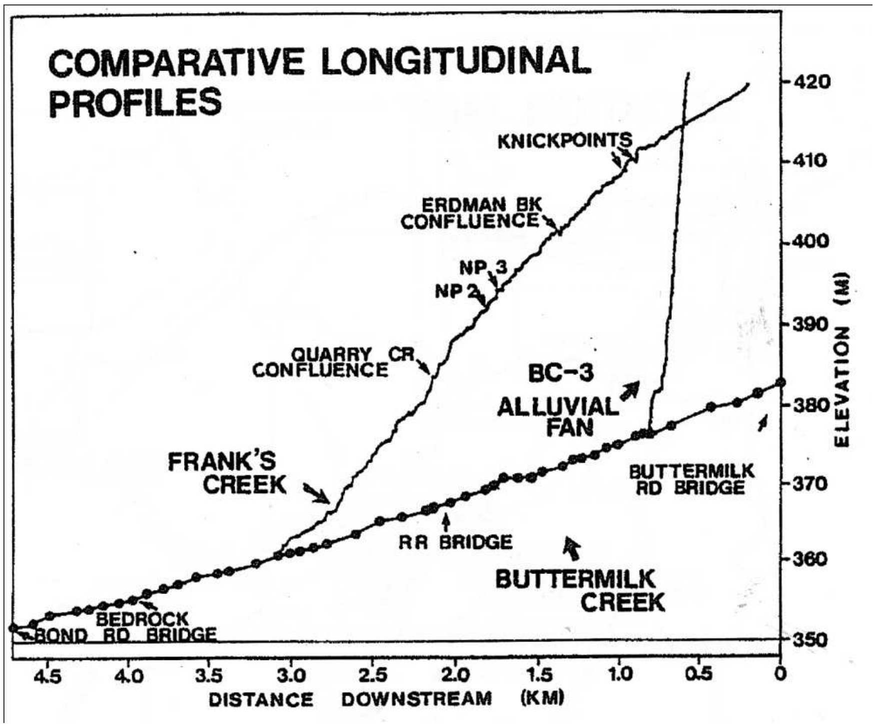

Figure 8 - Longitudinal profiles of Buttermilk Creek, Frank's Creek, and a small valley wall alluvial fan (Boothroyd et al., 1982)

Figure 9 - Active knickpoint on Erdman Brook. Stained gravel layer at waterline marks interface between fine-grained fluvial deposits (above) and Lavery till (below). Exposed branch below waterline dates to ~400 YBP. Total knickpoint height is ~1.5m.

Figure 10 - Active knickpoint on Frank's Creek. Stained gravel layer marks interface between fine-grained fluvial deposits (above) and Lavery till (below). Exposed branch dates to ~180 YBP. Total knickpoint height is ~2.5m.

Figure 11 - Beaver dam constructed on Frank's Creek near the radioactive waste disposal areas.

Figure 12 - Log exposed by migrating knickpoint in Frank's Creek shows evidence of having been felled by beavers. Log had been covered by approximately 2 meters of fine-grained deposits and was resting on intact Lavery till. Log dates to approximately 220 YBP.

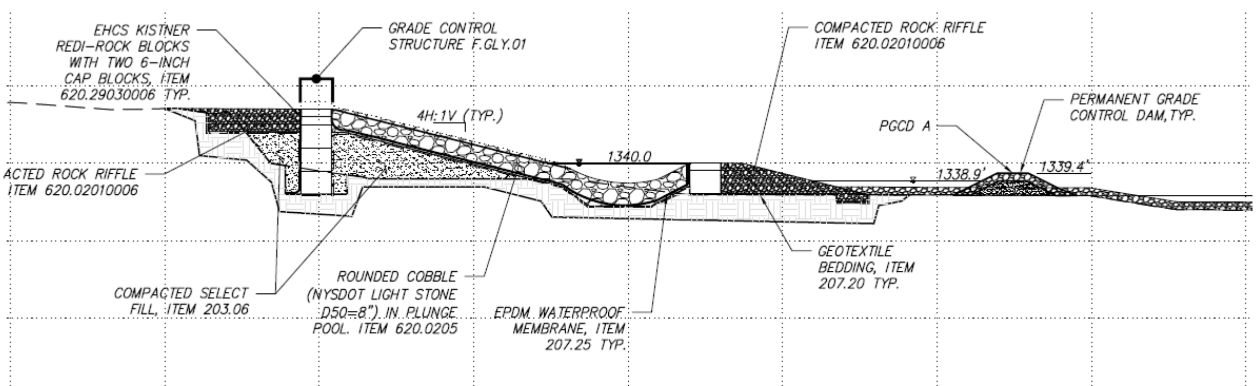

Figure 13 - Typical erosion control structure design with anchored grade control wall and pool-riffle sequence.

Figure 14 - Erosion Control Structures Installed on Erdman Brook. Shown are a series of pools and riffles. Looking downstream.

Trip Stops

Stop #1. The Ashford Office Complex, 9030 Route 219, West Valley, NY (Lat: 42.396014, Long: -78.674458): Trip participants will meet at the office of the New York State Energy Research and Development Authority to sign visitor forms and watch a safety video.

Travel to and enter **West Valley Demonstration Project (WVDP) and Western New York Nuclear Service Center (WNYNSC), 10282 Rock Springs Rd., West Valley, NY 14171** (Lat: 42.448975, Long: -78.657178): **Note: In order to enter the WVDP and WNYNSC, you are required to be escorted at all times by a NYSERDA employee.**

Stop #2. Erdman Brook Erosion Controls: Grade control and armored pool-riffle sequences for mitigating knickpoint erosion. Installed 2009-2012.

Stop #3. Franks Creek Erosion Controls: Grade control and armored pool-riffle sequence for mitigating knickpoint erosion. Installed 2013.

Stop #4. Buttermilk Creek Active Landslide: 180' landslide on west bank of Buttermilk Creek. Last major slide event during flood of August 9, 2009. Exposures of glacial till and lacustrine sediments.

Stop #5. Abandoned Hanging Meander: A 5,000-year old cutoff meander high on the valley wall.

Leave WVDP/WNYNSC.

Stop #6. Scoby Dam, Scoby Hill Rd., Springville, NY (Lat: 42.481144, Long: -78.700192): Visit Cattaraugus Creek near the confluence with Buttermilk Creek for discussion of baselevel control.

Stop #7. Connoisarauley Creek, Connoisarauley Rd. North, West Valley, NY (Lat: 42.448189, Long: - 78.715517) : Visit large stream terraces for discussion of aggradation/degredation over past 1000 years.

APPENDIX K
Optically Stimulated Luminescence Dating Results

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November 16, 2016

Luminescence dating report for Dr. Michael Wilson and Dr. Richard A. Young. Addendum to a prior report delivered in September 2016.

ISGS code	Sample	Mineral	Grain Size (µm)	Equivalent dose (Gy)	Dose rate (Gy/ka)	Age (ka)
424	WV T1 S2	K-Feldspar	150 - 250	43 ± 3	3.88 ± 0.13	11.2 ± 0.8[1]
426	WV T3 S1	K-Feldspar	150 - 180	9.6 ± 0.9	3.09 ± 0.10	3.1 ± 0.3[1]
428	WV T1 S1	K-Feldspar	150 - 250	68 ± 7	4.37 ± 0.13	15.6 ± 1.6[1]
429	WV Heinz	Quartz	150 - 250	27 ± 2	2.13 ± 0.08	12.7 ± 1.1[1]
430	WV T7 S1	K-Feldspar	150 - 180	42 ± 4	3.92 ± 0.13	10.6 ± 1.0[1]
451	WV-BC-OSL-S1	Quartz	150 - 250	6.4 ± 0.4	2.53 ± 0.10	2.5 ± 0.2[1]
452	WV-BC-OSL-S3a	Quartz	150 - 250	2.9 ± 0.2	2.33 ± 0.09	1.33 ± 0.12[1, 2]
453	WV-D1-S1	Quartz	150 - 250	38.5 ± 1.6	2.14 ± 0.08	18.0 ± 1.1
454	WV-MD-Pit2a	Quartz	150 - 250	28 ± 2	2.16 ± 0.08	12.8 ± 1.2[1]
473	UHT 8	Quartz	150 - 250	26.9 ± 0.9	2.84 ± 0.11	9.5 ± 0.5[1]
474	MT-36-OSL1	Quartz	150 - 250	19.0 ± 1.9	2.23 ± 0.09	8.5 ± 0.9[1]

[1]Minimum age model.
[2]Modeled burial depth.

Optically stimulated luminescence (OSL) dating was measured on quartz or K-feldspar grains, on small aliquots. For K-feldspar a fading correction was applied. Uncertainties are reported at a 1σ significance, providing a level of confidence of approximately 67%. The uncertainties combine random and systematic errors, added in quadrature.

Please note that nearly all samples were found to be poorly bleached at deposition (except for WV-D1-S1). The best age estimate presented above relied on the minimum age model. The age for WV T1 S1 reported here should be considered tentative. In addition, the uranium decay chains were found to be in disequilibrium for most samples. The dose rate shown here is calculated using present-day specific activity values. Further details can be found in the report.

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This is a report on the optically stimulated luminescence (OSL) dating of eleven samples delivered to us by Dr. Michael Wilson and Dr. Richard A. Young, in November 2015 (7), June 2016 (4) and August 2016 (2). The samples were retrieved in opaque tubes from excavated trenches or natural exposure. Sample WV T1 S2 was collected by digging in the exposure, in darkness (under an opaque tarp). The depositional environment is interpreted as fluvial or lacustrine (WV T1 S1) sediment. All samples are presumed to have been partially bleached prior to burial, which would lead to an age overestimation if not properly taken into account. For the purposes of internal identification, we labeled these samples ISGS 424 to 430, 451 to 454, 473 and 474. With the agreement of all parties two samples (WV T2 S1 and WV T4 S1) were withdrawn as quartz minerals extracted from these possessed ill-suited luminescence characteristics.

1. Sample preparation and equipment

The tubes were opened and the mineral extraction was conducted in a subdued orange light environment. One inch of sediment was removed from both ends of the tube because these might have been partially exposed to light during sampling. Sediment from the external portions was used to measure the *in situ* water content and its radioactive content (uranium, thorium, and potassium), both for dose rate calculation. Quartz of K-feldspar minerals for OSL dating were extracted from the remainder (inner portion) of each tube. Additional material was supplied for the external (gamma) dose rate by sampling nearby heterogeneous sedimentary units.

These minerals were wet sieved to retrieve the 150- to 250-μm grain size. A hydrochloric acid attack (HCl, 10%) was applied to dissolve any carbonate minerals that might be present. A solution of hydrogen peroxide (30 % for 24 hours) was mixed to sample UHT 8 since this sample showed visible traces of organic matter. Using a heavy liquid solution (2.62 g/mL) of lithium heteropolytungstate (LST), we separated K-feldspar and albite (>2.62) from the quartz minerals (<2.62). For sample WV T1 S1, WV T1 S2, WV T3 S1 and WV T7 S1 we performed a second density separation, at 2.58 g/ml, thus separating K-rich from Na-rich feldspar/plagioclase minerals. For quartz, further purification was done with a hydrofluoric acid (HF) attack (48% for 1 hour) to dissolve any remaining impurities. A second HCl attack was performed to dissolve calcium fluorite minerals, a potential by-product of HF dissolution of Ca-rich silicates. Finally, the purified quartz extracts were again sieved, at 150 μm, to remove partially dissolved impurities. A purity check was performed by doing an infrared over blue OSL stimulation. These quartz samples showed no significant contamination from feldspar. For samples WV T3 S1 and WV T7 S1 they were further sieved (dry) at the 150- to 180-μm grain size

To obtain the dose rate, sediments from the external portion of each sampling tube were dried, and a representative portion was encapsulated in petri dishes (~15 – 23 g) and sealed with paraffin wax. A minimum waiting time of 21 days after sealing is recommended to restore the radioactive equilibrium of radon-222 daughter products (Gilmore, 2008). The specific activities (Bq/kg) were measured with a broad-energy high-purity germanium detector (BEGe), in a planar configuration, shielded by 15 cm of thick lead. Efficiency calibration of the detector was obtained with a set of four certified standards (IAEA-RGU-1, IAEA-RGTh-1, IAEA-RGK-1, and IAEA-385).

2. Equivalent dose (De) measurements

For the equivalent dose (De) measurements, we relied on an automated Lexsyg Smart system equipped with a set of green (525-nm) and infrared (850-nm) LEDs for light stimulation. Detection was done in UV-blue light (combination of Schott BG3 glass and Delta BP 365/50 EX interference filters) for quartz. For K-feldspar we detected the blue emission (combination of Schott BG39 glass filter and Semrock HC 414/46 interference filter) during an infrared stimulation. For each sample, we dispensed quartz grains over a very small area (~ 1 mm), centered onto a silicon oil-covered stainless steel cup (10 mm in diameter). For K-feldspar we manually dispensed 1 grain onto each cup. For quartz a total of 240 or 432 aliquots were measured for each sample while for K-feldspar we measured from 36 to 80 aliquots. For sample WV Heinz (quartz), its equivalent dose (De) measurements relied on an automated Risø TL-DA-20 system equipped with a set of blue (470-nm) and infrared (870-nm) LEDs for light stimulation. Detection was done in UV light (Hoya U340 filter).

OSL measurements were carried out with a single-aliquot regenerative dose (SAR) protocol (Table 1). The optimal measurement parameters were selected by a dose recovery test (latent dose bleached twice with a UV (24 mW), Green (50 mW) and IR (51 mW) LED combinations, for 100 or 1000 seconds for quartz or feldspar; with blue LEDs for sample WV Heinz). An initial dose was given at first (that was a close match to the measured equivalent dose for each sample; from 17 to 40 Gy) and it was subsequently recovered by measuring its equivalent dose with the SAR protocol (Figure 1a). The samples responded reasonably well to the treatment. The optimal measurement treatment was verified and adjusted, as needed, for each sample. From this we selected a preheat temperature (Lx) of 180°C, 220°C or 240°C, for sample ISGS 451, 452 or 453. The preheat temperature for the test dose (Tx) was 40° lower. For sample 429 a preheat temperature (Lx) of 260°C was retained, with a 20°C lower temperature for the test dose (measured on the Risø). For K-feldspar, the preheat temperature for both IRSL measurements (Lx and Tx) was 220°C (Huot and Lamothe, 2003). The dose recovery test was performed for every sample using the most appropriate temperature (Figure 1b). It yielded an average measured-to-given dose ratios of 1.001 ± 0.013 and 0.934 ± 0.017, for quartz and feldspar. This outcome is positive. Considering this result, we opted to select the parameters in Table 1.

Table 1. Measurement steps for the single-aliquot regenerative protocol (Murray and Wintle, 2000; 2003)[1]

Step	Procedure (quartz)
1	Regeneration[1]/natural dose
2	Preheat (180 - 260°C), hold for 10 seconds
3	OSL[2] stimulation with green LEDs at 100°C for 40 seconds (L_x)
4	Test dose beta irradiation (17 Gy)
5	Cut heat (180°C) for 0 seconds
6	OSL stimulation with blue LEDs at 100°C for 40 seconds (T_x)
7	"hot bleach": 280°C for 200 seconds (only for sample WV Heinz (ISGS 429))
8	Repeat Steps 1–6 with further regeneration doses

[1]For equivalent dose measurements, we gave a range of laboratory-induced doses that would properly encompass the variability of the observed natural luminescence.

[2]For sample WV Heinz (ISGS 429), OSL stimulation was with blue LEDs at 125°C.

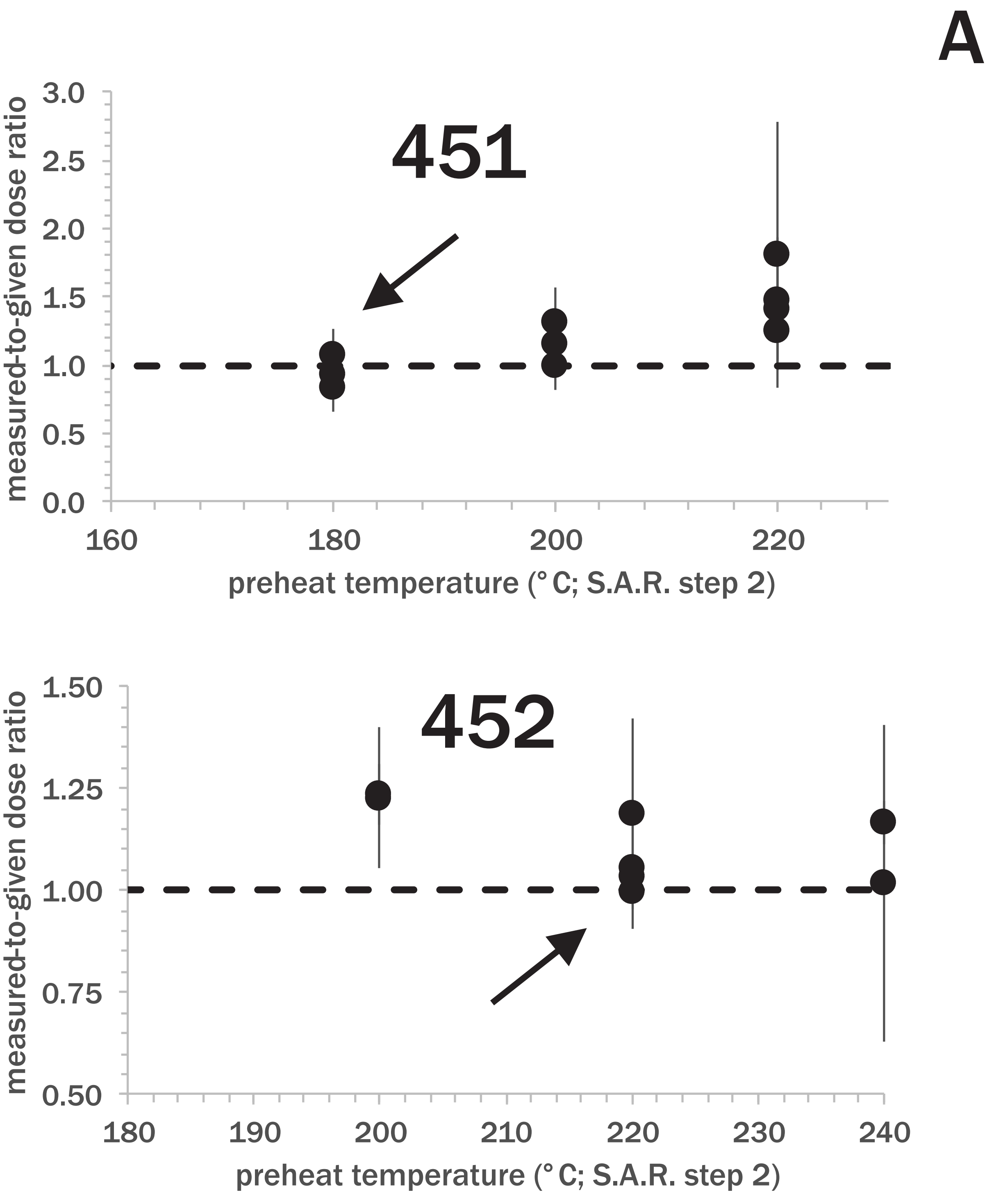
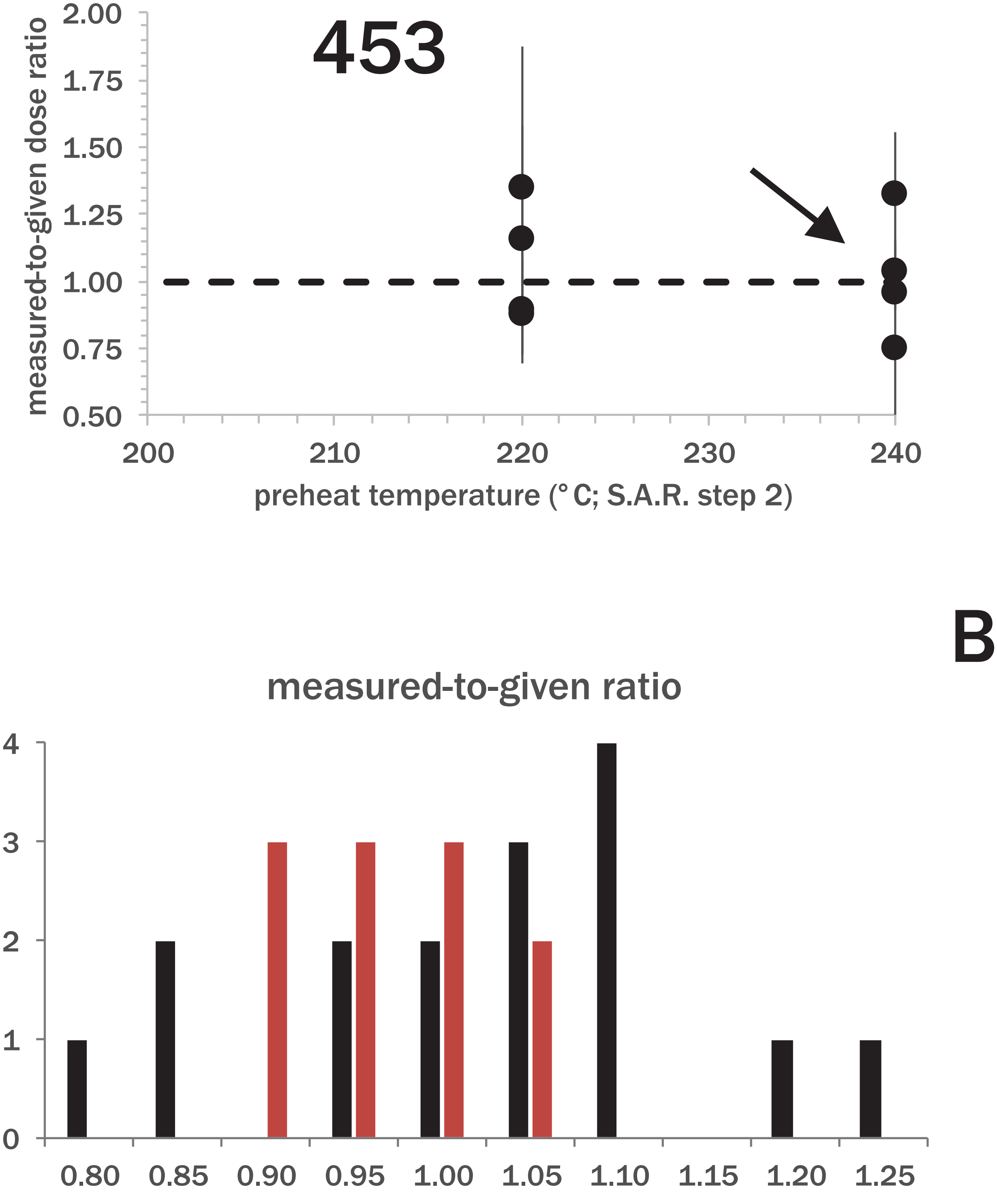


Figure 1. Result for the dose recovery test. A) Individual aliquots are shown for different preheat temperatures (i.e. step 2 of Table 1; ISGS 451, 452 and 453). The arrow points to the preheat temperature that was retained for measuring the equivalent dose (burial age) for the sediments. B) Summary for the dose recovery for every sample, for its selected and retained preheat temperature, for quartz (black) and K-feldspar (red). Luminescence dating tolerance tends to be conservative. For the dose recovery, we allow up to 10% variation from unity (i.e., 0.9 – 1.1).


453
measured-to-given dose ratio
2.00
1.75
1.50
1.25
1.00
0.75
0.50
200
210
220
230
240
preheat temperature (° C; S.A.R. step 2)
B
measured-to-given ratio
4
3
2
1
0
0.80
0.85
0.90
0.95
1.00
1.05
1.10
1.15
1.20
1.25

Step	Procedure (feldspar)
1	Regeneration[1]/natural dose
2	Preheat (220°C), hold for 60 seconds
3	Pause[3]
4	OSL stimulation with IR LEDs at 50°C for 100 seconds (L_x)
5	Optical bleach with green and IR LEDs for 100 seconds
6	Test dose beta irradiation (4 Gy)
7	Preheat (220°C) for 60 seconds
8	OSL stimulation with IR LEDs at 50°C for 40 seconds (T_x)
9	Optical bleach with green and IR LEDs for 100 seconds
10	Repeat Steps 1–9 with further regeneration doses

[3]For equivalent dose measurements there was no pause. A pause was observed here for anomalous fading measurements.

For the equivalent dose, all calculations were made using the "late light" approach for background subtractions, by taking the initial 10 data channels (5 seconds) from the OSL decay curve and removing the background from the end of the stimulation curve for quartz (25 data channels, 12.5 seconds; Figure 2). For sample WV Heinz (ISGS 429) we had to rely instead on the "early background" subtraction, by summing the initial 3 data channels (0.16 – 0.48 s)and removing the following 6 channels (0.64 – 1.44 s) (Cunningham and Wallinga, 2010). Aliquots were rejected (Table 2) because of feldspar contamination (10% threshold limit) or high recuperation (5% limit of the natural luminescence). In addition, numerous aliquots were rejected for having a low fast-ratio (Durcan and Duller, 2011).

2.1. Luminescence characteristics

Many the quartz minerals measured here had ill-suited characteristics for OSL dating. For instance, they OSL decay shape diverged from normality (Figure 2c). A good quartz OSL age must rely on an aliquot displaying a predominance of a "fast" OSL decay (e.g. Figure 2c, solid line; Wintle and Murray, 2006). An aliquot showing an 'ultra-fast' OSL decay component (dotted line) typically yield an abnormally young age (Jain et al., 2003). This ultra-fast decay component is known to be thermally unstable: it is absent from the natural OSL decay but present in the laboratory-induced OSL decay curves). In contrast, other quartz aliquots had a usually slower OSL decay (dashed line). Such an aliquot is characterized has having a small OSL intensity produced by the fast (the very first part of the OSL decay line up with the solid line) and a substantial OSL intensity from the medium component (the OSL intensity in the following data channels are all much higher than the solid line while decaying at a slower rate). Here, the medium OSL component is less sensitive to light (e.g. slower decay in Figure 2c), hence it is also slower to optically reset in the environment, during a sedimentary cycle (erosion, transport, sedimentation). Aliquots with a significant amount of this medium would thus yield an age over-estimation. However, the medium component is also known to be thermally unstable (but more so than the ultra-fast component, hence the medium component is apparent in the natural OSL decay curve); thus, this instability would induce an age under-estimation. Suffice it to say, the presence of the medium component is bad for dating!

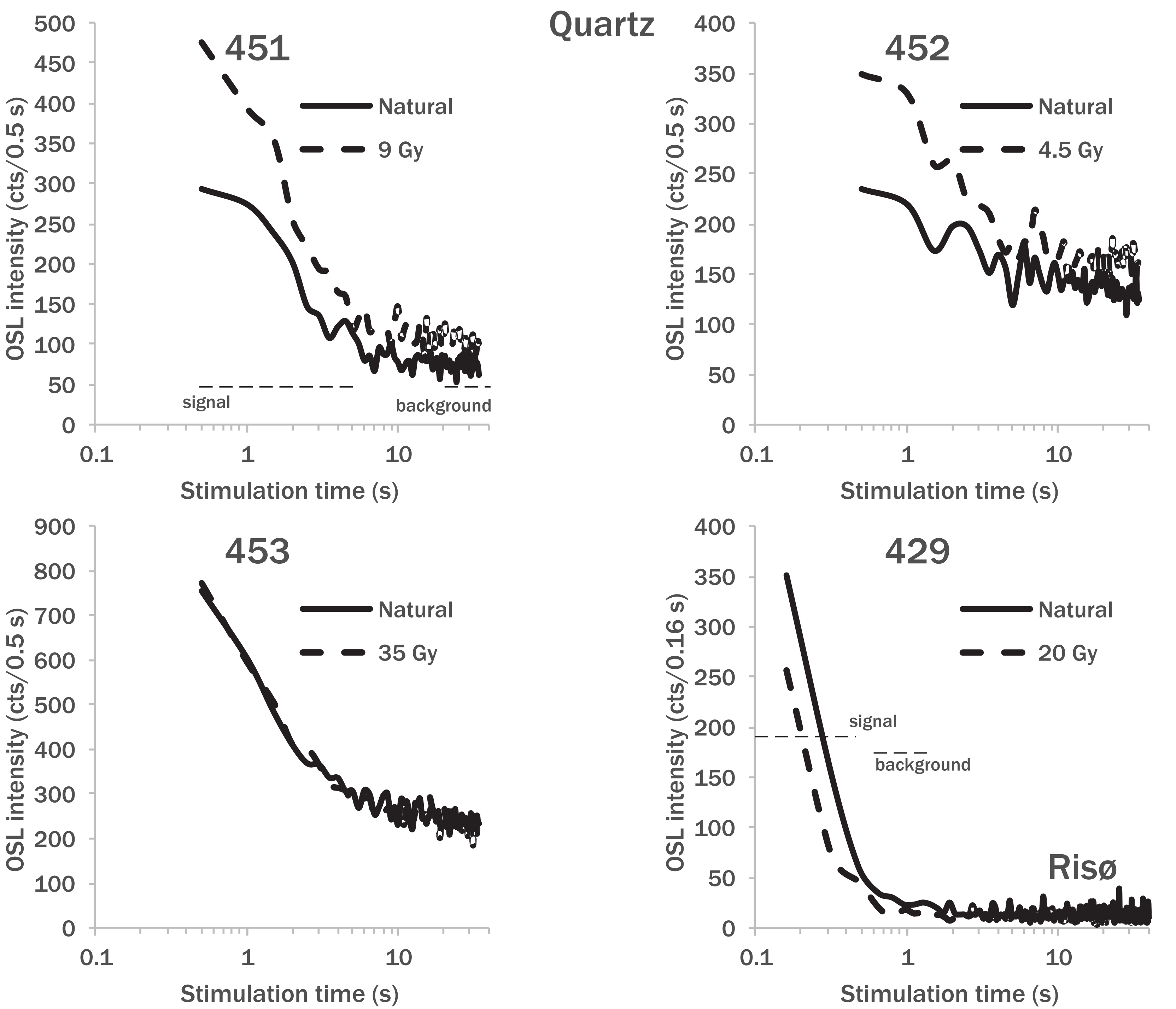
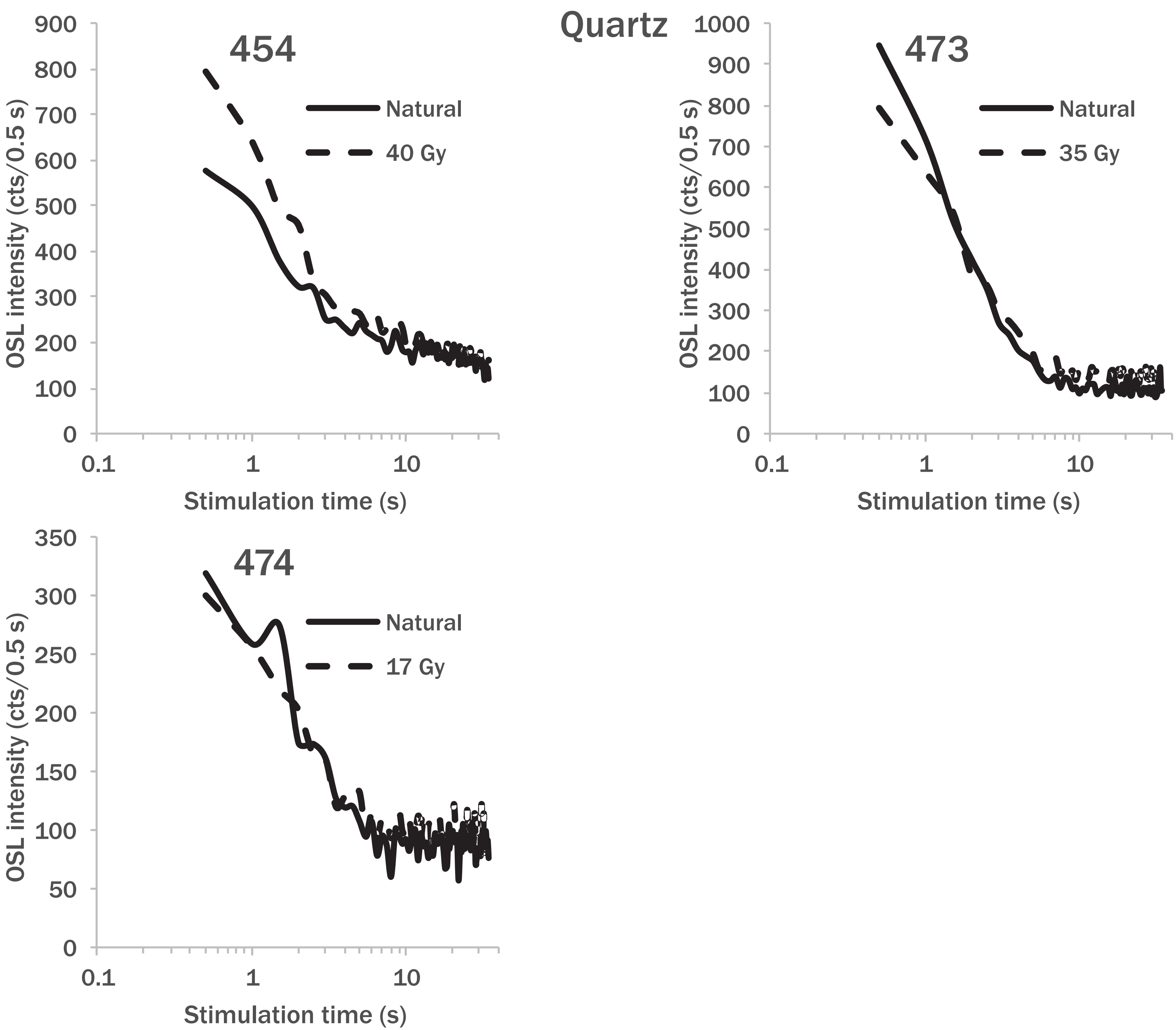
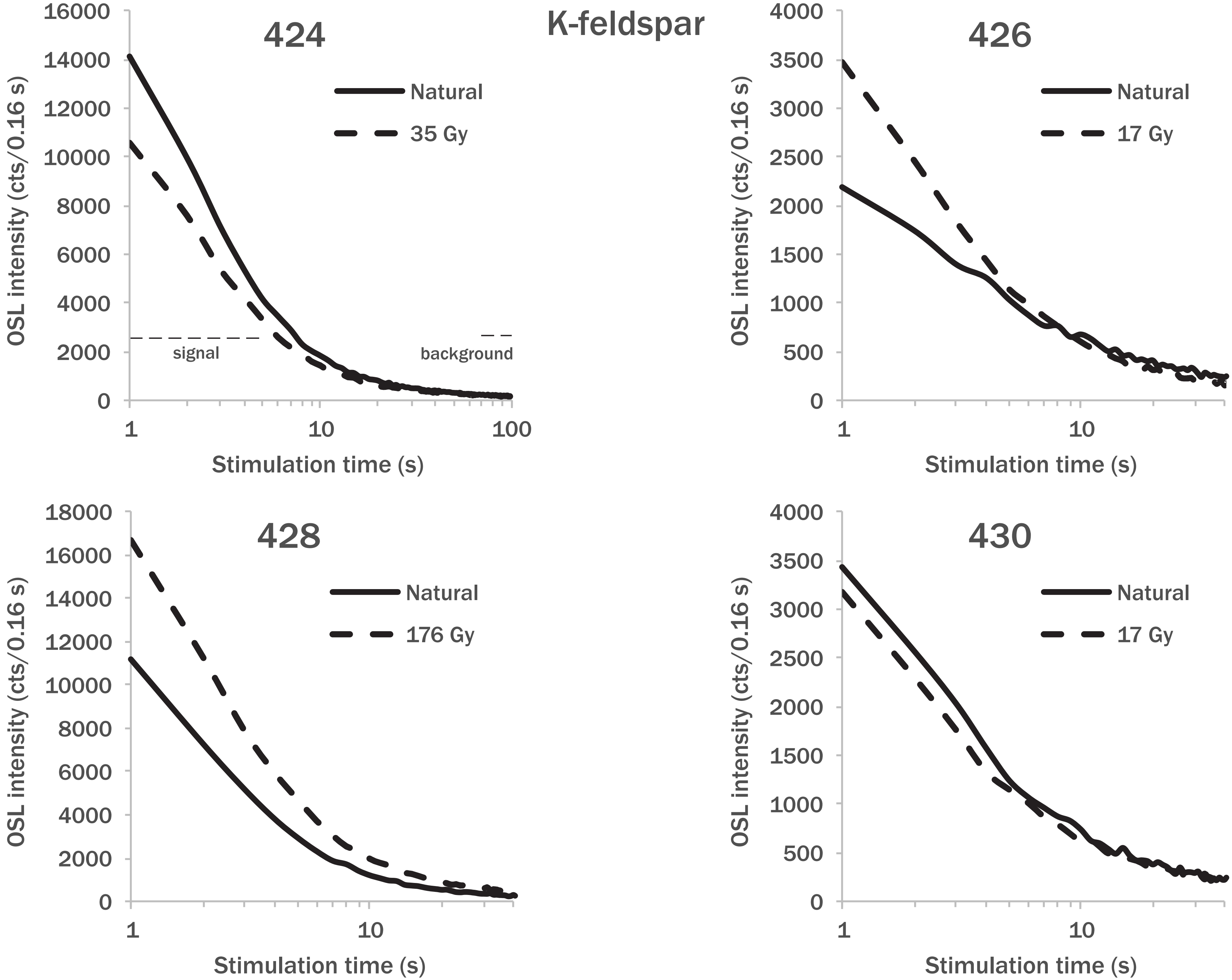


Figure 2. Typically OSL decay curve, for a naturally dose aliquot (solid curve) or laboratory-induced dose (dashed curve, in Gy). The area under the curve is proportional to the dose of radiation stored within the mineral. Their luminescence growth curve are shown in Figure 3.



Quartz
454
Natural
40 Gy
473
Natural
35 Gy
474
Natural
17 Gy
OSL intensity (cts/0.5 s)
Stimulation time (s)



K-feldspar
424
Natural
35 Gy
signal
background
426
Natural
17 Gy
428
Natural
176 Gy
430
Natural
17 Gy
OSL intensity (cts/0.16 s)
Stimulation time (s)

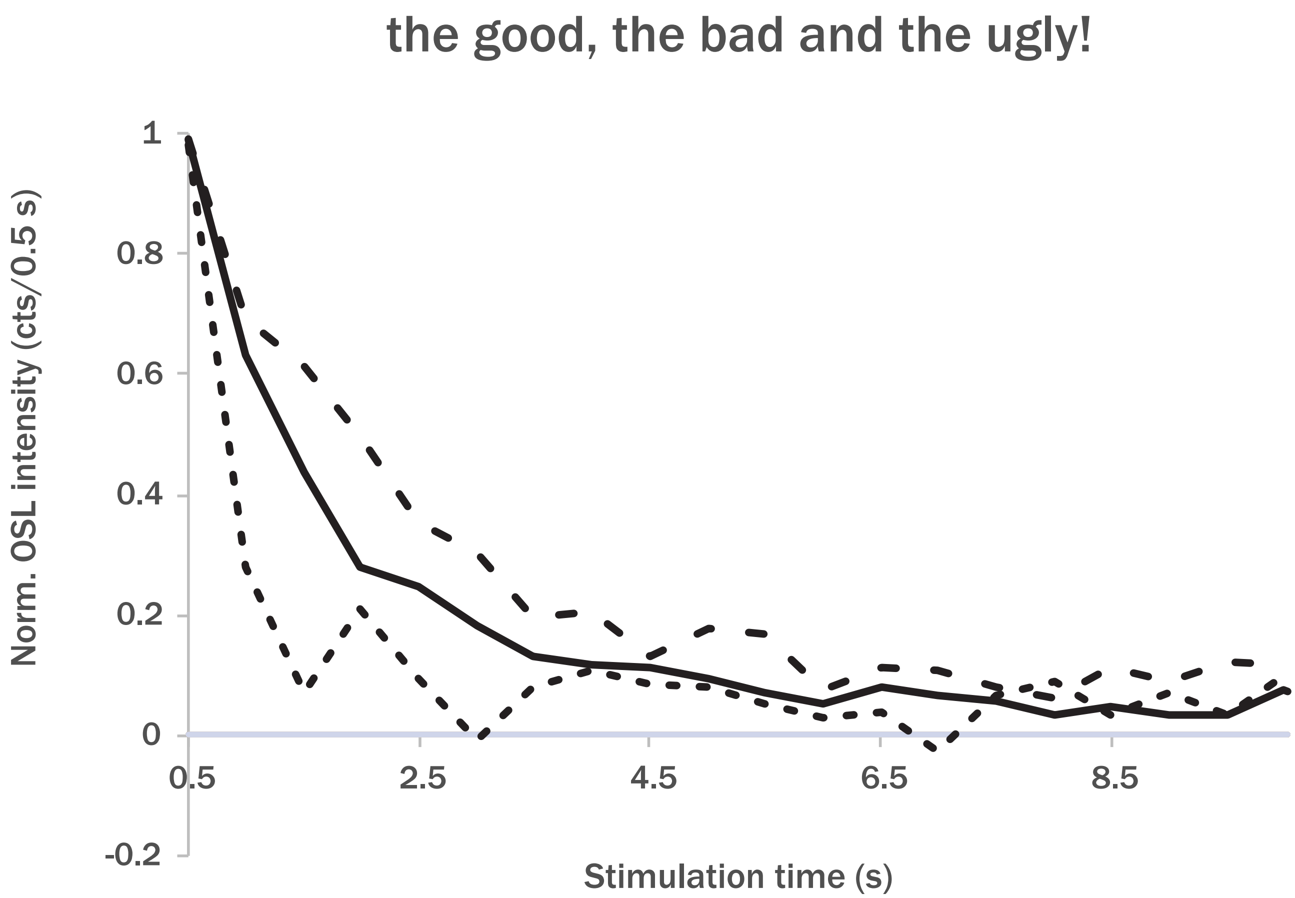


Figure 2c. Representative OSL decay curve (quartz) observed in these samples. The curve shown as a solid line is the desired shape for quartz minerals. The decay with dotted line has an unusually (ultra-)fast decay in the beginning whereas the curve with the long dashed line as a shorter decay (medium component). Stimulation with green LEDs at 100 ° C (Smart).

Due to this reason, all samples retrieved last autumn (field codes WV Tx Sx) had such problems of showing significant amounts of ultra-fast or medium component, with a small amount of the fast. In addition, the light yield was generally low, making it hard to discern from the instrumental background. A low luminescence light intensity was anticipated from the onset as the sediments are derived from a glaciated valley. It is known that such sedimentary environment to yield a low luminescence intensity from quartz (e.g. Rhodes, 2000). Why it is so remains unclear, although we have a working hypothesis (a high luminescence intensity, with a high proportion of the fast component, is usually found from sediment that have experienced numerous and repeated sedimentary cycles). There are exceptions to that rule, however. For example, we have successfully measured quartz retrieved from sediments from Ontario (Canada): these yielded excellent luminescence characteristics.

As an alternative we opted to measure K-feldspar minerals for these samples, even though it is harder to optically reset during a sedimentary cycle (hence, would yield an older age) and suffers from a phenomenon known as 'anomalous fading' (hence would yield a younger age). Suffice it to say, K-feldspar is not the first choice that comes to mind for this project! We chose to abandon two samples, WV T2 S1 and WV T4 S1, for these reasons. Also, to choice to abandon them was aided by noticing the improvement in luminescence characteristics from the 2nd batch of samples delivered in Spring 2016. After conferring with Dr Wilson and Young we offered to abandon these two samples, even though we had initiated luminescence measurements at the time, and substitute them for two new (hoping to have a better luck at the draw!), at no cost to Dr. Wilson and Young. We prefer to deliver a good age, rather than just a number!

Table 2. Tally of rejected aliquots.

ISGS code	Sample	n (accepted/total)	feldspar contaminated	recuperation	OSL decay shape	no signal
424	**WV T1 S2**	**29/80**	**–**	**2**	**–**	**49**
426	**WV T3 S1**	**35/62**	**–**	**–**	**–**	**27**
428	**WV T1 S1**	**21/36**	**–**	**–**	**–**	**15**
429	**WV Heinz**	**37/432**	**11**	**2**	**44**	**338**
430	**WV T7 S1**	**43/70**	**–**	**–**	**–**	**27**
451	**WV-BC-OSL-S1**	**45/240**	**13**	**1**	**34**	**147**
452	**WV-BC-OSL-S3a**	**69/240**	**12**	**–**	**1**	**158**
453	**WV-D1-S1**	**50/240**	**3**	**2**	**2**	**183**
454	**WV-MD-Pit2a**	**47/240**	**9**	**3**	**6**	**175**
473	**UHT 8**	**79/240**	**14**	**2**	**5**	**140**
474	**MT-36-OSL1**	**44/240**	**12**	**1**	**4**	**179**

Uncertainties relied on Poisson statistics. For curve fitting, we also propagated the uncertainties from the optimized parameters. In addition, when the observed scatter about the best fit regression line was too high, the uncertainties were increased (Figure 3; such as for the aliquot of sample 451). For this, we relied on the one-tailed probability χ^2 distribution, with N – 3 degrees of freedom (where N is the number of measured data points). When the probability was lower than 15% (i.e., the data points scattered above and beyond the best fit line), the uncertainties for the optimized parameters were expanded by Student's *t* values for N – 3 degrees of freedom (Brooks et al., 1972; Ludwig, 2003).

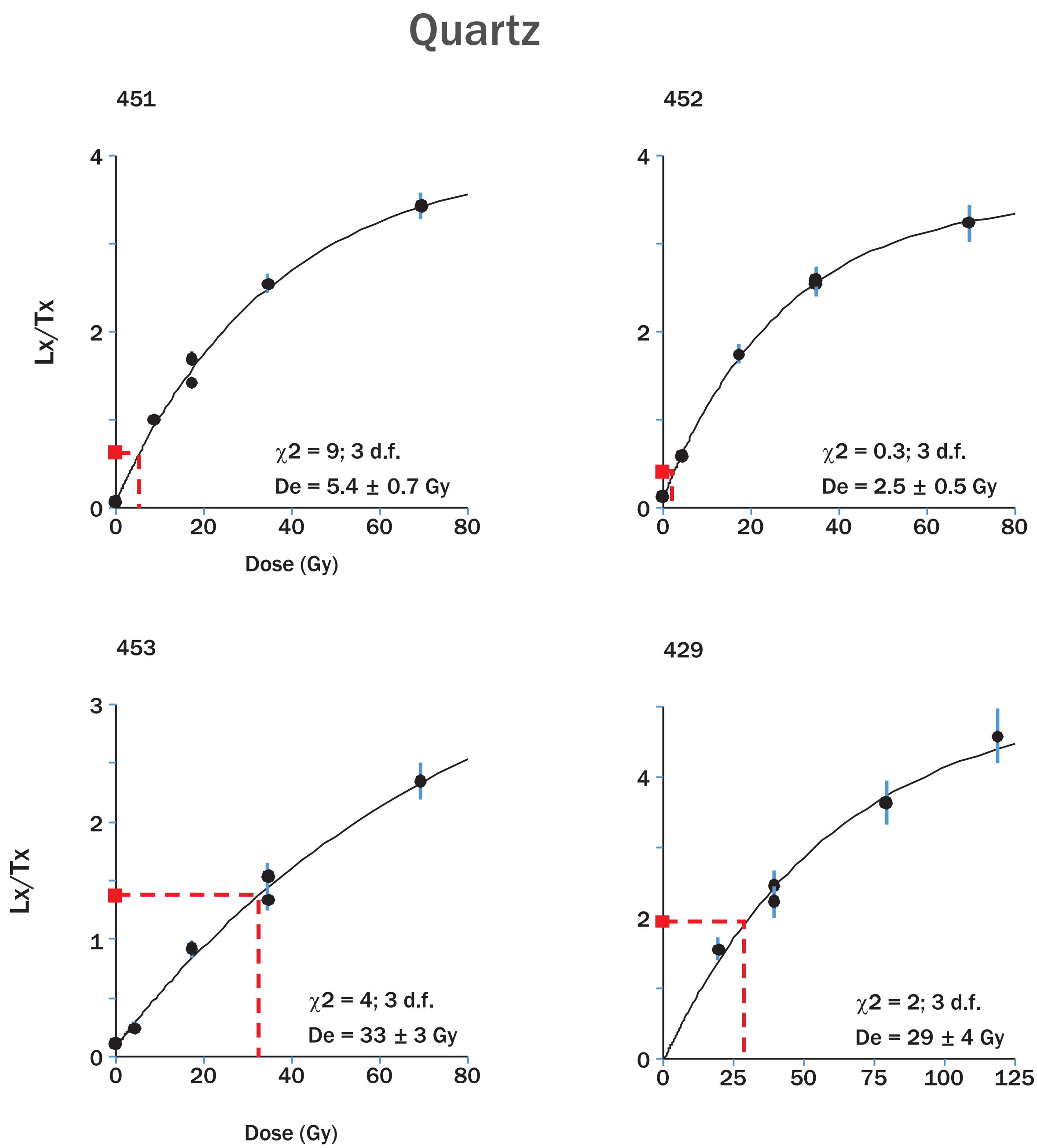
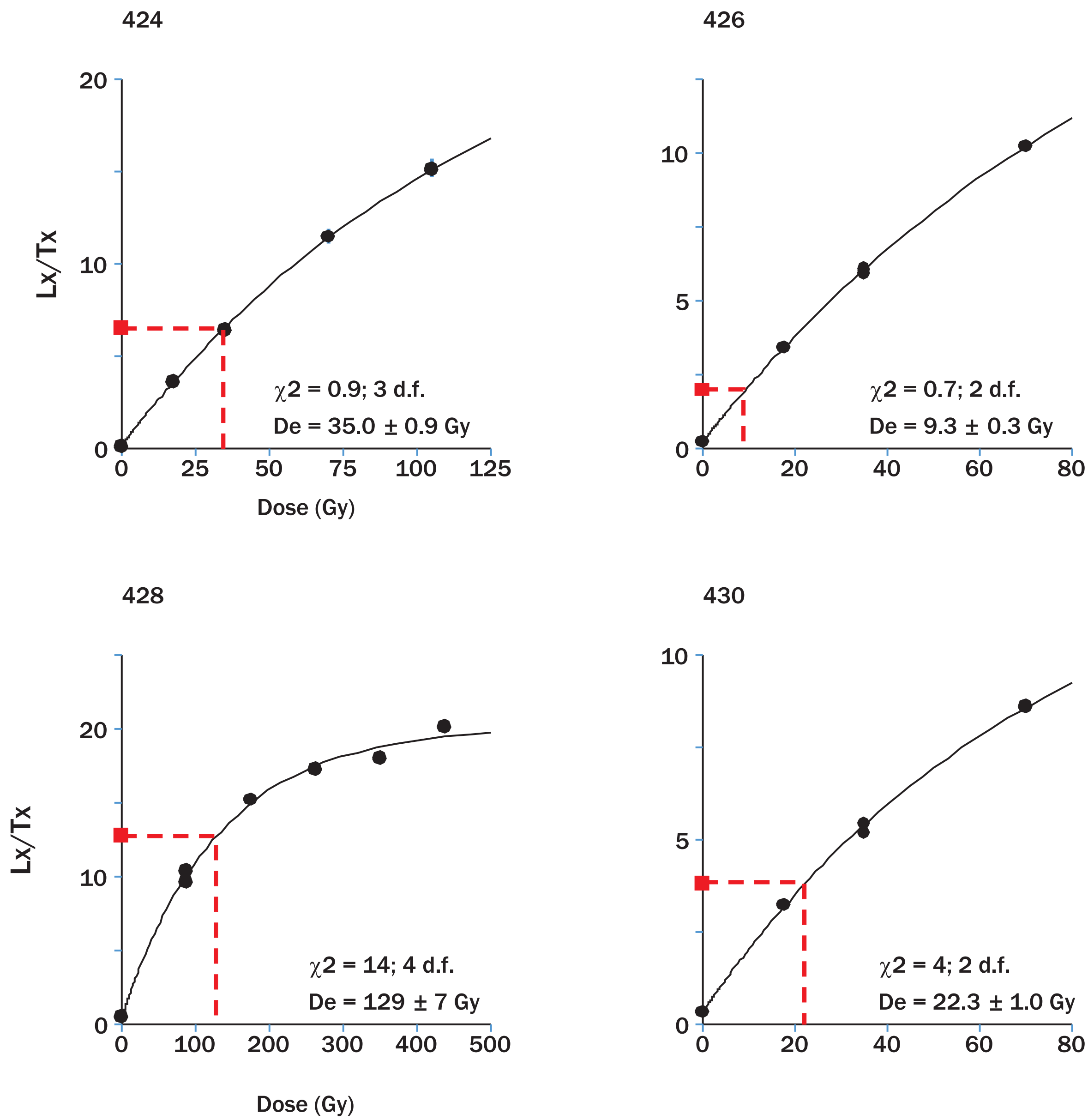
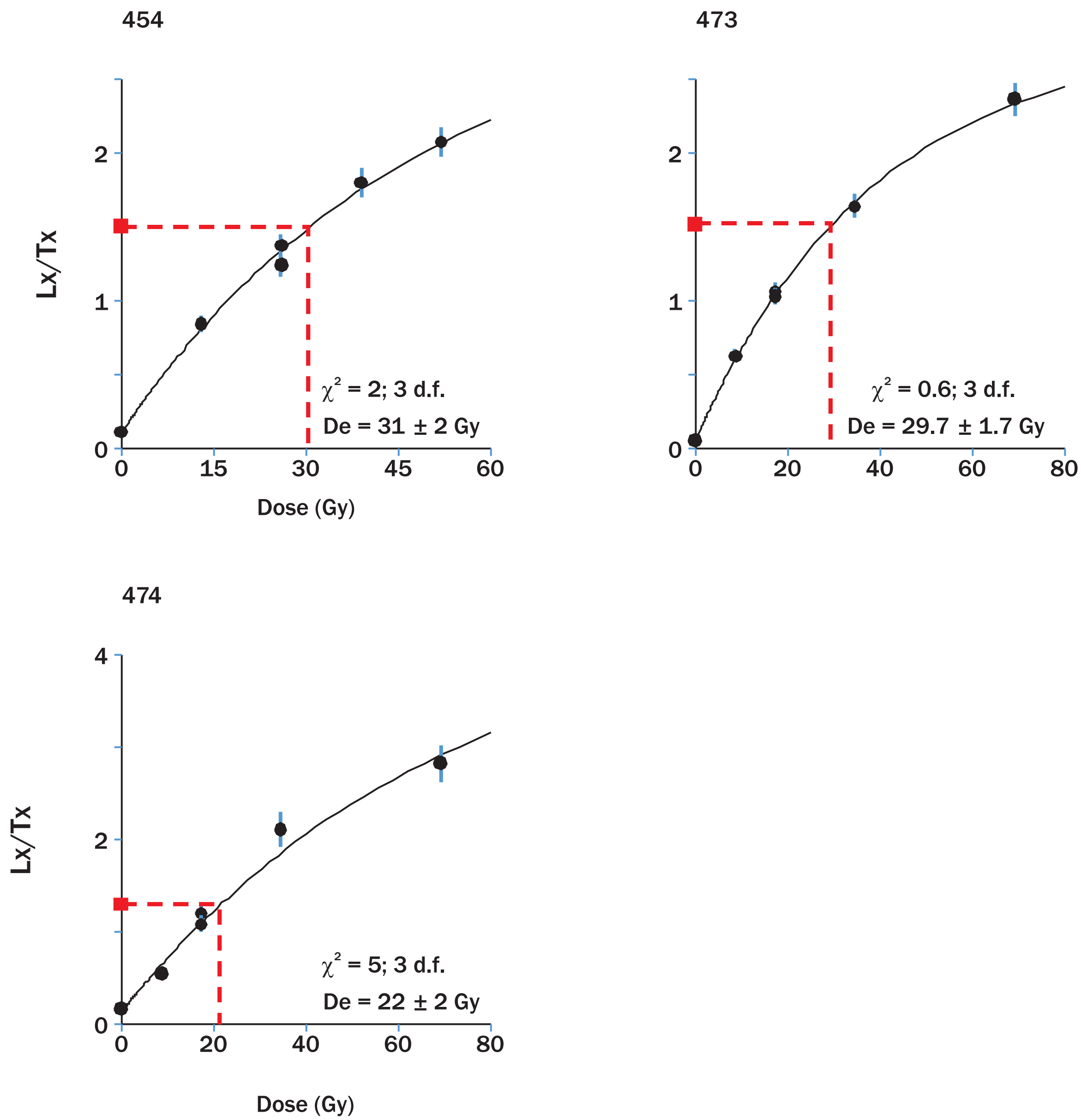


Figure 3. Luminescence dose response curve for the same aliquots shown in Figure 2. Each point corresponds to the OSL (Lx; measurement step 3 (quartz) or 4 (feldspar)) of a natural (red square) or laboratory-induced dose (black circles), normalized by the luminescence response to a fixed test dose (Ti; measurement step 6 (quartz) or 8 (feldspar)). The equivalent dose is obtained by interpolation. For the aliquots shown here, the observed measurements scatter well around the predicted model, but slightly less for sample 428, 430 and 451.

K-feldspar


424
Lx/Tx
χ2 = 0.9; 3 d.f.
De = 35.0 ± 0.9 Gy
Dose (Gy)
426
χ2 = 0.7; 2 d.f.
De = 9.3 ± 0.3 Gy
428
Lx/Tx
χ2 = 14; 4 d.f.
De = 129 ± 7 Gy
Dose (Gy)
430
χ2 = 4; 2 d.f.
De = 22.3 ± 1.0 Gy

Quartz



454
Lx/Tx
χ² = 2; 3 d.f.
De = 31 ± 2 Gy
Dose (Gy)
473
χ² = 0.6; 3 d.f.
De = 29.7 ± 1.7 Gy
474
Lx/Tx
χ² = 5; 3 d.f.
De = 22 ± 2 Gy
Dose (Gy)

2.2. Anomalous fading

The luminescence of feldspar is known to underestimate the 'true' burial age, typically by about 30 to 50 % (Aitken, 1998). The cause is known to us: anomalous fading (Wintle, 1973). Luminescence dating is akin to a filling a glass with water. At time zero, the glass is empty (i.e. the zeroing effect of sunlight). You pour water into it, at a constant rate (dose rate), but stop before reaching the top (sampling). The

volume of water contained in the glass represents the equivalent dose in luminescence (the total amount of radiation energy trapped by the mineral during burial). By dividing the volume (equivalent dose) by the rating of water filling (dose rate), we know when was the glass empty (length of burial).

Now, what if there is a very small hole in the glass. As you pour water into it, you lose water through that hole, at a steady rate. Now, the volume of water that remains in the glass underestimate the real amount of water that was poured in it. If you can measure the size of the hole, it is possible to calculate what would have been the real amount of water contained in the glass.

The luminescence of quartz (our workhorse) is akin to a perfect glass, whereas K-feldspar is that of a glass with a hole. At the time this phenomenon was first describe in feldspar, the mechanism underlying that lost, or fading, was unknown to us, hence, it was termed 'anomalous fading'. It was 'anomalous' because from thermodynamic principles, it is expected that a trapped electron would remain so for many millions of years (i.e. water can evaporate from your glass) at room temperature (i.e. just like water, the evaporation rate is temperature dependent). Yet, trapped elections in feldspar are leaking faster than they should and that rate of leakage is temperature independent. Hence, anomalous! There might come a day when we will fully understand what it is.

Nowadays, we know how to deal with it. We know how to measure the size of the hole (fading rate; Auclair et al., 2003) and we know how to correct for it (e.g. Huntley and Lamothe, 2001).

Anomalous fading measurements were performed on the same aliquot previously used for equivalent dose measurements. After the equivalent dose measurement cycles, the aliquots were taken outside the luminescence system, for sunlight bleaching (2 days), before passing over the anomalous fading sequence of measurements. It also employed the SAR protocol (table 1), with two adjustments. The laboratory-induced dose (step 1) was fixed, at 49 Gy, along with a test dose (step 6) of 12 Gy. Also, there was a 'pause' in effect, at Step 3, which ranged from 0.1 up to 240 hours (Figure 4; Auclair et al., 2003). Fading corrected ages relied on the model proposed by Huntley and Lamothe (2001).

2.3 Equivalent dose calculation

A weighted average (using the central age model; Galbraith et al., 1999) was used in all calculations, except when noted otherwise. The central age model provides an overdispersion parameter. This parameter characterizes the degree to which the observed weighted distribution is consistent with the predicted weighted distribution from the observed data. At 0%, the observed distribution is equal to the statistical prediction. In luminescence dating, it is common for the observed distribution to be slightly larger than the expected distribution by a value of approximately 20%. This means that our calculated uncertainties tend to underestimate the "real" uncertainties because of intrinsic (e.g., instrumental

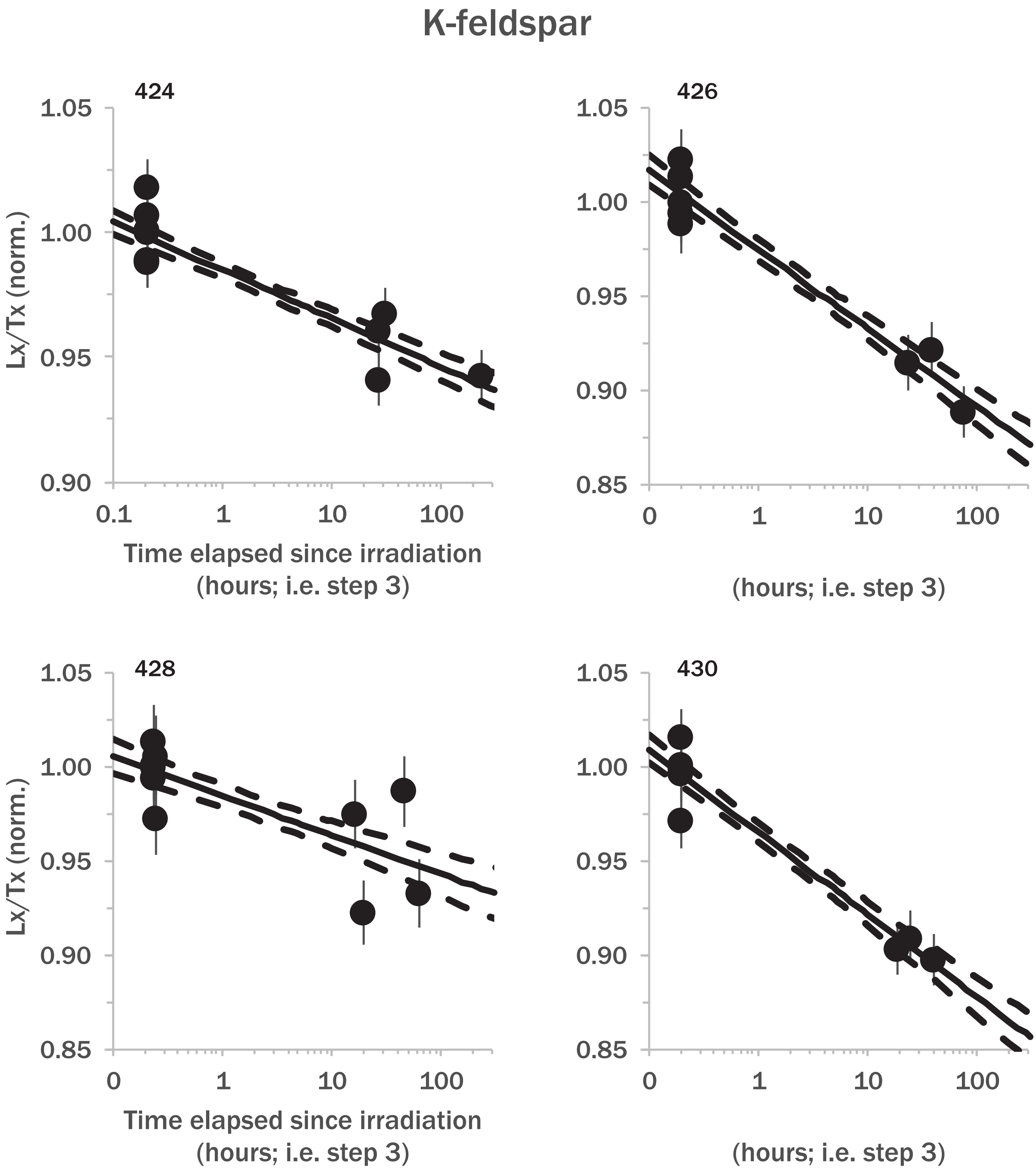


Figure 4. Anomalous fading measurement, for a representative aliquot of each sample. Repeated measurement cycles (Table 1) are made, on the same aliquot, with different delays between the irradiation and the OSL measurement (i.e. step 3). The slope is proportional to the fading rate, used in the fading correction model. The 2 dashed lines represent the 1σ error envelops. Note the logarithmic time axis.

uncertainties, anomalous fading) or extrinsic (e.g., partial bleaching, external microdosimetry, dose rate) factors. The central age model expands the age uncertainty in an attempt to take this discrepancy into account. Here, the overdispersions are above average (Table 3), except for sample WV-D1-S1. It indicates a large scatter in the calculated age distribution.

Table 3. Age overdispersion parameters[1]

ISGS code	Sample	Overdispersion (%)
424	WV T1 S2	98 ± 14
426	WV T3 S1	95 ± 12
428	WV T1 S1	64 ± 16
429	WV Heinz	77 ± 11
430	WV T7 S1	114 ± 13
451	WV-BC-OSL-S1	92 ± 11
452	WV-BC-OSL-S3a	88 ± 9
453	WV-D1-S1	20 ± 4
454	WV-MD-Pit2a	29 ± 5
473	UHT 8	30 ± 3
474	MT-36-OSL1	43 ± 6

[1]A value of 20% is typical in luminescence.

Nearly all samples display a significant broadness in age distribution (Figure 5). Given that these sediments originated from a fluvial deposit, of Holocene age, it is not surprising that a portion of the quartz grains were insufficiently exposed to sunlight (a few seconds up to a few minutes of direct sunlight is required) during their last sediment cycle (erosion, transport, sedimentation). To document the shape of the age distribution more clearly, we must reduce the number of quartz grains dispensed on each aliquot. Otherwise, in the presence of a multitude of quartz grains on one aliquot (some being well bleached and others not), each emitting a luminescence light signal, all these will sum to give an age overestimation (Arnold and Roberts, 2009). The only recourse here is to severely reduce the number of grains dispensed on the aliquot (Olley et al., 1999). At the extreme limit, we would measure the luminescence from a single grain.

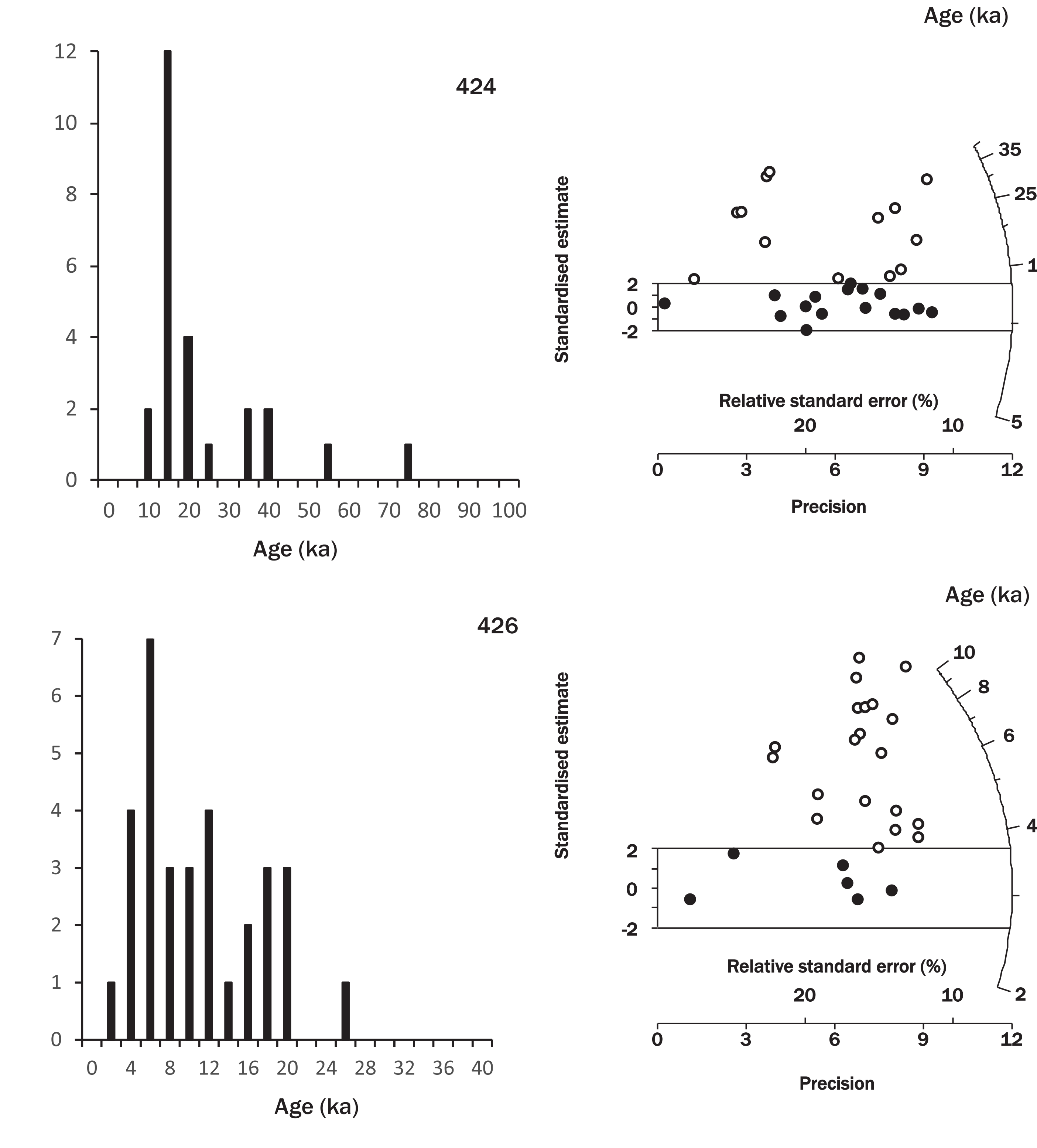
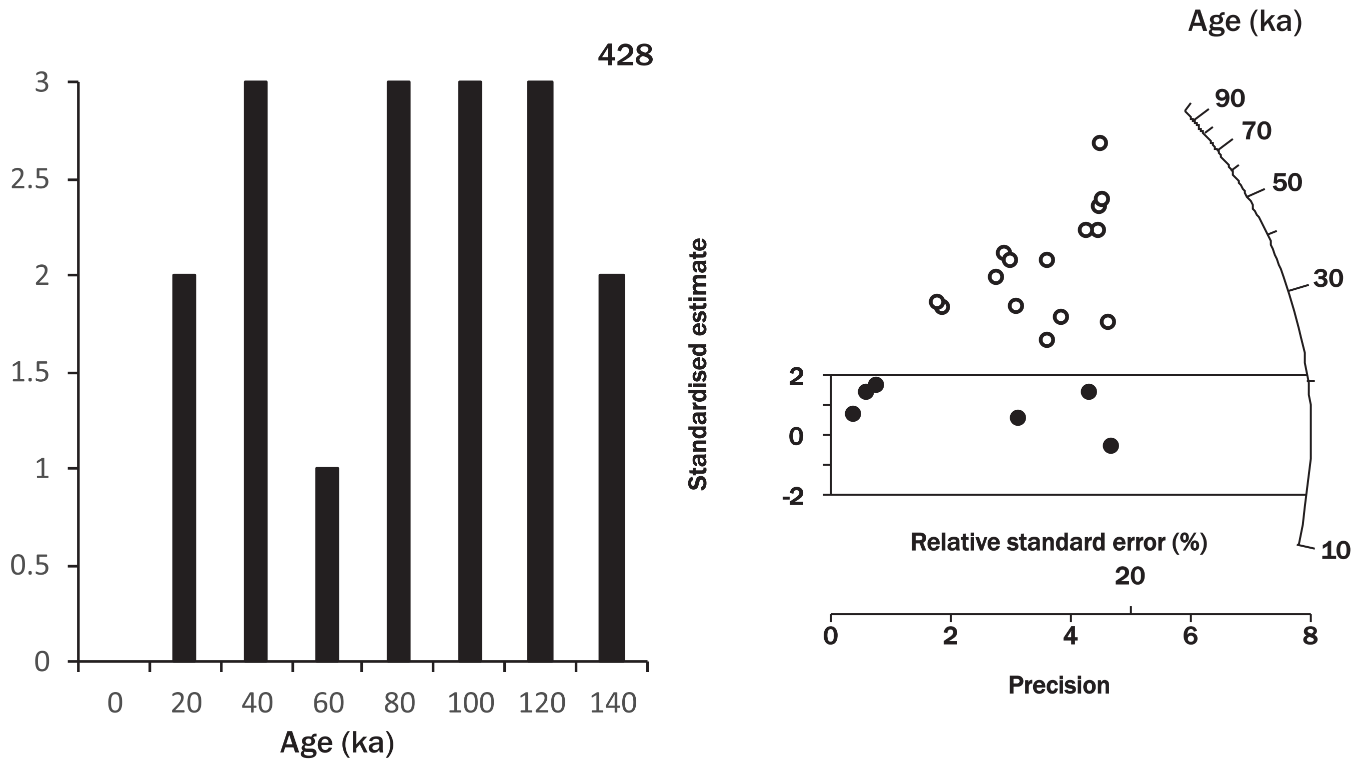
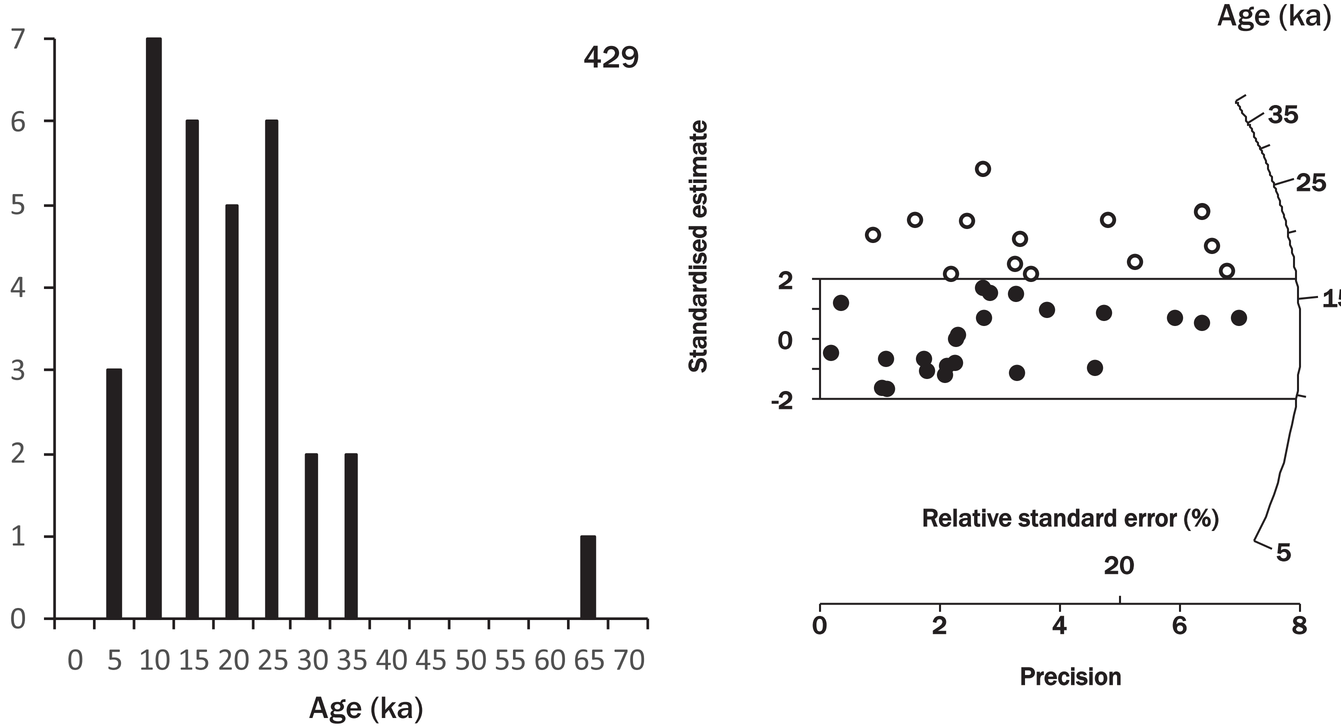
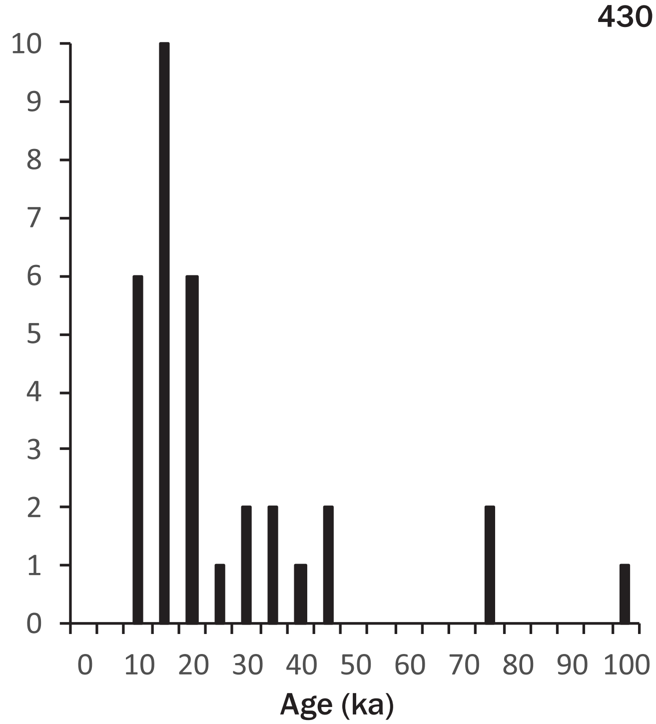
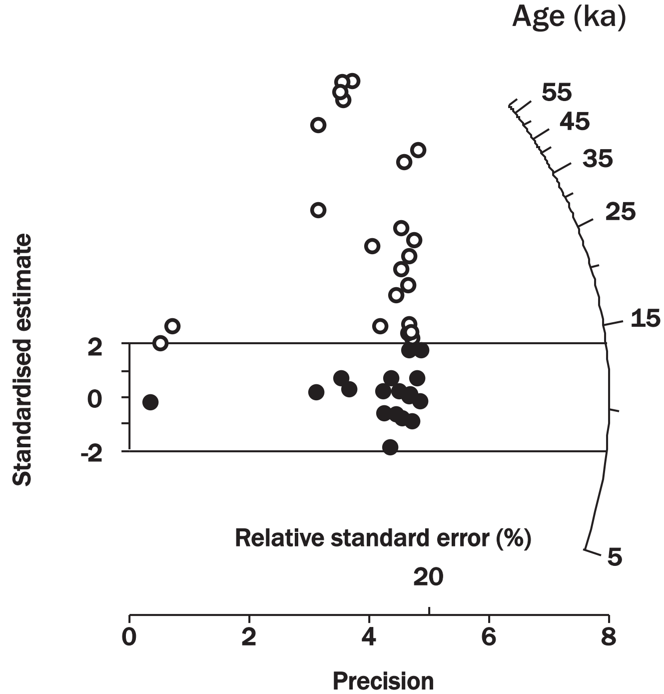


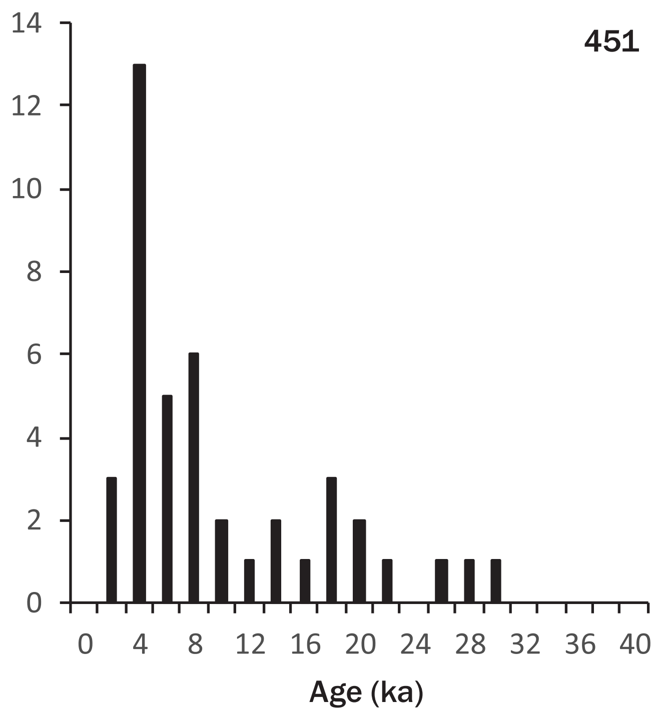
Figure 5. Age distributions, as an histogram and a radial plot, for all samples. Each circle on the radial plot represents the age and uncertainty, for a single aliquot. The age is read on the arc axis, by drawing a straight line from 0,0, passing through a circle and intersecting the arc-axis. The 0,0 coordinate corresponds to the 0 standardised estimate (y-axis) and 0 precision (x-axis). The uncertainty is read on the horizontal axis, by drawing a perpendicular line reaching the red symbol. Hence, two aliquots, having the same age, but with different uncertainty, will line on the same straight line (0,0 to the arc-axis). The aliquot with the small uncertainty will be closer to the arc. The two horizontal lines, at 2 and -2 standardised estimate, represent the 2σ standard deviations, for an horizontal age line. A cluster of aliquots within these two lines express confidence that we have a population of aliquots consistent with a single age (filled circles). For each plot, that horizontal line at 0 standardised estimate (not shown) corresponds to the weighted age.

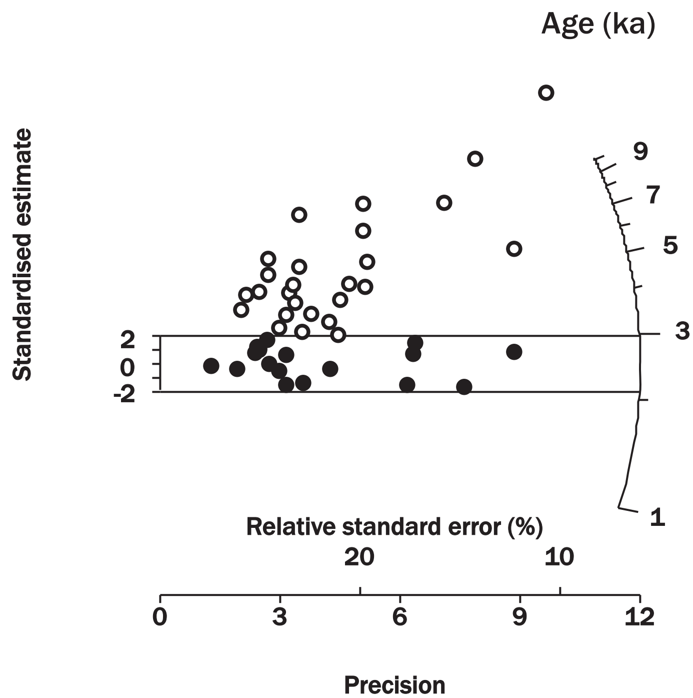

428
Age (ka)
0 20 40 60 80 100 120 140
0 0.5 1 1.5 2 2.5 3
Age (ka)
90 70 50 30 10
Standardised estimate
2 0 -2
Relative standard error (%)
20
0 2 4 6 8
Precision

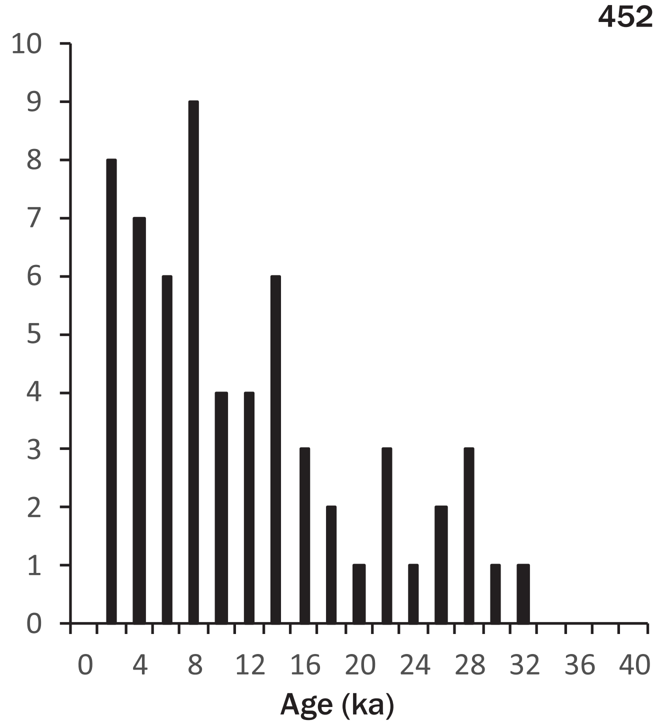

429
Age (ka)
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70
0 1 2 3 4 5 6 7
Age (ka)
35 25 15 5
Standardised estimate
2 0 -2
Relative standard error (%)
20
0 2 4 6 8
Precision

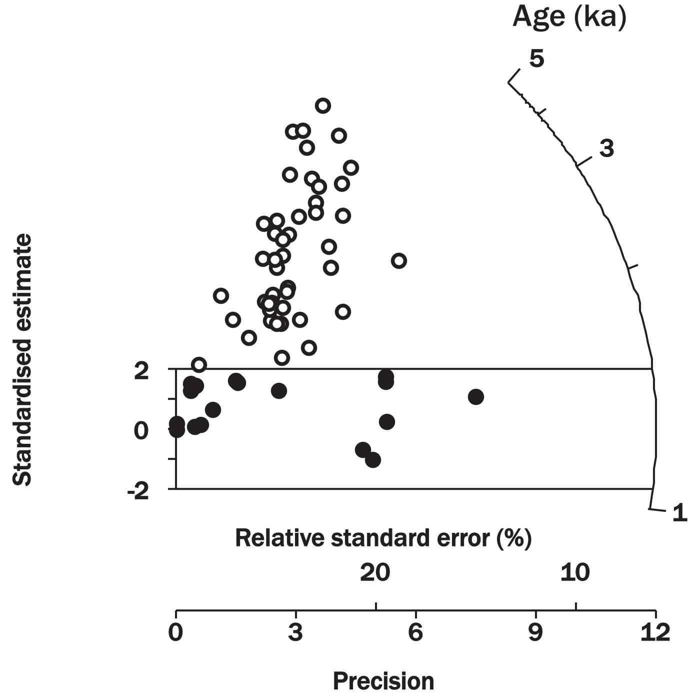

430
0
1
2
3
4
5
6
7
8
9
10
0 10 20 30 40 50 60 70 80 90 100
Age (ka)

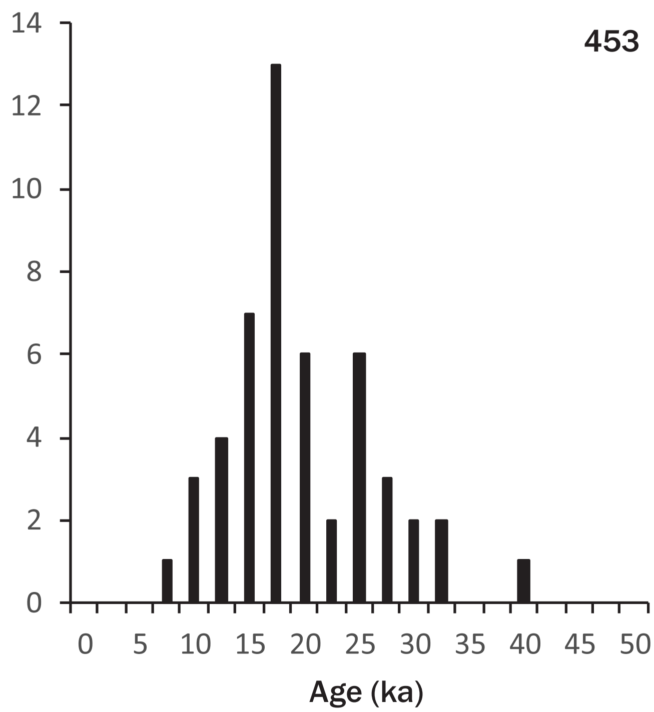

Age (ka)
55
45
35
25
15
5
Standardised estimate
2
0
-2
Relative standard error (%)
20
0 2 4 6 8
Precision

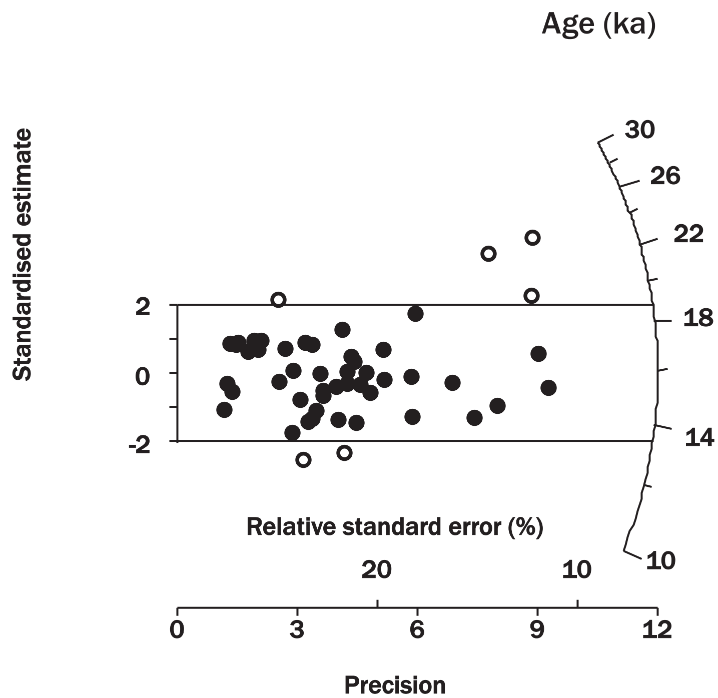

451
0
2
4
6
8
10
12
14
0 4 8 12 16 20 24 28 32 36 40
Age (ka)

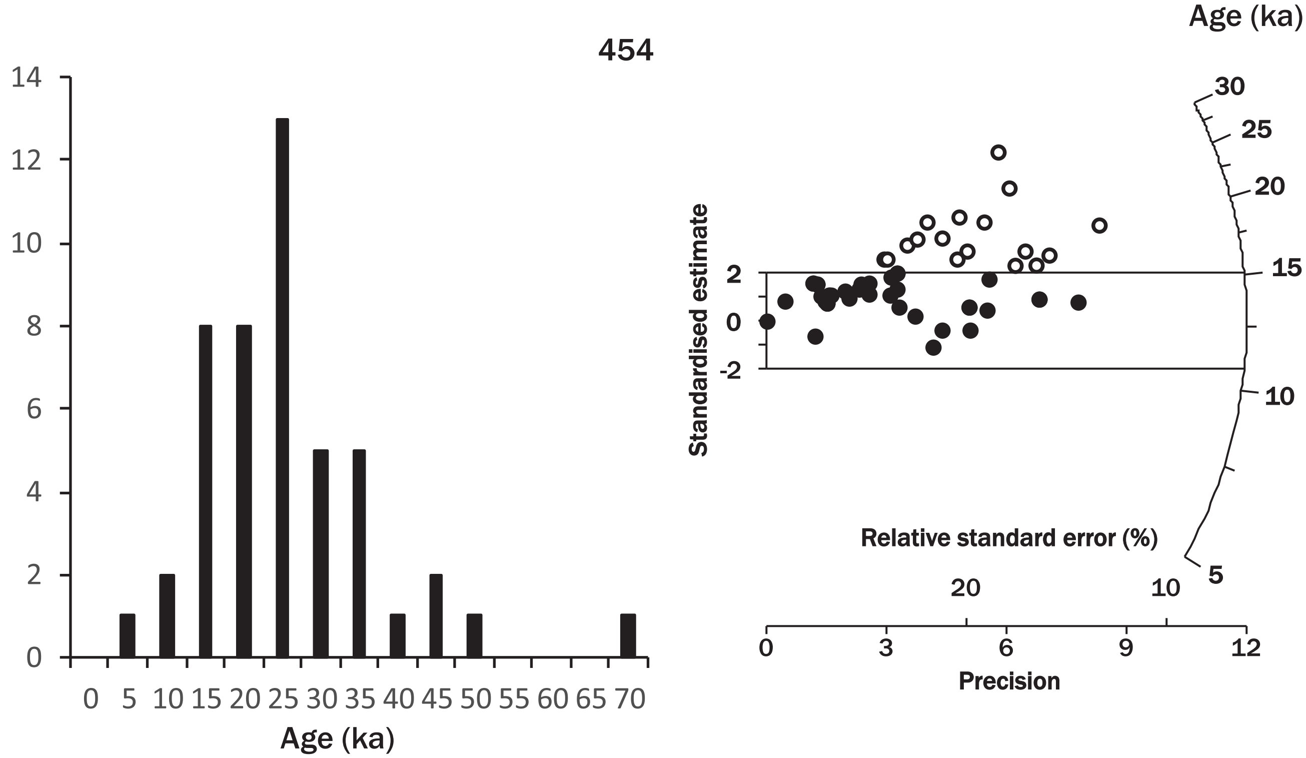

Age (ka)
9
7
5
3
1
Standardised estimate
2
0
-2
Relative standard error (%)
20
10
0 3 6 9 12
Precision


452
10
9
8
7
6
5
4
3
2
1
0
0 4 8 12 16 20 24 28 32 36 40
Age (ka)

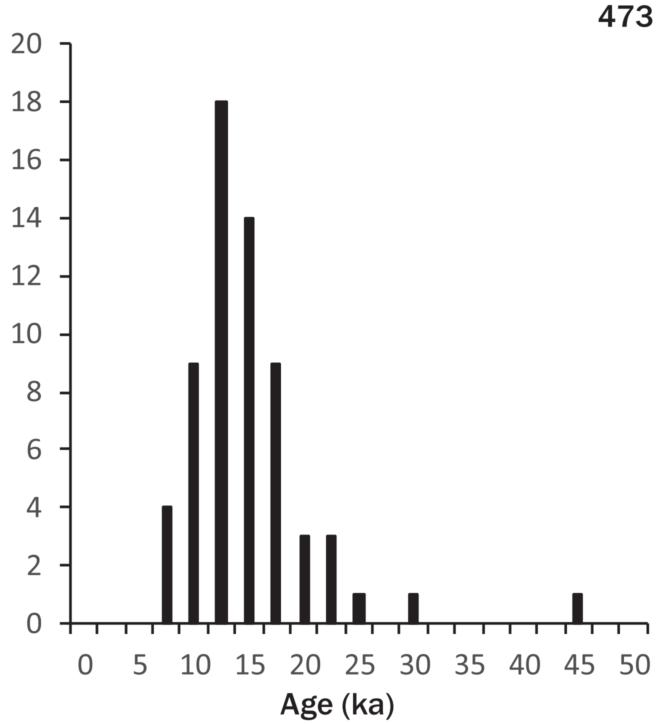

Age (ka)
5
3
1
Standardised estimate
2
0
-2
Relative standard error (%)
20
10
0 3 6 9 12
Precision

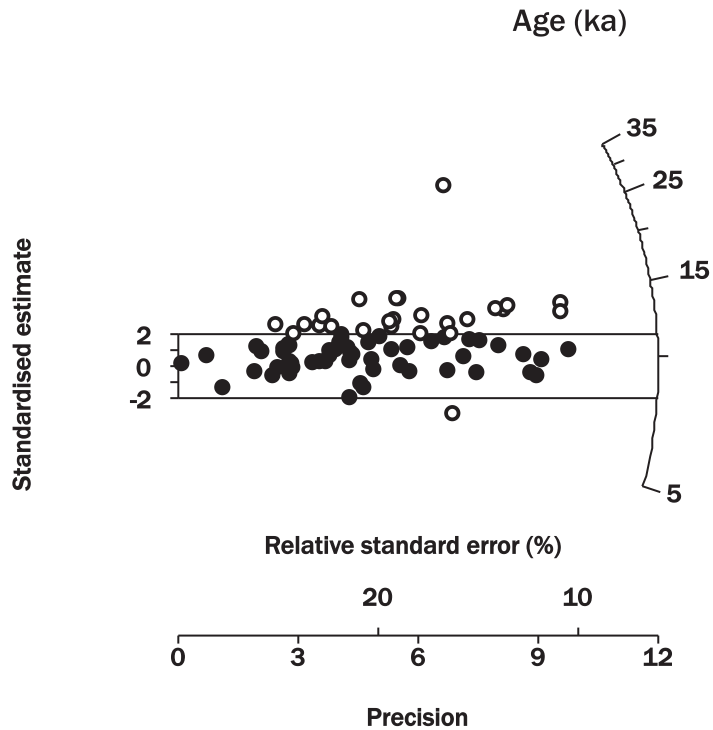

453
14
12
10
8
6
4
2
0
0 5 10 15 20 25 30 35 40 45 50
Age (ka)

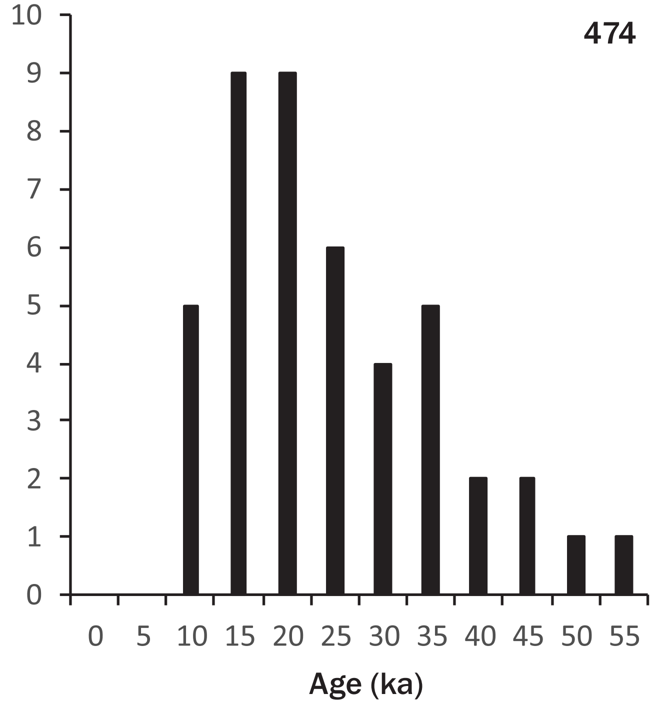

Age (ka)
30
26
22
18
14
10
Standardised estimate
2
0
-2
Relative standard error (%)
20
10
0 3 6 9 12
Precision

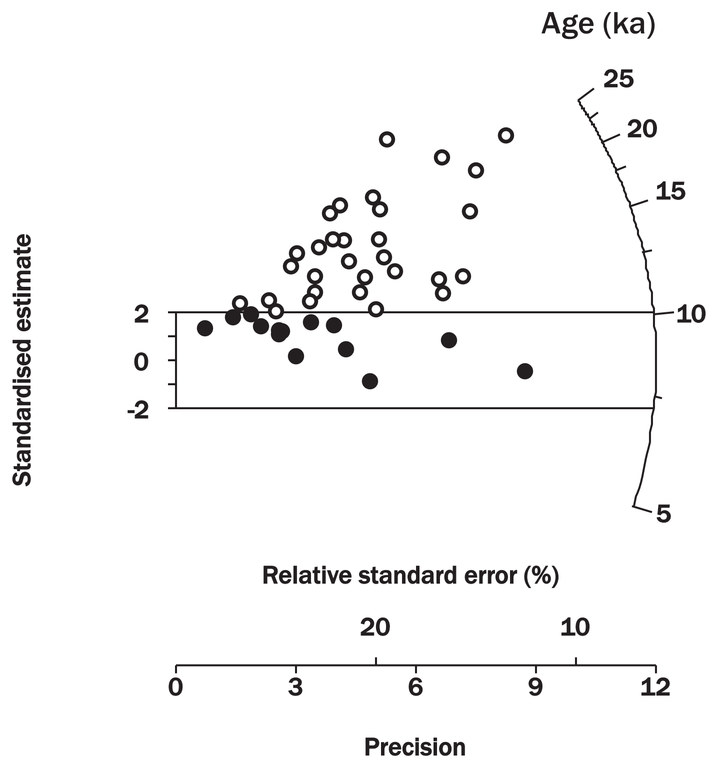


454
14
12
10
8
6
4
2
0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70
Age (ka)
Age (ka)
30
25
20
15
10
5
Standardised estimate
2
0
-2
Relative standard error (%)
20
10
0
3
6
9
12
Precision


473
20
18
16
14
12
10
8
6
4
2
0
0 5 10 15 20 25 30 35 40 45 50
Age (ka)


Age (ka)
35
25
15
5
Standardised estimate
2
0
-2
Relative standard error (%)
20
10
0 3 6 9 12
Precision


474
10
9
8
7
6
5
4
3
2
1
0
0 5 10 15 20 25 30 35 40 45 50 55
Age (ka)


Age (ka)
25
20
15
10
5
Standardised estimate
2
0
-2
Relative standard error (%)
20
10
0 3 6 9 12
Precision

The best tool for single-grain measurement is the Risø single-grain laser attachment. Unfortunately, the ISGS luminescence dating laboratory does not possess this attachment (in fact, very few OSL laboratories have such a device). As an alternative, we have relied on the “poor man’s approach,” which consists of dispensing a very small number of grains on each aliquot and hoping for the best! How it works is quite simple: most quartz grains are insensitive to radiation, or they yield extremely low luminescence light intensities, or both (Preusser et al., 2009). In a typical sediment, we can expect that, on average, only 5% of the quartz grains will yield decent luminescence characteristics (sufficient luminescence light intensity, successful recycling and recuperation tests; Duller, 2008). With this in mind, if we dispensed 20 quartz grains on an aliquot, we would detect a luminescence signal from only 1 grain, on average.

To increase our confidence that, whenever we saw a measurable luminescence signal, it came from only one grain, we ensured that a significant number of aliquots provided no (or a very low) measurable luminescence light signal. For all samples, more than 60% of the measured aliquots yielded no (or a very low) luminescence light signal (Table 2; no signal). Hence, that condition was fulfilled.

Usually, the best age estimate should rely on the average value. We can think of instances when this might be inappropriate. A positive skewness, such as is noted here for most samples (Figure 5), is a clear sign of partial bleaching. In other words, during the last sedimentary cycle (erosion, transport, deposition, and burial), not all sedimentary grains were sufficiently exposed to sunlight to completely reset the “dosimetric clock” that they had accumulated in their previous burial setting. Although the mean is the scientist’s best friend, it might prove to be an inappropriate estimator in some situations. Here, we opted to rely on the minimum age model (Galbraith et al., 1999). We chose to add an additional uncertainty (σb; 10% for quartz, 20% K-feldspar), in quadrature, to each individual aliquot before inserting the aliquots into the minimum age model. The modelled burial age fell between 1 and 15 ka (Figure 6; Table 4). The age for WV T1 S1 reported here should be considered tentative. It was hard to resolve with the minimum age model. Further measurements would be required and could be accomplished, if the sample is of importance.

Table 4. Burial age comparison between the weighted mean (central age model) and minimum age model (MAM). [1]Tentative age.

ISGS code	Sample	Age (ka) Average	MAM Age (ka)
424	WV T1 S2	16 ± 3	11.2 ± 0.8
426	WV T3 S1	6.6 ± 1.2	3.1 ± 0.3
428	WV T1 S1	22 ± 4	15.6 ± 1.6[1]
429	WV Heinz	18 ± 3	12.7 ± 1.1
430	WV T7 S1	15 ± 3	10.6 ± 1.0
451	WV-BC-OSL-S1	7.0 ± 1.0	2.3 ± 0.2
452	WV-BC-OSL-S3a	7.9 ± 1.0	1.23 ± 0.12
453	WV-D1-S1	17.3 ± 1.0	–
454	WV-MD-Pit2a	20.5 ± 1.5	12.8 ± 1.2
473	UHT 8	12.6 ± 0.7	9.5 ± 0.5
474	MT-36-OSL1	19.3 ± 1.7	8.5 ± 0.9

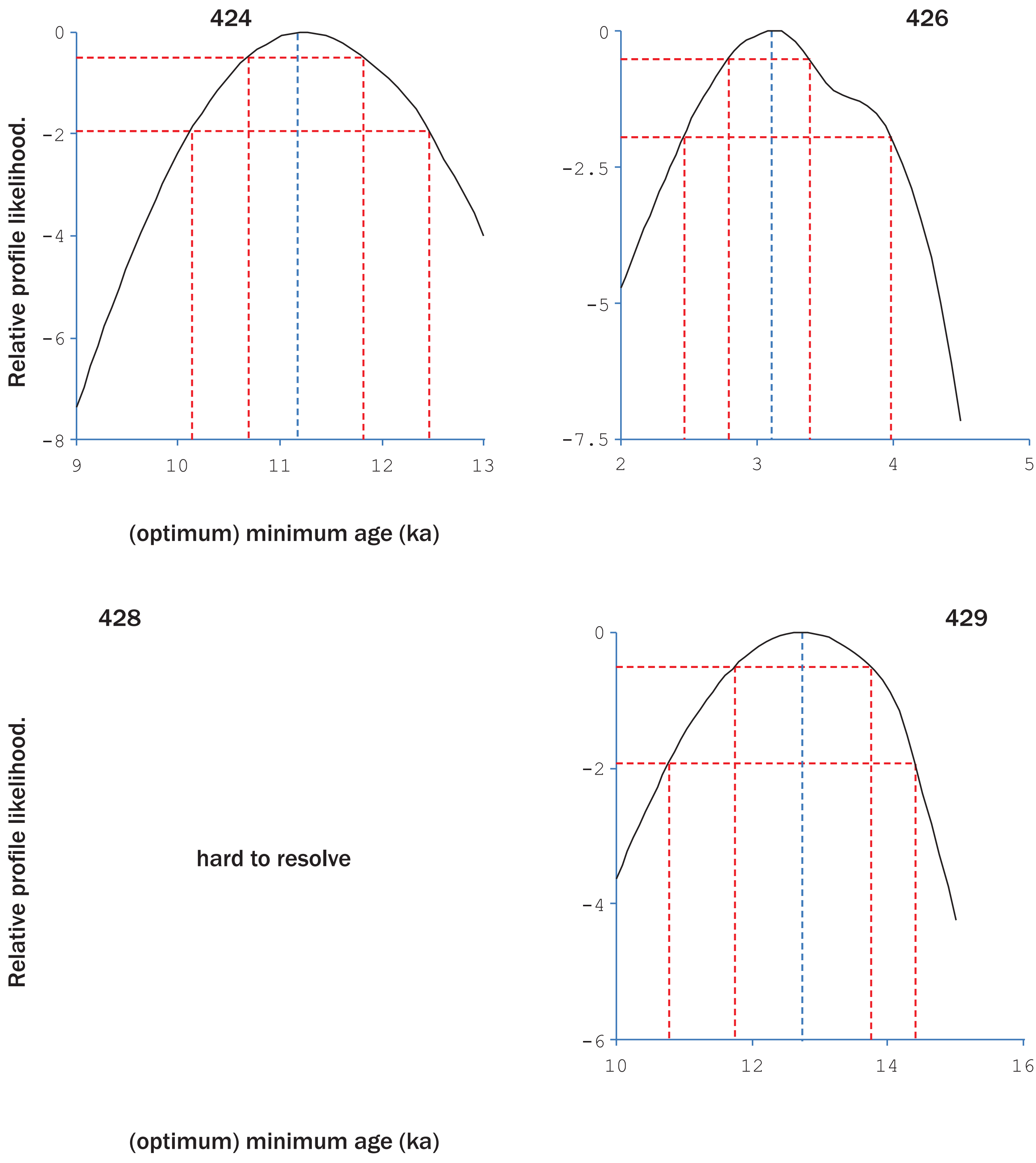
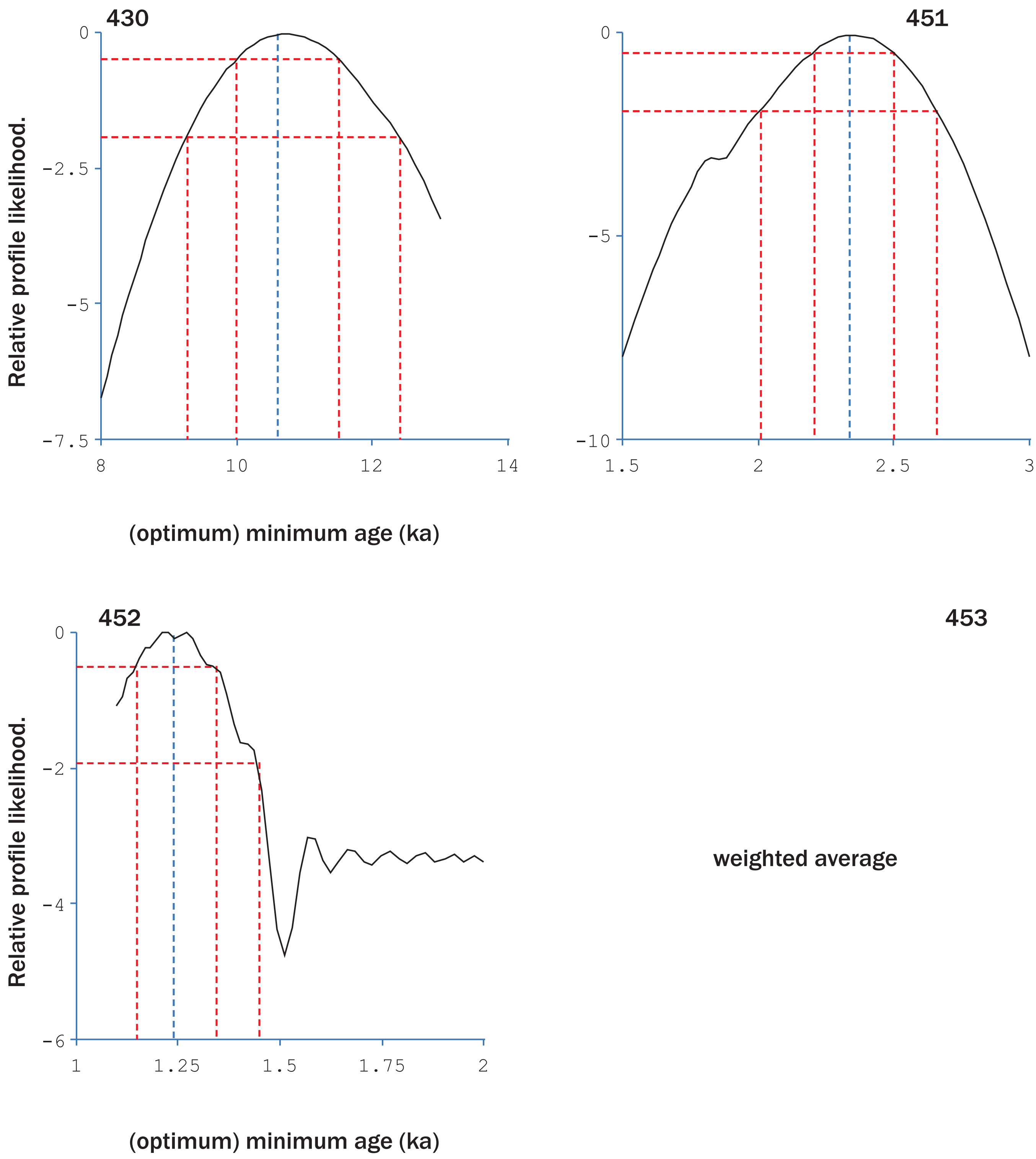
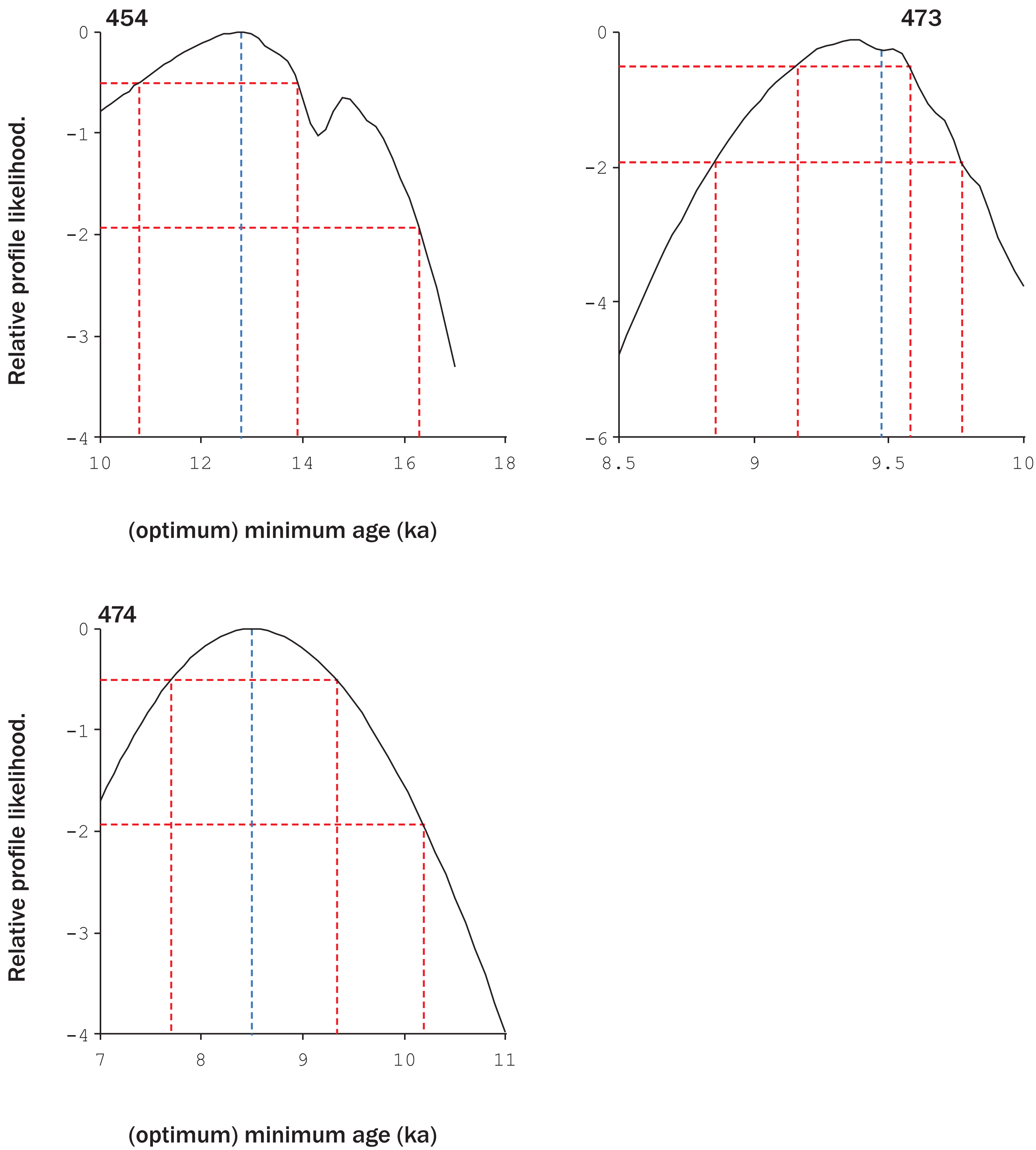


Figure 6. Relative profile likelihood. The minimum age is found at the maximum value of the profile (dotted blue line). The 1σ and 2σ age uncertainties are shown by the red dotted lines intersecting the profile.



430
0
-2.5
-5
-7.5
8
10
12
14
451
0
-5
-10
1.5
2
2.5
3
Relative profile likelihood.
(optimum) minimum age (ka)
452
0
-2
-4
-6
1
1.25
1.5
1.75
2
Relative profile likelihood.
(optimum) minimum age (ka)
453
weighted average


454
473
474
Relative profile likelihood.
Relative profile likelihood.
(optimum) minimum age (ka)
(optimum) minimum age (ka)
0
−1
−2
−3
−4
10
12
14
16
18
0
−2
−4
−6
8.5
9
9.5
10
0
−1
−2
−3
−4
7
8
9
10
11

3. Dose rate

The water content was measured for each sample. The as-received water content was relatively humid to very humid (Table 5). On discussing the issue with Dr. Wilson and Young we opted for the values presented in the table. We assigned a water content uncertainty of 5 % to account for possible variation during the entire length of burial.

Table 5. Water content, measured from the sample, along with the value presumed to have prevailed during the burial

sample	in situ (%)	presumed (%)
424	14	15 ± 5
426	19	20 ± 5
428	21	25 ± 5
429	21	20 ± 5
430	15	15 ± 5
451	10	20 ± 5
452	21	20 ± 5
453	11	20 ± 5
454	17	20 ± 5
473	12	20 ± 5
474	12	20 ± 5

Waiting times of 21 to 41 days were observed before measuring the radioactive activities of uranium, thorium, and potassium, from which we can derive contributions from alpha, beta, and gamma energy decay (Table 6). Some sample contained a large amount of large clasts. For dose rate calculations we had to separate the larger than 2 mm grain size fraction and measure its uranium, thorium and potassium content, distinct from the lower than 2 mm fraction. The content from smaller grains were used to evaluate the alpha, beta and gamma dose rate, whereas the larger grains were only used to evaluation their contribution to the gamma dose rate (Aitken, 1998; Urbanova et al., 2015). The relative gamma dose rate contribution, from the smaller and larger grain size, was weighted by their respective fractional mass (Figure 7). This was carried out for the sediments contained inside the OSL tube. For some sites, with heterogeneous sedimentary layer (within a 30 cm radius), additional material was supplied to evaluate their gamma ray contribution. For these, the uranium, thorium and potassium were measured from the bulk sample. As needed, samples were pulverized (primarily the larger than 2 mm fraction), in order to properly extract a representative sample for gamma spectrometry measurement. The content of sample ISGS 473 (UHT 8), along with the organic bed associated to sample ISGS 452 (WV-BC-OSL-S3a) were ashed (500°C for 24 hours) before sealing them in a petri dish as they contained visible organic matter (4 and 31 % of dry weight, respectively).

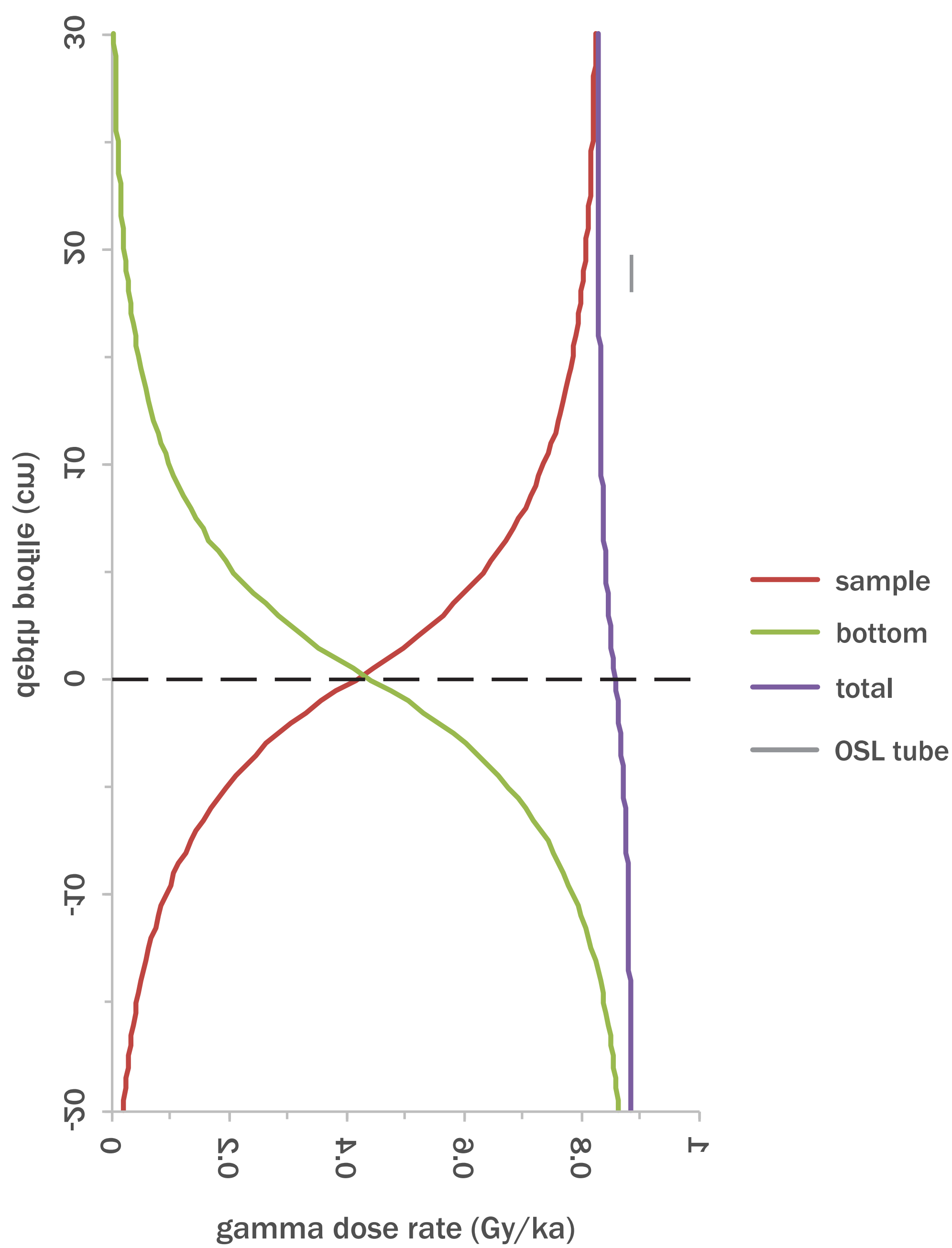


Figure 7. Calculated gamma ray contribution to the environmental dose rate against the depth profile. The gamma dose rate was calculated for each sub sample (ISGS 426). The length of the OSL tube is shown for reference. We assumed that each tube were retrieved from the middle of the sedimentary layer.

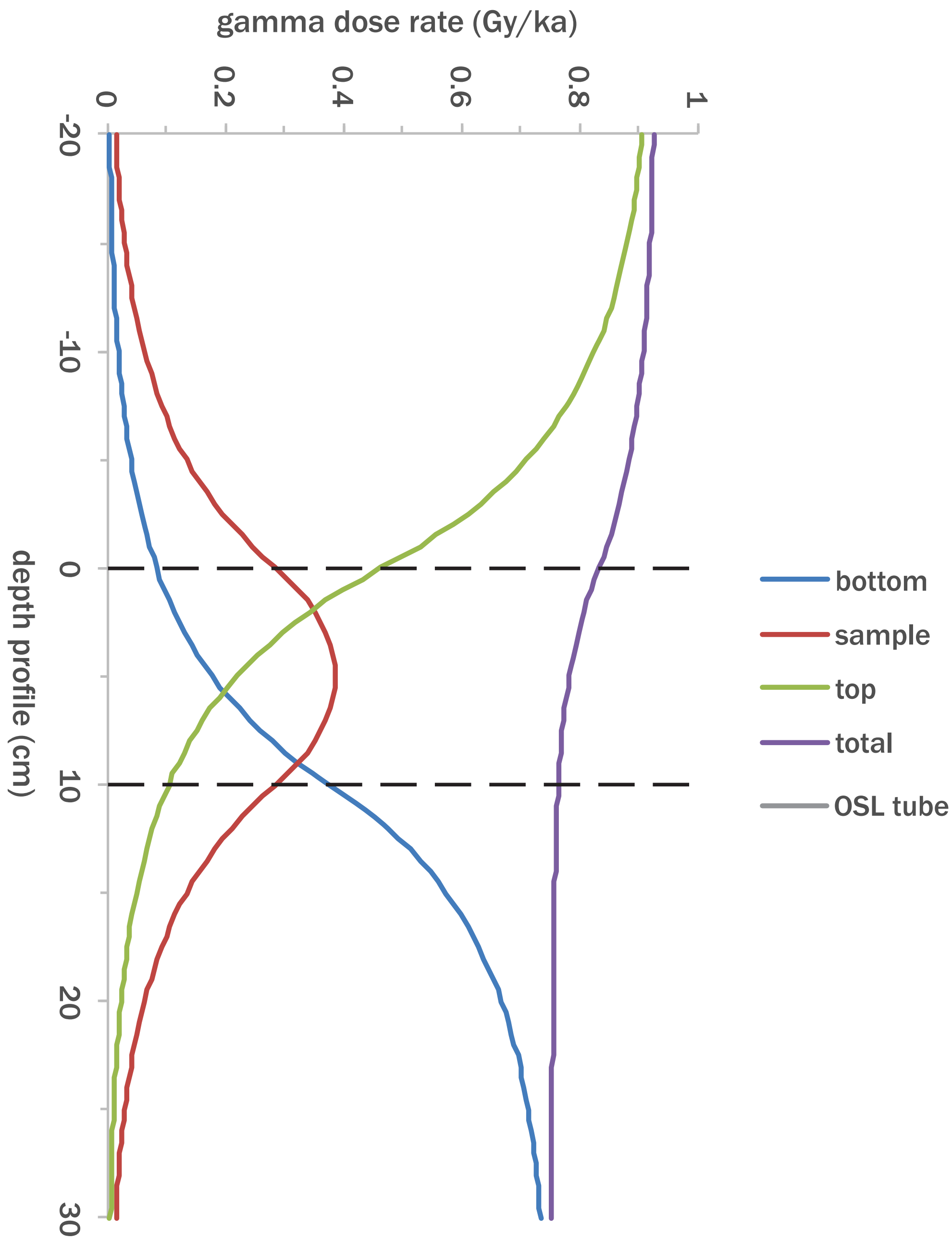


Figure 7. Calculated gamma ray contribution to the environmental dose rate against the depth profile. The gamma dose rate was calculated for each sub sample (ISGS 429). The length of the OSL tube is shown for reference. We assumed that each tube were retrieved from the middle of the sedimentary layer.

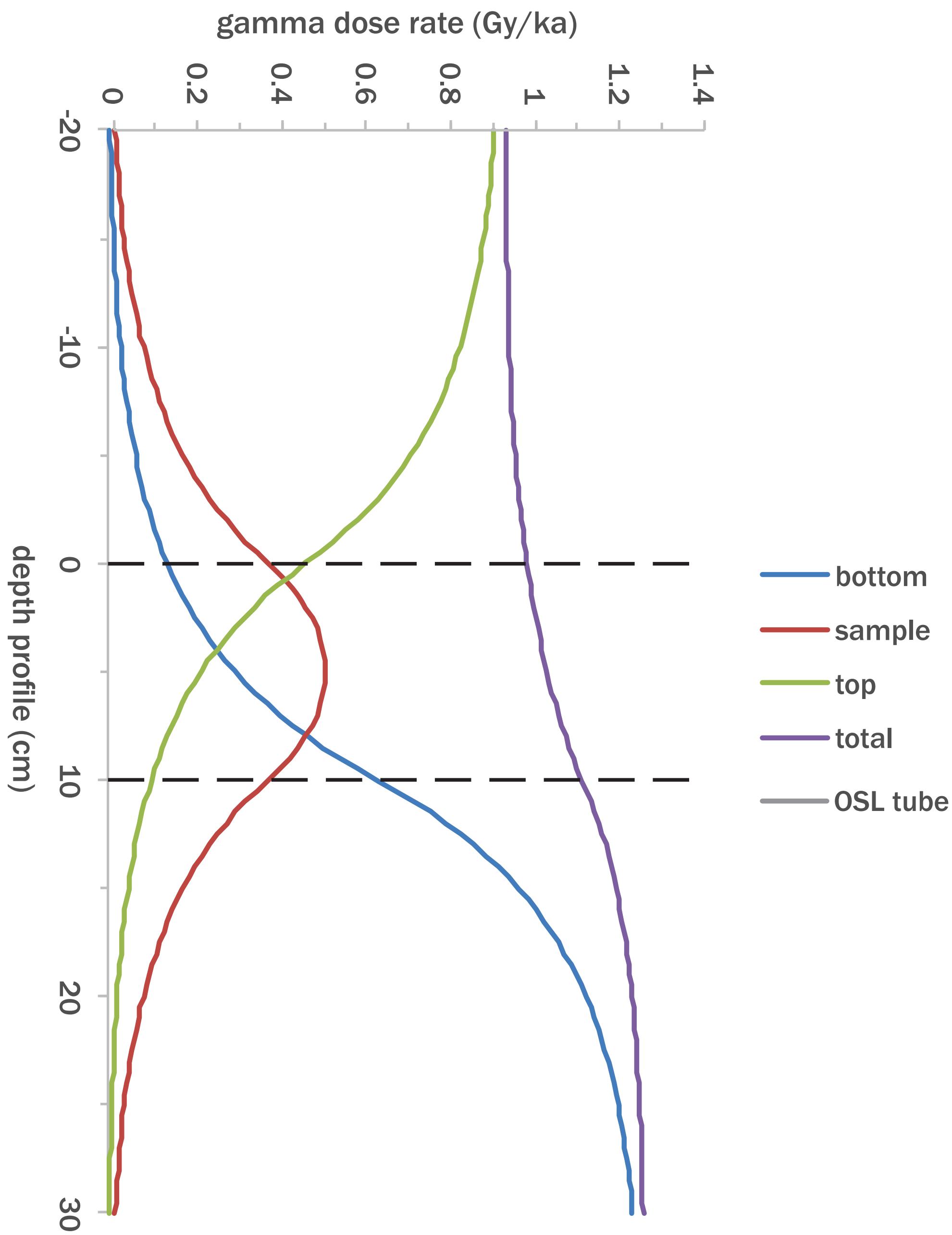
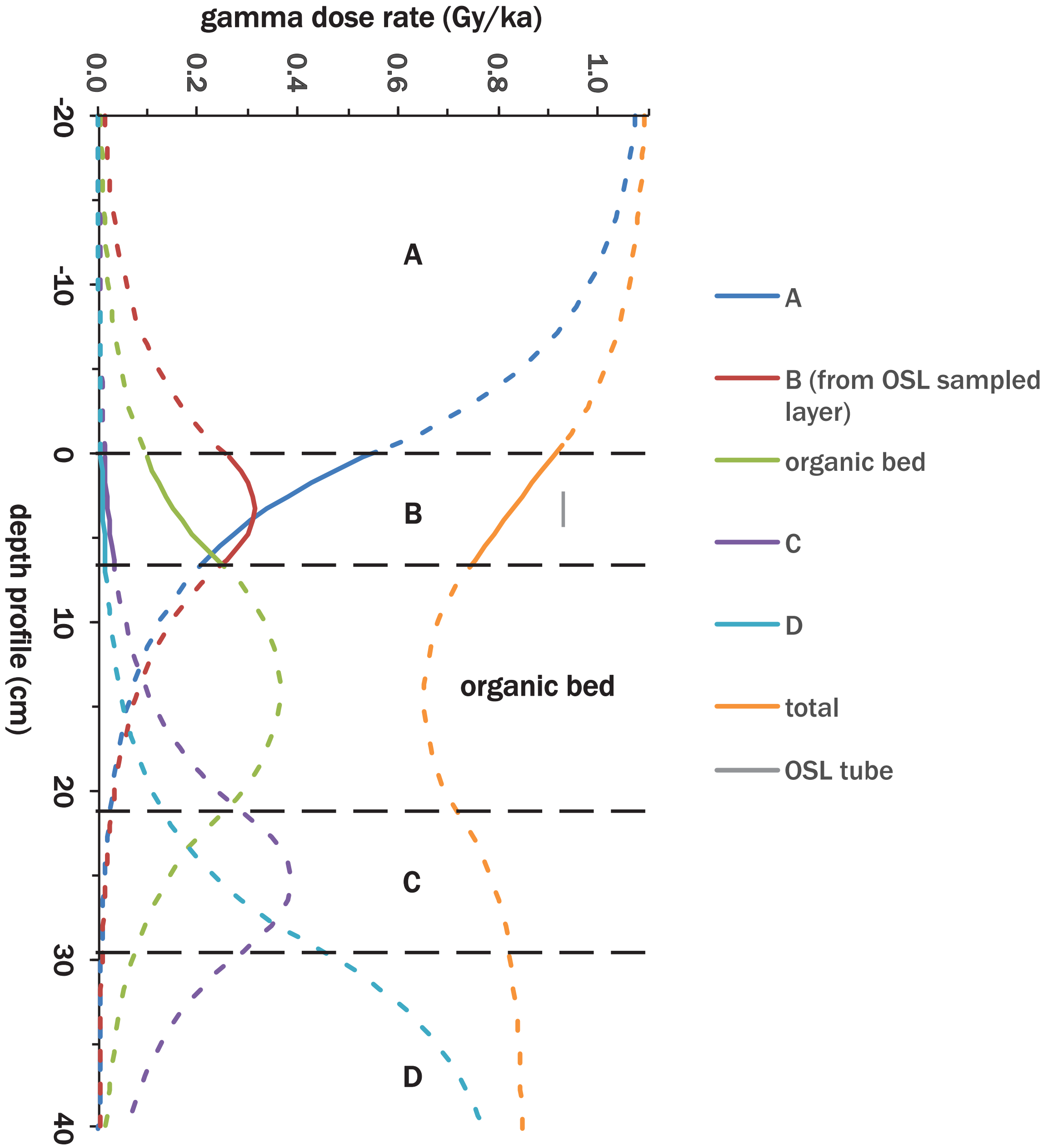


Figure 7. Calculated gamma ray contribution to the environmental dose rate against the depth profile. The gamma dose rate was calculated for each sub sample (ISGS 451). The length of the OSL tube is shown for reference. We assumed that each tube were retrieved from the middle of the sedimentary layer.

ISGS 452



gamma dose rate (Gy/ka)
0.0
0.2
0.4
0.6
0.8
1.0
depth profile (cm)
-20
-10
0
10
20
30
40
A
B
organic bed
C
D
A
B (from OSL sampled layer)
organic bed
C
D
total
OSL tube

Table 6. Specific activity (Bq/kg)

ISGS code	Sample	238U	226Ra	210Pb	232Th	40K
424		41.7 ± 2.5	49.2 ± 0.5	42.2 ± 3	49.3 ± 0.9	618 ± 11
424	> 2 mm	29.5 ± 2.3	25.1 ± 0.5	27 ± 3	30.7 ± 0.5	357 ± 10
426		28.5 ± 2.0	29.9 ± 0.4	33 ± 3	31.7 ± 0.4	472 ± 10
426	below 10'	25.1 ± 2.4	34.9 ± 0.6	29.0 ± 3.4	30.2 ± 0.5	529 ± 13
428		36.3 ± 2.4	40.1 ± 0.5	50 ± 4	45.0 ± 0.5	869 ± 12
429		25.0 ± 1.7	23.3 ± 0.6	30 ± 3	28.9 ± 0.4	438 ± 9
429	top	26.3 ± 1.9	23.9 ± 0.6	30 ± 3	29.7 ± 0.4	451 ± 9
429	bottom	25.8 ± 1.9	32.9 ± 0.4	40 ± 3	36.1 ± 0.4	398 ± 8
430		48.9 ± 3.0	32.4 ± 0.5	40 ± 3	42.6 ± 0.6	662 ± 11
430	> 2 mm	38.2 ± 2.9	30.1 ± 1.6	30 ± 4	31.7 ± 0.6	522 ± 14
451		35.9 ± 2.2	36.1 ± 0.5	35 ± 3	35.6 ± 0.4	584 ± 10
451	A	39.1 ± 2.7	41.2 ± 0.6	41 ± 4	37.6 ± 0.5	678 ± 13
451	B	32.0 ± 2.2	36.4 ± 0.5	37 ± 3	32.7 ± 0.4	560 ± 10
452		25.5 ± 1.8	25.1 ± 0.4	30 ± 3	29.4 ± 0.6	537 ± 9
452	A	42.7 ± 2.3	33.7 ± 0.4	44 ± 3	40.6 ± 0.4	702 ± 10
452	B	26.5 ± 1.7	28.8 ± 0.3	29 ± 2	27.5 ± 0.3	546 ± 8
452	C	22.9 ± 1.6	27.4 ± 0.4	30 ± 3	27.7 ± 0.5	494 ± 8
452	organic bed	30.7 ± 2.0	34.0 ± 0.4	33 ± 3	31.7 ± 1.1	544 ± 9
452	D, less than 2 mm	24.0 ± 2.5	33.6 ± 0.7	37 ± 4	31.6 ± 0.6	457 ± 14
452	D, more than 2 mm	23.6 ± 2.2	29.2 ± 0.6	30 ± 3	32.9 ± 0.5	330 ± 11
453	less than 2 mm	26.0 ± 1.8	33.1 ± 0.5	33 ± 3	28.9 ± 0.4	449 ± 8
453	more than 2 mm	23.4 ± 1.5	22.5 ± 0.3	23 ± 2	24.1 ± 0.3	400 ± 7
454		23.3 ± 1.8	23.9 ± 0.4	26 ± 3	24.2 ± 0.4	498 ± 10
473		32.9 ± 2.4	40.2 ± 0.5	35 ± 3	38.7 ± 0.8	589 ± 11
474		27.4 ± 1.8	25.1 ± 0.4	31 ± 3	22.0 ± 0.3	532 ± 10

For quartz, we assumed an internal content of 0.08 ± 0.02 ppm and 0.18 ± 0.03 ppm, for uranium and thorium, respectively (Vandenberghe et al., 2008). A conservative 0.04 ± 0.02 “a value” (efficiency of alpha particles compared with beta particles upon inducing a trapped charge in quartz and feldspar; i.e., alpha is only 4% as effective as beta) was retained. The external alpha dose rate contribution was assumed to be negligible here because we etched the quartz grains (Table 7).

For K-feldspar, we assumed an internal content of 12.5 ± 0.5 % and 400 ± 100 ppm, for potassium and rubidium, respectively (Huntley and Baril, 1997; Huntley and Hancock, 2001). A conservative 0.10 ± 0.05 “a value” was retained.

Table 7. Contribution to the dose rate, expressed in Gy/ka[1]

sample	Mineral	Alpha External	Beta External	Beta Internal	Gamma	Cosmic ray	depth (m)	Water Content (%)	Total
424	K-Feldspar	0.127 ± 0.019	1.83 ± 0.12	0.81 ± 0.04	0.91 ± 0.03	0.21 ± 0.01	0.9	15 ± 5	3.88 ± 0.13
426	K-Feldspar	0.095 ± 0.014	1.29 ± 0.08	0.67 ± 0.03	0.83 ± 0.02	0.21 ± 0.01	0.8	20 ± 5	3.09 ± 0.10
428	K-Feldspar	0.101 ± 0.015	2.05 ± 0.12	0.81 ± 0.04	1.23 ± 0.03	0.18 ± 0.01	1.8	25 ± 5	4.37 ± 0.13
429	Quartz	–	1.15 ± 0.08	–	0.73 ± 0.02	0.18 ± 0.01	1.8	20 ± 5	2.13 ± 0.08
430	K-Feldspar	0.15 ± 0.02	1.87 ± 0.12	0.67 ± 0.03	1.01 ± 0.03	0.20 ± 0.01	0.9	15 ± 5	3.92 ± 0.13
451	Quartz	–	1.52 ± 0.10	–	0.98 ± 0.03	0.17 ± 0.01	2.4	20 ± 5	2.53 ± 0.10
452	Quartz	–	1.33 ± 0.09	–	0.81 ± 0.02	0.15 ± 0.01	3.1	20 ± 5	2.33 ± 0.09
453	Quartz	–	1.20 ± 0.08	–	0.72 ± 0.02	0.20 ± 0.01	1.1	20 ± 5	2.14 ± 0.08
454	Quartz	–	1.22 ± 0.08	–	0.73 ± 0.02	0.19 ± 0.01	1.4	20 ± 5	2.16 ± 0.08
473	Quartz	–	1.55 ± 0.10	–	1.04 ± 0.03	0.23 ± 0.01	0.5	20 ± 5	2.84 ± 0.11
474	Quartz	–	1.30 ± 0.08	–	0.74 ± 0.02	0.18 ± 0.01	1.7	20 ± 5	2.23 ± 0.09

[1]We relied on an internal alpha dose rate of 0.01 ± 0.01 for quartz.

The beta dose rate absorption efficiencies were adjusted according to the specific grain size and mineral used for equivalent dose measurement (Nathan, 2011). For quartz, the beta dose rate contribution was further adjusted for one hour of HF etching (i.e., at a 10-μm etch dissolution depth). External beta and gamma contributions were attenuated for water content (Zimmerman, 1971). The energy-to-dose rate conversion coefficient relied on the update by Guérin et al. (2011).

3.1 Uranium disequilibrium

A problem was identified here while measuring the specific activities of uranium 238 and its daughter products (radium 226 and lead 210). The uranium decay chain is in disequilibrium for some sample (Table 8, Figure 8).

Table 8. Specific activity ratio of 226Ra to 238U and 210Pb to 226Ra.

ISGS code	Sample	226Ra/238U		210Pb/226Ra	
424		1.18 ± 0.07	slight excess	0.86 ± 0.07	–
424	> 2 mm	0.85 ± 0.07	–	1.06 ± 0.12	–
426		1.05 ± 0.07	–	1.12 ± 0.10	–
426	below 10'	1.39 ± 0.14	excess	0.83 ± 0.10	–
428		1.10 ± 0.07	–	1.24 ± 0.10	excess
429		0.93 ± 0.07	–	1.29 ± 0.12	excess
429	top	0.91 ± 0.07	–	1.27 ± 0.12	excess
429	bottom	1.28 ± 0.10	excess	1.20 ± 0.09	excess
430		0.66 ± 0.04	deficit	1.23 ± 0.10	excess
430	> 2 mm	0.79 ± 0.07	deficit	1.00 ± 0.14	–
451		1.00 ± 0.06	–	0.97 ± 0.08	–
451	A	1.05 ± 0.07	–	0.99 ± 0.09	–
451	B	1.14 ± 0.08	–	1.02 ± 0.09	–
452		0.99 ± 0.07	–	1.19 ± 0.11	–
452	A	0.79 ± 0.04	–	1.32 ± 0.10	excess
452	B	1.09 ± 0.07	–	1.01 ± 0.08	–
452	C	1.20 ± 0.09	excess	1.11 ± 0.09	–
452	organic bed	1.11 ± 0.07	–	0.97 ± 0.09	–
452	D, less than 2 mm	1.40 ± 0.15	excess	1.10 ± 0.11	–
452	D, more than 2 mm	1.24 ± 0.12	excess	1.01 ± 0.11	–
453	less than 2 mm	1.27 ± 0.09	excess	1.01 ± 0.08	–
453	more than 2 mm	0.96 ± 0.06	–	1.00 ± 0.09	–
454	WV-MD-Pit2a	1.03 ± 0.08	–	1.10 ± 0.11	–
473		1.22 ± 0.09	excess	0.87 ± 0.08	–
474		0.92 ± 0.06	–	1.23 ± 0.11	excess

In a perfect situation, i.e. with secular equilibrium, the specific activity (in Bq/kg) of each daughter products are equal to its immediate parent and ultimately to uranium 238. An image would be that of a series of water basins, at different height, forming a single chain. Each basin drains the overflow into the next lower basin. As long was water is being poured from the top (i.e. natural radioactivity), the overflow (the newly created daughter isotopes) will fall down into the next level. If you characterize well one level, by measuring the basin volume and the rate of overflow (i.e. the abundance and the radioactive half-live or, more simply, the specific activity of a single isotope along the chain) you can reconstruct the situation for the whole chain.

Now, imagine that midway along this single chain of water basins, a second water input suddenly appears; this will create a perturbation, propagating into each basin further down. The relationship of overflow and volume (i.e. specific activity) becomes different, above and below the perturbation level. Once a perturbation is initiated, it takes a finite amount of time for the water basins (isotopes) down the chain to equilibrate to this new situation. In the same way, once a perturbation is interrupted, it takes a finite amount of time for the isotopes down the chain to return to the former state of equilibrium (with the topmost parent of the chain, e.g. uranium 238). The time required to restore equilibrium, to the top of the chain or to a midpoint perturbation depends on the rate of overflow (i.e. radioactive half-live). It takes more than 5 half-lives of time for a given isotope to restore its equilibrium with its immediate parent. In real life, we can only see and quantify the water basins (isotopes) and overflow (radioactive half-live). Unless we can identify and quantify a source of perturbation we are forced to navigate in uncharted water. So far, it is very hard if not impossible, to characterize these perturbations in a real life situation.

Uranium 238 is sensitive to disequilibrium (i.e. external perturbation). Other dating techniques, such as uranium/thorium or uranium series, explicitly rely on this fact for dating. On the other hand, in luminescence dating, disequilibrium is bad! Uranium decays successively into many different isotopes, each one having different chemical properties, hence different ways to interact with its surrounding environment. In the case of uranium, among its daughter products we find radium 226 and radon 222. Radium is soluble in water while radon is a gas at normal pressure and temperature. It is common to have an excess of radium in groundwater, whereas radon emanation from soil is problematic for human dwellings in some specific geographical areas (Ivanovich and Harmon, 1992). Very close to the surface we can also notice an excess in lead 210. Its excess comes from the radon 222, released in the atmosphere. In a continental environment and for luminescence dating, the main concern will rest on radium.

As explained above, radium is soluble in water, hence it can move in the sediment. With a 1600-year half-life it takes more than 8000 years (5 x 1600) for radium 226 to restore its equilibrium with its parent, uranium 238, after the interruption of the external perturbation. For lead 210, its half-live is only 22 years. Hence, after 110 years of continuous (or lack of) perturbation, it will be in equilibrium with its parent radium 226.

Most likely the deviation from equilibrium are due to precipitation and groundwater flow sweeping the valley.

3.2 Uranium disequilibrium: implication

The currently observed excesses and deficits in radium 226 and lead 210 implies that the environmental dose rate was not constant, throughout the length of burial. How much does it matter? We can postulate three simple cases and calculate the dose rate (hence, the burial age) accordingly.

a) The present-day conditions have prevailed since the beginning
b) These variations are very recent
c) There was a long trend in excess radium and was recently depleted

For each hypothesis we can calculate a dose rate, hence an age (Table 9). As can be seen the various hypothesized ages are all undisguisable from each other, at 1 sigma. We can account this fortunate result to the fact that, for these samples, a large fraction of the dose rate is derived from potassium. The uranium decay chains account for 16 % of the total dose rate. In any plausible likelihood any excess or deficit along the decay chain would be small, else the sediment would most likely show signs of oxidization (and OSL sampling should thus to avoided!).

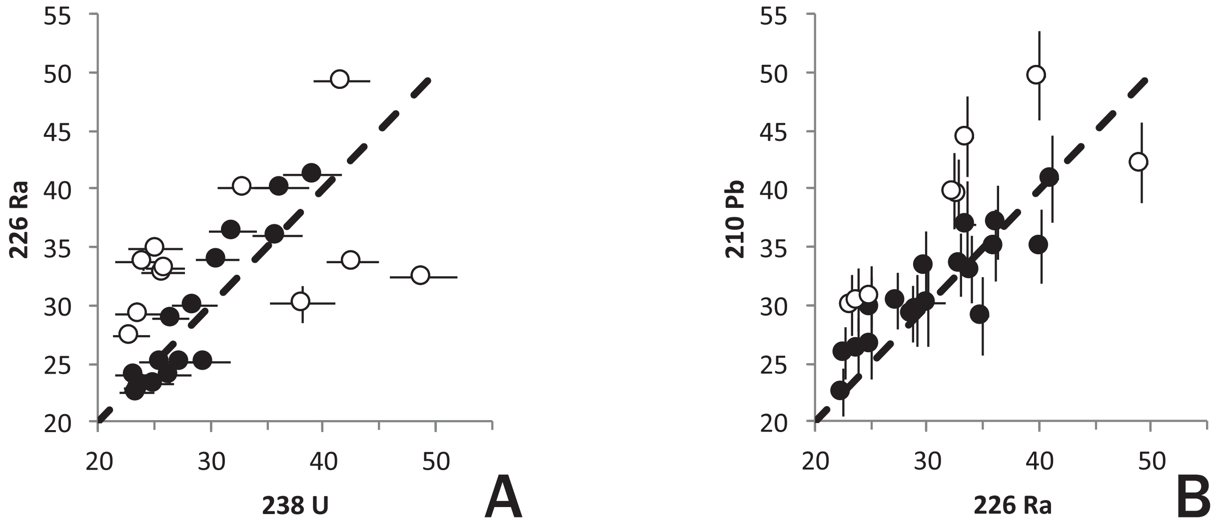


Figure 8. Specific activity (Bg/kg) for uranium 238, radium 226 and lead 210, for all samples. A), relationship of radium 226 versus uranium 238. B), relationship of lead 210 versus radium 226. The dashed line represents the 1:1 ratio. If a sample is in equilibrium, then the daughter isotope (y-axis) will match the activity of its parent (x-axis). Excesses and deficits (open circles) in radium 226 and lead 210 are clearly seen in some sample. Panel D shows a scatter plot of potassium 40 against thorium 232. Uncertainties are shown for 1σ.

Table 9. Various scenario for the time-dependence in the uranium decay chain.

ISGS code	Sample	a	b	c
424	WV T1 S2	11.2 ± 0.8	11.3 ± 0.8	11.0 ± 0.8
426	WV T3 S1	3.1 ± 0.3	3.1 ± 0.3	3.1 ± 0.3
428	WV T1 S1	15.6 ± 1.6	15.8 ± 1.7	15.6 ± 1.6
429	WV Heinz	12.7 ± 1.1	12.8 ± 1.1	12.8 ± 1.1
430	WV T7 S1	10.6 ± 1.0	10.3 ± 1.0	10.9 ± 1.0
451	WV-BC-OSL-S1	2.33 ± 0.19	2.34 ± 0.19	2.33 ± 0.19
452	WV-BC-OSL-S3a	1.23 ± 0.12	1.23 ± 0.12	1.23 ± 0.12
453	WV-D1-S1	18.0 ± 1.1	18.5 ± 1.1	18.0 ± 1.1
454	WV-MD-Pit2a	12.8 ± 1.2	12.8 ± 1.2	12.8 ± 1.2
473	UHT 8	9.5 ± 0.5	9.7 ± 0.5	9.4 ± 0.5
474	MT-36-OSL1	8.5 ± 0.9	8.4 ± 0.9	8.5 ± 0.9

3.3 Cesium 137

Cesium 137 was detected in one sample while measuring their gamma ray spectrometry. It was found in WV-BC-OSL-S3a (ISGS 452), subsample A (above the OSL dated layer). Its specific activity is 1.67 ± 0.19 Bg/kg, placing it well above the instrumental background. It means that subsample A was deposited very recently, less than 60 years ago.

This carries an implication for the calculated OSL age for sample WV-BC-OSL-S3a, as it would have been buried at a shallow depth up until very recently. At a shallow depth of approximately 3 cm (the OSL sampled layer is about 6.5 cm thick) the dose rate contribution from cosmic ray radiation increases, from 0.15 to 0.30 Gy/ka. In addition, the absence of subsample A reduces the dose rate contribution from gamma rays, from 0.83 to 0.49 Gy/ka.

The combined effect on the dose rate is a reduction, from 2.33 Gy/ka down to 2.14 Gy/ka, for the OSL layer buried at its current depth and from a hypothetical shallow depth. We can construct a hypothesis such that:

- subsample A was deposited 60 years ago and
- there was no significant erosion after the deposition of the OSL sampled layer

Given this the modeled age for sample WV-BC-OSL-S3a (ISGS 452) would be closer to 1.33 ± 0.12 ka.

4. Conclusion

In summary, most samples showed pronounced signs of having being poorly bleached during their last sedimentary cycle. The quartz from these samples were in general poorly behaved, which resulted in numerous rejected aliquots. The ages relied only on those quartz aliquots that displayed suitable luminescence characteristics. For some sample, we opted instead to rely on K-feldspar. For these, anomalous fading was individually measured and corrected for every aliquot.

Many samples show signs of uranium disequilibrium, but the long-term impact is small, due to a high abundance in potassium. At most, the long-term impact would amount to a systematic age offset of less than 100 years or 1 ka, for the youngest or oldest samples. We recommend relying on the present-day dose rate for age calculation.

Our best age estimates were provided by the minimum age model, except for sample WV-D1-S1, for which we relied on a weighted average. The age for sample WV T1 S1 is poorly defined and should be tentative. An unusually large amount of aliquots (K-feldspar) were poorly-bleached here.

Finally, unexpectedly, a cesium 137 gamma peak was detected in subsample A of the OSL sample WV-BC-OSL-S3a (ISGS 452). This places a constrain on the burial depth, as subsample A would have been absent during most of the burial length of time for sample WV-BC-OSL-S3a.

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APPENDIX L
Re-evaluation of Previous OSL Dating Results by Dr. Harrison Gray

Informal Technical Memorandum: Report on West Valley 2007 OSL Ages Following Modern Reanalysis

Harrison J. Gray

September 9, 2016

West Valley OSL dating

In 2007, 10 samples from the West Valley Site were collected for Optically Stimulated Luminescence (OSL) dating to determine the depositional ages of the valley Last Glacial Maximum (LGM) surface, as well as the ages of several fluival terraces in the Buttermilk, Cattaraugus, and Connoisarauley Valleys, prior to incision and erosion following retreat of glaciers at the end of the LGM. This reanalysis was prompted by the discovery of potentially disagreeing ages from other data such as C-14 dating. The original ages were in the range of 14.4-21.1 ka.

Age Reanalysis Methods

To reanalyze the 2007 ages, I used the equivalent dose, dose rate, and water content data from the 2007 informal report by S. Mahan. For reanalysis of the equivalent dose data, I used the r-Luminescence statistical package for the programming language R (Kreutzer et al., 2012). I also recalculated the dose rate and effects of the water content history using DRAC (Durcan et al., 2015). Since the production of these ages, there have been advances in the statistical tools used to calculate ages. I reanalyzed the original equivalent dose data and determined that the original analysis was satisfactory and that the use of new statistical tools did not considerably change the ages of the samples. For this analysis, I used two statistical 'Age Models' to calculate the appropriate equivalent dose in the age calculation. The first is the Central Age Model (CAM) and the second is the Minimum Age Model (MAM) (Galbraith and Roberts, 2012). The CAM acts under an assumption that the dispersion in equivalent dose present is due solely to scatter introduced due to a spatially varying radiation field. The MAM acts under the assumption that the dispersion within a sample is due to the unequal sunlight exposure histories grains undergo prior to deposition, leading to an additional population of grains that overestimate the depositional age of the sample.

Age Reanalysis Results and Discussion

The new and old OSL ages are presented in **Table 1**. A display of the equivalent dose data and age model results are shown in **Figure 1**. The new range of OSL ages I obtained is 8.4-25.2 ka. Reanalyzing underlying assumptions in age calculation, such as water content history, was not sufficient to explain the discrepancy between the ages from the higher and lower terraces. One possible explanation for the discrepancy is that the ages from the higher terrace are affected by partial bleaching. Partial bleaching occurs when a prior luminescence signal is not completely removed prior to deposition leading to an age underestimation. The protocol used to obtain ages during the inital 2007 analysis used large aliquots of sample where 100's of grains are measured for luminescence at a time. This causes the luminescence from grains with significant partial bleaching to be averaged with the luminescence of grains that were completely bleached. This might have led to the overestimation of the OSL ages. For this reason the new ages should be considered as age maxima.

Table 1: New Age Results

Sample Name	CAM Age	±	MAM Age	±	2007 Age	±	Percent Change in Age
WV-OSL-1	14.4	0.8	10.9	1.1	14.8	1.3	-26%
WV-OSL-2	16.9	0.6	15.7	1.1	16.2	1.3	-3%
WV-OSL-3	17.6	0.8	15.2	1.5	16.7	0.9	-9%
WV-OSL-4	14.7	2.4	8.4	2.2	16.1	2.0	-48%
WV-OSL-5	16.6	0.9	15.7	2.5	14.5	1.1	8%
WV-OSL-6	16.8	0.9	12.3	0.9	15.0	2.0	-18%
WV-OSL-7	15.3	1.4	9.0	1.2	15.2	1.8	-40%
WV-OSL-8	19.2	0.7	18.6	1.4	16.8	1.5	11%
WV-OSL-9	19.3	0.9	19.1	0.9	17.1	1.4	12%
WV-OSL-10	25.2	1.1	22.1	3.5	21.2	1.2	4%

Table 1: Results of age reanalysis and 2007 ages estimates. Uncertainties are reported at 1-sigma. Differences result from new statistical tools development in the years since original age calculation. Note that the Percent Change in Age column is the change in age compared to the MAM age for all samples. For samples where the CAM age and MAM age are outside of the uncertainty bounds, the MAM age is my preferred age for the sample. However, it is not impossible for the CAM age to be the true age for the sample so both age models are reported.

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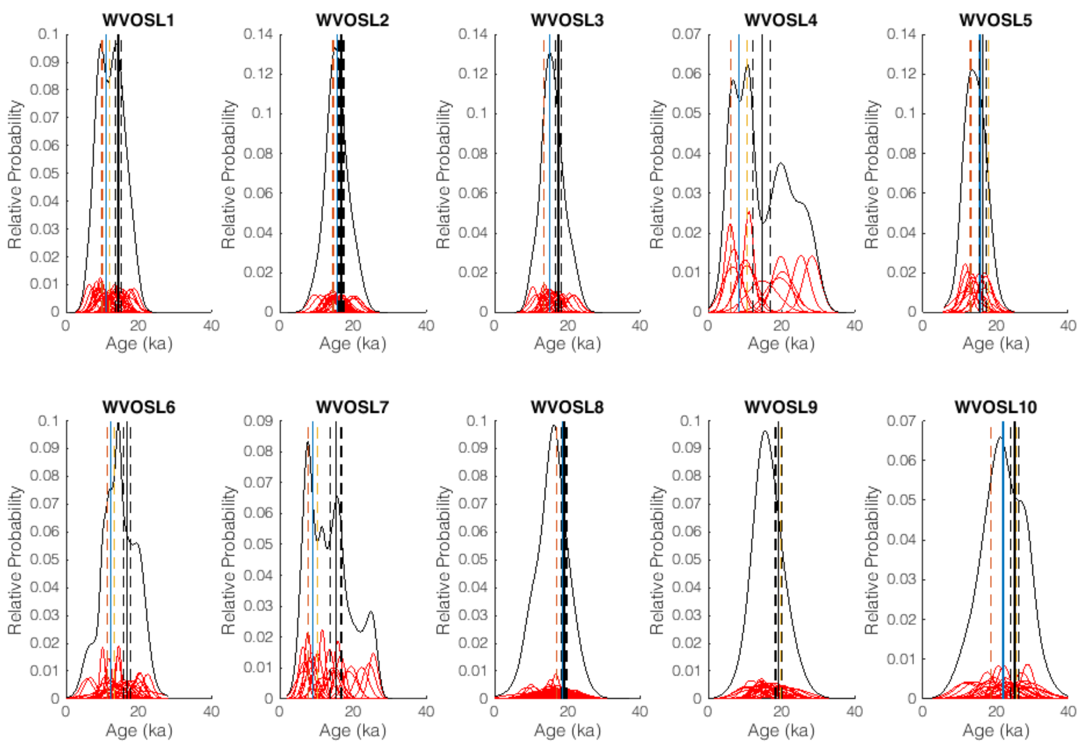
Figure 1 (next page): Kernal density estimates for equivalent dose measurements for West VAlley OSL samples. Red lines show mean and standard deviation of each equivalent dose measurement and black line indicates sum of red lines showing relative density of measurement overlap. Vertical solid and dashed black lines show CAM age and uncertainty. Vertical blue and brown/yellow dashed lines show MAM age


WVOSL1
WVOSL2
WVOSL3
WVOSL4
WVOSL5
WVOSL6
WVOSL7
WVOSL8
WVOSL9
WVOSL10
Relative Probability
Age (ka)

APPENDIX M
Cosmogenic Dating Results

Terrestrial cosmogenic nuclide ^{10}Be surface exposure dating of the Heinz Creek alluvial fan, West Valley

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December 19, 2016

Five boulders are dated on the Heinz Creek alluvial fan using ^{10}Be terrestrial cosmogenic nuclide methods to help determine the age of the apex and initiation of the alluvial fan. Samples were prepared at the geochronology laboratories in the University of Cincinnati and measured at the accelerator mass spectrometry facility at the PRIME Laboratory in Purdue University. Ages range from 15.3 to 23.0 ka, with an average age of the alluvial fan is 18.7 ± 3.1 ka. These data in turn help enable rates of incision to present river level to be calculated.

Background

Terrestrial cosmogenic nuclide (TCN) surface exposure dating provides a method to directly determine the timing of alluvial fan formation, erosion and/or deformation (e.g., Zehfuss et al., 2001; Frankel et al., 2007a, b, 2016; Arboleya et al., 2008; Spelz et al., 2008; Armstrong et al., 2010; Fletcher et al., 2010; Owen et al., 2011, 2014; Blisniuk et al., 2012). TCNs accumulate in rock and sediment as a consequence of spallation due to the bombardment of cosmic rays with minerals in a substrate (Gosse and Phillips, 2001). The concentration of TCNs is dependent on the TCN production rate and the duration of surface exposure. In essence, the TCN concentration is a function of age and determining it provides a means of dating a surface. TCN dating, therefore, defines the age of alluvial fan surfaces and therefore represents the timing of abandonment/incision of the surface being dated.

Beryllium-10 is most commonly used TCN because it is forms in quartz, a ubiquitous mineral in most rocks, and its production rates is well known. Other TCNs include, for example, ^{36}Cl, ^{26}Al, ^{14}C and ^{21}Ne. Samples for ^{10}Be dating are usually collected from quartz-rich boulders on individual alluvial fan surfaces by hammering off 400-500 g of the upper horizontal surface of individual boulder. These samples chemically processed for quartz are spiked with a low-background $^{10}Be/^{9}Be$ carrier, separated by ion chromatography, and precipitated as BeO onto targets using standard techniques (Kohl and Nishiizumi, 1992) in geochronology preparation laboratories. The $^{10}Be/^{9}Be$ ratio in extracted BeO are measured in an Accelerator Mass Spectrometer.

We follow these methods by collecting samples from five boulders on the Heinz Creek alluvial fan in West Valley. Details of laboratory procedure and results are presented below.

Heinz Creek alluvial fan

Using these methods and approaches, we date the Heinz Creek alluvial fan apex surface and initiation of alluvial fan construction using ^{10}Be. While we also planned to determine OSL ages for several lower Heinz alluvial fan surfaces and their relationship to Buttermilk terraces, we did not find sand layers for OSL dating in the apex of the alluvial fan. Finding ^{10}Be dateable boulders on the alluvial fan apex was fortuitous and it allowed us to obtain a critical age in the erosion sequence.

Large surface granite and gneiss boulders are present on the Heinz Creek alluvial fan, but are not very common. Five of these boulders were sampled on July 27 for ^{10}Be TCN dating (Figure 1 and Table 1). The sampled boulders were located on elevated sites on the alluvial fan surfaces, and were deeply embedded, yet stand relative high above the existing the surface. Such boulders are most likely to have been deposited during the final stages of alluvial fan deposition and are likely to have retained their original position since deposition, and were not shielded by any significant amount of sediment and/or snow cover. We avoided sampling from any boulder that showed signs of weathering, such as exfoliation, granular disintegration, or splitting. Photographs were taken of each boulder and the degree of weathering and the site conditions were recorded (Figure 1). The inclination from the boulder site to the tops of the surrounding mountain ridges and peaks was measured to determine the potential effect of topographic shielding. By dating five boulders from the surface we qualitatively assess the likelihood of spurious ages due to weathering or inheritance of TCNs within boulders that may have experienced prior exposure.

Laboratory methods

The collected samples will be chemically processed for quartz, spiked with a low-background Be carrier, separated by ion chromatography, and precipitated as Be oxides onto targets using standard techniques (Kohl and Nishiizumi, 1992) in the Geochronology Laboratories at the University of Cincinnati. The rock samples from boulders were crushed and sieved to obtain the 250–500 mm size fraction. This fraction was chemically leached with a minimum of four acid leaches: aqua regia for > 9 hours; two 5% HF/HNO_3 leaches for ~ 24 hours; and one or more 1% HF/HNO3 leaches each for ~ 24 hours. Acid-resistant and mafic minerals were removed from the residue after the first 5% HF/HNO_3 leach using magnetic separation and by a heavy liquid separation with lithium heteropolytungstate (density 2.7 g/cm^3). A low-background ^{9}Be carrier ($^{10}Be/^{9}Be = 2.00 \pm 0.19 \times 10^{-15}$ based on the weighted mean of 8 blanks) was added to pure quartz, which was then dissolved in concentrated HF and fumed with perchloric acid to remove fluorine atoms. Fifteen grams of quartz was assumed for determining acid volumes used in the processing of chemical blanks. The samples were then passed through anion and cation exchange columns to remove Fe and Ti and to separate the ^{10}Be fraction. Ammonium hydroxide was added to the Be fraction to precipitate beryllium hydroxide gel. The beryllium hydroxide was combusted by ignition at 750 ^{o}C for 40 minutes in quartz crucibles. Beryllium oxide was mixed with Nb powder and loaded in steel targets for the measurement of the $^{10}Be/^{9}Be$ ratios by accelerator mass spectrometry at the Purdue Rare Isotope Measurement (PRIME) Laboratory at Purdue University.

Calculating the ages

There is currently much debate regarding the appropriate production rate, scaling models and geomagnetic corrections to calculate TCN surface exposure ages (e.g., Pigati and Lifton 2004; Staiger et al. 2007; Balco et al., 2008; Borchers et al., 2016; Marrero et al., 2016). Ages are therefore calculated using several schemes. Firstly these were calculated using the CRONUS-Earth online calculator Version 2.3, applying appropriate ^{10}Be standardizations (Balco et al., 2008; http://hess.ess.washington.edu/) with a sea-level high latitude (SLHL) production rate of 3.92 ^{10}Be atoms/g of SiO_2/yr, a ^{10}Be half-life of 1.36 x 10^6 years (Nishiizumi et al., 2007) and a rock density of 2.75 g/cm^3 assuming a zero erosion rate and no snow cover (Table 1). In addition, the Northeastern North America (NENA) calibration data set of Balco et al. (2009; http://hess.ess.washington.edu/math/al_be_v22/alt_cal/Balco_NENA_age_input.html) is used to calculate the ages (Table 1). Furthermore, the recently developed ICE-D calculator of Martin et al. (2017; http://crep.crpg.cnrs-nancy.fr/) is used by selecting four calibration sites in Northeastern North America (at Beech Hill moraine complex, Glacial Lake Ashuelot, Cobblestone Hill spillway, and the Sleeping Astronomer moraine) that are located near West Valley. The calculator calculates a production rate of 4.22 ± 0.20 ^{10}Be atoms/g of SiO_2/yr, and uses the Lifton et al (2014) scaling scheme and geomagnetic correction.

Dating results

Ages range from 15.3 to 28.2 ka. The large uncertainly associated with the WVALL4 age is related to relatively low currents during the AMS measurements, and this age should is very approximate. Differences between ages using different production rates and scaling models vary by up to ~ 2 ka. Ages produced using the Martin et al. (2017) are favored because of the use of local calibration sites and the recent scaling models of Lifton et al. (2014) known as LSD. These range from 15.3 to 23.0 ka (omitting WVALL4) with a weighted mean of 18.0 ± 0.6 ka and an average age of 18.7 ± 3.1 ka (uncertainty = 1 σ).

Interpreting the ages

Numerous workers have discussed problems associated with applying TCN methods to date alluvial fans, and discussions and summaries are provided in Matmon et al. (2006), Owen et al. (2011) and Blisniuk et al. (2012). In essence, however, two sets of factors contribute to the dating uncertainty. Firstly, problems are introduced in calculation of the production rate of TCNs, especially the uncertainty in correcting for variations in the geomagnetic field intensity. The most recent schemes are presented in Borchers et al. (2016) and Marrero et al. (2016). Geological factors introduce the second set of uncertainty. These include weathering, exhumation, prior exposure, and shielding of the surface by sediment and/or snow. With the exception of prior exposure, these factors generally reduce the concentration of TCNs in surfaces, which results in an underestimate of the true age of the landforms. Episodes of prior exposure result in an overestimate of the true age. Uneven distribution of these geological processes can produce a large spread in apparent exposure ages on a landform. Researchers commonly assess these effects by collecting multiple samples on a surface to examine the range of ages. If multiple surface samples have similar apparent ages, the data suggest that the dated samples were not derived from older surfaces and/or were not weathered or exhumed. Since geologic processes acting on a surface are stochastic the spread of TCN ages on a particular surface would be large if geologic processes dominate.

The uncertainties in ages due to production rates and scaling models are in the order of about 5-10%. These variations are included in the individual age uncertainty for each TCN ^{10}Be age. The more significant uncertainty is introduced by the geologic conditions as is evident by the spread of ^{10}Be ages in this study. Disregarding sample WVALL4 that has a large uncertainty, the ages range from 15.3 ± 0.9 to 23.0 ± 1.3 ka. The younger ages may be the results of shielding by sediment and later exhumation, while the older ages might represent some inheritance of ^{10}Be due to prior exposure. It is not possible to determine which of these two sets (or a combination) of uncertainties contribute to the age spread. However, it is reasonable to suggest an average age of the alluvial fan is 18.7 ± 3.1 ka (uncertainty = 1 σ).

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Figure 1. Views of sampled boulders at their sites (left image) and close up of boulder showing areas sampled (right image).

Boulder WVALL1

Boulder WVALL2

Boulder WVALL3

Boulder WVALL4

Boulder WVALL5

Table 1. Terrestrial cosmogenic nuclide data for boulders and ^{10}Be age results.

Sample name	Latitude (°N)	Longitude (°W)	Altitude (m asl)	Boulder size height/ width/length (cm)	Sample lithology	Quartz mass (g)	Be carrier (g)	Be carrier concentration (mg/g)	$^{10}Be/^{9}Be$ (10^{-15})[a]	Sample thickness (cm)	^{10}Be concentration (atom/g SiO_2 SiO_2 x 10^4)
WVALL1	42.4527	78.6420	404	40/100/150	Microgranite	21.1084	0.3534	1.0459	69.59 ± 2.61	1.5	8.153 ± 0.31
WVALL2	42.4526	78.6416	415	30/70/80	Granite	19.5624	0.3491	1.0459	79.59 ± 4.54	1.5	9.939 ± 0.57
WVALL3	42.4527	78.6418	408	40/60/110	Granite	20.6724	0.3527	1.0459	103.98 ± 3.24	2.5	12.42 ± 0.39
WVALL4	42.4526	78.6416	406	30/80/110	Granite	20.1505	0.353	1.0459	126.11 ± 16.30	2	15.45 ± 2.00
WVALL5	42.4528	78.6419	394	30/70/90	Granite	4.2214	0.3497	1.0459	16.54 ± 1.66	2	9.59 ± 0.96

Sample name	CRONUS-Earth Online Calculator Version 2.3[c]					Balco et al. (2009) Northeastern North American (NENA) calibration data set[d]					ICE-D[f]
	Lal (1991), Stone (2000) time-independent Age (ka)[b,e]	Desilets et al. (2003, 2006) Age (ka)[n]	Dunai (2001) Age (ka)[b]	Lifton et al. (2005) Age Age (ka)[b]	Lal (1991), Stone (2000) time-dependent Age (ka)[b]	Lal (1991), Stone (2000) time-independent Age (ka)[b,e]	Desilets et al. (2003, 2006) Age (ka)[b]	Dunai (2001) Age (ka)[b]	Lifton et al. (2005) Age Age (ka)[b]	Lal (1991), Stone (2000) time-dependent Age (ka)[b]	Martin et al. (2017) LSD scaling Age (ka)[b,e,f]
WVALL1	15.2 ± 1.4 (0.6)	17.2 ± 2.2	17.3 ± 2.1	17.4 ± 2.1	15.5 ± 1.6	15.5 ± 1.0 (0.6)	16.1 ± 1.0	16.2 ± 1.0	16.2 ± 1.0	15.6 ± 1.0	**15.3 ± 0.9 (0.6)**
WVALL2	18.4 ± 1.9 (1.1)	20.6 ± 2.7	20.7 ± 2.7	20.8 ± 2.7	18.6 ± 2.0	18.8 ± 1.4 (1.1)	19.3 ± 1.5	19.3 ± 1.5	19.4 ± 1.5	18.7 ± 1.4	**18.4 ± 1.3 (1.0)**
WVALL3	23.4 ± 2.1 (0.7)	25.8 ± 3.2	25.9 ± 3.1	26.0 ± 3.1	23.5 ± 2.3	23.8 ± 1.4 (0.7)	24.1 ± 1.4	24.2 ± 1.4	24.2 ± 1.4	23.6 ± 1.4	**23.0 ± 1.3 (0.7)**
WVALL4	29.1 ± 4.5 (3.8)	31.7 ± 5.6	31.8 ± 5.6	31.8 ±5.5	29.0 ± 4.6	29.6 ± 4.1 (1.9)	29.6 ± 4.1	29.7 ± 4.1	29.6 ± 4.1	29.2 ± 4.1	**28.2 ± 3.7 (3.5)**
WVALL5	18.2 ± 2.4 (1.8)	20.4 ± 3.2	20.4 ± 3.2	20.6 ± 3.1	18.4 ± 2.5	18.5 ± 2.1 (1.9)	19.0 ± 2.1	19.0 ± 2.1	19.1 ± 2.1	18.5 ± 2.1	**18.2 ± 1.9 (1.7)**

[a] Corrected for eight $^{10}Be/^{9}Be$ blanks at 2.00 ± 1.98 *10^{-15}

[b] Ages determined using a rock density of 2.7 g/cm^3 and 07KNSTD standard. Uncertainties include analytical and production rate/scale model uncertainties. No samples required a correction for shielding.

[c] Calculated using the CRONUS-Earth online calculator at http://hess.ess.washington.edu/

[d] Calculated using CRIONU-Earth calculator at http://hess.ess.washington.edu/math/al_be_v22/alt_cal/Balco_NENA_age_input.html

[e] Analytical uncertainty (without prodcution rate uncertainty) is shown in parenthesis.

[f] Calculated using the ICE-D calculator at: http://crep.crpg.cnrs-nancy.fr/

APPENDIX N
Summary of Western New York Glacial Chronology

Supporting Data for Recessional Moraine Ages in Western New York (Kent, Lavery, Valley Heads, Defiance, or Lake Escarpment): Updated based on new circa 13,000 dates at WVDP, Kent moraine trenches, and Genesee Valley data
Table 1 based on regional geologic literature of radiocarbon ages (Ohio, Pennsylvania, NY localities), with suggestions for projected correlations with Atlantic Heinrich Event ages. Included are new data from WVDP current study and from unpublished Genesee Valley data of Young.

Heinrich Event Ages: (kyr = actual calendar years)

H1 = 16,800 kyr [proposed by some as Valley Heads-Lake Escarpment (Defiance) moraine]

H2 = 22-24,000 kyr

H3 = 22-24,000 kyr

H4 = 38-39,000 kyr (Genesee Valley site, circa 39,000 kyr; Young and Burr, 2006). Revised H4 age (39,000).

References for Heinrich Event Ages (above)**:**

Hemming, Sidney R.,2004, Heinrich events: Massive late Pleistocene detritus layers of the North Atlantic and their global climate imprint. Reviews of Geophysics, v. 42, no. 1.

Bond, G.C. and Lotti, R., 1995, Iceberg Discharges into the North Atlantic on Millennial Time Scales During the Last Glaciation: *Science* 267 , p. 1005–1010.

Vidal, L., Schneider, R.R., Marchal, O., Bickert, T., Stocker, T.F., and Wefer, G., 1999, Link between the North and South Atlantic during the Heinrich events of the last glacial period: *Climate Dynamics* 15 , no.12, p. 909–919.

NOTE: There is an emerging consensus that major Atlantic Heinrich event glacial surges correlate well with some major glacial moraines of Middle and Late Wisconsin glacial advances (readvances) in North America. This is true for H4 and the Middle Wisconsin Genesee Valley site (Young and Burr, 2006, Geomorphology, v. 75, p. 226-247); and possibly for the Valley Heads moraine in New York (see Table 1 below). The close agreement between Heinrich Event ages and radiocarbon chronology strengthens the case for both data sets. The new ages on glacial tills at WVDP and the Kent moraine site call into serious question the previously assumed ages of the youngest moraines and latest glacial events in western New York. The radiocarbon chronology references for Table 1 are listed below, with all conventional radiocarbon ages converted to kyr (calendar years before 1950) using (http://calib.org/calib/) (Stuiver et al., 2017)

Numbers in parentheses on the accompanying Table 1 refer to the numbered references compiled below:

(1) Miller, N.G., and Calkin, P.E., 1992, Paleoecological interpretation and age of an interstadial lake bed in western New York: Quaternary Research, v. 37, no. 1 p. 75-88.

(2) Muller, E.H., and Calkin, P.E., 1993, Timing of Pleistocene glacial events in New York State: Canadian Jour. Earth Sciences, v. 30, p. 1829-1845.

(3) Muller, E.H., Braun, D.D., Young, R.A., and Wilson, M.P., 1988, Morphogenesis of the Genesee Valley: Northeastern Geology, v. 10, no. 2, p. 112-133.

(4) Crowl, G.H., 1980, Woodfordian age of the Wisconsin glacial border in northeastern Pennsylvania: Geology, v. 8, p. 51-55.

(5) Ellis, K.G., Mullins, H.T., and Patterson, W.P., 2004, Deglacial to middle Holocene (16,600 to 6000 calendar years BP) climate change in the northeastern United States inferred from multi-proxy stable isotope data, Senaca Lake, New York; Jour. of Paleolimnology, v. 31, p. 343-361.

(6) Karrow, P.F., Dreimanis, A., and Barnett, P.J., 2000, A proposed diachronic revision of late Quaternary time-stratigraphic classification in the eastern and northern Great lakes area: Quaternary Research, v. 54, p. 1-12.

(7) LaFleur, R.G., 1980, Late Wisconsin stratigraphy of the Upper Cattaraugus Basin: Guidebook, 43rd Annual Reunion Northeast Friends of the Pleistocene.

(8) Fullerton, D.S., 1980, "Preliminary correlation of post-Erie interstadial events:" USGS Professional Paper 1089.

(9) Mickelson, D.M., Hooyer, T.S., Socha, B.J., and Winguth, Cornelia, 2007, Late-glacial ice advances and vegetation changes in east-central Wisconsin: In Hooyer, T.S. (Ed.), Late-glacial history of east-central Wisconsin: Guide book for the 53rd Midwest Friends of the Pleistocene Field Conference, May 18-20, 2007, Oshkosh, Wisconsin. 2007-01 Open-file report, p 73-87.

(10) Ridge, J.C., 1997, Shed Brook discontinuity and Little Falls Gravel: Evidence for the Erie interstade in central New York. Geol. Soc. America Bull., v. 109, no. 6, p.652-665

(11) Young, R.A., 1988a, Late Wisconsin Deglaciation of the Genesee Valley. In: Guidebook for 51st Annual meeting of the Friends of the Pleistocene (Ed. W.J. Brennan), May 27-29, p. 63, Figs. 3 and 4 (Dugan Creek boring).

(12) Young, R.A., 1988b, In: Muller et. al., Morphogenesis of the Genesee Valley. Northeastern Geology, v. 10, no. 2. pp. 124-125 (comments on Dugan Creek boring).

(13) Young, R.A., 2012, Genesee Valley Glacial and Postglacial Geology from 50,000 Years Ago to the Present: A Selective Annotated Review, Rochester Academy of Science (online at http://www.rasny.org/), p. 1-24. Overview and description of Avon, NY, Genesee river site (originally assumed to be circa 13,000 YBP landslide).

(14) Young, R.A., 2017, ^{14}C age on organic sediments in kettle pond excavation, Geneseo, NY, (13,710 ±40 ^{14}C BP = 16,545 calendar years BP). Pond sediments are directly overlain by dune sand. Ongoing study in progress (subject of current OSL analyses).

(15) Young, R.A. and Burr, G.S., 2006, Middle Wisconsin glaciations in the Genesee Valley, NY: A stratigraphic record contemporaneous with Heinrich Event, H4. Geomorphology, v. 75, p. 226-247.

(16) Young, R.A., and Scatterday, J.W., 1978, Significance of the remains of a Pleistocene Peccary (Platygonus compressus Le Conte) beneath glacial till in Livingston County, NY. Rochester Academy of Science, Pre-Meeting Abstracts, Fifth Annual Sessions for Scientific Papers, SUNY, Geneseo, NY, p. 46. (Description before ^{14}C date obtained)

Stuiver, M., Reimer, P.J., and Reimer, R.W., 2017, CALIB 7.1 [WWW program] at http://calib.org, accessed 2017-3-9

Table 1. Best ^{14}C Ages or Estimates for Glacial Moraines and Glacial Stadials in Western New York State

Radiocarbon ages below are selected from the 15 numbered references above (Years BP) with kyr conversions at right.

EVENT (references)	AGE (^{14}C Years BP)	CALENDAR YEARS (kyr) BP (CALIB)
Advance after Plum Point (Farmdale) at Lord Hill (approximate) (1, 2, 6, 7) Advance produced Kent moraine(?)	25,000-24,000 (approx.)	30,030 to 28,733 (approx.)
Kent moraine (2, 3, 7) *Heinrich H3 = 28-30,000*	25,450 (estimated) (Genesee Valley date) Muller et. al.(3)	30,400 (estimated)
Erie Interstade (Phase) (2,6)	16,000 (Approx.)	18,144 (Approx.)
Erie Interstade (Phase) (10)	14,100 (minimum age)	17,153 (minimum age)
Lavery till (4) Valid?	14,500 ±150; 14,300 ±350	16,840-17,140 (Approx.)
Valley Heads (Lake Escarpment?)	13,865 ±100 (Ice free Seneca Lake)	16,630 (from 5)
Valley Heads (Geneseo, NY) (14) Heinrich Event H-1?	>13,710 ± 40 (organics in kettle, minimum age on top of organics under sand dunes at Geneseo, NY)	>16,545 (Young, 2017 date) (Valley Heads must be older than kettle at Geneseo, NY)
(Port Bruce Stade?) (2,5,8) *Heinrich Event H1? = 16,800 kyr*	14,100 (Lake Maumee)	17,153 *H1 = 16, 800 (Hemming, 2004)*
*Lavery (?) (9) (Post Two Creeks) (meander till and moraine at Zerfas)	11,850-11,400 (?) (From Mickelson et al.)	13,200 to 13,600 (?) (agrees with WVDP & Genesee Valley)
*Younger Dryas advance(?) WVDP (9)	11,080 to 12,390 ± 50 range	Circa 13,000 ± 50 (approx.)
*Genesee Valley (11,12,13,16) (Agrees with Younger Dryas, WVDP)	11,180 ± 70; 11,145 ± 80 (peccary) Bone and collagen extraction ages	13,045 ± 70; 13,002 ± 80

***Question:** Does the Lavery till represent a separate (older) advance than the well dated circa 13,000 kyr (calendar years) event dated from numerous wood, peat, and bone samples found in shallow tills at the WVDP sites and in the Genesee Valley? Or is the Lavery advance accurately dated as described by Crowl (1980) as in reference (4) above.*

Attachments: The three attached glacial chronology figures from the literature illustrate the evolution and current status of the names of glacial stades (ice advances) and interstades (ice recession) for the eastern Great Lakes region (stades and interstades; are also called stadials and interstadials in some publications).

First attachment is from Muller and Calkin, 1993 (2 in list above).
Second attachment is from Johnson et al., 1997 (See References in main report).
Third attachment is from Karrow et al., 2000 (6 in list above)

TABLE 3. Provisional subdivision of the Pleistocene stades and interstades after Dreimanis and Karrow (1972) with boundary or midpoint and Middle Wisconsinan boundaries after Fulton et al. (1986)

Geologic time					ka BP	Oxygen-isotope stage
PLEISTOCENE	Late	Wisconsinan	Late	Two Creeks Interstade	... 11.9	1

				Port Huron Stade	... 13.0	
				Mackinaw Interstade		
				Port Bruce Stade		2
					---- 15.5	
				Erie Interstade		
					---- 16.5	
				Nissouri Stade		
					---- 23.0	----
			Middle	Plum Point Interstade (Port Washington)	---- 35.0	3
				Cherrytree Stade (Nassauan)		
					---- 40.0	
				Port Talbot Interstade		----
					---- 64.0	
			Early	Guildwood Stade		4

				St. Pierre Interstade	... 80.0	5a
						.
				Nicolet Stade		5b
						.
				[Eowisconsinan]		5d
					---- 117.0	----
	Middle	Sangamonian Interglacial				5e
					---- 130.0	...
		Illinoian				6, 7, 8
					---- 303.0	...
						9
					---- 734.0	19

NOTES: Approximate oxygen-isotope stage boundaries from Imbrie et al. (1984) and Martinson et al. (1987). Port Washington and Nassauan after Sirkin and Stuckenrath (1980). "Eowisconsinan" precedes Early Wisconsinan substage of Richmond and Fullerton (1986). ----, boundary; ..., midpoint.

TABLE 1

Illinois and Ontario Chronostratigraphic Classifications

Illinois (Willman and Frye, 1970)	Ontario (Dreimanis and Karrow, 1972)
Wisconsinan Stage	Wisconsin(an) Stage
Valderan Substage[a]	Late Wisconsin(an) Substage
	Driftwood Phase or Stadial
	North Bay Interval or Interstadial
	Valders Phase or Stadial
Twocreekan Substage	Two Creeks Interval or Interstadial
Woodfordian Substage	Port Huron Phase or Stadial
	Mackinaw Interval or Interstadial
	Port Bruce Phase or Stadial
	Erie Interval or Interstadial
	Nissouri Stadial
Farmdalian Substage	Middle Wisconsin(an) Substage
	Plum Point Interstadial
Altonian Substage	Cherrytree Stadial
	Port Talbot Interstadial
	Early Wisconsin(an) Substage
	Guildwood Stadial
	St. Pierre Interstadial
	Nicolet Stadial

[a] Renamed Greatlakean Substage by Evenson *et al.* (1976).

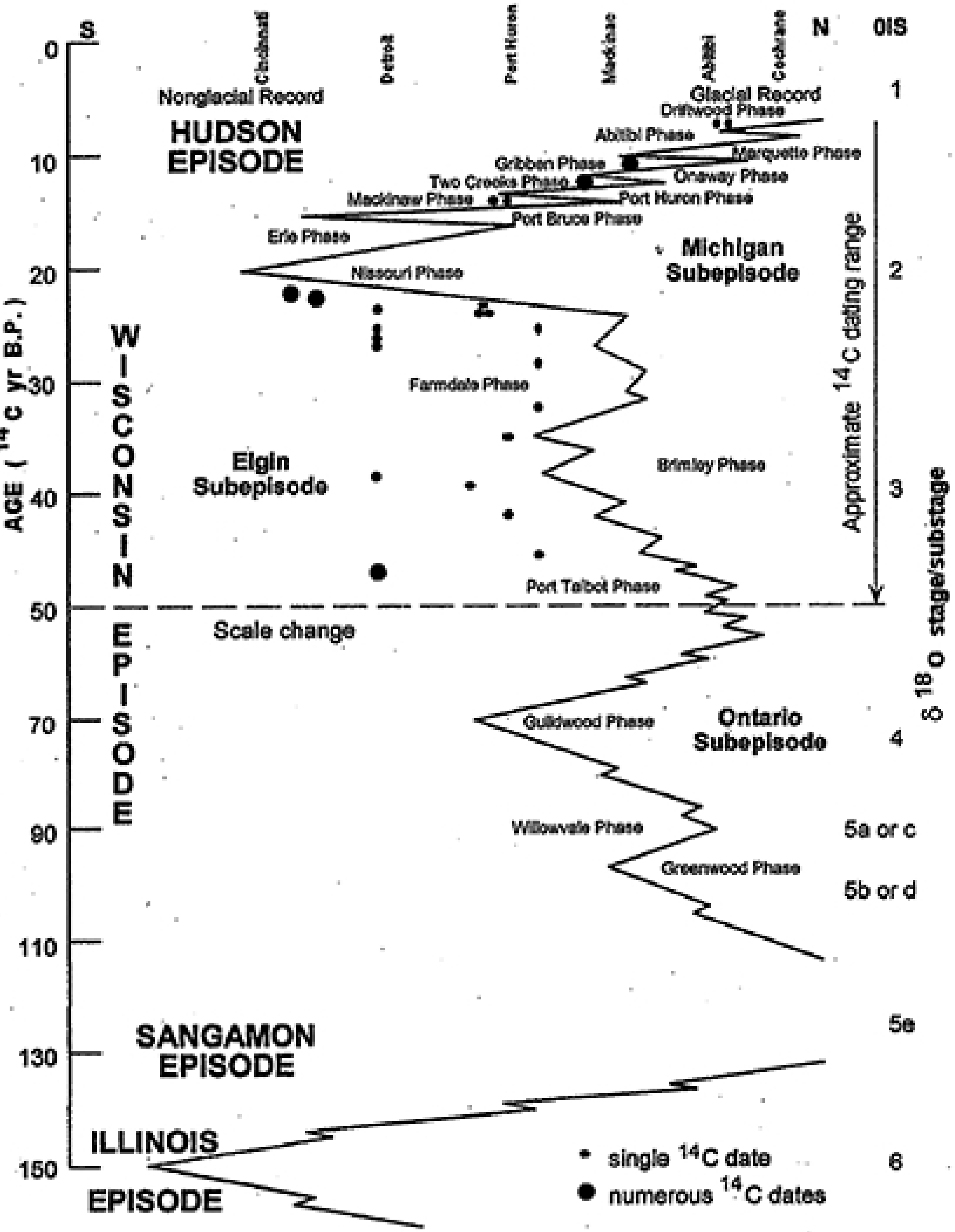

FIG. 1. Time–distance diagram showing a generalized conceptual sketch of late Quaternary history and diachronic time classification for the eastern and northern Great Lakes region. Corresponding oxygen isotope stages (OIS) are shown in the right column.