Appendix 2A
Supplemental Investigation Data Report
2013 Investigation

Table of Contents

LIST OF TABLES

LIST OF FIGURES

ATTACHMENTS

APPENDIX 2A
SUPPLEMENTAL INVESTIGATION DATA REPORT, 2013 INVESTIGATION

1.0 INTRODUCTION

The 2013 Supplemental Investigation (SI) was undertaken to meet the requirements of Agreed Order DE 2008 (Ecology 2005) between Washington State Department of Ecology (Ecology), Puget Sound Energy (PSE) and the City of Seattle (City), as amended (Ecology 2013). The purpose of the SI was to collect additional data from the upland portion of the area of investigation (AOI) to support completion of a remedial investigation/feasibility study (RI/FS) for the Gas Works Parks Site (GWPS) on the north shore of Lake Union in Seattle. In years past, a manufactured gas plant (MGP) and related industries occupied parts of the upland portion of the AOI, which has since been developed into a Seattle Parks and Recreation Department park (Gas Works Park). The SI was designed to meet specific objectives relating to chemical contaminants and their adverse effects:

- Evaluate historical and potential current source areas that may impact the upland.
- Characterize upland soil in targeted areas to assess potential ongoing impacts to groundwater.
- Characterize upland groundwater impacts to assess the pathway by which contaminants in groundwater may contribute to contamination in the sediment of the in-water portion of the AOI (i.e., the groundwater-to-sediment pathway).
- Assess the occurrence and mobility of light and dense non-aqueous phase liquid (LNAPL and DNAPL) that is present below ground surface in the upland, relative to potential impacts to sediment.

The SI followed a work plan (GeoEngineers 2013) documenting the field procedures to be used during the investigation. The resulting data are intended to allow further assessment of impacted soil and groundwater associated with former MGP, tar refinery and other industrial operations located at Gas Works Park and the Seattle Police Department Harbor Patrol property, in the upland portion of the AOI. Ecology approved the Supplemental Investigation Work Plan (SIWP) on March 11, 2013.

Field investigations occurred from February to October 2013 according to the procedures in the Ecology-approved SIWP, SI sampling and analysis plan (SAP) and SI quality assurance project plan (QAPP). Field elements in February to April 2013 included a well conditions survey, geophysical survey, laser-induced fluorescence probing (TarGOST®), geoprobe soil borings, shoreline well installation, monitoring well repair, a geotechnical investigation, petrophysical soil core collection, groundwater monitoring (well gauging, groundwater sampling, and NAPL sampling), NAPL baildown testing, slug testing and a professional survey of all wells and SI explorations. Field elements in October 2013 included groundwater monitoring (well gauging and groundwater sampling). This data report presents results of the investigation and deviations from the SIWP.

2.0 FIELD EXPLORATION METHODS

Several types of field exploration methods were used during the SI. Investigations were conducted sequentially, allowing refinement of later efforts using findings of the previous investigations. The field elements are presented in the table below, framed according to potential pathways evaluated.

Field Element	Season	Drill Rig Type	Source Character-ization	Leaching to Ground-water	Groundwater Transport to Sediment and Surface Water	NAPL Transport to Sediment and Surface Water
Well Conditions Survey	Spring	–	–	–	–	–
Monitoring Well Repair and Cap/Lock Replacement	Spring	–	–	–	–	–
Geophysical Survey (EM, Magnetic and GPR)	Spring	–	X	–	–	–
Laser Induced Fluorescence (TarGOST®)	Spring	Geoprobe with TarGOST®	X	X	–	X
Environmental Soil Borings, Subsurface Soil Sampling	Spring	Geoprobe	X	X	–	X
Shoreline Monitoring Well Installation and Development	Spring	Sonic	–	X	X	X
Geotechnical Drilling	Spring	Mud rotary/ sonic/HSA	–	–	–	–
Petrophysical Borings	Spring	Sonic	X		–	X
Groundwater Monitoring (Gauging, GW Sampling, NAPL Sampling)	Spring and fall	–	X	X	X	X
NAPL Baildown Testing	Spring to summer	–	–	–	–	X
Slug Testing	Spring	–	–	–	X	–
Professional Survey of All Monitoring Wells and SI Explorations	Spring	–	–	–	–	–

SI explorations are shown on Figure 2A-1 and noted below:

- Drilled explorations
  - TarGOST® borings (TG-01 through TG-46, TG-18B, and TG-42R)
  - Environmental soil borings (GEI-1 through GEI-15)
  - Geotechnical borings (GEO-1 through GEO-3)
  - Petrophysical borings (PT-01, PT-01B, PT-02, and PT-03)
  - Monitoring wells (MW-32S to MW-40S, MW-32D, MW36D, and MW-39D)
- Existing monitoring wells that were gauged, sampled, or both.

2.1. General Procedures

General field procedures for drilling, logging and sampling are discussed below. Specific methods for each field investigation element are discussed in Sections 2.2 to 2.9.

2.1.1. Drilling

Soil borings were drilled and logged with the following purposes:

- Collect soil samples for visual observation, field screening, and chemical analysis;
- Collect soil samples for physical properties testing to support geotechnical evaluations;
- Collect soil samples for petrophysical testing; and
- Install monitoring wells.

Drilling methods used include direct push, hollow-stem auger and sonic rotary (sonic). Drilling activities conformed to state and local regulations including Washington Administrative Code (WAC) 173-160, Minimum Standards for Construction and Maintenance of Wells. Before entering the GWPS, the drilling rigs and equipment were visually inspected for signs of contamination. Vehicles were inspected for fluid leaks before being allowed on-site. Only clean, unused sampling sleeves and bags were used. Management of investigation-derived waste (IDW) generated during drilling is discussed in Section 4. To avoid drilling through shallow utilities, including the Park's irrigation system, a post-hole digger was used to excavate the first 2 feet of soil at each location before drilling. Discrete soil samples were collected in laboratory-supplied containers and submitted for chemical analysis. Soil sampling strategy is described in Section 2.1.3.

2.1.1.1. Direct Push

Environmental soil borings were advanced using a track-mounted GeoProbe. The direct-push method uses hydraulically driven probes and a 4-foot soil sampler until reaching the planned boring depth or probe refusal. Soil sampler probes were lined with disposable acetate sleeves.

2.1.1.2. Sonic

Soil borings for monitoring well installation and petrophysical soil sampling were advanced using a track-mounted rotary sonic rig. The sonic drilling method advanced the borings by vibrating a steel casing and an internal sample barrel into the ground. Sonic drilling provided a continuous sample representative of subsurface conditions by advancing an inner sample barrel lined with a sample bag into the formation ahead of the casing.

In general, petrophysical and shallow monitoring well borings were advanced using a 6-inch casing for the first several feet, with a 4-inch casing advanced through a bentonite seal at the bottom of the 6-inch casing to the bottom of the boring. Deep monitoring well borings were drilled in a similar manner, except that a 10-inch casing was used in lieu of the 6-inch casing for the first several feet, and a 6-inch casing was used in lieu of the 4-inch casing to drill through the bentonite seal to the bottom of the boring.

2.1.1.3. Hollow-Stem Auger and Mud Rotary

Geotechnical borings were advanced using hollow-stem augers with or without mud rotary. Soil samples and geotechnical data were obtained by dropping a 140-pound or 300-pound hammer on a split-barrel sampler from a vertical distance of approximately 30 inches. The number of hammer blows required to advance the sampler the final 18 inches was recorded on the boring logs.

2.1.2. Borehole Logging

Lithology and field screening observations were recorded on the boring logs.

2.1.2.1. Lithologic Logging

As outlined in the SIWP, lithology was described in accordance with ASTM International (ASTM) D 2488 Standard Practice for Description and Identification of Soils and recorded on the boring logs. Percent recoveries, hammer blow counts, and sample depths were also recorded on the logs.

2.1.2.2. Field Screening

Soil samples were field-screened for evidence of possible contamination using four methods: visual screening, water sheen screening, headspace vapor screening, and shake test as described in the SIWP and below.

2.1.2.3. Visual Screening

Visual screening was performed as prescribed in the SIWP SAP. Soil samples, samplers, and gloves were observed for potential signs of contamination. Unusual odor, staining, color, and any other evidence of NAPL were recorded in the boring logs. Sidewalls of the sampling sleeves were observed for signs of staining. Wet material was observed for the nature of saturation and type of liquid (water or NAPL).

2.1.2.4. Water Sheen Screening and Headspace Vapor Screening

Water sheen screening and headspace vapor screening were performed as prescribed in the SIWP SAP.

Water sheen screening involved placing soil, approximately 1 cubic inch or about 1 tablespoon, in a black plastic pan partially filled with water and observing the water surface for signs of sheen.

Headspace vapor screening involved placing soil in a plastic bag, closing the bag and shaking the bag to expose soil vapors. The probe of a photoionization detector (PID) was then inserted into the bag and the PID measured the concentration of volatile organic vapors present within the sample bag headspace.

2.1.2.5. Shake Test

NAPL shake testing was performed on select samples where NAPL was suspected or observed to evaluate the presence, nature (i.e., DNAPL or LNAPL) and amount of NAPL present. A small volume of soil (5 to 10 grams) was removed from the sampler and placed in a small glass container (typical 4-ounce jar). Water was added until the container was approximately two-thirds full. The container was vigorously shaken until NAPL, if present, was displaced from the core matrix. The boring logs contain observations about staining and evidence of NAPL in the soil/NAPL/water solution; the shape and percent coverage of sheens on the surface of the solution was also recorded. The sidewalls of the jar were used to estimate the thickness of LNAPL on the water surface and the thickness of DNAPL accumulated at the bottom of the jar. The amount of sheen and blebs in the water surface was quantified using categories similar to those of the water sheen test. Naturally occurring sheen, which is often found in the field, was discerned from hydrocarbon sheen by its ability to dissolve or break up upon agitation. Results of the shake tests were characterized using the guidelines noted in the following table:

Appearance	Visual Description	Percent Coverage
Color and Shape of NAPL and Sheen Observations		
Rainbow	Multicolored	-
Metallic	Metallic gray-colored	-
Florets	Circular and multicolored	-
Blebs	Circular and black/brown	-
Streaks	Long and flowing shape	-
Sheen Classification		
None, trace	-	<2
Slight	-	2-15
Moderate	-	15-40
Moderate to heavy	-	40-70
Heavy	-	>70

2.1.3. Soil Sampling Strategy

Soil samples submitted for chemical analysis were placed into laboratory-supplied containers, lightly but securely packed and capped with a plastic lid. The samples were maintained on ice and delivered under chain-of-custody to the analytical laboratories Analytical Resources, Inc. (ARI) and PTS Laboratories. In general, soil samples were analyzed for benzene, toluene, ethylbenzene, and xylenes (BTEX); polycyclic aromatic hydrocarbons (PAHs); and arsenic, using the methods presented in the SAP. Some samples also were analyzed for alkylated PAHs.

Soil samples submitted for chemical analysis were primarily from subsurface soils rather than surface soils since most of the upland portion of the AOI has a vegetated cap. In general, samples were collected at the depth where the highest field screening impacts were observed and within the saturated zone; some of the samples targeted the water table and geologic horizons such as the Fill-native contact and top of Till.

Soil sampling was completed according to the SI SAP and QAPP. Field quality control (QC) samples collected include equipment rinsate blanks, trip blanks and field duplicates.

2.2. Monitoring Well Conditions Survey/Well Repair/Lock Replacement

An initial monitoring well survey was performed on February 27 and March 1, 2013 to identify existing, usable wells in the upland. Field staff recorded the condition of monuments and casings, signs of surface water infiltration, and sedimentation in the monitoring wells. Using an oil/water interface probe properly decontaminated between readings, field staff also recorded depth to groundwater, depth to LNAPL and DNAPL, and total monitoring well depth for all the usable wells except the multi-level sampler (MLS) wells.

Based on the well conditions survey, MW-17 was chosen for repair. The damaged flush-mount monument and surface seal were replaced to prevent surface infiltration. The repair was performed by Boart Longyear and GeoEngineers on March 2, 2013.

Lockable J-Plug well caps and keyed-alike padlocks were placed on May 13, 2013. On July 12, 2013, GeoEngineers replaced threaded bolts and repaired bolt holes with a heli-coil on all wells where they were missing.

The monitoring well survey, well repair and lock replacement was performed according to the SI SAP, except for the following:

- Multilevel sampler MLS-3 could not be located and was not surveyed.
- Monitoring wells PZ-5 and PZ-6, which had not been listed as potentially usable in the SI Work Plan, were located, surveyed, found to be in good condition and added to the list of usable monitoring wells.
- Monitoring well PZ-4 was discovered by GeoEngineers at the end of the spring investigation and was identified by using previous investigations maps (EPRI and PSE 1998). It was considered unusable because of a broken monument rim and clogged casing. Although considered neither repairable nor usable, it was not abandoned because of time constraints. Professional land surveyors surveyed the broken monument rim.

Bulk NAPL samples were not collected during the monitoring well conditions survey but rather during the spring groundwater monitoring event. However, small representative NAPL samples were collected during the monitoring well survey; these samples were submitted to Dakota Technologies, Inc. (Dakota) before mobilization for the spring TarGOST® drilling event to evaluate whether TarGOST® technology would be effective. Small NAPL samples (DNAPL from DW-4, DW-5, DW-7, and MW-18, as well as LNAPL from MW-9) were collected for TarGOST® readings using a disposable polycarbonate bailer and placed into 40-millileter (ml) volatile organic analysis (VOA) bottles before being sent to Dakota. LNAPL but not DNAPL was collected from monitoring well MW-09; the disposable polycarbonate bailer could not displace the viscous LNAPL on the surface of the groundwater to reach the deeper DNAPL.

2.3. Geophysical Investigation

Non-intrusive geophysical surveys were completed from March 5 through 8, 2013, using magnetic (MAG), electromagnetic (EM) and ground penetrating radar (GPR) technologies. Areas surveyed are shown in Figure 2A-2. The information obtained from the geophysical surveys was used to identify areas of potential anomalies for subsequent TarGOST® explorations and soil borings. Zonge International, Inc. (Zonge) conducted the geophysical survey. The draft report is included as Attachment 2A-1 to this appendix.

The geophysical surveys were completed using the procedures presented in the SI SAP, except that GPR was used where above-grade metal objects such as historical MGP structures and fences created interference (i.e., near MW-09 and the Northeast Corner). Penetration depth using GPR was limited to 2 to 3 feet in these areas because higher conductivity soils were encountered (Attachment 2A-1).

2.4. Laser Induced Fluorescent Investigation (TarGOST®)

TarGOST® was used for the following reasons:

- To evaluate areas where NAPL or tar has been encountered or suspected;
- To further delineate the extent of NAPL impacts in areas of limited data along the shoreline, or in historical or potential current source areas;

- To better locate soil borings; and
- To assess anomalies identified by the geophysical surveys.

TarGOST® explorations were performed from March 18 through 26, 2013 in locations shown on Figure 2A-1. The TarGOST® report, TarGOST® logs and accompanying material are in Attachment 2A-2.

In accordance with the SI SAP, the TarGOST® system was advanced with a GeoProbe. Dakota's fiber optic cables were strung through the driller's rods; the TarGOST® tip along with the rods were advanced into the ground with the rig. Depth was tracked with a string potentiometer system connected to the direct push rig and computer.

Forty-five TarGOST® explorations (TG-1 to TG-45) and two collocated explorations (TG-12R/46 and TG-42R) were advanced during the SI. In each area of proposed TarGOST® exploration, as designated in the SIWP, a primary TarGOST® exploration was drilled. Decisions regarding secondary and offset locations were based on observed TarGOST® response in, respectively, primary and secondary locations, as well as on time and spatial constraints (Figure 2A-1).

The TarGOST® investigation was conducted according to the SI SAP, except as noted below:

- DNAPL samples collected from monitoring wells DW-04, DW-05, DW-07 and MW-18, and a LNAPL sample collected from MW-09 were submitted to Dakota for evaluation of NAPL response to the laser-induced fluorescence (LIF) technology.
- Additional TarGOST® explorations near MW-18 were completed to further investigate NAPL observed in the well during the monitoring well survey.
- Additional TarGOST® explorations were completed along the eastern shoreline to compare LIF responses with NAPL observations from the Eastern Shoreline study in 2007 (AECOM 2008).
- An additional round of step-out TarGOST® explorations was advanced, noted as offset TarGOST® locations in Figure 2A-1. The need for offset/step-out explorations was determined from the observed degree of TarGOST® response in the primary and secondary TarGOST® explorations.
- Two pairs of collocated TarGOST® explorations were completed to evaluate response variability. TG-12R/46 and TG-42R were located adjacent to TG-12 and TG-42, respectively.
- Electrical conductivity (EC) was measured and recorded using TarGOST® at 19 explorations. The objective was to determine whether EC data correlated with geology and NAPL occurrence. Acceptable EC data are found in the logs for explorations TG-03 to TG-13, TG-17 to TG-18B and TG-33 to TG-37.
- Six confirmation borings were completed next to TarGOST® explorations. Selected interval depths were submitted to Dakota for signal (%RE) analysis, enabling comparison of fluorescence of individual soil samples with that of in-situ cores.
- Two locations (TG-18B and TG-32B) had to be re-drilled near the locations specified in the SI SAP because the first attempts met shallow refusal.
- Some depth intervals within certain TarGOST® borings had unreliable %RE responses, due to either pre-probing or broken fibers in the probe tip. These intervals, which have been excluded from the NAPL data set, include the following: TG-18B (15 to 15.6 feet), TG-33 (0 to 4.5 feet), TG-41 (0 to 10 feet), TG-18 (8 feet to total depth), TG-32B (0 to 10 feet), and TG-34 (0 to 2 feet).

2.5. Environmental Soil Borings

Fifteen environmental borings (GEI-1 to GEI-15) were completed from March 27 through April 2, 2013. Soil borings were drilled at the locations shown on Figure 2A-1. Boring logs are included in Attachment 2A-3. Photographs of the soil cores are included in Attachment 2A-4.

The general sampling strategy presented in Section 2.1.3 was followed for the GEI locations. In addition, for TarGOST® confirmation samples, soil borings were performed adjacent to TarGOST® explorations where various low and high %RE values were observed in order to evaluate TarGOST® response with respect to NAPL presence. The depth interval was specified to match a distinct TarGOST® response. Tests conducted on the soil samples are summarized in Table 2A-1. Analytical results are presented in Section 3.

The environmental soil borings were completed according to the SI SAP.

2.6. Shoreline Monitoring Well Installation

Monitoring wells were installed between March 25 and April 12, 2013 along the shore of the GWPS. This activity was undertaken to evaluate upland-to-sediment pathways, complete the monitoring well network along the entire shoreline and obtain additional information regarding groundwater conditions.

2.6.1. Monitoring Well Construction

Twelve shoreline monitoring wells were installed (MW-32S to MW-40S, MW-32D, MW-36D, and MW-39D) (Figure 2A-1). Three well pairs were installed, as shallow (MW-32S, MW-36S, and MW-39S) and adjacent deep (MW-32D, MW-36D, and MW-39D) wells. Well construction details for the newly installed monitoring wells are presented in Table 2A-2. Wells logs are included in Attachment 2A-3. Photographs of the soil cores are included in Attachment 2A-4.

In addition to the general soil sampling strategy presented in Section 2.1.3, emphasis was placed on targeting the saturated zone. Soil samples were collected at depths corresponding to the screen interval of each monitoring well. Composite soil samples representing the entire length of the screen interval were collected for grain size analysis.

The monitoring wells were constructed with 2-inch-diameter, Schedule 40 threaded polyvinyl chloride (PVC) riser and machine-slotted well screens. Shallow well screens have 0.010-inch-wide slots. Deep well screens have 0.020-inch-wide slots. PVC end caps were installed on the bottom ends of the well screens. Wells monitoring the groundwater table were constructed with screens 3 to 10 feet long. Shallow wells were constructed with 20/40 silica sand filter to limit entry of fine-grained particulates from the surrounding formation into the wells. Deep wells were constructed with 10/20 silica sand filter. In monitoring wells MW-32D and MW-39D, 20/40 silica sand was installed near the top of the sand filter to prevent bentonite intrusion into the sand filter. The sand filter extends from the bottom of the well screen to at least 1 foot above the top of the well screen. Annular seals consist of a minimum 1-foot-thick layer of hydrated bentonite pellets or chips installed between the filter pack and the concrete surface seal. Wells were completed using flush-mounted monuments installed in a concrete surface seal to prevent surface water from infiltrating the well. Each monitoring well was secured with an expandable well cap (J-plug) and corrosion-resistant lock.

Deep wells were drilled through the Fill unit into underlying glacial deposits using conductor casing to avoid cross-contamination, as noted on the deep well logs. The temporary conductor casing was installed no deeper than 1 foot above the depth of the deep well screen.

A summary of the SI wells installed is presented in Table 2A-2. Analytical results for soil samples collected are presented in Section 3.

2.6.2. Well Development

The new monitoring wells were developed 24 hours or more after installation, using a combination of surging and purging until at least five well casing volumes of water were removed from each well and turbidity was stabilized at less than the target of approximately 10 nephelometric turbidity units (NTU). Water quality parameters (e.g., temperature, pH, conductivity, turbidity) were measured and recorded during well development.

2.6.3. Deviations from Work Plan

Shoreline monitoring wells were completed and developed using the procedures in the SI SAP. There were no deviations from the work plan.

2.7. Kite Hill Geotechnical Investigation

Geotechnical drilling at Kite Hill was performed on April 11 and 12, 2013, to evaluate slope stability in anticipation of placing an engineered, vegetated soil cover on this portion of the AOI.

Three geotechnical borings (MW-32D/GEO-1, GEO-2, and GEO-3) were drilled. Boring logs are included in Attachment 2A-3. Photographs of the soil cores are included in Attachment 2A-4. Soil samples from three borings were collected and submitted to ARI for geotechnical testing. The laboratory tests completed included grain-size distribution (ASTM D422) and percent fine content (ASTM D1140). The laboratory report is included in Attachment 2A-5.

As discussed in Section 2.6, soil samples for chemical analyses were obtained from boring MW-32D/GEO-1. Boring MW-32D/GEO-1 was also completed as a shoreline monitoring well.

2.7.1. Deviations from Work Plan

The geotechnical investigation was completed according to the SI SAP, except for the following:

- Geotechnical borings were drilled using hollow-stem augers rather than mud rotary as planned. Mud rotary was proposed for installation of these wells because of concerns regarding heaving sands identified in previous borings drilled nearby; however, the mud rotary rig was heavy and concerns were raised regarding possible damage to the Park’s turf. In addition, mud was lost down-hole. These borings were completed successfully using hollow-stem augers. Soil sampling with a split-barrel sampler was performed as planned in the SI work plan.
- Atterberg limits testing was not performed because the samples collected were not sufficiently fine-grained. Soil samples for geotechnical testing were submitted to ARI for testing because of potential chemical contamination in the samples.

2.8. Petrophysical Investigation

The presence of NAPL in the AOI upland was evaluated during the SI in a petrophysical investigation on April 17 through 19, 2013. Four petrophysical borings (PT-01, PT-01B, PT-02, and PT-03) were completed (Figure 2A-1). Boring logs are included in Attachment 2A-3.

PT-01B was drilled because of poor recovery in PT-01. PT-02 was located on the eastern shoreline where NAPL was observed in SI explorations MW-36S, MW-36D, and TG-42R. PT-03 was located near the shoreline of Harbor Patrol where NAPL was observed in SI explorations GEI-14 and TG-20.

Undisturbed soil cores for petrophysical testing collected from the soil borings (in 4-inch-diameter polycarbonate Lexan™ sleeves) were immediately placed on dry ice and stored vertically. Cores were cut to 2.5-foot lengths, packed with dry ice and in large coolers and shipped to the lab. Cores were submitted for core photography (ASTM D5079) and free product mobility testing (ASTM D425M, Dean Stark). Petrophysical soil tests performed are summarized in Table 2A-3. Analytical results are presented in Section 3. Petrophysical laboratory reports are provided in Attachment 2A-6.

2.8.1. Deviations from Work Plan

The petrophysical investigation was completed according to the SI SAP, with one exception. Petrophysical borings were advanced using sonic drilling instead of hollow-stem augers. Samples were collected using a decontaminated split-spoon sampler. The sampling device was 5 feet long, with an inner diameter of 3.5 inches, an outer diameter of 3.75 inches and a clear polycarbonate Lexan™ tube liner.

2.9. Groundwater Monitoring

Two groundwater monitoring events were completed with a threefold purpose:

- Measure groundwater depths and evaluate groundwater elevations and gradients,
- Measure NAPL depths and thicknesses in wells where present, and
- Collect groundwater analytical data to evaluate the vertical and lateral extent of chemicals of concern at the shoreline and to estimate flux at the Lake Union shoreline.

Monitored wells are mapped on Figure 2A-1.

2.9.1. Groundwater and NAPL Measurements

Before the spring (April 22, 2013) and fall (October 14, 2013) groundwater monitoring events, depth-to-water measurements were recorded within a single 12-hour period from usable monitoring wells located in upland. After wells were opened to vent, depth to groundwater and total monitoring well depth were measured to the nearest 0.01-foot using a decontaminated interface probe. Groundwater elevations were used as the basis for groundwater contour figures in the RI. Depth to groundwater was not measured at MLS locations.

Wells from the adjacent Metro site also were measured and sampled in coordination with the SI (Arcadis 2013a, b). Depth-to-water measurements from monitoring wells MLU-1, MW-4 and MW-7 on the Metro site were incorporated in the RI evaluations. Water level measurements are included in Table 2A-6.

The depth and thickness of NAPL were measured and recorded during both groundwater monitoring events (April and October 2013). Results are presented in Table 2A-5.

2.9.2. Groundwater Sampling – Spring

The spring groundwater monitoring event occurred April 15 through 25, 2013. Monitoring wells and multi-level samplers included in the monitoring activities and analyses performed are listed in Table 2A-7. Depth-to-water measurements and groundwater elevations are presented in Table 2A-6. Analytical results are included in Attachment 2A-9. In summary:

- Excluding monitoring wells with NAPL, all other usable wells were sampled, for a total of 54 wells.
- Six of the total wells sampled are MLS wells, each consisting of three to five individual sampling ports targeting different depths.
- Groundwater samples were collected from 67 wells and ports.

Groundwater samples were obtained using the techniques outlined in the SIWP SAP. The samples were placed into a cooler with ice and logged on the chain-of-custody. Samples were submitted for analyses of BTEX and PAHs.

Groundwater analytical results are discussed in Section 3.

2.9.3. NAPL Sampling- Spring

Bulk NAPL samples were collected in April 2013. A summary of NAPL tests conducted is included in Table 2A-4. NAPL physical testing included density, specific gravity and kinematic viscosity using methods API RP40, ASTM D1481 and ASTM D445. Chemical analyses included expanded PAH analysis (43 alkyl-PAHs using SW-846 8270 with selective ion monitoring [SIM]) and volatile organic compounds (VOCs) using EPA 8260C.

2.9.4. Groundwater Sampling – Fall

The fall groundwater monitoring event occurred October 14 through 18, 2013. Monitoring wells and multi-level samplers included in the monitoring activities and analyses performed are presented in Table 2A-7. Depth-to-water measurements and groundwater elevations are presented in Table 2A-6. In summary:

- Shoreline monitoring wells plus two inland wells were sampled, for a total of 24 wells.
- One MLS well with three ports was sampled.
- Field-filtered and non-filtered samples were collected at all the shoreline wells and ports, and analyzed for PAHs, arsenic, BTEX or a combination thereof.

Shallow and deep shoreline monitoring wells were sampled to evaluated upland flux to Lake Union. Field-filtered samples were collected at MW-03 and MW-03D and analyzed for arsenic. This information was used to provide information regarding background concentrations of arsenic.

In addition to field-filtering, sample collection procedures were the same as those used in the spring groundwater sampling event. Unfiltered samples were submitted for analyses of BTEX and PAHs. Field-filtered samples were submitted for analysis of PAHs and dissolved arsenic (Table 2A-7). Groundwater analytical results are discussed in Section 3.

2.9.5. Deviations from Work Plan

Groundwater sampling was completed according to the SI SAP, except as noted below:

- Four of the spring groundwater samples were filtered in the laboratory using a 0.7-micron borosilicate glass fiber filter before being analyzed for PAHs, as outlined in Table 2A-7. This procedure was a last-minute addition to the regular unfiltered PAH analysis for all wells, with the goal of deciphering the effect of filtering on PAH concentrations.
- Fall groundwater sampling included collection of field-filtered groundwater samples for PAHs. PAH samples were also collected using traditional (non-filtered) methods. This change was verbally approved by Ecology in September 2013.
- Fall groundwater samples were analyzed for dissolved arsenic, elevated concentrations of arsenic having been measured in soil collected the prior spring. This change was verbally approved by Ecology prior to sampling in October 2013.

2.10. NAPL Baildown Testing

The presence of NAPL in the AOI upland was evaluated during the SI using NAPL baildown testing between April 29 and October 14, 2013.

A baildown test was performed in monitoring well MW-09, which contained a layer of LNAPL greater than 1-foot-thick. The LNAPL baildown test was completed using a decontaminated disposable polycarbonate bailer to remove as much product as possible, taking care to minimize the volume of water removed from the monitoring well. After LNAPL was removed from the monitoring well to the maximum extent practicable, an oil-water interphase probe was used to measure the depth to water and thickness of product until at least 80 percent of the initial thickness of LNAPL was recovered. Initial measurement intervals were within minutes. Eventually, measurement intervals were extended to 3 weeks because recovery was slow. A data logger placed in the well was programmed to record hydrostatic submergence pressure 8 times per second, supplementing the manual interface probe readings.

There were two deviations from the work plan:

- Although thicknesses of NAPL greater than 1 foot were encountered in at least five wells, NAPL baildown tests were performed only in MW-9. The test could not be performed in the other four wells for at least one of the following reasons: the DNAPL was too viscous, the DNAPL was not thick enough or the screen was clogged.
- A data logger was placed in the well to supplement the manual interface probe readings. It was programmed to record hydrostatic submergence pressure 8 times per second.

2.11. Slug Testing

Slug tests were performed on seven monitoring wells near the shoreline on April 24 and 25, 2013, to evaluate hydraulic conductivity (*K*) of the water-bearing units. The monitoring wells tested and estimated hydraulic conductivity values are presented in Attachment 2A-7.

The slug tests were consistent with the procedures in the SI work plan, with the following exceptions:

- Falling head tests were performed on some monitoring wells whose screened interval was partly above the water table. For wells with screened intervals spanning the water table, falling-head test data are not representative of aquifer response because some of the displaced water drains into the unsaturated zone above the water table. Data from these wells were not used in analysis.

2.12. Professional Survey

All SI explorations (including locations where refusal was encountered or multiple attempts were made) were surveyed on April 25, 2013 by the Washington-licensed professional land surveyor True North Land Surveying of Seattle Washington. All existing monitoring wells were surveyed by True North on April 29, 2013.

Locations were surveyed for X-Y-Z coordinates (Z for monitoring wells included both monument rim elevation as ground surface and top-of-casing/PVC). The horizontal accuracy of the wells and soil borings was 0.1 feet. The vertical accuracy of the soil borings was 0.1 feet. Vertical accuracy of the monitoring wells was 0.01 feet.

Elevations were referenced to U. S. Army Corps of Engineers (USACE) (Locks) datum and North American Vertical Datum of 1988 (NAVD88). Horizontal coordinates were referenced to the NAD 83, Washington State Plane North coordinate system. Survey results are included on boring and well logs (Attachment 2A-3).

Procedures for professional surveying outlined in the SAP were followed, except that the vertical accuracy of the soil borings was 0.1 foot, not 0.01 foot as specified in the SAP.

3.0 RESULTS

This section presents results from the 2013 SI. Because the data have been integrated into the main RI, the results are not discussed in detail in this appendix.

3.1. Monitoring Well Conditions Survey/Well Repair/Lock Replacement

The following observations were made during the monitoring well conditions survey and ensuing activities:

- The monument for monitoring well MW-17 was damaged, potentially allowing surface water infiltration. The monument was replaced during the SI.
- The casing for monitoring well MW-28 was too high and prevented the monument from closing properly when secured with a J-plug and lock. During the SI, the casing elevation was reduced from 34.35 feet to 34.24 feet relative to USACE datum.
- Monitoring well PZ-4 was considered unusable because of a broken monument rim and clogged casing. It was not sampled, developed, or gauged.
- J-plug type caps were placed on all existing wells at the site, where possible.
- Locks were replaced on all existing wells at the site, with keyed-alike padlocks.

Overall, 42 existing monitoring wells and seven MLS wells were considered usable. Well gauging information from the well survey is included in Table 2A-6. Wells considered usable are depicted on Figure 2A-1. Measured groundwater elevations and NAPL thicknesses in existing wells are included in Tables 2A-5 and 2A-6.

3.2. Geophysical Results

The draft geophysical report is presented in Attachment 2A-1. Although large anomalies indicative of buried tanks or structures were not found, anomalies A through J (Figure 2A-2) were identified as locations for further sampling or drilling. The anomalies can be divided into four categories:

- High conductivity soils,
- Magnetic anomalies,
- EM anomalies indicative of scattered metallic debris, and
- Linear anomalies indicative of pipe, cables, or other utilities.

An extended geophysical interpretation overlaying former MGP structures is presented in Figure 2A-2. Appendix 1B to the RI reviews geophysical anomalies in conjunction with historical documents.

3.3. TarGOST® Results

Six confirmation borings were completed next to TarGOST® explorations. Comparison figures including NAPL observations from the confirmation borings alongside the nearby TarGOST® logs are presented in Attachment 2A-2 Figures A2-1 to A2-7. Several types of TarGOST® data were generated during and after the SI:

- LIF responses to NAPL samples
- TarGOST® logs (consistent scale)
- TarGOST® logs depicting mirror images of the primary TarGOST® exploration and collocated exploration (referred to as butterfly logs)
- Table showing electrical conductivity measurement success, per log
- LIF responses to soil samples
- Classification plots for TarGOST® logs, soil samples and NAPL samples
- Non-negative least squares (NNLS) waveform analysis for TarGOST® logs and soil samples

The data are included and discussed in Attachment 2A-2. The results are also discussed in the main body of the RI and in the “NAPL Evaluation” (RI Appendix 5F).

3.4. Geotechnical Testing Results

Geotechnical laboratory tests were performed by ARI, located in Tukwila, Washington. Selected soil samples were tested for grain size (ASTM Method D422) and percent fines (greater than U.S. No. 200 sieve; Method ASTM D1140). Geotechnical laboratory reports are included in Attachment 2A-5.

3.5. Petrophysical Results

Petrophysical and NAPL physical laboratory tests were performed by PTS Laboratories Inc., located in Santa Fe Springs, California. Soil cores were tested for free product mobility using ASTM Method D425M, Dean-Stark. NAPL samples from monitoring wells were tested for kinematic viscosity and density by Methods ASTM D445, ASTM D1481 and API RP40.

Petrophysical and NAPL test results are summarized in Tables 2A-3 and 2A-4, respectively. The laboratory reports are included in Attachment 2A-6. Petrophysical results are discussed in the main body of the RI and in Appendix 5F.

3.6. NAPL Baildown Testing Results

NAPL recovery rates were low and the methods developed by Huntley (2000) and Kirkman (2012) to interpret the NAPL baildown measurements and calculate NAPL transmissivity could not be used. LNAPL transmissivity is a measure of the potential flux of LNAPL per unit drawdown, or the volume of LNAPL travelling through a unit width of an aquifer per unit time per unit drawdown (units of length squared per time). NAPL baildown results and interpretation are presented in Attachment 2A-8 and in Appendix 5F of the RI.

3.7. Slug Testing Results

Slug test results are presented in Attachment 2A-7. Plots of the slug test response and type curves analyzed are presented in Figures A7-1 through A7-7. Table A7-1 shows interpreted hydraulic conductivity values. Slug test results are discussed in Section 5 of Appendix 3E.

3.8. Chemical Results

Selected soil, groundwater and NAPL samples were submitted for chemical and physical analyses. This section presents a summary of analyses and tests performed. Laboratory reports and chain-of-custody reports are available in Attachments 2A-9 and 2A-6, respectively. Chemical results are discussed in more detail in Section 8 of the RI.

3.8.1. Soil

Chemical analyses on selected soil samples were performed by ARI for the following chemical constituents:

- BTEX by EPA Method 8260 (low level),
- PAHs by EPA Method 8270 SIM (low level),
- Arsenic by EPA Method 200.8, and
- Polychlorinated biphenyls (PCBs) by EPA Method 8082 (low level).

The analyses performed on soil samples are listed in Table 2A-1. The laboratory reports are shown in Attachment 2A-9. Soil results are discussed in the main body of the RI.

3.8.2. Groundwater

Chemical analyses of selected groundwater samples collected during the 2013 spring and fall groundwater monitoring events were performed by ARI. As noted in Section 2.9.5, some of the samples were filtered in the laboratory; others had been filtered in the field. The samples were submitted for the following analyses:

- Spring
  - BTEX by EPA Method 8260 (low level) and
  - PAHs by EPA Method 8270 SIM (low level), including the subset of samples that were lab-filtered.
- Fall
  - BTEX by EPA Method 8260 (low level),
  - PAHs by EPA Method 8270 SIM (low level), including the subset of samples that were field-filtered, and
  - Arsenic by EPA Method 200.8.

Analyses performed are listed in Table 2A-7. The laboratory reports are included in Attachment 2A-9. Results are discussed in the main body of the RI.

3.8.3. NAPL

Chemical analyses of NAPL were performed by ARI. NAPL samples from monitoring wells were submitted for the following analyses:

- PAHs and alkylated PAHs by EPA Method 8270 SIM,
- BTEX by EPA Method 8260 (low level), and
- VOCs and semivolatile organic compounds (SVOCs) by EPA Method 8260 (low level).

NAPL analyses performed are listed in Table 2A-4. The laboratory reports are included in Attachment 2A-9. NAPL results are discussed in the main body of the RI.

4.0 DECONTAMINATION PROCEDURES AND INVESTIGATION DERIVED WASTE

Decontamination was performed using procedures outlined in the SIWP SAP, with a minor modification: if residual NAPL was present or had been encountered, equipment was pre-cleaned with acetone or isopropyl alcohol and rinsed with hexane followed by the detergent wash and rinse.

IDW, including soil cuttings, groundwater, decontamination water, disposable sampling supplies and disposable personal protective equipment, was placed in labeled 55-gallon steel drums. The drums were sealed, chained to each other and stored several feet from structures within the Cracking Towers fenced area during the SI field activities. Composite drum samples were collected and analyzed for waste profile purposes.

Forty-nine drums of IDW were generated during the 2013 SI. On June 17, 2013, Kleen Environmental removed 47 drums for disposal at an approved offsite disposal facility. On November 25, 2013, Kleen Environmental removed the remaining two drums for disposal at an approved offsite disposal facility.

5.0 REFERENCES

Arcadis. 2013a. Groundwater Monitoring Report 2013, Former Chevron Bulk Plant No. 100-1327, Facilities North/King County (METRO), Seattle, Washington.

Arcadis. 2013b. Person communication (email from Samuel Miles, Arcadis, to Maura O'Brien, Washington State Department of Ecology, regarding up-to-date gauging data for KC Metro project [three tables]).

Electric Power Research Institute and Puget Sound Energy. 1998. Fate and Transport Assessment of Polycyclic Aromatic Hydrocarbons from Tar. Gas Works Park MGP Site.

GeoEngineers, Inc. 2013. Supplemental Investigation Work Plan, Gas Works Park Site, Seattle, Washington.

Huntley. 2000. "Analytic Determination of Hydrocarbon Transmissivity from Baildown Tests, Ground Water." 38 (1).

Kirkman. 2012. Refinement of Bouwer-Rice Baildown Test Analysis, Ground Water Monitoring & Remediation.

Washington Department of Ecology. 2005. Agreed Order DE 2008—Gas Works Park Sediment Site issued to the City of Seattle and Puget Sound Energy. State of Washington Superior Court.

Washington Department of Ecology. 2013. Approval of Request to Amend Agreed Order DE 2008--Gas Works Park Sediment Site.

Table 2A-1

Supplemental Investigation Soil Testing Summary

Gas Works Park Site
Seattle, Washington

Sample ID	Sample Depth (feet bgs)	Date	PAHs	Alkylated PAHs	BTEX	Arsenic	PCBs	Grain Size	Percent Fines
			EPA Method 8270 SIM	EPA 8270 SIM	EPA Method 8260 (Low level)	EPA 200.8	EPA 8082 (low level)	ASTM D422	ASTM D1140
GEI-1	0 to 3	4/01/13					X		
GEI-1	7 to 7.5	4/01/13					X		
GEI-1	12 to 12.5	4/01/13	X				X		
GEI-1	16.5 to 17	4/01/13	X		X		X		
GEI-1	17 to 17.5	4/01/13					X		
GEI-1	23 to 24	4/01/13	X		X		X		
GEI-2	0 to 3	4/01/13	X		X				
GEI-2	16 to 17	4/01/13	X		X				
GEI-2	5 to 6	4/01/13	X		X				
GEI-3	11.5 to 12	3/27/13		X	X	X			
GEI-3	16 to 17	3/27/13		X	X	X			
GEI-3	2 to 3	3/27/13				X			
GEI-3	22 to 23	3/27/13		X	X	X			
GEI-3	27 to 28	3/27/13	X		X				
GEI-3	8 to 9	3/27/13				X			
GEI-4	.5 to 1.5	3/27/13				X			
GEI-4	10 to 11	3/27/13				X			
GEI-4	15 to 16	3/27/13	X		X	X			
GEI-4	20 to 21	3/27/13				X			
GEI-4	30 to 31	3/27/13	X		X				
GEI-4	5.5 to 7	3/27/13	X		X	X			
GEI-5	1.5 to 2	3/28/13				X			
GEI-5	15 to 16	3/28/13	X		X				
GEI-5	5 to 7	3/28/13	X		X	X			
GEI-5	10 to 10.5	3/28/13				X			
GEI-5	22 to 23	3/28/13				X			
GEI-6	10 to 12.5	3/28/13	X		X				
GEI-6	20 to 21	3/28/13	X		X				
GEI-6	25 to 26	3/28/13	X		X				
GEI-6	5.5 to 6	3/28/13				X			
GEI-7	12 to 14	3/28/13	X		X				
GEI-7	20 to 21	3/28/13	X		X				
GEI-8	4 to 4.5	4/01/13	X		X				
GEI-8	5 to 6	4/01/13	X		X				
GEI-8	8.5 to 9.5	4/01/13	X		X				
GEI-9	11 to 11.5	4/01/13	X		X				
GEI-9	16 to 17	4/01/13	X		X				
GEI-10	2 to 3	3/29/13	X		X				
GEI-10	6.5 to 7.5	3/29/13	X		X				
GEI-11	16 to 17	3/29/13	X		X				
GEI-11	21.5 to 22.5	3/29/13	X		X				
GEI-11	26 to 26.5	3/29/13	X		X				
GEI-12	11 to 15	3/29/13	X		X				
GEI-12	15 to 17	3/29/13	X		X				
GEI-12	25 to 26	3/29/13	X						
GEI-12	5 to 7	3/29/13	X		X				
GEI-13	13 to 16	4/01/13		X	X				
GEI-13	23.5 to 24.5	4/01/13		X	X				
GEI-13	25 to 25.5	4/01/13	X		X				
GEI-13	8 to 9.5	4/01/13		X	X				
GEI-14	14.5 to 15.5	4/02/13		X	X				
GEI-14	27 to 28	4/02/13		X	X				
GEI-14	37 to 38	4/02/13	X		X				
GEI-14	8 to 9	4/02/13		X	X				
GEI-15	0 to 2	4/02/13	X		X				
GEI-15	12.5 to 13.5	4/02/13	X		X				

Sample ID	Sample Depth (feet bgs)	Date	PAHs	Alkylated PAHs	BTEX	Arsenic	PCBs	Grain Size	Percent Fines
			EPA Method 8270 SIM	EPA 8270 SIM	EPA Method 8260 (Low level)	EPA 200.8	EPA 8082 (low level)	ASTM D422	ASTM D1140
GEI-15	6.5 to 7	4/02/13	X		X				
GEO-2	14 to 16	4/11/13						X	
GEO-2	19 to 20.5	4/11/13							X
GEO-2	24 to 26	4/11/13						X	
GEO-2	34 to 36	4/11/13						X	
GEO-2	39 to 40.5	4/11/13						X	
GEO-2	44 to 44.5	4/11/13						X	
GEO-2	9 to 10.5	4/11/13						X	
GEO-3	15 to 17	4/12/13						X	
GEO-3	20 to 21.5	4/12/13						X	
MW-32D/GEO-1	10.5 to 12.5	4/10/13						X	
MW-32D/GEO-1	16.5 to 18	4/10/13						X	
MW-32D/GEO-1	18.5 to 20.5	4/10/13						X	
MW-32D/GEO-1	20.5 to 22.5	4/10/13						X	
MW-32D/GEO-1	22.5 to 24	4/10/13							X
MW-32D/GEO-1	26.5 to 28	4/10/13							X
MW-32D/GEO-1	28.5 to 30.5	4/10/13						X	
MW-32D/GEO-1	35.5 to 37	4/10/13						X	
MW-32D/GEO-1	42 to 43	4/10/13							X
MW-32D/GEO-1	8.5 to 10.5	4/10/13							X
MW-32D/GEO-1	43.5 to 44.5	4/12/13	X		X	X		X	
MW-32S	29 to 30	4/12/13	X		X	X		X	
MW-33S	12 to 22	3/28/13						X	
MW-33S	13 to 14	3/28/13	X		X				
MW-33S	17 to 17.5	3/28/13	X		X	X			
MW-34S	5 to 10	3/27/13						X	
MW-34S	7 to 8	3/27/13	X		X	X			
MW-35S	4.5 to 5	3/27/13				X			
MW-35S	4 to 7	3/27/13						X	
MW-35S	5 to 6	3/27/13	X		X				
MW-36D	23 to 24	3/28/13	X		X				
MW-36D	29 to 33	3/29/13						X	
MW-36D	31 to 32	3/29/13	X		X	X			
MW-36S	14 to 15	3/29/13	X		X	X			
MW-36S	22.5 to 23	3/29/13				x			
MW-36S	14 to 21	3/29/13						X	
MW-37S	.5 to 1	3/26/13				X			
MW-37S	7.5 to 20	3/26/13						X	
MW-37S	7.5 to 8	3/26/13				X			
MW-37S	8 to 9	3/26/13	X		X				
MW-37S	13.5-14.5	3/26/13				x			
MW-38S	3.5 to 13.5	3/25/13							
MW-38S	.5 to 1	3/26/13				X			
MW-38S	10 to 11	3/26/13				X			
MW-38S	5 to 15	3/26/13						X	
MW-38S	8 to 9	3/26/13	X		X				
MW-39D	.5 to 1.5	3/25/13				X			
MW-39D	8 to 10	3/25/13	X		X	X			
MW-39D	16 to 19	3/26/13						X	
MW-39D	17 to 18	3/26/13	X		X	X			
MW-39S	3.5 to 13.5	3/25/13						X	
MW-40S	17.5 to 18	4/01/13	X		X				
MW-40S	5 to 10	4/01/13						X	
MW-40S	5 to 6	4/01/13	X		X	X			

Table 2A-2

Supplemental Investigation Monitoring Well Construction Details

Gas Works Park Site

Seattle, Washington

Well ID	Installation Date	Diameter (inches)	Screen slot size (inches)	Well Location		Ground Surface Elevation	Current TOC Elevation	Total Depth (feet, TOC)	Screen Interval Depth (feet, bgs)		Geologic Unit of Screen Interval[a]
				Northing	Easting				Top	Bottom	
MW-32D	4/12/2013	2	0.02	238868.03	1269843.30	29.9	29.4	47.0	42.0	47.0	Qva
MW-32S	4/12/2013	2	0.01	238864.97	1269847.34	29.8	29.3	31.5	16.5	31.0	Fill
MW-33S	3/28/2013	2	0.01	238748.97	1270318.67	38.7	38.3	22.1	13.0	22.0	Fill
MW-34S	3/27/2013	2	0.01	238734.93	1270501.78	28.4	28.0	9.8	5.0	9.8	Fill
MW-35S	3/27/2013	2	0.01	238807.89	1270634.86	24.7	24.1	7.0	4.0	6.8	Fill
MW-36D	3/28/2013	2	0.02	239091.49	1270785.63	30.0	29.6	33.7	29.3	33.8	Qvr
MW-36S	3/29/2013	2	0.01	239086.77	1270783.61	30.1	29.6	12.9	8.0	22.8	Fill
MW-37S	3/26/2013	2	0.01	239231.18	1270816.75	27.1	26.9	14.8	5.1	14.8	Fill
MW-38S	3/26/2013	2	0.01	239318.10	1270820.88	25.9	25.4	16.9	7.1	16.6	Fill
MW-39D	3/25/2013	2	0.02	239391.05	1270814.56	27.0	26.7	22.5	17.0	21.8	Qva/Qpgt
MW-39S	3/25/2013	2	0.01	239397.29	1270814.09	26.9	26.6	14.1	3.9	14.1	Fill
MW-40S	4/1/2013	2	0.01	239491.03	1270790.39	25.7	25.2	10.9	4.0	10.9	Fill

Notes:

Elevation based on:

Horizontal Datum: NAD83 WA State Plane North.

Vertical Datum: US Army Corps of Engineers.

[a] Some screen intervals cross more than one geologic unit. Units listed here are the same as those assigned by Aspect in their groundwater modeling report, with the exception of MW-9, which was formerly interpreted as being screened across Qpgt (Aspect 2012).

Qpgt: Pre-Fraser Till

Qva: Vashon Advance Outwash

Qvr: Vashon Recessional Outwash

TOC: top of casing

Table 2A-3

Supplemental Investigation Petrophysical Testing Summary

Gas Works Park Site
Seattle, Washington

Boring/ Location	Sample ID	UV Photography Core Sample Depth (ft bgs)	Within Core Sample Depth (ft bgs)	Field Observation	Sheen	Free Product Mobility Test (ASTM D425M)	
						(Under Air/ "Drainage")	(Under Water/"Imbibition")
PT01B	PT01B-11-13.2A	11-13.2	12.9	"NAPL present, strong naphthalene-like odor" "HS PID 14.2 ppm"; "HS PID 93 ppm" Heavy sheen with NAPL	HS	x	
PT01	PT01-21.1-22B	21.1-22	21.2	"MS PID 15.3 ppm" "Sheen in small florets on outside of sample core" Slight to moderate sheen	SS-MS		x
PT02	PT02-10-13B	10-13	11.8	"coated in NAPL, with naphthalene-like odor" "HS PID 1.0 ppm"; "completely coated with NAPL" "HS PID 133 ppm"; "Rainbow color sheen appears in blobs, naphthalene-like odor" "HS 100% PID 61 ppm" Heavy sheen with NAPL	HS		x
	PT02-20-23	20-23	21.45	"coated in NAPL, but with no free NAPL, strong naphthalene-like odor" " HS PID 180 ppm"; "staining does not coat all pieces, small amount of NAPL observed" "HS PID 75 ppm"; "HS PID 62 ppm"; "heavily coated with free NAPL" "HS PID 88 ppm" Heavy sheen with NAPL	HS		x
PT03	PT03-8-10A	8-10	8.55	"HS 70% PID 24 ppm" Sheen has "Florets"; "NAPL impact; the NAPL is black very strong hydrocarbon odor, shake test: 1 mm NAPL on surface, stained and streaked on sides of jar" "HS 70% PID 89.9 ppm" Sheen has "Florets"; "stained black, ... black NAPL blebs" "HS PID <1 ppm" Sheen has "Florets" Heavy sheen with NAPL	HS	x	
	PT03-10-13B	10-13	10.85	"HS 70% PID 24 ppm" Sheen has "Florets"; "NAPL impact; the NAPL is black very strong hydrocarbon odor, shake test: 1 mm NAPL on surface, stained and streaked on sides of jar" "HS 70% PID 89.9 ppm" Sheen has "Florets"; "stained black, ... black NAPL blebs" "HS PID <1 ppm" Sheen has "Florets" Heavy sheen with NAPL	HS		x
	PT03-28-30B	28-30	29.7	"NAPL observed in 1/2 inch band"; "NAPL within pore space stained copper color" "HS PID <1 ppm"; "DNAPL to HS throughout" "HS PID 60 ppm"; "1/2 inch NAPL staining" "NS PID 42.3 ppm"; "1 inch NAPL staining" "HS PID <1 ppm" Heavy sheen with NAPL	HS		x

Notes

NS = no sheen

SS = slight sheen

MS = moderate sheen

HS = heavy sheen

ppm = parts per million

Field screening NAPL category

Table 2A-4

Supplemental Investigation NAPL Testing Summary

Gas Works Park Site
Seattle, Washington

Well Name	NAPL Phase	Sample Date	NAPL Sampling		
			Alkylated PAHs	VOCs	Kinematic Viscosity/Density
			EPA Method 8270SIM	EPA Method 8260C	ASTM D1481; ASTM D445
DW-04	DNAPL	4/15/2013			
DW-05	DNAPL	4/15/2013	x	x	x
DW-07	DNAPL	4/15/2013	x	x	x
MW-09	LNAPL	4/15/2013	x	x	x
MW-09	DNAPL	4/15/2013	x	x	x
MW-18	DNAPL	4/15/13; 4/22/13	x	x	x
PZ-03	DNAPL	4/17/2013	x	x	

Table 2A-5

Supplemental Investigation NAPL Thickness Data

Gas Works Park Site

Seattle, Washington

Well	Geological Unit of Screen Interval	Date Measured	Top of Casing Elev. (ft USACE)	Measured NAPL Data						Corrected/Equivalent Elevations		
				LNAPL Depth (ft TOC)	DTW (ft TOC)	DNAPL Depth (ft TOC)	Total Depth (ft TOC)	LNAPL Thickness	DNAPL Thickness	LNAPL Elevation (ft USACE)	Groundwater Elevation (ft USACE)	DNAPL Elevation (ft USACE)
DW-04	Till	2/27/2013	25.33		7.21	33.94	37.00		3.06		see Note 1	-8.62
DW-04	Till	4/15/2013	25.33		7.33	34.62	37.02		2.40		see Note 1	-9.30
DW-04	Till	4/22/2013	25.33		16.31	34.87	37.02		2.15		see Note 1	-9.55
DW-04	Till	4/29/2013	25.33		16.11	34.10	37.02		2.92		see Note 1	-8.78
DW-04	Till	10/14/2013	25.33		16.20	35.13	37.02		1.89		see Note 1	-9.81
DW-05	Qva	2/27/2013	25.12		4.31	26.70	29.38		2.68		20.81	-1.58
DW-05	Qva	4/15/2013	25.12		3.39	25.89	29.29		3.40		21.73	-0.77
DW-05	Qva	4/22/2013	25.12		3.21	28.50	29.38		0.88		21.91	-3.38
DW-05	Qva	10/14/2013	25.12		4.15	28.88	29.38		0.50		20.97	-3.76
DW-07	Qva	2/27/2013	24.99		4.30	40.36	42.50		2.14		20.69	-15.38
DW-07	Qva	4/15/2013	24.99		3.15	40.11	42.30		2.19		21.84	-15.13
DW-07	Qva	4/22/2013	24.99		3.18	41.96	42.30		0.34		21.81	-16.98
DW-07	Qva	10/14/2013	24.99		4.08	41.90	42.30		0.40		20.91	-16.92
MW-09	Till	2/27/2013	33.97	8.89	10.50		20.50	1.61		25.08	24.95	
MW-09	Till	4/15/2013	33.97	6.69	9.83	16.20	20.52	3.14	4.32	27.28	27.03	17.77
MW-09	Till	4/22/2013	33.97	6.43	8.29		20.52	1.86		27.54	27.39	
MW-09	Till	4/29/2013	33.97	6.52	8.07		20.52	1.55		27.45	27.32	
MW-09	Till	10/14/2013	33.97	8.95	9.86	18.51	20.52	0.91	2.01	25.02	24.94	15.46
MW-18	--	2/27/2013	38.21		16.41	32.15	33.57		1.42		21.80	6.06
MW-18	--	4/15/2013	38.21		15.87	33.04	33.59		0.55		22.34	5.17
MW-18	--	4/22/2013	38.21		15.40	32.51	33.57		1.06		22.81	5.70
MW-18	--	10/14/2013	38.21		16.63	32.25	33.57		1.32		21.58	5.96
PZ-03	Qvr	3/1/2013	34.52		12.97	14.49	15.38				21.55	
PZ-03	Qvr	4/15/2013	34.52		12.06	Trace	14.49		Trace		22.46	
PZ-03	Qvr	4/17/2013	34.52		12.05	Trace			Trace		22.47	
PZ-03	Qvr	4/22/2013	34.52		12.24	Trace	14.49		Trace		22.28	
PZ-03	Qvr	10/14/2013	34.52		13.41	Trace	14.49		Trace		21.11	

Notes:

1. Depth to water below lake level. Well damage suspected. Corrected Groundwater Elevation was not calculated.

LNAPL specific gravity, PTS result for MW09-130415-LNAPL (see Attachment A-6). Specific gravity of MW-09 LNAPL = 0.9212.

NM = not measured

Qva = Vashon Advance Outwash

Qvr = Vashon Recessional Outwash

Till = Qpgt = Pre-Fraser Till

TOC = top of casing

DTW = depth to water

Table 2A-6

Supplemental Investigation Groundwater Elevations

Gas Works Park Site
Seattle, Washington

Well ID	Well Location: Northing	Well Location: Easting	Well Diameter (in)	Ground Surface Elevation (ft USACE): When Installed	Ground Surface Elevation (ft USACE): Current	Top of Casing Elevation (ft USACE)	Screen Interval Depth at Time of Installation (ft bgs): Top	Screen Interval Depth at Time of Installation (ft bgs): Bottom	Geologic Unit of Screen Interval[a]	2/27/13 or 3/1/2013: Depth to Groundwater (ft TOC)	2/27/13 or 3/1/2013: Groundwater Elevation (ft USACE)	4/22/2013: Depth to Groundwater (ft TOC)	4/22/2013: Groundwater Elevation (ft USACE)	10/14/2013: Depth to Groundwater (ft TOC)	10/14/2013: Groundwater Elevation (ft USACE)
Gas Works Park Property															
TDW-1	239245	1269574	2	24.90	24.86	24.57	37.5	42.5	Qva	3.85	20.72	2.71	21.86	3.59	20.98
TSW-1	239252	1269586	2	25.77	25.74	25.40	5.3	10.3	Fill	4.73	20.67	3.59	21.81	4.49	20.91
TDW-2	238940	1269755	2	24.84	25.00	25.11	34.5	39.5	Qva	3.93	21.18	2.85	22.26	3.72	21.39
TSW-2	238955	1269763	2	27.53	27.52	28.14	7.0	12.0	Fill	6.55	21.59	5.42	22.72	6.28	21.86
TDW-3	238770	1269998	2	27.13	26.88	26.46	34.5	39.5	Qva	5.92	20.54	4.83	21.63	5.70	20.76
TSW-3	238776	1270000	2	27.53	27.50	27.82	6.0	11.0	Fill	6.45	21.37	5.35	22.47	6.23	21.59
MW-03	239454	1270269	2	38.69	38.64	38.23	1.6	10.6	Qpgt	8.17	30.06	4.81	33.42	7.05	31.18
MW-03D	239459	1270280	2	38.93	38.86	38.42	54.6	57.6	Qpgt	13.95	24.47	14.29	24.13	15.19	23.23
MW-09[b, c]	239136	1270551	2	34.35	34.41	33.97	10.8	20.8	Qva	10.5	23.47	8.29	27.39	9.86	24.11
MW-10	238982	1270112	2	32.42	32.31	32.99	5.3	15.3	Fill	9.84	23.15	8.42	24.57	10.10	22.89
MW-13	238836	1269903	2	32.86	32.48	32.72	7.3	17.3	Fill	11.49	21.23	10.35	22.37	11.26	21.46
MW-14	238795	1270188	2	27.22	26.93	27.53	2.5	9.5	Fill	5.46	22.07	4.59	22.94	5.62	21.91
MW-15	238857	1270255	2	38.07	37.65	38.25	9.5	19.5	Fill	16.23	22.02	14.90	23.35	16.17	22.08
MW-17	239089	1269812	2	33.07	33.08	32.66	6.5	16.5	Fill	12.21	20.45	10.83	21.83	11.78	20.88
MW-18	239327	1269776	2	38.51	38.48	38.21	unknown	unknown	unknown	16.41	21.80	15.40	22.81	16.63	21.58
MW-19	239212	1269916	2	39.39	39.34	39.14	unknown	unknown	unknown	16.43	22.71	16.06	23.08	17.41	21.73
MW-22	238721	1270122	2	24.69	24.30	25.07	24.0	34.0	Qva	3.31	21.76	2.21	22.86	3.10	21.97
MW-23	238718	1270190	2	23.79	23.60	23.92	22.0	32.0	Qpgt	2.38	21.54	1.27	22.65	2.16	21.76
MW-24	238719	1270125	2	24.64	24.28	24.87	5.0	15.0	Qvr	3.25	21.62	2.13	22.74	3.01	21.86
MW-25	238713	1270192	2	23.69	23.30	23.39	5.0	15.0	Qvr	2.28	21.11	1.20	22.19	2.05	21.34
MW-26	239414	1270609	2	32.94	33.55	32.81	9.0	12.6	Qpgt	7.78	25.03	7.69	25.12	9.49	23.32
MW-27	239268	1270426	2	35.42	35.48	35.26	12.0	15.0	Qpgt	6.19	29.07	5.51	29.75	8.59	26.67
MW-28[d]	238800	1270458	2	37.60	37.60	37.49	17.0	27.0	Qpgt	15.38	22.22	14.62	22.98	15.49	22.00
MW-29	238995	1270119	2	31.53	31.55	32.30	13.0	23.0	Qpgt	8.99	23.31	7.73	24.57	9.43	22.87
MW-30	238986	1270115	4	31.91	31.93	32.95	12.0	22.0	Qpgt	9.19	23.76	8.20	24.75	9.87	23.08
MW-31	239409	1269783	4	41.33	41.36	40.90	35.0	45.5	Qpgt	14.58	26.32	15.90	25.00	13.77	27.13
MW-32D	238868	1269843	2	29.92	29.92	31.35	42.0	47.0	Qva	--	--	7.54	23.81	8.40	22.95
MW-32S	238865	1269847	2	29.83	29.83	31.12	16.5	31.0	Fill	--	--	7.68	23.44	8.51	22.61
MW-33S	238749	1270319	2	38.70	38.70	39.08	13.0	22.0	Fill	--	--	16.45	22.63	17.31	21.77
MW-34S	238735	1270502	2	28.44	28.44	28.05	5.0	9.8	Fill	--	--	6.25	21.80	6.94	21.11
MW-35S	238808	1270635	2	24.69	24.69	24.15	4.0	6.8	Fill	--	--	2.38	21.77	3.24	20.91
MW-36D	239091	1270786	2	29.99	29.99	29.55	29.3	33.8	Qvr	--	--	7.82	21.73	8.70	20.85
MW-36S	239087	1270784	2	30.13	30.13	29.62	8.0	22.8	Fill	--	--	7.88	21.74	8.72	20.90
MW-37S	239231	1270817	2	27.14	27.14	26.85	5.1	14.8	Fill	--	--	5.11	21.74	5.98	20.87
MW-38S	239318	1270821	2	25.94	25.94	25.42	7.1	16.6	Fill	--	--	3.70	21.72	4.55	20.87
MW-39D	239391	1270815	2	26.99	26.99	26.74	17.0	21.8	Qva/Qpgt	--	--	5.00	21.74	5.85	20.89
MW-39S	239397	1270814	2	26.89	26.89	26.61	3.9	14.1	Fill	--	--	4.86	21.75	5.74	20.87
MW-40S	239491	1270790	2	25.69	25.69	25.18	4.0	10.9	Fill	--	--	3.48	21.70	4.31	20.87
PZ-03	239232	1269811	1	34.81	34.81	34.52	5	20	Qvr	12.97	21.55	12.24	22.28	13.41	21.11
PZ-09	239322	1269844	2	36.76	39.26	38.81	12.5	22.5	Qvr	16.1	22.71	14.55	24.26	16.03	22.78
PZ-10	239315	1269814	2	36.97	38.84	38.48	12.5	22.5	Qvr	16.1	22.38	14.09	24.39	16.20	22.28
RW-01	239317	1269857	4	36.91	39.56	39.02	12.5	22.5	Qvr	16.31	22.71	15.01	24.01	16.60	22.42
OBS-1	238946	1270752	2	23.13	23.11	23.59	2	11.7	Fill	3	20.59	1.88	21.71	2.73	20.86

Well ID	Well Location		Well Diameter (in)	Ground Surface Elevation (ft USACE)		Top of Casing Elevation (ft USACE)	Screen Interval Depth at Time of Installation (ft bgs)		Geologic Unit of Screen Interval[a]	Depth to Groundwater (ft TOC)	Groundwater Elevation (ft USACE)	Depth to Groundwater (ft TOC)	Groundwater Elevation (ft USACE)	Depth to Groundwater (ft TOC)	Groundwater Elevation (ft USACE)
	Northing	Easting		When Installed	Current		Top	Bottom		2/27/13 or 3/1/2013		4/22/2013		10/14/2013	
OBS-2	238962	1270739	2	26.46	26.52	26.21	2	11.7	Qpgt	5.71	20.50	4.57	21.64	5.44	20.77
OBS-3	238984	1270678	2	29.60	29.61	29.39	2	11.7	Fill	7.17	22.22	6.34	23.05	7.34	22.05
Harbor Patrol Property															
CMP-01	239055	1269720	2	25.24	25.20	24.97	6.5	21.5	Fill	4.32	20.65	3.19	21.78	4.04	20.93
DW-04	239159	1269736	2	25.86	25.86	25.33	32.0	37.0	Qpgt	7.21	18.12	16.31	9.02	16.20	9.13
DW-05	239141	1269718	2	25.44	25.45	25.12	24.0	29.0	Qva	4.31	20.81	3.21	21.91	4.15	20.97
DW-06	239095	1269675	2	25.04	25.00	24.67	37.0	42.0	Qva	3.86	20.81	2.83	21.84	3.62	21.05
DW-07	239055	1269726	2	25.35	25.43	24.99	37.5	42.5	Qva	4.3	20.69	3.18	21.81	4.08	20.91
PZ-01	239204	1269609	1	25.62	25.70	25.09	3.0	13.0	Qvr	4.46	20.63	3.20	21.89	4.17	20.92
PZ-05	239013	1269781	1	27.74	28.05	27.83	3.0	18.0	Fill	7.23	20.60	6.07	21.76	6.94	20.89
PZ-06	239074	1269764	1	27.16	27.69	27.13	5.0	20.0	Fill	6.53	20.60	5.50	21.63	6.22	20.91
PZ-08	239157	1269715	1	25.66	25.66	25.30	5.0	20.0	Qvr	4.51	20.79	3.38	21.92	4.32	20.98
Metro Property (South Yard)															
AGI-2	239488	1269432	unknown	21.60		33.93	8	23	Fill	NM	NM	11.96	21.97	12.94	20.99
MLU-1	239376	1269561	unknown	36.13	36.13	36.15	10	20	Qvr	NM	NM	14.14	22.01	15.5	20.65
MW-04	239365	1269468	unknown	21.40	21.40	27.95	9.7	19.4	Qvr	NM	NM	15.18	12.77	16.26	11.69
MW-07	239423	1269511	unknown	21.70		34.38	6.5	16.5	Fill	NM	NM	12.40	21.98	13.37	21.01
MW-8A	239469	1269368	unknown	33.96	33.96	33.56	unknown	unknown	Fill	NM	NM	11.70	21.86	12.65	20.91
MW-25	239445	1269400	4	33.19	33.19	34.16	5	20	Qvr	NM	NM	12.30	21.86	13.22	20.94
MW-26	239410	1269440	4	33.22	33.22	33.87	5	20	Fill	NM	NM	11.90	21.97	12.89	20.98
MW-27[e]	239751	1269439	unknown	37.66	37.66	37.26	4.5	19.5	Fill	NM	NM	7.34	29.93	10.16	27.10
SMPN-01	239748	1269435	unknown	37.43	37.43	37.03	unknown	unknown	unknown	NM	NM	8.75	28.28	10.49	26.54
SMPN-02	239746	1269439	unknown	37.50	37.50	37.10	unknown	unknown	unknown	NM	NM	7.88	29.22	10.50	26.60
SMPN-03	239740	1269434	unknown	37.46	37.46	37.06	unknown	unknown	unknown	NM	NM	8.30	28.76	10.52	26.54
Near Metro Property (In/Next to Roads)															
MW-09[e]	239767	1269388	unknown	27.30		39.71	11.9	21.9	Qva	NM	NM	11.07	29.18	14.10	25.70
MW-11	239705	1269431	unknown	23.90		103.86	6.0	15.5	unknown	NM	NM			11.04	92.82
MW-19	239721	1269253	unknown	34.52	34.52	34.12	9	19	Fill	NM	NM	12.18	21.94	13.10	21.02
MW-20	239651	1269334	unknown	35.14	35.14	34.74	13	23	unknown	NM	NM	12.80	21.94	13.72	21.02
MW-21	239539	1269546	unknown	34.91	34.91	34.51	5	23	Fill	NM	NM	12.47	22.04		
Lake Union Elevation											20.52		21.65		20.75

Notes:

[a] Some screen intervals cross more than one geologic unit. Units listed here are the same as those assigned by Aspect in their groundwater modeling report, with the exception of MW-9 which was formerly interpreted as being screened across Qpgt (Aspect 2012).

[b] Well contains LNAPL. Water elevation corrected based on a LNAPL specific gravity of 0.9212.

[c] LNAPL specific gravity, PTS result for MW09-130415-LNAPL. Specific gravity of MW-09 LNAPL = 0.9212.

[d] TOC elevation changed from 37.597 to 37.494 feet USACE after 4/25/2013 survey.

[e] Well contains LNAPL. Water elevation corrected based on a LNAPL specific gravity of 0.80.

Gray shading indicates uncertainty or unable to verify/populate.

Horizontal Datum: NAD83 WA State Plane North.

Vertical Datum: US Army Corps of Engineers (USACE).

NM = not measured

Qvr = Vashon Recessional Outwash

Qva = Vashon Advance Outwash

Qpgt = Pre-Fraser Till

-- = well not in existence at the time

Metro Ground Surface and Measuring Point Elevations: measurement elevation from May 2011 survey (Arcadis) unless otherwise noted.

TOC = top of casing

Table 2A-7

Supplemental Investigation Groundwater Testing Summary

Gas Works Park Site
Seattle, Washington

Well Name	Analysis					Geologic Unit of Screen Interval
	PAHs			BTEX	Dissolved Arsenic	
	EPA Method 8270 SIM (Low level)			EPA Method 8260 (Low level)	EPA Method 200.8	
	Unfiltered	Lab Filtered	Field Filtered	Unfiltered	Field Filtered	
CMP-01	S,F	S	F	S,F	F	Fill
DW-06	S			S		Qva
MLS-1-1	S			S		Till
MLS-1-2	S			S		Qvr
MLS-1-3	S			S		Qvr
MLS-2-1	S			S		Qva
MLS-4-2	S			S		Qva
MLS-4-3	S			S		Qva
MLS-4-5	S			S		Fill
MLS-5-1	S			S		Qva
MLS-5-2	S			S		Qva
MLS-5-3	S			S		Qvr
MLS-5-4	S			S		Qvr
MLS-5-5	S			S		Fill
MLS-6-1	S,F		F	S,F	F	Qva
MLS-6-2	S,F		F	S,F	F	Qvr
MLS-6-4	S,F		F	S,F	F	Fill
MLS-7-1	S			S		Qva
MLS-7-2	S			S		Qvr
MLS-7-4	S			S		Fill
MW-03	S			S	F	Till
MW-03D	S			S	F	Till
MW-10	S			S		Fill
MW-13	S			S		Fill
MW-14	S			S		Fill
MW-15	S			S		Fill
MW-17	S			S		Fill
MW-19	S			S		--
MW-22	S,F		F	S,F	F	Qva
MW-23	S,F		F	S,F	F	Till
MW-24	S,F		F	S,F	F	Qvr
MW-25	S,F		F	S,F	F	Qvr
MW-26	S			S		Till
MW-27	S			S		Till
MW-28	S			S		Till
MW-29	S			S		Till
MW-30	S			S		Till
MW-31	S			S		Till

Well Name	Analysis					Geologic Unit of Screen Interval
	PAHs			BTEX	Dissolved Arsenic	
	EPA Method 8270 SIM (Low level)			EPA Method 8260 (Low level)	EPA Method 200.8	
	Unfiltered	Lab Filtered	Field Filtered	Unfiltered	Field Filtered	
MW-32D	S,F		F	S,F	F	Qva
MW-32S	S,F		F	S,F	F	Fill
MW-33S	S,F		F	S,F	F	Fill
MW-34S	S,F		F	S,F	F	Fill
MW-35S	S,F	S	F	S,F	F	Fill
MW-36D	S,F	S	F	S,F	F	Qvr
MW-36S	S,F		F	S,F	F	Fill
MW-37S	S,F		F	S,F	F	Fill
MW-38S	S,F		F	S,F	F	Fill
MW-39D	S,F		F	S,F	F	Qva/Till
MW-39S	S,F	S	F	S,F	F	Fill
MW-40S	S,F		F	S,F	F	Fill
OBS-1	S,F		F	S,F	F	Fill
OBS-2	S			S		Till
OBS-3	S			S		Fill
PZ-01	S,F		F	S,F	F	Qvr
PZ-05	S			S		Fill
PZ-06	S			S		Fill
PZ-08	S			S		Qvr
PZ-09	S			S		Qvr
PZ-10	S			S		Qvr
RW-01	S			S		Qvr
TDW-1	S			S		Qva
TDW-2	S,F		F	S,F	F	Qva
TDW-3	S,F		F	S,F	F	Qva
TSW-1	S			S		Fill
TSW-2	S,F		F	S,F	F	Fill
TSW-3	S,F		F	S,F	F	Fill

Notes:

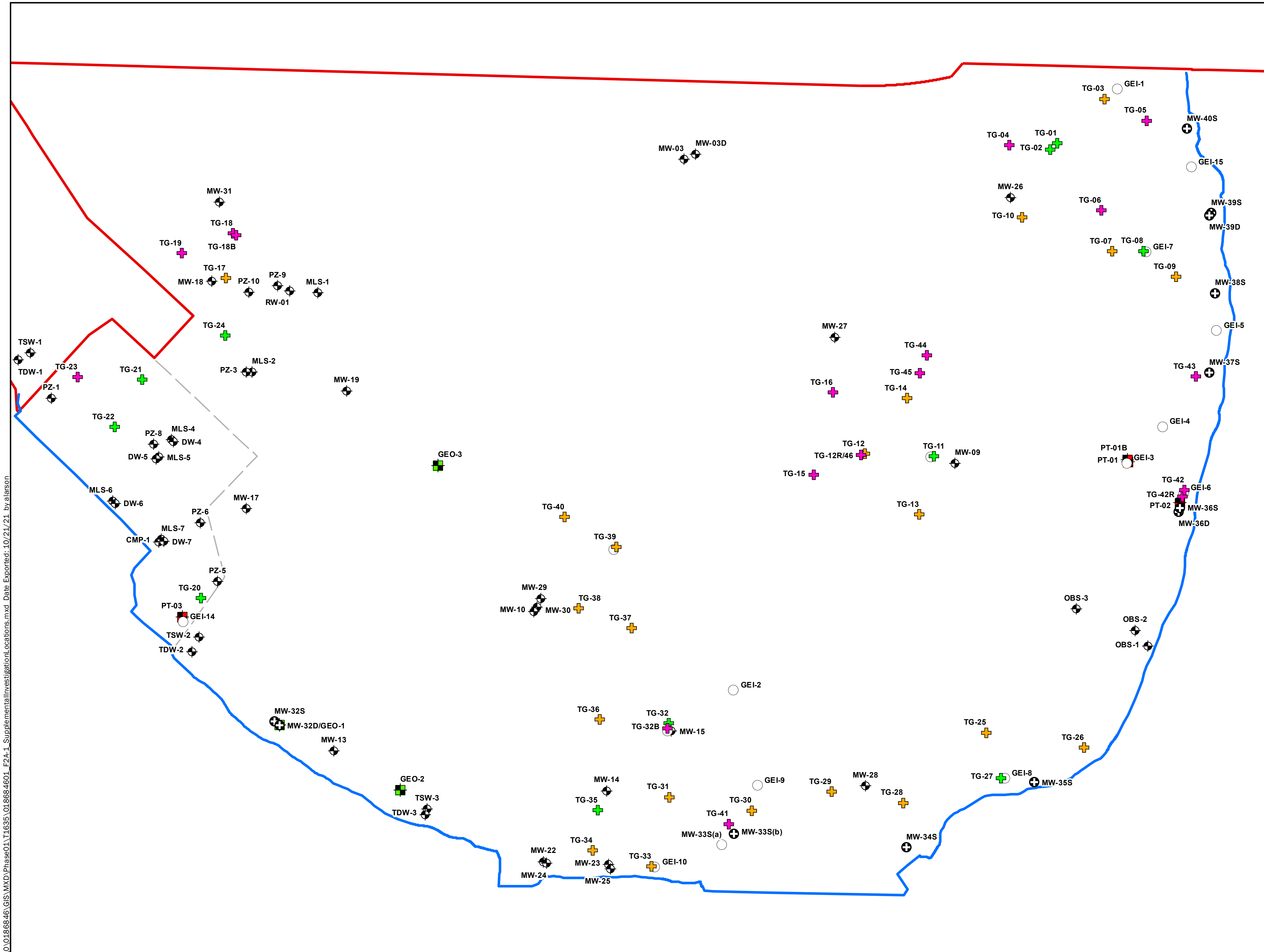
S = Sampled and Analyzed in Spring (April 2013) event

F = Sampled and Analyzed in Fall (October 2013) event

Qvr = Vashon Recessional Outwash

Qva = Vashon Advance Outwash

Till = Pre-Fraser Till (Qpgt)



P:\0\0186846\GIS\MXD\Phase01\T1635\018684601_F2A-1_SupplementalInvestigationLocations.mxd Date Exported: 10/21/21 by alarson

Legend

- Site Boundary
- Shoreline (OHWM)

TarGOST Exploration

- Primary
- Secondary
- Offset

Borings

- Environmental Soil Borings
- Monitoring Wells Installed
- Geotechnical Borings
- Petrophysical Borings
- Existing Monitoring Well

Notes:

1. Data Source: Basemap - 2005 USGS aerial photograph. Does not show current conditions.
2. Projection: NAD 1983 StatePlane Washington North FIPS 4601 Feet

DISCLAIMER: This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. The locations of all features are approximate. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

N
W E
S

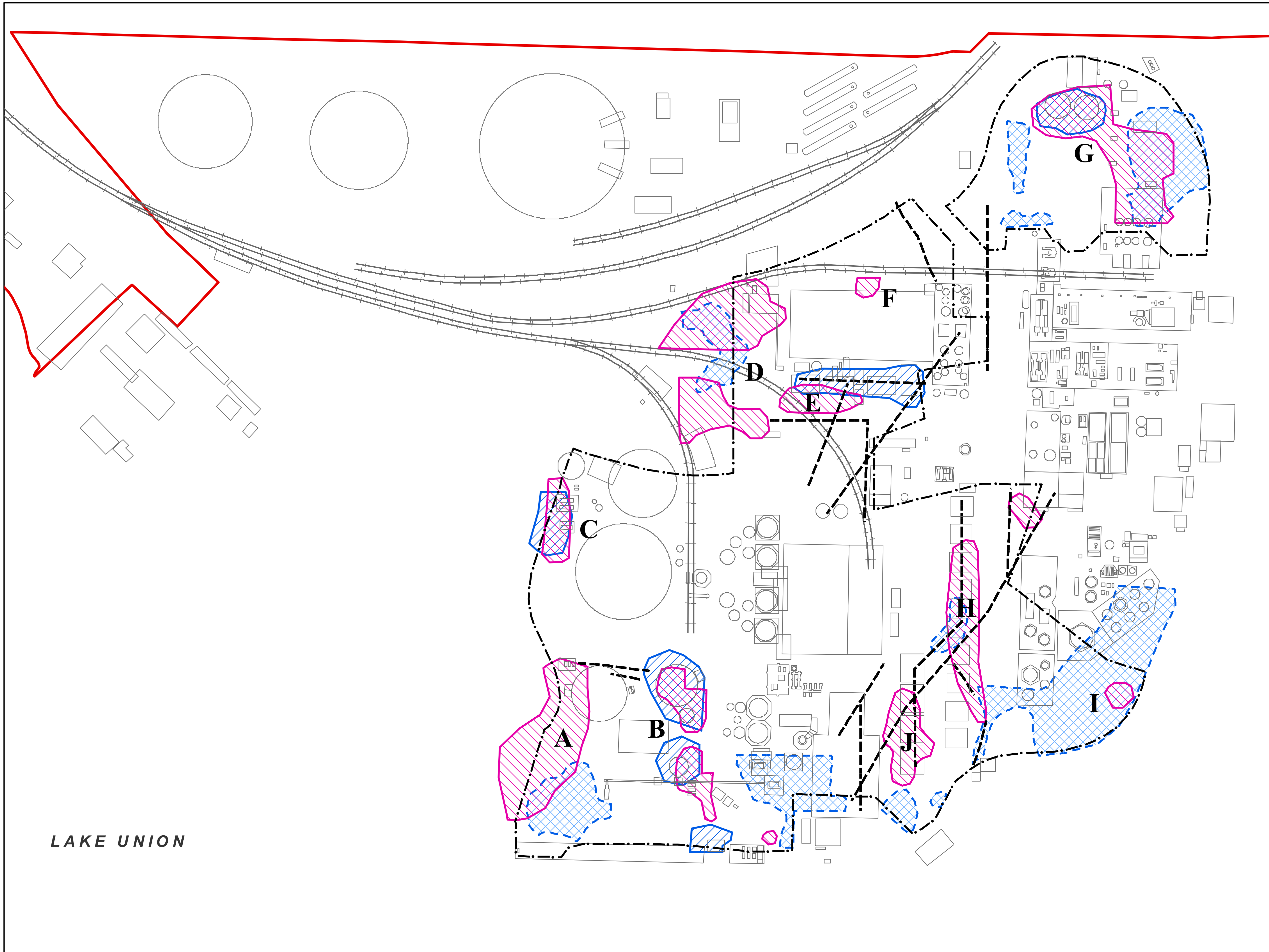
100 0 100

Feet

Supplemental Investigation Exploration Locations

Gas Works Park Site
Seattle, Washington

[redacted] **Figure 2A-1**



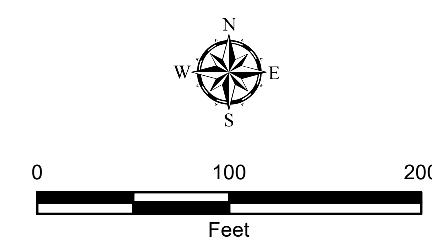
Legend

- Area of Investigation (AOI)
- Historical Railroad Features
- Interpreted Pipe or Utility
- Magnetic Anomalies
- EM Anomaly (Metallic Objects)
- High Conductivity Area (Conductive Soil)
- Geophysical Survey Limits

Notes:

1. Geophysical Site Investigation, Gas Works Park by Zone 2013.
2. Historical structures provided by Floyd|Snider, 2012.
3. Site structures delineated as shown in the General Plan, Lake Station, Seattle Gas Company, April 1949, revised in June 1953, the 1950 Oil Lines, Seattle Gas Co. Map, and a 1956 aerial photograph.
4. Historical railroad features shown as delineated in General Plan, Lake Station, Seattle Gas Co., June 1938.
5. Structure labels shown in *( ) indicate previous MGP operational uses (pre-1946).
6. Data Source: 2005 USGS aerial photograph. Does not show current conditions.

DISCLAIMER: This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. The locations of all features are approximate. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.



Geophysical Results and Historical Structures

Gas Works Park Site
Seattle, Washington

Figure 2A-2

Path: P:\0\0186846\GIS\MXD\Phase01\T1635\0186846-01_F2A-2_GeophysicalResults.mxd Map Revised: 21 October 2021 alarson

ATTACHMENT 2A-1
Zonge Geophysical Site Investigation Report
Gas Works Park April 2013

Agency Review Draft

GEOPHYSICAL SITE INVESTIGATION
GAS WORKS PARK
SEATTLE, WASHINGTON

Photo: City of Seattle: http://www.seattle.gov/tour/images/gasworks8.jpg

Prepared for:

GeoEngineers, Inc.
600 Stewart Street, Suite 1700
Seattle, WA 98101

Submitted by:

Zonge International, Inc.
8366 SW Nimbus Ave.
Beaverton, OR 97008
phone: 503-992-6723
Zonge Ref: 13024

April 2013

Table of Contents

List of Figures

Appendices

1.0 INTRODUCTION

Zonge International, Inc. (Zonge) conducted a geophysical site investigation at the Gas Works Park, Seattle, Washington. The investigation was conducted for GeoEngineers, Inc. as part of their supplemental investigation for Puget Sound Energy. This report describes the techniques and procedures used as well as presenting our results and interpretation.

The site, shown in Figure 1, was formerly a manufactured gas facility, manufacturing natural gas from coal and oil. Those operations ceased in 1956. The site also has a history of site alterations and decommissioning, removing structures, moving soils and debris. Soils are heterogeneous fill, often containing bricks, slag, and other construction and industrial materials. The site is currently a grass covered park with several areas of above ground vessels, towers, and piping remaining from the gas production facility.

The objective of the study was to identify buried objects, piping, tanks and other materials which may remain from the former operations on that site within the geophysical survey limits shown on Figure 1.

The geophysical investigation included:

- A magnetic (MAG) survey utilizing a Geometrics G858G magnetometer/gradiometer.
- An electromagnetic (EM) survey utilizing the Geonics EM31 terrain conductivity meter.
- A ground penetrating radar (GPR) survey utilizing a Geophysical Survey Systems Inc. SIR3000 control unit with a 400 MHz antenna.

Results of this geophysical investigation are summarized in Figures 2, *Primary Geophysical Targets*, and Figure 3, *Extended Geophysical Interpretation*, and discussed below in the Section 4, *Results and Interpretation*. Basic principles of these techniques are described in Appendix B, *Geophysical Detection of Buried Objects.*

2.0 FIELD SURVEY

Field work was conducted March 5, 6, & 7, 2013, by a senior geophysicist and a staff geophysicist from Zonge.

2.1 Magnetic Data Acquisition

The MAG survey was conducted using a Geometrics G858G cesium magnetometer/gradiometer. This instrument was run in the "continuous" sampling mode, recording the magnetic field at 0.1 second intervals (approximately 0.5 feet). Two magnetic sensors spaced 0.5 meters apart, one above the other, were used to obtain the vertical magnetic gradient. Line spacing for the MAG survey was 10 feet. Magnetic survey lines are shown on Figure 1 and the magnetometer data plots are provided in Appendix A.

2.2 EM Data Acquisition

EM data were acquired using a Geonics EM-31 terrain conductivity meter. Both quadrature-phase (apparent conductivity) and in-phase data were recorded. Data were recorded at a 0.2 second interval, corresponding to a distance of approximately 1 foot. Data were recorded on an Allegro handheld ruggedized field computer (Windows CE/DOS) running DAT31 MK2 software from Geomar of Mississauga, Ontario. EM survey lines are shown on Figure 1 and the EM data plots are provided in Appendix A..

2.3 GPR Data Acquisition

GPR was conducted in areas where cultural interference limited the resolution of the MAG and EM techniques. The GPR survey utilized a Geophysical Survey Systems, Inc. (GSSI) SIR3000 control unit and a 400 MHz antenna mounted within a survey cart. Figure 1 shows GPR profile locations. GPR data were acquired in areas where cultural interference limited the resolution on MAG and EM techniques.

2.4 Survey Positioning and Mapping

For the MAG and EM surveys, location data were acquired simultaneously with the geophysical data using Differential Global Positioning Systems (DGPS). MAG data were acquired using a Trimble Ag132 DGPS system. That system provides visual feedback to the operator to assure that he is "on line" and that the survey area is covered uniformly. For the EM31 survey a Trimble GeoExplorer 6000 XH was used. A grid was established with pin flags placed at the ends of, and at intermediate locations along the lines. Each system is a real time differential GPS unit with "sub-meter" accuracy; hence positions are generally good to ±1-2 feet, but may be off by 2-3 feet.

3.0 DATA PRESENTATION & ANALYSIS

Magnetic (MAG) and electromagnetic (EM) data were gridded and contoured using the Geosoft Oasis montaj data processing and analysis software system. Color contour data plots are included in Appendix A.

3.1 Magnetic Data

Magnetic data are displayed on two figures, one plot of the analytic signal (Figure A1) and the total magnetic signal (Figure A2). The analytic signal is our preferred presentation as it provides a simplified signature and better resolution of the anomalous areas than unprocessed field data. A high in the analytic signal occurs directly over the magnetic "source." The total magnetic field plot shows the data from the top sensor of the G858, which was also used to calculate the analytic signal.

The observed magnetic field responds strongly to steel objects. Depth of exploration depends on the mass of steel in the object. Generally, the larger the mass and the shallower the object the stronger the response. Typically a drum size object can be detected at a depth of 5-10 feet. Shape and orientation of elongated objects also influence the magnetic response.

3.2 Electromagnetic Data

Both quadrature-phase (apparent conductivity) and in-phase EM31 data were recorded in the field. Appendix B includes a discussion of these two measured parameters of the EM response. Plots of both data sets are included in Appendix A.

The EM31 responds both to soil (terrain) conductivity and to metallic or electrically conductive objects (tanks, pipelines, communication lines, fences, reinforcing steel, etc.). The EM31 in-phase signal responds strongly to metallic conductors and is less sensitive to soil conductivity than the quadrature response. The unit of measurement for the in-phase response is the ratio in parts per thousand of the secondary field to the primary EM field (ppt). The EM31 quadrature-phase signal is proportional to the soil conductivity and is reported in units of conductivity, millisiemen/meter (mS/m). The EM31 was set to clip the signal at 208 mS/m so no conductivity variation was recorded above that threshold. The measured apparent conductivity is a weighted average of soil conductivity over the depth of exploration (15-20 feet) with the stronger weighting on the near surface. The quadrature signal also responds to metallic objects and will not reflect the soil conductivity in areas where metallic objects are present.

The EM31 is designed to measure soil conductivities to depths of 10-15 feet. It can often detect strong metallic conductors at somewhat greater depth.

3.3 Ground Penetrating Radar Data

Ground penetrating radar records electromagnetic wave reflections from objects with contrasting dielectric properties. Metal objects are very good reflectors. Plastic objects and voids are also good reflectors.

GPR data profiles were analyzed for reflections consistent with subsurface tanks, pipes or other buried materials. Depth of investigation of the GPR is limited by the conductivity of the soil. Clays and conductive soils attenuate the signal rapidly. At this site, depth of investigation was generally limited to 2-3 feet.

4.0 RESULTS AND INTERPRETATIONS

4.1 General Comments

Preliminary results were conveyed to GeoEngineers on March 12, 2013. Those preliminary results included eleven (11) "Primary Geophysical Targets" shown on Figure 2. Those preliminary targets were conveyed to GeoEngineers as possible locations for further sampling or drilling. Throughout this report, we have kept that original designation for as "Primary Geophysical Targets" for those preliminary targets.

More extensive data analyses lead to our Extended Geophysical Interpretation which is presented in Figure 3. The extended interpretation includes additional general areas of anomalous response identified with letters A-J.

While many anomalous areas were identified, we did not find any large anomalies which would be indicative of massive vessels or structures which might contain several tons of steel.

Geophysical data color contour plots are included in Appendix A. These include Magnetic Analytic Signal, Total Magnetic Field, EM31 Apparent Conductivity, and EM31 In-Phase Response. In-phase response background levels are represented by green and light blue tones in Figure A4. Red (strongly positive) and dark blue (strongly negative) tones indicate potential EM anomalies. The EM31 response to a buried metallic object may be positive or negative (or some combination of both) based on the orientation of the transmitter and receiver coils relative to the target.

4.2 Primary Geophysical Targets

Preliminary, "Primary Geophysical Targets" as well as associated ArcGIS files, were conveyed to GeoEngineers after completion of the geophysical survey and a preliminary examination of the data plots. These results were provided in order to guide GeoEngineers in their intrusive field investigations. These targets, shown on Figure 2, are characterized by both MAG and EM anomalies and are judged as the anomalies most likely to represent buried steel objects such as underground tanks.

4.3 MAG Anomalies

In Figure 3 we have identified several magnetic anomalies where steel objects are likely present in the subsurface. Most of these areas show a clutter of anomalies, indicative of a collection of objects with no single object dominating the response.

4.4 EM Anomalies

In Figure 3, areas identified as **High Conductivity Areas** exhibited apparent conductivities above 200 mS/m. This is possibly an area of ash or slag and/or very conductive pore water (ionic solutions) in the soils. Extensive clays might also produce the observed response.

Areas identified as **EM Anomalies** exhibit a chaotic rapidly varying EM response typical of scattered metallic debris. Depths are likely less than 15 feet as the EM31 sensitivity is strongly reduced below 12-18 feet. The EM31 responds to conductive materials (steel, aluminum or copper), either linear conductors such as pipes and cables, and/or metallic objects such as tanks or machinery.

Anomalies designated as **Interpreted Pipe or Utility** are EM anomalies indicative of long linear conductors such as metallic pipes, underground power cables, and communication cables.

Petrochemicals and non-aqueous phase liquids (NAPL) have little effect on the EM response unless they have a thickness of a few feet.

4.5 GPR Results

No ground penetrating radar (GPR) anomalies indicative of large underground objects or collection of objects were noted on any of the profiles. A few small “point reflectors”, shallow utilities, and or tree roots were noted on some sections but we have not mapped those minor features. GPR depth of investigation was typically 2-3 feet and occasionally 4 feet. Shallow excavation features could be seen on some of the profiles around the large above ground tanks.

4.6 Discussion of Anomalies

Anomalies A through J are identified on Figure 3, *Extended Geophysical Interpretation*. These anomalous areas have been identified after a more complete data examination than the preliminary Primary Geophysical Targets. To a large degree, those primary targets are included within these anomalous areas.

Anomaly A

Anomaly A has a magnetic signature indicative of scattered buried steel objects. One of the stronger magnetic features was selected as a Primary Target. There is an area of high soil conductivity overlapping the southern portion of the MAG anomaly.

Anomaly B

Anomaly B includes two areas of chaotic MAG and EM response indicative of a collection of metallic materials. Two locations have been selected as Primary Targets.

Anomaly C

Anomaly C is an area with high magnetic response as well as an in-phase EM response, indicative of buried metallic objects. This is a broad feature with no single peak to identify as a primary target.

Anomaly D

Anomaly D is a broad area of MAG anomalies with an overlaying conductivity high. This is indicative of abandoned infrastructure, possibly pipes and other objects. One strong MAG anomaly has been selected as a Primary Target.

Anomaly E

Anomaly E is a broad EM and MAG anomaly, although the two do not appear entirely coincident. The EM anomaly may be due in part to a linear conductor, pipe or utility, possibly associated with additional metallic objects producing the MAG anomaly. No Primary Target was associated with this anomaly as it is more indicative of linear conductors and/or debris without a single strong anomalous target.

Anomaly F

Anomaly F is a strong, localized MAG anomaly near the concrete trestle structures. The monopole MAG response is indicative of the end of a pipe or vertical well casing. This anomaly was included as a Primary Target.

Anomaly G

Anomaly G includes an extensive area of strong and chaotic MAG and EM response. This is indicative of shallow buried materials. Four strong MAG anomalies that also included strong in-phase response were included as Primary Targets.

Anomaly H

Anomaly H is a linear trend of MAG anomalies, mostly coincident with linear EM anomalies. This feature is indicative of a steel pipe or series on pipes. As with Anomaly E, no Primary Target was associated with this anomaly as it is more indicative of a series of linear conductors without a single strong anomalous target.

Anomaly I

Anomaly I is a strong localized magnetic monopole within an area of high conductivity. This anomaly is indicative of a vertical pipe or well casing or perhaps moderate size steel object. It was selected as a Primary Geophysical Target.

Anomaly J

Anomaly J is a strong local MAG anomaly within an area of high conductivity. This is indicative of a buried object. We have assigned this as a Primary Geophysical Target. Its close proximity to the landscape structures (The Prow) and utility lines suggest that it may be associated with current infrastructure, irrigation or electrical.

5.0 SUMMARY AND CONCLUSIONS

The Gas Works Park is a busy site in terms of geophysical response and possible buried materials, as one would expect after 50 years of industrial operations and redevelopment/cleanup activities. We have outlined extensive anomalous areas indicative of scattered buried objects and several linear features indicative of buried pipes or utilities. Within those areas, we have highlighted several of the strongest anomalies, Primary Geophysical Targets, which could be indicative of buried tanks or other steel objects. We did not observe any large anomalies that might be associated with several tons of steel, e.g. large underground vessels or pieces of machinery.

6.0 CLOSURE

Zonge International, Inc. (Zonge) has performed this work in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions. No warranty, express or implied, beyond exercise of reasonable care and professional diligence, is made. This report is intended for use only in accordance with the purposes of the study described within.

Geophysical surveys performed as part of this survey may or may not successfully detect or delineate any or all subsurface objects or features present. Locations, depths and scale of buried objects or subsurface features mapped as a result of this survey are a result of geophysical interpretation only, and should be considered as confirmed, actual, or accurate only where recovered by excavation or drilling.

We appreciate the opportunity to perform this geophysical investigation. Should you require further information concerning the field investigation, or this report, please contact us at your convenience.

Respectfully Submitted,

Zonge International, Inc.

Rowland B. French, Ph.D., L.G.
Senior Geophysicist

Attachments: Figures 1 - 3
Appendix A - *Geophysical Data Plots*
Appendix B - *Geophysical Detection of Buried Objects*

FILE: Zonge Gas Works Geophysics r12.docx
REVISION: 2013-12-05
PROJECT: 13024

Agency Review Draft

ZONGE PROJECT: 13024 FILE: GasWorks BL.map DATE: MAARCH 2013 REVISION: E-08-NOV-13

Scale 1:1200

50 0 50 100 150 200 250

US survey foot

NAD83 / Washington North (ftUS)

LEGEND

- MAGNETIC DATA LINES
- EM31 DATA LINES
- GPR DATA LINES
- MONITORING WELL
- STORM GRATE
- MAN HOLE
- FIRE HYDRANT
- MARKED UTILITY
- FENCE (APPROX.)
- CULTURAL INTERFERENCE
- GEOPHYSICAL SURVEY PROPOSAL LIMITS

FIGURE 1

SITE EXPLORATION PLAN

Geophysical Site Investigation
Gas Works Park
Seattle, Washington

Prepared By:

Zonge TRUSTED GEOPHYSICS.

Prepared For:

GeoEngineers

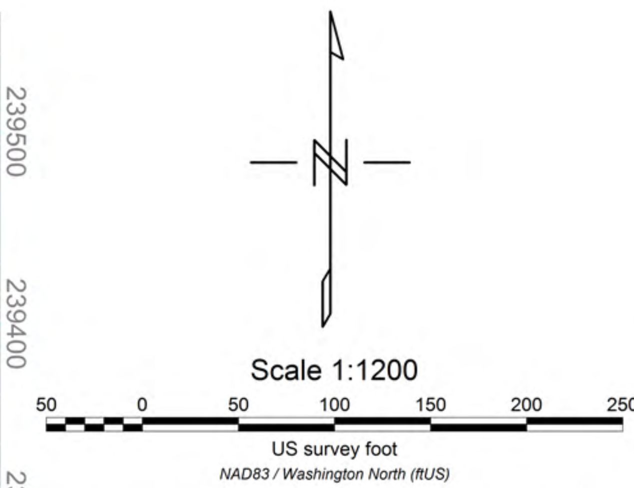
Agency Review Draft

REVISION: D-07-NOV-13

DATE: MAARCH 2013

FILE: Gas Works Primary Interp.map

ZONGE PROJECT: 13024



LEGEND

- MONITORING WELL
- STORM GRATE
- MAN HOLE
- FIRE HYDRANT
- FENCE (APPROX.)
- GEOPHYSICAL SURVEY PROPOSAL LIMITS

INTERPRETATION

- PRIMARY GEOPHYSICAL TARGETS ANOMALIES OBSERVED IN BOTH EM AND MAGNETIC DATA
- INTERPRETED PIPE OR UTILITY

FIGURE 2

PRIMARY GEOPHYSICAL TARGETS

Geophysical Site Investigation
Gas Works Park
Seattle, Washington

Prepared By:

Zonge TRUSTED GEOPHYSICS.

Prepared For:

GeoEngineers

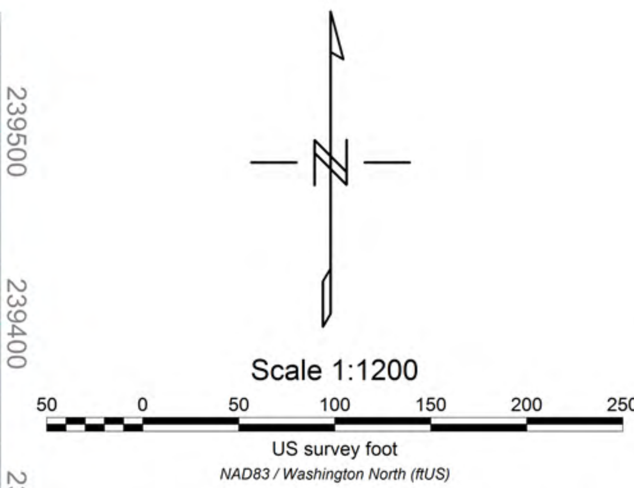
Agency Review Draft

REVISION: E-07-NOV-13

DATE: MAARCH 2013

FILE: Gas Works Interp.map

ZONGE PROJECT: 13024



LEGEND

- MONITORING WELL
- STORM GRATE
- MAN HOLE
- FIRE HYDRANT
- FENCE (APPROX.)
- CULTURAL INTERFERENCE
- GEOPHYSICAL SURVEY PROPOSAL LIMITS

INTERPRETATION

- PRIMARY GEOPHYSICAL TARGETS ANOMALIES OBSERVED IN BOTH EM AND MAGNETIC DATA
- INTERPRETED PIPE OR UTILITY
- A — ANOMALY DISCUSSED IN TEXT ("H" WITH CALL OUT ARROWS)
- MAGNETIC ANOMALIES
- HIGH CONDUCTIVITY AREA (CONDUCTIVE SOIL)
- EM ANOMALY (METALLIC OBJECTS)

FIGURE 3

EXTENDED GEOPHYSICAL INTERPRETATION

Geophysical Site Investigation
Gas Works Park
Seattle, Washington

Prepared By:

Zonge TRUSTED GEOPHYSICS.

Prepared For:

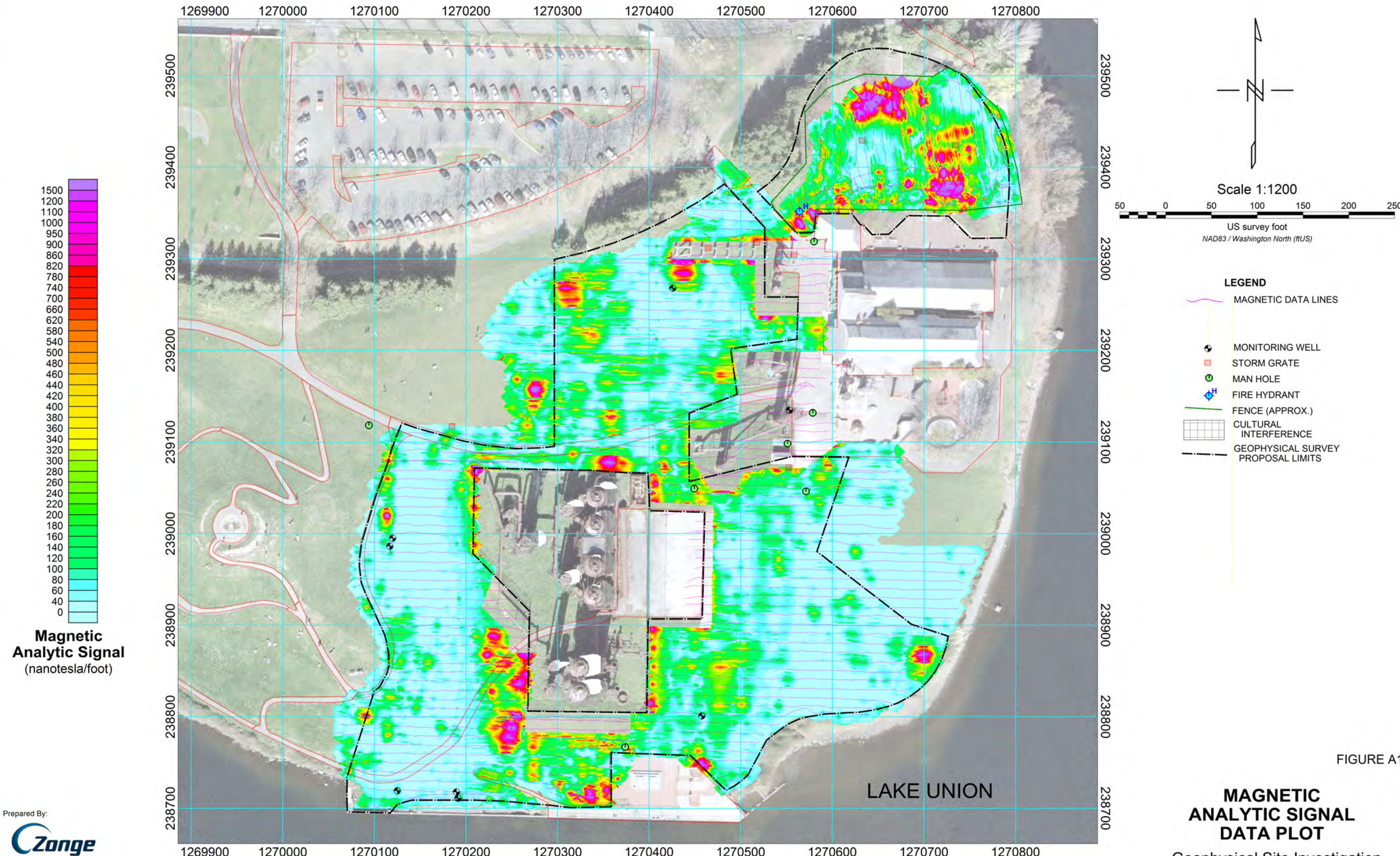
GeoEngineers

GEOPHYSICAL SITE INVESTIGATION GAS WORKS PARK SEATTLE, WASHINGTON

APPENDIX A

GEOPHYSICAL DATA PLOTS

Agency Review Draft



REVISION: E-08-NOV-13

DATE: MAARCH 2013

FILE: GasWorks BL.map

ZONGE PROJECT: 13024

FIGURE A1

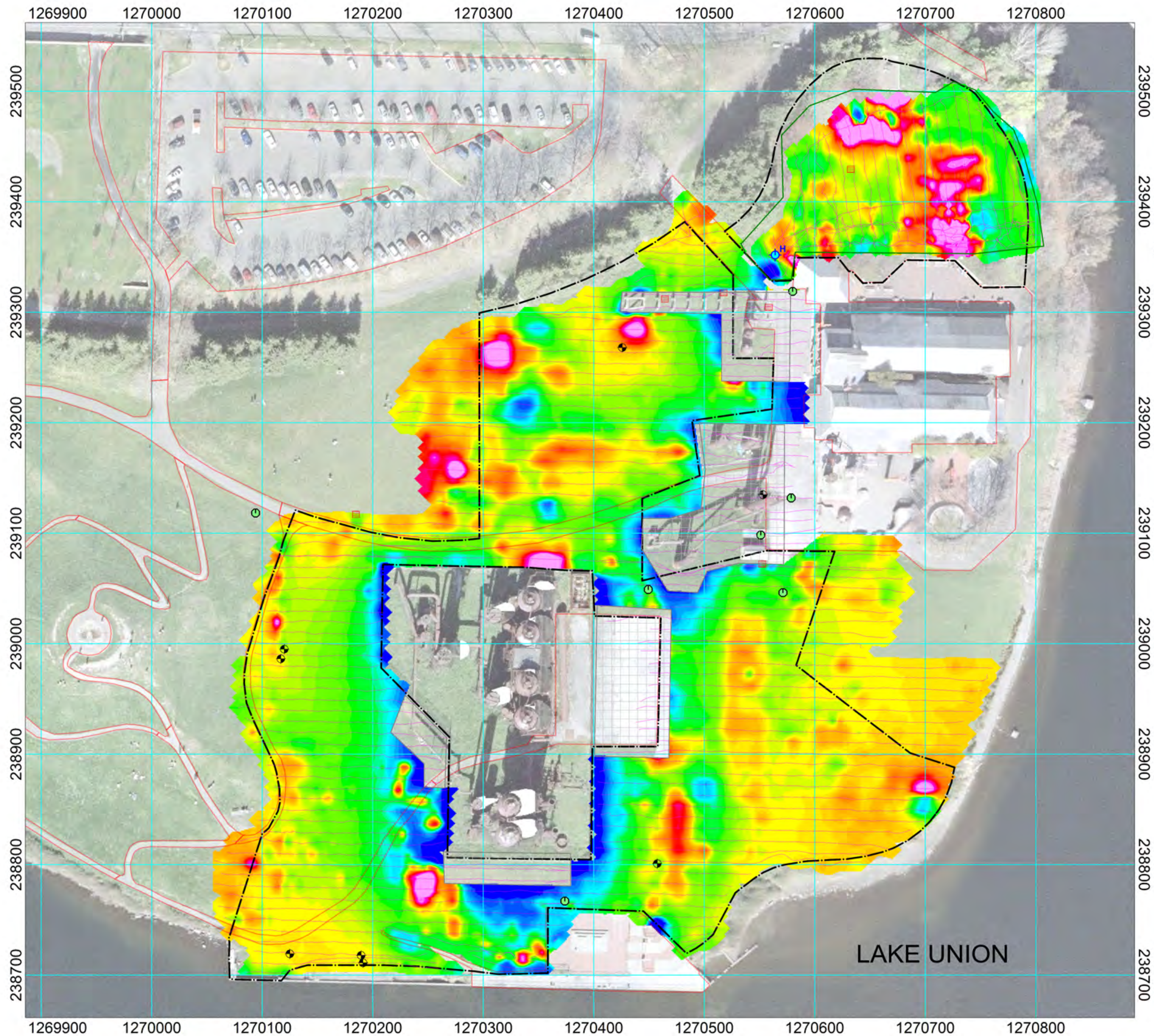
MAGNETIC ANALYTIC SIGNAL DATA PLOT

Geophysical Site Investigation
Gas Works Park
Seattle, Washington

Prepared By:
Zonge
TRUSTED GEOPHYSICS.

Prepared For:
GeoEngineers

REVISION: E-08-NOV-13
DATE: MAARCH 2013
FILE: GasWorks BL.map
ZONGE PROJECT: 13024



57243
56653
56251
55897
55656
55442
55253
55077
54914
54761
54615
54449
54315
54187
54059
53936
53814
53693
53573
53427
53307
53186
53064
52941
52813
52685
52551
52385
52239
52086
51923
51747
51558
51344
51103
50749
50347
49757

Total Magnetic Field
(nanotesla)

Scale 1:1200

50 0 50 100 150 200 250

US survey foot

NAD83 / Washington North (ftUS)

LEGEND

MAGNETIC DATA LINES
MONITORING WELL
STORM GRATE
MAN HOLE
FIRE HYDRANT
FENCE (APPROX.)
CULTURAL INTERFERENCE
GEOPHYSICAL SURVEY PROPOSAL LIMITS

FIGURE A2

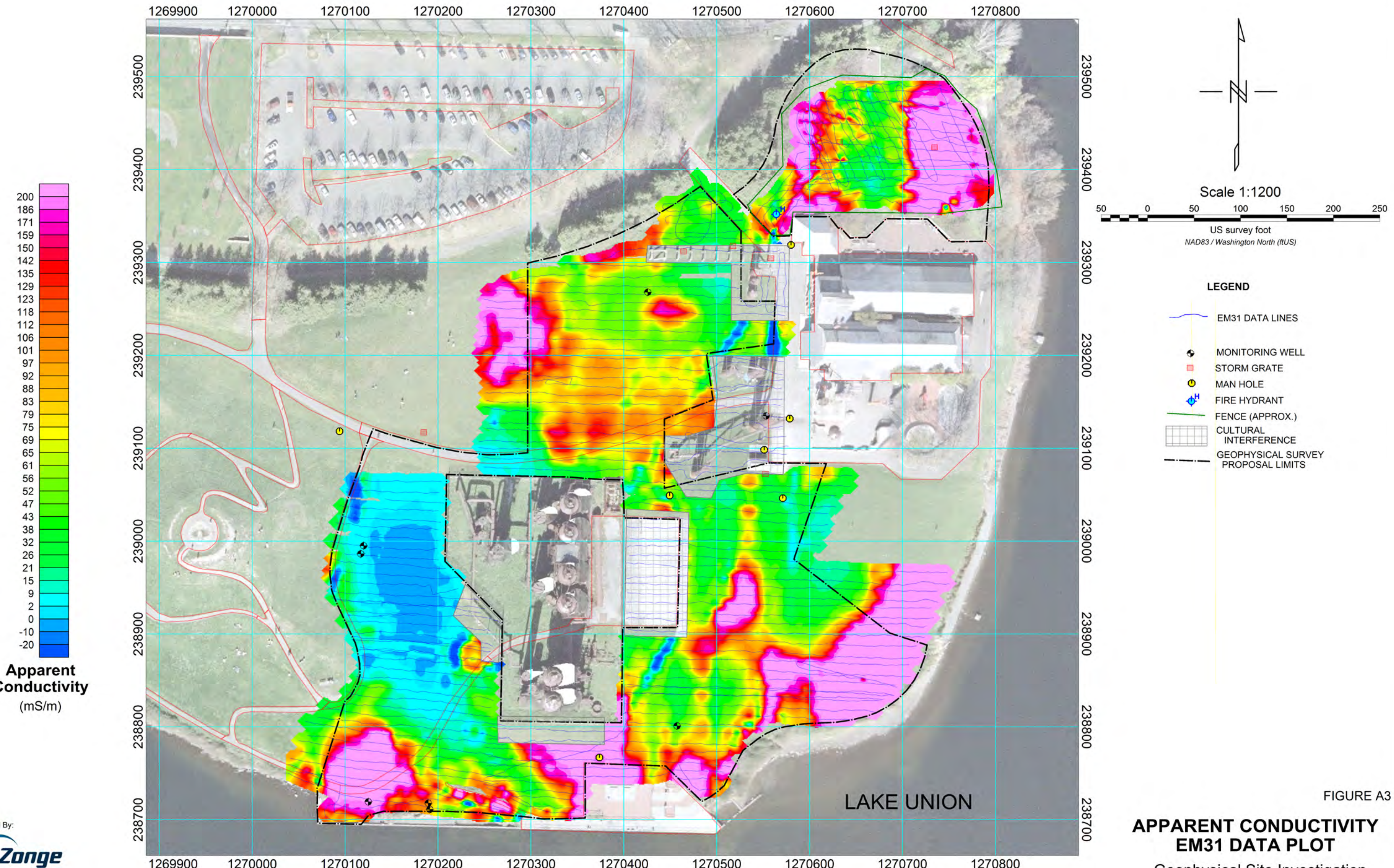
TOTAL MAGNETIC FIELD DATA PLOT

Geophysical Site Investigation
Gas Works Park
Seattle, Washington

Prepared By:
Zonge
TRUSTED GEOPHYSICS.

Prepared For:
GeoEngineers

Agency Review Draft



REVISION: E-08-NOV-13 DATE: MAARCH 2013 FILE: Gas Works EM31Q.map ZONGE PROJECT: 13024

Prepared By:

Zonge TRUSTED GEOPHYSICS.

Prepared For:

GeoEngineers

FIGURE A3

APPARENT CONDUCTIVITY
EM31 DATA PLOT

Geophysical Site Investigation
Gas Works Park
Seattle, Washington

Agency Review Draft

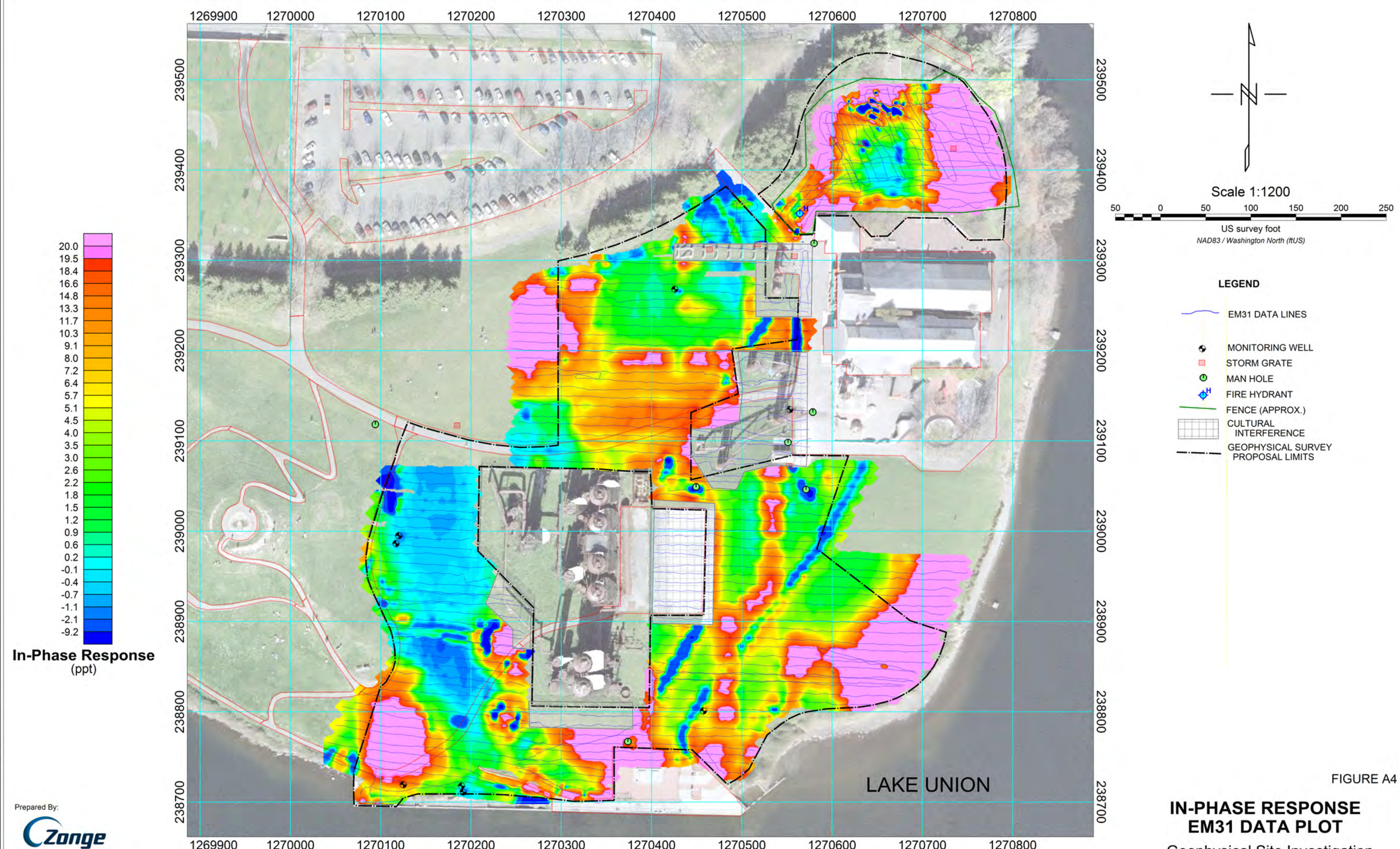


FIGURE A4

IN-PHASE RESPONSE
EM31 DATA PLOT

Geophysical Site Investigation
Gas Works Park
Seattle, Washington

Prepared By:
Zonge
TRUSTED GEOPHYSICS.
Prepared For:
GeoEngineers

GEOPHYSICAL SITE INVESTIGATION GAS WORKS PARK SEATTLE, WASHINGTON

APPENDIX B

TECHNICAL NOTE:

GEOPHYSICAL DETECTION OF BURIED OBJECTS

Photo 1-EM61

Photo 2-GPR

GEOPHYSICAL DETECTION OF BURIED OBJECTS

INTRODUCTION

Several geophysical techniques are used for locating buried objects such as underground storage tanks, pipes, utilities, drums and other debris. These techniques are used routinely, and are often recommended or required by state agencies, funding institutions and/or the EPA, particularly on sites where underground burial of steel drums or other debris may have occurred or where underground storage tanks are suspected.

Geophysics is generally used in the early reconnaissance phase of these investigations as a guide to sampling, excavation and/or placement of monitoring wells. In this paper we describe three of the most common geophysical techniques, electromagnetics (EM), magnetics (MAG) and ground penetrating radar (GPR).

Photo 3-Magnetometer

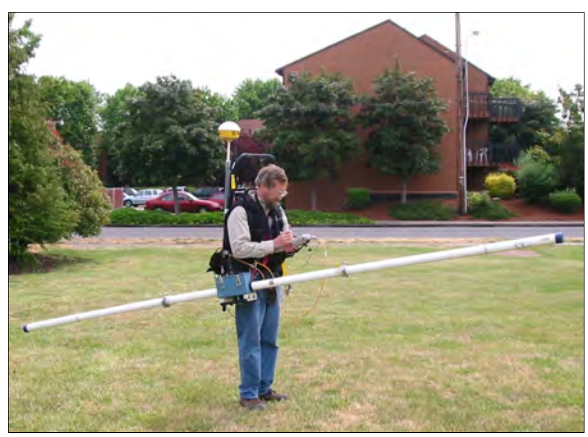


Photo 4-EM31

Zonge International, Inc.
8366 SW Nimbus Ave., Beaverton, OR 97008
(503) 992-6723 Fax: (503) 746-7094
www.zonge.com • ZongeOR@zonge.com

UTILITY OF GEOPHYSICS:

First, a few words about "geophysics" as used for environmental and geotechnical engineering applications. Surface geophysical techniques probe subsurface materials (soils and rock) using surface instruments. This is done by measuring physical signals which have interacted with the earth materials. These signals may be electrical, magnetic, acoustic (seismic) or electromagnetic.

Surface geophysics offers several advantages over other exploration techniques:

1) Surface geophysical methods are ***non-intrusive*** in that they do not disturb the ground surface, or stir up any contaminants which might be in the soil.

2) Geophysical methods ***measure earth properties over a large volume***. Whereas drilling only samples the earth at the point of the borehole, the measured geophysical response is affected by earth materials several feet, or tens of feet, away from the instrument sensor. This allows broad areas to be effectively "screened" with a series of surface measurements.

3) Most geophysical equipment used in environmental and geotechnical applications ***can be hand carried***. Geophysical surveys do not require vehicular access, but only a walking path, clear of brush and obstacles.

4) Geophysical surveys are relatively ***inexpensive*** and can be performed quickly.

TYPICAL OBJECTIVES:

Geophysics may be used in either a reconnaissance mode, or in a detailed survey mode. In the reconnaissance mode, geophysics is used to "screen" large areas to determine the presence or absence of buried objects. In more detailed surveys, the location and extent of the object is mapped in greater detail. This facilitates the efficient excavation of tanks or debris, aids the effective placement of monitoring wells, or improves the design of a sampling program.

The techniques discussed here are also useful for objectives other than identifying buried objects. Electromagnetic induction (EM) is especially useful in mapping changes in soil (e.g. sand or gravel channels), mapping clay aquitards, and mapping contaminant leachate plumes in groundwater. GPR can be used to map shallow stratigraphy or to map zones of disturbed soils.

GEOPHYSICAL METHODS:

Three geophysical methods are commonly used in the search for buried objects: 1) electromagnetic induction (EM), 2) magnetics (MAG), and 3) ground penetrating radar (GPR). EM and magnetics are complementary methods, most effective in the reconnaissance mode but also useful for more detailed work. GPR is most effective for detailed work, but may also be used in reconnaissance surveys.

Electromagnetic Methods:

The electromagnetic induction (EM) technique measures the electrical conductivity of the earth by inducing a time varying electric current in the earth. This is shown schematically in Figure 1. The EM technique was developed to measure natural soil conductivity to aid in identifying soil types and to measure rock conductivity in order to identify zones of conductive mineralization.

Man-made metallic objects are generally orders of magnitude more conductive than natural soils. Thus, the electric currents induced in the ground by EM instruments will be dramatically affected by the presence of any man made metallic object. Examples include pipes, tanks, cables, concrete reinforcing steel, or steel drums. By looking for anomalous signals which cannot be attributed to natural soils, buried metallic objects can readily be identified.

Frequency-domain EM – EM31

Frequency-domain EM systems transmit a sinusoidal waveform at a fixed frequency, or at multiple frequencies. The resulting secondary magnetic field may be phase shifted, depending on the nature of the target. Both the in-phase component (in phase with the primary magnetic field) and the quadrature phase component (shifted 90° from the primary field) can be measured to provide the phase shift information.

The Geonics EM31 is a common frequency domain EM instrument, often used for buried object detection. The cover photo 4 shows the EM31 in a field situation. Figure 1 is a schematic showing the principles of operation. A transmitter coil is in one end of the boom and a receiver coil in the other end. Depth of investigation for the EM-31 is generally 10-15 feet, but it may detect large metal objects at a somewhat greater distance. The instrument can quickly cover a wide area, mapping anomalous areas (metallic object locations) as well as changes in the soil character.

Figure 2 shows some sample data over a disposal site where 55 gallon steel drums had been dumped in a field and then covered with soil. The noisy and/or negative "apparent" conductivity is a clear indicator of metallic objects. The EM31 also records an "in-phase response" which aids in identifying metallic conductors. Data in Figure 2 indicate the zone of burial covers most of the northwest expanse of the site.

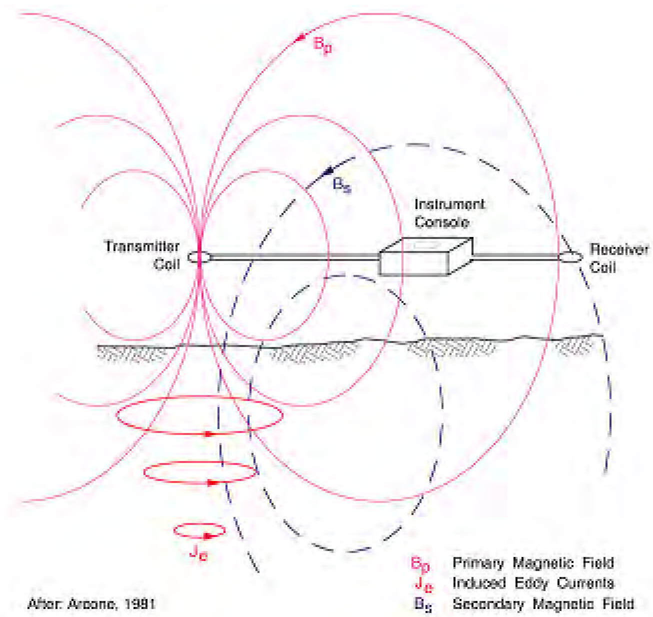
Time-domain EM – EM61

Time-domain EM systems transmit a magnetic pulse, with a duration in the order of tens of microseconds (μs). That magnetic pulse induces electric currents in the ground as well as in any metallic object which is buried (or on the surface) within its range of influence. Currents induced in metallic conductors decay at a much slower rate than currents induced in the ground. Hence, metallic conductors can be easily identified.

The EM61-MK2a (cover photo 1) is a time-domain metal detector manufactured by Geonics, Ltd., of Toronto, Canada. The EM61-MK2a instrument consists of two horizontal air cored coils, 1.0 meter by 0.5 meters in size. The bottom coil acts as a receiver and transmitter and the top coil as a receiver. The instrument weighs about 75 lbs. and is pulled by one operator.

FIGURE 1

PRINCIPLES OF ELECTROMAGNETIC INDUCTION



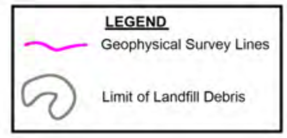
The Geonics EM61-MK2a has 4 time gates, to measure the rate of decay of the signal, and two receiver coils, to measure the field gradient. The rate of decay is dependant on the size, shape, and orientation of the metallic object. Generally, the EM61 is used to estimate gross target parameters, but can be used for more detailed discrimination of targets, particularly in identifying unexploded ordnance (UXO) materials.

The two receiver coils are very helpful in the differentiating between near surface objects and deeper objects. Since the amplitude of the response is highly dependent on the distance between the coil assembly and target, small near surface targets often produce a response orders of magnitude larger than targets having greater size at deeper depths. This masking effect from the near surface materials is drastically reduced by processing output of the two coils, essentially subtracting a portion of the bottom coil response from the top coil response. This is referred to as the differential mode or the differential signal.

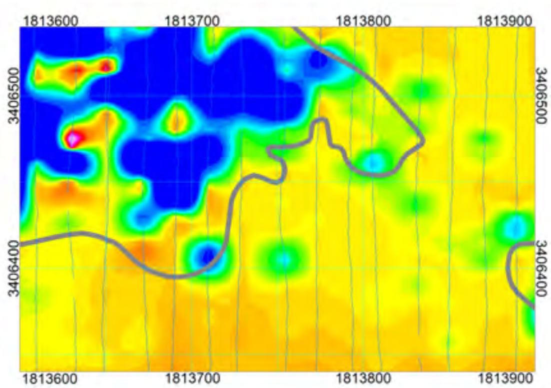
Figure 3 shows some sample data over a 55 gallon steel drum partially buried, essentially flush with the surface of the ground. The response from the top and bottom coils is indicative of a substantial metallic presence. The relatively weak differential response is indicative of a shallow target.

FIGURE 2

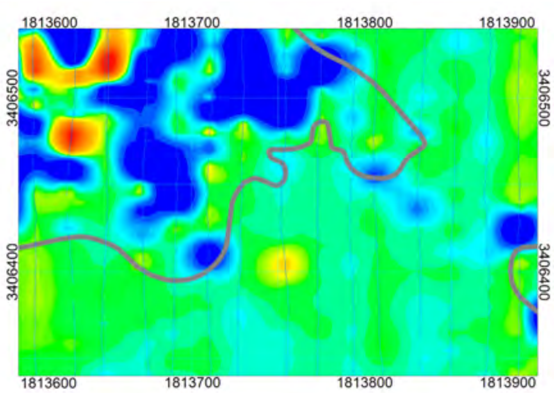
EM31 & MAGNETIC GRIDS



A) EM31 Apparent Conductivity

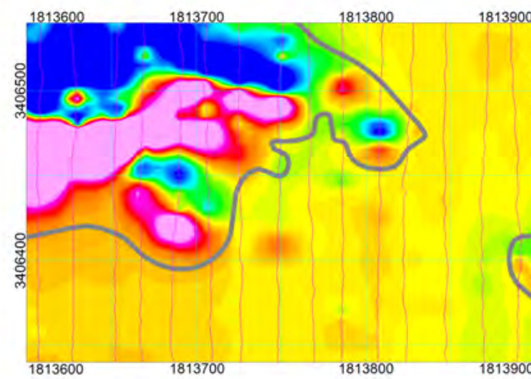


B) EM31 In-Phase Response

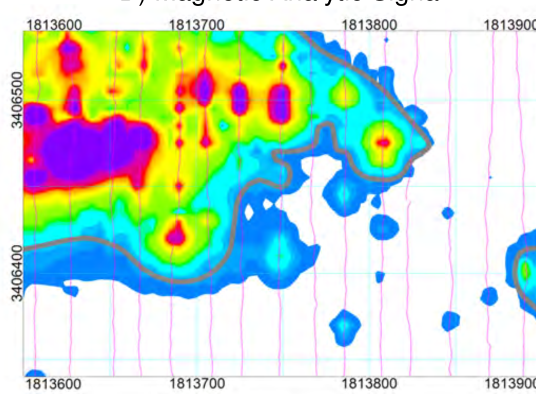


Distance (feet)

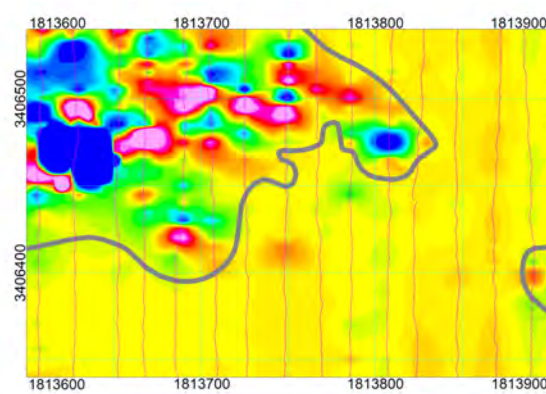
C) Total Magnetic Field



D) Magnetic Analytic Signal



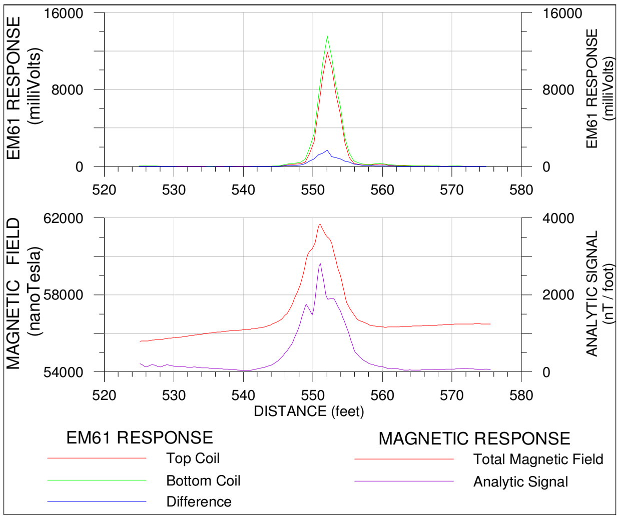
E) Vertical Magnetic Gradient



Distance (feet)

FIGURE 3

EM61 & MAGNETIC PROFILES OVER PARTIALLY BURIED 55 GALLON DRUM



Magnetic Methods:

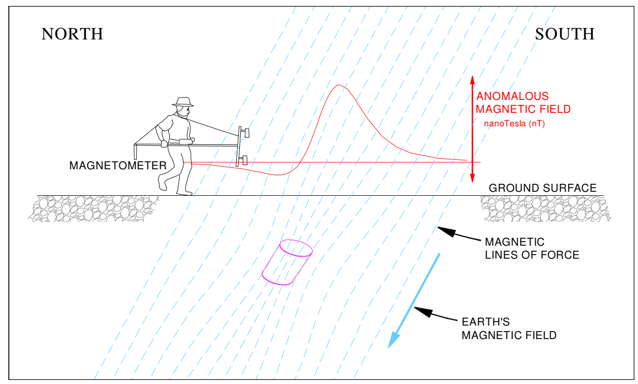
Magnetic methods measure disturbances in the earth's natural magnetic field. These disturbances are caused by magnetic materials, either magnetic rocks, or man made objects containing iron or steel. This is shown schematically in Figure 4. Most soils have negligible magnetization (both induced and remnant). Thus, most magnetic disturbances from shallow sources can be attributed to iron or steel objects which have been placed there by man's activities.

Magnetometers used for buried object detection usually measure the gradient of the magnetic field. This is done by measuring the difference between the magnetic field at two sensors separated vertically by two or three feet. This configuration is more sensitive to nearby disturbances, and is less effected by disturbances caused by distant objects or shallow bedrock.

Photo 3 on the cover shows a magnetometer/ gradiometer. This instrument can also cover wide areas quickly, providing complementary data to EM. Figure 2 includes total magnetic field data, gradiometer data, and magnetic analytic signal data over the barrel disposal area. The large deviations in both total field and gradient are indicative of steel objects in close proximity.

FIGURE 4

PRINCIPLES OF MAGNETIC EXPLORATION



Ground Penetrating Radar:

Ground penetrating radar (GPR), like other radar techniques, sends out an electromagnetic pulse (radio wave or microwave) which is reflected off a "target" and returns to the receiver. GPR operates at lower frequencies (80-1500 MHz) than other radar to obtain better penetration in the earth materials. The antenna is pulled slowly along the ground surface to produce a continuous subsurface profile.

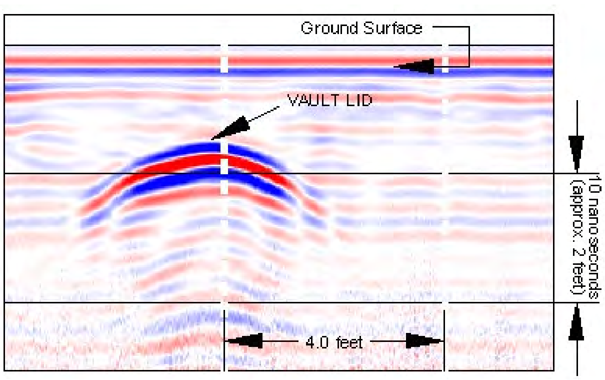
Photo 2 on the cover shows a GPR unit in operation. The 400 MHz antenna shown is being pushed in its cart. The control and recording unit is carried on the cart enabling one person operation.

Figure 5 is an example GPR profile over a shallow vault. The vertical scale is a time scale, giving the time for the radar pulse to travel down to the reflector and return to the receiver. Knowing the pulse velocity in the soils, we can convert this to depth. The horizontal scale corresponds to distance along the surface. Fiducial time marks on the record are placed at four foot intervals. The vault lid reflector shown appears as a hyperbola on the record. The vault lid produces a strong reflection with a characteristic ringing of the electronics, which appears as a dark red or blue band below the first arrival from the vault lid.

GPR is a tool for looking at selected areas in detail. Its continuous subsurface profiles give a graphic portrayal of subsurface conditions, and often provide an excellent means of accurately locating pipes and tanks. However, the GPR depth of exploration is strongly dependent on soil conductivity and subsurface conditions. In dry, sandy soils useful data may be obtained from depths down to 15 feet, whereas in conductive clay soils, typical of the Willamette valley, investigation depth is often limited to 2 or 3 feet.

FIGURE 5

SAMPLE GPR PROFILE



DISCUSSION:

As we have stressed, EM and magnetics are effective in screening large areas quickly to identify areas where buried objects may be present. Often these techniques can provide a rough estimate of the size and depth of the object causing the anomalous readings.

The choice of frequency domain EM (i.e. EM31) versus time-domain EM (i.e. EM61) depends on the objectives and the site. The EM61 is very effective at identifying small pieces of metal (e.g. unexploded ordnance), and offers some depth and discrimination capability. It is also less sensitive to cultural noise (e.g. buildings, vehicles, etc.) than the EM31. The EM61 can often resolve anomalies which are close together, where the EM31 does not. However, the EM61 requires a tight line spacing, typically 1 meter, to assure the area is covered. Also, the wheeled cart is difficult or impossible to operate on some sites (the EM61 can also be carried on a shoulder harness but is very awkward).

The EM31 is favored over the EM61 on more open sites where the objective is to locate underground tanks, drums, or collections of debris. The broader sphere of influence of the EM31 allows it to be run on a coarser line spacing, typically 5-20 feet depending on the target.

A major limitation of both EM and MAG is their sensitivity to cultural noise. Buildings, fences, metallic surface debris, and vehicles all create cultural noise. The EM and magnetic instruments respond to any metallic objects, whether buried or in plain view above ground. Thus, areas within 20 to 40 feet of buildings, vehicles or pipelines will be masked by the strong response from those objects. EM and magnetics will not be able to definitively identify other buried objects within that masked zone.

GPR on the other hand is fairly immune to those forms of cultural noise. The radar signal is confined to a broad beam, spreading at roughly a 45° angle, beneath the antenna. Most antennas are well shielded with little upward propagation of the pulse. Thus GPR can be run next to buildings, fences and parked vehicles. GPR may be run inside buildings and even over reinforced concrete.

Because the GPR beam is directional, it does not have the same utility as a reconnaissance tool as the EM and MAG techniques. Whereas the latter techniques would readily detect a large tank 10 or 20 feet off the survey line, GPR would not detect the tank unless the survey line passed directly over it.

CONCLUSIONS

No geophysical technique should be used without some form of "ground truth" provided by drilling, excavation, or some other form of sampling. The geophysical signature of an underground storage tank may be very similar to that of a buried automobile. However, geophysics can eliminate random drilling or extensive excavation when searching for underground tanks or other materials.

To conclude, EM, magnetic, and GPR methods are effective, complimentary techniques used in the detection and delineation of subsurface metallic objects. The choice of technique or techniques depends very much on both site conditions and the survey objective.

FURTHER READING:

Benson, R.C., Glaccum, R.A., and Noel, M.R., 1982, Geophysical techniques for sensing buried wastes and waste migration: Report prepared by TECHNOS, Inc. for EPA, Advanced Monitoring Systems Division, Las Vegas, pp.235.

Evans, R.B., 1982, Currently available geophysical methods for use in hazardous waste site investigations: from Risk Assessment at Hazardous Waste Sites, ACS symposium series No.204, p.93-115.

French, R.B., Williams, T.R., and Foster, A.R., 1988, Geophysical surveys at a superfund site, Western Processing, Washington: Proc. of SAGEEP, March 1988, Golden, Colorado, p.747-753.

McNeill, J.D., 1990, Use of electromagnetic methods for groundwater studies: in Geotechnical and Environmental Geophysics, ed.: S.H.Ward, SEG, IG#5, p.191:218.

Romig, Phillip, 1992, Engineering and Environmental Geophysics Get Top Billing at SAGEEP.: The Leading Edge Vol. 11, No. 11, P.36-37.

DISCUSSION OF GEOPHYSICAL TECHNIQUES

GEOPHYSICAL DETECTION OF BURIED OBJECTS

Zonge International, Inc.
8366 SW Nimbus Avenue
Beaverton, OR 97008
www.zonge.com
Phone: (503) 992-6723

FILE: B-B_TECH.pub
REVISION: 23-SEP-2010

ATTACHMENT 2A-2

TarGOST® Data Processing

Table of Contents

LIST OF FIGURES

SUB-ATTACHMENTS

ATTACHMENT 2A-2
TARGOST® DATA PROCESSING

1.0 INTRODUCTION

This attachment is intended to provide a summary of the Tar-Specific Green Optical Screening Tool (TarGOST®) investigation and related data generated during the 2013 Supplemental Investigation at the Gas Works Parks Site (GWPS, Site). TarGOST® is a laser-induced fluorescence (LIF) screening tool designed to delineate nonaqueous phase liquid (NAPL) in the subsurface, generating in-situ real-time data. TarGOST® guidance is included as Sub-attachment 2A-2.6 (TarGOST® Guide). TarGOST® technology was developed by Dakota Technologies, Inc. (Dakota).

TarGOST® is deployed with direct push drilling. At the Site, Dakota's fiber optic cables were strung through the driller's rods; the TarGOST® tip along with the rods were advanced into the ground with the rig. The procedure works as follows:

- A shock-protected optical chamber (SPOC) drill bit is connected to fiber optic cables strung through drilling rods.
- A TarGOST® drilling probe is sent vertically into the subsurface, attached to a GeoProbe.
- Most of the laser light emitted by the optical window is reflected by the soil. In the presence of oil-like material (OLM) and tar-like material (TLM), polycyclic aromatic hydrocarbons (PAHs) in the NAPL absorb the light and move to an excited state.
- When the PAHs are restored to ground state, the return wavelength generated is longer than that of the laser light. This fluorescence behavior is captured by the optical fibers and a spectrometer within the TarGOST® system.
- The returning fluorescence is divided into four wavelength channels plotted on charts referred to as waveforms (energy [milli- or pico-volts] vs. time [nanoseconds]).
  - The first channel is reflection from soil, referred to as scatter and abbreviated as "%Sctr" (percent scatter).
  - The remaining three channels are fluorescence response of soil, referred to as %Fluor.
  - The %Fluor is normalized by the scatter, yielding an output known as Signal %RE.
  - %RE stands for %Reference Emitter (% is to the calibrated value determined using gray paint).
  - %Fluor and Signal (%RE) are graphed versus depth on the TarGOST® logs.
- The %RE and %Fluor are color-coded to help alert to shifts in NAPL types, for example from light NAPL (LNAPL) to dense NAPL (DNAPL).

The following sections describe TarGOST® field methodology, TarGOST® data types generated during and following the 2013 Supplemental Investigation, and TarGOST® data reduction. Appendix 5F (NAPL Evaluation) to the main RI includes additional discussion related to TarGOST® and NAPL at the GWPS.

2.0 TARGOST® FIELD METHODOLOGY

Forty-five TarGOST® explorations (TG-1 to TG-45) and two co-located explorations (TG-12R/46 and TG-42R) were advanced during the Supplemental Investigation (SI) between March 18 and March 26, 2013. Dakota provided TarGOST® equipment, and Cascade Drilling provided direct push drilling equipment. Two locations (TG-18B and TG-32B) had to be re-drilled near the original attempted locations because the first attempts met shallow refusal.

The TarGOST® system was outfitted onto a utility vehicle comprising a generator, computer, rod- rack, fiber optic cables and TarGOST® probe tips. The TarGOST® tip has a sapphire optical window emitting pulses of 523-nanometers (nm; green) laser light through the fiber optic cables from the TarGOST® system (generator, computer and LIF source) (Sub-attachment 2A-2.6 – TarGOST® Guide). The sapphire optical window on the TarGOST® tip was calibrated before each TarGOST® location with a standard reference emitter (100 percent frequency), a unique gray paint used at all sites (Dakota 2013).

3.0 TARGOST® DATA TYPES

Several types of TarGOST® data were generated during and after the 2013 Supplemental Investigation: NAPL LIF responses, TarGOST® logs and associated electrical conductivity (EC) data, TarGOST® soil confirmation samples, Dakota three-dimensional (3D) modeling, classification plots, the Dakota site report, and non-negative least squares (NNLS) waveform analysis. These data are discussed in the following subsections.

3.1. NAPL Sample LIF Responses

LIF responses from five NAPL samples collected at the Site are included as Sub-attachment 2A-2.2.1. Small product samples were collected at the very beginning of the 2013 Supplemental Investigation from any well that had NAPL in it. DNAPL samples were collected from DW-4, DW-5, DW-7 and MW-18. An LNAPL sample was collected from MW-9. Samples were sent to Dakota in advance of the TarGOST® drilling work to verify that the LIF equipment could respond to the different types of NAPL at the Site. DNAPL samples submitted to Dakota for LIF response produced signal %RE with orange tone and shorter lifetime/"skinny"' waveform bases (plotted on the x-axis of the waveform callouts); the LNAPL sample produced signal %RE with yellow tone and longer lifetime/thicker waveform bases.

3.2. TarGOST® Logs and EC Data

TarGOST® logs for all 49 TG- probes are available in Sub-attachment 2A-2.2 (TarGOST® Logs and EC Data). The scale on the logs is consistent (0 to 40 feet deep and 0 to 600 %RE).

TarGOST® logs present %RE signal versus depth. Color-coding of signal %RE is generated by taking the normalized average of scatter and additional fluorescence channels. The call-out waveforms on the left of the log plot the channels. The waveforms plot signal in millivolts (mV) on the y-axis and time on the x-axis. Longer waveform bases also referred to as ski-slopes are indicative of solvated NAPL or petroleum products compared to skinny peaks indicative of "tar" (Dakota 2013). Fluorescence %RE is also presented on the logs. Because fluorescence removes scatter it is often more useful than waveforms in distinguishing different NAPLs. Scatter responds to soil type, with lighter soil resulting in higher scatter. When both the scatter and fluorescence go up, it is probably a false positive response due to geology (lighter soil). Examples include TG-25 at 9 feet, TG-31 at 12 feet and TG-41 at 20 feet, which range from 7 to 8 %RE. Therefore background response due to geology is at least 8 %RE.

EC readings were attempted at TarGOST® locations. However, difficult probing conditions resulted in sporadic EC data collection, with quality data collected at about 40 percent of the holes. For this reason, not all EC data depicted on the TarGOST® logs are accurate: a table summarizing accuracy of EC readings per log is included in Sub-attachment 2A-2.2.

3.3. TarGOST® Confirmation Samples

Six GeoEngineers' (GEI-) confirmation borings were completed next to TG- TarGOST® explorations. Soil impact observations and geology were logged. Twelve soil samples were collected from selected intervals within the six borings and split into two. One split sample was submitted to Analytical Resources, Inc. (ARI) for PAH analysis, and one split was submitted to Dakota for LIF %RE analysis. The TarGOST® responses from the soil samples are included in Sub-attachment 2A-2.3. Analytical concentrations for the split soil samples are included in Attachment 2A-9 to Appendix 2A. TarGOST® logs and classification plots were used in the process. Side-by-side comparison including analytical results, field screening and geologic units are presented in Figures 2A-2-1 to 2A-2-7.

Zones selected for sampling had a TG signal that was fairly uniform (not spikey) over a thickness of 6 inches or more. The selected zones included high, med and low TG responses.

Before splitting, soil samples were well-homogenized in a stainless steel bowl with a stainless steel spoon. The bowl was washed with alcohol between samples.

Each sample is represented as a separate log in Sub-attachment 2A-2.3. The naming convention for the soil splits on the logs is as follows: GEI_12_25_26 represents the split soil sample from GEI-12 from 25 to 26 feet deep. Dakota placed three different aliquots of each soil sample on the optical window for a preset amount of time (represented as feet on the log). Results indicate the heterogeneity within each sample. Then Dakota averaged the signals of the three aliquots to yield the best possible TG value for that sample.

3.4. Dakota 3D Modeling

Dakota completed 3D model of TarGOST® data collected at the GWPS. The model does not take into account analytical results, historic and recent field observations, geology or hydrogeology[1]. To assist with model development, GeoEngineers provided some guidance to Dakota regarding general NAPL trends observed at the GWPS.

The model reflects a recombination of three stand-alone "subdomains." In general, they are Harbor Patrol area and north and west; Cracking Tower area and south; and MW-09 area, eastern/southeastern portion of upland and the northeast corner.

The model shows rainbow-colored sticks for each TG probe in 3D, with a range of colors that represents %RE. Dakota modeled five shells: one each at 15 %RE, 25 %RE, 50 %RE, 75 %RE and 100 %RE. The model also shows radial cross-section views through Harbor Patrol area, west of Cracking Tower area, just south of the Play Barn, and the northeast corner.

---

[1] A separate 3D model developed by GeoEngineers for the GWPS includes geology, hydrogeology, chemistry and storm drain network information not included in Dakota's TarGOST® 3D Site-specific model.

3.5. Classification Plots

Dakota provided NAPL classification plots for TarGOST® logs, soil split samples, and NAPL samples (Sub-attachment 2A-2.4). NAPL Classification plots are derived from the waveforms, including scatter, average lifetime (tau) of the peaks on the y-axis and wavelength on the x-axis. Fill colors correspond to signal %RE from the TarGOST® logs. NAPL classification logs were used to distinguish NAPL types (i.e. LNAPL vs. DNAPL vs. mixes). Blue-shifted (left quadrant) and long-lived clusters are indicative of solvated[2] NAPL or petroleum products; red-shifted (right quadrant) short-lived clusters are indicative of heavier NAPL.

3.6. Dakota Report

The TarGOST® Investigation report by Dakota is available in Sub-attachment 2A-2.5 (TarGOST® Report). It includes detailed field notes, a calibration discussion, false positives/interference, a waveform discussion, and a table of production and observations.

3.7. NNLS Waveform Analysis

Waveforms provide insight into different types of NAPL. For example if TarGOST® response is observed on NAPL, longer waveform bases (ski-slopes) will appear in solvated NAPL or petroleum products compared to skinny peaks indicative of tar (Dakota 2013).

Dakota performed NNLS waveform analysis on all logs (Sub-attachment 2A-2.7). NNLS analysis separates the %RE LIF response to different NAPL types, called components, and a background component. Each component has a signature waveform. Software compares the component waveforms to the entire set of waveforms that make up a TarGOST® log. The log is broken into the matching components or NAPL types. Deviation or residual is also plotted on the left.

A "basis set" for the NNLS analysis (comprising distinct waveforms from a given depth range within a TarGOST® log) was chosen based on five lines of evidence: (1) samples that represented the greatest spatial coverage of the Site, (2) geographic clustering and classification plot clustering, (3) depth intervals that were "clean enough" to be harvested (i.e., not several NAPL types intermixed), (4) depth intervals that were located next to soil analytical samples and (5) discussion with Dakota.

The following four "basis set" components were selected:

- Dense 1 – DNAPL from the MGP (harvested from TG-15 northeast of the Cracking Towers, 27.31 to 28.68 feet below ground surface [bgs]),
- Dense 2 – DNAPL from Harbor Patrol and the former tar refinery (harvested from TG-21 at Harbor Patrol, 22.15 to 25.58 feet bgs),
- Light1 – Petroleum-like LNAPL from the gully (harvested from TG-39, 11.37 to 13.32 feet bgs) and
- Light 2 – MW-09-like LNAPL (harvested from TG-12 around 8.87 to 10.73 feet bgs).

[2] A solvated compound is one formed from the interaction of a solvent and a solute.

The entire set of TarGOST® logs was run with all four components so as to identify a "best fit" for all %RE[3]. Each log had its own background waveform analysis assigned by Dakota. On a few logs, there were signals Dakota was confident were not NAPL; for these logs, Dakota created temporary Basis Waveforms to eliminate the spurious (non-NAPL) results.

Dakota also performed NNLS analysis on the soil split confirmation samples. Because of a bug in the program, Dakota was unable to run NNLS analysis on the NAPL samples.

4.0 DATA REDUCTION

The TarGOST® data reduction process entailed the following: omitting data not representative of current conditions, deciding what to use for background, and creating an all-encompassing table showing interpreted NAPL intervals by depth for each TarGOST® boring. A discussion of TarGOST® data interpretation and TarGOST® correlation to NAPL field observations is included in Appendix 5F (NAPL Evaluation) to the RI report.

4.1. Data Exclusions

As discussed in the TarGOST® investigation report in Sub-attachment 2A-2.5, some depth intervals within certain TarGOST® borings had unreliable %RE responses, due to either pre-probing or broken fibers in the probe tip. As Dakota mentions (Sub-attachment 2A-2.5),

> *"… at many probing locations, the 0 to 3' interval was hand augered to look for the park irrigation system, then backfilled with the same material to provide lateral stability to the advancing the TarGOST® probe. Some locations were pre-probed with a dummy probe to 4.5' or deeper to get past rubble or obstructions. Locations that were hand augered or pre-probed do not provide reliable TarGOST® data in the disturbed interval. When looking at TarGOST® logs, keep in mind that the data in the upper interval may not represent subsurface contaminant distribution or concentration levels."*

The following intervals were excluded from the TarGOST® data set:

- TG-18, 8 feet bgs to total depth (8.98 feet bgs) – Inaccurate response identified by Dakota either on log or in report.
- TG-18B, 15.5 feet bgs to total depth (15.6 feet bgs) – Inaccurate response identified by Dakota either on log or in report. TarGOST® probe was broken and bent at this interval, resulting in a false positive. Because there are inaccurate responses on this log, the classification plot for TG-18B omits outliers.
- TG-32B, 0 to 10 feet bgs – Inaccurate response identified by Dakota either on log or in report.
- TG-33, 0 to 4.5 feet bgs – Inaccurate response identified by Dakota either on log or in report. This interval was pre-probed. This response may not be representative. This omits outliers on its classification plot. Because there are inaccurate responses on this log, the classification plot for TG-33 omits outliers.

[3] Note: scales are not consistent from log to log for the waveform analysis.

- TG-34, omit 0 to 2 feet bgs – Inaccurate response identified by Dakota either on log or in report. This interval was pre-cleared. This response may not be representative. This omits outliers on its classification plot. Because there are inaccurate responses on this log, the classification plot for TG-34 omits outliers.
- TG-37, omit 2 to 26.05 feet bgs – Inaccurate response identified by Dakota either on log or in report. Dakota report indicates the probe window was shifted. There is a clear elevated background signal with NNLS.
- TG-41, omit 0 to 10 feet bgs – Inaccurate response identified by Dakota either on log or in report.

During waveform analysis, Dakota identified an additional interval whose response was likely a result of "paint" or "grass: TG-02, omit 0 to 5.8 feet bgs.

4.2. Background %RE Determination/Inferred NAPL Presence

Background response due to geology is thought to be at least 8% RE (see Section 3.2). The TarGOST® %RE cutoff value to distinguish between the presence and absence of NAPL at GWPS is conservatively 10%RE; the rationale for this cutoff is described in Appendix O of the RI report.

4.3. TarGOST® "Picks" Table

Interpreted NAPL intervals by depth for each TarGOST® boring were tabulated for use in the conceptual site model (CSM) and remedial investigation (RI). Depth intervals for each TarGOST® boring were assigned one of the following categories:

- No data (see Section 4.1 for more detail)
    - Depth interval identified as inaccurate by Dakota on log or in report because, for example, fibers broke, probe rod broke or probe window shifted.
- No impacts
    - <10 %RE – depth intervals that had consistent %RE values of <10 %RE were considered to be "no impacts" or "background"
    - >10% %RE, but response was identified as grass or paint by Dakota during waveform analysis (e.g., TG-02, 0 to 5.8 feet bgs), or response had predominant waveform match to background basis set (TG-42, 0 to 8 feet bgs).
- NAPL impacts
    - LNAPL
        - LIGHT1 – depth intervals whose predominant waveforms match[4] LIGHT1 basis set
        - LIGHT2 – depth intervals whose predominant waveforms match LIGHT2 basis set
    - DNAPL
        - DENSE1 – depth intervals whose predominant waveforms match DENSE1 basis set
        - DENSE2 – depth intervals whose predominant waveforms match DENSE2 basis set

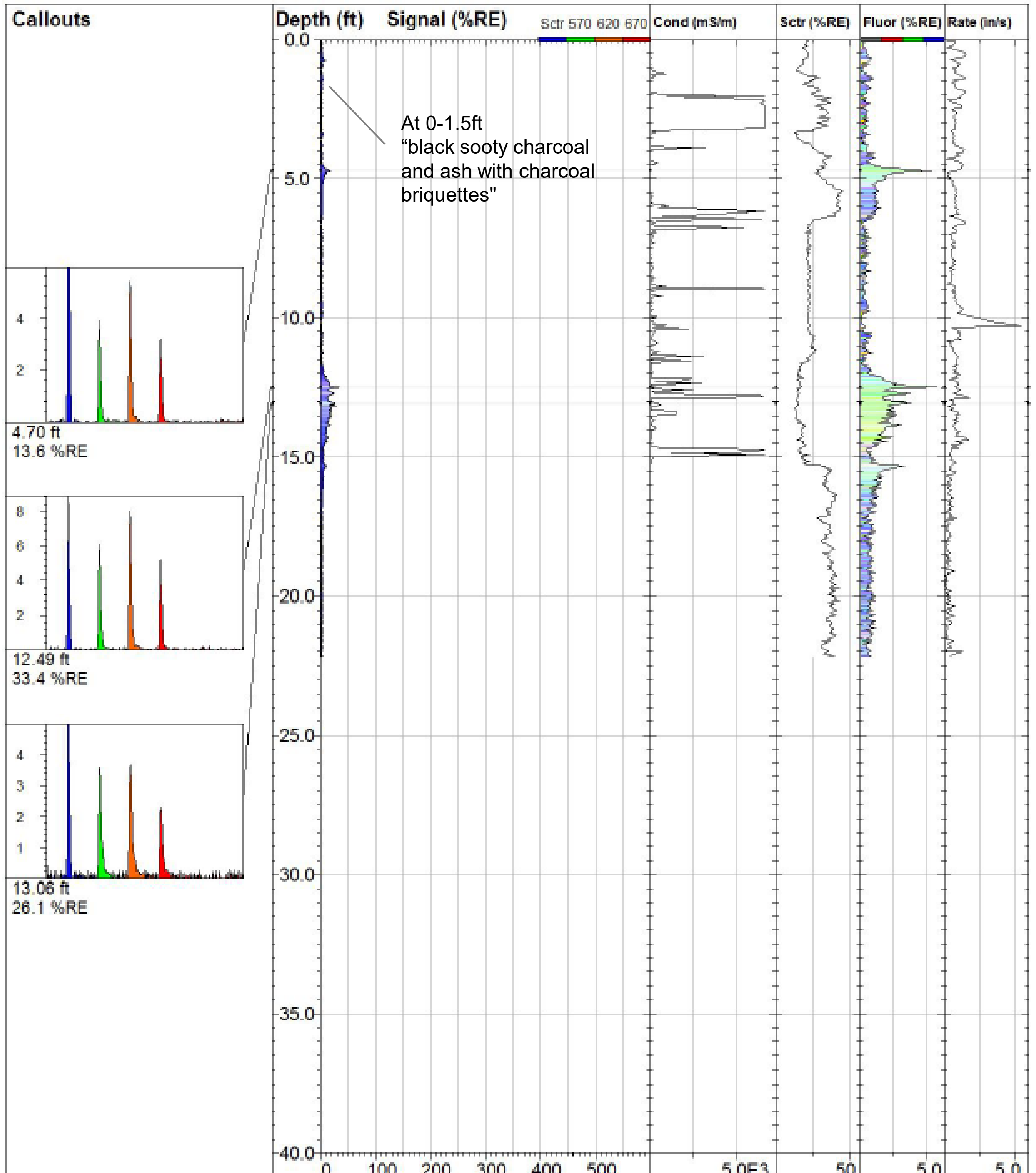
---

[4] Professional judgment was used in determining predominant waveform match for a given depth interval.

Correlation of TarGOST® picks to NAPL field observation picks is discussed further in Appendix 5F (NAPL Evaluation) of the RI report.

5.0 REFERENCES

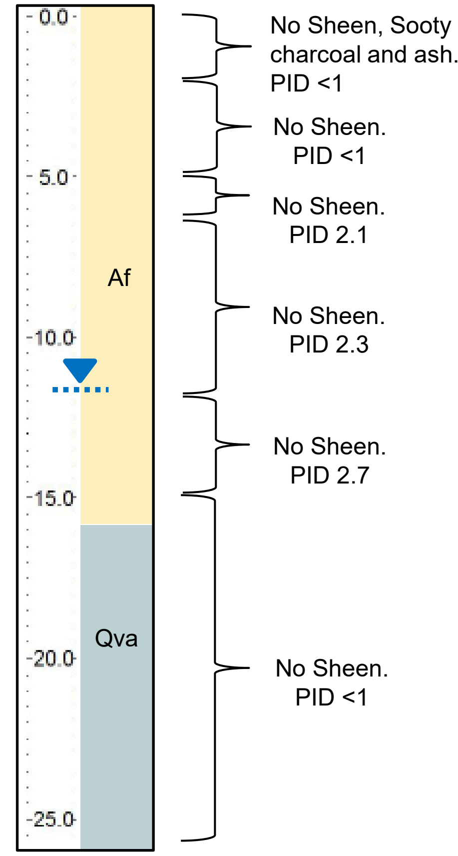
Dakota. 2013. Personal communication (telephone call from Randy St. Germain, Dakota, to GeoEngineers).



GWP_TG-08		**TarGOST By Dakota** www.DakotaTechnologies.com
Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **239358.1004 /**	*Final depth:* **22.16 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1270747.424 /**	*Max signal:* **33.4 %RE @ 12.49 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **32.7 ft**	*Date & Time:* **2013-03-19 14:35 PDT**

DAKOTA TECHNOLOGIES
Fargo, ND 701.237.4908
www.DakotaTechnologies.com

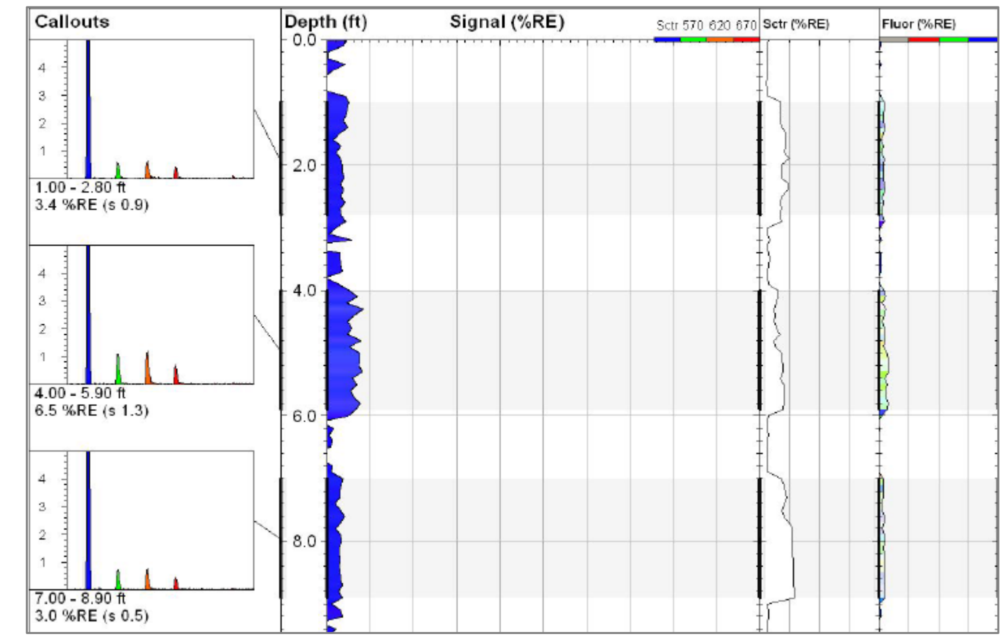
GEI-7 Geology and Field Screening



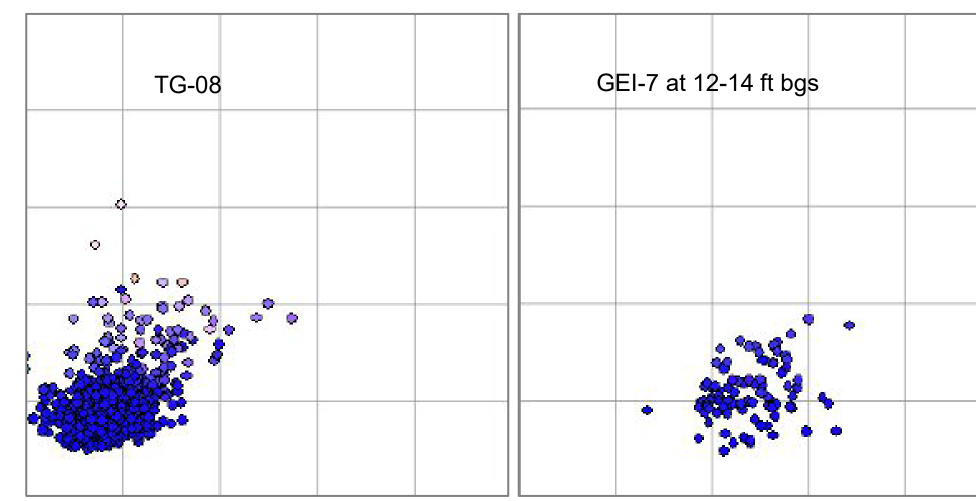
GEI-7 Analytical Results

Depth Ft bgs	TPAH	B(a)p	Naph-thalene	sum >4 rings PAHs
	mg/kg			
12-14	33	2.6	3.2	22.67
20-21	0.657	0.026	0.380	0.18

GEI-7 at 12-14 ft bgs Soil Confirmation TarGOST Screening



Classification Plots



Notes:

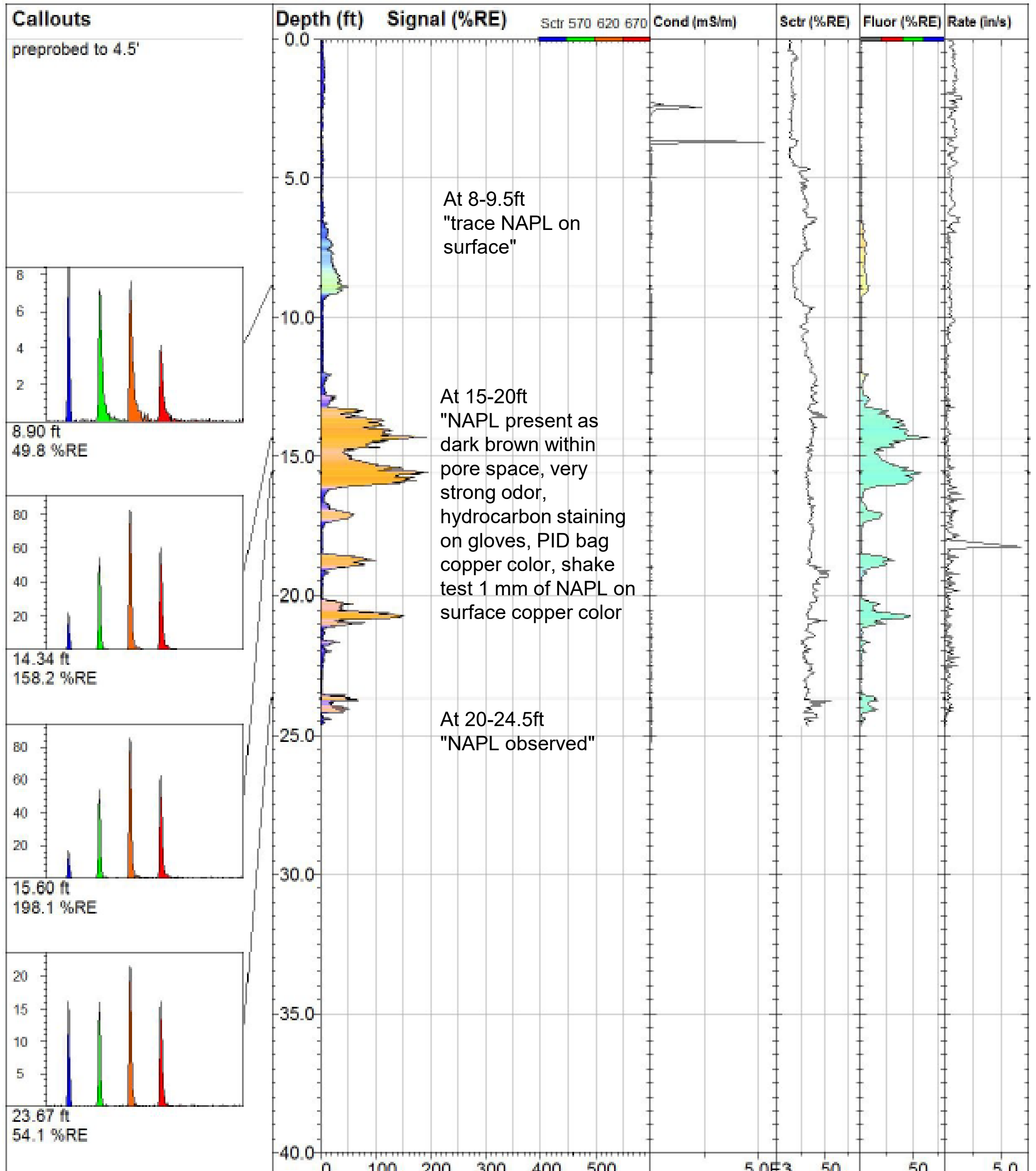
1. Refer to Attachment A-2 TarGOST Data Processing. Classification plots graph lifetime on vertical-axis and wavelength on horizontal-axis.
2. NAPL includes categories 'heavy sheen with NAPL' and 'tar or tar impacted interval' NAPL impact designation.
3. Geologic units: Af = fill; Qvr = Vashon recessional outwash; Qva = Vashon advanced outwash; Qpgt = pre-Fraser till.
4. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

TarGOST Confirmation Borings
TG-08/GEI-7

Gas Works Park Site
Seattle, Washington

GeoEngineers

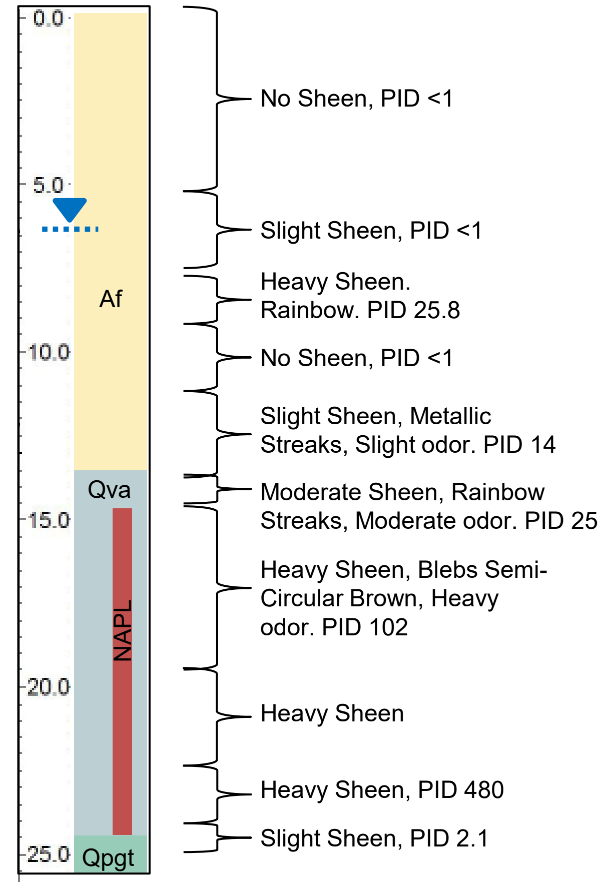
Figure 2A-2-1



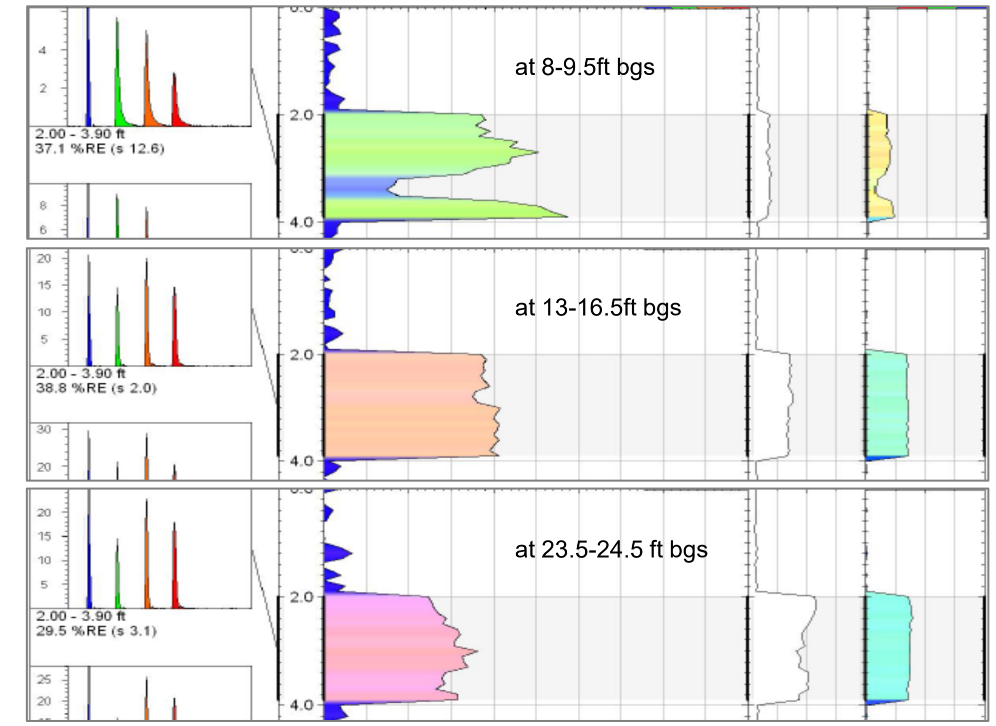
GWP_TG-11		TarGOST By Dakota www.DakotaTechnologies.com
Site: Gas Works Park	Y Coord.(Lat-N) / System: 239143.7821 /	Final depth: 24.64 ft
Client / Job: GeoEngineers /	X Coord.(Lng-E) / Fix: 1270529.323 /	Max signal: 198.1 %RE @ 15.60 ft
Operator / Unit: SDA / TG1004	Elevation: 35.0 ft	Date & Time: 2013-03-20 08:31 PDT

DAKOTA TECHNOLOGIES
Fargo, ND 701.237.4908
www.DakotaTechnologies.com

GEI-13 Geology and Field Screening



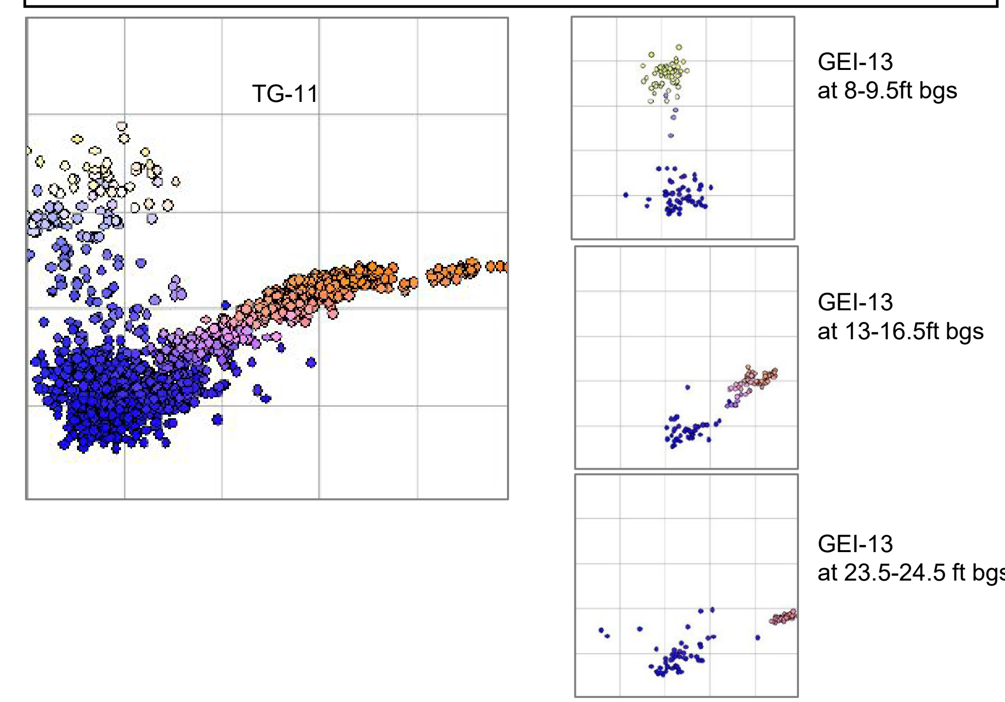
GEI-13 at Multiple Depths Soil Confirmation TarGOST Screening



GEI-13 Analytical Results

Depth Ft bgs	TPAH	B(a)p	Naph-thalene	sum >4 rings PAHs
	mg/kg			
8-9.5	24.9	1	2.1	10.72
13-16	341.21	3.7	190	44.41
23.5-24.5	731.7	9.4	380	106.3
25-25.5	107.39	1.7	50	18.64

Classification Plots



Notes:

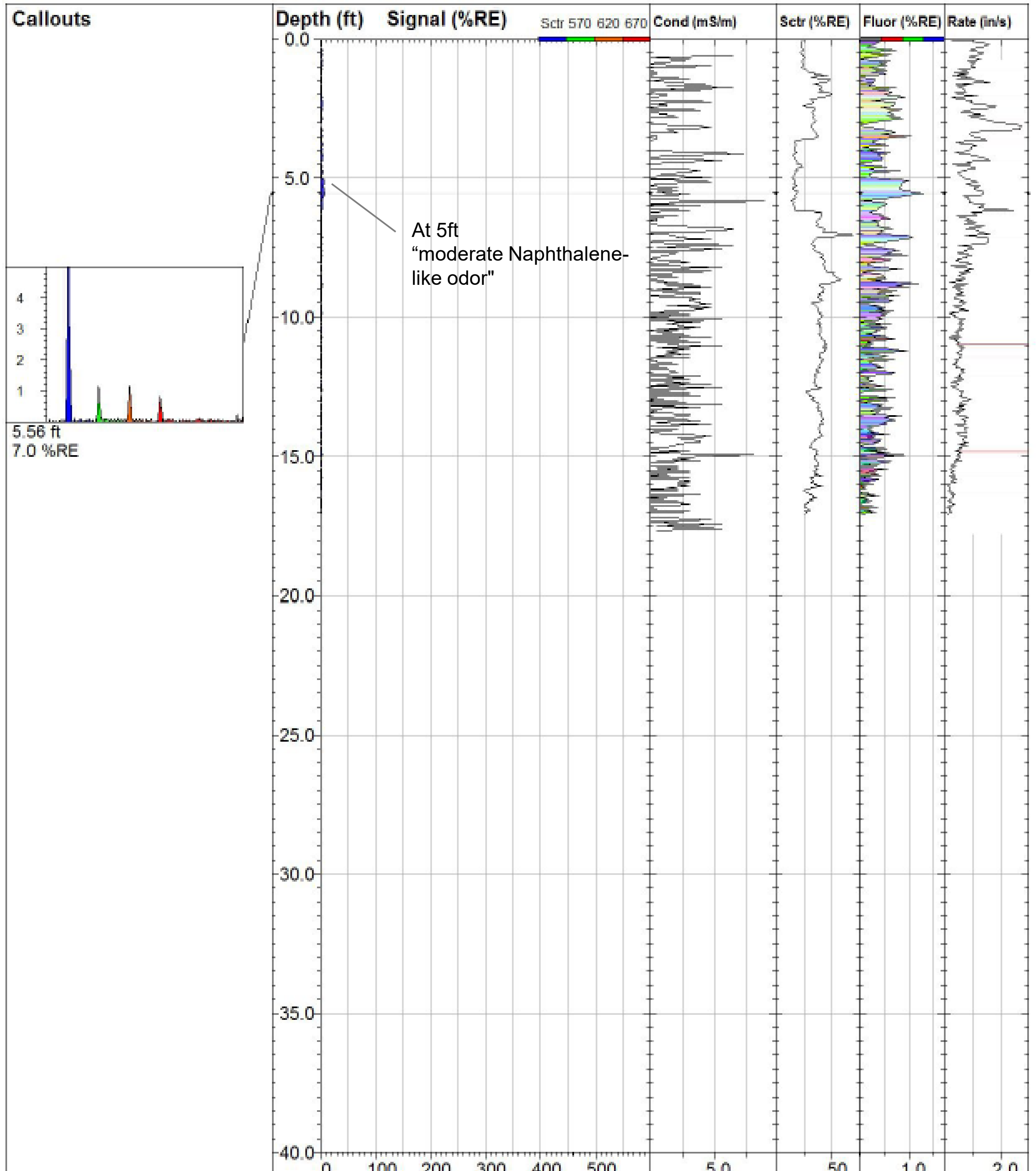
1. Refer to Attachment A-2 TarGOST Data Processing. Classification plots graph lifetime on vertical-axis and wavelength on horizontal-axis.
2. NAPL includes categories 'heavy sheen with NAPL' and 'tar or tar impacted interval' NAPL impact designation.
3. Geologic units: Af = fill; Qvr = Vashon recessional outwash; Qva = Vashon advanced outwash; Qpgt = pre-Fraser till.
4. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

TarGOST Confirmation Borings TG-11/GEI-13

Gas Works Park Site
Seattle, Washington

GEOENGINEERS

Figure 2A-2-2



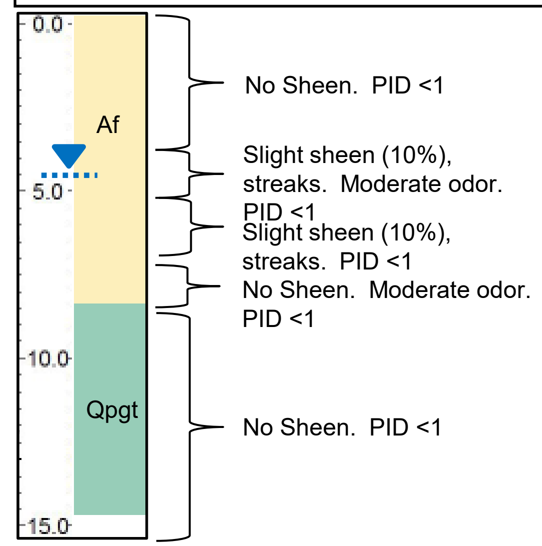
GWP_TG-27

TarGOST By Dakota
www.DakotaTechnologies.com

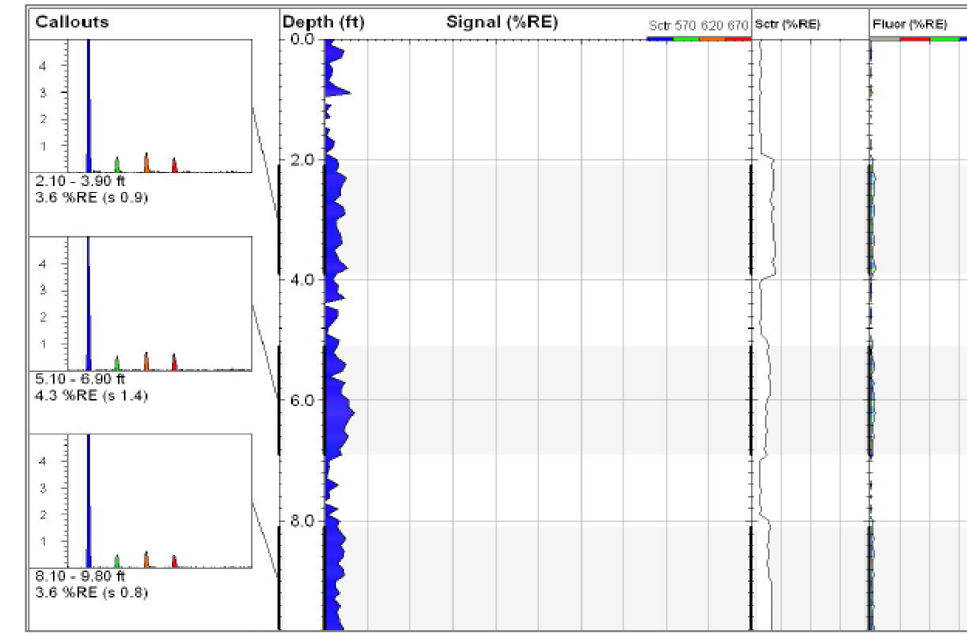
Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **238807.8902 /**	*Final depth:* **17.03 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1270599.03 /**	*Max signal:* **7.0 %RE @ 5.56 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **25.3 ft**	*Date & Time:* **2013-03-22 10:22 PDT**

DAKOTA TECHNOLOGIES
Fargo, ND 701.237.4908
www.DakotaTechnologies.com

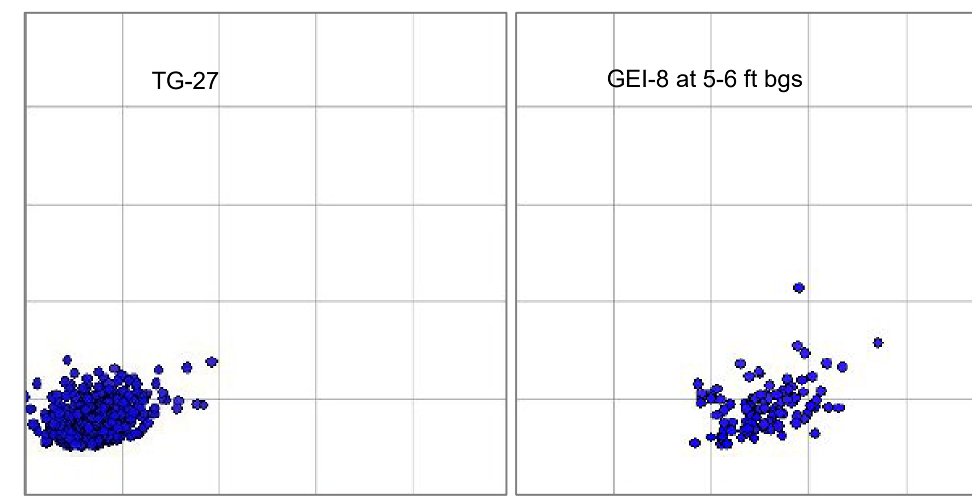
GEI-8 Geology and Field Screening



GEI-8 at 5-6 ft bgs Soil Confirmation TarGOST Screening



Classification Plots



GEI-8 Analytical Results

Depth Ft bgs	TPAH	B(a)p	Naph-thalene	sum >4 rings PAHs
	mg/kg			
4-4.5	1098	44	48	483.3
5-6	257	15	14	157.6
8.5-9.5	0.3452	0.019	0.039	0.196

Notes:

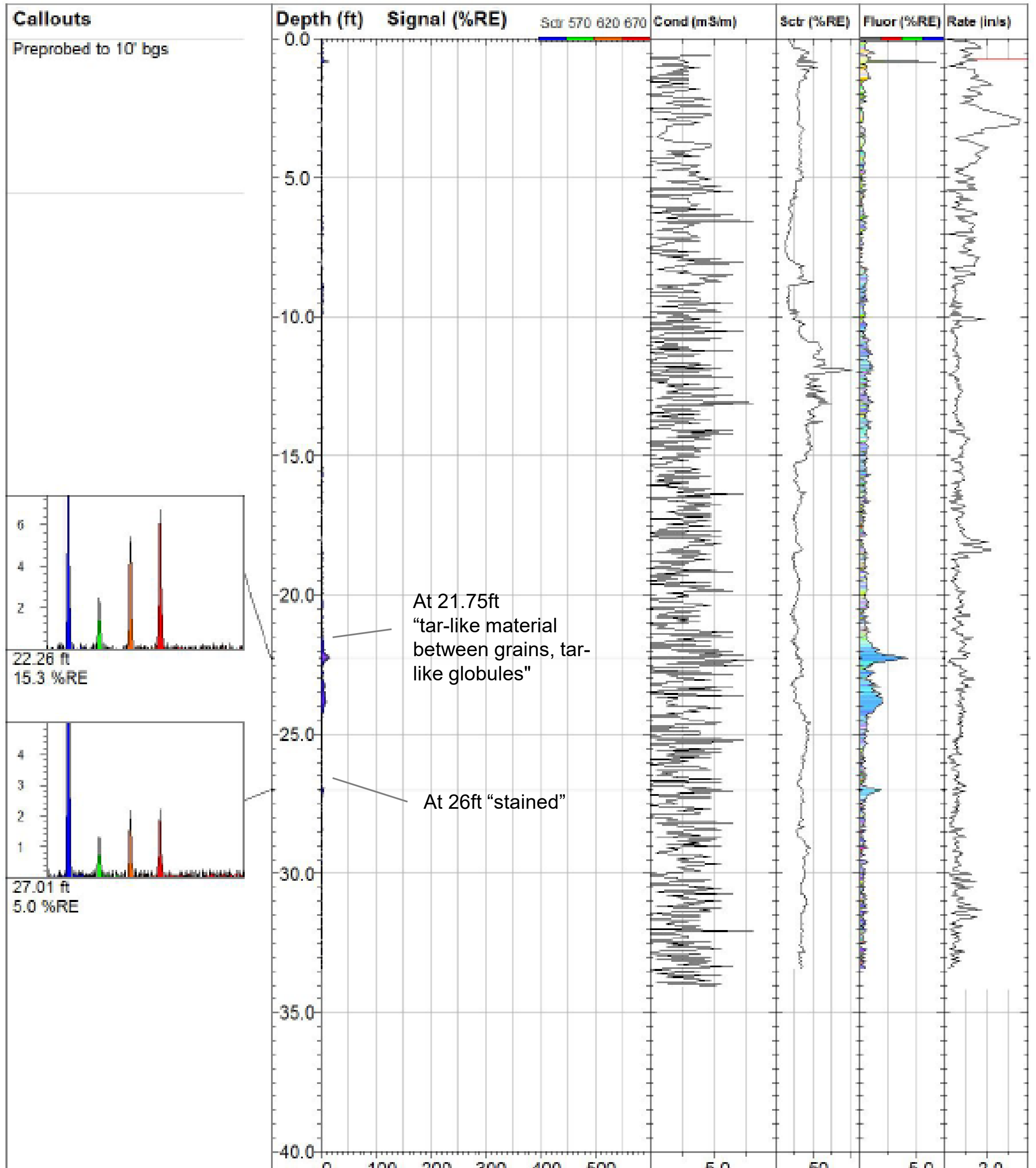
1. Refer to Attachment A-2 TarGOST Data Processing. Classification plots graph lifetime on vertical-axis and wavelength on horizontal-axis.
2. NAPL includes categories 'heavy sheen with NAPL' and 'tar or tar impacted interval' NAPL impact designation.
3. Geologic units: Af = fill; Qvr = Vashon recessional outwash; Qva = Vashon advanced outwash; Qpgt = pre-Fraser till.
4. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

TarGOST Confirmation Borings
TG-27/GEI-8

Gas Works Park Site
Seattle, Washington

GEOENGINEERS

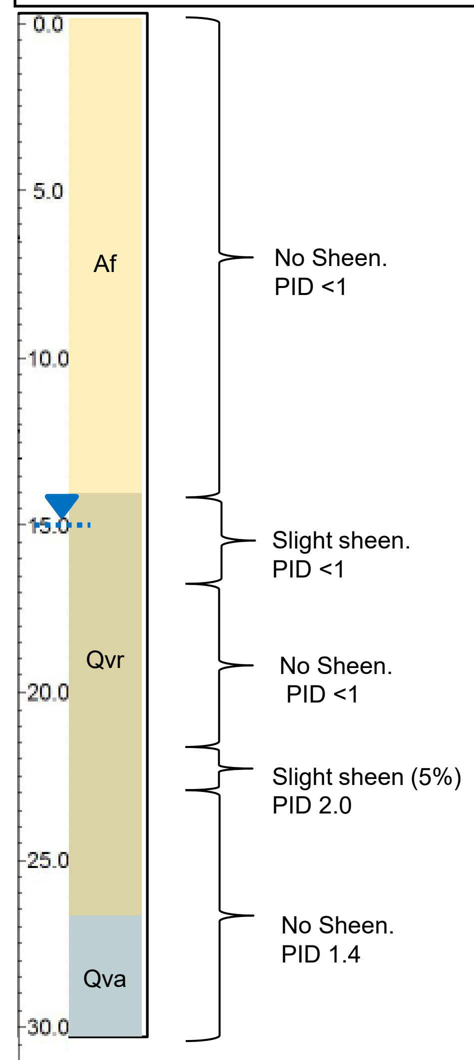
Figure 2A-2-3



DAKOTA TECHNOLOGIES
FARGO, ND 701.237.4908
WWW.DAKOTATECHNOLOGIES.COM

GWP_TG-32B		TarGOST By Dakota www.DakotaTechnologies.com
Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **238860.1566 /**	*Final depth:* **33.42 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1270251.303 /**	*Max signal:* **15.3 %RE @ 22.26 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **37.2 ft**	*Date & Time:* **2013-03-22 17:35 PDT**

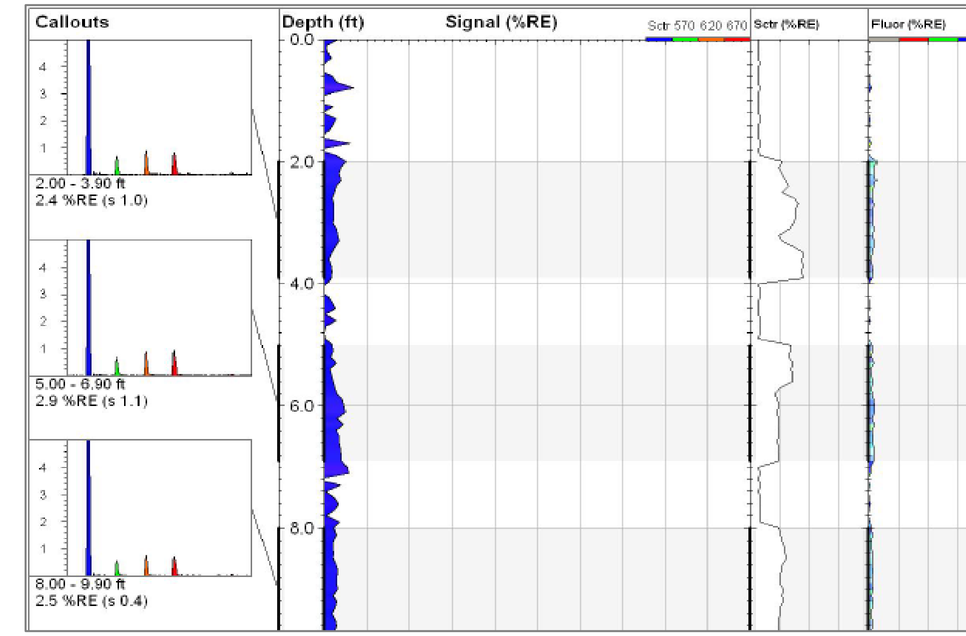
GEI-11 Geology and Field Screening



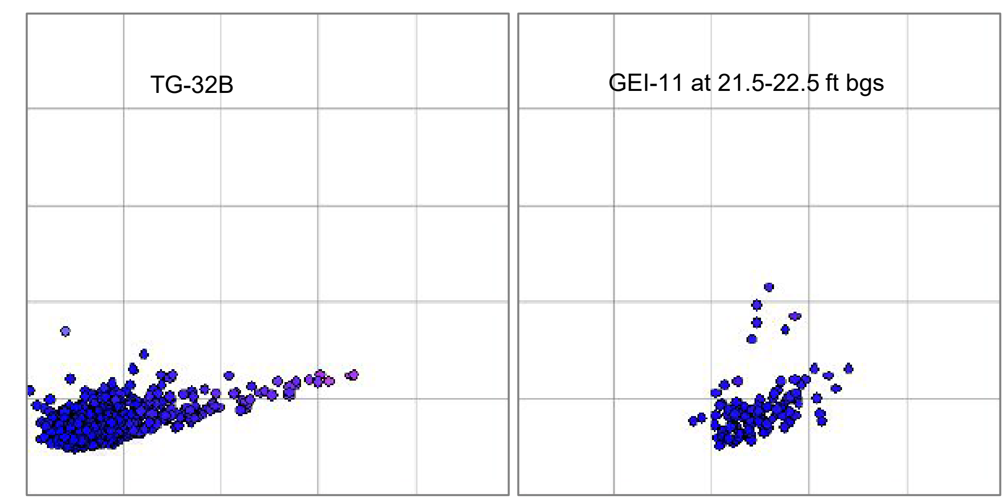
GEI-11 Analytical Results

Depth Ft bgs	TPAH	B(a)p	Naph-thalene	sum >4 rings PAHs
	mg/kg			
16-17	11.549	0.22	0.86	4.997
21.5-22.5	4247	220	620	2320
26-26.5	39.66	2.8	0.62	28.33

GEI-11 at 21.5-22.5 ft bgs Soil Confirmation TarGOST Screening



Classification Plots



Notes:

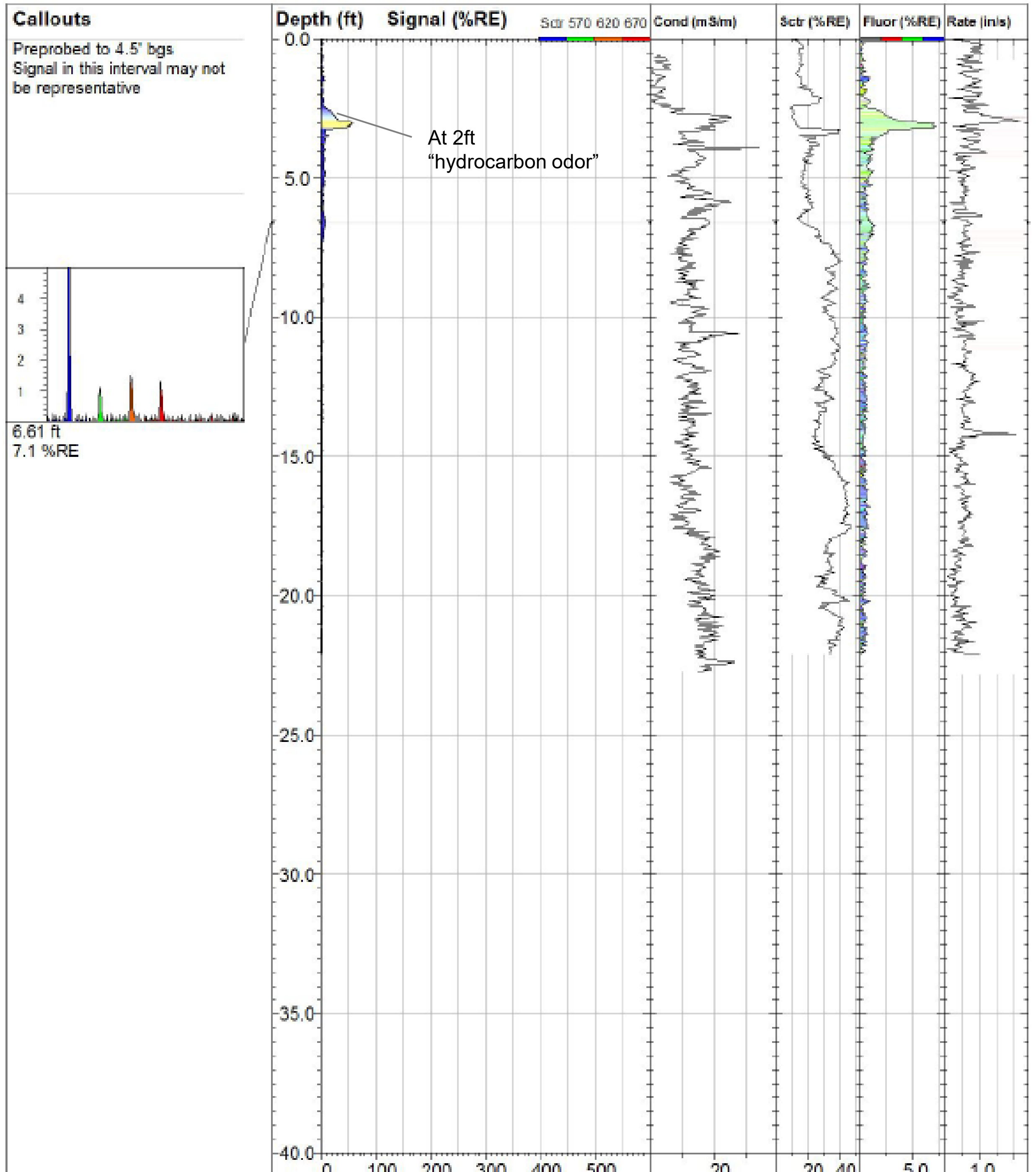
1. Refer to Attachment A-2 TarGOST Data Processing. Classification plots graph lifetime on vertical-axis and wavelength on horizontal-axis.
2. NAPL includes categories 'heavy sheen with NAPL' and 'tar or tar impacted interval' NAPL impact designation.
3. Geologic units: Af = fill; Qvr = Vashon recessional outwash; Qva = Vashon advanced outwash; Qpgt = pre-Fraser till.
4. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

TarGOST Confirmation Borings
TG-32B/GEI-11

Gas Works Park Site
Seattle, Washington

GEOENGINEERS

Figure 2A-2-4



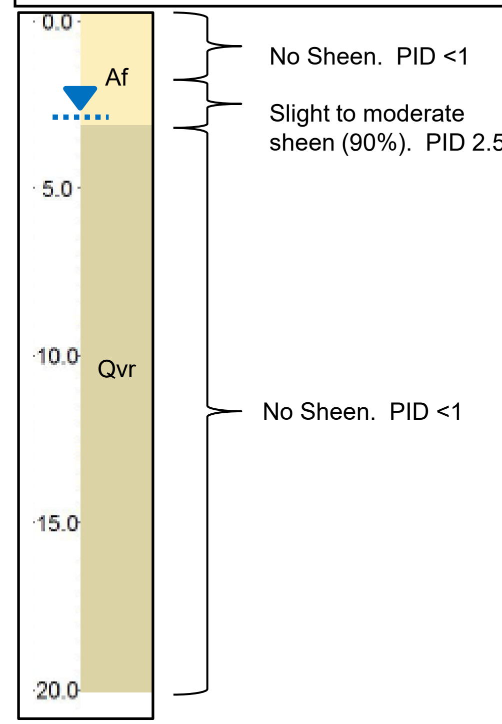
GWP_TG-33

TarGOST By Dakota
www.DakotaTechnologies.com

Site:	Y Coord.(Lat-N) / System:	Final depth:
Gas Works Park	238716.0311 /	22.08 ft
Client / Job:	X Coord.(Lng-E) / Fix:	Max signal:
GeoEngineers /	1270234.667 /	57.4 %RE @ 3.04 ft
Operator / Unit:	Elevation:	Date & Time:
SDA / TG1004	24.0 ft	2013-03-25 09:39 PDT

DAKOTA TECHNOLOGIES
FARGO, ND 701.237.4908
WWW.DAKOTATECHNOLOGIES.COM

GEI-10 Geology and Field Screening



Soil Confirmation TarGOST Screening

No GEI-10 soil sample analyzed with TarGOST"

Classification Plots

No GEI-10 soil sample analyzed with TarGOST"

GEI-10 Analytical Results

Depth Ft bgs	TPAH	B(a)p	Naph-thalene	sum >4 rings PAHs
	mg/kg			
2-3	6838	520	68 U	6159
6.5-7.5	1.2	0.075	0.065	0.819

Notes:

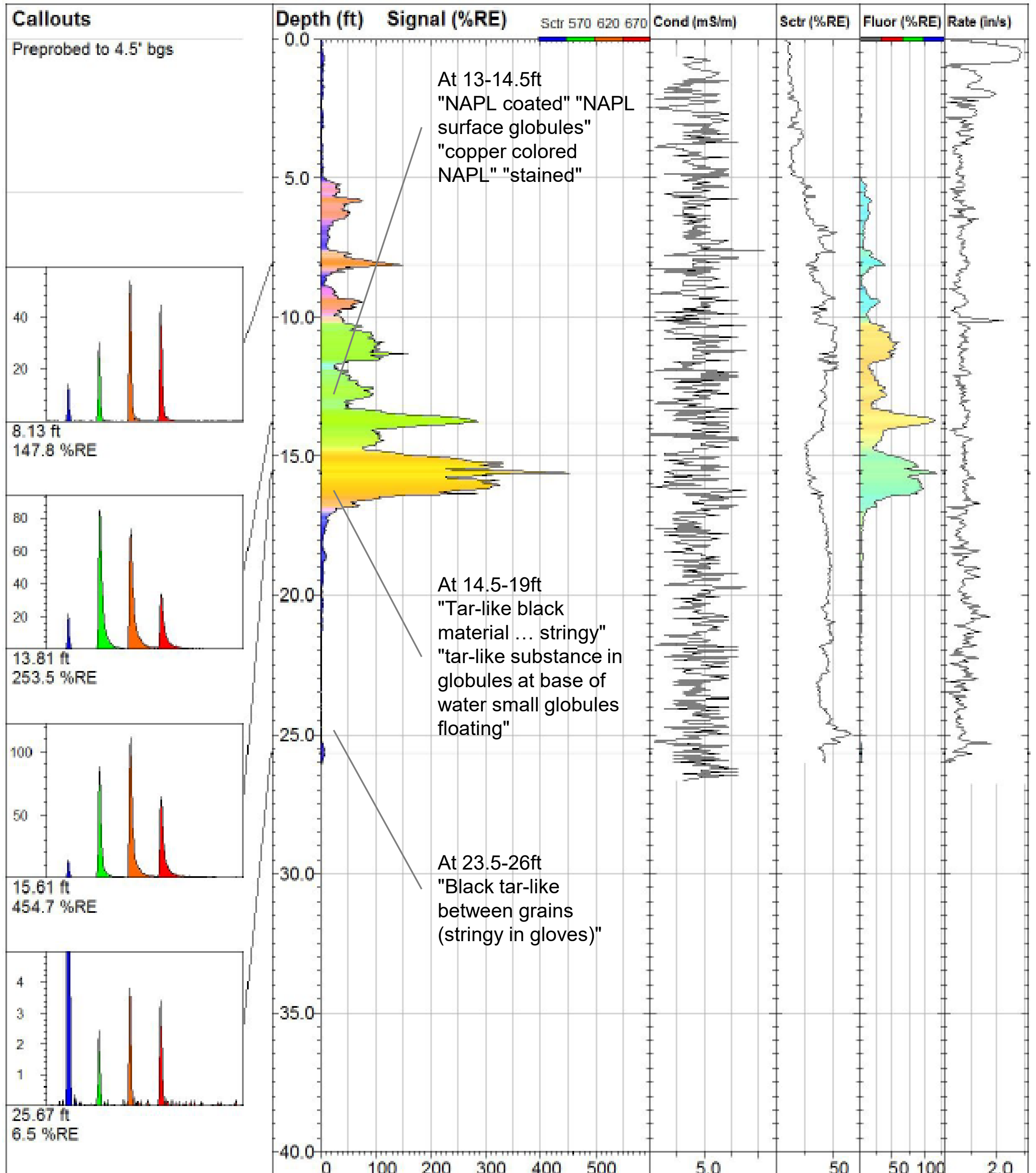
1. Refer to Attachment A-2 TarGOST Data Processing. Classification plots graph lifetime on vertical-axis and wavelength on horizontal-axis.
2. NAPL includes categories 'heavy sheen with NAPL' and 'tar or tar impacted interval' NAPL impact designation.
3. Geologic units: Af = fill; Qvr = Vashon recessional outwash; Qva = Vashon advanced outwash; Qpgt = pre-Fraser till.
4. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

TarGOST Confirmation Borings
TG-33/GEI-10

Gas Works Park Site
Seattle, Washington

GEOENGINEERS

Figure 2A-2-5



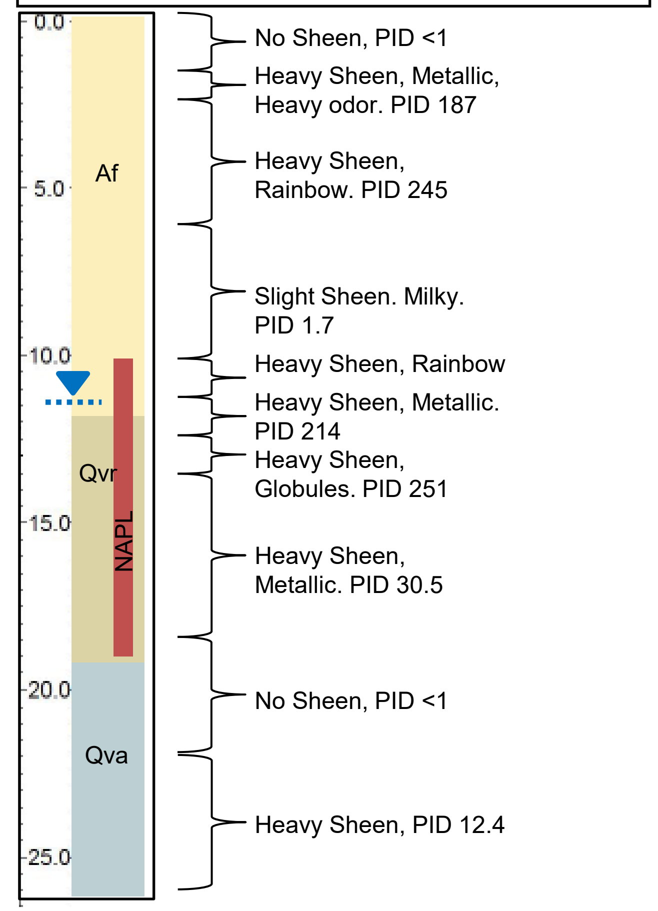
GWP_TG-39

TarGOST By Dakota
www.DakotaTechnologies.com

Site:	Y Coord.(Lat-N) / System:	Final depth:
Gas Works Park	239048.8756 /	26.03 ft
Client / Job:	X Coord.(Lng-E) / Fix:	Max signal:
GeoEngineers /	1270198.071 /	454.7 %RE @ 15.61 ft
Operator / Unit:	Elevation:	Date & Time:
SDA / TG1004	35.7 ft	2013-03-25 17:09 PDT

DAKOTA TECHNOLOGIES
Fargo, ND 701.237.4908
www.DakotaTechnologies.com

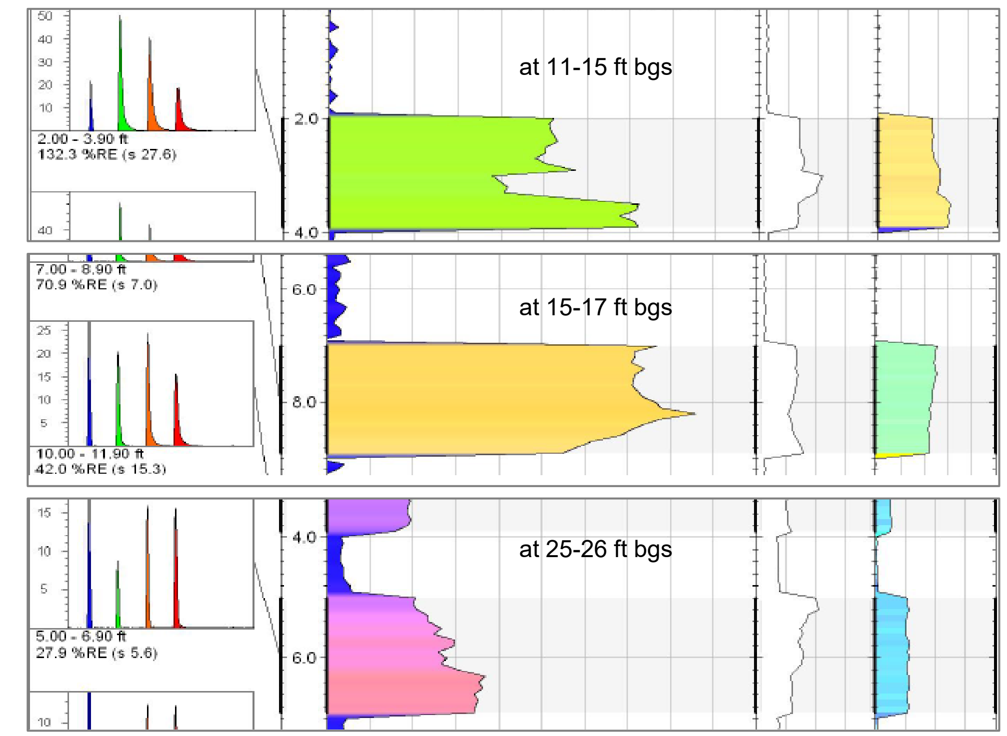
GEI-12 Geology and Field Screening



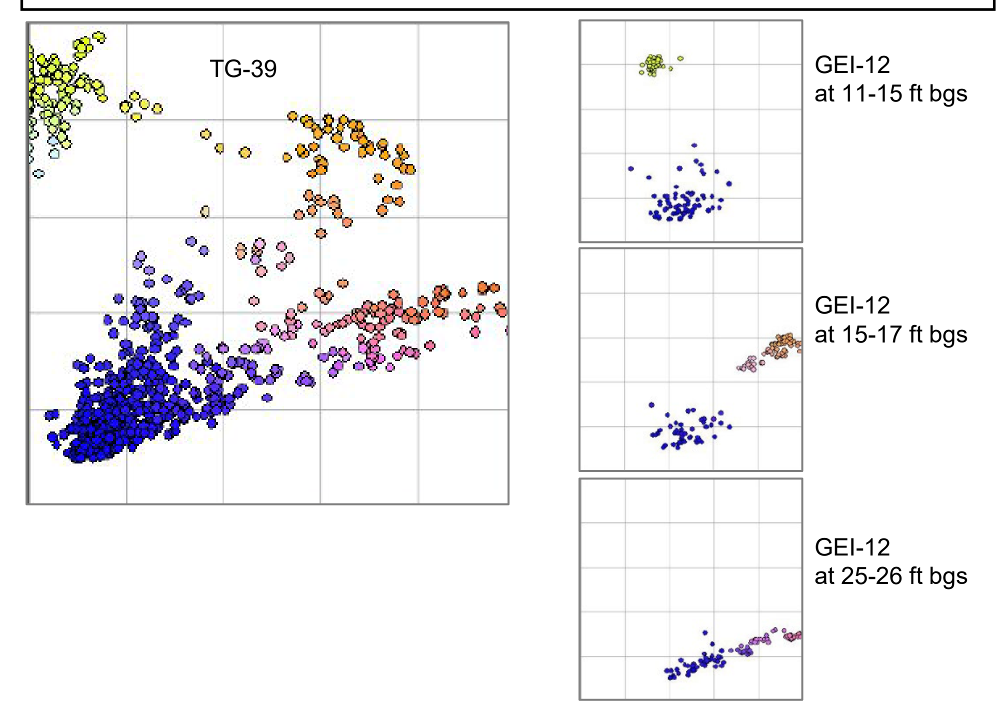
GEI-12 Analytical Results

Depth Ft bgs	TPAH	B(a)p	Naph-thalene	sum >4 rings PAHs
	mg/kg			
5-7	3152.8	72	1700	759.8
11-15	416.54	14	140	134.1
15-17	2247.7	110	280	1078.7
25-26	9232	340	790	3578

GEI-12 at Multiple Depths Soil Confirmation TarGOST Screening



Classification Plots



Notes:

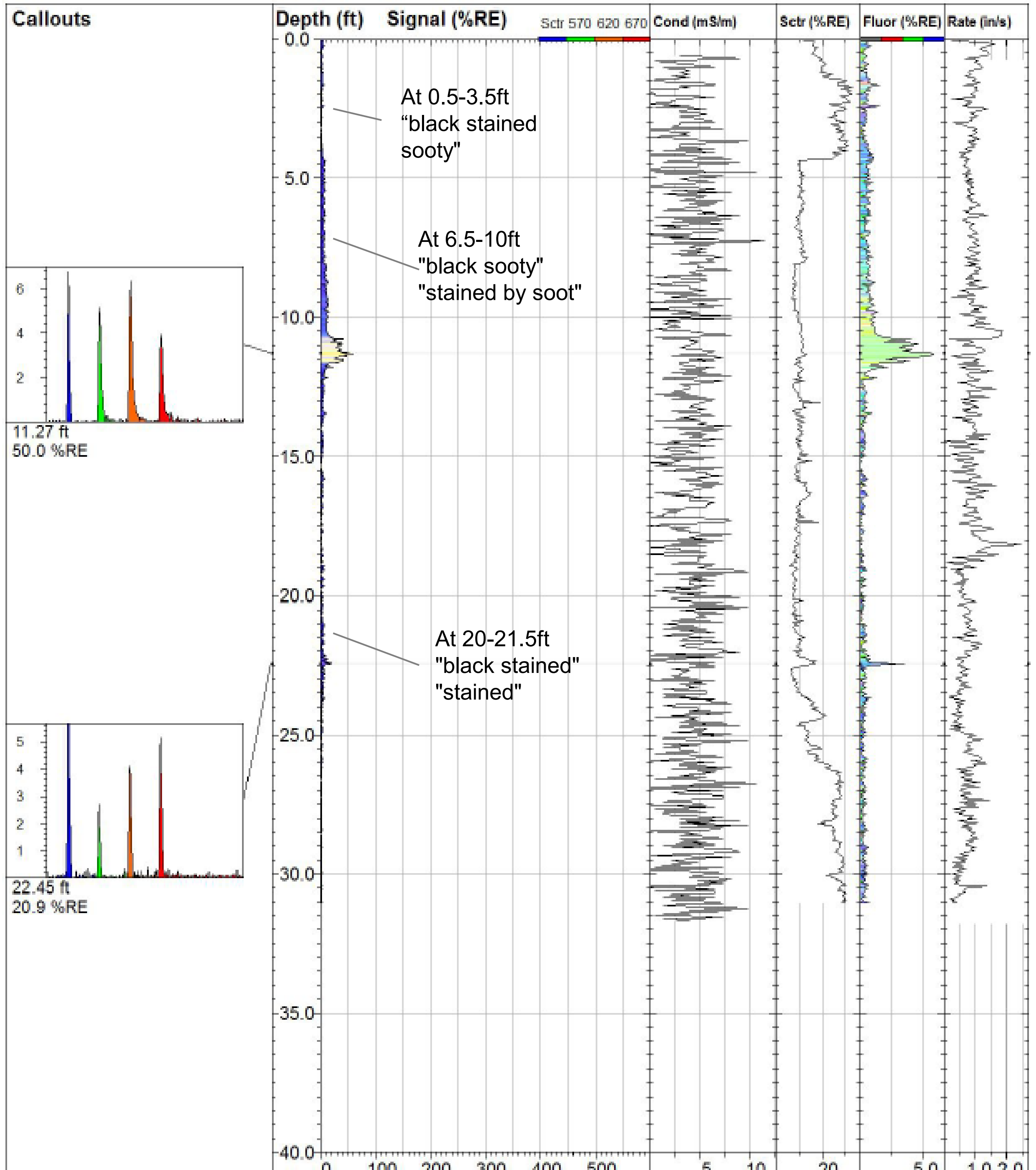
1. Refer to Attachment A-2 TarGOST Data Processing. Classification plots graph lifetime on vertical-axis and wavelength on horizontal-axis.
2. NAPL includes categories 'heavy sheen with NAPL' and 'tar or tar impacted interval' NAPL impact designation.
3. Geologic units: Af = fill; Qvr = Vashon recessional outwash; Qva = Vashon advanced outwash; Qpgt = pre-Fraser till.
4. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

TarGOST Confirmation Borings
TG-39/GEI-12

Gas Works Park Site
Seattle, Washington

GEOENGINEERS

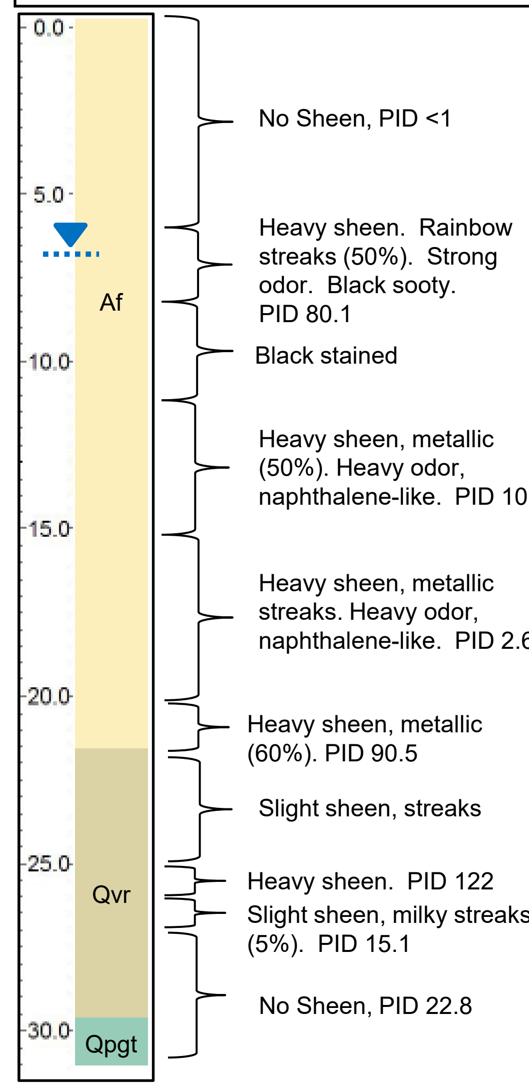
Figure 2A-2-6



GWP_TG-42		TarGOST By Dakota www.DakotaTechnologies.com
Site: Gas Works Park	Y Coord.(Lat-N) / System: 239108.2314 /	Final depth: 31.04 ft
Client / Job: GeoEngineers /	X Coord.(Lng-E) / Fix: 1270790.097 /	Max signal: 59.4 %RE @ 11.29 ft
Operator / Unit: SDA / TG1004	Elevation: 29.5 ft	Date & Time: 2013-03-26 10:19 PDT

DAKOTA TECHNOLOGIES
Fargo, ND 701.237.4908
www.DakotaTechnologies.com

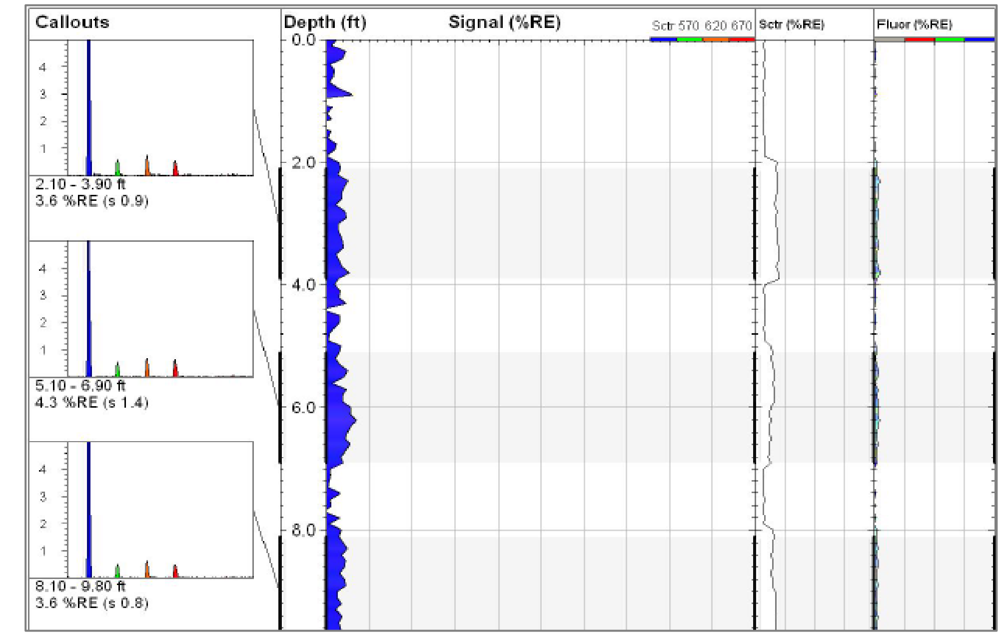
GEI-6 Geology and Field Screening



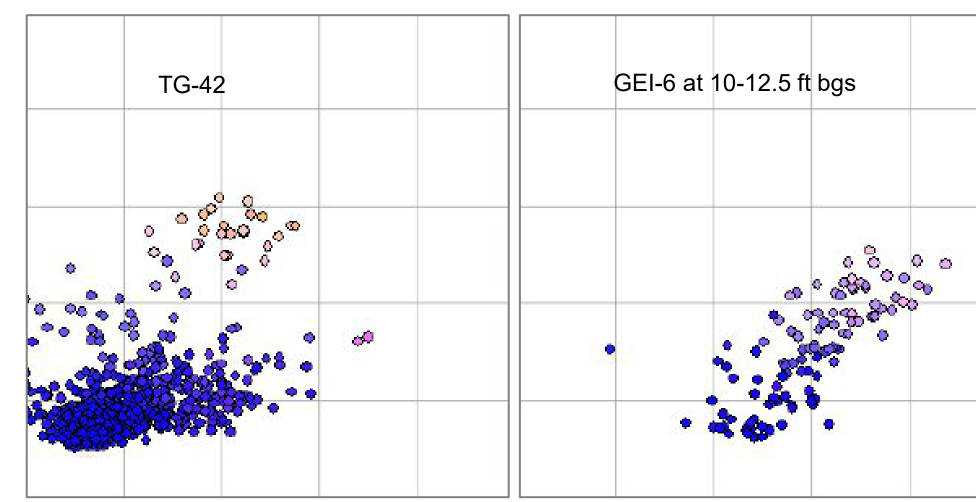
GEI-6 Analytical Results

Depth Ft bgs	TPAH	B(a)p	Naph-thalene	sum >4 rings PAHs
	mg/kg			
10-12.5	126970	630	110000	10500
20-21	3281	45	2200	525.1
25-26	88	2.9	35	27.84

GEI-6 at 10-12.5 ft bgs Soil Confirmation TarGOST Screening



Classification Plots



Notes:

1. Refer to Attachment A-2 TarGOST Data Processing. Classification plots graph lifetime on vertical-axis and wavelength on horizontal-axis.
2. NAPL includes categories 'heavy sheen with NAPL' and 'tar or tar impacted interval' NAPL impact designation.
3. Geologic units: Af = fill; Qvr = Vashon recessional outwash; Qva = Vashon advanced outwash; Qpgt = pre-Fraser till.
4. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

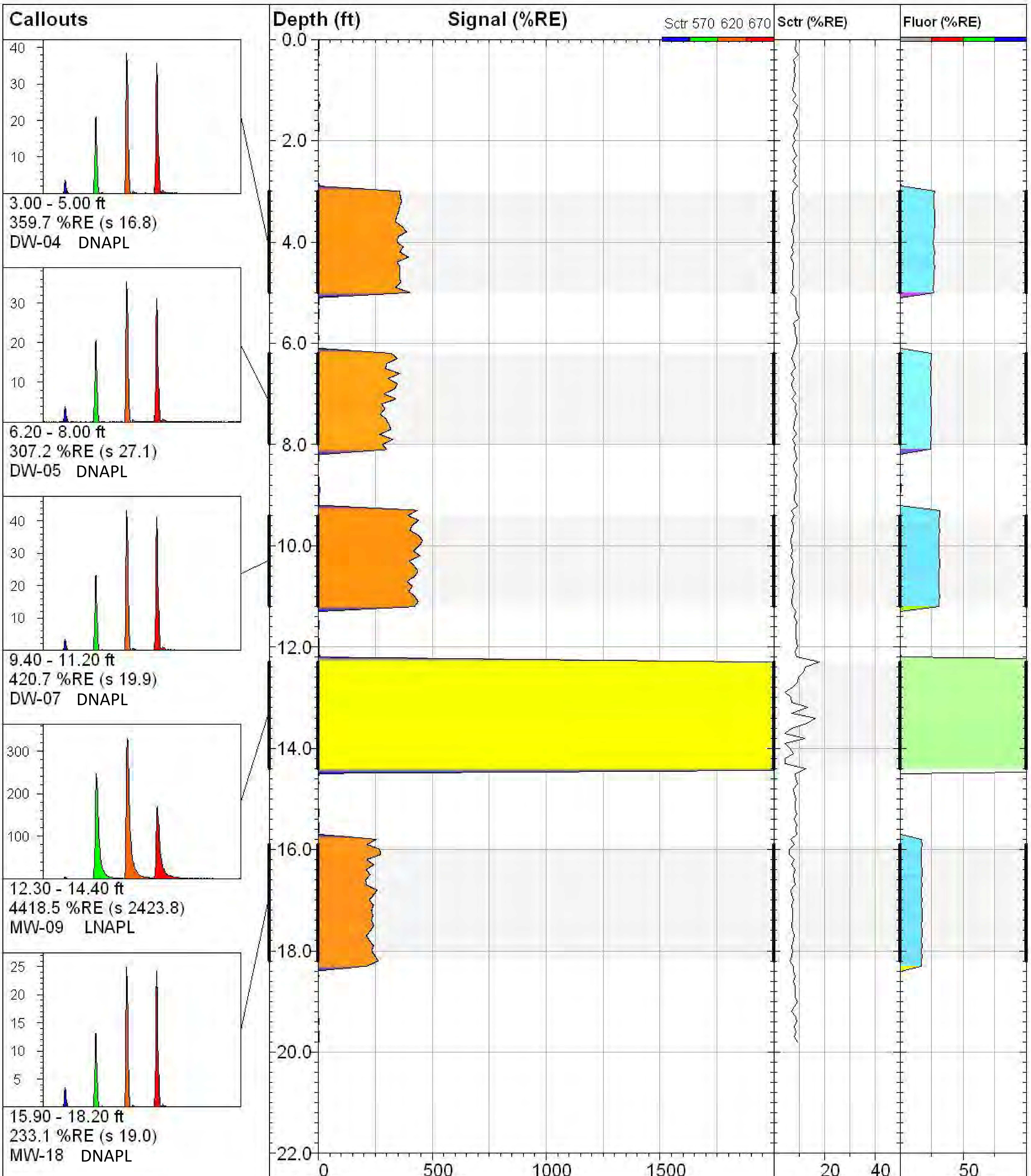
TarGOST Confirmation Borings
TG-42/GEI-6

Gas Works Park Site
Seattle, Washington

GEOENGINEERS

Figure 2A-2-7

SUB-ATTACHMENT 2A-2.1
TarGOST® NAPL Responses Logs



DAKOTA TECHNOLOGIES
FARGO, ND 701.237.4908
WWW.DAKOTATECHNOLOGIES.COM

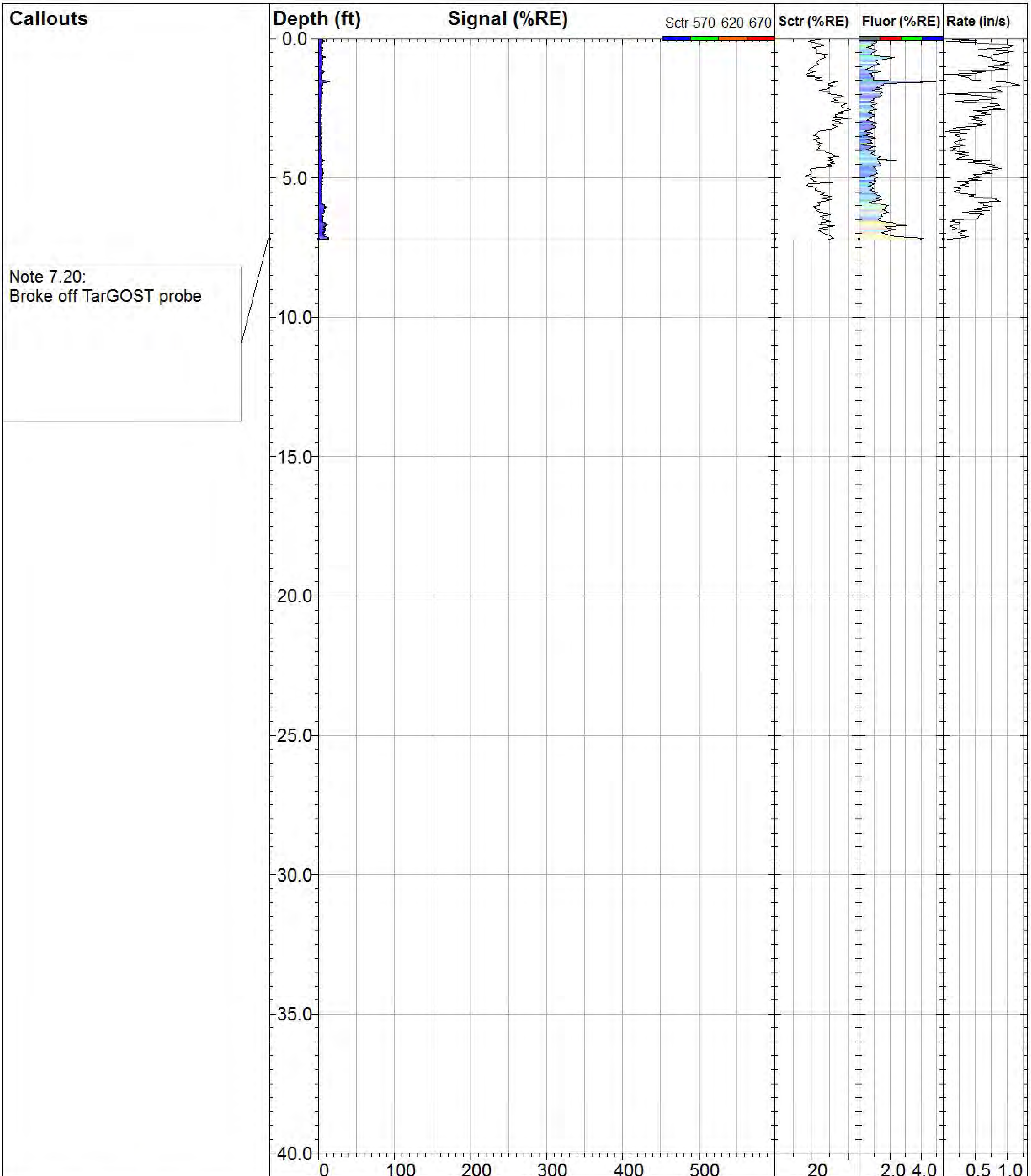
Gas Works Park

TarGOST By Dakota
www.DakotaTechnologies.com

Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **19.80 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **9144.9 %RE @ 13.70 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **Unavailable**	*Date & Time:* **2013-03-05 15:46 CST**

SUB-ATTACHMENT 2A-2.2
TarGOST® Logs and Electrical Conductivity Data

SUB-ATTACHMENT 2A-2.2.1
TarGOST® Logs



DAKOTA TECHNOLOGIES
FARGO, ND 701.237.4908
WWW.DAKOTATECHNOLOGIES.COM

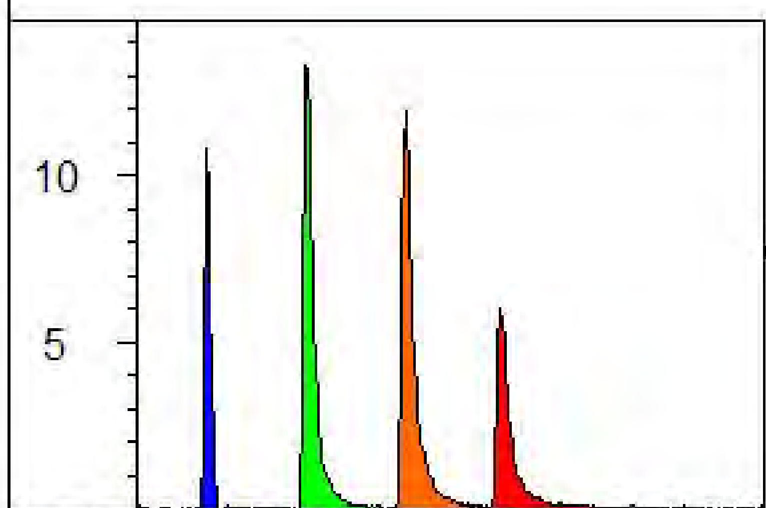
GWP_TG-01

TarGOST By Dakota
www.DakotaTechnologies.com

Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **239470.6644 /**	*Final depth:* **7.20 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1270657.528 /**	*Max signal:* **14.4 %RE @ 1.54 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **32.2 ft**	*Date & Time:* **2013-03-18 14:33 PDT**

Callouts

Note 3.77:
pVs area in each channel of callout two are:
41 85 89 55

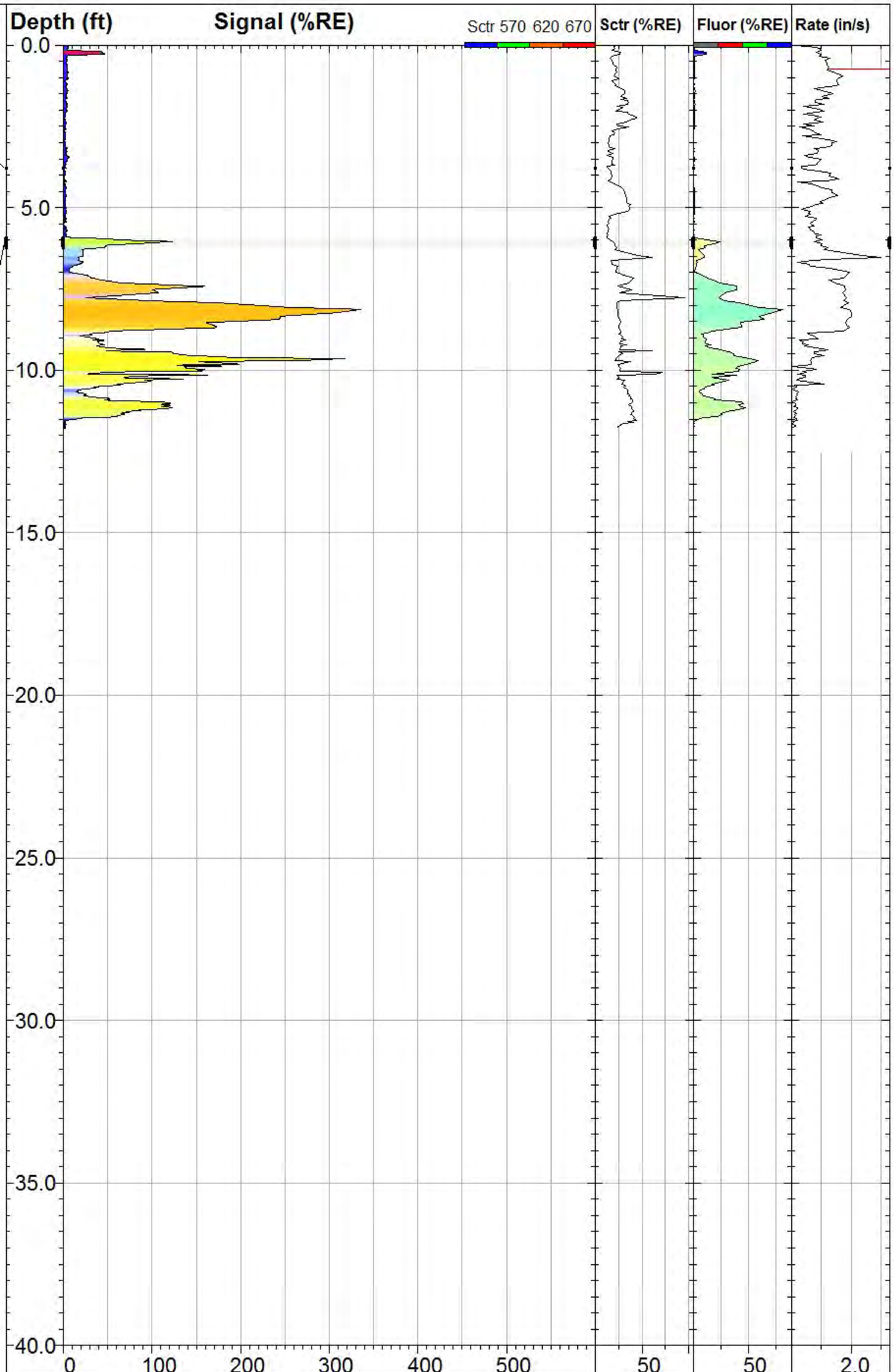


5.94 - 6.23 ft
69.9 %RE (s 33.4)

So Calc Color is
41 parts Blue
85 parts Green
89 parts Orange
55 parts Red

Fluor Only Color is
41 parts not used
85 parts Red
89 parts Orange
55 parts Blue

Those patch colors in upper right panel of the Callout Close-Ups match the same log regions where the waveforms came from.

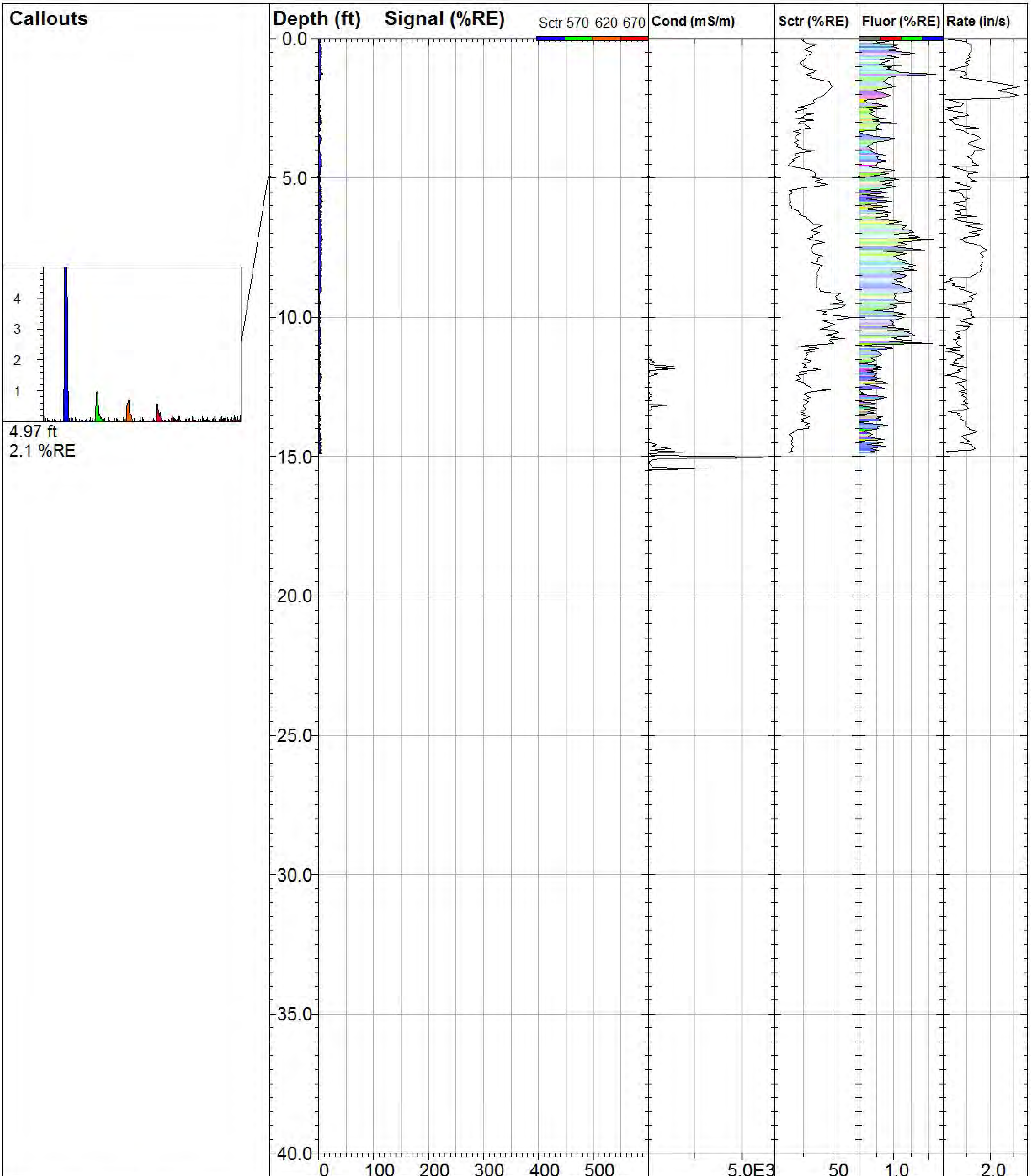


GWP_TG-02

TarGOST By Dakota
www.DakotaTechnologies.com

Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **239463.6624 /**	*Final depth:* **11.78 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1270650.304 /**	*Max signal:* **336.4 %RE @ 8.13 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **31.7 ft**	*Date & Time:* **2013-03-18 15:56 PDT**

DAKOTA TECHNOLOGIES
Fargo, ND 701.237.4908
www.DakotaTechnologies.com

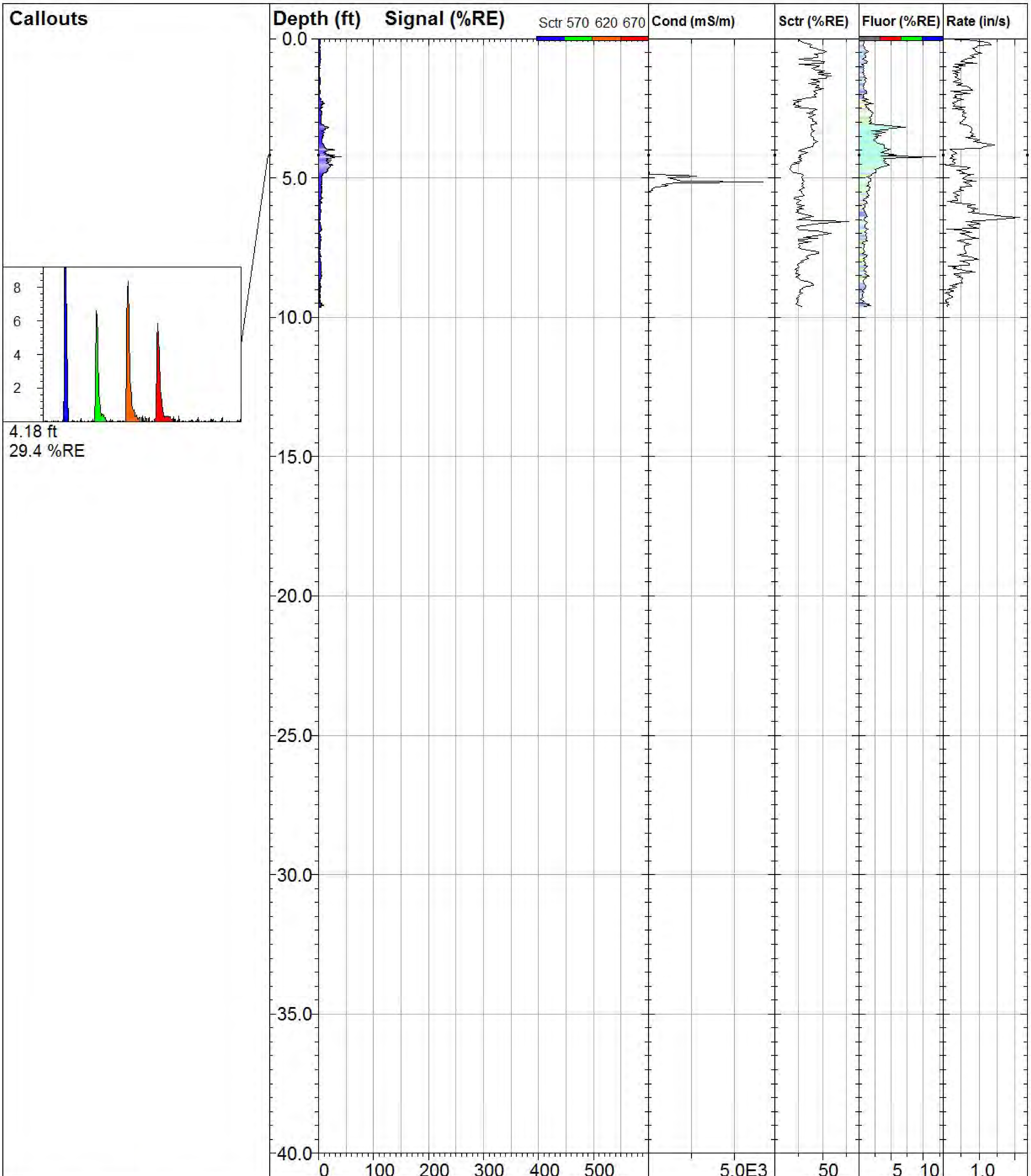


GWP_TG-03

TarGOST By Dakota
www.DakotaTechnologies.com

Site:	*Y Coord.(Lat-N) / System:*	*Final depth:*
Gas Works Park	**239516.783 /**	**14.89 ft**
Client / Job:	*X Coord.(Lng-E) / Fix:*	*Max signal:*
GeoEngineers /	**1270706.768 /**	**8.1 %RE @ 1.27 ft**
Operator / Unit:	*Elevation:*	*Date & Time:*
SDA / TG1004	**37.1 ft**	**2013-03-19 08:14 PDT**

DAKOTA TECHNOLOGIES
Fargo, ND 701.237.4908
www.DakotaTechnologies.com

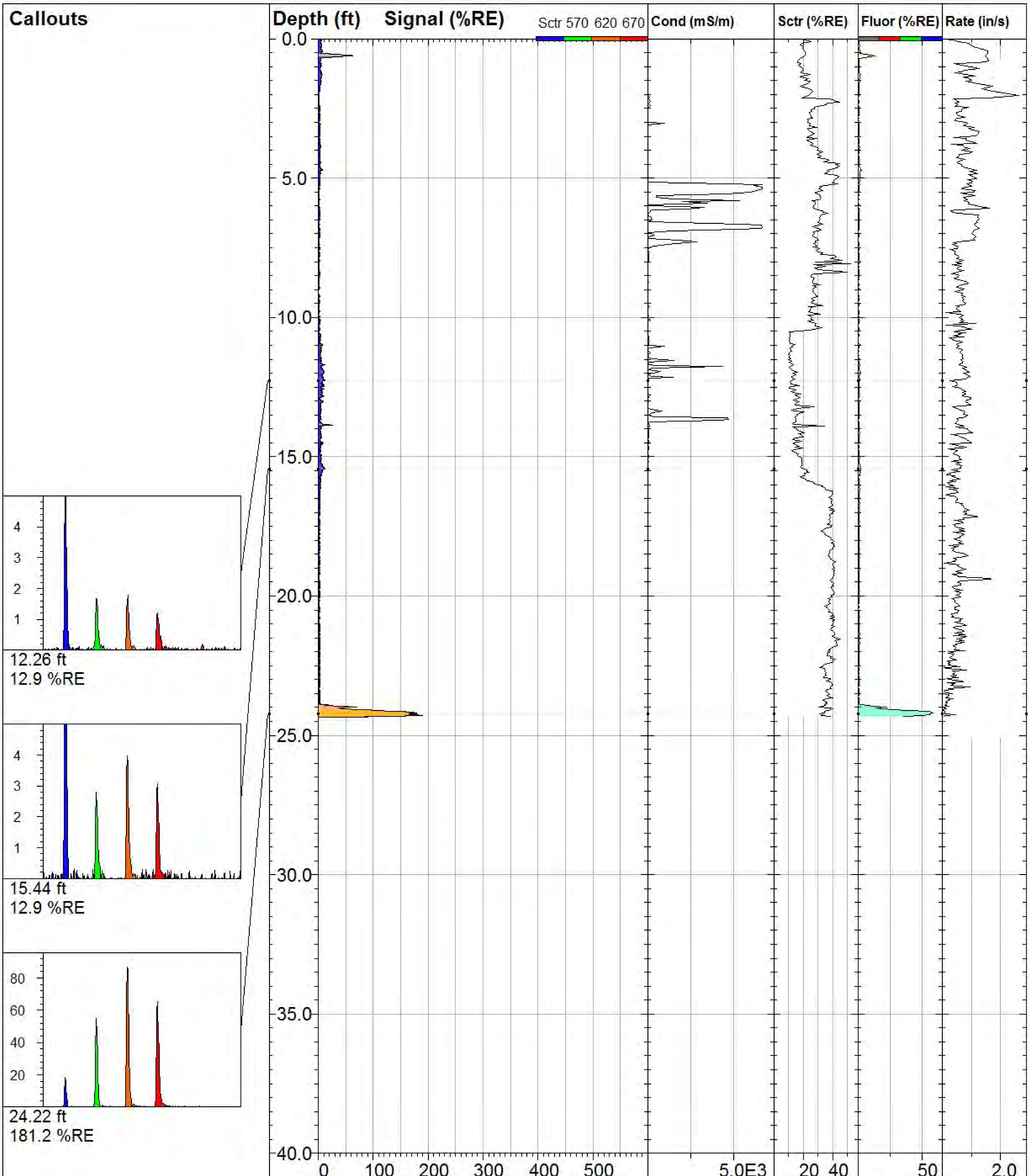


DAKOTA TECHNOLOGIES
FARGO, ND 701.237.4908
WWW.DAKOTATECHNOLOGIES.COM

GWP_TG-04

TarGOST By Dakota
www.DakotaTechnologies.com

Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **239468.597 /**	*Final depth:* **9.64 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1270607.696 /**	*Max signal:* **43.6 %RE @ 4.24 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **33.6 ft**	*Date & Time:* **2013-03-19 09:19 PDT**

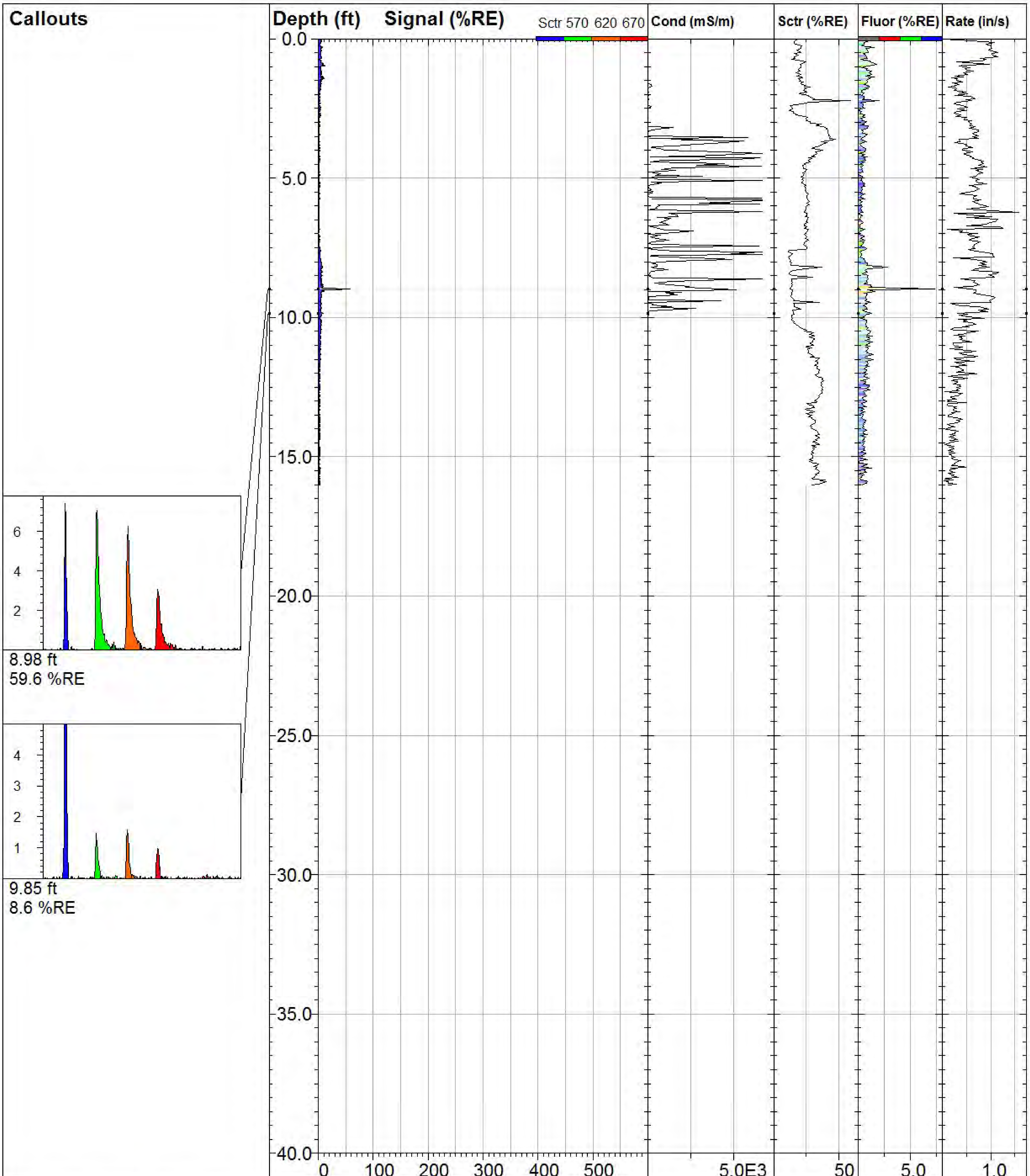


DAKOTA TECHNOLOGIES
Fargo, ND 701.237.4908
www.DakotaTechnologies.com

GWP_TG-05

TarGOST By Dakota
www.DakotaTechnologies.com

Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **239494.1244 /**	*Final depth:* **24.35 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1270751.378 /**	*Max signal:* **196.5 %RE @ 24.29 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **31.8 ft**	*Date & Time:* **2013-03-19 10:10 PDT**

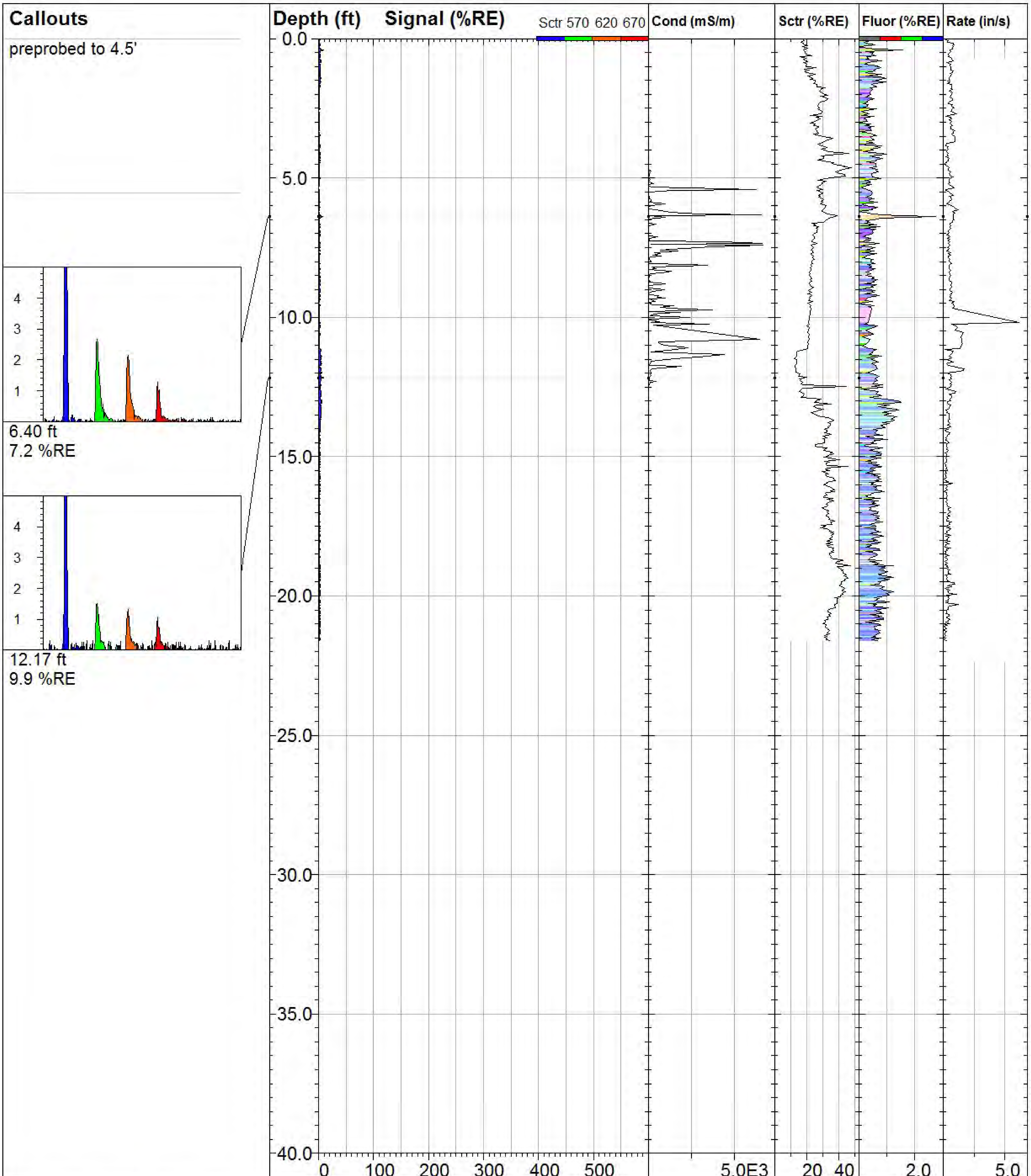


DAKOTA TECHNOLOGIES
FARGO, ND 701.237.4908
WWW.DAKOTATECHNOLOGIES.COM

GWP_TG-06

TarGOST By Dakota
www.DakotaTechnologies.com

Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **239400.5248 /**	*Final depth:* **16.01 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1270703.929 /**	*Max signal:* **59.6 %RE @ 8.98 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **29.4 ft**	*Date & Time:* **2013-03-19 11:10 PDT**

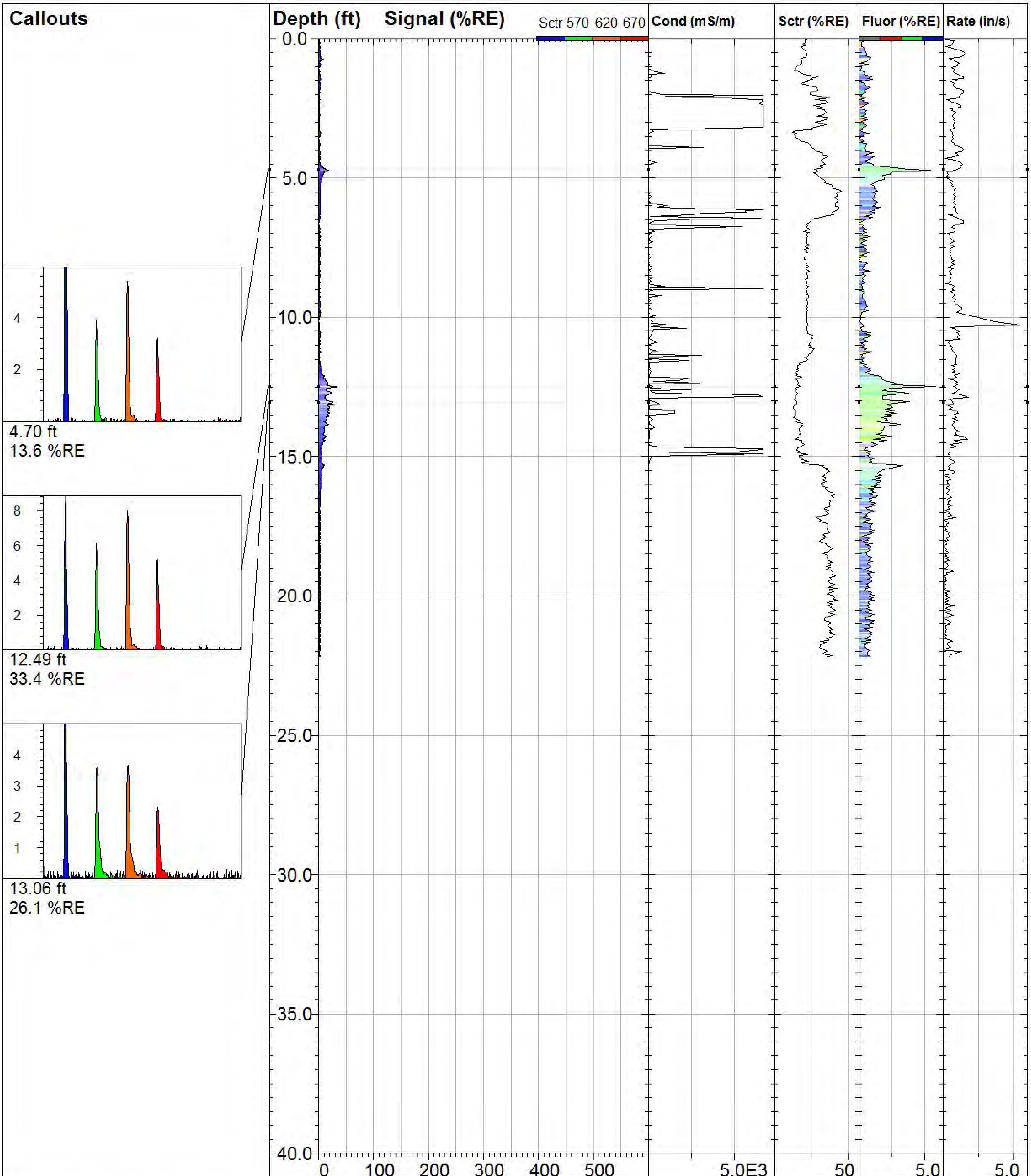


GWP_TG-07

TarGOST By Dakota
www.DakotaTechnologies.com

DAKOTA TECHNOLOGIES
Fargo, ND 701.237.4908
www.DakotaTechnologies.com

Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **239357.9123 /**	*Final depth:* **21.60 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1270715.347 /**	*Max signal:* **9.9 %RE @ 12.17 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **32.4 ft**	*Date & Time:* **2013-03-19 13:12 PDT**

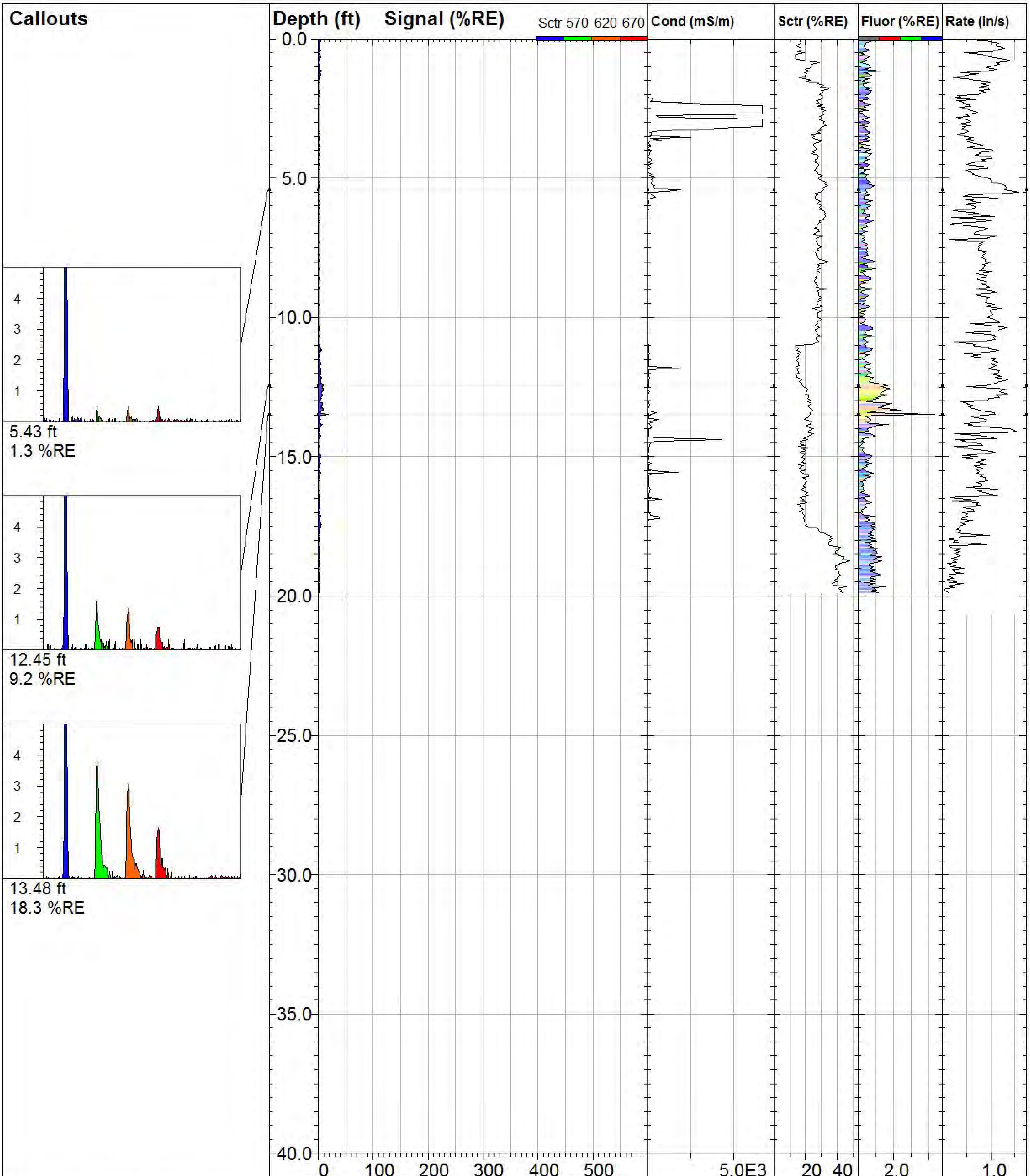


DAKOTA TECHNOLOGIES
Fargo, ND 701.237.4908
www.DakotaTechnologies.com

GWP_TG-08

TarGOST By Dakota
www.DakotaTechnologies.com

Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **239358.1004 /**	*Final depth:* **22.16 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1270747.424 /**	*Max signal:* **33.4 %RE @ 12.49 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **32.7 ft**	*Date & Time:* **2013-03-19 14:35 PDT**

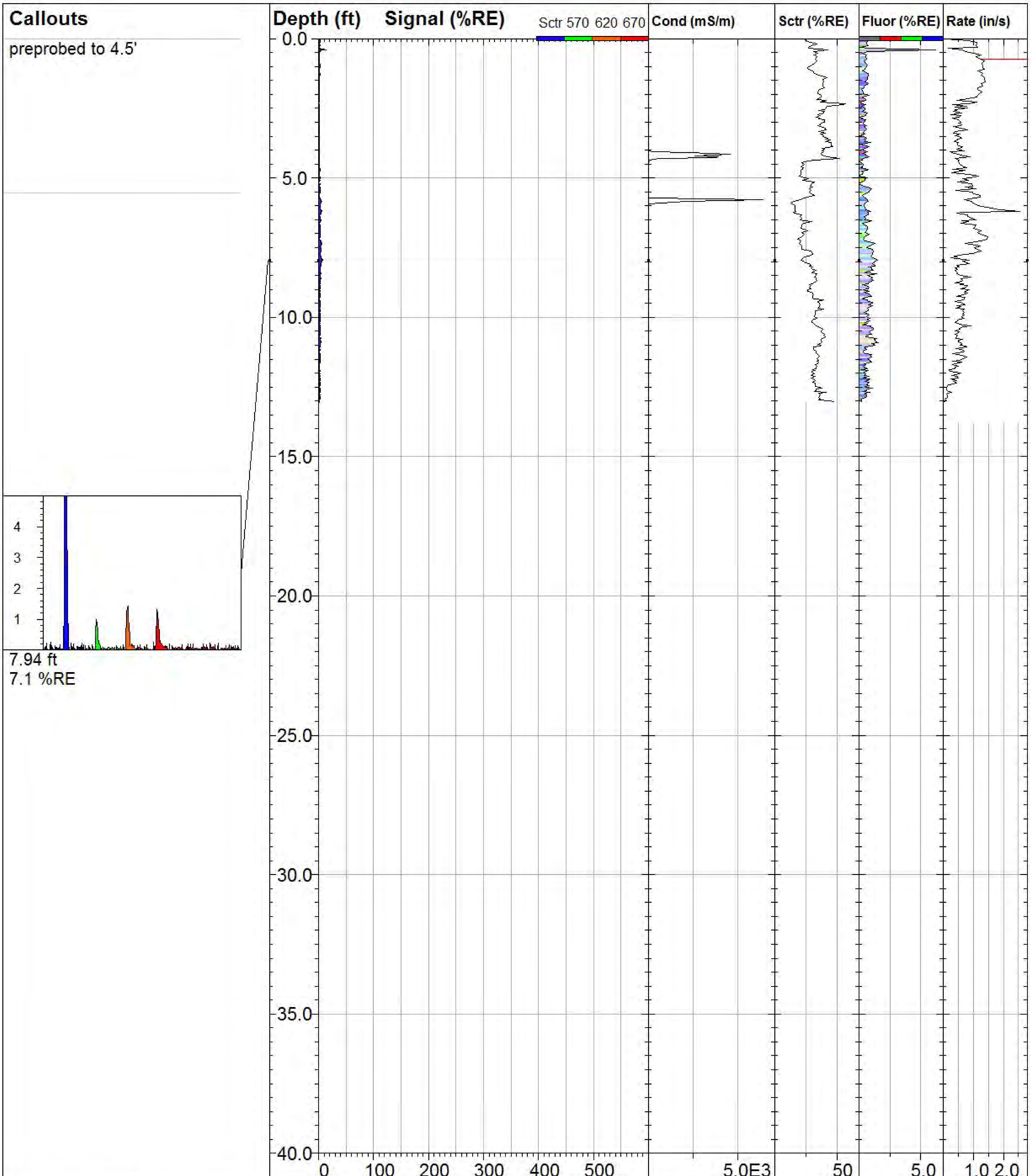


GWP_TG-09

TarGOST By Dakota
www.DakotaTechnologies.com

DAKOTA TECHNOLOGIES
Fargo, ND 701.237.4908
www.DakotaTechnologies.com

Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **239330.837 /**	*Final depth:* **19.89 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1270782.064 /**	*Max signal:* **18.3 %RE @ 13.48 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **32.1 ft**	*Date & Time:* **2013-03-19 15:26 PDT**

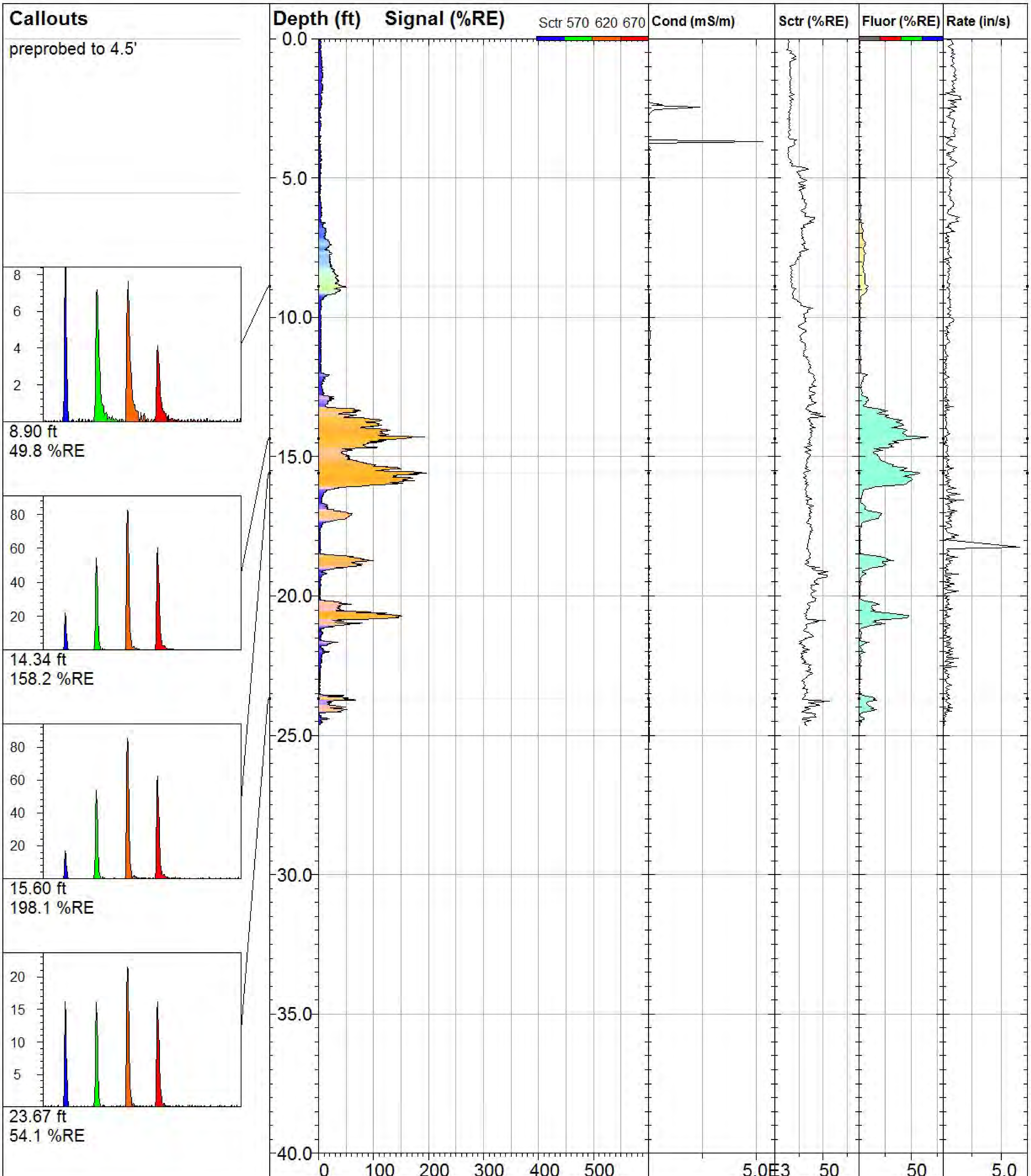


GWP_TG-10

TarGOST By Dakota
www.DakotaTechnologies.com

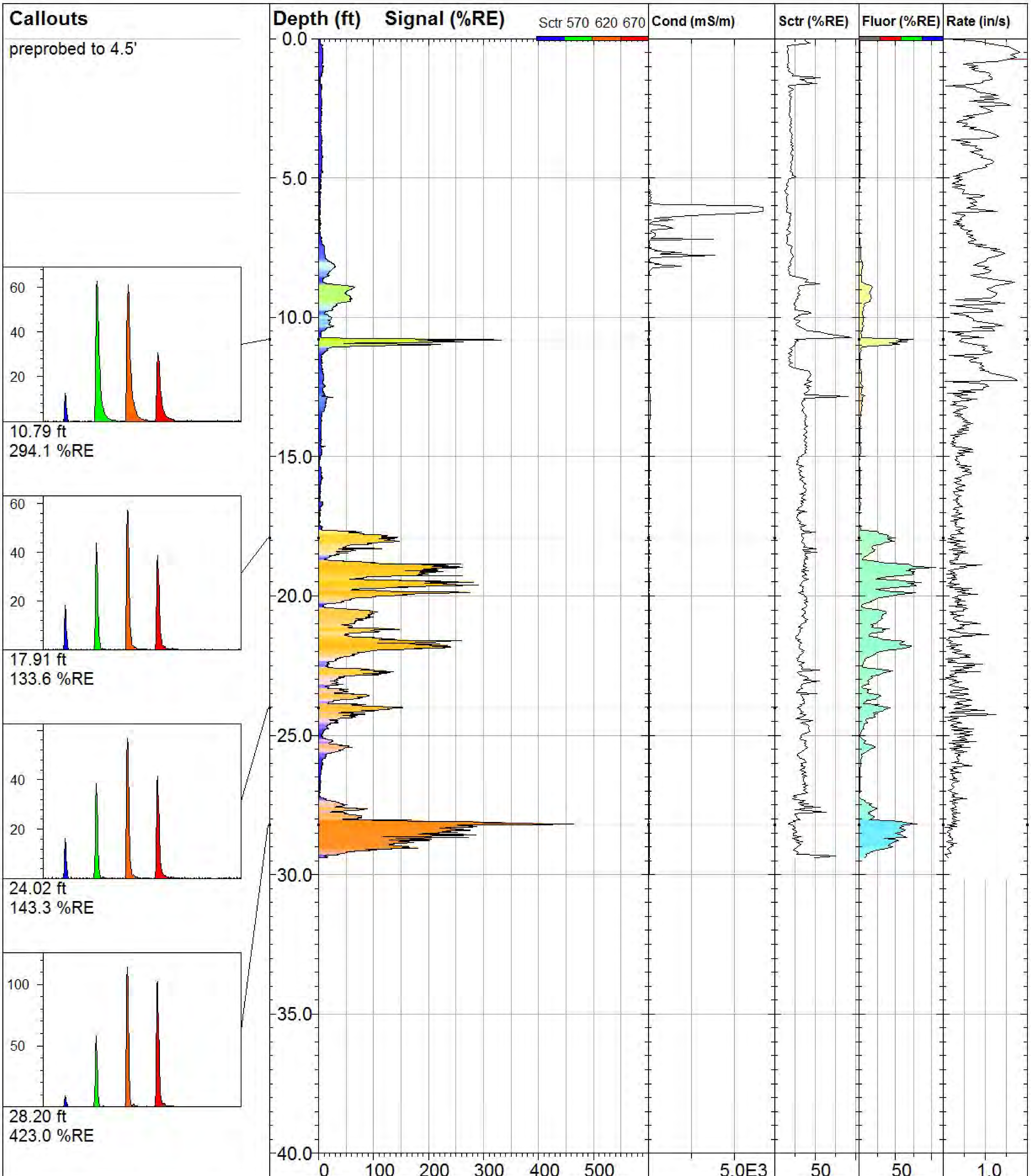
DAKOTA TECHNOLOGIES
Fargo, ND 701.237.4908
www.DakotaTechnologies.com

Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **239392.9768 /**	*Final depth:* **13.04 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1270620.876 /**	*Max signal:* **14.5 %RE @ 0.41 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **33.0 ft**	*Date & Time:* **2013-03-19 16:38 PDT**



GWP_TG-11		TarGOST By Dakota www.DakotaTechnologies.com
Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **239143.7821 /**	*Final depth:* **24.64 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1270529.323 /**	*Max signal:* **198.1 %RE @ 15.60 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **35.0 ft**	*Date & Time:* **2013-03-20 08:31 PDT**

DAKOTA TECHNOLOGIES
FARGO, ND 701.237.4908
WWW.DAKOTATECHNOLOGIES.COM



FARGO, ND 701.237.4908
WWW.DAKOTATECHNOLOGIES.COM

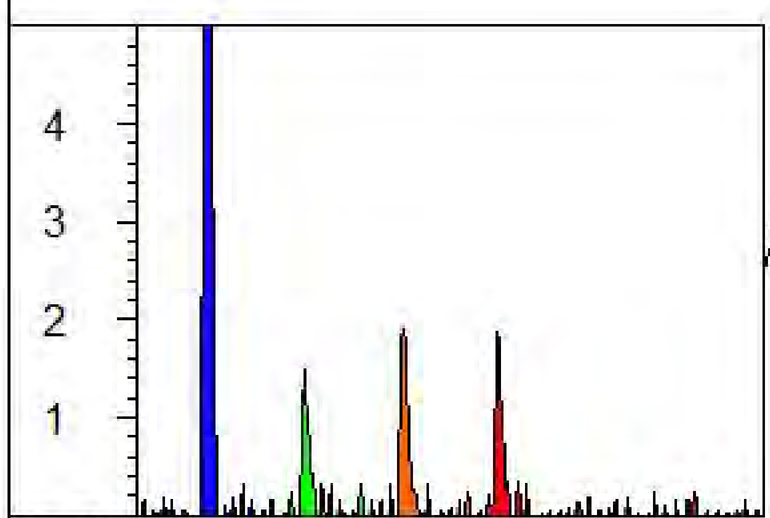
GWP_TG-12

TarGOST By Dakota
www.DakotaTechnologies.com

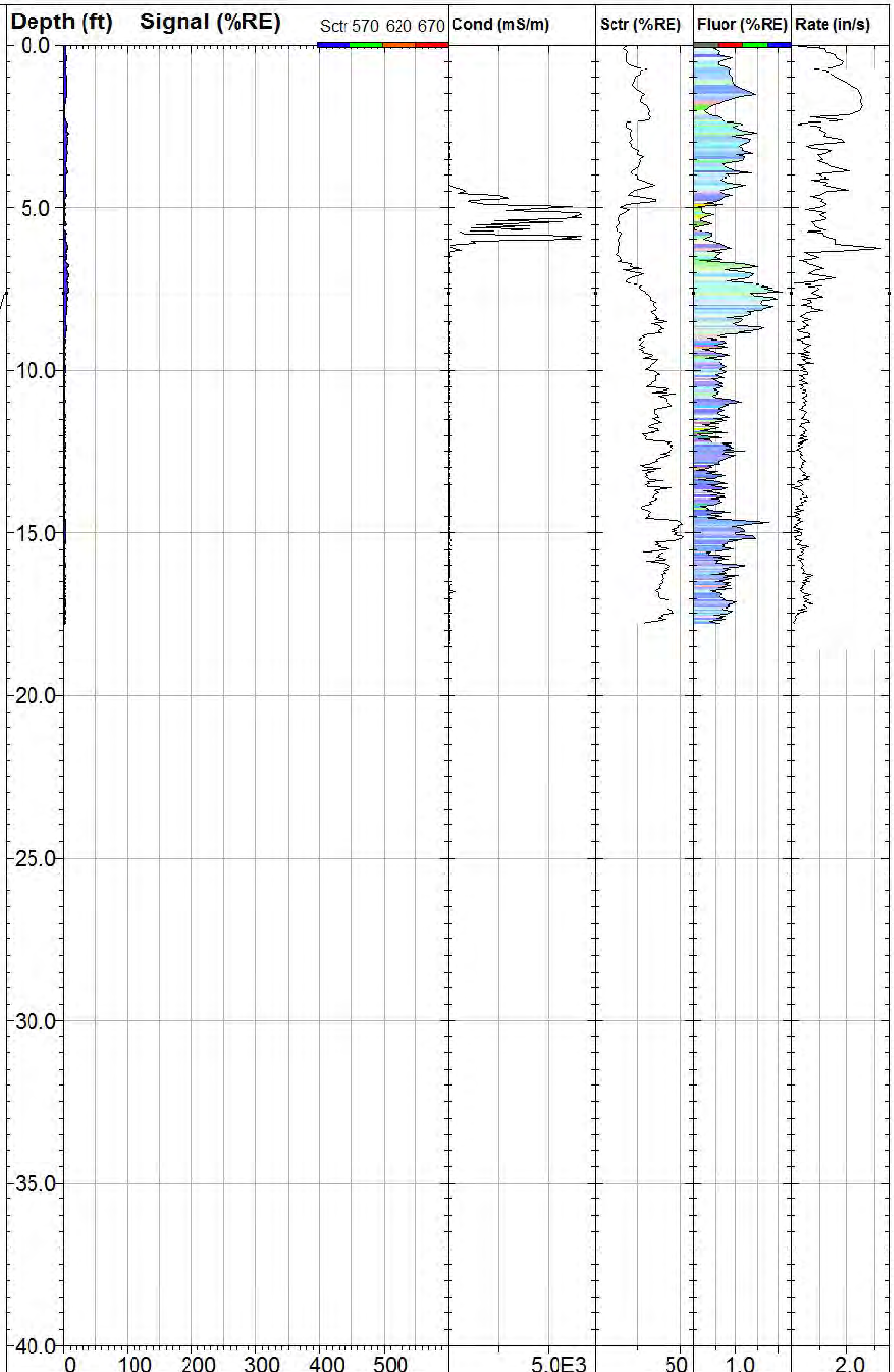
Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **239146.4143 /**	*Final depth:* **29.38 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1270457.178 /**	*Max signal:* **466.6 %RE @ 28.18 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **38.6 ft**	*Date & Time:* **2013-03-20 10:07 PDT**

Callouts

preprobed to 4.5'



7.65 ft
4.6 %RE

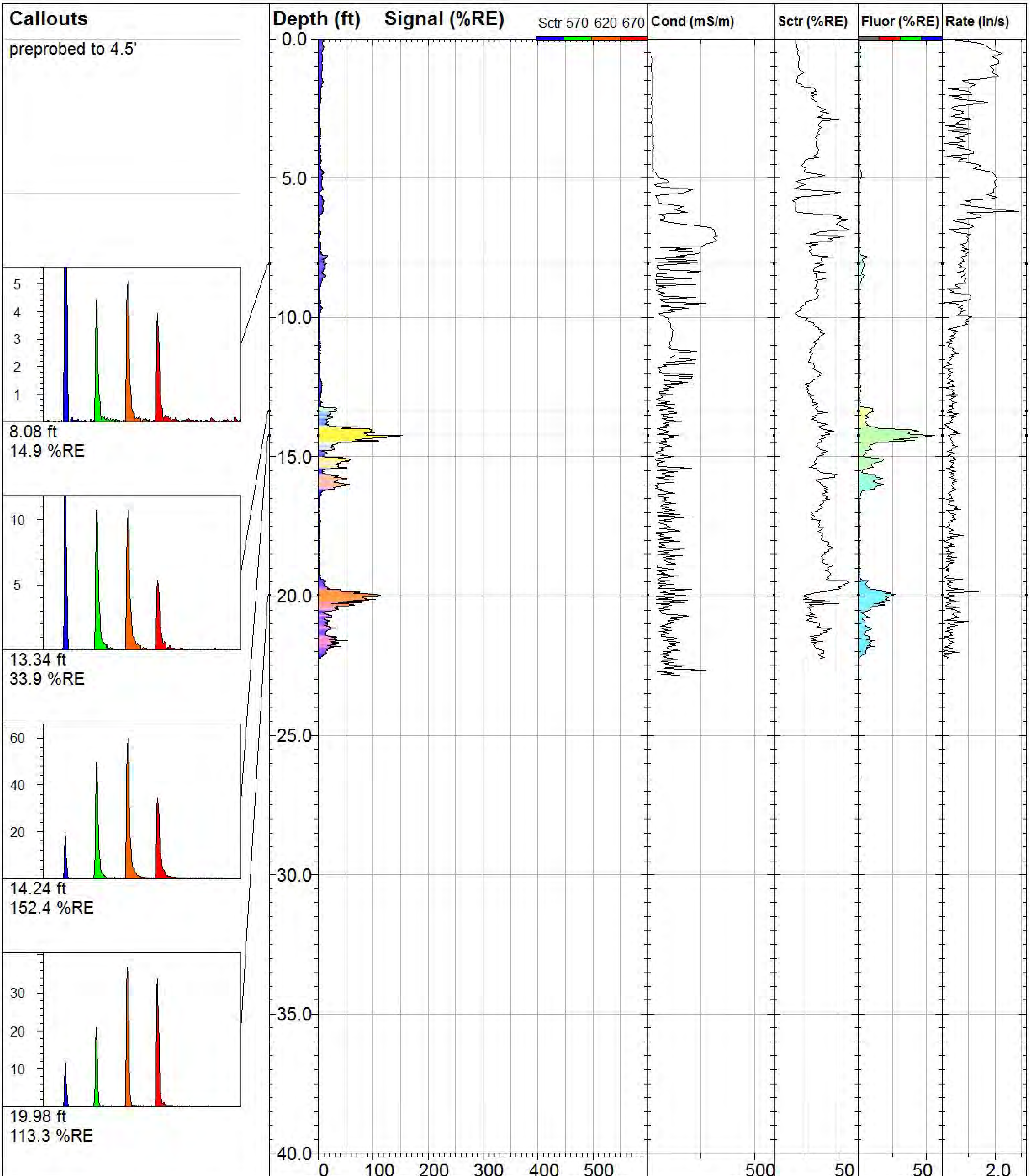


GWP_TG-13

TarGOST By Dakota
www.DakotaTechnologies.com

DAKOTA TECHNOLOGIES
Fargo, ND 701.237.4908
www.DakotaTechnologies.com

Site:	*Y Coord.(Lat-N) / System:*	*Final depth:*
Gas Works Park	**239083.0432 /**	**17.83 ft**
Client / Job:	*X Coord.(Lng-E) / Fix:*	*Max signal:*
GeoEngineers /	**1270514.067 /**	**7.8 %RE @ 6.74 ft**
Operator / Unit:	*Elevation:*	*Date & Time:*
SDA / TG1004	**35.1 ft**	**2013-03-20 11:31 PDT**

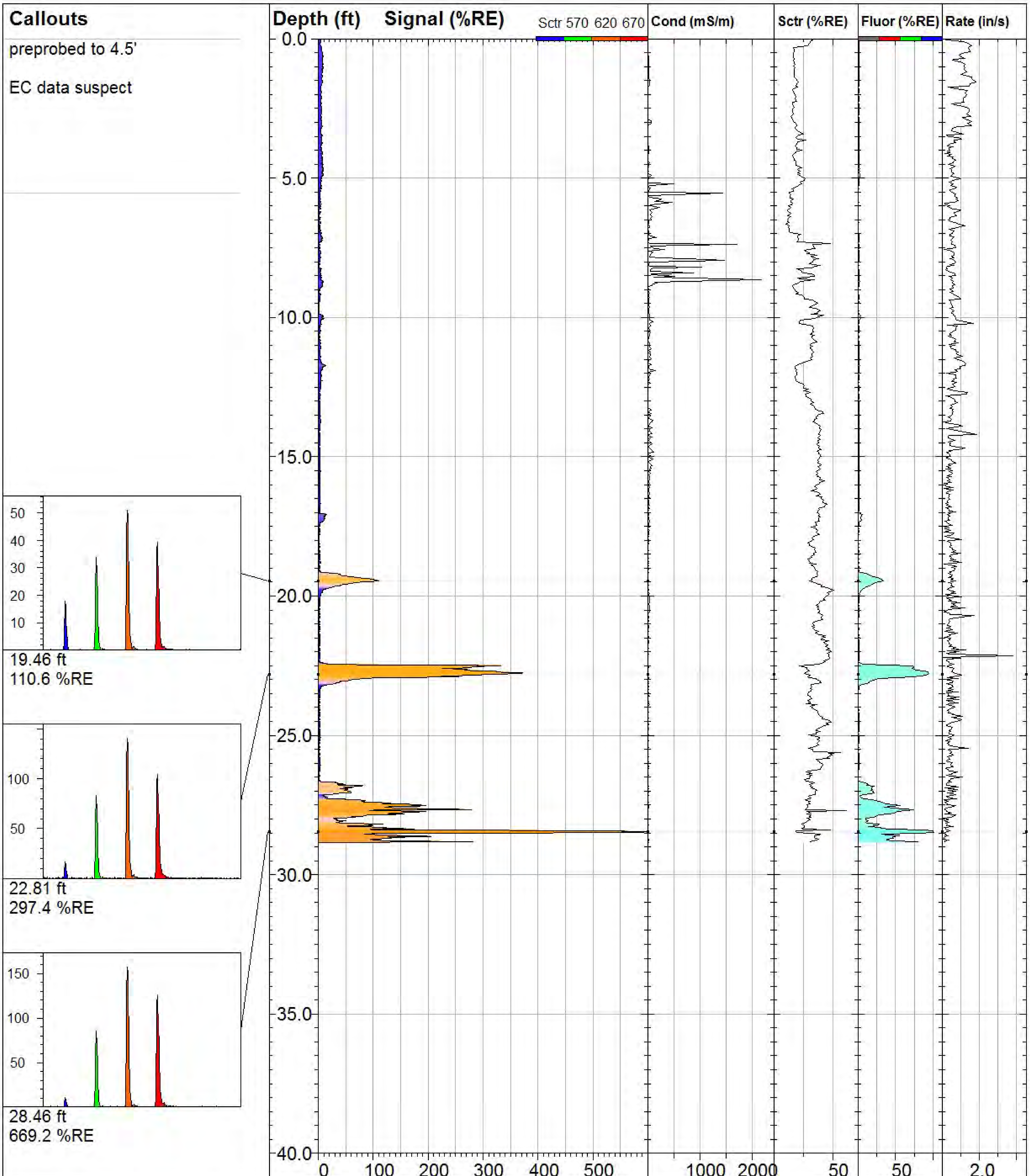


DAKOTA TECHNOLOGIES
Fargo, ND 701.237.4908
www.DakotaTechnologies.com

GWP_TG-14

TarGOST By Dakota
www.DakotaTechnologies.com

Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **239204.4909 /**	*Final depth:* **22.23 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1270500.945 /**	*Max signal:* **152.4 %RE @ 14.24 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **36.3 ft**	*Date & Time:* **2013-03-20 13:14 PDT**

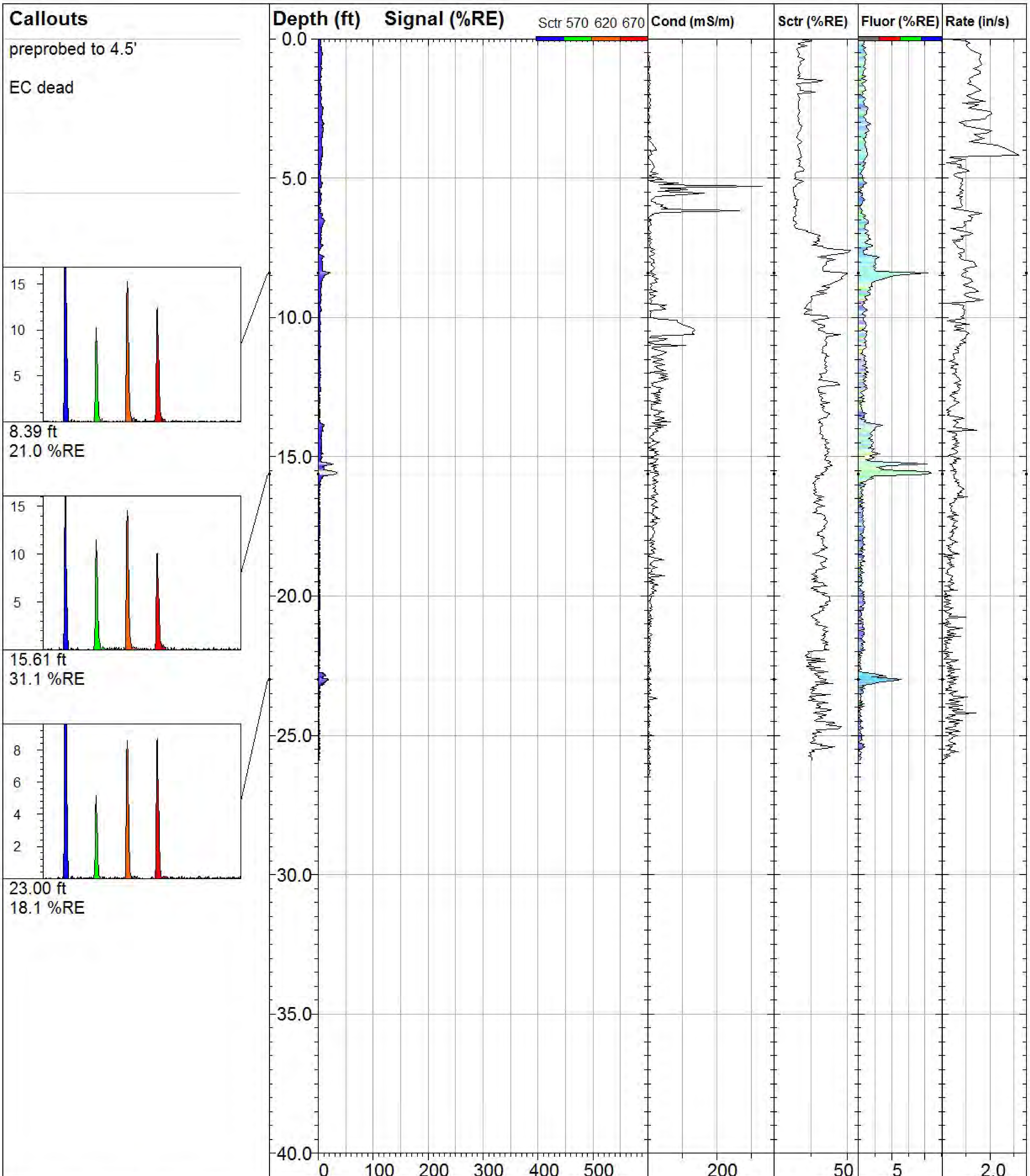


GWP_TG-15

TarGOST By Dakota
www.DakotaTechnologies.com

DAKOTA TECHNOLOGIES
Fargo, ND 701.237.4908
www.DakotaTechnologies.com

Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **239124.229 /**	*Final depth:* **28.83 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1270403.5 /**	*Max signal:* **669.2 %RE @ 28.46 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **39.6 ft**	*Date & Time:* **2013-03-20 14:16 PDT**

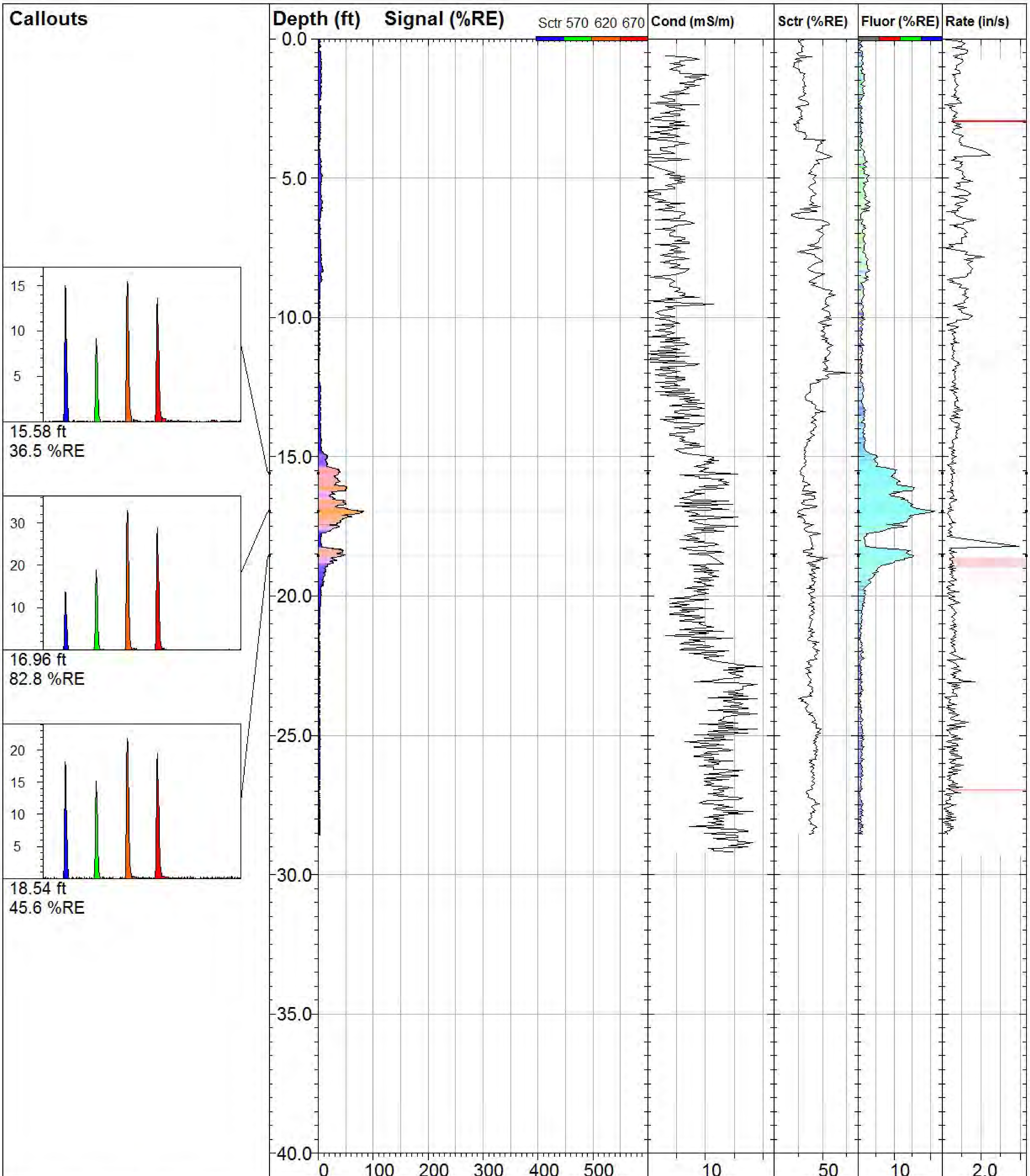


GWP_TG-16

TarGOST By Dakota
www.DakotaTechnologies.com

DAKOTA TECHNOLOGIES
Fargo, ND 701.237.4908
www.DakotaTechnologies.com

Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **239210.6132 /**	*Final depth:* **25.89 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1270423.502 /**	*Max signal:* **33.9 %RE @ 15.60 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **37.3 ft**	*Date & Time:* **2013-03-20 15:43 PDT**

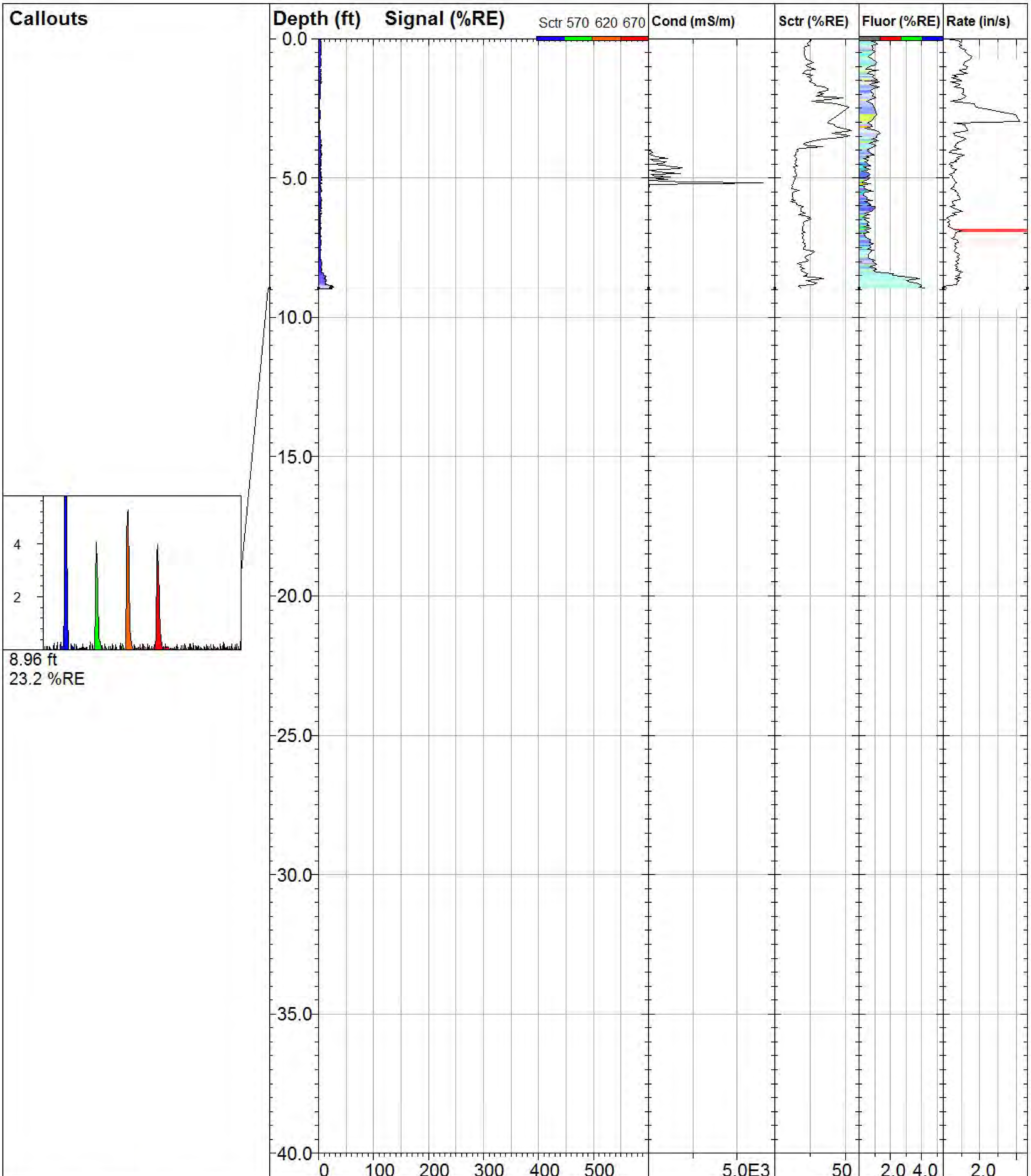


GWP_TG-17

TarGOST By Dakota
www.DakotaTechnologies.com

DAKOTA TECHNOLOGIES
Fargo, ND 701.237.4908
www.DakotaTechnologies.com

Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **239329.5381 /**	*Final depth:* **28.57 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1269790.288 /**	*Max signal:* **82.8 %RE @ 16.96 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **38.8 ft**	*Date & Time:* **2013-03-21 08:13 PDT**

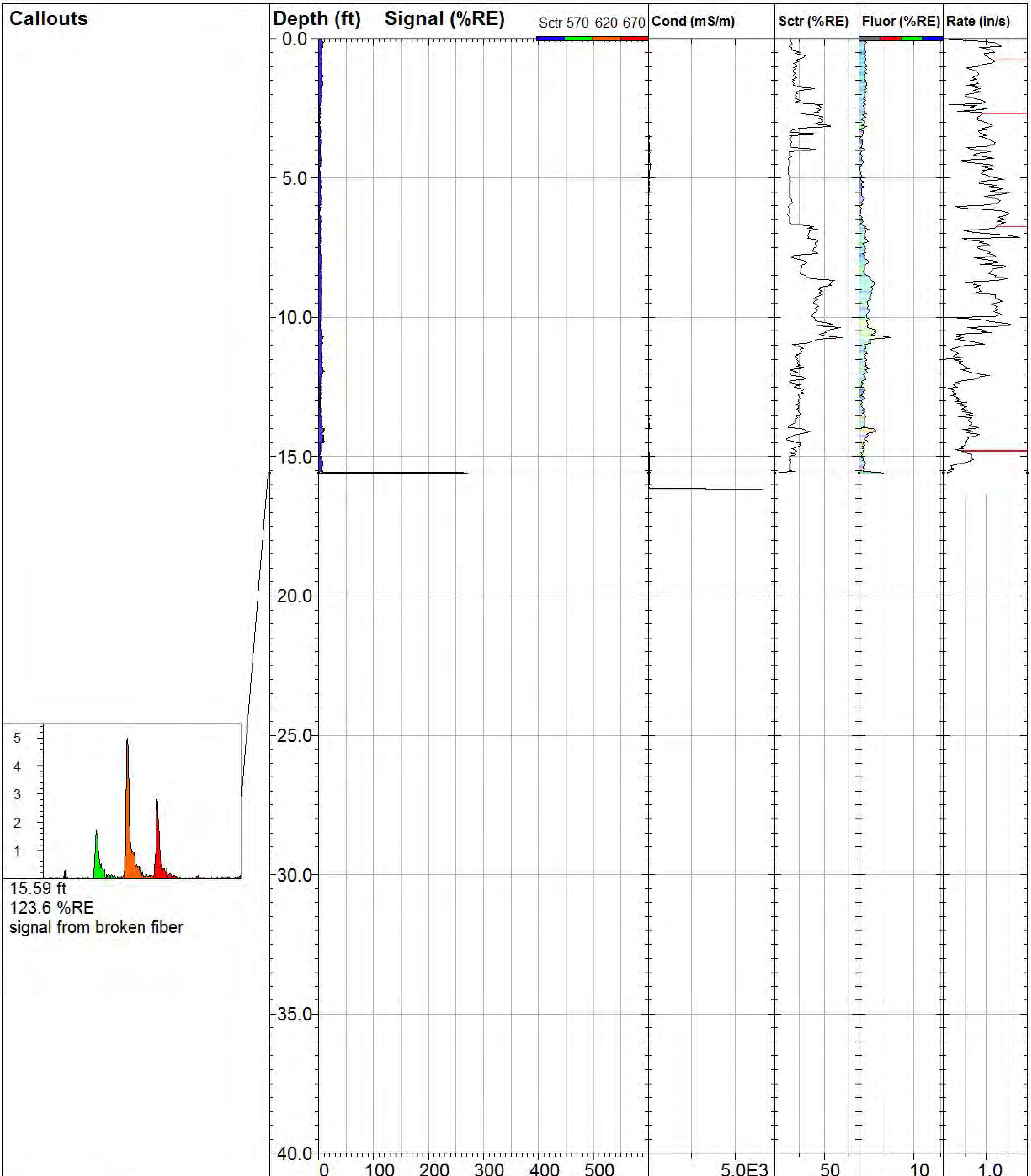


GWP_TG-18

TarGOST By Dakota
www.DakotaTechnologies.com

Site:	Y Coord.(Lat-N) / System:	Final depth:
Gas Works Park	**239376.3738 /**	**8.98 ft**
Client / Job:	*X Coord.(Lng-E) / Fix:*	*Max signal:*
GeoEngineers /	**1269797.8 /**	**27.0 %RE @ 8.91 ft**
Operator / Unit:	*Elevation:*	*Date & Time:*
SDA / TG1004	**39.9 ft**	**2013-03-21 09:32 PDT**

DAKOTA TECHNOLOGIES
Fargo, ND 701.237.4908
www.DakotaTechnologies.com

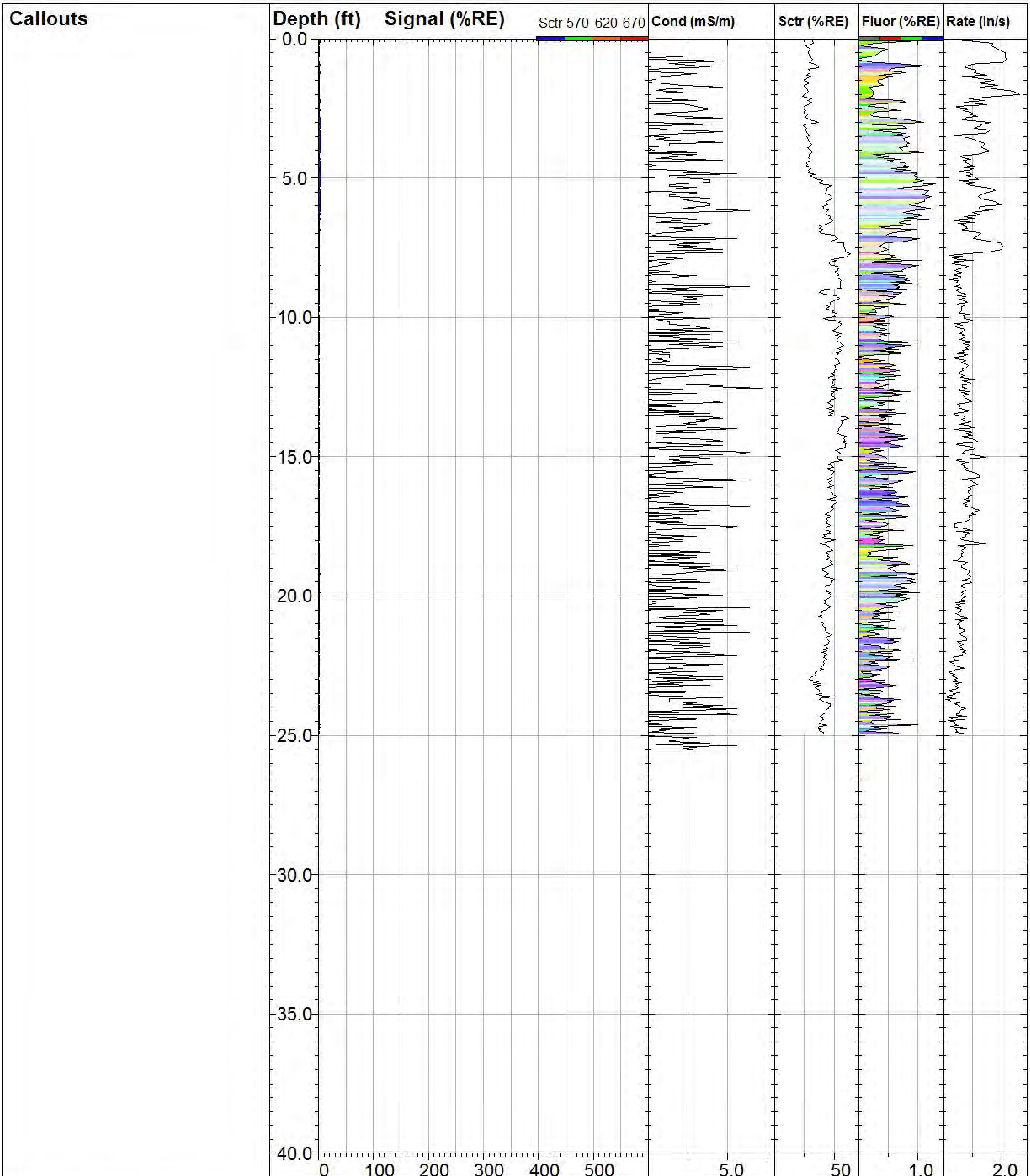


DAKOTA TECHNOLOGIES
FARGO, ND 701.237.4908
WWW.DAKOTATECHNOLOGIES.COM

GWP_TG-18B

TarGOST By Dakota
www.DakotaTechnologies.com

Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **239374.2509 /**	*Final depth:* **15.60 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1269800.769 /**	*Max signal:* **340.1 %RE @ 15.57 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **40.0 ft**	*Date & Time:* **2013-03-21 10:06 PDT**

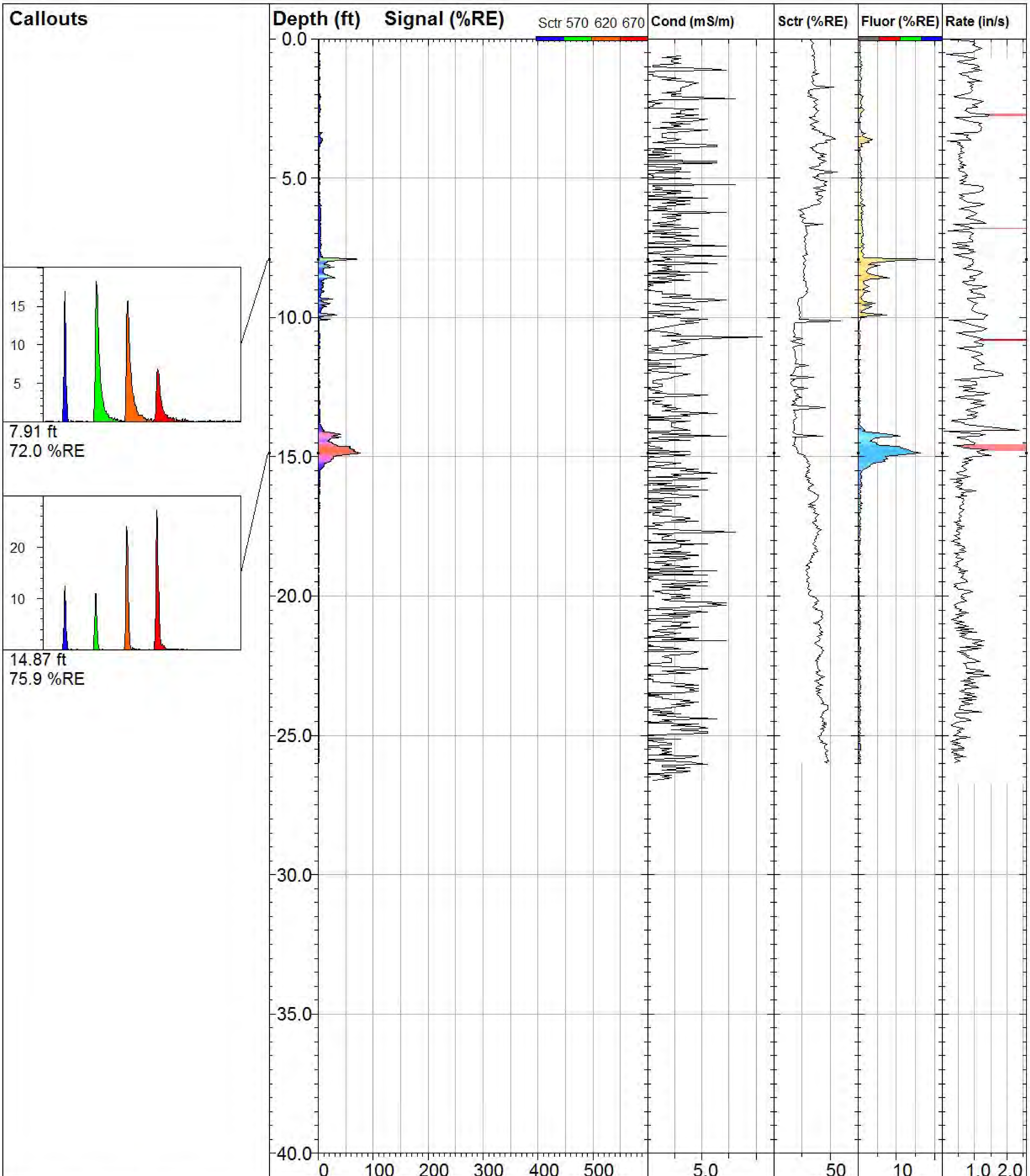


DAKOTA TECHNOLOGIES
FARGO, ND 701.237.4908
WWW.DAKOTATECHNOLOGIES.COM

GWP_TG-19

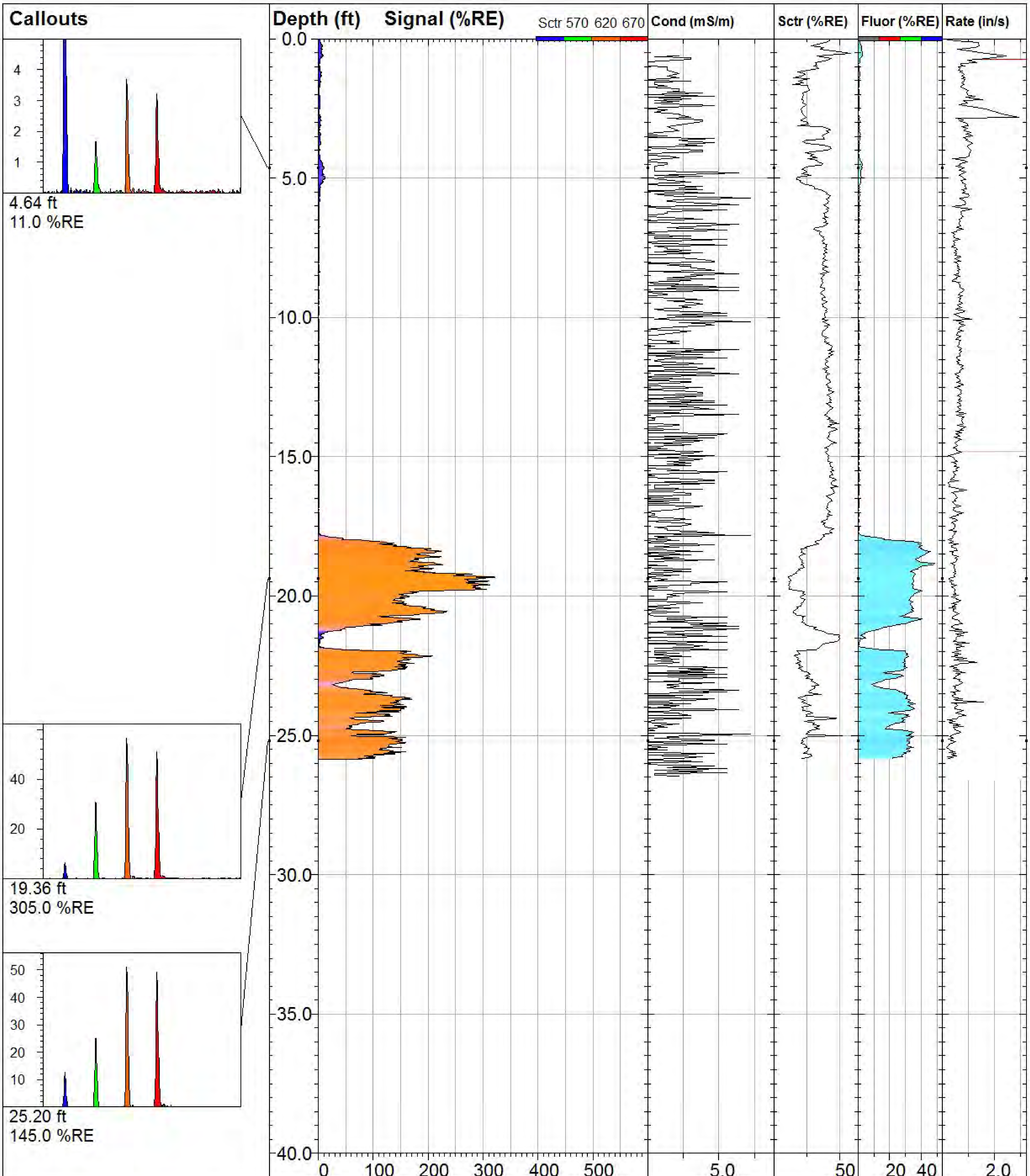
TarGOST By Dakota
www.DakotaTechnologies.com

Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **239355.5459 /**	*Final depth:* **24.95 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1269744.526 /**	*Max signal:* **3.5 %RE @ 4.07 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **38.0 ft**	*Date & Time:* **2013-03-21 17:09 PDT**



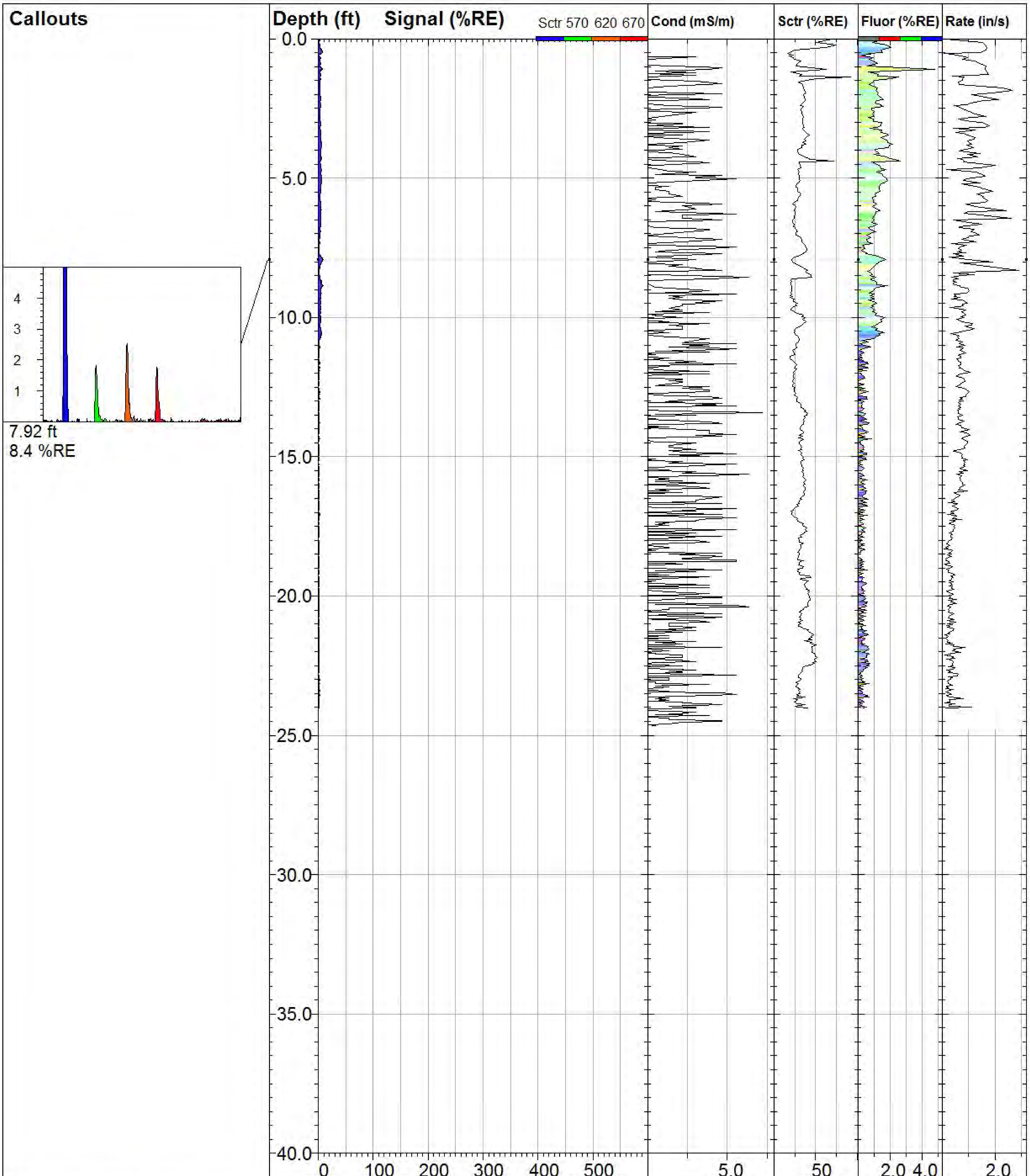
GWP_TG-20		TarGOST By Dakota www.DakotaTechnologies.com
Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **238996.0276 /**	*Final depth:* **25.99 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1269764.259 /**	*Max signal:* **75.9 %RE @ 14.87 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **27.6 ft**	*Date & Time:* **2013-03-21 12:18 PDT**

DAKOTA TECHNOLOGIES
FARGO, ND 701.237.4908
WWW.DAKOTATECHNOLOGIES.COM



GWP_TG-21		**TarGOST By Dakota** www.DakotaTechnologies.com
Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **239223.5495 /**	*Final depth:* **25.86 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1269703.395 /**	*Max signal:* **323.3 %RE @ 19.32 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **25.9 ft**	*Date & Time:* **2013-03-21 13:16 PDT**

DAKOTA TECHNOLOGIES
FARGO, ND 701.237.4908
WWW.DAKOTATECHNOLOGIES.COM

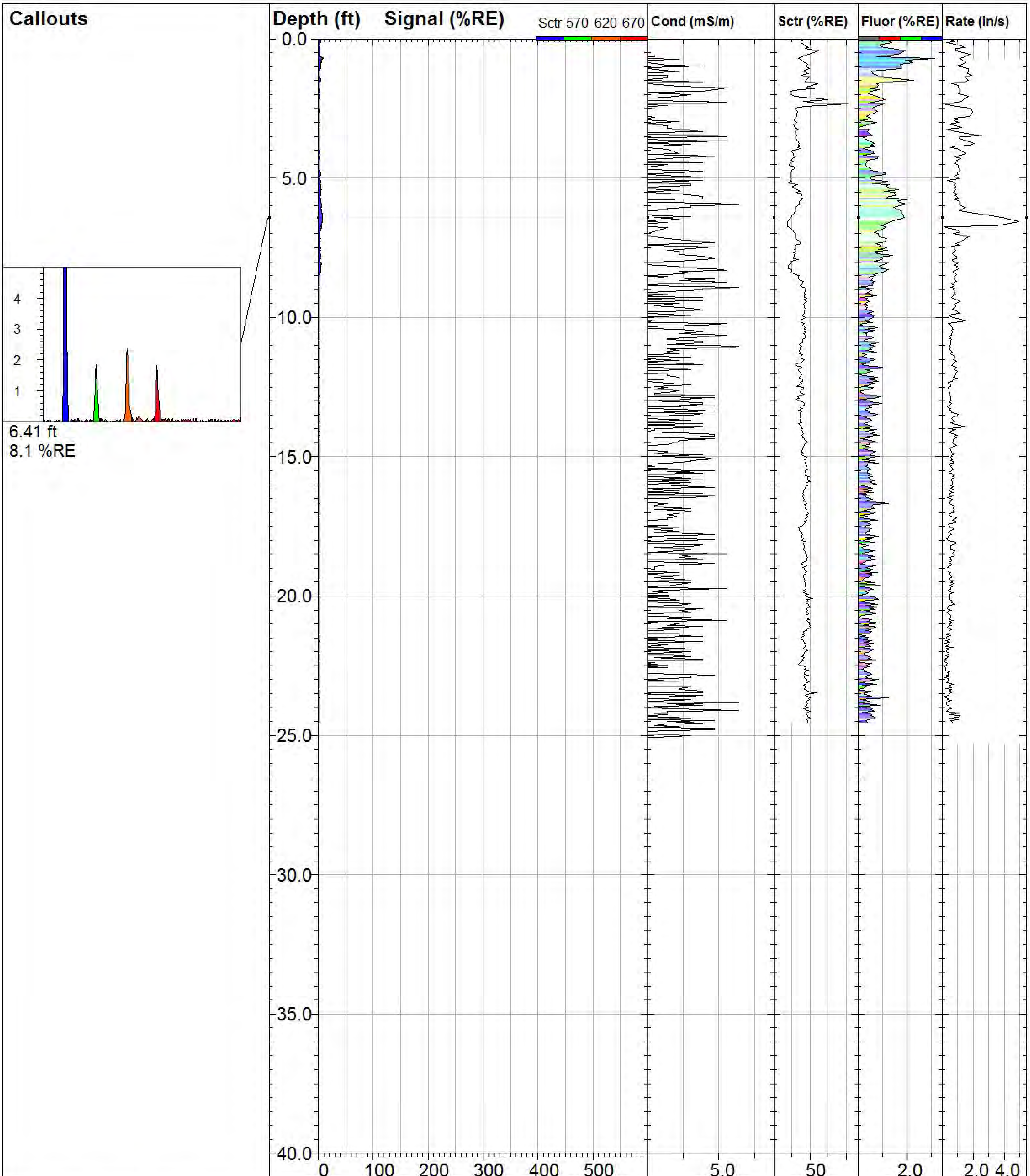


DAKOTA TECHNOLOGIES
FARGO, ND 701.237.4908
WWW.DAKOTATECHNOLOGIES.COM

GWP_TG-22

TarGOST By Dakota
www.DakotaTechnologies.com

Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **239174.3472 /**	*Final depth:* **24.04 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1269674.46 /**	*Max signal:* **8.6 %RE @ 8.86 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **25.8 ft**	*Date & Time:* **2013-03-21 14:21 PDT**

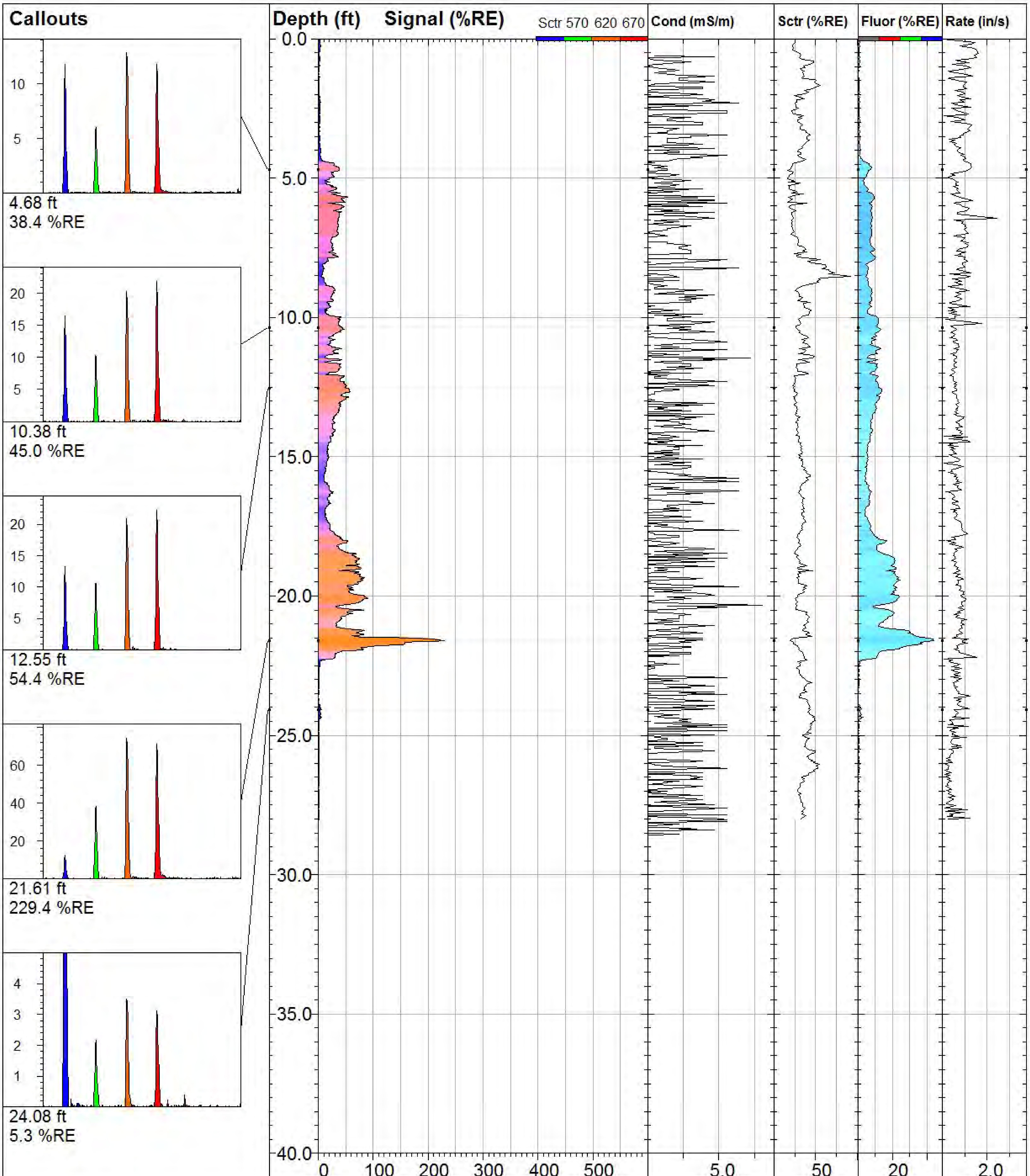


GWP_TG-23

TarGOST By Dakota
www.DakotaTechnologies.com

Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **239226.6014 /**	*Final depth:* **24.52 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1269636.056 /**	*Max signal:* **9.2 %RE @ 0.70 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **26.1 ft**	*Date & Time:* **2013-03-21 15:00 PDT**

DAKOTA TECHNOLOGIES
FARGO, ND 701.237.4908
WWW.DAKOTATECHNOLOGIES.COM

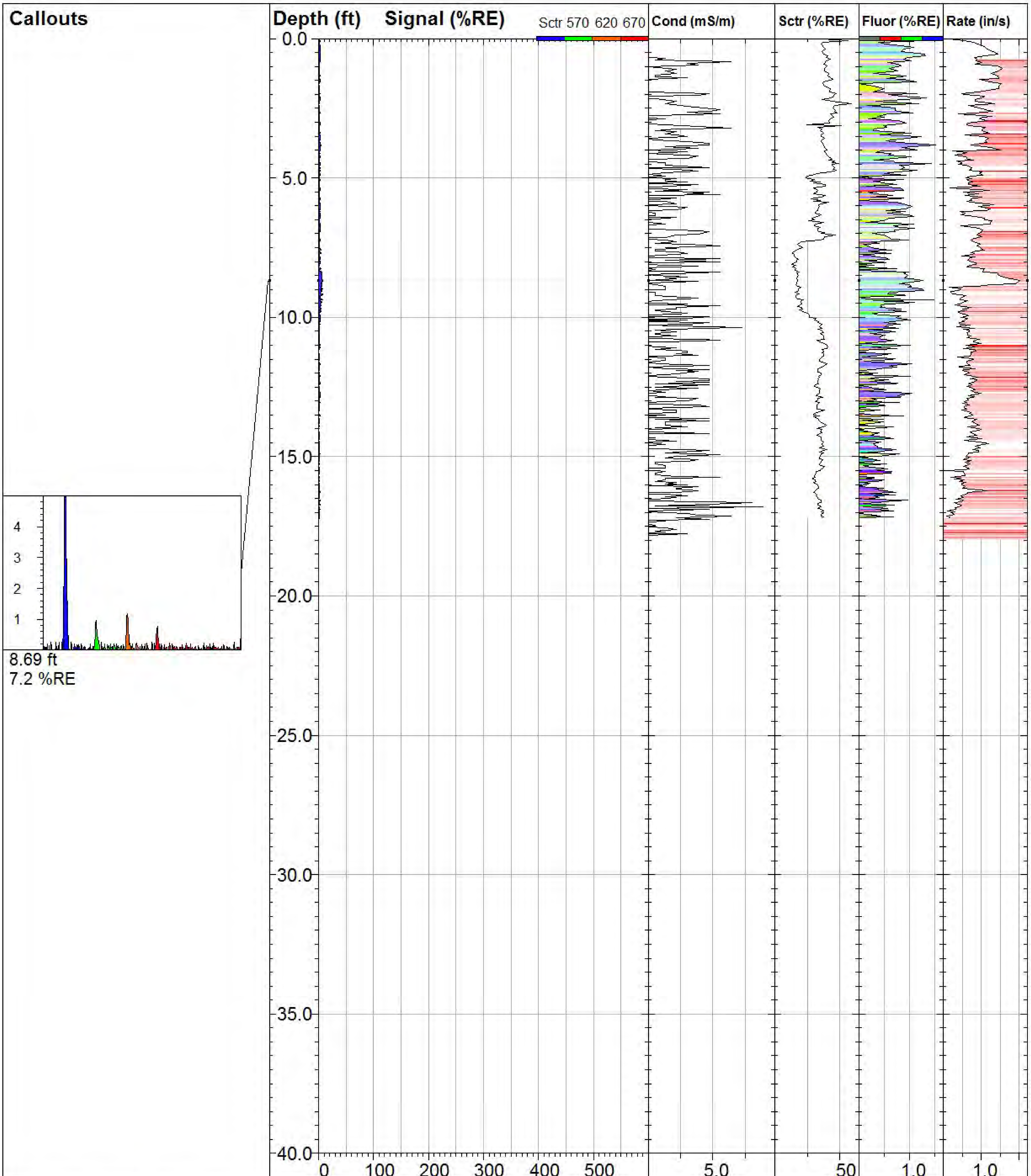


FARGO, ND 701.237.4908
WWW.DAKOTATECHNOLOGIES.COM

GWP_TG-24

TarGOST By Dakota
www.DakotaTechnologies.com

Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **239269.9628 /**	*Final depth:* **28.03 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1269789.805 /**	*Max signal:* **229.4 %RE @ 21.61 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **35.9 ft**	*Date & Time:* **2013-03-21 15:47 PDT**

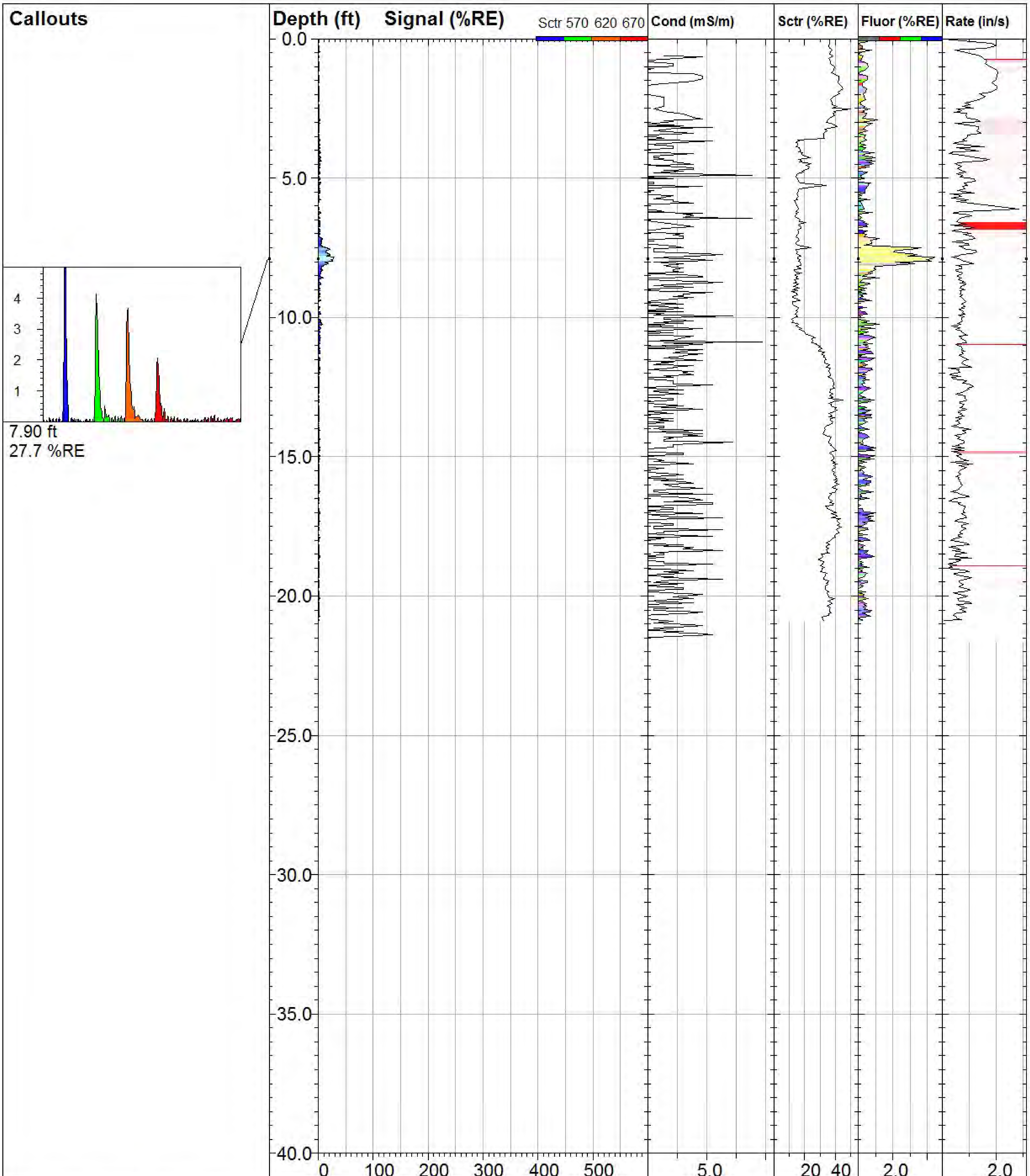


DAKOTA TECHNOLOGIES
FARGO, ND 701.237.4908
WWW.DAKOTATECHNOLOGIES.COM

GWP_TG-25

TarGOST By Dakota
www.DakotaTechnologies.com

Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **238855.4575 /**	*Final depth:* **17.22 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1270583.609 /**	*Max signal:* **8.0 %RE @ 9.16 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **30.0 ft**	*Date & Time:* **2013-03-22 08:29 PDT**

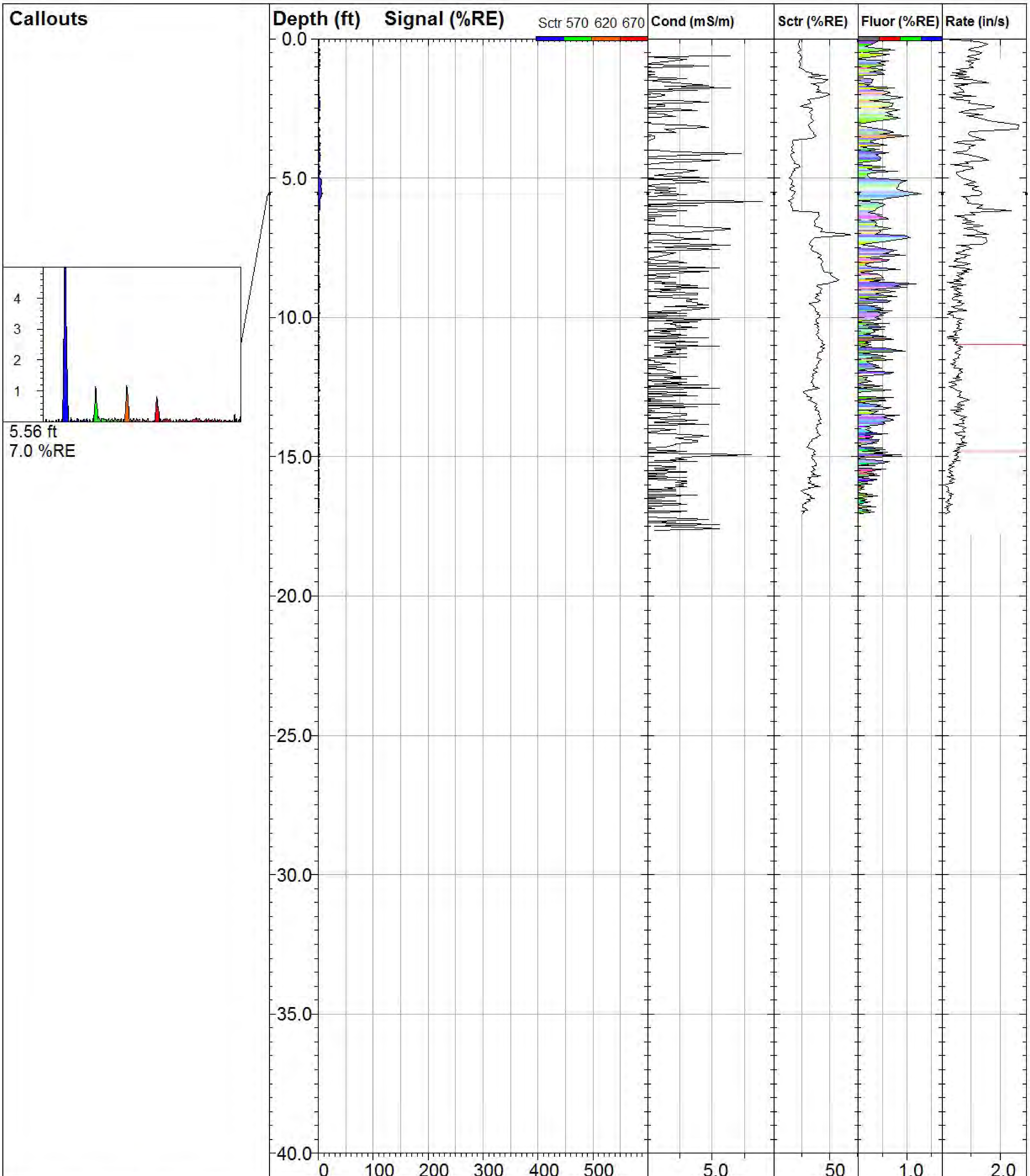


GWP_TG-26

TarGOST By Dakota
www.DakotaTechnologies.com

DAKOTA TECHNOLOGIES
Fargo, ND 701.237.4908
www.DakotaTechnologies.com

Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **238839.5312 /**	*Final depth:* **20.88 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1270685.92 /**	*Max signal:* **28.7 %RE @ 7.84 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **26.5 ft**	*Date & Time:* **2013-03-22 09:19 PDT**

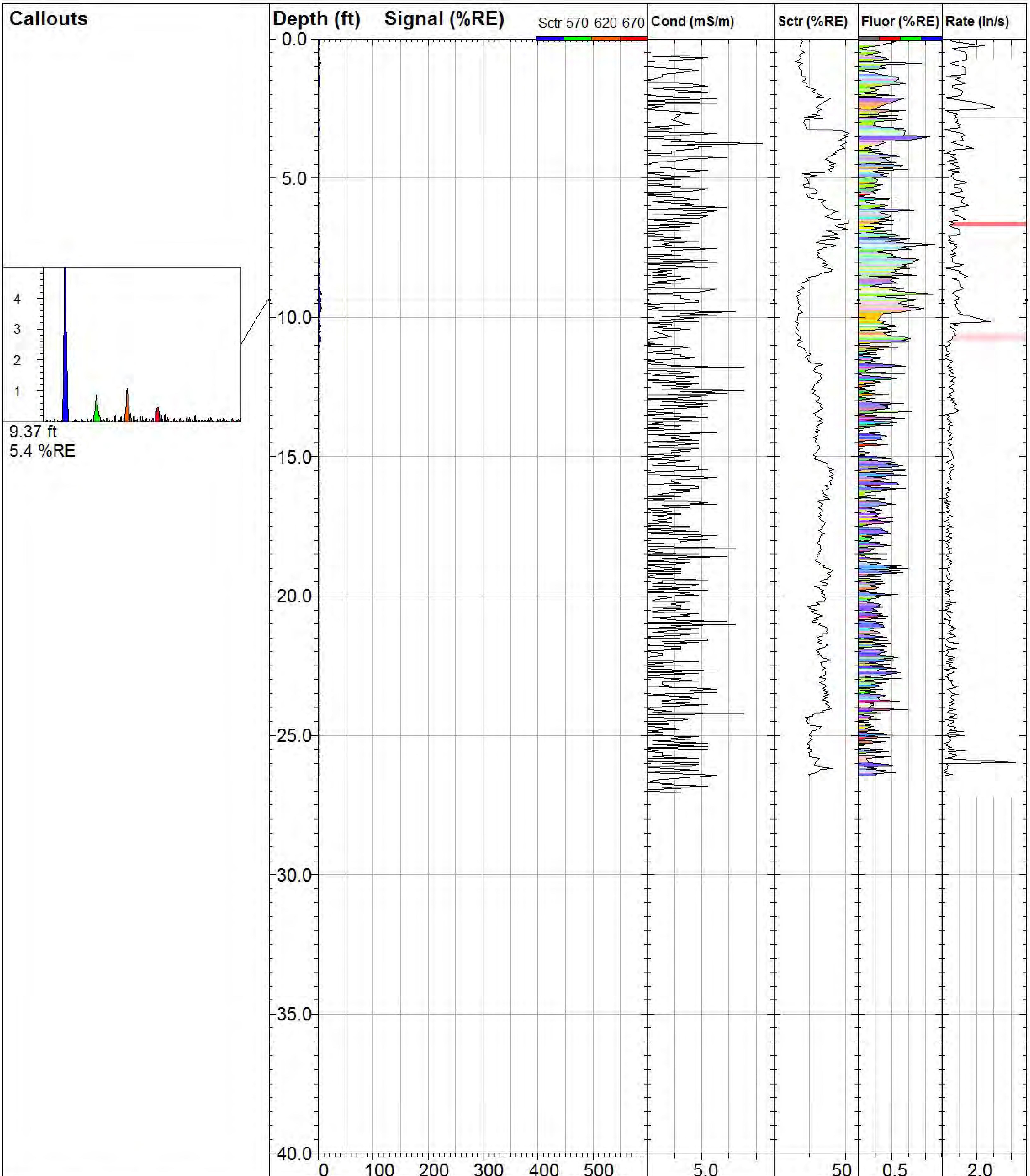


GWP_TG-27

TarGOST By Dakota
www.DakotaTechnologies.com

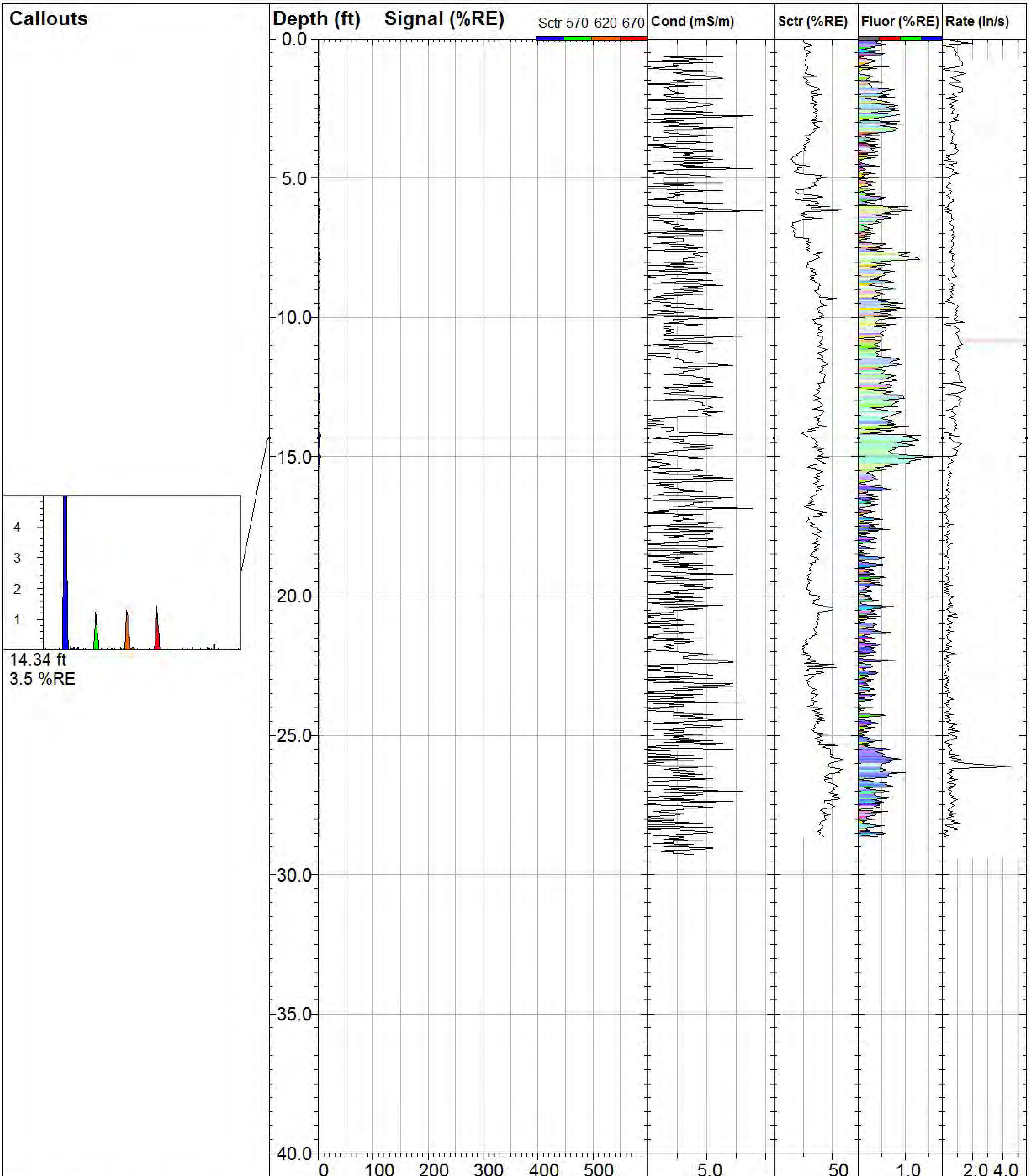
DAKOTA TECHNOLOGIES
Fargo, ND 701.237.4908
www.DakotaTechnologies.com

Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **238807.8902 /**	*Final depth:* **17.03 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1270599.03 /**	*Max signal:* **7.0 %RE @ 5.56 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **25.3 ft**	*Date & Time:* **2013-03-22 10:22 PDT**



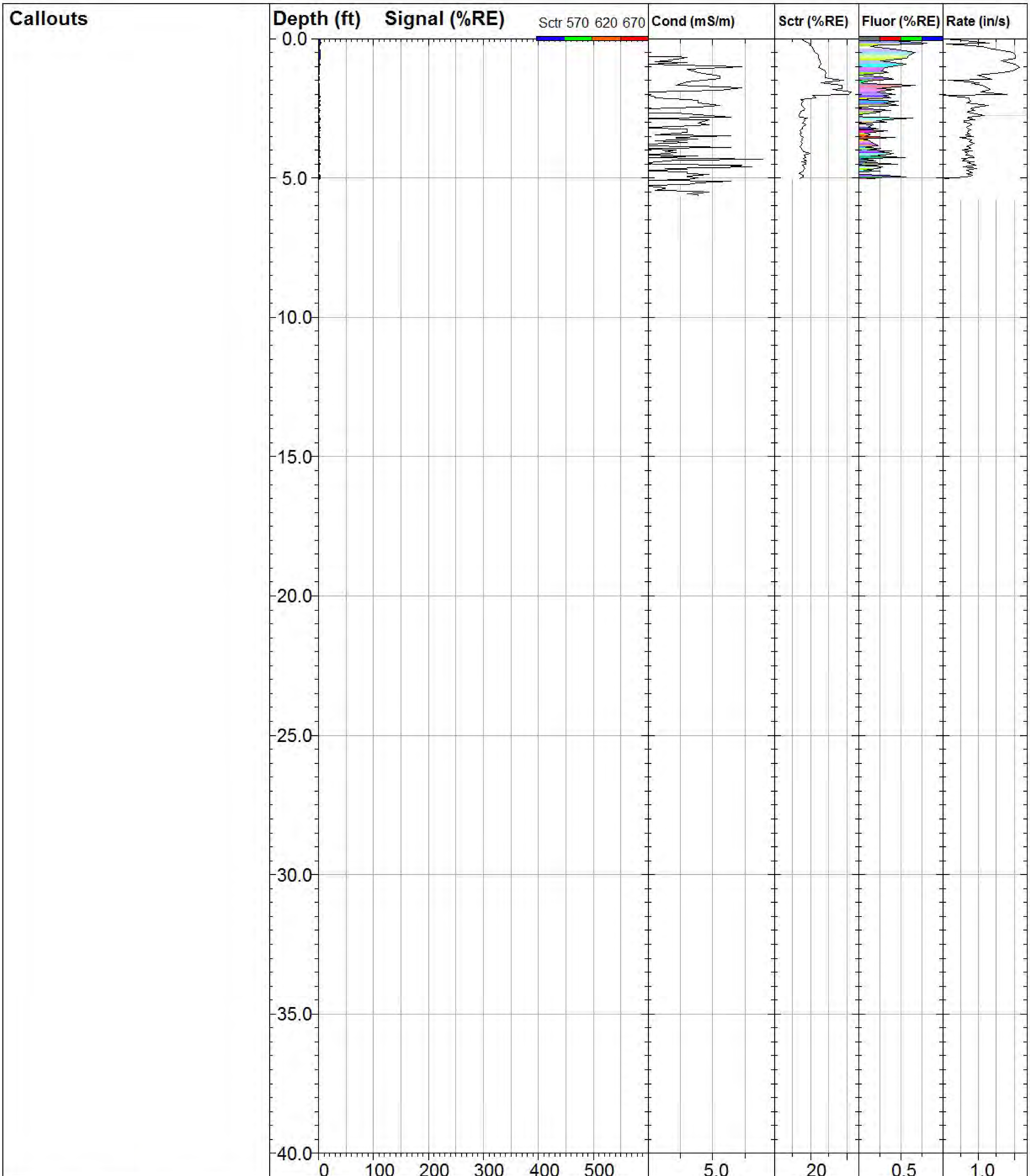
GWP_TG-28		**TarGOST By Dakota** www.DakotaTechnologies.com
Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **238782.1149 /**	*Final depth:* **26.43 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1270496.78 /**	*Max signal:* **5.9 %RE @ 9.17 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **32.3 ft**	*Date & Time:* **2013-03-22 11:29 PDT**

DAKOTA TECHNOLOGIES
Fargo, ND 701.237.4908
www.DakotaTechnologies.com



GWP_TG-29		TarGOST By Dakota www.DakotaTechnologies.com
Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **238793.7156 /**	*Final depth:* **28.65 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1270422.375 /**	*Max signal:* **4.8 %RE @ 14.23 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **38.3 ft**	*Date & Time:* **2013-03-22 13:30 PDT**

DAKOTA TECHNOLOGIES
FARGO, ND 701.237.4908
WWW.DAKOTATECHNOLOGIES.COM

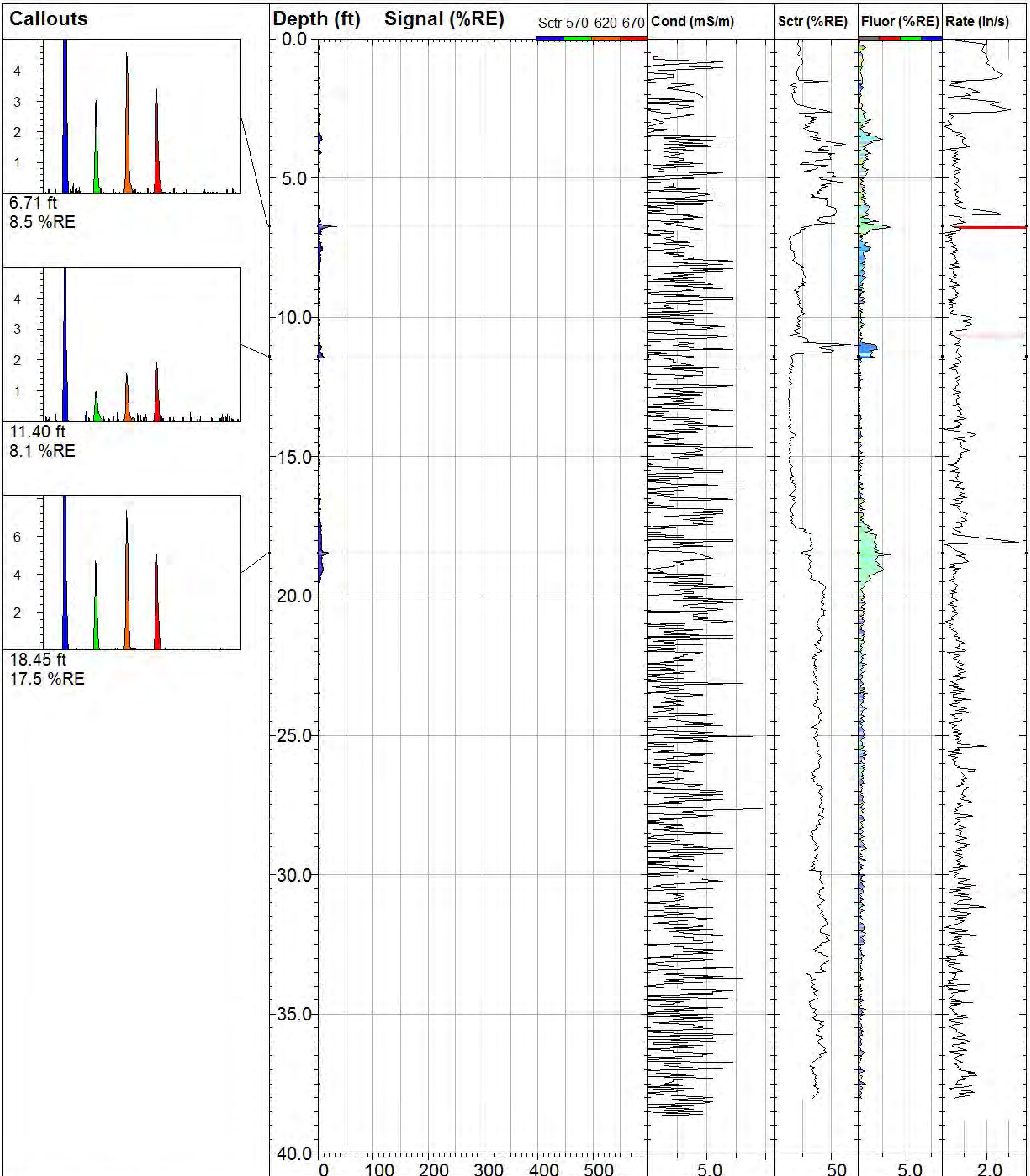


FARGO, ND 701.237.4908
WWW.DAKOTATECHNOLOGIES.COM

GWP_TG-30

TarGOST By Dakota
www.DakotaTechnologies.com

Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **238774.1539 /**	*Final depth:* **5.05 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1270339.165 /**	*Max signal:* **4.3 %RE @ 0.16 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **38.7 ft**	*Date & Time:* **2013-03-22 15:00 PDT**

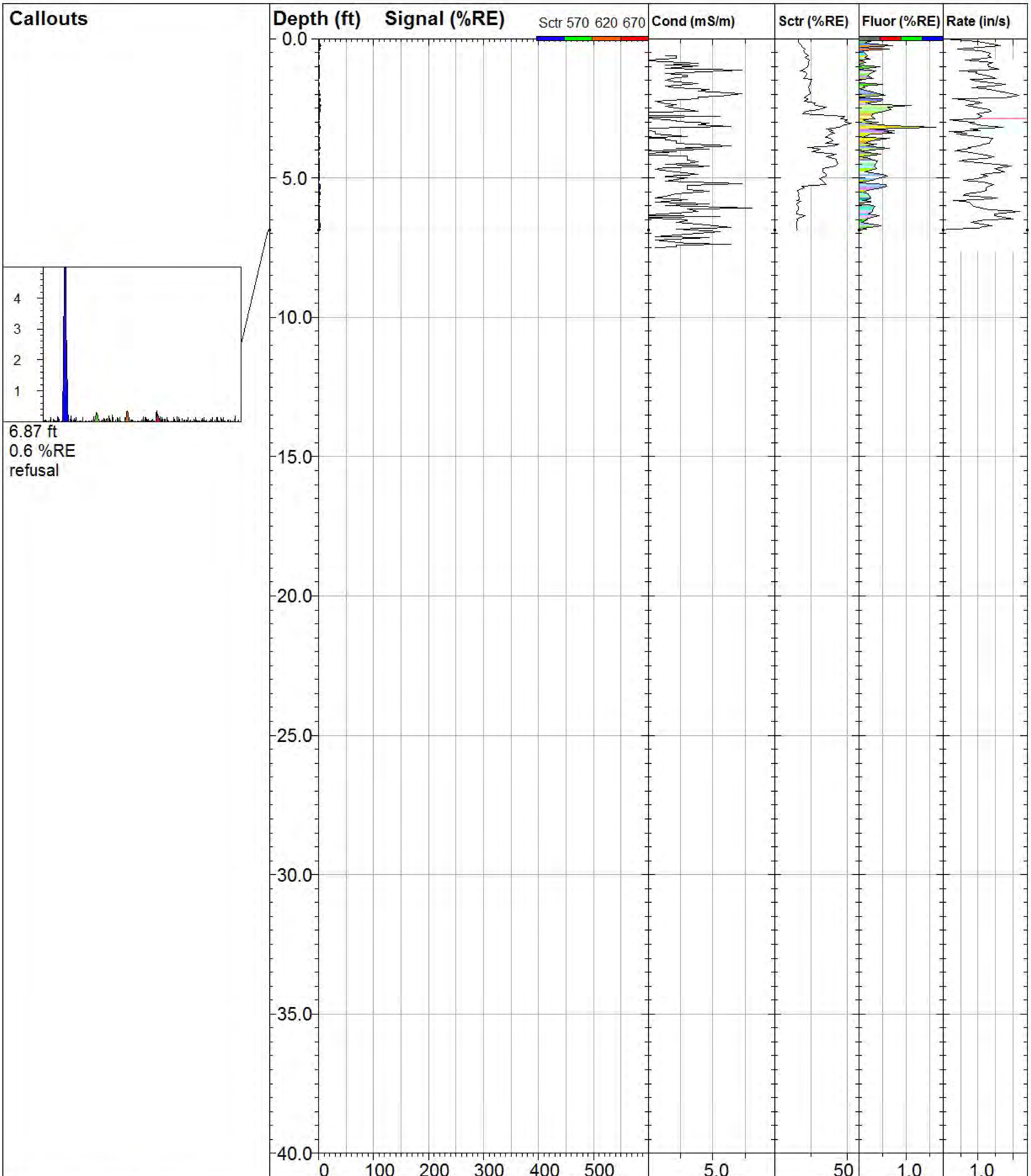


GWP_TG-31

TarGOST By Dakota
www.DakotaTechnologies.com

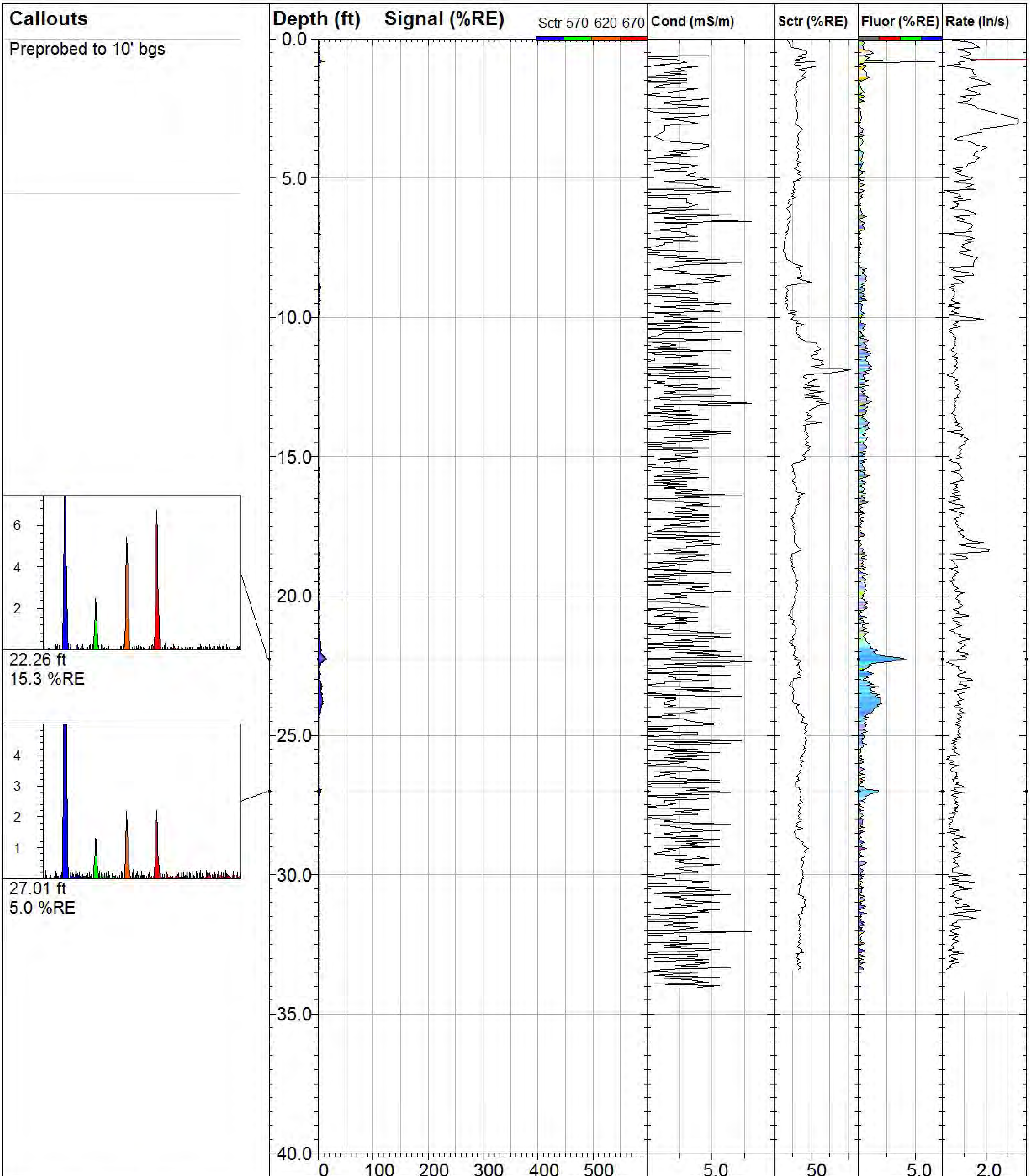
DAKOTA TECHNOLOGIES
Fargo, ND 701.237.4908
www.DakotaTechnologies.com

Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **238788.0712 /**	*Final depth:* **38.04 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1270253.225 /**	*Max signal:* **34.3 %RE @ 6.74 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **38.3 ft**	*Date & Time:* **2013-03-22 15:48 PDT**



GWP_TG-32		TarGOST By Dakota www.DakotaTechnologies.com
Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **238865.1085 /**	*Final depth:* **6.87 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1270252.611 /**	*Max signal:* **4.0 %RE @ 2.40 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **37.3 ft**	*Date & Time:* **2013-03-22 17:11 PDT**

DAKOTA TECHNOLOGIES
FARGO, ND 701.237.4908
WWW.DAKOTATECHNOLOGIES.COM

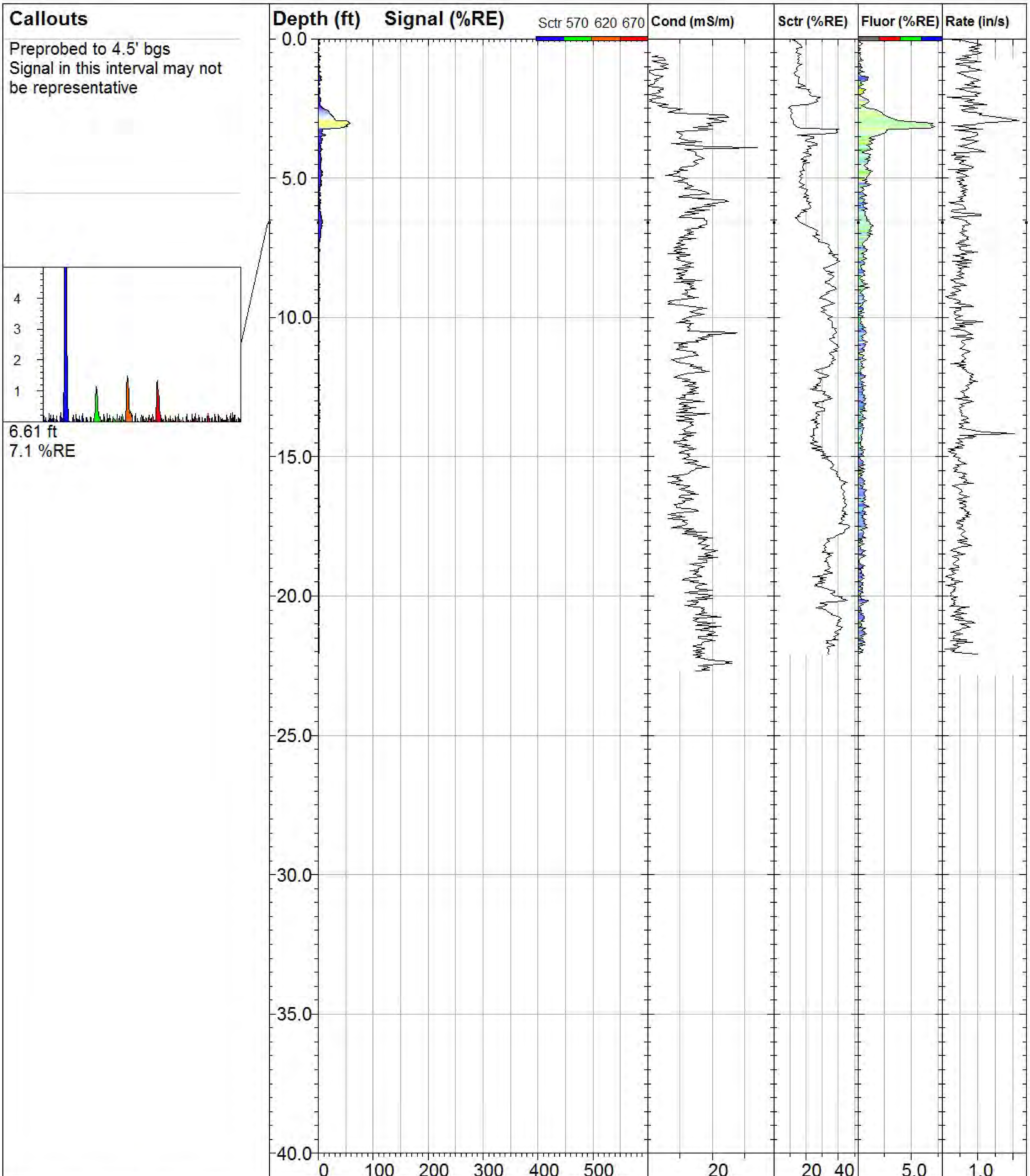


DAKOTA TECHNOLOGIES
FARGO, ND 701.237.4908
WWW.DAKOTATECHNOLOGIES.COM

GWP_TG-32B

TarGOST By Dakota
www.DakotaTechnologies.com

Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **238860.1566 /**	*Final depth:* **33.42 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1270251.303 /**	*Max signal:* **15.3 %RE @ 22.26 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **37.2 ft**	*Date & Time:* **2013-03-22 17:35 PDT**

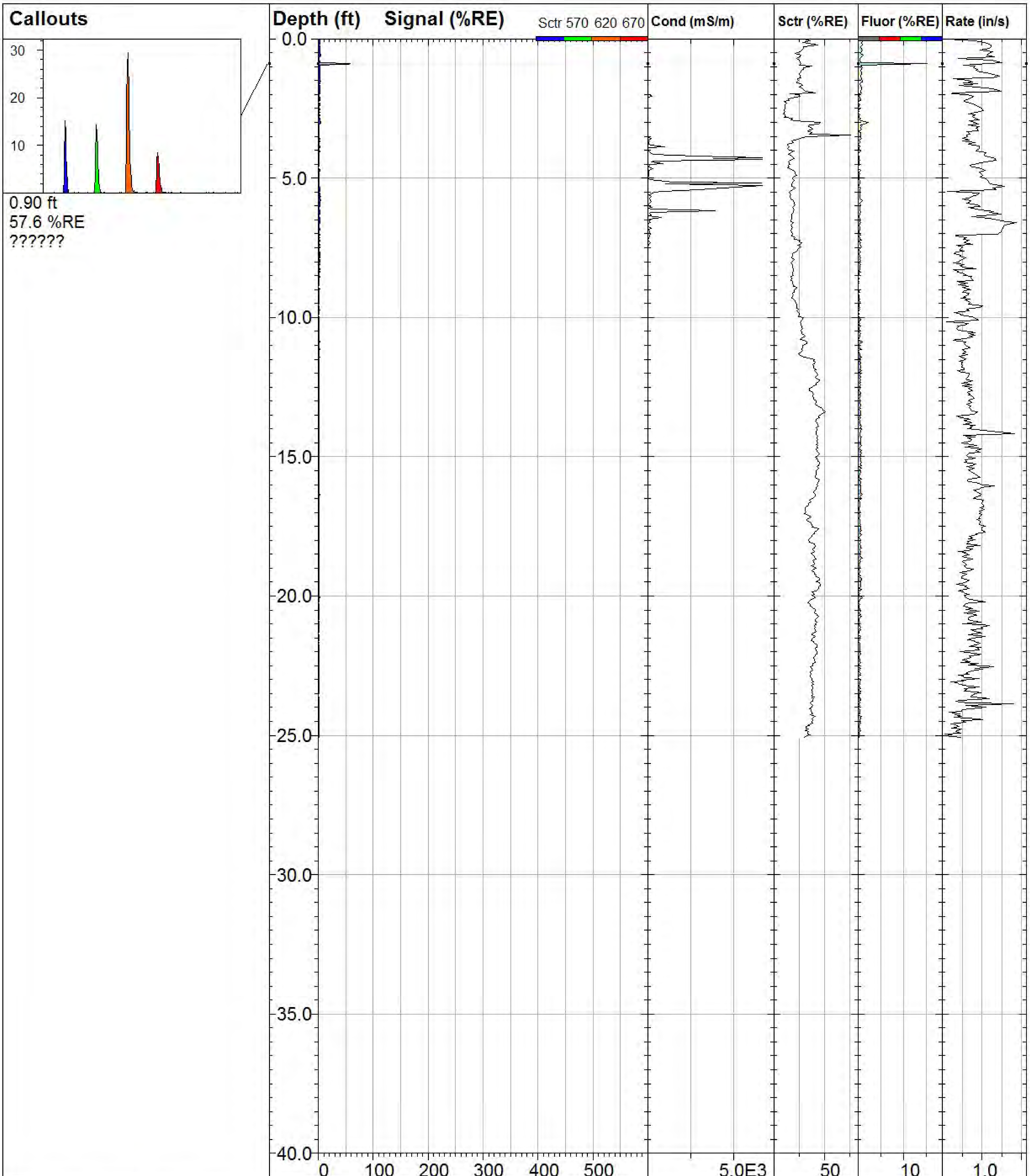


GWP_TG-33

TarGOST By Dakota
www.DakotaTechnologies.com

DAKOTA TECHNOLOGIES
Fargo, ND 701.237.4908
www.DakotaTechnologies.com

Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **238716.0311 /**	*Final depth:* **22.08 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1270234.667 /**	*Max signal:* **57.4 %RE @ 3.04 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **24.0 ft**	*Date & Time:* **2013-03-25 09:39 PDT**

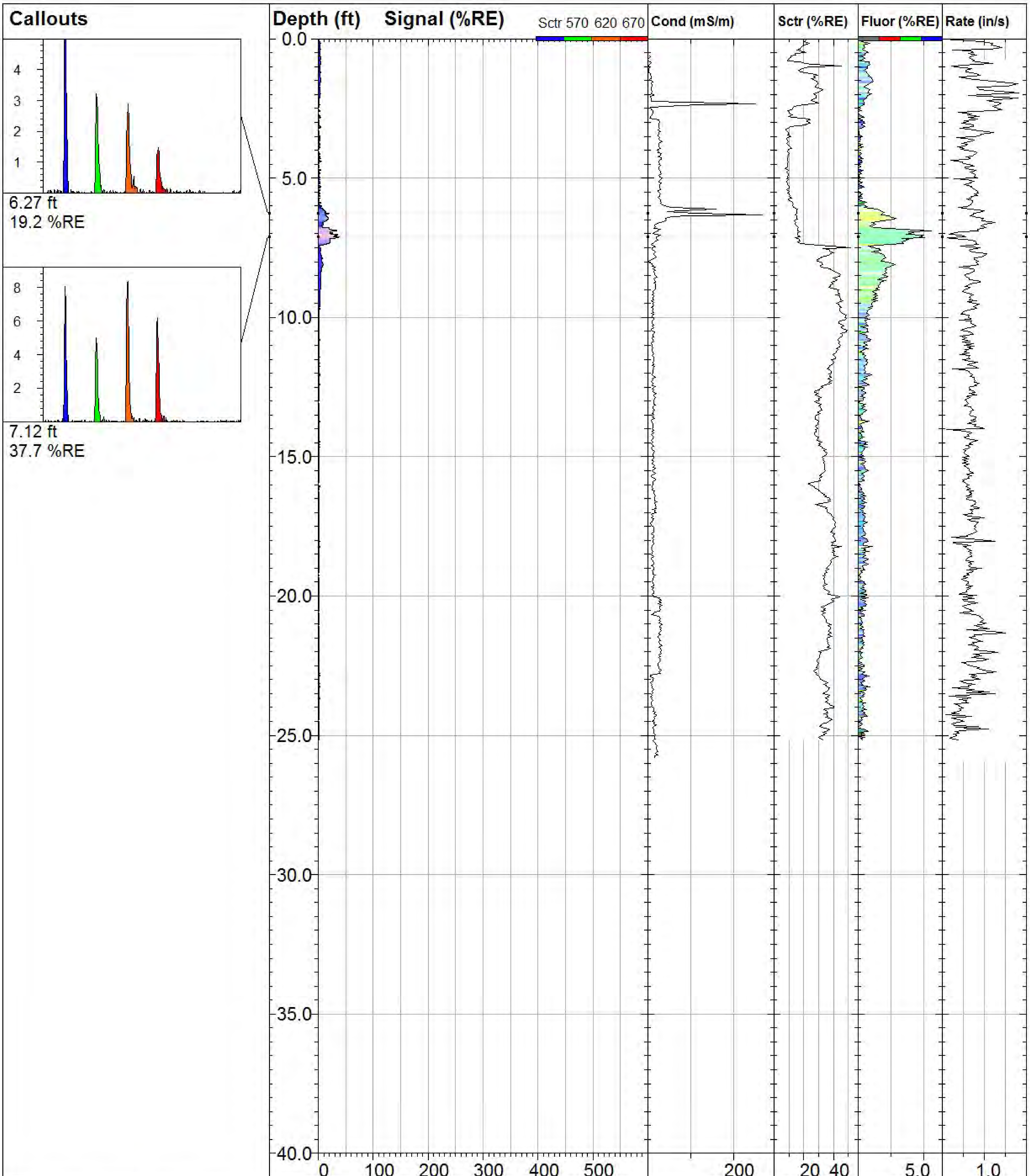


GWP_TG-34

TarGOST By Dakota
www.DakotaTechnologies.com

DAKOTA TECHNOLOGIES
Fargo, ND 701.237.4908
www.DakotaTechnologies.com

Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **238732.2498 /**	*Final depth:* **25.07 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1270172.794 /**	*Max signal:* **60.8 %RE @ 0.90 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **24.4 ft**	*Date & Time:* **2013-03-25 10:45 PDT**

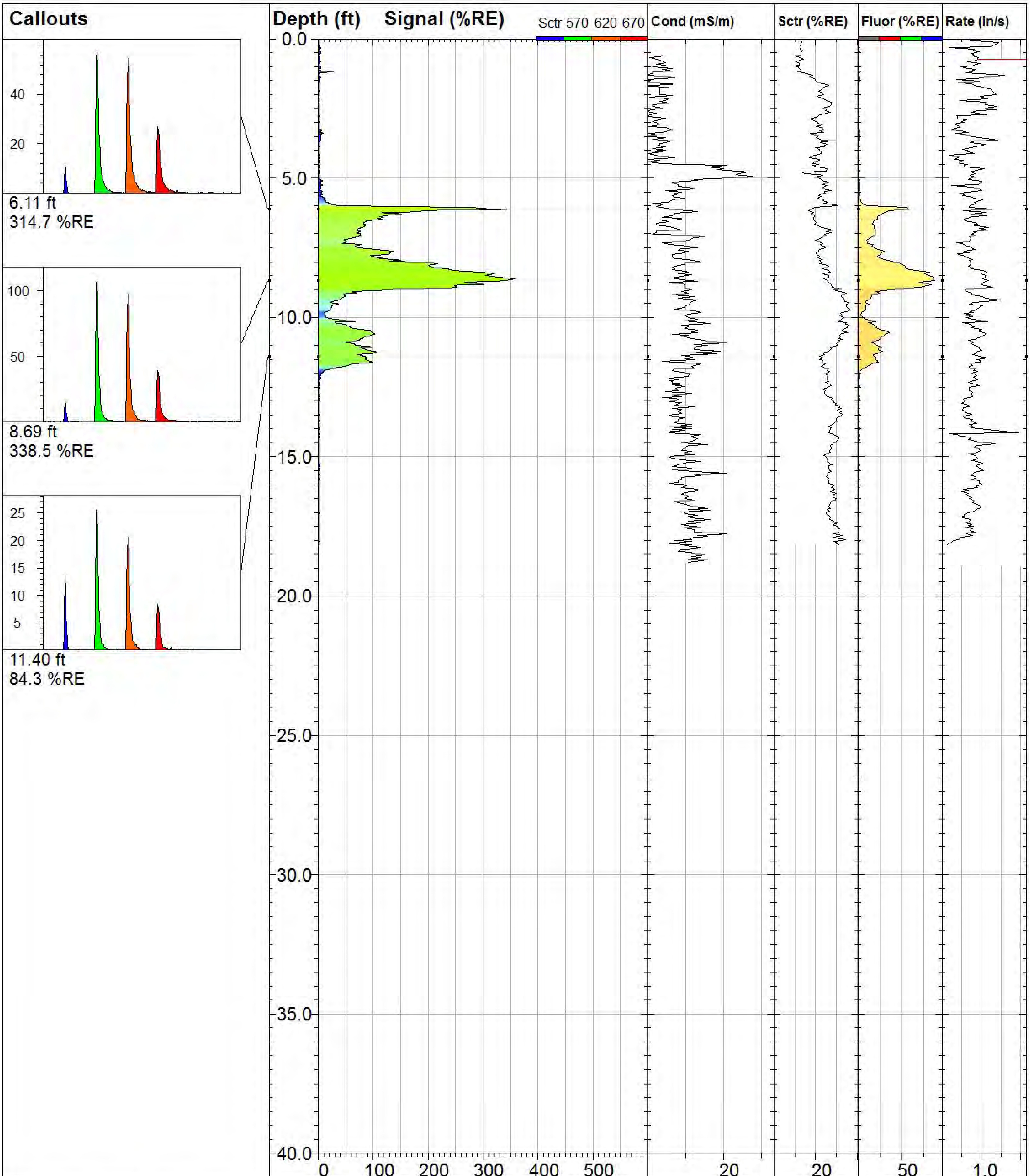


GWP_TG-35

TarGOST By Dakota
www.DakotaTechnologies.com

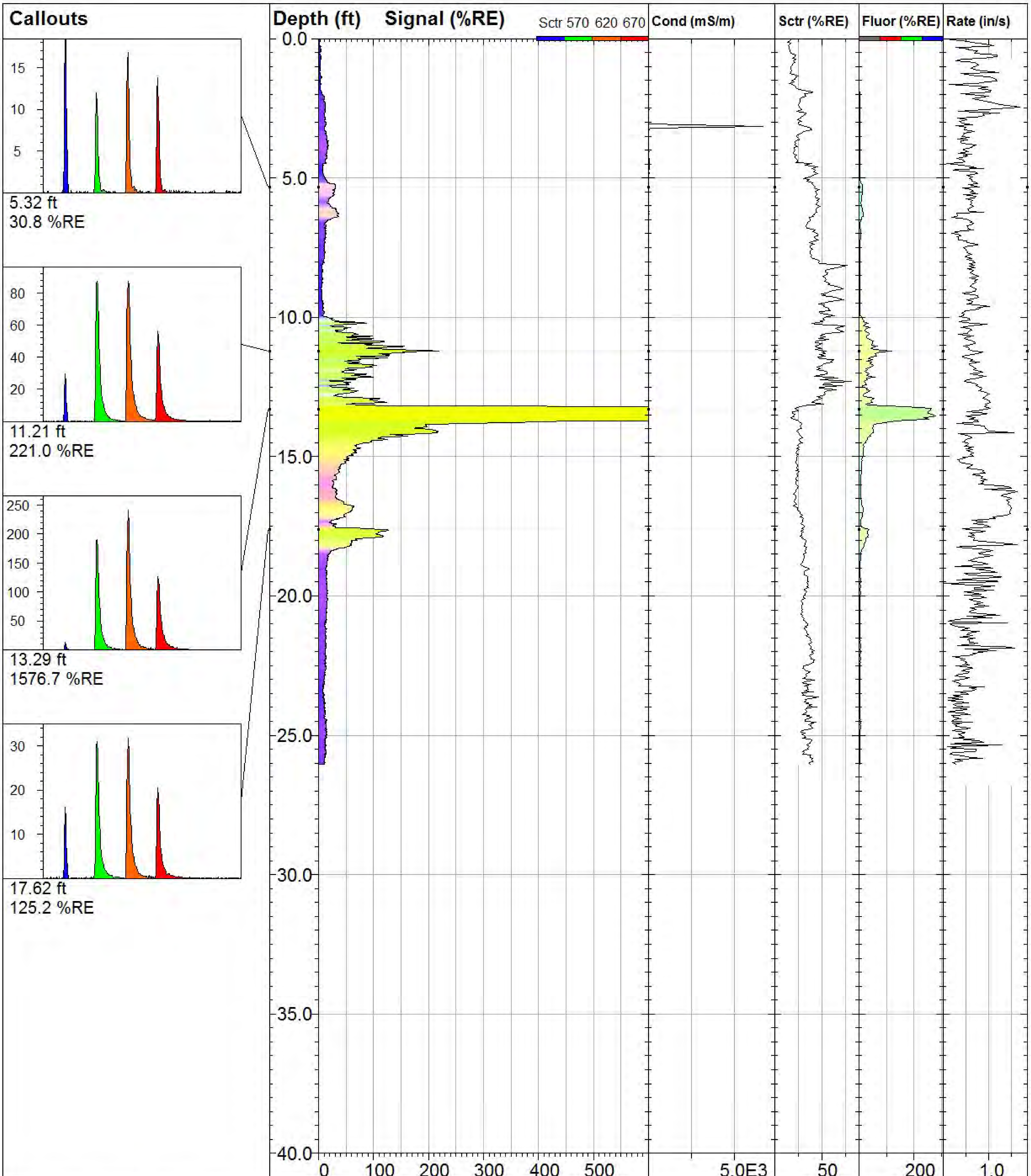
Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **238774.6398 /**	*Final depth:* **25.19 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1270178.383 /**	*Max signal:* **37.7 %RE @ 7.12 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **26.2 ft**	*Date & Time:* **2013-03-25 11:36 PDT**

DAKOTA TECHNOLOGIES
FARGO, ND 701.237.4908
WWW.DAKOTATECHNOLOGIES.COM



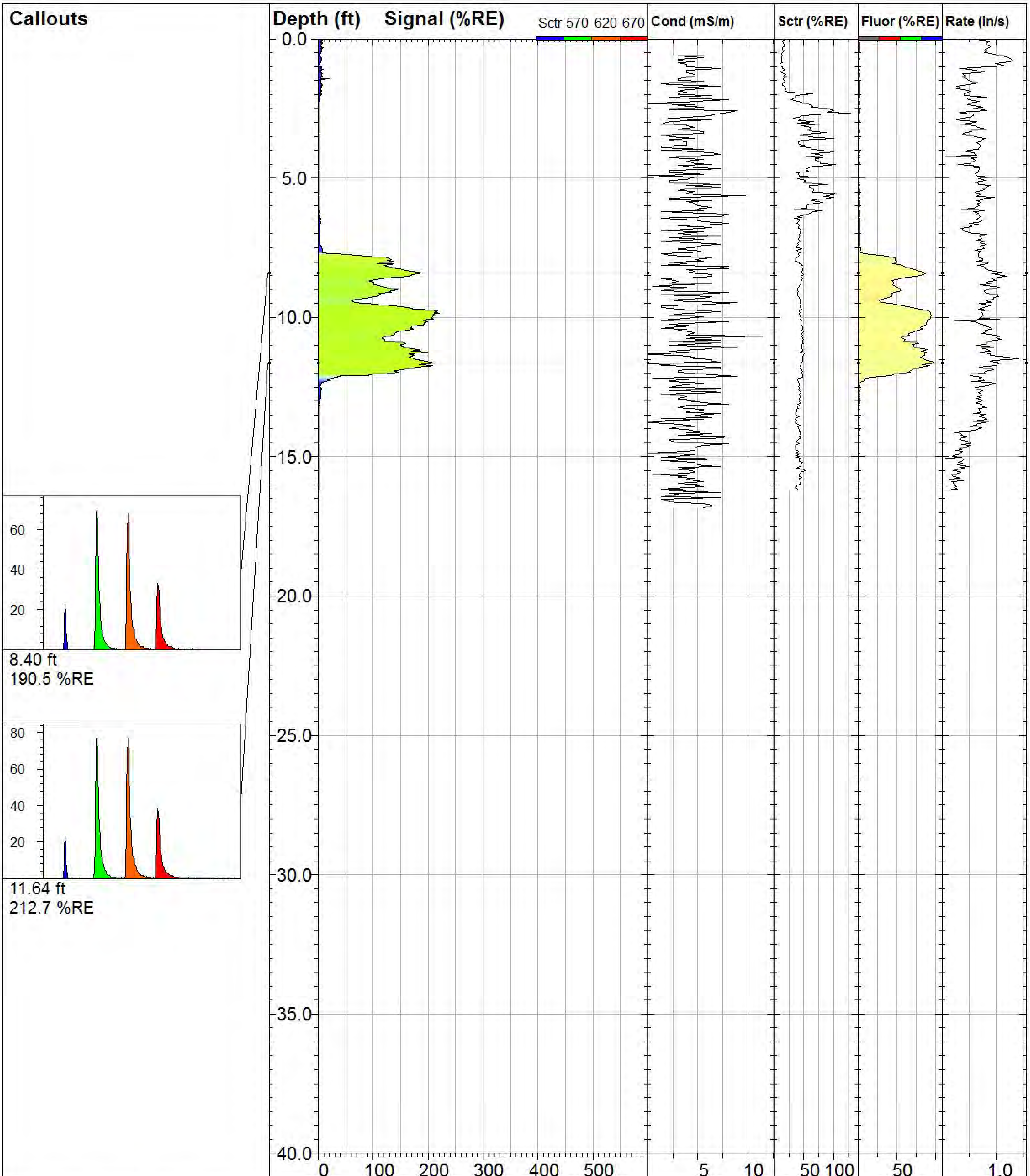
GWP_TG-36		TarGOST By Dakota www.DakotaTechnologies.com
Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **238869.2682 /**	*Final depth:* **18.17 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1270180.147 /**	*Max signal:* **357.5 %RE @ 8.62 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **28.2 ft**	*Date & Time:* **2013-03-25 13:49 PDT**

DAKOTA TECHNOLOGIES
Fargo, ND 701.237.4908
www.DakotaTechnologies.com



GWP_TG-37		**TarGOST By Dakota** www.DakotaTechnologies.com
Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **238964.4415 /**	*Final depth:* **26.05 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1270213.893 /**	*Max signal:* **1624.6 %RE @ 13.36 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **36.5 ft**	*Date & Time:* **2013-03-25 14:53 PDT**

DAKOTA TECHNOLOGIES
Fargo, ND 701.237.4908
www.DakotaTechnologies.com

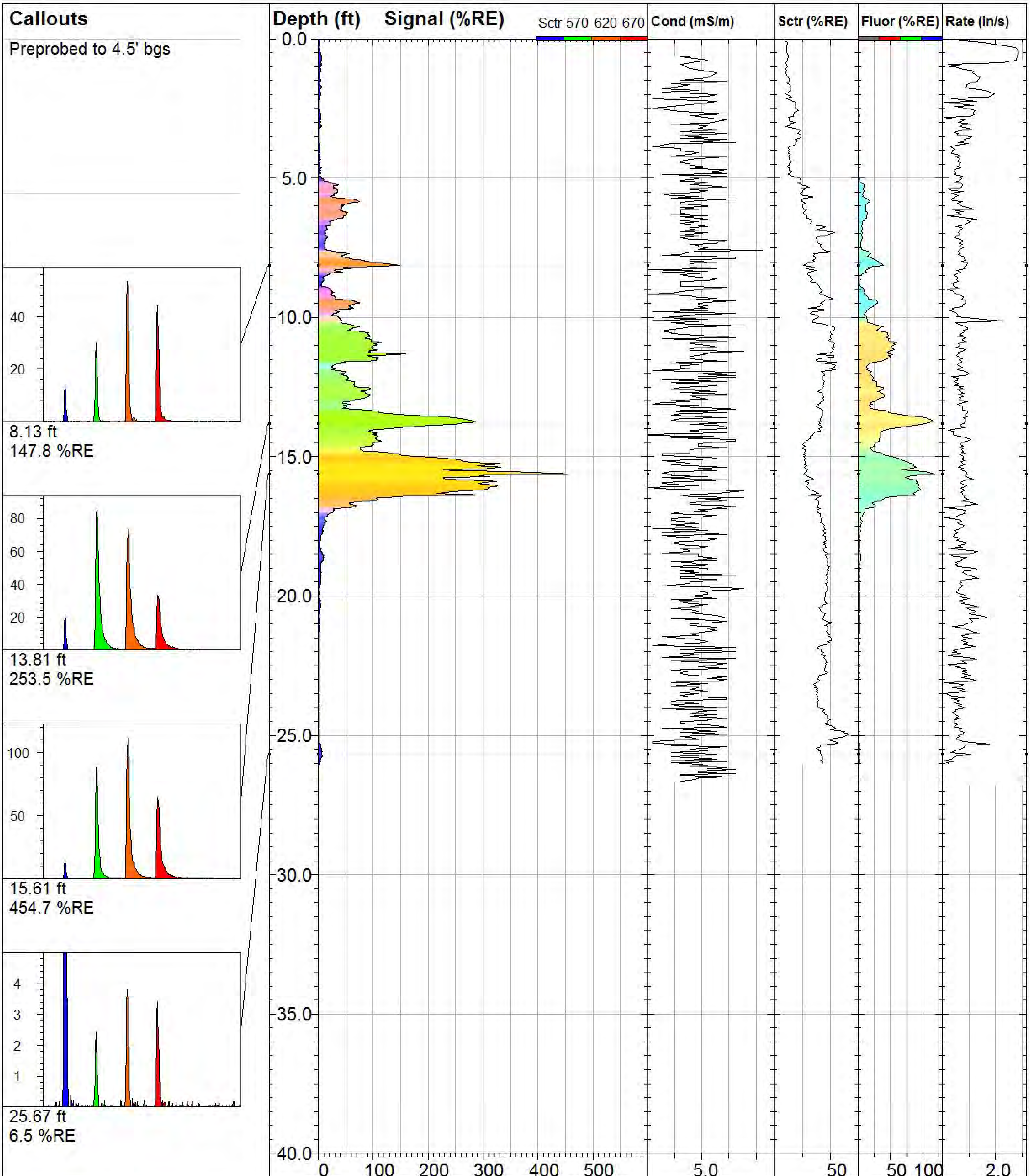


DAKOTA TECHNOLOGIES
FARGO, ND 701.237.4908
WWW.DAKOTATECHNOLOGIES.COM

GWP_TG-38

TarGOST By Dakota
www.DakotaTechnologies.com

Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **238985.015 /**	*Final depth:* **16.19 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1270158.344 /**	*Max signal:* **220.5 %RE @ 9.85 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **30.8 ft**	*Date & Time:* **2013-03-25 16:17 PDT**

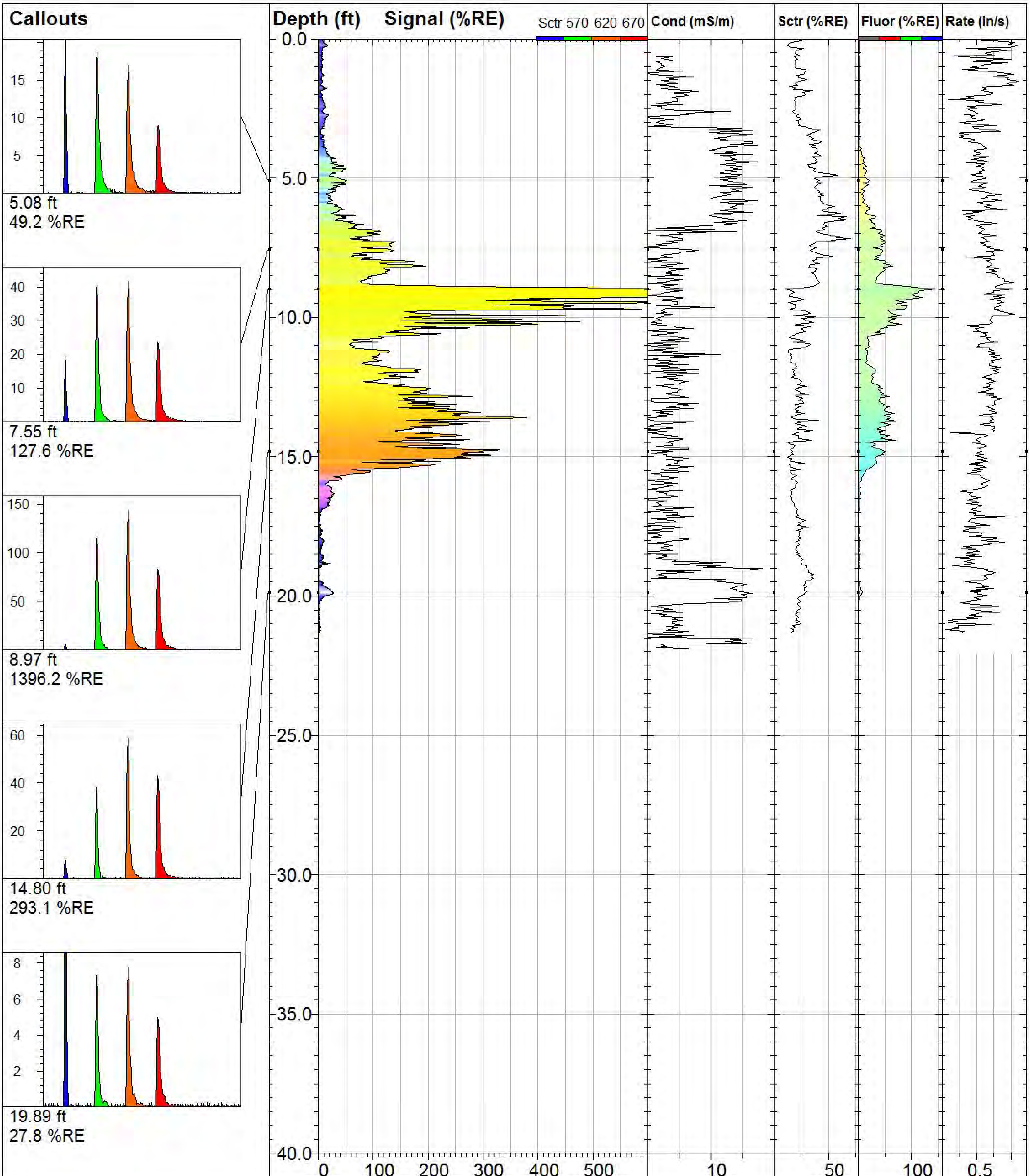


GWP_TG-39

TarGOST By Dakota
www.DakotaTechnologies.com

Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **239048.8756 /**	*Final depth:* **26.03 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1270198.071 /**	*Max signal:* **454.7 %RE @ 15.61 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **35.7 ft**	*Date & Time:* **2013-03-25 17:09 PDT**

DAKOTA TECHNOLOGIES
Fargo, ND 701.237.4908
www.DakotaTechnologies.com



GWP_TG-40

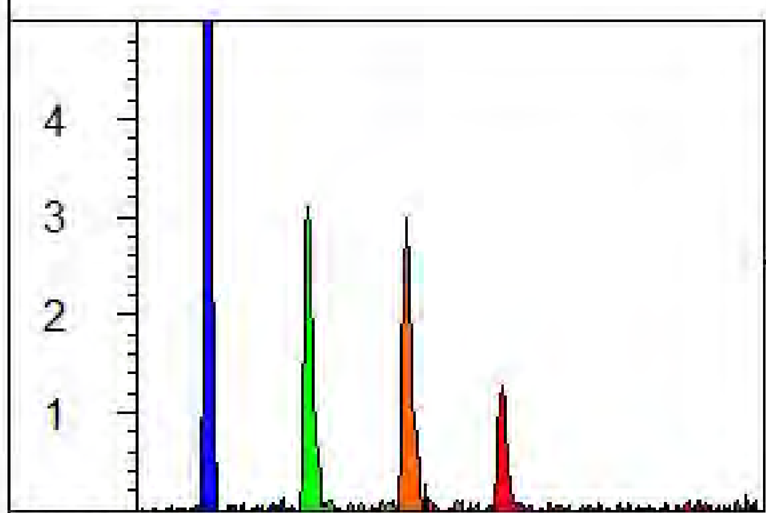
TarGOST By Dakota
www.DakotaTechnologies.com

DAKOTA TECHNOLOGIES
FARGO, ND 701.237.4908
WWW.DAKOTATECHNOLOGIES.COM

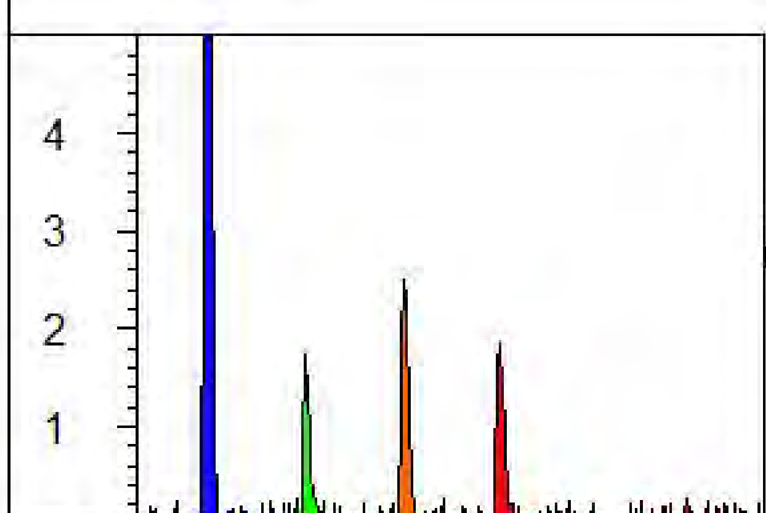
Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **239080.667 /**	*Final depth:* **21.30 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1270144.032 /**	*Max signal:* **1396.2 %RE @ 8.97 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **33.1 ft**	*Date & Time:* **2013-03-26 08:06 PDT**

Callouts

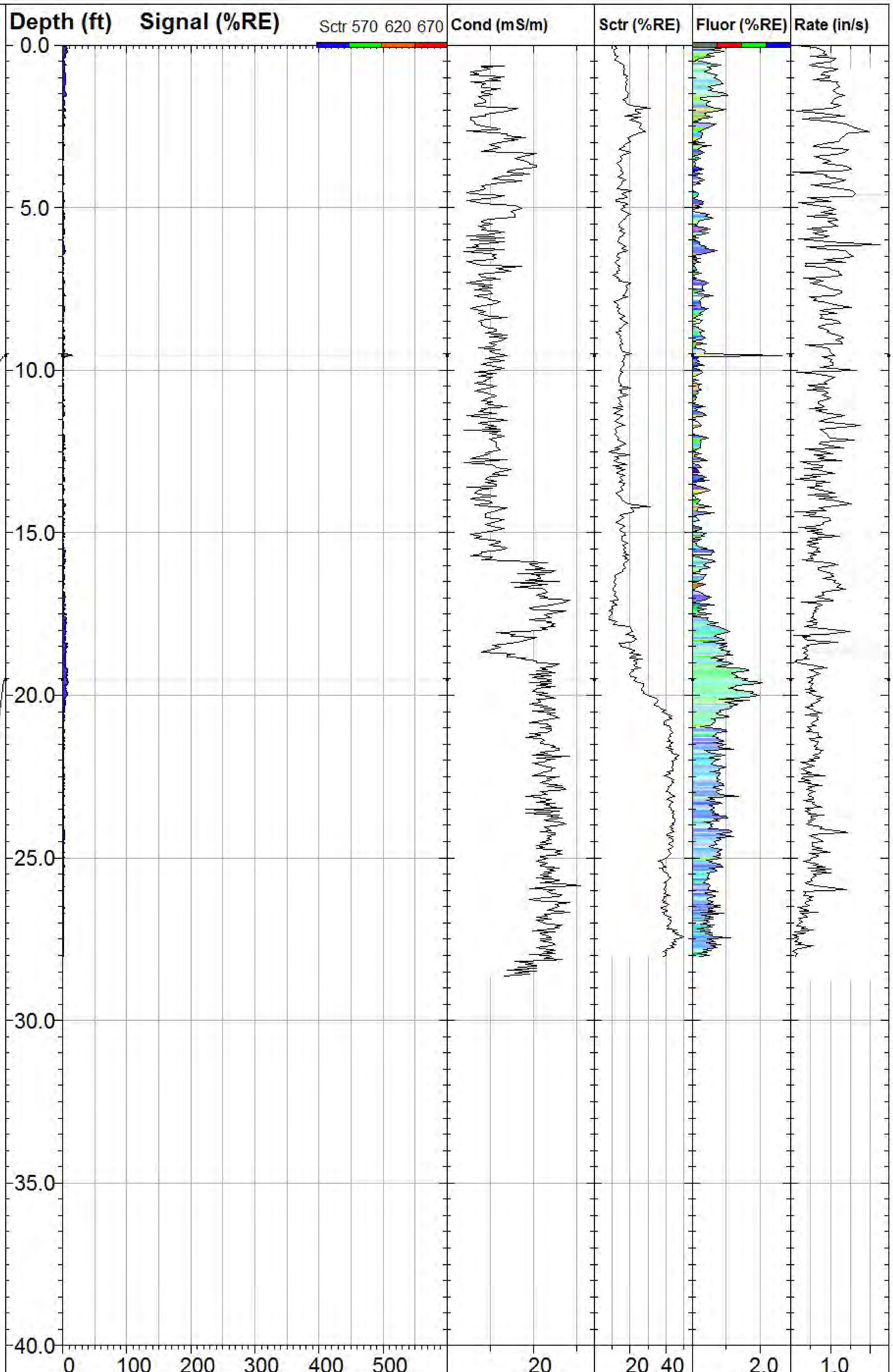
Preprobed to 10' bgs. Signal within this zone may not accurately represent signal depth or intensity



9.55 ft
15.9 %RE



19.52 ft
8.0 %RE

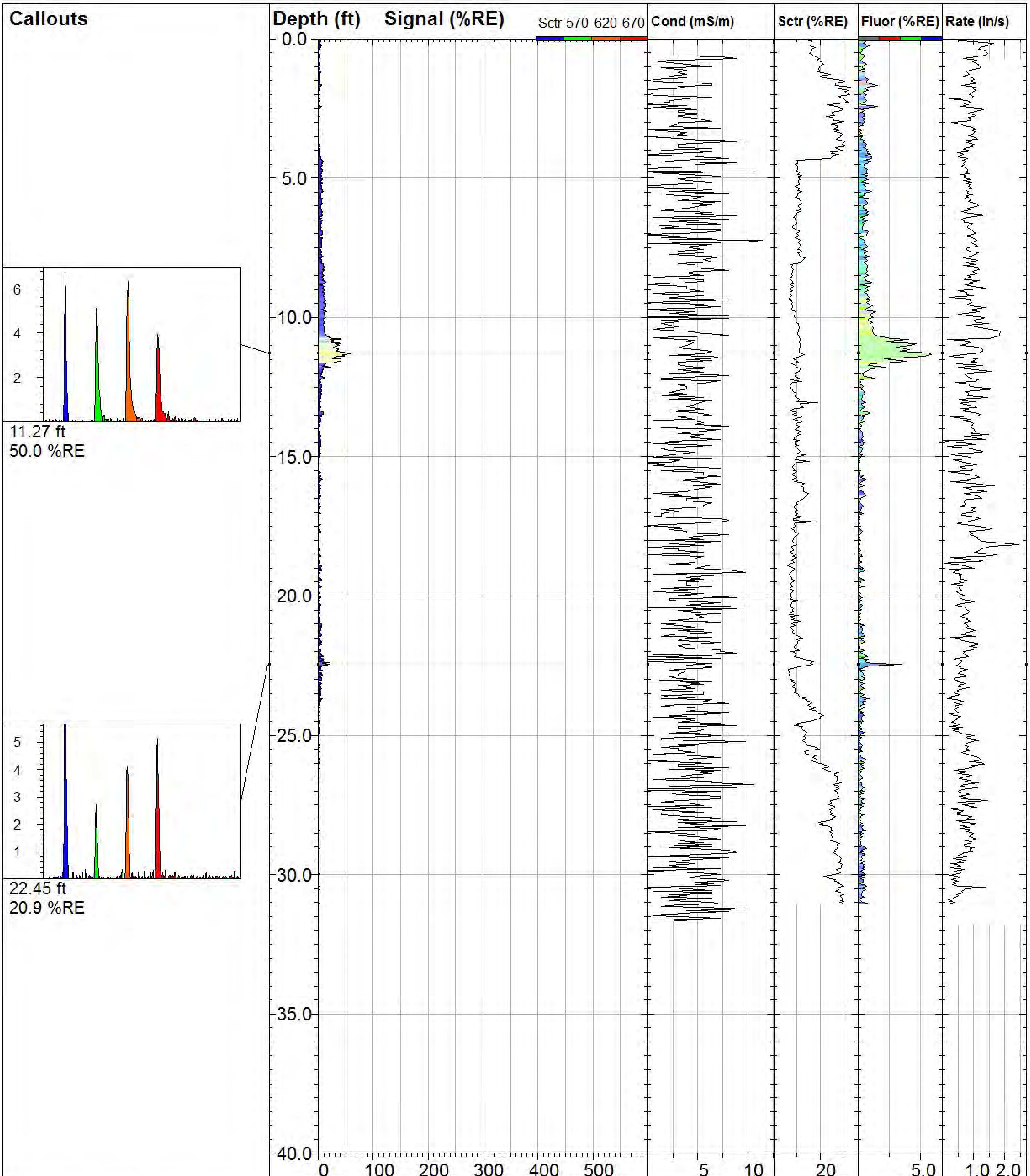


DAKOTA TECHNOLOGIES
FARGO, ND 701.237.4908
WWW.DAKOTATECHNOLOGIES.COM

GWP_TG-41

TarGOST By Dakota
www.DakotaTechnologies.com

Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **238760.1086 /**	*Final depth:* **28.05 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1270315.196 /**	*Max signal:* **15.9 %RE @ 9.55 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **38.8 ft**	*Date & Time:* **2013-03-26 09:00 PDT**

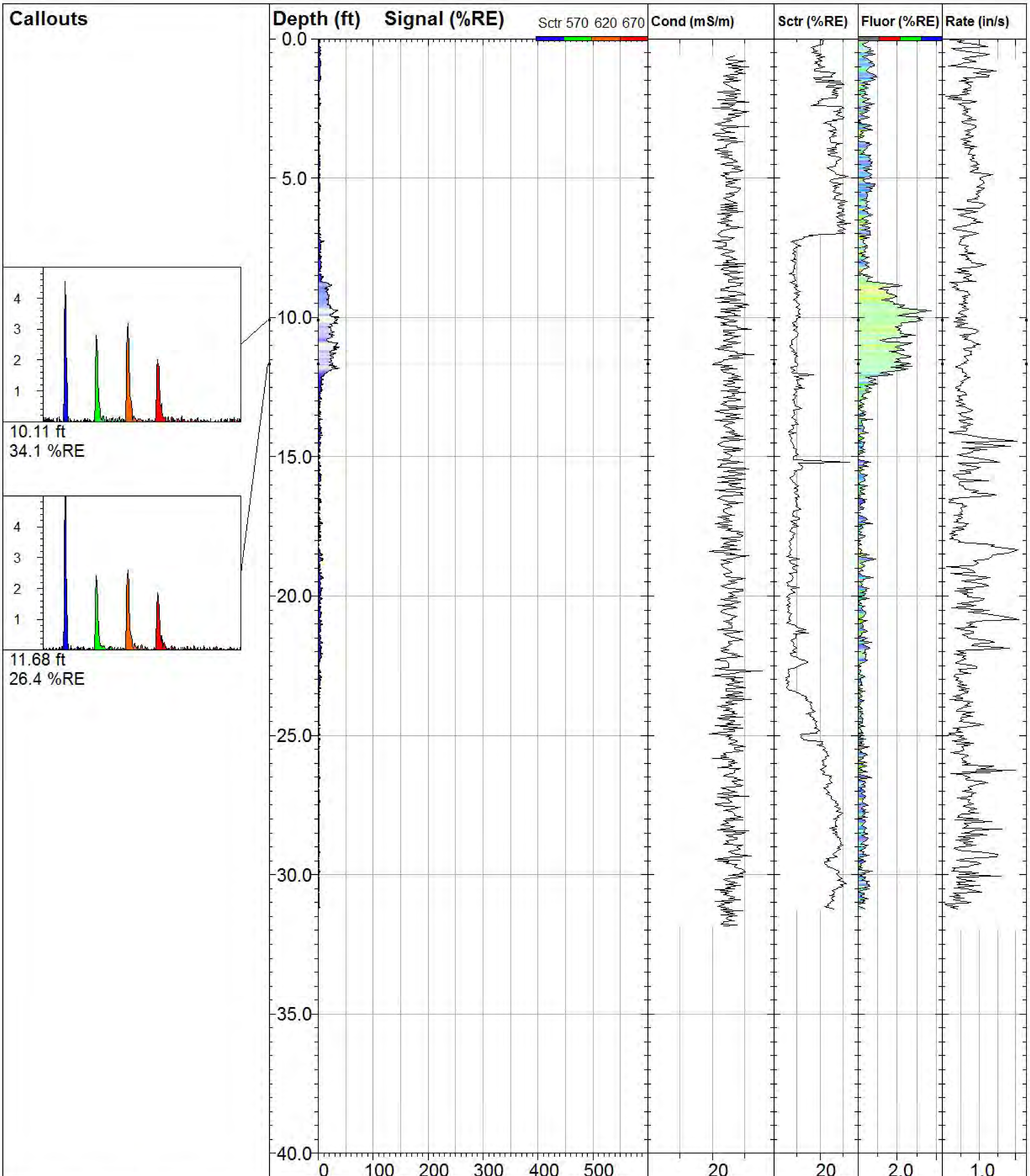


DAKOTA TECHNOLOGIES
Fargo, ND 701.237.4908
www.DakotaTechnologies.com

GWP_TG-42

TarGOST By Dakota
www.DakotaTechnologies.com

Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **239108.2314 /**	*Final depth:* **31.04 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1270790.097 /**	*Max signal:* **59.4 %RE @ 11.29 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **29.5 ft**	*Date & Time:* **2013-03-26 10:19 PDT**

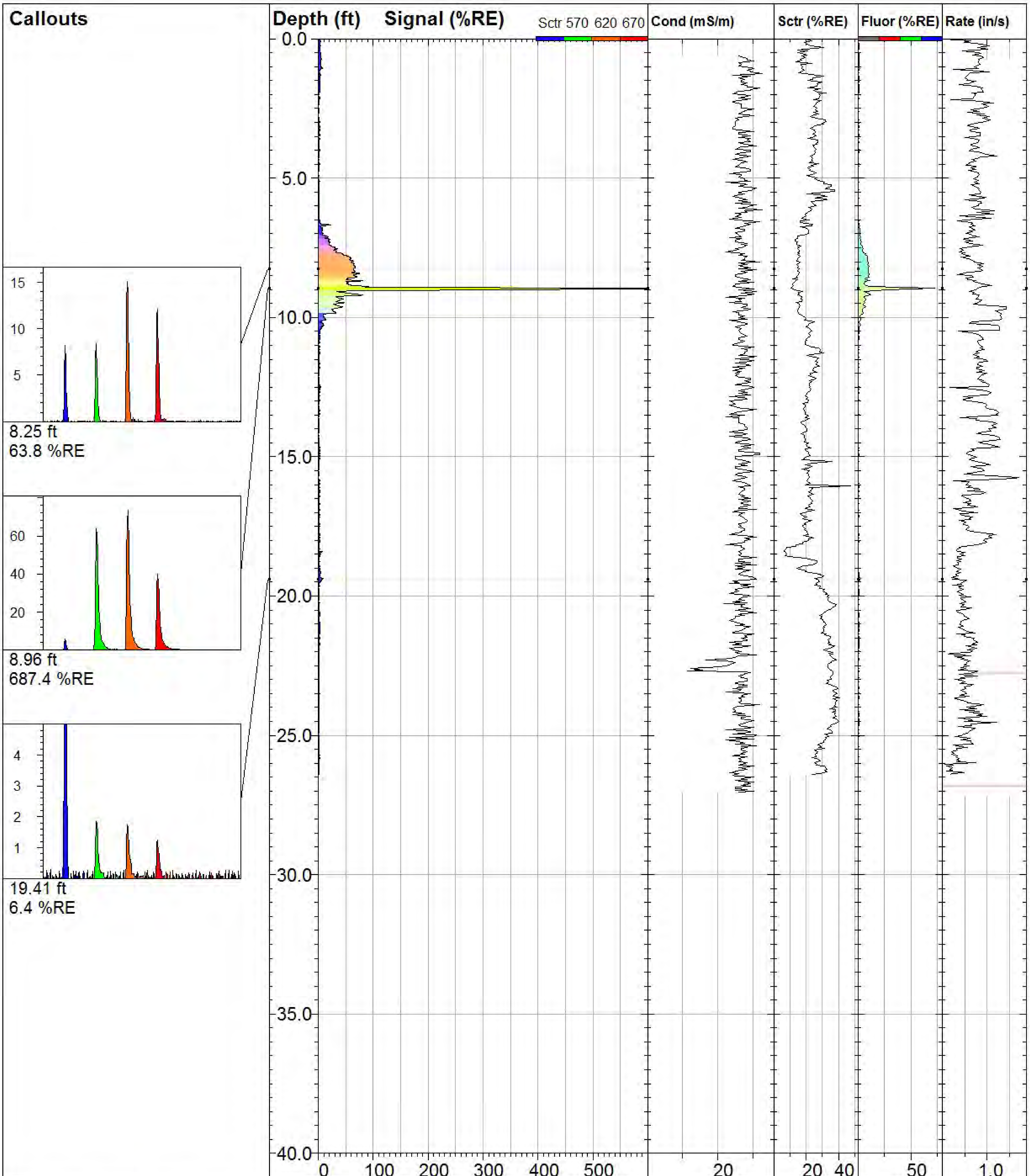


GWP_TG-42r

TarGOST By Dakota
www.DakotaTechnologies.com

DAKOTA TECHNOLOGIES
Fargo, ND 701.237.4908
www.DakotaTechnologies.com

Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **239101.9129 /**	*Final depth:* **31.22 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1270788.311 /**	*Max signal:* **39.4 %RE @ 10.00 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **29.8 ft**	*Date & Time:* **2013-03-26 11:21 PDT**

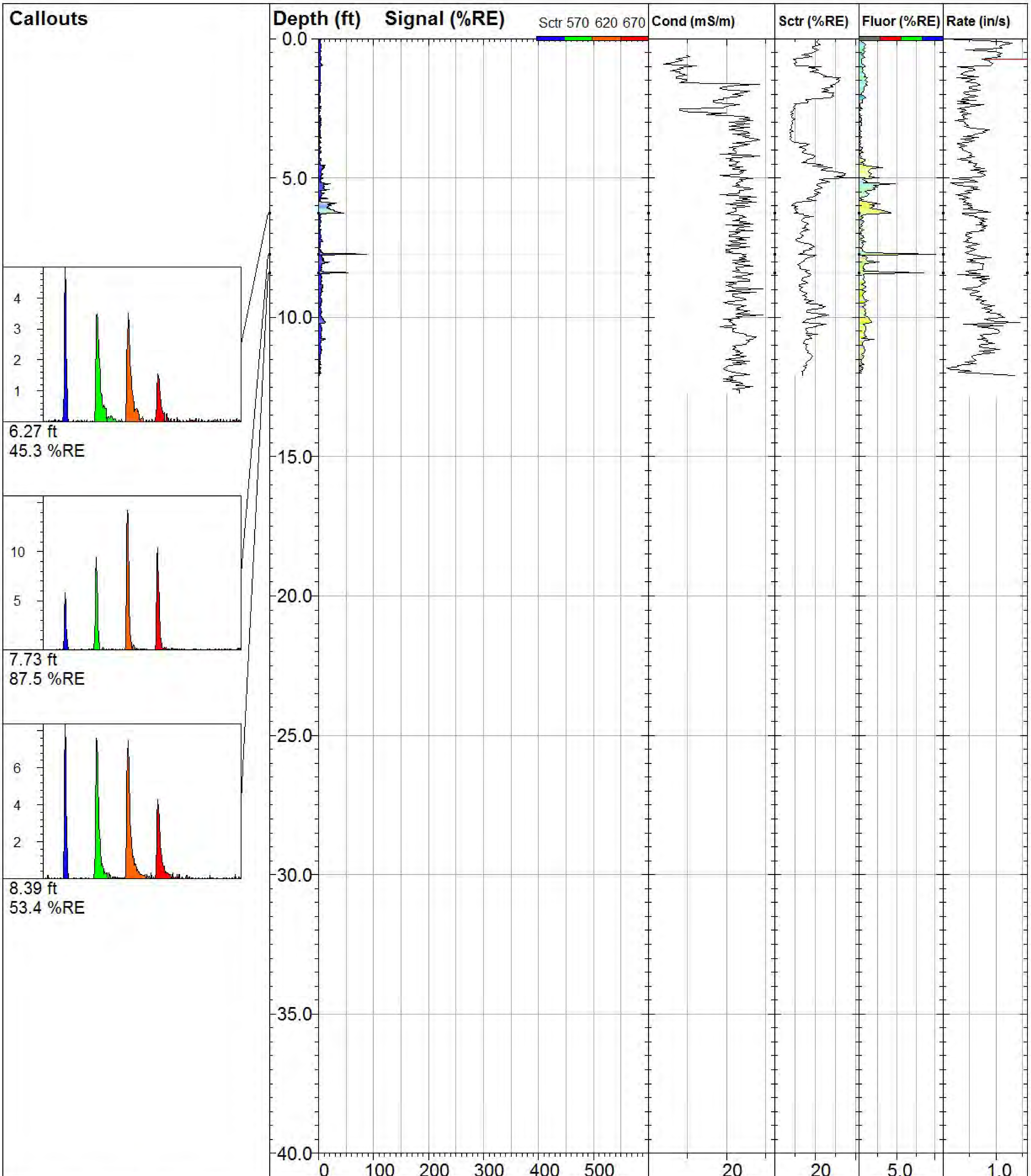


DAKOTA TECHNOLOGIES
FARGO, ND 701.237.4908
WWW.DAKOTATECHNOLOGIES.COM

GWP_TG-43

TarGOST By Dakota
www.DakotaTechnologies.com

Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **239226.8316 /**	*Final depth:* **26.41 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1270802.295 /**	*Max signal:* **687.4 %RE @ 8.96 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **28.5 ft**	*Date & Time:* **2013-03-26 13:12 PDT**

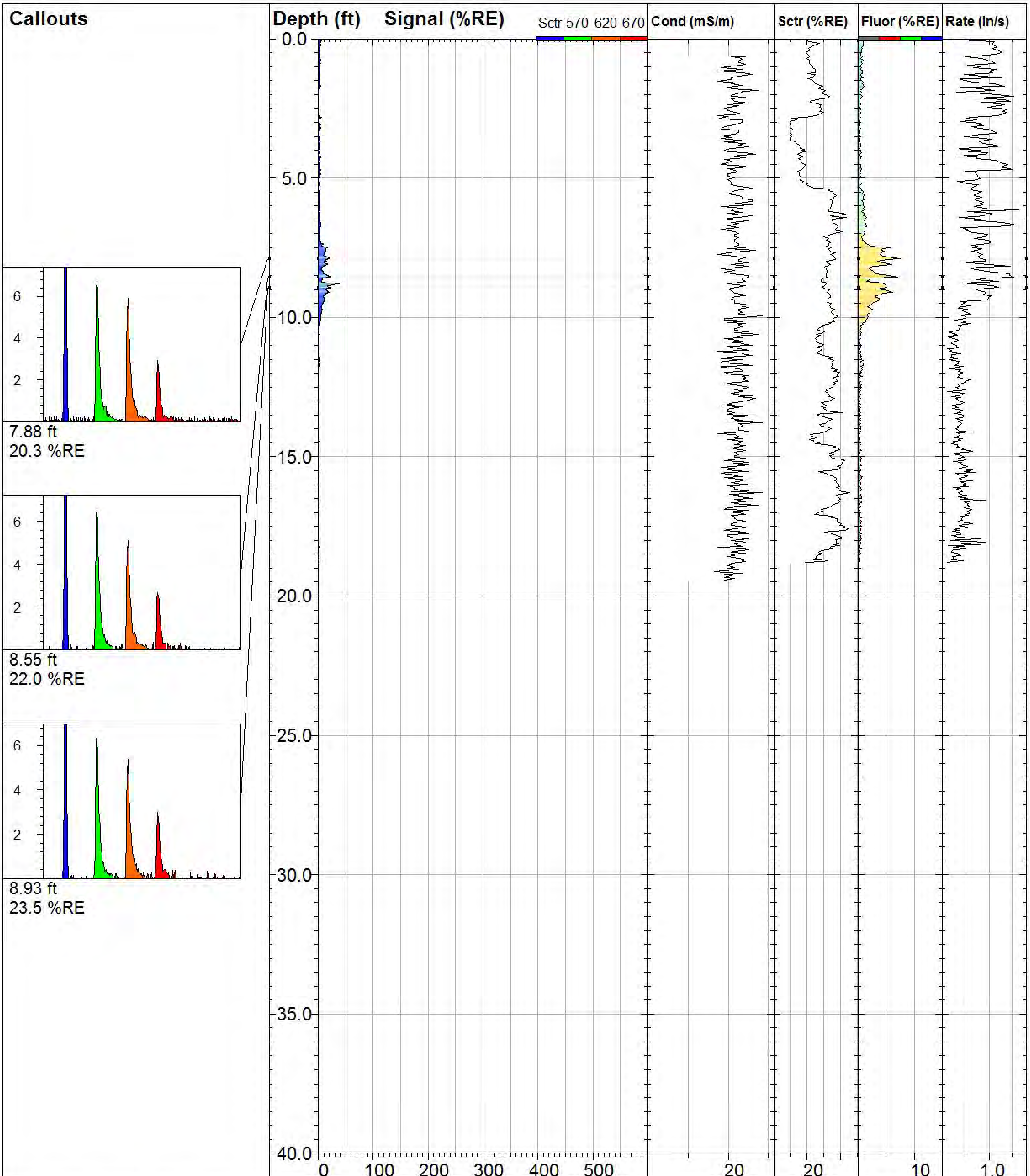


DAKOTA TECHNOLOGIES
FARGO, ND 701.237.4908
WWW.DAKOTATECHNOLOGIES.COM

GWP_TG-44

TarGOST By Dakota
www.DakotaTechnologies.com

Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **239249.0687 /**	*Final depth:* **12.10 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1270521.787 /**	*Max signal:* **87.5 %RE @ 7.73 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **34.3 ft**	*Date & Time:* **2013-03-26 14:16 PDT**

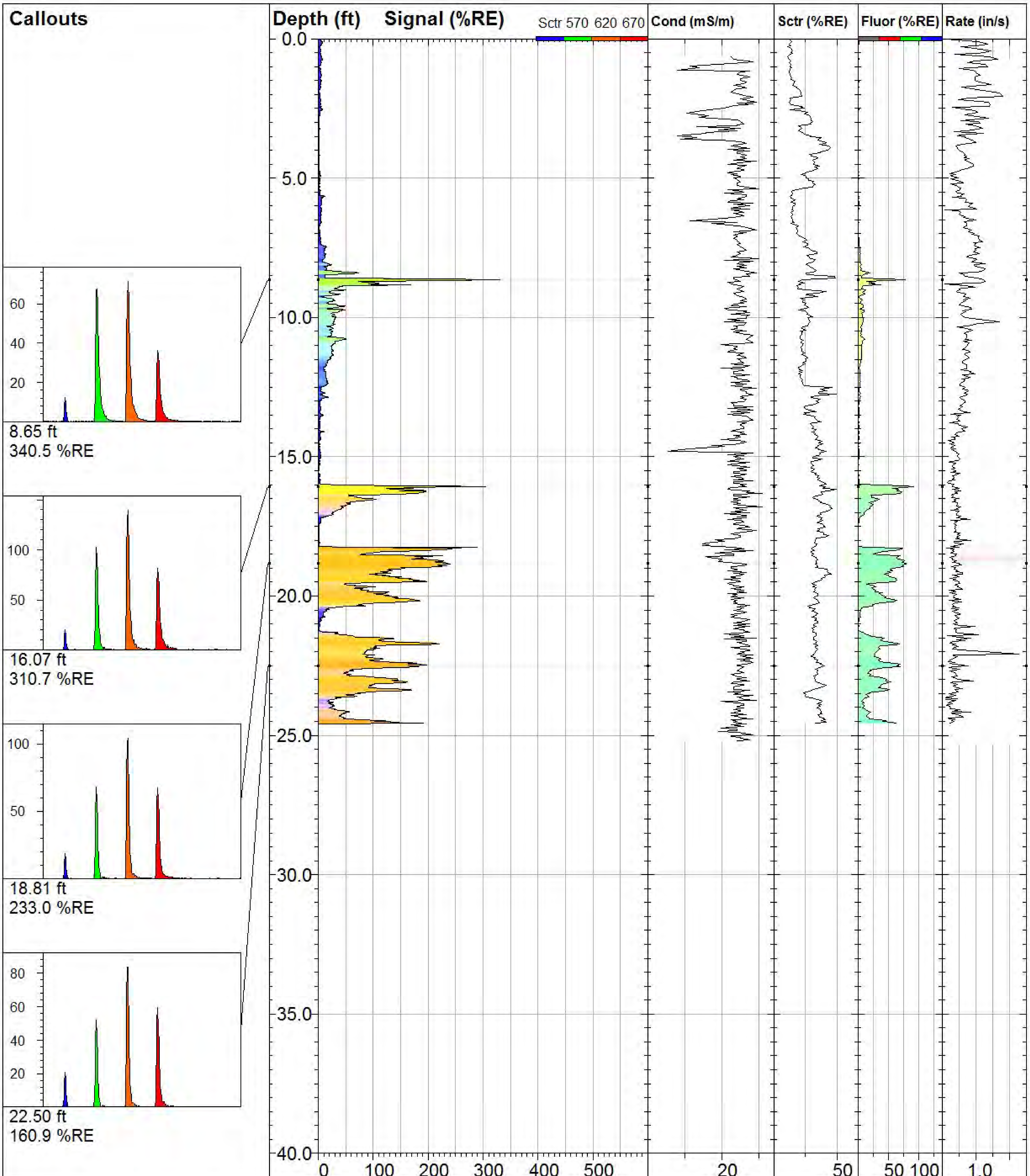


GWP_TG-45

TarGOST By Dakota
www.DakotaTechnologies.com

Fargo, ND 701.237.4908
www.DakotaTechnologies.com

Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **239230.2581 /**	*Final depth:* **18.82 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1270514.446 /**	*Max signal:* **41.4 %RE @ 8.78 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **35.5 ft**	*Date & Time:* **2013-03-26 14:56 PDT**



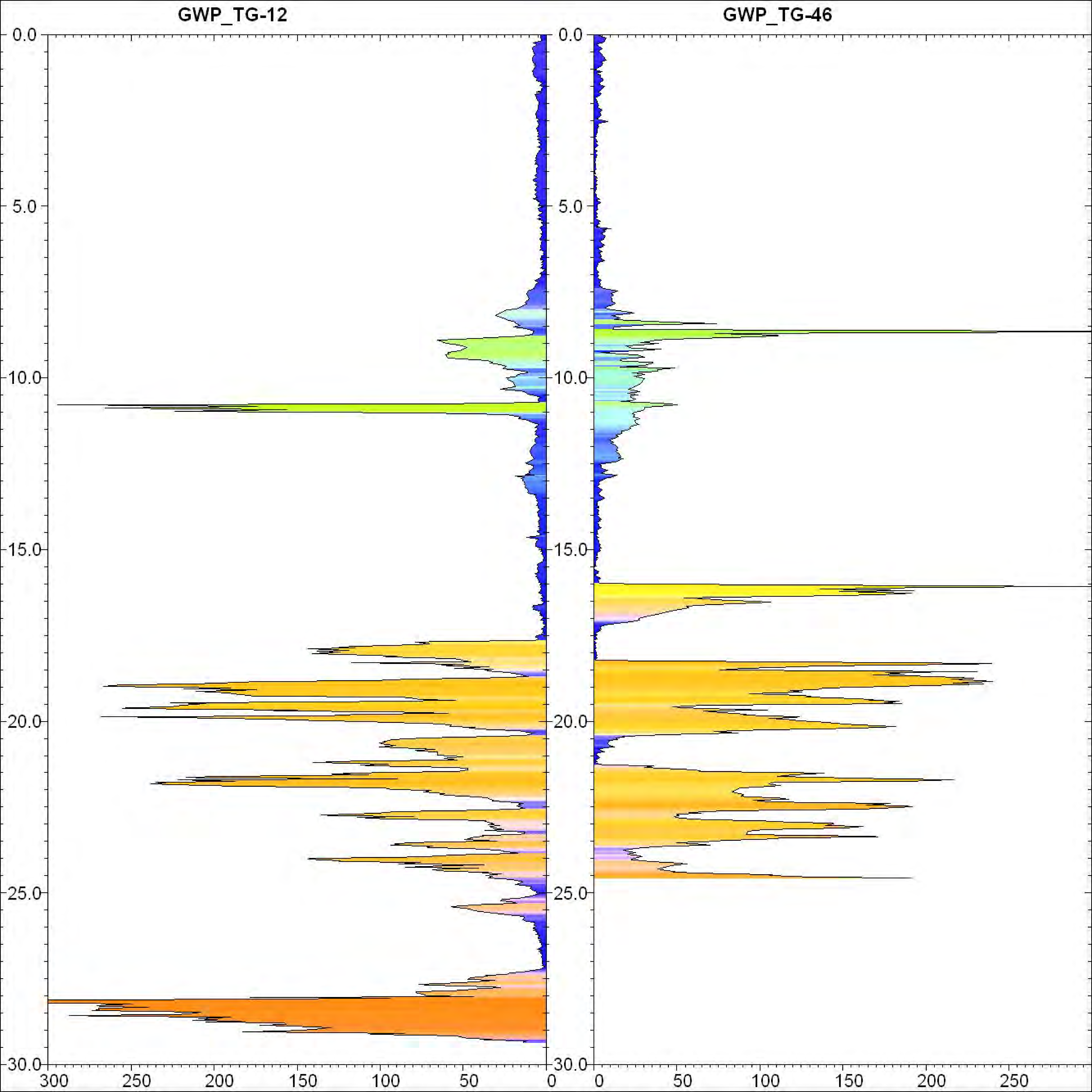
DAKOTA TECHNOLOGIES
FARGO, ND 701.237.4908
WWW.DAKOTATECHNOLOGIES.COM

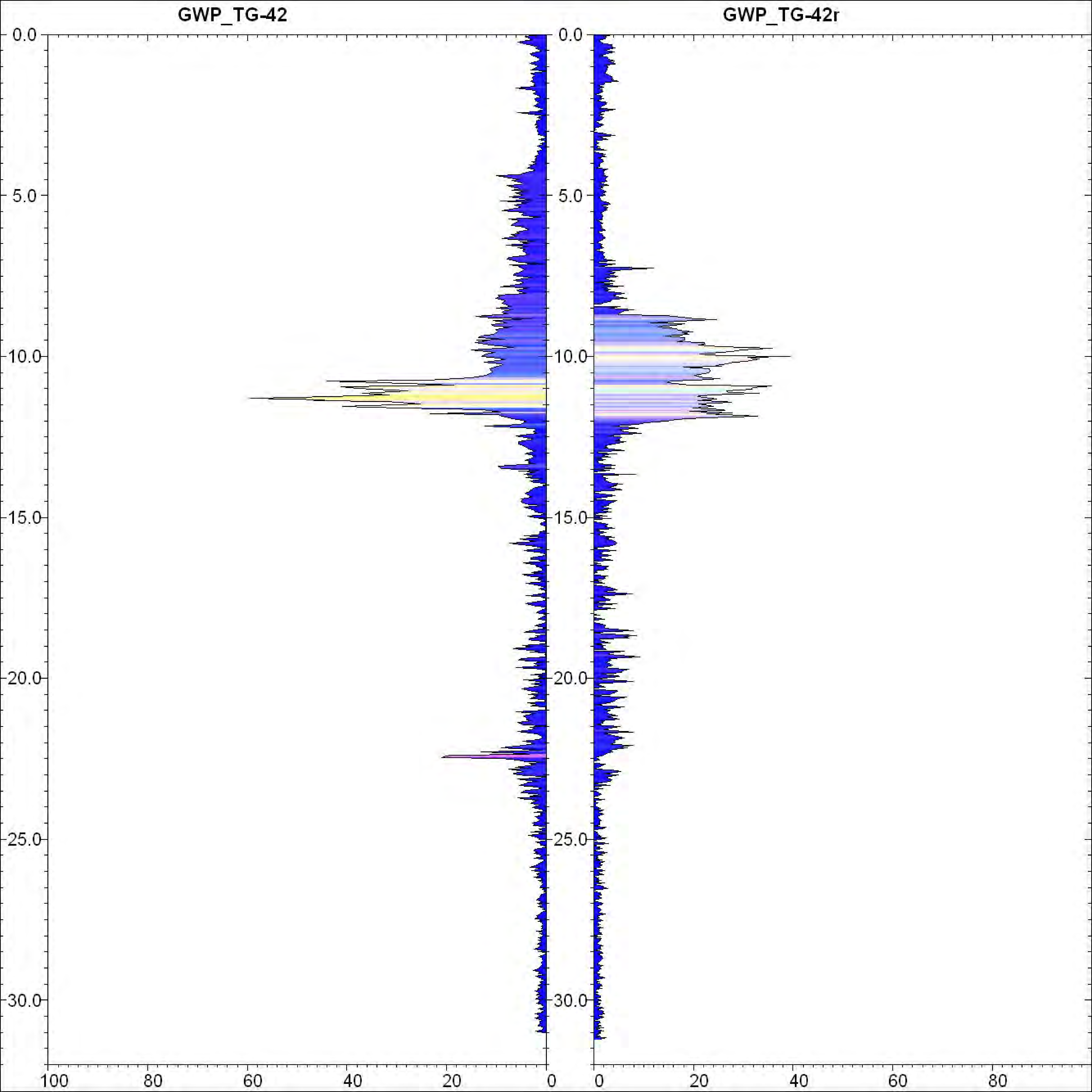
GWP_TG-46

TarGOST By Dakota
www.DakotaTechnologies.com

Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **239145.0135 /**	*Final depth:* **24.58 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **1270452.875 /**	*Max signal:* **340.5 %RE @ 8.65 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **38.7 ft**	*Date & Time:* **2013-03-26 15:44 PDT**

SUB-ATTACHMENT 2A-2.2.2
TarGOST® Butterfly Log Plots


GWP_TG-12
GWP_TG-46
0.0
5.0
10.0
15.0
20.0
25.0
30.0
300
250
200
150
100
50
0
0
50
100
150
200
250


GWP_TG-42
GWP_TG-42r
0.0
5.0
10.0
15.0
20.0
25.0
30.0
100
80
60
40
20
0
0
20
40
60
80

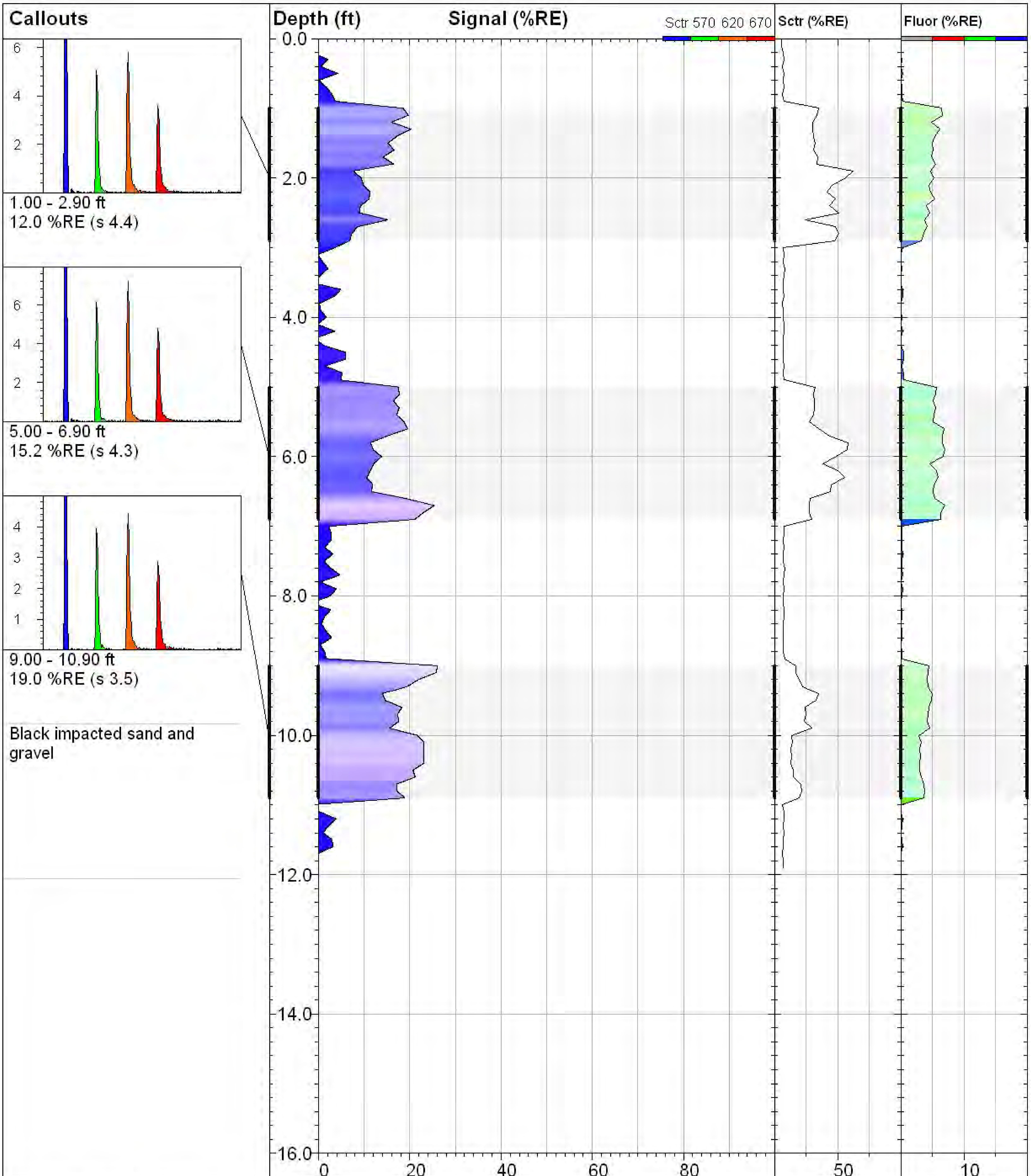
SUB-ATTACHMENT 2A-2.2.3
TarGOST® Electrical Conductivity Data

File	Date/Time	Final Depth	Max Signal	Max Signal D	RE Area	EC Good	EC Bad	EC NC*
GWP_TG-01	3/18/2013 14:33	7.2	14.4	1.5	1920.29			X
GWP_TG-02	3/18/2013 15:56	11.8	336.3	8.1	1923.46			X
GWP_TG-03	3/19/2013 8:14	14.9	8.1	1.3	1886.83	X		
GWP_TG-04	3/19/2013 9:19	9.6	43.6	4.2	1901.04	X		
GWP_TG-05	3/19/2013 10:10	24.3	196.5	24.3	1944.2	X		
GWP_TG-06	3/19/2013 11:10	16.0	59.6	9.0	1982.31	X		
GWP_TG-07	3/19/2013 13:12	21.6	9.9	12.2	1956.09	X		
GWP_TG-08	3/19/2013 14:35	22.2	33.4	12.5	1829.71	X		
GWP_TG-09	3/19/2013 15:26	19.9	18.3	13.5	1881.34	X		
GWP_TG-10	3/19/2013 16:38	13.0	14.5	0.4	1801.6	X		
GWP_TG-11	3/20/2013 8:31	24.6	198.0	15.6	1834.92	X		
GWP_TG-12	3/20/2013 10:07	29.4	466.6	28.2	1734.39	X		
GWP_TG-13	3/20/2013 11:31	17.8	7.8	6.7	1807.76	X		
GWP_TG-14	3/20/2013 13:14	22.2	152.4	14.2	1776.78		X	
GWP_TG-15	3/20/2013 14:16	28.8	669.2	28.5	1938.38		X	
GWP_TG-16	3/20/2013 15:43	25.9	33.9	15.6	1774.79		X	
GWP_TG-17	3/21/2013 8:13	28.6	82.8	17.0	1887.68	X		
GWP_TG-18	3/21/2013 9:32	9.0	27.0	8.9	1811.81	X		
GWP_TG-18B	3/21/2013 10:06	15.6	340.1	15.6	1749.96	X		
GWP_TG-19	3/21/2013 17:09	24.9	3.5	4.1	2077.19			X
GWP_TG-20	3/21/2013 12:18	26.0	75.8	14.9	2056.59			X
GWP_TG-21	3/21/2013 13:16	25.9	323.3	19.3	1971.11			X
GWP_TG-22	3/21/2013 14:21	24.0	8.6	8.9	2030.76			X
GWP_TG-23	3/21/2013 15:00	24.5	9.2	0.7	1996.97			X
GWP_TG-24	3/21/2013 15:47	28.0	229.4	21.6	2086.22			X
GWP_TG-25	3/22/2013 8:29	17.2	8.0	9.2	1839.87			X
GWP_TG-26	3/22/2013 9:19	20.9	28.7	7.8	1820.67			X
GWP_TG-27	3/22/2013 10:22	17.0	7.0	5.6	1794.48			X
GWP_TG-28	3/22/2013 11:29	26.4	5.9	9.2	1879.7			X
GWP_TG-29	3/22/2013 13:30	28.6	4.8	14.2	1889.64			X
GWP_TG-30	3/22/2013 15:00	5.0	4.3	0.2	1818.87			X
GWP_TG-31	3/22/2013 15:48	38.0	34.3	6.7	1801.83			X
GWP_TG-32	3/22/2013 17:11	6.9	4.0	2.4	1886.48			X
GWP_TG-32B	3/22/2013 17:35	33.4	15.3	22.3	1803.47			X
GWP_TG-33	3/25/2013 9:39	22.1	57.4	3.0	1858	X		
GWP_TG-34	3/25/2013 10:45	25.1	60.8	0.9	1857.76	X		
GWP_TG-35	3/25/2013 11:36	25.2	37.7	7.1	1813.13	X		
GWP_TG-36	3/25/2013 13:49	18.2	357.5	8.6	1954.42	X		
GWP_TG-37	3/25/2013 14:53	26.0	1624.4	13.4	1830.24	X		
GWP_TG-38	3/25/2013 16:17	16.2	220.5	9.8	1658.19		X	
GWP_TG-39	3/25/2013 17:09	26.0	454.6	15.6	1732.76		X	
GWP_TG-40	3/26/2013 8:06	21.3	1396.6	9.0	1808.95			X
GWP_TG-41	3/26/2013 9:00	28.0	15.9	9.5	1846.64			X
GWP_TG-42	3/26/2013 10:19	31.0	59.3	11.3	1878.98			X
GWP_TG-42r	3/26/2013 11:21	31.2	39.4	10.0	1880.06			X
GWP_TG-43	3/26/2013 13:12	26.4	687.3	9.0	1754.97			X
GWP_TG-44	3/26/2013 14:16	12.1	87.5	7.7	1794.74			X
GWP_TG-45	3/26/2013 14:56	18.8	41.4	8.8	1876.99			X
GWP_TG-46	3/26/2013 15:44	24.6	340.6	8.6	1741.52			X

[STATS]
File Count=49
Total Depth=1061.8
Max Depth=38.0
Max Signal=1624.4

* Not Recorded

SUB-ATTACHMENT 2A-2.3
TarGOST® Confirmation Sample Logs

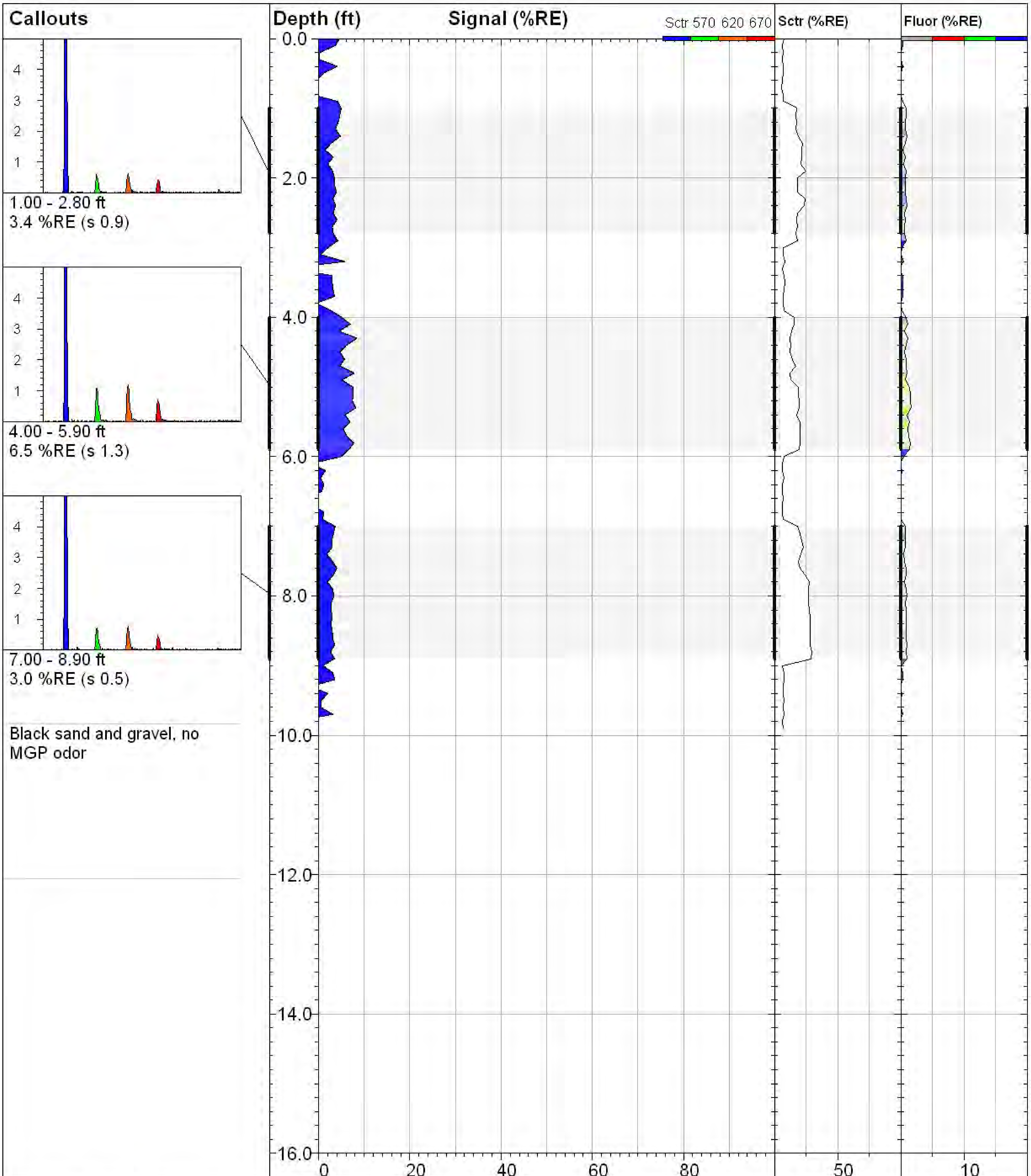


DAKOTA TECHNOLOGIES
FARGO, ND 701.237.4908
WWW.DAKOTATECHNOLOGIES.COM

GEI_6_10_12

TarGOST By Dakota
www.DakotaTechnologies.com

Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **11.90 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **26.1 %RE @ 9.00 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **Unavailable**	*Date & Time:* **2013-04-29 10:13 PDT**

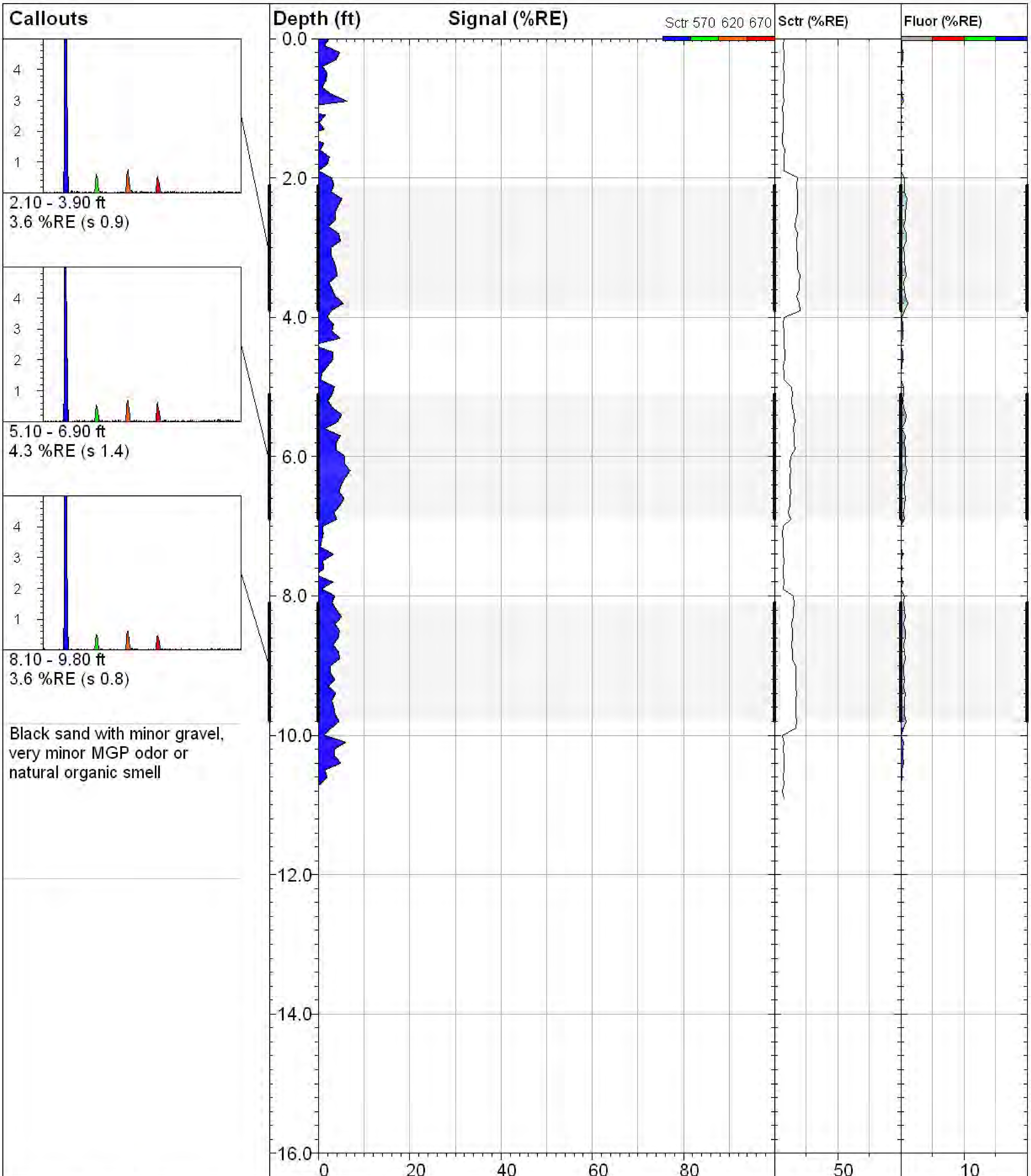


DAKOTA TECHNOLOGIES
FARGO, ND 701.237.4908
WWW.DAKOTATECHNOLOGIES.COM

GEI_7_12_14

TarGOST By Dakota
www.DakotaTechnologies.com

Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **9.90 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **8.4 %RE @ 4.30 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **Unavailable**	*Date & Time:* **2013-04-29 10:21 PDT**



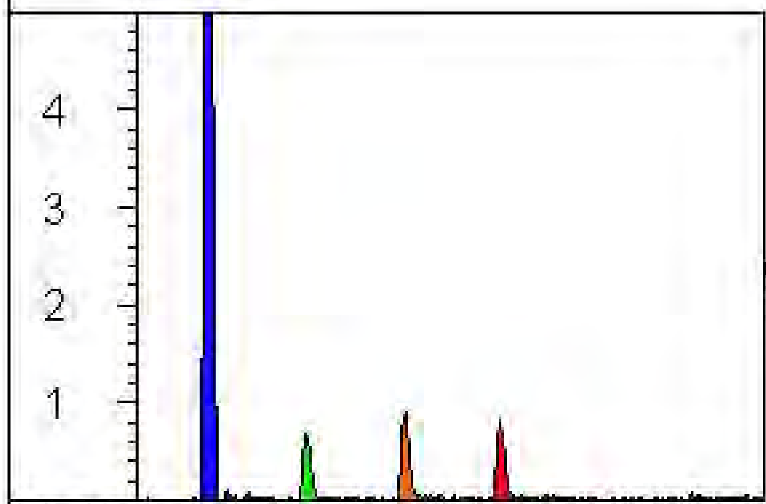
GEI_8_5_6

TarGOST By Dakota
www.DakotaTechnologies.com

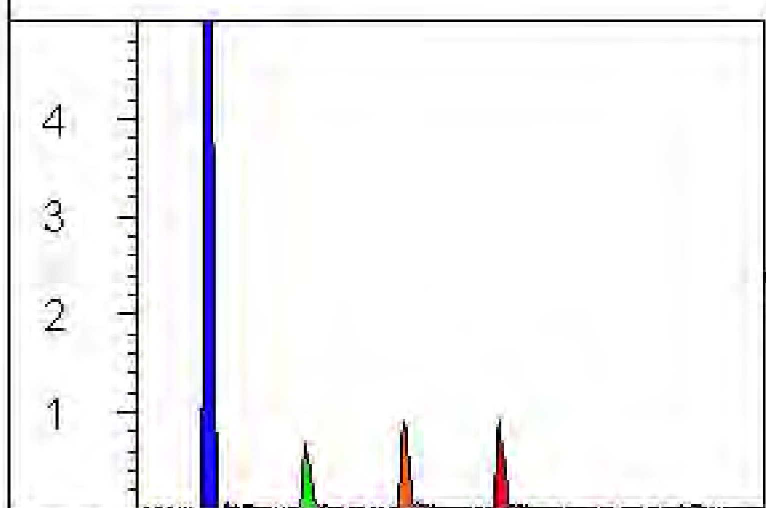
DAKOTA TECHNOLOGIES
Fargo, ND 701.237.4908
www.DakotaTechnologies.com

Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **10.90 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **6.9 %RE @ 6.20 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **Unavailable**	*Date & Time:* **2013-04-29 10:29 PDT**

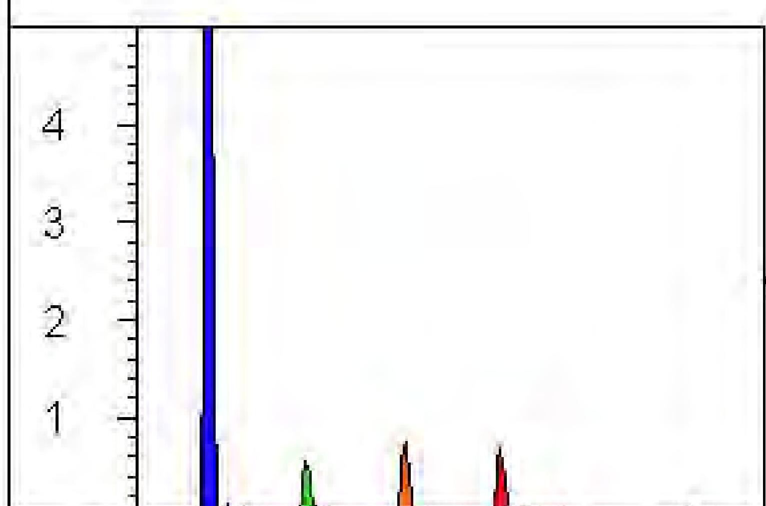
Callouts



2.00 - 3.90 ft
2.4 %RE (s 1.0)

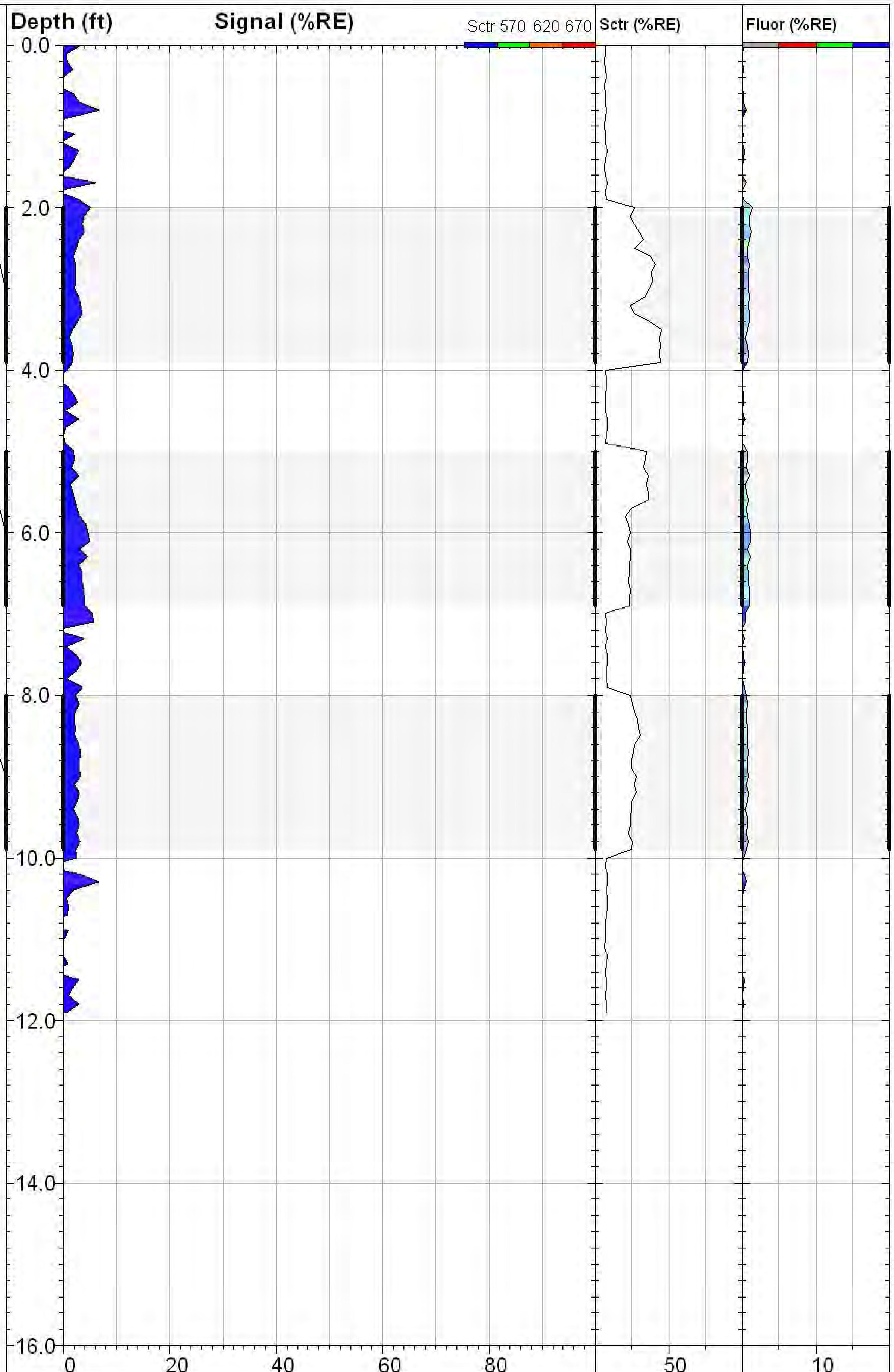


5.00 - 6.90 ft
2.9 %RE (s 1.1)



8.00 - 9.90 ft
2.5 %RE (s 0.4)

Black sand with minor gravel, very minor MGP odor

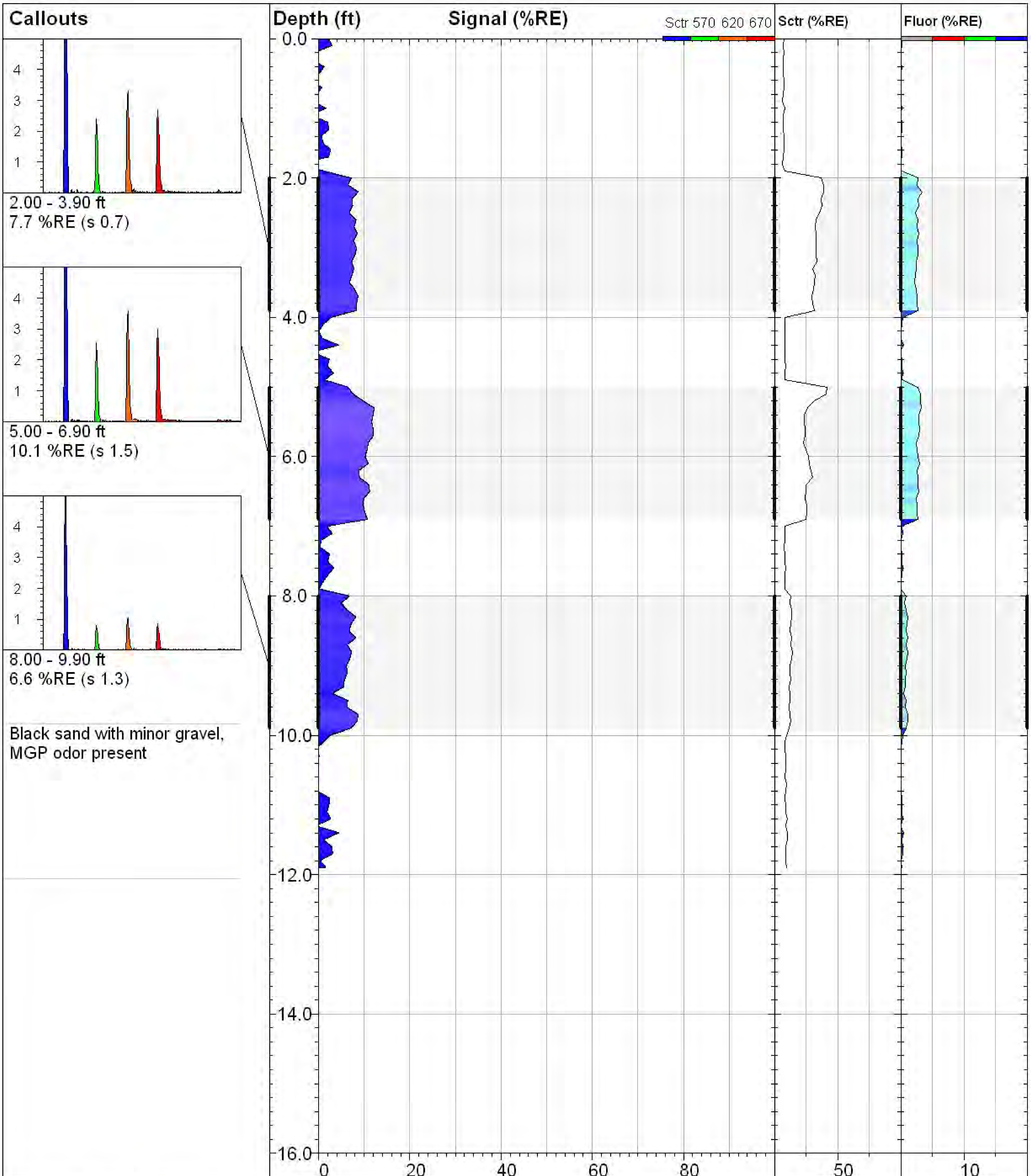


DAKOTA TECHNOLOGIES
Fargo, ND 701.237.4908
www.DakotaTechnologies.com

GEI_11_21_22

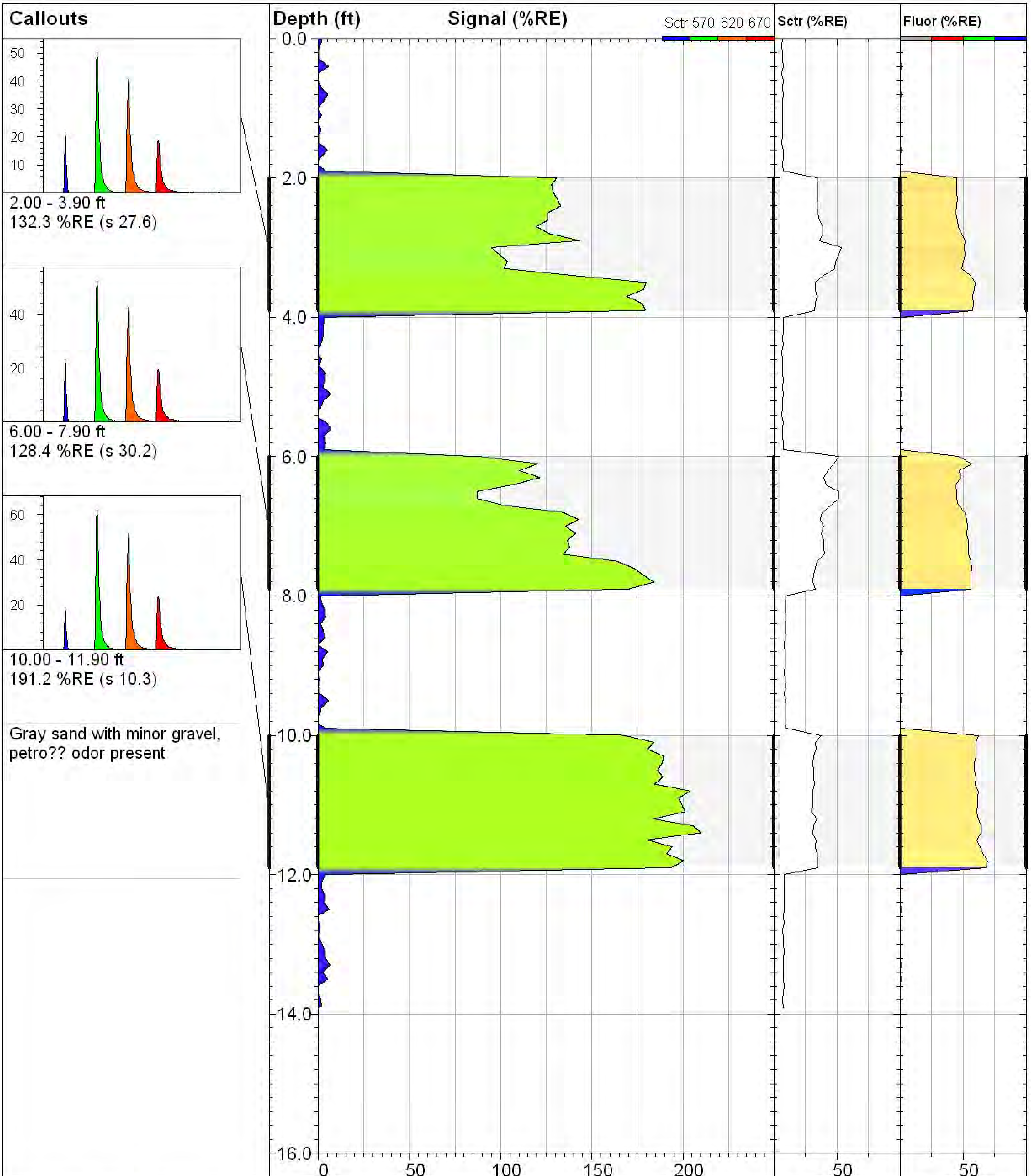
TarGOST By Dakota
www.DakotaTechnologies.com

Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **11.90 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **6.8 %RE @ 0.80 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **Unavailable**	*Date & Time:* **2013-04-29 10:36 PDT**



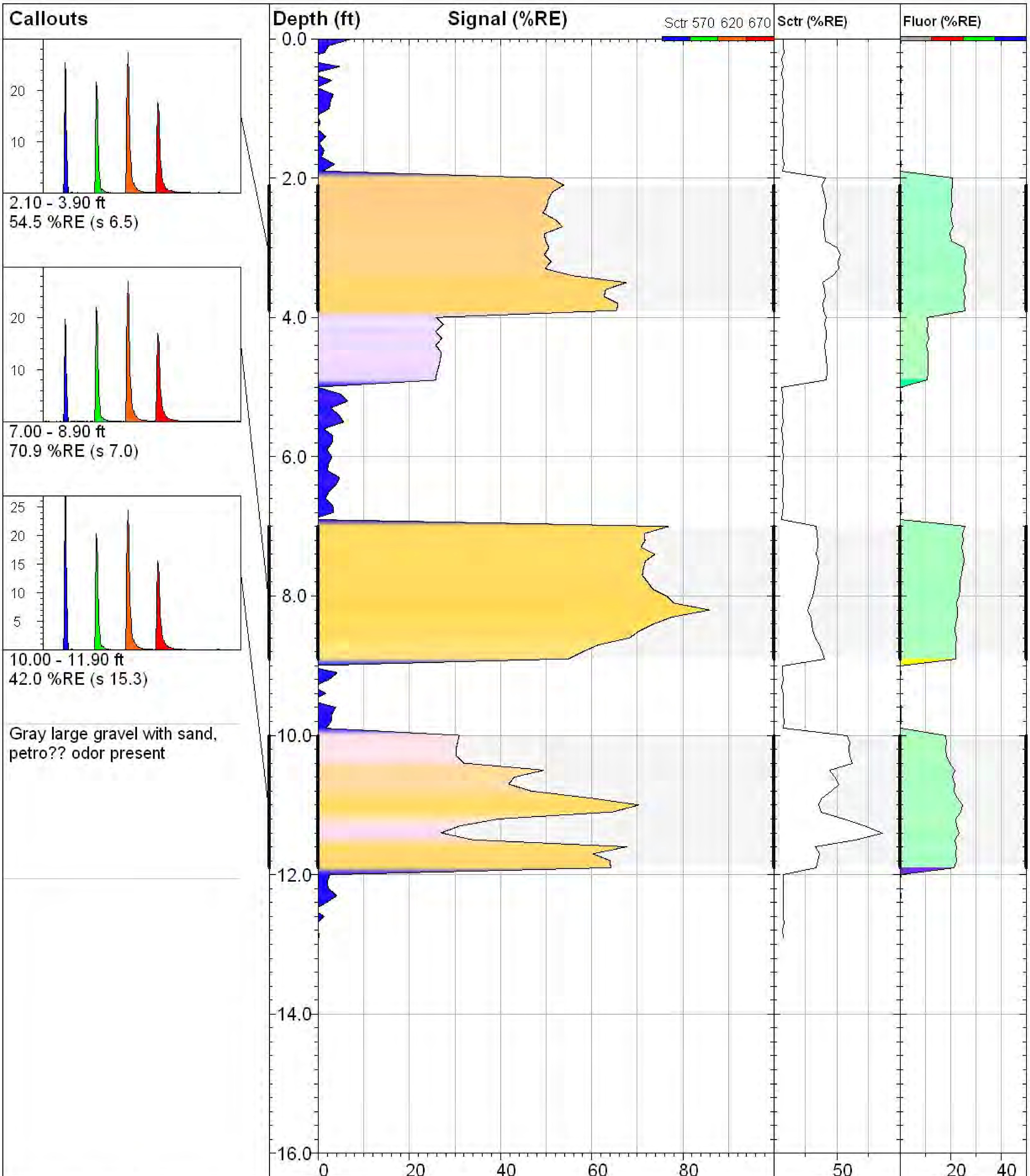
GEI_12_5_7		TarGOST By Dakota www.DakotaTechnologies.com
Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **11.90 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **12.2 %RE @ 5.30 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **Unavailable**	*Date & Time:* **2013-04-29 10:44 PDT**

DAKOTA TECHNOLOGIES
FARGO, ND 701.237.4908
WWW.DAKOTATECHNOLOGIES.COM



GEI_12_11_15		TarGOST By Dakota www.DakotaTechnologies.com
Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **13.90 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **210.1 %RE @ 11.40 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **Unavailable**	*Date & Time:* **2013-04-29 10:54 PDT**

DAKOTA TECHNOLOGIES
FARGO, ND 701.237.4908
WWW.DAKOTATECHNOLOGIES.COM

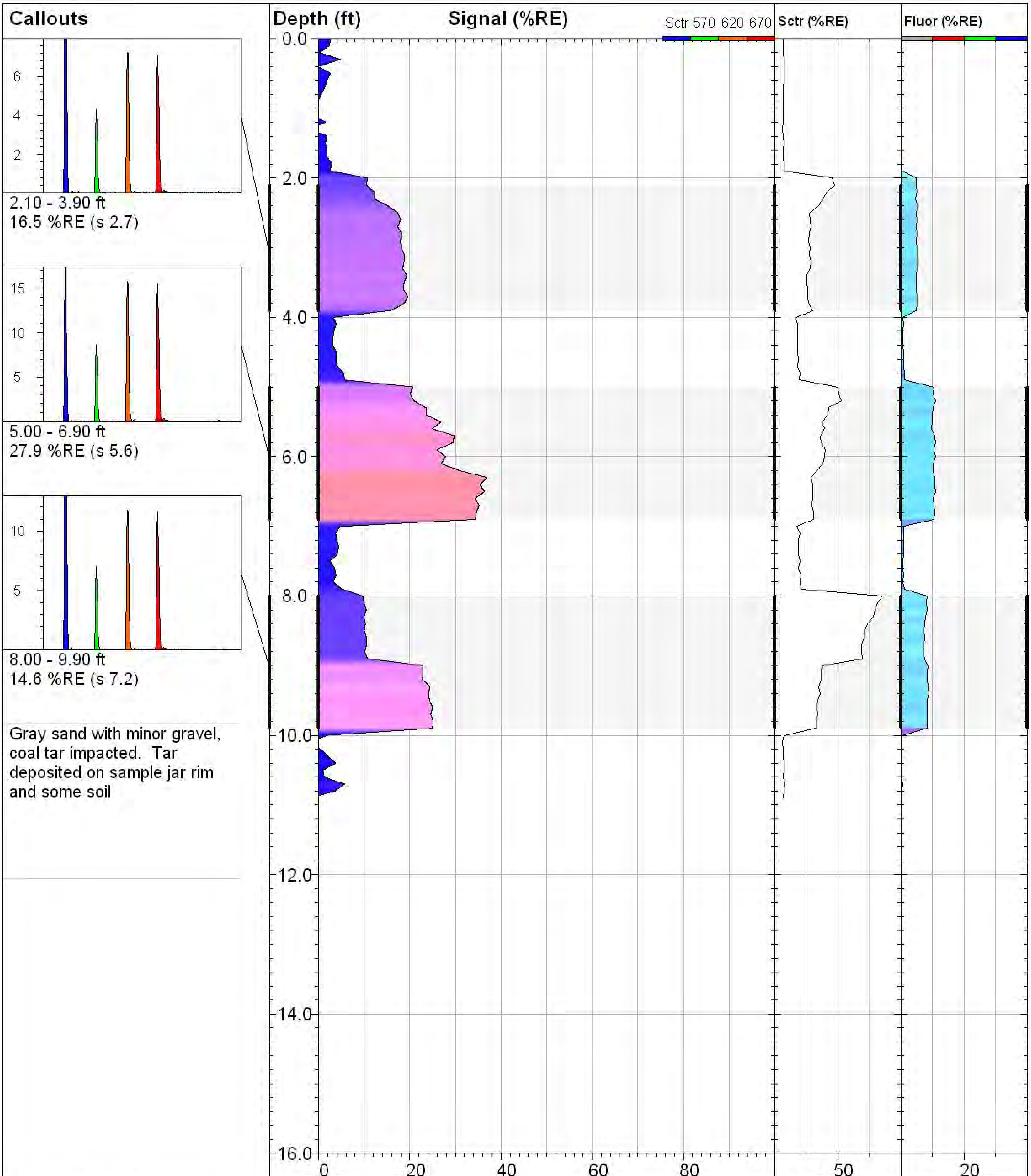


DAKOTA TECHNOLOGIES
Fargo, ND 701.237.4908
www.DakotaTechnologies.com

GEI_12_15_17

TarGOST By Dakota
www.DakotaTechnologies.com

Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **12.90 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **85.8 %RE @ 8.20 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **Unavailable**	*Date & Time:* **2013-04-29 11:03 PDT**



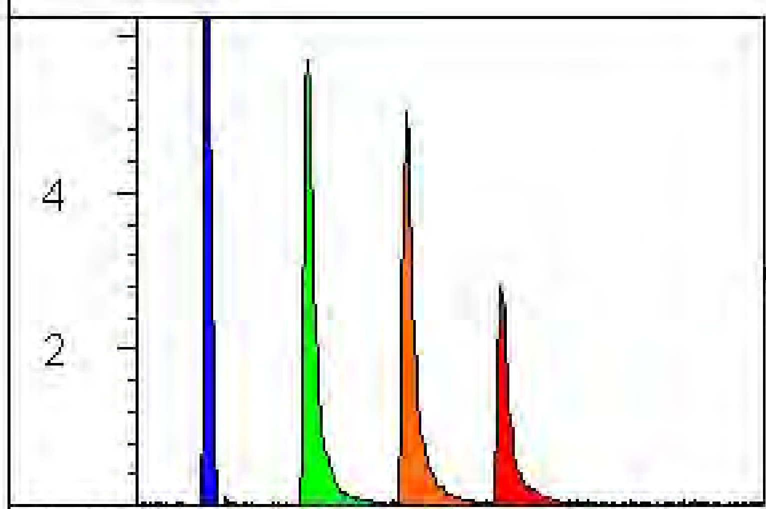
DAKOTA TECHNOLOGIES
FARGO, ND 701.237.4908
WWW.DAKOTATECHNOLOGIES.COM

GEI_12_25_26

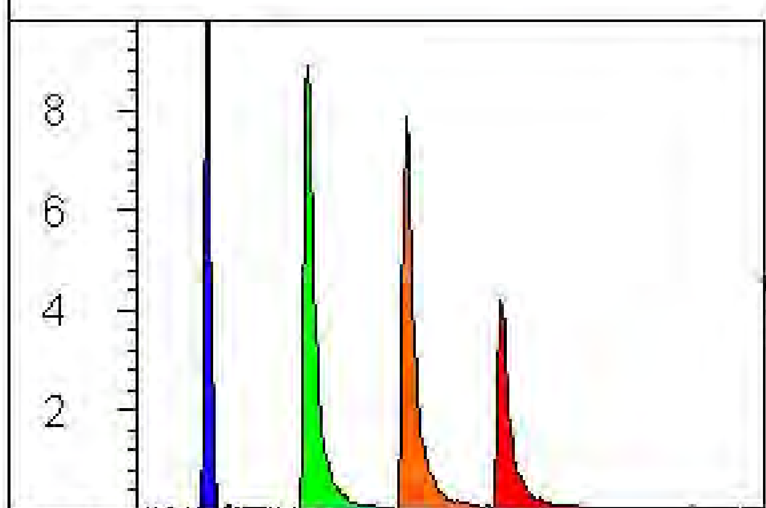
TarGOST By Dakota
www.DakotaTechnologies.com

Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **10.90 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **37.0 %RE @ 6.30 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **Unavailable**	*Date & Time:* **2013-04-29 11:21 PDT**

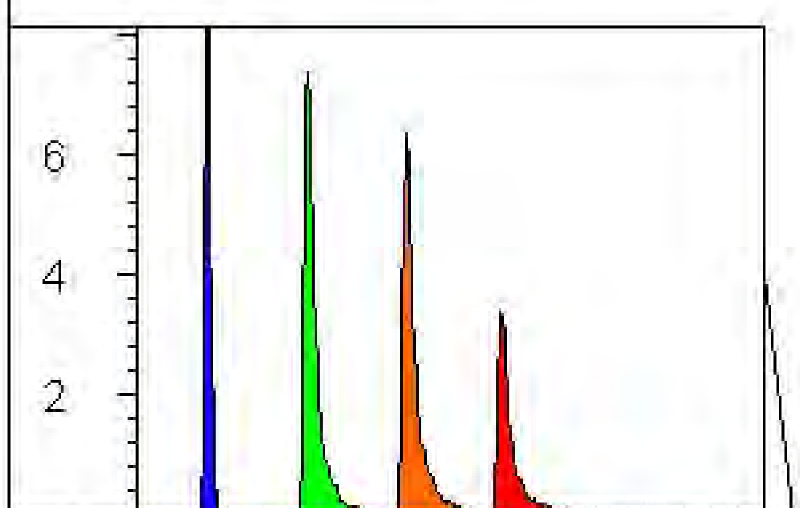
Callouts



2.00 - 3.90 ft
37.1 %RE (s 12.6)

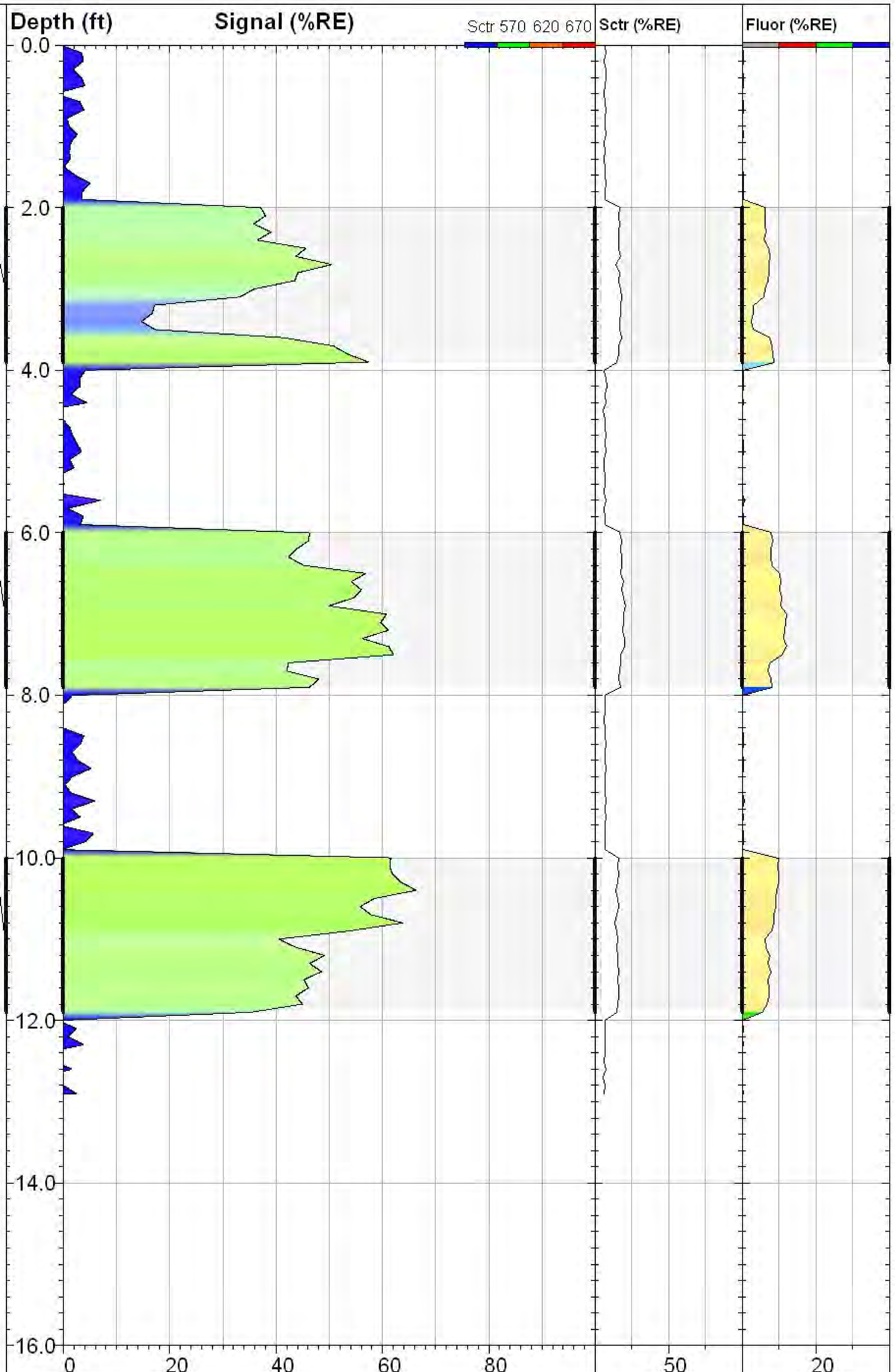


6.00 - 7.90 ft
52.0 %RE (s 7.2)



10.00 - 11.90 ft
52.3 %RE (s 9.1)

Dk brown sand with silt, some gravel and some organic matter. Petro?? odor.

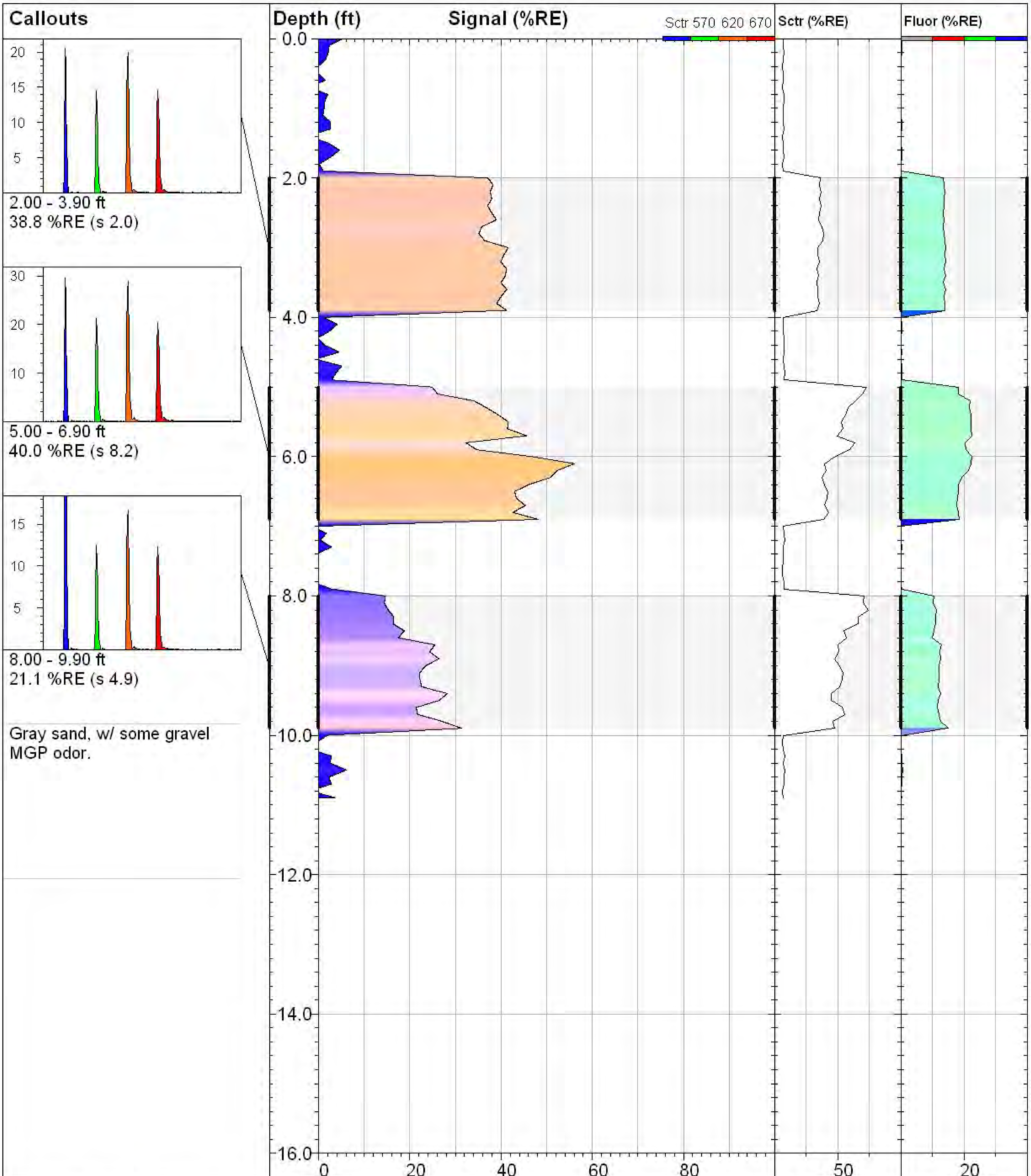


DAKOTA TECHNOLOGIES
FARGO, ND 701.237.4908
WWW.DAKOTATECHNOLOGIES.COM

GEI_13_8_9

TarGOST By Dakota
www.DakotaTechnologies.com

Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **12.90 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **66.3 %RE @ 10.40 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **Unavailable**	*Date & Time:* **2013-04-29 11:31 PDT**

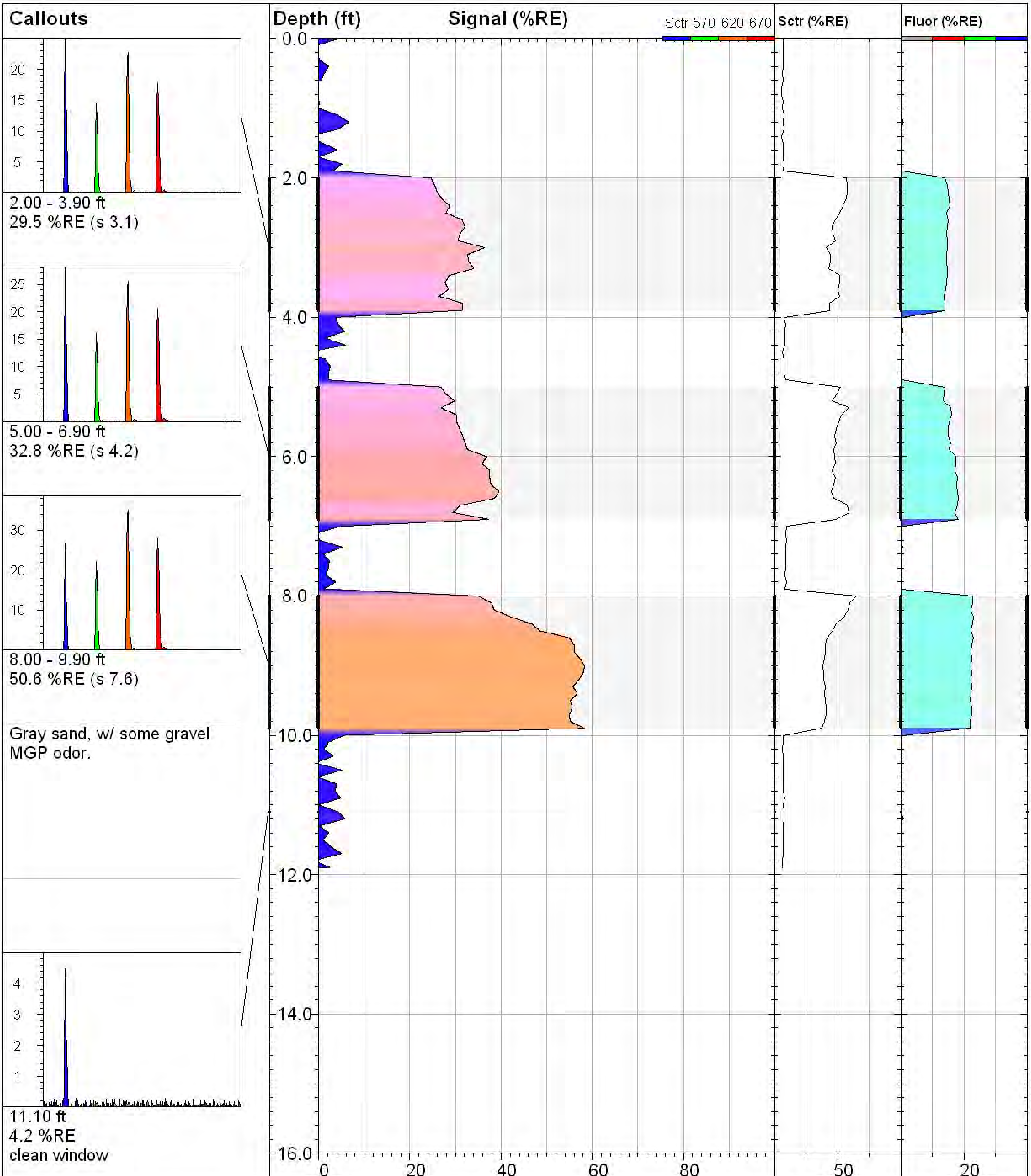


GEI_13_13_16

TarGOST By Dakota
www.DakotaTechnologies.com

DAKOTA TECHNOLOGIES
Fargo, ND 701.237.4908
www.DakotaTechnologies.com

Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **10.90 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **56.1 %RE @ 6.10 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **Unavailable**	*Date & Time:* **2013-04-29 11:40 PDT**



GEI_13_23_24

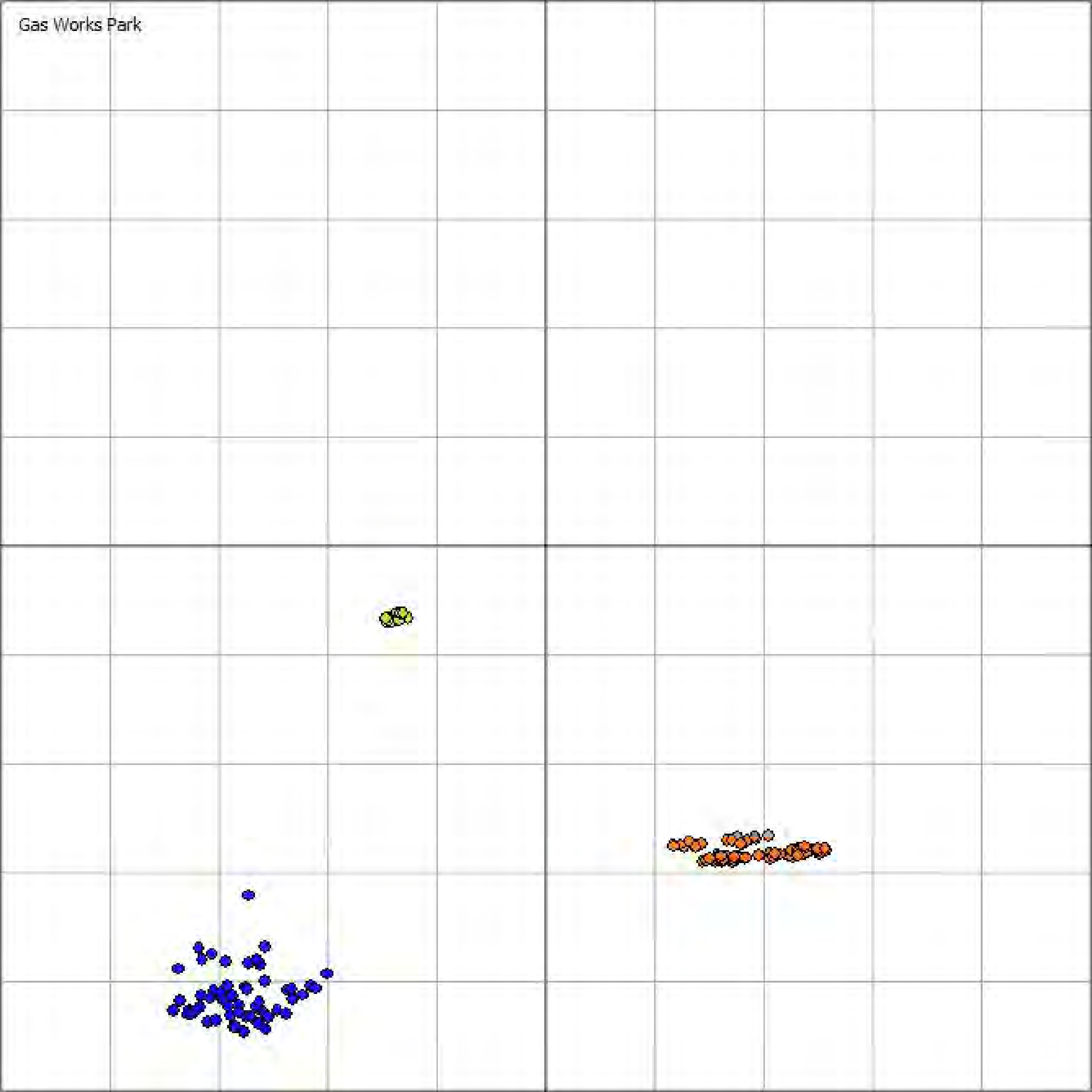
TarGOST By Dakota
www.DakotaTechnologies.com

DAKOTA TECHNOLOGIES
Fargo, ND 701.237.4908
www.DakotaTechnologies.com

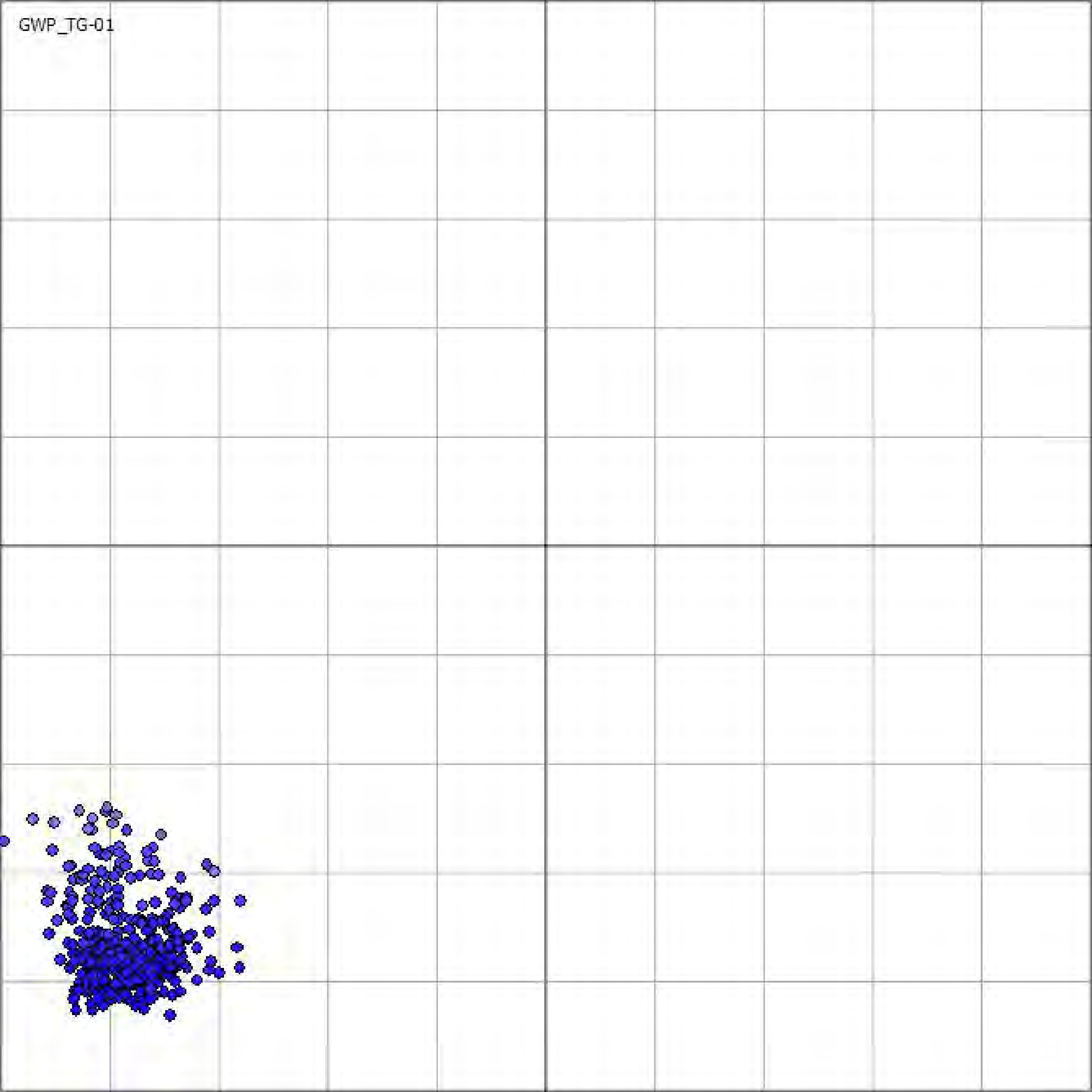
Site: **Gas Works Park**	*Y Coord.(Lat-N) / System:* **Unavailable / NA**	*Final depth:* **11.90 ft**
Client / Job: **GeoEngineers /**	*X Coord.(Lng-E) / Fix:* **Unavailable / NA**	*Max signal:* **58.4 %RE @ 9.90 ft**
Operator / Unit: **SDA / TG1004**	*Elevation:* **Unavailable**	*Date & Time:* **2013-04-29 11:49 PDT**

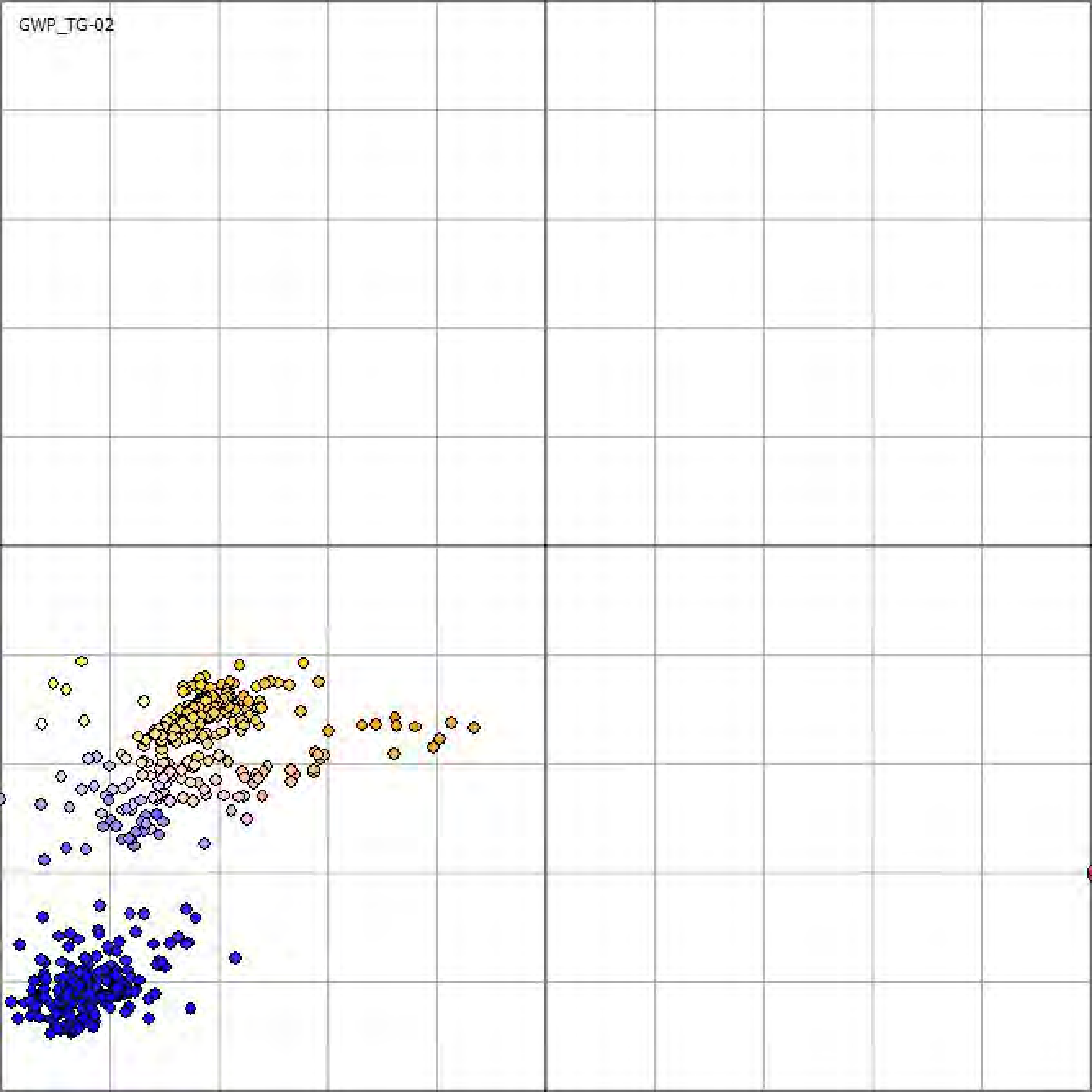
SUB-ATTACHMENT 2A-2.4
TarGOST® Classification Plots

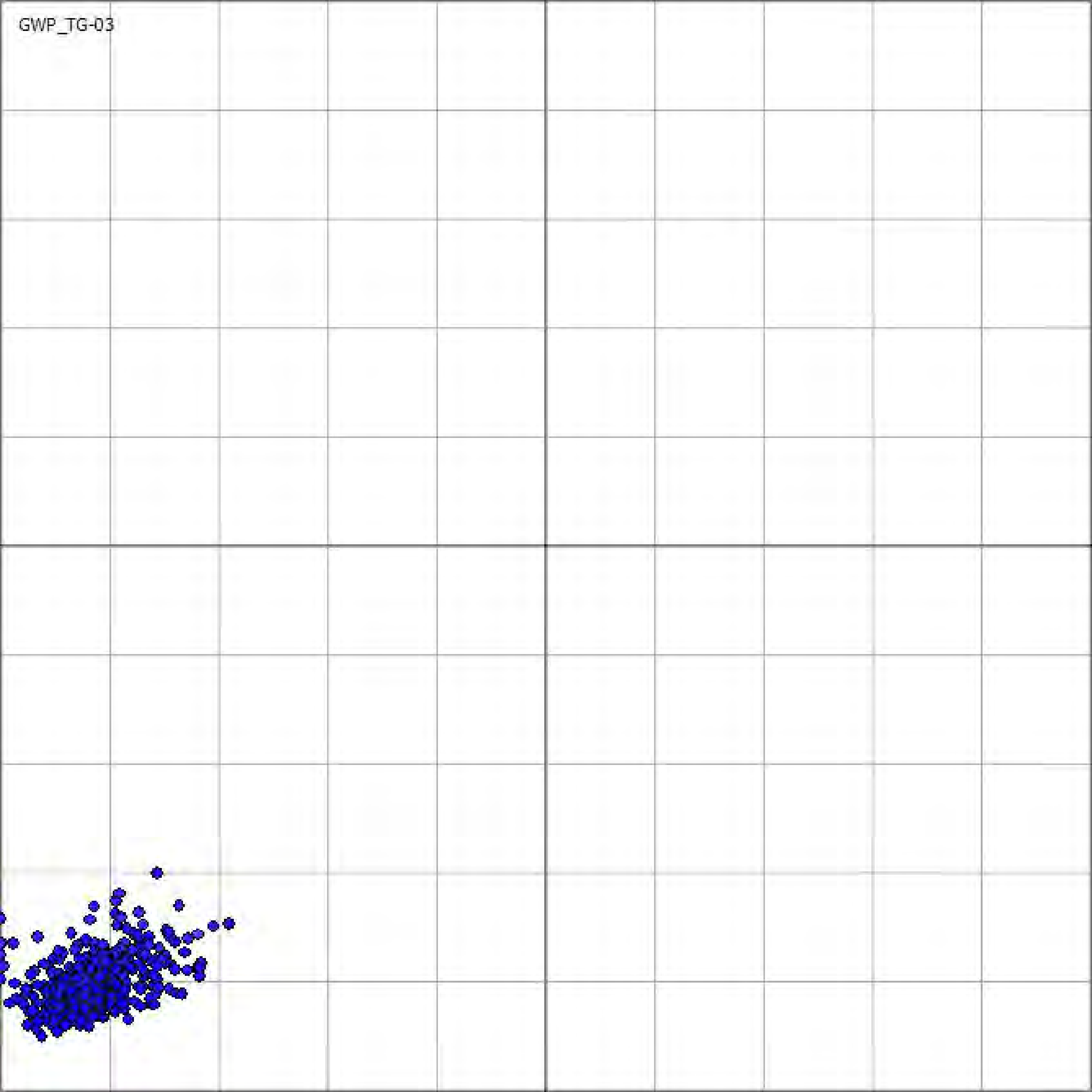
SUB-ATTACHMENT 2A-2.4.1
Classification Plots for NAPL Responses

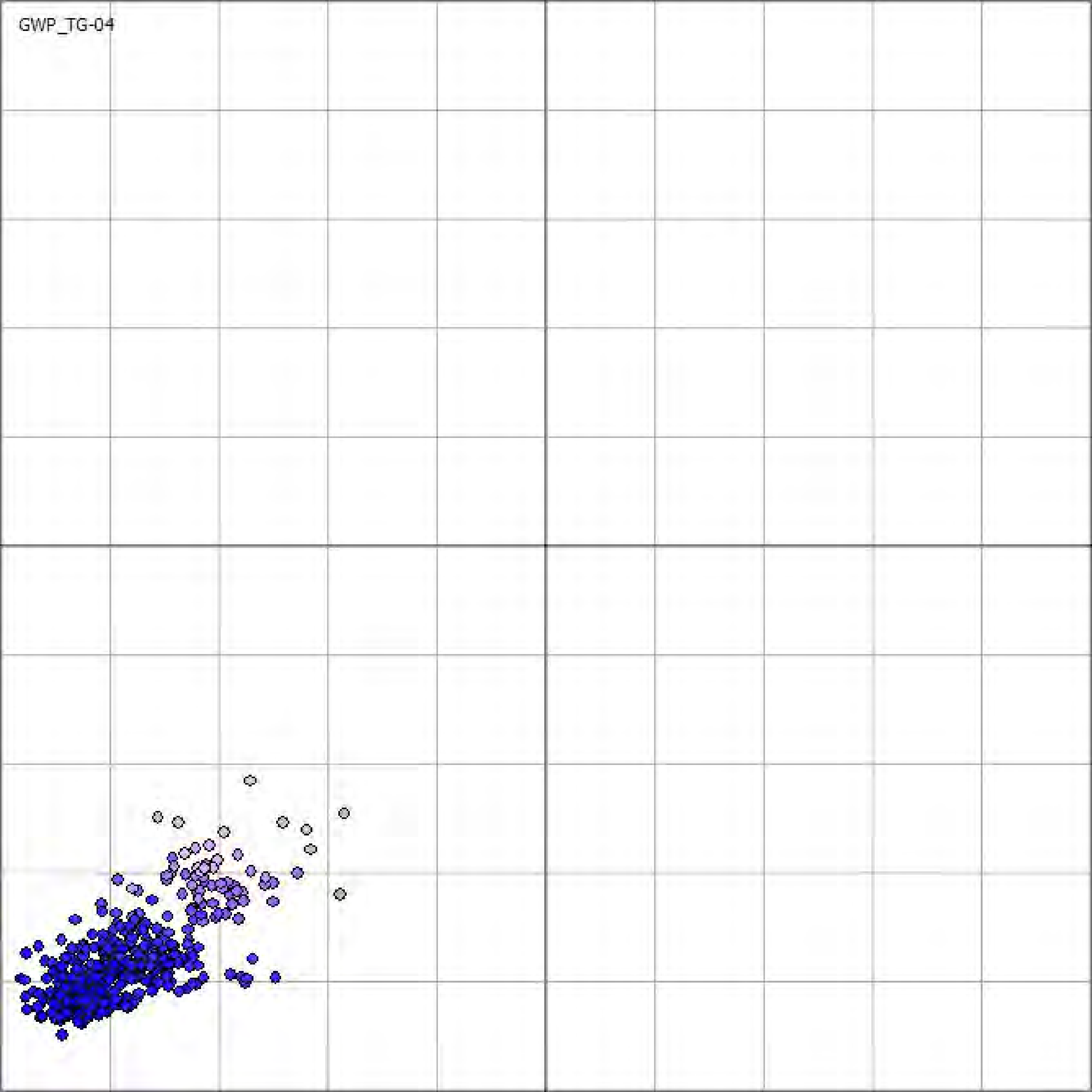

Gas Works Park

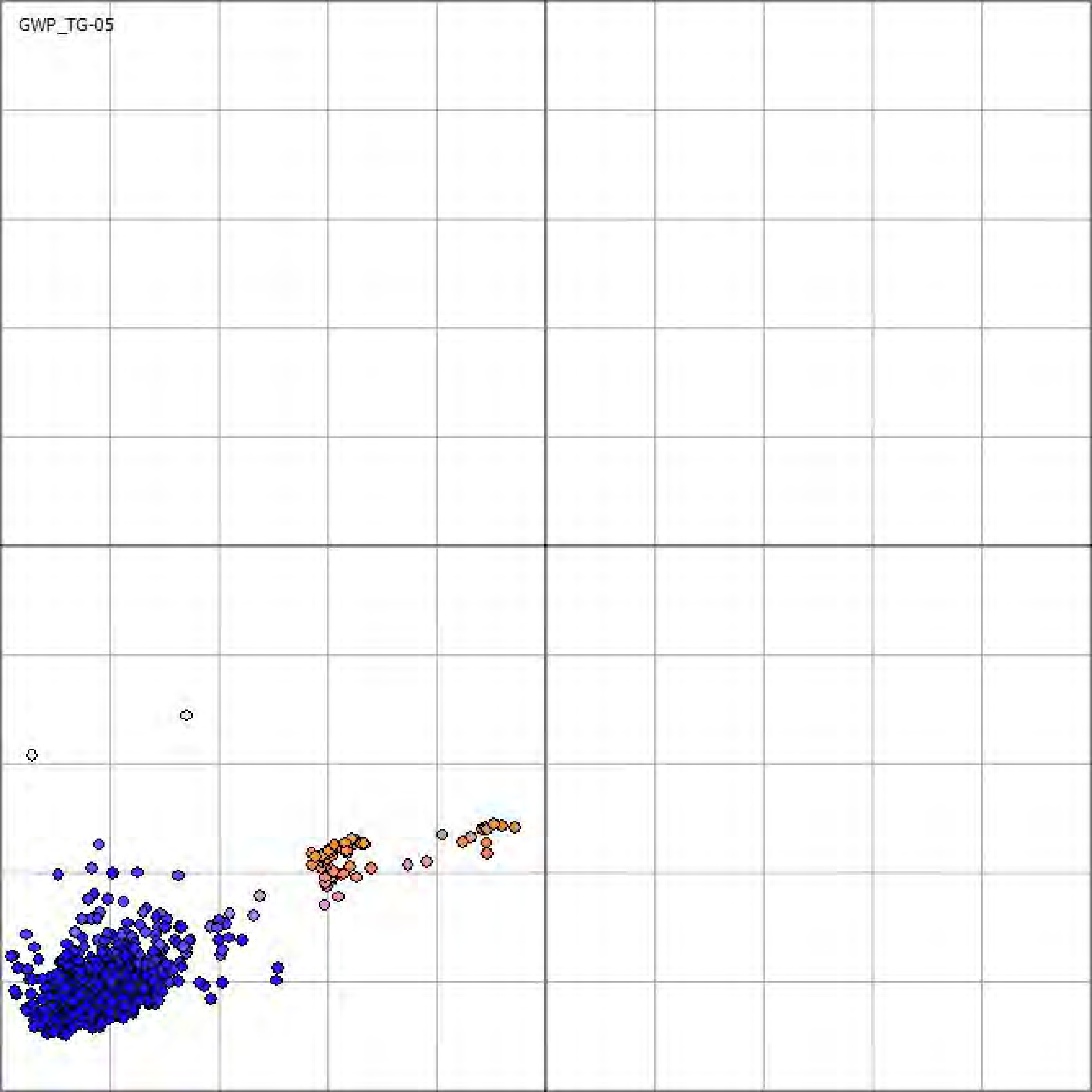
SUB-ATTACHMENT 2A-2.4.2
Classification Plots for TarGOST® Logs

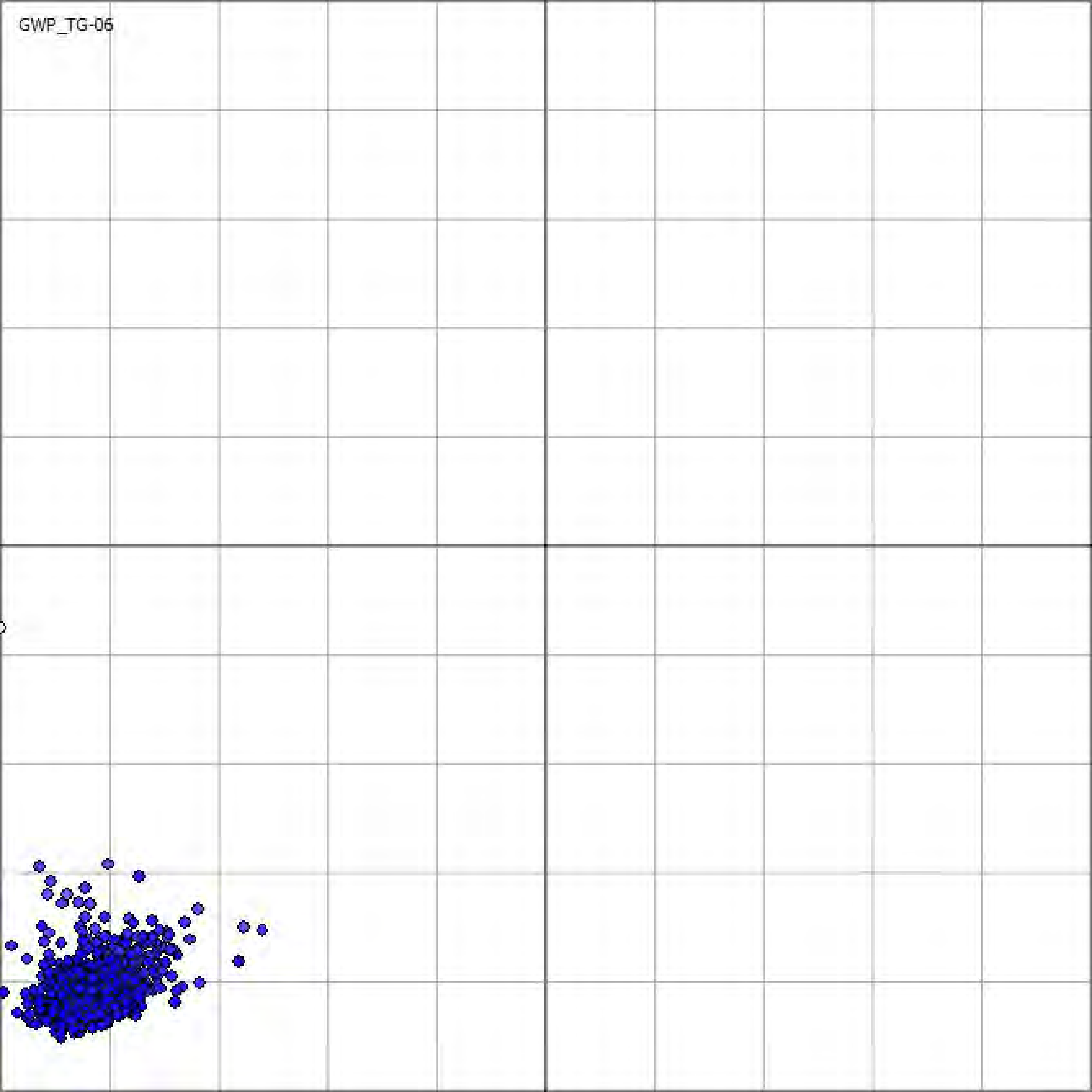

GWP_TG-01

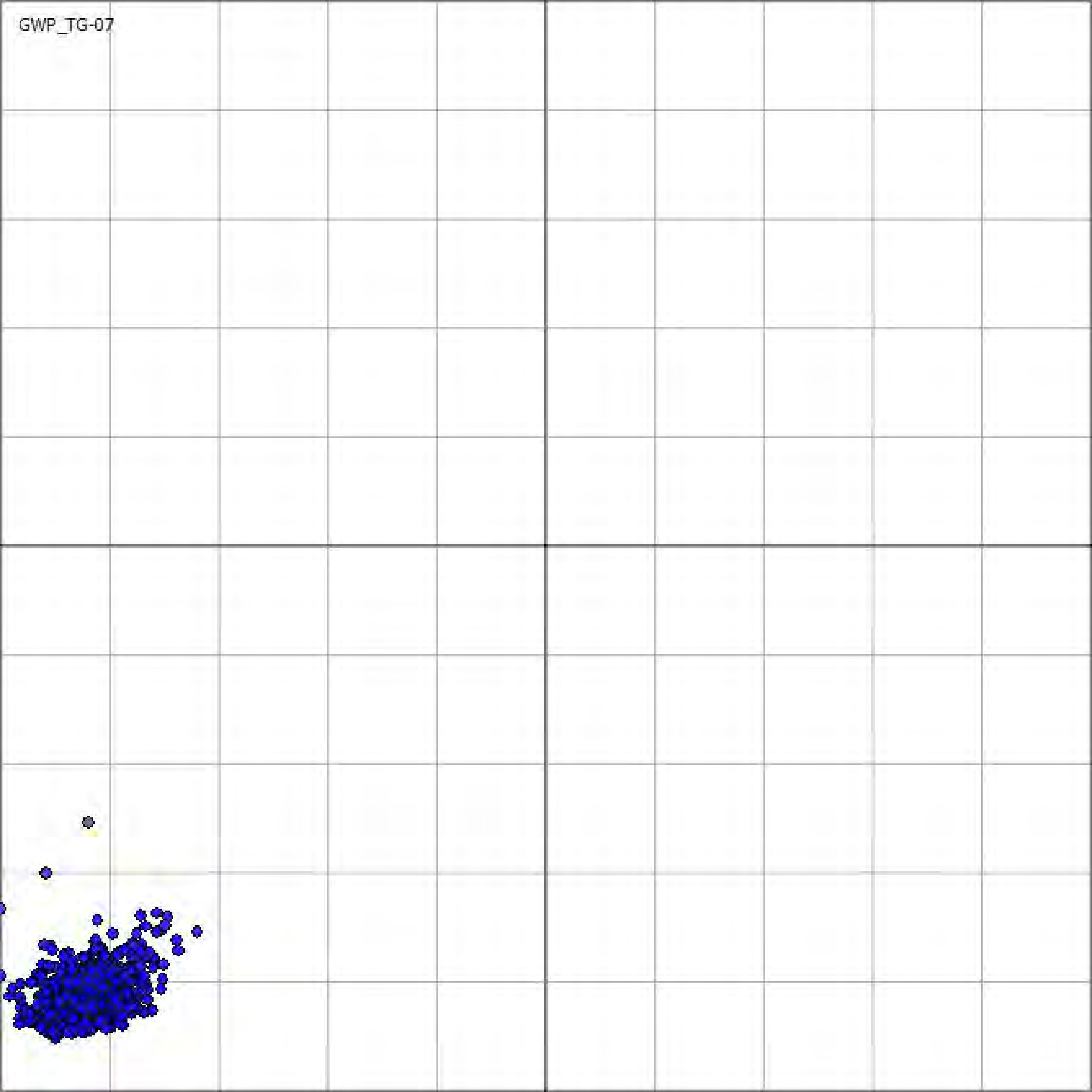

GWP_TG-02

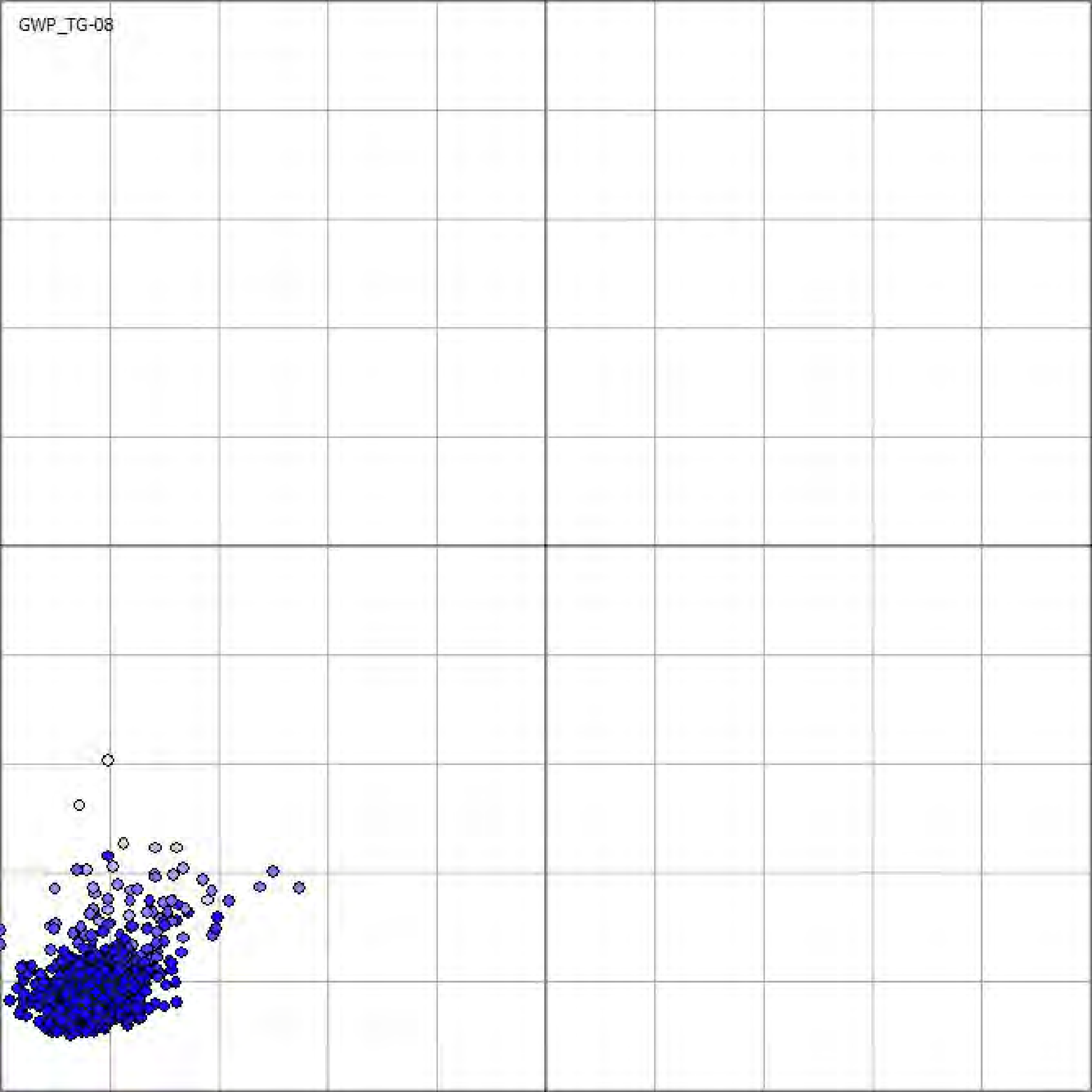

GWP_TG-03

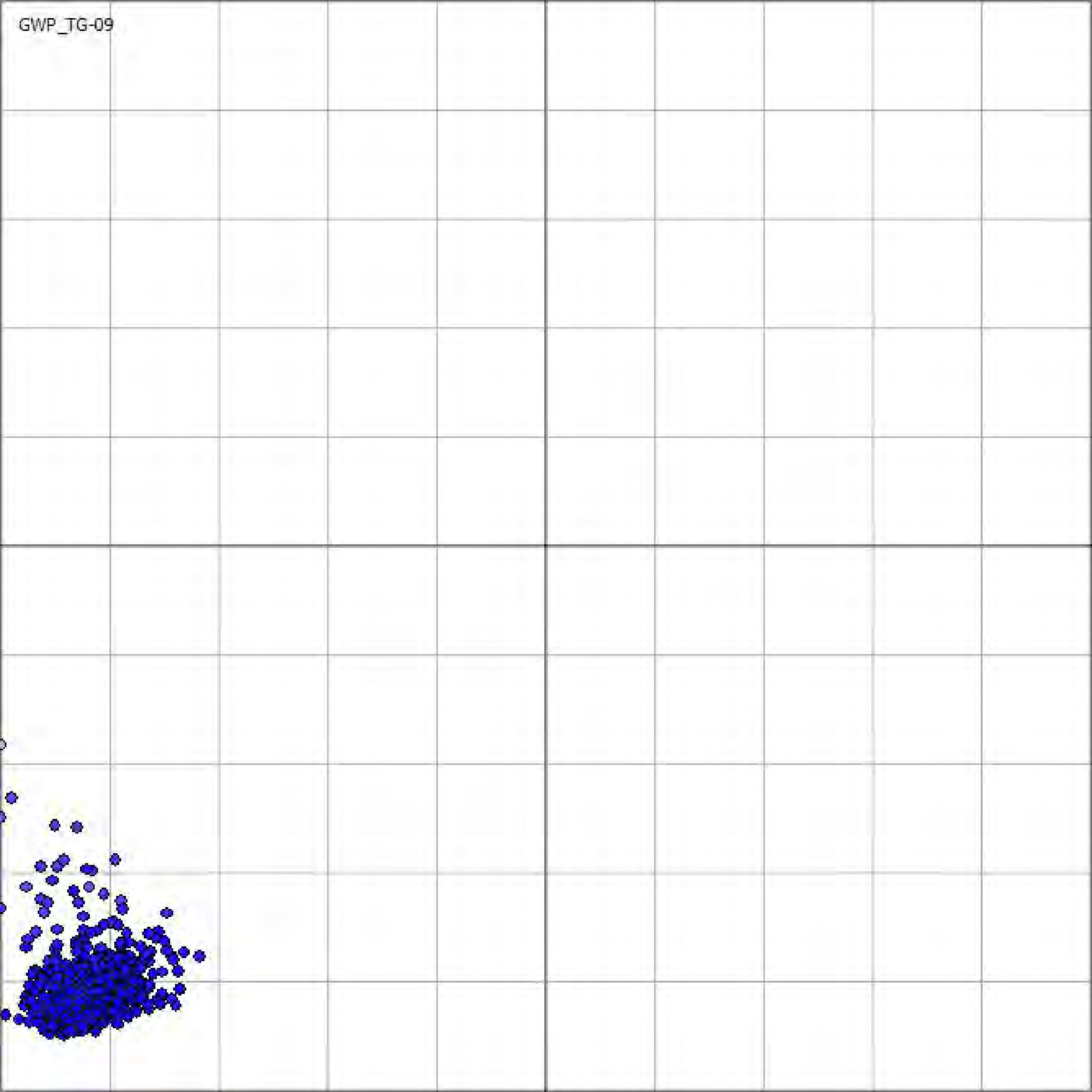

GWP_TG-04

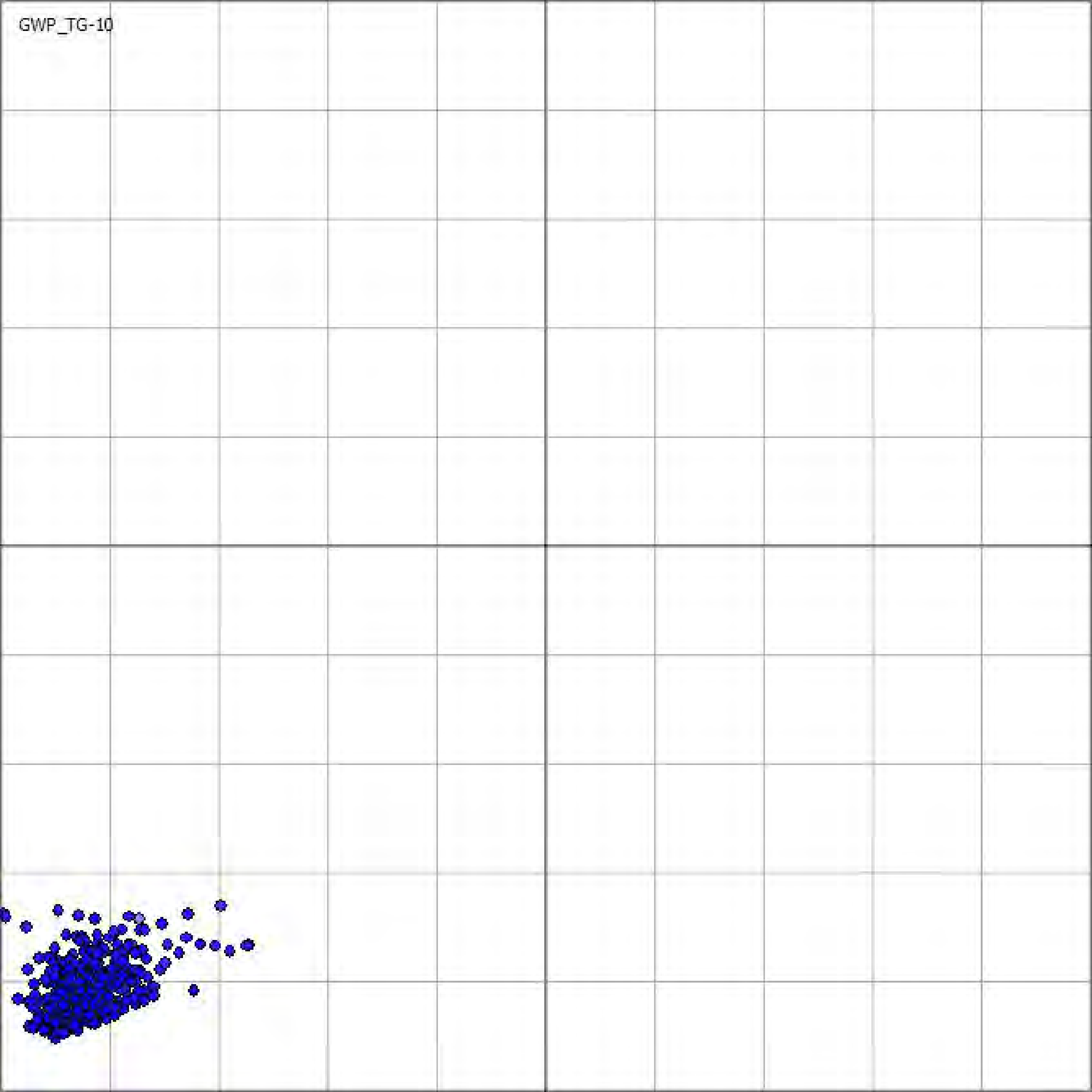

GWP_TG-05

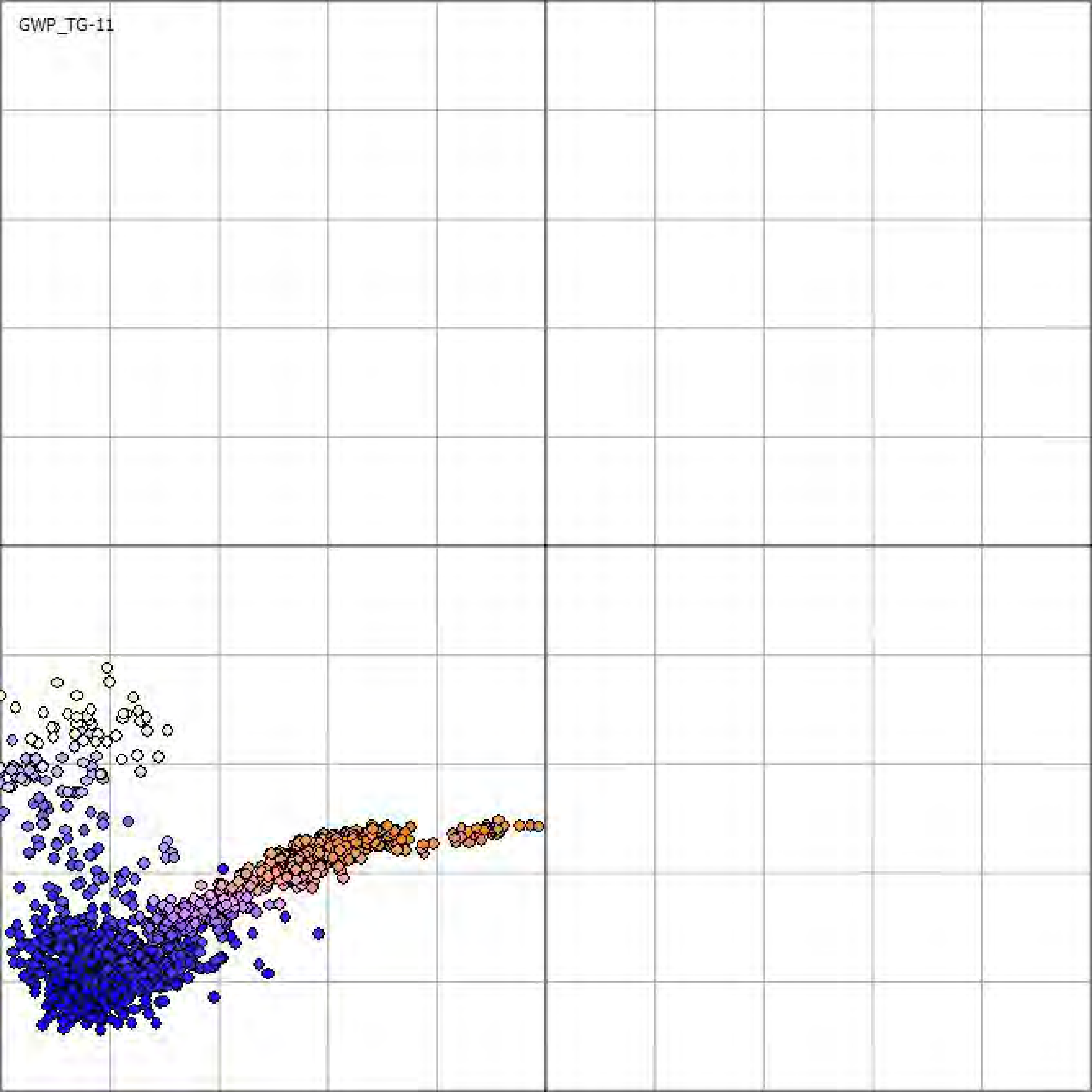

GWP_TG-06

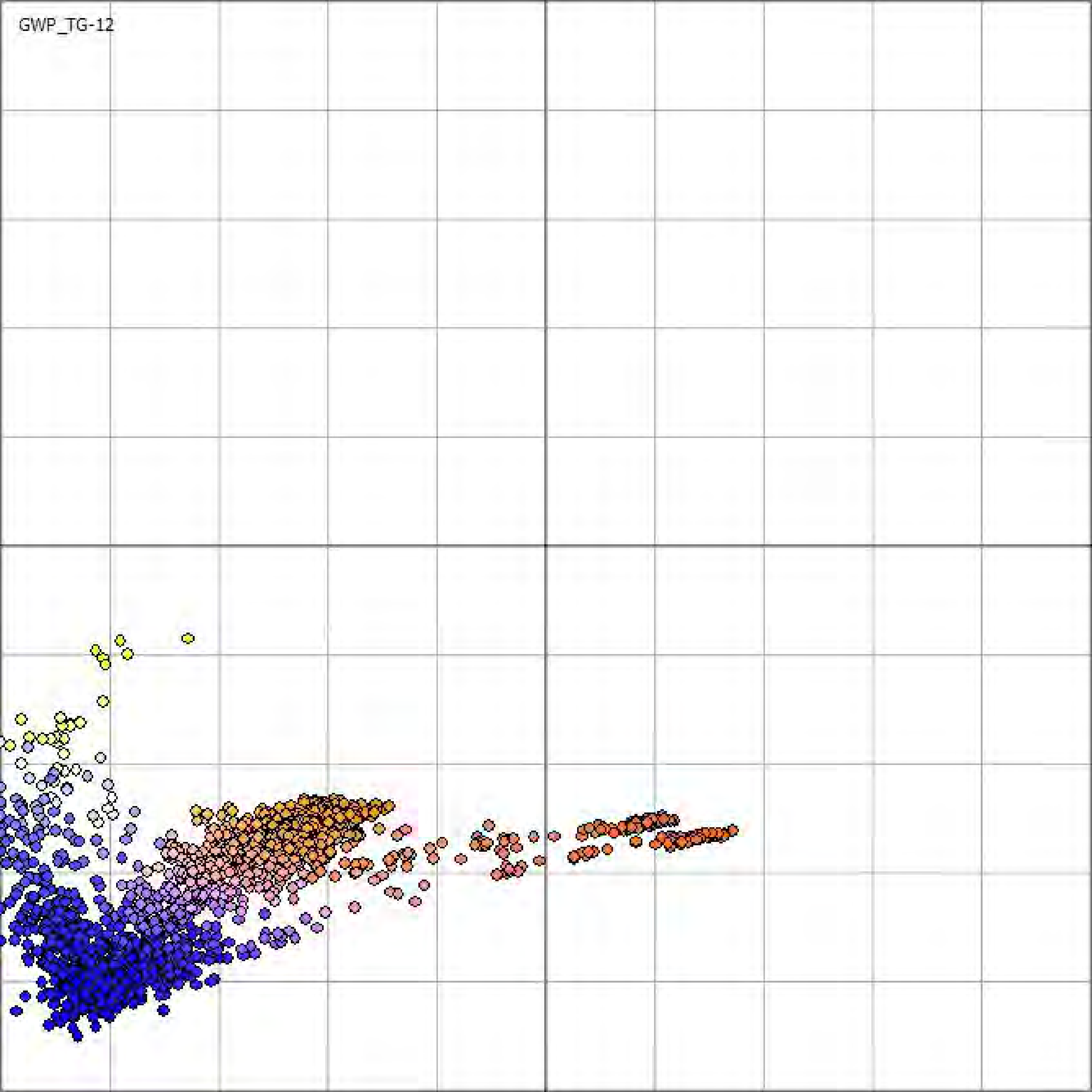

GWP_TG-07

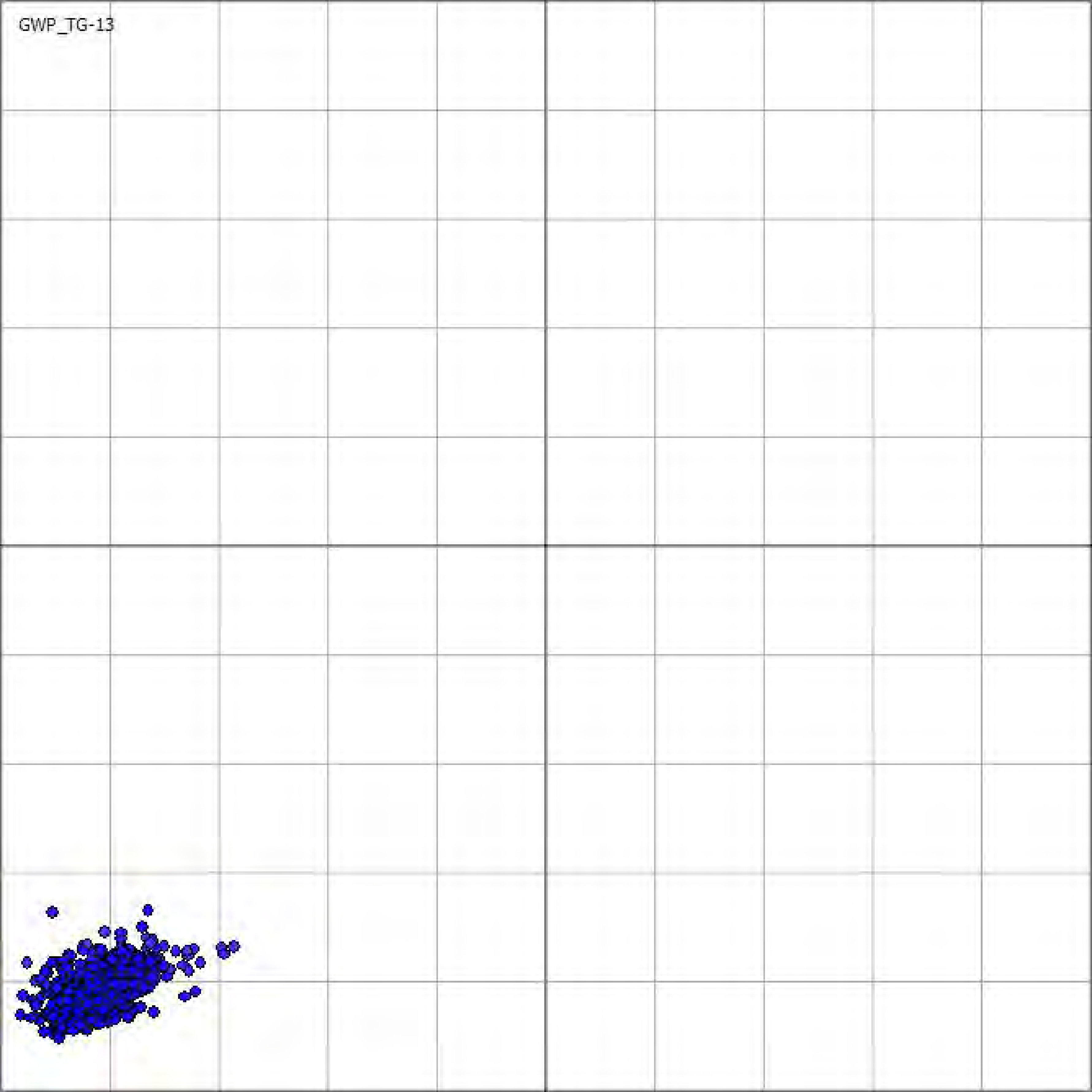

GWP_TG-08

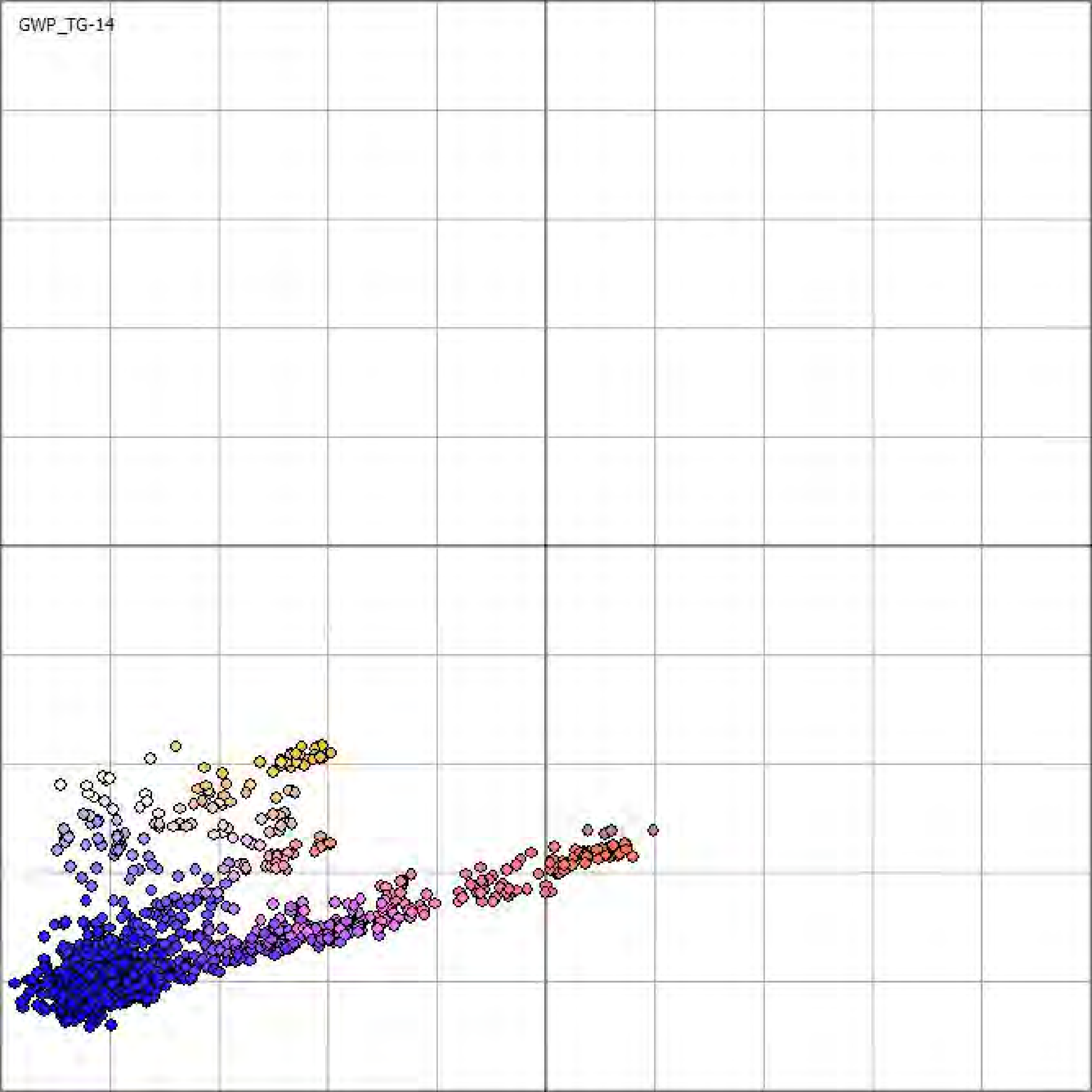

GWP_TG-09

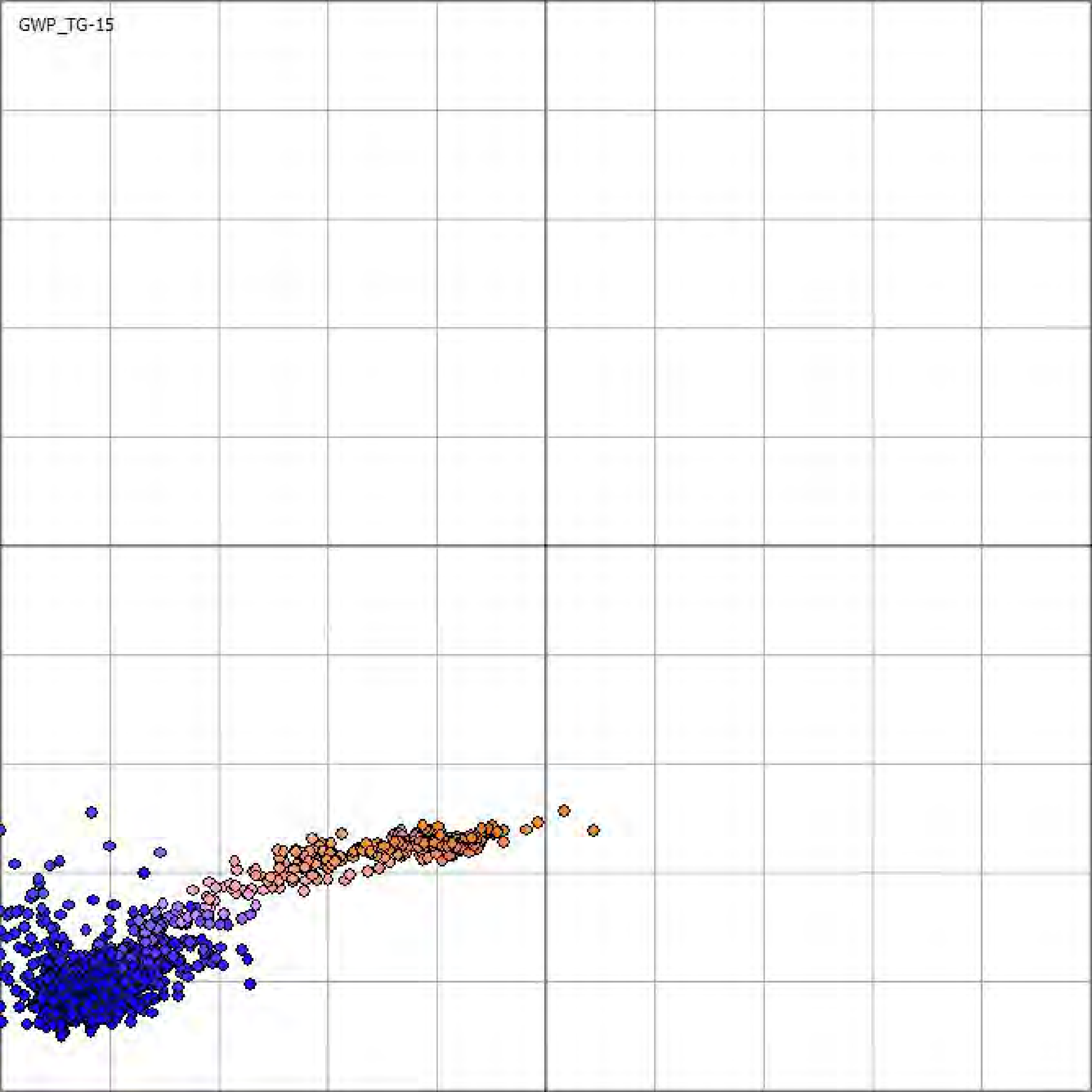

GWP_TG-10

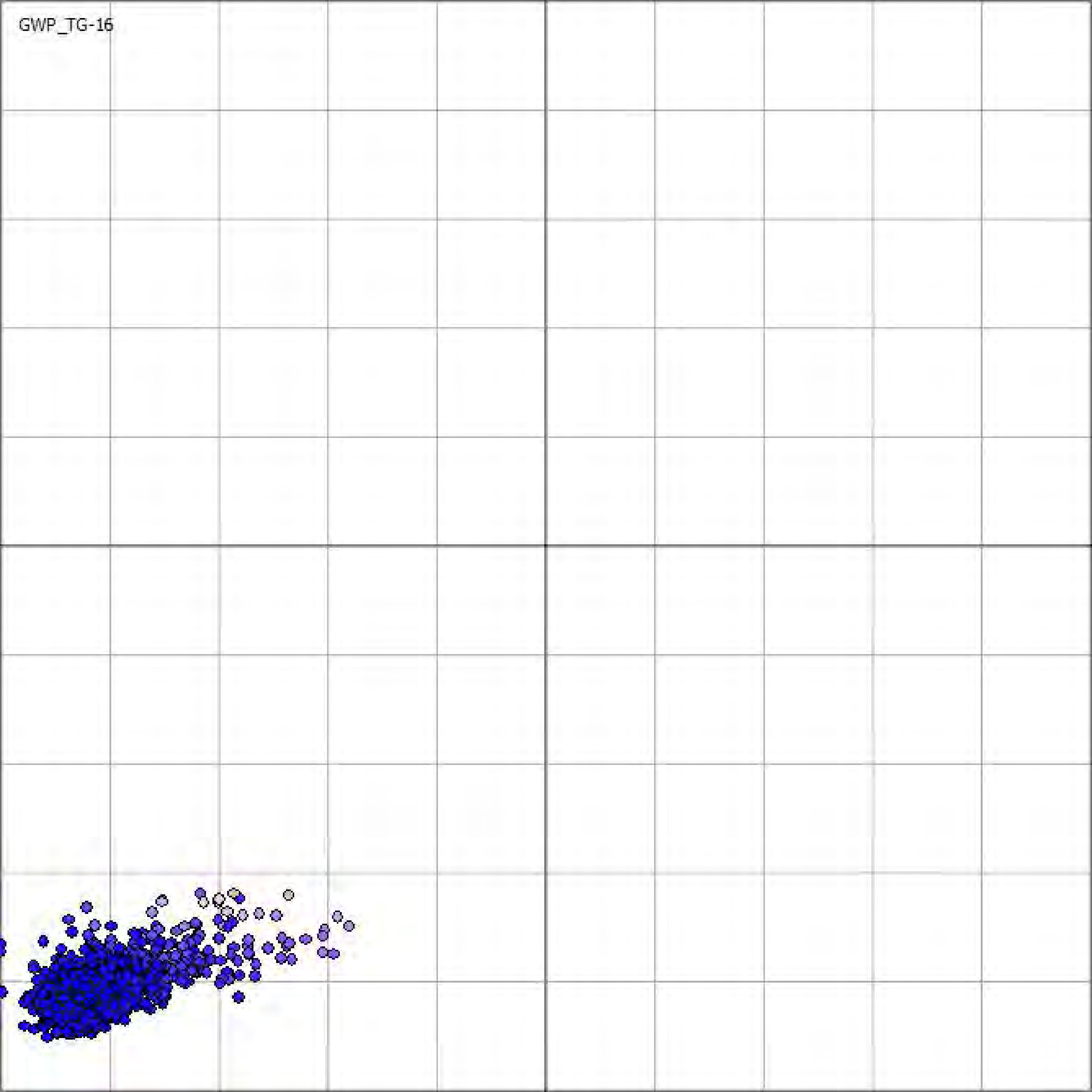

GWP_TG-11

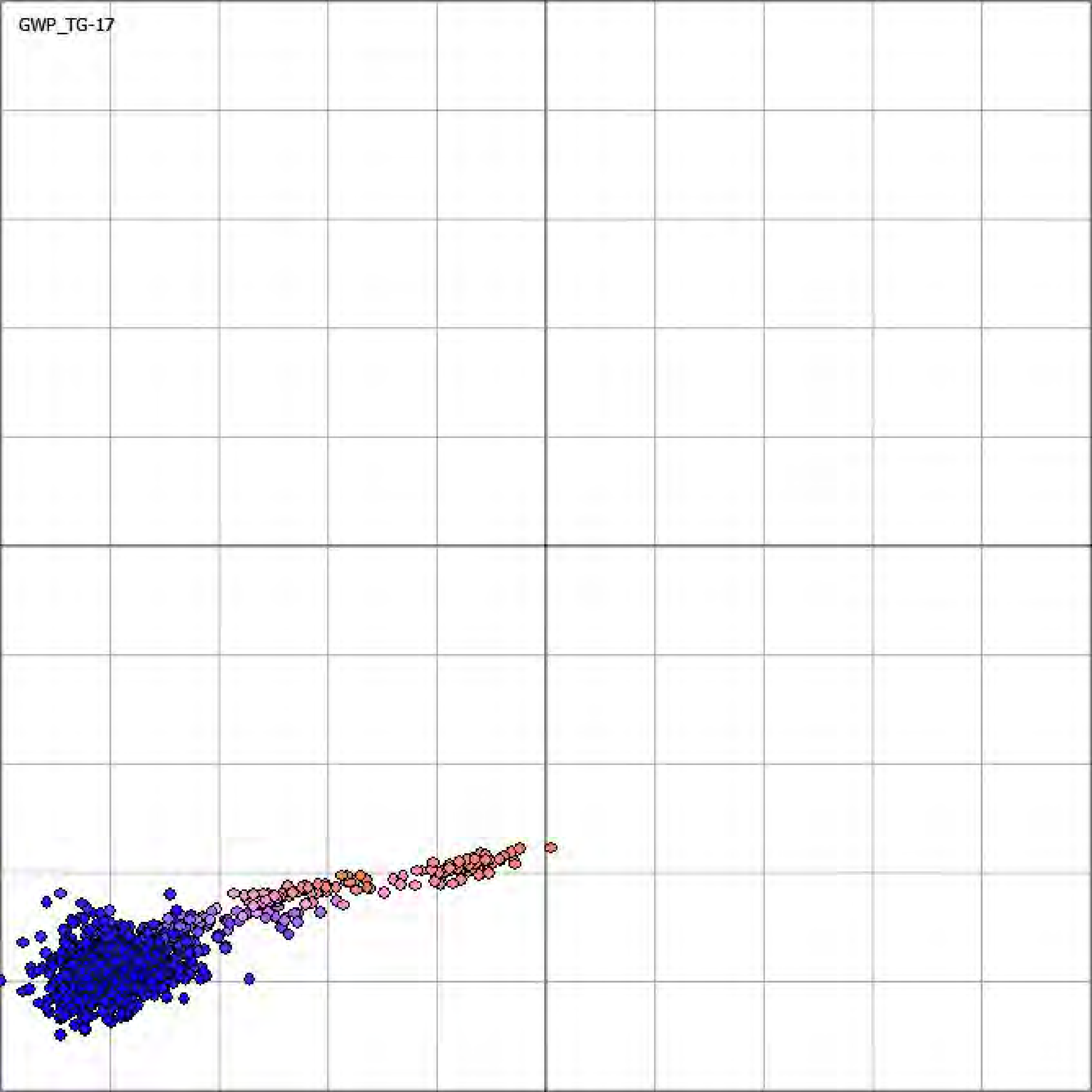

GWP_TG-12

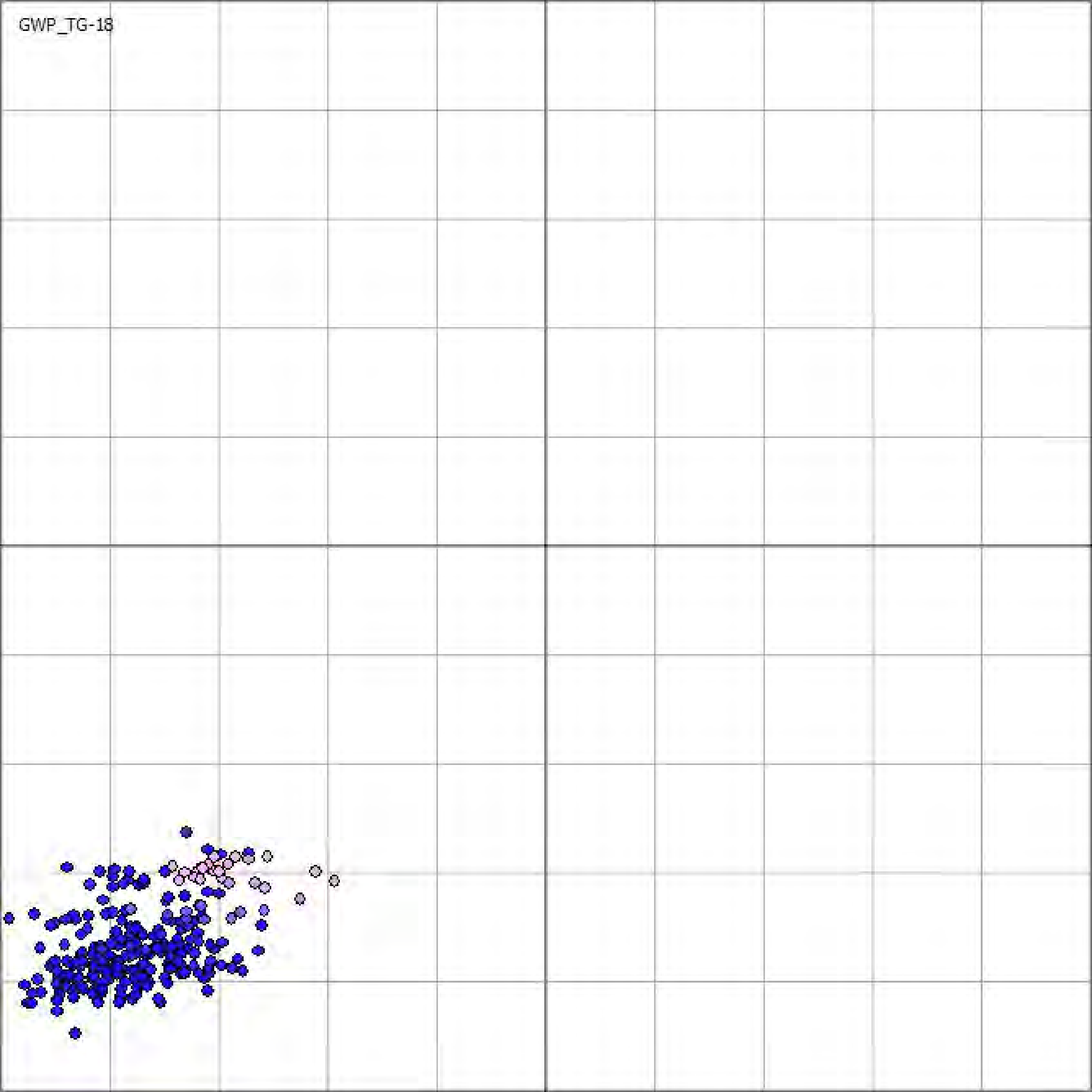

GWP_TG-13

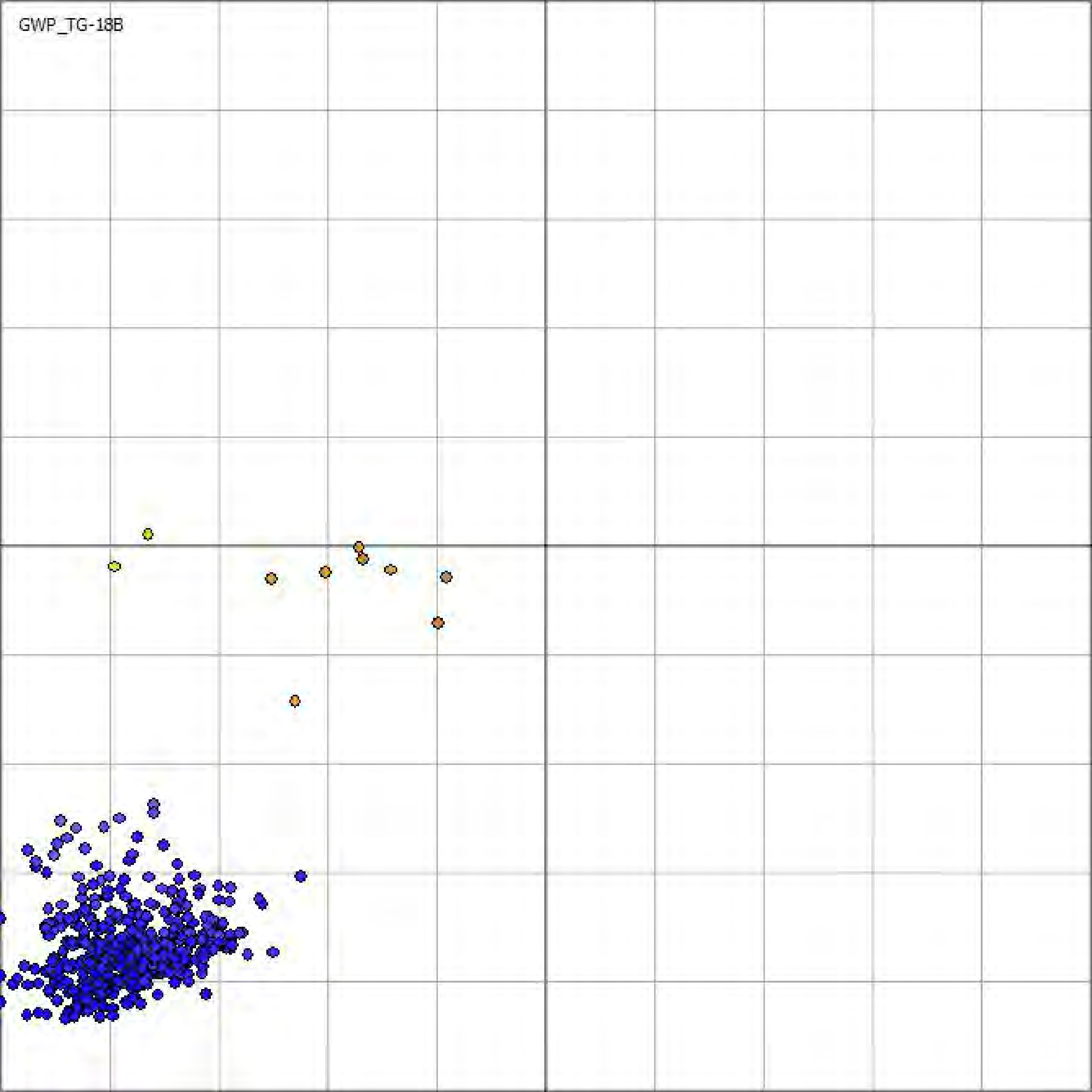

GWP_TG-14

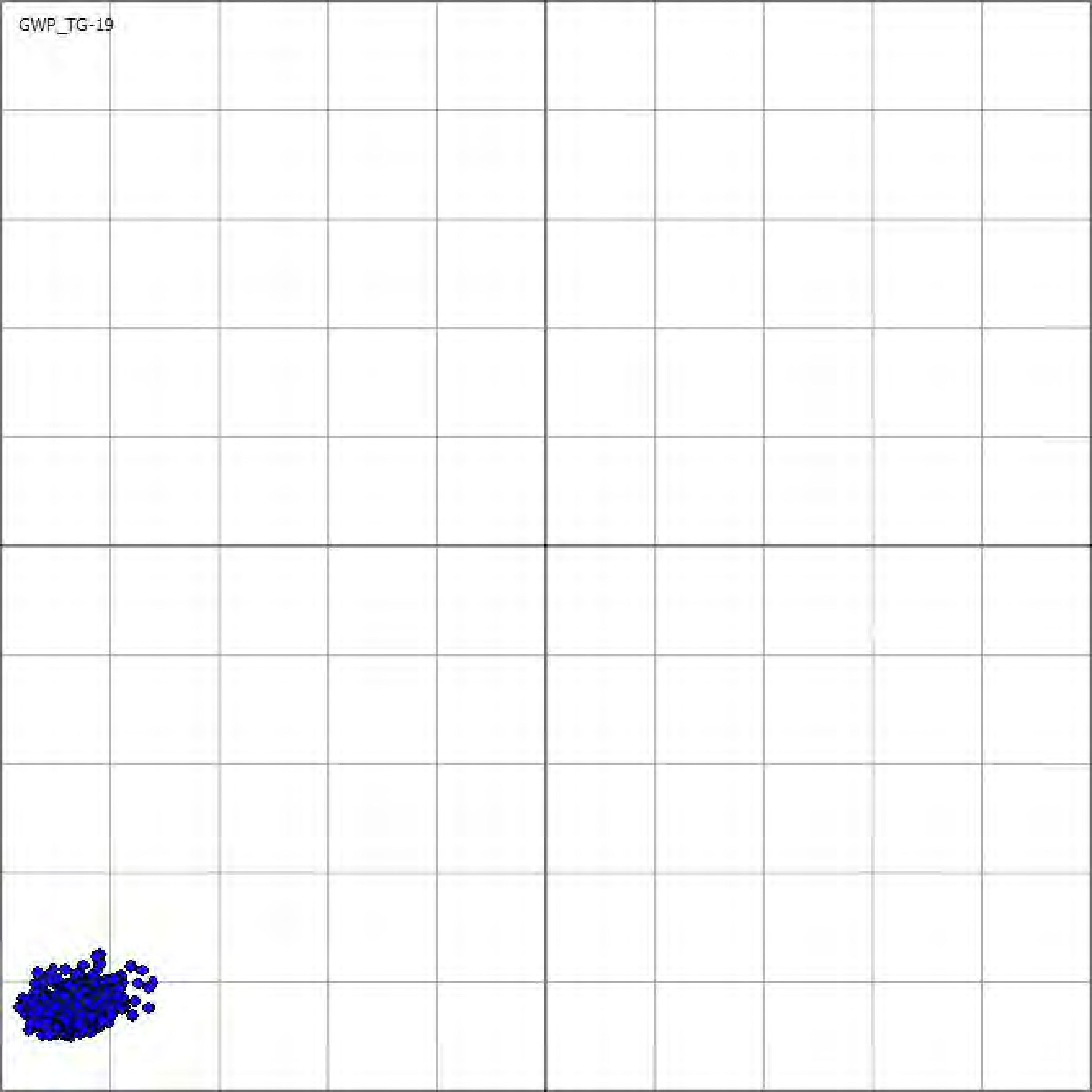

GWP_TG-15

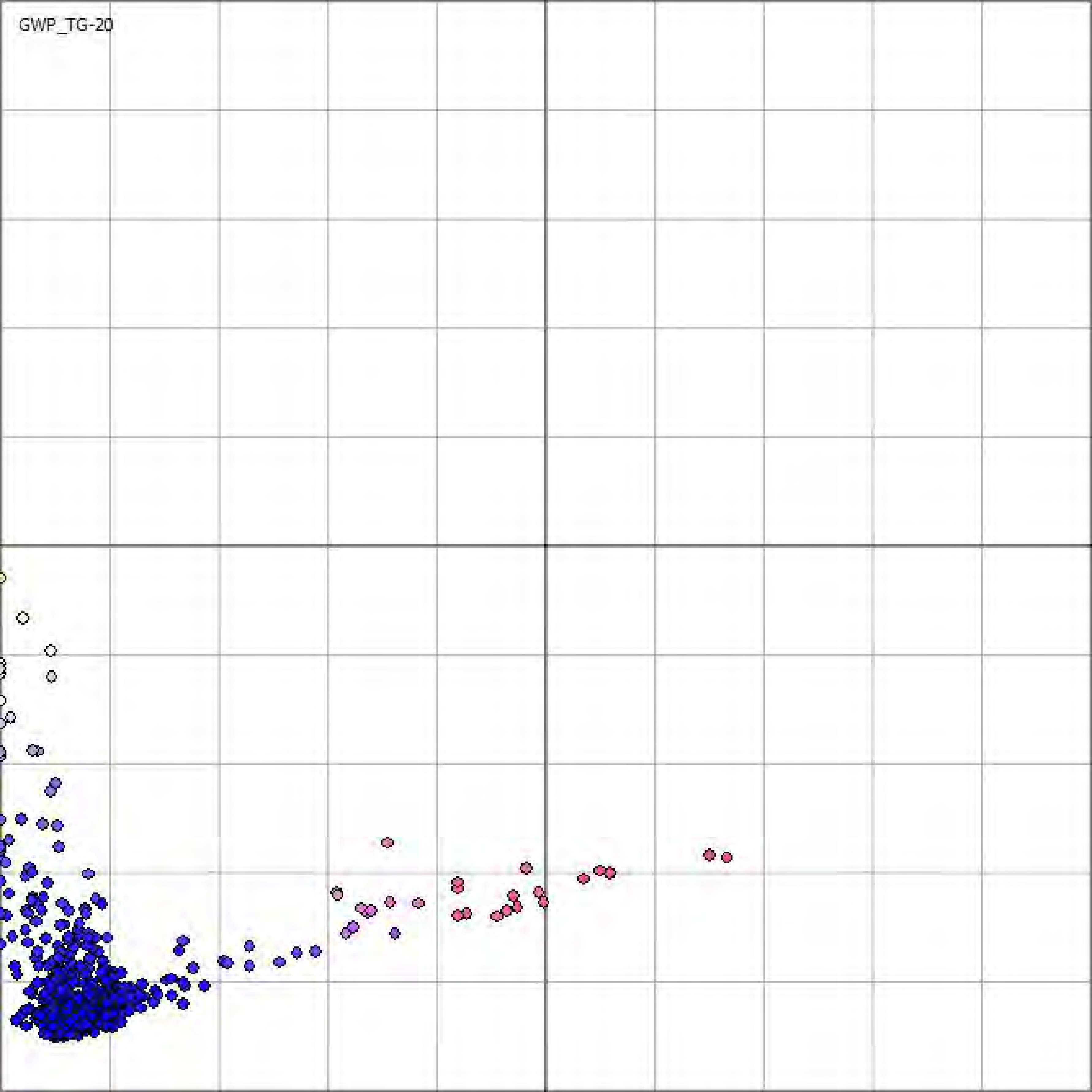

GWP_TG-16

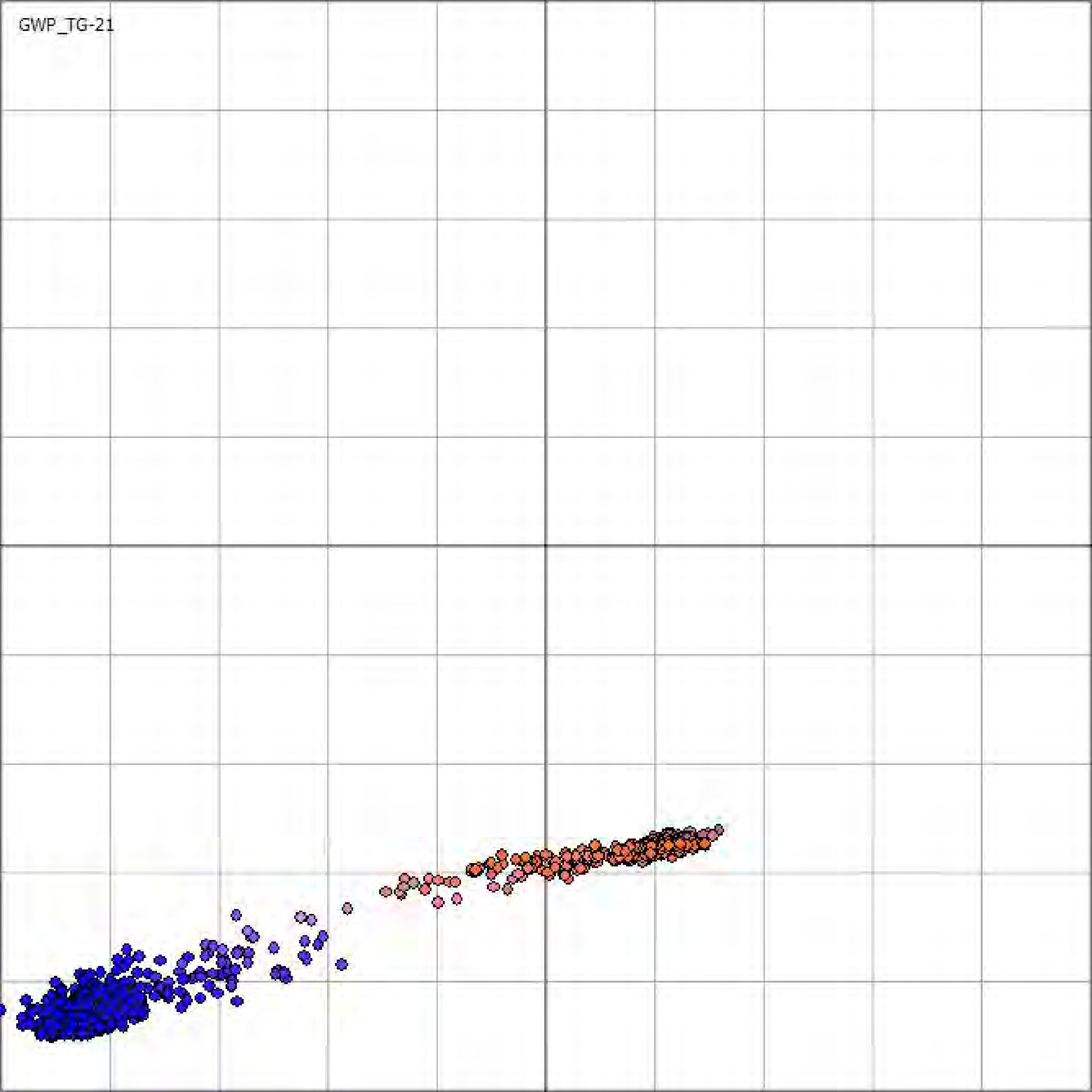

GWP_TG-17

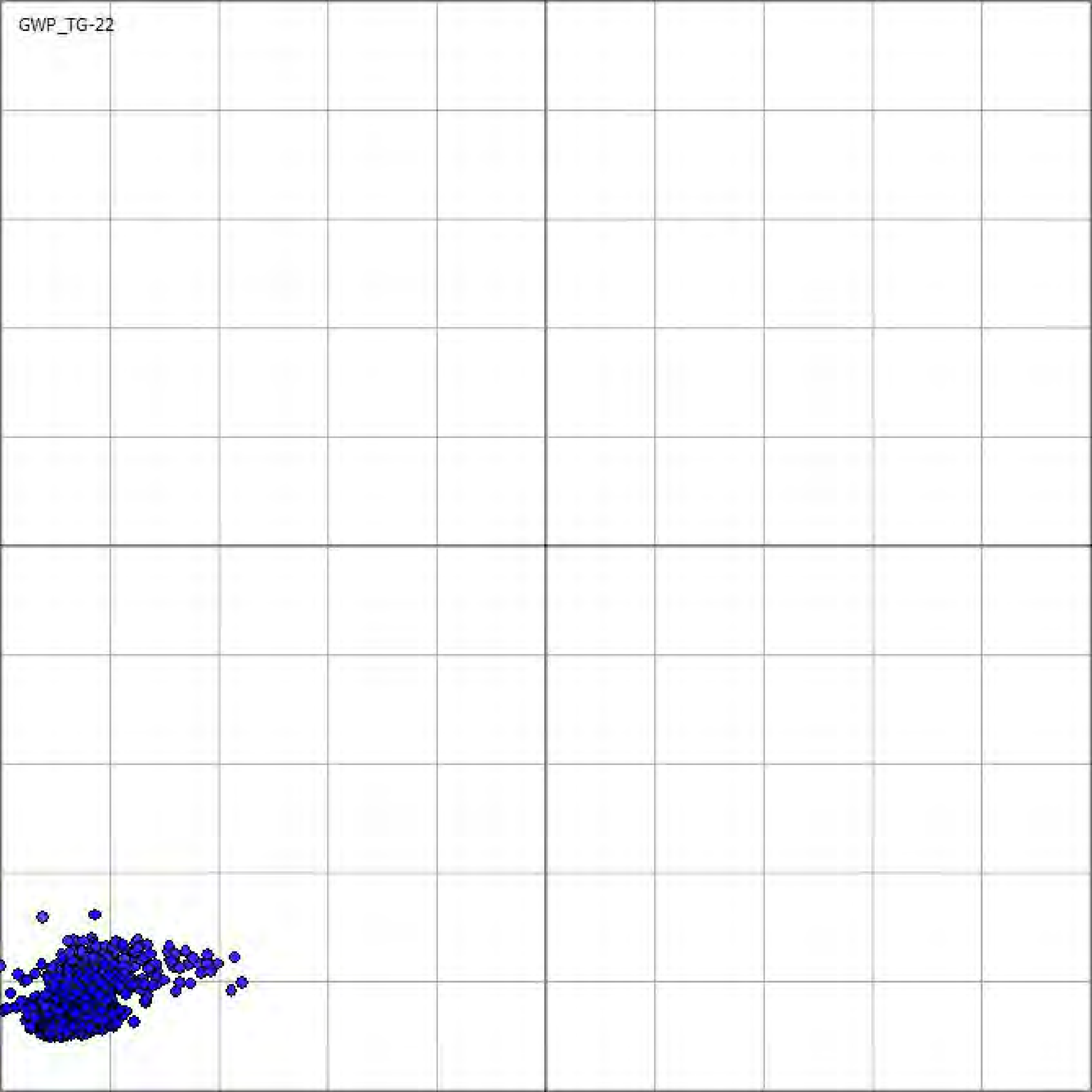

GWP_TG-18

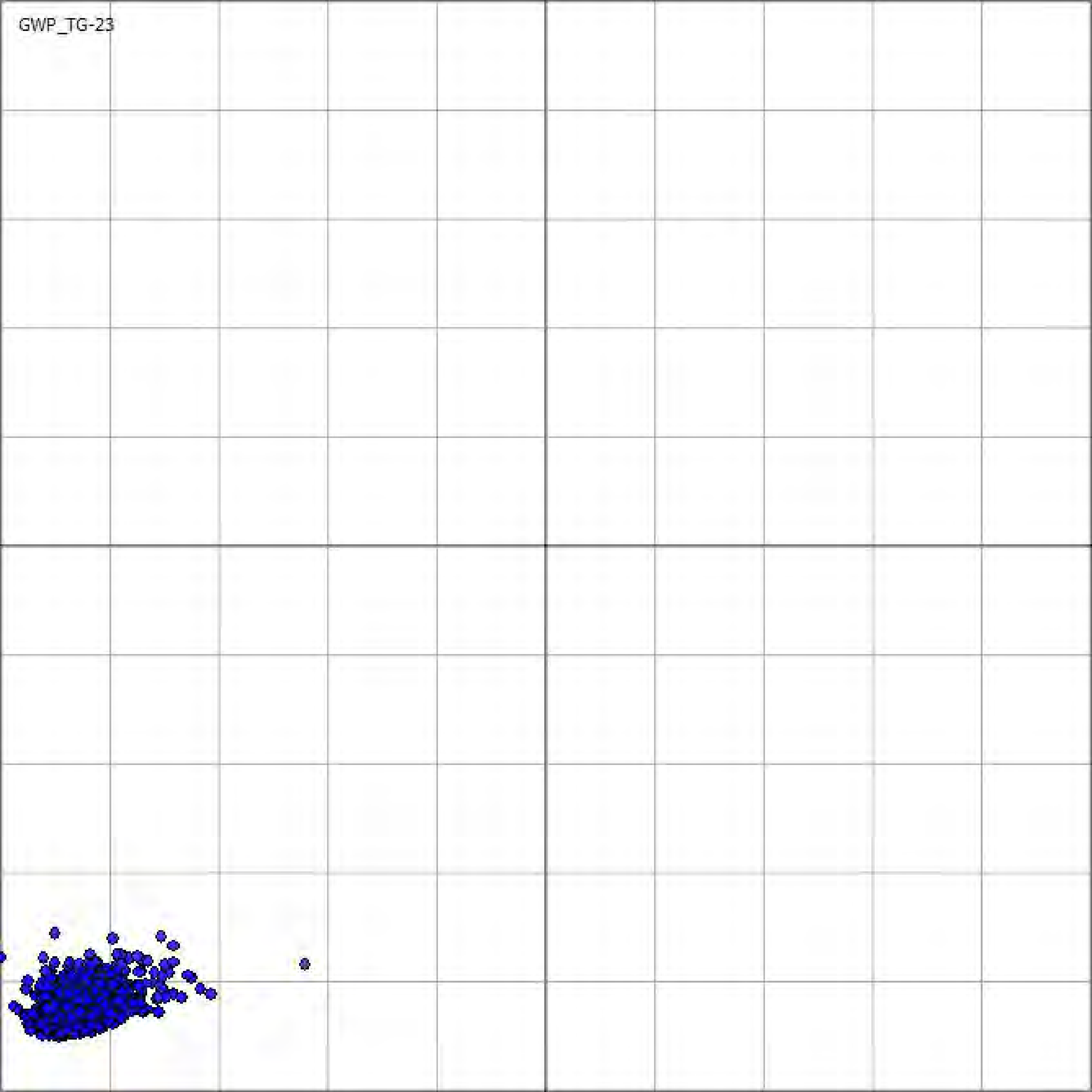

GWP_TG-18B

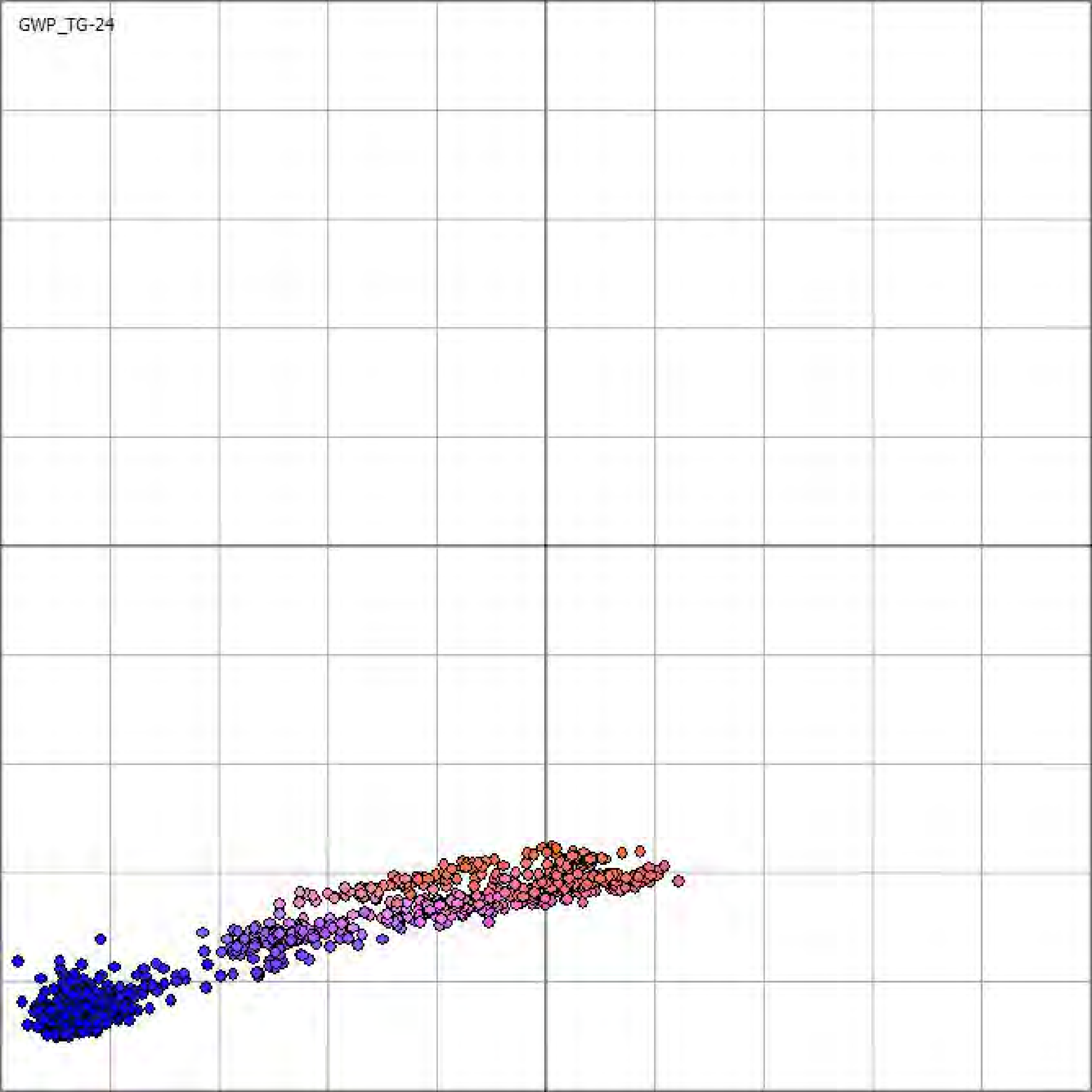

GWP_TG-19

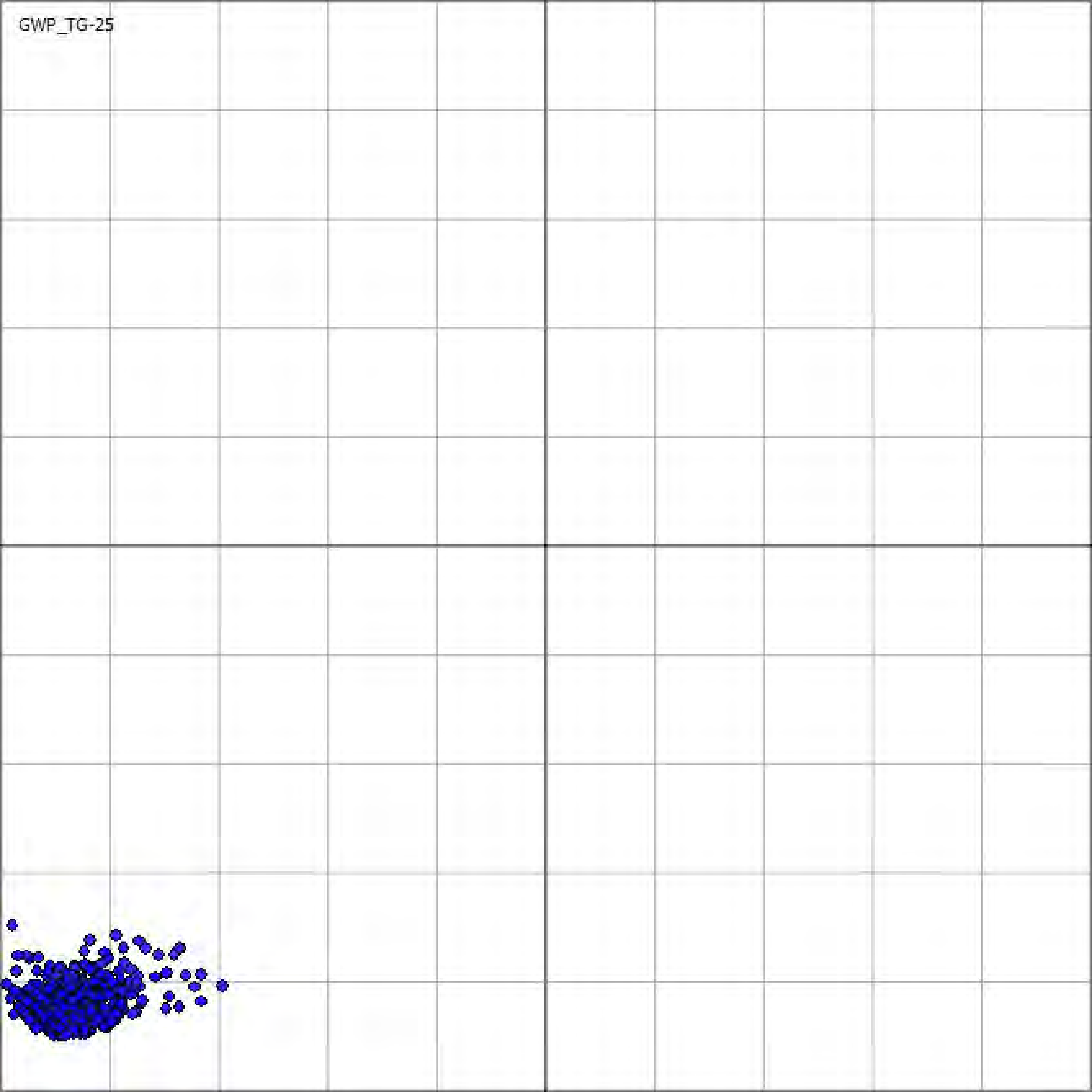

GWP_TG-20

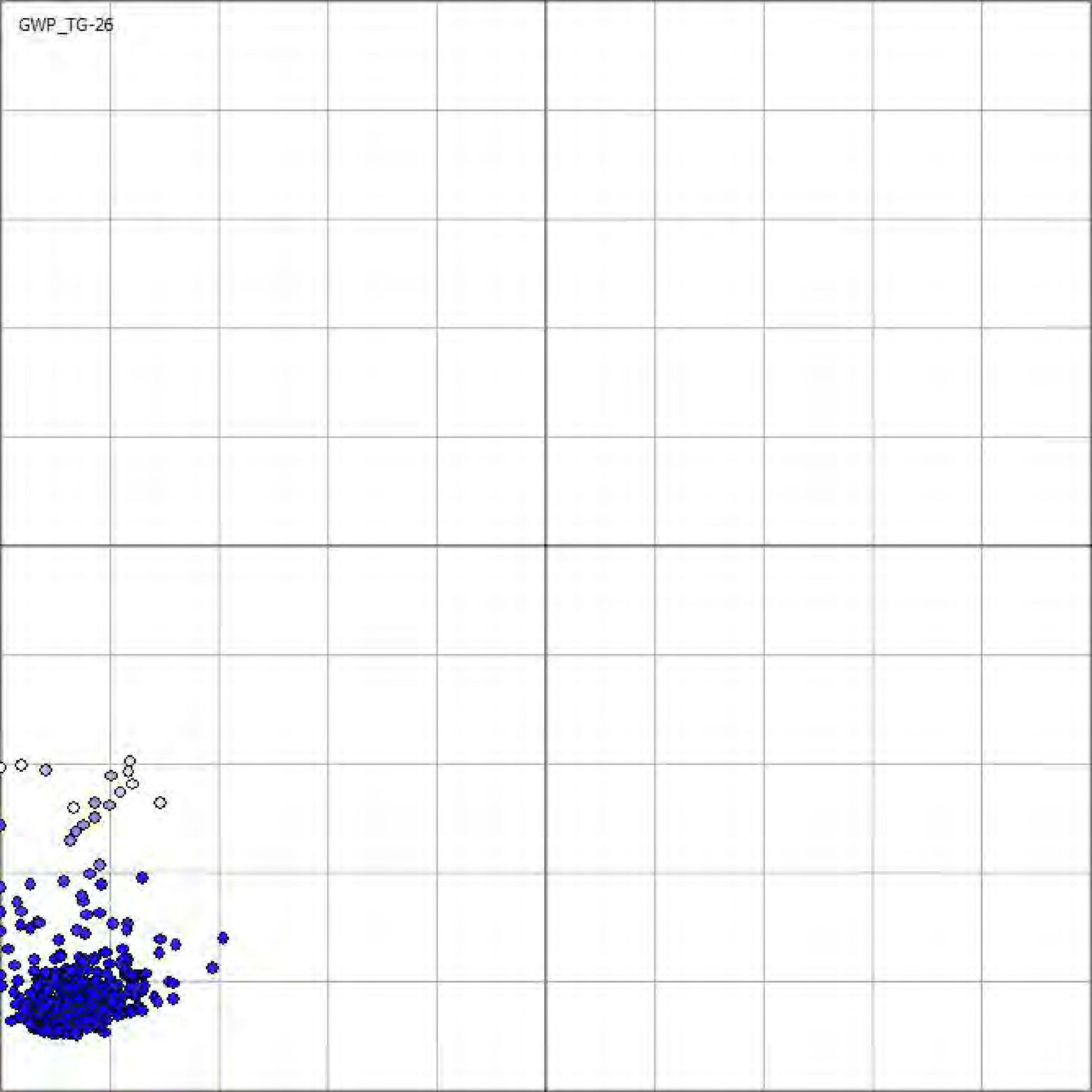

GWP_TG-21

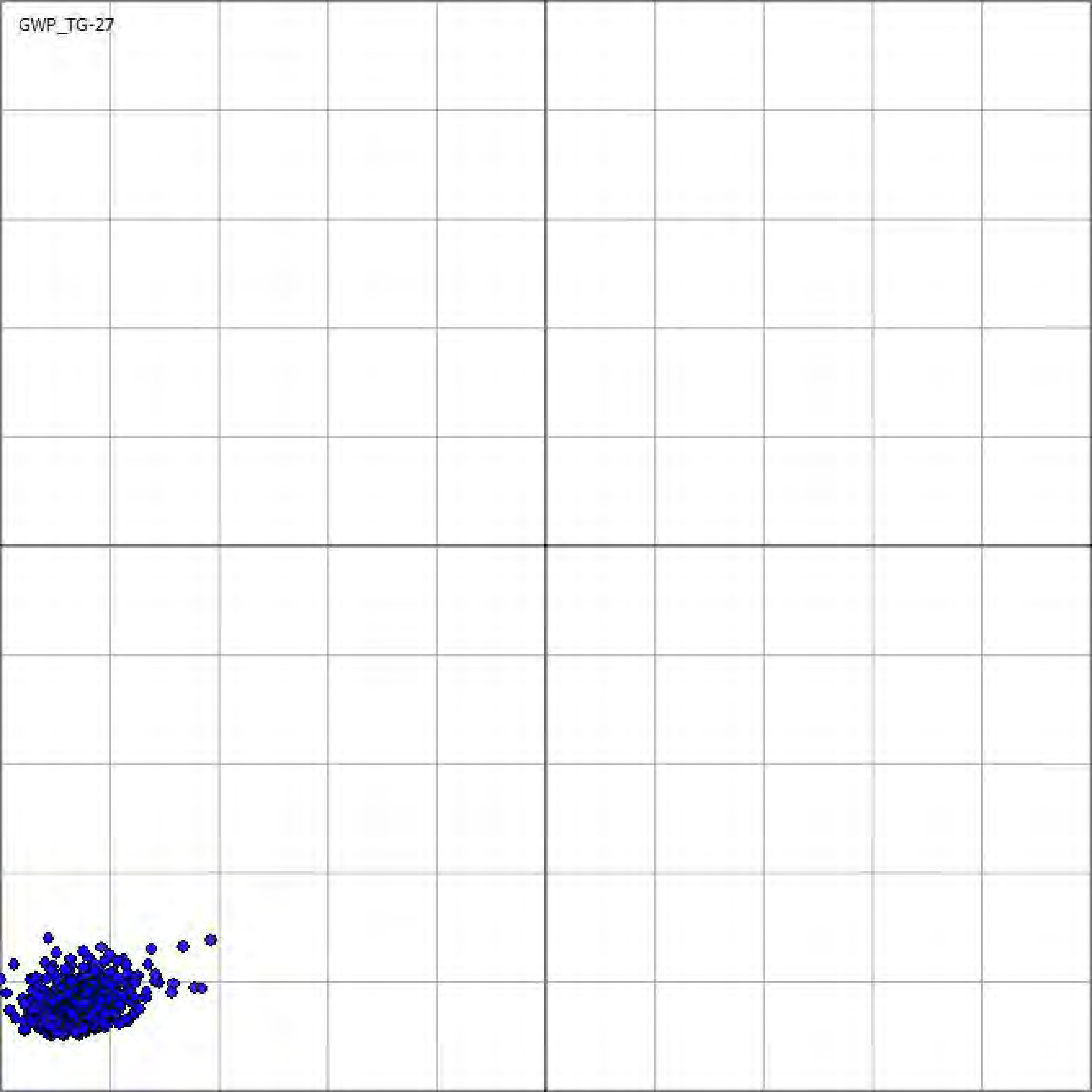

GWP_TG-22

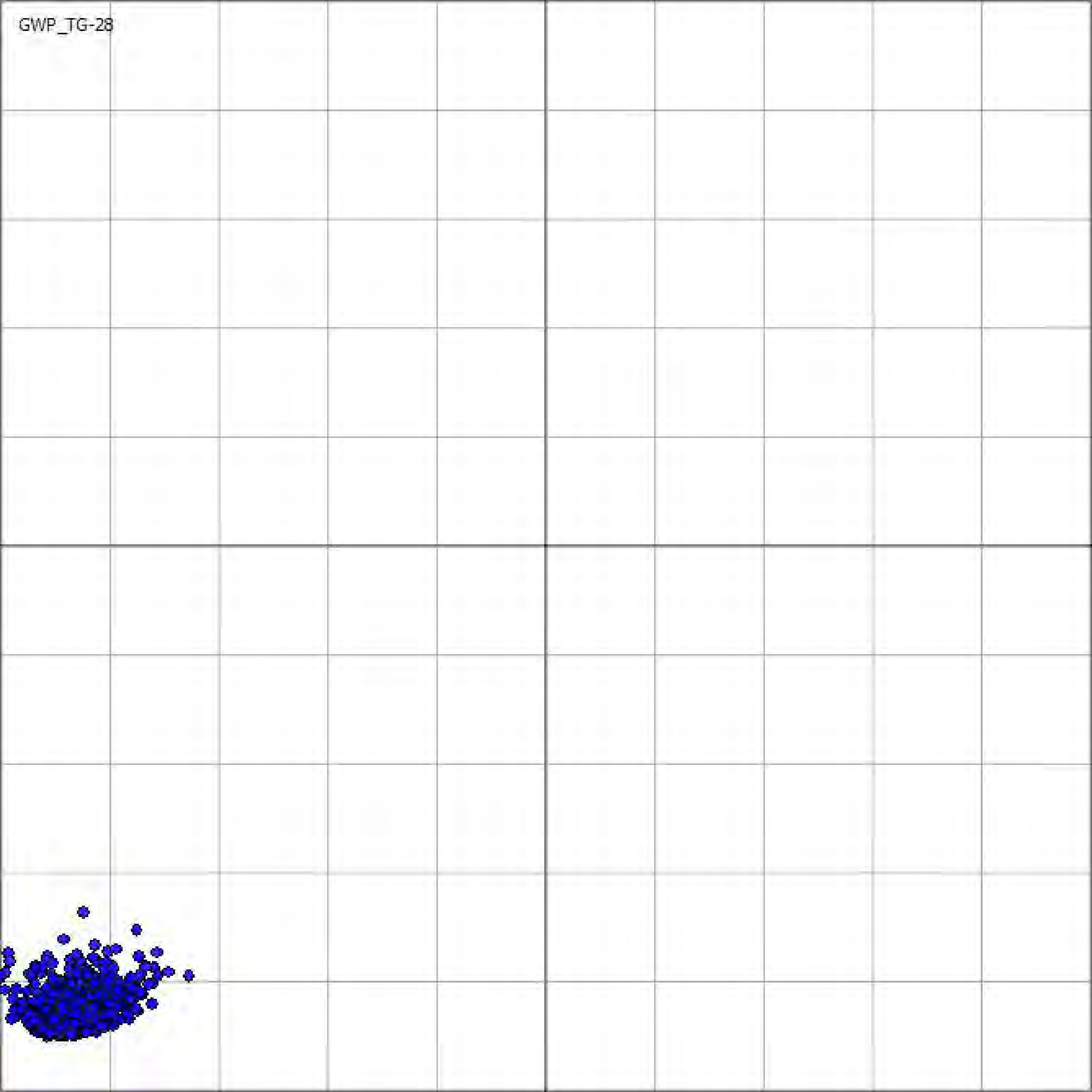

GWP_TG-23

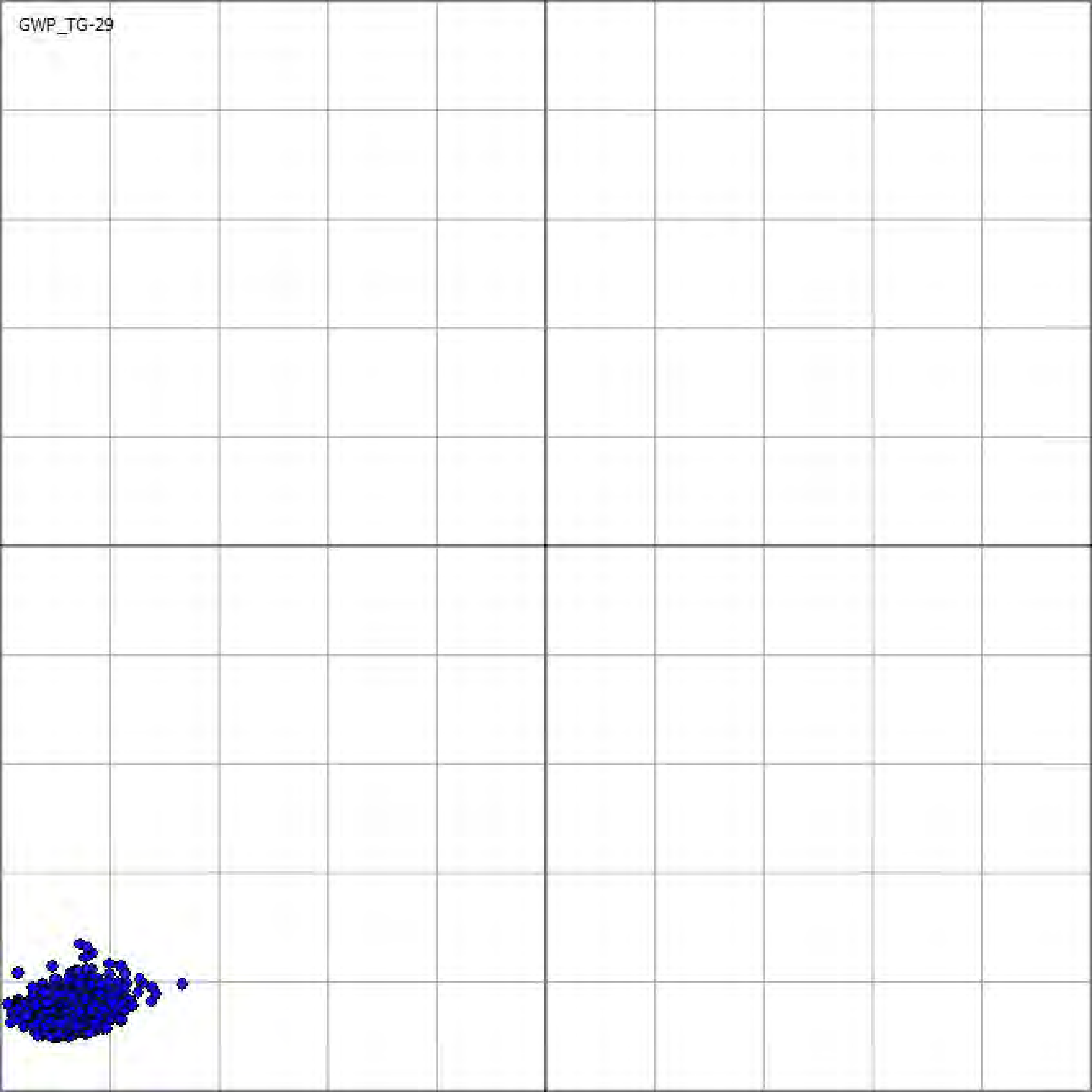

GWP_TG-24

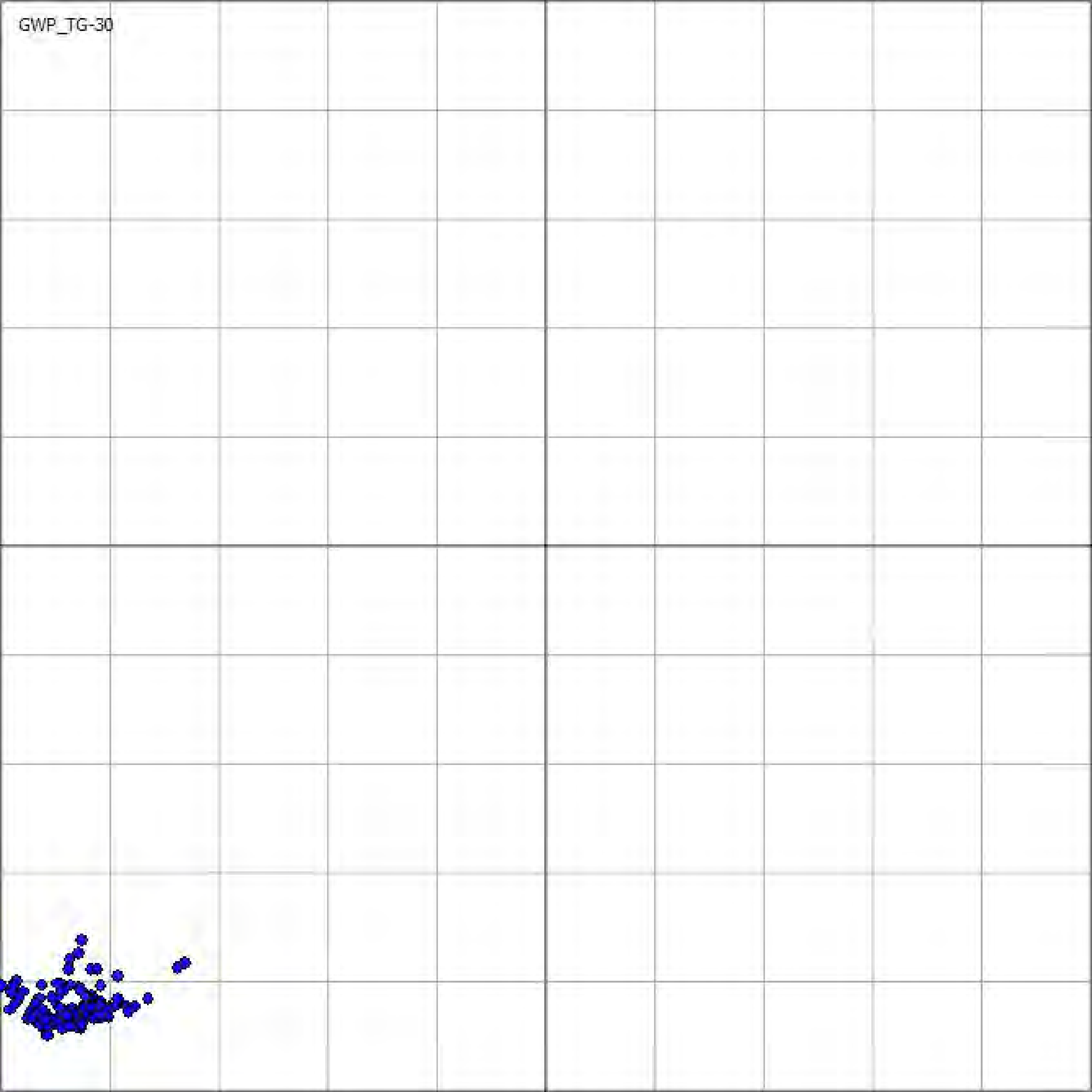

GWP_TG-25

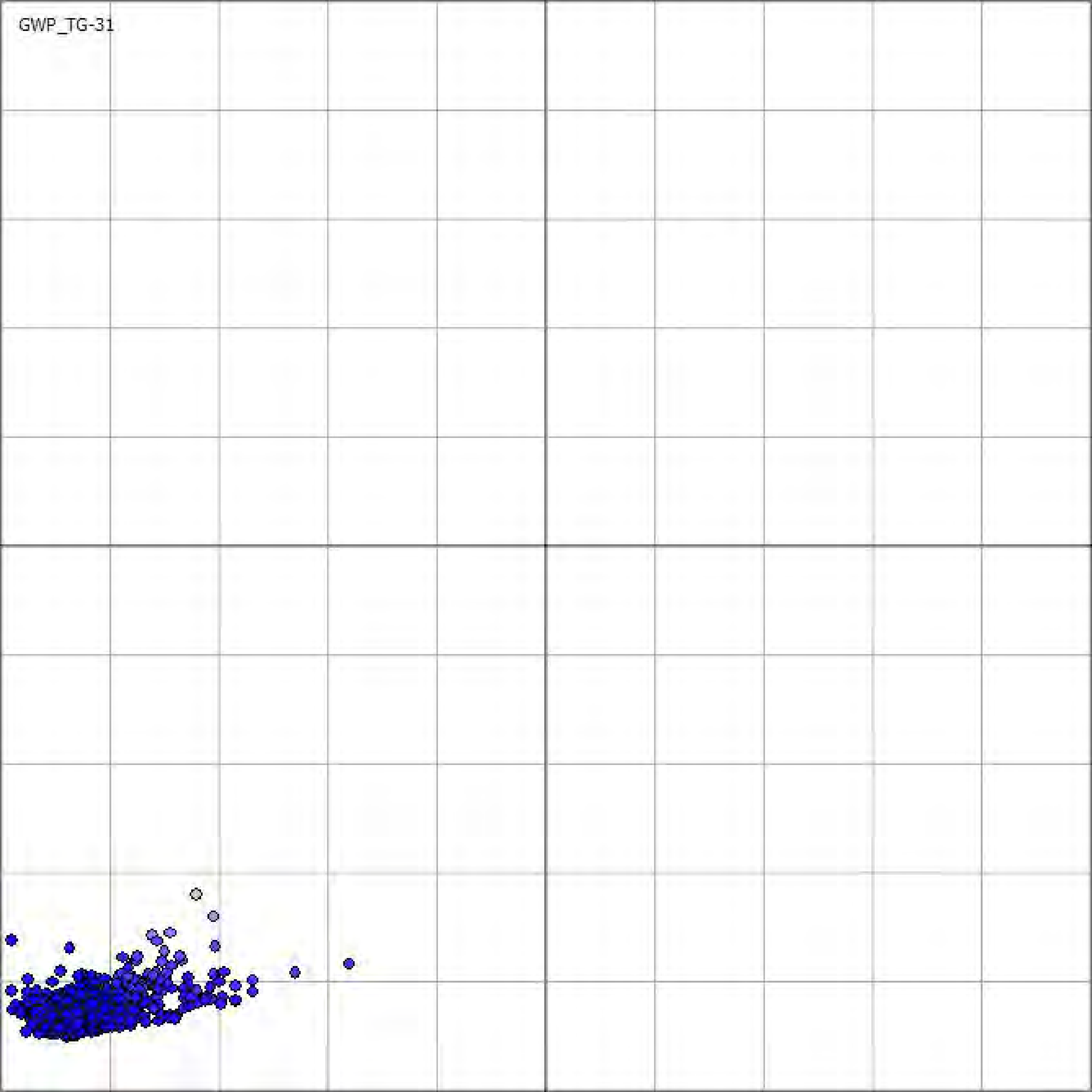

GWP_TG-26

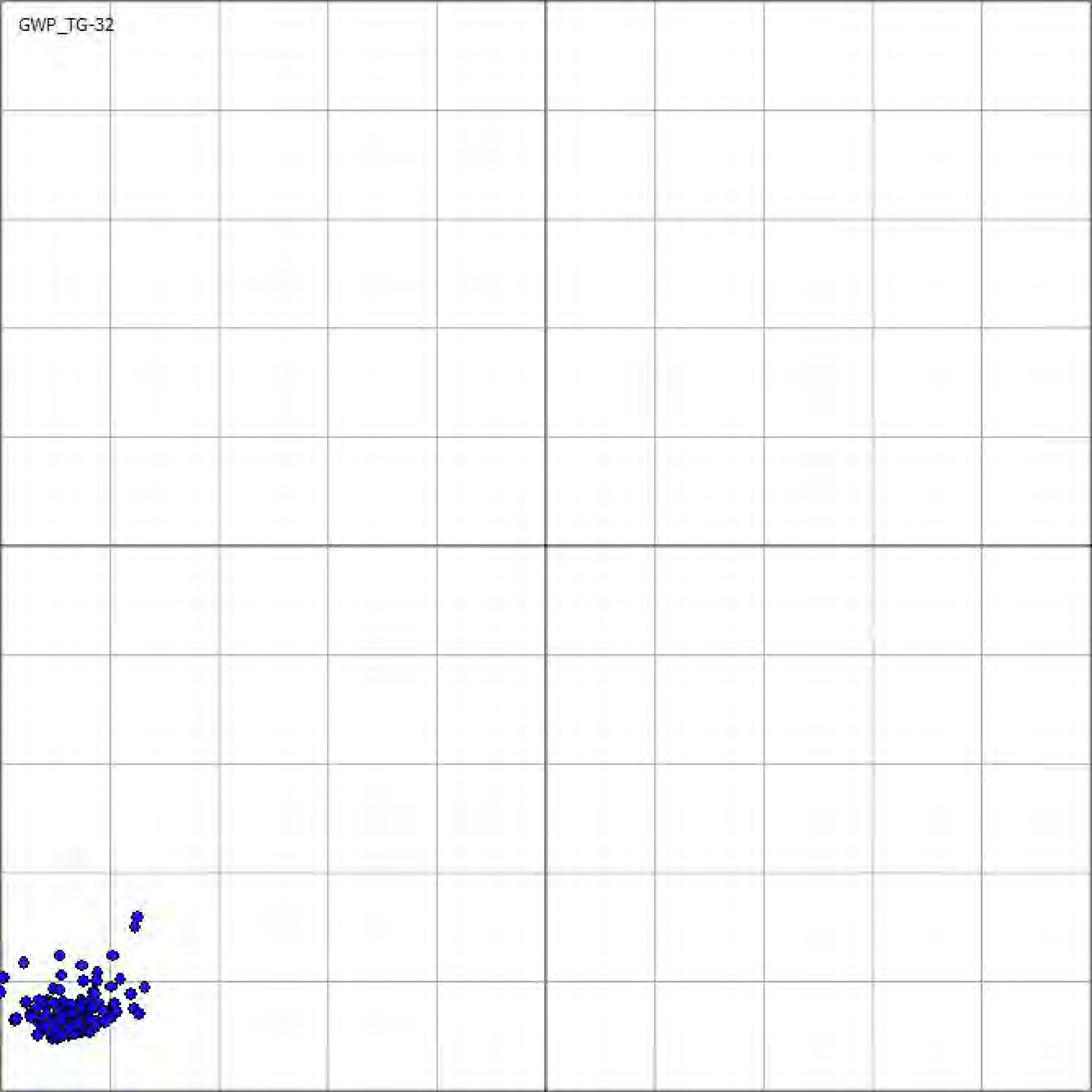

GWP_TG-27

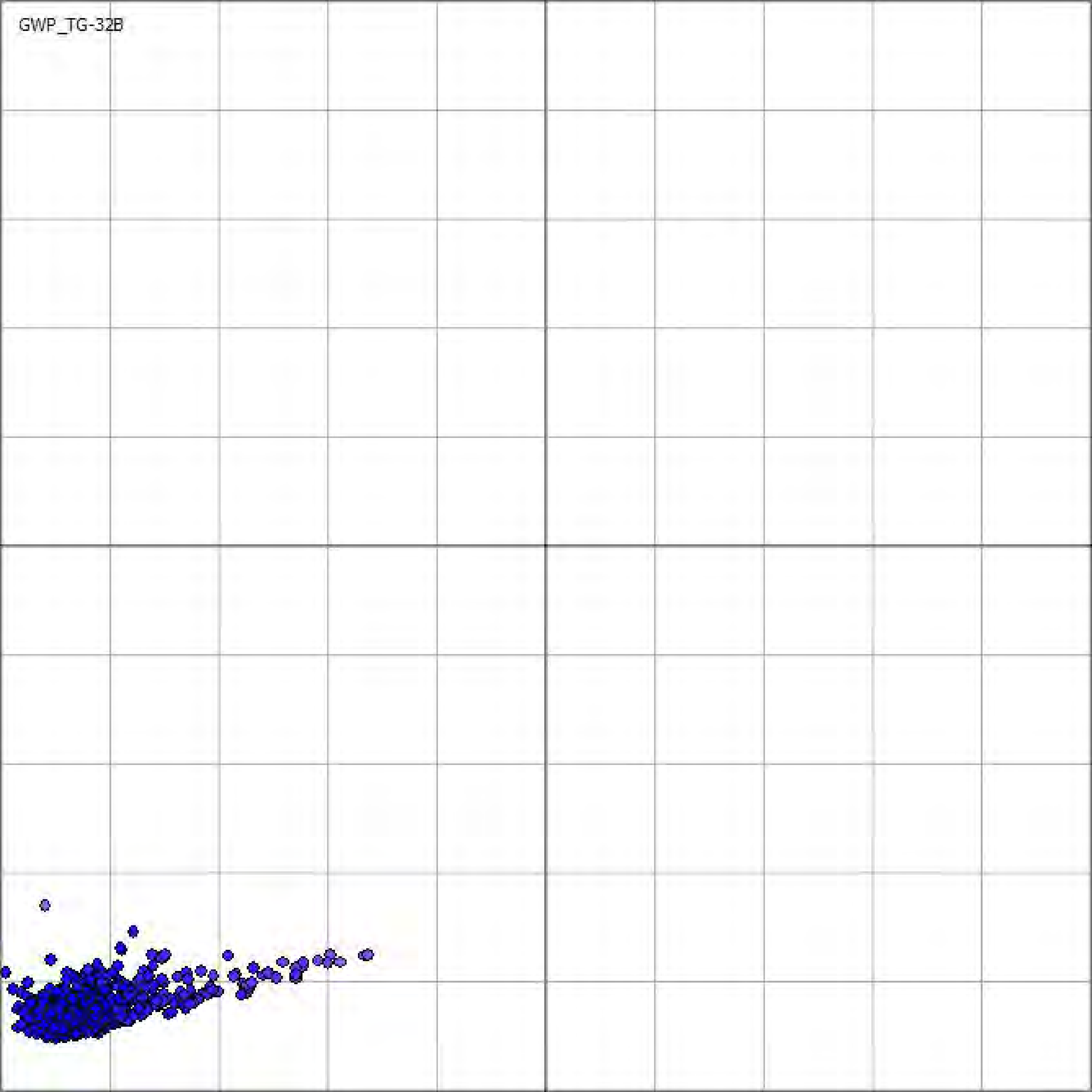

GWP_TG-28

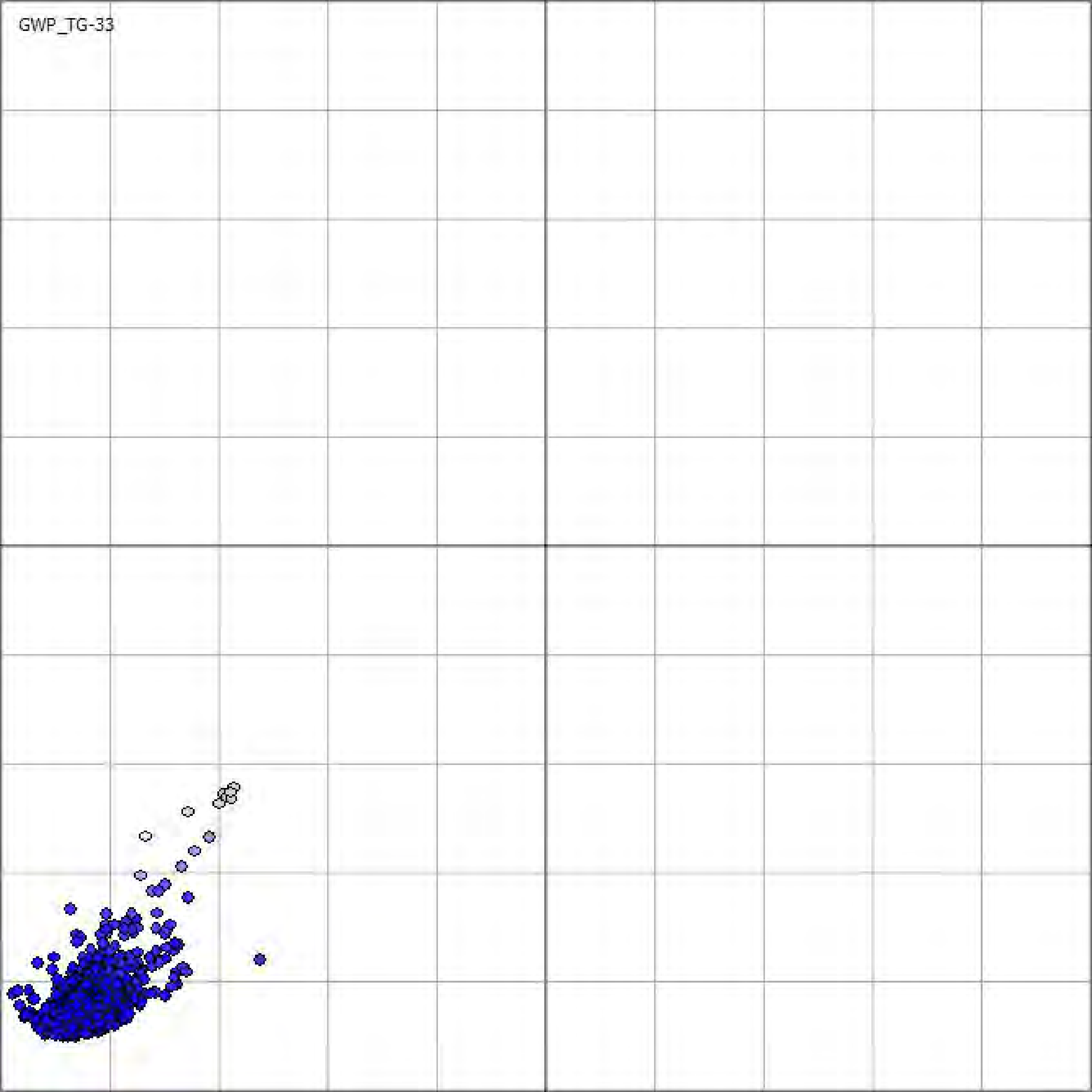

GWP_TG-29

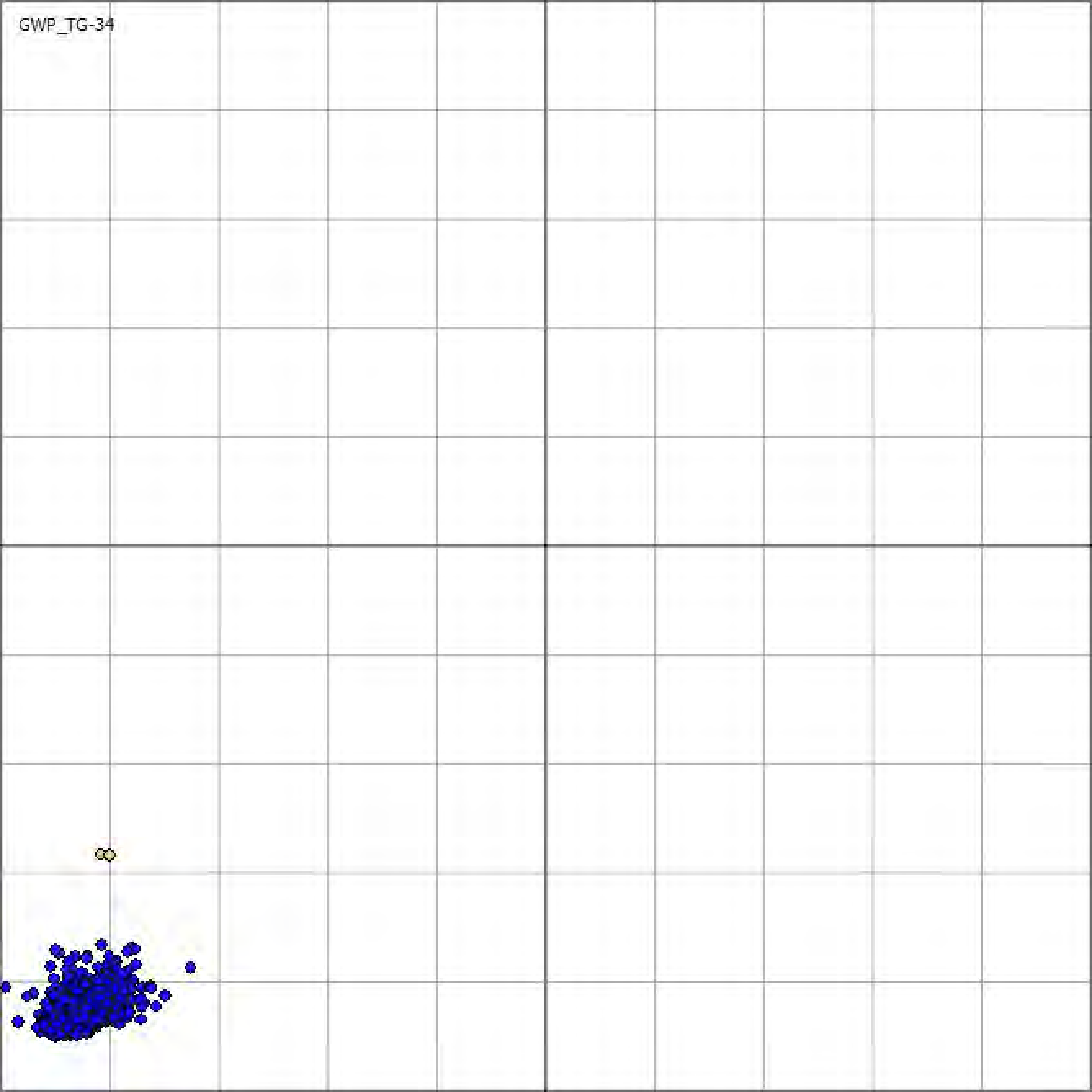

GWP_TG-30

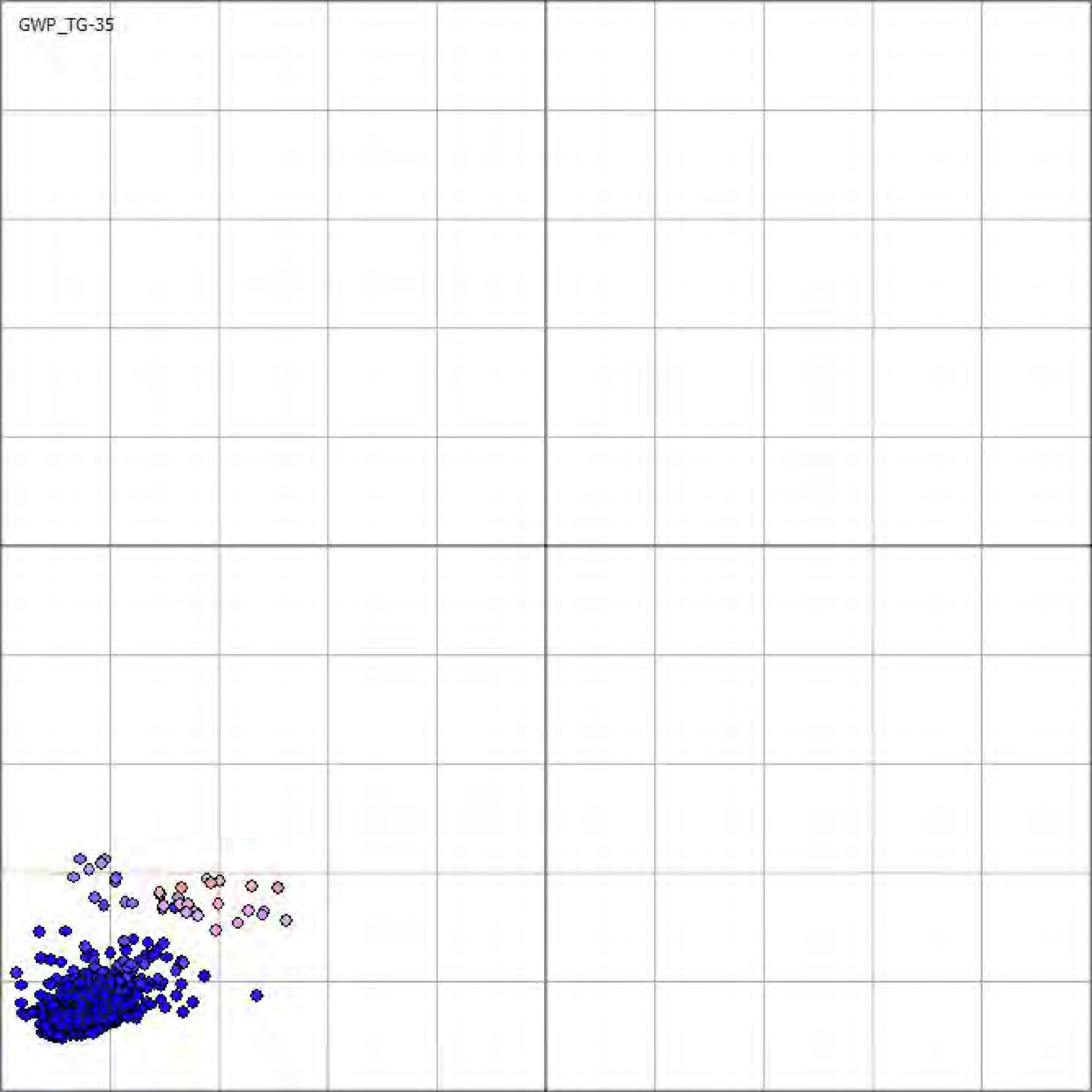

GWP_TG-31

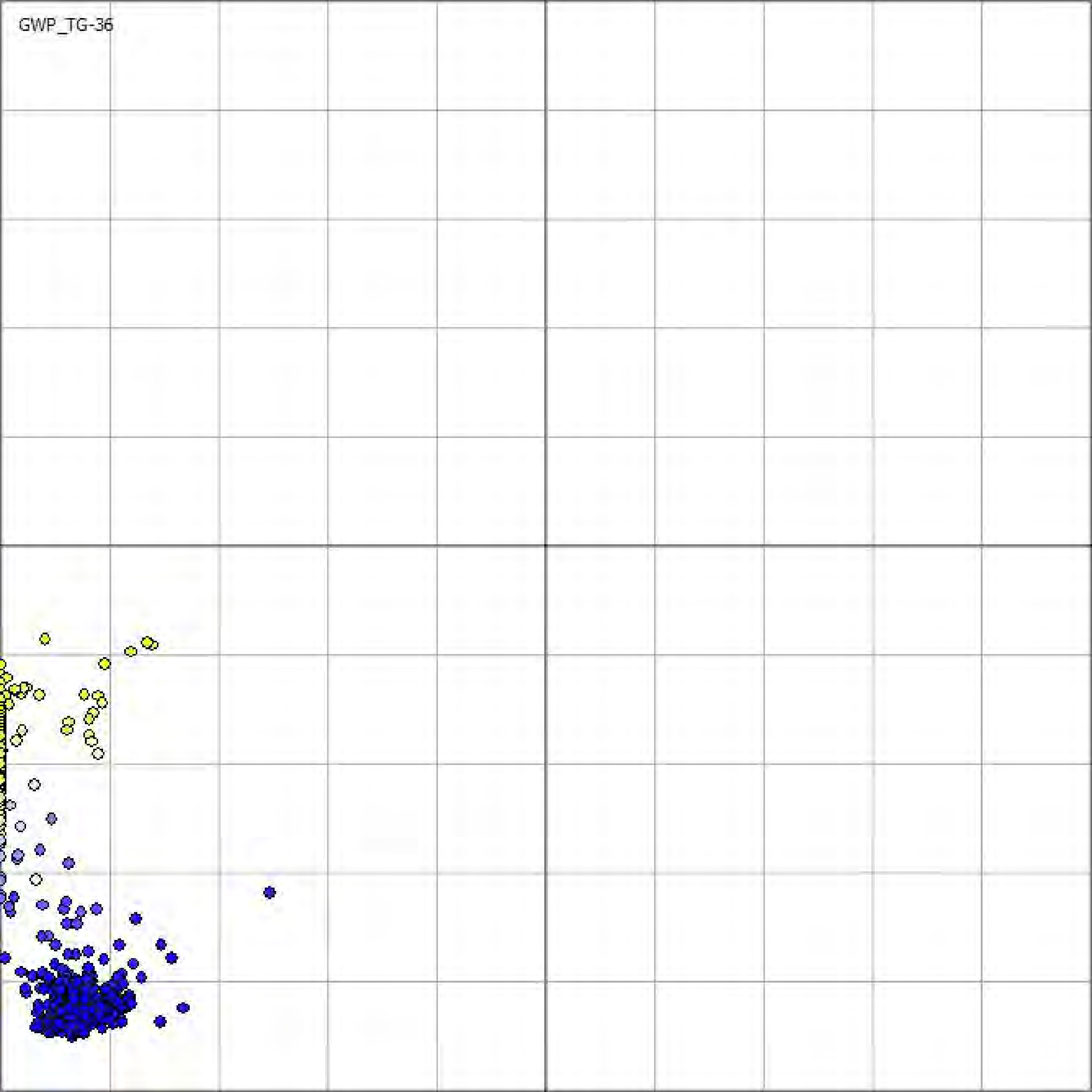

GWP_TG-32

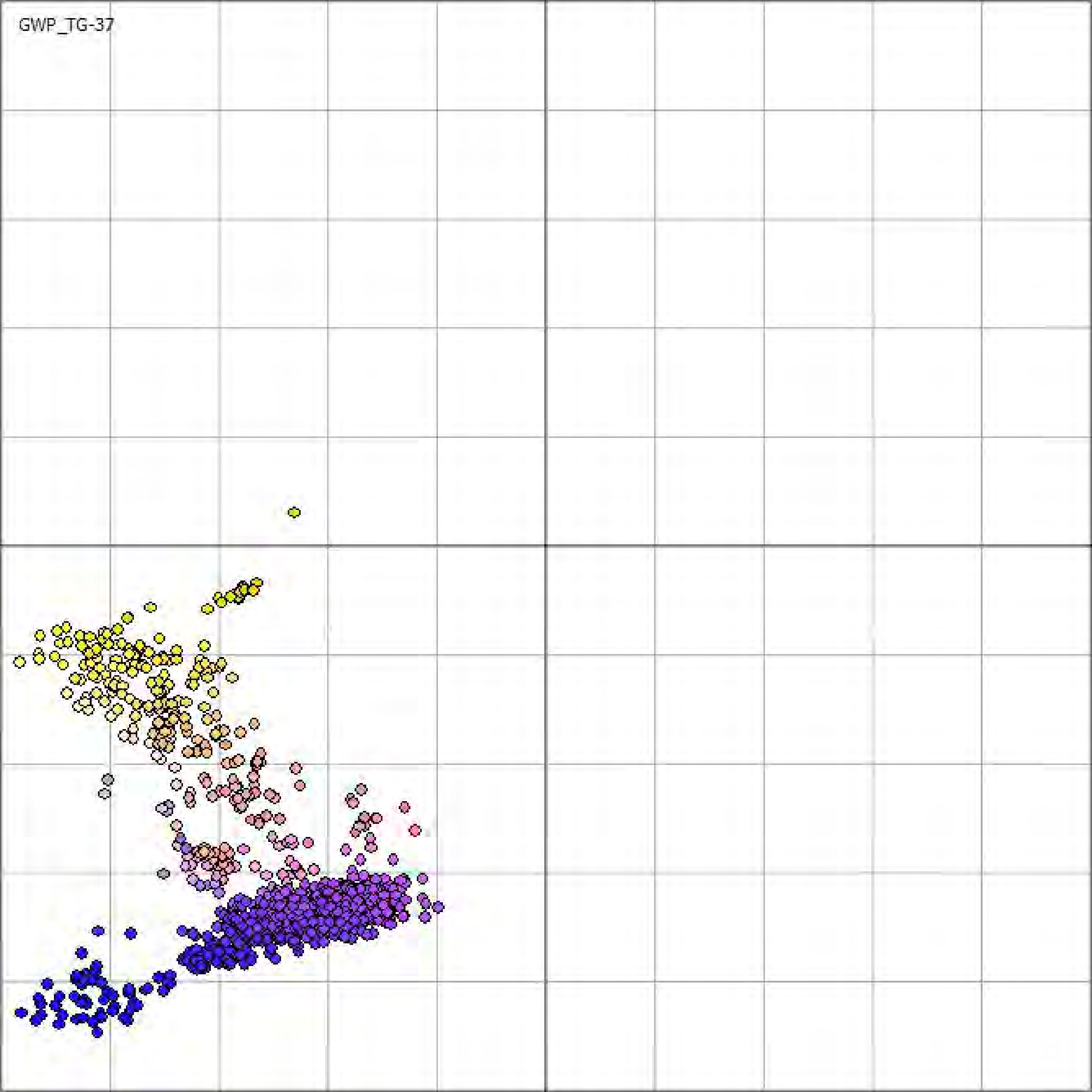

GWP_TG-32B

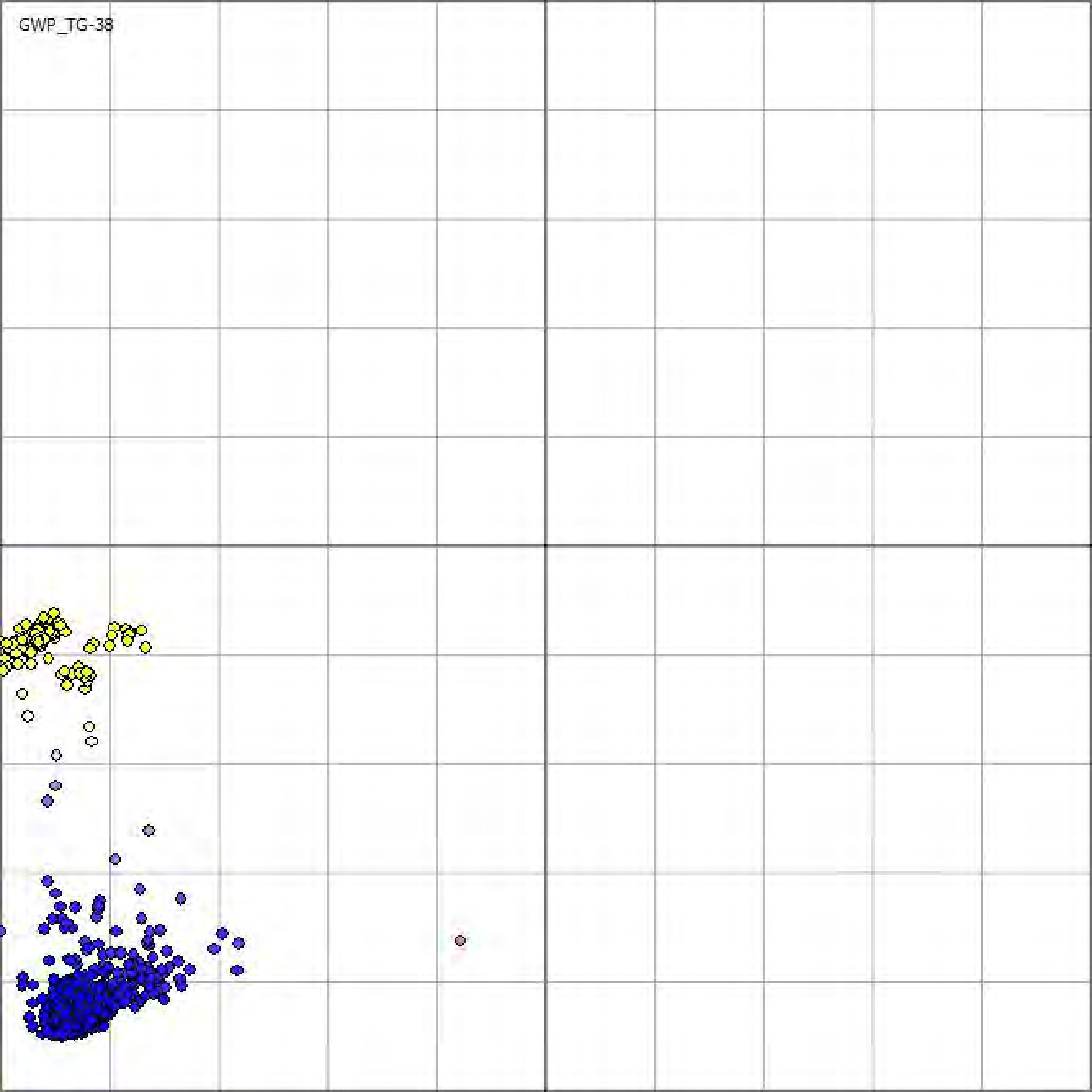

GWP_TG-33

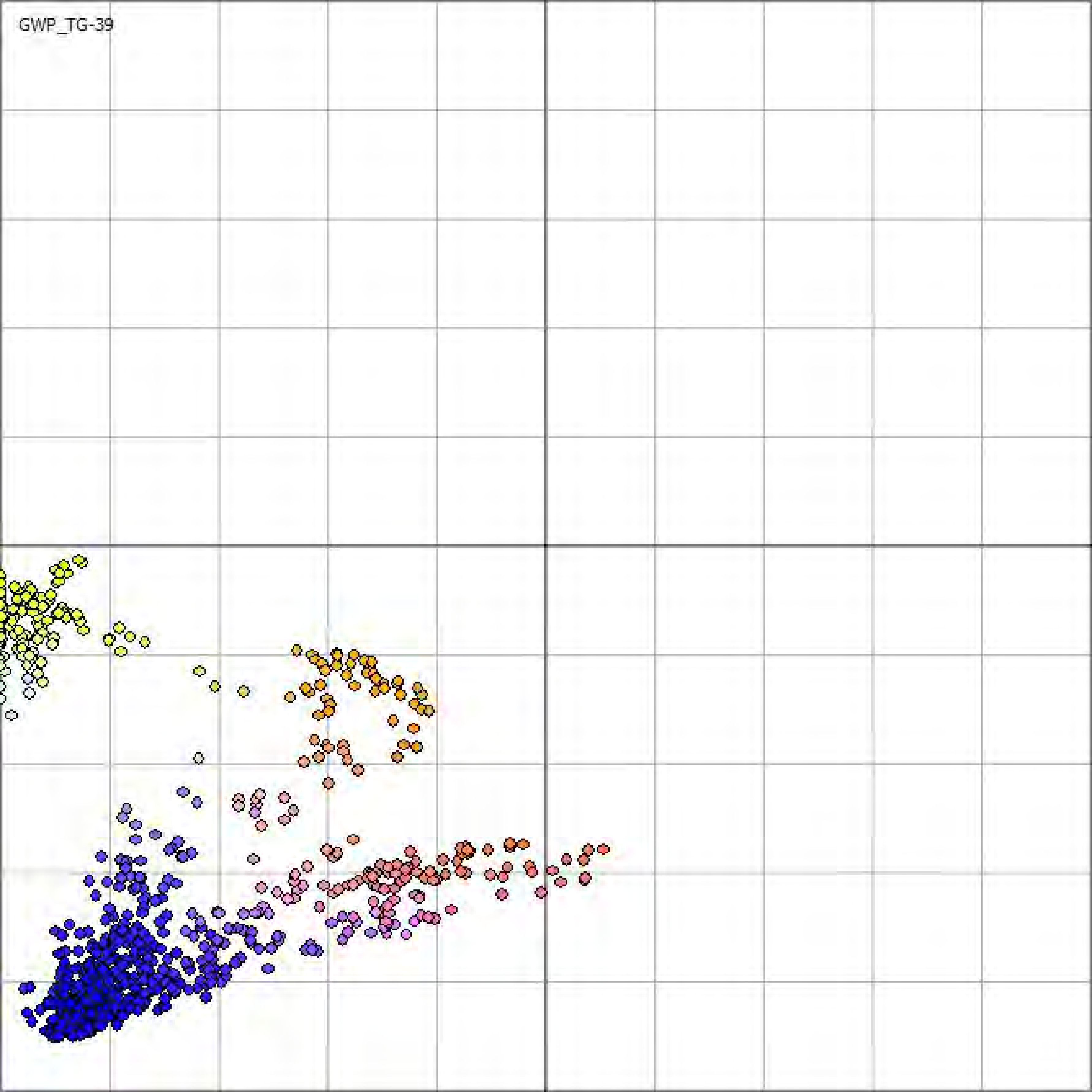

GWP_TG-34

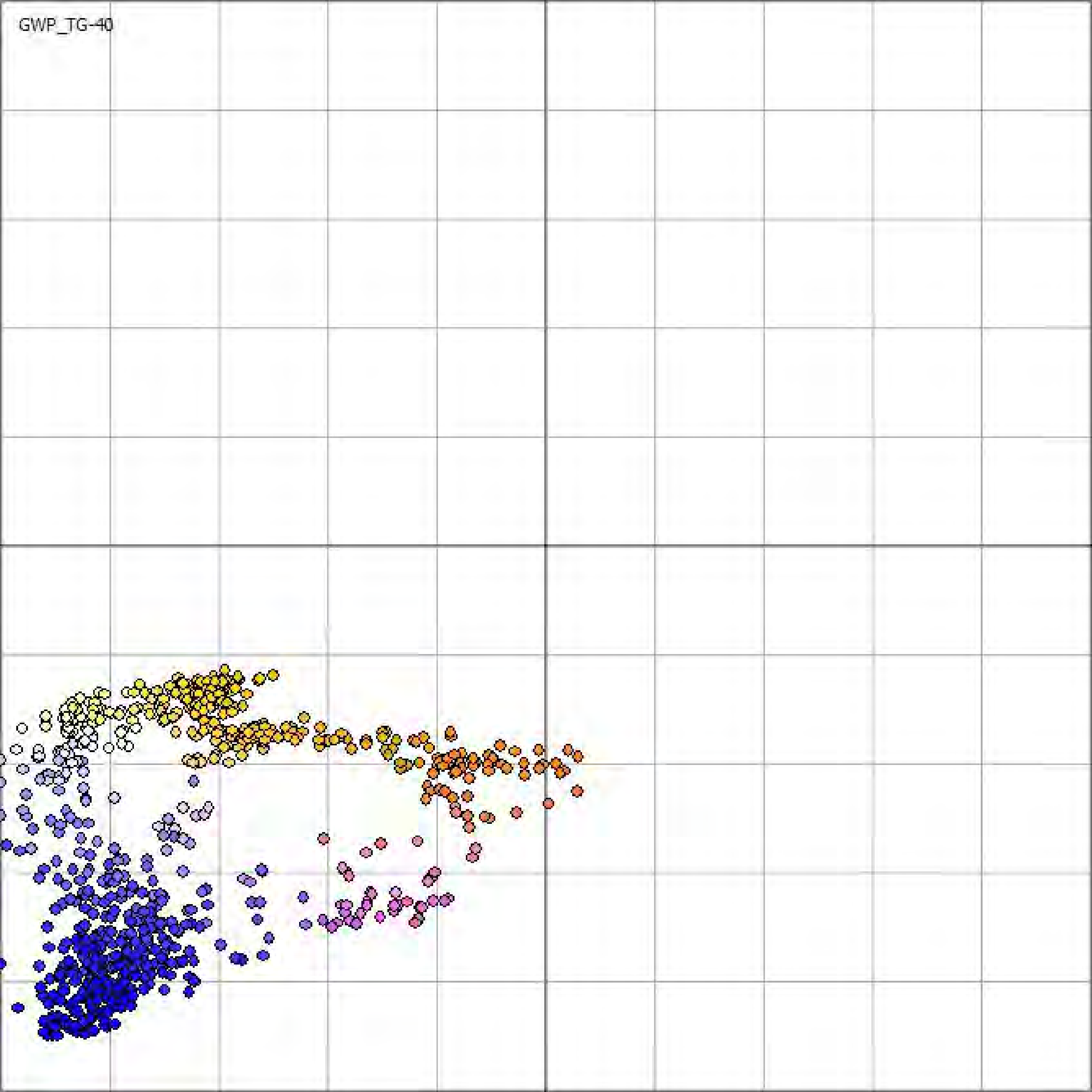

GWP_TG-35

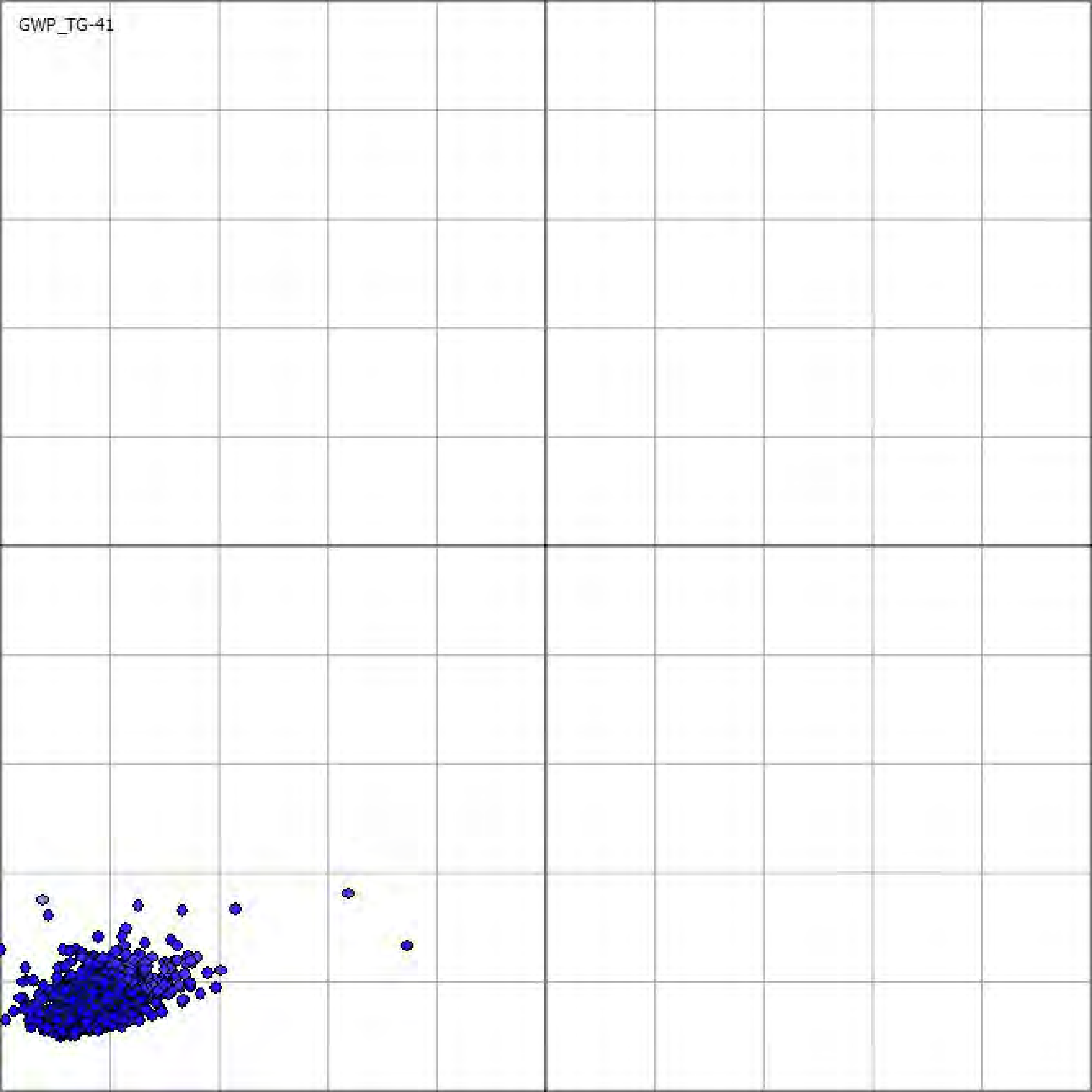

GWP_TG-36

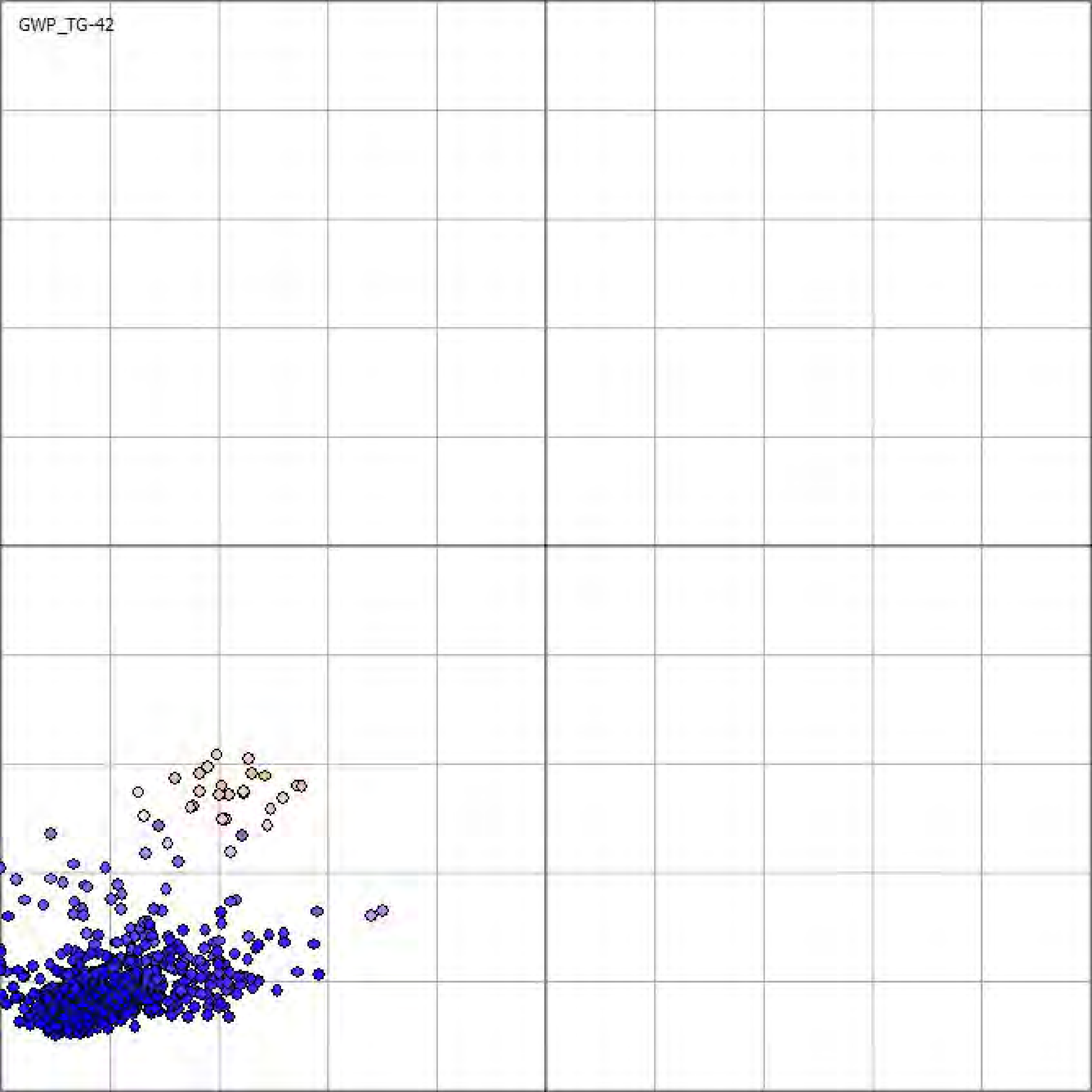

GWP_TG-37

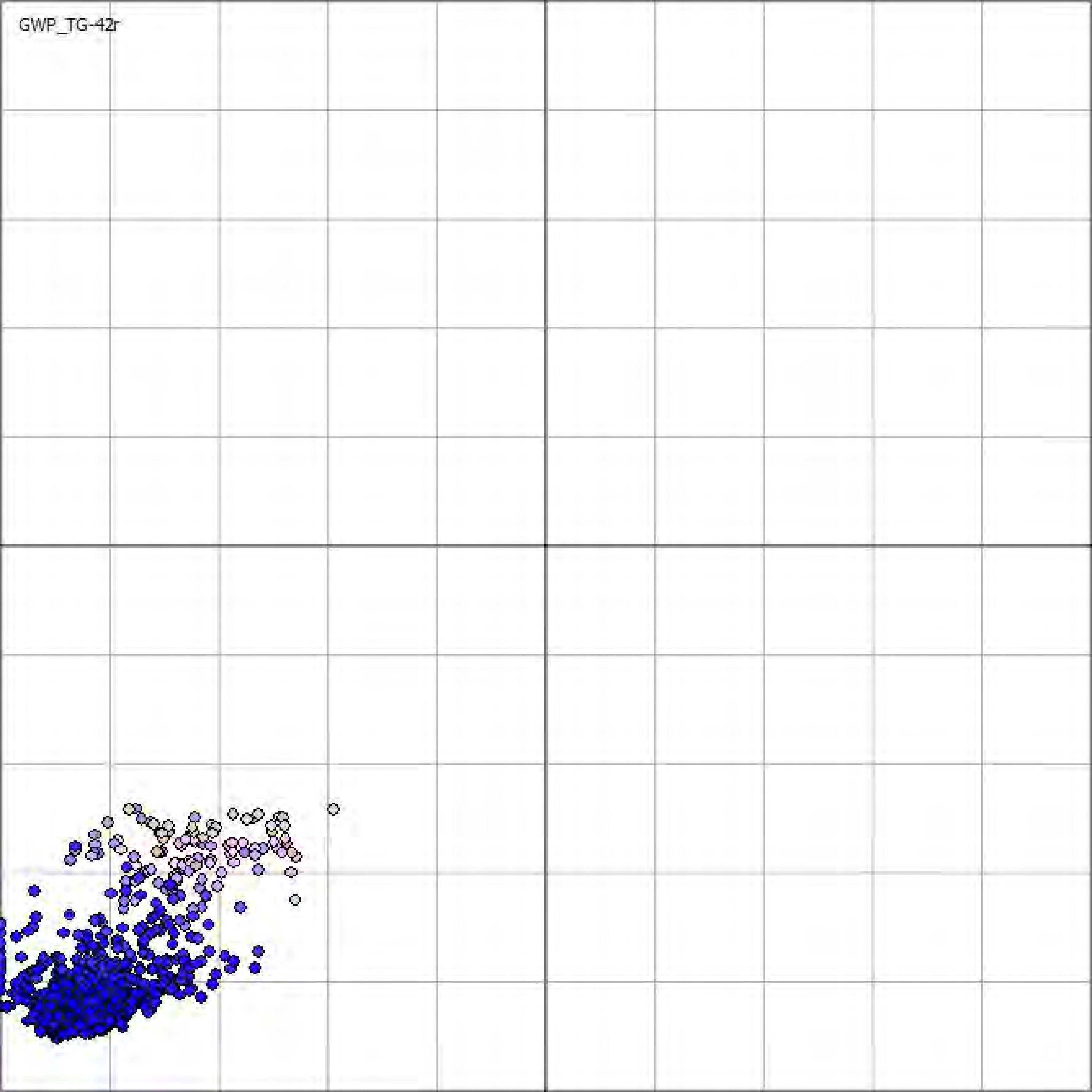

GWP_TG-38

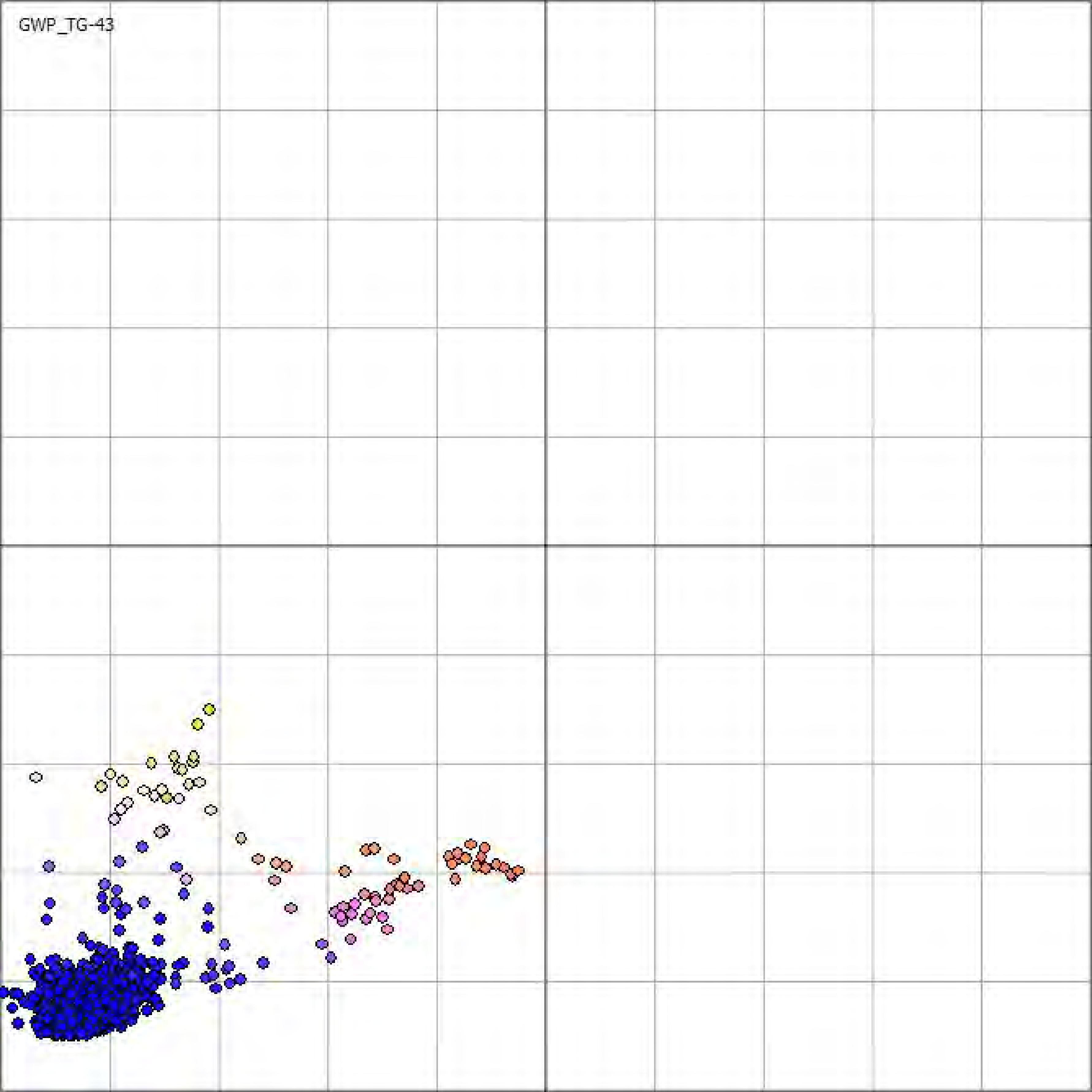

GWP_TG-39

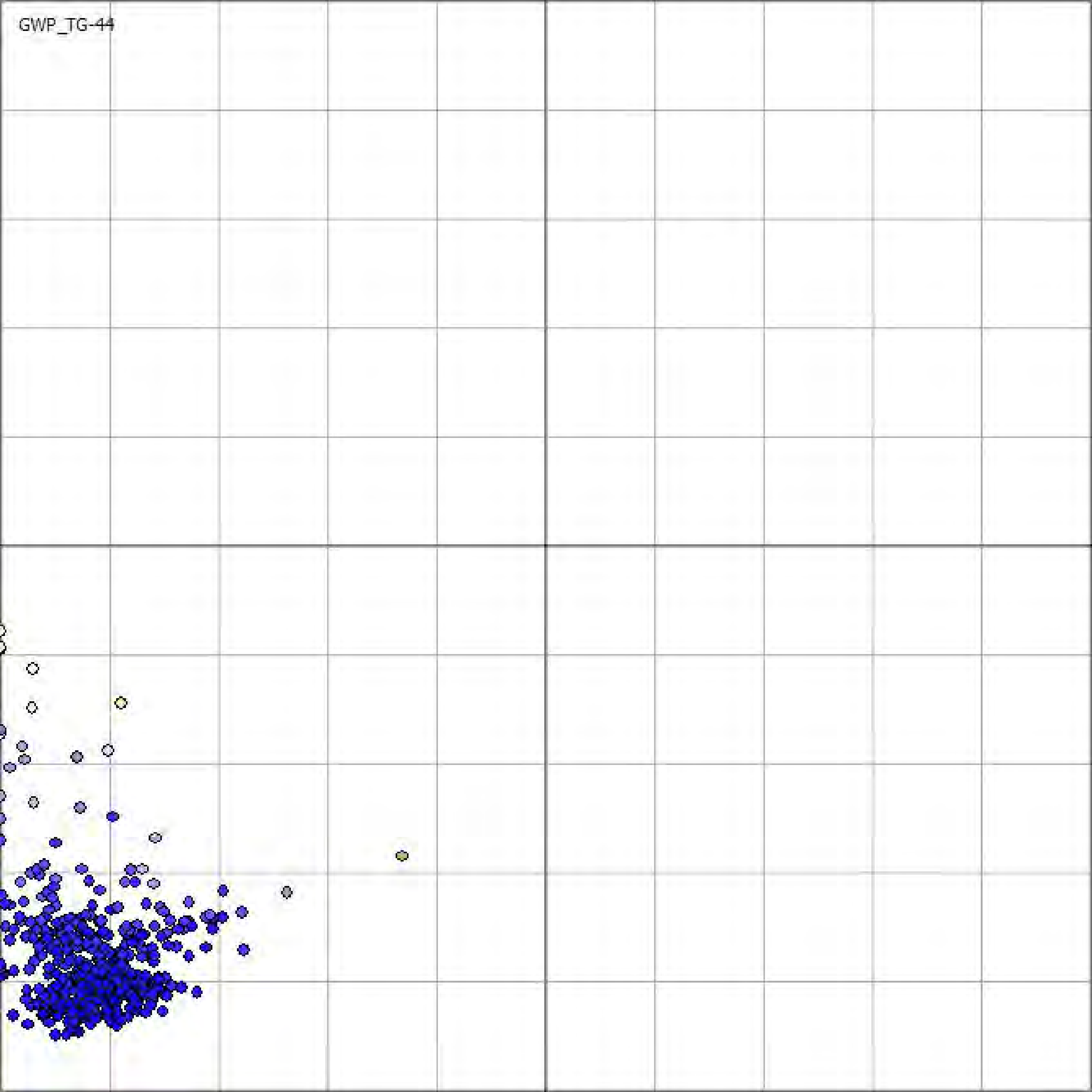

GWP_TG-40

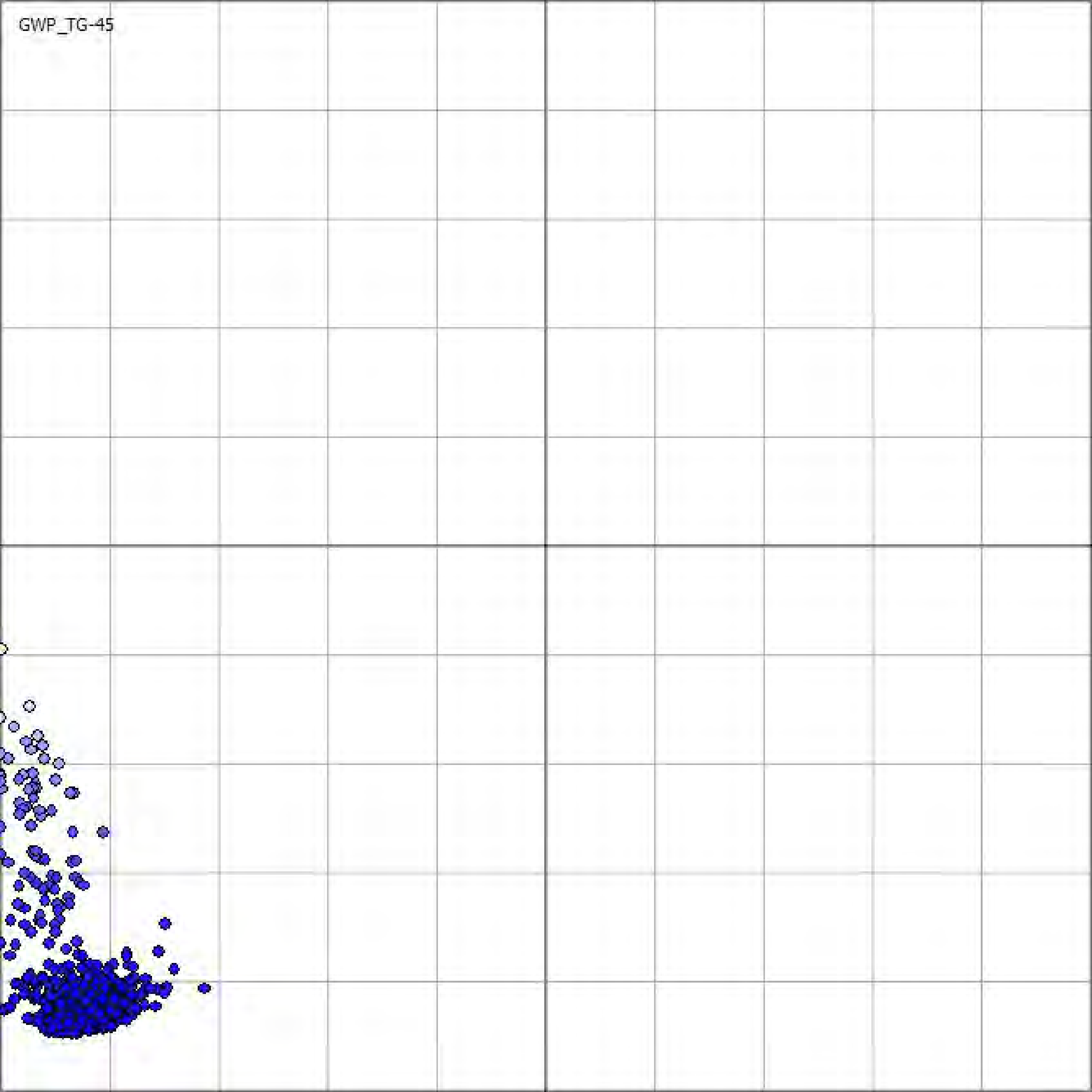

GWP_TG-41

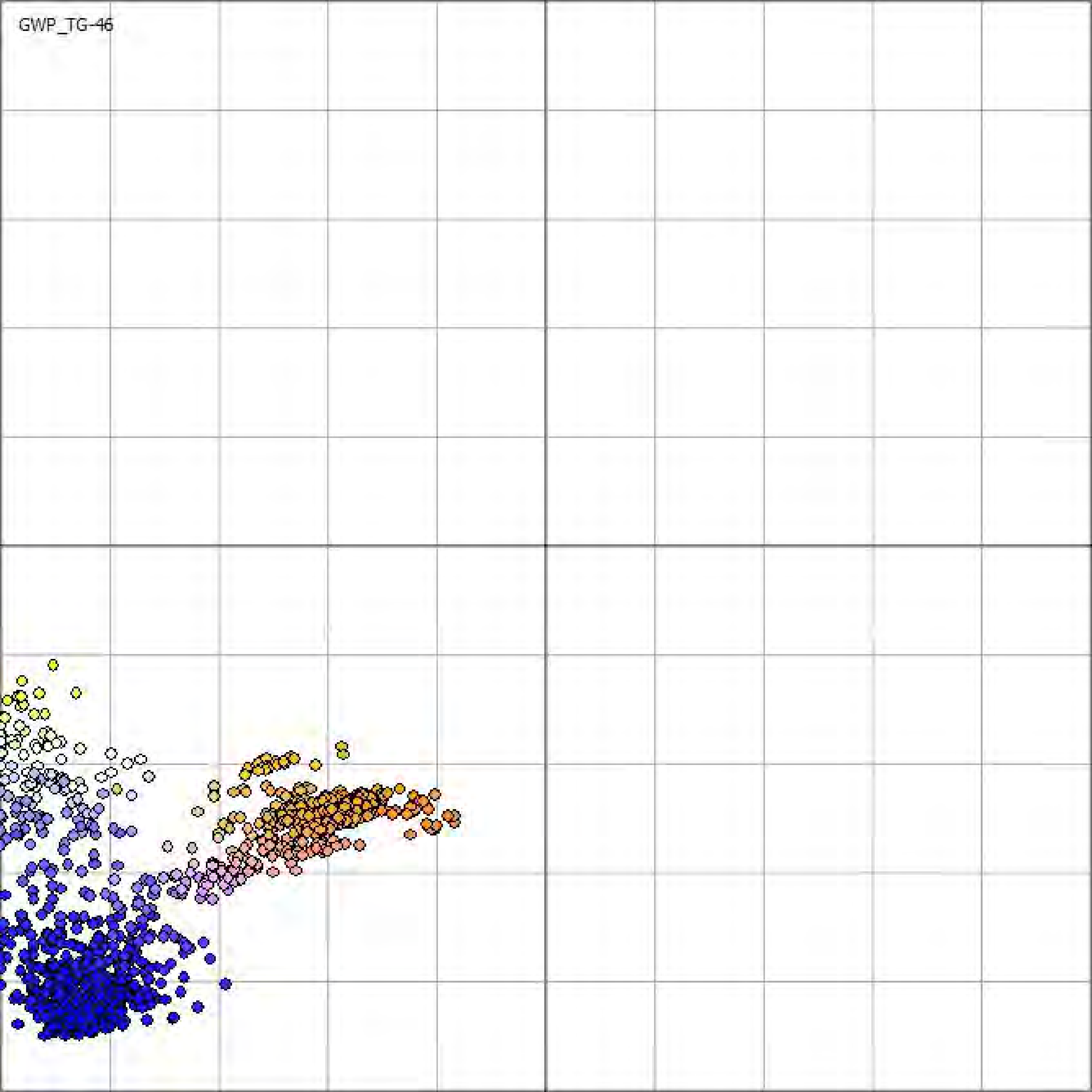

GWP_TG-42


GWP_TG-42r

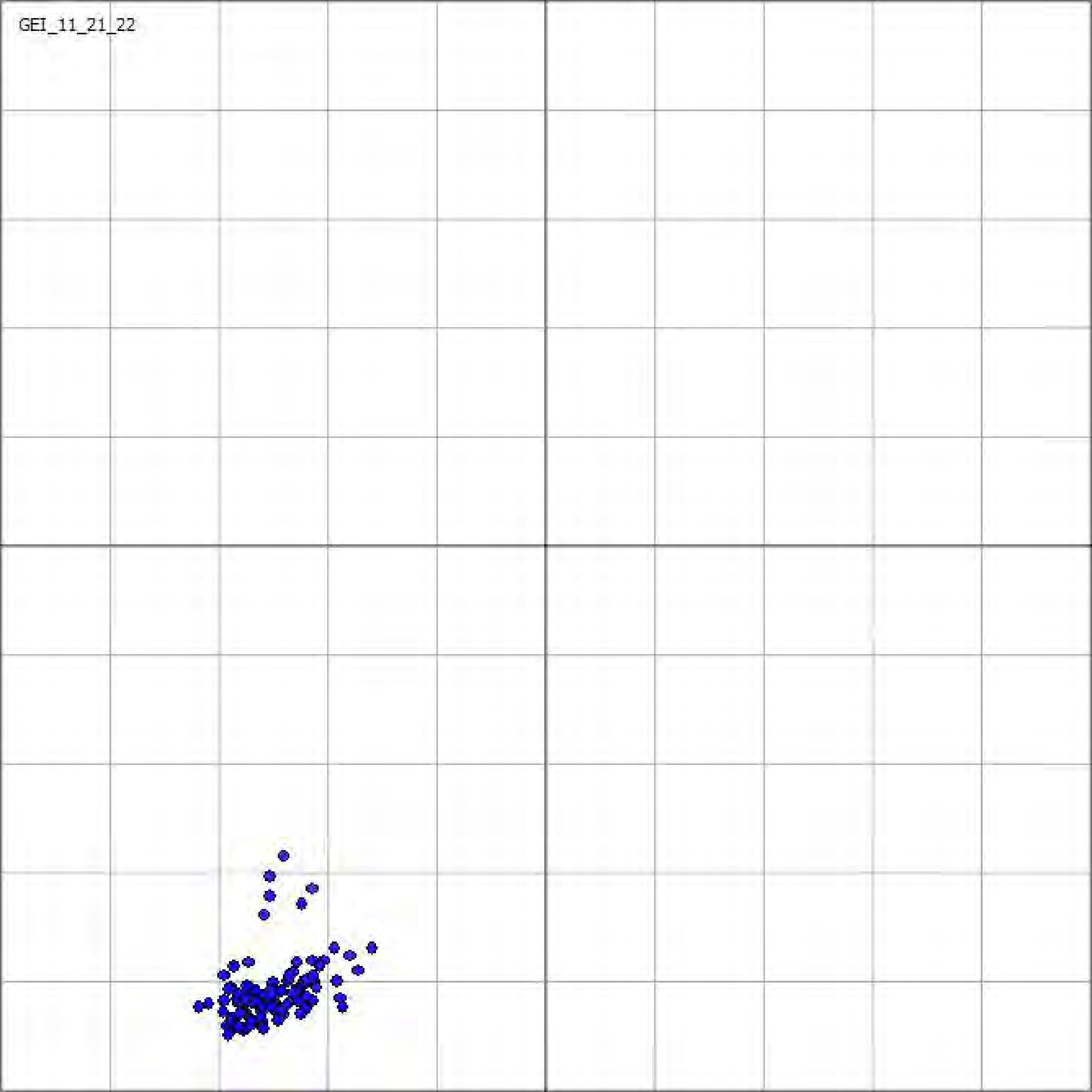

GWP_TG-43

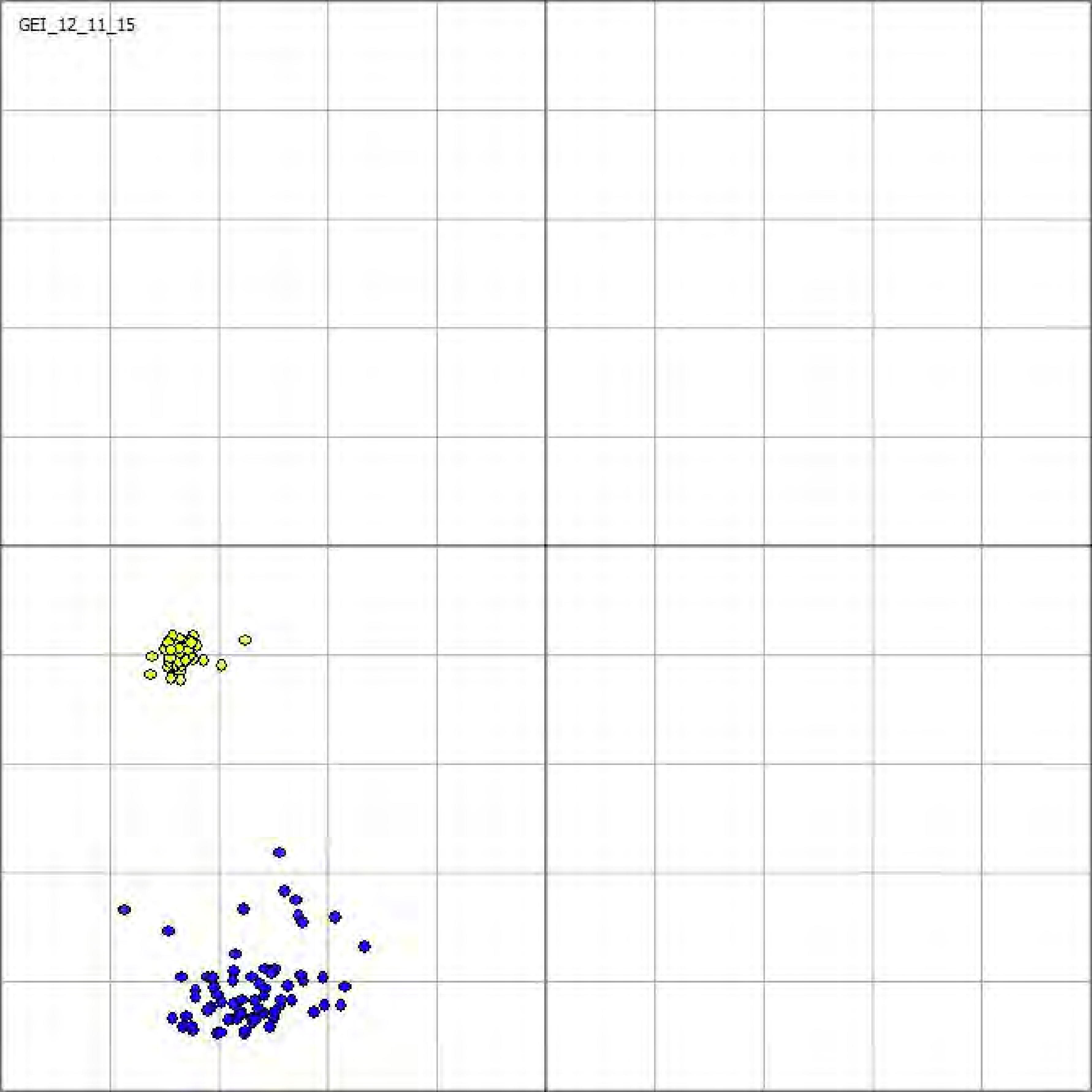

GWP_TG-44

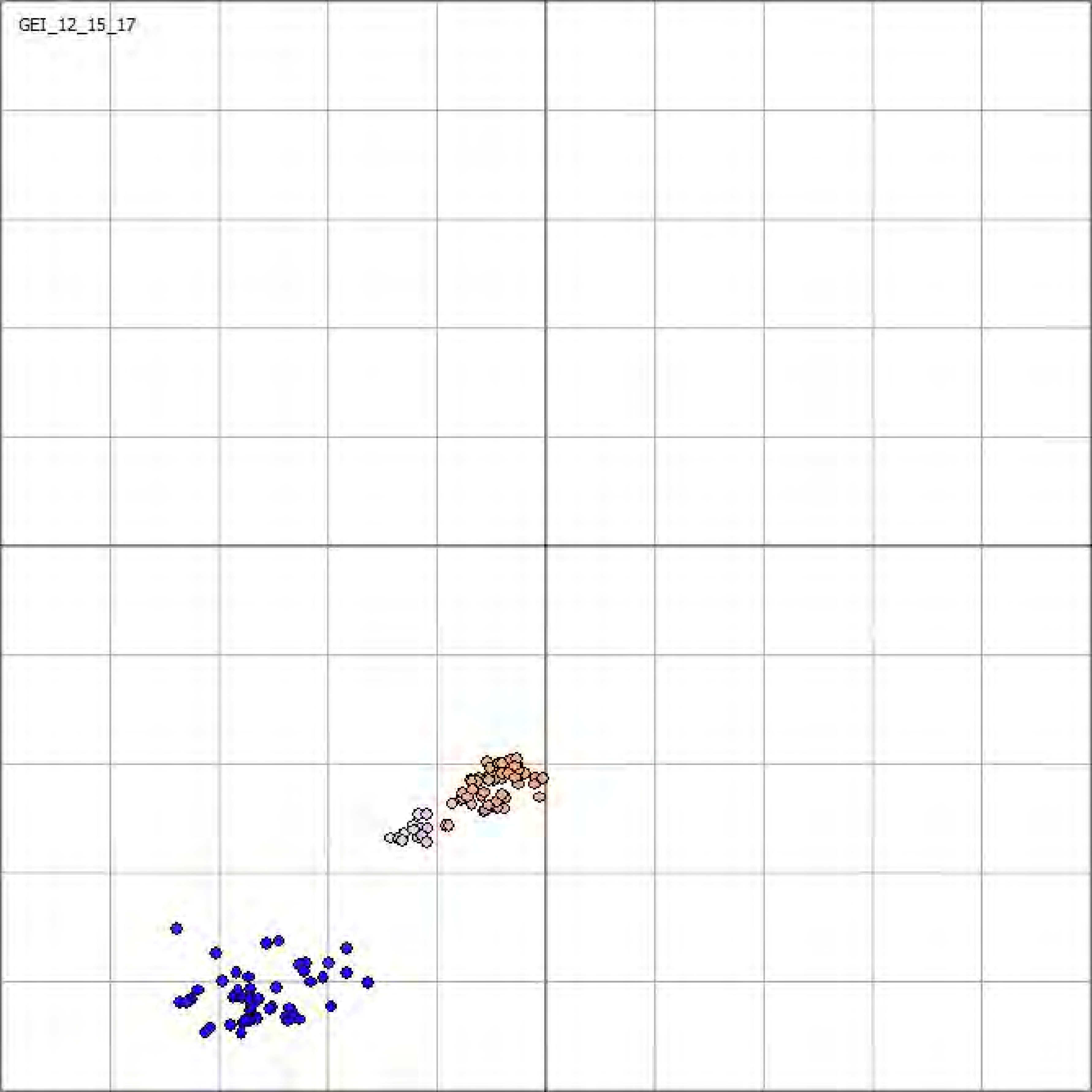

GWP_TG-45

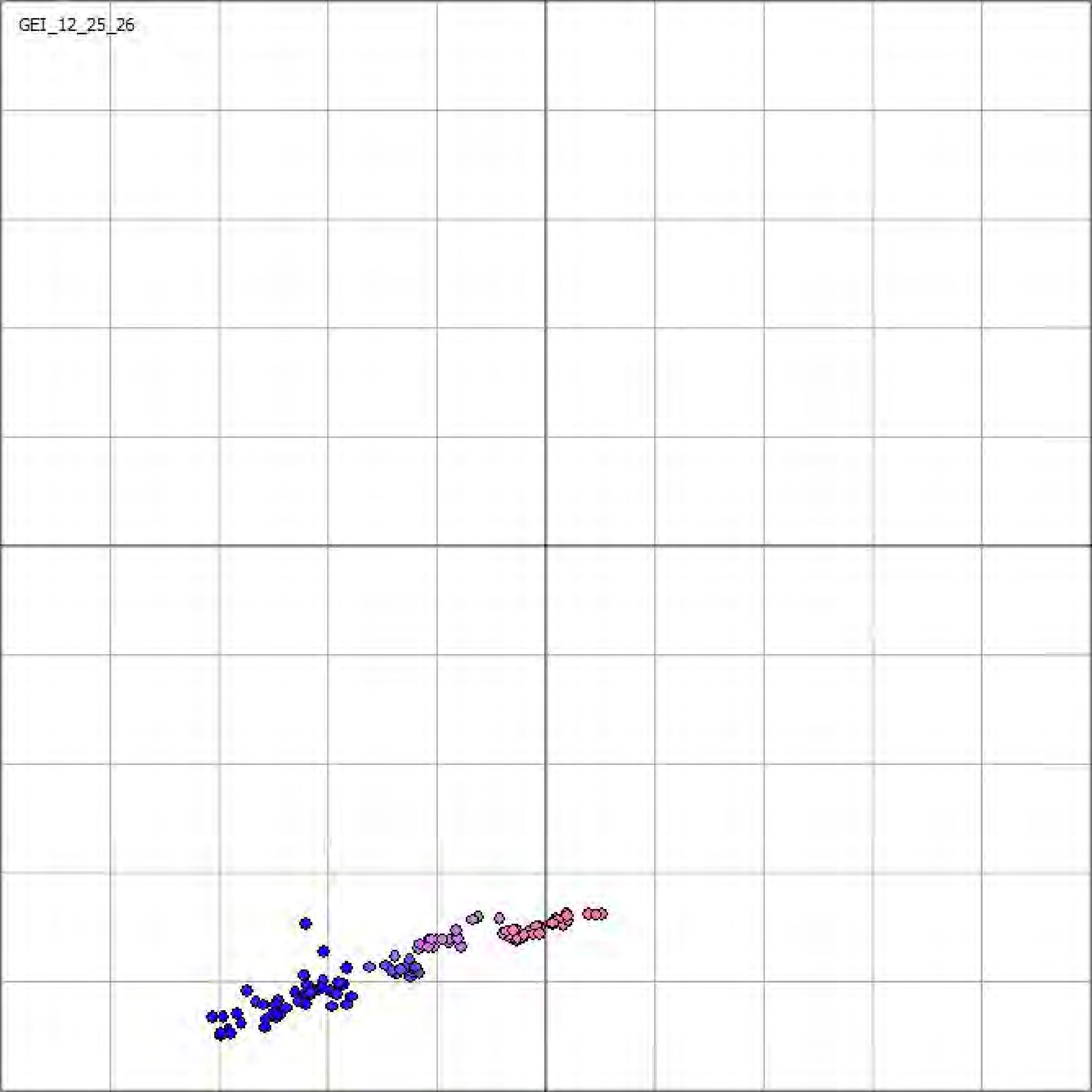

GWP_TG-46

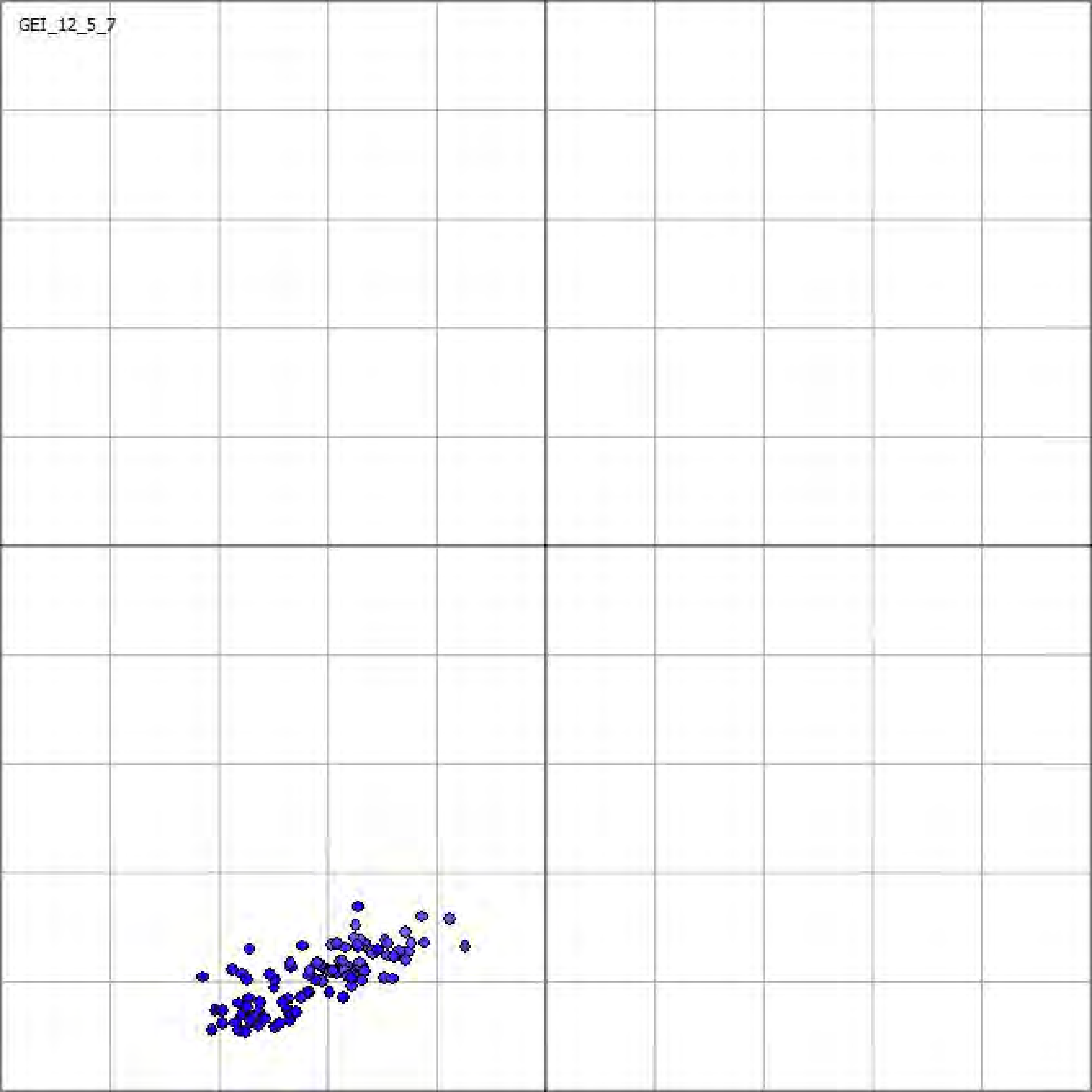
SUB-ATTACHMENT 2A-2.4.3
Classification Plots for Confirmation Samples

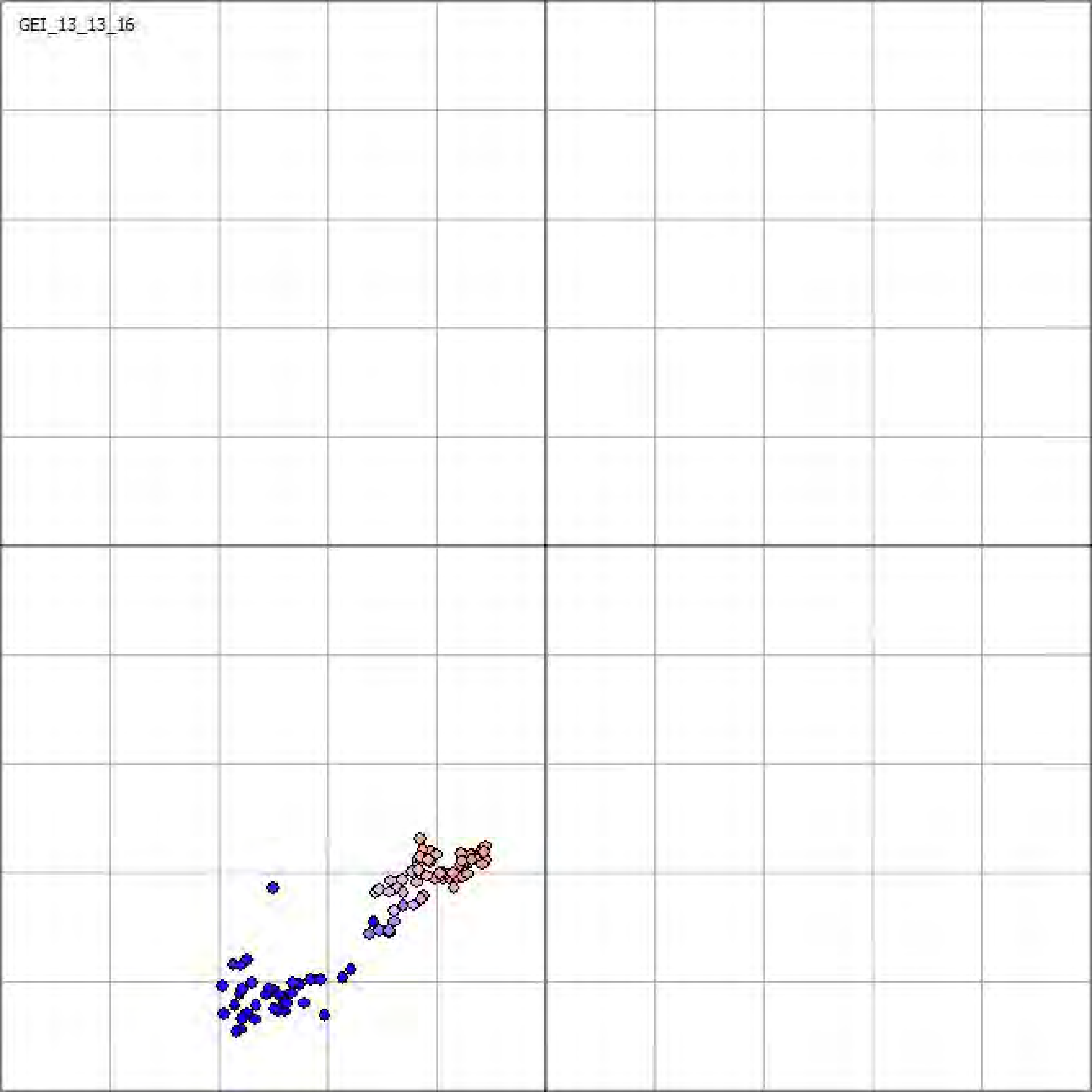

GEI_11_21_22

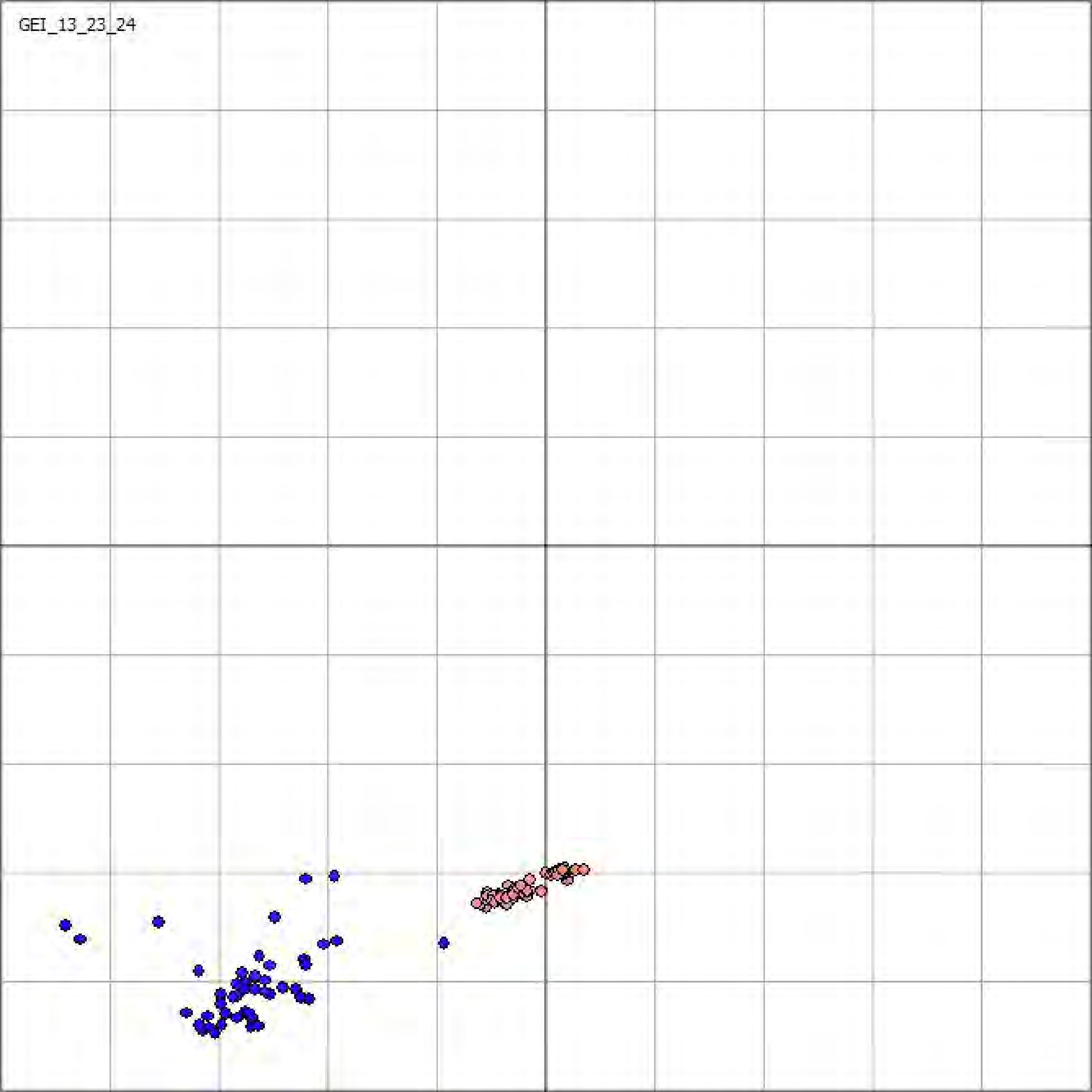

GEI_12_11_15

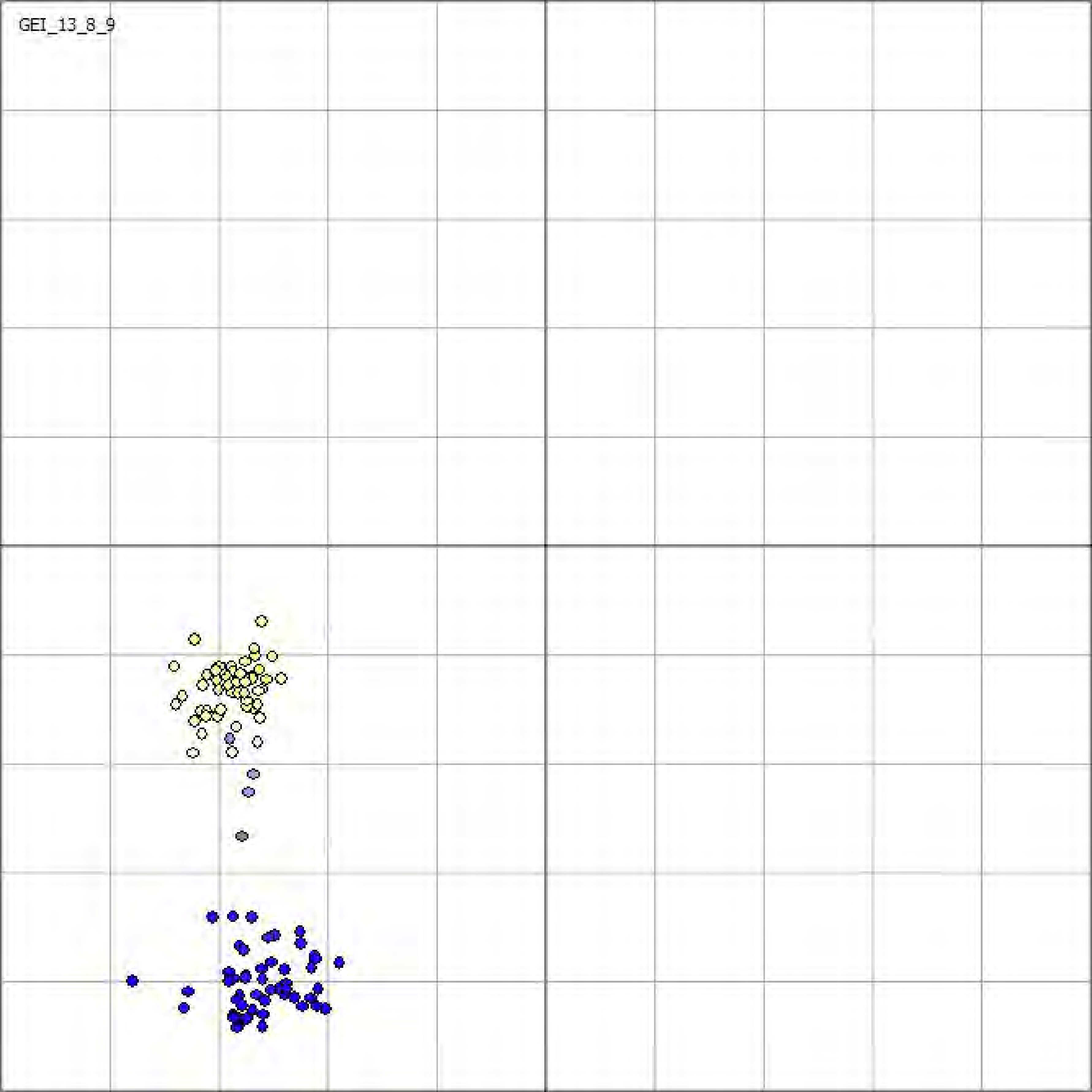

GEI_12_15_17

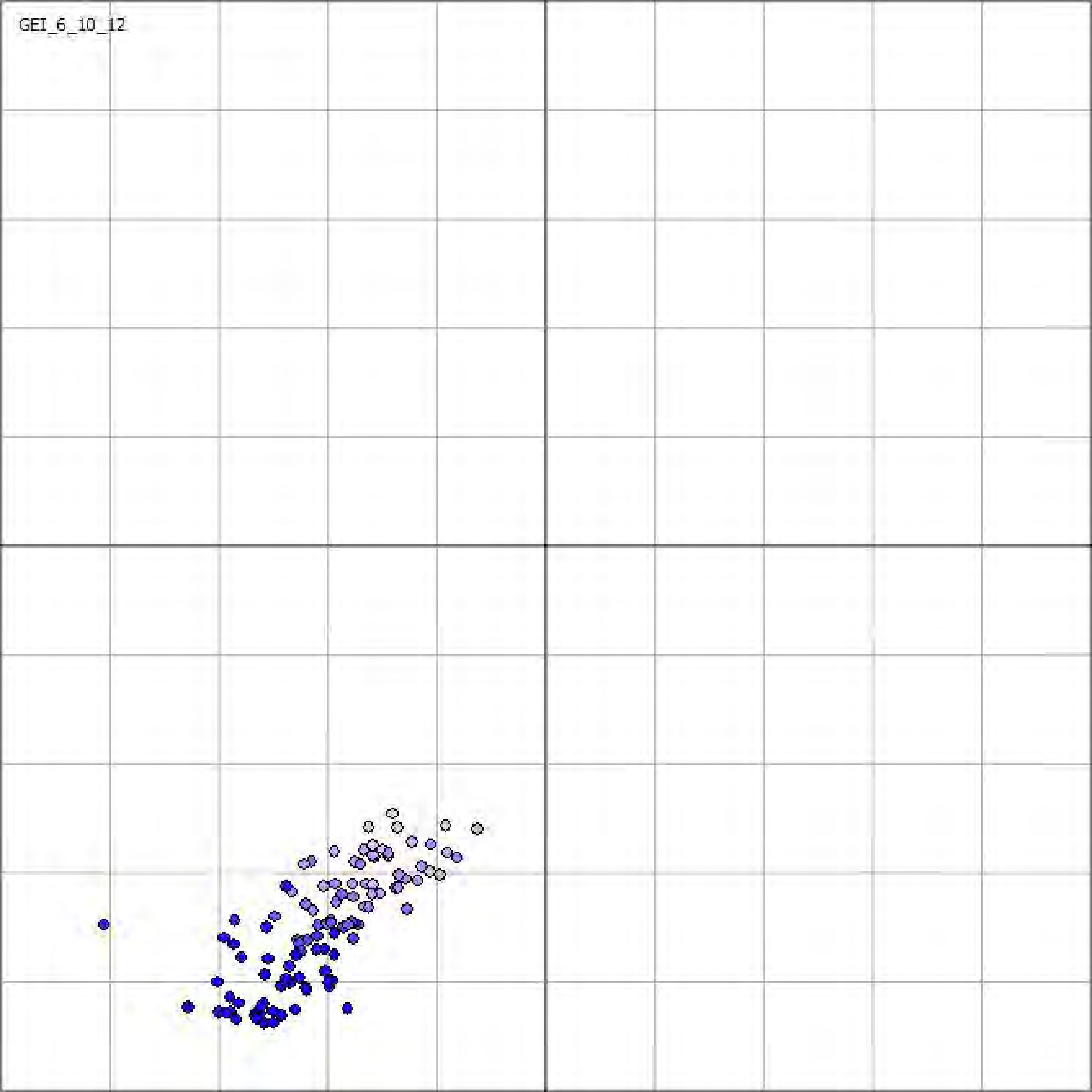

GEI_12_25_26

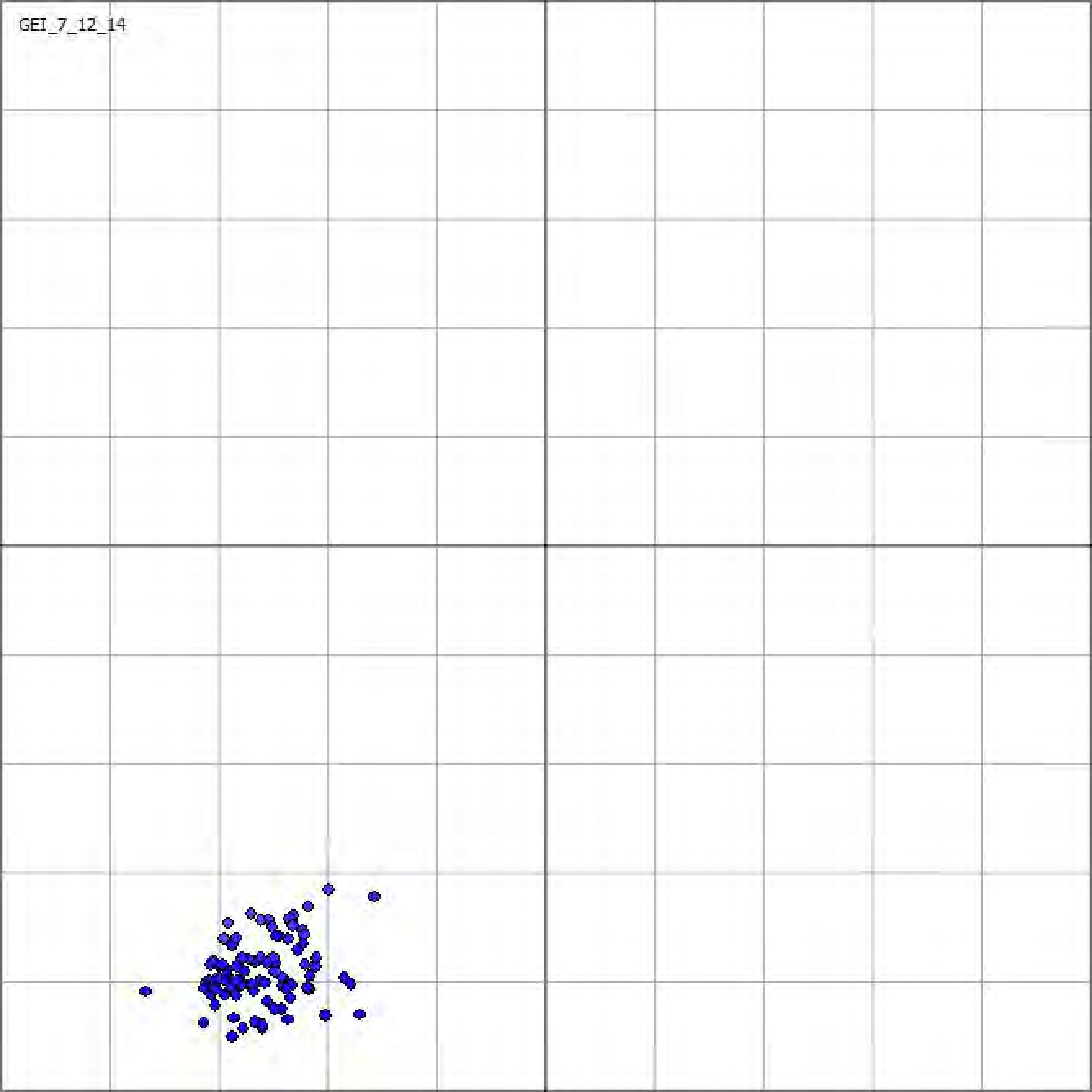

GEI_12_5_7

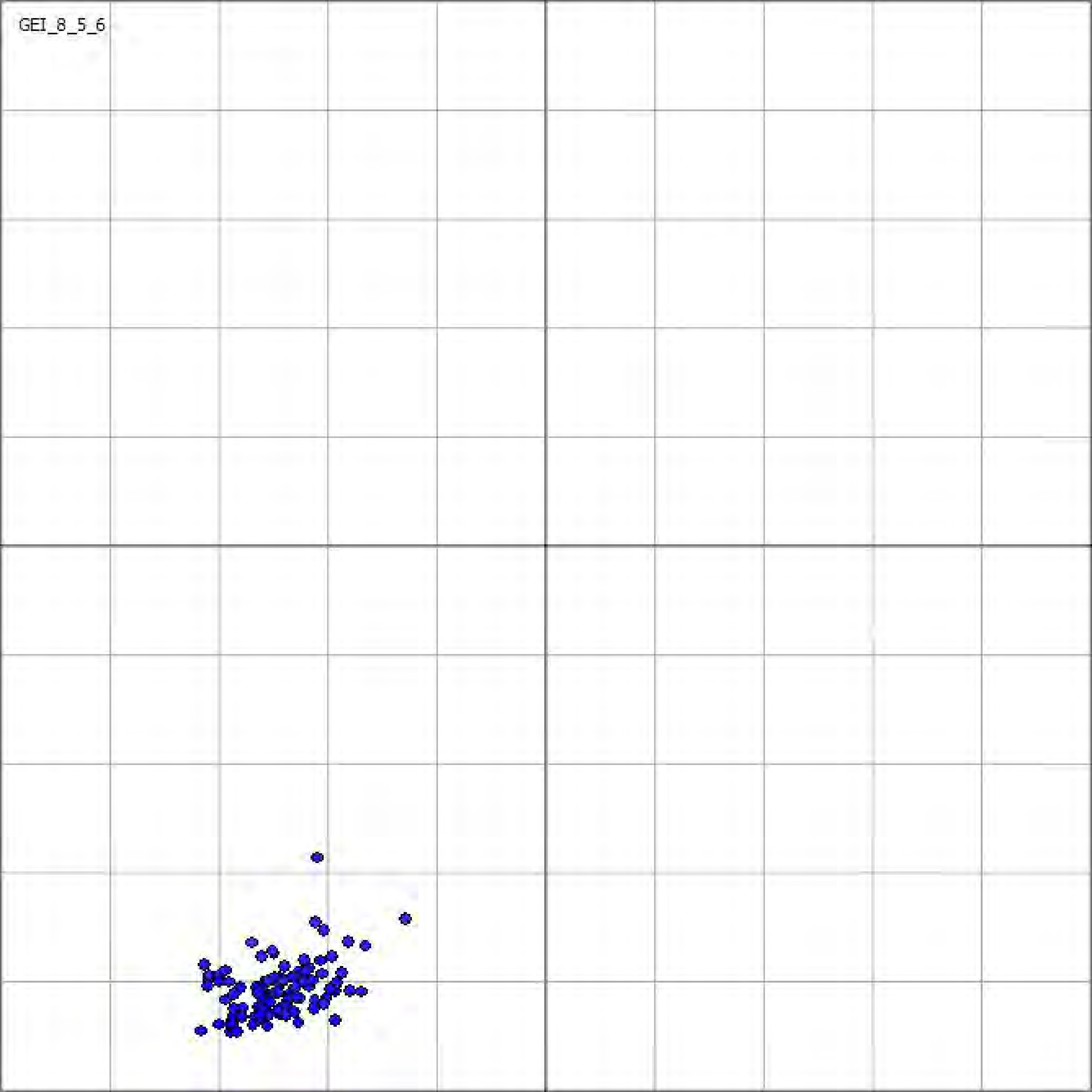

GEI_13_13_16


GEI_13_23_24


GEI_13_8_9


GEI_6_10_12


GEI_7_12_14


GEI_8_5_6

SUB-ATTACHMENT 2A-2.5

Dakota TarGOST® Investigation Report
Gas Works Park
July 2013

TarGOST® Investigation

Gas Works Park
Seattle, Washington

Report Date: July 18, 2013

Prepared for: GeoEngineers
Project Manager: Zanna A. Satterwhite, LG

Prepared by:
Steve Adamek, P.G. & Randy St. Germain
Dakota Technologies, Inc.
2201-A 12th St. N.
Fargo, ND 58102
Phone: (701) 237-4908
Fax: (701) 237-4926
sadamek@dakotatechnologies.com
stgermain@dakotatechnologies.com

This report summarizes the field deployment of the Tar-Specific Green Optical Screening Tool (TarGOST®) at the Gas Works Park Site located at 2101 N Northlake Way on the north side of Lake Union in Seattle, WA. It includes a project summary, general field observations, calibration of the TarGOST system, false positive/interference discussion, waveform discussion, and a daily production and observations table.

Project Notes

Sunday, March 17, 2013 – Dakota Technologies Inc. (Dakota) TarGOST operator, Steve Adamek traveled to Seattle, Washington. This was a travel day only, no TarGOST data was collected.

Monday, March 18, 2013 – Steve arrived on-site at 7:45 a.m. GeoEngineers site personnel conducted a site safety meeting and a site walk with all who were present. A secure staging area was setup in the parking lot of the Gas Works Park with a lockable storage container and a lockable fenced in area. A utility vehicle (UTV) from a local rental company arrived and was outfitted with the TarGOST system, a weather enclosure, generator and a rod rack. The Geoprobe rig and operator arrived about noon. It was discovered that the rods provided by Boart Longyear to push the TarGOST probe, were in very poor condition. Time was spent selecting the best rods, repairing many to make them useable, and then stringing the TarGOST fiber optical cable through them.

Data collection began at 1:30 p.m. at location number GWP-TG-01. We encountered rubble and the TarGOST probe broke off at 7' bgs. Steve was unable to remove the broken off probe and had to pull the fiber cable until it broke to recover the majority of the cable. The UTV and TarGOST system were taken back to the staging area to install a new probe and optical fiber cable.

Most locations were hand-augered to 3' bgs by Boart Longyear personnel to prevent damage to the park's irrigation system. Nearly all locations required the use of plywood pads to prevent damage to the grass. Considerable time was spent moving plywood to get to boring locations. GWP-TG-02 was started about 3 p.m. and reached a total depth of 12' bgs when refusal was encountered. Electrical conductivity (EC) data was inadvertently not recorded for either of the day's TarGOST locations. Holes were grouted and plywood pads moved to new locations. Crew left the site at 5:45 p.m.

Tuesday, March 19, 2013 – Dakota's TarGOST operator was on-site at 6:50 a.m. for a 7 a.m. requested start. The generator was fueled up and the TarGOST system started. GWP-TG-03 was started at 8:15 after preclearing to 3'. The probe was pushed to refusal at 14.89' bgs. Good TarGOST data was collected and the EC was working properly. GWP-TG-04, 05 and 06 were done before lunch. After lunch, work was resumed at location GWP-TG-07. The hole was pre-probed to 4.5' to get past some rubble before starting the TarGOST logging. GWP-TG-08, 09 and 10 were also advanced before ending work for the day. New probe rods had arrived so at the end of the day Steve removed the worn out rods and restrung with new rods. He left the site at 5:45 p.m.

Wednesday, March 20, 2013 – Steve was on-site at 7 a.m. He started logging at 8:32 a.m. and pushed GWP-TG-11 to refusal at 24.64' (encountered some rubble at the surface). GWP-TG-12 was started at 10:08 and after preprobing to 4.5' bgs GWP-TG-13 was started at 11:33 and pushed to refusal at 17.83'. The TarGOST data looked good. The crew took a lunch break started at 12:15. Location GWP-TG-14 was started at 1:15 p.m. The TarGOST data looked normal but the EC data seemed noisy. After completing the boring the EC wires were examined and cleaned. There appeared to be a break in the wire somewhere inside the cable. It was decided not to take the time to repair the break because it would probably take an hour or more to restring cables and put on new down-hole tooling. The crew began logging location GWP-TG-15 at 2:17 pm but the direct push rig was having electrical problems. We began location GWP-TG-16 at 3:42 p.m. and pushed to 25.89' bgs. The direct push rig had problems again after this hole so Steve took the TarGOST system back to the staging area to replace the TarGOST probe and EC dipole. Steve was able to get everything ready for Thursday. Steve left the site at 6:45 p.m.

Thursday, March 21, 2013 – Dakota personnel were on-site at 7 a.m. Started location GWP-TG-17 at 8:15 and pushed to 28.57'. GWP-TG-18 was pushed to 9'bgs and got hard refusal. The crew tried to probe through the obstruction with a dummy point with no success. They changed location and pre-probed to 12' bgs and then pushed location GWP-TG-18B through the pre-probed hole to refusal at 15.06'bgs. The probe broke off and bent first rod 10:28 a.m. Steve went back to the staging area to string up a new cable and attach a new TarGOST probe. Dakota had no fiber cables left on-site that have EC wires. TarGOST system was operational again at 11:43 a.m. The crew began probing GWP-TG-20 at 12:20 p.m. The location was pre-probed to 4.5'bgs and pushed to 25.99'. No EC data was collected at this location. GWP-TG-21, 22, 23 and 24 were done by 4:20 p.m. The crew started GWP-TG-19 at 4:50 p.m. but got refusal at 3.5', so overwrote TarGOST file and moved slightly. The new GWP-TG-19 was pushed to 24.95'. Steve left the site at 6 p.m.

Friday, March 22, 2013 – Crew was on-site at 7 a.m and started location GWP-TG-25 at 8:30 a.m. (pushed to refusal at 17.22' bgs). They also logged GWP-TG-26, 27 and 28 before lunch. GWP-TG-29 was started at 1:30 and was pushed to 28.65' bgs. Probe rig was having electrical problems again. Set up at location GWP-TG-30 but got refusal at 5' repeatedly. We started GWP-TG-31 about 4 p.m. and pushed to 38.04'. GWP-TG-32 was pre-probed to 4.5' but got refusal at 6.87' bgs. GWP-TG-32B was pre-probed to 10'bgs and started logging at 5:37 p.m. The log was terminated at 33.42'. TarGOST data was transferred to the client, and operator was off site by 6:30 p.m.

Saturday, March 23, 2013 – No field work (park is too busy on weekends)
Sunday, March 24, 2013 – No field work

Monday, March 25, 2013 – Dakota was on-site at 7:05 a.m. While Boart Longyear workers laid out mats for the first locations, Steve removed the fiber cable and installed one that had functional EC wires. The TarGOST system was ready to go about 9 a.m. Location GWP-TG-33 was pre-probed to 4.5' then logging began at 9:40 a.m. The probe was pushed to 22.08', TarGOST and EC data looked good. GWP-TG-34 and 35 were done before lunch. A lot of mats had to be moved to get to the next probe location. GWP-TG-36 was pre-probed to 4.5' and logging started at 1:51 p.m.; refusal was reached at 18.17' bgs. Log GWP-TG-37 was started at 2:55 p.m. The background of the TarGOST log was elevated for much of the log, very much different from other logs in the area. After recovering the rods and probe, the RE and background was checked to identify the problem. The RE was not much different than the original measurement made at the beginning of the push but the background was very high. After disassembly it was found that the parabolic mirror in the probe had (atypically) shifted position, resulting in the high background. Large signals were unaffected by the problem, small signals would have been buried in the high background however. The repair was done quickly while the rig was being moved to the next location. GWP-TG-38 and 39 were logged but the EC was not working properly. Work for the day was completed at 5:30; operator was off site at 6 p.m.

Tuesday, March 26, 2012 – Dakota was on-site at 7 a.m. EC was not operational because no more cables were available with intact EC wires. GWP-TG-40 was started at 8:07 a.m. and was pushed to 21.30' bgs. GWP-TG-41 was pre-probed to 10' bgs, started logging at 9 a.m. and pushed to 28.08'. GWP-TG-42 was located at the shore on the east edge of site. Crew began logging at 10:20 a.m. and penetrated some very loose cinder material, pushed to 31.04'bgs. It was decided to do a duplicate log here to get a feel for subsurface homogeneity. GWP-TG-42r was located 6.5' south of TG-42. Started log at 11:24 a.m. and pushed to 31.22'. After lunch GWP-TG-43, 44, 45 and 46 were logged. GWP-TG-46 was a duplicate log for location GWP-TG-12. Logging for the project was completed at 4:15 pm. Equipment was taken back to the staging area and disassembled for shipment back to Dakota. All digital TarGOST data was given to the client. Operator left site at 7 pm.

Wednesday, March 27, 2013 – Travel day

General Observations/Notes of Interest

Breakdowns/Standby: Production was below average for this TarGOST project. Several factors contributed to the slower than normal data collection rate. Site-related production restrictions included hand-augering to look for irrigation, site related rubble, and the need for plywood padding to drive on the grass. Work related production restrictions included TarGOST equipment failures do to difficult probing conditions (EC and mirror problems), grouting and probe machine break downs. Two probe break-offs and several cable changes resulted in approximately 4 hours of down-time. It should be noted that where possible, TarGOST related hardware was repaired or replaced before of after normal daily work.

Safety Incidents: NA

Validation/Sampling by Dakota: Soil samples collected by GeoEngineers during and after the TarGOST study generally correlated well with the *in-situ* logs.

General comments: As stated, the daily production was poor compared to historical averages but reasonable given the challenging subsurface and surface circumstances. The TarGOST data collected at this site was of high quality and the few anomalies in the data have been noted. EC data collection was somewhat sporadic with quality data collected at about 40% of the holes.

At many probing locations, the 0 to 3' interval was hand augered to look for the park irrigation system, then backfilled with the same material to provide lateral stability to the advancing the TarGOST probe. Some locations were pre-probed with a dummy probe to 4.5' or deeper to get past rubble or obstructions. Locations that were hand augered or pre-probed do not provide reliable TarGOST data in the disturbed interval. When looking at TarGOST logs, keep in mind that the data in the upper interval may not represent subsurface contaminant distribution or concentration levels.

Calibration of the TarGOST

Prior to conducting each log, two measurements (RE and Background) are recorded.

Reference Emitter (RE): The RE is a standard substance that is used to calibrate the TarGOST instrument prior to every log. It reflects and fluoresces at known and consistent levels. It serves two main purposes:

1) **Qualitative examination the performance of the instrument -** RE needs to be the correct shape so it is confirmed that all four channels (filters, etc.) are intact and functioning. A bad or misshapen RE waveform indicates potential damage of the detection system optics.

2) **Quantitatively "calibrate" the instrument -** RE is used to achieve the proper signal intensity (by adjusting laser energy). An RE in the proper range keeps the instrument in the optimum range for the fluorescence detector and electronics. The RE is a calibration for the response of the system to a known fluorescence signature, not a method of converting fluorescence to a known concentration. All downhole measurements are normalized to a percentage of the RE. A 100% RE reading simply means that a measured material has a

fluorescence/scatter signal that is identical to that of RE. A 200% RE means a substance has a fluorescence/scatter signal twice that of RE, and so forth.

RE range: RE area's typically fall between 1,600 and 2,000 pVs for TarGOST (picovolt-seconds, a measure of waveform area). Precise RE intensity 'tuning' by adjusting the laser excitation light to achieve an exact value is unnecessary because all signals are reported as a percent of this signal (%RE).

Background: The background is a measure of the optical cleanliness of the light path (e.g. fiber optics, mirror, window, filters). Sources of signal in the background include foreign material on fiber faces, filter auto-fluorescence, mirror and window fluorescence, and reflection/scatter from scratched/worn windows. The background waveform is not applied to the data collected (i.e. it is not subtracted as a background) and is taken only as a general data quality measure and is employed by the operator to insure that there are no significant defects that could raise the system background - making it more difficult to discern low NAPL saturation (staining) responses.

Background range: Background values can vary widely (in terms of relative percent difference) from 0.1% of the RE signal to 10%. In terms of area, the values can range from 0 to 50 pVs. As the background increases beyond 10% for TarGOST, a new window and a re-assembly of the probe may be needed. However, there is no hard cut-off value and a balance must be struck between site needs and available time.

False Positives / Interference

In some cases TarGOST will respond to naturally fluorescent minerals, biogenic minerals (shells) and organic matter like peat. Most often this response shows a sufficiently different signature or waveform and is of relatively low response compared to LNAPL and DNAPL, with relatively fresh rotting wood being a major exception in that it can fluoresce as intensely as tar/creosote. Questionable signals (fill colors and waveforms that differ from known NAPL responses) will most often be flagged by the operator and should be sampled to provide an understanding of the materials present and the resulting fluorescence signals. Feel free to call Dakota to discuss co-sampling locations or interpretation of the co-sampling results.

Waveform Discussion

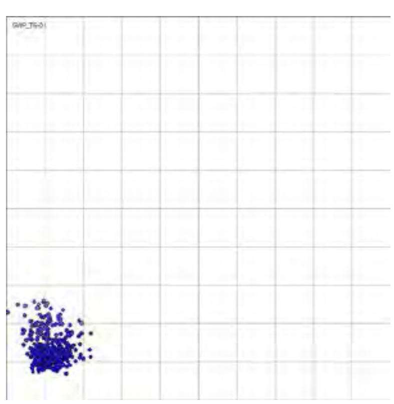
Careful co-sampling, examination, and analysis of soil cores are required to determine what benefit waveforms (three-dimensional fluorescence signatures) may or may not provide toward the site conceptual model. A relatively wide variety of waveforms were observed at this site, indicating relatively high heterogeneity of fluorescing materials. In complex fluorescent data sets like this (as opposed to sites with just one or two waveform types) it is not beneficial to write up descriptions in text, but rather provide graphics that assist visually – in a "picture is worth a thousand words" sense. A recently developed classification analysis method is the fastest method we have found to quickly survey for differences in waveforms between differing logs or differing response horizons within a single log (attached in a PDF). All the waveforms from each sounding are plotted on a single graphic – allowing a spatial method of matching or spotting unique fluorescence signatures. Below is a description of the classification plots and examples of how to employ them.

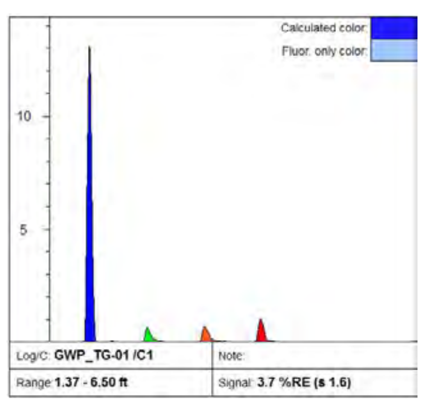
X-Axis: Wavelength
The "center of gravity" of the four peaks of the waveform determines the x-axis position. For example, a clean waveform dominated by the blue (laser scatter peak) plots to the left – while a waveform plotted heavily toward the orange and red peaks will plot further to the right. Imagine placing a fulcrum under the waveform and determining the center of balance on the time axis of the waveform.

Y-Axis: Lifetime
The average lifetime of the 4 peaks determines the position on the y-axis. Short lifetimes (near zero) are plotted very low. The longer the lifetimes get the higher on the y-axis the waveform's oval data point is plotted. Laser scatter (blue channel) domination causes baseline data points to be plotted near the bottom while LNAPLs have longer lifetimes and plot three to four units high on the y-axis.

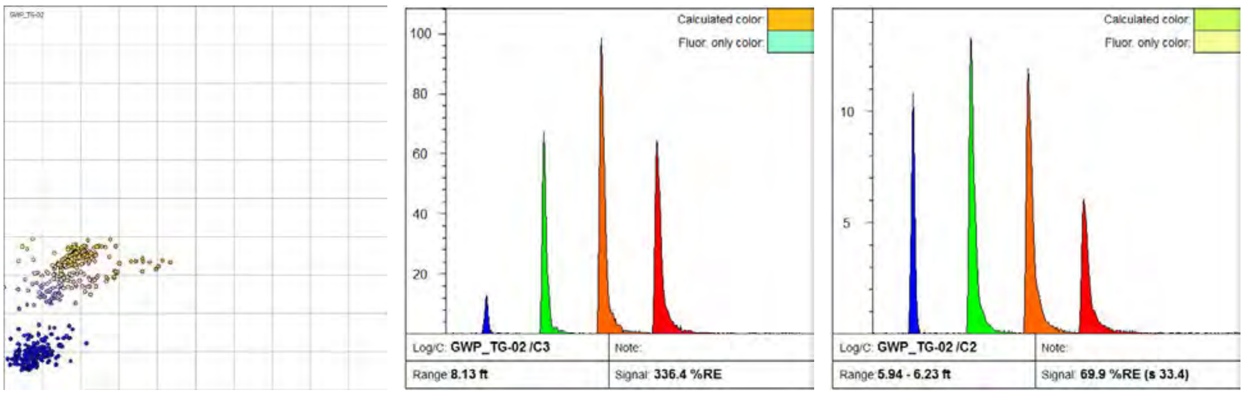
Color
The fill colors used in the log's fill of the Signal (%RE) on the standard TarGOST logs are also used to fill the ovals that represent each waveform. Use the fill color to find the depth along the TarGOST log where certain ovals originated. For instance, if the fill color of some plotted classification ovals are pink, look for where in the log (feet) the Signal (%RE) was filled with pink. This allows you to target where on the log to make further examination of the waveform to locate sampling depths or otherwise investigate your TarGOST data more fully.

Interesting classification plots to consider as examples include:

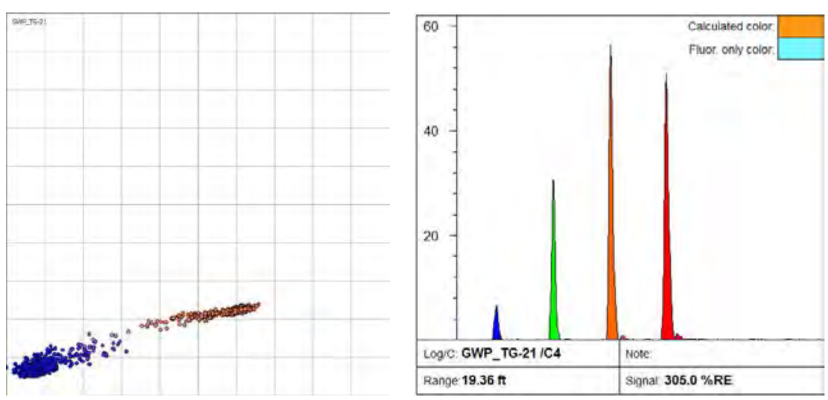




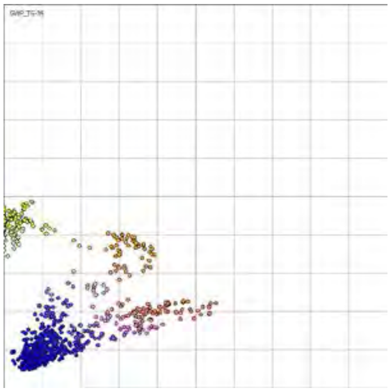
All "clean soils" (no fluorescence) are plotted in the lower left corner – this is because only the scatter provides significant contribution to both the x- and y-axis of the data set. Notice the blue data points match the blue fill of the baseline's low Signal (%RE) of the log. Example waveforms from TG-01 are shown next to the classification plot above so that you can get a "feel" for why the data is plotting where it is on the classification chart.

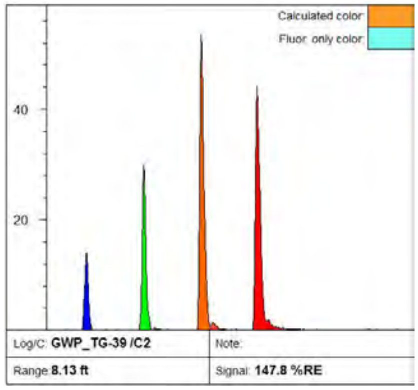


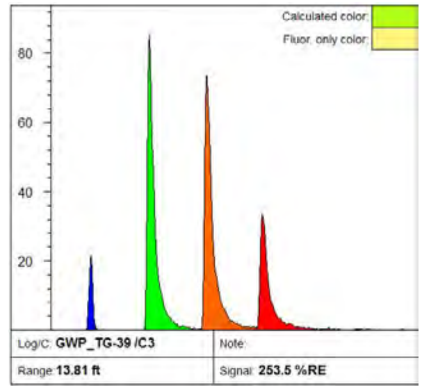
Log TG-02 had fluorescence waveforms with some long lifetimes amidst modestly long lifetimes and ranged from left-of-center to center on the lower left quadrant of the classification plot. Look at the two waveform types that were observed to understand why those colored ovals were plotted where they were on the classification chart. Remember to look at the fill colors (upper right in the waveform plot) to find the matching fill colors also used to fill the ovals in the classification plot. There is a modest amount of heterogeneity in this log's classification plot. That is readily apparent because there are ovals spread quite broadly about in the lower left quadrant. This indicates there is heterogeneity of the fluorescent materials, either due to differing NAPL qualities - or even the presence of false positives.



Opposite in behavior is this plot, which shows an example of very red-shifted and short-lived waveforms. Notice that this chart's data ovals are tightly grouped indicating only a single type of waveform or "class", indicating very homogeneous chemistry with depth. So even though the NAPL deposits spanned across many feet in this log, the fluorescence did not vary – and it's likely that chemistry then didn't vary to any significant degree. The plot "streams" out and away from the blue cluster because as the size/intensity of the fluorescence channels grow they get large enough to dominate their weighting on the chart. The ovals are strung along a line due to the data generated while entering and leaving the NAPL body. In other words, had we only logged NAPL-saturated and clean soils, there would simply be a blue cluster (clean) and an orange cluster (NAPL saturated) separated from each other. In this plot there are ovals connecting them in between (pink) which represent staining (lighter contamination).







Finally we have this chart which shows a high degree of heterogeneity and three fairly distinct clusters. The yellow/green ovals at upper left are quite likely LNAPL (blue-shifted fluorescence along with long lifetimes), while the lower right maroon "stream" is likely classic tar (orange dominated and very short lifetimes). The middle group between the extremes may indicate a mix of those two, just a differently weathered tar, tar released from a different point in the waste stream, or even a false positive. The only sure way to know is multiple lines of evidence (sampling, site layout/history, previous findings, or NAPL presence in nearby wells for instance).

You can also use these classification charts to find similarities or differences from log to log as well. For instance, TG-24 and TG-21 are very similar to each other, as are TG-39 and TG-40, but the first pair is very different from the second pair. If you flip back/forth to each of them in the PDF you can see for yourself.

Table of Production and Observations

File	Date/Time	Final Depth (ft)	Max Signal (%RE)	Max Signal Depth (ft)	EC Data	Observations
GWP_TG-01	3/18/2013 14:33	7.2	14	1.5		Rubble present, broke off TarGOST probe
GWP_TG-02	3/18/2013 15:56	11.8	336	8.1		EC not recorded
GWP_TG-03	3/19/2013 8:14	14.9	8	1.3	X	precleared with hand auger to 3' bgs
GWP_TG-04	3/19/2013 9:19	9.6	44	4.2	X	precleared with hand auger to 3' bgs
GWP_TG-05	3/19/2013 10:10	24.3	197	24.3	X	
GWP_TG-06	3/19/2013 11:10	16	60	9	X	
GWP_TG-07	3/19/2013 13:12	21.6	10	12.2	X	pre-probed to 4.5'
GWP_TG-08	3/19/2013 14:35	22.2	33	12.5	X	precleared with hand auger to 3' bgs
GWP_TG-09	3/19/2013 15:26	19.9	18	13.5	X	precleared to 2'
GWP_TG-10	3/19/2013 16:38	13	15	0.4	X	pre-probed to 4.5'
GWP_TG-11	3/20/2013 8:31	24.6	198	15.6	X	
GWP_TG-12	3/20/2013 10:07	29.4	467	28.2	X	precleared to 2', surface rubble
GWP_TG-13	3/20/2013 11:31	17.8	8	6.7	X	pre-probed to 4.5'
GWP_TG-14	3/20/2013 13:14	22.2	152	14.2		EC signal noisy
GWP_TG-15	3/20/2013 14:16	28.8	669	28.5		EC dead
GWP_TG-16	3/20/2013 15:43	25.9	34	15.6		Probe rig problems
GWP_TG-17	3/21/2013 8:13	28.6	83	17	X	
GWP_TG-18	3/21/2013 9:32	9	27	8.9	X	shallow refusal many times
GWP_TG-18B	3/21/2013 10:06	15.6	340	15.6	X	broke off TarGOST probe and bent first rod
GWP_TG-19	3/21/2013 17:09	24.9	4	4.1		very shallow refusal first time, pre-probed to 4.5'
GWP_TG-20	3/21/2013 12:18	26	76	14.9		pre-probed to 4.5', odor and sheen
GWP_TG-21	3/21/2013 13:16	25.9	323	19.3		pre-probed to 4.5'
GWP_TG-22	3/21/2013 14:21	24	9	8.9		pre-probed to 4.5'
GWP_TG-23	3/21/2013 15:00	24.5	9	0.7		pre-probed to 4.5'
GWP_TG-24	3/21/2013 15:47	28	229	21.6		precleared to 2'
GWP_TG-25	3/22/2013 8:29	17.2	8	9.2		
GWP_TG-26	3/22/2013 9:19	20.9	29	7.8		
GWP_TG-27	3/22/2013 10:22	17	7	5.6		
GWP_TG-28	3/22/2013 11:29	26.4	6	9.2		
GWP_TG-29	3/22/2013 13:30	28.6	5	14.2		rig problems again
GWP_TG-30	3/22/2013 15:00	5	4	0.2		many refusals at 5' bgs
GWP_TG-31	3/22/2013 15:48	38	34	6.7		pushed all rods available
GWP_TG-32	3/22/2013 17:11	6.9	4	2.4		shallow refusal
GWP_TG-32B	3/22/2013 17:35	33.4	15	22.3		pre-probed to 10' bgs
GWP_TG-33	3/25/2013 9:39	22.1	57	3	X	New EC cable. Preprobed to 4.5'
GWP_TG-34	3/25/2013 10:45	25.1	61	0.9	X	precleared to 2'
GWP_TG-35	3/25/2013 11:36	25.2	38	7.1	X	precleared to 2'
GWP_TG-36	3/25/2013 13:49	18.2	358	8.6	X	pre-probed to 4.5'
GWP_TG-37	3/25/2013 14:53	26	1624	13.4	X	precleared to 2', elevated background signal
GWP_TG-38	3/25/2013 16:17	16.2	221	9.8		EC quit working, broken wires
GWP_TG-39	3/25/2013 17:09	26	455	15.6		pre-probed to 4.5', multi product log

File	Date/Time	Final Depth (ft)	Max Signal (%RE)	Max Signal Depth (ft)	EC Data	Observations
GWP_TG-40	3/26/2013 8:06	21.3	1397	9		precleared to 2'
GWP_TG-41	3/26/2013 9:00	28	16	9.5		pre-probed to 10' bgs
GWP_TG-42	3/26/2013 10:19	31	59	11.3		precleared to 2', very soft slag, visible NAPL
GWP_TG-42r	3/26/2013 11:21	31.2	39	10		precleared to 2', duplicate 6.5' from previous
GWP_TG-43	3/26/2013 13:12	26.4	687	9		
GWP_TG-44	3/26/2013 14:16	12.1	88	7.7		
GWP_TG-45	3/26/2013 14:56	18.8	41	8.8		pre-probed to 4.5'
GWP_TG-46	3/26/2013 15:44	24.6	341	8.6		pre-probed to 4.5'

SUB-ATTACHMENT 2A-2.6
Dakota Technologies TarGOST® Guide

TarGOST® Guide

2010-04-22

A Introduction

The Tar-specific Green Optical Screening Tool (TarGOST®) is a laser-induced fluorescence (LIF) screening tool that is specifically designed to detect non-aqueous phase liquid (NAPL) in the subsurface. It responds almost exclusively to NAPLs found at former manufactured gas plants (MGPs) and wood-treating (creosote/pentachlorophenol) sites. It does this by sensing the fluorescence of polycyclic aromatic hydrocarbons (PAHs) and any other fluorescent molecules found in MGP and creosote LNAPLs and DNAPLs. TarGOST is a modified version of Ultra-Violet Optical Screening Tool (UVOST®). Dakota developed the UVOST early in the 1990's with U.S. Air Force funding. The UVOST platform is a mature technology that has been applied at hundreds of petroleum, oil, and lubricant (POL) contaminated sites in the U.S., Europe, and Japan since 1994. TarGOST has been in commercial use since March 2003.

B Principles of Operation

B.1 Components

The following gives an introduction to the basic components of the system.

- **Laser**

The laser is up-hole and produces concentrated light of one narrow range of wavelengths. For TarGOST, the laser produces short (5 billionths of a second) pulses green light, as opposed to Dakota's UVOST system that uses an ultra-violet laser for excitation.

- **Fiber-Optic Cable**

The fiber-optic cable is a robust plastic coated metal conduit that houses two fiber optic cables and the wires for the conductivity measurement. This cable is strung through the probe rods prior to field activities. One fiber carries the laser down to the probe while the other returns scattered laser and fluorescent light.

- **Shock Protected Optical Chamber (SPOC)**

The distal end of the fiber optic cable attaches to the SPOC. The SPOC houses a mirror that turns the light and a sapphire window. Light passes through the window and strikes the soil in immediate contact with the window. The resulting scattered and fluorescent light is sent up-hole for measurement. The SPOC has channels that allow the conductivity wiring to pass through to the dipole tip at the bottom of the assembly.

- **Spectrometer**

The TarGOST's custom spectrometer divides the returning light into four distinct wavelength (or color) bands and converts the light into a corresponding electrical current where the current amplitude is proportional to the light amplitude.

- **Analog to Digital Converter**

The A/D converter produces an averaged digital signal from the current provided by spectrometer that can be read by the computer software.

- **Conductivity**

The electrical conductivity of the soil can be logged simultaneously with the LIF information.

- **Depth Meter and Hammer Rate**

Depth is tracked by a string potentiometer system on the direct push equipment to insure that the optical data is tagged with its proper depth. Data density is generally less than one inch. We can also track our Hammer Rate when using a percussion delivery platform.

- **Computer and Software**

All data is logged using Dakota's proprietary Optical Screening Tool (OST) software running on a Windows platform. We use ruggedized field laptops.

B.2 Laser-Induced Fluorescence

The TarGOST system is, in its simplest sense, a front-face fluorometer that is coupled via fiber optics to a sapphire-windowed probe that is advanced into the ground.

> A front-face fluorometer is a device that shines excitation light onto, and collects emission from, the same surface. This is different from conventional fluorometers, which operate with the excitation and emission beams at 90° and usually involve clear liquid analytes.

The TarGOST system makes continuous measurements of the soil matrix as the windowed probe is pushed slowly into the subsurface.

> The measurements are made hundreds of times each second. Each individual measurement begins with a pulse of laser excitation light being launched into one of two optical fibers that are strung through the drill/push rod string. As the rod is advanced into the subsurface, the very fast pulses of laser light (nanoseconds in duration) are directed out the sapphire window and onto the soil surface that is pressed very firmly against the outside of the window.
>
> Pulses of laser light strike whatever is present just outside the surface of the window. Most of the laser light is simply reflected by the soil matrix. However, if oil-like material (OLM) or tar-like material (TLM) containing PAHs (or other fluorescent molecules) are present, the PAHs that exist in these NAPLs absorb some of the light and are driven into an electronically excited state. When these PAHs eventually return to the ground state (this typically takes less than 10 ns), a portion of the PAHs emit red-shifted light (longer wavelength light than the excitation laser). Some of this fluorescence, along with a portion of the reflected excitation laser light, are collected by the SPOC's mirror and focused into the collection optical fiber for return to the TarGOST instrument for detection.

The light returning from the windowed probe is directed into a spectrometer located inside the TarGOST system, yielding a waveform.

The TarGOST's custom spectrometer divides the returning light into four distinct wavelength (or color) bands and converts the light into a corresponding electrical current pulse where the current amplitude is proportional to the light amplitude. This current pulse is wired into a fast digital storage oscilloscope where it is converted into a transient voltage signal, is digitized, and recorded. This digitized transient is called a waveform.

Figure 1 shows an example waveform. Each peak (or channel) represents a different wavelength band. The laser light that is being reflected from the soil matrix is monitored in the first channel (blue, left-most) and the three fluorescence bands are observed in the three right-most channels (green, orange, and red).

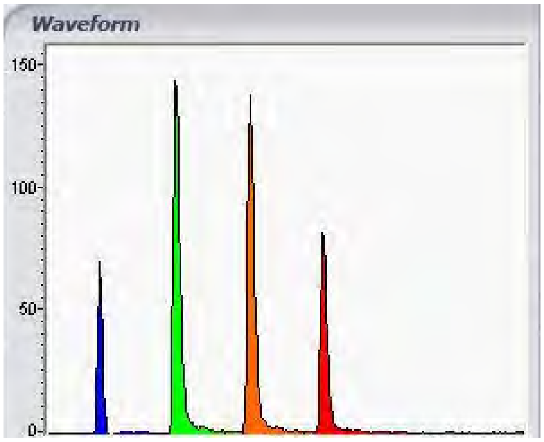


Figure 1. Example TarGOST Waveform

B.3 Scatter Correction

Due to complicated processes such as energy transfer, photon cycling, and other phenomena that "quench" the fluorescence in high NAPL concentration soils, fluorescence often does not scale linearly with concentration. To correct for this inherent property, the TarGOST system scatter corrects the data.

In calculating the TarGOST total signal, the fluorescence area is divided by the area under the laser scatter channel. This is referred to as scatter-correction or normalization. This is necessary because at very high concentrations the fluorescence does not continue to scale with concentration. The uncorrected TLM curve in Figure 2 illustrates the problem.

The addition of more and more NAPL to a soil sample should (if there were no quenching phenomenon) result in increasing fluorescence, but it only increases up to a certain point where the fluorescence response flattens out or begins to fall.

This poor type of response is called non-monotonic behavior and is obviously undesirable behavior for a screening tool. The laser scatter correction system is designed to prevent this "roll-over" affect. The scatter correction keeps this from occurring at the high end of concentrations (where soil is heavily contaminated or even saturated with NAPL). The scatter-corrected curves in Figure 2 illustrate the desired effect of scatter correction.

The laser scatter intensity is usually minimal until NAPL concentrations reach the tens or hundreds of thousands PPM level, where the quenching or saturation (non-linearity of fluorescence response) is most pronounced. Laser scatter correction generally doesn't "kick in" until high concentrations are being measured, where fluorescence response flattens out or rolls over. In this way, the scatter corrected fluorescence readings scale relatively well across a wide range of concentrations, from the typical limit of detection (LOD) of 250-500 ppm, to the almost neat NAPL encountered in soil saturated with free product. Remember that TarGOST is designed to respond only to the NAPL impacted soils, not the PAHs attached in "dry" form to soot or dissolved phase PAHs. This makes it ideal for delineating source term areas of mobile MGP NAPL.

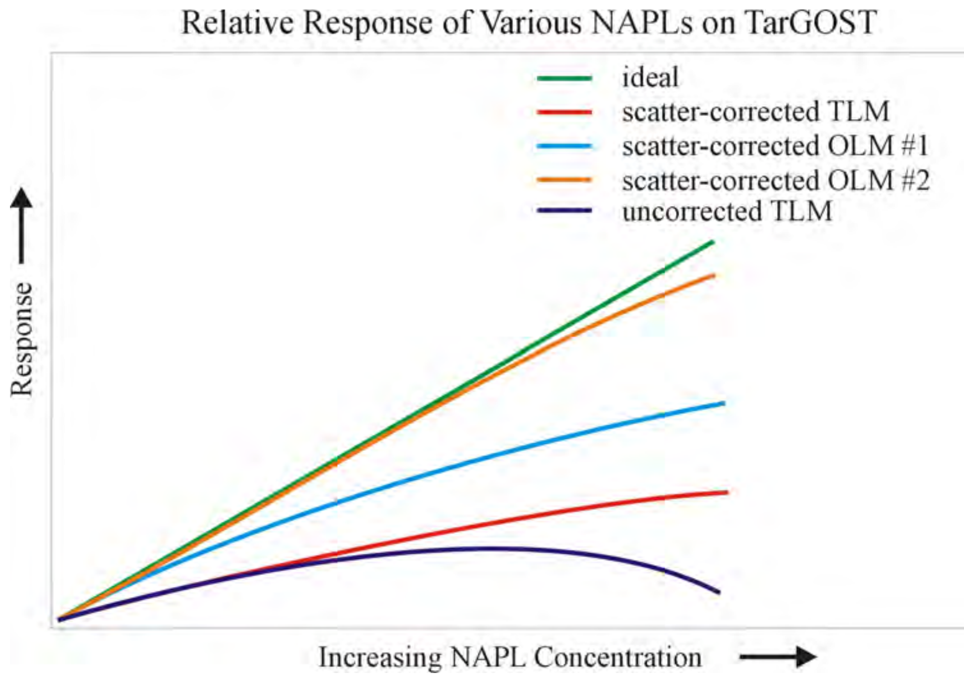


Figure 2. Variability of TarGOST Repsonse

The scatter correction works well, but it isn't perfect.

The TarGOST system is not an analytical instrument like a laboratory GC that sits in a clean, stable environment and only gets fed ultra-clean matrix-isolated analytes. Instead, it is asked to respond faithfully to an analyte that exists in a thousand different forms in an endless number of environments.

At high NAPL concentrations, even small variations in the laser scatter greatly influences the total signal, especially when the laser scatter gets close to zero.

For instance, let's imagine that with neat NAPL in front of the window, the fluorescence channels are averaging around 10,000 pico-Volt seconds (pVs) in area with each pulse of the laser. The laser scatter may be fluctuating between 400 and 800 pVs, because the scattered light is dim from being absorbed by the PAHs. Now, even if the fluorescence stays almost constant at 10,000 pVs every measurement, the relatively large variation in the tiny laser scatter that occurs will create a two or three-fold increase/decrease in total signal, even with the same NAPL sitting on the window. That's why very high readings (>500) often look unstable and jagged – because the laser scatter signal is so weak it "jitters" a lot compared to the fluorescence, causing large variations in signal, even though the fluorescence portion of the waveform is relatively stable. For this reason, any wide swings in large signals should "be taken with a grain of salt".

At low signals (0-100 %RE), it is often helpful to use the Fluor (%RE) or "Fluorescence Only" column of data. At low concentrations the change in scatter from the formation itself might actually "mess with" the Signal, causing it to change for reasons other that NAPL content. The Fluor column is the most reliable indicator of NAPL at near limits of detection quantities.

B.4 Calibration and Signal Calculation

The waveform shapes (the relative amount of signal in each channel or band and the decay time on the right side of each peak) tell us quite a bit about the qualitative nature of what's happening outside the window. But what interests people most is the amount of NAPL that is present vs. depth. We do this by portraying the signal vs. depth in a continuous log format, where the signal is relative to a known fluorescence reference emitter (RE).

To accomplish this we must reduce the waveform to a single quantitative number. We also need to normalize for any energy drift of the laser and optical alignment changes, so it is necessary to calibrate the system prior to each sounding and plot the down-hole data. The RE is a stable and known material that can be applied to the window and measured just prior to each sounding. The signal of the down-hole sample is then plotted as a function of depth and a percent of the RE.

Figure 3 graphically illustrates the calibration waveform and its use in the determination of an example %RE.

The RE both reflects some of the laser light and fluoresces at levels that are in the same general range as soils that are moderately to heavily contaminated with MGP NAPL. The Reference Emitter waveform shown in the figure is an actual RE waveform taken with the TarGOST. By definition the RE will always have a %RE value of 100%. The example waveform on the right is a real waveform of impacted soil; notice the low scatter in the example and its impact on the total signal level of 219%.

To calculate the %RE, the area under the three fluorescence channels of the waveform is determined. As discussed in the previous section on scatter correction, the fluorescence area is divided by the laser scatter area. This fluorescence over scatter value is divided by the corresponding RE value and reported as a percent.

Once the RE is measured, all subsequent measurements can be normalized by this RE waveform, providing an apples-to-apples presentation of the data regardless of laser energy drift or other changes that would cause a difference in raw signal amplitude over time. It may be useful to think of the RE waveform as the equivalent of the single-point 100ppm isobutylene calibration used for hand-held photo-ionization detectors.

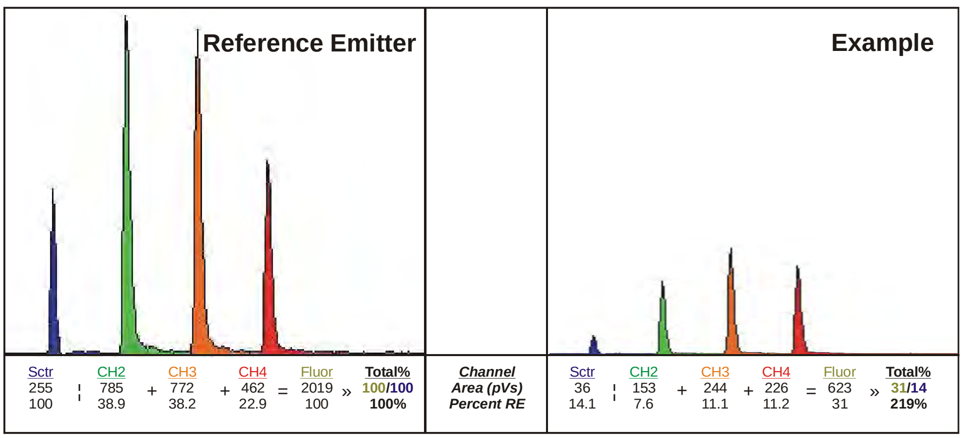


Figure 3. Example %RE Calculation

B.5 Signal vs. Depth Plotting

To better appreciate the qualitative information that TarGOST provides, the logs are color-coded by "filling in" the log's x-axis (%RE) with colors generated from the waveform at each and every depth. The color is determined by the amount of signal present in each of the four wavelength channels. See Figure 4 for an example.

This makes the interpretation of the logs easier to see "at-a-glance" as opposed to relying solely on the few selected waveforms to understand the qualitative nature of the data vs. depth. Color-coding alerts the observer to shifts in NAPL types and can also help identify weak interfering minerals like calcite and organic matter, both of which can sometimes (rarely) be mistaken for MGP waste.

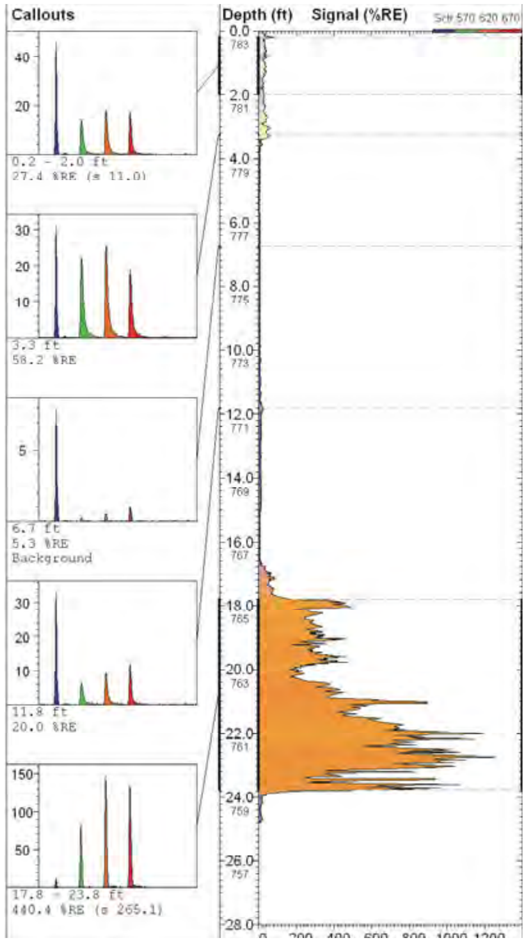


Figure 4. Depth vs %RE and Callouts

B.6 Variability and Preferential Response

NAPLs vary in fluoresce intensity and spectral distribution (color), even NAPLs found at the same site.

Figure 2 illustrates conceptually that TarGOST often responds with varying sensitivity toward different NAPLs, depending on their origin and/or variances in the conditions under which they've been exposed in the decades they've spent in the subsurface. For instance, a thick asphaltine TLM will typically fluoresce much less intensely than a less viscous "runny" OLM. This may well be due to the relative abundance of solvent in one matrix vs. the other. The more solvent available (i.e. the less viscous the NAPL), the higher the likelihood of PAHs being able to emit photons (fluoresce) before a non-radiative mechanism allows the PAH to come back down to the ground state without emitting a photon (quenching).

The preferential sensitivity of TarGOST toward the less viscous (more mobile) OLMs is welcomed by most users, since TarGOST seems to accentuate the presence of the more mobile NAPLs.

It is these more mobile NAPLs that are of the highest regulatory/compliance concern. There is an abundance of anecdotal evidence that suggests that some NAPLs may fractionate in the subsurface into OLM and TLM or even DNAPL and LNAPL. Dakota has participated in a number of investigations where a single NAPL body seems to have 'split' into two distinct NAPLs, with both NAPLs having similar but distinct waveform shapes as we moved away from the suspected release point and they appear to form two separate horizons (a "high" and "low" layer). Although there has been plenty of speculation, the exact mechanism for this phenomenon (if it actually occurs) is not known.

TarGOST uses a green laser to excite the larger (4 -5 rings and higher) PAHs that exist almost exclusively in NAPL form, as opposed to smaller (2-3 ring) PAHs that can more readily partition into the groundwater due to their much higher solubilities in water. UVOST on the other hand employs ultra-violet (UV) light which can and does excite the smaller 2-3 ring aqueous phase PAHs and sometimes detects (marginally) high concentrations dissolved phase PAHs such as naphthalenes in the groundwater. When this behavior is combined with UVOST's non-monotonic response for many NAPLs, extremely complicated logs are generated that need to be computer analyzed to separate the NAPL fluorescence contribution from that of the dissolved phase. The dissolved phase signals can even surpass NAPL signals, making confident NAPL delineation almost impossible at many sites. This is especially true for those sites with sand/gravel, where pockets of NAPL are perched in or amongst slow-moving or stagnant groundwater.

It should also be mentioned that TarGOST was designed to exclusively detect high concentration PAH NAPLs ("heavies"). TarGOST has, by design, a very limited response (if any) to lighter fuels. While this is often desirable, there are some cases where TarGOST "missing" lighter fuels is undesirable, but this is a limitation of the TarGOST technology.

C Results

Dakota has years of experience using TarGOST. The system has both been fully tested in the lab and in the field.

C.1 Laboratory Testing

Figure 5 illustrates waveforms that are typical of those generated with TarGOST.

If the soil is free of NAPL, the laser scatter channel (leftmost) is far more intense than the three fluorescence channels. The Clean Sand waveform in the figure illustrates what clean (or very low NAPL) soil typically looks like on the TarGOST system. If NAPL is present, the fluorescence channels begin to grow in comparison to the laser channel. The 1,000ppm and 10,000ppm waveforms in the figure illustrate such a condition. Finally, with pure NAPL on the window, the increase in the fluorescence channels is minimal, but there has been significant loss of signal in the laser reflectance channel, due to absorbance by the PAH-laden NAPL.

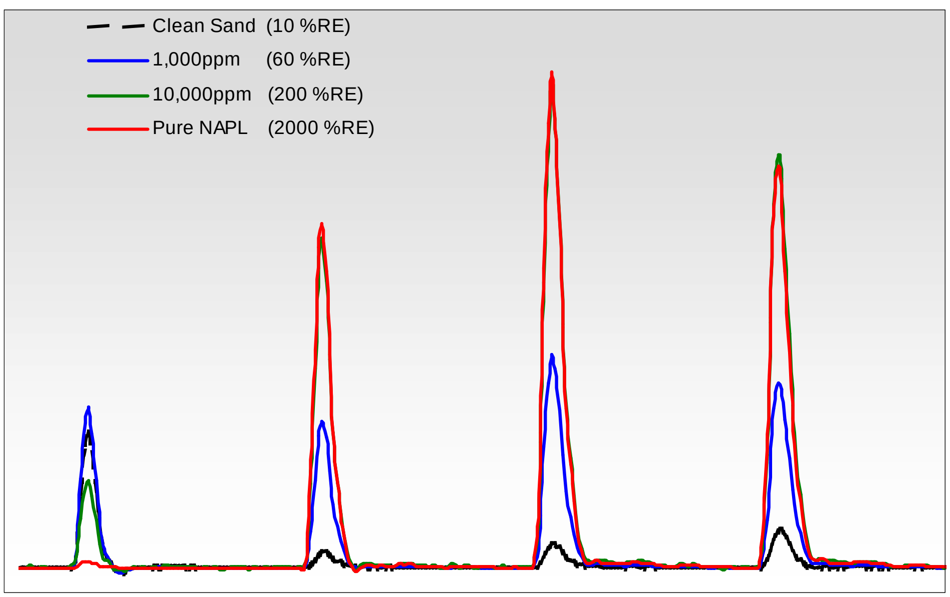


Figure 5. Example TarGOST Waveforms

Lab studies with MGP NAPL on moist Fisher® sea sand (and other soils) consistently demonstrate that TarGOST is capable of linear response vs. NAPL concentration over useful ranges, but some NAPLS are simply better behaved (more/less fluorescent) than others. Figure 6 shows examples of the range we see in TarGOST response for a variety of MGP NAPL on soils.

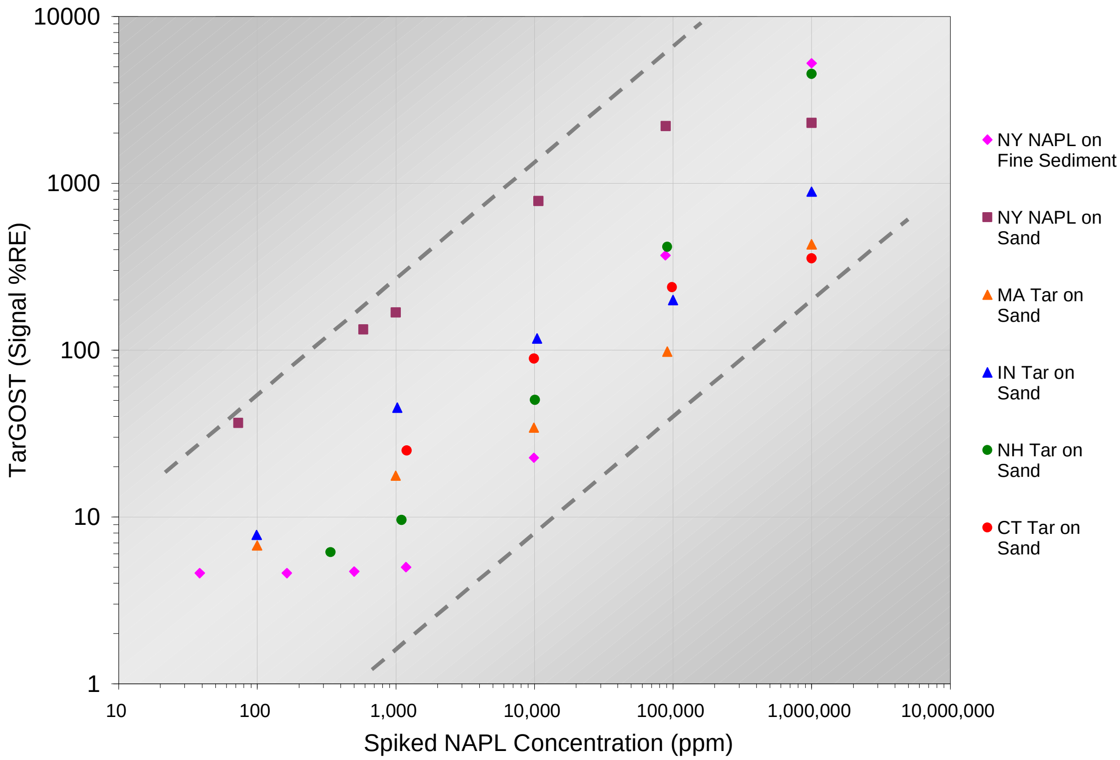


Figure 6. TarGOST response to a variety of MGP NAPLs

C.2 Real-World Data

Dakota has over twenty miles of vertical logging experience using TarGOST. Below are just a few logs of interest gathered over those years.

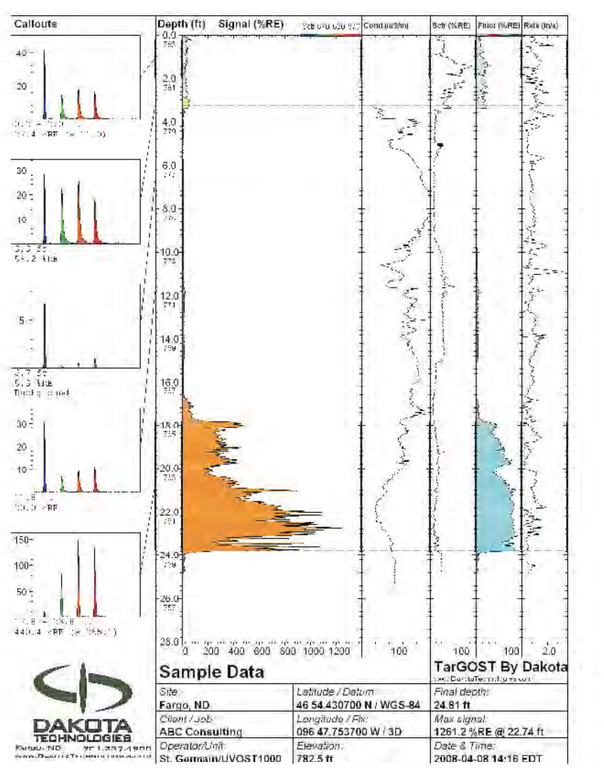


Figure 7. Example Log with EC

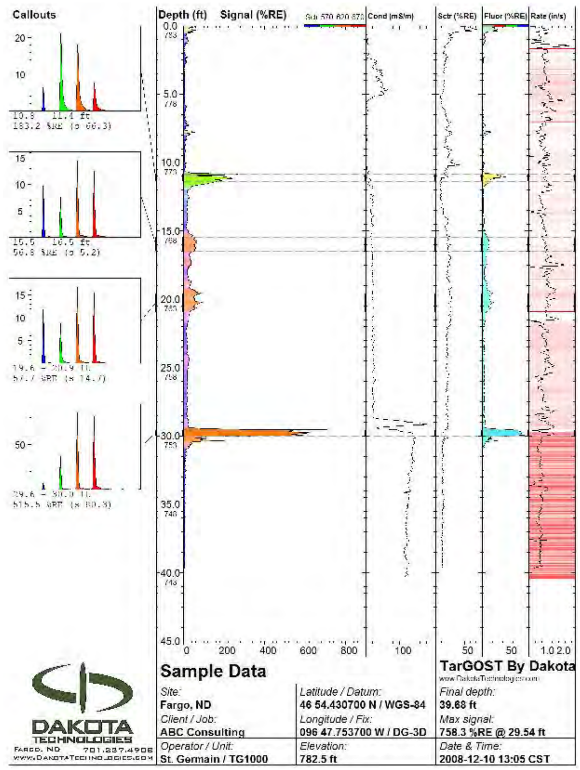


Figure 8. Example data including EC and Hammer Rate (red fill in right panel)

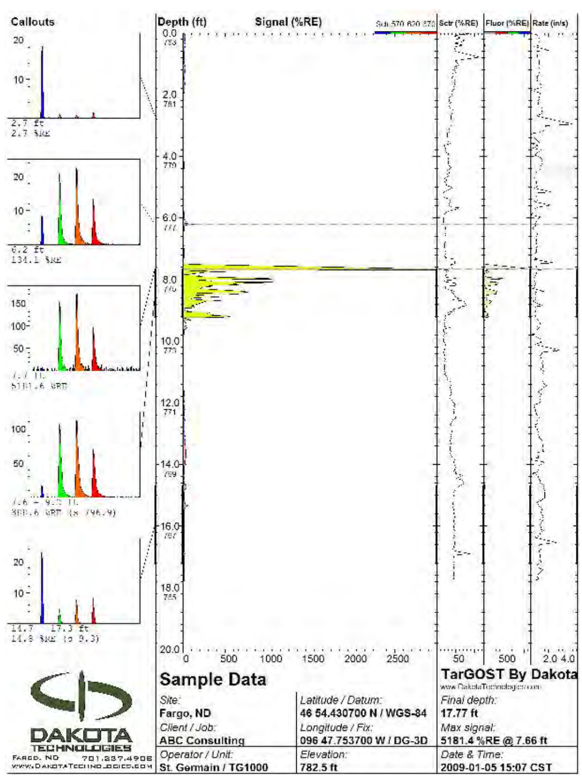


Figure 9. Example data with very high signal (low scatter)

D Theory and Results Summary

The following bulleted list is meant as a quick reference once the underlying principles of operation and results have been examined.

- TarGOST specifically targets the PAHs found in former MGP and creosote NAPLs and DNAPLs. There are most certainly other fluorescent molecular structures beside PAHs that contribute, but the PAHs dominate in most NAPLs
- TarGOST does detect moderate staining and residual levels of NAPL as well as free phase
- TarGOST is completely “blind” to aqueous (dissolved phase) PAHs
- TarGOST is not able to reliably detect “dry” PAHs (dry in the organic solvent sense) that are sorbed to soot, wood chips, and ash. They can generate a small signal but it is often weak and not easily teased out of the background. Many times we’re left wondering whether a small signal is caused by very high concentrations of “dry” PAHs on purifier chips or ash/soot or very low (100s of ppm) residual NAPL levels.
- TarGOST’s typical lab-determined LOD for NAPL on site soil is 100-500 ppm (weight of NAPL/weight of soil matrix). The more the NAPL fluoresces, the lower the LOD. Note that this is not the same as weight of Total PAHs /weight of soil matrix, since not all of a NAPL is PAHs
- TarGOST does, on occasion, respond to mineral or organic matter enough to be a nuisance. False positives include crushed limestone gravel fill, buried rotting wood/brush debris (the result of major flooding on a gravelly river), sea shells (shell hash), sawdust, quick lime, and some “mystery” solids/soils that were not identifiable
- TarGOST has been observed to significantly respond to peat material , but most peats fluoresce weakly – often there is NAPL in the peat so it’s difficult to know for sure whether it’s been the peat or NPAL staining that’s causing the fluorescence
- TarGOST does not respond to typical lighter end fuels like gasoline or kerosene (diesel can/has been detected) – unless they contain MGP waste or creosote that they are co-mingled in them (pentachlorophenol an obvious example)
- TarGOST is single-point calibrated with a reference emitter (RE) immediately prior to each sounding and the results are always plotted relative to RE (%RE)
- TarGOST calibration/setup isn’t perfect and the response for an identical NAPL can vary with optical platform and from lab to field. However, once set up on site, the response remains stable over time and from log-to-log. Changes to the spectrometer and mirror alignment/collimation SOP in 2007 made significant improvements to the consistency of the response
- NAPLs can vary greatly in their fluorescence response – even NAPLs found on the same site from the same source
- Thinner, less viscous NAPLs typically fluoresce much more (x10) than the more viscous TLMs. Asphalt-like TLMs which are solid/plastic fluoresce very poorly
- Scatter-correction is applied to TarGOST data to reduce/eliminate “response rollover” at high concentrations – but at low concentration (<100% RE) the Fluor (%RE) data column is better for judging “hits”
- Color-coding is determined by the relative waveform areas in each channel and provides “at-a-glance” recognition of waveform consistency or changes
- The waveforms contain both quantitative and qualitative information

E On-Site Fundamentals

E.1 Delivery Platform

Dakota has used its TarGOST systems in conjunction with nearly all commonly available direct-push (CPT and percussion) systems on land, ice, and on the water (barge).

- **Dakota's Probe Rig**

Dakota owns a Geoprobe® 5400 direct-push probe mounted on a Ford F-550 truck. When we operate our own system (TarGOST and Geoprobe) we generally send two experienced Dakota technicians.

- **Third Party Rig**

Dakota can rent a probe (for example a track rig) or our customers can hire a third party for the drilling activities. This third party option is generally a good idea when Dakota's mobilization fees are cost prohibitive or a special drilling license is required by the state.

- **Barge**

Dakota has extensive experience working from barges while providing TarGOST services. Barge sizes have ranged from 16' to 150' and we have worked in water depths of a couple of feet to 50'.

E.2 Pre-Planning

- **Free Sample Check**

Dakota will gladly look at your sample and let you know if TarGOST is the right choice for you. If your NAPL doesn't respond well with TarGOST, we'll also test your sample with UVOST to see if it is the better solution. Contact us for details, but it generally involves you sending us jars (from 5 to 40 ml) of your test NAPLs in an unrefrigerated shipping container, along with information regarding your site and contact information. In just a few days we'll let you know the results.

- **Probe Rig**

Arrange for Dakota to probe your site with our self-contained system or hire an outside drilling contractor. Dakota will need to communicate with your potential contractor to determine if they are capable of pushing direct sensing equipment. We have integrated with most Geoprobe models, many AMS probe machines, Marl rigs, homemade probe machines, CME drill rigs, mini CPT skids, tracked CPT machines and several brands of 40 ton CPT trucks.

- **Utility Clearance**

Dakota personnel have been instructed NOT TO PROCEED until underground utilities have been identified. Please communicate with Dakota to ensure that this is completed.

- **Site Access**

If any special security, permits or safety clearance is needed for Dakota's personnel or equipment is needed, alert Dakota prior to us showing up on-site.

- **Transport**

The main components of the TarGOST system are housed in a shock-protected enclosure measuring roughly 2x2x2 feet and weighing approximately 100 pounds. In addition to this enclosure, there is a rod-rack with generally four-foot rods, a computer, fiber cables, a generator, tools, spare probes and various peripheral items. When we ship the system, everything fits in a 4x4x4 foot enclosed pallet. A fork lift and secure storage should be arranged near the work site.

Figure 10. TarGOST and all peripherals in an enclosed palette being loaded for transport

- **Hole Locations**

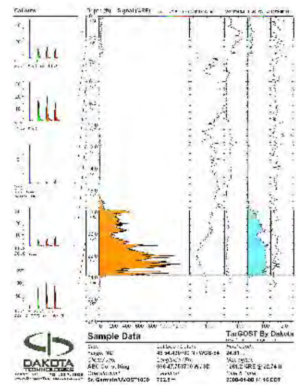
Some customers like to pre-plan the hole locations, mark the site accordingly, and record all relevant x-y and elevation data. A plan of bounding the contamination based on results determined on-site is also viable. Regardless if the hole placement follows a grid or bounding procedure, Dakota strongly prefers to start the job in what is believed to be “the heart” of the contamination. This gives everyone involved a feel for how well the NAPL is going to respond to TarGOST delineation.

- **Sampling**

Dakota recommends discrete sampling at 10% of the hole locations if semi-quantitative values are to be assigned to the LIF signals. Soil sampling can be reduced to approximately 5% of hole locations as a ground-truthing exercise. If an extensive sampling program is planned the client should consider hiring a more cost effective driller. Remember to build sampling time into you scope of work. Do consider getting TarGOST responses to homogenized splits of your samples. If your site has heterogeneous lithology (very typical), the chance of you sampling soils/NAPL that are representative of that which the TarGOST probe passed through are near zero. If heterogeneity exists, and you try to compare lab results to TarGOST %RE of adjacent logs rather than TarGOST %RE of those same samples, the correlation will be terrible (the expected result).

E.3 Daily Production

- **Footage**



TarGOST productivity can range anywhere from 200 to over 500 ft/day. If the pushes are fairly deep (>30 ft), and the obstructions or rubble are minimal, then the average is on the higher end because we spend a lot more time actually probing, not moving around from location to location and/or trying multiple times to get holes started through rubble. Other factors affecting production are grouting requirements, surface pavement, surface topography and vegetation. We typically can log between 10 and 20 locations a day.

- **Start-Up Time**

When the system first arrives on site, it is powered up and tested for proper function. If it is in Dakota's Geoprobe, the TarGOST is simply powered up and we're ready to begin probing after a very short warm-up. If a CPT or other direct-push machine is used, the TarGOST system is integrated into the delivery platform, rods are strung with the Dakota's optical fiber cable and proper depth measuring connections are made (about a 2 to 3 hour procedure).

- **Decontamination**

Typically Dakota uses a rubber rod wiper to "squeegee" any contaminated mud from the probe. If additional decontamination is required, production rates will be impacted accordingly.

- **Sampling**

If Dakota is contracted to collect soil samples, it will be prudent to do all the sampling at one time, preferably at the end of the job. Using LIF data, impacted zones can be identified and targeted for sampling, eliminating the need for continuous cores.

- **Barge Productivity**

TarGOST operations on a barge usually limit daily production to 50 – 200' of logged depth. Additional factors affecting barge productivity are; location accuracy needed, subsurface conditions, water depth and presence of current or tide.

E.4 Deliverables

- **JPEG Images**

Once a log is completed our TarGOST operators can immediately generate an image of the log. Callouts are used to show the waveform from areas of interest. Along with the %RE versus depth plot, the scatter and the fluorescence levels as a function of depth are provided. Secondary data such as the rate of probe advancement, the amount of hammering required to advance the probe with percussion systems, and conductivity may also be available. At the bottom of the log is the pertinent info for the data such as site name and location as well as basic stats such as total depth. These images can be printed on site.

- **Data in Text Format**

Along with the log image, our customers are given the data in ASCII tab delimited format. No string header is provided for the columns (to make importing into other programs easier). Each row is a unique depth reading. The columns are:

1	2	3	4	5	6	7	8	9	10	11
Depth	Total Signal (%RE)	Ch1 (%RE Sctr)	Ch2 (%RE Fluor),	Ch3 (%RE Fluor),	Ch4 (%RE Fluor),	Push Rate	Cond. Depth	Cond. Signal	Hammer Depth	Hammer Rate

TarGOST data collected with a CPT rig will not include the CPT data as that is an independent acquisition system. Dakota is only responsible for providing the LIF data.

E.5 Post-Investigation

- **Customer Care**

Dakota prides itself on going the extra mile from our customers. Whether it is providing detailed information such as this document, or walking the customer through the data on the phone long after we have left the site, we are committed to our customers being well informed and pleased with our service.

- **Hole Locations**

Once Dakota leaves, our customers may wish to survey all the TarGOST locations if it wasn’t done prior to the job. Getting good positional information, including elevation, is key to any future CAD and visualization efforts.

- **Conceptual Site Model Visualization**

Dakota now provides the capability to view TarGOST/UVOST/ROST site characterization data in static or dynamic format with unparalleled resolution. Dakota can also overlay the site with aerial photographs or building CAD models over GIS terrain data to provide an accurate overall picture of the site with relevant subsurface features.

» 2-D (fence or cross section) and 3-D models such as Plume and Stick provide a variety of methods to best represent the log data
» Capable of vertical resolution less than 1 inch
» Log interpolation between direct push locations using a highly accurate modeling algorithm
» Choose a variety of display formats including static graphics and dynamic video
» Overlay site aerial photographs or satellite images onto the model
» Integrate Dakota’s visual models with client’s existing AutoCAD drawings

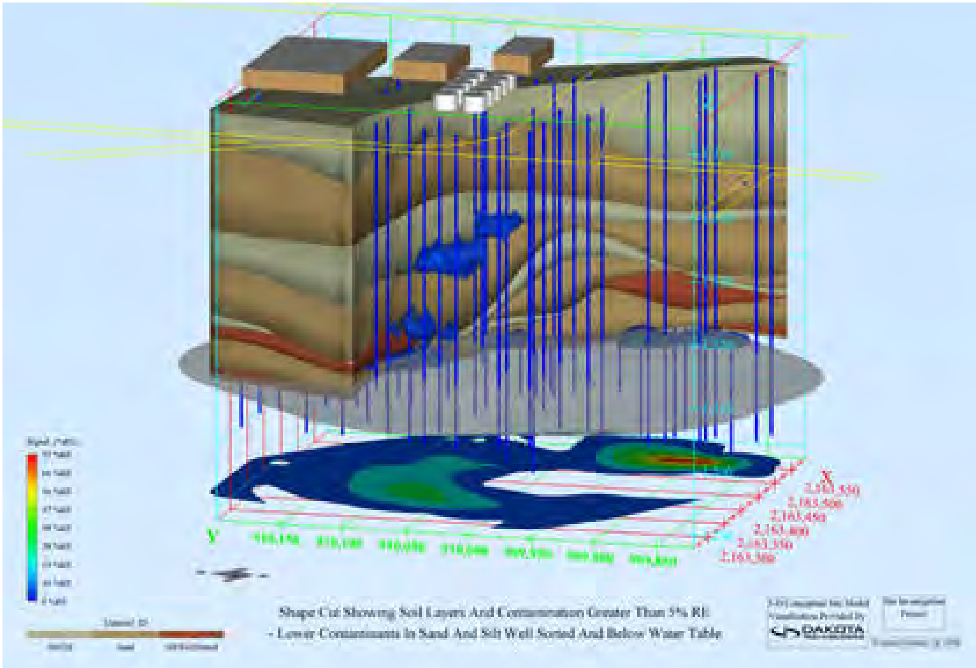
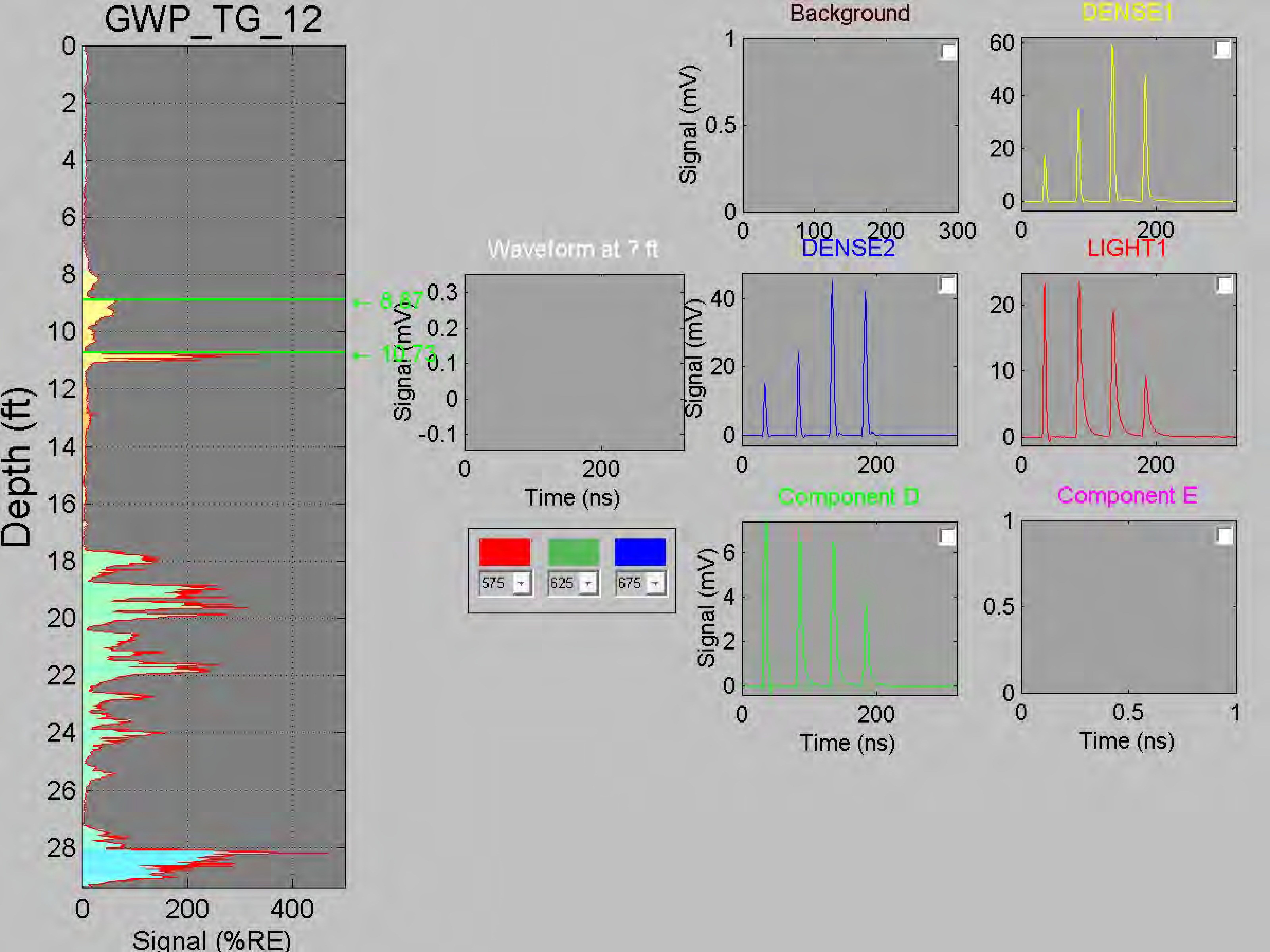


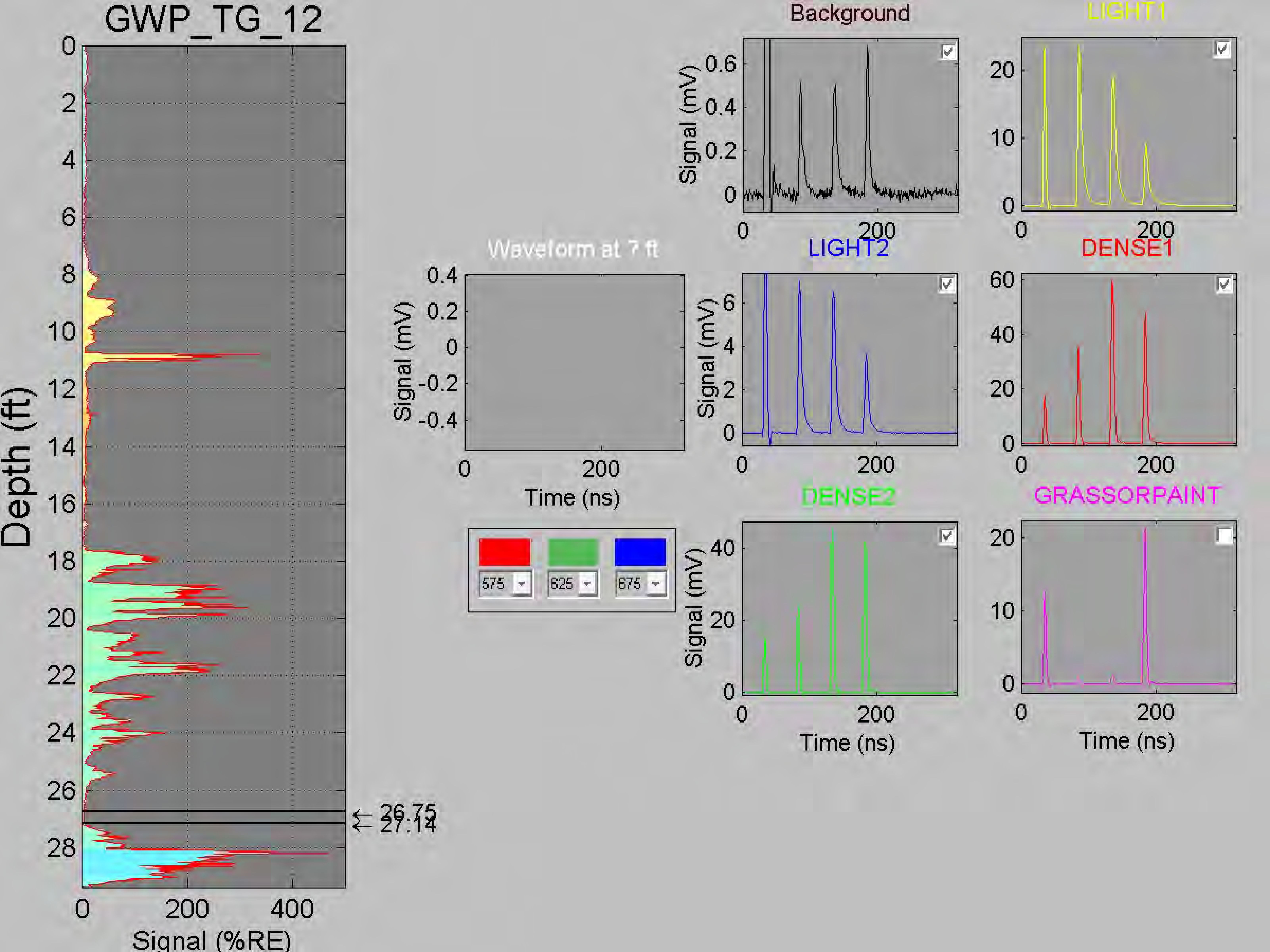
Figure 11. Geology slice and LIF data

Figure 12. 2D overlay of UVOST data and site photo

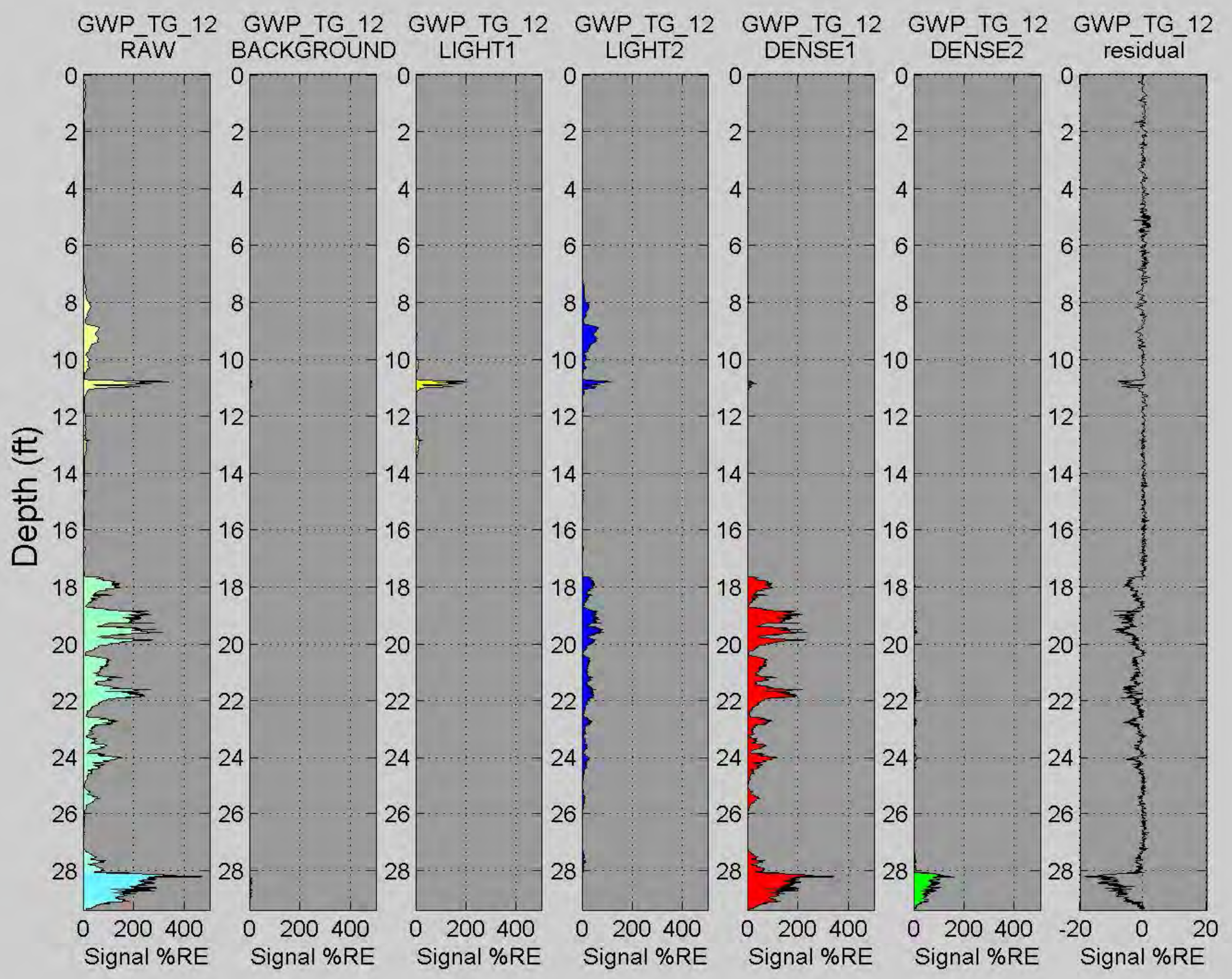
SUB-ATTACHMENT 2A-2.7
TarGOST® NNLS Waveform Analysis

SUB-ATTACHMENT 2A-2.7.1
NNLS Basis Set Components

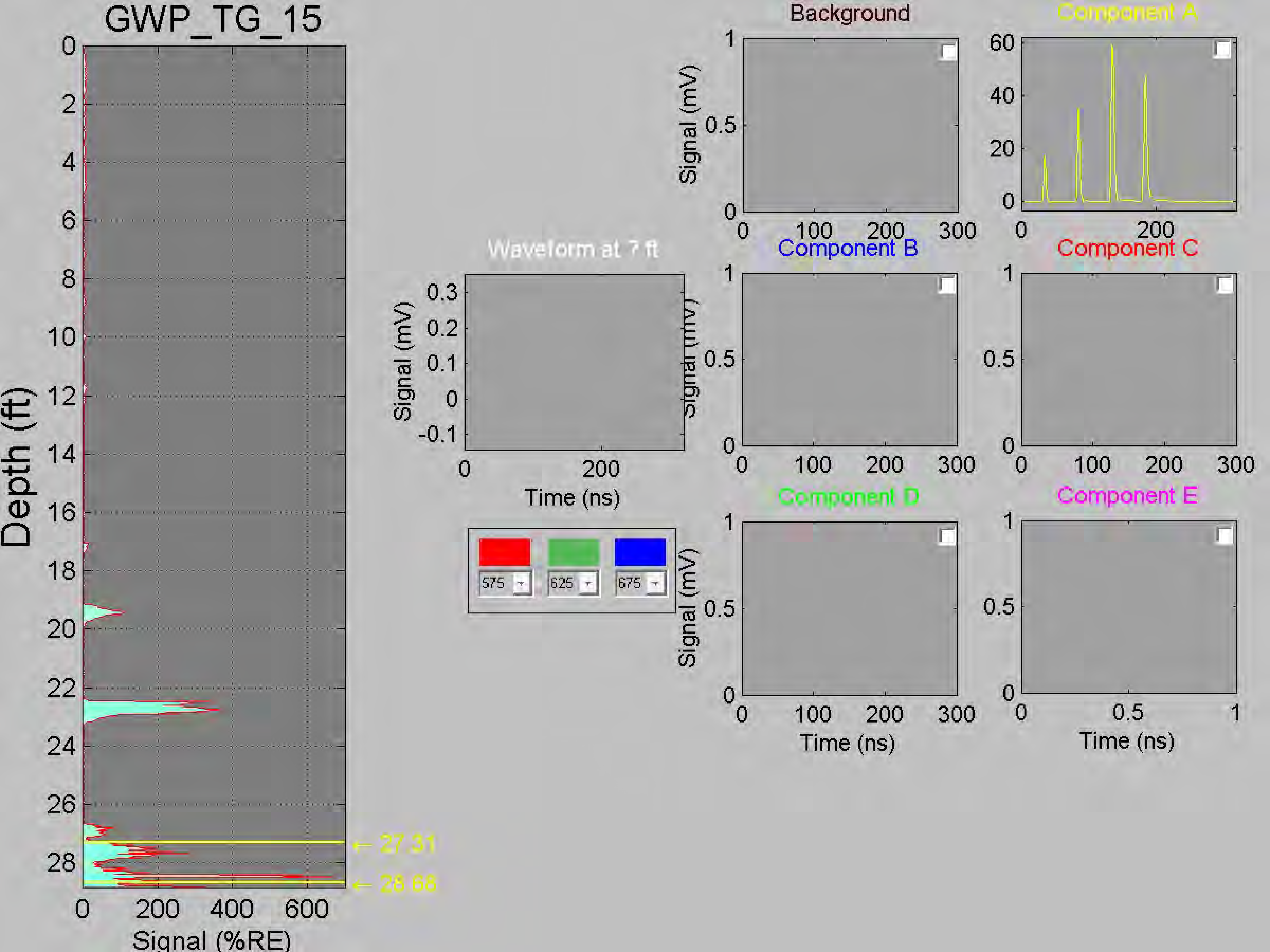

GWP_TG_12
Depth (ft)
Signal (%RE)
8.87
10.73
Waveform at 7 ft
Signal (mV)
Time (ns)
575
625
675
Background
DENSE1
DENSE2
LIGHT1
Component D
Component E



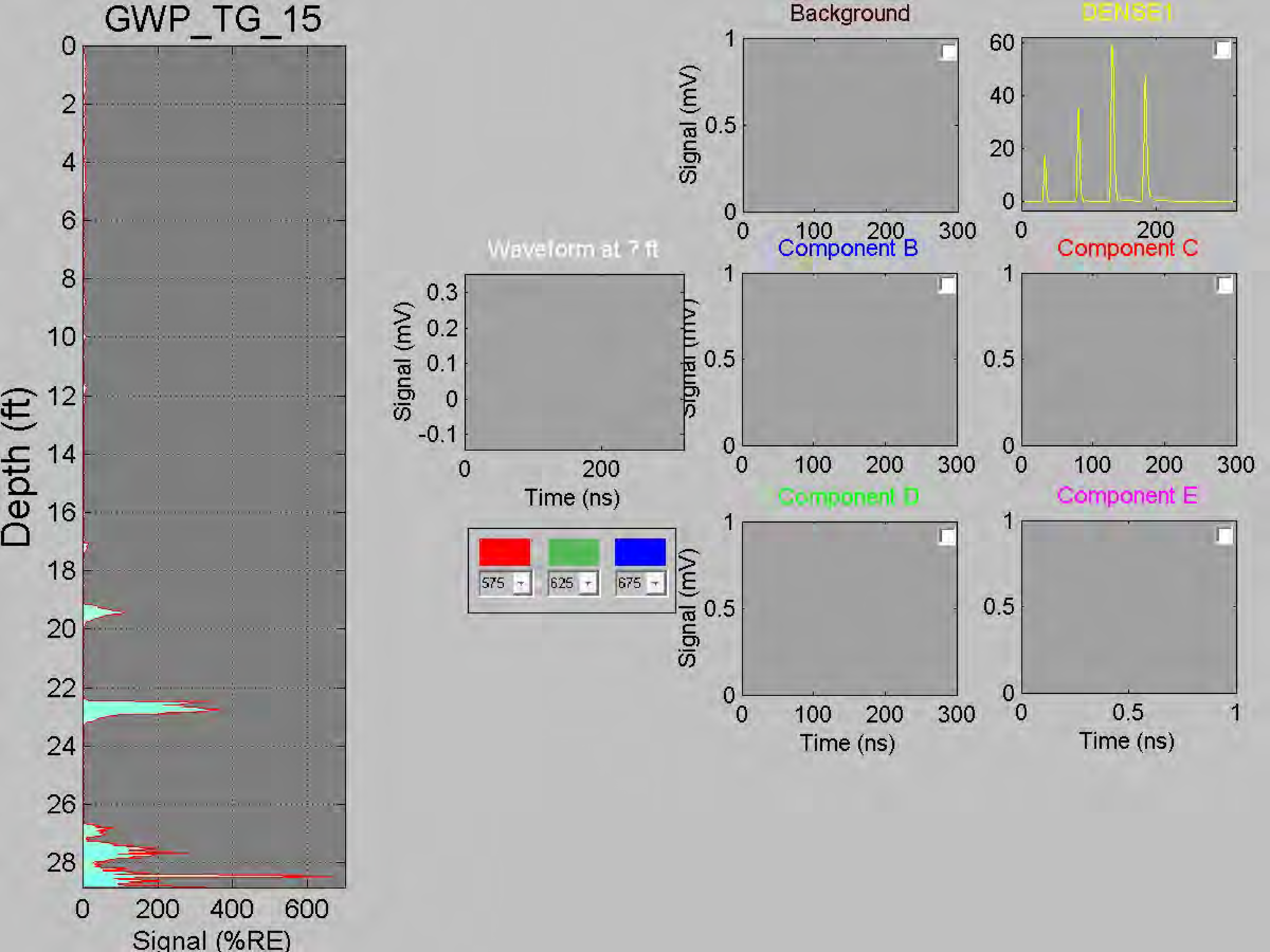
GWP_TG_12
Depth (ft)
Signal (%RE)
26.75
27.14
Waveform at 7 ft
Signal (mV)
Time (ns)
575
625
675
Background
LIGHT1
LIGHT2
DENSE1
DENSE2
GRASSORPAINT



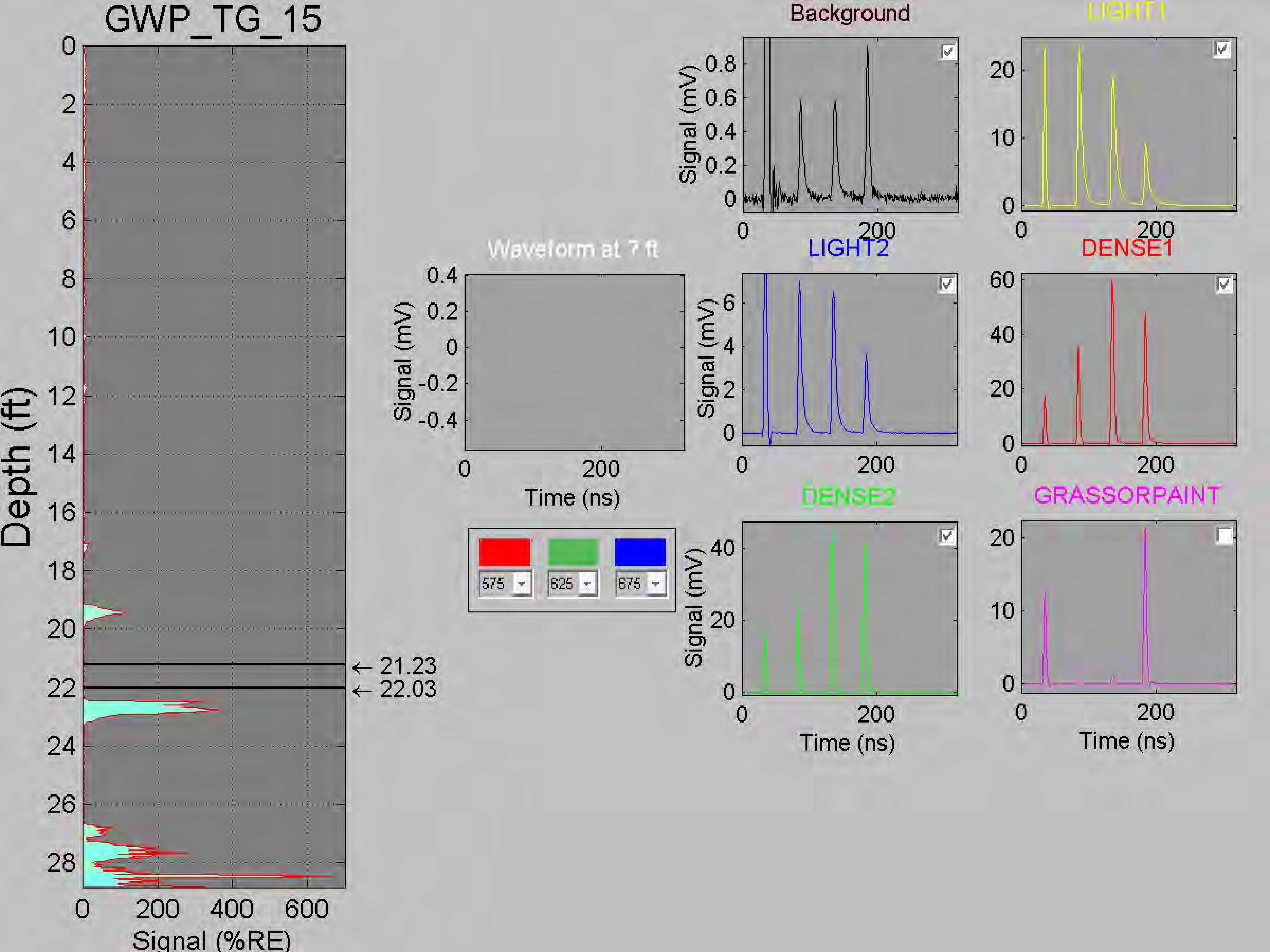
GWP_TG_12
RAW
GWP_TG_12
BACKGROUND
GWP_TG_12
LIGHT1
GWP_TG_12
LIGHT2
GWP_TG_12
DENSE1
GWP_TG_12
DENSE2
GWP_TG_12
residual
Depth (ft)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
0 200 400
-20 0 20
Signal %RE

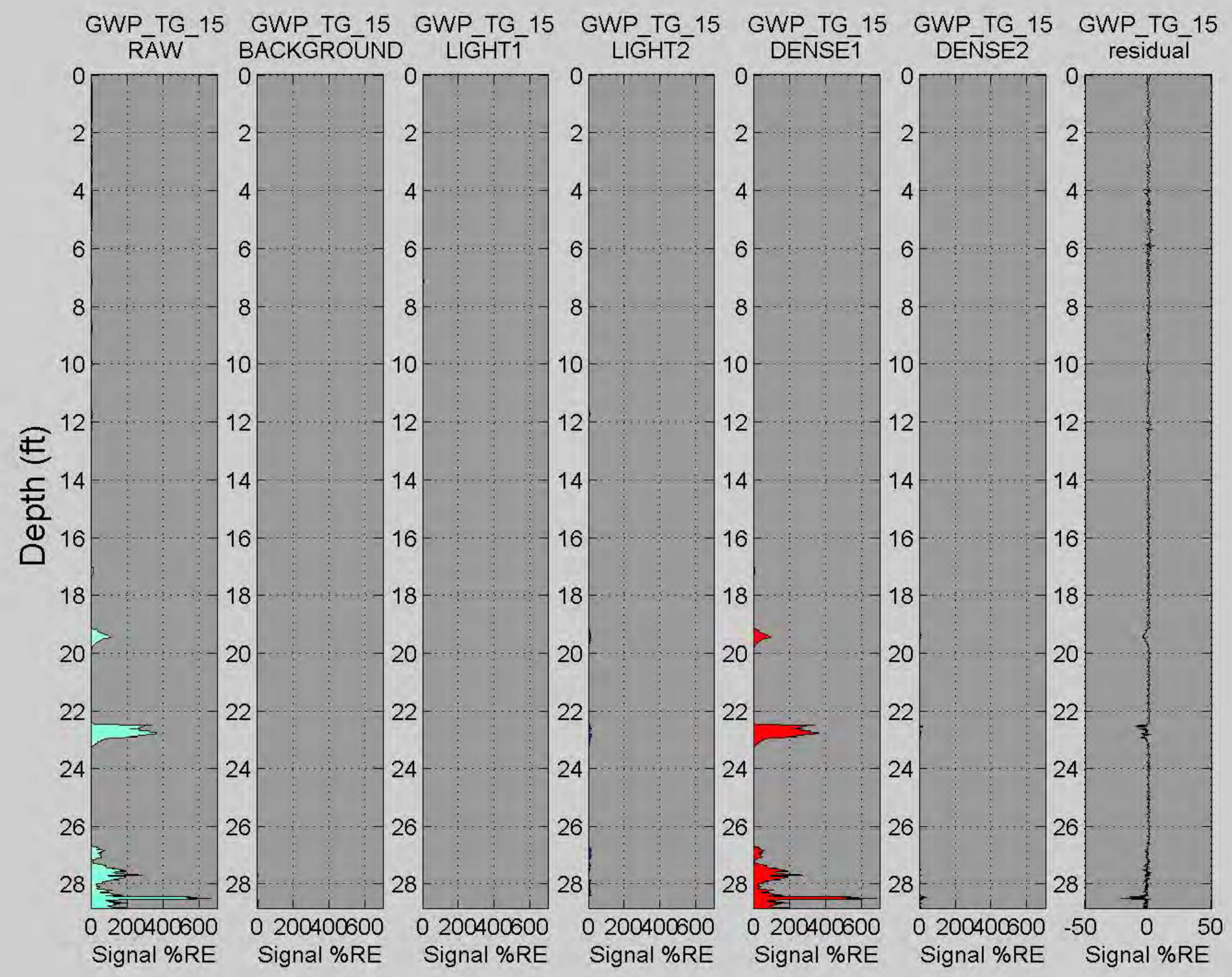


GWP_TG_15
Depth (ft)
Signal (%RE)
27.31
28.68
Waveform at 7 ft
Signal (mV)
Time (ns)
575
625
675
Background
Component A
Component B
Component C
Component D
Component E

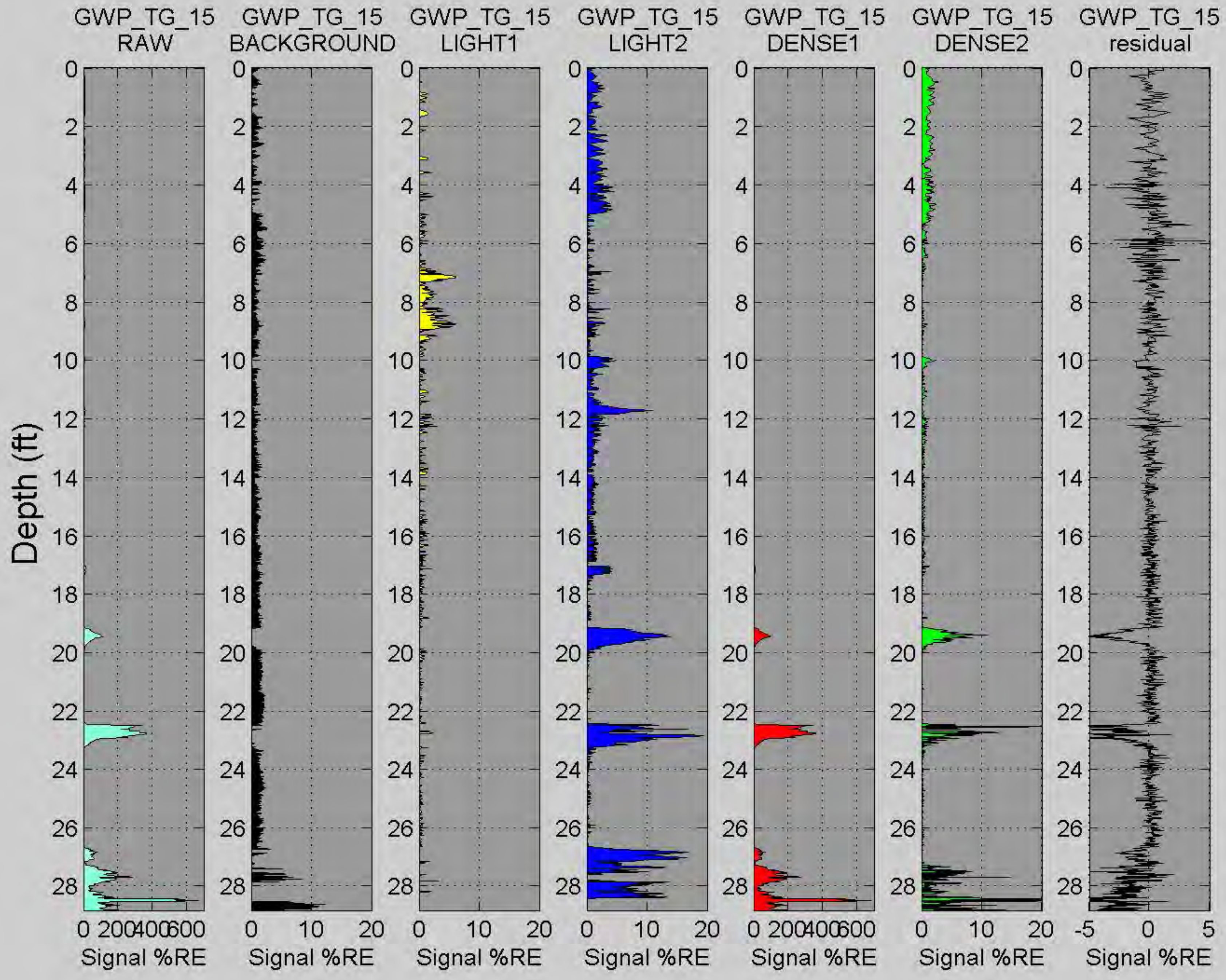


GWP_TG_15
Depth (ft)
Signal (%RE)
Background
DENSE1
Waveform at 7 ft
Component B
Component C
Component D
Component E
Signal (mV)
Time (ns)
575
625
675

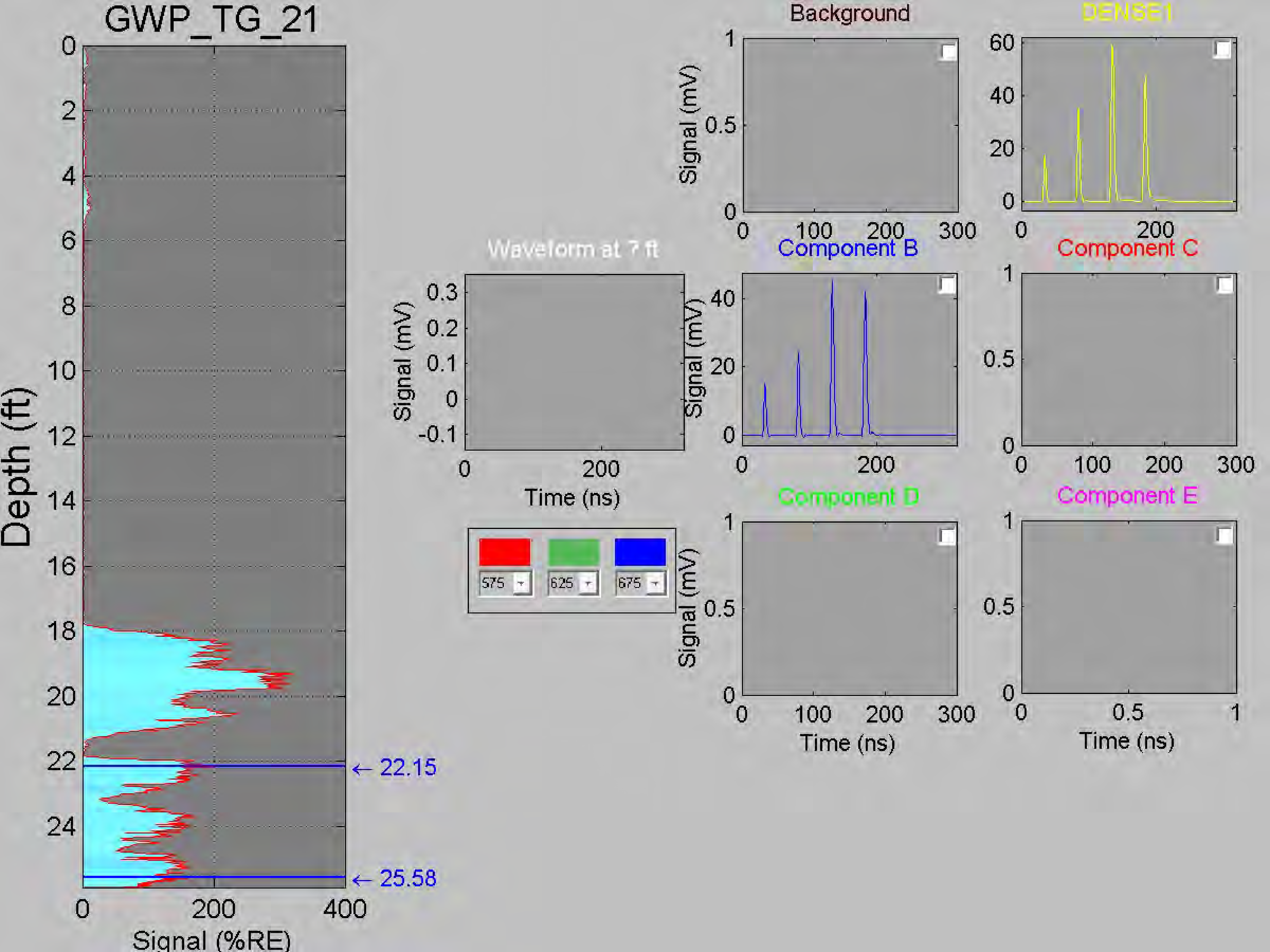

GWP_TG_15
Depth (ft)
Signal (%RE)
← 21.23
← 22.03
Background
LIGHT1
Waveform at 7 ft
LIGHT2
DENSE1
DENSE2
GRASSORPAINT
Signal (mV)
Time (ns)
575
625
675



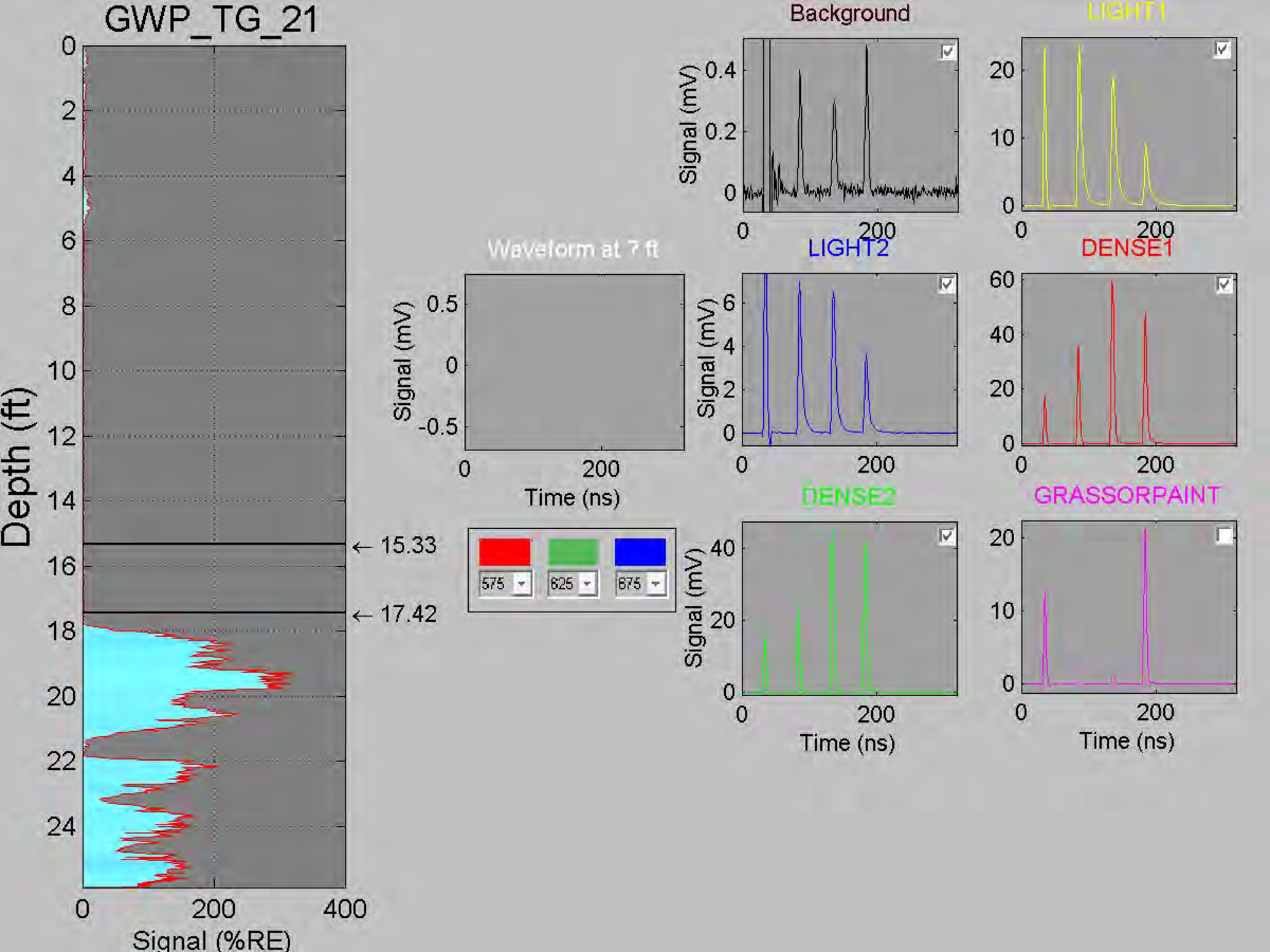
GWP_TG_15 RAW
GWP_TG_15 BACKGROUND
GWP_TG_15 LIGHT1
GWP_TG_15 LIGHT2
GWP_TG_15 DENSE1
GWP_TG_15 DENSE2
GWP_TG_15 residual
Depth (ft)
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28
0 200 400 600
-50 0 50
Signal %RE



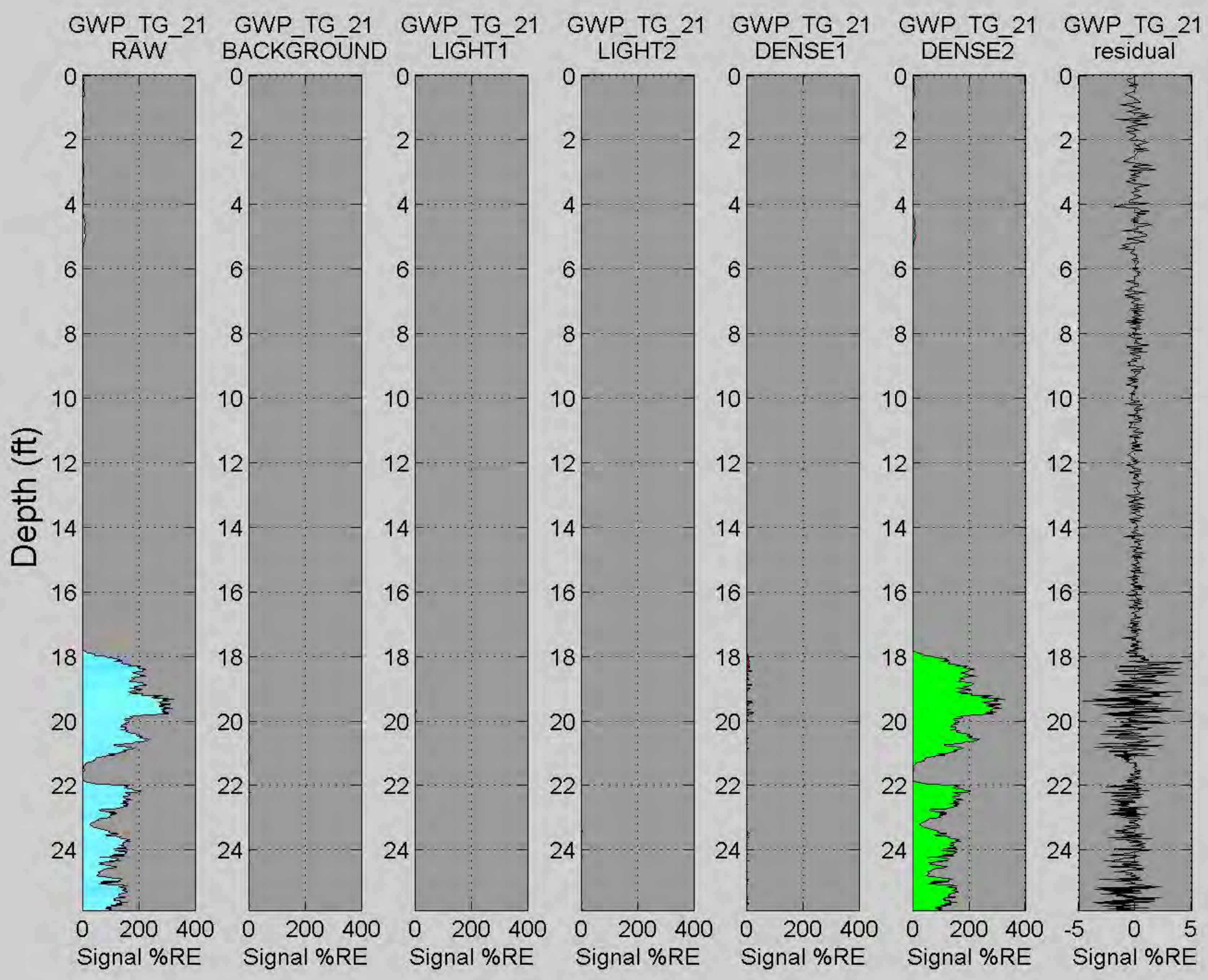
GWP_TG_15
RAW
GWP_TG_15
BACKGROUND
GWP_TG_15
LIGHT1
GWP_TG_15
LIGHT2
GWP_TG_15
DENSE1
GWP_TG_15
DENSE2
GWP_TG_15
residual
Depth (ft)
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28
0 200 400 600
0 10 20
-5 0 5
Signal %RE



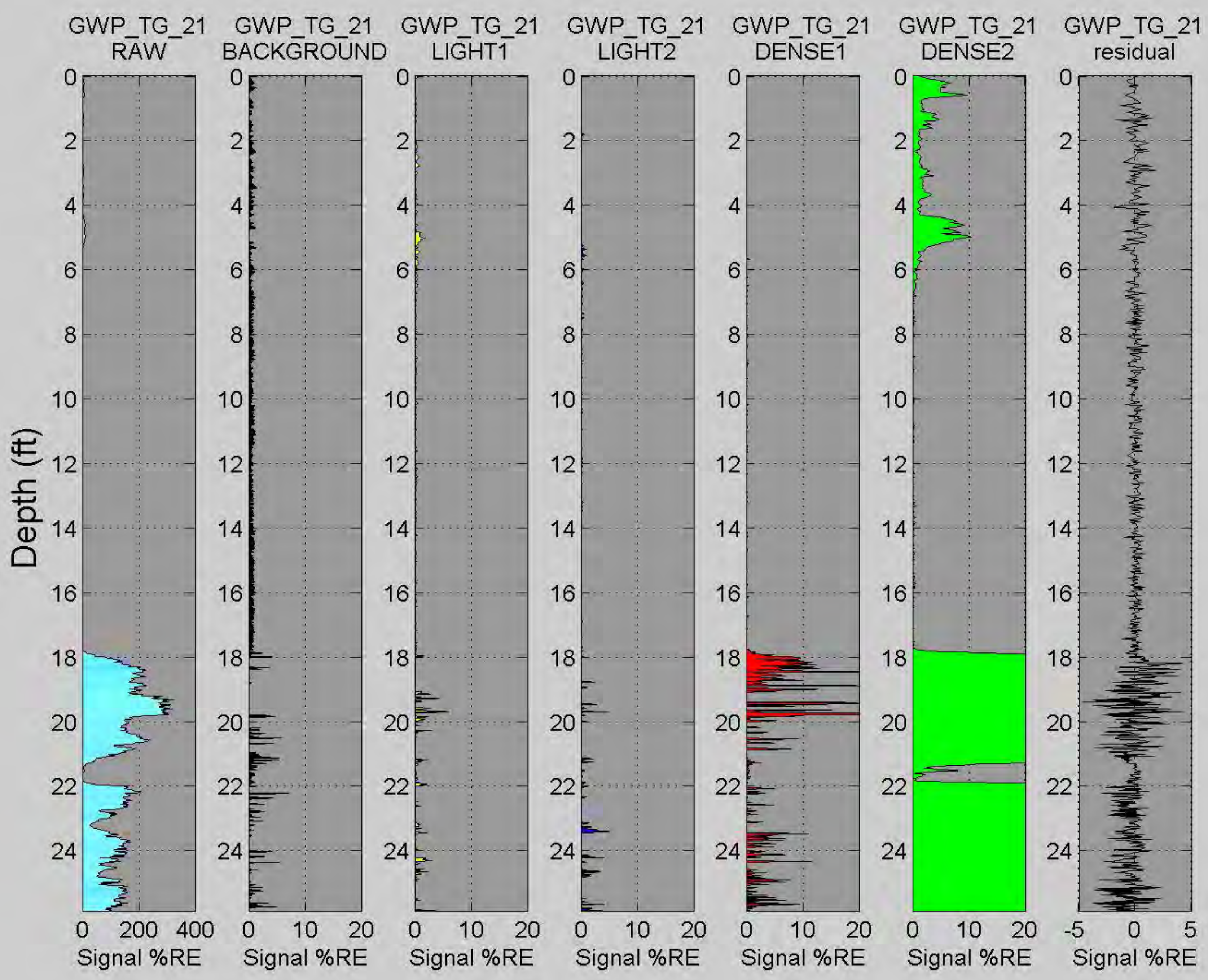
GWP_TG_21
Depth (ft)
Signal (%RE)
← 22.15
← 25.58
Background
DENSE1
Waveform at 7 ft
Component B
Component C
Component D
Component E
Signal (mV)
Time (ns)
575
625
675



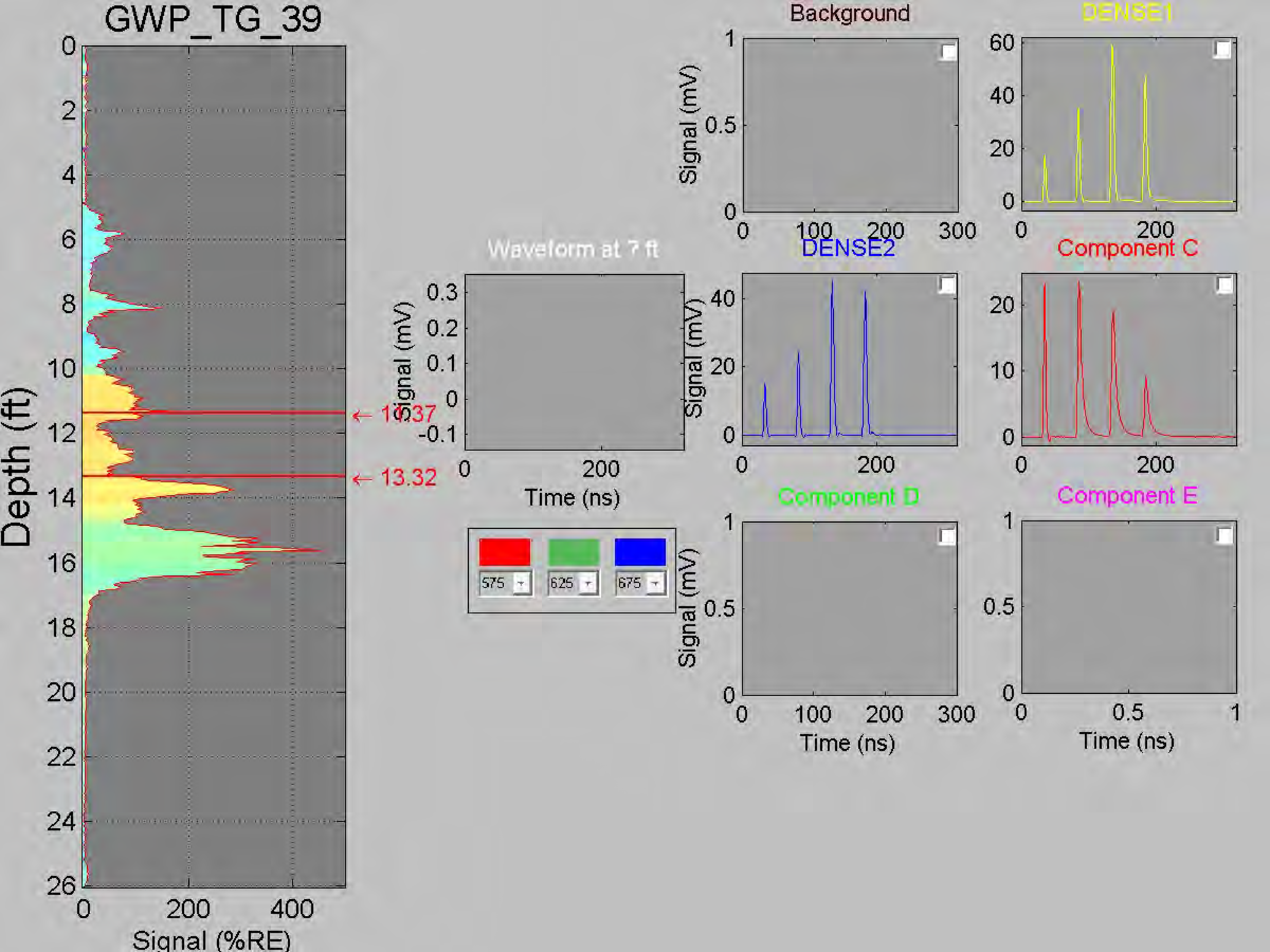
GWP_TG_21
Depth (ft)
Signal (%RE)
← 15.33
← 17.42
Waveform at 7 ft
Signal (mV)
Time (ns)
575
625
675
Background
LIGHT1
LIGHT2
DENSE1
DENSE2
GRASSORPAINT



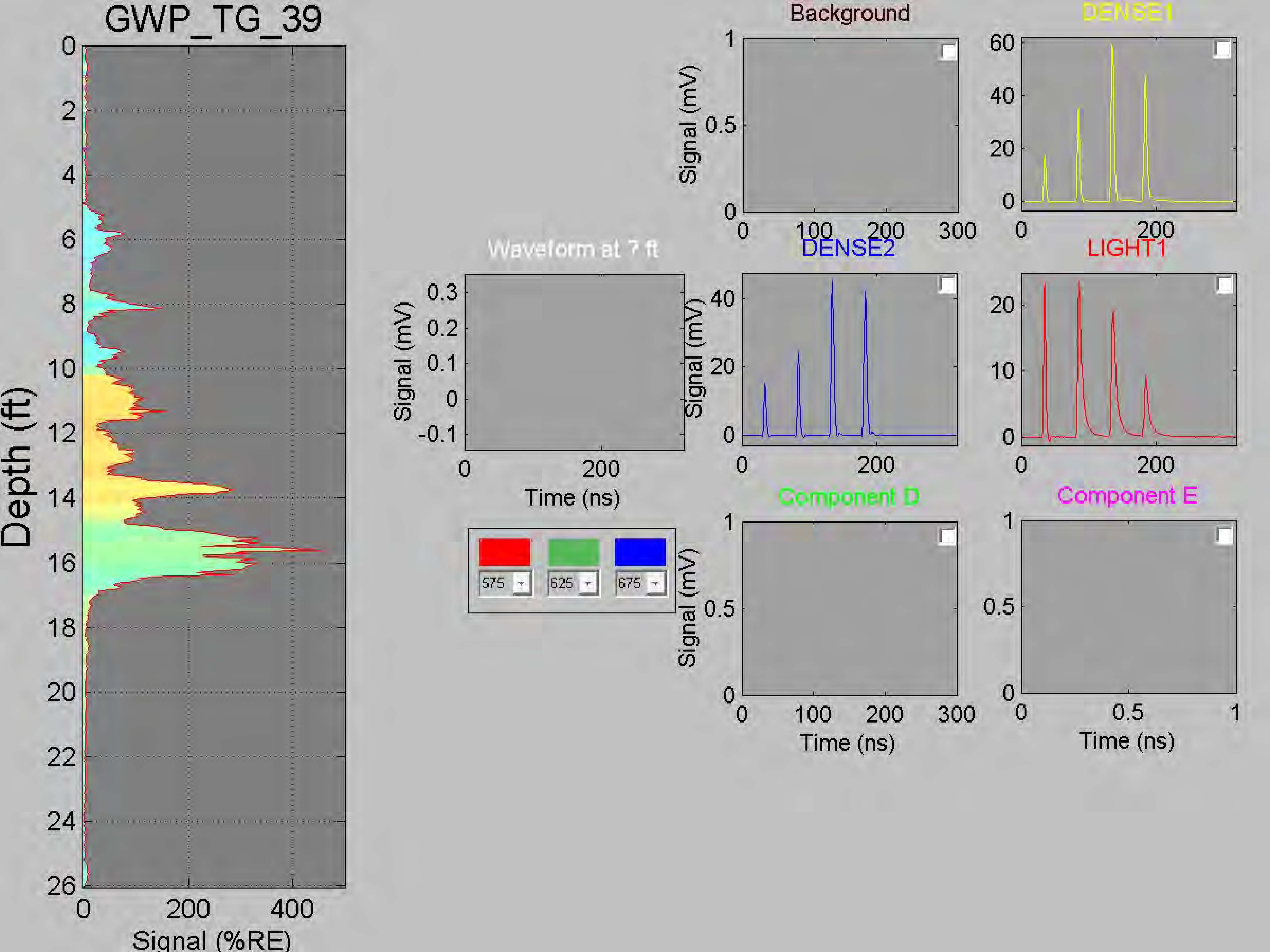
GWP_TG_21
RAW
GWP_TG_21
BACKGROUND
GWP_TG_21
LIGHT1
GWP_TG_21
LIGHT2
GWP_TG_21
DENSE1
GWP_TG_21
DENSE2
GWP_TG_21
residual
Depth (ft)
Signal %RE



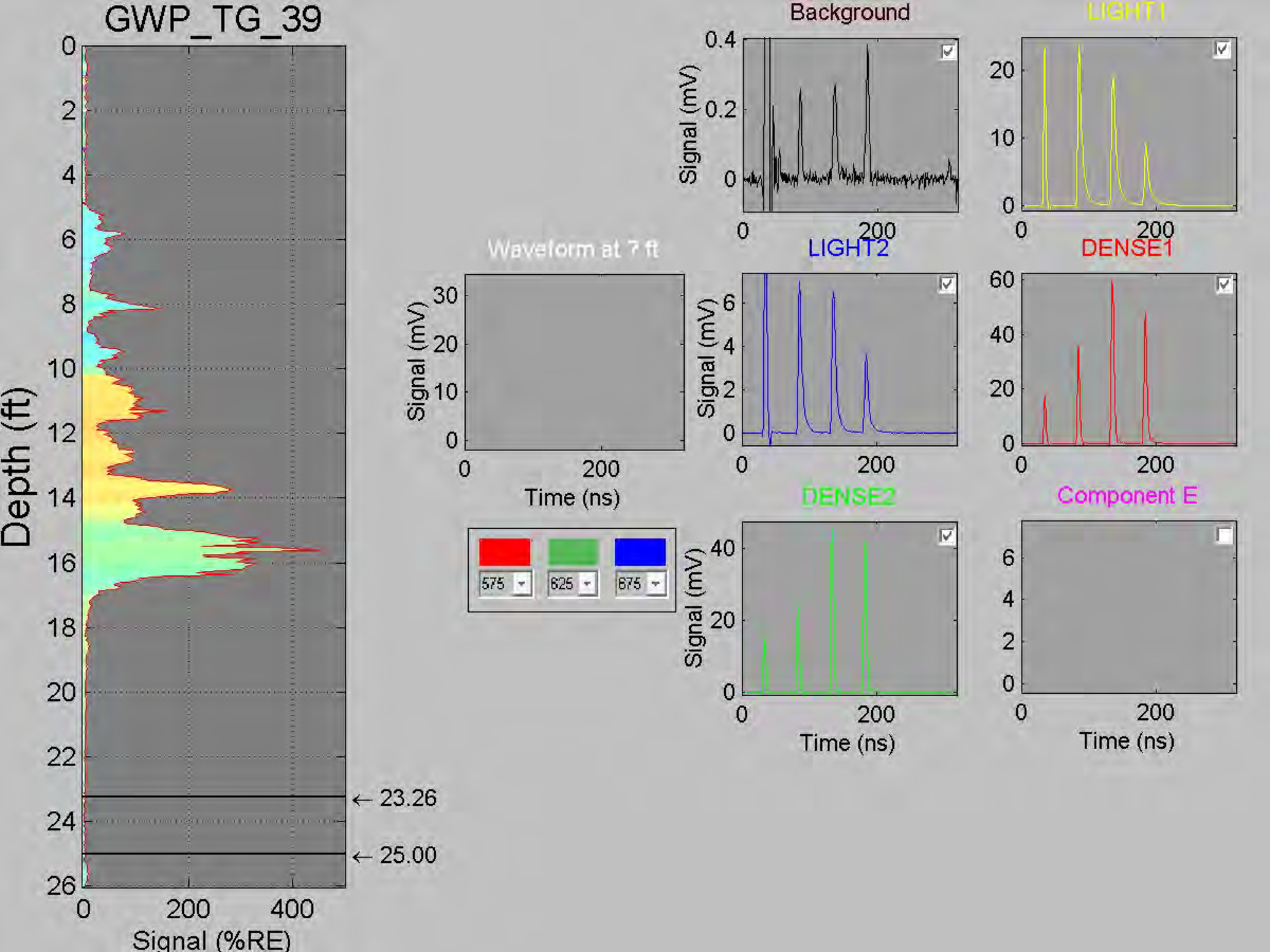
GWP_TG_21 RAW
GWP_TG_21 BACKGROUND
GWP_TG_21 LIGHT1
GWP_TG_21 LIGHT2
GWP_TG_21 DENSE1
GWP_TG_21 DENSE2
GWP_TG_21 residual
Depth (ft)
0 2 4 6 8 10 12 14 16 18 20 22 24
0 200 400
0 10 20
-5 0 5
Signal %RE



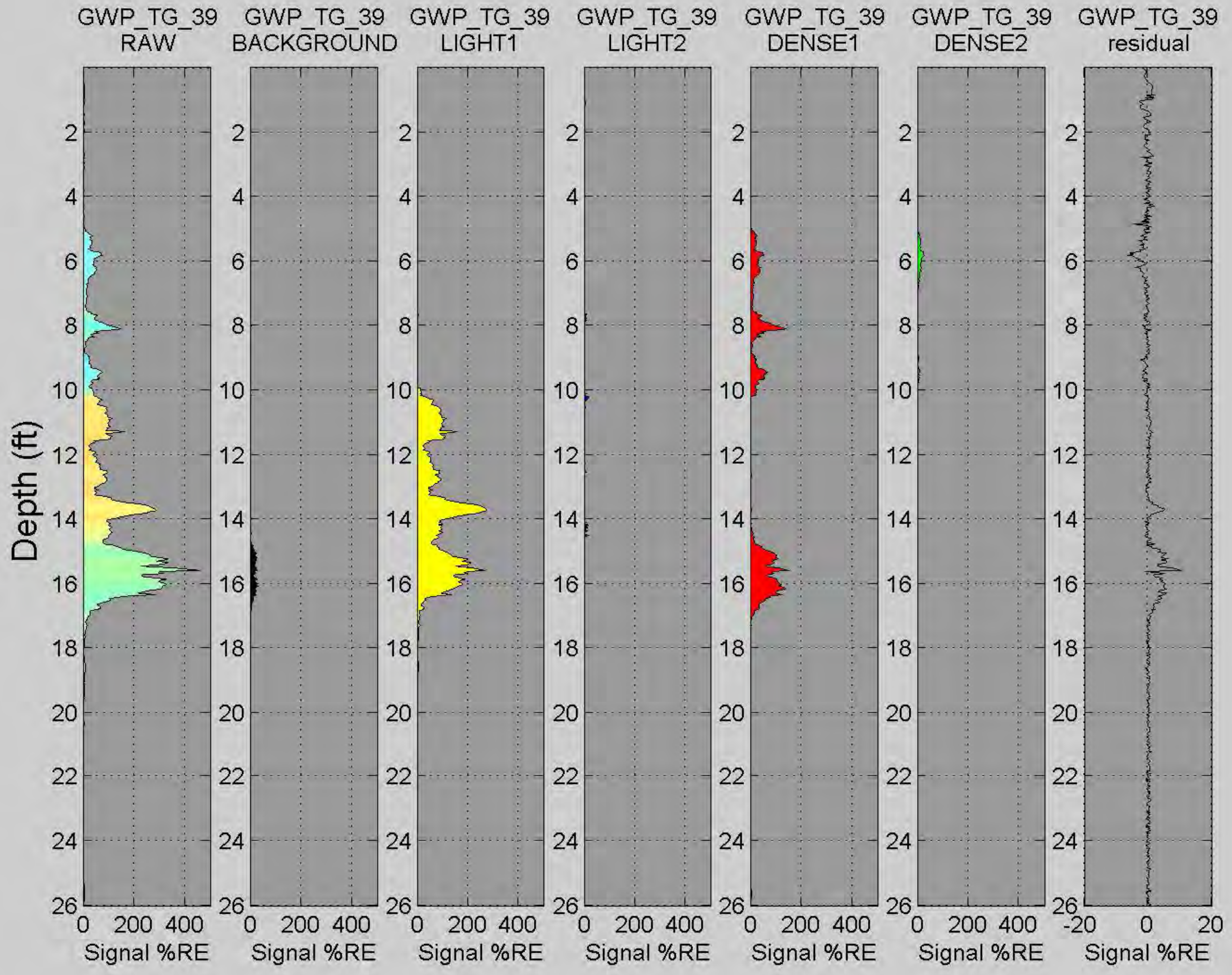
GWP_TG_39
Depth (ft)
Signal (%RE)
← 11.37
← 13.32
Waveform at 7 ft
Signal (mV)
Time (ns)
575
625
675
Background
DENSE1
DENSE2
Component C
Component D
Component E



GWP_TG_39
Depth (ft)
Signal (%RE)
Background
DENSE1
DENSE2
LIGHT1
Component D
Component E
Waveform at 7 ft
Signal (mV)
Time (ns)
575
625
675

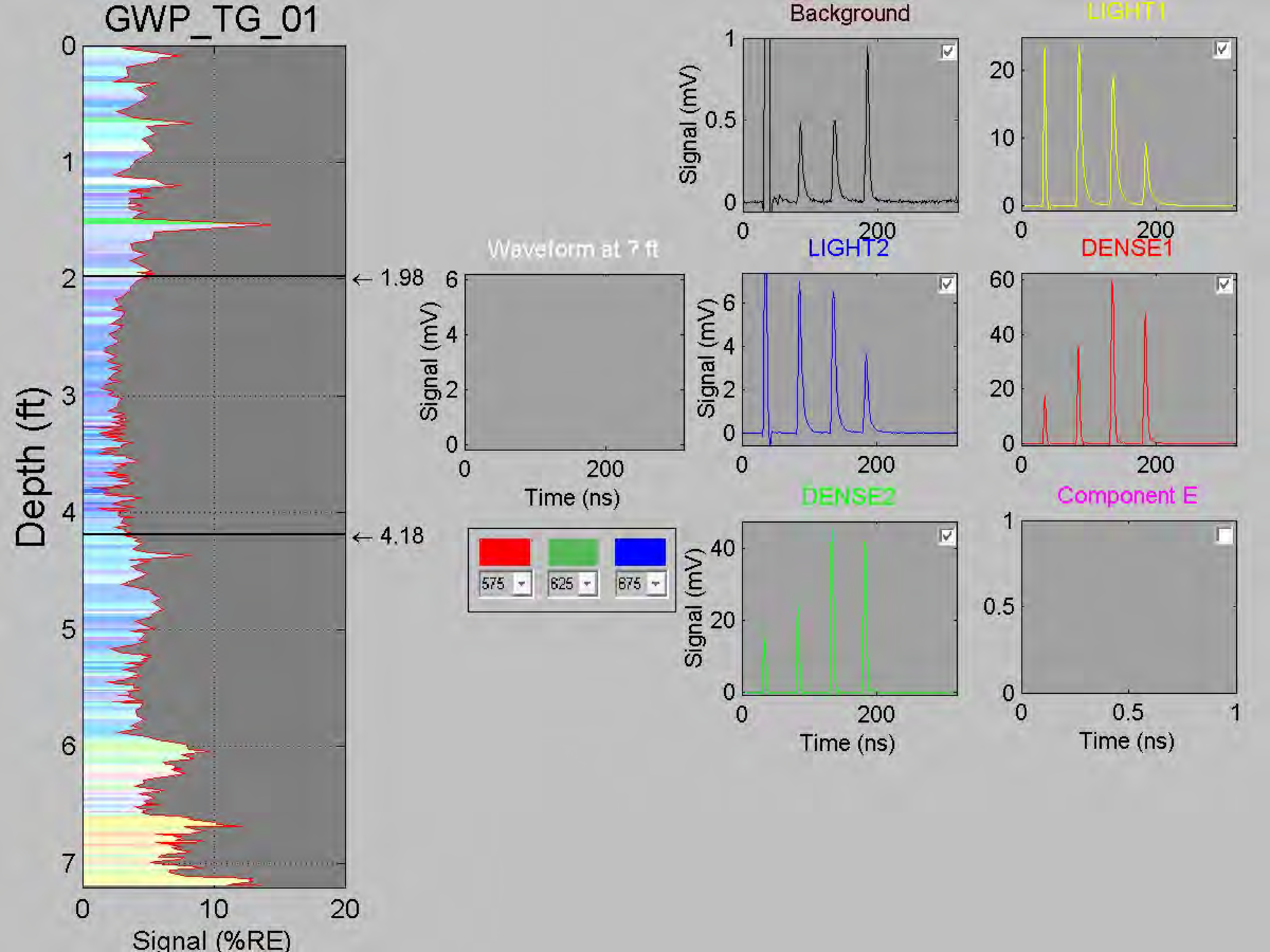


GWP_TG_39
Depth (ft)
Signal (%RE)
← 23.26
← 25.00
Background
LIGHT1
LIGHT2
DENSE1
DENSE2
Component E
Waveform at 7 ft
Signal (mV)
Time (ns)
575
625
675

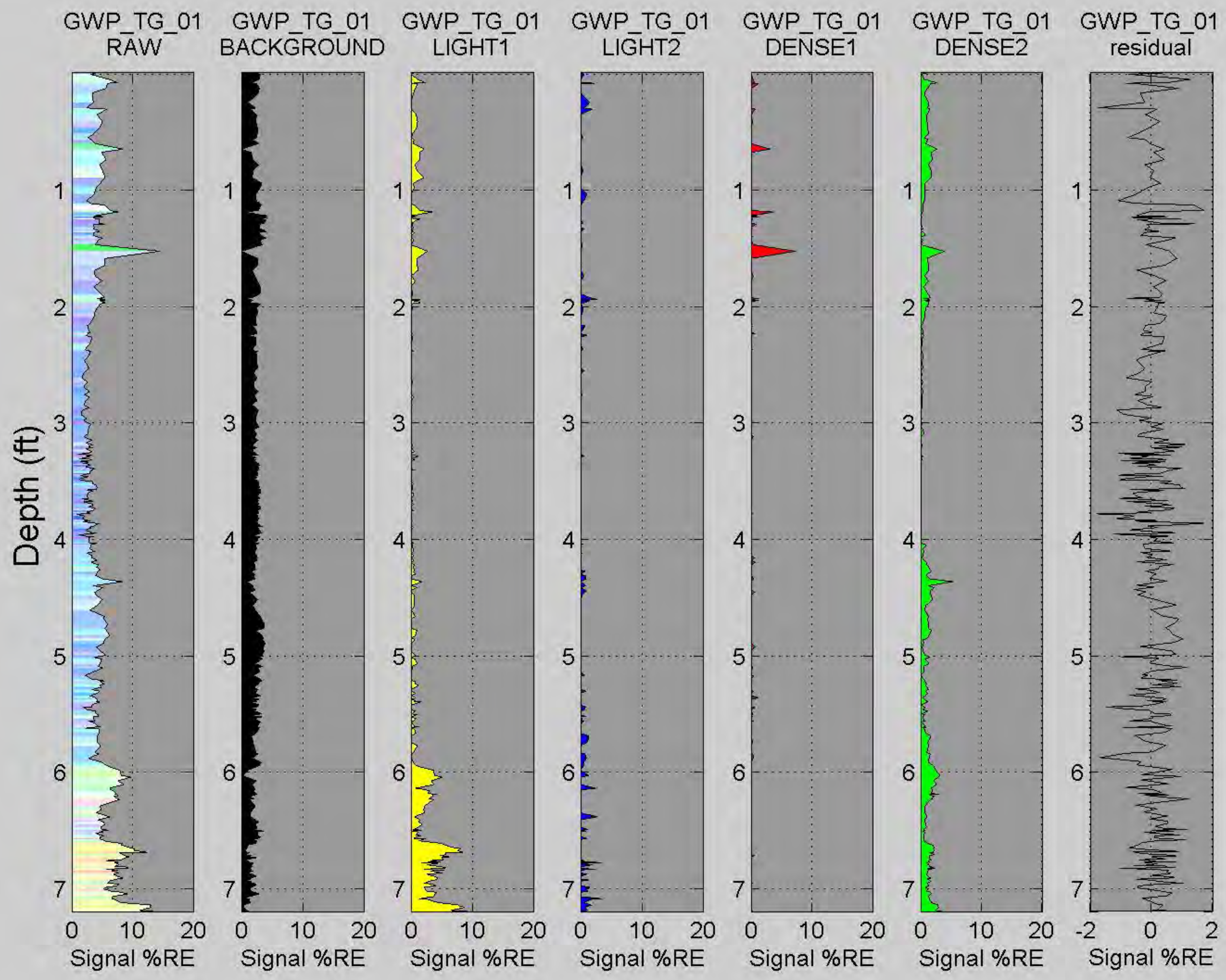


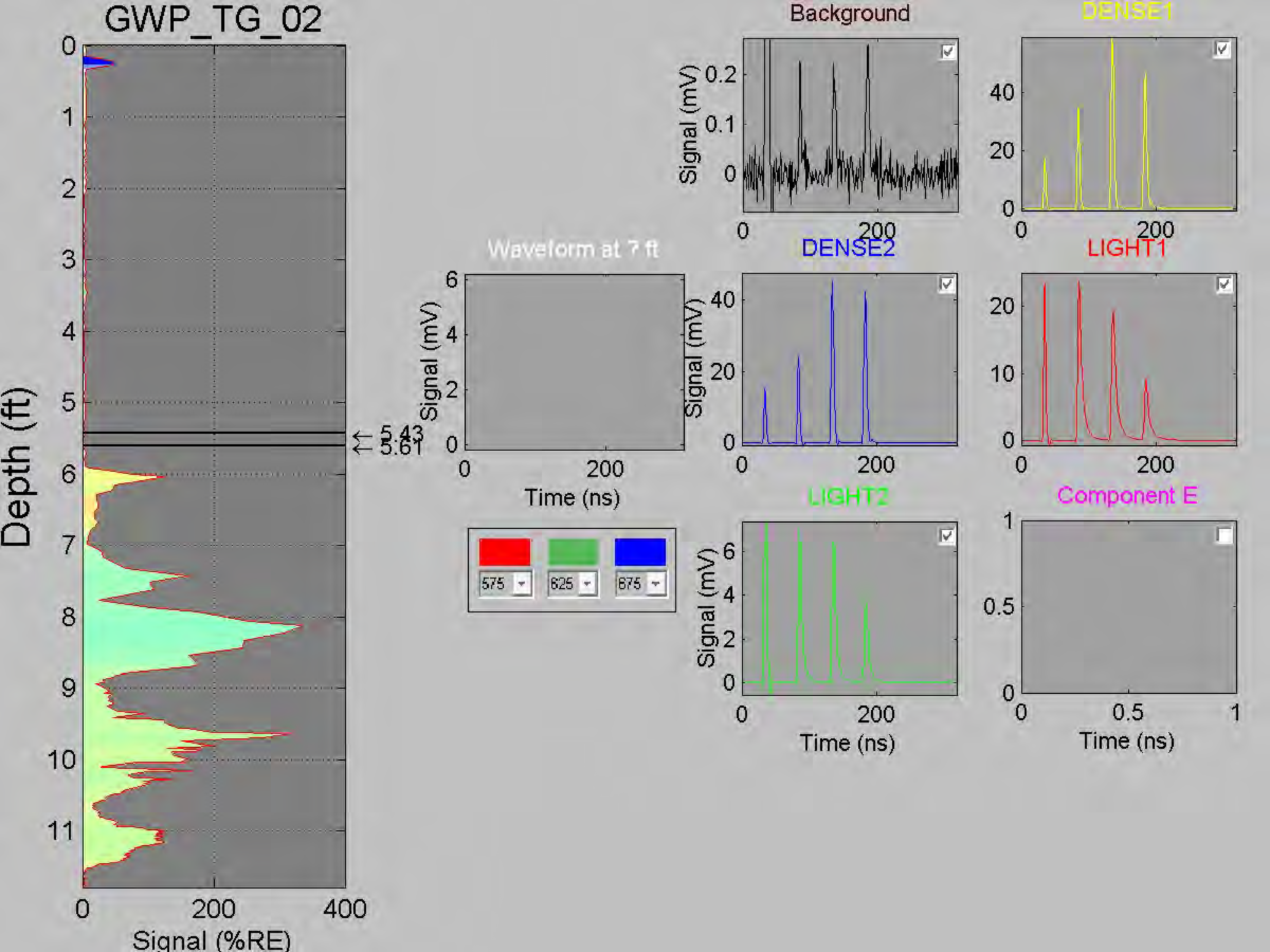
GWP_TG_39
RAW
GWP_TG_39
BACKGROUND
GWP_TG_39
LIGHT1
GWP_TG_39
LIGHT2
GWP_TG_39
DENSE1
GWP_TG_39
DENSE2
GWP_TG_39
residual
Depth (ft)
2
4
6
8
10
12
14
16
18
20
22
24
26
0
200
400
-20
0
20
Signal %RE

SUB-ATTACHMENT 2A-2.7.2
NNLS TarGOST® Logs

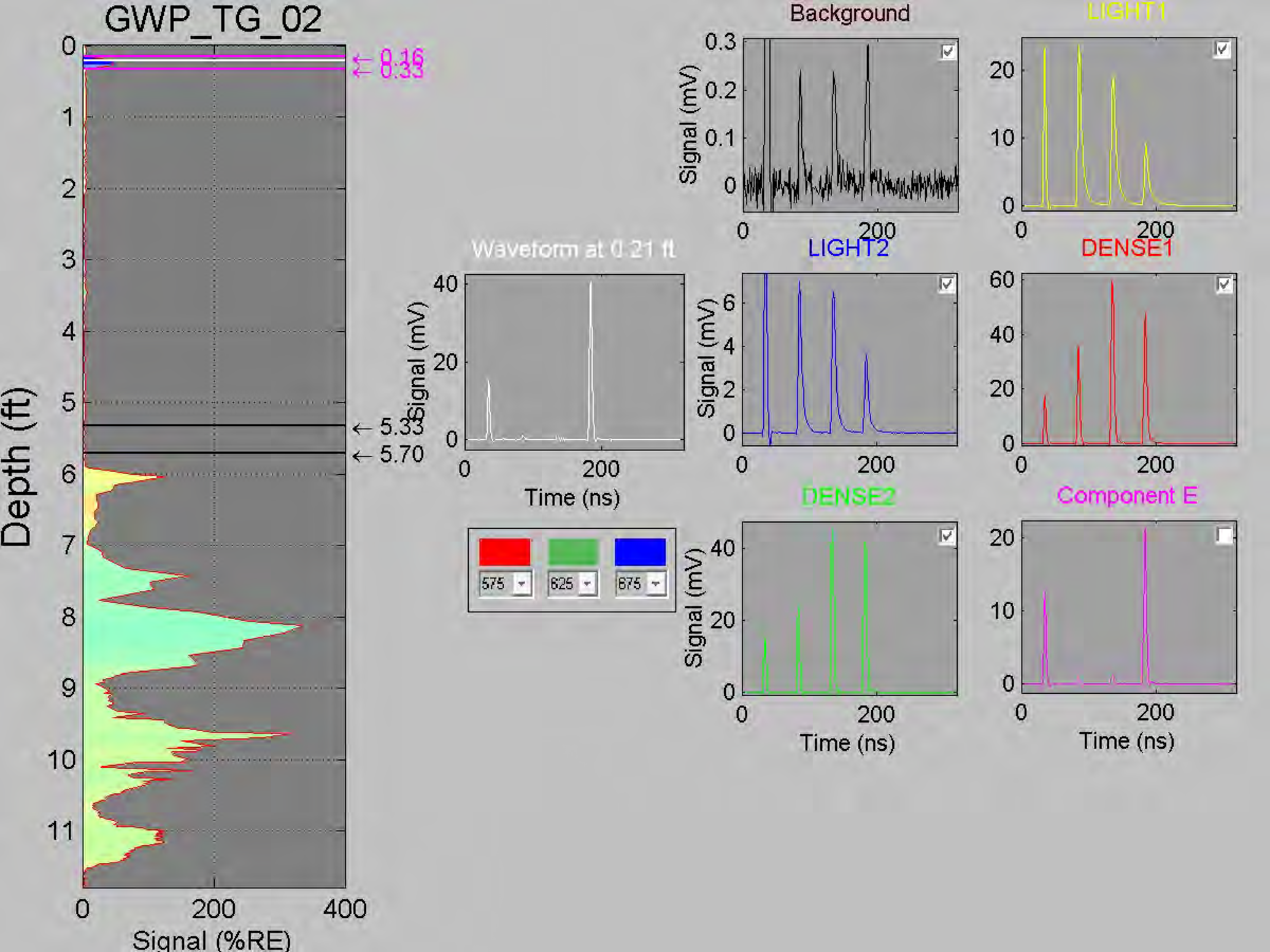


GWP_TG_01
Depth (ft)
Signal (%RE)
← 1.98
← 4.18
Waveform at 7 ft
Signal (mV)
Time (ns)
575
625
675
Background
LIGHT1
LIGHT2
DENSE1
DENSE2
Component E

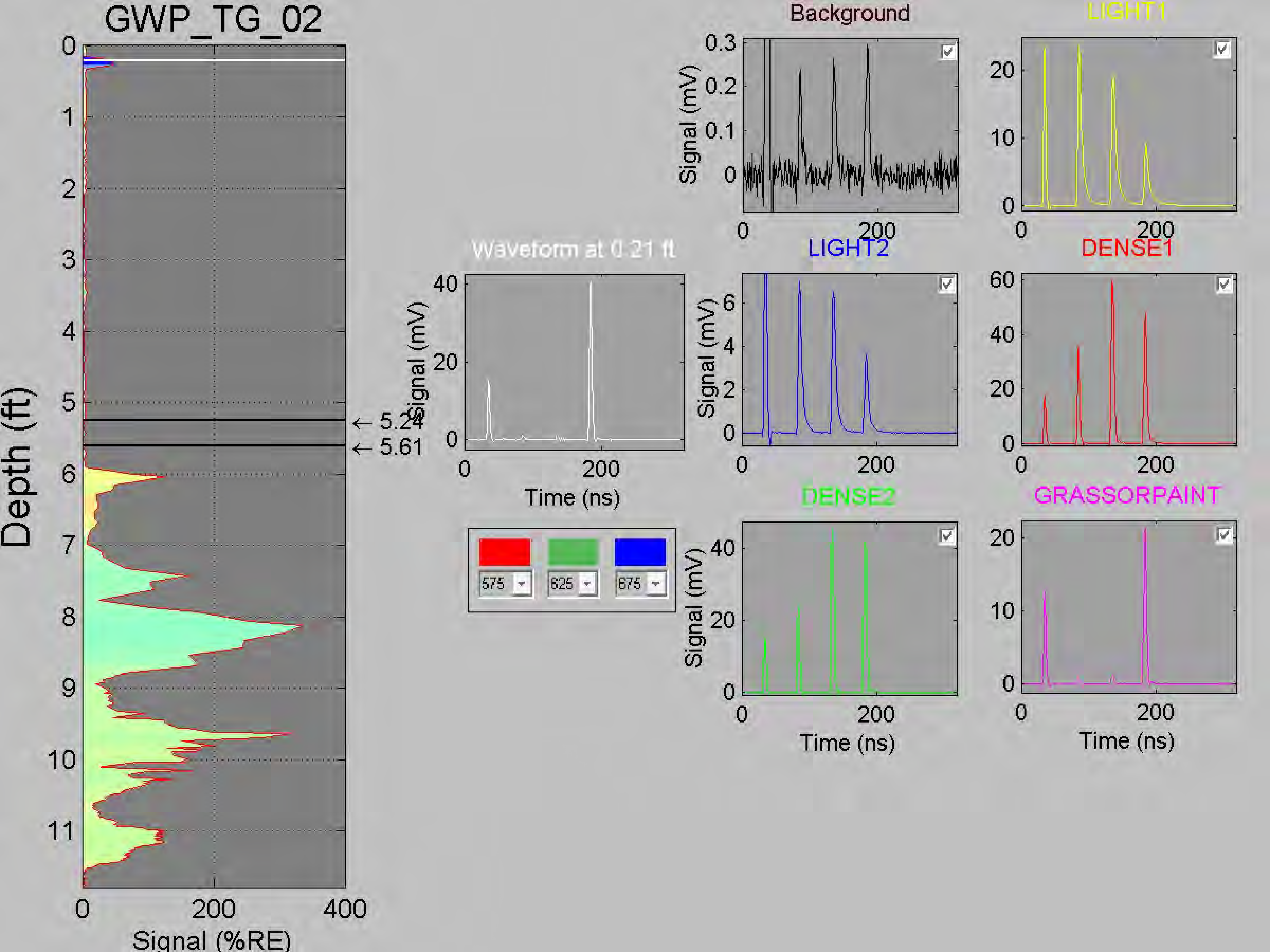

GWP_TG_01
RAW
GWP_TG_01
BACKGROUND
GWP_TG_01
LIGHT1
GWP_TG_01
LIGHT2
GWP_TG_01
DENSE1
GWP_TG_01
DENSE2
GWP_TG_01
residual
Depth (ft)
1
2
3
4
5
6
7
0 10 20
-2 0 2
Signal %RE



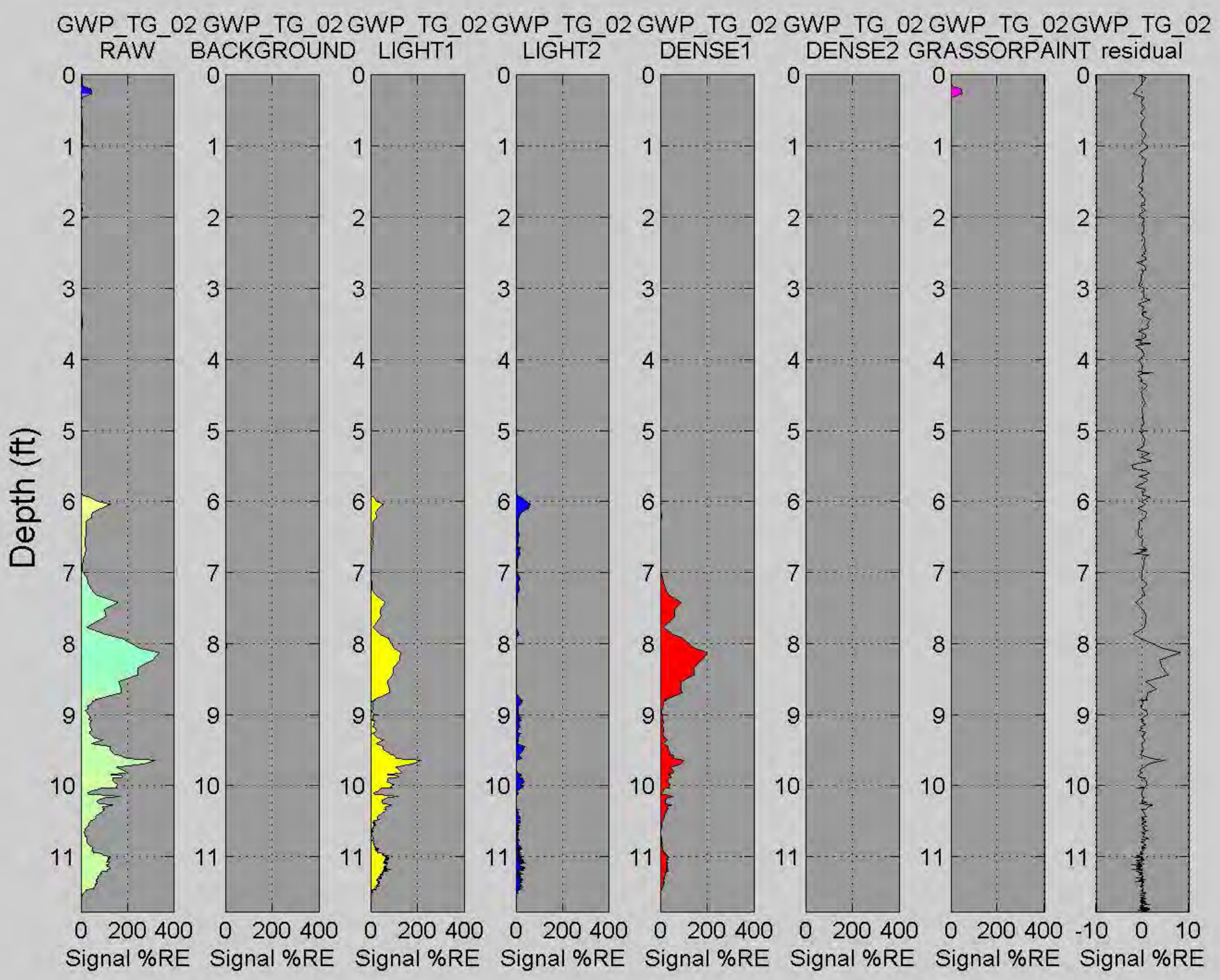
GWP_TG_02
Depth (ft)
Signal (%RE)
5.43
5.61
Background
DENSE1
Waveform at 7 ft
DENSE2
LIGHT1
LIGHT2
Component E
Signal (mV)
Time (ns)
575
625
675

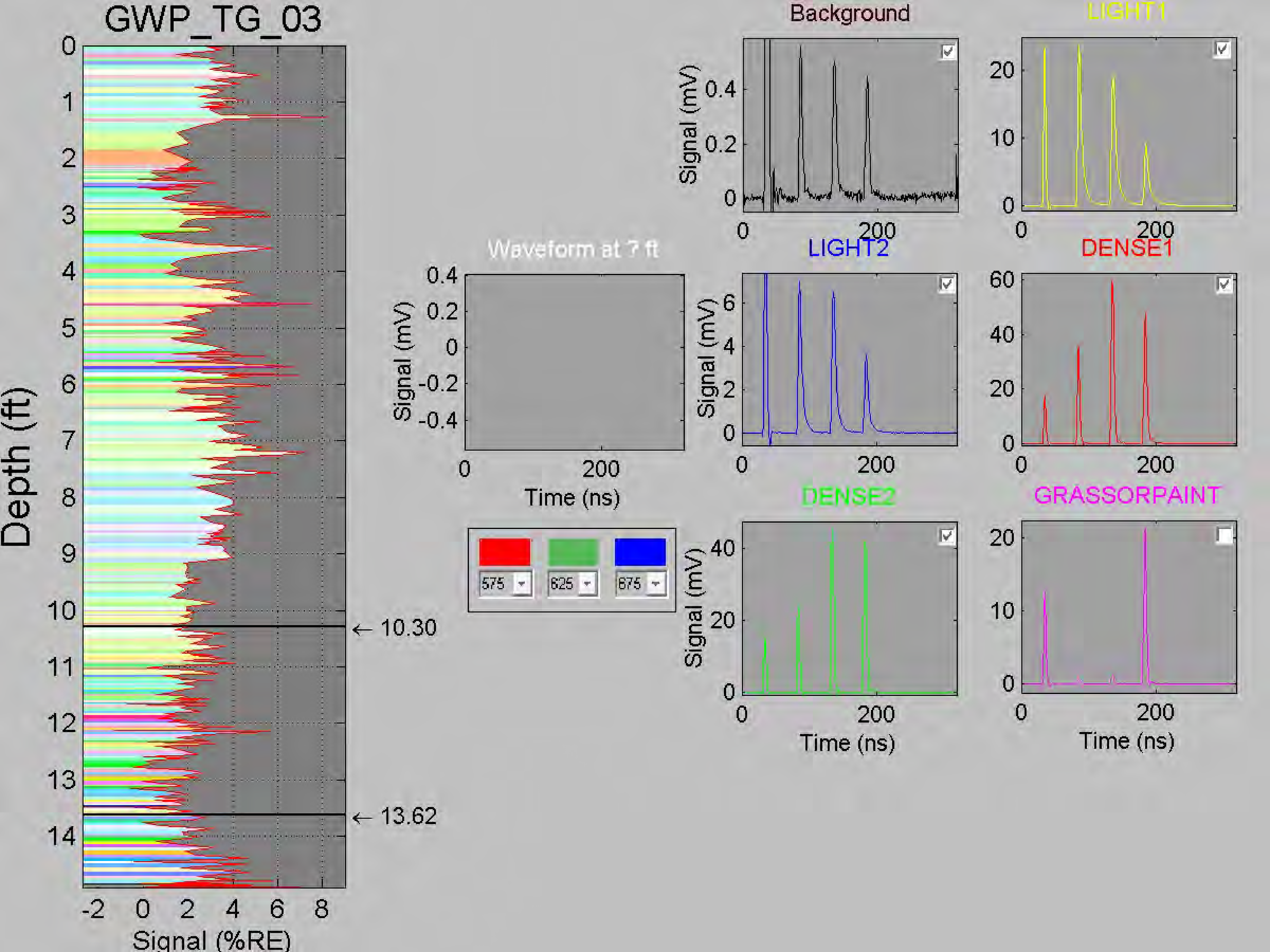


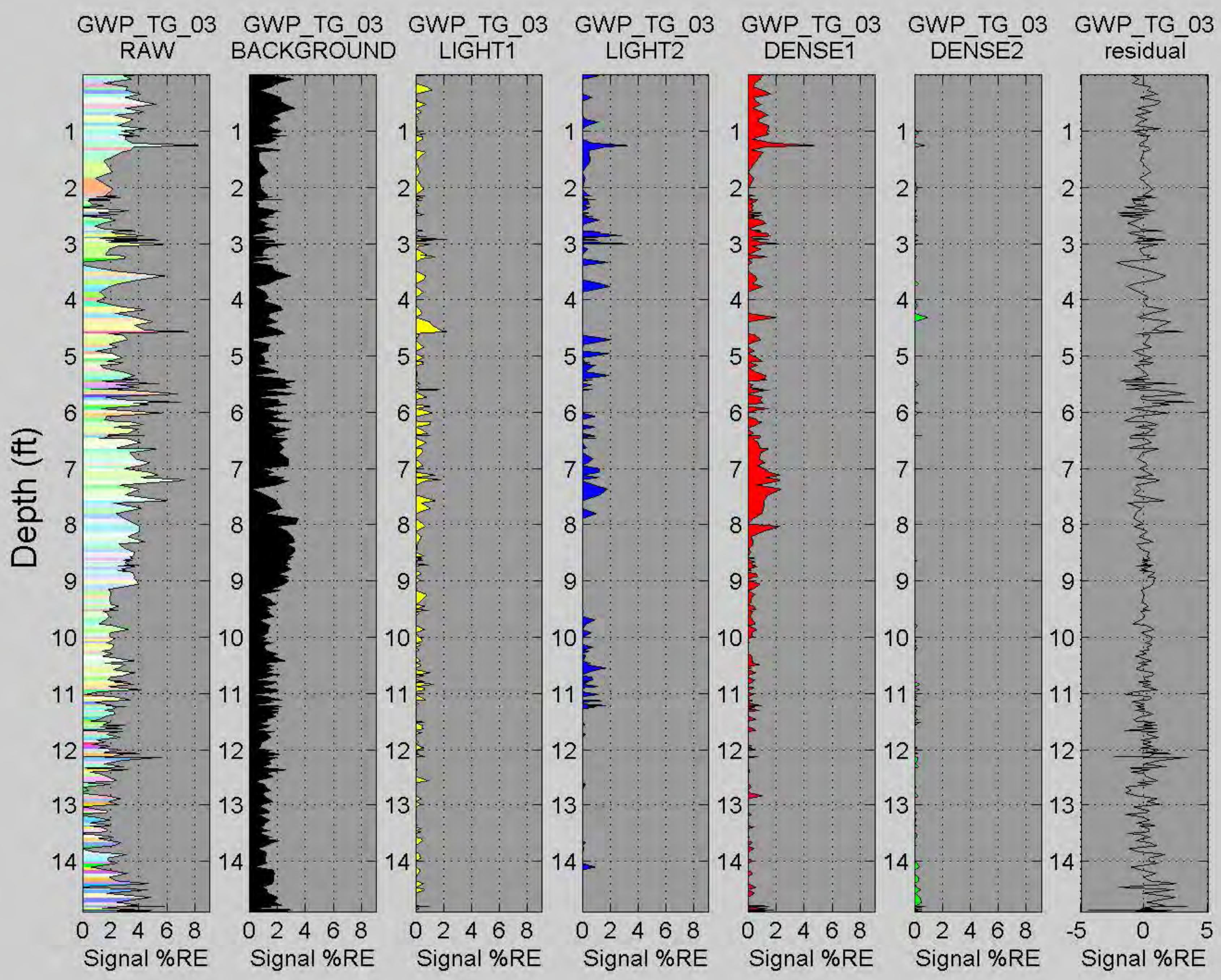
GWP_TG_02
Depth (ft)
Signal (%RE)
0.16
0.33
5.33
5.70
Background
LIGHT1
LIGHT2
DENSE1
DENSE2
Component E
Waveform at 0.21 ft
Signal (mV)
Time (ns)
575
625
675



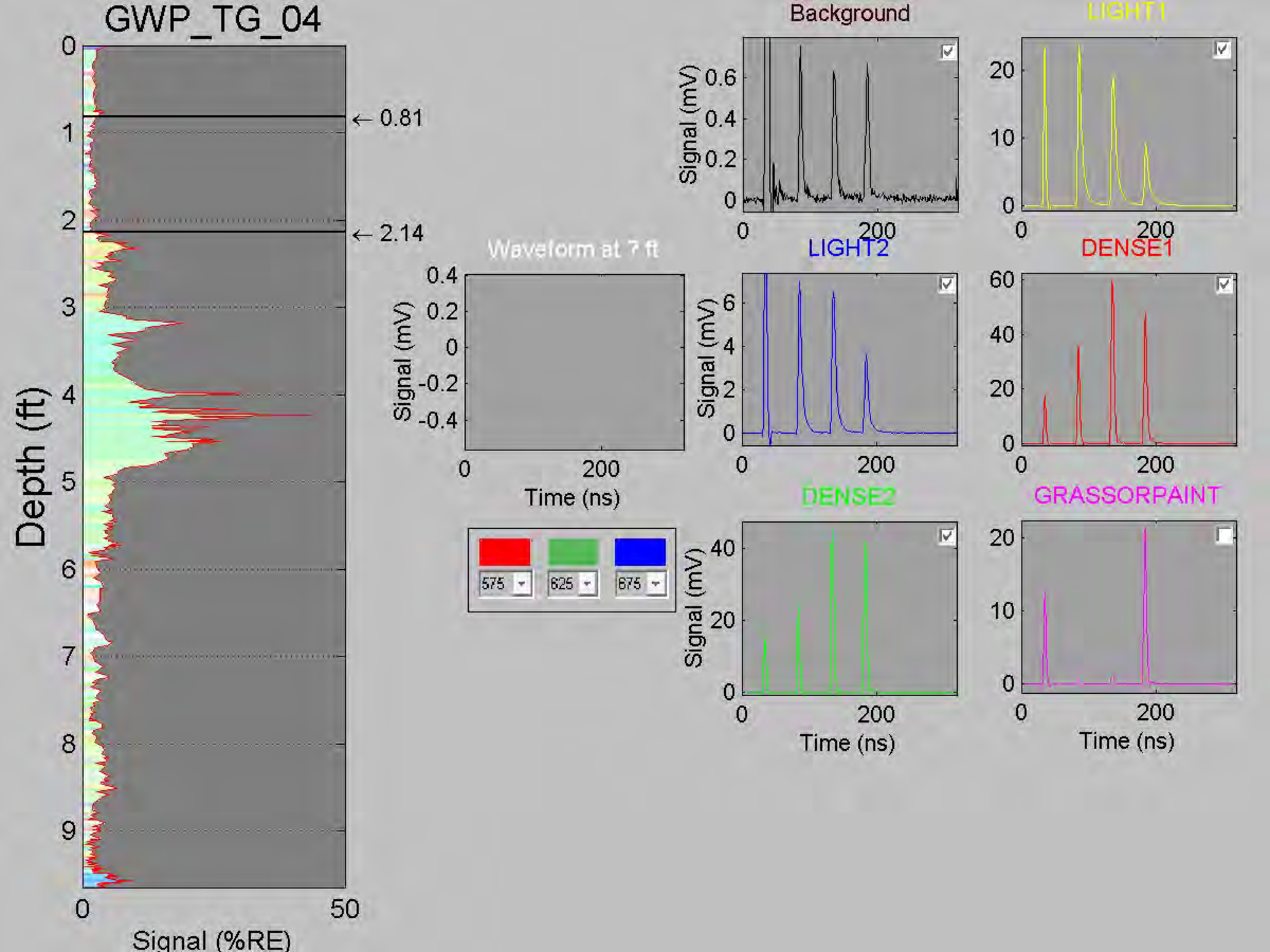
GWP_TG_02
Depth (ft)
Signal (%RE)
← 5.24
← 5.61
Waveform at 0.21 ft
Signal (mV)
Time (ns)
575
625
675
Background
LIGHT1
LIGHT2
DENSE1
DENSE2
GRASSORPAINT


GWP_TG_02 RAW
GWP_TG_02 BACKGROUND
GWP_TG_02 LIGHT1
GWP_TG_02 LIGHT2
GWP_TG_02 DENSE1
GWP_TG_02 DENSE2
GWP_TG_02 GRASSORPAINT
GWP_TG_02 residual
Depth (ft)
0 1 2 3 4 5 6 7 8 9 10 11
0 200 400
-10 0 10
Signal %RE

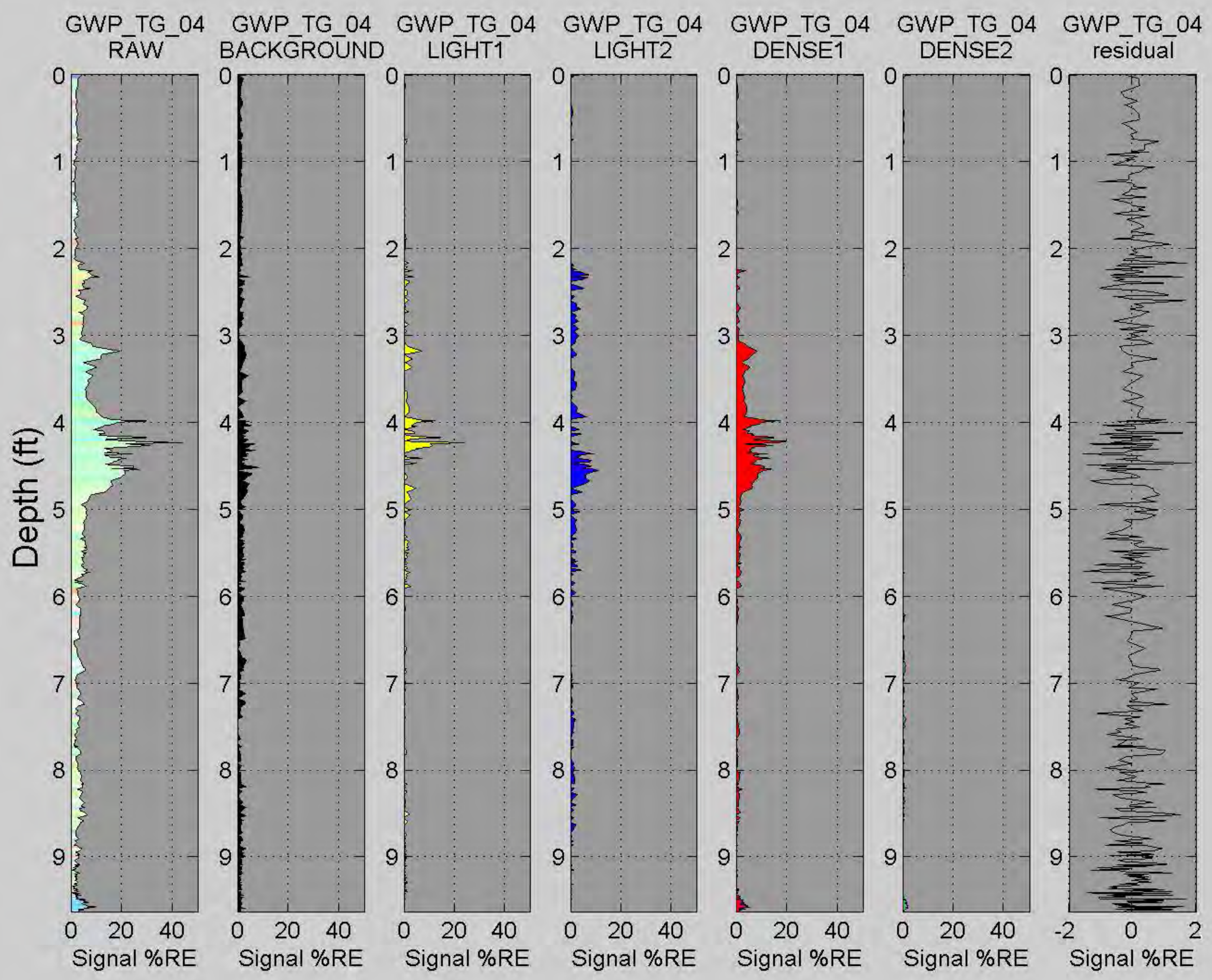

GWP_TG_03
Depth (ft)
Signal (%RE)
← 10.30
← 13.62
Waveform at ? ft
Signal (mV)
Time (ns)
575
625
675
Background
LIGHT1
LIGHT2
DENSE1
DENSE2
GRASSORPAINT



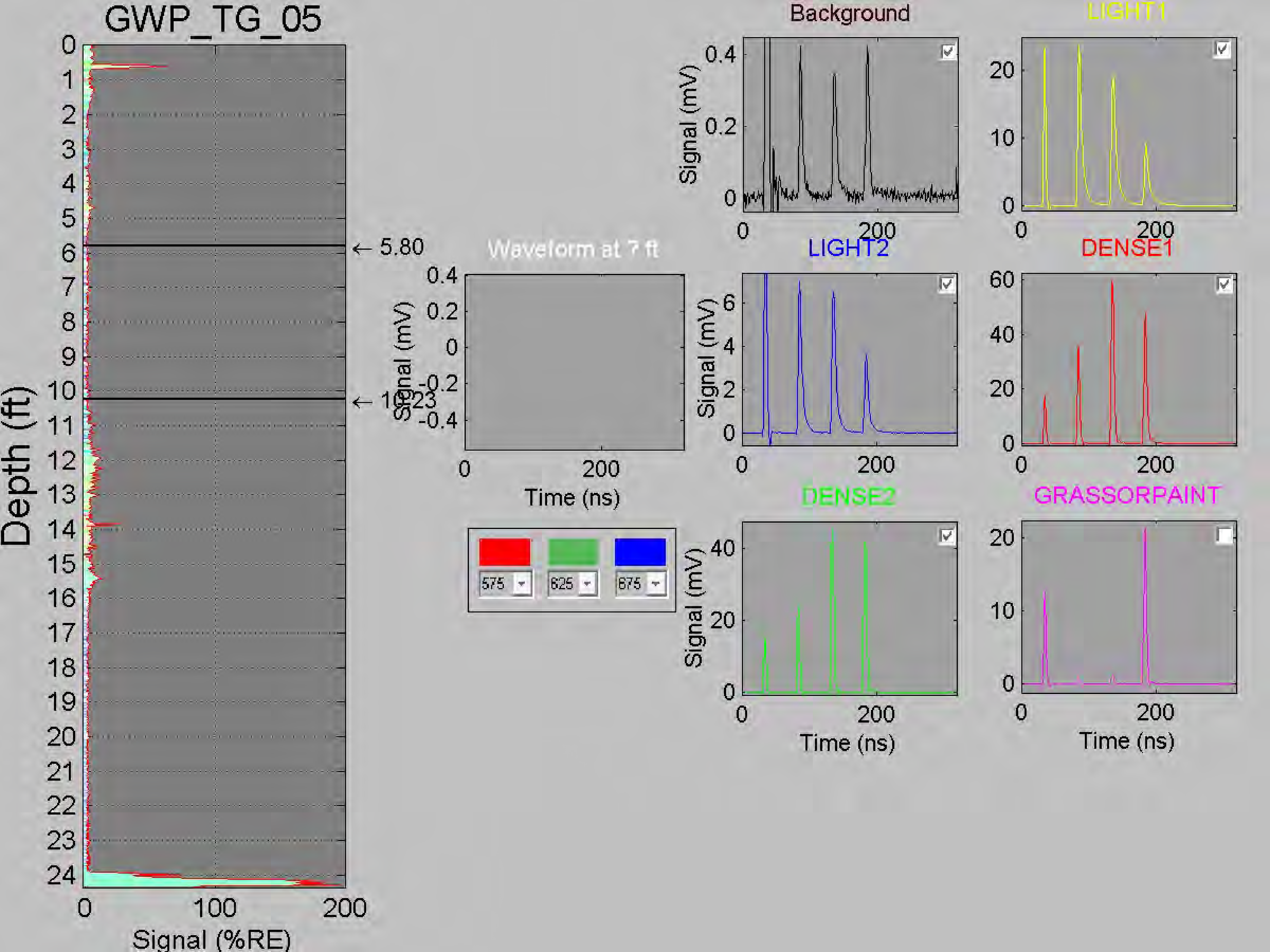
GWP_TG_03 RAW
GWP_TG_03 BACKGROUND
GWP_TG_03 LIGHT1
GWP_TG_03 LIGHT2
GWP_TG_03 DENSE1
GWP_TG_03 DENSE2
GWP_TG_03 residual
Depth (ft)
Signal %RE

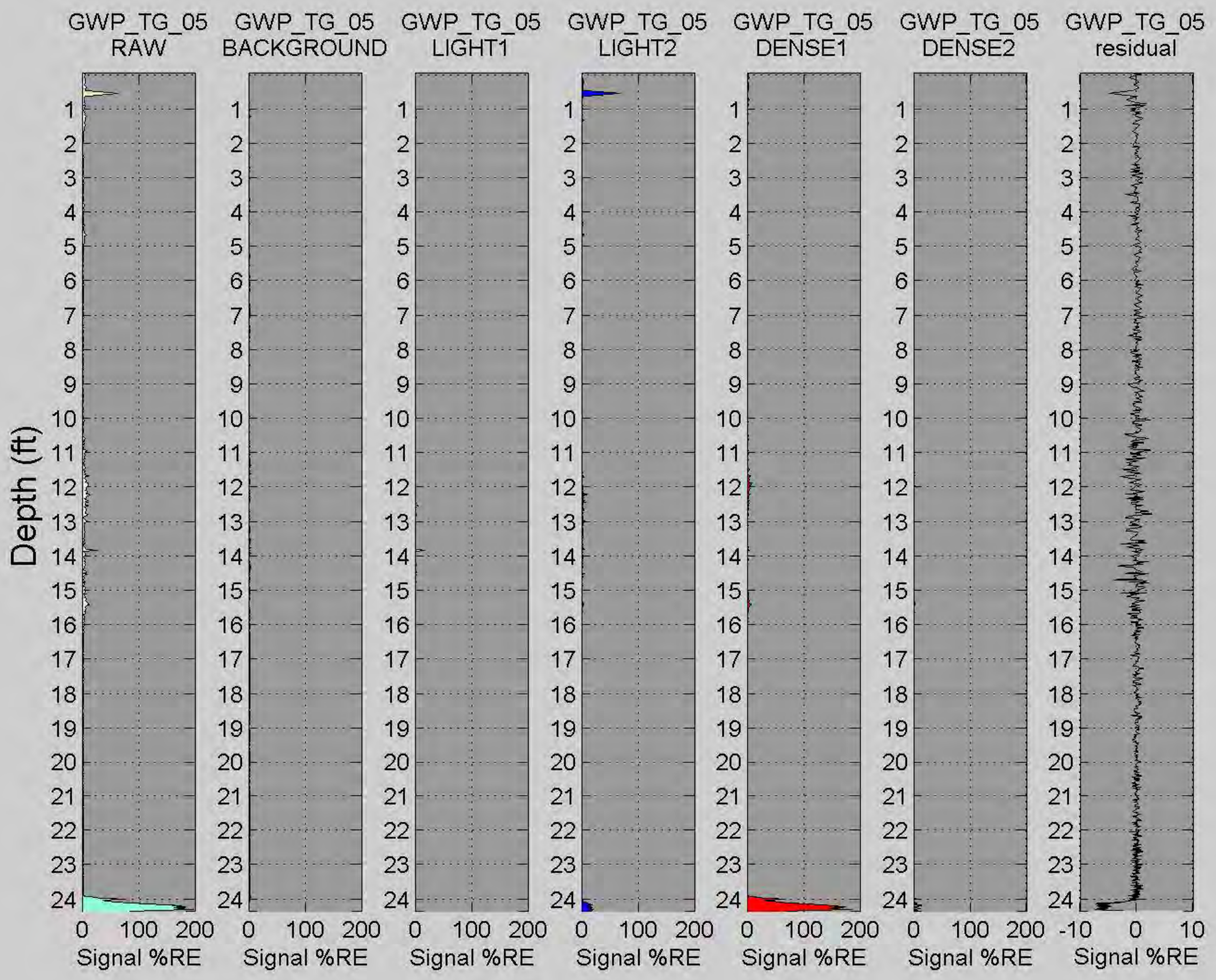


GWP_TG_04
Depth (ft)
← 0.81
← 2.14
Signal (%RE)
0
50
Background
LIGHT1
LIGHT2
DENSE1
DENSE2
GRASSORPAINT
Waveform at 7 ft
Signal (mV)
Time (ns)
575
625
675

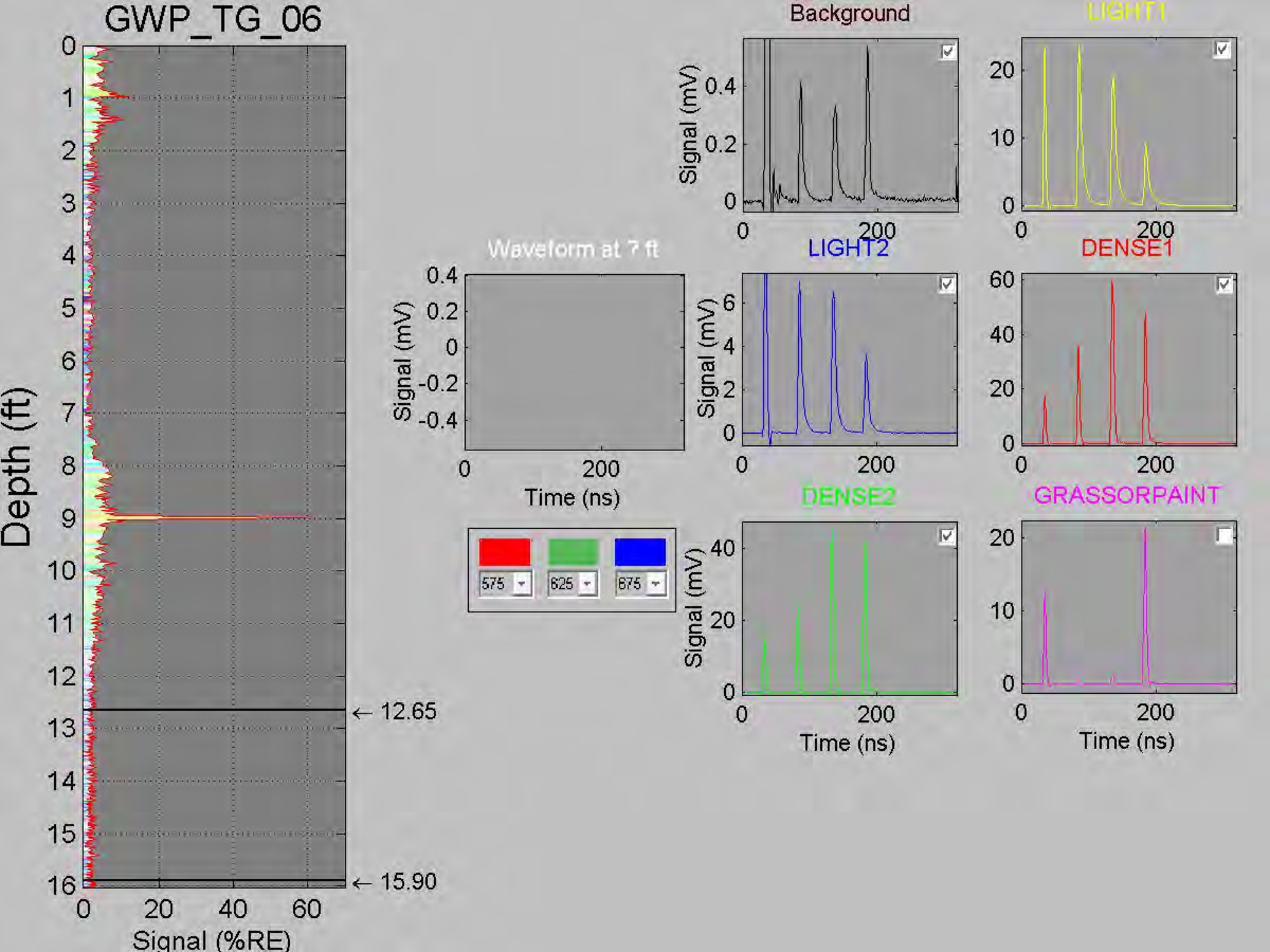


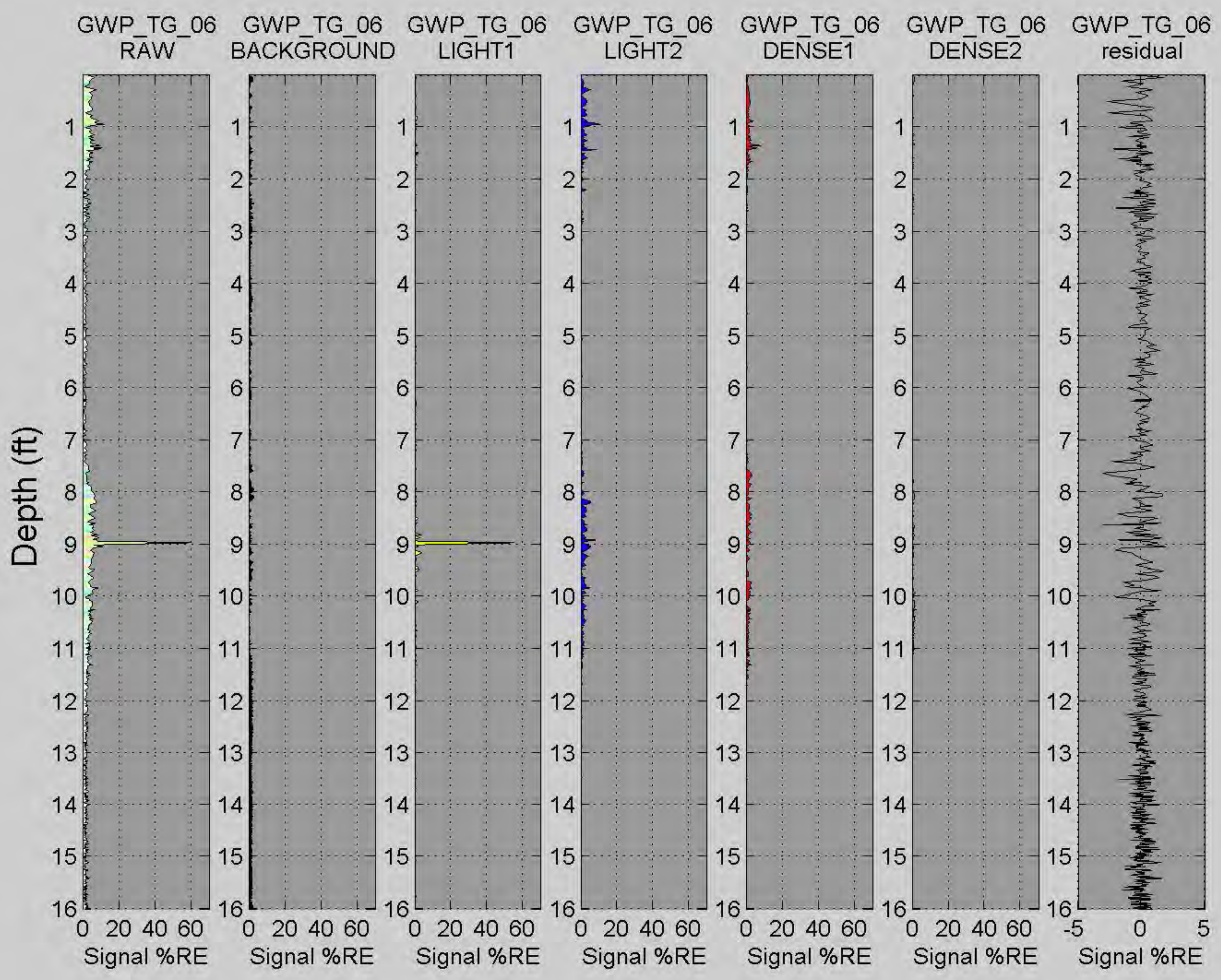
GWP_TG_04 RAW
GWP_TG_04 BACKGROUND
GWP_TG_04 LIGHT1
GWP_TG_04 LIGHT2
GWP_TG_04 DENSE1
GWP_TG_04 DENSE2
GWP_TG_04 residual
Depth (ft)
Signal %RE


GWP_TG_05
Depth (ft)
Signal (%RE)
← 5.80
← 10.23
Waveform at 7 ft
Signal (mV)
Time (ns)
575
625
675
Background
LIGHT1
LIGHT2
DENSE1
DENSE2
GRASSORPAINT

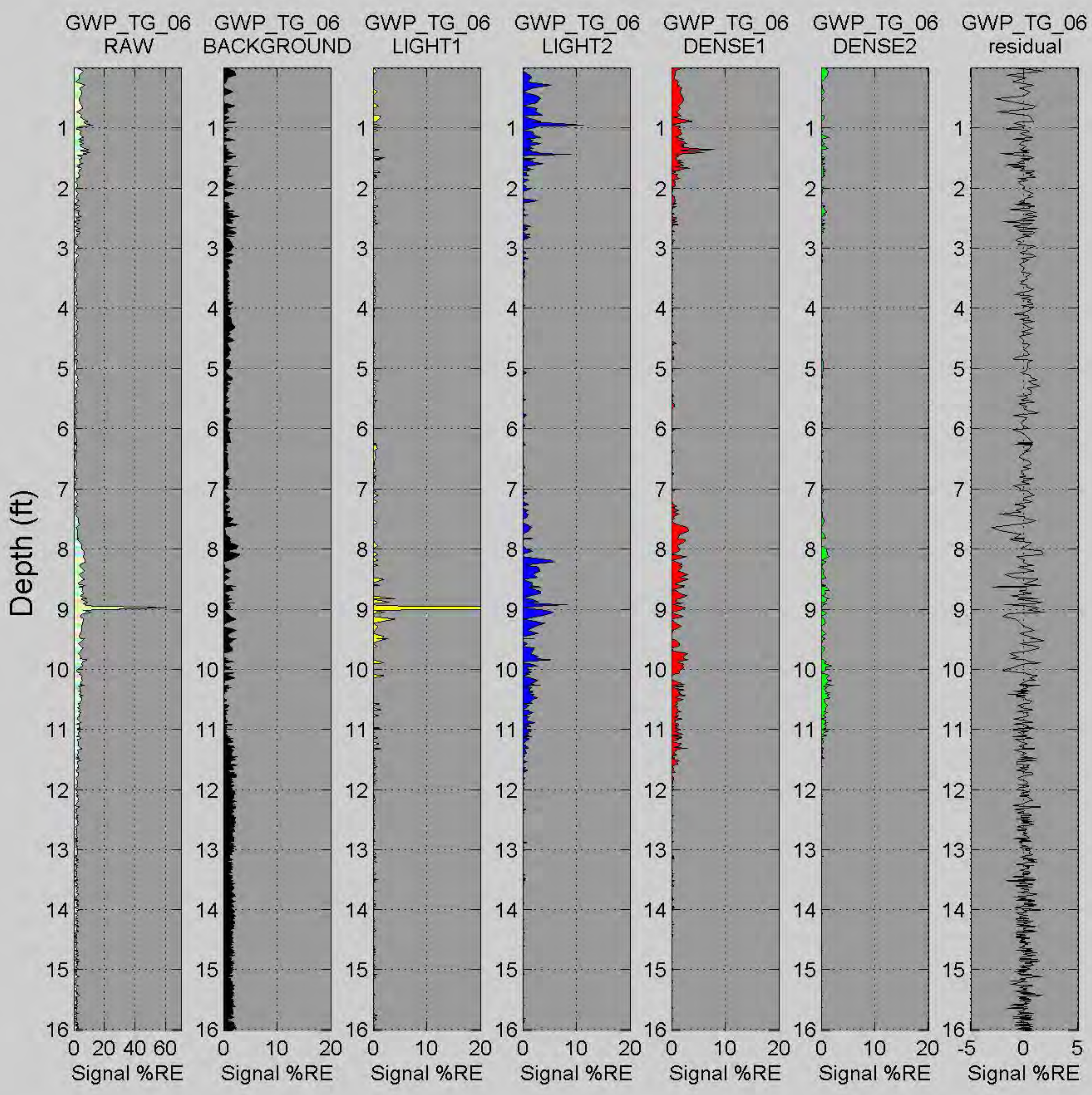


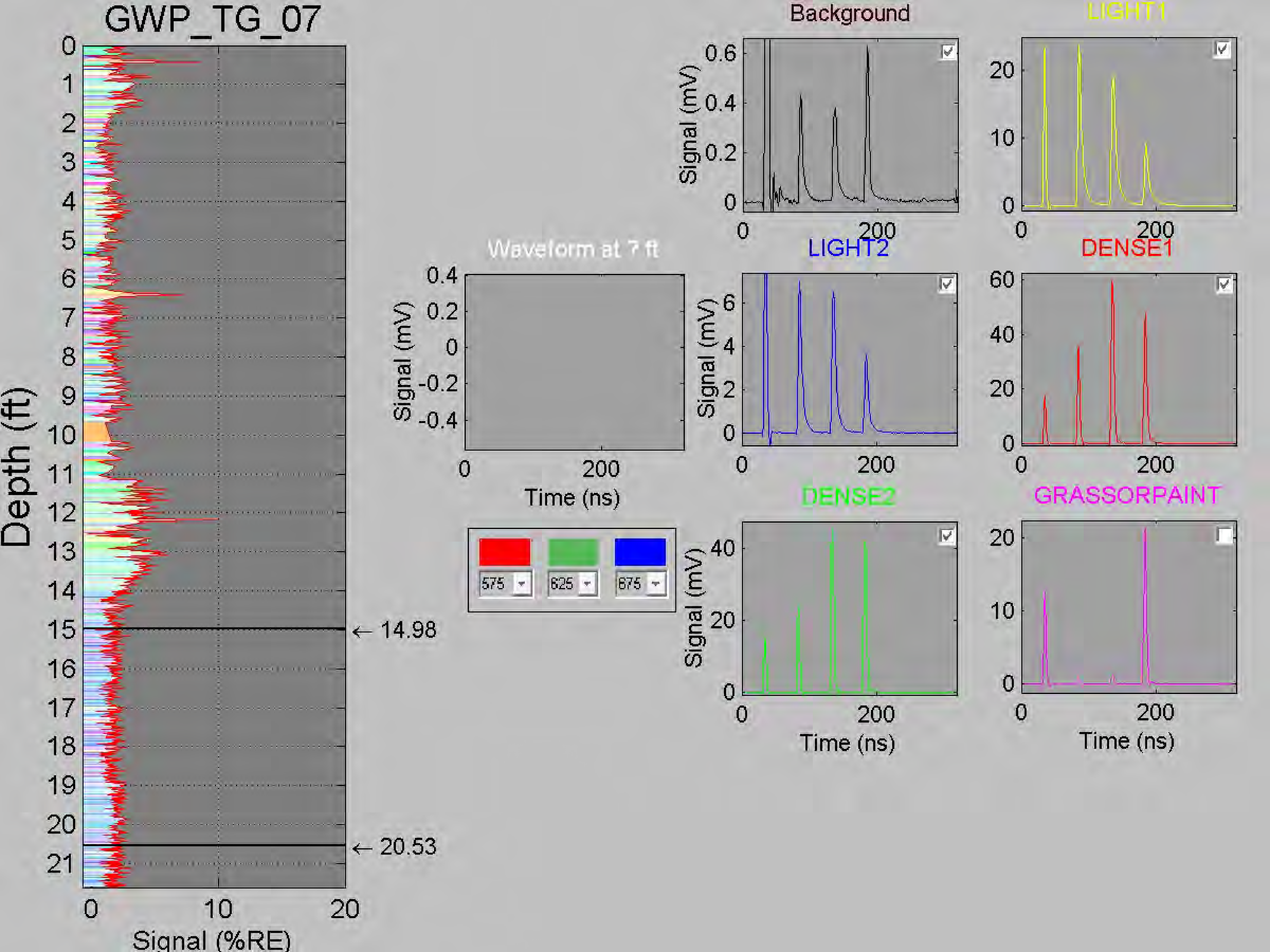
GWP_TG_05
RAW
GWP_TG_05
BACKGROUND
GWP_TG_05
LIGHT1
GWP_TG_05
LIGHT2
GWP_TG_05
DENSE1
GWP_TG_05
DENSE2
GWP_TG_05
residual
Depth (ft)
Signal %RE

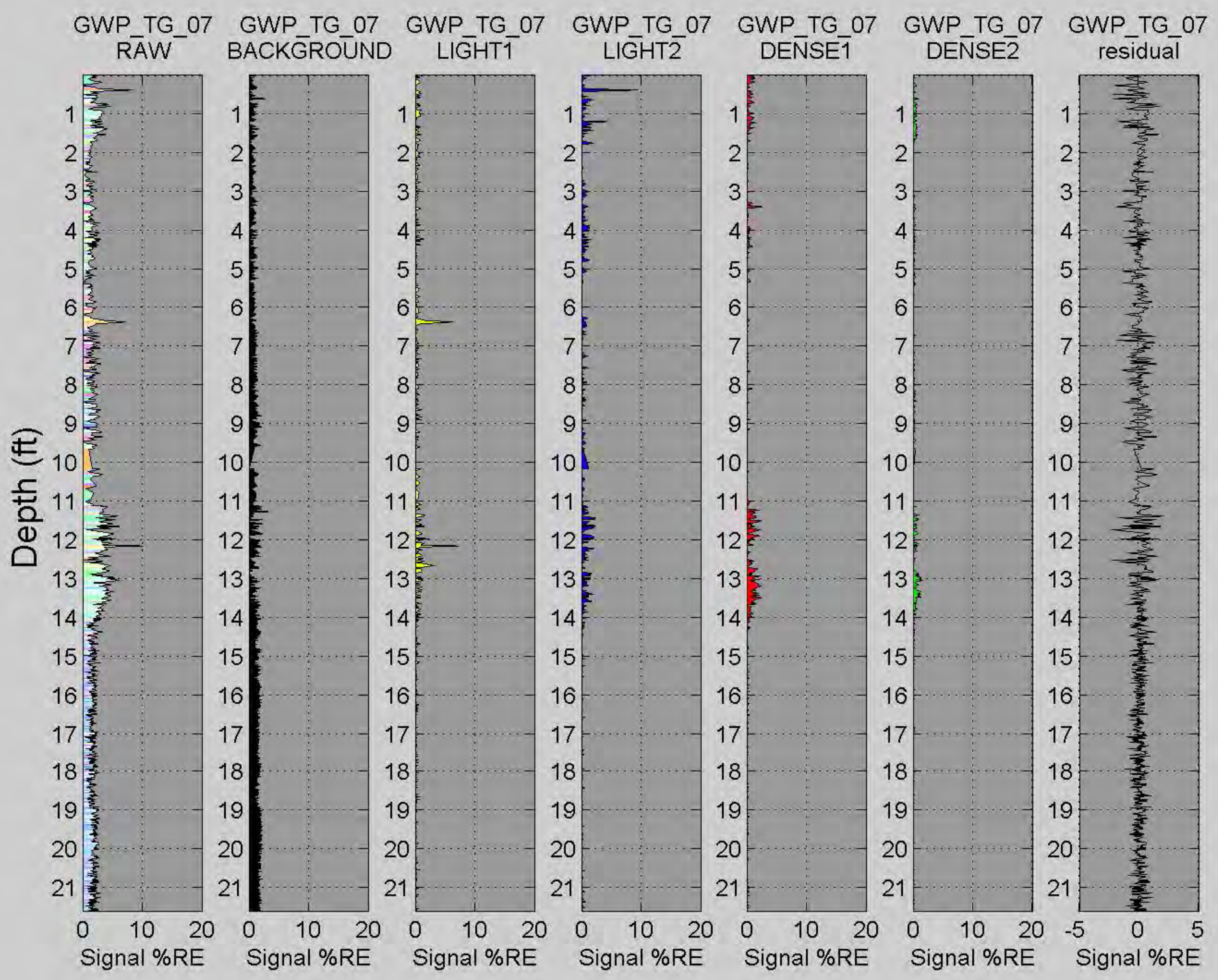

GWP_TG_06
Depth (ft)
Signal (%RE)
← 12.65
← 15.90
Background
LIGHT1
Waveform at 7 ft
LIGHT2
DENSE1
DENSE2
GRASSORPAINT
Signal (mV)
Time (ns)
575
625
675

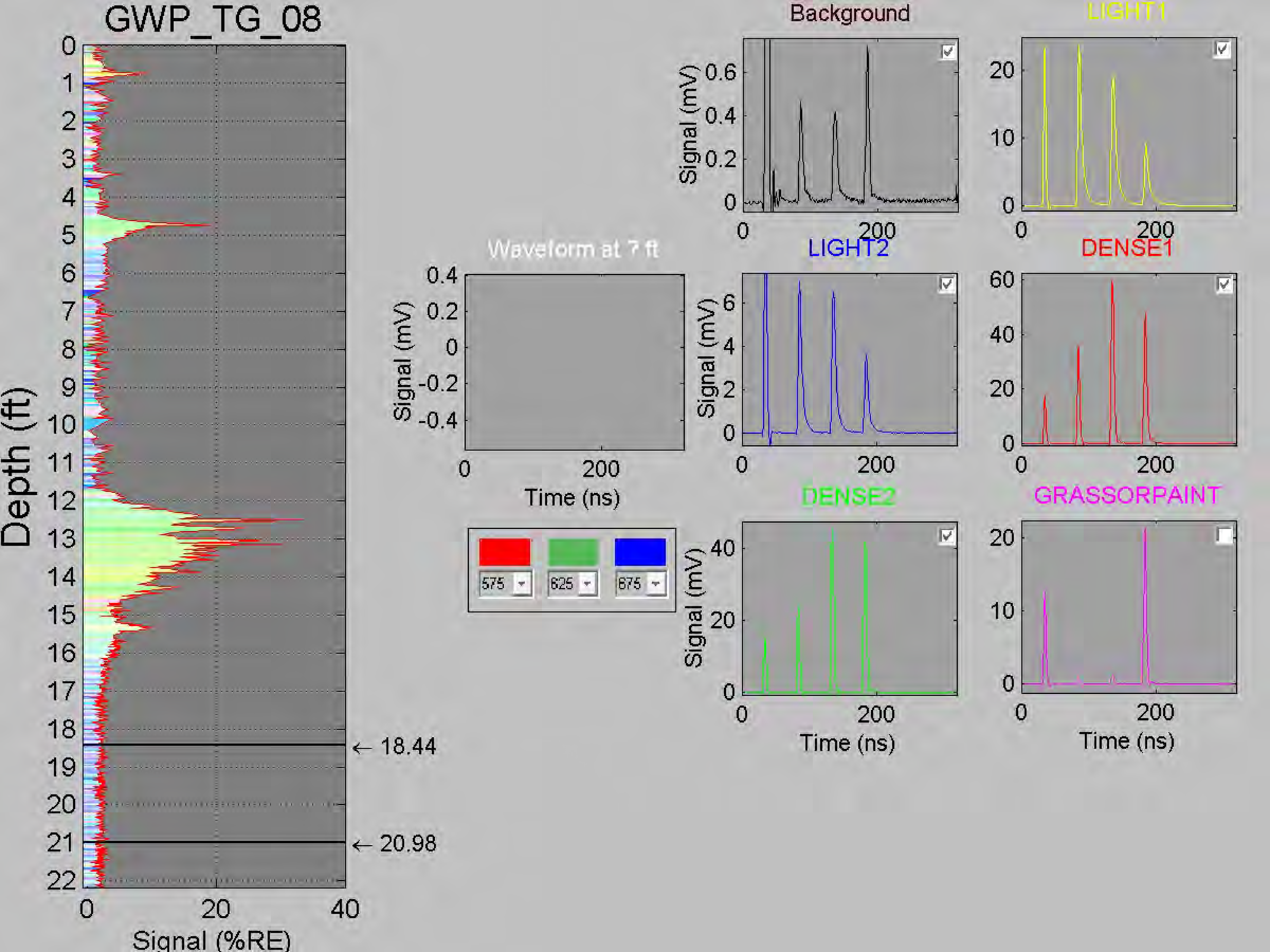


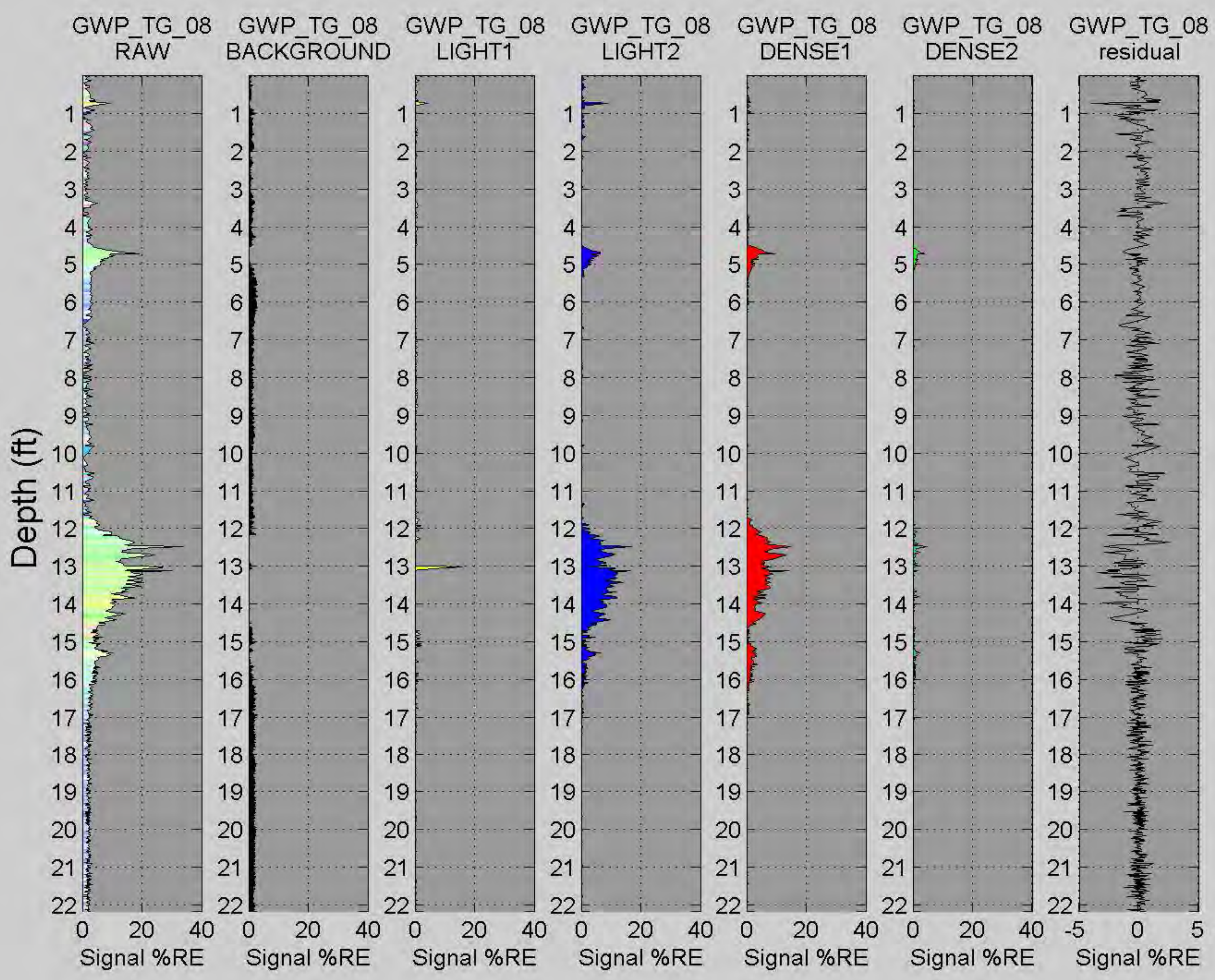
GWP_TG_06
RAW
GWP_TG_06
BACKGROUND
GWP_TG_06
LIGHT1
GWP_TG_06
LIGHT2
GWP_TG_06
DENSE1
GWP_TG_06
DENSE2
GWP_TG_06
residual
Depth (ft)
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
0 20 40 60
-5 0 5
Signal %RE

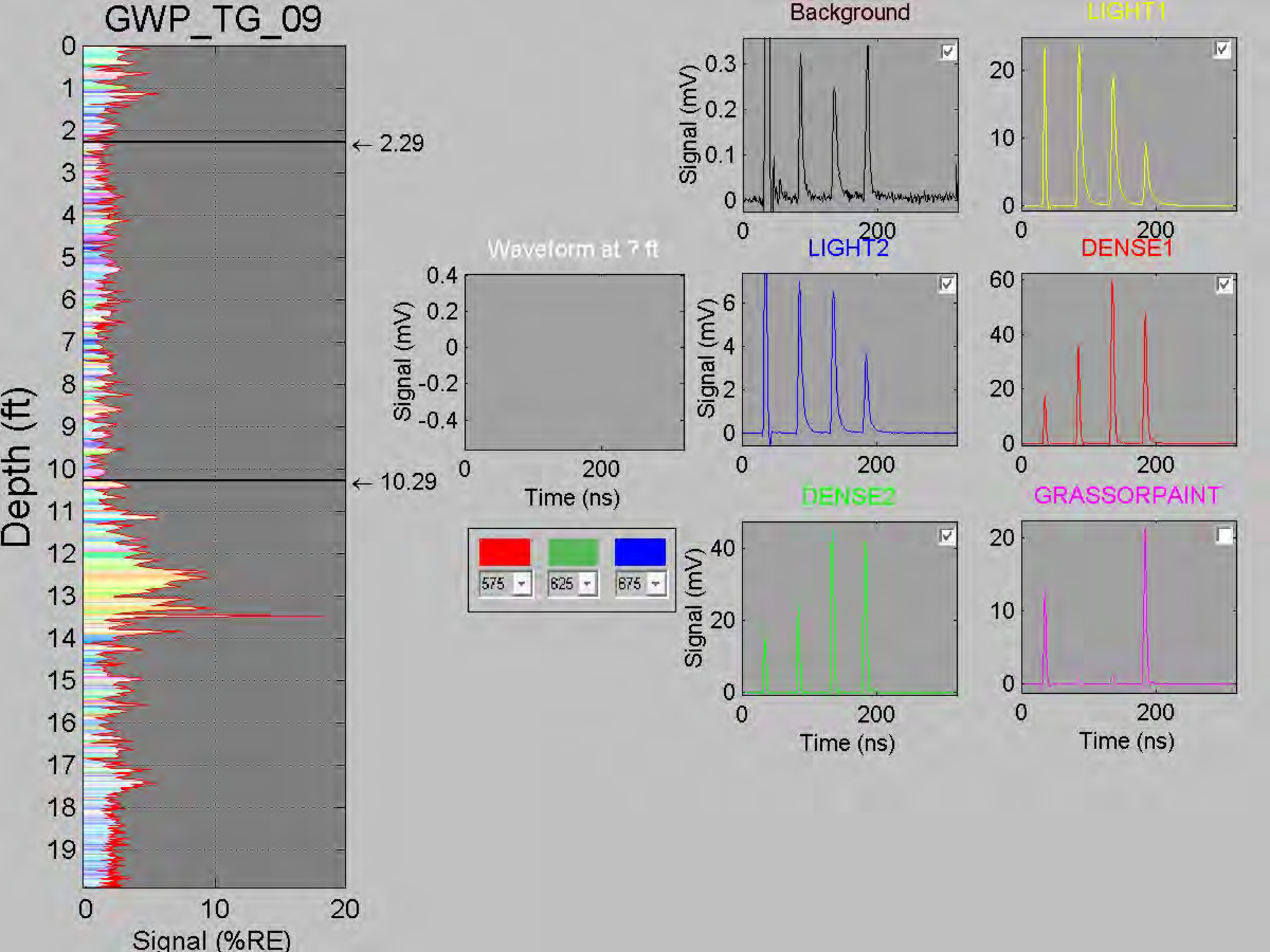

GWP_TG_06 RAW
GWP_TG_06 BACKGROUND
GWP_TG_06 LIGHT1
GWP_TG_06 LIGHT2
GWP_TG_06 DENSE1
GWP_TG_06 DENSE2
GWP_TG_06 residual
Depth (ft)
Signal %RE

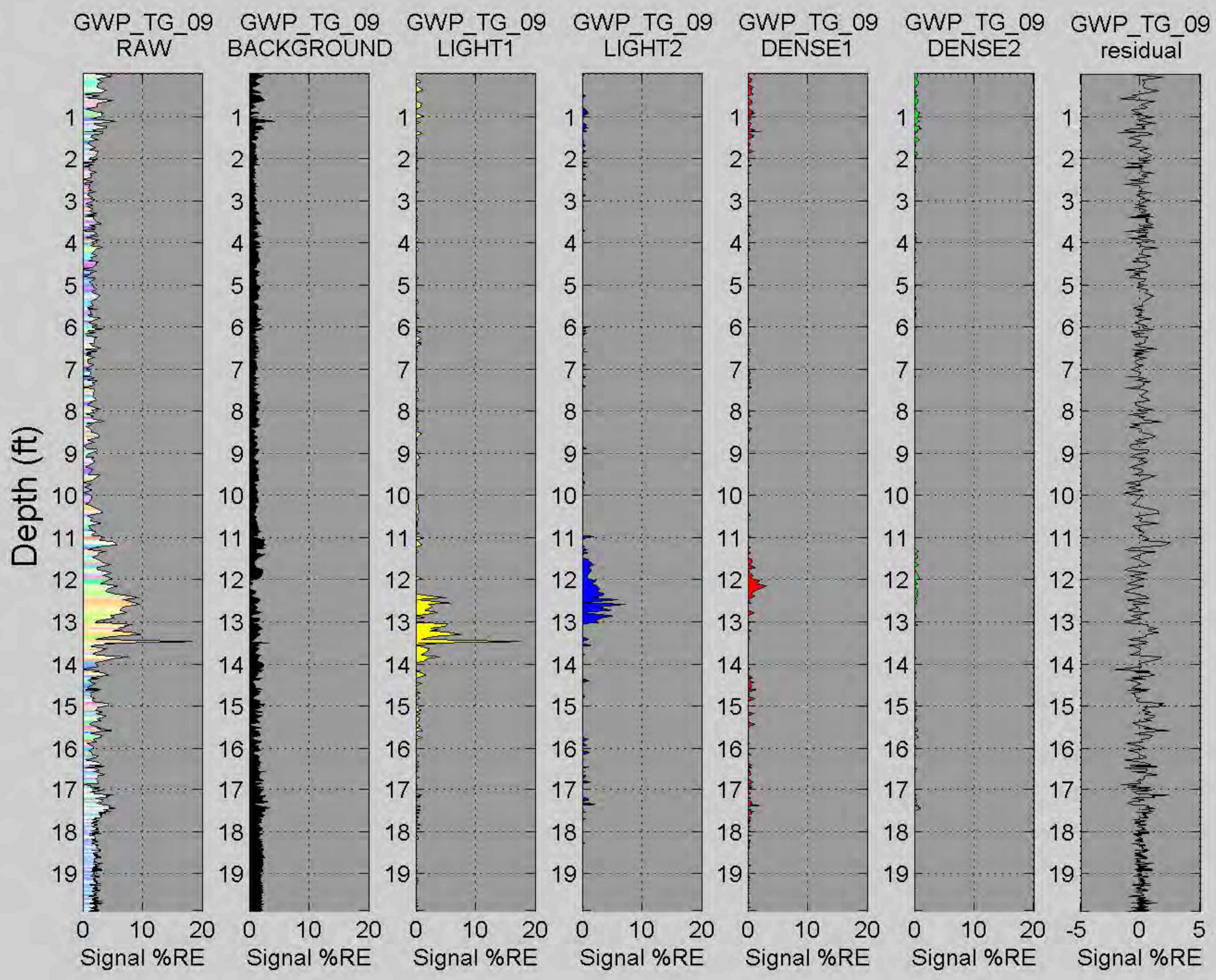

GWP_TG_07
Depth (ft)
Signal (%RE)
← 14.98
← 20.53
Waveform at 7 ft
Signal (mV)
Time (ns)
575
625
675
Background
LIGHT1
LIGHT2
DENSE1
DENSE2
GRASSORPAINT


GWP_TG_07 RAW
GWP_TG_07 BACKGROUND
GWP_TG_07 LIGHT1
GWP_TG_07 LIGHT2
GWP_TG_07 DENSE1
GWP_TG_07 DENSE2
GWP_TG_07 residual
Depth (ft)
Signal %RE

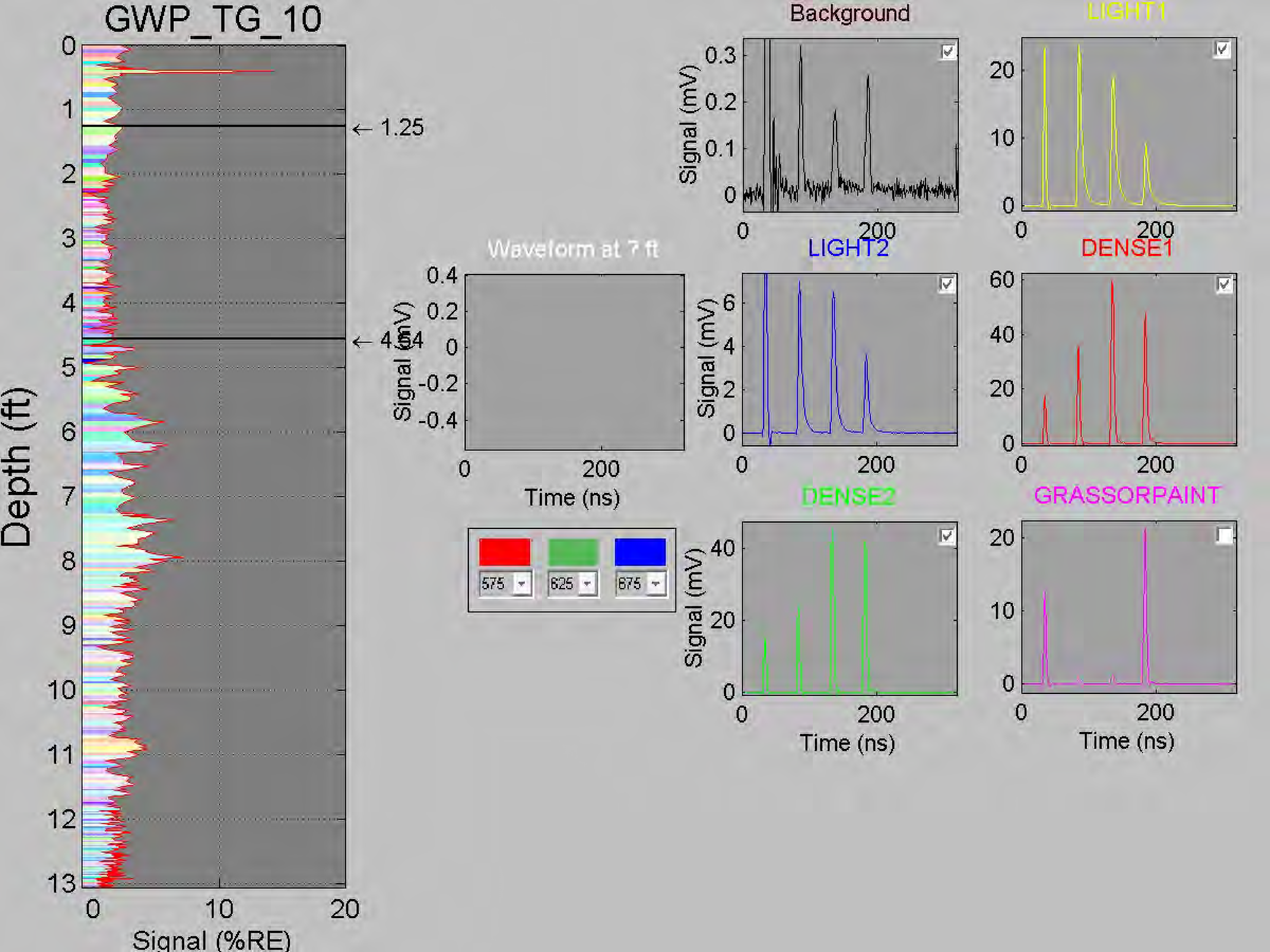

GWP_TG_08
Depth (ft)
Signal (%RE)
← 18.44
← 20.98
Background
LIGHT1
Waveform at 7 ft
LIGHT2
DENSE1
DENSE2
GRASSORPAINT
Signal (mV)
Time (ns)
575
625
675


GWP_TG_08 RAW
GWP_TG_08 BACKGROUND
GWP_TG_08 LIGHT1
GWP_TG_08 LIGHT2
GWP_TG_08 DENSE1
GWP_TG_08 DENSE2
GWP_TG_08 residual
Depth (ft)
Signal %RE

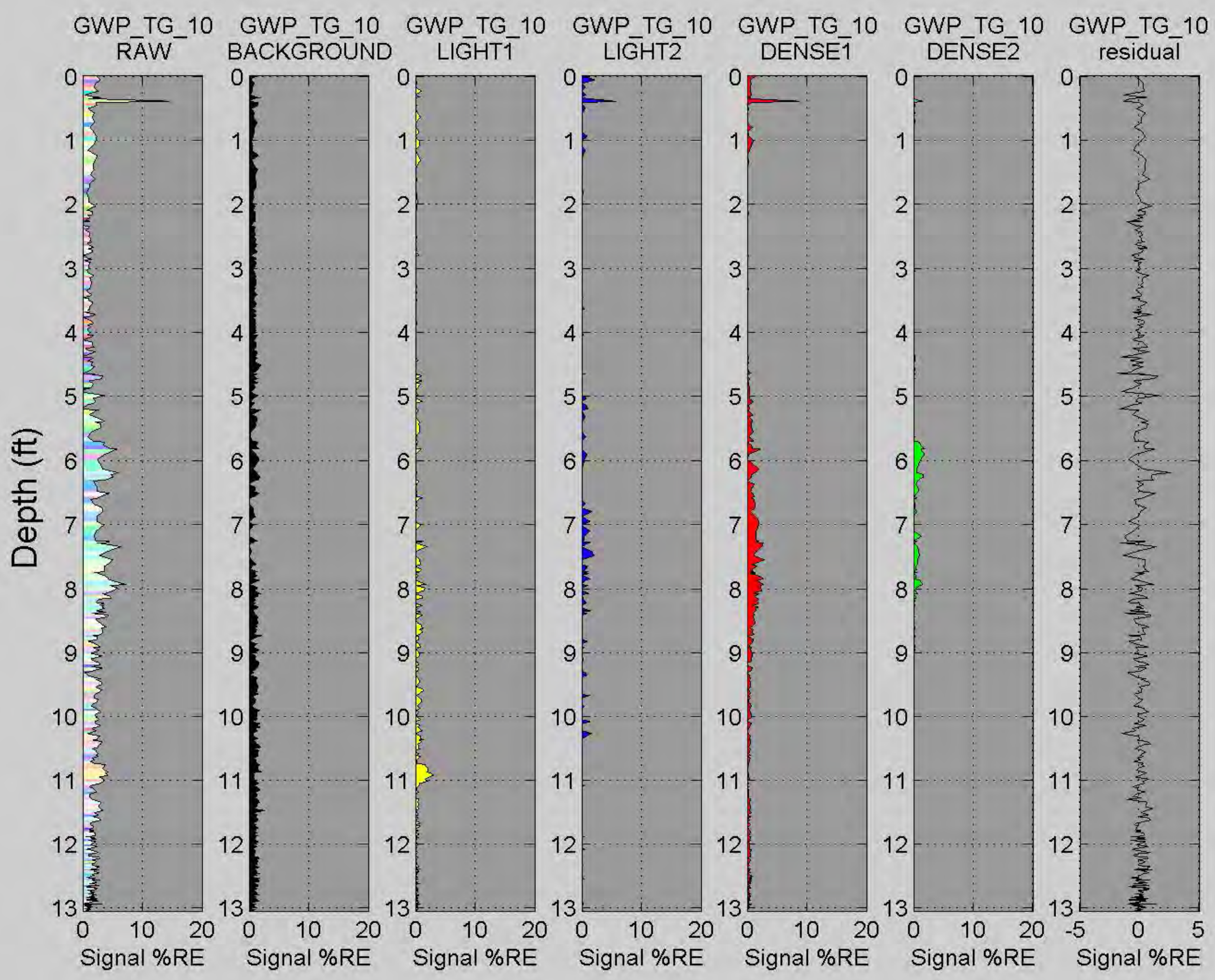

GWP_TG_09
Depth (ft)
Signal (%RE)
← 2.29
← 10.29
Background
LIGHT1
LIGHT2
DENSE1
DENSE2
GRASSORPAINT
Waveform at 7 ft
Signal (mV)
Time (ns)
575
625
675

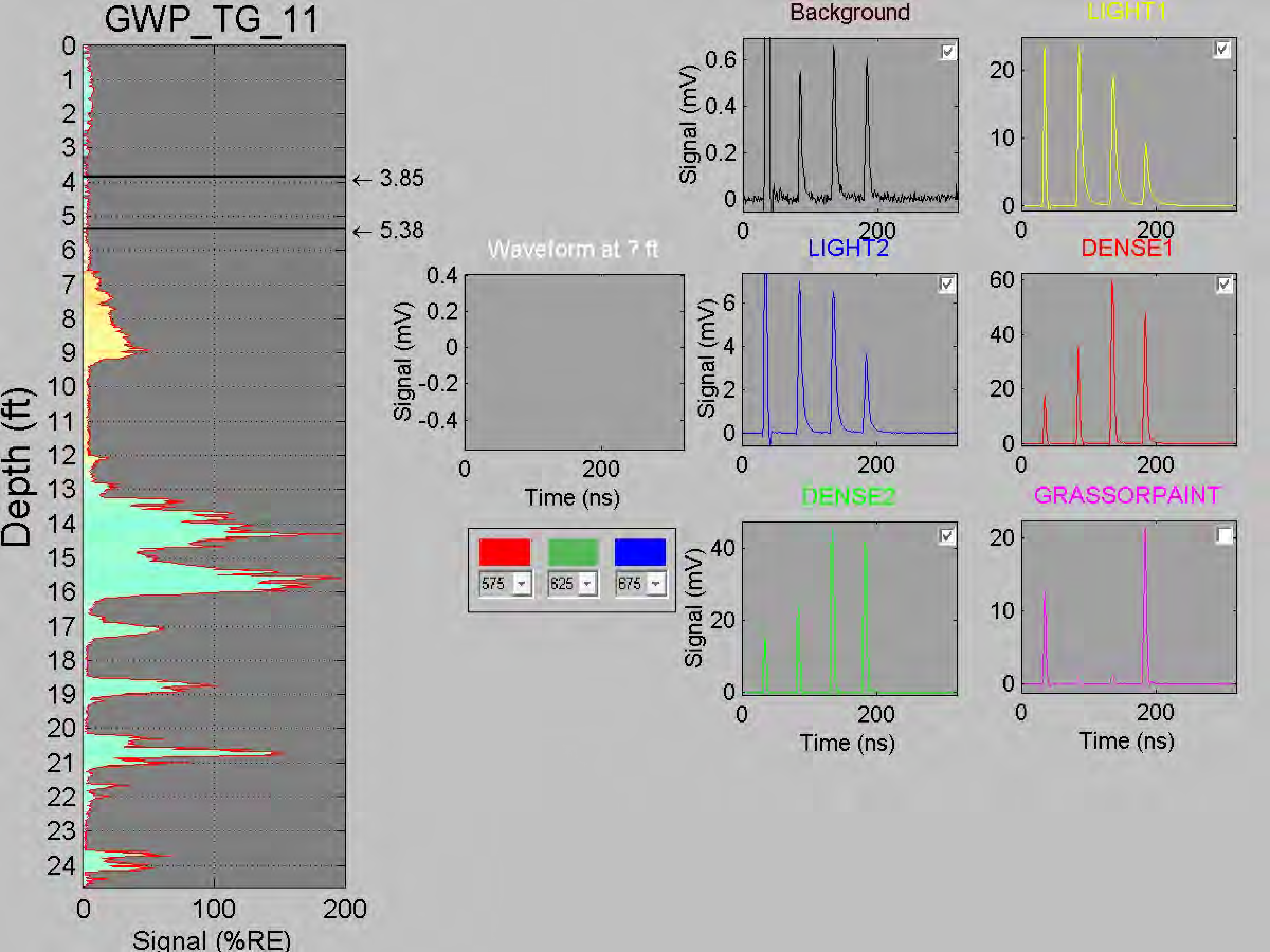


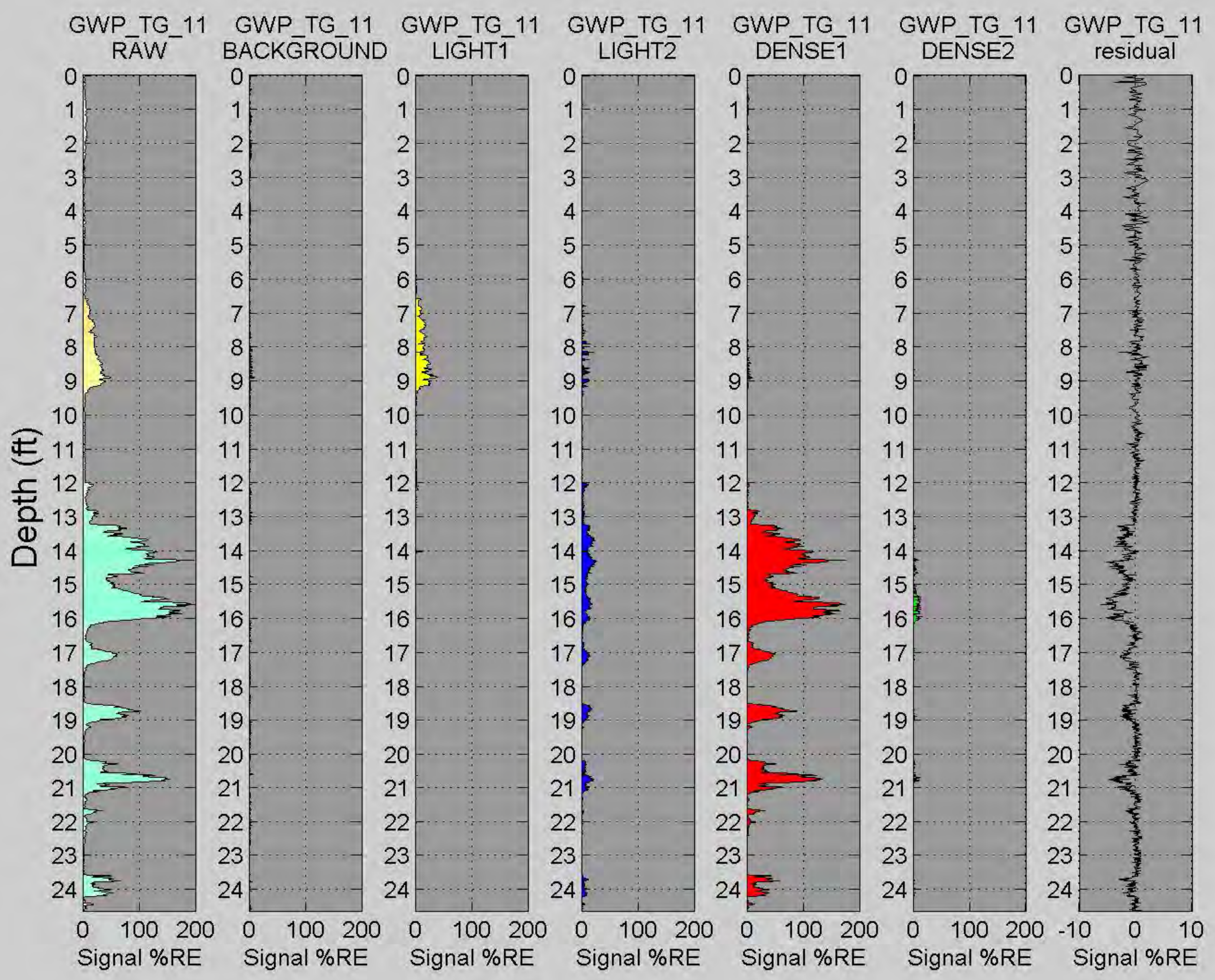
GWP_TG_09 RAW
GWP_TG_09 BACKGROUND
GWP_TG_09 LIGHT1
GWP_TG_09 LIGHT2
GWP_TG_09 DENSE1
GWP_TG_09 DENSE2
GWP_TG_09 residual
Depth (ft)
Signal %RE

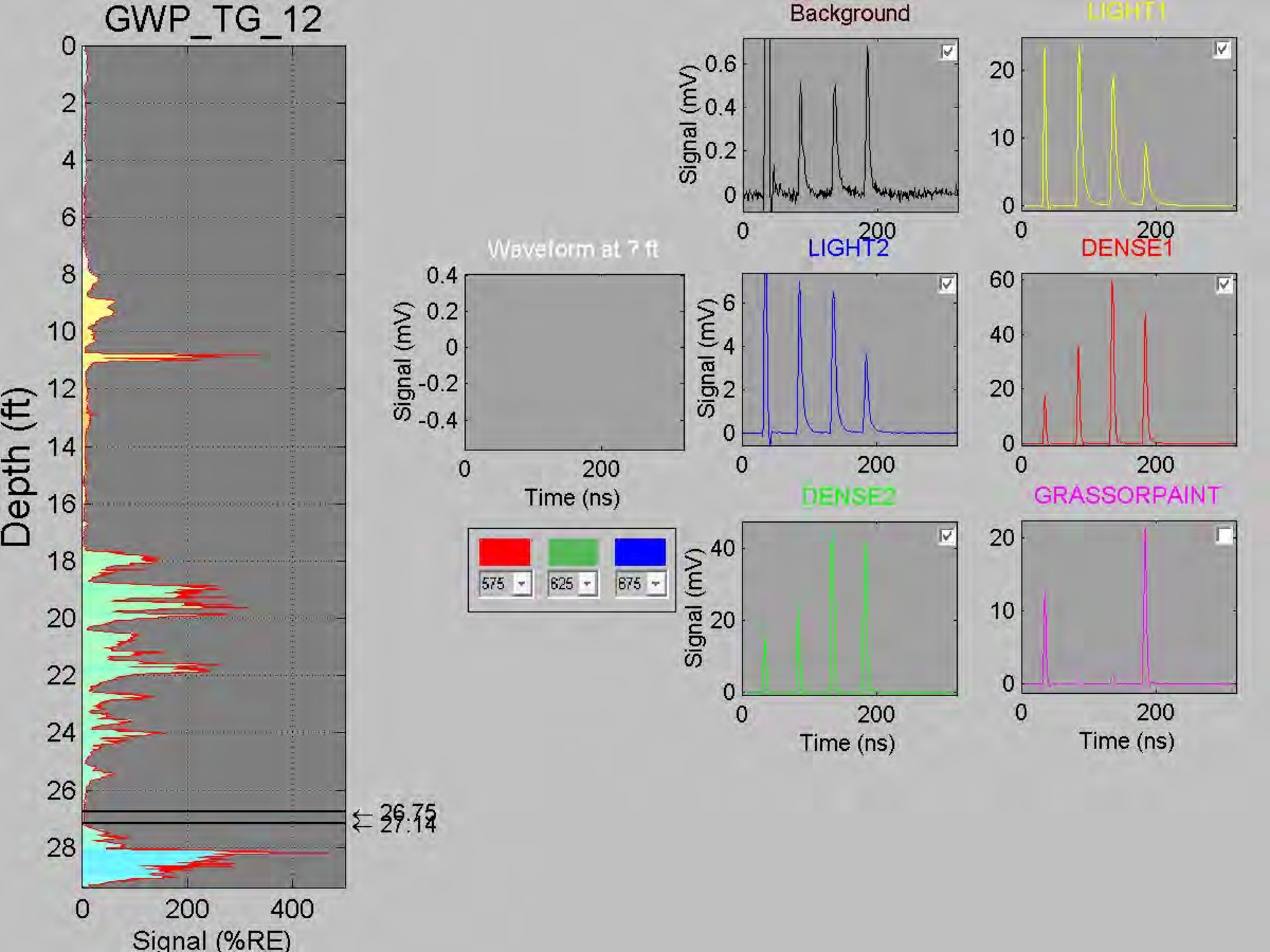


GWP_TG_10
Depth (ft)
Signal (%RE)
← 1.25
← 4.54
Waveform at 7 ft
Signal (mV)
Time (ns)
575
625
675
Background
LIGHT1
LIGHT2
DENSE1
DENSE2
GRASSORPAINT

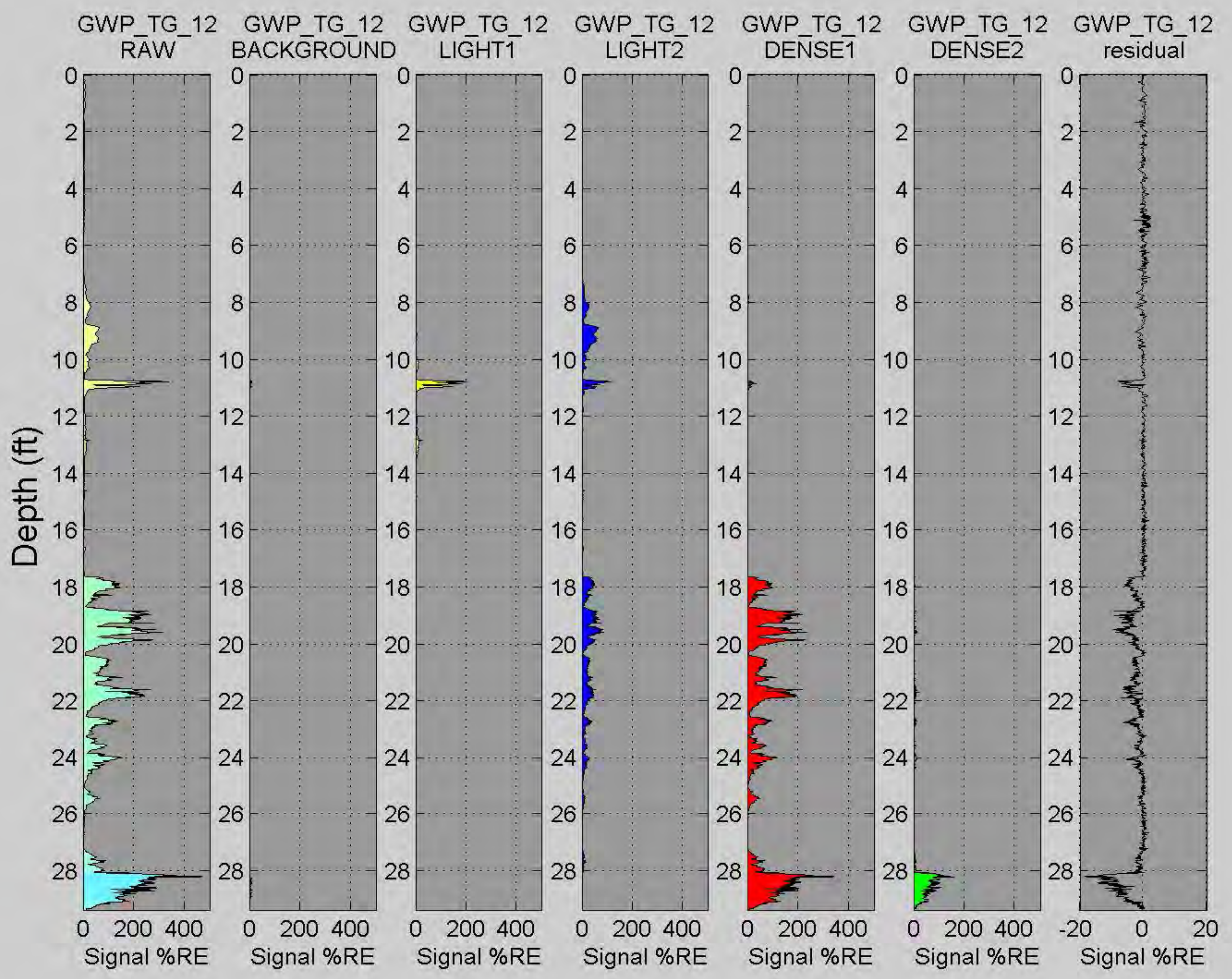

GWP_TG_10
RAW
GWP_TG_10
BACKGROUND
GWP_TG_10
LIGHT1
GWP_TG_10
LIGHT2
GWP_TG_10
DENSE1
GWP_TG_10
DENSE2
GWP_TG_10
residual
Depth (ft)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
0
10
20
-5
5
Signal %RE


GWP_TG_11
Depth (ft)
Signal (%RE)
3.85
5.38
Waveform at 7 ft
Signal (mV)
Time (ns)
575
625
675
Background
LIGHT1
LIGHT2
DENSE1
DENSE2
GRASSORPAINT

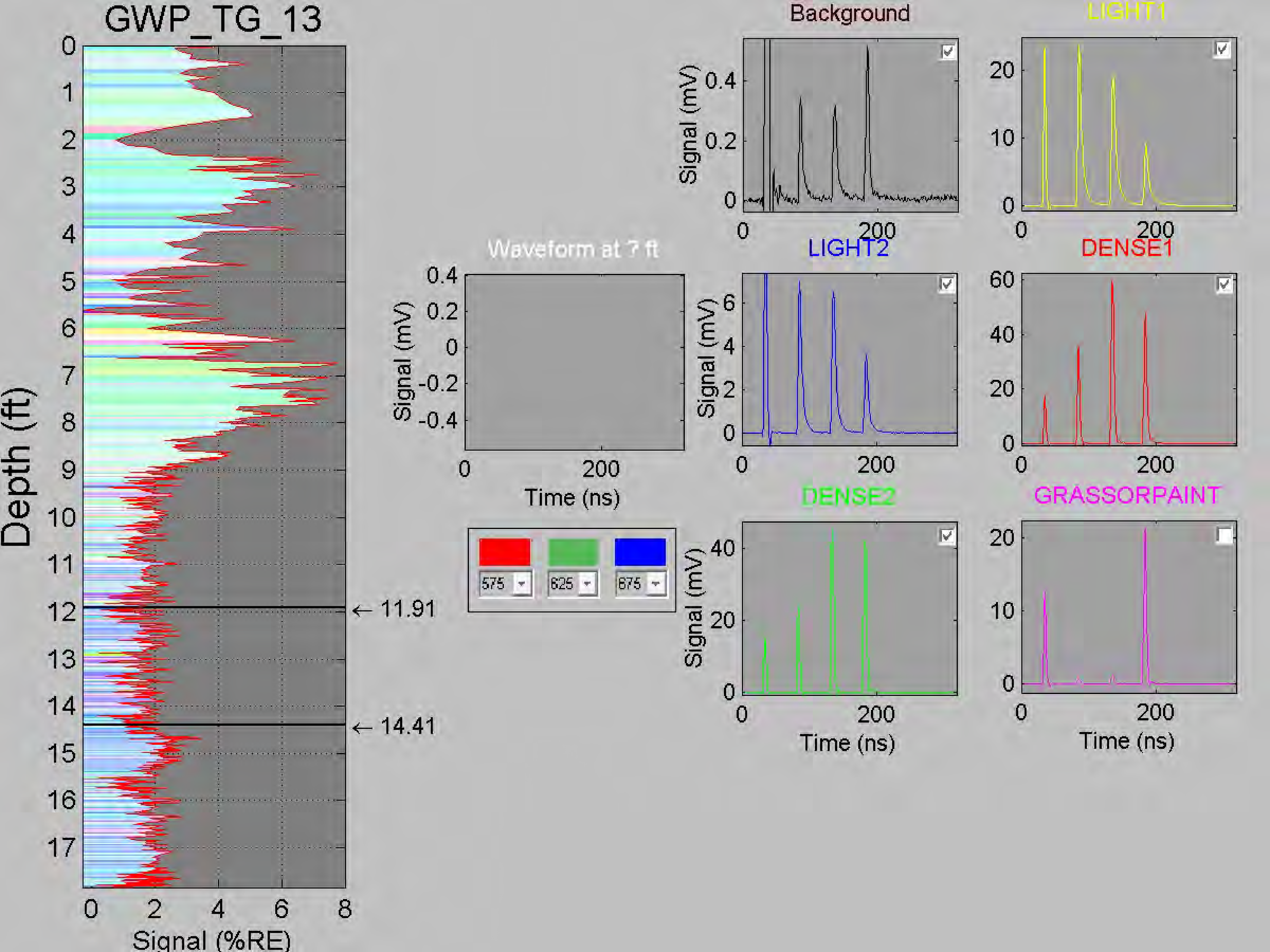

GWP_TG_11
RAW
GWP_TG_11
BACKGROUND
GWP_TG_11
LIGHT1
GWP_TG_11
LIGHT2
GWP_TG_11
DENSE1
GWP_TG_11
DENSE2
GWP_TG_11
residual
Depth (ft)
Signal %RE



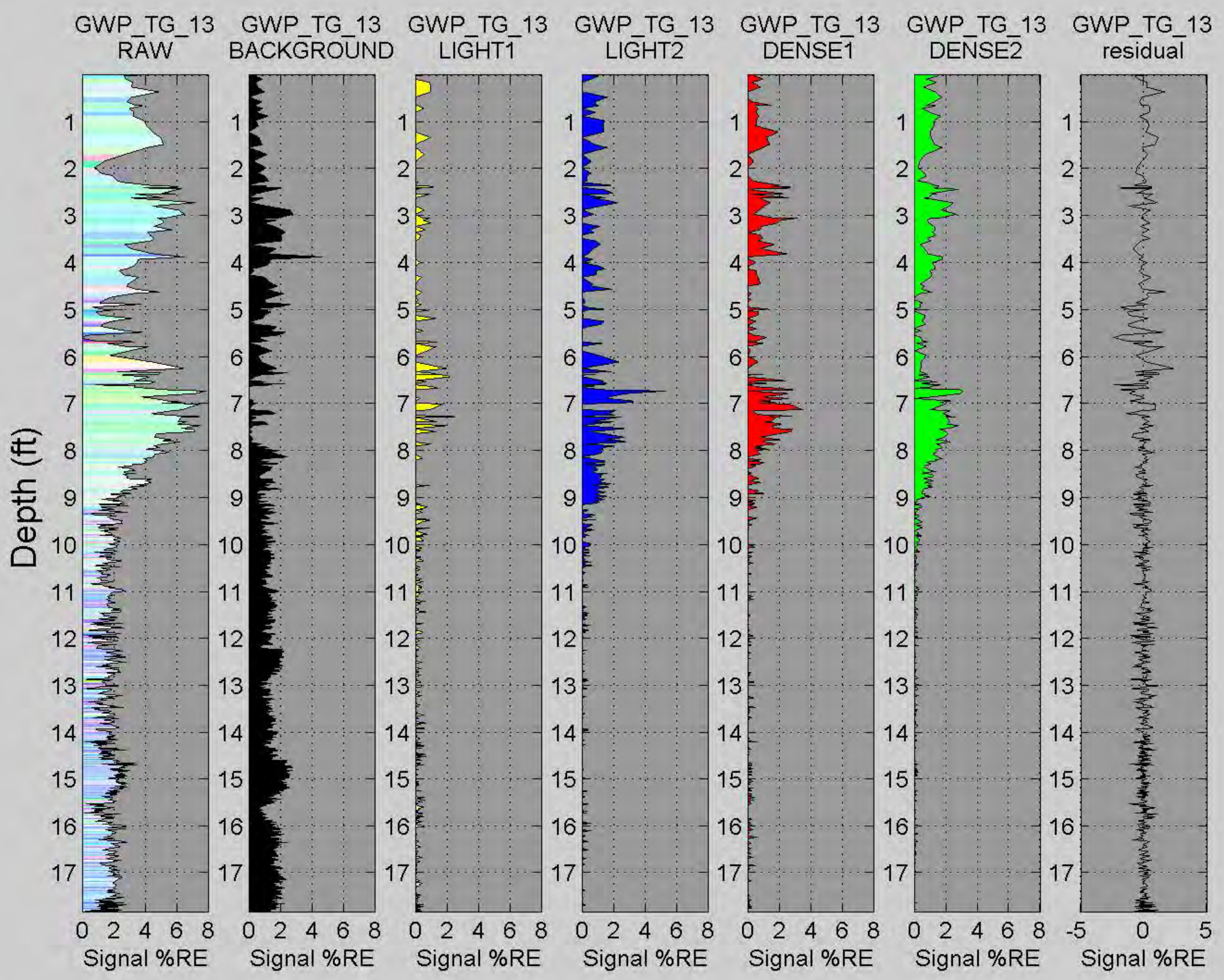
GWP_TG_12
Depth (ft)
Signal (%RE)
26.75
27.14
Background
LIGHT1
Waveform at 7 ft
LIGHT2
DENSE1
DENSE2
GRASSORPAINT
Signal (mV)
Time (ns)
575
625
675



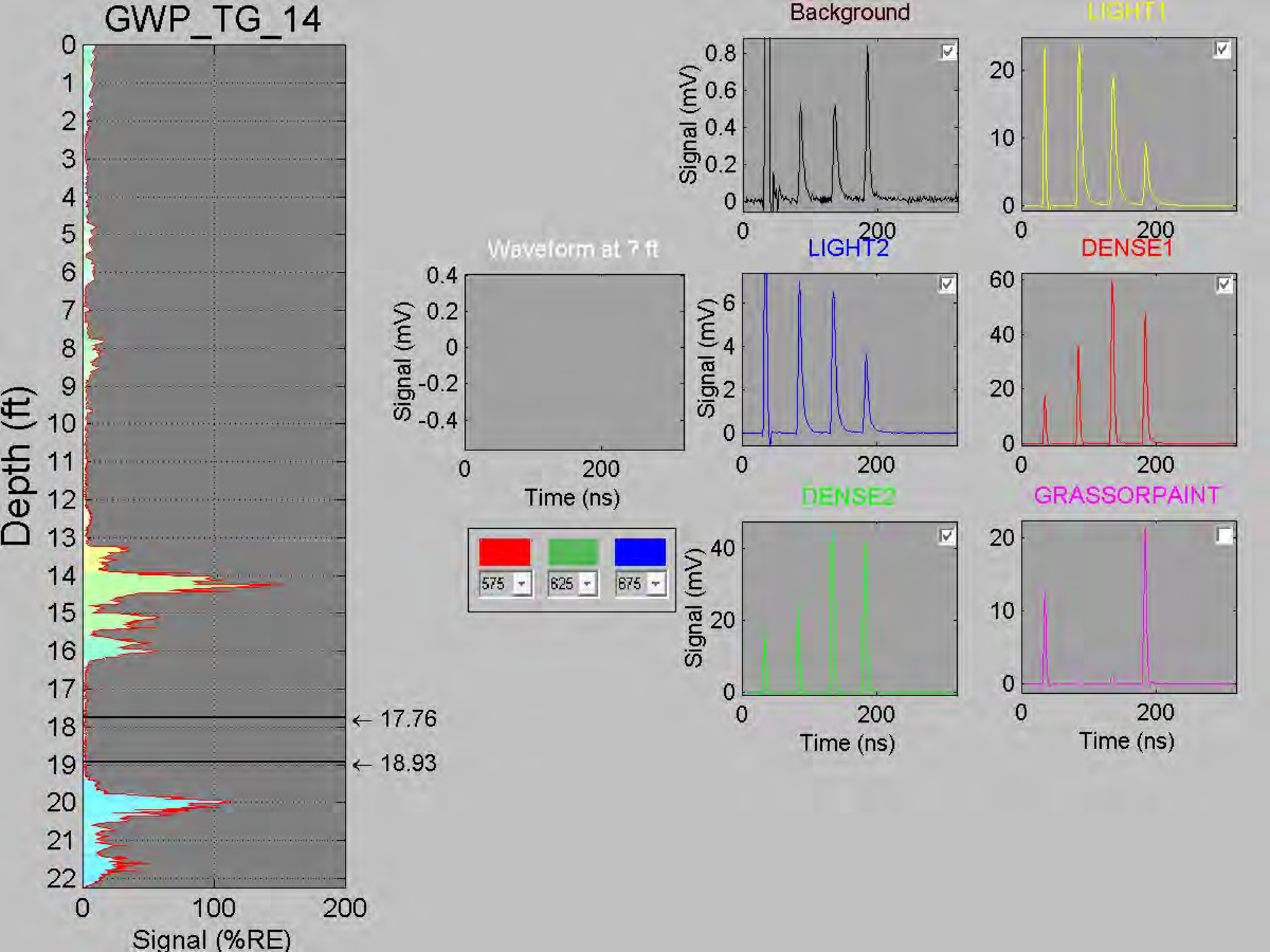
GWP_TG_12 RAW
GWP_TG_12 BACKGROUND
GWP_TG_12 LIGHT1
GWP_TG_12 LIGHT2
GWP_TG_12 DENSE1
GWP_TG_12 DENSE2
GWP_TG_12 residual
Depth (ft)
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28
0 200 400
-20 0 20
Signal %RE



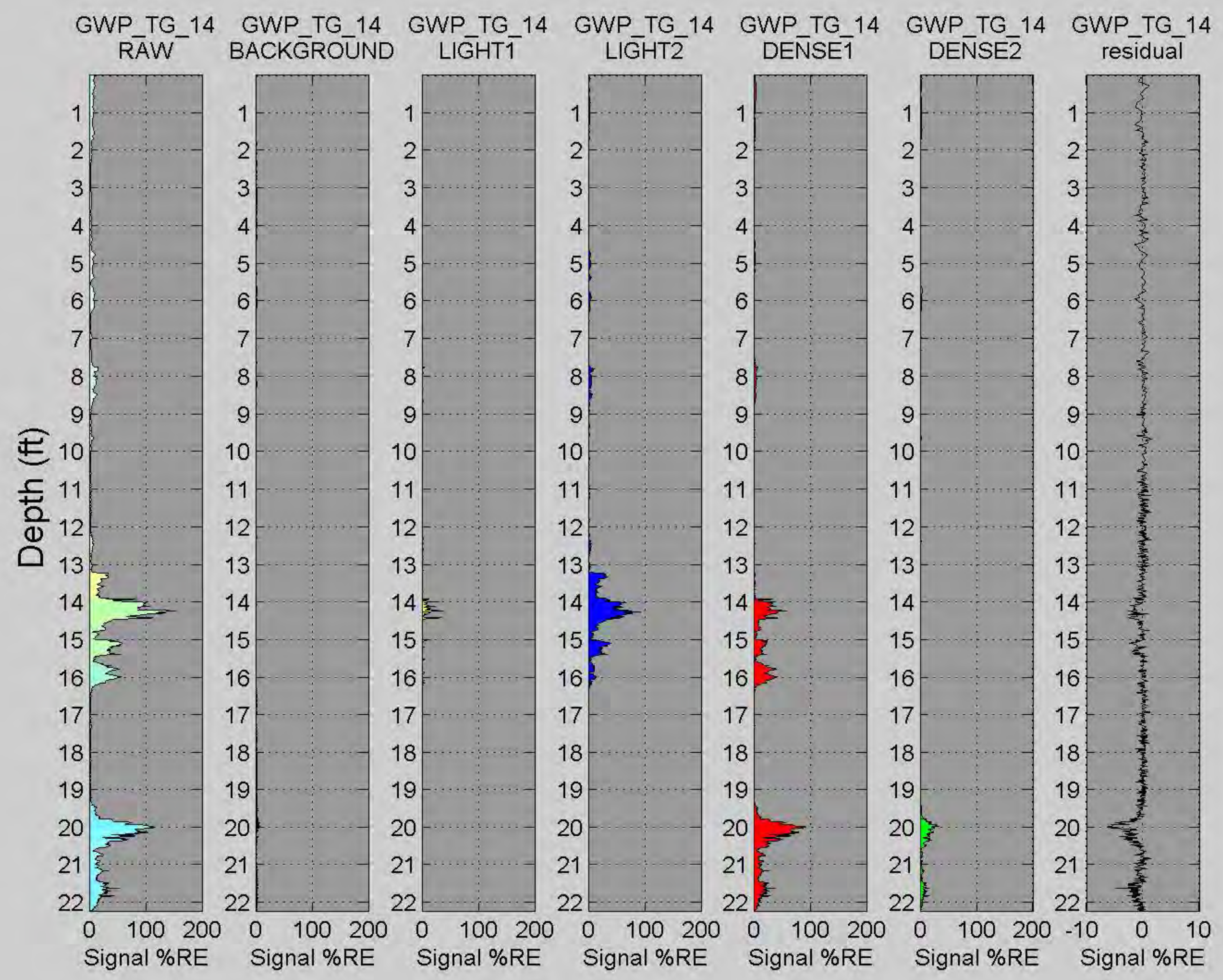
GWP_TG_13
Depth (ft)
Signal (%RE)
← 11.91
← 14.41
Waveform at ? ft
Signal (mV)
Time (ns)
575
625
675
Background
LIGHT1
LIGHT2
DENSE1
DENSE2
GRASSORPAINT



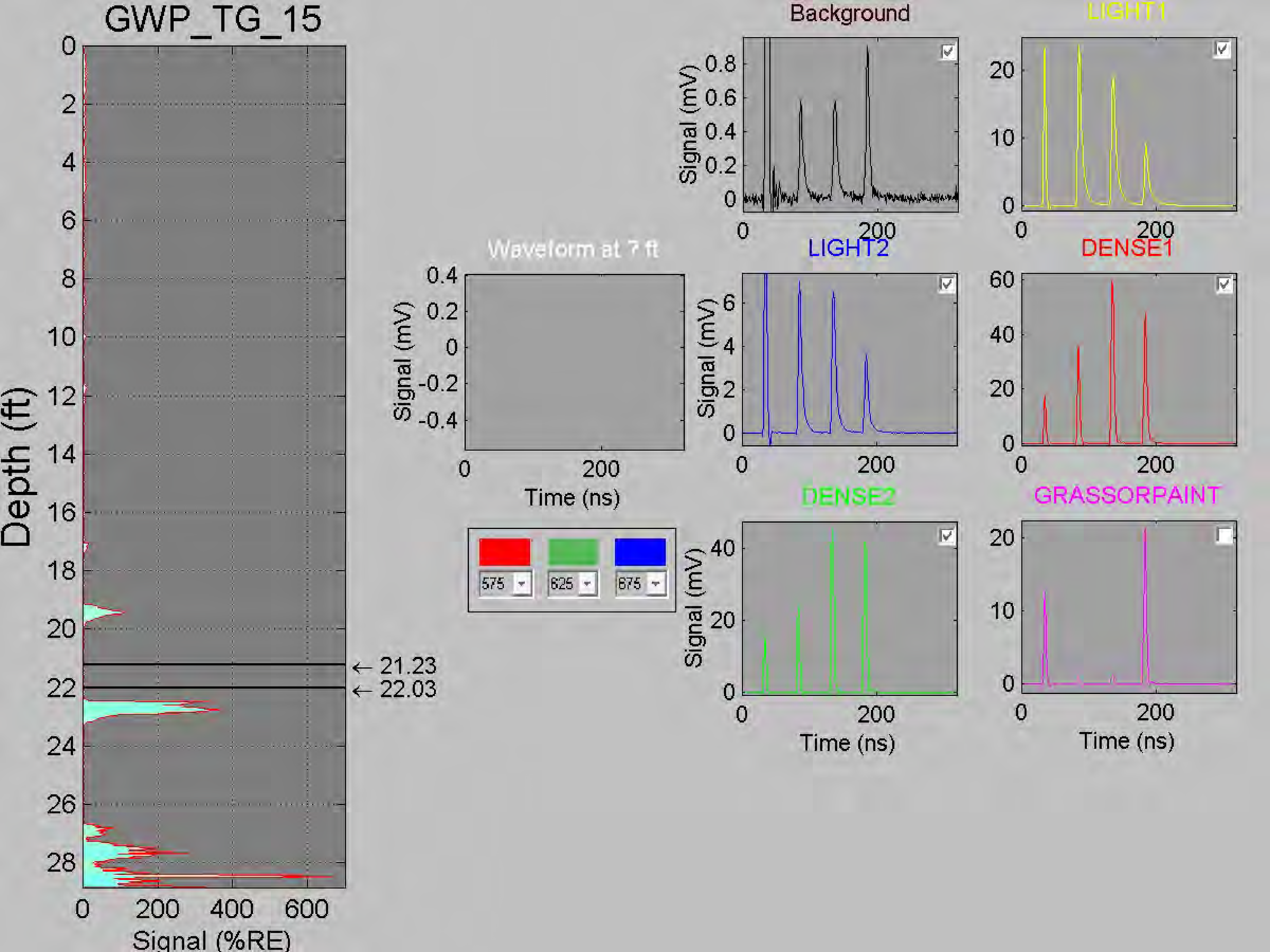
GWP_TG_13
RAW
GWP_TG_13
BACKGROUND
GWP_TG_13
LIGHT1
GWP_TG_13
LIGHT2
GWP_TG_13
DENSE1
GWP_TG_13
DENSE2
GWP_TG_13
residual
Depth (ft)
Signal %RE



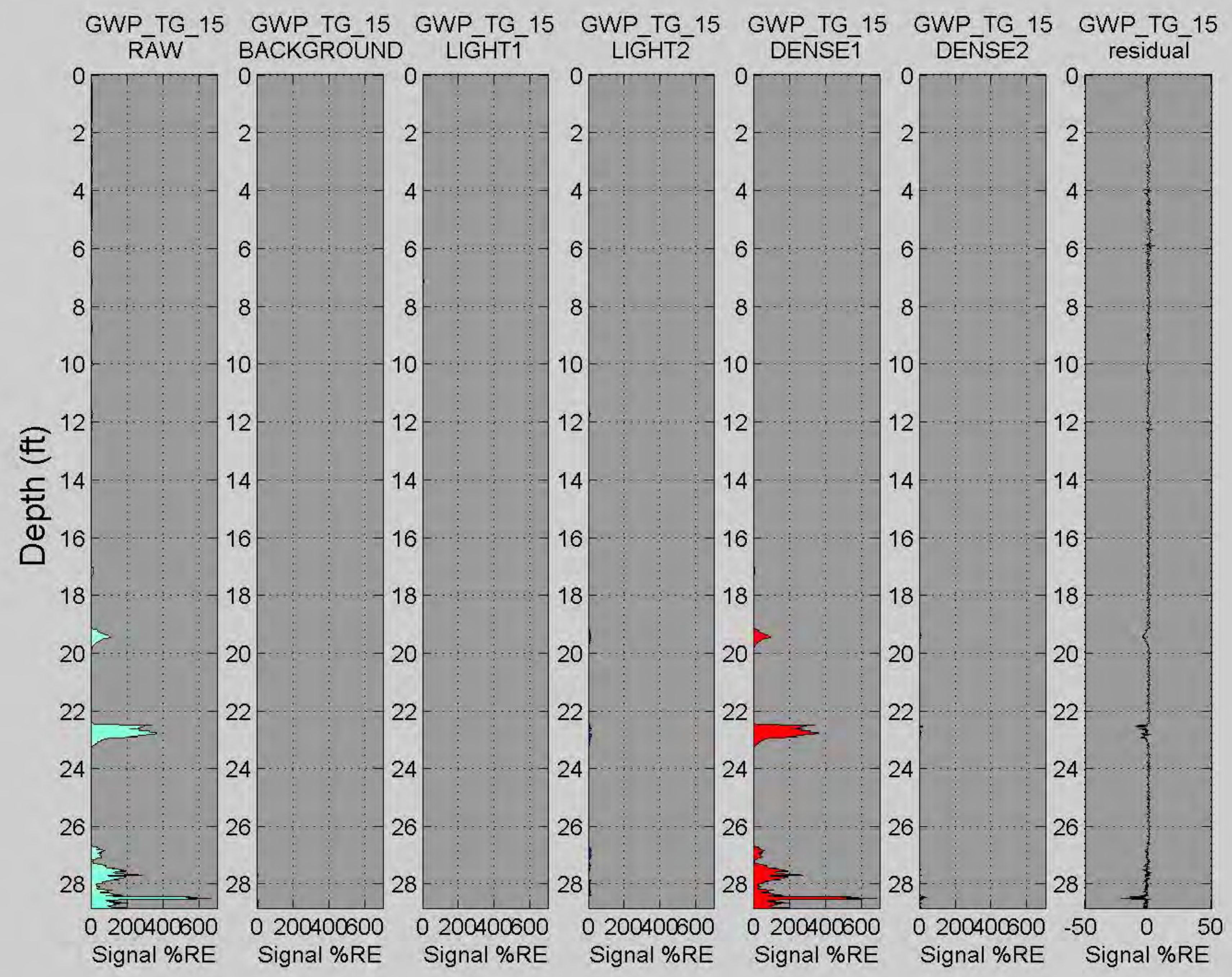
GWP_TG_14
Depth (ft)
Signal (%RE)
17.76
18.93
Waveform at 7 ft
Signal (mV)
Time (ns)
575
625
675
Background
LIGHT1
LIGHT2
DENSE1
DENSE2
GRASSORPAINT



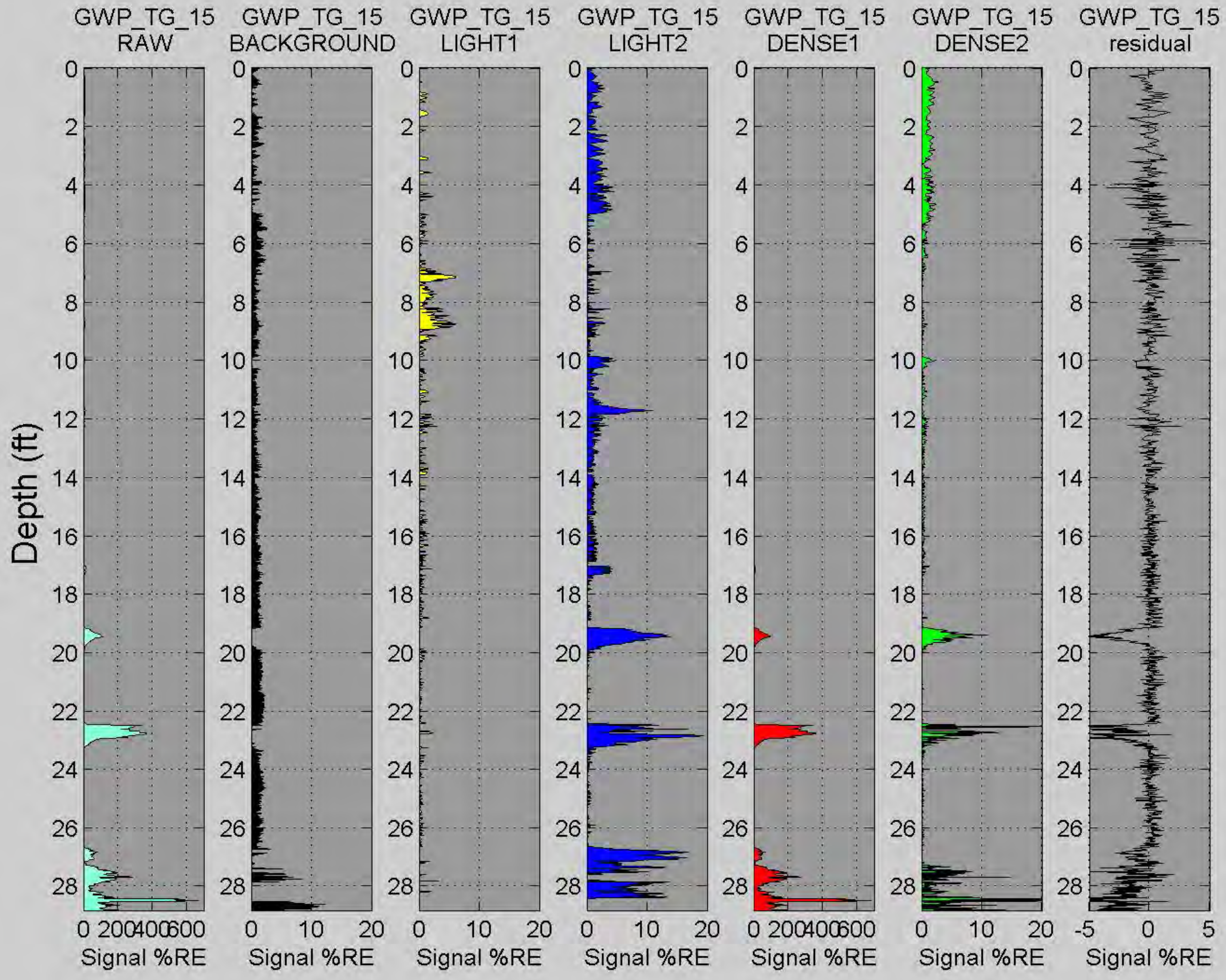
GWP_TG_14
RAW
GWP_TG_14
BACKGROUND
GWP_TG_14
LIGHT1
GWP_TG_14
LIGHT2
GWP_TG_14
DENSE1
GWP_TG_14
DENSE2
GWP_TG_14
residual
Depth (ft)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
0 100 200
-10 0 10
Signal %RE



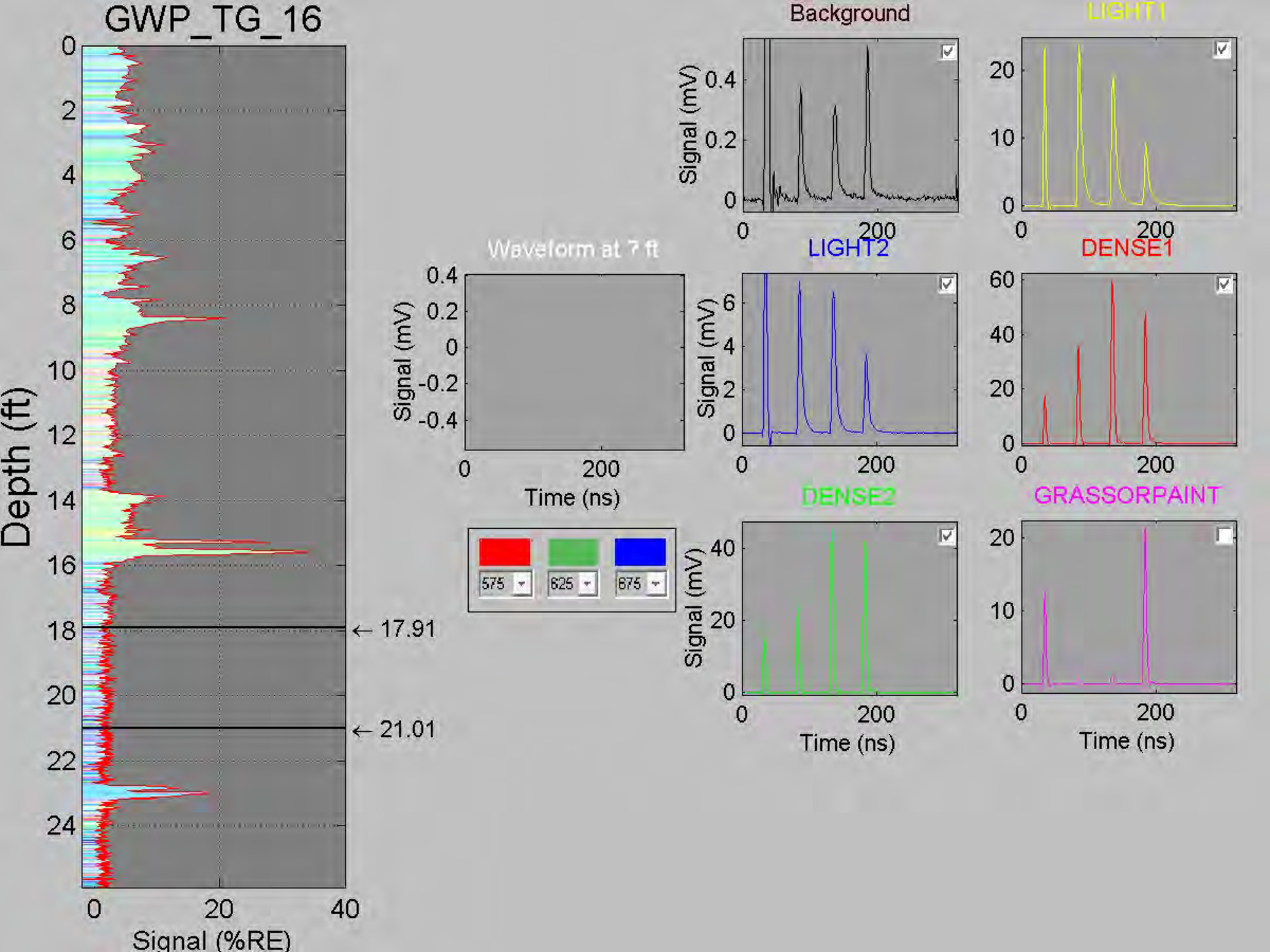
GWP_TG_15
Depth (ft)
Signal (%RE)
← 21.23
← 22.03
Waveform at 7 ft
Signal (mV)
Time (ns)
575
625
675
Background
LIGHT1
LIGHT2
DENSE1
DENSE2
GRASSORPAINT

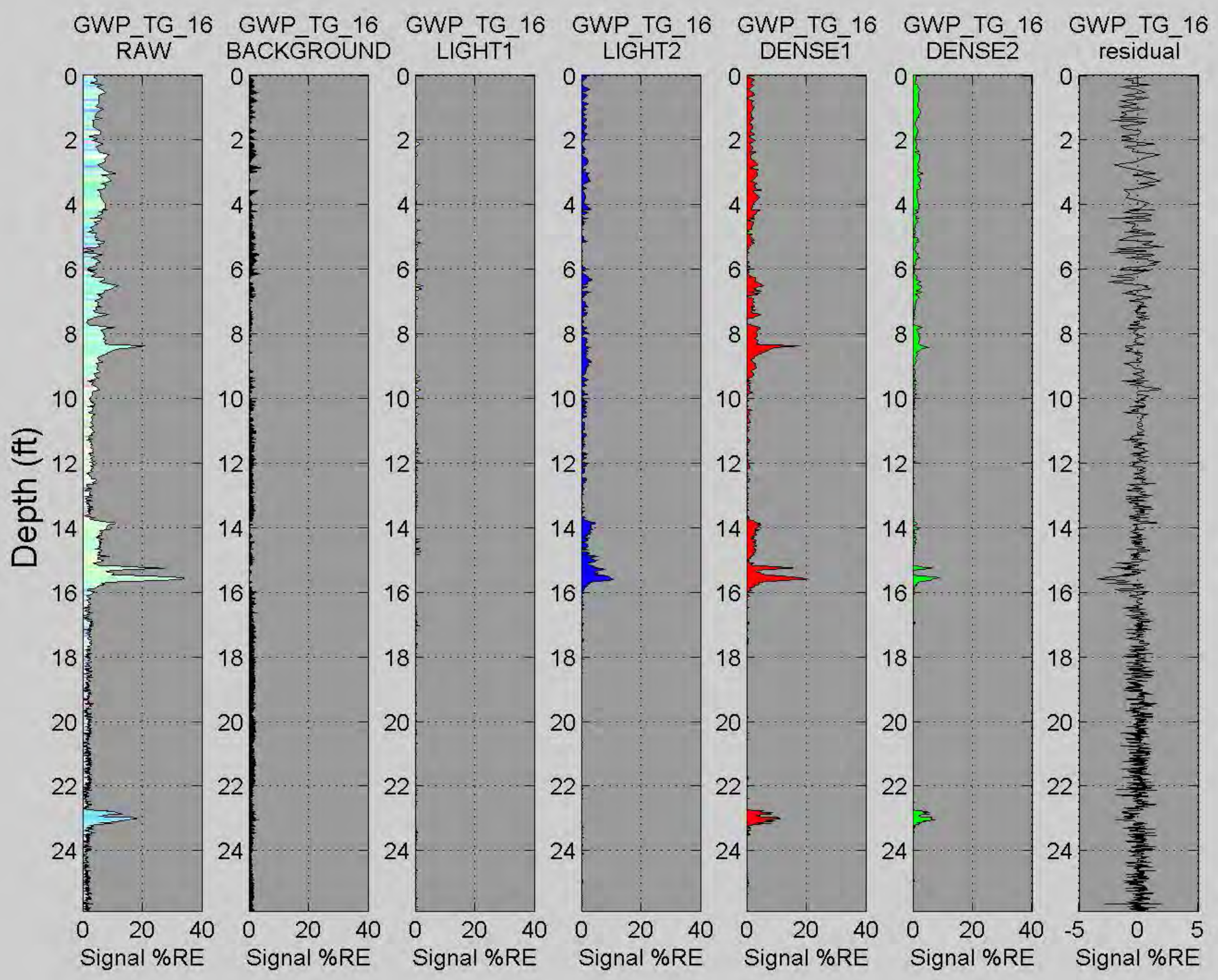


GWP_TG_15 RAW
GWP_TG_15 BACKGROUND
GWP_TG_15 LIGHT1
GWP_TG_15 LIGHT2
GWP_TG_15 DENSE1
GWP_TG_15 DENSE2
GWP_TG_15 residual
Depth (ft)
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28
0 200 400 600
-50 0 50
Signal %RE

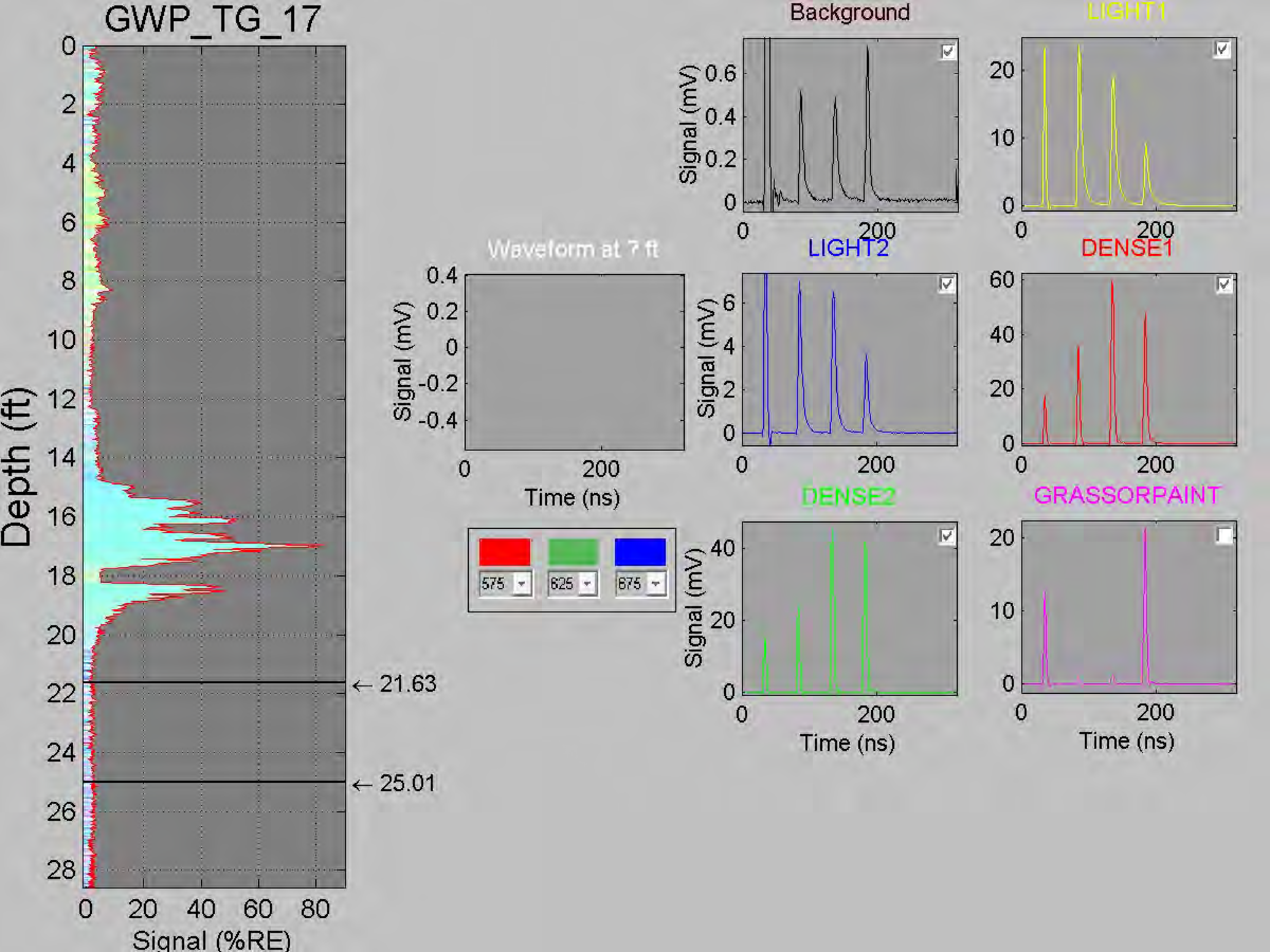


GWP_TG_15 RAW
GWP_TG_15 BACKGROUND
GWP_TG_15 LIGHT1
GWP_TG_15 LIGHT2
GWP_TG_15 DENSE1
GWP_TG_15 DENSE2
GWP_TG_15 residual
Depth (ft)
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28
0 200 400 600
0 10 20
-5 0 5
Signal %RE

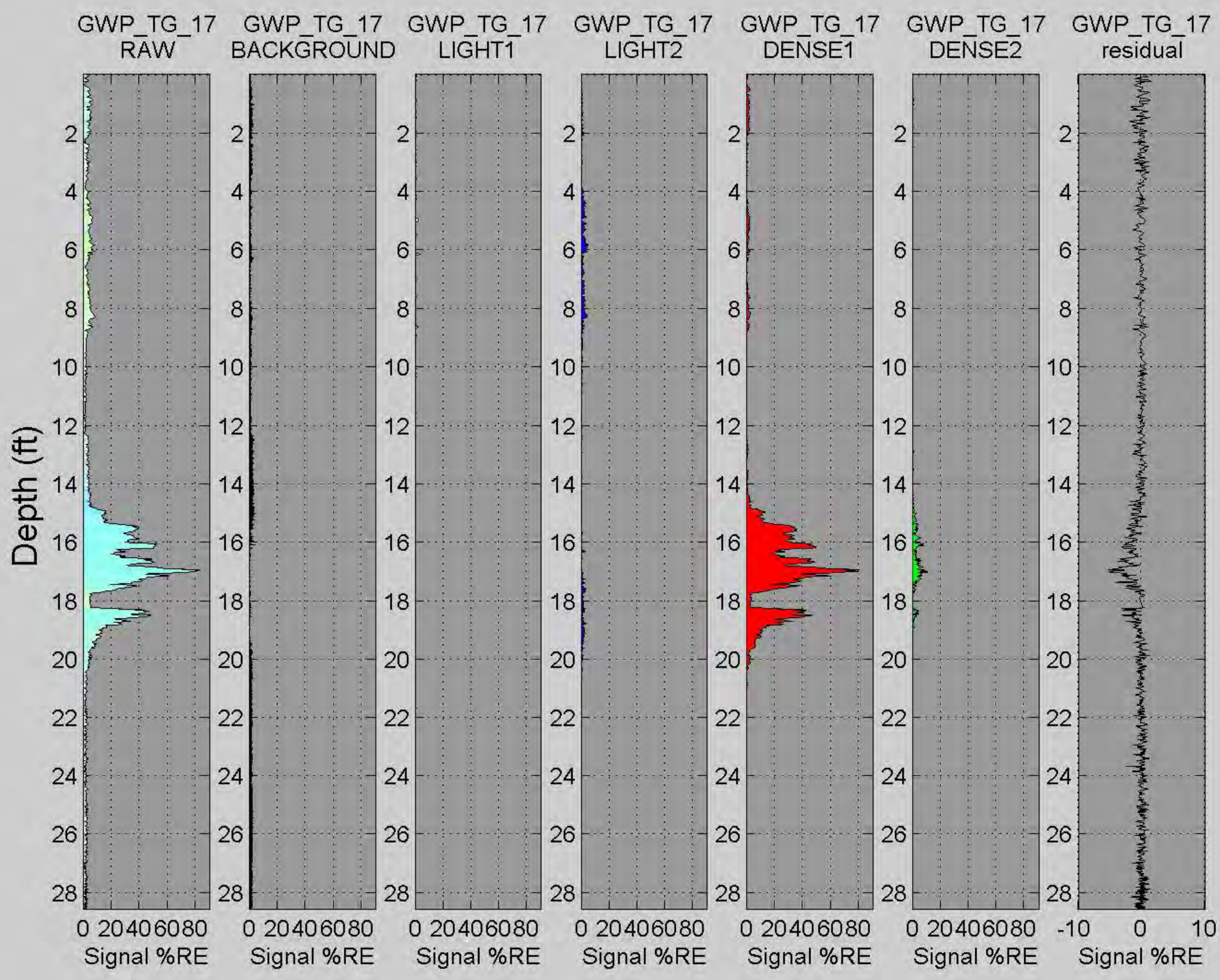

GWP_TG_16
Depth (ft)
Signal (%RE)
← 17.91
← 21.01
Waveform at 7 ft
Signal (mV)
Time (ns)
575
625
675
Background
LIGHT1
LIGHT2
DENSE1
DENSE2
GRASSORPAINT

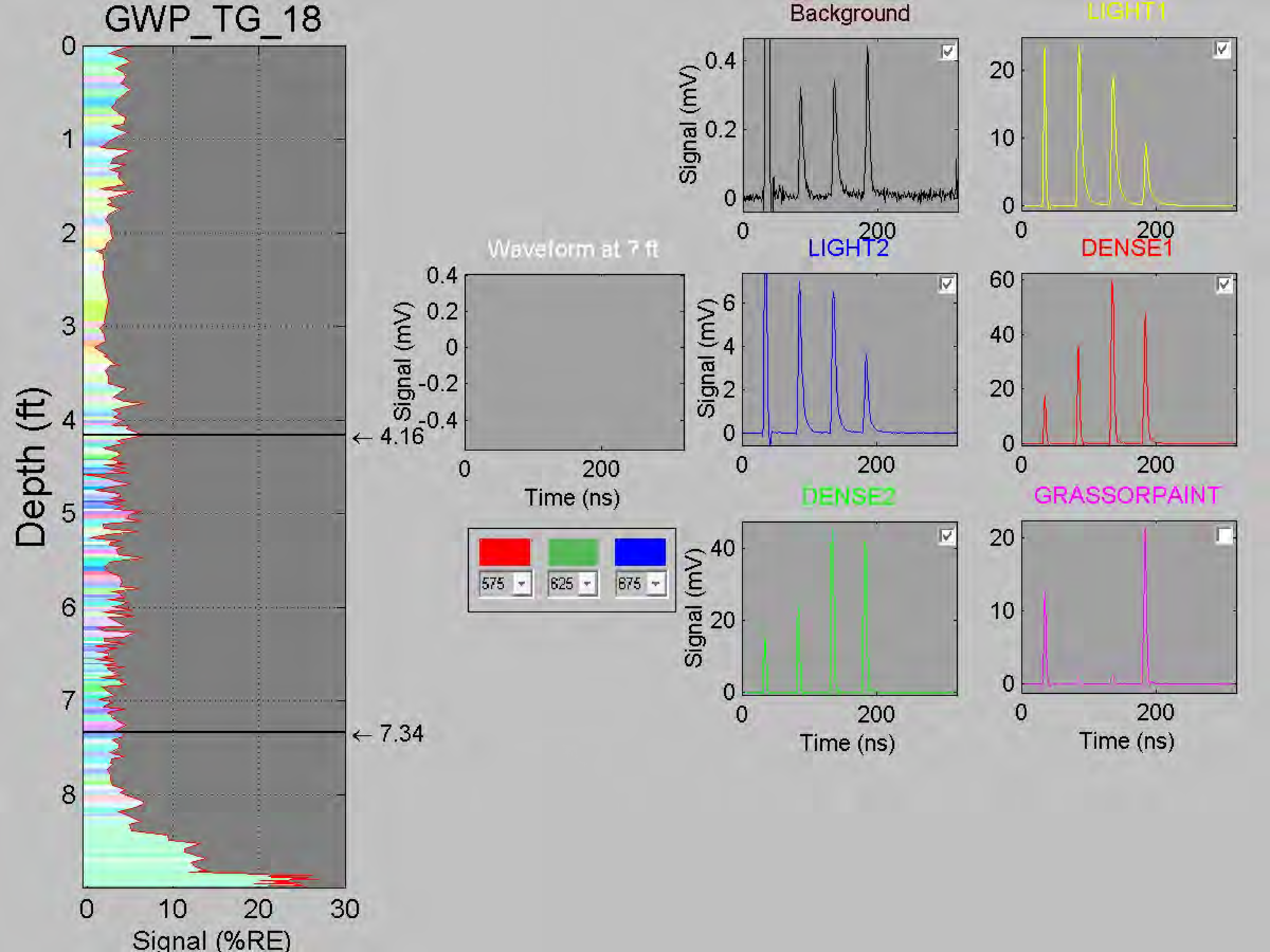


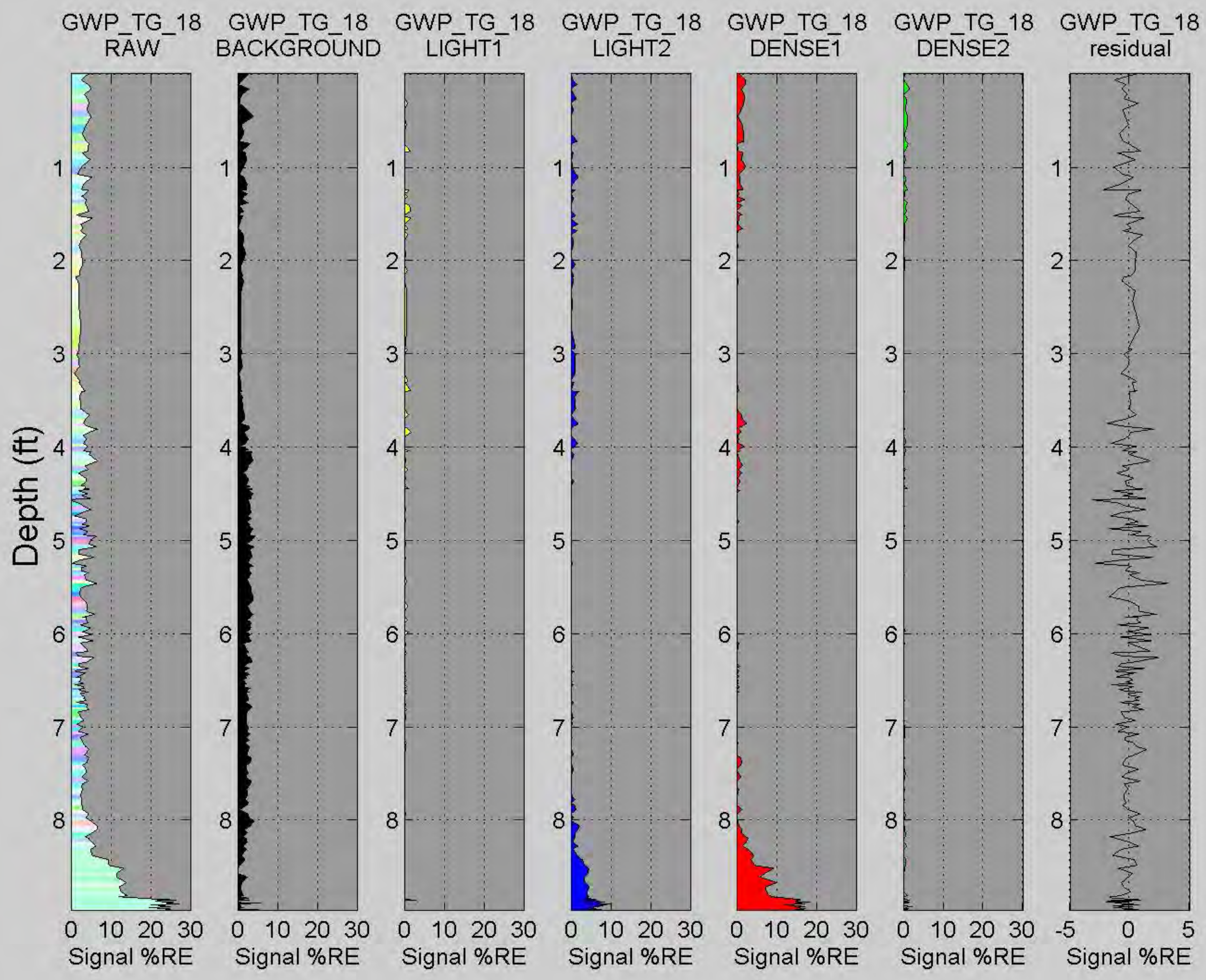
GWP_TG_16
RAW
GWP_TG_16
BACKGROUND
GWP_TG_16
LIGHT1
GWP_TG_16
LIGHT2
GWP_TG_16
DENSE1
GWP_TG_16
DENSE2
GWP_TG_16
residual
Depth (ft)
0 2 4 6 8 10 12 14 16 18 20 22 24
0 20 40
-5 0 5
Signal %RE



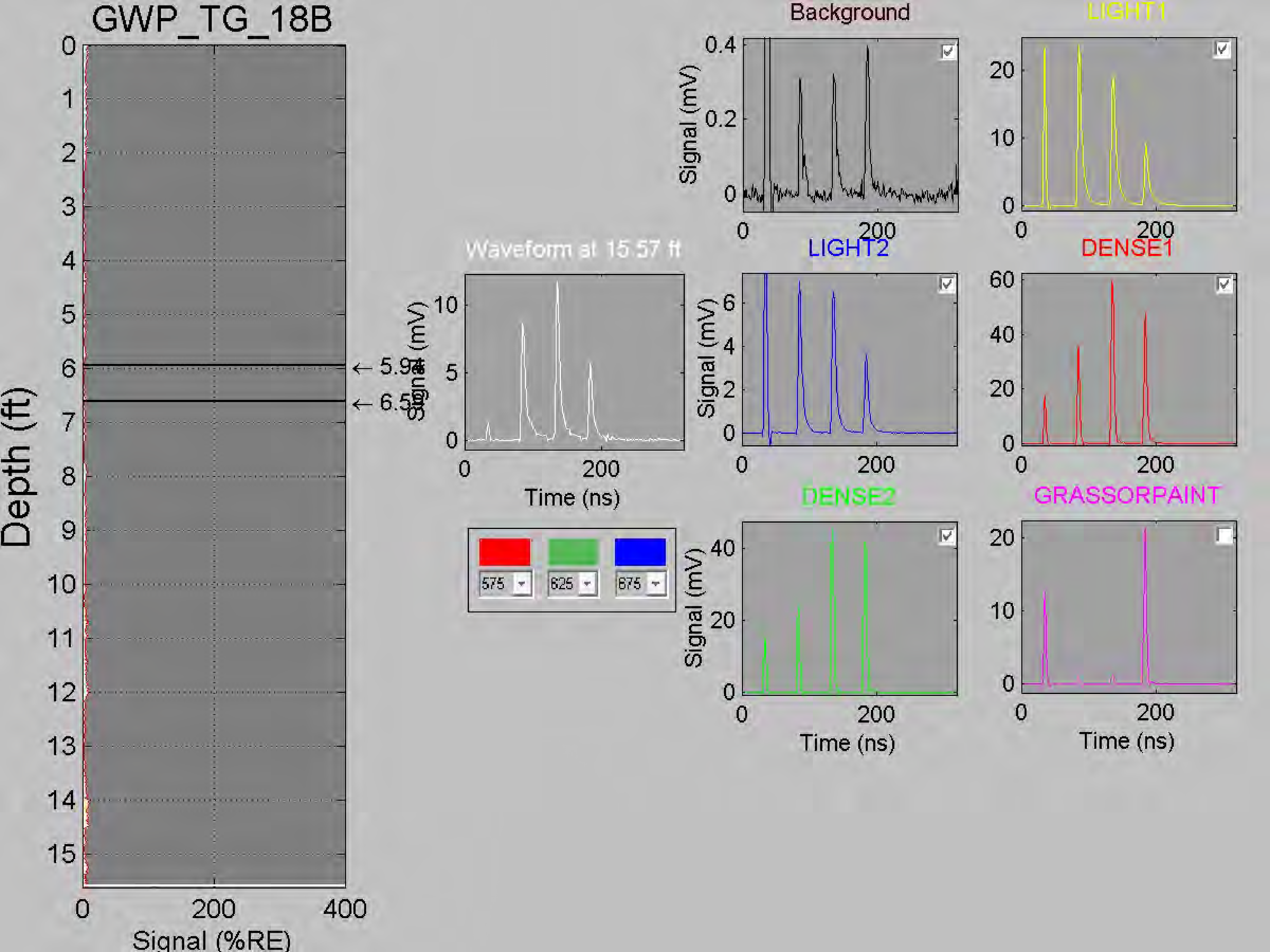
GWP_TG_17
Depth (ft)
Signal (%RE)
← 21.63
← 25.01
Waveform at 7 ft
Signal (mV)
Time (ns)
575
625
675
Background
LIGHT1
LIGHT2
DENSE1
DENSE2
GRASSORPAINT
Signal (mV)
Time (ns)

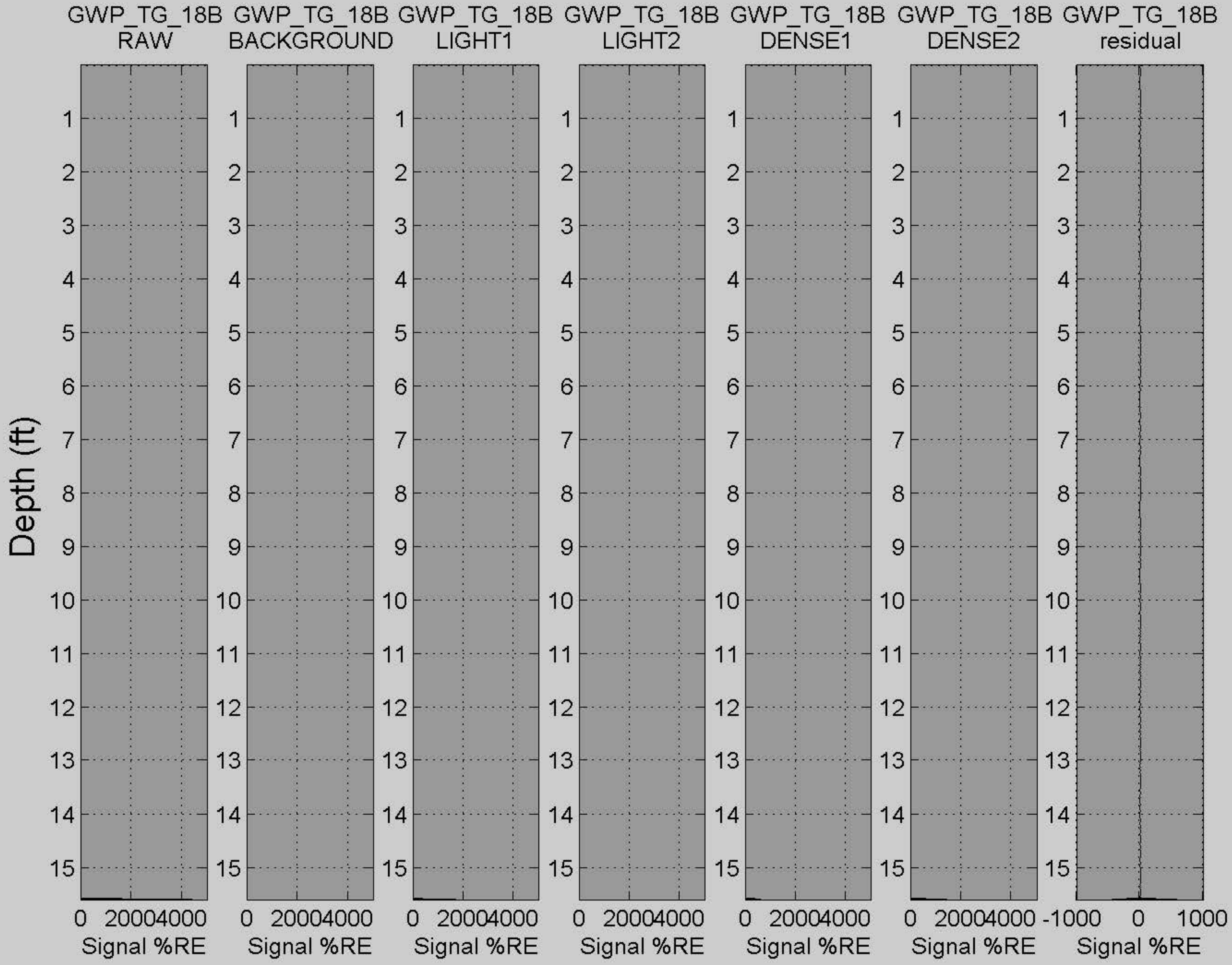

GWP_TG_17
RAW
GWP_TG_17
BACKGROUND
GWP_TG_17
LIGHT1
GWP_TG_17
LIGHT2
GWP_TG_17
DENSE1
GWP_TG_17
DENSE2
GWP_TG_17
residual
Depth (ft)
2
4
6
8
10
12
14
16
18
20
22
24
26
28
0 20 40 60 80
-10 0 10
Signal %RE

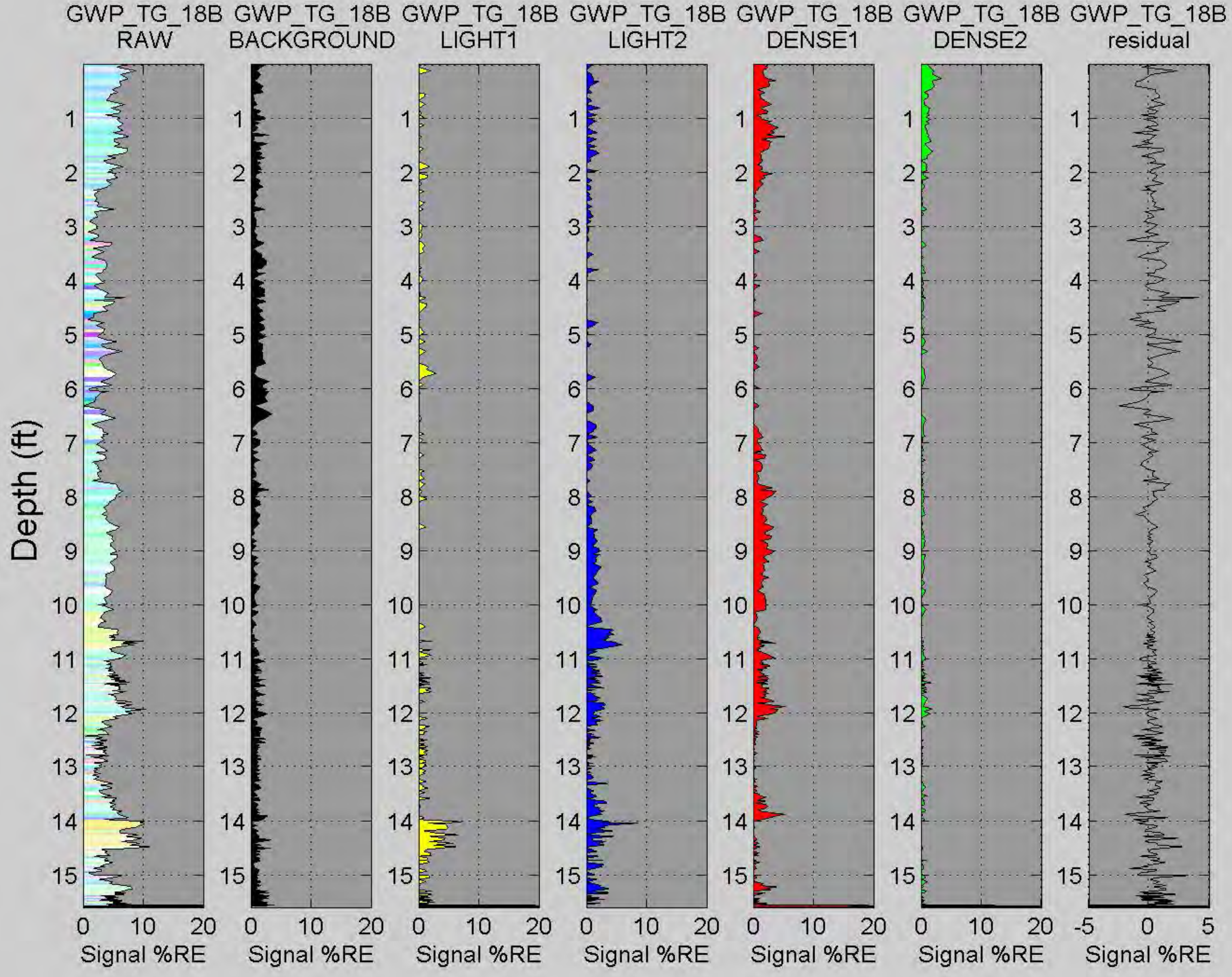

GWP_TG_18
Depth (ft)
Signal (%RE)
← 4.16
← 7.34
Waveform at 7 ft
Signal (mV)
Time (ns)
575
625
675
Background
LIGHT1
LIGHT2
DENSE1
DENSE2
GRASSORPAINT

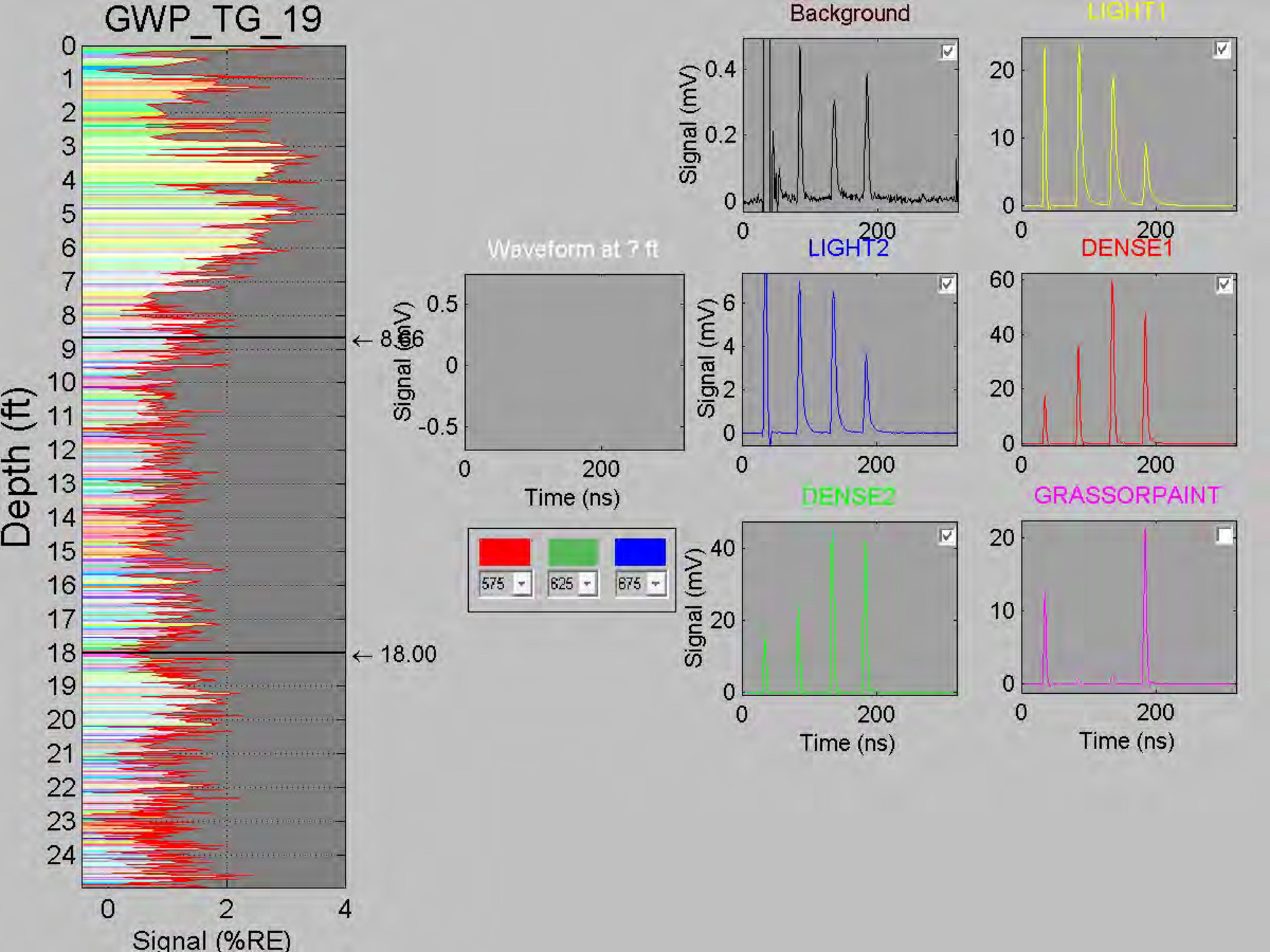


GWP_TG_18 RAW
GWP_TG_18 BACKGROUND
GWP_TG_18 LIGHT1
GWP_TG_18 LIGHT2
GWP_TG_18 DENSE1
GWP_TG_18 DENSE2
GWP_TG_18 residual
Depth (ft)
1
2
3
4
5
6
7
8
0 10 20 30
-5 0 5
Signal %RE

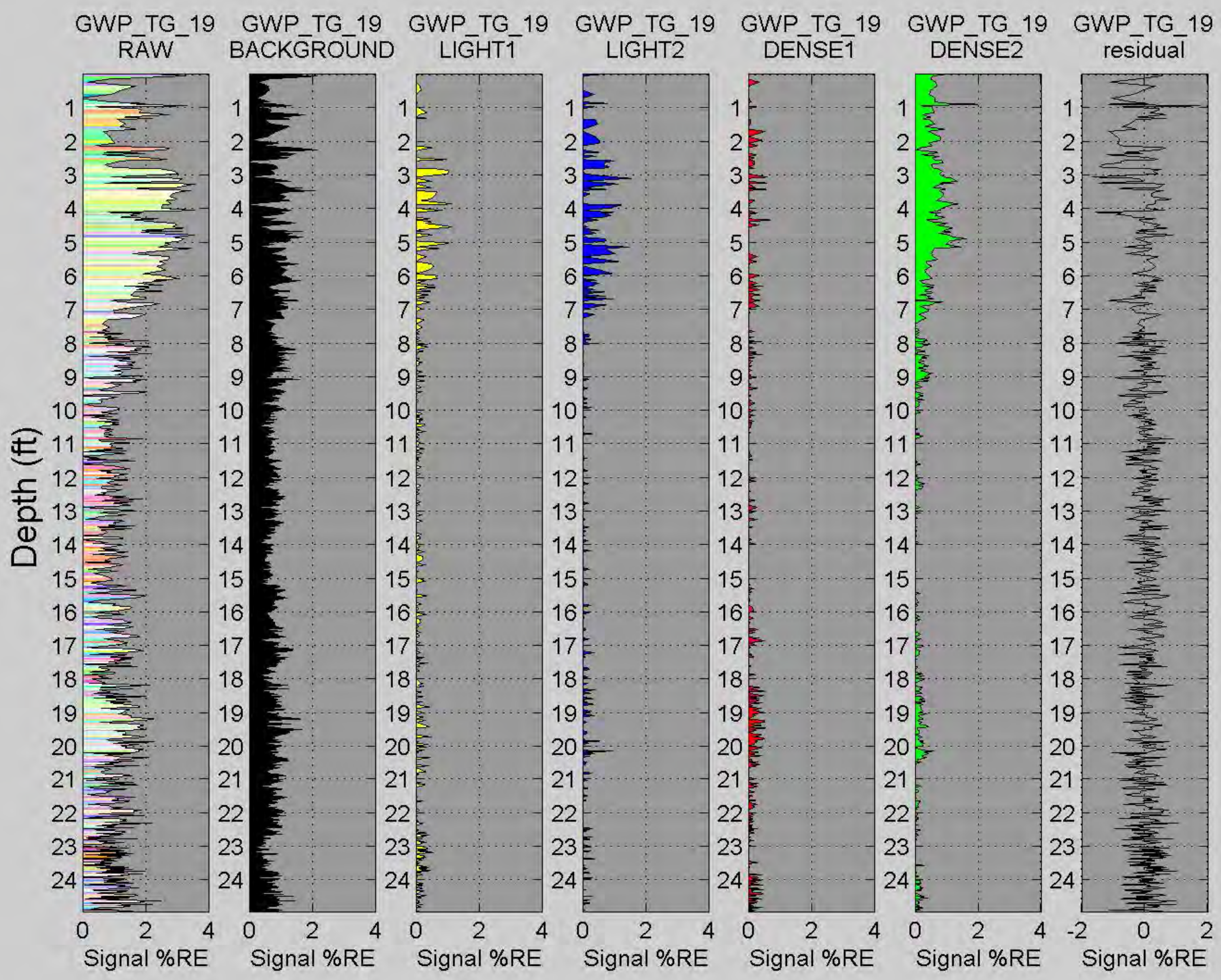

GWP_TG_18B
Depth (ft)
Signal (%RE)
← 5.94
← 6.53
Waveform at 15.57 ft
Signal (mV)
Time (ns)
575
625
675
Background
LIGHT1
LIGHT2
DENSE1
DENSE2
GRASSORPAINT


GWP_TG_18B RAW
GWP_TG_18B BACKGROUND
GWP_TG_18B LIGHT1
GWP_TG_18B LIGHT2
GWP_TG_18B DENSE1
GWP_TG_18B DENSE2
GWP_TG_18B residual
Depth (ft)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
0 2000 4000
-1000 0 1000
Signal %RE

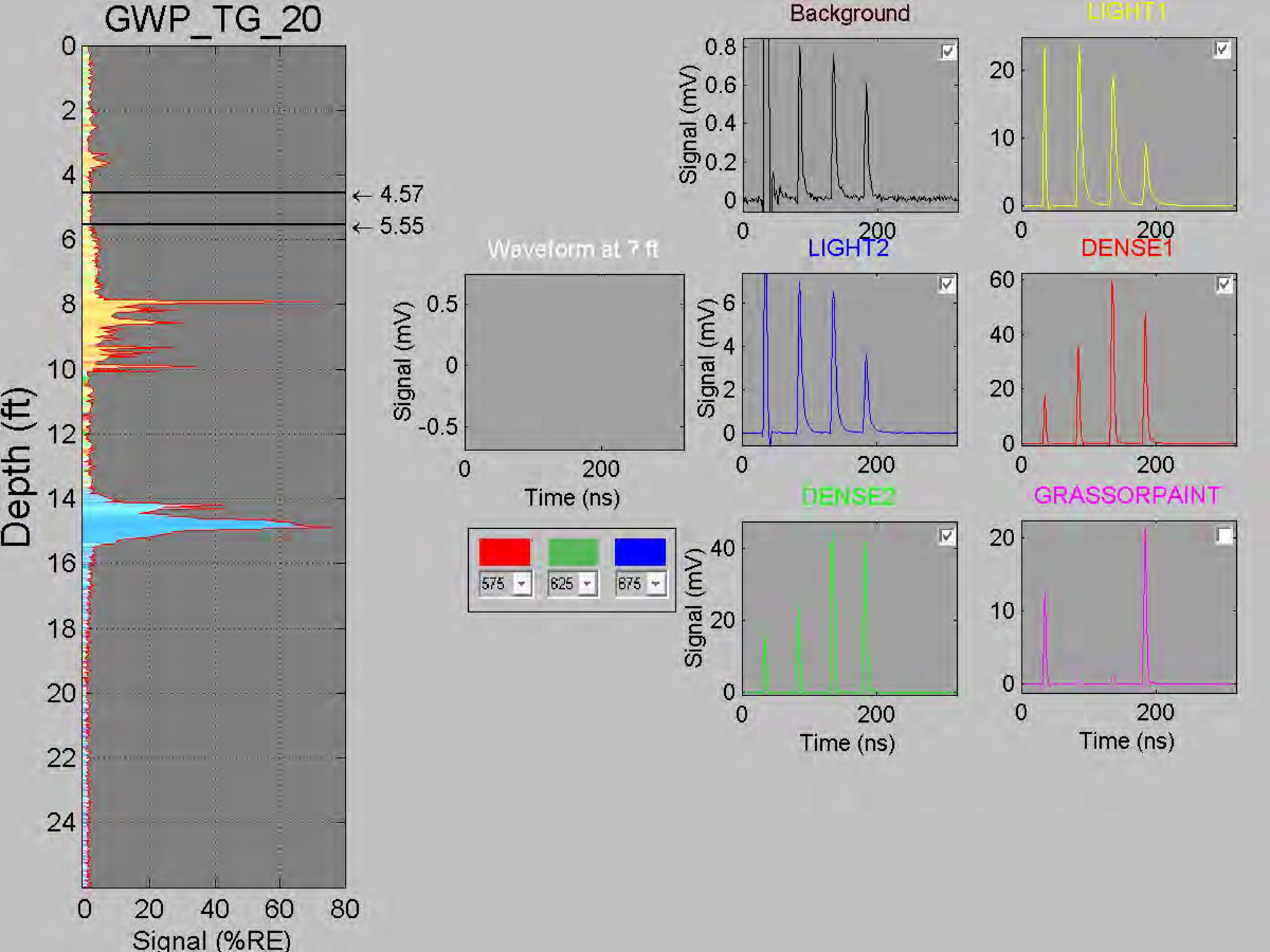

GWP_TG_18B RAW
GWP_TG_18B BACKGROUND
GWP_TG_18B LIGHT1
GWP_TG_18B LIGHT2
GWP_TG_18B DENSE1
GWP_TG_18B DENSE2
GWP_TG_18B residual
Depth (ft)
Signal %RE



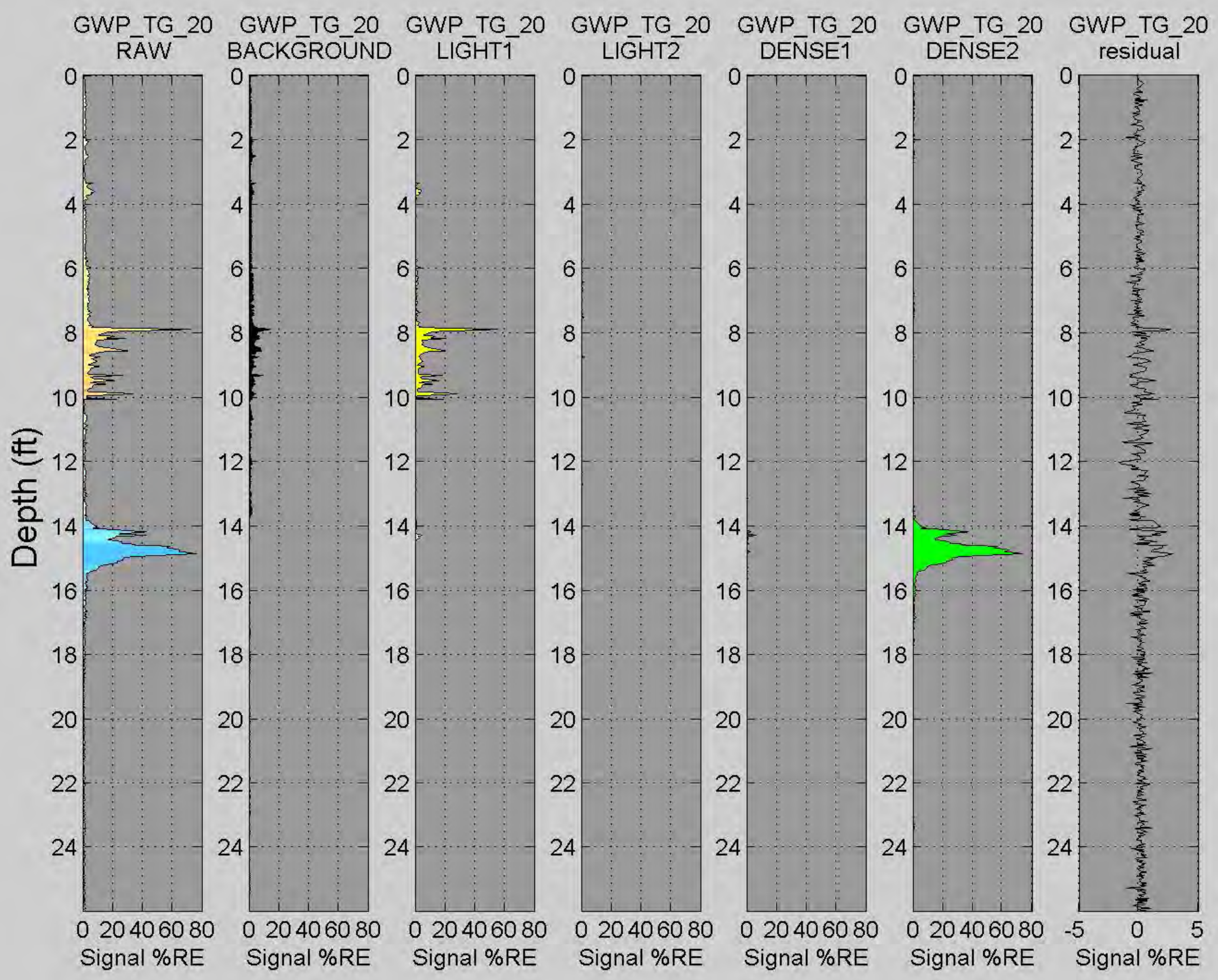
GWP_TG_19
Depth (ft)
Signal (%RE)
← 8.86
← 18.00
Waveform at 7 ft
Signal (mV)
Time (ns)
575
625
675
Background
LIGHT1
LIGHT2
DENSE1
DENSE2
GRASSORPAINT



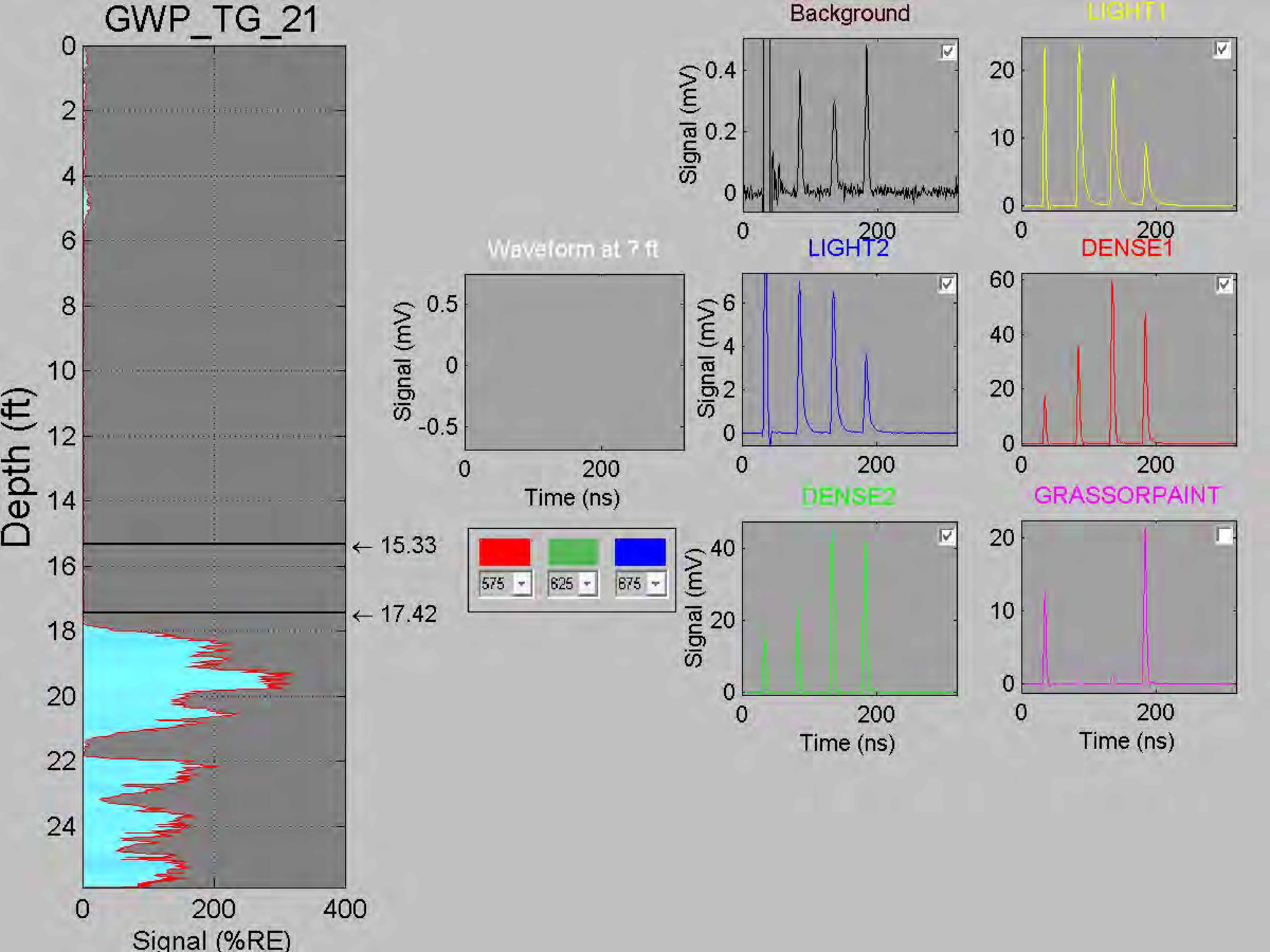
GWP_TG_19 RAW
GWP_TG_19 BACKGROUND
GWP_TG_19 LIGHT1
GWP_TG_19 LIGHT2
GWP_TG_19 DENSE1
GWP_TG_19 DENSE2
GWP_TG_19 residual
Depth (ft)
Signal %RE



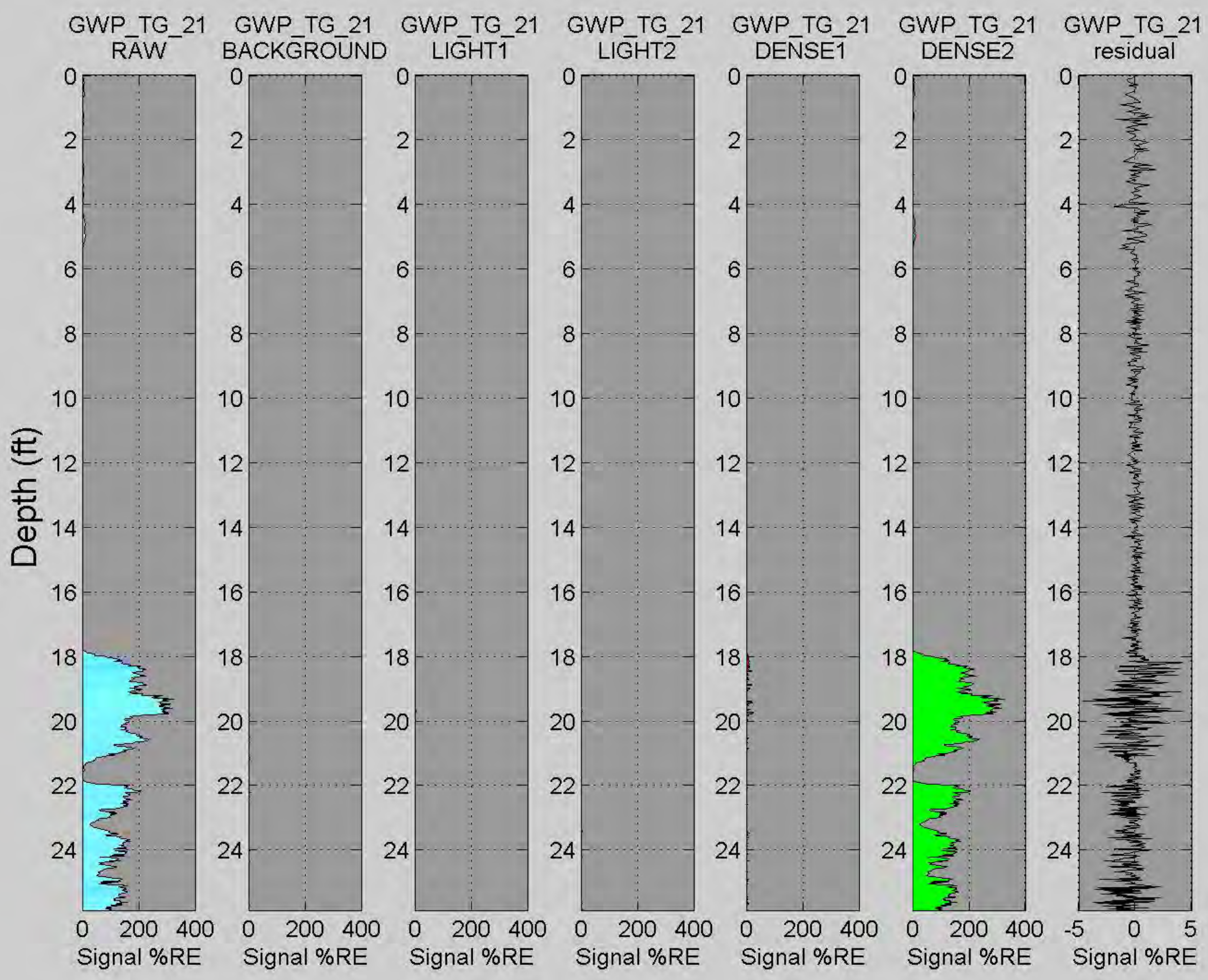
GWP_TG_20
Depth (ft)
Signal (%RE)
← 4.57
← 5.55
Waveform at 7 ft
Signal (mV)
Time (ns)
575
625
675
Background
LIGHT1
LIGHT2
DENSE1
DENSE2
GRASSORPAINT

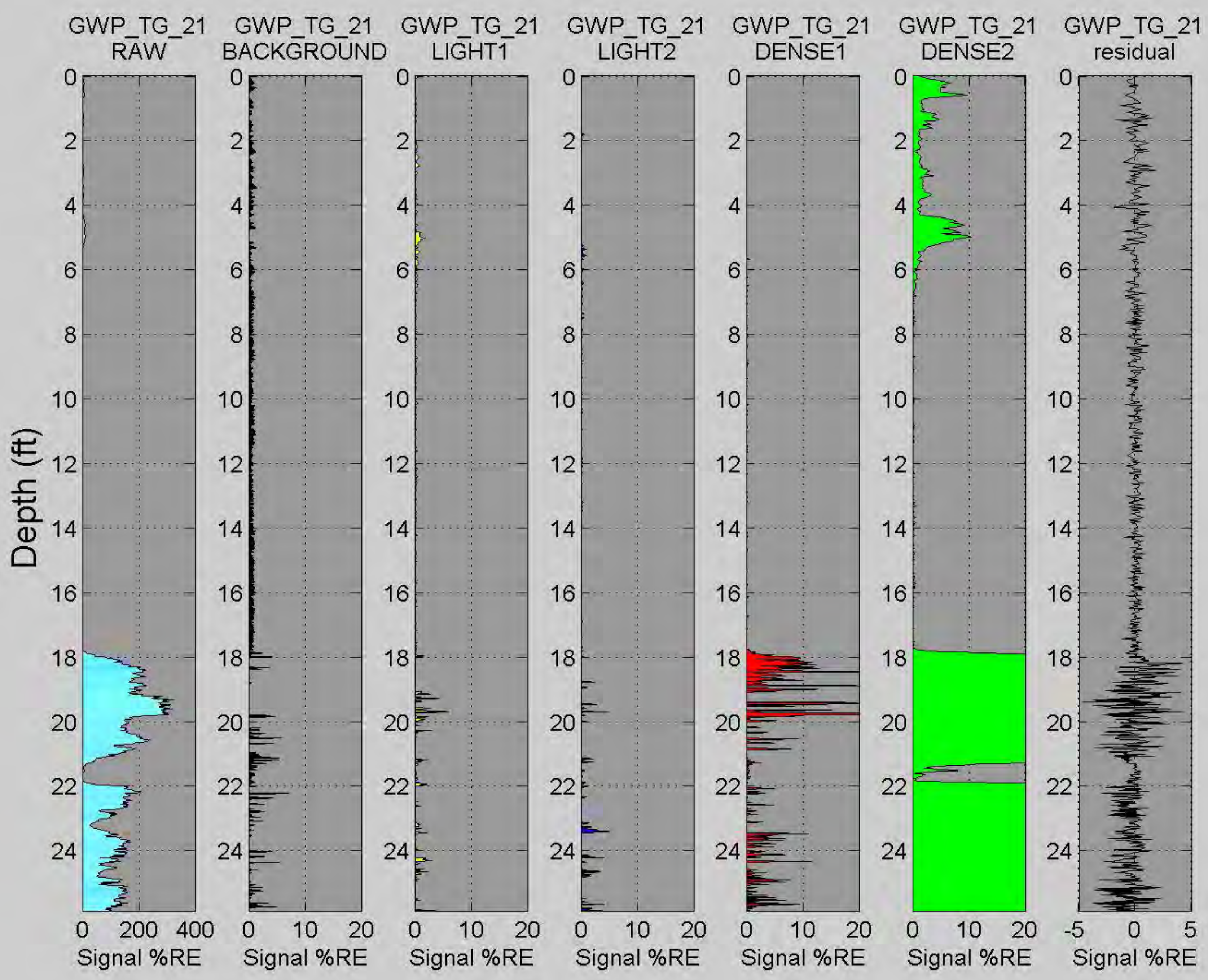


GWP_TG_20 RAW
GWP_TG_20 BACKGROUND
GWP_TG_20 LIGHT1
GWP_TG_20 LIGHT2
GWP_TG_20 DENSE1
GWP_TG_20 DENSE2
GWP_TG_20 residual
Depth (ft)
0 2 4 6 8 10 12 14 16 18 20 22 24
0 20 40 60 80
-5 0 5
Signal %RE

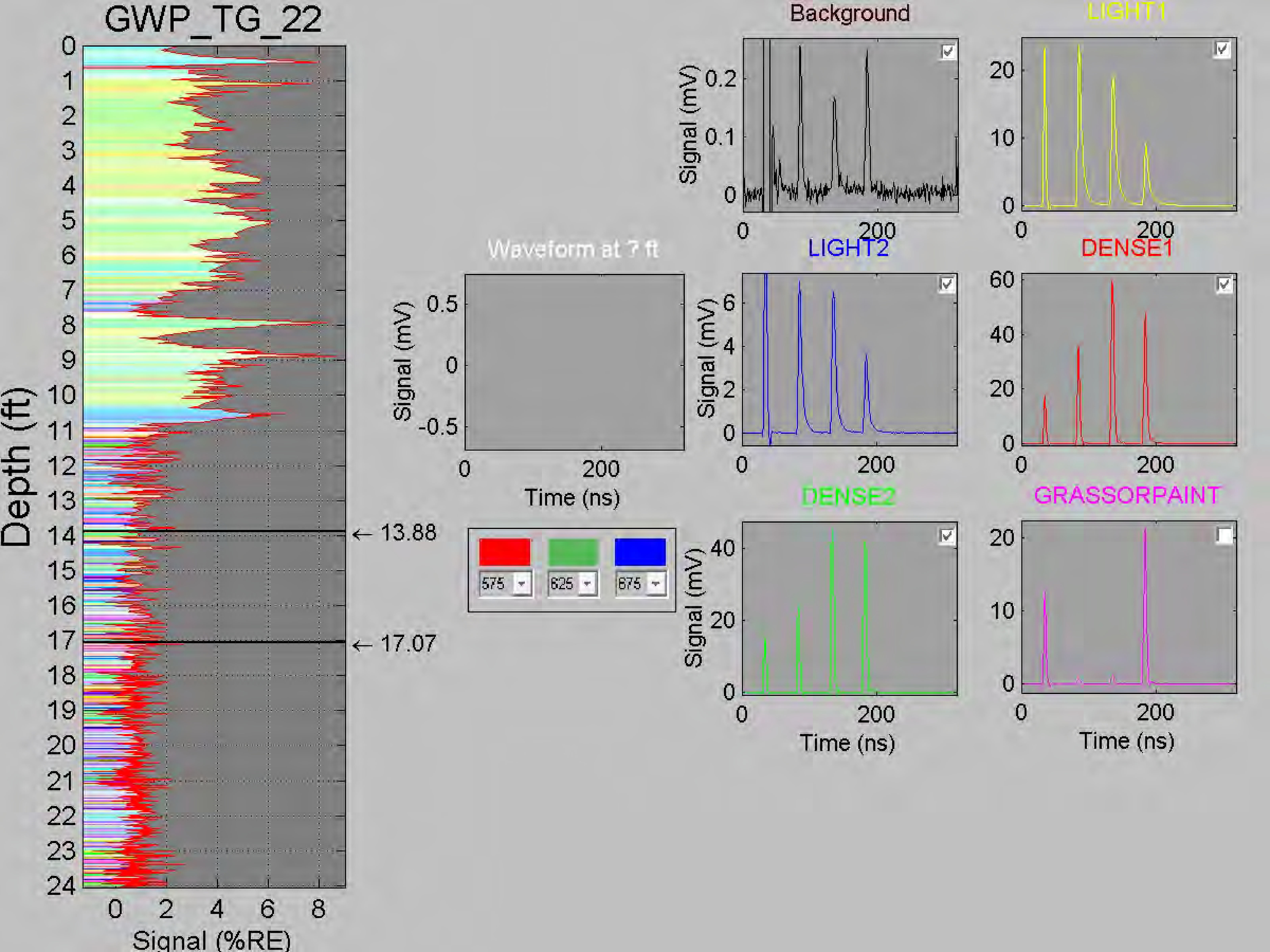


GWP_TG_21
Depth (ft)
Signal (%RE)
← 15.33
← 17.42
Waveform at 7 ft
Signal (mV)
Time (ns)
575
625
675
Background
LIGHT1
LIGHT2
DENSE1
DENSE2
GRASSORPAINT

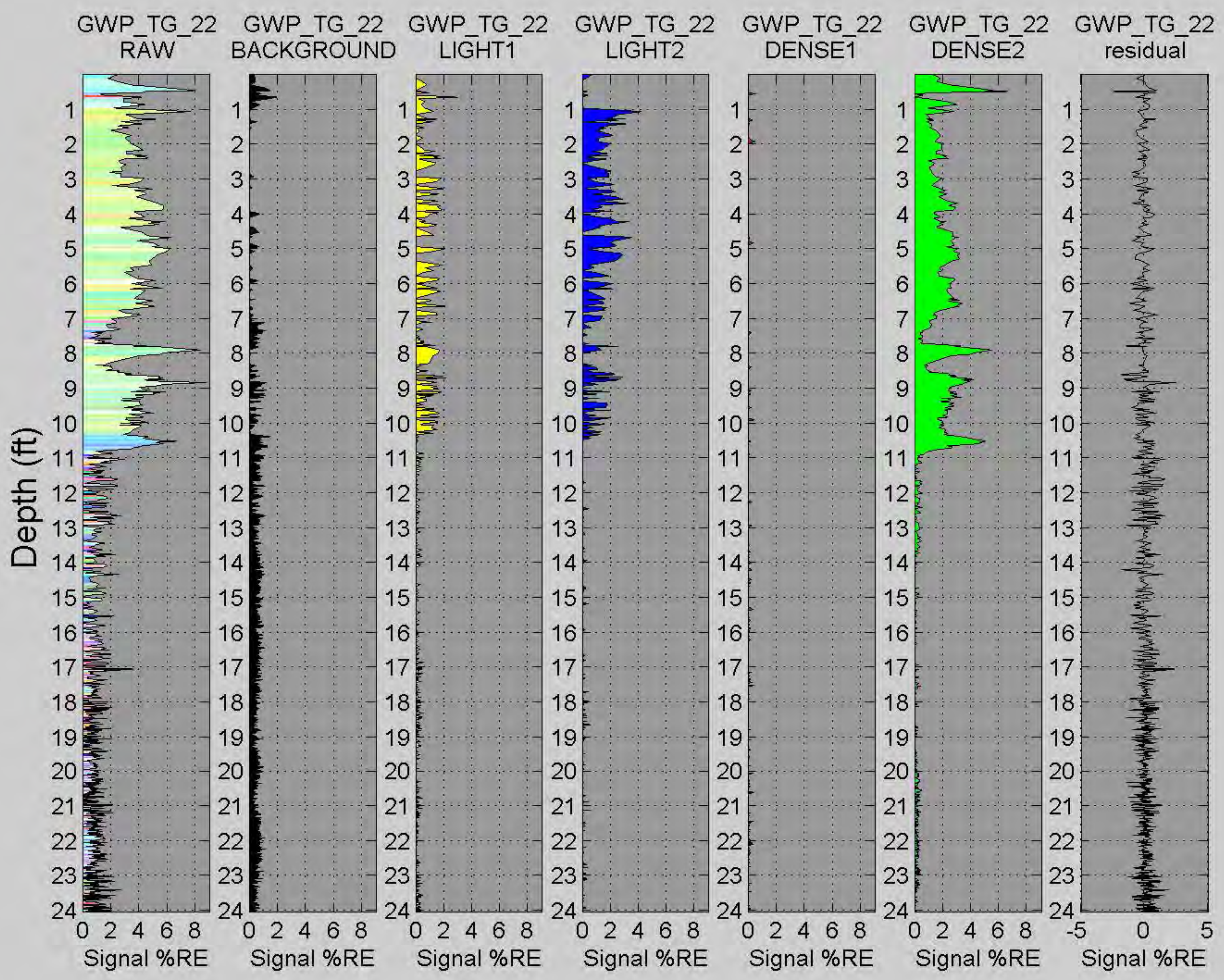

GWP_TG_21
RAW
GWP_TG_21
BACKGROUND
GWP_TG_21
LIGHT1
GWP_TG_21
LIGHT2
GWP_TG_21
DENSE1
GWP_TG_21
DENSE2
GWP_TG_21
residual
Depth (ft)
0
2
4
6
8
10
12
14
16
18
20
22
24
0 200 400
-5 0 5
Signal %RE



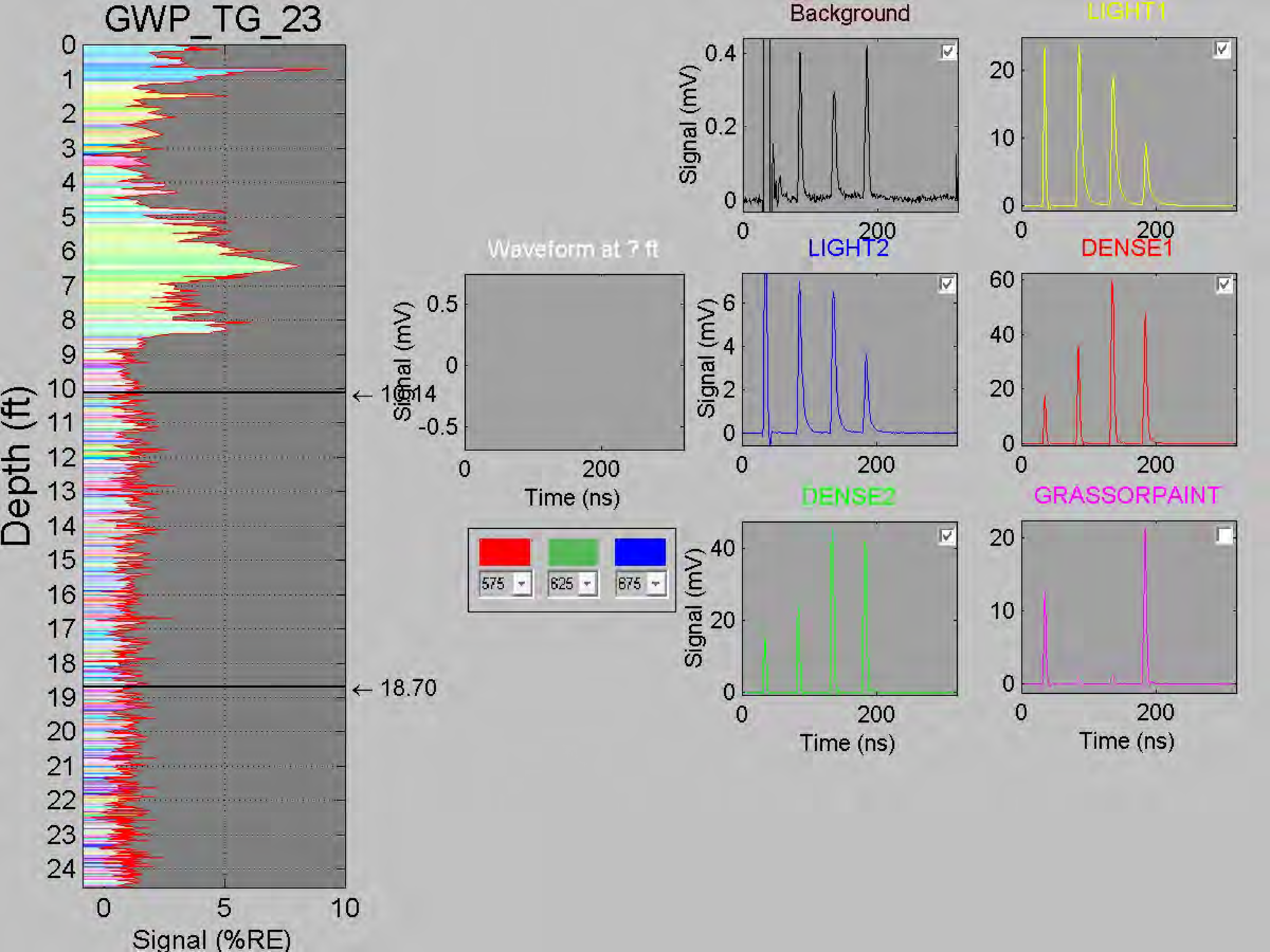
GWP_TG_21
RAW
GWP_TG_21
BACKGROUND
GWP_TG_21
LIGHT1
GWP_TG_21
LIGHT2
GWP_TG_21
DENSE1
GWP_TG_21
DENSE2
GWP_TG_21
residual
Depth (ft)
0 2 4 6 8 10 12 14 16 18 20 22 24
0 200 400
0 10 20
-5 0 5
Signal %RE



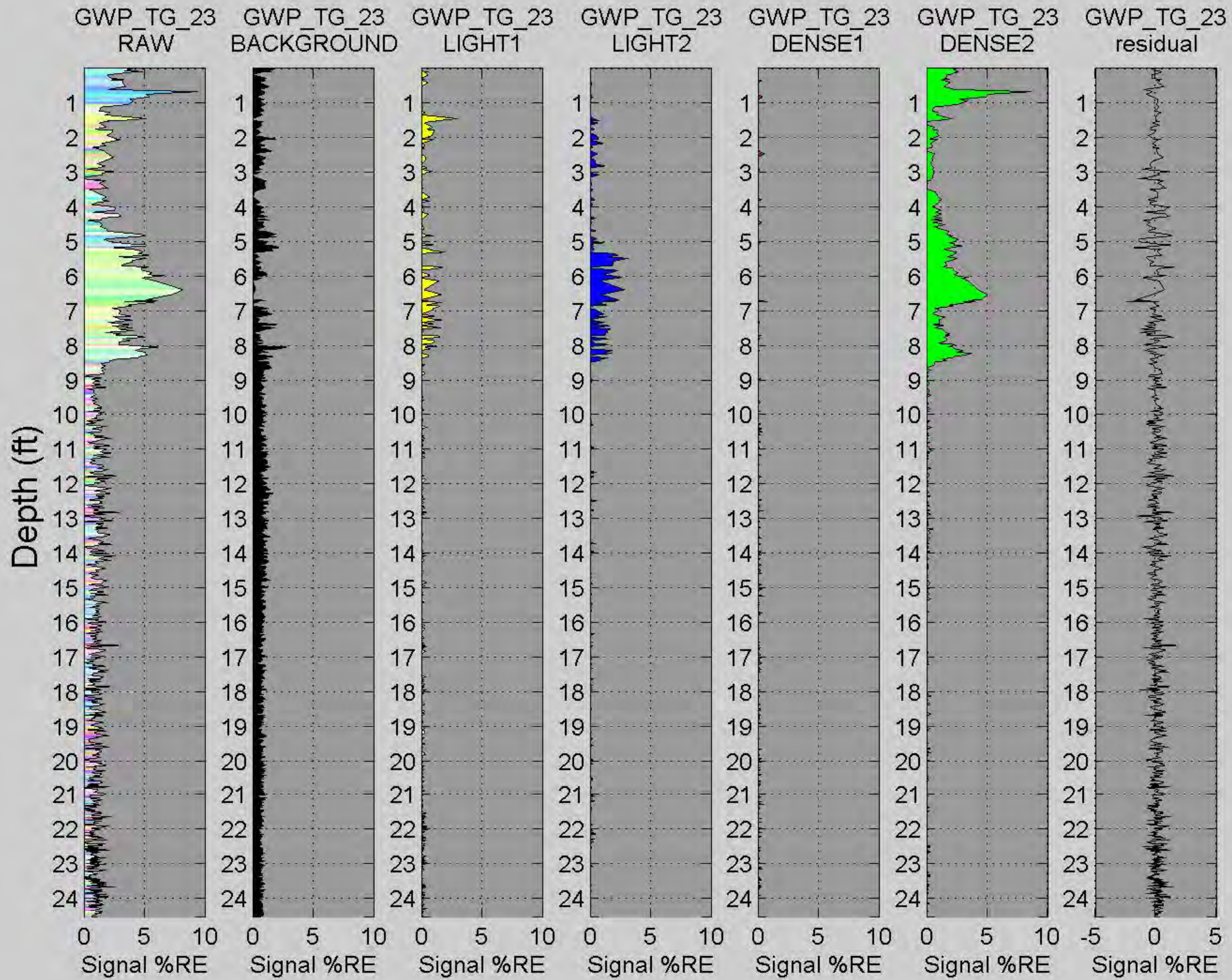
GWP_TG_22
Depth (ft)
Signal (%RE)
← 13.88
← 17.07
Waveform at ? ft
Signal (mV)
Time (ns)
575
625
675
Background
LIGHT1
LIGHT2
DENSE1
DENSE2
GRASSORPAINT



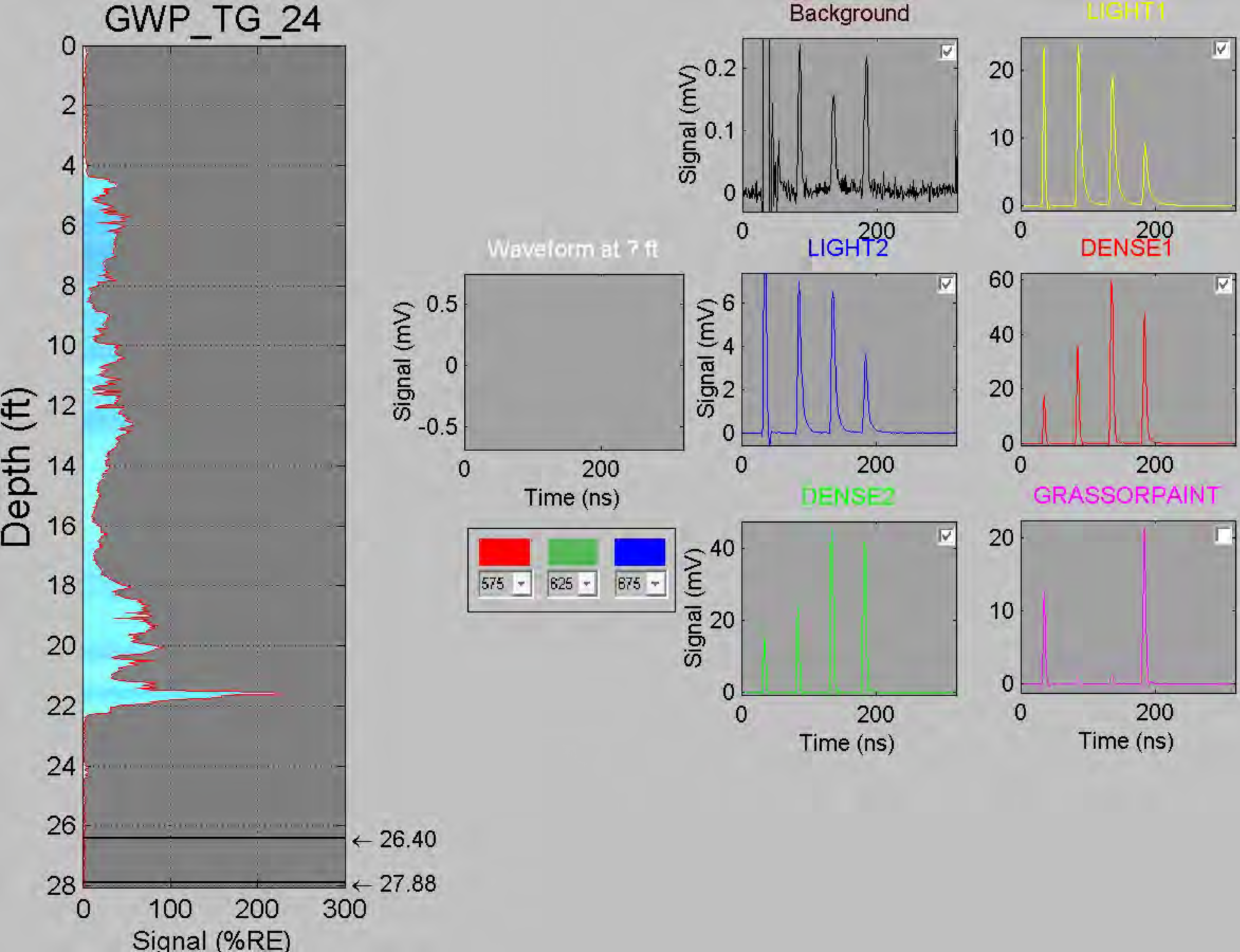
GWP_TG_22
RAW
GWP_TG_22
BACKGROUND
GWP_TG_22
LIGHT1
GWP_TG_22
LIGHT2
GWP_TG_22
DENSE1
GWP_TG_22
DENSE2
GWP_TG_22
residual
Depth (ft)
Signal %RE



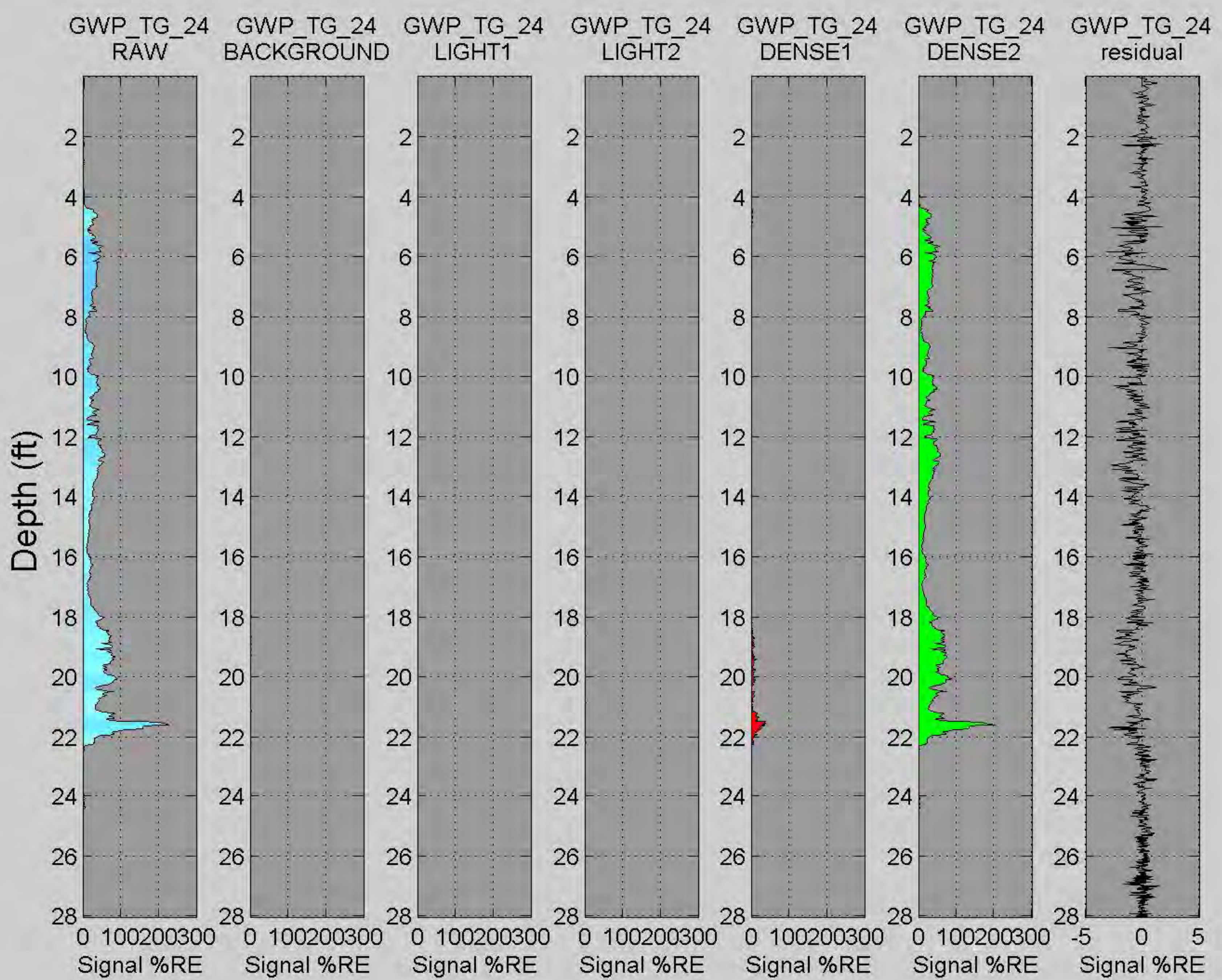
GWP_TG_23
Depth (ft)
Signal (%RE)
← 10.14
← 18.70
Waveform at 7 ft
Signal (mV)
Time (ns)
575
625
675
Background
LIGHT1
LIGHT2
DENSE1
DENSE2
GRASSORPAINT



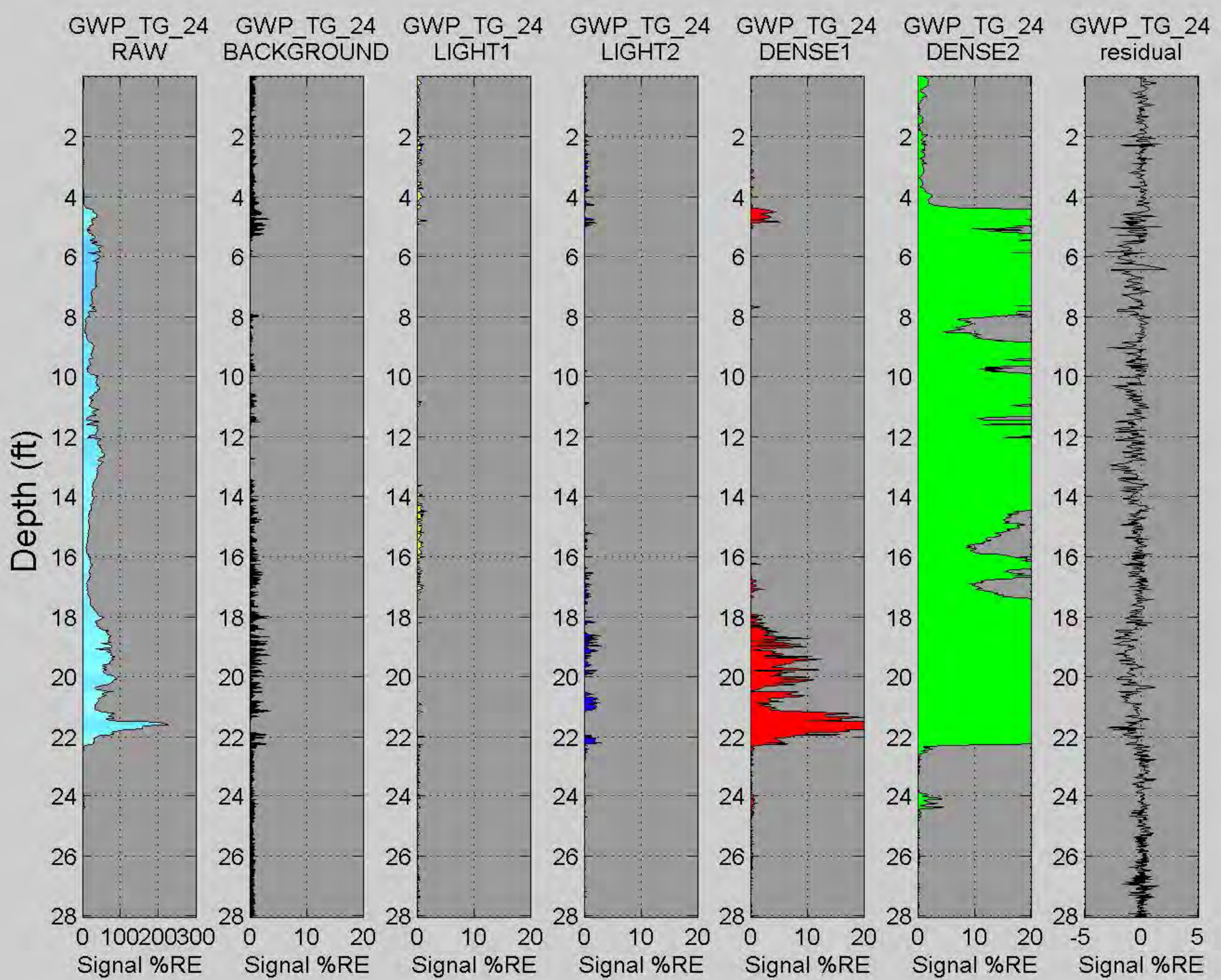
GWP_TG_23 RAW
GWP_TG_23 BACKGROUND
GWP_TG_23 LIGHT1
GWP_TG_23 LIGHT2
GWP_TG_23 DENSE1
GWP_TG_23 DENSE2
GWP_TG_23 residual
Depth (ft)
Signal %RE



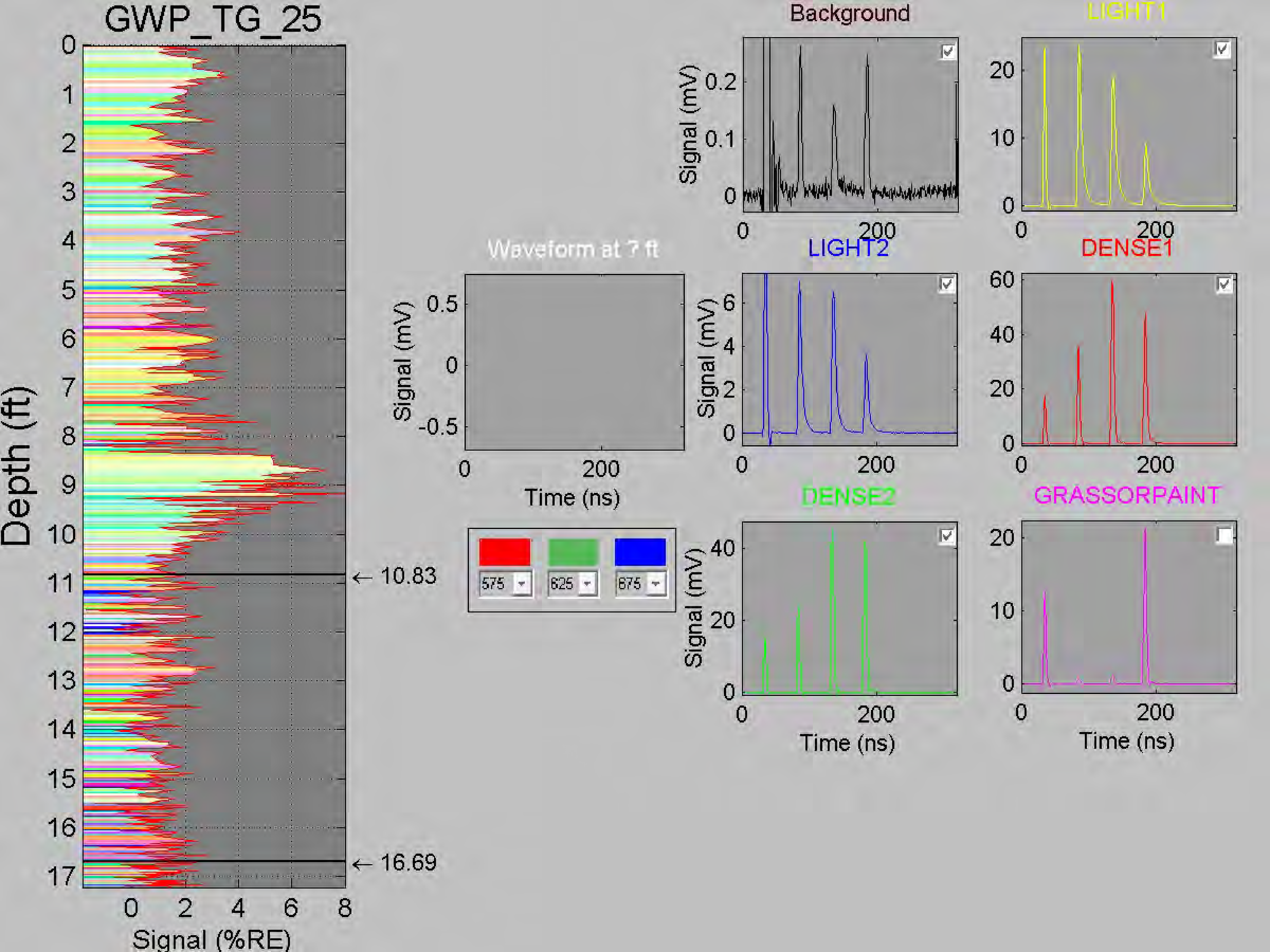
GWP_TG_24
Depth (ft)
Signal (%RE)
26.40
27.88
Background
LIGHT1
Waveform at 7 ft
LIGHT2
DENSE1
DENSE2
GRASSORPAINT
Signal (mV)
Time (ns)
575
625
675



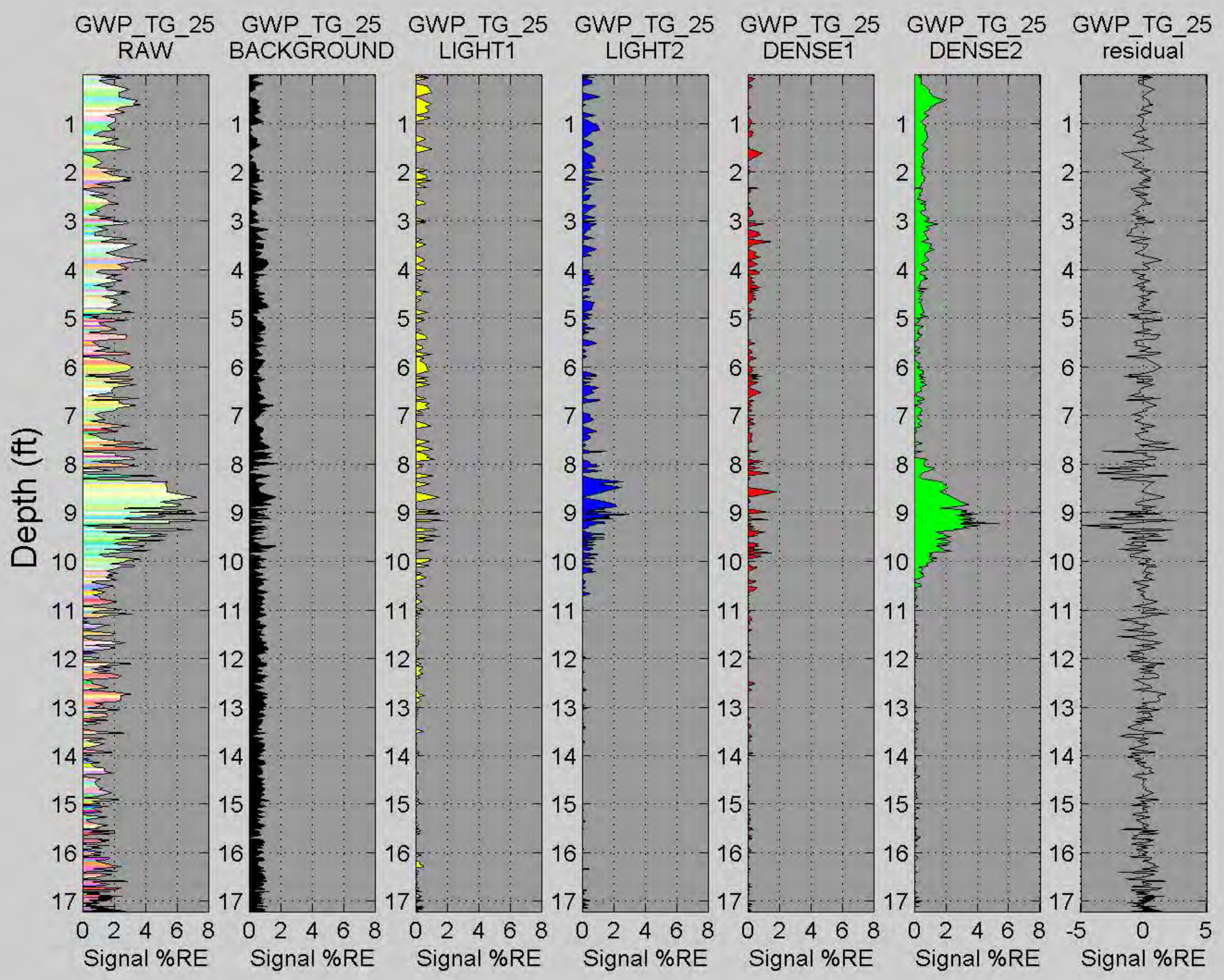
GWP_TG_24
RAW
GWP_TG_24
BACKGROUND
GWP_TG_24
LIGHT1
GWP_TG_24
LIGHT2
GWP_TG_24
DENSE1
GWP_TG_24
DENSE2
GWP_TG_24
residual
Depth (ft)
2
4
6
8
10
12
14
16
18
20
22
24
26
28
0 100200300
-5 0 5
Signal %RE



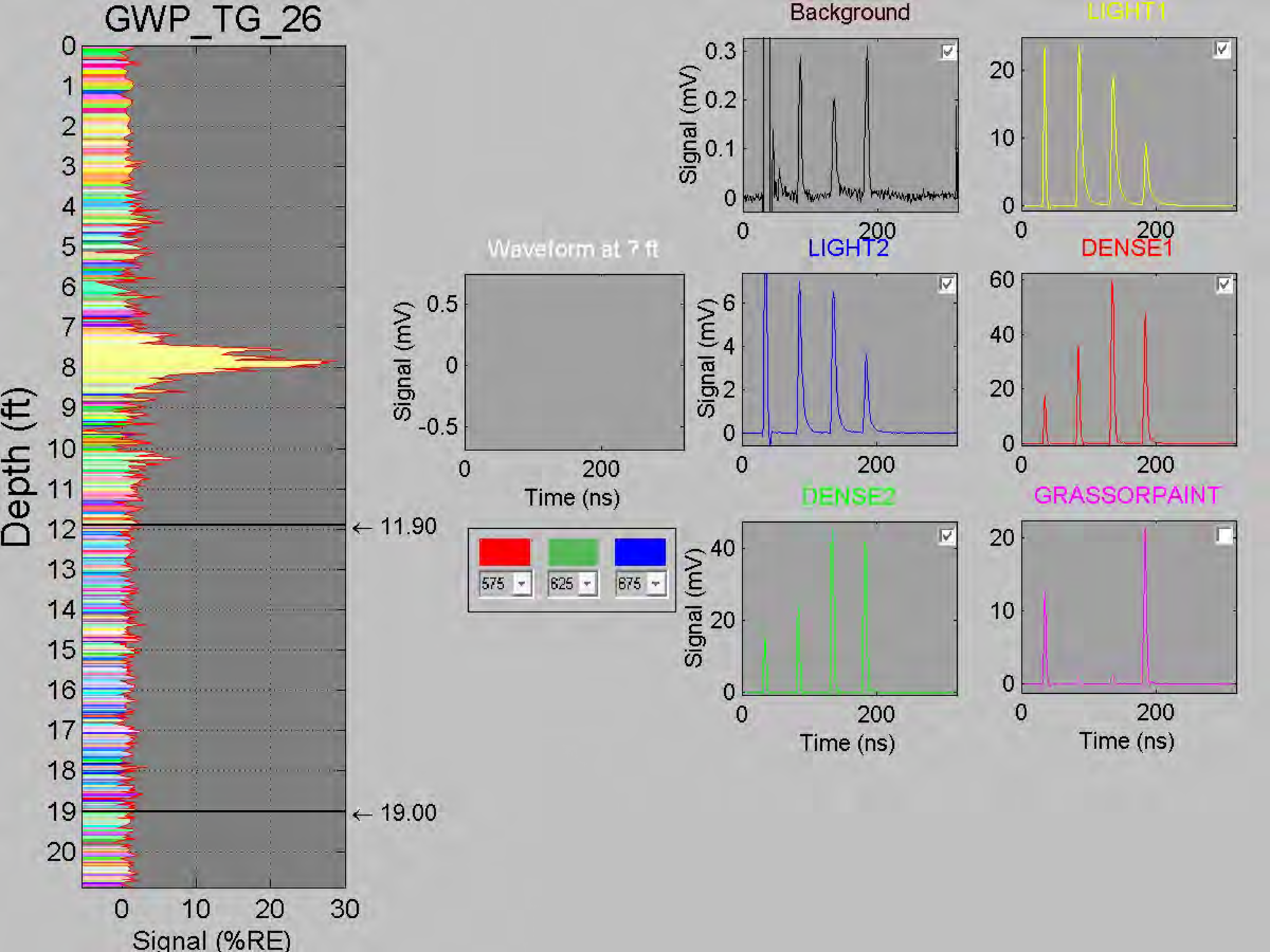
GWP_TG_24
RAW
GWP_TG_24
BACKGROUND
GWP_TG_24
LIGHT1
GWP_TG_24
LIGHT2
GWP_TG_24
DENSE1
GWP_TG_24
DENSE2
GWP_TG_24
residual
Depth (ft)
2 4 6 8 10 12 14 16 18 20 22 24 26 28
0 100 200 300
0 10 20
-5 0 5
Signal %RE

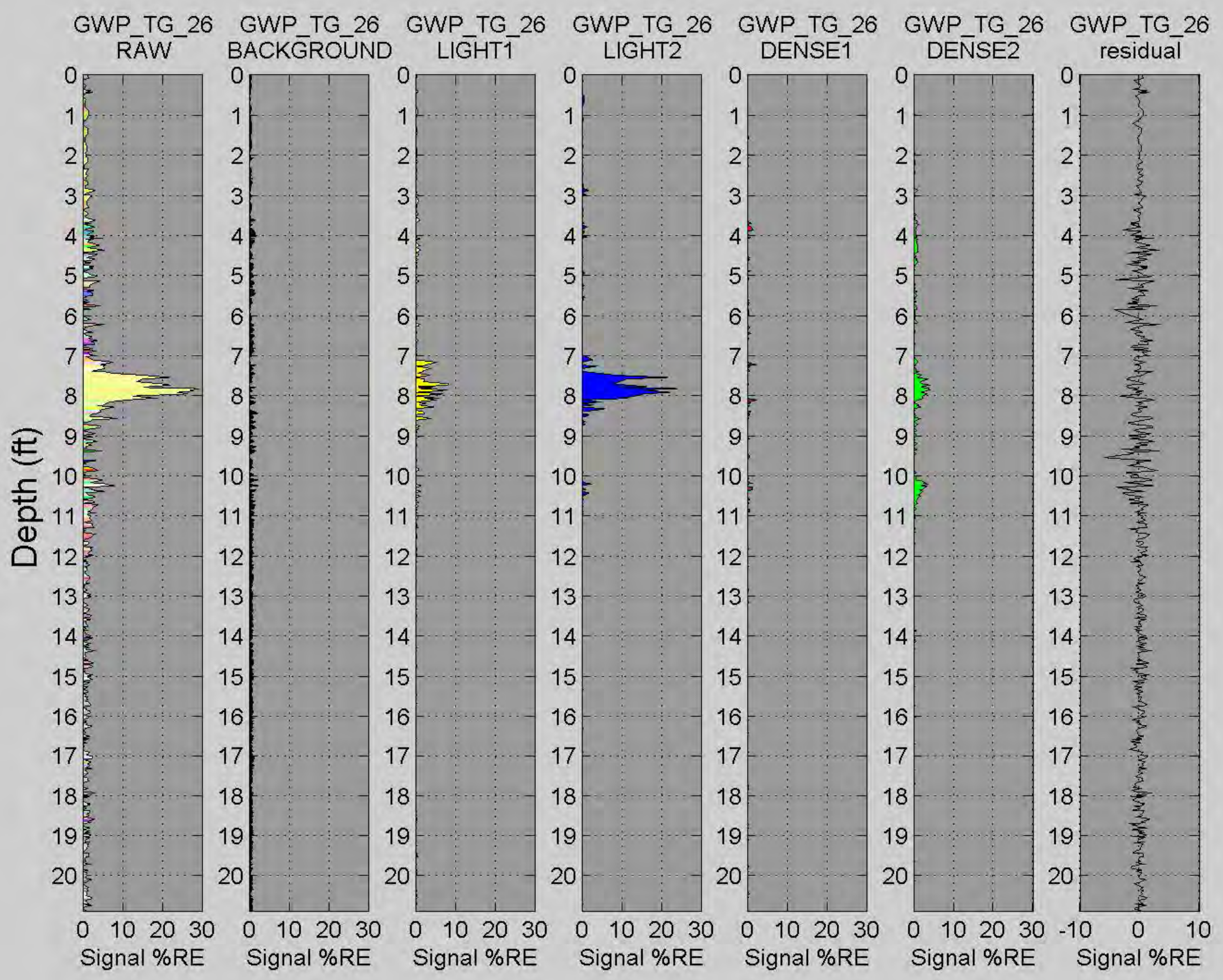


GWP_TG_25
Depth (ft)
Signal (%RE)
← 10.83
← 16.69
Waveform at ? ft
Signal (mV)
Time (ns)
575
625
675
Background
LIGHT1
LIGHT2
DENSE1
DENSE2
GRASSORPAINT
Signal (mV)
Time (ns)

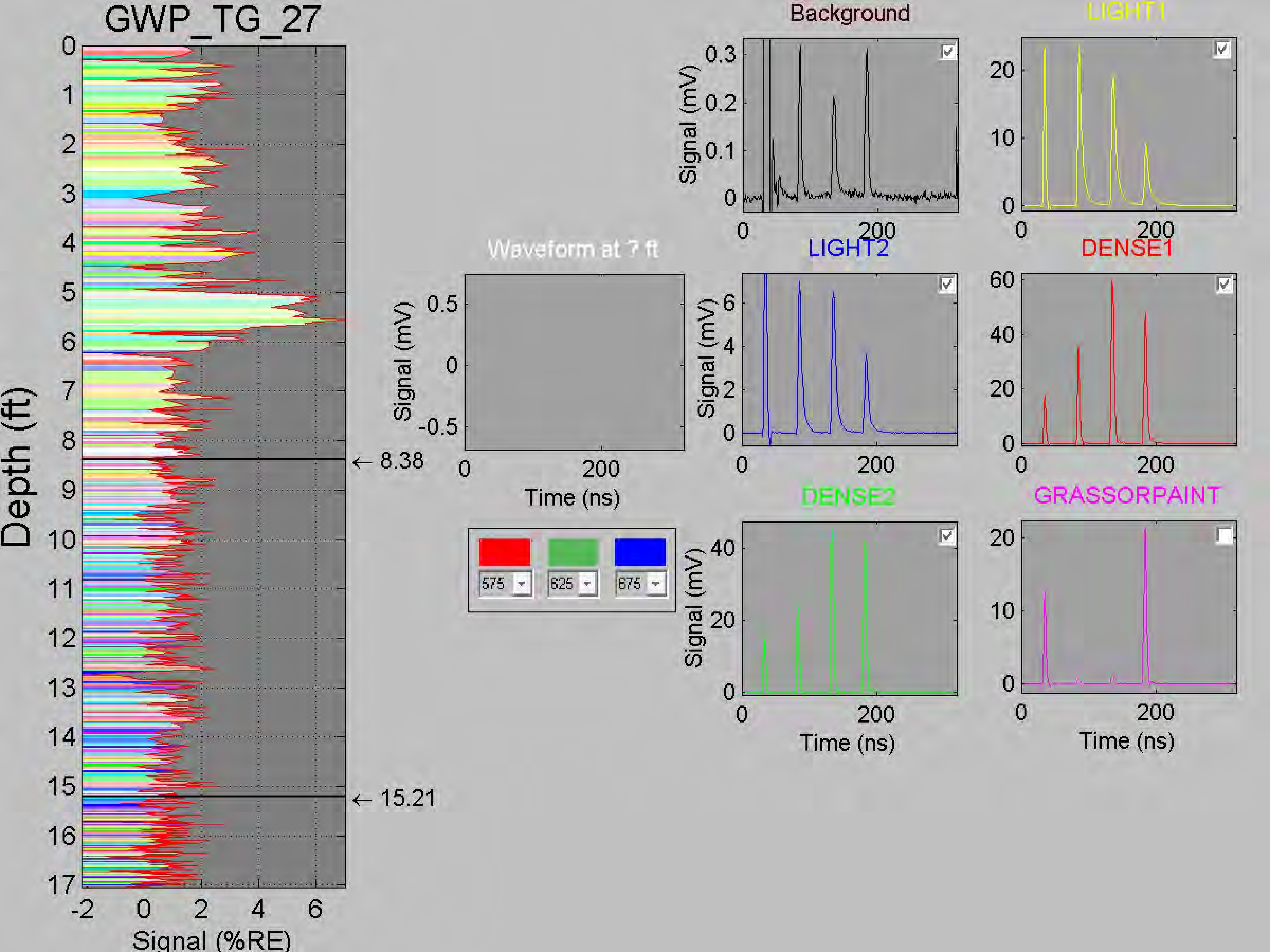


GWP_TG_25 RAW
GWP_TG_25 BACKGROUND
GWP_TG_25 LIGHT1
GWP_TG_25 LIGHT2
GWP_TG_25 DENSE1
GWP_TG_25 DENSE2
GWP_TG_25 residual
Depth (ft)
Signal %RE

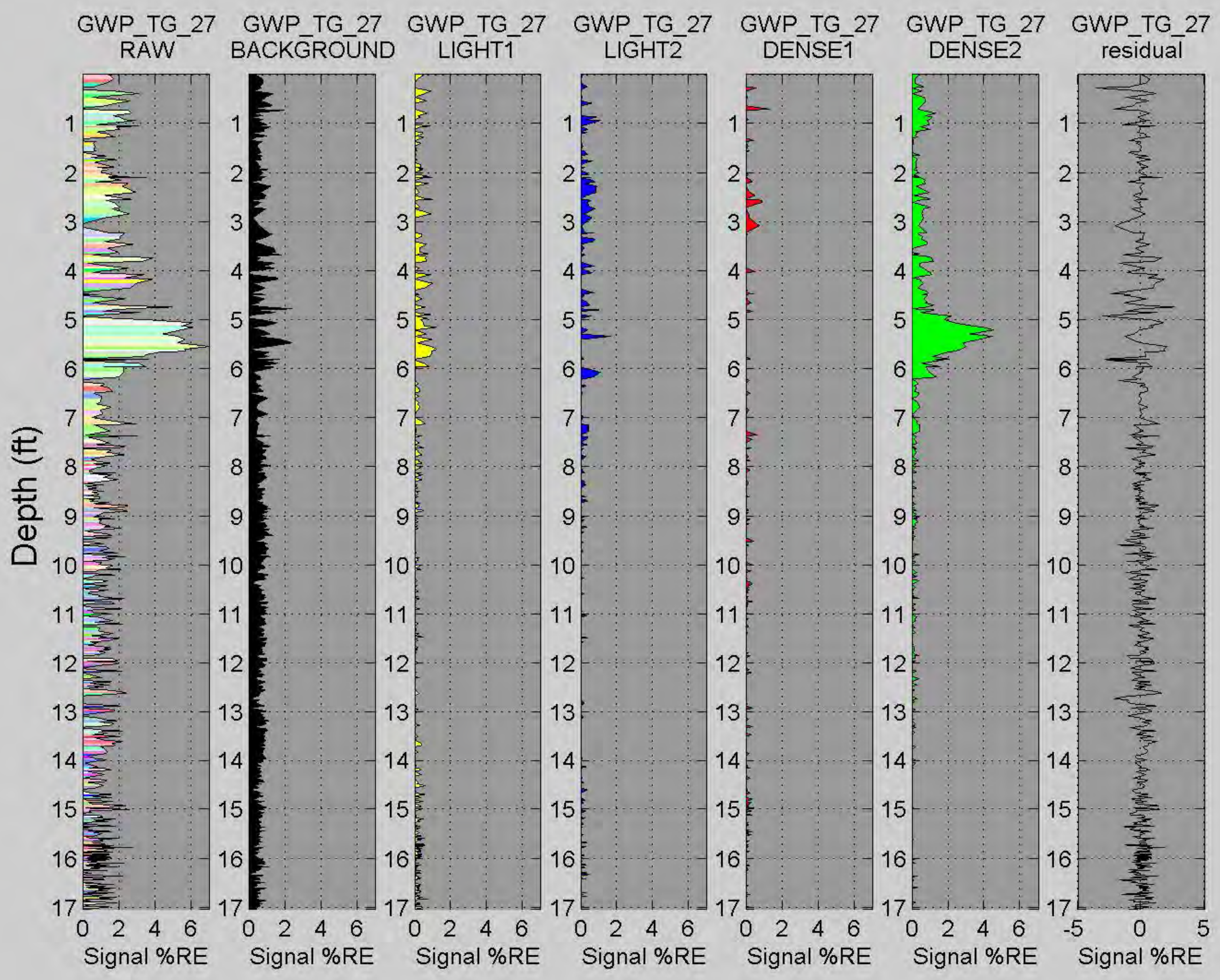

GWP_TG_26
Depth (ft)
Signal (%RE)
← 11.90
← 19.00
Waveform at 7 ft
Signal (mV)
Time (ns)
575
625
675
Background
LIGHT1
LIGHT2
DENSE1
DENSE2
GRASSORPAINT

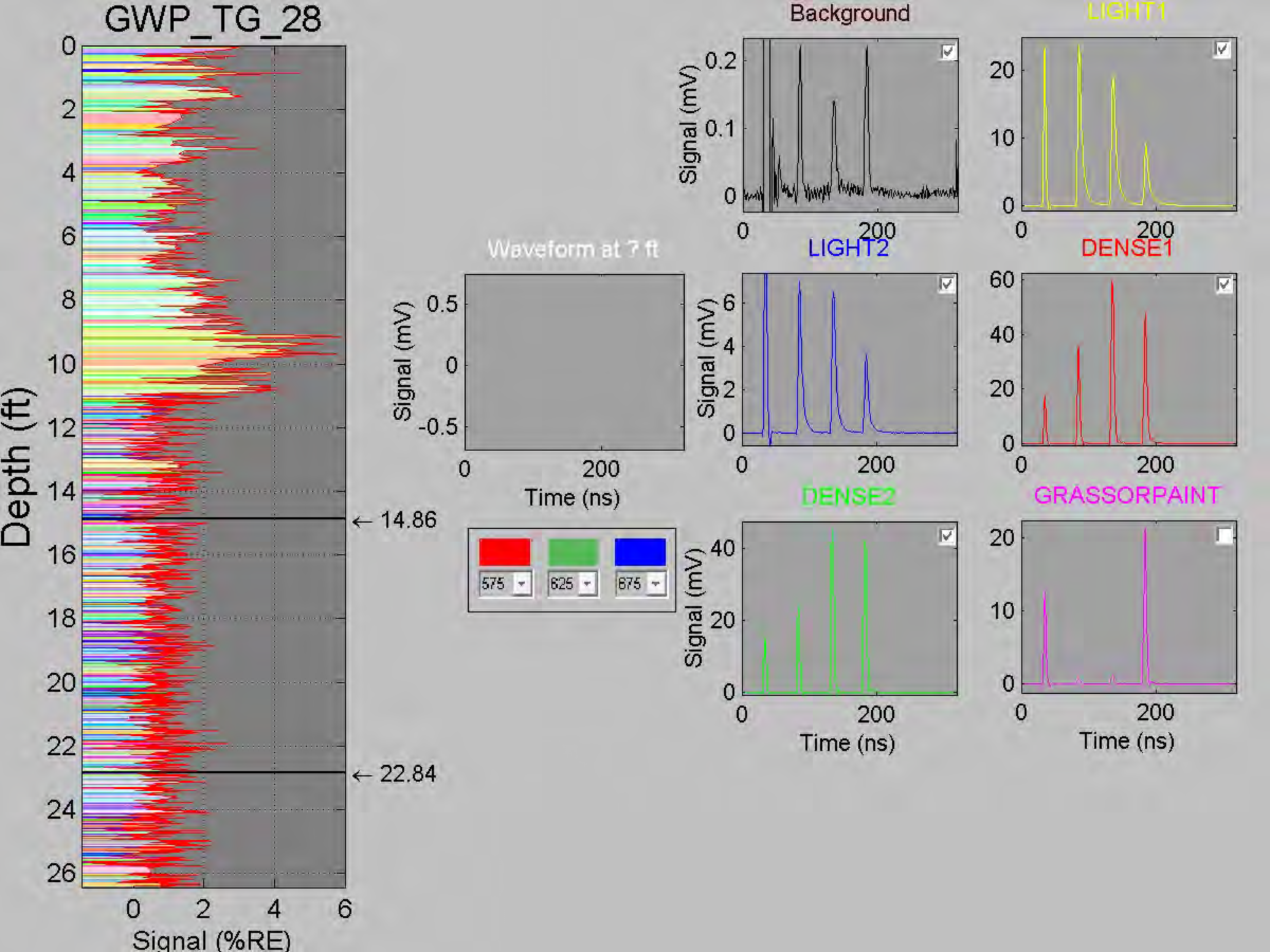


GWP_TG_26
RAW
GWP_TG_26
BACKGROUND
GWP_TG_26
LIGHT1
GWP_TG_26
LIGHT2
GWP_TG_26
DENSE1
GWP_TG_26
DENSE2
GWP_TG_26
residual
Depth (ft)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
0 10 20 30
-10 0 10
Signal %RE

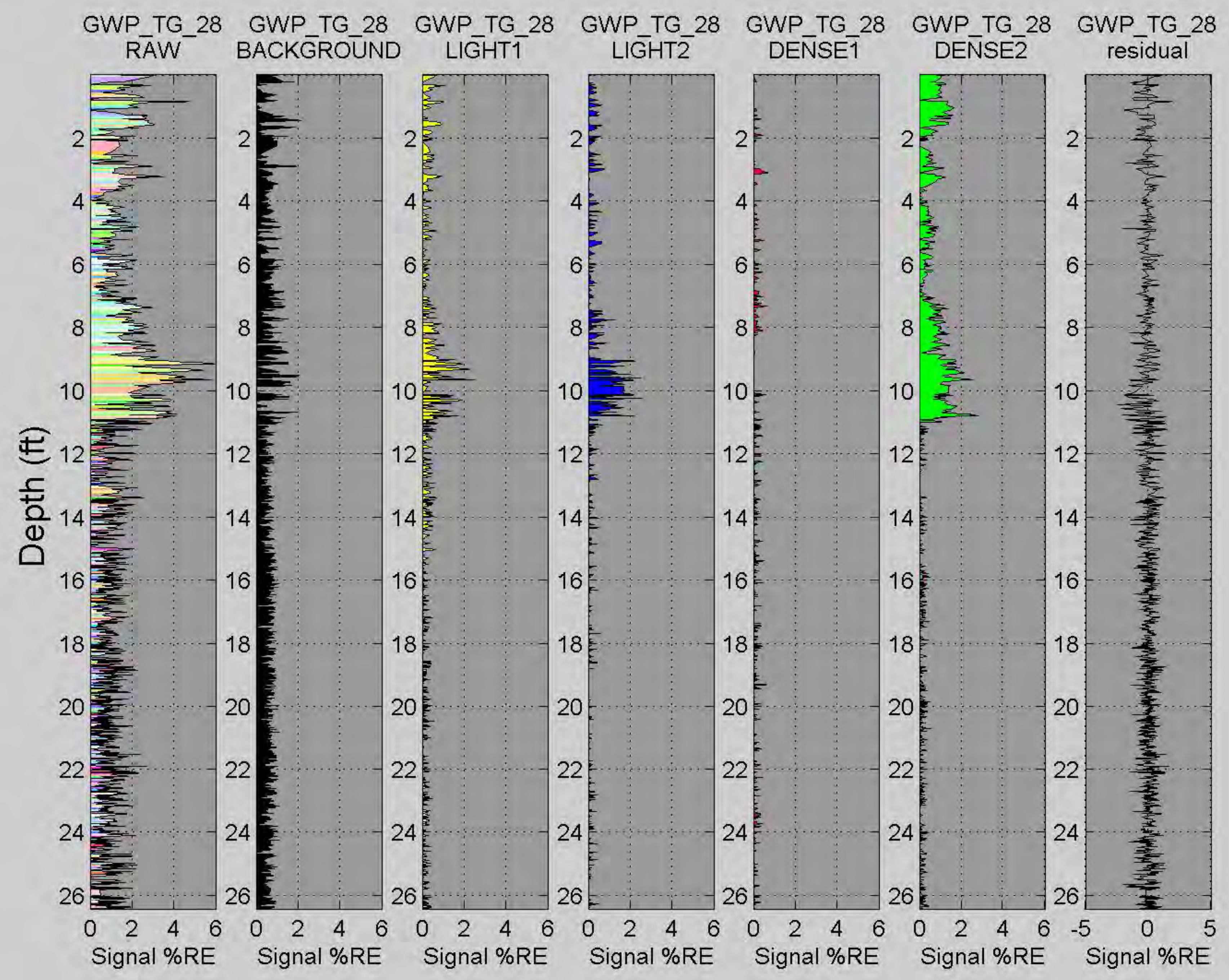


GWP_TG_27
Depth (ft)
Signal (%RE)
← 8.38
← 15.21
Waveform at ? ft
Signal (mV)
Time (ns)
575
625
675
Background
LIGHT1
LIGHT2
DENSE1
DENSE2
GRASSORPAINT

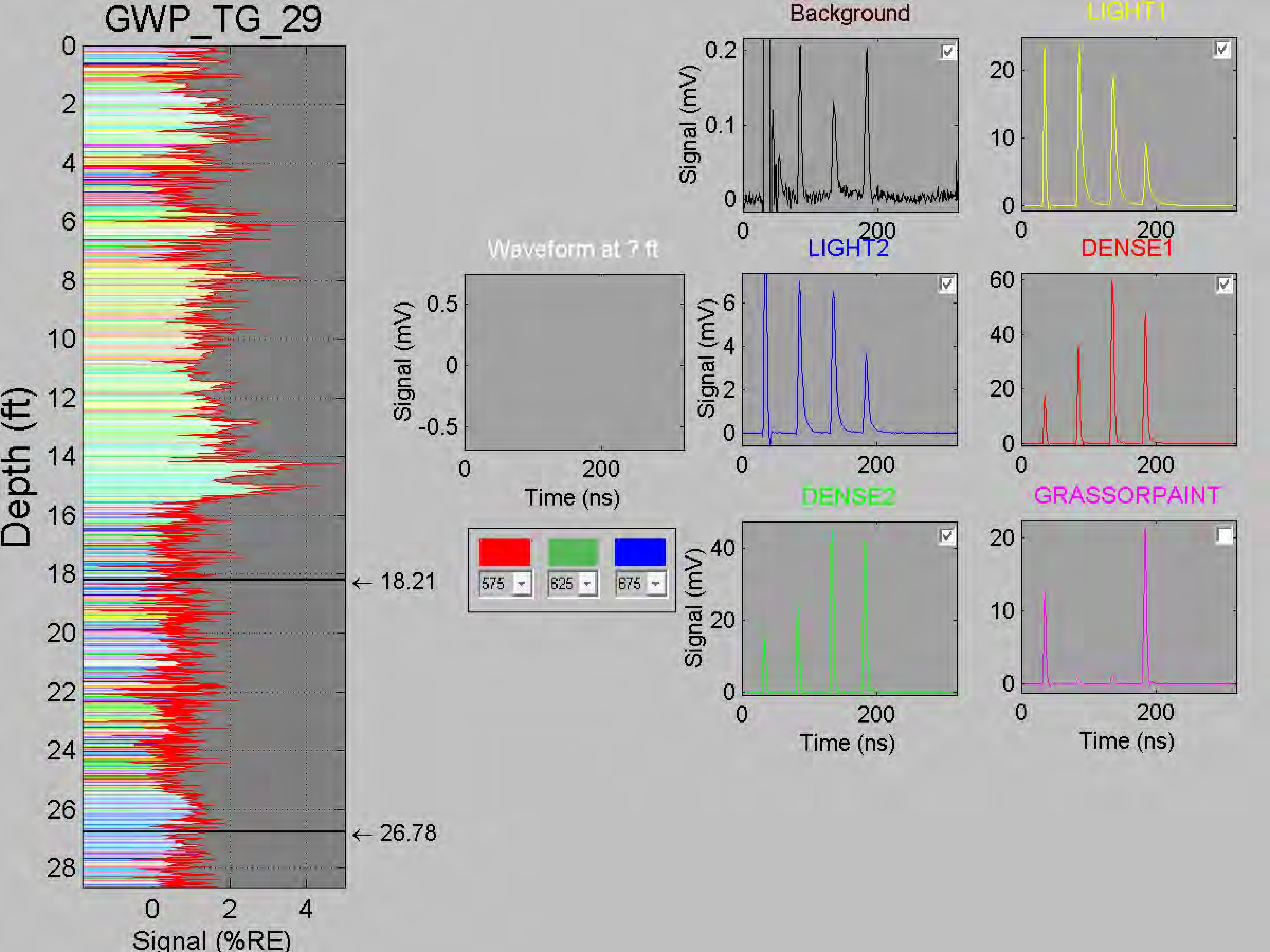

GWP_TG_27
RAW
GWP_TG_27
BACKGROUND
GWP_TG_27
LIGHT1
GWP_TG_27
LIGHT2
GWP_TG_27
DENSE1
GWP_TG_27
DENSE2
GWP_TG_27
residual
Depth (ft)
Signal %RE



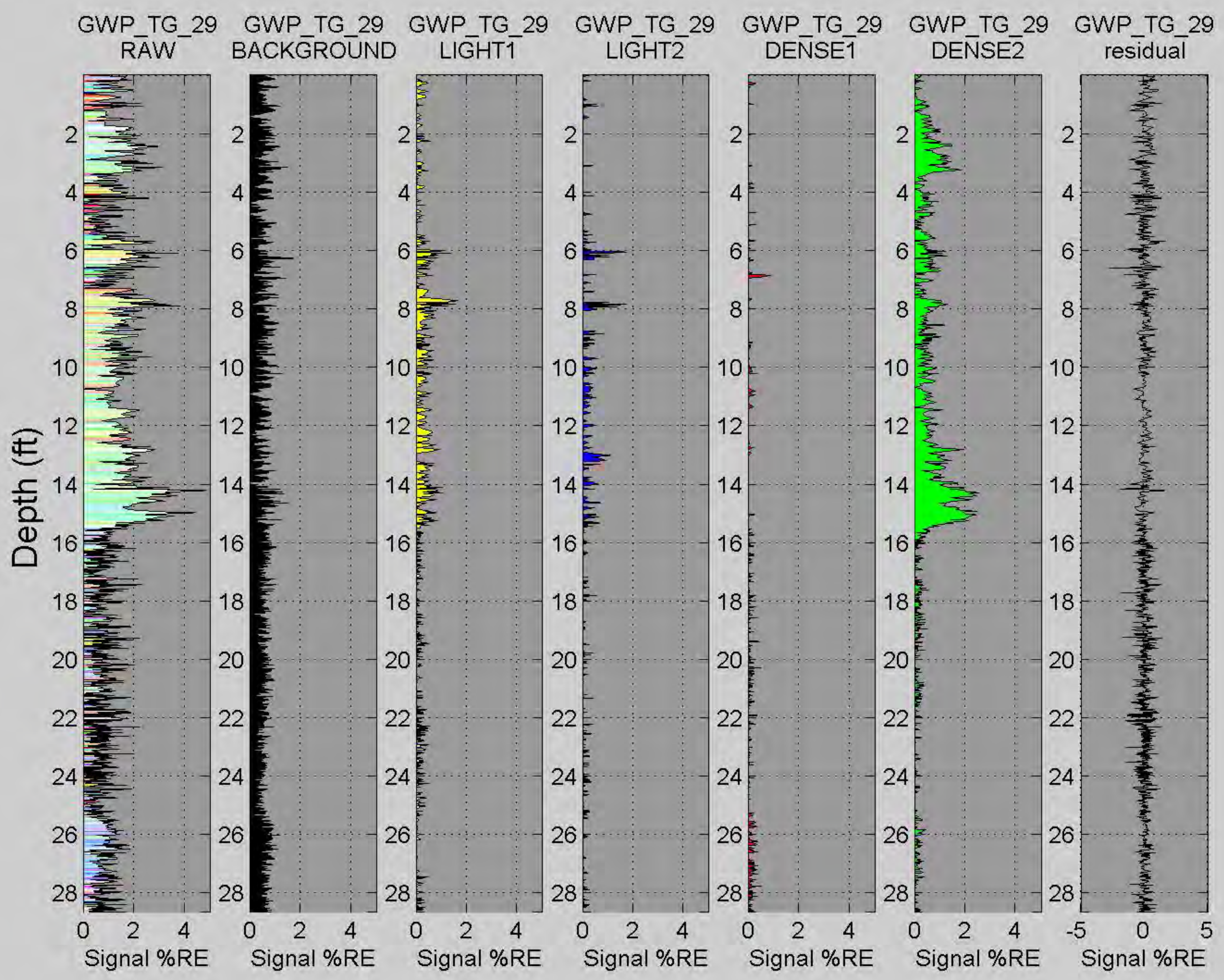
GWP_TG_28
Depth (ft)
Signal (%RE)
← 14.86
← 22.84
Waveform at ? ft
Signal (mV)
Time (ns)
575
625
675
Background
LIGHT1
LIGHT2
DENSE1
DENSE2
GRASSORPAINT



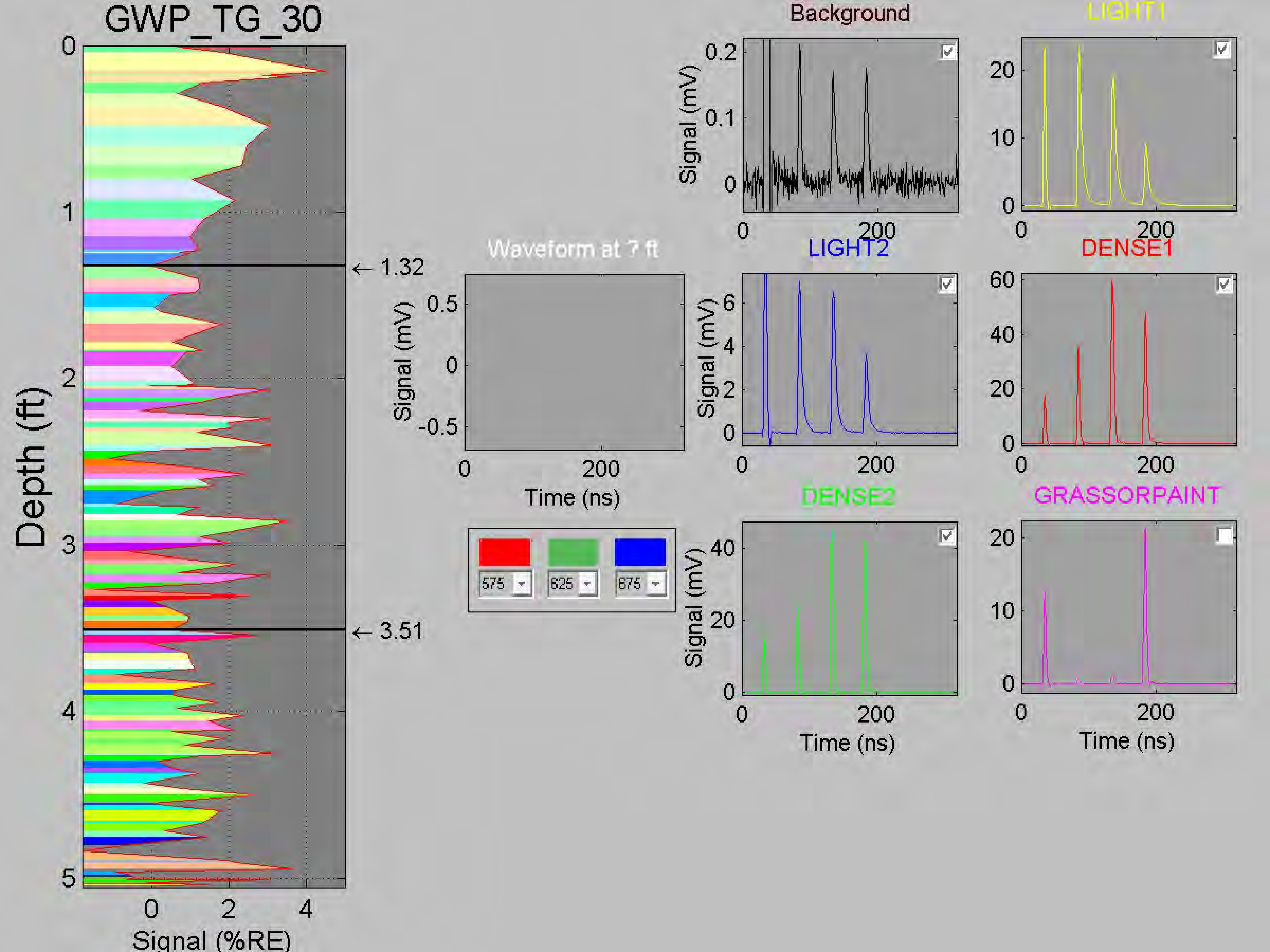
GWP_TG_28
RAW
GWP_TG_28
BACKGROUND
GWP_TG_28
LIGHT1
GWP_TG_28
LIGHT2
GWP_TG_28
DENSE1
GWP_TG_28
DENSE2
GWP_TG_28
residual
Depth (ft)
2
4
6
8
10
12
14
16
18
20
22
24
26
0 2 4 6
-5 0 5
Signal %RE



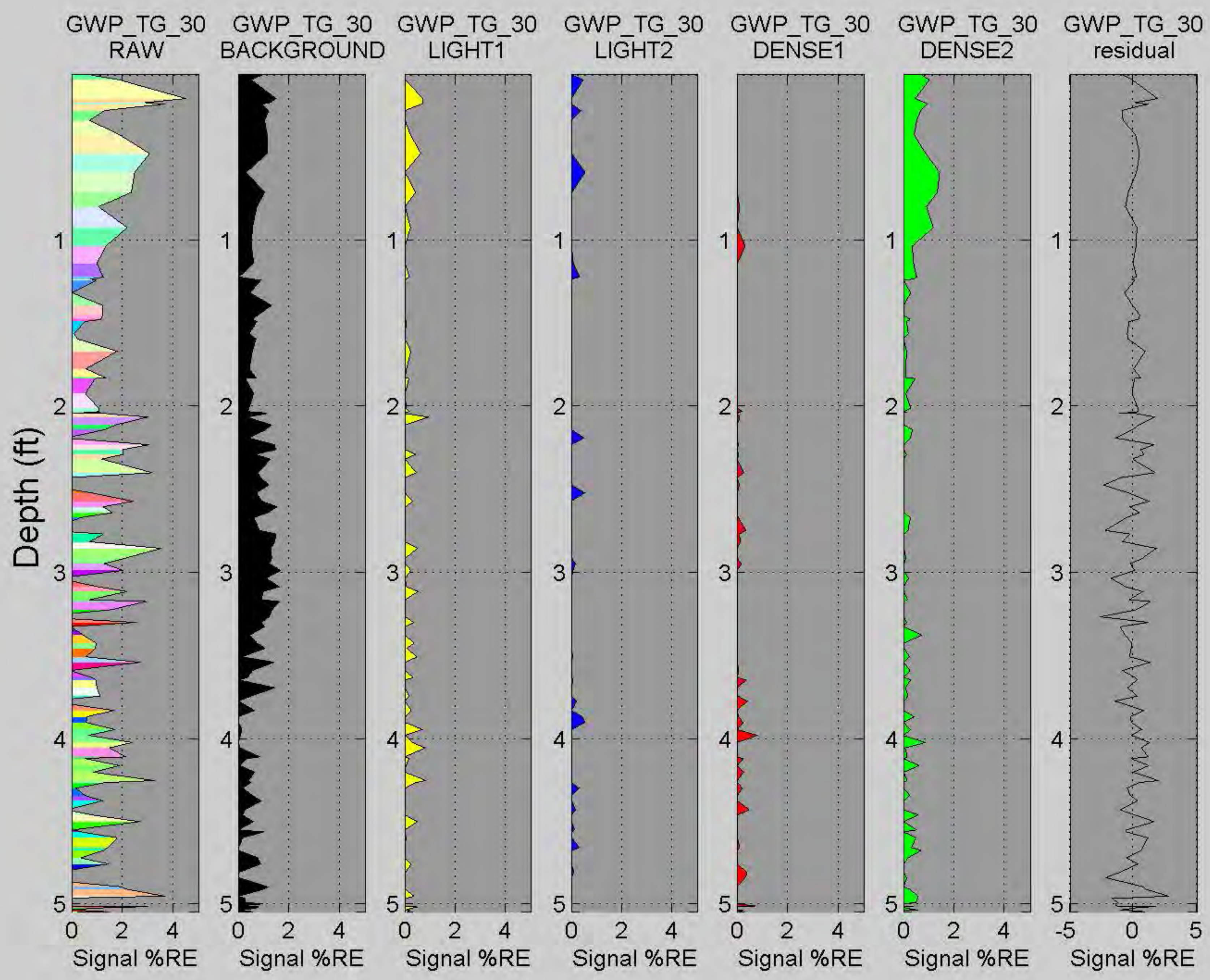
GWP_TG_29
Depth (ft)
Signal (%RE)
← 18.21
← 26.78
Waveform at ? ft
Signal (mV)
Time (ns)
575
625
675
Background
LIGHT1
LIGHT2
DENSE1
DENSE2
GRASSORPAINT

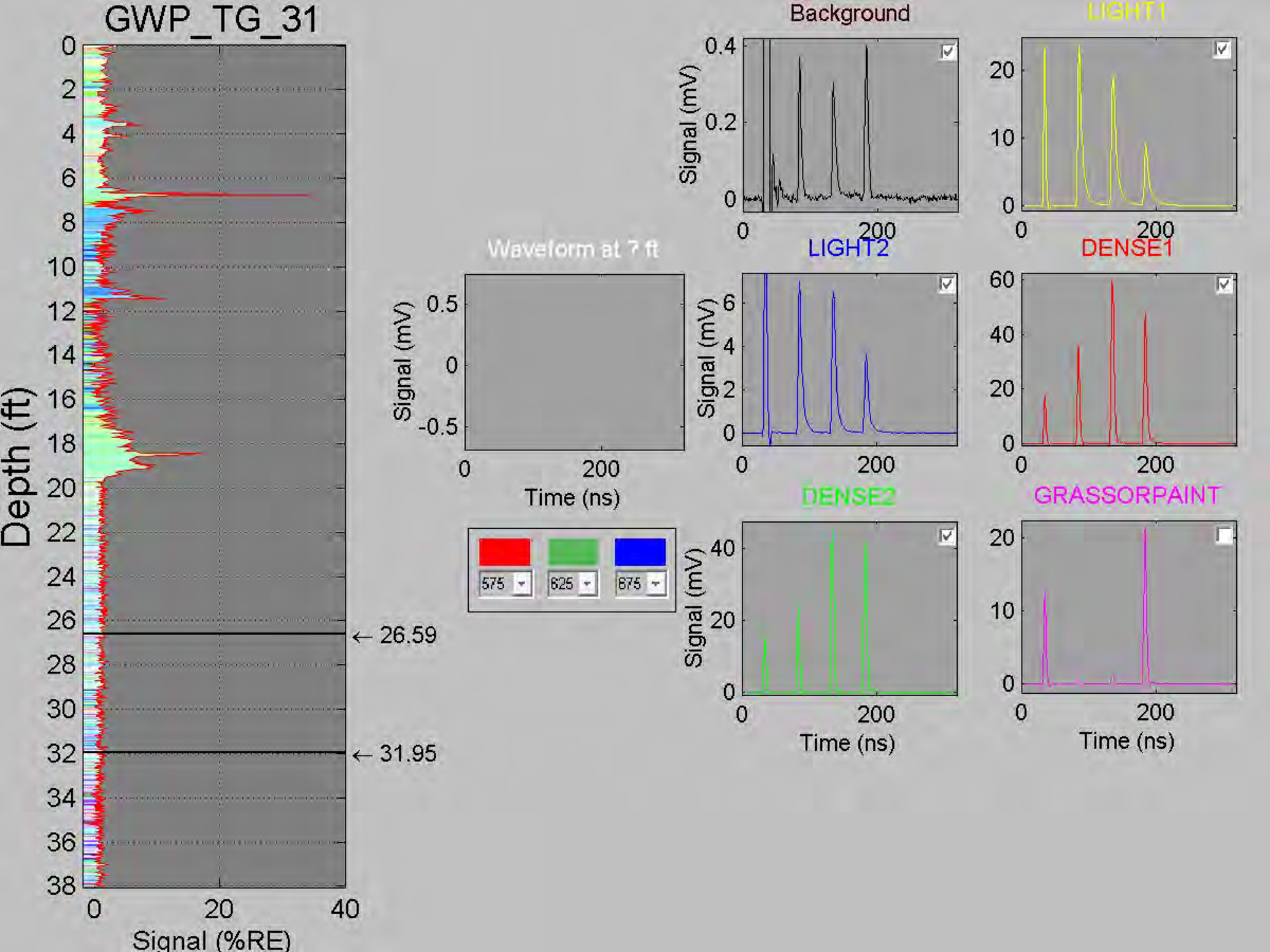


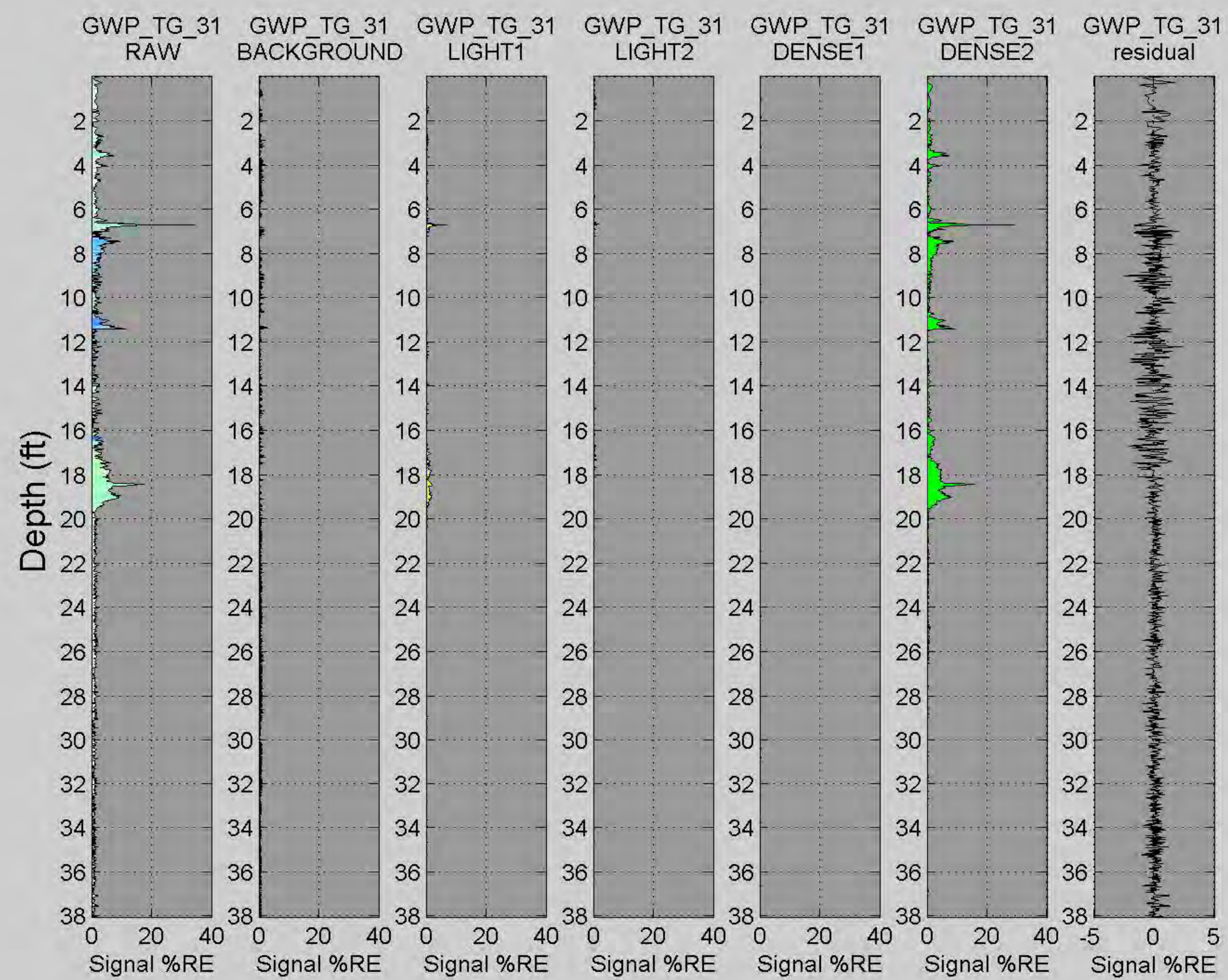
GWP_TG_29
RAW
GWP_TG_29
BACKGROUND
GWP_TG_29
LIGHT1
GWP_TG_29
LIGHT2
GWP_TG_29
DENSE1
GWP_TG_29
DENSE2
GWP_TG_29
residual
Depth (ft)
Signal %RE



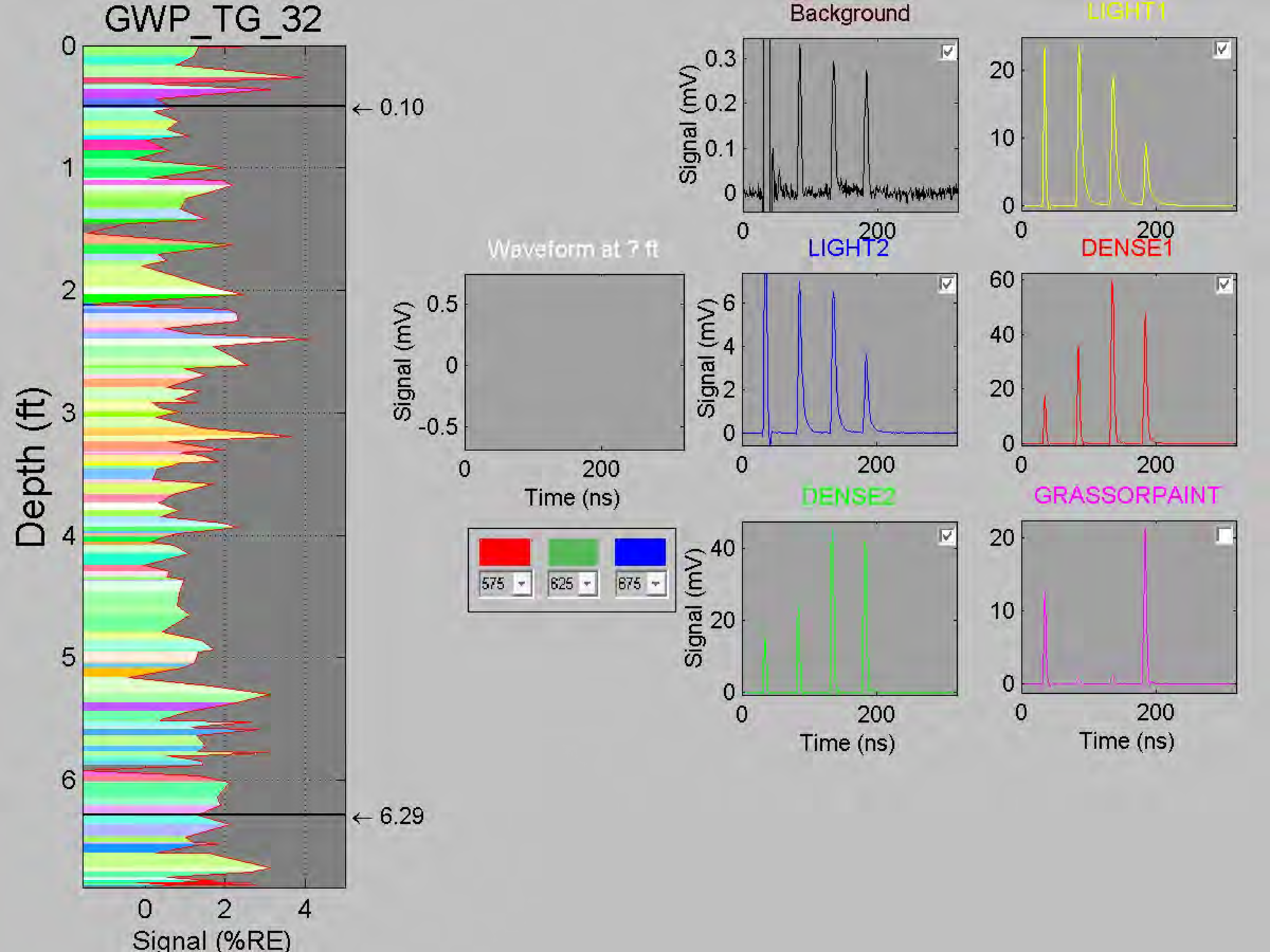
GWP_TG_30
Depth (ft)
Signal (%RE)
← 1.32
← 3.51
Waveform at ? ft
Signal (mV)
Time (ns)
575
625
675
Background
LIGHT1
LIGHT2
DENSE1
DENSE2
GRASSORPAINT


GWP_TG_30
RAW
GWP_TG_30
BACKGROUND
GWP_TG_30
LIGHT1
GWP_TG_30
LIGHT2
GWP_TG_30
DENSE1
GWP_TG_30
DENSE2
GWP_TG_30
residual
Depth (ft)
Signal %RE
Signal %RE
Signal %RE
Signal %RE
Signal %RE
Signal %RE
Signal %RE

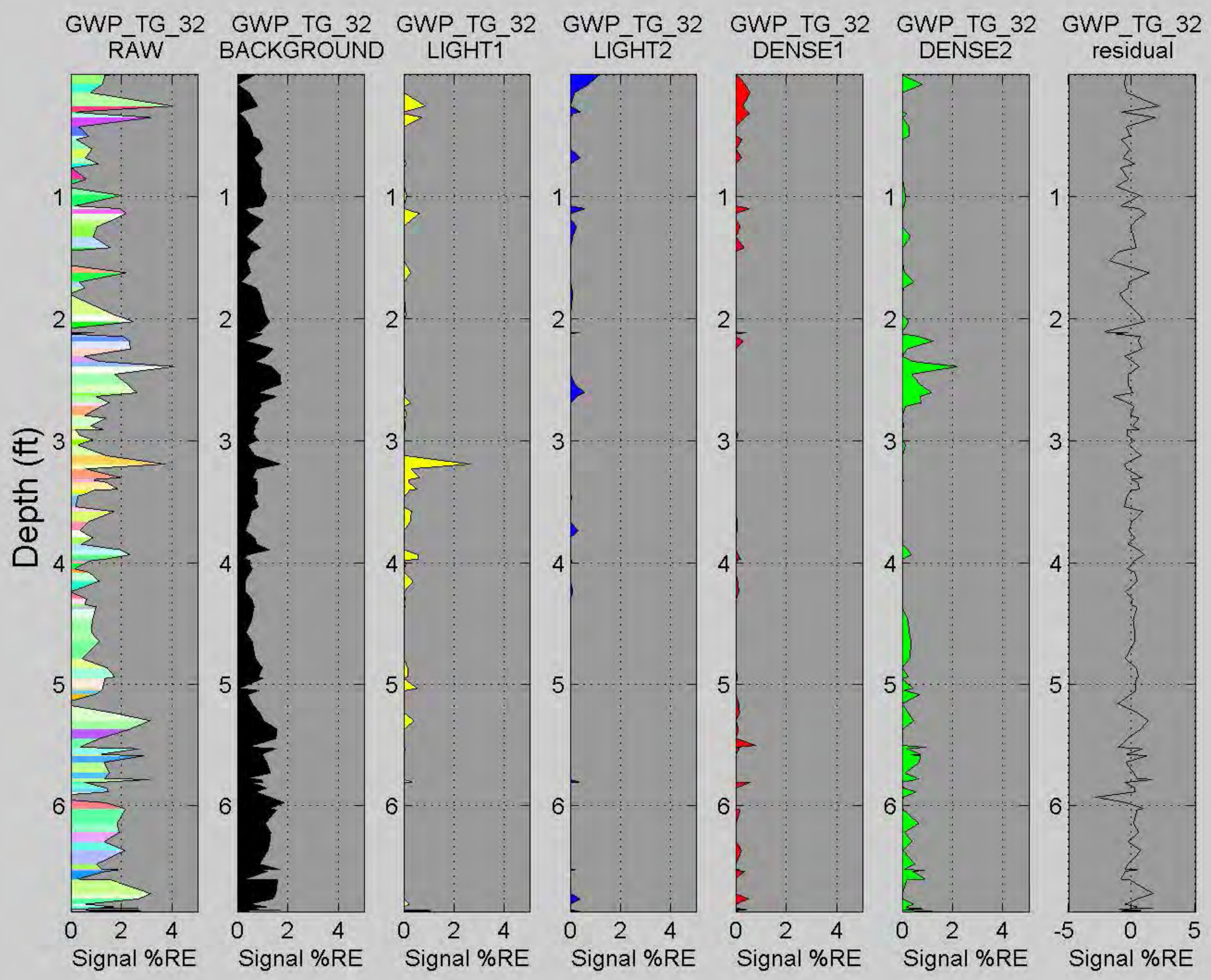

GWP_TG_31
Depth (ft)
Signal (%RE)
26.59
31.95
Waveform at 7 ft
Signal (mV)
Time (ns)
575
625
675
Background
LIGHT1
LIGHT2
DENSE1
DENSE2
GRASSORPAINT

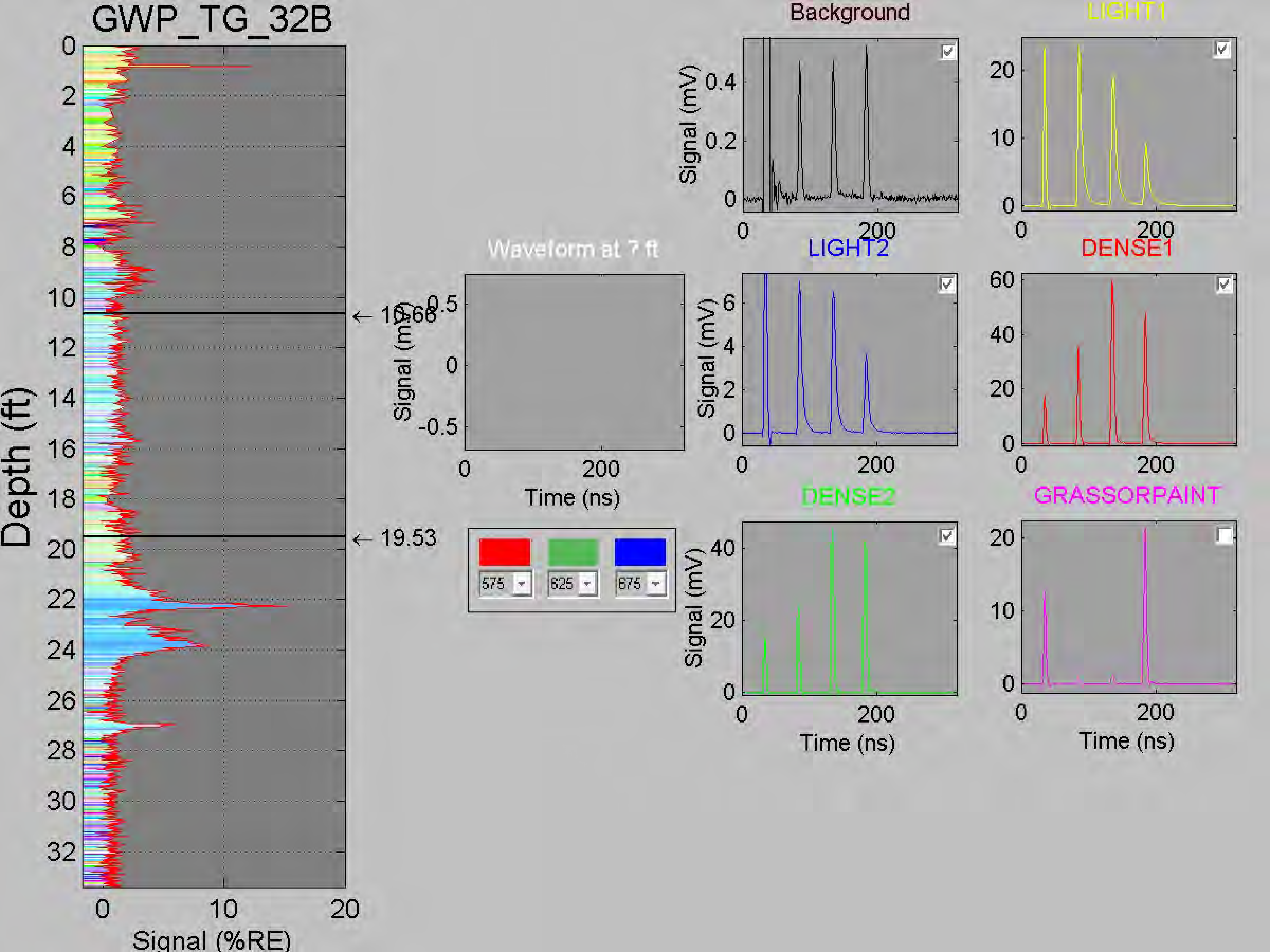


GWP_TG_31
RAW
GWP_TG_31
BACKGROUND
GWP_TG_31
LIGHT1
GWP_TG_31
LIGHT2
GWP_TG_31
DENSE1
GWP_TG_31
DENSE2
GWP_TG_31
residual
Depth (ft)
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38
0 20 40
-5 0 5
Signal %RE

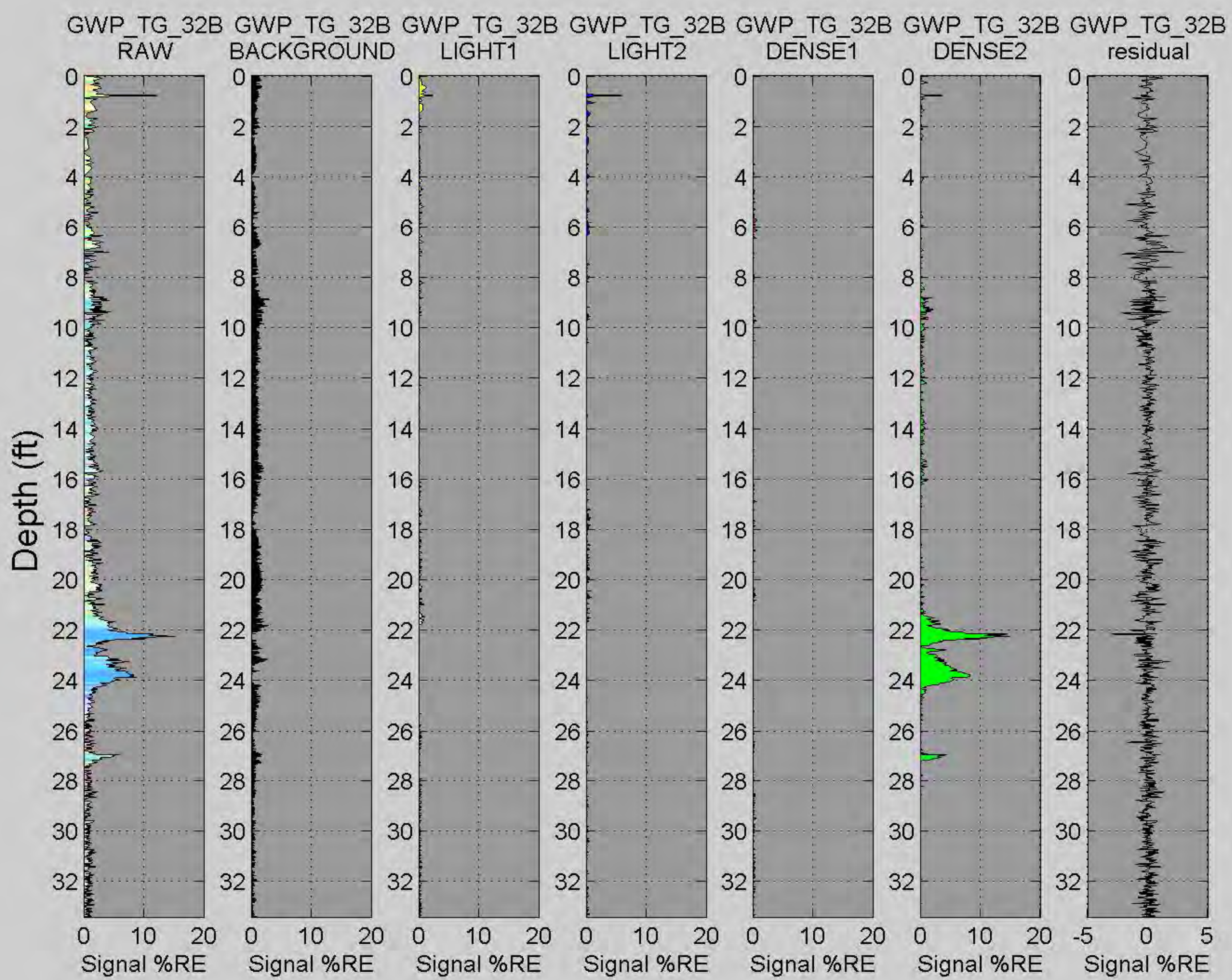


GWP_TG_32
Depth (ft)
Signal (%RE)
← 0.10
← 6.29
Background
LIGHT1
Waveform at 7 ft
LIGHT2
DENSE1
DENSE2
GRASSORPAINT
Signal (mV)
Time (ns)
575
625
675

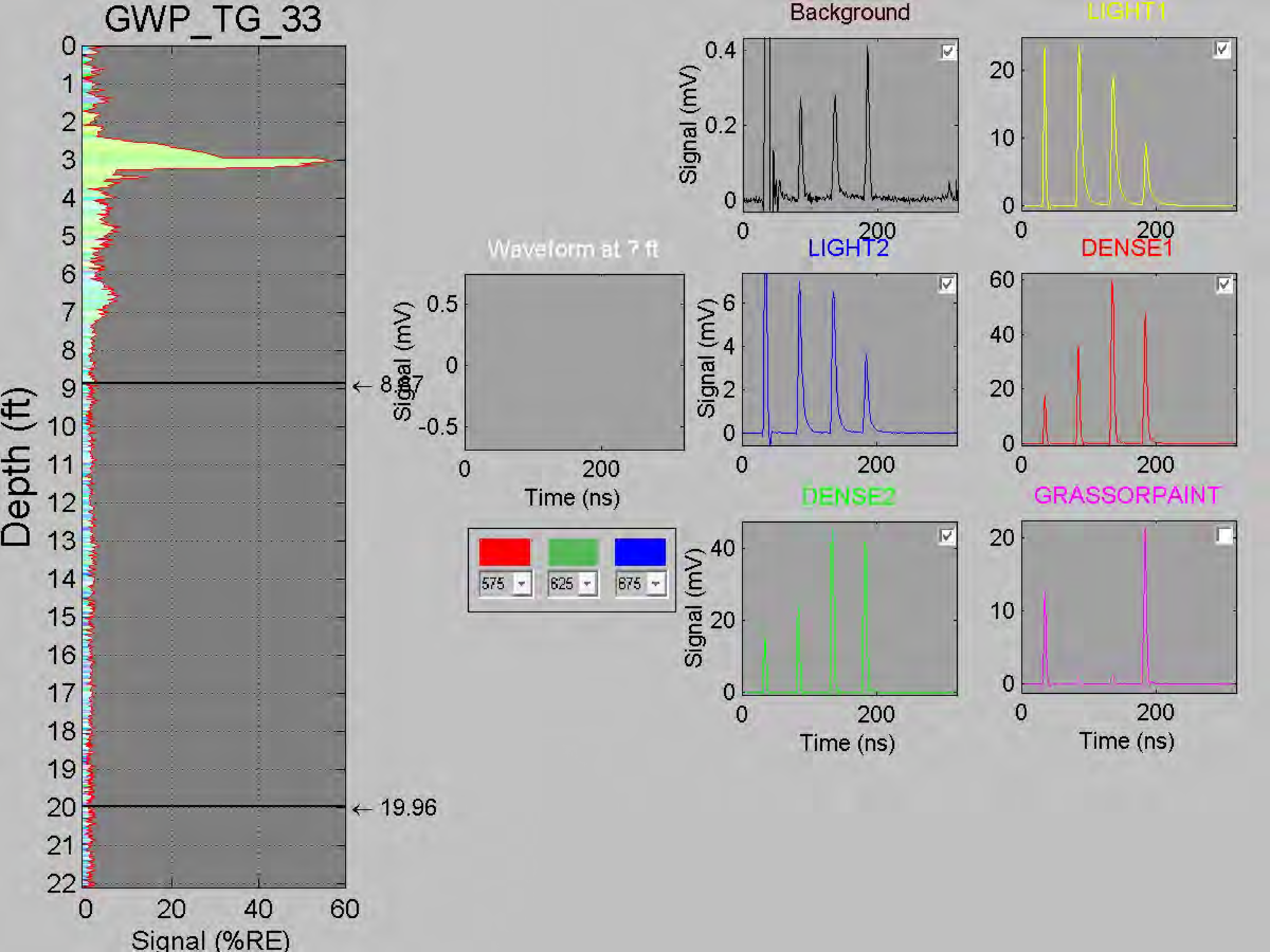

GWP_TG_32
RAW
GWP_TG_32
BACKGROUND
GWP_TG_32
LIGHT1
GWP_TG_32
LIGHT2
GWP_TG_32
DENSE1
GWP_TG_32
DENSE2
GWP_TG_32
residual
Depth (ft)
1
2
3
4
5
6
0
2
4
-5
0
5
Signal %RE



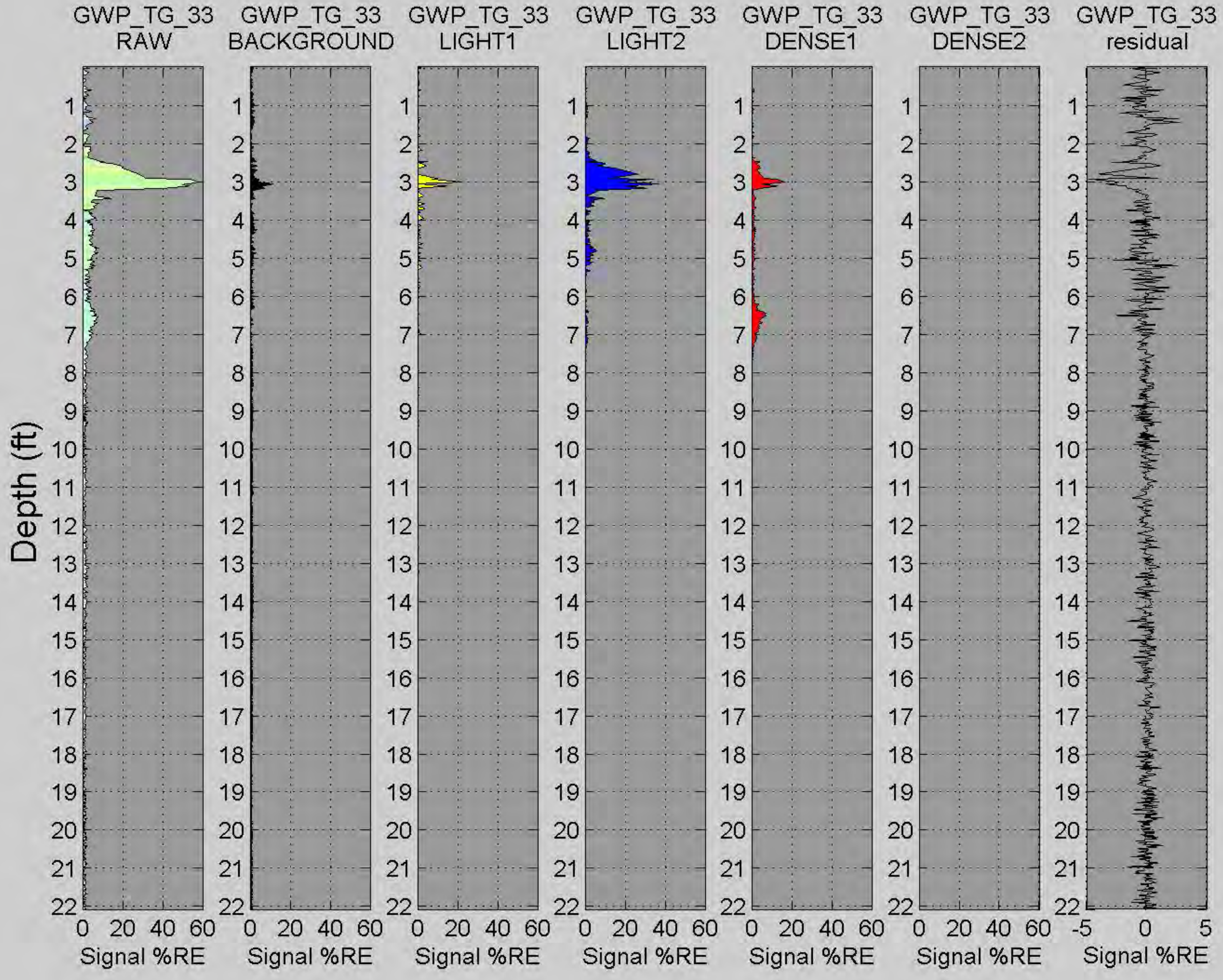
GWP_TG_32B
Depth (ft)
Signal (%RE)
← 10.66
← 19.53
Waveform at 7 ft
Signal (mV)
Time (ns)
575
625
675
Background
LIGHT1
LIGHT2
DENSE1
DENSE2
GRASSORPAINT



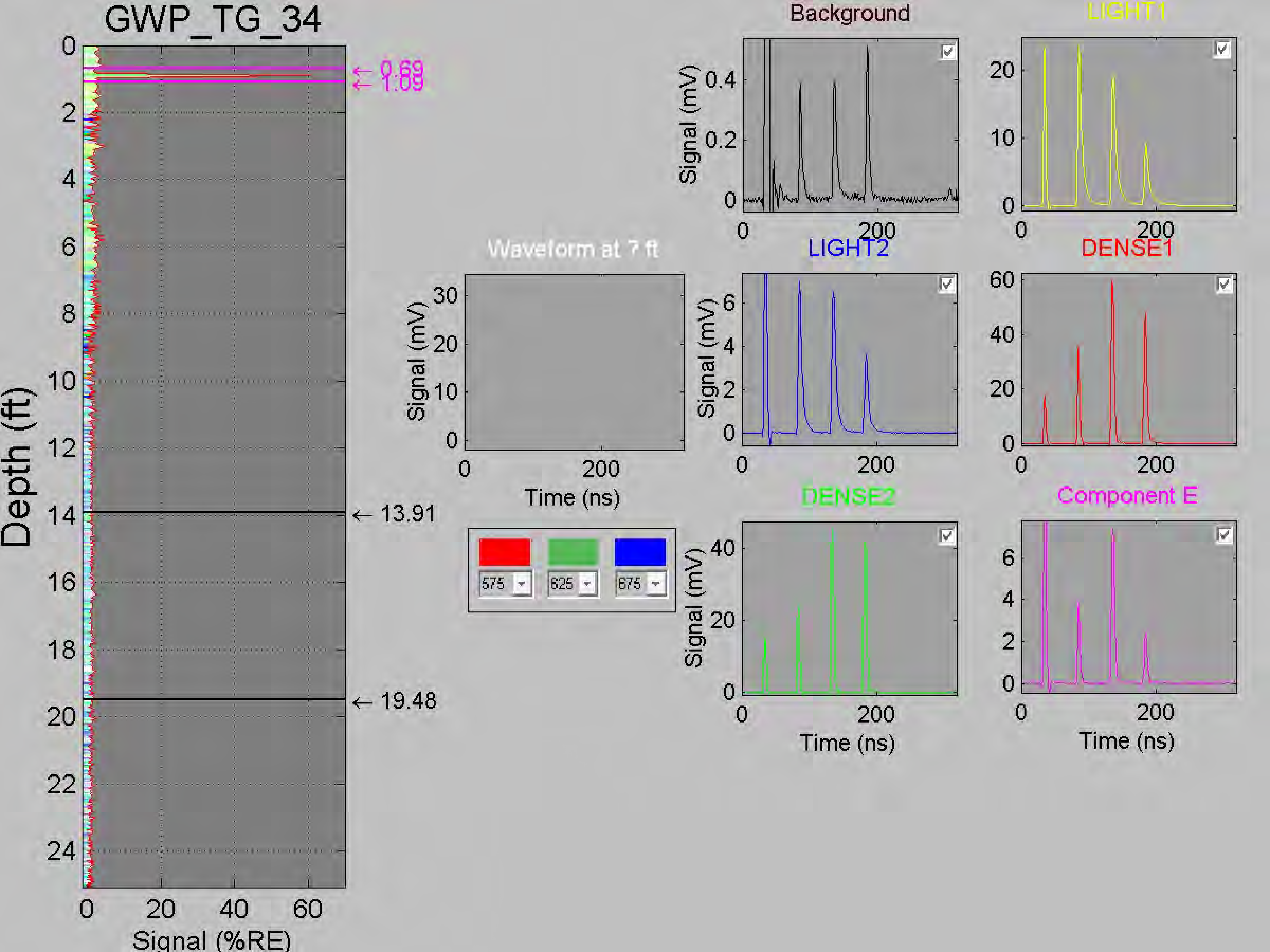
GWP_TG_32B RAW
GWP_TG_32B BACKGROUND
GWP_TG_32B LIGHT1
GWP_TG_32B LIGHT2
GWP_TG_32B DENSE1
GWP_TG_32B DENSE2
GWP_TG_32B residual
Depth (ft)
Signal %RE



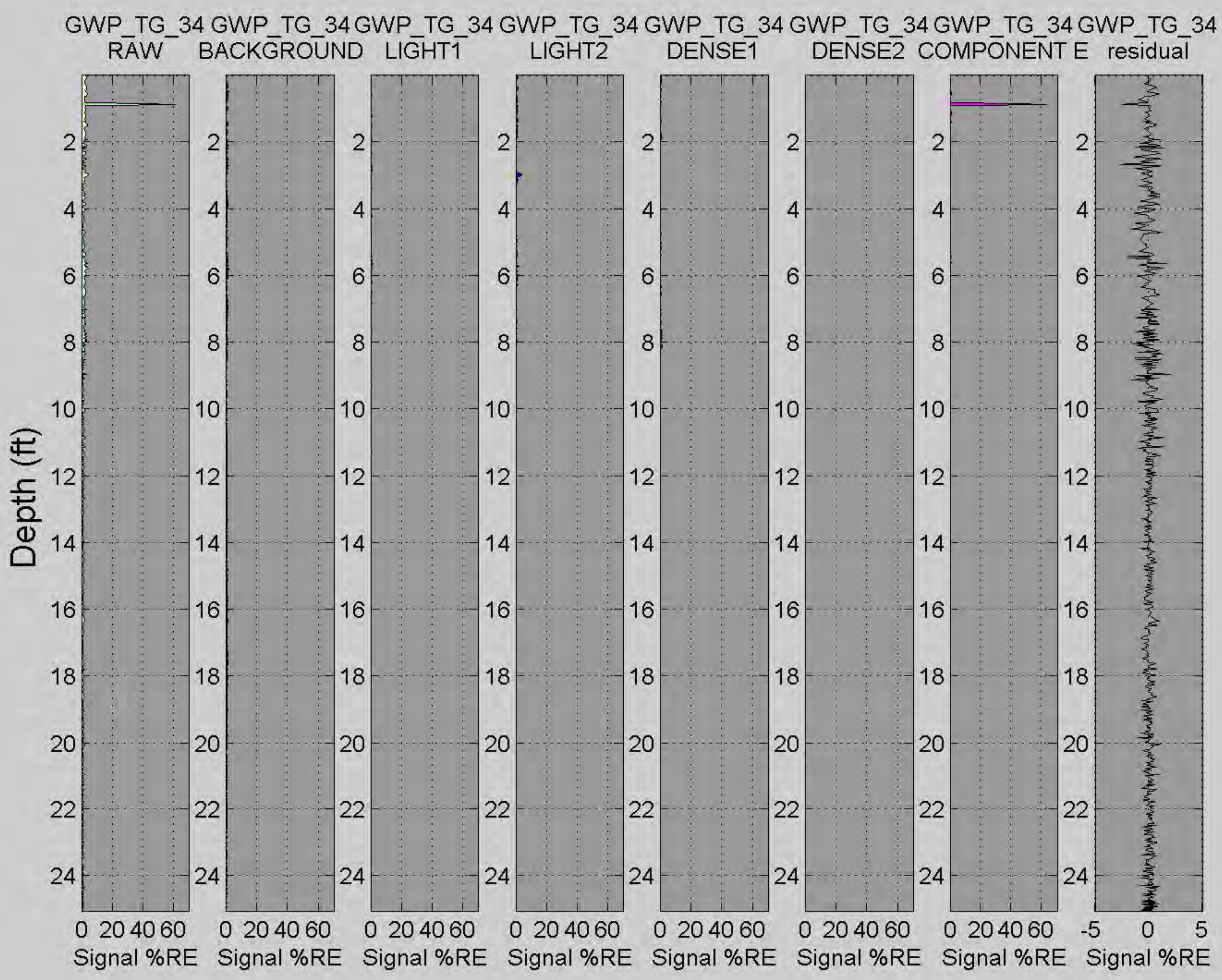
GWP_TG_33
Depth (ft)
Signal (%RE)
← 8.87
← 19.96
Waveform at 7 ft
Signal (mV)
Time (ns)
575
625
675
Background
LIGHT1
LIGHT2
DENSE1
DENSE2
GRASSORPAINT



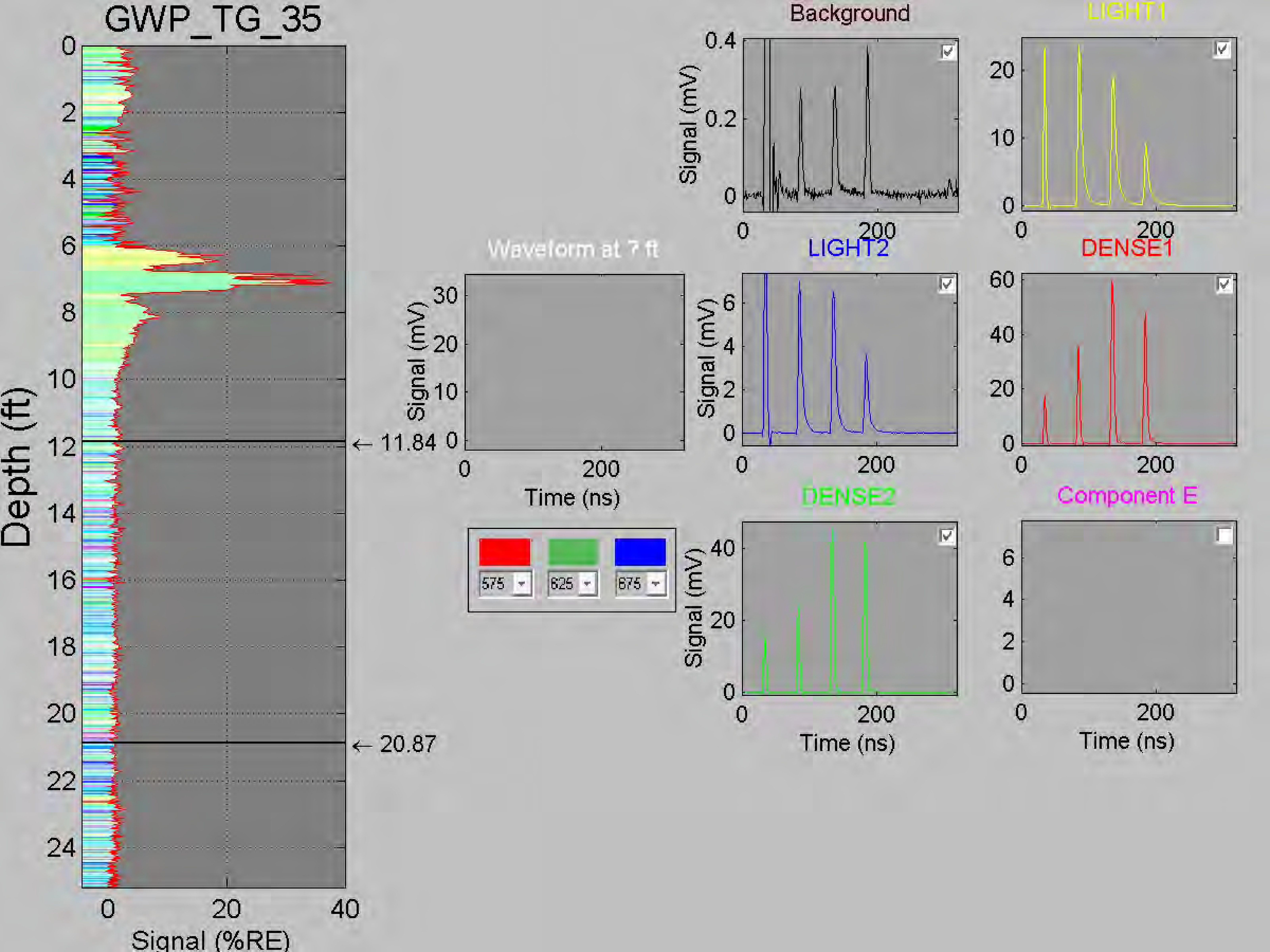
GWP_TG_33 RAW
GWP_TG_33 BACKGROUND
GWP_TG_33 LIGHT1
GWP_TG_33 LIGHT2
GWP_TG_33 DENSE1
GWP_TG_33 DENSE2
GWP_TG_33 residual
Depth (ft)
Signal %RE



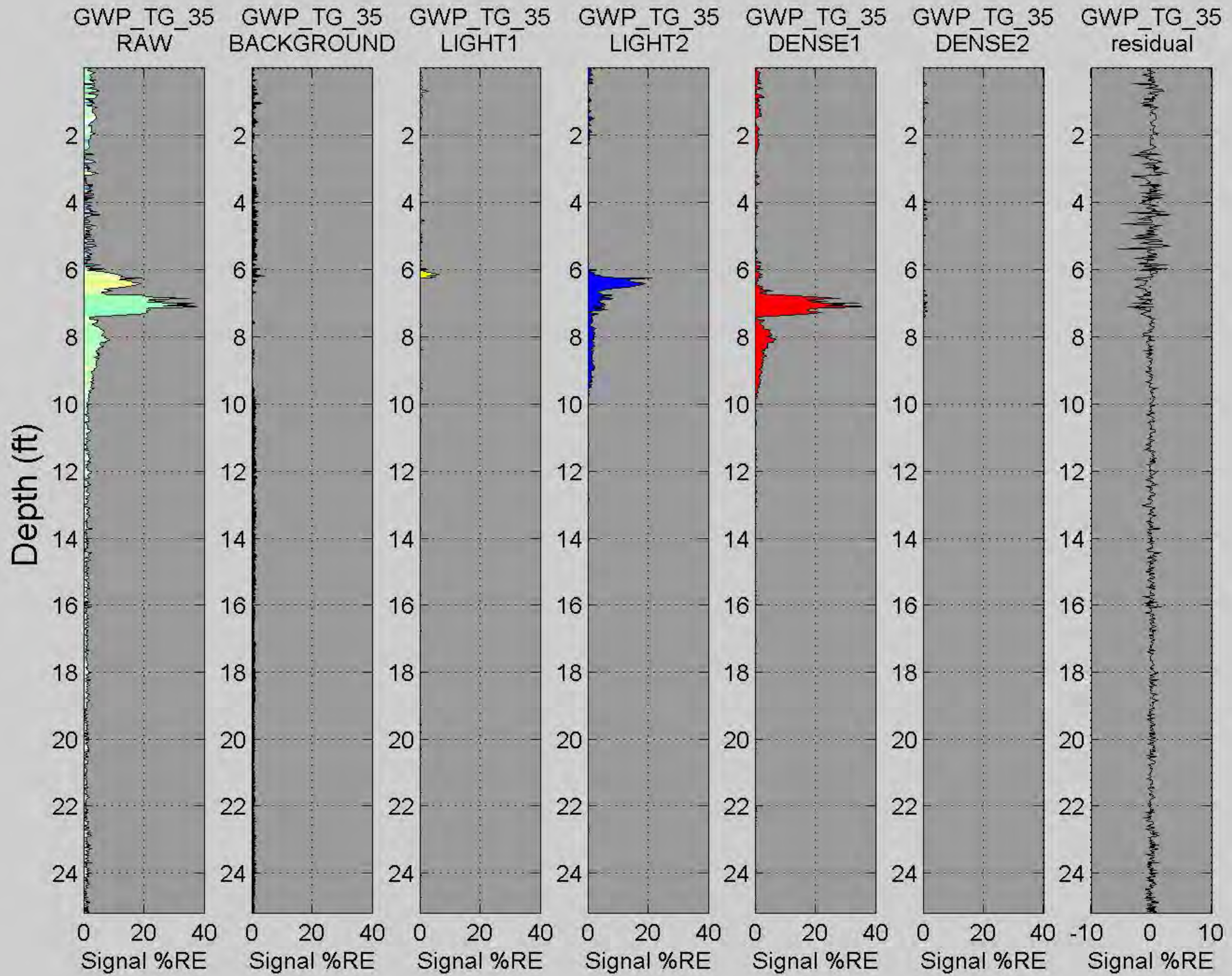
GWP_TG_34
Depth (ft)
Signal (%RE)
0.69
1.09
13.91
19.48
Background
LIGHT1
Waveform at 7 ft
LIGHT2
DENSE1
DENSE2
Component E
Signal (mV)
Time (ns)
575
625
675



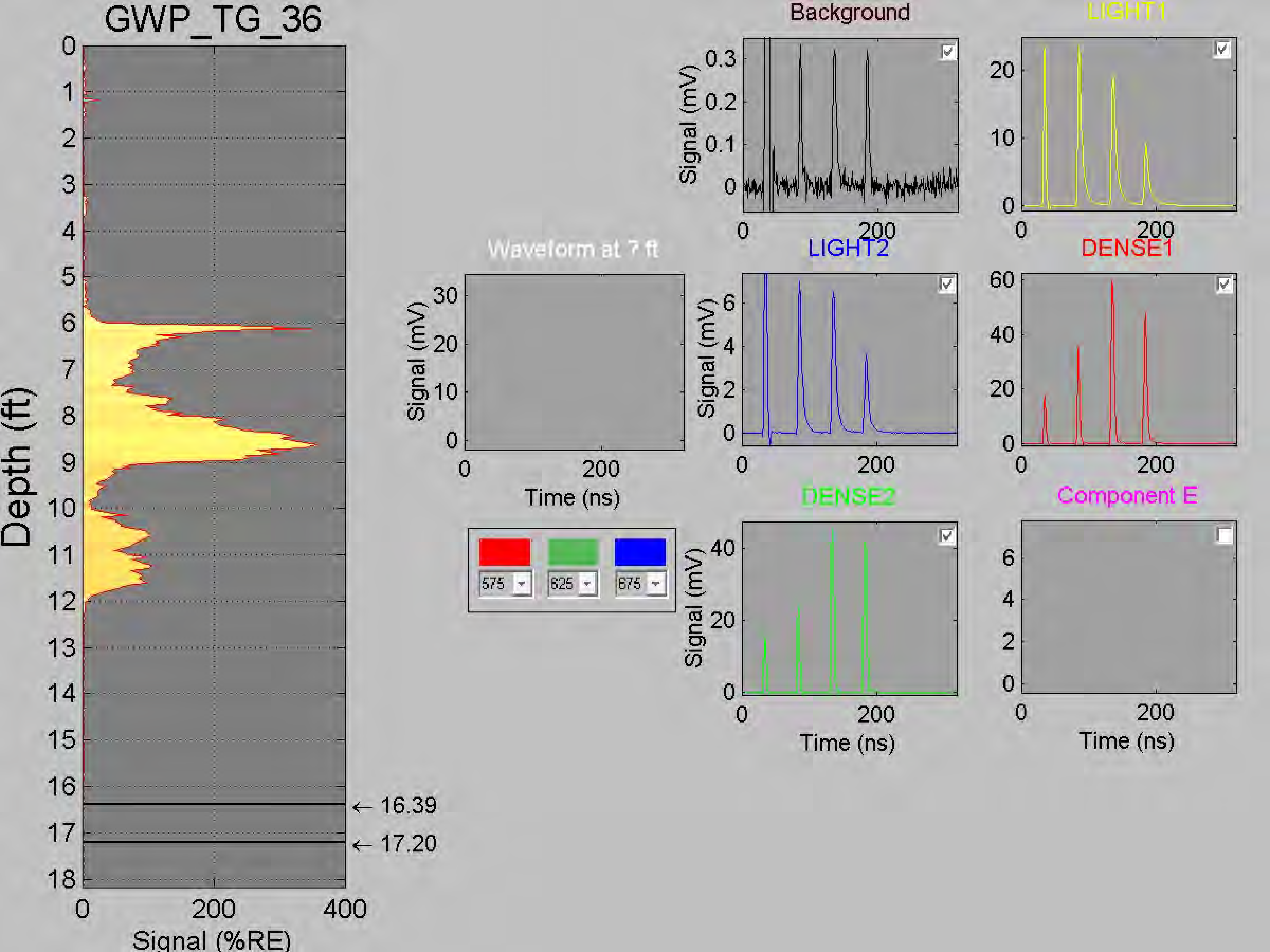
GWP_TG_34 RAW
GWP_TG_34 BACKGROUND
GWP_TG_34 LIGHT1
GWP_TG_34 LIGHT2
GWP_TG_34 DENSE1
GWP_TG_34 DENSE2
GWP_TG_34 COMPONENT E
GWP_TG_34 residual
Depth (ft)
2 4 6 8 10 12 14 16 18 20 22 24
0 20 40 60
-5 0 5
Signal %RE



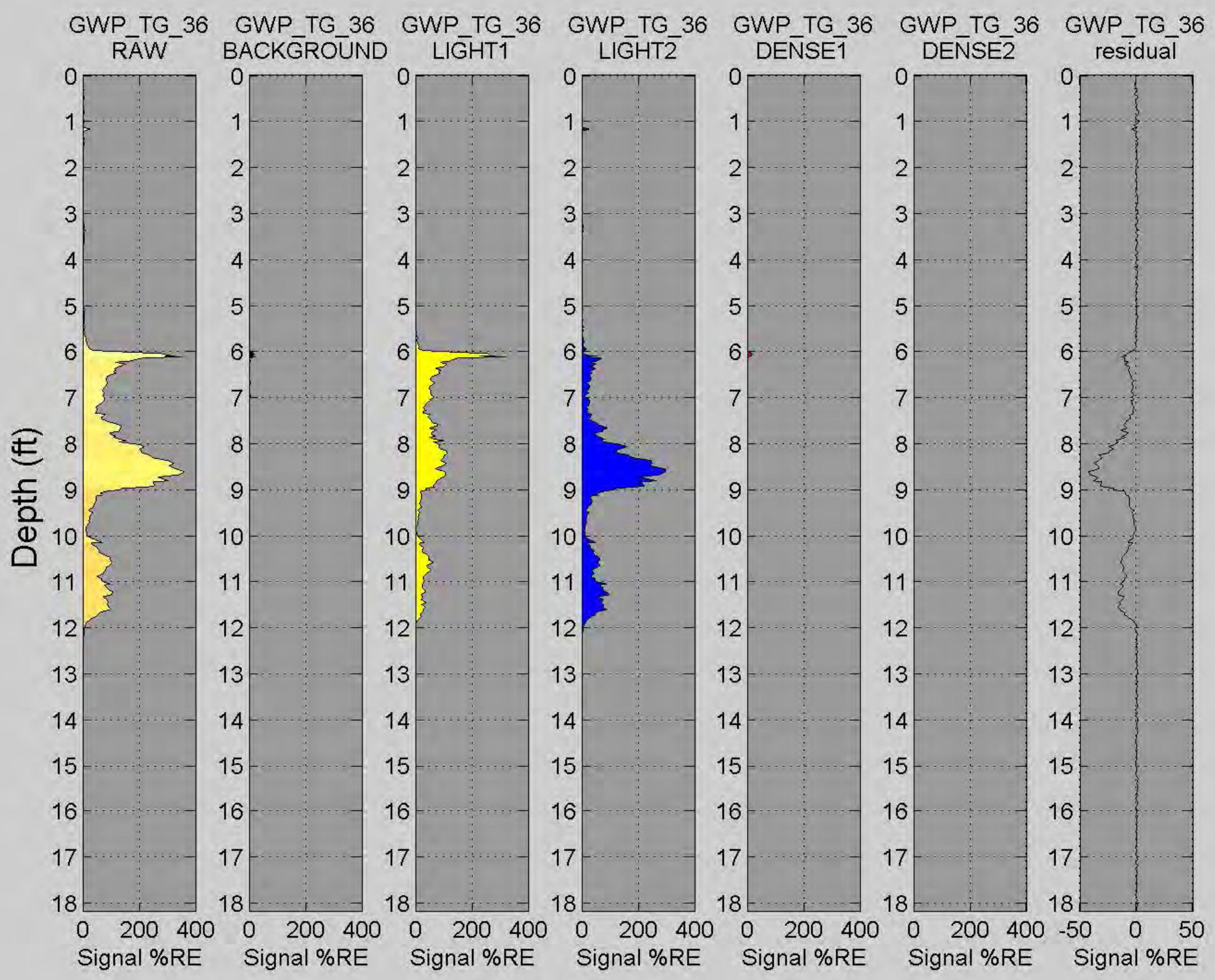
GWP_TG_35
Depth (ft)
Signal (%RE)
← 11.84
← 20.87
Waveform at 7 ft
Signal (mV)
Time (ns)
575
625
675
Background
LIGHT1
LIGHT2
DENSE1
DENSE2
Component E



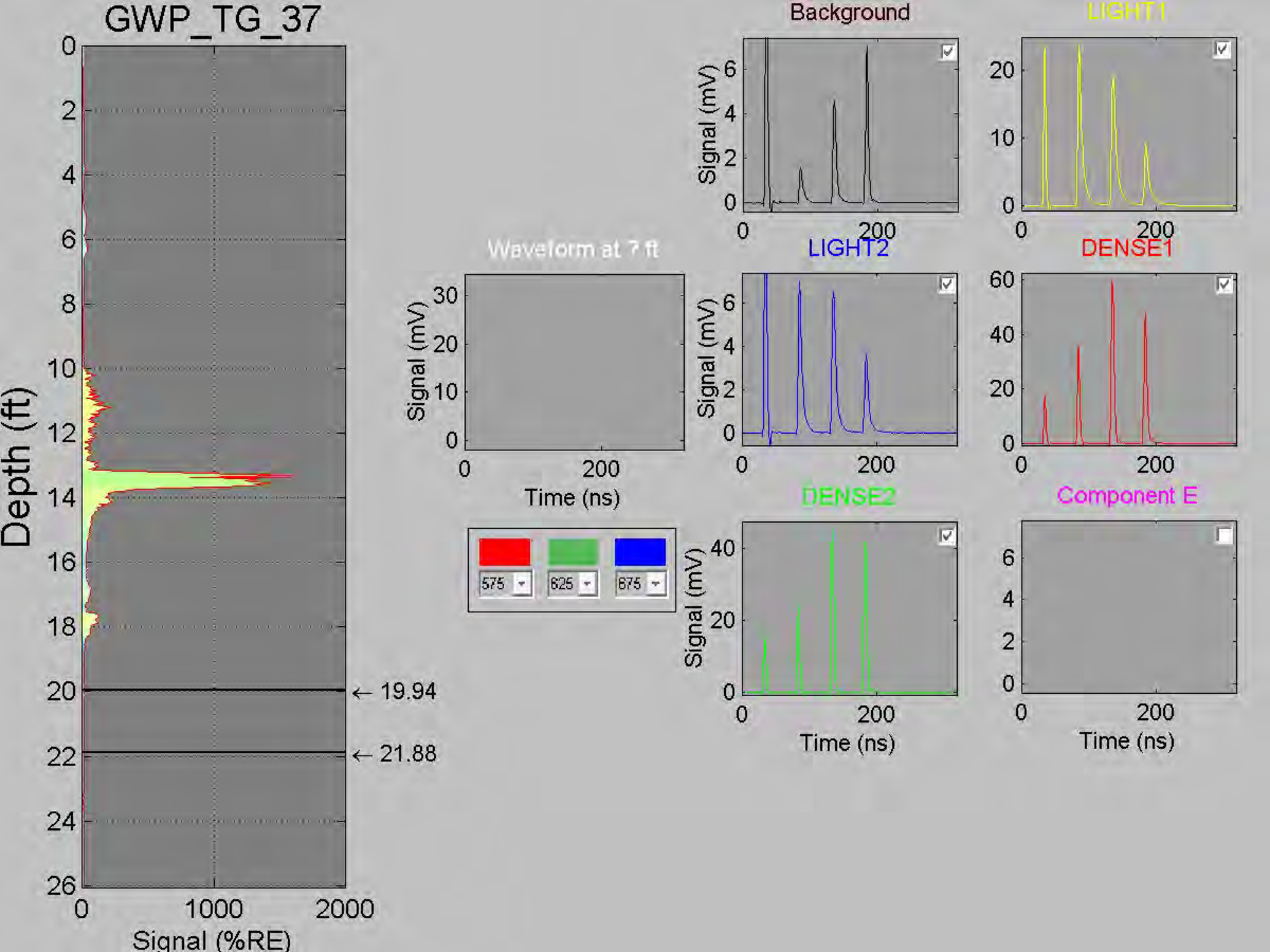
GWP_TG_35 RAW
GWP_TG_35 BACKGROUND
GWP_TG_35 LIGHT1
GWP_TG_35 LIGHT2
GWP_TG_35 DENSE1
GWP_TG_35 DENSE2
GWP_TG_35 residual
Depth (ft)
Signal %RE



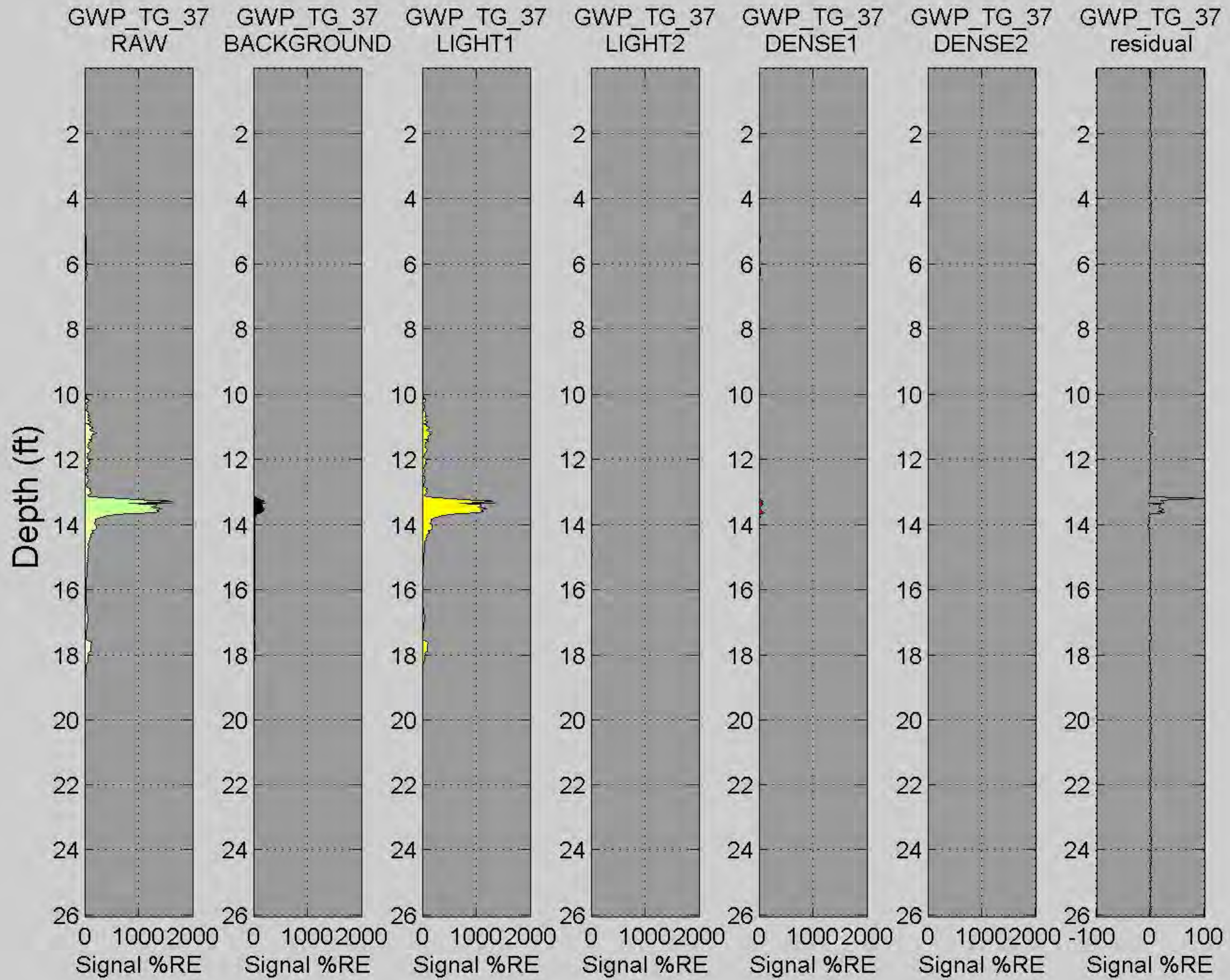
GWP_TG_36
Depth (ft)
Signal (%RE)
16.39
17.20
Background
LIGHT1
Waveform at 7 ft
LIGHT2
DENSE1
DENSE2
Component E
Signal (mV)
Time (ns)
575
625
675

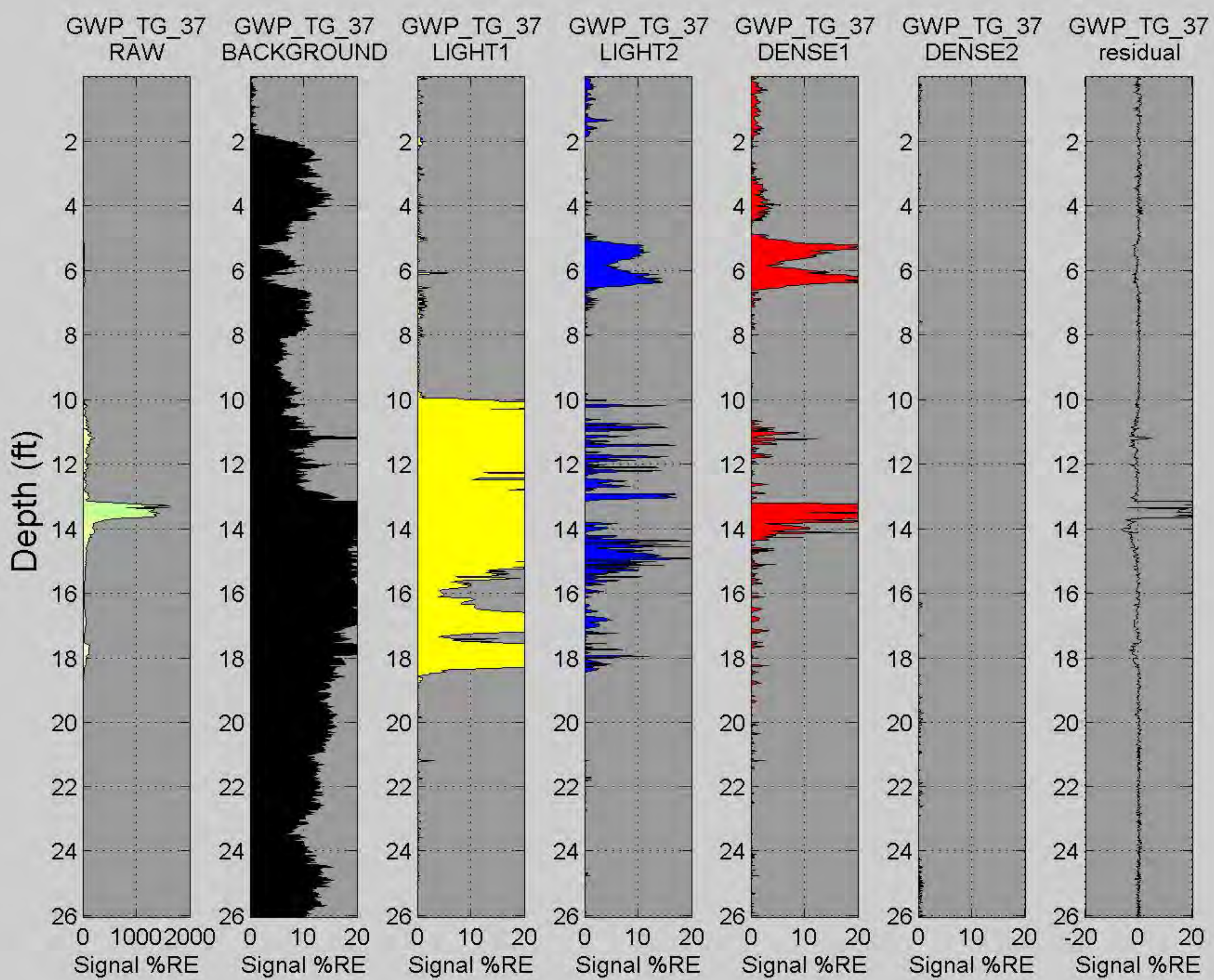


GWP_TG_36 RAW
GWP_TG_36 BACKGROUND
GWP_TG_36 LIGHT1
GWP_TG_36 LIGHT2
GWP_TG_36 DENSE1
GWP_TG_36 DENSE2
GWP_TG_36 residual
Depth (ft)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
0 200 400
-50 0 50
Signal %RE

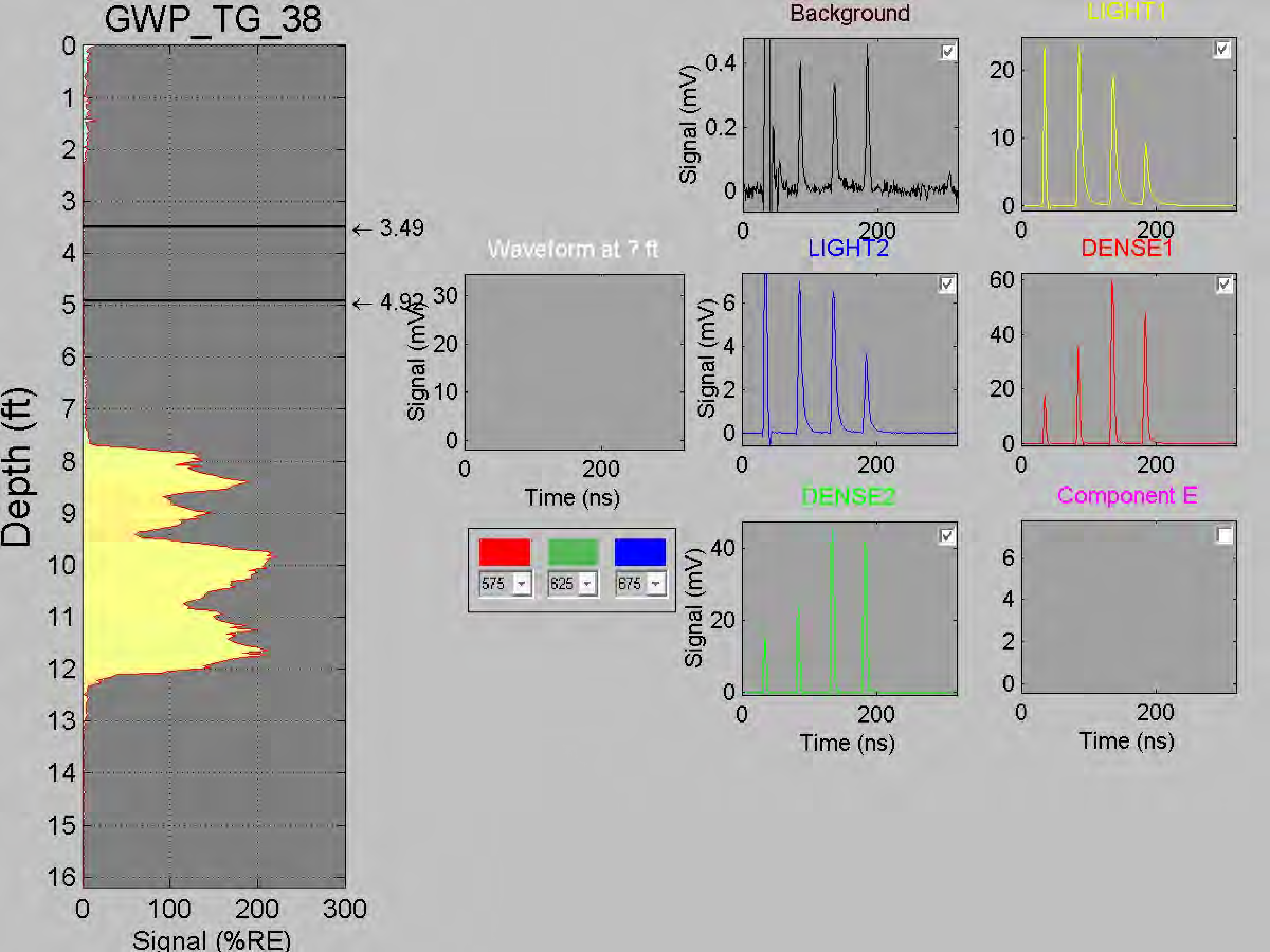


GWP_TG_37
Depth (ft)
Signal (%RE)
← 19.94
← 21.88
Waveform at 7 ft
Signal (mV)
Time (ns)
575
625
675
Background
LIGHT1
LIGHT2
DENSE1
DENSE2
Component E

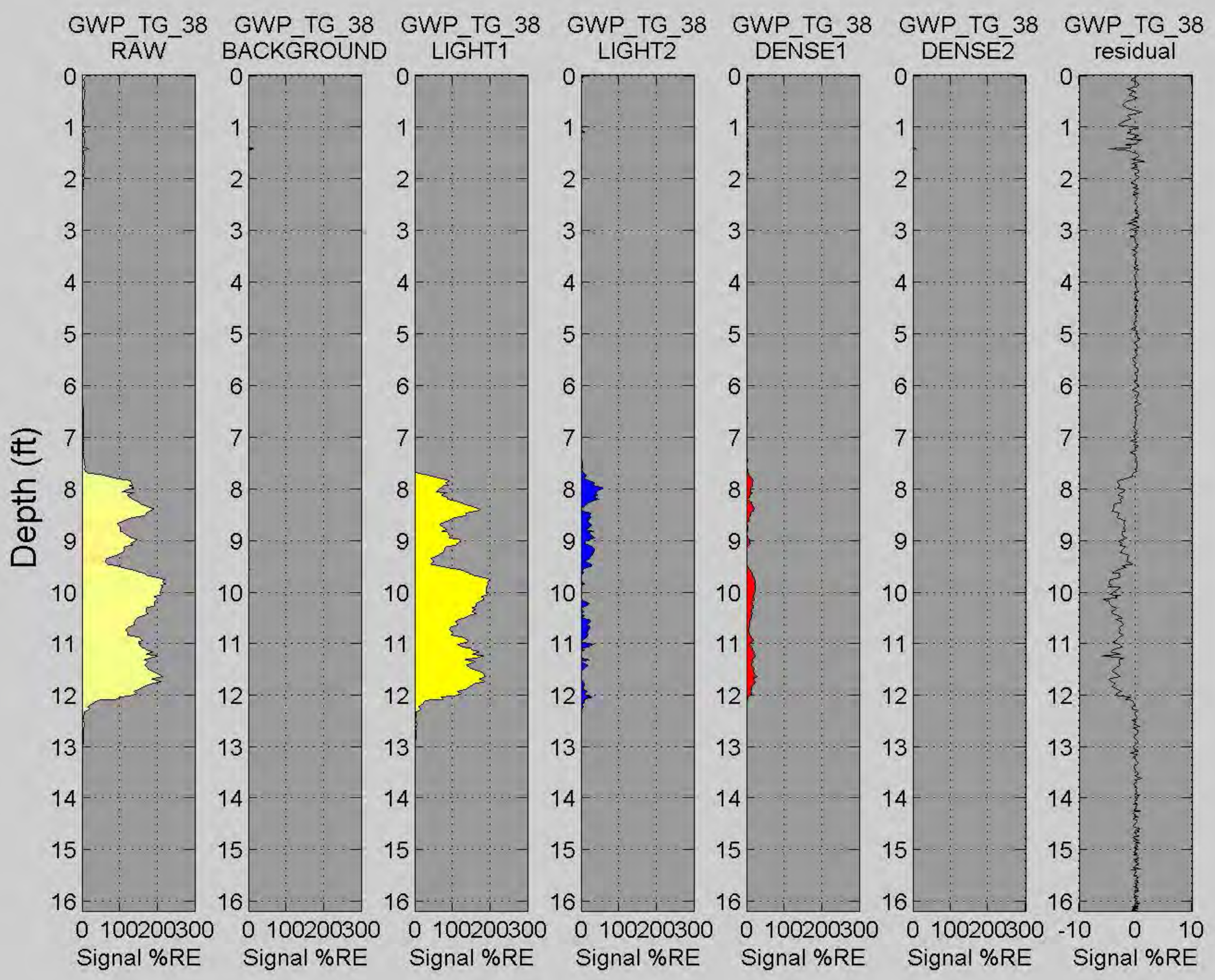

GWP_TG_37
RAW
GWP_TG_37
BACKGROUND
GWP_TG_37
LIGHT1
GWP_TG_37
LIGHT2
GWP_TG_37
DENSE1
GWP_TG_37
DENSE2
GWP_TG_37
residual
Depth (ft)
2
4
6
8
10
12
14
16
18
20
22
24
26
0
1000
2000
-100
0
100
Signal %RE



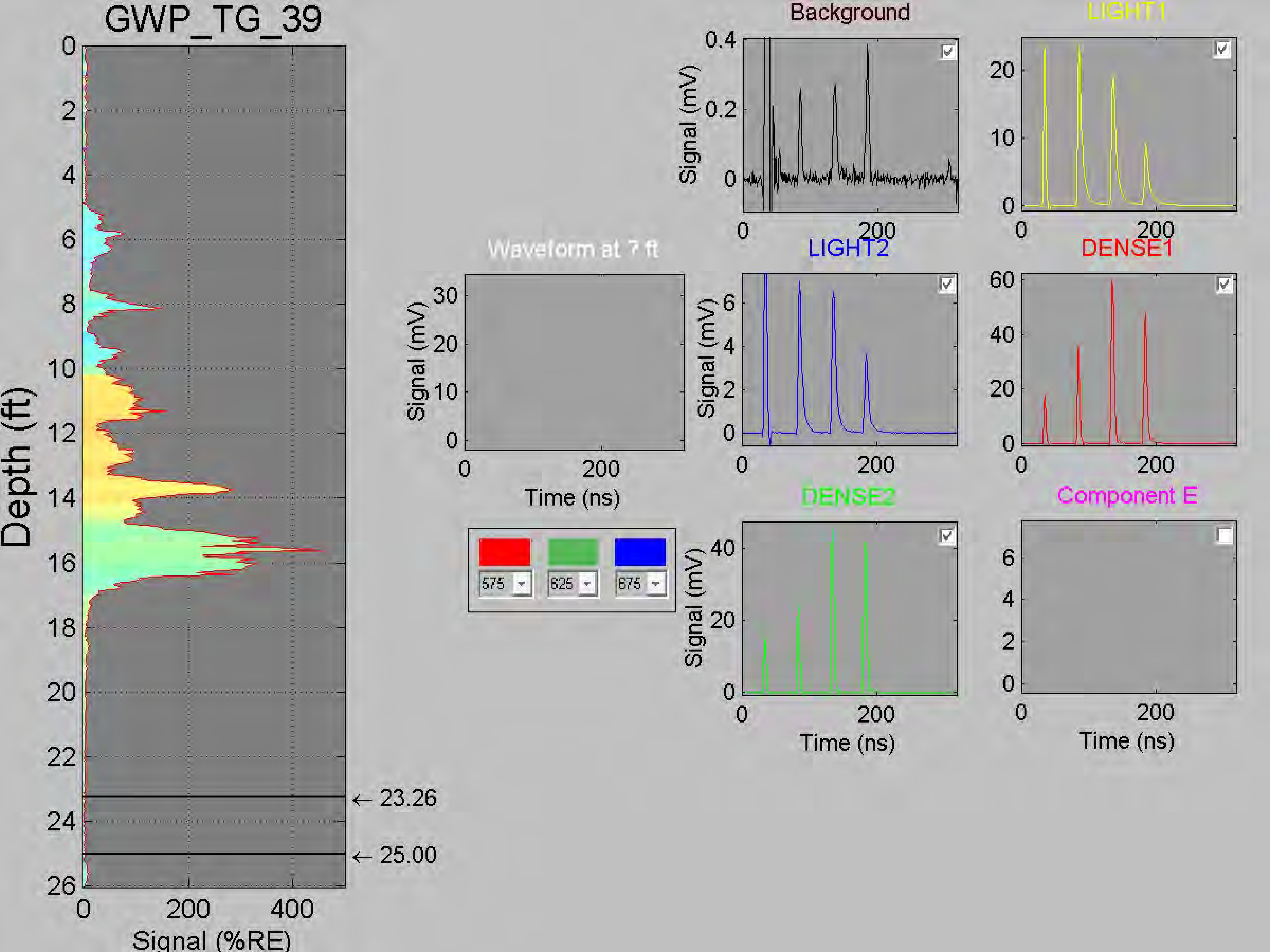
GWP_TG_37
RAW
GWP_TG_37
BACKGROUND
GWP_TG_37
LIGHT1
GWP_TG_37
LIGHT2
GWP_TG_37
DENSE1
GWP_TG_37
DENSE2
GWP_TG_37
residual
Depth (ft)
2
4
6
8
10
12
14
16
18
20
22
24
26
0
1000
2000
10
20
-20
Signal %RE



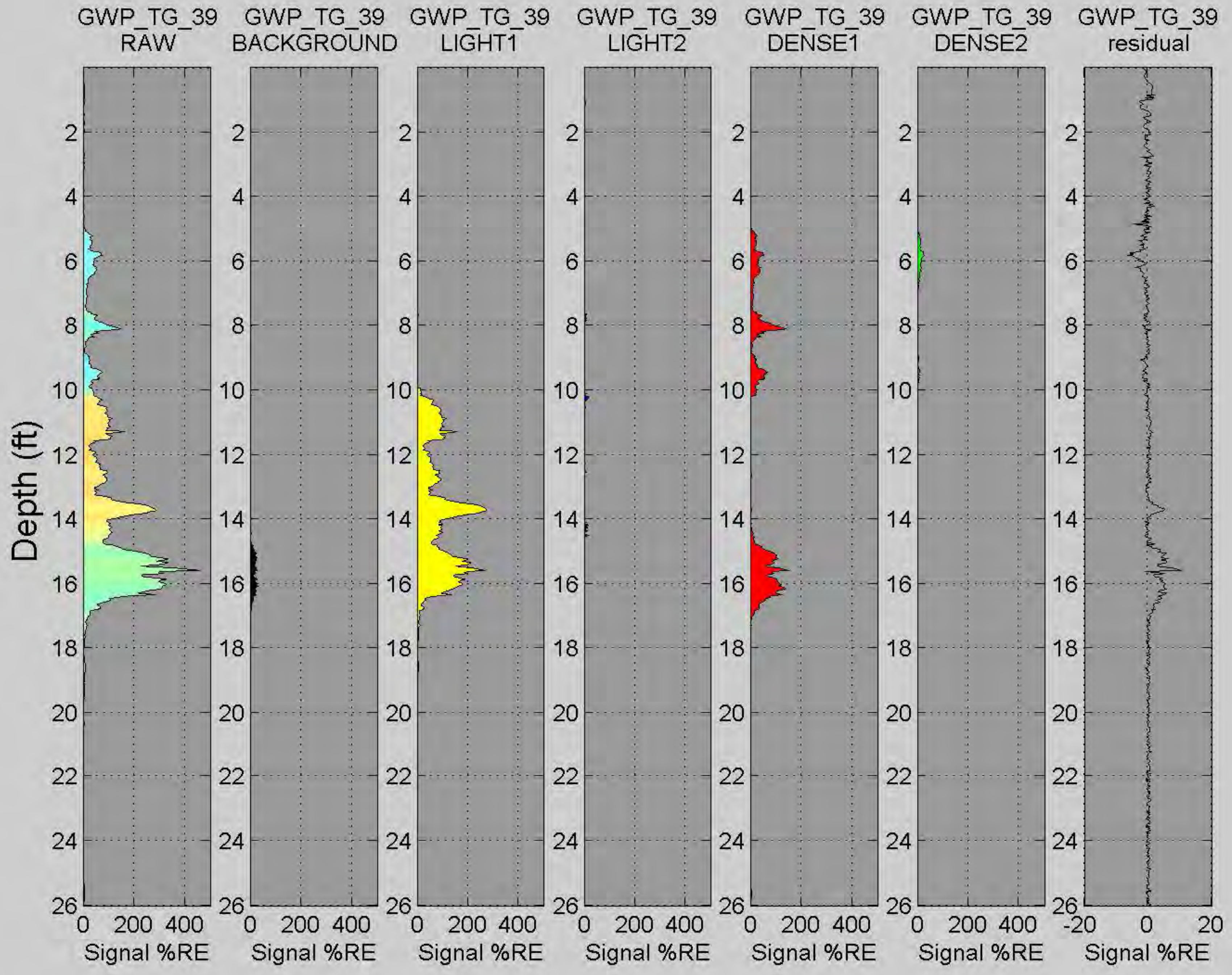
GWP_TG_38
Depth (ft)
Signal (%RE)
← 3.49
← 4.92
Waveform at 7 ft
Signal (mV)
Time (ns)
575
625
675
Background
LIGHT1
LIGHT2
DENSE1
DENSE2
Component E

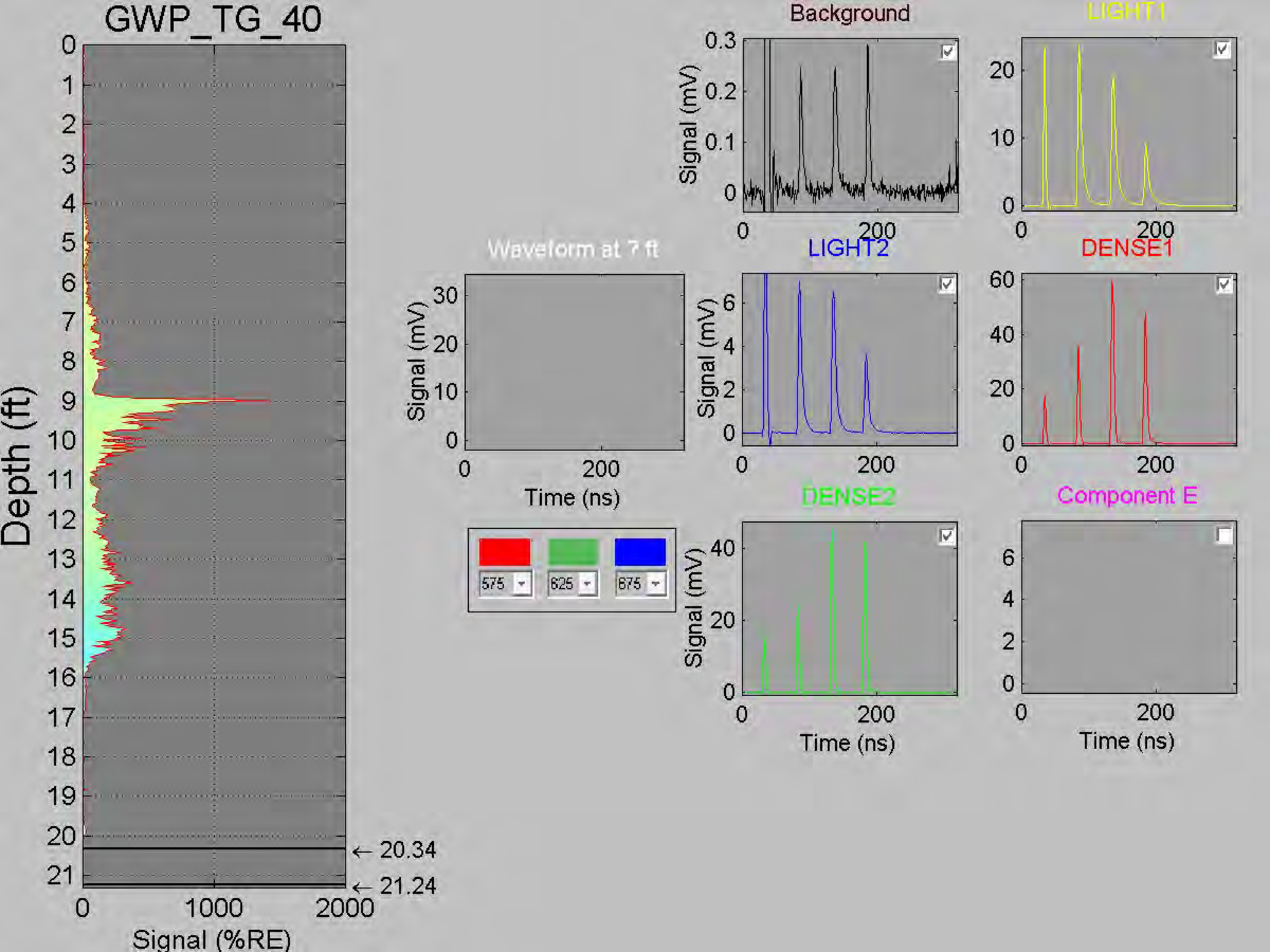


GWP_TG_38 RAW
GWP_TG_38 BACKGROUND
GWP_TG_38 LIGHT1
GWP_TG_38 LIGHT2
GWP_TG_38 DENSE1
GWP_TG_38 DENSE2
GWP_TG_38 residual
Depth (ft)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
0 100200300
-10 0 10
Signal %RE

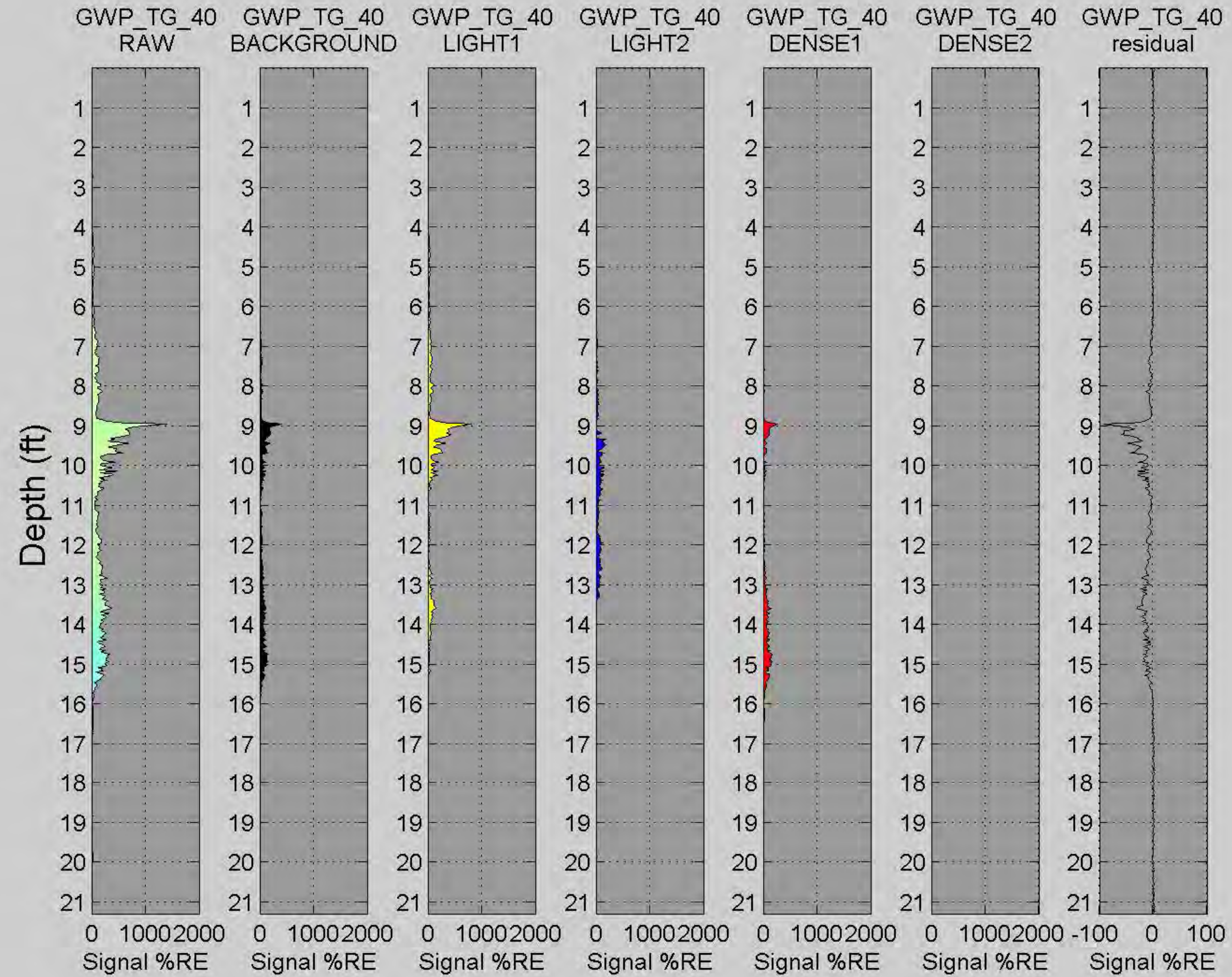


GWP_TG_39
Depth (ft)
Signal (%RE)
← 23.26
← 25.00
Waveform at 7 ft
Signal (mV)
Time (ns)
575
625
675
Background
LIGHT1
LIGHT2
DENSE1
DENSE2
Component E

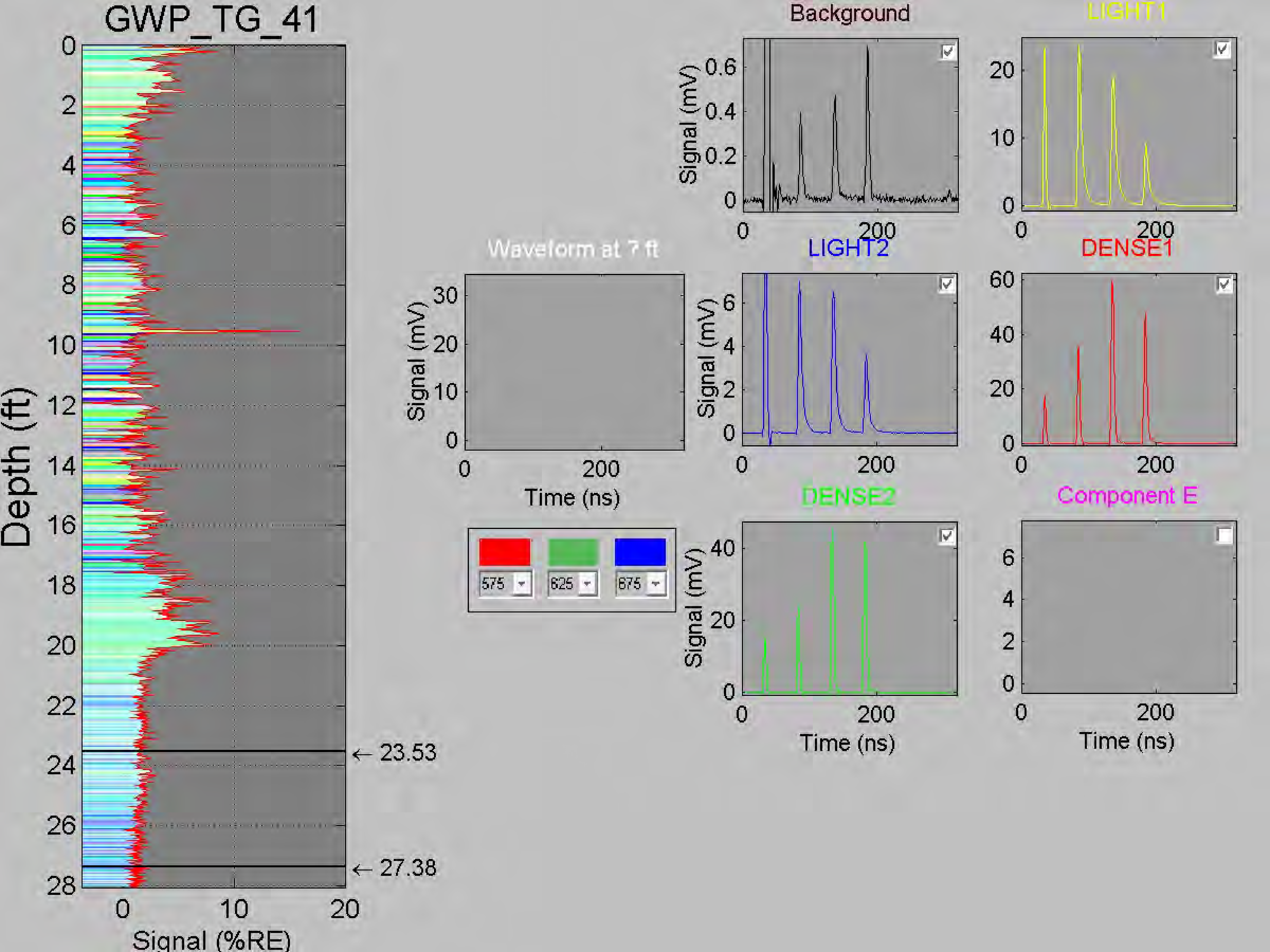

GWP_TG_39
RAW
GWP_TG_39
BACKGROUND
GWP_TG_39
LIGHT1
GWP_TG_39
LIGHT2
GWP_TG_39
DENSE1
GWP_TG_39
DENSE2
GWP_TG_39
residual
Depth (ft)
2
4
6
8
10
12
14
16
18
20
22
24
26
0
200
400
-20
0
20
Signal %RE

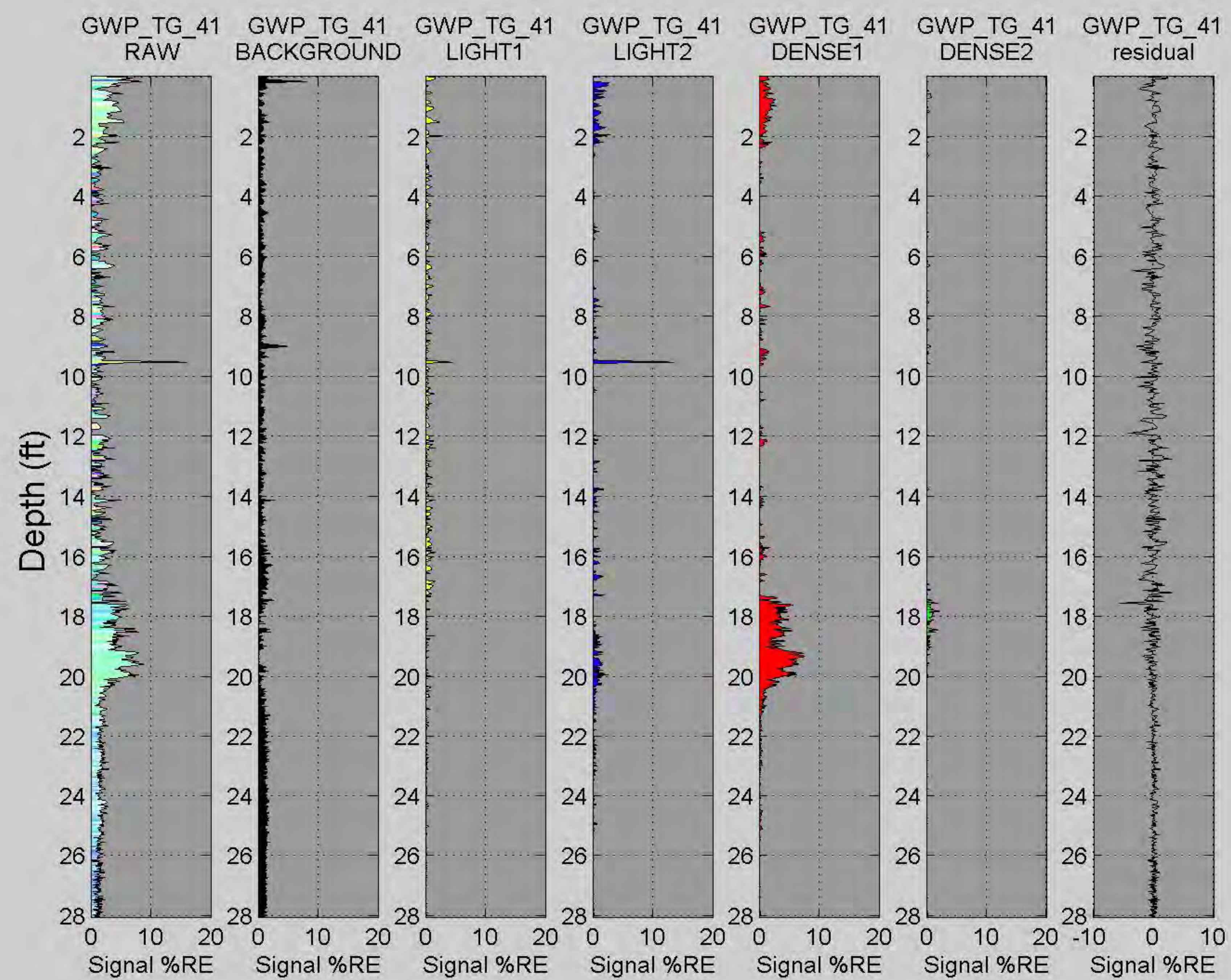


GWP_TG_40
Depth (ft)
Signal (%RE)
← 20.34
← 21.24
Background
LIGHT1
Waveform at 7 ft
LIGHT2
DENSE1
DENSE2
Component E
Signal (mV)
Time (ns)
575
625
675

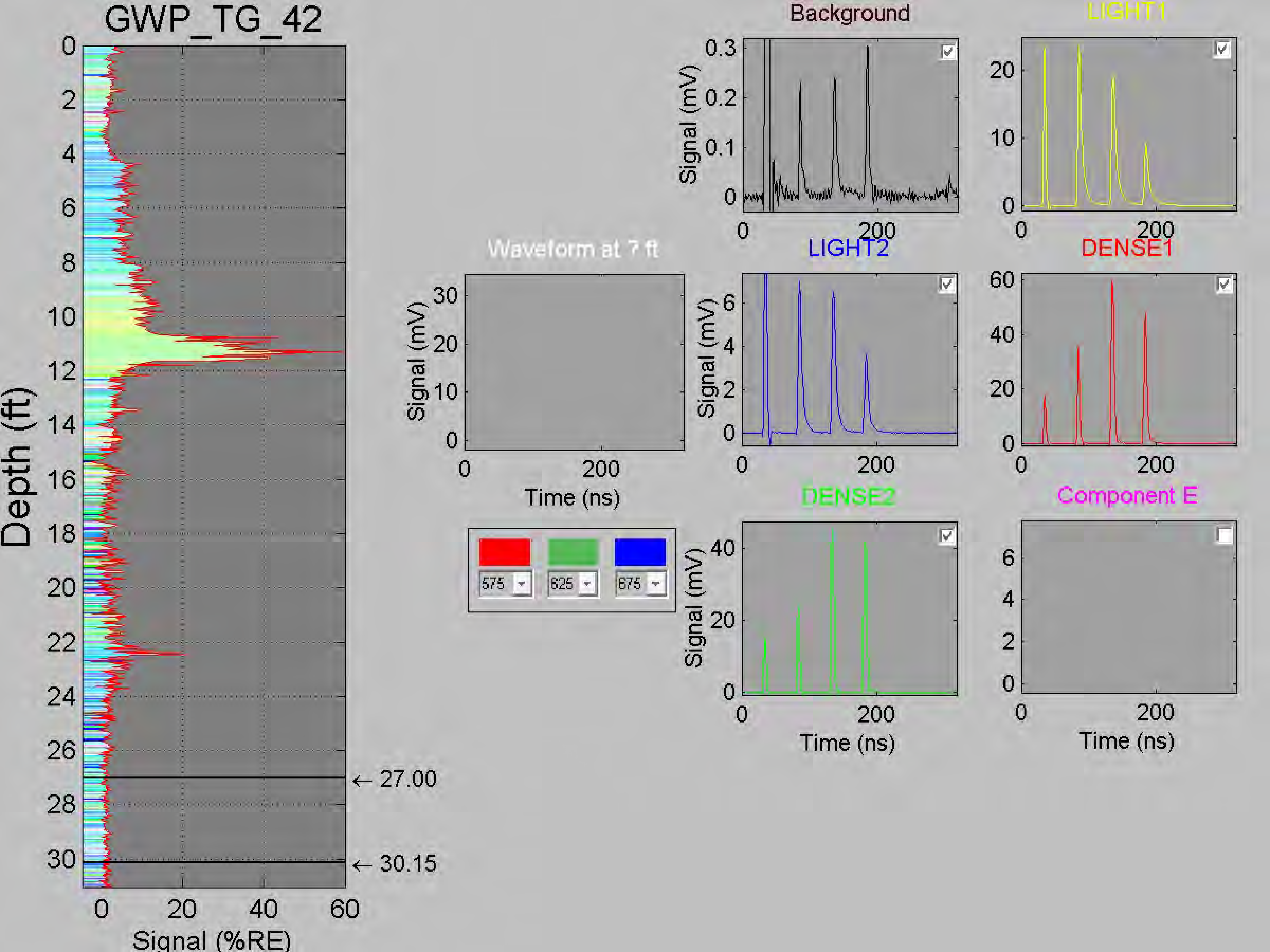


GWP_TG_40
RAW
GWP_TG_40
BACKGROUND
GWP_TG_40
LIGHT1
GWP_TG_40
LIGHT2
GWP_TG_40
DENSE1
GWP_TG_40
DENSE2
GWP_TG_40
residual
Depth (ft)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
0 1000 2000
-100 0 100
Signal %RE

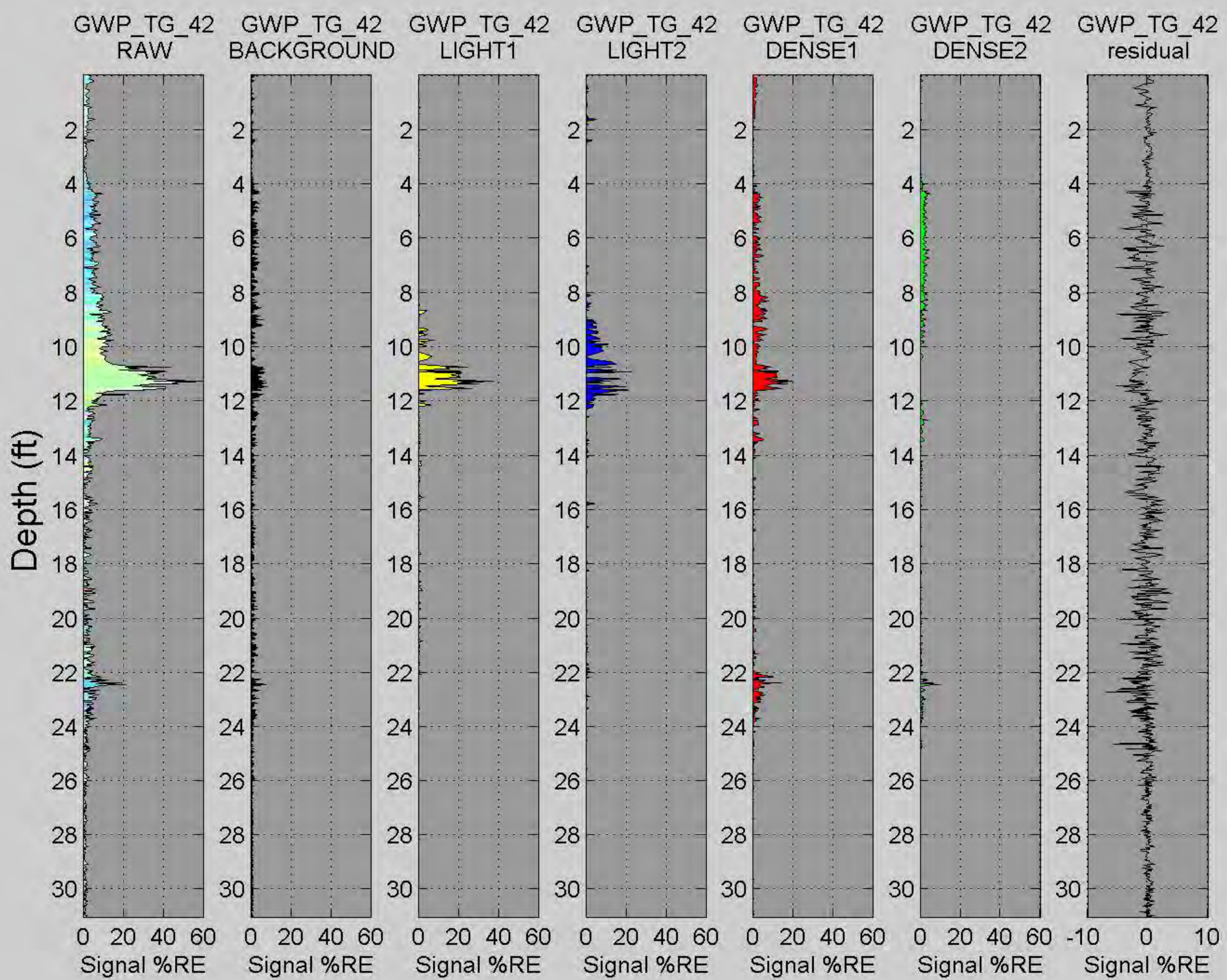

GWP_TG_41
Depth (ft)
Signal (%RE)
← 23.53
← 27.38
Waveform at 7 ft
Signal (mV)
Time (ns)
575
625
675
Background
LIGHT1
LIGHT2
DENSE1
DENSE2
Component E
Signal (mV)
Time (ns)



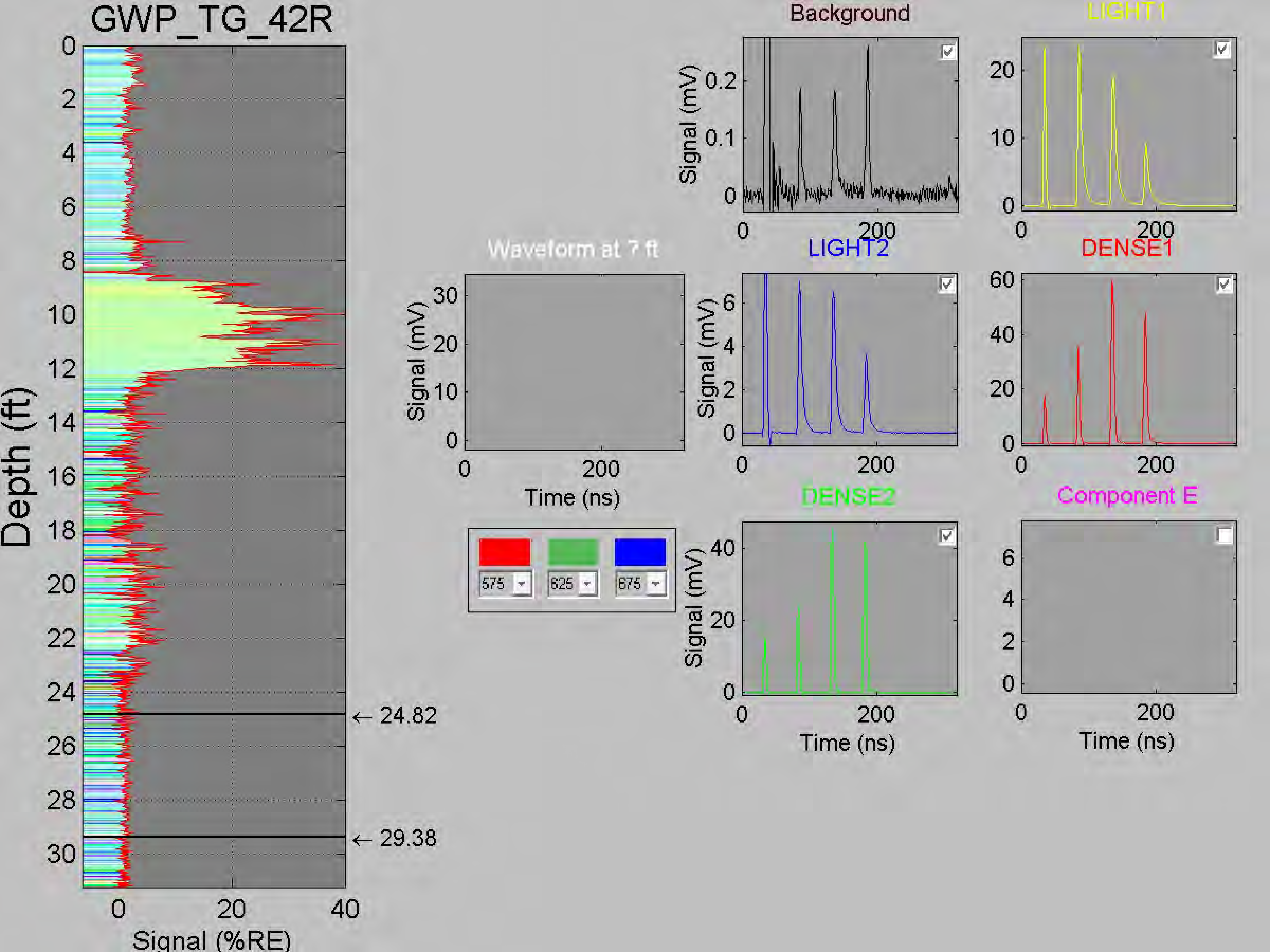
GWP_TG_41
RAW
GWP_TG_41
BACKGROUND
GWP_TG_41
LIGHT1
GWP_TG_41
LIGHT2
GWP_TG_41
DENSE1
GWP_TG_41
DENSE2
GWP_TG_41
residual
Depth (ft)
2
4
6
8
10
12
14
16
18
20
22
24
26
28
0
10
20
-10
Signal %RE



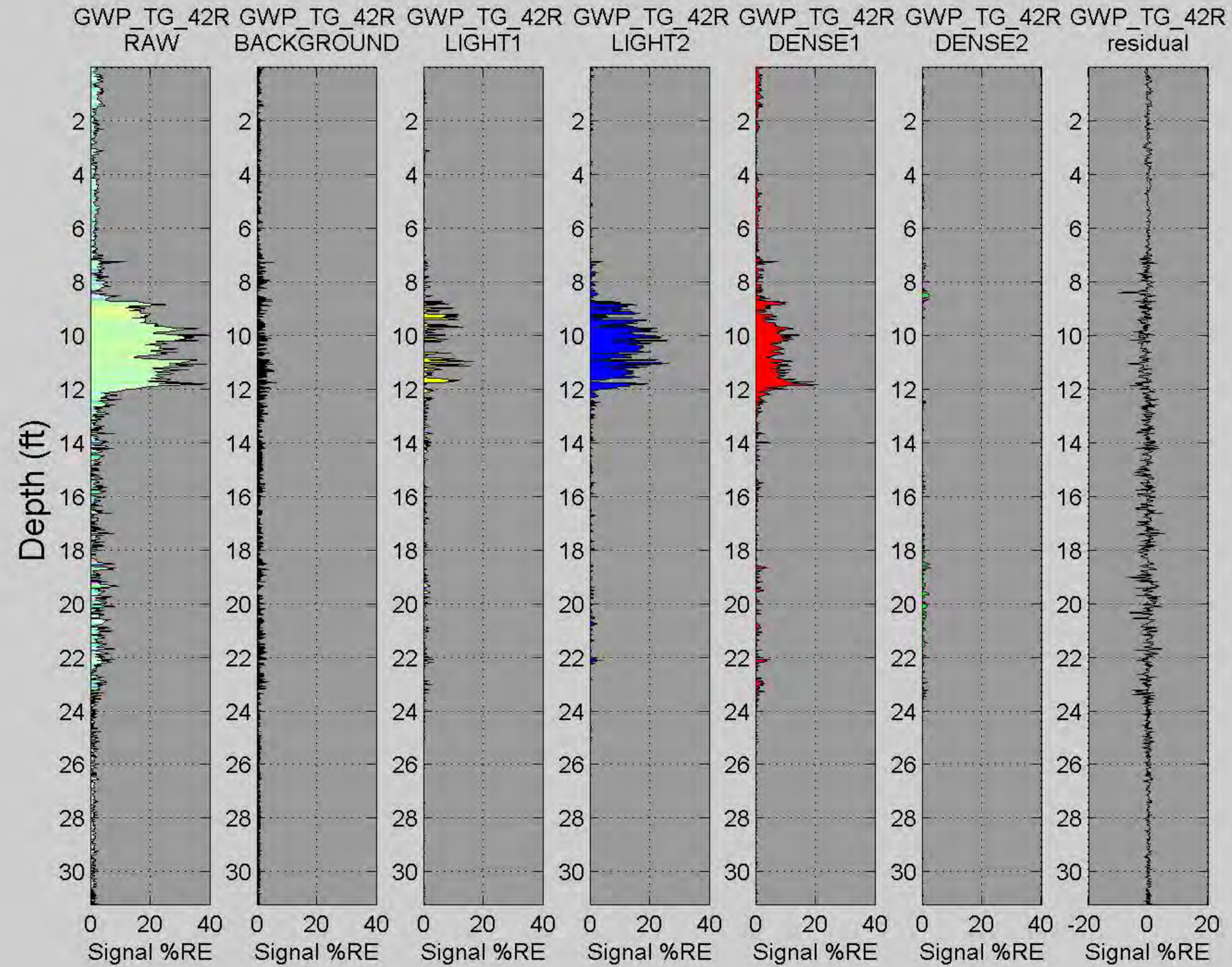
GWP_TG_42
Depth (ft)
Signal (%RE)
← 27.00
← 30.15
Background
LIGHT1
Waveform at 7 ft
LIGHT2
DENSE1
DENSE2
Component E
Signal (mV)
Time (ns)
575
625
675

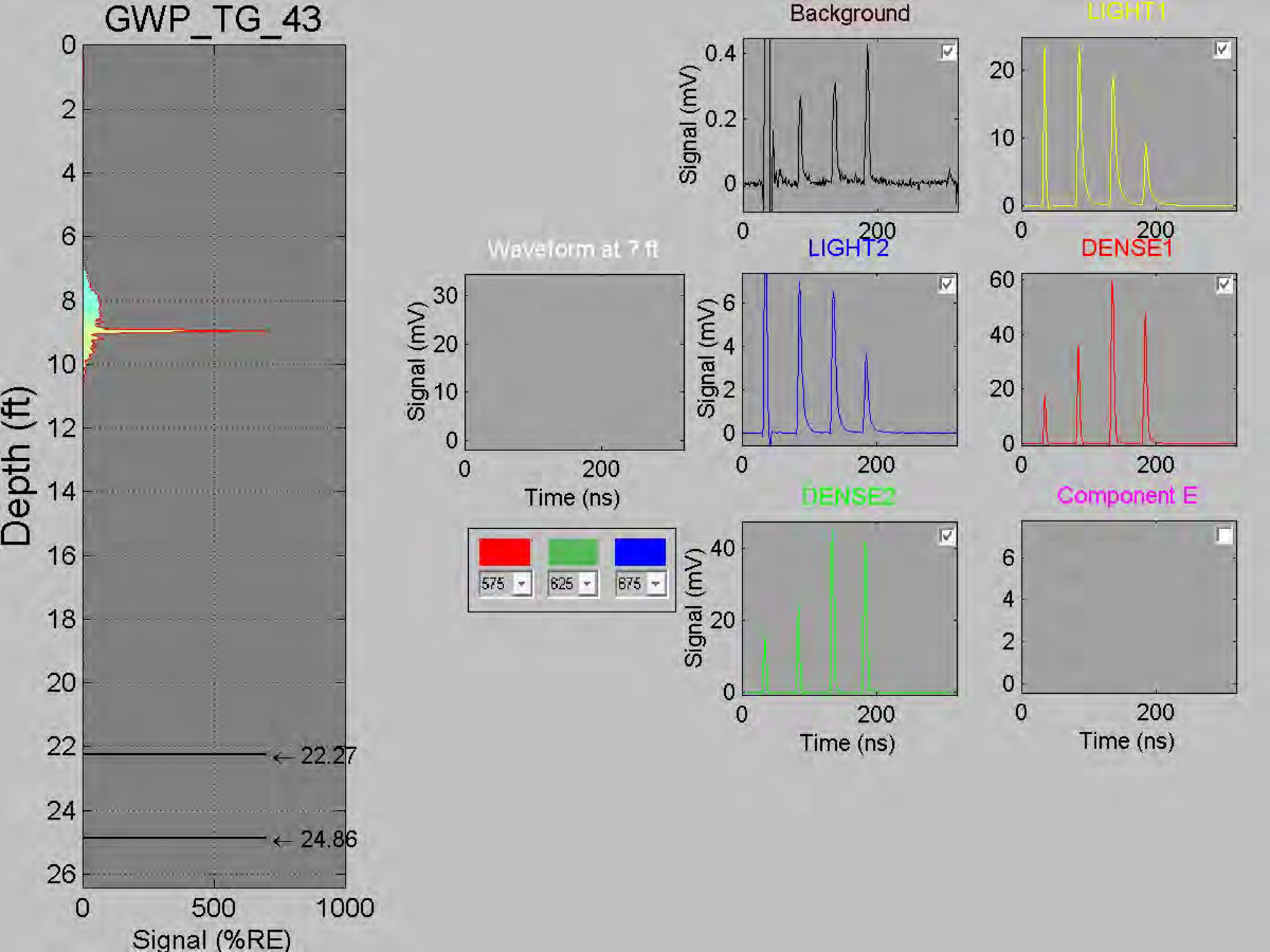


GWP_TG_42
RAW
GWP_TG_42
BACKGROUND
GWP_TG_42
LIGHT1
GWP_TG_42
LIGHT2
GWP_TG_42
DENSE1
GWP_TG_42
DENSE2
GWP_TG_42
residual
Depth (ft)
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
0 20 40 60
-10 0 10
Signal %RE

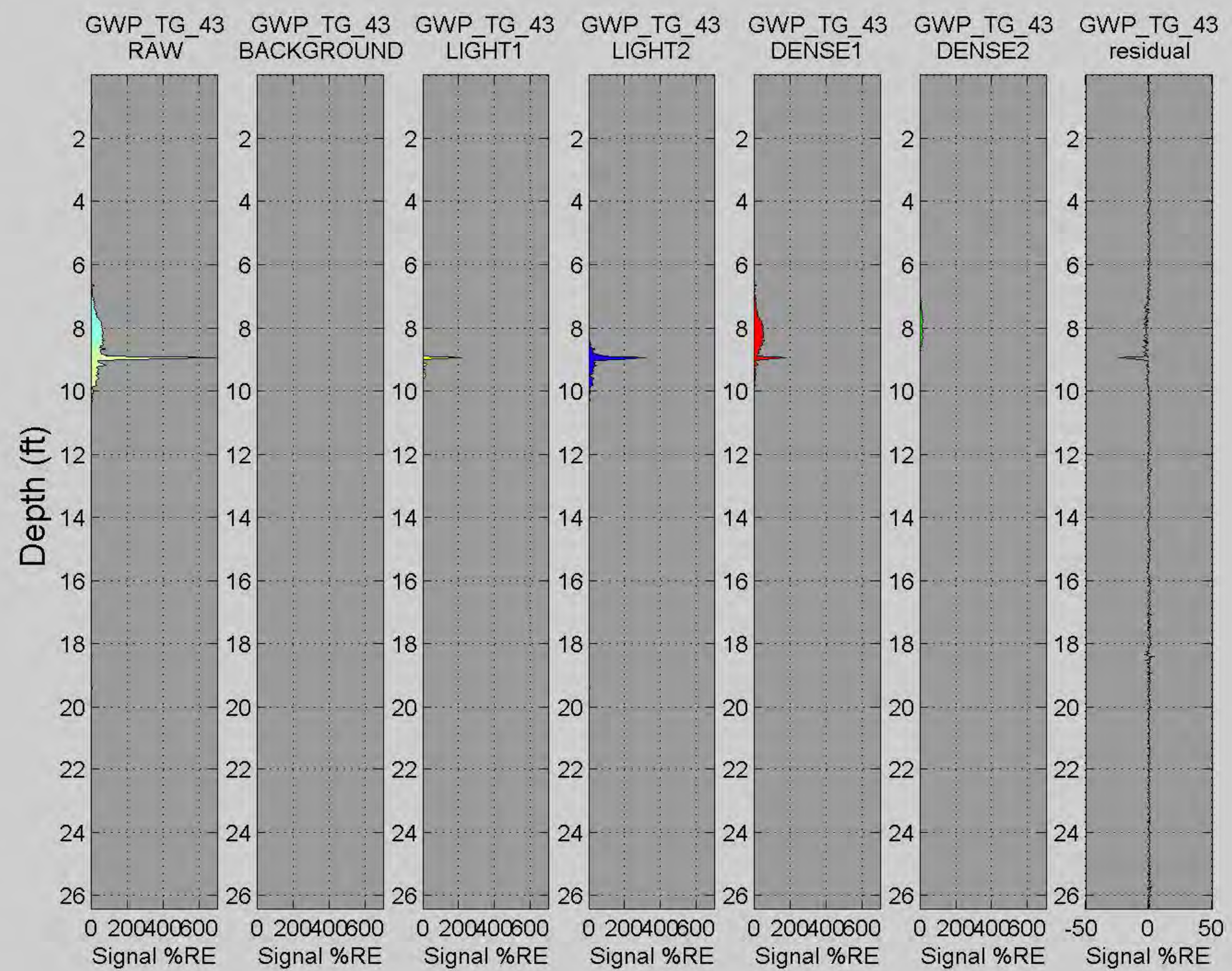


GWP_TG_42R
Depth (ft)
Signal (%RE)
← 24.82
← 29.38
Background
LIGHT1
Waveform at 7 ft
LIGHT2
DENSE1
DENSE2
Component E
Signal (mV)
Time (ns)
575
625
675

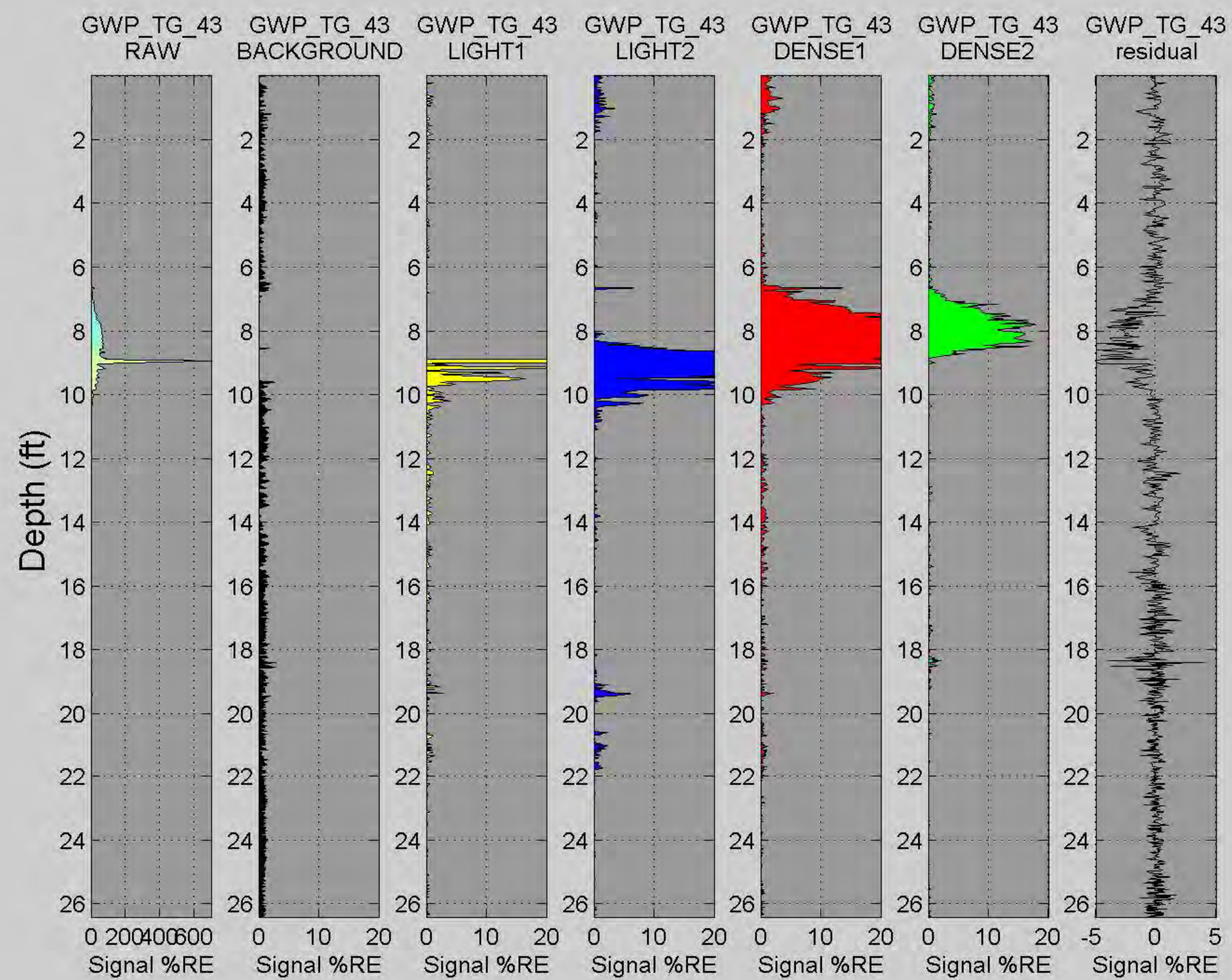

GWP_TG_42R RAW
GWP_TG_42R BACKGROUND
GWP_TG_42R LIGHT1
GWP_TG_42R LIGHT2
GWP_TG_42R DENSE1
GWP_TG_42R DENSE2
GWP_TG_42R residual
Depth (ft)
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
0
20
40
-20
Signal %RE



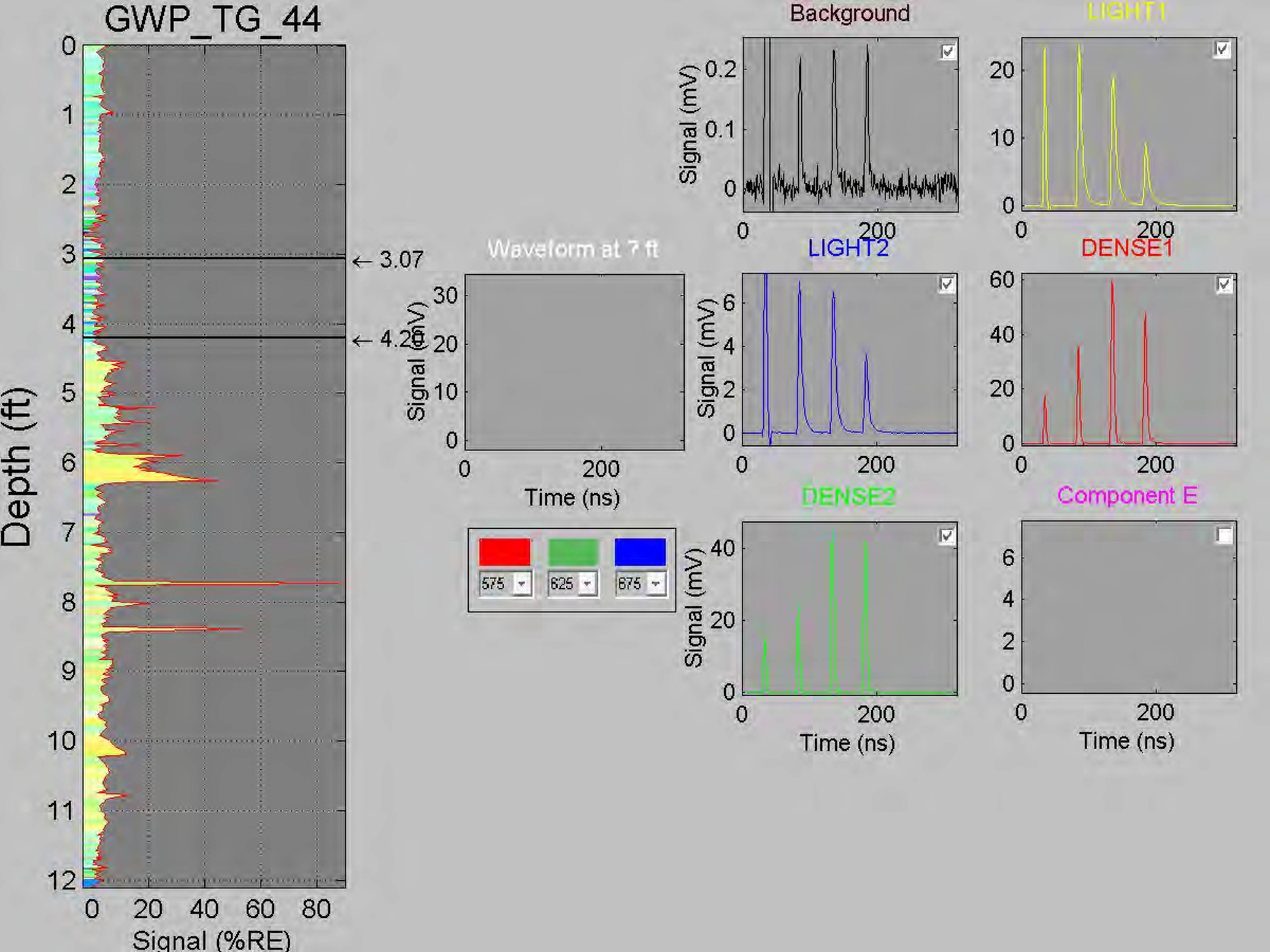
GWP_TG_43
Depth (ft)
Signal (%RE)
← 22.27
← 24.86
Background
LIGHT1
Waveform at 7 ft
LIGHT2
DENSE1
DENSE2
Component E
Signal (mV)
Time (ns)
575
625
675

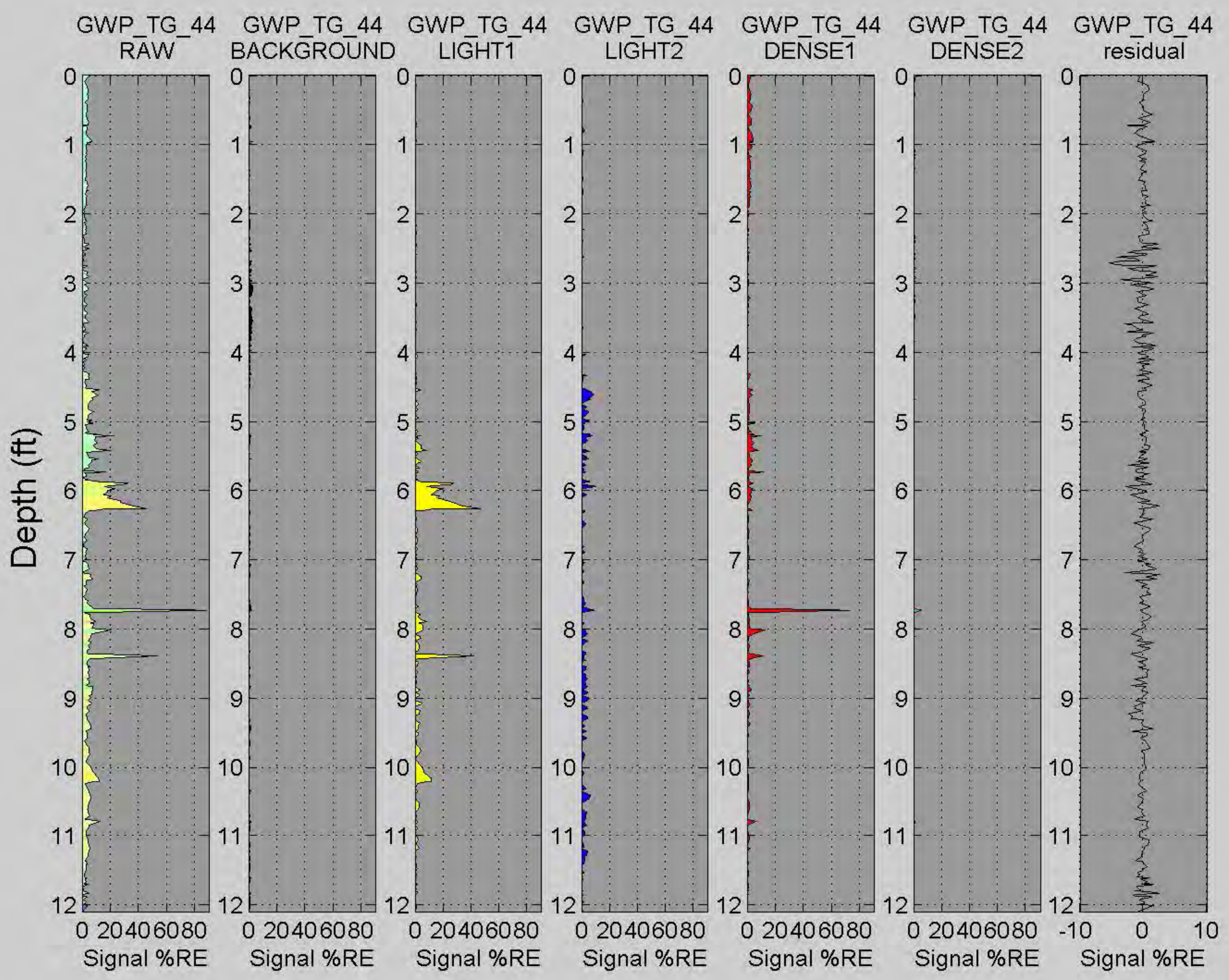


GWP_TG_43
RAW
GWP_TG_43
BACKGROUND
GWP_TG_43
LIGHT1
GWP_TG_43
LIGHT2
GWP_TG_43
DENSE1
GWP_TG_43
DENSE2
GWP_TG_43
residual
Depth (ft)
2
4
6
8
10
12
14
16
18
20
22
24
26
0 200400600
-50 0 50
Signal %RE

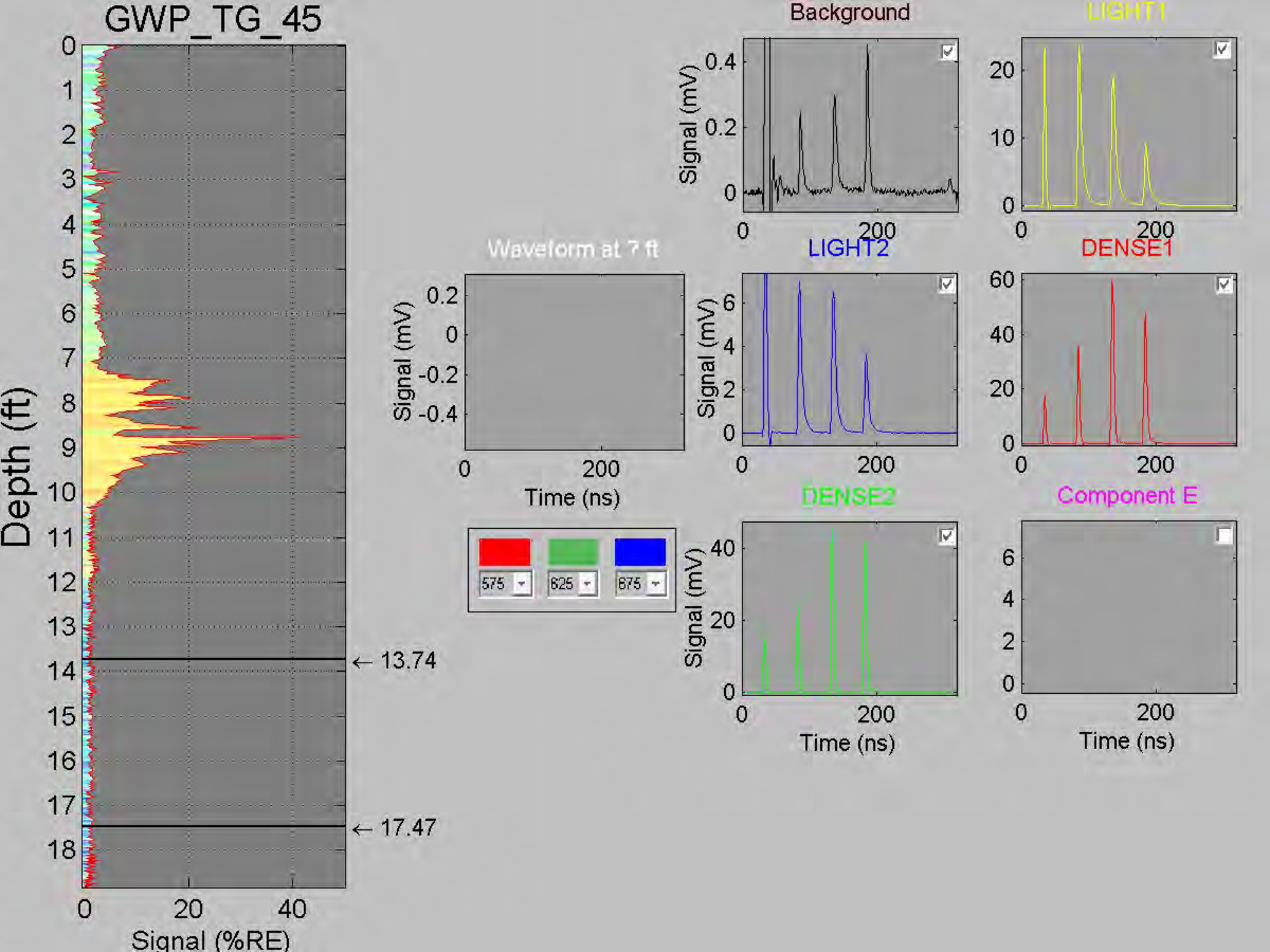


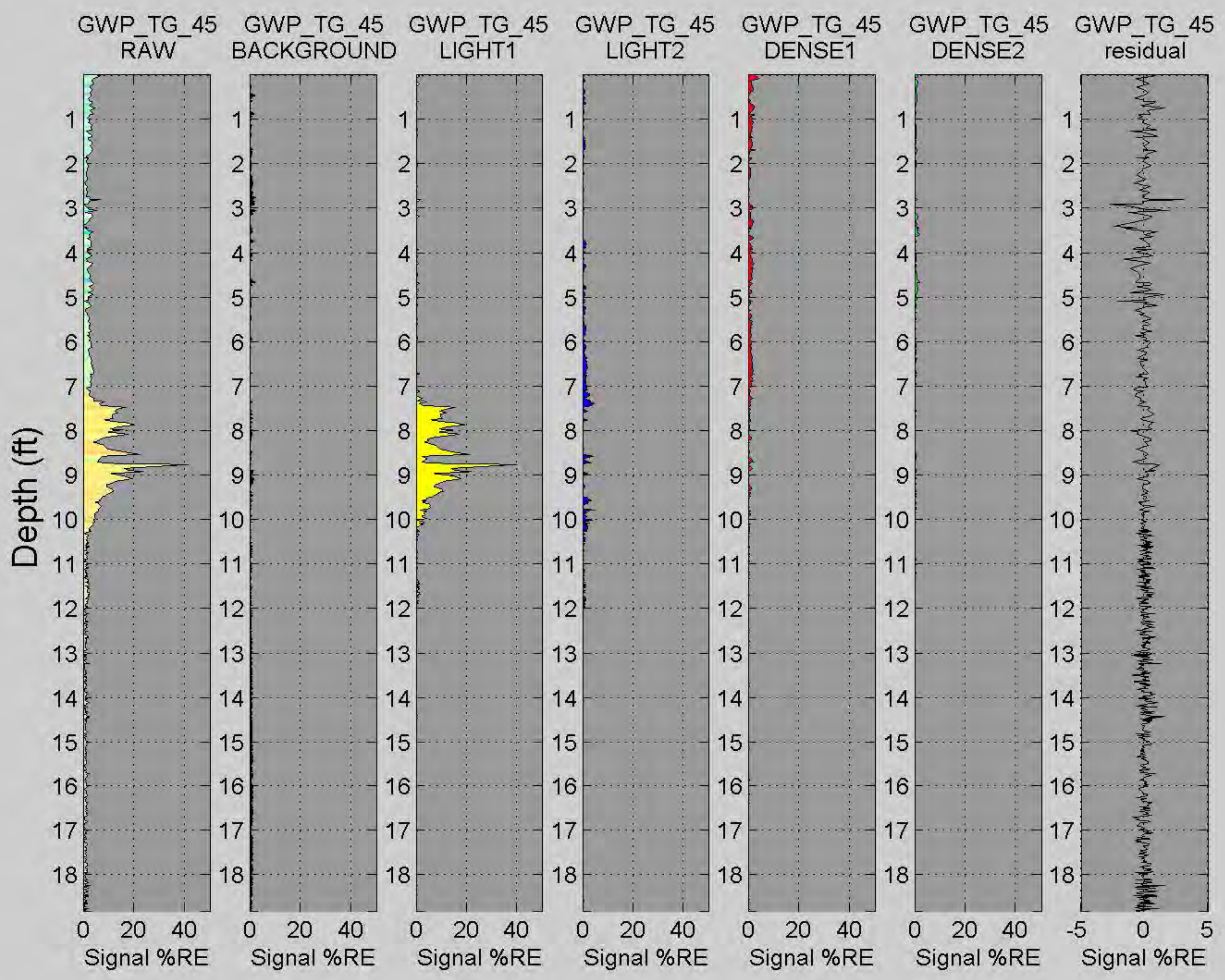
GWP_TG_43
RAW
GWP_TG_43
BACKGROUND
GWP_TG_43
LIGHT1
GWP_TG_43
LIGHT2
GWP_TG_43
DENSE1
GWP_TG_43
DENSE2
GWP_TG_43
residual
Depth (ft)
2
4
6
8
10
12
14
16
18
20
22
24
26
0 200 400 600
0 10 20
-5 0 5
Signal %RE


GWP_TG_44
Depth (ft)
Signal (%RE)
← 3.07
← 4.20
Waveform at 7 ft
Signal (mV)
Time (ns)
575
625
675
Background
LIGHT1
LIGHT2
DENSE1
DENSE2
Component E

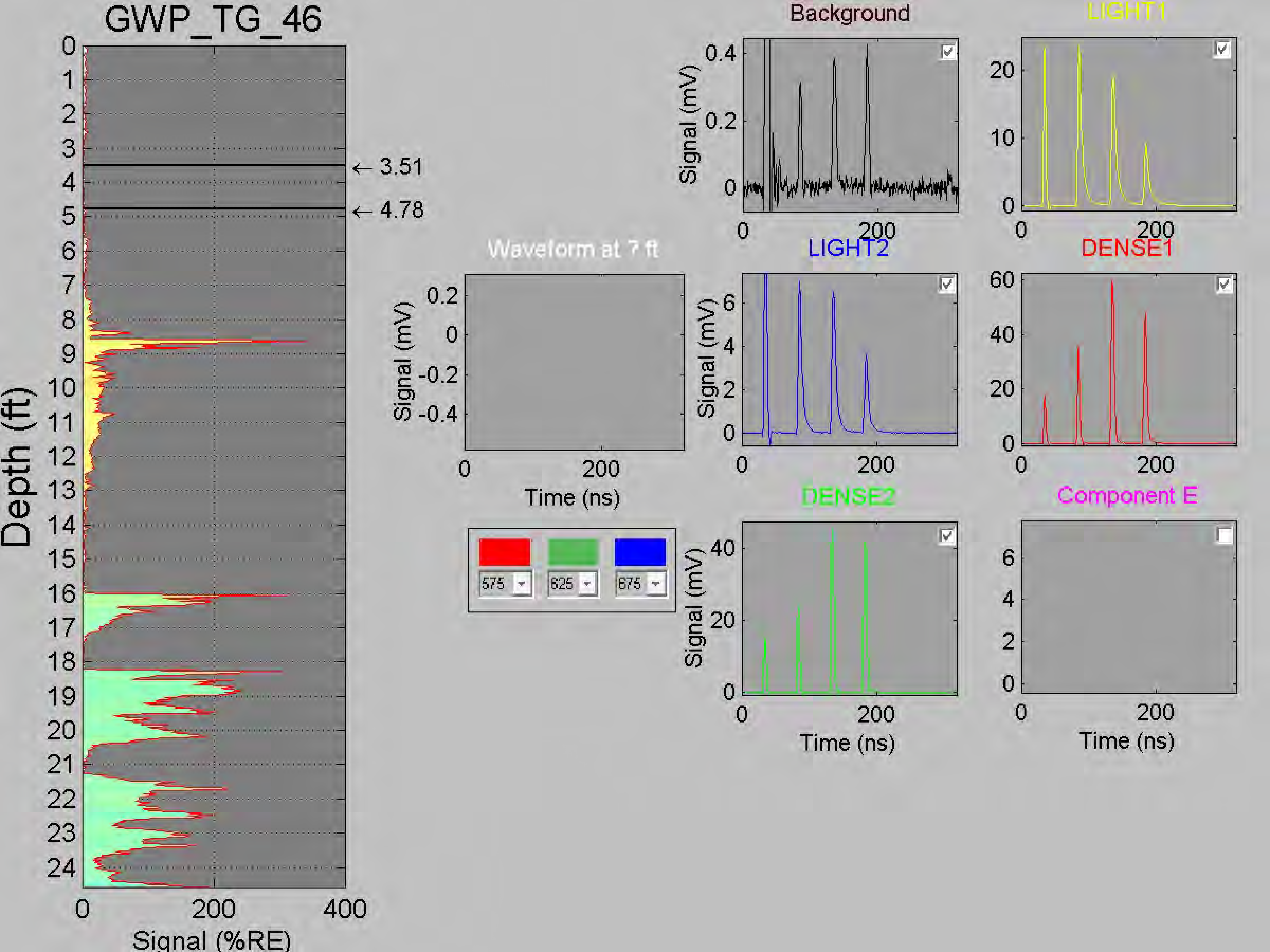


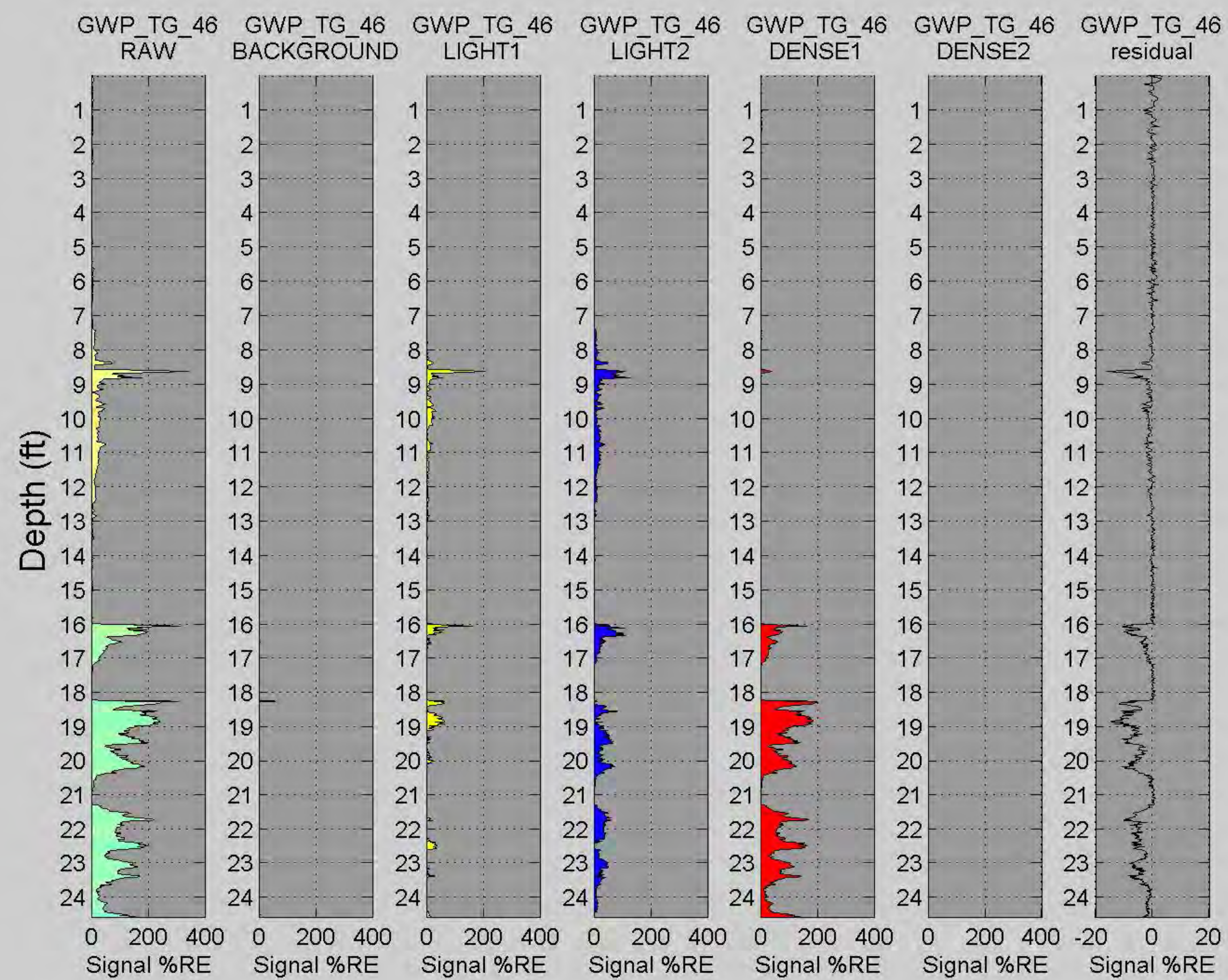
GWP_TG_44 RAW
GWP_TG_44 BACKGROUND
GWP_TG_44 LIGHT1
GWP_TG_44 LIGHT2
GWP_TG_44 DENSE1
GWP_TG_44 DENSE2
GWP_TG_44 residual
Depth (ft)
0 1 2 3 4 5 6 7 8 9 10 11 12
0 20 40 60 80
-10 0 10
Signal %RE


GWP_TG_45
Depth (ft)
Signal (%RE)
← 13.74
← 17.47
Background
LIGHT1
LIGHT2
DENSE1
DENSE2
Component E
Waveform at 7 ft
Signal (mV)
Time (ns)
575
625
675



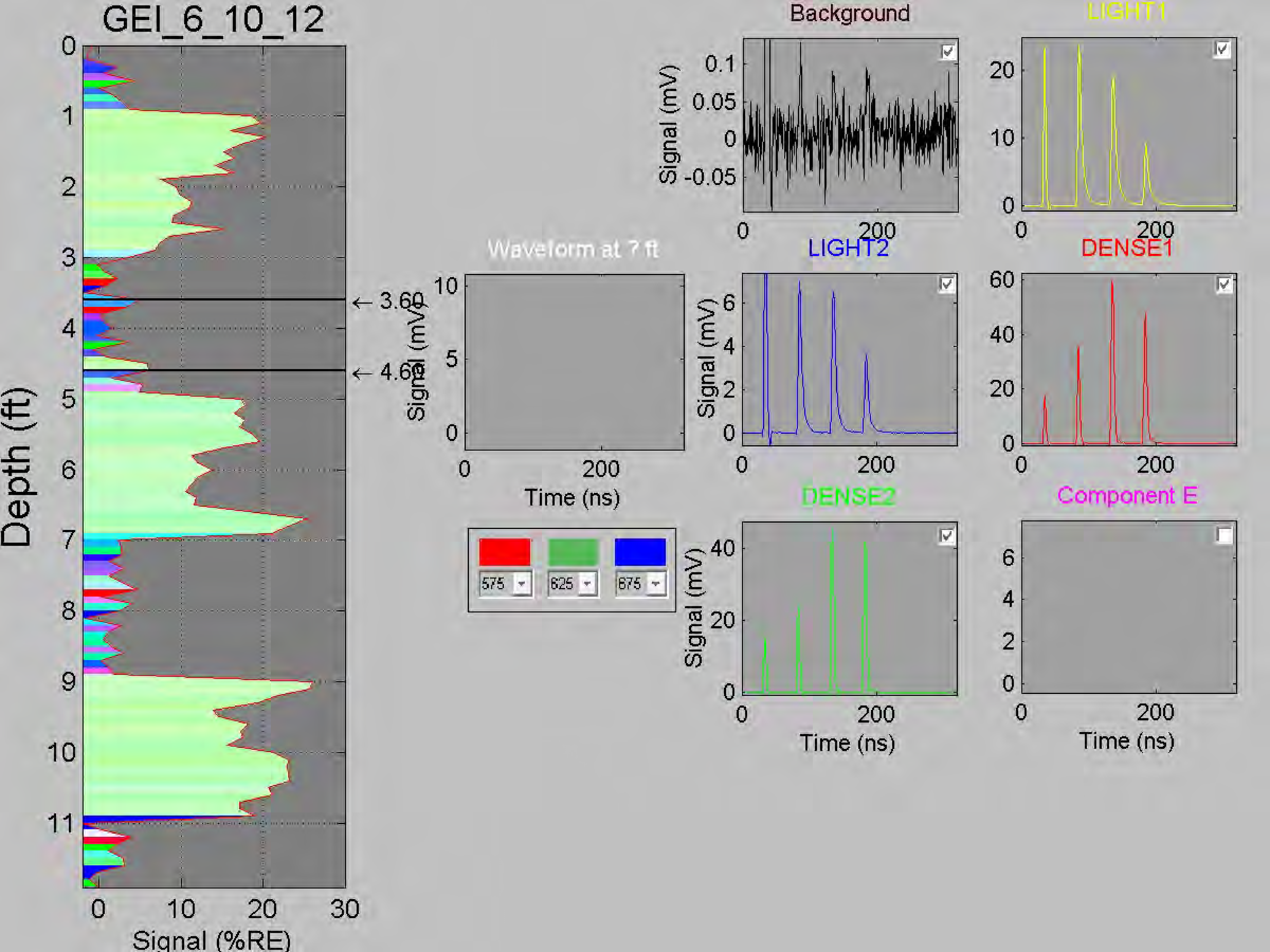
GWP_TG_45
RAW
GWP_TG_45
BACKGROUND
GWP_TG_45
LIGHT1
GWP_TG_45
LIGHT2
GWP_TG_45
DENSE1
GWP_TG_45
DENSE2
GWP_TG_45
residual
Depth (ft)
Signal %RE


GWP_TG_46
Depth (ft)
3.51
4.78
Signal (%RE)
Background
LIGHT1
Waveform at 7 ft
LIGHT2
DENSE1
DENSE2
Component E
Signal (mV)
Time (ns)
575
625
675

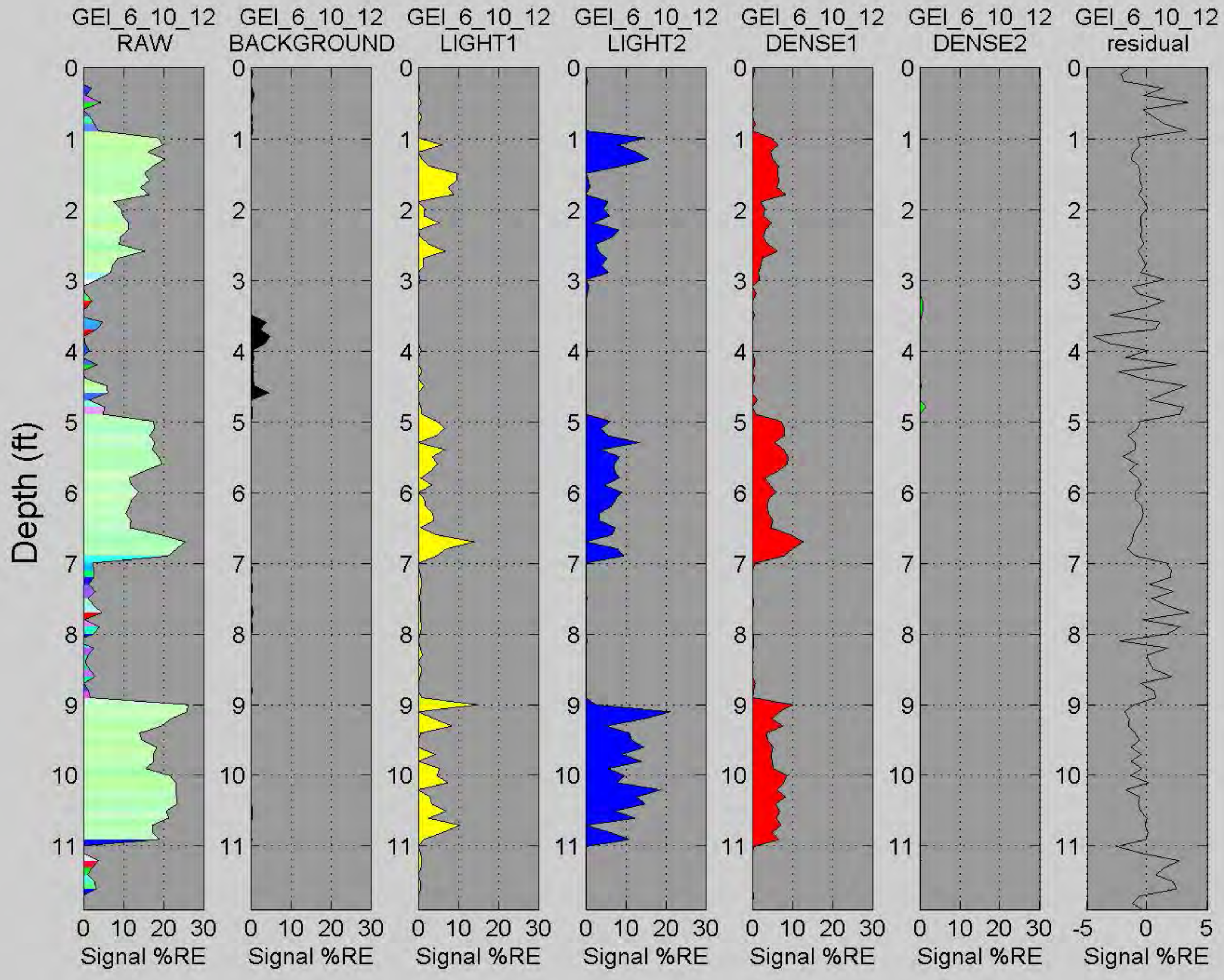


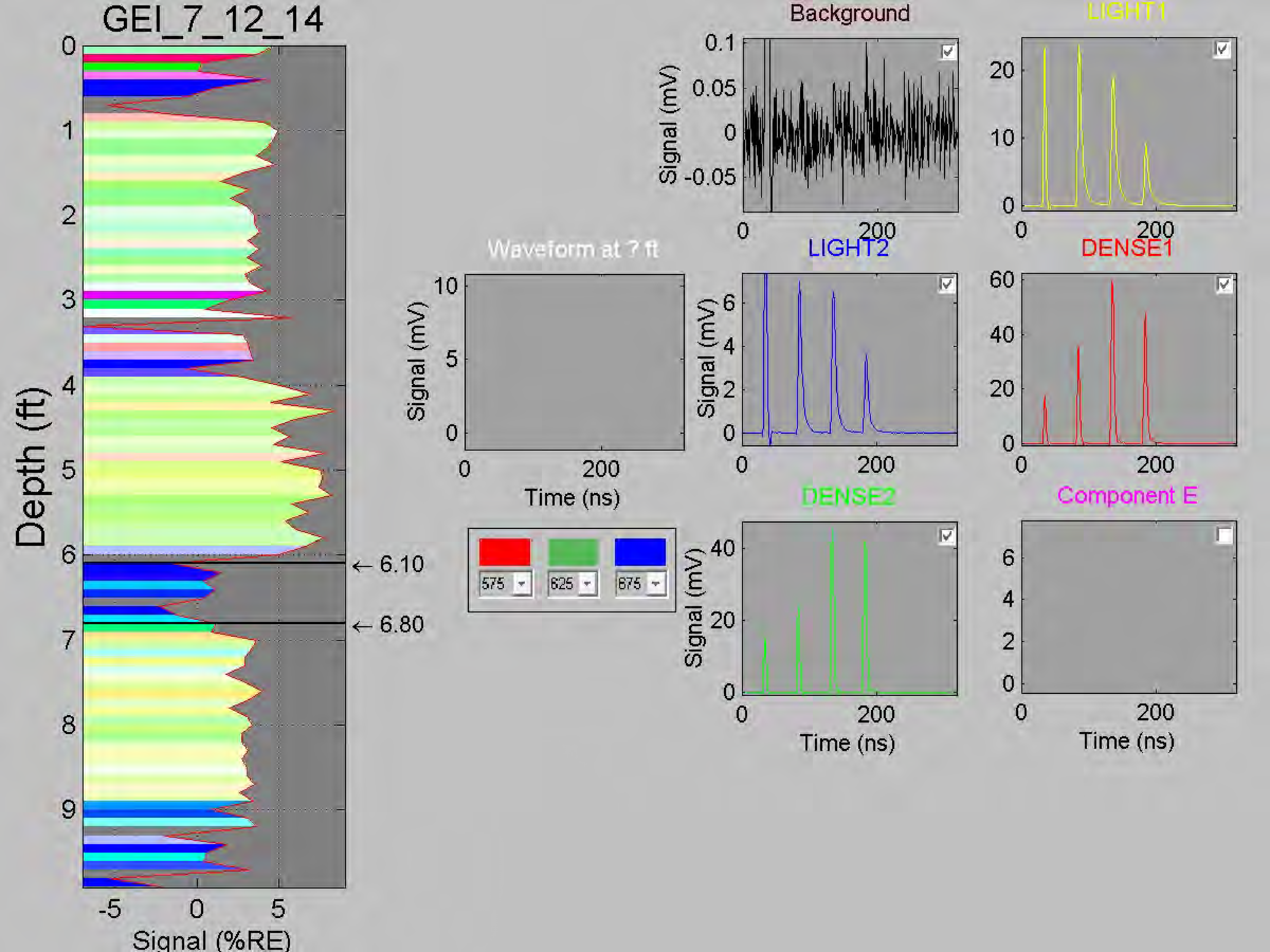
GWP_TG_46 RAW
GWP_TG_46 BACKGROUND
GWP_TG_46 LIGHT1
GWP_TG_46 LIGHT2
GWP_TG_46 DENSE1
GWP_TG_46 DENSE2
GWP_TG_46 residual
Depth (ft)
Signal %RE

SUB-ATTACHMENT 2A-2.7.3
NNLS Confirmation Samples

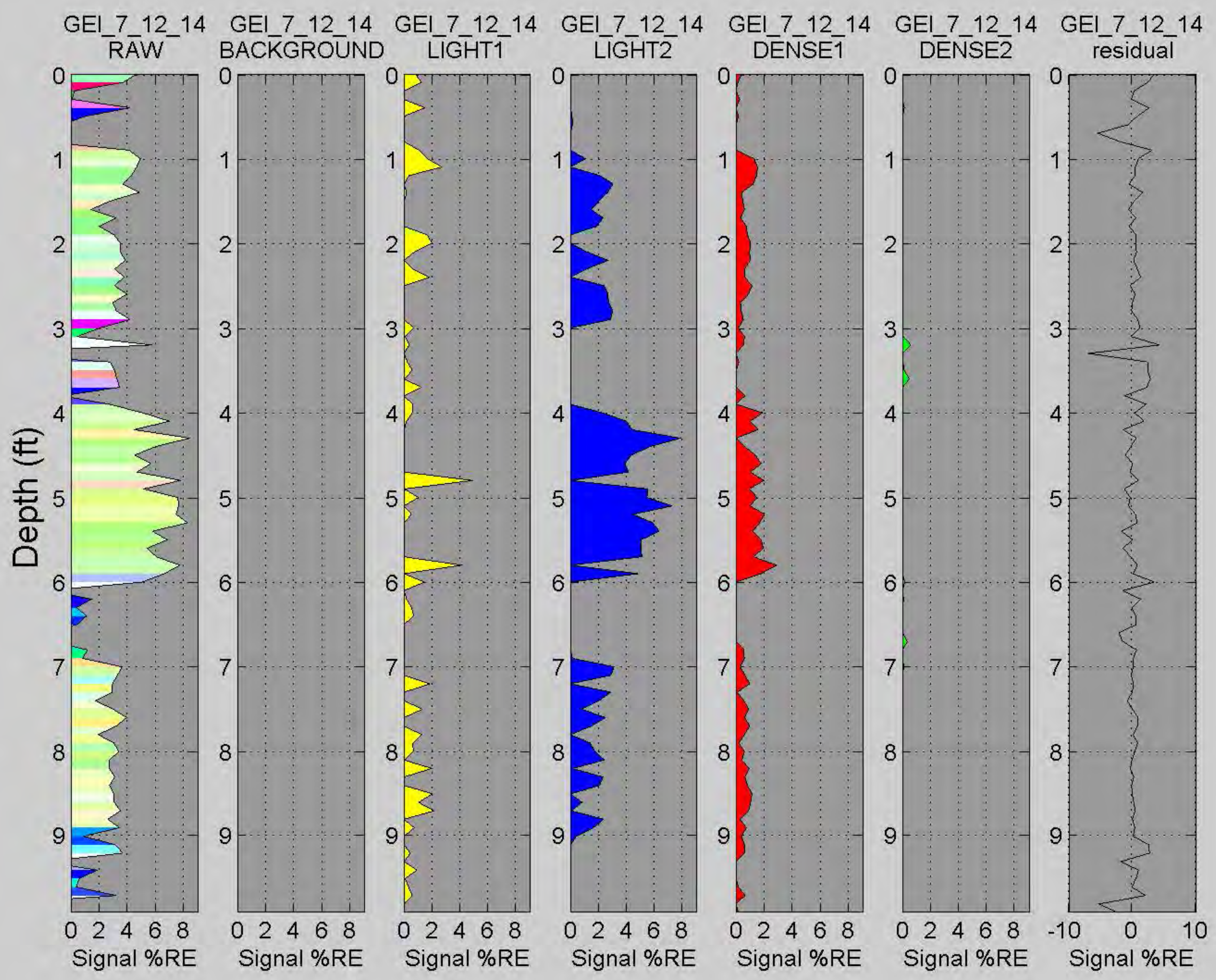


GEI_6_10_12
Depth (ft)
Signal (%RE)
← 3.60
← 4.60
Waveform at ? ft
Signal (mV)
Time (ns)
575
625
675
Background
LIGHT1
LIGHT2
DENSE1
DENSE2
Component E

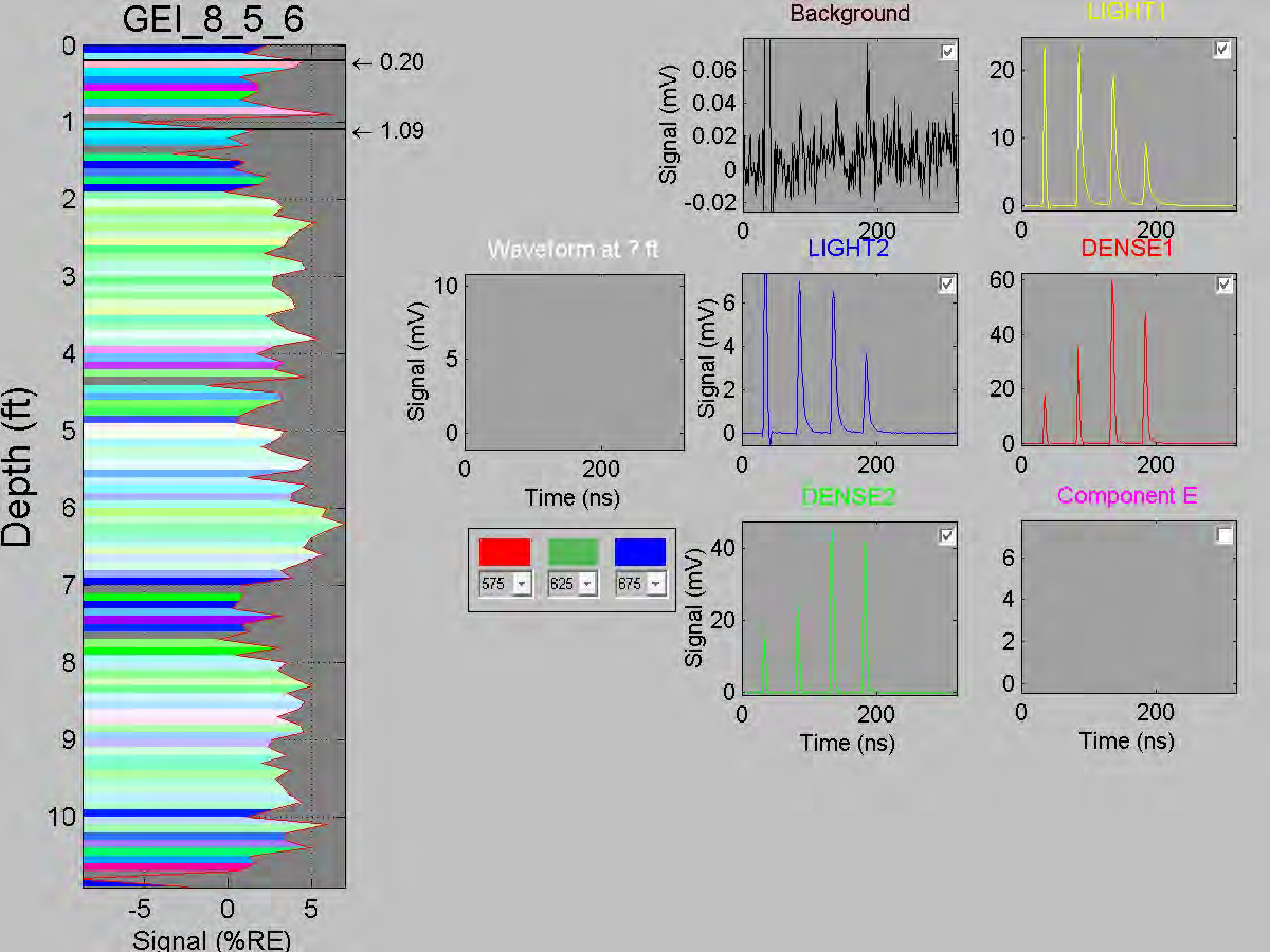

GEI_6_10_12 RAW
GEI_6_10_12 BACKGROUND
GEI_6_10_12 LIGHT1
GEI_6_10_12 LIGHT2
GEI_6_10_12 DENSE1
GEI_6_10_12 DENSE2
GEI_6_10_12 residual
Depth (ft)
Signal %RE



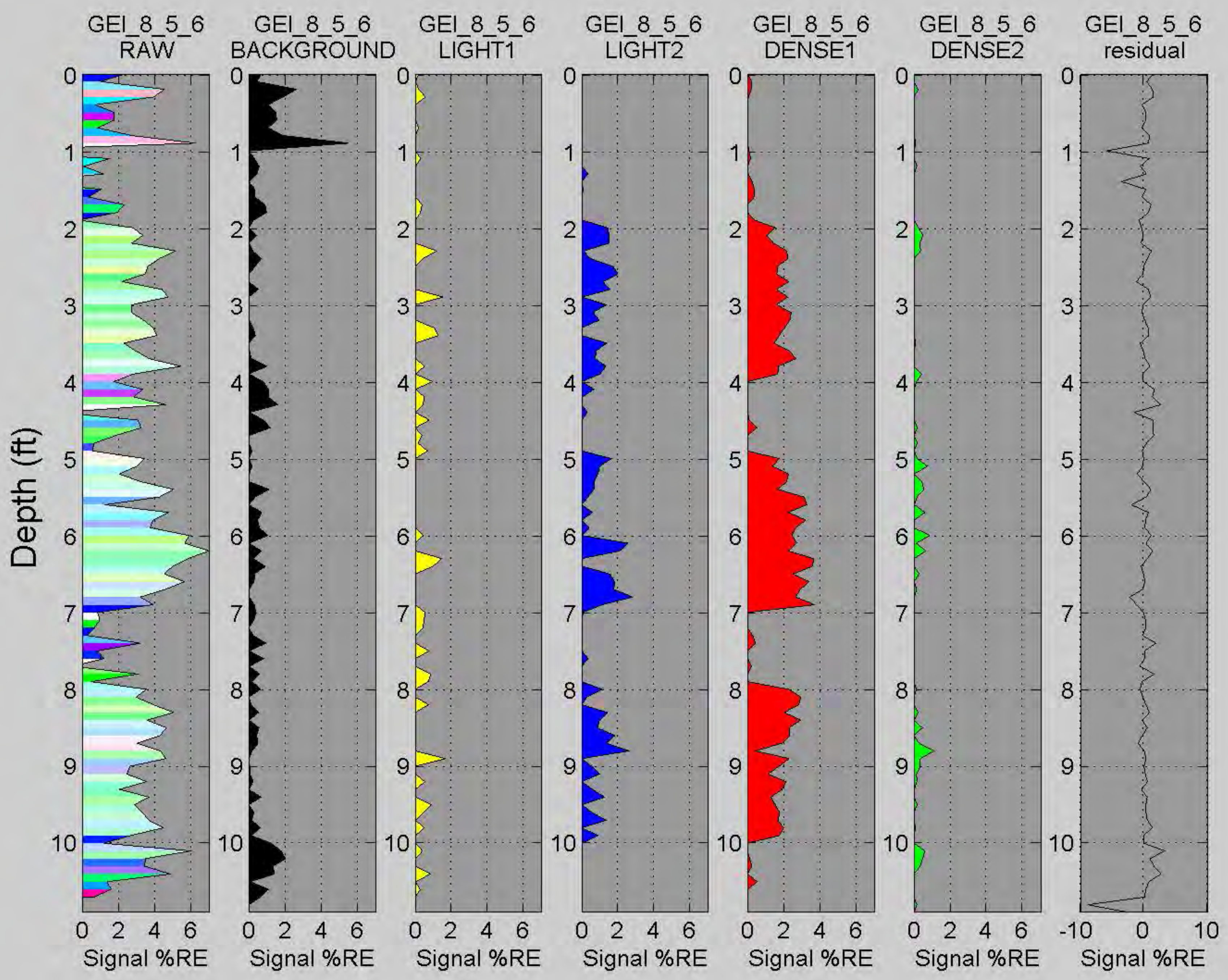
GEI_7_12_14
Depth (ft)
Signal (%RE)
← 6.10
← 6.80
Background
LIGHT1
Waveform at ? ft
LIGHT2
DENSE1
DENSE2
Component E
Signal (mV)
Time (ns)
575
625
675



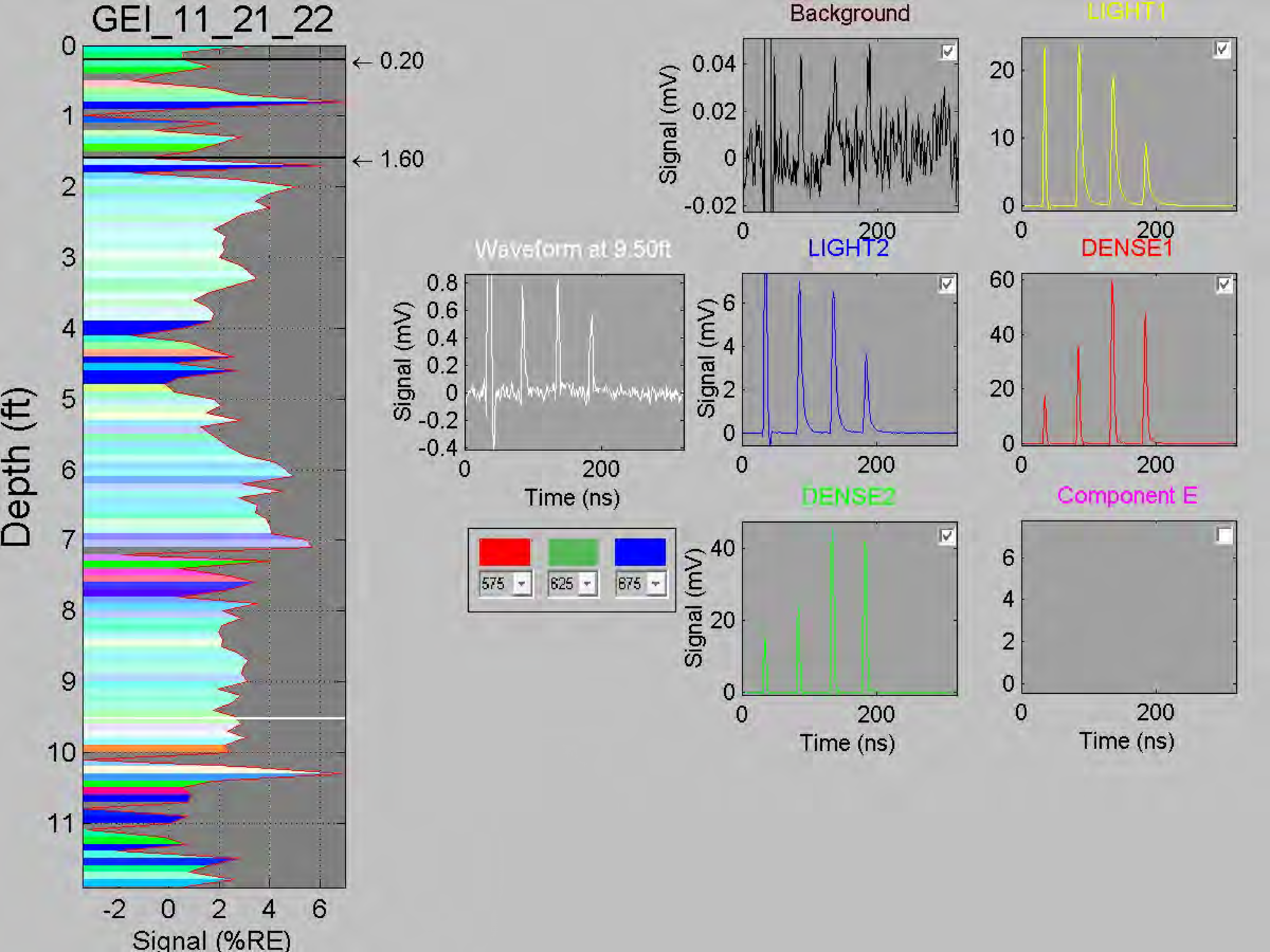
GEI_7_12_14
RAW
GEI_7_12_14
BACKGROUND
GEI_7_12_14
LIGHT1
GEI_7_12_14
LIGHT2
GEI_7_12_14
DENSE1
GEI_7_12_14
DENSE2
GEI_7_12_14
residual
Depth (ft)
0 1 2 3 4 5 6 7 8 9
0 2 4 6 8
-10 0 10
Signal %RE

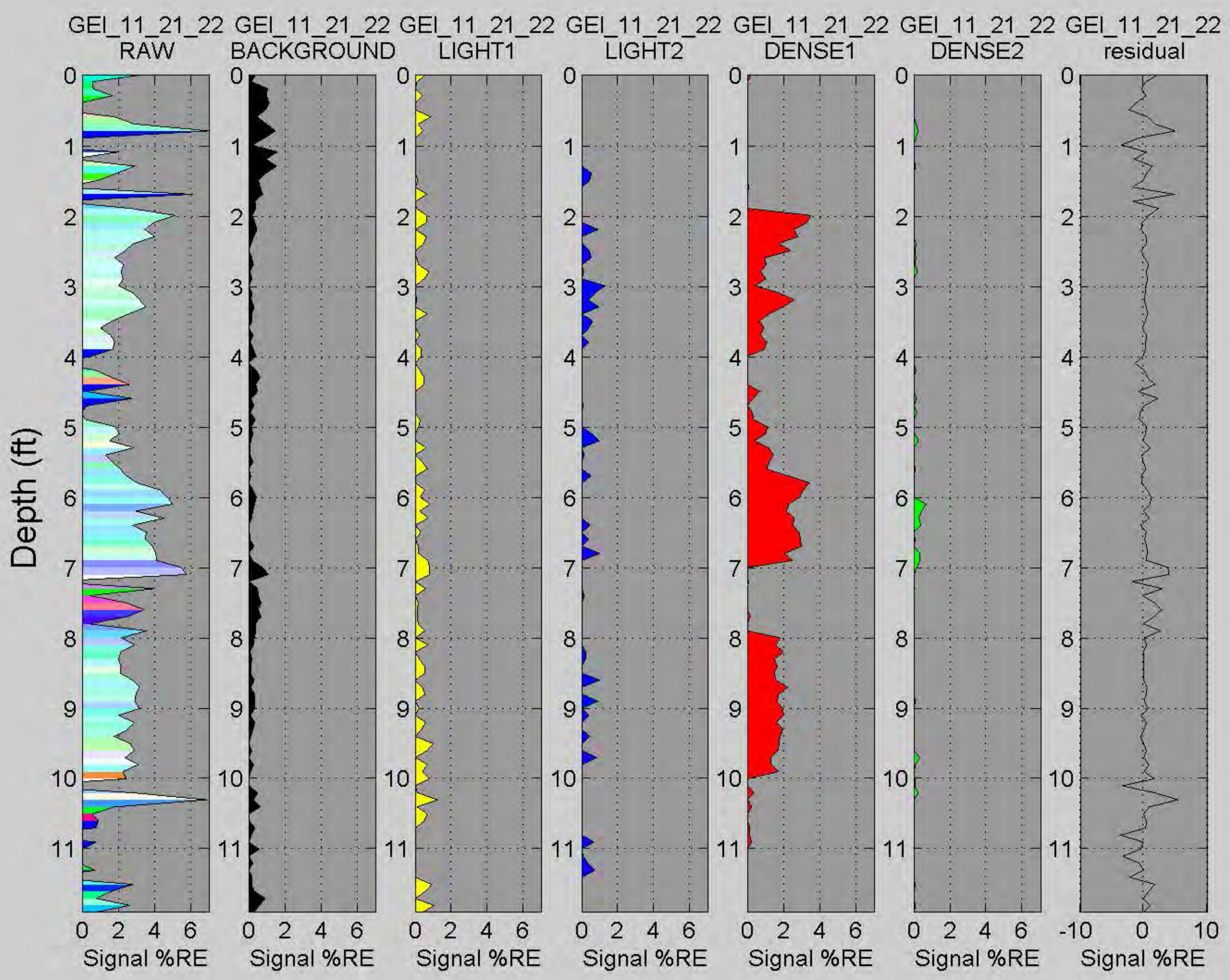


GEI_8_5_6
← 0.20
← 1.09
Depth (ft)
Signal (%RE)
Background
LIGHT1
Waveform at ? ft
LIGHT2
DENSE1
DENSE2
Component E
Signal (mV)
Time (ns)
575
625
675

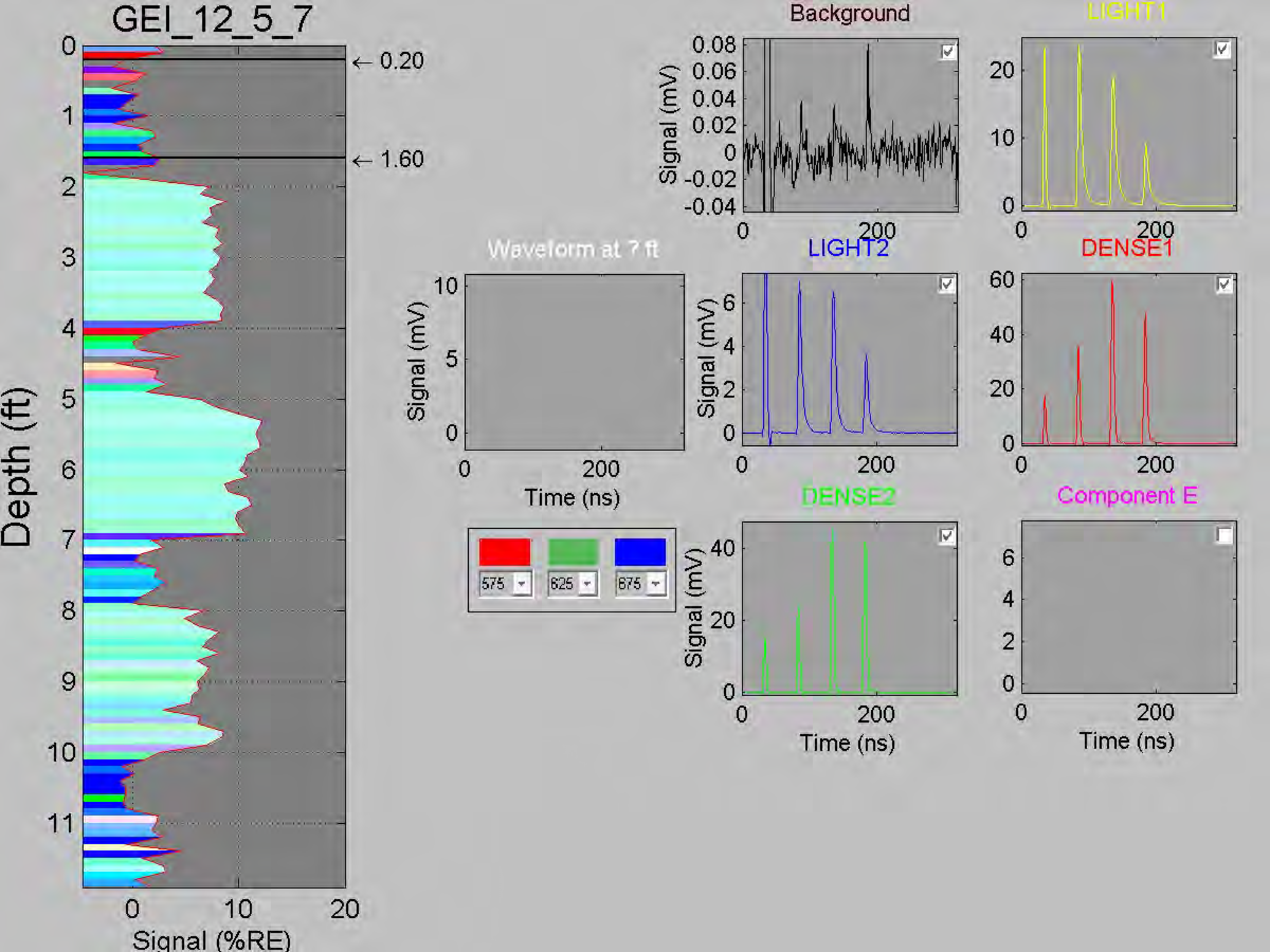


GEI_8_5_6
RAW
GEI_8_5_6
BACKGROUND
GEI_8_5_6
LIGHT1
GEI_8_5_6
LIGHT2
GEI_8_5_6
DENSE1
GEI_8_5_6
DENSE2
GEI_8_5_6
residual
Depth (ft)
Signal %RE

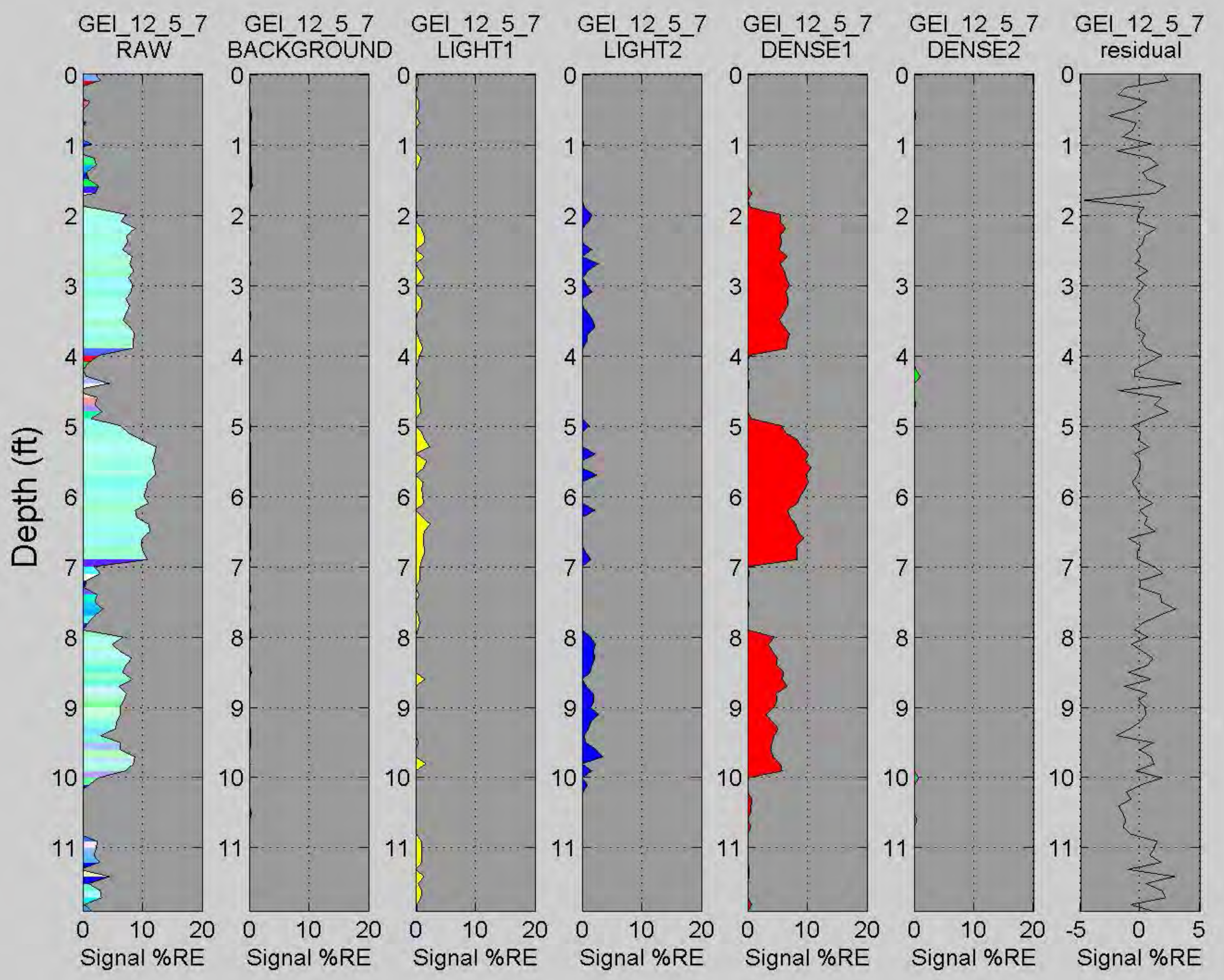

GEI_11_21_22
Depth (ft)
← 0.20
← 1.60
Signal (%RE)
Background
LIGHT1
Waveform at 9.50ft
LIGHT2
DENSE1
DENSE2
Component E
Signal (mV)
Time (ns)
575
625
675



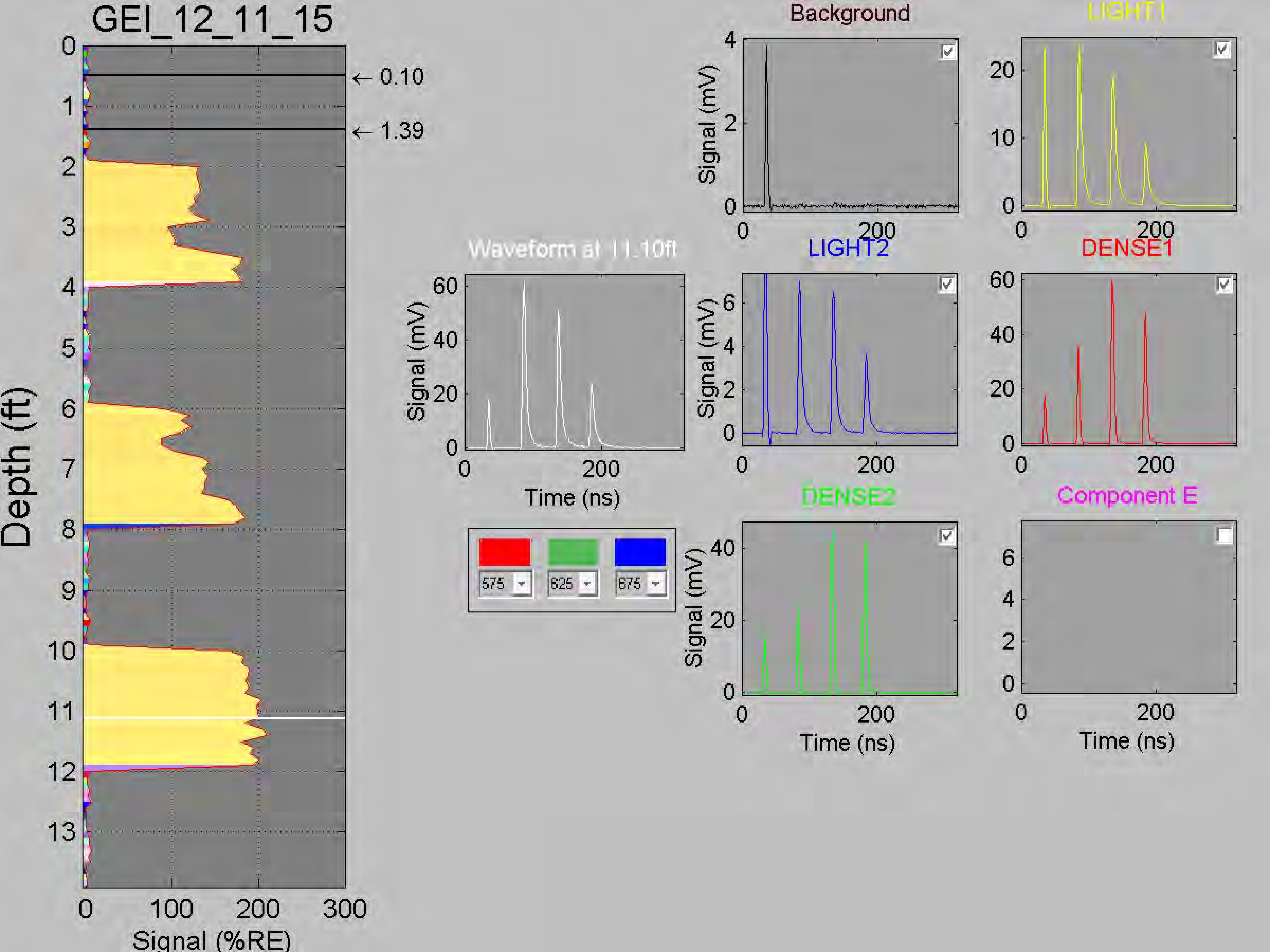
GEI_11_21_22 RAW
GEI_11_21_22 BACKGROUND
GEI_11_21_22 LIGHT1
GEI_11_21_22 LIGHT2
GEI_11_21_22 DENSE1
GEI_11_21_22 DENSE2
GEI_11_21_22 residual
Depth (ft)
Signal %RE

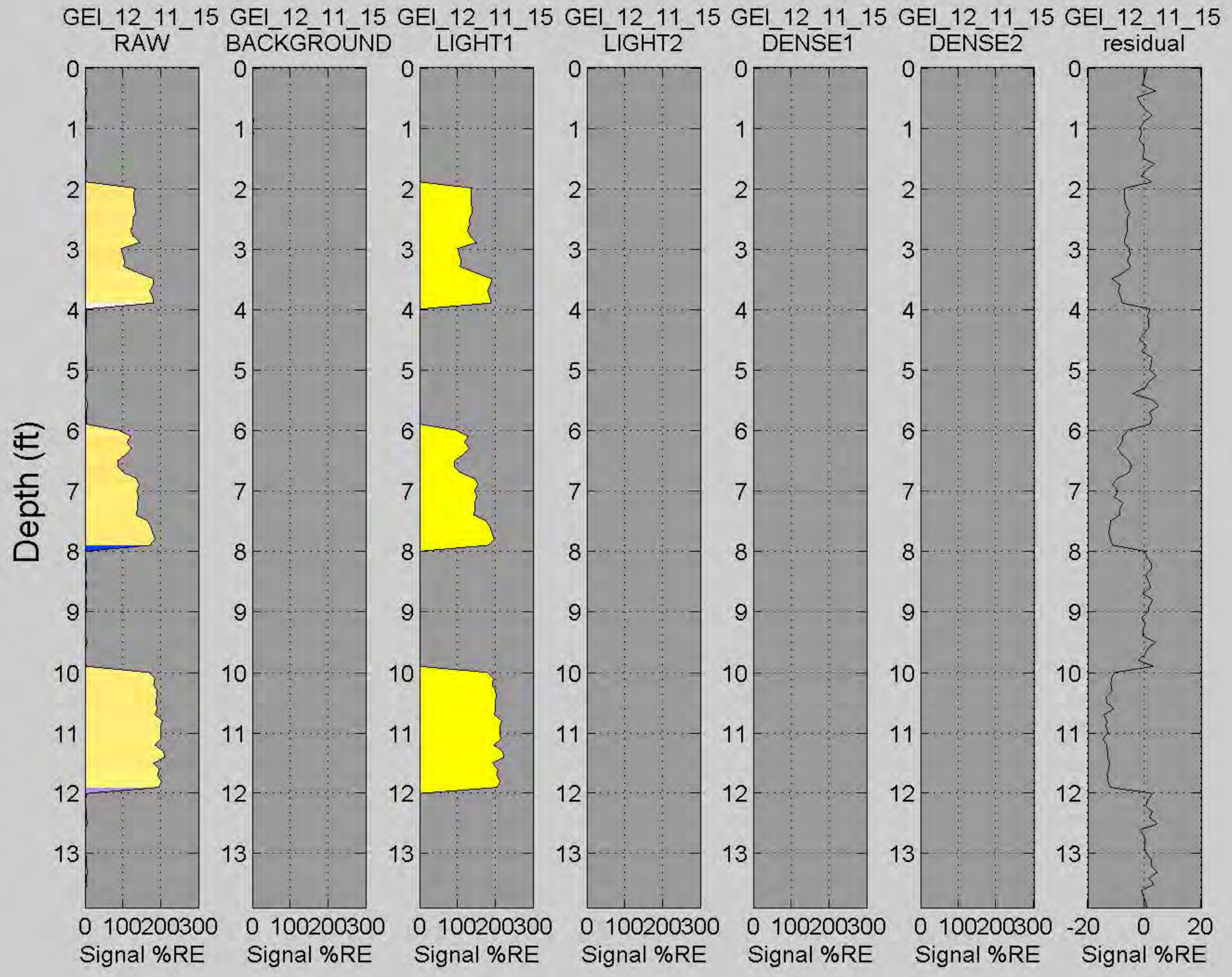


GEI_12_5_7
Depth (ft)
Signal (%RE)
← 0.20
← 1.60
Background
LIGHT1
LIGHT2
DENSE1
DENSE2
Component E
Waveform at ? ft
Signal (mV)
Time (ns)
575
625
675

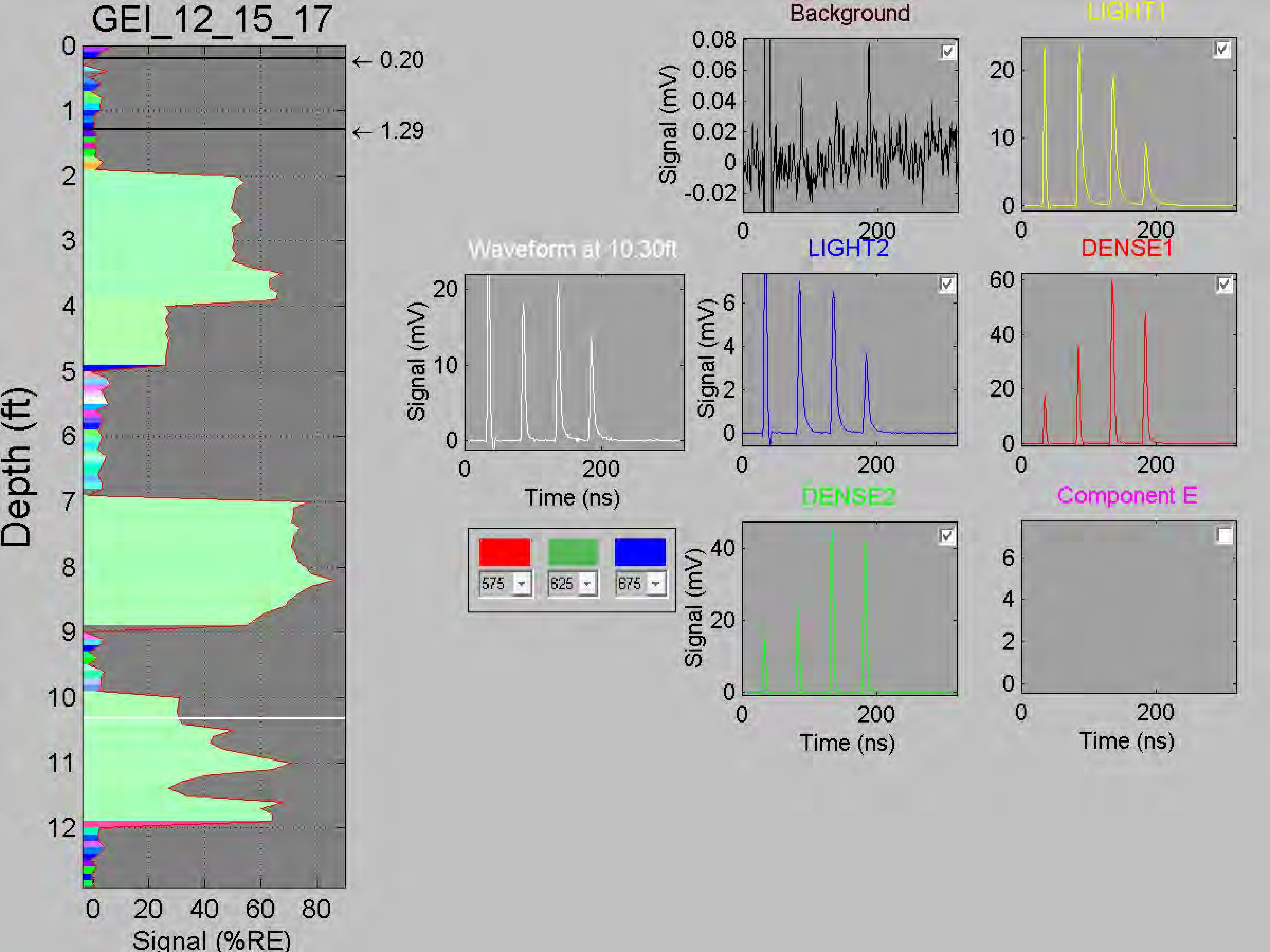


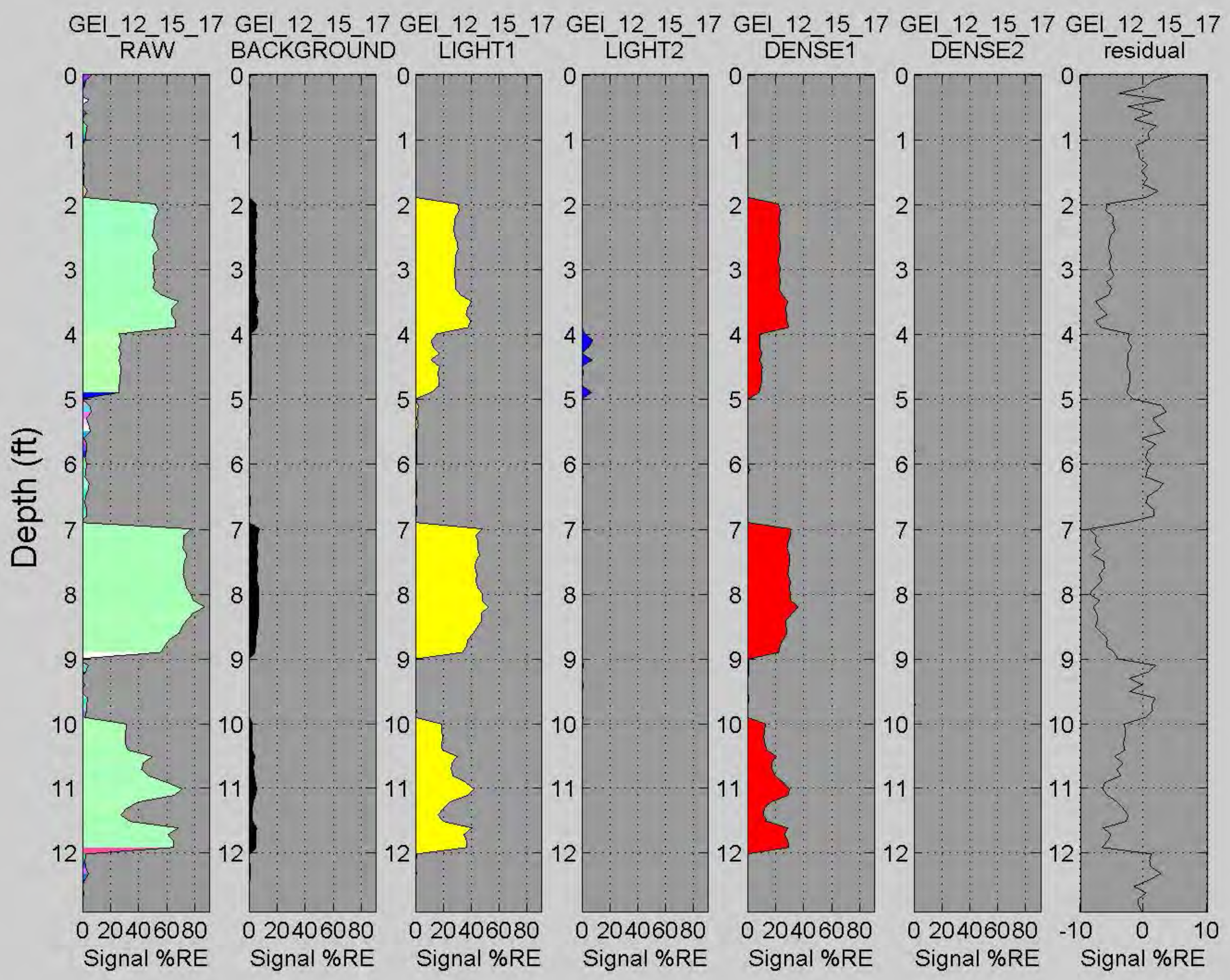
GEI_12_5_7
RAW
GEI_12_5_7
BACKGROUND
GEI_12_5_7
LIGHT1
GEI_12_5_7
LIGHT2
GEI_12_5_7
DENSE1
GEI_12_5_7
DENSE2
GEI_12_5_7
residual
Depth (ft)
Signal %RE

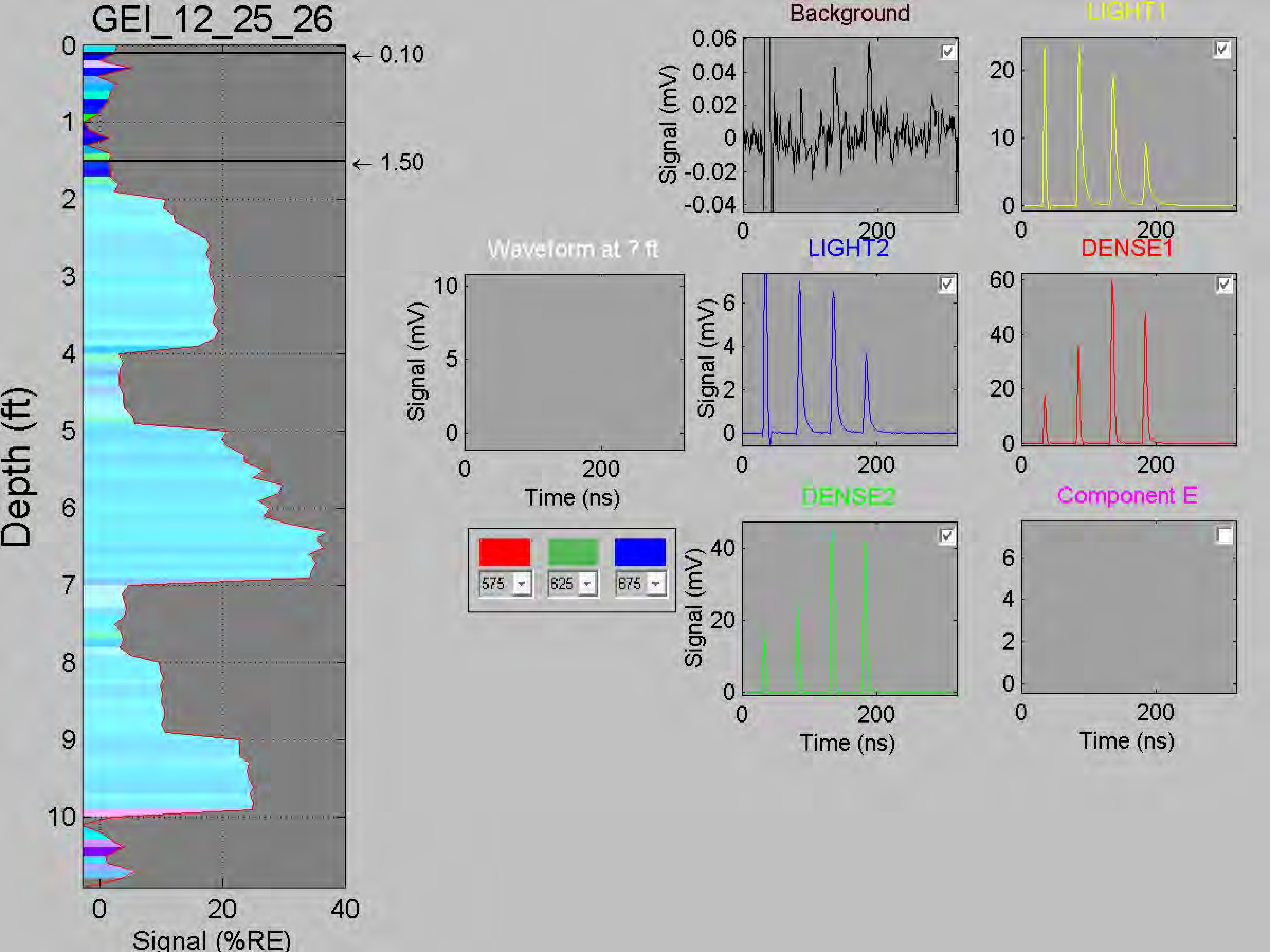

GEI_12_11_15
Depth (ft)
Signal (%RE)
← 0.10
← 1.39
Background
LIGHT1
LIGHT2
DENSE1
DENSE2
Component E
Waveform at 11.10ft
Signal (mV)
Time (ns)
575
625
675



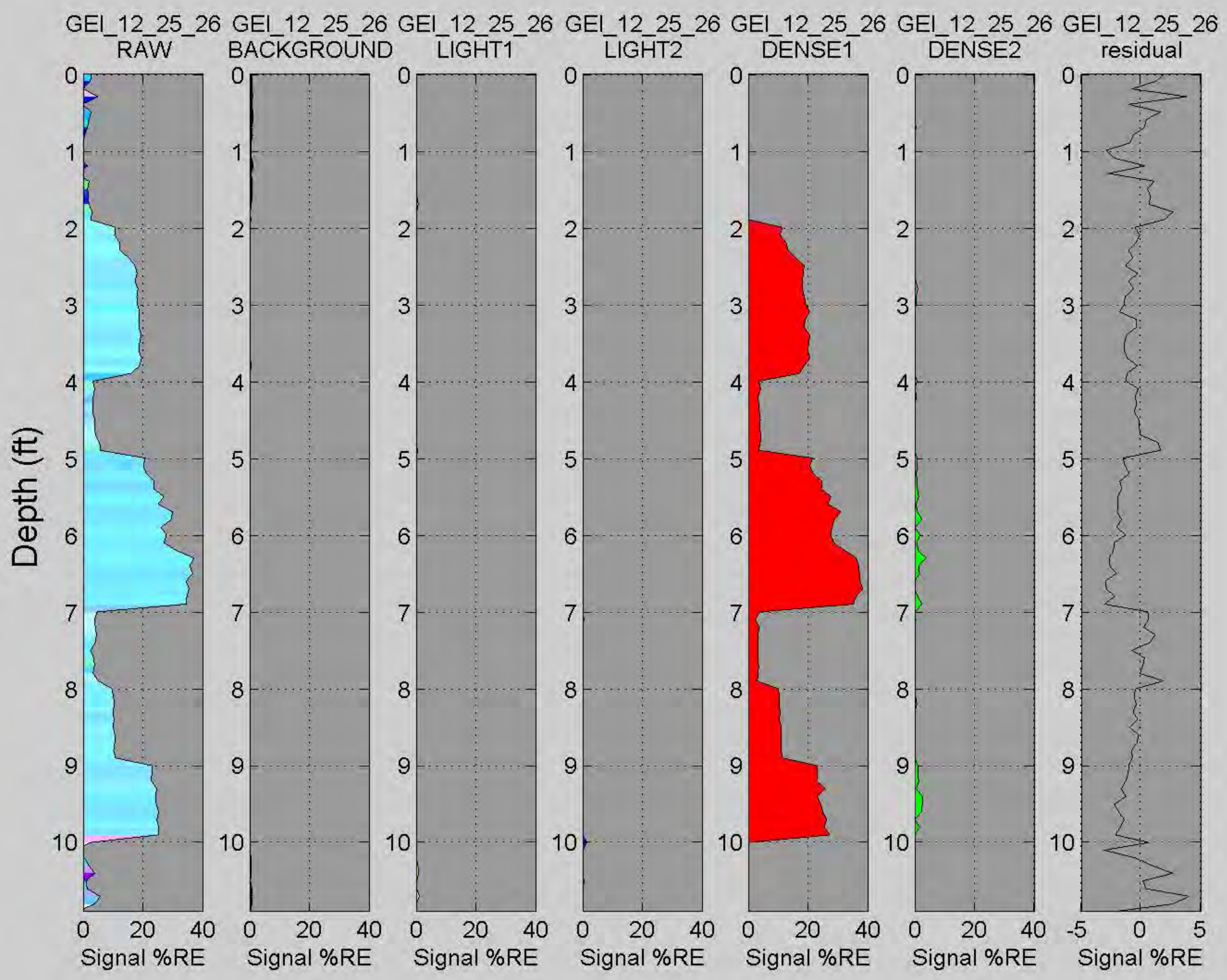
GEI_12_11_15 RAW
GEI_12_11_15 BACKGROUND
GEI_12_11_15 LIGHT1
GEI_12_11_15 LIGHT2
GEI_12_11_15 DENSE1
GEI_12_11_15 DENSE2
GEI_12_11_15 residual
Depth (ft)
0 1 2 3 4 5 6 7 8 9 10 11 12 13
0 100200300
-20 0 20
Signal %RE


GEI_12_15_17
Depth (ft)
Signal (%RE)
← 0.20
← 1.29
Waveform at 10.30ft
Signal (mV)
Time (ns)
575
625
675
Background
LIGHT1
LIGHT2
DENSE1
DENSE2
Component E

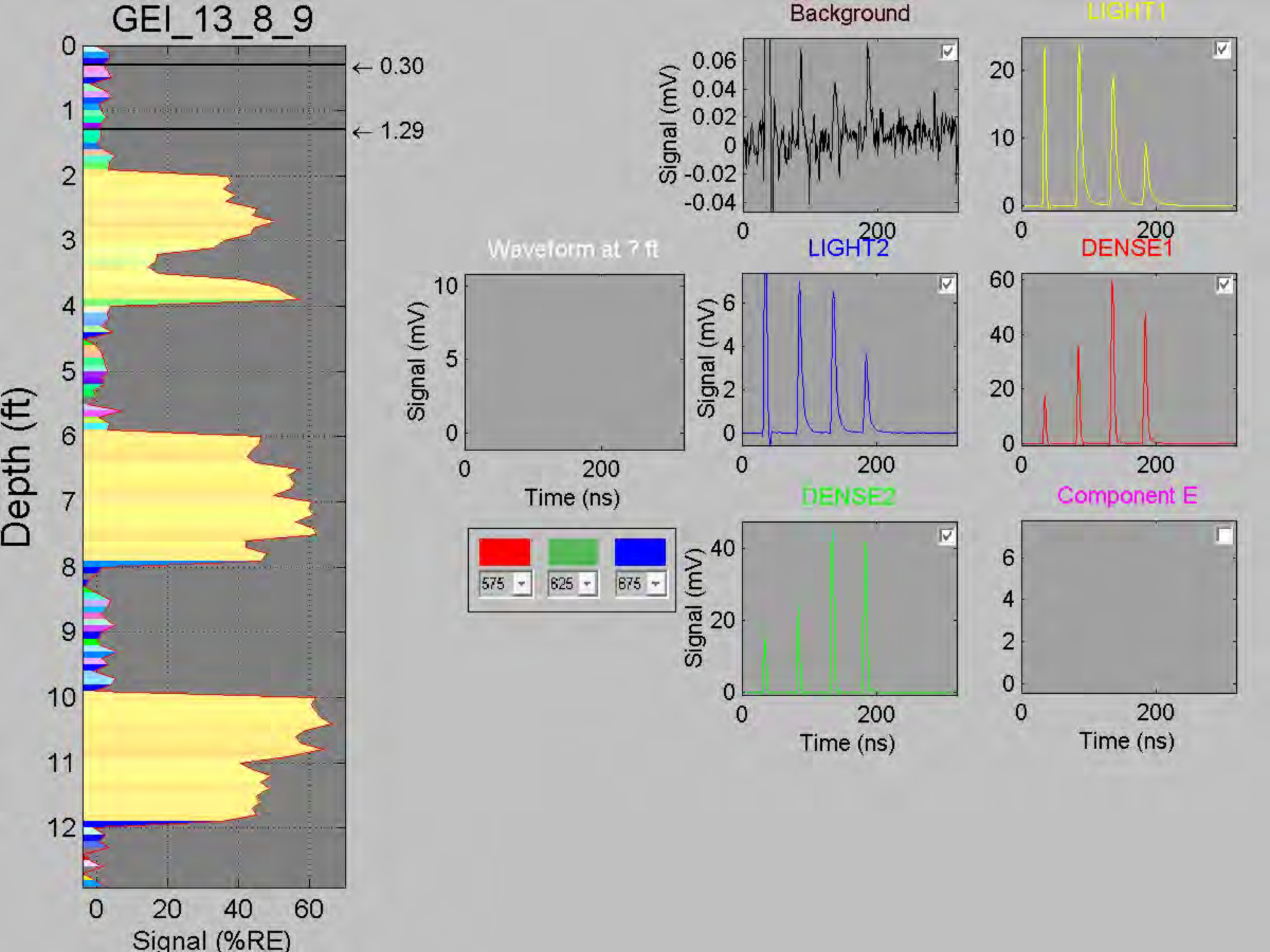

GEI_12_15_17
RAW
GEI_12_15_17
BACKGROUND
GEI_12_15_17
LIGHT1
GEI_12_15_17
LIGHT2
GEI_12_15_17
DENSE1
GEI_12_15_17
DENSE2
GEI_12_15_17
residual
Depth (ft)
0 1 2 3 4 5 6 7 8 9 10 11 12
0 20 40 60 80
-10 0 10
Signal %RE



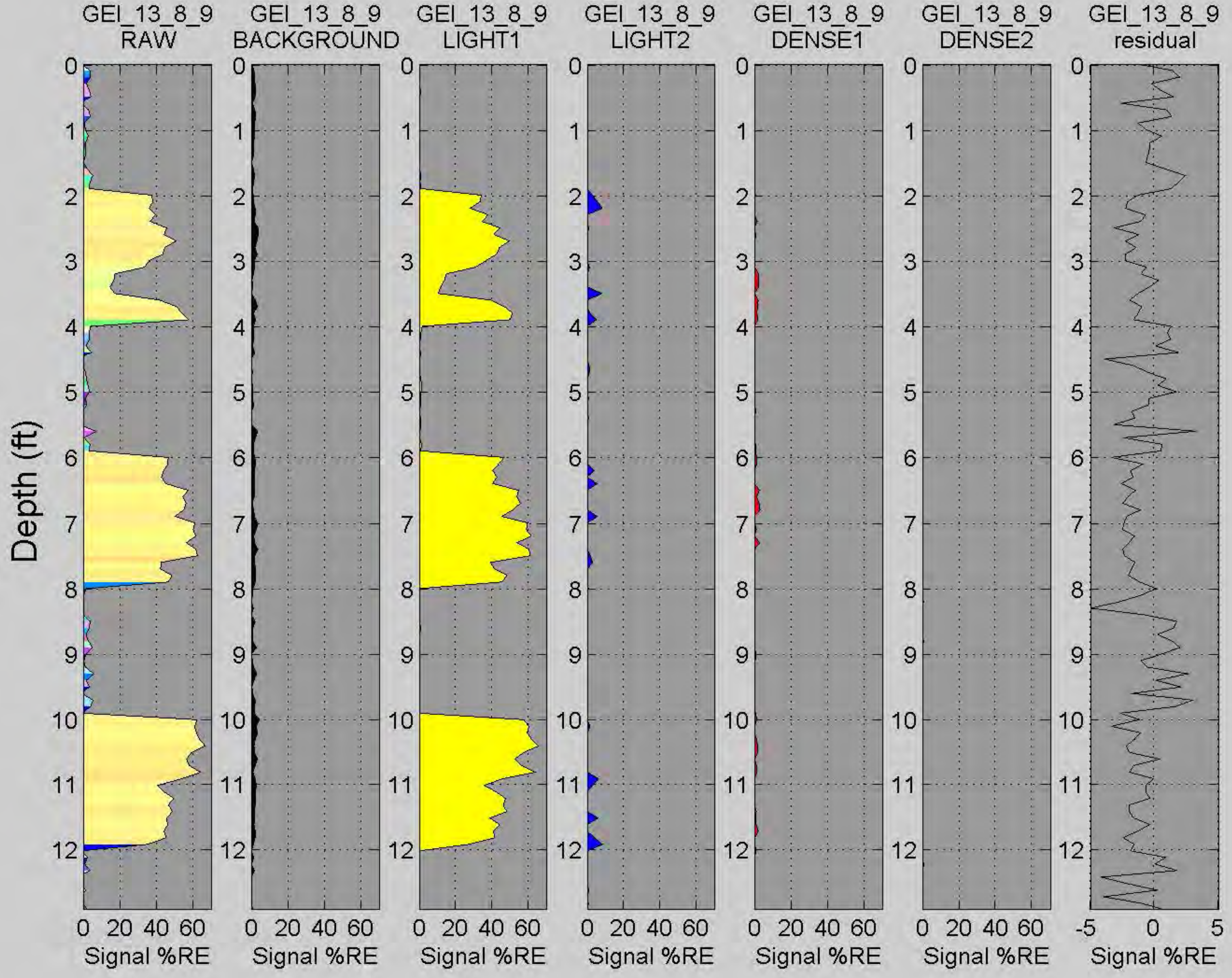
GEI_12_25_26
Depth (ft)
Signal (%RE)
← 0.10
← 1.50
Background
LIGHT1
LIGHT2
DENSE1
DENSE2
Component E
Waveform at ? ft
Signal (mV)
Time (ns)
575
625
675

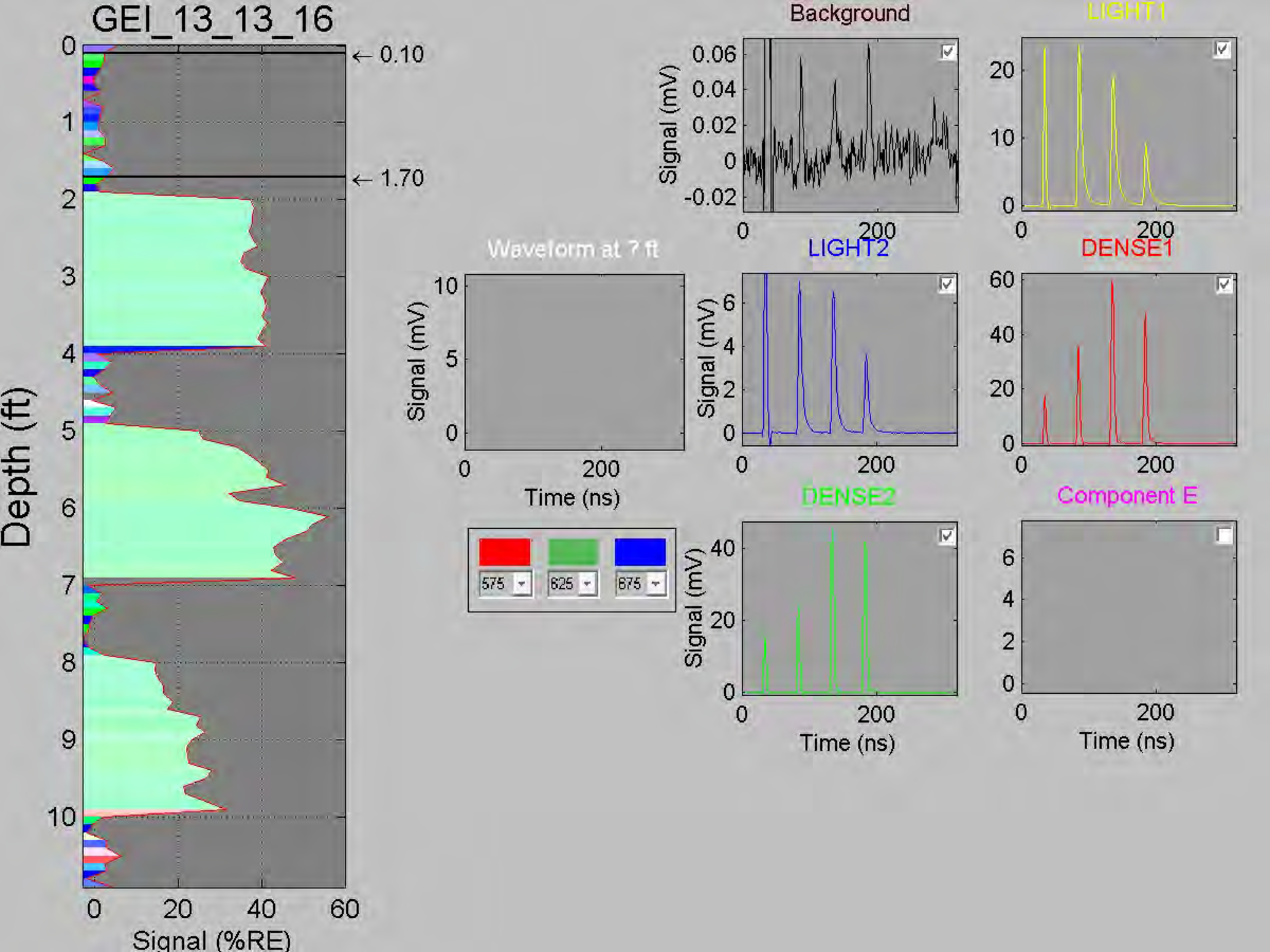


GEI_12_25_26 RAW
GEI_12_25_26 BACKGROUND
GEI_12_25_26 LIGHT1
GEI_12_25_26 LIGHT2
GEI_12_25_26 DENSE1
GEI_12_25_26 DENSE2
GEI_12_25_26 residual
Depth (ft)
Signal %RE

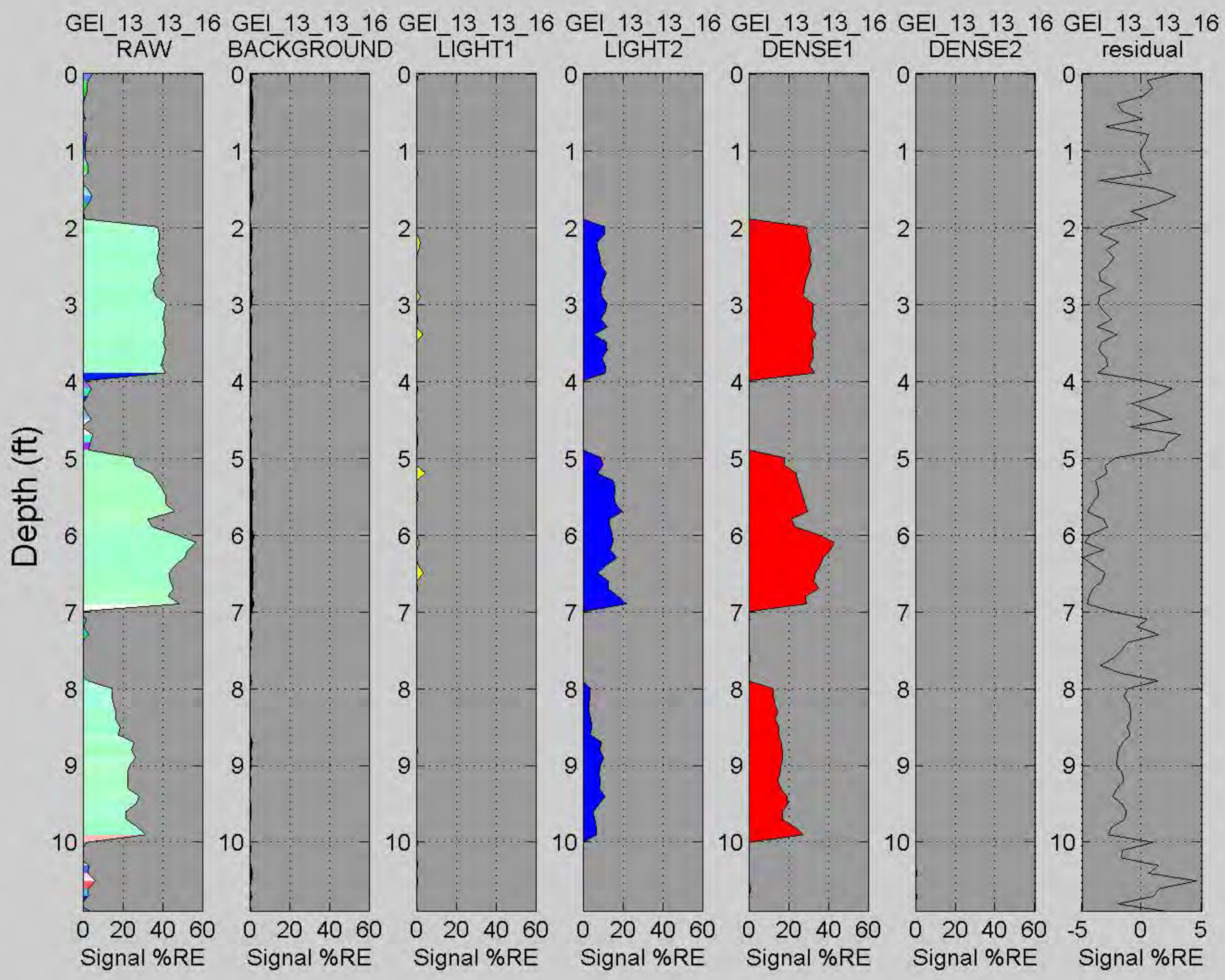


GEI_13_8_9
Depth (ft)
← 0.30
← 1.29
Signal (%RE)
Background
LIGHT1
Waveform at ? ft
LIGHT2
DENSE1
DENSE2
Component E
Signal (mV)
Time (ns)
575
625
675

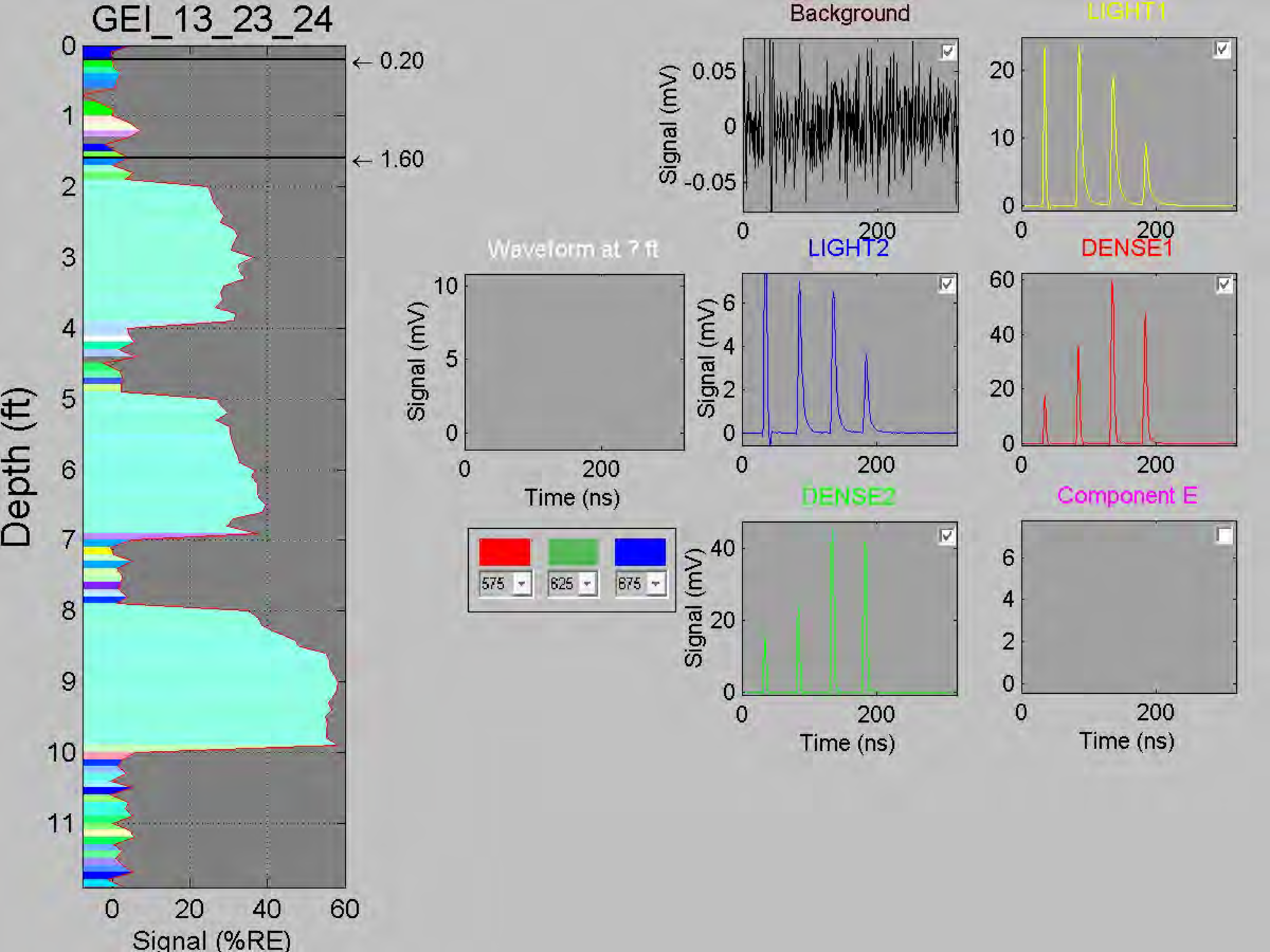

GEI_13_8_9
RAW
GEI_13_8_9
BACKGROUND
GEI_13_8_9
LIGHT1
GEI_13_8_9
LIGHT2
GEI_13_8_9
DENSE1
GEI_13_8_9
DENSE2
GEI_13_8_9
residual
Depth (ft)
0
1
2
3
4
5
6
7
8
9
10
11
12
0 20 40 60
Signal %RE
-5 0 5



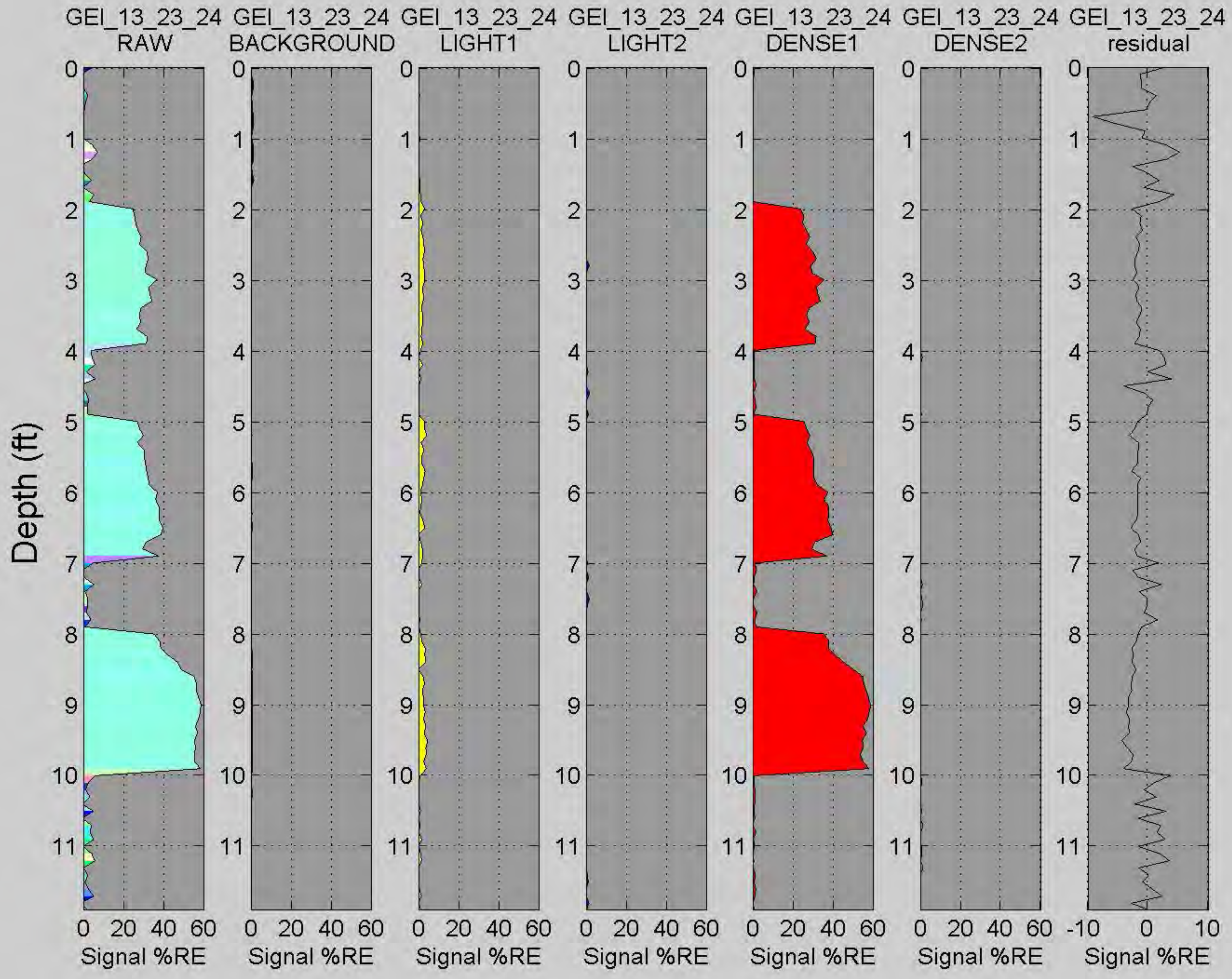
GEI_13_13_16
Depth (ft)
← 0.10
← 1.70
Signal (%RE)
Background
LIGHT1
LIGHT2
DENSE1
DENSE2
Component E
Waveform at ? ft
Signal (mV)
Time (ns)
575
625
675



GEI_13_13_16 RAW
GEI_13_13_16 BACKGROUND
GEI_13_13_16 LIGHT1
GEI_13_13_16 LIGHT2
GEI_13_13_16 DENSE1
GEI_13_13_16 DENSE2
GEI_13_13_16 residual
Depth (ft)
0 1 2 3 4 5 6 7 8 9 10
0 20 40 60
-5 0 5
Signal %RE



GEI_13_23_24
Depth (ft)
Signal (%RE)
← 0.20
← 1.60
Background
LIGHT1
Waveform at ? ft
LIGHT2
DENSE1
DENSE2
Component E
Signal (mV)
Time (ns)
575
625
675


GEI_13_23_24 RAW
GEI_13_23_24 BACKGROUND
GEI_13_23_24 LIGHT1
GEI_13_23_24 LIGHT2
GEI_13_23_24 DENSE1
GEI_13_23_24 DENSE2
GEI_13_23_24 residual
Depth (ft)
Signal %RE

ATTACHMENT 2A-3
SI Boring and Well Logs

ATTACHMENT 2A-3
SI Boring and Well Logs

SOIL CLASSIFICATION CHART

MAJOR DIVISIONS			SYMBOLS GRAPH	SYMBOLS LETTER	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	CLEAN GRAVELS (LITTLE OR NO FINES)		GW	WELL-GRADED GRAVELS, GRAVEL - SAND MIXTURES
				GP	POORLY-GRADED GRAVELS, GRAVEL - SAND MIXTURES
	MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	GRAVELS WITH FINES (APPRECIABLE AMOUNT OF FINES)		GM	SILTY GRAVELS, GRAVEL - SAND - SILT MIXTURES
				GC	CLAYEY GRAVELS, GRAVEL - SAND - CLAY MIXTURES
MORE THAN 50% RETAINED ON NO. 200 SIEVE	SAND AND SANDY SOILS	CLEAN SANDS (LITTLE OR NO FINES)		SW	WELL-GRADED SANDS, GRAVELLY SANDS
				SP	POORLY-GRADED SANDS, GRAVELLY SAND
	MORE THAN 50% OF COARSE FRACTION PASSING NO. 4 SIEVE	SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES)		SM	SILTY SANDS, SAND - SILT MIXTURES
				SC	CLAYEY SANDS, SAND - CLAY MIXTURES
FINE GRAINED SOILS	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50		ML	INORGANIC SILTS, ROCK FLOUR, CLAYEY SILTS WITH SLIGHT PLASTICITY
				CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
				OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
MORE THAN 50% PASSING NO. 200 SIEVE	SILTS AND CLAYS	LIQUID LIMIT GREATER THAN 50		MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS SILTY SOILS
				CH	INORGANIC CLAYS OF HIGH PLASTICITY
				OH	ORGANIC CLAYS AND SILTS OF MEDIUM TO HIGH PLASTICITY
HIGHLY ORGANIC SOILS				PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS

NOTE: Multiple symbols are used to indicate borderline or dual soil classifications

Sampler Symbol Descriptions

- 2.4-inch I.D. split barrel
- Standard Penetration Test (SPT)
- Shelby tube
- Piston
- Direct-Push
- Bulk or grab

Blowcount is recorded for driven samplers as the number of blows required to advance sampler 12 inches (or distance noted). See exploration log for hammer weight and drop.

A "P" indicates sampler pushed using the weight of the drill rig.

ADDITIONAL MATERIAL SYMBOLS

SYMBOLS GRAPH	SYMBOLS LETTER	TYPICAL DESCRIPTIONS
	AC	Asphalt Concrete
	CC	Cement Concrete
	CR	Crushed Rock/ Quarry Spalls
	TS	Topsoil/ Forest Duff/Sod

Groundwater Contact

Measured groundwater level in exploration, well, or piezometer

Measured free product in well or piezometer

Graphic Log Contact

Distinct contact between soil strata or geologic units

Approximate location of soil strata change within a geologic soil unit

Material Description Contact

Distinct contact between soil strata or geologic units

Approximate location of soil strata change within a geologic soil unit

Laboratory / Field Tests

%F	Percent fines
AL	Atterberg limits
CA	Chemical analysis
CP	Laboratory compaction test
CS	Consolidation test
DS	Direct shear
HA	Hydrometer analysis
MC	Moisture content
MD	Moisture content and dry density
OC	Organic content
PM	Permeability or hydraulic conductivity
PI	Plasticity index
PP	Pocket penetrometer
PPM	Parts per million
SA	Sieve analysis
TX	Triaxial compression
UC	Unconfined compression
VS	Vane shear

Sheen Classification

NS	No Visible Sheen
SS	Slight Sheen
MS	Moderate Sheen
HS	Heavy Sheen
NT	Not Tested

NOTE: The reader must refer to the discussion in the report text and the logs of explorations for a proper understanding of subsurface conditions. Descriptions on the logs apply only at the specific exploration locations and at the time the explorations were made; they are not warranted to be representative of subsurface conditions at other locations or times.

KEY TO EXPLORATION LOGS

GEOENGINEERS

FIGURE A-1

Drilled Start 4/10/2013 End 4/12/2013	Total Depth (ft) 47	Logged By PDR Checked By ZAS/TB	Driller Boart Longyear	Drilling Method Mud Rotary/Sonic (continuous core)
Hammer Data: Auto 140 (lbs) / 30 (in) Drop	Drilling Equipment: CME-850 Tracked Rig; Rubber Track-Mounted Spider 3 Sonic Rig		
Surface Elevation (ft): 29.92 Vertical Datum: USACE (Locks)	Top of Casing Elevation (ft): 29.43		
Easting (X): 1269843.3 Northing (Y): 238868.03	Horizontal Datum: NAD83 WA State Plane North		

A 2 (in) well was installed on 4/12/2013 to a depth of 47 (ft).

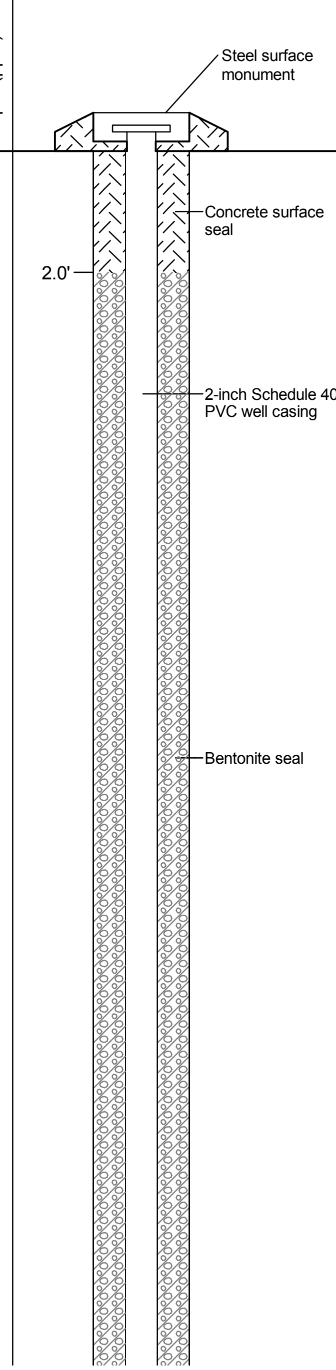
Groundwater Date Measured	Depth to Water (ft)	Elevation (ft)
4/22/2013	7.5	22.4

Notes: Hand-dug with posthole digger from 0 to 2 feet bgs; mud Rotary 2 to 18.5 feet; hollow-stem auger 18.5 to 41 feet, sonic 41 to 47 feet. Temporary conductor casing (10-inch diameter) used from 0 to 41 feet bgs with bentonite seal from 38 to 41 feet bgs.

FIELD DATA

Elevation (feet)	Depth (feet)	Recovered (in)	Blows/foot	Sample Name	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)
	0	24			SM	Brown silty fine to medium sand with occasional fine gravel and organics (topsoil)		
					ML	Gray/brown silt with fine sand and occasional gravel		
		10	16	1	SM	Brown silty fine to medium sand with fine gravel (loose to medium dense, moist)	NS	<1
25	5	0	4	2	SP	No recovery, coarse sand and fine gravel from washed cuttings		
		3	5	3		Brown fine to coarse sand with fine angular/subrounded gravel (loose, moist to wet) Coarse gravel in shoe Groundwater encountered at 7.7 feet (%F = 4)	NS	<1
		6	4	4 %F				
20	10	12	9	5 SA	SP/GP	Brown fine to coarse sand with fine to coarse gravel (loose, wet) (SA; %F = 6)		
					GP	Black low density/friable gravel (loose, wet)	NS	<1
		6	6	6	SM	Light brown silty fine to coarse sand with occasional fine gravel (loose, wet)		
					GP	Gray/black fine gravel with fine to coarse sand, agglomerate, wood debris (processed) in shoe, concrete pieces in sample (loose, wet) From 14 to 14.25 feet, black coating on gravel particles (has sheen)	SS <10%	
15	15	6	6	7	SM	Brown silty fine to coarse sand with fine to coarse, angular multi-colored gravel, slight blackening of grains, sheen dissipates quickly, no odor (loose, wet) (SA; %F = 20)	NS	<1
		6	6	8 SA				
		6	9	9 SA	SP-SM	Gray/black fine to coarse sand with fine gravel and silt, multi-color grains, angular and flat gravel with occasional wood chips (loose, wet) (SA; %F = 8)		
10	20				SP	Gray coarse sand with fine subrounded gravel and occasional fine to medium sand (loose,	NS	<1

WELL LOG



Note: Please see Figure A-1 for explanation of symbols

Seattle: Date:5/14/13 Path:C:\USERS\TNASH\DESKTOP\018684601.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_ENVIRONMENTAL_WELL

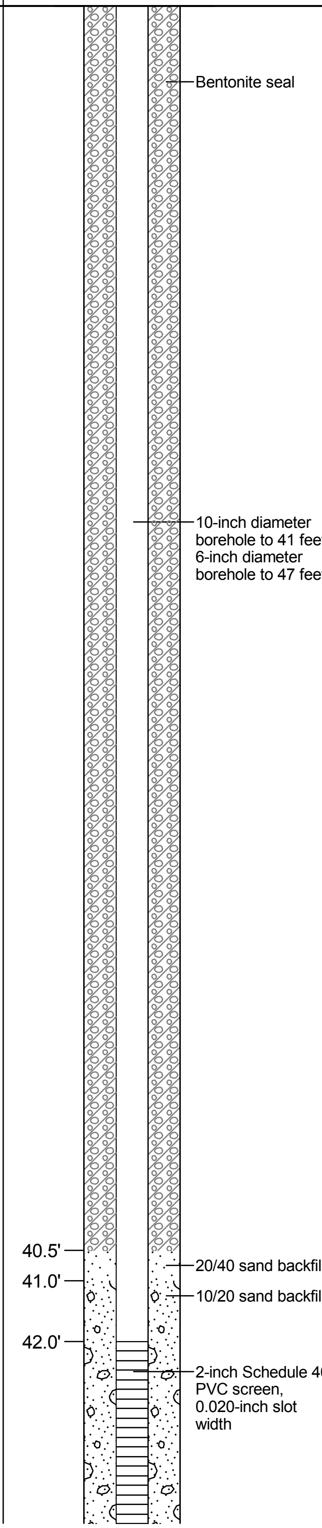
Log of Monitoring Well MW-32D/GEO-1

GeoEngineers

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Elevation (feet)	Depth (feet)	Recovered (in)	Blows/foot	Collected Sample	Sample Name	Group Classification	Material Description	Sheen	Headspace Vapor (ppm)
	20						wet)		
		6	7		10 / SA	SP-SM	Brown fine to coarse sand with silt (ground agglomerate) (loose, wet) (SA; %F = 11)	NS	<1
								NS	<1
							Thin band black coated particles from 22 to 22.5 feet	SS	<1
		6	8		11 / %F	SP-SM	Black coarse sand with silt and fine to coarse gravel, angular, friable, vesicular material, particles stained (loose, wet) (%F = 8)	SS	<1
5	25	0	6				No recovery		
		12	8		12				
						SM	Black silty fine to coarse sand with occasional fine to coarse gravel, some wood chips (milled), some thin metal chips and ceramic pieces (loose, wet) (%F = 20)	MS	<1
		12	32		13	SP	Black fine to coarse sand with ceramic pieces, metal pieces, wood debris, slight odor, angular (non-agglomerate) (dense, wet) (SA; %F = 3)		
0	30							NS	<1
		20	56		14	GP	Gray fine to coarse angular gravel with occasional medium to coarse sand (not agglomerate) (very dense, wet)		
						SP	Fine to medium sand lense (very dense, wet)		
						GP	Gray fine to coarse gravel with fine to coarse sand, trace silt (very dense, wet)	NS	<1
		18	58		15	SP	Gray fine to medium sand with trace silt and lenses of coarse sand with occasional fine to coarse gravel (very dense, wet)		
								NS	<1
		18	98		16				
-5	35							NS	<1
		18	64		17 / SA		(SA; %F = 3)		
								NS	<1
		12	78		18				
		18	52		19				
						SP-SM	Gray fine to medium sand with silt (very dense, wet)		
-10	40								
							Occasional coarse sand and fine gravel		
							Becomes finer	NS	<1
		12		↕	20;MW-32D (43.5-44.5)		(%F = 7)		
							With coarse gravel		
-15									

WELL LOG



Note: Please see Figure A-1 for explanation of symbols

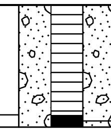
Log of Monitoring Well MW-32D/GEO-1 (continued)

GeoEngineers

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)
	45		12	81		21			SM	Gray silty fine to coarse sand with fine to coarse gravel (very dense, moist)	NS	<1

WELL LOG



Note: Please see Figure A-1 for explanation of symbols

Log of Monitoring Well MW-32D/GEO-1 (continued)

GeoEngineers

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Figure A-2
Sheet 3 of 3

Drilled	Start 4/11/2013	End 4/11/2013	Total Depth (ft)	49.5	Logged By ARJ Checked By ZAS/TB	Driller	Boart Longyear	Drilling Method	Hollow-stem Auger

Surface Elevation (ft) Vertical Datum	30.17 USACE (Locks)	Hammer Data	Autohammer 140 (lbs) / 30 (in) Drop	Drilling Equipment	CME-850 Tracked Rig
Easting (X) Northing (Y)	1269972.23 238799.4	System Datum	NAD83 WA State Plane North	Groundwater	Date Measured / Depth to Water (ft) / Elevation (ft)

Notes: Hand-dug with posthole digger from 0 to 2 feet bgs.

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name / Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)	REMARKS
30	0								SM	Brown silty fine to medium sand with occasional fine gravel, trace brick and asphalt fragments (loose, moist)	NS	<1	
			10	22		1					NS	<1	Concrete and rock in base of sampler Hard drilling
25	5									Black at 5.5 feet Rock and crushed concrete from 5.5 to 6 feet, one piece of tan friable agglomerate			
													Groundwater encountered at 8 feet
			17	6		2 SA				With white soft silt (bentonite like)			SA (%F = 17)
20	10									Gravelly fine sand with mostly decayed wood fragments and glass shards	NS	<1	Bentonite layer, pea gravel layer (1-inch thick), geomembrane at 10 feet
			22	7		3:GEO-2 14-16 SA			SP-SM	Black fine to coarse sand with gravel and silt; gravel is agglomerate red, white, friable, occasional glass fragments and rubber fragments, occasional fine gravel, trace mostly decayed wood, one ceramic piece with filigree (loose, wet)	SS	<1	SA (%F = 7)
15	15												
			9	10		4 %F			SP-SM	Black fine to medium sand; sand particles tan, white, brown, friable agglomerate, shell fragments?, occasional rubber, one piece thin metal highly corroded, trace wood fragments highly decayed, one piece of white ceramic with filigree (medium dense,	NS	<1	%F = 11
	20												

Note: Please see Figure A-1 for explanation of symbols

Log of Boring GEO-2

GeoEngineers

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Elevation (feet)	Depth (feet)	Recovered (in)	Blows/foot	Sample Name / Testing	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)	REMARKS
10	20					wet)			
		4	*50/5"	5 / SA	SM	Black silty fine to medium sand with trace rubber fragments, one piece of white fine gravel friable agglomerate (medium dense, wet)	NS	<1	SA (%F = 23) *Possibly poor blowcount data (heave?)
5	25								
					SP	Gray fine to medium sand with trace wood fragments (2-inch bark strand?) (medium dense, wet)			
		18	50/4"	6					
0	30						NS	<1	Heave in hole Possibly poor blowcount data
		18	26	7 / SA					SA (%F = 2)
-5	35					Occasional fine gravel, one piece of ceramic (slough from above?)			
					GP	Gray fine to coarse gravel with fine to medium sand (medium dense, wet)	NS	<1	Add water to prevent heave
		18	52	8 / SA					SA (%F = 2)
-10	40								
					GP	Gray fine to coarse gravel with medium to coarse sand (very dense, wet)			
									Rough drilling

Note: Please see Figure A-1 for explanation of symbols

Log of Boring GEO-2 (continued)

GeoEngineers

Project: Puget Sound Energy North Lake Union

Project Location: Gas Works Park, Seattle, Washington

Project Number: 0186-846-01

Figure A-3

Sheet 2 of 3

Elevation (feet)	Depth (feet)	Interval / Recovered (in)	Blows/foot	Collected Sample	Sample Name / Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)	REMARKS
		5	50/5"		9 SA					NS	<1	SA (%F = 2)
-15	45							SM	Gray silty fine to medium sand with gravel (very dense, wet) (till)			
		4	50/4"		10							

Note: Please see Figure A-1 for explanation of symbols

Log of Boring GEO-2 (continued)

GEOENGINEERS

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Figure A-3
Sheet 3 of 3

Drilled	Start 4/12/2013	End 4/12/2013	Total Depth (ft) 31.5	Logged By ARJ; Checked By ZAS/TB	Driller Boart Longyear	Drilling Method Hollow-stem Auger

Surface Elevation (ft) 40.18; Vertical Datum USACE (Locks)	Hammer Data: Autohammer 140 (lbs) / 30 (in) Drop	Drilling Equipment	CME-75 Truck-Mounted Rig
Easting (X) 1270009.66; Northing (Y) 239157.27	System Datum: NAD83 WA State Plane North	Groundwater	Date Measured / Depth to Water (ft) / Elevation (ft)

Notes: Hand-dug with posthole digger from 0 to 2 feet bgs.

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name / Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)	REMARKS
40	0		24						SM	Dark brown silty fine sand (topsoil)			
									SM	Tan silty fine to medium sand with occasional gravel, occasional concrete and trace brick fragments (loose, moist)	NS	<1	Strong odor
									SM	Black silty fine to medium sand with gravel, trace wood fragments, partially decayed (medium dense, moist)	NS	<1	
35	5		10	*50/5"		1					SS	<1	Large rock in sampler shoe *Blowcount not representative
									SP	Brown fine to medium sand with fine to coarse gravel, trace silt (medium dense, moist)			
30	10		14	19		2					NS	<1	
									GP	Tan with gray mottling fine to coarse gravel with medium to coarse sand (medium dense, moist)			
25	15		20	34		3 SA					NS	<1	SA (%F = 1)
									SP	Tan medium sand with occasional fine gravel (dense, wet)			
	20												

Note: Please see Figure A-1 for explanation of symbols

Seattle: Date:8/1/13 Path:P:\0\0186846\01\GINT\018684601.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_ENVIRONMENTAL_STANDARD

Log of Boring GEO-3

GeoEngineers

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name / Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)	REMARKS
20	20		16	53		4 SA							SA (%F = 5)
									SP	Gray medium to coarse sand with fine gravel (dense, wet)			
15	25		24	50/6"		5							Heave in hole
									GP	Gray fine to coarse gravel with medium to coarse sand (very dense, wet)			
									SM	Gray silty medium to coarse sand with fine gravel, layered with occasional medium to coarse sand with fine gravel (very dense, wet)			
10	30		17	50/5"		6							

Note: Please see Figure A-1 for explanation of symbols

Log of Boring GEO-3 (continued)

GeoEngineers

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Drilled	Start 4/12/2013	End 4/12/2013	Total Depth (ft) 35	Logged By PDR / Checked By ZAS	Driller Boart Longyear	Drilling Method Sonic (continuous core)

Hammer Data		Drilling Equipment	Rubber Track-Mounted Spider 3 Sonic Drill Rig
Surface Elevation (ft) / Vertical Datum	29.83 / USACE (Locks)	Top of Casing Elevation (ft)	29.29
Easting (X) / Northing (Y)	1269847.34 / 238864.97	Horizontal Datum	NAD83 WA State Plane North

A 2 (in) well was installed on 4/12/2013 to a depth of 31.3 (ft).

Groundwater

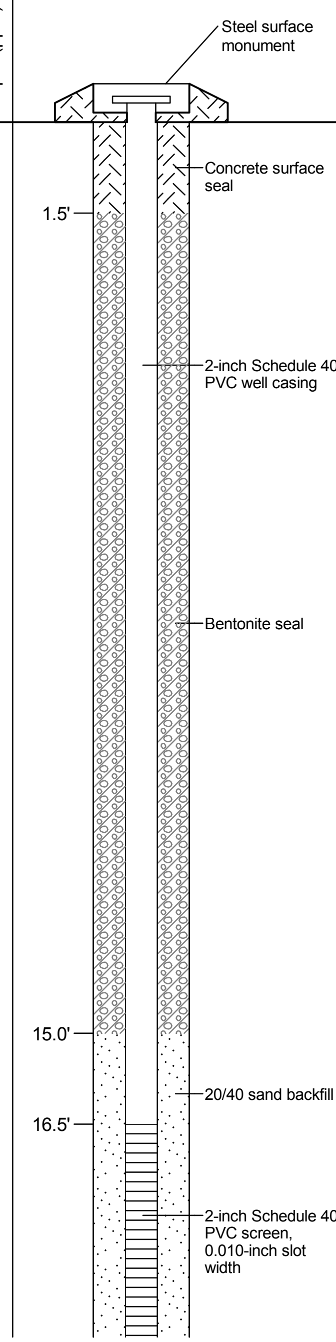
Date Measured	Depth to Water (ft)	Elevation (ft)
4/22/2013	7.7	22.2

Notes: Hand-dug with posthole digger from 0 to 2 feet bgs.

FIELD DATA

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name	Water Level	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)
	0		24					SM	Brown silty fine to coarse sand with fine to coarse gravel, brick debris, concrete debris, some surface organics (grass roots) Hand-dug first 24 inches		
								SM	From 2 to 15 feet bgs, please see log for MW-32D/GEO-1		
25	5		60								
							▼		Groundwater encountered at 7 feet		
20	10		60								
15	15		24					SP	Brown to black coarse sand with fine gravel and occasional medium sand, agglomerate, trash, metal, glass, ceramic	NS	<1
								WD	Wood debris (thick, fibrous)		
10	20							GP	Black fine to coarse subrounded to rounded gravel with fine to coarse sand and trace silt, black crushed agglomerate, metal fragments, wood debris, glass, wire, brick fragments,	MS <50%	<1

WELL LOG



Note: Please see Figure A-1 for explanation of symbols

Seattle: Date:5/14/13 Path:C:\USERS\TNASH\DESKTOP\018684601.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_ENVIRONMENTAL_WELL

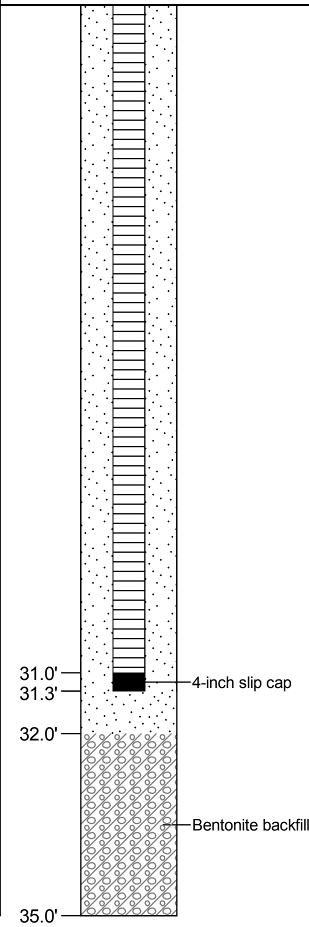
Log of Monitoring Well MW-32S

GeoEngineers

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Elevation (feet)	Depth (feet)	Recovered (in)	Blows/foot	Collected Sample / Sample Name	Water Level	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)
	20	60					nails, and ceramic, sheen is rainbow color, hydrocarbon odor		
5	25	60						SS	<1
				MW-32S (29-30) +DUP				SS	<1
0	30	60							
				MW-32S (31-32)		SP	Gray fine to coarse sand with trace silt	NS	<1
							With occasional fine gravel		
-5	35								

WELL LOG



Note: Please see Figure A-1 for explanation of symbols

Log of Monitoring Well MW-32S (continued)

GeoEngineers

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Drilled	Start 3/27/2013	End 3/27/2013	Total Depth (ft)	18	Logged By PDR	Checked By ZAS	Driller	Boart Longyear	Drilling Method	Sonic (continuous core)

Surface Elevation (ft) / Vertical Datum	37.96 / USACE (Locks)	Hammer Data		Drilling Equipment	Rubber Track-Mounted Spider 3 Sonic Drill Rig
Easting (X) / Northing (Y)	1270307.96 / 238739.05	System Datum	NAD83 WA State Plane North	Groundwater	Date Measured / Depth to Water (ft) / Elevation (ft)

Notes: Hand-dug with posthole digger from 0 to 2 feet bgs. Hit pipe at 18 feet bgs; abandoned hole. See MW-33S(b) for well installation.

Elevation (feet)	Depth (feet)	Recovered (in)	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)	REMARKS
	0	24	SM	Brown silty fine to medium sand with organics (roots)			
			SM	Black silty fine to coarse sand with occasional fine to coarse gravel (loose, moist)			
		60					
35			GM	Black fine to coarse gravel agglomerate with fine to coarse sand and silt (hard, angular)	NS	<1	
			SM	Brown silty fine to medium sand with fine to coarse gravel, with occasional silty interbeds (approximately 3 inches)			
	5						
		60					Perched groundwater encountered at 7 feet
30			SM	Gray silty fine to medium sand with occasional fine to coarse gravel	NS	<1	
	10		SP-SM	Gray fine to coarse sand with silt and occasional fine gravel, occasional black vesicular material, low density, small percentage of gravel			
25		36	SP	Red-orange fine to coarse sand with trace silt, grains are low density, weathered agglomerate Becomes black Becomes white Becomes black	NS	<1	
	15			No recovery from 15 to 17 feet Steel pipe piece			
20		12	SM	Gray silty fine to coarse sand with fine to coarse gravel			

Note: Please see Figure A-1 for explanation of symbols

Log of Monitoring Well MW-33S(a)

GeoEngineers

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Figure A-6
Sheet 1 of 1

Drilled	Start: 3/28/2013	End: 3/28/2013	Total Depth (ft)	30	Logged By: PDR / Checked By: ZAS	Driller: Boart Longyear	Drilling Method: Sonic (continuous core)

Hammer Data		Drilling Equipment	Rubber Track-Mounted Spider 3 Sonic Drill Rig
Surface Elevation (ft) / Vertical Datum	38.7 / USACE (Locks)	Top of Casing Elevation (ft)	38.26
Easting (X) / Northing (Y)	1270318.67 / 238748.97	Horizontal Datum	NAD83 WA State Plane North

A 2 (in) well was installed on 3/28/2013 to a depth of 22.5 (ft).

Groundwater Date Measured	Depth to Water (ft)	Elevation (ft)
4/22/2013	16.5	21.8

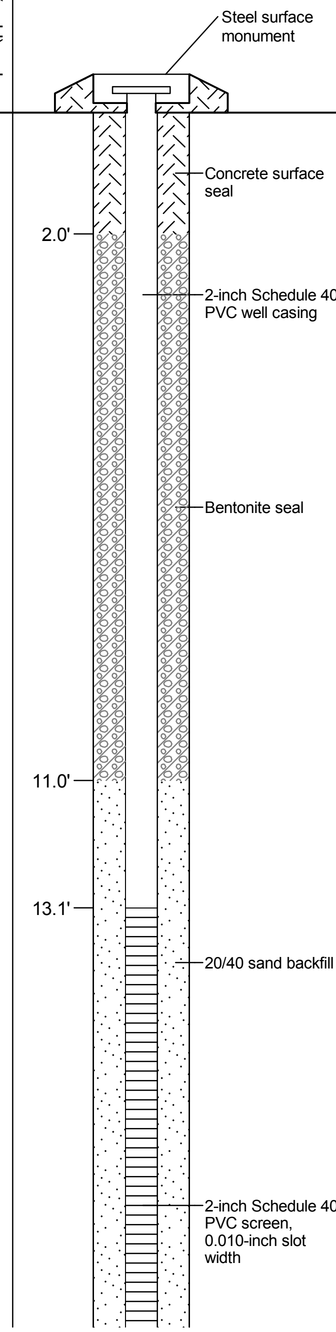
Notes: Second attempt. Hand-dug with posthole digger from 0 to 2 feet bgs.

FIELD DATA

Depth (feet)	Recovered (in)	Sample Name	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)
0	24		ML	Light brown silt with fine to medium sand and organics (roots)		
			SM	Brown silty fine to medium sand with occasional coarse gravel		
	36		SM	Light brown silty fine to medium sand with occasional fine gravel		
			ML	Black fine silt, low density, soot-like	NS	<1
5	60		SP	Red-brown to black medium to coarse sand with occasional coarse gravel, grains are red to white agglomerate (fine to medium sand sized), no longer fused		
				Black coarse sand with occasional fine to coarse gravel, grains are agglomerate where sand size is no longer fused	NS	<1
				With yellow brick fragments; no staining		
10	60			Lighter brown coarse sand, agglomerate no longer fused		
		MW-33S (12-22 composite)		Dark brown medium to coarse sand grains (multi-colored reds and browns)		
		MW-33S (13-14) +DUP		Black coarse sand with fine to coarse gravel, occasional black fused ash/soot-like very fine material	NS	<1
15	60					
		MW-33S (17-17.5)		Black coarse sand with coarse gravel, grains coated with NAPL, some milled wood pieces and fragments	SS 50%	<1
			SP-SM	Groundwater encountered at 17.3 feet		
				Black coarse sand with silt and coarse gravel		
			SM	Gray-green silty medium to coarse sand with fine to coarse gravel	NS	<1
20						

Elevation (feet): 35, 30, 25, 20

WELL LOG



Note: Please see Figure A-1 for explanation of symbols

Log of Monitoring Well MW-33S(b)

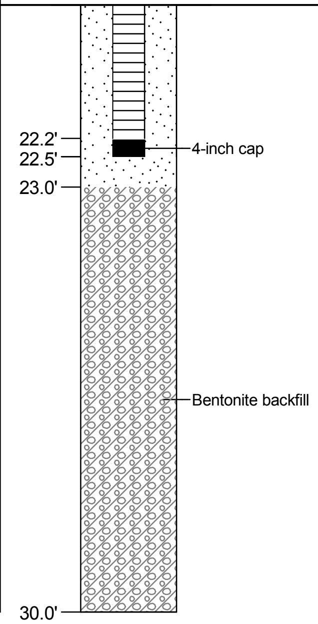
GeoEngineers

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Figure A-7
Sheet 1 of 2

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)
	20		60			MW-33S (20-21)			SP	Gray-brown to black fine to coarse sand with fine to coarse gravel, hydrocarbon odor; sheen, no color, dissipated quickly	SS 50%	8.4
									SP	Light brown medium to coarse sand with fine to coarse gravel, <5% fines (loose, wet)		
15												
	25		60						SP/GP	Light brown grading to gray coarse sand/fine gravel with occasional coarse rounded gravel (loose, wet)	NS	
									SP	Gray fine sand (dense, wet)		
10												
									ML	Gray fine sandy silt with occasional fine to coarse gravel	NS	
	30											

WELL LOG



Note: Please see Figure A-1 for explanation of symbols

Log of Monitoring Well MW-33S(b) (continued)

GeoEngineers

Project:	Puget Sound Energy North Lake Union
Project Location:	Gas Works Park, Seattle, Washington
Project Number:	0186-846-01

Figure A-7
Sheet 2 of 2

Drilled	Start	End	Total Depth (ft)	Logged By	Checked By	Driller	Drilling Method
	3/27/2013	3/27/2013	10	PDR	ZAS	Boart Longyear	Sonic (continuous core)

Hammer Data		Drilling Equipment	Rubber Track-Mounted Spider 3 Sonic Drill Rig
Surface Elevation (ft)	28.44	Top of Casing Elevation (ft)	28.05
Vertical Datum	USACE (Locks)		
Easting (X)	1270501.78	Horizontal Datum	NAD83 WA State Plane North
Northing (Y)	238734.93		

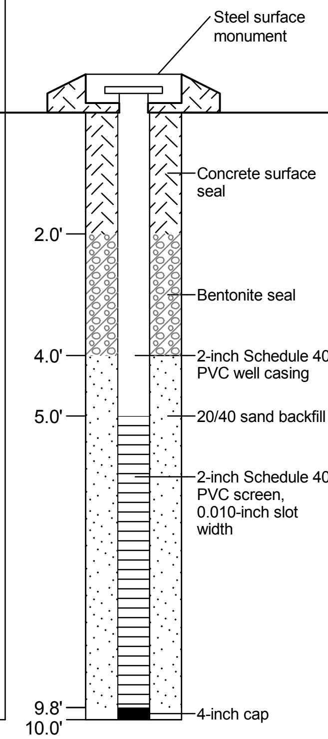
A 2 (in) well was installed on 3/27/2013 to a depth of 10 (ft).

Groundwater Date Measured	Depth to Water (ft)	Elevation (ft)
4/22/2013	6.3	22.2

Notes: Hand-dug with posthole digger from 0 to 2 feet bgs.

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name	Water Level	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)
	0		24					SM	Dark brown silty fine sand with occasional fine gravel and organics (roots)	NS	<1
25			42					SP-SM	Brown to red-brown fine to coarse sand with silt and occasional fine gravel, black vesicular, vitreous luster; orange to red agglomerate pieces (fine), no longer fused, gravel is <1" rounded	NS	<1
	5		60			MW-34S (5-10 composite)	▼				
						MW-34S (7-8)		SP	Black fine to coarse sand with tar-like substance coating grains, some wood debris (weathered, splintered); sheen is globular, dissipates	MS	1.6
20								ML	Brown silt with fine sand; black staining at top grades to gray		
	10							SM	Gray silty fine sand with occasional fine to coarse gravel	NS	<1
									Groundwater encountered at 9.5 feet		

WELL LOG



Note: Please see Figure A-1 for explanation of symbols

Seattle: Date:5/14/13 Path:C:\USERS\TNASH\DESKTOP\018684601.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_ENVIRONMENTAL_WELL

Log of Monitoring Well MW-34S

GeoEngineers

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Figure A-8
Sheet 1 of 1

Drilled	Start 3/27/2013	End 3/27/2013	Total Depth (ft)	15	Logged By PDR / Checked By ZAS	Driller	Boart Longyear	Drilling Method	Sonic (continuous core)

Hammer Data		Drilling Equipment	Rubber Track-Mounted Spider 3 Sonic Drill Rig
Surface Elevation (ft) / Vertical Datum	24.69 / USACE (Locks)	Top of Casing Elevation (ft)	24.15
Easting (X) / Northing (Y)	1270634.86 / 238807.89	Horizontal Datum	NAD83 WA State Plane North

A 2 (in) well was installed on 3/27/2013 to a depth of 7 (ft).

Groundwater

Date Measured	Depth to Water (ft)	Elevation (ft)
4/22/2013	2.4	22.3

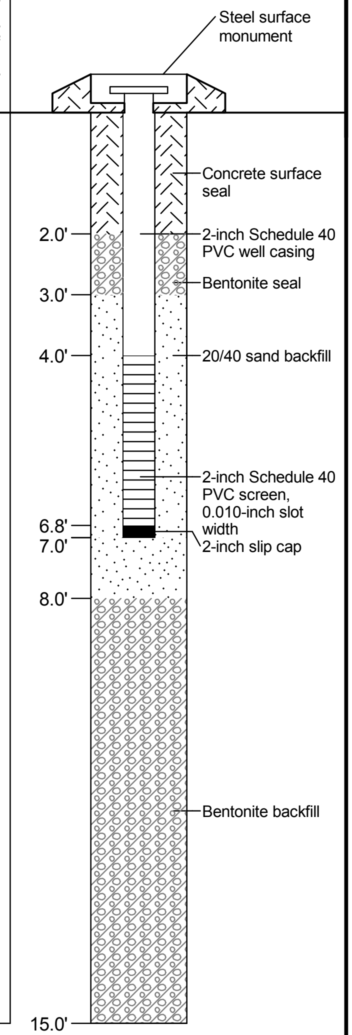
Notes: Hand-dug with posthole digger from 0 to 2 feet bgs.

FIELD DATA

Depth (feet)	Recovered (in)	Sample Name	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)
0	24		ML	Brown silt with fine sand, some organics (roots)		
		MW-35S (0.5-1)	ML	Brown to gray silt with fine to medium sand and occasional fine gravel		
	36		SP	Black coarse sand with occasional fine to coarse rounded gravel and some silt; grains coated with tar-like substance, asphalt-like odor, sheen, globular, little color, dissipates. Groundwater encountered at 3.2 feet	MS 20%	5.6
5	60	MW-35S (4-7 composite) MW-35S (4.5-5) MW-35S (5-6)		Matrix becomes brown with more silt		
			GP	Fine to coarse gravel with fine to coarse sand; grains coated with tar-like substance		
			ML	Gray plastic silt, very uniform	NS	<1
10	60	MW-35S (9-10)	SM	Gray silty fine to coarse sand with fine to coarse gravel (medium dense)	NS	<1
15						

Elevation (feet): 20, 15, 10

WELL LOG



Note: Please see Figure A-1 for explanation of symbols

Log of Monitoring Well MW-35S

GeoEngineers

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Figure A-9
Sheet 1 of 1

Log of Monitoring Well MW-36D

Drilled	Start 3/28/2013	End 3/29/2013	Total Depth (ft)	35	Logged By PDR / Checked By ZAS	Driller	Boart Longyear	Drilling Method	Sonic (continuous core)

Hammer Data		Drilling Equipment	Rubber Track-Mounted Spider 3 Sonic Drill Rig
Surface Elevation (ft) / Vertical Datum	29.99 / USACE (Locks)	Top of Casing Elevation (ft)	29.55
Easting (X) / Northing (Y)	1270785.63 / 239091.49	Horizontal Datum	NAD83 WA State Plane North

A 2 (in) well was installed on 3/29/2013 to a depth of 34.1 (ft).

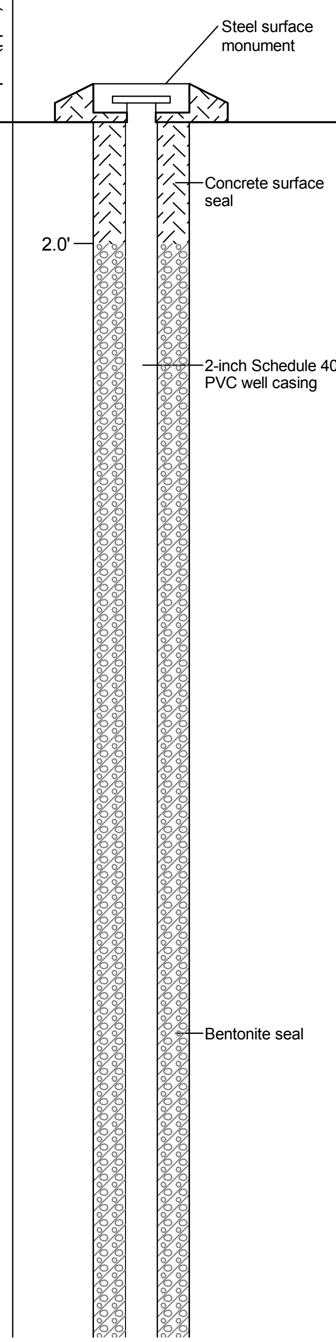
Groundwater Date Measured	Depth to Water (ft)	Elevation (ft)
4/22/2013	7.8	22.2

Notes: Hand-dug with poshole digger from 0 to 2 feet bgs. Temporary conductor casing (10-inch diameter) used from 0 to 28 feet bgs, with bentonite seal from 25 to 28 feet bgs.

FIELD DATA

Elevation (feet)	Depth (feet)	Recovered (in)	Sample Name	Group Classification	Material Description	Sheen	Headspace Vapor (ppm)
	0	24		SM	Brown silty fine to medium sand		
		36			Brick fragments		
				SP-SM	Black fine to coarse sand with silt and fine to coarse gravel; primarily agglomerate with varying color and fused size (sand through gravel)		
				ML	Black fused ash/cinders, crushed matrix in fines (soot-like)	SS	<1
25	5	60		SP	Brown to black coarse sand with coarse gravel; slight staining, occasional brick/crushed brick fragments		
				SP	Coarse sand with coarse gravel coated in NAPL, with naphthalene-like odor	HS	1.0
20	10	40		SP/GP	Black, yellow, red agglomerate, rounded coarse sand grains, fused coarse gravel, completely coated with NAPL, occasional pieces of vesicular material, low density, flat gravel Groundwater encountered at 10.5 feet		
			MW-36D (12-13)			HS	133
15	15	30			Rainbow color sheen appears in blobs, naphthalene-like odor	HS 100%	61
					Globular rainbow color sheen, slow to dissipate	MS <50%	130
10	20						

WELL LOG



Note: Please see Figure A-1 for explanation of symbols

Log of Monitoring Well MW-36D

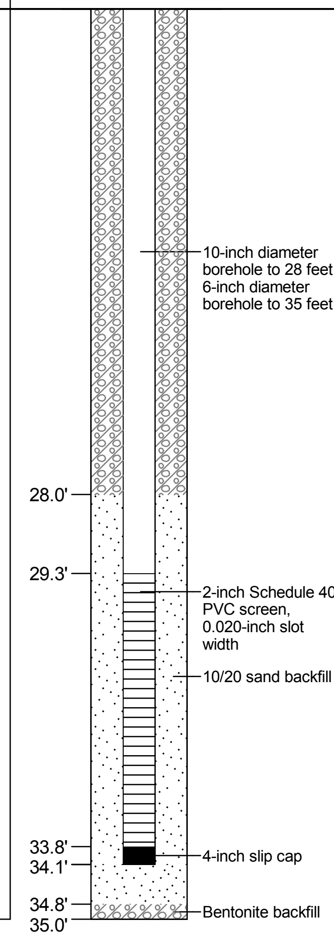
GeoEngineers

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Elevation (feet)	Depth (feet)	Recovered (in)	Sample Name	Group Classification	Material Description	Sheen	Headspace Vapor (ppm)
	20	60		SP	Black fine to medium sand lense		
			MW-36D (23-24) +DUP	GP	Black coarse gravel with coarse sand, multi-colored agglomerate with larger debris (brick)		
				SM	Gray to black silty fine to coarse sand with fine to coarse gravel	MS	31
5	25	60		SP-SM	Gray medium to coarse sand with silt and fine to coarse gravel, some silt lenses	SS	10.1
			MW-36D (29-33 composite)	SM	Silty fine to medium sand with occasional fine gravel (wet)		
0	30	60				MS	33.5
			MW-36D (31-32)			SS	10
				SM	Gray silty fine to medium sand with fine to coarse gravel (dense, moist)	NS	8.0
				ML	Gray silt with fine sand, occasional fine gravel		
-5	35						

Table column headings printed on the page: FIELD DATA (Interval, Recovered (in), Blows/foot, Collected Sample, Sample Name), Water Level, Graphic Log, Group Classification, MATERIAL DESCRIPTION, Sheen, Headspace Vapor (ppm).

WELL LOG



Note: Please see Figure A-1 for explanation of symbols

Seattle: Date:5/14/13 Path:C:\USERS\TNASH\DESKTOP\018684601.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_ENVIRONMENTAL_WELL

Log of Monitoring Well MW-36D (continued)

GEOENGINEERS

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Drilled	Start 3/29/2013	End 3/29/2013	Total Depth (ft) 24	Logged By PDR / Checked By ZAS	Driller Boart Longyear	Drilling Method Sonic (continuous core)

Hammer Data		Drilling Equipment	Rubber Track-Mounted Spider 3 Sonic Drill Rig
Surface Elevation (ft)	30.13	Top of Casing Elevation (ft)	29.62
Vertical Datum	USACE (Locks)		
Easting (X)	1270783.61	Horizontal Datum	NAD83 WA State Plane North
Northing (Y)	239086.77		

A 2 (in) well was installed on 3/29/2013 to a depth of 23 (ft).

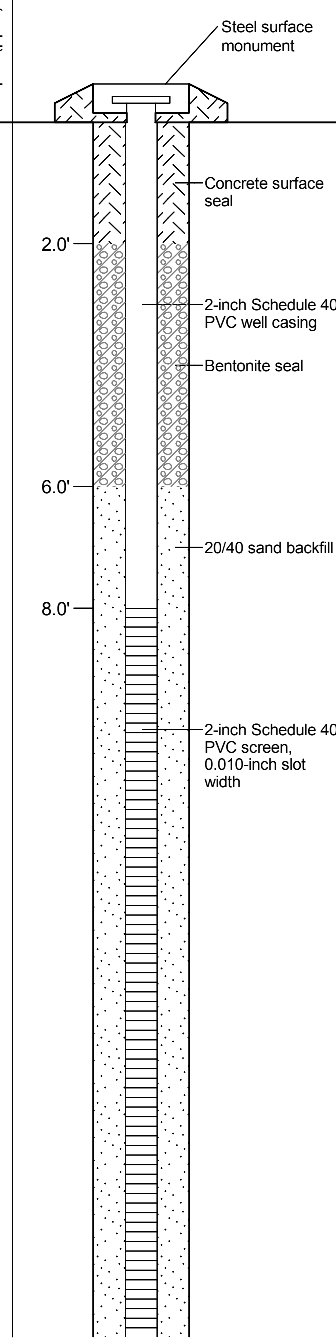
Groundwater Date Measured	Depth to Water (ft)	Elevation (ft)
4/22/2013	7.9	22.3

Notes: Hand-dug with posthole digger from 0 to 2 feet bgs.

FIELD DATA

Elevation (feet)	Depth (feet)	Recovered (in)	Sample Name	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)
30	0	24		SM	Brown to dark brown silty fine to medium sand with organics (roots)		
					Brick debris, concrete debris	NS	<1
		32		SP-SM	Brown fine to coarse sand with silt and coarse gravel		
				SW	Brown fine sand with occasional fine gravel		
				SP	Black to brown fine to coarse sand with occasional coarse gravel, sand and gravel made up of agglomerate in various states of fusion, some pieces have vitreous luster		
25	5	60					12
				GP	Black fine to coarse gravel with medium to coarse sand, primarily agglomerate, fused, low density, black color from staining, strong naphthalene-like odor (wet)	NS	74
20	10	60			Grades to increased sand		
				SP	Fine to coarse sand with occasional gravel, grains are rounded multi-colored Groundwater encountered at 11.3 feet	MS	80
			MW-36S (14-15) MW-36S (14-21 composite)	GP	Fine to coarse gravel made up of pieces of red-orange and yellow agglomerate, fused, coated in NAPL, but with no free NAPL, strong naphthalene-like odor	HS	180
15	15	60			No recovery from 15 to 18 feet		
				GP	Dark brown to black fine to coarse gravel with sand made up of red-orange, brown, and yellow agglomerate, some fine gravel, small wood fragments, staining does not coat all pieces, small amount of NAPL observed on water in the bag	HS	75
	20						

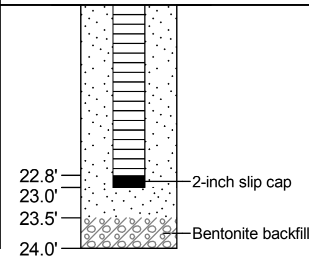
WELL LOG



Note: Please see Figure A-1 for explanation of symbols

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)
	20		48								HS	62
						MW-36S (22.5-23)				Black coarse gravel (1/2"), smaller pieces are broken up agglomerate, heavily coated with free NAPL	HS	88
									SM	Silty fine to medium sand with occasional fine gravel	SS	13

WELL LOG



Note: Please see Figure A-1 for explanation of symbols

Log of Monitoring Well MW-36S (continued)

GeoEngineers

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Figure A-11
Sheet 2 of 2

Drilled	Start	End	Total Depth (ft)	Logged By	Checked By	Driller	Drilling Method
	3/26/2013	3/26/2013	22	PDR	ZAS	Boart Longyear	Sonic (continuous core)

Hammer Data		Drilling Equipment	Rubber Track-Mounted Spider 3 Sonic Drill Rig
Surface Elevation (ft)	27.14	Top of Casing Elevation (ft)	26.85
Vertical Datum	USACE (Locks)		
Easting (X)	1270816.75	Horizontal Datum	NAD83 WA State Plane North
Northing (Y)	239231.18		

A 2 (in) well was installed on 3/26/2013 to a depth of 15.15 (ft).

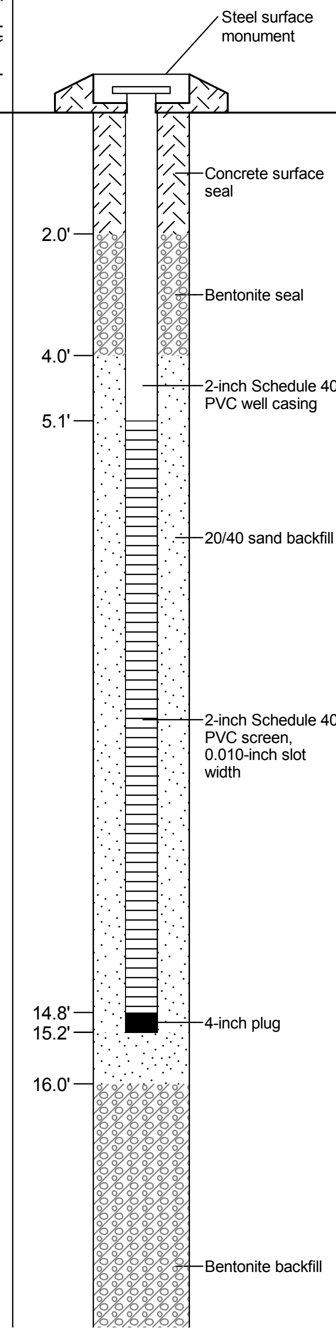
Groundwater Date Measured	Depth to Water (ft)	Elevation (ft)
4/22/2013	5.1	22.0

Notes: Hand-dug with posthole digger from 0 to 2 feet bgs.

FIELD DATA

Elevation (feet)	Depth (feet)	Recovered (in)	Collected Sample / Sample Name	Water Level	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)
	0	24	MW-37S (0.5-1)		SM	Dark brown to black silty fine to coarse sand, occasional fine gravel and organics (tree roots) Brick fragments, no staining	NS	
25		36			SP-SM	Black grading to brown fine to coarse sand with silt, agglomerate pieces rust stained (red brown), angular, low density		
	5	60		▼	GP-GM	Red-brown fine to coarse gravel with silt, agglomerate, low density Groundwater encountered at 5.6 feet		
20			MW-37S (7.5-8) (7.5-20 composite) MW-37S (8-9)		GP	Black fine to coarse sand with fine gravel coated in NAPL	HS	4.2
					GP	Black fine to coarse gravel with fine to coarse sand, gravel is agglomerate, rounded to angular, brown and black, low density		
	10	60			GP	Black coarse gravel with coarse sand, gravel is black agglomerate, low density, angular with metallic luster when broken, sand is red brown, subrounded	HS	<1
15			MW-37S (13.5-14.5)		SP	Brown fine to coarse sand, rounded, multi-colored grains		
	15	60			SP	Black to brown fine to coarse sand, rounded and multi-colored, primarily black		
10								
	20		MW-37S (19.5-20)		SM	Gray silty fine sand with fine to coarse gravel, gravel is rounded	NS	<1

WELL LOG



Note: Please see Figure A-1 for explanation of symbols

Log of Monitoring Well MW-37S

GEOENGINEERS

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)	WELL LOG
	20		24						SM	Gray silty fine to medium sand with occasional fine to coarse rounded gravel (dense, wet)			22.0'

Note: Please see Figure A-1 for explanation of symbols

Log of Monitoring Well MW-37S (continued)

GeoEngineers

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Drilled	Start	End	Total Depth (ft)	Logged By	Checked By	Driller	Drilling Method
	3/26/2013	3/26/2013	18	PDR	ZAS	Boart Longyear	Sonic (continuous core)

Hammer Data		Drilling Equipment	Rubber Track-Mounted Spider 3 Sonic Drill Rig
Surface Elevation (ft)	25.94	Top of Casing Elevation (ft)	25.42
Vertical Datum	USACE (Locks)		
Easting (X)	1270820.88	Horizontal Datum	NAD83 WA State Plane North
Northing (Y)	239318.1		

A 2 (in) well was installed on 3/26/2013 to a depth of 17 (ft).

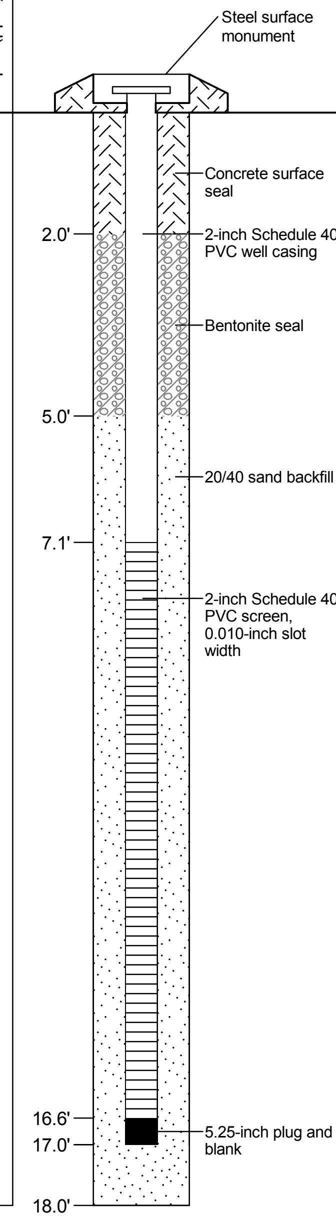
Groundwater Date Measured	Depth to Water (ft)	Elevation (ft)
4/22/2013	3.7	22.2

Notes: Hand-dug with posthole digger from 0 to 2 feet bgs.

Depth (feet)	Recovered (in)	Sample Name	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)
0	24	MW-38S (0.5-1)	SM	Dark brown to black silty fine to medium sand with occasional fine to coarse gravel; gravel up to 1.5" rounded, brick fragments, not stained, no odor	NS	
			SP-SM	Grades to increased medium to coarse sand, angular, low density		
	36			Black fine to coarse sand with silt, low density, angular grains		
				Grades to brown and then back to black (approximately 1" bands of color change) Groundwater encountered at 4.2 feet	NS	<1
5	60	MW-38S (5-15 composite)	SP/GP	Black and brown agglomerate with black vesicular material and fine to coarse sand		
				Grades to increased medium sand, less black vesicular material		
		MW-38S (8-9)	GP	Red-brown agglomerate with coarse sand, low density, angular, black vesicular material, no odor, very coarse grain sand matrix	NS	<1
			SP	Dark gray fine to coarse sand, no odor		
10	60	MW-38S (10-11)			NS	1.2
			GP	Red-brown agglomerate with coarse sand, low density, angular, black vesicular material, no odor, very coarse grain sand matrix		
15	36		SP	Black medium to coarse sand, no odor	NS	<1
			SM	Gray silty fine to coarse sand with occasional fine to coarse gravel; gravel up to 1.5" rounded		

Elevation (feet): 25, 20, 15, 10

WELL LOG



Note: Please see Figure A-1 for explanation of symbols

Seattle: Date:5/14/13 Path:C:\USERS\TNASH\DESKTOP\018684601.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_ENVIRONMENTAL_WELL

Log of Monitoring Well MW-38S

GeoEngineers

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Figure A-13
Sheet 1 of 1

Drilled	Start	End	Total Depth (ft)	Logged By	Checked By	Driller	Drilling Method
	3/25/2013	3/26/2013	22	PDR	ZAS	Boart Longyear	Sonic (continuous core)

Hammer Data		Drilling Equipment	Rubber Track-Mounted Spider 3 Sonic Drill Rig
Surface Elevation (ft)	26.99	Top of Casing Elevation (ft)	26.74
Vertical Datum	USACE (Locks)		
Easting (X)	1270814.56	Horizontal Datum	NAD83 WA State Plane North
Northing (Y)	239391.05		

A 2 (in) well was installed on 3/26/2013 to a depth of 22.1 (ft).

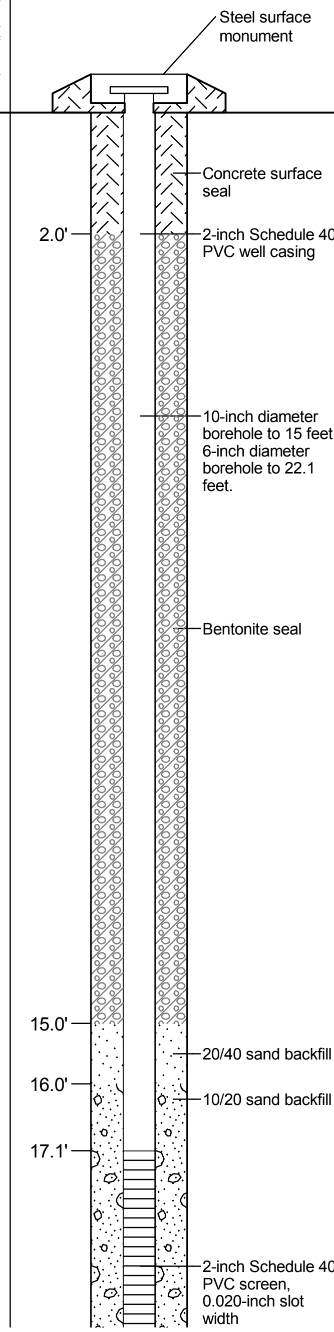
Groundwater Date Measured	Depth to Water (ft)	Elevation (ft)
4/22/2013	5.0	22.0

Notes: Hand-dug with posthole digger from 0 to 2 feet bgs. Temporary conductor casing (10-inch diameter) used from 0 to 15 feet bgs, with bentonite seal from 12 to 15 feet bgs.

FIELD DATA

Elevation (feet)	Depth (feet)	Recovered (in)	Sample Name	Water Level	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)
	0	24	MW-39D (0.5-1.5)		SM	Black silty fine to coarse sand with organics (tree roots), some brick fragments, no staining, no odor	NS	<1
25		36				Grades to increased medium to coarse sand		
					SP-SM	Brown to black medium to coarse sand with silt, occasional black, low density, angular vesicular material, fines portion very fine (possible cinders)	SS	<1
							NS	<1
	5	60		▼		Groundwater encountered at 6.1 feet		
20			MW-39D (8-10)		SP	Brown to black medium to coarse sand with trace silt, larger more common black, low density, angular vesicular material, occasional agglomerate light brown to orange color	NS	<1
	10	60				Brown to black medium to coarse sand with trace silt, numerous low density, angular vesicular material with vitreous luster, occasional small pieces of friable light colored agglomerate, sand grains light brown to red color	NS	<1
15						Drilling becomes harder at 13 feet		
			MW-39D (14-15)		SM	Gray silty fine to coarse sand with occasional coarse gravel	NS	<1
	15	60	MW-39D (16-19 composite)		SP-SM	Gray fine to coarse sand with silt and fine to coarse rounded gravel, gravel to 1.5", no odor, gravel color is white to orange	NS	<1
10			MW-39D (17-18)					
					SM	Gray silty fine to medium sand with occasional fine to coarse rounded gravel, dense, no odor	NS	<1
	20							

WELL LOG



Note: Please see Figure A-1 for explanation of symbols

Log of Monitoring Well MW-39D

GEOENGINEERS

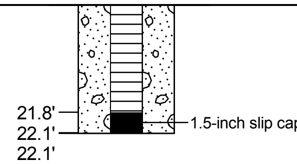
Project:	Puget Sound Energy North Lake Union
Project Location:	Gas Works Park, Seattle, Washington
Project Number:	0186-846-01

Figure A-14
Sheet 1 of 2

Seattle: Date:5/14/13 Path:C:\USERS\TNASH\DESKTOP\018684601.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_ENVIRONMENTAL_WELL

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)	WELL LOG
	20		24										
5													

FIELD DATA



Note: Please see Figure A-1 for explanation of symbols

Log of Monitoring Well MW-39D (continued)

GEOENGINEERS

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Figure A-14
Sheet 2 of 2

Drilled	Start 3/25/2013	End 3/25/2013	Total Depth (ft)	14	Logged By PDR / Checked By ZAS	Driller	Boart Longyear	Drilling Method	Sonic (continuous core)

Hammer Data		Drilling Equipment	Rubber Track-Mounted Spider 3 Sonic Drill Rig
Surface Elevation (ft) / Vertical Datum	26.89 / USACE (Locks)	Top of Casing Elevation (ft)	26.61
Easting (X) / Northing (Y)	1270814.09 / 239397.29	Horizontal Datum	NAD83 WA State Plane North

A 2 (in) well was installed on 3/25/2013 to a depth of 14.1 (ft).

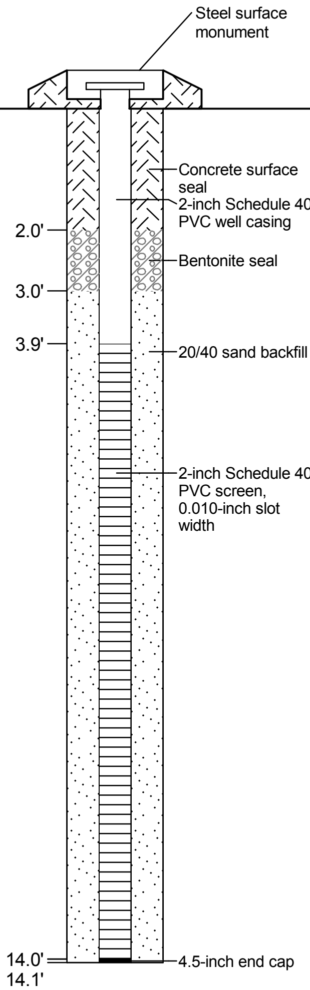
Groundwater Date Measured	Depth to Water (ft)	Elevation (ft)
4/22/2013	4.9	22.0

Notes: Hand-dug with posthole digger from 0 to 2 feet bgs.

FIELD DATA / WELL LOG

Elevation (feet)	Depth (feet)	Recovered (in)	Sample Name	Group Classification	Material Description	Sheen	Headspace Vapor (ppm)
	0	24		SM	Black silty fine to coarse sand with organics (tree roots)		
25		32		SP-SM	Brown to black fine to coarse sand with silt, grades to medium to coarse sand with less silt Black and red, low density, angular vesicular material, some small agglomerate, flat, light brown	NS	<1
	5	60	MW-39S (3.5-13.5 composite)				
20				SP	Brown and black medium to coarse sand with trace silt, large % made up of angular, low density agglomerate with small (coarse sand size) pieces, light brown, orange, red colors, sheen is globular Groundwater encountered at 7.6 feet	SS <5%	<1
	10	48					
15					Grades to increased coarse gravel	SS	<1
				SM	Gray silty fine to coarse sand with fine to coarse gravel	NS	<1

WELL LOG



Note: Please see Figure A-1 for explanation of symbols

Seattle: Date:5/14/13 Path:C:\USERS\TNASH\DESKTOP\018684601.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_ENVIRONMENTAL_WELL

Log of Monitoring Well MW-39S

GeoEngineers

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Figure A-15
Sheet 1 of 1

Drilled	Start	End	Total Depth (ft)	Logged By	Checked By	Driller	Drilling Method
	4/1/2013	4/1/2013	20	PDR	ZAS	Boart Longyear	Sonic (continuous core)

Hammer Data		Drilling Equipment	Rubber Track-Mounted Spider 3 Sonic Drill Rig
Surface Elevation (ft)	25.69	Top of Casing Elevation (ft)	25.18
Vertical Datum	USACE (Locks)		
Easting (X)	1270790.39	Horizontal Datum	NAD83 WA State Plane North
Northing (Y)	239491.03		

A 2 (in) well was installed on 4/1/2013 to a depth of 10.9 (ft).

Groundwater Date Measured	Depth to Water (ft)	Elevation (ft)
4/22/2013	3.5	22.2

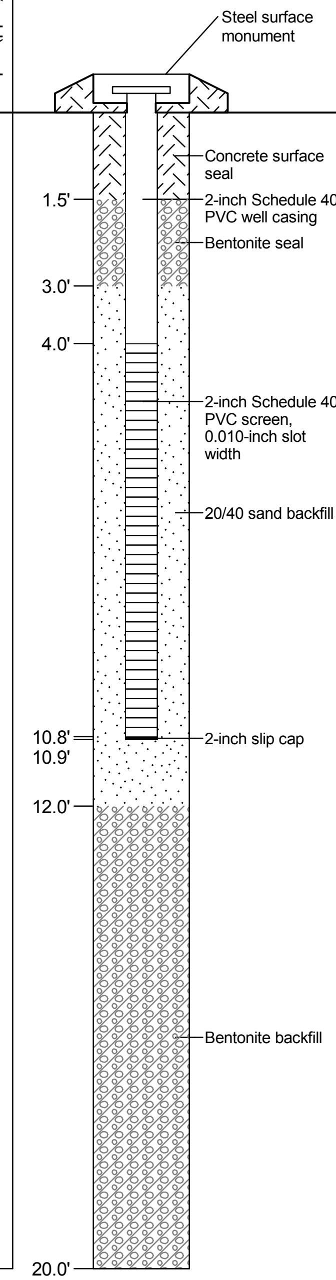
Notes: Hand-dug with posthole digger from 0 to 2 feet bgs.

FIELD DATA

Depth (feet)	Recovered (in)	Sample Name	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)
0	24		ML	Brown silt with occasional fine sand and organics (roots)		
0.5			SM	Black silty fine sand with occasional gravel; gravels appear to be agglomerate, grinds to fine black powder		
2	36					
3.5			SM	Gray-brown silty fine to coarse sand with small wood chips	NS	<1
4.5			SP/GP	Multi-colored agglomerate coarse sand grading to gravel-sized fused agglomerate, sheen, no color, no odor	SS 50%	<1
5	60	MW-40S (5-6) (5-10 composite)		Groundwater encountered at 4.5 feet		
6			GP	Black, red, white, large agglomerate gravel with low density, vesicular pieces, very low fines	NS	<1
10	60					
11			SP-SM	Gray fine sand with silt	NS	<1
15	60	MW-40S (15-15.5)			NS	<1
17.5		MW-40S (17.5-18)	SM	Gray silty fine to coarse sand with coarse gravel	NS	<1
18			ML	Gray silt with occasional gravel, slight naphthalene-like odor		
19.5		MW-40S (19.5-20)			NS	1.1
20						

Elevation (feet): 25, 20, 15, 10

WELL LOG



Note: Please see Figure A-1 for explanation of symbols

Log of Monitoring Well MW-40S

GeoEngineers

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Figure A-16
Sheet 1 of 1

Drilled	Start 4/1/2013	End 4/1/2013	Total Depth (ft) 27	Logged By ARJ / Checked By ZAS	Driller Boart Longyear	Drilling Method Direct Push

Surface Elevation (ft) / Vertical Datum	35.42 / USACE (Locks)	Hammer Data	Drilling Equipment: Geoprobe 6620 DT
Easting (X) / Northing (Y)	1270720.37 / 239526.8	System Datum: NAD83 WA State Plane North	Groundwater — Date Measured / Depth to Water (ft) / Elevation (ft)
Notes:			

Elevation (feet)	Depth (feet)	Recovered (in)	Collected Sample / Sample Name Testing	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)	REMARKS
35	0	30	GEI-1 (0-3)	SM	Brown silty fine to medium sand with occasional gravel, brick fragments, trace organics (rootlets) one black aspheltic gravel, fused black (medium dense, moist)	NS	<1	
				SM	Dark brown silty fine to medium sand with occasional gravel (medium dense, moist)	NS	<1	
						NS	<1	
						NS	<1	
					Grades to black			
30	5	30			Grades to brown	NS	<1	
			GEI-1 (7-7.5)	SP-SM	Black stained sooty fine to medium sand with silt and fine gravel (medium dense, moist)	NS	<1	
25	10	36		SP	Brown, tan, yellow, black coarse sand with gravel; gravel is agglomerate, fused, low density, vesicular, tan, brown, yellow and black fused low density vesicular, metallic luster (loose, moist)	NS	<1	
			GEI-1 (12-12.5)			SS <5%	<1	White, blocky Groundwater encountered at 13 feet
					Becomes black stained			
20	15	42		GP	Gray gravel with sand; gravel is agglomerate, red, black, tan, fused low density, vesicular material and black, vesicular, low density, metallic luster (medium dense, wet)			
			GEI-1 (16.5-17) GEI-1 (17-17.5)		Tar-like blebs within grain space Sawdust-like material, partially decayed	HS	<1	Tar-like, rainbow
				SP	Gray medium to coarse sand with occasional gravel (dense, wet)	NS	<1	
	20							

Note: Please see Figure A-1 for explanation of symbols

Log of Boring GEI-1

GeoEngineers

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Figure A-17
Sheet 1 of 2

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name / Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)	REMARKS
15	20		48								NS	<1	
											NS	<1	
						GEI-1 (23-24)			SM	Gray silty fine to medium sand with gravel (dense, wet)	NS	<1	
									SP	Gray medium sand with occasional gravel (dense, wet)			
10	25		24						SM	Gray silty fine to medium sand with gravel (very dense, wet)	NS	<1	

Note: Please see Figure A-1 for explanation of symbols

Log of Boring GEI-1 (continued)

GeoEngineers

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Drilled	Start 4/1/2013	End 4/1/2013	Total Depth (ft)	20	Logged By ARJ / Checked By ZAS	Driller	Boart Longyear	Drilling Method	Direct Push

Surface Elevation (ft) / Vertical Datum	37.87 / USACE (Locks)	Hammer Data		Drilling Equipment	Geoprobe 6620 DT
Easting (X) / Northing (Y)	1270319.96 / 238899.51	System Datum	NAD83 WA State Plane North	Groundwater: Date Measured / Depth to Water (ft) / Elevation (ft)	
Notes:					

FIELD DATA

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name / Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)	REMARKS
	0		24			GEI-2 (0-3)			AC	Approximately 2 inches asphalt concrete	NS	<1	
									SM	Brown silty fine sand with gravel, grades to tan fine sand at 0.25 feet	SS <5%	<1	Gray, blocky
									SP	Black stained medium to coarse sand with gravel (medium dense, moist)	NS	<1	
35													
									SP	Black stained medium to coarse sand with gravel; faint naphthalene-like odor (medium dense, moist)			
	5		48			GEI-2 (5-6)					NS	<1	
									GP	Gray to black fine to coarse gravel with sand (medium dense, moist)			
											NS	<1	
30											NS	<1	
											NS		
	10		50							Slight naphthalene-like odor	SS <15%	<1	White, blocky
25									SP	Tan medium to coarse sand with gravel (medium dense, moist) Red-brown 1-inch interbedded silt and fine sand Red-brown fine to coarse sand with gravel	NS	<1	
									SP	Brown medium to coarse sand (dense, moist)	NS	<1	Groundwater encountered at 14.5 feet
	15		40										
						GEI-2 (16-17)			SP-SM	Brown gray mottled medium to coarse sand with gravel and silt (dense, wet)	NS	<1	
20									SM	Gray silty fine to coarse sand with gravel (dense, wet)	NS	<1	
	20												

Note: Please see Figure A-1 for explanation of symbols

Log of Boring GEI-2

GEOENGINEERS

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Figure A-18
Sheet 1 of 1

Drilled	Start 3/27/2013	End 3/27/2013	Total Depth (ft)	29	Logged By ARJ / Checked By ZAS	Driller	Boart Longyear	Drilling Method	Direct Push

Surface Elevation (ft) / Vertical Datum	34.07 / USACE (Locks)	Hammer Data		Drilling Equipment	Geoprobe 6620 DT
Easting (X) / Northing (Y)	1270730.52 / 239136.77	System Datum	NAD83 WA State Plane North	Groundwater	Date Measured / Depth to Water (ft) / Elevation (ft)
Notes:					

FIELD DATA

Elevation (feet)	Depth (feet)	Recovered (in)	Collected Sample / Sample Name / Testing	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)	REMARKS
	0	30		Brick	Approximately 1-inch thick brick paver	SS 5%	<1	Blocky, metallic
				SP	Brown fine to medium sand (dry to moist) (fill) (paver sand)			
			GEI-3 (2-3)	SM	Dark gray silty fine to medium sand with occasional gravel (silt 30%, gravel 15%), moderate hydrocarbon odor	MS 40%	18.4	Rainbow
					Brick fragments	SS ~5%	1.5	Florets
30				SM	Brown to dark brown silty fine sand with occasional gravel, trace organics (mulch)			
	5	30				NS	1.3	
			GEI-3 (8-9)	SP	Black medium to coarse sand with gravel and soot, gravel red, tan, black, yellow agglomerate, low density fused and vesicular, irregular, angular, sand black soot stained, medium to coarse fragments, agglomerate, moderate naphthalene-like odor	MS 30%	3.7	Florets, streaks
25	10	24			Black, tan, red medium to coarse sand with occasional gravel, sand agglomerate fragments and cinders, fused, irregular gravel agglomerate, low density, angular, vesicular, metallic	MS	5.6	Florets, streaks
			GEI-3 (11.5-12)	GP	Olive green gravel with sand, NAPL present, strong naphthalene-like odor, agglomerate, fused, vesicular, angular to subrounded (wet)	HS	14.2	Groundwater encountered at 12 feet
20	15	18				HS	93	
				SOOT	Green gray to dark gray soot-like material	NS		
			GEI-3 (16-17)	SOOT	Dark gray to black soot-like material with partially decayed light brown wood fragments, strong naphthalene-like odor (wet)	HS	123	Strong naphthalene-like odor
15								Respirator used
				MH	Gray elastic silt with trace organics (rootlets)			
	20							

Note: Please see Figure A-1 for explanation of symbols

Log of Boring GEI-3

GeoEngineers

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Figure A-19
Sheet 1 of 2

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name / Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)	REMARKS
	20		60								MS	15.3	Sheen in small florets on outside of sample core
						GEI-3 (22-23)							
										1-inch layer silt with medium sand, small blobs black NAPL just below silt layer	HS		
									SP	Gray fine to medium sand with occasional gravel; slight naphthalene-like odor (dense, wet)	NS	14.7	
10						GEI-3 (24-25)							
	25		48								NS	8.1	
											NS		
						GEI-3 (27-28)							
									SM	Gray silty fine to medium sand with gravel; slight naphthalene-like odor (very dense, wet)	NS	6.4	
											NS		

Note: Please see Figure A-1 for explanation of symbols

Log of Boring GEI-3 (continued)

GEOENGINEERS

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Figure A-19
Sheet 2 of 2

Drilled	Start 3/27/2013	End 3/27/2013	Total Depth (ft)	31	Logged By ARJ / Checked By ZAS	Driller	Boart Longyear	Drilling Method	Direct Push

Surface Elevation (ft) / Vertical Datum	28.53 / USACE (Locks)	Hammer Data	
Drilling Equipment	Geoprobe 6620 DT		
Easting (X) / Northing (Y)	1270767.86 / 239174.48	System Datum	NAD83 WA State Plane North

Groundwater

Date Measured	Depth to Water (ft)	Elevation (ft)

Notes:

FIELD DATA

Depth (feet)	Recovered (in)	Sample Name / Testing	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)	REMARKS
0	18	GEI-4 (0.5-1.5)	AC	Approximately 2 inches asphalt concrete			
			SM	Dark brown to black silty fine sand with occasional fine gravel, trace brick fragments, asphalt fragments (loose, dry to moist)		<1	Organic sheen
						<1	Very loose, almost no hammer action
			SP	Black to brown fine to medium sand with gravel (red, tan, brown fine to coarse gravel, agglomerate, low density, fused) (black fine grained, low density, metallic luster, vesicular) (loose, moist)	MS 60%		Florets
5	24	GEI-4 (5.5-7)	GP	Gray to black fine to coarse gravel with sand, gravel is black agglomerate, low density, angular, fused; sand is black, tan to red agglomerate, low density, subrounded to angular	MS 15%	18	Florets, olive stained gloves Groundwater encountered at 6 feet
10	9	GEI-4 (10-11)			SS 3%	2.8	Streaks
15	12	GEI-4 (15-16)		Sand has soot coated grains, tan, red, black, angular to rounded, low density (wet)	SS 5%	5.0	Mothball-like odor
			SP-SM	Black to dark gray fine sand with gravel and silt; possibly stained (medium dense to dense, wet)			
20							

Elevation (feet): 25, 20, 15, 10

Note: Please see Figure A-1 for explanation of symbols

Log of Boring GEI-4

GeoEngineers

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Figure A-20
Sheet 1 of 2

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)	REMARKS
	20		42			GEI-4 (20-21)					NS	5.0	Moderate mothball-like odor
										Grades to gray			
5											NS	2.3	
									SM	Gray silty fine to medium sand with occasional gravel (dense, wet)			
	25		48										Slight mothball-like odor
											NS	1.8	
0						GEI-4 (28.5-29)			SP-SM	Dark gray fine sand with silt and occasional fine gravel (stained plastic sampler olive color) (very dense, wet)	HS 80%	1.1	Slight mothball-like odor Rainbow
	30		12			GEI-4 (30-31)					SS <5%	1.5	White streaks

Note: Please see Figure A-1 for explanation of symbols

Log of Boring GEI-4 (continued)

GEOENGINEERS

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Drilled	Start 3/28/2013	End 3/28/2013	Total Depth (ft)	24	Logged By ARJ / Checked By ZAS	Driller	Boart Longyear	Drilling Method	Direct Push

Surface Elevation (ft) / Vertical Datum	25.87 / USACE (Locks)	Hammer Data		Drilling Equipment	Geoprobe 6620 DT
Easting (X) / Northing (Y)	1270823.98 / 239274.93	System Datum	NAD83 WA State Plane North	Groundwater	Date Measured / Depth to Water (ft) / Elevation (ft)

Notes: Hand-dug with posthole digger from 0 to 2 feet bgs.

Depth (feet)	Recovered (in)	Sample Name	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)	REMARKS
0	24		SM	Dark brown silty fine to medium sand with organics (rootlets, wood fragments from tree roots) (loose, moist) (topsoil)	NS	<1	
		GEI-5 (1.5-2)					
2	34		SP	Tan, red, gray fine to coarse sand with gravel; 1-inch soft partially decayed wood chip	NS	<1	
				Sand made of angular, low density, agglomerate, friable; Gravel is tan, red agglomerate, low density, fused small vesicles (loose, moist)	NS	<1	
			SP	Gray to tan fine to coarse sand with occasional gravel (medium dense, wet); Sand is predominantly angular, low density agglomerate, friable, coarse sand includes red-brown fused agglomerate with vitreous luster; Gravel is red-brown fused agglomerate with vitreous luster, black agglomerate, vesicular, low density, slight odor			
5	34	GEI-5 (5-7)			NS		Groundwater encountered at 5 feet
					NS	9.6	
					NS		
10	30	GEI-5 (10-10.5)					
			GP	Black, tan, brown coarse gravel with medium to coarse sand (medium dense, wet); Gravel is black, tan, red, brown fused agglomerate, angular to small to no vesicles, low density, vitreous luster; Sand is angular, low density, agglomerate, friable, slight odor	NS	3.5	
					NS	8.5	
15	30	GEI-5 (15-16)			NS	1.8	
			SM	Gray silty medium to coarse sand with gravel, subrounded to rounded gravel, occasional 1/2-inch medium sand lense (dense, wet)			
					NS	1.4	Rock in sampler shoe
				Increasing silt			
			SM	Gray silty fine to coarse sand with coarse rounded gravel (very dense, wet)			
20							

Elevation (feet): 25, 20, 15, 10

Note: Please see Figure A-1 for explanation of symbols

Log of Boring GEI-5

GEOENGINEERS

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Figure A-21
Sheet 1 of 2

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name / Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)	REMARKS
-5	20		48								NS	4.5	
						GEI-5 (22-23)					NS	1.2	

Note: Please see Figure A-1 for explanation of symbols

Log of Boring GEI-5 (continued)

GeoEngineers

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Drilled	Start 3/28/2013	End 3/28/2013	Total Depth (ft) 31	Logged By ARJ / Checked By ZAS	Driller Boart Longyear	Drilling Method Direct Push

Surface Elevation (ft) / Vertical Datum	29.63 / USACE (Locks)	Hammer Data	Drilling Equipment: Geoprobe 6620 DT
Easting (X) / Northing (Y)	1270789.54 / 239105.07	System Datum: NAD83 WA State Plane North	Groundwater: Date Measured / Depth to Water (ft) / Elevation (ft)

Notes: Hand-dug with posthole digger from 0 to 2 feet bgs.

Depth (feet)	Recovered (in)	Sample Name / Testing	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)	REMARKS
0	24		SM	Dark brown silty fine sand with organics (rootlets) (medium dense, moist) (topsoil)	NS	<1	
			SM	Brown silty fine sand with gravel			
	30		SP	Black stained sooty fine to coarse sand with gravel, trace tan brick fragments, sand minor component, friable agglomerate, angular, platey (moist)			
			SP	Dark brown to tan fine to medium sand with occasional gravel (loose, moist); Sand is friable agglomerate particles;			
5	30	GEI-6 (5.5-6)		Gravel is tan, red, brown fused agglomerate, angular, vesicular, low density, and black, vesicular, low density agglomerate with metallic luster			
			SP	Black sooty coarse sand with gravel, all particles stained by soot; gravel agglomerate, blocky, vesicular material, strong odor (loose, wet)	HS 50%	80.1	Groundwater encountered at 6.5 feet; Rainbow streaks
			SP	Black stained fine to coarse sand with gravel (loose, wet)			
10	30	GEI-6 (10-12.5)		Black agglomerate, highly vesicular, angular (loose, wet) Shake test indicates lack of NAPL			
			GP	Black coarse gravel with sand, heavy odor, naphthalene-like (loose, wet)	HS 50%	105	Metallic
15	12				HS	2.6	Metallic streaks
20							

Elevation (feet): 25, 20, 15, 10

Note: Please see Figure A-1 for explanation of symbols

Log of Boring GEI-6

GEOENGINEERS

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Figure A-22
Sheet 1 of 2

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name / Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)	REMARKS
	20		24			GEI-6 (20-21)				Black stained fine to coarse gravel with coarse sand; gravel black vesicular agglomerate; sand stained, fused agglomerate, tan, red, brown, platey	HS 60%	90.5	Metallic
									SM	Dark gray to black silty fine sand with rounded to subrounded gravel (dense, wet)	SS		Streaks
5													
	25		48			GEI-6 (25-26)				Black silty fine sand with rounded gravel	HS	122	
										Grades to gray	SS 5%	15.1	Milky streaks
										Grades to very dense			
											NS		
											NS	10	
0									SM	Gray silty fine sand with gravel			
	30		12			GEI-6 (30-31)							
											NS	22.8	

Note: Please see Figure A-1 for explanation of symbols

Log of Boring GEI-6 (continued)

GEOENGINEERS

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Figure A-22
Sheet 2 of 2

Drilled	Start 3/28/2013	End 3/28/2013	Total Depth (ft) 25	Logged By ARJ / Checked By ZAS	Driller Boart Longyear	Drilling Method Direct Push

Surface Elevation (ft) / Vertical Datum	32.8 / USACE (Locks)	Hammer Data	Drilling Equipment: Geoprobe 6620 DT
Easting (X) / Northing (Y)	1270750.22 / 239356.88	System Datum: NAD83 WA State Plane North	Groundwater: Date Measured / Depth to Water (ft) / Elevation (ft)

Notes:

FIELD DATA

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)	REMARKS
	0		34						ASH	Black sooty charcoal and ash with charcoal briquettes	NS	<1	
									ML	Brown silt with medium to coarse sand and occasional gravel	NS	<1	
30													
	5		24							Trace brick fragments	NS	2.1	
									SP	Brown to black medium to coarse sand with gravel Gravel is low density, vesicular, agglomerate, reddish brown angular, fused, smooth texture, and black, low density, vesicular, agglomerate, metallic luster, angular	NS	2.3	
25													
	10		24										
													Groundwater encountered at 11.5 feet
					↕	GEI-7 (12-24)							
20													
											NS	2.7	
	15		24		↕	GEI-7 (15-16)			SP-SM	Gray fine sand with silt and occasional gravel (dense, wet)	NS	<1	
15													
									SM	Gray silty fine to medium sand with fine to coarse gravel, occasional 1-inch thick medium sand interbeds (very dense, wet)			
	20												

Note: Please see Figure A-1 for explanation of symbols

Log of Boring GEI-7

GeoEngineers

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Figure A-23
Sheet 1 of 2

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)	REMARKS
	20		48			GEI-7 (20-21)					NS	<1	
10									SP	Gray fine to medium sand (very dense, wet)			
											NS	<1	
	25												

Note: Please see Figure A-1 for explanation of symbols

Log of Boring GEI-7 (continued)

GeoEngineers

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Drilled	Start 4/1/2013	End 4/1/2013	Total Depth (ft) 15	Logged By ARJ / Checked By ZAS	Driller Boart Longyear	Drilling Method Direct Push

Surface Elevation (ft) / Vertical Datum	25.32 / USACE (Locks)
Hammer Data	
Drilling Equipment	Geoprobe 6620 DT
Easting (X) / Northing (Y)	1270602.79 / 238807.66
System Datum	NAD83 WA State Plane North
Groundwater	Date Measured / Depth to Water (ft) / Elevation (ft)

Notes: Hand-dug with posthole digger from 0 to 2 feet bgs.

FIELD DATA

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)	REMARKS
25	0		24						SM	Brown and tan mottled silty fine sand with occasional gravel, one fine gravel piece of black agglomerate, vesicular, metallic luster (moist)	NS		
			30										
						GEI-8 (4-4.5)			SP	Red, brown, black fine to medium sand with fine gravel; material is agglomerate, red to brown to black, fused; friable gravel is black vesicular agglomerate with metallic luster; moderate naphthalene-like odor (moist to wet)	SS 10%	<1	White streaks Groundwater encountered at 4.5 feet
20	5		48			GEI-8 (5-6)			SM	Dark brown to black silty fine sand with gravel; gravel includes black agglomerate, vesicular, metallic luster (medium dense, wet)	NS	<1	
									SP	Black fine sand with gravel (medium dense, wet)	SS 10%	<1	White streaks
									CL/ML	Gray soft clay/silt with occasional thin sandy silt interbeds, trace organics (rootlets) (soft, wet)	NS	<1	
											NS	<1	Moderate odor
						GEI-8 (8.5-9.5)			SP/SM	Gray medium sand and silty sand interbedded (dense, wet)	NS	<1	
15	10		50						SM	Gray silty fine to medium sand with gravel (dense, wet)	NS	<1	
	15												

Note: Please see Figure A-1 for explanation of symbols

Log of Boring GEI-8

GEOENGINEERS

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Log of Boring GEI-9

Drilled	Start	End	Total Depth (ft)	Logged By	Checked By	Driller	Drilling Method
	4/1/2013	4/1/2013	25	ARJ	ZAS	Boart Longyear	Direct Push

Surface Elevation (ft): 38.41
Vertical Datum: USACE (Locks)
Hammer Data:
Drilling Equipment: Geoprobe 6620 DT
Easting (X): 1270345.13
Northing (Y): 238800.28
System Datum: NAD83 WA State Plane North
Groundwater: Date Measured / Depth to Water (ft) / Elevation (ft)

Notes: Hand-dug with posthole digger from 0 to 2 feet bgs.

FIELD DATA

Elevation (feet)	Depth (feet)	Recovered (in)	Collected Sample / Sample Name / Testing	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)	REMARKS
	0	24		SM	Brown silty fine sand with trace gravel (medium dense, moist)	NS	<1	
				SM	Black silty fine sand with gravel (medium dense, moist)	NS	<1	
				CC	Concrete			
35		30	GEI-9 (2-3)	SM	Black silty medium to coarse sand with gravel; Gravel is rounded rock and stained black to tan, agglomerate, fused, vesicular, friable, and trace black agglomerate, vesicular, metallic luster (medium dense, moist)	NS	<1	Hard drilling 2 to 4 feet
	5	48			Black silty fine sand with trace gravel	SS <5%	<1	Metallic streak
					3-inch concrete layer at 5.25 and 6.25 feet			
				SP	Brown fine to medium sand with occasional gravel (loose, moist)	NS	<1	
30				SP	Red, tan, brown, black, white medium to coarse sand with gravel (loose, moist); Gravel is red, tan, brown fused agglomerate, friable with vitreous luster, some pieces vesicular; black, vitreous agglomerate with metallic luster Sand is smaller pieces of above	NS	<1	
	10	20	GEI-9 (11-11.5)		Increase in percentage of black vitreous agglomerate with metallic luster (loose, moist)			
				SM	Brown silty medium to coarse sand with gravel (dense, wet)	SS <5%		Flat metallic streak Groundwater encountered at 11.5 feet
25				SP	Brown/tan medium sand (dense, wet)			
	15	42	GEI-9 (16-17)			NS	<1	
						NS	<1	
20					2 inch silt lense			
				SM	Gray silty fine to medium sand with gravel (dense, wet)	NS	<1	
	20							

Note: Please see Figure A-1 for explanation of symbols

Seattle: Date:5/14/13 Path:C:\USERS\TNASH\DESKTOP\018684601.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_ENVIRONMENTAL_STANDARD

GeoEngineers

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Figure A-25
Sheet 1 of 2

Elevation (feet)	Depth (feet)	FIELD DATA: Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name / Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)	REMARKS
	20		46							Gray silty fine to medium sand with gravel (dense, wet)	NS	<1	
											NS		
15											NS	<1	
	25												

Note: Please see Figure A-1 for explanation of symbols

Log of Boring GEI-9 (continued)

GEOENGINEERS

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Drilled	Start 3/29/2013	End 3/29/2013	Total Depth (ft)	20	Logged By ARJ / Checked By ZAS	Driller	Boart Longyear	Drilling Method	Direct Push

Surface Elevation (ft) / Vertical Datum	23.92 / USACE (Locks)	Hammer Data		Drilling Equipment	Geoprobe 6620 DT
Easting (X) / Northing (Y)	1270238.07 / 238714.94	System Datum	NAD83 WA State Plane North	Groundwater	Date Measured / Depth to Water (ft) / Elevation (ft)
Notes:					

Depth (feet)	Recovered (in)	Collected Sample / Sample Name	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)	REMARKS
0	48		SM	Black to brown silty fine to medium sand with occasional gravel (loose, moist)	NS	<1	
2-3		GEI-10 (2-3)	GP-GM	Black gravel with silt and sand (medium dense, wet); gravel is black agglomerate, metallic luster, vitreous, sand is smaller particles of the same, moderate hydrocarbon odor	MS 90%	2.5	Groundwater encountered at 2.5 feet Flat metallic, faint
3			SM	Gray silty fine sand with gravel (medium dense, wet)	NS	<1	
4.5			SP	Gray medium to coarse sand with fine to coarse gravel	NS	<1	
5	30						
6				Increasing gravel			
6.5-7.5		GEI-10 (6.5-7.5)			NS	<1	
10	30				NS	<1	
11			SP	Gray fine to medium sand with fine to coarse gravel (dense, wet)	NS	<1	
15	48			Fine to medium sand	NS	<1	
16.5				Medium to coarse sand with coarse gravel	NS	<1	
20							

Elevation (feet): 20, 15, 10, 5

Note: Please see Figure A-1 for explanation of symbols

Log of Boring GEI-10

GeoEngineers

Project: Puget Sound Energy North Lake Union

Project Location: Gas Works Park, Seattle, Washington

Project Number: 0186-846-01

Figure A-26
Sheet 1 of 1

Drilled	Start 3/29/2013	End 3/29/2013	Total Depth (ft) 30	Logged By ARJ Checked By ZAS	Driller Boart Longyear	Drilling Method Direct Push

Surface Elevation (ft) 37.21 Vertical Datum USACE (Locks)	Hammer Data	Drilling Equipment	Geoprobe 6620 DT
Easting (X) 1270251.2 Northing (Y) 238857.14	System Datum NAD83 WA State Plane North	Groundwater	Date Measured / Depth to Water (ft) / Elevation (ft)

Notes: Hand-dug with posthole digger from 0 to 2 feet bgs.

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)	REMARKS
	0		24						SM	Dark brown silty fine to medium sand with occasional gravel			
35			24							Black silty fine to medium sand with occasional gravel, brick fragment	NS	<1	
									SM	Dark gray silty fine to medium sand with gravel and occasional brick fragments (medium dense, moist)			
	5		36								NS	<1	
30									GP-GM	Dark brown fine gravel with silt and sand; Gravel is tan, fused, friable agglomerate, and black agglomerate, vesicular, metallic luster (medium dense, wet)	NS	<1	Perched groundwater encountered at 6.5 feet
									SP-SM	Tan to brown and gray silty medium to coarse sand with fine gravel (medium dense, moist)	NS	<1	
25	10		48							Mottled tan, brown and gray silty fine to coarse sand with fine to coarse gravel (dense, moist)	NS	<1	
											NS		
											NS	<1	
	15		30						SP-SM	Gray fine to medium sand with silt (dense, wet)	SS	<1	Groundwater encountered at 15 feet
										3mm black fine to medium sand			
						GEI-11 (16-17)					NS	<1	
20									SP	Brown medium to coarse sand with fine gravel (dense, wet)	NS	<1	
	20												

Note: Please see Figure A-1 for explanation of symbols

Log of Boring GEI-11

GEOENGINEERS

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Figure A-27
Sheet 1 of 2

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name / Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)	REMARKS
	20		36										
										Grades to gray			
15						GEI-11 (21.5-22.5)				Tar-like material between grains at 21.75 feet Gray medium to coarse sand with coarse gravel interbedded with gray medium to coarse sand 2-inch thick band of gray fine to medium sand with tar-like globules	SS 5% NS	2.0 <1	Milky
	25		36			GEI-11 (26-26.5)					NS		
									SM	2-inch black medium to coarse sand with gravel, stained			
10										Silty gray fine to medium sand with rounded fine gravel (very dense, wet)	NS	1.4	
						GEI-11 (27.5-28)							
	30												

Note: Please see Figure A-1 for explanation of symbols

Log of Boring GEI-11 (continued)

GEOENGINEERS

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Drilled	Start	End	Total Depth (ft)	Logged By	Checked By	Driller	Drilling Method
	3/29/2013	3/29/2013	26	ARJ	ZAS	Boart Longyear	Direct Push

Surface Elevation (ft) / Vertical Datum	35.41 / USACE (Locks)	Hammer Data	
Drilling Equipment	Geoprobe 6620 DT		
Easting (X) / Northing (Y)	1270195.16 / 239046.6	System Datum	NAD83 WA State Plane North

Groundwater: Date Measured | Depth to Water (ft) | Elevation (ft)

Notes: Hand-dug with posthole digger from 0 to 2 feet bgs.

FIELD DATA

Elevation (feet)	Depth (feet)	Recovered (in)	Sample Name / Testing	Group Classification	Material Description	Sheen	Headspace Vapor (ppm)	Remarks
35	0	24		SM	Dark brown silty fine to medium sand with trace organics (rootlets) (moist)	NS	<1	
						NS	<1	
					Grades to black stained with gravel	NS		
				SP	Gray medium sand (moist)			
				SM	Black silty sand with fine gravel (slight odor)	NS	<1	
		36		BRICK	Crushed red brick			
				SP	Stained black to dark gray fine to medium sand (moist) (strong odor)	HS 100%	187	Metallic, thick
				SP	Black to dark gray fine to medium sand with trace brick fragments			
30	5	48	GEI-12 (5-7)			HS 100%	245	Rainbow, staining brown to PID bag
				ML/SM	Interbedded gray to dark brown silt to silty fine sand lenses			
				SP	Gray medium sand (moist)			
					With coarse gravel			
					With occasional 2 mm silt lenses	SS <5%	1.7	Milky
25	10	54			Gray to dark gray	HS >95%		Rainbow
			GEI-12 (11-15)	SM	Black silty medium sand with brick fragments			
				SP	Gray medium sand (medium dense, wet)			Groundwater encountered at 11.5 feet
					With fine to coarse gravel	HS >95%	214	Metallic
					NAPL coated grains			
					Shake test at 14 feet: NAPL surface globules, copper colored NAPL, stained plastic sampler, gloves stained olive color	HS 100%	251	Globules
20	15	30	GEI-12 (15-17)	SP	Gray medium to coarse sand with fine to coarse gravel (medium dense, wet) Tar-like black material from 15.5 to 16.5 feet, stringy between grains Shake test at 16 feet: tar-like substance in globules at base of water small globules floating	HS 70%	30.5	Metallic
				SP-SM	Gray fine sand with silt (dense, wet)			
	20							

Note: Please see Figure A-1 for explanation of symbols

Seattle: Date:5/14/13 Path:C:\USERS\TNASH\DESKTOP\018684601.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_ENVIRONMENTAL_STANDARD

Log of Boring GEI-12

GeoEngineers

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name / Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)	REMARKS
15	20		34								NS	<1	
										With gravel			
									SP	Gray medium to coarse sand with fine to coarse gravel (very dense, wet) Black tar-like between grains (stringy in gloves)			
10	25		12			GEI-12 (25-26)					HS	12.4	

Note: Please see Figure A-1 for explanation of symbols

Log of Boring GEI-12 (continued)

GeoEngineers

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Drilled	Start 4/1/2013	End 4/1/2013	Total Depth (ft) 25.5	Logged By ARJ, Checked By ZAS	Driller Boart Longyear	Drilling Method Direct Push

Surface Elevation (ft) / Vertical Datum	35.17 / USACE (Locks)	Hammer Data	
Drilling Equipment	Geoprobe 6620 DT		
Easting (X) / Northing (Y)	1270525.65 / 239143.21	System Datum	NAD83 WA State Plane North
Groundwater	Date Measured	Depth to Water (ft)	Elevation (ft)

Notes:

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)	REMARKS
35	0		54						SP	Brown fine sand with trace silt (medium dense, moist) (topsoil)	NS	<1	
									SP	Black to gray sooty stained medium to coarse sand with gravel (medium dense, moist)	NS	<1	
										With occasional red, tan vesicular fused agglomerate, coarse sand to fine gravel sized	NS	<1	
30	5		30						ML	Gray silt with occasional fine gravel (soft, wet)	SS	<1	Groundwater encountered at 6 feet
						GEI-13 (8-9.5) + DUP			SP	Dark gray to brown fine to medium sand with occasional gravel and trace organics (wood fragments, mostly decayed) Shake test from 8 to 9.5: trace NAPL on surface	HS 95%	25.8	Rainbow
25	10		52						ML	Gray silt with trace organics (wood fragments) (soft, wet)	NS	<1	
											SS	14	Metallic streaks
						GEI-13 (13-16)				Occasional 2 mm sandy silt lenses (slight odor)			
									SP-SM	Gray fine sand with silt and gravel (dense, wet) (moderate odor)	MS 40%	25	Rainbow streaks
20	15		30						SP	Gray fine sand with occasional gravel, NAPL present as dark brown within pore space, very strong odor, hydrocarbon staining on gloves, PID bag copper color, shake test 1 mm of NAPL on surface copper color (dense, wet)	HS 100%	102	Blebs semi-circular, brown
											HS		
											HS		
	20												

Note: Please see Figure A-1 for explanation of symbols

Log of Boring GEI-13

GEOENGINEERS

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name / Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)	REMARKS
15	20		60						SP	Gray fine to medium sand with trace silt and occasional gravel, less NAPL saturation (dense, wet)	HS 90%		Rainbow
										NAPL observed			
											HS		
											SS		
										NAPL observed	HS	480	
						GEI-13 (23.5-24.5)					SS		
										NAPL observed	HS		
									SM	Gray silty fine to medium sand with gravel (very dense, wet)	SS	2.1	
10	25		6			GEI-13 (25-25.5)					SS		

Note: Please see Figure A-1 for explanation of symbols

Log of Boring GEI-13 (continued)

GEOENGINEERS

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Figure A-29
Sheet 2 of 2

Drilled	Start 4/2/2013	End 4/2/2013	Total Depth (ft) 39.5	Logged By ARJ / Checked By ZAS	Driller Boart Longyear	Drilling Method Direct Push

Surface Elevation (ft) / Vertical Datum	27 / USACE (Locks)	Hammer Data	Drilling Equipment: Geoprobe 6620 DT
Easting (X) / Northing (Y)	1269745.67 / 238970.98	System Datum: NAD83 WA State Plane North	Groundwater — Date Measured / Depth to Water (ft) / Elevation (ft)

Notes: Hand-dug with posthole digger from 0 to 2 feet bgs.

Elevation (feet)	Depth (feet)	Recovered (in)	Sample Name / Testing	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)	REMARKS
	0	24		SM	Brown to tan silty sand with occasional gravel and trace organics (rootlets) (medium dense, moist)	NS	<1	
25		36			With brick fragments	NS	<1	
						HS 70%	24	Florets
	5	24						
20				SM	Brown to tan silty fine to medium sand with fine gravel, trace medium sand sized tan agglomerate friable, 1 glass fragment, trace wood fragments up to 1 inch in length possible milled edge	NS	5	
			GEI-14 (8-9)		With significant NAPL impact; the NAPL is black very strong hydrocarbon odor, shake test: 1 mm NAPL on surface, stained and streaked on sides of jar	HS 70%	89.9	Florets Groundwater encountered at 8.5 feet Stained sampler tube
	10	12		SP	Dark gray medium to coarse sand stained black, glass pieces, black NAPL blebs within sand	HS	<1	Florets
15				SP	Black medium to coarse sand with gravel, wood fibers, 1 inch metal wire and fabric			
	15	30	GEI-14 (14.5-15.5)			MS 40%		Florets
				SP	Gray medium to coarse sand with gravel (dense, wet)			Florets
10						NS	<1	
	20							

Note: Please see Figure A-1 for explanation of symbols

Seattle: Date:5/14/13 Path:C:\USERS\TNASH\DESKTOP\018684601.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_ENVIRONMENTAL_STANDARD

Log of Boring GEI-14

GeoEngineers

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)	REMARKS
	20		36							NAPL observed in 1/2 inch band within pore space	NS	4.1	
5											HS	<1	
										NAPL within pore space stained copper color			
	25		48							Less coarse sand; DNAPL to HS throughout	HS	60	
											HS		
0						GEI-14 (27-28)			SM	Gray silty fine to medium sand with occasional gravel, 1/2 inch NAPL staining	NS	42.3	
									SP	Gray medium sand with gravel (dense, wet) 1 inch NAPL staining	HS NS HS	<1	
											NS	1	
	30		48							Medium to coarse sand 1 mm silt lense at 30.3 feet			
											NS	1.9	
-5										Trace gravel	NS	1.4	
											NS	<1	
	35		18										
											NS	<1	
-10						GEI-14 (37-38)							Rock in sampler shoe Driller indicates till contact at approximately 38 feet

Note: Please see Figure A-1 for explanation of symbols

Log of Boring GEI-14 (continued)

GeoEngineers

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Figure A-30
Sheet 2 of 2

Drilled	Start	End	Total Depth (ft)	Logged By	Checked By	Driller	Drilling Method
	4/2/2013	4/2/2013	15	ARJ	ZAS	Boart Longyear	Direct Push

Surface Elevation (ft) / Vertical Datum	26.17 / USACE (Locks)	Hammer Data	
Drilling Equipment	Geoprobe 6620 DT		
Easting (X) / Northing (Y)	1270797.85 / 239445.61	System Datum	NAD83 WA State Plane North
Groundwater	Date Measured	Depth to Water (ft)	Elevation (ft)

Notes: Hand-dug with posthole digger from 0 to 2 feet bgs.

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name / Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)	REMARKS
25	0		24			GEI-15 (0-2)			SM	Brown to black silty fine sand with gravel and trace organics (roots and rootlets), trace asphaltic grains (loose, moist)	NS	<1	
	2		24							Increasing black asphaltic grains (hardened tar?)	NS	<1	
	2.5								SP	Coarse sand with gravel; black, tan, brown, yellow agglomerate, low density, vesicular, fused; and black agglomerate, low density, finely vesicular, metallic luster	NS	<1	Groundwater encountered at 4.5 feet
20	5		30						GP	Brown, tan, yellow, black fine to coarse gravel with coarse sand, gravel is agglomerate, brown, tan, yellow fused vesicular, low density, vitreous luster; and black, low density, vesicular, metallic luster, sand is smaller pieces of above	NS		
	6.5					GEI-15 (6.5-7)			SP	Black coarse sand with gravel	SS 10%	<1	Rainbow streaks
											NS		
15	10		42						SP	Black, tan, yellow medium to coarse sand with gravel, gravel is tan yellow agglomerate fused, low density, vesicular, and black agglomerate, low density, vesicular, metallic luster; sand is smaller particles of above.	NS	<1	
	12.5					GEI-15 (12.5-13.5)			GP	Gravel with sand			
	13.5								SP	Gray medium to coarse sand with fine gravel (dense, wet)	NS	<1	
	14					GEI-15 (14-14.5) + DUP			SM	Gray silty fine to medium sand with gravel (very dense, wet)	NS	<1	
	15												

Note: Please see Figure A-1 for explanation of symbols

Log of Boring GEI-15

GEOENGINEERS

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Figure A-31
Sheet 1 of 1

Drilled	Start	End	Total Depth (ft)	Logged By	Checked By	Driller	Drilling Method
	4/17/2013	4/17/2013	25	PDR	ZAS	Boart Longyear	Sonic (continuous core)

Surface Elevation (ft) / Vertical Datum	33.98 / USACE (Locks)	Hammer Data	
Drilling Equipment	Rubber Track-Mounted Spider 3 Sonic Drill Rig		
Easting (X) / Northing (Y)	1270731.54 / 239138.15	System Datum	NAD83 WA State Plane North

Groundwater

Date Measured	Depth to Water (ft)	Elevation (ft)

Notes: Sampling method: 5' by 3½" ID split spoon with lexan core sleeves.

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name / Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)	REMARKS
	0									Lithology not logged; see GEI-3			
30													
	5	5–10	60							Test sample 5 to 10 feet with 100% recovery			
25													
	10	11–16	24							15 inch recovery on 1st attempt, try 2nd to observe recovery, very poor recovery of mostly water and NAPL Black colored water with strong hydrocarbon odor (will re-drill for this sample in PT-01B)	HS	<1	
20													
	15												
15													
	20												

Note: Please see Figure A-1 for explanation of symbols

Log of Boring PT-01

GEOENGINEERS

Project: Puget Sound Energy North Lake Union

Project Location: Gas Works Park, Seattle, Washington

Project Number: 0186-846-01

Figure A-32
Sheet 1 of 2

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name / Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)	REMARKS
	20		58			PT-01 (20-21.1A); PT-01 (21.1-22B); PT-01 (22-25D)				Water and sediment in sampler (approximately 2 inches water in top of sampler), strong hydrocarbon odor			
10													
	25												

Note: Please see Figure A-1 for explanation of symbols

Log of Boring PT-01 (continued)

GeoEngineers

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Drilled Start 4/17/2013 End 4/17/2013	Total Depth (ft) 16	Logged By PDR Checked By ZAS	Driller Boart Longyear	Drilling Method Sonic (continuous core)
Surface Elevation (ft) 33.97 Vertical Datum USACE (Locks)	Hammer Data		Drilling Equipment Rubber Track-Mounted Spider 3 Sonic Drill Rig
Easting (X) 1270731.21 Northing (Y) 239140.12	System Datum NAD83 WA State Plane North		Groundwater: Date Measured / Depth to Water (ft) / Elevation (ft)

Notes: Sampling method: 5' by 3½" ID split spoon with lexan core sleeves.

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name / Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)	REMARKS
	0									Lithology not logged; see GEI-3			
30	5												
25	10												
	11	▮	30			PT-01B (11-13.2A)							
	12.5									No liquid on top of sampler, 30 inches good recovery from 11 to 13.5 feet			
20	15												

Note: Please see Figure A-1 for explanation of symbols

Log of Boring PT-01B

GeoEngineers

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Figure A-33
Sheet 1 of 1

Drilled	Start 4/17/2013	End 4/17/2013	Total Depth (ft) 23	Logged By PDR / Checked By ZAS	Driller Boart Longyear	Drilling Method Sonic (continuous core)

Surface Elevation (ft) / Vertical Datum	30.01 / USACE (Locks)	Hammer Data	Drilling Equipment: Rubber Track-Mounted Spider 3 Sonic Drill Rig
Easting (X) / Northing (Y)	1270785.87 / 239095.16	System Datum: NAD83 WA State Plane North	Groundwater: Date Measured / Depth to Water (ft) / Elevation (ft)

Notes: Hand dug with posthole digger from 0 to 2 feet bgs. Sampling method: 5' by 3½" ID split spoon with lexan core sleeves.

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name / Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)	REMARKS
	0	0–2 (not sampled)	24							Lithology not logged; see GEI-6			
25	5												
		8–13	54			PT-02 (8.7-10A); PT-02 (10-13B)				Black, strong naphthalene-like odor, staining on core tube, some water on top of sample			Good sample
20	10												
15	15												
		18–20	58			PT-02 (20-23)							
	20												

Note: Please see Figure A-1 for explanation of symbols

Log of Boring PT-02

GeoEngineers

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Figure A-34
Sheet 1 of 2

Elevation (feet)	Depth (feet)	FIELD DATA: Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name / Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)	REMARKS
	20									Black, strong odor (GP), staining, observed NAPL in shoe coating particles of gravel, heavy sheen, some water on top of sample	HS		

Note: Please see Figure A-1 for explanation of symbols

Log of Boring PT-02 (continued)

GeoEngineers

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Drilled	Start 4/18/2013	End 4/18/2013	Total Depth (ft) 30	Logged By PDR Checked By ZAS	Driller Boart Longyear	Drilling Method Sonic (continuous core)

Surface Elevation (ft) 27.24 Vertical Datum USACE (Locks)	Hammer Data	Drilling Equipment	Rubber Track-Mounted Spider 3 Sonic Drill Rig
Easting (X) 1269745.13 Northing (Y) 238975.54	System Datum NAD83 WA State Plane North	Groundwater	Date Measured / Depth to Water (ft) / Elevation (ft)

Notes: Sampling method: 5' by 3½" ID split spoon with lexan core sleeves.

Elevation (feet)	Depth (feet)	FIELD DATA: Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name / Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)	REMARKS
	0									Lithology not logged; see GEI-14			
25													
	5												
20													
	8	■	60			PT-03 (8-10A); PT-03 (10-13B)					HS		100% recovery
	9–10									Black coated gravel, strong naphthalene-like odor, high sheen, no fluid observed on sample, all soil, heavy staining on tube			Groundwater encountered at 9.5 feet
	10												
15													
	15												
10													
	20												

Note: Please see Figure A-1 for explanation of symbols

Seattle: Date:5/14/13 Path:C:\USERS\TNASH\DESKTOP\018684601.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_ENVIRONMENTAL_STANDARD

Log of Boring PT-03

GEOENGINEERS

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Elevation (feet)	Depth (feet)	FIELD DATA: Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name / Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)	REMARKS
	20												
-5													
	25	■	60			PT-03 (25-28A); PT-03 (28-30B)							100% recovery
-10										Black coated sand, strong naphthalene-like odor, heavy sheen, no fluid on top of sample, all soil, staining on tube	HS		
	30												

Note: Please see Figure A-1 for explanation of symbols

Log of Boring PT-03 (continued)

GeoEngineers

Project: Puget Sound Energy North Lake Union
Project Location: Gas Works Park, Seattle, Washington
Project Number: 0186-846-01

Figure A-35
Sheet 2 of 2

ATTACHMENT 2A-4
SI Soil Boring Core Field Photos

GEI-1 0 to 5 feet, 34.5 to 42 inches

GEI-1 0 to 5 feet, 42 to 49 inches

SI Soil Boring Core Field Photographs GEI-1

Gas Works Park Site
Seattle, Washington

GEOENGINEERS

Appendix 2A-4

GEI-1 0 to 5 feet, 48 to 55 inches

GEI-1 5 to 10 feet, 24 to 32 inches

SI Soil Boring Core Field Photographs GEI-1	
Gas Works Park Site Seattle, Washington	
GeoEngineers	Appendix 2A-4

GEI-1 5 to 10 feet, 29 to 37 inches

GEI-1 5 to 10 feet, 43 to 50.5 inches

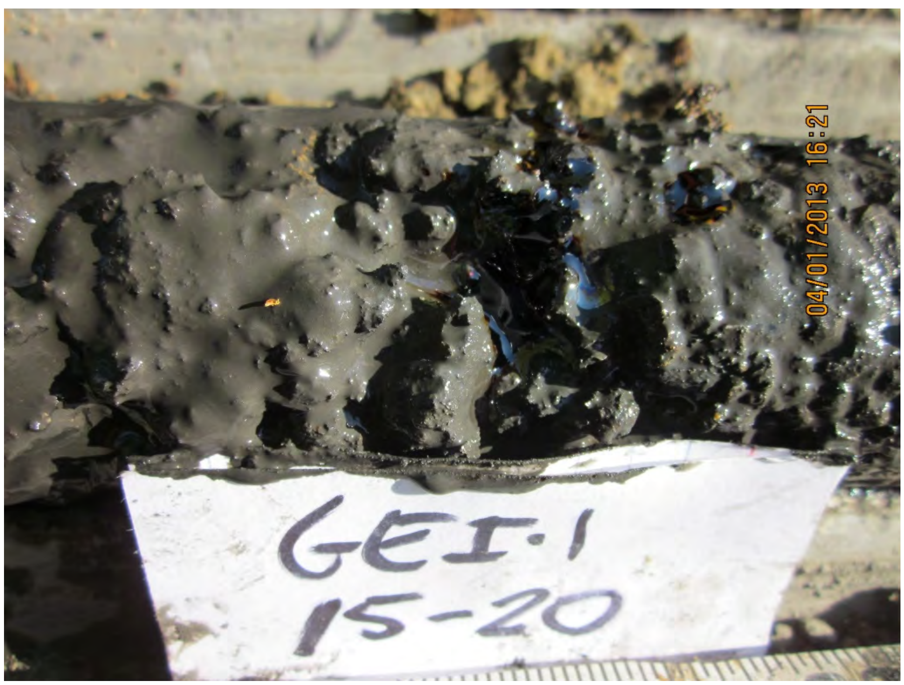
SI Soil Boring Core Field Photographs GEI-1

Gas Works Park Site
Seattle, Washington

GEOENGINEERS

Appendix 2A-4

GEI-1 15 to 20 feet, inches N/A



GEI-1 15 to 20 feet, inches N/A

SI Soil Boring Core Field Photographs GEI-1
Gas Works Park Site Seattle, Washington
GEOENGINEERS / **Appendix 2A-4**

GEI-1 15 to 20 feet, 33.5 to 42.5 inches

GEI-1 15 to 20 feet, 43.5 to 52 inches

SI Soil Boring Core Field Photographs GEI-1	
Gas Works Park Site Seattle, Washington	
GeoEngineers	Appendix 2A-4

GEI-1 15 to 20 feet, 32.5 to 42 inches

GEI-1 15 to 20 feet, inches N/A

SI Soil Boring Core Field Photographs GEI-1

Gas Works Park Site
Seattle, Washington

GeoEngineers | **Appendix 2A-4**

GEI-1 20 to 25 feet, 29 to 36 inches

GEI-1 20 to 25 feet, 45.5 to 52 inches

SI Soil Boring Core Field Photographs GEI-1

Gas Works Park Site
Seattle, Washington

GeoEngineers | **Appendix 2A-4**

GEI-1 25 to 27 feet, 39.5 to 45.6 inches

SI Soil Boring Core Field Photographs GEI-1

Gas Works Park Site
Seattle, Washington

GEOENGINEERS

Appendix 2A-4

GEI-2 0 to 5 feet, 28 to 37 inches

GEI-2 0 to 5 feet, 36 to 47 inches

SI Soil Boring Core Field Photographs GEI-2

Gas Works Park Site
Seattle, Washington

GEOENGINEERS

Appendix 2A-4

GEI-2 0 to 5 feet, 45.5 to 54.5 inches

GEI-2 5 to 10 feet, 17 to 24.5 inches

SI Soil Boring Core Field Photographs GEI-2	
Gas Works Park Site Seattle, Washington	
GEOENGINEERS	**Appendix 2A-4**

GEI-2 5 to 10 feet, 26 to 32 inches

GEI-2 5 to 10 feet, 38 to 44.5 inches

SI Soil Boring Core Field Photographs GEI-2

Gas Works Park Site
Seattle, Washington

GeoEngineers

Appendix 2A-4

GEI-2 5 to 10 feet, 48 to 54.5 inches

GEI-2 10 to 15 feet, 8 to 14.5 inches

SI Soil Boring Core Field Photographs GEI-2	
Gas Works Park Site Seattle, Washington	
GeoEngineers	**Appendix 2A-4**

GEI-2 10 to 15 feet, 21 to 29 inches

GEI-2 10 to 15 feet, 23 to 35 inches

SI Soil Boring Core Field Photographs GEI-2

Gas Works Park Site
Seattle, Washington

GeoEngineers

Appendix 2A-4

GEI-2 10 to 15 feet, 31 to 40.5 inches

GEI-2 10 to 15 feet, 44 to 55 inches

SI Soil Boring Core Field Photographs GEI-2

Gas Works Park Site
Seattle, Washington

GeoEngineers

Appendix 2A-4

GEI-2 15 to 20 feet, 18 to 28 inches

GEI-2 15 to 20 feet, 24 to 33 inches

SI Soil Boring Core Field Photographs GEI-2

Gas Works Park Site
Seattle, Washington

GeoEngineers

Appendix 2A-4

GEI-2 15 to 20 feet, 30 to 39 inches

GEI-2 15 to 20 feet, 34.5 to 43.5 inches

SI Soil Boring Core Field Photographs GEI-2

Gas Works Park Site
Seattle, Washington

GeoEngineers

Appendix 2A-4

GEI-3 0 to 5 feet, inches N/A

GEI-3 0 to 5 feet, inches N/A

SI Soil Boring Core Field Photographs GEI-3

Gas Works Park Site
Seattle, Washington

GEOENGINEERS

Appendix 2A-4

GEI-3 0 to 5 feet, inches N/A

GEI-3 0 to 5 feet, inches N/A

SI Soil Boring Core Field Photographs GEI-3

Gas Works Park Site
Seattle, Washington

GeoEngineers

Appendix 2A-4

GEI-3 0 to 5 feet, inches N/A

GEI-3 0 to 5 feet, inches N/A

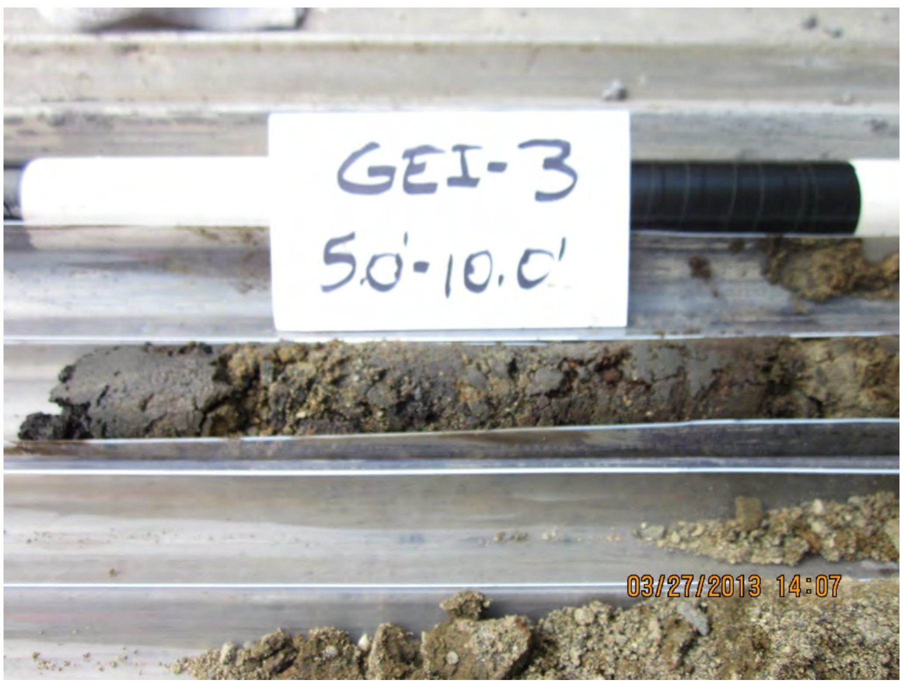
SI Soil Boring Core Field Photographs GEI-3

Gas Works Park Site
Seattle, Washington

GEOENGINEERS

Appendix 2A-4

GEI-3 5 to 10 feet, inches N/A



GEI-3 5 to 10 feet, inches N/A

SI Soil Boring Core Field Photographs GEI-3

Gas Works Park Site
Seattle, Washington

GeoEngineers

Appendix 2A-4

GEI-3 5 to 10 feet, inches N/A

GEI-3 5 to 10 feet, inches N/A

SI Soil Boring Core Field Photographs GEI-3

Gas Works Park Site
Seattle, Washington

GeoEngineers

Appendix 2A-4

GEI-3 5 to 10 feet, inches N/A

GEI-3 5 to 10 feet, inches N/A

SI Soil Boring Core Field Photographs GEI-3

Gas Works Park Site
Seattle, Washington

GeoEngineers

Appendix 2A-4

GEI-3 10 to 15 feet, inches N/A

GEI-3 10 to 15 feet, inches N/A

SI Soil Boring Core Field Photographs GEI-3

Gas Works Park Site
Seattle, Washington

GeoEngineers

Appendix 2A-4