REPORT

SURFACE FAULT RUPTURE HAZARD EVALUATION

CEDAR COVE SUBDIVISION LOT 28-A

6696 SOUTH 2850 EAST

WEBER COUNTY, UTAH

Prepared for

Trevor Anderson
2780 South 1415 West
Syracuse, Utah 84075

March 18, 2016

Prepared by

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Trevor Anderson
2780 South 1415 West
Syracuse, Utah 84075

SUBJECT: Surface Fault Rupture Hazard Evaluation
Cedar Cove Subdivision Lot 28-A
6696 South 2850 East
Weber County, Utah

Dear Mr. Anderson:

This report presents results of a surface fault rupture hazard evaluation conducted by Western GeoLogic, LLC (Western GeoLogic) for Cedar Cove Subdivision Lot 28-A at 6696 South 2850 East in unincorporated Weber County, Utah (Figure 1 – Project Location). The site is on generally southwest-facing slopes overlooking the Weber River about 0.4 miles southwest of Broad Hollow at the western base of the Wasatch Range, and is in the NW¼ Section 25, Township 5 North, Range 1 West (Salt Lake Base Line and Meridian). Elevation of the site ranges between about 4,635 and 4,670 feet above sea level. It is our understanding that the existing parcel is planned for subdivision and future development of two single-family residences.

PURPOSE AND SCOPE

Two east- and west-dipping traces of the active Weber segment of the Wasatch fault zone are mapped trending northward across the property on Weber County hazard maps, and the property is in the Surface Fault Rupture Special Study Area where trenching studies are required. The site area was previously evaluated by Kaliser (1997), who reported identifying one fault on the east side of the property. Kaliser (1997) recommended a 50-foot setback zone around this fault, but the report lacked supporting documentation such as trench logs on which the fault location and recommended setback could be verified. The purpose of our investigation was to evaluate the hazard from surface faulting at the site and update information provided in Kaliser (1997). Other geologic hazards possibly present were not evaluated and are beyond the scope of this study.

The following scope of services was performed in accordance with the above purpose:

- Excavation and logging of two exploratory trenches at the property to identify the presence and location of active faults at the site, assess zones of fault-related deformation, and recommend appropriate fault set-back distances and safe "buildable" areas should faults be discovered;

- Review of available geologic maps and reports; and

- Evaluation of available data and preparation of this report, which presents the results of our study.

This report follows the Guidelines for Evaluating Surface Fault Rupture Hazards in Utah (Christenson and others, 2003) and is in accordance with specifications provided in Chapter 27 of the Weber County Land Use Code. The original Project scope was approved in a work plan dated February 23, 2016 and approved in telephone discussions with Elliott Lipps, Weber County Contract Geologic Reviewer, and via email by Jared Andersen, Weber County Engineer. Weber County staff were offered the opportunity to inspect the trenches, but were unavailable. The trenches were digitally photographed at five-foot intervals to document subsurface conditions. The photos are not included herein, but are available upon request.

GEOLOGY

Seismotectonic Setting

The property is located along the western base of the Wasatch Range, a major north-south trending mountain range marking the eastern boundary of the Basin and Range physiographic province (Stokes, 1977, 1986). The Basin and Range province is characterized by a series of generally north-trending elongate mountain ranges, separated by predominately alluvial and lacustrine sediment-filled valleys and typically bounded on one or both sides by major normal faults (Stewart, 1978). The boundary between the Basin and Range and Middle Rocky Mountains provinces is the prominent, west-facing escarpment along the Wasatch fault zone (WFZ) at the base of the Wasatch Range. Late Cenozoic normal faulting, a characteristic of the Basin and Range, began between about 17 and 10 million years ago in the Nevada (Stewart, 1980) and Utah (Anderson, 1989) portions of the province. The faulting is a result of a roughly east-west directed, regional extensional stress regime that has continued to the present (Zoback and Zoback, 1989; Zoback, 1989).

The WFZ is one of the longest and most active normal-slip faults in the world, and extends for 213 miles along the western base of the Wasatch Range from southeastern Idaho to north-central Utah (Machette and others, 1992). The fault zone generally trends north-south and, at the surface, can form a zone of deformation up to several hundred feet wide containing many subparallel west-dipping main faults and east-dipping antithetic faults. Previous studies divided the fault zone into 10 segments, each of which rupture independently and are capable of generating large-magnitude surface-faulting earthquakes (Machette and others, 1992). The central five segments of the fault (Brigham City, Weber, Salt Lake, Provo, and Nephi) have each produced two or more surface-faulting earthquakes in the past 6,000 years (Black and others, 2003).

A main, west-dipping trace, and an east-dipping, antithetic trace of the Weber segment of the WFZ are shown crossing the eastern and western parts of the site on Weber County hazard maps. Yonkee and Lowe (2004; Figure 2) similarly show two faults crossing the site, although they incorrectly label the eastern trace as dipping to the east rather than to the west. Kaliser (1997) reportedly exposed evidence for the eastern fault trace in one trench south of the property, but did not expose evidence for the western trace. Kaliser (1997) recommended a 50-foot setback area around the former fault trace, but included only limited data.

The Weber segment of the WFZ extends for about 35 miles from the southern edge of the Plain View salient near North Ogden to the northern edge of the Salt Lake salient near North Salt Lake (Machette and others, 1992). Previous paleoseismic studies indicate four large-magnitude surface-faulting earthquakes have occurred on the Weber segment since mid-Holocene time. Nelson and others (2006) report finding evidence for four events at the Garner Canyon and East Ogden sites, including what they infer was a partial segment rupture (with 1.6 feet of displacement) around 500 years ago. This partial segment rupture was not evident at the Kaysville site of McCalpin and others (1994), although chronologic intervals for the remaining three earthquakes were similar. DuRoss and others (2009) report paleoseismic data from the 2007 Rice Creek site support a preferred scenario of six surface-faulting earthquakes in Holocene time, with four events since about 5,400 years ago, and confirm Nelson and others' (2006) partial segment rupture timing.

Lund (2005) indicates preferred earthquake timing for the last four surface-faulting earthquakes on the Weber segment is: (1) an event Z between 200 to 800 years ago (partial segment rupture) and/or between 500 and 1,400 years ago (complete segment rupture), (2) an event Y between 2,300 and 3,700 years ago, (3) an event X between 3,800 and 5,200 years ago, and (4) an event W between 5,400 and 6,800 years ago. The consensus preferred recurrence interval for the Weber segment, as determined by the Utah Quaternary Fault Working Group, is 1,400 years for the past four surface-faulting earthquakes (Lund, 2005).

The site is also in the central portion of the Intermountain Seismic Belt (ISB), a generally north-south trending zone of historical seismicity along the eastern margin of the Basin and Range province extending from northern Arizona to northwestern Montana (Sbar and others, 1972; Smith and Sbar, 1974). At least 16 earthquakes of magnitude 6.0 or greater have occurred within the ISB since 1850; the largest of these earthquakes was a M_S 7.5 event in 1959 near Hebgen Lake, Montana. However, none of these earthquakes occurred along the Wasatch fault or other known late Quaternary faults (Arabasz and others, 1992; Smith and Arabasz, 1991). The closest of these events was the 1934 Hansel Valley (M_S 6.6) event north of the Great Salt Lake.

Unconsolidated Deposits

Yonkee and Lowe (2004) map the site in late Pleistocene Lake Bonneville deposits on the southeast (unit Qlf4), post-lake alluvium and colluvium on the northeast (unit Qac), and Holocene alluvial-fan deposits on the west (unit Qaf1, Figure 2). Two traces of the Weber segment of the WFZ are showing crossing the site and along the western site boundary, although the eastern fault is incorrectly labeled as dipping to the east (Figure 2).

Yonkee and Lowe (2004) describe surficial geologic units in the site vicinity, from youngest to oldest in age, as follows:

> ***Qc – Colluvium.*** Weakly to non-layered, variably sorted, matrix- to clast-supported, pebble to boulder gravel and diamicton of local origin; contains angular to sub-angular clasts in variable amounts of clay, silt, and sand matrix; deposits formed mostly by creep and slope wash, also includes small landslides, talus, debris cones, minor alluvium, and small bedrock exposures; found mostly along vegetated slopes in Wasatch Range, and locally covering scarps along the Wasatch fault zone; thickness probably less than 15 meters (50 ft) in most areas.
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> ***Qac – Colluvium and alluvium, undivided.*** Pebble to boulder gravel and clay- to boulder-rich diamicton; includes hillslope colluvium, small fans, stream alluvium, and small landslide deposits; mapped along some vegetated canyon areas in Wasatch Range; thickness probably less than 15 meters (50 ft) in most areas.
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> ***Qmt – Talus.*** Deposits of angular pebble to boulder fragments with little or no matrix and little to no vegetation cover, which have accumulated at bases of some steep bedrock slopes and cliffs; thickness uncertain in most areas, but probably less than 15 meters (50 ft).
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> ***Qal1 – Younger stream alluvium, Holocene.*** Clast-supported, moderate- to well-sorted, pebble and cobble gravel, gravelly sand, and silty sand; deposited along modern channels and flood plains; mapped where fluvial processes are currently or episodically active; exposed thickness less than 6 meters (20 ft).
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> ***Qaf1 – Younger alluvial-fan deposits, Holocene.*** Mixture of gravel and sand deposited by streams, and diamicton deposited by debris flows; forms fans having distinct levees and channels at mouths of mountain-front canyons; exposed thickness less than 6 meters (20 ft).
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> ***Qms1 – Younger landslide deposits, Holocene.*** Unsorted, unstratified mixtures of gravel, sand, silt, and clay redeposited by slides, slumps, and flows; deposits display distinctly hummocky topography and fresh scarps, and are currently or have been recently active; many of these deposits are within older slide complexes.
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> ***Qaf2 – Older alluvial-fan deposits, Holocene***. Mixture of gravel and sand deposited by streams, and diamicton deposited by debris flows; forms fans with poorly preserved levees that are slightly incised by modern stream channels; exposed thickness less than 6 meters (20 ft).
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> ***Qms2 – Older landslide deposits, Holocene.*** Unsorted, unstratified mixtures of mostly sand, silt, and clay redeposited by single to multiple slides, slumps, and flows; deposits display hummocky topography but lack fresh scarps and are mostly inactive; deposits found mostly along moderate slopes where rivers and streams have incised into finer grained lacustrine and deltaic deposits; unit also includes slides of boulder-rich diamicton that reactivated parts of older slide complexes in the Wasatch Range.

Qaf3 – Alluvial-fan deposits, Bonneville regressive. Mixture of gravel and sand deposited by streams, and diamicton deposited by debris flows; contains mostly angular to subrounded clasts plus some recycled, well-rounded lacustrine clasts; forms fans having subdued morphology that are graded to the Provo or other regressive shorelines and are incised by modem stream channels; exposed thickness less than 9 meters (30 ft).

Qd3 – Deltaic deposits, Bonneville regressive. Main part of unit includes foreset beds of rhythmically interlayered, gently inclined, fine to medium sand and silt, and topset beds of clast-supported, moderately to well-sorted, pebble and cobble gravel and gravelly sand; gravels contain rounded to subrounded clasts; deposited when Lake Bonneville was at and regressing from Provo shoreline; forms large, gently westward-inclined surface that was locally reworked along regressive shorelines; total thickness locally as much as 30 meters (100 ft). Unit also includes moderately to well-sorted, pebble and cobble gravel in smaller terraces more than 30 meters (100 ft) above modern stream level that are graded to delta deposits and shorelines above the Gilbert level; exposed thickness of terrace gravels up to 6 meters (20 ft).

Qlg3 – Lacustrine gravel-bearing deposits, Bonneville regressive. Clast-supported, moderately to well-sorted, pebble to cobble gravel and gravelly sand, interlayered with some silt and sand; deposited and reworked in higher energy environments along the Provo and regressive shorelines near the mountain front; mapped at elevations below Provo shoreline; thickness less than 6 meters (20 ft).

Qaf4 – Alluvial-fan deposits, Bonneville transgressive. Mixture of gravel deposited by streams and diamicton deposited by debris flows; gravel contains mostly angular to subrounded clasts; locally weakly cemented with calcite; fans have subdued morphology, display top surfaces graded to the Bonneville shoreline, and are deeply incised by modern stream channels; total thickness of some composite fans as much as 60 meters (200 ft).

Qd4 – Deltaic deposits, Bonneville transgressive. Topset beds of clast-supported, moderately to well-sorted, pebble gravel and gravelly sand; contains abundant subrounded to rounded basement clasts; deposited as Lake Bonneville was near a transgressive shoreline at an elevation of about 1,520 meters (5,000 ft); thickness of topset beds 2 to 4 meters (7 - 13 ft).

Qlg4 – Lacustrine gravel-bearing deposits, Bonneville transgressive. Clast-supported, moderately to well-sorted, pebble to cobble gravel, with some silt to sand in interfluve areas and away from mountain front; gravels contain rounded to subrounded clasts, and some subangular clasts derived from reworking of mass-wasting and alluvial-fan deposits; deposited in higher energy environments along shorelines and small fan deltas as Lake Bonneville was transgressing; grades westward away from shorelines into fine-grained lacustrine deposits (Qlf4); total thickness locally as much as 60 meters (200 ft).

Qlf4 – Lacustrine fine-grained deposits, Bonneville transgressive. Intervals of calcareous clay to silt, and intervals of rhythmically interbedded fine to medium sand and silt near mouth of Weber Canyon; deposited in deeper water environments, and as delta bottomset beds during transgression of Lake Bonneville; total thickness, including subsurface deposits, locally as much as 150 meters (500 ft).

Tertiary Igneous Rocks:

Td – Tertiary igneous dikes. Dark colored, non-foliated dikes composed of altered hornblende, biotite, and feldspar phenocrysts in a fine-grained, highly altered matrix; interpreted to be Tertiary age.

Bedrock of the Farmington Canyon Complex:

Xfgh – Granitic gneiss of Ogden hanging wall. Light- to pink-gray, moderately to strongly foliated, fine- to medium-grained, hornblende-bearing granitic gneiss with rare orthopyroxene; gneiss is locally fractured and displays red hematite alteration; gneiss cut by variably deformed, light-colored pegmatitic dikes; unit also contains small pods of meta-gabbro and amphibolite; gradational contacts with migmatitic gneiss.

Xfm – Migmatitic gneiss. Medium- to light-pink-gray, strongly foliated and layered, migmatitic, quartzo-feldspathic gneiss with widespread garnet and biotite; gneiss cut by widespread, variably deformed, pegmatitic dikes; unit also contains widespread amphibolite layers, granitic gneiss bands, and some thin layers of biotite-rich schist; gradational contacts with granitic gneiss.

Xfb – Biotite-rich schist. Medium-gray to dark-brown, strongly foliated, biotite-rich schist with widespread garnet and sillimanite; displays alternating biotite-rich and quartz-feldspar-rich bands that are rotated into complex fold patterns; schist cut by variably deformed, garnet-bearing pegmatite dikes; unit also contains some thin layers of amphibolite, quartz-rich gneiss, and granitic gneiss; gradational contacts with migmatitic gneiss.

References included in the above unit descriptions are not provided in this report, but are provided in Yonkee and Lowe (2004).

Lake Bonneville History

Lakes occupied nearly 100 basins in the western United States during late-Quaternary time, the largest of which was Lake Bonneville in northwestern Utah. The Bonneville basin consists of several topographically closed basins created by regional extension in the Basin and Range (Gwynn, 1980; Miller, 1990), and has been an area of internal drainage for much of the past 15 million years. Lake Bonneville consisted of numerous topographically closed basins, including the Salt Lake and Cache Valleys (Oviatt and others, 1992). Sediments from Lake Bonneville are mapped in the southeast part of the site, but are mantled by younger deposits to the north and west.

Timing of events related to the transgression and regression of Lake Bonneville are indicated in Oviatt (2015). Approximately 30,000 years ago, Lake Bonneville began a slow transgression (rise) to its highest level of 5,160 to 5,200 feet above mean sea level. The lake rise eventually slowed as water levels approached an external basin threshold in northern Cache Valley at Red Rock Pass near Zenda, Idaho. Lake Bonneville reached the Red Rock Pass threshold and occupied its highest shoreline, termed the Bonneville beach, around 18,000 years ago. Headward erosion of the Snake River-Bonneville basin drainage divide, possibly combined with landsliding in the threshold area, then caused a catastrophic incision that caused the lake level to lower by about 425 feet in less than a year (Jarrett and Malde, 1987; O'Conner, 1993). Following the Bonneville flood, the lake stabilized and formed a lower shoreline referred to as the Provo shoreline up to about 16,000 years ago. Climatic factors then caused the lake to regress rapidly from the Provo shoreline, and by about 13,000 years ago the lake had eventually dropped below historic levels of Great Salt Lake. Oviatt and others (1992) deem this low stage the end of the Bonneville lake cycle. Great Salt Lake then experienced a brief transgression between 12,800 and 11,600 years ago to the Gilbert level at about 4,250 feet before receding to and remaining within about 20 feet of its historic average level (Lund, 1990; Oviatt, 2015). The site is located slightly below the Bonneville and Provo shorelines.

SURFACE FAULT RUPTURE HAZARD EVALUATION

Air Photo Observations

High-resolution orthophotography from 2012 0.5-meter resolution LIDAR imagery from 2014 available from the Utah AGRC was reviewed to check for evidence of fault-related topography, contrasts, or lineaments possibly associated with surface faulting (Figure 3). A west-facing scarp associated with the main trace of the Weber segment of the WFZ, possibly modified by prior site disturbance, is evident on the east side of the property (Figure 3A). Kaliser's (1997) fault (Figure 3A, in orange) appears to mark the upper crest of the fault scarp. A second possible fault lineament appears to trend along the western site boundary (Figure 3A). Two dirt roads were also evident crossing the property from northwest to southeast, and a fill pile (possibly for a planned building pad) is in the north part of the property (Figure 3A).

Subsurface Investigation

Two generally southwest-trending trenches were excavated at the site to evaluate subsurface geologic conditions and assess the potential hazard from surface faulting. Trench 1 extended S72°W for a total distance of 168 feet from about 20 feet west of the eastern site boundary. Trench 2 is about 50 feet northwest of Trench 1, and extends S55°W for a total distance of 50 feet. Figure 3B shows locations of the trenches at the site at a scale of 1 inch equals 80 feet (1:960). The trench locations were measured using trend and distance methods from known points, and verified by measurements from two handheld GPS units accurate to within 1 meter. We consider the locations to be accurate to within 1 foot. No surveying was conducted or considered necessary given there was good reference point availability to combine with the GPS measurements. The trenches extended to a depth sufficient to expose sediments capable of displaying evidence for any active

(Holocene) faulting. However, Trench 2 experienced wall stability issues and could not be excavated to a depth of more than about seven feet immediately west of the fault exposure. Ongoing wall collapse during excavation posed not only a safety risk, but also a risk that the exposure would not be loggable.

Figures 4 and 5 are detailed logs of the trenches at a scale of 1 inch equals 5 feet (1:60). Trench logging followed methodology in McCalpin (1996). Given the logging scale and trench length, Trench 1 is displayed on multiple 11” x 17” sheets (Figures 4A-C). An overview of this trench is therefore provided at a smaller scale on Figure 4D. Respective unit descriptions are provided on Figure 4C and 5.

Both trenches at the site exposed a sequence of poorly bedded, sandy to gravelly Pleistocene Lake Bonneville sediments (unit 1), overlain by what appeared to be a sequence of distal debris flood deposits (unit 2) that likely draped over the fault scarp and died out to the west. In Trench 1, this sequence is displaced 6.6 feet down to the west across a zone of three faults (F1a-F1c, Figure 4A) and buried by fault-zone colluvium and crack infill (unit 3). The upper part of unit 3 in Trench 1 (unit 3b), which appeared to be a slope-wash facies from fault scarp degradation, interfingers with younger Holocene alluvium (unit 4) to the west, which overlies the lacustrine sequence. The Holocene alluvium exposed in Trench 1 (unit 4) was observed to contain several gravel and sand channels suggestive of stream deposition (Figure 4B). No evidence for a second fault trace at the location of the lineament on Figure 3A was observed in Trench 1. Given the above, we believe this feature is likely from stream cutting and not faulting. We believe the multiple faults in Trench 1 are from an eastward stepover toward the confluence of two drainages on Kaliser’s (1997) Figure 2. Such a confluence would be an area of weakness from stream downcutting and cause shearing to embay upslope into the weakened area.

The lacustrine sequence in Trench 2 appeared similarly displaced as Trench 1 across the main fault, but only one trace was evident (Figure 5). No additional faults were observed west of this trace in Trench 2 during the time the exposure was visible prior to wall collapse. Correlative stratigraphy across the fault could not be exposed to the west in trench 2, but the displacement is more than 4.9 feet down to the west (Figure 5). Yonkee and Lowe (2004) indicate that lacustrine fines (unit Qlf4) should be at the site beneath Holocene alluvium and colluvium (Figure 2). However, the lacustrine sequence in both trench exposures was coarser grained and more likely correlative to their Qlg3 or Qd3 units (described above). The trenches otherwise exposed sediments correlating well with the surficial geologic mapping.

CONCLUSIONS AND RECOMMENDATIONS

Two traces of the active Weber segment of the WFZ are mapped crossing the site and near the west property boundary on Weber County hazard mapping and Yonkee and Lowe (2004). Kaliser (1997) previously identified the eastern trace, but did not observe the western trace. Surficial geology of the site is mapped as lacustrine deposits from Lake Bonneville on the southeast overlain by younger alluvium and colluvium to the north and west. Two trenches were excavated at the site to evaluate the hazard from surface faulting. The trenches exposed a main fault trace with 6.6 feet of down-to-the-west displacement about 35 feet west of Kaliser's (1997) inferred location. No evidence for the western fault was also observed in Trench 1, which extended past the western site boundary.

Given the above, the risk from surface faulting is high at the site. Based on the results of this investigation and our current understanding that surface fault rupture and deformation tend to follow past patterns, we recommend a non-buildable (setback) zone around the fault traces as shown on Figure 3B (shaded in red). Setback distances are based on guidelines in Christenson and others (2003).

The fault setback for the downthrown block side of the fault is calculated using the following formula:

$$S = U\,(2D + F/\tan\Theta)$$

where:

S = Setback distance

U = Criticality factor (1.5 for IBC class R residential structures with <10 dwellings)

D = Fault displacement (assumed to be 6.6 feet)

F = Maximum depth of footing or subgrade portion of the building (assumed to be 10 feet)

Θ = Dip of the fault (assumed to be the lowest measured dip angle of 72 degrees)

The fault setback for the upthrown block side of the fault is calculated using:

$$S = U\,(2D)$$

Based on the above, the calculated setback for the downthrown fault side is 24.7 feet, and the setback distance on the upthrown side is 19.8 feet. We conservatively apply these setbacks to the furthest west and east traces in the area of Trench 1 where there are multiple faults. No structure intended for human occupancy should be located in the setback zones on Figure 3B. It is generally accepted practice to allow streets, driveways, yards, patios, and other non-occupied, non-attached structures to be constructed within these areas.

The site is also subject to strong ground shaking in the event of a large-magnitude earthquake, which could cause substantial property damage or result in loss of life, and trenching evidence suggests there may have also been a risk from stream flooding and debris floods in the geologic past. However, it is likely that upslope development in the area has mitigated these latter hazards. No evidence of other geologic hazards was encountered in our investigation, and the site appears to be suitable for development from a fault-rupture perspective if our recommendation area is followed.

The following recommendations are provided with regard to the geologic characterizations in this report:

- ***Active Faulting*** – A fault setback zone has been identified around the active faults identified at the property, as shown on Figure 3B (shaded in red) and discussed above. No structure intended for human occupancy should be located in the setback zone.

- ***Excavation Inspection*** - This report does not reflect subsurface variations that may occur laterally away from an exploration trench. The nature and extent of such variations may not become evident until the course of construction, and are sometimes sufficient to necessitate structural or site plan changes. Thus, we recommend that we inspect the building footing or foundation excavations to recognize any differing conditions that could affect the performance of the planned structures and confirm that no faults are in the area of the homes.

- ***Geotechnical Investigation* -** A geotechnical investigation is recommended prior to construction to provide design-level recommendations for cut and fill, site grading, footing and foundation design, drainage, and seismic design. It is our understanding that Earthtec previously prepared a geotechnical report for the subdivision in 2000, and this evaluation may be acceptable if approved by Weber County Engineering staff.

- ***Excavation Backfill Considerations* -** The trenches may be in areas where structures could subsequently be placed. However, backfill may not have been replaced in the trenches in compacted layers. The fill could settle with time and upon saturation. Should structures be located in a trenched area, no footings or structure should be founded over the trench excavations unless the backfill has been removed and replaced with structural fill, if the fill is to support a structure.

- ***Availability of Report* -** The report should be made available to architects, building contractors, and in the event of a future property sale, real estate agents and potential buyers. This report should be referenced for information on technical data only as interpreted from observations and not as a warranty of conditions throughout the site. The report should be submitted in its entirety, or referenced appropriately, as part of any document submittal to a government agency responsible for planning decisions or geologic review. Incomplete submittals void the professional seals and signatures we provide herein. Although this report and the data herein are the property of the client, the report format is the intellectual property of Western Geologic and should not be copied, used, or modified without express permission of the authors.

LIMITATIONS

This investigation was performed at the request of the Client using the methods and procedures consistent with good commercial and customary practice designed to conform to acceptable industry standards. The analysis and recommendations submitted in this report are based upon the data obtained from site-specific observations and compilation of known geologic information. This information and the conclusions of this report should not be interpolated to adjacent properties without additional site-specific information. In the event that any changes are later made in the location of the proposed site, the conclusions and recommendations contained in this report shall not be considered valid unless the changes are reviewed and conclusions of this report modified or approved in writing by the engineering geologist.

This report has been prepared by the staff of Western GeoLogic for the Client under the professional supervision of the principal and/or senior staff whose seal(s) and signatures appear hereon. Neither Western GeoLogic, nor any staff member assigned to this investigation has any interest or contemplated interest, financial or otherwise, in the subject or surrounding properties, or in any entity which owns, leases, or occupies the subject or surrounding properties or which may be responsible for environmental issues identified during the course of this investigation, and has no personal bias with respect to the parties involved.

The information contained in this report has received appropriate technical review and approval. The conclusions represent professional judgment and are founded upon the findings of the investigations identified in the report and the interpretation of such data based on our experience and expertise according to the existing standard of care. No other warranty or limitation exists, either expressed or implied.

The investigation was prepared in accordance with the approved scope of work outlined in our proposal for the use and benefit of the Client; its successors, and assignees. It is based, in part, upon documents, writings, and information owned, possessed, or secured by the Client. Neither this report, nor any information contained herein shall be used or relied upon for any purpose by any other person or entity without the express written permission of the Client. This report is not for the use or benefit of, nor may it be relied upon by any other person or entity, for any purpose without the advance written consent of Western GeoLogic.

In expressing the opinions stated in this report, Western GeoLogic has exercised the degree of skill and care ordinarily exercised by a reasonable prudent environmental professional in the same community and in the same time frame given the same or similar facts and circumstances. Documentation and data provided by the Client, designated representatives of the Client or other interested third parties, or from the public domain, and referred to in the preparation of this assessment, have been used and referenced with the understanding that Western GeoLogic assumes no responsibility or liability for their accuracy. The independent conclusions represent our professional judgment based on information and data available to us during the course of this assignment. Factual information regarding operations, conditions, and test data provided by the Client or their representative has been assumed to be correct and complete. The conclusions presented are based on the data provided, observations, and conditions that existed at the time of the field exploration.

It has been a pleasure working with you on this project. Should you have any questions, please call.

Sincerely,
Western GeoLogic, LLC

LICENSED PROFESSIONAL GEOLOGIST
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ATTACHMENTS

Figure 1. Location Map (8.5"x11")
Figure 2. Geologic Map (8.5"x11")
Figure 3A. LIDAR Imagery (8.5"x11")
Figure 3B. Site Plan (8.5"x11")
Figure 4A-D. Trench 1 Log (four 11"x17" sheets)
Figure 5. Trench 2 Log (11"x17")

APPENDIX A
Environmental Professional Qualifications

REFERENCES

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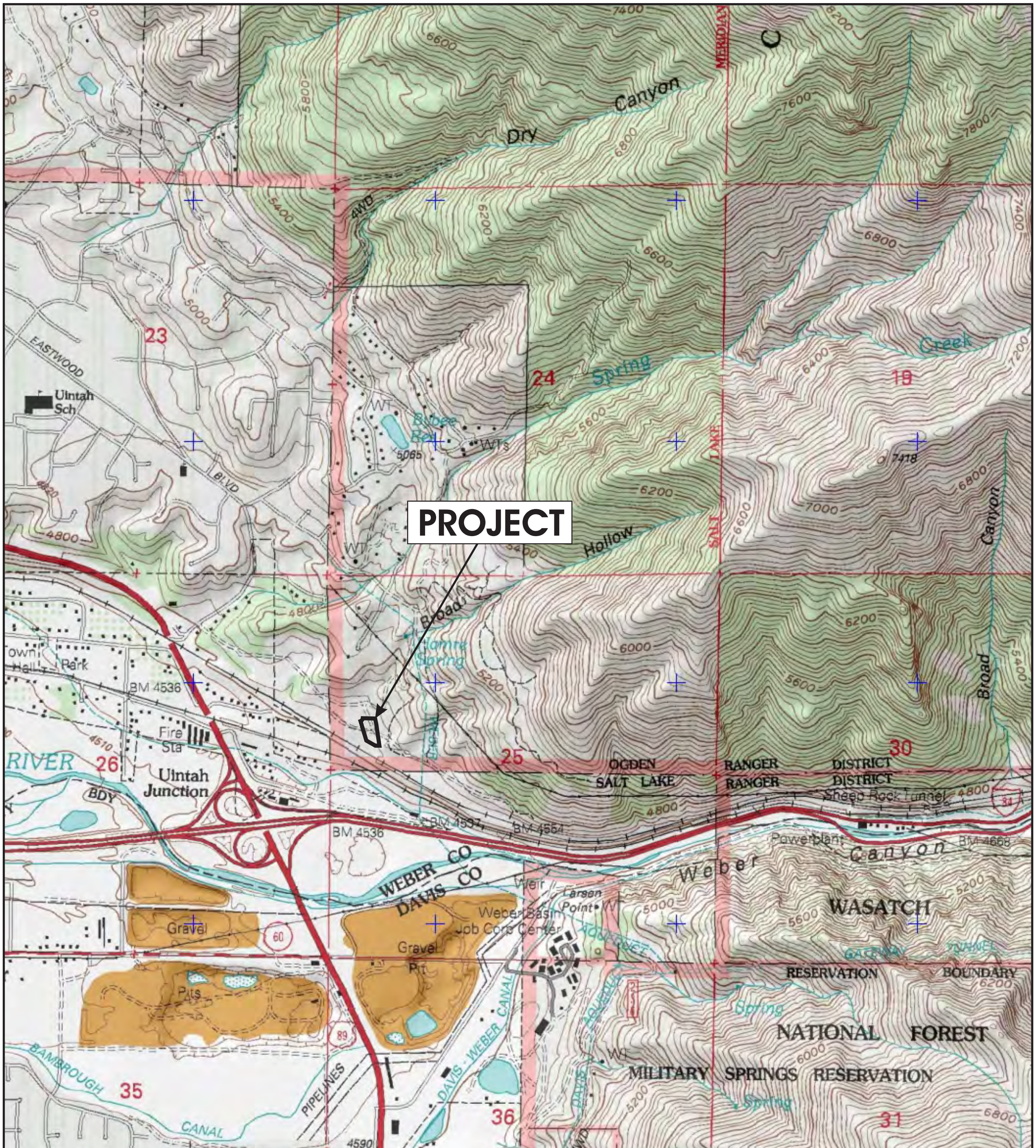
ATTACHMENTS



Source: U.S. Geological Survey Topographic Quadrangle, Ogden, UT, 1998.

N
W E
S

0 1000 2000 feet

Scale 1:24,000
(1 inch = 2000 feet)

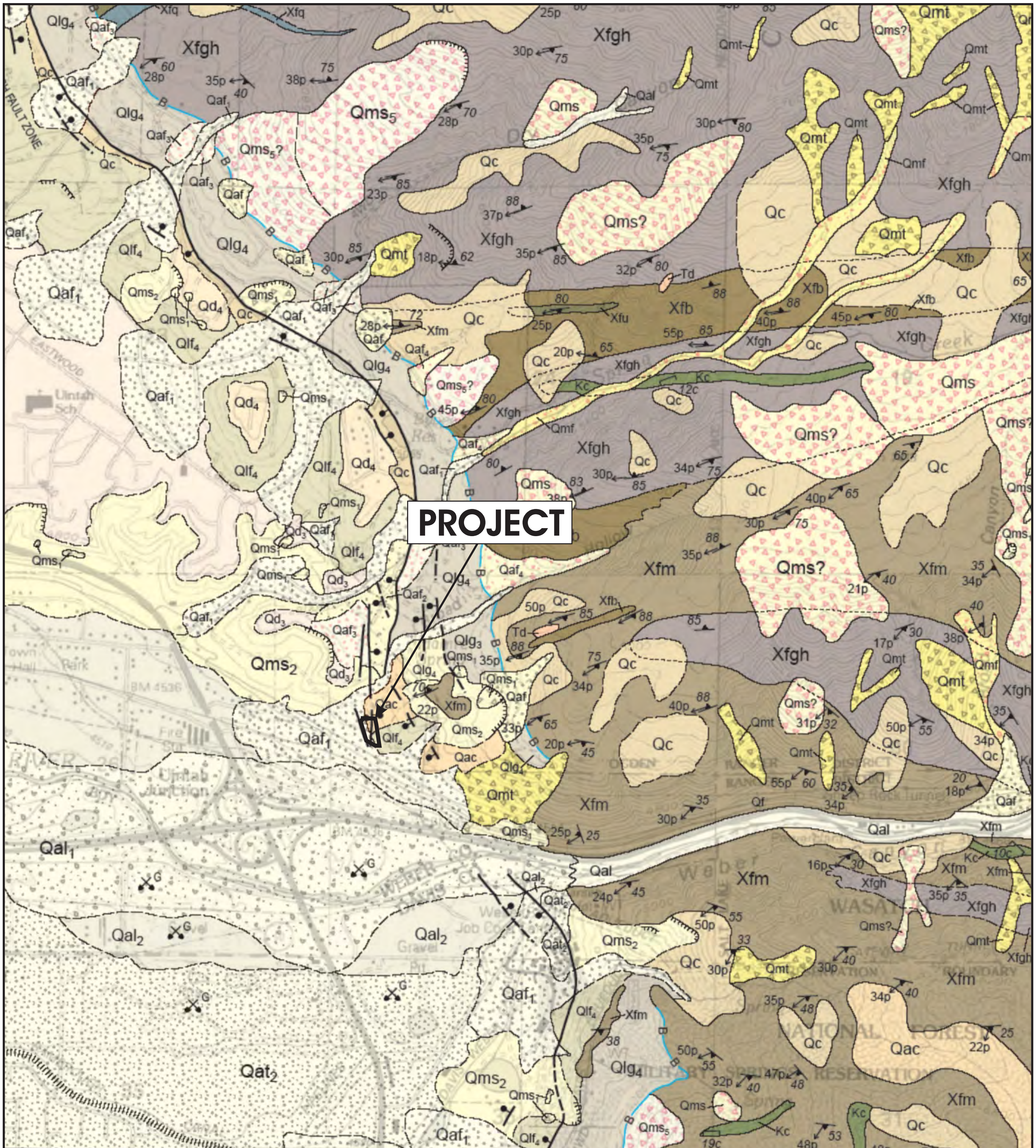
WESTERN GEOLOGIC

LOCATION MAP

SURFACE FAULT RUPTURE HAZARDS EVALUATION

Cedar Cove Subdivision Lot 28-A
6696 South 2850 East
Weber County, Utah

FIGURE 1



Source: Yonkee and Lowe (2004); see test for descriptions of nearby surficial geologic units.

N
W E
S

0 1000 2000 feet

Scale 1:24,000
(1 inch = 2000 feet)

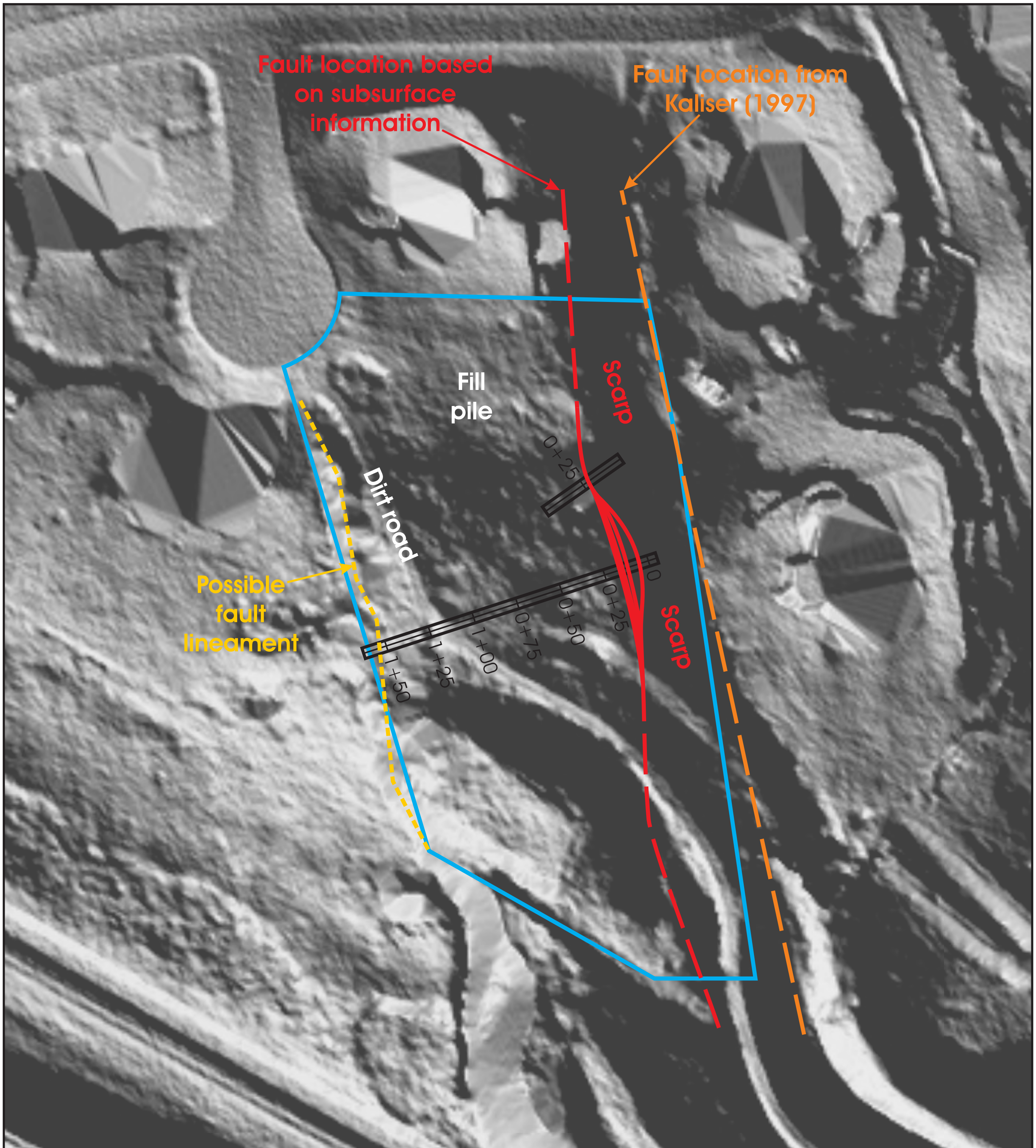
WESTERN GEOLOGIC

GEOLOGIC MAP

SURFACE FAULT RUPTURE HAZARDS EVALUATION

Cedar Cove Subsdivision Lot 28-A
6696 South 2850 East
Weber County, Utah

FIGURE 2



Base from 2014 Utah AGRC 0.5-meter LIDAR Bare Earth DEM.

WESTERN GEOLOGIC

N W E S

0 40 80 feet

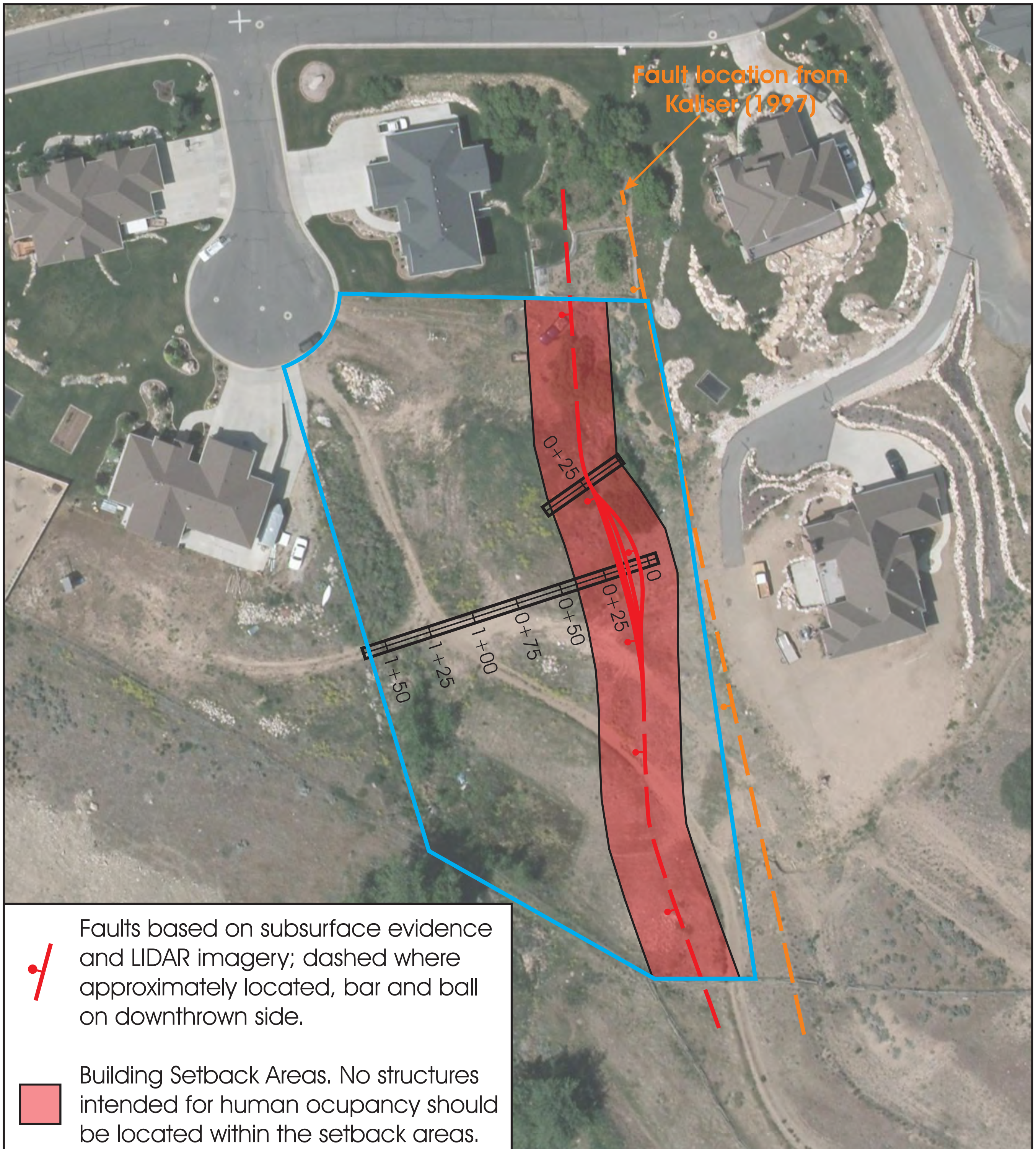
Scale 1:960
(1 inch = 80 feet)

LIDAR IMAGERY

SURFACE FAULT RUPTURE HAZARDS EVALUATION

Cedar Cove Subdivision Lot 28-A
6696 South 2850 East
Weber County, Utah

FIGURE 3A



Base from 2012 Utah AGRC High-Resolution Orthophoto.

WESTERN GEOLOGIC

N
W E
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0 40 80 feet

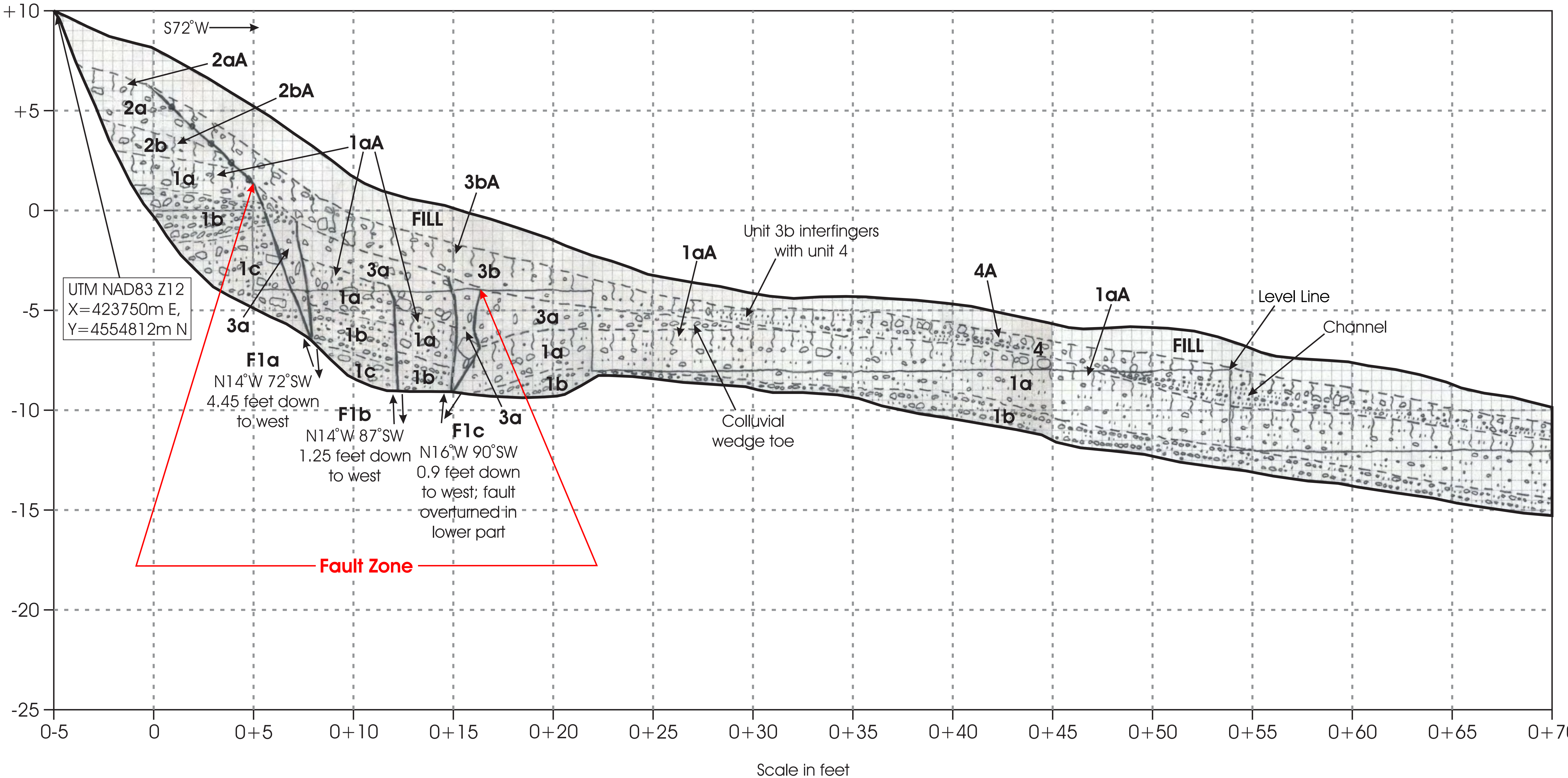
Scale 1:960
(1 inch = 80 feet)

SITE PLAN

SURFACE FAULT RUPTURE HAZARDS EVALUATION

Cedar Cove Subdivision Lot 28-A
6696 South 2850 East
Weber County, Utah

FIGURE 3B



WESTERN GEOLOGIC

SCALE: 1 inch = 5 feet
(no vertical exaggeration)
South Wall Logged, East to West

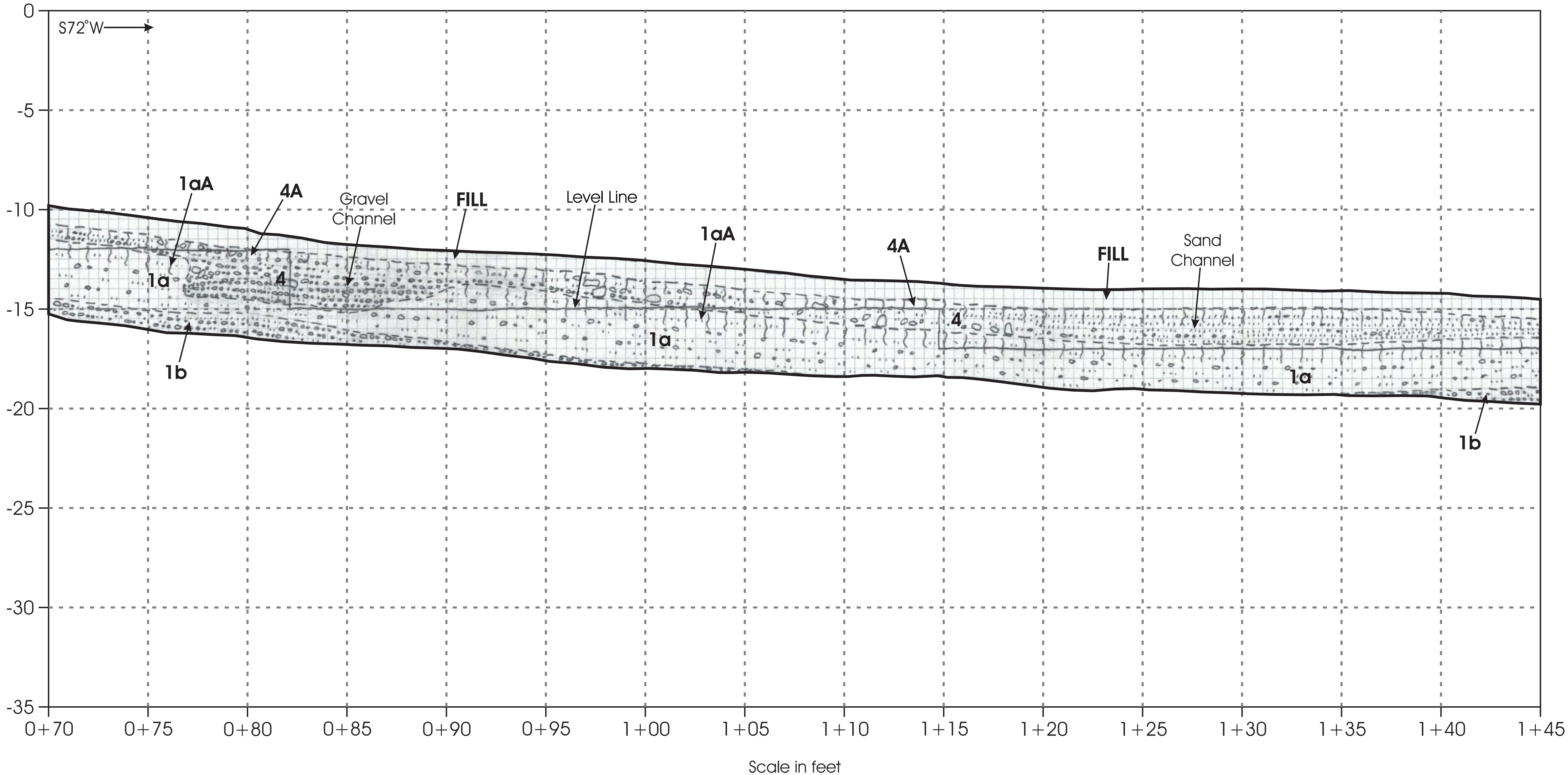
Trench logged by Bill D Black, P.G.
on March 10-11, 2016
Reviewed by Craig V Nelson, P.G.

TRENCH 1 LOG, SHEET 1

SURFACE FAULT RUPTURE HAZARD EVALUATION

Cedar Cove Subdivision Lot 28-A
6696 South 2850 East
Weber County, Utah

FIGURE 4A



SCALE: 1 inch = 5 feet
(no vertical exaggeration)
South Wall Logged, East to West

Trench logged by Bill D Black, P.G.
on March 10-11, 2016
Reviewed by Craig V Nelson, P.G.

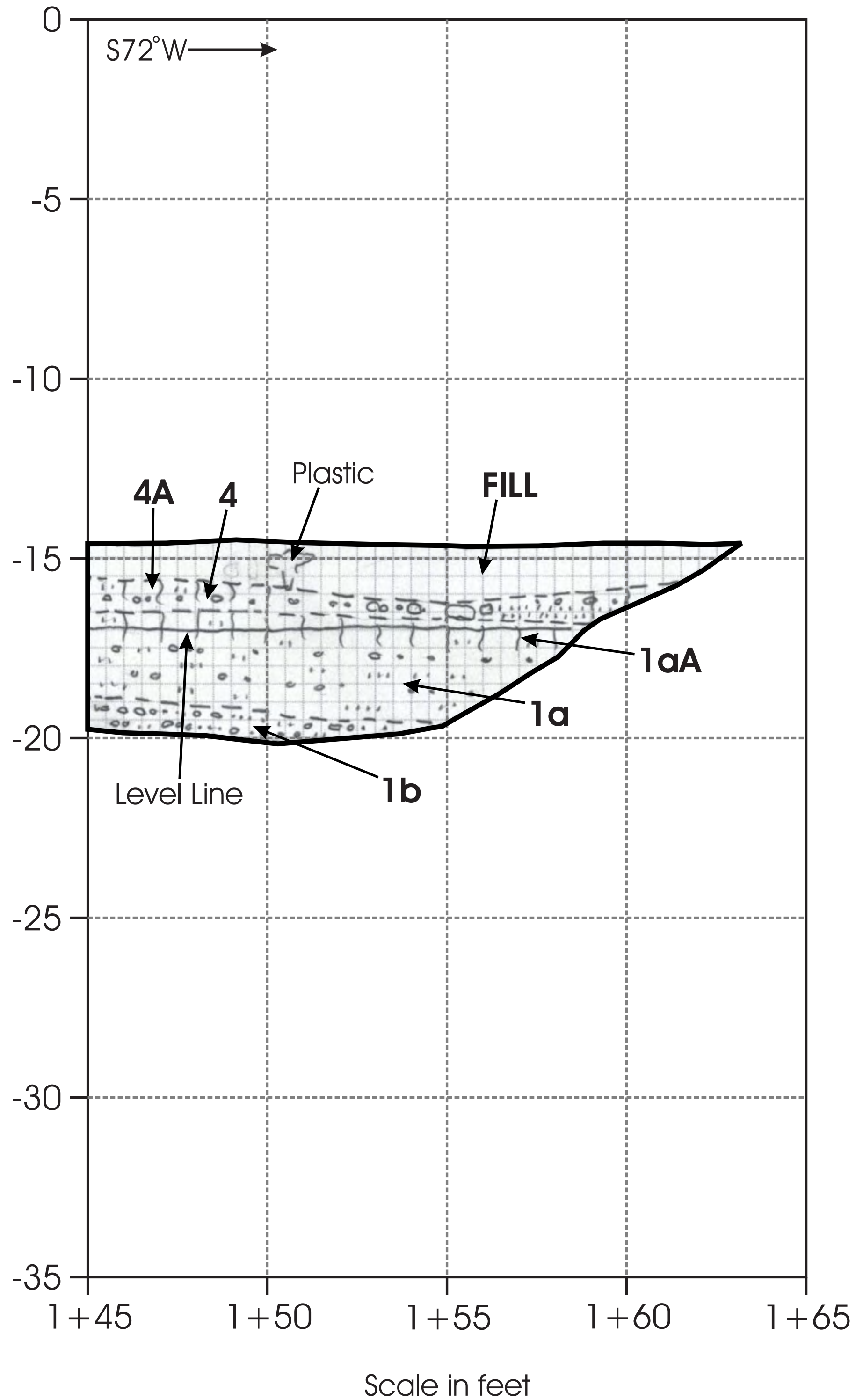
WESTERN GEOLOGIC

TRENCH 1 LOG, SHEET 2

SURFACE FAULT RUPTURE HAZARD EVALUATION

Cedar Cove Subdivision Lot 28-A
6696 South 2850 East
Weber County, Utah

FIGURE 4B



TRENCH 1 UNIT DESCRIPTIONS

Unit 1. *Lacustrine sediments related to the regressive stage of Late Pleistocene Lake Bonneville* - sequence of generally poorly bedded, low to moderate density, gravelly sand to sandy gravel with round to subangular cobbles; clasts with stage II carbonate coatings.

1a. Brown to reddish-brown gravelly sand (SW) with cobbles; correlates to unit 1a in Trench 2.
1aA. Paleosol A horizon formed in unit 1a.
1b. Brown gravel (GW) with sand and trace cobbles; correlates to unit 1c in Trench 2.
1c. Reddish-brown to brown sand (SW) with gravel and trace cobbles; correlates to unit 1d in Trench 2.

Unit 2. *Holocene alluvium and colluvium* - sequence of mixed slope wash and distal debris-flood deposits that likely draped over the fault scarp and tapered out to the west; overlain by fill from prior site disturbance and grading for home to east of site; generally massive, low density, and root penetrated.

2a. Brown sand (SW) with gravel and cobbles.
2aA. Modern A-horizon soil formed in unit 2a.
2b. Brown sand (SW) with gravel.
2bA. Paleosol A horizon formed in unit 2b; overlain by fill.

Unit 3. *Fault-zone and scarp-derived colluvium* - colluvium from faulting and fault-scarp degradation from the most-recent surface faulting earthquake on the Weber segment of the Wasatch fault zone.

3a. Crack fill and colluvial wedge; brown to reddish-brown, massive, low density, gravelly sand (SW) with cobbles.
3b. Upper slope-wash facies of colluvial wedge, generally similar to unit 3a but finer grained; interfingers with unit 4 to west.
3bA. Modern A-horizon soil formed in unit 3b; overlain by fill.

Unit 4. *Holocene alluvium* - mixed stream alluvium and slope wash comprised of brown to dark brown, poorly bedded, low to moderate density, sand (SW) with gravel and slight silt; unit contains channels of gravel and sand to west and interfingers with fault-zone colluvium to east; slightly root penetrated.

4A. Modern A-horizon soil formed in unit 4; overlain by fill and cut in places.

WESTERN GEOLOGIC

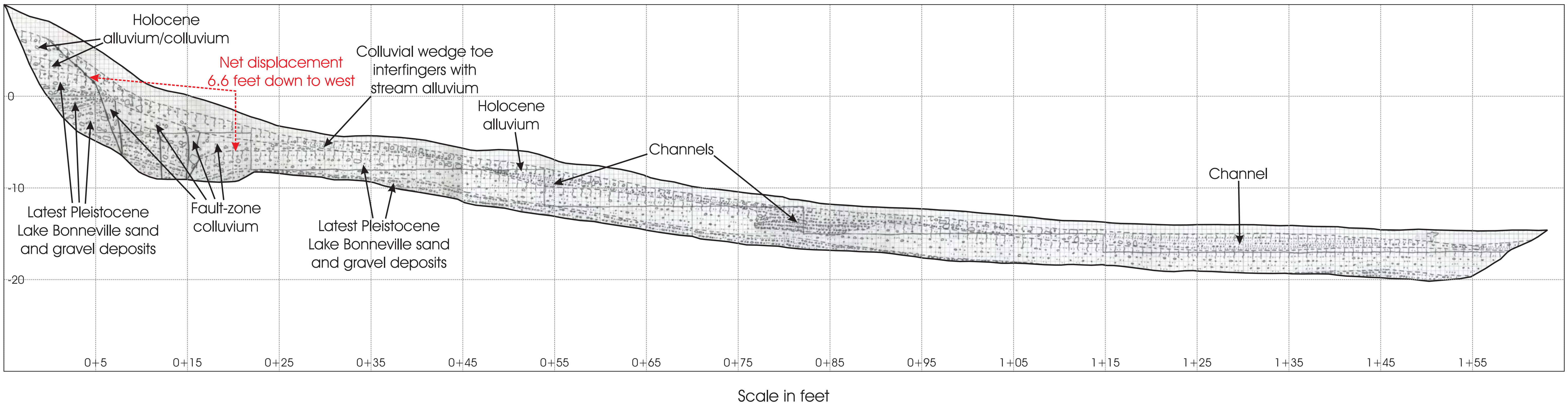
SCALE: 1 inch = 5 feet
(no vertical exaggeration)
South Wall Logged, East to West

Trench logged by Bill D Black, P.G.
on March 10-11, 2016
Reviewed by Craig V Nelson, P.G.

TRENCH 1 LOG, SHEET 3

SURFACE FAULT RUPTURE HAZARD EVALUATION
Cedar Cove Subdivision Lot 28-A
6696 South 2850 East
Weber County, Utah

FIGURE 4C



SCALE: 1 inch = 5 feet
(no vertical exaggeration)
South Wall Logged, East to West

Trench logged by Bill D Black, P.G.
on March 10-11, 2016
Reviewed by Craig V Nelson, P.G.

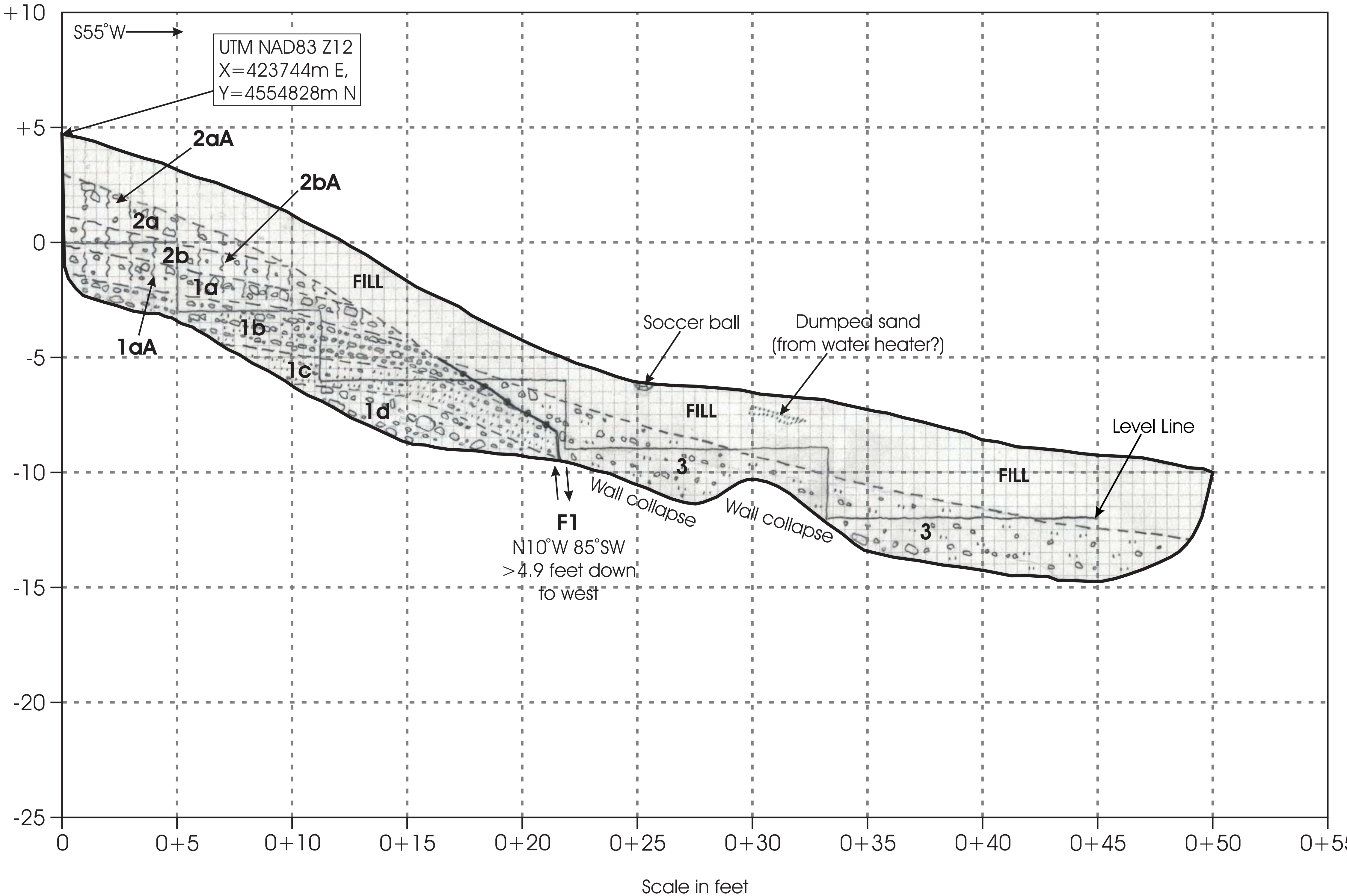
WESTERN GeoLogic

TRENCH 1 OVERVIEW

SURFACE FAULT RUPTURE HAZARD EVALUATION

Cedar Cove Subdivision Lot 28-A
6696 South 2850 East
Weber County, Utah

FIGURE 4D



SCALE: 1 inch = 5 feet
(no vertical exaggeration)
South Wall Logged, East to West

Trench logged by Bill D Black, P.G.
on March 10-11, 2016
Reviewed by Craig V Nelson, P.G.

UNIT DESCRIPTIONS

Unit 1. *Lacustrine sediments related to the regressive stage of Late Pleistocene Lake Bonneville* - sequence of generally poorly bedded, low to moderate density, gravelly sand to sandy gravel with round to subangular cobbles; clasts with stage II carbonate coatings.

- **1a.** Brown to reddish-brown gravelly sand (SW) with cobbles.
- **1aA.** Paleosol A horizon formed in unit 1a.
- **1b.** Reddish-brown sand (SW) with gravel; not present in Trench 1.
- **1c.** Brown gravel (GW) with sand and trace cobbles; correlates to unit 1b in Trench 1.
- **1d.** Reddish-brown to brown sand (SW) with gravel and trace cobbles; correlates to unit 1c in Trench 1.

Unit 2. *Holocene alluvium and colluvium* - sequence of mixed slope wash and distal debris-flood deposits that likely draped over the fault scarp and tapered out to the west; overlain by fill from prior site disturbance and grading for home to east of site; generally massive, low density, and root penetrated.

- **2a.** Brown sand (SW) with gravel and cobbles.
- **2aA.** Modern A-horizon soil formed in unit 2a.
- **2b.** Brown sand (SW) with gravel.
- **2bA.** Paleosol A horizon formed in unit 2b.

Unit 3. *Mixed Holocene alluvium and fault-zone/ scarp-derived colluvium* - brown, massive, sand (SW) with gravel and trace cobbles; upper part organic rich and root penetrated; very loose and caving in areas close to fault, wall instability prevented deeper excavation.

WESTERN GEOLOGIC

TRENCH 2

SURFACE FAULT RUPTURE HAZARD EVALUATION

Cedar Cove Subdivision Lot 28-A
6696 South 2850 East
Weber County, Utah

FIGURE 5

APPENDIX A

Environmental Professional Qualifications

BILL D. BLACK, P.G.

Title Senior Engineering Geologist

Expertise
Environmental Due Diligence
Environmental Geology
Engineering Geology
Geologic Hazards
Groundwater Geology

Academic Background B.S., Geology, Weber State University, 1986, cum laude

Registrations Professional Geologist – Utah #5224898

Experience Over 27 years of experience conducting environmental and geologic investigations with expertise in fault and seismic studies; geologic hazards mapping, analysis, and mitigation; landslides, debris flows, and slope instability; radon hazards; and environmental site assessment. Completed many geologic and environmental evaluations in Utah and the western United States as a consulting geologist with Western Geologic. Conducted geologic hazards mapping; various hazard evaluations and emergency hazard responses; environmental investigations for radon hazards, and landfill and wastewater soil-absorption system suitability; and consultant report reviews for local governments as a former project geologist with the Utah Geological Survey.

Environmental Site Assessments

- Conducted numerous Phase I Environmental Site Assessments, Phase II evaluations, and Environmental Transaction Screens for a variety of commercial and industrial facilities throughout the western U.S.

Hydrogeology Projects

- Three long-term spring monitoring efforts for Pacificorp under the Populus Terminal Power Line Project in Malad and Woodruff, ID, and Plymouth, UT.
- Well-site suitability evaluations for developments in Cache, Weber, and Morgan Counties; including evaluation of well sites for the town of Mendon, UT.
- Seismic refraction study for Spring City, Utah municipal water well location in cooperation with the Utah Division of Water Resources.
- Water quality and flow measurements for potential water sources, Antelope Island State Park, Utah.
- Percolation tests and field bedrock characterization for Duchesne County, Utah wastewater soil-absorption system suitability.
- Mapped areas of shallow ground water in Tooele Valley and the West Desert Hazardous Industry Area, Utah.
- Conducted shallow drilling studies to determine depth to the unconfined aquifer, Ogden Valley, Utah, for a water quality assessment.

Environmental Geology

- Authored and co-authored studies mapping and evaluating the radon-hazard potential of the lower Weber River area, Weber and Davis Counties, Utah; Tooele Valley, Tooele County, Utah; western Salt Lake Valley, Salt Lake County, Utah; and Sandy and Provo Cities, Salt Lake and Utah Counties, Utah.
- Author of statewide radon-hazard potential map for Utah.
- Geologic field reconnaissance for four landfill sites in Wasatch County, Utah.

Geologic Hazards

- Principal investigator for numerous Western Geologic consulting studies since 2003, including geologic evaluation of the Peruvian Gulch Lift Tunnel at Snowbird Ski Resort; surface-fault-rupture hazard evaluations for the Salt Lake City Public Safety Complex, Cottonwood Mall Redevelopment Project, and University of Utah USTAR Development; landslide hazard assessments for Snow Basin and Powder Mountain Ski Resorts, and debris-flow hazard evaluations for the Chatelain-Stewart Property in North Ogden, proposed Kotter Canyon Estates in Brigham City, proposed Deer Run Subdivision in Draper, and proposed Hidden Canyon Subdivision in Ogden, Utah.
- Geologic hazards evaluations for the Pacificorp Gateway West Power Line Project from Casper, WY. to Downey, ID.
- Author and co-author of six NEHRP fault and trenching studies at sites along the Wasatch fault zone, Oquirrh fault zone, Mercur fault, and West Cache fault zone in Tooele, Cache, Salt Lake, and Utah Counties, Utah.
- Co-investigator for the Mapleton Megatrench project, Provo segment of the Wasatch fault zone, Utah County, Utah in cooperation with URS Corp. (Oakland, CA) and the Utah Geological Survey.
- Principal author of the digital Quaternary fault and fold database and map of Utah.
- Geology and geologic hazards of Tooele Valley and the West Desert Hazardous Industry Area, Tooele County, Utah; co-author for Geologic hazards of the Ogden area and Geology of Salt Lake City.
- Numerous geologic hazard assessments for water tanks, schools, fire stations, and School Trust Lands in Utah.
- Evaluated and documented geologic effects associated with the 1992 St. George earthquake and Springdale landslide; evaluated causes and effects of the 1999 Weber-Davis Canal breach in Riverdale, Weber County, Utah; and responded to numerous other geologic hazard events in Utah resulting from landslides, rock falls, canal failures, and earthquakes.
- Numerous geologic hazard and site suitability assessments for water tanks, schools, fire stations, subdivisions, and State Trust land sales.

Geologic Hazards - Land Use Planning

- Prepared geologic hazards analyses and maps for Tooele County Planning Division for Tooele Valley and West Desert Hazardous Industry Area. Geologic hazards of prime consideration included: surface fault rupture, earthquake ground shaking, landslides, rock fall, debris flow, problem soils, stream flooding, liquefaction, shallow ground water, and radon.

Professional History

Senior Engineering Geologist, Western GeoLogic, Salt Lake City, UT (2003-present).
Project Geologist, Utah Geological Survey, Applied Geology Section (1995-1999).
Geologist, Utah Geological Survey, Applied Geology Section (1990-1995).
Geotechnician, Utah Geological Survey, Applied Geology Section (1986-1990).
Field Geotechnician, North American Exploration, Kaysville, Utah (1986).

Professional Awards

Co-recipient, Geological Society of America John C. Frye award for 1995.
Numerous Utah Geological Survey awards for excellence.
Utah Division of Radiation Control award for achievements in radon hazards.

Citizenship

United States

Countries Worked In

United States

Language Proficiency

English

CRAIG V. NELSON, P.G., C.E.G., C.E.M.

Title Principal Engineering Geologist – Environmental Professional

Expertise
Environmental Due Diligence
Engineering Geology
Groundwater Geology
Environmental Geology
Geologic Hazards
Litigation Support

Academic Background
M.B.A., Eccles School of Business, University of Utah, 1991
M.S., Geology, Utah State University, 1986
B.S., Geology, Utah State University, 1982

Registration and Certifications
Professional Geologist - Utah No. 5251804, California No. 4806, Wyoming No. PG-3766
Certified Engineering Geologist - California No. 1585
Certified Environmental Manager - Nevada No. 1975
Onsite Wastewater Systems Level I and II Qualified No. 0265-2002-OT12
Groundwater and Soil Sampler Certificate No. GS1399
Certified EPA/AHERA Asbestos Inspector No. 220765

Experience

Mr. Nelson has over 30 years of experience managing a wide variety of environmental and engineering geology projects. His expertise in geologic hazards mapping, analysis and mitigation stem from successful completion of numerous geologic hazard studies, fault and seismic investigations, rockfall probability assessments, landslide and debris flow studies, and slope stability projects. He has completed geologic studies and risk analysis for engineered structures, public facilities, subdivisions, dams, highways, and corridors throughout the western U.S. and Canada.

Mr. Nelson also has experience in engineering geology for surface and underground mining as well as economic evaluation of mineral deposits including metallic minerals, coal, sand and gravel, and other industrial minerals.

His environmental and hydrogeology work has included subsurface site characterizations, soil-gas surveys, Phase I Environmental Site Assessments, Transaction Screen analyses, and soil and groundwater remediation projects involving a variety of contaminants and remediation technologies. He has provided expert witness and third-party review services in a number of geology and groundwater related cases.

Environmental Site Assessments

- Mr. Nelson has directed, reviewed, or conducted over 2,000 Phase I Environmental Site Assessments and Transaction Screens for a variety of commercial and industrial facilities throughout the western U.S. (Alaska, Arizona, California, Colorado, Hawaii, Idaho, Illinois, Nebraska, New Mexico, North Dakota, Montana, Oregon, South Dakota, Texas, Utah, Washington, Wisconsin, and Wyoming), as well as Mexico, Ireland, Scotland, Great Britain, and Singapore. Mr. Nelson has completed the ASTM training course on the Phase I & Phase II Environmental Site Assessment Processes.

Groundwater Studies & Phase II Site Characterizations

- Managed and directed numerous Phase II environmental site characterizations to evaluate the extent and magnitude of soil and groundwater contamination.

Experienced with a variety of drilling and sampling technologies such as hollow-stem auger, direct push, and soil-gas screening. Experienced with geophysical exploration techniques such as seismic refraction, magnetometer, and ground-penetrating radar.

Professional History

Principal Engineering Geologist, Western GeoLogic, Salt Lake City, UT (2001-present)
V.P. Operations Manager, URS Corporation, Salt Lake City, UT (2000-2001)
V.P. Managing Principal-In-Charge, Dames & Moore, Salt Lake City, UT (1997-2000)
Sr. Geologist - Geoscience Manager, Dames & Moore Salt Lake City, UT (1995-97)
Sr. Engineering Geologist, Delta Geotechnical Consultants, Salt Lake City, UT (1992-95)
County Geologist, Salt Lake County Public Works, Salt Lake City, UT (1985-92)
Teaching and Research Assistant, Utah State University, Logan, UT (1983-85)
Staff Engineering Geologist, Seegmiller International, Salt Lake City, UT (1981-83)

Professional Awards

American Planning Association, *1991 Award of Merit* in recognition of achievement in information technology made to the state of Utah for the Earthquake Awareness and Hazard Mitigation Video.
American Planning Association: *1990 Award of Merit* for development of Salt Lake County's Natural Hazards Ordinance.
U.S. Geological Survey: *1989 Certificate of Appreciation* for implementation of measures to reduce losses due to earthquakes in Utah.

Professional Affiliations

Utah Geological Survey, Board Member and Chair (1997-2005)
Utah Geologic Association
Utah State University Department of Geology Advisory Board (2000-present)
University of Utah Geological Engineering Advisory Board (2000-2010)
Salt Lake School District Seismic Committee (1989-1992)
Geological Review Committee, Nuclear Repository Waste Siting Study, Davis/Lavender Canyons, Utah (1982-1983)

Citizenship United States

Countries Worked In United States, Canada, Jamaica

Language Proficiency English