CTL | THOMPSON INCORPORATED

DEBRIS FLOW/MUDFLOW ANALYSIS
FOREST LAKES SUBDIVISION (PHASE 2)
LINDBERGH ROAD AND W. BAPTIST ROAD
EL PASO COUNTY, COLORADO

Prepared For:

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Project No. CS18916.000-105

August 6, 2018

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SCOPE

CTL/Thompson, Inc. has analyzed the impact of potential debris flow/mudflow events within Phase 2 of Forest Lakes Subdivision in El Paso County, Colorado. We previously performed a Geologic Hazards Evaluation and Preliminary Geotechnical Investigation that included the Phase 2 area (Job No. CS-10,585; report dated August 15, 2001). Concurrent to this debris flow/mudflow analysis, our firm performed a supplemental geologic evaluation and geotechnical investigation for the property. Our geologic and geotechnical findings, opinions, and recommendations are presented in a separate report.

Our debris flow/mudflow analysis utilized our geologic and geotechnical information and included modeling with the HEC-RAS computer program to evaluate potential predevelopment (baseline) debris/water surface elevations resulting from the 10-year and 100-year storm events. This scope is intended to address concerns stated by the Colorado Geological Survey (CGS) in the Debris Flow/Debris Flood section of a letter dated February 6, 2018. Our report includes a discussion of our observations and methodology and presents our opinions and recommendations regarding potential risks from debris flow/mudflow events.

SITE DESCRIPTION

Phase 2 of the Forest Lakes development will be predominately in the south half of Section 28 and the southeast quarter of Section 29 within Township 11 South and Range 67 West of the 6th Principal Meridian. The subject property is about three miles southwest of the town of Monument in El Paso County, Colorado. Access to the parcel is via an unimproved dirt road (Lindbergh Road) from near the west end of Phase 1 of Forest Lakes subdivision. A vicinity map with the location of the site is shown on Figure 1.

The Phase 2 property includes the confluence of South Beaver Creek and North Beaver Creek, as well as about ¾-mile of each stream course above the confluence. Both creeks originate within the mountains of the Rampart Range to the west of the site. These creeks converge to form Beaver Creek which trends down to the east toward Bristlecone Reservoir. The reservoir is a manmade, on-channel water impoundment structure. Hell Creek, an approximately 1/3-mile tributary stream, joins Beaver Creek less than 150-feet downstream of the confluence of North and South Beaver Creeks. Existing ground surface topography is shown on Figure 2.

The valley floors along the creeks within Phase 2 are generally gently sloping. Steep hillsides are to the north and south. Terrace landforms cap the hillsides forming mesas along the edges of the property. A prominent topographic knob separates the North and South Beaver Creek basins just above the confluence. An old man-made pond with beaver activity is between the knob and confluence. Vegetation consists of riparian plants, grasses and trees along the valley floors. Cottonwoods and oaks are within the stream floodways. Scrub oak, pine and cactus are on the steeper hillsides. The parcel has been used for agriculture in the past.

PROPOSED DEVELOPMENT

Forest Lakes, Phase 2 will be developed for construction of single-family residences. Construction will include extending Forest Lakes Drive and Mesa Top Drive to the west. Utilities will be constructed below the road right-of-ways. A connecting road, Montane Mesa Way, and several cul-de-sac roads are also planned. A phasing exhibit by Classic Consulting Engineers (dated February 6, 2018) indicates 231 lots are platted along the roads in Phase 2. A Master Development Drainage Plan for Forest Lakes by Kiowa Engineering (last revised April 11, 2002) indicates the residential lots are intended to be outside of the 100-year floodway of North Beaver Creek and South Beaver Creek. At this writing, three

15-foot by 8-foot reinforced concrete box culverts are planned for both Forest Lakes Drive and Mesa Top Drive to facilitate crossing of North Beaver Creek. We were not provided with proposed grading plans for the lots and roads, or details of the culverts.

GEOLOGY AND SUBSOILS

Our geologic evaluation for Forest Lakes, Phase 2 is provided in a separate report under this project number. In general, the property is covered by sandy alluvium deposited by streams. The steeper ground is covered with slopewash colluvium with a few sedimentary bedrock outcrops. Gentle to moderate slopes north and west of the confluence of North and South Beaver Creek are predominantly alluvium and colluvium. These deposits are considered stable with some localized erosion channels. Alluvial gravel and cobble deposits are within the creek alignments. South Beaver Creek and Beaver Creek are incised into older terrace gravel deposits. These deposits form levees and terraces adjacent to South Beaver Creek. Beaver Creek below the confluence is well-defined with less evidence of geologically recent overbank flows. The North Beaver Creek drainage gradient flattens along the north border of the parcel. Past flood events have left abandoned channels and debris deposits. Stream channels within these deposits likely shift during periods of concentrated surface runoff.

To investigate subsurface conditions for our previous and recent geotechnical investigations, we have drilled a total of about 24 exploratory borings within the Phase 2 area of Forest Lakes. In general, our borings in the alluvial deposits within the North Beaver Creek floodplain encountered 20 to 25 feet of silty sand and gravel underlain by hard to cemented sandstone bedrock. Groundwater in these deposits was typically between 5 and 10 feet below the existing ground surface. Borings in the alluvial deposits in the vicinity of South Beaver Creek and Beaver Creek generally found 25 to 30 feet of silty to clayey sand and gravel underlain by hard sandstone bedrock. Groundwater adjacent to South Beaver

Creek is about 10 to 20 feet deep. Exploratory borings drilled within the stable alluvium and colluvium areas typically encountered 15 to more than 45 feet of interlayered sands and gravels. Groundwater was not found in most of the borings drilled in the upland areas.

SITE RECONNAISSANCE

James Kellogg, P.E., of CTL/Thompson, Inc. performed a site reconnaissance of Forest Lakes, Phase 2 on April 12, 2018 with Andrew Earles, PhD, P.E., and Karl Kingery, P.E., of Wright Water Engineers, Inc. (WWE). Our observations indicated that the drainageways of South Beaver Creek and Beaver Creek are well-defined and heavily vegetated. The North Beaver Creek drainage is characterized by multiple channels, abandoned channels, and boulder and cobble debris flow deposits. The drainageway of South Beaver Creek is flanked on both sides by levees of cobbles and boulders that were deposited by historic high flow events. Photographs from our reconnaissance are included in Appendix A.

Based on our site reconnaissance, we judge that the potential for debris flow and mudflow is generally limited to major drainage paths and adjacent overbank areas within the geologic floodplains of North Beaver Creek, South Beaver Creek, Beaver Creek, and Hell Creek. North Beaver Creek in particular flows across alluvial fan deposits with boulder levees and abandoned channels characteristic of "debris flow" deposition. Below these features are sand and gravel deposits that result from debris flows, mudflows, and/or mudfloods.

In our opinion, the alluvial and colluvial deposits north and west of the Beaver Creek confluence are less prone to generating debris flows and mudflows. Groundwater is not near the ground surface in these areas. Additionally, significant surface runoff does not appear to exist above these areas to mobilize rocks, sediment, and debris. A number of erosion channels are present within

the alluvial/colluvial deposits. These features are typical of relatively small-scale, progressive erosion and not indicative of debris flows or mudflows.

HYDROLOGIC ANALYSIS

A hydrologic review of the analysis by Kiowa Engineering (Kiowa) was performed to determine the peak discharges within the major drainageways that flow onto the Forest Lakes, Phase 2 property. This review was performed by WWE. The discharges from this analysis were used in the hydraulic modeling by CTL/Thompson, Inc. to determine the limits of inundation areas. Currently, both North and South Beaver Creeks are classified as Zone A approximate floodplains without a detailed hydraulic or hydrologic study. Peak discharge estimates were generated using existing land conditions in the drainage basins above Phase 2 for the 10-year and 100-year return periods.

The Kiowa study used the Soil Conservation Service (SCS) dimensional hydrograph method and modeling with the HEC-1 computer program to determine peak flows onto the property within North Beaver Creek and South Beaver Creek. A storm duration of 24 hours was used for the analysis. Maximum point rainfall amounts of 2.9 inches (10-year) and 4.2 inches (100-year) were developed from the NOAA Atlas 2, Volume III Colorado Manual. The hydrologic analysis performed by Kiowa incorrectly applied an aerial adjustment factor of 96.8 percent to these rainfalls. In order to compensate for this, the peak runoff from the Kiowa model was increased by 10 percent for the WWE modeling to provide conservative estimates of the 100-year peak discharges. Peak discharge estimates for North Beaver Creek, South Beaver Creek, Hell Creek, and Beaver Creek (upper and lower reaches) are summarized on Table 1 below.

Table 1 – Calculated Stream Flow Rates

Stream	10-year (cfs)	100-year (cfs)
North Beaver Creek	1,190	2,950
South Beaver Creek	4,980	11,880
Hell Creek	570	880
Beaver Creek (upper reach)	7,630	15,480
Beaver Creek (lower reach)	8,840	16,190

For on-site and local conveyance, the rational method should be used to size hydraulic structures, inlets, and drains. On-channel structures, including bridges and culverts, should be sized based on the flow rates in Table 1 with appropriate factors for sediment (described in HYDRAULIC MODELING section). This analysis is not part of this study. Culvert design and analysis is typically within the scope of the civil engineer.

HYDRAULIC MODELING

CTL/Thompson, Inc. utilized the US Army Corps of Engineers River Analysis System (HEC-RAS) developed by the Hydrologic Engineering Center for the hydraulic modeling. We performed a one-dimensional, steady state analysis to evaluate potential areas of inundation along the drainageways on the property. We used the flow values determined by the hydrologic analysis for the 10-year and 100-year events. These flows were summarized on Table 1 in the HYDROLOGIC ANALYSIS section.

We developed stream centerline alignments for North Beaver Creek, South Beaver Creek, Hell Creek, and Beaver Creek (upper and lower reaches) using exisiting ground surface topography provided by Classic Consulting Engineers. Most of the topography within the Phase 2 property was developed during previous land surveys. Topography of adjacent areas to the north, west and

south of the property was developed by Classic Consulting from recently-acquired LIDAR data. We understand that the datum for both sets of topographic data references North American Vertical Datum 88 (NAVD 88).

During our modeling, we found significant discontinuity in elevation contours along the match lines of the old and new surveys. Furthermore, it appears that the datum of the newer topographic data is as much as 30-feet higher than the older data. The horizontal datum was assumed by the surveyor and not referenced to a coordinate system. For our modeling, we used NAD 83 Colorado State Planes, Central Zone, U.S. Foot as the coordinate system. The ground surface data should be checked by the surveyor.

We estimated stream centerline alignments based on the topographic data provided to us, as well as satellite imagery. Ground surface contours were distorted in some areas, especially along North Beaver Creek. Much of this distortion appears to be due to trees and vegetation that were not stripped from the ground surface contour data. Using AutoCAD CIVIL 3D, we cut cross-sections at intervals and critical locations along the stream centerline alignments. The alignment and cross-section data were exported to HEC-RAS for hydraulic modeling and analysis. The stream centerline alignments and cross-sections that we developed are shown on Figure 2.

Research by Brunkal and Santi (see references) indicates that debris-flows have a significant difference in peak discharge as compared to the peak discharge of water floods. These researchers developed a table of recommended bulking factors, dependent on drainage basin area and burned versus unburned vegetation. Our hydraulic analysis involved multiplying the flows determined from the hydrologic analysis by a debris flow bulking factor of 1.4 to estimate the area of inundation by debris flow/mudflow. The bulked stream flows used for our hydraulic analysis are shown on Table 2 below.

Table 2 – Bulked Stream Flow Rates

Stream	10-year (cfs)	100-year (cfs)
North Beaver Creek	1,670	4,130
South Beaver Creek	6,970	16,630
Hell Creek	800	1,230
Beaver Creek (upper reach)	18,680	21,680
Beaver Creek (lower reach)	12,380	22,660

The steady flow component of HEC-RAS was used to model the subcritical flow regime water surface profiles. Energy losses in the computational procedure were evaluated by friction (Manning's Equation) and contraction/expansion, which is important at stream confluences and obstructions. Our estimates of Manning's n-values were based on review of vegetative cover shown on satellite imagery and our site reconnaissance observations.

CONCLUSIONS AND RECOMMENDATIONS

The results of our hydraulic modeling and analysis were used to develop a map of debris flow/mudflow areas of inundation. The critical case occurs with a storm with a recurrence interval of 100-years. Our map of debris flow/mudflow inundation area is included as Figure 3.

The lots currently proposed along South Beaver Creek, Beaver Creek, and Hell Creek do not encroach into the mapped area of inundation. Some of the lots along North Beaver Creek encroach into the area inundated by debris flow/mudflow events resulting from the 100-year storm event. These lots will need to be replatted or mitigation will be required.

Based on the extent of the potential debris flow it appears that the proposed culverts for the road crossings over North Beaver Creek will not pass the 100-year event. A detailed culvert analysis will need to be performed by the civil

engineer when grading plans are developed. Our HEC-RAS analysis can likely be modified and utilized to assist the civil engineer by modeling the proposed grading and final culvert design.

The hydraulic modeling by CTL/Thompson, Inc. provides a reasonable assessment of the debris flow/mudflow risk at the site to facilitate safe development for the proposed use. Discrepancies between the old and new survey data exist. As site grading and civil engineering plans progress, our analysis should be checked. We recommend that the two surveys be combined, reconciled, and stamped by a Professional Land Surveyor (PLS). This process should produce a ground surface contour map that is geo-referenced. Detailed analysis of the culverts would then be appropriate.

LIMITATIONS

This engineering report was developed in a manner consistent with that level of care and skill ordinarily exercised by professional engineers currently practicing under similar conditions in the locality of this project. The methods, conclusions, and recommendations in this report are based on field observations, document review, and hydrologic/hydraulic modeling and analysis. Geologic hazard events are unpredictable and no warranty, express or implied, is made. We are available to discuss the contents of this report.

CTL | THOMPSON, INC.

8/6/2015

James D Kellogg, P.E.
Division Manager

JDK:ac

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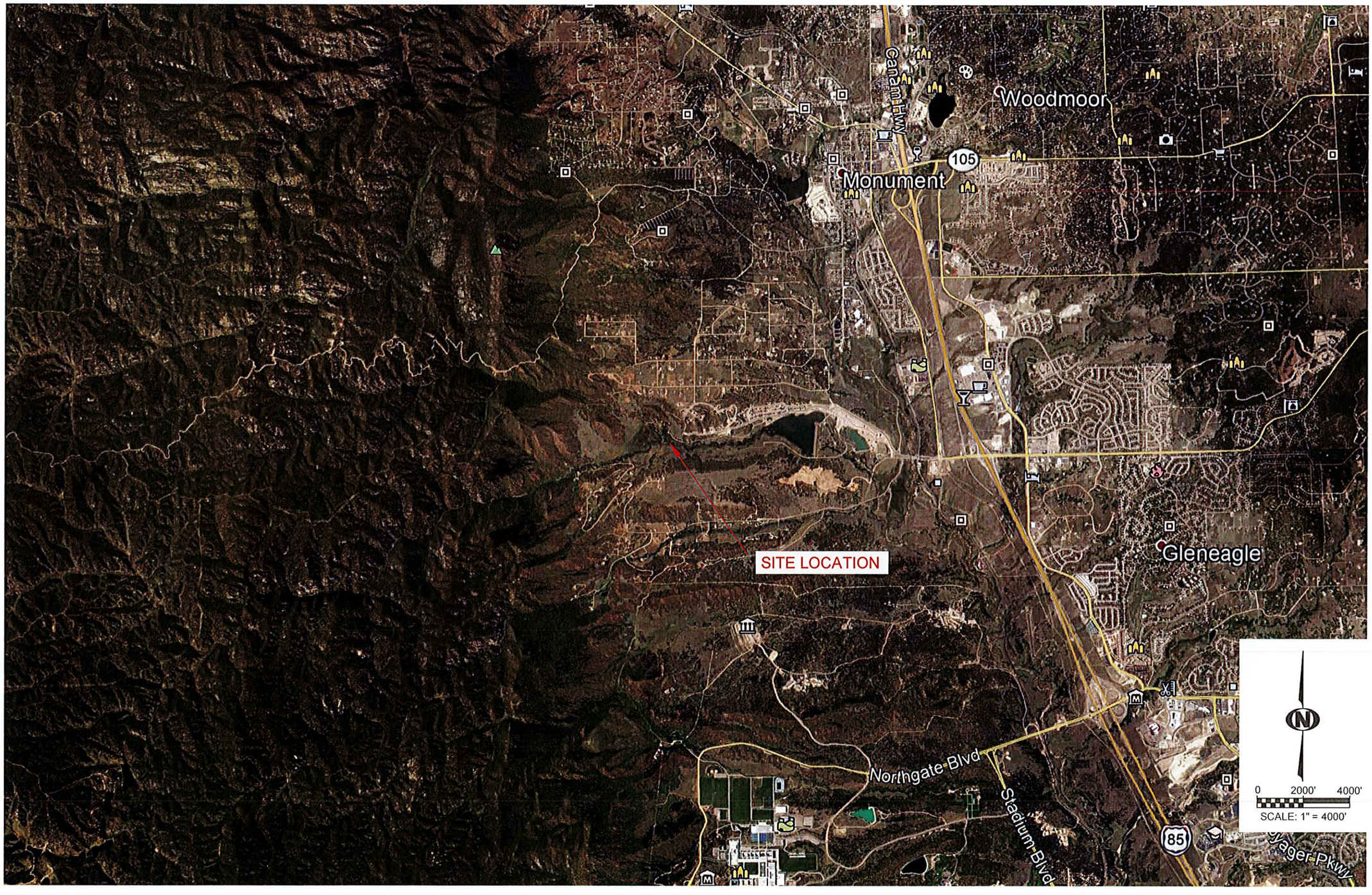

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Vicinity Map

FIG. 1

LEGEND:

STREAM CENTERLINE ALIGNMENT

1+00

STREAM CHANNEL CROSS-SECTIONS

NOTES:
1) EXISTING GROUND SURFACE TOPOGRAPHY PROVIDED BY CLASSIC CONSULTING ENGINEERS.
2) STREAM CENTERLINE ALIGNMENTS AND CROSS-SECTIONS DEVELOPED BY CTL/THOMPSON, INC.

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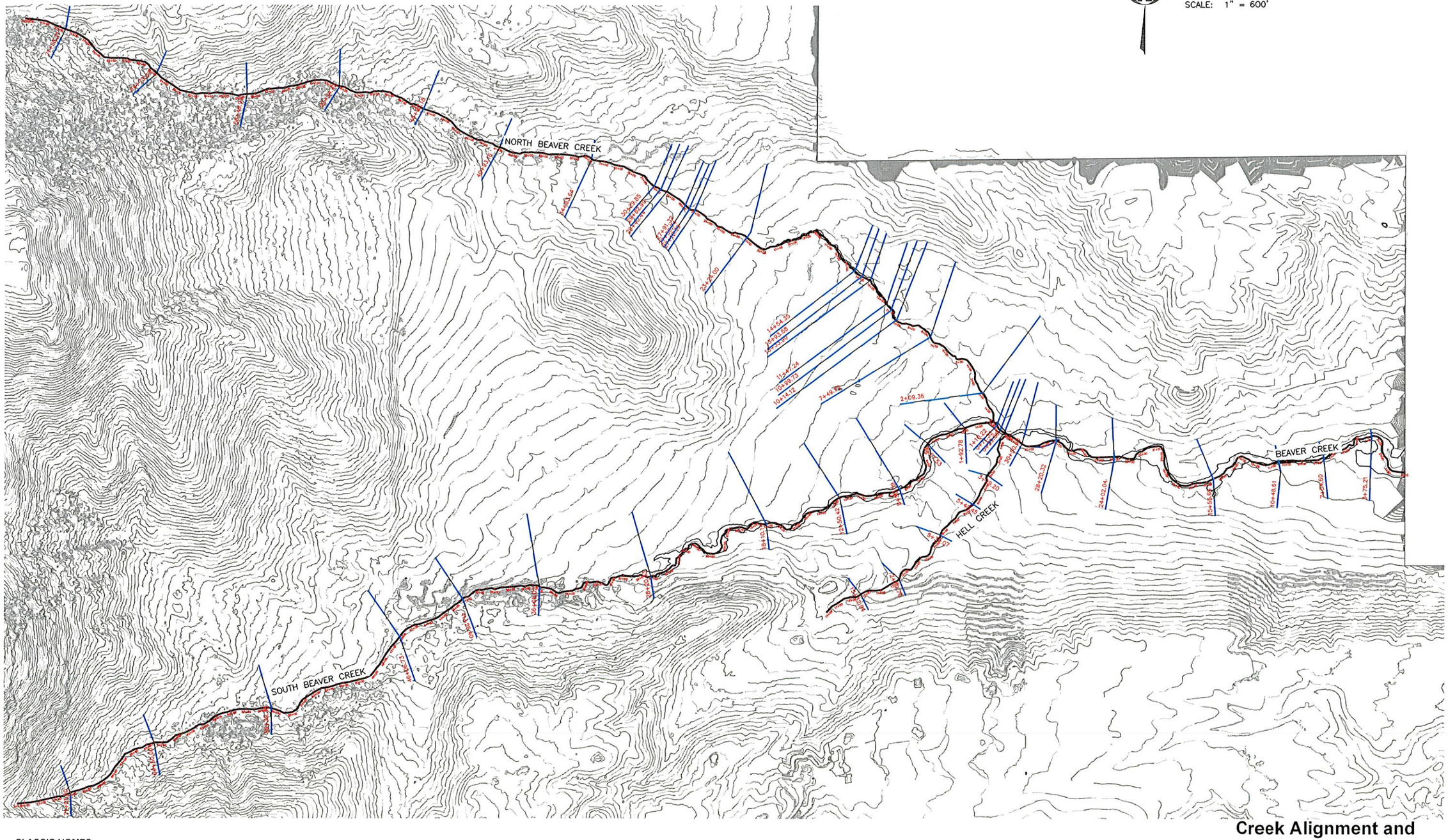

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Creek Alignment and Cross Sections

FIG. 2

NOTE:
DEBRIS FLOW/MUDFLOW INUNDATION AREA
BASED ON PEAK DISCHARGES RESULTING FROM
100-YEAR STORM AND BULKING FACTOR OF 1.4.

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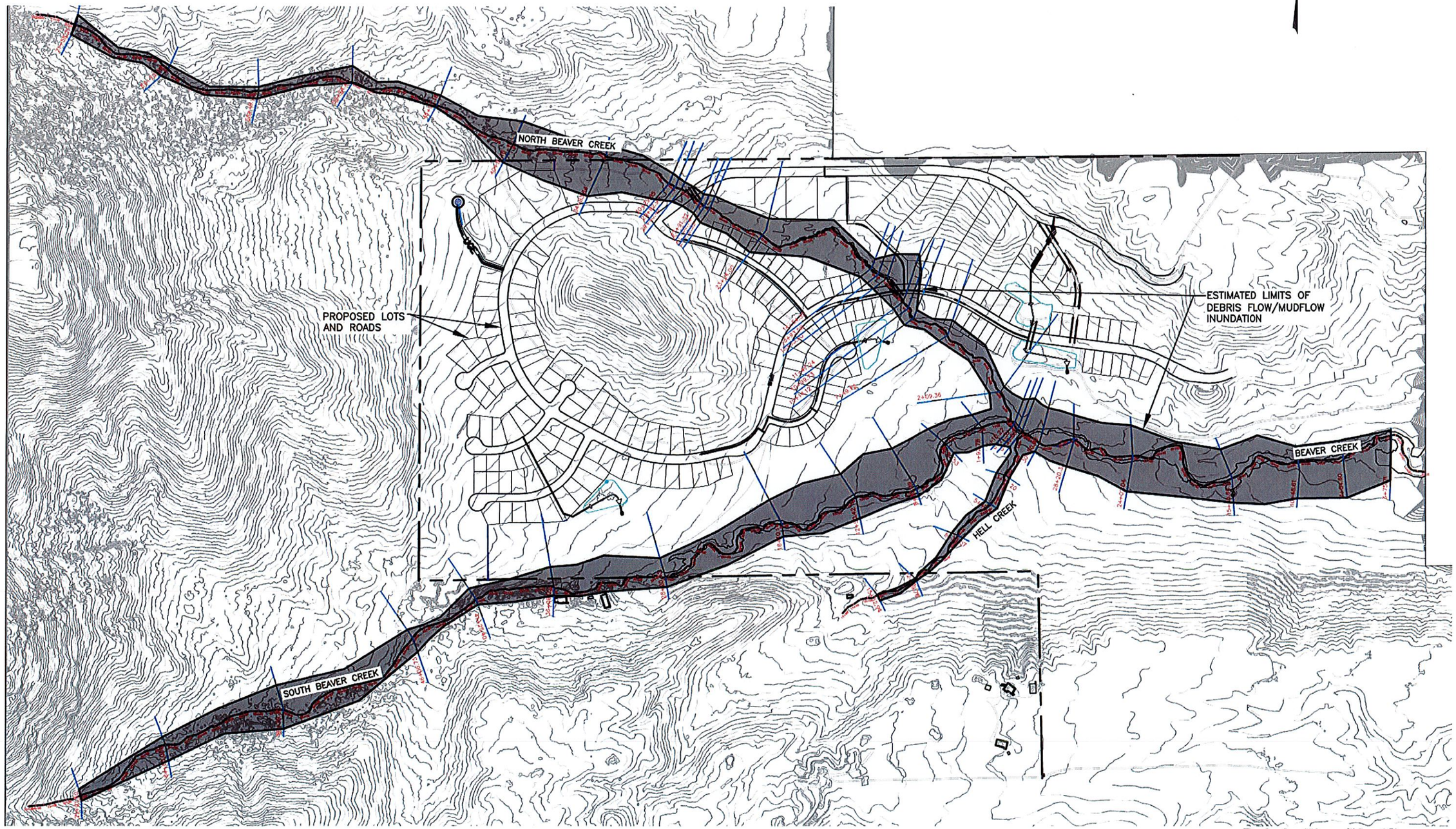

Debris Flow/Mudflow Inundation Area

FIG. 3

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APPENDIX A

SITE RECONNAISSANCE PHOTOGRAPHS

Looking toward South Beaver Creek drainage

South Beaver Creek drainage

South Beaver Creek

Debris levee along South Beaver Creek

Debris levee along South Beaver Creek

Debris levee along South Beaver Creek

Looking toward North Beaver Creek drainage

North Beaver Creek – lower channel

North Beaver Creek – ponded area

North Beaver Creek – ponded areas

North Beaver Creek with boulder deposits

North Beaver Creek abandoned channel

Manmade pond with beaver activity

Manmade pond with beaver activity

Beaver Creek below Hell Creek confluence

Beaver Creek