Appendix 8: Geologic Hazards Report

Ninyo & Moore
Geotechnical and Environmental Sciences Consultants

GEOLOGIC HAZARDS STUDY
THE HUB FACILITY
NORTHWEST CORNER OF WCR 6 AND WCR 7
WELD COUNTY, COLORADO

PREPARED FOR:
Baseline Engineering
700 12th Street, Suite 220
Golden, Colorado 80401

PREPARED BY:
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September 12, 2013
Project No. 500707001

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Mr. Noah Nemmers, PE
Baseline Engineering
700 12th Street, Suite 220
Golden, Colorado 80401

Subject: Geologic Hazards Study
The Hub Facility
Northwest Corner of WCR 6 and WCR 7
Weld County, Colorado

Dear Mr. Nemmers:

Transmitted herein are the findings of Ninyo & Moore's geologic hazards study for the proposed Hub Facility project located near the northwest corner of Weld County Road (WCR) 6 and WCR 7 in Weld County, Colorado. The purpose of our study was to review available documents and literature regarding geologic hazards in the vicinity of the project site related to the proposed development of an oil and gas hub facility. The conclusions provided in this report are intended for planning purposes. We appreciate the opportunity to be of service to you on this project.

Respectfully submitted,
NINYO & MOORE

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1. INTRODUCTION

In accordance with your request, Ninyo & Moore has performed a geologic hazards study for the proposed Hub Facility project located near the northwest corner of WCR 6 and WCR 7 in Weld County, Colorado. The purpose of our study was to evaluate the geologic hazards in the site vicinity by performing a geological site reconnaissance and reviewing available documents and literature regarding geologic conditions at the project site. The conclusions provided in this report are intended for planning purposes. A design-level geotechnical evaluation, including subsurface evaluation and laboratory testing, is being performed by Ninyo & Moore for the project and will be issued as a separate report upon completion.

2. SCOPE OF SERVICES

The scope of our geologic hazards study included the following:

- Review of pertinent background data listed in the *References* section of this report. The data reviewed included geotechnical data, aerial photographs, abandoned coalmine subsidence maps, and published geologic maps and literature.
- Performance of a geologic reconnaissance at the proposed site to observe surface conditions and to evaluate possible geologic hazards that may affect design and construction of the project.
- Compilation and analysis of the accumulated data.
- Preparation of this geologic hazards study report presenting our findings and conclusions.

3. PROJECT DESCRIPTION

Based on our conversations with Baseline Engineering (Baseline) personnel and our review of referenced project data, we understand that Owner is planning to design and construct The Hub Facility project on an approximately 55-acre site located northwest of the intersection of WCR 6 and WCR 7 in Weld County, Colorado (Figure 1). The project will consist of two water and oil tank batteries, holding tanks, process facilities, paved staging and loading pads, a water treatment building, and an office. Site improvements include paved access roads and drivelanes.

Anticipated grading is expected to consist of cuts and fills on the order of 10 feet, or less, to establish pad grades and drainage.

4. GENERAL SITE CONDITIONS

The project site is located in the western portion of Weld County and approximately 3 miles southeast of the Town of Erie, Colorado. Based on the preliminary site layout (Baseline, 2013), the project site is bordered on the east by WCR 7, on the south by WCR 6, and on the north and west by undeveloped agricultural properties. Based on our review of historic aerial photographs, the site has been in a similar condition since at least 1993.

During our field geotechnical site reconnaissance, the proposed site was undeveloped agricultural land. The ground surface was covered with irrigated crop land and irrigation ditches. The topography was relatively flat to slightly undulatory. The ground surface at the site generally slopes downward toward the east. The topographic information provided by Baseline indicates that the relatively higher elevations, on the order of approximately 5,225 feet above mean sea level (MSL), are located in the northwestern portions of the site. The relatively lower elevations (approximately 5,192 feet above MSL) are located in the eastern portions of the site. A shallow draw bisects the central portion of the site, extending in a roughly east-west direction. Generalized surface and subsurface conditions at the proposed site are provided in the following sections.

5. REGIONAL GEOLOGIC SETTING

The project site is located approximately 16 miles east of the southern Rocky Mountains, within the Colorado Piedmont section of the Great Plains Physiographic Province. The Town of Erie is located near the northern margins of a large north-south trending structural basin called the Denver Basin. The Denver Basin formed during the Laramide Orogeny that uplifted the Rocky Mountains during the late Cretaceous and early Tertiary (Trimble, 1980). Over time, the Denver Basin filled with alluvial sediments and wind-blown eolian deposits. The underlying bedrock is comprised of Tertiary to Cretaceous-age sedimentary units.

6. SITE GEOLOGY

The surficial geology of the site is mapped by Colton (1978) as Holocene to late Pleistocene-age Eolian Deposits (wind-blown) including dune sand and loess deposits, which were deposited in the post-glacial period. The mapped geology at the site is presented on Figure 2. The Eolian Deposits are generally composed of silt and clay with varying amounts of sand. The underlying formational bedrock unit is mapped as the Upper Cretaceous-age Laramie Formation consisting of an upper and a lower part. The upper part is described as mostly gray claystone, shale, sandy shale, and lenticular beds of sandstone and lignite. The lower part is described as light gray to light yellowish gray sandstone and sandy shale interbedded with clay, shale, and several beds of coal.

7. GROUNDWATER

Based on information from exploratory borings performed at the site (as a part of our site-specific geotechnical evaluation), the depth to groundwater ranges between 9.5 and 19 feet below the ground surface (bgs). This relatively shallow groundwater condition is due to perching on top of the underlying low permeability bedrock. The Laramie Fox Hills aquifer is the principal source of groundwater in the site vicinity for irrigation, accounting for the majority of groundwater for large capacity wells. The static groundwater table associated with the aquifer is expected to be at a depth greater than 50 feet bgs. Recharge to the aquifers occurs by infiltration of applied irrigation water and infiltration of precipitation.

Seasonal fluctuations in groundwater levels and surface water flow may occur. These fluctuations may be due to variations in ground surface topography, subsurface geologic conditions, rainfall, irrigation, and other factors. Evaluation of factors associated with groundwater fluctuations was beyond the scope of this study.

8. POTENTIAL GEOLOGIC HAZARDS

Ninyo & Moore's geotechnical study included an evaluation of the possible presence of geologic hazards, such as faults, landslides, and abandoned mine workings in the area of the site. This

evaluation included visual observation of the site for indications of adverse geologic features and review of published geologic maps and literature, and other data listed in the *References* section of this report. Referenced geologic data were also reviewed to evaluate seismic activity levels, and associated potential earthquake hazards, for faults in the vicinity of the site.

8.1. Faulting and Seismicity

Based on our field observations and our review of readily available published geological maps and literature, there are no known active faults underlying or adjacent to the subject site. A number of older faults are mapped in the site vicinity as concealed or inferred beneath the overlying Eolian Deposits or as faults within the Laramie Formation (Colton, 1978). The closest Quaternary-age fault to the site is the Golden Fault, which lies approximately 20 miles to the south-northwest (USGS & CGS, 2013). The fault is considered to be late Quaternary in age and has not shown displacement in Holocene time. Therefore, the probability of damage at the site from seismically induced ground surface rupture along faults is considered to be low.

Historically, several minor earthquakes have been recorded near the Weld County area. Using the referenced United States Geological Survey (USGS) seismic web application (USGS, 2012), estimated maximum considered earthquake spectral response accelerations for short (0.2 second) and long (1.0 second) periods were obtained for the project site. Based on the findings of our subsurface exploration program and the International Building Code developed by the International Code Council (ICC, 2012), a site specific Seismic Site Class D is appropriate for the project site. The parameters in the following table are characteristic of the project site for design purposes.

Table 1 – 2009 International Building Code Seismic Design Criteria

Seismic Design Factors	Value
Site Class	D
Site Coefficient, F_a	1.6
Site Coefficient, F_v	2.4
Mapped Spectral Acceleration at 0.2-second Period, S_s	0.178 g
Mapped Spectral Acceleration at 1.0-second Period, S_1	0.057 g
Spectral Acceleration at 0.2-second Period Adjusted for Site Class, S_{MS}	0.285 g
Spectral Acceleration at 1.0-second Period Adjusted for Site Class, S_{M1}	0.138 g
Design Spectral Response Acceleration at 0.2-second Period, S_{DS}	0.190 g
Design Spectral Response Acceleration at 1.0-second Period, S_{D1}	0.092 g

Horizontal peak ground accelerations for the site were calculated from the 2008 Probabilistic Seismic Hazard Assessment prepared by the USGS National Seismic Hazard Mapping Project (USGS, 2008). The horizontal peak ground accelerations for the site that have a 10, 5, and 2 percent probability of being exceeded in 50 years are 0.03g, 0.049g, and 0.091g, respectively. These ground motion values were calculated for "rock" sites, which correspond to a shear-wave velocity of approximately 2,500 feet per second in approximately the top 30 feet bgs. Different soil or rock conditions may amplify or de-amplify these values.

8.2. Liquefaction

Liquefaction is a phenomenon in which loose, saturated soils lose shear strength under short-term (dynamic) loading conditions. Ground shaking of sufficient duration results in the loss of grain-to-grain contact in potentially liquefiable soils due to a rapid increase in pore water pressure, causing the soil to behave as a fluid for a short period of time.

To be potentially liquefiable, a soil is typically cohesionless with a grain-size distribution generally consisting of sand and silt. It is generally loose to medium dense and has a relatively high moisture content, which is typical near or below groundwater level. The potential for liquefaction decreases with increasing clay and gravel content, but increases as the ground acceleration and duration of shaking increase. Potentially liquefiable soils need to be

subjected to sufficient magnitude and duration of ground shaking for liquefaction to occur. Based on the low expected site seismicity and dense nature of the underlying site soils, the potential for hazards due to liquefaction is considered negligible.

8.3. Mine Subsidence Hazards

The Boulder-Weld Coal Field in the Erie, Colorado area has experienced numerous instances of damage to structures and infrastructure related to mine subsidence from abandoned mine workings. The Erie, Colorado area experienced a heavy period of mining, both surface and subsurface, from the 1800's through the late 1970's. We have reviewed numerous background documents (see the *References* section of this report) related to previous mining activity and subsidence-related hazards. Review of referenced topographical maps and published maps depicting areas of coal extraction and mine subsidence hazards indicate past mining activities to the north and west this project site. The location of the site relative to mapped coalmine subsidence hazards is presented on Figure 3.

No evidence of abandoned mine working was observed underlying the proposed improvement areas. We have evaluated the potential for subsidence hazards due to possible collapse of the subterranean mine workings in the site vicinity and it is our opinion that the likelihood of subsidence related hazards to the proposed improvements is negligible.

8.3.1. Eagle Mine

The area north of the subject site was the location of the Eagle Mine, which was mined from the 1930's to the late 1970's. The Eagle Mine was a subterranean coalmine that extracted coal from relatively flat-lying coal seams within the Laramie Formation. Based on our review of information from the Colorado Mine Subsidence Information Center (2013) and Roberts et al. (2001), the depth of the coalmine workings was greater than 400 feet below the ground surface. The nearest subterranean mine workings of the Eagle Mine are approximately 1,000 feet north of the project site. Therefore, the subsi-

dence hazard risk from the collapse of subterranean voids related to mining of the Eagle Mine is considered negligible.

8.3.2. Columbine Mine

The area west of the subject site was the location of the Columbine Mine, which was mined from the 1920's to the mid 1940's. The Columbine Mine was a subterranean coalmine that extracted coal from relatively flat-lying coal seams within the Laramie Formation. Based on our review of information from the Colorado Mine Subsidence Information Center (2013) and Roberts et al. (2001), the depth of the coalmine workings ranged between approximately 150 and 300 feet below the ground surface. The nearest subterranean mine workings of the Columbine Mine are approximately 2,400 feet west of the project site. Therefore, the subsidence hazard risk from the collapse of subterranean voids related to mining of the Columbine Mine is considered negligible.

8.4. Compressible/Collapsible Soils

Compressible soils are generally comprised of soils that undergo consolidation when exposed to new loadings, such as fill or foundation loads. Soil collapse (or hydro-collapse) is a phenomenon where the soils undergo a significant decrease in volume upon an increase in moisture content, with or without an increase in external loads. Buildings, structures, and other improvements may be subject to excessive settlement-related distress when compressible soils or collapsible soils are present. Based on our review of published geologic maps of the site, we understand that the site is underlain by Eolian Deposits, composed of loess deposits and dune deposits, which are known to be subject to settlement from compressible or collapsible soils. The risk of settlement due to compressible or collapsible soils should be evaluated during site-specific, design-level geotechnical evaluations.

8.5. Expansive Soils

One of the more significant geologic hazards in the Front Range area is the presence of swelling clays in bedrock or surficial deposits. Wetting and drying of bedrock or surficial

deposits containing swelling clays can result in expansion and collapse of those units, which can cause major damage to structures. A review of a Colorado Geological Survey map delineating areas based on their relative potential for swelling in the site vicinity by Hart (1973-4) indicates that the soil and bedrock materials in the site vicinity have "High" swell potential. Based on our review of published geologic maps of the site, we understand that the site may be underlain by potentially expansive soils and bedrock. The risk of ground movement and subsequent damage to the proposed improvements due to expansive soils and bedrock should be evaluated during site-specific, design-level geotechnical evaluations.

8.6. Other Geologic Hazards

Ground fissures, generally believed to be caused by erosion and differential stress resulting from regional subsidence due primarily to withdrawal of groundwater, are known to occur in Colorado. Review of referenced geologic data does not indicate the presence of ground fissures at the project site and no ground fissures were observed during our field activities. The potential for hazards from ground fissures is considered negligible at the site.

The site is nearly level. No steep slopes exist that may cause a hazard to development. Landslide, rockfall, slope instability, mud flow, or debris fan hazards were not observed. The potential for hazards from unstable slopes is considered negligible at the site.

The site is not within a 100-year flood zone and it is not located in the flood plain of any river or stream. Therefore, the potential for river or stream flooding is considered negligible. Detailed flood zone evaluation should be performed by the project Civil Engineer.

9. PRELIMINARY CONCLUSIONS

Based on our preliminary field observations, review of referenced geology and abandoned coalmine subsidence data, it is our opinion that there are no known geotechnical or geologic conditions that would preclude development of The Hub Facility project at the proposed site, provided a future design-level geotechnical evaluation is performed. The conclusions provided in

this report should be considered preliminary and are intended for planning purposes. Once grades are established and structural loads are available, a design-level geotechnical evaluation, including subsurface evaluation and laboratory testing, will need to be performed for the project. Preliminary findings of this geologic hazard evaluation include the following:

- The subject site is considered suitable for the construction of The Hub Facility project, from a geotechnical perspective.

- Geologic hazards such as on-site faults, liquefaction, ground fissures, flood-prone areas, landslides or unstable slope hazards were not observed during our site reconnaissance and were not indicated in the referenced publications.

- The subject site is mapped in an area of low risk for mine subsidence. No evidence of abandoned mine workings was observed at the site and no subterranean mine workings are indicated beneath the site, based on our review of available documents.

- The site is mapped as being underlain by Eolian Deposits, underlain by bedrock of the Laramie Formation. The Eolian Deposits consist of wind-blown loess and dune deposits, composed of silt, clay, and sand. The Laramie Formation is expected to consist of gray claystone, shale, sandy shale, and lenticular beds of sandstone and lignite.

- Some of the near-surface Eolian Deposits are potentially moisture-sensitive and may be prone to settlement from compressible or collapsible soil conditions. These soils will likely not be suitable for support of structures and improvements in their existing condition. Shallow foundations, slabs-on-grade, exterior concrete flatwork, pavement sections, and other improvements will likely need to be founded on a zone of adequately placed and compacted engineered fill. The depth, lateral extent, and compaction levels will need to be specified in a design-level geotechnical evaluation.

- The site is mapped in an area of "High" risk of hazards from expansive soil and bedrock. The expansion potential of the soil should be evaluated and geotechnical recommendations for the mitigation of expansive soil and bedrock conditions should be provided in a design-level geotechnical evaluation.

- Adequate surface drainage should be provided to reduce ponding and infiltration of water into the subsurface soils. Surface runoff from surrounding areas should be intercepted, collected, and not permitted to flow or infiltrate into subsurface soils. Consideration should be given to utilization of swales, edge drains, building roof drains, tightlined downspouts, curbs and gutters, or combination of these drainage devices, to reduce the adverse effects of surface water runoff.

- Although chemical tests have not been performed, the native on-site soils may be potentially deleterious to concrete and corrosive to metal, based on the current use as agricultural land. Soil blending or replacement, and/or utilization of materials that are resistant to corrosion should be anticipated for the project.

- Information from exploratory borings at the site indicates a perched groundwater table beneath site ranging between 9.5 and 19 feet bgs. Static aquifer groundwater levels measured previously in wells in the site vicinity indicate that the aquifer groundwater table may be on the order of 50 or more feet below the existing ground surface.

- The preliminary seismic site classification was assumed to be Site Class "D".
- Ground elevations at the proposed site range from approximately 5,225 to 5,192 feet above mean sea level (MSL). An appropriate frost depth will need to be established for the design of site structures.

10. LIMITATIONS

The field evaluation and geotechnical analyses presented in this report have been conducted in general accordance with current practice and the standard of care exercised by geotechnical consultants performing similar tasks in the project area. No warranty, expressed or implied, is made regarding the conclusions, recommendations, and opinions presented in this report. There is no evaluation detailed enough to reveal every subsurface condition. Variations may exist and conditions not observed or described in this report may be encountered during the design geotechnical evaluation and/or construction. Uncertainties relative to subsurface conditions can be reduced through additional subsurface exploration. Please also note that our evaluation was limited to preliminary assessment of the geologic hazards in the project vicinity, and did not include performance of a design-level geotechnical evaluation or evaluation of structural issues, environmental concerns, or the presence of hazardous materials.

This document is intended to be used only in its entirety. No portion of the document, by itself, is designed to completely represent any aspect of the project described herein. Ninyo & Moore should be contacted if the reader requires additional information or has questions regarding the content, interpretations presented, or completeness of this document.

This report is intended for preliminary evaluation purposes only. It does not provide sufficient data for design purposes.

This report is intended exclusively for use by the client. Any use or reuse of the findings, conclusions, and/or recommendations of this report by parties other than the client is undertaken at said parties' sole risk.

11. REFERENCES

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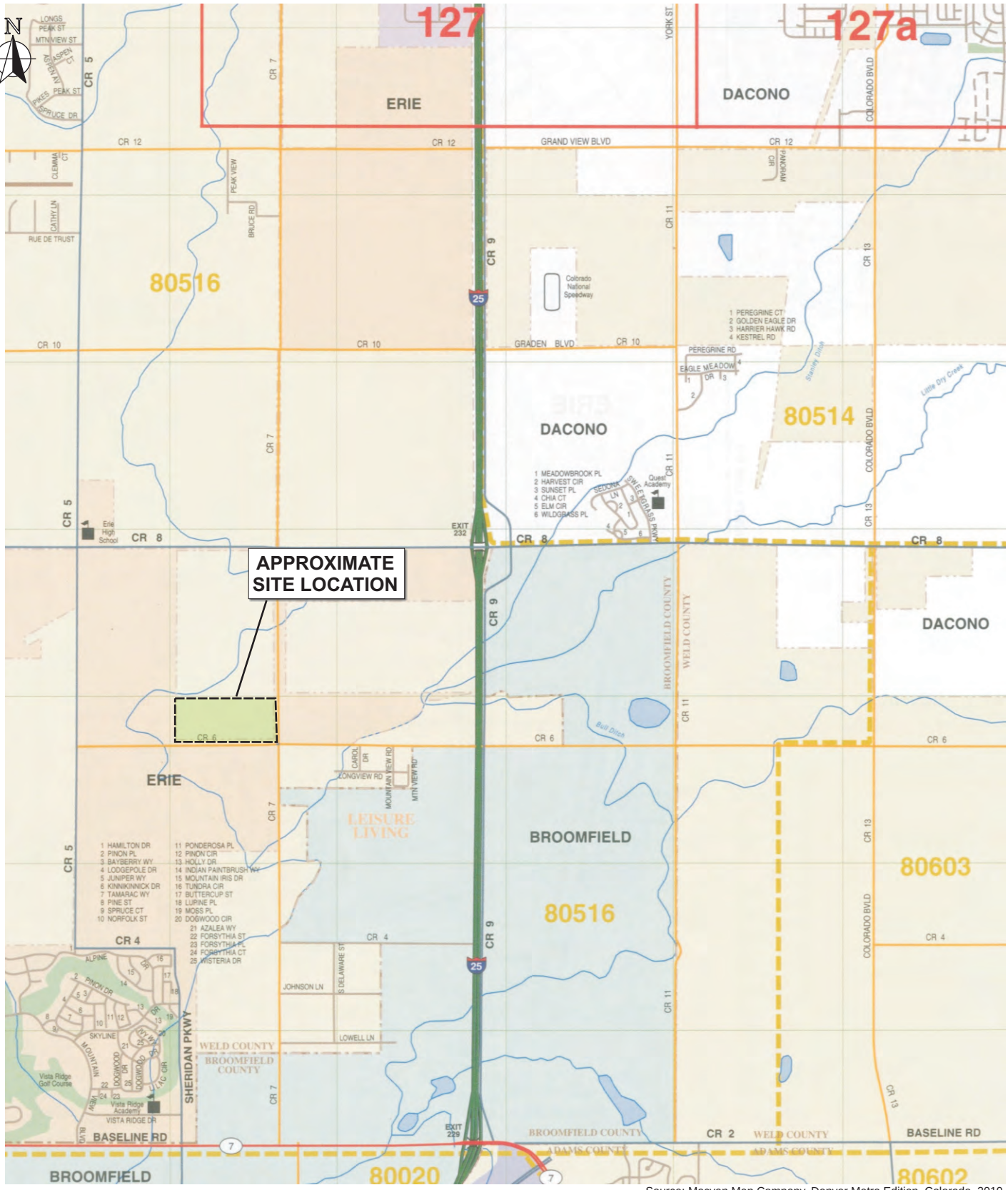
Widman, B.L., Kirkham, R.M., and Rogers, W.P., 1998, Preliminary Quaternary Fault and Fold Map and Database of Colorado: Colorado Geological Survey Open-File Report 98-08, 331 p.

Aerial Photograph References

Source	Dates
Google Earth	June 26, 1993, October 3, 1999; March 30, 2008; July 24, 2010; October 27, 2011; and October 7, 2012.



Note: Dimensions, directions, and locations are approximate.

Ninyo & Moore		SITE LOCATION	FIGURE 1
PROJECT NO: 500707001	DATE: 9/13	THE HUB FACILITY ERIE, COLORADO	

file no: 0707vmap0913

N

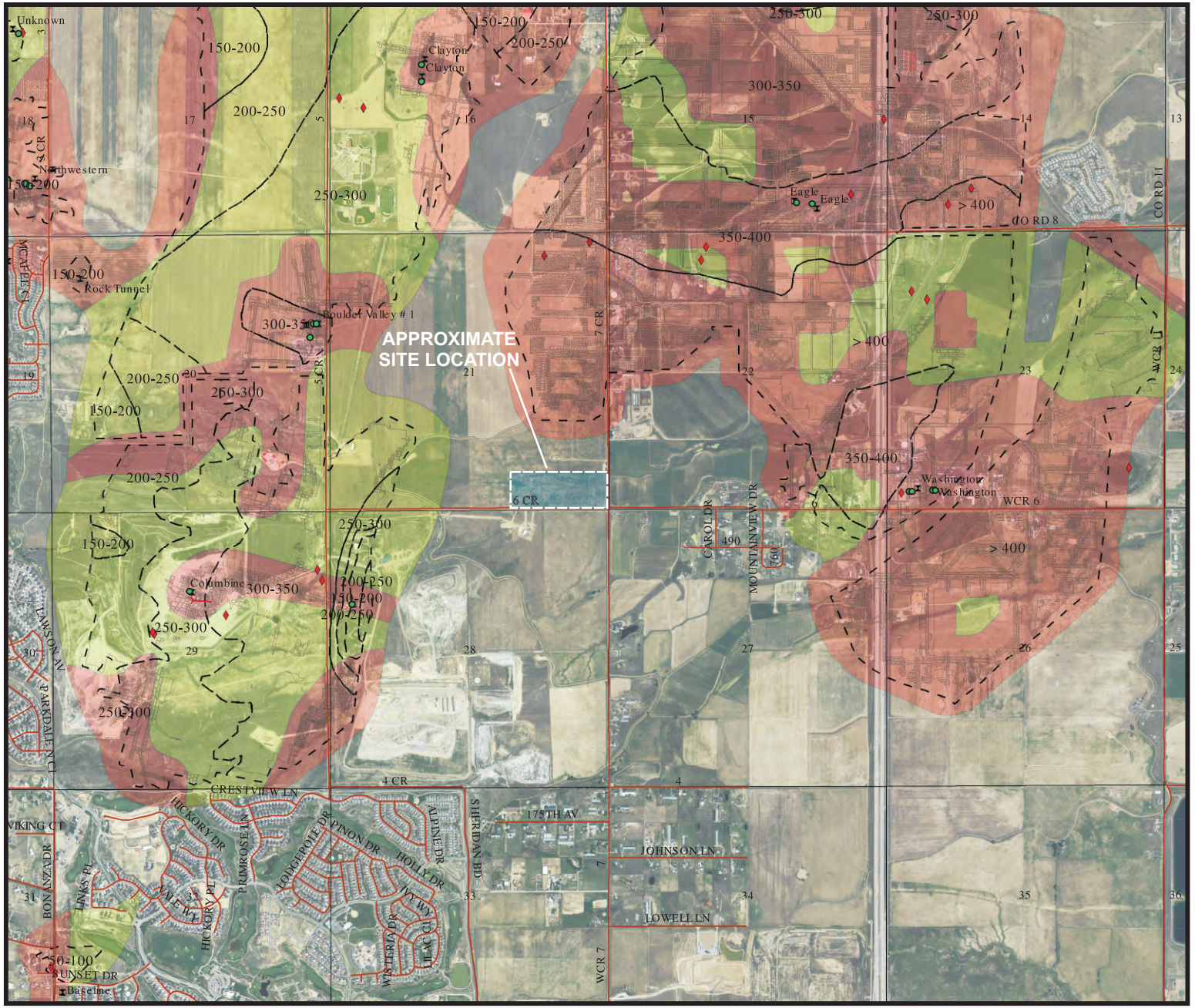
0 1 mile

Approximate Scale:
1 inch = 1 mile

Source: Geologic map of the Boulders, Fort Collins and Greeley area, Roger B. Colton, 1978.
Note: Dimensions, directions, and locations are approximate.

Ninyo & Moore		GEOLOGIC MAP	FIGURE 2
PROJECT NO: 500707001	DATE: 9/13	THE HUB FACILITY ERIE, COLORADO	

file no: 0707geo0913b



Legend

- Boundary Weld 1989 mine workings
- Subsidence Events Coal
- Depth to Mining, feet (USGS I-2735)

Subsidence Hazard (EG-09)

Hazard Rating

- SEVERE
- MODERATE
- LOW
- Coal Mine Shafts

N

0 2,000 4,000

Source: Mine Subsidene Information Center, Weld County Map of Historic Coal Mine Workings, NW corner of WCR 6 & WCR 7.
Note: Dimensions, directions, and locations are approximate.

file no: 0707haz0913

Ninyo & Moore	SUBSIDENCE HAZARD MAP	FIGURE
PROJECT NO: 500707001 / DATE: 9/13	THE HUB FACILITY ERIE, COLORADO	3