U.S. Department of Energy
2597 B ¾ Road
Grand Junction, CO 81503

March 10, 2006

WM - 110

Mr. Myron Fliegel
U. S. Nuclear Regulatory Commission
Mail Stop T7J8
Two White Flint North
11545 Rockville Pike
Rockville, MD 20852-2747

Subject: Transmittal of Calculation Sets, Attachment 2 Geology Report, Remedial Action Plan, Moab Uranium Mill Tailings Remedial Action (UMTRA) Project

Dear Mr. Fliegel:

Enclosed are three sets of the following calculation sets for the Moab UMTRA Project Remedial Action Plan (RAP):

1. Site and Regional Geology – Results of Literature Research
2. Geologic and Geophysical Properties – Surficial and Bedrock Geology of the Crescent Junction Disposal Site
3. Site and Regional Geomorphology – Results of Literature Research
4. Site and Regional Geomorphology – Results of Site Investigations
5. Site and Regional Seismicity – Results of Literature Research
6. Site and Regional Seismicity – Results of Maximum Credible Earthquake Estimation and Peak Horizontal Acceleration
7. Photogeologic Interpretation

At our planned April 4 and 5, 2006 meetings at your offices, DOE will present summary information covering each of the calculation sets listed above. Additionally, DOE will present approach and progress to date on the development of RAP Attachment 1, Disposal Cell Design and Attachment 3, Ground Water Hydrology.

If you have any questions, please call me at (970) 248-7612 or Joel Berwick of my staff at (970) 248 – 6020.

Sincerely,

Donald R. Metzler
Moab Federal Project Director

cc w/enclosure:
Project File MOA 2.12 (R. Burrows)

cc w/o enclosure:
J. Berwick, DOE (e)
K. Karp, Stoller (e)

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Office of Environmental Management – Grand Junction

MOAB UTAH

UMTRA Project

Remedial Action Plan and Site Design for Stabilization of Moab Title I Uranium Mill Tailings at the Crescent Junction, Utah, Disposal Site

Attachment 2: Geology

U.S. Department of Energy

Office of Environmental Management

Work Performed Under DOE Contract No. DE-AC01-02GJ79491
for the U.S. Department of Energy Office of Environmental Management.

Contents

U.S. Department of Energy—Grand Junction, Colorado

Calculation Cover Sheet

Calc. No.: MOA-02-08-2005-1-05-00 **Discipline:** Geologic and Geophysical Properties **No. of Sheets:** 7

Project: Moab Project

Site: Crescent Junction Disposal Site

Feature: Site and Regional Geology – Results of Literature Research

Sources of Data:

Published reports and maps – see list of references at end of calculation set.

Sources of Formulae and References:

See list of references at end of calculation set.

Preliminary Calc. ☐ **Final Calc.** ☐ **Supersedes Calc. No.**

Author: [signature] for CSG 8-30-05
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Problem Statement:

Determination of the suitability of the Crescent Junction disposal site as the repository for the Moab uranium mill tailings material, and development of the site and regional geology sections of the Remedial Action Plan (RAP) require a thorough review of available literature that applies to the Crescent Junction site. The compiled list of references is presented at the end of this calculation set and relevant information is summarized below.

This calculation will be incorporated into Attachment 2 (Geology) of the Remedial Action Plan (RAP) and Site Design for Stabilization of Moab Title I Uranium Mill Tailings at the Crescent Junction, Utah, Disposal Site, and summarized in the appropriate sections of the Remedial Action Selection (RAS) report for the Moab site.

Method of Solution:

Literature sources were identified using a combination of published reports and maps that were developed during the Crescent Junction site-selection process, on-line (internet-based) resources, and relevant literature citations from the other UMTRCA sites.

Assumptions:

It is assumed that the literature sources are reliable and representative of the current understanding of the geology of the region.

Calculation:

None required.

Discussion:

A general summary of geologic conditions based on the literature research is provided in this calculation set. This summary is preliminary and will be expanded as a result of future, detailed geologic studies. Additional information will be presented in the RAP.

Physiographic Setting

Crescent Junction is located approximately 19 miles east of the town of Green River, Utah, and approximately 30 miles north of Moab, Utah (Figure 1). The physiographic location of the Crescent Junction disposal site is on a broad, nearly level, plain at the base of the Book Cliffs. The elevation of Crescent Flat ranges from approximately 4,900 feet above mean sea level (ft amsl) at the southwest corner of the withdrawn area to approximately 5,120, ft amsl at the northeast corner of the withdrawn area. Crescent Flat is bounded to the north by the steep slopes of the Book Cliffs whose elevation rises to approximately 5,900 ft amsl.

General Geology

The Crescent Junction disposal site is on the Crescent Junction 7.5-minute topographic quadrangle in Section 27, T21S, R9E, approximately 1 mile north-northeast of Crescent Junction, Utah. Geologic maps for the area include the Salt Valley area geologic map (Woodward-Clyde Consultants 1984) at a scale of 1:62,500, and the Moab and eastern part of the San Rafael Desert 30' x 60' quadrangles at a scale of 1:100,000 (Doelling 2001 and 2002). Larger scale 1:24,000 geologic maps are available for 7.5-minute quadrangles Hatch Mesa (Chitwood 1994) and Valley City (Doelling 1997), west and south, respectively, of the Crescent Junction quadrangle.

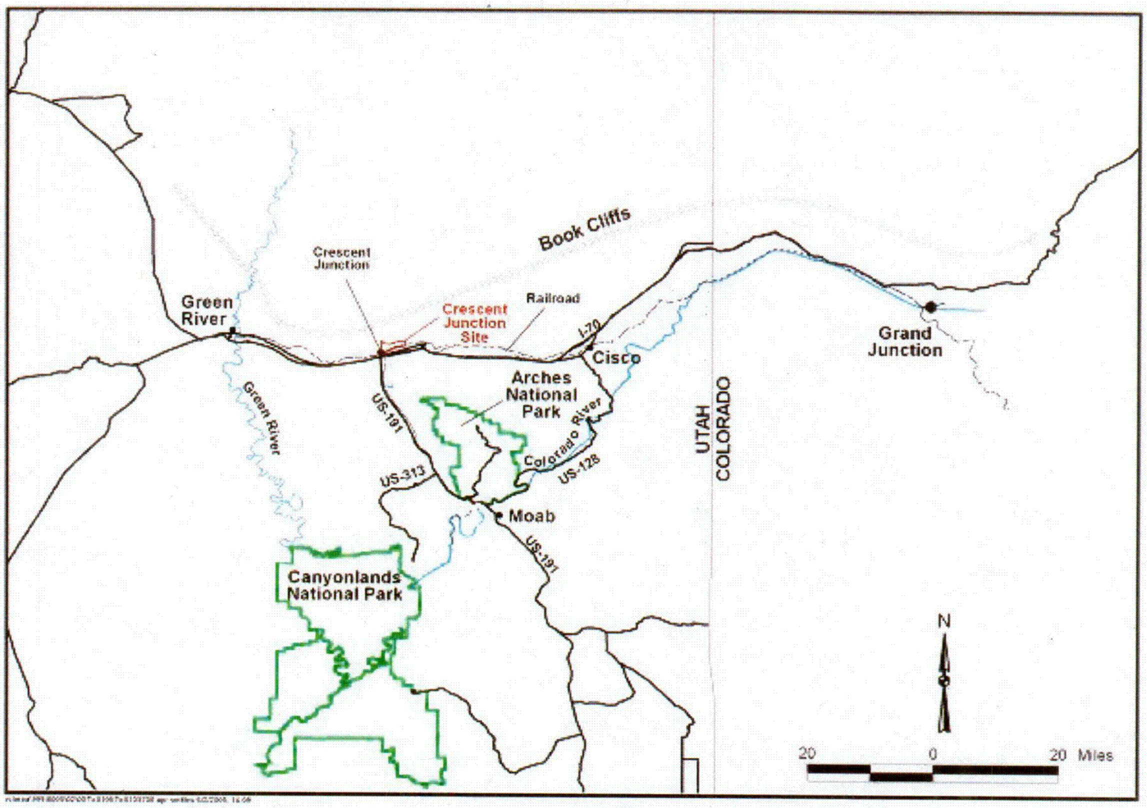

Figure 1. Site Location map for the Crescent Junction Site

Stratigraphic Setting

A general geologic map of the Crescent Junction site is presented in Figure 2. Bedrock exposed in several places at the Crescent Junction site is the Mancos Shale of Late Cretaceous age. Most of the Mancos Shale was deposited in an open marine environment of the Late Cretaceous western interior seaway. The upper part of the Mancos Shale underlies the site and is approximately 3,000 ft thick in this area. Approximately 1,000 ft of the upper part of the formation have been removed by erosion. Mancos Shale exposed in the site area is best described as a thickly bedded, calcareous mudstone (Chitwood 1994), with thinly-bedded siltstone, fine-grained sandstone, and bentonite interbeds widely spaced within the mudstone. The Ferron Sandstone Member of the Mancos Shale is approximately 60 ft thick and occurs in the lower 300 to 350 ft of the Mancos Shale. This member contains two sandstone beds with fine- to medium-gained sand. Below the Ferron Sandstone Member is the lowermost member of the Mancos Shale, the Tununk Shale Member.

The Dakota Sandstone of Early Cretaceous age underlies the Mancos Shale and consists of sandstone, conglomeratic sandstone, and shale. This formation is less than 100 ft thick in the site area and is likely the shallowest bedrock unit containing ground water. The Cedar Mountain Formation, also of Early Cretaceous age, underlies the Dakota Sandstone and consists of several sandstone and conglomeratic sandstone beds interbedded with thickly-bedded mudstone. Ground water is also present in the sandstone and conglomeratic sandstone beds of the Cedar Mountain Formation. Ground water in the Dakota Sandstone and Cedar Mountain Formation may be under slight artesian head from recharge to the north along the north edge of the Uinta Basin.

Exposures of the Mancos Shale bedrock are covered over much of the site by alluvial mud of Quaternary age (Doelling 2001). This unconsolidated gray material, less than 20 ft thick, fills swales in the Mancos Shale and consists of silt, clay, sand, and minor fragments of sandstone. Along the west side of the site area, Quaternary stream alluvium up to 20 ft thick from Crescent Wash covers Mancos Shale (Doelling 2001). This material consists of sand, silt, clay, pebbles, and sparse cobbles derived from the Book Cliffs, some 10 miles to the north.

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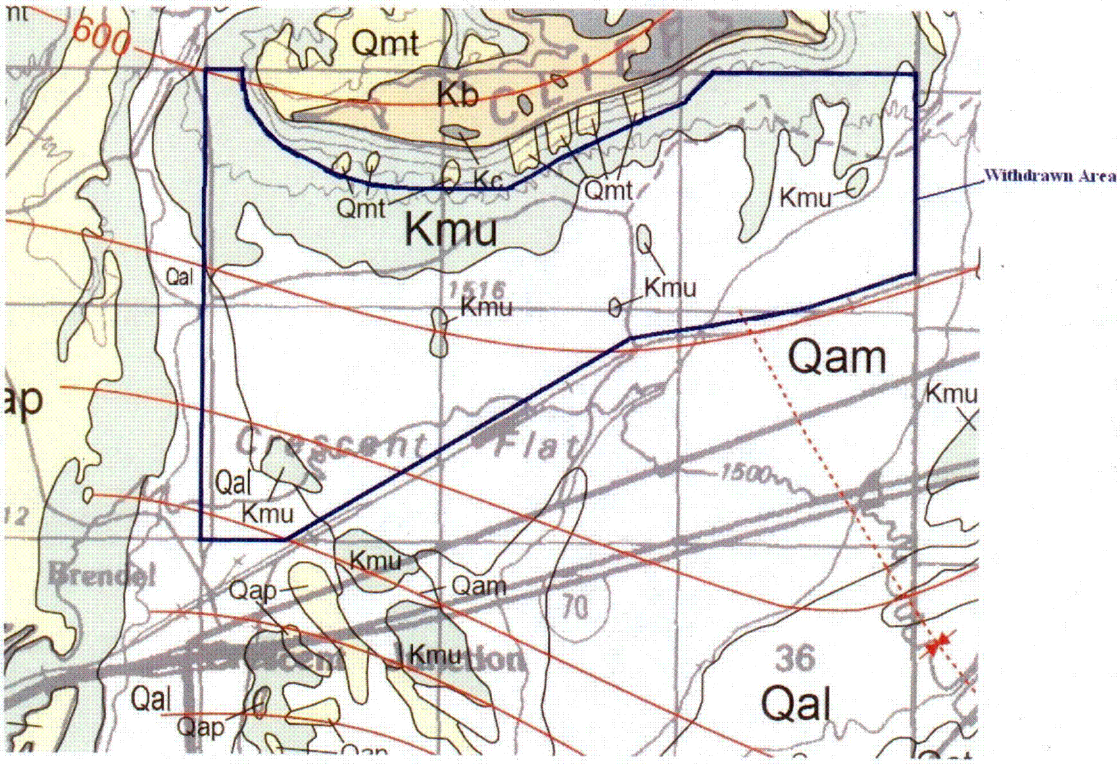

EXPLANATION OF GEOLOGIC UNITS

Quaternary Deposits

Qal	Stream alluvium -- Sand, silt, clay, granules, pebbles, and sparse cobbles
Qam	Alluvial mud -- Light- to medium-gray silt, clay, sand, and minor fragments of sandstone, mostly derived from members of the Cretaceous Mancos Shale
Qap	Pediment-mantle deposits -- Poorly to moderately sorted, rounded to angular boulders, cobbles, pebbles, granules, sand, silt, and clay.
Qmt	Talus and colluvium -- Rock-fall blocks, boulders, smaller angular gravel, sand, and silt

Cretaceous Rocks

Kc	Castlegate Sandstone -- Pale yellow-orange and light-gray, cross-bedded sandstone interbedded with minor mudstone, carbonaceous shale, and coal.
Kb	Blackhawk Formation -- Pale yellow-orange to light-brown sandstone interbedded with mudstone, carbonaceous shale, and coal.
Kmu, Kms	Upper shale (Blue Gate) member of Mancos Shale -- Mostly light-to dark- gray, marine, thinly laminated to thinly bedded, slope-forming shale, mudstone, and siltstone interbedded with calcareous sandstone.

Figure 2. Geologic Map of the Crescent Junction Site (Modified after Doelling 2001 and 2002)

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Structural Setting

The Crescent Junction disposal site is located in the southern edge of the Uinta Basin and overlies the northwestern part of the ancestral Paradox Basin (in the Paradox fold and fault belt). The Book Cliffs, less than 1 mile north of the site, are the erosional escarpment on the south flank of the Uinta Basin. Mancos Shale bedrock at the site dips gently (less than 10 degrees) to the north-northeast toward the axis of the subtle, northwest-trending Whipsaw Flat Syncline. Northwest-striking normal faults defining a graben of the northwest extension of the Salt Valley salt-cored anticline are approximately 1 to 2 miles to the southwest of the site. These faults are not exposed at the surface, but reportedly have as much as 1,000 ft of displacement (Fisher 1936) as determined by oil test wells drilled in the area in the 1920s and 1930s.

A northeast-striking normal fault extends into the southwest quarter of Section 27 in the site area. This fault was mapped in 1924 as part of oil exploration in the Crescent area (Harrison 1927, Figure 9). Fisher (1936) described the fault as a "minor dip fault with 100 ft of downthrow on the south". It is unlikely that this fault has a surface expression—it is not shown on geologic maps by Woodward-Clyde Consultants (1984) or Doelling (2001). Fisher (1936) noted that an oil test well (McCarthy No. 1) was being drilled in the NW 1/4 of Section 34 by Western States Development Company. Drilling had started in December 1924 and after several shut downs, the well was at a depth of 2,200 ft in March 1930. Later maps and references (Dane 1935 and Baker and others 1954) refer to this well as being drilled by the Crescent Oil Syndicate and show its location in the extreme southwest corner of Section 27. A possible log of this well was found on the Utah State Water Resources Well–Log Search webpage; a follow–on telephone conversation with the Oil and Gas Division revealed that this well is given the API reference No. 4301911525. The mapping of the minor fault seems to predate the drilling of the Crescent Oil Syndicate (McCarthy No. 1) well; therefore, it is unclear what subsurface evidence was used to justify the existence of the fault. Surface field work and an additional search for well data in the area will be undertaken to confirm or deny the existence of the fault. No other lineaments or geologic structures were noted by Friedman and Simpson (1980) in the site area during mapping of the northern Paradox Basin.

Resource Development

No significant oil and gas resources are known in the Cretaceous Rocks in the site area. The Crescent Oil Syndicate well described above encountered a natural gas pocket that "blew rocks over the top of the mast"; however, this appears to have been a shallow, isolated show. The nearest known petroleum accumulation is in the Morrison Formation of Jurassic age in the small and abandoned Crescent Junction field approximately 3 miles south-southwest of the site in the extension of the Salt Valley structure. Exploratory drilling for natural gas was completed recently at one location (MSC 26-1) just south of the withdrawn area ((API No. 43-019-31407-00-00) (http://utstnrogmsql3.state.ut.us/UtahRBDMSWeb/well_data_lookup.cfm)). Data concerning the targeted gas horizons and the actual results of this exploration are not currently available.

Potash resources are known in the Paradox Formation of Pennsylvanian age in the northwest extension of the Salt Valley structure approximately 3 miles south of the site. The site area, however, is northeast of the Salt Valley salt-cored anticline and thick saline deposits are not present.

Uranium and vanadium deposits are known in scattered locations in the region in the Morrison Formation of Jurassic age and the Chinle Formation of Triassic age. At the site, these formations are 3,000 to 4,000 ft below the surface, making exploration for such deposits very uneconomical. Copper and silver mineralization also is known to occur in a few locations in the region in fault-related deposits in the Morrison Formation (Woodward-Clyde Consultants 1984). Exploration for such deposits in the site area also would be uneconomical because of their great depth. Coal resources occur in the Book Cliffs several miles north of the site, but they are in stratigraphically younger rocks (Mesaverde Group of Late Cretaceous age) than are present at the site.

Black shales, such as the Mancos Shale, are naturally enriched to above background concentrations in metals such as uranium, copper, silver, vanadium, mercury, arsenic, and gold. These metals likely originated in volcanic ash material (since altered to bentonite) that was deposited during deposition of the

Mancos Shale. In a study by Marlatt (1991), sampling of Mancos Shale generally in the area between Salt Valley and the Book Cliffs found that gold content ranged from 30 to 100 parts per billion (ppb). These values are about ten times the background levels, but are much too low for economic extraction.

No sand and gravel deposits are present in the site area. Potential deposits of such material are present just south of the site in Section 34 and west of Crescent Wash approximately 0.5 mile west of the site (McDonald 1999). This material occurs as pediment-mantle deposits that cover Mancos Shale bedrock surfaces.

Geologic Hazards

Swelling clay (montmorillonite) in the Mancos Shale underlying the site area creates a potential geologic hazard (Mulvey 1992). Change in water content will cause shrinking and swelling leading to subsidence or heave of concrete slab structures, as evidenced by the constant maintenance required for Interstate Highway 70 crossing Mancos Shale just south of the site.

The site area has a moderate to high radon-hazard potential for occurrence of indoor radon based on the geologic factors of uranium concentration, soil permeability, and ground water depth (Black 1993). The moderate to high rating is created by the relatively high concentration of uranium in the Mancos Shale, the relatively high soil permeability caused by shrinking and swelling of the Mancos Shale-derived soil, and the relatively deep groundwater depths (shallow ground water retards radon migration).

Conclusion and Recommendations:

Based on preliminary evaluation of the results of the literature research effort, the Crescent Junction site appears to be suitable for disposal of the Moab uranium mill tailings and contaminated material. Potential geologic hazards appear to be limited to the presence of swelling clays. Although numerous geologic faults occur in the area, none appear to have a surface expression, suggesting any significant offset of the faults occurred prior to Quaternary deposition. Also, use of the area as a disposal site will not impede any potential mineral development. Additional information will be collected and reported in the RAP.

Computer Source:

Not applicable.

References:

Baker, A.A., Dane, C.H., and McKnight, E.T., 1954. *Preliminary Map Showing Geologic Structure of Parts of Grand and San Juan Counties*, Utah: U.S. Geological Survey Oil and Gas Investigations Map OM–169, scale 1:125,000.

Black, B.D., 1993. *The Radon-Hazard-Potential Map of Utah*: Utah Geological Survey Map 149, 12 p., scale 1:1,000,000.

Chitwood, J.P., 1994. *Provisional Geologic Map of the Hatch Mesa Quadrangle*, Grand County, Utah: Utah Geological Survey Map 152, 16 p., scale 1:24,000.

Dane, C.H., 1935. *Geology of the Salt Valley Anticline and Adjacent Areas, Grand County, Utah*: U.S. Geological Survey Bulletin 863, 184 p., scale 1:62,500.

Doelling, H.H., 1997. *Interim Geologic Map of the Valley City Quadrangle, Grand County, Utah*: Utah Geological Survey Open-File Report 351, 55 p., scale 1:24,000.

Doelling, H.H., 2001. *Geologic Map of the Moab and Eastern Part of the San Rafael Desert 30'x60' Quadrangles, Grand and Emery Counties, Utah, and Mesa County, Colorado*: Utah Geological Survey Map 180, scale 1:100,000.

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Fisher, D.J., 1936. *Book Cliffs Coal Field in Emery and Grand Counties, Utah*: U.S. Geological Survey Bulletin 852, 104 p., scale 1:62,500.

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Harrison, T.S., 1927. *Colorado-Utah Salt Domes*: American Association of Petroleum Geologists Bulletin, vol. 11, no. 2, p. 111-133.

Marlatt, Gordon, 1991. *Gold Occurrence in the Cretaceous Mancos Shale, Eastern Utah*: Utah Geological and Mineral Survey Contract Report 91-5, 21 p.

McDonald, G.N., 1999. *Known and Potential Sand, Gravel, and Crushed Stone Resources in Grand County, Utah*: Utah Geological Survey Open-File Report 369, 21 p.

Mulvey, W.E., 1992. *Soil and Rock Causing Engineering Geologic Problems in Utah*: Utah Geological Survey Special Study 80, 23 p., scale 1:500,000.

Woodward-Clyde Consultants, 1984. *Geologic Characterization Report for the Paradox Basin Study Region, Utah Study Areas, Volume VI, Salt Valley*: Walnut Creek, California, unpublished Consultant's Report for Battelle Memorial Institute, Office of Nuclear Waste Isolation, ONWI-290, 190 p., scale 1:62,500.

U.S. Department of Energy—Grand Junction, Colorado

Calculation Cover Sheet

Calc. No.: MOA-02-03-2006-1-01 **Discipline: Geology** **No. of Sheets: 15**

Project: **Moab UMTRA Project**

Site: **Crescent Junction Disposal Site**

Feature:

Geologic and Geophysical Properties – Surficial and Bedrock Geology of the Crescent Junction Disposal Site

Sources of Data:

Geologic mapping of the Crescent Junction disposal site area. Geologic literature research for a 30-mile radius of the disposal site area. Lithologic logs for boreholes and test pits emplaced at the disposal site area from August to December 2005.

Sources of Formulae and References:

See list of references at end of calculation set.

Preliminary Calc. ☐ **Final Calc.** ☐ **Supersedes Calc. No.**

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Problem Statement:

Preliminary site selection performed jointly by the U.S. Department of Energy (DOE) and the Contractor has identified a 2,300 acre withdrawal area in the Crescent Flat area just northeast of Crescent Junction, Utah, as a possible site for a final disposal cell for the Moab uranium mill tailings. The proposed disposal cell would cover approximately 300 acres. Based on the preliminary site-selection process, the suitability of the Crescent Junction disposal site is being evaluated from several technical aspects, including geomorphic, geologic, hydrologic, seismic, geochemical, and geotechnical. The objective of this calculation set is to discuss the surface and bedrock geology of the site and provide the geologic map, cross sections, and bedrock contour map that were generated during the investigation.

This calculation will be incorporated into Attachment 2 (Geology) of the Remedial Action Plan (RAP) and Site Design for Stabilization of Moab Title I Uranium Mill Tailings at the Crescent Junction, Utah, Site, and summarized in the appropriate sections of the Remedial Action Selection (RAS) report for the Moab site.

Method of Solution:

Surface geologic features were identified by aerial photography and field observation mapping. A geologic map of the site area (Plate 1) was prepared that shows these features. Subsurface features of the Quaternary material and bedrock were identified from lithologic logging at test pits and from core retrieved from coreholes and geotechnical boreholes (RAP, Attachment 5). Cross sections across the site area (Plate 2) were prepared from the borehole lithologic logs that show bedrock features. A bedrock (top of weathered Mancos Shale) contour map for the site area (Plate 3) was prepared from the borehole lithologic logs and mapped surface outcrops. Review of geologic literature for the region provided the stratigraphic framework for the surface and subsurface features identified in the site area.

Assumptions:

Not applicable

Calculation:

Not applicable – see discussion of information in next section.

Discussion:

1.0 Maps of Site Area

A geologic map (Plate 1) and bedrock contour map (Plate 3) were prepared for the Crescent Junction site area, which covers about 2 square miles (mi). For this calculation, the site area is synonymous with the (geologically) mapped area.

1.1 Geologic Map

The geologic map of the site area was prepared during field work in September and October 2005. The approximately 2 square mi mapped area includes the proposed disposal cell footprint and the larger area covered by characterization boreholes (coreholes and geotechnical boreholes) and test pits. Mapping was done on a base map with a 2-foot topographic contour interval at a scale of 1:4,800 (1 inch = 400 feet [ft]). Contacts of the few and scattered bedrock outcrops of Mancos Shale of Late Cretaceous age in the area are shown on the map. At these bedrock outcrops, a Brunton compass was used to measure strike and dip of bedding and strike of vertical joints in the few places these features could be observed. Contacts between several types of unconsolidated surficial material of Quaternary age are shown on the map; these contacts are subtle and gradational and are not as evident or as sharp as the contacts between bedrock units. Descriptions of the mapped units of Quaternary age and the mapped units in the Mancos Shale are in the following subsections. Also shown on the geologic map are lines for five cross sections (Plate 2) connecting the coreholes and geotechnical boreholes included in each section.

1.2 Bedrock Contour Map

A contour map of the top of bedrock topography is shown in Plate 3 at the same scale as the geologic map. The bedrock topography shows two subtle ridges that tend north-northwest. One ridge extends through the west part of the proposed disposal cell and one is through the east-central part. Both bedrock ridges coincide with subtle surface ridges in the proposed disposal cell area. In addition, the east-central bedrock ridge appears to be a southward continuation of the surface ridge north of the 3 ponds area. Local relief of as much as 20 ft occurs on the bedrock surface, as shown in the east end of the mapped area where bedrock in test pit 0156 is 20 ft lower than exposed bedrock on a nearby ridge to the southwest. Similar occurrences of high local bedrock relief are likely present in the proposed disposal cell area. These occurrences would be evident with closer spaced boreholes with depth to bedrock data.

2.0 Surficial Geology - Quaternary Material

Unconsolidated Quaternary material covers approximately 98 percent of the mapped area. This material covers Mancos Shale bedrock and reaches a thickness of nearly 25 ft. Five types of Quaternary material were mapped – the most significant from areal and volume perspectives are alluvial-mud (mixed silt and clay) deposits. Material along active sheet wash flow paths and litter from the Book Cliffs that mantles the alluvial mud are two other mapped units that are related to the alluvial mud. The two other Quaternary units mapped are sandy alluvium and pediment-mantling litter. Both of these are in the southwest and west parts of the mapped area and represent alluvial deposits from the Crescent Wash drainage system, which has transported sandy material southward from the Book and Roan Cliffs.

2.1 Alluvial-Mud Deposits

Gray mud, silt, and clay cover most of the surface of the site area at distances of more than 0.5 mi south of the base of the Book Cliffs. This material is mostly of alluvial origin, derived from sheet wash erosion from the lower slopes of the Book Cliffs where Mancos Shale is exposed. Some of the material is residual and forms from weathering of muddy outcrops of Mancos Shale. Alluvial-mud deposits covering Mancos Shale are mapped by Doelling (2001) who described these deposits in the site area and to the south in the Valley City quadrangle (Doelling 1997).

Surface expression of the alluvial mud is mostly in the form of silt to clayey silt and was described in the field as ML, in the Unified Soil Classification System (USCS). This fine-grained material is typically light brownish gray (10YR 6/2), highly calcareous, and represents successive sheet wash deposits. Laboratory test results of this material sampled from geotechnical boreholes indicates a high clay (CL in the USCS) content.

Below the surface, most of the alluvial mud is fine grained, but discontinuous layers of coarser grained material of eolian and channel-fill origin are also present around the site area. Material of eolian origin was found in several boreholes and test pits (see lithologic logs of test pits 0151 and 0153 in RAP, Attachment 5). Eolian material is typically sandy silt (ML in the USCS), light brown (7.5YR 6/4), 1 to 3 ft thick, and at depths of 6 to 12 ft. The brown eolian material exposed in test pit 0151 is shown in Figure 1. The sporadic occurrence of this material, not in a continuous layer, indicates it was removed by erosion and reworked after its deposition – probably in a dry period during mid-Holocene time.

Coarser grained, sand to gravel and small boulder-sized, material occurs also in sporadic, discontinuous layers and lenses in the alluvium. Several of the coreholes and geotechnical boreholes around the site area penetrated gravelly sand (SW in the USCS) layers that contained shale and sandstone fragments. Some of this deeper material has been calcareously cemented. The gravelly sand material represents alluvial detritus deposited in small channels similar to the litter deposits on the surface in the north part of the site area closer to the base of the Book Cliffs. Material up to small boulder in size also is present in a few locations – notably exposed in test pit 0156. Here, small boulders up to 2 ft in diameter are present that fill an alluvial channel cut into Mancos Shale bedrock at a depth of approximately 20 ft. Mancos Shale is exposed in the bottom of test pit 0156 in Figure 2. Sandstone bedrock is exposed at the surface (Plate 1) only about 200 ft to the southwest of this coarse bouldery material. This relief of at least 20 ft on the bedrock surface in a short distance and the coarse bouldery deposits indicates the presence of a high-energy paleochannel where coarse material was transported southward from the ancestral Book Cliffs (Plate 2, cross section E-E', and Plate 3). No indication of ground water was found in this paleochannel. Other paleochannels similar to this one exposed at test pit 0156 likely occur westward across the site area.

Figure 1. View of brown eolian material exposed at a depth of 7 ft in test pit 0151.

Figure 2. Test pit 0156–Alluvial-mud deposits are approximately 20 ft thick, and Mancos Shale is at bottom of pit. White 5-gallon buckets and shovel provide scale.

Alluvial mud in the site area has been deposited over Mancos Shale bedrock in a long-term process of successive sheet wash episodes during much of Quaternary time. The thickest accumulation of alluvial mud is in subtle bedrock lows between several north-northwest trending bedrock ridges that cross the site area (Plate 3). The thickest alluvial mud accumulations of about 23 ft were found in geotechnical boreholes 0014 and 0025, just north of the west part of the proposed disposal cell. A thick accumulation is also present along the east edge of the proposed disposal cell where 22 ft of alluvial mud was found in coreholes 0208 and 0209. The average thickness of alluvial mud at the proposed disposal cell is approximately 10 to 12 ft. Alluvial mud thickness overlying the two bedrock ridges in the west and east-central parts of the proposed disposal cell is less than 10 ft. Between these ridges, the thickness is from 10 to 20 ft, and along the east side of the eastern ridge, the thickness is from 10 to 22 ft.

2.2 Material Along Active Sheet Wash Flow Paths

Several paths along which the sheet wash process is presently active are shown on the geologic map (Plate 1). These paths are visible in the high-altitude vertical aerial photos by their drab-gray color and are shown in Plate 1 of the Photogeologic Interpretation calculation set. Vegetation is generally absent from the paths, and recently-deposited gray mud covers most of the surface. Some small fragments of sandstone transported from the flanks and base of the Book Cliffs may be scattered on the surface of the paths.

The active sheet wash paths are generally in the north part of the site area within about 0.5 mi of the base of the Book Cliffs. The north ends of these paths usually merge into gullies that drain away from the base of the Book Cliffs (Plate 1). Only two paths enter or cross the proposed disposal cell area. Of these, the most prominent is the north-northwest trending path that crosses the east part of the proposed cell area. This path extends southward from the drainage just west of the three ponds area (Plate 1 and Figure 3). Material transported down this drainage is deposited to the south along the path as the gradient decreases across the proposed cell area. The path extends south-southeastward to the Union Pacific Railroad.

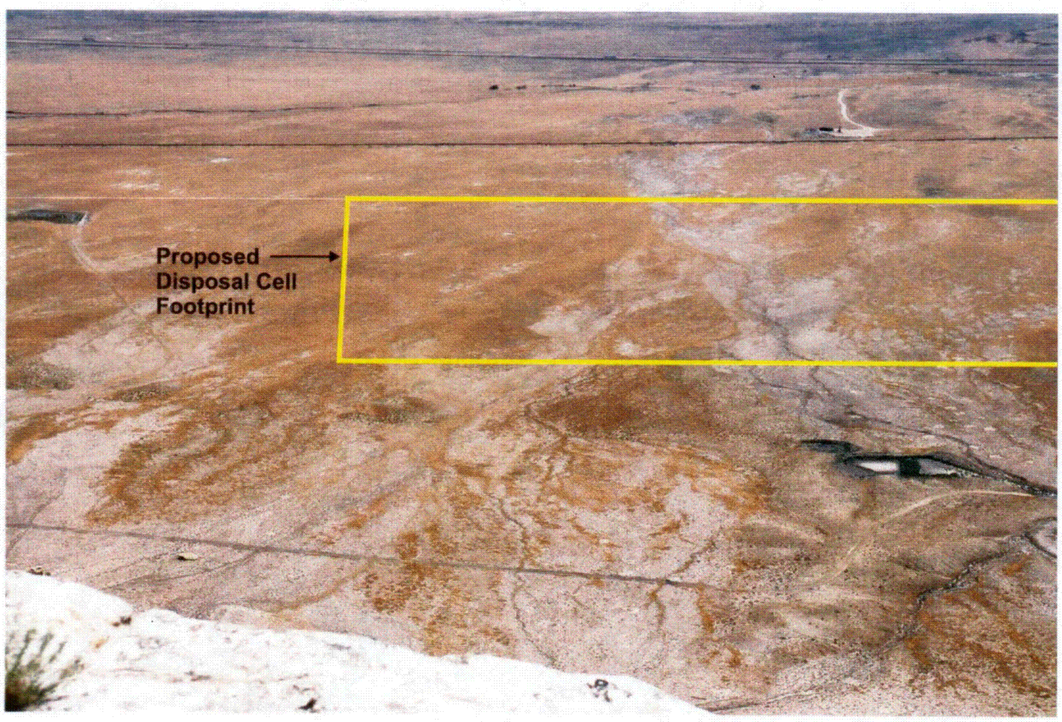

Figure 3. View south from top of Book Cliffs toward sheet wash path extending south-southeast from the three ponds across the eastern quarter of the proposed disposal cell area.

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Flows along the sheet wash paths are infrequent, but represents the main process by which alluvial mud has been slowly deposited over bedrock at the site area. One episode of active sheet wash flow was witnessed in late September 2005 during site characterization drilling. Flows occurred in several sheet wash paths (Figure 4) immediately following a high-intensity rain and hail event during which at least 0.5 inch of precipitation fell in less than one-half hour. It is estimated that events of this magnitude typically occur once per year or less.

Figure 4. View east of active sheet wash flowing over site access road just north of geotechnical borehole 0025, September 21, 2005.

2.3 Litter from Book Cliffs that Mantles Alluvial Mud and Mancos Shale

Mancos Shale and alluvial mud are increasingly covered from south to north across the mapped area by what is referred to as litter that is composed mainly of sandstone fragments ranging from one inch to as much as 3 ft in diameter. North of the mapped area and closer to the base of the Book Cliffs, sandstone boulders are as large as several tens of ft in diameter. The smaller sandstone fragments in the mapped area are derived from the top of the Book Cliffs and consist of tan, friable, subrounded fragments and chunks of fine-grained sandstone of the Blackhawk Formation and slabs of rusty-colored, brittle, well-cemented, fine-grained dolomitic sandstone of the Castlegate Sandstone. The surface areas covered by the litter are also characterized by dark cryptogamic soil that supports scattered prickly pear cactus.

Northward from the proposed disposal cell to the base of the Book Cliffs (nearer to the source of the sandstone), the sandstone litter covers most of the surface. Southward through the proposed disposal cell, the litter is present only in narrow strips that generally correspond to subtle, north-northwest trending ridges (Plate 1). The litter-covered low ridges also correspond, in most places in the proposed disposal cell area, to subtle bedrock ridges, as shown in Plate 3. The litter in the proposed disposal cell area represents residual sandstone material that was deposited along the base of the Book Cliffs as rock falls during erosion of the supporting Mancos Shale that has not yet been eroded away or has not been covered by sheet wash material during the accumulation of the alluvial-mud deposits.

C05

2.4 Sandy Alluvium

Alluvium from the Crescent Wash drainage system occurs in low ridges along the southwest edge of the mapped area. This material consists mainly of silty sand, and the sand is mostly fine- to very fine-grained. The sandy character of this alluvium is different from the Mancos Shale-derived alluvial mud and reflects the dominantly sandstone lithology present in the Book and Roan Cliffs area that the Crescent Wash system drains. A few sandstone chunks (rarely as large as boulders) and chert pebbles occur in the alluvium; these are representative of the Mesaverde Group sandstones and early Tertiary sandstones with chert that are present in the Crescent Wash drainage. The sandy alluvial ridges also support more vegetation than the alluvial mud flats.

Evidence of ancestral courses of Crescent Wash is expressed in the sandy alluvium as arcuate topographic lows in the west-central edge of Section 27 (Plate 1). These former stream courses were as much as 1,000 ft east of the present wash. Sandy alluvium is not present immediately east of the large incised meander of Crescent Wash near the northwest corner of Section 27. This indicates that no ancestral Crescent Wash has been present east of the present wash course at the large meander.

2.5 Pediment-Mantling Litter

Several small areas along the west and southwest edges of the mapped area are covered by a distinctive, resistant, gravelly material that veneers alluvial mud, sandy alluvium, or Mancos Shale outcrops. Pebbles in this gravelly material consist of brown sandstone and resistant white quartzite and distinctive, exotic, black chert (up to 2 inches in diameter). The pebbles are loose and scattered and "litter" the surface.

These deposits represent the erosion-resistant lag material from former pediment-mantling deposits laid down by the ancestral Crescent Wash drainage system. The pediment-mantling deposits are no longer preserved in place in the mapped area. These deposits are preserved in place about 0.5 mi west of the mapped area where they cap a low mesa about 100 ft above Crescent Wash and are mapped as pediment-mantle deposits by Doelling (2001). These in-place deposits contain the same type of resistant pebbles found as lag (or litter) in the mapped area. The distinctive, exotic, black chert and vari-colored quartzite pebbles in the pediment-mantle deposits are a constituent of a conglomerate in the Dark Canyon Sequence of the Wasatch Formation of early Paleocene age that crops out in the Roan Cliffs about 6 to 8 mi north up the Crescent Wash drainage (Franczyk and others 1990). The occurrence of this pediment-mantling deposit whose matrix contains Stage II carbonate development about 100 ft above present drainages probably correlates to similar cemented deposits on Mancos Shale pediments mapped by Willis (1994) in the Harley Dome area about 35 mi to the east-northeast. Those deposits were estimated by Willis (1994) to be 100,000 to 200,000 years old based on their height (50-110 ft) above present drainages and their carbonate development (Stage II).

At the southwest end of the mapped area, several areas of pediment-mantling litter lie on the sides of a low hill where weathered Mancos Shale is poorly exposed (Plate 1). This hill is likely an erosional remnant of a Mancos Shale pediment surface east of the present Crescent Wash that was capped by the pediment-mantle deposits about 100,000 to 200,000 years ago (late to middle Pleistocene age) emplaced by the ancestral Crescent Wash system. The other scattered small deposits of pediment-mantling litter (mainly in the area near corehole 0202) are evidence of the former extent of this pediment.

3.0 Bedrock Geology – Cretaceous Mancos Shale

The mapped site area is underlain by the Mancos Shale of Late Cretaceous age that dips gently northward. The shale forms a broad, east-trending belt immediately south of the Book Cliffs. Topographically, the shale forms the lower or buttressing part of the Book Cliffs and the wide expanse of lowlands, or "flats", extending several miles to the south (Fisher and others 1960).

Total thickness of the Mancos Shale, which generally represents the open-marine mudstones deposited in the Cretaceous Western Interior Seaway, is approximately 3,500 ft if measured from the top of the Book Cliffs just north of the site area. Most of the Mancos is a monotonously uniform, drab or bluish gray shale; however, in the site area, which is in the upper third of the formation, an anomalously sandy interval is present that represents some nearshore deposition. This sandy interval was earlier recognized as the "Mancos B" (zone or horizon) because of its natural gas-producing characteristics on the Douglas Creek arch near the Utah-Colorado border (Kellogg 1977). More recent stratigraphic studies have identified the nearshore facies of this sandy interval and formalized this unit and renamed it the Prairie Canyon Member (Cole and others 1997). Some facies of the Prairie Canyon Member, as identified by Hampson and others (1999) as fluvial-dominated delta front deposits, occur in the north part of the mapped area. These delta-front deposits, therefore, are mapped as representing the Prairie Canyon Member in the site area. From the sandy (generally very fine grained) nature of this member as exposed in a few outcrops, seen in several coreholes and test pits, and expressed as a marked reduction in the gamma ray geophysical log response from coreholes, the thickness of the Prairie Canyon Member in the mapped area is approximately 150 to 200 ft. Up to approximately 100 ft of the lower part of the Prairie Canyon Member is present along the north edge of the proposed disposal cell.

Underlying and overlying the sandy interval of the Prairie Canyon is the Blue Gate Member of the Mancos Shale. The Blue Gate consists mainly of open-marine mudstone and shale, with a few thin siltstone layers. In the site area, the Blue Gate is divided into lower and upper parts to accommodate the Prairie Canyon Member. Outcrops of both lower and upper parts of the Blue Gate are rare – only one of each was found in the mapped area (Plate 1). A thickness of approximately 2,000 ft of lower Blue Gate is present in the site area. Below the Blue Gate are the lowermost members of the Mancos Shale, the Ferron Sandstone underlain by the Tununk Shale, that combine for an approximate 300 to 400 ft thickness. It is therefore estimated that approximately 2,400 ft of Mancos Shale underlies the center of the proposed disposal cell; this includes all of the lower Blue Gate, the Ferron Sandstone, and the Tununk Shale.

The upper Blue Gate, above the Prairie Canyon, is approximately 700 to 800 ft thick. It is overlain by the Blackhawk Formation, the lowermost unit of the Mesaverde Group, that forms the sandstone crest of the Book Cliffs immediately north of the site area.

A generalized stratigraphic section of the mapped site area is shown in Figure 5. Characteristics of each member of Mancos Shale as seen in outcrops and in borehole core are discussed in the following subsections, in chronologic order from oldest to youngest. Detailed lithologic descriptions of bedrock from the ten deep (300 ft) coreholes are in Attachment 5 of the RAP. Five cross sections (Plate 2) across the site show the lithologic position of the Prairie Canyon Member in the subsurface. The bedrock contour map (Plate 3) shows subtle ridges and other variations in the bedrock topography.

3.1 Lower Blue Gate Member

The lower part of the Blue Gate Member does not crop out on or immediately around the proposed disposal cell; however, the unit is present in the subsurface and all of the ten coreholes penetrated part of the unit. The unit crops out in poor exposures in one place in the southwest edge of the mapped area on a low hill that is an eroded remnant of a pediment surface (Plate 1). Here, the exposures are mainly gray shale and minor, thin, lenticular beds of light gray to brown-orange (limonitic) siltstone that contains small tracks and other trace fossils.

Bedrock penetrated by four of the coreholes (0202, 0205, 0207, and 0209) consisted of the lower Blue Gate. Also, one packer test hole (0212) was cored solely in the lower Blue Gate, and the bottom of test pit 0154 was in the lower Blue Gate. The other coreholes passed through part of the Prairie Canyon Member before reaching total depth in the lower Blue Gate.

The lower Blue Gate penetrated by the coreholes is mostly medium gray (N5), calcareous, silty claystone, and is fissile in some places. Several thin zones occur that have a small percentage (less than 20%) of bioturbated bedding of siltstone or very fine grained sandstone that is lighter colored, very light gray (N8). Fine, black carbonaceous material and framboidal pyrite (plated on fossils in places) occur in trace amounts. Large fossils that were found in the core consist mainly of coiled and flattened cephalopods and pelecypods. Curious dense masses up to 2 inches in diameter of white, highly calcareous (porcelaneous-appearing) material occur rarely in the deeper part of the lower Blue Gate (more than 150 ft below the upper contact). Small beads (up to 0.05 inch diameter) of amber or resin occur in trace amounts in

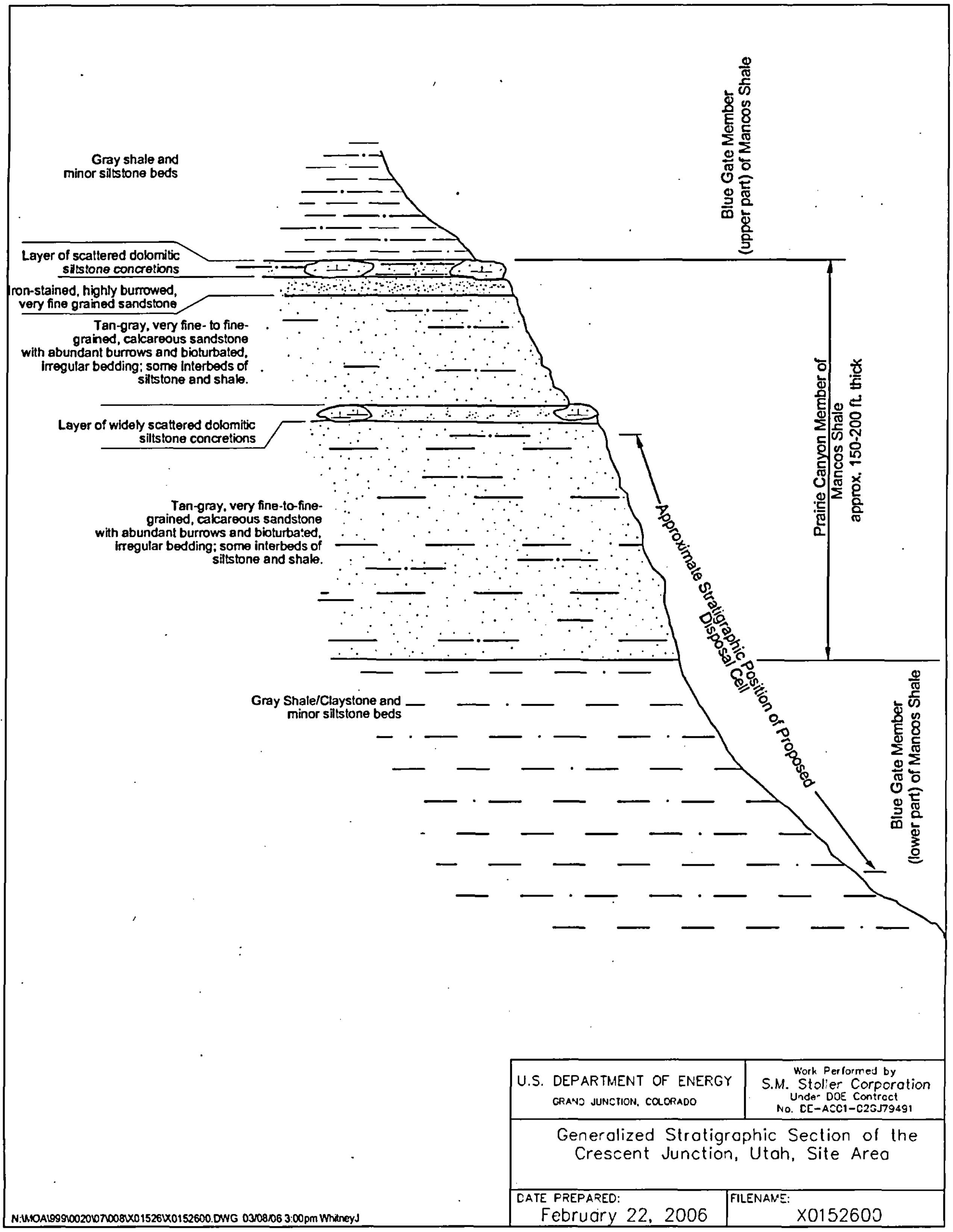

Figure 5. Generalized Stratigraphic Section of the Crescent Junction, Utah, Site Area

various depths in most coreholes into the lower Blue Gate. Below a depth of 100 ft into this bedrock, no natural fractures were noted and no evidence was seen of water movement (interior of broken core was dry).

The top of the lower Blue Gate occurs generally in the space of several ft where bioturbated bedding and associated very fine-grained sandstone increases to about 30 percent. This change is best seen in the geophysical logs as a marked reduction in gamma ray response. In the five coreholes that were geophysically logged, the depth of the contact of the lower Blue Gate and Prairie Canyon is picked as follows: 0203 – 117 ft, 0204 – 52 ft, 0206 – 107 ft, 0208 – 117 ft, and 0210 – 139 ft. In corehole 0201, which was not geophysically logged, the contact is placed where the amount of bioturbation increases very rapidly at approximately 157 ft. The Prairie Canyon – top of lower Blue Gate contact is shown in the north-south cross sections A-A', B-B', and C-C', and more along strike in the west-east cross section D-D' (Plate 2).

3.2 Prairie Canyon Member

Several outcrops of very fine-grained sandstone of the Prairie Canyon Member occur in the proposed disposal cell area (Plate 1). Additional small outcrop areas of sandstone occur east and north of the proposed disposal cell. A band of scattered small outcrops of dolomitic siltstone concretions also occurs across the north part of the site area marking the top of the Prairie Canyon Member. Three lithologic facies were selected for mapping (Plate 1) to show the variation of this member in the site area. The lower and thickest unit is a tan, burrowed sandstone. A thin, distinctive rusty brown, burrowed sandstone unit occurs just below the uppermost dolomitic siltstone concretions. A band of discontinuous, large, resistant, dolomitic siltstone concretions is present approximately 50 ft below the top band of concretions. Each of these facies is described in the following subsections, and they are similar in many characteristics to those described by Hampson and others (1999) in this part of the outcrop belt of the Prairie Canyon.

3.2.1 Tan, burrowed sandstone

This facies is exposed in the proposed disposal cell area on a subtle, north-trending ridge approximately along the section line between Sections 26 and 27 (Plate 1). Here, the light gray to tan sandstone is fine to very fine grained, calcareous, burrowed, and is exposed in lenticular to slabby beds about 1 inch thick.

This fine- to very fine-grained, burrowed sandstone subcrops under approximately the northern 60 percent of the proposed disposal cell area. This estimated subcrop of the base of the Prairie Canyon Member shown in Plate 1 is based on scattered outcrops of the tan and gray sandstone in the proposed disposal cell area and along strike just to the east in a low ridge near test pit 0156. Also, several geotechnical boreholes (0085 and 0087) noted the presence of sandstone bedrock at their total depths.

North of the proposed disposal cell and stratigraphically higher, the sandstone crops out in scattered locations – the largest is an area over 500 ft long along the west side of a low ridge extending south-southeast from the area of the 3 ponds (Plate 1). In this outcrop area, the slabby sandstone is tan, fine grained, calcareous, slightly friable, bioturbated, with abundant sole marks and burrows. Other outcrops of this sandstone occur along strike to the west (south of corehole 0201) and east (east and north of corehole 0210). These scattered northern outcrops occur mainly on the south side of a band of low mounds formed (capped) by resistant, large, dolomitic siltstone concretions.

Core from the several holes through the Prairie Canyon Member show that most of the rock is medium gray (N5) silty claystone to clayey siltstone, and usually only 10 to 30% of the rock is very light gray (N8), very fine-grained sandstone. The sandstone is bioturbated, wavy bedded, and contains traces of framboidal pyrite, fine carbonaceous (plant fragment?) material, and pelecypod and cephalopod imprints. The percentage of sandstone (up to 30%) shown in the core is more of a true account of the stratigraphy of this member, rather than reliance on the surface outcrops, which tend to be of the more resistant sandstone. Coreholes in the mapped area that penetrated part of the Prairie Canyon Member sandstones are 0201 (penetrated nearly all of the Prairie Canyon Member), 0204, 0206, 0208, and 0210. Lithologic logs from coreholes 0201, 0208, and 0210 contain the most detailed description of the lithology. Below a depth of about 80 ft into this bedrock, no natural fractures were noted and no evidence was seen of water movement (interior of broken core was dry).

3.2.2 Rusty brown, burrowed sandstone

This thin, distinctive facies crops out in scattered locations along an east-trending belt across the north part of the mapped area (Plate 1). The unit is only about 3 ft thick and typically occurs just below the large dolomitic siltstone concretions that form the northernmost line of low mounds. It consists of dense, resistant, rusty brown, very fine- to fine-grained sandstone that contains large burrows up to 1.5 inches in diameter, and abundant trace fossils and casts. This facies contains the most intense and diverse bioturbation. The unit was not seen in all of the northernmost dolomitic siltstone concretion mounds, possibly because of cover or poor outcrops.

3.2.3 Dolomitic siltstone concretion

This facies, the best exposed in the mapped area, occurs in two east-trending bands of low, scattered mounds up to 15 ft high in the north part of the mapped area just north of the proposed disposal cell. Each mound is capped by one or more large concretions of dolomitic siltstone. The lower band, represented by several widely scattered mounds, is stratigraphically about 50 ft below the upper band. The dolomitic concretion-capped mound just west of corehole 0210 represents this lower band (Plate 1).

The upper band contains more numerous mounds in the mapped area and consists of 10 to 15 scattered mounds. The top of these mounds represents the top of the Prairie Canyon Member in the mapped area, as shown in Plate 1. This contact of the top of the Prairie Canyon and base of the upper Blue Gate Member marks a delta-front abandonment and marine-flooding surface followed by deposition of marine shales of the upper Blue Gate (Cole and others 1997).

Concretions are hard, dense, brittle, up to 5 ft thick, and are composed of dolomitic siltstone; some contain calcite crystals and masses. Dolomitic siltstone on fresh surfaces is medium gray (N5) and weathered surfaces are grayish orange (10YR 7/4). Bedding is wavy, flaser (flame or streak)-shaped, and interrupted in places by burrowing. The concretion-capped mounds (Figure 6) vary in diameter from 20 or 30 ft to the large mound about 200 ft in exposed diameter just southwest of corehole 0201. The top of the resistant concretion mounds forms a north-dipping cuesta-like surface where the dip of the Mancos Shale could be measured in several places (Plate 1) at approximately 5 to 6 degrees. Vertical joints, some coated with limonite, form in the brittle dolomitic siltstone. These joints were measured in several locations (Plate 1). The principal joint direction is approximately N10E and subsidiary directions are N50W and N85W.

3.3 Upper Blue Gate Member

The only outcrop of the upper part of the Blue Gate Member in the mapped area is north of the 3 ponds area along a steep, west-facing slope above a small drainage. Cropping out on the slope is soft, gray brown, silty shale and some interbeds of slabby, thin, tan brown, very fine-grained, burrowed sandstone. Sandstone litter and sheet wash cover most outcrops north of the mounds, which mark the top of the Prairie Canyon Member, until the steep slopes of the Upper Blue Gate Member are reached at the base of the Book Cliffs.

3.4 Structural Features and Weathered Bedrock

No faults or evidence of faults (slickensides on fracture surfaces) were found in the deep coreholes. Lithologic logs, geophysical logs, and surface outcrops verify that the dip of Mancos Shale bedrock in most of the mapped area is approximately 5 to 6 degrees to the north. This is shown in cross sections B-B' and C-C' (Plate 2). Evidence that the northward dip may be slightly less in the western part of the mapped area is from the slightly wider subcrop belt of the Prairie Canyon Member shown in Plate 1 and the cross section A-A' (Plate 2).

Figure 6. View northeast of a low mound formed by the uppermost band of dolomitic siltstone concretions at the top of the Prairie Canyon Member of Mancos Shale.

Weathered bedrock characteristics were noted during lithologic logging of the deep coreholes. At depths of more than 40 to 45 ft, bedrock was usually competent without bedding plane fractures and had a fresh appearance. No natural fractures were noted in the core from depths greater than 80 to 100 ft.

Horizontal bedding plane fractures occur mainly in the top 20 to 30 ft of weathered bedrock; the numerous fractures rapidly decrease in frequency in the first 10 to 20 ft of depth (Figure 7). Typical colors of weathered and altered rock are yellowish gray (5Y 7/2), pale yellowish brown (10YR 6/2), and light olive gray (5Y 5/2). Limonitic alteration typically has a dark yellowish orange (10YR 6/6) color.

Higher-angle, non-bedding plane, fractures are abundant in the first 20 to 30 ft of bedrock. These fractures are typically coated or filled with white crystalline gypsum (and possibly some calcite), as shown in Figure 8. These shallow fractures and, particularly, the deeper fractures may be coated (stained) with limonite, indicating movement of small amounts of ground water (Figure 9). Only a few fractures extend below a depth of 50 ft, and those do not extend much deeper. Two deeper, limonite-stained fractures occur at 68 and 73 ft depths in corehole 0203, indicating some minor ground water movement in the past.

Conclusions

Interpretation and characterization of the surficial and bedrock geology of the mapped area in and around the proposed disposal cell area found no features that would adversely affect the geologic suitability of the disposal site. The following features and characteristics of the surficial and bedrock geology of the site area favor its suitability for a disposal cell.

- Approximately 2,400 ft of Mancos Shale, represented mainly by open-marine mudstone, is present beneath the center of the proposed disposal cell.
- No evidence for faults was noted in the surface or in bedrock units.
- No evidence of saturation in the bedrock was seen; core was dry when broken open.
- Natural fractures were mostly in the top 20 to 30 ft of bedrock and below that the rock is largely competent; fractures are rare below depths of 50 ft and not noted below 80 to 100 ft depths.
- Surficial deposits have been emplaced in a stable geologic environment mainly by a slow accumulation of material transported during infrequent heavy rainfall episodes from the base and sides of the Book Cliffs along active sheet wash paths.

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Figure 7. Core from hole 0210, from 26 (left) to 36 ft (right), showing progression in depth from highly weathered to slightly weathered bedrock.

Figure 8. Gypsum (white) filling a vertical fracture at 39.5 to 40.0 ft depth in weathered lower Blue Gate Member bedrock at corehole 0209.

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Figure 9. Limonite (orange) coating high-angle fracture at about 62 ft depth in slightly weathered lower Blue Gate Member bedrock at corehole 0207.

Computer Source:

Not applicable.

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D-03

U.S. Department of Energy—Grand Junction, Colorado

Calculation Cover Sheet

Calc. No.: MOA-02-08-2005-1-06-00 **Discipline:** Geology and Geophysical Properties **No. of Sheets:** 5

Project: Moab Project

Site: Crescent Junction Disposal Site

Feature: Site and Regional Geomorphology – Results of Literature Research

Sources of Data:

Published reports and maps – see list of references at end of calculation set.

Sources of Formulae and References:

See list of references at end of calculation set.

Preliminary Calc. ☐ **Final Calc.** ☐ **Supersedes Calc. No.**

Author: Mark Kautz 30 Aug '05
Name Date

Checked by: [signature] 30 Aug 05
Name Date

Approved by: [signature] 8-30-05
Name Date

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Problem Statement:

Determination of the suitability of the Crescent Junction disposal site as the repository for the Moab uranium mill tailings material, and development of the site and regional geomorphology sections of the Remedial Action Plan (RAP) require a thorough review of available literature that applies to the Crescent Junction site. The compiled list of references is presented at the end of this calculation set and relevant information is summarized below.

This calculation will be incorporated into Attachment 2 (Geology) of the Remedial Action Plan (RAP) and Site Design for Stabilization of Moab Title I Uranium Mill Tailings at the Crescent Junction, Utah, Disposal Site, and summarized in the appropriate sections of the Remedial Action Selection (RAS) report for the Moab site.

Method of Solution:

Literature sources were identified using a combination of published reports and maps that were developed during the Crescent Junction site-selection process, on-line (internet-based) resources, and relevant literature citations from the other UMTRCA sites.

Assumptions:

It is assumed that the literature sources are reliable and representative of the current understanding of the geomorphology of the region.

Calculation:

None required.

Discussion:

A general summary of geomorphologic conditions based on the literature research is provided in this calculation set.

Crescent Flat, the physiographic location for the Crescent Junction disposal site, is on a broad, nearly level, plain at the base of the Book Cliffs. The elevation of Crescent Flat ranges from approximately 4,900 feet above mean seal level (ft amsl) at the southwest corner of the withdrawn area to approximately 5,120 ft amsl at the northeast corner of the withdrawn area. Crescent Flat is bounded to the north by the steep slopes of the Book Cliffs whose elevation rises to approximately 5,900 ft amsl.

Drainage features across most of Crescent Flat consist of relatively subtle depressions that comprise Kendall Wash. The name Kendall Wash is a designation that appears on the 1:250,000-scale Moab topographic sheet but is absent from the later-published 1:24,000 scale topographic quadrangle map. For the purpose of this investigation, the name Kendall Wash will be reinstated to describe the watercourse that collects surface water from Crescent Flat. Kendall Wash has two forks across Crescent Flat: the "West Branch" and the "East Branch", which are informal designations created specifically for this study (Figure 1). These two forks collect surface water from most of the withdrawn area. Kendall Wash enters Thompson Wash approximately 3.5 miles south of Crescent Junction. Thompson Wash and Crescent Wash converge approximately 7.1 miles south of Crescent Junction and form Tenmile Canyon, which is a tributary to the Green River. The confluence of Tenmile Canyon with the Green River is approximately 23 miles southeast of Crescent Junction. The subtle drainages observed over the surface of Crescent Flat are an indication that depositional, rather than erosional, processes are dominant over the landscape.

The western margin of the withdrawn area coincides with Crescent Wash, which is a 22 square mile drainage feature that emerges from Crescent Canyon in the Book Cliffs. Crescent Canyon heads approximately 10 miles north of Crescent Flat. Crescent Wash is an intermittent channel that forms an erosional cut that is entrenched some 15 ft below the surface of Crescent Flat. Based on the depth of the cut, the steep canyon walls and high relief within Crescent Canyon, and the size of the detritus within the

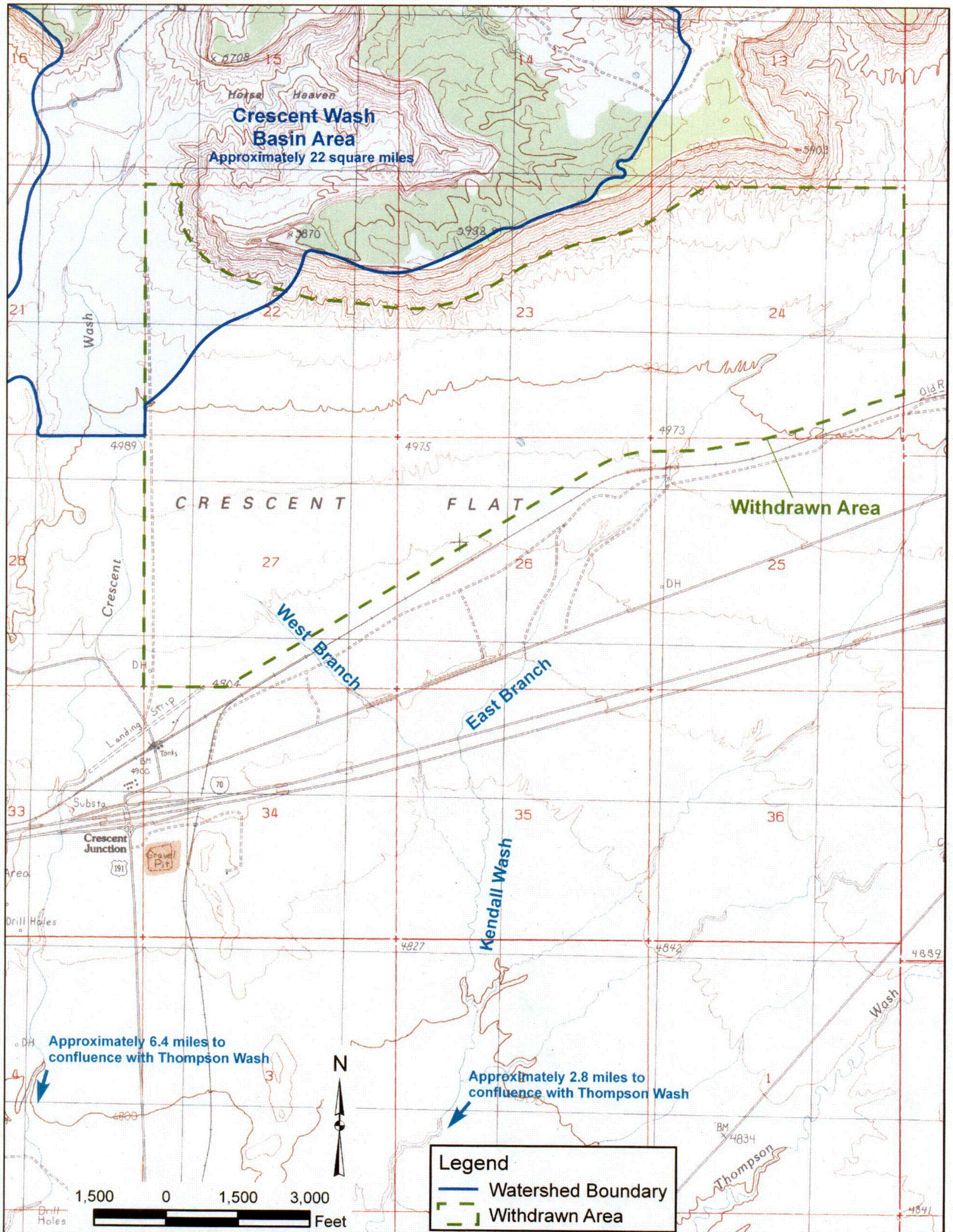

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Figure 1. Topographic Map of Crescent Junction Vicinity Showing the Locations of Surface Water Features

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channel, Crescent Wash appears capable of considerable erosion when it flows. The narrow and steep aspect of Crescent Canyon is prime location for flash floods. Crescent Wash is therefore considered a significant fluvial-geomorphic feature with regard to the proposed repository at the Crescent Junction disposal site.

The soil profile at Crescent Flat is rather poorly developed. Over much of the site, the bedrock is covered over by "alluvial mud" of Quaternary age (Doelling 2001). This unconsolidated gray material, less than 20 ft thick, fills swales in the Mancos Shale and contains rock fragments from the underlying parent material, detrital material shed from the Book Cliffs, and occasional remnants of lag gravels that formed on earlier pediment surfaces. The alluvial mud mantles the bedrock to varying degrees. Aerial photographs and field reconnaissance have shown lineaments that form where relatively resistant ledges of suspected siltstone bedrock occur in the shallow subsurface. Detrital materials within the mud are distributed somewhat randomly at the land surface over the entire breadth of Crescent Flat. Large rock fragments, primarily sandstone, are more abundant near the base of the Book Cliffs where rock falls are an important hillslope process.

The Mancos Shale is exposed along the face of the Book Cliffs. The calcareous shale beds strike approximately N60E and dip to the northwest at less than 10 degrees. The exposed shale supports little to no vegetation; consequently, the surface is vulnerable to erosional forces, such as rill and gully erosion by running water and attendant rock falls, which were described earlier. Erosion of the exposed face of the Book Cliffs forms contrasting slopes that are carved in calcareous shale and sandstone strata. The slope angles of the Book Cliffs are controlled by a combination of geologic structure and the strength of the rock mass of the bedrock material. Running water that enters Crescent Flat at the base of the Book Cliffs rapidly looses kinetic energy and signs of sheet flow and sediment deposition become more evident. As mentioned above, Crescent Flat exhibits only incipient fluvial channeling.

Conclusion and Recommendations:

Based on preliminary evaluation of the results of the literature research effort, the Crescent Junction site appears to be suitable for disposal of the Moab uranium mill tailings and contaminated material.

Computer Source:

Not applicable.

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U.S. Department of Energy—Grand Junction, Colorado

Calculation Cover Sheet

Calc. No.: MOA-02-08-2005-1-08-00 **Discipline:** Geologic and Geophysical Properties **No. of Sheets:** 8

Project: Moab Project

Site: Crescent Junction Disposal Site

Feature: Site and Regional Geomorphology – Results of Site Investigations

Sources of Data:

Refer to calculation.

Sources of Formulae and References:

References cited in this calculation set are listed in Calc. No. MOA-02-08-2005-1-06-00 (Site and Regional Geomorphology – Results of Literature Research).

Preliminary Calc. ☐ **Final Calc.** ☐ **Supersedes Calc. No.**

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Problem Statement:

Preliminary site selection performed jointly by the U.S. Department of Energy (DOE) and the Contractor has identified a 2,300 acre withdrawal area in the Crescent Flat area just northeast of Crescent Junction, Utah, as a possible site for a final disposal cell for the Moab uranium mill tailings. The proposed disposal cell would cover approximately 300 acres. Based on the preliminary site-selection process, the suitability of the Crescent Junction disposal site is being evaluated from several technical aspects, including geomorphic, geologic, seismic, and geotechnical. The objective of this calculation set is to identify geomorphic processes that affect the site.

This calculation will be incorporated into Attachment 2 (Geology) of the Remedial Action Plan (RAP) and Site Design for Stabilization of Moab Title I Uranium Mill Tailings at the Crescent Junction, Utah, Disposal Site, and summarized in the appropriate sections of the Remedial Action Selection (RAS) report for the Moab site.

Method of Solution:

Geomorphic characteristics of the withdrawn area for the Crescent Junction disposal site are described in this calculation set. Field reconnaissance of geomorphic features of the site was conducted from July 18 to 20, 2005. In addition to ground traverses across the site, a traverse across the top of the Book Cliffs was made on July 19, 2005 to view the site from the north. Low-sun angle (LSA) aerial photographs (from early-day and late-day sun angles) and high-altitude aerial photographs of the site area flown on July 8, 2005, by AeroGraphics, Inc. (2005a and 2005b), were also used to discern geomorphic features. Specific conclusions drawn from interpretation of LSA results are presented in the photogeologic interpretation calculation set. Test pits were excavated at two locations within the proposed footprint of the tailings repository. Significant site geomorphic features together with two test–pit locations are shown in Figure 1. Test pit logs are presented in Attachment 5 of the RAP.

Assumptions:

Not applicable.

Calculation:

None required.

Discussion:

The dynamic equilibrium that exists in topographically diverse areas may be explained as a balance that exists between degradational (erosional) and aggradational (depositional) processes. The degradational processes act on or near the sources of sediment, while the aggradational processes occur at or near sediment sinks. The landforms observed at the Crescent Flat area are discussed in terms of these two competing processes.

Degradational Processes

- **Crescent Wash**

  The basin area of Crescent Wash is approximately 22 square miles. Much of the area is composed of narrow canyons and steep slopes that gain up to 1,000 feet (ft) in elevation, but more commonly, the canyons comprise several hundred feet in vertical relief. Steep slopes within the canyon create high fluvial gradients capable of transporting significant quantities and size of sediment. Boulders derived from the canyon walls have been observed up to 4 ft in diameter in Crescent Wash (Figure 2). Runoff events within Crescent Wash were not observed first-hand during this site investigation. Results of geologic mapping (Doelling 2001) have shown that the eastward lateral extent of Crescent Wash alluvial deposits is contained within the subtle ridges of Mancos Shale bedrock that exist in the southwest corner of Section 27. Test pit 0151, constructed in the north-central part of Section 27, only showed minor fluvial channels, apparently not related to Crescent Wash. Material in the minor channel was locally derived detritus composed of shale and sandstone. Fluvial channeling was not observed in test pit 0153.

- **Kendall Wash Tributaries**

  Drainages originating at Crescent Flat coalesced into a feature that was formerly designated as Kendall Wash (1:250,000 scale Moab topographic sheet); however, this designation is not shown on the 1:24,000 scale topographic quadrangle maps. For this investigation, the northernmost tributaries of Kendall Wash are referred to as the "West Branch" and "East Branch". West Branch (Figure 3) drains to the southeast through the southeast quarter of Section 27. The West Branch collects surface drainage from Sections 27 and 22 and is incised up to approximately 10 ft deep at its intersection with old U.S. Highway 50. The West Branch is east of the subtle Mancos Shale ridge that divides the West Branch from alluvial deposits of Crescent Wash. No evidence exists that the West Branch cuts into the surface of the Mancos Shale. The head-ward migration rate of the West Branch was not determined quantitatively as part of this calculation set.

  The East Branch drains in a southwest direction through Sections 24 and 26, and collects surface drainage from Sections 23, 24, 25, and 26. Because its drainage area is larger than that of the West Branch, the East Branch is incised considerably deeper into Crescent Flat. North of the intersection of the East Branch with U.S. Highway 50, currently the Interstate 70 frontage road, the East Branch is incised approximately 15 ft into the surface of Crescent Wash (Figure 4).

  Part of the surface water entering both the West Branch and the East Branch descends through rills and gullies along the face of the Book Cliffs and spreads out as sheet flow. Sediment deposition occurs at the base of the Book Cliffs where the water velocity is slower. Holocene to Late-Pleistocene alluvial mud that covers the Mancos Shale in Crescent Flat is probably derived from the sheet flow action. Only minor incised channels exist in the northern reaches of Crescent Flat. The absence of active fluvial down-cutting along Crescent Flat, and the Holocene to Late-Pleistocene stability of Crescent Flat are favorable attributes of the site with regard to its proposed use.

Aggradational Processes

Alluvial mud is an expression of sheet wash deposition that accumulated as a consequence of erosion of the Book Cliffs face. The rill and gully erosion on the face of the Book Cliffs demonstrates that they are a source of sediment material. Present evidence of the sheet wash process is shown in Figure 3. The discolored areas of Crescent Flat with drab gray soils from the face of the Book Cliffs are slightly braided with the long axis oriented parallel to the flow direction. The most prominent sheet wash feature trends to the south-southeast from near the three ponds between Sections 22 and 23 (Figure 5).

Bedrock Geomorphology

Low cuesta–like ridges and mounds that appear as an easterly trend lie along the northern margin of Crescent Flat. The linear feature east of the three ponds is shown in Figure 5. A ground photo of the cuesta–like feature is shown in Figure 6. The linear feature also exists west of the three ponds. More resistant, calcareous siltstone beds in the Prairie Canyon Member of the Mancos Shale form the cuesta-like features.

Low hills scattered over Crescent Flat, particularly in the southwest quarter of Section 27 and the northeast corner of Section 34, are an expression of the former pediment–mantling material that capped the Mancos Shale. Figure 6 from just west of the site shows where the pediment mantling material is in place. The subtle mounds signifying the remnants of these features are scattered over Crescent Flat.

Rock–falls are another active erosional process observed at the base of the Book Cliffs. Figure 7 shows how some of the boulders attain large proportions. These rock falls occur episodically in response to the freezing action of water that seeps into cracks in the sandstone along the rim of the Book Cliffs. Although, the northward rate of advance of the escarpment along the face of the Book Cliffs was not estimated as part of this investigation, it is probably very long in comparison to the performance life of the proposed tailings repository. Additional information will be presented in the RAP. Because of limited precipitation, these boulders will likely take many years to disaggregate.

A large erosional feature exists north of the face of the Book Cliffs in an area known as Horse Heaven. This area is in the southern half of Section 15, the northern half of Section 22, and the eastern half of Section 14 (Figure 1). Landslide material mapped in this location by Doelling (2001) is reported to be Holocene to Pleistocene. This deposit demonstrates that mass–wasting processes are common along the north-facing canyon walls where slopes are exposed for longer periods to freezing and thawing water. Southward advance of the scarp in Horse Heaven appears to have intersected the cliff band of the Book Cliffs because dislocated bedding and phreatophytic vegetation are visible along the top of the cliff face near elevation-monument 5,870 (Figure 1) and above the vehicle in Figure 2. Because the age of the landslide deposits in Horse Heaven is long in comparison to the design life of the proposed repository, the mass wasting in Horse Heaven is not likely to impact the long-term stability of the proposed disposal cell.

Conclusion and Recommendations:

Land-forming processes at the Crescent Flat site include: (1) the rock falls from the top of the Book Cliffs; (2) formation of rills and gullies on the face of the Book Cliffs; (3) a veneer of alluvial mud deposited atop weathered Mancos Shale; (4) low cuesta-like ridges and mounds that appear as an easterly trend along the northern margin of Crescent Flat; (5) incised channel formation in Crescent Wash along the eastern boundary of the withdrawn area; and (6) incipient incised-channel formation in the West Branch and East Branch of Kendall Wash. These fluvial-geomorphologic features pose little risk to the proposed uranium mill tailings repository. Additional discussion will be provided in the RAP. However, water-carrying capacity of the West and East Branches of Kendall Wash will need to be considered carefully to maintain their long-term, post-construction stability.

Computer Source:

Not applicable.

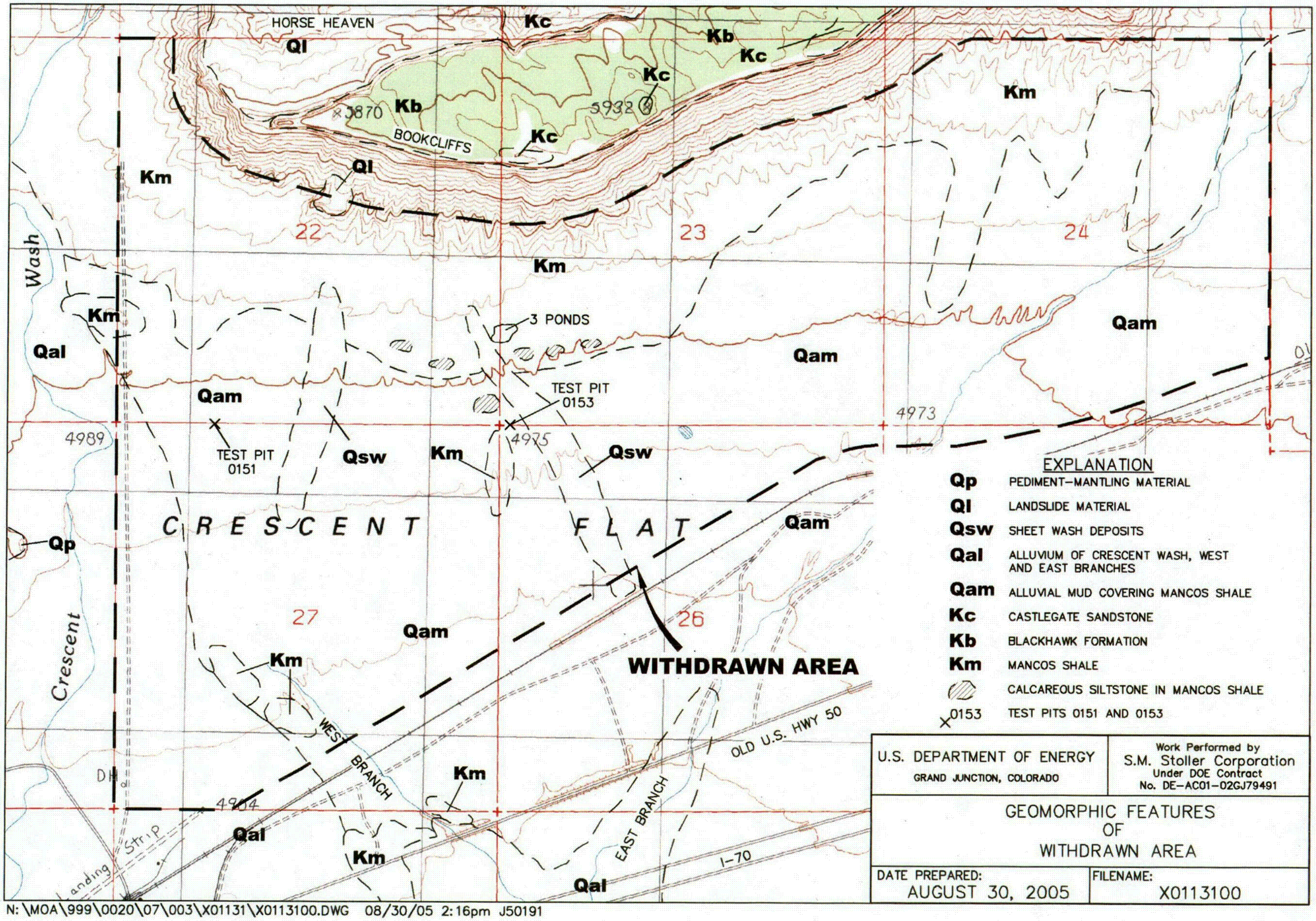

Figure 1. Geomorphic Features of the Withdrawn Area of Crescent Junction, Utah, Disposal Site

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Figure 2. View north–northeast of incised meander bend in Crescent Wash just southwest of corner of Sections 21, 22, 27, 28. Incision is about 12 ft deep and does not contact Mancos Shale bedrock. Diameter of boulders in bed of wash is up to 4 ft.

Figure 3. View southwest from top of Book Cliffs of West Branch, an incised drainage in the SE ¼ Section 27 that drains southeastward. Drab–gray discoloration in the foreground is interpreted as sediment deposition due to sheet flow.

Figure 4. View northeast of East Branch in SE¼ NE¼ Section 26. Incision at this location is about 15 feet deep and does not contact Mancos Shale bedrock; however, several hundred feet downstream of this location, the East Branch cuts several feet into weathered Mancos Shale.

Figure 5. View south–southwest from top of Book Cliffs toward linear feature that extends eastward from the three ponds. Linear feature marks where calcareous siltstone beds of the Prairie Canyon Member of the Mancos Shale crop out. Also note the drab–gray discoloration that is interpreted as evidence of sediment deposition due to sheet flow.

Figure 6. View east–northeast of resistant calcareous siltstone bed(s?) cropping out in a low cuesta–like hill. This hill and a similar one about 50 yards to the east are along the linear feature seen from the top of the Book Cliffs.

Figure 7. View northwest of large sandstone boulder from the Blackhawk Formation adjacent to road in NE¼ SW¼ Section 23. Boulders have fallen down as part of recession of the Book Cliffs escarpment.

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U.S. Department of Energy—Grand Junction, Colorado

Calculation Cover Sheet

Calc. No.: MOA-02-08-2005-07-00 **Discipline:** Geologic and Geophysical Properties **No. of Sheets:** 16

Project: Moab Project

Site: Crescent Junction Disposal Site

Feature:
Site and Regional Seismicity – Results of Literature Research

Sources of Data:

Published reports and maps -- see list of references at end of calculation set.

Sources of Formulae and References:

See list of references at end of calculation set.

Preliminary Calc. ☐ **Final Calc.** ☐ **Supersedes Calc. No.**

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Problem Statement:

Determination of the suitability of the Crescent Junction disposal site as the repository for the Moab uranium mill tailings material, and development of the site and regional seismotectonic sections of the Remedial Action Plan (RAP) requires a thorough review of available literature that applies to the Crescent Junction site. The compiled list of references is presented at the end of this calculation set and relevant information is summarized below.

This calculation will be incorporated into Attachment 2 (Geology) of the Remedial Action Plan (RAP) and Site Design for Stabilization of Moab Title I Uranium Mill Tailings at the Crescent Junction, Utah, Disposal Site, and summarized in the appropriate sections of the Remedial Action Selection (RAS) report for the Moab site.

Method of Solution:

This literature review is part of the seismotectonic calculation set to develop seismic design parameters for the disposal site. Specifically, the calculation set includes a review of the pertinent literature, development of an estimate of the Maximum Credible Earthquake (MCE) and determination of the resulting design vibratory ground motion at the site (peak horizontal ground acceleration). The objective of this literature review is to identify the appropriate previous studies and published data pertaining to seismicity in the area. This review will support a more detailed investigation of the MCE and peak horizontal ground accelerations to be calculated specifically for the Crescent Junction site.

Two studies for other Uranium Mill Tailings Remedial Action (UMTRA) sites in particular were referred to for this seismotectonic calculation set because of their similar project type and close proximity to the Crescent Junction site. Specifically, the seismotectonic studies from the RAP for the Green River, Utah, UMTRA site (DOE 1991a) and the Grand Junction UMTRA site (DOE 1991b) were principal resources for this review. The Green River, Utah site is a 380,000 cubic yard uranium disposal site located approximately 20 miles west of the Crescent Junction site, while the Grand Junction, Colorado, site is a 5.3 million cubic yard uranium disposal site located approximately 80 miles east of the Crescent Junction site. Although the Green River site is closer to the Crescent Junction site than the Grand Junction site, the seismotectonic investigation for Green River site was not as extensive as the investigation for Grand Junction. Therefore, the use of the Green River RAP as a reference is limited.

Assumptions:

It is assumed that the literature sources are reliable and representative of the current understanding of the seismotectonics of the region.

Calculation:

None required.

Criteria and Definitions:

The following are the standards and definitions that are applied to the evaluation of the seismicity of the Crescent Junction site as specified in the Technical Approach Document (TAD) (DOE 1989).

Design life. As specified by the U.S. Environmental Protection Agency (EPA) Promulgated Standards for Remedial Actions at Inactive uranium Processing Sites (40 CFR 192), the controls implemented at UMTRA Project sites are to be effective for up to 1,000 years, to the extent reasonably achievable and, in any case, for at least 200 years. For the purpose of the seismic hazard evaluation, a 1,000-year design life is adopted.

Design earthquake. For UMTRA Project sites, the magnitude(s) of the earthquake(s) that produces the largest on-site peak horizontal acceleration and that produces the most severe effects upon the site is the design earthquake. This earthquake could be either a floating earthquake or an earthquake whose magnitude is derived from a rèlationship between fault length and maximum magnitude. The latter case is applied for a verified or assumed capable fault of known rupture length.

Floating earthquake (FE). An FE is an earthquake within a specific seismotectonic province that is not associated with a known tectonic structure. Before assigning the FE magnitude, the earthquake history and tectonic character of the province are analyzed.

Capable fault. A capable fault is a vault that has exhibited one or more of the following characteristics:

-Movement at or near the ground surface at least once within the past 35,000 years or movement of a recurring nature within the past 500,000 years.

-Macroseismicity (magnitude 3.5 or greater) determined with instruments of sufficient precision to demonstrate a direct relationship with the fault.

-A structural relationship to a capable fault such that movement on one fault could be reasonably expected to cause movement on the other.

Acceleration. Acceleration is the mean of the peaks of the two orthogonal horizontal components of an accelerogram record. The exact term used is "peak horizontal acceleration" (PHA). The accelerations are determined from the constrained attenuation relationship based on distance and magnitude as developed by Campbell (1981). The mean-plus-one standard deviation (84th percentile) value is adopted. This value is considered a non-amplified PHA.

Surface acceleration. Surface acceleration is the site acceleration adjusted for the site soil attenuation or amplification effects.

Duration of strong earthquake ground motion. Duration is defined, after Krinitzsky and Chang (1977), as the bracketed time interval in which the acceleration is greater than 0.05g. The methodology of Krinitzsky and Chang (1977) is applied in estimating the duration of strong ground motion at a particular site.

Magnitude and intensity. Magnitude is the base-10 logarithm of amplitude of the largest deflection observed on a torsion seismograph 100 kilometers (km) from the epicenter (Richter 1958). This local magnitude value may not be the same as the body-wave and surface-wave magnitudes derived from measurements at teleseismic distances. Unless specified otherwise, Richter magnitude values for values less than 6.5 are used in UMTRA Project seismic hazard evaluations.

Intensity is the index of the effects of any earthquake on the human population and structures. The most commonly applied scale is the 1931 Modified Mercalli (MM) Intensity Scale, which will be used in this study.

Because pre-instrumental earthquake records are reported in intensity and more recent instrumental records are in magnitude, there may be a need to relate these values. The relationship developed by Gutenburg and Richter (1956) is used:

$$M = 1 + 2/3 \, Io$$

Where M = magnitude in the Richter scale and Io = Modified Mercalli intensity in the epicentral area.

Maximum earthquake. The term Maximum Earthquake (ME) was defined by Krinitzsy and Chang (1977) as the largest earthquake that is reasonably expected on a given structure or within a given area. No recurrence interval is specified for such an event.

Local regional study area. The regional study area is selected by calculating the distance at which the largest magnitude earthquake possible for a region, as determined by Algermissen et al. (1982), produces the minimum accepted on-site design acceleration (0.10 g). All further characterization work is then limited to this region. Using this definition, the maximum earthquake for the region as determined by

Algermissen et al. (1982) is magnitude 6.1. Using Campbell (1981) attenuation relations for constrained, 84th percentile values, distances within 29 km of the site are considered within the local regional study area.

Expanded regional study area. Although UMTRA defines the study area as discussed above, the U.S. Nuclear Regulatory Commission (NRC) for Title 10, Part 100, Appendix A requires an investigation within 200 miles of the site. For purposes of this seismotectonic evaluation, capable faults, historical earthquakes, and floating earthquakes associated with neighboring tectonic provinces that lie within 200 miles of the site and are capable of producing a minimum on-site acceleration of 0.10g or greater will be evaluated in the expanded regional study area.

Discussion:

Seismotectonic Setting

The Crescent Junction site is located in the northern portion of the Colorado Plateau tectonic province (Figure 1). The Colorado Plateau is a broad, roughly circular region of relative structural stability within a more structurally active region of disturbed mountain systems. Broad basins and uplifts, monoclines, and belts of anticlines and synclines are characteristic of the plateau (Kelley 1979). These basins and uplifts are generally considered to be inactive under the present seismotectonic regime. (DOE 1991b). All three of the referenced UMTRA sites are located within the northern portion of the Colorado Plateau physiographic and tectonic province.

The Colorado Plateau is surrounded by the provinces of the Wyoming Basin and Middle Rocky Mountains to the north, the Basin and Range province to the west and south, the Intermountain Seismic Belt (ISB) to the west, the Rio Grande Rift, and the Southern Rocky Mountains to the east (Keller and others 1979; Kelley and Clinton 1960; Kelley 1979; Allenby 1979; Kirkham and Rogers 1981). The boundaries of the provinces vary between authors; the Southern Rocky Mountains are divided into the Eastern and Western Mountain Province by Kirkham and Rogers (1981).

Within the Colorado Plateau, the Crescent Junction site lies in the northwestern part of the Paradox Basin (in the Paradox Fold and Fault Belt), approximately 8 miles south of the Uinta Basin sub-province. The Book Cliffs, less than 1 mile north of the Crescent Junction site, are the erosional escarpment on the south flank of the Uinta Basin. As shown in Figure 2, additional sub-provinces in the area include the San Rafael Swell to the west, Henry Basin, White Canyon Slope, Monument Upwarp, Blanding Basin and Four Corners Platform to the south, the San Juan Dome to the east, and the Uncompahgre Uplift to the northeast (Kelley 1955).

The Paradox Basin is characterized by complex systems of northwest-trending normal faults and landslide and slump features. Typical salt anticlinal collapse features extend to within about 2 miles of the site. These features have been active during Quaternary time and may be active today. However, since they result from very gradual processes of salt dissolution and flow, they are not likely capable of generating large earthquakes. Kirkham and Rogers (1981) estimate the maximum earthquakes possible on these features to be about magnitude 5 (DOE 1991b; Kelley and Clinton, 1960).

- **Intermountain Seismic Belt (ISB)**

  The ISB (Smith and Sbar 1974; DOE 1991a) is a zone of pronounced earthquake activity extending north from Arizona and terminating in northwestern Montana. It is described by Ryall and others (1966) as being surpassed in seismic activity in the United States only by the California and Nevada seismic zones. The ISB is coincident with the boundary between the Basin and Range province and the Colorado Plateau/Middle Rocky Mountains. The largest historical event in the ISB was the 1959 Hebgen Lake earthquake of Richter magnitude 7.7 plus or minus 0.2. More than 15 events with magnitudes greater than 6 have been reported since the mid 1800s. The site lies approximately 50 miles east of the highly active ISB.

- **Rio Grande Rift**

  The Rio Grande Rift (Kirkham and Rogers 1981, DOE 1991a) is a north-south trending extensional graben feature that extends from Chihuahua, Mexico, to northern Colorado. The rift was initiated in Neogene time and has experienced continued activity through the Quaternary. The rift is characterized by Neogene basin-fill sedimentary rocks, and a bimodal suite of mafic and silicic igneous rocks, and abundant features suggesting recently active faults, such as fault scarps in young alluvium, abrupt mountain fronts that exhibit faceted spurs, and deep, narrow linear valleys. A high percentage of all the potentially capable faults in Colorado and New Mexico lie within this province. Well-defined evidence of repeated Late Quaternary movement is abundant on several faults in the southern portion of the province, whereas such evidence is obscure in the northern portion. The closest approach of the Rio Grande Rift to the site area is about 270 km (170 miles).

- **Wyoming Basin**

  The Wyoming Basin (DOE 1991a) consists of a series of broad structural and topographic basins that merge with and resemble the adjoining part of the Colorado Plateau (Hunt 1967). These basins are partly filled with Tertiary deposits and are separated by low anticlinal uplifts of older rocks. The earthquake history of the Wyoming Basin is apparently similar to the widely distributed, low- to moderate-magnitude pattern of the stable interior portion of the Colorado Plateau. Witkind (1975) identified numerous suspected active faults in the Wyoming Basin along the Colorado-Wyoming border between 107 and 108 degrees west longitude, which may represent a continuation of structures associated with the Rio Grande Rift in Colorado. However, these faults are not known to have been associated with seismic activity.

- **Southern Rocky Mountains/Mountain Provinces**

  The Mountain Provinces are divided into the Eastern and Western Mountain Provinces by Kirkham and Rogers (1981). The Eastern Mountain Province includes the Front and Medicine Bow Ranges, Middle and South Parks, and the east flanks of the Mosquito and Sangre de Cristo Ranges. Most of the faults in this province have Laramide, late Paleozoic, or even Precambrian ancestry. Several of the faults show considerable Neogene movement. A few of these faults have moved during the Quaternary. The distribution, orientation, and character of Neogene movement on these faults suggest rejuvenation is related to the extensional stresses responsible for rifting. The Western Mountain Province includes the San Juan Mountains, Elk and West Elk Mountains, west flank of the Sawatch Range, White River uplift, and Gunnison uplift. Neogene faults are relatively scarce in this province. Many of the faults that are present are not truly tectonic features, but rather are the results of evaporate flowage or caldera collapse. Despite an apparent absence of major Neogene tectonic faults, numerous earthquakes have been felt and/or instrumentally located in the province. The site is located approximately 200 km (130 miles) from the nearest portion of the Southern Rocky Mountain province.

Quaternary Faults

Quaternary faults and folds were evaluated using the USGS Quaternary Fault and Fold database (USGS 2002) and the Quaternary Fault and Fold database from the Utah Geological Survey (Black et al. 2003). Quaternary faults that are within the expanded regional study area are presented in Figure 3 and in Appendix A. Faults that are within 40 miles of the site are numbered using the identification system in the USGS database on Figure 3 and are described below.

- **Salt Valley and Cache Valley Faults (2474)**

  The faults are within a northwest-trending zone of folding, faulting, and warping related to dissolution and collapse of the Salt Valley anticline in eastern Utah, north of Moab. Collapse of the Salt Valley anticline appears to largely post-date late Pliocene deposition of exotic fluvial gravels (likely derived from a since-eroded source in the Book Cliffs) on the rim and floor of Salt Valley and formation of an erosion surface on the flank of the anticline. Small depositional basins within Salt Valley containing Bishop ash (~740 ka) and Lava Creek B ash (670 ka) were localized by salt dissolution and collapse and/or salt flow during early and middle Quaternary time and record syn and post depositional folding and faulting. Faults are parallel and appear related to the major older structures of the anticline. At the lower end of the valley, slightly tilted and relatively undeformed middle to late Quaternary basin fill deposits unconformably overlie older more-deformed units. Structural relations exposed at other localities in the valley suggest that Quaternary sediments have been deformed and localized by movement within salt diapirs of the Paradox Formation. Playas and mudflats in upper Salt Valley indicate active deformation (due to salt flow or dissolution) and damming of surface runoff. A stream that crosses the south end of the Salt Valley anticline at a high angle is entrenched and bordered by probable late Holocene terraces north of the anticline and is braided and unentrenched in the short reach within Salt Valley, suggesting that the core of the anticline is presently subsiding and causing stream aggradation. In Cache Valley, a Quaternary erosion surface that apparently post-dates collapse related deformation is displaced by a major bedrock fault and may have been tilted. East of Cache Valley, Colorado River terraces are tilted upstream on the upstream side of the Cache Valley anticline, indicating that salt flowed into the collapsed structure during Quaternary time. Timing of most recent paleoevent is Quaternary (<1.6 Ma). The slip rate is unknown, but is likely to be <0.2 mm/yr. The length of the fault is 58 km (Black and others 2003).

- **Ten Mile Graben (2473)**

The Ten Mile Graben is a narrow zone of faulting displacing Cretaceous and Jurassic bedrock along Salt Wash southeast of Green River. The graben is on the northwestern edge of an area typified by northwest-trending, elongate, oval valleys that are collapsed or depressed anticlines. The graben is probably related to salt dissolution, but may have a tectonic component. Woodward-Clyde Consultants (1996) found no evidence for Quaternary deformation and did not consider the graben as a capable fault for seismic-hazard assessment purposes. Timing of most recent paleoevent is Quaternary (<1.6 Ma). The slip rate is unknown, but is likely <0.2 mm/yr. The length of fault is 35 km (Black and others 2003).

- **Moab Fault and Spanish Valley Faults (2476)**

The Moab Fault and Spanish Valley faults consist of a northwest-trending zone of faulting and warping from collapse of the Moab Valley anticline from salt dissolution. The Moab fault bounds the western side of the valley and may have a tectonic component. Shoemaker and others (1958) and Jones (1959) indicate that the fault may extend below the salt, offsetting pre Paradox Formation strata. Collapse of the Moab Valley anticline appears to largely post-date deposition of early and middle Pleistocene alluvium on and near the rim of the valley (Harden and others 1985). A well-preserved relic canyon on the rim of Moab Canyon, whose headwaters were apparently removed by collapse of the anticline, probably formed during late Tertiary to early Quaternary time (Oviatt 1988). Distribution of middle Pleistocene through Holocene alluvial deposits suggests differential subsidence in Spanish Valley (due to tectonism or salt dissolution/migration). Marshes at the lower end of Spanish Valley may be evidence of Holocene subsidence. Woodward-Clyde Consultants (1996) indicates the youngest rocks or structures demonstrably displaced by the Moab fault are Cretaceous or Tertiary in age, and did not consider the faults as capable faults for seismic-hazard assessment purposes. Timing of most recent paleoevent is Quaternary (<1.6 Ma). The slip rate is unknown, but is likely <0.2 mm/yr. The length of fault is 68 km. (Black and others 2003).

- **Price River Area Faults (2457)**

The Price River area faults are generally east-west striking faults along the Price River west of the Book Cliffs. The faults are in a long, sinuous area along the base of the Book Cliffs termed the Mancos Shale Lowlands, characterized by sloping pediments, rugged badlands, and narrow flat-bottomed alluvial valleys in Cretaceous rock. Some faults within the zone displace pre Wisconsin-age pediments less than 2 meters. Structural relations indicate that the fault zone forms the crest of a broad, collapsed anticline. The fault zone is similar in trend, pattern, and length to faults along the crest of the Moab Valley anticline (2476), although it is not as strongly developed. The faults are inferred to be related to a salt anticline at the northern margin of the Paradox basin. Early to middle Pleistocene pediments north of the fault zone steepen sharply at the base of the Book Cliffs, and may be warped due to elastic rebound of the Mancos Shale during erosional unloading and/or monoclinal folding. The ancestral course of Whitmore Canyon (near Sunnyside) also appears to be warped. Timing of most recent paleoevent is Quaternary (<1.6 Ma). The slip rate is unknown, but is likely <0.2 mm/yr. The fault length is 51 km. (Black and others 2003).

- **Little Dolores River Fault (2251)**

The Little Dolores River fault extends from Utah into Colorado on the northeast flank of the Uncompahgre uplift. Evidence for Quaternary movement on this fault was cited in Witkind (1976) based on personal communication with Fred Cater. Based on the timing of abandonment of Unaweep Canyon, Cater (1966) indicated uplift of the Uncompahgre Plateau began in the mid-Pliocene and continued into the Pleistocene, resulting in as much as 640 meters of differential uplift. Despite the lack of evidence of faulted Quaternary deposits along the Little Dolores River fault, it has been classified as a Quaternary fault (Howard and others 1978; Kirkham and Rogers 1981; Colman 1985), and no references have been published that refute this age assignment. Timing of most recent paleoevent is Quaternary (<1.6 Ma). Despite a lack of evidence for offset in Quaternary deposits, faults associated with the Uncompahgre uplift are often considered to have experienced Quaternary movement. The slip-rate category is unknown, but likely <0.2 mm/yr. The length of fault is 16 km (Black and others 2003).

- **Sand Flat Graben Faults (2475)**

The Sand Flat graben faults include the northern graben-bounding fault (Dry Gulch fault) and subsidiary within the Sand Flat graben. The southern graben-bounding fault is included in the discussion of the Ryan Creek fault zone (2263). The faults are west- to northwest-trending within the Sand Flat graben along the southwestern margin of the Uncompahgre uplift northeast of the Paradox Basin. The Uncompahgre uplift is a northwest-trending, east-tilted fault block. The Uinta Basin borders the northwest end of the uplift. Faults are part of a regional zone of northwest- to west-trending normal faults along the Utah-Colorado border, within a monoclinal flexure that forms the southwest margin of the Uncompahgre uplift. Different movement histories and cumulative Quaternary displacements have been inferred for the fault zone based on studies of the canyon and related drainage changes, but most studies suggest that differential uplift has continued into the early or late Pleistocene. Diversion of drainage, which followed impoundment and formation of a lake, occurred ~775 ka (Perry and Annis 1990). Timing of most recent paleoevent is Quaternary (<1.6 Ma). The slip rate is unknown, but is likely <0.2 mm/yr. The fault length is 23 km.

- **Ryan Creek Fault Zone (2263)**

The Ryan Creek fault zone trends east-west along the southwestern margin of the Uncompahgre uplift. About half of the fault length is in Utah. The fault extends east into Colorado from the flank of Haystack Peaks parallel to Ryan Gulch, and then bends southeast toward Unaweep Canyon. Individual faults in the fault zone form the southern margin of the Sand Flat graben in Utah and the northeast margin of the Ute Creek graben in Colorado. The Ryan Creek fault zone lies on the southwestern margin of the Uncompahgre uplift along the Utah-Colorado border. Evidence for Quaternary movement on this fault zone is cited in Witkind (1976) based on personal communication with Fred Cater. Cater (1966) indicated uplift of the Uncompahgre Plateau began in the mid-Pliocene and continued into the Pleistocene, resulting in as much as 640 meters of differential uplift. Despite the lack of evidence of faulted Quaternary deposits along the Ryan Creek fault zone, it has been classified as a Quaternary fault (Howard and others 1978; Kirkham and Rogers 1981; Colman 1985), and no references have been published that refute this age assignment. Timing of most recent paleoevent is Quaternary (<1.6 Ma). A small earthquake (ML 2.9) and several aftershocks in 1985 may have occurred on the Ryan Creek fault zone (Ely and others 1986). The slip-rate is unknown, but is likely <0.2 mm/yr. The fault length is 39 km. (Black and others 2003).

- **Granite Creek Fault Zone (2265)**

The Granite Creek fault zone is a northwest-trending fault zone, which extends from Utah into Colorado north of Steamboat Mesa on the southwest flank of the Uncompahgre uplift. Williams (1964) mapped Quaternary deposits as both concealing and abutting the fault. Cater (1966) indicated uplift of the Uncompahgre Plateau began in the mid-Pliocene and continued into the Pleistocene, resulting in as much as 640 meters of differential uplift. Despite the lack of evidence of faulted Quaternary deposits along the Granite Creek fault zone, it has been classified as a Quaternary fault (Kirkham and Rogers 1981; Colman 1985), and no references have been published that refute this age assignment. The Granite Creek fault zone consists of high-angle normal faults that are mostly down-to-the-northeast. The fault lies in a tectonically weakened area above the ancestral Uncompahgre fault zone (Stone 1977). Geomorphic indicators of youthful faulting have not been reported.

Timing of most recent paleoevent is Quaternary (<1.6 Ma). Offset of Quaternary deposits is inconclusive since Williams (1964) showed Quaternary deposits as abutting against the fault and concealing the fault. However, faults associated with the Uncompahgre uplift are often considered to have experienced Quaternary movement. Based on the timing of abandonment of Unaweep Canyon, Cater (1966) indicated uplift of the Uncompahgre Plateau began in the mid-Pliocene and continued into the Pleistocene, resulting in as much as 640 meters of differential uplift. The slip-rate category is unknown, but is likely <0.2 mm/yr. The fault length is 23 km.

- **Fisher Valley Faults (2478)**

The Fisher Valley faults are a result of late Quaternary folding and warping in Fisher Valley from salt dissolution and collapse. Fisher Valley is on the crest of a long anticlinal structure that includes Salt and Cache Valleys in Utah and Sinbad and Roc Creek Valleys in Colorado. The valley formed from collapse of the anticline (Onion Creek diapir) due to salt dissolution. The faults border and define Fisher Valley. Formation of the valley by collapse of the anticline beheaded streams whose broad shallow channels are preserved on the valley rim. Upper Cenozoic deposits, by far the thickest sequence in the Paradox basin (>125 meters thick), have ages between >2.5 Ma (based on paleomagnetic analysis) and about 250 ka (based on secondary carbonate accumulation rates) and record episodic deformation from movements of the Onion Creek salt diapir and basin subsidence (resulting from salt flowage into the diapir and/or salt dissolution and collapse). Timing of most recent paleoevent is Quaternary (<1.6 Ma), based on tephrachronology, soil development, and stream dissection rate. Young basin fill deposits demonstrating recent movement are absent, but evidence for rapid incision (3 millimeters/year based on 14C dates), and steep, unstable slopes where Onion Creek cuts through the cap rock, suggest that the diapir may be presently active. The slip rate is unknown, but is likely <0.2 mm/yr. The fault length is 16 km. (Black and others 2003).

Historical Earthquakes

Instrumentally and historically recorded earthquakes within a study area of 200 miles around the site were documented using the National Earthquake Information Center (NEIC) website (NEIC 2005). Databases searched included USGS/NEIC Preliminary Determinations of Epicenters (PDE) monthly listing, weekly listings (PDE-W), daily listings (PDE-Q), Significant U.S. Earthquakes (USHIS), and Eastern, Central, and Mountain States of the United States (SRA). The earthquakes are shown graphically in Figure 4 and also in table form in Appendix B.

Maximum Credible Earthquakes

A study by Kirkham and Rogers (1981) estimated the maximum credible earthquakes of tectonic provinces within the state of Colorado. In addition, the RAP for the Grand Junction/Cheney disposal site (DOE 1991b) estimated maximum earthquakes associated with regional tectonic provinces. Table 1 summarizes these estimates for the provinces within this study region.

Table 1. Estimate of Maximum Credible Earthquakes Associated with Tectonic Provinces

Tectonic Province	Maximum Credible Earthquake (MCE)	
	Kirkham and Rogers (1981)	DOE (1991b)
Rio Grande Rift	6 to 7.5	6.5 to 7.5
Eastern Mountain	6 to 6.75	
Western Mountain	6 to 6.5	
Colorado Plateau	5.5 to 6.5	6.5
Paradox Basin		4 to 5
Intermountain Seismic Belt		7.0-7.9
Wyoming Basin		5.7 to 6.5

Peak Ground Accelerations

A contour map for peak horizontal acceleration in rock with 90 percent probability to not being exceeded in 50 years is presented for the contiguous United States by Algermissen and others (1990), showing the site to have a peak horizontal acceleration of 0.025g. Contour maps developed for the National Seismic Hazard Mapping Project (Frankel and others 2002a and 2002b) show the peak acceleration to be 0.045 g with a 10 percent probability of exceedance in 50 years, and 0.12 g with a 2 percent probability of exceedance in 50 years.

Halling et al. (2002) developed peak acceleration maps for the state of Utah. In this study, the maximum credible earthquakes for all known or suspected Quaternary faults in the state were calculated using relationships developed by Wells and Coppersmith (1994). Ground motion was attenuated across the state using three different attenuation relationships. Contours of peak horizontal bedrock accelerations were developed. The peak ground acceleration for the Crescent Junction site was estimated to be between 0.41 and 0.60 g. These ground accelerations were predominately influenced by predicted ground motion from the Salt and Cache Valley faults.

For comparison purposes only, the peak ground accelerations determined for the UMTRA sites at Green River and Grand Junction/Cheney disposal site were investigated. The seismotectonic stability study performed for the Green River disposal site recommended the design acceleration based on a floating earthquake of magnitude (ML) 6.2 occurring 15 km (9.5 miles) from the site, resulting in a peak ground acceleration of 0.21 g.

Seismotectonic stability studies done for the Grand Junction mill tailings/Cheney disposal site identified a fault with a length of 11.0 km and a distance of 9.0 km from the site. Although no evidence of Quaternary displacement was proven, it was considered to be capable on the basis of its apparent association with a possibly active regional structure, the Uncompahgre Uplift. This fault was adopted as the design fault for the Cheney disposal site, resulting in a recommended design acceleration of 0.42 g.

Conclusion and Recommendations:

Determination of the suitability of the Crescent Junction disposal site as the repository for the Moab uranium mill tailings material, and development of the site and regional seismotectonic sections of the RAP requires a thorough review of available literature that applies to the Crescent Junction site. The results of this review indicate that there are nine Quaternary fault systems within 40 miles of the site that have been numbered using the identification system in the USGS database. The closest fault systems to the Crescent Junction Site are the Salt Valley and Cache Valley Faults (2474). However, these faults appear related to dissolution and collapse of the Salt Valley anticline in eastern Utah, north of Moab. Timing of most recent paleoevent is Quaternary (<1.6 Ma). The slip rate is unknown, but is likely to be <0.2 mm/yr. The length of the fault is 58 km (Black and others 2003). Further analysis of the faults, and historical earthquake events will be performed in additional calculation sets to determine the maximum credible earthquake and associated ground accelerations.

Computer Source:

Not applicable.

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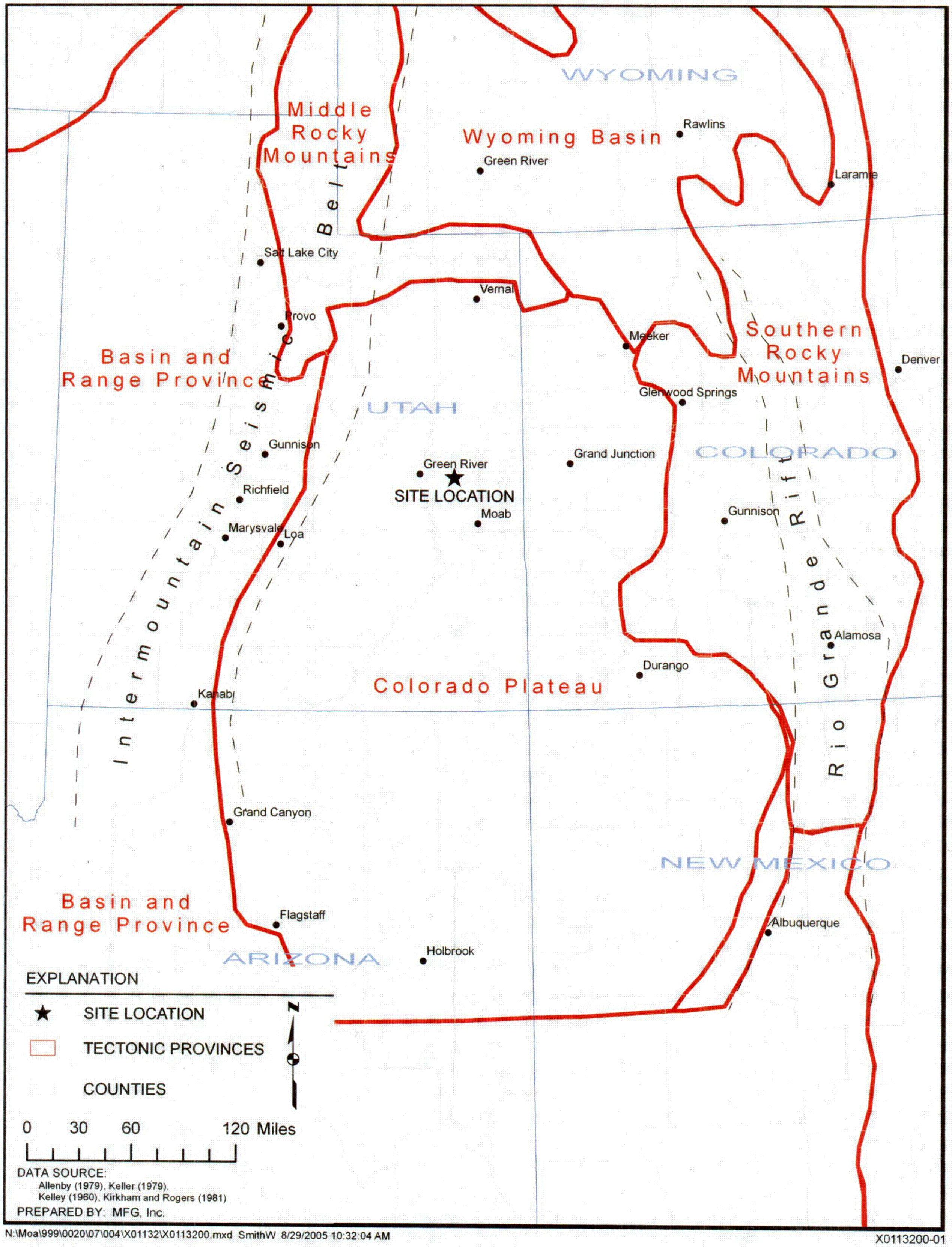

Figure 1. Regional Tectonic Provinces

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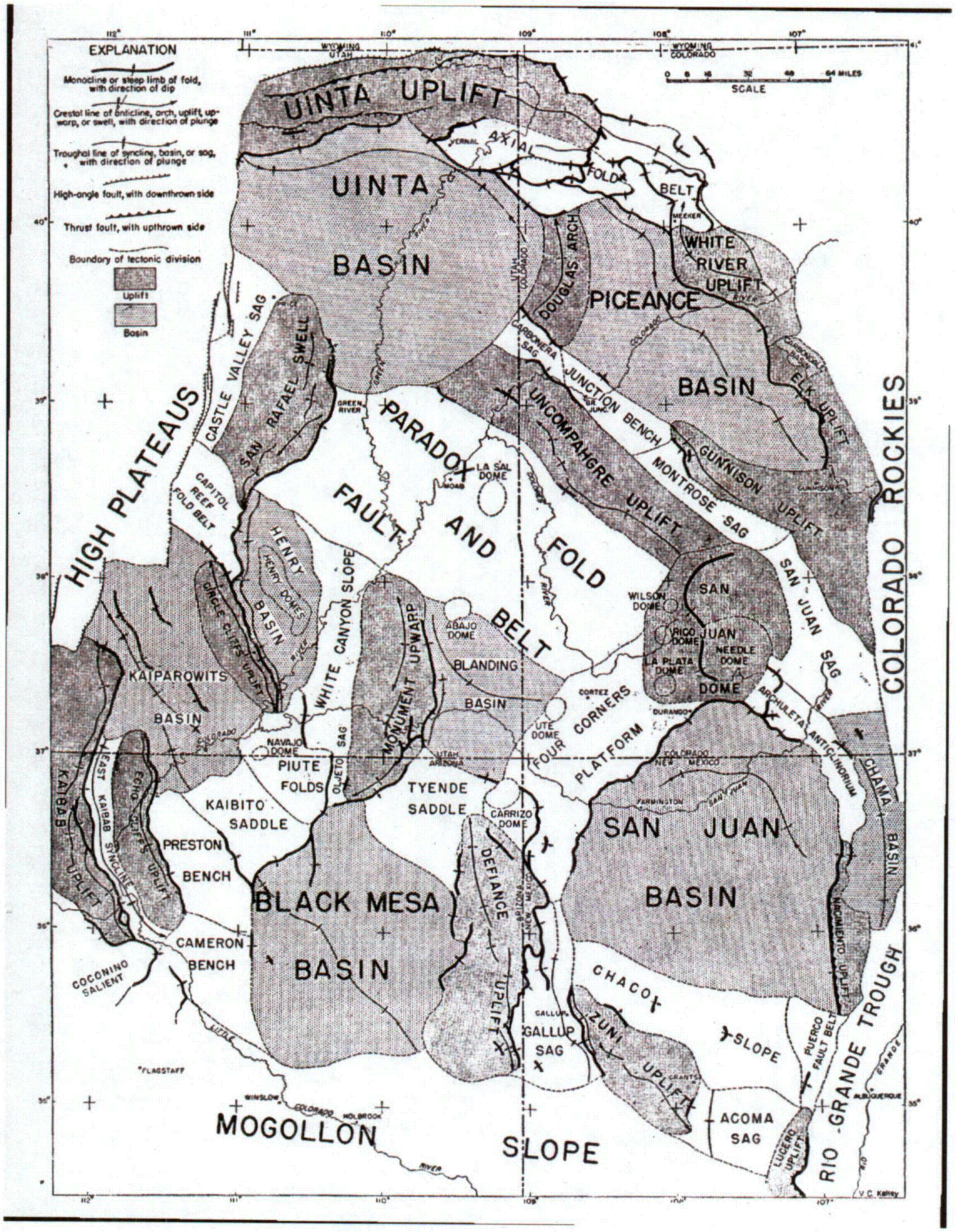

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Figure 2. Tectonic Sub-Provinces of the Colorado Plateau

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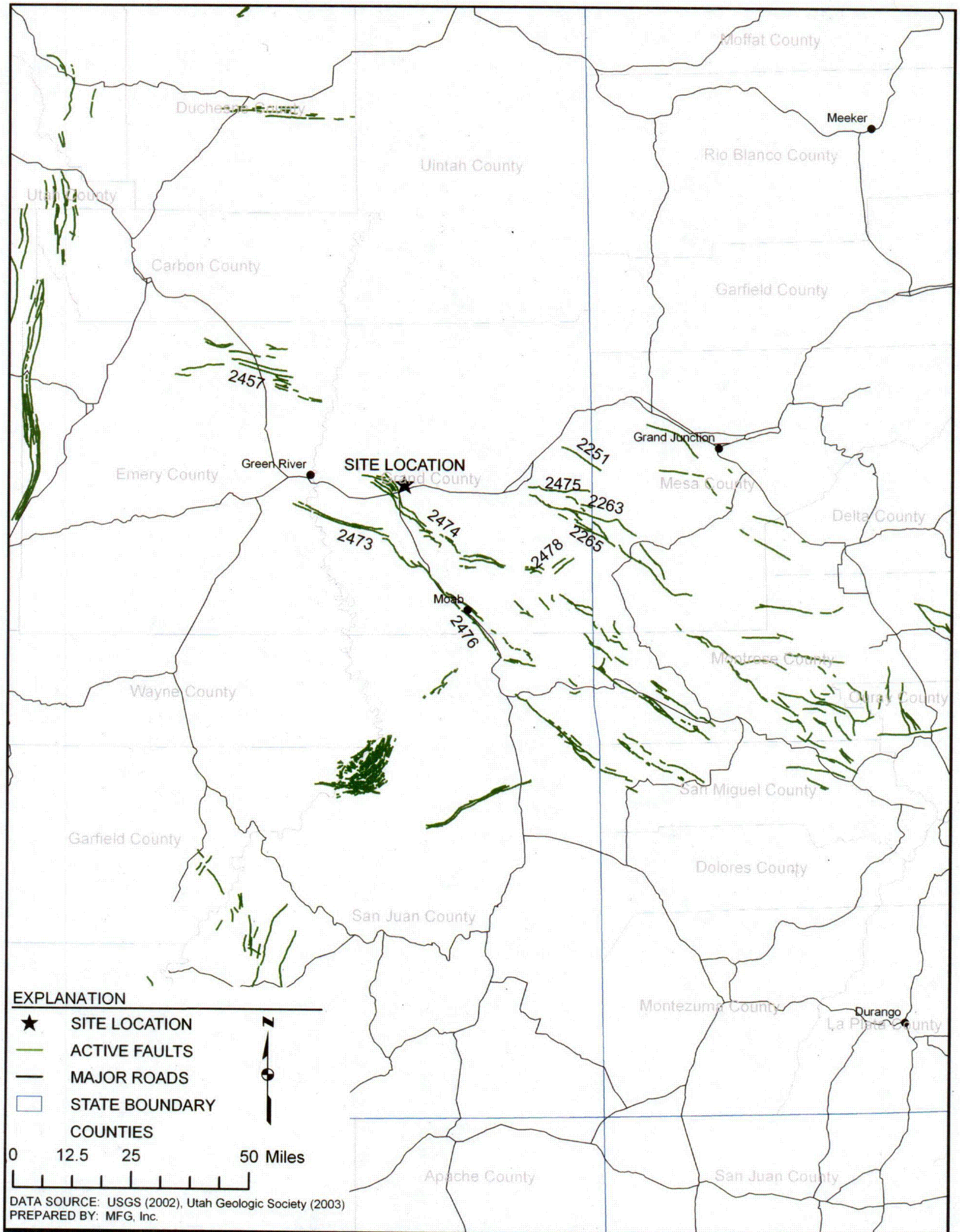

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Figure 3. Quaternary Faults Within Region

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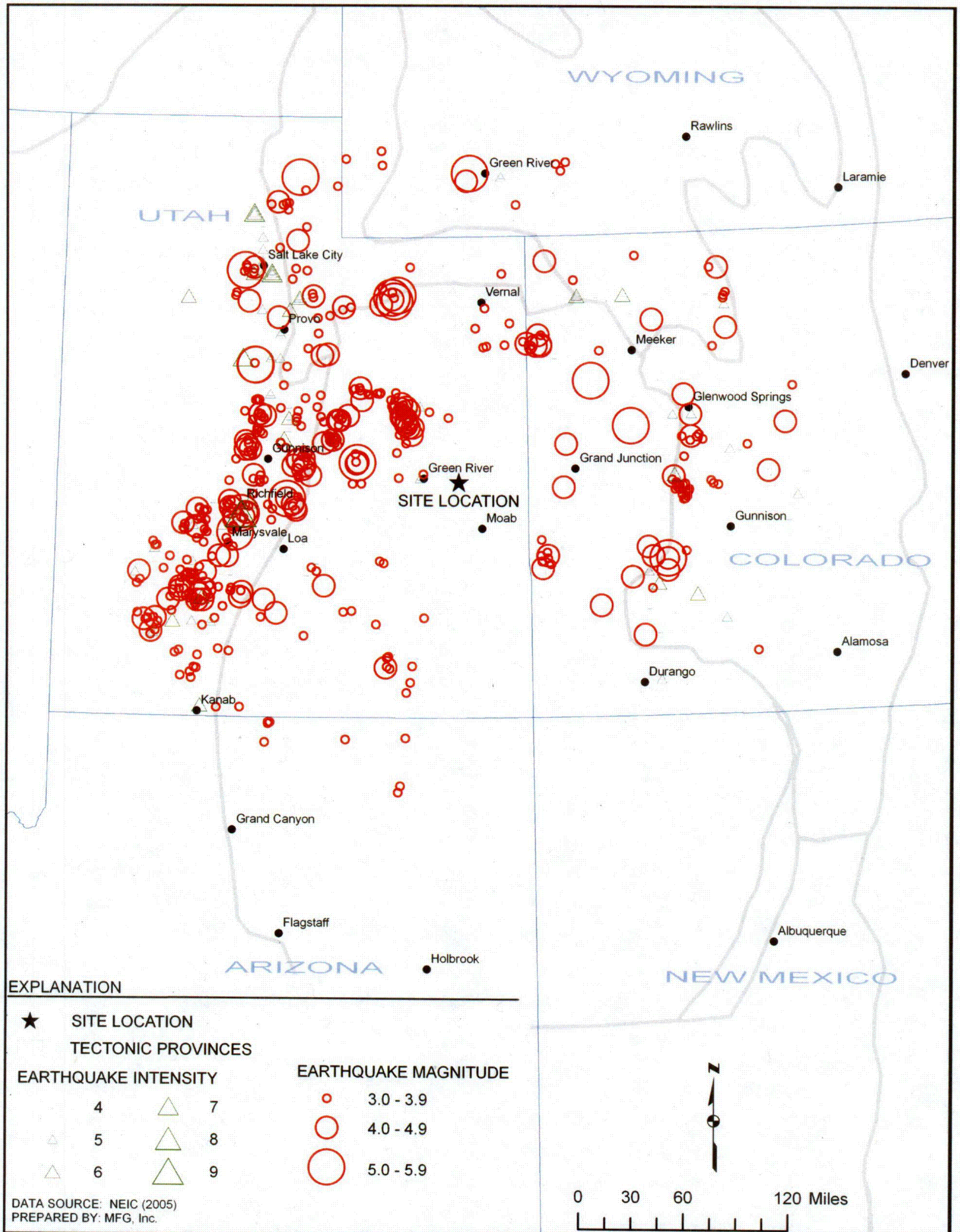

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Figure 4. Historical Earthquakes Within Region

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QUATERNARY FAULTS WITHIN EXPANDED SITE REGION

NAME	WWWURL	NUM	ACODE	AGE	RATE	Length (km)	Fault Type	distance from site (miles)
Salt and Cache Valleys faults (Class B)	33791	2474	6	Class B	<0.2	57.9	N	1.77
Ten Mile graben?faults (Class B)	33790	2473	6	Class B	<0.2	34.6	N	10.47
Moab fault and Spanish Valley faults (Class B)	33792	2476	6	Class B	<0.2	72.4	N	12.5
Price River area faults (Class B)	33788	2457	5	<1,600,000	<0.2	50.9	N	24.81
Ryan Creek fault zone	33670	2263	5	<1,600,000	<0.2	39.5	N	26.61
Sand Flat graben faults	33945	2475	5	<1,600,000	<0.2	23.1	N	26.39
Granite Creek fault zone	33672	2265	5	<1,600,000	<0.2	22.7	N	33.41
Paradox Valley graben (Class B)	33668	2286	5	<1,600,000	<0.2	56.4	N	49.63
Sinbad Valley graben (Class B)	33724	2285	5	<1,600,000	<0.2	31.8		39.31
Fisher Valley faults (Class B)	33794	2478	6	Class B	<0.2	15.9		30.95
Little Doloras River fault	33664	2251	5	<1,600,000	<0.2	15.7	R	34.52
Lisbon Valley fault zone (Class B)	33801	2511	5	<1,600,000	<0.2	37.5		50.9
Unnamed fault near Pine Mountain	32966	2267	5	<1,600,000	<0.2	30.7		47.15
Castle Valley faults (Class B)	33793	2477	6	Class B	<0.2	12.4		34.15
Bright Angel fault system (Class B)	33804	2514	5	<1,600,000	<0.2	102.3		89.57
Wasatch monocline (Class B)	33787	2450	5	<1,600,000	<0.2	103.5	?	90.31
Lockhart fault (Class B)	34080	2510	6	Class B	<0.2	15.7		40.78
Duchesne-Pleasant Valley fault system (Class B)	33782	2414	5	<1,600,000	<0.2	45.3	N	79.08
Needles fault zone (Class B)	33799	2507	6	Class B	<0.2	28.5		53.85
Joes Valley fault zone, east fault	33932	2455	2	<15,000	0.2-1	56.6		78.95
Shay graben faults (Class B)	33803	2513	6	Class B	<0.2	39.5		68.08
Joes Valley fault zone, west fault	33930	2453	2	<15,000	0.2-1	57.2		81.05
Redlands fault complex	32952	2252	5	<1,600,000	<0.2	21.1	N,R	53.07
Southern Joes Valley fault zone	33933	2456	4	<750,000	<0.2	47.2		77.22
Pleasant Valley fault zone, unnamed faults	33906	2425	5	<1,600,000	<0.2	31	N	86.06
Big Gypsum Valley graben (Class B)	32989	2288	6	Class B	<0.2	33.1		70.85
Unnamed fault of Lost Horse Basin	32963	2264	5	<1,600,000	<0.2	8.1		40.8
Gunnison fault	33785	2445	2	<15,000	<0.2	42	N	104.31
Joes Valley fault zone, intragraben faults	33931	2454	2	<15,000	<0.2	34		82.86
Monitor Creek fault	32967	2268	5	<1,600,000	<0.2	30.1		79.1
Thousand Lake fault	33962	2506	4	<750,000	<0.2	48.3		97.23
Sevier fault	33824	2355	5	<1,600,000	<0.2	41.3	N	126.42
Wasatch fault zone, Provo section	33763	2351g	2	<15,000	1-5	58.8		122.17
Unnamed faults near San Miguel Canyon (Class B)	32985	2284	6	Class B	<0.2	32.1		94.54
Unnamed faults of Pinto Mesa	32977	2277	5	<1,600,000	<0.2	19.7		78.35
Snow Lake graben	33929	2452	2	<15,000	<0.2	25.4		89.7
Sevier/Toroweap fault zone, Sevier section	33578	997a	3	<130,000	0.2-1	88.7		155.4
Unnamed faults south of Love Mesa	32970	2271	5	<1,600,000	<0.2	17.6		78.78
Unnamed fault at Red Canyon	32979	2279	5	<1,600,000	<0.2	24.2		90.94
Paunsaugunt fault	33960	2504	5	<1,600,000	<0.2	44.1		117.96
Red Rocks fault	32991	2291	5	<1,600,000	<0.2	38.3		111.79
Aquarius and Awapa Plateaus faults	33961	2505	5	<1,600,000	<0.2	35.7		108.63
Valley Mountains monocline (Class B)	33786	2449	5	<1,600,000	<0.2	38.6		112.9
Wasatch fault zone, Nephi section	33764	2351h	2	<15,000	1-5	43.1		119.91
West Kaibab fault system	33121	994	5	<1,600,000	<0.2	82.9	N	187.66
Roubideau Creek fault	32969	2270	2	<15,000	<0.2	20.5		88.7
Gooseberry graben faults	33905	2424	4	<750,000	<0.2	22.6		93.11
Pleasant Valley fault zone, graben	33907	2426	4	<750,000	<0.2	17.6		88.33
Central Kaibab fault system	33120	993	5	<1,600,000	<0.2	71.5	N	192.34
White Mountain area faults	33928	2451	5	<1,600,000	<0.2	16.4		90.5
Cannibal fault	33608	2337	3	<130,000	<0.2	49.3		148.93
East Tintic Mountains (west side) faults	33902	2420	4	<750,000	<0.2	33.1		129.63
Unnamed fault at Hanks Creek	32982	2281	5	<1,600,000	<0.2	17.5		98.96
Sevier Valley-Marysvale-Circleville area faults	33956	2500	4	<750,000	<0.2	34.9		133.72
Frontal fault	33000	2302	3	<130,000	0.2-1	75	N,R	190.08
Hogsback fault, southern section	34045	732b	3	<130,000	1-5	38.3		144.27
Sevier/Toroweap fault zone, northern Toroweap sectio	33579	997b	3	<130,000	<0.2	80.9		198.51
Bear River fault zone	33992	730	2	<15,000	0.2-1	33.2		140.36
Gallina fault	32810	2001	5	<1,600,000	<0.2	39.3		
Canones fault (Class B)	32812	2003	5	<1,600,000	<0.2	29.4		
Lobato Mesa fault zone	32813	2004	5	<1,600,000	<0.2	21.3		
La Canada del Amagre fault zone	32816	2005	5	<1,600,000	<0.2	17.2		
Black Mesa fault zone	32817	2006	5	<1,600,000	<0.2	18.5		
Pajarito fault	32818	2008	3	<130,000	<0.2	49.4		
Puye fault	32819	2009	3	<130,000	<0.2	16.7		
Pojoaque fault zone	32820	2010	5	<1,600,000	<0.2	46.5		
Sunshine Valley faults	32826	2016	3	<130,000	<0.2	14.1		

NAME	WWWURL	NUM	ACODE	AGE	RATE	Length (km)	Fault Type	distance from site (miles)
Red River fault zone	32828	2019	5	<1,600,000	<0.2	10		
Las Tablas fault	32829	2020	5	<1,600,000	<0.2	14.8		
Strong fault	32830	2021	5	<1,600,000	<0.2	8.1		
Los Cordovas faults	32831	2022	5	<1,600,000	<0.2	12.2		
Picuris-Pecos fault	32832	2023	5	<1,600,000	<0.2	98.2	N	
Nambe fault	32833	2024	5	<1,600,000	<0.2	47.8		
Rendija Canyon fault	32835	2026	3	<130,000	<0.2	11.1		
Guaje Mountain fault	32836	2027	2	<15,000	<0.2	10.7		
Sawyer Canyon fault	32837	2028	3	<130,000	<0.2	8.4		
San Francisco fault	32840	2031	5	<1,600,000	<0.2	25.7		
La Bajada fault	32841	2032	5	<1,600,000	<0.2	40.3		
Calabacillas fault	32843	2035	4	<750,000	<0.2	31.3		
County Dump fault	32846	2038	5	<1,600,000	<0.2	35.3		
Sand Hill fault zone	32847	2039	5	<1,600,000	<0.2	35.6		
Unnamed faults near Picuda Peak	32849	2041	5	<1,600,000	<0.2	10.6		
Faults north of Placitas	32851	2043	4	<750,000	<0.2	10.5		
Unnamed faults near Loma Barbon	32853	2045	5	<1,600,000	<0.2	1.2		
Zia fault	32854	2046	4	<750,000	<0.2	32.4		
Faults near of Cochiti Pueblo	32943	2142	5	<1,600,000	<0.2	32.2		
Glade Park fault	32954	2254	5	<1,600,000	<0.2	9.4	R	
Ladder Creek fault	32955	2255	5	<1,600,000	<0.2	6.2		
Bangs Canyon fault	32956	2256	5	<1,600,000	<0.2	6.3		
Unnamed fault east of Whitewater	32957	2257	5	<1,600,000	<0.2	1.9		
Cactus Park fault	32958	2258	5	<1,600,000	<0.2	1.9		
Unnamed fault near Bridgeport	32959	2259	5	<1,600,000	<0.2	11		
Unnamed fault at Big Dominquez Creek	32960	2260	5	<1,600,000	<0.2	3.9		
Unnamed fault at Little Dominquez Creek	32961	2261	5	<1,600,000	<0.2	14.2		
Unnamed fault near Wolf Hill	32965	2266	5	<1,600,000	<0.2	15.2		
Unnamed faults east of Atkinson Masa	32968	2269	5	<1,600,000	<0.2	41.1	N	
Unnamed faults east of Roubideau Creek (Class B)	32971	2272	6	Class B	<0.2	11.7		
Unnamed faults southeast of Montrose (Class B)	32972	2273	6	Class B	<0.2	9.2		
Busted Boiler fault	32973	2274	3	<130,000	<0.2	18		
Log Hill Mesa graben	32975	2275	3	<130,000	<0.2	9.5		
Ridgway fault	32976	2276	5	<1,600,000	<0.2	23.8		
Unnamed faults near Cottonwood Creek	32978	2278	5	<1,600,000	<0.2	10.8		
Unnamed fault north of Horsefly Creek	32980	2280	5	<1,600,000	<0.2	8.1		
Unnamed fault near Johnson Spring	32983	2282	5	<1,600,000	<0.2	7.1		
Unnamed faults at Clay Creek	32984	2283	5	<1,600,000	<0.2	9.2		
Unnamed fault at northwest end of Paradox Valley (Cla	32988	2287	6	Class B	<0.2	5.1		
Doloras fault zone (Class B)	32990	2289	6	Class B	<0.2	15.2		
Unnamed fault along Grand Hogback monocline (Class	32992	2292	6	Class B	<0.2	2.4		
Unnamed faults near Burns (Class B)	32993	2296	6	Class B	<0.2	13.3		
Greenhorn Mountain fault (Class B)	32995	2297	6	Class B	<0.2	21.5		
Unnamed faults of Red Hill (Class B)	32996	2298	6	Class B	<0.2	6.1		
Basalt Mountain fault (Class B)	32997	2299	6	Class B	<0.2	7		
Unnamed faults in Williams Fork Valley	32998	2300	4	<750,000	<0.2	18.4		
Williams Fork Mountains fault	32999	2301	2	<15,000	0.2-1	37.7		
Mosquito fault	33001	2303	3	<130,000	<0.2	51.5		
Unnamed faults south of Leadville	33002	2305	5	<1,600,000	<0.2	12.8		
Unnamed faults northwest of Leadville	33003	2306	5	<1,600,000	<0.2	18.8		
Unnamed faults near Twin Lakes Reservoir	33004	2307	5	<1,600,000	<0.2	14		
Unnamed fault west of Buena Vista	33005	2310	5	<1,600,000	<0.2	2.7		
Unnamed fault south of Shavano Peak	33006	2311	5	<1,600,000	<0.2	5.8		
Unnamed fault of Missouri Peak	33007	2312	3	<130,000	<0.2	5.9		
Western Boundary fault	33008	2313	5	<1,600,000	<0.2	20.1		
Lucky Boy fault	33009	2314	5	<1,600,000	<0.2	11.1		
Faults near Monte Vista	33010	2315	5	<1,600,000	<0.2	16.2		
West-Side Chase Gulch fault	33011	2316	3	<130,000	<0.2	2.7		
East-Side Chase Gulch fault	33012	2317	3	<130,000	<0.2	30.7		
Eleven Mile fault	33013	2318	3	<130,000	<0.2	4.7		
Villa Grove fault zone	33014	2319	2	<15,000	<0.2	19		
Mineral Hot Springs fault	33015	2320	3	<130,000	<0.2	7.8		
Faults of the northern Basaltic Hills	33016	2322	5	<1,600,000	<0.2	12.6		
Faults near Garcia	33017	2323	3	<130,000	<0.2	3.4		
Unnamed fault near Escalante	33026	2262	5	<1,600,000	<0.2	1.6		
Unnamed faults along the Grand Hogback monocline n	33027	2294	6	Class B	<0.2	2.5		
Unnamed faults along the Grand Hogback monocline n	33028	2295	6	Class B	<0.2	5.7		
Northern Boundary fault system	33029	2309	4	<750,000	<0.2	49		
Sunshine faults	33030	1000	3	<130,000	<0.2	29.2	N	

NAME	WWWURL	NUM	ACODE	AGE	RATE	Length (km)	Fault Type	distance from site (miles)
Gyp Pocket graben and faults	33031	1001	3	<130,000	<0.2	11.8	N	
Main Street fault zone	33032	1002	3	<130,000	<0.2	87.3	N	
Dutchman Draw fault	33033	1003	3	<130,000	<0.2	16.3	N	
Grand Wash fault zone	33035	1005	3	<130,000	<0.2	34.9	N	
Wheeler fault zone and graben	33036	1006	4	<750,000	<0.2	45.3		
Mesquite fault	33038	1007	3	<130,000	<0.2	36.2		
Littlefield Mesa faults	33039	1008	4	<750,000	<0.2	21.2		
Uinkaret Volcanic field faults	33043	1012	5	<1,600,000	<0.2	18.5		
Andrus Canyon fault	33044	1013	5	<1,600,000	<0.2	5.6		
Leupp faults	33048	1017	4	<750,000	<0.2	32.2		
Gray Mountain faults	33049	1018	5	<1,600,000	<0.2	23.6		
Arrowhead fault zone	33080	953	3	<130,000	<0.2	5.2		
Babbitt Lake fault zone	33081	954	4	<750,000	<0.2	7.6		
Black Point/Doney Mountain fault zone	33084	957	4	<750,000	<0.2	23.8	N	
SP fault zone	33085	958	3	<130,000	<0.2	12.5		
Campbell Francis fault zone	33086	959	4	<750,000	<0.2	10.1		
Cedar Ranch fault zone	33088	961	4	<750,000	<0.2	10.2		
Cedar Wash fault zone	33089	962	4	<750,000	<0.2	11.6		
Citadel Ruins fault zone	33090	963	5	<1,600,000	<0.2	4.5		
Deadman Wash faults	33091	964	5	<1,600,000	<0.2	1.8		
Double Top fault zone	33092	965	5	<1,600,000	<0.2	6.1		
Double Knobs fault	33093	966	5	<1,600,000	<0.2	6		
Ebert Tank fault zone	33094	967	4	<750,000	<0.2	3.1		
Hidden Tank fault zone	33097	970	4	<750,000	<0.2	10.2		
Large Whiskers fault zone	33099	972	5	<1,600,000	<0.2	11.6		
Lee Dam faults	33100	973	5	<1,600,000	<0.2	7.6		
Lockwood Canyon fault zone	33101	974	5	<1,600,000	<0.2	20.8		
Malpais Tank faults	33102	975	4	<750,000	<0.2	4.6		
Maverick Butte faults	33103	976	4	<750,000	<0.2	3.7		
Michelbach Tank faults	33105	978	4	<750,000	<0.2	13.4		
Pearl Harbor fault zone	33108	981	5	<1,600,000	<0.2	15.3		
Red House faults	33110	983	4	<750,000	<0.2	3.4		
Rimmy Jim fault zone	33111	984	5	<1,600,000	<0.2	8.2		
Sinagua faults	33113	986	3	<130,000	<0.2	4.9		
Mesa Butte North fault zone	33114	987	5	<1,600,000	<0.2	22.6		
Cameron graben and faults	33115	988	4	<750,000	<0.2	10.8		
Shadow Mountain grabens	33116	989	4	<750,000	<0.2	10.4		
Cataract Creek fault zone	33117	990	5	<1,600,000	<0.2	51.1	N	
Bright Angel fault zone	33118	991	5	<1,600,000	<0.2	66	N	
Eminence fault zone	33119	992	5	<1,600,000	<0.2	36		
Aubrey fault zone	33122	995	3	<130,000	<0.2	53.1		
Yampai graben	33123	996	5	<1,600,000	<0.2	6.9		
Sunshine Trail graben and faults	33124	999	3	<130,000	<0.2	17	N	
Washington fault zone, northern section	33143	1004a	2	<15,000	<0.2	36.2	N	
Washington fault zone, Mokaac section	33144	1004b	3	<130,000	<0.2	11.2	N	
Washington fault zone, Sullivan Draw section	33145	1004c	3	<130,000	<0.2	34.5	N	
Hurricane fault zone, Anderson Junction section	33154	998c	2	<15,000	0.2-1	42.2		
Hurricane fault zone, Shivwitz section	33155	998d	3	<130,000	<0.2	56.5	N	
Hurricane fault zone, Whitmore Canyon section	33156	998e	2	<15,000	<0.2	28.5		
Hurricane fault zone, southern section	33157	998f	5	<1,600,000	<0.2	66.6	N	
Nacimiento fault, northern section	33184	2002a	5	<1,600,000	<0.2	35.9		
Nacimiento fault, southern section	33185	2002b	5	<1,600,000	<0.2	45.2		
Embudo fault, Pilar section	33186	2007a	3	<130,000	<0.2	38.7		
Embudo fault, Hernandez section	33187	2007b	5	<1,600,000	<0.2	31.6		
Southern Sangre de Cristo fault zone, San Pedro secti	33188	2017a	3	<130,000	<0.2	24.4		
Southern Sangre de Cristo fault, Urraca section	33189	2017b	2	<15,000	<0.2	21.9		
Southern Sangre de Cristo fault, Questa section	33190	2017c	2	<15,000	<0.2	17.8		
Southern Sangre de Cristo fault, Hondo section	33191	2017d	2	<15,000	<0.2	22.2		
Southern Sangre de Cristo fault, Ca±on section	33192	2017e	2	<15,000	<0.2	15.2		
Jemez-San Ysidro fault, Jemez section	33193	2029a	5	<1,600,000	<0.2	24.1		
Jemez-San Ysidro fault, San Ysidro section	33194	2029b	5	<1,600,000	<0.2	30.1		
San Felipe fault, Santa Ana section	33195	2030a	5	<1,600,000	<0.2	43.8		
San Felipe fault, Algodones section	33196	2030b	5	<1,600,000	<0.2	15.9		
Tijeras-Ca±oncito fault system, Galisteo section	33197	2033a	5	<1,600,000	<0.2	37.1		
Unnamed faults of Jemez Mountains, Valles caldera se	33222	2143a	5	<1,600,000	<0.2	16.7		
Unnamed faults of Jemez Mountains, Toledo caldera s	33223	2143b	5	<1,600,000	<0.2	10.9		
Unnamed faults of Jemez Mountains, caldera margin s	33224	2143c	4	<750,000	<0.2	20.3		
Unnamed faults of Jemez Mountains, intracaldera secti	33225	2143d	5	<1,600,000	<0.2	11.3	N	
Mesita fault	33233	2015	3	<130,000	<0.2	27.9		

NAME	WWWURL	NUM	ACODE	AGE	RATE	Length (km)	Fault Type	distance from site (miles)
Strawberry fault	33571	2412	2	<15,000	<0.2	31.9		
Morgan fault, northern section	33573	2353a	4	<750,000	<0.2	7.9		
Morgan fault, central section	33574	2353b	2	<15,000	<0.2	4.9		
Morgan fault, southern section	33575	2353c	4	<750,000	<0.2	2.3		
Hurricane fault zone, Ash Creek section	33577	998b	2	<15,000	<0.2	32		
Sevier/Toroweap fault zone, central Toroweap section	33580	997c	2	<15,000	<0.2	60.4	N	
Sevier/Toroweap fault zone, southern Toroweap sectio	33581	997d	4	<750,000	<0.2	18.8		
Cimmarron fault, Bostwick Park section (Class B)	33585	2290a	6	Class B	<0.2	11.2		
Sawatch fault, northern section	33586	2308a	3	<130,000	<0.2	34		
Sawatch fault, southern section	33587	2308b	2	<15,000	<0.2	41.1		
Northern Sangre de Cristo fault, Crestone section	33588	2321a	2	<15,000	<0.2	79.1	N	
Northern Sangre de Cristo fault, Zapata section	33589	2321b	2	<15,000	<0.2	25.8		
Northern Sangre de Cristo fault, Blanca section	33590	2321c	2	<15,000	<0.2	6.7		
Northern Sangre de Cristo fault, San Luis section	33591	2321d	2	<15,000	<0.2	59.1	N	
Cimmarron fault, Poverty Mesa section (Class B)	33592	2290b	6	Class B	<0.2	24.1		
Cattle Creek anticline (Class B)	33593	2293	6	Class B	<0.2	8.6		
Unnamed syncline southwest of Carbondale (Class B)	33594	2332	6	Class B	<0.2	3		
Unnamed syncline northeast of Carbondale (Class B)	33595	2333	6	Class B	<0.2	1.5		
Unnamed syncline northwest of Carbondale (Class B)	33596	2334	6	Class B	<0.2	1.9		
Unnamed syncline west of Carbondale (Class B)	33597	2335	6	Class B	<0.2	0.6		
Grand Hogback monocline (Class B)	33598	2331	6	Class B	<0.2	22		
Cimmarron fault, Blue Mesa section	33599	2290c	5	<1,600,000	<0.2	22.5		
Ellison Gulch scarp (Class B)	33604	2304	6	Class B	<0.2	1.2		
Killarney faults	33607	2336	5	<1,600,000	<0.2	5.6		
Porcupine Mountain faults	33636	2380	3	<130,000	<0.2	34.6	N	
Southern Oquirrh Mountains fault zone	33653	2399	3	<130,000	<0.2	24.1		
Mountain Home Range (west side) faults	33720	2480	5	<1,600,000	<0.2	26.4		
Crawford Mountains (west side) fault	33725	2346	3	<130,000	<0.2	25.3		
Wasatch fault zone, City section	33757	2351a	3	<130,000	<0.2	39.6		
Wasatch fault zone, Clarkston Mountain section	33758	2351b	3	<130,000	<0.2	10.4		
Wasatch fault zone, Collinston section	33759	2351c	2	<15,000	<0.2	29.7		
Wasatch fault zone, Brigham City section	33760	2351d	2	<15,000	0.2-1	37.3		
Wasatch fault zone, Weber section	33761	2351e	2	<15,000	1-5	56.2		
Wasatch fault zone, Salt Lake City section	33762	2351f	2	<15,000	1-5	42.5		
Wasatch fault zone, Levan section	33765	2351i	2	<15,000	<0.2	30.1		
Wasatch fault zone, Fayette section	33766	2351j	2	<15,000	<0.2	15.6		
East Cache fault zone, northern section	33767	2352a	4	<750,000	<0.2	25.7		
East Cache fault zone, central section	33768	2352b	2	<15,000	0.2-1	16.5		
East Cache fault zone, southern section	33769	2352c	3	<130,000	<0.2	22.1		
East Great Salt Lake fault zone, Promontory section	33773	2369a	2	<15,000	0.2-1	49.2	N	
East Great Salt Lake fault zone, Fremont Island sectior	33774	2369b	2	<15,000	0.2-1	30.1		
East Great Salt Lake fault zone, Antelope Island sectio	33775	2369c	2	<15,000	0.2-1	35.1		
West Valley fault zone, Taylorsville fault	33776	2386a	2	<15,000	<0.2	15.1	N	
West Valley fault zone, Granger fault	33777	2386b	2	<15,000	0.2-1	16	N	
Beaver Basin faults, eastern margin faults	33778	2492a	2	<15,000	<0.2	34.2		
Beaver Basin faults, intrabasin faults	33779	2492b	2	<15,000	<0.2	38.9		
Lakeside Mountains (west side) fault (Class B)	33780	2384	6	Class B	<0.2	4.7		
Towanta Flat graben (Class B)	33781	2401	4	<750,000	<0.2	5.2		
Juab Valley (west side) faults (Class B)	33783	2423	4	<750,000	<0.2	13.2		
Clear Lake fault zone (Class B)	33784	2436	2	<15,000	<0.2	35.5		
Wah Wah Valley (west side) faults (Class B)	33795	2484	6	Class B	<0.2	2.1		
Escalante Desert faults (Class B)	33796	2488	6	Class B	<0.2	6.6		
Cove Fort fault zone (Class B)	33797	2491	6	Class B	<0.2	22.2		
Buckskin Valley faults (Class B)	33798	2499	6	Class B	<0.2	3.5		
Pine Ridge faults (Class B)	33802	2512	6	Class B	<0.2	5.5		
Bear Lake (west side) fault (Class B)	33805	2531	5	<1,600,000	<0.2	5.5		
Red Hills fault	33806	2532	3	<130,000	<0.2	13.8		
Markagunt Plateau faults (Class B)	33807	2535	4	<750,000	<0.2	56.4		
Sevier Valley faults and folds (Class B)	33808	2537	3	<130,000	<0.2	23.6		
Johns Valley fault (Class B)	33809	2539	6	Class B	<0.2	2.1		
Goose Creek Mountains faults (Class B)	33850	2356	6	Class B	<0.2	4		
Grouse Creek and Dove Creek Mountains faults	33851	2357	4	<750,000	<0.2	47.7		
Hansel Valley fault	33852	2358	1	<150	<0.2	13		
Hansel Mountains (east side) faults	33853	2359	4	<750,000	<0.2	14.7		
Hansel Valley (valley floor) faults	33854	2360	4	<750,000	<0.2	19.5		
North Promontory fault	33855	2361	2	<15,000	<0.2	25.8		
North Promontory Mountains fault	33856	2362	5	<1,600,000	<0.2	6.3		
Blue Springs Hills faults	33857	2363	4	<750,000	<0.2	2.5		
Saleratus Creek fault	33858	2365	4	<750,000	<0.2	37.6		

NAME	WWWURL	NUM	ACODE	AGE	RATE	Length (km)	Fault Type	distance from site (miles)
Big Pass faults	33859	2366	5	<1,600,000	<0.2	17.3		
Dolphin Island fracture zone	33860	2367	4	<750,000	<0.2	19.2		
East Lakeside Mountains fault zone	33861	2368	5	<1,600,000	<0.2	36		
Dayton fault (Class B)	33862	2370	6	Class B	<0.2	16.3		
Eastern Pilot Range fault	33863	2371	5	<1,600,000	<0.2	10.6		
Mantua area faults	33864	2373	4	<750,000	<0.2	21.1		
Hyrum fault	33865	2374	5	<1,600,000	<0.2	3.1		
Ogden Valley southwestern margin faults	33866	2375	4	<750,000	<0.2	17.8		
Ogden Valley North Fork fault	33867	2376	4	<750,000	<0.2	26.1		
Broadmouth Canyon faults	33868	2377	3	<130,000	<0.2	3.4		
James Peak fault	33869	2378	3	<130,000	<0.2	6.3		
Ogden Valley northeastern margin fault	33870	2379	5	<1,600,000	<0.2	12.8		
Silver Island Mountains (west side) fault	33871	2381	5	<1,600,000	<0.2	6.4		
Silver Island Mountains (southeast side) fault	33872	2382	2	<15,000	<0.2	1.8		
Puddle Valley fault zone	33873	2383	2	<15,000	<0.2	6.5		
Sinbad Valley graben (Class B)	33874	2385	5	<1,600,000	<0.2	9.9		
Skull Valley (mid-valley) faults	33875	2387	2	<15,000	<0.2	54.8	N	
Parleys Park faults (Class B)	33876	2388	6	Class B	<0.2	3.4		
Frog Valley fault	33877	2389	5	<1,600,000	<0.2	4.6		
Bald Mountain fault	33878	2390	5	<1,600,000	<0.2	2.3		
East Kamas fault	33879	2391	5	<1,600,000	<0.2	14.6		
Diamond Gulch faults	33880	2393	5	<1,600,000	<0.2	20.2		
Pot Creek faults	33881	2394	5	<1,600,000	<0.2	13.4		
Stansbury fault zone	33882	2395	2	<15,000	<0.2	49.8	N	
Clover fault zone	33883	2396	3	<130,000	<0.2	4		
Saint John Station fault zone	33884	2397	3	<130,000	<0.2	5.2		
Oquirrh fault zone	33885	2398	2	<15,000	<0.2	21.1		
Round Valley faults	33886	2400	4	<750,000	<0.2	12.8	N	
Deep Creek Range (northwest side) fault zone	33888	2403	3	<130,000	<0.2	10.7		
Lookout Pass fault	33889	2404	5	<1,600,000	<0.2	3.9		
Sheeprock fault zone	33890	2405	3	<130,000	<0.2	11.7		
Vernon Hills fault zone	33891	2406	3	<130,000	<0.2	3.7		
Topliff Hill fault zone	33892	2407	3	<130,000	<0.2	19.9		
Cedar Valley (south side) fault	33893	2408	4	<750,000	<0.2	2.8		
Bear River Range faults	33894	2410	5	<1,600,000	<0.2	62.9	N, Dextral	
Little Diamond Creek fault	33895	2411	4	<750,000	<0.2	20		
Stinking Springs fault	33896	2413	3	<130,000	0.2-1	10		
Lime Mountain fault	33897	2415	5	<1,600,000	<0.2	10.6		
Deep Creek Range (east side) faults	33898	2416	4	<750,000	<0.2	20.7		
Fish Springs fault	33899	2417	2	<15,000	<0.2	29.7		
Simpson Mountains faults	33900	2418	4	<750,000	<0.2	10.8		
Sheeprock Mountains fault	33901	2419	5	<1,600,000	<0.2	6.7		
Long Ridge (west side) faults	33903	2421	4	<750,000	<0.2	15.2		
Long Ridge (northwest side) fault	33904	2422	5	<1,600,000	<0.2	20.8		
Pleasant Valley fault zone, Dry Valley graben	33908	2427	4	<750,000	<0.2	12.4		
Snake Valley faults	33909	2428	2	<15,000	<0.2	45.3	N	
Foote Range fault	33910	2429	4	<750,000	<0.2	3.1		
House Range (west side) fault	33911	2430	2	<15,000	<0.2	45.5	N	
Swasey Mountain (east side) faults	33912	2431	4	<750,000	<0.2	3.8		
Drum Mountains fault zone	33913	2432	2	<15,000	<0.2	51.5	N	
Crater Bench faults	33914	2433	2	<15,000	<0.2	15.9		
Cricket Mountains (north end) faults	33915	2434	4	<750,000	<0.2	2.8		
Deseret faults	33916	2435	4	<750,000	<0.2	7.1		
Sugarville area faults	33917	2437	2	<15,000	<0.2	4.3		
Pavant faults	33918	2438	2	<15,000	<0.2	30.1		
Little Valley faults	33919	2439	2	<15,000	<0.2	19.2		
Scipio Valley faults	33920	2440	2	<15,000	<0.2	7.3		
Scipio fault zone	33921	2441	2	<15,000	<0.2	12.5		
Pavant Range fault	33922	2442	2	<15,000	<0.2	14.2		
Maple Grove faults	33923	2443	2	<15,000	<0.2	12.8		
Sage Valley fault	33925	2444	5	<1,600,000	<0.2	10.5		
Japanese and Cal Valleys faults	33926	2447	4	<750,000	<0.2	30.1		
Raft River Mountains fault	33927	2448	4	<750,000	<0.2	1.5		
Little Rough Range faults	33934	2458	4	<750,000	<0.2	3.2		
North of Wah Wah Mountains faults	33935	2459	4	<750,000	<0.2	12.5		
Cricket Mountains (west side) fault	33936	2460	2	<15,000	<0.2	41		
Black Rock area faults	33937	2461	3	<130,000	<0.2	8.2		
Faults of Cove Creek Dome	33938	2462	5	<1,600,000	<0.2	18.8		
Beaver Ridge faults	33939	2464	3	<130,000	<0.2	14.2		

NAME	WWWURL	NUM	ACODE	AGE	RATE	Length (km)	Fault Type	distance from site (miles)
Tabernacle faults	33940	2465	2	<15,000	<0.2	7.9		
Meadow-Hatton area faults	33941	2466	2	<15,000	<0.2	4		
White Sage Flat faults	33942	2467	3	<130,000	<0.2	11.8		
Red Canyon fault scarps	33943	2471	2	<15,000	<0.2	9.4		
Annabella graben faults	33944	2472	2	<15,000	<0.2	12.5		
Pine Valley faults	33946	2481	4	<750,000	<0.2	3.7		
Pine Valley (south end) faults	33947	2482	5	<1,600,000	<0.2	10.7		
Wah Wah Mountains faults	33948	2483	5	<1,600,000	<0.2	53.6		
Wah Wah Mountains (south end near Lund) fault	33949	2485	3	<130,000	<0.2	40.2		
San Francisco Mountains (west side) fault	33950	2486	4	<750,000	<0.2	41.4		
Black Mountains faults	33951	2487	4	<750,000	<0.2	25.9		
Mineral Mountains (west side) faults	33952	2489	2	<15,000	<0.2	36.6		
Mineral Mountains (northeast side) fault (Class B)	33953	2490	6	Class B	<0.2	14.2		
Fremont Wash faults	33954	2495	4	<750,000	<0.2	7.2		
Spry area faults	33955	2498	4	<750,000	<0.2	5.1		
Tushar Mountains (east side) fault	33957	2501	5	<1,600,000	<0.2	18.5		
Sevier Valley fault	33958	2502	5	<1,600,000	<0.2	7.4		
Koosharem fault	33959	2503	5	<1,600,000	<0.2	2.2		
Gunlock fault (Class B)	33963	2515	6	Class B	<0.2	7.5		
Enterprise faults	33964	2516	4	<750,000	<0.2	8.4		
Antelope Range fault	33965	2517	4	<750,000	<0.2	24.5		
Escalante Desert faults near Zane	33966	2518	3	<130,000	<0.2	3.9		
Volcano Mountain faults	33967	2520	4	<750,000	<0.2	2.9		
Cross Hollow Hills faults	33968	2524	5	<1,600,000	<0.2	5.3		
Kolob Terrace faults	33969	2525	4	<750,000	<0.2	12.1		
Escalante Desert (east side) faults	33970	2526	2	<15,000	<0.2	6.4		
Cedar Valley (west side) faults	33971	2527	4	<750,000	<0.2	12.8		
Enoch graben faults	33972	2528	2	<15,000	<0.2	17.2		
Cedar Valley (north end) faults	33973	2529	3	<130,000	<0.2	15.5		
Parowan Valley faults	33974	2533	2	<15,000	<0.2	16.3		
Paragonah fault	33975	2534	3	<130,000	0.2-1	27.2		
Sevier Valley faults north of Panguitch	33976	2536	3	<130,000	<0.2	6.2		
Utah Lake faults	33977	2409	2	<15,000	<0.2	30.8		
Elsinore fault (fold)	33978	2470	5	<1,600,000	<0.2	28.1		
Joseph Flats area faults and syncline (Class B)	33979	2468	6	Class B	<0.2	3.2		
Dry Wash fault and syncline	33981	2496	3	<130,000	<0.2	18.6		
Cedar City-Parowan monocline (and faults)	33982	2530	2	<15,000	<0.2	24.8		
North Hills faults	33983	2522	4	<750,000	<0.2	5		
East Canyon fault, Northern East Canyon section (Clas	33985	2354a	6	Class B	<0.2	22.5		
East Canyon fault, Southern East Canyon section	33986	2354b	4	<750,000	<0.2	8.4		
Rock Creek fault	33991	729	2	<15,000	0.2-1	40.5	N	
Martin Ranch fault	33994	731	2	<15,000	0.2-1	3.7		
Sublette Flat fault	33996	733	4	<750,000	<0.2	36		
Eastern Bear Valley fault (Class B)	33997	734	6	Class B	<0.2	47.2		
Western Bear Valley faults	33998	735	5	<1,600,000	<0.2	12.4		
Elk Mountain fault	33999	736	5	<1,600,000	<0.2	7.8		
North Bridger Creek fault	34000	737	5	<1,600,000	<0.2	4.2		
Spring Creek fault	34001	738	5	<1,600,000	<0.2	2.3		
The Pinnacle fault	34002	739	5	<1,600,000	<0.2	2.3		
Ryckman Creek fault	34003	740	5	<1,600,000	<0.2	5.3		
Whitney Canyon fault	34004	741	2	<15,000	<0.2	5.5		
Almy fault zone	34005	742	5	<1,600,000	<0.2	10.7		
Duncomb Hollow fault	34006	743	5	<1,600,000	<0.2	2.4		
Faults on north flank of Phil Pico Mountains	34007	744	3	<130,000	<0.2	4.4		
Chicken Springs faults	34037	780	2	<15,000	<0.2	13.7		
Hogsback fault, northern section	34044	732a	4	<750,000	0.2-1	22.4		
South Granite Mountains fault system, Seminoe Mount	34071	779e	6	Class B	<0.2	35		
Eastern Bear Lake fault, southern section	34078	2364c	2	<15,000	0.2-1	34.8		
East Canyon (east side) fault (Class B)	34079	2350	5	<1,600,000	<0.2	28.9		
West Cache fault zone, Clarkston fault	34081	2521a	2	<15,000	0.2-1	13		
West Cache fault zone, Junction Hills fault	34082	2521b	2	<15,000	<0.2	24.3		
West Cache fault zone, Wellsville fault	34083	2521c	2	<15,000	<0.2	19.9		
Eastern Bear Lake fault, central section	34106	2364b	2	<15,000	<0.2	23.8		
Hurricane fault zone, Cedar City section	34202	998a	2	<15,000	<0.2	13.2		
Snake Valley fault	34546	1246	2	<15,000	<0.2	41.1		
Unnamed faults on southeast side of Kern Mountains	34550	1256	5	<1,600,000	<0.2	11.4	N	
Southern Snake Range fault zone	34578	1433	3	<130,000	<0.2	27.5	N	
Judd Mountain fault	34616	1597	5	<1,600,000	<0.2	20.4		
Unnamed fault southeast of China Mountain	34617	1598	5	<1,600,000	<0.2	2.9		

NAME	WWWURL	NUM	ACODE	AGE	RATE	Length (km)	Fault Type	distance from site (miles)
Pilot Range faults	34618	1599	5	<1,600,000	<0.2	40.2		
Unnamed fault zone in Ferber Hills	34633	1721	5	<1,600,000	<0.2	37.3		
Overton Arm faults	34733	1119	3	<130,000	<0.2	50.9		
Unnamed fault west of White Rock Mountains	34846	1437	5	<1,600,000	<0.2	27.7		
Curlew Valley faults	35175	3504	2	<15,000	<0.2	20		
Western Bear Lake fault	35194	622	2	<15,000	<0.2	58.2		
Faults in Raft River Valley	35216	3503	4	<750,000	<0.2	35.2		
West Pocatello Valley faults	35218	3506	5	<1,600,000	<0.2	7.7		
East Pocatello valley faults	35219	3507	2	<15,000	<0.2	6.8		
Woodruff fault	35220	3508	5	<1,600,000	<0.2	12.5		
East Dayton-oxford fault	35221	3509	3	<130,000	<0.2	23.2	N	

APPENDIX B

NEIC: Earthquake Search Results

UNITED STATES GEOLOGICAL SURVEY

EARTHQUAKE DATA BASE

This file includes all earthquakes in PDE, SRA, and USHIS databases within 200 miles (320 km) of site with magnitudes greater than or equal to 3.0 and intensities greater than or equal to 3.0.

FILE CREATED: Tue Jul 26 09:46:31 2005
Circle Search Earthquakes= 598
Circle Center Point Latitude: 38.970N Longitude: 109.790W
Radius: 320.000 km
Catalog Used: PDE
Data Selection: Historical & Preliminary Data
Catalog Used: PDE
Data Selection: Preliminary Data Only
Catalog Used: SRA
Data Selection: Eastern, Central and Mountain States of U.S. (SRA)
Catalog Used: USHIS
Data Selection: Significant U.S. Earthquakes (USHIS)

CATALOG SOURCE	DATE YEAR	MO	DA	ORIGIN TIME	COORDINATES LAT	LONG	DEPTH km	MAGNITUDES mb	Ms	CONTRIBUTED VALUES	INFORMATION I E M F M D I P F / N F A P O E D F L / T F P S P E D G; PHEMOMENA D T S V N W G	RADIAL DIST km
Largest magnitude earthquake possible for region 016 as determined by Algermissen et al. (1982)												29
SRA	1850	2	22	22 Z	40.70	-111.80					4	257
SRA	1853	12	1	1845 Z	40.00	-111.80					5	207
SRA	1859	8	28	Z	37.70	-112.80					4	298
SRA	1868	10	17	1030 Z	39.40	-111.60					3	163
SRA	1871	10		Z	40.50	-108.50					6	202
SRA	1873	7	31	315 Z	38.30	-112.60					5	255
SRA	1873	12	27	3 Z	41.00	-111.90					4	288
SRA	1874	6	18	6 Z	40.70	-111.80					4	257
SRA	1876	3	22	Z	39.50	-111.60					6	166
SRA	1877	1	1	Z	38.80	-112.10					4	201

CATALOG SOURCE	DATE YEAR	MO	DA	ORIGIN TIME	COORDINATES LAT	LONG	DEPTH km	MAGNITUDES mb	Ms	CONTRIBUTED VALUES	INFORMATION: I N T, E F F, M A P, F P S, M O, D E P, I D E, P F D, F L G, PHEMOMENA D T S V N W G	RADIAL DIST km
SRA	1878	8	14	Z	38.60	-112.60					5	247
SRA	1880	9	17	627 Z	40.70	-111.80					5	257
SRA	1881	8	4	430 Z	38.30	-112.60					3	255
SRA	1881	10	16	7 Z	39.50	-111.50					3	158
SRA	1882	2	11	830 Z	37.30	-107.00					4	306
SRA	1882	11	23	Z	37.70	-107.70					3	230
SRA	1883	9	28	11 Z	39.90	-112.10					4	223
SRA	1884	12	8	Z	41.20	-112.00					3	311
SRA	1885	9	5	335 Z	37.10	-112.50					3	315
SRA	1885	10	26	610 Z	38.30	-113.00					4	289
SRA	1885	12	17	1 Z	38.20	-112.30					4	234
SRA	1887	12	5	1530 Z	37.10	-112.50					6	315
SRA	1889	1	15	22 Z	39.50	-107.30					5	222
SRA	1889	12	7	11 Z	39.30	-111.60					4	160
SRA	1891	12		21 Z	40.50	-108.00					6	228
SRA	1894	1	1	10 Z	37.90	-107.80					4	210
SRA	1894	2	5	330 Z	38.80	-112.40					4	227
SRA	1894	7	18	2250 Z	41.20	-112.00					6	311
SRA	1895	3	22	20 Z	40.50	-107.10					4	286
SRA	1895	7	27	2225 Z	39.50	-111.50					4	158
SRA	1896	9	12	130 Z	39.70	-111.80					4	191
SRA	1896	10	14	14 Z	38.40	-110.70					3	101
SRA	1897	8	3	7 Z	38.20	-107.80					5	193
SRA	1899	11	10	9 Z	38.30	-112.60					4	255
SRA	1899	12	13	1350 Z	40.70	-111.80					4	257
SRA	1899			230 Z	40.50	-108.00					4	228
SRA	1900	8	1	745 Z	40.00	-112.10					7	229
SRA	1901	8	11	18 Z	40.20	-111.70					4	213
SRA	1901	11	14	432 Z	38.70	-112.10					9	202
SRA	1901	11	15	10 Z	38.80	-106.20					5	311
SRA	1902	7	31	7 Z	38.30	-112.60					4	255
SRA	1903	7	12	1630 Z	38.80	-112.10					3	201
SRA	1903	7	23	834 Z	41.10	-111.90					4	297
SRA	1906	4		Z	40.50	-108.30					4	212
SRA	1906	5	24	2110 Z	41.20	-112.00					5	311
SRA	1906	12	21	1610 Z	39.60	-107.60					3	201
SRA	1908	4	15	Z	38.40	-113.00					5	286

CATALOG SOURCE	DATE YEAR	MO	DA	ORIGIN TIME	COORDINATES LAT	LONG	DEPTH km	mb	MAGNITUDES Ms	CONTRIBUTED VALUES	INFORMATION I NT	E F F	M A P S	F P S	M O	D E P	I D E	P F D	F L G	PHEMOMENA D	T	S	V	N	W	G	RADIAL DIST km
SRA	1910	1	10	13 Z	38.70	-112.10					6	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	202
SRA	1910	5	22	1428 Z	40.70	-111.80					7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	257
SRA	1910	7	26	130 Z	41.50	-109.30					5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	283
SRA	1913	10	20	10 Z	37.80	-112.40					4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	262
SRA	1913	11	11	2155 Z	38.10	-107.70					6	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	206
SRA	1914	4	8	1606 Z	41.00	-111.90					5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	288
SRA	1914	5	13	1715 Z	41.20	-112.00					7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	311
SRA	1915	2	28	751 Z	39.10	-108.60					3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	103
SRA	1915	7	15	22 Z	40.40	-111.60					6	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	221
SRA	1915	8	11	1020 Z	40.50	-112.70					6	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	301
SRA	1915	9	20	128 Z	40.00	-111.50					3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	186
SRA	1915	10	3	148 Z	40.70	-111.80					3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	257
SRA	1915	10	25	1713 Z	38.60	-112.20					3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	213
SRA	1916	2	5	625 Z	40.00	-111.80					5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	207
SRA	1919	5	7	2330 Z	39.50	-111.60					4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	166
SRA	1920	8	18	820 Z	38.30	-112.60					3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	255
SRA	1920	12	29	250 Z	39.50	-107.50					5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	206
SRA	1921	2	4	826 Z	38.60	-106.30					4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	305
SRA	1921	9	29	1412 Z	38.70	-112.10				5.2 UK	8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	202
SRA	1923	5	14	1210 Z	38.20	-113.20					5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	309
SRA	1924	1	1	2315 Z	37.30	-112.60					3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	308
SRA	1925	12	1	830 Z	41.20	-110.90					3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	264
SRA	1926	5	15	1951 Z	37.30	-112.60					3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	308
SRA	1926	12	19	330 Z	40.00	-112.00					4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	221
SRA	1927	5	22	5 Z	38.80	-112.10					3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	201
SRA	1928	4	30	1550 Z	37.80	-107.00					5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	276
SRA	1930	7	28	935 Z	41.50	-109.30					4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	283
SRA	1932	11	11	10 Z	40.50	-111.50					4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	224
SRA	1933	1	20	1305 Z	37.80	-112.80					6	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	293
SRA	1934	1	30	2021 Z	40.70	-111.80					3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	257
SRA	1934	3	13	Z	40.10	-112.40					3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	256
SRA	1934	4	7	216 Z	41.50	-111.50				5.5 ML	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	316
SRA	1935	7	9	1059 Z	40.70	-111.80					4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	257
SRA	1935	10	6	3 Z	37.90	-111.40					4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	183
SRA	1936	9	2	2337 Z	38.50	-112.40					3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	232
SRA	1937	2	18	630 Z	37.80	-112.60					5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	277
SRA	1938	3	18	Z	40.00	-111.50					3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	186

CATALOG SOURCE	DATE YEAR	MO	DA	ORIGIN TIME	COORDINATES LAT	LONG	DEPTH km	MAGNITUDES mb	Ms	CONTRIBUTED VALUES	INFORMATION I E M F M D I P F PHEMOMENA D T S V N W G (INT FAPS MAPS FPS MOE DEP IDE PFD FLG)	RADIAL DIST km
SRA	1938	6	30	1337 Z	40.70	-111.80					5	257
SRA	1940	4	8	17 Z	39.30	-106.80					3	260
SRA	1940	11	23	13 Z	39.30	-111.60					4	160
SRA	1941	8	29	1134 Z	37.30	-107.70					5	260
SRA	1942	3	28	141030	38.50	-112.50					4	241
SRA	1942	6	4	2304 Z	39.60	-111.60					4	171
SRA	1942	7	23	1940 Z	40.50	-108.50					5	202
SRA	1943	1	16	115018	37.70	-113.00					5	313
SRA	1943	2	22	1420	40.70	-112.00					6	269
SRA	1943	3	12	1345 Z	39.40	-111.60					4	163
SRA	1943	8	14	540 Z	38.20	-111.40					4	164
SRA	1943	11	3	1030 Z	38.60	-112.30					5	221
SRA	1944	6	5	1545 Z	38.60	-112.10					3	204
SRA	1944	9	9	41220 Z	39.00	-107.50					6	198
SRA	1944	10	5	1405 Z	39.20	-106.80					4	259
SRA	1945	3	28	1040 Z	39.70	-111.80					4	191
SRA	1945	4	29	1708 Z	37.70	-107.70					4	230
SRA	1945	11	18	10741 Z	38.80	-112.00					6	192
SRA	1946	1	31	2245 Z	39.60	-107.30					4	225
SRA	1946	10	25	1653 Z	40.70	-112.10					4	275
SRA	1947	3	28	1102 Z	40.70	-111.90					5	263
SRA	1948	11	4	1318 Z	39.30	-111.60					4	160
SRA	1949	3	7	650 Z	40.70	-111.80					6	257
SRA	1950	1	18	15551	40.50	-110.50				5.3 UK	5	180
SRA	1950	5	5	735 Z	38.20	-112.20					4	226
SRA	1950	5	8	2235 Z	40.00	-111.70					5	200
SRA	1951	1	23	1333 Z	39.70	-111.80					4	191
SRA	1951	8	12	26 Z	40.20	-111.70					5	213
SRA	1952	7	22	1 Z	40.00	-111.80					4	207
SRA	1952	9	28	20 Z	40.40	-111.90					5	240
SRA	1953	4	18	515 Z	38.60	-112.10					4	204
SRA	1953	5	24	25429	40.50	-111.50					5	224
SRA	1953	7	30	545 Z	39.00	-110.20					5	35
SRA	1953	8	16	16 Z	40.80	-112.00					4	277
SRA	1953	10	22	3 Z	37.80	-112.40					5	262
SRA	1954	2	21	202051	40.00	-108.75					4	145
SRA	1954	3	31	14 Z	39.00	-110.20					4	35

CATALOG SOURCE	DATE YEAR	MO	DA	ORIGIN TIME	COORDINATES LAT	LONG	DEPTH km	MAGNITUDES mb	Ms	CONTRIBUTED VALUES	INFORMATION: I E M F M D I P F / N F A P O E D F L / T F P S P E D G; PHEMOMENA D T S V N W G	RADIAL DIST km
SRA	1955	2	2	1923 Z	40.80	-111.90					5	271
SRA	1955	2	10	1730 Z	40.40	-106.90					5	294
SRA	1955	3	27	1213 Z	38.30	-111.30					4	150
SRA	1955	5	12	2257 Z	40.90	-111.90					5	279
SRA	1955	8	3	63942 Z	38.00	-107.30					6	242
SRA	1956	2	12	3 Z	40.50	-109.50					4	171
SRA	1956	10	3	202140	41.50	-110.00					4	281
SRA	1957	5	3	830 Z	37.80	-106.90					3	283
SRA	1957	7	18	152420	40.00	-110.50					4	129
SRA	1958	2	13	2252	40.50	-111.50					6	224
SRA	1958	11	28	133039 Z	39.70	-111.80					5	191
SRA	1958	12	11	930 Z	39.50	-111.00					4	119
SRA	1959	2	27	221952	38.00	-112.50					6	259
SRA	1959	9	17	620 Z	38.40	-112.20					4	218
SRA	1960	10	11	80530.5	38.30	-107.60	49			5.5 mb	6	204
SRA	1960	10	17	16 Z	39.20	-106.90					5	251
SRA	1961	4	16	50239.3	39.33	-111.65					6	165
SRA	1961	5	6	161220.7	39.60	-110.20	25				5	78
SRA	1961	11	27	5545.7	39.00	-106.10	33				4	319
SRA	1962	1	13	1333 Z	38.40	-107.80				4.4 ML	4	184
SRA	1962	2	5	144551.1	38.20	-107.60	25			4.7 ML	5	208
SRA	1962	6	5	222945	38.00	-112.10	33			4.5 ML	. . . .	228
SRA	1962	8	19	173241.4	38.05	-112.09	7			3.2 ML	. . . .	224
SRA	1962	9	5	160427.8	40.72	-112.09	7	5.1		5.2 ML	6	276
SRA	1962	9	7	165023.8	39.20	-110.89	7			3.1 ML	. . . .	98
SRA	1962	12	11	102813.5	39.36	-110.42	7			3.4 ML	. . . .	69
SRA	1963	6	19	83844.9	38.02	-112.53	7	4.2		3.7 ML	. . . .	261
SRA	1963	7	7	192039.6	39.53	-111.91	7	4.9		4.4 ML	6	193
SRA	1963	7	9	202525.8	40.03	-111.19	7	4.1		4 ML	. F	168
SRA	1963	9	30	91739.3	38.10	-111.22	7	4.5		4.3 ML	. . . .	157
SRA	1963	11	13	61730.1	38.30	-112.66	7	3.8		3.2 ML	. . . .	260
SRA	1964	1	17	1503.5	38.19	-112.62	7			3.3 ML	. . . .	261
SRA	1964	8	5	151756.2	38.95	-110.92	7			3 ML	. . . .	97
SRA	1964	8	24	15100.6	38.77	-112.23	7			3.1 ML	. . . .	212
SRA	1964	9	6	190333.8	39.18	-111.46	7			3.1 ML	. . . .	146
SRA	1965	5	30	173104.1	39.40	-106.30	33	4.3			. . . .	305
SRA	1965	6	29	74628.7	39.50	-110.39	7	4.3		3.2 ML	. . . .	78

CATALOG SOURCE	DATE YEAR	MO	DA	ORIGIN TIME	COORDINATES LAT	LONG	DEPTH km	MAGNITUDES mb	Ms	CONTRIBUTED VALUES	INFORMATION (I E M F M D I P F / N F A P O E D F L / T F P S P E D G) PHEMOMENA (D T S V N W G)	RADIAL DIST km
SRA	1965	7	13	180315.4	37.71	-112.98	7			3 ML	. . . .	311
SRA	1965	7	18	35551.4	39.50	-109.90	33	3.1			. . . .	59
SRA	1965	7	20	144924.9	38.03	-112.44	7			3 ML	. . . .	253
SRA	1965	9	10	214744.6	39.43	-111.47	7			3 ML	. . . .	153
SRA	1966	1	23	4 Z	37.90	-106.90					3	278
SRA	1966	4	23	202053.3	39.10	-111.55	7	4.4		3.5 ML	. . . .	153
SRA	1966	5	20	134047.9	37.98	-111.85	7	4.3		4.1 ML	. . . .	210
SRA	1966	7	6	54708.4	40.09	-108.95	7	4.1		3.7 ML	. . . .	143
SRA	1966	9	4	95234.5	38.30	-107.60	33	4.2			. . . .	204
SRA	1966	10	21	71348.9	38.20	-113.16	7			4.2 ML	. . . .	305
SRA	1966	11	1	74028	40.20	-106.90	33	4		3.9 ML	. . . .	283
SRA	1966	12	19	205233.3	39.00	-106.50	5	4.6		3.3 ML	3	284
SRA	1967	1	12	35206.2	38.98	-107.51	33	4.4			. . . .	197
SRA	1967	1	16	92245.9	37.67	-107.86	33	4.1			. . . .	221
SRA	1967	1	18	61200.6	40.05	-107.05	33	3.8			. . . .	264
SRA	1967	2	5	100716.6	39.55	-110.10	33	3			. . . .	69
SRA	1967	2	15	32803.5	40.11	-109.05	7	4.5		4 ML	5	141
SRA	1967	4	4	225339.5	38.32	-107.75	33	4.5		3 ML	. . . .	191
SRA	1967	7	22	215127.4	38.80	-112.22	7	4.2		3.6 ML	. . . .	211
SRA	1967	9	24	50028.6	40.71	-112.10	7	3.7		3 ML	5	276
SRA	1967	10	4	102012.8	38.54	-112.16	7	5.2		5.2 ML	7	211
SRA	1967	10	25	24134.6	39.47	-110.35	0	4		3.2 ML	. . . .	73
SRA	1967	12	7	133322.5	41.29	-111.74	7	4.3		3.7 ML	3	306
SRA	1968	1	16	94252.1	39.27	-112.04	7	4		3.9 ML	. . . .	197
SRA	1968	2	20	63426.4	41.72	-110.61	7	3.7		3.2 ML	. . . .	313
SRA	1968	6	2	185923.2	39.21	-110.45	7	3.8		3.3 ML	. . . .	62
SRA	1968	6	23	201613	39.31	-107.41	33	3.8			. . . .	209
SRA	1968	9	24	21049.6	38.04	-112.08	7	4		3.6 ML	. . . .	224
SRA	1968	11	17	143338.2	39.52	-110.97	7	4.6		3.5 ML	. . . .	118
SRA	1969	4	10	83705.5	38.66	-112.07	7			3.6 ML	. . . .	200
SRA	1969	5	23	52451.6	39.02	-111.97	7	4		3.3 ML	. . . .	188
SRA	1970	2	3	55935.6	37.92	-108.31	33	4			. . . .	173
SRA	1970	2	21	61348	39.49	-110.35	7	4.1		3.1 ML	. . . .	75
SRA	1970	4	14	104054.1	39.65	-110.82	7	4.2		3 ML	. . . .	116
SRA	1970	4	21	85352.4	40.10	-108.90	4	4.3		3.9 ML	5	146
SRA	1970	5	23	225523.2	38.06	-112.47	7	4.6		3.9 ML	. . . .	254
SRA	1970	10	25	74821.9	39.17	-111.41	7			3.1 ML	. . . .	141

CATALOG SOURCE	DATE YEAR	MO	DA	ORIGIN TIME	COORDINATES LAT	LONG	DEPTH km	MAGNITUDES mb	Ms	CONTRIBUTED VALUES	INFORMATION I N T	E F F	M A P	F P S	M O	D E P	I D E	P F D	F L G	PHEMOMENA D	T	S	V	N	W	G	RADIAL DIST km
SRA	1971	1	7	203952.1	39.49	-107.31	33	4.3		3.8 ML	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	221
SRA	1971	3	18	90859.9	40.70	-106.97	10	4.4			5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	308
SRA	1971	4	22	230102.8	39.41	-111.94	7			3.1 ML	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	191
SRA	1971	6	23	60835.9	38.61	-112.71	7	4.6		3.1 ML	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	256
SRA	1971	7	10	172236.8	40.24	-109.60	7	3.8		3.7 ML	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	141
SRA	1971	11	10	141023	37.80	-113.10	7	4.5		3.7 ML	.	F	.	.	.	.	.	.	.	.	.	.	.	.	.	.	316
SRA	1971	11	12	93044.6	38.91	-108.68	5			4 ML	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	96
SRA	1971	12	15	125814.5	36.79	-111.82	5			3 ML	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	300
SRA	1972	1	3	102038.9	38.65	-112.17	7	4.6		4.4 ML	6	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	209
SRA	1972	6	2	31548.2	38.67	-112.07	7	4.6		4 ML	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	200
SRA	1972	10	1	194229.5	40.51	-111.35	7	4.7		4.3 ML	6	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	216
SRA	1972	11	16	21745.2	37.53	-112.77	7			3.6 ML	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	305
PDE	1973	2	9	173837 *	36.43	-110.43	5			3.2 ML	.	.	.		.	4	.	P	.	.	.	.	.	.	.	.	287
SRA	1973	2	18	93139.6	38.10	-113.18	7			3.3 ML	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	310
PDE	1973	7	16	63642.8 *	39.15	-111.51	10	4.2			.	.	.		.	1	.	P	.	.	.	.	.	.	.	.	149
PDE	1974	3	31	115847.1	40.70	-107.05	5			3.5 ML	2	F	.		.	4	.	P	.	.	.	.	.	.	.	.	303
PDE	1974	4	29	73551.8	37.81	-112.98	5	4.4		3.2 ML	3	F	.		.	4	.	P	.	.	.	.	.	.	.	.	306
PDE	1974	11	4	90228	38.34	-112.33	17	4.3		3.9 ML	3	F	.		.	4	.	P	.	.	.	.	.	.	.	.	231
PDE	1975	1	30	144840.3	39.27	-108.65	5	4.4		3.7 ML	.	F	.		.	4	.	P	.	.	.	.	.	.	.	.	104
PDE	1975	9	10	63942.5 *	38.48	-112.56	5			3.3 ML	.	F	.		.	4	.	P	.	.	.	.	.	.	.	.	247
PDE	1975	10	6	155046.9 *	39.07	-111.45	5	4.2		3.2 ML	2	F	.		.	4	.	P	.	.	.	.	.	.	.	.	143
SRA	1976	7	30	221900.2	40.75	-110.30	7			3.1 MD	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	202
SRA	1976	8	13	103021.1	38.42	-112.18	7			3.1 MD	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	216
PDE	1976	8	19	132953.3 U	39.27	-111.08	2			3.3 ML	.	.	.		.	4	.	P	.	.	.	.	.	.	.	.	116
PDE	1976	10	6	111504.1	39.08	-111.51	2			3 ML	.	.	.		.	4	.	P	.	.	.	.	.	.	.	.	148
SRA	1976	11	26	222629.4	39.51	-111.26	7			3.1 ML	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	140
PDE	1977	2	9	4216.4 U	39.31	-111.15	7			3.4 ML	.	F	.		.	4	.	P	.	.	.	.	.	.	.	.	123
SRA	1977	6	3	13722	39.65	-110.51	7			3.2 MD	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	97
PDE	1977	9	24	111648.4	39.31	-107.31	5	4		3 ML	.	.	.		.	4	.	P	.	.	.	.	.	.	.	.	217
PDE	1977	9	30	101921	40.52	-110.44	5	5		5.1 ML	6	D	.		.	4	.	P	.	.	.	.	.	.	.	.	180
SRA	1977	11	29	213123.4	36.82	-110.99	7			3 MD	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	260
SRA	1978	2	24	194948.8	38.33	-112.84	2			3.5 ML	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	274
PDE	1978	3	9	63051.8 U	40.76	-112.08	9			3.3 ML	6	D	.		.	4	.	P	.	.	.	.	.	.	.	.	279
PDE	1978	5	29	164518	39.28	-107.32	5			3 ML	.	.	.		.	4	.	P	.	.	.	.	.	.	.	.	216
PDE	1978	9	23	82006.6 U	39.32	-111.09	2			3 ML	.	.	.		.	4	.	P	.	.	.	.	.	.	.	.	119
PDE	1978	12	9	145948.3 U	38.66	-112.53	4			3.3 ML	.	.	.		.	4	.	P	.	.	.	.	.	.	.	.	240
PDE	1979	1	20	65908.4 *	40.82	-107.86	5			3.3 ML	.	.	.		.	4	.	P	.	.	.	.	.	.	.	.	263

CATALOG SOURCE	DATE YEAR	MO	DA	ORIGIN TIME	COORDINATES LAT	LONG	DEPTH km	MAGNITUDES mb	Ms	CONTRIBUTED VALUES	INFORMATION I NT	E FF	M AP	F PS	M O	D EP	I DE	P FD	F LG	PHEMOMENA D	T	S	V	N	W	G	RADIAL DIST km
PDE	1979	2	24	124338.2 *	41.65	-111.00	5			3.5 ML	.	.	.		.	4	.	P	.	.	.	.	.	.	.	.	314
PDE	1979	3	19	145929.7	40.18	-108.90	2			3.3 ML	4	F	.		.	4	.	P	.	.	.	.	.	.	.	.	154
PDE	1979	4	30	20710.3 U	37.88	-111.02	7			3.8 ML	4	F	.		.	4	.	P	.	.	.	.	.	.	.	.	161
PDE	1979	10	6	101235.2 U	39.29	-111.69	7			3.2 ML	.	F	.		.	4	.	P	.	.	.	.	.	.	.	.	167
SRA	1979	10	23	41719.9	37.89	-110.93	7			3.5 ML	.	F	.	.	.	.	.	.	.	.	.	.	.	.	.	.	155
PDE	1980	5	24	100336.3 U	39.94	-111.97	5	5		4.2 ML	5	F	.		.	4	.	P	.	.	.	.	.	.	.	.	215
PDE	1981	2	20	91301.4 W	40.33	-111.72	7	4.7		3.9 ML	5	F	.		.	4	.	P	.	.	.	.	.	.	.	.	224
PDE	1981	5	14	51104.1 U	39.48	-111.06	1	4.5		3.5 ML	5	F	.		.	4	.	P	.	.	.	.	.	.	.	.	123
SRA	1981	5	29	30902.2	36.83	-110.37	1			3 MD	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	242
SRA	1981	8	8	62016.9	38.05	-112.80	1			3.3 MD	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	281
PDE	1981	9	10	75509.32 U	37.51	-110.54	7			3.1 ML	.	.	.		.	4	.	P	.	.	.	.	.	.	.	.	174
PDE	1981	9	21	80133.93 U	39.58	-110.44	7			3.2 ML	3	F	.		.	3	.	P	.	.	.	.	.	.	.	.	87
PDE	1982	2	12	104413.7 U	37.41	-112.55	7			3.6 ML	.	.	.		.	4	.	P	.	.	.	.	.	.	.	.	297
PDE	1982	5	24	121327 U	38.71	-112.04	8	4.7		4 ML	6	D	.		.	4	.	P	.	.	.	.	.	.	.	.	197
SRA	1983	1	27	233711.8	37.78	-110.67	7			3.3 MD	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	153
PDE	1983	3	22	111235.7 U	39.54	-110.42	7			3.1 ML	.	.	.		.	4	.	P	.	.	.	.	.	.	.	.	83
PDE	1983	5	3	124338.1 U	38.29	-110.59	7			3 ML	.	.	.		.	3	.	P	.	.	.	.	.	.	.	.	102
PDE	1983	8	14	190830.7 *	38.36	-107.40	5			3.4 ML	2	F	.		.	4	.	P	.	.	.	.	.	.	.	.	218
SRA	1983	8	29	125311.5	41.08	-111.43	10			3 ML	.	F	.	.	.	.	.	.	.	.	.	.	.	.	.	.	272
PDE	1983	9	24	165745.8	40.79	-108.84	5			4.1 ML	3	F	.		.	4	.	P	.	.	.	.	.	.	.	.	217
PDE	1983	10	8	115754.2 U	40.75	-111.99	4	4.5		4.3 ML	6	D	.		.	3	.	P	.	.	.	.	.	.	.	.	272
PDE	1983	12	9	85841.34 U	38.58	-112.58	7	4.3		3.6 ML	3	F	.		.	4	.	P	.	.	.	.	.	.	.	.	246
SRA	1984	3	1	181300.9	41.54	-108.64	2			3.2 MD	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	301
PDE	1984	3	21	111930.3 U	39.33	-111.10	1			3.5 ML	.	F	.		.	4	.	P	.	.	.	.	.	.	.	.	119
PDE	1984	5	14	101417.3 *	39.32	-107.23	5			3.2 ML	4	F	.		.	4	.	P	.	.	.	.	.	.	.	.	224
PDE	1984	8	16	141921.8 U	39.38	-111.90	9			3.7 ML	4	F	.		.	4	.	P	.	.	.	.	.	.	.	.	188
SRA	1984	9	14	190426.3	41.61	-108.58	2			3.2 MD	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	310
SRA	1985	6	27	103629.5	39.56	-110.40	1			3 MD	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	83
SRA	1985	10	7	203340.1	40.41	-109.50	21			3 MD	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	161
PDE	1986	3	24	224023.5 U	39.24	-112.01	0	4.7		4.4 ML	5	F	.		.	4	.	P	.	.	.	.	.	.	.	.	194
PDE	1986	5	14	150257.4	37.43	-110.56	5			3.2 ML	.	.	.		.	4	.	P	.	.	.	.	.	.	.	.	183
PDE	1986	6	5	80541.8 U	41.27	-111.69	7			3.6 ML	.	F	.		.	4	.	P	.	.	.	.	.	.	.	.	301
PDE	1986	8	22	132633.4	37.42	-110.57	5			4 ML	5	F	.		.	4	.	P	.	.	.	.	.	.	.	.	185
PDE	1986	8	26	20602.61	38.90	-107.04	5			3.1 ML	3	F	.		.	4	.	P	.	.	.	.	.	.	.	.	238
PDE	1986	9	3	62050.98	38.91	-107.09	5			3.5 ML	5	F	.		.	4	.	P	.	.	.	.	.	.	.	.	234
PDE	1986	10	5	154733.5 U	38.64	-112.56	1			3.3 ML	3	F	.		.	4	.	P	.	.	.	.	.	.	.	.	243
SRA	1986	11	7	13153.7	37.43	-110.30	1			3 MD	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	176

CATALOG SOURCE	DATE YEAR	MO	DA	ORIGIN TIME	COORDINATES LAT	LONG	DEPTH km	MAGNITUDES mb	Ms	CONTRIBUTED VALUES	INFORMATION (I N T, F F, M A P, F P S, M O, D E P, I D E, P F D, F L G) PHEMOMENA (D T S V N W G)	RADIAL DIST km
PDE	1987	3	5	30250.49 U	40.44	-110.62	1	4		3.7 ML	4 F . . 4 . P	178
PDE	1987	3	11	153103 U	39.25	-111.64	1			3 ML	. F . . 4 . P	162
PDE	1987	4	4	62434.82 U	37.68	-113.03	5			3 ML	5 F . . 4 . P	317
PDE	1987	6	26	123627.5	38.74	-111.77	5			3.5 ML	. . . . 4 . P	173
PDE	1987	9	2	50020.55 U	38.56	-112.70	1			3.4 ML	. . . . 4 . P	256
PDE	1987	10	19	71709.71 U	39.66	-111.43	0			3.8 ML	4 F . . 3 . P	160
PDE	1987	12	16	174307.6	39.29	-111.23	5			4 ML	. . . . 4 . P	129
PDE	1988	1	15	73329.2	37.52	-106.68	5			3.1 ML	. F . . 4 . P	316
PDE	1988	2	14	183240.5	40.63	-108.53	5			3.3 ML	4 F . . 4 . P	213
PDE	1988	7	10	204559.4 U	41.23	-111.63	7			3.6 ML	. . . . 4 . P	295
PDE	1988	7	11	114656 U	39.19	-111.99	1			3.1 ML	4 F . . 4 . P	191
PDE	1988	7	15	3809.59 *	36.37	-110.45	5			3.3 ML	. . . . 4 . P	293
PDE	1988	8	14	200303.9 U	39.13	-110.87	9	5.5		5.3 ML	6 D U . 4 . P . . . . S	95
PDE	1988	9	21	175825.9 U	39.31	-111.17	9			3.1 MD	. . . . 4 . P	124
PDE	1988	11	6	153058.8 U	40.72	-111.42	11			3.3 ML	5 F . . 4 . P	239
PDE	1989	1	30	40622.78 U	38.82	-111.61	24	5	4.8	5.4 ML	6 D U M 4 . P	158
PDE	1989	4	9	112419.4 U	40.42	-110.94	9			3.2 ML	2 F . . 4 . P	188
PDE	1989	5	13	210148.8 U	38.47	-108.92	7			3.1 MD	. . . . 4 . P	93
PDE	1989	8	9	152833.4 U	38.19	-112.59	2			3.3 MD	. F . . 4 . P	258
PDE	1989	11	19	32113.61	38.06	-107.77	5			3 ML	. F . . 4 . P	203
PDE	1990	2	5	102325.2 U	39.50	-111.52	10			3.1 ML	3 F . . 4 . P	160
PDE	1990	4	7	153754.9 U	40.08	-109.52	3			3.5 ML	. . . . 4 . P	125
PDE	1990	6	25	171533.5 U	38.95	-110.83	11			3 MD	. . . . 4 . P	89
PDE	1990	9	1	181229.4 U	39.30	-111.14	7			3.3 MD	. . . . 4 . P	121
PDE	1990	9	12	213857.6	39.70	-106.21	5			3 ML	5 F . . 4 . P	319
PDE	1990	10	23	84912.5 U	38.73	-111.53	1			3.2 MD	. . . . 4 . P	152
PDE	1991	1	26	214938 U	37.68	-111.43	9			3.3 ML	3 F . . 3 . P	202
PDE	1991	2	21	112345.6 U	38.96	-111.90	1	3.4		3.4 ML	4 F . . 4 . P	182
PDE	1991	3	2	84137.49 U	40.09	-109.48	1	3		3.3 ML	. . . . 4 . P	127
PDE	1991	3	22	145959.2 U	37.82	-113.00	3	3.2		3.1 ML	. F . . 4 . P	307
PDE	1991	4	20	125651.1 U	38.05	-112.73	2	4		3.8 ML	4 F . . 4 . P	275
PDE	1991	5	23	73840.57 U	39.30	-111.15	12	3.5		3.6 ML	3 F . . 3 . P	122
PDE	1991	6	25	210213.6 U	37.21	-110.36	1			3 MD	. . . . 4 . P	201
PDE	1991	8	21	134706.3 U	39.36	-111.88	3			3 ML	. . . . 4 . P	185
PDE	1991	11	8	131505.3 U	40.10	-109.29	2	3.4		3.8 ML	3 F . . 4 . P	132
PDE	1991	12	21	202635.7 U	37.57	-112.32	7	3.6		3.8 ML	3 F . . 4 . P	270
PDE	1992	3	16	144249.5 U	40.47	-112.04	12	4.4		4.2 ML	5 F . . 4 . P	254

CATALOG SOURCE	DATE YEAR	MO	DA	ORIGIN TIME	COORDINATES LAT	LONG	DEPTH km	MAGNITUDES mb	Ms	CONTRIBUTED VALUES	INFORMATION I N T	E F F	M A P	F P S	M O	D E P	I D E	P F D	F L G	PHEMOMENA D	T	S	V	N	W	G	RADIAL DIST km
PDE	1992	6	24	73120.21 U	38.78	-111.55	0	4.4		4.4 ML	.	F	.		.	4	.	P	.	.	.	.	.	.	.	.	154
PDE	1992	9	10	62012.6 U	39.70	-110.63	0			3.4 MD	.	.	.		.	4	.	P	.	.	.	.	.	.	.	.	108
PDE	1992	9	24	143541 U	37.97	-112.53	3			3.1 MD	.	.	.		.	4	.	P	.	.	.	.	.	.	.	.	263
PDE	1993	2	25	112714.4 U	39.69	-111.26	8			3.1 MD	.	.	.		.	4	.	P	.	.	.	.	.	.	.	.	150
PDE	1993	3	15	104849.9	39.55	-112.08	5			3.3 ML	.	.	.		.	4	.	P	.	.	.	.	.	.	.	.	207
PDE	1993	5	13	161326.1	40.13	-109.09	5			3 ML	.	.	.		.	4	.	P	.	.	.	.	.	.	.	.	141
PDE	1993	5	27	62153.98	37.08	-112.09	10	3.3		3.5 ML	3	F	.		.	3	.	P	.	.	.	.	.	.	.	.	290
PDE	1993	6	16	72224.2	38.06	-112.69	5			3.5 MD	.	.	.		.	4	.	P	.	.	.	.	.	.	.	.	272
PDE	1993	7	8	40352.25	39.23	-106.72	5			3.1 ML	.	F	.		.	4	.	P	.	.	.	.	.	.	.	.	267
PDE	1993	7	20	35703.06 U	38.77	-112.06	2			3.6 MD	5	F	.		.	4	.	P	.	.	.	.	.	.	.	.	197
PDE	1993	9	27	112100.9 U	39.33	-111.16	1			3.3 MD	.	.	.		.	4	.	P	.	.	.	.	.	.	.	.	124
PDE	1993	10	5	22409.85	38.14	-112.62	5			3.1 ML	.	.	.		.	3	.	P	.	.	.	.	.	.	.	.	263
PDE	1993	10	21	220716.3	38.98	-111.86	5			3.5 MD	4	F	.		.	4	.	P	.	.	.	.	.	.	.	.	179
PDE	1993	11	6	73003.44	37.88	-112.81	5			3 ML	.	.	.		.	4	.	P	.	.	.	.	.	.	.	.	290
PDE	1994	5	6	224246 U	40.08	-111.40	1			3.2 MD	.	.	.		.	3	.	P	.	.	.	.	.	.	.	.	185
PDE	1994	6	3	42529.08	38.45	-112.23	5			3.3 ML	.	.	.		.	4	.	P	.	.	.	.	.	.	.	.	219
PDE	1994	9	6	34837.63	38.08	-112.33	5	3.9		4.3 ML	4	F	.		.	4	.	P	.	.	.	.	.	.	.	.	242
PDE	1994	9	10	63341.76	39.47	-111.52	5			3.7 ML	4	F	.		.	4	.	P	.	.	.	.	.	.	.	.	159
PDE	1994	9	13	60123.01	38.15	-107.98	10	4.4		4.6 ML	6	D	.		.	4	.	P	.	.	.	.	.	.	.	.	182
PDE	1994	11	3	114010.1	40.04	-108.27	5			3.4 ML	.	.	.		.	4	.	P	.	.	.	.	.	.	.	.	176
PDE	1994	11	17	111101.2	38.22	-112.73	5			3.6 MD	.	F	.		.	4	.	P	.	.	.	.	.	.	.	.	269
PDE	1994	11	19	180144.6	37.79	-112.95	5			3.1 ML	4	F	.		.	4	.	P	.	.	.	.	.	.	.	.	305
PDE	1994	11	23	163049	39.50	-111.52	5			3.3 ML	3	F	.		.	4	.	P	.	.	.	.	.	.	.	.	160
PDE	1995	3	20	124616.4	40.18	-108.93	5	4.2		4.1 ML	5	F	.		.	4	.	P	.	.	.	.	.	.	.	.	153
PDE	1995	4	27	195558.1 U	38.09	-112.42	5			3.7 MD	.	.	.		.	4	.	P	.	.	.	.	.	.	.	.	249
PDE	1995	7	6	2223.31	39.93	-111.63	10			3.3 ML	.	.	.		.	4	.	P	.	.	.	.	.	.	.	.	190
PDE	1995	7	21	172146.9	38.23	-112.90	5			3.6 ML	.	.	.		.	4	.	P	.	.	.	.	.	.	.	.	283
PDE	1995	10	8	62502.61	40.91	-111.72	5			3.2 ML	.	F	.		.	4	.	P	.	.	.	.	.	.	.	.	270
PDE	1995	11	3	70941.84 U	37.99	-112.83	1			3.1 MD	.	.	.		.	4	.	P	.	.	.	.	.	.	.	.	286
PDE	1995	12	3	230542.6 U	38.20	-112.66	0			3.1 MD	.	.	.		.	4	.	P	.	.	.	.	.	.	.	.	264
PDE	1995	12	6	42528.23 U	40.74	-111.54	10	3.4		3.5 ML	5	F	.		.	4	.	P	.	.	.	.	.	.	.	.	246
PDE	1995	12	31	121107.9 U	38.99	-111.97	1			3.1 MD	.	.	.		.	4	.	P	.	.	.	.	.	.	.	.	189
PDE	1996	1	6	125558.6 U	39.12	-110.88	0	4.3		4.2 MD	5	F	.		.	4	.	P	.	.	.	.	.	.	.	.	95
PDE	1996	2	2	21114.62 U	39.47	-111.23	1			3.2 ML	.	.	.		.	4	.	P	.	.	.	.	.	.	.	.	135
PDE	1996	12	6	135314.4 U	39.71	-110.66	3			3.4 ML	.	.	.		.	3	.	P	.	.	.	.	.	.	.	.	110
PDE	1996	12	28	113502.8	37.86	-113.17	5			3.2 ML	.	.	.		.	3	.	P	.	.	.	.	.	.	.	.	319
PDE	1997	4	14	93048.42	39.05	-111.39	5			3.1 MD	.	.	.		.	3	.	P	.	.	.	.	.	.	.	.	138

CATALOG SOURCE	DATE YEAR	MO	DA	ORIGIN TIME	COORDINATES LAT	LONG	DEPTH km	MAGNITUDES mb	Ms	CONTRIBUTED VALUES	INFORMATION I N T	E F F	M A P	F P S	M O	D E P	I D E	P F D	F L G	PHEMOMENA D	T	S	V	N	W	G	RADIAL DIST km
PDE	1997	8	13	142401.4	38.01	-112.59	5			3.7 ML	.	.	.		.	3	.	P	.	.	.	.	.	.	.	.	266
PDE	1997	9	17	3900.1 U	40.54	-112.18	1			3 ML	.	.	.		.	3	.	P	.	.	.	.	.	.	.	.	268
PDE	1997	10	20	70220.73	37.83	-111.88	10			3.1 ML	.	.	.		.	3	.	P	.	.	.	.	.	.	.	.	221
PDE	1998	1	2	72829.08	38.21	-112.47	5			4.5 ML	.	F	.		.	3	.	P	.	.	.	.	.	.	.	.	248
PDE	1998	1	5	22046.04	40.20	-111.29	5			3 ML	.	.	.		.	3	.	P	.	.	.	.	.	.	.	.	187
PDE	1998	1	30	215315.2	37.97	-112.55	5	4		4 ML	.	F	.		.	3	.	P	.	.	.	.	.	.	.	.	264
PDE	1998	2	5	51956.62 U	39.75	-110.85	1	3.6		3.7 ML	.	F	.		.	3	.	P	.	.	.	.	.	.	.	.	125
PDE	1998	3	29	121242 U	38.25	-111.35	3	3		3.2 ML	.	F	.		.	3	.	P	.	.	.	.	.	.	.	.	157
PDE	1998	4	10	65216.4	38.27	-108.83	5			3 ML	.	F	.		.	3	.	P	.	.	.	.	.	.	.	.	114
PDE	1998	4	10	200716 U	38.42	-113.00	5			3.9 ML	.	F	.		.	3	.	P	.	.	.	.	.	.	.	.	285
PDE	1998	6	18	110040 U	37.97	-112.49	2	4		4.2 ML	.	F	.		.	3	.	P	.	.	.	.	.	.	.	.	260
PDE	1999	1	8	152415.2 U	38.76	-111.55	0	3.5		3.8 ML	.	.	.		.	3	.	P	.	.	.	.	.	.	.	.	154
PDE	1999	1	14	103651 U	38.42	-112.98	5			3.2 ML	.	F	.		.	3	.	P	.	.	.	.	.	.	.	.	284
PDE	1999	1	26	214928 U	38.71	-112.49	1			3.2 ML	.	.	.		.	3	.	P	.	.	.	.	.	.	.	.	236
PDE	1999	1	30	90547 U	37.55	-112.21	1	3.2		3 ML	.	.	.		.	3	.	P	.	.	.	.	.	.	.	.	263
PDE	1999	2	23	32041 U	37.08	-112.33	10			3.1 ML	.	.	.		.	3	.	P	.	.	.	.	.	.	.	.	305
PDE	1999	3	9	123909 U	37.82	-112.36	0	3.4		3.5 ML	.	.	.		.	3	.	P	.	.	.	.	.	.	.	.	258
PDE	1999	4	19	144232 U	38.72	-112.14	0			3.5 ML	.	F	.		.	3	.	P	.	.	.	.	.	.	.	.	205
PDE	1999	4	25	52207 U	37.76	-112.49	2			3.1 ML	.	.	.		.	3	.	P	.	.	.	.	.	.	.	.	271
PDE	1999	6	3	153534.3 BR	38.29	-108.92	4			3.6 ML	.	F	.		.	3	.	P	.	.	.	.	.	.	.	.	106
PDE	1999	6	30	152732.6 U	40.65	-111.58	11	3.5		3.7 ML	.	F	.		.	3	.	P	.	.	.	.	.	.	.	.	241
PDE	1999	7	6	220545.2	38.32	-108.86	5			3.5 ML	.	F	.		.	3	.	P	.	.	.	.	.	.	.	.	108
PDE	1999	7	19	102638 U	40.33	-111.30	1			3.2 ML	.	.	.		.	3	.	P	.	.	.	.	.	.	.	.	198
PDE	1999	8	4	183312 U	38.59	-112.18	0			3.3 ML	.	F	.		.	3	.	P	.	.	.	.	.	.	.	.	211
PDE	1999	10	11	224315 U	38.76	-112.02	2			3.9 ML	.	F	.		.	3	.	P	.	.	.	.	.	.	.	.	194
PDE	1999	10	22	175115.6 U	38.08	-112.73	5			4.2 ML	.	F	.		.	3	.	P	.	.	.	.	.	.	.	.	274
PDE	1999	12	22	80331 U	38.75	-111.53	2	4.1		3.9 ML	.	.	.		.	3	.	P	.	.	.	.	.	.	.	.	152
PDE	2000	3	7	21604 U	39.75	-110.84	1	4.3		4.2 ML	.	F	.		.	3	.	P	.	.	.	.	.	.	.	S	125
PDE	2000	3	15	121427.5	38.37	-108.87	5			3.3 ML	.	.	.		.	3	.	P	.	.	.	.	.	.	.	.	104
PDE	2000	5	26	32404.59 U	38.07	-112.19	0	3		3.6 ML	.	.	.		.	3	.	P	.	.	.	.	.	.	.	.	231
PDE	2000	5	27	215818.8	38.34	-108.86	5			4.3 ML	.	F	.		.	3	.	P	.	.	.	.	.	.	.	.	106
PDE	2000	6	20	175546 U	40.69	-109.31	1			3 ML	.	.	.		.	3	.	P	.	.	.	.	.	.	.	.	195
PDE	2000	8	3	133412 U	39.58	-111.69	5			3.2 ML	.	.	.		.	3	.	P	.	.	.	.	.	.	.	.	177
PDE	2000	11	11	211753 U	40.28	-109.23	5			3.7 ML	.	.	.		.	3	.	P	.	.	.	.	.	.	.	.	153
PDE	2000	12	10	193901 U	40.50	-111.35	13			3 ML	.	.	.		.	3	.	P	.	.	.	.	.	.	.	.	216
PDE	2001	2	23	214350 U	38.73	-112.56	0			4.1 ML	.	F	.		.	3	.	P	.	.	.	.	.	.	.	.	241
PDE	2001	5	24	24040 U	40.38	-111.94	0	2.9		3.3 ML	.	F	.		.	3	.	P	.	.	.	.	.	.	.	.	241

CATALOG SOURCE	DATE YEAR	MO	DA	ORIGIN TIME	COORDINATES LAT	LONG	DEPTH km	MAGNITUDES mb	Ms	CONTRIBUTED VALUES	INFORMATION I N T	E F F	M A P	F P S	M O	D E P	I D E	P F D	F L G	PHEMOMENA D	T	S	V	N	W	G	RADIAL DIST km
PDE	2001	7	8	135551 U	40.74	-112.07	13			3.4 ML	3	F	.		.	3	.	P	.	.	.	.	.	.	.	.	276
PDE	2001	7	19	201534 U	38.73	-111.52	3	4.5		4.3 ML	.	F	.		.	3	.	P	.	.	.	.	.	.	.	.	152
PDE	2001	8	9	223854.5	39.66	-107.38	5			4 ML	4	F	.		.	3	.	P	.	.	.	.	.	.	.	.	221
PDE	2001	11	5	83423.02	38.85	-107.38	1			3.4 ML	.	F	.		.	3	.	P	.	.	.	.	.	.	.	.	209
PDE	2001	11	19	213625.1 U	38.56	-112.48	1			3.6 ML	.	.	.		.	3	.	P	.	.	.	.	.	.	.	.	238
PDE	2002	1	8	172606 U	37.34	-112.71	8			3.2 ML	.	.	.		.	3	.	P	.	.	.	.	.	.	.	.	313
PDE	2002	1	31	181745.5	40.29	-107.69	5			4.3 ML	3	F	.		.	3	.	P	.	.	.	.	.	.	.	.	231
PDE	2002	6	6	122910 U	38.34	-108.93	1			3.2 ML	.	.	.		.	3	.	P	.	.	.	.	.	.	.	.	102
PDE	2002	6	14	74546 U	41.39	-111.44	7			3.1 ML	.	.	.		.	3	.	P	.	.	.	.	.	.	.	.	303
PDE	2002	8	12	13140 U	38.15	-112.61	0			3.4 ML	.	.	.		.	3	.	P	.	.	.	.	.	.	.	.	261
PDE	2002	9	26	103210 U	37.41	-110.53	3			3 ML	.	.	.		.	3	.	P	.	.	.	.	.	.	.	.	184
PDE	2002	11	8	125522 U	38.84	-111.50	5			3.2 ML	.	.	.		.	3	.	P	.	.	.	.	.	.	.	.	148
PDE	2003	1	3	50212 U	41.27	-111.82	12	3.4		3.7 ML	4	F	.		.	3	.	P	.	.	.	.	.	.	.	.	308
PDE	2003	2	11	90042 U	38.70	-112.26	0			3.3 ML	3	F	.		.	3	.	P	.	.	.	.	.	.	.	.	216
PDE	2003	4	17	10419 U	39.52	-111.86	0	4.7		4.4 ML	5	F	.		.	1	.	P	.	.	.	.	.	.	.	.	188
PDE	2003	7	8	22033 U	36.95	-111.79	6			3.3 ML	.	.	.		.	3	.	P	.	.	.	.	.	.	.	.	284
PDE	2003	7	12	15440 U	41.28	-111.62	9			3.7 ML	3	F	.		.	3	.	P	.	.	.	.	.	.	.	.	300
PDE	2003	11	29	223308 U	38.45	-112.49	1			3.1 ML	.	.	.		.	3	.	P	.	.	.	.	.	.	.	.	241
PDE	2003	12	27	3924 U	39.64	-111.93	1			3.8 ML	3	F	.		.	3	.	P	.	.	.	.	.	.	.	.	199
PDE-W	2004	9	19	60943.8 A	38.85	-107.36	1			3.5 ML	.	.	.		.	3	.	P	.	.	.	.	.	.	.	.	211
PDE-W	2004	11	7	65459 U	38.24	-108.92	0			4.1 ML	4	F	.		.	3	.	P	.	.	.	.	.	.	.	.	111
PDE-W	2005	3	14	53327 U	39.51	-111.90	1			3 ML	.	.	.		.	3	.	P	.	.	.	.	.	.	.	.	191
PDE-W	2005	5	18	192146 U	41.43	-111.09	1			3.3 ML	.	.	.		.	3	.	P	.	.	.	.	.	.	.	.	294
PDE-Q	2005	6	24	130133 U	37.51	-112.53	6			3.6 ML	3	F	.		.	3	.	P	.	.	.	.	.	.	.	.	289
PDE-Q	2005	7	20	70615 U	38.60	-112.69	1			3.5 ML	.	.	.		.	3	.	P	.	.	.	.	.	.	.	.	255

U.S. Department of Energy—Grand Junction, Colorado

Calculation Cover Sheet

Calc. No.: MOA-02-09-2005-01-09-01 **Discipline:** Geologic and Geophysical Properties **No. of Sheets:** 18

Project: Moab Project

Site: Crescent Junction Disposal Site

Feature:
Site and Regional Seismicity – Results of Maximum Credible Earthquake Estimation and Peak Horizontal Acceleration

Sources of Data:

Published reports and maps – see list of references at end of calculation set.

Sources of Formulae and References:

Wells and Coppersmith (1994) relationships are used to estimate the maximum credible earthquake (MCE) from fault rupture length and rupture area data.

Campbell and Bozorgnia (2003) relationships are used to estimate attenuation of peak horizontal acceleration (PHA) to the site.

References: see list of references at end of calculation set.

Preliminary Calc. ☐ **Final Calc.** ☐ **Supersedes Calc. No. MOA-02-09-2005-01-09-00**

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Problem Statement:

Determination of the suitability of the Crescent Junction disposal site as the repository for the Moab uranium mill tailings material, and development of the site and regional seismotectonic sections of the Remedial Action Plan (RAP) requires an estimation of the Maximum Credible Earthquake (MCE) and the attenuation of the peak horizontal acceleration (PHA) associated with this MCE to the site.

Method of Solution:

The estimation of MCE and the associated PHA are part of the seismotectonic calculation set to develop seismic design parameters for the disposal site. Following procedures outlined in the UMTRA – DOE Technical Approach Document (TAD) (DOE 1989), the calculation set includes an estimation of the floating earthquake (FE) associated with the Colorado Plateau province applied 15 km from the site, the MCE associated with all pertinent outlying provinces, and the MCE associated with all known or suspected Quaternary faults within the study region. For each of these identified earthquake events, the on-site PHA is assessed and the design PHA is established.

Assumptions:

It is assumed that the literature sources are reliable and representative of the current understanding of the seismotectonic characteristics of the region.

Calculation:

MCE estimations are calculated using the formulas developed by Wells and Coppersmith (1994) as follows:

$$M = 5.08 + 1.16 \times \log(SRL) \qquad \text{(Eq. 1)}$$
$$M = 4.07 + 0.98 \times \log(RA) \qquad \text{(Eq. 2)}$$

Where M is Moment Magnitude, SRL is surface rupture length (km), and RA is rupture area (km^2). The coefficients in these equations are based on regression data developed for all slip types.

Attenuation to the site is calculated using the corrected peak ground acceleration, mean-plus-one standard deviation (84th percentile) relationship developed by Campbell and Bozorgnia (2003) as follows:

$$\ln Y = c_1 + f_1(M_w) + c_4 * \ln\sqrt{f_2(M_w, r_{seis}, S)} + f_3(F) + f_4(S) + f_5(HW, F, M_w, r_{seis}) + \varepsilon \qquad \text{(Eq. 3)}$$

Where Y = peak horizontal ground acceleration,
c_1, c_4 = coefficients corresponding to corrected PHA regression analysis,
M_w =moment magnitude,
R_{seis} = closest distance from site to seismogenic rupture (km), where depth to seismogenic rupture is a minimum of 3 km (Campbell 1997)
S = local site condition factors (consistent with firm rock sites for Crescent Junction),
F = faulting mechanism factors (consistent with normal faulting for Crescent Junction),
HW = hanging-wall effect factor for faults with surface projection within 5 km of site and fault dip less than or equal to 70 degrees, and
ε = random error term equivalent to zero for mean and standard deviation equal to $\sigma_{\ln y}$, defined as a function of magnitude.

The Campbell and Bozorgnia (2003) relationship is an updated attenuation relationship to the Campbell (1981) relationship referenced in the TAD (DOE 1989).

Criteria and Definitions:

The following are the standards and definitions that are applied to the evaluation of the seismicity of the Crescent Junction site as specified in the TAD (DOE 1989, p. 133).

Design life. As specified by the U.S. Environmental Protection Agency (EPA) Promulgated Standards for Remedial Actions at Inactive Uranium Processing Sites (40 CFR 192), the controls implemented at UMTRA Project sites are to be effective for up to 1,000 years, to the extent reasonably achievable and, in any case, for at least 200 years. For the purpose of the seismic hazard evaluation, a 1,000-year design life is adopted.

Design earthquake. For UMTRA Project sites, the magnitude(s) of the earthquake(s) that produces the largest on-site peak horizontal acceleration and that produces the most severe effects upon the site is the design earthquake. This earthquake could be either a floating earthquake or an earthquake whose magnitude is derived from a relationship between fault length and maximum magnitude. The latter case is applied for a verified or assumed capable fault of known rupture length.

Floating earthquake (FE). An FE is an earthquake within a specific seismotectonic province that is not associated with a known tectonic structure. Before assigning the FE magnitude, the earthquake history and tectonic character of the province are analyzed.

Capable fault. A capable fault is a fault that has exhibited one or more of the following characteristics:

- Movement at or near the ground surface at least once within the past 35,000 years or movement of a recurring nature within the past 500,000 years.
- Macroseismicity (magnitude 3.5 or greater) determined with instruments of sufficient precision to demonstrate a direct relationship with the fault.
- A structural relationship to a capable fault such that movement on one fault could be reasonably expected to cause movement on the other.

Acceleration. Acceleration is the mean of the peaks of the two orthogonal horizontal components of an accelerogram record. The exact term used is "peak horizontal acceleration" (PHA). The accelerations are determined from the corrected peak horizontal ground acceleration attenuation relationship based on distance and magnitude as developed by Campbell and Bozorgnia (2003). The mean-plus-one standard deviation (84th percentile) value is adopted. This relationship is an update to the Campbell (1981) relationship referenced in the TAD (DOE 1989).

Surface acceleration. Surface acceleration is the site acceleration adjusted for the site soil attenuation or amplification effects.

Magnitude and intensity. Magnitude is the base-10 logarithm of amplitude of the largest deflection observed on a torsion seismograph 100 km from the epicenter (Richter 1958). This local magnitude value may not be the same as the body-wave and surface-wave magnitudes derived from measurements at teleseismic distances. Unless specified otherwise, Richter magnitudes for values less than 6.5 are used in UMTRA Project seismic hazard evaluations. Intensity is the index of the effects of any earthquake on the human population and structures. The most commonly applied scale is the 1931 Modified Mercalli (MM) Intensity Scale, which will be used in this study.

Maximum earthquake. The term Maximum Earthquake (ME) was defined by Krinitzsy and Chang (1977) as the largest earthquake that is reasonably expected on a given structure or within a given area. No recurrence interval is specified for such an event.

Local regional study area. The regional study area is selected by calculating the distance at which the largest magnitude earthquake possible for a region, as determined by Algermissen et al. (1982), produces the minimum accepted on-site design acceleration (0.10g). All further characterization work is then limited to this region. Using this definition, the maximum earthquake for the region as determined by Algermissen et al. (1982) is magnitude 6.1. Using Campbell and Bozorgnia (2003) attenuation relations for corrected peak ground accelerations, 84th percentile values, distances within 30 km of the site are considered within the local regional study area.

Expanded regional study area. Although UMTRA defines the study area as discussed above, the U.S. Nuclear Regulatory Commission (NRC) for Title 10, Part 100, Appendix A requires an investigation within 200 miles of the site. For purposes of this seismotectonic evaluation, capable faults, historical earthquakes, and floating earthquakes associated with neighboring tectonic provinces that lie within 200 miles of the site and are capable of producing a minimum on-site acceleration of 0.10g or greater will be evaluated in the expanded regional study area.

Discussion:

Floating Earthquake

The purpose of the FE evaluation is to estimate a "background" level of seismicity within a tectonic province. The FE evaluation allows for potential low to moderate earthquakes not associated with tectonic structures to affect the site. Large earthquakes would be expected to leave a detectable surface expression, especially in arid to semiarid climates, with slow erosion rates and limited vegetation. The maximum magnitude associated with an FE event is assumed to be 6.2, consistent with that used in the Grand Junction RAP (DOE 1991, pg. 71).

Historical earthquake data for the area within a 200-mile radius of the Crescent Junction site were obtained for the initial phase of this study. The complete data file was included in Appendix B of the literature review calculation set (Calculation Set No. MOA-02-08-2005-07-00). To assess the FE magnitude and recurrence interval associated with the Colorado Plateau, a second historical earthquake search was conducted to limit events to those occurring within the boundaries of the Colorado Plateau (NEIC 2005). A rectangular search was conducted initially, with the latitudes constrained to between 34.5 and 40.75 degrees north, and the longitude between 106.5 and 112.5 degrees west. After the initial search, events with epicenters lying outside the boundaries of the Colorado Plateau as shown in Figure 1 were deleted. For consistency, moment magnitude (M_w) was used where possible. Consistent with Campbell (1981) attenuation equations, M_w was considered approximately equal to surface wave magnitudes (M_s) for events greater than 6.0, and approximately equal to local magnitude (M_L) for events smaller than 6.0. Modified Mercalli Intensity (MMI) values were converted to Richter scale using the following equation:

$$M = 1 + \frac{2}{3} * I_o \qquad \text{(Eq. 4)}$$

where M = magnitude on the Richter scale, and I_o is the MMI in the epicentral area.

Magnitudes were used in this order of preference: M_w, M_s if >6.0, M_L if ≤ 6.0, other reported magnitudes, and MMI values converted to magnitude.

Events were filtered to include only events with magnitudes equal or greater than 3.0. Events that are thought to be non-tectonic in origin or induced by non-natural causes are not considered further in the evaluation. One cluster of such events is described by Smith and Sbar (1974) to include a swarm of events at latitude 39.5 N and longitude 110.75 W located along the Book Cliffs in the coal mining district of eastern Utah. These earthquakes, the largest of magnitude 4.5, are thought to be indirectly triggered by subsurface coal mining in an area of high regional stress. Other events include those associated with fluid injection at the Rangely oil field along the border between northeastern Utah and northwestern Colorado, and a series of events associated with the Paradox Valley desalinization project that included deep water injections beginning in 1995 (Colorado Geological Survey 2002). In addition, the earthquake data was declustered to remove aftershocks and foreshocks. The events considered in the evaluation of the Colorado Plateau FE are shown in Appendix A.

As shown in Figure 1, there is more activity on the borders of the Colorado Plateau than within the interior portions. This increased activity is associated with the transitional area of crustal thinning (30 – 35 km along the perimeter area) associated with extension. The interior of the Plateau has a crustal thickness of approximately 45 km (Keller et al. 1979). For the FE evaluation, a conservative recurrence of events was evaluated for the entire Colorado Plateau; the interior and perimeter portions were not evaluated separately.

The regional study area is located in an area with a relatively quiet recorded earthquake history. The first recorded earthquake in the state of Utah was estimated to have a Modified Mercalli Intensity (MMI) of IV, and occurred near Salt Lake City in 1850 (Arabasz et al. 1979). The earliest recorded earthquake event in Colorado had a MMI of VI, and occurred near Pueblo in 1870 (Kirkham and Rogers 1981). Since this time, only approximately 15 events have been recorded within the Colorado Plateau with an intensity greater than VI or a magnitude greater than 5. Most of these early events were recorded in populated areas. This short recorded history can be misleading when attempting to predict future events, especially in sparsely populated areas such as the Colorado Plateau, and should be used with caution (Kirkham and Rogers 1981). The historical completeness record was estimated by examining the data set of events and the frequency of recorded occurrence as grouped by magnitude. By examining the frequency distribution with time, the completeness record can be estimated, as shown in Figures 2, 3, and 4. For this report, it is estimated that the historical record is complete since approximately 1890 for events with a magnitude 5.0 or greater, approximately 1960 for events with a magnitude of 4.0 or greater, and approximately 1970 for events with a magnitude of 3.0 or greater. This is in general agreement with the completeness record assumed for the Cheney disposal cell in Grand Junction, Colorado (DOE 1991, p. 68).

A log-frequency versus magnitude plot was generated for the Colorado Plateau, and a straight line fit to the data. The estimated recurrence interval for the Colorado Plateau was estimated to be represented by the equation

$$M = 4.35 - 0.82 * \log(\frac{1}{y}) \qquad \text{(Eq. 5)}$$

where y is the recurrence interval. The graphical representation is shown in Figure 5. The frequency-magnitude data can also be normalized with area to be of the form

$$M = 4.35 - 0.82 * \log\frac{A_p}{y * a}, \qquad \text{(Eq. 5)}$$

Where Ap= area of the Colorado Plateau Province (approximately 117,000 square miles or 303,000 square km),
y = recurrence interval, and
a = area of interest.

When normalized to 1 square km, the recurrence interval is represented by

$$M = -0.14 - 0.82 * \log(\frac{1}{y}). \qquad \text{(Eq. 6)}$$

Limiting the FE event to magnitude 6.2, and assuming this event occurs at a radial distance of 15 km (9 miles) from the site, results in a PHA of 0.22 g (using Campbell and Bozorgnia 2003 corrected peak horizontal ground acceleration, 84th percentile relationship). Based on the above Eq. 5, the recurrence interval of a 6.2 event occurring within 15 km of the site is 77,000 years. The probability of this event being exceeded within the assumed design life of 1,000 years is one percent.

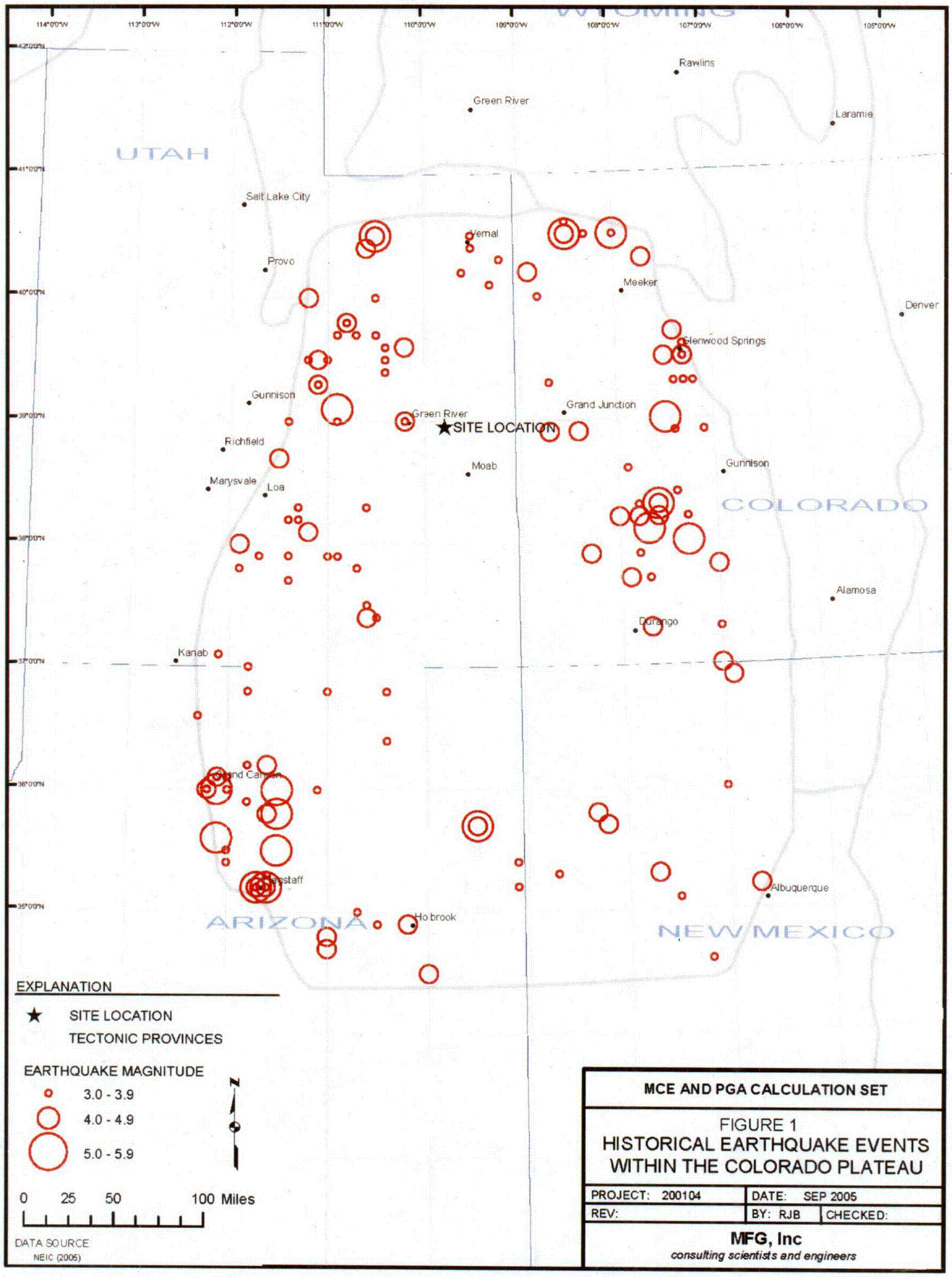

Figure 1. Historical Earthquake Events within the Colorado Plateau

C18

MCE associated with Outlying Tectonic Provinces

The MCE values for remote seismotectonic provinces, such as the Intermountain Seismic Belt, Rio Grande Rift, Wyoming Basin, and Southern Rocky Mountains were taken from published studies (Kirkham and Rogers 1981, DOE 1991). The MCE from each event is attenuated to the site assuming that the event occurs at the point within the outlying province that is closest to the site. The PHA calculated for each event is shown in Table 1.

Table 1. PHA associated with MCE event in outlying tectonic provinces

Tectonic Province	MCE	Closest point to site (miles)	PHA (g)
Rio Grande Rift	7.5	180	0.02
Intermountain Seismic Zone	7.9	65	0.08
Eastern Mountain	6.75	200	0.01
Western Mountain	6.5	140	0.02
Wyoming Basin	6.5	140	0.02

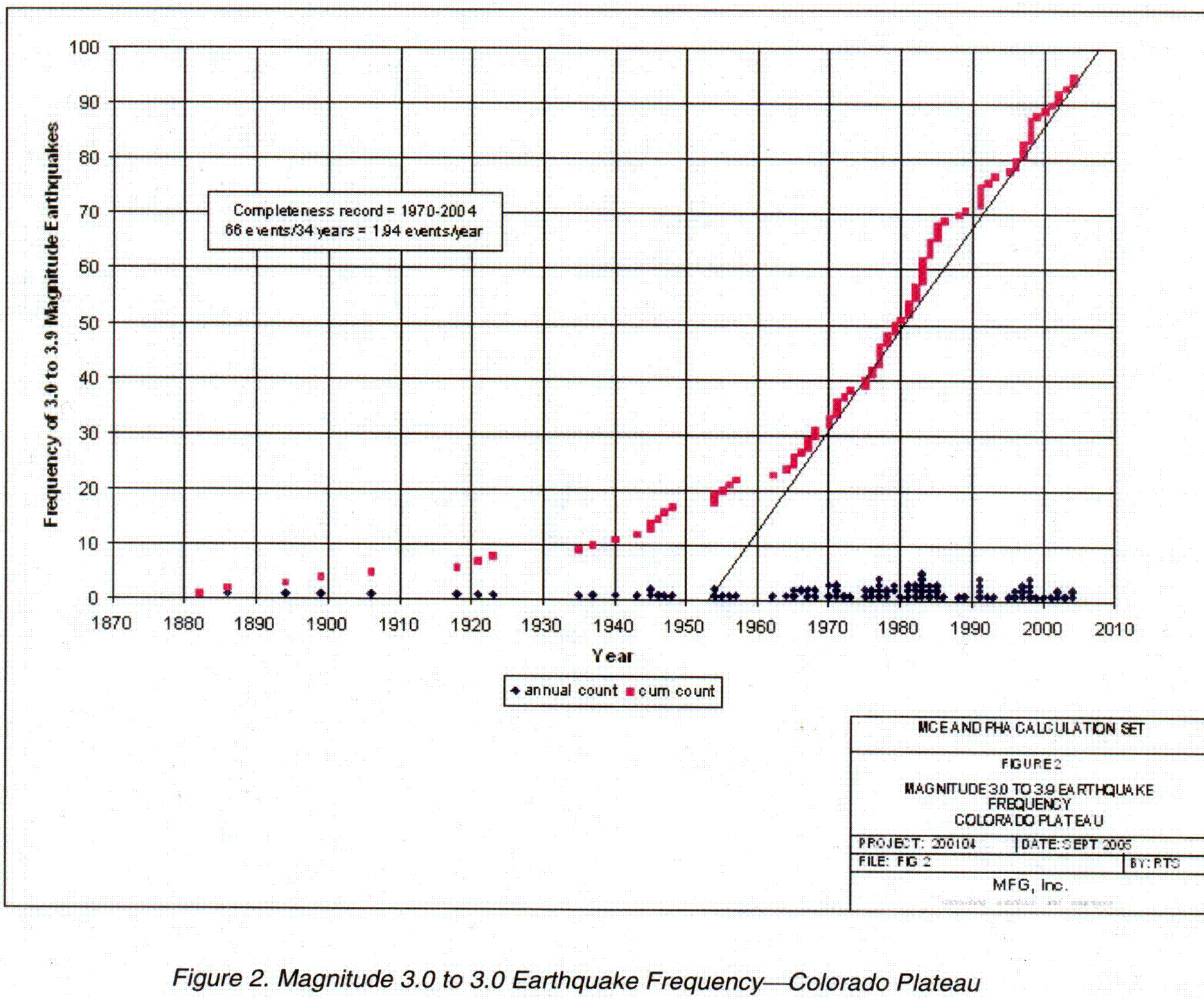

Figure 2. Magnitude 3.0 to 3.0 Earthquake Frequency—Colorado Plateau

C19

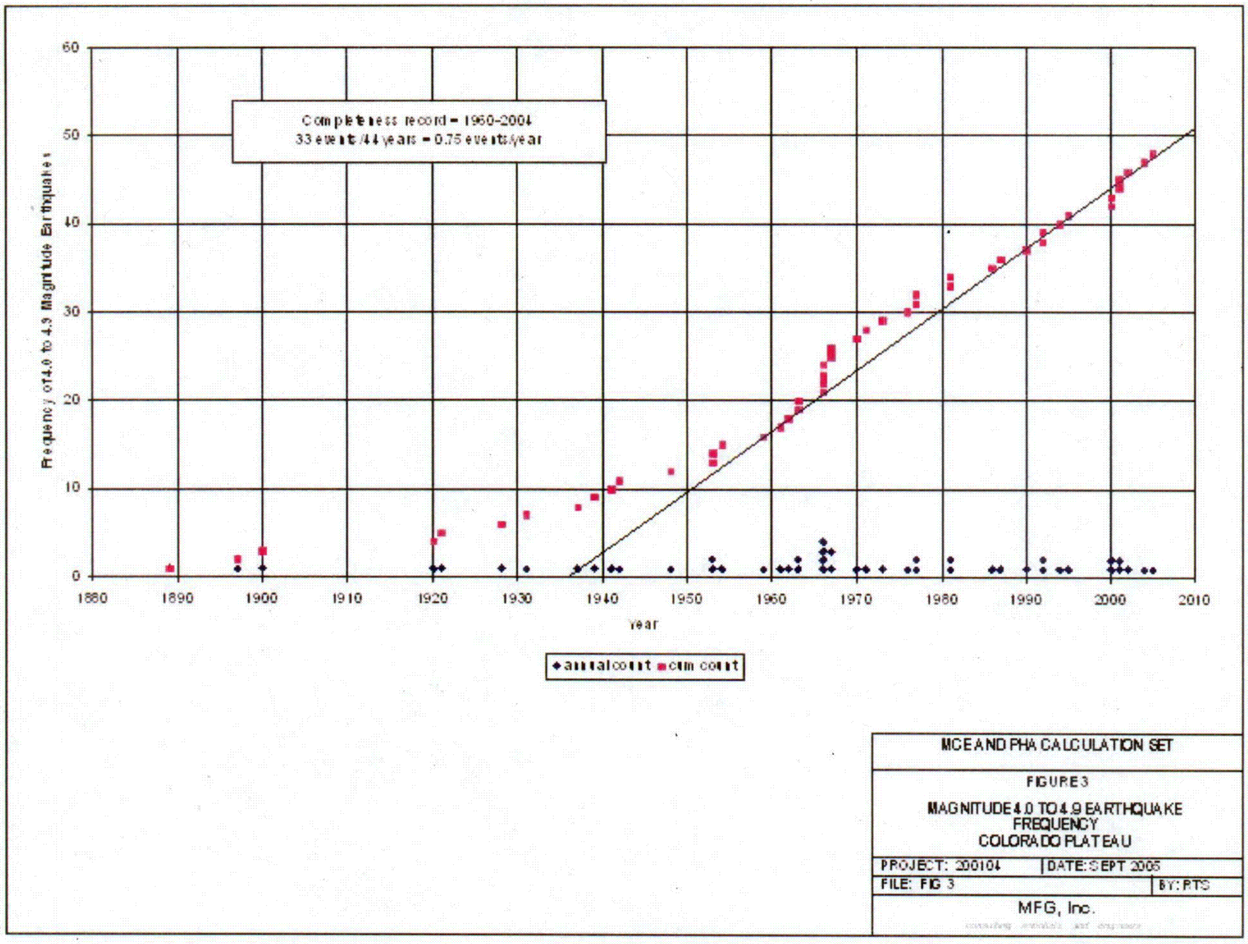

Figure 3. Magnitude 4.0 to 4.9 Earthquake Frequency—Colorado Plateau

C20

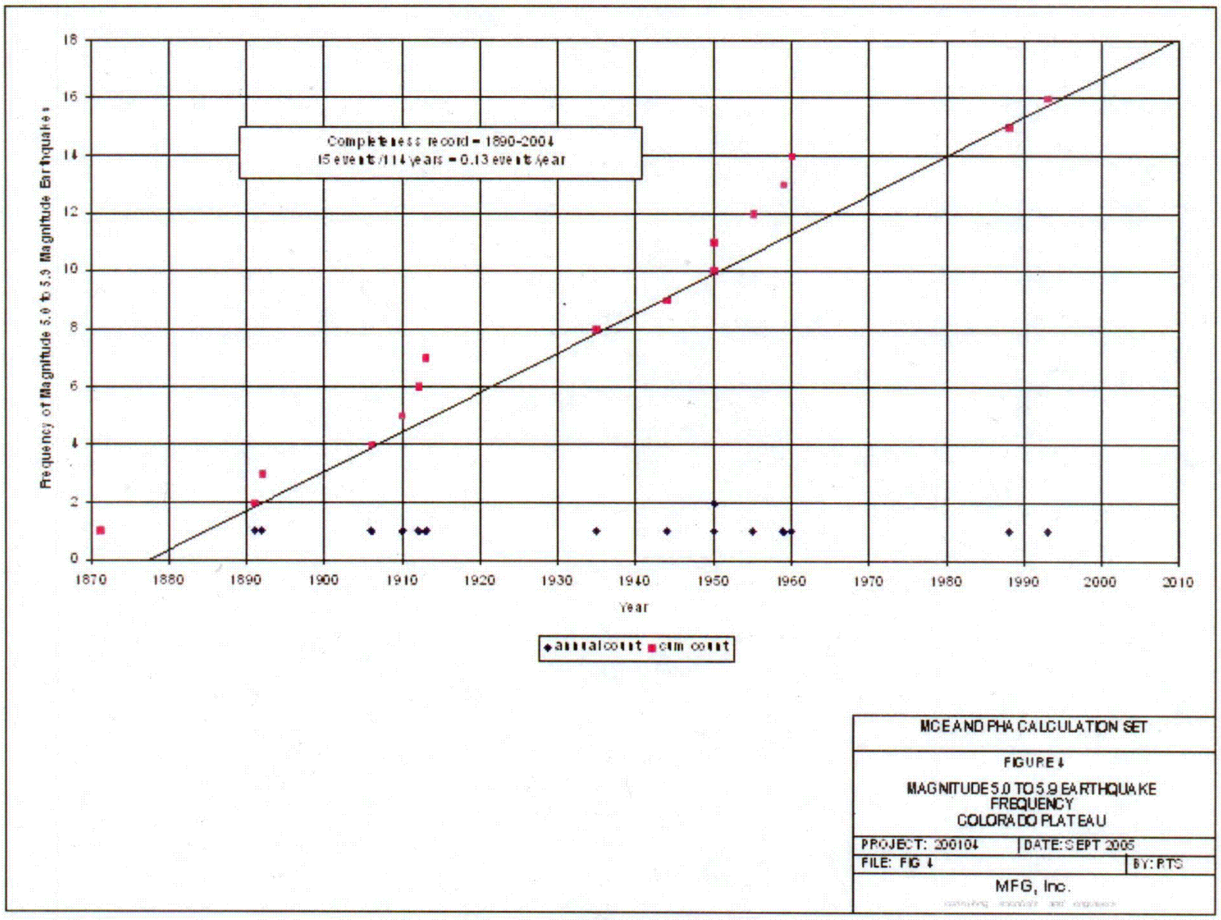

Figure 4. Magnitude 5.0 to 5.9 Earthquake Frequency—Colorado Plateau

CZ1

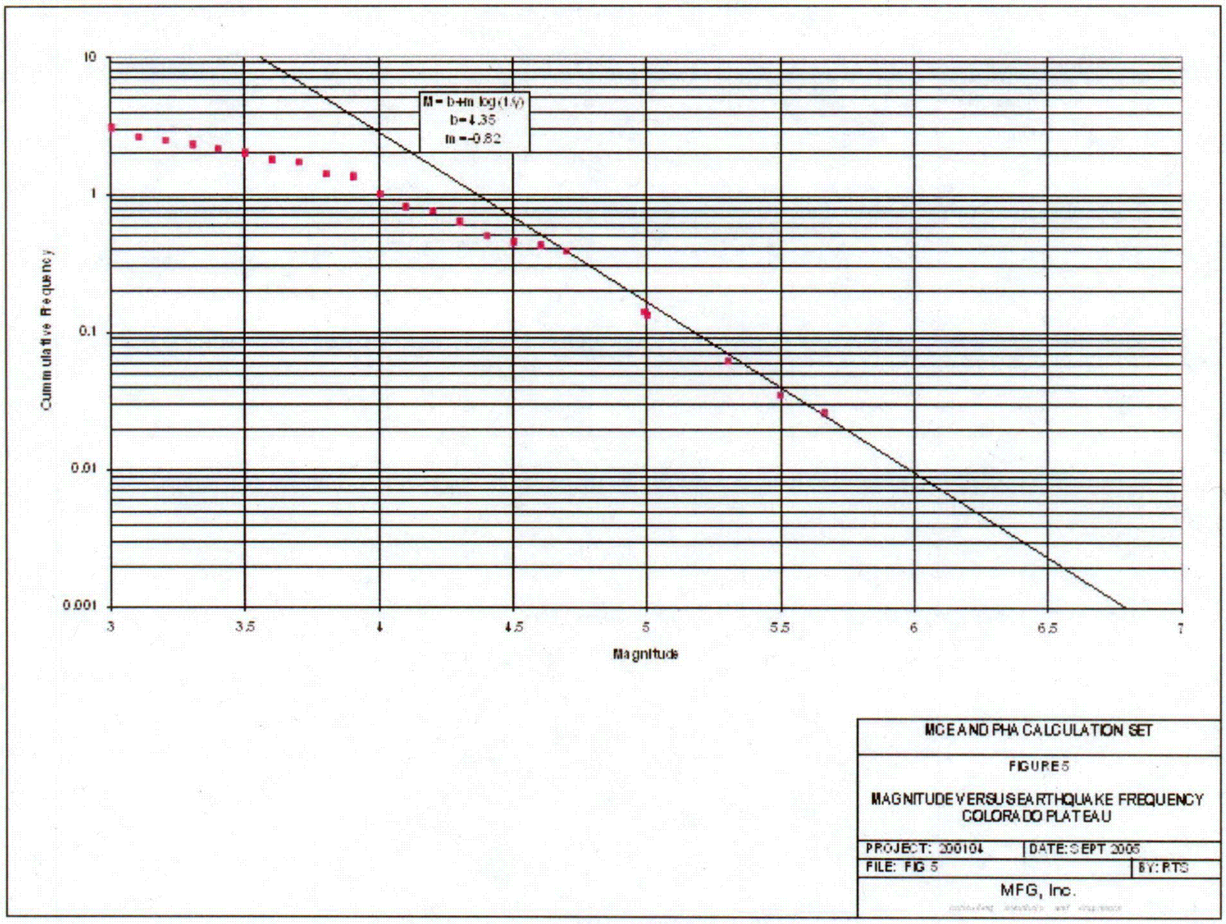

Figure 5. Magnitude Versus Earthquake Frequency—Colorado Plateau

C22

As shown in the above table, the greatest PHA associated with an outlying province is a 7.9 magnitude event occurring within the Intermountain Seismic Zone, resulting in a PHA of 0.08 g.

MCE associated with known or suspected Quaternary faults

Quaternary faults were identified using the USGS and Utah Geological Survey Quaternary Fault and Fold databases (Black et al. 2003, USGS 2002). An initial search for critical Quaternary faults was conducted using the minimum fault lengths given in NRC document 10 CFR part 100, Appendix A, as shown in Table 2. The complete list of faults meeting these minimum length requirements was included in the Literature Review calculation set, Appendix A.

Table 2. Minimum length of fault to be considered in establishing MCE

Distance from Site		Minimum Length	
miles	**kilometers**	**miles**	**kilometers**
0 to 20	0 to 32	1	1.6
Greater than 20 to 50	Greater than 32 to 80	5	8
Greater than 50 to 100	Greater than 80 to 161	10	16
Greater than 100 to 150	Greater than 160 to 240	20	32
Greater than 150 to 200	Greater than 240 to 320	40	64

In addition to faults included in the Quaternary Fault and Fold database, faults of undetermined age that are shown on geologic maps in the area (Williams 1964, Gualtieri 1988, Witkind 1995, Williams and Hackman 1971), were considered if the PHA associated with these structures (if considered Quaternary) is greater than 0.1 g. The faults considered in this study are shown in Figure 6. In addition, a tabular form of the data is shown in the current calculation set as Appendix B. Figure 7 shows the considered faults overlain by historical earthquakes in the area. No historical earthquake events (above magnitude 3.0) are associated with any of the considered faults that could impact the site.

The MCE associated with each fault was calculated using Wells and Coppersmith (1994) relationships. PHA was calculated using Campbell and Bozorgnia (2003) attenuation equations. Using these relationships, thirteen faults were initially identified as potentially capable of producing site PHA values greater than 0.10 g, and are summarized in Table 3.

As discussed in the literature review (Calculation Set No.MOA-02-08-2005-07-00), the Salt and Cache Valley faults, Ten Mile Graben, and the Moab and Spanish Valley faults are all associated with the salt structures within the Paradox Basin. Reports by Olig et al. (1996), Woodward-Clyde (1996), and Woodward-Clyde (1984) found no evidence of Quaternary tectonic deformation of these structures. Based on detailed mapping, structural evidence, and geophysical data, Olig et al (1996) determined that the faults within the Moab and Spanish Valley are most likely related to salt-dissolution. They concluded that the primary movement on the Moab Fault is tectonic and occurred during a period of Tertiary extension. In addition, most, if not all, of the slip on the Moab fault is pre-Quaternary, and that the Moab Fault is a shallow structure that probably soles into the Moab salt-cored anticline within 2 km depth along much of its length. Therefore, it would most likely not be capable of producing significant earthquakes.

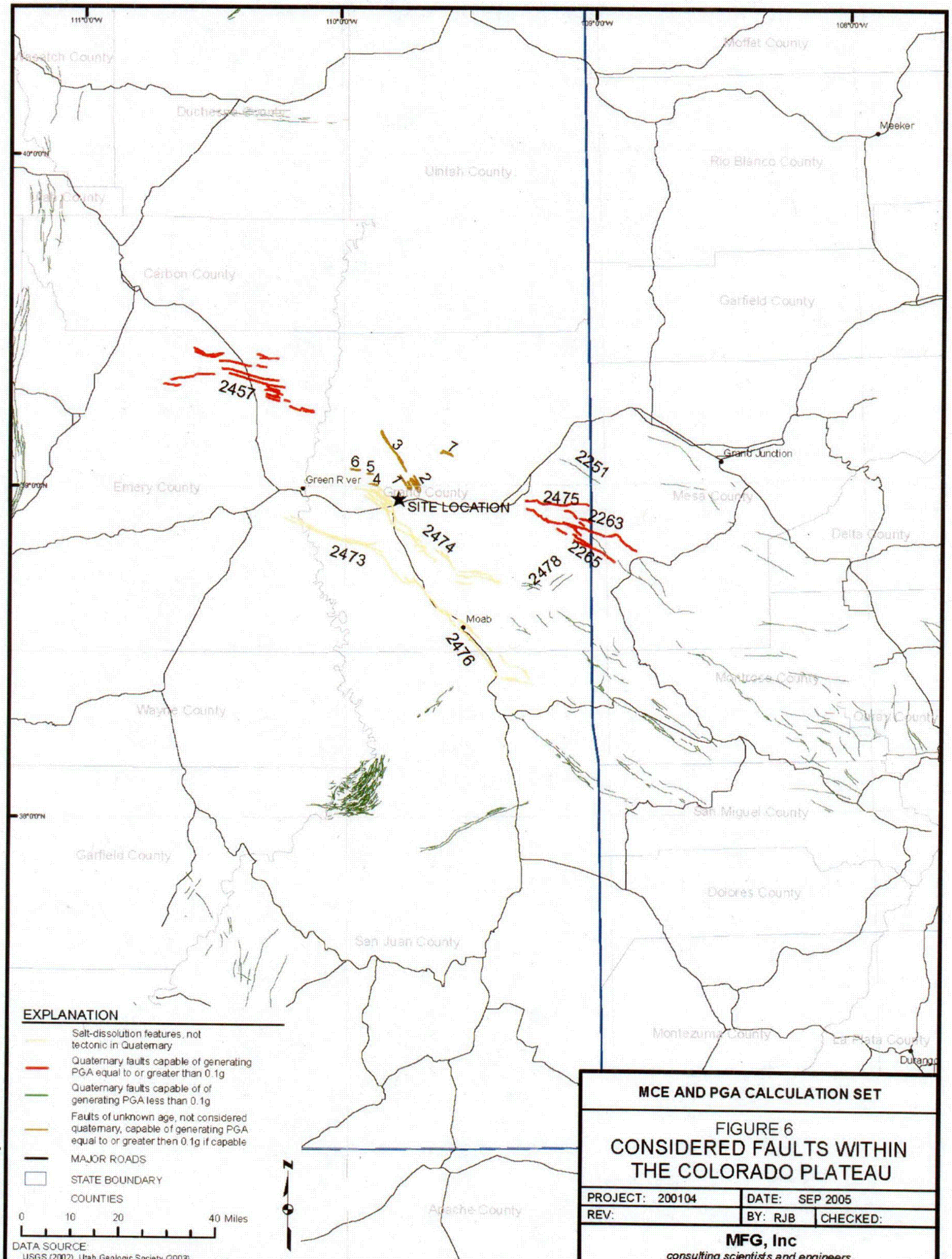

Figure 6. Considered Faults within the Colorado Plateau

C23

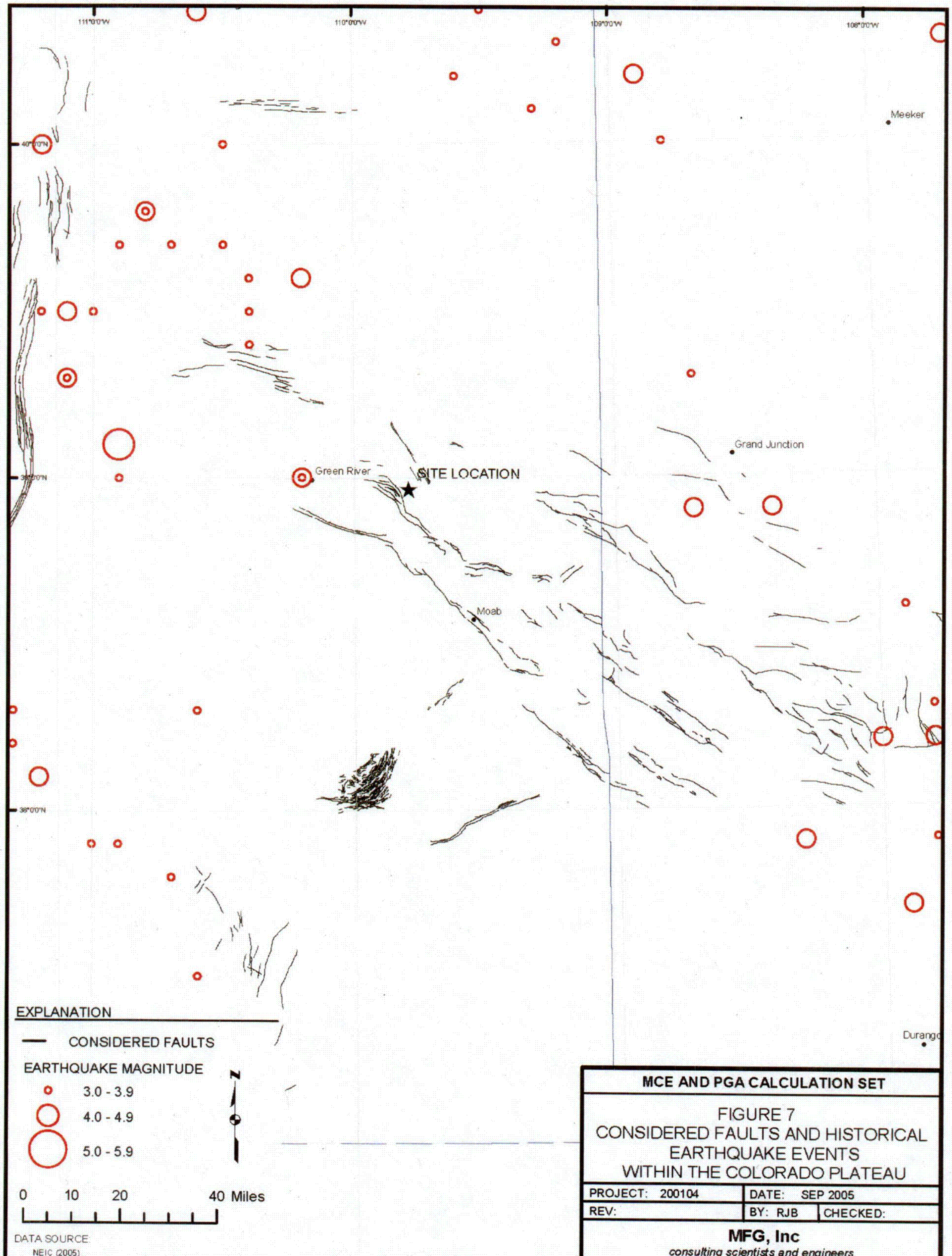

Figure 7. Considered Faults and Historical Earthquake Events within the Colorado Plateau

C24

Table 3. Preliminary MCE associated with Quaternary faults and faults of unknown age

Fault Name	Fault Number[a]	Length (km)	Depth of Rupture (km)	Rupture Area (km^2)	Distance from site (mi)	MCE (M_w)[b]	PHA (g) Campbell (1981)	PHA (g) Campbell and Bozorgnia (2003)	Comment
Salt and Cache Valleys faults	2474	57.9	<2	115.8	1.8	6.09	0.54	0.67	Fault determined to not be active in Quaternary based on field evidence and lack of microearthquake activity (Wong et al. 1996, Woodward Clyde 1984). Not potential design fault.
Ten Mile graben faults	2473	34.6	<2	69.2	10.5	5.87	0.15	0.16	Fault likely not active in Quaternary (Woodward Clyde 1996). Shallow structure not likely capable of large events (Olig et al. 1996). Potential design fault.
Moab fault and Spanish Valley faults	2476	72.4	<2	114.8	12.5	6.19	0.16	0.16	Fault likely not active in Quaternary (Olig et al. 1996). Shallow structure likely not capable of large events (Olig et al. 1996). Potential design fault.
Price River area faults	2457	50.9			24.8	7.06	0.15	0.13	Potential design fault.
Ryan Creek fault zone	2263	39.5			26.6	6.93	0.13	0.11	Potential design fault.
Sand Flat graben faults	2475	23.1			26.4	6.66	0.10	0.10	Potential design fault.
Unnamed fault in Westwater Quad, R19E, T21S	1	8.0			2.4	6.13	0.50	0.60	Associated with Thompson Anticline. Subsidence features. Not potential design fault.
Unnamed parallel faults in Westwater Quad, R20E, T21S	2	6.4			3.1	6.02	0.42	0.49	Associated with Thompson Anticline. Subsidence features. Not potential design fault.

Table 3 (continued). Preliminary MCE associated with Quaternary faults and faults of unknown age

Fault Name	Fault Number[a]	Length (km)	Depth of Rupture (km)	Rupture Area (km^2)	Distance from site (mi)	MCE (M_w)[b]	PHA (g) Campbell (1981)	PHA (g) Campbell and Bozorgnia (2003)	Comment
Unnamed fault in Westwater Quad, R19E, T19S	3	15.7			5.3	6.47	0.38	0.42	Associated with Thompson Anticline. Subsidence features. Not potential design fault.
Unnamed fault in Westwater Quad, R18E, T21S	4	2.9			4.9	5.62	0.26	0.29	No evidence of Quaternary faulting. Potential design fault.
Unnamed fault in Westwater Quad, R18E, T20S	5	1.9			7.0	5.40	0.16	0.19	No evidence of Quaternary faulting. Potential design fault.
Unnamed fault in Westwater Quad, R17E, T20S	6	3.3			9.6	5.68	0.14	0.16	No evidence of Quaternary faulting. Potential design fault.
Unnamed fault in Westwater Quad, R21E, T20S	7	4.4			12.4	5.83	0.12	0.13	No evidence of Quaternary faulting. Potential design fault.

[a]Fault number identical to UGS Quaternary Fault and Fold Database if fault is included in database, otherwise assigned number 1 – 7 unique to this report.
[b]MCE based on rupture area, where data available, otherwise based on rupture length.

In addition, geomorphic expression of the fault indicates very low rates of activity. The report also indicates that the earthquake potential of the other salt structures within the Paradox Basin may also be similarly low. From these discussions, the MCE associated with these structures was calculated using Wells and Coppersmith (1994) relationships based on rupture area, assuming that the rupture depth is 2 km.

In 1979, a seismic monitoring program was initiated to assess the seismicity of the Paradox Basin at the microearthquake level. A report by Woodward-Clyde (1984) studying the Salt Valley area indicated that from 1979 time through 1984, only two events were detected in the Salt Valley area (M_L of 1.2, and 2.1). They concluded that the seismicity associated with the study area is generally diffusely distributed and of low level and small magnitude, consistent with the longer historical record of the interior of the Colorado Plateau. From these data, it is assumed that there is no seismicity associated with the Salt and Cache Valley faults, and the faults are not considered capable.

The unnamed faults in the Westwater 30' x 60' quadrangle map are of undocumented age. Faults 1, 2, and 3 are associated with the Thompson anticline. They are described by Gualtieri (1988) as "high-angle normal faults and are the result of subsidence following the exsolution of salt." Thus, the faults may have initiated due to salt movement. There is currently a lack of evidence suggesting Quaternary displacement. Faults 4 through 7 are also of unknown age. However, the PHA of faults 5 through 7, if active, are below that calculated for the FE event (0.22 g). The PHA of fault 4 (0.29 g) is above that calculated for the FE event.

A preliminary field investigation of several of the unnamed faults listed in Table 3 was conducted by Craig Goodknight, S.M. Stoller, and Greg Smith, consultant, on November 22, 2005. Unnamed faults 1 and 2 were investigated for evidence of Quaternary displacement. These faults, associated with the Thompson Anticline (Willis, 1986; Doelling, 2001), showed no evidence of Quaternary movement (no Quaternary deposits were displaced by the faults). Farther to the north, unnamed fault 3 was not investigated, but it is of similar strike and also occurs along the Thompson Anticline. It was concluded that no recent movement has occurred along these faults associated with the Thompson Anticline, and that they reflect slow, incipient subsidence related to dissolution of deep salt deposits along the northeast edge of the Paradox Basin. This conclusion is also drawn by Gualtieri (1988) as "high-angle normal faults and are the result of subsidence following the exsolution of salt".

Also as part of the investigation, several faults in the northern part of the system of Salt and Cache Valley faults were checked for evidence of Quaternary movement. These west-northwest-striking faults are east and west of Floy Wash in the Hatch Mesa 7.5-minute quadrangle (Chitwood, 1994; Doelling, 2001). Associated with the Salt Valley Anticline, these faults showed no evidence of Quaternary movement (no displacement of Quaternary deposits by the faults). Just to the north of these faults in the Westwater 30' x 60' quadrangle, unnamed faults 4, 5, and 6 were not investigated, but they are of similar strike and also are related to the Salt Valley Anticline. It was similarly concluded that no Quaternary movement has occurred on these faults associated with the Salt Valley Anticline, and that they are also related to dissolution of deep salt deposits in the northern Paradox Basin.

Conclusion and Recommendations:

Of the faults that are suspected of being active in the Quaternary, none are expected to have an impact on the site greater than that calculated for an FE event occurring 15 kilometers from the site. Therefore, the design PHA is estimated to be 0.22 g. Features such as the Salt and Cache Valley faults, and the faults associated with the Thompson Anticline are not thought to be seismogenic.

Computer Source:

- Not applicable.

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Appendix A

NEIC: Earthquake Search Results

APPENDIX A
NEIC: Earthquake Search Results

U N I T E D S T A T E S G E O L O G I C A L S U R V E Y

E A R T H Q U A K E D A T A B A S E

FILE CREATED: Mon Aug 15 14:28:55 2005
Geographic Grid Search Earthquakes= 549
Latitude: 40.750N - 34.500N
Longitude: 106.500W - 112.500W
Catalog Used: PDE
Data Selection: Historical & Preliminary Data

FILE CREATED: Mon Aug 15 14:31:32 2005
Geographic Grid Search Earthquakes= 991
Latitude: 40.750N - 34.500N
Longitude: 106.500W - 112.500W
Catalog Used: SRA
Data Selection: Eastern, Central and Mountain States of U.S. (SRA)

FILE CREATED: Mon Aug 15 14:30:22 2005
Geographic Grid Search Earthquakes= 64
Latitude: 40.750N - 34.500N
Longitude: 106.500W - 112.500W
Catalog Used: USHIS
Data Selection: Significant U.S. Earthquakes (USHIS)

BOLD EVENTS ARE EVENTS CAUSED BY WELL INJECTION AND ARE NOT INCLUDED IN RECURRENCE CALCULATIONS

CATALOG SOURCE	Date YEAR	MO	DA	ORIGIN TIME	COORDINATES LAT	LONG	DEPTH km	MAGNITUDES mb	Ms	CONTRIBUTED VALUES	INFORMATION I N T	E F F M A P F P S M O D E P I D E P F D F L G D T S V N W G	Converted Magnitude	Comments
SRA	1871	10	0	0 Z	40.5	-108.5					6	. . . .	5	
SRA	1882	2	11	830 Z	37.3	-107					4	. . . .	3.66	
SRA	1886	7	0	0 Z	38.2	-107.3					4	. . . .	3.66	
SRA	1889	1	15	22 Z	39.5	-107.3					5	. . . .	4.33	
SRA	1891	12	0	21 Z	40.5	-108					6	. . . .	5	

SRA	1892	2	2	830 Z	35.2	-111.6				6	5
SRA	1894	1	1	10 Z	37.9	-107.8				4	3.66
SRA	1897	8	3	7 Z	38.2	-107.8				5	4.33
SRA	1899	0	0	230 Z	40.5	-108				4	3.66
SRA	1900	5	0	0 Z	36.9	-106.9				5	4.33
SRA	1906	1	25	213230 Z	35.2	-111.7				7	5.66
SRA	1906	4	0	0 Z	40.5	-108.3				4	3.66
SRA	1910	9	24	405 Z	35.8	-111.5				7	5.66
SRA	1912	8	18	2112 Z	36	-111.5				7	5.66
SRA	1913	11	11	2155 Z	38.1	-107.7				6	5
SRA	1918	4	28	1258 Z	35.2	-111.6				4	3.66
SRA	1920	12	29	250 Z	39.5	-107.5				5	4.33
SRA	1921	4	6	2107 Z	34.9	-110.2				5	4.33
SRA	1921	7	31	355 Z	36	-107				4	3.66
SRA	1923	9	28	0 Z	35.2	-111.7				4	3.66
SRA	1928	4	30	1550 Z	37.8	-107				5	4.33
SRA	1931	4	17	1238 Z	34.5	-110				5	4.33
SRA	1935	1	10	810 Z	36	-112.1				6	5
SRA	1935	10	6	3 Z	37.9	-111.4				4	3.66
SRA	1937	4	8	12 Z	35.7	-109.5				5	4.33
SRA	1937	12	17	2330 Z	35.2	-111.7				4	3.66
SRA	1939	3	9	1330 Z	36.1	-112.1				5	4.33
SRA	1940	10	16	1325 Z	35.2	-111.7				4	3.66
SRA	1941	8	29	1134 Z	37.3	-107.7				5	4.33
SRA	1942	7	23	1940 Z	40.5	-108.5				5	4.33
SRA	1943	8	14	540 Z	38.2	-111.4				4	3.66
SRA	1944	9	9	41220 Z	39	-107.5				6	5
SRA	1945	4	29	1708 Z	37.7	-107.7				4	3.66
SRA	1945	7	0	1155 Z	36.1	-112.1				4	3.66
SRA	1946	1	31	2245 Z	39.6	-107.3				4	3.66
SRA	1947	10	27	41540 Z	35.5	-112				4	3.66
SRA	1948	8	8	2320 Z	36.1	-112.1				5	4.33
SRA	1948	12	3	1845 Z	35	-110.7				4	3.66
SRA	1950	1	17	51 Z	35.7	-109.5				6	5
SRA	1950	1	18	15551	40.5	-110.5			5.3 UK	5	5.3
SRA	1953	7	30	545 Z	39	-110.2				5	4.33
SRA	1953	10	8	201946 Z	34.8	-111				5	4.33
SRA	1954	2	21	202051	40	-108.8				4	3.66
SRA	1954	3	31	14 Z	39	-110.2				4	3.66
SRA	1954	11	3	2039 Z	35.2	-106.7				5	4.33
SRA	1955	3	27	1213 Z	38.3	-111.3				4	3.66
SRA	1955	8	3	63942 Z	38	-107.3				6	5
SRA	1956	2	12	3 Z	40.5	-109.5				4	3.66
SRA	1957	7	18	152420	40	-110.5				4	3.66
SRA	1959	2	11	1401 Z	35.2	-111.7				5	4.33
SRA	1959	10	13	815	35.5	-111.5		5	5 ML	5	5
SRA	1960	10	11	80530	38.3	-107.6	49		5.5 mb	6	5.5

SRA	1961	5	6	161220	39.6	-110.2	25			5	4.33	
SRA	1962	2	5	144551	38.2	-107.6	25		4.7 ML	5	4.7	
SRA	1962	12	11	102813	39.4	-110.4	7		3.4 ML	0	3.4	
SRA	1963	7	9	202525	40	-111.2	7	4	4 ML	0 F	4	
SRA	1963	9	30	91739	38.1	-111.2	7	5	4.3 ML	0	4.3	
SRA	1964	8	5	151756	39	-110.9	7		3 ML	0	3	
SRA	1965	6	7	142801	36	-112.2	33		3.5 mb	0	3.5	
SRA	1965	6	29	74628	39.5	-110.4	7	4	3.2 ML	0	3.2	
USHIS	1966	1	23	15638	37	-107	3	5	4.99 Mw	7 F	4.99	
SRA	1966	5	20	134047	38	-111.9	7	4	4.1 ML	0	4.1	
SRA	**1966**	**7**	**6**	**54708**	**40.1**	**-109**	**7**	**4**	**3.7 ML**	**0**	**3.7**	**oil and gas withdrawal**
SRA	1966	7	30	32531	39.4	-110.4	7	4	3.1 ML	0	3.1	
SRA	1966	9	4	95234	38.3	-107.6	33	4		0	4.2	
SRA	1966	10	3	160350	35.8	-111.6	34	4		0	4.4	
SRA	1967	1	16	92245	37.7	-107.9	33	4		0	4.1	
SRA	**1967**	**2**	**15**	**32803**	**40.1**	**-109.1**	**7**	**5**	**4 ML**	**5**	**4**	**oil and gas withdrawal**
SRA	1967	4	4	225339	38.3	-107.8	33	5	3 ML	0	3	
SRA	1967	9	4	232746	36.2	-111.6	33		4.2 ML	0	4.2	
SRA	1967	10	25	24134	39.5	-110.4	0	4	3.2 ML	0	3.2	
SRA	1968	6	23	201613	39.3	-107.4	33	4		0	3.8	
SRA	1968	11	17	143338	39.5	-111	7	5	3.5 ML	0	3.5	
SRA	1970	2	3	55935	37.9	-108.3	33	4		0	4	
SRA	1970	2	21	61348	39.5	-110.4	7	4	3.1 ML	0	3.1	
SRA	1970	4	18	104211	37.9	-111.7	7	4	3.7 ML	0	3.7	
SRA	**1970**	**4**	**21**	**85352**	**40.1**	**-108.9**	**4**	**4**	**3.9 ML**	**5**	**3.9**	**oil and gas withdrawal**
SRA	1971	1	7	203952	39.5	-107.3	33	4	3.8 ML	5	3.8	
SRA	1971	7	10	172236	40.2	-109.6	7	4	3.7 ML	0	3.7	
SRA	1971	11	12	93044	38.9	-108.7	5		4 ML	3	4	
SRA	1971	12	15	125814	36.8	-111.8	5		3 ML	0	3	
SRA	1972	4	20	132816	35.3	-111.6	5	4		4	3.7	
SRA	1973	2	9	173837	36.4	-110.4	5		3.2 ML	0	3.2	
SRA	1973	12	24	22014	35.3	-107.7	18	4	4.1 ML	6	4.1	
SRA	1975	1	30	144840	39.3	-108.7	5	4	3.7 ML	5	3.7	
SRA	1975	3	7	31613	34.6	-107.2			3 ML	0	3	
SRA	1976	1	5	62332	35.8	-108.3	25	5	4.6 ML	6	4.6	
SRA	1976	2	28	205358	35.9	-111.8	5		3 ML	0	3	
SRA	1976	4	19	233545	35.4	-109.1	5		3.5 ML	5 ?	3.5	
SRA	1977	2	9	4216	39.3	-111.1	7		3.2 ML	6	3.2	
USHIS	1977	3	5	30055	35.7	-108.2	44	5	4.2 ML	6 F	4.2	
SRA	1977	6	3	13722	39.7	-110.5	7		3.2 MD	0	3.2	
SRA	1977	9	24	111648	39.3	-107.3	5	4	3 ML	0	3	
SRA	1977	9	30	101920	40.5	-110.5	6	5	4.5 ML	6	4.5	
SRA	1977	11	29	213123	36.8	-111	7		3 MD	0	3	
SRA	1978	5	29	164518	39.3	-107.3	5		3 ML	0	3	
SRA	1978	9	23	82006	39.3	-111.1	2		3 ML	0	3	
SRA	**1979**	**3**	**19**	**145929**	**40.2**	**-108.9**	**2**		**3.1 ML**	**4**	**3.1**	**oil and gas withdrawal**
SRA	1979	4	30	20710	37.9	-111	7		3.8 ML	3	3.8	

SRA	1979	10	23	41719	37.9	-110.9	7			3.5 ML	0 F	3.5
SRA	1980	6	1	84027	35.4	-112	5			3.6 ML	2	3.6
PDE	1981	5	14	51104 U	39.5	-111.1	1	5		4 UK	5 F . . 4 . P	4
SRA	1981	5	29	30902	36.8	-110.4	1			3 MD	0	3
SRA	1981	9	10	75509	37.5	-110.6	2			3.1 MD	0	3.1
PDE	1981	9	21	80133 U	39.6	-110.4	7			3.5 ML	3 F . . 3 . P	3.5
SRA	1981	12	6	90920	35.2	-111.6					5	4.33
SRA	1982	4	17	60012	38.2	-111.3	9			3 ML	0	3
SRA	1982	11	3	175411	35.3	-108.7	5			3 ML	0	3
SRA	1982	11	19	205734	36	-112	5			3 ML	0 F	3
SRA	1983	1	27	233711	37.8	-110.7	7			3.3 MD	0	3.3
SRA	1983	3	22	111235	39.5	-110.4	2			3.1 MD	0 F	3.1
PDE	1983	5	3	124338 U	38.3	-110.6	7			3.2 ML	0 . . . 3 . P	3.2
SRA	1983	8	14	190830	38.4	-107.4	5			3.4 ML	2	3.4
SRA	1983	8	31	81008	36.1	-112	5			3.3 ML	0 F	3.3
SRA	1984	3	21	111930	39.3	-111.1	0			3.5 ML	0 F	3.5
SRA	1984	5	14	101417	39.3	-107.2	5			3.2 ML	4	3.2
SRA	1984	7	18	142931	36.2	-111.8	5			3 ML	0	3
SRA	1985	4	14	214800	35.2	-109.1	5			3.3 ML	3	3.3
SRA	1985	6	27	103629	39.6	-110.4	1			3 MD	0	3
SRA	1985	10	7	203340	40.4	-109.5	21			3 MD	0	3
SRA	1986	8	22	132633	37.4	-110.6	5			4 ML	5	4
SRA	1986	9	3	62050	38.9	-107.1	5			3.5 ML	5	3.5
PDE	1987	3	5	30250 U	40.4	-110.6	1	4			4 F . . 4 . P	4
PDE	1988	2	14	183240	40.6	-108.5	5				4 F . . 4 . P	3.66
USHIS	1988	8	14	200303	39.1	-110.9	10	6		5.3 ML	6 F	5.3
PDE	1989	2	3	180821 U	39.7	-110.9	0				4 F . . 4 . P	3.66
PDE	1990	10	21	43119	38.9	-108.4	10				5 F . . 4 . P	4.33
PDE	1991	1	26	214938 U	37.7	-111.4	9			3.5 ML	3 F . . 3 . P	3.5
PDE	1991	4	26	130820	36.6	-112.3	10	3			4 F . . 4 . P	3.3
PDE	1991	5	23	73840 U	39.3	-111.1	12	4		3.6 ML	3 F . . 3 . P	3.6
PDE	1991	11	8	131505 U	40.1	-109.3	2	3			3 F . . 4 . P	3.4
PDE	1992	5	15	213624	38.6	-107.9	5				4 F . . 4 . P	3.66
PDE	1992	7	5	181729	36	-112.2	5	4			0 F . . 4 . P	4
PDE	1992	7	5	122223	39.3	-111.1	5	4			3 F . . 1 . P	4
PDE	1993	4	29	82100	35.6	-112.1	10	6	5	5.3 Mw	5 D U M 3 . P	5.3
PDE	1993	5	27	62153	37.1	-112.1	10	3		3.5 MD	3 F . . 3 . P	3.5
PDE	1994	9	13	60123	38.2	-108	10	4			6 D . . 4 . P	4.4
PDE	1995	3	20	124616	40.2	-108.9	5	4			5 F . . 4 . P	4.2
PDE	1995	4	17	82346	36	-112.2	5	4			5 D . . 4 . P	3.7
PDE	1996	2	2	21114 U	39.5	-111.2	1			3.2 ML	0 . . . 4 . P	3.2
PDE	1996	12	6	135314 U	39.7	-110.7	3			3.4 ML	0 . . . 3 . P	3.4
PDE	1997	3	31	73448	35.5	-112	5			3.7 ML	0 F . . 3 . P	3.7
PDE	1997	4	14	93048	39	-111.4	5			3.1 MD	0 . . . 3 . P	3.1
PDE	1997	10	20	70220	37.8	-111.9	10			3.1 ML	0 . . . 3 . P	3.1
PDE	1998	1	6	83646	34.9	-110.5	5			3.9 ML	0 D . . 3 . P	3.9
PDE	1998	2	5	51956 U	39.8	-110.8	1	4		3.7 ML	0 F . . 3 . P	3.7

PDE	**1998**	**4**	**10**	**65216**		**38.3**	**-108.8**	**5**		**3**	**ML**	**0 F . . 3 . P . . . .**	**3**	**Paradox Valley injection**
PDE	1998	10	18	71310		36	-111.1	5		3.4	ML	0 F . . 3 . P	3.4	
PDE	**1999**	**6**	**3**	**153534**	**BI**	**38.3**	**-108.9**	**4**		**3.6**	**ML**	**0 F . . 3 . P . . . .**	**3.6**	**Paradox Valley injection**
PDE	2000	3	7	21604	U	39.8	-110.8	1	4	4.2	ML	0 F . . 3 . P . . . . S	4.2	
PDE	**2000**	**5**	**27**	**215818**		**38.3**	**-108.9**	**5**		**4.3**	**ML**	**0 F . . 3 . P . . . .**	**4.3**	**Paradox Valley injection**
PDE	2000	11	11	211753	U	40.3	-109.2	5		3.7	ML	0 . . . 3 . P	3.7	
PDE	2001	7	19	201534	U	38.7	-111.5	3	5	4.3	ML	0 F . . 3 . P	4.3	
PDE	2001	8	9	223854		39.7	-107.4	5		4	ML	4 F . . 3 . P	4	
PDE	2001	11	5	83423		38.9	-107.4	1		3.4	ML	0 F . . 3 . P	3.4	
PDE	2002	1	31	181745		40.3	-107.7	5		4.3	ML	3 F . . 3 . P	4.3	
PDE	**2002**	**6**	**6**	**122910**	**U**	**38.3**	**-108.9**	**1**		**3.2**	**ML**	**0 . . . 3 . P . . . .**	**3.2**	**Paradox Valley injection**
PDE	2002	9	26	103210	U	37.4	-110.5	3		3	ML	0 . . . 3 . P	3	
PDE	2003	7	8	22033	U	37	-111.8	6		3.3	ML	0 . . . 3 . P	3.3	
PDE-W	2004	9	19	60943	A	38.9	-107.4	1		3.5	ML	0 . . . 3 . P	3.5	
PDE-W	**2004**	**11**	**7**	**65459**	**U**	**38.2**	**-108.9**	**0**		**4.1**	**ML**	**4 F . . 3 . P . . . .**	**4.1**	**Paradox Valley injection**
PDE-W	2004	11	24	101638	A	35.1	-107.5	5		3	ML	0 . . . 3 . P	3	
PDE-W	2005	3	2	111257	A	34.7	-111	5	5	4.6	ML	3 F . . 1 . P	4.6	

BOLD

Appendix B

Quarternary and Undated Faults within Expanded Site Region

APPENDIX B:
QUATERNARY AND UNDATED FAULTS WITHIN EXPANDED SITE REGION

NAME	WWWURL	NUM	ACODE	AGE	RATE	Length (km)	Fault Type	distance from site (miles)	distance from site (km)	depth to seismo-genic rupture (km)	r_{seis} (km)	MCE (All slip types, Wells and Coppersmith, 1994)	Rupture depth (km)	Rupture area (km²)	MCE (based on fracture area, Wells and Coppersmith, 1994)	Limited MCE (based on Kirkham and Rogers, 1981)	PGA using rupture length (Campbell, 1981)	PGA using rupture area (Campbell, 1981)	PGA using limited MCE	PGA (Campbell-Bozorgnia 2003) corrected, plus 1SD (based on Mw)
Salt and Cache Valleys faults (Class B)	33791	2474	6	Class B	<0.2	57.9	N	1.8	2.9	3	4.2	7.12	2.00	115.80	6.09	5.00	0.65	0.54	0.38	0.67
unnamed fault in Westwater Quad, R19E, T21S (no. 1)						8.0		2.4	3.8	3	4.8	6.13					0.50			0.60
unnamed fault in Westwater Quad, R20E, T21S (no. 2)						6.4		3.1	5.1	3	5.9	6.02					0.42			0.49
unnamed fault in Westwater Quad, R19E, T19S (no. 3)						15.7		5.3	8.5	3	9.0	6.47					0.38			0.42
Moab fault and Spanish Valley faults (Class B)	33792	2476	6	Class B	<0.2	72.4	N	12.5	20.1	3	20.3	7.24	2.00	144.80	6.19	5.00	0.31	0.16	0.06	0.16
Ten Mile graben?faults (Class B)	33790	2473	6	Class B	<0.2	34.6	N	10.5	16.8	3	17.1	6.87	2.00	69.20	5.87	5.00	0.29	0.15	0.07	0.16
unnamed fault in Westwater Quad, R18E, T21S (no. 4)						2.9		4.9	7.9	3	8.4	5.62					0.26			0.29
unnamed fault in Westwater Quad, R18E, T20S (no. 5)						1.9		7.0	11.3	3	11.7	5.40					0.16			0.19
Price River area faults (Class B)	33788	2457	5	<1,600,000	<0.2	50.9	N	24.8	39.9	3	40.0	7.06					0.15			0.13
unnamed fault in Westwater Quad, R17E, T20S (no. 6)						3.3		9.6	15.5	3	15.7	5.68					0.14			0.16
Ryan Creek fault zone	33670	2263	5	<1,600,000	<0.2	39.5	N	26.6	42.8	3	42.9	6.93					0.13			0.11
unnamed fault in Westwater Quad, R21E, T0S (no. 7)						4.4		12.4	19.9	3	20.1	5.83					0.12			0.13
Sand Flat graben faults	33945	2475	5	<1,600,000	<0.2	23.1	N	26.4	42.5	3	42.6	6.66					0.10			0.10
Granite Creek fault zone	33672	2265	5	<1,600,000	<0.2	22.7	N	33.4	53.8			6.65					0.07			
Sinbad Valley graben (Class B)	33724	2285	5	<1,600,000	<0.2	31.8		39.3	63.2			6.82					0.07			
Fisher Valley faults (Class B)	33794	2478	6	Class B	<0.2	15.9		31.0	49.8			6.47					0.07			
Paradox Valley graben (Class B)	33668	2286	5	<1,600,000	<0.2	56.4	N	49.6	79.9			7.11					0.07			
unnamed fault in Salina Quad, R13E, T24S						19.6		36.0	57.9			6.58					0.06			
Little Dolores River fault	33664	2251	5	<1,600,000	<0.2	15.7	R	34.5	55.5			6.47					0.06			
unnamed fault in Salina Quad, R11E, T22S						22.7		41.6	66.9			6.65					0.06			
Unnamed fault near Pine Mountain	32966	2267	5	<1,600,000	<0.2	30.7		47.2	75.9			6.81					0.05			
Lisbon Valley fault zone (Class B)	33801	2511	5	<1,600,000	<0.2	37.5		50.9	81.9			6.91					0.05			
unnamed fault in Salina Quad, R11E, T23S						25.8		44.7	72.0			6.72					0.05			
Castle Valley faults (Class B)	33793	2477	6	Class B	<0.2	12.4		34.2	54.9			6.35					0.05			
Lockhart fault (Class B)	34080	2510	6	Class B	<0.2	15.7		40.8	65.6			6.47					0.05			
Needles fault zone (Class B)	33799	2507	6	Class B	<0.2	28.5		53.9	86.6			6.77					0.04			
unnamed fault in Salina Quad, R11E, T21S						14.0		42.1	67.7			6.41					0.04			
unnamed fault in Price Quad, R12E, T19S						13.7		42.4	68.2			6.40					0.04			
Bright Angel fault system (Class B)	33804	2514	5	<1,600,000	<0.2	102.3		89.6	144.1			7.41					0.04			
Wasatch monocline (Class B)	33787	2450	5	<1,600,000	<0.2	103.5	?	90.3	145.3			7.42					0.04			
Redlands fault complex	32952	2252	5	<1,600,000	<0.2	21.1	N,R	53.1	85.4			6.62					0.04			
Shay graben faults (Class B)	33803	2513	6	Class B	<0.2	39.5		68.1	109.5			6.93					0.04			
Joes Valley fault zone, east fault	33932	2455	2	<15,000	0.2-1	56.6		79.0	127.0			7.11					0.04			
unnamed fault in Salina Quad, R12E, T24S						10.1		42.6	68.6			6.25					0.04			
Joes Valley fault zone, west fault	33930	2453	2	<15,000	0.2-1	57.2		81.1	130.4			7.12					0.04			
Southern Joes Valley fault zone	33933	2456	4	<750,000	<0.2	47.2		77.2	124.2			7.02					0.03			
Unnamed fault of Lost Horse Basin	32963	2264	5	<1,600,000	<0.2	8.1		40.8	65.6			6.13					0.03			
unnamed fault in Salina Quad, R12E, T23S						9.0		43.5	70.0			6.19					0.03			
Duchesne-Pleasant Valley fault system (Class B)	33782	2414	5	<1,600,000	<0.2	45.3	N	79.1	127.2			7.00					0.03			
Big Gypsum Valley graben (Class B)	32989	2288	6	Class B	<0.2	33.1		70.9	114.0			6.84					0.03			
unnamed fault in Salina Quad, R16E, T28S						9.0		43.9	70.6			6.19					0.03			
unnamed fault in Salina Quad, R11E, T24S						9.8		47.0	75.7			6.23					0.03			
unnamed fault in Price Quad, R16E, T13S						9.5		48.6	78.2			6.22					0.03			
Monitor Creek fault	32967	2268	5	<1,600,000	<0.2	30.1		79.1	127.3			6.80					0.03			
Joes Valley fault zone, intragraben faults	33931	2454	2	<15,000	<0.2	34.0		82.9	133.3			6.86					0.03			
Thousand Lake fault	33962	2506	4	<750,000	<0.2	48.3		97.2	156.4			7.03					0.02			
Pleasant Valley fault zone, unnamed faults	33906	2425	5	<1,600,000	<0.2	31.0	N	86.1	138.5			6.81					0.02			
Unnamed faults of Pinto Mesa	32977	2277	5	<1,600,000	<0.2	19.7		78.4	126.1			6.58					0.02			
Gunnison fault	33785	2445	2	<15,000	<0.2	42.0	N	104.3	167.8			6.96					0.02			
Unnamed faults near San Miguel Canyon (Class B)	32985	2284	6	Class B	<0.2	32.1		94.5	152.1			6.83					0.02			
Wasatch fault zone, Provo section	33763	2351g	2	<15,000	1-5	58.8		122.2	196.6			7.13					0.02			
Snow Lake graben	33929	2452	2	<15,000	<0.2	25.4		89.7	144.3			6.71					0.02			
Unnamed faults south of Love Mesa	32970	2271	5	<1,600,000	<0.2	17.6		78.8	126.8			6.52					0.02			
Unnamed fault at Red Canyon	32979	2279	5	<1,600,000	<0.2	24.2		90.9	146.3			6.69					0.02			

NAME	WWWURL	NUM	ACODE	AGE	RATE	Length (km)	Fault Type	distance from site (miles)	distance from site (km)	depth to seismo-genic rupture (km)	r_{seis} (km)	MCE (All slip types, Wells and Coppersmith, 1994)	Rupture depth (km)	Rupture area (km^2)	MCE (based on fracture area, Wells and Coppersmith, 1994)	Limited MCE (based on Kirkham and Rogers, 1981)	PGA using rupture length (Campbell, 1981)	PGA using rupture area (Campbell, 1981)	PGA using limited MCE	PGA (Campbell-Bozorgnia 2003) corrected, plus 1SD (based on Mw)
Aquarius and Awapa Plateaus faults	33961	2505	5	<1,600,000	<0.2	35.7		108.6	174.8			6.88					0.02			
Roubideau Creek fault	32969	2270	2	<15,000	<0.2	20.5		88.7	142.7			6.60					0.02			
Red Rocks fault	32991	2291	5	<1,600,000	<0.2	38.3		111.8	179.9			6.92					0.02			
Paunsaugunt fault	33960	2504	5	<1,600,000	<0.2	44.1		118.0	189.8			6.99					0.02			
Valley Mountains monocline (Class B)	33786	2449	5	<1,600,000	<0.2	38.6		112.9	181.7			6.92					0.02			
Gooseberry graben faults	33905	2424	4	<750,000	<0.2	22.6		93.1	149.8			6.65					0.02			
Sevier/Toroweap fault zone, Sevier section	33578	997a	3	<130,000	0.2-1	88.7		155.4	250.0			7.34					0.02			
Wasatch fault zone, Nephi section	33764	2351h	2	<15,000	1-5	43.1		119.9	192.9			6.98					0.02			
Pleasant Valley fault zone, graben	33907	2426	4	<750,000	<0.2	17.6		88.3	142.1			6.52					0.02			
Sevier fault	33824	2355	5	<1,600,000	<0.2	41.3	N	126.4	203.4			6.95					0.02			
White Mountain area faults	33928	2451	5	<1,600,000	<0.2	16.4		90.5	145.6			6.49					0.01			
Unnamed fault at Hanks Creek	32982	2281	5	<1,600,000	<0.2	17.5		99.0	159.2			6.52					0.01			
Cannibal fault	33608	2337	3	<130,000	<0.2	49.3		148.9	239.6			7.04					0.01			
East Tintic Mountains (west side) faults	33902	2420	4	<750,000	<0.2	33.1		129.6	208.6			6.84					0.01			
Sevier Valley-Marysvale-Circleville area faults	33956	2500	4	<750,000	<0.2	34.9		133.7	215.2			6.87					0.01			
West Kaibab fault system	33121	994	5	<1,600,000	<0.2	82.9	N	187.7	301.9			7.31					0.01			
Hogsback fault, southern section	34045	732b	3	<130,000	1-5	38.3		144.3	232.1			6.92					0.01			
Bear River fault zone	33992	730	2	<15,000	0.2-1	33.2		140.4	225.8			6.84					0.01			
Frontal fault	33000	2302	3	<130,000	0.2-1	75.0	N,R	190.1	305.8			7.26					0.01			
Sevier/Toroweap fault zone, northern Toroweap section	33579	997b	3	<130,000	<0.2	80.9		198.5	319.4			7.29					0.01			
Central Kaibab fault system	33120	993	5	<1,600,000	<0.2	71.5	N	192.3	309.5			7.23					0.01			
Gallina fault	32810	2001	5	<1,600,000	<0.2	39.3						6.93								
Canones fault (Class B)	32812	2003	5	<1,600,000	<0.2	29.4						6.78								
Lobato Mesa fault zone	32813	2004	5	<1,600,000	<0.2	21.3						6.62								
La Canada del Amagre fault zone	32816	2005	5	<1,600,000	<0.2	17.2						6.51								
Black Mesa fault zone	32817	2006	5	<1,600,000	<0.2	18.5						6.55								
Pajanto fault	32818	2008	3	<130,000	<0.2	49.4						7.04								
Puye fault	32819	2009	3	<130,000	<0.2	16.7						6.50								
Pojoaque fault zone	32820	2010	5	<1,600,000	<0.2	46.5						7.01								
Sunshine Valley faults	32826	2016	3	<130,000	<0.2	14.1						6.41								
Red River fault zone	32828	2019	5	<1,600,000	<0.2	10.0						6.24								
Las Tablas fault	32829	2020	5	<1,600,000	<0.2	14.8						6.44								
Strong fault	32830	2021	5	<1,600,000	<0.2	8.1						6.13								
Los Cordovas faults	32831	2022	5	<1,600,000	<0.2	12.2						6.34								
Picuris-Pecos fault	32832	2023	5	<1,600,000	<0.2	98.2	N					7.39								
Nambe fault	32833	2024	5	<1,600,000	<0.2	47.8						7.03								
Rendija Canyon fault	32835	2026	3	<130,000	<0.2	11.1						6.29								
Guaje Mountain fault	32836	2027	2	<15,000	<0.2	10.7						6.27								
Sawyer Canyon fault	32837	2028	3	<130,000	<0.2	8.4						6.15								
San Francisco fault	32840	2031	5	<1,600,000	<0.2	25.7						6.72								
La Bajada fault	32841	2032	5	<1,600,000	<0.2	40.3						6.84								
Calabacillas fault	32843	2035	4	<750,000	<0.2	31.3						6.81								
County Dump fault	32846	2038	5	<1,600,000	<0.2	35.3						6.88								
Sand Hill fault zone	32847	2039	5	<1,600,000	<0.2	35.6						6.88								
Unnamed faults near Picuda Peak	32849	*2041*	5	<1,600,000	<0.2	10.6						6.27								
Faults north of Placitas	32851	2043	4	<750,000	<0.2	10.5						6.26								
Unnamed faults near Loma Barbon	32853	2045	5	<1,600,000	<0.2	1.2						5.17								
Zia fault	32854	2046	4	<750,000	<0.2	32.4						6.83								
Faults near of Cochiti Pueblo	32943	2142	5	<1,600,000	<0.2	32.2						6.83								
Glade Park fault	32954	2254	5	<1,600,000	<0.2	9.4	R					6.21								
Ladder Creek fault	32955	2255	5	<1,600,000	<0.2	6.2						6.00								
Bangs Canyon fault	32956	2256	5	<1,600,000	<0.2	6.3						6.01								
Unnamed fault east of Whitewater	32957	2257	5	<1,600,000	<0.2	1.9						5.40								
Cactus Park fault	32958	2258	5	<1,600,000	<0.2	1.9						5.40								
Unnamed fault near Bridgeport	32959	2259	5	<1,600,000	<0.2	11.0						6.29								
Unnamed fault at Big Dominquez Creek	32960	2260	5	<1,600,000	<0.2	3.9						5.77								
Unnamed fault at Little Dominquez Creek	32961	2261	5	<1,600,000	<0.2	14.2						6.42								

NAME	WWWURL	NUM	ACODE	AGE	RATE	Length (km)	Fault Type	distance from site (miles)	distance from site (km)	depth to seismo-genic rupture (km)	r_{seis} (km)	MCE (All slip types, Wells and Coppersmith, 1994)	Rupture depth (km)	Rupture area (km^2)	MCE (based on fracture area, Wells and Coppersmith, 1994)	Limited MCE (based on Kirkham and Rogers, 1981)	PGA using rupture length (Campbell, 1981)	PGA using rupture area (Campbell, 1981)	PGA using limited MCE	PGA (Campbell-Bozorgnia 2003) corrected, plus 1SD (based on Mw)
Unnamed fault near Wolf Hill	32965	2266	5	<1,600,000	<0.2	15.2						6.45								
Unnamed faults east of Atkinson Masa	32968	2269	5	<1,600,000	<0.2	41.1	N					6.95								
Unnamed faults east of Roubideau Creek (Class B)	32971	2272	6	Class B	<0.2	11.7						6.32								
Unnamed faults southeast of Montrose (Class B)	32972	2273	6	Class B	<0.2	9.2						6.20								
Busted Boiler fault	32973	2274	3	<130,000	<0.2	18.0						6.54								
Log Hill Mesa graben	32975	2275	3	<130,000	<0.2	9.5						6.21								
Ridgway fault	32976	2276	5	<1,600,000	<0.2	23.8						6.68								
Unnamed faults near Cottonwood Creek	32978	2278	5	<1,600,000	<0.2	10.8						6.28								
Unnamed fault north of Horsefly Creek	32980	2280	5	<1,600,000	<0.2	8.1						6.13								
Unnamed fault near Johnson Spring	32983	2282	5	<1,600,000	<0.2	7.1						6.07								
Unnamed faults at Clay Creek	32984	2283	5	<1,600,000	<0.2	9.2						6.20								
Unnamed fault at northwest end of Paradox Valley (Class B)	32988	2287	6	Class B	<0.2	5.1						5.90								
Doloras fault zone (Class B)	32990	2289	6	Class B	<0.2	15.2						6.45								
Unnamed fault along Grand Hogback monocline (Class B)	32992	2292	6	Class B	<0.2	2.4						5.52								
Unnamed faults near Burns (Class B)	32993	2296	6	Class B	<0.2	13.3						6.38								
Greenhorn Mountain fault (Class B)	32995	2297	6	Class B	<0.2	21.5						6.63								
Unnamed faults of Red Hill (Class B)	32996	2298	6	Class B	<0.2	6.1						5.99								
Basalt Mountain fault (Class B)	32997	2299	6	Class B	<0.2	7.0						6.06								
Unnamed faults in Williams Fork Valley	32998	2300	4	<750,000	<0.2	18.4						6.55								
Williams Fork Mountains fault	32999	2301	2	<15,000	0.2-1	37.7						6.91								
Mosquito fault	33001	2303	3	<130,000	<0.2	51.5						7.07								
Unnamed faults south of Leadville	33002	2305	5	<1,600,000	<0.2	12.8						6.35								
Unnamed faults northwest of Leadville	33003	2306	5	<1,600,000	<0.2	18.8						6.56								
Unnamed faults near Twin Lakes Reservoir	33004	2307	5	<1,600,000	<0.2	14.0						6.41								
Unnamed fault west of Buena Vista	33005	2310	5	<1,600,000	<0.2	2.7						5.58								
Unnamed fault south of Shavano Peak	33006	2311	5	<1,600,000	<0.2	5.8						5.97								
Unnamed fault of Missouri Peak	33007	2312	3	<130,000	<0.2	5.9						5.97								
Western Boundary fault	33008	2313	5	<1,600,000	<0.2	20.1						6.59								
Lucky Boy fault	33009	2314	5	<1,600,000	<0.2	11.1						6.29								
Faults near Monte Vista	33010	2315	5	<1,600,000	<0.2	16.2						6.48								
West-Side Chase Gulch fault	33011	2316	3	<130,000	<0.2	2.7						5.58								
East-Side Chase Gulch fault	33012	2317	3	<130,000	<0.2	30.7						6.81								
Eleven Mile fault	33013	2318	3	<130,000	<0.2	4.7						5.86								
Villa Grove fault zone	33014	2319	2	<15,000	<0.2	19.0						6.56								
Mineral Hot Springs fault	33015	2320	3	<130,000	<0.2	7.8						6.11								
Faults of the northern Basaltic Hills	33016	2322	5	<1,600,000	<0.2	12.6						6.36								
Faults near Garcia	33017	2323	3	<130,000	<0.2	3.4						5.70								
Unnamed fault near Escalante	33026	2262	5	<1,600,000	<0.2	1.6						5.32								
Unnamed faults along the Grand Hogback monocline near Fourmile	33027	2294	6	Class B	<0.2	2.5						5.54								
Unnamed faults along the Grand Hogback monocline near Freeman	33028	2295	6	Class B	<0.2	5.7						5.96								
Northern Boundary fault system	33029	2309	4	<750,000	<0.2	49.0						7.04								
Sunshine faults	33030	1000	3	<130,000	<0.2	29.2	N					6.78								
Gyp Pocket graben and faults	33031	1001	3	<130,000	<0.2	11.8	N					6.32								
Main Street fault zone	33032	1002	3	<130,000	<0.2	87.3	N					7.33								
Dutchman Draw fault	33033	1003	3	<130,000	<0.2	16.3	N					6.49								
Grand Wash fault zone	33035	1005	3	<130,000	<0.2	34.9	N					6.87								
Wheeler fault zone and graben	33036	1006	4	<750,000	<0.2	45.3						7.00								
Mesquite fault	33038	1007	3	<130,000	<0.2	36.2						6.89								
Littlefield Mesa faults	33039	1008	4	<750,000	<0.2	21.2						6.62								
Uinkaret Volcanic field faults	33043	1012	5	<1,600,000	<0.2	18.5						6.55								
Andrus Canyon fault	33044	1013	5	<1,600,000	<0.2	5.6						5.95								
Leupp faults	33048	1017	4	<750,000	<0.2	32.2						6.83								
Gray Mountain faults	33049	1018	5	<1,600,000	<0.2	23.6						6.67								
Arrowhead fault zone	33080	953	3	<130,000	<0.2	5.2						5.91								
Babbitt Lake fault zone	33081	954	4	<750,000	<0.2	7.6						6.10								
Black Point/Doney Mountain fault zone	33084	957	4	<750,000	<0.2	23.8	N					6.68								
SP fault zone	33085	958	3	<130,000	<0.2	12.5						6.35								

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Campbell Francis fault zone	33086	959	4	<750,000	<0.2	10.1						6.25								
Cedar Ranch fault zone	33088	961	4	<750,000	<0.2	10.2						6.25								
Cedar Wash fault zone	33089	962	4	<750,000	<0.2	11.6						6.31								
Citadel Ruins fault zone	33090	963	5	<1,600,000	<0.2	4.5						5.84								
Deadman Wash faults	33091	964	5	<1,600,000	<0.2	1.8						5.38								
Double Top fault zone	33092	965	5	<1,600,000	<0.2	6.1						5.99								
Double Knobs fault	33093	966	5	<1,600,000	<0.2	6.0						5.98								
Ebert Tank fault zone	33094	967	4	<750,000	<0.2	3.1						5.65								
Hidden Tank fault zone	33097	970	4	<750,000	<0.2	10.2						6.25								
Large Whiskers fault zone	33099	972	5	<1,600,000	<0.2	11.6						6.31								
Lee Dam faults	33100	973	5	<1,600,000	<0.2	7.6						6.10								
Lockwood Canyon fault zone	33101	974	5	<1,600,000	<0.2	20.8						6.61								
Malpais Tank faults	33102	975	4	<750,000	<0.2	4.6						5.85								
Maverick Butte faults	33103	976	4	<750,000	<0.2	3.7						5.74								
Michelbach Tank faults	33105	978	4	<750,000	<0.2	13.4						6.39								
Pearl Harbor fault zone	33108	981	5	<1,600,000	<0.2	15.3						6.45								
Red House faults	33110	983	4	<750,000	<0.2	3.4						5.70								
Rimmy Jim fault zone	33111	984	5	<1,600,000	<0.2	8.2						6.14								
Sinagua faults	33113	986	3	<130,000	<0.2	4.9						5.88								
Mesa Butte North fault zone	33114	987	5	<1,600,000	<0.2	22.6						6.65								
Cameron graben and faults	33115	988	4	<750,000	<0.2	10.8						6.28								
Shadow Mountain grabens	33116	989	4	<750,000	<0.2	10.4						6.26								
Cataract Creek fault zone	33117	990	5	<1,600,000	<0.2	51.1	N					7.06								
Bright Angel fault zone	33118	991	5	<1,600,000	<0.2	66.0	N					7.19								
Eminence fault zone	33119	992	5	<1,600,000	<0.2	36.0						6.89								
Aubrey fault zone	33122	995	3	<130,000	<0.2	53.1						7.08								
Yampai graben	33123	996	5	<1,600,000	<0.2	6.9						6.05								
Sunshine Trail graben and faults	33124	999	3	<130,000	<0.2	17.0	N					6.51								
Washington fault zone, northern section	33143	1004a	2	<15,000	<0.2	36.2	N					6.89								
Washington fault zone, Mokaac section	33144	1004b	3	<130,000	<0.2	11.2	N					6.30								
Washington fault zone, Sullivan Draw section	33145	1004c	3	<130,000	<0.2	34.5	N					6.86								
Hurricane fault zone, Anderson Junction section	33154	998c	2	<15,000	0.2-1	42.2						6.97								
Hurricane fault zone, Shivwitz section	33155	998d	3	<130,000	<0.2	56.5	N					7.11								
Hurricane fault zone, Whitmore Canyon section	33156	998e	2	<15,000	<0.2	28.5						6.77								
Hurricane fault zone, southern section	33157	998f	5	<1,600,000	<0.2	66.6	N					7.20								
Nacimiento fault, northern section	33184	2002a	5	<1,600,000	<0.2	35.9						6.88								
Nacimiento fault, southern section	33185	2002b	5	<1,600,000	<0.2	45.2						7.00								
Embudo fault, Pilar section	33186	2007a	3	<130,000	<0.2	38.7						6.92								
Embudo fault, Hernandez section	33187	2007b	5	<1,600,000	<0.2	31.6						6.82								
Southern Sangre de Cristo fault zone, San Pedro section	33188	2017a	3	<130,000	<0.2	24.4						6.69								
Southern Sangre de Cristo fault, Urraca section	33189	2017b	2	<15,000	<0.2	21.9						6.63								
Southern Sangre de Cristo fault, Questa section	33190	2017c	2	<15,000	<0.2	17.8						6.53								
Southern Sangre de Cristo fault, Hondo section	33191	2017d	2	<15,000	<0.2	22.2						6.64								
Southern Sangre de Cristo fault, Caton section	33192	2017e	2	<15,000	<0.2	15.2						6.45								
Jemez-San Ysidro fault, Jemez section	33193	2029a	5	<1,600,000	<0.2	24.1						6.68								
Jemez-San Ysidro fault, San Ysidro section	33194	2029b	5	<1,600,000	<0.2	30.1						6.80								
San Felipe fault, Santa Ana section	33195	2030a	5	<1,600,000	<0.2	43.8						6.98								
San Felipe fault, Algodones section	33196	2030b	5	<1,600,000	<0.2	15.9						6.47								
Tijeras-Catoncito fault system, Galisteo section	33197	2033a	5	<1,600,000	<0.2	37.1						6.90								
Unnamed faults of Jemez Mountains, Valles caldera section (Class	33222	2143a	5	<1,600,000	<0.2	16.7						6.50								
Unnamed faults of Jemez Mountains, Toledo caldera section (Class	33223	2143b	5	<1,600,000	<0.2	10.9						6.28								
Unnamed faults of Jemez Mountains, caldera margin section (Class	33224	2143c	4	<750,000	<0.2	20.3						6.60								
Unnamed faults of Jemez Mountains, intracaldera section (Class B)	33225	2143d	5	<1,600,000	<0.2	11.3	N					6.30								
Mesita fault	33233	2015	3	<130,000	<0.2	27.9						6.76								
Strawberry fault	33571	2412	2	<15,000	<0.2	31.9						6.82								
Morgan fault, northern section	33573	2353a	4	<750,000	<0.2	7.9						6.12								
Morgan fault, central section	33574	2353b	2	<15,000	<0.2	4.9						5.88								

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Morgan fault, southern section	33575	2353c	4	<750,000	<0.2	2.3						5.50								
Hurricane fault zone, Ash Creek section	33577	998b	2	<15,000	<0.2	32.0						6.83								
Sevier/Toroweap fault zone, central Toroweap section	33580	997c	2	<15,000	<0.2	60.4	N					7.15								
Sevier/Toroweap fault zone, southern Toroweap section	33581	997d	4	<750,000	<0.2	18.8						6.56								
Cimmarron fault, Bostwick Park section (Class B)	33585	2290a	6	Class B	<0.2	11.2						6.30								
Sawatch fault, northern section	33586	2308a	3	<130,000	<0.2	34.0						6.86								
Sawatch fault, southern section	33587	2308b	2	<15,000	<0.2	41.1						6.95								
Northern Sangre de Cristo fault, Crestone section	33588	2321a	2	<15,000	<0.2	79.1	N					7.28								
Northern Sangre de Cristo fault, Zapata section	33589	2321b	2	<15,000	<0.2	25.8						6.72								
Northern Sangre de Cristo fault, Blanca section	33590	2321c	2	<15,000	<0.2	6.7						6.04								
Northern Sangre de Cristo fault, San Luis section	33591	2321d	2	<15,000	<0.2	59.1	N					7.14								
Cimmarron fault, Poverty Mesa section (Class B)	33592	2290b	6	Class B	<0.2	24.1						6.68								
Cattle Creek anticline (Class B)	33593	2293	6	Class B	<0.2	8.6						6.16								
Unnamed syncline southwest of Carbondale (Class B)	33594	2332	6	Class B	<0.2	3.0						5.63								
Unnamed syncline northeast of Carbondale (Class B)	33595	2333	6	Class B	<0.2	1.5						5.28								
Unnamed syncline northwest of Carbondale (Class B)	33596	2334	6	Class B	<0.2	1.9						5.40								
Unnamed syncline west of Carbondale (Class B)	33597	2335	6	Class B	<0.2	0.6						4.82								
Grand Hogback monocline (Class B)	33598	2331	6	Class B	<0.2	22.0						6.64								
Cimmarron fault, Blue Mesa section	33599	2290c	5	<1,600,000	<0.2	22.5						6.65								
Ellison Gulch scarp (Class B)	33604	2304	6	Class B	<0.2	1.2						5.17								
Killarney faults	33607	2336	5	<1,600,000	<0.2	5.6						5.95								
Porcupine Mountain faults	33636	2380	3	<130,000	<0.2	34.6	N					6.87								
Southern Oquirrh Mountains fault zone	33653	2399	3	<130,000	<0.2	24.1						6.68								
Mountain Home Range (west side) faults	33720	2480	5	<1,600,000	<0.2	26.4						6.73								
Crawford Mountains (west side) fault	33725	2346	3	<130,000	<0.2	25.3						6.71								
Wasatch fault zone, City section	33757	2351a	3	<130,000	<0.2	39.6						6.93								
Wasatch fault zone, Clarkston Mountain section	33758	2351b	3	<130,000	<0.2	10.4						6.26								
Wasatch fault zone, Collinston section	33759	2351c	2	<15,000	<0.2	29.7						6.79								
Wasatch fault zone, Brigham City section	33760	2351d	2	<15,000	0.2-1	37.3						6.90								
Wasatch fault zone, Weber section	33761	2351e	2	<15,000	1-5	56.2						7.11								
Wasatch fault zone, Salt Lake City section	33762	2351f	2	<15,000	1-5	42.5						6.97								
Wasatch fault zone, Levan section	33765	2351i	2	<15,000	<0.2	30.1						6.80								
Wasatch fault zone, Fayette section	33766	2351j	2	<15,000	<0.2	15.6						6.46								
East Cache fault zone, northern section	33767	2352a	4	<750,000	<0.2	25.7						6.72								
East Cache fault zone, central section	33768	2352b	2	<15,000	0.2-1	16.5						6.49								
East Cache fault zone, southern section	33769	2352c	3	<130,000	<0.2	22.1						6.64								
East Great Salt Lake fault zone, Promontory section	33773	2369a	2	<15,000	0.2-1	49.2	N					7.04								
East Great Salt Lake fault zone, Fremont Island section	33774	2369b	2	<15,000	0.2-1	30.1						6.80								
East Great Salt Lake fault zone, Antelope Island section	33775	2369c	2	<15,000	0.2-1	35.1						6.87								
West Valley fault zone, Taylorsville fault	33776	2386a	2	<15,000	<0.2	15.1	N					6.45								
West Valley fault zone, Granger fault	33777	2386b	2	<15,000	0.2-1	16.0	N					6.48								
Beaver Basin faults, eastern margin faults	33778	2492a	2	<15,000	<0.2	34.2						6.86								
Beaver Basin faults, intrabasin faults	33779	2492b	2	<15,000	<0.2	38.9						6.92								
Lakeside Mountains (west side) fault (Class B)	33780	2384	6	Class B	<0.2	4.7						5.86								
Towanta Flat graben (Class B)	33781	2401	4	<750,000	<0.2	5.2						5.91								
Juab Valley (west side) faults (Class B)	33783	2423	4	<750,000	<0.2	13.2						6.38								
Clear Lake fault zone (Class B)	33784	2436	2	<15,000	<0.2	35.5						6.88								
Wah Wah Valley (west side) faults (Class B)	33795	2484	6	Class B	<0.2	2.1						5.45								
Escalante Desert faults (Class B)	33796	2488	6	Class B	<0.2	6.6						6.03								
Cove Fort fault zone (Class B)	33797	2491	6	Class B	<0.2	22.2						6.64								
Buckskin Valley faults (Class B)	33798	2499	6	Class B	<0.2	3.5						5.71								
Pine Ridge faults (Class B)	33802	2512	6	Class B	<0.2	5.5						5.94								
Bear Lake (west side) fault (Class B)	33805	2531	5	<1,600,000	<0.2	5.5						5.94								
Red Hills fault	33806	2532	3	<130,000	<0.2	13.8						6.40								
Markagunt Plateau faults (Class B)	33807	2535	4	<750,000	<0.2	56.4						7.11								
Sevier Valley faults and folds (Class B)	33808	2537	3	<130,000	<0.2	23.6						6.67								
Johns Valley fault (Class B)	33809	2539	6	Class B	<0.2	2.1						5.45								

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Goose Creek Mountains faults (Class B)	33850	2356	6	Class B	<0.2	4.0						5.78								
Grouse Creek and Dove Creek Mountains faults	33851	2357	4	<750,000	<0.2	47.7						7.03								
Hansel Valley fault	33852	2358	1	<150	<0.2	13.0						6.37								
Hansel Mountains (east side) faults	33853	2359	4	<750,000	<0.2	14.7						6.43								
Hansel Valley (valley floor) faults	33854	2360	4	<750,000	<0.2	19.5						6.58								
North Promontory fault	33855	2361	2	<15,000	<0.2	25.8						6.72								
North Promontory Mountains fault	33856	2362	5	<1,600,000	<0.2	6.3						6.01								
Blue Springs Hills faults	33857	2363	4	<750,000	<0.2	2.5						5.54								
Saleratus Creek fault	33858	2365	4	<750,000	<0.2	37.6						6.91								
Big Pass faults	33859	2366	5	<1,600,000	<0.2	17.3						6.52								
Dolphin Island fracture zone	33860	2367	4	<750,000	<0.2	19.2						6.57								
East Lakeside Mountains fault zone	33861	2368	5	<1,600,000	<0.2	36.0						6.89								
Dayton fault (Class B)	33862	2370	6	Class B	<0.2	16.3						6.49								
Eastern Pilot Range fault	33863	2371	5	<1,600,000	<0.2	10.6						6.27								
Mantua area faults	33864	2373	4	<750,000	<0.2	21.1						6.62								
Hyrum fault	33865	2374	5	<1,600,000	<0.2	3.1						5.65								
Ogden Valley southwestern margin faults	33866	2375	4	<750,000	<0.2	17.8						6.53								
Ogden Valley North Fork fault	33867	2376	4	<750,000	<0.2	26.1						6.72								
Broadmouth Canyon faults	33868	2377	3	<130,000	<0.2	3.4						5.70								
James Peak fault	33869	2378	3	<130,000	<0.2	6.3						6.01								
Ogden Valley northeastern margin fault	33870	2379	5	<1,600,000	<0.2	12.8						6.36								
Silver Island Mountains (west side) fault	33871	2381	5	<1,600,000	<0.2	6.4						6.02								
Silver Island Mountains (southeast side) fault	33872	2382	2	<15,000	<0.2	1.8						5.38								
Puddle Valley fault zone	33873	2383	2	<15,000	<0.2	6.5						6.02								
Sinbad Valley graben (Class B)	33874	2385	5	<1,600,000	<0.2	9.9						6.23								
Skull Valley (mid-valley) faults	33875	2387	2	<15,000	<0.2	54.8	N					7.10								
Parleys Park faults (Class B)	33876	2388	6	Class B	<0.2	3.4						5.70								
Frog Valley fault	33877	2389	5	<1,600,000	<0.2	4.6						5.85								
Bald Mountain fault	33878	2390	5	<1,600,000	<0.2	2.3						5.50								
East Kamas fault	33879	2391	5	<1,600,000	<0.2	14.6						6.43								
Diamond Gulch faults	33880	2393	5	<1,600,000	<0.2	20.2						6.59								
Pot Creek faults	33881	2394	5	<1,600,000	<0.2	13.4						6.39								
Stansbury fault zone	33882	2395	2	<15,000	<0.2	49.8	N					7.05								
Clover fault zone	33883	2396	3	<130,000	<0.2	4.0						5.78								
Saint John Station fault zone	33884	2397	3	<130,000	<0.2	5.2						5.91								
Oquirrh fault zone	33885	2398	2	<15,000	<0.2	21.1						6.62								
Round Valley faults	33886	2400	4	<750,000	<0.2	12.8	N					6.36								
Deep Creek Range (northwest side) fault zone	33888	2403	3	<130,000	<0.2	10.7						6.27								
Lookout Pass fault	33889	2404	5	<1,600,000	<0.2	3.9						5.77								
Sheeprock fault zone	33890	2405	3	<130,000	<0.2	11.7						6.32								
Vernon Hills fault zone	33891	2406	3	<130,000	<0.2	3.7						5.74								
Topliff Hill fault zone	33892	2407	3	<130,000	<0.2	19.9						6.59								
Cedar Valley (south side) fault	33893	2408	4	<750,000	<0.2	2.8						5.60								
Bear River Range faults	33894	2410	5	<1,600,000	<0.2	62.9	N, Dextral					7.17								
Little Diamond Creek fault	33895	2411	4	<750,000	<0.2	20.0						6.59								
Stinking Springs fault	33896	2413	3	<130,000	0.2-1	10.0						6.24								
Lime Mountain fault	33897	2415	5	<1,600,000	<0.2	10.6						6.27								
Deep Creek Range (east side) faults	33898	2416	4	<750,000	<0.2	20.7						6.61								
Fish Springs fault	33899	2417	2	<15,000	<0.2	29.7						6.79								
Simpson Mountains faults	33900	2418	4	<750,000	<0.2	10.8						6.28								
Sheeprock Mountains fault	33901	2419	5	<1,600,000	<0.2	6.7						6.04								
Long Ridge (west side) faults	33903	2421	4	<750,000	<0.2	15.2						6.45								
Long Ridge (northwest side) fault	33904	2422	5	<1,600,000	<0.2	20.8						6.61								
Pleasant Valley fault zone, Dry Valley graben	33908	2427	4	<750,000	<0.2	12.4						6.35								
Snake Valley faults	33909	2428	2	<15,000	<0.2	45.3	N					7.00								
Foote Range fault	33910	2429	4	<750,000	<0.2	3.1						5.65								
House Range (west side) fault	33911	2430	2	<15,000	<0.2	45.5	N					7.00								

NAME	WWWURL	NUM	ACODE	AGE	RATE	Length (km)	Fault Type	distance from site (miles)	distance from site (km)	depth to seismogenic rupture (km)	r_{seis} (km)	MCE (All slip types, Wells and Coppersmith, 1994)	Rupture depth (km)	Rupture area (km^2)	MCE (based on fracture area, Wells and Coppersmith, 1994)	Limited MCE (based on Kirkham and Rogers, 1981)	PGA using rupture length (Campbell, 1981)	PGA using rupture area (Campbell, 1981)	PGA using limited MCE	PGA (Campbell-Bozorgnia 2003) corrected, plus 1SD (based on Mw)
Swasey Mountain (east side) faults	33912	2431	4	<750,000	<0.2	3.8						5.75								
Drum Mountains fault zone	33913	2432	2	<15,000	<0.2	51.5	N					7.07								
Crater Bench faults	33914	2433	2	<15,000	<0.2	15.9						6.47								
Cricket Mountains (north end) faults	33915	2434	4	<750,000	<0.2	2.8						5.60								
Deseret faults	33916	2435	4	<750,000	<0.2	7.1						6.07								
Sugarville area faults	33917	2437	2	<15,000	<0.2	4.3						5.81								
Pavant faults	33918	2438	2	<15,000	<0.2	30.1						6.80								
Little Valley faults	33919	2439	2	<15,000	<0.2	19.2						6.57								
Scipio Valley faults	33920	2440	2	<15,000	<0.2	7.3						6.08								
Scipio fault zone	33921	2441	2	<15,000	<0.2	12.5						6.35								
Pavant Range fault	33922	2442	2	<15,000	<0.2	14.2						6.42								
Maple Grove faults	33923	2443	2	<15,000	<0.2	12.8						6.36								
Sage Valley fault	33925	2444	5	<1,600,000	<0.2	10.5						6.26								
Japanese and Cal Valleys faults	33926	2447	4	<750,000	<0.2	30.1						6.80								
Raft River Mountains fault	33927	2448	4	<750,000	<0.2	1.5						5.28								
Little Rough Range faults	33934	2458	4	<750,000	<0.2	3.2						5.67								
North of Wah Wah Mountains faults	33935	2459	4	<750,000	<0.2	12.5						6.35								
Cricket Mountains (west side) fault	33936	2460	2	<15,000	<0.2	41.0						6.95								
Black Rock area faults	33937	2461	3	<130,000	<0.2	8.2						6.14								
Faults of Cove Creek Dome	33938	2462	5	<1,600,000	<0.2	18.8						6.56								
Beaver Ridge faults	33939	2464	3	<130,000	<0.2	14.2						6.42								
Tabernacle faults	33940	2465	2	<15,000	<0.2	7.9						6.12								
Meadow-Hatton area faults	33941	2466	2	<15,000	<0.2	4.0						5.78								
White Sage Flat faults	33942	2467	3	<130,000	<0.2	11.8						6.32								
Red Canyon fault scarps	33943	2471	2	<15,000	<0.2	9.4						6.21								
Annabella graben faults	33944	2472	2	<15,000	<0.2	12.5						6.35								
Pine Valley faults	33946	2481	4	<750,000	<0.2	3.7						5.74								
Pine Valley (south end) faults	33947	2482	5	<1,600,000	<0.2	10.7						6.27								
Wah Wah Mountains faults	33948	2483	5	<1,600,000	<0.2	53.6						7.09								
Wah Wah Mountains (south end near Lund) fault	33949	2485	3	<130,000	<0.2	40.2						6.94								
San Francisco Mountains (west side) fault	33950	2486	4	<750,000	<0.2	41.4						6.96								
Black Mountains faults	33951	2487	4	<750,000	<0.2	25.9						6.72								
Mineral Mountains (west side) faults	33952	2489	2	<15,000	<0.2	36.6						6.89								
Mineral Mountains (northeast side) fault (Class B)	33953	2490	6	Class B	<0.2	14.2						6.42								
Fremont Wash faults	33954	2495	4	<750,000	<0.2	7.2						6.07								
Spry area faults	33955	2498	4	<750,000	<0.2	5.1						5.90								
Tushar Mountains (east side) fault	33957	2501	5	<1,600,000	<0.2	18.5						6.55								
Sevier Valley fault	33958	2502	5	<1,600,000	<0.2	7.4						6.09								
Koosharem fault	33959	2503	5	<1,600,000	<0.2	2.2						5.48								
Gunlock fault (Class B)	33963	2515	6	Class B	<0.2	7.5						6.10								
Enterprise faults	33964	2516	4	<750,000	<0.2	8.4						6.15								
Antelope Range fault	33965	2517	4	<750,000	<0.2	24.5						6.69								
Escalante Desert faults near Zane	33966	2518	3	<130,000	<0.2	3.9						5.77								
Volcano Mountain faults	33967	2520	4	<750,000	<0.2	2.9						5.62								
Cross Hollow Hills faults	33968	2524	5	<1,600,000	<0.2	5.3						5.92								
Kolob Terrace faults	33969	2525	4	<750,000	<0.2	12.1						6.34								
Escalante Desert (east side) faults	33970	2526	2	<15,000	<0.2	6.4						6.02								
Cedar Valley (west side) faults	33971	2527	4	<750,000	<0.2	12.8						6.36								
Enoch graben faults	33972	2528	2	<15,000	<0.2	17.2						6.51								
Cedar Valley (north end) faults	33973	2529	3	<130,000	<0.2	15.5						6.46								
Parowan Valley faults	33974	2533	2	<15,000	<0.2	16.3						6.49								
Paragonah fault	33975	2534	3	<130,000	0.2-1	27.2						6.74								
Sevier Valley faults north of Panguitch	33976	2536	3	<130,000	<0.2	6.2						6.00								
Utah Lake faults	33977	2409	2	<15,000	<0.2	30.8						6.81								
Elsinore fault (fold)	33978	2470	5	<1,600,000	<0.2	28.1						6.76								
Joseph Flats area faults and syncline (Class B)	33979	2468	6	Class B	<0.2	3.2						5.67								
Dry Wash fault and syncline	33981	2496	3	<130,000	<0.2	18.6						6.55								

NAME	WWWURL	NUM	ACODE	AGE	RATE	Length (km)	Fault Type	distance from site (miles)	distance from site (km)	depth to seismogenic rupture (km)	r_{seis} (km)	MCE (All slip types, Wells and Coppersmith, 1994)	Rupture depth (km)	Rupture area (km^2)	MCE (based on fracture area, Wells and Coppersmith, 1994)	Limited MCE (based on Kirkham and Rogers, 1981)	PGA using rupture length (Campbell, 1981)	PGA using rupture area (Campbell, 1981)	PGA using limited MCE	PGA (Campbell-Bozorgnia 2003) corrected, plus 1SD (based on Mw)
Cedar City-Parowan monocline (and faults)	33982	2530	2	<15,000	<0.2	24.8						6.70								
North Hills faults	33983	2522	4	<750,000	<0.2	5.0						5.89								
East Canyon fault, Northern East Canyon section (Class B)	33985	2354a	6	Class B	<0.2	22.5						6.65								
East Canyon fault, Southern East Canyon section	33986	2354b	4	<750,000	<0.2	8.4						6.15								
Rock Creek fault	33991	729	2	<15,000	0.2-1	40.5	N					6.94								
Martin Ranch fault	33994	731	2	<15,000	0.2-1	3.7						5.74								
Sublette Flat fault	33996	733	4	<750,000	<0.2	36.0						6.89								
Eastern Bear Valley fault (Class B)	33997	734	6	Class B	<0.2	47.2						7.02								
Western Bear Valley faults	33998	735	5	<1,600,000	<0.2	12.4						6.35								
Elk Mountain fault	33999	736	5	<1,600,000	<0.2	7.8						6.11								
North Bridger Creek fault	34000	737	5	<1,600,000	<0.2	4.2						5.80								
Spring Creek fault	34001	738	5	<1,600,000	<0.2	2.3						5.50								
The Pinnacle fault	34002	739	5	<1,600,000	<0.2	2.3						5.50								
Ryckman Creek fault	34003	740	5	<1,600,000	<0.2	5.3						5.92								
Whitney Canyon fault	34004	741	2	<15,000	<0.2	5.5						5.94								
Almy fault zone	34005	742	5	<1,600,000	<0.2	10.7						6.27								
Duncomb Hollow fault	34006	743	5	<1,600,000	<0.2	2.4						5.52								
Faults on north flank of Phil Pico Mountains	34007	744	3	<130,000	<0.2	4.4						5.83								
Chicken Springs faults	34037	780	2	<15,000	<0.2	13.7						6.40								
Hogsback fault, northern section	34044	732a	4	<750,000	0.2-1	22.4						6.65								
South Granite Mountains fault system, Seminoe Mountains section?	34071	779e	6	Class B	<0.2	35.0						6.87								
Eastern Bear Lake fault, southern section	34078	2364c	2	<15,000	0.2-1	34.8						6.87								
East Canyon (east side) fault (Class B)	34079	2350	5	<1,600,000	<0.2	28.9						6.77								
West Cache fault zone, Clarkston fault	34081	2521a	2	<15,000	0.2-1	13.0						6.37								
West Cache fault zone, Junction Hills fault	34082	2521b	2	<15,000	<0.2	24.3						6.69								
West Cache fault zone, Wellsville fault	34083	2521c	2	<15,000	<0.2	19.9						6.59								
Eastern Bear Lake fault, central section	34106	2364b	2	<15,000	<0.2	23.8						6.68								
Hurricane fault zone, Cedar City section	34202	998a	2	<15,000	<0.2	13.2						6.38								
Snake Valley fault	34546	1246	2	<15,000	<0.2	41.1						6.95								
Unnamed faults on southeast side of Kern Mountains	34550	1256	5	<1,600,000	<0.2	11.4	N					6.31								
Southern Snake Range fault zone	34578	1433	3	<130,000	<0.2	27.5	N					6.75								
Judd Mountain fault	34616	1597	5	<1,600,000	<0.2	20.4						6.60								
Unnamed fault southeast of China Mountain	34617	1598	5	<1,600,000	<0.2	2.9						5.62								
Pilot Range faults	34618	1599	5	<1,600,000	<0.2	40.2						6.94								
Unnamed fault zone in Ferber Hills	34633	1721	5	<1,600,000	<0.2	37.3						6.90								
Overton Arm faults	34733	1119	3	<130,000	<0.2	50.9						7.06								
Unnamed fault west of White Rock Mountains	34846	1437	5	<1,600,000	<0.2	27.7						6.75								
Curlew Valley faults	35175	3504	2	<15,000	<0.2	20.0						6.59								
Western Bear Lake fault	35194	622	2	<15,000	<0.2	58.2						7.13								
Faults in Raft River Valley	35216	3503	4	<750,000	<0.2	35.2						6.87								
West Pocatello Valley faults	35218	3506	5	<1,600,000	<0.2	7.7						6.11								
East Pocatello valley faults	35219	3507	2	<15,000	<0.2	6.8						6.05								
Woodruff fault	35220	3508	5	<1,600,000	<0.2	12.5						6.35								
East Dayton-oxford fault	35221	3509	3	<130,000	<0.2	23.2	N					6.66								

U.S. Department of Energy—Grand Junction, Colorado

Calculation Cover Sheet

Calc. No.: MOA-02-11-2005-1-02-00 **Discipline:** Geologic and Geophysical Properties **No. of Sheets:** 6

Project: Moab UMTRA Project

Site: Crescent Junction, Utah

Feature: Photogeologic Interpretation

Sources of Data:

Aero-graphics, Inc., 2005. *Crescent Junction Photography* – one set of 12 -- 10"x10" color contact prints of the high-altitude flight. Transmittal No. 13224 for S.M. Stoller Corporation. August 1, 2005.

Aero-graphics, Inc., 2005. *Crescent Junction Photography* – two sets of 10 -- 10"x10" color contact prints of the low-sun angle flight. Transmittal No. 13330 for S.M. Stoller Corporation. October 3, 2005.

Sources of Formulae and References:

N/A.

Preliminary Calc. ☐ **Final Calc.** ☐ **Supersedes Calc. No.**

Author: Craig Goodknight 2/27/06 (Name, Date)

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Approved by: Kenneth Karp 3-6-06 (Name, Date)

Problem Statement:

Preliminary site selection performed jointly by the U.S. Department of Energy (DOE) and the Contractor has identified an approximately 300-acre location in the Crescent Flat area just northeast of Crescent Junction, Utah, as a possible site for final disposal of the Moab uranium mill tailings. The 300-acre site is within a withdrawal area consisting of approximately 2,300 acres. Situated between the Union Pacific Railroad and the base of the Book Cliffs, the withdrawal area extends for about 3 miles (mi) in an east-west direction and is approximately 1 mi wide in a north-south direction (Plate 1). Based on the preliminary site-selection process, the suitability of the Crescent Junction disposal site is being evaluated from several technical aspects, including geomorphic, geologic, hydrologic, seismic, geochemical, and geotechnical. The objective of this calculation set is to interpret stereographic color aerial photographs (including High Altitude Vertical [HAV] and Low Sun-Angle [LSA] photographs) of the area to analyze structural and geomorphic conditions that may affect the site.

Findings from this calculation will be incorporated into Attachment 2 (Geology) of the Remedial Action Plan (RAP) and Site Design for Stabilization of Moab Title I Uranium Mill Tailings at the Crescent Junction, Utah, Disposal Site, and summarized in the appropriate section of the Remedial Action Selection (RAS) report for the Moab site.

Method of Solution:

Color aerial photographs of an area of approximately 25 square mi, which included the proposed disposal site, the withdrawal area, and surrounding area, were taken by Aero-graphics, Inc., in July 2005. Both HAV and LSA photographs of the area were made at a scale of 1:24,000. The HAV photographs were taken on July 8, and two sets of the LSA photographs were taken—one in the morning and one in the evening—on July 27. Both HAV and LSA aerial photographs were taken in two flight lines from west to east across the north and south parts of the site area. The photographic coverage extends approximately 2.5 mi outside of the site withdrawal area in all directions. These photographs were interpreted to provide an assessment of geologic structures and geomorphic conditions that may affect the disposal site. Standard procedures and techniques were used to perform these analyses.

Assumptions:

Not applicable.

Calculation:

None required.

Discussion:

Results of these interpretations are used to assess structural and geomorphic conditions that may affect the Crescent Junction disposal site. These results are also used to confirm and supplement other field observations associated with site geologic mapping and with fault investigation for the site and regional seismicity calculation set. These interpretations contribute toward the comprehensive evaluation of the area relative to its suitability for location of the disposal facility. Features noted from inspection of the HAV and the LSA photographs are described in the following subsections along with an explanation of their significance, if known. Also, the features are divided into two groups: those which occur on or adjacent to the withdrawal area (numbered 1 through 6), and those which occur outside the withdrawal area (a through h). Each feature was assigned a relative importance by their number and letter order. All features are shown, with their relation to the withdrawal area, in Plate 1.

High-Altitude Vertical Photographs

1. Paths of active sheet wash flow are shown in gray (the color of Mancos Shale) from the base of the Book Cliffs south to south-southeast across parts of the site withdrawal area. Water flowing in this sheet wash drains across the site to the West and East Branches of Kendall Wash. These sheet wash deposits are quite evident on the ground and are mapped as such in the geologic map of the proposed site and nearby area included in the Field and Drilling Investigation Results calculation set. The active sheet wash areas continue the process of deposition of alluvial mud, which may be up to 25 feet (ft) thick, covering the Mancos Shale bedrock over most of the site.

2. An east-trending discontinuous line of low mounds that appear as a lineament are in the SE ¼ Section 22 and SW ¼ Section 23. These mounds are up to 15 ft high and are capped by a calcareous, dolomitic concretionary layer that marks the top of the Prairie Canyon Member of the Mancos Shale in this area, as described by Cole and others (1997) and Hampson and others (1999). The straight line of these mounds follows the strike direction of the Mancos Shale in this area and indicates that the stratigraphic horizon in the Mancos Shale is not displaced by faults.

3. The incised course of the N45W-trending West Branch of Kendall Wash is well exposed in the southwest part of the withdrawal area in the south-central part of Section 27. This trend reflects the prominent bedrock joint trend in this area. No exposed bedrock has been found in the wash bottom, which has been incised to a depth of about 10 ft north of the Union Pacific Railroad. Incision of the wash appears to be actively advancing to the northwest.

4. In the west parts of Sections 22 and 15, the west end of the Book Cliffs terminates abruptly along a linear feature that trends several degrees east of north. This feature continues northward across Crescent Canyon into the west part of Section 10. Mapped from Landsat images of the northern Paradox Basin as a lineament by Friedman and Simpson (1980), this feature is also shown in Friedman and others (1994). The feature does not coincide to any faults mapped for the area by Doelling (2001) or Gualtieri (1988), but the trend is similar to a joint system measured in the withdrawal area in the SW ¼ of Section 22. It is concluded that this topographic lineament or feature is likely an expression of a prominent joint system in the area trending several degrees east of due north. This feature may have influenced the direction of Crescent Wash, just west of the withdrawal area.

5. An abandoned wash course in SE ¼ of Section 24 in the northeast part of the withdrawal area trends south and extends for nearly 0.5 mi. The north end of the abandoned wash appears to intersect the incised present course of the southwest-draining East Branch of Kendall Wash. From the photographs, it appears that the south-trending drainage was abandoned either by capture from headcutting of the present East Branch or by blockage of the drainage by railroad personnel to consolidate drainages and minimize the number of rail crossings. Field examination of this abandoned drainage found that it was naturally abandoned, many thousand years ago. No connection with the present East Branch exists at the north end of the drainage; the floor of the drainage is approximately 10 ft higher than the incised depth of the East Branch. The drainage bottom is wide and flat, and the depth of the broad drainage decreases from about 8 ft at the north end to nearly zero at the south end near the Union Pacific Railroad. Abundant sandstone boulders, 2 to 5 ft in diameter, line the top sides of the drainage and occur in a broad fan (expressed as a boulder field) at the south (filled in) end of the drainage. This large material more than a mile away from its source, the top of the Book Cliffs, is anomalous for this area. These boulders indicate that the drainage was one of the major ones draining the Book Cliffs, possibly several hundred thousand to 1 million years ago when the front of the Book Cliffs was much closer (less than 0.5 mi).

6. Several slump blocks containing sandstone of the Blackhawk Formation are along the south face of the Book Cliffs, immediately north of the site withdrawal area, in Sections 22 and 23. These slump blocks are lighter colored (tan to yellowish brown) than the typical gray Mancos Shale in the lower slope of the Book Cliffs and appear to represent erosional remnants of larger slumps that slid down from the Book Cliffs in wetter Pleistocene times. Two additional slump blocks

covering larger areas are well shown. One is north of the withdrawal area in the south part of Horse Heaven just north of the western point of the Book Cliffs (elevation point 5,870 ft). The other is northeast of the withdrawal area just north of the detached block of the Book Cliffs (elevation point 5,903 ft, which is mislabeled and should be 5,803 ft) in the south-central part of Section 13. Both of these are shown in the landslide map by Harty (1993), and the slides were likely initiated in wetter times during the Pleistocene.

a. The head of south-draining Crooked Wash, about 0.5 mi northwest of the northwest end of the withdrawal area, bends abruptly to strike N45W and forms an embayment in the Book Cliffs in the NW ¼ of Section 16. This trend extends farther to the northwest and influences topography, forming an elongated cliff face just southwest of elevation point 5,882 ft. Southeastward along this trend, at the northwest end of the withdrawal area, is the abrupt west end of the Book Cliffs in the NW ¼ of Section 22. No fault coincides with this feature from mapping by Doelling (2001) for this area. The N45W trend is a common joint orientation in the area, and it is concluded that this major joint imparts some topographic control on the shape of the front of the Book Cliffs.

b. A linear feature that trends approximately N50W appears to control the shape of the front of the Book Cliffs in the NE ¼ of Section 13 approximately 1 mi north of the northeast end of the withdrawal area. This feature appears to extend northwestward for at least 0.5 mi into the SW ¼ of Section 12 where it forms a low saddle on the ridge northwest of elevation point 6,545 ft. No fault corresponds to this feature from mapping of the Moab 30' x 60' quadrangle by Doelling (2001) and mapping of the adjacent Westwater 30' x 60' quadrangle to the north by Gualtieri (1988). Nearest fault to this feature is about 0.5 mi to the northeast and it strikes almost parallel at N40W (Doelling 2001). Prominent vertical joints that strike N40W were measured along the top of the Book Cliffs about 1.5 mi to the southwest of this feature at elevation point 5,932 ft. From the orientation of this joint system and faults of similar orientation to the northeast of this feature, it is concluded that this feature is a major joint that imparts some topographic control on the shape of the face of the Book Cliffs and drainages/ridges to the north.

c. Approximately 20 small pits are spaced about 200 ft apart in an area mainly north of old U.S. Highway 50, south of the Union Pacific Railroad, and just east of the East Branch of Kendall Wash. Field examination of the pits indicates that they are about 60 ft long, 25 ft wide, and 5 ft deep. Several 4 inch by 4 inch wooden posts were also found scattered on the ground through this area. These pits were likely dug as part of assessment work for mining claims staked for gold in the late 1970s and early 1980s. This area was part of a larger area (Floy to Cisco) sampled in a study by Marlatt (1991) for analysis of gold content in Mancos Shale. He found the gold content ranged from 30 to 100 parts per billion (ppb), which is about ten times the background level, but much too low for economic extraction.

d. Green vegetation just north of old U.S. Highway 50 occurs in washes from the area of the East Branch of Kendall Wash westward to the West Branch of Kendall Wash. This occurrence of vegetation coincides with and verifies the location of the buried (and leaking) water line from Thompson Springs to Crescent Junction.

Low Sun-Angle Photographs

The LSA photographs covering the withdrawal area show that no terraces or mantled pediment surfaces are displaced and no scarps or linear features are present that would suggest the presence of faulting.

e. Best-shown of all the structural features in the LSA photographic coverage area are the bounding normal faults of the graben that strikes N20W along the axis of the Thompson anticline. This graben structure is about 2 mi northeast of the northeast end of the withdrawal area. The southwest-bounding fault of the graben has the greater displacement (up to 90 ft) of the two faults (Willis 1986) and is well shown in the evening LSA photographs. The faults displace resistant sandstone beds of the Blackhawk Formation and Castlegate Sandstone, both of which cap the Book Cliffs. No displacement on these faults has been discerned where they contact the underlying, soft Mancos Shale on the slopes of the Book Cliffs.

f. A prominent vertical joint system that strikes N55W is well shown in sandstone of the Blackhawk Formation exposed on a point on the Book Cliffs in Horse Heaven in the east-central part of Section 15 approximately 1 mi north of the withdrawal area. No displacement occurs along this joint and it is a common joint orientation exposed elsewhere in the surrounding area.

g. An abrupt change in elevation of the terrace surface occurs just north of Interstate 70 across from the rest area about 0.5 mi west of Crescent Junction. The highest surface, at elevation point 4,995 ft near the center of Section 33, abruptly drops down 40 to 50 ft to the northwest to a lower surface. Both surfaces are covered by pediment-mantling material as mapped by Doelling (2001). It is uncertain whether the two surfaces represent two terrace (or pediment) levels or they are the same surface that has been displaced by a fault. The higher terrace surface to the south corresponds to what is mapped as Crescent Bench to the south of Interstate 70.

h. A pediment mantled by surficial (terrace?) material (mapped by Doelling 2001) that is possibly displaced is about 1.5 mi west of the west edge of the withdrawal area. This pediment is about 0.5 mi southeast of Thompson Pass in SE ¼ SW ¼ of Section 17. The faint linear feature along which displacement possibly has occurred could also be an old geophysical seismic exploration line because the linear feature extends to the east-southeast for nearly a mile toward Crooked Wash.

Conclusion and Recommendations:

Interpretation of aerial photographs for the withdrawal area supplement what is observed on the ground regarding areas of active sheet wash, the line of low mounds indicating the top of the Prairie Canyon Member of the Mancos Shale, and the headward incision of the West Branch of Kendall Wash. A south-trending (and draining) wash course that appears to drain away from the East Branch of Kendall Wash in the northeast part of the withdrawal area represents a major drainage course that was in place several hundred thousand to as much as 1 million years ago. This drainage is not related to the present East Branch, and it appears to have been naturally abandoned many thousand years ago. Known and possible fault displacements were noted in areas near but outside of the withdrawal area, but far enough away that they do not adversely affect the geologic suitability of the disposal site. Aerial photographs covering the withdrawal area showed no features that would suggest the presence of faulting. Also, no structural features outside of the withdrawal area were identified that would be of sufficient significance to be addressed further in the calculation set for Site and Regional Seismicity – Results of Maximum Credible Earthquake Estimation and Peak Horizontal Acceleration.

Computer Source:

Not applicable.

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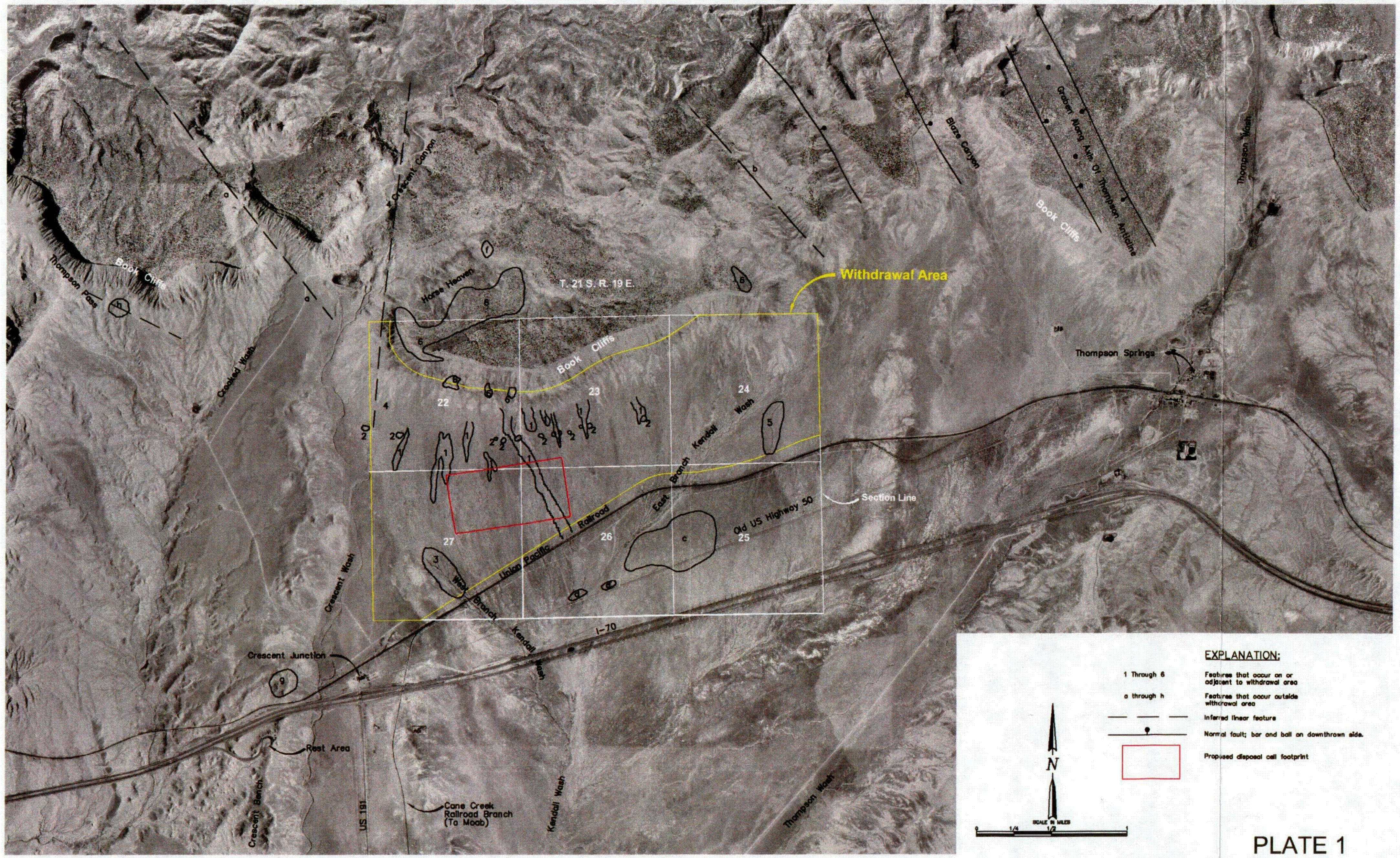

PLATE 1

U.S. DEPARTMENT OF ENERGY GRAND JUNCTION, COLORADO	Work Performed by S.M. Stoller Corporation Under DOE Contract No. DE-AC01-02GJ79491

AERIAL PHOTOGRAPHY INTERPRETATION FOR CRESCENT JUNCTION WITHDRAWAL AREA and NEARBY SURROUNDING AREA

DATE PREPARED:	FILENAME:
JANUARY 27, 2006	X0136200

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