GEOLOGIC SURFACE EFFECTS OF UNDERGROUND NUCLEAR TESTING, YUCCA FLAT, NEVADA TEST SITE, NEVADA

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Table of Contents

Section 1

1.1 – Acknowledgments 3

1.2 – Introduction 4

1.3 – A Brief History of Surface Effects Investigations 4

Section 2—Mapping Surface Effects

2.1 – What Are Surface Effects? 5

2.2 – How Were Surface Effects Mapped? 6

Section 3—Preparing The GIS Map

3.1 – Methods 6

3.2 – Map Accuracy 7

3.3 – Map Features 8

3.4 – GIS Digital Data 9

Section 4

4.1 – References 10

4.2 – Figures

Figure 1. Location of Yucca Flat and other testing areas at the Nevada Test Site, Nye County, Nevada 11

Figure 2. Location of underground nuclear detonation sites, Yucca Flat, Nevada 12

Figure 3. Surface effects mapped at site U-4d, Yucca Flat, Nevada 13

Figure 4. GIS composite surface effects map of U-4d and surrounding sites, Yucca Flat, Nevada 14

Figure 5. Aerial photograph of collapse sink at site U-2ax, Yucca Flat, Nevada 15

Figure 6. Aerial photograph of collapse sink at site U-2am, Yucca Flat, Nevada 16

Figure 7. GIS composite surface effects map of U-2dg and surrounding sites, Yucca Flat, Nevada 17

4.3 – Tables

Table 1. Detonations mapped for surface effects by NTS Operational Area, Yucca Flat, Nevada 18

4.4 – Glossary 19

Plate 1 ..... *(Accompanies this pamphlet)*

GEOLOGIC SURFACE EFFECTS OF UNDERGROUND NUCLEAR TESTING, YUCCA FLAT, NEVADA TEST SITE, NEVADA

SECTION 1

1.1 Acknowledgments

This report presents a new Geographic Information System composite map of the geologic surface effects caused by underground nuclear testing in the Yucca Flat Physiographic Area of the Nevada Test Site, Nye County, Nevada. The tedious task of mapping these surface effects was originally conducted by many investigators of the U.S. Geological Survey, the Los Alamos National Laboratory, the Lawrence Livermore National Laboratory, and the Defense Threat Reduction Agency. These investigators comprehensively documented the surface effects of more than two-thirds of all underground nuclear detonations conducted at Yucca Flat.

The field and laboratory procedures they used to map these sites are summarized by Garcia (1997, p. 3), who graciously acknowledges the painstaking efforts of the following investigators:

> *Surface effects mapping itself is a time consuming and tedious task, but one that has been completed with considerable attention to detail. Surface effects documentation was pioneered by F.A. McKeown and F.N. Houser in the early 1960's. Many other USGS geologists have been involved in the process including F.M. Byers Jr., H.R. Covington, D.D. Dickey, G.L. Dixon, M.N. Garcia, E.C. Jenkins, Florian Maldonado, P.P. Orkild, T.L. Prather, R.P. Snyder, R.R. Spengler, Susan Steele Wier, Pete Thompson, W.S. Twenhofel, and Dean Townsend. Geologists from the National Laboratories included Brian Allen, Anne Cavazos, Sigmund Drellack, Jose Gonzales, Ward Hawkins, Richard McArthur, Lawrence McKague, William McKinnis, Lance Prothro, William Davies, Casey Schmidt, and Margaret Townsend. Their combined mapping efforts and reports have documented surface effects at the Nevada Test Site for the past 40 plus years.*

The latest cooperative endeavor between the U.S. Geological Survey (USGS) and the U.S. Department of Energy (DOE), under Interagency Agreement DE-AI08-96NV11967, involves the digital compilation and archiving of these surface effects maps using computer-based Geographic Information System (GIS) technologies. This report and the composite GIS map that accompanies it present the results of this endeavor for Yucca Flat. The many long hours of compilation work to complete the GIS surface effects maps for Yucca Flat may not have been realized without the persistent efforts of Martha Garcia, USGS, and the gracious support of Steve Leedom and Bonnie Thompson, DOE. I thank you and the many others who directly and indirectly supported this project. This report and the digital GIS data that were produced will preserve the arduous achievements of those who spent countless hours in the pursuit of knowledge and understanding about the surface effects of underground nuclear testing at the Nevada Test Site.

1.2 Introduction

The Nevada Test Site (NTS) was established in 1951 as a continental location for testing nuclear devices (Allen and others, 1997, p. 3). Originally known as the “Nevada Proving Ground,” the NTS hosted a total of 928 nuclear detonations, of which 828 were conducted underground (U.S. Department of Energy, 1994). Three principal testing areas of the NTS were used: (1) Yucca Flat, (2) Pahute Mesa, and (3) Rainier Mesa including Aqueduct Mesa. Underground detonations at Yucca Flat and Pahute Mesa were typically emplaced in vertical drill holes, while others were tunnel emplacements. Of the three testing areas, Yucca Flat was the most extensively used, hosting 658 underground tests (747 detonations) located at 719 individual sites (Allen and others, 1997, p. 3-4).

Figure 1 shows the location of Yucca Flat and other testing areas of the NTS. Figure 2 shows the locations of underground nuclear detonation sites at Yucca Flat. Table 1 lists the number of underground nuclear detonations conducted, the number of borehole sites utilized, and the number of detonations mapped for surface effects at Yucca Flat by NTS Operational Area.

The first underground nuclear detonation at Yucca Flat (or Yucca Valley, as it is also known) was Uncle, conducted on November 29, 1951 as a crater, weapons effect experiment in Area 10. The first “deep” underground detonation at Yucca Flat was Pascal-A (U-3j), conducted on July 26, 1957 at a depth of 152 m (499 ft) in an uncased, unstemmed borehole in Area 3 (Allen and others, 1997, p. 3). On September 23, 1992 the last underground nuclear test was conducted at the NTS by the detonation of Divider (U-3mL) in Area 3 just prior to the signing of a one-year moratorium on underground nuclear testing by President Bush in late 1992. Subsequently, President Clinton extended this moratorium and later signed the Comprehensive Test Ban Treaty, which prohibits all underground nuclear testing.

Allen and others (1997) provide detailed descriptions of underground nuclear testing at the NTS from 1951 to 1992, and furnish a comprehensive synopsis of the environmental effects of testing. Much of the nomenclature and descriptions of the surface effects presented in this report were adopted from Allen and others (1997) and Garcia (1997).

1.3 A Brief History of Surface Effects Investigations

The USGS became involved with the nuclear testing program in 1957 as part of an aggressive effort to map the geology of the NTS at a scale of 1:24,000 (Garcia, 1997). This mapping effort not only provided the first detailed geologic maps of the area, but also gave scientists an opportunity to explore the containment characteristics of the geologic environment. For example, Carothers (1995) discusses how the geologic environment became a test parameter for nuclear testing. These early experiments revealed that geology and hydrology were important siting characteristics, and conversely, provided insight into our understanding of the geology of the NTS. Supported by the Atomic Energy Commission (AEC), the Energy Research and Development Administration (ERDA), and the Department of Energy (DOE), the USGS began an extensive research program to evaluate the geophysical, hydrological, and geological environments of the NTS. One component of this work focused on mapping the surface effects of underground nuclear detonations.

Post-detonation surface effects maps were produced for many testing sites using field and aerial-photo mapping techniques. The fractures produced by these underground nuclear detonations were mapped and reported on in many USGS Technical Letter reports. Features mapped included surface cracks (and fractures), collapse sinks, various types of faults, pressure ridges, and reactivated cracks. The procedures used to prepare these maps are explained in detail by Garcia (1997) in what has informally become known as the "How-To Publication" on surface effects mapping. Ultimately, a final "crack map," as they are often called, was prepared in ink on stable-base mylar drafting film for use in USGS publications and reports. These final crack maps were then stored by the USGS in map files at the Denver Federal Center in Lakewood, Colorado.

The latest phase of surface effects map preparation by the USGS is reported on in this publication. In October 1997 a pilot project was implemented to evaluate methods for storing (archiving) the original mylar crack maps in a more permanent and accessible format. A Geographic Information System was used because of its abilities to store map data with associated attribute information, and because GIS provides methods to easily query, retrieve, and display these data as needed. Simply stated, the goals of this project were: (1) to reproduce the original mylar maps in a digital format that would allow them to be directly used for various computer-aided research, management, and readiness activities, and (2) to preserve, in a permanent digital archive, the many years of painstaking surface effects mapping work that was conducted at the NTS.

This report summarizes the actions taken to address these goals and presents a composite view of more than 40 years of surface effects maps for Yucca Flat in their new GIS digital format. The large-scale, composite GIS map, presented in this report as Plate 1, contains all of the surface effects originally mapped at underground nuclear detonation sites throughout Yucca Flat.

SECTION 2: MAPPING SURFACE EFFECTS

2.1 What Are Surface Effects?

Surface effects are categorized by Allen and others (1997) as geologic and hydrologic effects, ecological effects, and cultural-feature effects. This report focuses on the geologic surface effects of underground nuclear testing at Yucca Flat. These include collapse sinks, craters, cracks, fractures, faults, and pressure ridges. Definitions of these features are given in the Glossary of this report. The terminology used here was adopted from, and closely follows, that presented by Allen and others (1997) and Garcia (1997). For more detailed descriptions, examples, and illustrations of surface effects at the NTS the reader is referred to Allen and others (1997).

The formation of geologic surface effects is dependent upon many factors including the lithology of the surface material, as well as the yield and depth of burial (DOB) of the nuclear device (Garcia, 1997). For example, a small-yield detonation in alluvium will generally produce fewer, observable surface effects than a large-yield detonation in the same medium and at the same DOB. These and other geologic and non-geologic variables account for the many different types of surface effects and patterns seen at detonation sites throughout Yucca Flat.

2.2 How Were Surface Effects Mapped?

Surface effects mapping was initiated by the USGS in the late 1950's and continued by the Los Alamos National Laboratory in 1977, the Lawrence Livermore National Laboratory in 1980, and the Defense Nuclear Agency (now the Defense Threat Reduction Agency) in 1982 (Garcia, 1997). Investigators from these agencies produced a surface effects map to document the effects of testing at the site shortly following each underground nuclear detonation. The timing of these activities was critical because post-detonation weather conditions and construction activities would often quickly destroy the resultant surface features.

Surface effects maps were produced using field mapping, stereo aerial photography, and photogrammetric techniques (Garcia, 1997). Each map comprehensively documented any new surface effects of the nuclear detonation under investigation, as well as the presence of any reactivated surface effects (that is, movements on pre-existing features caused by a prior detonation). To ensure accuracy, these maps were produced on stable-base drafting film (mylar) at scales of 1:12,000 or larger.

SECTION 3: PREPARING THE GIS MAP

3.1 Methods

Surface effects maps were produced for 498 of the 747 underground nuclear detonations conducted at Yucca Flat between November 29, 1951 (Uncle) and September 23, 1992 (Divider) (Table 1). The earliest surface effects maps consisted only of a simple outline of the sink (or crater) formed by the detonation. Examples of these include Uncle (Operation Jangle, 1951) and Ess (Operation Teapot, 1955) in Area 10; and Fisher (U-3ah; 1961), Ringtail (U-3ak; 1961), and Stoat (U-3ap; 1962) in Area 3 (Plate 1). The first detailed surface effects map was produced for the Stillwater (U-9c; 1962) detonation in Area 9. This map not only showed the location of the sink, but also the pattern of surface cracks produced by the detonation near the Yucca Fault Zone. Over the next thirty years many complex surface effects maps were produced. In total, approximately 67 percent of all detonations conducted at Yucca Flat were mapped for surface effects (Table 1). The last surface effects map was produced following the late-1991 Bristol (U-4av) detonation in Area 4.

Plate 1 is a composite map of all surface effects maps produced for Yucca Flat. It was prepared as a GIS composite of the new digital versions of individual surface effects maps representing 498 individual detonations. Combined, the number of unique surface effects shown for these sites in Yucca Flat exceeds 55,600 with a combined length of 1,487 miles. The locations of mapped detonation sites are illustrated in Figure 2.

A new digital surface effects map was produced for each of the original, post-detonation mylar site maps. Each mylar map was scanned, georeferenced, and digitized into a comprehensive set of GIS project files for Yucca Flat. Scanning was done at a resolution of 300-600 dots-per-inch to preserve map detail and accuracy. The scanned, digital (raster) copy of the map was then georeferenced to a common map coordinate system—Nevada State Plane (Central, 2702, in feet), North American Datum 1927 (NAD27)—using 4-12 ground control points placed at known grid coordinates on each map. The raster map was then resampled pixel-by-pixel into the Nevada State Plane coordinate system using a bilinear algorithm applied to the ground control reference points. Each new georeferenced map was produced with a new pixel size of 0.5 x 0.5 meter, for large-scale (1:6,000) maps, or 1.0 x 1.0 meter, for small-scale (1:12,000) maps. Subsequently, these new georeferenced copies of the original mylar maps were inserted into the GIS mapping program as raster-based map layers from which each site's surface effects could be digitized. Figure 3 shows a georeferenced, raster-based copy of the original mylar map of site U-4d prior to digitizing (upper frame) and the final GIS vector-based digital reproduction of this same map (lower frame).

Digitizing refers to the drawing (or tracing) of points, lines, and polygons from a reference map. While often done using a digitizing tablet, the operator has little control over the original scale of the map, and subsequently, the resolution and precision of the digitizing process. Another method of digitizing, which was implemented and perfected for this project, is to digitize on-screen from a digital, georeferenced reproduction of the original map. This approach allows the operator to zoom in to very large map scales, thus controlling not only the resolution and accuracy of digitizing, but also the precise placement of the line segments (arcs and nodes) that comprise the variety of surface effects and symbols shown on the map.

Surface effects maps of Yucca Flat were digitized on-screen at very large scales. For most areas, a digitizing scale of 1:500 (1 inch equals 42 feet) to 1:1,200 (1 inch equals 100 feet) was used. For areas containing very complex surface effects, however, digitizing scales as large as 1:50 (1 inch equals 4.2 feet) were necessary. As part of the digitizing process, each map element (surface effects feature) was attributed (identified) with such unique information as site number, feature type, feature length, and source map information. These spatial and attribute data for each site map were then stored in a comprehensive set of GIS files and related databases for Yucca Flat.

As digital data, it is now possible to query and retrieve map and attribute information, and prepare individual site maps or composite maps of multiple sites. The GIS compilation map of site U-4d (Fig. 3) is an example of an individual site map. The GIS composite map of U-4d and surrounding sites (Fig. 4) is an example map of multiple detonation sites. Together, these maps clearly illustrate the complex pattern of surface effects produced by underground nuclear testing and the abundance of detailed map information that were produced for this part of Yucca Flat during the 20-year period 1966 to 1986.

3.2 Map Accuracy

The accuracy of these GIS surface effects maps is equivalent to that of the original mylar maps. That is to say, the methods used to produce each new GIS digital map from its original mylar map yielded very precise results; thus furnishing an exact duplicate of the original. One way to quantify this reproduction accuracy is to measure the spatial error (the root mean square error) for each newly produced georeferenced mylar map. This was done for each site map during the production of these maps. The results showed that the amount of error, as measured on-the-ground, was less than 1 pixel (that is, less than 0.5 to 1.0 meter) for nearly every georeferenced map. In a few cases, however, this on-the-ground error approached 2-3 meters for some of the oldest and most poorly persevered original maps.

3.3 Map Features

Surface effects within Yucca Flat consist of collapse sinks, craters, cracks, fractures, faults, and pressure ridges (Plate 1). One of the most striking surface effects seen in Yucca Flat are collapse sinks. Sinks are commonly circular to elliptical in shape with distinctive edges. Aerial photographs of the collapse sinks at site U-2ax (Fig. 5) and U-2am (Fig. 6), for example, show the distinctive edges and steep walls of these sinks shortly after detonation. Often, a complex pattern of radial, concentric, and tangential fractures extended from the rims of these sinks (Fig. 3; Fig. 6); and at some sites (for example, U-2x, U-3cn, U-9ao, U-10c, and U-10k; Plate 1), a “zone of abundant fractures” formed adjacent to the sink. At other sites, however, these features may be subdued or altogether absent (Fig. 5). The collapse sinks at some detonation sites may also contain one or more interior sinks. These are thought to be the result of post-detonation collapse of near-surface voids within the chimney (Allen and others, 1997). Also, irregular or angular collapse sinks formed at sites located in highly fractured or faulted areas of Yucca Flat. The site of the Bilby detonation (U-3cn) is one such example (Plate 1).

Another notable surface effect of underground nuclear testing at Yucca Flat is the preferential cracking and fracturing along named faults. The Yucca Fault Zone trends north-south through Yucca Flat and is clearly visible on GIS composite maps (Plate 1) and on individual site maps (Figs. 3 and 4). Similarly, the Carpetbag Fault Zone, a large north-south trending fault system west of site U-2dg (Carpetbag) in Area 2, is clearly visible on GIS composite maps (Plate 1) and on individual site maps (Fig. 7). Other notable faults in Yucca Flat include the Area 3 Fault, the Area 7 Fault, the Area 9 Fault, and the Topgallant Fault Zone (Plate 1).

Each detonation site throughout Yucca Flat presents a unique number, pattern, and complexity of surface effects that are thought to be related to such site characteristics as underlying sediment or rock type, the geologic structure of the site, and the size and depth of the detonation. For example, McKeown and Dickey (1967, p. 3) reported the following about site U-2ce:

> *The Nash explosion at the U-2ce site produced a steep-walled sink, as did other explosions in this immediate area [western part of Area 2]. The steeper walls of the sinks in this part of Yucca Valley as compared to other areas in the valley is believed to be due to better cementation and greater strength of the alluvium. Most of the fractures produced by the Nash explosion are radial and tangential to ground zero.*

The type of surface effects mapped may also differ from area to area across Yucca Flat depending on the emphasis placed on these features by the mapping program during its different operational phases. In Area 3, for example, emphasis was placed on mapping collapse sinks during this phase of testing. Hence, the original surface effects maps for many of these Area 3 sites show only the collapse sinks caused by underground nuclear testing.

The sites shown on Plate 1 were categorized as follows: (1) Sites mapped for surface effects where surface effects exist, (2) Sites mapped for surface effects where no surface effects were observed, and (3) Sites not mapped for surface effects. For the sites mapped for surface effects, all collapse sinks and associated cracks, fractures, faults, and pressure ridges that formed at, and extend outward from, surface ground zero (SGZ) are shown. For sites having a "zone of abundant fractures" adjacent to the sink, the complex pattern of crack were drawn stylistically on the original mylar maps and digitally reproduced. At some sites, for example U-7b, the collapse sink either did not form or was not mapped. In other cases, a subsequent detonation may have destroyed the surface effects produced by a prior detonation. For these sites, all surface effects are shown except those that would have been destroyed within the collapse sink of the subsequent detonation. It should be noted that these features were digitized as originally mapped and are therefore present in the GIS databases. However, to produce the GIS composite map it was necessary to apply a line-removal technique to clear these features from within the collapse sinks of subsequent detonations. The result of this approach is that no surface effects are shown within the sink of a more recent detonation, thus producing a chronologically correct composite map. An example of this is seen in the vicinity of sites U-7bp and U-7ae in Area 7. The southeastern portion of the U-7ae sink is not shown because it was destroyed within the collapse sink caused by the subsequent detonation at site U-7bp (Plate 1). Similarly, the southwestern part of the U-4d sink (a 1974 detonation) is not shown because it was destroyed by the 1979 detonation at U-4L (Fig. 4). As a result of this approach, the composite GIS map should be viewed as a representation of what the current pattern of surface effects would look like now, after more than 40-years of underground testing, if these features had not been altered, subdued, or completely removed by wind, rain, and other natural or human-induced activities.

3.4 GIS Digital Data

Plate 1 provides a comprehensive look at the combined surface effects of underground nuclear testing throughout Yucca Flat. However, it does not show the real power of these GIS digital data. These data are most useful when scientifically analyzed in combination with other related site and/or environmental information; and because these data are now in digital format, such analyses can be easily performed. For example, these GIS surface effects data can be easily queried, retrieved, updated, and interactively viewed in map or tabular formats. Plate 1 is an example of one such data retrieval and mapping operation; in this case a retrieval and map composite of all available data. Similarly, numerous other surface effects analyses operations and spatial or attribute queries can be performed on individual sites or site clusters selected according to some combination of chronological, geographical, geological, and/or hydrological factors.

Work is currently underway to provide these new digital surface effects maps and associated base maps and databases for Yucca Flat and Pahute Mesa in GIS digital formats. These data will be made available on both CD-ROM, in an upcoming USGS Open File Report, and on the Internet available through DOE/NV and USGS Internet sites.

SECTION 4

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U.S. Department of Energy, 1994, United States Nuclear Tests, July 1945 through September 1992, DOE/NV-209, Revision 14.; Available only from U.S. Department of Commerce, National Technical Information Service, Springfield, Virginia, 22161.

4.2 Figures

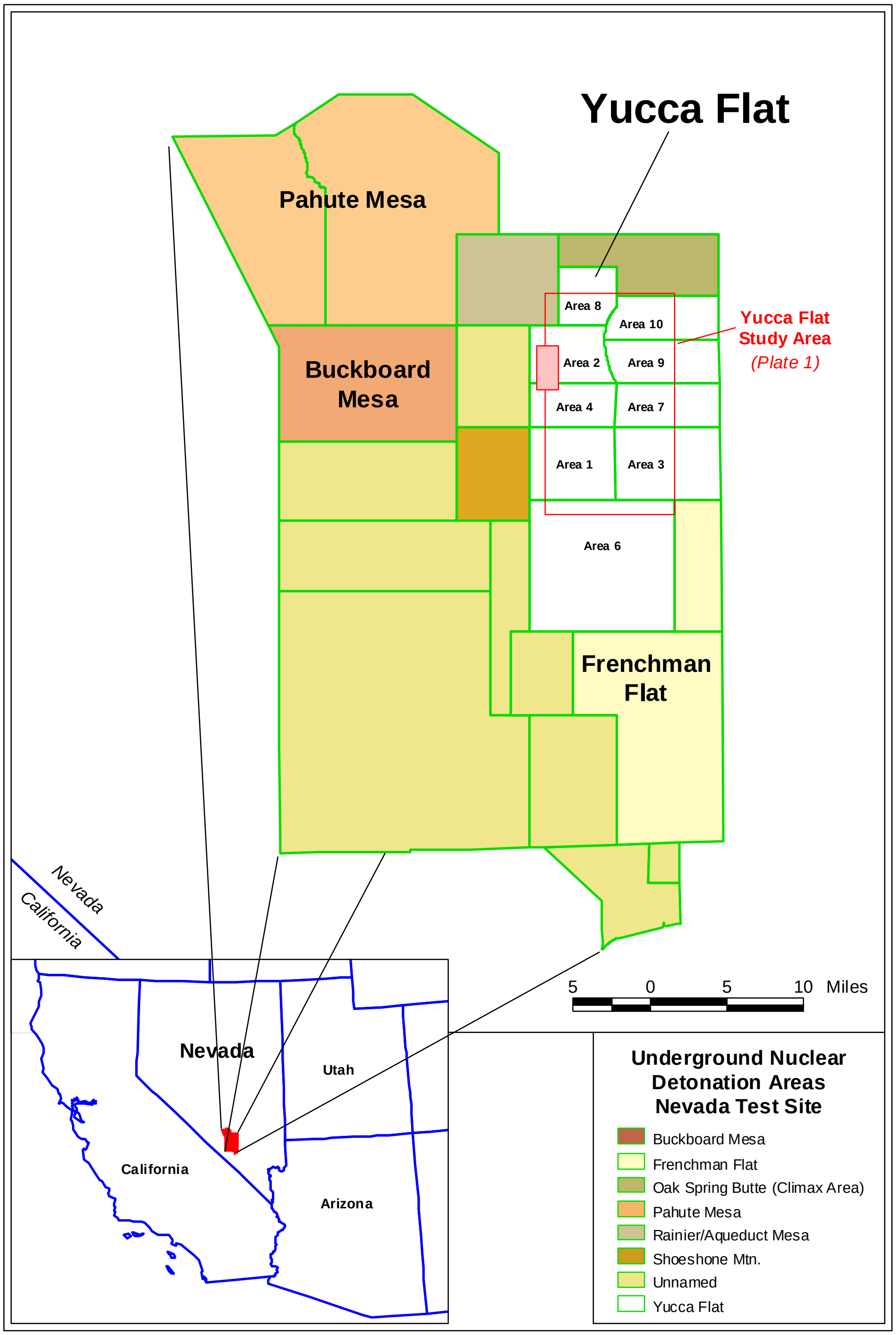

Figure 1—Location of Yucca Flat and other testing areas at the Nevada Test Site, Nye County, Nevada. Area of Plate 1 and Area 2 inset map shown by red outlines.

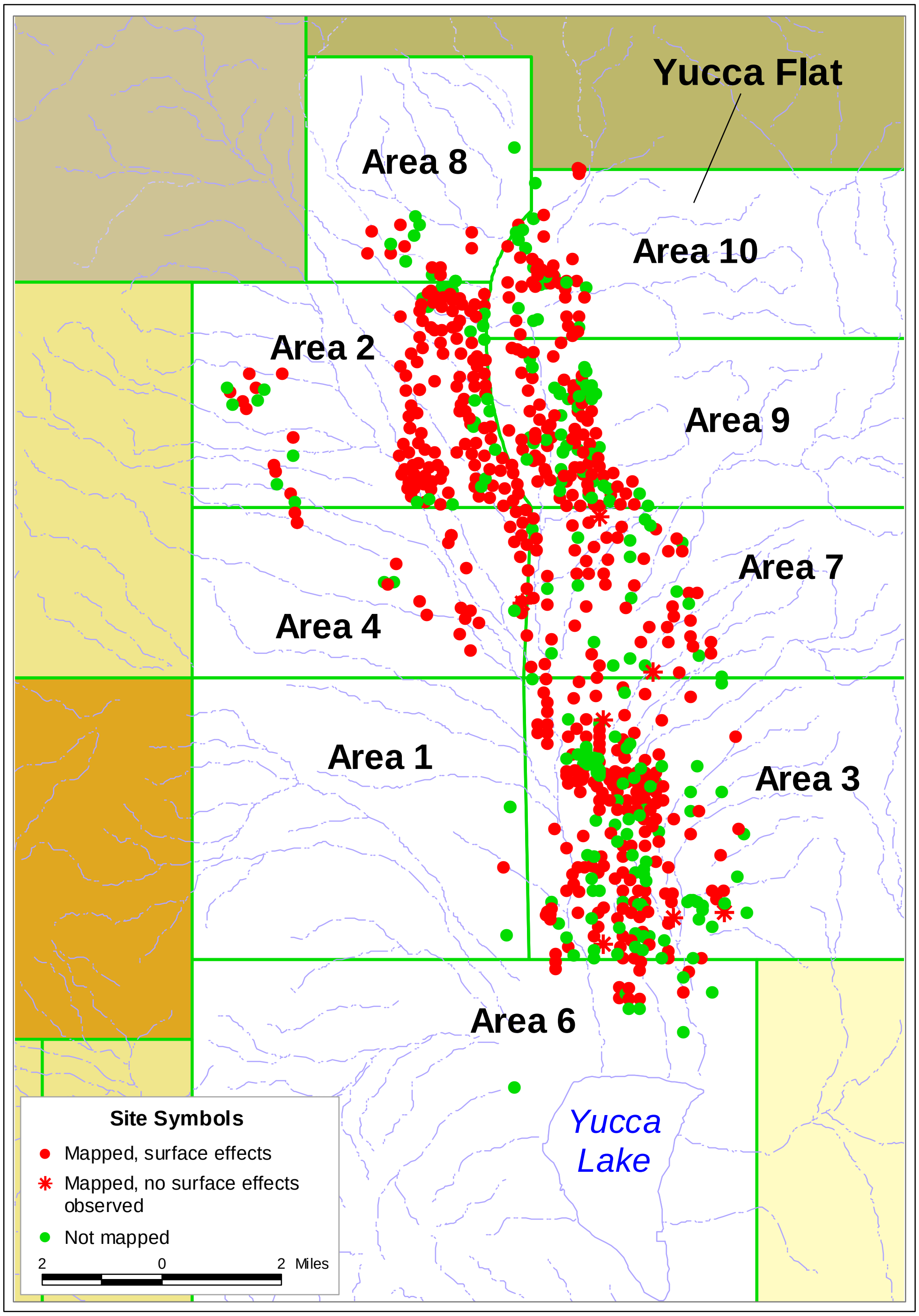

Figure 2—Location of underground nuclear detonation sites, Yucca Flat, Nevada.

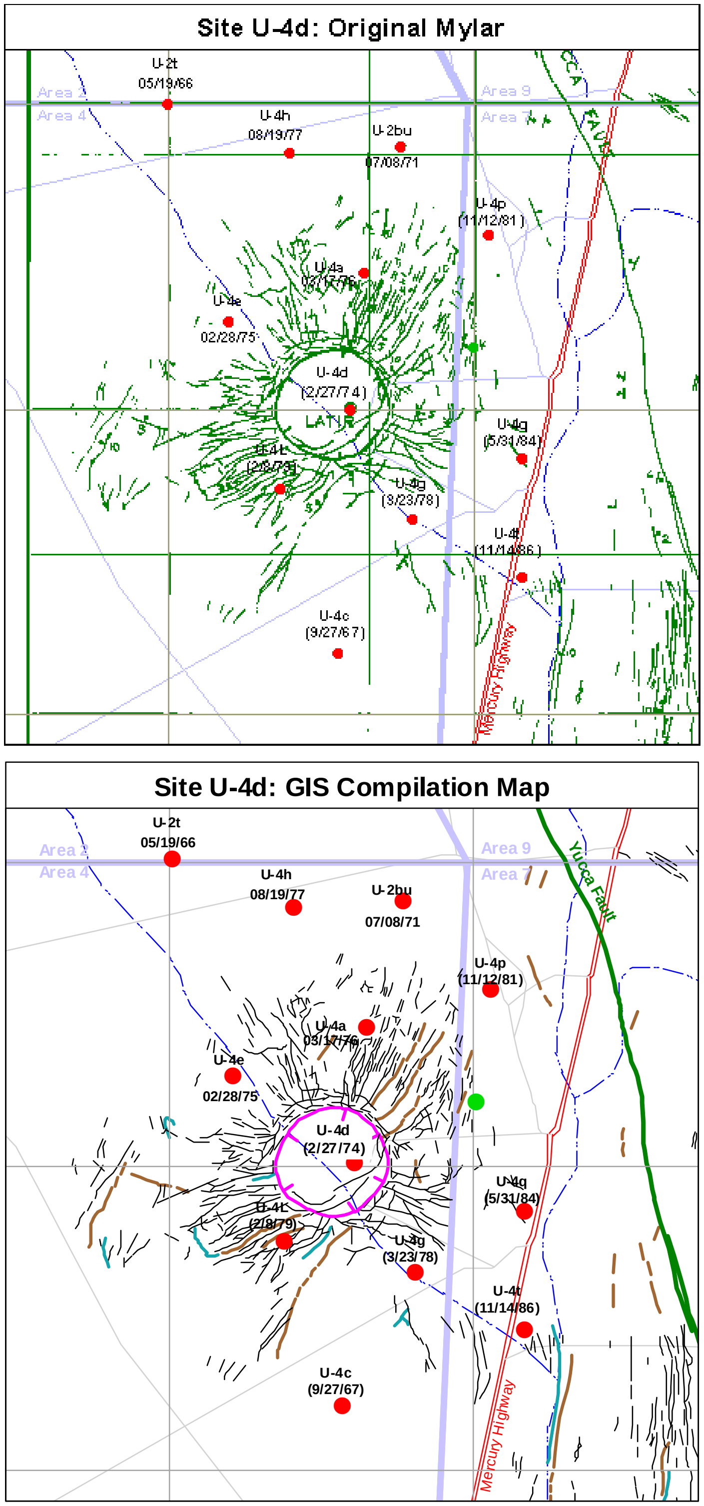

Figure 3—Surface effects mapped at site U-4d, Yucca Flat, Nevada. The original mylar map (upper frame) is compared to the new GIS compilation map (lower frame) for this site. Red dots indicate the location of detonation sites mapped for surface effects; green dots indicate sites not mapped.

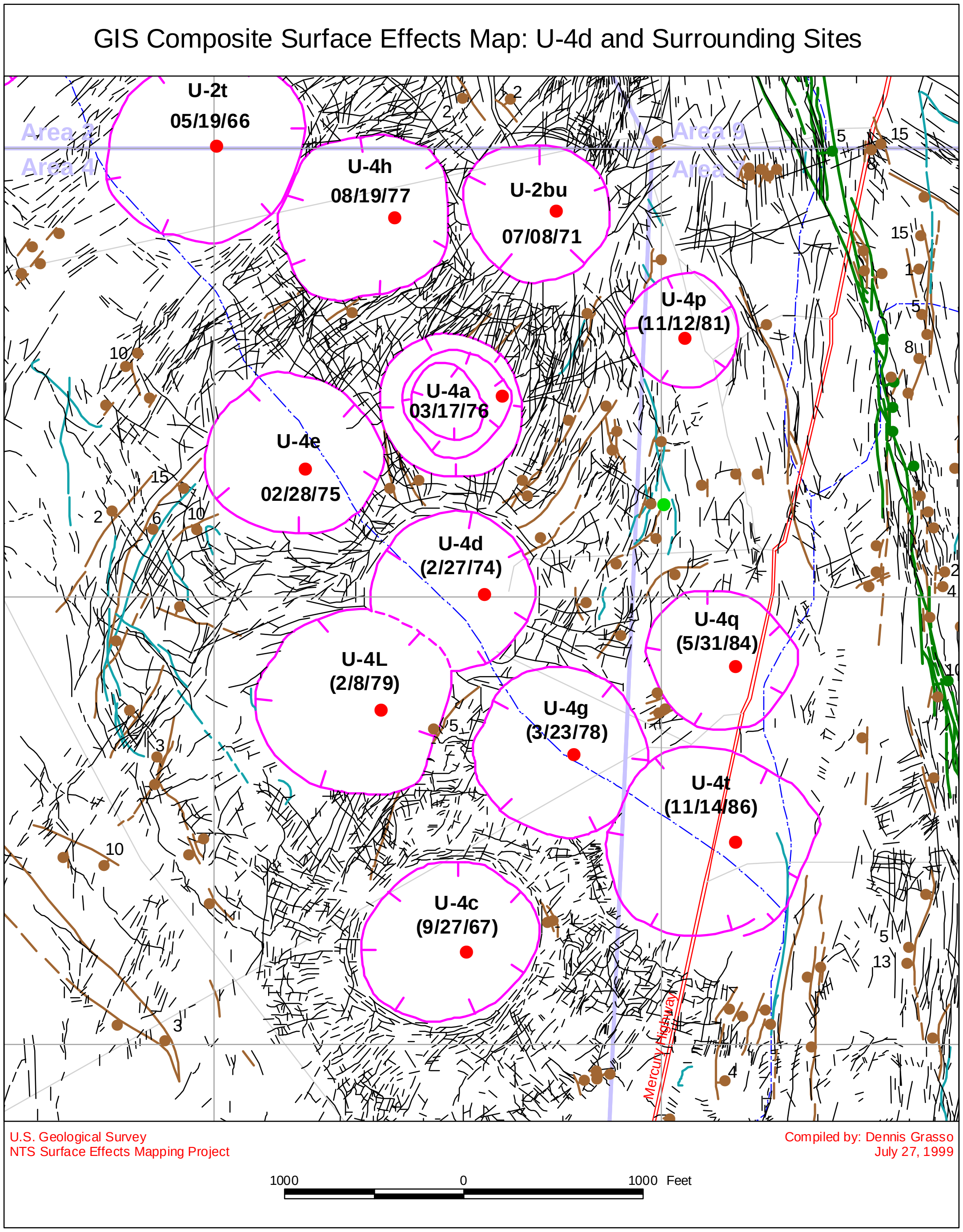

Figure 4—GIS composite surface effects map of U-4d and surrounding detonation sites, Yucca Flat, Nevada. Red dots indicate the location of detonation sites mapped for surface effects; green dots indicate sites not mapped.

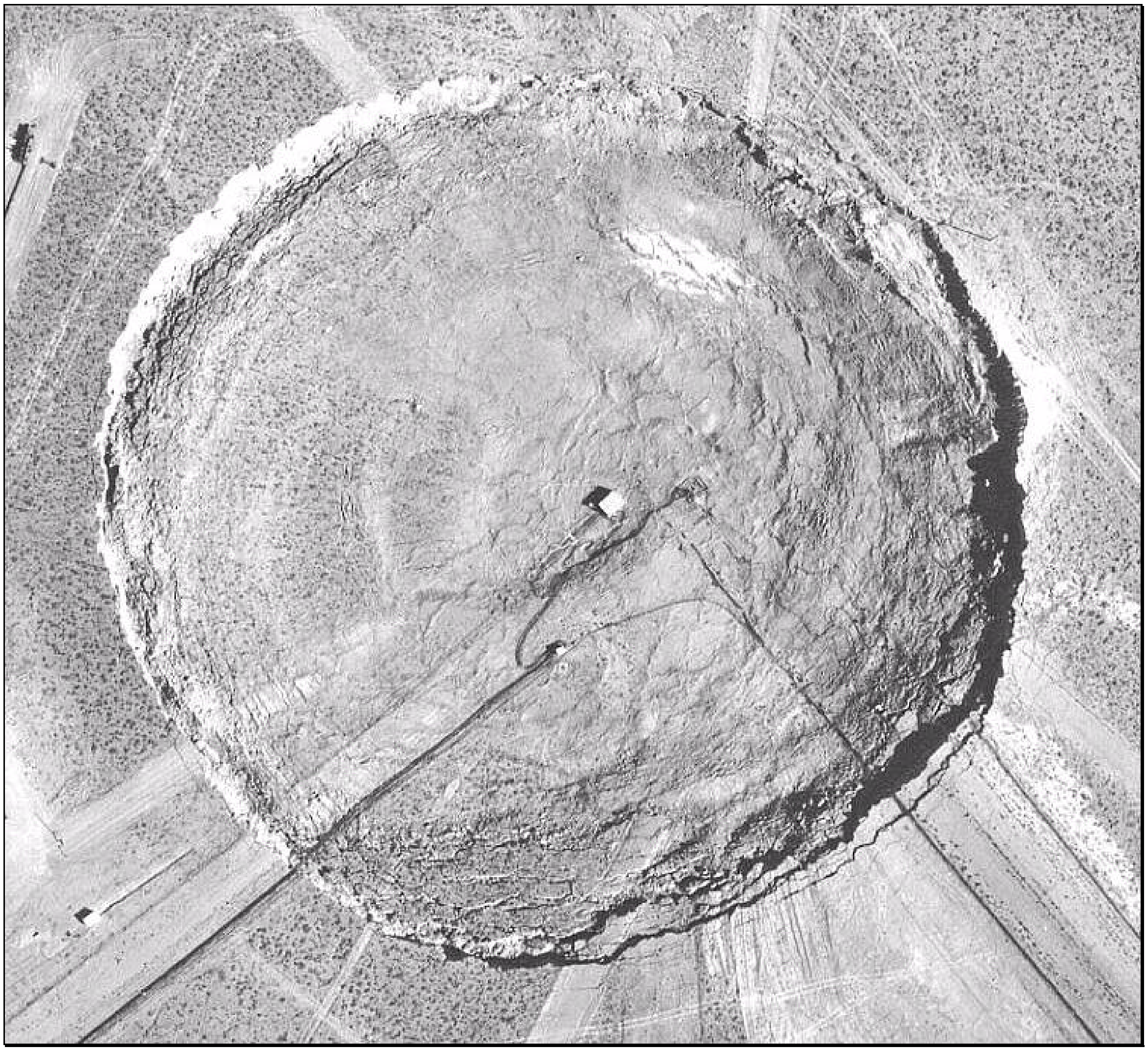

Figure 5—Aerial photograph of collapse sink at site U-2ax, Yucca Flat, Nevada. Portmanteau was detonated on August 30, 1974. This photograph was taken seven days later on September 6, 1974. Note the distinct edge of the collapse sink and presence of surface materials that slumped into the sink at its perimeter following surface collapse.

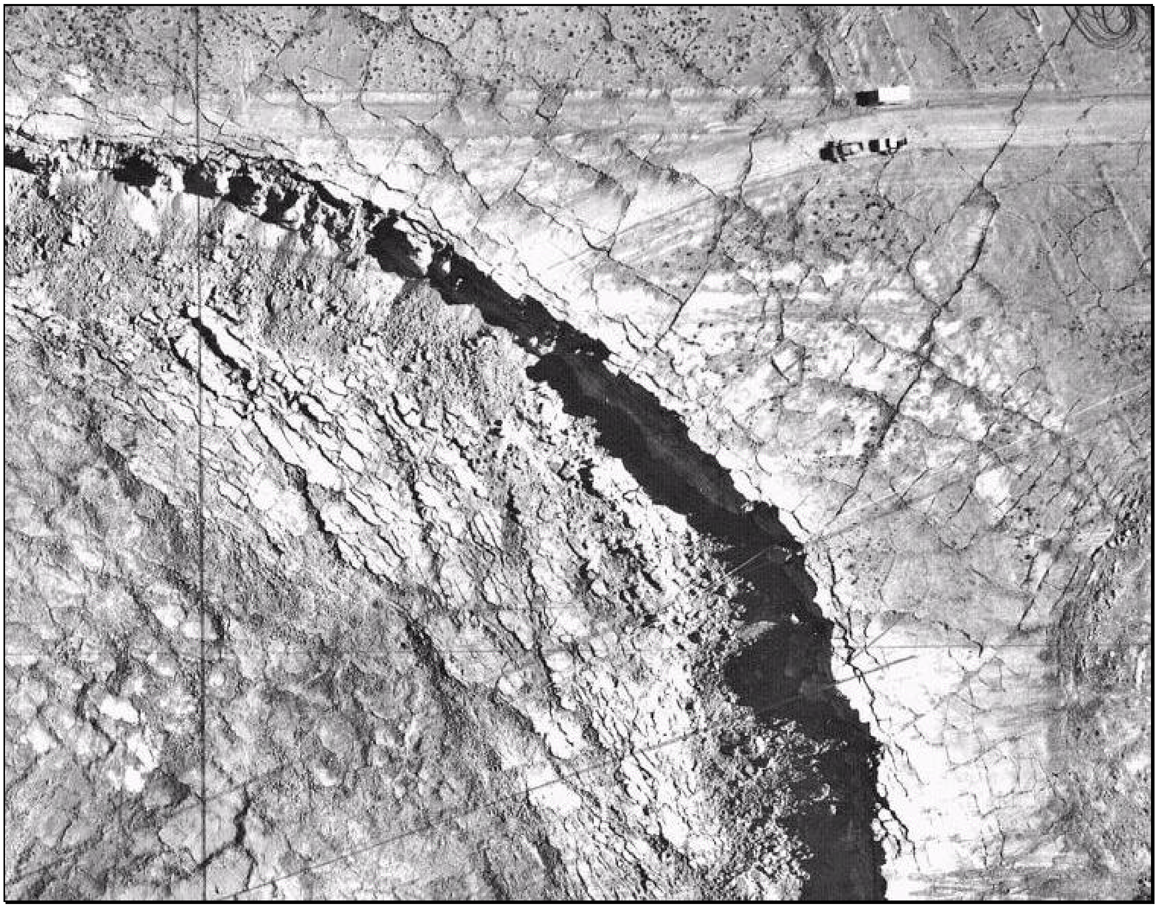

Figure 6—Aerial photograph of collapse sink at site U-2am, Yucca Flat, Nevada. Commodore was detonated on May 20, 1967. The distinct edge of the sink, and presence of radial and concentric cracks that extend from its perimeter, are noteworthy surface effects. Note the two trucks on the "truncated" dirt road at upper right.

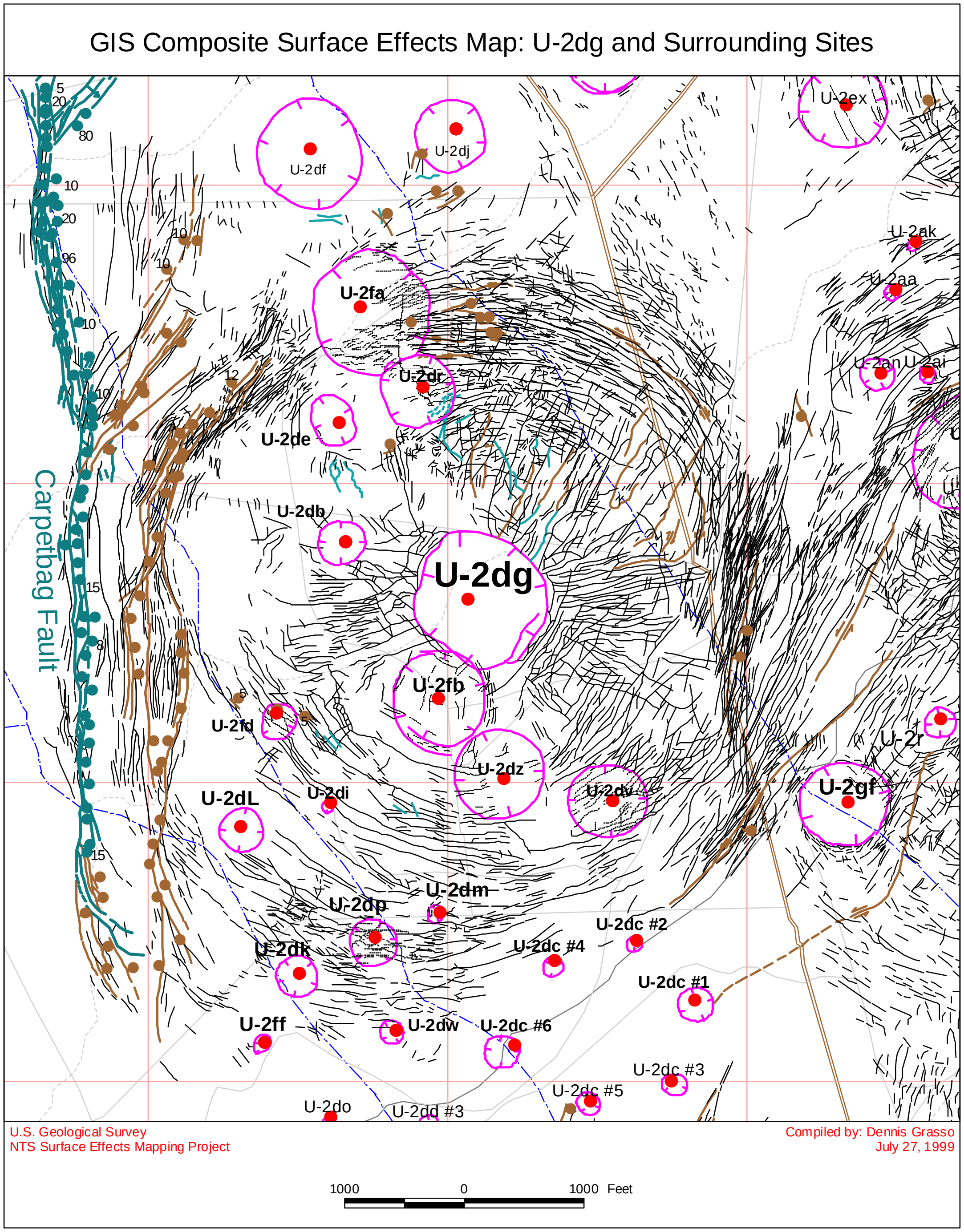

Figure 7—GIS composite surface effects map of U-2dg and surrounding sites, Yucca Flat, Nevada. Red dots indicate the location of detonation sites mapped for surface effects.

4.3 Tables

Table 1—Detonations mapped for surface effects by NTS Operational Area, Yucca Flat, Nevada.
[Note: Number of Underground Detonations and Number of Borehole Sites (holes) listed for each NTS Operational Area is based on their Redbook identification number, not on their locations within the present-day boundaries of NTS Operational Areas.]

NTS Operational Area	Number of Underground Nuclear Detonations	Number of Borehole Sites (holes)	Detonations Mapped for Surface Effects	Detonations Not Mapped for Surface Effects
Area 1	4	3	1	3
Area 2	162	153	132	30
Area 3	274	272	164	110
Area 4	39	35	35	4
Area 6	6	6	2	4
Area 7	62	62	46	16
Area 8	12	10	5	7
Area 9	118	114	70	48
Area 10	70	64	43	27
Total	*747*	*719*	*498*	*249*

4.4 Glossary

The following features are commonly observed surface effects of underground nuclear testing at the Nevada Test Site. These definitions were compiled from a variety of sources including Allen and others, 1997; Garcia, 1997; Houser, 1970; Drellack, 1988; and Garcia, Drellack, and McKinnis, *[unpublished data]*.

Collapse sink (or sink): A topographic depression caused by surface subsidence within the chimney above an underground nuclear detonation, at or near surface ground zero. Often informally referred to as a crater at the Nevada Test Site, collapse sinks are distinct from craters in that there is no throw-out or vaporization of surface materials.

Crack (or fracture): A break or parting of the ground surface formed by explosion-induced mechanical failure of the geologic surface material. Cracks generally range from "hairline" to several tens of centimeters in width, and from several centimeters to several hundreds of meters in length. The largest cracks are usually associated with the highest-yield detonations and/or nearby faults (Allen and others, 1997, p. 29). In the context of surface effects mapping, a *crack* that has a limited vertical extent below the ground surface is referred to as a *fracture*. However, because this distinction was not made on the original surface effects maps, the words crack and fracture are used synonymously in this report. The following types of fractures (cracks) are present in Yucca Flat.

- ***Concentric fractures***: Surface fractures that form in a circular orientation around surface ground zero of an underground explosion.
- ***Hairline fracture***: A surface fracture having a width (aperture) of less than 3 mm. Hairline fractures tend to form on prepared surfaces, such as roads.
- ***Linear fracture***: Surface fractures that form in a series (or trend) of discontinuous, en echelon, parallel, or sub-parallel linear features.
- ***Radial fracture***: Surface fractures oriented in a "spoke-like" pattern around surface ground zero.
- ***Reactivated fracture***: A pre-existing fracture on which failure recurs during subsequent testing.

Crater: A topographic depression caused by an explosion at or near the surface that forms as a result of compaction, throw-out (ejecta), and/or vaporization of surface materials. The largest crater in Yucca Flat is Sedan, which was produced as an excavation experiment in 1962 under the Plowshare Program.

Fault: A vertically extensive fracture along which vertical and/or horizontal displacement has occurred. The relative motion on either side of the fault defines the type of fault. When the motion is primarily vertical, the fault is said to be a normal fault. When the motion is primarily horizontal, the fault is said to be a lateral fault. And when the motion is compressional and one side overrides the other, the fault is said to be a thrust fault. Although a fault is commonly referred to in the singular, the largest faults in Yucca Flat (for example, Yucca Fault, Carpetbag Fault, and Area 3 Fault) consist of several parallel or en echelon faults that form along a fracture zone.

Pressure ridge: A narrow, low topographic ridge raised above the ground surface by compressional stresses or as an artifact of “slap down” resulting from the detonation. Pressure ridges are typically straight to slightly curved or locally sinuous.

Surface effects: A stress-induced surface feature that forms as a result of the underground nuclear detonation.

Surface Ground Zero (SGZ): That point on the ground surface directly above an underground nuclear detonation.